BROWNFIELD SOLUTIONS LTD

GEO-ENVIRONMENTAL ENGINEERING EXCELLENCE

BELLWAY HOMES LIMITED (NORTH WEST)

Lathom Pastures (Phase 2)

Geo-Environmental Assessment Report

TM/C4380/9070 Rev A

April 2020

EXECUTIVE SUMMARY	
Location and Brief Site Description	The site is located circa 2km west of Skelmersdale Town Centre and mostly comprises boggy, overgrown fields. Although largely featureless, the site is occupied by several mostly disused buildings, a storage yard in the centre and a series of greenhouses in the south-west. Potentially contaminative sources include two above ground storage tanks (ASTs), a suspected inspection pit and several locations where suspected asbestos cement sheets were present.
Ground Conditions	Natural topsoil was encountered across the majority of the site, typically underlain by variably clayey sands to circa 1.0mbgl over soft to firm slightly gravelly slightly sandy clays. Superficial sand was present to greater depths (typically 1.5m to 2.0m) in the south of the site and was underlain by a 0.1m thick layer of peaty sand and peat, before continuing onto soft clays interbedded with sands. Bedrock was encountered at approximately 2.0mbgl in the north-east, becoming gradually deeper to a maximum of 10.6m in the south-west and typically comprised light grey mudstone interbedded with sandstone, siltstone and coal seams. The Rushy Park Seam is between 0.40m and 0.70m thick beneath the site with an apparent dip of 7.4° to the south-east and was intact in every drilling location. Calculations indicate the subcrop of this seam is circa 50m east of the site. The Bone Mine seam is between 0.50m and 1.30m thick beneath the site with an apparent dip of 6.5° towards the south-east and evidence of workings was recorded in this seam between 16.00mbgl and 17.30mbgl in RO08.
Soil Contamination	Based on the testing undertaken, the soils are generally considered chemically suitable for use within a residential with plant uptake environment. A sample of made ground topsoil in the far south of the site was elevated with respect to lead and the made ground topsoil in this area frequently contained sharps (glass) as a gravel constituent and will not be suitable for re-use within the proposed residential development.
Ground Gas	Potential on-site sources of ground gases include coal seams and workings, made ground and natural organic soils. Based on the assessments made and the ground gas monitoring undertaken, the site is classified as NHBC Amber 1 based on the Boyle and Witherington methodology, and ground gas protection measures are required.
Outline Remedial Strategy	The made ground topsoil in the south of the site which is elevated in lead and frequently contains glass should be stripped and stockpiled separately prior to removal from the site. The ASTs should be removed and the suspected inspection pit subject to source removal in addition to any contents and soils grossly impacted with hydrocarbons, if encountered. Suspected asbestos cement sheeting found stacked in several areas of the site should be removed and disposed off-site to a suitably licensed facility. Gas protection measures are required in line with NHBC Amber 1. Further confirmatory intrusive investigations should be undertaken following demolition of the buildings and floor slabs occupying areas of the site. This should also include further investigation beneath the concrete slab housing the AST in the Mallinson land.
Waste	Based on the waste classification database assessment, the made ground and natural soils have been classified as non-hazardous.
Foundations and Floor Slabs	Subject to successful remediation of the shallow mine workings by drilling and grouting, the ground conditions across the majority of the site should be suitable for traditional shallow strip foundations bearing onto firm clay at a depth of 1.00m. An allowable net bearing capacity of 100kN/m^2 should be available across the Caruthers, Ramsbottom, Mallinson and Woods areas. The presence of compressible organic soils over soft clays to circa 2.50mbgl to 3.00mbgl in the southern areas of the site is likely to preclude the use of shallow foundations. Vibro stone columns are likely to be the most suitable option, although further intrusive investigation to obtain information on the ground conditions and geotechnical data is required.
Drainage	Due to the presence of shallow groundwater and the presence of impermeable clays underlying the site, the use of soakaway drainage is not considered feasible within the proposed development.

EXECUTIVE SUMMARY	
Mining Risk	In accordance with CIRIA C758 and the 10t criterion, the risk from potential coal mining has been determined and the site zoned into risk areas. Across the majority of the site, the risk to proposed buildings and structures is considered to be low, although a significant area of the site above the Bone Mine Seam is considered to be at moderate risk and drilling and grouting will be required to enable development in this area, defined as Risk Zone 3. A number of confirmatory rotary boreholes are recommended in Risk Zones 2 and 5 during the drilling and grouting phase to provide additional reassurances that treatment of potential workings is not required in these areas.

Further Work	• Supplementary Intrusive site investigations comprising:
	  ○ Trial pits and cable percussive boreholes in Mather & Blundell, Hurst and Peet Areas
	  ○ Trial pits within previously inaccessible building footprints and adjacent to ASTs
	• Demolition Asbestos survey.
	• Tree survey by qualified arboriculturist.
	• Detailed foundation design, including foundation zonation plan and depth schedule.
	• Design of Remedial Strategy and confirmation with the Local Authority and NHBC.
	• Design of drill and grout specification.
	• Production of Ground Gas Protection Measures Verification Plan, if required.
	• Production of Materials Management Plan (MMP) under the CL:AIRE DoWCoP, if required.
	• Implementation of the Drill and Grout Specification, and verification reporting upon completion.
	• Implementation of the Remedial Strategy and verification of the remedial works.

This executive summary should be read in conjunction with the full report, reference TM/C4380/9070 Rev A, and not as a standalone document.

PROJECT QUALITY CONTROL DATA SHEET

Site Name:	Lathom Pastures (Phase 2)		
Document Name:	Geo-Environmental Assessment Report		
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1.0 INTRODUCTION

1.1 Objectives

This report describes a Geo-Environmental Assessment carried out by Brownfield Solutions Limited (BSL) for Bellway Homes Limited (North West) on a site off Old Engine Lane, Lathom, Skelmersdale and has been completed in general accordance with the following guidance:

- CLR11 Model Procedures for the Management of Land Contamination.
- BS 10175:2011+A2:2017 Investigation of Potentially Contaminated Sites.
- BS5930: 2015 Code of Practice for Ground Investigations.
- BS EN 1997-1:2004+A1:2013 Eurocode 7. Geotechnical design. General rules plus UK National Annex.
- BS EN 1997-2:2007 Eurocode 7 Geotechnical design. Ground investigation and testing plus UK National Annex.

1.2 Objectives and Scope

The objectives of this Geo-Environmental Assessment were to determine the environmental setting and ground conditions of the site, highlighting potential risks and areas of concern that may govern the development under the current planning regime. This assessment is also intended to fulfil the requirements of a Ground Investigation Report (GIR) as detailed in BS EN 1997-2:2007.

Following the Desk Study, an exploratory intrusive investigation was undertaken to confirm the findings of the preliminary CSM and risk assessment and meet any objectives that had not been satisfied. The exploratory investigation was undertaken using trial pitting, window sampling, rotary drilling, gas and groundwater monitoring, laboratory chemical and geotechnical testing, with reporting on the findings.

1.3 Proposed Development

The proposed development is for a residential end use comprising approximately 196 traditional dwellings with access roads, private gardens and communal soft landscaping areas as shown on the proposed development plan, drawing No. BHNW117/SK01/P2 provided to BSL by the client.

1.4 Previous Reports

This report should be read in conjunction with Groundtech Consulting Limited Preliminary Environmental Risk Assessment (Ref. 19255/1167_1.1) issued in December 2019 and Waterco Flood Risk Assessment (Ref. 12832-Flood Risk Assessment-01) issued in January 2020.

In addition, there are a number of reports pertaining to the adjoining site to the west which was undergoing development at the time of writing. The client has provided BSL with the following which have been considered as part of this assessment:

- Coopers Consulting Engineers, Site Investigation Report for land at Firswood Road, Lathom, Skelmersdale, reference 6242si (Rev 1), dated October 2015.
- Coopers (Chester) Ltd, Outline Design and Specification for Treatment of Coal Workings beneath land at Firswood Road, Lathom, Skelmersdale, reference 6242ODS, dated October 2016.
- Coopers (Chester) Ltd Validation of Coal Mining Mitigation Works beneath Firswood Road, Skelmersdale, reference 6242vcm, dated February 2018.

1.5 Limitations

This assessment has been prepared in accordance with the relevant current legislative framework, guidance and risk assessment methodology as outlined in Appendix A. BSL is not liable for any subsequent changes in the guidance and legislation.

The findings and opinions conveyed via this report are based on information obtained from a number of sources as detailed within this report, BSL have assumed this information is correct and reliable. Nevertheless, BSL cannot and does not guarantee the authenticity or reliability of the information it has relied upon.

There may be other conditions prevailing on the site which are outside the scope of work and have not been highlighted by this assessment and therefore have not been considered by this report. Responsibility cannot be accepted for such site conditions not revealed by the assessment.

This report has been prepared for the sole use and reliance of the Client, Bellway Homes Limited (North West). No other third parties may rely upon or reproduce the contents of this report without the written permission of Brownfield Solutions Ltd (BSL). If any unauthorised third party comes into possession of this report, they rely on it at their own risk and BSL do not owe them any Duty of Care.

The investigation carried out on the site has been conducted to provide the best information on the ground conditions within site access and budgetary constraints. The inherent variation of ground conditions allows only for definition of the actual conditions at the locations and depths of exploratory locations at the time of the investigation. Different ground conditions may exist that have not been identified within this investigation.

The recommendations in this report assume that ground levels will remain as existing, unless stated otherwise within the report. If there is to be any re-profiling (e.g. to create development platforms or flood defences) then the recommendations may not apply.

The groundwater results described are only representative of the dates on which they were recorded, and levels may vary seasonally (e.g. due to changes in weather).

This assessment has been based on the proposed planning layouts provided. Any subsequent change to the planning layout may have an impact on the validity of recommendations made within this report. Furthermore, new information, changed practices or new legislation may necessitate revised interpretation of the report after the date of its submission.

Although every effort has been made to position exploratory holes in the least sensitive areas of the site, exploratory hole positions were located approximately as part of this investigation and no guarantee can be given as to their accuracy. Consideration should be given to the possibility that exploratory holes excavated as part of this investigation and indeed any previous ground investigation work by others may be encountered beneath or within the influence of individual foundations. BSL cannot be held responsible for structural failures caused by the location of foundations of any form of structure within the influence of exploratory holes.

Where it has not been possible to reasonably use an EC7 compliant investigation technique, a practical alternative has been adopted to obtain indicative soil parameters and any interpretation is based upon engineering experience, local precedent where applicable and relevant published information.

The chemical testing carried out for this report was not scoped to comply with the requirements of the water supply company and further work may be required, unless otherwise stated.

Notwithstanding site observations concerning the presence or otherwise of archaeological issues, asbestos-containing materials (ACM) or invasive weeds (e.g. Japanese knotweed), this report does not constitute a formal survey of these potential issues.

The site plans enclosed in this report should not be scaled off. Any site boundary line depicted on plans does not imply legal ownership of land.

Any recommendations made in this report should be confirmed with the Regulatory Authorities prior to implementation to ensure compliance.

2.0 THE SITE

2.1 Location

The site is located between Firswood Road, Old Engine Lane, Neverstitch Road and Ormskirk Road in Lathom, WN8 8EQ. It is situated circa 2.25km west of Skelmersdale Town Centre, approximately centred on National Grid Reference 346273, 406615 as shown on the Site Location Plan, Drawing No. C4380/01.

2.2 Site Description

An initial walkover survey was carried out on the site on the 28th November 2019 and further observations were made during an intrusive ground investigation which took place between 13th and 20th January 2020. The main site features and potential issues identified during the site visits are detailed below and are shown on the Site Features Plan, drawing C4380/02.

It should be noted that the site has been subdivided into different parcels of land based on the different landowners and conditions in each area of land; these subdivisions are indicated on the Site Features Plan, drawing C4380/02, which should be used in reference to the site description below.

Feature	Description
Site Area	The site covers a total of approximately 7.9 hectares.
Site Access	Access to the Ramsbottom, Mallinson and Woods (2) land is gained off Old Engine Lane to the north, while the Caruthers land is accessed via the Ramsbottom land. Access to the southern extent which comprises the Mather, Mather & Blundell, Hurst and Peet areas are accessed via Ormskirk Road to the south. The Halliwell land, indicated to the north-west of Mather & Blundell, did not form part of the subject area for this assessment.
Current Land Use and Site Features	The majority of the site comprises overgrown fields typically featuring sporadic semi-mature and mature trees with the fields typically lined with hedgerows. Details of the current land uses and features for each parcel of land are given below. *Caruthers Land* A broadly rectangular parcel of grass-covered land currently used as a horse paddock. An overhead power line is present along the southern boundary of the field, which is generally flat and enclosed by wooden fencing. *Ramsbottom Land* Comprises a large, generally flat, overgrown field enclosed by hedgerows. Very soft and locally boggy ground was present across the entire field with significant areas of standing water present in the far western and far eastern extents. Discussions with the landowner indicate a shed was formerly present in the north of the field and areas of hardstanding may still be present in this area, although this was not observed due to dense vegetation. *Mallinson Land* The majority is currently used as a storage yard used for aggregates with plant and equipment used for landscaping. An elongated single storey building is present along the northern boundary of the storage yard. The areas adjacent to the building are surfaced in concrete, whereas the eastern areas of the Mallinson land are covered in grass. Overhead power lines are present along the southern boundary, running parallel to a dismantled railway line immediately south of this area of the site. A possible badger sett was identified close to the boundary with the Caruthers land, although this appeared to be overgrown and is possibly no longer in active use.

