GROUND INVESTIGATION REPORT

for the site at

28 MARESFIELD GARDENS, SOUTH HAMPSTEAD, LONDON NW3 5SX

on behalf of

MR AND MRS FREEDMAN C/O VINCENT AND RYMILL

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	Roger Foord BA (Hons) MSc DIC FGS MSoBRA Senior Geotechnical Engineer	Francis Williams M.Geol. (Hons) FGS Cgeol CEnv AGS MSoBRA Director
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1.0 INTRODUCTION

1.1 General

Ground and Water Limited were instructed by Mr and Mrs Freedman c/o Vincent and Rymill, on the 27th July 2014, to undertake a Ground Investigation on a site at 28 Maresfield Gardens, South Hampstead, London NW3 5SX. The scope of the investigation was detailed within the Ground and Water Limited fee proposal ref: GWQ2986, dated 20th July 2016.

1.2 Aims of the Investigation

The aim of the investigation was understood to be to supply the client and their designers with information regarding the ground conditions underlying the site to assist them in preparing an appropriate scheme for development.

The investigation was to be undertaken to provide parameters for the design of foundations by means of in-situ and laboratory geotechnical testing undertaken on soil samples recovered from trial holes.

The requirements of the London Borough of Camden, Camden Geological, Hydrogeological and Hydrological Study, Guidance for Subterranean Development (November 2010) was reviewed with respect to this report.

A Desk Study and full scale contamination assessment were not part of the remit of this report.

The techniques adopted for the investigation were chosen considering the anticipated ground conditions and development proposals on-site, and bearing in mind the nature of the site, limitations to site access and other logistical limitations.

1.3 Conditions and Limitations

This report has been prepared based on the terms, conditions and limitations outlined within Appendix A.

2.0 SITE SETTING

2.1 Site Location

The site comprised a 720m^2 rectangular shaped plot of land, orientated in a west to east direction, located on the eastern side of Maresfield Gardens, ~20m south of its junction with Nutley Terrace. The site was located in South Hampstead, north-west London, within in the London Borough of Camden.

The national grid reference for the centre of the site was approximately TQ 26603 84938. A site location plan is given within Figure 1. A plan showing the site area is given within Figure 2.

2.2 Site Description

A Site Walkover was undertaken in August 2014. The site comprised a detached three storey property with lower ground floor/semi-basement. Open vehicular access was noted off Maresfield Gardens with ornamental front garden. Gated access was noted at the eastern end of the tarmac drive leading to a paved patio and then grassed rear garden, surrounded by mature trees. A raised kerb was noted outside the property adjacent to Maresfield Gardens.

Maresfield Gardens, located adjacent to the western boundary of the site, appeared to be at ~72.0m AOD. The rear garden was situated at 70.15m AOD.

The sites environs were noted to be sloping gently to moderately down in a southerly/south-westerly direction. An aerial view of the site is given within Figure 3.

2.3 Proposed Development

At the time of reporting, August 2016, the proposed development was understood to comprise the construction of a single storey rear and side excavation and a basement below the proposed rear extension, extending out below the rear garden. A founding depth of ~4.70m bgl for the basement has been proposed. A Plan View and Section View of the proposed development can be seen in Figure 4 and Figure 5 respectively.

The proposed development fell within Geotechnical Design Category 2 in accordance with Eurocode 7. The proposed foundation loads were not known to Ground and Water Limited at the time of reporting but are likely to range from 75 – 150kN/m^2.

The proposed development was understood not to involve any re-profiling of the site and its immediate environs. It is understood that no trees will be removed to facilitate the construction of the basement.

2.4 Geology

The geology map of the British Geological Survey of Great Britain of the South Hampstead area (Sheet No. 256 North London) revealed the site to be situated on the London Clay Formation.

Figure 3 of the Camden Geological, Hydrogeological and Hydrological Study indicated that no Made Ground or Worked Ground was noted within a close proximity of the site (see Figure 6 of this report).

London Clay Formation

The London Clay Formation comprises stiff grey fissured clay, weathering to brown near surface. Concretions of argillaceous limestone in nodular form (Claystones) occur throughout the formation.

Crystals of gypsum (Selenite) are often found within the weathered part of the London Clay Formation, and precautions against sulphate attack to concrete are sometimes required.

The lowest part of the formation is a sandy bed with black rounded gravel and occasional layers of sandstone and is known as the Basement Bed.

Examination of the online BGS borehole records revealed a BGS borehole ~250m south-west revealed 0.50m of Made Ground over a brown fissured silty clay to 10.30m and then a dark brown fissured clay to 15.20m bgl.

2.5 Hydrogeology and Hydrology

A study of the aquifer maps on the Environment Agency website, and Figure 8 of the Camden Geological, Hydrogeological and Hydrological Study, revealed the site to be located on **Unproductive Strata** relating to the bedrock of the London Clay Formation. No designation was given for any superficial deposits due to their likely absence.

Unproductive strata are rock layers with low permeability that have negligible significance for water supply or river base flow. These were formerly classified as non-aquifers.

