Providing Ground Solutions

BoKlok Housing UK Limited

Hoodlands, Harry Stoke

Geotechnical And Geoenvironmental Interpretive Report

Revision 2

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Contents

FIGURES

APPENDICES

EXECUTIVE SUMMARY

Card Geotechnics Limited (CGL) have been commissioned by BoKlok Housing UK Limited to undertake a geoenvironmental and geotechnical ground investigation at a site known as Hoodlands, Harry Stoke. The site currently comprises a private residential property, a storage area to the south-east, with the remainder of the site considered to be open fields. The proposed development consists of 50 residential properties with private gardens and associated infrastructure.

A review of the historical maps indicates that from the earliest available maps in 1881 the site has remained undeveloped, comprising open fields, before the existing Hoodland private resident development was recorded on the 1935 mapping. Since then, no significant changes are noted.

The ground conditions encountered during the investigation were generally consistent with the published geology, comprising Topsoil overlying the cohesive Mercia Mudstone Group. Made Ground was encountered across the site at a maximum thickness of 0.5m within the field areas, and 1.5m towards the eastern section of the storage area. Made Ground was identified with all exploratory holes locations with the exception of position TP04 and WS03. Groundwater was not encountered during the investigation. The cohesive soils across the site are of medium volume change potential[10].

Three gas monitoring visits have been completed with a maximum carbon dioxide concentration of 17.6% and a maximum methane concentration of 0.3%. Characteristic Situation 2 (or Amber 1) protection measures are recommended but this can potentially be refined with more data. We therefore recommend that at least three further visits are completed.

The results of chemical testing of representative soil samples indicated that determinants were recorded below the applicable human health assessment criteria for a residential use. On this basis, specific remedial measures to address risks to human health are not required for the proposed development.

A shallow foundation solution is feasible at the site within the near surface soils. The foundations should be extended through the Topsoil and formed in the cohesive Mercia Mudstone Group deposits and at a minimum depth of 0.9mm below ground level (bgl), based on soils of medium volume change potential, with a minimum 300mm embedment into the Mercia Mudstone Formation. A 'Presumed Bearing Resistance' of 125kN/m^2 is considered appropriate for this stratum at the above depth.

Suspended floor slabs should be adopted based on the presence of cohesive soils and Made Ground. Buried concrete should conform to a Design Sulfate class DS-1 - AC1s within all soil types. Based on the ground conditions encountered, a California Bearing Ratio (CBR) of 3% within the cohesive natural deposits, is considered appropriate.

1. INTRODUCTION

Card Geotechnics Limited (CGL) have been commissioned by BoKlok Housing UK Limited to undertake geoenvironmental and geotechnical ground investigation works at its site Hoodlands, Hambrook Lane, Harry Stoke, South Gloucestershire, BS34 8QG, herein referred to as 'the site'. This report aims to:

- provide a desk-based review of ground conditions at the site and associated geoenvironmental and geotechnical risks based on available published and unpublished data;
- detail the ground conditions encountered during this ground investigation and to provide analysis and interpretation of chemical and geotechnical laboratory testing undertaken on representative soil samples;
- provide a source-pathway-receptor risk assessment based on the findings of the ground investigation and results of chemical testing;
- provide geoenvironmental recommendations for addressing soil and groundwater contamination and material management / re-use; and
- provide geotechnical recommendations for foundation design, roads/pavement design and sulfate protection for buried concrete.

The objectives of this report are to provide recommendations to enable the development of the site for its intended purpose.

2. SITE CONTEXT

2.1 Site Location

The site is located off Hambrook Lane, Harry Stoke, South Gloucestershire, some 1.2km east of Bristol Parkway train station. The site is roughly square in shape covering an area of some 1.5 hectares, bound on all sides by mature hedgerows with open field beyond. The National Grid reference for the approximate centre of the site is 363570, 179475.

A site location plan is presented as Figure 1.

2.2 Site Description

A site walkover was undertaken at the time of the ground investigation works on the 7th July 2020 and the site comprised of two main land uses. A private residential property associated garden and a storage area connected to the above property in the south and south-east of the site. The remainder of the site comprises open fields with light vegetation, with a paddock area separated by fencing in the north-west. Along the north-east boundary, a depression associated with a historical pond is located. Within the centre of the site an area of rough, hummocky ground was noted.

The topography of the site falls at a consistent gradient from some 58m Ordnance Datum (OD) in the west to approximately 48m OD in the east.

A high voltage overhead power line traverses the western boundary of the site, running in a north-east to south-west orientation.

A photosheet displaying the general site conditions is presented in Figure 2.

2.3 Proposed Development

It is currently understood that the outline development plans for the site indicate that the construction of 50 low rise residential properties with private gardens, areas of public open space and associated infrastructure. An layout of the proposed development is presented in Appendix A.

2.4 Summary of Desk Study Information

Historical development of the site has been traced using Ordnance Survey maps dating from 1881 to 2020, using 1: 2,500, 1:10,000 and 1: 10,560 scale mapping. The historical maps are presented in Appendix B.

2.4.1 Site History

Based on a review of the historical maps, the site has remained relatively undeveloped since the earliest available map (1881), shown to comprise open fields. By 1935, *Hoodland* private residents is indicated, with a segregated paddock area located in the north-west section of the site. Overhead lines run near to and across the site, associated with the wider electricity network and the development of Hoodland. The mapping shows that there has been no further significant development recorded.

Offsite, the earliest development of note appears within the area approximately 100m to the north of the site in 1902, associated with the construction of a railway embankment, running east west, later identified in 1921 as the *South Wales and Bristol Direct Line*. By the late 1930s, urban expansion of Stoke Gifford was recorded to occur to the west of the site, with the appearance of residential properties with private gardens and associated infrastructure. Between 1955 and 1965, overhead electricity lines identified as *ETL* are located some 30m to the west, as well as the construction of the M4 and M32 approximately 400m to the east and south-east of the site. The most recent development constructed by 2020 is the nearby Stoke Gifford bypass, labelled as *Great Stoke Way*, located some 100m to the west, running north-south.

2.4.2 Published Geology

With reference to the British Geological Survey (BGS)[1] website, the site is anticipated to be underlain by the solid geology of the Mercia Mudstone Group, described by the BGS as *red, less commonly green-grey, mudstones and subordinate siltstones*. Recent superficial deposits are not indicated across the site, however given the sites development history Made Ground may be present.

2.4.3 Unpublished Geology

With reference to the BGS website, no historical boreholes are located within 250m of the site.

2.5 Ground Workings

The pertinent risk from ground workings in the vicinity of the site has been assessed from the environmental disclosure report presented in Appendix C. In summary:

- There are three areas of Artificial and Made Ground are located within 250m of the site. Worked ground, located 86m to the north-west, described as a void and Made Ground deposits, located 87m to the north and 176m to the south, both referenced as artificial

[1] British Geological Survey (BGS). www.bgs.ac.uk/geoindex. [Accessed July 2020]

deposits. These are both linked with infrastructure development, i.e. the railway to the north and motorway to the south;

- There are no historical underground workings indicated within 250m of the site;
- There are twelve surface ground workings recorded within 250m of the site. These are all recorded as cuttings and the nearest of which is 72m north west. These are connected to the railway development*;*
- The site is within a coal mining area although no historical mining has been identified within 1km of the site. The Coal Authority mapping[2] shows that there are no shallow workings located within 1 kilometre of the site, with the nearest mine entry being approximately 2km south west. The nearest entry in the abandoned mine catalogue as around 1 kilometre to the south. Therefore, there is considered to not be a plausible link to this potential hazard.

