Card Geotechnics Limited

Providing Ground Solutions

Ironside & Malone Design & Build Limited

9 Arkwright Road, Hampstead, London

Geotechnical Interpretative Report – Revision 1

May, 2012

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EXECUTIVE SUMMARY

Ironside & Malone Design and Build Limited (Ironside) is proposing the redevelopment of 9 Arkwright Road, Camden, London. It is understood that the proposed development will comprise the part-demolition and extension of the existing building with the provision of a new basement.

The site is roughly square and about 0.17 hectares in area. A 19th century building is located in the north-western half of the site with a garden to the rear. An access way extends along the north-eastern site boundary terminating at a small car park at the rear. The site is bound by Arkwright Road to the north-west and residential properties on all other boundaries.

The site remained relatively undeveloped until around 1894 when the current site boundary was established and the western half of the existing building was constructed. Mapping from 1915 shows the completion of the current building on the site.

The ground conditions encountered during the investigation were in general agreement with the published geology. These comprised Made Ground to depths of between 1.6mbgl and 3.7mbgl, over the Claygate Beds and the London Clay Formation. The top of the London Clay was encountered at depths of between 7.1mbgl and 9.4mbgl. Groundwater was recorded at levels of between 86mAOD and 89mAOD.

The proposed formation level for the majority of the new basement structure is 89.35mAOD. At this level shallow foundations would be expected to be founded on the Claygate Beds, with a typical thickness of approximately 4.0m of Claygate Beds over the London Clay Formation. An allowable bearing capacity of 75kPa is recommended for shallow foundation design.

Piled foundations will be required to support the increased loads of the new building. CFA or cased Bored piled methods will be most appropriate to limit noise and vibration impacts. CFA piling is considered preferable as it is less likely to be affected by the presence of potential water bearing sands in the Claygate Beds. It would be prudent to allow for casing in the Claygate Beds during pile construction to limit ground loss local to the piles (flighting) due to water ingress.

Retaining walls should be designed by the temporary works contractor using the parameters set out in Section 5 of this report. Secant piles are recommended for the majority of the retaining walls. It is recommended that they are toed into the London Clay to provide an effective groundwater seal. Care should be taken during construction to limit ground loss local to the piles due to water ingress within the granular, potentially water bearing, Claygate Beds. Ground surface movements due to excavation in front of the wall would typically be expected to be some 0.15% of the total retained height for this type of wall, assuming high support stiffness (high propped wall, top-down construction). A building damage assessment/ground movement analysis may be required to establish acceptable movement limits.

It is understood that traditional underpinning will be required along the southern half of the existing north-eastern building façade due to space constraints inhibiting the construction of a secant pile wall. Assuming a formation level of approximately 89.35mAOD, these foundations are likely to be formed within the Claygate Beds, and an allowable bearing capacity of 75kPa is recommended for design. This may potentially give rise to differential settlement between the different foundation segments and it is recommended that a settlement analysis is undertaken to assess this effect over the long-term.

Typical excavations to achieve the proposed formation level of 89.35mAOD are some 3m to 4m resulting in an unloading of the underlying Claygate Beds of the order of 54kPa to 72kPa during excavation. Under these conditions the amount of heave is likely to be around 30mm to 40mm. The majority of excavations will be within the Claygate Beds and will have to be shored or battered back to stable angles (approximately 30°) to remain stable in the short term.

Recorded standing groundwater levels were within the Claygate Beds and indicated that the basement will generally rest at or above site groundwater level. Excavations will take place within an effectively sealed box and as such there will be a finite volume of groundwater to be removed during excavation. It is proposed to use secant piled retaining walls, which will limit groundwater ingress during construction. Sump-pumping may be required to remove any residual seepage.

Low infiltration rates (10^{-7} to 10^{-8} m/s) have been recorded in the existing rear garden area of the site and relatively higher infiltration rates (10^{-6} m/s) were recorded in the vicinity of the proposed basement (BH01 and BH04). Therefore, soakaways are not considered suitable at this site.

A CBR value of 2% is recommended for roads and pavements founded on the Made Ground and Claygate Beds.

Buried concrete in the Made Ground and Claygate Beds should be designed to Design Sulphate Class DS-2 and ACEC Class AC-2s according to BRE guidance and based on the results of geotechnical sulphate and pH testing on the soils.

The results of ground gas monitoring indicate that the site conforms to Characteristic Situation 1 and NHBC Green. On this basis no specific gas protection measures are considered necessary.

1. INTRODUCTION

Ironside & Malone Design and Build Limited (Ironside) is proposing the redevelopment of 9 Arkwright Road, Camden, London. It is understood that the proposed development will comprise the part-demolition and extension of the existing building. A new basement will be constructed under the south-eastern corner of the proposed building footprint and in the eastern quadrant of the site, under the existing car parking area and rear garden.

Card Geotechnics Limited (CGL) has been commissioned by Adair Associates on behalf of Ironside to undertake a desk based study and Phase 2 geotechnical intrusive investigation.

The objectives of the investigation are to;

- Provide information on the ground conditions;
- Confirm the presence and extent of existing foundations;
- Provide geotechnical recommendations for foundation, retaining wall, pavement, drainage and concrete design.

This report discusses the work undertaken and presents information that may be used in the planning, design and construction of the development. This document does not address the geoenvironmental aspects of the project, which have been discussed previously in CGL's *Geoenvironmental and Flood Risk Interpretative Report*[1].

[1] Card Geotechnics Limited. September 2011. *Arkwright Road, Hampstead London: Geoenvironmental and Flood Risk Interpretative Report*. Reference CG/5595

2. SITE CONTEXT

2.1 Site location

The site is located on 9 Arkwright Road, Camden, London, and is currently occupied by a large 19th century house, previously converted into offices. The approximate National Grid Reference for the centre of the site is 526421, 185320. A Site location plan is presented in Figure 1.

2.2 Site description

The site is roughly square in shape and covers an area of approximately 0.17 hectares. The 19th century building is located in the north-western half of the site and comprises two buildings with a link in the middle. A small grassed slope extends across much of the north-western site boundary, between Arkwright Road and the front façade of the existing building. The area between this soft landscaping and the façade is covered with paving stones with light wells, which extend to the level of the ground floor (at approximately 93mAOD). Additional light wells are located on the north-eastern façade of the property. A basement boiler room is located in the northern corner of the existing building and is accessible via a stairwell in the northern corner of the site.

An access road adjoining Arkwright Road (at an elevation of around 96mAOD) slopes down towards the south-east on the north-eastern site boundary. This access road terminates at a relatively flat area of hardstanding, currently used as a small car park, at an elevation of approximately 94mAOD, which occupies around half of the eastern quadrant of the site.

The rear garden of the property is situated in the remaining area of the eastern and southern quadrants. This area comprises soft landscaping with turf and several trees, including young to mature cypress, sycamore and birch species. Full details of vegetation and trees on the site are provided separately in a Arboriculture Impact Assessment Report produced by Landmark Trees. The area between the garden and the rear of the existing building is currently covered with slab paving and tarmac hardstanding.

