Mr & Mrs Gausen and Mr de Botton

32 Glenilla Road, London

Geotechnical Interpretative Report and Basement Impact Assessment - Revision 2

November, 2016

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1. INTRODUCTION

It is proposed to develop No.32 Glenilla Road, London, NW3 4AN, in the London Borough of Camden (LBC). The proposed development comprises the demolition of an existing church and the construction of two detached houses, each two storeys in height with a single basement level beneath. Card Geotechnics Limited (CGL) has been instructed to revise the previous *Basement Impact Assessment* (BIA) to take into account changes to the proposed basement layout. The BIA includes a detailed ground movement analysis for the proposed development to determine its potential effect on nearby structures, services, surface water runoff and groundwater flow

The London Borough of Camden's guidance document *"CPG4, Basements and Lightwells*[1]*",* requires a Basement Impact Assessment (BIA) to be undertaken for new basements in the Borough and sets out 5 stages for a BIA to "enable the Borough to assess whether any predicted damage to neighbouring properties and the water environment is acceptable or can be satisfactorily ameliorated by the developer". The five stages are set out below:

1. Screening
2. Scoping
3. Site investigation
4. Impact assessment
5. Review and decision making

This report is intended to address the screening, scoping, site investigation and impact assessment stages identified above. It identifies the key issues relating to land stability, hydrogeology and hydrology as part of the screening process (Stage 1) and includes a review and interpretation of existing site investigation data to establish a conceptual site model (Stages 2 and 3).

The report provides an impact assessment (Stage 4) of potential ground movements on adjacent structures and the hydrogeology of the surrounding area for the purposes of planning.

[1] Camden Planning Guidance, CPG4, Basements and Lightwells, July 2015.

2. SITE CONTEXT

2.1 Site location

The site is located at No.32 Glenilla Road, London, NW3 4AN. The National Grid Reference for the approximate centre of the site is 527141E, 184866N. The site location is shown in Figure 1.

2.2 Site layout

The site boundary is broadly rectangular and is approximately 30m in length and 19m in width, orientated southwest to northeast. The existing on-site building comprises a disused two storey church which is some 19m in length and 11m in width. Concrete hard-standing and two areas of soft landscaping are located to the front of the church, whilst the remainder of the site is occupied by soft landscaping, gravel and a paved footpath to the northern side entrance of the church. Several trees are located on site, the largest of which is against the southern perimeter of the site behind the church building.

The site is bounded to the northeast by a pavement some 2.5m in width, beyond which is Glenilla Road. The northwest and southeast boundaries are demarcated by wooden fences beyond which are the properties of Nos. 30 and 34 Glenilla Road, respectively. The site does not share any party wall with neighbouring buildings; No.30 Glenilla Road is approximately 1m from the northwest site boundary (5m from the existing church) whilst the garage of No.34 Glenilla Road is 1m from the southeast boundary of the site. The residential property of No.34 Glenilla Road is some 6m from the existing church.

A brief review of local planning applications suggests that recent developments have been undertaken on the nearest neighbouring structures on Glenilla Road including an extension to an existing lower ground floor level at No.34 Glenilla Road which was granted planning permission in 2010. No.32 Glenilla Road has also undergone recent above ground developments.

CGL's archive information indicates that the site lies approximately 250m south of two Network Rail tunnels which are orientated east to west. A major sewer is located some 50m east of the site, running in a north-south orientation. A site layout plan is presented in Figure 2.

No evidence of Japanese Knotweed was noted during the on-site investigation works.

2.3 Topography

Ordnance Survey mapping of the area records spot height elevations of 60.7 metres above Ordnance Datum (mOD) approximately 50m south of the site within the centre of Belsize Park Gardens and 64.3mOD within the centre of Belsize Avenue some 160m northwest of the site. The site is situated on a gently downwards gradient sloping towards the southeast. A topographic survey provided by the project's Structural Engineers, Price and Myers, indicates an average site level of 61.8mOD.

Locally the highest point is 135mOD, recorded at Hampstead Heath approximately 2km to the northwest of the site. Parliament Hill is also located approximately 1.5km northeast of the site. Local ground levels gradually increase towards these points.

Figure 16 of the Camden Geological, Hydrogeological and Hydrological Study[2] (CGHHS) records that the site is not located on a slope of greater than 7 degrees. Figure 17 of the CGHHS records the site as not being located within an area of significant landslide potential. Shallow valleys are recorded some 900m north and 550m west of the site representing relict river channels of the *River Fleet* and *River Tyburn*, respectively.