Superficial (Drift) deposits are permeable unconsolidated (loose) deposits, for example, sands and gravels. The bedrock is described as solid permeable formations e.g. sandstone, chalk and limestone.

Examination of the Environment Agency records showed that the site did not fall within a Groundwater Source Protection Zone as classified in the Policy and Practice for the Protection of Groundwater.

From analysis of hydrogeological and topographical maps, groundwater was anticipated to be encountered at depth (>6m below existing ground level (bgl)) and it was considered that the groundwater was flowing in a south-westerly direction in accordance with the local topography.

Examination of the Environment Agency records showed that the site was not situated within a floodplain or flood warning area.

2.6 Radon

BRE 211 (2015) Map 5 of London, Sussex and West Kent revealed the site **was not** located within an area where mandatory protection measures against the ingress of Radon were required. The site **was not** located within an area where a risk assessment was required.

3.0 FIELDWORK

3.1 Scope of Works

Fieldwork was undertaken on the 5th August 2016 and comprised the drilling of one Dart Windowless Sampler Borehole (BH1) to a depth of 10.45m bgl and one Hand Held Window Sampler Borehole (WS2) to a depth of 5.00m bgl. Standard Penetration Testing (SPT's) was undertaken at 1.00m intervals in BH1. A 50mm combined bio-gas and groundwater monitoring well was installed in BH1 to 5.00m bgl.

In addition, two trial pit foundation exposures (TP/FE1 and TP/FE2) were excavated to enable measurement of the shape and configuration of the existing foundations at the rear of the property.

The approximate locations of the trial holes can be seen within Figure 6.

Prior to commencing the ground investigation, a walkover survey was carried out to identify the presence of underground services and drainage. Where underground services/drainage were suspected and/or positively identified, exploratory positions were relocated away from these areas.

Upon completion of the site works, the trial holes were backfilled and made good/reinstated in relation to the surrounding area.

3.2 Sampling Procedures

Small disturbed samples were recovered from the trial holes at the depths shown on the trial hole records. Soil samples were generally retrieved from each change of strata and/or at specific areas of concern. Samples were also taken at approximately 0.5m intervals during broad homogenous soil horizons.

A selection of samples were despatched for geotechnical testing purposes.

4.0 ENCOUNTERED GROUND CONDITIONS

4.1 Soil Conditions

All exploratory holes were logged by Roger Foord of Ground and Water Limited, generally in accordance with BS EN 14688 'Geotechnical Investigation and Testing – Identification and Classification of Soil'.

The ground conditions encountered within the trial holes drilled on the site generally conformed to that anticipated from examination of the geology map. A capping of Made Ground was noted to overlie the soils of the London Clay Formation.

The ground conditions encountered during the investigation are described in this section. For more complete information about the Made Ground and the London Clay Formation at particular points, reference must be made to the individual trial hole logs within Appendix B.

The trial hole location plan can be viewed in Figure 6.

For the purposes of discussion the succession of conditions encountered in the trial holes in descending order can be summarised as follows:

Made Ground
London Clay Formation

Made Ground

Made Ground was encountered from ground level to 0.90m bgl in WS2, and beneath a 0.20 - 0.26m of tarmac/yorkstone over a crushed brick and concrete sub-base to 0.60m bgl in BH1, 0.30m bgl in TP/FE1 and 0.80m bgl in TP/FE2. The Made Ground generally comprised a dark brown slightly gravelly silty clay. The gravel was occasional, fine to medium, sub-angular to sub-rounded brick and rare to occasional, fine, sub-angular to sub-rounded carbonaceous material (ash/clinker).

London Clay Formation

Soils of the London Clay Formation were encountered underlying the Made Ground for the remaining depth of each of the trial holes, a maximum depth of 10.45m bgl in BH1. The soils generally comprised a brown silty clay, with rare fine selenite crystals, for the remaining depth of TP/FE1, a depth of 0.50m bgl, and TP/FE2, a depth of 0.80m bgl, and to a depth of 2.60m bgl and 1.90m bgl in BH1 and WS2 respectively. A band of brown silty clay with fine selenite crystals and sub-rounded flint gravel was noted between 1.90 - 2.20m bgl in WS2. Pockets/veins of grey silt were noted with depth in the boreholes.

The soils became a dark grey brown silty clay with rare selenite crystals below 7.20m bgl in BH1.

4.2 Foundation Exposure

A description of the foundation layout and ground conditions encountered within the hand dug trial pit/foundation exposure are given within this section of the report.

TP/FE1

Trial pit foundation exposure TP/FE1 was hand excavated from ground level close to the centre of the rear wall of the existing property. The exact location of the trial hole can be seen in Figure 6 with a section drawing of the foundation encountered in Figure 7.

The foundation exposure was measured from ground level.

The foundation layout encountered consisted of a brick wall to ground level. From ground level to a depth of 0.08m bgl a brick wall was noted resting upon a brick step that stepped out by 0.15m and was 0.22m bgl in thickness. The brick step was underlain by a concrete footing that stepped out by 0.07m and was 0.50m in thickness. The concrete footing was founded upon the London Clay Formation comprising a brown silty clay at a depth of 0.80m bgl. Made Ground was noted to a depth of 0.30m bgl.

