

14.2 Zone 2 Ground Conditions

Table 11: Summary of soils encountered within Zone 2

Depth From (m)	Depth To (m)	Soil Type	Description
GL	0.10 / 0.50	TOPSOIL	Brown to reddish brown silty sandy clayey TOPSOIL with occasional rootlets. Plant debris noted in LTP102 (Encountered within LTP102, MWS11, MTP8 and MTP18 only.)
GL / 0.10	1.1 / >3.0	MADE GROUND	Brown to dark brown silty clayey sandy gravelly MADE GROUND with variable quantities of. Gravel comprises sub-angular to sub-rounded flint, brick and chalk. Concrete cobbles along with blacktop, glass timber and plastic were noted in LTP101, LHP102 and HP104. Polystyrene and slate and metal were noted in LHP102, LHP103 and LHP104. (Encountered in TP101, MTP17, BH103, HP102, HP103 and HP104 only.)
GL / 0.70	1.0 / 2.50	MADE GROUND (Chalk Fill)	Greyish white slightly clayey silty gravelly MADE GROUND. Gravel is fine to cobbles sized sub-angular to sub-rounded chalk with occasional brick and flint. (Noted in MWS11, MWS12, BH105, WS101, WS102 and WS103.)
0.3 / 2.1	1.4 / 7.0	CLAY (Raised Marine Deposits)	Soft locally firm brown and grey to bluish grey locally mottled orange green and black silty gravelly CLAY.
0.5	1.5	CLAY (Raised Beach/ River Terrace Deposits)	Soft yellow brown silty CLAY. Encountered in TP103 only
1.5 / 7.0	2.4 / 8.5	Structureless CHALK	Off white weathered structureless medium to high density CHALK with occasional flints recovered as silty chalk gravel.
2.4 / 8.5	14"	Structured CHALK	Off white structured high-density CHALK with occasional flints recovered as silty chalk gravel.

The majority of Zone 2 was capped with made ground. The northern section encountered thicknesses of made ground comprising clayey sandy gravel with the gravel consisting mostly of concrete and brick although fragments of timber, plastic and metal were also noted, with the base of the made ground within TP101 extending below the full depth of investigation (3.0m bgl).

Discussion with the engineer on site indicated that this portion of the site had previously been a ditch which has since been "cleared" and backfilled with material from elsewhere on site.



The engineer indicated that the fill had been placed in layers and compacted, however, no certificates to confirm this have been made available at the time of writing.

The northern end of the wetlands area around the former buildings is generally capped by made ground comprising silty gravelly chalk fill varying in thickness between 1.0m – 2.50m. It is considered that this material was historically used to raise levels on site to provide a sound construction platform for the former buildings.

Underlying the made ground, firm becoming soft gravelly clay thought to represent the Raised Marine Deposits was found across the majority of the Zone. The thickness of the clay was highly variable extending to depths of between 1.4 and 7.0m bgl.

The depth to chalk rock head was also noted to be highly variable. However, the depth was greatest in the wetlands area. The depth to the top of the chalk within the west of the zone ranged from 1.2m to 3.3m compared to 1.8m to 7.0m in the east of the zone. zone where deep areas of Raised Marine Deposits were encountered. It is considered that this may represent a former infilled channel feature.

Zone 1 recorded multiple groundwater strikes within the Chalk Aquifer at depths from 1.40 m bgl (2.03 m AOD) to 3.10 m bgl (0.50 m AOD), with the majority described as fast flowing seepages. Water seepages were also recorded in several exploratory holes within the superficial deposits, these were typically towards the base of the stratum.

Zone 2 recorded water strikes in made ground, Raised Marine Deposits and the Chalk. Flow rates were typically fast within the superficial deposits and in the chalk. A water strike was recorded within the made ground at LWS102 only.



14.3 Monitoring

Groundwater monitoring results for the Stage 1 investigation are summarised as follows:-

Table 12: Groundwater Monitoring Results

Monitoring well	Depth to groundwater m bgl (m AOD)					
	17/01/20	29/01/20	07/02/20	18/02/20	04/03/20	18/03/20
Zone 1						
BH104 (4.23)	5.61 (-1.38)	3.08 (1.15)	2.5 (1.73)	n/r	n/r	2.33 (1.90)
HP101	-	Dry	Dry	Dry	Dry	Dry
BH106 (4.49)	^	2.7 (1.79)	2.47 (2.02)	2.60 (1.89)	2.55 (1.94)	2.72 (1.77)
Zone 2						
WS103 (2.29)	0.80 (1.49)	0.66 (1.63)	0.80 (1.49)	0.45 (1.83)	0.50 (1.92)	0.50 (1.92)
WS104 (2.81)	1.70 (1.11)	1.58 (1.23)	1.20 (1.61)	1.35 (1.46)	1.20 (1.61)	1.25 (1.56)
Zone 3						
BH101 (7.24)	5.62 (1.62)	5.63 (1.61)	5.36 (1.88)	5.34 (1.90)	5.40 (1.84)	5.25 (1.99)

^ not drilled at time of monitoring visit

It should be noted that groundwater monitoring during January and February was undertaken during a period of prolonged wet weather. Based on the latest groundwater elevations (18/03/20), the groundwater within the Chalk Aquifer beneath the site is estimated to flow towards the SSE.

14.4 Visual and Olfactory Evidence of Contamination

Visual and olfactory evidence of contamination noted during the investigation works is summarised in the following table.

Table 13: Summary of Visual and Olfactory Evidence

Hole ID	Depth (m)	Olfactory Evidence	Visual Evidence
LTP101	0.5	Faint to moderate ammonia odour detected	
LTP101	2.8	Faint hydrocarbon odour detected	
LTP123	0.5		Large concrete post-base encountered
LTP123	2.1	Faint anaerobic odour detected	
LTP124	0.6	-	Large plastic pipe encountered
LTP133	0.8	-	Single fragment of chrysotile asbestos cement sheet encountered
LTP133	1.0	-	Large blocks of concrete encountered



E GEOTECHNICAL INFORMATION

15 Strata Encountered

15.1 Zone 1 - North

15.1.1 Made Ground/ reworked

Made Ground is identified on the geology maps to be present within Zone 1. Made Ground or fill is by nature highly variable in both composition and bearing capacity and can be subject to large differential settlements when loaded. It is therefore generally unsuitable for use as a bearing stratum. In addition, made ground may contain contaminated and/or putrescible material. It can therefore be a potential source of contamination and landfill gas.

The results of the geotechnical laboratory testing are summarised in the following tables.

Table 14: Summary of Geotechnical Test Results for Made Ground and reworked Clay -- Zone 1 - North

Test	Range
SPT 'N values'	27-28

Only trial pits were excavated in this area and so SPTs were limited to perth penetrometer testing carried out at a depth of 1.0m.

15.1.2 Raised Marine Deposits

Underlying the reworked soils the Raised Marine Deposits were found to extend to the full depth of investigation in this area.

Table 15: Summary of Geotechnical Test Results for Raised Marine Deposits -- Zone 1 - North

Test	Range
Moisture Content (%)	38.2
Liquid Limit (%)	57
Plastic Limit (%)	22
Plasticity Index (%)	35
pH	8.2
Sulphate Content (g/l)	<0.01

Only a single sample of the blue grey alluvial clays was tested from TP125 and has been classified as being of a high plasticity with an NHBC medium Volume Change Potential (VCP).



15.2 Zone 1 - South

15.2.1 Made Ground/ Reworked

Made Ground is identified on the geology maps to be present across Zone 1. Made Ground or fill is by nature highly variable in both composition and bearing capacity and can be subject to large differential settlements when loaded. It is therefore generally unsuitable for use as a bearing stratum. In addition, made ground may contain contaminated and/or putrescible material. It can therefore be a potential source of contamination and landfill gas.

The results of the geotechnical laboratory testing are summarised in the following tables.

Table 16: Summary of Geotechnical Test Results for Made Ground and Reworked – Zone 1 - South

Test	Range
SPT 'N value'	0-35
Moisture Content (%)	20.1-36.8 (24)
Liquid Limit (%)	29-44 (32)
Plastic Limit (%)	14-31 (16)
Plasticity Index (%)	13-19 (16)
pH	7.3-8.5 (8.2)
Sulphate Content (g/l)	0.018-0.055 (0.02)
CBR (%)	0.9-71

Results in parenthesis are from historic reports

Due to the variable nature of made and reworked ground these values are only indicative of the soils tested and it is not possible to derive any kind of design parameters from them.