2.4 Proposed development

It is proposed to demolish the existing church and to divide the existing plot into two separate residential developments. Each construction will be a semi-detached three-storey residential home, including single-storey basement levels at each property. The basements will be situated primarily beneath the proposed buildings, with small areas beneath the driveways to the front of the properties and two lightwells in the rear garden.

Drawings provided by the project's Structural Engineers (Price and Myers) indicate the finished floor level of the basements will be at 3.0 metres below ground level (mbgl) or 58.8mOD. The basements will not share party walls with any other buildings.

Information from the Structural Engineers (see Appendix A) indicates that the basements will be constructed together as one excavation using a piled retaining wall around the perimeter of the site. The internal walls will then be constructed off the basement slab.

Plans of the proposed development are provided as Appendix B.

[2] Ove Arup and Partners. (2010) Camden Geological, Hydrogeological and Hydrological Study: Guidance for subterranean development. London Borough of Camden.

2.5 Site History

A brief review of the site's historical development has been undertaken using available literature and CGL's in-house resources. The findings are summarised as follows:

Historical mapping dated 1827 records the site as unoccupied and part of the grounds of *Belsize House*. The surrounding area was rural in character and two lakes were noted to the east of the site. *Belsize House* was noted on the 1870 map as *Hillfield* and the lakes were no longer present. *Glenilla Road* had not been developed at this stage but residential housing was noted to be present to the south of the site along *Saint Margaret's Road* (later noted as *Belsize Park Gardens*). A feature, possibly a pond, was noted on the 1870 map, located along the southwestern boundary of the site. Mapping dated 1890 shows that this feature was no longer in existence, having been replaced by woodland which separated the grounds of *Hillfield* from the rear gardens of the houses to the south of the site.

Glenilla Road was shown to have been developed by 1910, but the site itself was not shown to have been developed by this time. The grounds of *Hillfield* had been extensively developed with residential properties, incorporating a *Town Hall.* The first indication of the present day site was seen in mapping dated 1930, which shows the site boundaries to be defined. There were no buildings indicated on the site apart from a small unlabelled structure in the north-western corner of the site.

Mapping dated 1950 shows that the site had been developed and that a building labelled as a *"Church of the Christian Community"* was situated within the centre of the site. The southeastern boundary of the site was not shown, and the plot appears open to *34 Glenilla Road* which is situated next to it to the southeast. The church shows redevelopment in maps dating 1960, with an extension being made, expanding the building to the southwest at the rear of the church. A boundary segregating the church from *34 Glenilla Road* was shown to the rear of the building, but not to the front. Aerial photography dating 1999 shows the earliest evidence of soft landscaping observed for the site, in the same design observed for the site today.

No.32 Glenilla Road is not recorded as having sustained any damage during the Second World War bombings[3]. A residential property on the corner of *Glenilla* Road and *Howitt Road* is recorded to have sustained “general blast damage – not structural” and four buildings approximately 150m north-east of the site are recorded to have been totally damaged, with blast damage effecting several neighbouring properties on either side. The nearest V1 flying bombs are recorded on King Henry’s Road, some 850m south-east of the site. The area has since been redeveloped into residential apartment blocks and therefore the risk of unexploded ordnance (UXO) on site is considered to be low.

2.6 Published geology

The British Geological Survey (BGS) sheet[4] of the area indicates the site to be underlain by the London Clay Formation with no record of superficial deposits on site.

The London Clay Formation is an over-consolidated firm to very stiff, becoming hard with depth, fissured, blue to grey silty clay of low to very high plasticity. The upper and lower parts may contain silty or fine grained sand partings. The stratum may also contain laminated, structured, nodular claystone and rare sand partings. Crystals of gypsum (selenite) are often present within the weathered London Clay Formation. The stratum is generally horizontally bedded.

BGS basal contour mapping demonstrates the base of the London Clay Formation is present below the site to an elevation of approximately -20.0mOD, suggesting an overall thickness of approximately 50m on site.

The overlying Claygate Member is recorded approximately 500m northwest of the site at approximately 80mOD. Due to the regional hillslope setting, Head Deposits may be present on site, formed by solifluction and hill creep in a peri-glacial environment. These are likely to comprise clay dominated deposits resulting from the reworking of the London Clay with overlying sands and clays of the Claygate Member and River Terrace Gravels. Head Deposits are typically less than 2m in thickness and described as clays incorporating occasional angular frost shattered flints, often with basal gravelly clays of approximately 0.2m in thickness derived from local outcrops of high-level gravels[5].