Feature	Description
	Woods Land Comprises a broadly rectangular area of land, the majority of which was densely covered in vegetation comprising bramble thickets, reeds and sporadic semi-mature trees. Very soft, boggy ground was present across the entire area with significant areas of standing water present towards the eastern end adjacent to Neverstitch Road. A disused two-storey building is present in the centre of the Woods land and a smaller hut is located along the north-eastern boundary. The Woods land extends to the north-east of Old Engine Lane and is indicated on the Site Features Plan, although investigation of this land area was outside of the scope of this assessment. *Mather & Blundell* This area comprises a large overgrown field which is locally soft and boggy, particularly along the southern boundary. A linear ditch filled with water runs north-south crossing the south eastern corner, to the south-east of which is a substantially overgrown area with numerous semi-mature trees and bramble thickets. A polytunnel frame is located broadly in the centre of the field with fly tipping evident in the vicinity, including two abandoned vehicles in the south-west of the field. A possible badger sett was encountered adjacent to the north-western boundary. *June Hurst & Stephen Peet* The majority of this land was occupied by large greenhouses which did not appear to be in use. An above ground storage tank (AST) and possible inspection pit are located in the centre east. *Mather* A small parcel of land in the far southern corner of the site, however this area was inaccessible during the investigation due to dense vegetation and detailed observations were not possible.
Potential Sources of Gross Contamination	Possible asbestos cement sheeting was encountered in several areas of the site. A series of stacked sheets were noted adjacent to the small hut along the north-eastern boundary of the Woods (2) Land, in the south-eastern corner of the Mather & Blundell land and the north-western corner of the June Hurst & Stephen Peet area. Due to the age of the buildings currently occupying the site, these are likely to contain asbestos and suspected asbestos cement sheeting was observed cladding the base of the greenhouses in the Hurst & Peet area. An above ground storage tank (AST) and possible inspection pit were noted in the centre-east of the June Hurst & Stephen Peet land and a larger AST was located on concrete hard standing adjacent to the workshop building in the Mallinson land.
Vegetation	There are sporadic mature/semi-mature trees across the site and hedgerows typically form the boundaries between the different land parcels comprising the site. Further details on the distribution of vegetation in each area are provided in the current land uses and features section. Suspected Japanese knotweed was noted in the strip of land between the southern extent of the Woods (2) land and the northern extent of the Mather & Blundell land.
Topography	The majority of the site is topographically flat. However, the Ramsbottom land is circa 0.5m to 1.0m lower than the adjacent fields. Following discussions with the landowner, BSL understands this is a result of historical sand extraction which took place on the Ramsbottom land prior to 1948. The dismantled railway running NW to SE through the site forms a gradual depression circa 1.0m to 2.0m below adjacent areas.

Feature	Description
Site Boundaries	The site is generally enclosed by hedgerows, with some limited areas either open to residential gardens or enclosed by wooden fencing.
Surrounding Area	The site is set within a semi-rural residential area on the outskirts of Skelmersdale. Residential houses are present to the east and south and a new residential estate was under construction to the west at the time of writing.

3.0 SUMMARY OF PREVIOUS REPORTS

3.1 Summary of Desk Study Assessment

A summary of the relevant points from the Preliminary Environmental Risk Assessment completed by Groundtech Consulting is presented below:

- The site has had previous development since 1849 including a railway and parallel tramway traversing NW-SE through the centre of the site, a sand wash with railway lines in the east (Woods land), a football ground and allotment gardens (Mallinson land) and a series of glass houses (June Hurst & Stephen Peet land).
- The surrounding area has historically featured coal pits, railway tracks and a factory and garage to the south and south-west.
- There is an authorised process relating to unloading and storage of petrol at the service station located 120m south-east and a generic tank is indicated to be located 55m south.
- The superficial deposits comprise the sand of the Shirdley Hill Sand Formation (Secondary A Aquifer) underlain by Glacial Till (Secondary Undifferentiated Aquifer) comprising clay to sandy clay with common pebbles, cobbles and some boulders.
- Bedrock of the Pennine Lower Coal Measures (Secondary A Aquifer), comprising mudstone, sandstone and coal seams is indicated to be present beneath the site.
- The nearest watercourse is a drain in the south eastern corner and a pond is located immediately north-east of the site. The nearest named watercourse is Slate Brook c.55m east.
- The site is not located within 500m of a Source Protection Zone (SPZ) and there are no potable or groundwater abstraction licences within 2000m of the site.
- No radon protection measures are required.
- The risk to human health from contaminated soils was considered to be moderate.
- The risk to human health from ground gases was considered to be moderate to high.
- The risk to controlled waters was considered to be low.
- The site is not located within a Zone 2 or Zone 3 floodplain and the Risk of Flooding from Rivers or Sea (RoFRaS) is very low.
- The site is located within an area where coal seams are abundant, and the majority of the site is within a Development High Risk Area.
- The Arley seam, Rushy Park Coal and Bone Mine (Half Yard seam) are indicated to dip beneath the site, whereas the Rushy Park and Bone Mine seams are indicated to subcrop on site beneath the superficial deposits.
- According to the Coal Authority, the Arley seam is indicated to have been worked beneath the site at depths of between 62m and 74m and is up to 1.50m in thickness, dipping south at 9.5°, last worked in 1895.
- According to the Coal Authority, the Rushy Park seam is indicated to have been worked at between 12m and 32m below the site and is typically 0.6m in thickness, dipping south between 5.7° and 9.5°, last worked in 1933.
- Coal mining abandonment plans, Drawing Ref 10905, indicate the 'Rushy Park Mine' present beneath the eastern part of the site. However, based on the anticipated depth of the coal seams underlying the site, the abandonment plans are likely to be a record of the workings within the Bone Mine seam.
- The Desk Study indicates three mine entries are present on site. However, it is noted that the subject area of the desk study is larger than for the subject of the current assessment, within which no recorded mine entries are present. A number of recorded mine entries are present to the north of Old Engine Lane.
- An intrusive mining investigation was recommended to investigate the presence of recorded shallow mine workings and the high potential for unrecorded mine workings and entries.

3.2 Summary of Flood Risk Assessment

A summary of the relevant points from the Flood Risk Assessment completed by Waterco is presented below:

- The site is located within EA designated Flood Zone 1
- The risk from fluvial flooding was considered to be very low.
- The risk from tidal flooding was considered to be very low.
- According to the EA 'Flood Risk from Surface Water' map, the majority of the site is at very low risk of surface water flooding. Isolated areas have a higher risk, including the northern and eastern areas (low risk) and the former railway cutting (medium and high risk, although no buildings are intended in the dismantled railway cutting).
- The risk from sewer flooding is low.
- The risk from groundwater flooding was considered to be low.
- The risk of flooding from artificial sources was considered to be very low.
- The overall risk of flooding from all sources was considered to be low and therefore the report did not recommend the installation of any flood risk mitigation measures.
- However, it was recommended that finished floor levels are set at a minimum of 150mm above surrounding ground levels.

3.3 Summary of Reports for Adjacent Site

A summary of the relevant points from the reports completed by Coopers pertaining to the adjacent site is presented below:

- A total of 26 machine excavated trial pits, 2 hand dug trial pits, 5 window sample boreholes, 4 rotary cored boreholes and 10 rotary open boreholes were completed on the land immediately south and west of the subject area for the current assessment in August 2015.
- The ground conditions comprised topsoil of dark brown fine to medium sand from ground level to between 0.25mbgl and 0.85mbgl, typically underlain by firm to very stiff slightly silty sandy and/or gravelly clay encountered to a maximum depth of 7.5mbgl. Fine to medium sand was sporadically present beneath the topsoil with a typical thickness of between 0.2m and 0.5m.
- Made ground was generally absent, except for one location of a former pond where a combination of cohesive and granular made ground was encountered to 2.4mbgl.
- Groundwater was encountered between 0.35mbgl and 2.72mbgl during the monitoring period.
- Due to elevated concentrations of carbon dioxide being recorded in two boreholes, the site was classified as Characteristic Situation 2 and ground gas protection measures were recommended.
- The Bone Mine seam was encountered at shallow depths through the centre of the site (between 2.4m and 5.2m, increasing in depth towards the east. The Bone Mine Seam ranged in thickness from 0.4m to 1.3m.
- The Rushy Park Mine (Seam) was encountered at greater depths beneath the site, ranging from 10.2m to 25m. The subcrop was not encountered but was anticipated to be towards the far west of the site.
- The bedrock was found to dip at an angle of 10° from northwest to southeast and at an angle of 1° from north to south.
- No evidence of mine workings was identified in the August 2015 investigation, and no evidence of bell pits, shafts or void was identified.
- However, historical mine abandonment plans for the Rushy Park Mine indicate pillar and stall workings were present between 11.28mbgl and 16.76mbgl. Therefore, it was considered likely the recorded 'Rushy Park Mine' workings actually mined the Bone Mine seam based on the depths this seam was encountered below the site.
- Although no evidence of coal workings was identified during the August 2015 investigation, a drill and grout investigation was designed to target the areas of the site where the Rushy Park Mine (Seam) and Bone Mine (Seam) were anticipated at shallow depths without sufficient competent rock cover.

- The Coal Mining Mitigation Works comprised the drilling of Primary boreholes on a 4.2m square pattern, with secondary borehole being drilled on a 3.0m square pattern where a primary borehole accepted 5 or more tonnes of grout.
- A total of 130 boreholes were drilled into the anticipated extent of the Rushy Park Seam. No signs of shallow mine workings were identified within this seam and grout takes were very low (0.04 to 0.06 tonnes, i.e. equivalent to filling the boreholes).
- A total of 612 boreholes were drilled to target the Bone Mine Seam. Evidence of workings were identified within a total of 78 boreholes. No open voids were encountered in any of the boreholes, indicating the workings had been progressively backfilled with goaf (mine waste).
- Collapsed mine workings were identified in boreholes within one area on the eastern boundary of one of the areas of elevated risk from mine workings, therefore additional precautionary drill and grout boreholes were drilled in several additional nearby areas despite having rock cover of greater than ten times the coal seam.

4.0 METHOD OF INVESTIGATION

4.1 Objectives

To confirm the risks to the identified receptors and confirm the ground conditions in respect to the identified geotechnical and geo-environmental risks, an appropriate intrusive investigation was undertaken as per the recommendations of the Phase I Desk Study Assessment.

The aim of the fieldwork was to:

- Investigate ground conditions on the site and the potential need for detailed investigation.
- Install standpipes to allow future monitoring.
- Assess the potential contamination on the site and obtain samples for contamination screening.
- Assess the potential impact of any contamination on controlled waters.
- Obtain geotechnical information on the ground conditions at the site for preliminary foundation design and preliminary pavement design purposes.
- Give an assessment of the geo-environmental risks associated with redevelopment of the site.
- Assess the potential for instability caused by historical coal extraction.

4.2 Site Works

The following site works have been undertaken as part of the intrusive investigation between the dates of 13th January and 20th January 2020.

Method	No.	Range Depths (m bgl)	Purpose
Trial pits – 15 tonne tracked excavator	17	2.90 – 3.50	Establish general ground conditions and gain good coverage, especially in areas of soft/boggy ground.
Trial Trenches – 15 tonne tracked excavator and JCB-3CX	5	3.50 – 4.95	TT01 and TT02 located to define subcrop of Rushy Park Mine (Coal Seam). TT03, TT04 and TT05 located to define subcrop of Bone Mine (Coal Seam).
Window sample boreholes – Tracked WS rig	21	2.95 – 4.45	Establish general ground conditions on site and gain good coverage. Allow Standard Penetration Tests (SPTs) to be carried out and obtain samples for contamination and geotechnical and testing. Installation of ground gas and water monitoring wells. WS15 and WS16 placed to target above ground storage tank and possible inspection pit.
Rotary open boreholes	11	20.00 – 40.00	Investigate the presence and depths of coal seams and recorded and potential unrecorded mine workings. Allow installation of ground gas monitoring wells.

Due to the presence of significant quantities of standing water, as indicated on the Site Features Plan C4380/03, large areas of the Ramsbottom and Woods land areas were inaccessible, therefore exploratory holes were repositioned accordingly and TT03 was unable to be extended towards the south-east as a result.

Extremely soft and boggy ground was encountered throughout the Woods land, resulting in large areas being inaccessible for both the rotary and window sampling rigs and subsequently window sampling holes intended for this area were not completed and additional trial pits were excavated instead. RO08 was originally intended for this area, but was relocated into the Mallinson land, where more favourable shallow ground conditions were encountered.

The surveyed locations of the exploratory holes are indicated on the Exploratory Hole Location Plan, Drawing No C4380/03. The Exploratory Hole Logs are presented in Appendix B.

The exploratory holes were logged by an experienced geo-environmental engineer in general accordance with the following guidance:

- BS 5930:2015 Code of Practice for Site Investigations.
- BS EN 14688-1:2018 Geotechnical Investigation and Testing – Identification and classification of soil.
- BS EN ISO 14689:2018 Geotechnical investigation and testing – Identification and classification of rock.

4.3 Sampling

During the drilling of the exploratory holes, representative samples were taken at regular intervals to assist in the identification of the soils and to allow subsequent laboratory testing. They were stored and transported in general accordance with BS 10175:2011+A2:2017.

The type of sample was dependent upon the stratum and the purpose of analysis in accordance with current environmental and geotechnical guidance.

The distribution of samples taken across the site is recorded on the exploratory logs and a summary of the samples taken is presented in the table below:

Type	Number
Environmental (ES)	118
Disturbed (D)	107

4.4 Laboratory Testing

As part of the initial assessment for potential contamination of the site, selected samples were taken for the purpose of chemical contamination testing.

The potentially contaminative processes on site included former railway and tramline usage, localised fuel storage in above ground tanks and a possible inspection pit. Suspected asbestos sheeting was also identified in three locations. Therefore, the following suite of determinands were chosen to screen for potential site impacts at a UKAS approved laboratory:

Determinand	No of Samples
BSL Default Soil Suite: Arsenic, Cadmium, Chromium (III), Chromium (VI), Copper, Nickel, Mercury, Lead, Zinc, Selenium, speciated polycyclic hydrocarbons (PAH 16), total phenol, free cyanide, water soluble sulphate (2:1 Extract), soil organic matter and pH.	14
Petroleum Hydrocarbons (TPH CWG) inc BTEX and MTBE.	3
Asbestos Screen and ID.	6

The Chemical Laboratory Testing Results are presented in Appendix C.