15.2.2 Raised Beach Deposits

Underlying the Made Ground / Reworked soils the investigation progressed into the sands and clay of the Raised Beach Deposits.

Table 17: Summary of Geotechnical Test Results for Raised Beach Deposits – Zone 1 - South

Test	Range
SPT 'N value'	8-38
Moisture Content (%)	23.8-24.3
Liquid Limit (%)	36
Plastic Limit (%)	18-19
Plasticity Index (%)	17-18
pH	7.6-8.1
Sulphate Content (g/l)	0.019-0.11



The SPTs in the clay portion of these deposits were generally in the range of 15-38 with only one test result below a value of 10. Whilst they were classified as being of intermediate plasticity with a low VCP.

Table 18: Summary of Particle Size Distribution tests for Raised Beach Deposits – Zone 1 – South

Clay and Silt (%)	Sand (%)	Gravel (%)	Cobbles (%)
18-19	57-66	15-27	0

The limited classification testing on the sand deposits describe these soils as slightly clayey gravelly sands.

15.2.3 Structureless Chalk

Structureless weathered chalk was found from depths of between 0.3 and 7.0m bgl.

Table 19: Summary of Geotechnical Test Results for Structureless Chalk – Zone 1 – South

Test	Range
SPT 'N' value	3-21 (15)
Saturated Moisture Content (%)	13-25
Intact Dry Density (Mg/m ³)	1.62-2.01

Results in parenthesis are from historic reports

The laboratory testing on the intact chalk fragments classifies it as being medium to very high density.

15.2.4 Structured Chalk

Structured chalk was found from depths of between 4.0 and 8.5m bgl.

Table 20: Summary of Geotechnical Test Results for Structured Chalk– Zone 1 – South

Test	Range
SPT 'N' value	8-50
Saturated Moisture Content (%)	9.3-22
Intact Dry Density (Mg/m ³)	1.69-2.16

The laboratory testing on the intact chalk fragments classifies it as being medium to very high density.

15.3 Zone 2

15.3.1 Made Ground

Zone 2 is underlain by made ground to between 1.0 and >3.0m, generally comprising silty clayey gravel of flint chalk and occasional fragments of concrete and brick.

Made ground or fill is by nature highly variable in both composition and bearing capacity, and can be subject to large differential settlements when loaded. It is therefore generally unsuitable



for use as a bearing stratum. In addition, made ground may contain contaminated and/or putrescible material. It can therefore be potential source of contamination and landfill gas.

15.3.2 Raised Marine Deposits

Underlying the made ground across the majority of Zone 2 firm or stiff becoming soft grey silty clays of the Raised Marine Deposits have been found to extend to depth of between 1.4 and 7.0m bgl.

The results of the geotechnical laboratory testing are summarised below.

Table 21: Summary of Geotechnical Test Results for Raised Marine Deposits – Zone 2

Test	Range
SPT 'N value'	1-14
Moisture Content (%)	20-66.3
Liquid Limit (%)	30 - 89
Plastic Limit (%)	19 - 30
Plasticity Index (%)	10 - 59
Sulphate Content (g/l)	0.019 - 0.4
Shear Strength (kPa)	3
Angle of Shearing Resistance (°)	3
Coefficient of volume compressibility m_v (m^2/MN)	0.008 - 2.2
pH	8 - 10.2
CBR (%)	0.2 - 114

The shallow SPT results were noted to be higher than those at depth and is suggestive of a higher density “crust” at the top of the Raised Marine Deposits which seems to extend to a depth of at least 1.0m bgl.

The clay samples tested returned plasticity index values ranging from 10 to 59%, classifying the as clays low to very high plasticity and having an NHBC high Volume Change Potential (VCP).

DCP CBR testing carried out from ground level provided values of between 0.2-114% with a value of between 5.5 and 13.0% at a nominal formation depth of 0.4 – 0.6m bgl. Shallow soft spots were noted within DCP2 to a depth of 0.4m bgl.

15.3.3 Raised Beach Deposits

Particle size distributions were not scheduled on geotechnical samples collected from the Phase 4 and Central Wetlands area, as sands or gravels were not prevalent within this area and were only encountered in LWS104 between 0.8 m to 1.8 m bgl, comprising slightly clayey slightly gravelly medium sand.

Geotechnical tests carried out on sand soils within these land plots, are summarised below.



Table 22: Summary of Geotechnical Test Results for Sand/Gravel

Test	Range
SPT 'N' value	4

15.3.4 Structureless Chalk

Structureless weathered chalk was found from depths of between 0.3 and 8.5m bgl.

Table 23: Summary of Geotechnical Test Results for Chalk

Test	Range
SPT 'N' value	4->50
Saturated Moisture Content (%)	15-20
Intact Dry Density (Mg/m ³)	1.75-1.91

The laboratory testing on the intact chalk fragments classifies it as being medium to high density.

A correlation of SPT N values increasing with depth is observed, as illustrated by the SPT vs depth graph in Appendix B. The plots shows that the majority of the SPTs carried out within the chalk refused after 50 blows

15.3.5 Structured Chalk

Structured chalk was found from depths of between 2.4 and 8.5m bgl.

Table 24: Summary of Geotechnical Test Results for Chalk

Test	Range
SPT 'N' value	10->50
Saturated Moisture Content (%)	14-24
Intact Dry Density (Mg/m ³)	1.65-1.97

The laboratory testing on the intact chalk fragments classifies it as being medium to very high density.

A general correlation of SPT N values increasing with depth is observed, as illustrated by the SPT vs depth graph in Appendix B. The plots shows that the majority of the SPTs carried out within the chalk refused after 50 blows



F GEOTECHNICAL APPRAISAL

The foregoing geotechnical appraisal does not constitute a Geotechnical Design Report in accordance with BSEN1997. The following recommendations are for preliminary design purposes only.

For the detailed design, the short-term and long-term design situations must be considered. Where relevant, the following limit states should be considered:-

- Loss of equilibrium of the structure or the ground, considered as a rigid body, in which the strengths of structural material and the ground are significant in providing resistance (EQU)
- Internal failure or excessive deformation of the structure or structural elements in which the strength of structural materials is significant in providing resistance (STR)
- Failure or excessive deformation of the ground, in which the strength of soil or rock is significant in providing resistance (GEO)
- Loss of equilibrium of the structure or the ground due to uplift by water pressure or other vertical actions (UPL)
- Hydraulic heave, internal erosion and piping in the ground caused by hydraulic gradients (HYD)

The following factors should also be considered.

- Overall stability and ground movements
- Nature and size of the proposed construction including the design life
- Conditions with regards to the surroundings (e.g. neighbouring structures, traffic, utilities, vegetation, contamination etc.)
- Ground and groundwater conditions
- Influence of the environment.

16 Swelling and Shrinkage

16.1 Zone 1 - North

Based on the laboratory test results in Section E, an overall classification of NHBC **MEDIUM** Volume Change Potential (VCP) is recommended for the clay soils in Zone 1 - North.

Due to the ground conditions in this part of Zone 1 (Made Ground/ reworked clays to around 1-2.7m over soft clays of the Raised Marine Deposits which extended to >3.0m bgl) shallow foundations are not considered unsuitable for use in this area.



16.2 Zone 1 – South

The ground conditions found within Zone 1 – South mainly consisted of interbedded sands and clays to depths of between 0.5 and 2.0m bgl overlying chalk.

Based on the laboratory test results in Section E, an overall classification of NHBC **LOW** Volume Change Potential (VCP) is recommended for the sandy clay soils in Zone 1 - South.

Foundations will therefore require deepening in accordance with NHBC Chapter 4.2 where clay soils are encountered near trees. Foundation depths should be calculated based on the mature height of the tree, however, the existing height is relevant for trees which are to be removed. Deepening can be terminated where chalk is encountered at depth.

16.3 Zone 2

Only limited geotechnical laboratory testing has been carried out on the samples taken from the Raised Marine Deposits found across the majority of Zone 2. Based on the laboratory test results in Section E, an overall classification of NHBC **HIGH** Volume Change Potential (VCP) is recommended for the soft clay soils of the Raised Marine Deposits. However, it is likely that with further testing the clay soils identified at the southern end of Zone 2 may be found to have a lower plasticity more inline with those encountered within Zone 1 – South.

Foundations will therefore require deepening in accordance with NHBC Chapter 4.2 where clay soils are encountered near trees. Foundation depths should be calculated based on the mature height of the tree, however, the existing height is relevant for trees which are to be removed. Deepening can be terminated where chalk is encountered at depth or within the more granular Raised Beach Deposits.

