



Main Investigation Report

at
Land east of Westergate, Chichester, West Sussex PO20 3RD

for
CALA Homes

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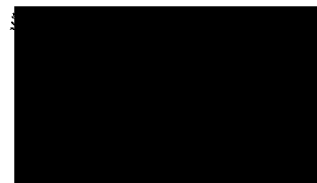
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Prepared by

S J Bevins BSc.(Hons) MSc. CEng CEnv MIMMM FGS MCorIE RoGEP



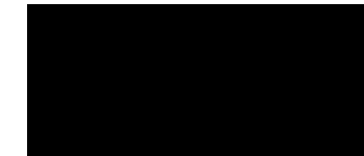
First check by

C Swainston BSc. (Hons.), PGCE., FGS, CGeol, CLAireQP, MIAH



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Current regulations and good practice were used in the preparation of this report. The recommendations given in this report must be reviewed by an appropriately qualified person at the time of preparation of the scheme design to ensure that any recommendations given remain valid in light of changes in regulation and practice, or additional information obtained regarding the site.

Commission

Soils Limited was commissioned by CALA Homes to undertake an intrusive ground investigation and prepare a Main Investigation Report on land at Land east of Westergate, Chichester, West Sussex PO20 3RD. The scope of the investigation was outlined in the Soils Limited quotation reference Q24788, dated 9th June 2021.

This document comprises the Main Investigation Report and incorporates the results, discussion and conclusions to this intrusive works.

This Main Investigation Report must be read in conjunction with the Preliminary Investigation Report undertaken on the above site by Soils Limited, Report ref: 19522/PIR, dated September 2021.

Standards

The site works, soil descriptions and geotechnical testing was undertaken in accordance with the following standards:

- BS 5930:2015 and BS EN ISO 22476-2:2005+A1:2011
- BS EN 1997-1:2004+A1:2013 Eurocode 7.
- BS EN ISO 14688-1:2018
- BS EN ISO 14688-2:2018
- BS 8004:2015
- BS 1377:1990 Parts 1 to 8
- NHBC Standards 2021
- BRE Digest 241 "Low-rise buildings on shrinkable clay soils: Part 2
- Stroud, M. A. 1974, "The Standard Penetration Test – its application and interpretation", Proc. ICE Conf. on Penetration Testing in the UK, Birmingham. Thomas Telford, London
- BS 10175:2011+A1:2013
- SP1010: Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination December 2014
- BRE "*Cover Systems For Land Regeneration, Thickness Design of Cover Systems for Contaminated Land, BRE, March 2004*"
- CIRIA C733, Asbestos in soil and made ground: a guide to understanding and managing risks and CAR2012 regulations.
- CIRIA 665 Assessing risks posed by hazardous ground gases to buildings
- BS 8485:2015+A1:2019 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings

- British Geological Survey Website & iGeology App (accessed August 2021)
- Google Earth (accessed August 2021)

The geotechnical laboratory testing was performed by GEO Site & Testing Services Ltd (GSTL) in accordance with the methods given in BS 1377:1990 Parts 1 to 8 and their UKAS accredited test methods.

For the preparation of this report, the relevant BS code of practice was adopted for the geotechnical laboratory testing technical specifications, in the absence of the relevant Eurocode specifications (ref: ISO TS 17892).

The chemical analyses were undertaken by Derwentside Environmental Testing Services (DETS) in accordance with their UKAS and MCERTS accredited test methods or their documented in-house testing procedures. This investigation did not comprise an environmental audit of the site or its environs.

Trial hole is a generic term used to describe a method of direct investigation. The term trial pit, borehole or window sample borehole implies the specific technique used to produce a trial hole.

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Section I Introduction

I.1 Objective of Investigation

Soils Limited was commissioned by CALA Homes to undertake an intrusive ground investigation and to prepare a Main Investigation Report to supply the client and their designers with information regarding ground conditions, to assist in preparing a foundation scheme for development that was appropriate to the settings present on the site.

The investigation was to be undertaken to provide comment on appropriate foundation options for the proposed residential development. The investigation was to be made by means of in-situ testing and geotechnical laboratory testing undertaken on soil samples taken from the trial holes.

Soil samples were taken for chemical laboratory testing to enable recommendations for the safe redevelopment of the site and the protection of site workers, end-users and the public from any contamination identified as dictated by the Conceptual Site Model (CSM) in the Preliminary Investigation Report undertaken for the site by Soils Limited (Report ref: 19522/PIR, September 2021) and/or the Revised Conceptual Site Model presented in Appendix C.1.

I.2 Location

The site was located at Land east of Westergate, Chichester, West Sussex PO20 3RD and was centred around an approximate O.S Land Ranger Grid Reference of SU 94104 04798.

The site location plan is given in Figure 2.

I.3 Site Description

The site comprised agricultural fields and grassland with no structures noted within the site boundary. The site was covered with a variety of vegetation including mature trees along line field boundaries, the open areas being completely overgrown in some areas with ruderal growth. The field to the southwest of the site was cropped and occasional dirt tracks were noted running across the site.

The site was generally undulating with dips of <5° towards the water courses running approximately west to east through the centre of the site, and north to south along the eastern boundary. The slope of the wider aspect was down to the southeast and east.

The surrounding area comprised residential with gardens to the north and west, and agricultural fields to the south and east.

An aerial photograph of the site and its environs has been included in Figure 3.

1.4 Proposed Development

The proposal comprised redevelopment of the site from farmland to housing with gardens and areas of open recreational space. At time of writing only a speculative plan has been provided for the development and this report must be reviewed and revised in relation to actual site-specific proposals if it is to be presented as evidence in pursuit of a planning application. All conclusions and findings in this report will therefore be essentially generic in nature and should be viewed in this light.

In compiling this report reliance was placed on drawing number 00163_CALA_CN_01, dated October 2020 and was prepared by the client. The recommendations provided within this report must be reviewed and revised when a finalised scheme is prepared and must not be applied without further consultation with Soils Limited.

The speculative development plans provided by the client are presented in Appendix D.

1.5 Anticipated Geology

The 1:50,000 BGS map showed the site to be located upon bedrock of the London Clay Formation with various overlying superficial deposits recorded across the site area, as described below.

The site has a water course running through its centre from west to east, feeding into another water course which runs north to south along the eastern site boundary. Alluvium is recorded adjacent to both water courses, beyond which no superficial deposits are noted, then Raised Beach Deposits are evident. To the north of these deposits, Head is noted and to the south, River Terrace Deposits are present. Made Ground is noted on the south eastern boundary as a Railway embankment.

1.5.1 Made Ground

Made Ground comprises material that has been placed by man or spread by man. It can comprise demolition material from former structures on the site or imported material placed to raise levels. Its composition can be very variable both laterally and with depth and may contain putrescible matter and voids.

1.5.2 Alluvium

Alluvium is the most recent river or estuarine deposit and generally comprises silty clays usually with an appreciable organic content. Lenses of sand and gravel are also commonly found, as are pockets of peat.

The BSI Code of Practice for Foundations, BS8004: 1986, Clause 2.2.2.3.4 Peat and organic soils, includes the caveat that 'all these soils are highly compressible, and even lightly loaded foundations will be subject to considerable settlements over a long period if placed on them. For this reason, these soils are not suitable for carrying the loads for important structures'.

1.5.3 Head

Head deposit are drifts produced by solifluxion, the downslope movement of debris outwash during the periglacial period, and characteristically comprise poorly sorted sands gravels and chalk of local derivation.

1.5.4 Raised Beach Deposits

Raised Beach Deposits consist of shingle, sand, silt and clay. Beach deposits may be in the form of dunes, sheets or banks, now above the level of the present shoreline as a result of earth movement or a general fall in sea level.

1.5.5 River Terrace Deposits

The rivers Test and Itchen have deposited extensive spreads of River Terrace Deposits in the Southampton area, representative of ancient floodplains. In total, eleven terraces have been recorded. The River Terrace Deposits consist predominantly of gravels made up of subangular to subrounded flints with a significant sand component locally with lenses of silt, clay or peat.

The five highest terraces have appreciable clay content. Poorly sorted, clayey and sandy silts and silty clays overlie the 1st, 3rd, 5th and 6th terraces and locally at above terrace gravels.

1.5.6 London Clay Formation

The London Clay Formation in the Hampshire region comprises silty and sandy clay, clayey and sandy silt, silty sand; sporadic claystones and thin beds of flint pebbles. The formation includes the Bognor Sand, Whitecliff Sand, Durley Sand, Portsmouth Sand and Nursling Sand Members. Crystals of gypsum (Selenite) are often found within the weathered part of the London Clay, and precautions against sulphate attack to concrete are sometimes required.

The lowest part of the London Clay Formation rests on the Lambeth Group.

1.6 Limitations and Disclaimers

This Main Investigation Report relates to the site located at Land east of Westergate, Chichester, West Sussex PO20 3RD and was prepared for the sole benefit of CALA Homes (The "Client"). The report was prepared solely for the brief described in Section 1.1 of this report.

The contents, recommendations and advice given in the report are subject to the Terms and Conditions given in Quotation Q24788, dated 9th June 2021 accepted by the client in their Purchase Order Q24788, dated 8th July 2021.

Soils Limited disclaims any responsibility to the Client and others in respect of any matters outside the scope of the above.

This report has been prepared by Soils Limited, with all reasonable skill, care and diligence within the terms of the Contract with the Client, incorporation of our General Conditions of Contract of Business and taking into account the resources devoted to us by agreement with the Client.

The report is personal and confidential to the Client and Soils Limited accept no responsibility of whatever nature to third parties to whom this report, or any part thereof, is made known. Any such party relies on the report wholly at its own risk.

The Client may not assign the benefit of the report or any part to any third party without the written consent of Soils Limited.

The ground is a product of continuing natural and artificial processes. As a result, the ground will exhibit a variety of characteristics that vary from place to place across a site, and also with time. Whilst a ground investigation will mitigate to a greater or lesser degree against the resulting risk from variation, the risks cannot be eliminated.