2.6 Radon

The site is located within an area where less than 1% of homes are estimated to be above the radon action level.

2.7 Hydrology and Hydrogeology

The Environmental Disclosure report, included in Appendix C, record the following:

- The solid geology of the Mercia Mudstone Group is designated as a Secondary B Aquifer, described as *predominantly lower permeability layers which may store/yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons, and weathering*;
- The site is not located within a groundwater Source Protection Zone (SPZ);
- The site is located in an area where the risk from groundwater flooding is considered negligible;
- No premises with active groundwater abstraction licences are located within 1km of the site; and
- Four surface water features are located within 250m of the site, all of which are unnamed and associated with *inland rivers narrower than 5m*, the nearest being around 111m to the west.

[2] http://mapapps2.bgs.ac.uk/coalauthority/home.html (Accessed July 2020)

2.8 Environmental Summary

A review of the environmental disclosure report, included within Appendix C, has been undertaken to provide information on the environmental setting of the site and possible sources of ground contamination. A summary is outlined below.

- A single current industrial land use is recorded on site, listed as *N McKillop Scaffolding*, associated with *Construction and Tool Hire*. In addition, 7 industrial land uses are recorded within 250m of the site, including *pylons, an electrical substation* and *mast*;
- Historical industrial land uses are not denoted to have been present on site. Within 250m of the site, 12 records of *cuttings* are denoted to the north and north-west linked with the railway line;
- No historical tanks are recorded to be present on site. Within 250m of the site, a single *unspecified tank* is recorded some 79m west;
- No active or historical landfills are located within 250m of the site boundary;
- No sites recorded to be contaminated under Part 2A of the Environmental Protection Act 1990 are recorded to be present within 250m;
- No licensed discharges to controlled waters are located within 250 m of the site; and
- The site is located within two Site of Special Scientific Interest (SSSI) impact risk zones, for which specific types of development require further consultation. These types of development include any "*discharge of water or liquid waste of more than 20m^3/day to ground (i.e. to seep away) or to surface water, such as a beck or stream (NB This does not include discharges to mains sewer which are unlikely to pose a risk at this location)".*

3. PRELIMINARY CONCEPTUAL SITE MODEL

Historical contamination of land may present harm to human health and the environment. Current UK legislation stipulates that the risk associated with any potential land contamination is assessed and remediated, if necessary. Under the Town and Country Planning Act 1990 (as amended), potential land contamination is a "material planning consideration" together with the National Planning Policy Framework (February 2019) which means that a planning authority must consider contamination when they prepare development plans or consider individual applications for planning permission. It is the responsibility of the developer to carry out the remediations where it is required and satisfy the Local authority that the remediations has been carried out as agreed.

Additionally, Part 2A of the Environmental Protection Act 1990 requires that a significant source-pathway-receptor linkage exists to determine a site as contaminated land. This means that there must be a contaminant present, a receptor that could be harmed by this contaminant, and a pathway linking the two. Part IIA deals with the contamination risk from a site in its current use, however the planning system requires that the proposed use be considered. Where remediation is carried out under the planning system, it should be ensured that the site is in such a condition that it would still not meet the definition of contaminated land under Part 2A.

A preliminary Conceptual Site Model has been compiled for the site based on the information within this desk study, the environmental disclosure report and from the site walkover to determine the potential sources of contamination and the significance of potential pollutant linkages.

3.1 Potential Sources

Potential contamination sources can include current and historical activities on the site. The following potential sources have been identified at the site.

3.1.1 On-site sources

- *Agricultural land use* – since the earliest historical maps, the majority of the site has comprised agricultural land. The rough hummocky ground noted may be as a consequence of this historical land use;

- *Historical Pond* - A historical pond is identified on supplied plans and was noted as a circular depression during the site walkover in the north east corner. Potential hazards include organic gas generating soils, inorganic and organic compounds either being dumped here or transported as run-off;

- *Storage area* - A storage area within the south east of the site, believed to have been used by a scaffold company. Potential contaminants associated with these land uses include asbestos, heavy metals, inorganic and organic compounds; and

- *Pylons, overhead and underground services* - during the installation and maintenance of these there may have been stockpiling of materials (e.g. metals, lubricants) and fuel spills.

3.1.2 Off-site Sources

- *Adjacent land uses* – since the earliest historic maps, the surrounding land use has been recorded as being agricultural land and more recently residential properties and associated infrastructure, including pylons and overhead lines. From these offsite land uses no sources of contamination have been identified with plausible contaminant linkages; and

- *Railway line* - To the north of the site, the railway line is a potential source of elevated Polycyclic Aromatic Hydrocarbons in dust/ashes, dispersed by wind.

3.2 Potential Pathways

The potential migration pathways that may be present at the site include:

- *Ingestion* – contaminants within any Made Ground may result may be taken up through home-grown produce or direct ingestion;

- *Inhalation* – contaminated dust, including asbestos fibres and soil gases;

- *Dermal contact* – with contaminated soils or water can result in the permeation of contaminants through the skin;

- *Direct contact* - with contaminated soils or water can result in the permeation of contaminants through building material;

- *Migration through permeable soils* – contaminants could leach or migrate through permeable soils carried by infiltration / perched water / groundwater. However, given the distance to the nearest surface waters and the status of the underlying geology as a Secondary B Aquifer it is thought that there is no plausible link to this potential pathway;

- *Ground gas migration* – migration of ground gases through the soil matrix; and

- *Root uptake* – migration of contaminants from underlying soils into plant media via roots.

3.3 Potential Receptors

It is understood that the site is to be developed for a residential end use. Therefore, the receptors considered are for the most conservative end use of *residential housing with private gardens*. The main receptors at the site are considered to be:

- Site end users;
- Offsite residents;
- Construction workers;
- Surface waters;
- Plants and vegetation; and
- Buildings and infrastructure.

3.4 Preliminary Qualitative Risk Assessment

A preliminary qualitative risk assessment has been undertaken based on a review of the desk-based information summarised in previous sections. An assessment of potential pollutant linkages that may exist at the site has been undertaken in accordance with the guidance given in Contaminated Land Report (CLR) 11[3]. Using criteria broadly based on those presented in CIRIA Report C552[4], the magnitude of the risk associated with potential pollutant linkages has then been assessed and is summarised below in, Table 1. The risk assessment methodology is presented in Appendix D.

[3] The Environment Agency. (2004). Model Procedures for the Management of Land Contamination. CLR 11.
[4] CIRIA (2001) Contaminated Land Risk Assessment. A guide to good practice. C552.

