

Midland Heart

Phase 2 Geo-environmental Interpretative Report

Hilltop Farm
Earl Shilton, Leicestershire

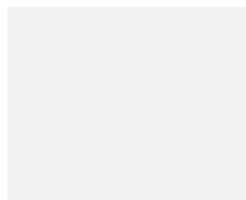
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Phase 2 Geo-Environmental Interpretative Report

Hilltop Farm

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This report dated 04 October 2022 has been prepared for Midland Heart (the "Client") in accordance with the terms and conditions of appointment dated 23 May 2022(the "Appointment") between the Client and **Arcadis (UK) Limited** ("Arcadis") for the purposes specified in the Appointment. For avoidance of doubt, no other person(s) may use or rely upon this report or its contents, and Arcadis accepts no responsibility for any such use or reliance thereon by any other third party.

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1 Introduction

1.1 General

Arcadis Consulting (UK) Limited (Arcadis) was commissioned by Midland Heart Development Limited (the 'client') to undertake a ground Investigation and prepare a geo-environmental (geotechnical and contaminated land) interpretative report to support the planning application for redevelopment of Hilltop Farm, Earl Shilton, LE9 7DP ("the Site") as residential housing.

Intrusive ground investigation works have been completed in accordance with a proposal issued on 20th January 2022, with additional intrusive investigative works confirmed by e-mail on 30th June 2022. The proposed exploratory hole location plan is included within Appendix A and a Site location plan has been included in Appendix B.

This report has been produced in accordance with the following UK guidance on the assessment of land condition:

- Land Contamination Risk Management (LCRM). The Environment Agency, April 2021 (1)
- NHBC/ CIEH / Environment Agency, Guidance for the Safe Development of Housing on Land Affected by Contamination R&D66: 2008 (2)

1.2 Regulatory Context

An application for redevelopment of the Site has been submitted under Planning application 20/00916/FUL. At the time of writing the outcome of the planning application was pending.

This document has been prepared to provide sufficient information on the sub-surface conditions at the site to support the proposed development and the associated planning application.

Planning guidance relating to the development of land potentially affected by contamination is detailed in the National Planning Policy Framework (NPPF), updated July 2021, and constitutes guidance for Local Planning Authorities (LPA). In this case the LPA is the Hinckley and Bosworth Borough Council.

The NPPF sets out the Government's planning policies for England and how these should be applied. Under the NPPF the planning process aims to ensure that land is suitable for its proposed future use, in particular:

'Planning policies and decisions should also ensure that new development is appropriate for its location taking into account the likely effects (including cumulative effects) of pollution on health, living conditions and the natural environment, as well as the potential sensitivity of the site or the wider area to impacts that could arise from the development.'

The NPPF also states that:

- Strategic policies should set out a clear strategy for accommodating objectively assessed needs, in a way that makes as much use as possible of previously developed or 'brownfield' land.
- Give substantial weight to the value of using suitable brownfield land within settlements for homes and other identified needs, and support appropriate opportunities to remediate despoiled, degraded, derelict, contaminated or unstable land.

Therefore, planning policies and decision should ensure that:

- A Site is suitable for its proposed use taking account of ground conditions and any risks arising from land instability and contamination. This includes risks arising from natural hazards or former activities such as

mining, and any proposals for mitigation including land remediation (as well as potential impacts on the natural environment arising from that remediation).

- After remediation, as a minimum, land should be capable of not being determined as contaminated land under Part 2A of the Environmental Protection Act 1990 (4).
- Adequate ground investigation information, prepared by a competent person, is available to inform these assessments.

The planning system should contribute to and enhance the natural and local environment by:

- preventing both new and existing development from contributing to or being put at unacceptable risk from, or being adversely affected by, unacceptable levels of soil, air, water or noise pollution or land instability.
- Remediating and mitigating despoiled, degraded, derelict, contaminated and unstable land, where appropriate.

The statutory definition of contaminated land is given under Part 2A of the Environmental Protection Act (EPA) 1990 (Part 2A) (4) This does not include land that is already regulated through other means, such as Waste Management Legislation or the Environmental Permitting Regulations 2010 (4).

1.3 Project Background & Proposed Development

Most of the Site is covered in fields which slope down in a northerly direction. There is an occupied residential building/cottage in the approximate centre of the Site (shaded as blue on rg+p proposed layout drawing 40963/008L dated 11/11/2019 - Appendix B in this report) (5) which is surrounded by hardstanding, parking and outbuildings/farm buildings which are in poor states of repair.

The proposed redevelopment of the Site includes the demolition of existing Site buildings, to be replaced by the development of 50No. new houses with gardens (49No. 2-storey houses and 1No. bungalow), a pumping station, a SuDS (sustainable drainage system) feature, new access roads, footpaths, and public-use soft landscaping areas. A proposed layout for the Site is shown on the rg+p 40963/008L - Appendix B (5).

As part of the redevelopment is its anticipated that earthworks (cut and fill) will be required to create suitable Site levels for construction. Proposed Site levels have been indicated on Arcadis drawing 10015653-ARC-XX-XX-SK-C-0001-01 (6), in Appendix B of this report.

A desk study has been prepared by Arcadis in 2017 (*Phase 1 Geo-environmental Desk Study Report for AS224 Earl Shilton, Hinkley, Ref: 1001565301_02*) (6) the details of which have been summarised in Section 2. The desk study report should be read in conjunction with this report.

1.4 Project Objectives

This report presents a summary of the desk study information (7), and preliminary ground investigation undertaken of the site. The objectives are to assess the geo-environmental conditions of the Site by investigating and assessing the contamination profile and geotechnical constraints (ground abnormals) and the possible impacts on the development, and to further support the planning application.

The geo-environmental ground investigation was designed and specified to characterise the Site geology and potential contamination in accordance with recommended guidance including LC:RM (1), BS10175 (8) and BS5930 (9), BS EN 1997 (10). The investigation was designed to address the following:

- Develop the ground model;
- Assess the groundwater regime;
- Assess the contamination profile;
- Develop the ground borne gas profile and source and, if necessary, remedial requirements;

- Assess the nature and engineering properties of materials (Made Ground and natural deposits) to inform preliminary foundation options and pavement design; and
- Provide infiltration rates to assist SuDS design.

Based on the findings of the ground investigation a revised conceptual site model (CSM) is presented and potential development abnormalities/constraints are identified to support the proposed redevelopment of the Site. Recommendations for mitigating the constraints to the proposed development are presented where appropriate.

1.5 Reliability / Limitations of Information

This report has been prepared for the Client in accordance with the terms and conditions of appointment. Arcadis cannot accept any responsibility for any use of or reliance on the contents of this report by any third party. The copyright of this document shall remain the property of Arcadis.

This report has been compiled from several sources (see below), which Arcadis understands to be trustworthy. However, Arcadis is unable to guarantee the accuracy of information provided by others. The report is based on information available at the time of writing. Additional information may become available in the future which may have a bearing on the conclusions of this report and for which Arcadis cannot be held responsible.

Project references:

- Arcadis in 2017 Phase 1 Geo-environmental Desk Study Report (7).
- Arcadis in 2020 Preliminary Ecological Appraisal (11).

Ground investigations by nature only reveal a small percentage of the ground conditions present beneath the site. The possibility of significant variation in ground conditions existing between sampling locations cannot be discounted. Soil borne gas and groundwater conditions are based on observations made at the time of the investigation and during subsequent monitoring visits and may be subject to significant variation due to atmospheric, seasonal, or other effects.

Access into parts of the Site were locally restricted as follows:

- Exploratory holes were placed in readily accessible areas only – not near to structures, the footprint of the existing house or within hardstanding area (to avoid disruption to the resident).
- Some areas of Site were not accessible due to landform features (bunds) or dense vegetation; approximate locations are shown on sketched on Site Features Plan drawing 1001565301-AUK-XX-XX-SK-ZZ-0013-P1- attached in Appendix B (12).
- At the time of the investigation, the fields were heavily overgrown and clearance and creating access for vehicles was required to access parts of the Site. Vegetation clearance was carried out by a specialist ecological clearance contractor (Three Shires Ltd) who cleared access routes and exploratory hole locations and working areas prior to the commencement; see Section 3. Temporary ramps were constructed from soils near to the ramp in the paddock area as there is a sudden level change between the concrete paving and the level of the paddock; approximate locations are shown on a Site Limitations Sketch attached in Appendix B (12).
- Avoidance of areas of ecological constraints included badger setts, Japanese Knotweed and protected vegetation; see Section 3 for further details.
- The proposed depths of cable percussion (CP) boreholes were 10m below ground level (bgl), which was considered appropriate based on the expected geology of the area. However, poor ground

conditions were encountered, and the CP boreholes were extended where possible. An additional day of dynamic probe (DP) holes were added and drilled to refusal (where possible).

- Due to access limitations a tractor towed water tanker was used for soakaway testing.

All depths are relative to the ground levels at the time of the ground investigation.

This report excludes recommendations relating to ecological constraints, slope stability and detailed design.

A copy of Arcadis' Study Limitations is presented in Appendix C.

2 Site Setting

The following information has been based on the Arcadis desk study (7) prepared in 2017 and additional observations of the Site made by Arcadis during a walkover in May 2022 and investigation in June 2022.

Table 1 Summary of Desk Study and Site Walkover

Desk Study Summary and walkover findings	
Site Location	The Site is located immediately to the north of the town of Earl Shilton, Leicestershire. The approximate national grid reference for the centre of the Site is 446805 298331 and the closest postcode is LE9 7DP. A Site location plan is presented in Appendix B.
Site Description	The Site is irregular in shape and covers an area of approximately 1.5 hectares (ha). At the time of the investigation, most of the Site was covered by overgrown un-managed farming land with a two-storey residential property and multiple disused farm buildings/outbuildings in the south and east. Areas of concrete hardstanding were noted around the buildings. An above ground heating tank (oil) was noted adjacent to the eastern wall of the house. There was no obvious signs or evidence of leakage. An open and walled structure was in the south-western corner of the Site with a mound of stockpiled material abutted against it. It was overgrown with grass and weeds at the time of the investigation and estimated at circa 25-50m³. The fields were vegetated and overgrown with tall grass, brambles, mature shrubbery, and some trees. Denser areas of grass and shrubbery exceeding 0.5-1.m in height is present locally; see Site Features Plan in Appendix B (12). Areas of Japanese Knotweed are present in the south-east (9). The Site is bounded by fencing and walls on the southern, eastern, and western sides, with open fields to the north. The Site slopes downwards from the south towards the north (northerly) with an overall elevation change of approximately 10m. The Site typically slopes at C.5° from the horizontal. Vehicular access to the Site is gained via Leicester Road (south-east) where there is a shared access adjacent to Hilltop House.
Surrounding Area	The Site is located on the northern side of the town of Earl Shilton. It is bounded by agricultural fields to the north. Leicester Road (the main road running through Earl Shilton) and Hilltop House on the eastern boundary with further residential and light commercial properties beyond. To the south are further residential properties and 2No. small factories to the west there is a mix of residential and recreational land/open space/fields.
Historical Summary	Historical mapping shows a long history of agricultural use (fields, possible orchard in the east, farm, and associated buildings) on-site however the following has been identified: • A pond feature on the northern boundary dating from 1888-1903. A second small pond is mapped on-site, near to the southern boundary (1888-1960s). • Buildings possibly associated with the farm was first noted from 1888 near to the eastern boundary (fronting onto Leicester Road). By the 1960s, these were removed, and additional buildings mapped within the south/east. Further buildings were mapped by the 1980s. The 1990s map shows buildings and associated access areas/hardstanding covering about 40% of the Site. • The 1888 map shows a spring near the western boundary but not shown after 1916.

Desk Study Summary and walkover findings

- The 2000 mapping shows possible reprofiling in west.

Off-site uses are limited given the largely agricultural/rural setting of the site however within the town, 2No. factories are mapped from 1964-present adjacent to the southern Site boundary. It is understood that these factories were historically used for footwear manufacture from circa 1900. A ruin is shown on the Envirocheck maps between the site and the factory to the south.

Anticipated Geology	British Geological Survey (13) mapping shows the southern half of the Site as being underlain by sands and gravels of the Wigston Member, while no superficial deposits were mapped to the north. The bedrock geology mapped is the Gunthorpe Member mudstone, typified as red-brown mudstone with some siltstone and sandstone. No faults were mapped within 1km of the Site boundary. Made Ground is not mapped beneath the Site; however, it is anticipated within the vicinity of former structures in the south/east and around the farm buildings and in areas of deposited soils/mound. No records of historical mining have been identified nor is the Site located within a coal mining area. No publicly available BGS boreholes were identified for the local vicinity of the Site
Hydrogeology	The aquifer classification indicates that the superficial deposits beneath the Site comprise a Secondary A aquifer. The bedrock geology is classified as a Secondary B Aquifer (7). 3No. licenced groundwater abstractions were recorded within 1km of the Site, the closest is approximately 35m south of the Site and used for agricultural and domestic use (registered to Hill Top Farm for the farm however it is mapped to the adjacent factory). 2No. further abstractions for farming and domestic uses are recorded but are over 250m from the Site (approximately 540m west and 1km south-west). No potable groundwater abstractions are recorded within 2km of the Site.
Hydrology	An unnamed pond is present identified 35m west of the Site, with a second 340m to the east. Thurlaston Brook is present 760m west-north-west flowing in a north-easterly direction. There are no surface water abstractions within 2km of the Site. Three permitted discharge consents are found within a 250m radius of the Site, the nearest being 173m northeast and registered to a Sewage Disposal Works discharging final effluent to a freshwater stream or river.
Ecology	Ecological constraints have been identified (badger setts, JKW and areas of tall grass) and are discussed in the PEA (9), for the purposes of the investigation these areas were avoided/exclusion zone or carried out under an Ecology Watching brief – See Section 3.
Radon	The Site is not located in an area affected by radon gas.
Industrial land uses	There are several companies noted within 250m of the Site, the closest being tractor parts agricultural vehicles (potentially including maintenance) recorded 17m to the south. The remainder comprise supplier, electrical engineers, air conditioning supplier, garages, builder's merchants. The nearest petrol filling station is 135m south.

