
Phase III Site Investigation Report

Zones 1 and 2, Toddington
Lane, North Littlehampton,
West Sussex
BN17 7PP

for Persimmon Homes
Limited

Report Reference : LP2128

Report Date : 21st April 2020

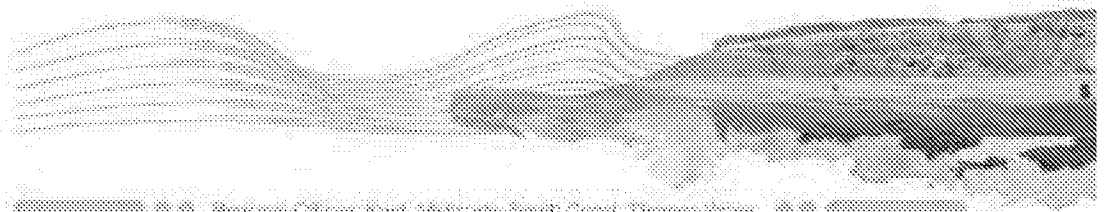


TABLE OF CONTENTS

A	INTRODUCTION.....	1
1	Authority.....	1
2	Proposed Development.....	1
3	Previous Studies.....	2
4	Objectives.....	2
5	Scope of Works.....	3
5.1	General Site Information.....	3
5.2	Intrusive Investigation Scope.....	4
6	Limitations.....	5
B	GENERAL INFORMATION.....	6
7	Environmental Setting.....	6
7.1	Site Location and Description.....	6
7.2	Stage 1 Investigation Area - Zone 1 and Zone 2.....	7
7.3	Background Information.....	9
8	Site Usage.....	11
8.1	Current Land Use.....	11
8.2	Historical Land Uses.....	11
8.3	Waste Planning and Landfill Records.....	13
8.4	Radon.....	13
9	Previous Investigations.....	14
9.1	Merebrook Consulting Ltd Geo-Environmental Assessment Report Ref. GEA-18426-14-69.....	14
9.2	Idom Merebrook Gas Risk Assessment Report Ref. 18426-2.4.2-14-S326-MSG17	
9.3	Idom Merebrook Asbestos Survey - Demolition report Ref. AS-18426b-15-14317	
9.4	Idom Merebrook Remediation Strategy report Ref. RMS-18426C-14-288.....	17
9.5	Idom Merebrook "Additional Geotechnical Assessment, North Littlehampton West Sussex" GR-18426E-15-167 RevA dated 27.08.15.....	18
9.6	CC Ground Investigations Ltd "Factual Report, Proposed Enabling Infrastructure, North Littlehampton" C5300 dated 22.12.16.....	18
C	CONCEPTUAL SITE MODEL.....	19
10	Environmental Risk Assessment.....	19



10.1	Conceptual Site Model (CSM).....	19
10.2	Sources	19
10.3	Receptors	20
10.4	Pathways and Potential Contaminant Linkages	21
10.5	Qualitative Risk Assessment of Contaminant Linkages	21
10.6	Conclusions	22
11	Geotechnical Risk Register	22
11.1	Conclusions	22
D	PHASE II - Intrusive Investigation.....	24
12	Investigation Rationale.....	24
13	Site Work.....	25
13.1	Date and Weather Conditions	25
13.2	Site Work Methods	25
13.3	Field Tests	27
13.4	Ground Gas and Groundwater Monitoring.....	27
13.5	Laboratory Analysis	28
14	Ground Conditions.....	30
14.1	Zone 1 Ground Conditions.....	30
14.2	Zone 2 Ground Conditions.....	33
14.3	Monitoring.....	35
14.4	Visual and Olfactory Evidence of Contamination.....	35
E	GEOTECHNICAL INFORMATION.....	36
15	Strata Encountered	36
15.1	Zone 1 - North.....	36
15.2	Zone 1 - South.....	37
15.3	Zone 2.....	38
F	GEOTECHNICAL APPRAISAL.....	41
16	Swelling and Shrinkage	41
16.1	Zone 1 - North.....	41
16.2	Zone 1 – South.....	42
16.3	Zone 2.....	42
17	Sulphates.....	42
17.1	Zone 1 – Both.....	42
17.2	Zone 2.....	43
18	Groundwater – Zones 1 and 2	43
19	Bearing Capacity and Foundations	43



19.1	Shallow Foundations - Zone 1	43
19.2	Shallow Foundations - Zone 2	44
19.3	Construction Supervision – All Zones.....	44
19.4	Piling – All Zones.....	45
19.5	Services – Zone1 - North and Zone 2	46
20	Floor Slabs – All Zones.....	46
21	Roads.....	47
21.1	Zone 1.....	47
21.2	Zone 2.....	47
22	Excavations – All Zones.....	48
23	Filling - All Zones.....	48
24	Settlement.....	49
24.1	Zone 1.....	49
24.2	Calculated Settlement - Zone 2.....	49
25	Heave and Uplift – All Zones	50
26	Swallow Holes / Solution Features – All Zones.....	50
G	GEO-ENVIRONMENTAL APPRAISAL.....	52
27	Conceptual Site Model.....	52
28	Testing Strategy	52
28.1	Soil Sampling.....	52
28.2	Groundwater monitoring.....	53
28.3	Land gas / vapour monitoring.....	53
29	Assessment Criteria.....	53
29.1	Human Health Assessment Criteria	53
29.2	Land Gas Assessment Criteria	56
30	Analytical Test Results – Soils.....	56
30.1	Zone 1.....	56
30.2	Zone 2.....	57
30.3	Central Wetlands Area.....	57
31	Land Gas Monitoring Results.....	58
32	Risk Assessment	59
32.1	Human Health.....	59
32.2	Controlled Waters	60
32.3	Land Gases.....	62
32.4	Vapour Risk	64



33	Waste Disposal	64
34	Recommendations for further works.....	65
35	Recommendations for remediation	65

APPENDIX A – Limitations

APPENDIX B – Figures

APPENDIX C – Qualitative Risk Assessment Model Geoenvironmental

APPENDIX D – Qualitative Risk Assessment Model Geotechnical

APPENDIX E – Site Photographs

APPENDIX F – Trial Hole and Borehole Logs

APPENDIX G – DCP Results

APPENDIX H –Laboratory Test Results

APPENDIX I – Soil Screening Results

APPENDIX J –Field Monitoring Records

APPENDIX K – Preliminary Waste Classification



EXECUTIVE SUMMARY

The investigation areas form part of the wider North Littlehampton Strategic Development Site (NLSDS), which is being developed by the Client and others. Thirteen land parcels (namely A2, B6, Phase 4, D1-D2, E1-E6, F1-F2 and two allotment areas) are to be investigated. This report relates to an area of investigation LEAP has termed Stage 1 Zone 1 and 2 and comprises land parcels, D1, D2, E1, E2, Phase 4 and the wetlands northern crossing. Together they cover an area approximately 14 hectares in size. The Zone 1 sites are generally flat and level and consisted of open land with various soil stockpiles. The Wetlands in Zone 2 was noted to be at a significantly lower elevation with areas of open water. Whilst ground levels on the northern part of Phase 4 were noted to have been recently raised with imported fill.

It is proposed that Zones 1 and 2 will be developed with low and medium rise residential units with a new approximately 3.0m high causeway constructed across the wetlands area.

Prior to development works the NLSDS was predominantly occupied by soft fruit growing nurseries and associated infrastructure, including cold storage / commercial uses (horticultural supplier) within the central wetlands area. Demolition works occurred across the wider site area from 2015-2017. The site is not mapped in an area that will require protection from Radon.

Zone 1 is shown on the British Geological Survey (BGS) web viewer as being underlain by Made Ground over Raised Beach Deposits, which in turn are underlain by the New Pit Chalk Formation to the South and the undifferentiated Lewes Nodular, Seaford, Newhaven, Culver and Portsdown Chalk Formations to the north. On and beyond the Zone's northern boundary the superficial deposits are shown as Raised Marine Deposits.

An area of Made Ground is also shown adjacent to the north western boundary of Zone 2, with the Zone shown to be underlain by Raised Marine Deposits overlying Raised Beach Deposits. Raised Beach Deposits are shown to outcrop along the Zone's south western boundary only. Underlying the superficial deposits, the southern half of the Zone is underlain by the New Pit Chalk Formation, with the undifferentiated Lewes Nodular, Seaford, Newhaven, Culver and Portsdown Chalk Formation in the north.

Groundwater was recorded during a period of level monitoring completed between January and March 2020 at depths of between 2.4 and 5.6m bgl within Zone 1 and 0.45 and 1.7m bgl within Zone 2.

An allowable bearing capacity of 100kPa is recommended for the firm and stiff clay identified at a depth of around 1.0m or the structureless chalk found at around 1.5m bgl within Zone 1 - South.



Some areas of deep made ground were identified across Zone 1 especially in the northern, western and southern corners. Further works would be required in this area to determine the full extent of this deep soft/loose soil.

Across the majority of Zone 2 the soft superficial soils will be unsuitable for shallow foundations. However, in the southern part of Phase 4 (TP102 and 103) firm and stiff clays of the Raised Beach/ River Terrace Deposits were identified. The investigation in this area is limited. It is considered that shallow foundations bearing on to the clays with an allowable bearing pressure of 80kPa may be possible, subject to further confirmatory investigation. Across the remaining parts of Zone 2 a piled foundation will be required. For preliminary designs example calculations suggest that a 12m long 300mm diameter cfa pile would have a design compressive resistance of around 295kN. The final design must be carried out by the specialist contractor in accordance with their preferred method of formation.