Table 1. Preliminary Qualitative Risk Assessment

Source/Medium	*Potential Exposure Route*	*Receptor*	*Consequence*	*Probability*	*Risk Rating*
Onsite					
Agricultural land use	Ingestion, inhalation, and dermal contact	Construction workers	Severe	Low likelihood	Moderate
		Site end users	Medium	Low likelihood	Moderate / Low
	Inhalation	Off-site users	Medium	Low likelihood	Moderate / Low
	Direct contact	Buildings and infrastructure	Mild	Low likelihood	Low
	Root uptake	Plants and Vegetation	Minor	Low likelihood	Very Low
	Migration through permeable soils	Surface waters	Mild	Low likelihood	Low
Historic uses of the site – historical pond, development of storage areas and overhead lines	Ingestion, inhalation, and dermal contact	Construction workers	Severe	Low likelihood	Moderate
		Site end users	Medium	Low likelihood	Moderate / Low
	Inhalation	Off-site users	Medium	Low likelihood	Moderate / Low
	Direct contact	Buildings and infrastructure	Mild	Low likelihood	Low
	Root uptake	Plants and Vegetation	Minor	Low likelihood	Very Low
	Migration through permeable soils	Surface waters	Mild	Low likelihood	Low
Offsite					
Railway Line	Ingestion & inhalation	Construction workers	Medium	Unlikely	Low
		Site end users	Medium	Unlikely	Low

4. GROUND INVESTIGATION

4.1 Fieldwork

A ground investigation was undertaken by CGL across the 7th and 8th July 2020, with the works supervised and directed by an Engineer from CGL. The site works were undertaken in accordance with BS10175[5] and BS5930[6]. The exploratory holes were positioned to provide general coverage across the site.

The soils were logged by an engineer from CGL, with representative samples obtained for geotechnical and chemical analysis. The investigation comprised the excavation of six machine excavated trial pits (TP01 to TP05 and SA01, the latter of which was subjected to infiltration testing in accordance with BRE 365[7]) and six windowless sample boreholes (WS01 to WS06).

A photosheet displaying the general ground conditions is presented as Figure 3 and Figure 4. An exploratory hole location plan is presented as Figure 5, with exploratory hole records provided in Appendix E.

4.2 Installations

Three of the windowless sample boreholes (WS01, WS04 and WS06) were installed with combined ground gas and groundwater monitoring standpipes with response zones constructed at varying depths within the Made Ground and underlying Mercia Mudstone Group stratum. The locations and depths of the standpipes are summarised in Table 2 below.

Table 2. Installation details

Exploratory Hole ID	*Standpipe Response Zone Depth (m bgl) [founding strata]*
WS01	0.5 to 1.5 [Made Ground]
WS04	1.0 to 2.0 [Mercia Mudstone Group]
WS06	1.0 to 2.0 [Mercia Mudstone Group]

4.3 Laboratory testing

4.3.1 Chemical

Representative soil samples were collected from site and sent to i2 Analytical (a UKAS and MCERTS accredited laboratory) for chemical testing. The analysis included testing for the following contaminants and the results of the chemical analyses are presented in Appendix F.

[5] BS10175. 2011 + A2:2017. *Investigation of potentially contaminated sites.*
[6] BS5930: 2015 *Code of Practice for Ground Investigations.*
[7] BRE (2005). *Soakaway design*. BRE 365.

- Soil Organic Matter (SOM);
- Heavy metals / metalloids including; antimony, arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium, and zinc;
- Total Petroleum Hydrocarbons Criteria Working Group (TPH CWG);
- Polycyclic Aromatic Hydrocarbons (PAH);
- Water soluble sulfate;
- pH determination;
- Total Monohydric Phenols;
- Total cyanide; and
- Asbestos screening (Made Ground only).

4.3.2 Geotechnical

Representative soil samples were sent to GSTL (a UKAS accredited laboratory) for geotechnical testing. The following classification testing was undertaken, and the full results are presented in Appendix G.

- Moisture content and Atterberg Limits; and
- Particle size distribution (wet sieve).

5. GROUND AND GROUNDWATER CONDITIONS

5.1 Summary

The ground conditions encountered across the site were generally consistent with the published and unpublished geology for the site with the exception of the presence of Made Ground deposits, anticipated to be present within the storage area. These deposits were recorded to a depth of 1.5m (bgl), however a thin veneer (up to some 0.5m in thickness) was also encountered in the area considered open fields. Made Ground was identified at all exploratory locations with the exception of TP04 and WS03.

Underlying this, varying weathered and intact grades of the Mercia Mudstone Group were encountered, the base of which was not proven during this investigation. The ground conditions encountered are summarised in Table 3 below.

Table 3. Summary of Ground Conditions

Stratum	*Depth to Top of Stratum (m bgl)*	*Typical Thickness (m)*
Grass over dark brown and brown sandy silt. (SA01, TP01 to TP05, WS04 and WS05 only) [TOPSOIL]	Ground level	0.1 to 0.3
Soft to firm dark grey and dark brown clay with varying proportions of sand and gravel. The gravel fraction consists of brick, concrete and ceramics decomposed roots, plastic, and glass fragments. (SA01, TP01, TP02, TP03, TP05, WS01, WS02, WS04 to WS06 only) [MADE GROUND]	Ground level to 0.2	0.25 to 1.5
Soft to stiff reddish brown locally slightly sandy slightly gravelly clay. The gravel fraction comprises lithorelicts of very stiff clay to extremely weak mudstone. (All exploratory hole location) [MERCIA MUDSTONE GROUP – ZONES IVb and IVa][8]	0.0 to 1.5	0.6* to 2.7*

Notes: * base not proven

5.2 Groundwater

During the ground investigation, the presence of groundwater or groundwater strikes were not encountered.

5.3 Visual and olfactory indicators of contamination

Made Ground, containing anthropogenic materials, was identified at all exploratory hole locations with the exception of TP04 and WS03. These deposits comprised a soil matrix with anthropogenic materials including brick, concrete and rare ceramic fragments. The Made Ground recorded in WS01 and WS06, was located in the eastern section of the site and was recorded to be significantly thicker (between 0.8m

[8] CIRIA Report C570. Engineering in Mercia Mudstone (2001).

and 1.5m) at this location. The deposits here were recorded to include the addition of rare plastics, decomposed roots, and glass.

Further significant visual or olfactory evidence of contamination was not observed during the ground investigation works.

5.4 Soakaway Testing

Soakaway testing was undertaken within SA01 in accordance with BRE 365, in the vicinity of the proposed Sustainable Drainage System (SuDS) pond indicated on the proposed development plans in Appendix A. The results of the soakaway testing are summarised in Table 4 below, with infiltration rate calculations included as Appendix H.

Table 4. Summary of soakaway testing results

Soakaway	*Test Number*	*Trial Pit Depth (m bgl)*	*Depth Range Tested (m bgl)*	*Cohesive or Granular*	*Calculated infiltration rates (m/s)*[9]	*Test completed to 75%?*
SA01	1	3.0	1.1 to 3.0	Cohesive	-	No

5.5 Geotechnical test results

Based on the results of the in-situ laboratory testing, a summary of the geotechnical properties of the soils is presented in Table 5 below. A figure showing the SPT 'N' values against depth is presented in Figure 6, a Particle Size Distribution chart is included as Figure 7 and a plasticity index chart is included as Figure 8.

