

Proposed Lidl, Cross Keys Lane, Hoyland

Phase 2 Ground Investigation Report

Curtins Ref: 078794-CUR-00-XX-RP-GE-001-V01

Revision: V02

Issue Date: 23 December 2021

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Phase 2 Ground Investigation Report

Rev	Description	Issued by	Checked	Date
V01	Issue for information	CB	CB	23 December 2021
V02	Inclusive of Supplementary Investigation	ML	RA	23 December 2021

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Phase 2 Ground Investigation Report

Executive Summary

Appointment	In April 2021, Curtins were instructed by Lidl GB to undertake a Ground Investigation at site located off Cross Keys Lane, Hoyland, Barnsley. The site is centred at National Grid Reference (NGR) 35205 00470. It is proposed that the site will be developed as a Lidl store with associated car parking areas and landscape embankments. The proposed redevelopment plans are enclosed within Appendix A.
Current Site Status	The site is currently vacant. The site is grassed with a strip of vegetation including bushes and trees along the centre of the site running north south. The site is accessed via a single gate on the eastern site boundary.
Summary of Phase 1	A detailed review of the available historical mapping and other information for the site, was undertaken by GD Pickles Limited (GDP) in 2021 (1). Historical mapping included within the Phase 1 report indicates the site has primarily been used as agricultural land. The South Yorkshire Mining Advisory Service Report (2) indicates that the western part of the site is within the boundary of Rockingham Opencast Coal Mine. A review of available historical mapping and information including within the Phase 1 report indicates the following geological sequence underlying the site: • Made ground - quarry spoil/overburden on the western side of the site; • Superficial deposits – none identified. • Bedrock -Pennine Middle Coal Measures The GDP Phase I Environmental Site Assessment summarised the environmental site setting and developed a conceptual site model. The report identified five contaminant sources: soil contamination, groundwater contamination, off site sourced contamination, ACM's and ground gas. The identified human health risks from soil and groundwater were Low or Very Low. The ACM risk to end users and construction workers was classified as Moderate/Low. The ground gas risk was classified as moderate. The identified risk from soil to construction materials (aggressive ground) was classified as moderate.
Fieldworks Undertaken	A first phase of site investigation was undertaken on the 17th to 21st May 2021 comprised, two rotary boreholes, seven window sample boreholes (three installed with gas and groundwater monitoring wells), ten trial pits, three trial trenches and twelve dynamic probe holes. Selected soil samples were subjected to laboratory analysis and four return gas monitoring visits have been undertaken. A second phase was undertaken on the 26th and 27th October aimed at further information the ground profile and location of the high wall and comprised additional window sample holes, trial trenches and CPT testing.
Encountered Ground Conditions	Surface cover across the site was grass. Topsoil was found in all locations across the site, the topsoil was typically brown sandy gravelly clay. Gravel was medium sub angular to angular of shale. Made Ground on the west of the site (infilled opencast area) typically comprised red and black sandy gravel, variable thickness 0.0 to > 4.7m, underlain by clayey gravel of siltstone and mudstone (colliery spoil). The thickness of the made ground deposits varied spatially across the western side of the site. The base of the made ground was not identified during the site investigation. On the eastern side of the site Made Ground was not found beneath the topsoil layer. Superficial deposits were identified in WS103 to WS107, TP105, TP106, TP107, TP109, TP111, TT101, R101 and R102 in the first phase of works, and TT201, TT202, TT204 and TT205 in the second phase of works. The superficial deposits were typically described as light brown soft sandy gravelly clay. Weathered bedrock typically comprising mudstone sandstone and siltstone was encountered in WS103, WS105, WS107, TP107 and TP108 in the first phase of SI, and in TT203 in the second phase. Solid geology owing to the PMCM formation comprising mudstone and sandstone at depths ranging from 1.2 to 30 m bgl was encountered in R101, R102, TP105, TP107 and TP110 in the first phase of works, and WS201, WS203 and WS204 in the second phase. Perched water levels across the site were variable. Within the opencast backfill area shallow groundwater strikes were between 0.3 and 0.9 m bgl. Groundwater was not encountered in the shallow monitoring wells installed on the east of the site.
Environmental Laboratory Testing and	The environmental chemistry soil results have been compared with the General Assessment Criteria for soils with respect to human health against 'Commercial' thresholds with a SOM of 2.5%. With respect to the proposed end-use of the site. With respect to the proposed end-use of the site, no exceedances of the GAC were reported. Asbestos was not detected in any of the samples scheduled for asbestos testing. Due to the proposed nature of the proposed development (Lidl store with associated car parking) it is unlikely that site users will come into contact with soil at the site. There is low likelihood that the soils at the site will present an unacceptable risk to human health.

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Ground Gas Monitoring Results	The results from the ground gas monitoring from both phases are indicative of a CS1 scenario. The foundation solution selected will need to be taken into account when assessing the ground gas risks at the site.
Ground Contamination and Ground Gas Assessment	A Low risk rating has been proposed to commercial end users from made ground on site. A Low risk rating from asbestos inhalation has been proposed for commercial end users, construction workers and residents of adjacent properties. A Moderate/Low risk rating is proposed to residential end users associated with ground gases and mine gases. The risk to the sensitive Secondary A Aquifer, which underlies the is assessed as Low.
Geotechnical Assessment and Recommendations	Summary The presence of deep backfill material and mining legacy features, notably the highwall are key constraints to the proposed development. The made ground (opencast backfill area to the west and the made ground to east) is not considered a suitable founding stratum due to its inherent variability in composition and consistency. The superficial deposits encountered are predominantly described as soft. They have been encountered in limited thickness therefore limited testing has been undertaken on these deposits. The soft superficial deposits are compressible and therefore unsuitable as a founding stratum. Foundation Design To the eastern areas where shallow rock has been encountered, foundations solutions such as deep trench filled foundations, founded on bedrock or adoption of a ground improvement solution such as Vibro Stone Columns can be adopted. Within the western areas, subject to further ground investigations within the made ground, ground improvement solutions such as Vibro Stone Columns, Controlled Module Columns or Piled foundations can be adopted. Static cone penetration testing undertaken within the second phase of works, with 12 locations in the eastern part of the site, and 4 locations in the area of the highwall. The results of the CPT's support the above recommendations that Vibro Stone Columns are likely to be suitable. However, it is recommended that a specialist designer is consulted to confirm the detailed design of adopted ground improvement. Any ground improvements or deep foundations solutions must be designed by a suitably qualified and experienced ground improvement contractor/piling designer. Ground Floor Slabs Based on observation onsite together with the results of laboratory tests it is recommended that, ground floor slabs should be suspended. However, where ground improvement is utilised, it can be designed and installed to allow adoption of a ground bearing slab. Road and Pavement Design For detailed design the designer should assess the appropriate CBR value to be adopted based on the proposed formation level, determined following detailed design of proposed carriageways/hardstanding and (where applicable) the minimum Local Highway Authority requirements for carriageway construction thicknesses. The designer should take into account the nature of the deposits that will form the sub-formation to any proposed capping and subbase design. The predominantly cohesive nature of the shallow soils encountered is likely to be sensitive to seasonal changes and inclement weather. Any CBR value adopted in detailed design (including any values taken from the results appended to this report) must be confirmed on site at the time of construction through appropriate inspection and validation testing at the specific line and level of the proposed carriageway/hardstanding sub-formation. A suitable Earthworks Strategy must be adopted which details suitable validation testing methods and criteria. The Strategy should provide suitable process for dealing with the potential degradation of the sub-formation during periods of heavy rain or other inclement weather conditions (e.g. frost). Based on the current layout it is identified that the majority of car parking and external hard standing is within the fill areas to the west of the site. The potential for the backfill material to continue to settle is considered likely. Investigations to date have not conclusively confirmed the depth to bedrock however historic information (Section 3) suggests that that all exploratory holes in the area refuse between depths of c 3.5m and 7m depth. This accords with Curtins dynamic probing. Although the settlement potential of the fill will reduce over time differential settlement will be observed in this material owing to the varying thickness of the fill. Of note is the highwall in the centre of the site which is stepped where differential settlement may be most observed. However, the total potential differential settlement will be dependent on the thickness of fill and any proposed changes in loading through construction. It is recommended that the depth to bedrock within the fill is confirmed to confirm the likely settlement potential of the fill and the requirement for any additional mitigation with regards to long term settlement

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1.0 Introduction

1.1 Project Background

In April 2021, Curtins were instructed by Lidl GB to undertake a Ground Investigation at site located off Cross Keys Lane, Hoyland, Barnsley. The site is centred at National Grid Reference (NGR) 35205 00470.

It is proposed that the site will be developed as a Lidl store with associated car parking areas and landscape embankments. The proposed redevelopment plans are enclosed within *Appendix A*.

1.2 Scope of Services

A Phase 1 Preliminary Environmental Assessment providing an overview of the geo-environmental site setting has been undertaken by GD Pickles Limited.

A Phase 2 Ground Investigation Report (GIR) has subsequently been undertaken to address the findings of the Phase 1.

The GIR will be sufficient to support discharge of planning conditions relating to contamination and coal mining legacy and to support civil and structural design.

Specifically, the Phase 2 investigation and report are intended to provide:

- An assessment of the near surface and underlying ground conditions;
- Chemical analysis of soil data followed by human health risk assessment;
- Screening of environmental soil samples to obtain relevant waste codes for near surface soils;
- Geotechnical soils testing of the founding strata to assess its strength and to determine suitable grades of buried concrete;
- An updated coal mining risk assessment;
- Ground gas monitoring and risk assessment appropriate to the site's proposed end use;

Consideration of flood risk, ecology and archaeological issues are outside of the scope of this report.