The site is bound by Arkwright Road to the north-west and residential properties to the north-east, south-west and south-east.

The current site layout is presented in Figure 2.

2.3 Proposed development

It is understood that the proposed development consists of the part demolition and reconfiguration of the rear façade of the current building. The garden level is to be extended to the south-east to occupy the patio area of the existing rear garden. A new basement is proposed under the south-eastern corner of the proposed footprint and will extend under the current parking area and rear garden. The proposed basement level is approximately 89.35mAOD. The existing access road will remain relatively unchanged.

The proposed development plans are included in Appendix A.

2.4 Ground and groundwater conditions

2.4.1 Published geology

According to British Geological Map Sheet 256[2], the site lies on the Claygate Member over London Clay Formation. A nominal layer of Made Ground is anticipated across the site, given the lack of historic development.

The Claygate Member[3] is the top part of the London Clay Formation and generally consists of a repetitive sequence of low to very high plasticity, overconsolidated, fissured, firm to very stiff, silty clays, silts and medium dense to dense, fine sands. The clay beds are subject to shrinkability and this is further compounded by the more permeable sandy beds, which act as conduits for the movement of moisture in and out of the clay units. The response of moisture content to seasonal changes may therefore be more pronounced and occur more rapidly. In its weathered state, the clays are brown in colour, but in general show little difference in behaviour compared to the unweathered material. According to the BGS geological map[2], the Claygate Member can be up to 10m to 20m thick in the area of the site. However, given the location of the site in relation to the lateral extent of these deposits, the Claygate Member is more likely to be in the region of 5m thick over the site.

The London Clay Formation[3] is an overconsolidated, firm to very stiff, fissured, silty clay of low to very high plasticity. The clay is susceptible to shrinkage and swelling under the effects of seasonal change in moisture content and tree growth or removal. In its weathered state the clay becomes brown in colour and is accompanied by an increase in

[2] British Geological Survey. (1993). *North London.* England and Wales Sheet 258. 1:50,000 Series. Solid and Drift Geology, Sheet 258.
[3] British Geological Survey. (1997. *The Engineering Geology of the London Area*. Technical Report: WN/97/27.

moisture content. In dry periods, a superficial desiccation zone may form, reversing the moisture content and strength profile. Weathering may be present to a depth of up to 5m to 10m below the surface of the formation. The BGS geology map indicates the base is at approximately -10mOD to -20mOD, with a thickness[2] of about 80m to 90m.

2.4.2 Unpublished geology

British Geological Survey (BGS) borehole records were obtained to confirm the published geology in the area of the site. The records are located at either end of Arkwright Road, approximately 180m to the north-east (BH reference TQ28NE44) and around 500m the south-west (TQ28NE129 & TQ28NE130) of the site. The ground conditions encountered generally confirmed the published geology, with the Claygate Beds overlying the London Clay Formation.

The BGS borehole records are presented in Appendix B.

2.5 Hydrology and hydrogeology

The Environment Agency has produced an aquifer designation system consistent with the requirements of the Water Framework Directive. The designations have been set for superficial and bedrock geology, and are based on the importance of aquifers for potable water supply and their role in supporting surface water bodies and wetland ecosystems.

With reference to the Environment Agency website[4], the bedrock geology (Claygate Beds) has been classified as a Secondary A aquifer. These are permeable layers capable of supporting water supplies at a local rather than strategic scale and in some cases forming an important source of base flow for rivers. The underlying London Clay Formation is classified as an unproductive stratum. These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow. No superficial deposits are located on the site.

The site does not lie within a Groundwater Source Protection Zone. The nearest surface water body to the site has been identified between 51-250m of the site boundary. Although this is not evident from the mapping within the environmental disclosure report, it is understood to relate to a tributary of the Westbourne at a level of approximately 70mAOD. The River Thames is located some 6km to the south-east of the site.

[4] http://maps.environment-agency.gov.uk

The site is not located within 250m any Environment Agency indicative Zone 2 or 3 floodplains. With reference to the Environment Agency website[5], the site is significantly outside the area susceptible to flooding from rivers or sea without defences and the extent of extreme flooding.

2.5.1 Radon gas

A radon risk report was obtained from *UKradon* for the site in order to assess the risks posed by radon gas on existing properties and new buildings. Based on this report, and with reference to BRE and HPA guidance on radon protection, the site is situated in an area where less than 1% of homes are at or above the action level for radon. On this basis, no radon protection measures are considered necessary. The radon risk report is included in Appendix C.

http://maps.environment-agency.gov.uk/wiyby/

3. PRESENT GROUND INVESTIGATION

3.1 Fieldwork

An intrusive investigation was undertaken between 25th July 2011 and 2nd August 2011. The investigation comprised the excavation of two machine dug trial pits (TP01 to TP02), four cable percussion boreholes (BH01 to BH04) and fifteen foundation inspection pits (FIP01 to FIP15).

The cable percussion boreholes were excavated to a depth of between 10mbgl to 25mbgl with in-site testing (SPTs) and undisturbed sample (U100s) recovery. Groundwater and soil gas monitoring standpipes were installed in each borehole.

In order to obtain samples for laboratory chemical testing and to fully characterise the near surface ground conditions across the site, the trial pit and borehole arisings were recorded and representatively sampled by an suitably qualified engineer from CGL.

Service drawings were provided prior to the intrusive investigation and each exploratory hole location was surveyed by a specialist service location contractor and was also scanned with a cable avoidance tool (CAT) prior to the works commencing.

The locations of all the exploratory holes are indicated in Figure 2 and copies of the exploratory hole records and photographic sheets are provided in Appendix D and E, respectively.

The investigation was undertaken generally in accordance with the requirements of current UK guidance including BS 5930:1999[6] (incl. amendment 2) and BS 10175:2001[7].

3.2 Laboratory testing

3.2.1 Chemical

Representative soil and groundwater samples were sent to i2 Analytical Limited (a UKAS and MCERTS accredited laboratory) for chemical testing. The results of analyses, which included the following potential contaminants, are included in Appendix F. These have

[6] British Standards Institution. (1999). *Code of practice for site investigations*. BS5930:1999.
[7] British Standards Institution. (2001). *Investigation of potentially contaminated sites: Code of practice.* BS10175:2001.

been assessed and discussed in the previous geoenvironmental interpretative report and are not considered further in this report.

- Soil Organic Matter (SOM);
- Heavy metals including; arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc;
- Benzene, Toluene, Ethylbenzene, Xylenes (BTEX) compounds;
- Total Petroleum Hydrocarbons (TPH) and Polycyclic Aromatic Hydrocarbons (PAH);
- Total Monohydric Phenols;
- Total cyanide,
- Sulfate; and
- pH determination.

Results and interpretation are reported separately in the companion report on geo-environmental issues.

3.2.2 Geotechnical

Selected representative soil samples were sent to the laboratories of K4 Soils to undergo the following testing and the full results are presented in Appendix G:

- Moisture content and Atterberg limits;
- Sulphate testing to BRE SD1;
- Bulk and dry density;
- Particle size distribution by sieving and sedimentation;
- Quick undrained triaxial;

3.3 Monitoring

Groundwater level and soil gas monitoring visits were undertaken on three separate occasions between 1st September and 15th September 2011. Groundwater sampling was undertaken on 7th September 2011. Copies of the monitoring records are presented in Appendix H.