Table 5. Geotechnical Test Data

Atterberg Limits						
Strata	*Moisture content (%)*	*Liquid Limit (%)*	*Plastic Limit (%)*	*% material <425µm*	*Modified Plasticity Index*	*Volume change potential*[10]
Mercia Mudstone Group	19 to 26	35 to 63	18 to 33	86 to 95	16 to 34	Low to Medium
Particle Size Distribution (wet sieve)						
Strata	*Clay/Silt (%)*	*Sand (%)*	*Gravel (%)*	*Cobbles (%)*	*Notes*	
Mercia Mudstone Group	5 to 53	15 to 50	23 to 64	0	Consistent with field descriptions	
SPT 'N' data						
Strata		*SPT 'N' value range [No. of tests]*		*Correlated Strength (kPa)*[11] *(Measured Strength (kPa))*		*Classification*
Made Ground		4 [1]		n/a		n/a
Mercia Mudstone Group		19 to <50 [10]		85 to 225		High to extremely high strength

[9] BRE. (2005). *Soakaway design*. BRE 365
[10] National House Building Council. (2015). Building near trees. Chapter 4.2.
[11] Stroud. (1974). The standard penetration test in insensitive clays and soft rock.

5.6 pH and Sulfate

A total of five soil samples (three of Made Ground and two from natural soils) from across the site have been tested in accordance with BRE SD1 for pH and sulfate conditions. The results of the testing are summarised in Table 6 below and full records are presented in Appendix F.

Table 6. Sulfate and pH Conditions

Strata	pH	Water Soluble Sulfate (2:1) (mg/l)
Made Ground	8.0 to 9.0	62 to 270
Mercia Mudstone Group	7.9 to 9.0	5.8 to 7.9

5.7 Monitoring

Three return gas and groundwater monitoring visit were undertaken between the 15th July 2020 and 19th August 2020. This visit was completed during steady and falling atmospheric conditions (between 999mb and 1011mB). The results of this monitoring visit are summarised in Table 7 below, with full monitoring records available in Appendix I.

Table 7. Summary of Gas Monitoring Data

Location	*Response Zone Strata*	*Groundwater level (m bgl)*	*Flow rate (max l/hr)*	*Flow rate (residual l/hr)*	*O2 (min %)*	*CO2 (max %)*	*CH4 (max %)*
WS01	Made Ground	1.46 to 1.47	0.1	<0.1	0.1 to 4.8	12.1 to 17.6	<0.1 to 0.3
WS04	Mercia Mudstone Group	Dry	0.1	<0.1	14.8 to 17.1	4.6 to 5.8	<0.1
WS06	Mercia Mudstone Group	Dry	0.1	<0.1	14.7 to 16.6	2.2 to 2.9	<0.1

5.8 Ground Model

The ground conditions encountered during the investigation were generally consistent with those contained within the published geology for the area, with the exception of the presence of Made Ground deposits, which were encountered as a thin veneer in the areas of open fields and to a greater extent within the area of the storage area, where thicker Made Ground is thought to be associated with its construction.

The Made Ground within the storage area varied between cohesive and granular soils, with a single in-situ standard penetration test (SPT) completed within the former recording an 'N' value of 4. Made Ground encountered within the remainder of the site was largely consistent, comprising a cohesive material with rare anthropogenic granular material. The area of rough hummocky ground was noted to be an area of Made Ground deposition.

The solid geology of the Mercia Mudstone Group was recorded to underly Topsoil or Made Ground across the site from depths of between ground level and 1.5mbgl, with SPT results confirming strength increasing with depth.

Groundwater was not encountered during the ground investigation or during the, three return monitoring visits.

With respect to ground gas, concentrations of carbon dioxide were recorded to rise above 5% within installation wells with response zones within both the Made Ground and underlying Mercia Mudstone Group with the exception of WS06. Carbon dioxide levels within WS04 (installed within the Mercia Mudstone Group) rose to a high of 5.8%, however within the 15-minute monitoring period this had reduced to 2.5%. Negligible methane (<0.1%) values were recorded within WS04 and WS06.

Within WS01 (Installed within Made Ground) a maximum carbon dioxide level of 17.6% and a maximum methane level of 0.3% was recorded. Within all exploratory holes a maximum flow rate of 0.1l/hr was recorded.

6. CONTAMINATION ASSESSMENT & CONCEPTUAL SITE MODEL

6.1 Introduction

This section evaluates risks to potential receptors at the site from identified chemical contamination building on the preliminary conceptual site model within Section 3 and findings of the ground investigations. Potential receptors have been identified with reference to the Part 2A regime and associated DEFRA guidance. As with the Part 2A regime, under the planning regime relevant receptors (humans, controlled waters, ecology, and buildings) have been considered if there is the potential for them to be adversely affected by exposure to contamination. The risk assessment methodology is presented in Appendix D and detailed information on the assessment criteria adopted is presented in Appendix J1.

6.2 Risks to Human Health (Long-term Chronic Risks)

6.2.1 Risks from Soil Contamination

Current development plans indicate the site is to be developed with a number of low-rise residential properties with private gardens, areas of public open space and associated infrastructure. The laboratory test results from the ground investigation have therefore been compared against Generic Assessment Criteria (GAC), that have been derived in-house by CGL, for a "*Residential with Plant Uptake"* land use category to assess the risk to human health from contamination in soils.

A total of ten samples (one Topsoil, seven of Made Ground, and two from natural soils) obtained during the ground investigation were analysed for a suite of contaminants. Within samples retrieved from both Topsoil and natural soils, all determinants were recorded below the applicable GAC for a residential site with plant uptake.

Within the Made Ground, all determinants recorded below the applicable GAC, with the exception of arsenic andlead. These exceedances are listed below:

- Arsenic – a single exceedance of arsenic was recorded in SA01 at a depth of 0.2mbgl, recording a concentration of 39mg/kg which exceeds the assessment criteria of 28mg/kg and when the results are further analysed the US_{95} value is still above the GAC (36mg/kg); and

- Lead – two exceedances were recorded in SA01 at a depth of 0.2mbgl and WS06 at a depth of 0.05mbgl, with concentrations recorded at 220mg/kg and 260mg/kg, respectively. The GAC value for this is 200mg/kg and when the results are further analysed the US_{95} value is below the GAC (196mg/kg).

Five samples of Made Ground were submitted for testing for an asbestos screen. Loose chrysotile asbestos fibres were identified in a single sample location within the storage area (WS01 at a depth of 0.3mbgl). Quantification analysis indicated that this sample contained <0.001% of chrysotile fibres.

On the basis of the above, the risks to human health (future site users) are considered to be **moderate / low** based on the presence of arsenic, lead and loose fibres of asbestos within the Made Ground. The risks of potential short-term exposure to construction workers from the presence of loose asbestos fibres both within the Made Ground is considered to be moderate but can be mitigated through good health & safety practices and use of appropriate personal protective equipment (PPE) as discussed in Section 7.5 of this report.

6.2.2 Risks from Ground Gas

As part of the investigation, ground gas monitoring has been undertaken at the site in accordance with the current guidance[12, 13, 14]. The potential risk of ground gas was assessed as part of the desk study to be associated with the sites historical land uses, including a former pond and the storage area.

The results of the gas monitoring completed at the site have been assessed to characterise the gas regime and assess the potential risk to the proposed development, Gas Screening Values (GSV) have been calculated, for the bulk gases, carbon dioxide and methane, using the following equation:

GSV = borehole flow rate (l/h) x gas concentration (% in mathematical form i.e. 50% is 0.5).

CIRIA 665 outlines two methods of characterising levels of risk associated with a site; Situation A which one applies to low rise housing only, which was developed by the National House Building Council (NHBC), and Situation B which applies another for any other type of development. The assessment below relates solely to Situation A. Both methods use the Gas Screening Value (GSV) to characterise the site.