2.0 Phase 1 Preliminary Site Assessment

2.1 Current Setting

Site use, location and description are shown below in *Table 2.1* and *Figure 2.1*.

Table 2-1 Site Details

Site Address	Cross Keys Lane, Hoyland, Barnsley S74 0PY (nearest postcode).
NGR	35205 00470
Area of Site	2.3 acres
Current Site Use and Description	The site is currently vacant. The site is grassed with a strip of vegetation including bushes and trees along the centre of the site running north south. The site is accessed via a single gate on the eastern site boundary.

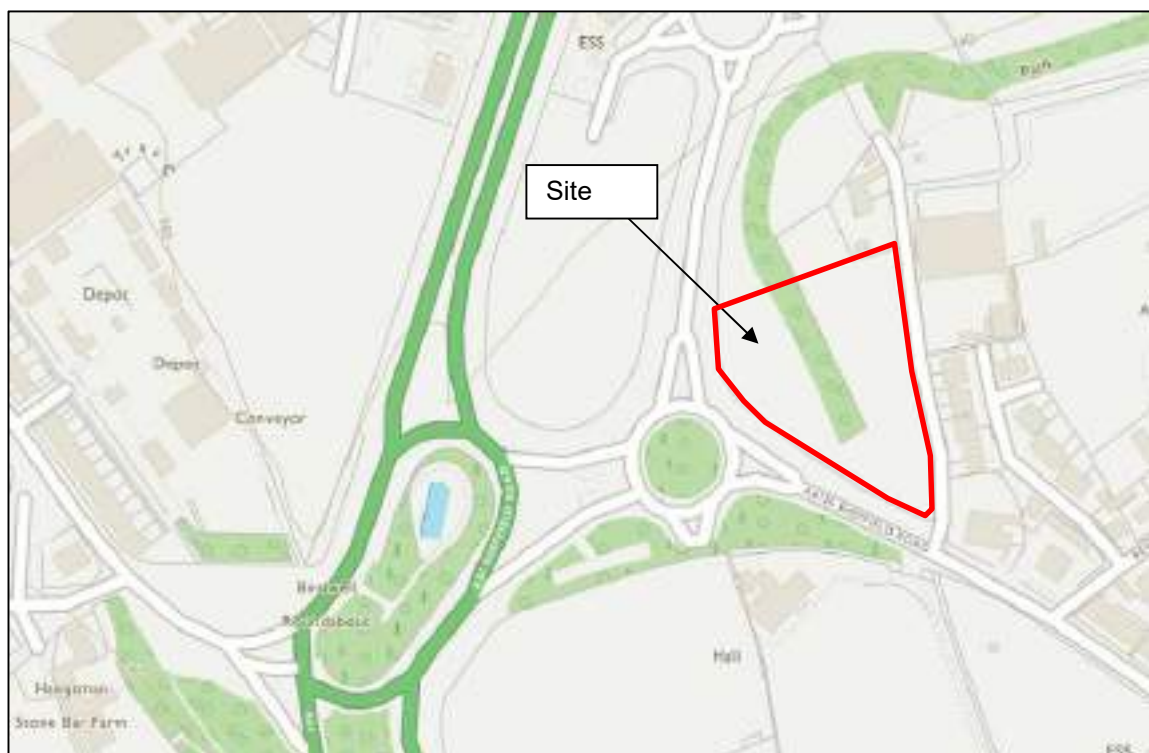


Figure 2.1 – Site Location Plan

Table 2-2 Surrounding Area

Surrounding Area	N	Residential properties and fields
	E	Cross Keys Lane, residential properties, lorry garage/scrap yard
	S	Sheffield Road, Rockingham Colliery Cricket Club
	W	Sheffield Road and the A6195

2.2 Previous Site Use

A detailed review of the available historical maps and other information for the site, was undertaken by GD Pickles Limited (GDP) in 2021 (1).

Historical maps included within the Phase 1 report indicates the site has primarily been used as agricultural land. The South Yorkshire Mining Advisory Service Report (2) indicates that the western part of the site is within the boundary of Rockingham Opencast Coal Mine. A plan of the site is included in Appendix A.

2.3 Geology and Hydrogeology

2.3.1 Geology and Hydrogeology

A study of the Groundsure Report (3) contained in the GDP report (1) and the British Geological Survey's (BGS) Geology of Britain Viewer (4) and The 1:50,000 scale BGS Map Sheet 87 'Barnsley', dated 2008 mapping records indicates the following geological and hydrogeological succession underlying the site:

Table 2-3 Geological/Hydrogeological Succession

Geology	Hydrogeological Classification
Made Ground	Associated Hydrogeological Classification
Reference to the Groundsure report indicates that Artificial/Made Ground is not present on site. However as noted in section 2.2 the western part of the site is located within the boundary of an opencast coal mine which has been subsequently backfilled with overburden/spoil.	Not Classified
Superficial Geology	Associated Hydrogeological Classification
None identified.	Not Classified
Bedrock Geology	Associated Hydrogeological Classification
Pennine Middle Coal Measures (PMCM) The eastern half of the site is underlain by a sandstone unit and the western half is	Secondary A Aquifer ¹ .

Geology	Hydrogeological Classification
underlain by mudstone and siltstone. To the west of the site a coal outcrop is indicated orientated approximately north to south which dips below the site.	

Notes:

1. These are permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.

The 1:50,000 scale BGS Map Sheet 87 'Barnsley', dated 2008 indicates the coal outcrop to the west of the site to be the Swallow Wood Coal which is indicated to be between 0.2 and 3.7m thick. The Swallow Wood Coal is underlain by the Haigh Moor (Kexbrough) Rock, a named sandstone unit between 0.0 and 28m thick. Further coal seams (Top Haigh Moor Coal, Haigh Moor Coal and Low Haigh Moor Coal) are indicated to be present within the lower part of the sandstone unit.



Figure 2.3 Map Extract from 1:50,000 scale BGS Map Sheet 87 'Barnsley', dated 2008

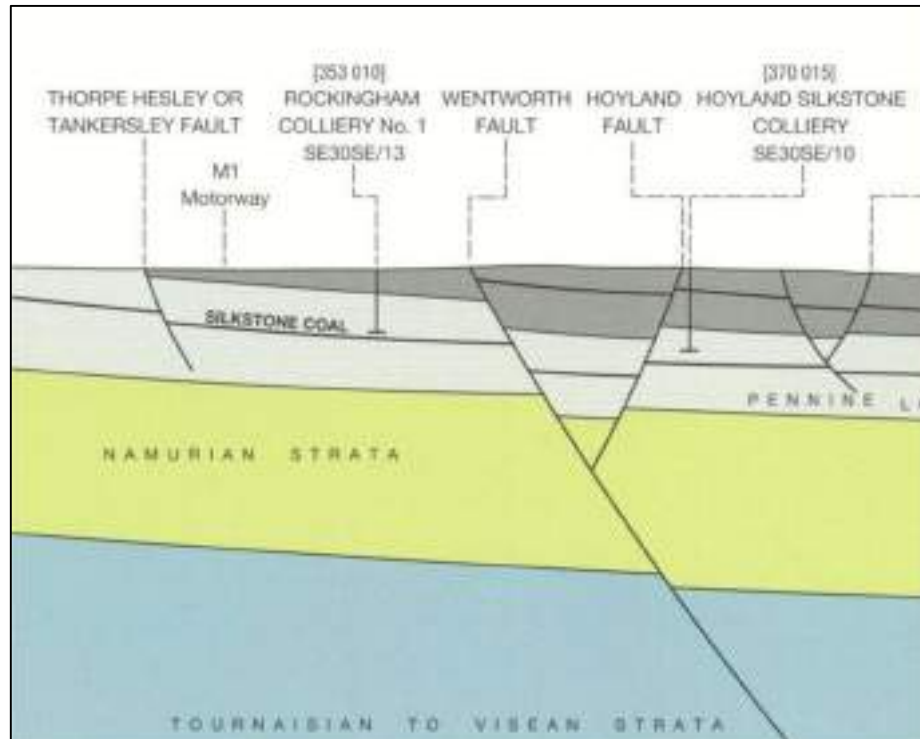


Figure 2.4 'Cross Section Showing The General Relationships of Rocks' extracted from Map 1:50,000 scale BGS Map Sheet 87 'Barnsley', dated 2008

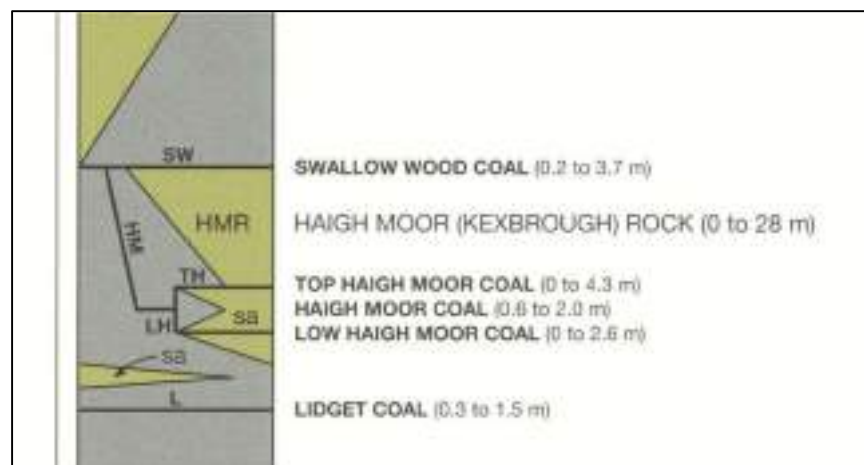


Figure 2.5 Vertical Cross Section from Map Extract from 1:50,000 scale BGS Map Sheet 87 'Barnsley', dated 2008

Approximately 100m to the southwest of the site a fault line is indicated, orientated northwest to southeast with the downthrown side to the southwest (As shown on Figure 2-3).