Desk Study Summary and walkover findings

Two historical landfill records exist within 1km of the Site, the closest of which was located approximately 540m to the south (Weaver Close) and received inert, commercial, and household waste. The dates of operation are unknown, although it is noted that gas control measures were in place at some point. Mountfield Road landfill is registered 649m west of the Site and last received waste in December 1960 and licensed to receive inert, commercial, and household waste.

Unexploded Ordnance	Records relating to former RAF bases and war time bombing exist in the wider Earl Shilton area. A pre-desk study risk assessment was completed by Zetica Limited (14) which indicated that the Site is likely to have a low Unexploded Ordnance (UXO) hazard level.
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A preliminary risk assessment and a preliminary CSM (PCSM) was produced as part of the desk study (7) summarising plausible pollutant linkages on the Site.

Table 2 Preliminary Conceptual Site Model

Potential Source	Potential Pathway	Potential Receptor
On-site: Probable Made Ground; infilled pond(s) and derelict, disused, demolished buildings, and structures Possible Made Ground (hummocky field) Former orchard Historical tanks, heating oil tank, spills Natural geology <u>Potential sources</u> of metals (including heavy metals), Polycyclic Aromatic Hydrocarbons (PAHs), Total Petroleum Hydrocarbon (TPH) and asbestos Ground gas pH/sulphates Residual pesticides and herbicides	Dermal contact with contaminants in soil, water, and dust. Accidental ingestion of contaminants within soil, water, and dust. Consumption of home grown produce Inhalation of dusts, vapours, or hazardous ground gas.	Future Residents
Off-site industrial sources (factories) Made Ground (infilled pond and former/present buildings) <u>Potential sources</u> of metals (including heavy metals), PAHs, TPH Potential source of ground gas/vapours	Inhalation of dusts, vapours, or hazardous ground gas. Migration through granular superficial deposits/preferential pathways to neighbouring resident structures Leaching of impacted soils and subsequent vertical and lateral migration of contaminants through permeable geology into underlying groundwater	Neighbouring Residents Controlled waters: Secondary A Aquifer Superficial Deposits) and Secondary B Aquifer (bedrock)
Aggressive ground conditions - on-site and off-site Made Ground, filled ponds, natural geology	Direct contact	Foundations, buried concrete

Potential Source	Potential Pathway	Potential Receptor
On-site and off-site Made Ground, filled ponds, organic contamination Potential source of ground gas/vapours	Lateral migration of ground gases through permeable geology or services/foundation which build up beneath structures causing asphyxiation or explosions / vapour build up	Future Residents & Neighbouring Residents

In general, the contamination potential for the site was considered LOW based on the general environmental setting and history. The short-term risks to construction workers were not considered significant.

3 Ground Investigation Summary

The preliminary ground investigation was designed based on the findings of the desk study, targeting areas of interest and for general coverage. The actual works were carried out between 20th and 28th of June 2022 but differed slightly to the original scope of works due to the presence of Site constraints such as access, services (Section 1.3) and ground conditions as summarised below. The ground investigation was carried out in accordance with BS:10175 (8) BS:5930:2015+A1:2020 (9), and BS EN 1997 (10).

- An initial site walkover to assess access and view ecology constraints;
- Obtaining utility plans;
- Preparation of a Health and Safety Plan;
- Vegetation clearance of access routes and investigation locations was completed by suitably trained contractors under the supervision of an ecological Clerk of Works (CoW);
- Utility clearance using electromagnetic detection of each investigation location and a 5m surrounding work area;
- 6No. cable percussion (CP) boreholes - see Table 3;
- 11No. dynamic probe (DP) holes using a modified window sampling rig - see Table 3;
- 7No. inspection pits excavated using insulated hand tools targeting a depth of 1.2m;
- 11No. machine excavated trial pits using a wheeled JCB 3CX to a circa 3.5m;
- 1No. infiltration test within a trial pit, filled using a tractor towed water tanker;
- In-situ geotechnical testing via SPTs / U100s at each CP drilling location (as appropriate);
- Collection of soil samples at regular intervals for head-space screening using a Photoionization Detector (PID);
- Collection of soil samples for ex-situ geotechnical and environmental laboratory analyses (to aid foundations design, environmental assessment, soil reuse considerations and future potential soil waste disposal);
- Installation of monitoring wells in all 6No. CP holes, to allow ground-gas and groundwater monitoring post fieldwork;
- Purging and development of groundwater monitoring wells and 6No. return visits to monitor ground gas, water levels; and,
- 1No. round of groundwater sampling by low-flow methods on the second return visit to collect groundwater samples and measure hydrological parameters.

The following summarises the exploratory locations and rationale.

Table 3 Rationale

Intrusive Location	Rationale
BH101, BH104 – BH106	Providing spatial coverage across the Site to assess general ground conditions and allow gas and groundwater monitoring. Borehole locations were placed in areas of proposed houses. All boreholes originally planned to 10m based on anticipated geology (from BGS mapping) but were extended to 9.5m (BH103) – 12.4m (BH104). Due to time/equipment constraints at the time, it was not possible to confirm refusal (N value >50) in BH104 or BH106.
BH102	Borehole targeting proposed location of new foul pumping station to assess general ground conditions and allow gas and groundwater monitoring. Borehole was planned to 10m but extended 10.27m in bedrock (refusal).

Intrusive Location	Rationale
BH103	Borehole targeting the footprint of new housing and in a proposed cut slope. It was extended to 10.45m in bedrock (refusal).
TP101-102, TP106 – TP110	Providing spatial coverage, targeting proposed new housing structures. The target depth of all trial pits was 3-3.5m and were completed to 3-4.3m bgl. TP105 was a planned trial pit location, however, was not carried out due to limitations on time.
TP103	Trial pit targeting historical infilled pond in the north and for spatial coverage. TP103 terminated at 3.6m.
TP104	Trial pit to 2.6m in the location of proposed SuDS for infiltration test in natural ground.
TP111	Trial pit to 3.7m targeting historical buildings, near to adjacent factory on the sub-surface ground conditions and for coverage.
TP112	Trial pit to 3m targeting historical building locations and for coverage.
HP101 – HP107	Provide spatial coverage and completed in areas inaccessible to a mechanical excavator (vegetation or existing structures). HP101-104 were placed in areas of proposed structures to allow assessment of the contaminative nature of the soils. HP105-106 within a stockpile / mound for sampling and testing purposes. HP107 targeted the external oil tank. All hand pits were planned to a depth of 1m but ranged between 1m and 1.5m except HP107 that terminated at 0.3m.
DCP101- 108	Targeting roads and hardstanding areas. 3No. additional locations (DCP106 A-C) were added given the depth to competent strata around BH105 to 7-10m. There was in-sufficient time to undertake additional locations.

3.1 Ground Investigation Methodology

The methodology and process of the ground investigation is outlined below. A plan with exploratory hole locations is attached in Appendix B.

3.1.1 Utility survey and vegetation clearance

Table 4 Site Preparation Works

Data	Information
Utility clearance	Service clearance was undertaken in general accordance with the PAS128 (14) standard. Service plans were obtained and consulted prior to the investigation, with additional spot clearance undertaken by SVS Limited using electromagnetic detection to ensure investigation locations were clear from utilities, including an approximate area of 5m x 5m (where possible) around each location. In addition, every location was scanned using a cable avoidance tool operated by trained Arcadis personnel – recorded on the Arcadis permit to dig.

Data	Information
Vegetation Clearance	Clearance of overgrown areas was carried out by a specialist ecological clearance contractor (Three Shires Limited), to create access to exploratory hole locations. It was completed using a small excavator and conventional handheld strimming techniques, supervised by an Ecological Clerk of Works. Works were completed in accordance with an ecological method statement for the Site (16),

3.1.2 Intrusive Investigation and Soil Sampling Methodology

Table 5 Investigation Details

Data	Information
Intrusive investigation methods	6No. CP boreholes were drilling to a maximum depth of 12.4m (BH104) using a Dando150 drill rig operated by suitably trained drillers. A 1.2m hand excavated service pit prior to the advancement of each exploratory hole. The method comprised the dropping and raising of a weighted shell tool by a mechanical winch, which captures soils that can be raised to the surface for inspection and sampling. In-situ Standard Penetration Tests (SPTs) were carried out set intervals by dropping a weighted hammer on an anvil, driving rods into the sub-surface. The number of blows required to drive the rod 450mm into the sub-surface is recorded and reported as an N value. 11No. DP were advanced to a maximum depth of 10m. The dynamic probes were completed using an Archway competitor dart drill rig. The method comprises the dropping of a mechanized drop-weight that repeatedly falls onto an anvil driving probing rods into the ground. The number of blows to drive the rods 100mm into the ground is reported as the N100 value. All holes were completed from ground level to enable the collection of shallow ground strength data. 7No. hand excavated pits were excavated to a maximum depth of 1.5m by a two-man hand pitting crew and insulated tools. 11No. machine excavated trial pits to a maximum depth of 4.3m bgl using a JCB 3CX. Each location was supervised and logged by an Arcadis consultant. Further details are presented on the exploratory hole logs in Appendix D.
Soil logging	Soil samples were logged on-site by Arcadis in accordance with BS 5930:2015+A1:2020 (9).
Field screening	During drilling and pitting, soil samples were collected at approximately 1m intervals, or more frequently in accordance with changes in geology, to a maximum depth of 4m. and placed into two polythene bags. The first bag was sealed to enclose as much air as possible around the soil sample. Where possible, the soil sample within the first bag was gently broken up and left for approximately 15 minutes, prior to the bag being pierced and a Photo-Ionisation Detector (PID) fitted with a 10.6eV Ultraviolet (UV) lamp being inserted to test for ionisable Volatile Organic Compounds (VOCs). Results from PID screens are recorded on the logs in Appendix D.
Backfilling	Hand pits and trial pits were backfilled using arisings and placed in the same order they were excavated. Each location was left slightly proud to allow for future settlement. DCP locations were backfilled using bentonite pellets and hydrated to form a seal. Upon completion, monitoring standpipes were installed into all CP boreholes as shown on the logs in Appendix D.

3.1.3 Geotechnical In Situ Testing

Table 6 Geotechnical Testing Summary

Data	Information
Geotechnical testing and sampling	Standard Penetration Tests (SPTs) / Cone Penetration Tests (CPTs in granular soils) and undisturbed samples (U100's) were carried out in the CP boreholes.
	In the DCP, continuous in-situ testing was undertaken, recording the number of blows per 100mm penetration through the sub-surface profile.
	Where suitable cohesive materials were identified in trial pits hand shear vane tests were undertaken on representative samples of material.
	Disturbed soil samples were also collected from CP boreholes, hand pits and trial pits for laboratory testing.
	Further information and results of the in-situ testing are presented in Appendix D.
Infiltration testing	An infiltration (soakaway) test was completed in one location (TP104) in accordance with the guidance in BRE SD 365 (17)
	A trial pit was excavated within a location of a proposed new Sustainable Drainage System (SuDS) to a depth of 2.6m; design depths were not provided but the test was carried out in natural superficial deposits to investigate infiltration rates. The trial pit was excavated to the smallest dimensions possible and logged by an Arcadis Consultant (trial pit log has been included in Appendix D). Each pit edge was squared off using an excavator bucket to create measurable and straight edges prior to filling with water. Following excavation, the dimensions of the pit were measured.
	The pit was filled with water as quickly as practical using a tractor towed water tanker until the pit was sufficiently full for the test. The depth of the water from the surface was measures immediately after filling, and then at set intervals to measure the fall in water level over time. The recorded measurements were then used to calculate the effective soakage of the stratum.
	The pit was only filled once, not three times as BRE SD 365 (17) suggests, as the water failed to drain away, and effective soakage was not achieved. Upon completion the water was pumped from the pit by the tractor towed bowser, and the pit backfilled with arisings to make the area safe. The pit was left slightly proud to allow for future settlement
	Full results from the infiltration test have been included in Appendix E.

3.1.4 Well Installation and Monitoring

Table 7 Well installation Summary

Data	Information
Monitoring well type	Groundwater and ground gas monitoring wells (50mm HDPE) were installed within BH101-BH106 as shown in Appendix D.
Monitoring well development	The monitoring wells were developed to remove fine sediment ahead of the groundwater sampling event. Ten times the well volume was removed from each well during a visit on 21 st July 2022.

3.1.5 Groundwater Monitoring and Sampling

The methodology and process followed during the groundwater monitoring and sampling works is summarised below – all results are presented in Appendix F:

Table 8 Groundwater Monitoring Summary

Data	Information
Date of monitoring	6No. return monitoring visits have been carried out on 21st July 2022 and 28 th September 2022. One round of groundwater sampling was carried out on 20 th May 2022.
Monitoring wells sampled	BH101-BH106 were sampled using low flow methodology, the depths to groundwater are presented however, sampling depths presented in results may differ.
Equipment used	Interface probe, peristaltic pump, dedicated disposable tubing, multiprobe analyser.
Details recorded	Depth to Non-Aqueous Phase Liquid (NAPL), if present; Depth to groundwater, if present; Thickness of NAPL, if present; Depth to base of monitoring well; and, Dissolved Oxygen, pH, Oxygen Reduction Potential, Conductivity and Specific conductance (during groundwater testing only).

