RB Geotechnical

7 Carr Manor View, Leeds, LS17 5AG

Telephone: 07909331251

Email:rbgeotechnical@gmail.com

Proposed Development at Old Shoulder Of Mutton

Phase II Interpretative Report

April 2024

Document Control

Project:	Development at Old Shoulder of Mutton Phase II Intrusive Investigation
Client:	TMU Property Ltd
Job Number:	RBG312

Prepared and Issued by Ross Blake BSc MSc FGS, Engineer. Signed:

Issue	**Date**	**Status**
003	April 2024	Final

Contents Page

Disclaimer **6**

1.0 Introduction **7**

1.1 Brief and Scope 7

1.2 Terms and Conditions 7

1.3 Scope and Objectives of Report 7

1.4 Constraints and Limitations 8

1.5 Sources of information 8

2.0 Site Details **9**

2.1 Site Location and Description 9

2.2 Proposed Development 9

3.0 Existing Information **10**

3.1 Site History 10

3.2 Geology, Hydrology and Hydrogeology 10

3.3 Preliminary Contamination Assessment 10

4.0 Intrusive Investigation **11**

4.1 Design 11

4.2 Ground Investigation Activities 11

4.3 Sampling and In-Situ Testing 11

4.4 Laboratory Testing – Environmental 12

4.5 Laboratory Testing – Geotechnical 12

4.6 Ground Gas Monitoring Standpipe 13

5.0 Intrusive Ground Investigation Findings **14**

5.1 Ground Conditions Encountered 14

5.2 Ground Gas Risk Assessment 14

5.3 Ground Water 16

6.0 Preliminary geotechnical recommendations **18**

6.1 Foundations 18
6.2 Buried Concrete 18
6.3 Excavations 18
7.0 Ground Contamination – Generic Quantitative Risk Assessment 19
7.1 Human Health Assessment 19
7.2 Vegetation Assessment 20
8.0 Discussion Of Results 22
8.1 Human Health Hazards 22
8.2 Vegetation Hazards 23
9.0 Conceptual Site Model 25
9.1 Introduction 25
9.2 Hazard Identification 26
9.3 Discussion of Risks 32
10.0 Conclusions 34
11.0 Recommendations 35
12.0 References 36

APPENDIX CONTENTS

Appendix A	**Proposed Development Plan and Exploratory Hole Location Plan**
Appendix B	**Exploratory Hole Logs**
Appendix C	**Contaminated Land Laboratory Testing**
Appendix D	**Geotechnical Laboratory Testing**
Appendix E	**Ground Gas Monitoring Results**

DISCLAIMER

This report was produced by RB Geotechnical for TMU Property Ltd (The client), for the specific purposes of a Phase II Intrusive Investigation and Interpretative Report, for the proposed residential development at the former Old Shoulder of Mutton pub in Batley, West Yorkshire. This report may not be used by anyone else other than the client without their express permission. In any event, RB Geotechnical accepts no liability for any costs, liabilities or losses arising from the use of reliance upon the contents of this report by anyone other than the client.

1.0 INTRODUCTION

1.1 Brief and Scope

RB Geotechnical was commissioned by the client, to carry out a Phase II Intrusive Site Investigation at the land of the Former Old Shoulder of Mutton in Batley, West Yorkshire. The site is intended to have the main pub building refurbished and the addition of two storey flats to the east of this building.

RB Geotechnical undertook an intrusive ground investigation on 12th September 2022, to gain the necessary information required to assess the underlying ground conditions. This assessment was designed to assess for possible soil contamination risks in addition to preliminary geotechnical considerations and a ground gas risk assessment.

This report discusses the findings of this ground investigation and provides an analysis which includes a series of conclusions and recommendations relating to the potential risks and constraints of the proposed development.

1.2 Terms and Conditions

This report has been prepared for TMU Property Ltd, for the purpose of assessing the ground conditions on site.

1.3 Scope and Objectives of Report

The purpose of this report is to provide factual and interpretative information required to comply with the requirements of a Phase II Intrusive Site Investigation and land contamination assessment. The scope of the report is as follows:

- To provide general information on the site such as location and description;
- To summarise the environmental and historical setting of the site; e.g., landfills, permits, sensitive land uses and historical land uses;
- To summarise the ground investigation and its findings;
- Provide factual information and descriptions of ground conditions;
- To assess geotechnical parameters of the site;
- To provide a quantitative risk assessment for the proposed end use of the site; and

- To provide recommendations for further works where necessary.

1.4 Constraints and Limitations

This report is intended for the client for assisting them in assessing the site for possible soil contamination risks in addition to geotechnical risks and ground gas risks.

RB Geotechnical has endeavoured to assess all information provided to them. The report includes summaries of information from external sources and cannot offer any guarantees or warranties for the completeness or accuracy of information relied upon.

The conclusions resulting from this study are not necessarily indicative of future conditions or operating practices at or adjacent to the site.

It should be noted that although every effort has been made to ensure the accuracy of the data obtained from the investigation, the possibility exists for variations in ground and groundwater conditions between and around the borehole locations. In addition, groundwater levels will vary seasonally and with changes in weather conditions.

1.5 Sources of information

Environmental information has been obtained following a review of the contaminated land laboratory test results, along with the findings of the intrusive ground investigation.

The sources of information used for this report are:

- RB Geotechnical, Old Shoulder of Mutton Phase I Desk Study Report, RBG271, January 2022;
- Mugen Windowless Sample Borehole Logs, September 2022; and
- I2 Analytical Report No. 22-85260, 22-85558 and 22-85559 November 2022.