Rising head tests were undertaken within the standpipes in each borehole position on 7th September 2011 and the records are presented in Appendix I.

4. GROUND AND GROUNDWATER CONDITIONS

4.1 Summary

The ground conditions encountered during the intrusive investigation generally confirmed those expected from the desk study and are summarised in Table 1 below.

Table 1. Summary of ground conditions.

Strata	Depth encountered (mbgl)	Thickness (m)
[MADE GROUND] Medium dense light brown gravelly sand and sandy gravel, and soft to firm brownish grey gravelly very sandy clay and silt. Gravel is typically fine to coarse rounded to angular of brick and flint.	0.0	1.6 to 3.7
Loose to medium dense ochreous brown slightly clayey very silty fine SAND & firm light ochreous brown clayey very sandy SILT and CLAY. [CLAYGATE BEDS]	1.6 to 3.7	3.4 to 7.8
Firm, becoming very stiff with depth, dark grey sandy silty CLAY with occasional sand partings. [LONDON CLAY]	7.1 to 9.4	Proven to 25m bgl

4.2 Made Ground

Made Ground was encountered within each exploratory hole below hardstanding or topsoil, with thicknesses ranging between 1.6m to 3.7m. The Made Ground was encountered at its maximum thickness in BH02 (2.6m) and BH03 (3.7m) within the rear garden area of the site. Given the site and surrounding topography slopes towards the south-east, it is likely that this Made Ground is associated with site level make up.

The Made Ground generally comprised sands, clays and silts with variable proportions of minor constituents including sand, clay and gravel. The gravel was typically fine to coarse, rounded to angular of brick and flint.

No visual or olfactory evidence of contamination was noted in the boreholes or trial pits. However, ashy material was noted in the shallow Made Ground beneath hardstanding within the foundation inspection pits.

SPT ‘N’ values in the Made Ground were typically in the range of 6 to 9, corresponding to a relative density of ‘loose’ or consistencies of ‘soft’ to ‘firm’ (Cu of 30kPa to 45kPa based on f_1 = 5[8]). Plots of SPT ‘N’ values and Cu versus level are presented in Figures 3 and 4, respectively.

Based on a typical design SPT ‘N’ value of 7, a design angle of friction of 29°[9] and Cu of 35kPa is recommended for the granular and cohesive elements of the Made Ground, respectively.

4.3 Claygate Beds

The Claygate Beds were encountered at typical depths of between 1.6mbgl and 3.7mbgl. As previously discussed, the Made Ground/Claygate Beds interface was found to be at greater depths within the soft landscaped area in the south-west quadrant of the site, increasing in depth towards the centre and south of the site (boreholes BH02 and BH03). This is considered to be representative of the erosional surface at the top of the Claygate Beds (i.e. natural ground level before re-profiling of the site), given the topography of the surrounding area.

The Claygate Beds generally comprised a combination of granular and cohesive horizons. The granular horizons were found to occasionally grade into cohesive material, however clear definition between these deposits has not been possible.

The granular horizons of the Claygate Beds generally comprised loose to medium dense, ochreous, brown, slightly clayey, very silty, fine SAND. These horizons were encountered in BH01 between 3.4mbgl and 9.3mbgl, in BH02 between 3.4mbgl and 5.3mbgl and in BH04 between 4.4mbgl and 9.4mbgl, but were generally absent in BH03. The material was noted to occasionally grade into very clayey, sandy SILT in BH01 between 3.4mbgl and 9.3mbgl. A relatively thin horizon of slightly silty, slightly sandy gravel was noted between 3.7mbgl and 4.8mbgl in BH03.

[8] Stroud, M.A. (1975*).* The standard penetration test in insensitive clays and soft rocks. *Proceedings of the European Symposium on Penetration Testing in the UK*, **2**, 367-375.
[9] Peck et al. (1967). *Foundation Engineering*. 2nd Edition, John Wiley, New York.

The cohesive horizons of the Claygate Beds generally comprised firm, light ochreous brown, clayey, very sandy, SILT and CLAY and was mottled grey where encountered at greater depths. This material was encountered at the following depths in the following boreholes:

- BH01, 2.9mbgl to 3.4mbgl,
- BH02, 2.6mbgl to 3.4mbgl, and 5.3mbgl to 7.8mbgl,
- BH03, 4.8mbgl to 7.1mbgl, and
- BH04, 3.0mbgl to 4.4mbgl.

Moisture content and Atterberg limit testing within the cohesive horizons of the Claygate Beds recorded moisture contents in the range of 14% to 29%, Liquid Limits of between 32% and 45%, and Plastic Limits of between 17% and 24%. Plasticity indices were in the range of 8% to 25% corresponding to a clay of 'low' to 'intermediate' plasticity and silt of 'low plasticity'[6]. On this basis the cohesive elements of the Claygate Beds have a low to medium volume change potential[10].

SPT 'N' values in the Claygate Beds were typically in the range of 6 to 15, corresponding to relative densities of 'loose to 'medium dense' or consistencies of 'soft' to 'firm' (Cu of 30kPa to 75kPa based on f_1 = 5[8]). A SPT 'N' value of 21 was recorded in BH03 at 6mbgl, which is outside of the typically range recorded in the formation. Plots of SPT 'N' values and Cu versus level are presented in Figures 3 and 4, respectively.

Based on a typical design SPT 'N' value of 7, a design angle of friction of 29°[9] and Cu of 35kPa is recommended for the granular and cohesive elements of the Claygate Beds, respectively.

4.4 London Clay Formation

The top of the London Clay Formation was encountered below the Claygate Beds at depths of between 7.1mbgl and 9.4mbgl and was proven to a depth of 25mbgl in BH01. The material generally comprised firm, becoming stiff with depth, dark grey sandy, silty clay with occasional sand partings.

[10] NHBC. (2007). *NHBC Standards*.

A cemented claystone was encountered at a depth of 13.6mbgl in borehole BH02 and is reflected in a very high SPT 'N' value in this location.

Moisture contents within the London Clay were recorded in the range of 26% to 31%.

SPT 'N' values within the London Clay were generally found to increase with depth from a typical value of 12 at the top of the stratum to 40 at the base corresponding to an undrained shear strength (Cu) in the order of 54kPa to 180kPa, or 'firm' to 'very stiff' (based on f_1 = 4.5[8]). These values are consistent with the results of quick undrained triaxial (QUU) testing, which recorded undrained shear strength (Cu values) in the range of 58kPa to 81kPa, generally increasing with depth.

The Cu value of 58kPa was recorded from borehole BH02 at a depth of 12mbgl. This value is consistent with the generally increasing shear strength of the London Clay with depth in BH02. Plots of SPT 'N' values and Cu versus level are presented in Figures 3 and 4, respectively.

