

Brookleigh

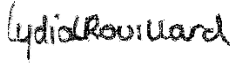
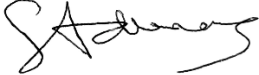
Western Park (WP) and Central Avenue
Ground Investigation Report

Homes England

Project number: 60610807

January 2024

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The methodology adopted and the sources of information used by AECOM in providing its services are outlined in this Report. The work described in this Report was undertaken between **July 2022** and **December 2023** and is based on the conditions encountered and the information available during the said period of time. The scope of this Report and the services are accordingly factually limited by these circumstances. AECOM disclaim any undertaking or obligation to advise any person of any change in any matter affecting the Report, which may come or be brought to AECOM's attention after the date of the Report.

The exploratory holes carried out during the fieldwork, which investigate only a small volume of the ground in relation to the size of the site, can only provide a general indication of site conditions. The comments made and recommendations given in this Report are based on the ground conditions apparent at the site of the exploratory holes. There may be exceptional ground conditions elsewhere on the site which have not been disclosed by this investigation and which have therefore not been taken into account in this Report.

The comments made on groundwater conditions are based on observations made during site work and the limited monitoring programme. It should be noted that groundwater levels might vary owing to seasonal or other effects.

The site reconnaissance consisted of a general external inspection of the site aimed at identifying any obvious signs of geotechnical hazards and potential sources of ground contamination affecting the site. An environmental compliance audit and/or detailed structural inspection of existing buildings were outside the project brief. Similarly, the site visit excluded detailed consideration of the ecological or archaeological aspects of the site, and if such are believed to be of potential significance then it is recommended that specialist advice is sought.

Any risks identified in this Report are perceived risks, based on the information reviewed during the study and therefore partially based on conjecture from available information. The investigation itself was designed generally to meet the objectives of an exploratory investigation, as defined by BS10175:2011 Investigation of Potentially Contaminated sites: Code of Practice (BSI). As an exploratory investigation, the results may not provide sufficient data to make detailed estimates of the quantities involved in any remediation work, if required.

The opinions expressed in this Report concerning any contamination found and the risks arising there from are based on current good practice assessment and comparison with available soil guideline values, AECOM generic assessment criteria and other guidance values.

It should be noted that the effects of ground and water borne contamination on the environment are constantly under review, and authoritative guidance values are potentially subject to change. The conclusions presented herein are based on the guidance values available at the time this Report was prepared, however, no liability by AECOM can be accepted for the retrospective effects of any changes or amendments to these values.

Reference to historical Ordnance Survey (OS) maps and/or data provides invaluable information regarding the land use history of a site. However, it should be noted that historical evidence will be incomplete for the period pre-dating the first edition and between the release of successive maps and/or data.

Certain statements made in the Report that are not historical facts may constitute estimates, projections or other forward-looking statements and even though they are based on reasonable assumptions as of the date of the Report, such forward-looking statements by their nature involve risks and uncertainties that could cause actual results to differ materially from the results predicted. AECOM specifically does not guarantee or warrant any estimate or projections contained in this Report.

Table of Contents

1.	Executive Summary	8
2.	Introduction	9
2.1	Scope and Objectives.....	9
2.2	Description of Project.....	9
2.3	Geotechnical Category of Project	10
2.4	Contamination Risk of Project	10
3.	Existing Information	11
3.1	Topographical Map	11
3.2	Geological Maps and Memoirs	11
3.3	Soils and Soil Chemistry.....	12
3.4	Hydrology	13
3.5	Hydrogeology	14
3.6	Aerial Photographs and Historical Mapping.....	14
3.7	Record of Mineral Deposits	19
3.8	Existing Ground Investigations	19
3.9	Unexploded Ordnance.....	19
4.	Field and Laboratory Studies	20
4.1	Walkover Survey.....	20
4.2	Ground Investigation and Fieldwork	20
4.3	Laboratory Testing	27
5.	Ground Model.....	31
5.1	General.....	31
5.2	Summary of Strata Encountered	31
5.3	Summary of Groundwater Conditions.....	32
6.	Ground Conditions and Material Properties	35
6.1	General.....	35
6.2	Topsoil	35
6.3	Made Ground.....	35
6.4	Residual Soil.....	38
6.5	Weald Clay Formation	48
6.6	Soil and Groundwater Chemistry (Sulphates).....	52
6.7	Road Cores	53
6.8	Soakaway Testing.....	53
6.9	Summary of Derived Geotechnical Parameters.....	54
7.	Engineering Recommendations	57
7.1	Soakaways	57
7.2	Shallow Foundations and Earthworks	57
7.3	Deep Foundations	57
7.4	Road Pavement.....	57
7.5	Design of Buried Concrete.....	57
8.	Geo-environmental Assessment	58
8.1	Conceptual site Model and Preliminary Risk Assessment	58
8.2	Ground Investigation.....	64
8.3	Contamination Assessment	65
8.4	Ground Gas	68
8.5	Contamination Assessment - Discussion.....	70
8.6	Updated Conceptual Site Model	72
9.	Geotechnical and Geo-environmental Risk Register	75
10.	References	80

Appendix A Illustrative Layout Central Avenue	82
Appendix B Exploratory Hole Location Plan	83
Appendix C GEL Factual Report	84
Appendix D Envirocheck Report 157544920_1_1	85
Appendix E Envirocheck Report 315537553_1_1	86
Appendix F UXO Pre-Desk Study Assessment	87
Appendix G Geo-environmental sample screening	88
Appendix H Groundwater Contour maps	89

Figures

Figure 2-1 Brookleigh phasing and disposal plan revision 01. Western Park and Central Avenue highlighted in red (January 2022)	10
Figure 3-1 Topography of the site using EA 1m Lidar Data (2022)	11
Figure 3-2 Flood Risk Map for the Western Park (Environment Agency 2023)	13
Figure 3-3 Flood Risk Map for the Central Avenue (Environment Agency 2023)	14
Figure 5-1 Groundwater level monitoring	34
Figure 6-1 Residual Soil Moisture Content and Atterberg Limits	39
Figure 6-2 Residual Soil Casagrande A-Line Plot	40
Figure 6-3 Residual Soil Particle Size Distribution	41
Figure 6-4 Residual Soil N60 Standard Penetration Test Values v depth	45
Figure 6-5 Undrained Shear Strength of Residual Soil	46
Figure 6-6 Unconfined Compressive Strength Weald Clay	51
Figure 6-7 Rock Quality Designation Weald Clay	52

Tables

Table 3-1 Summary of Published Geology	11
Table 3-2 Summary of BGS Borehole Records	12
Table 3-3. Anticipated Soil Chemistry	12
Table 3-4 Phasing Strategy Locations vs Envirocheck Report	15
Table 3-5 Review of Historical Mapping at 1:10,000 and 1:10,560 scale – Western Park	15
Table 3-6 Review of Historical Mapping at 1:2,500 scale – Western Park	16
Table 3-7 Review of Aerial Imagery – Western Park	16
Table 3-8 Review of Historical Mapping at 1:10,000 and 1:10,560 scale- Central Avenue	17
Table 3-9 Review of Historical Mapping at 1:2,500 scale- Central Avenue	18
Table 3-10 Review of Aerial Imagery- Central Avenue	18
Table 4-1 Identified constraints	20
Table 4-2 Alterations to scope	21
Table 4-3. Details of Ground Gas Monitoring Events	23
Table 4-4. Details of Groundwater Monitoring Events	24
Table 4-5 Geotechnical Testing Undertaken in 2023 Investigation	27
Table 4-6 Geo-environmental Testing Undertaken in 2023 Investigation	28
Table 4-7. Details of Soil Sampling Chemical Analysis	29
Table 4-8. Details of Soil Leachate Sampling Chemical Analysis	29
Table 4-9. Details of Ground Water Sampling & Testing schedule	30
Table 5-1 Ground Model Western Park	31
Table 5-2 Ground Model Central Avenue	32
Table 5-3 Groundwater Strike Summary	32
Table 5-4 Summary of Groundwater Monitoring Data	32
Table 6-1 LWD testing in Residual Soil- Western Park	37
Table 6-2 Classification Tests Residual Soil	38
Table 6-3 Summary of Composition Residual Soil	40

Table 6-4 Made Ground CBR summary from Laboratory Testing	41
Table 6-5 LWD testing in Residual Soil	42
Table 6-6 Summary of Undrained Shear Strength of Residual Soil	45
Table 6-7 Summary of Youngs Modulus of Residual Soil	47
Table 6-8 Dry Density/ Moisture Content Residual Soil	47
Table 6-9 Residual Soil Consolidation Test Results	47
Table 6-10 Weathered Weald Clay CBR summary from Laboratory Testing – Central Avenue	49
Table 6-11 Point Load Axial and Diametral Results- Mudstone	50
Table 6-12 Point Load Axial and Diametral Results- Siltstone	50
Table 6-13 Intact Modulus: Weald Clay Central Avenue and Western Park	51
Table 6-14 Summary of BRE SD1 Assessment	52
Table 6-15 Summary of Derived Geotechnical Parameters	54
Table 8-1 Classification of Severity	60
Table 8-2 Classification of Probability	60
Table 8-3 Risk Evaluation	61
Table 8-4 Summary of Tier 1 Preliminary Risk Assessment	62
Table 8-5. Soil leachate samples exceedances of GAC	67
Table 8-6. Groundwater samples exceedances of GAC	67
Table 8-7. Summary of Ground Gas Monitoring Results	69
Table 8-8 Ground Gas Results Summary	70
Table 8-9 Updated CSM	73
Table 9-1 Classification of Probability and Impact	76
Table 9-2: Risk Matrix	76
Table 9-3: Classification of Risk Rating	76
Table 9-4 Geotechnical & Geoenvironmental Risk Register	77

1. Executive Summary

AECOM Infrastructure & Environment UK Limited (AECOM) was commissioned to prepare a Ground Investigation Report (GIR) to inform the design of the proposed Brookleigh development scheme, in Burgess Hill, West Sussex (the “site”). The report’s aim is also to assist on the discharge of the associated contaminated land planning conditions and for this reason includes a Phase 2 Generic Qualitative Risk Assessment.

The GI followed a site walkover carried out by AECOM in 2022. The ground investigation (GI) was completed by Geotechnical Engineering Ltd (GEL) under the technical observation of AECOM between the 17 July and 22 August 2023. The GI comprised 6 rotary cored borehole to up to 20m depth, 14 mechanically excavated trial pits, 2 dynamic sampling holes to up to 4.7m depth and 3 road cores. Soakaway tests were undertaken in some trial pits and lightweight deflectometer testing was also undertaken. Geotechnical laboratory testing was undertaken to determine soil and rock properties.

The ground investigation was not designed to provide complete coverage of the site for detailed design of the proposed development. The ground investigation was designed to allow an initial assessment of potential geotechnical and geoenvironmental risks associated with the proposed development. Further ground investigation may therefore be required.

The GI proved the geology to be fairly consistent across the site, with topsoil overlying Weald Clay Formation with varying weathering increments. Made Ground was also found in one location at the site associated with historical farm buildings and at another location associated with road cores drilled to provide details of the existing road construction of Cuckfield Road.

An interpretation of the ground conditions based on the field and laboratory results is presented. A Ground model for the site have been proposed and geotechnical parameters have been derived. The designer should select an appropriate ground profile and parameters for the structure being designed based on both exploratory hole descriptions and test data local to the structure. Further ground investigation may therefore be required to provide appropriate parameters for detailed design. The geotechnical risk register has been reviewed and updated accordingly.

The site is classified as a Geotechnical Category 2 in accordance with HD22/08 and BS EN 1997-1:2005.

Samples were analysed for a range of determinants and screened against human health Generic Assessment Criteria (GAC) were not recorded. No asbestos was identified in 17 samples submitted for asbestos identification. Ground gases concentrations were considered to be within the typical range for a greenfield site.

Soil leachate and groundwater samples from the site recorded exceedances of Drinking Water Standards (DWS) or Environmental Quality Standards (EQS) for polycyclic aromatic hydrocarbons (PAH), metals and ammoniacal nitrogen. However, based on the current condition of groundwater at the site, groundwater does not appear to be significantly impacted upon by soil contamination and unacceptable risks to groundwater and surface water receptors are not considered to be present.

Overall, geoenvironmental risks to identified human health and controlled waters are considered to be low.

2. Introduction

2.1 Scope and Objectives

AECOM Limited (AECOM) was instructed by Homes England (the Client) to undertake a ground investigation (GI) at the Western Park and Central Avenue area (the site) of the proposed wider Brookleigh development to provide further assessment of the geotechnical and geoenvironmental conditions of the site to inform geotechnical due diligence, planning, contaminated land assessment and remediation requirements for the development.

The Ground Investigation Report has been prepared in accordance with the requirements of CD 622 “Managing Geotechnical Risk”, BS EN 1993-2:2007 (Eurocode 7), BS 10175:2011+A2 2017 Investigation of Potentially Contaminated sites – Code of Practice and BS 5930 Code of Practice for Ground Investigations.

The objectives of the report are to:

- Present available information on ground and groundwater conditions of the site;
- Present ground profiles and geotechnical material properties relevant to the geotechnical design of the proposed works; and
- Present an initial assessment of potential geotechnical and geoenvironmental risks associated with the proposed development.

Intrusive works were undertaken by Geotechnical Engineering Ltd (GEL). (CDM Principal Contractor) in July to August 2023 under the supervision of AECOM. A copy of the GEL Factual ground investigation report can be found in Appendix C.

2.2 Description of Project

2.2.1 Proposed Development

The proposed wider development is termed ‘Brookleigh’ and will comprise up to 3,500 new homes, plus amenity facilities, new schools, healthcare facilities and commercial land uses.

The subject site forms part of the wider Brookleigh proposed development and includes:

- Western Park, an area of open amenity space with up to 150m² of Community Garden (Class D1) and five proposed attenuation ponds (which form part of the Sustainable Drainage Systems for Brookleigh); and
- An access road (termed the ‘Central Avenue’) which runs west-east across the wider Brookleigh development.

The proposed layout is shown in Figure 2-1. Western Park and Central Avenue are highlighted in red on the drawing.

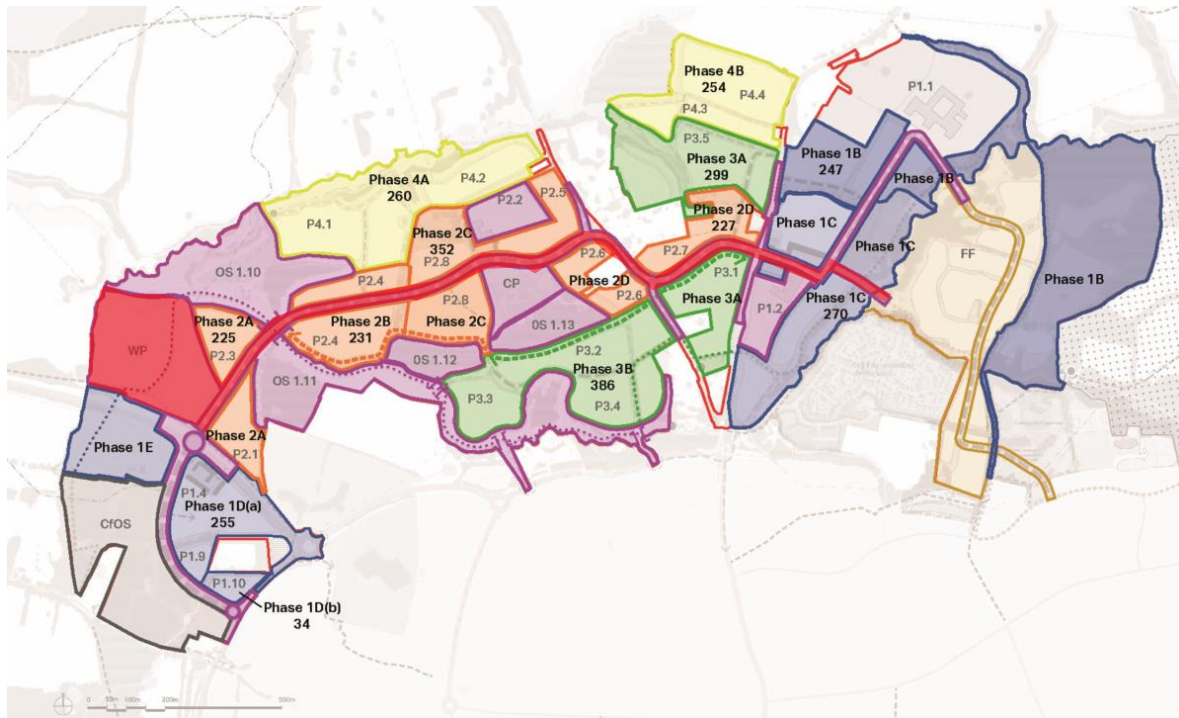


Figure 2-1 Brookleigh phasing and disposal plan revision 01. Western Park and Central Avenue highlighted in red (January 2022)

2.2.2 Site Description

The site is located north of Burgess Hill, West Sussex. The Western Park development encompasses an area of 8 hectares of land currently being used for agricultural purposes adjacent to Goddards Green Wastewater treatment plant at TQ 289206: it is understood to have been under the ownership of Homes England since February 2018. Central Avenue is proposed to connect the entire development to Cuckfield Road (A2300), Isaac's Lane (A273) and Frees Farm at TQ308208. A detailed illustrative layout of the Central Avenue is presented in Appendix A.

The Western Park (labelled WP) and Central Avenue development currently comprises;

- Agricultural land; and
- Densely wooded areas.

2.3 Geotechnical Category of Project

Due to the nature of the proposed construction the site is considered to fall under Geotechnical Category 2 in accordance with BSEN 1997-1:2004 +A1:2013.

Projects in Geotechnical Category 2 include conventional types of geotechnical structures, earthworks and activities, with no exceptional geotechnical risks, unusual or difficult ground or loading conditions. For this category, geotechnical data analysis will normally be required to ensure that the fundamental requirements are satisfied. Geotechnical risks to the scheme are summarised in the Geotechnical Risk Register, included in Section 9 of this report. The register is a live document that should be developed and refined as the project progresses.

2.4 Contamination Risk of Project

The site is predominantly greenfield with no major sources of contamination identified in the preparatory works for the ground investigation. Geoenvironmental testing has been undertaken in order to characterise the site and to confirm there are no unexpected adverse conditions.

3. Existing Information

3.1 Topographical Map

Based on freely available LiDAR data (accessed November 2023) from the Environment Agency (EA), the Brookleigh site slopes towards the southwest from a maximum elevation of approximately 33m above Ordnance Datum (AOD), plateaus across the central area of the site at approximately 25m AOD, then gently slopes to approximately 20m AOD towards the River Adur.

The elevations of exploratory locations undertaken in the GEL 2023 site-specific GI, discussed in Section 4 & 5 of this report, had an average elevation of 26.7mAOD. A maximum elevation of 33.3m AOD was encountered within the west of the site at E:529238 N:120517 and a minimum elevation of 17.7mAOD in the east of the site at E:529163 N:120711.

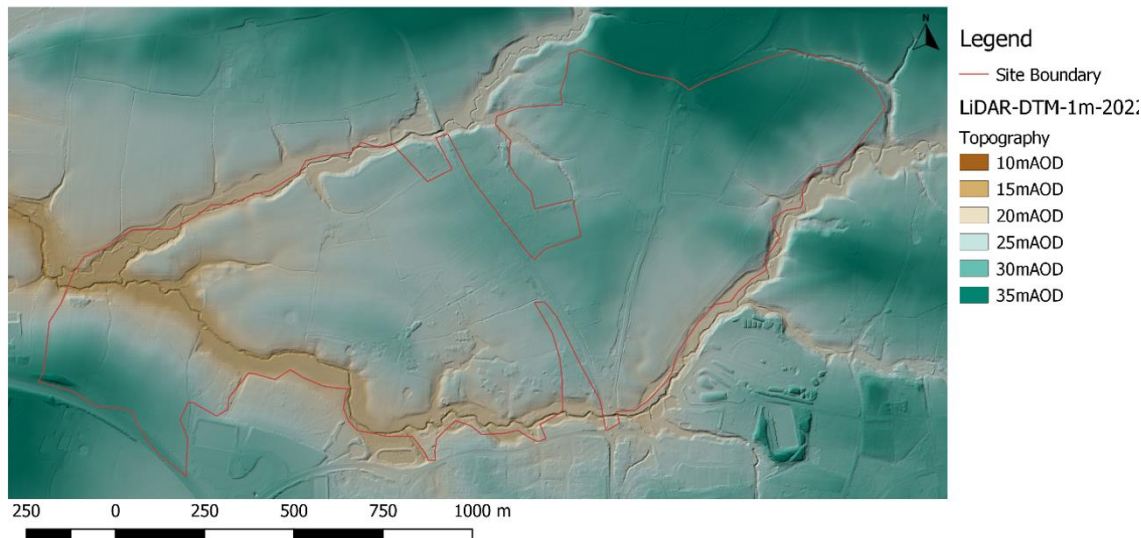


Figure 3-1 Topography of the site using EA 1m Lidar Data (2022)

3.2 Geological Maps and Memoirs

The British Geological Survey (BGS) England and Wales Sheet 318/333 1:50,000 scale mapping for Brighton and Worthing (1996) indicates the majority of the site is directly underlain by Weald Clay Formation. This formation is characterised by dark grey mudstones with subordinate siltstones, sandstones, and includes clay ironstones. Clay ironstones are shown as elongated outcrops in the south-central part of the site in a west to east orientation.

The site at Western Park is shown to be locally underlain by Alluvium deposits associated with the tributary of the River Adur (Copyhold Stream) which conflues with the Copyhold Stream west of the site. Along the Central Avenue it is not anticipated to encounter Alluvium for except where crossing the tributary.

Table 3-1 summarises the published geology of the site as it was understood prior to the ground investigation.

Table 3-1 Summary of Published Geology

Geology	Age	Strata	Description	Anticipated Thickness *(m)
Superficial Deposits	Quaternary	Alluvium	Elongated outcrop associated with the River Adur East (i.e. the eastern end of the site only) and its tributaries. Comprises clay, silt, sand and gravel, but it can also contain peat and basal gravel.	<10
Solid Geology	Hauterivian Age (KH) — Barremian Age (KB)	Weald Clay Formation	Directly underlies the majority of the site. Comprises mudstones with subordinate siltstones, limestones, sandstones, and clay ironstones.	120-275
	Hauterivian Age (KH)	Horsham Stone Member	Localised elongated outcrop running east-west, indicated to be east of Isaac's Lane. Comprises sandstone.	0-3 (up to 9m)

*Taken from Sheet 318/333 1:50,000 stratigraphic column

The bedrock at the site is shown to be the Weald Clay Formation of Hauterivian to Barremian age. This is described by the BGS as dark grey thinly bedded shales and mudstones with subordinate siltstones. There are also bands of fine to medium grained calcareous sandstone of the Horsham Stone Member and clay ironstones of the Weald Clay Formation mapped in a general east-west alignment across the site area.

There are no recorded Artificial deposits from British Geological Survey (BGS) mapping at 1:50,000 scale but due to land usage it is expected Made Ground will be present in the vicinity of farm buildings and within shallow ground beneath roadways.

East of Isaac's lane, the geology is affected by the Burgess Hill Fault with the near surface geology becoming the Horsham Stone Member together with Weald Clay Formation. Horsham Stone Member is characterised by sandstone.

The BGS maintains an archive of historical exploratory hole records throughout the UK. AECOM has searched the database for those which are considered to provide useful information on the ground profile at the site. A total of 8 no. records are located on the southern perimeter to the site on the A2300 as presented in Table 3-2.

Table 3-2 Summary of BGS Borehole Records

ID	Date	Distance to site*	Grid Reference	Elevation (mAOD)	General description of log
TQ22SWE52	1991	50m Southwest	E529268 N:120368	31.21	Topsoil 0-0.5m Weathered Weald Clay 0.5-4.0m
TQ22SE51	1991	50m Southwest	E:529262 N:120422	32.91	Made Ground 0-0.5m Weathered Weald Clay 0.5-4.0m
TQ22SE50	1991	50m Southwest	E:529110 N:120400	34.40	Topsoil 0-0.3m Weathered Weald Clay 0.3-6.0m
TQ22SE49	1991	50m Southwest	E:529133 N:120467	33.24	Topsoil 0-0.3m Weathered Weald Clay 0.3-6.0m
TQ32SW24	1986	300m South	E:530210 N:120300	21.50	Topsoil 0-0.2m Made Ground 0.2-0.3m Mudstone 0.3-12.40m (Chiselling from 8.35m) Groundwater Strike 5.4m
TQ32SW25	1986	300m South	E:530210 N:120290	22.20	Topsoil 0-0.2m Mudstone 0.2-12.20m (Chiselling from 9.10m) Groundwater Strike 4.5m
TQ32SW26	1986	300m South	E:530560 N:120390	NA	Topsoil 0-0.2m Mudstone 0.2-5.0m Groundwater Strike 1.7m
TQ32SW27	1986	300m South	E:530450 N:120320	NA	Made Ground 0-0.35m Mudstone 0.35-3.0m

*taken as Western Park boundary

3.3 Soils and Soil Chemistry

According to the Cranfield University Soilscape online viewer, the site lies within Soilscape 20 described as loamy and clayey floodplain soils with naturally high groundwater, associated with the River Adur.