Although every effort has been made to ensure the accuracy of the information contained herein, no checks have been carried out to ensure the accuracy of information obtained from third parties and no liability can be accepted for any errors or misinterpretation of the third-party information where it has been incorporated into this report.

2.0 SITE DETAILS

2.1 Site Location and Description

The 0.10ha sized site, is situated off Upper Road in Batley, West Yorkshire. It is currently occupied by a large two storey sandstone block built 'now derelict' pub building. The land to the East of the main pub building is tarmac car parking. Some old small brick-built garages are located in the North East corner of the site. The National Grid Reference for the centre of the site is 423708, 422859.

2.2 Proposed Development

The proposed development is to comprise redevelopment of the current Old Shoulder of Mutton Pub building into a new residential property, with the addition of two storey flats to the East of the main building. The North of the site will be used as private amenity space, with soft landscaped gardens.

The proposed development and exploratory hole location plan is included as Appendix A.

3.0 EXISTING INFORMATION

3.1 Site History

The pub building has been on the site since at least 1855 (the earliest available historical map). By the early 1900s an outhouse on the site has expanded in size, with further expansion in the 1950s. By the late 1960s the small outhouse buildings had been demolished, with only the addition of a new building in the North of the site during the early 1970s.

3.2 Geology, Hydrology and Hydrogeology

3.2.1 Geology

According to the published geological maps the site is underlain by bedrock of the Pennine Lower Coal Measures, Mudstone, Siltstone and Sandstone.

3.2.2 Hydrology and Hydrogeology

The underlying bedrock is classified as being a Secondary A Aquifer. There are no water networks within 250m of the site boundary and the site is at Low flood risk from rivers and sea.

3.3 Preliminary Contamination Assessment

An old quarry mapped from 109m to the North of the site, along with other noted ground workings within 250m of the site boundary have been identified as the main off-site sources of potential contamination risks, due to the possibility of ground gas accumulations.

The presence of an electrical sub-station adjacent to the site also needs considering. However the location of this substation (adjacent to the South- East corner boundary), is not thought to pose a significant risk to the proposed development site as in this area the hardstanding is to remain, and there will be no areas of soft landscaping nearby, hence reducing the risk of possible human contact with contaminated soils associated with this sub-station.

It was however recommended that Phase II Intrusive Investigation be carried out in order to assess the site for potential soil contamination and potential off-site ground gas risks.

4.0 INTRUSIVE INVESTIGATION

4.1 Design

The Ground Investigation was designed by RB Geotechnical to investigate the ground conditions of the site.

4.2 Ground Investigation Activities

The Ground Investigation was undertaken in general accordance with:

- BS 5930 (1999). Code of Practice for Ground Investigation;
- BS1377. Methods of test for Soils for Civil Engineering Purposes; and
- BS 10175:2011 (2011). Investigation of Potentially Contaminated Sites – Code of Practice.

The Ground Investigation comprised the following:

- Three Windowless Sample Boreholes to obtain shallow soil samples for soil contamination and geotechnical testing and for in-situ testing to allow for strength assessment of underlying soils
- Installation of ground gas monitoring standpipe in three Windowless Sample Boreholes;
- One hand dug trial pit to obtain shallow soil samples for soil contamination testing, in area unable to be reached by drilling rig.

This Ground Investigation was undertaken on 12th September 2022. The exploratory holes were logged and sampled by a qualified engineer.

An exploratory hole location plan is shown in Appendix A.

4.3 Sampling and In-Situ Testing

Small, disturbed samples were recovered from the boreholes and stored in plastic pots and jars placed into a cool box.

4.4 Laboratory Testing – Environmental

All chemical (contamination) laboratory testing was scheduled by RB Geotechnical and was intended to provide contamination data for the specific areas sampled. The scope of the testing was designed to enable comments regarding characterisation of potential contamination on site.

A total of seven soil samples were sent to I2 Analytical, which is a registered UKAS Testing laboratory. Table 4.1 summaries the Laboratory Testing carried out. Full chemical laboratory testing results are shown in Appendix C. Note that the laboratory results attached state that the samples were 'Deviating'. According to I2 Analytical policy the sample is noted as 'Deviating' if it is incorrectly labelled without a sample date, as was the case in this instance. The samples were collected within a suitable time period, were suitably stored and tested within an appropriate timeframe so the quality of the sample was not compromised.

Table 4.1 Summary of Chemical Laboratory Testing

Analysis	Total number of Samples
Heavy Metals	7
Cyanide	5
Speciated PAH	6
Total TPH	6
Asbestos	4

4.5 Laboratory Testing – Geotechnical

All geotechnical laboratory testing was scheduled by RB Geotechnical and was intended to provide geotechnical data for the specific areas sampled. The scope of the testing was designed to enable comments regarding foundation options for the site.

A total of five soil samples were sent to I2 Analytical, which is a registered UKAS Testing laboratory. Table 4.2 summaries the Laboratory Testing carried out. Full geotechnical laboratory testing results are shown in Appendix D.

Table 4.2 Summary of Geotechnical Laboratory Testing

Analysis	Total number of Samples
Moisture Content	3
Atterberg Limit	3
Sulphate	3
pH	3

4.6 Ground Gas Monitoring Standpipe

Ground gas monitoring standpipe was installed in three Windowless Sample Boreholes (WS01, WS02 and WS03), with the construction details as follows:

- WS01: 0.5m plain pipe and 1.3m slotted, with bentonite seal to 0.5m and pea gravel from 0.5m to 1.8m;
- WS02: 0.5m plain pipe and 1.0m slotted, with bentonite seal to 0.5m and pea gravel from 0.5m to 1.5m; and
- WS04: 0.5m plain pipe and 1.0m slotted, with bentonite seal to 0.5m and pea gravel from 0.5m to 1.5m.