17 Sulphates

17.1 Zone 1 – Both

1 No. sample of the Raised Marine Deposits and 6 No. samples of the Raised Beach Deposits (sand and clay deposits) were tested for sulphate and pH content. In accordance with the BRE¹⁶ methodology and the number of samples tested, the site has been classified on the mean of the highest two measured sulphate contents and two lowest pH results.

¹⁶ Building Research Establishment Special Digest 1: 2005. Concrete in aggressive ground. Part 1: Assessing the aggressive chemical environment.



Based on the results detailed in Section E and the above, the soils are classified by the BRE as sulphate design class DS-I, and, assuming a mobile groundwater table, the ACEC class is AC-I.

17.2 Zone 2

3 No. samples of the Raised Marine Deposits were tested for sulphate content and pH. In accordance with the BRE¹⁷ methodology and the number of samples tested, the site has been classified on the highest measured sulphate content.

Based on the results detailed in Section E and the above, the soils are classified by the BRE as sulphate design class DS-I, and, assuming a mobile groundwater table, the ACEC class is AC-I.

18 Groundwater -- Zones 1 and 2

The groundwater monitoring was completed over six visits between January and March 2020 results/observations are given in Section D. On the basis of these results, groundwater should be anticipated at about 2.0m bgl within Zone 1 and 1.0m below ground level within the Wetlands area of Zone 2. Given the raised elevation of the Phase 4 part of Zone 2 it is likely that groundwater will be at similar levels to that found within Zone 1 -- South.

Should deep excavations below the groundwater table be necessary then dewatering will be required. It should be noted that dewatering within the Wetlands part of Zone 2 maybe technically difficult and should be avoided if possible.

19 Bearing Capacity and Foundations

19.1 Shallow Foundations - Zone 1

The soils encountered within Zone 1 - North will be unsuitable for shallow foundations. However, in Zone 1 -- South the shallow firm and stiff clays, medium dense gravelly sand deposits and the chalk will be suitable for shall strip foundations. At this stage for low rise housing, based on local experience and BS8103¹⁸ Table 8, an allowable bearing capacity of 100kPa is recommended for shallow foundations, on the firm/stiff clays, medium dense sand

¹⁷ Building Research Establishment Special Digest 1: 2005. Concrete in aggressive ground. Part 1: Assessing the aggressive chemical environment.

BS8103-1:2011 Structural design of low-rise buildings. Code of practice for stability, site investigations, foundations, precast concrete floors and ground floor slabs for housing



deposits encountered at depths of around 1.0m and on the structureless chalk encountered at around 1.5m bgl. A preliminary assessment of VCP found the clay soils within this part of zone 1 should be classified as having an NHBC LOW VCP and deepening near trees will be required. Deepening may terminate where the chalk is encountered.

Deep soft and loose soils have been identified around trial pit LPTPI16 in Zone 1 – South. The horizontal extent of these soils is not known and further delineation testing is recommended to assess. It is considered that strip foundation will not be suitable in areas where deep soft or loose soils is encountered and alternative foundation such as piling is therefore recommended in this area.

Where foundations are stepped or span different soil types, allowance should be made for nominal reinforcement.

19.2 Shallow Foundations - Zone 2

Across the majority of Zone 2 the underlying soft soils will be unsuitable for shallow foundations. However, in the southern part of Phase 4 (TPI02 and I03) firm and stiff clays of the Raised Beach/ River Terrace Deposits were identified. The investigation in this area is limited and so the detailed extent of these deposits has not been confirmed and it is considered that following further confirmatory investigation, shallow foundations maybe possible in this area. At this stage for low rise housing, based on local experience and BS8103¹⁹ Table 8, an allowable bearing capacity of 80kPa is recommended for shallow foundations, on the firm and stiff clays below about 1m. A preliminary assessment of VCP using the results from the Raised Marine Deposits found elsewhere in Zone 2 an NHBC HIGH VCP should be assumed and deepening near trees will be required. It may be possible that with further targeted testing this could be reduced.

Where foundations are stepped or span different soil types, allowance should be made for nominal reinforcement.

19.3 Construction Supervision -- All Zones

Deep soft and loose soils have been identified across this part of the site and it is considered that foundation excavations should be inspected by a suitably qualified engineer prior to pouring concrete to ensure competent soils, in this case the firm clays and/or medium dense sands are encountered at formation level.

BS8103-1:2011 Structural design of low-rise buildings. Code of practice for stability, site investigations, foundations, precast concrete floors and ground floor slabs for housing



The site is situated within an area at risk of solution features. Where solution features can be positively identified, in accordance with CIRIA C574, consideration may be given to the following treatment methods:

- Excavation and replacement with compacted suitable material
- Bridging
- Ground stabilisation by grouting
- Ground treatment by grouting
- Piling
- Control of drainage

Where solution features are prevalent, the chalk is often overlain by a significant thickness of superficial soils. In these cases, CIRIA C574 suggested that foundations may be designed to bridge over voids (assuming diameter <5m). This may be achieved by the following:-

- Cruciform shaped, reinforced foundations, designed to extend at least 1m beyond the proposed building corner in each direction and with a minimum span of 5m (as per CIRIA C574)
- Proposed footprints should be kept as square as possible. Long terraces and linked buildings should be avoided.
- Foundation trenches should be inspected to ensure competent soils are encountered at founding level, and probing of the foundations is recommended to locate any soft areas (SPT N value should be >10 blow counts/300mm).

Whilst there are local pockets of loose superficial soils, which may be the result of historic solutioning, there is no consistent evidence that solution features are **prevalent** in the subject area of the site. As such, nominal reinforcement with deepening through loose soils should be acceptable, subject to findings during groundworks.

19.4 Piling -- All Zones

It is assumed that foundations within Zone 1 – North, the north end of Phase 4 Zone 2 and the bridge abutments within the Wetlands of Zone 2 will be piled. For the ground conditions encountered on site, driven, bored or continuous flight augered (cfa) piles may be considered.

Allowance should be made for negative skin friction loads where ground levels are to be raised.

Discussions should be held with the specialist piling contractors to assess the technical and financial merits of their various systems for the ground conditions encountered, and the depth and size of pile required, with an adequate safety margin.



The final pile design will be determined by the selected piling contractor as the method of pile formation will affect the bearing capacity. For the purpose of preliminary design, the following soil model may be adopted:

Table 25: Soil model for preliminary pile design

Depth to base (m)	Soil Type	Characteristic Shear Strength (kPa)
3	Made Ground	Nil
7	Raised Marine Deposits / soft clay	3
8.5	High density Structureless Chalk	
16	High density Structured Chalk	

Adopting the above model and using the pile design methodology outlined in CIRIA C574, example calculations suggest that a 12m long 300mm diameter CFA pile would have a design compressive resistance of around 295kN whilst a 400mm diameter pile could have around 469kN. The final design must be carried out by the specialist contractor in accordance with their preferred method of formation.

Where a risk of dissolution features has been identified, this must be considered in the pile design. Dissolution features are rarely vertical and may be evident under significant thicknesses of intact chalk. On that basis, care must be taken to not rely on end bearing piles.

The construction of piles can also have a destabilising effect on loosely infilled solution features if encountered, due to disturbance from both vibrations and the use of flush, and this in turn may affect the shaft integrity of CFA and cast-in place piles. Where CFA piles are to be adopted, and a risk of dissolution features has been identified on site, CIRIA PR86²⁰ recommends that a CPT is undertaken at each pile location.

19.5 Services -- Zone 1 - North and Zone 2

Given the presence of deep areas of made ground/soft/loose soils at depth and a high groundwater table it is likely that drain chambers and other large buried services may also require piling. To protect from potential differential settlement between chambers and drain runs it will be necessary to over dig and proof roll runs constructed in these soils.

20 Floor Slabs -- All Zones

With reference to NHBC Standard 5.2, suspended floor slabs are recommended:-

- Where the depth of fill exceeds 600mm

²⁰ CIRIA PR86 Shaft Friction of CFA piles in chalk 2003



- Where foundations are deepened below 1.5m in accordance with NHBC Standards Chapter 4.2
- Where desiccated soils are encountered
- Where vibratory ground improvement techniques have been used
- Where foundations have been piled.

Suspended floor slabs are therefore recommended on site.

21 Roads

21.1 Zone 1

21.1.1 Test Results

A series of 22 No. dynamic cone CBR tests were carried out along the line of the proposed access "Loop" road which runs between areas D1, D2 and E1, E2 and in a south westerly direction along the south eastern boundary of area D2. The results at a nominal formation depth of between 0.4 and 0.7m bgl were in the range 0.9% to 71% but typically fall between 2.9 and 8.0%.