3.1.6 Ground Gas Monitoring

The methodology and process followed during the ground-gas monitoring is summarised below:

Table 9 Gas Monitoring Summary

Data	Information
Date(s) of monitoring	21st July and 28 th September 2022
Equipment used	Infra-red Gas Analyser
Details recorded	Depth to groundwater, if present; Depth to base of monitoring well; Levels of Methane, Carbon Dioxide, Oxygen, Carbon Monoxide and Hydrogen Sulphide; Gas flow; and, Relative pressure.

3.1.7 Storage, Preservation and Transport of Samples

Samples were collected in laboratory provided containers in compliance with their methodology required for analysis. Samples were delivered to the lab with 24 hrs of collection.

3.1.8 Geotechnical Analytical Strategy

Table 10 Geotechnical Testing Strategy

Data	Information
Geotechnical laboratory	Professional Soils Laboratory Ltd (PSL)
Accreditation	PSL is UKAS accredited and an Arcadis approved supplier.
Geotechnical testing	• Moisture Content (MC); • Atterberg Limits (PI); • Particle Density (PD); • Particle Size Distribution (PSD); • Sedimentation (Pipette); • Dry density moisture content 2.5kg (OMC/MDD); • Determination of the California bearing ratio (CBR) value of an undisturbed sample; • One-dimensional consolidation properties, test period 5 days; • Hand vanes at compaction points; • Consolidated undrained triaxial compression test; • Quick undrained shear strength; • Drained shear box testing; • BRE SD1 sulphate suite; • Water soluble sulphate; and, • pH. Laboratory certificates of analysis are presented as Appendix G.

3.1.9 Environmental Analytical Strategy

Table 11 Environmental Testing Strategy

Sample Type	Information
Chemical laboratory	ALS Global Ltd
Accreditation	ALS Global Ltd is United Kingdom Accreditation Service (UKAS) & Monitoring Certification Scheme (MCertS) accredited (for selected chemical analysis) and an Arcadis approved supplier.
Soil	Testing was scheduled by Arcadis using the below suite of analysis. The testing completed on each sample was decided based on-site observations made by Arcadis. • Heavy metals by Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES); • Total Petroleum Hydrocarbons Criteria Working Group (TPH CWG) by Gas Chromatography-Flame Ionisation Detection (GC-FID);

Sample Type	Information
	• Benzene, Toluene, Ethylbenzene and total Xylenes (BTEX) and Methyl <i>Tertiary</i>-Butyl Ether (MTBE) by Gas Chromatography – Mass Spectroscopy (GC-MS); • United States Environmental Protection Agency (US EPA) 16 Polycyclic Aromatic Hydrocarbon compounds (PAH) by GC-MS; • Hexavalent Chromium by Discrete analyser; • Volatile Organic Compounds (VOC) by GC-MS; • Semi Volatile Organic Compounds (SVOC) by GC-MS; • Cyanide (Comp/Free/Total/Thiocyanate); • pH by GL pH meter; • Soil Organic Matter; • Asbestos screen by visual identification; • Asbestos quantification (where asbestos screen made a positive identification); • Leachate BSEN: 12457 (2:1) Prep; • Leachate Suite (Arsenic, Boron, Cadmium, Chromium, Chromium IV, Lead, Mercury, Nickel, copper, Zinc, pH); • Pesticide Suite; and, • Waste Acceptance Criteria (WAC) Inert suite. Laboratory certificates of analysis are presented as Appendix H.
Groundwater	Testing was scheduled by Arcadis using the below suite of analysis. The testing completed on each sample was decided based on-site observations made by Arcadis. • Dissolved metals suite (see leachate suite) by ICP-MS; • Hexavalent Chromium; • Mercury Dissolved; • Cyanide (Comp/Free/Total/Thiocyanate); • pH value; • PAH by GC-MS; • TPH CWG by GC-FID; • VOC by GC-MS; and, • Sulphate as SO₄ by Discrete analyser. Laboratory certificates of analysis are presented as Appendix H.

4 Ground Investigation Findings

The key findings of the ground investigation undertaken at the Site are summarised.

4.1 Ground Conditions

A detailed description of the ground conditions encountered at the Site during the intrusive investigation is included on the exploratory hole logs, presented in Appendix D of this report and summarised below. The descriptions below have been based on logs from cable percussion holes, trial pits and hand pits (24No.) - excludes dynamic probe holes.

Table 12 Summary of Ground Conditions

Interpreted soil type / geological unit	Minimum depth to base (m bgl)	Maximum depth to base (m bgl)*	Maximum encountered thickness (m)*	Description
Surfacing	-	0.3	0.3	Surfacing is described as grass at all locations except 5No. locations (BH104, TP111, HP102-HP104) where concrete was recorded (in the south and east) around the buildings and ranged between 0.1-0.3m thick. Reinforcement was not noted.
Topsoil	0.3	0.9	0.9	Underlying the grass at 7/25 locations (BH101-102, TP101, TP103, TP104, TP108, TP109), Topsoil was encountered (generally in the fields in the north and northeast) and ranged between 0.3m (TP104) and 0.5m (TP103, TP109) at BH102, it was thickest at 0.9m deep. The topsoil is variable and described as SAND with variable fractions of clay, silt, and gravel (chert and quart) and abundant roots/rootlets.
Made Ground	0.3	2.0	2	Made Ground was encountered underlying the surfacing in 17/24 locations (predominantly around the existing buildings) and was thickest near the occupied house and the stockpile/mound. It is generally variable described as sandy gravels, gravelly sand, silty gravelly sand, clayey gravelly sand and sandy gravelly clay. Anthropogenic materials were common throughout including brick, ceramic, metal and concrete etc as gravel and cobbles. Possible reworked natural soils were reported in BH106 at 0.3-2m as orangish brown mottled cream slightly sandy gravelly (brick, mudstone, sandstone) clay.
Wigston Member	1.2	8	7.3	Encountered underlying the Made Ground / Topsoil (TP101-TP104, TP106-TP112, BH101-106 & HP101-HP104) to depths ranging between 1.2m (TP101) and 8m (BH105); it is deepest and thickest in the south/south-east (BH103, BH105, BH106). The base was not proven in 9No. locations (TP104, TP106, TP107, TP109, TP111, TP112, HP101-HP104) beyond 1m (HP102) and 4.3m (TP106) which terminated in the stratum. It is described as a loose (locally medium dense) brown/orange/red SAND with variable secondary

Interpreted soil type / geological unit	Minimum depth to base (m bgl)	Maximum depth to base (m bgl)*	Maximum encountered thickness (m)*	Description
				fractions of gravel, clay and silt. Gravel is flint, chert, siltstone, sandstone, quartzite.
Thrussington Member	5	10.3	8.8	Identified within 11/24 locations (BH101-BH106, TP101-TP10, & TP110) to depths of 5m (BH101) and 10.3m (BH104). The base was only proven in the CP boreholes and TP110 at 1.6m; the remaining 4 TPs terminated in the Thrussington Member at depths of >3.2m (TP101) and >3.6m (TP103). It is thickness (8.8m) in BH104. It is described as very soft/soft-firm brownish red CLAY / SILT with variable secondary fractions of gravel (siltstone, sandstone, chert), sand, clay, silt and locally with organic material and odours (BH101, BH104). In BH104 it is dark reddish brown very silty fine to medium SAND (6-10.3m).
Gunthorpe Member	>9.5	>12.5	NP	The weathered Gunthorpe Member is described as brown and red firm to very stiff CLAY with variable secondary fractions of silt, gravel (siltstone, sandstone, mudstone) and sand. It is described as extremely weak narrowly bedded reddish brown mottled grey MUDSTONE recovered as gravels in BH103 and distinctly weathered to clay in places.

*where proven NP – not proven

Four geological cross sections summarising ground conditions encountered overlain with the current and proposed levels are included in Appendix B.

4.2 Groundwater

Groundwater encountered during the Site works are summarised in the table below.

Table 13 Groundwater Strike Summary

Location	Strike Depth (m bgl)	Strike Depth (m AOD)	Level after 20 minutes (m bgl)	Level after 20 minutes (m AOD)	Comments
BH101	1.5	106.61	1.25	107.86	Noted in slightly clayey fine to coarse SAND (Wigston Member)
BH103	3.7	107.15	3	107.85	Noted in slightly gravelly silty fine to coarse SAND (Wigston Member)

Location	Strike Depth (m bgl)	Strike Depth (m AOD)	Level after 20 minutes (m bgl)	Level after 20 minutes (m AOD)	Comments
BH104	6	108.5	5.8	108.7	Noted in boundary between a silty sandy CLAY overlaying a silty SAND (Thrussington Member)
BH105	4	107.78	2.8	108.98	Noted in slightly clayey very silty fine SAND (Wigston Member)
BH106	7	107.04	5.7	108.34	Noted in very sandy SILT (Thrussington Member)
TP107	3.6	107.19	3.6	107.19	Noted in gravelly clayey fine to coarse SAND (Wigston Member)
TP110	3.7	109.3	3.7	109.3	Noted in slightly gravelly very clayey fine to medium SAND (Thrussington Member)

Based on the encountered water levels, a groundwater flow towards the south-west is implied.

Groundwater seepages / damp soils were encountered at the following locations:

- TP107 - Slight seepage at 3.5m (Wigston Member)
- TP108 - Wet at 2.6->3.4m (Thrussington Member)
- TP109 - Moist at 3->3.6m (Wigston Member)
- TP110 - Slight seepage at 3.7m (Wigston Member)
- TP111 - Moist 1.4->3.7m (Wigston Member)

Details of the groundwater and ground gas monitoring wells can be seen on the logs in Appendix D. Details are also summarised in section 8.1. At the time of writing 4No. rounds of groundwater level monitoring had been completed with a further 2No. scheduled and will be presented in the final report.

4.3 Visual and Olfactory evidence of Contamination

Table 14 Visual and Olfactory Contamination Summary

Data	Information
Visual Evidence	No visual evidence of contamination was noted during the investigation
Olfactory Evidence	Organic odours were noted at the following locations: • TP107 – 1.1-1.8m bgl (Made Ground) • HP101 – 0.5-0.9m bgl (Made Ground) • HP105 – 0-1.5m bgl (Made Ground) • HP106 – 0-1.5m bgl (Made Ground) • BH101 – 0.4-0.9m bgl (Wigston Member) • BH104 – 2.4-5.0m bgl (Thrussington Member)

Data	Information
Non-aqueous Phase Liquid (NAPL)	Evidence of NAPL was not noted during the investigation
Field Screening	PID testing was undertaken on all collected environmental samples, with most readings not exceeding the limit of detection (1 ppm). Two of the results of PID screening values were slightly above detection limits (>1ppm) in the Made Ground; HP107 at 0.3m 1.6ppm and TP110 at 0.3m 2.2ppm. 6.1ppm was recorded in BH102 at 2.5m but the test was carried out in the natural soil and may have been a result of the sample being in direct sunlight. PID readings were taken where organic odours were noted, however no readings above detection limits were identified. No additional evidence of contamination was identified within the locality of these PID readings.
Asbestos Containing Materials (ACM)	Suspected asbestos containing material (ACM) was noted sporadically on the surface of the Site, however this has been assessed and managed by others. Asbestos/ACM was not identified during logging, but ACM fibres were identified within 3/4 Made Ground samples tested, at the following locations and discussed further in Section 7: • HP103 at 0.5m • HP104 at 0.4m • HP107 at 0.3m The ACM is described as chrysotile and when quantified concentrations <0.001%. Additionally suspected ACM was noted within buildings on Site, but this is not within the scope of this report.

5 Geotechnical Test Results

The following sections are a summary of the in-situ and laboratory geotechnical testing completed for each stratum. SPT N_{60} values have been plotted as metres below ground level (m bgl) and as elevation (m AOD) in Figures 1 and 2 below.