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The sandstone unit underlying the eastern part of the site overlays the Swallow Wood Coal. Therefore, the coal seam is likely to extend under the site, very likely the seam taken in the Rockingham opencast site up to the mapped high wall and possibly underground from there.

Mining and Quarrying

Information presented on the Coal Authority Interactive Web Viewer (5) indicates that the site is located within a Development High Risk area.

A Coal Authority mining report was obtained for the site as part of the Phase 1 Assessment undertaken by GDP (1).

Table 2-4 Summary of the Coal Authority Consultants Coal Mining Report

Detailed findings of Coal Authority Report	Does it affect the site
Past or present underground mining	Seven worked coal seams were present on site: • Lidgett (last worked in 1942) • Low Fenton (last worked in 1948) • Top Fenton (last worked in 1920) • Parkgate (last worked in 1885) • Middleton Main (last worked in 1904) • Silkstone (last worked in 1918) • Whinmoor (last worked in 1948)
Future underground coal mining	The property is not in an area where the Coal Authority has plans to grant a licence to remove coal using underground methods. The property is not in an area where a licence has been granted to remove or otherwise work coal using underground methods. The property is not in an area likely to be affected from any planned future underground coal mining. However, reserves of coal exist in the local area which could be worked at some time in the future. No notices have been given, under section 46 of the Coal Mining Subsidence Act 1991, stating that the land is at risk of subsidence.
Mine entries within 100m of the site boundary	There are no known coal mine entries within, or within 100 metres of, the boundary of the property.
Coal Mining Subsidence	The Coal Authority has not received a damage notice or claim for the subject property, or any property within 50 metres, since 31 October 1994. There is no current Stop Notice delaying the start of remedial works or repairs to the property. The Coal Authority is not aware of any request having been made to carry out preventive works before coal is worked under section 33 of the Coal Mining Subsidence Act 1991.
Mine Gas	The Coal Authority has no record of a mine gas emission requiring action within 500m of the site boundary.

Detailed findings of Coal Authority Report	Does it affect the site
Past, present or future opencast coal mining	The property is located within the boundary of a former opencast site 'Rockingham' from which coal has been removed by opencast methods. There are no current or future licence requests outstanding to remove coal by opencast methods within 200 metres of the boundary.

2.3.2 Other Ground Stability Issues

The Groundsure report (3) indicates that the hazards from shrink-swell clays, landslides, running sands, compressible deposits and collapsible deposits are very low and the hazard from ground dissolution of soluble rocks is negligible.

2.4 Land Gases

2.4.1 Landfill and Infilled Land

There is an Environment Agency historic landfill located 239m northwest of the site. There are two historic waste sites derived from local authority planning records located 285m northwest and 474m north.

As specified in section 2.3 the western half of the site (former opencast area) is infilled with spoil/overburden.

2.4.2 Radon

According to the Groundsure report the site is not in a Radon Affected Area as less than 1% of properties are above the action level. Radon protection measures are therefore not required as part of new dwellings or extensions. In the event a basement is to be incorporated in the proposed development the advice of a radon specialist should be obtained.

2.5 Hydrology

The closest surface water feature is a land drain 94m northeast located within the area of the former tip.

Reference to the Groundsure Enviro Insight report indicates the Site is not vulnerable to the risk of flooding from rivers and seas. Consideration of the potential risks from flooding fall outside the scope of this assessment.

2.6 Unexploded Ordnance (UXO) Risk Assessment

A Reference to the Zetica UXO Unexploded Bomb Risk Map (6) indicates the site lies in a Low Risk Area.

3.0 Existing Reports

As part of this assessment Curtins have been provided the following documents:

- GDP Phase 1 Environmental Assessment and Desk Based Coal Mining Risk Assessment Proposed Retail Development, Cross Keys Lane, Hoyland 2021.
- WSP Parsons Brinkerhoff Phase 1 Ground Conditions Report, no 70019822-001, Land at Rockingham Barnsley, March 2016 (available on the Planning Portal).

3.1 GDP Phase 1 Environmental Assessment and Desk Based Coal Mining Risk Assessment, 2021

The GDP Phase I Environmental Site Assessment summarised the environmental site setting and developed a conceptual site model. The report identified five contaminant sources: soil contamination, groundwater contamination, off site sourced contamination, ACM's and ground gas. The identified human health risks from soil and groundwater were Low or Very Low. The ACM risk to end users and construction workers was classified as Moderate/Low. The ground gas risk was classified as moderate. The identified risk from soil to construction materials (aggressive ground) was classified as moderate.

3.2 WSP Parsons Brinkerhoff Phase 1 Ground Investigation Report no 70019822-001, Land at Rockingham Barnsley, March 2016

The WSP Phase 1 report covers three plots of land, the area of relevance to the proposed Lidl store is Plot 3. The report summarises the site environmental setting, potential contaminated land constraints as well as potential ground engineering constraints. The report also includes borehole logs from the historic site investigations undertaken by Mott Macdonald in 2003 BH02 and BH04 located on the east of the site note depths of made ground 4.5 and 7.6 m bgl respectively.

4.0 Preliminary Conceptual Site Model & Qualitative Risk Assessment

The preliminary conceptual site model (PCSM) and Qualitative Risk Assessment (QRA) are presented in the table presented in this section.

The PCSM details the source-pathway-receptor linkages or potential pollutant linkages (PPL) that have been identified for the site. The QRA details the associated level of risk relating to these potential pollutant linkages.

The PCSM and QRA concern risk to human health and water environment with additional, more specific risk assessment protocols contained within the main body of this reporting, as detailed in *Section 4.1*.

The QRA follows the framework outlined within CIRIA C552 (7) which is summarised within *Appendix G*.

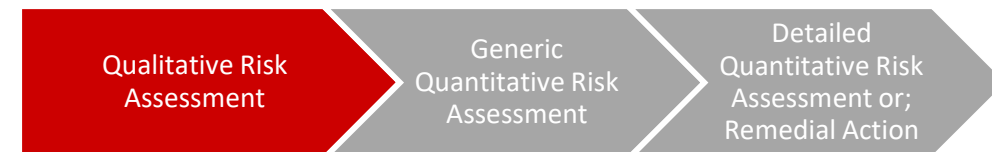
The 'risk rating' within the QRA refers to the risk that the source, pathway, receptor linkage or PPL is complete. Unless specifically stated it does not necessarily refer to an immediate risk and is intended to be used as a tool to assess the necessity for further assessment/investigation.

4.1 Additional Risk Assessments

The following risk assessments, listed below, are not included within the main CSM and QRA as they are not of relevance to this site. They have already been considered as listed below;

- The risk presented by Radon is discussed and assessed in *Section 2.4.2* and
- The risk presented by Unexploded Ordnance is discussed and assessed in *Section 0*.

Under current health and safety legislation, employers are required to carry out their own appropriate risk assessments and mitigation to protect themselves and their employees, other human receptors and the environment from potential contamination. Such risks must be adequately mitigated by law, specifically the Construction Design Management (CDM) Regulations (2015) (8), which require that potential risks to human health and the environment from construction activities are appropriately identified and all necessary steps taken to eliminate / manage that risk. It has been assumed that any future construction works on site will be undertaken in compliance with these requirements and therefore construction workers involved in the building works at the site.



- The table below represents the first stage in the land quality risk assessment process: The Qualitative Risk Assessment.
- For a development site to be deemed 'suitable for use', the level of risk needs to be brought down to acceptable levels, i.e. low to very low risk. The purpose of each stage of risk assessment is ultimately to establish, if there is a requirement for additional levels of assessment to be made to have sufficient confidence to support a risk characterisation or management decision, e.g. remedial action.
- In the absence of specific site data, a Generic Quantitative Risk Assessment is invariably recommended.

Conceptual Site Model			Qualitative Risk Assessment			Recommended Actions
Source	Pathway(s)	Receptor(s)	Consequence	Likelihood of Occurrence	Risk Rating	
Made Ground (colliery spoil and overburden)	Direct contact/ingestion/inhalation of contaminated soils and shallow/ surface groundwater	Site End Users Commercial	Medium Chronic health risk.	Unlikely	Low	Ground Investigation and Contamination Testing Generic Quantitative Risk Assessment.
		Construction and maintenance workers	Medium Chronic health risk.	Unlikely Standard Health & Safety precautions likely to be adopted by construction workers which will reduce likelihood of contact with contaminated soils.	Low	Construction Workers should be provided with appropriate PPE during all groundwork activities. Generic Quantitative Risk Assessment.
	Ingestion, inhalation of asbestos fibres	Site End Users Commercial	Medium Chronic health risk.	Low	Moderate/Low	Ground Investigation with Contamination Testing
		Construction and maintenance workers	Medium Chronic health risk.	Unlikely Standard Health & Safety precautions likely to be adopted by construction workers which will reduce likelihood of contact with contaminated soils.	Low	Construction Workers should be provided with appropriate PPE during all groundwork activities. Generic Quantitative Risk Assessment.
		Residents of adjacent properties	Medium Chronic health risk.	Low	Moderate/Low	Ground Investigation with Contamination Testing
	Horizontal and vertical migration of contaminants	Controlled Waters Surface Water Drain located 94 m to the north of the site	Mild Pollution of non-sensitive waters.	Low Given the distance from the site to the nearest surface water receptor	Low	Ground investigation to confirm no mobile/gross contamination in shallow soils
		Controlled Waters Groundwater Bedrock - Secondary A Aquifer	Medium Site is not located within a Source Protection Zone.	Low The underlying bedrock predominantly comprises mudstone which limits vertical migration of contaminants.	Moderate/Low	Ground investigation to confirm no mobile/gross contamination in shallow soils



Conceptual Site Model			Qualitative Risk Assessment			Recommended Actions
Source	Pathway(s)	Receptor(s)	Consequence	Likelihood of Occurrence	Risk Rating	
	Direct contact	Construction Materials	Medium	Low	Moderate/Low	Ground Investigation with aggressive ground testing.
	Horizontal and vertical migration of ground gas	Site End Users (Commercial)	Medium	Low	Moderate/Low	Ground gas monitoring under the building footprint.