Based on established correlations for the London Clay[11] and undrained triaxial testing, the following design shear strength is recommended for the London Clay:

Cu = 45 + 10z (kPa)

Where z = depth below the top of the London Clay stratum.

4.5 Groundwater

Groundwater levels were recorded in the monitoring standpipes in the boreholes between 1st and 15th September 2011 and are summarised in Table 2 below. Groundwater strikes were encountered during the investigation at depths of between 9.2mbgl (84.8mAOD) and 13.7mbgl (81mAOD). Groundwater seepage and slightly wet to wet material was recorded at depths of between 3.4mbgl (89.4mAOD) and 9.6mbgl (83.2mAOD).

Standing groundwater levels were recorded within the Claygate Beds at elevations of between 89.07mAOD to 89.36mAOD across much of the site (BH01, BH02 and BH04) and at 86.70mAOD (BH03) in the southern corner of the site. Given the topography of the site and surrounding area, which dips towards the south, the lower groundwater level

[11] Stroud, M.A., The standard penetration test in insensitive clays and soft rocks. *Proceedings of the European Symposium on Penetration Testing,* **2,** 367-375 (1975).

recorded in BH03 is likely to represent the generally southerly slope of the phreatic surface.

Rising head tests were undertaken in each borehole on 7th September 2011 and recorded infiltration rates of the order of 10^{-6} to 10^{-8} m/s, with the lower infiltration rates recorded in BH02 and BH03, which are both positioned in the rear garden of the property.

Table 2. Summary of groundwater monitoring.

Exploratory hole number	Groundwater level (approx. mAOD) [Depth bgl]		
	1st September 2011	7th September 2011	15th September 2011
BH01	89.19 [4.82mbgl]	89.22 [4.78mbgl]	89.17 [4.83mbgl]
BH02	89.07 [3.73mbgl]	89.41 [3.39mbgl]	89.09 [3.71mbgl]
BH03	86.74 [5.56mbgl]	86.70 [5.60mbgl]	86.70 [5.60mbgl]
BH04	89.34 [5.36mbgl]	89.36 [5.34mbgl]	89.20 [5.50mbgl]

4.6 Foundation inspection pits

Fifteen foundation inspection pits have been excavated to investigate the foundations of the existing building and the north-eastern and south-western site boundary walls. Records and photographs are included in Appendix D and E respectively.

North-western façade

Along the north-western building façade the walls are generally shown to be founded at depths of between 1.23mbgl and 2.63mbgl (90.43mAOD to 91.97mAOD). The foundations exposed in each of these pits (FIP01, FIP02 and FIP13) comprised corbelled brick over concrete stepping out a total of between 0.22m and 0.49m. The foundation inspection pits (FIP03 and FIP04) located in the vicinity of the existing boiler basement in the north-eastern corner of the existing building did not encounter the base of this structure.

North-eastern façade

Two inspection pits were located along the north-eastern façade (FIP04 and FIP05). FIP04 was located at the bottom of the stairs leading to the existing basement boiler room. A significant amount of concrete was encountered in this location, and the formation level was not encountered. The inspection pit was noted to fill with water, although a source was not determined. FIP05 was located in a light well towards the south-east corner of the existing building. The foundations exposed comprised corbelled brick over concrete founded at a depth of approximately 2.63mbgl (90.83mAOD) and stepped out a total of 0.42m.

South-eastern façade

Along the south-eastern building façade the walls are shown to be founded at depths of between 1.15mbgl to 2.13mbgl (91.39mAOD to 92.05mAOD). The foundations exposed in each of these pits (FIP06 to FIP08) comprised corbelled brick over concrete stepping out a total of between 0.15m to 0.7m.

South-western façade

The foundations along the south-western façade were found to comprise corbelled brick over mass concrete, founded at between 1.14mbgl to 1.15mbgl (approximately 92.2mAOD), stepping out a total of between 0.34m and 0.41m .

South-western boundary wall

The base of the south-western boundary wall (FIP10 and FIP12) was encountered at depths of between 1.0mbgl and 1.3mbgl (approximately 91.9mAOD to 92.43mAOD) and comprised corbelled brick over mass concrete stepping out between 0.14m and 0.2m.

North-eastern boundary wall

The north-eastern boundary wall (FIP14 and FIP15) was founded at depths of between 0.5mbgl and 0.98mbgl (approximately 94.5mAOD and 93.16mAOD) and comprised corbelled brick over mass concrete in FIP15. The corbelled brick was absent in FIP14.

4.7 Soil gas

Soil gas concentrations and flow rates were recorded from the monitoring standpipes in the boreholes between 1st and 15th September 2011. The results indicate that there are negligible concentrations of methane in the ground and concentrations of carbon dioxide are consistent with natural soils with low organic content or ‘typical’ made ground. Oxygen levels are generally normal, or slightly depressed where measureable concentrations of carbon dioxide were present. A maximum flow rate of 0.5 l/h was recorded. Full records of soil gas monitoring are included as Appendix H and a summary of the soil gas monitoring is presented in Table 3.

Table 3. Summary of soil borne gas monitoring.

	Ranges of Recorded Values from All Boreholes			
Date	**CH_4 (% Vol.)**	**CO_2 (% Vol.)**	**Oxygen (min % by vol)**	**Flow (l/hr)**
1st September 2011	0.0	0.0 to 3.3	14.7	-0.1 to 0.1
7th September 2011	0.0	0.1 to 4.2	13.4	-0.4 to 0.5
15th September 2011	0.0	0.0 to 2.4	16.8	-0.4 to 0.0

The results of the monitoring from across the site have been converted into Gas Screening Values (GSV) in accordance with CIRIA Report C665[12]. The calculated GSV for carbon dioxide of 0.021 l/hr indicates that the site conforms to Characteristic Situation 1 and NHBC Green.

[12] Wilson, S. et al. (2007). *Assessing the risks posed by hazardous ground gases to buildings.* C665. CIRIA.

5. GEOTECHNICAL DESIGN PARAMATERS

Geotechnical design parameters for the proposed development are summarised in Table 4 below, these are based on the results of SPT testing and published data for the well-studied London Geology.

Table 4: Geotechnical design parameters.

Stratum	Design Level (mOD)	Bulk Unit Weight γ_b (kN/m^3)	Undrained Cohesion c_u (kPa) [c']	Friction Angle ϕ' (°)	Young's Modulus E_u (MPa) [E']
Made Ground (Cohesive)	92.3 to 94.73	18	25 [0]	25[a]	12.5[d] [9.4][e]
Made Ground (Granular)		18	-	29[b]	[9.4]
Claygate Beds (cohesive)	88.6 to 93.13	18	35	29[b]	17.5[d] [13][e]
Claygate Beds (granular)		18	-	29[b]	[13]
London Clay	84.2 to 85.33	20	45 + 10z[c] [5]	22[a]	22.5 + 4.8z[d] [16.9 + 3.6z][e]

a. BS 8002:1994 Code of practice for Earth retaining structures, British Standards institution.
b. Peck, R.B., Hanson, W.E., and Thornburn, T.H., Foundation Engineering, 2nd Edn, John Wiley, New York, 1967, p.310.
c. z = depth below surface of the London Clay
d. Based on 500 Cu
e. Based on 0.75Eu

The parameters in Table 3 are unfactored 'moderately conservative' design values.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Proposed development

It is understood that the proposed development will comprise the part-demolition and extension of the existing building with the provision of a new basement under the south-eastern corner of the proposed building footprint and in the south-eastern quadrant of the site, under the existing car parking area and rear garden. The front and side façades are to be retained from garden level with the rear façade retained for the two main parts of the existing building, excluding the link, from ground level. The internal walls and floors of the existing structure will be removed and replaced with a reinforced concrete frame.