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[3] London Topographical Society (2005). *Bomb Damage Maps 1939-1945*. The London City Council.
[4] British Geological Survey Sheet 256 (1993) *North London – Solid and Drift Geology* 1:50,000. Keyworth, BGS.
[5] Elison, R. A. et al. (2004) *Geology of London.* Memoir of the British Geological Survey, Sheets 256 (North London), 257 (Romford), 270 (South London) and 271 (Dartford). British Geological Survey, Keyworth, Nottingham.

2.7 Unpublished geology

A total of nine historical British Geological Survey (BGS) borehole records were reviewed, at distances of between 100m and 550m of the site boundary. Selected records and an indicative location plan are provided in Appendix C. The strata encountered within the boreholes are summarised in Table 1.

Table 1. Summary of BGS Borehole Records

Stratum	Top of stratum (mbgl)	Thickness(m)
[MADE GROUND] Soft to firm grey brown sandy silty gravelly CLAY. Gravel is fine to coarse of flint, brick, glass, coal and quartzite. Localised cinder ash, and surface tarmac or concrete noted.	0.0 to 0.3	0.45 to 3.0
[LONDON CLAY FORMATION] Soft to stiff, mottled orange brown and grey, slightly sandy silty CLAY with occasional fine gravel of quartzite. Occasional shell fragments. Localised rootlets and organic matter present. Becomes less sandy and locally laminated at depth. Occasional fissuring present at depth.	0.5 to 3.0	Proven to 20mbgl[1]

1. *Thickness proven in three out of nine boreholes only.*

No groundwater was encountered in the boreholes which were recorded as dry on completion.

2.8 Hydrogeology and hydrology

The Environment Agency[6] (EA) 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.

The site does not overlie a designated superficial or bedrock aquifer and is noted as being underlain by the London Clay Formation, designated a ‘non-productive stratum’ by the Environment Agency.

The site does not fall within a Groundwater Vulnerability Zone as indicated by EA mapping, nor is the site located within a groundwater source protection zone (GSPZ). The nearest GSPZ is located approximately 250m south from the site on Lancaster Grove, and is

[6] http://www.environment-agency.gov.uk (accessed October 2015)

classified as an "Outer Zone - Zone 2" GSPZ, it is likely that this relates to abstraction from the deep Chalk aquifer.

The closest significant bodies of surface water are the *Hampstead Ponds* located approximately 950m to the north of the site. Environment Agency mapping indicates the site is not located within a zone at of risk of flooding by river or sea, reservoirs. It does however have a high risk of surface water flooding. Figure 15 of the Guidance for Subterranean Development indicates that *Glenilla Road* was not flooded during extreme rainfall events in 1975 and 2002. However, *Belsize Park Gardens* located approximately 50m south-east of the site and *Belsize Avenue* located approximately 250m north of the site were subject to flooding in 1975 and 2002, respectively.

Reference to CGL archives and Barton's *Lost Rivers of London*[7] indicates that a tributary of the historical *River Tyburn* may cut across, or close to, the western corner of the site in a northeast to southwest direction. It is noted that the course of this river is not identified on historical mapping of the area, including the earliest available map, dated 1827. However, two lakes were noted to the east of the site on the 1827 and 1830 maps. These were no longer noted on the later 1870 map, which showed a separate feature, thought to be a pond, to be located along the southwestern site boundary. This feature was not noted on the 1890 map.

Another tributary of the *River Tyburn* is recorded to have flowed approximately 550m west and south-west of the site and a second 'lost' river, the *River Fleet*, runs northwest to southeast approximately 700m north-east of the site.

Owing to local topography it is considered that surface waters will drain towards the line of watercourse in a general south to south east trend. This is illustrated in Figure 11 of the Guidance for Subterranean Development.

As the London Clay Formation is identified below the site, it is assumed this forms an impermeable boundary and will form the base of an overlying groundwater table where any permeable superficial deposits permit lateral groundwater flow. It is possible that this is shallow perched groundwater within Made Ground or resting upon the surface of the London Clay Formation that is not expected to be laterally pervasive.