Table 3-3 lists the anticipated background soil chemistry on site according to the UK Soil Observatory (UKSO).

Table 3-3. Anticipated Soil Chemistry

Element	Concentration (mg/kg)
Arsenic	17.29
Cadmium	0.34
Chromium	16.67

Element	Concentration (mg/kg)
Copper	24.40
Lead	99.5
Manganese	2600
Nickel	40.1
Zinc	99.31

3.4 Hydrology

Two tributaries of the River Adur are located within the site boundary, these are the Copyhold Stream which flows northeast to southwest across the northern boundary of the site and World's End stream which flows southeast to southwest across the southern boundary. According to the Environment Agency's Online Main River viewer the River Adur has a statutory main river designation.

The EA flood risk maps for planning, an extract of which is shown below in Figure 3-3 illustrates that the Western Park site is located within Flood Zone 1 Flood. However as shown in Figure 3-3 there are areas of land located in Zone 3 across the Central Avenue associated to the River Adur. Land and property in Flood Zone 1 have a low probability of flooding which is defined as having a less than 1 in 1,000 annual probability of river flooding. Flood Zone 3 is defined as land with a 1 in 100 or greater annual probability of river flooding in any year.

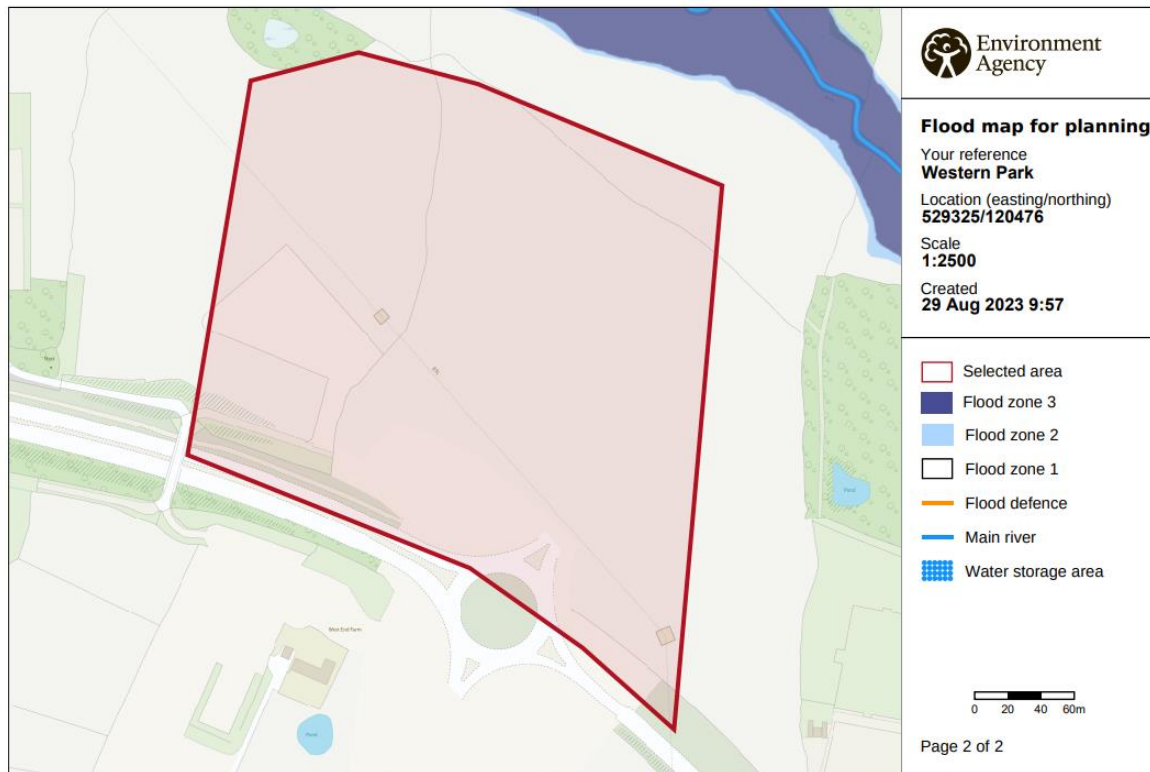


Figure 3-2 Flood Risk Map for the Western Park (Environment Agency 2023)

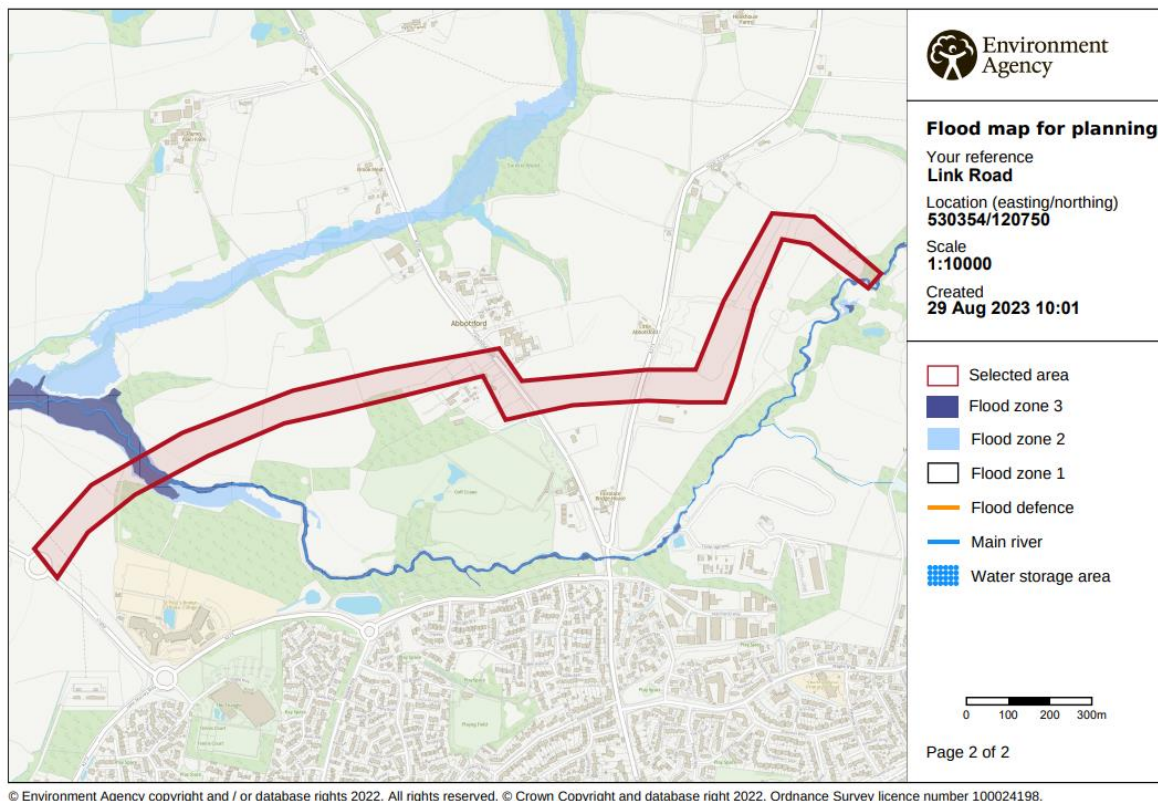


Figure 3-3 Flood Risk Map for the Central Avenue (Environment Agency 2023)

3.5 Hydrogeology

The Department for Environment, Food and Rural Affairs (DEFRA)'s MAGIC Map indicates that the Alluvium and bands of the Horsham Stone Member are classed as Secondary A aquifers, whilst the underlying Weald Clay Formation is an unproductive strata. Secondary A aquifers are described by the EA as permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

The EA's groundwater vulnerability map indicates that the area lies within an unproductive groundwater zone, classed as areas that have negligible significance for water supply or baseflow to rivers, lakes and wetlands. The bedrock has low permeability, naturally offering protection to any aquifers that may be present beneath.

The Alluvium is shown to have a low vulnerability risk which is characterised by low-leaching soils and/or the presence of low-permeability superficial deposits and offer the greatest protection to groundwater from pollution.

The bands of Horsham Stone Member are shown to be of high risk and can easily transmit pollution to groundwater. They are characterised by high-leaching soils and the absence of low-permeability superficial deposits.

The site is not located within a groundwater source protection zone (SPZ) nor are there any SPZ boundaries located within a 500m radius of the site (Magic, 2023).

3.6 Aerial Photographs and Historical Mapping

Historical Ordnance Survey (OS) maps of the site and the wider environs were provided in the Envirocheck (2018) Report (scales 1:2,500, 10:10,000 and 1:10,560). The historical Ordnance Survey (OS) maps obtained with the Envirocheck (2018) report date between 1879 and 1999.

Historical mapping has been reviewed to evaluate potential on and off-site past activities (up to a distance of 250m), that may have impacted the environmental condition and land quality of the site. A summary of the historical mapping review is presented in Table 3-5, Table 3-6, Table 3-7, Table 3-8, Table 3-9 and Table 3-10. It should be noted that due to the size of the site, the Envirocheck mapping is split into 4 areas (A, B, C and D). On the smaller scale mapping these areas are split further as required and a plan showing this is included in Appendix D.

The historical mapping was obtained from Landmark previously when the red line boundary was slightly different to its current position. As such the following areas in the Envirocheck report have not been included in the below review of historical mapping: site A10, A11, A12, B9, B10, B14, C, C3, C4, D, D1 and D2.

The Envirocheck Areas correspond to the following phasing strategy of the site;

Table 3-4 Phasing Strategy Locations vs Envirocheck Report

Envirocheck Section	Phasing Diagram
A	Western Park, Central Avenue (west)
A14	Western Park (north), Central Avenue
A15	Western Park (north), Central Avenue
A16	Central Avenue
B	Central Avenue (east)
B13	Central Avenue (east)

3.6.1 Western Park

Where dates are stated, these refer to the dates of maps on which the features are present, have changed use or are no longer annotated, and do not necessarily refer to the exact dates of existence of a particular feature. Development that may have occurred between map editions is recorded as occurring on the later published map, hence there are some limitations to the accuracy to the date of development unless supplementary evidence is available.

Table 3-5 Review of Historical Mapping at 1:10,000 and 1:10,560 scale – Western Park

Area	Year (Scale)	Features on-site	Features off-site
A	1879 (1:10,560)	Land is shown to be occupied by open land likely used for agricultural purposes, footpaths shown crossing the site from the northwest to southeast. Floods Barn is located in the southwest of the site (529200, 120200).	Unnamed road in the present day location of the A2300 (orientated east to west) south of the site. Tributaries (unnamed) of the River Adur are shown mapped on the site with a footbridge labelled in the north (529400, 120600). A large portion of land located west of the present day Cuckfield Road is shown to be covered by woodland. An unnamed pond is shown at 529600 120600 (Phase 2A).
A	1899 (1:10,560)	No significant observations to change in land usage.	Footbridge no longer labelled.
A	1912 (1:10,560)	No significant observations to change in land usage.	An unnamed pond identified on the 1879 mapping is still visible; 529600, 120600 (Phase 2A).
A	1938-1952 (1:10,560)	No significant observations to change in land usage.	No significant observations to change in land usage.
A	1962-1963 & 1969 (1:10,000)	Electrical Pylons shown northeast to southwest.	No significant observations to change in land usage.
A	1974-1978 (1:10,000)	No significant observations to change in land usage.	No significant observations to change in land usage.

Area	Year (Scale)	Features on-site	Features off-site
A	1992-1994 (10,000)	No significant observations to change in land usage.	West End Farm now mapped with multiple buildings south of the previous location of Floods Barn.
A	2000 (10,000)	No significant observations to change in land usage.	No significant observations to change in land usage.
A	2006 & 2018 (10,000)	No significant observations to change in land usage.	St Paul's Catholic College is constructed southeast of the site.

Table 3-6 Review of Historical Mapping at 1:2,500 scale – Western Park

Area	Year (Scale)	Features on-site	Features off-site
A14	1874-1881, 1911, 1937 1957-1958, 1974-1975 (1:2,500)	Floods barn shown in southeast of the site. Three Unnamed Ponds shown south of Floods Barn at Floods Barn and North of Floods Barn.	Two ponds shown present on site, one north off site and one located in the northeast of the site. Lower Barn is shown as one singular structure.
A14	1992, 1996 (1:2,500)	West End Farm shown present in the southwest of the site area with multiple structures and pond.	Burgess Hill Sewage Treatment works present northwest of the site.
A15	1881 (1:2,500)	The map shows an unmarked stream running northwest to southeast across the site. A copse of trees is shown potentially marking a pond or pitted area in the east. A small cluster of unmarked structures are present to the northeast, likely farming related shelters.	No significant observations.
A15	1897 (1:2,500)	The copse of trees is no longer marked on the map, the area is instead shown as a pit.	No significant observations.
A15	1937 , 1957 , 1975 (1:2,500)	The pit is no longer shown on the mapping (1937), one pond remains in the southwest of the site area within woodland.	Pond mapped in marsh land adjacent to northeaster boundary (1957).
A15	1992, 1994 , 1996 (1:2,500)	Electricity transmission line (ETL) marked on southwest of the mapping in an approximate north to south orientation. Woodland no longer shown as present (1994).	No significant observations.

Table 3-7 Review of Aerial Imagery – Western Park

Area	Year (Scale)	Features on-site	Features off-site
A15	Aerial Imagery (1999)	Electrical pylon is shown within the southwest of the site.	The aerial imagery shows the previously noted woodland is still present in the mapping areas, the detail looks to have been omitted from 1994 onwards. The A2300 is shown constructed in the southwest of the site.
A	Aerial Photography 1947 (1:10,560)	At the time of the photograph the site is shown to be five fields are shown to be ploughed.	No significant observations.

3.6.2 Central Avenue

The alignment of the central Avenue was not finalised at the time of obtaining the Envirocheck report. As the alignment is a linear structure the features have been described within 250m of the route.

Where dates are stated, these refer to the dates of maps on which the features are present, have changed use or are no longer annotated, and do not necessarily refer to the exact dates of existence of a particular feature. Development that may have occurred between map editions is recorded as occurring on the later published map, hence there are some limitations to the accuracy to the date of development unless supplementary evidence is available.

Table 3-8 Review of Historical Mapping at 1:10,000 and 1:10,560 scale- Central Avenue

Area	Year (Scale)	Features <250m
A	1879 (1:10,560)	Land is shown to be occupied by open land likely used for agricultural purposes, footpaths shown crossing the alignment from the northwest to southeast. Floods Barn is located in the west at 529200, 120200. Tributaries (unnamed) of the River Adur are shown mapped on the alignment with a footbridge labelled in the north (529400,120600). A large portion of land located west of the present day Cuckfield Road is shown to be covered by woodland. The following ponds (unnamed) are shown at the alignment 529000,119600 (Phase 2B); 530000,120400 (Phase 3B);
A	1899 (1:10,560)	Ponds are marked as a pit notation at; 529600,120600 (Phase 2C); 530000,120400 (Phase 4A). Unnamed but suspected farm buildings shown at 529600 120600 (Phase 2C).
A	1912 (1:10,560)	The village of Abbotsford is shown to have multiple buildings assumed residential dwellings. The following ponds (unnamed) identified on the 1879/ 1899 mapping are still visible; 529400,120400 (Phase 3B); 530200,120400 (Phase 4A); 529600,120600 (Phase 2C).
A	1938-1952 (1:10,560)	Cuckfield Road named in present day location. Bridge Hall Farm named at Cuckfield Road.
A	1962-1963 & 1969 (1:10,000)	Drain is shown present in the north of the alignment flowing towards Cuckfield Road. The area of woodland has reduced in the eastern part of the alignment surrounding Bridge Hall Farm. Weir is mapped south of the alignment at 53000, 120200
A	1974-1978 (1:10,000)	A school is marked as present opposite Bridge Hall Farm in the Abbotsford Village.
A	1992-1994 (10,000)	West End Farm now mapped with multiple buildings at the previous location of Floods Barn. Electrical substation present on the unnamed roadway shown in the previous mapping at 529400,120000.
.A	2000 (10,000)	Golf Driving range shown mapped west of Cuckfield Road. A273 and A2300 labelled with roundabout leading to Murray Way. Additional bodies of water shown: 529200,120200 (Phase 1E); 529400,120400 (Phase 3B); 53000,120400 (Phase 4A); 529600,120400 (Phase 2C); 530200,120400 (Phase 3B).
A	2006 & 2018 (10,000)	No significant observations to change in land usage.
B	1879, 1899, 1912, 1938-1950 (1:10,560)	Sewage Farm is shown present and occupies the majority of the south of the alignment boundary.
B	1962-1963,1969, 1974-1978 (1:10,000)	The Sewage Farm has shown to extend in size with additional tanks and beds visible. The London Road is shown to have many residential buildings along the route to central Burgess Hill Town.
B	1985, 1992 (1:10,000)	No significant observations to change in land usage, mapping is partially missing for maps in 1985 and 1992.
B	2000, 2006, 2018 (1:10,000)	The alignment area shows little to no development since its original mapping in 1899. The pond located at 531200,120620 (Phase 1C/Pond 22). is still present. Isaacs Lane has continued to be marked in its present day location.

Table 3-9 Review of Historical Mapping at 1:2,500 scale- Central Avenue

Area	Year (Scale)	Features <250m
B13	1875-1881, 1897, 1910-1911 (1:2,500)	Unnamed River/stream is present along the south eastern boundary. Land usage is divided into agricultural fields. A small pond is shown east of Isaacs Lane.
B13	1937, 1956 (1:2,500)	No significant observations as to change in land usage on alignment
B13	1970, 1976, 1977-1989 (1:2,500)	River annotated with County Constituency and River Boundary, showing to flow west.
B13	1979-1992, 1983, 1985, 1991 (1:2,500)	Mapping is partially incomplete for the alignment area. No significant observations to land change shown.
B13	1994 (1:2,500)	The alignment is shown to remain largely unchanged from its initial mapping in 1875. The roads remain in their present day locations.
A14	1874-1881, 1911, 1937, 1957-1958, 1974-1975 (1:2,500)	Floods barn shown in southeast of the alignment. Three Unnamed Ponds shown south of Floods Barn at Floods Barn and North of Floods Barn.
A14	1992, 1996 (1:2,500)	West End Farm shown present in the southwest of the alignment area with multiple structures and pond.
A15	1881 (1:2,500)	The map shows an unmarked stream running northwest to southeast across the alignment. A copse of trees is shown potentially marking a pond or pitted area in the east. A small cluster of unmarked structures are present to the northeast, likely farming related shelters.
A15	1897 (1:2,500)	The copse of trees is no longer marked on the map, the area is instead shown as a pit.
A15	1937, 1957, 1975 (1:2,500)	The pit is no longer shown on the mapping (1937), one pond remains in the southwest of the alignment area within woodland.
A15	1992, 1994, 1996 (1:2,500)	Electricity transmission line (ETL) marked on southwest of the mapping in an approximate north to south orientation. Woodland no longer shown as present (1994).
A16	1881, 1897, 1911 (1:2,500)	The land usage is shown to be two thirds agricultural land and one third (towards the north) of woodland. Two ponds or pits are located in the south. The river is shown flowing west at the alignment boundary.
A16	1937 (1:2,500)	No significant observations.
A16	1957, 1970, 1975-1976, 1983-1992 (1:2,500)	Electrical pylons shown mapped northeast to southwest from Cuckfield road to end of the alignment boundary. Four pylons are marked within the alignment boundary.
A16	1970, 1975-1976, 1983-1992 (1:2,500)	Access road (unmarked) running west from Bridge Hall, Cuckfield road to the alignment centre is marked. Additional pond mapped west of the alignment.
A16	1989-1992, 1992, 1994, 1996 (1:2,500)	No significant observations to change in land usage, mapping is partially missing for maps in 1992, 1994 and 1996.

Table 3-10 Review of Aerial Imagery- Central Avenue

Area	Year (Scale)	Features <250m
B13	Aerial Imagery (1999)	The aerial imagery confirms the land usage to be largely of ploughed agricultural fields with some areas of vegetation surrounding the river.
A16	Aerial Imagery (1999)	Mapping shows the golf course is present south of the alignment, likely constructed from 1992 to 1999 based on no changes shown of the land area.
A15	Aerial Imagery (1999)	The aerial imagery shows the previously noted woodland is still present in the mapping areas, the detail looks to have been omitted from 1994 onwards.

Area	Year (Scale)	Features <250m
		Electrical pylon is shown within the southwest crossing the alignment The A2300 is shown constructed in the southwest of the alignment.
A14	Aerial Imagery 1999	Aerial imagery confirms that the pond location shown at West End farm is a partially infilled pit.
A	Aerial Photography 1947 (1:10,560)	At the time of the photograph five fields are shown to be ploughed, four to be covered by woodland. The pond areas are not visible as covered by trees.

3.7 Record of Mineral Deposits

According to the Envirocheck Report presented in Appendix D there is no history of coal mining and the area is indicated as an area not affected by coal mining. It is also indicated that there are no known mineral reserves in the area and that the risk of non-coal mining is classed as highly unlikely.

Suspected backfilled clay pits or ponds have been shown on historical mapping within the original extent of the Envirocheck report. The locations of infilled suspected ponds are not shown to be present at the Western Park site or within the Central Avenue Alignment.

3.8 Existing Ground Investigations

There are no known previous ground investigation works undertaken across the site area. However, there are recent phases of investigation undertaken for the purpose of the Brookleigh development located east of the Central Avenue alignment, but have not been reported on within this report.

- WYG “Land off Maple Drive, Burgess Hill Geo-Environmental Factual & Interpretative Report A101197”, dated October 2017
- Structural Soils “Maple Drive Central Avenue Factual Report on Ground Investigation 563139-1 (02)”, dated August 2019
- Structural Soils “HE Northern Arc, Burgess Hill- Freeks Farm Ground Investigation 562943-Freeks Farm” , dated July 2019
- AECOM Ground Investigation Report “Northern Arc- Burgess Hill- Eastern Bridge Central Avenue including A273 Isaac’s Lane Junction and Bridge to Freek’s Farm” , dated September 2019
- AECOM Ground Investigation Report “Northern Arc- Freek’s Farm & Maple Drive”, dated September 2019

3.9 Unexploded Ordnance

A pre-desktop study assessment (PDSA) has been undertaken by Zetica for the entire Brookleigh site and noted that several Anti-Tank (AT) obstacles were established on the site. No readily available records were identified to indicate that the site was bombed; however, Burgess Hill Urban District (UD) officially recorded 20 No. High explosive bombs (HE) with a bombing density of 9.9 bombs per 405 hectares.

Risk Mapping for the site is shown to be low with an anticipated bomb density of less than 15 per 100 acres. The PDSA and Risk Mapping for the site can be found in Appendix F.

The Zetica PDSA recommend that a detailed desk study, whilst always prudent, is not considered essential in this instance.

4. Field and Laboratory Studies

4.1 Walkover Survey

A walkover survey was carried out by AECOM prior to the ground investigation works commencing in May 2023. During this visit the site was assessed for access to the investigation locations and to observe the extents of identified constraints during the planning of intrusive works. Constraints identified on site during the walkover are listed in Table 4-1.

