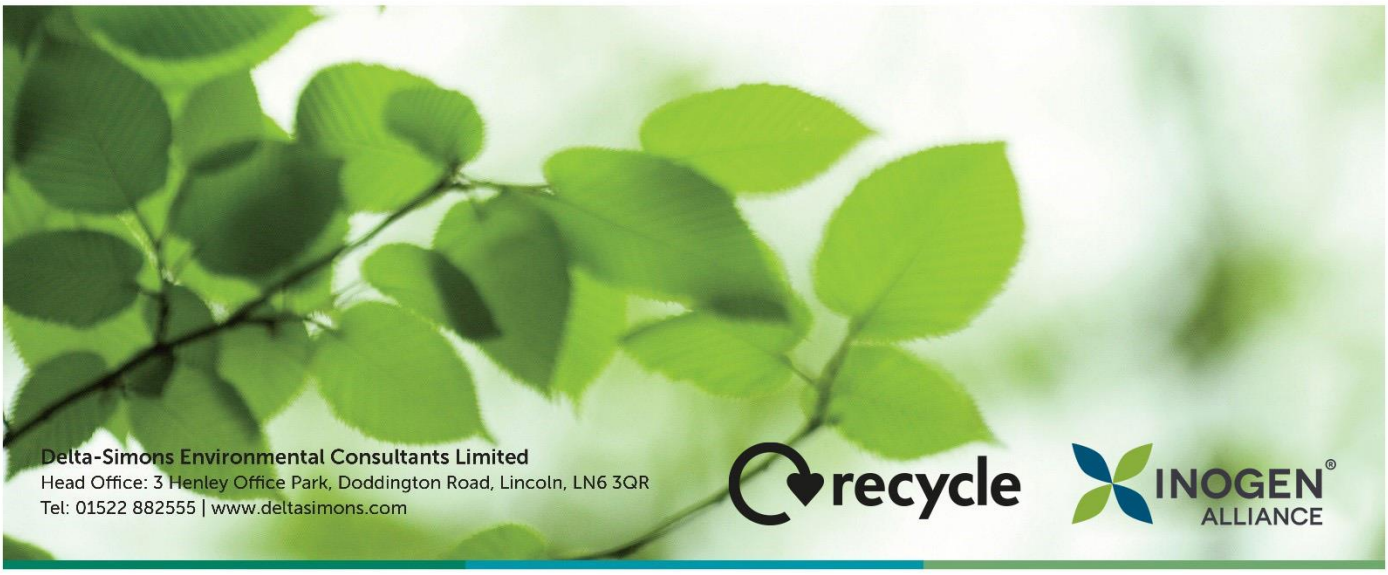
Geo-Environmental Assessment

Wood Walk, Hoyland, Barnsley

Presented to **Yelcon Ltd**

Issued: August 2021

Delta-Simons Project No. 16-0406.03



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Report Details

Client	Yelcon Ltd
Report Title	Geo-Environmental Assessment
Site Address	Land off Wood Walk, Hoyland, Barnsley
Project No.	16-0406.03
Report Date	August 2021
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Quality Assurance

Issue No.	Status	Issue Date	Comments	Author	Technical Review	Authorised
4	**Final**	**17/08/2021**	**Updated report with NPPF update and latest proposed plans.**		 	 
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About us

Delta-Simons is a trusted, multidisciplinary environmental consultancy, focused on delivering the best possible project outcomes for customers.

Specialising in Environment, Health & Safety and Sustainability, Delta-Simons provide support and advice within the property development, asset management, corporate and industrial markets. Operating from across the UK we employ over 120 environmental professionals, bringing experience from across the private consultancy and public sector markets.

Delta-Simons is proud to be a founder member of the Inogen Environmental Alliance, enabling us to efficiently deliver customer projects worldwide by calling upon over 5000 resources in our global network of consultants, each committed to providing superior EH&S and sustainability consulting expertise to our customers. Inogen Environmental Alliance offers its clients more consultants, with more services in more countries than the traditional multinational consultancy.

Delta-Simons is a '***Beyond Net-Zero'*** company. We have set a Science-Based Target to reduce our Scope 1 and Scope 2 carbon emissions in line with the Paris Agreement and are committed to reducing Scope 3 emissions from our supply chain. Every year we offset our residual emissions by 150% through verified carbon removal projects linked to the UN Sustainable Development Goals.

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Executive Summary

Brief	Delta-Simons Environmental Consultants Limited ('Delta-Simons') was instructed by Yelcon Limited (the 'Client') to undertake a Geo-Environmental Assessment for land situated north of Wood Walk, Hoyland, Barnsley, S74 9SH (hereafter referred to as the 'Site'). It is understood that the Site is to be redeveloped to accommodate traditional low-rise residential housing, with associated driveways, gardens, soft-landscaping, access roads and an area of public open space. The purpose of this assessment is to identify the potential for land contamination issues to be present at the Site, in the context of the proposed development, as well as to provide a preliminary geotechnical assessment.
Site Setting	The Site is currently comprised of greenfield / agricultural land, with a small wooded copse and clearing situated at the eastern end. The land is bordered by Dearne Valley Parkway (A6195), Wood Walk (B6096) and a roundabout to the north, south and east, respectively. Historically, the Site appears to have been undeveloped greenfield / agricultural land from as early as 1855, up until the early-1990s. Based upon the reviewed information, it is understood that the Site was partly incorporated into an opencast colliery from 1993, up until 1994 after which the opencast was backfilled and the Site restored to a greenfield / agricultural land use.
Ground Conditions	The current ground investigation recorded a variable thickness of topsoil across the Site, which was locally underlain by a thin layer of subsoil and / or variably thick Made Ground. Within the extent of the former opencast, granular and cohesive colliery spoil was present to a maximum proven depth of 22m. Below the colliery spoil completely weathered to weathered bedrock (Pennine Middle Coal Measures Formation) was present. In the area outside of the former opencast, shallow bedrock was present below the topsoil / Made Ground comprising completely weathered to weathered Pennine Middle Coal Measures and Woolley Edge Rock.
Land Contamination Assessment	<u>Human Health</u> No visual and / or olfactory evidence of soil or groundwater contamination was recorded during the investigation works. In addition, comparison of Generic Assessment Criteria (GAC), based upon a Residential (with Plant Uptake) end use, reported no exceedances within chemical analysis results from topsoil and / or other samples taken from across the Site. <u>Ground Gas</u> The Site is classified as Green / CS-1 and no gas protection measures are required. <u>Controlled Waters</u> No potential risk to controlled waters has been identified in this shallow investigation. This is based upon the absence of visual and / or olfactory evidence of potentially mobile contamination within the excavated locations and the distance to controlled surface water receptors. <u>Built Environment</u> Given the absence of identified hydrocarbon contamination at the Site, it is considered that there is a low risk of water pipes to be affected by such contaminants. Buried concrete may be designed in accordance with DS-2 and AC-2.

Geotechnical Assessment	Outside of the former opencast, based on the Site investigation undertaken, shallow strip foundations are considered to be suitable, founded at a minimum depth of 1.0 m bgl within sands and gravels (Completely Weathered Woolley Edge Rock) or firm to stiff clay (Completely Weathered Pennine Middle Coal Measures Formation) with a minimum undrained shear strength of 50 kPa. Where cohesive soils exhibit an undrained shear strength in excess of 50 kPa, an allowable bearing capacity of 100 kPa is likely to be achieved (limited to < 25 mm settlement). Within the backfilled opencast, shallow foundations are not considered suitable without some form of ground improvement. We understand that the preferred solution is to excavate and recompact the top 3.0 m of colliery spoil (from existing ground level), to achieve a uniform and strengthened layer to enable raft foundations to be adopted. Based on the engineered fill achieving a minimum undrained shear strength of 75 kPa, an Ultimate Dead Load (UDL) of 35 kPa may be achieved, limited to less than 15 mm settlement. The plasticity index results suggest that the cohesive completely weathered Pennine Middle Coal Measures Formation has a medium volume change potential. Ground bearing floor slabs may be feasible subject to the removal of topsoil, Made Ground, and any soft soils. The formation should be thoroughly proof rolled. Where unsuitable soils are removed, they should be replaced with a well compacted granular fill. Where Made Ground is greater than 600 mm thick, the NHBC recommends that floor slabs are suspended. It is recommended that a conservative California Bearing Ratio (CBR) value of 2.5 % should be assumed for the shallow soils, for preliminary pavement design. It is recommended that plate CBR tests are undertaken at formation level, upon completion of the earthworks to finalise the design CBR. The Site classifies as Design Sulphate Class DS-2 and ACEC Class AC-2, when considering the most appropriate type of concrete to be used in order to resist chemical attack.
Recommendations	Based on the findings of this Report, the following supplementary work is recommended. ▲ Production of a Materials Management Plan (MMP) to facilitate the re-use of soils on- and/or off-Site and registering of the Site as a donor on the CL: AIRE materials register. ▲ Production of a Remediation Strategy to provide a suitable cover system over re-engineered colliery spoil in gardens and landscaped areas. ▲ Production of an earthwork's specification for the proposed excavation, screening, and replacement of the top 3.0 m of colliery spoil within the extent of the former opencast. ▲ A preliminary conservative CBR value has been recommended for shallow soils, for preliminary pavement design in external areas. However, it is recommended that plate CBR tests are undertaken at formation level across the Site. ▲ Seek Local Authority criteria / requirements / specifications prior to designing the access for road design. ▲ Liaise with Local Authority and warranty providers from the early stages of ground improvement and foundation design proposals to ensure agreement in principal.

	▲ Initial classification testing suggests colliery spoil will likely fall into Class 2C (stony cohesive material). However, it is recommended that an allowance is made for the removal and / or crushing of oversize fragments during re-engineering / replacement. ▲ It is recommended that Site-won topsoil, proposed to be re-used at the Site, should be suitably stockpiled and screened for anthropogenic materials and oversized fraction (e.g. large gravels/cobbles) prior to reuse, in order to provide an improved growing medium. ▲ It is recommended that further environmental analysis be undertaken on Site-won topsoil, prior to potential reuse at the Site, in order to comply with YALPG guidance.
This is intended as a summary only. Further detail and the limitations of the assessment are provided within the main body of the Report.	

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Drawings

Drawing 1 — *Proposed Site Plan* by Enjoy Design Ltd (Drawing No. 00-001, Rev P4, dated 05/07/21)

Drawing 2 — *Overall Engineering Schematic Plan* by RWO Consulting Engineers Ltd (Drawing No. Y19072-D900-5).

Drawing 3a — *One Point Foundation Plan (sheet 1 of 2)* by RWO Consulting Engineers Ltd (Drawing No. Y19072-S100-1).

Drawing 3b — *One Point Foundation Plan (sheet 2 of 2) by RWO Consulting Engineers Ltd* (Drawing No. Y19072-S101-1).

Figures

Figure 1 — Site Location Plan

Figure 2 — Exploratory Hole Location Plan

Figure 3 — Exploratory Hole Location Plan and Coal Authority Opencast Mining Extent Map Overlay

Figure 4a — Geological Cross Section RH101 – RH103 (Section E – E')

Figure 4b — Geological Cross Section RH106 – CP103 (Section F – F')

Appendices

1.0 Introduction

1.1 Appointment

Delta-Simons Environmental Consultants Limited ("Delta-Simons") was instructed by Yelcon Limited (the "Client") to prepare a Geo-Environmental Assessment for land situated north of Wood Walk, Hoyland, Barnsley, S74 9SH (the "Site").

1.2 Context & Purpose

The aim of the study was to complete a Geo-Environmental Assessment of the proposed development area. The investigation has obtained information regarding ground conditions, from which risks to end-users, the environment and structures have been assessed, with mitigation measures suggested where necessary.

The investigation has also gathered geotechnical information to inform comment on suitable engineering solutions for the Site, including enabling earthworks and preliminary foundation design/associated infrastructure.

The Report provides recommendations for further work, where appropriate, based on the findings of the investigation.

It is understood that the Site is to be redeveloped to accommodate traditional low-rise residential housing, with associated driveways, gardens, soft-landscaping, access roads and an area of public open space. It is also understood that potential consideration is being given to reengineering the top 3.0 m of ground within the extent of a former opencast coal mine, in order to facilitate the use of shallow foundations (e.g., rafts). Such proposals will be dependent on the findings of this investigation, and other subsequent works.