In-situ gas monitoring was carried out in each of these Boreholes, using a portable gas meter which measures Oxygen, Methane, Carbon Dioxide and air pressure.

5.0 INTRUSIVE GROUND INVESTIGATION FINDINGS

The exploratory hole location plan is shown in Appendix A and full exploratory hole logs are included as Appendix B.

5.1 Ground Conditions Encountered

5.1.1 Made Ground

Brown and dark grey slightly gravelly silty clayey MADE GROUND with gravels of sandstone, brick and coal, was encountered from ground level in all three Windowless Sample Boreholes to depths of 0.25mbgl (metres below ground level) to 0.30mbgl.

5.1.2 Highly Weathered Bedrock

Highly weathered bedrock was encountered beneath Made Ground at depths from 0.25mbgl to 0.30mbgl, typically as a firm to stiff slightly gravelly silty CLAY, extending to depths of 1.50mbgl to 1.80mbgl (the base of the boreholes).

Standard Penetration Testing (SPTs) were carried out throughout this stratum, with SPT N values found to range from 12 to refusal, generally increasing with depth.

Atterberg Limit Testing was carried out on two samples taken from this stratum, with measured Moisture Contents of 15% to 20%, Liquid Limits of 81% to 98%, Plastic Limits of 14% to 16% and Plasticity Indices of 12% to 20%. These results classify the soil as being of a Low to Intermediate Plasticity and after NHBC 2022, Building Near Trees, these soils can be classified as being of a Low Volume Change Potential.

After the relationship between SPTs and Plasticity Index established by Stroud, an approximate shear strength in the region of 75kPa could be achieved, increasing with depth.

5.2 Ground Gas Risk Assessment

The risks associated with ground gases have been considered in accordance with British Standard BS 8485:2015+A1:2019 “Code of Practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings” and CIRIA Report C665 “Assessing Risks Posed by Hazardous Gases to Buildings”.

Ground Gas Monitoring was carried out on six separate occasions following the intrusive Ground Investigation on the following dates: 19th September 2022, 26th September 2022, 5th October 2022, 14th October 2022, 26th October 2022 and 8th November 2022. Full gas monitoring results are shown in Appendix E.

As noted in section 4.6, the ground gas monitoring standpipe response zones were designed to allow for an assessment of potential ground gas ingress from nearby infilled land features such as the historical quarry and mill pond. The response zone in each borehole was therefore placed within the highly weathered bedrock (silty gravelly clay) stratum, ensuring it was within an unsaturated zone, above groundwater levels which are likely to be deeper within the aquifer of the underlying intact bedrock. The response zones placed within the highly weathered bedrock was deemed suitable to assess for potential ground gas ingress from the nearby infilled land features.

The methodology used to carry out a semi-quantitative estimate of the risks from ground gas at the site is that described in BS8485:2015+A1:2019 and CIRIA Report C665 which recommends following the classification system proposed by Wilson and Card in CIRIA Report 149.

The highest levels of ground gas flow were recorded in exploratory hole WS01. This exploratory hole had the deepest gas monitoring standpipe, with the longest response zone and this borehole was located in the most eastern extent of the site (closest to the backfilled historical mill ponds off site). It is unclear why ground gas flow rates were measured to be highest in this borehole, but there are a number of possible reasons. It is possibly due to its location being closer to the ground gas sources (mill ponds and quarries) in addition to potential underlying groundwater levels within the bedrock aquifers below this area of the site having more of an effect on the gas flow regime in this borehole compared to the other boreholes due to its increased depth and potentially more permeable bedrock in this area of the site. Therefore, following the guidelines set in BS8485:2015+A1:2019, the Gas Screening Values (GSV) for the site was calculated using the highest gas values (using both Methane and Carbon Dioxide) and flow rate.

The highest measured gas value on this site was Carbon Dioxide of 3.70%, with a Flow Rate of 4.30l/hr. The GSV for the site has therefore been calculated to be 0.159 l/hr.