Table 8. Ground Gas Assessment

Gas	*Peak Flow (l/hour)*	*Residual concentration (Carbon Dioxide %)*	*Maximum Concentration (%)*	*GSV*	*Characteristic Situation*	*NHBC Traffic Light Classification*[15]
Carbon Dioxide	0.1	17.6	-	0.0176	CS2*	***Amber 1****
Methane	0.1	-	0.3	0.0003	CS1	***Green***

Notes: * - based on ground gas concentration not GSV.

[12] CIRIA C665. (2007). *Assessing risks posed by hazardous ground gases to buildings.*
[13] British Standard. (2013). Guidance on investigations for ground gas. Permanent gases and Volatile Organic Carbons. BS8576.
[14] British Standard. (2019). Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings. BS8485:2015+A1:2019.
[15] NHBC. (2007). Guidance on Evaluation Of Development Proposals On Sites Where Methane and Carbon Dioxide Are Present Report Edition No.: 04 March 2007

Based on the concentrations and GSVs recorded for carbon dioxide, the gas regime would be classified as *Characteristic Situation (CS) 2* in accordance with the BS 8485[14] and on the basis of the elevated concentrations of carbon dioxide in the footprint of Storage Areas as *Amber 1* in accordance with the NHBC traffic light classification, based on the ground gas concentration. On this basis, ground gas conditions within this area are considered to represent a risk. To further refine the risk assessment, it is recommended that additional gas monitoring visits and further investigation of the extent of Made Ground are completed.

With reference to the Environmental Disclosure Report contained within the desk study report, the site is located in an area where less than 1% of properties are above the radon action level. On this basis, radon protection measures are not considered necessary in the construction of new buildings, and the risk across the site from ground gas is considered to be **low**.

6.3 Risks to Controlled Waters

Concentrations of contaminated recorded within the natural soils are generally considered to be representative of background concentrations and the potential for leaching is considered to be low. Furthermore, the underlying geology is classified as a Secondary B Aquifer and the nearest surface water feature is located over 100m away from the site. Finally, groundwater was not encountered with the exploratory hole locations completed during the investigation and follow up monitoring visits.

On this basis, an unacceptable risk to controlled waters is not considered to be present at the site and risks are considered to be **Very Low.**

6.4 Risks to Buildings and Structures

6.4.1 Water Supply Pipes

With reference to the UK Water Industry Research Guidance[16] exceedances were identified within a single sample (WS06 at 0.05m) for aliphatic and aromatic compounds in the C21 to C40 fraction (State values). It is recommended that if required barrier pipe is used if placing water supply pipes within the Made Ground. Polyethylene of PVC water supply pipes can be used if placed within the natural Mercia Mudstone Group but this should be checked with the local water authority.

It is considered that special precautions, with regards water supply pipes, are unlikely to be required for services placed within the Mercia Mudstone Group based on the contaminant concentrations recorded within this stratum. The requirements for barrier pipe or similar within Made Ground deposits should

[16] UK Water Industry Research. 2010. *Guidance for the selection of water supply pipes to be used in brownfield sites.*

this be preferable will need to be confirmed with the local water authority based on the findings of this report.

6.4.2 Risks to Vegetation and Plants

Plant growth can be affected by phytotoxic contaminants, such as boron, copper, nickel, and zinc, see Tables 5.1 to 5.3 in Appendix J5. Concentrations of zinc were recorded above the assessment criteria within the Topsoil, Made Ground and natural soils, with copper also recording an exceedance in the Made Ground. The exceedances within the natural soils and Topsoil are considered to be representative of normal background concentrations, in addition evidence of die back was not recorded at the site. On this basis the elevated zinc is not considered to pose a significant risk to plant growth.

It is noted that the composition of the Made Ground is unlikely to be suitable for reuse as part of a growing medium. It is recommended that a copy of this reports and the chemical results are provided to the landscape engineer such that appropriate planting can be used.

Based on this, the risk to vegetation and plants is considered **Low**.

6.4.3 Sulfate and pH Conditions

Chemical analysis has been undertaken on three samples of Made Ground and two of the natural soils in accordance with BRE SD1[17] to determine concrete classification. On the basis of the pH and water soluble sulfate concentrations a Design Sulfate Class of DS -1, ACEC Class ACS-1s is applicable.

Therefore, the risks to buildings and structures, associated with aggressive ground conditions, are considered to be **Very Low**.

6.5 Revised Conceptual Site Model

Based upon the information obtained from the ground investigation and laboratory testing, the conceptual site model has been revised and is summarised below in Table 9, below.

Table 9. Revised Qualitative Risk Assessment.

Source/Medium	*Potential Exposure Route*	*Receptor*	*Consequence*	*Probability*	*Risk Rating*
Onsite					
Agricultural land use	Ingestion, inhalation, and dermal contact	Construction workers	Severe	Unlikely	Moderate / Low
		Site end users	Medium	Unlikely	Low
	Inhalation	Off-site users	Medium	Unlikely	Low
	Direct contact	Buildings and infrastructure	Mild	Unlikely	Very Low
	Root uptake	Plants and Vegetation	Minor	Likely	Low

[17] BRE. Special Digest 1, 2005. *Concrete in aggressive ground.*

	Migration through permeable soils	Surface waters	Mild	Unlikely	Low
Historic uses of the site – historical pond, development of storage areas and overhead lines	Ingestion, inhalation, and dermal contact	Construction workers	Severe	Low likelihood	Moderate
		Site end users	Medium	Unlikely	Low
	Inhalation	Off-site users	Medium	Unlikely	Low
	Direct contact	Buildings and infrastructure	Mild	Unlikely	Very Low
	Root uptake	Plants and Vegetation	Minor	Likely	Low
	Migration through permeable soils	Surface waters	Mild	Unlikely	Very Low
Offsite					
Railway Line	Ingestion & inhalation	Construction workers	Medium	Unlikely	Low
		Site end users	Medium	Unlikely	Low

7. GEOENVIRONMENTAL RECOMMENDATIONS

7.1 General

The proposed development is to comprise the construction of low-rise residential dwellings with private gardens, associated infrastructure, and areas of public open space. As such, the following recommendations are based on the worst-case scenario of a *'residential (with plant uptake)*' end use. An assessment of the material classification has also been undertaken so that an appropriate material management plan can be implemented during the groundwork operations. Other receptors, including controlled waters and off-site residents, have also been considered. An assessment of material classification has also been undertaken so that an appropriate material management plan can be implemented during groundwork operations.

7.2 Contamination and Remediation

Within the area comprising open fields where a thin veneer of Made Ground was encountered, it is recommended that this be removed (excavated down to natural strata) in areas of proposed private gardens and areas of public open space. Where hardstanding is present, the Made Ground may remain in-situ, although its engineering suitability will have to be considered.

Within the storage area, due to the presence of loose asbestos fibres and Made Ground, it is considered that a potential risk to future site users and construction workers during construction activities has been identified from exposure to asbestos in Made Ground without adequate remedial/mitigation measures.

Where Made Ground is present in proposed areas of soft landscaping or private gardens, a clean capping layer of suitable material will be required or Made Ground removed, subject to further testing. Within areas of proposed hardstanding (e.g. beneath buildings and/or pavements) no protective measures would be required.