Table 4-1 Identified constraints

Constraint	Affected Area	Influence on Ground Investigation
Access	All parcels of land	The land usage of active agricultural fields at the site with the planned intrusive investigation to be undertaken during the season of growing prior to harvest requires minimal vehicle traffic through operational fields to avoid damage to any crops/vegetation on the fields. Routes must be predefined and agreed with the landowner prior to works being undertaken. A weak footbridge was identified as a point of access for the ground investigation. A weight limit of around 5 tonnes was applied to the bridge by Campbell Reith (on behalf of Homes England) and as such machine types to cross the bridge were restricted. No access was allowed via farm entrances and tracks from north of the site.
Ecology	All parcels of land	Significant ecological constraints have been identified ahead of the planning of the ground investigation, standoff distances and alterations to the ground investigation programme based on the following flora and fauna identified on site; ancient woodland, reptile population, dormice, badgers, and bats. Restrictions adjacent to water bodies, longstanding farm buildings, densely vegetated areas. Compliance with the relevant authorities is to be undertaken by the GI contractor during the works.
site Users	Phase 2	Restriction to working hours for accessing locations where livestock are required to be moved prior to works being undertaken.

4.2 Ground Investigation and Fieldwork

4.2.1 Description of Fieldwork

The aim of the GI was to undertake exploratory holes distributed across the Brookleigh development area for the purpose of providing future developers at each land parcel sufficient data to understand ground related risks. The GI was undertaken to characterise the ground profile and to determine geotechnical parameters and likely behaviours, the GI also considered geo-environmental data to assess the risk of contamination at the site, identify potential mitigation measures, and assess the feasibility of material re-use.

The GI was undertaken by GEL between 17th July to 22nd August 2023 with AECOM carrying out full time technical supervision. Soil and rock descriptions were carried out in accordance with BS5930:2015+A1:2020.

The GI works for the entire Brookleigh development (Phases 2, 3, and 4, Central Avenue, Western Park, Green Super Highway and Pond 22) consisted of the following:

- 24 Rotary Cored Boreholes to a depth of up to 20.00m bgl
- 18 Dynamic Sample Boreholes to a depth of up to 3.60m bgl
- 46 Machine Dug Trial Pits to a depth of up to 3.00m bgl; and
- 3 Road Cores to a depth of up to 1.20m bgl
- In-situ Testing comprised of:
 - 17 Soakaway Infiltration tests within specified trial pits;
 - 2 Falling head permeability tests

- 46 Lightweight deflectometers adjacent to trial pit locations;
- 3 Mackintosh probes with hand auger follow on to depths of up to 3.60m bgl
- 16 Dynamic Probes adjacent to dynamic sample boreholes where refusal occurred shallower than proposed depths;
- Hand vane, hand penetrometer strength testing at all exploratory hole locations;
- Standard Penetration Testing (SPT) at all borehole locations; and
- Photo Ionisation Detector (PID) screening at all exploratory locations
- The results of the GI can be found in the factual report in Appendix C.

4.2.2 Relevant Exploratory Locations

The following exploratory locations have been identified as relevant to the Western Park ;

- 2 Boreholes (BH02, BH03)
- 6 Trial pits (TP02, TP03, TP05, TP06, TP08, TP41)
- 2 Dynamic Sampling holes (DS01 & DS02)
- 3 Road Cores (RC01-RC03)
- 7 Soakaway tests (TP08, TP10, TP17, TP18, TP19, TP41, TP46)

The following exploratory locations have been identified as relevant to the Central Avenue;

- 5 Boreholes (BH01, BH02, BH05, BH08, BH15)
- 9 Trial pits (TP02, TP04, TP08, TP10, TP17 to TP19, TP27, TP30, TP42)
- 2 Dynamic Sampling holes (DS01 & DS02)
- 3 Road Cores (RC01-RC03)
- 5 Soakaway tests (TP08, TP10, TP17, TP18, TP19)

The above listed locations are therefore included in Section 4.2.4 onwards of this report as presented in Appendix B.

It should be noted that on-site changes to the proposed works were undertaken due to identified constraints. Changes to the pre-planned GI details are noted in Table 4-2. The proposed and final locations can be viewed on the site location plans in Appendix B.

Table 4-2 Alterations to scope

Original Scope	Alteration and Rationale
TP02	Moved away from land boundary fence
TP08	Terminated shallower due to smaller machine due to bridge access constraint
TP10	Terminated shallower due to smaller machine due to bridge access constraint
TP17	Moved due to ecological constraints. Terminated shallower due to smaller machine due to bridge access constraint
TP18	GPR identified gas main within stand off distance – location moved. Terminated shallower due to smaller machine due to bridge access constraint
TP19	Terminated shallower due to smaller machine due to bridge access constraint
TP27	Moved due to ecological constraints
TP30	Moved away from overhead power cables
TP46	Moved due to ecological constraints

4.2.3 Other Fieldwork

Ongoing ecological surveys are being undertaken by AECOM for the monitoring and assessment of the sensitive flora and fauna present at the site. The findings of these reports are presented separately. Additionally, an arboricultural report will be presented separately.

4.2.4 Gas and Groundwater Monitoring

During the 2023 intrusive investigation work two rounds of groundwater monitoring took place on 2nd August and 7th August 2023. A further six rounds of post fieldwork groundwater level monitoring were completed in 14 No. installations, between 14th September and 9th November 2023.

Ground gas monitoring was completed in two installations on the six visits between 14th September and 9th November. Full groundwater and ground gas monitoring records can be reviewed within the GEL 2023 Factual Report in Appendix C.

Section 5.3 presents the plot of groundwater levels from monitoring specific to Western Park (WP) and the Central Avenue.

Details of ground gas monitoring events are noted in Table 4-3 while details of groundwater monitoring are noted in Table 4-4

Borehole Location	Installation (m bgl)	Response Zone (m bgl)	Ground Gas monitoring Event
BH01-D	50mm dual water/gas install – 4.5 – 9.5	4.2 – 10.0	MR2 - 18th September 2023
			MR3 - 28th September 2023
			MR4 - 5th October 2023
			MR5 - 11th October 2023
			MR6a – 20th October 2023
BH02-D	50mm dual water/gas install – 2.2 – 5.5	2.1 – 5.5	MR1 - 14th September 2023
			MR2 - 18th September 2023
			MR3 - 28th September 2023
			MR4 - 5th October 2023
			MR5 - 11th October 2023
BH03-D	50mm dual water/gas install – 3.5 - 5.0	3.2 – 5.2	MR6b – 9th November 2023
			MR1 - 14th September 2023
			MR2 - 18th September 2023
			MR3 - 28th September 2023
			MR4 - 5th October 2023
BH05-D	50mm dual water/gas install – 1.8 – 6.0	1.6 – 6.5	MR5 - 11th October 2023
			MR6 – 9th November 2023
			MR1 - 14th September 2023
			MR2 - 21st September 2023
			MR3 - 28th September 2023
BH08-D	50mm dual water/gas install – 4.0 – 8.0	4.0 – 8.0	MR4 - 5th October 2023
			MR5 - 12th October 2023
			MR6a – 20th October 2023
			MR1 – 14th September 2023
			MR2 - 19th September 2023
			MR3 - 28th September 2023
			MR4 - 5th October 2023

Borehole Location	Installation (m bgl)	Response Zone (m bgl)	Ground Gas monitoring Event
BH15-D	50mm dual water/gas install – 4.5 – 10.0	4.0 – 10.5	MR5 - 8th October 2023
			MR6b – 8th November 2023
			MR1 – 14th September 2023
			MR2 – 21st September 2023
			MR3 - 27th September 2023
			MR4 - 4th October 2023
			MR5 - 11th October 2023
DS02	50mm dual water/gas install – 0.5 – 2.0	0.5 – 2.0	MR6b – 9th November 2023
			MR1 - 14th September 2023
			MR2 - 18th September 2023
			MR3 - 28th September 2023
DS02-D	50mm dual water/gas install – 3.0 – 4.0	3.0 – 4.78	MR5 - 11th October 2023
			MR1 - 14th September 2023
			MR2 - 18th September 2023
			MR3 - 28th September 2023
			MR4 - 4th October 2023
			MR5 - 11th October 2023
DS02-D	50mm dual water/gas install – 3.0 – 4.0	3.0 – 4.78	MR6 – 9th November 2023
			MR1 - 14th September 2023
			MR2 - 18th September 2023
			MR3 - 28th September 2023
			MR4 - 4th October 2023
			MR5 - 11th October 2023

Table 4-3. Details of Ground Gas Monitoring Events

Borehole Location	Installation (m bgl)	Response Zone (m bgl)	Ground Gas monitoring Event
BH01-D	50mm dual water/gas install – 4.5 – 9.5	4.2 – 10.0	MR2 - 18 th September 2023
			MR3 - 28 th September 2023
			MR4 - 5 th October 2023
			MR5 - 11 th October 2023
			MR6a – 20 th October 2023
BH02-D	50mm dual water/gas install – 2.2 – 5.5	2.1 – 5.5	MR1 - 14 th September 2023
			MR2 - 18 th September 2023
			MR3 - 28 th September 2023
			MR4 - 5 th October 2023
			MR5 - 11 th October 2023
BH03-D	50mm dual water/gas install – 3.5 - 5.0	3.2 – 5.2	MR6b – 9 th November 2023
			MR1 - 14 th September 2023
			MR2 - 18 th September 2023
			MR3 - 28 th September 2023
			MR4 - 5 th October 2023
BH05-D	50mm dual water/gas install – 1.8 – 6.0	1.6 – 6.5	MR5 - 11 th October 2023
			MR6 – 9 th November 2023
			MR1 - 14 th September 2023
			MR2 - 21 st September 2023

Borehole Location	Installation (m bgl)	Response Zone (m bgl)	Ground Gas monitoring Event
			MR3 - 28 th September 2023
			MR4 - 5 th October 2023
			MR5 - 12 th October 2023
			MR6a – 20 th October 2023
BH08-D	50mm dual water/gas install – 4.0 – 8.0	4.0 – 8.0	MR1 – 14 th September 2023
			MR2 - 19 th September 2023
			MR3 - 28 th September 2023
			MR4 - 5 th October 2023
			MR5 - 8 th October 2023
			MR6b – 8 th November 2023
BH15-D	50mm dual water/gas install – 4.5 – 10.0	4.0 – 10.5	MR1 – 14 th September 2023
			MR2 – 21 st September 2023
			MR3 - 27 th September 2023
			MR4 - 4 th October 2023
			MR5 - 11 th October 2023
			MR6b – 9 th November 2023
DS02	50mm dual water/gas install – 0.5 – 2.0	0.5 – 2.0	MR1 - 14 th September 2023
			MR2 - 18 th September 2023
			MR3 - 28 th September 2023
			MR5 - 11 th October 2023
DS02-D	50mm dual water/gas install – 3.0 – 4.0	3.0 – 4.78	MR1 - 14 th September 2023
			MR2 - 18 th September 2023
			MR3 - 28 th September 2023
			MR4 - 4 th October 2023
			MR5 - 11 th October 2023
			MR6 – 9 th November 2023

Source: (Geotechnical Engineering Ltd , 2023) Appendix C

MR = Monitoring Round

Table 4-4. Details of Groundwater Monitoring Events

Borehole Location	Installation (m bgl)	Response Zone (m bgl)	Ground Water monitoring Event
BH01	19mm Piezo Pipe – 0.9 – 2.2	0.8 – 2.2	MR1 - 14 th September 2023
			MR2 - 18 th September 2023
			MR3 – 28 th September 2023
			MR4 - 5 th October 2023
			MR5 – 11 th October 2023
			MR6 – 20 th October 2023
BH01-D	50mm dual water/gas install – 4.5 – 9.5	4.2 – 10.0	MR1 - 14 th September 2023
			MR2 - 18 th September 2023
			MR3 - 28 th September 2023

Borehole Location	Installation (m bgl)	Response Zone (m bgl)	Ground Water monitoring Event
BH02	19mm Piezo Pipe – 0.6 – 1.7	0.5 – 1.8	MR4 - 5 th October 2023
			MR5 - 11 th October 2023
			MR6a – 20 th October 2023
			2 nd August 2023
			7 th August 2023
			MR1 – 14 th September 2023
			MR2 – 18 th September 2023
			MR3 – 28 th September 2023
			MR4 – 5 th October 2023
BH02-D	50mm dual water/gas install – 2.2 – 5.5	2.1 – 5.5	MR5 – 11 th October 2023
			MR6b – 9 th November 2023
			2 nd August 2023
			7 th August 2023
			MR1 – 14 th September 2023
			MR2 – 18 th September 2023
			MR3 – 28 th September 2023
			MR4 – 5 th October 2023
			MR5 – 11 th October 2023
BH03	19mm piezo pipe – 0.6 – 2.0	0.5 – 2.2	MR6b – 9 th November 2023
			2 nd August 2023
			7 th August 2023
			MR1 - 14 th September 2023
			MR2 - 18 th September 2023
			MR3 - 28 th September 2023
			MR4 - 5 th October 2023
			MR5 - 11 th October 2023
			MR6b – 9 th November 2023
BH03-D	50mm dual water/gas install – 3.5 - 5.0	3.2 – 5.2	MR6b – 9 th November 2023
			2 nd August 2023
			7 th August 2023
			MR1 - 14 th September 2023
			MR2 - 18 th September 2023
			MR3 - 28 th September 2023
			MR4 - 5 th October 2023
			MR5 - 11 th October 2023
			MR6b – 9 th November 2023
BH05	19mm Piezo Pipe – 0.6 – 1.2	0.5 – 1.3	MR6a – 20 th October 2023
			2 nd August 2023
			7 th August 2023
			13 th August 2023
			MR1 - 14 th September 2023
			MR2 – 18 th September 2023

Borehole Location	Installation (m bgl)	Response Zone (m bgl)	Ground Water monitoring Event
			MR3 - 28 th September 2023
			MR4 - 5 th October 2023
			MR5 - 12 th October 2023
			MR6a – 20 th October 2023
BH05-D	50mm dual water/gas install – 1.8 – 6.0	1.6 – 6.5	2 nd August 2023
			7 th August 2023
			13 th August 2023
			MR1 - 14 th September 2023
			MR2 – 18 th September 2023
			MR3 - 28 th September 2023
			MR4 - 5 th October 2023
			MR5 - 12 th October 2023
			MR6a – 20 th October 2023
BH08	19mm Piezo Pipe – 0.6 – 2.5	0.5 – 2.7	2 nd August 2023
			7 th August 2023
			13 th August 2023
			MR1 - 14 th September 2023
			MR2 – 19 th September 2023
			MR3 - 28 th September 2023
			MR4 - 5 th October 2023
			MR5 - 12 th October 2023
BH08-D	50mm dual water/gas install – 4.0 – 8.0	4.0 – 8.0	MR6b – 8 th November 2023
			2 nd August 2023
			7 th August 2023
			13 th August 2023
			MR1 - 14 th September 2023
			MR2 – 19 th September 2023
			MR3 - 28 th September 2023
			MR4 - 5 th October 2023
BH15	19mm Piezo Pipe – 0.6 – 2.60	0.5 – 2.8	MR5 - 12 th October 2023
			MR6b – 8 th November 2023
			2 nd August 2023
			12 th August 2023
			MR1 - 14 th September 2023
			MR2 – 21 st September 2023
			MR3 - 27 th September 2023
			MR4 - 4 th October 2023
BH15-D	50mm dual water/gas install – 4.5 – 10.0	4.0 – 10.5	MR5 - 11 th October 2023
			MR6b – 9 th November 2023
			2 nd August 2023
			12 th August 2023

Borehole Location	Installation (m bgl)	Response Zone (m bgl)	Ground Water monitoring Event
			MR1 - 14 th September 2023
			MR2 - 21 st September 2023
			MR3 - 27 th September 2023
			MR4 - 4 th October 2023
			MR5 - 11 th October 2023
			MR6b - 9 th November 2023
DS02	50mm dual water/gas install – 0.5 – 2.0	0.5 – 2.0	MR1 - 14 th September 2023
			MR2 - 18 th September 2023
			MR3 - 28 th September 2023
			MR4 - 4 th October 2023
			MR5 - 11 th October 2023
			MR6b - 9 th November 2023
DS02-D	50mm dual water/gas install – 3.0 – 4.0	3.0 – 4.78	2 nd August 2023
			7 th August 2023
			MR1 - 14 th September 2023
			MR2 - 18 th September 2023
			MR3 - 28 th September 2023
			MR4 - 4 th October 2023
			MR5 - 11 th October 2023
			MR6b - 9 th November 2023

Source: (Geotechnical Engineering Ltd , 2023) Appendix C MR = Monitoring Round

4.3 Laboratory Testing

4.3.1 Description of Geotechnical Tests

Geotechnical laboratory testing was undertaken by GEL on selected samples as scheduled by AECOM. All geotechnical soil and rock testing work was carried out in accordance with the various sections of BS1377:1990 “Methods of tests for soils in civil engineering purposes”, BS EN ISO 17892 “Geotechnical investigation and testing. Laboratory testing of soil” and ISRM Suggested Methods 2007 edition to UKAS accreditation where applicable.

Table 4-5 details the geotechnical tests undertaken in this phase of investigation for the purpose of the exploratory locations outlined in Section 4.2.2. It does not include any testing associated with the additional site locations.

Table 4-5 Geotechnical Testing Undertaken in 2023 Investigation

Type of Test	Standard	Number of Tests
Moisture Content	BS1377:1990 Part 2BS EN ISO 1782-1:2014:5	52
4 Point Plastic Limit and Liquid Limit	BS EN ISO 17892-12:2018	52
Particle Size Distribution by Wet Sieving	BS EN ISO 17892-4:2016: 5.2	64
Particle Size Distribution by Pipette	BS EN ISO 17892-4:2016:	62

Type of Test	Standard	Number of Tests
	5.4BS1377:1990 Part 2	
Dry Density/Moisture Content Relationship using 2.5kg rammer	BS1377:1990 Part 4	9
California Bearing ratio on re-compacted disturbed sample	BS1377:1990 Part 4	16
One-dimensional consolidation properties	BS EN ISO 17892-5:2017	3
Undrained shear strength of a Single 70mm and 100mm Diameter specimen in triaxial compression without the measurement of pore pressure	BS EN ISO 17892-8: 2018	6
Rock	Point Load Test	ISRM Suggested Methods 2007 edition
	Unconfined Compressive Strength	ISRM Suggested Methods 2007 edition
Chemical	BRE Suite D	BS1377:1990 Part 3 BRE SD1
	Organic Matter Content	BS1377:1990 Part 3

4.3.2 Description of Geo-environmental Tests

43 soil samples have been taken during the excavation of 1 borehole (BH03), 2 dynamic samples (DS01/02) and 11 trial pits (TP02-03, TP05, TP08, TP10, TP17 to TP19, TP27, TP30 and TP41) with total samples scheduled for analysis summarised in Table 4-6. Details of specific samples schedule for soil analysis are presented within Table 4-7, leachate chemical analysis within Table 4-8 and groundwater chemical analysis found within Table 4-9.

Table 4-6 Geo-environmental Testing Undertaken in 2023 Investigation

Type of Test	Standard	Number of Tests
Soil	Suite E – Asbestos Screen, Metal Analysis (As, B, Cd, Cr III + VI, Cu, Pb, Hg, Ni, Se, Zn) Nitrate, pH, Ammoniacal Nitrogen as N, Sulphate, Total Organic carbon, Speciated polyaromatic hydrocarbons (USEPA 16) + coronene, Moisture content and TPH C6-C40.	MCERTS/ UKAS
	Semivolatile organic compounds [SVOCs] Suite (exc. PAHs)	MCERTS/ UKAS
	Volatile organic compounds [VOCs] Suite	MCERTS/ UKAS
	Poly-chlorinated biphenyls [PCBs] (EC 7 and WHO 12)	MCERTS/ UKAS
	Criteria Working Group Total Petroleum Hydrocarbons with aliphatic and aromatic split – [TPH CWG] & BTEX/ MTBE	MCERTS/ UKAS
	Free cyanide, total cyanide and thiocyanate	MCERTS/ UKAS
	Extractable petroleum hydrocarbons [EPH] interpretation	MCERTS/ UKAS
	Organo-Chlorine Suite, Organo-Phosphorous Suite, Triazine Suite, Urea Herbicide Suite, Synthetic Pyrethroid Suite, Carbamate Herbicide Suite, Glyphosate, Organo Tins [Pesticide & Herbicide]	MCERTS/ UKAS
	Suite F – Metal Analysis (As, B, Cd, Cr III + VI, Cu, Pb, Hg, Ni, Se, Zn), pH, , Sulphate (as SO ₄), TPH CWG with aliphatic and aromatic split, Nitrate as N, Nitrite, Speciated polyaromatic hydrocarbons (USEPA 16), Free cyanide and total cyanide and Ammoniacal nitrogen expressed as N	UKAS
	SVOCs suite	UKAS
Leachate	VOCs suite	UKAS
	Organo-Chlorine Suite, Organo-Phosphorous Suite, Triazine Suite, Urea Herbicide Suite, Synthetic Pyrethroid Suite, Carbamate Herbicide Suite, Glyphosate, Organo Tins [Pesticide & Herbicide]	UKAS
	2-stage Waste Acceptance Criteria [WAC]	UKAS

Type of Test	Standard	Number of Tests
Groundwater Suite F – Metal Analysis (As, B, Cd, Cr III + VI, Cu, Pb, Hg, Ni, Se, Zn), pH, , Sulphate (as SO ₄), TPH CWG with aliphatic and aromatic split, Nitrate as N, Nitrite, Speciated polyaromatic hydrocarbons (USEPA 16), Free cyanide and total cyanide and Ammoniacal nitrogen expressed as N	UKAS	4
BRE Suite D - pH, water soluble sulphate, Total sulphur, Acid soluble sulphate	UKAS	2

Table 4-7. Details of Soil Sampling Chemical Analysis

Borehole Location	Depth (m bgl)	Suite E	SVOCs Suite	VOC Suite	PCBs Suite	TPH CWG	Cyanide	EPH	Pesticides	2-stage WAC Suite
BH03	1.00	X								
DS01	0.10	X	X	X		X	X	X	X	
	1.00	X								
DS02	0.10	X								
TP03	0.30	X			X		X			
	1.00	X	X	X	X	X	X	X		X
TP05	1.00	X	X	X						
TP08	0.30-0.50	X								
TP10	1.00-1.20	X								
TP17	0.40-0.50	X								
	1.00-1.20	X								
TP18	0.30-0.50	X								
	0.80-1.00	X								
TP19	0.20-0.40	X	X	X		X	X		X	
	1.00-1.20	X								
TP27	0.30-0.40	X								
TP30	0.30-0.40	X								
TP41	0.30-0.40	X								X

Source: (Geotechnical Engineering Ltd , 2023) – Appendix C

Table 4-8. Details of Soil Leachate Sampling Chemical Analysis

Borehole Location	Depth (m bgl)	Suite F	SVOCs Suite	VOC Suite	Herbicide & Pesticides Suite	2-stage WAC Suite
TP03	1.00	X	X	X		X
TP10	1.00-1.20	X				
TP17	0.40-0.50	X				
TP19	0.20-0.40	X			X	
TP30	0.30-0.40	X				
TP41	0.30-0.40					X

Source: (Geotechnical Engineering Ltd , 2023) – Appendix C

Table 4-9. Details of Ground Water Sampling & Testing schedule

Borehole Location	Date	Suite F	BRE Suite D
BH03-D	11 th October 2023	X	X
DS02-D	11 th October 2023	X	X

Source: (Geotechnical Engineering Ltd , 2023) – Appendix C

5. Ground Model

5.1 General

An interpretation of the existing information and the results from field and laboratory studies has been carried out, upon which the following ground model is presented.

5.2 Summary of Strata Encountered

5.2.1 Western Park

Based on the results of the ground investigation a general ground model has been derived for the site. The ground model is presented in Table 5-1.

The average ground level across the locations undertaken as part of the Western Park was 24.4mAOD. A maximum elevation of 33.3mAOD was encountered towards the west of the site at E:529237 N:120516 (TP03) and a minimum elevation of 17.7mAOD towards the northwest of the site at E529163N: 120711 (TP41).