Suspended floor slabs are recommended with piled foundations or where made ground is found to be in excess of 600mm deep.

Soil sulphates across the site fall within BRE design class DSI and the site conditions fall within the ACEC class AC1.

A preliminary design CBR value of 3% is recommended for the silty clay soils found within the majority of Zone 1 South and the majority of Zone 2. However, the potential for soft spots is high and these will require over excavation and backfilling where encountered. For Zone 1 North and the northern part of Zone 2 a design CBR of 0.5% is recommended due to the variable soft and loose soils which were found across these parts of the site.

A geo-environmental risk assessment has been carried out. Contamination testing of the soils in Zone 1 did not identify significant land contamination, with the exception of two isolated areas of asbestos containing material were identified in land parcels D2 and E1, respectively. All other potential contaminants of concern were reported at concentrations below generic assessment criteria for a residential with plant update land use. Parts of the northern section of land parcel E1 were inaccessible during this stage of the investigation due to soft ground and dense vegetation cover. Limited shallow ground investigation is recommended to confirm the chemical composition of soils in this area once improved access is available.

Contamination testing of the placed soils in Phase 4 land parcel in Zone 2 did not identify potential contaminants of concern above generic assessment criteria (GAC) values for a residential with home grown produce land use.

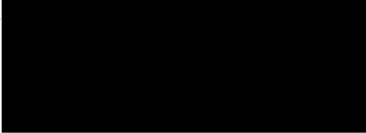
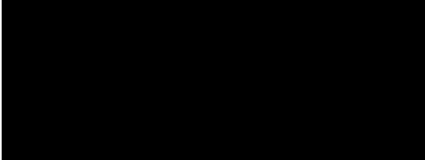
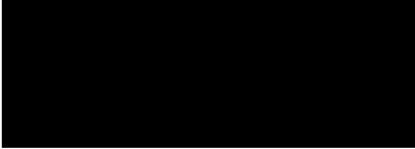
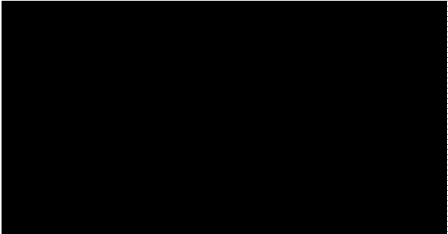
Limited further soil testing was undertaken in the wetlands northern crossing area. Lead was identified above the GAC for a public open space for residential land use in one soil sample. A statistical assessment of the laboratory test data including that from a previous investigation concluded that lead in soil would not pose an unacceptable risk to end users.



6No. land gas monitoring visits have been carried out primarily to confirm land gas conditions around MWS12, which was previously identified as Amber 2, due to a single elevated concentration of carbon dioxide. Land gas monitoring has also been undertaken in land to the north of land parcel E1, where deeper made ground was identified. Land gases have not been recorded at concentrations that would require gas protection measures. However, additional gas monitoring is recommended to further characterise made ground soils around in northern areas of Zone 1 with confirmatory checks in the monitoring wells around MWS12 during low atmospheric pressure conditions.

As with any redevelopment site, there is always the risk of hitherto undetected contamination, and further investigations should be carried out prior to redevelopment.

Much of the soils on site will be expected to be classified as non-hazardous waste, with the exception where asbestos containing material is identified which is a hazardous waste.

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Date :	21 April 2020
Revision:	Issue 1



A INTRODUCTION

1 Authority

Leap Environmental Ltd (hereafter referred to as ~~LEAF~~) has been appointed by Persimmon Homes Thames Valley Limited (the Client) to undertake an intrusive Site Investigation of land parcels within a wider development site referred to as North Littlehampton Strategic Development Site (NLSDS), Littlehampton, West Sussex BN17 7PP. The instruction was given in an email dated 14/11/2019 and signed by Martin Edgley of Persimmon Homes Thames Valley.

2 Proposed Development

The investigation areas form part of the wider North Littlehampton Strategic Development Site (NLSDS), which is being developed by the Client and others.

Thirteen land parcels (namely A2, B6, Phase 4, D1-D2, E1-E6, F1-F2 and two allotment areas) are included within our investigation area. Proposed land uses include residential, commercial, educational and allotment uses, as well as associated hard and soft landscaping including access roads, parking and open space recreational and a central wetlands area. We understand that site levels may need to be raised for flood defence purposes, although at time of writing proposed land raise levels are not known. An outline Masterplan for the proposed development is included in Appendix B.

The investigation is to be carried over two stages (as shown on Figure 3), with 'Stage 1' comprising the following land parcels:

- Residential land uses at A2, B6, Phase 4, D1-D2, and E1-2;
- Southern allotment plot; and
- New unadopted 'loop' road through the Stage 1 area, including a 3.0m high road embankment within the central wetlands area.

To assist with reporting the Stage 1 area has been subdivided into 'zones', namely:

- Zone 1 comprising land parcels D1, D2, E1 and E2;
- Zone 2 comprising land parcels Phase 4 and the central wetlands area; and
- Zone 3 comprising land parcels A2, B6 and the southern allotments area.

This report is for the Zone 1 and Zone 2 part of the Stage 1 investigation area only. No detailed design plans have been submitted for either zones, at time of writing. However, we understand that the proposed end use is for low-rise residential properties within the land parcels, with the exception of the central wetlands area, which will remain a wetland area and



include a section of 'loop road' aligned east to west on a raised earth embankment crossing central portion of the wetlands area.

The 'Stage 2' investigation will be completed from Q2:2020 and comprise the remaining land parcels.

3 Previous Studies

The wider NLSDS has been the subject of previous investigations by others. The following site investigation reports have been supplied by the Client and the reader is referred to these earlier reports, which should be read in conjunction with this report.

- Merebrook Consulting "Geo-Environmental Assessment, North Littlehampton West Sussex" GEA-18426-14-69 dated 28.02.2014.
- Idom Merebrook "Gas Risk Assessment, North Littlehampton, West Sussex" L-18426-2.4.2-14-S326-MSG dated 04.07.2014.
- Idom Merebrook "Remediation Strategy, North Littlehampton, West Sussex" RMS-18426C-14-288" dated October 2014.
- Idom Merebrook "Asbestos Survey – Demolition, North Littlehampton" AS-18426b-15-143 dated 25.06.2015.
- Idom Merebrook "Additional Geotechnical Assessment, North Littlehampton West Sussex" GR-18426E-15-167 RevA dated 27.08.15.
- CC Ground Investigations Ltd "Factual Report, Proposed Enabling Infrastructure, North Littlehampton" C5300 dated 22.12.16.
- LEAP Environmental Ltd "North Littlehampton Bypass - Factual Letter Report on a Suspected Soft Spot" LP2214 dated 19/03/20.

4 Objectives

As listed above the wider NLSDS has been subject to a previous investigation by Merebrook in 2014. However, the sampling density of the 2014 investigation was not compliant with BS 10175:2011+A2:2017 for a preliminary investigation. On the basis of the above, the objectives of this report are to:

- Provide geoenvironmental and geotechnical information to inform detailed design, including:
 - Non-targeted investigation within each land parcel to meet the requirements of BS 10175:2011+A2:2017
 - targeted investigation in land parcels where previous land contamination was identified;



- Assess the potential health and other environmental risks posed by the site to the proposed development and to other specifically identified receptors; and
- Assess the potential for offsite contamination to adversely affect the proposed development.
- Provide further coverage for geotechnical information, most notably to include deep borehole information on each building of the 13 remaining build phases, and to update the previous ground model and geotechnical recommendations where necessary.

5 Scope of Works

This report describes a two-stage process whereby the site is investigated, and risks are assessed. The terms geotechnical and geoenvironmental are referred to throughout the report.

Geoenvironmental refers principally to the chemical nature of the ground and the degree of soil, water and/or land gas contamination and the impact that contamination may have on current or future development and also on the wider environment.

Geotechnical refers to all other aspects of the ground conditions and the impact they may have on the physical construction of existing or future development, principally foundations, slope stability, drainage, pavement and road design and groundwater control.

5.1 General Site Information

The first part of this report presents a summary of background information relating to the wider development boundaries and Stage 1 investigation area. This is based on a review of previous report, as detailed above and publicly accessible sources of information¹ listed below:

- BGS 'Geology of Britain' online viewer accessed on 04.02.2020.
- BGS Borehole log refs. TQ00SW51 (north-west of the site) and TQ00SW174 (500m west of the site).
- BGS 'Sheet 6: Hydrogeological Map of the South Downs and Adjacent Parts of the Weald (1:100,000) – 1978' online map scan viewer accessed on 04.02.2020.
- Brimstone Site Investigation 'Stage 2 Detailed UXO Risk Assessment' ref. DRA-19-1155 dated 09.01.2020.
- Groundsure.io 'Enviro Data' online viewer accessed on 04.02.2020.
- Arun District Council Planning Portal accessed on 04.02.2020.

¹ The report contains British Geological Survey materials ©UKRI 2020 and public sector information licensed under the Open Government Licence v3.0.