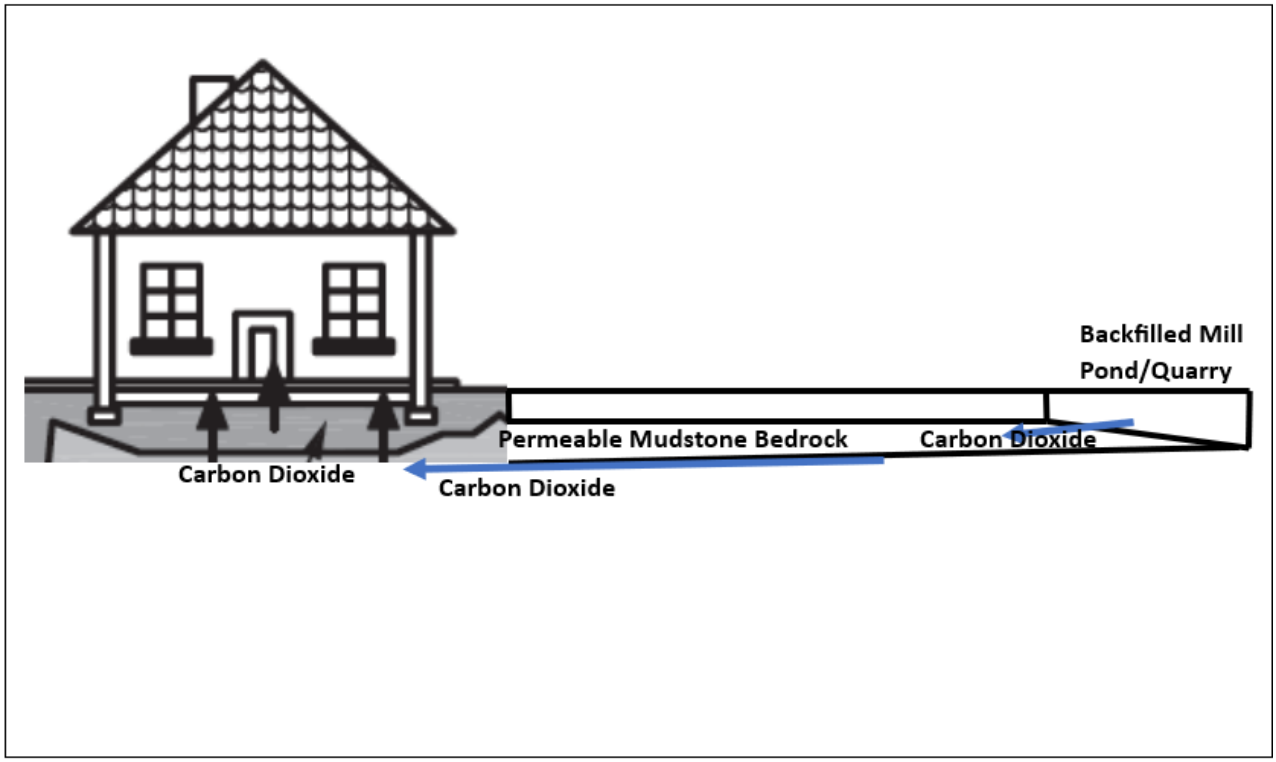
Using Table 2 from BS8485:2015+A1:2019, the site GSV of 0.159l/hr classifies it as having a ‘Low’ Hazard Potential, with a CS value of CS2.

Using Table 3 from BS8485:2015+A1:2019, the site can be defined as being building type 'Type A', which is defined as being a private building, with conventional building constructing.

Using Table 4 from BS8485:2015+A1:2019, the gas protection score by CS and type of building, for this site is: 3.5, which means some gas protective measures are necessary.

Figure 5.1 below shows the diagrammatic conceptual site model.

Figure 5.1 Conceptual Site Gas Model



It is recommended that a retrospectively fitted Carbon Dioxide Gas Barrier (to standard CS2) is installed during construction. This should include a pressure relief system or sub-floor void venting, with the capacity to achieve the minimum 3.5 gas protection score required.

5.3 Ground Water

During the Intrusive Investigation and the following six gas monitoring visits, no groundwater was encountered. It is likely that groundwater exists at a deeper depth within the bedrock. Therefore, it is not likely that groundwater will have an effect on proposed foundations, sub-structures or any ground gas regime.

6.0 PRELIMINARY GEOTECHNICAL RECOMMENDATIONS

6.1 Foundations

The windowless sample boreholes refused at depths from 1.50mbgl to 1.80mbgl across the site, on bedrock. It is recommended that for the new block of flats that foundations are placed onto this bedrock, where an allowable bearing pressure in excess of 150kPa could be achieved.

All foundation excavations must be inspected to ensure that no footings are placed upon any existing weak Made Ground, softer materials, or any other weak materials that would be incapable of safely sustaining the applied foundation loads. This is particularly important wherever any appreciable amounts of Made Ground occur. Additionally, all foundation excavations should be inspected to confirm that the proposed bearing stratum is rid of any largely clayey spots and is uniformly compacted.

Wherever any suspect Made Ground is encountered at proposed foundation level, then that footing must be deepened until a satisfactory bearing medium is obtained.

6.2 Buried Concrete

Three samples of the underlying soils were tested for pH and Sulphate Content, with measured pH values of 7.2 to 7.8 and water soluble sulphate measurements of 11mg/l to 29mg/l. A design sulphate class of DS-1 can be adopted along with an ACEC class of AC-1 can be taken for this stratum, after BRE Special Digest 1:2005, Concrete in aggressive ground.

6.3 Excavations

For any deep excavation in excess of 1.20m where vertical sides are necessary, the sides are expected to be largely across the site due to the clayey soils.

7.0 GROUND CONTAMINATION – GENERIC QUANTITATIVE RISK ASSESSMENT

The following assessment was performed in the context of the planning regime and considering Part 2A of the Environmental Protection Act (1990) to determine if unacceptable risks to humans, vegetation or to specific parts of the wider environment are present on the site. The risk assessment follows the source, pathway, receptor methodology, as described in Contaminated Land Report (CLR) 11, which is used to build a conceptual site model to determine the presence of any pollutant linkages at the site. Should pollutant linkages exist at the site it is deemed necessary to further develop the risk assessment by comparing contamination test results with generic or site-specific assessment criteria in order to determine if an unacceptable level of risk is present at the site. If legislation or guidance changes, or the proposed end use is modified, then it will be necessary to reassess the risks which may require further sampling and testing.

We understand our brief to comprise the following items related to the contamination aspects of this investigation.

- Compare laboratory test results with generic assessment criteria;
- Determine a conceptual site model and identify any pollutant linkages at the site;
- Determine the level of risk posed by environmental hazards on site to human health, vegetation, controlled waters and structures; and
- Make recommendations for further work or remediation strategies.

Soil samples were recovered in accordance with current industry practice and were sent to i2 Analytical Ltd to be analysed for the determinants listed in section 4.4 of this report.