Table 5-1 Ground Model Western Park

Strata	Depth to top (m bgl)	Depth to base (m bgl)	Thickness (m)	General Description
Topsoil*	0	0.2-0.3	0.2-0.3	Grass over stiff light brown slightly sandy slightly gravelly silty clay. Gravel is sub-rounded fine and medium mudstone.
Made Ground**	0	1.8	1.8	Grass over stiff brown slightly sandy gravelly silty clay. Gravel is angular to subrounded fine to coarse flint limestone chalk and rare brick with rare wood fragments. From 0.50m becoming firm and stiff greyish brown rarely mottled slightly sandy slightly gravelly silty clay with rare rootlets and faint organic odour.
Weald Clay-Residual Soil/Completely Weathered	0.3-1.8	2.0-9.3	1.2-9.0	Stiff to very stiff, locally firm brown-grey occasionally mottled orange slightly gravelly slightly sandy silty clay with occasional to frequent lenses of light grey silt. Occasionally described as stiff thinly and thickly laminated light grey mottled orangish brown clayey silt locally tending to siltstone with black staining and reddish-brown staining. Tending to extremely weak mudstone or Siltstone at base. Gravel layers found within the Weald Clay include very weak to medium strong light grey siltstone or fine sandstone.
Weald Clay-Slightly to Unweathered	2.0-9.3	Base not encountered	>14.6***	Extremely weak to very weak brown siltstone with frequent black staining, recovered as tabular fine to coarse siltstone gravel. Extremely weak to very weak light bluish grey mudstone with very closely and closely spaced thick laminae to very thin beds of light yellowish brown calcareous mudstone. Very weak orangish brown, brownish grey and brown fine sandstones. Fractures are sub horizontal and subvertical very closely and closely spaced planar smooth stained dark orangish brown and black.

Notes:

*The Topsoil was not separated from underlying strata, although it is anticipated that the thickness of Topsoil on the site is between 0.2m and 0.3m.

**Made Ground was only encountered in one exploratory location: TP03.

*** Not fully penetrated

5.2.2 Central Avenue

Based on the results of the ground investigation a general ground model has been derived for the site. The ground model is presented in Table 5-2.

The average ground level across the locations undertaken as part of the Western Park was 25.4mAOD.. A maximum elevation of 32.4mAOD was encountered towards the west of the site at E: 529310 N:120427 (TP02) and a minimum elevation of 18.0mAOD towards the east of the site at E:529597 N:120656 (TP08).

Table 5-2 Ground Model Central Avenue

Strata	Depth to top (m bgl)	Depth to base (m bgl)	Thickness (m)	General Description
Topsoil*	0	0.2-0.3	0.2-0.3	Grass over stiff light brown slightly sandy slightly gravelly silty clay. Gravel is sub-rounded fine and medium mudstone.
Made Ground**	0	0.6-0.8	0.6-0.8	Variable across site. See Section 6.2 for details. Road surfacing comprising tarmacadam and sand sublayer to 0.7m underlain by sand and gravel comprising flint, siltstone and brick. Occasional Chalk and Concrete noted.
Weald Clay-Residual Soil/Completely Weathered	0.3-1.4	0.8-9.3	0.5-9.0	Stiff to very stiff, locally firm brown-grey occasionally mottled orange slightly gravelly slightly sandy silty clay with occasional to frequent lenses of light grey silt. Occasionally described as stiff thinly and thickly laminated light grey mottled orangish brown clayey silt locally tending to siltstone with black staining and reddish-brown staining. Tending to extremely weak mudstone or Siltstone at base. Gravel layers found within the Weald Clay include very weak to medium strong light grey siltstone or fine sandstone.
Weald Clay-Slightly to Unweathered	0.8-9.3	Base not encountered	>17.4***	Extremely weak to very weak brown siltstone with frequent black staining, recovered as tabular fine to coarse siltstone gravel. Extremely weak to very weak light bluish grey mudstone with very closely and closely spaced thick laminae to very thin beds of light yellowish brown calcareous mudstone. Very weak orangish brown, brownish grey and brown fine sandstones. Fractures are sub horizontal and subvertical very closely and closely spaced planar smooth stained dark orangish brown and black.

Notes:

*The Topsoil was not separated from underlying strata, although it is anticipated that the thickness of Topsoil on the site is between 0.2m and 0.3m.

**Made Ground was only encountered in one exploratory location: RC01-RC03

*** Not fully penetrated

5.3 Summary of Groundwater Conditions

Groundwater strikes and seepages were encountered in 2 of the exploratory locations within the Western Park and Central Avenue GI locations completed in 2023. These are summarised in Table 5-3.

Table 5-3 Groundwater Strike Summary

Exploratory Hole	Strike Level (m bgl)	Strike Level (m AOD)	Strike Geology	Max Rise (m bgl)	Max Rise (m AOD)
RC02	1.10	22.6	Residual Soil	0.0	23.7
TP03	2.90	18.5	Residual Soil	Seepage only	

Due to the use of flush during the drilling process groundwater levels were unable to be recorded in any of the boreholes during the ground investigation.

During the 2023 investigation 2 rounds of fieldwork groundwater level monitoring were completed in eleven installations, between 2 August and 13 August 2023. A further 6 rounds of post fieldwork groundwater level monitoring were completed in fourteen installations, between 14 September and 11 November 2023. Full groundwater monitoring records can be reviewed within the GEL 2023 Factual Report in Appendix C. These are summarised in Table 5-4.

Table 5-4 Summary of Groundwater Monitoring Data

Area	Borehole ID	Installation Response Zone (m bgl) [Stratum]	Installation Pipe Depth (m)	Groundwater Level Range (m bgl)	Groundwater Elevation Range (m AOD)
	BH01 (s)	Residual Soil	2.20	1.14 to 1.16	28.64 to 28.86

Area	Borehole ID	Installation Response Zone (m bgl) [Stratum]	Installation Pipe Depth (m)	Groundwater Level Range (m bgl)	Groundwater Elevation Range (m AOD)
Central Avenue	BH01 (d)	Weald Clay	9.50	2.39 to 3.43	26.37 to 27.41
	BH02 (s)	Residual Soil	1.70	0.46 to 1.46	24.34 to 24.34
	BH02 (d)	Residual Soil	5.50	2.20 to 3.67	21.13 to 22.60
	BH03 (s)	Residual Soil	2.00	0.7 to Dry	24.43 to >23.15
	BH03 (d)	Residual Soil	5.00	2.9 to 3.7	21.4 to 22.2
	BH05 (s)	Residual Soil	1.20	1.52 to Dry	20.63 to >20.95
	BH05 (d)	Residual Soil	6.00	1.66 to 1.83	20.32 to 20.55
	BH15 (s)	Residual Soil	2.60	1.41 to 2.22	26.13 to 26.94
	BH15 (d)	Weald Clay	10.00	1.53 to 2.15	26.20 to 26.82
Western Park	BH08 (s)	Residual Soil	2.5	2.24 to Dry	21.86 to >24.1
	BH08(d)	Residual Soil	8	2.7 to 2.99	21.1 to 21.4
	DS02 (s)	Residual Soil	2.00	1.1 to Dry	20.9 to >25.6
	DS02 (d)	Residual Soil	4.00	1.38 to Dry	20.62 to >23.6

Note: s refers to shallow installation , d refers to deep installation

Figure 5-1 presents the plot of groundwater levels from monitoring specific to Western Park and Central Avenue showing the installation depths both shallow and deep.

Groundwater data from monitoring wells across the wider Brookleigh development have been interpreted to create groundwater contour plans (included within Appendix H). The plots have been generated using monitoring data from monitoring wells screened between 19 m AOD and 25 m AOD. The plots have been compared to those included in the Phase 2,3,4 report (AECOM, 2023) which included data for all monitoring well installations. The contour plots generated with data from restricted installation depths are considered to broadly correspond with those using all monitoring data, and indicates that the groundwater flow is generally towards the tributaries of the River Adur (Copyhold Stream & eastern Adur). The variation in groundwater elevations across the central avenue reflect the topographical change across the site.

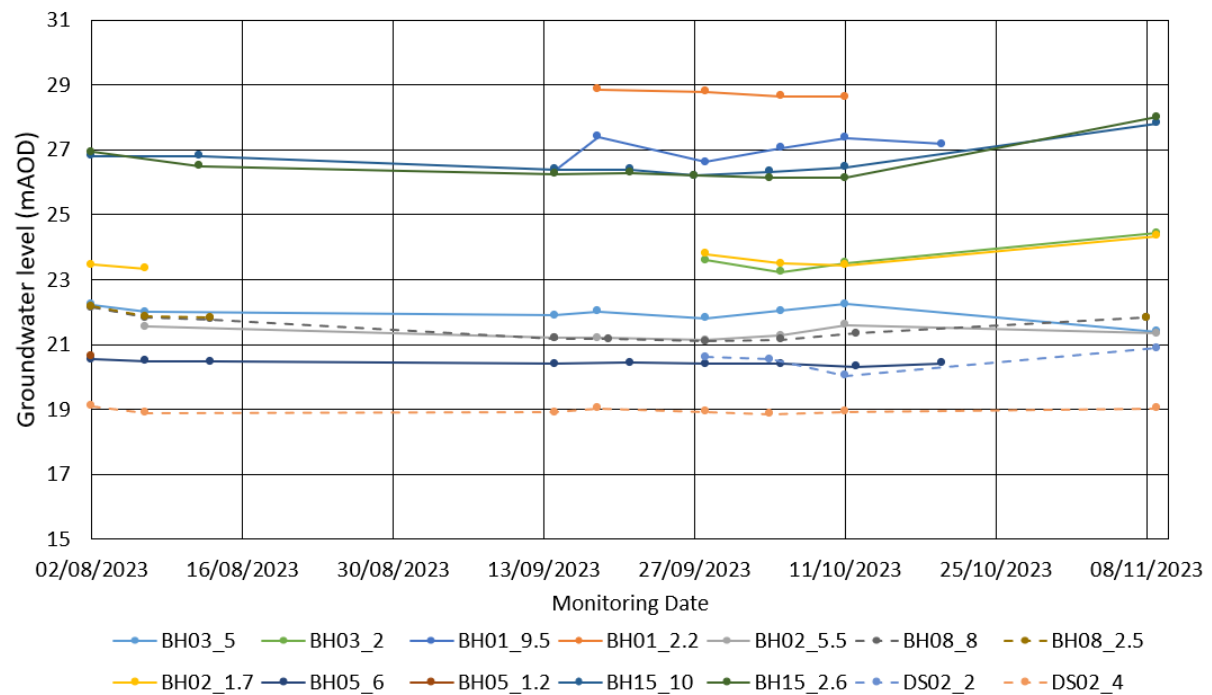


Figure 5-1 Groundwater level monitoring

In Figure 5-1 the legend reference (e.g. BH01_1) gives borehole identification and standpipe base depth. Dashed lines refer to locations within the Western Park site, solid lines refer to locations along the Central Avenue alignment.

6. Ground Conditions and Material Properties

6.1 General

6.1.1 Infilled Ponds/ Clay Pits

No locations of suspected infilled ground (ponds or pits) were targeted in the investigation, the locations suspected to be at or adjacent to previous infilled ground can be reviewed in the AECOM (2023) Phase 2, 3, 4 Ground Investigation Report.

6.1.2 Weald Clay Formation

Where encountered on site the Weald Clay Formation varies from stiff clays to medium strong mudstones, siltstones and sandstones.

The Weald Clay is encountered as Residual Soil/ Completely Weathered soil beneath the Topsoil and Made Ground. The depth to rockhead is understood to be variable and subject to interpretation at the site due to the in-situ strength testing (i.e. SPTs) refusing within the weathering profile. and variation within strength descriptions within the interbedded lithologies.

The classification of the Weald Clay has been interpreted based on Fookes (1997) scale of weathering grades of rock mass. Based on the soil and rock descriptions within the logs, attached as Appendix C Grade II to Grade I Weald Clay have been considered as rockhead for the purpose of this analysis and to have rock derived parameters.

Overlying the Grade I and II rock the Weathered Weald Clay was generally encountered as soil. Grade III and IV were largely absent being occasionally represented by more resistant siltstone and sandstone beds in the soil. Residual Soil/ Completely weathered (Grade V and VI) in this report, in most exploratory locations, is noted as stiff clays tending to extremely weak rock at the base of these grades. This stratum has been characterised by soil parameters only.

6.2 Topsoil

Topsoil was encountered in 12 No. exploratory holes from surface level. The factual report does not separate Topsoil from the underlying strata, although it is anticipated that the thickness of Topsoil on the site is between 0.2m and 0.3m.

It is recommended that Topsoil material is stripped from the footprints of earthworks and structures prior to construction and stockpiled on site for re-use. As a result, in-situ Topsoil material will not be considered in the stability analyses of earthworks and structures. Consequently, no geotechnical parameters have been derived for the in-situ material.

site won Topsoil may be suitable for re-use as Specification for Highway Works (SHW) Class 5A Topsoil material. Depending on the scheme's landscaping proposals, specific testing may be required to determine if the Topsoil is suitable for use as a planting medium.

6.3 Made Ground

Made Ground was encountered in 4 exploratory holes; RC01, RC02, RC03 and TP03 which are located along Cuckfield Road and southwest of Western Park.

The Made Ground within RC01 to RC03 was described as Tarmacadam from surface to 0.13m bgl and 0.15m bgl, becoming dark grey and black silty gravelly fine to coarse sand. Concrete was encountered in RC02 from 0.13m bgl to 0.3m bgl. Gravel is angular and subangular fine to coarse crystalline and coal and flint, found to a depth of up to 0.75m bgl.

TP03 is located within the vicinity of Floods Barn which are shown on historical mapping from 1897 to 1975. The Made Ground present may therefore be due to previous infilling of ground. The Made Ground was described as subrounded fine to coarse gravel of flint, limestone, chalk and rare brick with rare wood fragments from surface to 0.5m, becoming firm and stiff greyish slightly sandy gravelly silty clay with rare rootlets and faint organic odour to 1.8m. Gravel is angular to subrounded fine and medium flint limestone, chalk and rare brick.

The Made Ground was encountered to depths of between 0.13m bgl and 1.8 m bgl with an average base depth of 0.49m bgl. The following laboratory tests were undertaken in the Made Ground from TP03 only;

- 4 No. Natural moisture content determination
- 4 No. Atterberg Limits
- 3 No. Lightweight Deflectometer Tests
- 1 No. Particle Size Distribution (PSD) by wet sieving
- 1 No. Particle Size Distribution (PSD) by pipette
- 1 No. Pocket Penetrometer

Made Ground is generally very variable and can change laterally and with depth. The parameters detailed below should be used with caution as they may not be suitable for all Made Ground encountered during construction. In addition areas of Made Ground may be encountered during construction that were not found during this exploratory phase ground investigation.

6.3.1 Classification Tests

The results of the natural moisture content and Atterberg Limits testing for Made Ground on one sample at 0.5m bgl in TP03 are;

- Natural Moisture Content (NMC)-17%
- Liquid Limit (LL)-51%
- Plastic Limit (PL)-22%
- Plasticity Index (PI)-29%
- Percentage passing 425um-55%
- Modified Plasticity Index (I'P)-16%

The modified plasticity index indicates the material has a low volume change potential in accordance with NHBC guidelines

A bulk unit weight of between 17 kN/m³ is estimated for the Made Ground based on the soil descriptions and typical values for similar soils presented in Table 1 BS8002.

The results show that the sample tested comprised of fine grained soil (silt 33% and clay 29%), with 11% sand, and 27% gravel. Subgrade Modulus and California Bearing Ratio

6.3.1.1 Light Weight Deflectometer Testing

Three Light Weight Deflectometer (LWD) tests were undertaken adjacent to TP03 at surface, 0.5m bgl and 1.0m bgl. The surface modulus (E_0) has been calculated by Geotechnical Engineering Ltd returning values of 40 to 102 MPa. It is worth noting the LWD test devices may not be suitable for thicker stiffer pavement foundations (IAN 73/06 Rev 1). The zone of influence for the test typically extends to between 1 and 1.5 times the plate diameter, therefore testing the Made Ground and strata below it.

In accordance with CD225, Equation 2.4 has been used:

$$E = 17.6(CBR^{0.64}).$$

The result from the LWD testing was used to calculate the California Bearing Ratio (CBR) value of 3.61% at surface and 4.14% at 1.0m bgl. The remaining result is considered to be outside the acceptable CBR calculated values based on criteria provided in CD225 (equation is valid for CBR values in the range of 2-12%).

Guidance from CD 225 Revision 1 states that when the subgrade surface modulus is lower than 30 MPa (about 2.5% CBR), improvement of the subgrade shall be undertaken. CD225 also states that foundations built on a construction subgrade surface modulus of 50 MPa (about 5% CBR) or less have a relatively high risk of structural rutting during construction. This can be prevented through subgrade improvement and/or the use of a capping layer. It is recommended that all surface material be stripped prior to construction.

It should be noted that the results of tests carried out at ground level (0.00m) should be used with caution. It is recommended that all surface soils be stripped prior to construction.

Table 6-1 LWD testing in Residual Soil- Western Park

Location	Reference	Summary Soil Description	Test Depth (m)	Average Surface Modulus, E_0 (MPa)	Average CBR Value (%)
TP03	TP03-1	Stiff brown slightly sandy gravelly silty clay. Gravel is angular to subrounded fine to coarse flint limestone chalk and rare brick with rare wood fragments.	0.00	40.00	3.61
	TP03-2	Firm and stiff greyish brown rarely mottled slightly sand gravelly silty clay with rare rootlets and a faint organic odour. Gravel is angular to subrounded fine to coarse flint limestone chalk and rare brick.	0.50	102.00	>12%**
	TP03-3		1.00	43.67	4.14

Note:

“*” denotes the surface moduli which are below 30MPa and require subgrade improvement.

“**” denotes the CBR values which are out of range and not valid.

6.3.1.2 Plasticity Index

Equilibrium CBR for the cohesive Made Ground encountered in TP03 with the proposed Western Park has been estimated from the plasticity index of 29%, and material composition in accordance with TRRL Laboratory Report 1132, 1984 ‘The Structural Design of Bituminous Roads’. An equilibrium CBR value of 3.5% can be adopted based on thin construction and 5.0% based on thick construction. The CBR value assumes a high groundwater table and good construction conditions. In selecting the Design CBR value for the subgrade, consideration must be given to the likely moisture conditions applying during construction.

6.3.2 Strength

6.3.2.1 Undrained Shear Strength

The undrained shear strength of Made Ground was recorded on one sample using pocket penetrometer. The pocket penetrometer recorded the undrained shear strength in TP03 at 1.0m bgl and results ranged from 80kPa to 120kPa within the firm to stiff silty clay.

The designer should note this was based on one set of tests and that Made Ground is inherently variable therefore these values should be used with caution.

6.3.2.2 Drained Shear Strength

For drained shear strength of cohesive Made Ground the proposed correlation by Santamarina et al., (2003) has been used to estimate the effective constant volume angle of shearing resistance ϕ'_{cv} based on the returned plasticity index (I_p) of the Made Ground encountered in TP03 within the proposed Western Park from Atterberg Limit testing summarised earlier in Classification Testing. The following formula was used;

$$\phi'_{cv} = 42^\circ - 12.5 \log_{10}(I_p)$$

The Plasticity Index result of 29% resulted in the correlated ϕ'_{cv} of 26° .

The designer should note this was based on one sample only.

6.3.3 Stiffness

The undrained stiffness of the Made Ground can be obtained by using the relationship proposed by Jamiolkowski et al., (1979) which correlated E_u/C_u ratio to I_p and OCR. For an I_p of 16% and an OCR of 1 (a normally consolidated soil), an E_u/C_u ratio of 300 is obtained, yielding an average stiffness of between 24MPa to 36MPa, based on an undrained shear strength range of 80kPa to 120kPa.

The designer should note this was based on one set of tests and that Made Ground is inherently variable therefore these values should be used with caution.

6.4 Residual Soil

Weald Clay weathered to Residual Soil was encountered in 16 No. locations across the site. In the following section Grade V and VI are both referred to as Residual Soil. The top of the Residual Soil was therefore encountered between 0.3m bgl and 1.8m bgl to a maximum depth of 9.3mbgl. The description of Residual Soil varied across the site. It is typically described as stiff to very stiff, locally firm, brown-grey occasionally mottled orange slightly gravelly slightly sandy silty clay with occasional to frequent lenses (up to 1mmx20mmx20mm) of light grey silt.

The soil was occasionally described as stiff thinly and thickly laminated light grey mottled orangish brown clayey silt locally tending to siltstone with black and reddish-brown staining. The unit was also found to be tending to extremely weak mudstone or siltstone towards the base.

The Residual Soil showed to increase in gravel content from 1.0m bgl. Where present, the gravel bands are shown to be between 0.20m thickness and 0.6m thickness, and these gravel layers are expected to be more resistant to weathering. Lithorelics within the samples were described as fine to coarse of siltstone, mudstone and rare sandstone.

The following tests were undertaken in the Residual Soil:

- 64 No. Standard Penetration Tests (SPT)
- 52 No. Natural moisture content determination
- 52 No. Atterberg limits
- 6 No. Undrained Unconsolidated Triaxial
- 3 No. Consolidation
- 36 No. Lightweight Deflectometer Tests
- 30 No. Particle Size Distribution (PSD) by wet sieving
- 29 No. Particle Size Distribution (PSD) by pipette
- 9 No. Dry Density/Moisture Content Relationship Tests – 2.5kg
- 9 No. laboratory CBR

6.4.1 Classification Tests

The natural moisture content and Atterberg limits tests results (LL, PL and PI) for Residual Soil are presented in Table 6-2 from a total of 52 samples undertaken within the residual soil at Western Park and across the Central Avenue.

Table 6-2 Classification Tests Residual Soil

Statistic	MC %	LL %	PL %	PI %	% passing 425 µm	I _p (%)
Minimum	11	37	19	16	50	16
Maximum	29	76	32	49	100	49
Average	21	58	25	33	93	31
Lower Quartile	16	51	23	27	90	23

Natural moisture content (MC) and Atterberg limits tests results for Residual Soil are shown in Figure 6-1. The natural moisture content generally plots close to or below the plastic limit, with many plastic limits being equal to the moisture content. Therefore, some of the soil is anticipated to behave in a plastic manner when in its in situ state.

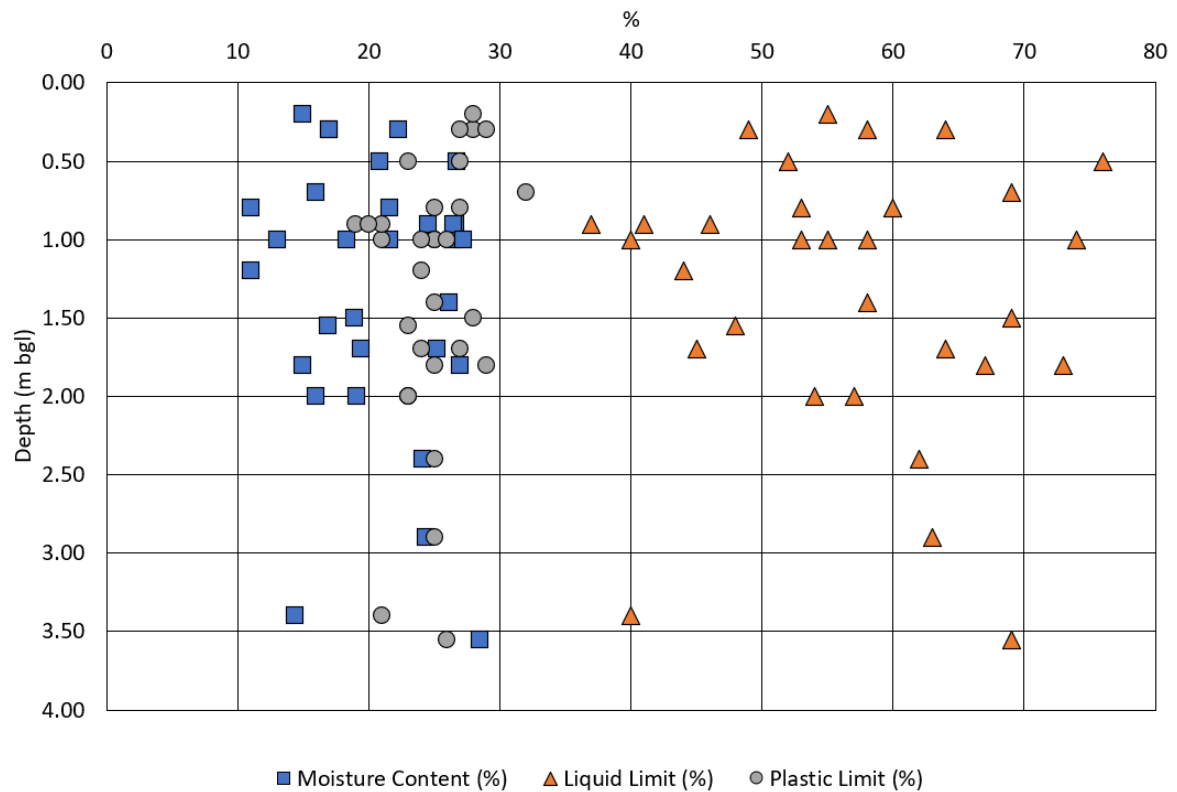


Figure 6-1 Residual Soil Moisture Content and Atterberg Limits

Based on the Casagrande A-line plot in Figure 6-2, generally, the Residual Soil ranges from an intermediate to very high plasticity clay.