5.2 Intrusive Investigation Scope

The intrusive investigations have been undertaken with reference to the Client's 'Ground Investigation Brief' (specification document dated September 2019). The results of this and previous investigation reports are used to validate and/or update the conceptual site model. Stage 1 Zone 1 and Zone 2 investigations within the following land parcels Phase 4, Central Wetlands Area, D1, D2, E1 and E2:

- 5 No. 15-20m cable percussion boreholes with groundwater monitoring wells installed to 6m depth in selected borehole;
- 4 No. 4m deep windowless boreholes drilled with a tracked rig with gas monitoring wells in targeted locations;
- 35 No. 3-4m deep machine excavated trial pits;
- 6 No. 0.5-1m hand excavated trial pits, with a shallow gas monitoring well installed in one location;
- 29 No. *in-situ* dynamic cone penetrometer CBR tests;
- *In-situ* geotechnical testing including Standard Penetrometer Tests in the boreholes and trial pits;
- Geotechnical Laboratory Testing including Atterberg Limit Tests, Particle Size Distribution, Natural Moisture Content, Oedometer Consolidation, BRE SD 1 Suite, Quick Undrained Triaxial, Intact Dry Density and Sulphate Tests; and
- Chemical Laboratory tests including 48 No. LEAP standard soil suite tests and selected soil samples tested for pesticides, volatile organic compounds, speciated petroleum hydrocarbons and waste acceptance criteria tests.

The intrusive works were completed by contractors who have been scrutinised and are on LEAP's approved contractor list. The windowless sampling was carried out by Oakland Site Investigation Limited, cable percussive boreholes by RM Foster Drilling Services, the machine excavated trial pits were carried out by T M Coates and supervised by LEAP.

The geo-environmental laboratory testing has been carried out by The Environmental Laboratory Ltd at its laboratories in East Sussex.

The geotechnical laboratory testing has been carried out by Geolabs Ltd at its laboratories in Watford.

The final stage in the geoenvironmental assessment comprises a quantitative risk assessment and update of the Conceptual Site Model. The risk assessment has been carried out in



accordance with UK industry standards and in particular in accordance with CLR11² and BS10175:2011+A2:2017.

The final stage of the geotechnical assessment is the provision of preliminary soil parameters for use in geotechnical design, and broad recommendations for appropriate foundation options. It is intended that the Geotechnical Information section of this report will fulfil the general requirements of the Ground Investigation Report as set out in Section 6 of Eurocode7³.

6 Limitations

This report has been prepared by Leap Environmental Ltd on the basis of information received from a variety of sources which Leap Environmental Ltd believes to be accurate. Nevertheless, Leap Environmental Ltd cannot and does not guarantee the authenticity or reliability of the information it has obtained from others.

Leap Environmental Ltd has used all reasonable skill, care and diligence in the design and execution of this report, taking into account the manpower and resources devoted to it in agreement with the Client. Although every reasonable effort has been made to obtain all relevant information, all potential contamination, environmental constraints or liabilities associated with the site may not necessarily have been revealed.

The conclusions reached in this report are necessarily restricted to those which can be determined from the information consulted and may be subject to amendment in the light of additional information becoming available. These conclusions may not be appropriate for alternative schemes.

This report is confidential to the Client, and Leap Environmental Ltd accepts no responsibility whatsoever to third parties to whom this report, or any part thereof, is made known, unless formally agreed by Leap Environmental Ltd beforehand. Any such party relies upon the report at their own risk.

Full details of the limitations are provided in Appendix A.

² Environment Agency, 2004. Model Procedures for the management of land contamination. Contaminated Land Report 11.

³ BS EN 1997 Eurocode 7- Geotechnical Design- Part 1:General rules (2004) Part 2: Ground Investigation and Testing (2007)



B GENERAL INFORMATION

7 Environmental Setting

7.1 Site Location and Description

The site is located at land off Toddington Lane, North Littlehampton, West Sussex, BN17 7PP as shown in Figure 1, Appendix B.

The approximate National Grid Reference of the site is TQ 03895 04003. The site lies at an estimated elevation range of 1.3 to 8.0 m Above Ordnance Datum (m AOD⁴).

The NLSDS is approximately 79 hectares (ha) in size, land parcels within the Stage 1 investigation area cover ~14.2 ha. A site layout is shown in Figure 2, Appendix B.

A walkover survey was carried out in November 2019 and photographs are included within Appendix E.

A general description of the NLSDS boundaries and a more detailed description of the Stage 1 land parcels is provided below.

North Littlehampton Strategic Development Site NLSDS (79 ha)

At the time of the walk over, the wider strategic land area was characterised by recently developed residential properties and land undergoing development to the west of the central wetlands area and undeveloped former nursery land to the east. The northern boundaries comprised low-lying flood plains of the Black Ditch River. The southern boundary of the NLSDS was largely characterised by Toddington Lane in a partial cutting relative to surrounding land and aligned east to west. Residential properties bound the site to the west and undeveloped open fields to the east. Three reservoirs associated with the former land use as a nursery were present along the eastern site boundary (within the Stage 2 investigation area). Broadly, the topography of the NLSDS was characterised by flat open land, sloping gently to the north with lower lying channels associated with the central wetlands area, land east of the reservoirs and the flood plains of the Black Ditch. The Black Ditch floodplains, which bound site to the north (aligned east to west) are demarcated by a drop in levels (of

⁴ We note that ground levels have been approximated from a LiDAR tile 'DTM TQ0000 PI0749 20190108 20190117' available from:

<https://environment.data.gov.uk/DefraDataDownload/?Mode=survey>



~1.0-1.5 m) from the former nursery areas down to the flood plains along the full northern extent of the site.

During the walkover none of the historical monitoring wells installed by Merebrook could be located, with the exception of MWS12, which was located and then subsequently lost during clearance work by others in the central wetlands area.

7.2 Stage 1 Investigation Area - Zone 1 and Zone 2

The Stage 1 investigation area is split across three Zones. Zone 1 includes Development Areas D1, D2, E1 and E2; Zone 2 entails Phase 4 and the Wetlands; and Zone 3 consists of A2, B6 and the Southern Allotments. Zones 1 and 2 are located in the north east of the wider development whilst Zone 3 is located in the south west of the development. A plan showing the Zone locations is presented as Figure 3 of Appendix B.

7.2.1 Zone 1

Land Parcel D1 (0.93 ha)

Parcel D1 was a triangular shaped parcel of land located to the east of the central wetlands area. A concrete surfaced road formed part of the western boundary of D1, which extended north into area E1, as an unsurfaced track lined by trees and hedgerows. In the northern portion of D1 an archaeological excavation pit was present covering an area of ~500 m² and extended to a depth of ~ 1.0 m. Over burden was stockpiled to the north and east of the excavation. A grass covered earth mound was also present west of the central section. A works compound was present in the south east corner, which also spanned part of the D2 land parcel. The works area was partially secured by heras fencing. Construction plant, bowzers, and building materials / waste (pallets of bricks, drainage covers and pipes) were present in this area. The eastern half of the site lies at ~4.0 m AOD, while the mound within the western half of the site is at ~5.80 m AOD. The western boundary slopes gently down towards the low lying central wetlands area.

Land Parcel D2 (2.42 ha)

D2 was an approximately rectangular shaped parcel of land that spanned three former nursery areas containing green houses. The local topography of D2 was generally level ~4.3 m AOD, land within the far northern boundary is lower than the remainder of the land parcel by ~0.5 m. East to west the parcel was generally level. The northern most portion of D2 partially extended on to a rectangular grass covered field (part of E2), which was at a lower level than the central area of D2 (~3.5 m AOD compared with ~4.3 m AOD) and separated by a chain linked fence aligned east to west. The central portion of D2 was generally covered by scrub vegetation. A concrete covered access road aligned east to west was present within the southern boundary of the site and land south of this road is slightly elevated relative to the central portion (~4.6 m AOD). An electrical substation (disused) was present in the southwest



of D2. Land within the western portion of the site was separated from the central areas by a chain linked fence aligned north to south and appeared to bound a footpath open to the general public. An infilled brick lined pond was also present within the western boundary. Access to the site was either through D1 or the concrete covered road to the west.

Land Parcel E1 (2.43 ha)

At the time of the walkover, E1 was a grass covered field bound by hedgerows with mature trees on the western boundary and rows of mature conifer trees (+8 m in height) within the eastern and northern boundaries. E1 spans two former nursery areas. Based on aerial imagery land in the west was formerly occupied by poly tunnels and in the east by greenhouses. The development boundaries extend beyond the tree lines in the north into an area of densely vegetated, marshy ground. We understand [from an informal discussion with a former nursery worker] that waste materials from the nursery may have been buried in this area. Land to the east extended into a flat open field that forms part of the E2 land parcel. In the southeast corner of E1 a large grass covered stockpile (~2,500 m³) was present on thick plastic sheeting, which extended onto E2. The stockpile was reported to contain Japanese knotweed contaminated soils. An unsurfaced access track aligned north to south was present within the western site boundary and within the southern portion of the site a concrete covered track was present and extended to the east. At the time of the walkover a new gas main was being laid ~10 m beyond the northwest corner of the site. It was reported that groundwater was high in the gas trench, which required dewatering. The site was generally flat and level, the northern boundary was slightly higher (5.0-4.6 m AOD) with respect to the southern boundary (4.3 m AOD), with an approximate slope of 0.4°. The floodplains around the Black Ditch, north of the development boundary lie at ~1.3 m AOD with an approximately 10° down from the northern boundary to the lower lying flood plains. This area is currently heavily vegetated but the slope is evident from the available LIDAR data. E1 appears raised in the central portion (4.3 m AOD) relative to the western (~3.5 m AOD) and eastern boundaries (~3.7 m AOD).

Land Parcel E2 (1.82 ha)

E2 was to the immediate east of parcel E1 and largely occupied a grass covered field that was formerly a nursery area occupied by greenhouses. The eastern boundary was formed by a line of mature conifers aligned north to south. As with E1 a row of conifer trees aligned east to west were present within the northern boundary, separating the larger field from the vegetated marshy ground in the north. Three concrete covered tracks were present aligned east to west in the northern, central and southern portion of the site and a fourth track aligned north to south was present within the eastern boundary. This track was used by the general public and secured from the former nursery site by heras fencing. E2 was generally flat and level at ~3.2 m AOD from north to south. The site sloped gently (0.2°) from west (~3.5 m AOD) to east (~3.0 m AOD), as with E1, land sloped steeply down to the flood plains to the north.