The ground conditions encountered directly surrounding the foundation are shown in Figure 7.

TP/FE2

Trial pit foundation exposure TP/FE2 was hand excavated from ground level on the southern side of the rear wall of the existing property. The exact location of the trial hole can be seen in Figure 6 with a section drawing of the foundation encountered in Figure 8.

The foundation exposure was measured from ground level.

The foundation layout encountered consisted of a brick wall to ground level. From ground level to a depth of 0.60m bgl a brick wall was noted resting upon a brick step that stepped out by 0.11m and was 0.20m in thickness. The brick step was underlain by a concrete footing stepped out by 0.18m and was 0.40m in thickness. The concrete footing was founded upon the London Clay Formation comprising a brown silty clay at a depth of 1.210m bgl. Made Ground was noted to a depth of 0.80m bgl.

The ground conditions encountered directly surrounding the foundation are shown in Figure 8.

4.3 Roots Encountered

Fresh roots were noted to 1.50m bgl in BH1 and 1.00m bgl in WS2. Decaying roots were noted at 3.50m bgl in both boreholes.

It must be noted that the chance of determining actual depth of root penetration through a narrow diameter borehole is low. Roots may be found to greater depths at other locations on the site, particularly close to trees and/or trees that have been removed both within the site and its close environs.

4.4 Groundwater Conditions

Groundwater was not encountered during the intrusive investigation.

A return visit to monitor the combined bio-gas and groundwater well installed in BH1 was undertaken by a Ground and Water Limited Engineer on the 21st September 2016. Water was noted to be resting at 2.70m bgl in the 5.00m deep well installed.

Changes in groundwater level occur for a number of reasons including seasonal effects and variations in drainage. Exact groundwater levels may only be determined through long term measurements from monitoring wells installed on-site. The investigation was undertaken in August and September 2016 when groundwater levels are likely to be close to their annual minimum (lowest elevation).

Isolated pockets of groundwater may be perched within any Made Ground found at other locations around the site.

4.5 Obstructions

No artificial or natural sub-surface obstructions were noted during construction of the trial holes.

5.0 INSITU AND LABORATORY GEOTECHNICAL TESTING

5.1 In-Situ Geotechnical Testing

Standard Penetration Testing (SPT's) was undertaken at 1.00m intervals in BH1. The results of the SPT's have not been amended to take into account hammer efficiency, rod lengths and overburden pressure in accordance with Eurocode 7. The test results are presented on the trial hole logs within Appendix B.

Windowless and Window Sampler Boreholes provide samples of the ground for assessment but they do not give any engineering data. The standard penetration test (SPT) is an in-situ dynamic penetration test designed to provide information on the geotechnical engineering properties of soil. The test uses a thick-walled sample tube, with an outside diameter of 50 mm and an inside diameter of 35 mm, and a length of around 650mm. This is driven into the ground at the bottom of a borehole by blows from a slide hammer with a weight of 63.5 kg falling through a distance of 760 mm. The sample tube is driven 150 mm into the ground and then the number of blows needed for the tube to penetrate each 150 mm up to a depth of 450 mm is recorded. The sum of the number of blows is termed the "standard penetration resistance" or the "N-value".

The cohesive soils of the London Clay Formation were classified based on the table below.

Undrained Shear Strength from Field Inspection/ SPT "N" Blow Counts Cohesive Soils (EN ISO 14688-2:2004 & Stroud (1974))		
Classification	**Undrained Shear Strength (kPa)**	**Field Indications**
Extremely High	>300	-
Very High	150 – 300	Brittle or very tough
High	75 – 150	Cannot be moulded in the fingers
Medium	40 – 75	Can be moulded in the fingers by strong pressure
Low	20 – 40	Easily moulded in the fingers
Very Low	10 – 20	Exudes between fingers when squeezed in the fist
Extremely Low	<10	-

An interpretation of the in-situ geotechnical testing results is given in the table below.

In-Situ Geotechnical Testing Results Summary					
Strata	**SPT "N" Blow Counts**	**Undrained Shear Strength kPa (Based on Stroud, 1974)**	**Soil Type**		**Trial Hole**
			Cohesive	**Granular**	
London Clay Formation	4 – 32	20 – 160	V Low/Low – V High (Stroud)	-	BH1 (0.60 – 10.45m bgl)

It must be noted that field measurements of undrained shear strength are dependent on a number of variables including disturbance of sample, method of investigation and also the size of specimen or test zone etc.

The test results are presented on the trial hole logs within Appendix B.

5.2 Laboratory Geotechnical Testing

A programme of geotechnical laboratory testing, scheduled by Ground and Water Limited and carried out by K4 Soils Laboratory and QTS Environmental Limited, was undertaken on samples recovered from the London Clay Formation. The results of the tests are presented in Appendix C.

The test procedures used were generally in accordance with the methods described in BS1377:1990.