1.3 Scope of Works

The scope of the investigation and layout of this Report has been designed with consideration of guidance on Land Contamination: Risk Management pages of the GOV.UK web pages, the relevant requirements of the National Planning Policy Framework (NPPF) (as revised 2021) (paragraphs 174 & 183-184)[1] and the Planning Practice Guidance (Land Affected by Contamination)[2].

The project was carried out to an agreed brief as set out in Delta-Simons' proposal dated 28th February 2020 (Ref. 16-0406.02 v3). The scope of works is outlined in Section 3.2.1.

Specific sections of this Report may generally follow guidance set out in Eurocode 7 for a Ground Investigation Report (GIR), as defined in BS EN 1997-1:2004 and BS EN 1997-2:2007. Eurocode 7 includes specific guidance on the number and spacing of investigation positions, methods of investigation and sample quality to be achieved which may not have been met by this investigation. The Report also includes information which may support a Geotechnical Design Report (GDR) as defined in BS EN 1997-1:2004; however, unless otherwise explicitly stated, the investigation has not been undertaken in accordance with Eurocode 7 and the preliminary geotechnical interpretation, assessments, risk register and recommendations presented within this report may not meet the full requirements of a GDR.

1.4 Existing Information

The following information has been made available to Delta-Simons for review, and should be read in conjunction with this Report:

- *Phase I Desk Study Report* by Delta-Simons (Report Ref. 16-0406.01, dated 23rd June 2016).
- *Coal Mining Risk Assessment* by Delta-Simons (Report Ref. 16-0406.01, dated 23rd June 2016); and

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/779764/NPPF_Feb_2019_web.pdf
[2] https://www.gov.uk/guidance/land-affected-by-contamination

1.5 Limitations

The assessment is limited to the issues agreed within the proposal for the works. Notes on limitations associated with this assessment are provided in Appendix A. In addition, there are the following specific limitations that apply to this assessment:

- Given the presence of mature trees and fencing in the eastern portion of the Site, no excavation could take place within that area.
- A series of overhead powerlines are present at the Site, trending from the eastern edge to the south-western corner. At least four wooden pylons are also present across the Site, associated with the lines. Consequently, no excavation could take place beneath or within at least 6.0 m either side of the overhead service.
- All excavations were progressed in a way that was safe to do so. In the event that significant groundwater seepage (north-west part of the Site) and / or excavation instability (trial pits / trenches within the former opencast) were encountered, such locations were not progressed further.
- In the southern, eastern, and western portions of the Site, bedrock was encountered at relatively shallow depths. Therefore, trial pits were terminated at the depth at which excavation became difficult, due to scraping on suspected weathered bedrock.
- The location of the highwall has been extrapolated between trial trench locations (see Figure 2). The actual location of the highwall in between the trial trench locations may be different to the line shown.

Specific limitations associated with the construction and monitoring of Maintained Load Tests are summarised as:

- The composition of the fill by nature is heterogeneous. The three load tests established are targeting specific localities across the Site and may not be fully representative of the fill.
- Settlement may occur at depth within the fill owing to causes other than structural load, and the load tests will provide no indication of this.

2.0 Site Details

2.1 Site Setting

A summary of the current Site status, environmental setting and key historical features is presented below. This has been summarised from the existing report(s) listed in Section 1.4 which should be consulted for further detail.

Co-ordinates	Centred approximately at National Grid Reference 437370, 401710	Elevation	~133 to 139 m AOD
		Area	3.55 Ha
Site Location	The Site is located approximately 5.3 km south-east of Barnsley, in the town of Hoyland. The Site is bordered by Dearne Valley Parkway (A6195), Wood Walk (B6096) and a roundabout to the north, south and east, respectively. Wombwell Railway Station is situated approximately 1.4 km to the north-east. A Site Location Plan is provided as Figure 1.		
Current Site Use	The Site is currently comprised of greenfield / agricultural land, which is accessed via a gate in the south-east corner, off Wood Walk (B6096). Towards the eastern edge of the Site there is a small clearing, in which a series of beehives and a small fire pit are present. Directly north of this clearing is a small copse, which is separated from the rest of the Site by wire fencing. In general, the Site topography rises towards the centre of the field, gently decreasing to the east and west.		
Proposed Development	It is understood that the Site is to be redeveloped to accommodate traditional low-rise residential housing, with associated driveways, gardens, soft-landscaping, access roads and an area of public open space. A Feasibility Site Plan is provided as Drawing 1. Identified human and built environment receptors (R) relevant to the proposed development comprise: ▲ Construction workers. ▲ Third parties during construction (adjacent Site users and adjacent residents). ▲ Future Site users (residents) and maintenance workers. ▲ The Built Environment (new buildings, infrastructure, and utilities).		
Environmental Setting	The Site is not indicated to be underlain by superficial deposits. Bedrock is indicated to be the Woolley Edge Rock (Carboniferous sandstone) to the east, and undifferentiated bedrock of the Pennine Middle Coal Measures Formation (Carboniferous mudstone, siltstone, and sandstone) to the west. Both are classified as a Secondary A Aquifer. Two faults are indicated to intersect the Site, with both trending north-west to south-east along the western edge and within the eastern portion of the Site, respectively. In addition, a coal seam is indicated to outcrop at the Site, also trending north-west to south-east, through the approximate centre of the field. Based upon information provided within the *Coal Mining Risk Assessment* by Delta-Simons (Report Ref. 16-0406.01, dated 23rd June 2016), this seam is understood to be the Meltonfield Coal Seam, which is approximately 1.07 to 1.3 m thick and dips to the north-east. The nearest surface water feature is indicated to be an unnamed drain, situated approximately 50 m south-west of the Site. The Site is not indicated to be situated within an area that is a designated Source Protection Zone (SPZ).		

	Based upon the above, the following controlled water / environmental receptors have been identified: ▲ The underlying Secondary A Aquifers.
Key Historical Features	<u>On-Site</u> Based upon information provided within the *Phase I Desk Study Report* and *Coal Mining Risk Assessment* by Delta-Simons (Report Refs. 16-0406.01, dated 23rd June 2016), the Site appears to have been undeveloped greenfield / agricultural land from as early as 1855, up until the present day. However, from as early as 1993, up until 1994, it is understood that the approximate central-northern portion of the Site was incorporated into an opencast coal mine, in which the Meltonfield Coal Seam was extracted, as well as another unnamed seam. A Coal Authority opencast mining extent map (Ref. 16596, Woodhead Farm), associated with the former opencast site, reports that "*coaling commenced*" on the 26th July 1993 and "*coaling* (was) *complete*" by the 17th June 1994, with the base of the mine achieving a depth of up to approximately 25.0 m below ground level (bgl) as was at the time of open casting. The opencast has since been backfilled with "*coal measure strata*", with the Site reverting to its previous greenfield / agricultural land use. Additional coal seams, at greater depth within the geological sequence, were also identified to be within potential influencing distance of the surface. Therefore, there is the potential for underground workings to also be present beneath the former opencast. <u>Off-Site</u> From as early as 1855, coal mining activity is indicated approximately 250 m west of the Site. By 1893, this is mapped as Hoyland Silkstone Colliery, with associated cooling ponds, railway tracks and suspected tanks situated between approximately 250 m and 500 m west of the Site. The colliery is absent from the reviewed mapping by 1980. A Garage was indicated approximately 65 m south-west of the Site by 1993, with the structure having been present since 1931. The site was demolished / cleared by 2002.

2.2 Preliminary Conceptual Site Model

A summary of the main risks identified in the preliminary Conceptual Site Model undertaken as part of the Preliminary Geo-Environmental Risk Assessment (Phase 1 desk study) is presented below. Risks previously considered very low, have not been included in the below summary.

Source(s)	Potential Contaminants of Concern (CoC)	Pathway(s)	Receptor(s)	Preliminary Risk Rating
Potential ground gas associated with the infilling of the former on-Site opencast coal mine (c.1993 to 1994)	Hazardous ground gases	P3	R1, R2, R3 & R6	Medium Risk
Suspected significant Made Ground associated with the infilling of the former on-Site opencast coal mine (c.1993 to 1994)	PAHs, heavy metals, asbestos, petroleum hydrocarbons	P1, P2, P4 & P5	R1, R2, R3, R4, R5 & R6	Low Risk
Potential contamination from identified off-Site sources, including a former garage	Petroleum hydrocarbons	P2 & P5	R1, R3 & R6	Low Risk

Pathways:

- P1 - Direct contact, ingestion or inhalation of soil bound contaminants / dust during or following redevelopment.
- P2 - Inhalation of organic vapours associated with contamination.
- P3 - Migration of ground gas / vapours into on-Site buildings causing asphyxiation or risk of explosion.
- P4 - Leaching of contamination into groundwater followed by migration of groundwater to the wider groundwater environment or discharge to surface waters.
- P5 - Direct contact between aggressive ground conditions and new infrastructure.

Receptors

- R1 - Construction workers.
- R2 - Third parties during construction (adjacent Site users and adjacent residents).
- R3 - Future Site users and maintenance workers.
- R4 - Surface waters (e.g. the unnamed drain).
- R5 - The underlying Secondary A Aquifers.
- R6 - The Built Environment (new buildings, infrastructure, and utilities).

3.0 Site Investigation

3.1 Intrusive Investigation

Delta-Simons carried out initial intrusive investigation works from the 23rd to 25th March 2020 to assess the potential linkages identified in the outline conceptual model (see Section 2.2 above) and to provide preliminary geotechnical information in relation to the former opencast high wall, the general composition of fill material and to establish the areas of the Site not directly impacted by former opencast operations.

Delta-Simons returned to the Site to carry out supplementary intrusive investigation works from the 2nd to 28th August 2020 to determine the depth and nature of the fill within the opencast, the settlement characteristics of opencast fill, the presence of shallow mine workings below the Site and the presence of ground gas.

3.1.1 Health & Safety Considerations

Service plans for the Site were provided by the Client, and a utilities clearance specialist attended the Site on the 23rd March 2020 and 2nd August 2020 to trace services on and around the Site prior to excavation of exploratory hole locations. As a further precaution for the avoidance of buried services, each position was scanned with a CAT & Genny (Cable Avoidance Tool) by the utility's clearance specialist.

An initial assessment of the Site identified a Low risk in relation to Unexploded Ordnance (UXO) and so no specific precautionary measures were required for the works.

Future Contractors should undertake their own assessment of UXO risk in relation to their specific proposed scope of works.

3.2 Scope of Ground Investigation and Rationale

3.2.1 Scope

The ground investigation comprised the following items:

23rd – 25th March 2020 (16-0406.02)

- Initial service avoidance exercise and surveying of intrusive locations by a utility's clearance specialist.
- Supervision of all works by a Delta-Simons (DS) Geo-Environmental Engineer. All intrusive locations were logged to BS5930:2015+A1:2020 Code of practice for ground investigations.
- Collection of a range of representative environmental and geotechnical soil samples.
- Undertaking of in-situ geotechnical testing (e.g. hand shear vane tests), where feasible.
- Excavation of 11 trial pits (TP101 to TP111), to a maximum depth of 4.8 m below ground level (bgl); and
- Excavation of six trial trenches to delineate the path of the former opencast highwall (TT101 to TT106c), to a maximum depth of 4.1 m bgl.

2nd – 28th August 2020 (16-0406.03)

- Supervision of all works by a DS Geo-Environmental Engineer, service avoidance/surveying of intrusive locations and collection of environmental and geotechnical soil samples as above.
- Drilling of three boreholes utilising cable percussion techniques to depths up to 25 m bgl or refusal on bedrock (whichever is shallower).
- Drilling of six rotary boreholes utilising open hole techniques (three to 45 m bgl and three to 30 m bgl) and suitable flush methodologies such as air/mist and water flush.
- Installation of all cable percussive boreholes and three rotary borehole locations as return ground gas/groundwater monitoring wells; and
- Construction of three 'Maintained Load Test' locations to assess the settlement characteristics of opencast fill material.