The investigation, interpretations, and recommendations given in this report were prepared for the sole benefit of the client in accordance with their brief. As such these do not necessarily address all aspects of ground behaviour at the site.

Current regulations and good practice were used in the preparation of this report. An appropriately qualified person must review the recommendations given in this report at the time of preparation of the scheme design to ensure that any recommendations given remain valid in light of changes in regulation and practice, or additional information obtained regarding the site.

The depth to roots and/or of desiccation may vary from that found during the investigation. The client is responsible for establishing the depth to roots and/or of desiccation on a plot by plot basis prior to the construction of foundations. Supplied site surveys may not include substantial shrubs or bushes and is also unlikely to have data on any trees, bushes or shrubs removed prior to or following the site survey.

Where trees are mentioned in the text this means existing trees, substantial bushes or shrubs, recently removed trees (approximately 20 years to full recovery on cohesive soils) and those planned as part of the site landscaping).

It should be noted that a detailed survey of the possible presence or absence of invasive species, such as Japanese Knotweed, is outside of the scope of investigation.

Ownership of land brings with it onerous legal liabilities in respect of harm to the environment. "Contaminated Land" is defined in Section 57 of the Environment Act 1995 as:

"Land which is in such a condition by reason of substances in, on or under the land that significant harm is being caused or that there is a significant possibility of such harm

being caused or that pollution of controlled waters is being, or is likely to be caused”.

The investigation, analysis or recommendations in respect of contamination are made solely in respect of the prevention of harm to vulnerable receptors, using where possible best practice at the date of preparation of the report. The investigation and report do not address, define or make recommendations in respect of environmental liabilities. A separate environmental audit and liaison with statutory authorities is required to address these issues.

Ownership of copyright of all printed material including reports, laboratory test results, trial pit and borehole log sheets, including drillers log sheets remains with Soils Limited. License is for the sole use of the client and may not be assigned, transferred or given to a third party.

Section 2**Site Works****2.1 Proposed Project Works**

The proposed intrusive investigation was designed to provide information on the ground conditions and to aid the design of foundations for the proposed residential development. The intended investigation, as outlined within the Soils Limited quotation (Q24788, dated 9th June 2021), was to comprise the following items:

- 5 days of windowless sampler boreholes and dynamic probes
- 1 day of additional dynamic probes
- Installation of 9No. combined soil gas and groundwater monitoring wells (4No. in proposed balancing ponds and 5No. general spread).
- 2 days of machine excavated trial pitting
- 2 days in-situ CBR testing (DCP/TRL probe)
- Geotechnical laboratory testing
- Contamination laboratory testing
- 6No. winter groundwater monitoring visits (assumed October to March inclusive)

2.1.1 Actual Project Works

The actual project site works were undertaken between 14th and 20th July 2021 with subsequent laboratory testing and reporting, and comprised:

- 28No. windowless sampler boreholes (WS01 to WS28)
- 28No. dynamic probe (DPSH) (DP01 to DP28)
- Installation of 9No. combined soil gas and groundwater monitoring wells
- 30No. in-situ CBR tests using TRL DCP probe (DCP01 to DCP30)
- Geotechnical laboratory testing
- Contamination laboratory testing
- 6No. winter groundwater monitoring visits (to follow)

It was agreed with the client to replace the proposed machine excavated trial pits with further windowless sampler boreholes to minimise any damage to the cropped fields, which formed some of site area.

Nine windowless sampler boreholes (WS01, WS06, WS09, WS12, WS16, WS17, WS19, WS23, WS28) were backfilled with gravel and bentonite following the installation of monitoring wells. The installations comprised plain 35mm internal diameter pipework with bentonite backfill from ground level to 1.0m below ground level (bgl) with perforated pipework and granular response zone below, to the base of each borehole.

The remainder of the windowless sampler boreholes were backfilled with gravel. All trial hole locations have been presented in Figure 4 and Figure 5.

Following completion of site works, soil cores were logged and sub-sampled so that samples could be sent to the laboratory for contamination and geotechnical testing.

2.2 Ground Conditions

On dates between 14th and 20th July 2021 28no. windowless sampler boreholes (WS01 to WS28) were drilled, using a Premier Compact 110 rig and Dando Terrier rig, to depths ranging between 1.00m and 5.00m below ground level (bgl) at locations selected by Soils Limited using a development plan provided by the client.

28No. dynamic probes, super heavy, (DP01 to DP28) were driven prior and adjacent to their corresponding windowless sampler borehole to depths ranging between 4.00m and 6.00m bgl. A single standpipe was installed in 9No. window sample borehole locations (WS01, WS06, WS09, WS12, WS16, WS17, WS19, WS23, WS28) to allow for continued monitoring of both groundwater and soils gas, where present.

The maximum depths of trial holes have been included in Table 2-1.

All trial holes were scanned with a Cable Avoidance Tool (C.A.T.) and GENNY prior to excavation to ensure the health and safety of the operatives.

Table 2-1 Final Depth of Trial Holes

Trial Hole	Depth (m bgl)	Trial Hole	Depth (m bgl)	Trial Hole	Depth (m bgl)
WS01 (w)	5.00	WS11	4.00	WS21	2.60
WS02	4.00	WS12 (w)	3.60	WS22	2.00
WS03	1.00	WS13	2.70	WS23 (w)	2.50
WS04	3.00	WS14	4.00	WS24	4.00
WS05	2.40	WS15	4.00	WS25	2.50
WS06 (w)	4.00	WS16 (w)	3.65	WS26	2.20
WS07	3.00	WS17 (w)	4.00	WS27	2.40
WS08	3.00	WS18	4.00	WS28 (w)	1.00
WS09 (w)	2.50	WS19 (w)	3.00	-	
WS10	4.00	WS20	2.00	-	
DP01	6.00	DP11	6.00	DP21	6.00
DP02	6.00	DP12	6.00	DP22	6.00
DP03	6.00	DP13	6.00	DP23	6.00
DP04	6.00	DP14	6.00	DP24	6.00
DP05	6.00	DP15	6.00	DP25	4.00
DP06	6.00	DP16	6.00	DP26	4.50
DP07	6.00	DP17	6.00	DP27	4.60
DP08	6.00	DP18	6.00	DP28	4.90
DP09	6.00	DP19	6.00	-	
DP10	6.00	DP20	6.00	-	

Note: w - well installation

The soil conditions encountered were recorded and soil sampling commensurate with the purposes of the investigation was carried out. The depths given on the trial hole logs and quoted in this report were measured from ground level.

The soils encountered from immediately below ground surface have been described in the following manner. Where the soil incorporated an organic content such as either decomposing leaf litter or roots or has been identified as part of the in-situ weathering profile, it has been described as Topsoil both on the logs and within this report. Where man has clearly either placed the soil, or the composition altered, with say greater than an estimated 5% of a non-natural constituent, it has been referred to as Made Ground both on the log and within this report.

For more complete information about the soils encountered within the general area of the site reference should be made to the detailed records given within Appendix A, but for the purposes of discussion, the succession of conditions encountered in the trial holes in descending order can be summarised as:

Made Ground/Topsoil (MG/TS)
Alluvium (ALV)
Head (HEAD)
River Terrace Deposits (RTD)
London Clay Formation (LC)

A breakdown of the test hole locations related to the anticipated geology is given in Figure 1, below.

The ground conditions encountered in the trial holes are summarised in Table 2-2.