7.2.2 Zone 2

Land Parcel Phase 4 (0.60 ha)

The Phase 4 area was a narrow strip of land along the western boundary of the central wetland area. We understand along the north western boundary of the Phase 4 land parcel was a drainage ditch that was recently filled as part of the construction of adjacent residential properties to the west. At the time of the walkover the northern half of this land comprised an area of recently placed gravelly clay fill. This is ~1.0 m higher than the central wetlands area. The southern portion comprised grass covered undeveloped land and partially flooded land, which was not accessible. The boundaries were formed by newly constructed residential properties to the northwest, open fields and commercial land use to the southwest, the central wetlands area to the east, an access road to the south and Black Ditch flood plains to the north. During the walkover and site investigation a drainage system was being laid in the northern portion of the site and it was understood to be related to a new loop road. We also understand that offsite buildings west of the central section of the Phase 4 land parcel were constructed over a recently infilled reservoir. The reservoir does not appear to extend onto Phase 4. The reservoir was understood to be infilled at the same time as the drainage ditch.

Central Wetlands Area (~3.90 ha)

The central wetlands area is characterised as a low-lying channel aligned north to south. At the time of the walkover the southern portion of the wetlands area was extensively flooded. We understand that parts of this land area were formerly occupied by Fargro Ltd a supplier of horticultural products and cold storage facilities. The eastern boundary of the wetlands area was formed by a concrete covered access road aligned north to south, with three tracks branching off this in the southern, central and northern sections. In the northern portion of the site several stockpiles of crushed concrete and general demolition waste material were present. One of the stockpiles was secured by Heras and reported to contain asbestos containing demolition waste.

7.3 Background Information

A summary of the geology and hydrogeology is provided in Table 1, below.

Table 1: Summary of Environmental Setting

Information	Details
Geology	The underlying superficial geology varies across the site and can easily be categorised according to Zone and proposed development area. Zone 1 is shown on the British Geological Survey (BGS) web viewer as being underlain by Made Ground over Raised Beach Deposits which in turn are underlain by the New Pit Chalk Formation to the South and the undifferentiated Lewes Nodular, Seaford, Newhaven, Culver and Portsdown Chalk Formation to the north. On and beyond the Zone's northern boundary the superficial deposits are shown as Raised Marine Deposits. An area of Made Ground is also shown adjacent to the north western boundary of Zone 2, with the Zone shown to be underlain by Raised Marine Deposits overlying Raised



	Beach Deposits. Raised Beach Deposits are shown to outcrop along the Zone's south western boundary only. Underlying this, the southern half of the Zone is underlain by the New Pit Chalk Formation to the south and the undifferentiated Lewes Nodular, Seaford, Newhaven, Culver and Portsdown Chalk Formation to the north. Zone 3 is underlain by the River Terrace Deposits overlying the New Pit Chalk Formation. Made Ground shown across Zone 1 and 2 is described on the BGS lexicon as "an area where the pre-existing land surface is raised by artificial deposits". These materials have likely been used to bring site levels up out of the flood plain. Raised Marine deposits are shown to the north and east of the site whilst the Raised Beach deposits are shown across the central, south eastern and south western parts of the site. The River Terrace Deposits are shown to outcrop along the southern boundary only. Superficial deposits of the two channels and the flood plains of the Black Ditch are mapped as Raised Marine Deposits (RMD). Topographical maps highlight the geological succession, with the RTDs being at the highest elevations and the RMD being at the lowest levels. Raised Beach Deposits can comprise sands and gravels and Raised Marine Deposits clay, silt, sand and gravel and are likely to contain organic content including plants and shells. River Terrace Deposits are those of a braided river system and generally comprise a sheet of variably graded sand and gravel, with local lenses of silts/clays and peats. The Chalk is a very fine-grained white limestone consisting predominantly of the disaggregated skeletal remains of tiny planktonic algae and is composed of almost pure calcium carbonate. Layers of flint are common. Flint is composed of silica derived from the dissolved skeletons of siliceous sponges and microfossils. The White Chalk Subgroup is a Major Aquifer in SE England. Chalk is particularly affected by weathering and the effects of dissolution. The top surface of the chalk is usually irregular and may include deep drift filled solution pipes for example. Chalk is also susceptible to frost action.
BGS Boreholes	Three BGS boreholes are mapped within the NLSDS boundaries. Only one borehole is recorded within the Stage 1 area. TQ00SV51 is located in parcel D2 (Zone 1) and records superficial deposits to ~2.43 m bgl; over chalk and marl to ~3.96 m bgl; over hard chalk, with very hard layers to 45.72 m bgl. Groundwater is recorded at 5.18 m bgl.
Hydrogeology	The superficial deposits mapped beneath the Stage 1 area are classified as a Secondary A aquifer with underlying chalk bedrock associated as a Principal aquifer. The BGS hydrogeological map for the area shows groundwater flow in the Chalk Aquifer is in a southerly direction. The site is not located within a Groundwater Source Protection Zone. However, the Stage 1 investigation area is located within a medium vulnerability zone due to presence of a Chalk aquifer beneath the site. There is one groundwater abstraction licence recorded by Merebrook within the NLSDS boundaries and recorded as being located in the western part of the site used as a water supply for crop growing.
Surface Water	The Black Ditch River forms the northern boundary of the NLSDS and flows towards the River Arun approximately 2 km to the west. Nineteen secondary / tertiary watercourses



	(surface water ditches) are identified predominantly in the northern floodplains. Three reservoirs (related to the former use as a nursery) are present in the Stage 2 investigation area, along the eastern boundary of the NLSDS. There are two surface water abstraction licenses from Black Ditch located on the site (details unknown) with two additional abstraction licenses within 1 km of the site. Zones 1 and 3 are not located within an area mapped as being susceptible to flooding. However, according to the EA flood mapping Zone 2 is located in a Flood Zone 3 i.e. land and property have a high probability of flooding. The flood plains of the Black Ditch that bound Zone 1 to the north are located in a Flood Zone 3. The Environmental Agency indicated that the site is located within a groundwater flooding zone with a very high susceptibility to groundwater flooding.
Solution Features	Solution features generally occur where preferential weathering of the chalk occurs along discontinuities or joints. They are more common along geological boundaries, where surface water runoff from impermeable soils meets the more permeable underlying chalk. They are generally infilled with loose/soft soils and can be visible at ground level due to surface depressions, although this may be masked by overlying superficial deposits. They may lie dormant for many years, and are generally reactivated by the introduction of water from, for example, a leaking drain, soakaway etc.
UXO	A Detailed UXO desk study was commissioned for the site that identified the majority of the subject land parcels as Low to Moderate Risk, with the exception of parts of E1/E2 (Zone 1), which were identified as moderate risk. The assessment was made on the basis that an important radar station (RAF Poling) ~700 m northeast of the site was targeted. A radius of 900 m from the centre of RAF Poling was deemed as moderate risk and that encompassed northern parts of the site. The desk study recommended that UXO awareness briefing was provided for all intrusive works; and in moderate risk areas that an EOD engineer should be present during site investigations and to include non-intrusive and intrusive magnetometer surveys, prior to construction phase open excavations and at pile positions.

8 Site Usage

Records of historical land uses, and potential on and off-site sources of contamination are recorded in the previous Merebrook report. Pertinent information is summarised below.

8.1 Current Land Use

The current site layout is shown in Figure 2, Appendix B.

A summary of existing uses of the land parcels within the Stage 1 Zone 1 and Zone 3 are described in S7.2.1 and S7.2.2, above.

8.2 Historical Land Uses

Prior to development works the NLSDS was predominantly occupied by soft fruit growing nurseries and associated infrastructure, including cold storage / commercial uses (horticultural



supplier) within the central wetlands area. Demolition works occurred across the wider site area from 2015-2017. A summary of historical⁵ land uses within the Stage 1 Zone 1 and Zone 2 investigation areas is summarised below:

8.2.1 Zone 1

- **D1/D2/E1/E2** – These land parcels are shown to be undeveloped on historical maps dated 1876-1957. From 1974, the majority of land parcel D2 is occupied by glasshouses associated with a large nursery which extends to the south and east. From 1981, the nurseries are shown to extend to the north and occupy the majority of land parcel E2. Some development is also shown to have occurred across land parcels D1 and E1, as roads are shown and a triangular structure is shown present in the central portion of D1. There are no significant changes from 1992-2002, although a small 'pond' like structure is shown present in the southern part of land parcel D1. The nurseries are labelled as Zuider Zee Nurseries. Aerial imagery from 2001-2016, shows the features in more detail. An area of hardstanding is present in the central/northern portion of land parcel D1 and appears to be used for storage of materials associated with the nursery (on an aerial image dated 2013). The majority of land parcel E1 is covered by poly-tunnel type structures from 2007-2013. Dense tree lines separate E1/E2 and within the northern boundaries of both land parcels. Parts of D1 are also shown to be vegetated with mature trees on aerial imagery. By 2018 all above ground structures are shown to be demolished on aerial images. Aerial imagery dated 2018 shows two stockpiles of material in D2 land parcel, possibly associated with archaeological excavations, which appear to be located adjacent to the stockpiles. A large stockpile is present in land parcels E1 and E2. This is understood to be a stockpile containing Japanese knotweed.