3.2.2 Rationale

Location	Rationale	Key Contaminants of Concern
TP101 to TP105	To target areas suspected to be underlain by opencast colliery spoil, in order to assess the nature of the fill and collect representative environmental and geotechnical samples.	PAHs, heavy metals, asbestos, petroleum hydrocarbons
TP106 to TP111	To target areas suspected to be underlain by shallow bedrock outside of the former opencast extents, in order to assess the nature of weathered bedrock and collect representative environmental and geotechnical samples.	N/A
TT101 to TT106c	To assess the location and path of the former opencast highwall at locations predetermined from an associated abandonment plan (Ref. 16596, Woodhead Farm), as well as collect representative environmental and geotechnical samples.	N/A
CP101 to CP103	To investigate the composition, material properties and thickness of opencast fill material, establish the depth to the base of the opencast and provide in-situ geotechnical testing and sample specimens for geotechnical analysis.	N/A
RH101 – RH106	To investigate the potential for shallow coal workings underlying the existing former opencast.	N/A
MLTA – MLTC	To investigate the settlement characteristics of untreated opencast fill material and to determine the rate and volume of settlement over time.	N/A

3.3 Ground Investigation Factual Data

The investigation locations were surveyed in by the appointed surveying contractor to an accuracy of approximately +/- 0.1m. Intrusive Exploratory Hole Location Plans are presented as Figure 2 and 3.

Delta-Simons exploratory hole logs are presented as Appendix B.

3.4 In-Situ Testing and Sampling

Where feasible, hand vane shear tests were undertaken on cohesive soils encountered within trial pits / trenches. Test results are included on exploratory hole logs presented in Appendix B.

Sampling comprised disturbed tub, jar, vial, and bulk samples, as detailed on the exploratory hole logs.

3.5 Geotechnical Laboratory Testing

A selection of soil samples were submitted to the UKAS accredited laboratory for a range of geotechnical testing, the results of which are included in Appendix C.

The programme of geotechnical testing undertaken on samples obtained from both anthropogenic and natural soils is presented within the table below. The purpose of the laboratory testing was to assess the classification properties of the soils encountered in order to inform the outline geotechnical design advice.

Suspected Colliery Spoil Testing		
Analysis	**No. Tested**	**Rationale**
Moisture Content	20	To assess the classification properties of granular and cohesive soils.
Plasticity Index – 4 Point Liquid Limit	18	
Particle Size Distribution (PSD) [Wet / Dry Sieve]	2	
Particle Size Distribution (PSD) [Sedimentation]	6	
Optimum Moisture Content (OMC) / Maximum Dry Density (MDD) Relationship	13	To assess the geotechnical properties of the soil for earthworks.
One Dimensional Consolidation Test	1	
Particle Density	1	
Calorific Value	2	To assess the potential for combustion of the colliery spoil.
Made Ground (Suspected Subsoil) Testing		
Analysis	**No. Tested**	**Rationale**
Particle Size Distribution (PSD) [Wet / Dry Sieve]	1	To assess the classification properties of granular and cohesive soils.
Natural Soil Testing		
Analysis	**No. Tested**	**Rationale**
Moisture Content	3	To assess the classification properties of granular and cohesive soils.
Plasticity Index – 4 Point Liquid Limit	3	
Particle Size Distribution (PSD) [Wet / Dry Sieve]	2	
Particle Size Distribution (PSD) [Sedimentation]	1	

3.6 Environmental Sampling, In-Situ Testing and Laboratory Analysis

Soils collected for laboratory analysis were placed in a variety of containers appropriate to the anticipated testing suite. Samples were stored in accordance with Delta-Simons' quality procedures to maintain sample integrity and preservation, and to minimise the chance of cross contamination. Records of the samples taken as part of the site investigation works, including their depths and location, are included within the exploratory hole records in Appendix B.

Samples analysed for environmental purposes were placed in chilled cool boxes at the Site and transported to the laboratory for analysis on completion of the site investigation works.

The rationale for chemical analysis is presented in the table below and the results of the chemical laboratory analysis are included in Appendix D.

Analytes	No. of Soil Samples Tested	Rationale
Asbestos	18	Common potential contaminant of concern, analysed in a range of topsoil and Made Ground samples from across the Site.
As, Cd, Cu, Cr, Cr (VI), Hg, Pb, Ni, Zn, speciated Polycyclic Aromatic Hydrocarbons (PAHs)	18	Common potential contaminants of concern, analysed in a range of topsoil and Made Ground samples from across the Site.

Analytes	No. of Soil Samples Tested	Rationale
Total Petroleum Hydrocarbons, Criteria Working Group Method (TPH CWG), Benzene, Toluene, Ethylbenzene and Xylene (BTEX)	18	Common potential contaminants of concern, analysed in a range of topsoil and Made Ground samples from across the Site.
pH, Sulphate (water soluble)	18	To assess potential for chemical attack on buried concrete from soils.
DS Concrete Suite (pH, water soluble sulphate, total sulphate, total sulphur)	14	
Soil Organic Matter (SOM)	6	To allow comparison of potentially elevated contaminants against their relevant assessment criteria.

3.7 Monitoring Programme

Six rounds of groundwater level and ground gas monitoring were undertaken on newly installed wells (RH101, RH105, RH106 and CP101 – CP103) between 16th September 2020 and 22nd October 2020. Measurements of the depth to groundwater within the monitoring wells were taken using an electronic dip meter. The groundwater level monitoring sheets are included as Appendix E.

To characterise the ground gas regime at the site, an infrared gas meter was used to measure gas flow, concentrations of carbon dioxide (CO_2), methane (CH_4) and oxygen (O_2) in percentage by volume. Initial and steady state concentrations were recorded. The atmospheric pressure before and during monitoring, together with the weather conditions, was recorded. All monitoring results obtained to date together with the temporal conditions are contained within Appendix E.

4.0 Ground Summary

4.1 Introduction

The sections below summarise the ground and groundwater conditions encountered during the site investigation.

4.2 Ground Model

A summary of the observed ground conditions at the Site is provided below.

Summary of Observed Ground Conditions					
Strata	**Typical Strata Description**	**Depth Range of Strata Base**		**Maximum Proven Thickness (m)**	**Comments**
		(m bgl)	**(m AOD)**		
Topsoil	Granular Example *Dark brown very clayey gravelly fine to medium SAND. Gravel is angular to subrounded is fine to coarse of sandstone and mudstone with rare red brick fragments, glass, and china.* Cohesive Example *Very soft to soft dark brown slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to subrounded fine to coarse of sandstone and mudstone with rare red brick fragments, glass, and china.*	*0.15 to 0.4*	*138.150 to 133.068*	*0.4 (TT101b, TT103a & TT103b)*	Topsoil was encountered in all trial pit locations.
Subsoil	Granular Example *Dark orangish brown very clayey gravelly fine to medium SAND. Gravel is angular to subangular fine to coarse of sandstone and mudstone.* Cohesive Example *Very soft to soft brown sandy CLAY. Sand is fine to coarse.*	*0.35 to 0.5*	*138.050 to 135.527*	*0.2 (TP107)*	Subsoil was only encountered within TP107 to TP109.
Made Ground (Suspected Subsoil)	*Orangish brown very clayey very sandy angular to subrounded fine to coarse GRAVEL of sandstone, mudstone, and rare red brick fragments. Sand is fine to coarse.* or *Orangish brown very clayey very gravelly fine to coarse SAND. Gravel is angular to subrounded fine to coarse of sandstone and mudstone.*	*0.5 to 1.2*	*137.642 to 134.321*	*0.95 (TT102a)*	This Made Ground was encountered in all locations apart from TT106c and TP106 to TP111.
Suspected Colliery Spoil	Granular Examples *Light to dark grey varying to black slightly clayey very sandy angular to subangular GRAVEL of mudstone. Sand is fine to coarse. Frequent angular to subangular cobbles and boulders of mudstone.* *Light to dark grey varying to black very sandy very gravelly angular to subangular COBBLES of mudstone. Sand is fine to coarse. Gravel is angular to subrounded fine to coarse of mudstone. Frequent angular to subangular boulders of mudstone.*	*1.7 to 22.0*	*135.896 to 116.65*	*22.0 (RH103)*	Suspected colliery spoil was not encountered in locations situated outside the extent of the former opencast (TT101c, TT102b, TT104a, TT106c and TP106 to TP111).

Summary of Observed Ground Conditions					
Strata	**Typical Strata Description**	**Depth Range of Strata Base**		**Maximum Proven Thickness (m)**	**Comments**
		(m bgl)	**(m AOD)**		
	Cohesive Examples *Soft to firm dark grey slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to subangular fine to coarse of mudstone and sandstone. Frequent angular to subangular cobbles and boulders of mudstone and sandstone.* *Firm to stiff friable dark grey slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to subangular fine to coarse of mudstone. Frequent angular to subangular cobbles of mudstone.*				
Completely Weathered Woolley Edge Rock	*Orangish brown varying to cream and brownish cream very clayey very gravelly fine to coarse SAND. Gravel is angular to subangular fine to coarse of sandstone.*	*0.8 to 1.4*	*137.4 to 132.468*	*1.05 (TT106c)*	Such strata were predominantly encountered in the eastern portion of the Site, within TT104a, TP106c and TP106 to TP108.
Weathered Woolley Edge Rock	*Light orangish brown slightly clayey very sandy angular to subangular GRAVEL of sandstone. Sand is fine to coarse. Frequent angular to subangular cobbles and boulders of sandstone* and / or *Very weak to weak thickly laminated varying to thinly bedded light grey fine to medium SANDSTONE. Recovered as: Light grey stained orangish brown very sandy very gravelly angular to subangular COBBLES of sandstone. Frequent angular to subangular boulders of sandstone.*	*>1.4 to >3.0*	*<136.7 to <131.068*	*>1.4 (TP106)*	Such strata were predominantly encountered in the eastern portion of the Site, within TT104a, TT105b, TT105c, TT106b, TT106c and TP106 to TP108. Base not proven.
Completely Weathered Pennine Middle Coal Measures Formation	*Firm to stiff orangish brown (and / or light bluish grey) mottled grey, dark grey and orange sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is angular to subangular fine to coarse of mudstone, siltstone, and coal.* and / or *Firm to stiff locally laminated friable dark bluish grey mottled orange and black slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to subangular fine to coarse of mudstone and siltstone.*	*1.1 to 3.5*	*134.077 to 132.271*	*2.5 (TP111)*	Such strata were predominantly encountered in the western portion of the Site, within TT101, TT101c, TT101e, TT102b, TP109 to TP111.
Weathered Pennine Middle Coal	*Dark bluish grey (and / or light grey mottled orange and brown) clayey sandy angular to subangular fine to coarse GRAVEL of mudstone and siltstone. Sand is fine to coarse. Frequent angular to*	*>1.45 to >4.1*	*<134.996 to <132.165*	*>0.9 (TT103b)*	Such strata were predominantly encountered in the western

Summary of Observed Ground Conditions					
Strata	**Typical Strata Description**	**Depth Range of Strata Base**		**Maximum Proven Thickness (m)**	**Comments**
		(m bgl)	**(m AOD)**		
Measures Formation	*subangular cobbles and boulders of mudstone and siltstone.* and / or *Very weak to weak thickly laminated dark bluish grey MUDSTONE (and SILSTONE). Recovered as: Dark bluish grey slightly clayey sandy angular to subangular fine to coarse GRAVEL of mudstone (and siltstone). Sand is fine to coarse. Frequent angular to subangular cobbles and boulders of mudstone (siltstone).* and / or *Very weak to weak thickly laminated varying to thinly bedded light grey fine to medium SANDSTONE. Recovered as: Light grey mottled orange and brown very sandy angular to subangular GRAVEL of sandstone. Sand is fine to coarse. Frequent angular to subangular cobbles and boulders of sandstone.*				portion of the Site, within TT101, TT101c, TT101e, TT102b, TT103a, TT103b and TP109 to TP111. Base not proven in trial pit locations.
Pennine Middle Coal Measures Formation	*Grey MUDSTONE or intact COAL.*	*>30.0 – >45.0*	*>108.09 ->91.44*	*22.5 (RH101)*	Competent strata were encountered underlying the base of the former opencast within all rotary borehole locations. Base not proven.

Locations of the individual exploratory locations are presented on Figure 2 and Figure 3.

The current ground investigation recorded a variable thickness of topsoil across the Site, which was locally underlain by a thin layer of natural subsoil (TP107 to TP109) and / or Made Ground (subsoil).