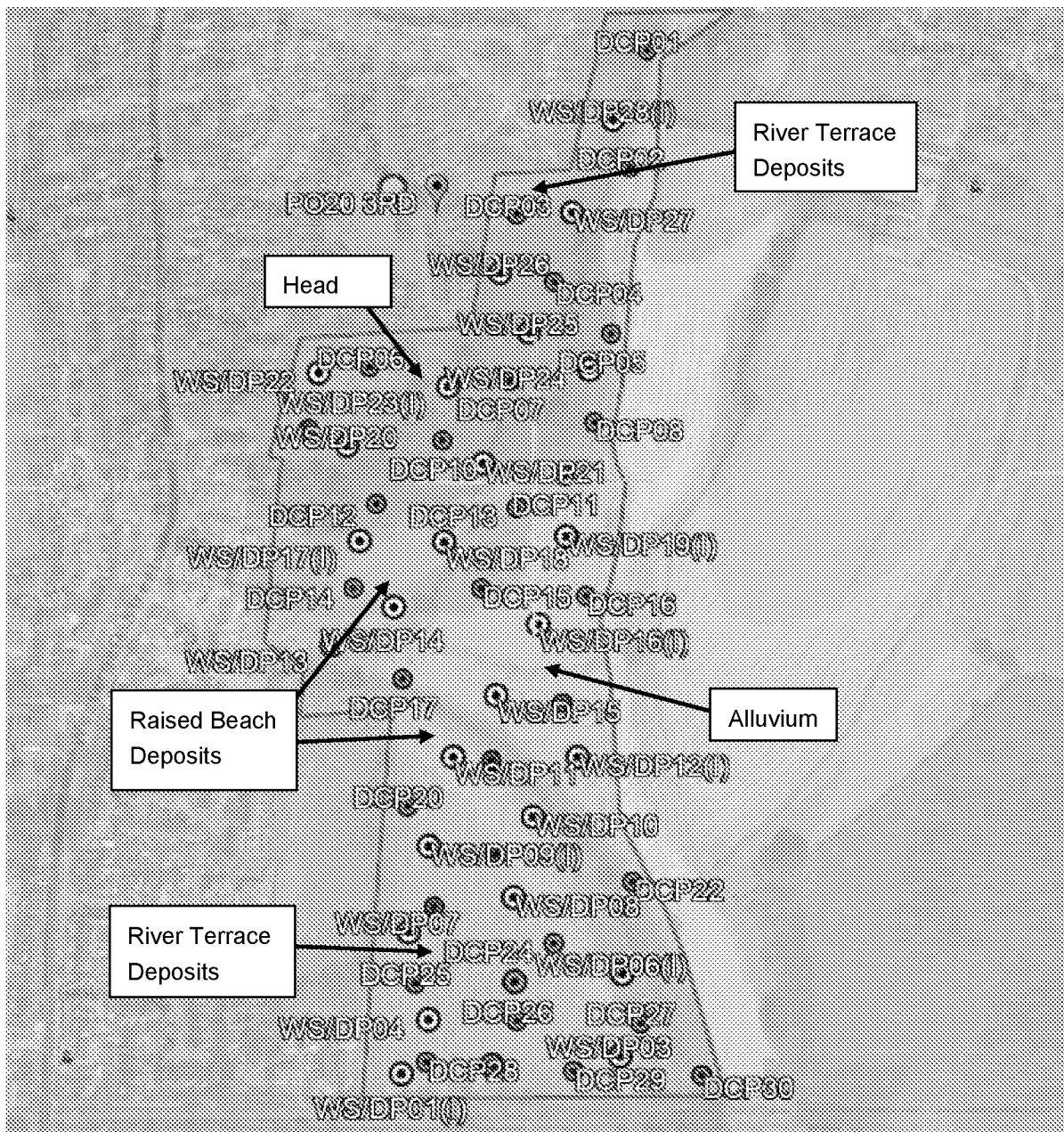
Table 2-2 Ground Conditions

Strata	Epoch	Depth Encountered (m bgl)		Typical Thickness (m)	Typical Description
		Top	Bottom		
MG/TS	Anthropocene	G.L.	0.12-0.60	0.30	MG: Soft grey and orangish brown slightly clayey slightly sandy SILT with occasional rootlets. Locally with rare angular to sub-angular fine gravel. TS: Soft dark grey and brown silty CLAY with occasional rootlets. Locally with rare angular to sub-angular fine gravel.
ALV	Holocene	0.30-0.60	1.00 ¹ -2.60 (2.00) ³	1.50 (where proven) ²	Soft grey and orangish brown slightly sandy CLAY. Locally with pockets of fine to coarse sand, occasional gravel and black discolouration.
HEAD	Holocene	0.12-0.50	1.00 ¹ -4.00 ¹ (4.10) ³	2.20 (where proven) ²	Firm brown gravelly CLAY / clayey sandy GRAVEL with fine roots and rootlets. Locally silty and with pockets of sand. Gravel is angular to sub-angular fine to coarse flint.

Strata	Epoch	Depth Encountered (m bgl)		Typical Thickness (m)	Typical Description
		Top	Bottom		
RTD	Holocene	0.25-2.50	1.00-4.70 (4.90) ³	2.50 (where proven) ²	Orangish brown fine to coarse slightly gravelly SAND, locally sandy gravelly CLAY. Gravel is angular to sub-angular fine to coarse flint.
LC	Eocene	1.00-4.70	1.90 ¹ -5.00 ¹ (6.00 ¹) ³	Not proven	Firm dark grey silty CLAY with rare shell fragments and rare fine selenite crystals.

Note: ¹ Final depth of trial hole. ² Base of strata not encountered. ³ Inferred from the dynamic probes

Figure 1 - Superficial Geology of Site Area with Trial Hole Locations



The superficial geology underlying the site is provided in Figure 1 with trial hole locations overlain for reference.

As shown, the superficial geology is complex and varies across the site area. The Alluvium (yellow) is anticipated to be present adjacent to the water courses, which run through the centre of the site from west to east, and north to south along the eastern site boundary. Raised Beach Deposits (pale green) are evident beyond the Alluvium with some areas in between recorded with no superficial deposits present. To the north of the Alluvium and Raised Beach Deposits, Head (purple) is noted and to the southwest, River Terrace Deposits (orange) are present.

2.3 Ground Conditions Encountered in Trial Holes

The ground conditions encountered in trial holes have been described below in descending order. The engineering logs are presented in Appendix A.1.

2.3.1 Made Ground and Topsoil

Soils described as Made Ground were encountered in thirteen of the twenty-eight trial holes from ground level to depths ranging between 0.30m and 0.60m bgl.

The Made Ground typically comprised soft grey and orangish brown slightly clayey slightly sandy SILT with occasional rootlets. Locally with rare angular to sub-angular fine gravel.

Soils described as Topsoil were encountered in fifteen of the twenty-eight trial holes from ground level to depths ranging between 0.12m and 0.60m bgl.

The Topsoil comprised soft dark grey and brown silty CLAY with occasional rootlets. Locally with rare angular to sub-angular fine gravel.

The depth of Made Ground and Topsoil has been included in Table 2-3.

Table 2-3 Final Depth of Made Ground/Topsoil

Trial Hole	Strata	Depth (m bgl)	Trial Hole	Strata	Depth (m bgl)
WS/DP01	MG	0.30	WS/DPI5	MG	0.50
WS/DP02	MG	0.30	WS/DPI6	TS	0.30
WS/DP03	MG	0.40	WS/DPI7	TS	0.25
WS/DP04	MG	0.30	WS/DPI8	TS	0.50
WS/DP05	MG	0.30	WS/DPI9	TS	0.30
WS/DP06	MG	0.40	WS/DP20	TS	0.40
WS/DP07	MG	0.30	WS/DP21	TS	0.20
WS/DP08	MG	0.40	WS/DP22	TS	0.20
WS/DP09	MG	0.30	WS/DP23	TS	0.30
WS/DPI0	MG	0.60	WS/DP24	TS	0.15
WS/DPI1	MG	0.30	WS/DP25	TS	0.40
WS/DPI2	TS	0.60	WS/DP26	TS	0.40
WS/DPI3	MG	0.50	WS/DP27	TS	0.20

Trial Hole	Strata	Depth (m bgl)	Trial Hole	Strata	Depth (m bgl)
WS/DPI4	TS	0.40	WS/DP28	TS	0.12

2.3.2 Alluvium

Soils of the Alluvium were recorded directly underlying the Made Ground or Topsoil in seven of the twenty-eight trial holes and were recorded to depths ranging between 1.00m and 2.60m bgl, generally within the areas anticipated in the east and centre of the site, as shown in Figure 1. They were also inferred to 2.00m bgl in DP03.

The Alluvium typically comprised soft grey and orangish brown slightly sandy CLAY. Locally with pockets of fine to coarse sand, occasional gravel and black discolouration.

The depth of Alluvium has been included in Table 2-4.

Table 2-4 Final Depth of Alluvium

Trial Hole	Depth (m bgl)	Trial Hole	Depth (m bgl)
WS/DP01	N/e	WS/DPI5	N/e
WS/DP02	N/e	WS/DPI6	N/e
WS/DP03	1.00 ¹ / 2.00	WS/DPI7	N/e
WS/DP04	N/e	WS/DPI8	N/e
WS/DP05	N/e	WS/DPI9	N/e
WS/DP06	2.60	WS/DP20	N/e
WS/DP07	1.80	WS/DP21	N/e
WS/DP08	2.00	WS/DP22	N/e
WS/DP09	N/e	WS/DP23	N/e
WS/DPI0	2.00	WS/DP24	N/e
WS/DPI1	2.30	WS/DP25	N/e
WS/DPI2	1.90	WS/DP26	N/e
WS/DPI3	N/e	WS/DP27	N/e
WS/DPI4	N/e	WS/DP28	N/e

Note: ¹ Final depth of trial hole. N/e – not encountered

2.3.3 Head

Soils of the Head were encountered directly underlying the Made Ground or Topsoil in twelve of the twenty-eight trial holes and were recorded to depths ranging between 1.00m and 4.00m bgl, in both cases the base of the borehole. They were also inferred to depths of up to 4.10m bgl within dynamic probe holes. The Head was generally located in the northern half of the site, to the north of the central water course, as shown on Figure 1.

The Head typically comprised firm brown gravelly CLAY / clayey sandy GRAVEL with fine roots and rootlets. Locally silty and with pockets of sand. Gravel is angular to sub-angular fine to coarse flint.

The depth of Head has been included in Table 2-5.

Table 2-5 Final Depth of Head

Trial Hole	Depth (m bgl)	Trial Hole	Depth (m bgl)
WS/DP01	N/e	WS/DPI 5	N/e
WS/DP02	N/e	WS/DPI 6	N/e
WS/DP03	N/e	WS/DPI 7	3.80
WS/DP04	N/e	WS/DPI 8	3.10
WS/DP05	N/e	WS/DPI 9	N/e
WS/DP06	N/e	WS/DP20	2.00
WS/DP07	N/e	WS/DP21	2.60 ¹ / 2.70
WS/DP08	N/e	WS/DP22	2.00 ¹ / 2.20
WS/DP09	N/e	WS/DP23	2.50 ¹ / 3.20
WS/DPI 10	N/e	WS/DP24	4.00 ¹ / 4.10
WS/DPI 11	N/e	WS/DP25	2.50 ¹ / 2.60
WS/DPI 12	N/e	WS/DP26	2.20 ¹ / 2.50
WS/DPI 13	N/e	WS/DP27	2.40 ¹ / 3.60
WS/DPI 14	4.00 ¹ / 4.10	WS/DP28	1.00 ¹ / 3.70

Note: ¹ Final depth of trial hole. N/e – not encountered

2.3.4 River Terrace Deposits

The River Terrace Deposits were encountered directly beneath the Made Ground, Topsoil, Head or Alluvium in eleven trial holes and were recorded to depths ranging between 0.90m and 4.70m bgl. They were also inferred from a further four dynamic probes holes to a maximum depth of 4.90m bgl. The River Terrace Deposits were located in the southwest of the site, to the south and west of the water courses, and also to the far north of the site, as shown on Figure 1.

The River Terrace Deposits typically comprised orangish brown fine to coarse slightly gravelly SAND, locally sandy gravelly CLAY. Gravel is angular to sub-angular fine to coarse flint.