8.2.2 Zone 2

- **Phase 4** - Shown to be undeveloped on historical maps dated 1876 until 1981, when a large structure / depot is shown within the southern half of the land parcel. Two smaller depots are also shown within the central section of the Phase 4 boundaries. Aerial imagery dated 2001-2016 shows the two central structures, with an additional warehouse adjacent to the southern structure. Areas of hardstanding including carparking are present around the depots/warehouses.
- **Wetlands Area** - Shown to be undeveloped on historical maps dated 1876 until 1974 when a large structure is shown in the northern half of the wetlands area and a smaller structure in the southern half. From 1981-2002 additional structures are shown on historical maps, mainly in the northern sections. Two tank-like structures appear in the northeast section on a map dated 2002. Aerial imagery from 2001-2016 show in more detail the warehouses / depot with extensive hardstand surfacing. All structures

⁵ Based on information contained within Merebrook Consulting Geo-Environmental Assessment Report Ref. GEA-18426-14-69



were shown to be demolished by 2018. Merebrook refer to an above ground (fuel) storage tank in the northern section of the wetlands area and an electrical substation south of the centre of the wetlands. It is understood that this land was formerly occupied by Fargro Ltd a horticultural wholesale supplier.

8.3 Waste Planning and Landfill Records

8.3.1 Recorded Landfill and Waste Management Sites

With reference to online sources⁶ there is one authorised landfill site within the NLSDS boundaries and two historical landfill record within 250m of the NLSDS boundaries.

The authorised landfill site is located within the Stage 2 investigation area, specifically parcel F2. It is named as Tulley's Nurseries (license number TUL001) and located ~160 m southeast of E2 . It is mapped to be rectangular in shape with approximate dimensions of 80 m by 330 m and is recorded as having received non-biodegradable waste. It has been anecdotally described to LEAP that inert wastes were disposed of in the area, including agricultural grade 2 soils.

The closest historical landfill record is named as Norway Farm and located adjacent to the southeast boundary of the Northern Allotment in the Stage 2 investigation area. It is recorded as having received waste from 1950-1960.

A second historical landfill site is named as Fargro (reference WD27/255, WD13/5/36) is located ~210m north of land parcel E1 (Zone 1) and has received waste between 1979 to 1980.

A household waste recycling facility is located to the immediate west of the NLSDS site on Mill Lane.

8.4 Radon

With reference to the Public Health England Radon Affected Area maps for the United Kingdom⁷ the Stage 1 Zone 1 and Zone 2 are located in an area with a maximum radon potential of 1 – 3 % of the houses above the action level for radon. The web page also indicates that radon protection in new buildings might be considered if there are high risk locations, such as a routinely occupied basement.⁸

⁶ <https://groundsure.io/>

⁷ <https://www.ukradon.org/information/ukmaps>

⁸ <https://www.ukradon.org/information/radonsearches>



The updated BRE 211 guidance⁹ does not map the subject site within an area that should be subject to radon protection measures for new buildings.

9 Previous Investigations

The site has been the subject of several reports undertaken by Merebrook and are summarised below.

9.1 Merebrook Consulting Ltd Geo-Environmental Assessment Report Ref. GEA-18426-14-69

Merebrook undertook a combined Phase I and Phase II site investigation across the NLSDS area in 2014, prior to the demolition of existing structures.

The desk study identified a number of potential sources of contamination within the wider NLSDS boundaries that included use of pesticides and herbicides, kerosene fuel use and storage; electrical sub-stations; boiler rooms; above and under-ground storage tanks (ASTs/USTs); composting areas; garages; chemical storage; Japanese knotweed contamination; hoppers and silos. Vehicle repair, industrial repair and chimney were also noted within the wider site boundaries. Historical records relevant to the Stage 1 Zone 1 and Zone 2 land parcels are summarised in S8.2.1 and S8.2.2, above.

Merebrook also recorded two pollution incidents in the 'northern' portion of the site, but the exact locations are not provided. These incidents are related to historical diesel spills and have been classified as having a minor impact and are unlikely to have impacted the surface water.

The Merebrook intrusive investigation across the NLSDS site comprised the following:

- 6 No. cable percussion boreholes to 15 m bgl and installation of groundwater monitoring wells within the Chalk Aquifer;
- 35 No. shallow window sample boreholes to a depth of 3 m bgl;
- 11 No. shallow hand window sample probe holes to a depth of 2 m bgl;
- 18 No. shallow land gas monitoring well installations;
- 25 No. machine-dug trial pits to a depth of 3 m bgl;
- Three hand dug trial pits to a maximum depth of 1.3 m bgl; and
- Eight machine-dug soakage pits to a maximum depth of 3 m bgl.

⁹ Radon – Guidance on protective measures for new buildings, Building Research Establishment, BR211 – 2015 edition

This is approximately equivalent to 1.1 exploratory hole per hectare or if based on a non-targeted grid it would be on an approximately 95 m spacing, which does not meet the requirements of BS10175:2011+A2:2017 for a preliminary investigation.

A summary of the ground conditions encountered by Merebrook relevant to the Stage 1 development parcels is summarised in Table 2, below.

Table 2: Summary of Ground Conditions Encountered during Merebrooks Site Investigation

Land parcel/ Zone	No. exploratory positions	Ground Conditions Encountered	Groundwater Strikes (m bgl)
D1 /1	Three MWS6, MTP13 SP5	Grass over topsoil to 0.20m; over dense silty SAND or dense silty CLAY to 1.0 m; medium to dense SAND to 1.40-2.40; weathered CHALK recorded in MWS6 from 1.40 to 3.0 m, only. Log for soakage pit not available. Four soil samples sent for geo-environmental laboratory analysis. No Potential Contaminant of Concern (PCoC) detected above current Generic Assessment Criteria (GAC), where published.	Not recorded on logs
D2 /1	Four MWS5, 7, MWS8 SP6	Made ground identified in MWS5 to 0.80 m only, which is located adjacent to an existing substation. Soft to firm SILT (MWS5) or fine SAND (MWS7) recorded to 1.40 m; over white light brown to brown soft to firm CLAY to 2.4-2.5 m. Chalk logged in MWS5 and MWS7 to 3.0 m. Log for soakage pit not available. Three soil samples sent for laboratory analysis, no PCoC detected above GAC, where published. PCBs not detected above LoD in MWS5.	Not recorded on logs
E1 /1	Three MWS10, MBH3, MTP12	Made ground identified in MWS10 and MTP12 between 1.6-1.8 m. Soft to firm silty sandy CLAY to 1.2 m (MBH3); brown dense clayey SAND to 2.6 m (MWS10); brown sandy silt to 1.7 m (MTP12). Chalk was identified in MWS10 and MBH3 only. Six soil samples sent for laboratory analysis, no PCoC detected above GAC, where published.	MBH3 4.0 m bgl (~0.46 m AOD*) * based on approximate ground level from LIDAR survey
E2 /1	Five MWS9, HWS7, MTP11, SP6, SP7	Made ground to 1.5 m only identified in MWS9. Grey dense to brown dense silty SAND from 0.45 to 3.0 m (MWS9/HWS7). Brown sandy SILT/CLAY to stiff becoming soft grey mottled orange CLAY (MTP11). Chalk in HWS7 only. Logs for soakage pits not available.	Not recorded on logs



Land parcel/ Zone	No. exploratory positions	Ground Conditions Encountered	Groundwater Strikes (m bgl)
		Five soil samples sent for laboratory analysis, no PCoC detected above GAC, where published.	
Phase 4 /2	Two MWS13 MTP18	Grass over topsoil, over brown SILT/CLAY with gravels of flint and chalk to 1.50 m, over silty clayey CHALK with gravels of flint and chalk to 3.00 m. Log for MWS13 missing in Merebrook's report. Three soil samples sent for geo-environmental laboratory analysis from MTP18. No PCoC detected above GAC, where published.	Not recorded on logs
Wetlands Areas /2	Seven MWS11,12 MTP7,8,9,17,19	Made ground identified in MWS12 and MTP17 to 2.50 m bgl. Hydrocarbon odour noted throughout MWS12 to 2.50 m. Chalk fill / reworked ground noted in MTP19 and MWS11 to 1.30-1.50 m bgl. Topsoil over firm becoming soft grey CLAY or grey mottled brown SILT / CLAY to 2.70- 3.00 m in MTP8 and MTP9. Soft grey clay noted at base of MTP17,19 and MWS11 (~2.70-3.00 m). Chalk encountered in MWS12, MTP7, MTP9 from ~2.0-2.70 m. Fourteen soils samples were sent for laboratory analysis. Aromatic TPH EC12-16, EC16-21, EC21-35 exceeded GAC in MWS12 from a soil sample collected at 0.40-0.50 and 1.50-1.70 m only. Dibenzofuran was detected above analytical LoD in MWS12 0.40-0.50 m. Asbestos fibres recorded in a sample from MTP17 at 1.3-2.5 m depth. A sample taken from MTP17 0.0 -1.3 m depth did not record asbestos. PCBs were not detected in MWS11, located next to the electrical sub-station.	Not recorded on logs

Based on the above summary, ground contamination was limited to the central wetlands area, where petroleum hydrocarbons and asbestos were detected.

Merebrook reported that groundwater within shallow monitoring wells indicated pockets of groundwater and that a 'continuous shallow groundwater body is not present'. However, given that many of the wells were screened across multiple strata it is not possible determine the site wide characteristics of groundwater within the superficial deposits. Merebrook did not describe a groundwater flow direction in the Chalk Aquifer, but resting water levels in deep boreholes were recorded at between 1.758 m (MBH3) and 5.385 (MBH6).