However, within areas of public open space or private gardens a capping layer would be required. Details of the proposed capping layer for areas of public open space and private gardens are presented in Table 10 below with topsoil to comply with BS 3882[18]. The thickness and extent of the capping layer could be reduced by undertaking further testing.

[18] BSI (2015) BS3882 Specification for Topsoil and requirements for use.

Table 10 Composition of engineered capping layer

Layer	Minimum thickness (mm) – private gardens	Minimum thickness (mm) – public open space
Topsoil	150	150
Cohesive subsoil	450[1]	300[1]
Geotextile (Terram® 1000 or similar)	Required [2,3]	Required [2,3]

Notes:
1. Additional Topsoil can be substituted for the subsoil; as long as the total soil thickness is maintained.
2. Terram 1000 is a non-woven geotextile with a pore size of 0.15 mm and a nominal thickness of 0.8 mm.
3. It should be noted if trees/shrubs are planted this may require localised deepening.

Placement of a capping layer and import specification would be subject to agreement with the Local Authority in the event land levels in private gardens and areas of public open space need to be raised. Capping layers are not required within areas of proposed hardstanding (e.g. beneath buildings, pavements and/or car parking).

If, during the development of the site, materials are encountered that are not consistent with the findings of this investigation, further inspection and testing should be undertaken by a suitably qualified geoenvironmental engineer in conjunction with a Discovery Strategy, outlined in Section 7.6 below.

During construction good working practices, environmental controls and appropriate personal protection and respiratory protection (PPE and RPE) will be required to protect construction workers and off-site receptors from exposure to contamination and asbestos. A suitable risk assessment and mitigation measures must be implemented in accordance with The Control of Asbestos Regulations (CAR) 2012 and guidance given in CAR-SOIL Control of Asbestos Regulations 2012: Interpretation for Managing and Working with Asbestos in Soil and Construction & Demolition materials: Industry Guidance (CL:AIRE 2016). Such measures are likely to comprise dust control, air monitoring, use of appropriate PPE, staff training/awareness and maintaining a close watching brief for contamination and fibrous materials during earthworks.

7.3 Ground Gas Protection Measures

Gas screening values have been calculated in accordance with CIRIA 665 based on the results of the three monitoring visits undertaken to date. The site is characterised as *Characteristic Situation 2* based on current CIRIA guidance or as *Amber 1* in accordance with NHBC guidance. The following protection measures are recommended[12]:

- reinforced concrete cast in situ floor slab (suspended, non suspended or raft) with minimum 1200g DPM and underfloor venting;

- block and beam or precast concrete slab and 2000g DPM /or reinforced gas membrane and underfloor venting; and
- All joints and penetrations sealed

The site is not located in a radon affected area; therefore, radon protection measures are not required in the construction of new dwellings.

The site is in an area where less than 1% of properties are above the radon action level. On this basis, radon specific protection measures are not required for the proposed residential developments.

7.4 Material Management

The chemical results have been used to classify soils for waste disposal offsite should this be required, based on guidance contained within WM3[19]. The chemical analysis results indicate that the natural soils are deemed as *'not hazardous'* and they are likely to be considered inert given their natural derivation.

On the basis of the chemical testing completed and the percentage concentration of asbestos identified being less than 0.1% by weight, then the Made Ground would be accepted to a landfill which is licensed to accept low quantities of asbestos as non-hazardous waste. However, if larger fragments of asbestos were to be identified this may change the classification to hazardous. A watching brief is recommended with handpicking larger fragments as an option.

WAC testing may be required by the receiving landfill to confirm its suitability for disposal. It should be noted that all waste will require pre-treatment, where possible, before disposal to a licensed landfill. However, there is no pre-treatment requirement if waste is sent for recovery (i.e. a soil treatment facility) instead of disposal.

If any surplus material is excavated, then the natural soils could be offered for re-use via the CL:AIRE register of material. The material will require transporting and disposal in accordance with the Environmental Protection (Duty of Care) Regulations, 1990. CGL can aid with this and submit a Material Management Plan if required and provide guidance on the best code of practice for such activities

7.5 Health and Safety

Construction workers have the potential to come into direct contact with dusts and soils during the course of their activities. Based on the findings of the investigation the risk to construction workers is

[19] Environment Agency. 2015. *Waste Classification - Guidance on the classification and assessment of waste* (WM3)

assessed as low. Notwithstanding this, appropriate health and safety measures should be incorporated during construction. Such precautions should include, but not be limited to:

1. Personal hygiene, washing and changing procedures.
2. Personal protective equipment, including disposable overalls, gloves etc.
3. Measures to avoid surface water ponding and positive collection and disposal of all on-site run-offs.
4. Regular cleaning of all site roads, access roads and the public highway including dust suppression methods (e.g. water spraying), if necessary.

Off-site residents could also be affected by dust generated; however, it is anticipated that appropriate dust suppression will be implemented as part of the works.

7.5.1 Health and Safety – Asbestos in Soil

Laboratory studies (by Addison et al., 1988[20]) carried out on artificial soil samples with homogenous asbestos fibre contamination have shown that concentrations of respirable fibres of asbestos in soil as low as 0.001% by weight may, in loose dry soils, give rise to measurable levels of asbestos fibres if disturbed. However, the implementation of some relatively straightforward mitigation measures to minimise the risks to construction workers and the general public, outlined below will allow construction to proceed.

The protection of workers from exposure to asbestos from work activities is regulated by the Control of Asbestos Regulations, even when only trace elements of asbestos are present regardless of whether it is considered to be 'hazardous waste' or not. All reasonably practicable measures should be taken to prevent exposure and spread of asbestos. The mitigation measures presented below are aimed at minimising the risk to construction workers and offsite receptors during the groundworks phase. The HSE does not have to be notified of the works.

7.5.2 Dust Suppression

Dust suppression measures (damping down) should be available on site for the duration of all potentially dust-producing activities to minimise the potential for asbestos fibres to become airborne, until hardstanding is placed over all exposed soils or all Made Ground soils have been removed from site. The frequency and timing of dust suppression required will depend on site conditions, (e.g. how dry the soil

[20] Addison, J., Davies, L. S. T., Robertson, A., & Willey, R. J. (1988). The release of dispersed asbestos fibres from soils. Edinburgh: Institute of Occupational Medicine.

is and the potential for dust generation); however, the soils should be inspected prior to works commencing, with a designated member of the groundworkers staff monitoring the dust production and holding responsibility for implementing the suppression measures. No works should take place unless appropriate arrangements for damping down soils are available on site.

7.5.3 Unexpected Finds Protocol

If during works asbestos containing materials (ACM) become exposed, it is recommended the following procedure is undertaken:

- Personnel will move away from the area and will immediately notify the site manager; and
- Impacted soils / exposed ACM will be sprayed to minimise potential for dust generation and covered with clean soils to allow decisions to be made on the long-term destination of these materials.