The proposed structure will be significantly heavier than the existing building and it is proposed that the increased loads will be supported by pile foundations. The existing façades may also be tied to the new foundations to limit differential settlement.

6.2 Foundations

The proposed formation level for the majority of the new structure is 89.35mAOD. At this level shallow foundations would be expected to be founded on the Claygate Beds, with a typical thickness of approximately 4.0m of Claygate Beds over the London Clay Formation.

No significant increase in shear strength with depth has been identified within the Claygate Beds, and on this basis an allowable bearing capacity at formation level of 75kPa is recommended for shallow foundation design. Given the proposed loads will likely apply pressures greater than the allowable bearing capacity, piled foundations are likely to be required to transfer the loads to the underlying London Clay Formation.

Given the urban nature of the site it is likely that CFA or cased bored piled methods will be appropriate to limit disturbance to neighbours. CFA piling is considered preferable as it is less likely to be affected by the presence of potential water bearing sands in the Claygate Beds, although it would be prudent to allow for casing in the Claygate Beds during pile construction to limit ground loss local to the piles (flighting) due to water ingress.

Preliminary pile working loads are presented in Figure 5 based on CFA piles with an adhesion value of 0.5 within the London Clay and a factor of safety of 2.6 as recommended in current LDSA guidance[13]. This assumes that no pile testing is undertaken. It should be noted that this factor of safety can be reduced to 2.2 on completion of a representative number (1% of total number of piles) of working load tests and to 2.0 on completion of working load tests and preliminary pile tests.

6.3 Retaining walls

Retaining walls should be designed by the temporary works contractor using the parameters set out in Section 5 of this report.

Secant piles are recommended for the majority of the retaining walls for the construction of the proposed basement. It is recommended that they are toed into the London Clay to provide an effective groundwater seal. Care should be taken during construction to limit ground loss local to the piles (flighting) due to water ingress within the granular, potentially water bearing, Claygate Beds.

It is understood that the majority of the proposed superstructure load will be on dedicated foundation piles and there will be minimal loading of the retaining walls. However, it is recommended that additional analysis should be undertaken should significant loading of the retaining walls be required.

There are existing structures along each of the proposed basement walls that may be sensitive to ground movements. Ground surface movements due to excavation in front of the wall would typically be expected to be some 0.15% of the total retained height[14] for this type of wall, assuming high support stiffness (high propped wall, top-down construction). A building damage assessment/ground movement analysis may be required to establish acceptable movement limits.

It is understood that traditional underpinning will be required along the southern half of the existing north-eastern building façade due to space constraints, associated with the swimming pool within the basement, inhibiting the construction of a secant pile wall. Assuming a formation level of approximately 89.35mAOD, these foundations are likely to be formed within the Claygate Beds, and an allowable bearing capacity of 75kPa is recommended for design. This may potentially give rise to differential settlement between

[13] London District Surveyor's Association. 2009. Foundations, No.1 Guidance Notes for the Design of Straight Shafted Bored Piles in London Clay. LDSA publications

[14] CIRIA. 2003. *Embedded retaining walls – guidance for economic design*. CIRIA C580.

the different foundation segments and it is recommended that a settlement analysis is undertaken to assess this effect over the long-term.

6.4 Excavations

Typical excavations to achieve the proposed formation level of 89.35mAOD are between around 3m to 4m resulting in an unloading of the underlying Claygate Beds of the order of 54kPa to 72kPa during excavation. Under these conditions the amount of heave is likely to be around 30mm to 40mm[15, 16].

Excavations will take place within an effectively sealed box and as such there will be a finite volume of groundwater to be removed during excavation. It is proposed to use secant piled retaining walls, which will limit groundwater ingress during construction. Sump-pumping may be required to remove any residual seepage.

The majority of excavations will be within the Claygate Beds and will have to be shored with trench sheets/boxes or battered back to stable angles (approximately 30°) to remain stable in the short term.

6.5 Groundwater

Standing groundwater levels were recorded at elevations of between 86.7mAOD and 89.36mAOD within the Claygate Beds indicating that the basement will generally rest at or above site groundwater level. Although it is considered that the proposed basement will not form an obstruction to regional flow due to the size of the basement being considered, control of groundwater migration into basement excavations is likely to be required during the construction phase of the works, although this will be subject to seasonal variation in groundwater levels.

The sealed basement box approach limits the volume of groundwater likely to be encountered. Should the groundwater not be entirely removed from the box then an alternative drainage strategy – possibly local sumps and drainage – will be required.

[15] Newmark, N.M. (1935). *Simplified computations of vertical pressure in elastic foundations*. University of Illinois Engineering Experiment Station Bulletin No. 429.
[16] Terzaghi, K. & Peck, R. B. (1967). *Soils Mechanics in Engineering Practice*, 3rd Edition, John Wiley, New York.

6.6 Drainage

Rising head tests indicate infiltration rates in the Claygate Beds of the order of 1 x 10^{-6} to 1 x 10^{-8} m/s, with the lower infiltration rates recorded in BH02 and BH03 which are both positioned in the rear garden of the property. Given that relatively higher infiltration rates were recorded in areas in the vicinity of the proposed basement (BH01 and BH04) and that low infiltration rates have been recorded elsewhere on site, soakaways are not considered suitable for the proposed development. Instead, active drainage will be required.

6.7 Pavement design

Given the vertical extent of the Made Ground recorded on the site, particularly in areas likely to be developed (i.e. the rear garden of the existing property), proposed roads and pavements will likely be founded on this material. On this basis, a CBR value of 2% is recommended for roads and pavements founded on the Made Ground or Claygate Beds.

6.8 Concrete design

Buried concrete in the Made Ground and Claygate Beds should be designed to Design Sulphate Class DS-2 and ACEC Class AC-2s according to BRE guidance and based on the results of geotechnical sulphate and pH testing on the soils.

6.9 Gas protection measures

The maximum GSV calculated for the site (carbon dioxide at 0.021 l/hr) based on results of ground gas monitoring indicate that the site generally conforms to Characteristic Situation 1 and NHBC Green in accordance with current guidance. On this basis no specific gas protection measures are considered necessary.