9.2 Idom Merebrook Gas Risk Assessment Report Ref. 18426-2.4.2-14-5326-MSG

Merebrook stated gas monitoring was undertaken over a four month period from February to June 2014. Levels of methane, carbon dioxide and oxygen and associated parameters of borehole flow and ambient air pressure were recorded in each standpipe. Merebrook characterised the majority of the NLSDS as 'Green' classification under NHBC Traffic Light system for low rise residential housing with ventilated sub-floor voids. However, an 'Amber 2' classification was given to land in vicinity of MWS12 in the central wetlands area, where a maximum concentration of carbon dioxide of 11.8% v/v and a maximum steady flow of 0.4 l.hr⁻¹ were recorded (albeit at different dates). Merebrook recommended remediation in ground around MWS12 to treat hydrocarbon contamination, the "likely source of ground gas". No PID readings were recorded for MWS12 during the site investigation and post SI land gas monitoring rounds. Following remediation, it was indicated that the classification gas risk could change and localised monitoring would be required to prove this.

LEAP note that the Amber 2 classification for MWS12 was based on the maximum recorded carbon dioxide concentration greater than 10%. However, a gas screening value (GSV) of 0.047 L/hr can be derived based on maximum gas and flow rates. This GSV would equate to a classification as Green (to NHBC:2007) or very low risk (to BS8485:2015+A1:2019). Carbon dioxide was only recorded above 10% on one occasion and on all other occasions, readings ranged between 0.6-1.2% v/v at MWS12. We also note that RB17:2012 'A Pragmatic Guide to Ground Gas Risk Assessment' states that the 'presence of hydrocarbons collecting in the well can degrade and produce methane and carbon dioxide. The degradation process and volume of hydrocarbons is generally small and will result in small volumes of methane and carbon dioxide giving high gas concentrations in the well head space.'

A second location (MWS01) in the west of the NLSDS, within the Stage 2 investigation area was classified as Amber 1 by Merebrook, due to marginally elevated methane concentrations above 1% on two monitoring rounds.

9.3 Idom Merebrook Asbestos Survey - Demolition report Ref. AS-18426b-15-143

Merebrook were commissioned to undertake an Asbestos Demolition Survey to establish presence of any ACMs, in Area A and B2 prior to demolition of the derelict glasshouses and other unused buildings on site. Area A is north of Zone 3 and Area B2, which is land west of Zone 2. No information relating to Zone 1 or Zone 2 areas is available.

9.4 Idom Merebrook Remediation Strategy report Ref. RMS-18426C-14-288

Following the initial site investigation and subsequent gas risk assessment and asbestos survey, Idom Merebrook were commissioned to develop a remediation strategy for the NLSDS.



Merebrook identified that with the exception of localised areas of contamination (from hydrocarbon and asbestos contamination) it was considered that site clearance, incidental homogenisation of topsoil and usable subsoil and routine need for provision of soil cover for amenity purposes in gardens and landscapes areas, would suffice the need for specific remedial works to remove or isolate contamination, subject to appropriate soil segregation, management and confirmatory testing.

Localised hydrocarbon staining and odour in central wetlands related to made ground and natural soils in location MWS12. Merebrook proposed soil excavation and verification testing to the top of the Chalk stratum. Further that perched groundwater would be allowed to accumulate within the excavation to be tankered off site, until <10 ug/l TPH was achieved. It was recommended for the use of potable water pipes to be implemented following completion of a pipeline risk assessment.

Merebrook also recommended further shallow sampling and testing for asbestos in soils around MTP17. It is not known if any remediation work has been undertaken in this area as part of the demolition works.

Identified Japanese knotweed was recommended to undergo a programme of spraying or physical removal by a knotweed eradication contractor.

Ground gas protection measures were recommended in around MWS01, but this is located within the Stage 2 investigation area.

The document also included details on protocols for dealing with unexpected contamination; construction workers; waste management; control of emissions; and a verification plan.

9.5 Idom Merebrook "Additional Geotechnical Assessment, North Littlehampton West Sussex" GR-18426E-15-167 RevA dated 27.08.15

Merebrook were commissioned to undertake further ground investigation along the route of the proposed Lyminster Bypass located ~350 m west of the Zone 2 area, as such has not been summarised for this report.

9.6 CC Ground Investigations Ltd "Factual Report, Proposed Enabling Infrastructure, North Littlehampton" C5300 dated 22.12.16

CC Ground Investigations Ltd undertook further investigation along the proposed Lyminster Bypass route located ~350 m west of the Zone 2 area, as such has not been summarised for this report.



C CONCEPTUAL SITE MODEL

10 Environmental Risk Assessment

10.1 Conceptual Site Model (CSM)

A risk-based approach is used to assess contaminated or potentially contaminated land within the UK. For a potential risk to exist, there must be a contaminant linkage in place, i.e. there must be a source of contamination, a potential receptor, and a pathway linking the two.

The sections below present the updated CSM based on the findings of the previous ground investigation and the walkover survey. We note that the 'driver' for this investigation is to increase sampling density to that provided in guidance (BSI0175:2011+A2:2017) and to investigate potential data gaps i.e. areas which were not well characterised previously.

10.2 Sources

10.2.1 Onsite Sources

Based on a review of the available site information, site walkover with reference the previous reports by Merebrook, the following potential contaminants of concern are proposed:

Table 3: Sources of contamination in the Stage 1 investigation area

Source	Potential Contaminants of Concern
<i>Phase 4 -- Zone 2</i>	
Land raise associated with housing development	Heavy metals, PAHs
<i>Wetlands Area -- Zone 2</i>	
Above ground fuel storage	Localised petroleum hydrocarbon contaminated soils and groundwater around MWS17
Made ground associated with former commercial buildings	Heavy metals, PAHs, asbestos
Stockpiled demolition waste including stockpile containing asbestos demolition waste	Heavy metals, PAHs, asbestos
Deep asbestos contaminated soils	Asbestos fibres below 1.3 m in MTP17
<i>D1/D2/E1/E2 -- Zone 1</i>	
Made ground associated with former nursery buildings	Heavy metals, PAHs, asbestos
Chemical use	Herbicide / pesticide use
Nursery heating systems	Kerosene



japanese knotweed	Stockpile of japanese knotweed containing material spanning E1/E2 land parcels
Made ground associated with possible buried nursery waste in land north of E1/E2	Heavy metals, PAHS, asbestos
Phase 4 -- Zone 2	
Land raise associated with housing development	Heavy metals, PAHS
Wetlands Area -- Zone 2	
Above ground fuel storage	Localised petroleum hydrocarbon contaminated soils and groundwater around MWS17
Made ground associated with former commercial buildings	Heavy metals, PAHS, asbestos
Stockpiled demolition waste including stockpile containing asbestos demolition waste	Heavy metals, PAHS, asbestos
Deep asbestos contaminated soils	Asbestos fibres below 1.3 m in MTP17

10.2.2 Offsite Sources (relative to Stage 1 Zone 1 and Zone 2 investigation areas)

The following potential off-site sources of contamination are highlighted:

Table 4: Offsite sources of contamination (relative to the Stage 1 area)

Source	Distance from Site (m)	Contaminants of Concern
Made ground surrounding the site	1-100	Land gas
Historical Landfill (in Stage 2 area)	200 southeast	Land gas, leachate
Historical Landfill	Adjacent to southeast of NLSDS boundary (250 m southeast of D2)	Land gas, leachate

10.3 Receptors

Potential receptors are those which may be impacted by any of the contaminants of concern identified above, and include the following:-

- Future residents
- Construction workers
- Groundwater – Secondary A Aquifer (River Terrace Deposits, Raised Beach Deposits, Raised Marine Deposits), Principal Aquifer (Chalk bedrock)



- Surface Water – Central wetlands area, surface water features in Stage 2 area (reservoirs within east eastern boundaries of NLSDS), Black Ditch and associated flood plains / drainage ditches to the north of the site
- Ecological Receptors
- Material construction of buildings and infrastructure
- Neighbouring properties

10.4 Pathways and Potential Contaminant Linkages

The development will include private gardens and public open space. All potential contaminant linkages involving resident humans and soil contaminants will be active i.e. direct ingestion of soil, ingestion of soil attached to plants as well as via plant uptake, inhalation of indoor and outdoor vapour and of dust tracked back into the house and finally ingestion of water carried by plastic water pipes through contaminated ground. Ground workers are at risk as a result from all of the above, except for those involving edible plants.

Previous laboratory analysis by Merebrook in 2014 only identified limited soil and groundwater contamination. Potential contaminants of concern at concentrations above screening criteria were only recorded in the central wetlands area where no residential properties are proposed.

The site is underlain by a Secondary A (River Terrace Deposits, Raised Beach Deposits and Raised Marine Deposits) and Principal (Chalk Bedrock) Aquifers of high leaching potential. Near surface geology previously reported in Zone 1 comprised CLAY to loose to dense silty SAND or in vicinity of D1/D2/E1/E2. Merebrook reported low soil permeability with infiltration rates in Zone 1 ranging from 4.15×10^{-6} m/s to 1×10^{-8} m/s in i.e. moderate to low permeability.

On the basis of the low to moderate permeability of the superficial deposits and the low concentrations of potential contaminants of concern identified in soils, the risk posed to the principal aquifer is considered low.

Where surficial contamination is present, there is the potential for run-off and contaminant migration to impact surface water receptors, namely the Black Ditch to the north of the site.

10.5 Qualitative Risk Assessment of Contaminant Linkages

Risk levels within the preliminary CSM are determined on a qualitative basis following review of the available desk-based information. The significance of particular contaminant linkages is dependant both upon the severity and likelihood of the risk. These two factors are summarised in the following tables.