7.6 Watching Brief and Discovery Strategy

It is recommended that a watching brief is maintained by the Principal Contractor, particularly during ground works undertaken in areas where unexpected gross contamination, such as oily material or material of an unusual colour or odour, is encountered, the following discovery strategy is recommended:

- Works to cease in that area;
- The man works contractor is to notify a suitably qualified geoenvironmental engineer, to attend site and sample the material for appropriate analysis and risk assessment. Dependent on the recommendations of the engineer, it may be necessary to notify Contaminated Land Officers of the Local Authority and Environment Agency, as appropriate;
- If required by the risk assessment, a geoenvironmental engineer shall supervise the excavation/removal of contaminated material. Contaminated soils should be placed in a bunded area and covered to prevent rainwater infiltration. To facilitate appropriate waste disposal and potential re-use of materials all excavated soils should be segregated and stockpiled depending on their soil classification;
- Soil samples should be obtained by the geoenvironmental engineer from both the excavated material, and the soils in the sides and base of the excavation to demonstrate that the full area of contamination has been excavated. Where appropriate, in-situ testing should be undertaken on the sides and base of the excavation to assess the presence of residual contamination in the soils;

- On receipt of chemical test results, the soils may be classified for disposal, or treatment if appropriate, and dealt with accordingly;
- Detailed records of the stockpile sizes, source and location should be kept and regularly updated to allow materials to be easily tracked from excavation until leaving the site.

Records of excavated areas and the results of chemical testing should be incorporated within the final verification report for the site.

8. GEOTECHNICAL RECOMMENDATIONS

8.1 General

The following recommendations are based on the ground and groundwater conditions encountered during the ground investigation works and the results of subsequent geotechnical testing. The soil descriptions and geotechnical laboratory data have been interpreted to provide recommendations for foundations for a typical low rise (two / three storey) development, access roads, excavations, and buried concrete.

Should the end use be different, then it may be necessary to review the findings and recommendations to ensure that they are appropriate for the development.

8.2 Foundations

Based on the ground conditions encountered and the anticipated Design Actions (loadings) from the proposed low-rise structure it is considered that conventional strip foundations or raft foundations are likely to be appropriate. A minimum founding depth of 0.90mbgl within the cohesive Mercia Mudstone Group stratum is recommended based on a medium volume change potential and with a minimum embedment of 300mm. Therefore, it has been assumed that an actual depth of at least 1.2mbgl will be adopted by the contractor.

A 'Presumed Bearing Resistance' of 125kN/m^2 is considered appropriate for the materials encountered at the site, based on encountering Mercia Mudstone Group at a depth of at least 0.6mbgl. Where Made Ground is encountered this may need to be locally deepened to achieve this value. It should be noted that this value is based on the in-situ testing completed to date and the ground conditions encountered. Should there be any variation then a geotechnical engineer should be consulted for advice.

It is recommended that prior to pouring concrete, the bases of all excavation should be inspected by a suitability qualified geotechnical engineer or Engineering Geologist to ensure that no loose or soft spots are present (and if present these are removed) prior to concreting. This will also allow variations in ground conditions to be identified. Once inspected, the footings should be immediately blinded to preserve the formation integrity.

Groundwater was not encountered within any excavation during the fieldwork and therefore groundwater is unlikely to be encountered at shallow depths during any excavation works, subject to the prevailing groundwater conditions at the time.

There remains the possibility of perched and seasonal groundwater rises on site. Heavy and prolonged rainfall may give rise to an increased groundwater level on site and an increased risk from surface water runoff.

Further monitoring visits are scheduled to be completed at the site and further consideration for the presence of groundwater will be assessed upon completion of these visits.

Additionally the variability in ground conditions across the site needs to be considered. Within the storage area and within the field to the north of this area a thickness of made ground of up to 1.5m was identified and in this area founding depths will need to be locally deepened, depending on the finished floor levels required.

8.3 Excavations

During the ground investigation, all the trial pits remained stable, as such excavations are likely to remain stable in the short term, however operatives should not enter any unshored excavations and these should be inspected by a competent person[21] following the guidelines presented in CIRIA Report 97 and by operatives who have undertaken the relevant health and safety training for such works and is dependent on the prevailing ground conditions.

8.4 Floor Slabs

On the basis of the ground investigation and laboratory analysis, it is recommended that suspended floor slabs be adopted, this being in accordance with NHBC 4.2 and soils of a medium volume change potential. It is recommended that the formation level is proof rolled prior to the construction of the floor slab. Should loose spots be identified, these should be locally removed and replaced with suitably compacted granular fill.

8.5 Buried concrete

Following laboratory testing and in accordance with BRE SD1 a Design Sulfate Class of DS-1 with an ACEC of AC-1s would apply for buried concrete, assuming static water conditions.

8.6 Road / Pavement Design

In accordance with Interim Advice Note 73/06 Rev 1 2009 & LR1132[22] it is recommended that all Topsoil is removed in areas of proposed road or pavement.

[21] CIRIA. (1992). *Trenching Practices (Second Edition).* Construction Industry Research and Information Association Report 97.
[22] DFT. (2009). *Interim Advice Note 73/06 Rev 1 2009 & LR1132*.

Where cohesive Mercia Mudstone Group deposits are recorded below Topsoil, a CBR value of 3% is recommended. It is not recommended to construct pavements within the Made Ground.

All materials within 450mm of the road surface shall be non-frost susceptible in accordance with Paragraph 6.2, Chapter 6 of IAN 73/06. Frost susceptible soils shall not be used as capping in any proposed roads. Samples of the Mercia Mudstone Group subject to geotechnical analysis recorded a modified plasticity index of greater than 15%, therefore it is unlikely that these soils would be subject to frost susceptible[23].

During construction, the sub-grade formation should be proof rolled and inspected by the Supervising Engineer (SE). Should localised soft areas of inadequate sub-grade be encountered at sub-formation level, then these should be excavated and replaced with adequately compacted capping material or sub-base.

8.7 Drainage

A single trial pit infiltration test was attempted to between 1.1 and 3.0m at trial pit SA01. This test was conducted within the Mercia Mudstone Group and a 75% drop in water level was not achieved during the test period with an infiltration rate not possible to be calculated.

8.8 Geotechnical Risk Register

Unforeseen ground conditions and geotechnical and geo-environmental hazards pose one of the largest threats in terms of delay and cost overrun to any development. To be effective in terms of reducing risk and identifying opportunities, geotechnical risk management should be started as soon as possible following project identification[24].

This register is not intended to be exhaustive at present. There is the provision that additional hazards can be identified as new information and data is brought to light throughout the detailed design and construction process. Therefore, a geotechnical risk register (Table 12) has been produced for the scheme in order to identify potential hazards, the probability of the hazard occurring, impact and risk rating. It is a very simple qualitative risk assessment and should not be viewed as definitive. This Risk Assessment reflects the current level of understanding of the geotechnical and geo-environmental aspects of the scheme and will be subject to revision.

Risk rating is defined by the following relationship:

[23] Croney, D. & Jacobs, J.C. 1967. The Frost Susceptibility of Soils and Road Materials. Road Research Laboratory. Crowthorne.
[24] Clayton, C.R.I., 2001, *Managing geotechnical risk: improving productivity in UK building and construction* (Institution of Civil Engineers), Thomas Telford, 80pp.