5.0 Phase 2 Investigation Scope of Works

Site investigation works were undertaken on the 17th to 21st May and 26th to 27th October 2021.

The scope of the ground investigation was designed in general accordance with current UK guidance including the Environment Agency's Land Contamination Risk Management (9), British Standard (BS) 10175 (10), BS5930:2010 (11), and BSEN1997: Part 2:2007 Eurocode 7 (12). A summary of the scope and rationale are summarised in Table 5-1. Table 5-1 Scope and Rationale of Fieldwork

Table 5-1 Scope and Rationale of Fieldwork

Exploratory Hole Type	Exploratory Hole Ref.	Exploratory Hole Depth (mbgl)	Rationale
Rotary Boreholes	R101 R102	30 30	To investigate the eastern side of the site to identify the presence of voids or coal.
Window Sample Boreholes	WS101A WS101B WS102 WS103* WS104 WS105 WS106* WS107* WS201 WS202* WS203* WS204	0.7 0.9 1.8 1.94 1.2 1.3 2.0 2.2 1.6 2.6 2.6 2.4	To investigate ground conditions across the site. To obtain soil samples for environmental and geotechnical testing. Installation of gas monitoring wells.
Trial Pits	TP101 TP102 TP103 TP105 TP106 TP107 TP108 TP109 TP110 TP111	3.5 0.3 0.3 1.6 0.3 3.2 0.4 0.4 1.2 0.5	To investigate ground conditions across the site. To obtain soil samples for geotechnical and environmental testing. CBR Testing (selected trial pits).
Trial Trenches	TT101 TT102 TT103 TT201 TT202 TT203 TT204 TT205 TT206	5.0 4.7 4.7 2.0 4.0 4.0 1.5 1.5 0.3	To locate and investigate the highwall.
Dynamic Probe Hole	DP101 DP102 DP103 P101A P101B P101C	5.6 3.3 3.6 3.4 2.3 2.0	To investigate the depth of fill across the high wall zone, to investigate the depth of fill on the west of the site and to obtain geotechnical data to characterise the ground.

	P102A	3.9	
	P102B	2.3	
	P102C	2.2	
	P103A	2.8	
	P103B	3.0	
	P103C	2.2	
CPT Probes	CPT101	2.48	To inform potential ground improvement design
	CPT102	2.63	
	CPT103	2.22	
	CPT104	1.34	
	CPT104A	1.96	
	CPT105	1.05	
	CPT106	1.29	
	CPT107	2.78	
	CPT108	1.09	
	CPT108A	1.1	
	CPT109	1.78	
	CPT109A	1.34	
	CPT110	2.18	
	CPT110A	3.44	
	CPT111	2.37	
	CPT112	1.87	
	CPT112A	2.45	
	CPT113	2.29	
	CPT114	1.87	
	CPT115	2.31	
	CPT116	2.31	

Notes

*Installed as gas monitoring well

Bold denotes CBR Testing

Exploratory Hole Location Plan ref. 078794-CUR-00-XX-DR-GE-002 records the locations of the intrusive investigation, a copy of which is included within *Appendix A*.

5.1 Soil Logging and Sampling

Exploratory hole arisings were logged onsite by a qualified Engineer and in accordance with the requirements of BS5930 (11), including recording observed visual and olfactory indications of contamination. Exploratory hole logs for the rotary boreholes, window sample boreholes and trial pits are provided in *Appendix B*. Due to varying geology laterally across the trial trenches the trial trench logs are presented on cross section drawings, provided in *Appendix B*.

5.2 Monitoring Well Installations

Ground gas monitoring installations (50 mm diameter) were installed in three window sample boreholes (WS103, WS106, WS107) in the first phase of works, with a further two window sample boreholes (WS202 and WS203) installed in phase 2. A bentonite seal was placed above and below the screened section of the borehole to minimise potential for downward migration of contaminants and the creation of a preferential migratory pathway. A gravel surround was installed in the annulus between the sides of the borehole and the slotted sections of pipe.

A summary of the response zones is presented in *Table 5.2* on the following page.

Table 5-2 Monitoring Well Response Zones

Borehole Ref.	Response Zone(s) (m bgl)	Strata Description(s)
WS103	1.0 – 1.94	PMCM
WS106	1.0 – 2.0	Cohesive Superficial
WS107	1.0 – 2.2	PMCM
WS202	1.0 – 2.5	Made Ground
WS203	1.0 – 2.5	Made Ground

Copies of borehole logs can be referred to in *Appendix B* of this report.

6.0 Laboratory Analysis

Representative soil samples were selected for laboratory chemical analysis, based on field observations and to provide a characterisation of the Made Ground and natural strata encountered. Selected soil and groundwater samples were placed in laboratory provided containers and stored in cool boxes prior to being transported to the nominated laboratory under the laboratory's chain of custody documentation. The laboratory selected by Curtins for chemical and geotechnical analysis was i2 Analytical Laboratories (UKAS and MCERTS accredited).

Soil samples were recovered across all exploratory hole locations in a non-targeted, systematic array to give adequate and representative coverage of the site accounting for the historical site use, proposed end-use and the immediate environmental setting.

6.1 Soil Analysis

The soils were tested as per the environmental testing suite listed below in Table 6-1.

Table 6-1 Environmental Chemistry Analysis Suite: Soils

Suite Ref.	Analyte	LOD
Soils Suite A	Asbestos Screen, pH and Soil Organic Matter (SOM)	-
	Arsenic, Chromium, Chromium VI, Copper, Lead, Selenium, Zinc, Nickel	1 to 1.2 mg/kg
	Boron (water soluble)	0.2 mg/kg
	Cadmium	0.2 mg/kg
	Mercury	0.3 mg/kg
	Cyanide (total)	1 mg/kg
	Sulphate as SO ₄ (water soluble)	1.25 mg/l
	Total Phenols (screen)	1 mg/kg
	Speciated PAHs (USEPA 16)	0.05 to 0.1 mg/kg
	TPH CWG (Aro/Alk Split) including BTEX and MTBE	0.1 to 10 mg/kg
	Ammoniacal Nitrogen (NH ₃ & NH ₄)	0.5 mg/kg
	Cyanide (free)	1 mg/kg
	SVOCs	0.05 to 0.3 mg/kg
	VOCs	1 mg/kg

Ten soil samples were submitted for soils analysis (suite A). Two samples were also submitted for WAC (Waste Acceptance Criteria) testing to inform preliminary waste disposal options.

Copies of the environmental chemistry testing certificates are presented in *Appendix C*.

6.2 Geotechnical Analysis

Soil samples for testing were prepared in accordance with BS1377: Part 1:2016 (13) and representative sub-samples were taken for testing. The geotechnical tests carried out are listed in *Table 6.2*.

Table 6-2 Geotechnical Analysis: Soils

Test Type	Quantity
Moisture Content	8
Atterberg Limit (4 point)	6
Particle Size Distributions (Wet Sieve)	5
BRE Suite D	5
Compaction Testing	3

The results of the geotechnical testing are summarised in *Section 7.0*. Copies of the geotechnical testing certificates are presented in *Appendix D*.

7.0 Encountered Ground Conditions & Ground Model

7.1 General

A summary of the ground conditions encountered during the site investigation works is presented below, with detailed information presented in the exploratory hole logs included in *Appendix B*.

Due to anticipating a high wall, and the ground conditions encountered on site including the thickness of made ground identified on the western side of the site, the site has been divided into western and eastern sections, see drawing 078794-CUR-00-XX-DR-GE-001.

Table 7.1 – Summary of Ground Conditions Encountered (Western Part of the Site)

Stratum	Depth to top of strata (mbgl)	Thickness (m)		Description
		Min	Max	
MADE GROUND (TOPSOIL)	0.0	0.15	0.3	Brown sandy gravelly clay topsoil. Gravel medium sub angular to angular of brick and shale.
MADE GROUND (Colliery Spoil)	0.25	0.05*	4.7*	Red and black sandy gravel of shale.
MADE GROUND (Colliery Spoil)	0.15	Not present in some locations	3.2*	Clayey gravel of siltstone, sandstone and mudstone.

* Thickness not proven.