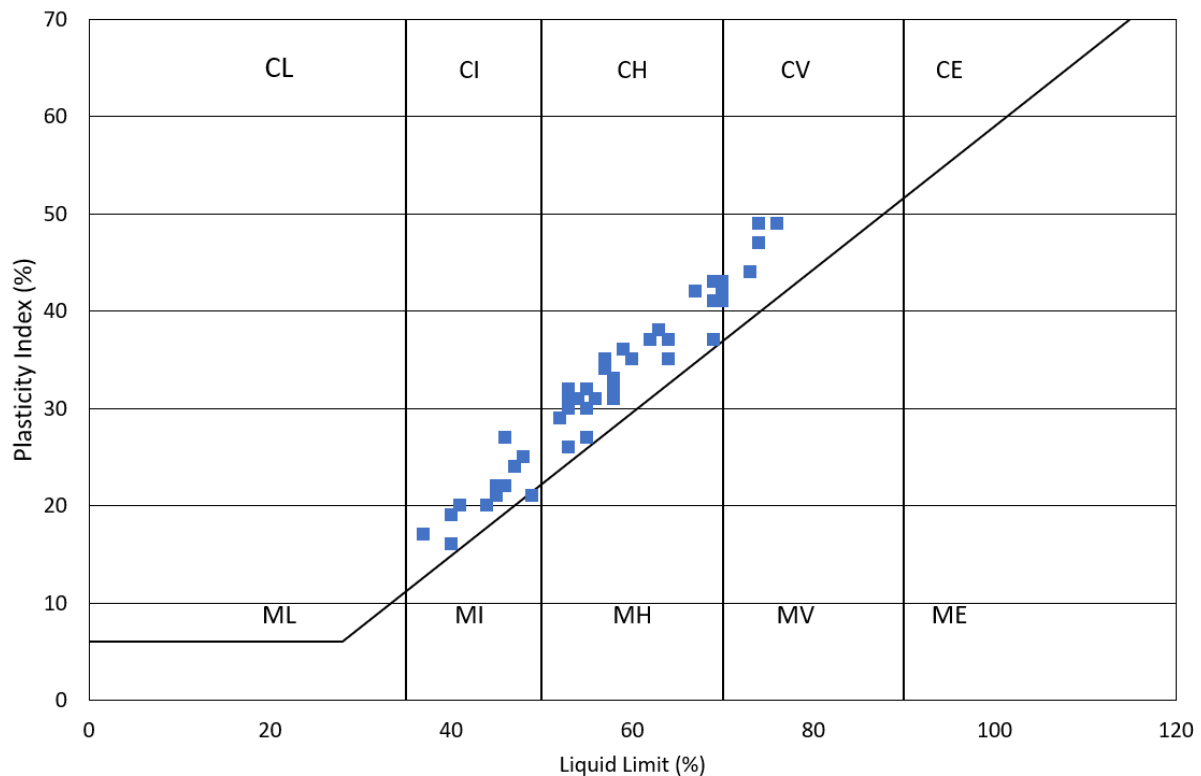


Figure 6-2 Residual Soil Casagrande A-Line Plot

Figure 6-3 show the results of the 30 No. PSD tests. The results show the Residual Soil to be consistent with a cohesive material with the composition mostly of silt and clay.

There is one significant outlier in the data undertaken at TP30 at 1.0m bgl at a lithological boundary containing a gravel layer, the lab report described the sample as light brown mottled grey slightly gravelly slightly sandy silty clay, however the results of the PSD show the material to be a gravel comprising of siltstone composed of the underlying layer. As shown on Figure 6-3 this was comprised of 60% gravel, 15% sand and 25% fines.

In addition, BH15 at 2.2m was located at the base of the residual soil above a thin bed of dark orangeish brow and black ironstone comprising the gravel portion of the sample. As shown on Figure 6-3 this was comprised of 39% gravel, 12% sand and 49% fines.

Table 6-3 Summary of Composition Residual Soil

Statistic	Cobbles %	Gravel %	Sand%	Fines% (Silt/Clay)	Silt%	Clay %
Minimum	0	0	1	25	19	20
Maximum	0	60	16	99	77	79
Average	0	5	5	89	50	40
Lower Quartile	0	0	2	84	40	30

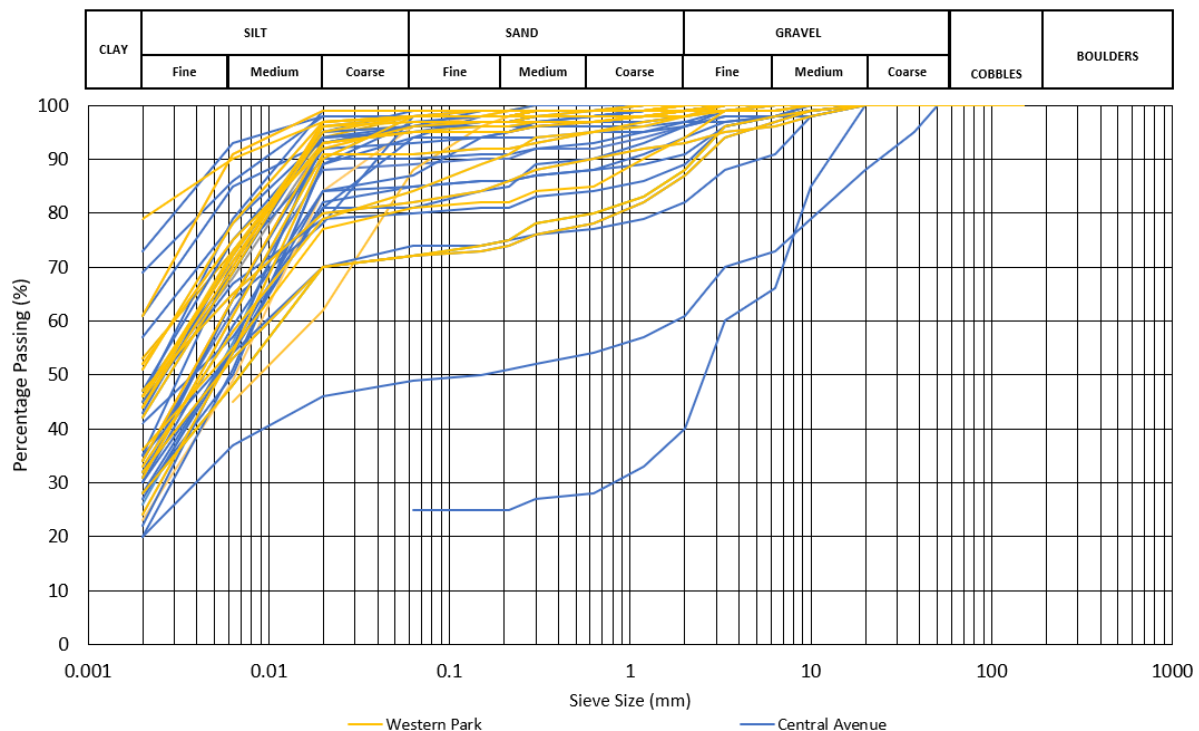


Figure 6-3 Residual Soil Particle Size Distribution

6 No. bulk density tests were carried out on the Residual Soil within the Western Park Site as a part of the oedometer tests and undrained triaxial tests and the values ranged from 1.95Mg/m^3 to 2.20Mg/m^3 , with a lower quartile value of 1.95Mg/m^3 . Based on these results a unit weight of 19kN/m^3 is suggested for this soil.

Within the Residual Soil 6 No. organic matter content tests were undertaken, with an anomalous low result in BH02 at 0.6m returning a value of 3.3% the remaining 5 tests returned results between 5.7% to 6.9%, with an average of 6.4% and lower quartile of 6.2%. BS5930 indicates that soils with organic contents of 6% to 30% have significant organic content.

6.4.2 Surface Modulus and California Bearing Ratio

6.4.2.1 Laboratory Testing

Laboratory CBR testing was carried out at depths between 0.9m bgl and 2.0m bgl within the Residual Soil.

A total of 9 No. CBR tests were carried out in the laboratory on bulk samples. The results of these are summarised in Table 6-4. Where soaked tests were undertaken Swelling occurred up to 3.3mm.

Table 6-4 Made Ground CBR summary from Laboratory Testing

Area	Hole ID	Depth	Summary Soil Description	Test type	Natural Moisture content (%)	Bulk Density (Mg/m^3)	CBR Value Top (%)	CBR Value Bottom (%)
Central Avenue	RC01	0.90	Greyish brown slightly sandy silty clay	Unsoaked	26.6	1.91	2.3	2.8
	RC02	0.90	Yellowish brown mottled greyish brown slightly gravelly slightly sandy silty clay	Unsoaked	26.5	1.92	0.96	1.7
	RC03	0.90	Greyish brown slightly gravelly slightly sandy silty clay	Soaked	24.5	1.93	1.6	1.8

Area	Hole ID	Depth	Summary Soil Description	Test type	Natural Moisture content (%)	Bulk Density (Mg/m ³)	CBR Value Top (%)	CBR Value Bottom (%)
	TP02	2.00	Greyish brown and yellowish brown slightly sandy silty clay	Unsoaked	19.1	1.83	10	4.4
	TP05	1.00	Greyish brown and bluish grey slightly sandy silty clay with occasional rootlets	Soaked	16.3	1.70	1.2	0.55
	TP06	1.00	Greyish brown slightly sandy silty clay	Unsoaked	21.1	1.80	9.3	3.6
	TP19	0.80	Light brown mottled orange slightly sandy slightly gravelly silty clay with rare rootlets	Unsoaked	17.3	1.69	17	7.8
	TP19	1.50	Orangish brown slightly gravelly slightly sandy silty clay	Unsoaked	14.6	1.83	10	5.9
Western Park	TP41	1.00	Brown slightly sandy silty clay with occasional rootlets	Unsoaked	19.9	1.52	10	4.9

6.4.2.2 Light Weight Deflectometer Testing

A total of 36 No. Light Weight Deflectometer (LWD) tests were undertaken adjacent to 12 No. trial pit locations containing Residual Soil as presented in Table 6-5. The surface modulus (E_0) has been calculated by GEL ranging from 12 MPa to 214 MPa with an average of 63 MPa and lower quartile of 32 MPa. It is worth noting the LWD test devices may not be suitable for thicker stiffer pavement foundations (IAN 73/06 Rev 1). The zone of influence for the test typically extends to between 1 and 1.5 times the plate diameter.

Table 6-5 LWD testing in Residual Soil

Area	Hole ID	Reference	Summary Soil Description	Test Depth (m)	Average Surface Modulus, E_0 (MPa)	Average CBR Value (%)
Central Avenue	TP02	TP02-1	Stiff brown slightly sandy silty clay with frequent rootlets.	0.00	12.00*	<2.5%**
		TP02-2	Stiff greyish brown silty clay with frequent black staining.	0.50	36.67	3.15
		TP02-3	Firm orangish brown mottled light grey silty clay with frequent black staining.	1.00	82.67	11.21
	TP05	TP05-1	Firm brown clayey silt with rare rootlets.	0.00	33.67	2.76
		TP05-2	Very stiff orangish brown silty clay with rare rootlets.	0.50	59.67	6.74
		TP05-3		1.00	58.67	6.56
	TP08	TP08-1	Stiff brown slightly gravelly silty clay.	0.00	20.33*	<2.5%**
		TP08-2		0.50	104.67	>12%**
		TP08-3	Very stiff mottled light bluish grey and orangish brown gravelly silty clay.	1.00	142.33	>12%**
	TP10	TP10-1	Stiff brown slightly gravelly silty clay with frequent rootlets.	0.00	12.00*	<2.5%**
		TP10-2	Very stiff brown slightly gravelly clayey silt.	0.50	45.00	4.34

Area	Hole ID	Reference	Summary Soil Description	Test Depth (m)	Average Surface Modulus, E0 (MPa)	Average CBR Value (%)
		TP10-3	Stiff light brown mottled bluish grey and light grey slightly gravelly silty clay.	1.00	73.67	9.36
	TP17	TP17-1	Stiff brown slightly sandy silty clay with frequent rootlets	0.00	24.00*	<2.5%**
		TP17-2	Very stiff mottled light bluish grey and orangish brown locally black silty clay	0.50	77.00	10.04
		TP17-3	Orangish brown mottled light bluish grey gravelly clayey silt.	1.00	84.00	11.50
	TP18	TP18-1	Stiff brown slightly sandy silty clay with frequent rootlets	0.00	38.33	3.37
		TP18-2	Very stiff mottled light bluish grey, brown and orangish brown silty clay.	0.50	52.67	5.54
		TP18-3	Extremely weak light bluish grey stained dark orangish brown siltstone, recovered as silty angular and subangular fine to coarse siltstone Gravel and subangular siltstone Cobbles.	1.00	111.00	>12%**
	TP19	TP19-1	Stiff brown slightly sandy silty clay with frequent rootlets	0.00	69.33	8.52
		TP19-2	Very stiff mottled light grey and orangish brown clayey silt.	0.50	57.33	6.33
		TP19-3		1.00	213.67	>12%**
	TP27	TP27-1	Stiff brown slightly gravelly clayey silt with frequent rootlets	0.00	32.00	2.54
		TP27-2	Firm becoming stiff light grey and brown silty clay with frequent black staining and rare lignite fragments (up to 2mm)	0.50	30.00	2.30
		TP27-3	Stiff friable light brownish grey clayey silt rarely stained reddish brown	1.00	28.33*	2.10
Western Park	TP41	TP41-1	Stiff brown clayey silt with frequent rootlets.	0.00	23.67*	<2.5%**
		TP41-2	Very stiff brown slightly sandy silty clay with rare rootlets.	0.50	29.33*	2.22
		TP41-3		1.00	70.33	8.71

Note:

"*" denotes the surface moduli which are below 30MPa and where subgrade improvement is recommended in accordance with CD 225.

"**" denotes the CBR values which are out of range and not valid based on restrictions in CD 225.

The results from the LWD testing were used to calculate the California Bearing Ratio (CBR) values in accordance with CD225, Equation 2.4, $E = 17.6(CBR^{0.64})$. However, this equation is only valid for CBR values in the range of 2-12%. Therefore, all CBR values calculated outside of this range have been reported as either less than 2.5% or greater than 12%. The CBR values (within the calculated range) averaged a value of 6 and a lower quartile of 3.

Guidance from CD 225 Revision 1 states that when the subgrade surface modulus is lower than 30 MPa (about 2.5% CBR), improvement of the subgrade shall be undertaken. 7 No. tests gave a surface modulus value of under 30MPa, with 5 No. being at ground level. It should be noted that the results of tests carried out at ground level (0.00m) should be used with caution. It is recommended that all surface soils be stripped prior to construction.

The remaining tests with a surface modulus under 30 MPa, which were not at ground level, were recorded in 2 No. of exploratory holes. These were TP27 at 1m bgl and TP41 at 0.5m bgl.

TP41 is in close proximity to the streams and ponds on site which could be the reason for their low subgrade surface modulus, so further investigation may be required. TP27 appears to be located away from any watercourse and therefore could be considered a localised soft spot.

CD225 also states that foundations built on a construction subgrade surface modulus of 50 MPa or less have a relatively high risk of structural rutting during construction. This can be prevented through subgrade improvement and/or the use of a capping layer.

Since the results show the majority of the tested soil needs subgrade improvement, it is recommended that further testing is undertaken using equipment complying with BS 1924-2 (2018).

6.4.2.3 Plasticity Index

Equilibrium CBR for the Residual Soil has been estimated from the plasticity index range of 20% to 33%, with a lower quartile of 26%, and material composition in accordance with TRRL Laboratory Report 1132, 1984 'The Structural Design of Bituminous Roads'. A CBR value of 3.5% can be adopted based on thin construction and 5.0% based on thick construction. The CBR value assumes a high water table and good construction conditions. In selecting the Design CBR value for the subgrade, consideration must be given to the likely moisture conditions applying during construction.

Where silt is predominant at subgrade level, as indicated on some exploratory hole logs and in PSD test results, the TRRL Laboratory Report 1132 indicates a CBR value of 1% or 2% is likely. In this situation subgrade improvement will be required and the potential for frost heave will also need to be taken into account.

The lower value of either the short term values from the LWD tests or the equilibrium values should be selected for design.

6.4.3 Standard Penetration Test

64 No. Standard Penetration Tests (SPT's) were undertaken in the Residual Soil in 8 No. exploratory holes across Western Park and Central Avenue. All the results have been corrected using the energy ratio of the SPT hammer to give an N_{60} value.

The results of the SPT tests N_{60} values plotted against depth can be seen in Figure 6-4. The N values range between 10 and 50 with the average being 44 and the lower quartile being 36. The N_{60} values range between 14 and 68 with the average being 50 and the lower quartile being 45. The results show that in general the strength increases with depth and there is no significant difference between locations located at Western Park and along the Central Avenue alignment.

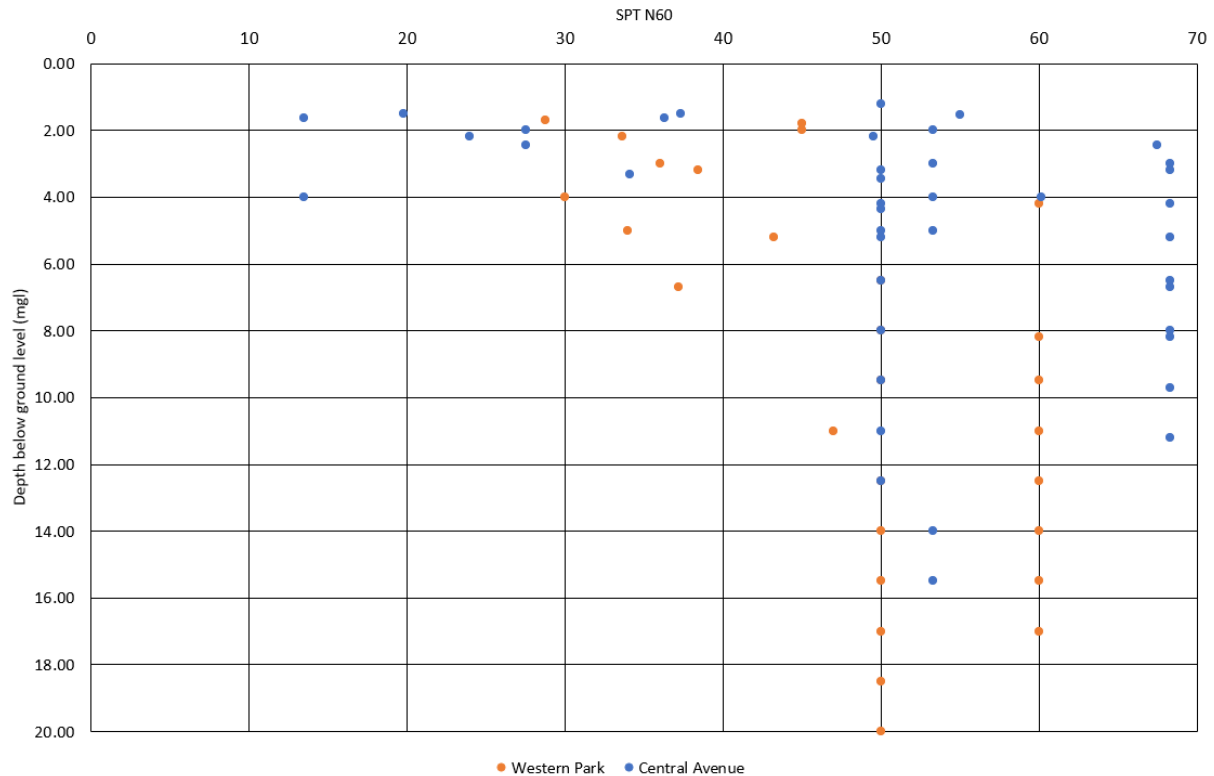


Figure 6-4 Residual Soil N60 Standard Penetration Test Values v depth

6.4.4 Strength

6.4.4.1 Undrained Shear Strength

The undrained Shear strength of Residual soil based on the SPT results has been calculated using the Stroud correlation where $c_u(\text{kPa}) = f_1 \times N_{60}$ ($f_1=5.0$ for Plasticity Index of 29%).

Table 6-2 summarises the results of in situ strength testing from Hand shear Vanes, Pocket Penetrometers and SPT testing in addition to Undrained Unconsolidated Triaxial testing.

Table 6-6 Summary of Undrained Shear Strength of Residual Soil

Statistic	SPT N_{60} *correlation	Hand Shear Vanes (peak)	Hand Shear Vanes (residual)	Pocket Penetrometer	Undrained Unconsolidated Triaxial
No. Tests	64 (8 Locations)	57 (13 Locations)	57 (13 Locations)	12 (4 Locations)	6 (4 Locations)
Minimum	61	28	12	100	32
Maximum	308	150	56	225	300
Average	225	98	25	158	112
Lower Quartile	202	69	16	101	37

*Based on the SPT results and using the Stroud correlation, $c_u(\text{kPa}) = f_1 \times N_{60}$ (where $f_1=5.0$ for Plasticity Index of 29%),

Table 6-2 summarises the results of in situ strength testing from hand shear vanes, pocket penetrometers and SPT testing in addition to undrained unconsolidated triaxial testing.

Figure 6-5 shows the triaxial, pocket penetrometer, and SPT N_{60} derived values and indicates a general increase in undrained shear strength with depth. The designer should select an undrained shear strength profile appropriate to the structure being designed and based on the results local to the structure/works.

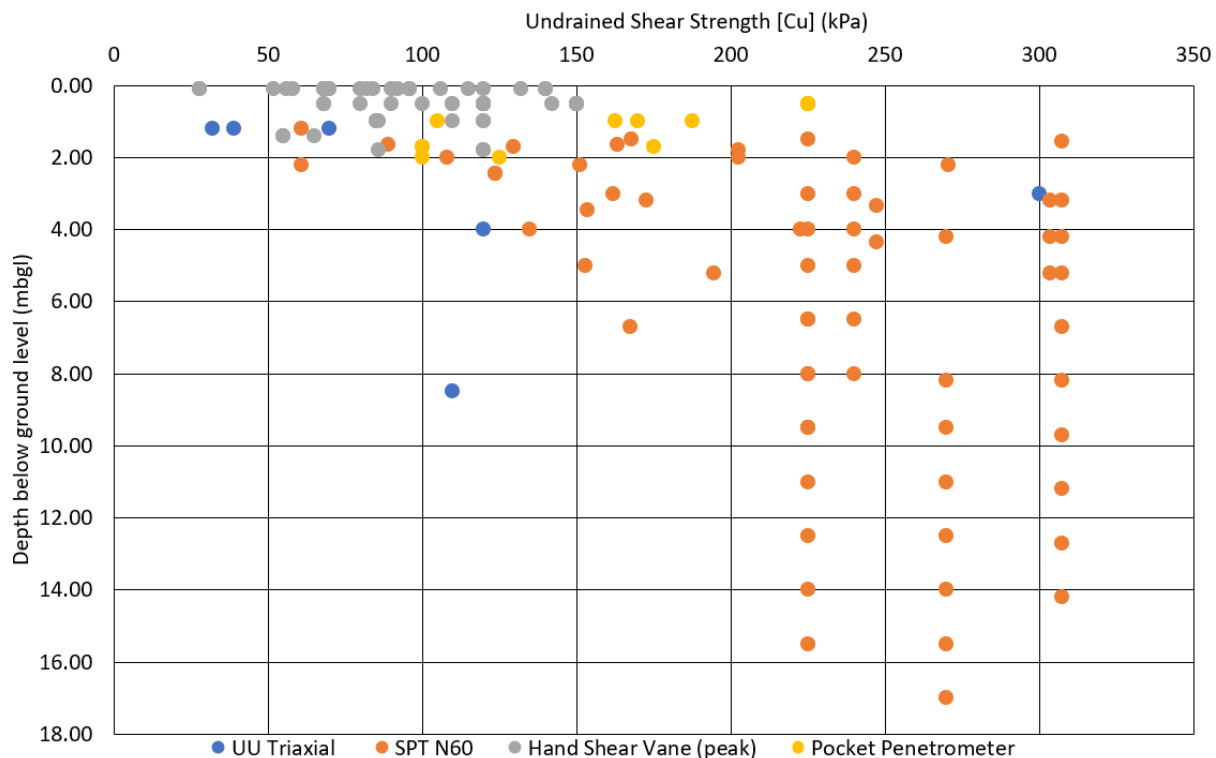


Figure 6-5 Undrained Shear Strength of Residual Soil

6.4.4.2 Drained Shear Strength

For drained shear strength of cohesive Residual Soil the proposed correlation by Santamarina et al., (2003) has been used to estimate the effective constant volume angle of shearing resistance ϕ'_{cv} . This is based on the returned plasticity indices (I_p) of the Residual Soil from Atterberg Testing summarised in Section 6.4.1. The following formula was used;

$$\phi'_{cv} = 42^\circ - 12.5 \log_{10}(I_p)$$

The modified Plasticity Index results ranged between 16% and 49% with an average of 25% and lower quartile of 23%, resulting in the correlated ϕ'_{cv} between 21° to 27° with an average of 24° and lower quartile of 22° .