The potential contaminant linkages are summarised in the table appended in Appendix C and given a qualitative risk classification in accordance with current guidance. The details of the risk assessment methodology are presented in Appendix C.

10.6 Conclusions

We note that although the previous investigations did not identify significant land contamination, the sampling density from the 2014 site investigation was not adequate in regard to the guidance (BS10175:2011+A2:2017) and data gaps are likely to be present.

Consequently, contaminants potentially presenting a low to moderate risk to future residents and construction workers include hydrocarbons, PAHs, herbicides and pesticides and asbestos.

A potential land gas risk was identified in land centred around MWS12, where possible hydrocarbons were given as a potential gas source.

11 Geotechnical Risk Register

The preliminary geotechnical risk register for the proposed development is summarised in the table in Appendix D. Details of the risk assessment methodology are presented in Appendix D

11.1 Conclusions

The following geotechnical hazards have been identified as substantial to intolerable risks:-

- The presence of Made Ground/soft-loose reworked soils across site and specifically Zone 1 and 2 will likely require foundation deepening;
- Compressible ground associated with the presence of Made Ground/ reworked soils is probable especially where land raising activities have taken or are due to take place;
- High groundwater table recorded in historic BGS boreholes as well as during previous phases of investigation. Collapses, running sand conditions and excavation inundation maybe likely and significant dewatering techniques will be required;
- The presence of deep made ground (identified to 3.5 m bgl in places during previous works) will require foundations to be deepened and precautions for deep excavations should be taken;
- Potential for excessive settlement and bearing capacity failure due to made ground cannot be discounted;
- During the previous investigation works the plasticity index of soils was found to range between 13 and 44% suggesting shrinkable soils of Low to High volume change potential. As such risk of heave cannot be discounted and is classified as substantial at this time;



- Zone 1 is underlain by Made Ground/reworked soils of unknown origin and may be a potential source of land gases/ contamination;
- The site was previously used as a commercial nursery and so there is a potential that previously unidentified contaminants may be present which will require remediation which could effect ground conditions on site.

On the basis of the initial review and preliminary risk assessment, the site is given a Geotechnical Classification of **Geotechnical Category 1** in accordance with EN1997-1 §2.1(14)-(21).



D PHASE II - INTRUSIVE INVESTIGATION

12 Investigation Rationale

A total of 50 trial holes were excavated across Zone 1 and Zone 2. These included 35 No. machine excavated trial pits to a depth of around 3m, 5No. cable percussion boreholes to depths of between 14m and 20m, 4 No. windowless sampler boreholes to depths of between 3m and 4m and 6 No. hand excavated trial pits to depths between 0.5m and 1m.

The trial holes were located to give general coverage, taking into consideration the proposed development and the potential geoenvironmental and geotechnical risks/hazards highlighted by the CSM in accordance with BS10175. The trial hole spacing was consistent with the recommended density of 25 to 50m for an exploratory investigation after BS10175 Section 7.7.

The investigation rationale for the trial holes / test locations is summarised below:

Table 5 Rationale for Investigation Locations

Trial Hole/Test Location	Rationale	Proposed Depth (m bGL)	Notes
LBH103- LBH107	Provide information on ground conditions and geotechnical parameters for foundation design, location of groundwater well and provide samples for geotechnical testing within A2/B6/D1/D2/E1/E2, only	25	Some boreholes were terminated below target depth, due to hard stratum encountered, generally from below 12 m. LBH105 was relocated from D1 to the new road embankment in the central wetlands area, due to soft clays identified in WS101 and WS103.
LWS101- LWS104	To provide information on ground conditions within the vicinity of the new embankment only and to further characterise gas situation around MWS12.	3-4	Gas monitoring well installed in WS103 and WS104, to further characterise gas risk around MWS12. A gas well was not installed in LWS102, due to the high-water table (0.50 m bgl)
LTP101- LTP134, and LTP140	Provide information on ground conditions and geotechnical parameters for pile design and provide samples for contamination and geotechnical testing within A2/B6/D1/D2/E1/E2, only	3	TP124 relocated due to drainage pipe encountered.
LMP101- LMP106,	Provide environmental samples and location of gas well.	0.5-1	Gas well installed in LMP101.
LDCP1- LDCP29	Provide geotechnical parameters for the proposed road.	N/A	

The site investigation locations are shown on Figures 4A-B, Appendix B.



13 Site Work

13.1 Date and Weather Conditions

The intrusive investigations were undertaken between 04/12/2019 and 27/01/2020. At the time of the investigations, the weather was generally overcast, windy and rainy with occasional sunny dry periods. January rainfall was 100% of average (based on values between 1981 and 2010), December rainfall was 116% of the average, and in November rainfall was 97% of the average.

13.2 Site Work Methods

13.2.1 Borehole Drilling

Boreholes were drilled using a cable percussion rig. The boreholes were excavated at 200mm diameter, reducing to 150mm to allow for clean drilling and to achieve target depth.

13.2.2 Windowless Sampler

The Windowless sampling rig consists of a tracked barrow with a sampling unit mounted on the top. When in the required position, the mast was raised to a height allowing a mechanised drop weight to fall repeatedly onto an anvil, and drive attached sample tubes or probe rods into the ground to produce reasonably intact continuous samples which were then extracted using the integrated hydraulic ram.

To reduce any tendency of the tubes to stick in the ground, a succession of smaller diameters may be used to obtain full depth. Excavated soils were placed aside for inspection and sampling.

On completion the trial hole was backfilled with excavated material, placed in reverse order, and the surface reinstated unless otherwise specified.

13.2.3 Trial Pitting

Trial pits were dug by a backhoe excavator. The trial pits had a target depth of 3m bgl and were typically 0.75m wide by 2m long. Spoil was placed on plastic sheeting to prevent cross-contamination and was replaced in reverse order. Trial pits were left mounded to allow for future settlement.

13.2.4 Hand Pitting

Hand pits were excavated using hand tools at 100mm diameter. Spoil was placed on plastic sheeting to prevent cross contamination and was reinstated in reverse order.

13.2.5 Soil Logging and Sampling

Soil samples were recovered from the boreholes and trial pits for field screening, logging and sampling.



Boreholes were logged in general accordance with the requirements of BS 5930:2015¹⁰ and BS EN ISO 14688¹¹. Borehole logs are presented in Appendix F.

Visual and olfactory evidence of contamination was noted if encountered. These observations were used to aid scheduling of samples for chemical laboratory analyses and are included on the borehole logs in Appendix F and summarised in Section 14.1.5.

Samples were collected with a clean sampling trowel or by hand (using dedicated nitrile gloves for each sampling location). Samples were placed into laboratory supplied sampling containers, specific to the type of analyses required.

All sample containers were sealed and labelled with a unique location identity, depth and date of sampling.

13.2.6 Monitoring Well Installation

Three groundwater monitoring wells were installed during this investigation to target the Chalk Aquifer. The monitoring wells were constructed of 50mm diameter HDPE pipe. The response zone within the cable percussive boreholes were typically targeted to intercept the groundwater surface and was surrounded by washed filter gravel. The plain zone was surrounded with bentonite to provide a seal.

Shallower monitoring wells were installed within the windowless sampler boreholes in the vicinity of MWS12 to further characterise the Amber 2 land gas classification by Merebrook. A land gas monitoring well was placed in LHP101 with the response zone targeting shallow made ground fill in the northern section of parcel E1. The installations were finished with bungs with gas taps and raised steel covers, with the exception of LWS103 where a flush steel cover was used, as it was located in a trafficked haul road. Monitoring well installations are shown on the borehole logs and summarised in the following table.

¹⁰ BS5930:2015 Code of Practice for Ground Investigation

¹¹ BS EN ISO 14688 Parts 1-2 (2018) Geotechnical Investigation and Testing. Identification and classification of soil



Table 6: Borehole installation details

Borehole	Zone	Type G-gas W-water	Plain Well Screen (mbgl) and ID (mm)	Slotted Well Screen (mbgl)	Bentonite Seal (mbgl)
LBH101	3	W	GL - 4	4 - 7	GL - 4
LBH104	1	W	GL - 3	3 - 6	GL - 3
LBH106	1	W	GL - 3	3 - 6	GL - 3
LWS103	2	G	GL - 1	1 - 2	GL - 1
LWS104	2	G	GL - 0.5	0.5 - 1.5	GL - 0.5
LHP101		G	GL - 0.5	0.5 - 1	GL - 0.5

13.3 Field Tests

13.3.1 Standard Penetration Tests

Standard penetration tests were undertaken in the boreholes at 1m centres until 5.0m, there after taken every 1.5m and where feasible, alternating with UT100 samples in cohesive soils, in accordance with BS EN ISO 22476-3:2005. Uncorrected blow counts, 'N values', are recorded on the borehole logs in Appendix F.

13.3.2 In-situ California Bearing Ratio Test -- Dynamic Cone Penetrometer

29 No. *in-situ* CBR tests have been undertaken across the site using the Dynamic Cone Penetrometer (DCP), recording blow counts over 900mm of penetration from test level. The test method and interpretation of the results have been undertaken in accordance with DMRB HD 29/08¹² using a modified DCP. The results are attached in Appendix G.

13.4 Ground Gas and Groundwater Monitoring

13.4.1 Groundwater level monitoring

6 No. rounds of groundwater monitoring have been undertaken to date. The visits were completed between 17/01/2020 and 18/03/2020. Groundwater monitoring wells were inspected for the presence of water using an electronic dip meter. Field monitoring records are provided in Appendix J.