5.1 Made Ground

Table 15 Made Ground Geotechnical Testing Summary

Test	Number of Tests	Result
In-situ SPT's	1	Due to the limited Made Ground, 1No. SPT was carried out BH106 at 1.2m bgl (possible reworked natural) and recorded a N_{60} value of 7 (soft).
Natural Moisture Content	1	12% (TP112 0.5m bgl)
Atterberg Limits	N/A	Not scheduled due to large granular content of the material
Particle Density (measured)	1	2.54 mg/m ³ (BH106 0.5m bgl)
Laboratory CBR	1	Top: 8.8 % Bottom: 8.1% (TP112 0.5m)
Particle Size Distribution (PSD)	1	Total percentage of soil fractions: Cobbles: 0 Gravel: 5 Sand: 49 Silt: 28 Clay: 18 Slightly gravelly very sandy clayey SILT BH106 0.5m bgl

Table 16 Summary of OMC/MDD results

Test	Location	Maximum Dry Density (MDD) (mg/m ³)	Optimum Moisture Content (OMC) (%)	Natural Moisture Content* (NMC) (%)	Hand Vane (HV) at each Compaction Point (kPa)	NMC at each compaction point (%)
OMC/MDD with 2.5kg rammer	BH106 – 0.5m bgl	1.95	11	11%	>150, >150, 66, 27, 15	4.5, 7.6, 11, 14, 17

*Referred to as initial moisture content in laboratory certificate

5.2 Wigston Member

Table 17 Wigston Member Geotechnical Testing Summary

Test	Number of Tests	Results
In-situ SPT's	19	SPT N values of 0-21 (very loose-medium dense), with a mean SPT N of 9 (loose). N ₆₀ values varied from 0-25, with an average of N ₆₀ =25.
Natural Moisture Content	10	13-20% (19% average)
Atterberg Limits	1	Plasticity Index: 15% low plasticity Clay Modified Plasticity Index range: 14.7% (low volume change potential) - TP106 3m bgl
Particle Density	4	2.57 - 2.67 Mg/m ³ (2.63 Mg/m ³ average)
Laboratory CBR	2	Top 6.8% Bottom 4.7% (BH103 1.2m bgl) Top 0.5% Bottom 0.8% (TP108 1.0m bgl)
PSD	3	Cobbles: 0 Gravel: 2-15 Sand: 20-38 Silt/clay: 47 - 67 Described as - very sandy silty CLAY, slightly gravelly silty clayey SAND, & slightly gravelly sandy silty CLAY
Consolidated drained shear box test	1	Peak angle of shearing resistance: 35° Effective cohesion: 2 kPa (BH105, 2.0-2.45m bgl)

Table 18 Summary of OMC/MDD results

Test	Location	Maximum Dry Density (MDD) (mg/m ³)	Optimum Moisture Content (OMC) (%)	Natural Moisture Content* (NMC) (%)	Hand Vane (HV) at each Compaction Point (kPa)	NMC at each compaction point (%)
OMC/MDD with 2.5kg rammer	BH104 0.6-1.1m bgl	1.80	15	19	>150, >150, 120, 62, 42	9, 12, 15, 18, 21
	BH106 3-3.45m bgl	1.84	15	19	>150, >150, 130, 44, 21	4.5, 7.6, 11, 14, 17
	TP112 1m bgl	1.89	13	13	-	-

*Referred to as initial moisture content in laboratory certificate

5.3 Thrussington Member

Table 19 Thrussington Member Geotechnical Testing Summary

Test	Number of Tests	Results
In-situ SPT's	14	SPT N values range from 0-28 very loose to medium dense, and very soft to firm, and a mean SPT N of 9.6 (loose/firm). N ₆₀ values varied from 0-34, with an average of N ₆₀ =12.
Natural MC	9	16-27% (21% average)
Atterberg Limits	7	Plasticity Index range: 10-20% intermediate plasticity Clay Modified Plasticity Index range: 9.7-18.6% (low volume change potential)
Particle Density	2	2.57-2.61 Mg/m ³ (2.59 Mg/m ³ average)
Laboratory CBR	2	Top 2% Bottom 2% (BH104 4m bgl) Top 0.3% Bottom 0.2% (TP110 3.7m bgl)
PSD	4	Total percentage of soil fractions: Cobbles: 0 Gravel: 4 - 23 Sand: 17 - 40 Silt/clay: 47 - 75 Slightly to gravelly sandy to very sandy SILT/CLAY, slightly sandy clayey SILT
Consolidated drained shear box test	1	Peak angle of shearing resistance: 24° Effective cohesion: 20 kPa (BH106, 5.0-5.45m bgl)

Table 20 Summary of OMC/MDD results

Test	Location	Maximum Dry Density (MDD) (mg/m ³)	Optimum Moisture Content (OMC) (%)	Natural Moisture Content* (NMC) (%)	Hand Vane (HV) at each Compaction Point (kPa)	NMC at each compaction point (%)
OMC/MDD with 2.5kg rammer	BH104 2-2.4m bgl	1.82	15	22	>150, >150, 124, 63, 32	9, 12, 15, 18, 21
	TP110 1.6m bgl	1.85	13	20	-	-

*Referred to as initial moisture content in laboratory certificate

Table 21 Summary of One-Dimensional Consolidation Test Results

Test	Location (depth mbgl)	Pressure Range (kPa)					
			0-50	50-100	100-200	200-400	400-100
One Dimensional Consolidation	BH101 (4.0-4.45)	Mv (m ² /MN)	1.002	0.275	0.177	0.100	0.013
		Cv (m ² /yr)	2.534	3.119	4.365	5.087	28.973
	BH102 (3.0-3.45)		0-50	50-100	100-200	200-100	100-50
		Mv (m ² /MN)	0.212	0.231	0.159	0.026	0.083
		Cv (m ² /yr)	21.749	14.796	11.380	39.205	20.600
			0-75	75-150	150-300	300-600	600-150
	BH104 (3.0-3.45)	Mv (m ² /MN)	0.379	0.228	0.156	0.098	0.009
		Cv (m ² /yr)	8.149	7.781	6.139	5.387	21.573

5.4 Gunthorpe Member

Table 22 Gunthorpe Member Geotechnical Testing Summary

Test	Number of Tests	Results
In-situ SPT's	20	SPT N values generally range from 15->50 (firm to stiff to very stiff) and a mean SPT N in excess of 30 (very stiff). One SPT N=7 was recorded (BH105, 10m bgl) however, this is reported at the boundary between superficial and bedrock strata and may not be representative. N₆₀ values varied from 8-157, with an average of N₆₀=68.
Natural Moisture Content	5	17-28% (21% average).
Atterberg Limits	7	Plasticity Index range: 10-19% intermediate plasticity Clay) Modified Plasticity Index range: 9.9-18.2% (low volume change potential)
PSD	1	Total percentage of soil fractions: Cobbles: 0 Gravel: 7 Sand: 21 Silt/clay: 72 A sandy slightly gravelly SILT/CLAY (BH101 5m bgl)
Undrained Shear Strength (Multistage) without pore pressure	1	Stage 1 - Cell pressure 75 kPa, Shear strength 48 kPa Stage 2 – Cell pressure 150 kPa, Shear strength 63 kPa Stage 3 – Cell pressure 250 kPa, Shear strength 76 kPa (BH101, 6.0 - 6.45m bgl)

The SPT values measured during the ground investigation have been corrected to account for the energy ratio of the SPT hammer, which was measured at 72%, to produce N₆₀ values.

A summary of the SPT N₆₀ Values in relation to ground level and the soil lithology is illustrated in Figure 1 below.

Figure 1 shows SPT N₆₀ Value In relation to depth (m bgl) and soil lithology.

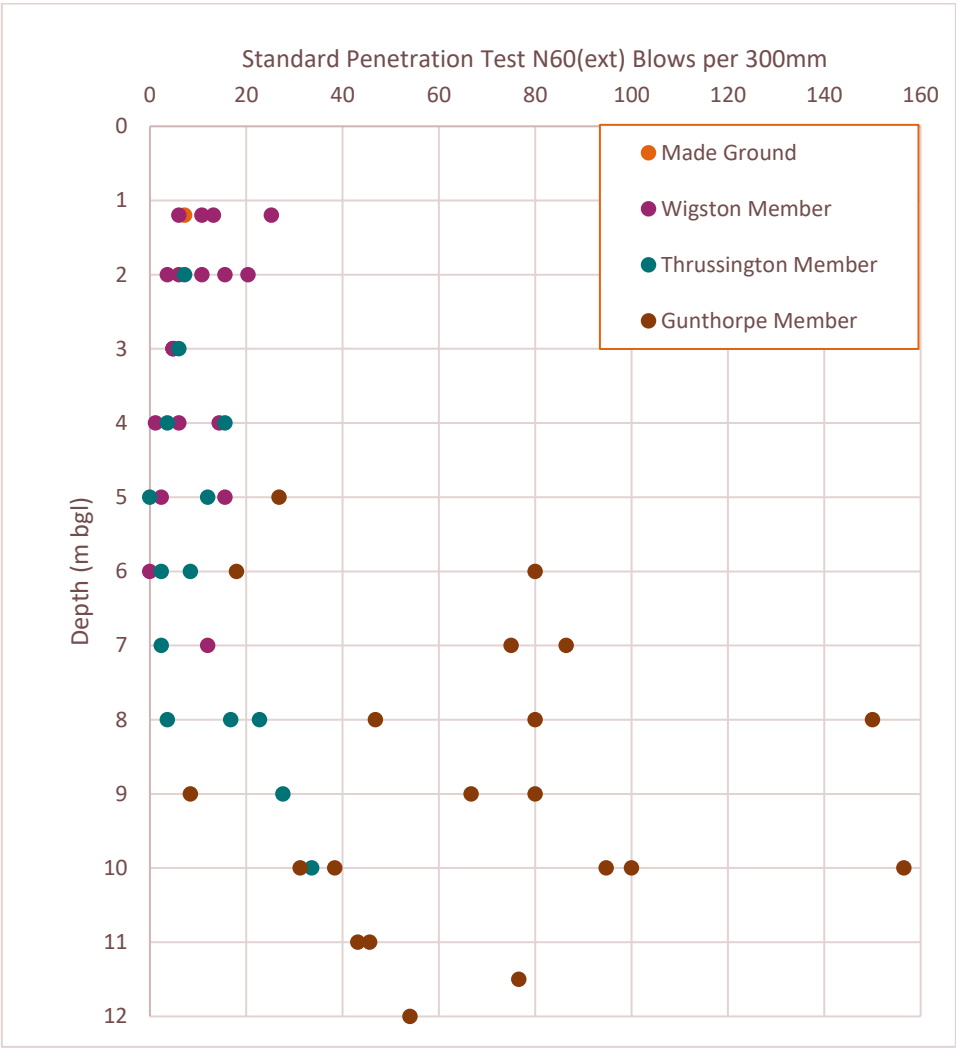
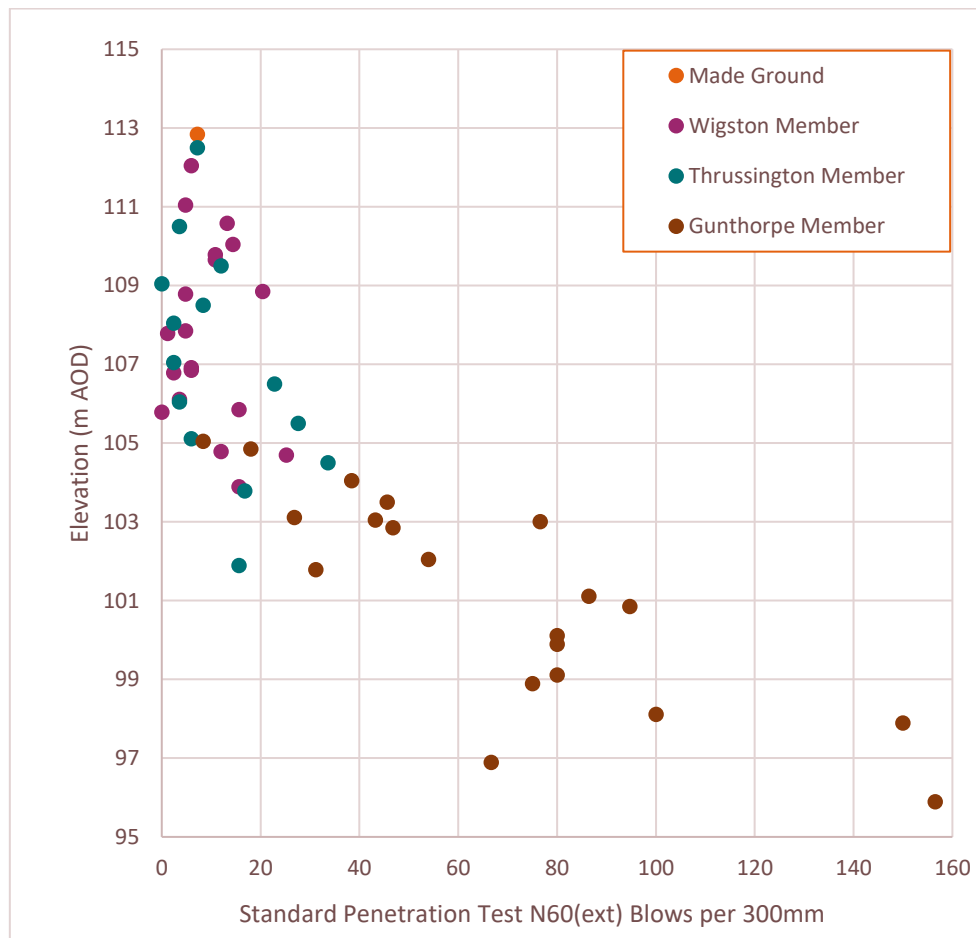


Figure 2 shows SPT N₆₀ Value In relation to depth (elevation) and soil lithology.



6 Geotechnical Appraisal

6.1 Scheme Details and Anticipated Structural Loadings

The proposed development comprises demolition of the existing farm buildings, clearance, and construction of a residential development, comprising 50 No. new houses (of which one is a bungalow) with gardens, car parking/driveways, internal access roads and associated infrastructure. A foul water pumping station is proposed in the north, adjacent to a proposed SuDS area as per the development drawing attached in Appendix B (5).

rg+p drawing 40963/042A, dated October 2020 (18) in Appendix B show 2 generalised cross sections (A-A and B-B) of the Site with the current and proposed levels. The proposed development levels will require cut in the upslope (in the south) up to 3.8m and filling is proposed in the lower, northern area by up to 1.25m.

At the time of writing, no structural details/loadings have been provided, however, low-rise residential construction has been assumed as comprising 1-3 storey housing of conventional load bearing masonry or timber framed construction. The following assessment and recommendations have been based on the current proposals for the Site and will need to be reviewed when design details of the development are known. Further design specific ground investigation may also be required.

6.2 Site Preparation and Earthworks

Prior to construction works any Topsoil, and/or any areas of particularly poor-quality Made Ground should be removed beneath proposed buildings and hardstanding areas, to facilitate construction.

Cut and fill earthworks are proposed at the south of the Site (cut up to 3.8m) and the north of the site (up to 1.2m). Material placement should be completed in line with an appropriate earthworks specification in order to deliver the required performance. Reuse of materials is discussed further in Section 6.14, below.

Indicative geological cross sections showing ground conditions encountered overlain with the proposed development levels are presented in Appendix B. Based on these it is anticipated that the bulk of the cut materials will comprise both Made Ground and superficial deposits of the Wigston Member.