6.4.4.3 Stiffness

The Jamiolkowski et al. (1979) correlation can be used to derive the undrained Youngs Modulus where:

$$E_u = 300 \cdot C_u$$

Which gives an undrained Youngs Modulus ranging between 10 MPa and 90 MPa as summarised in Table 6-7.

Assuming linear elasticity, the drained Youngs Modulus can be estimated according to the following formula where ν' is estimated to be 0.25.

$$E' = E_u \cdot 2 \frac{(1 + \nu')}{3}$$

Resulting in values ranging between 9MPa and 80MPa as summarised in Table 6-7.

Table 6-7 Summary of Youngs Modulus of Residual Soil

Statistic	Eu		E'	
	SPT	Triaxial	SPT	Triaxial
Minimum	18	10	15	9
Maximum	81	90	68	80
Average	45	34	38	30
Lower Quartile	36	11	30	10

6.4.5 Compaction

Compaction tests (2.5kg) were carried out on 9 No. samples of Residual Soil. The results are displayed in Table 6-8. The results show that the average optimum moisture content of 24% is 1% higher than the average natural moisture content of 23%.

Table 6-8 Dry Density/ Moisture Content Residual Soil

Area	Hole ID	Depth (m bgl)	Description	Natural Moisture Content (NMC) %	Maximum Dry Density (Mg/m3)	Optimum Moisture Content (%)
Central Avenue	RC01	0.90	Greyish brown slightly sandy silty clay	27	1.57	22
	RC02	0.90	Yellowish brown mottled greyish brown slightly gravelly slightly sandy silty clay	27	1.58	22
		0.90	Greyish brown slightly gravelly slightly sandy silty clay	25	1.60	22
	TP02	2.00	Greyish brown and yellowish brown slightly sandy silty clay	19	1.63	22
	TP03	1.00	Greyish brown slightly sandy slightly gravelly silty clay	22	1.60	24
	TP08	1.00	Light brown slightly gravelly slightly sandy silty clay	22	1.56	25
	TP19	0.80	Light brown mottled orange slightly sandy slightly gravelly silty clay with rare rootlets	20	1.56	21
	TP19	1.50	Orangish brown slightly gravelly slightly sandy silty clay	24	1.49	28
Western Park	TP41	1.00	Brown slightly sandy silty clay with occasional rootlets	20	1.49	26

6.4.6 Compressibility

3 No. one dimensional consolidation tests were undertaken in the Residual Soil at Western Park (DS01 & DS02) and a further sample along the Central Avenue Alignment is reported below (BH08). The samples were loaded to a level beyond their in-situ stress conditions, after which an unloading-reloading cycle was applied, followed by another stress increment. The coefficient of volume compressibility, M_v , and coefficient of consolidation, C_v , measured during oedometer testing is presented in Table 6-9. According to Tomlinson (2001), the Residual Soil has a very low to medium compressibility characteristics.

Table 6-9 Residual Soil Consolidation Test Results

Area	Hole ID	Test Depth	Stress (kPa)	Void Ratio	Volume Compressibility Coefficient (m_v) (m^2/MN)	Coefficient of Consolidation (c_v) ($m^2/year$)
	DS01	2.0	120	0.746	-	-

Area	Hole ID	Test Depth	Stress (kPa)	Void Ratio	Volume Compressibility Coefficient (m_v) (m^2/MN)	Coefficient of Consolidation (c_v) ($m^2/year$)
Western Park			40	0.719	0.063	-
			60	0.727	0.023	1.8
			80	0.727	0.056	2
			160	0.725	0.094	3.5
			40	0.712	0.055	-
			180	0.720	-	-
			360	0.712	0.042	12
			120	0.700	0.072	-
			160	0.729	0.013	3.3
			240	0.728	0.081	1.3
			480	0.717	0.075	0.84
			120	0.686	0.061	-
			60	0.647	-	6.3
			120	0.639	0.13	7.3
Central Avenue	BH08	1.2	40	0.627	0.11	-
			60	0.641	0.18	5.3
			80	0.635	0.081	3.3
			160	0.632	0.11	8.1
			40	0.619	0.095	-

6.4.7 Permeability

The permeability in vertical direction (K_v) has been derived from each oedometer test using the following equation:

$$K_v = c_v \cdot \gamma_w \cdot m_v$$

Where:

- c_v = coefficient of consolidation
- m_v = coefficient of volume compressibility
- γ_w = unit weight of water taken as 9.81 kN/m³

Permeabilities between 2.19×10^{-7} m/s and 4.47×10^{-5} m/s were estimated from the coefficients of consolidation derived from both the log-fitting methods.

6.5 Weald Clay Formation

The Weald Clay Formation was encountered in five locations across the site, at depths from 0.8m bgl to 9.3m bgl. The depth to base was not encountered in any exploratory locations.

The Weald Clay was described as extremely weak to weak grey and light grey thinly and thickly interlaminated mudstone and siltstone, fractures are sub-horizontal closely and medium spaced planar smooth. It is frequently described as weak grey and light grey siltstone with extremely closely to closely spaced thin laminae to very thin beds of mudstone and sandstone. Bedding fractures are described as sub-horizontal closely and medium space planar.

In addition, beds of medium strong mudstone, siltstone or sandstone were encountered. Described as slightly weak becoming medium strong, light brown to dark grey mudstone in BH03 between 19.10m bgl and 20.09m bgl and in BH05, a 0.35m thick band of medium strong grey and brown fine sandstone was noted from 15.50m to 15.85m bgl.

A summary of rock properties is provided in the following sections. Whilst some soil testing has been undertaken on samples recovered as gravel they are not representative of the rock properties in situ and therefore have not been presented but can be reviewed in the Factual Report in Appendix C.

The following tests were undertaken in the Weald Clay:

- 21 No. Standard Penetration Tests (SPT)
- 4 No. Uniaxial Compressive Strength Tests (UCS)
- 16 No. Point Load Index Tests (PLT)
- 1 No. Lightweight Deflectometers

6.5.1 Surface Modulus and California Bearing Ratio

6.5.1.1 Light Weight Deflectometer Testing

One Light Weight Deflectometer (LWD) test was undertaken adjacent to TP18 containing Weald Clay at 0.75m depth as presented in Table 6-10. The trial pit log indicates the top of siltstone at this depth.

The results from the LWD testing using the Equation 2.4, $E = 17.6(CBR^{0.64})$ from CD225 to calculate the California Bearing Ratio (CBR) value would yield a result outside the range for which this equation is applicable i.e. outside the range of 2-12%.

Table 6-10 Weathered Weald Clay CBR summary from Laboratory Testing – Central Avenue

Location	Reference	Summary Soil Description	Test Depth (m)	Average Surface Modulus, E0 (MPa)	Average CBR Value (%)
TP18	TP18-3	Extremely weak light bluish grey stained dark orangish brown siltstone recovered as silty angular and subangular fine to coarse siltstone gravel and subangular siltstone cobbles.	1.00	111.00	>12%*

Note:

“*” denotes the CBR values outside of CD225 equation applicable range

6.5.2 Strength

The majority of the rock encountered was described as extremely weak to very weak rock comprising of mudstone.

The strength of rock, as noted in BS5930:2015+A1 2020, with the strength descriptor of extremely weak rock corresponds to UCS of 0.6 MPa – 1 MPa and very weak rock corresponds to UCS of 1 MPa – 5 MPa.

With depth some log descriptions note bands of weak Mudstone and Siltstone which as noted in BS5930:2015+A1 2020 corresponds to UCS of 5 MPa – 25 MPa.

Occasional bands of Mudstone, Siltstone, and Sandstone were described as medium strong rock, which is noted in BS5930:2015+A1 2020 corresponds to UCS of 25MPa – 50 MPa.

6.5.2.1 Standard Penetration Test

21 No. Standard Penetration Tests (SPT) were undertaken in the Weathered Weald Clay material. A minimum SPT N value of 47 was recorded within the Weathered Weald Clay, the remainder reached refusal value of 50.

The four results where the SPT did not refuse were in rock described as extremely weak mudstone corresponding to a UCS of 0.6-1.0 MPa as indicated in BS5930:2015+A1 2020 as presented in Figure 6-6

6.5.2.2 Unconfined Compressive Strength and Point Load Test

A bulk unit weight of 22-23 kN/m³ is recommended for the Weald Clay Formation based on four results from UCS laboratory testing on Mudstone. The results of UCS testing ranged from 0.10 MPa to 0.40 MPa, failing by shear and axial cataclasis.

16 No. point load tests were carried out on samples taken from the Weald Clay Formation within Mudstone and Siltstone to determine the strength index values, reported as I_{s50} . The results of the testing are presented in Table 6-11, Table 6-12 and Figure 6-6 which show that generally axial test results are higher than diametral results for both mudstone and siltstone and there is an increase in strength with depth.

A correlation between the rock description and strength was identified for the Brookleigh site, as reported in the Phase 2,3,4 GIR. The factors applied are based on site specific correlations between PLT and UCS testing on similar sample depths and rock description, across the Brookleigh site. For Mudstones using 19 test results a correlation factor of 14 was applied, and for siltstones using 2 tests a correlation factor of 29 was applied.

The results indicate that the rock, is based on BS 5930, ranging predominantly from less than extremely weak rock (<0.6MPa) to very weak from the results of UCS and PLT rock testing.

Table 6-11 Point Load Axial and Diametral Results- Mudstone

Orientation	Western Park		Central Avenue	
	Axial	Diametral	Axial	Diametral
No. Tests	5	5	1	1
Range	0.03-0.18	0.04-0.18	0.10	0.01
Average	0.11	0.08	-	-

Table 6-12 Point Load Axial and Diametral Results- Siltstone

Orientation	Western Park		Central Avenue	
	Axial	Diametral	Axial	Diametral
No. Tests	1	1	1	1
Range	0.01	0.01	0.34	0.11

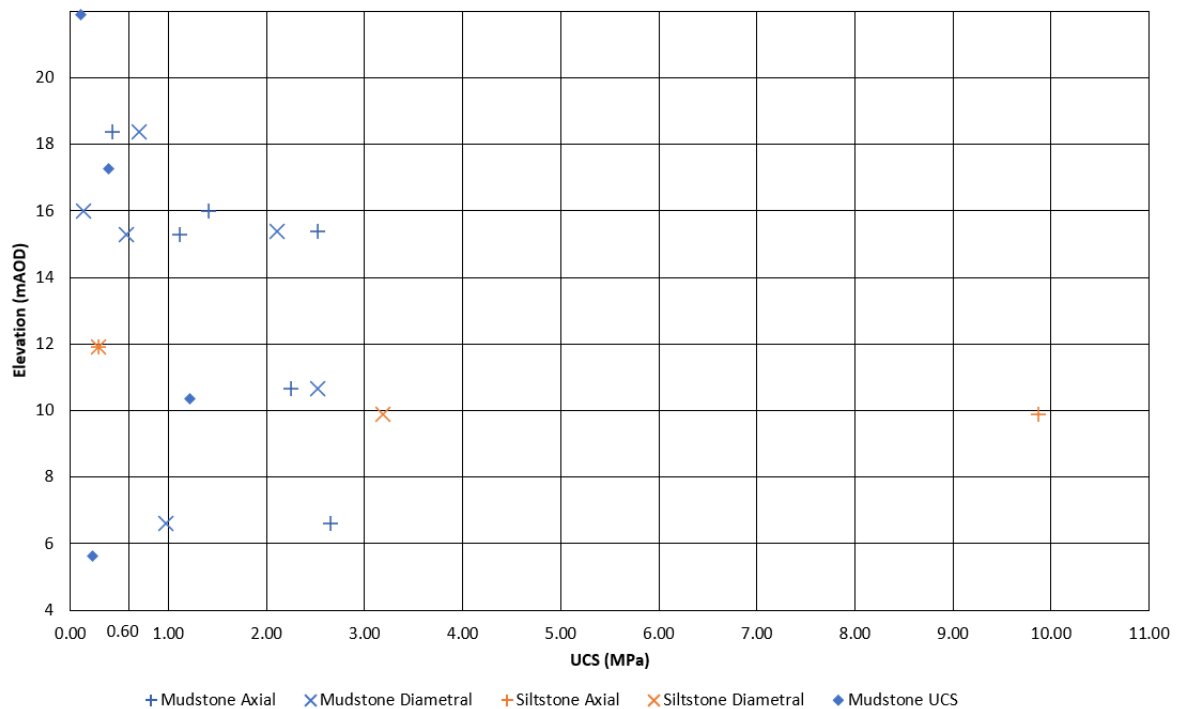


Figure 6-6 Unconfined Compressive Strength Weald Clay

6.5.3 Deformation Modulus of Rock Mass

The parameters used as inputs to determine the Intact Modulus (E_i) of the mudstone are summarised below.

- Geological Strength Index (GSI) = 30 - Based on structure and surface conditions of fracture in rock with bedding planes and laminated zones noted.
- $M_i = 4$ (Based on typical values for 'Claystone' from RocScience RocLab)
- Uniaxial compressive strength for intact rock (σ_{ci}) and
- Modulus ratio (MR), a ratio of mass to intact modulus (E_{rm}/E_i).

The following formula was applied using RocScience RocLab;

$$E_i = MR \sigma_{ci}$$

Where:

- σ_{ci} was based on the UCS and PLT testing
- Modulus ratio (MR) = 250 (Based on typical values in RocLab for Mudstone & Siltstone (claystone))

Table 6-13 Intact Modulus: Weald Clay Central Avenue and Western Park

Strength Description	UCS (MPa)	Mudstone/ Siltstone E_i (MPa)
Extremely Weak	0.6-1.0	150-250
Very Weak	1.0-5.0	250-1250
Weak	5.0-25.0	1250-6250
Medium Strong	25-50	6250-12500

The designer should select an unconfined compressive strength profile appropriate to the structure being designed and based on both borehole descriptions and test data local to the structure.

6.5.1 Rock Quality Designation (RQD)

Rock Quality Designation (RQD) values were derived from all solid core recovered from BH01 to BH03, BH05, BH08 and BH15 within the GEL 2023 GI. The frequency of RQD is presented in Figure 6-7.

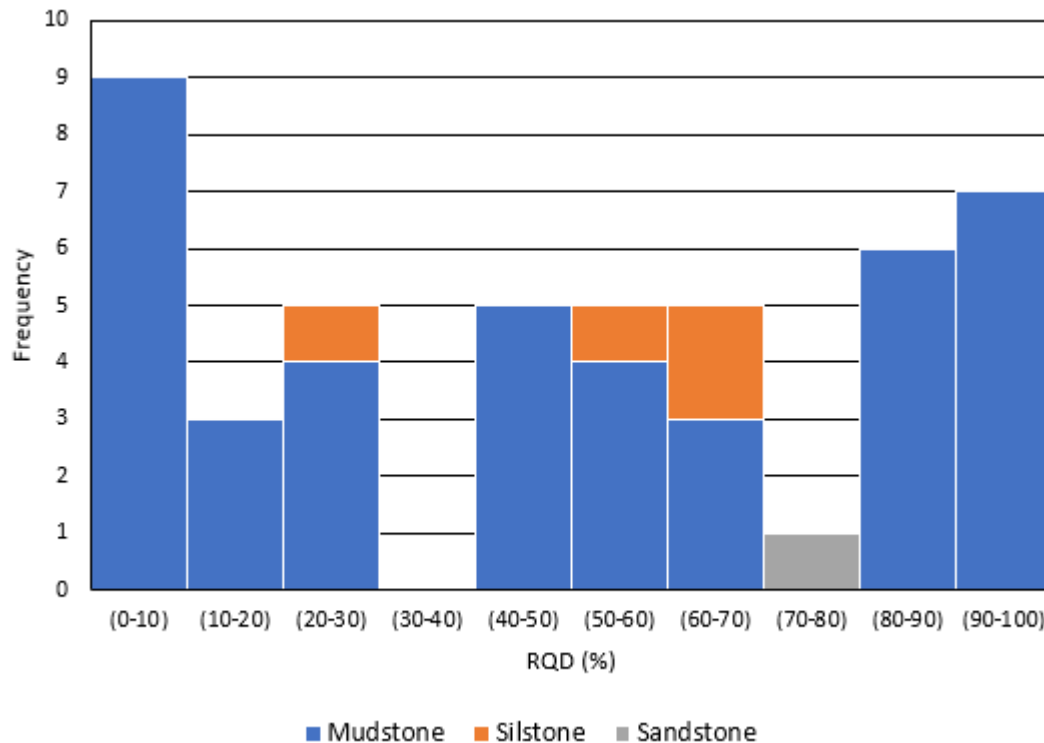


Figure 6-7 Rock Quality Designation Weald Clay

The RQD was considered in line with descriptions on exploratory logs. The recovery for Sandstone and Siltstone Bands was 100% across the Site however presented RQD of between 37% and 85%. There is no correlation between depth and RQD.

6.6 Soil and Groundwater Chemistry (Sulphates)

The results of site-specific ground aggressivity testing have been reviewed against the procedure outlined in BRE Special Digest 1:2005 Concrete in aggressive ground, to determine the Design Sulphate (DS) and Aggressive Chemical Environment for Concrete (ACEC) classes for the strata beneath the site. Brownfield conditions have been assumed for all strata and groundwater has been assumed to be static. The DS and ACEC class were based on the 2:1 water soluble sulphate since the amount of oxidisable sulphides were not greater than 0.3% SO₄ in a significant number of samples of any of the strata.

Table 6-14 summarises the DS and ACEC classes to be adopted for the design of buried concrete across Western Park and Central Avenue.

Table 6-14 Summary of BRE SD1 Assessment

Sample	Property	No. of Tests	Results Range	Characteristic value	DS Class	ACEC Class
Made Ground	2:1 Water soluble sulphates (SO ₄ mg/l)	1	21	21	DS-1	AC-1s
	Total Potential Sulphates (SO ₄ %)		0.09	0.09		
	pH		7.9	7.9		
Residual Soil	2:1 Water soluble sulphates (SO ₄ mg/l)	11	10-130	112	DS-1	AC-1s

Sample	Property	No. of Tests	Results Range	Characteristic value	DS Class	ACEC Class
	Total Potential Sulphates (SO ₄ %)		0.03-0.12	0.58		
	pH		5.6-8.4	5.6		
Weald Clay	2:1 Water soluble sulphates (SO ₄ mg/l)	9	10-96	96	DS-1	AC-1s
	Total Potential Sulphates (SO ₄ %)		0.03-0.42	0.42		
	pH		5.6-9.3	5.6		
Groundwater*	Sulphates (SO ₄ mg/l)	32	14-910 (Weald Clay)	1400	DS-2	AC-2
			120-1400 (Residual Soil)			
	pH		6.6-7.3 (Weald Clay)	6.6		
			7.1-7.2 (Residual Soil)			

*Groundwater samples were only undertaken within samples of Residual Soil and Weald Clay

It should be noted that BRE SD1 lists the Weald Clay as a formation that is known to contain pyrite. It also mentions that the Weald Clay is one of the formations likely to have substantial sulphate concentrations. The DS-1 and AC-2 classes given above could potentially underestimate the soil aggressivity where pyrite content is high. Selenite (produced by weathering of pyrite) was noted within Residual Soil and Partially Weathered Weald Clay at three exploratory locations; TP04, TP05 and TP41. It is possible that it was present in additional locations on site.

6.7 Road Cores

Three road cores (RC01 to RC03) were carried out within Cuckfield Road to confirm the road construction at these locations. Tarmacadam was found from surface for between 0.13m and 0.15m. In RC02 the tarmacadam was underlain by 0.2m of concrete. All locations had Made Ground underlying the road construction comprising of sands and gravel. The Made Ground was found to be to depths of between 0.6m bgl and 0.75m bgl with residual soil of Weald Clay in the base of the excavations.

6.8 Soakaway Testing

A total of 6 number of soakaway tests were carried out in trial pits (TP08, TP10, TP17 to TP19, and TP41). The testing was carried out in general accordance with BRE 365. All the testing was unsuccessful, and no infiltration rates were recorded due to very slow water ingress regardless of underlying geology in Residual Soil or Partially Weathered Weald Clay.

6.9 Summary of Derived Geotechnical Parameters

A summary of geotechnical parameters for the Made Ground, Residual Soil and Weald Clay is provided in the Table below. The designer should select an appropriate ground profile and parameters for the structure being designed and based on both exploratory hole descriptions and test data local to the structure.

Table 6-15 Summary of Derived Geotechnical Parameters

Parameter	Unit	Topsoil	Made Ground	Residual Soil (Grades V & VI)	Weald Clay (Grades I to II)	Justification
Uncorrected SPT N Value	Blows/300mm	-	-	10-50	47-50	In situ strength testing
SPT 'N60'	-	-	-	14-68	-	In situ strength testing
Natural Moisture Content (MC) %	%	-	17*	11-29 (AV 21, LQ 16)	-	*one sample only Classification laboratory testing
Plastic Limit (PL)	%	-	22*	19-32 (AV 25, LQ 23)	-	*one sample only Classification laboratory testing
Liquid Limit (LL)	%	-	51*	37-76 (AV578, LQ 51)	-	*one sample only Classification laboratory testing
Plasticity Index (PI)	%	-	29*	16-49 (AV 33, LQ 27)	-	*one sample only Classification laboratory testing
Modified Plasticity Index (I _p)	%	-	16*	16-49 (AV 31, LQ 23)	-	*one sample only Classification laboratory testing
Unit Weight of Material	kN/m ³	-	17	19	-	Classification laboratory testing and Table 1 BS8002
Undrained Shear Strength (Cu)	kPa	-	80-120 [Pocket Penetrometer - PP]	61-308 (AV 225, LQ 202) [SPTN60] 100-225 (AV 158, LQ 101) [PP] 32-300 (AV 112, LQ 37) [Triaxial UU]	-	In situ strength testing and laboratory undrained unconsolidated (UU) Triaxial testing
Effective Strength, angle of constant shearing resistance (ϕ'_{cv})	°	-	26	21-27 (AV 24)	-	Santamarina et al., (2003)

Parameter	Unit	Topsoil	Made Ground	Residual Soil (Grades V & VI)	Weald Clay (Grades I to II)	Justification
Drained Stiffness	MPa	-	-	9-80 (AV 30, LQ 10)	-	Jamiolkowski et al., (1979)
Undrained Stiffness	MPa	-	24-36	10-90 (AV 34, LQ 11)	-	Made Ground stiffness based on corelation with pocket penetrometer tests. Further testing is required to verify these values if Made Ground properties are required for design. Jamiolkowski et al. (1979)
CBR (test values)	%	-	3.6- 4.1 [LWD]	Top 0.96-17 Base 0.55-7.8 [Lab] 2-11 (AV 6, LQ 3) With some values less than 2.5% [LWD]	>12% [LWD] On siltstone. Further testing may be required where other lithologies are present at subgrade	Lightweight Deflectometer (LWD) using TRRL Laboratory Report 1132, Laboratory Soaked and Unsoaked CBR
CBR (equilibrium values)	%	-	3.5-5.0	3.5-5.0	-	TRRL Laboratory Report 1132 Laboratory Plasticity Index Testing
Permeability (kv)	m/s	-	-	$2.19 \times 10^{-7} - 4.47 \times 10^{-05}$	-	Consolidation Testing
Volume Compressibility Coefficient (Mv)	m ² /MN	-	-	0.023-0.081	-	One dimensional consolidation tests
Optimum Moisture Content	%	-	-	21- 28 (AV 24)	-	Compaction Testing
Maximum Modified Dry Density	Mg/m ³	-	-	1.49-1.63 (AV 1.56)	-	Compaction Testing
Unconfined Compressive Strength (UCS)	MPa	-	-	-	0.1 to 0.4	UCS Testing Rock descriptions indicate that the Weald Clay (Grades I and II) is predominantly extremely weak to very weak. Figure 6-6 indicates strengths less than extremely weak can be present as recorded in UCS and PLT testing.
Point Load Testing (PLT)	MPa	-	-	-	Siltstone 0.01-0.11 (Diametral) 0.01-0.34 (Axial) Mudstone 0.01-0.18 (Diametral)	Point Load Testing

Parameter	Unit	Topsoil	Made Ground	Residual Soil (Grades V & VI)	Weald Clay (Grades I to II)	Justification
0.10-0.18 (Axial)						
Intact Modulus(Ei) – mudstone/siltstone	MPa	-	-	-	Extremely Weak 150-250 Very Weak 250-1250 Weak 1250-6250 Medium Strong 6250-12550	Rocscience Roclab

Notes:

LQ – lower quartile; AV - average

7. Engineering Recommendations

7.1 Soakaways

The results of all infiltration testing indicated that the ground conditions are not suitable for infiltration due to the limited infiltration achieved during the testing.