Details of the specific tests used in each case are given below:

Standard Methodology for Laboratory Geotechnical Testing		
Test	**Standard**	**Number of Tests**
Atterberg Limit Tests	BS1377:1990:Part 2:Clauses 3.2, 4.3 & 5	4
Moisture Content	BS1377:1990:Part 2:Clause 3.2	8
Water Soluble Sulphate & pH	BS1377:1990:Part 3:Clause 5	2
BRE Special Digest 1 (incl. Ph, Electrical Conductivity, Total Sulphate, W/S Sulphate, Total Chlorine, W/S Chlorine, Total Sulphur, Ammonium as NH4, W/S Nitrate, W/S Magnesium)	BRE Special Digest 1 "Concrete in Aggressive Ground (BRE, 2005).	2

5.2.1 Atterberg Limit Tests

A précis of Atterberg Limit Tests undertaken on four samples of the London Clay Formation can be seen tabulated below.

Atterberg Limit Tests Results Summary							
Stratum/Depth	**Moisture Content (%)**	**Passing 425 µm sieve (%)**	**Modified PI (%)**	**Soil Class**	**Consistency Index (Ic)**	**Volume Change Potential**	
						NHBC	**BRE**
London Clay Formation	32 - 38	99 – 100	49.0 – 51.5	CV	Stiff	High	High

NB: NP – Non-plastic
BRE Volume Change Potential refers to BRE Digest 240 (based on Atterberg results)
Soil Classification based on British Soil Classification System.
Consistency Index (Ic) based on BS EN ISO 14688-2:2004.

5.2.2 Comparison of Soil's Moisture Content with Index Properties

5.2.2.1 Liquidity Index Analyses

The results of the Atterberg Limit tests undertaken on four samples of the London Clay Formation were analysed to determine the Liquidity Index of the samples. This gives an indication as to whether the samples recovered showed a moisture deficit and their degree of consolidation. The results are tabulated overpage.

The test results are presented within Appendix C.

Liquidity Index Calculations Summary					
Stratum/Trial Hole/Depth	**Moisture Content (%)**	**Plastic Limit (%)**	**Modified Plasticity Index (%)**	**Liquidity Index**	**Result**
London Clay Formation **BH1/1.50m bgl** (Brown silty CLAY with rare roots)	33	26	49.00	0.14	Heavily Overconsolidated.
London Clay Formation **BH1/3.00m bgl** (Brown and occasional grey silty CLAY with rare fine selenite crystals)	38	30	56.00	0.14	Heavily Overconsolidated
London Clay Formation **WS2/1.00m bgl** (Brown and rare orangish brown silty CLAY with traces of carbonaceous materials and rare fine to coarse sub-angular gravel)	33	26	52.47	0.13	Heavily Overconsolidated.
London Clay Formation **WS2/2.50m bgl** (Brown and rare orangish brown silty CLAY with rare fine mudstone fragments and rare fine gravel)	32	28	51.48	0.08	Heavily Overconsolidated.

Liquidity Index testing revealed no evidence for moisture deficit within the heavily overconsolidated samples of the London Clay Formation tested.

5.2.2.2 Liquid Limit

A comparison of the soil moisture content and the liquid limit can be seen tabulated below.

Moisture Content vs. Liquid Limit				
Strata/Trial Hole/Depth/Soil Description	**Moisture Content (MC) (%)**	**Liquid Limit (LL) (%)**	**40% Liquid Limit (LL)**	**Result**
London Clay Formation **BH1/1.50m bgl** (Brown silty CLAY with rare roots)	33	75	30.0	MC > 0.4 x LL (No significant moisture deficit)
London Clay Formation **BH1/3.00m bgl** (Brown and occasional grey silty CLAY with rare fine selenite crystals)	38	86	34.4	MC > 0.4 x LL (No significant moisture deficit)
London Clay Formation **WS2/1.00m bgl** (Brown and rare orangish brown silty CLAY with traces of carbonaceous materials and rare fine to coarse sub-angular gravel)	33	79	31.6	MC > 0.4 x LL (No significant moisture deficit)
London Clay Formation **WS2/2.50m bgl** (Brown and rare orangish brown silty CLAY with rare fine mudstone fragments and rare fine gravel)	32	80	32.0	MC = 0.4 x LL (No significant moisture deficit)

The results in the table above indicated that the samples of the heavily overconsolidated London Clay Formation tested showed no evidence of a significant moisture deficit.

5.2.4 Moisture Content Profiling

The moisture content versus depth plot for BH1 and BH2 can be seen within Figures 20 and 21 respectively.

Figure 9 shows a possible moisture deficit in BH1 at a depth of ~2.50m bgl due to a lowering of the moisture content of the sample at that depth. Fresh roots were noted to a depth of 1.50m bgl by the supervising engineer and geotechnical classification tests with decayed roots noted at ~3.50m bgl. The strata in the borehole was generally described as brown silty clay with rare fine selenite crystals. Geotechnical analyses has shown the soils to be heavily overconsolidated. Therefore the apparent moisture deficit could be a result of the lithology of the soils rather than the water demand from the roots.