[7] Barton, N. (1983) *The Lost Rivers of London* Hertfordshire Historical Publications

3. STAGE 1 - SCREENING

3.1 Introduction

A screening assessment has been undertaken based on structured guidance presented in Camden Borough Council's CPG4[1]. Responses to the questions posed by the flowcharts are presented below and where 'yes' or 'unknown' may be simply answered with no analysis required, these answers have been provided.

3.2 Subterranean (Groundwater) Screening Assessment

This section answers questions posed by Figure 3 in CPG4:

Table 2. Responses to Figure 3, CPG4

Question	**Response**	**Action required**
1a. Is the site located directly above an aquifer?	No. The site is directly underlain by the London Clay Formation, designated an unproductive stratum by the Environment Agency. However, reference to Barton's *Lost Rivers of London*[7] indicates that a tributary of the historical *River Tyburn* may have passed through, or close to, the western corner of the site.	Investigation
1b. Will the proposed basement extend beneath the water table surface?	No. The proposed basement is proposed to extend approximately 3.0mbgl. Local historical ground investigations have not encountered groundwater.	None
2. Is the site within 100m of a watercourse, well or potential spring line?	Possibly. Reference to Barton's *Lost Rivers of London*[7] indicates that a tributary of the historical *River Tyburn* may have passed through, or close to, the western corner of the site.	Investigation
3. Is the site within the catchment of the pond chains on Hampstead Heath?	No.	None

Question	Response	Action required
4. Will the proposed basement development result in a change in the proportion of hard surfaced/paved areas?	Yes. The proposed basement and above ground structures will increase the proportion of hard-standing across the site. However, the underlying London Clay is relatively impermeable and therefore the development is not considered to significantly impact infiltration rates.	None
5. As part of site drainage, will more surface water than at present be discharged to ground (e.g. via soakaways and/or SUDS)?	No. Soakaways are not likely to prove effective in the London Clay due to low infiltration rates.	None
6. Is the lowest point of the proposed excavation close to or lower than, the mean water level in any local pond or spring-line?	No.	None

The proposed development is underlain by the London Clay Formation, designated an 'unproductive stratum' by the EA. A review of available data has been conducted to determine groundwater conditions on site and suggests shallow perched groundwater may be encountered within Made Ground or fine sand laminations within the London Clay Formation, however, this is not expected to be laterally pervasive.

Reference to Barton's *Lost Rivers of London*[7] indicates that a tributary of the historical *River Tyburn* may have passed through, or close to, the western corner of the site. However, a review of historical mapping notes that the river feature is not identified on the mapping, suggesting that it may be off-site, or previously buried.

The proposed basement and new structures will increase the proportion of hard-standing across the site, however, sunken gardens are proposed at basement level in each plot. Due to the incorporation of soft landscaping in the proposed development and the relatively impermeable nature of the underlying London Clay, the development is not likely to significantly affect infiltration to groundwater.

3.3 Slope/Land Stability Screening Assessment

This section answers questions posed by Figure 4 in CPG4.

Table 3. Responses to Figure 4, CPG4

Question	Response	Action required
1. Does the site include slopes, natural or man-made, greater than about 1 in 8?	No.	None
2. Will the proposed re-profiling of the landscaping at site change slopes at the property boundary to greater than about 1 in 8?	No.	None
3. Does the development neighbour land including railway cuttings and the like with a slope greater than about 1 in 8?	No.	None
4. Is the site within a wider hillside setting in which the general slope is greater than about 1 in 8?	No.	None
5. Is the London Clay the shallowest strata on site?	Yes. The proposed development is in close proximity to two neighbouring properties, and therefore the effect of heave in the underlying London Clay due to basement excavation will need to be considered.	Investigation and assessment
6. Will any trees be felled as part of the proposed development and/or are any works proposed within any tree protection zones where trees are to be retained?	Yes. Five trees will be felled as part of the proposed development and therefore the effects of shrink/swell subsidence should be considered.	Investigation and assessment
7. Is there a history of shrink/swell subsidence in the local area and/or evidence of such at the site?	Unknown. The shallowest stratum beneath the site is the London Clay Formation and therefore the effect of heave in the underlying London Clay due to basement excavation will need to be considered.	None
8. Is the site within 100m of a watercourse or a potential spring line?	Possibly. Reference to Barton's *Lost Rivers of London*[7] indicates that a tributary of the historical *River Tyburn* may have passed through, or close to, the western corner of the site.	Investigation