This unit may include Raised Beach Deposits, which are also recorded by the BGS as comprising Sand and Gravel and therefore very difficult to distinguish from the River Terrace Deposits, particularly given their limited and inconsistent presence.

The depth of River Terrace Deposits has been included in Table 2-6.

Table 2-6 Final Depth of River Terrace Deposits

Trial Hole	Depth (m bgl)	Trial Hole	Depth (m bgl)
WS/DP01	4.70	WS/DPI 5	2.50
WS/DP02	3.40	WS/DPI 6	1.00
WS/DP03	N/e	WS/DPI 7	N/e
WS/DP04	3.00 ¹ / 4.20	WS/DPI 8	N/e
WS/DP05	3.70	WS/DPI 9	1.90

Trial Hole	Depth (m bgl)	Trial Hole	Depth (m bgl)
WS/DP06	N/e	WS/DP20	N/e
WS/DP07	3.00 ¹ / 3.80	WS/DP21	N/e
WS/DP08	3.00 ¹ / 3.60	WS/DP22	N/e
WS/DP09	1.90	WS/DP23	N/e
WS/DP10	N/e	WS/DP24	N/e
WS/DP11	N/e	WS/DP25	N/e / 4.00 ¹
WS/DP12	N/e	WS/DP26	N/e / 4.50 ¹
WS/DP13	2.70 ¹ / 3.80	WS/DP27	N/e / 4.60 ¹
WS/DP14	N/e	WS/DP28	N/e / 4.90 ¹

Note: ¹ Final depth of trial hole. N/e – not encountered

2.3.5 London Clay Formation

The London Clay Formation was encountered directly underlying the Alluvium, Head or River Terrace Deposits in twenty-four of the twenty-eight trial holes and recorded to the full depth of the investigation at 5.00m bgl. It was also inferred to 6.00m bgl in the dynamic probe holes.

The London Clay Formation typically comprised firm dark grey silty CLAY with rare shell fragments and rare fine selenite crystals.

The depth of London Clay Formation has been included in Table 2-7.

Table 2-7 Final Depth of London Clay Formation

Trial Hole	Depth (m bgl)	Trial Hole	Depth (m bgl)
WS/DP01	5.00 ¹ / 6.00 ¹	WS/DP15	4.00 ¹ / 6.00 ¹
WS/DP02	4.00 ¹ / 6.00 ¹	WS/DP16	4.00 ¹ / 6.00 ¹
WS/DP03	N/e / 6.00 ¹	WS/DP17	4.00 ¹ / 6.00 ¹
WS/DP04	N/e / 6.00 ¹	WS/DP18	4.00 ¹ / 6.00 ¹
WS/DP05	N/e / 6.00 ¹	WS/DP19	1.90 ¹ / 6.00 ¹
WS/DP06	4.00 ¹ / 6.00 ¹	WS/DP20	N/e / 6.00 ¹
WS/DP07	N/e / 6.00 ¹	WS/DP21	N/e / 6.00 ¹
WS/DP08	N/e / 6.00 ¹	WS/DP22	N/e / 6.00 ¹
WS/DP09	2.50 ¹ / 6.00 ¹	WS/DP23	N/e / 6.00 ¹
WS/DP10	4.00 ¹ / 6.00 ¹	WS/DP24	N/e / 6.00 ¹
WS/DP11	4.00 ¹ / 6.00 ¹	WS/DP25	N/e
WS/DP12	3.60 / 6.00 ¹	WS/DP26	N/e
WS/DP13	N/e / 6.00 ¹	WS/DP27	N/e
WS/DP14	N/e / 6.00 ¹	WS/DP28	N/e

Note: ¹ Final depth of trial hole. N/e – not encountered

2.4 Roots

Roots were encountered in each of the twenty-eight trial holes at depths ranging between 0.75m and 3.10m bgl. Desiccated roots were also recorded to depths of between 2.70m and 3.40m bgl in two trial holes.

It must be noted that the roots to crops can extend to a significant depth of the order or between one and two metres below ground level.

The depths of root penetration have been included in Table 2.8.

Table 2-8 Depth of Root Penetration

Trial Hole	Depth (m bgl)	Trial Hole	Depth (m bgl)
WS01	1.40	WS15	1.00
WS02	1.60	WS16	2.00
WS03	1.00 ¹	WS17	1.00
WS04	1.30	WS18	3.10
WS05	0.80	WS19	0.90
WS06	1.50	WS20	1.00
WS07	1.50	WS21	0.75
WS08	1.50	WS22	0.80
WS09	1.30	WS23	1.40
WS10	2.00 / 3.40 ²	WS24	1.10
WS11	2.10	WS25	2.50
WS12	1.20	WS26	1.10
WS13	1.00 / 2.70 ²	WS27	1.60
WS14	1.50	WS28	1.00 ¹
Note: ¹ Final depth of trial hole. ² Desiccated roots			

Roots may be found to greater depth at other locations on the site particularly close to trees and/or trees that may have been removed both within the site and its close environs. The site comprised a number of open fields, some appearing to be used for agriculture. Mature trees were noted along the boundaries of these fields, both along the site boundaries and within the site area. They were particularly abundant within the central western part of the site.

A review of Google Earth historical satellite imagery showed that no significant vegetation has been removed or added to the site in past 20 years.

It must be emphasised that the probability of determining the maximum depth of roots from a narrow diameter borehole is low. A direct observation such as from within a trial pit is necessary to gain a better indication of the maximum root depth.

2.5 Groundwater

Groundwater was encountered within ten of the twenty-eight trial holes. The details are included in Table 2-9.

Table 2-9 Groundwater Monitoring During Site Works

Trial Hole	Depth to Water (m bgl)		Notes
	Strike	After Standing 20mins	
WS01	2.00	1.70	-

Trial Hole	Depth to Water (m bgl)		Notes
	Strike	After Standing 20mins	
WS02	1.10	0.76	-
WS04	2.00	0.76	-
WS05	2.00	1.76	-
WS06	2.00	1.70	-
WS12	2.00	1.70	-
WS13	1.10	0.76	-
WS17	1.20	1.42	Seepage only.
WS19	2.00	1.55	-
WS21	1.10	1.10	No rise observed.

Changes in groundwater level occur for a number of reasons including seasonal effects and variations in drainage.

The investigation was conducted in July (2021), when groundwater levels should be falling towards their annual minimum (lowest) elevation, which typically occurs around September. The annual maximum (highest) elevation typically occurs around March.

Groundwater has been recorded in ten boreholes at depths varying between 0.76m and 1.70m bgl for short-term settled levels. Given the site has two water courses running through and alongside it and is situated between ~5m and ~10m AOD, shallow groundwater would be anticipated, particularly in the east of the site where the site lies adjacent to a water course and is lower. It is noted that the areas immediately adjacent to the water courses, through the centre of the site and along the eastern edge, comprise a flood zone with no residential development proposed.

Further groundwater monitoring is proposed for the winter period, commencing in October for six months, ending in March 2022. This will allow the worst-case groundwater levels to be determined. Given the levels observed during the investigation, groundwater levels are likely to have a significantly impact on the proposed development and the recommendations made in this report must be reviewed following the above monitoring period.

Section 3 Discussion of Geotechnical In-Situ and Laboratory Testing

3.1 Dynamic Probe Tests

Dynamic probing (DPSH) was undertaken at twenty-eight locations (DP01 to DP28) adjacent and prior to the drilling of their respective windowless sampler borehole, to depths ranging between 4.00 and 6.00m bgl. The results were converted to equivalent SPT “N60” values based on dynamic energy using commercial computer software (Geostru). The results were then interpreted based on the classifications outlined in Appendix B.1, Table B.1.1 to Table B.1.2.

The SPT “N60” values presented have been corrected in accordance with BS EN 22476 Part 3, to account for the rig dynamic probe trip hammer efficiency, borehole depth, overburden factors etc. Further correction of the ‘N’ values should therefore not be necessary. The energy ratio of the drilling rigs was 85.86% and 77%. The energy ratio for each location is presented on the individual logs within Appendix A.1.

3.1.1 Alluvium

The Alluvium recorded equivalent SPT “N60” values between 0 and 12 within cohesive beds and 0 to 8 in granular beds. The cohesive beds were classified as extremely low to medium strength with an inferred undrained cohesive strength ranging between <10kPa and 60kPa. The granular beds were classified as very loose to loose relative density. The zero values were recorded at various depths within the top 2.00m bgl, some near surface some at 2.00m bgl, with no obvious correlation between strength/density and depth within this unit.

3.1.2 Head

The Head recorded equivalent SPT “N60” values between 0 and 33 within cohesive beds and 0 to 33 in granular beds. The cohesive beds were classified as extremely low to very high strength with an inferred undrained cohesive strength ranging between <10kPa and 165kPa. The granular beds were classified as very loose to dense relative density. The strength/density profile with depth was highly variable, often with medium dense soils overlying loose and very loose soils. The zero values were recorded at depths of over 3.00m bgl in some cases, with no obvious correlation between strength/density and depth within this unit.

3.1.3 River Terrace Deposits

The River Terrace Deposits recorded equivalent SPT “N60” values between 0 and 25 within cohesive beds and 0 to >50 in granular beds. The cohesive beds were classified as extremely low to high strength with an inferred undrained cohesive strength ranging between <10kPa and 125kPa. The granular beds were classified as very loose to very dense relative density. The zero values were recorded at depths of up to 3.00m in some cases, with no obvious correlation between strength/density and depth within this unit.

3.1.4 London Clay Formation

The London Clay Formation recorded equivalent SPT “N60” values between 4 and 29, classifying the cohesive soils as low to high strength and inferred undrained cohesive strength of 20kPa to 145kPa, generally increasing with depth.

A full interpretation of the DPSH tests is outlined in Appendix B.2, Table B.2.1.