The shallow soils are assessed as frost susceptible, based on the results of the plasticity testing (see Section E).

21.1.2 Recommendations

A design CBR value of 3% is recommended for the silty clay and clayey sand subgrade along the line of the proposed access "Loop" road. However, the presence of soft spots is likely and over digging, proof rolling and backfilling with a suitable granular fill would be required where soft spots are encountered.

It should be assumed that pavements constructed in the Zone 1 – North part of the site will be underlain by soils of variable consistency and it is likely that deep areas of soft ground maybe present from shallow depths. Where soft spots such as this are encountered a design CBR of 0.5% is considered appropriate and it is recommended that pavements will need to be excavated to a depth of 1.0m bgl proof rolling and then controlled back filling to formation level with a suitable granular fill is recommended.

Further confirmatory testing may be required if the proposed roads are to be adopted.

21.2 Zone 2

21.2.1 Test Results

A series of 5 No. dynamic cone CBR tests were carried out along the line of the proposed access road. The results at a nominal formation depth of between 0.4 and 0.7m bgl were in the range 5.5% to 13%.



The shallow soils are assessed as frost susceptible, based on the results of the plasticity testing (see Section E).

21.2.2 Recommendations

A design CBR value of 3% is recommended for the silty clay subgrade. However, the presence of soft spots is likely within the denser “crust” of the Raised Marine Deposits and over digging, proof rolling and backfilling with a suitable granular fill would be required where soft spots are encountered.

The northern half of the Phase 4 part of Zone 2 is underlain by a significant thickness of imported made ground which is reported to have been used to raise levels. In this area a design CBR of 0.5% is considered appropriate and it is recommended that all pavements should be excavated to a depth of 1.0m bgl proof rolling and then controlled back filling to formation level with a suitable granular fill is recommended.

Further confirmatory testing may be required if the proposed roads are to be adopted.

22 Excavations -- All Zones

Excavations in made ground and loose superficial soils are likely to be unstable and subject to collapse. Close lateral support will be required in all excavations where man entry is required.

Excavations below the water table at about 2.0m, within Zone 1 and the Phase 4 part of Zone 2; and 1.0m below ground level within the Wetlands area of Zone 2, will be unstable in the made ground and the granular soils. Running sands and piping in excavation bases should also be anticipated. Excavations extending below the water table will require dewatering.

It is recommended that further groundwater level monitoring is carried out on the Phase 4 part of Zone 2 to confirm groundwater levels. Further monitoring may also be required across the remaining areas of Zone 1 and 2 to confirm groundwater levels over a longer period.

Appropriate Health and Safety precautions must be adhered to where man entry into excavations is required. Even stiff clay soils at shallow depth can collapse, particularly following wet weather. Alternative foundation methods may need to be adopted where trench footings cannot be safely or satisfactorily constructed.

23 Filling - All Zones

It is understood that land raising activities have already occurred across the north portion of Zone 2 (Phase 4) and in parts across the whole of Zone 1 (Made Ground/ Reworked). Further land raises are also possible across both Zones to achieve final construction levels.

It is probable that these raising activities will induce significant settlement, particularly across the areas of deep made ground and soft/loose soils, which could adversely affect foundation



design, drainage etc. Where significant changes in ground levels are proposed then further investigation will be required to assess the impact of such earthworks on the above recommendations.

24 Settlement

24.1 Zone 1

Based on the allowable bearing capacity given in Section 19, foundation settlements should be within typical tolerable limits for the low rise development proposed.

If soft clays are encountered at formation level or below, significant settlement should be anticipated and serviceable limit state analyses will be required. For Geotechnical Category 2 and 3 structures, detailed settlement analyses are usually required.

It is understood that land raising activities have already occurred and that further land raises may occur. At this stage it is not known what degree of raising is proposed to achieve finished levels but if major level raises occur, this may induce significant settlement in the natural soils and detailed settlement analyses will be required.

Where foundations are stepped or span different soil types, differential settlement should be anticipated and allowance should be made for nominal reinforcement.

24.2 Calculated Settlement - Zone 2

A review of the Peter Brett plan of the proposed north crossing causeway drawing number 35944/1507/003 P04 shows that the causeway will be approximately 3.3m high relative to existing ground level. The ground conditions in the area of the causeway and within the Wetlands area of Zone 2 consist of a variable depth of Made Ground (1.0-2.5m) overlying soft and locally firm clay soils of the Raised Marine Deposits to around 7.0m bgl over chalk. A settlement calculation has therefore been prepared assuming a uniform unit weight of the embankment materials as 20kN/m³ with Made Ground extending to a depth 1.0m underlain by the Raised Marine Deposits to 7.0m. Groundwater has been assumed to be at 1.0m depth.

A settlement profile of the shallow underlying soils has been produced using derived m_v values from the one-dimensional oedometer tests. The assessment was carried out assuming that the proposed culvert structures would be piled into the underlying chalk at depths of in excess of 7.0m. Therefore, only loads associated with the placement of the embankment, were applied. Using the characteristic values for m_v described above, the estimated total settlements have been calculated for the made ground as 0.2mm and the Raised Marine Deposits as around 70-100mm per metre of land raise. The primary settlements in the Raised Marine Deposits could be expected to be relatively quick (circa <5years), although secondary creep settlement will apply thereafter which would be expected to continue for a much longer



period. With this in mind, a clearer understanding of the extent of settlements will be critical to the final design and it is envisaged that a more detailed assessment will be required once final levels, and hence thicknesses of land raise are confirmed.

It is recommended at this stage that allowance is made for surcharging and monitoring of land raise areas which will take time to stabilise. Ground improvement will be required where sufficient construction time is not available.

The settlement calculations show that excessive settlements should be expected within the Raised Marine Deposits anywhere that ground levels are raised.

25 Heave and Uplift -- All Zones

In accordance with NHBC Standards Chapter 4.2, precautions against heave should be used where foundations are within the influence of trees and the resulting foundation depth is greater than 1.5m. Compressible material must be provided against the inside faces of all external wall foundations greater than 1.5m in depth. For pier and beam foundations, additional voids are required below ring beams.

For piled foundations, the effect of uplift induced by heave must be included in the pile design. Piles should be reinforced for the length of pile governed by the heave design, and allowance should be made for the inclusion of void former or similar on the underside of ground beams.

Uplift from buoyancy effects may be experienced in deeper manhole chambers or where groundwater is particularly shallow. Allowance for same will need to be made in design of underwater structures and/or foundations.

26 Swallow Holes / Solution Features -- All Zones

The site is situated within an area at potential risk of solution features. A PBA database search found no natural cavities within 2.5km of the site and therefore the site was reported by them to have a low risk from solution features. However, localised soft/loose soils have been found on site (BH105 in Zone 2) which extend to the top of the chalk and resemble areas of potential dissolution, possibly relating to inactive or collapsed former features.

This report provides recommendations for precautions for the design and construction of foundations taking account of the current level of risk of solution features and swallow holes. The precautions recommended within this report, if designed and constructed correctly, will minimise the risk to the proposed foundations and structures.

However, the risk of swallow holes opening within the wider site, away from structures, remains the same. As such the potential for swallow holes to occur on site cannot be discounted or designed against and the reputational (and possibly financial) impact of any such



occurrence should not be underestimated. It is essential that **all efforts to minimise surface water migration into the ground are adhered to**. In particular, the design of water supply and sewer pipes should take into account the potential for relatively large settlements to occur where ground levels are raised and be designed accordingly. Where possible, ground level raises should be avoided.



G GEO-ENVIRONMENTAL APPRAISAL

27 Conceptual Site Model

The conceptual site model has identified a number of potential contaminant linkages.

On-site sources of contamination likely to impact the site include residual hydrocarbons from historical fuel storage, heavy metals, PAH and asbestos within made ground and pesticide / herbicide contamination in near surface soils and potential land gases.

Following the investigation areas of deeper made ground were identified to the north Zone 1 area and within the northern part of the Phase 4 land parcel and across the central wetlands area.

However, based on previous laboratory analysis sources are considered to pose a low to moderate risk to human receptors and a low to moderate risk to controlled waters.

A number of off-site potential contamination sources have been identified, which have the potential to cause contaminant migration onto the Stage 1 area. The risk to human receptors from these off site sources is considered to be low.