13.4.2 Land gas monitoring

Six rounds of ground gas monitoring were specified for this investigation. The visits undertaken to date were completed between 17/01/2020 and 18/03/2020. The wells were monitored for

¹² HD22/08 Data for Pavement Assessment. Design Manual for Roads and Bridges; Volume 7 Pavement Design and Maintenance; Section 3 Pavement Maintenance Assessment Part 2

methane, carbon dioxide, oxygen, hydrogen sulphide and carbon monoxide using a GFM 436 portable gas analyser.

Field monitoring records are provided in Appendix J.

13.5 Laboratory Analysis

13.5.1 Chemical Soil Analysis

Selected samples of soil have been subjected to laboratory testing. Sampling techniques and storage have been undertaken as per BS 10175:2011+A2:2017 Code of Practice for Investigation of Potentially Contaminated Sites. The laboratory testing has been carried out by The Environmental Laboratory Ltd at its laboratories in East Sussex. Where available, the tests procedures are UKAS and MCERTS accredited.

The following analyses were completed on selected samples:-

- LEAP standard Soil suite (metals, speciated PAHs, asbestos)
- Petroleum Hydrocarbons
- Volatile Organic Compounds
- Organochloride Pesticide suite
- Asbestos Quantification
- WAC tests

The full laboratory test results are presented in Appendix H.

13.5.2 Geotechnical Laboratory Testing

Selected samples of the soils have been classified by laboratory analysis for geotechnical design purposes. The laboratory testing has been carried out by Geolabs Ltd at its laboratories in Watford, in accordance with BS1377¹³ and BS EN ISO17892¹⁴. The sampling technique, type, storage and transport and the number of laboratory tests have been undertaken where possible in accordance with BS EN 1997-2:2007 and BS EN ISO 22475¹⁵. Conventional U100 sampling techniques have been used to collect undisturbed samples. As such, these samples are not suitable for shear strength testing in accordance with Eurocode specification and the results should be used for guidance only.

The following laboratory tests have been undertaken:-

¹³ BS1377 Parts 1-9:1990 Methods of test for Soils for Civil Engineering Purposes

¹⁴ BS EN ISO 17892 Parts 1-12 Geotechnical Investigation and Testing. Laboratory testing of soil

¹⁵ BS EN ISO 22475 Parts 1-3 Geotechnical Investigation and Testing. Sampling methods and groundwater measurements



Table 7 Geotechnical Laboratory Testing – Zone 1

Test	Number of tests			
	Made Ground/ reworked	Raised Marine	Raised Beach and River Terrace Deposits	Chalk Bedrock
Moisture Content	14 (1)	1	1	24-
Atterberg Limit Test	14 (1)	1	1	-
Particle Size Distribution Test			3	1
Saturated Moisture Content				23
Undrained Triaxial Test	1			-
One Dimensional Consolidation	2			
BRE SD1 Suite (Sulphate Determination and pH)	7 (1)		2	(2)

Values in parenthesis taken from previous reports

Table 8 Geotechnical Laboratory Testing – Zone 2

Test	Number of tests	
	Raised Marine	Chalk Bedrock
Moisture Content	5	7
Atterberg Limit Test	5	-
Saturated Moisture Content		7
BRE SD1 Suite (Sulphate Determination and pH)	3	



14 Ground Conditions

The ground conditions are described in detail in the logs attached in Appendix F. Based on the ground conditions encountered and the mapped geology the site has been broadly grouped into three distinct zones. These include development areas E1, E2, D1 and D2, which are collectively referred to hereafter as Zone 1. The central wetlands and Phase 4 which are referred to as Zone 2 and areas A2 and B6 reported under separate cover as Zone 3. The ground conditions encountered within these zones are summarised below.

14.1 Zone 1 Ground Conditions

With the exception of the northern boundary of development areas E1 and E2 the ground conditions within Zone 1 were largely similar across each of development areas. As such, the ground conditions have been split into two for this Zone with the northern area having its own ground conditions and recommendations.

14.1.1 Zone 1 – North

Zone 1- North, covers an area located along the northern boundaries of E1 and E2 and includes trial holes LPTP122, LPTP125, LPTP126, LPTP134, MTP10 and MTP11.

Table 9: Summary of soils encountered within Zone 1 -North.

Depth From (m)	Depth To (m)	Soil Type	Description
GL	0.2 / 0.4	TOPSOIL	Brown to reddish brown silty clayey TOPSOIL. (LTP126 and MTP11 only)
GL / 0.40	0.6* / 2.7	MADE GROUND/ REWORKED GROUND	Predominantly comprises light brown reworked gravelly sandy clay with variable amounts of demolition rubble. Gravel is medium to coarse chalk, flint, brick and concrete. A fragment of potential asbestos cement was noted in TP133. Plastic was noted in TP125 whilst polystyrene was observed within MTP10. Wood and other vegetation were noted in LTP122.
1.2 / 2.7	3.0* / 3.4*	CLAY (Raised Marine Deposits)	Stiff becoming soft with depth bluish grey silty CLAY

*full depth of excavation.

The made ground/ reworked soils in this part of the site are likely to represent the made ground shown on the BGS geology maps and generally extended to a depth of around 2.0m. Underlying these soils the investigation progressed into generally stiff becoming soft silt clays. These soils have been described in the former Merebrook reports as Alluvium or alluvial in nature. However, the BGS map identifies these soils as being Raised Marine Deposits. Similar to alluvial deposits is that the upper 600-800mm of the clay deposits is recorded as being stiff becoming softer with depth.



The base of these deposits was not confirmed, and the chalk was not encountered in this area.

14.1.2 Zone 1 – South

Zone 1 – South, forms the remaining areas of this Zone and includes all remaining trial hole locations.

Table 10: Summary of soils encountered within Zone 1 -South

Depth From (m)	Depth To (m)	Soil Type	Description
GL	0.25 – 0.50	TOPSOIL / SUBSOIL	Brown to reddish brown silty clayey TOPSOIL with fine to coarse flint gravel and rare fine chalk gravel. Frequent rootlets present throughout. Topsoil was not encountered within LTP108, MTP19, LBH106, LTP114 MWSS8, LBH104, MWSS11, LBH107, LTP125, LTP122, LTP117 and MTP10.
0.5 / 0.8	1.0 / > 3.1	Reworked Soils	Soft grey and brown clays or loose brown sand deposits with variable proportions of flint gravel. LPTP107, LPTP113, LPTP114, LPTP116 LPTP120, LPTP123, LPTP129, MWSS, MWSS7 and MWSS8
0.15 / 0.50	0.50 / 3.4*	Interbedded SANDS and CLAYS	Generally firm becoming stiff orangish brown silty slightly gravelly CLAY. Gravel is fine to coarse sub-angular to sub-rounded flint and fine chalk. Ironstone gravel was noted in LTP106 and LTP126. Interbedded with medium dense orangish brown slightly silty slightly gravelly clayey SAND. With pockets of clay. Gravel is sub-rounded flint cobbles and fine chalk.
0.30 / 2.7	4.0 / 8.5	Structureless CHALK	Off white to cream medium to high density structureless CHALK recovered as silty clayey chalk gravel with occasional sub-angular to sub-rounded flint gravel.
4.0 / 8.5	19.5*	Structured CHALK	Off white to cream structured high density Chalk recovered as silty chalk gravel with occasional sub-rounded flint gravel.

*full depth of excavation.

Localised made ground was observed within trial holes LPTP133, LPTP140 and MTP12 located at the north western corner of Zone 1 and Merebrook locations MWSS5 and MWSS9. The trial holes located in the north western corner found the made ground to consist of brown sandy gravel of chalk and flint and within MTP12 the log reports a large concrete obstruction at 1.7m bgl which stopped works, whilst within LTP133 this consisted of large blocks of concrete recorded at a depth of 1.0m bgl and a fragment of potential asbestos containing material was identified at a depth of 0.8m. Within LTP140, the made ground is recorded as being reworked silty gravelly clays to a depth of 2.7m which was underlain with a grey and black gravelly clay with fragments of timber, brick and plastic bag to in excess of 3.1m bgl.



Within borehole MWS5 and MWS9 the made ground was formed of clay with variable proportions of concrete and brick gravel and occasional fragments of timber and extended to depths of between 0.8 and 1.5m bgl.

Deposits of generally looser or softer sand and clay soils were also noted in several trial holes and are thought to represent areas of Reworked or Made Ground soils as shown on the BGS maps. These soils have been found within trial holes LTP107, LTP113, LTP114, LTP116 LTP120, LTP123, LTP129, MWS5, MWS7 and MWS8 and generally extend to a maximum depth of between 0.8 and 1.4m although deeper reworked soils were identified within LTP116 where they extended to a depth of 2.7m bgl. Although not continuous these deposits seem to be located along a central belt across the middle of the site roughly along the line of the proposed loop road with a second area located at the southern point of development area D2.

The topsoil, made ground and reworked soils were underlain by interbedded brown gravelly clays and clayey gravelly sands. The clays encountered were generally firm to stiff whilst the sands were medium dense.

The depth to chalk rock head was highly variable across the site ranging from 0.20m within TPI18 to in excess of 2.7m in LTP116. The chalk rock head was not encountered within trial holes LTP132, , MWS9, MTP13 and HWS8 which all extended to a minimum depth of 3.0m bgl and with the exception of LTP132 and LTP140, which are located in close proximity in the north western corner of the Zone, were spread across the Zone.

Based on the observations within the cable percussion boreholes the chalk generally comprised weathered, structureless, medium to high density chalk to depths of between 4.0m and 10.0m overlaying structured high-density chalk to the full extent of excavation.