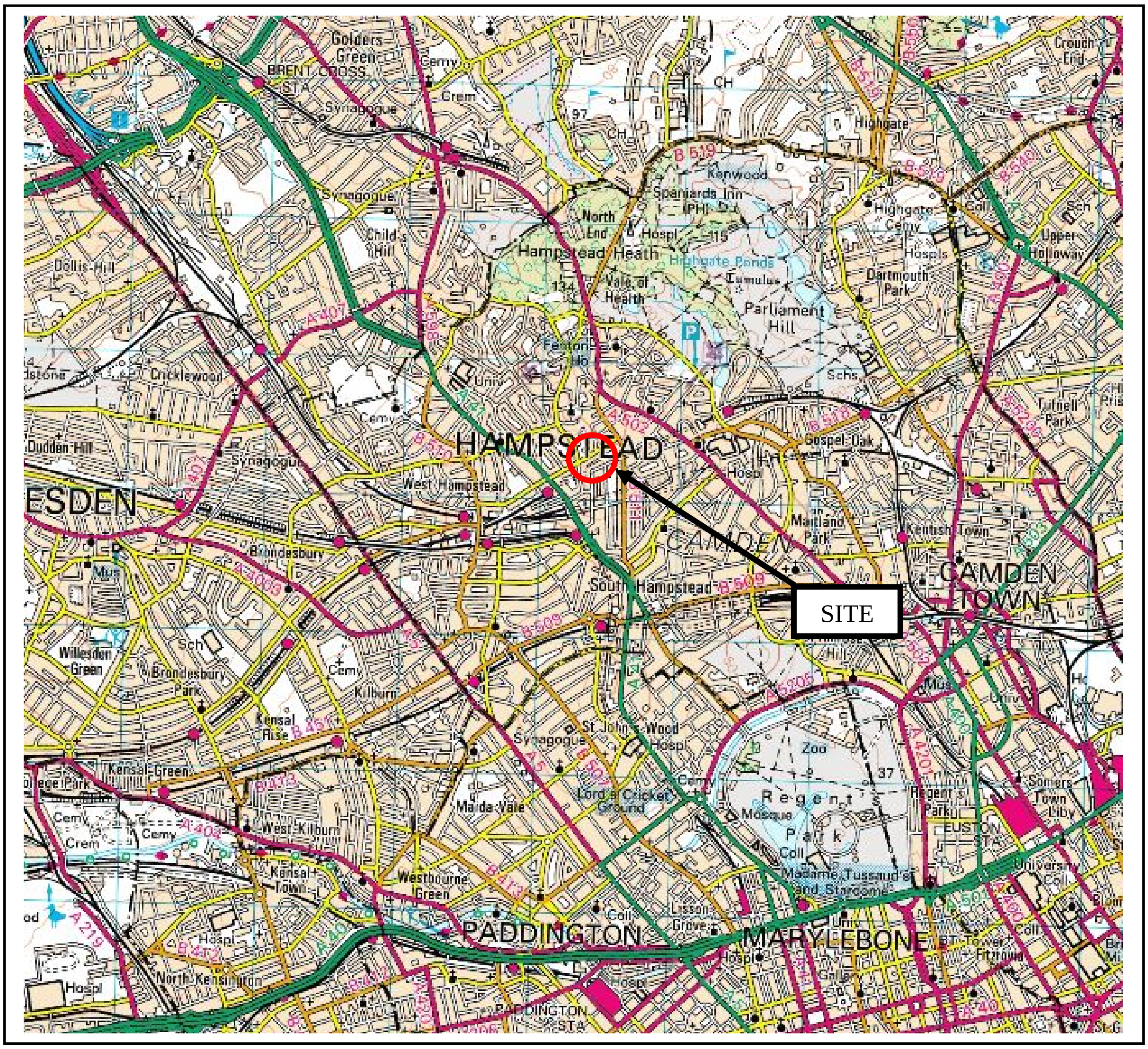
6.10 Health and safety

All site works should be undertaken in accordance with the guidelines prepared by the Health and Safety Executive (HSE, 1991). In this context, the risks should be negligible to low and nominal safety precautions should be acceptable (the adoption of good hygiene practices and the use of overalls, gloves and dust masks if necessary).

During the redevelopment, precautions should be taken to minimise exposure of workers and the general public to potentially harmful substances. Attention should also be paid to restricting possible off-site nuisance such as dust and odour emissions. Such precautions should include, but not be limited to:

- Personal hygiene, washing and changing procedures.
- Personal protective equipment, including disposable overalls, gloves etc.
- Measures to avoid surface water ponding and positive collection and disposal of all on-site run-off.
- Regular cleaning of all site roads, access roads and the public highway including dust suppressions methods (e.g. water spraying), if necessary.

FIGURES



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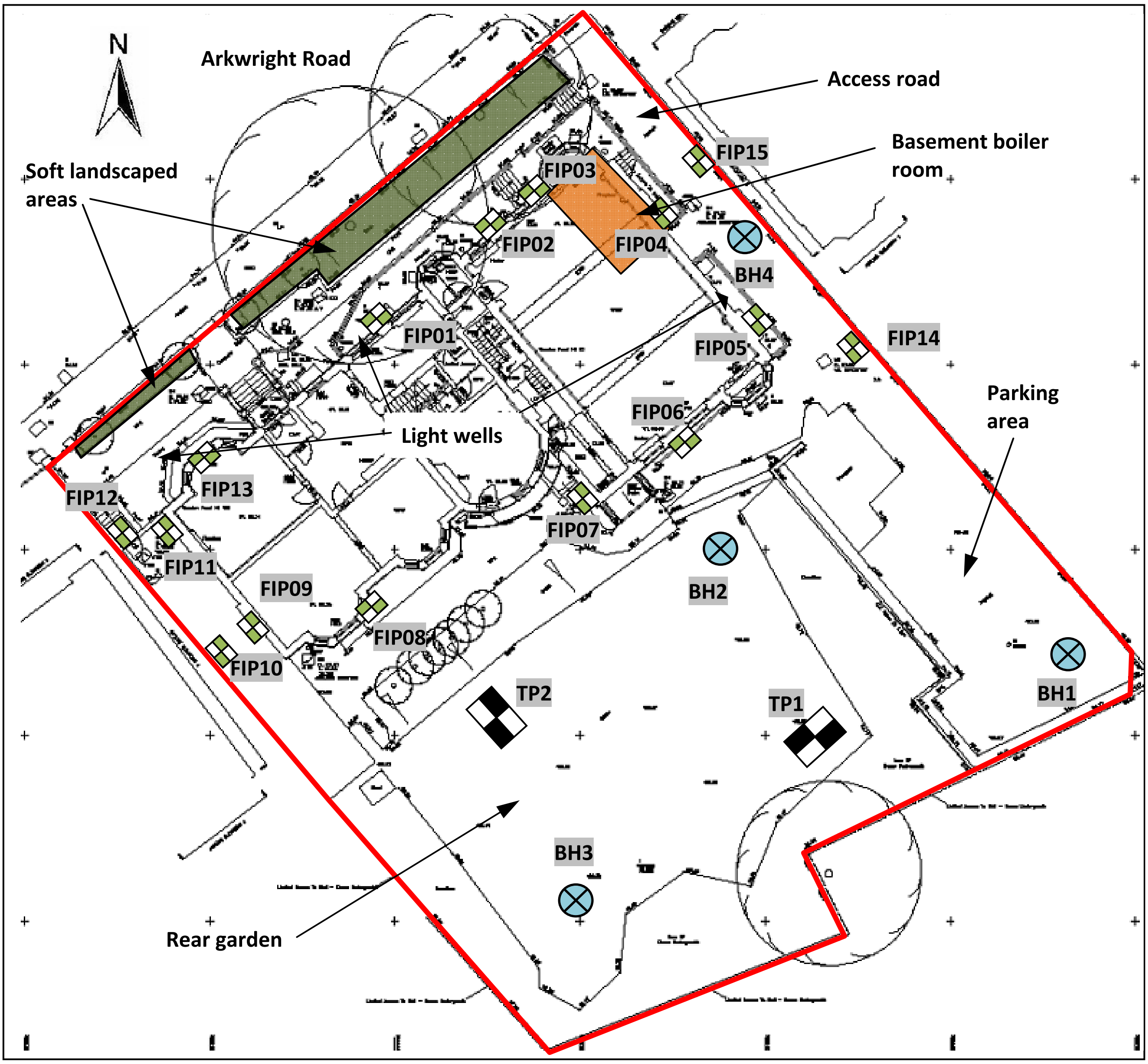
Client	Project	Job No
Ironside & Malone Design & Build Ltd	**9 Arkwright Road, Hampstead, London**	**CG/5595**
CGL	Title **Site location plan**	**Figure 1**