28 Testing Strategy

28.1 Soil Sampling

Trial hole locations were generally spread evenly across the site to provide even, non-targeted coverage. The trial hole spacing was consistent with the recommended density of 25 to 50m for an exploratory investigation after BS10175 Section 7.7. With the exception of the following:

- WS101-104 were targeted to further assess the land gas risk from MWS12 and to provide geotechnical information relating to a new road embankment.
- LTP122, 125-126, 133-134, 140 and HPI01 were to target land to the north of the treeline in E1/E2 that had only limited previous investigation.
- HPI02-104 were to provide greater coverage in the northern part of the Phase 4 area, which comprised recent filling.
- HPI05 and HPI06 were additional pits to provide greater coverage in D1 and D2.

Selected samples have been tested for the presence of the identified contaminants of concern (heavy metals, PAH compounds, petroleum hydrocarbons, VOCs, organochloride pesticides and asbestos).

Selected samples have been tested for waste classification purposes.



28.2 Groundwater monitoring

Monitoring wells have been located to allow determination of the groundwater regime within the Chalk Aquifer beneath the site, including groundwater flow direction.

Groundwater levels were monitored on six occasions.

28.3 Land gas / vapour monitoring

The land gas investigation strategy was designed specifically to validate the Amber 2 classification around MWS12 and also where made ground was present and had not previously been characterised i.e. in land north of tree line in E1/E2.

It was not possible to locate historical gas monitoring wells, with the exception of MWS12, which was available for one monitoring round, prior to being lost due to stockpile movement work in the vicinity of MWS12 during the investigation period.

It should also be noted that no residential properties are proposed in the central wetlands area where MWS12 is located, thus the potential risk is from lateral migration of land gas to proposed properties on adjoining land, in Phase 4 and parcel E1.

Fortnightly monitoring over a three-month period has been proposed based on the following:

- Previous risk characterisation around MWS12 (moderate gas generation potential); and
- sensitivity of the receptor is considered high (residential properties with gardens) in vicinity of HP101.

At the end of the monitoring period an assessment of the sufficiency of data will be undertaken with reference to Annex F of BS8576:2013. Further monitoring may be required.

No elevated PID readings were recorded during the monitoring period that indicates volatile vapours are not a significant issue at the site.

29 Assessment Criteria

29.1 Human Health Assessment Criteria

The generic quantitative risk assessment (GQRA) for human health compares the analytical results from the current investigation to Generic Assessment Criteria (GAC). These were selected using the following rationale and assumptions.



Defra and the EA have published a limited number of Soil Guideline Values (SGVs)²¹ that represent minimal chronic risk to human health. CL:AIRE has published a limited number of Category Four Screening Levels (C4SLs)²² which represent a low but still strongly precautionary level of chronic risk to human health. Both the SGVs and C4SLs have both been derived for a Soil Organic Matter (SOM) content of 6%, which is not always representative of the low SOM that are encountered within Made Ground on brownfield sites.

LQM responded to the demand for a more comprehensive set of screening values for a wider range of SOM and produced Suitable for Use Levels (S4ULs)²³ which are a hybrid of SGVs and C4SLs. The S4ULs have been endorsed by the Chartered Institute of Environmental Health (CIEH).

LEAP uses C4SLs where they are available as generic assessment criteria to quantitatively assess the potential chronic risks to human health. Where C4SLs are not available, the S4ULs are used. It is noted that S4ULs are not equivalent to C4SLs in all their exposure assumptions but are generally more conservative in their assumptions. For benzene and benzo(a)pyrene, LEAP has calculated equivalent C4SLs for 1% and 2.5% SOM. This does not affect the inorganic contaminants.

In accordance with current Public Health England (PHE) guidance²⁴, the assessment of PAHs has been carried out using a surrogate marker approach, whereby the assessment of risk from benzo(a)pyrene also captures potential risks from other carcinogenic PAHs that may be present. The alternative S4ULs for PAHs using the Toxic Equivalent Factor (TEF) approach have not been used because this approach is likely to under predict the true carcinogenicity of PAHs and is not advocated by PHE. The threshold PAHs have been assessed similarly, by using naphthalene as a marker compound due to its high volatility relative to other PAHs.

Cyanide has not been modelled using CLEA because it has high acute toxicity. Assuming an acute risk and based on a single dose of 3 g of soil, an assessment criterion of 33 mgkg⁻¹ free inorganic cyanide and 544 mgkg⁻¹ complex cyanide may be derived. At this stage we have adopted a conservative screening value of 20 mgkg⁻¹ for total cyanide (essentially the sum of free and complex cyanides) to highlight any potential risks to human health.

²¹ Environment Agency Science Report SC050021 series.

²² CL:AIRE Final Project Report. SP1010 – Development of Category 4 Screening Levels for assessment of land affected by contamination. CL:AIRE, December 2013

²³ The LQM/CIEH S4ULs for Human Health Risk Assessment, Nathaniel P et al, 2015. Copyright Land Quality Management Ltd, reproduced with permission: Publication Number S4UL3509

²⁴ HPA Contaminated Land Information Sheet. Risk Assessment Approaches for Polycyclic Aromatic Hydrocarbons (PAHs). Public Health England, 2017.



Total phenols have been assessed against the S4UL for phenol and total chromium has been assessed against the S4UL for trivalent chromium.

Theoretical soil saturations have not been considered in the evaluation of organic compounds and as such, some of the S4ULs for the less sensitive exposure scenarios are lower than their more sensitive equivalents.

Sets of GACs have been generated for SOMs of 1%, 2.5% and 6%. In this case, a 1% SOM was considered to be appropriate to maintain conservatism.

For some contaminants of concern, direct contact will be the dominant pathway for exposure. In order to support with development options, human exposure to all unsaturated soils, irrespective of depth, was assumed possible for the purpose of this assessment. This will maximise the information available to the design team on the suitability of all unsaturated material and can support with their materials management options. Soil screening results are provided in Appendix I.

Risks to human health from inhalation of vapours derived from groundwater were in the CSM based on the recommendations from previous ground investigations. However, the no evidence for non-aqueous phase liquids or significant hydrocarbon staining was noted in any exploratory hole excavated by Leap. However, a re-assessment of the risk from inhalation of groundwater derived vapours based on the earlier laboratory testing has been undertaken.

Potential risks to human health from soil gases are assessed in Section 33.3.

29.1.1 Statistical Assessment

In assessing soil test results and comparing them to any threshold or screening value, an assessment must first be made as to how accurately the test results reflect the true mean of the contaminant level within the ground. In this assessment for each parameter the test data have been subjected to statistical assessment based on the methodology set out in *CIEH report 2008: Guidance on comparing Soil Contamination Data with a Critical Concentration*. The Upper Confidence Level or U₉₅ value is thereby calculated as being the level at which we would be 95% confident that the true mean is **less** than this value. For the purposes of this assessment, a conservative approach has been adopted in the statistics. All non-detect values have been treated as being equal to half the limit of detection.

It should be noted that for the purposes of these assessments, no statistical outliers have been excluded. The CIEH guidance document that accompanies the statistics calculator states:

outliers should be excluded from a dataset ONLY where they:

- *are obviously and demonstrably the result of an error that can be identified and explained,*
or
- *clearly indicate that more than one soil population exists within the dataset and this can be justified by (or informs the further development of) the conceptual model*



29.2 Land Gas Assessment Criteria

An initial assessment has been made using the method outlined in CIRIA 665²⁵ for low rise housing. This is consistent with current NHBC guidance for low rise housing.

In this assessment the model low rise house is assumed, i.e.. one with a floor plan area of 8mx8m, a well-ventilated sub-floor void of 150mm and a minimum ventilation rate of one complete volume change per 24 hours.

A risk-based method is used to allow for identification of gas protection measures for such housing by comparing measured emission rates to generic "Traffic Lights". Typical maximum concentrations of methane and carbon dioxide are considered and where these exceed typical maximums for the generation potential of the particular source then risk based Gas Screening Values are considered. In this assessment the highest concentrations have been combined with the highest flow rates to provide a conservative Tier 1 assessment.

The source is then rated as Green, Amber 1, Amber 2 or Red and appropriate design protection measures recommended in line with NHBC guidance and BS8485:2015.

30 Analytical Test Results -- Soils

Soil samples were sent for laboratory analyses of a standard suite of potential contaminants of concern including arsenic, cadmium, chromium VI, copper, lead, mercury, nickel and zinc), speciated PAH and asbestos. Selected samples were sent for pesticide, VOC or speciated TPH analysis.