Beneath this, and within the extent of the former opencast (central-northern portion of the Site [including TT101, 101e, 101b, 102a, 104b, 106a, 106b, 105a, 105b, 105c and TP101 to 105]), the ground typically comprised granular and cohesive colliery spoil with a significant portion of cobbles and boulders of mudstone and sandstone (boulders up to 1.1 m in length [TT106a]).

A discernible layer of cobbles and boulders was present in the colliery spoil, encountered at 0.6 (TT105c) to 2.05 (TP101) m bgl [137.165 (TP103) to 133.738 (TT102a) m AOD] up to a maximum depth of between 1.85 (TT105c) to 3.9 (TT105a) m bgl [136.092 (TP104) to 131.872 (TT106a) m AOD]. The maximum thickness of this layer was 2.8 m, in TT105a.

Completely weathered to weathered bedrock, without overlying colliery spoil, were encountered underlying topsoil, subsoil and / or the Made Ground to the south, east and west of the former opencast extents (TT101c, 102b, 104a, 106c and TP106 to 111). The completely weathered bedrock typically comprised cohesive and granular material in the western (west of, and including, TT103b) and eastern (east of, and not including, TT103b) halves of the Site, respectively, which are assumed to be the Pennine Middle Coal Measures Formation and Woolley Edge Rock.

Where trial pits and trenches were excavated outside the extent of the former opencast, digging ceased at the depth at which excavation became difficult, due to scraping on suspected weathered bedrock.

A targeted investigation to assess the extent of the former opencast colliery was undertaken by the progression of trial trenches (TT101 to TT106c). The individual trenches were carried out at predetermined locations, based upon the anticipated highwall location indicated on a Coal Authority opencast mining extent map (Ref. 16596, Woodhead Farm).

Each trench was excavated approximately perpendicular to the proposed location of the highwall, with the aim of encountering the edge of the colliery spoil and assessing the nature of the underlying and / or adjacent highwall bedrock. At each trench location, at least two individual pits were excavated (i.e. TT102a and TT102b), with at least one of these encountering colliery spoil at increasingly shallower depths, subsequently underlain by completely weathered to weathered bedrock variants.

The gradient of the highwall varied between locations, with TT101 resembling a shallow slope and TT102 to TT106 showing a stepped and sloping profile. Plates A to D, below, show the edge of the former opencast and nature of the backfill.

Based upon the observed edge of the colliery spoil, and the subsequent presence of underlying and / or adjacent bedrock, the path of the proposed highwall / colliery extent was extrapolated between each trench location (see

Plate A: View of TT105, with associated arisings. Facing east.

Plate B: Tapering edge of colliery spoil (dark grey) overlying a slope of weathered bedrock and sandstone cobble fill in TT105b / 105c. Facing south-east.

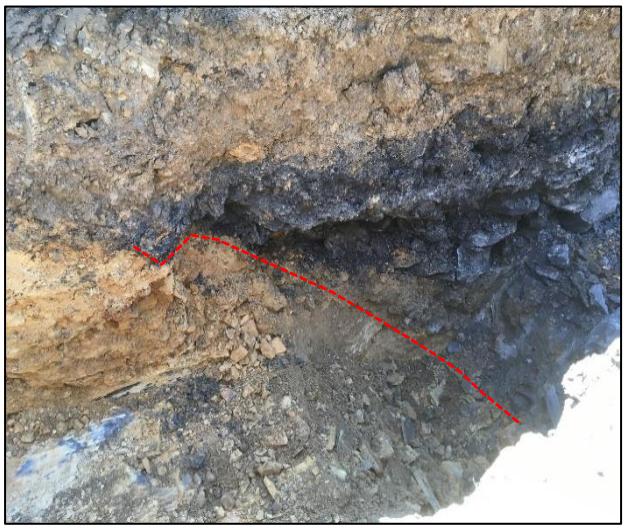

Plate C: Tapering edge of colliery spoil (dark grey) overlying a ramp of weathered bedrock (suspected highwall) in TT106b / 106c. Facing south.

Plate D: View into TT106b/106a, from TT106c, with a transition from weathered bedrock (light orangish brown) into colliery spoil (dark grey). Facing south-west.

Figure 2). Comparison of this inferred highwall path with that presented on the Coal Authority (CA) opencast mining extent map (Ref. 16596, Woodhead Farm), indicates that the two are broadly consistent (see Figure 3). Further investigation would be required to accurately plot the path of the highwall in the areas between the trench locations.

No obvious high wall was encountered along the western extremity of the former opencast, suggesting that a ramp may have been used to facilitate extraction. The geometry of the opencast recorded from deeper borehole investigation supports this and aligns with the CA abandonment plan (Ref. 16596, Woodhead Farm) provided in Appendix G. Boreholes drilled to specifically investigate the nature and depth of the colliery spoil and the potential for shallow workings predominantly encountered colliery spoil, mudstone (Middle Coal Measures Formation) and intact coal.

The base of the former open cast varied between locations, however it generally increased in depth, downdip (to the north-east) as would be expected. RH103 and RH104 recorded the deepest and thickest extent of colliery spoil at a depth of 22.0 m bgl (116.65 m AOD and 115.89 m AOD) and is concurrent with the CA abandonment plan (Ref. 16596, Woodhead Farm).

Suspected broken ground was recorded in RH106 between 20.00 – 20.50 m bgl (118.09 – 117.59 m AOD). Further discussion regarding the risk of shallow coal workings to the Site is provided in Section 5.2. A summary of the coal seams encountered is provided in the table below.

Borehole Location	Depth	
	m bgl	m AOD
RH101	7.50 – 8.50	127.90 – 126.90
RH102	12.00 – 13.00	124.44 – 123.44
	22.00 – 22.40	114.44 – 114.04
	38.30 – 38.40	98.14 – 98.04
RH103	24.00 – 24.50	114.65 – 114.15
	31.00 – 32.00	107.65 – 106.65
RH104	24.00 – 24.40	113.89 – 113.49
	32.00 – 32.30	105.89 – 105.59
RH105	10.80 – 11.10	125.36 – 125.06
	22.00 – 22.40	114.16 – 113.76
RH106	4.00 – 4.40	134.09 – 133.69
	15.00 – 15.30	123.09 – 122.79
	16.50 – 16.70	121.59 – 121.39
	20.50 – 21.00	117.59 – 117.09

4.3 Visual and Olfactory Evidence of Contamination - Soils

No visual and / or olfactory evidence of potential gross contamination was observed during the investigation.

4.4 Groundwater

4.4.1 Strikes During Investigations

Groundwater strikes recorded as excavations progressed during the site investigation range from 1.5 to 2.7 m bgl (136.09 to 132.92 m AOD). The groundwater strikes recorded during excavation are summarised below.

Exploratory Hole	Water strike during excavation		Stratum	Area of Site	Comment
	m bgl	m AOD			
TP104	2.05	136.09	Suspected Colliery Spoil	Centre	Fast seepage of groundwater suspected to be confined to the surface of a cohesive fill layer.
TT101b	1.5	134.53	Suspected Colliery Spoil	North-west / west	Fast seepage of groundwater from a layer of granular fill.
TT101c	2.7	132.92	Weathered Pennine Middle Coal Measures Formation	North-west / west	Slow pooling of groundwater on the surface of weathered mudstone bedrock.

Groundwater was only encountered within the north-western / western (TT101b and TT101c) and central (TP104) portions of the Site. Given the relatively low topography of the north-western / western edge of the field, it is considered reasonable that groundwater may be at a shallower depth in this area. The most significant groundwater seepages were encountered within suspected colliery spoil (TP104 and TT101b), where potentially confined groundwater is considered to have been exposed during excavation. It is possible that there is a perched groundwater source within the colliery spoil. Slight pooling of groundwater was also reported on the surface of mudstone bedrock (TT101c), which is suspected to be locally confined between the mudstone and completely weathered bedrock (clay). No notable groundwater strikes were observed during drilling of either the cable percussive or rotary borehole locations. Given the variable heterogeneous nature of the fill, it is possible that any shallow perched water bodies are discontinuous both laterally and vertically.

4.4.2 Levels During Monitoring Programme

Groundwater levels were monitored on a total of six occasions between 16th September 2020 and 22nd October 2020. Monitoring data and LNAPL measurements are provided in Appendix E and summarised in the table below.

Exploratory Hole	Response Zone		Water level range during monitoring		LNAPL Y/N	Stratum
	m bgl	m AOD	m bgl	m AOD.		
RH101	1.00 – 10.00	134.40 – 125.4	1.80 – 6.52	133.60 – 128.88	N	Suspected Colliery Spoil & Pennine Middle Coal Measures Formation
RH105		135.16 – 126.16	1.45 – 4.48	134.71 – 131.68	N	
RH106	1.00 – 3.00	137.09 – 135.09	2.79 – 4.47	135.30 – 133.62	N	

Groundwater levels during monitoring varied between 1.45 and 6.49 m bgl (131.68 to 133.60 m AOD). The Site investigation data suggests that there is no evidence of an established groundwater table within the backfilled opencast. Minor seepages were observed within some trial pits and this has been interpreted to be perched groundwater within the colliery spoil.

4.5 Visual and Olfactory Evidence of Contamination - Groundwater

No visual and / or olfactory evidence of potential gross contamination was observed during the investigation.

4.6 Material Properties

The table below summarises the factual material properties based upon the results of in-situ and laboratory test data and where appropriate provides derived geotechnical parameters.

Parameter	Suspected Colliery Spoil (Granular)	Suspected Colliery Spoil (Cohesive)	Completely Weathered Pennine Middle Coal Measures Formation (Cohesive)
Water Content - w	-	7.6% - 24%	12% - 36%
Laboratory Received Moisture Content (from OMC testing) - w	0% - 21%	14% - 20%	-
Liquid Limit - w_L	-	30% - 73%	42% - 68%
Plastic Limit - w_P	-	17% - 30%	22% - 36%
Plasticity Index - I_P	-	13% - 27%	18% - 32%
Modified Plasticity Index – I'_P	-	10% - 21%	18% - 32%
Bulk Density	-	2.04 – 2.28 Mg/m^3	
Maximum Dry Density	1.85 – 2.05 Mg/m^3	1.67 – 2.07 Mg/m^3	-
Optimum Moisture Content (OMC)	9% - 15%	9% - 19%	-
Uncorrected SPT N Value	8 – 50	2 – 68	50
Corrected SPT[1,2] (N_{60})	9 - 58	2 – 78	58
In-Situ Undrained Shear Strength[3] - C_u	-	-	69 – 108 kPa
Particle Density	2.67 Mg/m^3	2.66 Mg/m^3	-
Calorific Value	6.59 MJ/Kg	0.873 MJ/Kg	-

Notes:

1. SPT N values corrected for energy delivered to drive rods utilising the determined energy ratio (Er): N_{60} = (Er x N)/$_{60}$ after BS EN ISO 22476-3:2005.
2. Consideration must be given to the heterogenous and variable nature of fill material when interpreting N values produced by in-situ SPT testing.
3. In-Situ testing undertaken by Hand Shear Vane.

4.6.1 Earthworks Material Classification

Earthworks and Particle Size Distribution (PSD) testing has been undertaken as part of this assessment. The table below summarises material grading results and the corresponding earthworks classification, in accordance with the Specification for Highways Works, Series 600, Table 6/2. It should be noted that it was not practical for oversize particles (e.g., large cobbles and boulders) to be included within the samples for screening and as such these coarse fractions are not accurately represented below, and reference should also be made to the exploratory hole logs.