Question	Response	Action required
9. Is the site within an area of previously worked ground?	No.	None
10. Is the site within an aquifer?	No.	None
11. Is the site within 50m of the Hampstead Heath ponds?	No.	None
12. Is the site within 5m of a highway or pedestrian right of way?	No. Glenilla Road is located adjacent to the front of the site, approximately 8m from the proposed basement. Construction works are unlikely to impact the highway assuming good workmanship and well-constructed scheme are carried out.	None (see below)
13. Will the proposed basement significantly increase the differential depth of foundations relative to neighbouring properties?	Yes. It is understood that the neighbouring property of No.34 Glenilla Road has an existing lower ground floor level, however it is likely that No.30 Glenilla Road does not currently have a basement level.	Impact Assessment
14. Is the site over (or within the exclusion zone of) any tunnels?	No.	None

A review of local topography and reference to Figure 16 of CGHHS[3] suggests that local and wider hillslopes do not exceed a gradient of 1 in 8. Figure 17 of the Study indicates the site is not located in an area of landslide potential. It is understood that trees will be felled as part of the proposed development.

In summary, an impact assessment is required to investigate the magnitude of ground movements resulting from the basement excavation and the removal of trees. The basement excavation will result in unloading of the London Clay Formation at depth which without significant structural reloading may result in heave movements. The construction of the basement will significantly increase the differential depth of foundations between Nos.32 and 30 Glenilla Road. The impact assessment will assess potential damage caused by ground movements to adjacent properties and will recommend measures to mitigate such potentially damaging movements.

The proposed basements will be located approximately 8.0m from the Glenilla Road highway and ground movements resulting from the excavations are considered to be negligible assuming good workmanship and well-constructed scheme are carried out.

3.4 Surface Flow and Flooding Screening Assessment

This section covers the main surface flow and flooding issues as set out in Figure 5, CPG4.

Table 4. Responses to Figure 5, CPG4

Question	Response	Action required
1. Is the site within the catchment area of the pond chains on Hampstead Heath?	No	None
2. As part of the proposed site drainage, will surface water flows (e.g. volume of rainfall and peak run-off), be materially changed from the existing route?	Yes. An increase in discharge is anticipated due to the change of use from commercial (a church) to residential.	Assessment by others
3. Will the proposed development result in a change in the proportion of hard surfaced/paved external areas?	Yes. The proposed basement and above ground structures will increase the proportion of hard-standing across the site. However, the underlying London Clay is relatively impermeable and therefore the development is not considered to significantly impact infiltration rates.	None (see below)
4. Will the proposed basement result in a change to the profile of the inflows of surface water being received by adjacent properties or downstream watercourses?	No.	None
5. Will the proposed basement result in changes to the quality of surface water being received by adjacent properties or downstream watercourses?	No. The proposed excavation would remove the majority of any Made Ground that may be present on site and as such will not impact on water quality.	None
6. Is the site in an area known to be at risk from surface flooding, or is it at risk from flooding because the proposed basement is below the static water level of a nearby surface water feature?	No.	None

The proposed development is for two residential properties, therefore an increase in discharge is anticipated, in comparison with the previous Church building. The impact of this has been assessed as part of a flood risk assessment and detailed drainage design undertaken by others, included as Appendix D. The proposed basement and new structures will slightly increase the proportion of hard-standing across the site, however, sunken gardens are proposed at basement level in each plot. Due to the incorporation of soft landscaping in the proposed development and the relatively impermeable nature of the underlying London Clay, the development is not considered to significantly affect run-off/surface attenuation characteristics.

3.5 Summary

On the basis of this screening exercise, further stages of basement impact assessment are required for this site. These should address the following:

Table 5. Summary of Basement Impact Assessment requirements

Item	Description
1.	*Groundwater flow* Investigation – reference to Barton's *Lost Rivers of London*[7] indicates that a tributary of the historical *River Tyburn* may have passed through, or close to, the western corner of the site. Ground investigation will be required to confirm the presence of this historical river course. The basement will be constructed entirely within the London Clay and therefore groundwater is not expected to be encountered. Given the relatively impermeable nature of the London Clay, infiltration will be negligible.
2.	*Slope (land stability)* Investigation and assessment – The proposed development and neighbouring properties are potentially at risk from shrink/swell of the London Clay Formation. The impact of the basement construction on adjacent party walls and neighbouring structures requires consideration and an impact assessment is required. The impact of removing trees on site will be considered.
3.	*Surface flow and flooding* None – the proposed basement and new structures will increase the proportion of hard-standing across the site, however, sunken gardens are proposed at basement level in each plot. However, due to the impermeable nature of the underlying London Clay Formation and the incorporation of soft landscaping at basement level, the run-off surface attenuation characteristics are not significantly affected. The site is not located in an area at risk from surface water flooding.
4.	*Cumulative impacts* As groundwater flow would not be expected within the London Clay, it is expected that cumulative impacts from the construction of the basement will be negligible.