30.1 Zone 1

30.1.1 Land Parcels D1/D2/E1/E2

Thirty-eight soil samples collected by LEAP from across land parcels D1/D2/E1/E2 were tested for the standard laboratory test suite. In addition, seven soil samples were tested for organochloride pesticides and three samples were tested for speciated TPH.

No potential contaminant of concern (PCoC) exceeded the generic assessment criteria for a residential with plant uptake land use.

Asbestos was identified in two sampling locations, namely in Land Parcel E1, TP133 at 0.80 m bgl as a fragment of chrysotile asbestos cement, with no loose fibres identified in the

²⁵ Wilson S, Oliver S, Mallett H, Hutchings H and Card G. 2007. Assessing risks posed by hazardous ground gases to buildings. CIRIA Report 665.

corresponding soil sample analysis; and a fragment of chrysotile asbestos cement in Land Parcel D2 TPI13 at 0.50 m.

Merebrook tested 17No soil samples across Zone 1 area for a range of potential contaminants of concern (PCsoC) including heavy metals, PHC, PAHs, PCBs and pesticides/herbicides. The results have been compared by LEAP against GACs for residential with home grown produce. No soil sample tested was found to contain PCsoC at concentrations above the GACs for residential with home grown produce.

Asbestos was not detected in samples tested by Merebrook in 2014.

30.2 Zone 2

30.2.1 Land Parcel Phase 4

Seven soil samples collected by LEAP from the Phase 4 area from depths ranging from 0.10 m to 2.90 m and analysed the standard suite of tests. Two soil samples were analysed for speciated TPH and one sample was tested for volatile organic compounds.

No PCoC was detected above generic assessment criteria for residential with plant uptake.

Asbestos was not detected in the samples tested.

Merebrook tested three soil samples from this area (all from MTP18) for a range of PCoC including heavy metals, PHC, PAHs and pesticides/herbicides. The results have been compared by LEAP against GACs for residential with home grown produce. No soil sample tested was found to contain PCsoC at concentrations above the GACs for residential with home grown produce.

30.3 Central Wetlands Area

Four soil samples collected by LEAP from WS101 to WS104 were sent for the standard laboratory test suite.

One soil sample recorded lead at concentrations above the generic assessment criteria for public open space residential (630 mg/kg), namely WS104 at 0.25 m bgl with a lead concentration of 930 mg/kg. All other PCsoC were recorded at concentrations less than generic assessment criteria or below analytical limits of detection. A combined dataset of lead test results from the central wetlands area (Leap and Merebrook) has been subject to a statistical analysis to derive a UCL₉₅ of the mean. The UCL value for the combined dataset is 317 mg/kg, which is less than the GAC of 630 mg/kg.

Asbestos was not detected in the samples tested by LEAP.

Merebrook tested 14No. soil samples from this area for a range of PCsoC including heavy metals, PHC, PAHs and pesticides/herbicides. The results have been compared by LEAP against GACs for public open space residential. No soil sample tested was found to contain



PCsoC at concentrations above the GACs for public open space residential, although MWS12 did record total petroleum hydrocarbon concentrations above 1000 mg/kg in MWS12 at 0.4-0.5 m and 1.5-1.7 m with 6,000 mg/kg and 2,780 mg/kg recorded respectively. Dibenzofuran was also detected above analytical limits of detection.

Asbestos was identified by Merebrook in one sample as chrysotile loose fibres in MTP17 at 1.30-2.50 m depth. MTP17 is located in the northwest of the wetlands area, close to the Phase 4 boundary. A shallow sample (0.0-1.3 m) at the same location did not record asbestos.

31 Land Gas Monitoring Results

The gas monitoring results are summarised in Table 26 below:

Table 26: Summary of land gas monitoring results

BH Ref	Maximum Recorded Concentration*						
	CO ₂ (%)	CH ₄ (%)	CO (%)	O ₂ (%)	Flow rate (l/hr)	Atmospheric Pressure (mB)	Was response zone flooded?
04/12/19							
MWS12	0.7	0.1	0	20.1	0.0	1011	Partially
17/01/20							
WVS103	Water monitoring well fully flooded not possible to record gas reading						
WVS104	2.7	0.0	0.0	11.8	0.0	1037	No
HP101	n/r	n/r	n/r	n/r	n/r	n/r	n/r
29/01/20							
WVS103	Water monitoring well flooded not possible to record gas reading						
WVS104	(*)	(*)	(*)	(*)	(*)	(*)	No
HP101	(*)	(*)	(*)	(*)	(*)	(*)	No
07/02/20							
LWS103	3.7	0.2	2	15.9	-0.8	1020	Yes
LWS104	3.1	0.2	0	10.4	0.0	1020	Partially
LHP101	3.4	0.2	1	18.8	0.0	1020	No
18/02/20							
LWS103	3.5	0.2	0.0	19.2	0.2	1012	Yes
LWS104	2.5	0.2	0.0	11.3	0.2	1012	No



BH Ref	Maximum Recorded Concentration*						
	CO ₂ (%)	CH ₄ (%)	CO (%)	O ₂ (%)	Flow rate (l/hr)	Atmospheric Pressure (mb)	Was response zone flooded?
LHP101	n/r	n/r	n/r	n/r	n/r	n/r	n/r
04/03/20							
LWS103	3.1	0.1	0	19.9	0.0	1012	Yes
LWS104	3.1	0.2	0	12.1	0.2	1012	Partially
LHP101	1.4	0.0	0	20.8	0.1	1012	No
18/03/20							
LWS103	2.9	0.1	0	20.1	0.0	1026	Yes
LWS104	2.9	0.2	0	10.9	0.0	1026	Partially
LHP101	0.3	0.2	0	21.0	0	1026	No

Notes to table

* With the exception of Oxygen which is recorded as minimum; n/r = not recorded; (^) equipment failure

One gas monitoring round was recorded from MWS12 during this period, and although a high water table (0.67 m bgl) was noted the log records the response zone is from 0.50 m bgl. The monitoring did not record elevated land gas concentrations. We note that LWS103 the response zone was flooded on all of the monitoring rounds, as such the results are not representative of land gases at the site. LWS104 located approximately 25 m to the north east of MWS12 and gas readings were recorded on during all visits to date, with the exception of 29/01/20 when an equipment failure prevented gas readings to be collected during that round.

Gas monitoring visits did not coincide with low atmospheric pressure conditions (<1000 mb).

32 Risk Assessment

32.1 Human Health

32.1.1 Zone 1 Land Parcels D1/D2/E1/E2

The works to date have not identified any significant contamination in soils samples tested with respect to identified human health receptors, with the exception of asbestos cement fragments in made ground soils from D2 and E1 parcels.

Cement bound chrysotile asbestos fragments were identified in two locations, namely a fragment of chrysotile asbestos cement in land parcel D2 (TPI13 at 0.50 m) and a fragment of



chrysotile asbestos cement, with no loose fibres identified in the corresponding soil sample analysis in land parcel E1 (TPI33 at 0.80 m). These appear to represent localised hotspots.

We note that deeper made ground was identified in the Zone 1 North Area, beyond the tree line present within the northern boundaries of land parcels E1 and E2. Parts of this were inaccessible during the investigation due to dense vegetation cover and soft ground. Further investigation is recommended particularly in the area between LTPI33 and LTPI40 once improved access is available.

32.1.2 Zone 2 Phase 4

The works to date have not identified any significant contamination in soils samples tested with respect to identified human health receptors.

32.1.3 Zone 2 Central Wetlands

The works to date have not identified any significant contamination in soils samples tested with respect to identified human health receptors. One soil sample record an exceedance of lead GAC in shallow soils at WS104. A statistical assessment of lead test results in made ground soils, incorporating both the Leap and Merebrook data for soil depth 0.0 to 1.0 m (n = 12) recorded an UCL₉₅ of 463 mg/kg, which is less than the GAC of 630 mg/kg. This suggests that made ground within the central wetlands area does not pose an unacceptable risk to human health for the proposed end use.

Asbestos was identified in one location at depth in the Central Wetlands Area in 2014 by Merebrook at depth. This may represent a localised hotspot of contamination.

32.2 Controlled Waters

32.2.1 Groundwater

The site is located above a secondary aquifer (River Terrace Deposits, Raised Beach Deposits, Raised Marine Deposits) and the Principal Aquifer, the Chalk. The site is not situated within a potable water supply Source Protection Zone. The nearest groundwater source protection zone is located ~1.93 km to the south east of the site.

Specific groundwater laboratory testing has not been carried out as part of this investigation. Previous laboratory testing of the chalk aquifer did not identify potential contaminants of concern at concentrations above screening criteria, with the exception of nickel a marginally elevated concentration of nickel at 0.028 mg/l (against UKDWS of 0.02 mg/l) in MBH1, located in the Stage 2 investigation area.