Location	Depth (m bgl)	Geology	Cobble Content (%)	Gravel Content (%)	Sand Content (%)	Fines Content <0.063mm (%)		Series 600 Earthworks Class (Table 6/2)
						Silt	Clay	
TP101	2.6 – 3.5	Suspected Colliery Spoil (Granular)	0.0	63.2	19.2	17.6		Class 2C
TP103	0.8 – 1.1	Suspected Colliery Spoil (Cohesive)	0.0	22.4	24.9	28.9	23.8	Class 2C
TP105	0.3 – 0.8	Made Ground (Suspected Subsoil) (Granular)	8.5	40.2	34.8	16.5		Class 2C
TP107	1.2 – 1.4	Completely Weathered Woolley Edge Rock (Granular)	8.9	61.5	22.6	7.0		Class 1A
TT101c	1.5 – 2.0	Completely Weathered Pennine Middle Coal Measures Fm. (Cohesive)	0.0	0.0	5.9	39.8	54.3	Class 2A & 2B
TT102a	1.7 – 2.0	Suspected Colliery Spoil (Granular)	0.0	36.8	19.2	31.1	12.9	Class 2C
TT106a	2.5 – 2.9	Suspected Colliery Spoil (Granular)	0.0	41.3	27.2	31.5		Class 2C
CP101	3.0 – 3.45	Suspected Colliery Spoil (Cohesive)	0.0	32.7	30.1	27.0	10.2	Class 2C
CP101	4.0 – 4.45	Suspected Colliery Spoil (Granular)	0.0	20.8	37.4	41.7		Class 2C
CP102	3.0 – 3.45	Suspected Colliery Spoil (Cohesive)	0.0	21.9	17.7	35.7	24.7	Class 2C
CP103	3.0 – 3.45	Suspected Colliery Spoil (Granular)	0.0	45.6	25.0	20.7	8.70	Class 2C
CP103	4.0 – 4.45	Suspected Colliery Spoil (Granular)	0.0	43.3	22.1	25.8	8.8	Class 2C

4.7 Geochemical Testing

Geochemical analysis was undertaken on soil samples of anthropogenic and natural material which were tested for selective contaminants in accordance with BRE Special Digest 1:2005 [3rd Edition], Concrete in Aggressive Ground, the results of which are summarised in the table below.

Tests	Minimum Value	Maximum Value
Colliery Spoil		
Soil – pH	7.0	7.8
Soil - Total Sulphur	0.03%	0.172%
Soil – Acid Soluble Sulphate	0.014%	0.064%
Soil - Water Soluble Sulphate	19.9 mg/L	317.0 mg/L
Subsoil (Made Ground)		
Soil – pH	6.9	6.9
Soil - Total Sulphur	0.007%	0.007%
Soil – Acid Soluble Sulphate	0.007%	0.007%
Soil - Water Soluble Sulphate	12.0 mg/L	12.0 mg/L
Natural Soils		
Soil – pH	4.5	7.9
Soil - Total Sulphur	<0.005%	0.041%
Soil – Acid Soluble Sulphate	<0.005%	0.02%
Soil - Water Soluble Sulphate	6.0 mg/L	74.1 mg/L

5.0 Geotechnical Assessment

The investigation was undertaken to assess the likely presence and location of the high wall of a former opencast in relation to the rest of the Site area, understand the properties of colliery spoil material in central/northern areas, and establish the risk posed to the Site from the possible presence of shallow coal workings.

The principle geotechnical constraints associated with the Site are related to the infilled opencast itself, the high wall associated with former opencast operations, possible presence of underlying shallow coal workings and the relationship between heterogenous colliery spoil fill and natural weathered bedrock. The level of mitigation measures required based on the above constraints will be dependent on the findings and conclusions of this assessment.

It is understood that elevations will be increased in the north-eastern part of the Site to establish a suitable topographic gradient for drainage purposes.

5.1 Summary of Development Proposals

It is understood that the Site is to be redeveloped to accommodate traditional low-rise residential housing, with associated driveways, gardens, soft-landscaping, access roads and an area of public open space. A Feasibility Site Plan is provided as Drawing 1.

It is understood that the preferred founding solution in areas to south, southeast, and east of the opencast perimeter would ideally comprise of traditional strip footings.

It is also understood that consideration is being given by the design team to re-engineering the top 3.0 m of fill within the extent of the former opencast coal mine, in order to facilitate the use of shallow raft foundations.

Proposed finished levels have been provided to Delta-Simons and are presented in Drawing 2.

5.2 Intrusive Coal Mining Risk Assessment (CMRA)

A previous detailed desk-based Coal Mining Risk Assessment (CMRA) was undertaken for the Site in June 2016 (16-0406.01) and should be read in conjunction with this report for wider context. The conclusions of that assessment in conjunction with the findings of the current intrusive investigation are summarised below.

5.2.1 Information Sources

- Published 1:50,000 geological mapping (Sheet Number 87 [Barnsley]).
- Previous Delta-Simons Coal Mining Risk Assessment (16-0406.01).
- Review of historical OS mapping.
- CA mine abandonment plans (Cat No.16596, Woodhead Farm, Cat No. NE556_44_3601, Cat No. NE853_44_3601); and
- Coal Authority online database (Interactive Map Viewer).

5.2.2 Geological Mapping

The published 1:50,000 geological mapping (Sheet No. 87 [Barnsley]) shows that the Site area directly underlain by the Pennine Middle Coal Measures Formation, comprising Carboniferous mudstones and siltstones interbedded with sandstones and coal seams in central and central western areas of the Site. In eastern areas, the Woolley Edge Rock (sandstone) is recorded to underlie the Site. Unlike the Pennine Middle Coal Measures Formation, the Woolley Edge Rock is not considered to be carbonaceous strata.

Two faults are located on Site in the north-east and south-west. Both faults are mapped as trending north-west to south-east, with the downthrow to the north-east in accordance with the local geological dip direction. The maximum angle of dip in the wider geological catchment is recorded as 5° and has been assumed for this assessment.

The mapping shows that the Meltonfield Coal seam, approximately 1.07 m to 1.30 m thick (maximum of 1.40 m on BGS 1:50,000 mapping) outcrops centrally on the Site, trending in accordance with the local geology as described above, dipping to the north-east. A thin, unnamed seam is also mapped, and overlies the Meltonfield Coal. Underlying the Meltonfield Coal, the Two-Foot Coal, Winter Coal, Top Beamshaw Coal, Low Beamshaw Coal and Kent's Thin Coal are recorded as underlying the Site, despite not sub-cropping on-Site.

A Generalised Vertical Section (GVS) inclusive of seam thickness is provided for reference below:

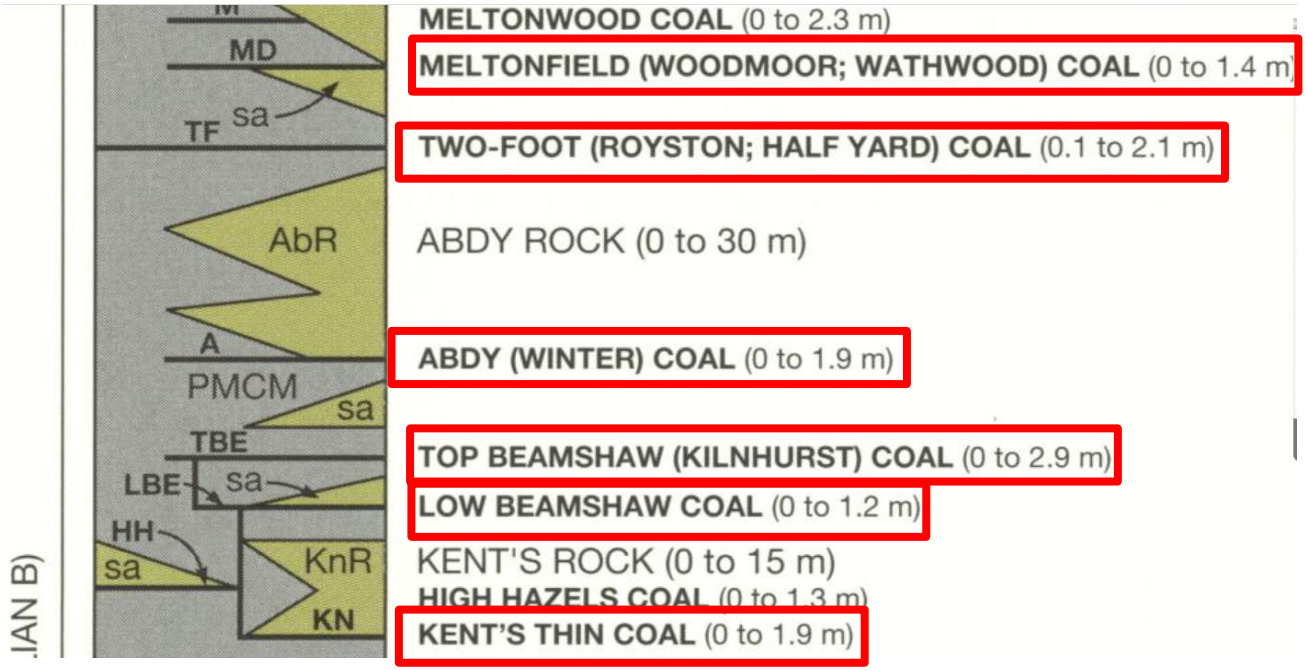

Plate E: Generalised Vertical Section (GVS) of local geology (Source: BGS© Sheet No.87, Barnsley, bedrock & superficial (2008)).

Considering the above seams, the previous Delta-Simons CMRA (16-0406.01) provided depth conjecture information based on a 5° dip angle, and concludes that workable seams potentially posing a risk to the Site are:

- Meltonfield Coal (surface to 4 m bgl).
- Two-Foot Coal (9 m bgl – 22 m bgl).
- Winter Coal (15 m bgl – 28 m bgl); and
- Top Beamshaw Coal (29 m bgl – 42 m bgl).

The Low Beamshaw Coal and Kent's Thin Coal are considered to be at sufficient depth as to not pose a risk to the surface in the event of workings collapse.

5.2.3 Mine Abandonment Plans

Delta Simons has obtained copies of Mine Abandonment Plans held for local collieries by the Coal Authority (CA) included and are included as Appendix G.

Abandonment plan reference 16596, Woodhead Farm confirms that the former opencast extracted an unnamed coal seam and the underlying Meltonfield Coal that is recorded to sub-crop on-Site. Abandonment plans NE556_44_3601 and NE853_44_3601 show workings in the Parkgate Seam and Top Fenton Seam respectively however are recorded at extensive depth underlying the Site between 130 m and 500 m bgl. These seams are not considered to represent a risk to the Site.

The previous CMRA stated that although no evidence of workings in the Two-Foot Coal, Winter Coal or Top Beamshaw Coal has been identified, shallow workings in those corresponding seams at that stage could not be discounted.

No shafts or adits were indicated to be situated on or in the local vicinity of the Site, with the nearest mine entry located approximately 200 m southwest of the Site associated with Hoyland Silkstone Colliery.

5.2.4 Findings of Borehole Investigation

The investigation identified the base of the opencast in all cable percussive and rotary series boreholes, gradually deepening in a north-easterly direction and orientation. This increase in depth ranges from 7.50 m bgl (127.90 m AOD) in the far south-west corner, to 22.0 m bgl (116.65 m AOD) adjacent to the northern boundary of the Site. This relationship is concurrent with the gradual phased extraction of both the unnamed coal and Meltonfield seams in a down geological dip orientation. Geological cross sections presenting both the conjectured opencast geometry from abandonment plans and depth to opencast base from investigation borehole data are included as Figures 4a and 4b.

The rotary boreholes identified intact coal in all locations (RH101 – RH106) at a variety of depths and thicknesses. Possible broken ground was encountered in one location, RH106 between 20.00 – 20.50 m bgl (118.09 – 117.59 m AOD). Despite this observation from drilling arisings, loss of flush has been described as “momentary” with no report of resistance loss on the drill string. Given the observations, it is deemed unlikely that this is representative of broken ground given continued drill string resistance. As a result, a valid explanation for a momentary loss of flush could be a natural fissure within competent bedrock which has rapidly filled allowing flush to return.

Standard practice in the UK is to follow CIRIA guidance ‘Abandoned mine workings manual, published in 2019. As a general ‘rule of thumb’, for there to be a reduced risk of mine-workings collapse propagating to the surface, there should be an overburden thickness ratio of at least 10:1 (i.e. 10 m of competent overburden to 1 m seam or void thickness).

In the event that broken ground is in fact present in RH106, the table below shows the overburden that would be required based on the thickness of possible broken ground beneath the Site. The 10:1 ratio is likely to be achieved in this situation:

Detail / Borehole	RH106
Depth to suspected broken ground (m) (Elevation m OD)	20.00 – 20.50 (118.09 – 117.59 m OD)
Thickness of suspected void / broken ground (m)	0.50
Approximate overburden thickness required to satisfy the 10:1 ratio (m)	5.00
Overburden thickness (m)	16
Criteria met?	Yes
Evidence of workings / void / broken ground	Momentary Loss of flush, drilling arisings

5.2.5 Conclusions

The investigation has successfully identified the geometry of the former opencast colliery on-Site with the subsequent confirmation of the absence and assumed extraction of an unnamed seam, in addition to the Meltonfield Coal.