7.2 Shallow Foundations and Earthworks

Information on the final design and loadings of structures is not yet available. For typical house construction of 2-3 storeys, with low magnitude loads, shallow foundations are likely to be suitable. For more heavily loaded developments such as apartment blocks, and multistorey business infrastructure piles may be required. The depth to groundwater will need to be considered in the foundation design.

The depth of the foundations in shrinkable soils is dependent on the shrinkage potential of the soil and the presence of any existing, recently removed or proposed vegetation. Based on the classification testing the Residual Soil at the site is indicated to be of medium and high volume change potential for which a minimum foundation depth of 1.0m is recommended in the NHBC standards outside the no tree planting zone or the zone where any existing trees may have an influence. Where foundations will be within the zone of influence of vegetation the founding depth will need to be increased in accordance with published standards (e.g. NHBC).

The exploratory holes in Weald Clay indicate the ground may be relatively stable in the short term in open excavations. All excavations requiring person entry should be battered well back or be provided with close/continuous support. The exploratory holes also indicate that groundwater seepage/flow should be expected as shallow as 1.3m bgl with ongoing monitoring returning results at surface.

Ground improvement may be required in areas of land raising to control excessive post construction settlements. The need for ground improvement would need to be assessed when further detailed design of the proposed works become available.

7.3 Deep Foundations

It is likely that deep foundations such as piling will be required for multi-occupation buildings such as apartment blocks. Pile foundations are also likely to be required for commercial buildings located to the west at Western Park. This will need to be assessed when further details of structures are available.

7.4 Road Pavement

The estimated minimum range of equilibrium CBR values for soils and groundwater conditions described above, under a completed pavement, is based on TRL LR1132. The recommended sub-grade soil CBR value for road pavement design is presented per tested strata in section 6 with a summary included in Table 6-15. The values assume that during construction the formation level will be carefully compacted, and any soft spots or silt dug out and replaced by a compacted suitable granular fill and that continuous monitoring will be undertaken during construction to ensure that the in situ CBR values is always higher than the design. The soaked CBR lab test results indicate that CBR values can be less than 2% if the formation is allowed to become saturated. Drainage may need to be considered to prevent the formation becoming saturated.

The sub-grade soils can be regarded as potentially frost -susceptible, due to description of Residual Soil in parts as silt and weathered Siltstone within the Weald Clay after the criteria given in Manual of Contract Documents for Highway works Series 700. Where the sub-grade is frost-suspectable the thickness of subbase must be sufficient to give a total thickness of non-frost susceptible pavement over the soil of not less than 450mm.

7.5 Design of Buried Concrete

Assessment of the results of pH and sulphate testing indicates that concrete in contact with the soils will need to be designed for at least Design Sulphate Class of DS-2 and an ACEC class of AC-2. Consideration should be given to higher classes due to the potential mentioned in BRE SD1 that Weald Clay related formations are likely to have substantial sulphate concentrations.

8. Geo-environmental Assessment

This section presents a Tier 1 and Tier 2 contaminated land assessment undertaken in general accordance with Land Contamination Risk Management (LCRM) guidance, following the completed GI work covering the Western Park (WP) and Central Avenue areas of the Northern Arc – Brookleigh development.

This assessment aims to identify potential risks and constraints arising from land contamination. Both past and current potentially contaminative land uses, along with data obtained during the GI, have been considered. Note localised areas of contamination may not have been identified due to the distribution of the exploratory locations and the limited coverage of the GI works.

8.1 Conceptual site Model and Preliminary Risk Assessment

A preliminary conceptual site model (CSM) has been developed for the site considering the proposed land use, which includes public open space (Western Park), with five attenuation ponds that form part of the Sustainable Drainage System, and the Central Avenue access road. The CSM is based on the environmental setting of the site and a review of current and historical development on-site (and in the immediate surroundings).

8.1.1 Sources

8.1.1.1 On-site Sources

Historical mapping (sourced from a Envirocheck report, available to view as Appendix C) shows that the site has been occupied by woodland and open fields with sporadic infrastructure and buildings, with on-site surface water tributaries of the River Adur since earliest available historical mapping (published 1879). There has been little development since in infrastructure and buildings, with the present site still occupied predominantly by fields. A detailed summary of the historical maps is included in Section 3.6.

Based on historical and existing land uses, the following potential sources of contamination have been identified on-site:

- Agricultural land use.

8.1.1.2 Off-site Sources

Off-site developments include roads, residential properties present from 1879 and two sewage treatment works. The first to the south from 1899 to present and the second present to the west since 1992. Further residential development occurred during the 1960s to 1970s, as well as isolated buildings associated with farming practices, schools and hospitals.

Based on historical and existing land uses, the following potential sources of contamination have been identified within 250 m from the site:

- Sewage Farms;
- Historical Electrical Substation;
- Agricultural land uses; and
- a golf course.

Uncontrolled fly tipping has been noted in the Freek's Farm site to the east. The Freek's Farm site has been investigated previously (AECOM, 2019) and it is understood that the waste has been remediated as part of previous phases of work. As such it is not considered to be a viable source of contamination to the site.

Potential sources of contamination located at more than 250 m from the site are considered unlikely to affect ground conditions at the site and are therefore not considered further in this assessment.

8.1.1.3 Contaminants of Potential Concern

Based on the potentially contaminative land uses described above, the following contaminants of potential concern (CoPC) have been identified:

- Asbestos;

- Metals;
- Inorganics including nitrate, pH, ammoniacal nitrogen as N;
- Polycyclic aromatic hydrocarbons (PAH);
- (Total) petroleum hydrocarbons (TPH);
- benzene, toluene, ethyl benzene, and xylenes (BTEX) and Methyl tert-butyl ether (MTBE);
- Poly-chlorinated biphenyls (PCBs);
- Volatile and semi-volatile organic compounds (VOCs and SVOCs);
- Pesticides and herbicides;
- Sulphate; and
- Ground gases (CH₄ and CO₂).

8.1.2 Potential Pathways for Exposure and Migration

For the purpose of this assessment, the principal pathways for contaminant exposure and migration are considered to be as follows:

- Human Health:
 - Direct contact (soil ingestion, dermal contact, dust ingestion/inhalation) with contaminated soils and asbestos fibres in areas of soft standing, and;
 - Plant uptake and consumption of homegrown produce from community gardens; and
 - Migration of vapours and ground gases via permeable strata to enclosed spaces, with subsequent inhalation by offsite building occupants (in future residential buildings).
- Controlled Waters:
 - Leaching of contaminants and vertical migration through permeable unsaturated strata into groundwater; and,
 - Lateral and vertical migration via the underlying groundwater.
- Risks to property:
 - Corrosion of concrete and ground structures and services; and
 - Gas ingress to buildings and creation of hazardous atmospheres.

8.1.3 Potential Receptors

For the purposes of this assessment, the principal receptors are as follows:

- Human health:
 - site users, including future residents at the wider development, users of the park and community garden, maintenance workers and visitors; and
 - Neighbouring residential receptors.
- Controlled Waters:
 - Groundwater, the Secondary A aquifers of the Alluvium and the Horsham Stone Member. The site is not located within 500m of an SPZ. The Weald Clay is classified as an unproductive stratum so is not considered to be a viable receptor.
 - Surface Water: the nearest surface water feature are two tributaries of the River Adur which are present on-site.
- Building structures and services.
 - Below ground elements of the proposed housing development, associated infrastructure and services.
 - On and off-site buildings that could be affected by ground gas ingress.

It should be noted that the CSM considers the long-term use of the site rather than potential short-term and typically higher frequency of exposure for construction and maintenance workers carrying out earthworks or below-ground maintenance (e.g. repair of underground utilities).

These short-term potential exposure routes should be managed using appropriate health and safety controls during the construction and operational phases, respectively. As such, construction workers are not considered further as receptors in this assessment.

8.1.4 Preliminary Risk Assessment

In accordance with Land Contamination Risk Management (LCRM) guidance, the Tier 1 assessment has identified a range of viable contaminant linkages. The approach to the preliminary risk assessment has been based on the CIRIA C552 guidance (Contaminated Land Risk Assessment: A Guide to Good Practice). For each pollutant linkage an estimate of the potential severity (consequence) and probability (likelihood) has been undertaken. Table 8-4 below summarises the identified linkages and the identified risk magnitude.

Using criteria based on those presented in the Construction Industry Research and Information Association (CIRIA) publication C552, the magnitude of the risk associated with potential contamination at the site has been assessed. To do this an estimate is made of:

- The magnitude of the potential consequence (i.e., severity).
- The magnitude of probability (i.e., likelihood).

The severity of the risk is classified according to the criteria in Table 8-1 below.

Table 8-1 Classification of Severity

Risk	Description
Severe	• Short term (acute) risks to human health likely to result in "significant harm" as defined by Part 2A of the Environment Protection Act 1990 (e.g., high concentrations of cyanide at the surface in recreational areas) • Catastrophic damage to buildings/property (e.g., potential for explosion causing building to collapse) • Short term risk pollution / major pollution of controlled waters (e.g., major spillage of contaminants into controlled waters) • Short term risk to a particular ecosystem or organism forming part of an ecosystem
Medium	• Chronic (long-term) risk to human health likely to result in "significant harm" (contaminant concentrations exceeding generic or site-specific assessment criteria) • Pollution of sensitive controlled waters (e.g., leaching of contaminants into surface watercourses or principal / secondary aquifers) • Significant change in an ecosystems or organism forming part of an ecosystem (e.g., death of a species within a designated nature reserve)
Mild	• Pollution of non-sensitive waters (e.g., unproductive strata) • Significant damage to crops, buildings, structures and / or services (e.g., rendering a building unsafe to occupy from instability due to foundation damage) • Damage to sensitive buildings, structures, services or the environment
Minor	• Harm, although not necessarily significant harm, which may result in financial loss or expenditure to resolve (e.g., loss of plants in a landscaping scheme) • Non-permanent human health effects to humans (easily prevented by means such as personal protection clothing) • Easily repairable damage to buildings, structures or services

The probability of the risk occurring is classified according to the criteria shown in Table 8-2.

Table 8-2 Classification of Probability

Probability	Description
High Likelihood	• There is a pollution linkage and an event either appears very likely in the short term and almost inevitable over the long term, or there is evidence at the receptor of harm or pollution

Likely	There is a pollution linkage and all the elements are present and in the right place which means that it is probable that an event will occur
Low Likelihood	There is pollution linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a longer period such an event would take place, and it is less likely in the shorter term.
Unlikely	There is a pollution linkage but circumstances are such that it is improbable that an event would occur even in the very long term.

An overall evaluation of the level of risk is gained from a comparison of the severity and probability, as shown in Table 8-3.

Table 8-3 Risk Evaluation

		Severity			
Likelihood		SEVERE	MEDIUM	MILD	MINOR
	HIGH	Very High	High	Moderate	Moderate/Low
	LIKELY	High	Moderate	Moderate/Low	Low
	LOW	Moderate	Moderate/Low	Low	Very Low
	UNLIKELY	Moderate/Low	Low	Very Low	Very Low

Table 8-4 Summary of Tier 1 Preliminary Risk Assessment.

Source	Pathway	Receptor	Severity	Likelihood	Risk Rating	Comments
On-site: Agricultural land uses. <i>(Potential contaminants including but not limited to asbestos, metals, PAH, TPH, PCBs, SVOCs VOCs, Pesticide & Herbicides,)nitrate, ammoniacal nitrogen as N, sulphate, ground gases</i>	Dermal absorption or ingestion of soil	Human Health: Future site users (users of the park, community garden and transitory users of the road), maintenance workers, and members of the public.	Medium	Low	Moderate/Low	Limited potential for unacceptable risk as no significant contamination sources identified.
	Plant uptake and consumption of homegrown produce	Human Health: Future site users notably those using the community garden.	Medium	Low	Moderate/Low	Limited potential for unacceptable risk as no significant contamination sources identified.
	Migration of contaminants via airborne dusts followed by inhalation.	Human Health: Future site users, maintenance workers, and members of the public; and Off-site residents and workers.	Medium	Unlikely	Low	Limited potential for unacceptable risk as no significant contamination sources identified.
	Vapour and/or ground gas intrusion and inhalation.	Human Health: Off-site occupants of residential housing Maintenance workers in confined spaces	Medium	Unlikely	Low	Limited potential for unacceptable risk as no significant contamination sources identified.
	Leaching of chemicals and vertical migration via permeable unsaturated strata into groundwater	Controlled Waters: Groundwater, specifically the Secondary A Aquifers of Alluvium and the Horsham Stone Member.	Medium	Low	Moderate / Low	Limited potential for elevated concentrations of chemicals based on the identified sources.
	Lateral migration of impacted groundwater off-site towards surface water.	Controlled Waters: Surface water, tributaries for the River Adur, and surface water ponds.	Mild	Low	Low	Limited potential for elevated concentrations of chemical and a limited pathway to adjacent surface water

Source	Pathway	Receptor	Severity	Likelihood	Risk Rating	Comments
						receptors, unlikely to exceed EQS criteria.
	Direct contact causing corrosion of sub-surface concrete foundations and ground structures/services with aggressive ground conditions	Property & infrastructure: Residential, commercial and community facilities, Infrastructure, services, and landscaped area.	Mild	Low	Low	Limited potential for elevated concentrations of corrosive aggressive chemical environments and limited underground infrastructure.
	Migration of hazardous gases and organic vapours via permeable strata and/or through preferential pathways created by buried services – creation of hazardous atmospheres	Property & infrastructure, On-site confined spaces and off-site buildings.	Mild	Low	Low	Limited potential for elevated concentrations of ground gases
Offsite sources: Sewage Farm (located ~ 170 m south of the site), Agricultural/golf course land uses, substation. .	Migration of contaminants via airborne dusts followed by inhalation.	Human Health: Future site users, maintenance workers, and members of the public.	Medium	Unlikely	Low	Limited anticipated presence of airborne dust from adjacent site activities
<i>(Potential contaminants including but not limited to asbestos, metals, PAH, TPH, PCBs, SVOCs, VOCs, Pesticide & Herbicides, nitrate, ammonical nitrogen as N, sulphate)</i>	Lateral migration of impacted groundwater towards the site	Controlled Waters: Groundwater, specifically the Secondary A aquifers of the Alluvium and the Horsham Stone Member.	Mild	Low	Low	Low potential for elevated concentrations of chemical from offsite sources to aquifers underlying site
	Lateral migration of impacted Surface water towards the site	Controlled Waters: Surface water, tributaries for the River Adur	Mild	Low	Low	Low potential for elevated concentrations of chemical from offsite sources to surface water present on site

8.2 Ground Investigation

As described in Section 4 GI was completed at the site between 17th July to 22nd and August 2023 , followed by six rounds of ground gas and groundwater monitoring between 14th September 2023 and 9th November 2023.

Geo-environmental laboratory analysis was carried out on selected soil and groundwater samples collected during the ground investigation and subsequent monitoring. A Factual Report detailing the work completed is provided in Appendix C.

8.2.1 Geo-environmental Soil Sampling

A total of 43 soil samples have been taken during the excavation of 1No. rotary boreholes (BH03), 2 Dynamic Sampling Boreholes (DS01-02), and 11 Trial Pits (TP02-03, TP05, TP08, TP10, TP17-19, TP27, TP30 & TP41) with 14 samples scheduled for laboratory soil analysis and 6 samples scheduled for soil leachate/WAC analysis. The analyses undertaken were for a variety of chemicals and selected based on the current/historical land uses of the site. Soil samples were obtained from a range of depths extending from between 0.1m bgl to 1.0-1.2 bgl.

Asbestos was not observed within any of the exploratory locations and was not detected in any of the 14 samples scheduled for asbestos identification analysis.

Full details of the samples taken during the GI, borehole logs and laboratory certificates are provided in the factual report in Appendix C with the ground conditions encountered discussed in Section 4.3.2 above.

The site location plan and exploratory hole location plans are provided in Appendix A.

8.2.2 Groundwater Monitoring and Sampling

Two groundwater monitoring events took place during the ground investigation occurring between 2nd and 13th August 2023, a further six groundwater monitoring events were undertaken post site works completion between 14th September 2023 and 9th November 2023, which involved taking water level readings from a total of four monitoring wells using an oil-water interface probe.

Groundwater sampling was undertaken on the site during monitoring Round 5 (11th October 2023), with samples collected from two well installations. The samples were collected from standpipes with response zones within the Weald Clay Formation.

No water samples were collected from the shallow 19mm standpipes.

The groundwater levels from the boreholes are provided in Section 5.2.2 above and in the 2023 factual report in Appendix C.

8.2.3 Visual and Olfactory Evidence of Contamination

No visual or olfactory evidence of contamination was recorded at any of the exploratory locations.

Headspace readings of soil samples were taken on-site during borehole development monitoring for volatile vapours using a MiniRAE Lite Photoionization Detector (PID) with a 10.6eV gas discharge lamp. Three PID readings reported a concentration greater than the instrument detection limit of 0.1 ppm, ranging from 0.3 – 2.7ppm, with the highest reading noted in TP03 at a depth of 1.0m bgl. All samples with readings >0.5ppm were scheduled for VOC/SVOC analysis.

8.2.4 Ground Gas

Six rounds of ground gas monitoring were undertaken between 14th September 2023 and 9th November 2023. Ground gas concentrations were recorded at three monitoring wells.

No ground gas monitoring was undertaken from the shallow 19mm standpipe at BH03.

The results are presented in the factual report in Appendix C.

8.3 Contamination Assessment

8.3.1 Generic Quantitative Risk Assessment (GQRA) Methodology

AECOM has completed a Tier 2 Generic Quantitative Risk Assessment (GQRA) in general accordance with Land Contamination Risk Management (LCRM) guidance for the chemical data collected as part of the GI works.

The purpose of GQRA as defined in LCRM guidance is to establish where Generic Assessment Criteria (GAC) and assumptions about a site are appropriate for assessing risks and, if so, to apply them to site data in order to establish whether there are actual or potentially unacceptable risks.

The GQRA also determines whether further detailed assessment is required. In doing so, it confirms whether the potential contaminant linkages identified in the preliminary risk assessment are of concern or not.

The assessment methods and criteria adopted for the GQRA are described below, followed by a comparison of the analytical data against the assessment criteria. The tabulated data screened against the relevant human health (HH) and controlled waters (CW) assessment criteria are included in Appendix G.

8.3.2 Human Health Screening Assessment Methodology

8.3.2.1 Selection of Human Health Generic Assessment Criteria Soils

Stage 1, Tier 2 GQRA has been undertaken in general accordance with LCRM guidance as an initial conservative screen based on default assumptions about land use, soil type and pathway.

The likely pathways associated with risk to human health, relevant to the GQRA are:

- Direct contact (ingestion, dermal contact, inhalation of dusts) with contaminated soils and groundwater during future use (by residents or maintenance workers).
- Exposure to contaminants via the vapour pathway for future site users or maintenance workers. However, there is the potential for maintenance workers to be exposed to vapours if accessing inspection chambers.

Soils results have therefore been assessed using assessment criteria appropriate to pathways including direct contact and vapour intrusion.

AECOM understands that development at the site will comprise a park and an access road, which formed part of a wider residential-led development. To assess the risk to future users of the site assessment criteria has been selected based on the scenario of 'allotments' and 'public open space – park' at 1% SOM for a sandy loam soil. Average TOC in soil samples was 3.3%, which equates to approximately 1.9% SOM. Based on the soil descriptions in the logs, the soils contain clays and silts and therefore a generic description as a 'loam' is considered appropriate. Genotoxic PAH have been screened using the surrogate marker approach (CL:AIRE, 2014).

AECOM has screened the soil data against human health GAC taken from various published sources from authoritative organisations including:

- Defra Category 4 Screening Levels (C4SLs) (2014) and CL:AIRE Phase 2 C4SLs (2021).
- AECOM modified C4SLs (using CLEA v1.071).
- Land Quality Management/Chartered Institute of Environmental Health (LQM/CIEH) Suitable 4 Use Levels (S4ULs) 2015.
- AECOM modified S4ULs (using CLEA v1.071).
- Environmental Industries Commission (EIC) and Association of Geotechnical & Geo-environmental Specialists (AGS) and CL:AIRE GAC.
- AECOM GAC, modified EIC.
- Dutch Soil Remediation Circular 2013 - Soil Intervention Values [& soil type correction].
- US Environmental Protection Agency, Regional Screening Levels, Nov 2021.

In addition groundwater samples have been compared to HH groundwater vapour GAC:

- The Society of Brownfield Risk Assessment Groundwater GAC Residential. 2017

8.3.3 Human Health GQRA

No exceedances of either set of GAC were reported within the 17 soil samples analysed.

It should also be noted that the Method Detection Limit (MDL) available during analysis for a number of compounds¹ exceeded the applied GAC. However, none of the compounds were reported at concentrations above the MDL in any sample and therefore there is no evidence that they are present on site.

Construction workers are not considered as a receptor in this assessment.

The laboratory chemical analysis results are presented in Appendix C within the Factual Report. Screening tables are reported in Appendix G

8.3.3.1 Hazard Index for TPH Assessment

The Environment Agency Report "The UK Approach for Evaluating Human Health Risk from Petroleum Hydrocarbons in Soils" (SR:P5-080/TR3, 2005) states that even where guideline values for the individual TPH fractions are not exceeded potential additive toxicological effects between the fractions may result in a potential risk to human health.

The calculated HQ and HI are reported in Appendix G. In total, three soil samples were analysed for the TPH-CWG chemical suite. None of the samples recorded a HI with a value of >1.

8.3.3.2 Asbestos Analysis and Assessment

No asbestos was reported in the 17 samples submitted for asbestos identification analysis.

8.3.3.3 Groundwater Vapour Assessment

Groundwater samples were screened against Groundwater Vapour GAC (SOBRA, 2017). There were no exceedance of Groundwater Vapour GAC.

8.3.4 Controlled Waters Screening Assessment Methodology

8.3.4.1 Selection of Controlled Waters Generic Assessment Criteria

Groundwater and soil leachate data have been screened against controlled waters GAC that are designed to be protective of drinking water (drinking water standards (DWS)) and fresh surface water sources (Environmental Quality Standards (EQS)).

Risks to controlled waters have been assessed using a tiered approach based on that described in the EA's Remedial Targets Methodology (RTM). Controlled waters GAC selected for groundwater are primarily Environmental Quality Standards (EQS) for protection of surface water and England & Wales Drinking Water Standards (DWS) for aquifer protection. However, these are not published for certain determinants and so, in the absence of an EQS or DWS, reference has been made to the following in order of preference:

Drinking Water Standards or similar

- Water, England & Wales - Water Supply (Water Quality) Regulations, 2016 No. 614;
- Guidelines for Drinking-water Quality (4th Edition inc. the First Addendum). World Health Organisation. 2017;
- WHO, Petroleum Products in Drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality WHO/SDE/WSH/05.08/123, 2008;
- Drinking Water Guidelines Calculated using WHO Methodology; and
- US Environmental Protection Agency, Regional Screening Levels, Nov 21. Tapwater.