Table 7.2 – Summary of Ground Conditions Encountered (Eastern Part of the Site)

Stratum	Depth to top of strata (mbgl)	Thickness (m)		Description/Notes
		Min	Max	
MADE GROUND (TOPSOIL)	0.0	Not present in some locations	0.4	Brown sandy gravelly clay topsoil. Gravel medium sub angular to angular of shale.
CLAY	0.3	0.7	1.7	Yellowish brown soft gravelly clay.
PENNINE MIDDLE COAL MEASURES (Cohesive Natural Deposits)	1.0	-	28.3*	Mudstone, siltstone & sandstone
COAL	8.4	0.3		Only encountered in R102

* Thickness not proven.

7.2 Made Ground

7.2.1 Topsoil

Topsoil was encountered in all locations across the site, the topsoil was typically brown sandy gravelly clay. Gravel was medium sub angular to angular of shale.

7.2.2 Made Ground – Western side of the site

Made Ground on the west of the site (infilled opencast area) typically comprised red and black sandy gravel of shale with a variable thickness between 0.05 and > 4.7m, underlain by clayey gravel of siltstone, mudstone and sandstone.

The thickness of the made ground varied across the western side of the site. The base of the made ground was not identified during the site investigation.

CPT tests undertaken to the west of the highwall generally recorded a medium dense to dense sand.

7.2.3 Made Ground – Eastern side of the site

On the eastern side made ground was only encountered as topsoil to maximum depth of 0.4m bgl.

7.2.4 Summary of Geotechnical Results

A summary of the geotechnical test results recorded within the made ground are presented in Table 7-1. Full details of the geotechnical results recorded are presented on the exploratory hole logs in *Appendix B* and test result certificates in *Appendix D*.

Table 7-1 Summary of Geotechnical Test Results – Made Ground

Parameter	No. of tests	Minimum	Maximum	Average
In-situ Testing				
SPT 'N' Value Made Ground	2	21, >50		
Laboratory Testing				
pH	9	6	7.6	7
Water Soluble Sulphate (mg/l)	2	31, 38		
Moisture Content (%)	1	9.7		
Liquid Limit (%)	1	37		
Plastic Limit (%)	1	24		

Plasticity Index (%)	1	13
Modified Plasticity Index (%) ⁽¹⁾	1	7.02
PSD (%)	1	0
Cobbles		62
Gravel		23
Sand		10
Silt		5
Clay		

Due to highly variable nature of made ground and its unsuitable nature to act as a founding stratum, in its current conditions, no parameters have been derived for this stratum.

7.3 Superficial Deposits (Clay)

Superficial deposits were identified in WS103 to WS107, TP105 to TP107, TP109, TP111, TT101, R101 and R102 in the first phase of the investigation, then in TT201, TT202, TT204 and TT205 in the second phase of SI. The superficial deposits were typically described as light brown soft sandy gravelly clay.

7.3.1 Summary of Geotechnical Results

Table 7-2 Summary of Geotechnical Test Results – Clay

Parameter	No. of tests	Minimum	Maximum	Average
pH	5	5.5	6.8	6.2
Water Soluble Sulphate (mg/l)	2	14.9 & 18.2		
SPT 'N' Value – Clay	3	11, 14, 54		
Moisture Content (%)	5	17	23	20.6
Liquid Limit (%)	5	31	45	38.6
Plastic Limit (%)	5	21	24	22
Plasticity Index (%)	5	10	21	16.6
Modified Plasticity Index ⁽¹⁾ (%)	5	9.6	18.43	14.88

(1) Modified plasticity index is the plasticity of components <425 µm.

Three SPT 'N' values were recorded ranging between 11 and >50. The results are reflective of very soft to very stiff clays. The SPT of >50 is likely due to the presence of a gravel/cobble. The SPT 'N' values are variable at the equal depths therefore do not show spatial uniformity across the site with regards to strength.

Two SPT refusals were reported at WS104 1.2 m bgl and WS106 2.0 m bgl, these 'N' values were not included in any parametric analysis as it is anticipated these are refusals on rockhead.

An estimation of undrained shear strength (c_u) has been determined from the relationship between SPT 'N' values and the Plasticity Indices (PI), based on the equation by Tomlinson (14) as presented below:

$$C_u = SPT \ N \cdot F_1$$

Where:

C_u is the Undrained Shear Strength

N is SPT 'N' value

F₁ is the Stroud Factor

c_u values ranging from 71 to 325 kPa were estimated.

CPT tests undertaken within the second phase of works recorded a generally high to very high undrained shear strength, with occasional recordings of medium strengths.

An estimation of Modulus of Compressibility m_v has been determined using the following equation:

$$m_v = 1/F_2 \cdot SPT \ N$$

Where:

m_v is the Modulus of Compressibility

N is the SPT 'N' value

F₂ is the Stroud Factor

m_v values ranging from 0.03 to 0.135 m^2/MN were estimated. The results are of very low to medium compressibility.

The Drained Angle of Shearing Resistance (ϕ_d) for cohesive soils has been derived from the correlation with Plasticity Indices, after Gibson, 1953. The ϕ_d values are presented on Figure 7.4. A moderately conservative characteristic value of 29° is deemed suitable for the clay.

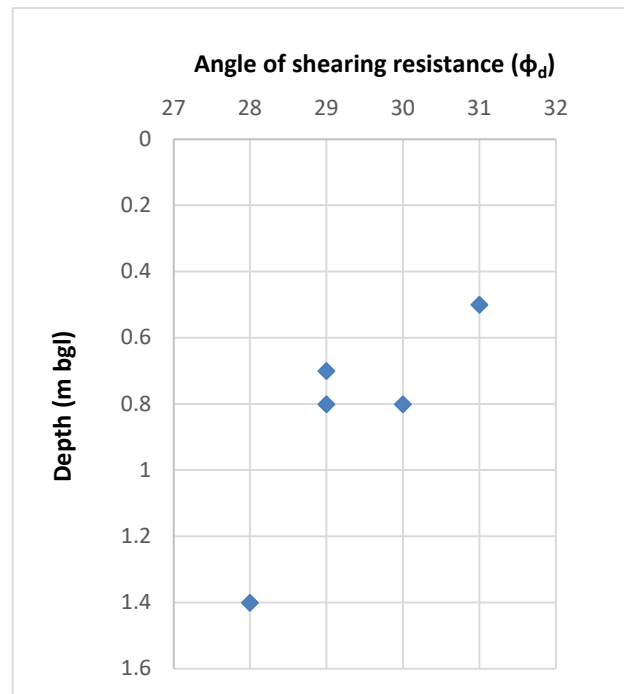


Figure 7.4 Angle of Shearing Resistance (Clay)

Following a review of published values, a moderately conservative unit weight, γ' , of 17-22kN/m³ (above the water table) and 19-24 (below the water table) has been deemed suitable.

7.4 Bedrock

Weathered bedrock typically comprising mudstone sandstone and siltstone was encountered in WS103, WS105, WS107, TP107 and TP108.

Solid geology owing to the PMCM formation comprising mudstone and sandstone at depths ranging from 1.2 to 30 m bgl was encountered in R101, R102, TP105, and TP107.

7.4.1 Summary of Geotechnical Results

A summary of the geotechnical test results recorded within the solid geology are presented in Table 7-3. Full details of the geotechnical results recorded are presented on the exploratory hole logs in *Appendix B* and test result certificates in *Appendix D*.

Table 7-3 Summary of Geotechnical Test Results – Solid Geology

Parameter	No. of tests	Values
pH	1	5.7
Water Soluble Sulphate (mg/l)	1	14.9
SPT 'N' Value ⁽²⁾	3	50, 50, >100

Parameter	No. of tests	Values
PSD (%)	2	0
Cobbles		62
Gravel		23
Sand		10
Silt		5
Clay		

(1) Modified plasticity index is the plasticity of components <425µm.

(2) Includes SPT refusals

7.5 Coal

Coal was identified in one location, R102 between 8.4 and 8.7 m bgl. Due to the limited thickness of the coal it is unlikely that coal workings underneath the site will affect the construction works at the site.

7.6 Classification Testing

Compaction tests were undertaken on three samples, the results are summarised in Table 7-4 below.

Table 7-4 Dry Density/ Moisture Content Relationship Results

Location	Depth	Optimum Moisture Content (%)	Maximum Dry Density Mg/m ³
TT101	2.00	16	1.77
TP105	0.7	17	1.77
TP110	0.5	8.1	2.09

7.7 Highwall Assessment

The position and nature of the highwall was investigated through dynamic probing and targeted trial pitting and trenching.

7.7.1 Dynamic Probing

Dynamic probing was undertaken in a total of twelve locations to a maximum depth of 5.6 m bgl. Three transects each of three dynamic probe holes (P101A-C, P102A-C and P103A-C) were located across the high wall to inform an assessment of the profile of the wall.

Three additional dynamic probes, DP101, DP102 and DP103 located on the western side of the site to further investigate the made ground, specifically the presence of boulders.

The depth to refusal of the dynamic probing is presented on *Figure 7.2* and the dynamic probing results are included as Appendix D2.