Figure 10 shows a possible moisture deficit in WS2 at a depth of ~2.00m bgl due to a lowering of the moisture content of the sample at that depth. Fresh roots were noted to a depth of 1.00m bgl, with decayed roots noted at ~3.50m bgl by the supervising engineer. The strata in the borehole was generally described as a brown silty clay with fine selenite crystals and sub-rounded flint gravel. Geotechnical analyses has shown the soils were heavily overconsolidated. Therefore, the apparent moisture deficit could be a result of the lithology of the soils (heavily overconsolidated with fine to coarse gravel) rather than the water demand from the roots.

5.2.4 Sulphate and pH Tests

A sulphate and pH test was undertaken on two samples from the London Clay Formation (BH1/1.00m and WS2/2.00m bgl). The sulphate concentration was 280 - 300mg/l with a pH of 8.3.

5.2.5 BRE Special Digest 1

In accordance with BRE Special Digest 1 ‘Concrete in Aggressive Ground’ (BRE, 2005) two samples of the London Clay Formation (WS1/2.50m and WS2/1.50m bgl) were scheduled for laboratory analysis to determine parameters for concrete specification.

The results are given within Appendix C and a summary is tabulated below.

Summary of Results of BRE Special Digest Testing			
Determinand	**Unit**	**Minimum**	**Maximum**
pH	-	7.1	7.2
Ammonium as NH_4	mg/kg	4.9	5.5
Sulphur	mg/kg	<0.02	0.05
Chloride (water soluble)	mg/kg	15	16
Magnesium (water soluble)	mg/l	2.9	16
Nitrate (water soluble)	mg/kg	<3	<3
Sulphate (water soluble)	g/l	0.41	0.41
Sulphate (total)	%	0.04	0.14

6.0 ENGINEERING CONSIDERATIONS

6.1 Soil Characteristics and Geotechnical Parameters

Based on the results of the intrusive investigation and geotechnical laboratory testing the following interpretations have been made with respect to engineering considerations.

- Made Ground was encountered from ground level to 0.90m bgl in WS2, 0.60m bgl in BH1, 0.30m bgl in TP/FE1 and 0.80m bgl in TP/FE2.

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

  Made Ground may be found to deeper depth at other locations on the site, especially close to former structures/foundations and service runs.

- Soils of the London Clay Formation were encountered underlying the Made Ground for the remaining depth of each of the trial holes, a maximum depth of depth of 10.45m bgl in BH1.

  The soils generally comprised a brown silty clay with rare fine selenite crystals for the remaining depth of TP/FE1, a depth of 0.50m bgl, and TP/FE2, a depth of 0.80m bgl, and to a depth of 2.60m bgl and 1.90m bgl in BH1 and WS2 respectively. A band of brown silty clay with fine selenite crystals and sub-rounded flint gravel was noted between 1.90 - 2.20m bgl in WS2. Pockets/veins of grey silt were noted with depth in the boreholes.

  The soils of the London Clay Formation were shown to have a **high** potential for volume change in accordance both BRE240 and NHBC Standards Chapter 4.2.

  The cohesive soils of the London Clay Formation comprised very low/low to very high undrained shear strength (20 - 160kPa in accordance with Stroud (1974)). The undrained shear strength of the soils generally increased with depth.

  Visual appraisal of the soils within WS2 indicated the deposits of the London Clay Formation to be of firm to stiff consistency.

  Consistency Index calculations indicated the London Clay Formation to be stiff. Geotechnical analysis revealed the soils to be heavily overconsolidated with no potentially significant root exacerbated moisture deficits.

  The soils of the London Clay Formation were heavily overconsolidated cohesive soils and are therefore likely to be a suitable stratum for the proposed traditional strip or mat foundations associated with the basement. The settlements induced on loading are likely to be low to moderate.

  The final design of foundations will need to take into account the volume change potential of the soil, the depth of root penetration and/or moisture deficit and the likely serviceability and settlement requirements of the proposed structure. These parameters for design are discussed in the next section of this report.

- Groundwater was not encountered during the intrusive investigation.

  A return visit to monitor the combined bio-gas and groundwater well installed in BH1 was undertaken by a Ground and Water Limited Engineer on the 21st September 2016. Water was noted to be resting at 2.70m bgl in the 5.00m deep well installed and was considered to represent seepages of perched water from within the Made Ground or silt bands of the London Clay Formation accumulating in a standpipe installed within impermeable soils of the London Clay Formation.

- Roots were noted to 1.50m bgl in BH1 and 1.00m bgl in WS2. Decaying roots were noted at 3.50m bgl in both boreholes. The decaying roots were assumed to be relict and therefore unlikely to affect the serviceability of the foundations of the basement.

6.2 Spread and Basement Foundations

At the time of reporting, September 2016, the proposed development was understood to comprise the construction of a single storey rear and side excavation and a basement below the proposed rear extension, extending out below the rear garden. A founding depth of ~4.70m bgl for the basement has been proposed. A Plan View and Section View of the proposed development can be seen in Figure 4 and Figure 5 respectively.

The proposed development fell within Geotechnical Design Category 2 in accordance with Eurocode 7. The proposed foundation loads were not known to Ground and Water Limited at the time of reporting but are likely to range from 75 – 150kN/m^2.