Risk rating (R) = Probability (P) x Impact (I)

Table 11. Definition of Risk Rating

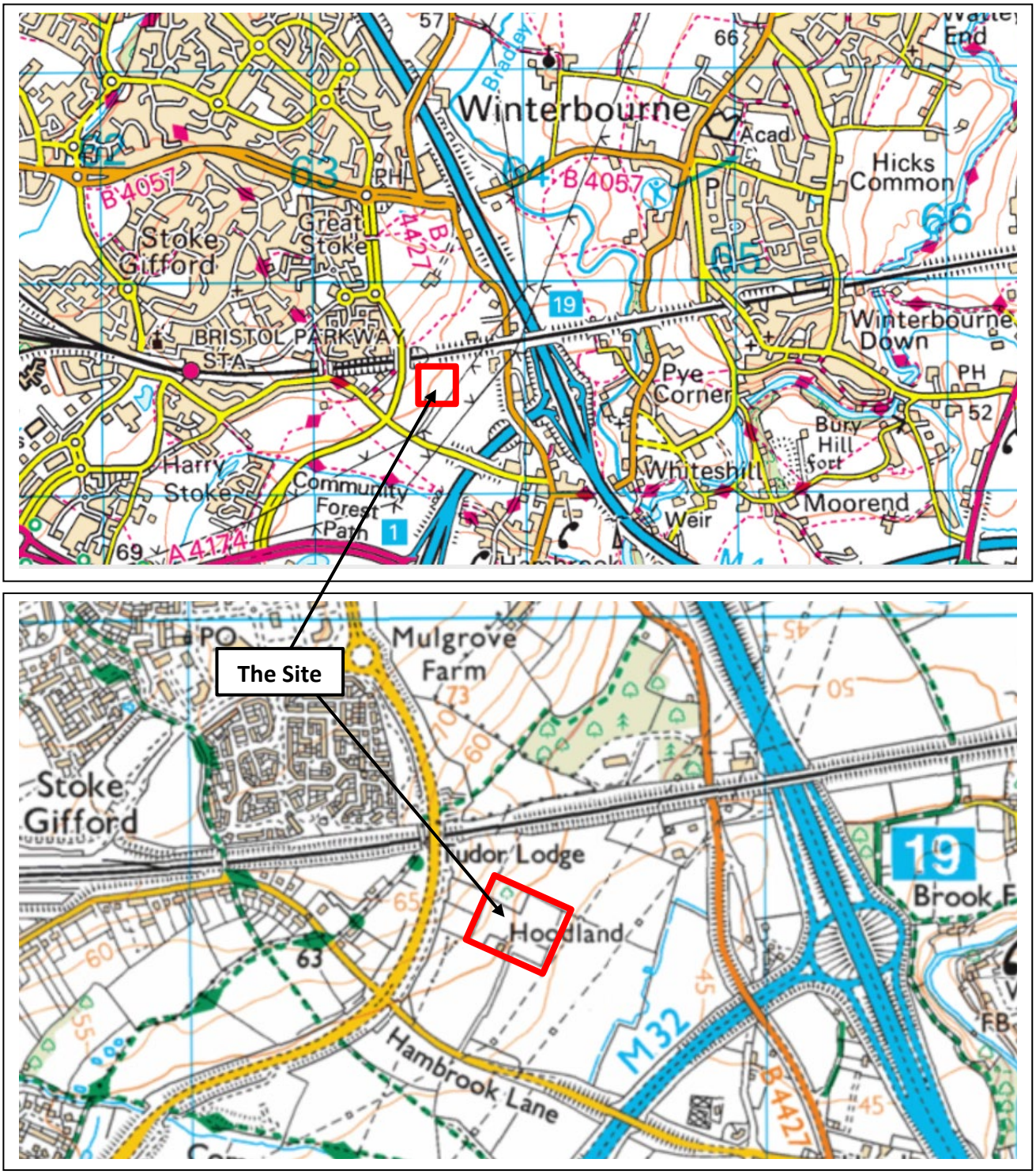
Degree of Risk = Likelihood (L) x Effect (E)			
Likelihood (L)		**Effect (E)**	
Very Likely	5	Very High	5
Likely	4	High	4
Probable	3	Medium	3
Unlikely	2	Low	2
Negligible	1	Very Low	1
Degree of Risk			
16-25	Very High		
11-15	High		
6-10	Medium		
0-5	Low	No Action Required	

Table 12. Geotechnical Risk Register

Risk ID	Hazard	Undesired Event	Consequence	Pre-control measures			Mitigation
				L	E	R	
1	Soft ground / drainage problems	Un-trafficable construction site	Delays in construction. Buildability constraints.	2	2	4	Adequate construction drainage. Dedicated haul roads
2	Variable ground conditions beneath structure	Bearing capacity failure Differential settlement	Collapse of structures Delays in construction and additional costs Alternative foundation solutions required at construction phase Damage to adjacent services	2	4	8	Detailed assessment of ground conditions to determine extent, composition, and geotechnical properties of soils Assessment of bearing capacity of soils beneath structures and adoption of suitable foundations On site verification by suitably qualified geotechnical engineer for forming strata.
3	Competent bedrock at shallow depth	Difficult excavation	Increased construction cost Construction delays	2	3	6	Allowance for suitable plant and time
4	Groundwater	Seasonal groundwater changes and encountering groundwater at depth within the solid geology	Delays in construction Additional costs	2	5	10	Further detailed monitoring programme.
5	Made Ground	Bearing capacity failure Differential settlement	Collapse of structures Delays in construction and additional costs Alternative foundation solutions required at construction phase Damage to adjacent services	2	4	8	Do not use Made Ground in an engineering capacity Remove Made Ground where practical On site verification by suitably qualified geotechnical engineer for forming strata.

Risk ID	Hazard	Undesired Event	Consequence	Pre-control measures			Mitigation
				L	E	R	
6	Shrink/Swell Potential	Structural damage Differential settlements Damage to services	Increased construction cost Construction delays Damage to adjacent services	3	4	12	Use a suspended floor slab Found structures at an appropriate depth

FIGURES



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Client	Project	Job No
BoKlok Housing UK Limited	**Hoodlands, Harry Stoke**	**CGE/16484**
CGL	Title: **Site Location Plan**	**Figure 1**

PHOTO SHEET

Photograph 1 – Looking south-east towards the storage area, showing the access route into the field.

Photograph 2 – Looking east, showing hummocked area towards the centre of the site.

Photograph 3 – Looking north-west, showing the fenced paddock area.

Photograph 4 – Looking south-west, showing the private residents, garden, and field area beyond.

Photograph 5 – Looking east from the entrance to the storage area.

Photograph 6 – Looking south-east, showing an additional view of the storage area.

Client	Project	Job No
BoKlok Housing UK Limited	**Hoodlands, Harry Stoke**	**CGE/16484**
CGL	Title: **Photo Sheet – General Site Conditions**	**Figure 2**

PHOTO SHEET

Photograph 1 – Displaying arisings at SA01, Topsoil and Made Ground (near side) along with the underlying Mercia Mudstone Group (far side).

Photograph 2 – Displaying the underlying Mercia Mudstone Group excavated from TP01.

Photograph 3 – Displaying arisings (Mercia Mudstone Group) and trial pit of TP03 located, within the hummocked aera in the centre of the site.

Photograph 4 – Displaying the in-situ shallow Mercia Mudstone Group, taken from TP04.

Photograph 5 – Displaying the arisings excavated from TP04, showing Topsoil (on the left) and the Mercia Mudstone Group (right).

Photograph 6 – Showing an example of how all trial pit excavations were backfilled, taken from TP01.

Client	Project	Job No
BoKlok Housing UK Limited	**Hoodlands, Harry Stoke**	**CGE/16484**
CGL	Title **Photo Sheet – General Ground Conditions – Trial Pit Excavations**	**Figure 3**