Key;

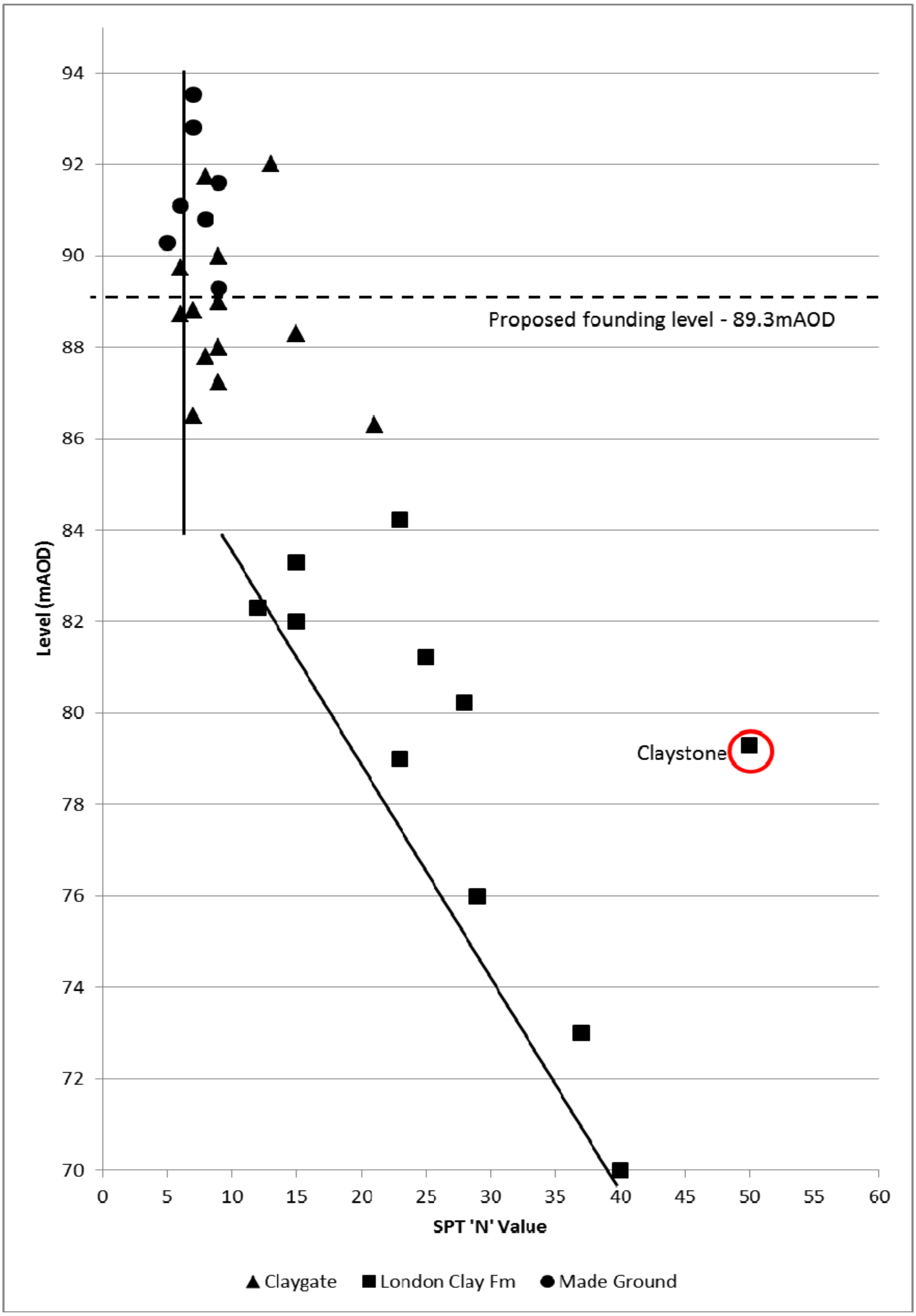
FIP01 – Foundation inspection pit

TP01 – Trial pit location

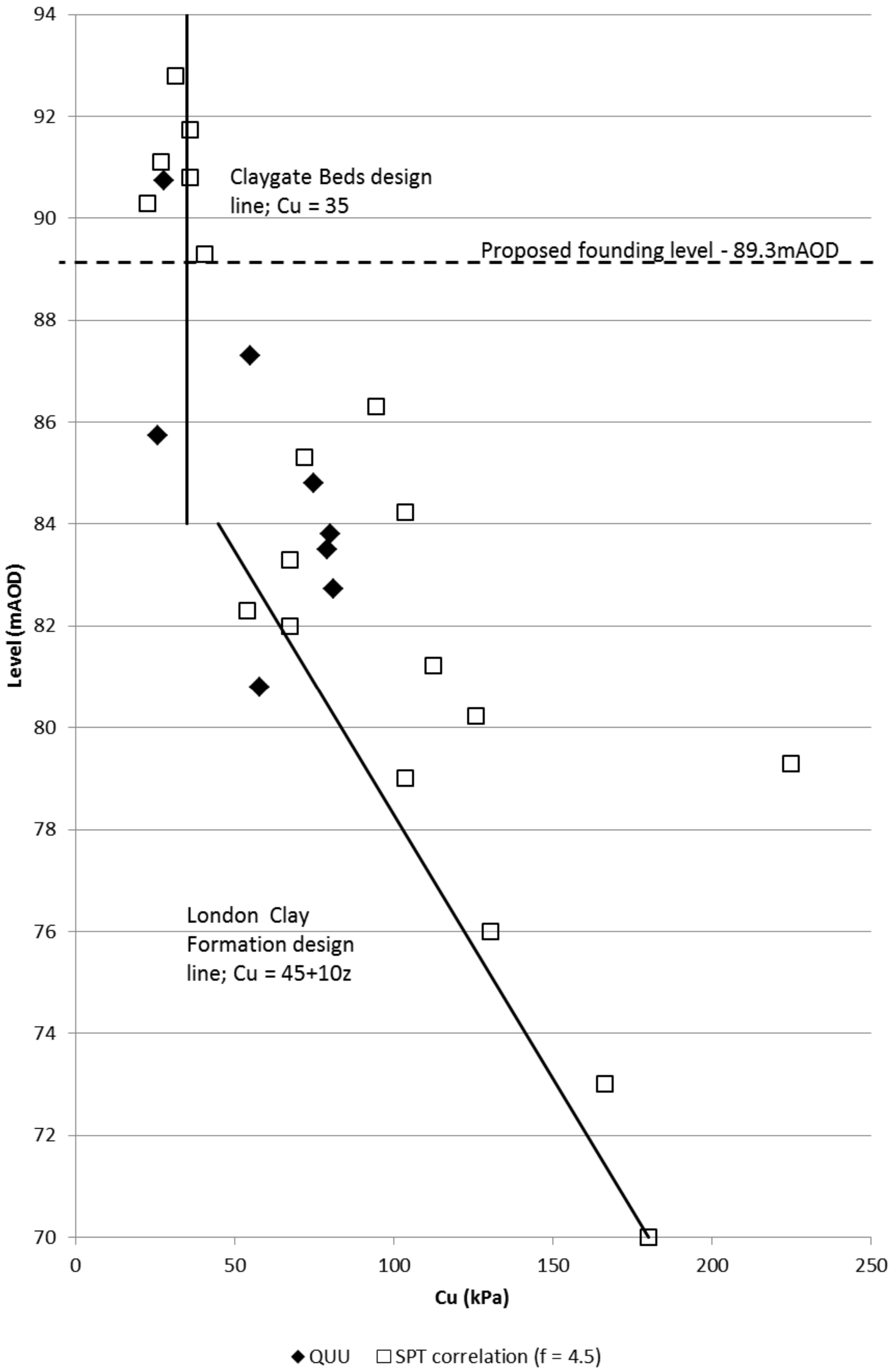
BH01 – Cable percussion borehole

NOT TO SCALE

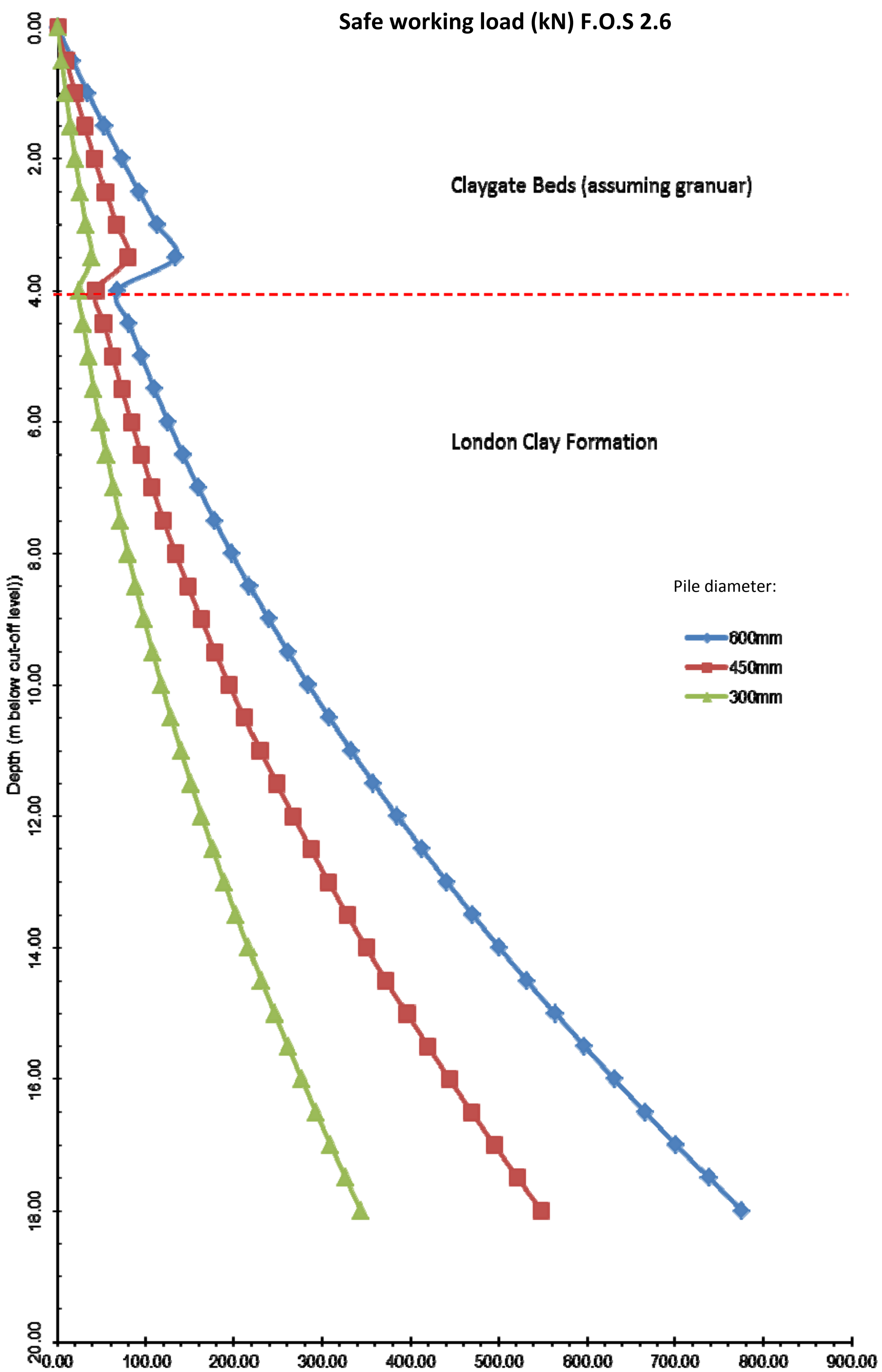
Client	Project	Job No
Ironside & Malone Design and Build Ltd	**9 Arkwright Road, Hampstead, London**	**CG/5595**
CGL	Title **Site layout and exploratory hole location pan**	**Figure 2**



Client	Project	Job No
Ironside & Malone Design & Build Ltd	**9 Arkwright Road, Hampstead, London**	**CG/5595**
CGL	Title **SPT ‘N’ versus level**	**Figure 3**



Client	Project	Job No
Ironside & Malone Design & Build Ltd	**9 Arkwright Road, Hampstead, London**	**CG/5595**
CGL	Title **Cu versus level**	**Figure 4**



Client	Project	Job No
Ironside & Malone Design & Build Ltd	**9 Arkwright Road, Hampstead, London**	**CG/5595**
CGL	Title **Preliminary pile working loads**	**Figure 5**