Foundations should be designed in accordance with soils of **high volume change potential** in accordance with BRE Digest 240 and NHBC Chapter 4.2.

Given the cohesive nature of the shallow deposits foundations must therefore **not** be placed within cohesive root penetrated and/or desiccated soils and the influence of the trees surrounding the site must be taken into account (NHBC Standards Chapter 4.2). It is recommended that foundations are taken at least 300mm into non-root penetrated strata or granular soils of no volume change potential.

Where trees are mentioned in the text this means existing trees, recently removed trees (approximately 15 years to full recovery on cohesive soils) and those planned as part of the site landscaping. Should trees be removed from the footprint of the proposed building then an alternative foundation system, such as piles or isolated pads should be considered.

Roots were noted to 1.50m bgl in BH1 and 1.00m bgl in WS2. Decaying roots were noted at 3.50m bgl in both boreholes. The decaying roots were assumed to be relict and therefore unlikely to affect the serviceability of the foundations of the basement. Made Ground was noted to a maximum depth of 0.90m bgl.

Given the above and the depth of roots noted in the boreholes, it was concluded that a minimum founding depth of 1.80m was required for the side extension and the proposed foundation depth of ~4.70m bgl was considered suitable for the proposed basement.

The formation level for the extension must be carefully inspected for the presence of fresh/live roots. Should live roots be noted at formation level then the formation level should be extended at least 300mm into non-root penetrated soils.

It is considered likely the proposed basement will be constructed with load bearing concrete retaining walls with semi-ground bearing concrete floors. The following bearing capacities could be adopted for 5.0m long by 0.75m and 1.0m wide footings, a 1.5m by 1.5m pad constructed at 1.80m bgl and 4.70m bgl.

Limit State: Bearing Capacities Calculated (Based on BH1)		
Depth (m BGL)	Foundation System	Limit Bearing Capacity (kN/m^2) (EC2)
1.80m	5.00m by 0.75m Strip	75.47
	5.00m by 1.00m Strip	77.26
	1.50m by 1.50m Pad	82.27
4.70m	5.00m by 0.75m Strip	282.16
	5.00m by 1.00m Strip	288.65
	1.50m by 1.50m Pad	310.06

Serviceability State: Settlement Parameters Calculated (Based on BH1)			
Depth (m BGL)	Foundation System	Limit Bearing Capacity (kN/m^2)	Settlement (mm)
1.80m	5.00m by 0.75m Strip	75	<12
	5.00m by 1.00m Strip	75	<16
	1.50m by 1.50m Pad	80	<14
4.70m	5.00m by 0.75m Strip	200	<23
	5.00m by 1.00m Strip	190	~25
	1.50m by 1.50m Pad	200	<24

It must be noted that a bearing capacity of less than 75kN/m^2 at 4.70m bgl could result in heave due to a reduction in effective stress at depth. This will need to be taken into account in final design.

Excavations must be kept dry and either concreted or blinded as soon after excavation as possible. If water were allowed to accumulate on the formation for even a short time not only would an increase in heave occur resulting from the soil increasing in volume by taking up water, but also the shear strength and hence the bearing capacity would also be reduced.

Groundwater was not encountered during the intrusive investigation. A return visit to monitor the combined bio-gas and groundwater well installed in BH1 was undertaken by a Ground and Water Limited Engineer on the 21st September 2016. Water was noted to be resting at 2.70m bgl in the 5.00m deep well installed and was considered to represent seepages of perched water from within the Made Ground or silt bands of the London Clay Formation accumulating in a standpipe installed within impermeable soils of the London Clay Formation.

Perched water is therefore likely to be encountered within the Made Ground or/and silty pockets of the London Clay Formation, especially after period of prolonged rainfall. The advice of a reputable dewatering contractor, familiar with the type of ground and groundwater conditions encountered on this site, should be sought prior to finalising the design of the excavation for the basement.

The basement must be suitably tanked to prevent ingress of groundwater and also surface water run-off. The basement must also be designed to take into account pressure exerted by the presence of groundwater in and around the basement.

It must be mentioned that it was assumed that excavations will be kept dry and either concreted or blinded as soon after excavation as possible. If water were allowed to accumulate on the formation for even a short time not only would an increase in heave occur resulting from the soil increasing in volume by taking up water, but also the shear strength and hence the bearing capacity would also be reduced.

If the construction works take place during the winter months, when the groundwater level is expected to be at its higher elevation, perched water could accumulate thus dewatering could be required to facilitate the construction and prevent the base of the excavation blowing before the slab was cast.

General Recommendations for Spread Foundations:

- Foundation excavations must be carefully bottomed out and any loose soil or soft spots removed prior to the foundation concrete or blinding being placed. Failure to ensure that foundation excavations are suitably bottomed out could result in additional settlements.

- Inspection of foundation excavations, prior to concreting, must be made by a competent and suitably qualified person to check for any soft spots and to check for the presence of roots.

- The excavation must be kept dry as accumulation of water could result in increased settlements.