3.2 Dynamic Cone Penetrometer Tests

The Transport Research Laboratory (TRL), Dynamic Cone Penetrometer (DCP) were undertaken at thirty locations (DCP01 to DCP30). The results were interpreted based on the classification outlined in Appendix B.1.

The results from DCP testing indicated CBR values of between 2% and 212% for the soils encountered in the top 0.95m bgl, as detailed in Table 3-1.

The high CBR values encountered were anticipated to be large gravel clasts or Made Ground inclusions struck during the test.

Table 3-1 Summary of DCP CBR Results

DCP No.	Anticipated Strata	CBR Range (%)	DCP No.	Anticipated Strata	CBR Range (%)
01	MG/TS over HEAD	3 – 18	16	MG/TS over ALV	5 – 53
02	MG/TS over ALV	3 – 212	17	MG/TS over ALV	17
03	MG/TS over RTD	3 – 14	18	MG/TS over ALV	4 – 28
04	MG/TS over HEAD	7 – 77	19	MG/TS over ALV	10
05	MG/TS over HEAD	3 – 63	20	MG/TS over RTD	7 – 28
06	MG/TS over HEAD	3 – 39	21	MG/TS over RTD	10 – 50
07	MG/TS over HEAD	3 – 33	22	MG/TS over ALV	5 – 38
08	MG/TS over HEAD	5 – 67	23	MG/TS over RTD	14
09	MG/TS over HEAD	19	24	MG/TS over ALV	7 – 39
10	MG/TS over HEAD	12	25	MG/TS over RTD	3 – 35
11	MG/TS over HEAD	2 – 20	26	MG/TS over RTD	11
12	MG/TS over HEAD	9 – 29	27	MG/TS over ALV	12 – 50
13	MG/TS over HEAD	4 – 24	28	MG/TS over RTD	11
14	MG/TS over RTD	4 – 14	29	MG/TS over ALV	6 – 24
15	MG/TS over RTD	5 – 31	30	MG/TS over ALV	4 – 27

All locations are expected to be underlain by Made Ground / Topsoil with superficial deposits underlying. Given the nature of the test, the actual soil types are not known, but based on anticipated geology, the following observations can be made.

3.2.1 Head

In locations anticipated to be underlain by Head DCP testing indicated CBR values of between 2% and 77%.

3.2.2 Alluvium

In locations anticipated to be underlain by Alluvium DCP testing indicated CBR values of between 3% and 212%.

3.2.3 River Terrace Deposits

In locations anticipated to be underlain by River Terrace Deposits DCP testing indicated CBR values of between 3% and 50%.

The DCP results are presented in Appendix B.3.

3.3 Atterberg Limit Tests

Atterberg Limit tests were performed on twenty-four samples, six obtained from the Alluvium, eight from the Head, seven from the cohesive parts of the River Terrace Deposits and the remaining three from the London Clay Formation. The results were classified in accordance with BRE Digest 240 and NHBC Standards Chapter 4.2.

3.3.1 Alluvium

The cohesive beds of the Alluvium were classified as low to medium volume change potential in accordance with both BRE Digest 240 and NHBC Standards Chapter 4.2.

3.3.2 Head

The cohesive beds of the Head were classified as low/none to high volume change potential in accordance with BRE Digest 240 and NHBC Standards Chapter 4.2 respectively.

3.3.3 River Terrace Deposits

The cohesive beds of the River Terrace Deposits were classified as low to high volume change potential in accordance with both BRE Digest 240 and NHBC Standards Chapter 4.2.

3.3.4 London Clay Formation

The London Clay Formation was classified as medium to high volume change potential in accordance with both BRE Digest 240 and NHBC Standards Chapter 4.2.

A full interpretation of the Atterberg Limit tests are outlined in Table B.2.2, Appendix B.2 and the laboratory report in Appendix B.3.

3.4 Particle Size Distribution Tests

Particle Size Distribution (PSD) tests were performed on thirteen samples, six obtained from the River Terrace Deposits, one from the Alluvium and six from the Head.

One of the samples tested from the River Terrace Deposits was predominately cohesive, recording 53% silt and clay, albeit with 45% sand.

3.4.1 Alluvium

The PSD tests classified the granular beds of the Alluvium as having no volume change potential in accordance with BRE Digest 240 and NHBC Standards Chapter 4.2.

3.4.2 Head

The PSD tests classified the granular beds of the Head as having a volume change potential in accordance BRE Digest 240 in three of six samples. The results from grading analysis showed that each of the six samples tested had no volume change potential in accordance with NHBC Standards Chapter 4.2. Note that a cohesive soil is only classified as having a volume change potential if it is also plastic and an Atterberg Limit test can be conducted on the strata.

3.4.3 River Terrace Deposits

The PSD tests classified the granular beds of the River Terrace Deposits as having no volume change potential in accordance with BRE Digest 240 and NHBC Standards Chapter 4.2.

A full interpretation of the PSD tests are outlined in Table B.2.3, Appendix B.2 and the laboratory report in Appendix B.3.

3.5 Sulphate and pH Tests

One sample was taken from the Alluvium, two from the River Terrace Deposits, two from the Head and one from the London Clay Formation for water soluble sulphate (2:1) and pH testing in accordance with Building Research Establishment Special Digest 1, 2005, 'Concrete in Aggressive Ground'.

The tests recorded water soluble sulphate between <10mg/l and 22mg/l with pH values of 7.5 to 8.1.

The significance of the sulphate and pH Test results are discussed in Section 4.5 and the laboratory report in Appendix B.3.

Section 4 Foundation Design

4.1 General

An engineering appraisal of the soil types encountered during the site investigation and likely to be encountered during the redevelopment of this site is presented. Soil descriptions are based on analysis of disturbed samples taken from the trial holes.

4.1.1 Made Ground and Topsoil

The terms *Fill* and *Made Ground (non-engineered fill)* are used to describe material, which has been placed by man either for a particular purpose e.g. to form an embankment, or to dispose of unwanted material. For the former use, the Fill and/or Made Ground may well have been selected for the purpose and placed and compacted in a controlled manner. With the latter, great variations in material type, thickness and degree of compaction invariably occur and there can be deleterious or harmful matter, as well as potentially methanogenic organic material.

The BSI Code of Practice for Foundations, BS 8004:2015, Clause 4.1.2.2 states, *'Spread foundations should not be placed on non-engineered fill unless such use can be justified on the basis of a thorough ground investigation and detailed design.'*

Peat and organic soils highly compressible, and even lightly loaded foundations will be subject to considerable settlements over a long period if placed on them. For this reason, these soils are not suitable for carrying the loads for important structures.

Soils described as Made Ground were encountered in thirteen of the twenty-eight trial holes from ground level to depths ranging between 0.30m and 0.60m bgl. The Made Ground typically comprised soft grey and orangish brown slightly clayey slightly sandy SILT with occasional rootlets. Locally with rare angular to sub-angular fine gravel.

Soils described as Topsoil were encountered in fifteen of the twenty-eight trial holes from ground level to depths ranging between 0.12m and 0.60m bgl. The Topsoil comprised soft dark grey and brown silty CLAY with occasional rootlets. Locally with rare angular to sub-angular fine gravel.

A result of the inherent variability, particularly of uncontrolled Topsoil, Fill and/or Made Ground is that it is usually unpredictable in terms of bearing capacity and settlement characteristics. Foundations should, therefore, be taken through any Topsoil and/or Made Ground and either into, or onto a suitable underlying natural stratum of adequate bearing characteristics.

4.1.2 Alluvium

Soils of the Alluvium were recorded directly underlying the Made Ground or Topsoil in seven of the twenty-eight trial holes and were recorded to depths ranging between 1.00m and 2.60m bgl, generally within the areas anticipated in the east and centre of the site, as shown in Figure 1. They were also inferred to 2.00m bgl in DP03.

The Alluvium typically comprised soft grey and orangish brown slightly sandy CLAY. Locally with pockets of fine to coarse sand, occasional gravel and black discolouration.

The results from DPSH testing inferred that the cohesive soils of the Alluvium were of an **extremely low to medium strength** with inferred undrained cohesive strength of **<10kPa to 60kPa**. The granular beds were classified as very loose to loose relative density. The zero values were recorded at various depths within the top 2.00m bgl, some near surface some at 2.00m bgl, with no obvious correlation between strength/density and depth within this unit.

The results from Atterberg Limits tests showed that the cohesive soils of the Alluvium had **low to medium volume change potential** in accordance with both BRE Digest 240 and NHBC Standards Chapter 4.2.

Soils of the Alluvium are normally consolidated, both cohesive and granular soils and as such are expected to display low to moderate bearing capacities with moderate to high settlement characteristics. The soils of the Alluvium were not considered suitable for the proposed development due to likely variations both in composition and depositional thickness.

4.1.3 Head

Soils of the Head were encountered directly underlying the Made Ground or Topsoil in twelve of the twenty-eight trial holes and were recorded to depths ranging between 1.00m and 4.00m bgl, in both cases the base of the borehole. They were also inferred to depths of up to 4.10m bgl within dynamic probe holes. The Head was generally located in the northern half of the site, to the north of the central water course, as shown on Figure 1.

The Head typically comprised firm brown gravelly CLAY / clayey sandy GRAVEL with fine roots and rootlets. Locally silty and with pockets of sand. Gravel is angular to sub-angular fine to coarse flint.

The results from DPSH testing inferred that the cohesive soils of the Head were of an **extremely low to very high strength** with an inferred undrained cohesive strength ranging between **0kPa and 165kPa**. The granular beds were classified as **very loose to dense** relative density. The strength/density profile with depth was highly variable, often with medium dense soils overlying loose and very loose soils. The zero values were recorded at depths of over 3.00m bgl in some cases, with no

obvious correlation between strength/density and depth within this unit.

The results from Atterberg Limits tests showed that the cohesive soils of the Head had **low/none to high volume change potential** in accordance with BRE Digest 240 and NHBC Standards Chapter 4.2 respectively.