The results of these analyses are included in Appendix C of this report.

7.1 Human Health Assessment

UK guidance recommends that a risk-based approach is taken for the assessment of contaminated land and as such, DEFRA have introduced the CLEA methodology, SGV's and Category 4 Screening Values (C4SL). The CLEA methodology is a deterministic risk assessment model that estimates the long-term

exposure to contaminants in the soil for children and adults and predicts the amount of contaminant to which a person might be exposed based on a given soil concentration. By comparison with relevant health criteria on tolerable or acceptable intakes of various contaminants the model was used by DEFRA and the Environment Agency to generate SGV's and C4SL's.

At the time of writing this report the DEFRA and Environment Agency has not published SGV's/C4SL using the CLEA 1.071 software for all anthropogenic toxic substances with C4SL's for further contaminants due to be produced at some point in the future. As such, it was necessary to use other methods to generate target concentrations for contaminants of concern on site.

In order to generate generic assessment criteria which are protective of human health, for use in human health risk assessment, where CLEA SGV's and C4SL's are not available the Environment Agency recommends the use of the CLEA 1.071 software in conjunction with advice found on the GOV.UK CLEA web pages. Accordingly, the Chartered Institute of Environmental Health (CIEH) in partnership with Land Quality Management (LQM) derived a set of Generic Assessment Criteria Values following the approach set out in the DEFRA research project SP1010, C4SL. The GAC for missing contaminants of concern were calculated using the CLEA 1.06 software released in July 2009 and termed Suitable 4 Use Levels (S4UL's). The input parameters used for calculating each S4UL value are listed in the substance specific chapters of the reference document associated with the S4UL's, namely 'The LQM/CIEH S4ULs for Human Health Risk Assessment (Land Quality Press, 2015). Where published UK guidance values are not available (I.e., for TPH), the results have been determined in-house using published toxicological data and UK government endorsed risk models.

The current view of the Environment Agency is that the C4SL's are considered to be a trigger value at which an exceedance may cause concern for human health and generally requiring further investigation and/or assessment.

The DEFRA C4SL and LQM/CIEH S4UL's for a residential with gardens land use has been selected as this matches the proposed future land use.

7.2 Vegetation Assessment

As the CLEA methodology only takes account of the risks to human health, a different approach is required to determine the risks to vegetation. In order to determine if levels of phyto-toxic contaminants in soil, not

normally considered to be harmful to humans, are suitable to maintain growth of vegetation the published reference values produced by the Ministry of Agriculture, Fisheries and Food (MAFF) have been used in this assessment.

8.0 DISCUSSION OF RESULTS

8.1 Human Health Hazards

In exploratory hole WS01 (located in the North East corner of the site) elevated levels of TPH, Benzo(a)anthracene, Benzo(b)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-c,d)Pyrene and Dibenzo(a,h)anthracene were measured in the Made Ground.

It is likely these contaminants exist due to it being in an area where cars and vehicles have been parked throughout the years of the site being used for a pub. Remedial measures will therefore be required in the proposed soft landscaped garden areas in the North East of the site.

Table 8.1 Comparison of Soil Test Results with Residential with Gardens C4SI/S4UL

Determinant	Assessment Criteria (mg/kg)		Recorded Concentrations Across The Site (mg/kg)	
	C4SL Screening Levels	S4UL Generic Assessment Criteria/RB Geotechnical Generic Assessment Criteria	Highest Recorded Value	Location of Highest Recorded Value and other Exceedances
Metals, semi- metals and non-metals				
Arsenic	37	37	7.8	WS03
Cadmium	17	11	<0.2	All
Copper	NC	2400	25	WS03
Chromium Total	NC	910	21	WS03
Lead	210	NC	72	WS03
Mercury (elemental)	NC	1.2	<0.3	All
Nickel	NC	130	41	WS02
Selenium	NC	250	<1.0	All
Zinc	NC	3700	120	WS03
PAH (total)	NC	NC	123	WS01
TPH (total)	NC	150-550(4)	330	WS01
Naphthalene	NC	1.5	1	WS01
Acenaphthylene	NC	170	0.24	WS01
Acenaphthene	NC	210	2.4	WS01
Fluorene	NC	170	1.8	WS01
Phenanthrene	NC	95	17	WS01
Anthracene	NC	2400	4.6	WS01

Determinant	Assessment Criteria (mg/kg)		Recorded Concentrations Across The Site (mg/kg)	
	C4SL Screening Levels	S4UL Generic Assessment Criteria/RB Geotechnical Generic Assessment Criteria	Highest Recorded Value	Location of Highest Recorded Value and other Exceedances
Fluoranthene	NC	280	23	WS01
Pyrene	NC	620	20	WS01
Benzo(a)anthracene	NC	7.2	10	WS01
Chrysene	NC	15	9.6	WS01
Benzo(b)fluoranthene	NC	2.6	11	WS01
Benzo(k)fluoranthene	NC	77	4.2	WS01
Benzo(a)pyrene	3.2	2.2	8.7	WS01
Indeno(1,2,3-c,d)Pyrene	NC	2.3	3.8	WS01
Dibenzo(a,h)anthracene	NC	0.24	1.1	WS01
Benzo(g,h,i)perylene	NC	320	4.4	WS01
Others				
Cyanide (total)*	NC	5	<1	All

NOTES:
(1) C4SL/LQM S4UL 2015 for Residential with gardens land use scenario at 1% organic matter content
(2) *= Dutch Target value used as screening value for cyanide.
(3) NC = No criterion.
(4) Limit based on CCME sum of C10-C34 (for most conservative screening value). Includes $C_{10} – C_{16}$ limit = 150mg/kg (worst case minimum value) and $C_{16} – C_{34}$ = 400mg/kg. Only for use as preliminary screening value, where hydrocarbons not suspected. If TPH>150mg/kg the value will be assessed in addition to levels of other related inorganics from the same sample, to establish if further assessment is necessary.