General turnover of the uppermost strata may be locally required (i.e., beneath the footprints of new buildings and along service routes) to allow the breaking out and removal of former sub-structures including brick and concrete foundations. Concrete and masonry should be crushed to a suitable grading (e.g., 6F2) for re-use in the development (e.g., working platforms, road capping etc).

Excavations formed during demolition activities will require adequate backfilling to a suitable specification to ensure appropriate performance.

Sorting and screening to remove deleterious materials and crushing of oversized items (concrete blocks, blocks of masonry, etc.) should be undertaken where necessary to facilitate and improve the compaction of site-won fill materials during placement. This process may generate material that is unsuitable for re-use (including potentially deleterious materials such as timber) and as such these are likely to require off-site disposal.

Site won granular materials should be used preferentially in areas beneath proposed structures to reduce the effects of long-term settlement. Site won cohesive materials would be used as general fill (in landscape areas for example) where settlement is less critical.

Ground conditions should be capable of excavation using traditional hydraulic plant. However, sides may become unstable, particularly where groundwater is encountered in the Made Ground or granular superficial deposits, and allowance should be made for battering excavations at a suitable angle. Site trials could be undertaken to confirm the appropriate angles of slope batter.

6.3 Obstructions

Hardstanding was noted at the surface within the Site, in areas of current buildings and structures. Obstructions were not encountered below ground during the investigation, however, given locations of exploratory holes were positioned to avoid disruption their presence cannot be discounted.

Possible obstructions may also exist in areas underneath existing structures on Site – the foundation design of these structures is unknown at this stage.

If structures are found to be particularly deep below the existing buildings (e.g., old piles), total removal may not be practical or economical and therefore the positions of such obstructions should be accurately recorded to allow new foundations to be designed accordingly.

Based on the findings of mechanically dug trial pits, excavations to at least 2-3m depth are likely to be feasible with conventional excavation plant and machinery. Pneumatic breakers may be required to break out and remove localised hardstanding, masonry obstructions or similar.

Services are present within the Site and include overhead cables that cross the Sites eastern boundary.

6.4 Preliminary Foundation Options

The following assessment of foundation options is for guidance only and will be subject to further assessment of detailed design when the loading and settlement criteria become available. It is assumed at this stage that lightly loaded residential structures will be constructed on Site.

6.4.1 Typical Ground Conditions

As discussed in Section 4.1, the preliminary ground investigation has revealed a mantle of Topsoil/subsoil and Made Ground to typically 1-2m depth, overlying a variable thickness of loose (locally very loose) to medium dense sandy Wigston Member and soft, locally very soft and firm cohesive Thrussington Member. Standard Penetration Test (SPT) N values of zero were locally recorded within the superficial deposits. Similarly, N100 values, completed during continuous dynamic penetration testing (CDPT) revealed zones where blow counts of 0-1/100mm extended down to 7.5m (DP106A).

The Gunthorpe Member (typically observed as a firm to very stiff clay, becoming extremely weak mudstone), was proven below the superficial deposits at depths of typically below 5m. Groundwater was typically encountered during investigation at between 2.8m to 5.8m, and locally (BH101) higher at 1.25m.

6.4.2 Strip Footing Foundations

Made Ground, is by its very nature, is highly variable and not considered to provide a suitable founding stratum.

The superficial deposits, in their current state, are unlikely to be able to provide suitable and predictable bearing strata for new strip or pad foundations due to the variable nature and presence of very loose / soft zones which are deep; identified within dynamic probe holes to depths of up to 7.8m (DP106B).

The Gunthorpe Member was typically encountered below 5-6m but is deeper in the south/east of the site (9-9.5m in BH105 & BH106). While this stratum is likely to be capable of supporting spread foundations, at such depths, these may not be economically or practically feasible.

6.4.3 Raft Foundations

Raft foundations would likely require a form of ground improvement (see below) in the form of excavate and replace or stone columns to mitigate potential total and differential settlement of the made ground/ superficial deposits of the Wigston Member.

6.4.4 Ground Improvement

Consideration has been given to improving the shallow to moderate depth superficial deposits by introducing vibro-stone columns. Such techniques can be successful in reducing anticipated settlement, however, may not be practicable (without mitigation such as use of geotextile wraps) where very soft/very loose soils are encountered with SPT N/N100 values of zero due to the risk of excessive stone take/loss.

If ground improvement techniques are to be considered further, it is recommended an experienced contractor, familiar with the ground conditions encountered is provided with a copy of this report and asked to comment further, specifically on aspects such as treatment spacings and depths.

Due consideration should also be given to the following limitations:

- NHBC standards require that vibro-treatment beneath structures is taken through the full thickness of Made Ground into underlying competent strata,
- Consideration should be given to the impact during construction, in terms of noise/vibration etc. upon nearby structures, services and developments.
- There are distance limitations of vibro-treatment adjacent to existing structures/services, and consideration should be given to buildings on adjacent land.

Other ground improvement measures such as excavation of poor founding soils and replacement with imported granular fill can also be considered as an option.

6.4.5 Piled Foundations

Piled foundations may offer a technically and cost-effective foundation solution. A wide range of both driven and bored piles may be suitable in the ground conditions proven. Piled foundations should be taken through the Made Ground and superficial deposits (Wigston Member and Thrussington Member) to the more competent Gunstone Member at depth. Using available information two drawings (1001565301-AUK-XX-XX-SK-ZZ-0014-P1-Depth to comp strata m AOD & 1001565301-AUK-XX-XX-SK-ZZ-0015-P1-Depth to comp strata m bgl – both attached in Appendix B) have been produced showing the depths to competent strata were identified within intrusive investigation locations. Competent strata has been interpreted to be where a SPT N value was encountered >50, or where geotechnical testing found a refusal within cable percussive or dynamic probing locations. It should be noted that the interpreted depth to competent strata will not necessarily reflect the depth to the toe of pile.

A piling contractor should be consulted regarding pile design and piles should be designed in accordance with Eurocode 7 (10)

Detailed pile designs (in terms of pile type, depths, and method of installation) would be dependent upon the required working loads/settlement criteria and should be undertaken in conjunction with a reputable specialist piling contractor; ideally with experience of the ground conditions proven.

Should a piled foundation solution be adopted, then a working platform must be provided, the thickness of which will be determined by the type of piling rig employed and the strength of near surface soils. The design of the platform should be undertaken in accordance with the procedures and specification given in the BRE publication entitled Working platforms for tracked plant (BR-470) dated 2004 (20)

Depending on preliminary pile design, supplementary, deeper boreholes may be required to confirm deeper ground conditions.

If required, the effect of shrink/ swell movement of the ground can be largely negated by installing a slip membrane around the circumference of the pile to an appropriate depth.

It is recommended that foundation options be reviewed once the structural loading and settlement tolerances have been finalised.

6.5 Effect of Trees

Where predominantly cohesive materials have been tested, soils of intermediate plasticity have been recorded with a plasticity index of 14-20%. (2 of 8 cohesive samples tested for plasticity index returned results classed as a low plasticity clay. BH106 at 5.75m bgl, and TP106 at 3m). Intermediate plasticity clays can exhibit volume change due to changes in moisture content such as that caused by trees. While no trees are present within the immediate vicinity of the proposed houses, the Site Is bounded by trees to the east and west. The detailed design should confirm whether the proposed foundations are, or could be in the future, within influencing distance of trees and be designed accordingly. Further guidance on the influencing distance of trees and minimum foundation depths is provided in NHBC Standards Chapter 4.2 Building near Trees (19).

6.6 Ground Floor Slabs

In line with NHBC guidelines (19) ground floor slabs should be designed as suspended where they are underlain by a depth of (non-engineered) Made Ground which exceeds 600mm.

Based on the findings of the preliminary investigation (Section 4), along with the proposed cutting and filling, a mixture of ground bearing and suspended ground floor slabs may be feasible.

6.7 Retaining Structures

No details of proposed retaining structures are currently known. However, based on the available drawings (rg+p - Ref: 40963-001, rg+p – Ref40963/042A), retaining structures may be required at the upslope, southern boundary of the site to support adjacent land/property, and mid-slope, to support upfilling. The maximum height of retaining walls could be in the order of 1-3m.

Based on the above, retaining walls may require piled foundations, and consideration could be given to the adoption of sheet piled walls, continuous driven piles, and CFA piles.

Formation of retaining walls, and in particular, those adjacent to the southern, upslope boundary, must be constructed to ensure no negative impact or loss is experienced by upslope neighbours.

Retaining walls should also be designed to allow for hydrostatic pressure behind the wall.

Should a piled retaining wall(s) be adopted, then a working platform must be provided, the thickness of which will be determined by the type of piling rig employed and the strength of near surface soils. The design of the platform should be undertaken in accordance with the procedures and specification given in the BRE publication entitled Working platforms for tracked plant (BR-470) dated 2004 (20).

6.8 Pavement Design

In situ CBR tests were not completed as part of the preliminary ground investigation.

In consideration of the ground conditions encountered, it is likely that the pavement subgrade exposed at formation levels will comprise predominantly granular / cohesive Made Ground or cohesive superficial deposits.

Laboratory CBR testing reported variable values across the Site. One sample within the Made Ground returned a CBR value of 8.8%, however, the nature of Made Ground is variable, and this may not be wholly representative of overall condition of the Made Ground.

Superficial deposits returned variable laboratory CBR values ranging from 0.2-6.8%, indicating soft and variable conditions across the Site.

Given that the pavement formations within the Site are likely to be variable, for preliminary design purposes, a CBR value of up to 2% is considered appropriate.

This value is based upon table C1 of TRRL Report 1132, 'The structural design of bituminous roads' (21) and assumes a high-water table, average construction conditions and a thin road pavement.

Pavement and road design should be based upon a suitable (equilibrium) CBR value for such formation soils. It is recommended that once the site has been graded to the appropriate pavement formation level, it is inspected and, if necessary, in situ CBR testing be conducted on the subgrade to confirm the appropriate pavement design (i.e., to determine the subbase and capping thickness).

In addition, the formation should be proof-rolled, and any soft/loose pockets encountered should be excavated and replaced with well compacted granular fill prior to pavement construction.

Requirements for the design of road pavements are given in the NBS, 'Design for new pavement foundations' (22).

6.9 Settlement and Services

With possible cut and fill activities there is potential to generate additional total and differential settlement across the Site. Consideration should be given to settlement effects on planned services to be placed within the ground.

6.10 Slope Stability

The Site slopes down to the north at typically C.5° below horizontal. Groundwater levels are variable and ground conditions include localised very soft cohesive deposits.

Cutting and filling works are proposed and there is a risk that unsupported slopes may fail due to poor strength of fill soils or instability of founding strata.

Appropriate slope design is required to ensure both short term (during construction) and long-term (design life) stability across the site. Such design must take into account appropriate load case scenarios which may be experienced during the proposed design life of the Site.

Measures to ensure stability may include incorporation of retaining structures and/or appropriate battering of slopes. The design of any slopes and / or retaining structures must consider current and long-term groundwater conditions.

6.11 Groundwater Control

Groundwater was recorded during monitoring at 0.42m bgl at the shallowest location (BH101).

Excavations have the potential to encounter and extend below existing groundwater levels.

Good management of groundwater and surface water will be required during temporary works.

Any design of slopes and filled areas may need to incorporate permanent drainage measures to ensure short and long-term slope stability and bearing capacity of the fill. The design will also need to consider the water regime of the surrounding areas.

If areas of cutting intercept the groundwater table, initial groundwater egress from these areas will require management, including any surface water / run-off.

Earthworks may be susceptible to adverse effects associated with high groundwater. Temporary and/or permanent works to control the ground water and associated pressures (uplift and pre pressure) may be required. Such measures may include (*inter alia*) lateral, basal, vertical, or linear land drains.

Discharge licences may be required to discharge the water collected, if appropriate.

6.12 Material Reuse

The primary consideration for the geotechnical suitability for reuse of Site won materials will be the moisture content of the soils relative to the optimum moisture content. Results of the testing has been summarised below:

Table 23 Moisture Content Assessment

Strata	MC Range (%)	MC Average (%)	Maximum Dry Density (mg/m ³)	Optimum Moisture Content (%)
Made Ground	11 - 12	11.5	1.95	11
Wigston Member	13 - 20	18.6	1.80-2.65	13-15
Thrussington Member	16 - 27	21.2	1.82-1.85	13-15
Gunthorpe Member*	17 - 28	20.8	-	-

* Not tested for OMC/MDD as unlikely to be reused due to depth of strata

In general, both the Made Ground and superficial deposits were found to be wet of optimum and as such may require moisture reduction measures to ensure the material is suitable for use as geotechnical fill material.

The materials should ideally be compacted at their optimum moisture contents to achieve suitable compaction and the seasonal variation in natural moisture content of the soils would also need to be considered. The placement of these materials should ideally be undertaken in suitable weather conditions to minimise the

requirement for excessive drying or wetting of the materials. Additional testing may be required to accurately classify materials if they are to be placed in accordance with any geotechnical specification.

Any earthworks/upfilling required that will include Site won material should comply with the requirements of a suitable earthwork's specification and materials management plan. This is discussed further in section 7.7.

It should be noted that the reuse of Topsoil has not been considered within this geotechnical assessment as they generally do not need to comply with the same reuse criteria as other fill materials. Topsoil materials are unlikely to require any compaction and/or placement to a geotechnical specification. Topsoil should be retained and re-used where possible.

The impact from upfilling (i.e., inducement of additional settlement) should be considered further during design.

No chemical exceedances were identified within the Site soils which may impact their potential for reuse.

6.13 Aggressive Ground

An assessment with respect to buried concrete has been completed in accordance with the BRE Special Digest 1: 2005 "Concrete in aggressive ground" guidance (23). The table below shows the values and assessment undertaken.