Aside from possible broken ground encountered in RH106, there were no other anomalies observed during the drilling of all rotary series boreholes. Intact coal of what is interpreted to be the Two Foot Coal and discontinuous Winter Coal was encountered in accordance with local geological dip and conjecture and presented no evidence to suggest that any of the coal deposits had been previously exploited. As such, the findings of this investigation

suggest that the risk of shallow coal workings underlying and out with the former opencast to the Site is considered to be low.

5.3 Maintained Load Tests

Due to the ground model at the Site comprising of extensive thicknesses of suspected colliery spoil Made Ground, three Maintained Load Tests (MLTA, MLTB and MLTC) were constructed to assess the settlement characteristics of the shallow fill. The data from the analysis will likely inform the compaction specification of any subsequent earthworks at the Site. The test locations are shown on Figures 2 and 3.

5.3.1 Setup & Methodology

The Maintained Load Settlement tests were setup and constructed in general accordance with *BRE Building on Fill, Chapter 7.6 Load Tests.* The general setup of each location comprised of the following:

- Preparation of test location by removing any topsoil to a depth of 300 mm.
- Placement of sand blinding to a depth no greater than 100 mm.
- Placement of a steel plate (1.25m x 1.25m x 25mm) onto the sand blinding; and
- Placement of 7200kg load (concrete kentledge and steel plate) to simulate at least 150 % of the anticipated design loading as provided by the engineer assuming a raft foundation.

Once the test locations were constructed, a surveyor undertook initial benchmarking of the four corners of each testing to establish GPS locations and initial elevation data in order to commence the testing.

Plate F: Site example of the constructed Maintained Load Test.

5.3.2 Monitoring Methodology & Frequency

The monitoring of the settlement tests commenced on 25th August 2020 and completed on 5th May 2021, with 24 monitoring visits undertaken in total over a period of 252 days.

Upon each visit, the surveyor obtained current elevation data for the four corners (A1 – A4, B1 – B4, C1 – C4) of each settlement test in comparison to surrounding benchmarks. By taking four elevation readings on each settlement test per visit, any evidence of differential settlement can be recorded alongside total settlement.

5.3.3 Monitoring Results & Interpretation

The monitoring results are provided in Appendix F and in the table below.

Maintained Load Test (MLT)	Corner	Total Settlement (mm) [1]	Total Settlement (mm) [2]	Total Settlement (mm) [3]
A	1	4	2	3
A	2	3	1	2
A	3	2	1	2
A	4	5	3	4
B	1	11	7	9
B	2	7	5	6
B	3	8	5	6
B	4	9	6	7
C	1	5	3	3
C	2	7	4	4
C	3	7	5	5
C	4	5	3	3

[1] Total settlement up to and including 23rd February 2021.
[2] Total settlement up to and including 7th April 2021.
[3] Total settlement as of last monitoring visit on 5th May 2021.

There are discrepancies with data obtained on the final two monitoring events with the MLTs showing upward movement, contrary to the ongoing trend of settlement (primary consolidation). The cause of this is unknown, however the fixed monitoring datum has likely recently been damaged.

Regardless of this, the level of settlement recorded over a period of circa 8.5 months is reasonable (maximum 9 to 11 mm in circa 8.5 months) however it is important to note that based on the data obtained, in cannot be demonstrated that primary consolidation settlement is completed, and we do not know how long it will go on for. This has been established by plotting the settlement (mm) against time (days) as a logarithmic scale. The plots are presented as Figures 7, 8 and 9.

5.3.4 Summary

From the monitoring data obtained, it is not yet clear how long primary consolidation will take place for, nor the likely total volume of consolidation over that period. After 8.5 months of monitoring, Figures 7, 8 and 9 do not show a sufficient reduction in the rate or volume of settlement to suggest that primary consolidation is finalising. It is important to note that the maximum primary consolidation settlement recorded to date is 9 to 11 mm (+/- 1mm) and has been recorded on otherwise un-improved ground. As such, it is likely that the overall rate of

primary consolidation is low, however could progress over the foreseeable future assuming soils remain un-improved.

The warranty provider will likely request detailed settlement data in order to ensure that settlement risk to the proposed development has been properly considered and assessed at the Site, and the data obtained over the monitoring period can be provided for this purpose. This data becomes especially important when signing off future plots. Further MLTs post earthworks, to demonstrate performance of the fill, will also be required for this purpose.

5.3.5 Currently proposed engineering solution

It is currently understood that an earthworks contractor has been engaged with regards an engineered solution to the Site to reduce risks associated with total and differential settlement of the fill. This, in brief, comprises the excavation and re-engineering, via controlled compaction in layers, of the top 3.0m of colliery backfill. We understand this is a solution that has obtained warranty provider approval on similar schemes in the past and can achieve a better control of the nature and performance of the engineered backfill as opposed to alternate methods such as dynamic compaction. Raft foundations are proposed in conjunction with the underlying engineered fill.

Re-engineering the top 3.0 m of soil across the Site to an engineering specification will improve the geotechnical properties of the shallow soils and as a result the primary consolidation settlement is likely to reduce accordingly. By creating a uniform rigid layer of engineered fill, this will help to mitigate the risk of excessive differential settlement. The Site investigation data suggests that there is no evidence of an established groundwater table within the backfilled opencast and due to the time elapsed since the fill was placed regional groundwater levels are likely to have recovered. Minor seepages were observed within some trial pits and this has been interpreted to be perched groundwater within the colliery spoil. It is therefore considered that the risk of collapse compression associated with inundation of the colliery spoil is low, and the risk will be further mitigated by the construction of areas of hardstanding and installation of surface water drainage systems.

5.4 Foundations

The Site can be characterised by the requirement for varying founding solutions potentially including, but not limited to, reinforced raft foundations and traditional strip footings where different geotechnical properties are present. Therefore, it is considered necessary to undertake “foundation zoning” and a drawing showing differing founding solutions is included as Figure 5.

5.4.1 Highwall

The indicative location of the highwall is shown on Figure 10 and this is based on an extrapolated line between the trial trench locations, where the edge of the colliery spoil was observed during the intrusive Site investigation and information from the CA abandonment plan. The actual location of the highwall may vary in between investigation locations.

Although this feature is referred to as a high wall, the geometry suggests it is more indicative of a buried slope, with gradients of circa 12 degrees recorded in the west, and circa 50 degrees recorded in the east.

Assuming a slope angle of 45 degrees, it is considered that a recommended minimum ‘no build’ offset of 5 m from the line of the ‘high wall’ is likely to be sufficient to avoid shallow foundations influencing outside of natural undisturbed bedrock strata.

Proposed properties within the former opencast appear to be at least 5 m from the buried ‘high wall’ and when this is considered in conjunction with the maintained load test data, the proposal to re-engineer the top 3.0 m of colliery spoil and utilise reinforced raft foundations, the risk of excessive differential settlement is considered to be low. It is recommended that this 5 m offset from the line of the ‘high wall’ is maintained.

Should the masterplan be revisited, it is recommended that the 5 m no build zone from the line of the ‘high wall’ is maintained.

5.4.2 Plots 1 – 19 and 72 – 84 (not within backfilled opencast)

Thin deposits of Made Ground ranging between maximum depths of 0.15 – 0.50 m bgl have been encountered. These areas are situated to the south, southeast and east of the high wall.

Based on the Site investigation undertaken, shallow strip foundations are considered to be suitable, founded at a minimum depth of 1.0 m bgl within sands and gravels (Completely Weathered Woolley Edge Rock) or firm to stiff clay (Completely Weathered Pennine Middle Coal Measures Formation) with a minimum undrained shear strength of 50 kPa.

Where cohesive soils exhibit an undrained shear strength in excess of 50 kPa, an allowable bearing capacity of 100 kPa is likely to be achieved (limited to < 25 mm settlement).

Where possible all foundations should be founded within one material type i.e. clay or sand, to reduce the potential for differential settlement. Localised over excavation may be required to ensure the minimum undrained shear strength is achieved in cohesive soils. All foundation excavations should be inspected by a suitably qualified geotechnical engineer prior to casting to ensure the appropriate depth, founding strata and strength characteristics have been achieved.

5.4.3 Plots 20 – 71 (within backfilled opencast)

5.4.3.1 Earthworks

The colliery spoil encountered comprised of varying clay, sand, and gravel deposits. By nature of this variation, it is considered that opencast fill material is likely to be too unpredictable and compressible for shallow foundations, in its current untreated form.

It is understood that ground improvement in the form of excavate and replace is proposed within the former opencast. We understand that the preferred solution is to excavate and recompact the top 3.0 m of colliery spoil (from existing ground level), to achieve a uniform and strengthened layer to enable raft foundations to be adopted. As a result of undertaking ground improvement, the total volume of primary consolidation will be reduced, and the risk of excessive differential settlement mitigated.

Materials used as fill will need to be placed to a suitable engineering specification with the degree of compaction required dependent on end usage and serviceability criteria. For example, a lesser degree of compaction may be suitable for paved areas, however the main development platform supporting foundations and ground bearing slaps will require a higher degree of compaction.

With reference to Section 4.6.1, it is likely that the excavated soils will classify as a Class 2C Acceptable Earthworks Material in accordance with the Specification for Highways Works Series 600 Table 6/2. It is recommended that at least 95 % maximum dry density and less than 5 % air voids is achieved by compaction and the dry density / moisture content relationship testing suggests that the cohesive colliery spoil is likely to be wet of optimum, with some degree of drying out (e.g. soil stabilisation) likely to be required to achieve the compaction criteria. It is recommended that the formation is thoroughly proof rolled and inspected by a geotechnical engineer prior to the placement of any fill.

Cohesive soils are very susceptible to ‘wet weathering working’ and we strongly recommend that consideration should be given to lime and/or cement stabilisation of these materials if the earthworks are undertaken during inclement weather or the winter period. Unprotected stockpiled materials often deteriorate due to water infiltration and they may become unsuitable for incorporation in the works.

5.4.3.2 Foundations

For a reinforced raft foundation and based on the engineered fill achieving a minimum undrained shear strength of 75 kPa, a Uniformly Distributed Load (UDL) of 35 kPa may be achieved, limited to less than 15 mm settlement (not inclusive of residual primary and secondary long-term consolidation).

5.4.4 Volume Change Potential

The volume change potential should be considered in any foundation schedule for structures and services located within the influence zone of trees or bushes (including those proposed, existing or to be removed) and

appropriate precautions and / or founding depths should be designed accordingly. In cohesive soils, foundations will therefore need to be designed in accordance with NHBC Standard Chapter 4.2 *Building Near Trees*.

The plasticity index results suggest that the cohesive completely weathered Pennine Middle Coal Measures Formation has a medium volume change potential.

5.5 Floor Slabs (plots outside of backfilled opencast)

Ground bearing floor slabs may be feasible subject to the removal of topsoil, Made Ground, and any soft soils. The formation should be thoroughly proof rolled. Where unsuitable soils are removed, they should be replaced with a well compacted granular fill.

Where Made Ground is greater than 600 mm thick, the NHBC recommends that floor slabs are suspended.

5.6 Roads and Pavements

It is recommended that a conservative California Bearing Ratio (CBR) value of 2.5 % should be assumed for the shallow soils, for preliminary pavement design. It is recommended that plate CBR tests are undertaken at formation level, upon completion of the earthworks to finalise the design CBR.

5.7 Excavations & Obstructions

It is expected that conventional mechanical excavators will readily remove the topsoil, subsoil, Made Ground, colliery spoil and completely weathered bedrock anticipated to be encountered in shallow excavations. Excavation through shallow competent bedrock may require the use of a breaker.

All shallow foundation or service excavations at the Site should be considered unstable; therefore, temporary support of all excavations should be considered when excavating on-Site. Excavations within the colliery spoil were noted to be particularly unstable during the ground investigation.

5.8 Groundwater

The Site investigation data suggests that there is no evidence of an established groundwater table within the backfilled opencast. Minor seepages were observed within some trial pits and this has been interpreted to be perched groundwater within the colliery spoil. Strikes within TT101b and TP104 were being noted as fast seepages. It is considered possible that groundwater strikes may be encountered during shallow excavation works. Should groundwater be encountered, then local dewatering via sump and pump may be suitable; however, treatment prior to disposal to sewer may be required.