Concentrations of potential contaminants of concern recorded in on site soils are generally low and mean average concentrations in soil samples tested by Leap are analogous to normal background concentrations in the UK i.e. in general site soils do not appear to pose an additional burden to controlled waters receptors than that which may be expected from normal UK soils.



Table 27: Normal background concentrations vs mean average concentrations

PCoC	Normal background concentrations (mg/kg)	Mean average concentration (mg/kg)		
		Zone 1 D1/D2/E1/E2	Zone 2 Phase 4	Zone 2 Central Wetlands
Arsenic	32	14.3 (13)	16.4 (14.5)	10.9 (10.5)
Cadmium	1	0.5 (0.4)	0.6 (0.5)	0.6 (0.5)
Copper	62	18.9 (17)	29.6 (10.3)	78.1 (27.9)
Mercury	0.5	0.5 (0.3)	0.5 (0.3)	0.5 (0.3)
Nickel	42	21.3 (18)	24.2 (27.5)	14.3 (15.5)
Lead	180	21.3 (17)	29.5 (13.5)	241* (54.3)
Benzo(a)pyrene	0.5	0.1 (0.3)	0.3 (0.1)	0.3 (0.5)

*One sample recorded lead above NBC, but <urban background concentrations of 820 mg/kg; values in parenthesis taken from previous reports

On the basis of the low concentrations of PCsoC previously reported in the Chalk aquifer by Merebrook and the low levels of PCsoC in site soils identified by LEAP the risk to the Principal Aquifer is assessed as Low.

With respect to the localised petroleum hydrocarbon contamination identified in groundwater at MWS12, it has not been possible to re-sample and test this location. However, based on observations during drilling of adjacent exploratory holes by LEAP (LWS101-LWS104) and laboratory analysis of soil samples, petroleum hydrocarbon contamination was not identified in surrounding land.

Merebrook did not record NAPL or significant hydrocarbon staining in soil or groundwater at MWS12 (although Merebrook reported a sheen in groundwater). Laboratory analysis of a groundwater sample from MWS12 reported petroleum hydrocarbons at concentrations above analytical detection limits in the aliphatic / aromatic C10-C21 range. C10-C21 hydrocarbon bands falls within kerosene, diesel and light gas oil carbon signatures, which corresponds to potential historical land uses on site.

The highest reported TPH concentration recorded in groundwater at MWS12 was aliphatic C16-C21 (0.31 mg/l). Aliphatic hydrocarbons in the C10-C21 range have been indicated as low risk by the Environment Agency²⁶. Aromatic hydrocarbons C10-C12 (based on naphthalene) are indicated as moderate risk, but aromatic carbon bands +C12 are indicated

²⁶ Table 7.1 Petroleum Hydrocarbons in Groundwater: Supplementary Guidance for Hydrogeological Risk Assessment Environment Agency *Withdrawn*

as low risk. Naphthalene was detected at 0.0012 mg/l in MWS12. There is no published UK Drinking Water Standard for TPH fractions or naphthalene.

In the absence of a UK screening value, for this assessment we have used published WHO guidance values for TPHCWG fractions in drinking water²⁷ to screen the groundwater results detected by Merebrook in MWS12. No TPH concentration exceeded the WHO guidance values. Petroleum hydrocarbons in groundwater at MWS12 are unlikely to pose a significant risk to groundwater receptors, as they are at low concentrations and localised.

32.2.2 Surface Water

The closest surface water feature are the surface drains within the central wetlands area and flood plains associated with the Black Ditch along the northern boundary. Shallow perched water is considered to be discontinuous i.e. there is lack of a significant pathway between the shallow groundwater and surface water receptors and groundwater flow within the Chalk Aquifer is away from the Black Ditch (based on most recent groundwater level monitoring data) The generally low concentrations of PCoC in onsite soils are unlikely to pose a significant risk to surface water receptors.

Petroleum hydrocarbons previously identified at MWS12 are unlikely to pose a significant risk for the reasons described above.

32.3 Land Gases

The land gas monitoring was to confirm the land gas risk classification around MWS12 and in an area of made ground soil not previously assessed.

With respect to MWS12, two land gas monitoring wells have been installed, albeit one was flooded on all monitoring rounds to date. Adopting the methods described in 28.3 and 29.2, Gas Screening Values calculated for both methane and carbon dioxide land for LWS104 only.

Table 28: Calculated Gas Screening Values

Gas Screening Value	Flow rate	Carbon Dioxide	Methane
	l/hr	l/hr	l/hr
17/01/20	0.1	0.0027	0.0001
29/01/20	-	-	-
07/02/20	0.1	0.0031	0.0002
18/02/20	0.2	0.005	0.0004

²⁷ Table 5.4 Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies CL:AIRE 2017

Gas Screening Value	Flow rate	Carbon Dioxide	Methane
	L/hr	L/hr	l/hr
04/03/20	0.2	0.0062	0.0004
18/03/20	0.1	0.0029	0.0002
Classification based on maximum values	0.2	0.0062	0.0004

A maximum methane concentration of 0.1% is assumed when methane is not detected (the detection limit of the equipment used by LEAP).

Based on the gas screening values, land around LWS104 would be classified as green under NHBC:2007 or very low risk under BS8485:2015+A1:2019.

This is indicative that land in the vicinity of MWS12 is not producing significant volumes of land gas. As previously described above the Amber 2 classification was based on a single carbon dioxide reading with no flow rate and a high water table. Given that no properties are proposed within the central wetlands area and that RB17:2012 suggests the presence of hydrocarbons in wells can result in high gas concentrations, but low volumes and the monitoring undertaken at LWS104 did not identify a significant land gas risk, the risk to adjacent properties in land parcel Phase 4 and land parcels D1/ E1 is low.

With respect to the land to the north of E1/E2 a single shallow gas monitoring well was installed and adopting the methods described in 28.3 and 29.2, Gas Screening Values calculated for both methane and carbon dioxide land around HP101 is as follows:

Table 29: Calculated Gas Screening Values

Gas Screening Value	Flow rate	Carbon Dioxide	Methane
	L/hr	L/hr	l/hr
17/01/20	0.2	0.0034	0.0002
04/03/20	0.1	0.0014	0.0001
18/03/20	0.1	0.0003	0.0002
Classification based on maximum values	0.2	0.0034	0.0002

HP101 is located ~14 m west of TP134 where 2.6 m of made ground was recorded. Based on the gas screening values, land around LHP101 would be classified as green under NHBC:2007 or very low risk under BS8485:2015+A1:2019.



However, we do note that following the pragmatic approach to gas risk assessment (Research Bulletin CL:AIRE:2012) that where deeper made ground is present (in vicinity of LTPI22, LTPI33, LTPI34, LTPI40) that TOC values of 0.33-4.8% are recorded, which is indicative of CS3 moderate gas situation value.

Based on the limited gas monitoring wells in Zone 1 – North, moderately high TOC values further investigation to confirm the land gas risk in this area is recommended.

32.4 Vapour Risk

32.4.1 Soil Vapours

Visual or olfactory evidence of volatile compounds was not identified in any of the exploratory holes undertaken by LEAP. Laboratory testing did not record volatile organic compounds at concentrations above generic assessment criteria in the soil samples analysed by LEAP. The risk posed to residential end users from volatile vapours in soil is considered low.

32.4.2 Groundwater vapours

Results of previous groundwater monitoring relating to borehole MWS12 indicated a possible hydrocarbon vapour risk in groundwater, which recorded concentrations for petroleum hydrocarbon aliphatic fractions C10-C12 (50 µg/l) marginally above the SoBRA $GAC_{gw vap}$ of 37 µg/l. However, on the basis that no new properties are proposed over MWS12 and the petroleum hydrocarbon contamination is localised the risk from groundwater vapours to adjacent residential properties in land parcels Phase 4 and D1/E1 is considered low.

33 Waste Disposal

It is anticipated that the proposed development will generate waste soils and materials will need to be removed from site as part of the construction process.

Where soils are to be disposed off-site, it is the duty of the waste producer, in this case Persimmon Homes Thames Valley, to ensure that all waste is disposed of appropriately and that any that is sent to landfill is sent to an appropriately licensed one. All waste sent to landfill must be classified and must be pre-treated. There are various forms of pre-treatment that are acceptable. In this case it could include “reduction in volume”, which could be achieved by segregating the Made Ground and re-using part of it on site.