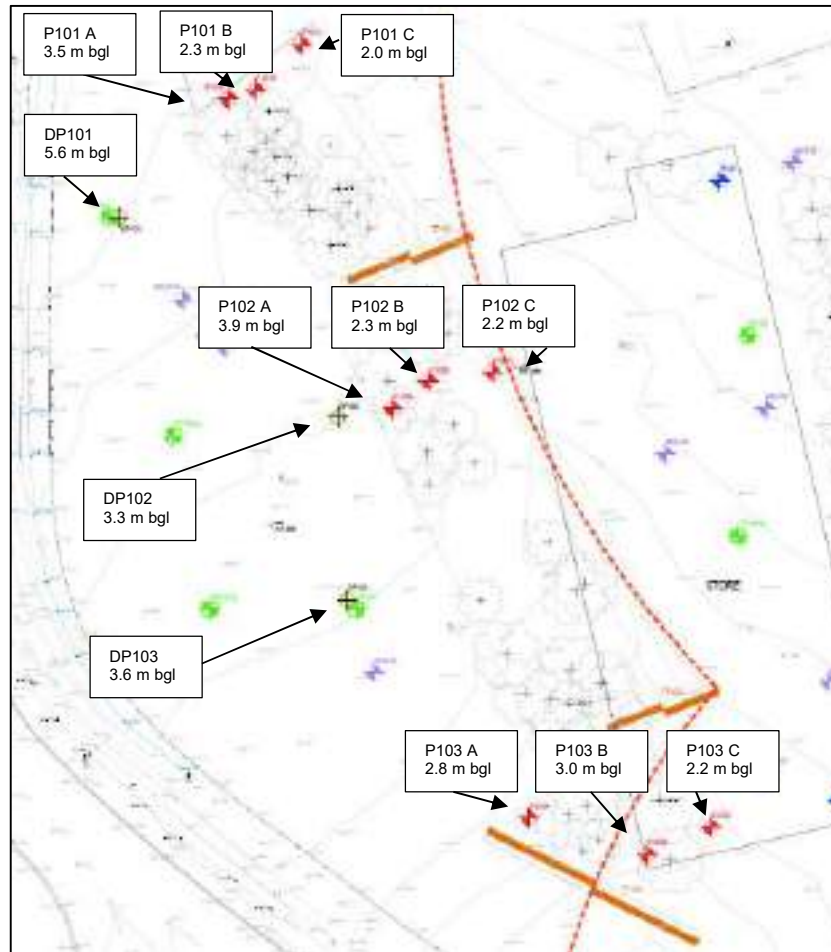


Figure 7.2 Dynamic Probe - Depth to Refusal Results

The dynamic probe results for P101A-C, P102A-C and P103A-C suggest rock comes in at between 2.0 and 4.0 m bgl (across the stepped high wall) deepening towards the west as shown on Figure 7.2.

Refusal depths observed in P101 are reflective of the stepped highwall observed in TT101. P102 and P103 off a less clear highwall profile with suspected refusals on boulders.

The dynamic probe results for DP101, DP102 and DP103 located on the western side of the site record refusals at 5.6, 3.3, and 3.6 m bgl respectively, these refusals are likely to be obstruction such as boulders. The CPTs undertaken in the western part of the site all refused between 2.18m and 3.44m bgl, with a medium dense to dense material reported up to refusal.

7.7.2 Trial Trenching

Cross sections of the stepped high wall are presented in Appendix B.

The stepped high wall was clearly visible in several trial trenches, however the stepped high wall was less evident in TT102 where a steep wall was encountered to the base of the trial pit. In the second

phase of ground investigation, the highwall boundary was further delineated, with TT201, TT202, TT204 and TT205 all positively identified the stepped highwall.

7.8 Observed Potential Contamination

No visual or olfactory evidence of contamination was identified during the site investigation.

7.9 Groundwater

A summary of groundwater and perched water levels recorded during the site investigation are presented in Table 7-5.

Table 7-5 Groundwater and Perched Water Noted During Site Investigation

Exploratory Hole Location	Water Strikes	
	Strike Depth (mbgl)	Strata
WS101A	0.3	Made Ground
WS101B	0.3	Made Ground
WS102	0.9	Made Ground
TT103	Groundwater seepage at 2.6 m bgl on the eastern side of the trench	Made Ground
TP101	Slight seepage from 1m	Made Ground
TP107	Water seepage from 3.1 m	Mudstone, siltstone and sandstone
TP110	Water strike at 0.8 m bgl	Mudstone

Groundwater strikes in the made ground are considered to represent perched water.

Four rounds of groundwater monitoring have been undertaken between 26 May and 25 June 2021, the results are presented in Table 7-6.

Table 7-6 Groundwater Monitoring Results

Borehole Ref.	Installation Strata	Response Zone (m bgl)	26/05/2021	03/06/2021	10/06/2021	25/06/2021
			Depth (mbgl)	Depth (mbgl)	Depth (mbgl)	Depth (mbgl)
WS103	PMCM	1 – 1.94	Dry	Dry	Dry	Dry
WS106	Cohesive Superficial	1 – 2.0	Dry	Dry	Dry	Dry
WS107	PMCM	1 – 2.2	2.03	Dry	Dry	Dry

No groundwater was recorded with WS202 and WS203 in the return monitoring visits following the completion of phase 2.

7.10 Aggressive Ground Conditions

The classification of the site in terms of concrete in aggressive ground is based on the guidance provided in Table C2 of the Building Research Establishment (BRE) Special Digest 1, third edition of 2005 (14). Table 7-7 details the classification.

Table 7-7 Aggressive Chemical Environment for Concrete (ACEC) Site Classification

Stratum	Design Sulphate Class	ACEC Class
Made Ground	DS1	AC-1
Clay	DS1	AC-1
Mudstone, siltstone and sandstone	DS1	AC-1

8.0 Ground and Groundwater Contamination Assessment

This section of the report includes the assessment of the potential contamination identified on the subject site which may present a risk to the proposed end-users, associated utilities and the wider environment.

In guidance published by the Environment Agency, the risk to human health or Water Environment is determined through an assessment of pollutant linkages between a source of contamination (within the ground or groundwater either on or off site) and a sensitive receptor such as end-users of the site, building materials, edible plants grown in gardens or groundwater abstracted for drinking. This is termed a source-pathway-receptor relationship. The same model is applied to the assessment of risk arising from ground gases as detailed within BS8576:2013 (15).

These models have a common approach, which is one of a tiered assessment. At each stage of the assessment further detail can be applied to the conceptual site model to provide a detailed interpretation on a site by site basis. As part of the planning process this approach is adopted to establish either if the site is 'suitable for use' or whether additional work or else remedial work is required for the site to be deemed so.

The sub-sections hereafter therefore incorporate the first tier (Tier 1) of this approach otherwise referred to as the Generic Quantitative Risk Assessment (GQRA). The GQRA builds on the qualitative risk assessment presented in Section 4.0 in conjunction with observations made during the ground investigation and is based solely on the results of the chemical and other testing data obtained as part of Curtins ground investigation. The GQRA is used to build/refine the Conceptual Site Model (CSM) for the site as detailed and presented in *Section 10.0* of this report.

The following sections present more detail on the risk assessment methodology rationale for the main receptors.

8.1 Human Health GQRA

Detailed guidance on human health risk assessment is available within several documents, published by both the Environment Agency and Defra. Guidance includes Contaminated Land Exposure Assessment (CLEA) v1.071 model (16), (Report SC050021/SR2: Human Health Toxicological Assessment of Contaminants in Soil (17) and Report SC059921/SR3: Updated Technical Background to the CLEA Model (18).

A generic quantitative risk assessment (GQRA) has been carried out for the Potential Contaminant Linkages (PCLs) investigated by screening of soil contamination data against relevant Generic Assessment Criteria (GAC) where available, including:

- i) **Soil Guideline Values (SGVs):** These have been published by the Environment Agency and are trigger values for screening out low risk areas of land contamination. SGV's give an indication of representative average concentrations of chemicals in soil, below which long-term health risks are likely to be minimal. SGVs have been published for several contaminants

including arsenic, cadmium, mercury, nickel, selenium, BTEX, phenols and dioxins, furans and dioxin-like PCB substances for land uses including residential, allotments and commercial. The SGVs have been developed for a sandy loam soil with 6% soil organic matter (SOM) content;

- ii) **Supplementary Screening Values (SSVs):** In addition to the SGVs developed by the EA, other third-party organisations have derived SSVs for a wider range of contaminants and land uses using the CLEA Model. Curtins have adopted these numbers where applicable, including those developed by Atkins AtriskSoil™, the LQM/CIEH Suitable for Use Levels (S4UL) and EIC/AGS/CL:AIRE published thresholds;
- iii) **Category 4 Screening Levels (C4SLs):** In March 2014 Defra published C4SLs for arsenic, benzene, benzo(a)pyrene, cadmium, hexavalent chromium and lead. These values were derived to support the revised Part 2A Statutory Guidance issued in 2012 (19) in which four categories of contaminated land are included, ranging from Category 1 (significant/high risk) to Category 4 (low risk). C4SLs are not representative of significant possibility of significant harm (SPoSH) and are low risk levels which, and therefore where the C4SLs are not exceeded, land can be demonstrated to be in Category 4 and cannot be determined as contaminated land.

8.1.1 Adopted Soil Human Health GACs Screening Methodology

It is anticipated that the end-use of the site be most analogous with a *Commercial* end-use scenario and so assessment has been undertaken against the following GACs, in order of preference:

1. Environment Agency Soil Guideline Values,
2. CL:AIRE, AGS, EIC. Soil Generic Assessment Criteria for Human Health Risk Assessments,
3. LQM/CIEH 2015 S4ULs for Human Health Risk Assessment, and
4. DEFRA Category 4 Screening Levels.

The soil organic matter (SOM) content has an influence on the sorption capacity of contaminants. Soil organic matter (SOM) values for the site soils (ranged from 0.4 % to 9.5%). The geometric average SOM of ten soil samples collected across the site is 2.96%. As such, a comparison against *Residential* end-use General Assessment Criteria SOM of 2.5% has been adopted. The adopted GAC's are listed in *Appendix F*.