5.9 Chemical Attack on Buried Concrete

In accordance with the recommendations of BRE Special Digest 1, (*Concrete in Aggressive Ground*, 2005), the conditions of the soils at the Site classify as Design Sulphate Class DS-2 and ACEC Class AC-2, when considering the most appropriate type of concrete to be used in order to resist chemical attack from elevated sulphate present in the soils (assuming mobile groundwater in potentially pyritic soils).

5.10 Calorific Value

Preliminary calorific value analysis of two colliery spoil samples yielded results of 6.59 MJ/Kg and 0.873 MJ/Kg for the granular and cohesive variant, respectively. There is no statutory guidance for the assessment of potential combustibility of in-situ material; however, ICRCL Guidance Note 61/84 (*Notes on the fire hazards of contaminated land* (1990)) states that materials with calorific values exceeding 10 MJ/Kg are likely to ignite, and there is an unacceptable risk of smouldering for materials with a calorific value exceeding 7 MJ/Kg. Therefore, for the purpose of this assessment, a calorific value of 7 MJ/Kg has been adopted as the screening criteria, which neither of the tested samples exceeded. During the earthworks phase verification testing is likely to be required to ensure no material with a calorific value greater that 7 MJ/Kg is placed within 2.0 m of the formation level.

6.0 Generic Quantitative Risk Assessment

6.1 Introduction

The presence of hazardous substances in or on a site is generally only of concern if an actual or potential unacceptable risk exists. Legislation and guidance on the assessment of contaminated sites, consistent with UK best practice, acknowledges the need for a tiered risk-based approach. A Preliminary Risk Assessment is presented in Section 2.2. This section represents a Generic Quantitative Risk Assessment (GQRA) being a comparison of Site contaminant levels against Generic Assessment Criteria (GAC).

6.2 Human Health GQRA

The assessment of risks in relation to human health has been undertaken using Generic Assessment Criteria (GAC) as detailed within the appropriate tables. Risks from soil, groundwater, and Non-Aqueous Phase Liquids (NAPL) have been considered. The GAC are predominantly based on long-term (chronic) risk to health. However, in the limited circumstances where short-term (acute) risks are more pronounced, these GAC have been utilised to ensure a thorough and conservative initial assessment is undertaken.

The end use scenario adopted for the assessment is a Residential (with Plant Uptake) end use, which is considered appropriate based on the proposed residential development.

6.2.1 Risks from Soil Sources

Based on the proposed end use of the Site for residential use, the soil chemical analysis data has been compared against a Residential (with Plant Uptake) end use GAC, for a 1% Soil Organic Matter (SOM) content.

None of the contaminant concentrations reported in the analysed soil samples exceeded the relevant GAC. Therefore, the soil contaminant concentrations are not considered likely to represent a risk to human health, in the context of the proposed development.

The laboratory results for contaminants exceeding detection limit compared to their respective GAC are presented in the table below.

The primary exposure pathways considered in the risk assessment are as follows:

- Ingestion of soil and indoor dust and / or oral background exposure.
- Consumption of home-grown produce and attached soil.
- Inhalation of dust (background and indoor).
- Direct dermal contact; and
- Inhalation of vapour (background and indoor).

Contaminant	No. Samples	Max Conc. (mg/kg)	GAC (mg/kg)	GAC Source	No. Exceed GAC	Volatile	Location of Exceedances (depth) = Concentration (mg/kg)	Area of Site of Exceedance
Metals and metalloids								
Arsenic	18	23	37	LQM	0	N	-	-
Cadmium	18	0.4	11	LQM	0	N	-	-
Chromium III	18	26	910	LQM	0	N	-	-
Chromium VI	18	3.3	6.0	LQM	0	N	-	-
Copper	18	38	2400	LQM	0	N	-	-
Lead	18	71	200	C4SL	0	N	-	-
Nickel	18	39	130	LQM	0	N	-	-
Zinc	18	100	3700	LQM	0	N	-	-
Polyaromatic Hydrocarbons								
Naphthalene	18	0.91	2.3	LQM	0	Y	-	-
Phenanthrene	18	0.52	95	LQM	0	N	-	-
Fluoranthene	18	0.93	280	LQM	0	N	-	-
Pyrene	18	0.85	620	LQM	0	N	-	-
Benzo[a]anthracene	18	0.55	7.2	LQM	0	N	-	-
Chrysene	18	0.77	15	LQM	0	N	-	-
Benzo[b]fluoranthene	18	0.65	2.6	LQM	0	N	-	-
Benzo[k]fluoranthene	18	0.53	77	LQM	0	N	-	-
Benzo[a]pyrene	18	0.58	2.2	LQM	0	N	-	-
Indeno (1,2,3-c, d) pyrene	18	0.32	27	LQM	0	N	-	-
Benzo [g, h, i] perylene	18	0.34	320	LQM	0	N	-	-
Petroleum Hydrocarbons								
Aromatic TPH >C12-C16	18	2.9	140	LQM	0	Y	-	-
Aromatic TPH >C16-C21	18	13	260	LQM	0	N	-	-
Aromatic TPH >C21-C35	18	32	1100	LQM	0	N	-	-
Total Petroleum Hydrocarbons (C5-C35)	18	44	5000	DS	0	Y	-	-

Notes: LQM = Land Quality Management / CIEH S4Uls for Human Health Risk Assessment, 2014.
C4SL = Category 4 Screening Levels (C4SLs) published by DEFRA.
DS = In-house GAC derived by Delta-Simons Environmental Consultants Ltd, 2018.

The soil analysis results are considered further in the Conceptual Site Model (CSM) presented in Section 7.0 with regard to potential contaminant linkages.

6.2.2 Risks from Non-Aqueous Phase Liquids (NAPL)

Soil and groundwater exposure models used in generating GAC do not account for the potential for NAPL to represent a source of risk to human health, principally due to the production of vapours. Whilst it is possible to calculate theoretical soil saturation limits, in reality, due to co-solubility effects, these are not an appropriate indicator of the presence of NAPL. In order to assess the presence of NAPL, for petroleum hydrocarbons, an assessment criterion of 5,000 mg/kg has been applied based on professional experience.

The following has been identified in relation to NAPL at the Site:

- No observations of NAPL were made within the soils observed during excavation.
- No concentrations of Total Petroleum Hydrocarbons in excess of 5,000 mg/kg were recorded in the analysed soil samples: and
- No NAPL was observed in groundwater encountered during excavation.

On this basis, there is no evidence of NAPL being present on the Site.

6.3 Built Environment

6.3.1 Potable Water Supply Pipes

The investigation requirements for the selection of potable water pipe material are set out in UKWIR Report 10/WM/03/21. Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites (UKWIR, 2010). This report has very specific and onerous investigation requirements and as such the detailed investigation of each utility route was not within the scope of this investigation.

A preliminary review of the results indicates that a relevant linkage is unlikely to exist associated with organic contaminants and, therefore, polyethylene (PE) and / or polyvinyl chloride (PVC) water supply pipes may be suitable for use on the development.

It should be noted that at the time of this investigation the future routes of water supply pipes had not been established, hence the investigation and sampling strategy is not likely to be considered fully compliant with UKWIR recommendations. Consequently, a targeted investigation and specific sampling / analytical strategy may be required at a later date once the route(s) of the supply pipe(s) are known. In addition, it is recommended that the relevant water supply company be contacted at an early stage to confirm its requirements for assessment, which may not necessarily be the same as those recommended by UKWIR.

6.3.2 Building Materials

Risks to building materials associated with aggressive ground conditions is addressed in Section 5.7.

6.4 Waste Classification

This investigation was not undertaken to classify materials in terms of waste disposal. Where waste disposal is proposed then a specific and detailed investigation in accordance with Environment Agency Guidance WM3 would typically be required.

Should there be a surplus of natural soils at the Site, sustainable options for their reuse on other Sites should be considered in the first instance.

7.0 Ground Gas Risk Assessment

7.1 Ground Gas Conceptual Site Model

7.1.1 Sources

Historically the Site has comprised of undeveloped greenfield / agricultural land until circa. 1993 when the central and northern areas of the Site were incorporated into a wider opencast colliery. The opencast is understood to have extracted primarily the Meltonfield Coal, in addition to an otherwise unnamed seam. The opencast in these areas was subsequently backfilled upon completion of opencast extraction. This has therefore led to the presence of a significant thickness of colliery spoil fill, extending to a maximum recorded depth of 22.00 m bgl.

The colliery spoil fill generally comprised of a heterogeneous mix of cohesive and granular soils, with frequent cobbles and boulders. Given the nature of the fill, gravels were generally representative of natural lithologies mainly comprising of sandstone and mudstone. As such, although the Made Ground is considered to represent a potential source of ground gas, the volume of putrescible material appears to be low.

The Pennine Middle Coal Measures Formation with recorded intact coal are present beneath the Site area, underlying the opencast and natural Woolley Edge Rock sandstone. No current or former waste management facilities (landfills) have been identified within a 250 m radius of the site.

7.1.2 Receptors

The principal receptors under consideration are future residents. Other receptors include adjacent site occupiers and future maintenance/construction workers.

7.1.3 Pathways

The underlying geology is likely to be of variable permeability with respect to ground gases. The Made Ground colliery fill is heterogeneous and likely to allow preferential migration locally. The underlying Pennine Middle Coal Measures Formation are likely to comprise of fractures and may allow lateral and vertical migration of any mine gases.

The most significant pathways with respect to future residents relate to the potential for gases to enter future dwellings. At present, no gas protections measures are assumed. Consequently, ingress into dwellings may be possible through voids in the floor including service entry points and cracks.

Future maintenance/construction workers may come into contact with hazardous ground gases via entry into below ground confined spaces such as excavations or service entries/inspection points.

7.2 Duration & Extent of Monitoring

Tables 5.5a and 5.5b within CIRIA C665 detail current recommended monitoring duration and frequency for sites in the UK. Based on the identification of potential sources in the preceding section, the gas generation potential is considered to be low, whilst the sensitivity of the proposed development is high. On this basis, CIRIA C665 recommends between 6 visits over a minimum period of 3 months.

Gas monitoring has been carried out upon the Site on six occasions between September 2020 and October 2020. Barometric pressures during the gas monitoring period ranged from 986 mBar to 1025 mBar and all visits were completed during periods of falling pressure.

7.3 Ground Gas Risk Assessment

7.3.1 Background

Based on the proposed residential end use, the following documents have been consulted when assessing the gas regime at the site:

- NHBC/RSK Group PLC (2007), Guidance on Evaluation of Development Proposals on Sites where Methane and Carbon Dioxide are Present, Report Edition No. 4.

- British Standards Institute (BSI, 2019): Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings, BS:8485:2015+A1:2019.

The presence of a source of hazardous gas within the ground does not necessarily indicate a risk will be present. Consideration of recorded gas flows together with source concentrations can allow an initial assessment to be made of the potential both for generation and subsequent migration of gas. A Characteristic Situation (CS) is derived from an assessment of the ground gas data and forms the basis of determining mitigation measures.

7.3.2 Gas Screening Value (GSV)

The Gas Screening Value (gas concentration as a fraction x maximum recorded flow) is used to provide an initial assessment of risks to future site users. The GSVs calculated for the monitoring wells are presented in the following table.

Location	Maximum Methane (%v/v)	Maximum Carbon Dioxide (%v/v)	Maximum Flow Rate (l/hr)	GSV/Characteristic Situation				Flooded well (Frequency)
				Methane		Carbon Dioxide		
				GSV	CS	GSV	CS	
RH101	<0.1	<0.1	<0.1	0.0001	1	0.0001	1	0 of 6
RH105	<0.1	0.6	<0.1	0.0001	1	0.0006	1	0 of 6
RH106	<0.1	0.7	<0.1	0.0001	1	0.0007	1	0 of 6
CP101	<0.1	4.7	<0.1	0.0001	1	0.0047	1	0 of 6
CP102	<0.1	4.2	<0.1	0.0001	1	0.0042	1	0 of 6
CP103	<0.1	0.6	<0.1	0.0001	1	0.0006	1	0 of 6
Notes: CS1+ = Calculated GSV is CS1; however, peak methane exceeds 1%v/v and/or peak carbon dioxide exceeds 5%v/v, therefore, consider increase in CS value.								