8.2 Vegetation Hazards

The concentrations of the various phytotoxic contaminants encountered in the shallow soils indicate that no elevated levels of heavy metals exist across the site.

Table 8.2 Soil Test Results Vs Phyto-Toxic Chemical Assessment Criteria

Determinant	MAFF Reference Value (mg/kg)		Recorded Concentrations Across Sampled Area (mg/kg)	
	Maximum Permissible Concentration		Highest Recorded Value	Location of Highest Recorded Value
	pH 5.0-5.5	pH >7		
Metals and semi- metals				
Arsenic	50	NL	7.8	WS03
Copper	80	200	25	WS03
Nickel	50	110	41	WS02
Zinc	200	300	120	WS03
Cadmium	3	NL	<0.2	All

Lead	300	NL	72	WS03
Selenium	3	NL	<1.0	All

NOTES: (1) NL = indicates that no level has been set

9.0 CONCEPTUAL SITE MODEL

9.1 Introduction

The information obtained from this investigation has been collated and evaluated to develop a refined Conceptual Model for the site.

The site has been assessed in line with current UK guidelines, namely the Contaminated Land (England) Regulations 2000 and Part IIA of the Environmental Protection Act 1990 and follows the procedures set out in the Environmental Agency 'Model Procedures for the Management of Land Contamination – Contamination Land Report (CLR).11'.

CLR.11 provides the technical framework for structured decision making about land contamination and builds on previous work carried out under the Contaminated Land Research Programme of the former Department of the Environment. CLR 11 has adopted and refined the methodology and terminology that has been used in contaminated land risk assessment for a number of years.

CLR.11 defines the three essential elements to any risk:

- A contaminant **source** - a substance that is in, on or under land and has the potential to cause harm or to cause pollution of controlled waters;
- A **receptor** – in general terms, something that could be adversely affected by a contaminant, such as people, an ecological system, property or a water body; and
- A **pathway** - a route or means by which a receptor can be exposed to or affected by a contaminant.

Each of these elements can exist independently, but they create a risk only where they are linked together, so that a particular contaminant affects a particular receptor through a particular pathway. This kind of linked combination of source-pathway-receptor is described as a **pollutant linkage**.

This report presents a Phase 2 Conceptual Model and Quantitative Risk Assessments for the site, based on the proposed conservative end use of residential with home grown vegetables.

9.2 Hazard Identification

9.2.1 Potential Contamination Sources

Historically the site has been used a pub with car parking area. It was therefore established that a possible risk of soil contamination exists due to potential fuel/oil leaks due to this historical land use.

Additionally, offsite infilled land features were identified which could create off-site sources of ground gas.

A summary of potentially significant sources of contamination encountered are presented in Table 9.1.

Table 9.1 Summary of Contaminant Sources & Contaminants

Structure / Process	Contaminants Present on Site
TPH contamination due to Made Ground and possible fuel leaks.	• Elevated levels of TPH, Benzo(a)anthracene, Benzo(b)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-c,d)Pyrene and Dibenzo(a,h)anthracene were measured.
Offsite infilled land features	• Elevated levels of Carbon Dioxide and Flow Rate.

9.2.2 Potential Receptors

The following are considered as potential receptors in relation to the current and proposed use of the site.

- **Future Residential users** – Female child aged 0-6 years using communal gardens;
- **Utility / Construction / Demolition / Site Investigation workers** – Workers undertaking routine / non-routine work involving ground disturbance works and maintenance of below ground services (assuming workers are only wearing standard construction / utility worker PPE);
- Underlying **Secondary A Aquifer** – Underlying bedrock
- **New potable water supply pipes**
- **Ingress of ground gases into structures**

9.2.3 Potential Contamination Pathways

The following are considered plausible contamination pathways given the nature of the site and the potential contaminative sources identified, and assuming a continued current use.

- Dermal contact and ingestions of soils;
- Inhalation of dust/fibres and vapours;
- Ingestion of home grown produce; and
- Risk from ground gases, asphyxiation or explosion.

9.2.4 Quantitative Risk Assessment

By considering the sources, pathways and receptors, an assessment of the environmental risks is made with reference to the significance and degree of the risk. This assessment is based on consideration of whether the source contamination can reach a receptor and hence whether it is of major or minor significance.

An initial conceptual model of the source-pathway-receptor linkages has been developed based on the information derived from the Phase I Desk Study and this intrusive investigation. The Conceptual Site Model has been used to identify Relevant Pollutant Linkages for the current and proposed end uses which have been assessed quantitatively and qualitatively using CIRIA 552 guidance, as described in Table 9.2 and Table 9.3.

Table 9.2 Methodology for Assessing Consequence of Harm

Consequence	Criteria
Severe	Short term (acute) risk to Human Health likely to result in "significant harm" as defined by the Environmental Protection Act 1990, Part IIa. Short term risk of pollution of sensitive water resource. Catastrophic damage to buildings / property
Moderate	Chronic damage to Human Health likely, over a long term, to result in "significant harm" as defined by the Environmental Protection Act 1990, Part IIa. Pollution of sensitive water resources
Mild	Health effects to Human Health that are unlikely to result in "significant harm" as defined by the Environmental Protection Act 1990, Part IIa. Pollution of non-sensitive water resources. Significant damage to crops, buildings, structures and services. Damage to sensitive buildings / structures / services or the environment
Negligible	Non-permanent health effects to Human Health that are unlikely to result in "significant harm" as defined by the Environmental Protection Act 1990, Part IIa. Those that are easily prevented by means such as personal protective clothing. Harm, although not necessarily significant harm, which may result in a financial loss, or expenditure to resolve.