Table 24 Aggressive Ground Assessment

Geological Unit / Matrix	No. of samples	Characteristic Sulphate Value (mg/l)	Design Sulphate Class	Characteristic pH Value	ACEC Class
Made Ground	1	11	DS1	6.31	AC1 ^d
Wigston Member	4	39	DS1	8	AC1 ^d
Thrussington Member	7	570	DS2	7.5	AC2
Gunthorpe Member	6	36.5	DS1	7.9	AC1 ^d
Groundwater	6	326	DS1	6.73	AC1 ^d

When considering the Site as a whole, a conservative approach of adopting the worst-case scenario would indicate that all concrete to be used on Site should be classified as AC2-DS2.

6.14 Infiltration Testing

One infiltration test was carried out in TP104 targeting the proposed Sustainable Drainage System (SuDS) in the north of the Site in accordance with the BRE 365 guidance (17).

Water was discharged into the trial pit however the water did not soakaway and effective soakage was not achieved. The factual results are presented in Appendix E.

6.15 Geotechnical Risk Register

A summary of the potential geotechnical hazards that may be encountered on the site are included in the table below. The risk identification has been defined according to guidance set out by Clayton (2001) (24). As shown in Figure 3 below, the degree of the risk has been calculated by multiplying the effects of the risk by the likelihood of the occurrence.

Figure 3: Classification of probability and impact

Effects	Likelihood	Degree of Risk	Risk Level	Action Required	Geotechnical Actions
1	1	1	Trivial	None	Can be ignored
2	2	2			
3	3	3			
4	4	4	Significant	Consider more cost-effective solutions or improvements at no extra cost	Low risk may be acceptable
		6			
		8			
		9	Substantial	Work must not start until risk has been reduced. Additional resources required	High risk apply mitigation or transfer risk
		12			
		16	Intolerable		Eliminate risk e.g. redesign

Table 25 Geotechnical Risk Register Table

Geotechnical Hazard	Geotechnical Risk and Consequence	Before Mitigation			Mitigation Measures	After Mitigation		
		Effect	Likelihood	Risk		Effect	Likelihood	Risk
Foundations	Variability identified within Made Ground and superficial deposits which may result in lateral changes in ground strength and geological conditions. This may lead to variations in foundation requirements across the Site. Heave from unloading and cutting Volume Change potential from trees	4-High	4-High	16	Appropriate conservative design parameters are used to account for variation in superficial deposits, and construction controls are in place. Appropriate piling contractor to be engaged	4-High	1-Low	4
High Groundwater	Groundwater was recorded during monitoring at 0.5m at its shallowest point. General excavations have the potential to intercept and extend below existing groundwater levels. Good management of groundwater and surface water will be required during temporary works. Areas of material cut unlikely to intercept groundwater table based on proposed designs seen at the time of reporting, however, any design of slopes	3-Medium	4-High	12	If areas of cut intercept the groundwater table initial groundwater egress from these areas will require management and should account for surface water and run off. Design of earthworks, may be susceptible to adverse effects of high groundwater, may require a sufficient permanent drainage system that may include lateral, basal, vertical, or linear land drains as part of the temporary and permanent works to control the groundwater and associated pressures (uplift and pore water). Discharge licences may also be required to	3-High	2-Low	6

Geotechnical Hazard	Geotechnical Risk and Consequence	Before Mitigation			Mitigation Measures	After Mitigation		
		Effect	Likelihood	Risk		Effect	Likelihood	Risk
	and filled areas may need to incorporate permanent drainage measures to ensure short and long-term slope stability and bearing capacity of the fill. Design will need to consider the water regime of surrounding area.				discharge the water collected if appropriate.			
Slope Stability & Retaining Structures	Cut and fill works are to be completed on a sloping Site with variable groundwater levels and sometimes very soft cohesive deposits. Slopes may fail due to poor strength of fill soils or instability of founding strata. Retaining structures may be included in design.	4-High	3-Medium	12	Appropriate design is required to ensure stability during construction and in the long-term considering development loads during subsequent development and use. Retaining walls to be designed to ensure long-term stability. Design must consider groundwater.	4-High	2-Medium	8
Materials Management	Site won materials are likely to be a combination of cohesive/granular Made ground, granular superficial deposits with secondary fractions of cohesive materials, and cohesive superficial deposits. Such materials are susceptible to moisture content changes, where suitability for use will	4-High	4-High	16	Treatment of unsuitable materials to render them suitable may be required. Alternatively, import of suitable materials due to potential requirement for removal of unsuitable materials off-site. Additional costs would be incurred.	4-High	2-Medium	8

Geotechnical Hazard	Geotechnical Risk and Consequence	Before Mitigation			Mitigation Measures	After Mitigation		
		Effect	Likelihood	Risk		Effect	Likelihood	Risk
	tend to deteriorate with increasing water content. If materials are not managed appropriately, they may be unsuitable for inclusion in the works.							
Earthworks – filling	Instability, failure, excessive settlement, slow settlement	4-High	3-Medium	12	Appropriate design parameters, use of appropriate earthworks specification and materials management plan, drainage measures as required, maintenance, removal of weak soils, construction monitoring	4-High	2-Low	8
Earthworks – cutting	Instability, failure, undermining of adjacent land/properties	4-High	4-High	16	Appropriate design parameters, slope protection and support, drainage measures, adoption of appropriately designed and staged retaining structures	4-High	2-Low	8
Buried Structures	Existing structures were present on Site at the time of the investigation to which the foundations are unknown. The presence of previous foundations could cause hard spots which could cause structural damage. Alternatively grubbing up old	3-Medium	2-Medium	6	The formation should be proof rolled and any loose, hard, or soft, organic or otherwise unsuitable materials should be removed and replaced with well compacted granular materials.	3-Medium	1-Low	3

Geotechnical Hazard	Geotechnical Risk and Consequence	Before Mitigation			Mitigation Measures	After Mitigation		
		Effect	Likelihood	Risk		Effect	Likelihood	Risk
	foundations could form deeper areas of Made Ground.							
Soft spots	DCP and SPT testing identified areas within the superficial deposits where N and N100 values were found to be 0-1, suggesting that local areas of extremely soft material (or potentially even voids) may be present.	4-High	3-Medium	12	Soft spots should, where practically and economically feasible, be removed and replaced with suitable compacted fill to reduce the risk of settlement, enable good compaction to be achieved. Geotechnical design of new structures must consider and overcome the risk from such soft spots.	4-High	2-Medium	8
Frost Heave	Frost heave leading to cracking of permanent pavement.	4-High	2-Medium	8	Design pavement thicknesses appropriately with respect to the frost index at location	4-High	1-Low	4
Radon	The migration of Radon gas into on site structures posing a risk to workers and residents.	3-Medium	2-Medium	6	The site is identified as being in an area of less than 1% maximum radon potential, therefore no radon protection measures are required for the site.	2-Medium	1-Low	2
Aggressive Ground	Aggressive conditions may pose risk of attack and degradation to buried concrete	3-Medium	3-Medium	9	Use of appropriate concrete based on laboratory testing in line with BRE SD-1 to ensure sufficiently protective in anticipated ground conditions	3-Medium	1-Low	3
Pavements	Sub-grade deformation. Soft, inadequate pavement thickness, prolonged formation exposure	4-High	3-Medium	12	Appropriate design parameters, construction controls, appropriate design, good drainage, and site management	4-High	1-Low	4

Geotechnical Hazard	Geotechnical Risk and Consequence	Before Mitigation			Mitigation Measures	After Mitigation		
		Effect	Likelihood	Risk		Effect	Likelihood	Risk
General Construction Work	Buried services strike	4-High	4-High	16	Refer to /obtain PAS128 compliant drawings. Scan for services. Adopt Permit to Dig system. Inspection pits to appropriate depth.	4-High	1-Low	4

7 Contamination Assessment

7.1 Generic Quantitative Risk Assessment

Laboratory testing was undertaken on 28No. soil samples comprising 1No. Topsoil sample, 14No. Made Ground samples and 13No. natural soil samples. Samples were tested for a range of potential contaminants listed within Section 3.2.9 and laboratory results are in Appendix H.

The preliminary CSM identified that the contamination potential for the Site was considered low based on the general environmental setting and history, however evidence of possible contamination sources was present. Testing was completed on representative samples of the Site soils with results being compared to Arcadis derived Generic Assessment Criteria (GAC) for a low-density housing scenario with gardens. The scenario has been chosen as it is both conservative and is considered to best represent the proposed development.

The criteria have been derived by Arcadis in line with guidance provided by the Environment Agency (EA). The methodology behind the derivation of the Arcadis GAC is presented in Appendix I and the results of the soil and groundwater generic quantitative risk assessment are presented in the tables within Appendix J.

The Site has been considered as one averaging area for this assessment.

7.2 Human Health

7.2.1 Asbestos

Suspected Asbestos Containing Materials (ACM) were visually identified by an Arcadis consultant in both the existing buildings at the Site and on the surface during the investigation – this has been assessed by others. ACM within buildings does not fall under the scope of this report and as such are not discussed further.

Suspected ACM was not identified during the logging of soil samples during the investigation. 3/14 Made Ground samples tested confirmed the presence of chrysotile fibres at concentrations of <0.001% w/w.

All soil results are presented in Appendix H.

7.2.2 Soil Contaminants

All 28No. soil samples were screened against an Arcadis derived Generic Assessment Criteria (GAC) for a low-density housing scenario with gardens.

Of the 28No. samples tested there were no exceedances except for a slightly elevated concentration of mercury in TP102 at 0.3m (1.03mg/kg). Reference to the log does not reveal significant anthropogenic contamination within the shallow Made Ground located at TP03 except for fragments of metal – the potential source of the mercury. However, it should be noted that the screening value for mercury is based on the presence of elemental mercury (the most conservative) and if present in an inorganic state (the likely form) a screening value of 1,120mg/kg would be considered, for which the results fall significantly below. Therefore, based on the above and the low concentrations (below detection limits) for mercury recorded in the remaining samples; the risks are considered to be low.

7.3 Controlled Waters

10No. soil samples were tested for leachate potential of selected determinands and screened against the same WQS. 6No. groundwater samples were also obtained during the monitoring visit on the 3rd August 2022. All leachate and groundwater results were tested and assessed against the appropriate Water Quality Standards (WQS) to assess the risk to controlled waters.

The superficial deposits at the Site host a Secondary A Aquifer, while the bedrock is considered to have a Secondary B aquifer. Three groundwater abstractions are located within a 1km radius of the Site the closest being 32m south at Hill Top Farm where groundwater was abstracted for general farming and domestic use. 2No. further abstractions for farming and domestic uses are recorded at approximately 540m west and 1km southwest of the Site. No records of potable groundwater abstractions are recorded within 2k of the Site. Based on this, the results have been screened against Drinking Water Standards (DWS) which are considered protective of groundwater aquifers.

The closest surface water feature to the Site is an unnamed pond located approximately 35m towards the west. A further unnamed pond is located c. 340m east, and a watercourse is present c. 760m west-north-west of the Site and is indicated to be flowing north-east in a valley feature. Due to the presence of granular deposits and variable groundwater levels, potential pathway to surface waters could exist. Therefore, samples have also been compared to Environmental Quality Standards for freshwater (EQS) considered appropriate for the protection of surface waters.

7.3.1 Leachate Samples

10No. soil samples collected during the investigation were tested for the leachate potential of selected determinands. The results have been compared to EQS and DWS to assess potential risk from contamination within the soil leaching to sensitive receptors. Full results and screening levels have been attached in Appendix J. The exceedances have been summarised in the table below:

Table 26 Summary of Leachate Samples comparison to screening values

Determinand	DWS Screening Value (µg/L)	EQS Screening Value (µg/L)	Concentration range (µg/L)	Number of exceedances	Locations
Arsenic	10	50	17.9	Aquifer: 1/10	HP103 – 0.5m
				Surface Water: 0/10	-
Chromium	50	3.4	4.7	Aquifer: 0/10	-
				Surface Water: 1/10	TP101 – 0.4m
Copper	2000	1	9.99 – 81.9	Aquifer: 0/10	-
				Surface Water: 10/10	TP101 – 0.4m TP102 – 0.3m

Determinand	DWS Screening Value (µg/L)	EQS Screening Value (µg/L)	Concentration range (µg/L)	Number of exceedances	Locations
					BH106 – 0.8m-0.9m TP106 – 4m TP107 – 1.2m TP110 – 0.3m BH102 – 2.5m HP103 – 0.5m BH104 – 4m HP105 – 0.1-0.2m
				Aquifer: 2/10	TP101 – 0.4m TP102 – 0.3m
Lead	10	1.2	1.72 – 18.5	Surface Water: 4/10	TP101 – 0.4m TP102 – 0.3m TP110 – 0.3m HP103 – 0.5m
				Aquifer: 1/10	BH104 – 4m
Mercury	1	0.07	0.215 – 2.22	Surface Water: 3/10	TP101 – 0.4m TP102 – 0.3m BH104 – 4m
				Aquifer: 0/10	-
Nickel	20	4	5.06 – 8.61	Surface Water: 4/10	TP101 – 0.4m TP102 – 0.3m HP103 – 0.5m BH104 – 4m
				Aquifer: 0/10	-
Zinc	3000	12.1	17.5 – 59.1	Surface Water: 6/10	TP101 – 0.4m TP102 – 0.3m TP106 – 4m HP103 – 0.5m TP110 – 0.3m

Determinand	DWS Screening Value (µg/L)	EQS Screening Value (µg/L)	Concentration range (µg/L)	Number of exceedances	Locations
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HP105 – 0.1-0.2m

In summary, some exceedances of metals have been identified above the respective GAC for both aquifer and surface water protection within the leachate samples. Most of the exceedances identified fall within one order of magnitude and as such are considered minor.