Representative disturbed samples were obtained for all soil types encountered. Selected samples were scheduled for testing at an approved laboratory in accordance with BS 1377 'Method of Test for Soils for Civil Engineering Purposes' and BS EN ISO 17892- Parts 1-12:2018 'Geotechnical investigation and testing. Laboratory testing of soil'.

The following tests were scheduled for geotechnical purposes:

Description	No of Samples
Natural Water Content.	10
Plasticity Index Analysis.	10
Calorific Value	2
pH Value.	7
Water Soluble Sulphate Contents.	7
SD1 BRE Full Suite.	3

The Geotechnical Laboratory Testing Results are presented in Appendix D.

4.5 Monitoring

Gas and water monitoring standpipes were installed in 8 boreholes and subsequently 6 monitoring visits have been undertaken. All gas monitoring was undertaken using a GFM 436 infrared gas meter with integral electronic flow analyser.

Flow measurements on each standpipe (l/hr) were taken. Measurements of the percentage volume in air (%v/v) of oxygen (O_2), carbon dioxide (CO_2) and methane (CH_4) were recorded in addition to the percentage Lower Explosive Limit (%LEL) of methane (Note: 100% LEL equates to 5% by volume), the atmospheric pressure (mb) and average temperature during the visit (°C).

Standpipes were constructed in general accordance with the relevant guidance. A summary of the installation construction is presented in the table below:

Location and Depth	Internal Diameter Pipe	Response Zone (m bgl)	Targeted Strata	Purpose
RO02 14.00m	35mm PVC	10.00 – 14.00	Natural Strata (Coal)	Ground Gas
RO08 18.00m	35mm PVC	16.00 – 18.00	Natural Strata (Coal Workings)	Ground Gas
WS01	35mm PVC	0.50 – 2.50	Natural Strata	Ground Gas
WS05	35mm PVC	1.00 – 3.00	Natural Strata	Ground Gas
WS06	35mm PVC	1.00 – 4.00	Natural Strata	Ground Gas
WS09	35mm PVC	1.00 – 4.00	Natural Strata	Ground Gas
WS15	35mm PVC	0.50 – 2.00	Natural Strata	Ground Gas and Groundwater
WS18	35mm PVC	0.50 – 2.00	Natural Strata	Ground Gas

The gas monitoring visits recorded peak and steady state conditions. Peak results are those that occur on opening the valve on the borehole tap. Steady state conditions are those that occur a period of time afterwards when the initial (accumulated) gases have been purged from the borehole.

Full ground gas monitoring results are presented in Appendix E of this report.

5.0 GROUND CONDITIONS

5.1 Made Ground

Made ground was absent in the majority of exploratory holes but was encountered from ground level to between 0.30mbgl and 0.85mbgl in several discrete areas of the site, as summarised in the table below.

Ownership area of site	Exploratory Hole Location(s)	Range of depths (m bgl)	Typical composition of made ground
Ramsbottom	WS04	GL – 0.50m	Made ground topsoil with low cobble content containing brick and coal.
Hurst & Peet	All exploratory holes in this area: WS16, WS15, WS14 & WS13	GL to between 0.40m and 0.70m	Near-surface brick layer over gravelly sand containing brick, concrete and glass.
Mather & Blundell	Southern areas: WS07, WS08, WS21, WS09, WS10 & WS21	GL to between 0.30m and 0.70m	Made ground topsoil containing brick, concrete, glass and plastic.
Mallinson	RO04	GL – 0.60m	Made ground topsoil with low cobble content containing brick, concrete and coal.
Woods	TP13	GL to 0.85m	0.40m of topsoil over gravelly clayey sand with railway sleeper and mild hydrocarbon odour at 0.80mbgl.

5.2 Natural Topsoil

Topsoil was encountered across the majority of the site from ground level to between 0.15m and 0.70m bgl, generally comprising dark brown sand with rootlets and varying proportions of gravel and clay. Topsoil of dark brown sandy clay was sporadically encountered in the Mather & Blundell land.

For the purpose of this assessment, topsoil is defined as the upper darker and more fertile layer of the soil profile which is a product of natural chemical, physical, biological and environmental processes. This does not imply compliance with BS 3882:2015.

5.3 Natural Superficial Strata

Ramsbottom, Caruthers, Mallinson and Woods Areas
In the northern areas of the site, the natural strata generally comprised brown, locally clayey, fine to coarse sand encountered beneath the topsoil or made ground to depths varying between 0.6mbgl and 1.40mbgl.

The sand was underlain by firm to stiff brown slightly gravelly slightly sandy clay which was encountered in the trial pits and window sample boreholes to depths ranging between 2.25mbgl to 4.65mbgl. Although engineering descriptions are unavailable for the rotary boreholes, the thickness of the superficial deposits typically increased towards the east and south-east, with up to 10.0m of 'drift' encountered in RO10 in the Woods area.

Mather & Blundell, June Hurst and Stephen Peet Areas
The shallow natural sand was encountered to greater depths in the southern areas (Mather & Blundell, June Hurst and Stephen Peet), to between 1.45 and 2.60, where running sand conditions were frequently encountered within the window sample boreholes. The sands were assumed to be very loose to loose close to ground level, based on the stability characteristics of the borehole inspection pits, and this was confirmed based on the results of SPTs at 1.20mbgl. Beneath the shallow very loose to loose sands, soft to firm slightly gravelly slightly sandy clays were encountered, typically interbedded with fine to medium sands to 4.45mbgl. The rotary boreholes in this part of the site (RO09 and RO11) encountered superficial deposits to 9.80mbgl and 10.60mbgl, respectively.

A thin layer of organic, locally peaty, sand was sporadically encountered at the base of the shallow sands at the following locations and depths.

Location	Depth (m)	Strata
WS07	1.75 – 1.85	Brown clayey peaty SAND
WS09	1.55 – 1.65	Dark brown fibrous PEAT
WS11	1.95 – 2.00	Brown clayey peaty SAND
WS13	1.80 – 1.85	Brown clayey peaty SAND
WS15	1.90 – 2.00	Brown clayey peaty SAND
WS18	1.70 – 1.80	Brown clayey peaty SAND
WS20	1.50 – 1.52	Brown slightly sandy PEAT

5.4 Solid Geology

Extremely weak to very weak mudstone bedrock was typically encountered in the trial pits, trial trenches and window samples boreholes in the north-western Ramsbottom, Caruthers and Mallinson areas. The shallowest depth at which bedrock was encountered was in TT02 at 2.00mbgl and the depth to bedrock increased gradually towards the east and south-east. The deeper solid geology encountered in the rotary boreholes comprised a series of interbedded mudstones, siltstone, sandstones and coal seams.

Two coal seams were encountered beneath the site during the investigation; the Rushy Park Seam and the Bone Mine Seam. The conjectured subcrops of these seams are indicated on the Exploratory Hole Location Plan, drawing no. C4380/03 and cross sections of the coal seams underlying the site are presented in the drawings section. The locations of section lines A-A', B-B' and C-C' are indicated on the Exploratory Hole Location Plan (C4380/03). General observations made with respect to coal underlying the site are described below.

Rushy Park Coal Seam
The Rushy Park seam was encountered at the following locations and depths across the site.

Location	Depth (m)	Thickness (m)	Intact / Non-intact
RO01	23.50 – 23.90	0.40	Intact
RO02	14.50 – 15.20	0.70	Intact
RO03	14.00 – 14.70	0.70	Intact
RO04	34.00 – 34.60	0.60	Intact
RO05	28.30 – 29.00	0.70	Intact
RO06	34.00 – 34.70	0.70	Intact

Trial trenches TT01 and TT02 were positioned to target the Rushy Park seam in the far north-west of the site, but no coal was encountered. This seam was between 0.40m and 0.70m in thickness and has an apparent dip of 7.4° towards the south-east below the site. Full water flush return was recorded for the duration of rotary drilling through this seam.

Bone Mine Coal Seam
The Bone Mine seam was encountered at the following locations and depths:

Location	Depth (m)	Thickness (m)	Intact / Non-intact
TT04	4.65 – 4.85	Lateral outcrop 1.0m	Intact
TT05	3.40 – 3.50	Lateral outcrop 1.0m	Intact
RO04	12.30 – 13.10	0.80	Intact
RO05	5.50 – 6.20	0.70	Intact
RO06	11.10 – 12.10	1.00	Intact
RO07A	19.20 – 20.00	0.80	Intact

Location	Depth (m)	Thickness (m)	Intact / Non-intact
RO08	16.00 – 17.30	1.30[1]	Non-intact /100% flush loss
RO09	23.50 – 24.10	0.60	Intact
RO10	24.00 – 24.80	0.80	Intact
RO11	16.50 – 17.00	0.50	Intact

[1] No coal encountered in this location; 1.30m of broken ground inferred to represent a worked coal seam.

Trial trenches TT03, TT04 and TT05 were positioned to target the anticipated subcrop of the Bone Mine seam, which was encountered within TT04 and TT05, which define the location of the subcrop. Coal was not encountered within TT03, which could not be extended any further east due to the presence of a large area of standing water.

Full water flush return was typically recorded in the rotary boreholes, indicating intact coal, with the exception of RO08 where broken ground and 100% loss of flush was encountered between 16.00mbgl and 17.30mbgl, indicating the likely presence of mine workings at this location.

The thickness of the Bone Mine seam varied considerably, with thicknesses of intact coal ranging from 0.50m to 1.00m. Based on the locations and recorded thicknesses of the Bone Mine seam, this seam appears to have a broadly elliptical profile beneath the site, thickening to at least 1.3m towards the centre of the site, assuming the broken drilling in RO08 represents 100% coal. The seam has an apparent dip of 6.5° towards the south-east.

5.5 Groundwater

Shallow groundwater was encountered in every exploratory hole, typically seeping with small to medium flows between 0.10mbgl and 0.60mbgl. Details on individual groundwater strikes are recorded on the Exploratory Hole Logs in Appendix B.

Groundwater was encountered at the following locations and depths during the monitoring period:

Location	Depth during monitoring period (range) (m)
WS01	0.00 – 0.60
WS05	0.00 – 0.80
WS06	0.00 – 0.64
WS09	0.00 – 0.80
WS15	0.00 – 0.87
WS18	0.00 – 0.80
RO02	0.00 – 0.77
RO08	3.15 – 3.35

5.6 Observations

Contamination
During the works undertaken by BSL, observations for both visual and olfactory evidence of contamination were undertaken.

Evidence of contamination was generally not identified across the majority of the site, with a few localised exceptions. The made ground topsoil present across the southern area of the Mather & Blundell, June Hurst and Stephen Peet frequently contained sharp inorganic contaminants in the form of glass as a gravel constituent.

A mild hydrocarbon odour was encountered within the natural sand between 0.45mbgl and 1.90mbgl in WS15 and between 0.70mbgl and 1.80mbgl in WS16. It is noted that these exploratory holes were located in the vicinity of an above ground storage tank and a suspected former inspection pit. A mild hydrocarbon

odour was also noted within made ground in TP13, where a railway sleeper was also encountered within the trial pit at 0.80mbgl.

Although no asbestos was observed within soils, stacks of suspected asbestos cement sheeting were observed in several locations over the site; against a small brick hut close to the north-western boundary to the Woods area, close to a linear ditch in the south-eastern corner of the Mather & Blundell area and in the north-western corner of the June Hurst area. Due to their age, the buildings currently occupying the site are also considered likely to contain asbestos and suspected asbestos cement sheeting was observed cladding the base of the greenhouses in the Hurst & Peet area. The locations where suspected asbestos was encountered are shown on the Site Features Plan, drawing C4380/02.

Excavations

The sides of the trial pits were generally unstable in the granular strata within the top metre of the trial pits in the Ramsbottom, Caruthers, Mallinson and Woods areas, and generally stable within the underlying cohesive strata.

Due to the soft ground conditions which precluded access with a JCB-3CX, no trial pits were excavated in the Mather & Blundell, Hurst and Peet areas. However, running sand conditions were frequently observed during hand-excavation of the borehole inspection pits, indicating the sides of any mechanical excavations would likely be unstable through the shallow granular strata in the southern part of the site.

Evidence of Mine Workings

Aside from the above-mentioned instability of mechanical and hand-excavated trial pits due to poorly consolidated shallow granular strata, no evidence of mining-related features such as bell pits or shallow mine workings was recorded in the trial pits and window sample holes.

No mine shafts or features suspected to represent mine shafts were observed within excavations or at the surface.

Evidence of shallow mine workings in the form of broken ground was recorded in RO08, which is described in detail in section 5.4 and discussed further in section 7.7.

6.0 TEST RESULTS

6.1 Chemical Test Results - Soils

The samples were tested for an assessment of the chemical contamination and results were examined with reference to a selection of guidance documents as detailed in Appendix A. In this case the LQM/CIEH S4ULs and DEFRA C4SLs for a residential end use with homegrown produce have been adopted as Tier 1 generic screening values.

The apparent exceedance of the relevant screening value for a residential with homegrown produce end use is taken as indicating further detailed assessment or remedial action is required.

A summary of the chemical testing is presented below:

Metals
One sample from the shallow made ground at the southern end of the Mather & Blundell land contained the following elevated determinand.

Location	Metal	Concentration (mg/kg)	S4UL (mg/kg)
WS09 0.20m	Lead	290	200

Asbestos
Asbestos was not detected in any of the samples tested.

Poly Aromatic Hydrocarbons (PAHs)
No elevated PAHs have been detected above residential end use screening values.

Total Petroleum Hydrocarbons (TPH CWG)
Elevated petroleum hydrocarbons have not been detected above the adopted screening values in any of the samples tested.

BTEX and MTBE
Elevated BTEX compound and MTBE have not been detected above laboratory detection limits or the adopted screening values in any of the samples tested.