Table 9.3 Methodology for Assessing Likelihood of Consequence Occurring

Probability	Criteria
Almost Certain	Circumstances are such that an event either appears very likely in the short term and almost inevitable over the long term or there is evidence of currently harm occurring
Likely	Circumstances are such that an event, whilst not inevitable, is possible in the short term and is likely to occur over the long term
Unlikely	Circumstances are such that it is possible an event could occur, but it is by no means certain to occur even over a longer period, and it is less likely in the shorter term
Very Unlikely	Pollutant linkage may be present, but the circumstances under which harm would occur are improbable even in the medium to long term
Extremely Unlikely	Pollutant linkage may be present, but the circumstances under which harm would occur are highly improbable even in the long term

The risk assessment table and apportioned scores presented in Table 9.4 are in general accordance with CIRIA 552. The main exception is that irreversible risks to human health are considered to have a severe consequence irrespective of whether the effects are chronic or acute in nature.

Table 9.4 Comparison of Consequence and Likelihood

Consequence / Probability	Severe	Moderate	Mild	Negligible
Almost Certain	Very High Risk	High Risk	Moderate Risk	Low Risk
Likely	High Risk	Moderate Risk	Moderate/ Low Risk	Low Risk
Unlikely	Moderate Risk	Moderate/ Low Risk	Low Risk	Very Low Risk
Very Unlikely	Low Risk	Low Risk	Very Low Risk	Very Low Risk
Extremely Unlikely	Very Low Risk	Very Low Risk	Very Low Risk	Very Low Risk

The categories of risk are defined as follows:

Very High Risk: There is a probability that severe harm is almost certain to arise to a designated receptor from an identified source, or there is evidence that severe harm to a designated receptor is currently occurring.

High Risk: There is a probability that severe harm is likely to arise to a designated receptor from an identified source, or there is a probability that moderate harm is almost certain to arise.

Low Risk: There is a possibility that harm could arise to a designated receptor from an identified source, but it is likely that this harm, if realised, would be mild at worst.

Very Low Risk: There is a very low possibility that harm could arise to the receptor, but it is likely that this harm, if realised, would be mild at worst.

In accordance with CLR11, professional judgement has been employed to evaluate the risk on a qualitative basis using available information.

A summary of the pollution linkages is provided in Table 9.5

Table 9.5 Conceptual Site Model

Source	Receptor	Pathway	Risk	Pollutants Encountered/Chemicals of Concern	Remedial Option(s)/Next Steps
On Site: Elevated levels of TPH, Benzo(a)anthracene, Benzo(b)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-c,d)Pyrene and Dibenzo(a,h)anthracene **Off Site:** Elevated levels of Carbon Dioxide and Gas Flow	Residential Homeowners	• Dermal contact or ingestion contaminants in soil-derived dust and entrained surface water run-off from areas where soil is exposed at the surface or where excavation takes place and in shallow groundwater in the natural strata if excavation takes place below the water table. • Inhalation of contaminants in soil derived dust from areas where soil is exposed at the surface of where excavation takes place. • Inhalation of soil and water derived vapours and ground gas outdoors • Inhalation of soil derived, and water derived vapours and ground gas indoors where it may have accumulated in buildings and enclosed spaces.	Moderate/Low	Elevated levels of TPH, Benzo(a)anthracene, Benzo(b)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-c,d)Pyrene and Dibenzo(a,h)anthracene	Elevated levels of a range of contaminants were identified in the Made Ground of WS01.m This is in an area of proposed soft landscaping and therefore remedial measures will be necessary. These remedial measures are likely to take the form of the removal of all Made Ground soils and replacement with a clean imported sub-soil and topsoil.
	Construction Workers		Low		
	Groundwater within the underlying superficial soils and bedrock	• Leaching of contaminants and/or migration of free phase contaminants from the unsaturated zone soils to groundwater in the natural strata • Vertical migration of contaminants in shallow groundwater to deeper strata and aquifer.	Low	No Further Assessment Required	
	Surface Water	• Lateral migration of contaminants and/or migration of free phase contaminants present in the Made Ground via groundwater to surface water discharge • Lateral migration of contaminants and/or migration of free phase contaminants present in the Made Ground and entrained in surface water runoff	Low	No Further Assessment Required	
	Building	• Accumulation of soil and water derived vapours/and or ground gas in enclosed spaces	Moderate/Low	Elevated levels of Carbon Dioxide and Gas Flow	Elevated levels of Carbon Dioxide and Gas Flow encountered during gas monitoring assessment. Therefore some form of ground gas barrier or protection will be necessary for the new and development. Likely in the form of a Carbon Dioxide grade barrier along with voiding, in order to satisfy the conditions for a CS2 level gas risk.

	Potable Water Supply Routes	• Migration of contaminants into newly placed potable water supply routes	Low	No Further Assessment Required

9.3 Discussion of Risks

The risk assessment presented in the above sections and summarised within the CSM presented in Table 9.5 shows that Contaminant Linkages have been identified at the site from both on-site and off-site sources, in the form of contaminated soils and elevated levels of ground gas. The following sections provide a discussion of the environmental risks based on the ground investigation and laboratory data.