- Foundations must not be cast over foundations of former structures and/or other hard spots.

- Any groundwater or surface water ingress must be prevented from entering foundation trenches.

- Isolated Pad Foundations must be at least 1.5 times the width of the widest pad apart to keep to the anticipated settlements.

- Final designs for the foundations should be carried out by a suitably qualified Engineer based on the findings of this investigation and with reference to the anticipated loadings, serviceability requirements for the structure, volume change potential of the soils encountered and the developments proximity to former, present and proposed trees.

6.3 Piled Foundations

Based on the results of the ground investigation, piled foundations are unlikely to be required at the site.

6.4 Basement Excavations & Stability

Shallow excavations in the Made Ground and the London Clay Formation are likely to be marginally stable at best. Long, deep excavations, through both of these strata are likely to become unstable.

The excavation of the basement must not affect the integrity of the adjacent structures beyond the boundaries. The excavation must be supported by suitably designed retaining walls. It is considered unlikely that battering the sides of the excavation, casting the retaining walls and then backfilling to the rear of the walls would be suitable given the close proximity of the party walls.

The retaining walls for the basement will need to be constructed based on cohesive soils with an appropriate angle of shear resistance (*Φ'*) for the ground conditions encountered.

Based on the ground conditions encountered within the boreholes the following parameters could be used in the design of retaining walls. These have been designed based on the SPT profile recorded, results of geotechnical classification tests and reference to literature.

Retaining Wall/Basement Design Parameters					
Strata	**Unit Volume Weight (kN/m^3)**	**Cohesion Intercept (c') (kPa)**	**Angle of Shearing Resistance (Ø)**	**Ka**	**Kp**
Made Ground	~15	0	12	0.66	1.52
London Clay Formation	~20 - 22	0	20	0.49	2.04

Unsupported earth faces formed during excavation may be liable to collapse without warning and suitable safety precautions should therefore be taken to ensure that such earth faces are adequately supported before excavations are entered by personnel.

Based on the groundwater readings taken during this investigation to date, it was considered likely that significant perched groundwater would be encountered during basement construction. Dewatering from sumps introduced into the floor of the excavation is likely to be required, especially after a period of excessive rainfall. Consideration should be given to creating a coffer dam using contiguous piled or sheet piled walls to aid basement construction below the perched water table. The advice of a reputable dewatering company should be sought.

6.5 Assessment of Ground Movement

An assessment of ground movements has been carried out as follows:

- Movement has been assessed for the neighbouring properties due to the excavation of the basement. The site was surrounded by detached two storey brick built residential properties.
- The northern flank wall of No. 26 Maresfield Gardens at its closest point to the proposed basement was ~4.20m away with its southern flank wall ~18.00m away.
- The southern flank wall of No. 30/32 Maresfield Gardens at its closest point to the proposed basement was ~3.60m away with its northern flank wall ~17.00m away.
- The magnitude of ground movements has been assessed for the excavation in front of the traditional underpinned retaining wall structures.
- It is important to note that CIRIA Report C580 was written for embedded retaining walls. Therefore movement calculations for the excavation of soil and installation of the underpins does not strictly apply to C580.

The following parameters have been used to inform this assessment:

- The maximum excavation depth is approximately 4.70m below the level of the existing

ground floor slab;
- The method of basement construction will be traditional underpinning;
- A high wall stiffness has been assumed;
- In the permanent case the wall will always be propped at high level;
- The width of No. 26 to the south of the subject site is ~13.80m. The width of No. 30/32 to the north of the subject site is ~13.40m.
- Both buildings were estimated to be ~15.0m high.
- Soil comprising a stiff clay has been assumed.

Based on reference to C580 the following ground movements have been developed based on of the excavation of soils to form the basement.

No. 26 Maresfield Gardens:

The total horizontal movement due to the excavation was calculated to be 5.38mm at the nearest wall, reducing to negligible movement at its far end.

The total vertical movement due to the excavation was calculated to be 3.43mm at the nearest wall, reducing to negligible movement at its far end.

No. 30/32 Maresfield Gardens:

The total horizontal movement due to the excavation was calculated to be 5.82mm at the nearest wall, reducing to negligible movement at its far end.

The total vertical movement due to the excavation was calculated to be 3.76mm at the nearest wall, reducing to negligible movement at its far end.

Other issues to note:
- Trees are present close to the proposed structure. Removal of trees and bushes, or their retention and its effect on ground movement has not been accounted for in the calculations.

In terms of building damage assessment and with reference to Table 2.5 of C580 (after Burland et al, 1977), the 'Description of typical damage' given the calculated movements it is likely that the damage assessment will fall into Category 0, 'Negligible'.

There are a number of key points to note in using this assessment:

- Most ground movement will occur during excavation and construction so the adequacy of temporary support will be critical in limiting ground movements;
- The speed of propping and support is key to limiting ground movements;
- Good workmanship will contribute to minimising ground movements;
- The assessment assumes the wall is in competent clay;
- Larger movements will be expected where soft soils are encountered at, above and below formation;
- Ground movement can be minimised by adopting a number of measures, including;
- Ensuring that adequate propping is in place at all times during construction;
- Minimise deterioration of the central soil mass by the use of blinding/covering with a waterproof membrane;

- Installation of the first (stiff) support quickly and early in the construction sequence for each underpin panel;
- Control dewatering to minimise fines removal and drawdown;
- Avoid overbreak.