6.2 Permanent Ground Gas and Vapours

Six ground gas monitoring visits have been carried out between the dates of 3rd February and 9th April 2020. Results are summarised in the table below:

	CH_4 (%)		CO_2 (%)		O_2 (%)		CO (ppm)		H_2S (ppm)		TVOC (ppm)		Flow	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Peak	0.0	1.2	0.0	10.9	2.8	20.7	0.0	36.0	0.0	0.0	N/A	N/A	-1.6	35.8
Steady	0.0	0.4	0.0	9.9	4.0	20.9							0.0	4.0

Notes: CH_4 = Methane; CO_2= Carbon dioxide; O_2= Oxygen; CO= Carbon Monoxide; H_2S= Hydrogen Sulphide; TVOC (PID)= Total Volatile Organic Compounds (as measured with Photo Ionisation Detector); ppm= Parts Per Million.

The highest carbon dioxide concentrations were recorded within WS05 on the fifth and sixth visits (10.9% v/v and 10.6% v/v, respectively). The highest concentration of carbon dioxide recorded in the other monitoring locations was in RO02 on the first visit (9.7% v/v).

Carbon monoxide was recorded within WS15 in four out of six monitoring visits, ranging from 10ppm to 36ppm.

Methane was detected in just one monitoring visit in just one location, WS05, with a peak concentration of 1.2%v/v.

The maximum initial flow of 35.8 l/hr was recorded within WS15 on the second visit, however the subsequent steady state flow was 0.0 l/hr. The maximum steady state flow of 4.0 l/hr was recorded in WS15 on the sixth visit.

Hydrogen sulphide was not detected in any of the monitoring wells throughout the monitoring period.

The atmospheric pressure ranged between 982mb and 1030mb over the monitoring period, of which visits were conducted over a range of steady, rising and falling pressure trends.

Groundwater levels were generally recorded above the response zones in the first four visits, and below in the final two visits.

6.3 Geotechnical Testing

In Situ Hand Shear Vane Tests
Sixty-two hand shear vane tests were carried out on suitable cohesive soils recovered from the trial pits. Each shear vane result recorded represents the mean value of three tests undertaken at the specified depth.

The results and distribution of the hand shear vane tests are recorded in kPa on the Exploratory Hole Logs which are presented in Appendix B.

In Situ Standard Penetration Tests
Standard Penetration Tests (SPTs) were carried out within the window sample boreholes at regular 1.0m intervals. The results of the individual blows and the N-values are recorded on the Exploratory Hole Logs.

All SPT N values are uncorrected. Density and strength descriptors are reported in accordance with the guidelines stated in BS 5930:2015, incorporating requirements of BS EN ISO 14688-1:2002, BS EN ISO 14688-2:2004 and BS EN ISO 14689-1:2003.

Plasticity Index Analysis
Plasticity index results ranged between 12% and 17% indicating the clays to be of low plasticity. Associated water contents ranged between 13% and 19%.

After modification of particle size in accordance with NHBC Chapter 4.2 the modified plasticity indices are in the range 9.9% to 15.6% indicating the soils to be of low volume change potential.

Calorific Value Analysis
Calorific Value Analysis was undertaken on two samples of coal recovered from TT04 and TT05, which had calorific values of 29.0MJ/kg and 15.6MJ/kg, respectively.

6.4 Aggressive Ground Conditions

Water soluble sulphate testing was undertaken on five samples of made ground, eighteen samples of the natural clay and sand and one sample of the natural peat.

Made Ground
The results revealed soluble sulphate (SO_4) contents of between 0.013 g/l and 0.072 g/l. Associated pH values were obtained which ranged between 6.9 and 7.5 indicating neutral to slightly alkaline conditions.

Natural Strata – Sand and Clay
The results revealed soluble sulphate (SO_4) contents of between 0.0067 g/l and 0.053 g/l. Associated pH values were obtained which ranged between 5.2% and 8.4% indicating slightly acid to slightly alkaline conditions.

Natural Strata – Peat
The results revealed soluble sulphate (SO_4) contents of 0.86 g/l with an associated pH value of 7.1, indicating neutral conditions.

BRE SD1 suite testing was undertaken on three samples of natural strata. The results are shown in the table below.

Determinand	Natural CLAY	Natural SAND
Soluble Chloride mg/l	1.8 – 2.4	5
Soluble Nitrate mg/l	<2.0	<2.0
Soluble Magnesium mg/l	5.2 - 13	4.6
Soluble Sulphate mg/l	23 - 39	9.8
pH	7.7 – 7.9	7.4
Sulphur as S, Total %	0.040 – 0.064	0.008
Sulphate, as SO4, Total %	0.023 – 0.025	0.006

7.0 GEOTECHNICAL ASSESSMENT

7.1 Ground Model Summary

The majority of the site comprises overgrown fields featuring substantial areas of boggy ground across most of the subject area. Large areas of the Ramsbottom and Woods land areas were submerged by up to approximately 300mm of standing water during the intrusive investigation in January 2020, despite the site lying within an EA designated Flood Zone 1.

The site in general does not feature buildings or structures, with some exceptions. These include a former shed and possible area of hard standing in the Ramsbottom land at the northern end, an elongated barn-like building adjacent to the storage yard in the Mallinson land in the centre of the site, a disused two-storey building and small outhouse in the Woods area and a series of greenhouses covering the majority of the Hurst and Peet areas in the south-western corner.

Typically, the ground conditions comprised natural sandy clay or gravelly clayey sand topsoil over fine to coarse sand to circa 1.0mbgl, which was underlain by generally firm to stiff slightly gravelly slightly sandy clay. In the Mather & Blundell, Hurst and Peet areas in the south, the superficial sands were present up to a maximum of 2.50mbgl and were generally loose. Running sand conditions were common in the shallow superficial sands in this area of the site. The shallow natural sands were typically underlain by a thin layer of clayey peaty sand, locally peat, observed up to a maximum thickness of 10cm. Underlying the shallow natural sands and peat (where present), were interbedded soft to firm clays and medium dense sands to 4.45mbgl.

Groundwater was encountered in every exploratory hole and was typically encountered within the top 0.50mbgl.

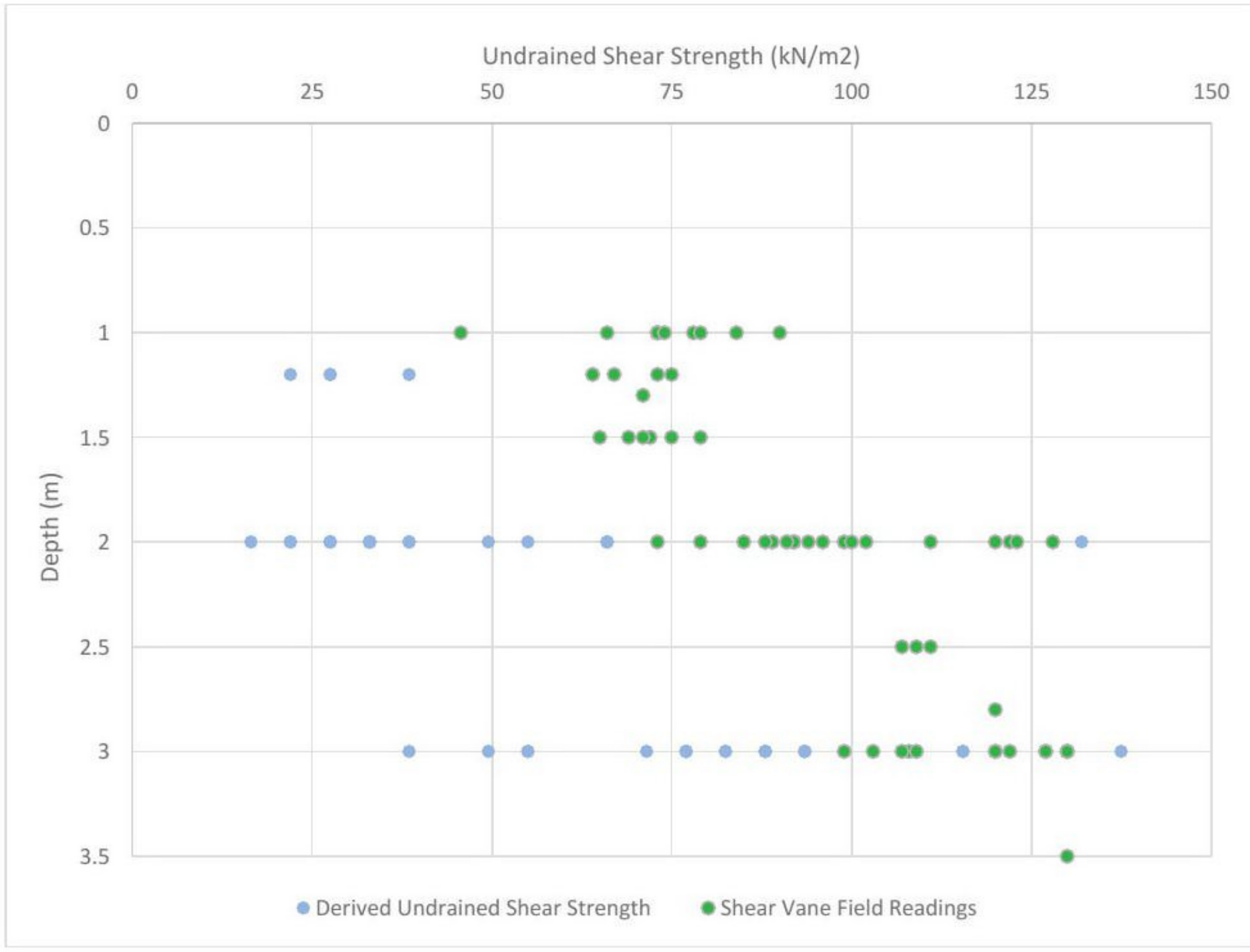
The shallow bedrock underlying the site comprised extremely weak to very weak light grey mudstone. The depth to bedrock ranged from 2.00mbgl in the far north-west to 10.60mbgl in the far south-east, with a gradual increase in the thickness of superficial cover towards the south-east. The bedrock comprised interbedded mudstones, siltstones and sandstones with coal seams.

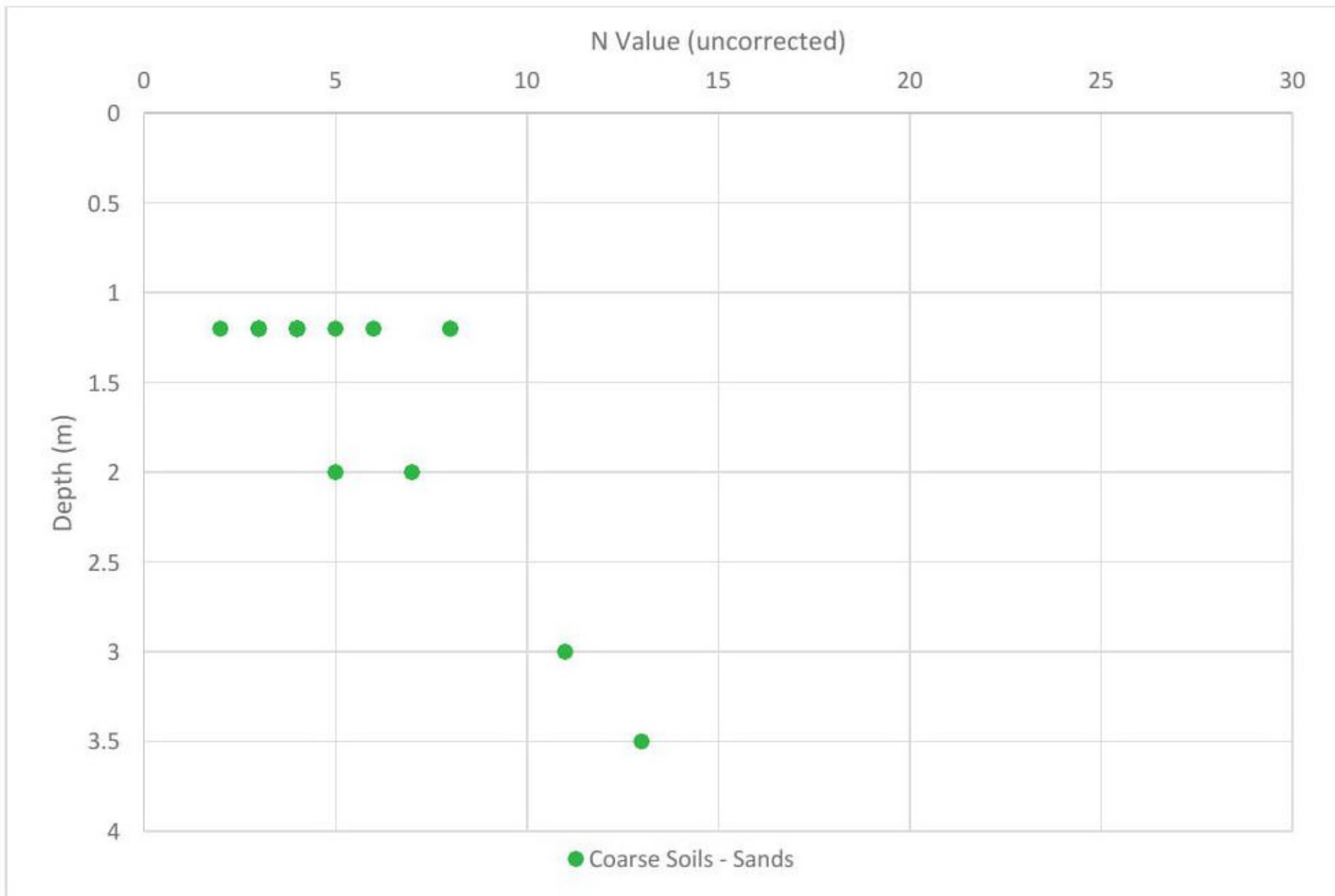
Two coal seams were encountered beneath the site; the Rushy Park Seam between 0.40m and 0.70m in thickness and the Bone Mine Seam between 0.50m and 1.30m in thickness. Based on the flush return during rotary drilling, the coal underlying the site was generally intact except for in RO08, when a total loss of flush was recorded at the approximate depth the Bone Mine Seam is expected to have been encountered.