Where made ground soil is to be re-used on site then it is recommended that this is carried out under the CL:AIRE Definition of Waste Industry Code of Practice (DoWCoP) for re-use of soils²⁸.

²⁸ The Definition of Waste: Development Industry Code of Practice. Version 2 2011. CL:AIRE

Laboratory test results from this investigation and the previous Merebrook investigation have been preliminarily screened using the online tool HazWasteOnline®. All the samples have been preliminarily assessed as non-hazardous waste, with the exception where of where asbestos was identified and in the Merebrook sample MWS12, where TPH concentrations exceed hazardous waste thresholds of 1000 mg/kg. Preliminary classification results are provided in Appendix K.

Asbestos cement fragments are classed as hazardous waste.

Three samples were tested for waste classification purposes, TPI03 at 0.30 m and TPI17 at 0.50 m and TPI11 at 0.15 m. It is considered that the soils would be classified as inert for waste disposal purposes.

Further testing and inspection of soils will be required to confirm waste classification of material leaving the site.

It is strongly advised that detailed discussions be held with remediation/groundworks contractors and that receiving landfill sites are identified in advance of commencing any waste removal.

34 Recommendations for further works

Further shallow gas monitoring wells should be installed in the deeper made ground soils in Zone 1 north to confirm the gas characteristic situation. This can be undertaken as part of the Stage 2 ground investigation works when improved access to the area is expected to be available.

We recommend that additional gas monitoring of all shallow wells is completed during low or falling atmospheric pressure conditions.

Where asbestos has been identified we recommend limited further investigation of near surface soils to delineate the extent of asbestos contamination.

A soil leachate test can be considered in soils around LWS104 to confirm that the elevated lead concentration in near surface soils is not mobile.

35 Recommendations for remediation

A final remediation method statement will be required to be prepared once the final site designs are complete. This method statement should be submitted to the appropriate regulatory authorities. It is advised that the local authority is advised of the intended build programme in order that they can phase the sign off of planning conditions as required.

The remediation strategy will require the importation of clean topsoil, and possibly subsoil. Imported soils should be tested at source by the supplier. The validation engineers should then make spot checks as and when necessary once material has been imported.



Provision should also be made for dealing with further localised hotspots of contamination which may come to light during construction (for example the potential for petroleum hydrocarbon contamination around MWS12). Any such soils should be inspected by the validation engineers and appropriate remedial action taken as necessary.



APPENDIX A -- Limitations

Limitations



LIMITATIONS

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. Unless explicitly agreed otherwise in writing, this report has been prepared under LEAP's standard terms and conditions, as included in the quotation for this works.

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. LEAP cannot be held responsible for any disclosures or changes in regulation that are provided post production of this report, and will not automatically update the report.

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.

The extent of the exploratory holes, laboratory testing and monitoring undertaken may have been restricted due to a number of factors including accessibility, the presence of buried or overhead services, current development and site usage, timescales or client's specification. The exploratory holes only assess a small proportion of the site area with respect to the site as a whole, and as such may only provide an overall assessment of ground conditions on site. The presence of hotspots of undisclosed contamination or exceptional and unforeseen ground conditions cannot be discounted.

Eurocode 7 gives guidance on the type of sampling, sample quality, number and spacing of intrusive investigations, and number of laboratory tests required. 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 Eurocode⁷²⁹, although this is subject to the restrictions imposed on the investigation as listed above. For geotechnical design, Eurocode 7 requires the Geotechnical Design Report to address both the geotechnical and

²⁹ BS EN 1997 Eurocode 7- Geotechnical Design - Part 1: General Rules (2004) and Part 2: Ground Investigation and Testing (2007)



structural aspects of the geotechnical design for both the limit and serviceability states. The Geotechnical Appraisal section of this report will not meet the requirements of a Geotechnical Design Report (GDR), and should therefore be used for preliminary guidance only.

The presence of asbestos may be noted during the site walkover survey, intrusive investigations and/or from the results of contamination testing. However, this report does not constitute an asbestos survey. On this basis, the presence of asbestos on site cannot be discounted and a full asbestos survey should be undertaken.



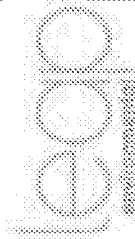
APPENDIX B – Figures

Figures





Site Location



Client:

Persimmon Homes

Title:

Site Location

Project ID:

LP2128

Project:

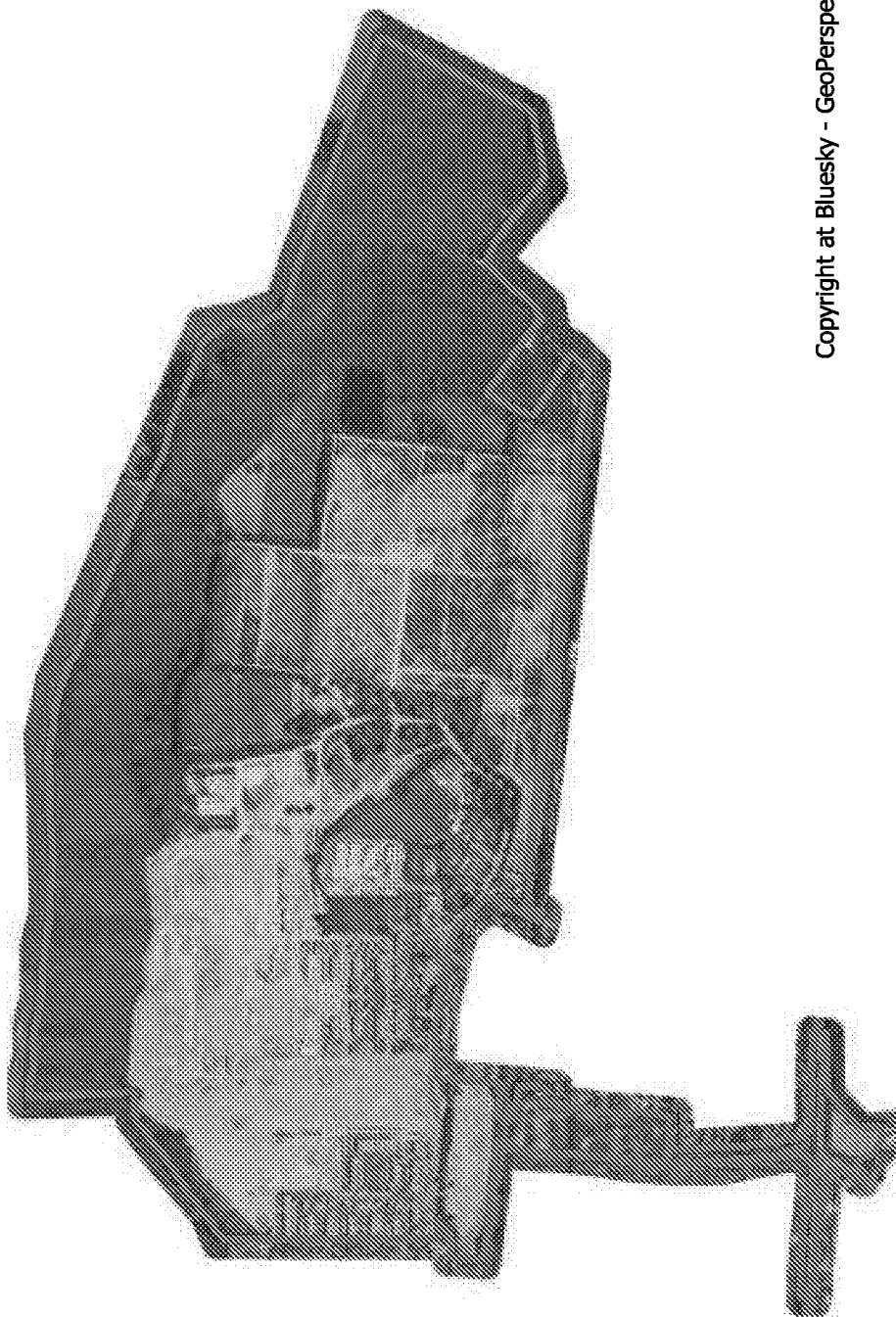
Toddington Lane North
Littlehampton

Date:

March 2020

Figure No

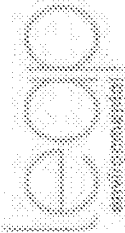
1



0 100 200 m



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		Client:	Persimmon Homes	Title:	Existing Site Layout	Project ID:	LP2128
Project:		Toddington Lane North Littlehampton		Date:	March 2020	Figure No	2