8.1.2 Generic Assessment Criteria Screening of Soil Laboratory Results

The results of the environmental testing can be referred to in *Appendix C*.

With respect to the proposed end-use of the site, no exceedances of the GAC were reported.

8.1.3 Asbestos

Ten samples of were scheduled for asbestos identification.

Asbestos was not detected in any of the ten samples scheduled for asbestos testing.

8.1.4 Discussion of Human Health Assessment

No exceedances of the commercial GAC were identified. Furthermore, due to the proposed nature of the proposed development (Lidl store with associated car parking) it is unlikely that site users will come into contact with soil at the site, there is low likelihood that the soils at the site will present an unacceptable risk to human health.

8.2 Materials Management

8.2.1 Re-use of Site Soils

Based on the geochemical testing results presented as part of this investigation it is considered that there is no specific requirement to remove soils from site because of them presenting an unacceptable risk to human health or the environment.

The re-use of site-won soils may therefore be undertaken if the following principles are met:

- i) the geotechnical suitability of the material needs to be confirmed;
- ii) the re-use of the material needs to be covered as part of the planning approval, e.g. site levels maintained within agreed limits;
- iii) the volume of the material being re-used needs to be confirmed and traceable; and
- iv) regulatory approval from the relevant authorities has been sought.

These principles are outlined within the CL:AIRE Definition of Waste Code of Practice (v2) (20) and if and where the re-use of site-won soils is proposed as part of the development works it is recommended that a Materials Management Plan is produced in line with the Definition of Waste Code of Practice to detail and document the process.

8.2.2 Preliminary Waste Assessment

A preliminary Waste Soils Characterisation Assessment has been undertaken using CAT-WASTE Soil. This assessment was based on ten soil samples recovered be representative of the variable Made Ground strata encountered.

Table 8-2 below provides a summary of the waste screening.

Table 8-2 Preliminary Waste Assessment Summary

Hole ID	Sample Depth	Strata	WM3 Screen	Waste Code
TP110	0.3	Made Ground - Granular	Non hazardous	17 05 04
TP105	0.7	Clay	Non hazardous	17 05 04
WS102	0.1	Made Ground - Cohesive	Non hazardous	17 05 04
WS105	0.5	Clay	Non hazardous	17 05 04
WS107	0.15	Clay	Non hazardous	17 05 04
TT101	0.4	Clay	Non hazardous	17 05 04
TT102	1.5	Made Ground - Granular	Non hazardous	17 05 04
TP101	0.2	Made Ground – Cohesive	Non hazardous	17 05 04
TP101	0.35	Made Ground	Non hazardous	17 05 04
TP105	0.2	Made Ground	Non hazardous	17 05 04

Based on the above it is anticipated that the vast majority of soils removed from site would be considered non-hazardous (waste code 17 05 04).

The results presented herein and summarised above should be provided to the proposed waste carrier/receiver and should be considered preliminary. Landfill operators are not obliged to accept waste and may require additional testing above that provided here prior to classifying and or receiving the waste.

9.0 Ground Gas Assessment

The assessment of risk presented by ground gases is assessed with reference to guidance published by CIRIA (Assessing Risks Posed by Hazardous Ground Gases to Buildings, C665 (21), BSI Publication (Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings BS8485:2015 (22) and other broadly accepted references such as the Ground Gas Handbook 2009 (23).

The gas risk assessment adopts a tiered approach. In the first instance this involves a re-evaluation of the Conceptual Site Model described within *Section 4* and thereafter validating this conceptual model with the ground gas data, the semi-quantitative risk assessment.

9.1 Conceptual Site Model

The Conceptual Site Model presented within the Phase 1 Preliminary Site Assessment in *Section 4* identified potential ground gas sources associated with made ground, identified in the preliminary as a **Low** Risk, and potential sources of mine gas on site identified as **Moderate/Low** Risk.

The Curtins 2021 ground investigation identified made ground (colliery spoil/overburden) present from the centre of the site to the western site boundary.

9.2 Ground Gas Monitoring Results

To characterise the site's ground gas regime and validate the qualitative assessment of ground gas risk standpipe installations were incorporated within three borehole locations as detailed in *Section 5.2*.

Four gas monitoring visits were undertaken between 26th May and 25 June 2021 for the boreholes from the first phase, with barometric pressure recorded between 995 and 1002mb. Two further gas monitoring visits have been undertaken for the boreholes installed within the second phase, with barometric pressures ranging 1005 to 1006. The results log sheets are contained within *Appendix E* and summarised in Table 9-1:

Table 9-1 Summary of Ground Gas Monitoring Results

Borehole Ref.	Maximum CH ₄ Concentration (%)	Maximum CO ₂ Concentration (%)	Minimum Steady O ₂ Concentration (%)	Maximum gas flow (l/hr)	
				Peak	Steady State
WS103	<0.1	4.1	14.5	<0.1	<0.1
WS106	<0.1	3.2	15.6	<0.1	<0.1
WS107	<0.1	3.2	14.5	<0.1	<0.1
WS202	<0.1	1.6	16.3	<0.1	<0.1
WS203	<0.1	3.0	14.3	<0.1	<0.1

9.3 Ground Gas Assessment

The results from WS103, WS106 and WS107 are indicative of a CS1 scenario. WS202 and WS203 were installed in the made ground to the west of the highwall, as previous recommended, and the results are considered to be in accordance with the results from the first phase, with a CS1 classification still considered appropriate.

The foundation solution selected will need to be taken into account when determining the ground gas risks at the site.

The potential risks from ground gases to the excavations are to be dealt with by the Contractor, in accordance with the Confined Space Regulations, during construction. Appropriate ground gas monitoring and safety measures should be in place during the works, as the potential presence of ground gases could pose a risk in any confined spaces of deep excavations.

10.0 Revised Conceptual Site Model

The Preliminary Conceptual Site Model (PCSM) presented in *Section 4.0* of this report has been revised following the GQRA in *Section 8.0 and 9.0* above. The Revised Conceptual Site Model (CSM) is summarised in the table overleaf.

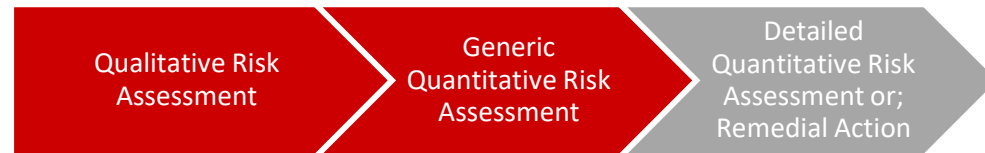
The CSM details the source-pathway-receptor linkages or potential pollutant linkages (PPL) that have been identified as relevant for the site. The GQRA details the associated level of risk relating to these potential pollutant linkages.

The CSM follows the framework outlined within CIRIA C552 (7) which is summarised within *Appendix G*.

The 'risk rating' within the CSM refers to the risk that the source, pathway, receptor linkage or PPL is complete. Unless specifically stated it does not necessarily refer to an immediate risk and is intended to be used as a tool to assess the necessity for further assessment/investigation.

Risks presented by Unexploded Ordnance are discussed and assessed in *Section 2.6*.

Under current health and safety legislation, employers are required to carry out their own appropriate risk assessments and mitigation to protect themselves and their employees, other human receptors and the environment from potential contamination. Such risks must be adequately mitigated by law, specifically the Construction Design Management (CDM) Regulations, 2015 (8) which require that potential risks to human health and the environment from construction activities are appropriately identified and all necessary steps taken to eliminate / manage that risk. It has been assumed that any future construction works onsite will be undertaken in compliance with these requirements. Reference should be given to the environmental testing results discussed within *Section 6.0* and presented within *Appendix C*.



- The table below represents the Second stage in the land quality risk assessment process; the Revised Conceptual Site Model following the Quantitative Risk Assessment.
- For a development site to be deemed 'suitable for use' the level of risk needs to be brought down to acceptable levels, i.e. low to very low risk. The purpose of each stage of risk assessment is ultimately to establish if there is a requirement for additional levels of assessment to be made to have sufficient confidence to support a risk characterisation or management decision, e.g. remedial action.
- In the absence of specific site data, a Generic Quantitative Risk Assessment is invariably recommended.

Conceptual Site Model			Qualitative Risk Assessment			Recommended Actions
Source	Pathway(s)	Receptor(s)	Consequence	Likelihood of Occurrence	Risk Rating	
Made Ground (colliery spoil and overburden)	Direct contact/ingestion/inhalation of contaminated soils and shallow/ surface groundwater	Site End Users Commercial	Medium Chronic health risk.	Unlikely No exceedances of GAC's were identified in the GQRA.	Low	No further action required
		Construction and maintenance workers	Medium Chronic health risk.	Unlikely No exceedances of GAC's were identified in the GQRA. Standard Health & Safety precautions likely to be adopted by construction workers which will reduce likelihood of contact with contaminated soils.	Low	Construction Workers should be provided with appropriate PPE during all groundwork activities.
	Ingestion, inhalation of asbestos fibres	Site End Users Commercial	Medium Chronic health risk	Unlikely No asbestos detected in the samples tested. Made ground backfill was colliery spoil, no evidence of material which would potentially contain asbestos.	Low	No further action required. Capping the made ground would remove the pathway and therefore remove the risk.
		Construction and maintenance workers	Medium Chronic health risk	Unlikely Standard Health & Safety precautions likely to be adopted by construction workers which will reduce likelihood of contact with contaminated soils.	Low	Construction Workers should be provided with appropriate PPE during all groundwork activities.
		Residents of adjacent properties	Medium Chronic health risk	Unlikely No asbestos detected in the samples tested. Made ground backfill was colliery spoil, no evidence of material which would potentially contain asbestos.	Low	No further action required. Capping the made ground would remove the pathway and therefore remove the risk.
	Horizontal and vertical migration of contaminants	Controlled Waters Surface Water Drain located 94 m to the north of the site	Mild Pollution of non-sensitive waters.	Low Given the distance from the site to the nearest surface water receptor. No contamination identified in the site investigation.	Low	No further action required.
		Controlled Waters Groundwater Bedrock - Secondary A Aquifer	Medium Site is not located within a Source Protection Zone.	Unlikely No contamination identified in the site investigation.	Low	No further action required.