7.2 Soil Parameters

The test results have been evaluated to derive geotechnical soil parameters for the site. Due to the presence of both cohesive and granular soils at shallow depths in different areas of the site, graphs depicting depth vs Cu (for cohesive soils) and depth vs SPT N value (for granular soils) are provided below to provide a profile of the ground conditions underlying the site.

Cu values presented include both those from shear vane readings taken on clay soils in the trial pits and trenches and those derived from SPT N values within clay strata using the correlation of Stroud (1975), adopting an f1 value of 5.5 based on the low volume change potential of the clays.


Undrained Shear Strength (kN/m2)
0
25
50
75
100
125
150
0
0.5
1
1.5
2
2.5
3
3.5
Depth (m)
Derived Undrained Shear Strength
Shear Vane Field Readings


N Value (uncorrected)
0
5
10
15
20
25
30
0
0.5
1
1.5
2
2.5
3
3.5
4
Depth (m)
Coarse Soils - Sands

Characterisation of the geotechnical parameters above has been undertaken to obtain a characteristic value, which is a cautious estimate of the value affecting the occurrence of the limit state.

There is broad correlation between the derived undrained shear strengths and the field shear vane readings, however the shear vane readings are preferred in this assessment given this is a direct measurement and does not rely on empirical correlations. Based on the field shear vane readings, the characteristic value for undrained shear strength in clays at 1.00m is interpreted to be 60kN/m^2, increasing to 75kN/m^2 at 2.00m.

In the southern areas of the site (Mather & Blundell, June Hurst and Stephen Peet), the natural clays underlying the loose sands and organic peaty soils (where present) were generally soft with a characteristic SPT value of 5 at 2.00mbgl. No trial pits were excavated in this area, therefore SPTs represent the best form of geotechnical data in this area of the site. Based on the correlation of Stroud (1975) and an f1 value of 5.5, the characteristic shear strength of the clays at 2.00mbgl is 27.5kN/m^2 in these areas of the site.

In the Mather & Blundell, June Hurst and Stephen Peet areas, the characteristic SPT N value in the sands at 1.00m is interpreted to be 3. Therefore, the characteristic ϕ' value at 1.00m is interpreted to be 28° for Ultimate Limit State conditions based on the SPT 'N' value data and the correlation of Peck (1967).

7.3 Foundations

The development will comprise traditional low-rise residential housing and is considered to be classed as Geotechnical Category 2 in accordance with Eurocode 7.

Preliminary design by calculation has been undertaken to determine the design resistance of the bearing strata in the following section. No proposed structural loads were available at the time of writing, therefore the following recommendations are provisional and should be reviewed at the detailed design stage. However, for the purpose of this assessment a typical load of 50kN has been assumed per storey.

The variance of existing levels and proposed levels will likely influence founding depths and should be considered at the detailed design stage. The below also assumes a drill and grout scheme has been carried out to stabilise any workings.

Due to the variation in ground conditions between the areas of land to the north of the dismantled railway (i.e. Caruthers, Ramsbottom, Mallinson and Woods) and the areas to the south of the dismantled railway (Mather & Blundell, Stephen Peet and June Hurst), these areas have been considered separately with regards to recommended foundation solutions.

Area 1 – Caruthers, Ramsbottom, Mallinson and Woods

The most suitable foundations for the proposed houses in the northern areas of the site are considered to be strip fill foundations at a minimum depth of 0.75m bgl based on the ground conditions and the low volume change potential clays and deeper near trees and hedges in accordance with NHBC Chapter 4.2.

Based on the design soil parameters provided in Section 7.2 report, as a guide, an allowable net bearing capacity of 100kN/m^2 should be available for a strip fill foundation bearing on the natural firm clay soils at a depth of 1.00m bgl. This value includes a factor of safety of 3.0 which should keep total and differential settlements within acceptable limits.

General Advice for Shallow Foundations

Note where foundations require deepening to greater than 2.5m below ground level, they must be designed by an engineer, as specified in NHBC Technical Requirement R5.

Trees are noted within and close to the area of the site proposed for development. Depending on their size, type and maturity, the required depth of founding based on the recommendations of NHBC Chapter

4.2 may exceed 2.5m. Should this prove to be the case, then piled foundations should be considered, unless it can be proven that the soils are not desiccated.

The bearing stratum should be inspected for 'soft spots' within the natural clay strata, resulting for instance from localised groundwater perched within the overlying fill materials. If soft soils are encountered, then foundations will need to be deepened to found on suitable strata.

If the ground conditions encountered during the construction phase differ significantly to the conditions encountered during construction, work should cease and BSL contacted for further advice.

During the construction phase supervision should be on a continuous basis to check the design assumptions are correct and construction conforms to design. Supervision should include inspections, Control Ground Investigations and monitoring.

Area 2 – Mather & Blundell, Stephen Peet and June Hurst
A thin layer (up to 10cm) of peaty sand, locally peat, was encountered sporadically across these areas of the site, although was more commonly encountered in the southern areas, typically between approximately 1.50m to 1.90m bgl. The presence of soft, highly compressible organic soils will preclude the use of shallow strip foundations within the overlying loose sands. The underlying clay soils are typically soft, becoming firm from between circa 2.50mbgl to 3.00mbgl, which is likely to be too deep and preclude the use of deeper trench fill foundations within the clays, which were notably softer in the southern areas of the site. As a result, a deeper foundation solution is required. The possibility of underground coal workings is likely to preclude the use of piles, which are unlikely to be a commercially viable option.

Ground improvement options could include the use of vibro stone columns (VSCs), which could be considered to provide a suitable platform for the development. This will create a stiffened layer which will help to spread the building loads and thus minimise differential settlement.

The vibro stone columns would need to penetrate through the made ground and underlying any soft cohesive natural strata, down to a competent horizon. Highly organic soils are considered unsuitable for VSCs and an appropriate contractor should be contacted to confirm suitability. It may be necessary to pre-excavate the thin band of peat / peaty sand in this area.

Following ground improvement, pad foundations could be used bearing onto the improved ground over the VSCs. Typically, allowable bearing capacities of the order of 150kN/m^2 – 200kN/m^2 can be achieved, keeping total and differential settlements within tolerable limits, although this should be discussed with specialist VSC contractors. Alternatively, a raft foundation could be used to distribute the structural loads across a stiffened granular layer.

In any case, given shallow foundations are unlikely to be feasible, further intrusive investigation to obtain detailed information and geotechnical data on the deeper ground conditions will be required for foundation design purposes in this area of the site.

7.4 Building Near Trees

The clay soils on site are of low volume change potential. Where foundation excavations (or piles if adopted) encounter cohesive strata in the vicinity of existing, proposed or recently removed trees, foundations should be adjusted in full accordance with NHBC Standards Chapter 4.2. All foundations should be deepened below roots of greater than 5mm diameter during excavations for footings.

A survey of all trees and hedges on the site and within influencing distance of the site boundary should be undertaken to identify tree species and heights by a qualified arboriculturist in accordance with

BS 5837:2012 and NHBC guidance. This information will be required in order to assess the effects of trees on the cohesive strata.

Where foundation depths due to trees already present or recently removed exceeds 1.50m there is a possibility for heave to occur on removal of the tree and guidance states that compressible material or void former is required against the inside face of the foundation or ground beam if piles are adopted.

7.5 Floor Slabs

Given the low volume change potential of the clay soils underlying the site, suspended floor slabs may be adopted in accordance with NHBC standards.

Where foundation depths due to trees already present exceeds 1.50m there is a possibility for heave to occur on removal of the tree. NHBC Guidance states that either a precast concrete floor, a suspended timber or in-situ concrete floor must be used. We recommend the former, the required void size for beneath floor slabs on this site is 200mm.

Based on the Flood Risk Assessment by Waterco (reference 12832-Flood Risk Assessment-01) issued in January 2020, it was recommended that finished floor levels be a minimum of 150mm above surrounding ground levels. This recommendation should be considered during foundation and floor slab design.

7.6 Site Preparation and Construction

Topsoil and subsoil should be removed from beneath all buildings and hardstanding areas.

If organic soils or peat are encountered below the proposed buildings, such as in Area 2 (Mather & Blundell, June Hurst and Stephen Peet) these will need to be removed as they are considered to be highly susceptible to consolidation settlement over time, which is likely to lead to unacceptable total and differential settlements for proposed structures in this area.

Dependant on requirements, it may be feasible to over dig into the underlying superficial deposits to remove the peat deposits entirely and then replaced with suitable materials in an engineered manner, thus removing the development constraint. It should be noted that undertaking treatment locally or using deepened foundations (i.e. focussing only on the footprint of structures) means that the surrounding areas (roads, gardens and landscaping) are likely to settle relative to the structures if disturbed. This risk can be mitigated by undertaking more widespread ground improvement through techniques such as dynamic compaction, surcharging or excavation and re-compaction.

There are a number of services crossing the site, the vast majority of which are understood run above ground (overhead). To allow construction, all services will need to be disconnected and any suspected dead services are confirmed as dead by testing.

Collapsing of the trial pit sides was observed in the natural strata and temporary shoring maybe required. Otherwise the foundation excavations will be significantly wider than anticipated and costs will be incurred for additional volumes of concrete. Instability of the made ground, where present, should also be allowed for. All excavations should be carried out in accordance with CIRIA Report 97 'Trenching Practice'.

Excavation depths should generally be readily achieved using conventional plant (JCB or similar). However, due to the very soft, locally boggy conditions across large areas of the site, high specification plant (tracked 360° or similar) is recommended to avoid delays and maintain the build programme.

Potential Japanese Knotweed has been identified on site and specialist advice should be sought. The approximate locations where Japanese Knotweed was identified are indicated on the Site Features Plan, drawing no. C4380/02.

Calorific values were determined for two samples of coal recovered from TT04 and TT05 with results of 15.6MJ/kg and 29.0MJ/kg. These are above the threshold value of 10MJ/kg and is therefore considered to be 'certainly combustible'. Although combustion and propagation of flames within coal seams and workings is possible, it is highly unlikely due to the low oxygen concentrations likely to be present within underground coal seams and abandoned mine workings and slow smouldering is a more realistic, although still unlikely, possibility. Given the coal seams are overlain by a minimum of 2.0m of superficial deposits, this may be considered to act as a non-combustible, inert cap. In addition, the high groundwater table on site is likely to reduce the risks to acceptable levels.

Recorded post site works groundwater levels typically ranged between 0.09m and 0.87m bgl and therefore will be encountered within likely excavation depths. Based on the exploratory hole logs and monitoring, it is considered that methods such as sump pumping are likely to be sufficient to deal with anticipated flows. Further guidance is provided in CIRIA C750 "Groundwater Control: Design and Practice".

It should be noted that during the intrusive investigation in January 2020 and during the subsequent monitoring period, significant areas of standing water were present across large areas of the site, particularly in the Ramsbottom and Woods areas. Widespread drainage of the site may be required to produce a suitable development environment and it may be beneficial to approach a specialist dewatering contractor for advice.

It should be noted that groundwater levels will vary seasonally, and the timing of construction may influence requirements.

7.7 Mine Workings and Entries

The Coal Mining Risk Assessment identified a risk to the proposed development from recorded and unrecorded mine workings and both recorded and unrecorded mine entries.

Mine Workings
Two coal seams were encountered beneath the site during the investigation: the Rushy Park Seam and the Bone Mine Seam. Cross sections of the coal seams underlying the site are presented in the Site Sections presented in the drawings section.

The Rushy Park Seam was encountered in six rotary boreholes with thicknesses ranging between 0.40m and 0.70m and is therefore not considered to be of workable thickness beneath the site. This seam was intact, with no loss of flush recorded in every rotary borehole in which it was encountered. Based on the findings of the mining investigation, this seam has an apparent dip of 7.4° towards the south-east. Based on the apparent dip of the seams and the absence of coal within trenches TT01 and TT02, the evidence suggests that the Rushy Park Seam is unlikely to outcrop beneath the site and is likely to outcrop approximately 50m west.

The Bone Mine Seam was encountered in eight rotary boreholes and the subcrop location defined within TT04 and TT05. This seam appears to trend north-east to south-west through the centre of the site and the conjectured subcrop is indicated on both the Exploratory Hole Location Plan (C4380/03) and the plan showing Coal Mining Risk Areas (C4380/04). The thickness of the Bone Mine Seam varied considerably and was typically less than 1.00m in thickness. However, the seam appears to have a broadly elliptical profile beneath the site, become thicker towards the centre where intact coal 1.00m in thickness was recorded in RO06 and broken ground (and complete loss of water flush) was recorded in RO08 between 16.00mbgl and 17.30mbgl, indicating underground workings are present beneath the site.

Recorded underground workings are indicated to be present beneath the site, as shown on the Plan of the Rushy Park Mine Workings (drawing no. 10905) and are in the general vicinity of RO08. However, given

the Bone Mine coal seam is encountered at shallower depths than the Rushy Park Seam in this area of the site, it is considered more likely that the so-called Rushy Park Workings targeted the Bone Mine seam.

Given the presence of coal workings beneath the site, further assessment is required and is discussed further in section 7.8.

Mine Entries
The Preliminary Coal Mining Risk Assessment within the Desk Study stated that three recorded mine entries are present in the north-eastern area of the site. After consultation with the Coal Authority Consultants Mining Report appended to the Desk Study, these mine entries are indicated to lie within the Woods land area north-east of Old Engine Lane, which was outside the subject area of this assessment and is outside the proposed development area according to the Sketch Layout of the proposed development (drawing no. BHNW117/SK01/P2) provided to BSL. As a result, there is no evidence to suggest any shafts are present on the subject area of this assessment.

Although no evidence of mine entries, shafts, adits or bell pits were observed by BSL during the works, a potential risk remains from unrecorded mine entries due to the proven presence of shallow coal of workable thickness beneath the site.

A watching brief is recommended during all groundworks to determine the presence or otherwise of possible unrecorded mine entries.

If encountered, where mine shafts are present it will be necessary to install a cap to a structural specification. The design will require agreement with building control, the Coal Authority and the NHBC. It is recommended that where possible the positioning of structures over shafts is avoided.