9.3.1 Human Health

Proposed residential property users

The ground investigation and laboratory testing showed that elevated levels of TPH, Benzo(a)anthracene, Benzo(b)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-c,d)Pyrene and Dibenzo(a,h)anthracene were measured in the proposed soft landscaped area in the North East corner of the site. Remedial measures will therefore be necessary here.

Therefore, the current risks to human health has currently been assessed to be **MODERATE/LOW**

Utility / Construction / Demolition / Site Investigation (i.e. Ground Disturbance) Workers

The probability of contact with contaminated soils increases for workers involved with ground excavation (e.g., during development, site investigation or maintenance works). However, due to the exposure time to contaminants on site and the assumption that appropriate PPE will be worn the risks to site operatives is considered **LOW**.

9.3.2 Aquifer

The risks to the underlying aquifer has been assessed to be **LOW.**

9.3.3 Surface Water

The risk of contaminants to controlled waters is considered to be **LOW**.

9.3.4 Potable Water Supply Pipes

No elevated levels of heavy metals were recorded. Therefore, the current risk to proposed new utility routes is **LOW**.

9.3.5 Buildings

Elevated levels of Carbon Dioxide and Gas Flow rates were measured during the ground gas assessment. Therefore, it is recommended that a ground gas barrier or protective measures are put in place during construction. These measures must be suitable to satisfy the conditions posed by a ground gas risk level CS2. This risk of ground gases into the new building are therefore considered to be **MODERATE/LOW**.

10.0 CONCLUSIONS

Potential on-site sources of contamination were considered a possibility due to the past use of the site as a pub with car parking, in addition to many off-site infilled land features resulting in possible ground gas risks.

An intrusive investigation was therefore carried out across the site comprising three Windowless Sample Boreholes and one hand dug trial pit, to allow for collection of shallow soil samples to be tested for a range of soil contaminants in addition to installation of ground gas monitoring standpipe to allow for a ground gas assessment.

Ground conditions were found to comprise Made Ground to depths of around 0.30mbgl, underlain by a highly weathered bedrock in the form of a silty gravelly clay, extending to depths of 1.50mbgl to 1.80mbgl, where the bedrock becomes more intact.

It has been recommended therefore that typical strip footings placed into the intact bedrock at depths from 1.50mbgl, should suffice for the new building, where an allowable bearing pressure in the region of 150kPa could be achieved.

Elevated levels of a range of soil contaminants were encountered in the shallow soils of WS01 (located in the North East corner of the site in an area of proposed soft landscaping). Therefore, some form of remedial measures will be necessary, likely requiring removal of the contaminated soils and replacement with a clean imported sub-soil and topsoil. A formal remediation strategy and validation report will be required for the site.

Elevated levels of Carbon Dioxide and Gas Flows were recorded during the ground gas monitoring assessment. The site was classified as being a ground gas risk of CS2. In order to satisfy the standards of this level of ground gas risk, some form of protective ground gas barrier will be required. The new ground gas protective measures will require validation by a suitably qualified professional.

11.0 RECOMMENDATIONS

Due to the presence of a range of soil contaminants in the North East corner of the site, soil remedial measures will be necessary. It is likely this will comprise:

- Excavation of all Made Ground soils in proposed soft landscaped areas;
- Replace with clean imported sub-soil and topsoil.

A detailed formal remediation strategy and validation report is required for the site.

Elevated levels of Carbon Dioxide and Gas Flow also means that some form of ground gas barrier is required to meet the standard necessary for a gas risk level CS2. Following installation of this gas barrier, a suitably qualified professional will be required to validate it to ensure it has been correctly installed.

12.0 REFERENCES

- BRE Special Digest 1:2005: Concrete in aggressive ground, BRE Construction Division
- BS 5930: (2015): Code of Practice for Site Investigation. British Standards Institution
- BS 10175: (2011): Code of Practice for the Investigation of Potentially Contaminated Sites. British Standards Institution
- BS 8485: (2015); Code of Practice for the Design of Protective Measures for Methane and Carbon Dioxide Ground Gases for New Buildings
- CIRIA Special Publication (2002) Construction over abandoned mine workings.
- CIRIA C665 (2007) Assessing risks posed by hazardous ground gases to buildings.
- CL:AIRE (2013) SP1010 – Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination
- DEFRA and Environment Agency (2004) Model Procedures for the Management of Land Contamination, R&D Publication CLR11.
- Environment Agency (2009) CLEA Software (Version 1.06) Handbook, Scientific Report SC050021/SR4
- Environment Agency (2009) Updated technical background to the CLEA Model, Scientific Report SC050021/SR3
- Environment Agency (2000) Secondary Model Procedure for the Development of Appropriate Soil Sampling Strategies for Land Contamination, R&D Technical Report P5-066/TR.
- Interim Advice Note 73/06 (2009) Design Guidance for Road Pavement Foundations, Draft HD25.
- Meyerhof, G (1957) The Ultimate Bearing Capacity of Foundations on Slopes, Proceedings of the 4th International Conference, Vol. 3, pp. 384 – 386.

- Ministry of Agriculture, Fisheries and Food (1998) Code of Good agricultural Practice for the Protection of Soil. MAFF Publications, London
- Nathanail, C.P., McCafferey. C., Gillett, A., Ogden, R.C., and Nathanail, J.F. (2015) The LQM/CIEH S4ULs for Human Health Risk Assessment. Land Quality Press, Nottingham.
- NHBC (2007) Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide are Present, Report Edition No. 4.
- NHBC (2008) Guidance for the Safe Development of Housing on Land Affected by Contamination.
- NHBC (2022) Part 4 Building Near Trees