6.6 Hydrogeological Effects

The proposed development is located on an **Unproductive Strata** relating to the bedrock of the London Clay Formation.

The ground conditions encountered generally comprised a capping of Made Ground over cohesive soils of the London Clay Formation. Based on a visual appraisal of the soils encountered the permeability of the London Clay Formation Beds were likely to be very low to negligible permeability.

Groundwater was not encountered during the intrusive investigation. A return visit to monitor the combined bio-gas and groundwater well installed in BH1 was undertaken by a Ground and Water Limited Engineer on the 21st September 2016. Water was noted to be resting at 2.70m bgl in the 5.00m deep well installed and was considered to represent seepages of perched water from within the Made Ground or silt bands of the London Clay Formation accumulating in a standpipe installed within impermeable soils of the London Clay Formation.

Based on the above it is considered unlikely that the basement will be constructed below the groundwater level. However, significant perched groundwater is likely to be encountered during construction, especially after a period of excessive rainfall.

In relation to the basement, once constructed, the Made Ground will act as a slightly porous medium for water to migrate however additional drainage should be considered as the London Clay Formation will act as a barrier for groundwater migration.

6.7 Sub-Surface Concrete

Sulphate concentrations measured in 2:1 water/soil extracts taken from the London Clay Formation, from both the geotechnical and chemical laboratory testing, fell into Class DS-1 of the BRE Special Digest 1, 2005, *'Concrete in Aggressive Ground'.*

Table C1 of the Digest indicated an ACEC (Aggressive Chemical Environment for Concrete) classification of AC-1s for foundations within the London Clay Formation. For the classification given, the "static" and "natural" case was adopted given the cohesive soils and the residential use of the site.

The sulphate concentration in the samples ranged from 280 - 410mg/l with a pH range of 7.1 - 8.3. The total sulphate concentration recorded was 0.04 - 0.14%.

Concrete to be placed in contact with soil or groundwater must be designed in accordance with the recommendations of Building Research Establishment Special Digest 1, 2005, *'Concrete in Aggressive Ground'* taking into account the pH of the soils.

It is prudent to note that pyrite nodules may be present within the London Clay Formation. Pyrite can oxidise to gypsum and this normally only occurs in the upper weathered layer, but excavation allows faster oxidation and water soluble sulphate values can rapidly increase during construction. Therefore rising sulphate values should be taken into account should ferruginous staining/pyrite nodules be encountered within the London Clay Formation.

6.8 Surface Water Disposal

Soakaways constructed within the cohesive soils of the London Clay Formation are unlikely to prove satisfactory due to negligible to low anticipated infiltration rates. Therefore an alternative method of surface water disposal is required.

Consultation with the Environment Agency must be sought regarding any use that may have an impact on groundwater resources.

The principles of sustainable urban drainage system (SUDS) should be applied to reduce the risk of flooding from surface water ponding and collection associated with the construction of the basement.

6.9 Discovery Strategy

There may be areas of contamination that have not been identified during the course of the intrusive investigation. For example, there may have been underground storage tanks (UST's) not identified during the Ground Investigation for which there is no historical or contemporary evidence.

Such occurrences may be discovered during the demolition and construction phases for the redevelopment of the site.

Groundworkers should be instructed to report to the Site Manager any evidence for such contamination; this may comprise visual indicators, such as fibrous materials within the soil, discolouration, or odours and emission. Upon discovery advice must be taken from a suitably qualified person before proceeding, such that appropriate remedial measures and health and safety protection may be applied.

Should a new source of contamination be suspected or identified then the Local Authority will need to be informed.

6.10 Waste Disposal

The excavation of foundations is likely to produce waste which will require classification and then recycling or removal from site.

Under the Landfill (England and Wales) Regulations 2002 (as amended), prior to disposal all waste must be classified as;

- Inert;
- Non-hazardous, or;
- Hazardous.

The Environment Agency's Hazardous Waste Technical Guidance (WM2) document outlines the methodology for classifying wastes.

Once classification was established the waste can be removed to the appropriately licensed facilities, with some waste requiring pre-treatments prior to disposal.

INERT waste classification should be undertaken to determine if the proposed waste confirms to INERT or NON-HAZARDOUS Waste Acceptable Criteria (WAC).

6.11 Imported Material

Any soil which is to be imported onto the site must undergo chemical analysis to prove that it is suitable for the purpose for which it is intended.

The Topsoil must be fit for purpose and must either be supplied with traceable chemical laboratory test certificates or be tested, either prior to placing (ideally) or after placing, to ensure that the human receptor cannot come into contact with compounds that could be detrimental to human health.

6.12 Duty of Care

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

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

The site should be securely fenced at all times to prevent unauthorised access. Washing facilities should be provided and eating restricted to mess huts.