It may also be possible to consider geophysical methods to locate abandoned shafts as a precautionary measure. Advice should be sought from a specialist contractor on the application of geophysics in view of the ground conditions present.

7.8 Treatment of Mine workings

CIRIA SP32 and CIRIA C758 indicates that a void will not migrate to the surface where there is more than ten times the seam thickness of rock cover. Up to this depth, the void will begin to choke with rock from the roof, which is represented by broken ground. Beyond 10 times the seam thickness the rock will arch and prevent upwards migration of the void.

The thickness of the superficial deposits increases towards the south-east, which is mirrored in the reduction in thickness of competent bedrock cover towards the south-east. Based on this, and the thickness profiles of the Rushy Park seam and Bone Mine seam beneath the site, the site has been zoned into risk areas based on the thickness of rock cover and depth of coal seams. The risk zones are indicated on the plan of Coal Mining Risk Areas (drawing C4380/04) and are justified below.

Zone 1 – Moderate Risk
Coal associated with the Rushy Park seam is expected at depths where there is insufficient competent bedrock cover, therefore mining related subsidence carries a moderate risk. The majority of this zone is located off-site, although marginally encroaches into the far north-west of the Ramsbottom land.

Zone 2 – Low Risk
Coal associated with the Rushy Park seam is expected at depths where competent bedrock cover is in excess of ten times the thickness of the coal seam.

However, the superficial deposits are typically between 2.00m and 3.00m in thickness in this area of the site, which is considered to significantly increase the likelihood for unrecorded workings, bell pits and adits

due to the accessibility of the coal seam where drift cover is unsubstantial. Although the maximum thickness of the Rushy Park seam was 0.70m during the investigation, if roadways are present servicing unrecorded workings these would likely be 1.50m in height, significantly increasing the thickness of overburden required.

Although no evidence of workings was encountered within the Rushy Park seam, due to the density of rotary boreholes extended in this area, the possibility that the boreholes were extended through pillars cannot be fully ruled out. Although the risk is considered to be low, it would be prudent to extend a number of confirmatory boreholes into this area during drill and grout operations to fully confirm the risk.

Zone 3 – High Risk
Coal associated with the Bone Mine seam is expected at depths where there is insufficient competent bedrock cover. In addition, recorded underground workings are indicated to be present in this approximate area and were encountered in RO08, therefore the risk from subsidence is considered to be high.

Zone 4 – Low Risk
Coal associated with the Bone Mine seam is expected at depths where competent bedrock cover is in excess of ten times the thickness of the coal seam (0.8m thick in this area).

Zone 5 – Low Risk
The superficial deposits are present to in excess of 10m bgl in this area of the site, however the Bone Mine Seam in both RO09 and RO11 is considerably thinner than elsewhere on the site (a maximum of 0.6m thick), therefore sufficient competent bedrock cover is likely to be present to reduce the risk from subsidence to acceptable levels.

However, due to the density of rotary boreholes within this area of the site and to provide additional data to support the above, it would be prudent to extend several additional rotary boreholes into this area during drill and grout operations to confirm the risk.

Based on CIRIA SP32 there is insufficient solid rock cover for the Rushy Park Seam within Zone 1 and the Bone Mine seam within Zone 3 to prevent upward migration of collapses affecting the future development and mitigation measures are required in the form of drilling and grouting within these zones. A number of confirmatory boreholes are also recommended within zones 2 and 5 to confirm the risks and provide additional reassurances that treatment of any potential underground workings are unlikely to be required in these areas.

A drill and grout specification will be required to enable a contractor to carry out the works. It is recommended that the works are reviewed by BSL as they progress and as the ground conditions require. It should be noted that the scope of the investigation undertaken to date may not have identified all potential workings within the site boundary and additional investigation may be required to verify the design of the mine stabilisation scheme, although this could be undertaken immediately prior to or concurrently with the drilling and grouting operation.

It would also be prudent to extend a selected number of boreholes undertaken as part of the grouting works to greater depth to verify the absence of deeper workings in the underlying strata. Alternatively, drill holes could be terminated upon the satisfaction of the supervising engineer that an appropriate thickness of solid drilling has been proven to discount the risk of instability due to workings in deeper seams.

It will be necessary to continue treatment to a satisfactory distance outside of the footprint of proposed dwellings to ensure stability in the occurrence of collapse of adjacent ground that has not been subject to

treatment. This may extend to 3m beyond the proposed footprint of dwellings, subject to confirmation from the Coal Authority. Consideration should also be given to the stabilisation of site access roads.

A licence will be required from the Coal Authority to undertake the drilling and grouting works, this typically takes 3-4 weeks to obtain. The Coal Authority may have requirements in respect of control of emissions of gas and mine water as a condition of issue of a licence. The Coal Authority terms and conditions may pose restrictions on the choice of drilling flushing medium in response to recent public safety issues.

Upon completion of drilling and grouting a validation report will be required for presentation to the regulators detailing hole locations, seams targeted, grout takes etc.

It should be noted that as large areas of the site lie within a High-Risk Development Area, the Coal Authority is likely to be a statutory consultee as part of the planning process or may be consulted by the Local Authority. The findings of this assessment should be confirmed with the Local Authority, and Coal Authority if necessary, prior to any irrevocable action at the site

7.9 Concrete Classification

Laboratory pH and sulphate testing was undertaken on five samples of the made ground. The data set had between five and nine results and as such the mean of the highest two sulphate values and lowest pH values were taken as characteristic values.

The characteristic value for soluble sulphate in the made ground is 0.0495g/l and the pH is 6.95.

Laboratory pH and sulphate testing was undertaken on 18 samples of natural superficial deposits. The data set had over ten results and as such the mean of the highest 20% of the test results has been taken as the characteristic value which is 0.0415g/l. The characteristic value of the lowest 20% of the pH of the samples is 5.8.

Laboratory pH and sulphate testing was undertaken on one sample of natural peat. The value for soluble sulphate is 0.86g/l and the pH is 7.1.

The site is underlain by impermeable deposits therefore the groundwater has been classified as static.

The results of laboratory pH and sulphate content indicate that ACEC Class AC-1s and sulphate class DS-2 conditions prevail in accordance with BRE Special Digest 1 "Concrete in aggressive ground" 2005. The specific concrete mixes (the Design Concrete Class) to be used on site will be determined by the site-specific concrete requirements in terms of the durability and structural performance. These are assessed in terms of the Structural Performance Level (SPL) and any need for Additional Protective Measures (APM) detailed in Part D of BRE Special Digest 1 with further guidance in Pt E and F.

7.10 Highways

Based on Table 5.1 from DMRB IAN 73/06 Rev 1 equilibrium CBR values of 5% are likely to be achieved in undisturbed natural granular soils and 2% for natural clays soils for pavement design purposes, unless proven otherwise by in-situ testing at formation level by a specialist geotechnical engineer. Equilibrium CBR values are likely to be 2% within the made ground.

Where the CBR is found to be less than 2%, the sub-grade is unlikely to be suitable for both the trafficking of site plant and as a permanent highway foundation without improvement of the soils.

To achieve the required design CBR value, improvement works should be carried out in accordance with DMRB IAN 73/06 Rev 1 Chapter 5 and may include proof rolling, excavation and re-engineering / replacement of weaker soils, the inclusion of a geogrid or use of stabilisation techniques such as the addition of hydraulic binders (e.g. cement/lime).

Where peat is encountered beneath proposed pavements it is recommended that this is removed to mitigate against settlement.

Based on the fines content of the soils, they are considered to be frost susceptible, therefore highway construction should be a minimum thickness of 450mm to mitigate against the risk.

Care should be taken to ensure the stratum at formation level is protected against inclement weather, as this is likely to lead to surface deterioration and a decrease in soils strengths.

Where areas of hard standing, such as highways, car parks or pavements, are proposed over former mine workings which require treatment (i.e. Risk Zone 3 as shown on drawing C4380/04), installation of a geogrid reinforcement beneath these areas should be considered to mitigate the risk from potential mining related instability.

7.11 Soakaways

Although BSL was instructed to undertake soakaway tests at the site, this was not feasible due to the collapsing of trial pits readily observed in the top circa 1.0mbgl and the presence of shallow groundwater within every exploratory hole excavated during the January 2020 investigation (typically encountered between 0.10m and 0.60m).

Note the base of any soakaway incorporated into the future development of the site is required to be at least 1m above the water table. With the exception of RO08, with a deep response zone extending well beyond the base of the superficial deposits, post site works groundwater levels at the site have been recorded between 0.09m and 4.21m bgl.

In any case, it is considered that the use of soakaways within the natural ground is unlikely to be feasible at the site due to the presence of relatively impermeable strata underlying the vast majority of the site.

8.0 ENVIRONMENTAL ASSESSMENT

8.1 Contamination

Soils
The proposed development is of residential end use therefore residential without plant uptake screening values have been used.

Based on the testing undertaken it would appear that the vast majority of the soils present on site are chemically suitable for retention within a residential with plant uptake scenario.

One exceedance of the screening values for lead was identified in a sample of shallow made ground topsoil in the far south-eastern corner of the site, therefore further assessment in this area is required.

Permanent Ground Gases
In order to assess the ground gas situation and the requirement for ground gas precautionary measures at the site, guidance was taken from CIRIA C665 'Assessing risks posed by hazardous ground gases to buildings' and BS8485:2015+A1:2019 'Code of Practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings'.

As the proposed end-use is for low rise residential, guidance dictates that the gas monitoring results should be assessed in accordance with the Boyle and Witherington methodology.

The Boyle and Witherington methodology uses the concept of a Gas Screening Value (GSV) which is derived using the following equation: (max gas concentration / 100) x maximum flow.

A maximum positive steady-state flow of 4.0l/hr has been used to derive the GSVs. The GSV's for the site are presented below.

Gas	GSV (l/h)	Typical Concentrations Exceeded	Classification based on GSV
Methane	0.048	Yes	Green
Carbon Dioxide	0.436	Yes	Amber 1

The GSV for methane place the site the site into Green classification of the Boyle and Witherington Traffic Light System as outlined in CIRIA C665, however, the GSV for carbon dioxide places the site within Amber 1. Due to concentrations of carbon dioxide greater than 5% v/v and methane greater than 1% v/v being recorded, the site will be classified as NHBC Amber 1.

Utilities
The level of protection for the clean potable water supply pipes should be determined using the local water company risk assessment criteria in accordance with UKWIR.

8.2 Qualitative Risk Assessment

The CSM has been revised based on the findings of the site investigation and laboratory testing results and these are presented overleaf. Unless stated otherwise, in respect to off-site sources, only risks that are assessed as moderate and above within the preliminary CSM have been carried forward to this section, or where a previously unidentified potential source, pathway and / or receptor has been identified from the recent site works.

Human Health						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
On site Made Ground and Existing Buildings Metals, PAHs, asbestos, petroleum hydrocarbons.	Root uptake, ingestion, direct contact, inhalation of dusts	End-users	Low likelihood	Medium	Moderate / Low	Made ground was absent across the majority of the site. Where present, the made ground typically comprised topsoil with minor quantities of brick, concrete and coal and chemical testing indicates the vast majority of the topsoil and made ground topsoil did not contain contaminants in concentrations exceeding residential with plant uptake screening values. Made ground and made ground topsoil was encountered more widely in the southern areas of the site (Mather & Blundell, June Hurst and Stephen Peet areas) and elevated concentrations of lead were detected in WS09 at the far southern end of the site. The made ground topsoil across this area frequently contained glass. Further assessment and remediation is required in this area of the site. Due to access restrictions, intrusive investigation was not possible within the existing buildings occupying the site at the time of the investigation, which should be assumed to contain asbestos and are highly likely to be underlain by made ground of unknown composition. Further investigation of these areas is required when access is available.
On site Topsoil Pesticides	Root uptake, ingestion, direct contact	End-users	Unlikely	Medium	Low	The topsoil across the site did not contain any elevated concentrations of metals, hydrocarbons or inorganics and is generally considered suitable for re-use on site within a residential with plant uptake setting. There is no indication from the available information that the site has been used for arable farming. Even if present, historical pesticides are likely to have now degraded and the overall risk is considered to be low.
On site Made Ground Metals and organic contamination	Migration into/chemical attack of water supply pipelines	Water Pipelines / End users	Unlikely	Medium	Low	Contaminants within the soil/groundwater could potentially attack the clean potable water supply pipe. However, due to the general absence of organic contamination within the soils, it is considered unlikely these would impact the potable water supply pipe. Contaminants should be assessed in accordance with the relevant guidance to determine the correct pipe material and level of precautions required.

Human Health						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
On Site ASTs, Possible Inspection Pit Hydrocarbon vapours	Migration into confined spaces, inhalation and asphyxiation/ explosion	End-users / Property / Structures	Unlikely	Medium	Low	An unbunded AST and a suspected inspection pit were noted in the June Hurst and Stephen Peet areas and a further AST seated on concrete was identified within the Mallinson area. No visual or olfactory evidence of hydrocarbon impaction was noted in the Ramsbottom and Mallinson areas, therefore it is considered unlikely that the AST in this area has impacted the underlying soils. The shallow natural sands in WS15 and WS16, adjacent to the AST and possible inspection pit in the Hurst and Peet areas, were noted to have a mild hydrocarbon odour. However, subsequent chemical testing indicates the soils are only marginally impacted, with levels of hydrocarbons below residential with plant uptake screening values. Hydrocarbon fractions were typically below laboratory detection limits with only heavier fractions detected, which are less prone to volatilisation. The overall risk to end users/property and structures is therefore considered to be low.
Made Ground and organic soils Ground Gas (carbon dioxide and methane)	Migration into confined spaces, inhalation and asphyxiation/ explosion	End-users / Property / Structures	Unlikely	Severe	Moderate	Made ground was generally not encountered and where present did not exceed 0.85m in thickness, typically comprising topsoil devoid of putrescible materials based on visual inspection. A 10cm layer of peaty sand, locally peat, was encountered in the southern areas of the site, but due to its thickness this is considered unlikely to have a high gas generation potential. Ground gas monitoring installations have been installed to target areas of made ground and organic soils and significant concentrations of ground gases have been detected in certain locations. Based on observations during the investigations and the results of ground gas monitoring, the risk from ground gases is considered to be moderate and gas protection measures are required.
Coal Seams & Mine Workings Ground Gas (carbon dioxide, methane, carbon monoxide and hydrogen sulphide)	Migration into confined spaces, inhalation and asphyxiation/ explosion	End-users / Property / Structures	Unlikely	Severe	Moderate	Monitoring wells were installed within RO02 (targeting the Rushy Park seam) and RO08 (targeting workings in the Bone Mine seam). Concentrations of carbon dioxide exceeding 9% v/v have been detected in RO02 during three monitoring visits, whereas elevated concentrations of ground gases have not been detected within RO08. The risk is considered to be moderate and gas protection measures are required.