Conceptual Site Model			Qualitative Risk Assessment			Recommended Actions
Source	Pathway(s)	Receptor(s)	Consequence	Likelihood of Occurrence	Risk Rating	
	Direct contact	Construction Materials	Medium	Unlikely	Low	No further action required.
	Horizontal and vertical migration of ground gas	Site End Users (Commercial)	Medium	Low	Low	

10.1 Summary of Pollutant Linkages

No exceedances of the commercial GAC were identified. Furthermore, due to the proposed nature of the proposed development (Lidl store with associated car parking) it is unlikely that site users will come into contact there is low likelihood that the soils at the site will present an unacceptable risk to human health. A **Low** risk rating has been proposed to residential end users from contaminated made ground on site.

Asbestos was not identified in the samples tested, a **Low** risk rating from asbestos inhalation has been proposed for residential end users and construction workers. However, if the site is capped with clean hardstanding, this pathway would be removed and therefore the risk from asbestos would be removed.

The initial ground gas monitoring results are indicative of a CS1 scenario and ground gas protection measures are not anticipated to be required; however this will need to be re assessed following the installation of an additional monitoring well under the building footprint and to the west of the high wall and follow up monitoring. A **Moderate/Low** risk rating is proposed to residential end users associated with ground gases and mine gases.

The risk to the sensitive Secondary A Aquifer, which underlies the site from leachable contamination in site soils through vertical and horizontal migration through the superficial deposits is assessed as **Low** as no contamination was identified during the site investigation.

11.0 Engineering Assessment and Recommendations

11.1 Introduction

This section will assess the relevant geotechnical issues for a proposed commercial development. The engineering assessment considers foundation design, bearing capacity, excavations, ground floor slabs and concrete design for the site. The structure proposed for the site is a single storey Lidl store as shown on the Proposed Site Plan in Appendix A. It should be noted that detail may change in the development of designs beyond the issue of this Phase 2 Report and the Construction Designer should satisfy themselves regarding the adequacy of their design and proposed approach to construction by reference to the on-going project design proposals, the site investigation information and their own examination of the site.

11.2 Summary of Ground Conditions

Based on a review of the readily available information and the ground investigation outcome, it is understood that the western part of the site forms part of an opencast coal mine which has been subsequently backfilled with colliery spoil/overburden. The ground conditions in the opencast backfill area generally comprised granular made ground. The western site has been separated from the eastern part, by a stepped highwall located to the centre of the site (running approximately north south) as identified partially during the ground investigation works.

The eastern part of the site the ground conditions generally comprised topsoil, underlain by cohesive superficial deposits and further by the solid geology of Pennine Middle Coal Measures.

Based on the current proposed development plans, included in Appendix A of this report, the majority of the building footprint is located within the eastern part of the site, however the southwest corner of the building is located over the highwall.

Perched water levels across the site were variable. Within the opencast backfill area shallow groundwater strikes were between 0.3 and 0.9 m bgl. Groundwater was not encountered in the shallow monitoring wells installed on the east of the site.

11.3 Foundation Design

It is understood that the proposed development is to consist of one single storey retail store.

The proposed foundations solution is dictated by the observed ground conditions.

The made ground (opencast backfill area to the west and the made ground to east) is not considered a suitable founding stratum due to its inherent variability in composition and consistency.

The superficial deposits encountered are predominantly described as soft. They have been encountered in limited thickness therefore limited testing has been undertaken on these deposits. The soft superficial deposits are compressible and therefore unsuitable as a founding stratum.

To the eastern areas where shallow rock has been encountered, foundations solutions such as deep trench filled foundations, founded on bedrock or adoption of a ground improvement solution such as Vibro Stone Columns can be adopted.

Within the western areas, subject to further ground investigations within the made ground, ground improvement solutions such as Vibro Stone Columns, Controlled Module Columns or Piled foundations can be adopted.

Within the second phase of ground investigation, Cone Penetration Testing was undertaken, with 12 locations in the eastern part of the site and 4 locations in the zones of the highwall. The results are considered to support the above recommendations of Vibro Stone Columns. However, it is recommended that a specialist designer is consulted for adoption of ground improvement solution.

Any ground improvements or deep foundations solutions must be designed by a suitably qualified and experienced ground improvement contractor/piling designer.

11.4 Ground Floor Slabs

Based on observation onsite together with the results of laboratory tests it is recommended that, ground floor slabs should be suspended. However, where ground improvement is utilised, it can be designed and installed to allow adoption of a ground bearing slab.

11.5 Road and Pavement Design

CBR values have been derived from plate load tests (455mm diameter) undertaken in five trial pits at depths between 0.3 and 0.5 m bgl, the average CBR value was 7.5 %. The results are summarised below in table 11-1. The CBR testing report is included as Appendix D3.

Table 11-1 CBR Testing Summary

Location	Depth (m)	Geology	Area of site	CBR Value %
TP102	0.3	Made Ground - Colliery Spoil	Car Park Area	17.7
TP103	0.3	Made Ground - Colliery Spoil	Car Park Area	11.5
TP106	0.3	Superficial Deposits	Store footprint	3.7
TP108	0.4	Superficial Deposits	Road	8.8
TP109	0.4	Superficial Deposits	Road	0.7

Location	Depth (m)	Geology	Area of site	CBR Value %
TP111	0.5	Superficial Deposits -	Road	2.7

For detailed design the designer should assess the appropriate CBR value to be adopted based on the proposed formation level, determined following detailed design of proposed carriageways/hardstanding and (where applicable) the minimum Local Highway Authority requirements for carriageway construction thicknesses.

The designer should take into account the nature of the deposits that will form the sub-formation to any proposed capping and subbase design. The predominantly cohesive nature of the shallow soils encountered is likely to be sensitive to seasonal changes and inclement weather.

Any CBR value adopted in detailed design (including any values taken from the results appended to this report) must be confirmed on site at the time of construction through appropriate inspection and validation testing at the specific line and level of the proposed carriageway/hardstanding sub-formation. A suitable Earthworks Strategy must be adopted which details suitable validation testing methods and criteria. The Strategy should provide suitable process for dealing with the potential degradation of the sub-formation during periods of heavy rain or other inclement weather conditions (e.g. frost).

Based on the current layout it is identified that the majority of car parking and external hard standing is within the fill areas to the west of the site.

The potential for the backfill material to continue to settle is considered likely. Investigations to date have not conclusively confirmed the depth to bedrock however historic information (Section 3) suggests that that all exploratory holes in the area refuse between depths of c 3.5m and 7m depth. This accords with Curtins dynamic probing.

Although the settlement potential of the fill will reduce over time differential settlement will be observed in this material owing to the varying thickness of the fill. Of note is the highwall in the centre of the site which is stepped where differential settlement may be most observed. However the total potential differential settlement will be dependent on the thickness of fill and any proposed changes in loading through construction. It is recommended that the depth to bedrock within the fill is confirmed to confirm the likely settlement potential of the fill and the requirement for any additional mitigation with regards to long term settlement.

11.6 Utilities

Similar to the consideration for external areas and pavement design proposed utilities placed within deep fill should consider the potential for ongoing and differential settlement.

11.7 Chemical Attack on Buried Concrete

See *Section 7.9*.

11.8 Excavation and Support

Given the mining legacy features encountered and the variable fill material it is recommended that all excavations on the west of the highwall should be considered unstable.

Any excavations progressed on the site should be undertaken in accordance with CIRIA (2001) Trenching Practice, 2nd Edition (report no. 97) (25) taking into account the ground conditions encountered on site. The temporary works designer is responsible for design of the temporary works and ensuring that the excavations remain stable throughout the period of the works. An experienced temporary works contractor must be consulted.

Perched water is likely to be encountered in shallow excavations.

11.9 Drainage

In the event that Soakaways are considered for the site these should not be located in areas of opencast backfill where the localised release of water may cause inundation settlement within the fill.

12.0 Environmental Conclusions & Recommendations

12.1 Conclusions and Recommendations

A revised tabulated revised Conceptual Site Model has been derived following the findings on the Generic Quantitative Risk Assessment risk assessment and is presented in *Section 9.0*.

12.1.1 Ground Contamination

Environmental testing indicates that there is low risk to future site users and low risk to controlled water receptors from levels of contaminants in the soils encountered as part of the ground investigation.

The risks from asbestos are low, no further actions are required, however capping and clean cover would eliminate the risk

The results from the ground gas monitoring are indicative of a CS1 scenario. The foundation solution selected will need to be taken into account when assessing the ground gas risks at the site.

It is recommended that construction workers are provided with appropriate PPE and sanitary facilities with reference to the environmental testing results presented herein.

It is recommended that a Materials Management Plan is produced if and where the re-use of site-won soils is proposed as part of the development works.

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