7.3.2 Groundwater Samples

One groundwater sample was collected from each monitoring well during one monitoring visit and tested and screened; exceedances are presented in the table below.

Groundwater results and comparison tables are provided within the Appendix H and J respectively.

Table 27 Groundwater comparison to screening values

Determinand	DWS Screening Value (µg/L)	EQS Screening Value (µg/L)	Concentration range (µg/L)	Number of exceedances	Locations
Cadmium	5	0.08 – 0.25	0.116-0.727	Aquifer:	-
				Surface Water:	6/6
Copper	2000	1	1.46-8.42	Aquifer:	-
				Surface Water:	6/6
Nickel	20	4	7.1-13.5	Aquifer:	-
				Surface Water:	6/6
Zinc	3000	12.1	3.58 – 18.5	Aquifer:	-
				Surface Water:	2/6 (BH103 & BH104)
Benzo(a)pyrene	0.01	0.00017		Aquifer:	

Determinand	DWS Screening Value (µg/L)	EQS Screening Value (µg/L)	Concentration range (µg/L)	Number of exceedances	Locations
			<0.002 - 0.00325	Surface Water:	1/6 (BH103)

There were no exceedances when compared against the DWS and only minor exceedance when compared against EQS.

In addition, water quality parameters of the groundwater were measured during the collection of the groundwater sample. The records of this can be seen in Appendix F, with a summary in the table below. The summarised result represents values recorded when measurements had stabilised:

Table 28 Summary of water quality parameters

Parameter	Measurement Range	Average
Temperature (°C)	12.5 – 16.3	14.6
Dissolved oxygen (%)	3.7 – 63.6	24.6
Dissolved oxygen (mg/l)	0.37 – 4.7	2.53
Specific Conductance (S/m)	543 - 1551	1123
Electrical Conductivity (µS/cm)	429.6 - 1292	903.6
pH	6.51 - 7	6.7
Oxidation Reduction Potential (mV)	125.9 – 210.2	165.1

7.4 Risk Evaluation

7.4.1 Human Health

No exceedances above the adopted GAC screening levels were identified within the soil testing results and based on Site observations during the investigation, site-wide remediation of the Site is not considered necessary.

Asbestos fibres (at low concentrations) were confirmed in 3No. Made Ground samples and given the former uses of the Site (phases of demolition and redevelopment), the presence of ACM or unforeseen contamination within the Site cannot be discounted. Suspected ACM fragments around the Site and on buildings (these will need to be cleared/managed appropriately by others) however, all enabling and earthworks etc. should be undertaken within the requirements of the Control of Asbestos Regulations (25).

7.4.2 Controlled Waters

Leachate testing identified concentrations of determinands above the respective GAC, however, a comparison of the leachate GAC exceedances and the groundwater GAC exceedances do not show a strong correlation, suggesting that there is no active contamination pathway from the soil to the underlying groundwater. Additionally, the concentrations recorded were not considered to be grossly elevated.

Groundwater testing results were below DWS and marginally above EQS; the risks to controlled waters were not considered significant.

7.5 Potable Water Supply Protection

Installation of any potable water supply pipes should be completed in consultation with the local authority, and in accordance with the guidelines set out in the "Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites" produced by the UK Water Industry Research (UKWIR) (26).

7.6 Waste Characterisation and Disposal

The results of the soil testing were screened using HazWasteOnline™ (27) to provide a preliminary indication whether excavated materials will be likely to be exceed hazardous or non-hazardous waste classifications in the event that materials may require off-site disposal, although it is anticipated that re-use of materials will be maximised within the Site. Samples of both Made Ground (including the mound of stockpiled materials to the south-west) and natural materials have been assessed.

All soil samples tested were classified as **non-hazardous** waste if being considered for off-site disposal - Appendix K.

Further Waste Acceptance Criteria testing was carried out on 3No. samples of the Made Ground (BH106 at 0.8-0.9m, HP105 at 0.1-0.2m, and TP107 at 1.2m). Of the 3No samples two were classified as inert and one (HP105 – 0.1-0.2m) remains as non-hazardous. The results are presented in Appendix H.

In general, Topsoil found on Site which typically would not be suitable for disposal as inert waste due to its high organic content but it is anticipated Topsoil will be re-used where possible within the Site.

It results indicate that the Made Ground material may be suitable for disposal at an inert facility but will require additional confirmatory testing prior to disposal. It should be noted that acceptance of materials to any facility is fully at the discretion of the waste receiver, and they are under no obligation to accept waste based on this classification. Any waste receiver will also likely require further testing of any waste materials prior to acceptance.

Should visible ACM be identified during works it should be removed from the waste stream as much as reasonably practicable and disposed of separately, or the waste could be assessed as a mixed demolition waste.

Additionally, the exploratory holes completed to date only provide localised information with respect to the ground conditions. There remains the potential for other unidentified hotspots of contamination to exist which may constitute Hazardous Waste when segregated and at the point of disposal (if required).

A management facility may require additional testing of the actual material that is to be disposed of off-Site prior to acceptance, and that there is no obligation on a landfill operator to accept the waste. EU Directives, UK Government policy and regulations require that construction waste to landfill is minimised.

Should the excavated material not be required or be physically or chemically unsuitable for use as backfill or as other engineering fill within the Site, the excess material would be waste and will need to be removed off-

Site. If only disposal to landfill was an option, further Waste Acceptance Criteria (WAC) testing and separation of waste for off-Site disposal may be required to ensure accurate classification of material to reduce wastes sent to non-hazardous and hazardous landfill. Natural excavated arisings would be classified as inert if segregated from Made Ground materials. Inert waste is anticipated to be the least expensive for disposal and the material could be reused on-Site.

Under European Council Directive (2008/98/EC), known as the Hazardous Waste Directive (28), a list of all wastes, hazardous or otherwise has been compiled known as the European Waste Catalogue (EWC, 1994, Commission Decision 94/3/EC). A revised EWC was released in 2002 under Commission Decision 2000/532/EC. This commission decision has been amended in turn by Commission Decisions 2001/118/EC, 2001/119/EC and 2001/573/EC. The EWC is a catalogue of all wastes, grouped according to generic industry process or waste type. It differentiates between non-hazardous and hazardous.

7.7 Re-use of Excavated Materials On-Site

The re-use of on-site soils may be undertaken either under the via one of two routes – Environmental Permitting (formerly Waste Exemptions); or in accordance with the CL:AIRE Definition of Waste: Development Industry Code of Practice (29).

If excavated material can be classed as inert it can be re-used without constraint provided that the works for which it is used are presented on plans and levels approved under planning consents.

Under the EPR, material that is contaminated but otherwise suitable for re-use is classified as waste and its re-use should be in accordance with the EPR.

Under the CoP materials excavated on-site are not deemed contaminated if suitable for re-use within the Site. Material that may have been classified as hazardous waste under the EPR may be re-used. The CoP regime requires that a 'Qualified Person' as defined under the CoP reviews the development of the Materials Management Plan, including review of Risk Assessments and Remediation Strategy/Design Statement together with documentation relating to Planning and Regulatory issues, and signs a Declaration which is forwarded to the Environment Agency, and which confirms compliance with the CoP.

It is recommended that the CL:AIRE CoP approach to the re-use of excavated arisings is adopted.

7.8 Updated Conceptual Site Model and Risk Assessment

Based on the CSM the following table presents an updated plausible Source-Pathway-Receptor (SPR) linkages.

Table 29 - Updated Conceptual Site model

Source	Pathways	Receptor	Risk	Justification / Mitigation
On-site Sources	Dermal Contact & Ingestion	Human Health		Low/very low risk on the basis of the ground investigation and assessment. The potential for asbestos elsewhere and unforeseen contamination cannot be discounted therefore a watching brief is recommended.
Made Ground (asbestos & unforeseen contamination)	Inhalation Dust Vapour Inhalation	current / future site end users and neighbours	Low - Very Low	In addition, construction works risks will be controlled in such a manner as to mitigate

Source	Pathways	Receptor	Risk	Justification / Mitigation
				exposure risk by appropriate use of PPE, dust control measures and good working practices. Potential migration of ground gases and vapours along preferential pathways of new services and foundations.
Off-site Sources Made Ground	Soil Leaching / Aqueous Migration Vapour Inhalation		Low	
Made Ground – potential ground gas and vapours	Along services / foundations	Buildings / Property / Buried Structures (off-site)	Low-Moderate	Gross hydrocarbon contamination (vapour) was not encountered during the investigation; therefore, the risk is anticipated to be low. CS2 protection measures based on available results.
Aggressive Ground Conditions – sulphates, pH in Made Ground / natural soils	Direct contact	Buildings / Property / Buried Structures (concrete / foundations/ water supply / services)	Low	A sulphate class of DS-1 and ACEC class AC-2 as a conservative assessment. Gross hydrocarbon contamination was not encountered therefore upgrading of water pipes is not anticipated.

8 Ground Gas Assessment

The proposed residential development would be considered a sensitive receptor and would likely comprise Type A buildings according to BS8485 (30).

8.1 Gas Monitoring Results

The table below summarised the response zones and associated groundwater levels identified within each of the monitoring wells completed by Arcadis.

Table 30 Summary of Well Response Zones and Recorded Groundwater Levels

Borehole ID	Response Zone (m bgl)	Response Zone Stratum	Recorded Groundwater level (m bgl)	Average resting Water Level (m bgl)	Comments
BH101	1 – 2.5	Wigston Member	0.42 – 0.68	0.54	Saturated
BH102	1 – 2.5	Wigston Member	0.99 - 1.13	1.05	Minimal unsaturated response zone. Saturated on 2 of 6 monitoring rounds
BH103	2 – 5	Wigston Member	2.69 – 2.78	2.73	-
BH104	2 – 12	Thrussington Member & Gunthorpe Member	5.78 - 6.24	5.9	Pockets of silts, organic matter and natural organic odours
BH105	2 – 8	Wigston Member	3.76 - 3.91	3.85	-
BH106	6 – 7.5	Thrussington Member	5.54 – 5.69	5.63	Saturated

The ground gas monitoring was undertaken using an infra-red gas analyser and flow pod. Concentrations of methane (CH₄), carbon dioxide (CO₂) and oxygen (O₂) in %, Hydrogen Sulphide (H₂S) and Carbon Monoxide in ppm and ground gas flow in litres per hour (l/h) were recorded during the visit. After the monitoring was undertaken, the well was dipped to record the groundwater level.

Below is a summary of the maximum ground gas concentrations (CH₄ and CO₂) recorded at the Site, and the maximum borehole hazardous gas flow rates (Q_{hg}) calculated for each monitoring location and each monitoring event. The full gas monitoring data is included in included Appendix F.

Table 31 Gas Risk Assessment Calculations – 4 visits only

Borehole ID	Max +ve Flow (l/hr)	Max CH ₄ (%v/v)	Max CH ₄ (Steady State %v/v)	Max CO ₂ (%v/v)	Max CO ₂ (Steady State %v/v)	Max CH ₄ Qhg (l/hr)	Max CO ₂ Qhg (l/hr)	Characteristic Situation
BH101	0	0.1	0.1	5.2	5.2	0	0	2
BH102*	0.1	0.1	0.1	0.3	0.1	0.0001	0.0003	1
BH103	0.2	0.1	0.1	5.5	5.5	0.0002	0.011	2
BH104	0.2	0.1	0.1	10.5**	9.8**	0.0002	0.021	2
BH105	0	0.1	0.1	3.4	3.4	0	0	1
BH106	0	0.1	0	2.7	2.7	0	0	1

*The bung on BH102 was found to be ill-fitting during visits 1-4 which may have impacted the accuracy of the results.

** Results taken from borehole purging tests to represent works case scenario

Due to sustained levels of CO₂ in BH104, which was inconsistent with monitoring from the rest of the Site, two gas purges were completed within the borehole on monitoring visit 5 and 6. Gas extraction was completed on BH104 for a period of 30 minutes, with results recorded before, during, and after the test. The monitoring found that the levels of CO₂ remained relatively consistent, validating the levels of CO₂ monitored in the borehole. Results from these have been included within the monitoring data in Appendix F. Monitoring completed following the purge tests found.

Additionally, monitoring within BH101 recorded flow errors on 4 of 6 monitoring visits during monitoring. Considering the construction of the well and the groundwater levels, this is considered to be due to the creation of a vacuum in the well during the gas extraction, further suggesting there was minimal gas production in this location.

8.2 Hazardous Gas Ground Gas Assessment

The table below is derived from BS8485 (30) and CIRIA C665 (31) and presents the relationship between thresholds in the monitoring data and “Characteristic Situations”.

Table 32 Characteristic Situation Parameters

Characteristic Situation	Risk Classification	Qhgs (l/hr) / GSV	Additional Factors
1	Very Low	<0.07	Typically, ≤1% CH ₄ and ≤5%CO ₂
2	Low	≥0.07 - <0.7	Typical measured flow rate <70l/hr
3	Moderate	≥0.7 - <3.5	
4	Moderate to High	≥3.5 - <15	
5	High	≥15 - <70	
6	Very High	≥70	

8.2.1 General

Hydrocarbon vapour was assessed via Photo Ionisation Detection (PID) analysis of the soils during the investigation. Only three readings were recorded at levels greater than <1ppm. These are summarised below:

Table 33 Summary of PID results

Location	Depth (m bgl)	Reading (PPM)	Comment
BH102	2.5	6.1	Engineer noted that reading may have been impacted by sample being left in direct sunlight prior to testing
TP110	0.3	2.2	-
HP107	0.3	1.6	-

Visual or olfactory evidence of gross contamination (e.g., hydrocarbon odours / free oils) was not encountered which is confirmed by the PID results.