Human Health						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
Off Site substation, garage, former cotton mill, former gas works Hydrocarbons, PCBs	Root uptake, ingestion, direct contact, inhalation of dusts	End-users	Unlikely	Medium	Low	Observations and chemical testing of the soils on site indicates that hydrocarbons are almost entirely absent from the site. Localised areas of hydrocarbon impacted soils are likely to be associated with on-site sources. Based on this, it is considered unlikely that off-site sources of hydrocarbons are impacting the site, therefore the overall risk from off-site sources is considered to be low. There is also considered to be a low risk from PCBs which may be associated with the off-site substation due to the immobile nature of this contaminant.
Off Site Made/Worked Ground, Infilled pits and ponds Ground Gas (carbon dioxide and methane)	Migration into confined spaces, inhalation and asphyxiation/ explosion	End-users / Property / Structures	Unlikely	Severe	Moderate / Low	Significant concentrations of ground gases have generally not been detected on site within the monitoring period. Although superficial sands are present these are typically not substantial thicknesses and are underlain by impermeable clays. Therefore, it is considered unlikely that potential off-site sources of ground gases are impacting the site and the overall risk is moderate / low.

Controlled Waters						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
Made Ground PAH's, Metals	Overland flow, / migration through saturated zone	Drain onsite and Slate Brook 55m E (Surface waters)	Unlikely	Medium	Low	Significant thicknesses of made ground were not encountered onsite. Concentrations of contaminants within the made ground which is present generally do not exceed residential with plant uptake screening values, as a potential indicator of groundwater contamination. In addition, the redevelopment of the site into residential housing will likely contribute to an overall "betterment" of groundwater quality. Given contaminants are not present in significant quantities, it is considered unlikely that the made ground poses a risk to surface waters and the overall risk is considered to be low.
	Leaching through unsaturated zone / Migration through saturated zone	Superficial Secondary A Aquifer (Ground-water)	Unlikely	Medium	Low	The superficial Shirdley Hill Sands are classified by the Environment Agency as a Secondary A Aquifer, although the site is not within a Source Protection Zone and there are no groundwater or potable water abstraction licences within 2km of the site. Made ground was absent from the majority of the site and visual or olfactory evidence of contamination was typically not observed. Given the general absence of made ground and given that contaminants are not present in significant quantities, it is considered unlikely that the made ground poses a risk to the superficial aquifer and therefore the overall risk is considered to be low.
	Migration through saturated zone	Bedrock Secondary A Aquifer (Ground-water)	Unlikely	Medium	Low	As stated above, made ground was typically absent and, where present, contaminants were generally not present above screening values for a residential end use with plant uptake (as a potential indicator for groundwater contamination). In addition, the topsoil, made ground and superficial sands are underlain by impermeable clay strata across the entire site, which is likely to prevent vertical migration of any potential near-surface contaminants. The overall risk is therefore considered to be low.
ASTs, possible inspection pit Petroleum Hydrocarbons	Overland flow, / migration through saturated zone	Drain onsite and Slate Brook 55m E (Surface waters)	Unlikely	Medium	Low	The AST and possible inspection pit in the south are located over 100m from the drain in the south-east of the site. Exploratory holes adjacent to the AST and possible inspection pit contained evidence of minor hydrocarbon impaction of the shallow natural sands, however olfactory indicators suggest this is highly localised and unlikely to migrate over 100m to the surface water receptor. The overall risk is therefore considered to be low.

Controlled Waters						
Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk	Justification
	Leaching through unsaturated zone / Migration through saturated zone	Superficial Secondary A Aquifer (Ground-water)	Low Likelihood	Medium	Moderate / Low	As stated above, a mild hydrocarbon odour was noted within the shallow natural sands in WS15 and WS16, adjacent to the AST and possible inspection pit, but this was not identified in any other exploratory holes in this area of the site, suggesting the impacted soils are highly localised to the likely source. As a potential indicator of groundwater contamination, fractions of petroleum hydrocarbons in these locations were mostly below laboratory detection limits and did not exceed the LQM S4ULs for a residential with plant uptake end use, therefore the hydrocarbon impaction is considered to be both minor and localised. The AST in the Mallinson area was seated on concrete and no indications of spillages were noted. By virtue of the development taking place, this will result in the removal of the ASTs and possible inspection pit from the site, thus removing the source which will reduce the risks to controlled waters to acceptable levels.
	Migration through saturated zone	Bedrock Secondary A Aquifer (Ground-water)	Unlikely	Medium	Low	As stated above, the shallow superficial sands in the vicinity of the possible inspection pit show evidence of minor and localised hydrocarbon impaction. However, it is considered this is unlikely to impact the aquifer in the bedrock due to the presence of impermeable clays up to 10m thick underlying the entire site, which are likely to break the pathway. The overall risk is therefore considered to be low.

8.3 Summary of Identified Risks

Human Health
Made ground was not present across the majority of the site. Where present, the made ground typically consisted of topsoil containing minor quantities of brick, concrete and coal. Chemical testing of the made ground and natural soils indicated these are generally suitable for the proposed end use with plant uptake.

The only identified exception is the made ground in one location at the far southern end of the Mather & Blundell land area, which is elevated above the LQM S4UL screening criteria with respect to lead. In addition, the made ground and topsoil present in the June Hurst, Stephen Peet and the southern half of the Mather & Blundell land area contained notable quantities of glass as a gravel constituent.

Asbestos was not observed in any exploratory holes and was not detected in any of the soil samples tested. However, suspected asbestos cement sheeting was identified in three locations across the site. It should be noted that several buildings are present on site and, due to their age, should be assumed to contain asbestos until proven otherwise. Due to access restrictions, intrusive investigation within the footprint of the existing buildings was not possible and it should be assumed the buildings are underlain by made ground of unknown composition.

The made ground, organic soils, shallow coal seams and former underground workings underlying the site are a potential source of ground gases. Based on the results of the gas monitoring programme, the site has been classified as Amber 1 and gas protection measures will be required.

Controlled Waters
Due to the absence of significant quantities of made ground, which is largely not contaminated with respect to a residential end use with plant uptake, the risk to controlled waters is considered to be low and no remedial action is required with respect to this source.

The presence of ASTs and a suspected inspection pit are considered to pose a moderate / low risk to the superficial Secondary A Aquifer. Significant and widespread contamination was not identified, although remedial measures are required to reduce the risk.

8.4 Remedial Measures

The level of protection for the clean potable water supply pipes should be determined using the local water company risk assessment criteria in accordance with UKWIR.

Despite the vast majority of soils being chemically suitable for re-use on the site, the presence of glass and elevated concentrations of lead in the shallow made ground in the southern areas of the site presents an unacceptable risk to end users. Given the contaminated made ground comprises topsoil material, the most appropriate remedial option is likely to comprise source removal in the form of stripping the topsoil contaminated with sharps and lead and removal of this material off site. It must be ensured that the contaminated topsoil is stockpiled separately to site-won topsoil stripped from other areas of the site.

Asbestos was not observed within any soils on site and was not detected in soils during laboratory testing. However, suspected asbestos cement sheeting was noted to be stacked in several areas of the site. The composition of this material should be determined and disposed of at a suitably licenced facility.

The ASTs and suspected inspection pit are considered to present a moderate / low risk to the superficial Secondary A Aquifer underlying the site. It is recommended that the ASTs and their contents be removed from the site and disposed of at a suitably licenced facility. The suspected inspection pit should be excavated and removed from site along with any grossly impacted soils, if present. The remaining in-situ

soils should be validated as "clean" down to an acceptable concentration, which will result in an acceptable removal of the source. Prior to removal, the contents of the inspection pit, if any, should be removed and disposed off-site to a suitably licenced facility.

Due to access restrictions during the exploratory intrusive investigation in January 2020, ground investigation within the buildings was not possible and it is likely that these may be underlain by made ground of an unknown nature. Further confirmatory investigations should be undertaken post-demolition to ensure no previously unidentified contamination is present in the vicinity of the existing buildings.

The AST located in the Mallinson land area towards the centre of the site was seated on concrete at the time of the investigation. During the supplementary intrusive investigation following demolition of the buildings and breakup of the concrete slab, it is recommended that several exploratory holes are positioned to target the underlying soils and inspect for signs of gross hydrocarbon contamination.

Gas Protection Measures

The gas monitoring programme has revealed mitigation measures will be required. The gas screening values indicate the site falls into the NHBC Green classification for methane and NHBC Amber 1 for carbon dioxide. However, as carbon dioxide greater than 5% v/v and methane greater than 1%v/v has been detected, the site is placed within Amber 1 and protection measures are required.

Amber 1 is a low to intermediate gas regime, which requires low-level gas protection measures, comprising a carbon dioxide resistant membrane and ventilated sub-floor void to create a permeability contrast to limit the ingress of gas into buildings. Gas protection measures should be as prescribed in BRE Report 414 (Johnson, 2001). Ventilation of the sub-floor void should facilitate a minimum of one complete volume change per 24 hours.

The design of gas protection measures according to BS8485:2015+A1:2019 requires the proposed structures to be categorised into one of four building types (Type A to D).

For a site classified as CS2 (comparable to amber 1) in accordance with BS 8485 for a Type A building, a minimum of 3.5 points is required to be obtained from gas protection measures. The gas protection system should consist of at least two separate elements including a structural barrier, ventilation measures and/or a gas resistant membrane.

The required level of protection should be obtained from a combination at least two or more different elements from the following options in line with BS8485:

a) Structural barrier of the floor slab, or of the basement slab and walls if the basement is present– i.e. *A cast in situ monolithic reinforced ground bearing raft or reinforced cast in situ suspended floor slab with minimal penetrations* [1 or 1.5 point score dependant on construction quality].
b) Ventilation measures-i. e A pressure relief pathway [0.5 point score] (Required as a minimum in all systems) or passive sub-floor dispersal layer [1.5 point score - good performance or 2.5 point score - very good performance]. Note for type A buildings active ventilation measures are inappropriate.
c) Gas resistant Membrane- i.e. a gas resistant membrane which is suitably impervious to carbon dioxide [2 point score].

Note that If the installation of the membrane is not verified by a suitably qualified independent engineer in accordance with CIRIA C735, then this will score 0 points and the criteria will not be met. This may have serious implications in terms of achieving regulatory sign off, potentially causing costly delays and potentially placing end users of the site and the structure at risk.

All installations should be subject to verification. The verifier should be independent, competent and suitably trained; BSL can provide this service. We recommend validation requirements should be discussed with the Local Authority prior to installation.

No radon protection is required for new buildings at this location.

As part of any enabling or remedial works, it is recommended that all boreholes with monitoring installations are decommissioned in line with EA guidance in order to remove preferential pathways for ground gas migration.

General
It is recommended that the approval of the Regulators (Local Authority and NHBC) is obtained in regard to the above prior to any irrevocable action is taken at the site.

Once the above bodies have approved the above outline remedial proposals, a Remedial Strategy will need to be produced to meet planning requirements and submitted to the regulatory authorities for approval. This will also give guidance to enable a suitably qualified contractor to carry out the works.

In addition, the writing and approval of a Materials Management Plan (MMP) or suitable exemptions/permits will be required to allow re-use of suitable material at the site.

A watching brief is recommended during groundworks for any unidentified sources of contamination. If any gross contaminated material is encountered works should cease in that area and BSL consulted.

Once remediation is complete, verification reports will need to be produced by a suitably qualified independent geo-environmental engineer, such as BSL, in order to achieve regulatory sign off.

8.5 Asbestos

The investigation of asbestos issues within structures was beyond the scope of this report. However, guidance from UK Government indicates that asbestos should be assumed to be present in buildings unless proven otherwise.

Any asbestos within and around structures will require removal prior to re-development. This will need to be done by a suitably qualified experienced and licensed contractor, who ensures that adequate PPE is provided to operatives, and that all the relevant legislation is adhered to.

In addition, the suspected asbestos cement sheeting which was identified in several areas of the site will require testing (to confirm the presence or otherwise of asbestos) and should subsequently be disposed off-site to a suitably licenced facility. If asbestos is confirmed to be present, an asbestos management plan will be required, and a safe system of work should be set up to address the risk to construction workers. This may include but not be limited to:

- The use of qualified personnel where required.
- Hand-picking of suspected asbestos prior to excavation to reduce potential for fibre release.
- Careful segregation of stockpiles on site.
- Defining transport routes.
- Cleaning down of machinery in designated areas.
- Decontamination unit for ground workers.
- Damping down of soils to prevent dust migration.

Excavations in soils containing asbestos should comply with the CL:AIRE publication 'Interpretation for Managing and working with Asbestos in Soil and Construction and Demolition Materials' (CARSOIL) and CAR 2012. All such works will need to be agreed with the regulatory bodies (HSE and/or LA).

Additional guidance is provided within the BSL methodology Guidance Note in Appendix A.