The outcomes of the screening assessment are carried forward into the Basement Impact Assessment in the following report sections.

4. STAGE 2 - SCOPING

On the basis of the screening report, an intrusive investigation is required on site.

The intrusive investigation should:

1. Determine the ground conditions on site and their variability;
2. Install groundwater monitoring standpipes to determine groundwater levels;
3. Undertake in-situ testing to assess the strengths of the ground and to support geotechnical assessment; and
4. Obtain soil samples for geotechnical laboratory testing in order to classify the soils on site, to determine where desiccation is present on site, and to support geotechnical design.

A site investigation has been undertaken by CGL and the findings are presented within Section 5.

5. STAGE 3 - GROUND INVESTIGATION

5.1 Current site investigation

An intrusive investigation was undertaken by CGL in August 2015. The investigation comprised a single cable percussion borehole (BH01) to a depth of 15.5mbgl and five window sampler boreholes (WS01 to WS03, WS05 and WS06) to depths of 5.0mbgl. In addition, three trial pits (TP01 to TP03) were excavated by hand adjacent to the site boundaries. The ground investigation was undertaken in accordance with BS 1377:1990[8] and BS 5930:1999[9].

Standard Penetration Tests (SPTs) and undisturbed U100 samples were undertaken within the boreholes and groundwater monitoring wells were installed within boreholes BH01, WS01 and WS02.

The borehole logs and foundation inspection pit logs are presented as Appendix E and Appendix F, respectively, and the exploratory hole location plan is presented in Figure 2.

5.2 Monitoring

A single ground gas and groundwater monitoring visit was undertaken on 3rd September 2015 following completion of the site works. The results of the monitoring are summarised in Sections 6.3 and 7.3 and the monitoring records are presented as Appendix G.

5.3 Laboratory testing

5.3.1 Chemical

Nine representative soil samples, one leachate sample and three groundwater samples were submitted to i2 Analytical Limited (a UKAS and MCERTS accredited laboratory) for chemical testing. The analysis included the following determinants and the results are presented in Appendix H:

- Soil Organic Matter (SOM);
- Heavy metals including; arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc;

[8] British Standards Institution. (1990). *Methods of Test for Soils for Civil Engineering purposes*. BS1377:1990.
[9] British Standards Institution. (2015). *Code of practice for ground investigations*. BS5930:2015

- Total Petroleum Hydrocarbons (TPH) and Polycyclic Aromatic Hydrocarbons (PAH);
- Total Monohydric Phenols;
- Total Cyanide;
- Sulfate;
- pH determination and;
- Asbestos screen

The chemical results are included as Appendix H.

5.3.2 Geotechnical

Selected soil samples were submitted to an accredited laboratory for geotechnical testing including the following:

- Atterberg Limits tests;
- Undrained triaxial compression tests;
- Moisture content; and
- BRE analysis in accordance with BRE SD1.

The geotechnical analysis results are included as Appendix I.

6. STAGE 3 - GROUND AND GROUNDWATER CONDITIONS

6.1 Ground conditions

6.1.1 Summary

The ground conditions encountered during the intrusive investigation broadly corresponded to the published geology and are summarised in Table 6 below.

Table 6. Summary of ground conditions

Stratum	Depth to top of stratum (mOD) [mbgl]	Thickness (m)
[MADE GROUND] Concrete and ornamental gravel overlying soft to firm dark grey to light orange brown gravelly clay. Gravel is fine to coarse subrounded to angular of flint, brick, chalk and concrete	61.8 [0.0]	1.6 to 3.2
Firm to stiff dark brown CLAY. 5.8mbgl to 5.9mbgl: band of claystone Becoming slightly sandy with fine selenite crystals from 10.0mbgl [LONDON CLAY FORMATION]	58.56 to 60.1 [1.6 to 3.2]	Proven to 46.3mOD (15.5mbgl)

The ground conditions are discussed in the following sections together with the results of the in-situ and laboratory geotechnical tests.