8.2.2 Preliminary Hazard Gas Assessment

Current guidance for the assessment of risk associated with the presence of hazardous ground gases (principally methane and carbon dioxide within ground gas) is provided in two key documents listed below which have been used for the assessment:

- Code of Practice for the Design of Protective Measures for Methane and Carbon Dioxide Ground Gases for New Buildings. British Standard Institution (BS 8485: 2015+A1:2019) (30) and
- Assessing Risks posed by Hazardous Ground Gases to Buildings. CIRIA (C665, 2007) (31)

A semi-quantitative estimate of risk from hazardous ground gases can be provided, based upon the qualitative risk model and gas monitoring results.

Based on the measured flow rates and measured hazardous gas concentrations, individual “hazardous gas flow rates” (Q_{hg}) can be derived for each monitoring point, from which the “site characteristic hazardous gas flow rate” (Q_{hgs}), and then the “Characteristic Situation” can be determined.

BS8485 provides guidance on the level of required gas protection based upon the characteristic situation and the type of development.

A Gas Screening Value (GSV) is calculated using the following equation.

GSV = borehole flow rate (l/h) x gas concentration (v/v %)

Methane – 0.1 (v/v %)

Carbon Dioxide – 10.5 (v/v %)

Flow Rate – 0.2 (l/h)

GSV = 0.0001 (l/h) (methane)

GSV = 0.021 (l/h) (carbon dioxide)

In addition to the use of GSV for Site characterisation, the British Standard (30) also has additional factors for the characterisation of a Site as either a Characteristic Situation (CS) 1 or CS2. These are:

- A CS1 will typically have <1% methane concentration and <5% carbon dioxide concentration (otherwise consider an increase to CS2); and,
- A CS2 will display a typical measured flow rate <70 L/h (otherwise consider an increase to CS3).

The following is based on the available results and will be re-assessed upon completion.

The GSV values calculated for the Site indicate that a CS1 would be appropriate, however, CO₂ values >5% were recorded in BH101 (1No. occasion), BH103 (1No. occasion) and BH104 (3No. occasions) to a maximum concentration of 10.5%.

Reference to the log and response zones reveal pockets of grey silt, dark organic matter and (natural) organic odours within the superficial deposits which may be the source of the recorded ground gas. Typically, these would be associated with methane rather than carbon dioxide in aerobic conditions however, impermeable clays can create anaerobic conditions which may create elevated level of CO₂.

On the basis of the above Site would be a Characteristic Situation 2, and as such all new developments would require basic ground gas protection measures.

9 Conclusions

- Ground conditions were generally found to comprise a mantle of Topsoil/subsoil and Made Ground to typically 1-2m depth, overlying a variable thickness of superficial deposits comprising the loose (locally very loose) to medium dense sandy Wigston Member and soft, locally very soft and firm cohesive Thrussington Member. Bedrock, where encountered, was found to be the Gunthorpe Member, typically observed as a firm to very stiff clay, becoming extremely weak mudstone.
- A Preliminary foundation assessment has been completed based on the available information. The assessment found that a piled foundation may offer a technically and cost-effective foundation solution for the project, based on the encountered ground conditions.
- It is understood that Site won material may be reused on Site as part of a cut and fill exercise. The material identified on Site was generally found to be wet of its optimum moisture content and as such may require moisture reduction measures to ensure it is suitable for use.
- An assessment of potential aggressive ground was completed based on laboratory testing results obtained as part of the investigation. The assessment suggests that any concrete that is to be used as part of the development should comply with a AC2-DS2 classification.
- One infiltration test was completed in the location of a proposed SuDS feature. Successful soakage was not achieved during the test.
- Visual evidence of contamination identified during the investigation was limited to the presence of suspected Asbestos Containing Materials (ACM) on the surface of the Site. No additional ACM was identified within the trial pits. No further evidence of gross contamination was identified.
- Assessment of laboratory testing did not identify contaminant concentrations at levels that present unacceptable risks to current/future Site users or controlled waters.
- Due to levels of CO₂ recorded above 5% on multiple locations within various boreholes, the Site has been classed as a Characteristic Situation 2, requiring all new developments to have suitable gas protection measures.
- In the absence of a contaminant linkage of concern (source-pathway-receptor), based on the available information, the Site is considered likely to be suitable for the proposed residential development.

10 Recommendations

- The detailed design of the proposed foundation solution may require supplementary investigative holes to accurately characterise the ground conditions at depths greater than those achieved during the investigation. This will depend on the foundation solution adopted and the required performance characteristics required.
- A methodology for management of unexpected contamination is recommended during ground works for the proposed development. Which may include a watching brief.

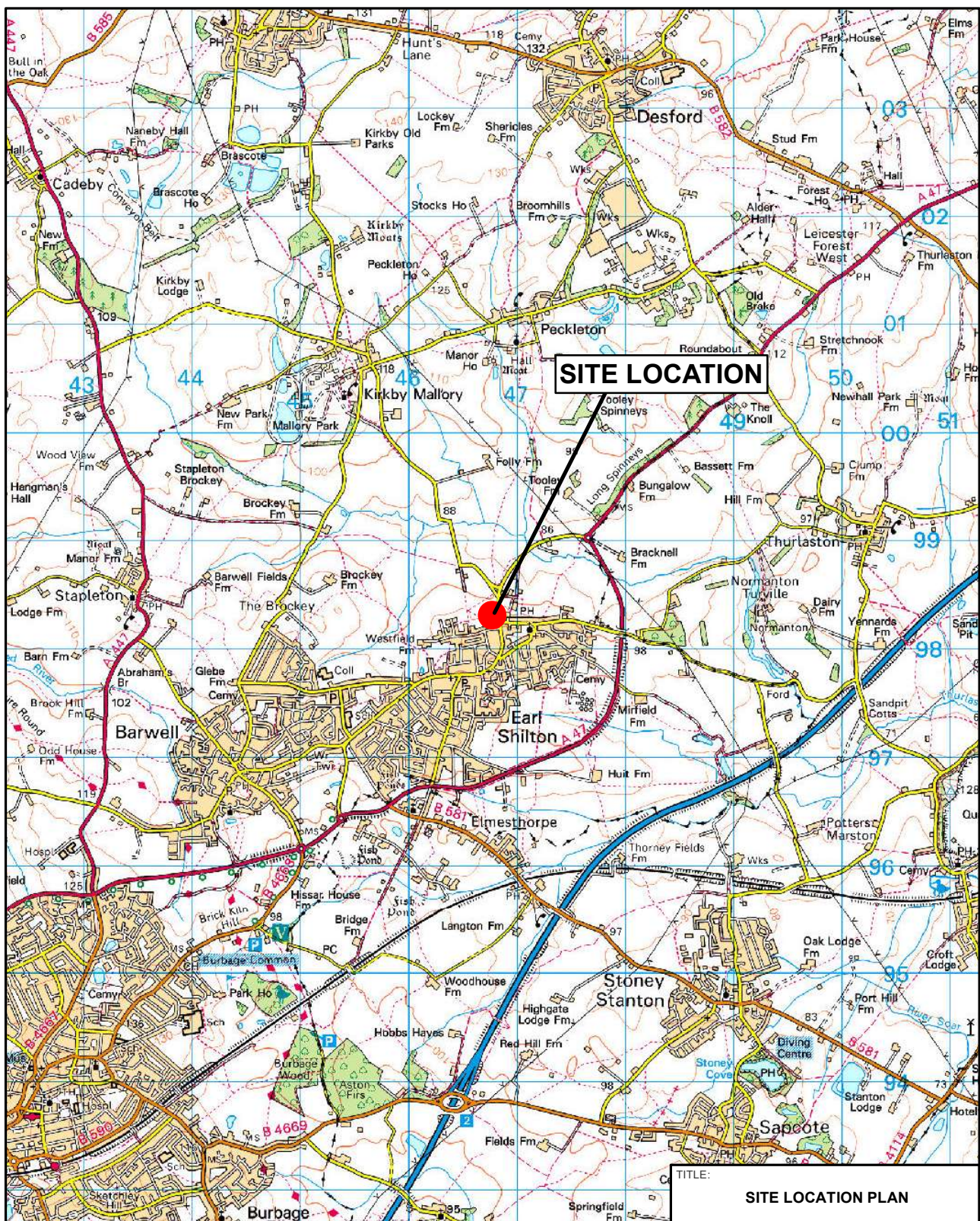
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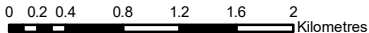
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Appendix B

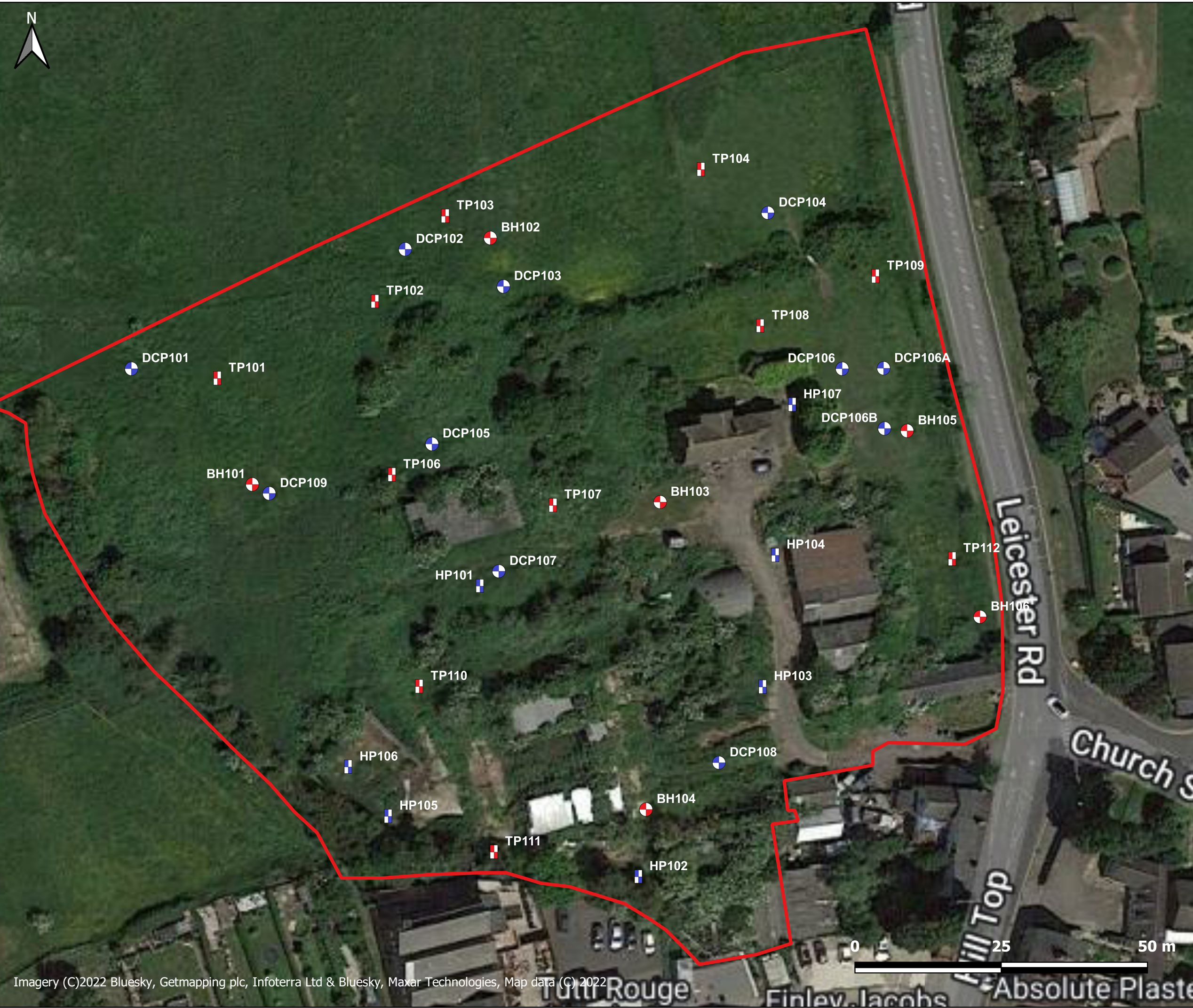
Drawings



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LEGEND	NOTES
 SITE LOCATION	SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE.
 	

TITLE: SITE LOCATION PLAN	
SITE : EARL SHILTON	
CLIENT : MIDLAND HEART	
PROJECT : 10015653	FIGURE 1
DATE : 01/12/17	DRAWN BY : BNB
DRG No. : 1001565302 GIS	
SCALE : 1 : 50,000	PRINT : A4
 Design & Consultancy for natural and built assets	



Legend

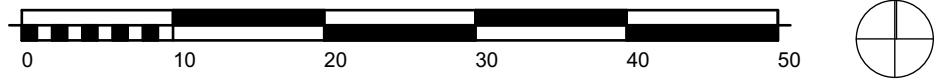
- Site Boundary
- Completed Site Investigation Locations
 - Cable Percussive Borehole
 - Dynamic Cone Penetration Location
 - Hand Excavated Pit
 - Trial Pit

Notes

Symbols for investigation locations are representations of location only and unless otherwise specified, do not represent the true size of the feature.

Locations presented are indicative only.

TITLE:		COMPLETED SITE INVESTIGATION LOCATIONS	
SITE:		HILLTOP FARM,	EARL SHILTON
CLIENT:		MIDLAND HEART	
DRG No:		10056074-AUK-XX-XX-SK-ZZ-0004-P1-Completed SI	
PROJECT NUMBER:		10056074	
DATE:		05/07/2022	DRAWN BY: RL
SCALE:		1:998	PRINT: A3
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