8.6 Health and Safety Issues

During the reclamation and construction phases of the site development it will be necessary to protect the health and safety of site personnel. The risk to construction and ground workers is assessed in the table below:

Potential Source	Potential Pathway	Potential Receptor	Likelihood	Severity	Level of Risk
Made Ground	Ingestion, direct contact, inhalation of dusts.	Construction Workers	Low likelihood	Medium	Moderate / Low
Suspected Asbestos Cement	Direct contact, inhalation of dusts.	Construction Workers	Likely	Medium	Moderate
Ground gas	Inhalation in confined spaces/trenches	Construction Workers	Low likelihood	Severe	Moderate

The risk from made ground will be mitigated by standard PPE including gloves. Welfare facilities should be made available to wash before hand to mouth activities.

The suspected asbestos sheeting identified in several areas of the site will need to be tested to confirm its composition. If proven to contain asbestos, this will need to be removed from the site by a specialist contractor and disposed of at a suitably licenced facility.

It is noted that concentrations of carbon dioxide (an asphyxiant) in the soil exceed HSE Workplace Exposure Limits for personnel in the working environment of 1.5% for short term (15 minutes) exposure and/or 0.5% for long term exposure. Furthermore, soil concentrations of oxygen are below the HSE recommendations of 18%. Carbon monoxide has also been detected up to 36ppm in WS15 in the far southern end of the site, which also exceeds the HSE Workplace Exposure Limits of 20ppm for long term exposure.

Soil gas concentrations are not necessarily reflected by those in the breathing zone, all contractors and maintenance workers should be made aware of the possible presence of carbon dioxide and should take all necessary health and safety precautions when working in trenches or confined spaces.

General guidance on these matters is given in the Health and Safety Executive (HSE) document "Protection of Workers and the General Public during the Redevelopment of Contaminated Land". In summary, the following measures are suggested to provide a minimum level of protection:

- All ground workers should be issued with the relevant protective clothing, footwear and gloves. These protective items should not be removed from the site and personnel should be instructed as to why and how they are to be used.
- Hand-washing and boot-washing facilities should be provided.
- Care should be taken to minimise the potential for off-site migration of contamination by the provision of dust suppression control and wheel cleaning equipment during the construction works.
- Good practices relating to personal hygiene should be adopted on the site.

- The contractor shall satisfy the Health and Safety Executive with regard to any other matters concerning the health, safety and welfare of persons on the site.

8.7 Waste

As described in the 'Waste Duty of Care Code of Practice (2016)' any substance or object that the holder discards, intends to discard or is required to discard is a waste. It is the responsibility of the waste producer to classify this waste. The classification process is described in the 'Guidance on the classification and assessment of waste' WM3 and aims to determine whether the waste is Hazardous or Non-Hazardous to human health and the environment.

Any material excavated on site may be classified as waste and it is a statutory responsibility of the holder of a material to form their own view on whether or not it constitutes waste. This includes determining when waste that has been treated in some way can cease to be classed as waste for a particular purpose.

The most sustainable and economic method of dealing with waste soil is usually the retention and re-use on site. If soils are required to be removed from site, then there are three main options for the disposal of soils:

1. Re-use on another site (subject to suitability of the soils and complying with relevant waste legislation).
2. Disposal to a permitted waste recycling facility.
3. Disposal to a landfill site.

Note that wastes should first be classified based on their total concentrations and given the classification of either hazardous or non-hazardous. WAC testing is then **only** required if the end disposal route is landfill. Leaching test results obtained as part of landfill WAC analysis must **not** be used for waste classification and hazardous waste assessment purposes.

Details of how material should be classified for waste disposal are presented in the BSL Methodology and Guidance in Appendix A and are summarised in the table below.

	PRIOR TO LEAVING SITE			
Classification based on Total Concentrations[1]	**Non-Hazardous Waste**		**Hazardous Waste**	
	IF SOILS CANNOT BE RE-USED ELSEWHERE AND MUST GO TO LANDFILL			
WAC testing	Below inert WAC limit values	Above inert WAC limit values	Below hazardous WAC limit values[4]	> WAC limit values
Landfill requirements	INERT landfill	NON-HAZARDOUS landfill[2]	HAZARDOUS landfill	PRE-TREATMENT[3]

1 Total concentrations are defined as tests results on solids as opposed to leachate (i.e. a liquid).
2 Individual sites may have certain limit values pre-determined in their licence.
3 After pre-treatment the material characteristics may have changed to an extent that allow the soil to be re-classified.
4 Possibility that wastes could be classified as stable Nonreactive HAZARDOUS waste in non-hazardous Landfill (e.g. soils containing low concentrations of asbestos, gypsum or sulphate bearing soils).

Waste classified as non-hazardous can be accepted into a non-hazardous landfill without having to pass any numerical WAC.

Soils above hazardous WAC limit values require pre-treatment prior to disposal. The effective pre-treatment, typically involving separation, sorting and screening, can offer cost savings through reducing

the hazardous nature and volumes of soil. Costs for disposal of non-hazardous/hazardous soils are significant compared to the disposal of inert material.

Waste Classification - Total Concentrations
We have reviewed the testing results and assessed them through a waste classification database which allows users to code and classify waste as defined in the EWC (European Waste Catalogue) based on EC Regulation 1272/2008 on the Classification, Labelling and Packaging of Substances and Mixtures (CLP) and latest Environment Agency guidance (WM3 "Guidance on the classification and assessment of waste - Technical Guidance").

Fifteen samples were tested to assess whether they contained any contaminants in the hazardous range when screened against assessment criteria within WM3.

Based on the waste classification database assessment, the made ground and natural soils have been classified as **non-hazardous.** The Waste Classification Report is presented in Appendix F.

Further testing of the soils (WAC testing) may be required in order to satisfactorily categorise the soil for its suitability for disposal to landfill.

Asbestos
A watching brief should be maintained for evidence of Asbestos Containing Materials (ACMs), any ACMs observed should be handpicked and disposed of in accordance with current asbestos disposal regulations.

The possibility of automatic inert classification of the naturally occurring "clean" soils should be explored in accordance with Section 4.3 of the EA guidance document. The Council Decision includes a list of wastes in Section 2.1.1 of the document that are assumed to be inert and therefore acceptable at a landfill for inert waste without testing. This is the case if:

- They are single stream waste of a single waste type (although different waste types from the list may be accepted together if they are from a single source); and
- There is no suspicion of material or substances such as metals, asbestos, plastics, chemicals, etc to an extent which increases the risk associated with the waste sufficiently to justify contamination and they do not contain other classes of landfill.

Waste Acceptance Criteria (WAC)
Waste Acceptance Criteria (WAC) testing was outside the scope of this investigation and the guidance given below is general.

General
If any gross hydrocarbon contaminated material is encountered during the construction phase, it is possible that this may be classified as hazardous and testing should be undertaken at that time.

Where it is necessary to dispose material off site it is recommended that materials are segregated and sufficient time is allowed to further classify the actual soil arisings that constitute the waste, including discussion with landfill sites and waste transfer stations to find the best disposal route. It is illegal to dilute and mix soils without a suitable permit.

As a significant proportion of the soils likely to be generated on site are clean it is recommended that where possible that the soils could be recycled at a suitable local waste treatment plant or transfer station rather than a landfill disposal route.

Re-use of Soils

By definition in law, any material excavated from the ground becomes waste at the moment of excavation. If that soil (now a "waste") is then placed on another part of the development site (or used on another development site) without an appropriate materials management plan, permit or exemption being in place, by law this material is defined as "illegally deposited waste".

Landfill tax rules were updated on 1 April 2018 and as a result of the change, HM Revenue & Customs (HMRC) can now recover landfill tax on illegally deposited waste on construction sites. This could lead to excessive costs without the correct documentation in place. In addition, a person who makes, knowingly causes or knowingly facilitates a disposal to be made at an unauthorised site, is now also liable to pay Landfill Tax.

In order to comply with UK legislation and avoid excessive costs, if the re-use of soils is proposed on site, this should be done in accordance with the CL:AIRE "Development Industry Code of Practice for the Definition of Waste" (CL:AIRE DoWCoP) also known as a Materials Management Plan (MMP). Regardless of implementing the DoWCoP or not, all sites should have some form of materials tracking in place in compliance with current legislation. Any re-use scheme should also be designed to minimise disposal costs. Further guidance is provided in the BSL Methodology and Guidance in Appendix A.

To implement the DoWCoP, there is a requirement to notify the Environment Agency and Local Authority of the intention to use the code of practice in principal, after which there is a 21-day notice period for their response.

In order to re-use soils under the DoWCoP, there are four key criteria that need to be met:

- The aims and objectives of the project meet the requirements of the Waste Framework Directive.
- The soils can be demonstrated to be suitable for use (backed up by chemical/geotechnical testing and assessment).
- There is certainty of use (i.e. materials tacking which should be in place as part of good site practice in any case).
- Quantity (the quantity of materials used should be known).

Information on existing site levels, proposed levels, volumes generated (e.g. foundation / drainage excavation arisings) would need to be known in order to complete the MMP.

If the DoWCoP is the chosen route, it is an absolute that the CoP should be in place and declared by a Qualified Persons (QP) before works commence, otherwise excavated soils could constitute an illegal deposit of waste and enforcement action could be taken by the EA and HMRC.

In regard to "clean" naturally occurring soils only that are to be re-used on their site of origin, these are covered by a Waste Framework Directive (WFD) exclusion. So long as the project can prove the four criteria (listed above) then permits or the DoWCoP are not required. However, many projects still use the DoWCoP to ensure compliance.

Re-use of soils containing asbestos should comply with the CL:AIRE publication 'Interpretation for Managing and working with Asbestos in Soil and Construction and Demolition Materials' (CAR-SOIL™) and CAR 2012.

In terms of the re-use of brick/concrete crush materials, the DoWCoP does cover aggregates, but only on the site of origin and the EA WRAP aggregate Quality Protocol might best apply to ensure quality standards.

9.0 CONCLUSIONS

9.1 Summary

Environmental
Chemical testing indicates that the vast majority of soils across the site are chemically suitable for retention within a residential with plant uptake setting.

Made ground was generally absent across the vast majority of the site but was sporadically encountered in the northern areas. In the far south within the Mather & Blundell, June Hurst and Stephen Peet land areas, made ground similar to topsoil was more widespread and typically contained sharps (glass) as a gravel constituent, in addition to an elevated concentration of lead detected in one shallow soil sample. It is recommended that the made ground topsoil material be stripped and stockpiled separately prior to offsite disposal, effectively removing the source and any risks to site end users.

Minor olfactory evidence of hydrocarbon impaction of the natural sands appears to be localised to an area adjacent to the AST and suspected inspection pit in the south-west of the site. Chemical testing indicates that the affected soils do not exceed the LQM S4ULs for residential end use with plant uptake, although the presence of the AST and possible inspection pit is considered to present a moderate / low risk to controlled waters. It is recommended that the ASTs be removed from site and the inspection pit are subject to source removal, alongside any grossly contaminated soils if encountered.

Due to access restrictions preventing investigation within a number of buildings occupying some areas of the site, additional ground investigations will be required to target these areas and to further investigate the ground beneath ASTs, once removed and underlying floor slabs are no longer present.

The made ground, organic soils, shallow coal seams and former underground workings underlying the site are a potential source of ground gases and the site has been classified as Amber 1, with gas protection measured required.

Based on the waste classification database assessment, the made ground and natural soils have been classified as non-hazardous.

Geotechnical
The coal mining investigation has confirmed the presence of two coal seams present at shallow depths beneath the site; the Rushy Park Seam between 0.40m and 0.70m in thickness and the Bone Mine Seam between 0.50m and 1.30m in thickness. The coal seams were generally intact; however, evidence of underground workings within the Bone Mine Seam was identified in RO08 and appears to correlate with the location of recorded underground workings underlying the site.

In accordance with CIRIA C758 and the 10t criterion, the risk from potential coal mining has been determined and the site zoned into risk areas. Across the majority of the site, the risk to proposed buildings and structures is considered to be low, although a significant area of the site above the Bone Mine Seam (Zone 3) is considered to be at high risk. A zone of moderate risk (Zone 1) also exists in the north-west of the site where sufficient thicknesses of competent bedrock overlying the Rushy Park Seam is unlikely to be present. Drilling and grouting will be required to enable development in these areas. During the drill and grout works, additional confirmatory boreholes should be extended within Coal Risk Zones 2 and 5 to supplement the findings of this assessment and provide additional reassurances that treatment of any potential underground workings are not required in these areas.

Assuming completion of the drilling and grouting scheme to stabilise the mine workings, the most suitable foundations for the proposed two storey houses are considered to be traditional strip foundations bearing

onto the natural firm clays at a depth of 1.00mbgl. An allowable net bearing capacity of 100kN/m^2 should be available across the Caruthers, Ramsbottom, Mallinson and Woods areas.

Due to the presence of a layer of peaty sand, locally peat, at depths of circa 1.50mbgl to 1.90mbgl, underlain by soft clays, traditional shallow foundations will be unsuitable in the southern areas of the site (Mather & Blundell, June Hurst and Stephen Peet areas).

The use of ground improvement techniques, such as vibro stone columns (VSCs), could be considered to provide a suitable platform for the development. Further intrusive investigations are required to obtain geotechnical information on the deeper ground conditions to inform foundation design.

Due to the presence of shallow groundwater and the presence of impermeable clays underlying the site, the use of soakaway drainage is not considered feasible within the proposed development.

9.2 Further Work

The following further work is considered necessary to progress the site to construction phase:

- Supplementary Intrusive site investigations comprising:
  - Trial pits and cable percussive boreholes in Mather & Blundell, Hurst and Peet Areas
  - Trial pits within previously inaccessible building footprints and adjacent to ASTs
- Demolition Asbestos survey.
- Tree survey by qualified arboriculturist.
- Detailed foundation design, including foundation zonation plan and depth schedule.
- Design of Remedial Strategy and confirmation with the Local Authority and NHBC.
- Design of Drill and Grout Specification.
- Production of Ground Gas Protection Measures Verification Plan, if required.
- Production of Materials Management Plan (MMP) under the CL:AIRE DoWCoP, if required.
- Implementation of the Drill and Grout Specification, and verification reporting upon completion of works.
- Implementation of the Remedial Strategy and verification of the remedial works.

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