¹ Vinyl chloride, Carbon tetrachloride, Trichloroethene, 1,2-dichloroethane, 1,2-dichloropropane, 1,2,3-trichloropropane, 1,2-dibromo-3-chloropropane (0.01mg/kg), b-BHC, g-BHC (Lindane) & Dichlorvos (0.1mg/kg)

Environmental Quality Standards or similar

- The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 – AA-EQS Inland;
- The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 – MAC-EQS Inland;
- The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 – Freshwater Standards;
- The Water Environment (River Basin Management Planning etc.) (Miscellaneous Amendments) (Scotland) Regulations 2015. Scottish SI 2015 No. 211. AA-EQS Inland; and
- SEPA – Supporting Guidance (WAT-SG-53) Environmental Quality Standards for Discharges to Surface Waters. V6. Dec 2015. Fresh EQS – AA.

8.3.5 Controlled Water GQRA

Details of the GAC exceedances noted within the soil leachate samples are presented within Table 8-5 and groundwater samples exceedances of GAC are presented within Table 8-6 below.

Table 8-5. Soil leachate samples exceedances of GAC

Chemical Analysis	Unit	<u>DWS</u>		<u>EQS</u>		Maximum Value
		Number of Exceedances	GAC Value	Number of Exceedances	GAC Value	
Fluoranthene	µg/L	0	4	3	0.0063	0.02
Copper	µg/L	0	2000	5	1	3
Lead	µg/L	0	10	1	1.2	1.5

Source: (Geotechnical Engineering Ltd , 2023) Appendix C

Details of the exceedances noted within the groundwater samples are summarised below.

Table 8-6. Groundwater samples exceedances of GAC

Chemical Analysis	Unit	<u>(GAC WTV EN/WA DWS</u>		<u>GAC WTV EN/WA EQS-Fresh</u>		Maximum Value
		Number of Exceedances	GAC Value	Number of Exceedances	GAC Value	
Fluoranthene	µg/L	0	4	1	0.0063	1.1
Copper (Filtered)	µg/L	0	2000	2	1	1.4
Nickel (Filtered)	µg/L	0	20	1	4	8.8
Zinc (Filtered)	µg/L	0	6000	2	10.9	150

Source: (Geotechnical Engineering Ltd , 2023) Appendix C

It should also be noted that the Method Detection Limit available during analysis for; benzo(a) pyrene, indeno(1,2,3-c,d)pyrene, dibenz(a,h)anthracene, benzo(g,h,i)perylene, benzo(b)fluoranthene, Benzo(k)fluoranthene (0.01µg/L), chromium (hexavalent) (7µg/L) and cyanide (free) (0.02µg/L), are all greater than the EQS . However, none of the compounds were reported at concentrations above the MDL in any sample and therefore there is no evidence that they are present on site.

Exceedances of the DWS have not been recorded within groundwater or soil leachate samples.

Exceedances of the EQS have been noted within both groundwater samples for, zinc and copper, and in DS02 only for nickel, and BH03 only for fluoranthene.

Soil leachate analysis recorded exceedances of the EQS for fluoranthene in three samples, copper in five samples and lead one sample.

8.4 Ground Gas

Monitoring of ground gas concentrations was undertaken during six monitoring rounds between 14th September and 9th November 2023.

.Recorded atmospheric pressure ranged between 994 mbar and 1023 mbar throughout the monitoring period.

It is noted that the following limitations apply to the monitoring:

- Not all monitoring well installations were monitored during each monitoring round, and monitoring of shallow monitoring well installations was not undertaken, and;
- Generally high atmospheric pressure conditions (>1000 mB) were recorded throughout the majority (4 of 6) of the monitoring rounds.
- DS02 reported a fully saturated response zone during monitoring rounds 3, 5 and 6, while BH03 reported a fully saturated response zone during monitoring rounds 2, 4 and 5.
- The results of the ground gas monitoring are summarised in Table 8-7 below.

Table 8-7. Summary of Ground Gas Monitoring Results

Well	Response Zone (m bgl)	Depth to water (m bgl)	No. of MR	Range. CH ₄ (% v/v)	Max Steady CH ₄ (% v/v)	Range. CO ₂ (% v/v)	Max Steady CO ₂ (% v/v)	Range. O ₂ (% v/v)	Min Steady O ₂ (% v/v)	Range. CO (ppm)	Max Steady CO (% v/v)	Range. H ₂ S (ppm)	Max Steady H ₂ S (% v/v)	Range Flow Rate (l/hr)	Max Steady Flow Rate (l/hr)	Range PID (ppm)	Max Steady PID (ppm)
BH01-D (50mm)	4.2 - 10.0	2.39 – 3.43	5*#	0 - 0	0	0.5 - 0	0.5	21.3 - 19.2	19.3	10 - 0	1	0 - 0	0	91 - -0.3	0.5	21 - 0	20.2
BH02-D (50mm)	2.1 - 5.5	2.2 – 3.67	6#	0 - 0	0	5.6 - 0	5.6	21 - 10.8	12.4	0 - 0	0	0 - 0	0	20.1 - -10.6	0.2	12 - 0	7.2
BH03-D (50mm)	3.2 - 5.2	2.9 – 3.75	6#	0 - 0	0	1.4 - 0	1.2	21.6 - 18.9	21	0 - 0	0	0 - 0	0	57.9 - -7.3	0.0	5.2 - 0	3.8
BH05-D (50mm)	1.6 - 6.5	1.6 – 1.83	6@	0 - 0	0	0.9 - 0	0.5	21.1 - 18.5	18.7	0 - 0	0	0 - 0	0	49.3 - 0	0.0	106 - 0	38.2
BH08-D (50mm)	4.0 - 8.0	1.96 – 2.99	6#	0 - 0	0	2.4 - 0	2	21.1 - 10.6	12.6	10 - 0	10	0 - 0	0	1 - -8.1	0.0	4.9 - 0	4.3
BH15-D (50mm)	4.0 - 10.5	0.53 – 2.15	6#	0 - 0	0	2.9 - 0	1.7	20.8 - 0	17.0	10 - 0	10	0 - 0	0	38.2 - 0	0.0	18.8 - 0	6.5
DS02	0.5 - 2.0	Dry	4	0 - 0	0	0.0-0.7	0.1	20.1-21.1	20.5	0 - 0	0	0 - 0	0	0.0	0.0	0.0 - 30.0	7.5
DS02-D (50mm)	3.0 - 4.78	1.1 – Dry	6#	0 - 0	0	0.7 - 0	0.3	21.4 - 20	20.9	0 - 0	0	0 - 0	0	3.1 - 0	0.0	35.3 - 0	22.7

MR - monitoring rounds

* No Gas readings for Monitoring Round 1 (14th September 2023).# - Well response zone saturated during all monitoring rounds, @ - well response zone saturated during at least one round.

Groundwater levels have been recorded between 1.1m bgl to 3.75m bgl across the 2 borehole locations and monitoring events, with both locations reporting the wells had the response zones fully saturated during 3 of the monitoring rounds. This data is summarised in Table 8-7 above.

8.4.1 Ground Gas Assessment

The primary ground gas guidance in the UK is contained within BS8485:2015+A1:2019, CIRIA C665 and NHBC guidance. However, this guidance is primarily applied to buildings which will not be present on the proposed use as an area of open amenity space, community garden and an access road.

As such, the gas monitoring data has been reviewed but an assessment has not been undertaken.

8.4.1.1 Ground Gas Monitoring Results

The GI Factual Report (Appendix C) indicates gas monitoring of the well array has been undertaken on 6 monitoring rounds between 14th September and 9th November 2023.

Ground gas monitoring results are summarised in Table 8-8 below.

Table 8-8 Ground Gas Results Summary

	Units	Steady		Peak		Comment
		Minimum	Maximum	Minimum	Maximum	
Methane	% v/v	0	0	0	0	Methane was not detected above the detection limit in any of the monitoring installations.
Carbon dioxide	% v/v	0.1	5.6	0	5.6	The maximum concentrations were recorded in BH02D during the first monitoring round.
Carbon Monoxide	ppm	0	10	0	10	Carbon monoxide concentrations were typically reported below the instrument detection limit. However, BH08D and BH15D reported steady concentrations of 10ppm on 14/09/2023. Concentrations were zero during other monitoring rounds so it is possible that this relates to instrumental error.
Oxygen	% v/v	12.6	21.0	10.8	21.6	Lowest oxygen concentrations were reported at BH02D and BH08D
Hydrogen Sulphide	ppm	0	0	0	0	Hydrogen sulphide concentrations were reported below the instrument detection limit throughout monitoring.
Total ground gas flow rates	litres per hour (l/hr)	0.0	0.5	0.0	91.0	Steady flow rates maximum was reported during the first monitoring round at BH01D, typically steady flow rates were below detection at other locations.

Methane and hydrogen sulphide were not recorded at concentrations above instrument detection limits. Carbon dioxide was recorded at a maximum concentration of 5.6 % and oxygen was recorded at a minimum concentration of 10.8 %. These concentrations are in line with expected conditions for a greenfield site.

8.5 Contamination Assessment - Discussion

8.5.1 Future site Users

No observations of contamination were recorded during the ground investigation. No asbestos was recorded in any of the samples taken from the site.

No exceedances of the public open space or allotment GAC or have been recorded within any of the 17 samples analysed, nor was asbestos identified. Therefore it is suitable for the planned end use as a park, community garden and access road.

For ground gas no receptors have been identified on site, with off-site buildings being the only viable receptor. Methan concentrations were recorded below detection limits. Carbon dioxide were typically below 1% and where elevated concentrations were recorded they were not typically maintained over the course of the monitoring rounds. The exception to this was BH02D where concentrations over 2% were recorded during all visits. Given that there are no buildings proposed for the site and enclosed structures are likely to be limited to manhole chambers the elevated carbon dioxide concentrations at BH02D are not considered to pose potential risks to future site users and are likely to be within the typical range for a greenfield site.

Overall, significant sources of contamination have not been identified at the site and risks to future site users are considered to be low.

8.5.2 Controlled Waters

The ground investigation has recorded the geology underlying the site as topsoil over Weald Clay (including weathered layers and 'residual soil'). The Weald Clay is classified as unproductive strata and is therefore not considered to be a viable Controlled Waters receptor. The Secondary A aquifers of the Alluvium and the Horsham Stone Member were not identified in any exploratory holes at the site. Therefore, groundwater is not considered to be a controlled waters receptor. It could, however, form a potential pathway to surface water receptors.

Soil leachate and groundwater samples from the site both recorded exceedances of EQS for fluoranthene and copper, with lead above EQS analysed in one soil leachate sample and nickel and zinc above EQS in groundwater samples.

Metal concentrations in the soil samples collected from the site were generally within the range of background concentrations for the soil in the area. Background screening concentrations for the metals listed can be viewed in Section 3.3, and mean concentrations across the site were below the background concentrations. As such, and given no specific on-site sources have been identified, it is considered likely that the concentrations of metals detected in groundwater are indicative of the typical concentrations of metals for the area. In addition, the EQS for copper, nickel and zinc do not take into account the bioavailability and, therefore, direct comparison of the chemical testing results is likely to be conservative. Overall, the recorded exceedances of EQS for metals are not considered to pose unacceptable risks. No exceedances of the DWS were recorded in soil leachate or groundwater samples submitting for analysis.

Exceedances of EQS for fluoranthene were limited to one location in groundwater (BH03) and three of soil leachate (TP10, TP17 and TP19) samples. Concentrations were close to the laboratory method detection limit. No observations of contamination were made at these locations and therefore the source of the PAH at this location is unknown. However, it is not considered to represent a widespread source of PAH across the site and is not considered to pose an unacceptable risk to controlled water receptors.

Based on the current condition of groundwater at the site, groundwater does not appear to be significantly impacted upon by soil contamination and unacceptable risks to controlled waters receptors are not considered to be present.

8.6 Updated Conceptual Site Model

Following the GI and assessment of the available data, the preliminary CSM (previously presented in [Table 8-4](#)) has been updated to produce below.

Table 8-9 Updated CSM

Source	Pathway	Receptor	Severity	Likelihood	Risk Rating	Comments
On-site: Agricultural land uses. (Potential contaminants including but not limited to asbestos, metals, PAH, TPH, VOC, SVOCs, Pesticide & Herbicides, nitrate, ammoniacal nitrogen, sulphate)	Dermal absorption or ingestion of soil	Human Health: Future site users, maintenance workers, and members of the public; and Off-Site residents and workers.	Medium	Unlikely	Low	No exceedance of soil GAC recorded.
	Plant uptake and consumption of homegrown produce	Human Health: Future site users, notably the users of the community gardens.	Medium	Unlikely	Low	No exceedances of the soils GAC.
	Vapour and/or ground gas intrusion and inhalation.	Human Health: Off-site occupants of residential housing Maintenance workers in confined spaces	Medium	Unlikely	Low	Low concentrations of ground gases recorded, considered typical for a greenfield development.
	Migration of contaminants via airborne dusts followed by inhalation.	Human Health: Future site users, maintenance workers, and members of the public; and Offsite residents and workers.	Medium	Unlikely	Low	No asbestos, or other hazardous airborne compounds, identified in samples submitted for analysis
	Leaching of chemicals and vertical migration via permeable unsaturated strata into groundwater	Controlled Waters: Groundwater, specifically the secondary A Aquifer of Alluvium and the Horsham Stone Member.	Mild	Low	Low	No exceedances for DWS GAC has been reported from either groundwater or soil leachate samples. No widespread contamination has been identified with soil samples with exceedances isolated to individual locations with concentrations marginally above the respective GACs suggesting limited risk. Alluvium has not been identified on site.
	Lateral migration of impacted groundwater off-site towards surface water	Controlled Waters: Surface water, tributaries for the River Adur, and surface water ponds.	Moderate	Unlikely	Low	Exceedances for EQS freshwater within groundwater and leachate samples limited to Fluoranthene, Copper, Lead, Nickel, and Zinc. Metal concentrations are within background ranges, and Fluoranthene exceedances close to the MDL with no source identified however is not identified as widespread.

Source	Pathway	Receptor	Severity	Likelihood	Risk Rating	Comments
Off site sources: Sewage Farm (located ~ 170 m south of the site), Agricultural/golf course land uses, substation. . (Potential contaminants including but not limited to asbestos, metals, PAH, TPH, PCBs, SVOCs, VOCs, Pesticide & Herbicides, nitrate, ammonical nitrogen as N, sulphate)	Direct contact causing corrosion of sub-surface concrete foundations and ground structures/services with aggressive ground conditions	Property & infrastructure: Residential, commercial and community facilities, Infrastructure, services, and landscaped area.	Mild	Low	Low	Assessment of concrete specification for aggressive soils has been undertaken, see Section 7.5.
	Migration of hazardous gases and organic vapours via permeable strata and/or through preferential pathways created by buried services – creation of hazardous atmospheres and vapour inhalation	Property & infrastructure: On-site confined spaces and off-site buildings.	Mild	Low	Low	Low concentrations of ground gases recorded, considered typical for a greenfield development.
	Lateral migration of impacted groundwater towards the site	Controlled Waters: Groundwater, specifically the secondary A Aquifer of the Alluvium and the Horesham Stone Member.	Mild	Low	Low	Groundwater flow is suggested towards the surface water tributaries on and adjacent to Site, and no sources so significant contamination are identified up gradient of the Site.
	Migration of contaminants via airborne dusts followed by inhalation.	Human Health: Future Site users, including residential property users, community & occupational facility users, maintenance workers, and members of the public.	Medium	Unlikely	Low	The sewage works and other sources are largely covered by buildings, hardstanding or vegetation (grass cover), which minimises the potential for dust generation from these sources.
	Lateral migration of impacted groundwater towards the site	Controlled Waters: Groundwater, specifically the secondary A Aquifer of the Alluvium.	Mild	Low	Low	Groundwater flow is suggested towards the surface water tributaries onsite or adjacent, and no sources of significant contamination are identified up gradient of the site.
	Lateral migration of impacted Surface water towards the Site	Controlled Waters: Surface water, tributaries for the River Adur	Mild	Low	Low	No sources so significant contamination sources have been identified upstream of the site.

9. Geotechnical and Geo-environmental Risk Register

It is noted that Geotechnical Category Classifications are determined on the basis of the geotechnical works and risk implications.

The following geotechnical and geoenvironmental risks are anticipated. Unforeseen ground conditions might lead to construction delays and redesign (site specific risks are detailed below);

- Variability of Made Ground and presence of voids or obstructions;
- Localised weak/ compressible soils might lead to differential settlement and increased maintenance liability and cause differential settlement within foundations;
- The historical mapping indicates ponds/pits are present and then later are absent on the mapping. This could indicate locally infilled areas. Two trial pits identified Made Ground at these locations.
- Presence of Alluvium adjacent to streams and rivers
- Shrinkage or swelling of soils with volume change potential especially where trees are planted or removed;
- Variability of natural strata – presence of Horsham Stone Member and clay ironstone bands in Weald Clay Formation causing obstructions to foundations and excavations and potential for higher permeability leading to groundwater ingress and potentially artesian groundwater conditions;
- Legacy periglacial landscape resulting in reactivation of pre-existing shear surfaces at low slope angles parallel and sub-parallel to the ground surface (see Weeks, 1969);
- Unforeseen groundwater levels; high groundwater levels may lead to poor drainage and construction problems; artesian water leading to construction problems especially if cast in-situ bored piling is to be used, and flooding;
- Areas of unexpected contamination not documented on available mapping or other resources, or encountered during the ground investigation;
- Presence of soils with low subgrade modulus requiring ground improvement for road design
- Presence of silt with potential for frost susceptibility requiring appropriate road design to ensure no damage to pavements
- Encountering unexploded ordnance might cause delays or endanger life;
- Encountering existing services. Cost and programme delays for reinstatement/ diversion of existing services, loss of life if gas/ electrical mains are hit; and
- Chemical attack on buried concrete which may result in maintenance problems.

More details regarding geotechnical risks can be found in the Geotechnical & Geoenvironmental Risk Register below. The Geotechnical & Geoenvironmental Risk Register is a live document and will be further developed and updated in the following reports with more recent information.

The degree of risk (R) is determined by combining an assessment of the likelihood (L) of the hazard with an assessment of the severity (S) of the hazard. The scale against which the likelihood and severity are measured, and the resulting degree of risk determined is presented below.

There is potential on site for ecological and arboricultural constraints which are not covered in this report.

Table 9-4 presents the risk register for the proposed scheme.

Table 9-1 Classification of Probability and Impact

Likelihood (L)		Severity (S)	
Very Likely	5	Very High	5
Likely	4	High	4
Probable	3	Medium	3
Unlikely	2	Low	2
Negligible	1	Very Low	1

Table 9-2: Risk Matrix

Likelihood	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
		Severity				

Table 9-3: Classification of Risk Rating

Risk rating	Response
Intolerable	Unacceptable
Substantial	Early Attention
Tolerable	Regular Attention
Trivial	Monitor

Table 9-4 Geotechnical & Geoenvironmental Risk Register

Identified Geotechnical Hazard	Cause	Risk before Control			Consequence	Mitigation Measures	Risk after Control		
		L	S	RR (Lex's)			L	S	RRR (LxS)
Existing Underground and Overhead Services at proposed site of works	Ground Investigation Works; site construction works, site clearance and site set-up (compound, haul roads etc.) At the time of writing this report out-dated utility drawings were available	4	4	16	The proposed GI works may encounter unforeseen services. Increased cost and delay to divert or lower services; Health & Safety impact during any excavations during Ground Investigation or construction; Relocation of ground investigation or site area to avoid overhead services; Scheme design alterations to avoid overhead/underground services.	Obtain up to date service plans and records; Undertake safe digging procedures in accordance with HSE publication HSG47 and PAS128; Undertake GPR surveys and mark out services prior to any investigations; Plan site works to avoid buried and Overhead services; when working near overhead cables follow the guidance in HSE publication HSGS6 Design proposed scheme to minimise impact on existing services.	2	4	8
Unforeseen Ground Conditions	Variability in ground conditions across site	4	3	12	Unforeseen ground conditions e.g. Soft ground, variable thickness of Made Ground can cause programme delays	Project specific intrusive ground investigation must be carried out to improve the accuracy of ground models. Due to the inherent and variable nature of Made Ground conditions, variation is to be expected during the construction works and appropriate site monitoring by a competent engineer should be undertaken.	2	3	6
Natural obstructions/hard strata	Encountering obstructions in the form of hard limestone, sandstone and mudstone bands.	4	3	12	Obstructions can result in additional costs and programme delay	Findings from the site-specific GI should be reviewed and probing at pile locations should be considered	2	3	6
Secondary A aquifer contamination during GI or intrusive works	Water from excavations. Creation of new contamination pathways.	2	2	4	Water from excavations may contaminate the Secondary A Aquifer	Soil and groundwater arisings (e.g. water pumped from excavations) to be appropriately contained before any necessary treatment and disposal	1	2	2
Artesian Groundwater	Artesian groundwater pressures due to confined groundwater within Weald Clay Formation	3	3	9	Construction difficulties especially where bored cast in-situ piling used	Design should account for this potential when selecting foundation types and depths.	1	3	3
Buried obstructions	Buried dis-used foundations and substructures	4	4	16	Intrusive GI and construction works could strike buried obstructions such as dis-used foundations and substructures	Prior to intrusive works the contractor should ensure that accurate and up-to-date As built existing drawings showing the locations of existing substructures, have been obtained and reviewed against the proposed works scope. Appropriate survey work should be carried out prior to commencing the intrusive works.	1	4	4

Identified Geotechnical Hazard	Cause	Risk before Control			Consequence	Mitigation Measures	Risk after Control		
		L	S	RR (Lex's)			L	S	RRR (LxS)
Aggressive Ground Chemistry	Concentrations of sulphate within Made Ground, Residual Soils or Weald Clay (weathered or unweathered)	4	2	8	Deleterious effects on buried concrete/piles. Pavement Heave. May impact some forms of ground improvement e.g. lime stabilisation.	Analyse BRE SD1 test results and design concrete mix and the additional protective measures during detailed design in accordance with BRE SD1 guidance. Consider presence during design of ground improvement.	1	3	3
Localised weak/compressible soils, e.g. silt	May not support proposed load, may change seasonally or with planting	4	3	12	Instability, total and differential settlement and increased maintenance.	Appropriate ground investigation, design, excavation and replacement where required. Further ground investigation may need to be carried out to delineate areas of soft ground associated with watercourses.	3	2	6
High groundwater levels.	Surface water features and adjacent river tributaries on site	3	3	9	Poor drainage and construction difficulties.	Assess groundwater conditions prior to construction and design appropriate groundwater control and temporary support to excavations.	2	2	4
Poor drainage.	Low permeability soils present at surface	3	3	9	Construction difficulties leading to redesign, cost increase and project delay.	Assess drainage conditions prior to construction and design appropriate drainage measures.	2	2	4
Excavations causing slope instability.	Weak residual soils of weathered bedrock and Alluvium are present at site. Potential presence of preexisting slip surfaces that may be reactivated by excavations and other earthworks.	3	4	12	Slope failure. Possible impact on site safety. Increased cost and delay.	Fully supported trenches, limited open length to that which can be completed in one shift. Unsupported excavations may not be entered. During ground investigation observations should be recorded from the narrow end of the pit. Pits shall be backfilled immediately upon signs of instability. Close or continuous support will be required for any person entry to excavations. Residual shear strengths may need to be considered in slope stability designs.	3	2	6
UXO	Historical UXO risk	2	5	10	Delays caused by clearance works or initiation endangering life.	Adopt appropriate mitigation measures.	1	5	5
Contaminated soils and groundwater	Localised contamination associated with past or present land uses that has not been identified during the GI completed.	3	3	9	Increased development costs, risks to human health and controlled waters	The ground investigation and risk assessment have not identified unacceptable risks to human health and controlled waters. Therefore, remediation is not considered to be required, and given the low risk historical land uses substantial previously unidentified impact is unlikely to be present. However, the potential for unexpected contamination to be uncovered during development works should be addressed through a Discovery Strategy within a Remediation Strategy for the site.	1	3	3

Identified Geotechnical Hazard	Cause	Risk before Control			Consequence	Mitigation Measures	Risk after Control		
		L	S	RR (Lex's)			L	S	RRR (LxS)
Frost damage to pavements and cracking/deflection of pavements.	Presence of silt with potential for frost susceptibility. Presence of weak subgrade as indicated by some in situ test results	4	3	12	Damage to pavements and maintenance cost	Removal of frost susceptible soils and weak subgrade soils and replacement with appropriate fill to ensure adequate subgrade pavement. Appropriate road design to ensure no damage to pavements.	4	1	4
High volume change soils	Shrink swell of soils especially in vicinity of trees	4	3	12	Damage to structures particularly with moisture content changes	High volume change soils have been identified on the site. Adequate design considerations should be taken in areas of existing or proposed trees and other vegetation.	4	1	4

10. References

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