The preliminary data indicates that the Site can be provisionally classified as CS1 (very low hazard potential) in accordance with BS 8485:2015 Table 2 and Green in accordance with NHBC classification for low rise housing.

7.4 Ground Gas Risk Mitigation

The ground gas regime at the Site has been classified as Green / CS1 and no gas protection measures are required within the new development.

7.5 Radon

The Site is located within an area where radon protective measures are not required.

7.6 Organic Vapours

Sources of volatile vapours have not been identified for this Site, as such, no further action is required.

8.0 Revised Conceptual Site Model

A revised CSM is presented in the table below and has been formulated taking into account all of the available data from the Delta-Simons intrusive investigation, suitable for a Site with a proposed residential end-use with consumption of home grown produce.

Revised Conceptual Site Model				
Source	**Pathways**	**Receptors**	**Confirmed Risk?**	**Further Investigation/Mitigation**
Potential ground gas associated with the infilling of the former on-Site opencast coal mine (c.1993 to 1994)	Indoor exposure / explosive hazard via enclosed space accumulation of ground gas	Human health – future residents and / or construction workers	No	The ground gas regime at the Site has been classified as Green / CS1 and no gas protection measures are required within the new development.
Significant colliery spoil associated with the infilling of the former on-Site opencast coal mine (c.1993 to 1994)	Consumption of home grown produce and attached soil	Human health – future residents	No	Although no exceedances of the adopted Residential (with Plant Uptake) GAC were reported from the tested colliery spoil samples, the analysed samples are not considered to represent the entirety of the fill. However, no additional visual and / or olfactory evidence of significant contamination was observed during the works. Based upon the proposed residential development, it is understood that the Site will be covered by either building footprints, gardens, soft landscaping, and an area of public open space, as well as hardstanding roads, driveways and / or pavements. It is assumed that the provision of a screened and chemically verified, suitably thick, clean cover system will be implemented in proposed gardens, soft landscaped areas, and the public open space; therefore, breaking the direct linkage where the colliery spoil is present. At this stage, it would be considered prudent to implement a minimum 600 mm topsoil cover system in gardens, and 450mm in soft landscaping and public open space proposed to overly areas of reengineered colliery spoil, in order to provide a suitable growing medium. On-site soils could be stripped, screened, and suitably stockpiled for this cover system subject to further confirmatory testing. **Recommendations:** 1. Further testing of the soils if they are to be reused on Site within the residential gardens 2. Re-use of topsoil in line within an appropriate Remediation Strategy and Materials Management Plan.

	Ingestion and / or inhalation of soil / dust		No	Although no exceedances of the adopted Residential (with Plant Uptake) GAC were reported from the tested colliery spoil samples, the analysed samples are not considered to represent the entirety of the fill. However, no additional visual and / or olfactory evidence of significant contamination was observed during the works. **Recommendations:** It is considered that short term risks to construction workers, associated with any unidentified contamination, would be mitigated by use of appropriate PPE and provision of suitable welfare facilities.
		Human health – construction workers		
	Migration of contaminants into groundwater	Secondary A Aquifer(s) (Pennine Middle Coal Measures Fm. and Woolley Edge Rock)	No	No notable contamination has currently been identified within the colliery spoil. Furthermore, given the current Site is part of a much larger backfilled former opencast, the regional impacts to groundwater, if any, will be similar in nature.
	Migration of contaminants into surface waters	Unnamed drain (50 m to the south-west)		
Potential contamination from identified off-Site sources, including a former garage	Migration of contaminants into groundwater	Human health – future residents	No	There was no evidence of potential impact from the former off-site garage identified as part of this investigation. Given the distance from site and that the garage is located topographically and hydrologically down gradient, this is not considered to represent a plausible contaminant linkage.
	Migration of ground gases	Proposed residential development, including future residents and / or construction workers	Unknown	No notably elevated concentrations of ground gases have been identified as part of this investigation.

9.0 Conclusions & Recommendations

9.1 Geotechnical Summary

The intrusive ground investigations have successfully identified the geometry of the former opencast colliery on-Site with the subsequent confirmation of the absence and assumed extraction of an unnamed seam, in addition to the Meltonfield Coal.

Aside from “possible” broken ground encountered in RH106 (0.5m thick), there were no other anomalies observed during the drilling of all rotary series boreholes. Intact coal of what is interpreted to be the Two Foot Coal and discontinuous Winter Coal was encountered in accordance with local geological dip and conjecture and presented no evidence to suggest that any of the coal deposits had been previously exploited. As such, the findings of this investigation suggest that the risk of subsidence affecting the Site caused by shallow workings is considered to be low.

For plots located outside of the former opencast, shallow strip foundations are considered to be suitable, founded at a minimum depth of 1.0 m bgl within sands and gravels (Completely Weathered Woolley Edge Rock) or firm to stiff clay (Completely Weathered Pennine Middle Coal Measures Formation) with a minimum undrained shear strength of 50 kPa. Where cohesive soils exhibit an undrained shear strength in excess of 50 kPa, an allowable bearing capacity of 100 kPa is likely to be achieved (limited to < 25 mm settlement).

The colliery spoil within the former opencast comprised of varying clay, sand, and gravel deposits. By nature of this variation, it is considered that opencast fill material is likely to be too unpredictable and compressible for shallow foundations, in its current untreated form.

Re-engineering the top 3.0 m of soil across the Site to an engineering specification will improve the geotechnical properties of the shallow soils and as a result the primary consolidation settlement is likely to reduce accordingly. By creating a uniform rigid layer of engineered fill, this will help to mitigate the risk of excessive differential settlement and ensure a uniform and strengthened layer to enable raft foundations to be adopted. Materials used as fill will need to be placed to a suitable engineering specification.

It is understood that ground improvement in the form of excavate and replace is proposed within the former opencast. We understand that the preferred solution is to excavate and recompact the top 3.0 m of colliery spoil (from existing ground level), to achieve a uniform and strengthened layer to enable raft foundations to be adopted. Materials used as fill will need to be placed to a suitable engineering specification.

For plots located within the former opencast, based on the engineered fill achieving a minimum undrained shear strength of 75 kPa, an Ultimate Dead Load (UDL) of 35 kPa may be achieved, limited to less than 15 mm settlement.

The plasticity index results suggest that the cohesive completely weathered Pennine Middle Coal Measures Formation has a medium volume change potential, and this should be considered with any foundation solution with regards to new planting.

Ground bearing floor slabs may be feasible subject to the removal of topsoil, Made Ground, and any soft soils. Where Made Ground is greater than 600 mm thick, the NHBC recommends that floor slabs are suspended.

It is recommended that a conservative California Bearing Ratio (CBR) value of 2.5 % should be assumed for the shallow soils, for preliminary pavement design. It is recommended that plate CBR tests are undertaken at formation level, upon completion of the earthworks to finalise the design CBR.

In accordance with the recommendations of BRE Special Digest 1, (Concrete in Aggressive Ground, 2005), the conditions of the soils at the Site classify as Design Sulphate Class DS-2 and ACEC Class AC-2.

9.2 Contamination Issues

The investigation has been carried out in order to provide preliminary information regarding the quality of soil/colliery spoil beneath the Site, in the context of land contamination, for a proposed residential end use.

9.2.1 Human Health

None of the contaminant concentrations reported in the analysed soil samples exceeded the adopted Residential (with Plant Uptake) GAC. Therefore, the soil contaminant concentrations are not considered likely to represent a risk to human health, in the context of the proposed development. However, in the event that Site-won topsoil is to be reused for soft landscaping and / or gardens within the proposed development, it would be prudent for further sampling and environmental testing be undertaken, in order to comply with YALPAG[3] cover system verification guidance.

Further to this, given that gravel comprising sandstone, rare glass, rare red brick fragments and rare china was reported in topsoil from locations across the Site, it is recommended that such material is suitably screened and stockpiled, in order to provide an improved growing medium prior to potential re-use within the proposed development. Within the backfilled opencast, it would be prudent to implement a minimum 600 mm topsoil cover system in gardens and 450 mm in soft landscaping areas, in order to provide a suitable growing medium. This will be subject to agreement of a Remediation Strategy with the Local Authority and, in the absence of notable contamination within the Made Ground, reduced levels may be permissible if this is advantageous to overall site levels. It may however be preferable to retain topsoil on site.

Outside of the backfilled opencast where shallow bedrock is present, the provision of a suitable growing medium and a minimum 150 mm topsoil cover system is considered suitable.

Although not identified during the investigation, future groundworkers and subsurface maintenance workers should be made aware of the possibility of encountering unanticipated soil contamination. In particular, the potential presence of asbestos should be flagged, and an appropriate protocol put in place to mitigate exposure of the workforce and general public, as required. The Contractor will need to prepare a risk assessment which identifies a safe system of work to handle the asbestos containing soils, which is likely to include asbestos awareness training, a protocol for unexpected finds (should gross asbestos materials be identified), as well as safe working procedures (e.g. damping down of excavations and stockpiles in line with general dust generation mitigation). The risk assessment will need to identify the appropriate levels of PPE and / or RPE required. This recommendation should be captured in Site health and safety documentation and in maintenance plans.

9.2.2 Controlled Waters

Based upon the information obtained during this investigation, limited potential risks to controlled waters have been identified. This is based upon an absence of visual and / or olfactory evidence of potentially mobile contaminants having been identified within the excavated locations, as well as the distance to controlled surface water receptors.

The Site investigation data suggests that there is no evidence of an established groundwater table within the backfilled opencast. Minor seepages were observed within some trial pits and this has been interpreted to be perched groundwater within the colliery spoil.

9.3 Recommendations for Supplementary Work

Based on the findings of this report, the following recommendations for supplementary works are made:

9.3.1 Further Investigation Works

- It is recommended that further investigation is undertaken at the Site in order to:
  - Further characterise on Site topsoil, prior to potential reuse at the Site, in order to comply with YALPG guidance (see Section 9.2.1).

9.3.2 Earthworks/Enabling Works

- Production of an earthwork's specification for the proposed excavation, screening, and replacement of the top 3 m of colliery spoil within the extent of the former opencast.

[3] Recommendation of at least one sample per 250 m^3 of material [Yorkshire and Lincolnshire Pollution Advisory Group (YALPAG). November 2017. *Verification Requirements for Cover Systems*. Version 3.4].

- During the earthworks phase verification testing is likely to be required to ensure no material with a calorific value greater that 7 MJ/Kg is placed within 2.0 m of the formation level.
- Initial classification testing suggests colliery spoil will likely fall into Class 2C (stony cohesive material), for both the granular and cohesive variants. However, it is considered prudent that allowance will need to be made for the removal and / or crushing of oversize fragments during reengineering / replacement.
- Production of a Materials Management Plan (MMP) to facilitate the reuse of soils on- and/or off-Site and registering of the Site as a donor on the CL: AIRE materials register.
- A preliminary conservative CBR value has been recommended for shallow soils, for preliminary pavement design in external areas. However, it is recommended that plate CBR tests are undertaken post earthworks and at formation level to finalise the design CBR.
- In the event that unanticipated contamination is encountered during the proposed redevelopment works, it is recommended that a suitably qualified consultant is present to provide a watching brief of excavation works, as well as to verify the removal of such contamination; and
- It is recommended that Site-won topsoil, proposed to be reused at the Site, should be suitably screened for anthropogenic materials (e.g. glass) and stockpiled prior to reuse, in order to provide a suitable growing medium.

9.3.3 Regulatory Engagement

- Seek Local Authority criteria / requirements / specifications prior to designing the access for road design.
- Liaise with Local Authority and warranty providers from the early stages of ground improvement and foundation design proposals to ensure agreement in principal.

9.3.4 Preliminary Remediation Strategy

- In the backfilled opencast it would be prudent to allow for a minimum 600 mm screened topsoil cover system in gardens, and 450 mm in soft landscaping and / or public open space areas, in order to provide a suitable growing medium. In the absence of notably elevated contamination within the colliery spoil, it may be possible to agree reduced thicknesses with the regulator.

Drawing 1 – *Proposed Site Plan* by Enjoy Design Ltd (Drawing No. 00-001, Rev P4, dated 05/07/21)