Soils of the Head are normally consolidated, both cohesive and granular soils and as such are expected to display low to moderate bearing capacities with moderate to high settlement characteristics. The soils of the Head were not considered suitable for the proposed development due to likely variations both in composition and depositional thickness.

4.1.4 River Terrace Deposits

The River Terrace Deposits were encountered directly beneath the Made Ground, Topsoil, Head or Alluvium in eleven trial holes and were recorded to depths ranging between 0.90m and 4.70m bgl. They were also inferred from a further four dynamic probes holes to a maximum depth of 4.90m bgl. The River Terrace Deposits were located in the southwest of the site, to the south and west of the water courses, and also to the far north of the site, as shown on Figure 1.

The River Terrace Deposits typically comprised orangish brown fine to coarse slightly gravelly SAND, locally sandy gravelly CLAY. Gravel is angular to sub-angular fine to coarse flint.

The results from DPSH testing inferred that the cohesive soils of the River Terrace Deposits were of an **extremely low to high strength** with an inferred undrained cohesive strength ranging between **0kPa and 125kPa**. The granular beds were classified as **very loose to very dense** relative density, generally increasing with depth. The zero values were recorded as depths of up to 3.00m in some cases, with no obvious correlation between strength/density and depth within this unit.

The results from Atterberg Limits tests showed that the cohesive soils of the River Terrace Deposits had **low to high volume change potential** in accordance with both BRE Digest 240 and NHBC Standards Chapter 4.2.

Soils of the River Terrace Deposits are normally consolidated, predominately granular soils and as such are expected to display moderate bearing capacities with moderate settlement characteristics. The soils of the River Terrace Deposits were considered a suitable bearing stratum for the proposed development subject to sufficient bearing capacity being achieved.

4.1.5 London Clay Formation

The London Clay Formation was encountered directly underlying the Alluvium, Head or River Terrace Deposits in twenty-four of the twenty-eight trial holes and recorded to the full depth of the investigation at 5.00m bgl. It was also inferred to 6.00m bgl in the dynamic probe holes.

The London Clay Formation typically comprised firm dark grey silty CLAY with rare shell fragments and rare fine selenite crystals.

The results from DPSH testing inferred that the cohesive soils of the London Clay Formation were of a **low to high strength** and inferred undrained cohesive strength of **20kPa to 145kPa**, generally increasing with depth.

The results from Atterberg Limits tests showed that the soils of the London Clay Formation had **medium to high volume change potential** in accordance with both BRE Digest 240 and NHBC Standards Chapter 4.2.

The soils of the London Clay Formation are heavily overconsolidated cohesive soils and as such are expected to display moderate bearing and settlement characteristics. The soils of the London Clay Formation were considered a suitable bearing stratum for the proposed development, but given the depth encountered in most locations, a piled foundation solution would be required.

4.1.6 Roots

Roots were encountered in each of the twenty-eight trial holes at depths ranging between 0.75m and 3.10m bgl. Desiccated roots were also recorded to depths of between 2.70m and 3.40m bgl in two trial holes.

Roots may be found to greater depth at other locations on the site particularly close to trees and/or trees that may have been removed both within the site and its close environs. The site comprised a number of open fields, some appearing to be used for agriculture. Mature trees were noted along the boundaries of these fields, both along the site boundaries and within the site area. They were particularly abundant within the central western part of the site.

A review of Google Earth historical satellite imagery showed that no significant vegetation has been removed or added to the site in past 20 years.

4.1.7 Groundwater

Groundwater was encountered within ten of the twenty-eight trial holes. The details are included in Table 2.9.

Changes in groundwater level occur for a number of reasons including seasonal effects and variations in drainage. The investigation was conducted in July (2021), when groundwater levels should be falling towards their annual minimum (lowest) elevation, which typically occurs around September. The annual maximum (highest) elevation typically occurs around March.

Groundwater has been recorded in ten boreholes at depths varying between 0.76m and 1.70m bgl for settled levels. Given the site has two water courses running through and alongside it and is situated between ~5m and ~10m AOD, shallow

groundwater would be anticipated, particularly in the east of the site. It is noted that the areas immediately adjacent to the water courses, through the centre of the site and along the eastern edge, comprise a flood zone with no residential development proposed.

Further groundwater monitoring is proposed for the winter period, commencing in October for six months, ending in March 2022. This will allow the worst-case groundwater levels to be determined. Given the levels observed during the investigation, groundwater levels are likely to have a significantly impact on the proposed development and the recommendations made in this report must be reviewed following the above monitoring period.

4.2 Foundation Scheme General

The proposal comprised redevelopment of the site from farmland to housing with gardens and areas of open recreational space. At time of writing only a speculative plan has been provided for the development and this report must be reviewed and revised in relation to actual site-specific proposals if it is to be presented as evidence in pursuit of a planning application. All conclusions and findings in this report will therefore be essentially generic in nature and should be viewed in this light.

In compiling this report reliance was placed on drawing number 00163_CALA_CN_01, dated October 2020 and was prepared by the client. The recommendations provided within this report must be reviewed and revised when a finalised scheme is prepared and must not be applied without further consultation with Soils Limited.

The speculative development plans provided by the client are presented in Appendix D.

4.3 Guidance on Shrinkable Soils

The Building Research Establishment (BRE) Digests 240, 241 and 242 provide guidance on 'best practice' for the design and construction of foundations on shrinkable soils.

4.3.1 Alluvium

The results from Atterberg Limits Tests showed that the Alluvium had **low to medium volume change potential** in accordance with both BRE Digest 240 and NHBC Standards Chapter 4.2.

4.3.2 Head

The cohesive beds of the Head were classified as **low/none to high volume change potential** in accordance with BRE Digest 240 and NHBC Standards Chapter 4.2 respectively.

4.3.3 River Terrace Deposits

The cohesive beds of the River Terrace Deposits were classified as **low to high volume change potential** in accordance with both BRE Digest 240 and NHBC

Standards Chapter 4.2.

4.3.4 London Clay Formation

The London Clay Formation was classified as **medium to high volume change potential** in accordance with both BRE Digest 240 and NHBC Standards Chapter 4.2.

Given that placing foundations into the soils of the Alluvium is not recommended, **high volume change potential** must therefore be adopted where foundations pass through or into the cohesive soils of the Head, River Terrace Deposits or London Clay Formation.

The granular soils of the Head and River Terrace Deposits had no volume change potential.

The depth to roots and/or of desiccation may vary from that found during the investigation. The client is responsible for establishing the depth to roots and/or of desiccation on a plot by plot basis to establish an appropriate founding depth prior to the construction of foundations. This must take account of trees, substantial bushes and hedgerows that are to remain, those that have already been removed or are to be removed or those that are to be planted as part of the site landscaping. When trees are felled it can take up to twenty years for desiccation caused by roots to recover. Supplied site surveys may not include substantial shrubs or bushes and is also unlikely to have data on any trees, bushes or shrubs removed prior to or following the site survey.

The BRE Digest 241 states: *“An increasingly common, potentially damaging situation is where trees or hedges have been cut down prior to building. The subsequent long-term swelling of the zone of clay desiccated by the roots, as moisture slowly returns to the ground, can be substantial. The rate at which the ground recovers is very difficult to predict and if there is any doubt that recovery is complete then bored pile foundations with suspended beams and floors should be used”.*

The stated intention of the NHBC is to ensure that shrinkage and swelling of plastic soils does not adversely affect the structural integrity of foundations to such a degree that remedial works would be required to restore the serviceability of the building. It must be borne in mind that adherence to the NHBC tables and design recommendations may not, in all cases, totally prevent foundation movement and cracking of brickwork might occur.

The BRE Digest 240 suggests: *“Two courses of action are open:*

Estimate the potential for swelling or shrinkage and try to avoid large changes in the water content, for example by not planting trees near the foundations.

Accept that swelling or shrinkage will occur and take account of it. The foundations can be designed to resist resulting ground movements or the superstructure can be designed to accommodate movement without damage.”

The design of foundations suitable to withstand movements is presented in BRE Digest 241 "Low-rise buildings on shrinkable clay soils: Part 2"

4.4 Geotechnical Appraisal

The is underlain by a complex series of superficial deposits including Alluvium, Head, River Terrace Deposits and Raised Beach Deposits. These are underlain by the London Clay Formation, encountered or inferred across all the site except the far north.

4.4.1 Alluvium

The Alluvium is predominantly cohesive and typically of very low cohesive strength, so is not considered suitable for supporting any form of significant structures. Generally, these soils are found in the east and centre of the site adjacent to the water courses on and adjacent to the site, areas which have been designated as flood zone, with no residential development proposed.

4.4.2 Head

The Head is highly varied with a wide range of soil strengths evident across a wide range of depths. The Head was generally located in the northern half of the site, to the north of the central water course, as shown on Figure 1. With the occasional exception these soils are unlikely to provide a suitable bearing stratum for the proposed development, with soils of very low cohesive strength / density (zero blow counts in DPs) noted to depths of greater than 3.00m bgl in several locations.

4.4.3 River Terrace Deposits

The River Terrace Deposits and Raised Beach Deposits have been considered together given they are both predominately granular soils, although are also recorded as cohesive with high gravel content. The River Terrace Deposits were located in the southwest of the site, to the south and west of the water courses, and also to the far north of the site, as shown on Figure 1. These soils could be suitable as a founding stratum for the proposed development, although some areas were noted with poor engineering properties (DP04).

In addition to the designated flood zone area, the site can be broadly divided into three areas:

- Zone 1 - The southwest section, which is marked by the cropped field and forms a roughly triangular shaped area west and south of the flood zone (WS/DP01 to WS/DP11).
- Zone 2 – The central section, which forms the centre of the site to the west and north of the flood zone (WS/DP14, 16, 18, 20 to WS/DP24).
- Zone 3 – The northern section, which forms the northern third of the site, west of the flood zone (WS/DP25 to WS/DP28).

These zones are delineated in Figure 6.

4.4.4 Zone 1 – Southwest Section

The soils in the far southwest corner generally comprise River Terrace Deposits with reasonable engineering properties that could provide suitable bearing capacities at depths of around 1.20m bgl. Further north and east Alluvium was noted overlying and deepening of foundation will be required to ensure founding in the River Terrace Deposits, or where they are absent, the London Clay Formation. Based on the data available, foundation depths of up to 2.50m bgl will be required, increasing with proximity to the flood zone to the north and east. Roots were also noted to depths ranging between 0.80m and 2.10m in this zone, and foundations must be deepened accordingly, within cohesive soils.

However, it must be noted that shallow groundwater was recorded in several boreholes within this zone, noted at depths between 0.76m and 1.70m bgl. As such, shallow foundations may not be feasible. It must also be noted that soils of poor engineering properties were encountered in DP04 with zero blow counts recorded at 2.70m and 3.20m bgl. If a shallow foundation option is preferred, further investigation is required in this area to delineate any problematic areas. It is recommended that a review of the foundation options is undertaken following the winter groundwater monitoring that is planned, when a greater understanding of the groundwater conditions is gained.

4.4.5 Zone 2 – Central Section

The soils underlying this area of the site were predominately Head, which as noted above are highly variable, but generally provide an unsuitable founding stratum. The dynamic probes recorded very low strength soils to depths of at least 3.00m bgl in three locations across this area with poor ground conditions evident elsewhere as well. Shallow groundwater was also noted in this zone and as such, it is recommended that piled foundations be adopted.

Alternatively, and subject to groundwater levels being manageable, further investigation may allow shallow foundations to be adopted in some parts of this zone. Dynamic probes undertaken on a plot-by-plot basis would provide greater certainty of the ground conditions and allow specific foundation options to be considered.

4.4.6 Zone 3 – Northern Section

The soils encountered in this area included Head and River Terrace Deposits and were predominately granular. Typically, a dense upper layer was noted to depths of between 1.00m and 1.50m bgl, underlain by loose to medium dense soils to depths ranging from 2.50m to 3.00m bgl, before becoming dense and very dense again. These shallow soils are likely to be suitable for the adoption of shallow foundations, with sufficient bearing capacities provided at around 1.00m bgl.

However, one of the four dynamic probes undertaken in this zone (DP27) recorded zero blow counts at depths between 2.30m and 3.10m bgl. Given the four dynamic probes generally follow the same profile, these very loose soils may also present

elsewhere. As such, further investigation is recommended to provide greater certainty of ground conditions. A plot-by-plot approach could also be taken here to delineate any problematic areas.

Groundwater was not recorded during the investigation within this zone but may be present during the winter monitoring.

4.4.7 Summary

The poor and highly variable ground conditions, shallow groundwater and significant root depths recorded dictate that the use of shallow or deepened trench fill foundations is not feasible across all areas of the site. Further investigation including winter groundwater monitoring and additional intrusive investigation may provide sufficient confidence to allow shallow foundations to be adopted in certain areas, but at this stage there remains too much uncertainty to propose such an approach.

4.4.8 Ground Floor Slab

NHBC Standards 2019 states ground floors should be constructed as suspended floors where:

- *“the foundation depth dictated by the NHBC Standards 2019, Chapter 4.2.10 would exceed 1.5m bgl;”*
- *“ground floor construction is undertaken when the surface soils are seasonally desiccated;”*
- *“the depth of fill exceeds 600mm;”*
- *“there is shrinkable soil that could be subject to movement, expansive material or other unstable soils;”*
- *“the ground has been subject to vibratory improvement;” or*
- *“ground or fill is not suitable to support ground-bearing slabs.”*

Given the highly variable ground conditions encountered, including cohesive soils of up to high volume change potential, suspended ground floor slabs are recommended.

4.4.9 Piled Foundations

If adopted the piled foundations must be taken through any Made Ground/Topsoil and superficial deposits into suitable strength soils of the London Clay Formation.

The construction of a piled foundation is a specialist job with the actual pile working load depending on the particular type pile and installation method. Prior to finalising the foundation design the advice from a reputable contractor who is familiar with the ground and groundwater conditions present at the site should be sought.

To prevent necking of the green concrete, temporary casing may be required where the pile passes through the Made Ground/Topsoil and superficial deposits or

London Clay Formation and below the groundwater table (if encountered). To achieve the full bearing value a pile should penetrate the bearing stratum by at least five times the pile diameter.

4.5 Subsurface Concrete

Sulphate concentration measured in 2:1 water/soil extracts fell into Class **DS-1** of the BRE Special Digest 1 2005, *'Concrete in Aggressive Ground'*. Table C2 of the Digest indicated ACEC (Aggressive Chemical Environment for Concrete) site classifications of **AC-1**. The pH of the soils tested ranged between 7.5 and 8.1. The classification given was determined using the mobile groundwater case, in view of groundwater being encountered. The laboratory results are presented in Appendix B.3.

Concrete to be placed in contact with soil or groundwater must be designed in accordance with the recommendations of Building Research Establishment Special Digest 1 2005, *'Concrete in Aggressive Ground'* taking into account any possible exposure of potentially pyrite bearing natural ground and the pH of the soils.

4.6 Excavations

Shallow excavations in the Made Ground/Topsoil and superficial deposits are likely to be marginally stable in the short term at best.

Deeper excavations taken into the London Clay Formation are likely to be stable in the short term, depending on the thickness of overlying superficial deposits. Unsupported earth faces formed during excavation may be liable to collapse without warning and suitable safety precautions should therefore be taken to ensure that such earth faces are adequately supported or battered back to a safe angle of repose.

Excavations beneath the groundwater table are likely to be unstable and dewatering of foundation trenches may be necessary.

4.7 Pavements

The results from DCP testing indicated CBR values of between 2% and 212% for what were assumed to be the soils of the Made Ground, Topsoil and superficial deposits based on the findings of the windowless sampler boreholes. The high CBR values encountered were anticipated to be large gravel clasts struck during the test.

CBR values within the Made Ground are expected to be highly variable due to changes in moisture content and marked variations within ground conditions, therefore **in-situ testing must be undertaken** immediately prior to the installation of pavements/roads.

Any soft spots at formation level, within the Made Ground, must be dug out and replaced with a suitably compacted granular fill. Prior to construction the formation level should be proof rolled.

The percentage of material passing the 75um BS test sieve within the granular River Terrace deposits was noted to be greater than 10% in three out of four samples; in the granular Head in four out of five samples; and in the granular Alluvium not in one sample. Therefore, and in accordance with the Road Research Laboratory LR90, the granular soils of the River Terrace Deposits and Head are likely to be **frost susceptible**.

The cohesive soils of the Alluvium recorded modified plasticity index ranging between 15% and 38%. The cohesive soils of the Head recorded modified plasticity index ranging between 6% and 48%. The cohesive soils of the River Terrace Deposits recorded modified plasticity index ranging between 17% and 47%. Therefore, and in accordance with the Road Research Laboratory LR90, the cohesive superficial deposits must be treated as **frost susceptible**, as in each case their plasticity index may be less than 20%.

The thickness of any pavements are likely to be dictated by the frost susceptibility of the sub-grade.

Section 5 Determination of Chemical Analysis

5.1 Site Characterisation and Revised Conceptual Site Model

The Preliminary Investigation Report undertaken by Soils Limited (report ref: 19522/PIR dated September 2021) did not identify any risk of ground contamination and from previous usage of the site and offsite sources. However, intrusive investigation was recommended to confirm these findings.

The Main Investigation Report identified Made Ground to depths between 0.30m and 0.60m bgl, typically comprising soft grey and orangish brown slightly clayey slightly sandy SILT with occasional rootlets. Locally with rare angular to sub-angular fine gravel.

There were no visual or olfactory indicators of contamination noted during the investigation.

Shallow groundwater was recorded on site within the superficial deposits, as anticipated.

The conceptual site model was updated to take account of the above findings and presented in Appendix C.1.

5.2 Soil Sampling

Trial hole locations were set out to provide an overview of ground conditions across the site, together with enabling the collection of samples to enable chemical characterisation of the underlying strata.

Representative samples for potential environmental testing were obtained from the trial holes at depths of between 0.10m and 1.00m bgl to allow a representation of the materials encountered, with additional samples to be obtained, if necessary, where there was visual or olfactory evidence of contamination.

The analytical testing was based on a suite of commonly occurring inorganic and organic contaminants, considering the Conceptual Site Model and the ground conditions encountered.

5.3 Determination of Chemical Analysis

The suite of chemical analyses has been based upon the findings of the Preliminary Investigation Report (PIR) and this investigation, to examine the potential sources of contamination identified in the conceptual site model. The chemical analyses were carried out on twenty-seven samples prepared from the Made Ground, Topsoil and subsoil from across the site. The nature of the analyses is detailed below:

- 27 No. Metal suites: Arsenic, Boron, Cadmium, Chromium (trivalent & hexavalent), Copper, Lead, Mercury, Nickel, Vanadium, Selenium, Zinc

- 27 No. pH values
- 27 No. Polycyclic aromatic hydrocarbons (PAH) – USEPA 16 suite
- 27 No. Organic matter contents
- 27 No. Asbestos screens
- 27 No. Monohydric Phenols
- 27 No. Texas banded Total Petroleum Hydrocarbons

The soil testing was carried out in accordance with the MCERTS performance standard, and the results are shown in Appendix C.2, Test Report 21-09625.

Section 6 Qualitative Risk Assessment

6.1 Assessment Criteria

The assessment criteria used to determine risks to human health are derived and explained within Appendix C.3.

6.2 Representative Contamination Criteria - Soil

The proposal comprised redevelopment of the site from farmland to housing with gardens and areas of open recreational space. At time of writing only a speculative plan has been provided for the development and this report must be reviewed and revised in relation to actual site-specific proposals if it is to be presented as evidence in pursuit of a planning application. All conclusions and findings in this report will therefore be essentially generic in nature and should be viewed in this light.

In compiling this report reliance was placed on drawing number 00163_CALA_CN_01, dated October 2020 and was prepared by the client. The recommendations provided within this report must be reviewed and revised when a finalised scheme is prepared and must not be applied without further consultation with Soils Limited.

Based on the proposed development, the results of the chemical analysis have been compared against generic guidance values for a '**Residential with home grown produce**' end use, as presented in SP1010: Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination December 2014 (C4SL), derived for the protection of human health. Where this document has not published screening values for determinants, generic screening values derived for the same end use have been adopted from the following published guidance; DEFRA Soil Guideline Values (SGV) and LQM/CIEH/Suitable 4 Use Level (S4UL).

To assess the potential toxicity of organic determinants (Petroleum Hydrocarbons and Polyaromatic Hydrocarbons) to the human health, soils samples were analysed for Soil Organic Matter (SOM). The selected samples analysed recorded, SOM values of between 0.4% and 13.0%. For each soil sample tested, the resultant Soil Organic Matter allowed for the correct comparison to be made with the appropriate guideline value for each organic determinants analysed.

Table 6-1 outlines the samples that have exceeded their relevant assessment criteria. The full laboratory report is presented in Appendix C.2.

Table 6-1 Summary of Chemical Analysis of Soils Sample Exceedance

Substance	Sample locations where SGV, C4SL or S4UL adopted were exceeded for the 'Residential with home grown produce' land-use scenario
None recorded	

Asbestos locations where material found (no threshold just presence)

None recorded

The guideline values are assessed against the 'Residential with home grown produce' land-use scenario, which was considered the most appropriate land-use scenario, given the type of the proposed redevelopment.

In summary, none of the samples tested recorded concentrations above the 'Residential with home grown produce' end-use screening values.

6.2.1 Asbestos

Asbestos Containing Material (ACM) was not detected within any of the samples tested.

As asbestos containing material was identified in one of the samples tested it is possible that asbestos is present in other areas of the site. If encountered, care must be taken to ensure any such material is separated and disposed of in an appropriate manner to a licensed waste facility.

6.3 Risk to Groundwater

The site was located on secondary aquifers, both Secondary A and Undifferentiated, with Unproductive Strata of the London Clay Formation underlying. The superficial aquifers are medium to highly vulnerable. The site was not located within a Source Protection Zone and there are no potable abstraction points noted within 1km.

There are five inland rivers noted on the site principally through the centre running west to east and along the eastern boundary from north to south.

The vulnerability of controlled waters was low to moderate given the absence of identified sources or elevated concentrations recorded in the shallow soils analyses undertaken across the site, the risk to controlled waters is deemed to be low to negligible.

6.4 Risk Assessment

Risk assessments are undertaken for the soil, groundwater and soil gas. The CSM has been updated to take account of the assessments below and presented in Appendix C.1. The full laboratory chemical report is presented in Appendix D.2.

6.4.1 Soils

None of the samples tested recorded concentrations above the 'Residential with home grown produce' end-use screening values.

Asbestos Containing Material (ACM) was not detected within any of the samples tested.

The Tier 1 Quantitative risk assessment therefore established that there was **no risk to the human health receptors** of construction workers or future end-users.

6.4.2 Groundwater

An assessment based on the soils analysis and the vulnerability of the site established that **there was no risk** to the groundwater receptor.

6.4.3 Soil Gas

The Preliminary Investigation Report did not identify any potential sources of gas on or around the site. However, the investigation has recorded soils with organic content as high as 13%, and Alluvium was present in significant parts of the site, particularly along the eastern side.

Whilst the risk was relatively low, this does pose a possible soil gas risk to the site (strata >1m and >2.5% organic matter) and further works are therefore advised, as detailed in Section 6.5, to further investigate this unknown.

6.5 Recommendations

Soil chemical analysis did not record any elevated concentrations when compared to 'Residential with home grown produce' end-use screening values and the risk to groundwater was deemed to be negligible.

As such, no further work in respect of soils or controlled water is considered necessary, subject to approval from the local authority, which should be sought at the earliest opportunity.

A site-specific soil gas risk assessment is recommended to establish any risk posed by the naturally organic-rich soils present on site. In conjunction with the winter groundwater monitoring, the wells installed on site should be monitored for soil gas on 6No. occasions (residential low risk) and a risk assessment undertaken in accordance with BS8485:2016, CIRIA and NHBC guidance.

6.6 Duty of Care

Groundworkers must maintain a good standard of personal hygiene including the wearing of overalls, boots, gloves and eye protectors and the use of dust masks during periods of dry weather.

To prevent exposure to airborne dust by both the general public and construction personnel the site should be kept damp during dry weather and at other times when dust is generated as a result of construction activities. The site should be securely fenced at all times to prevent unauthorised access.

Washing facilities should be provided and eating restricted to mess huts.

6.7 Excavated Material

Excavated material as waste must be defined or classified prior to any disposal, transport, recycling or re-use at or by an appropriately licensed or exempt carrier and/or off-site disposal facility. The requirements inherent in both Duty of Care and Health and Safety must also be complied with. In order to determine what is to happen, what is suitable, appropriate and most effective in the disposal of wastes, especially those subject to CDM waste management plan requirements, several factors must be considered and competent advice should always be sought.

The amount, type and nature of the material to be removed will in part determine the amount and type of analysis that may be required to comply with current waste guidance, and thereby allow a competent person to suitably classify the material. Often this data is uncertain or unavailable, especially in the early stages of a project, and therefore further investigation, testing and analysis may be required as additional information regarding the development becomes available.

Wastes must be classified and defined by their solid characteristics to comply with current waste guidance. Existing information and analysis derived for environmental purposes may therefore be suitable for use in this context. Waste Acceptance Criteria (WAC) report the leachability of materials and therefore cannot be used to classify, characterise or define wastes. The only purpose of a WAC analysis is to determine the suitability of a given material for acceptance at one of the three different types of available licenced landfills (inert, stable non-reactive hazardous or hazardous).

Other options are available that may lead to significant savings against disposal to landfill and expert advice should always be sought from a competent person to advise on their relative costs or benefits and advise on any additional analysis, sampling or investigation that may be required to reduce remaining uncertainties and comply with current guidance. Further consideration of results using HazWasteOnline™ can be undertaken on request to give an indication of potentially hazardous properties in the materials analysed.

6.8 Re-use of Excavated Material On-site

The re-use of on-site soils may be undertaken either under the Environmental Permitting Regulations 2007 (EPR), in which case soils other than uncontaminated soils are classed as waste, or under the CL:AIRE Voluntary Code of Practice (CoP) which was published in September 2008 and is accepted as an alternative regime to the EPR.

Under the EPR, material that is contaminated but otherwise suitable for re-use is also classified as waste and its re-use should be in accordance with the Environmental Permitting Regulations 2007 (EPR). Environmental Permit Exemptions (EPE) are for the re-use of non-hazardous or inert waste only; hazardous waste cannot be re-used under a permit exemption. EPE apply only to imported inert waste materials; inert material arising on site and recovered on site is not classified as waste and does not require an exemption. It is possible that materials arising on-site will be classified as inert and would

not need an exemption.

Environmental Permit Exemptions are only allowed for certain activities, placing controls on the quantities that can be stored and re-used. The re-use of waste shall be within areas and levels defined in planning applications and permissions for the development. An EPE requires a site-specific risk assessment for the receptor site to demonstrate that the materials are suitable for use, i.e. that they will not give rise to harm to human health or pollution of the environment.

Under the CL:AIRE voluntary code of practice (CoP) materials excavated on-site are not deemed contaminated if suitable for re-use at specified locations or generally within the site.

Material that may have been classified as hazardous waste under the EPR may be re-used. The CoP regime requires that a 'Qualified Person' as defined under the CoP reviews the development of the Materials Management Plan, including review of Risk Assessments and Remediation Strategy/Design Statement together with documentation relating to Planning and Regulatory issues, and signs a Declaration which is forwarded to the Environment Agency and which confirms compliance with the CoP.

Should it be necessary to import materials from another site where materials are excavated and which is not material from a quarry or produced under a WRAP protocol, then an EPE would be necessary for the imported material whether the work was managed under the CoP or the EPR.

6.9 Imported Material

Any soil, which is to be imported onto the site, must undergo chemical analysis to permit classification prior to its importation and placement in order to ascertain its status with specific regard to contamination, i.e. to prove that it is suitable for the purpose for which it is intended.

6.10 Discovery Strategy

There may be areas of contamination not identified during the course of the investigation. Such occurrences may also be discovered during the demolition and construction phases for the redevelopment of the site.

Care should be taken during excavation works especially to investigate any soils, which appear by eye (e.g. such as fibrous materials, large amounts of ash and unusual discolouration), odour (e.g. fuel, oil and chemical type odours or unusual odours such as sweet odours or fishy odours) or wellbeing (e.g. light headedness and/or nausea, burning of nasal passages and blistering or reddening of skin due to contact with soil) to be contaminated or of unusual and/or different character to standard soils or those analysed.

In the event of any discovery of potentially contaminated soils or materials, this discovery should be quarantined and reported to the most senior member of site staff or the designated responsible person at the site for action. The location, type and quantity must be recorded and the Local Authority, and a competent and appropriate third party Engineer/Environmental consultant notified immediately. An approval from the Local authority must be sought prior to implementing any proposed mitigation action.

The discovery strategy must remain on site at all times and must demonstrate a clear allocation of responsibility for reporting and dealing with contamination. A copy of the strategy must be placed on the health and safety notice board and /or displayed in a prominent area where all site staff are able to take note of and consult the document at any time. Any member of the workforce entering the site to undertake any excavation must be made aware of the potential to discover contamination and the discovery strategy.

Soils Limited
Geotechnical & Environmental Consultants

**Newton House
Cross Road, Tadworth
Surrey KT20 5SR**



W soilslimited.co.uk