6.1.2 Made Ground

Made Ground was found to comprise concrete or gravel overlying soft to firm dark grey to light orange brown gravelly clay to a level of between 58.56mOD to 60.1mOD. No visible or olfactory evidence of contamination was recorded.

Standard SPT testing within this stratum recorded 'N' values of between 4 and 16, corresponding to a 'very soft' to 'firm' clay[9].

6.1.3 London Clay Formation

The surface of the London Clay Formation was encountered at between 58.56mOD to 60.1mOD and the stratum was found to comprise firm to stiff brown clay. The London Clay Formation extended to the base of borehole BH01 at 46.3mOD (15.5mbgl)

Triaxial testing undertaken on samples collected between 2.0mbgl and 15.0mbgl recorded undrained shear strength (c_u) values between 49kPa to 134kPa, generally increasing with depth. These values correspond to clay of 'medium' to 'high' strength[9]. These values are supported by the in-situ SPT testing which recorded 'N' values of between 7 and 24, corresponding to a 'soft' to 'stiff' clay. Plots of SPT and c_u against level are presented as Figure 3 and Figure 4, respectively.

The results of the geotechnical laboratory analyses have indicated index properties for the London Clay in the following ranges:

- Moisture Contents between 29% and 35%;
- Liquid Limits between 69% and 78%;
- Plastic Limits between 24% and 27%; and
- Plasticity Indices between 45% and 52%.

Based on the above data, the London Clay Formation may be classified as clay of 'very high' plasticity with a high volume change potential which is consistent with published data.

6.2 The historical River Tyburn

Reference to Barton's Lost Rivers of London7 indicates that a tributary of the historical *River Tyburn* may have passed through, or close to, the western corner of the site. However, no evidence of this was noted during the ground investigation, indicating that the course of the historical river does not pass through the site.

6.3 Groundwater

Groundwater was encountered during drilling adjacent to a claystone band at 56mOD (5.8mbgl). During the subsequent monitoring visit, groundwater was encountered at between 1.88mbgl and 4.15mbgl (57.74mOD to 59.81mOD), within the Made Ground and upper parts of the London Clay Formation. The boreholes were bailed dry during sampling of the groundwater. The recharge in all three boreholes monitored was noted to be slow.

It is anticipated that the groundwater encountered within the London Clay Formation is perched water within the claystone band and is not representative of a groundwater table.

6.4 Sulfate and pH conditions

Two samples of Made Ground and two samples of London Clay Formation were analysed for pH and sulfate. The laboratory results are included in Appendix H and are summarised in Table 7.

Table 7. Summary of pH and sulfate results

Sample location	Sample depth (mbgl)	Strata	pH	Total sulfate as SO_4 (mg/kg)	Water Soluble sulfate as SO_4 (2:1 leachate equivalent) (g/l)	Total sulfur (mg/kg)
WS01	0.5	Made Ground	7.7	830	0.044	-
WS01	1.0	Made Ground	7.6	690	0.16	-
WS01	4.0	London Clay Formation	7.5	120,000	2.6	40,000
WS06	3.0	London Clay Formation	7.8	1,300	0.49	480

The implications of these results on the building design are discussed in further detail in Section 9.1.4.

6.5 Geotechnical design parameters

Geotechnical design parameters are recommended based on the available information from the intrusive investigation and published information. These are summarised in Table 8. The values are unfactored (Serviceability Limit State) parameters and are considered to be characteristic values for the local soils.

Table 8. 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	61.8	19	35 [1]	28[a,b]	21[b] [15.75]
London Clay Formation	59.5	20	$40 + 5.17z$[c] [5]	21[a]	$24 + 3.1z$[d] [$18 + 2.3z$][e]

a. BS 8002:2015 Code of practice for Earth retaining structures, British Standards institution.
b. Burland et. al (Eds) (2001) Building response to tunnelling, CIRIA Special Publication 200, CIRIA
c. z = depth below upper surface of the London Clay
d. Based on 600 Cu - Burland, Standing J.R., and Jardine F.M. (eds) (2001), Building response to tunnelling, case studies from construction of the Jubilee Line Extension London, CIRIA Special Publication 200.
e. Based on 0.75Eu - Burland, Standing J.R., and Jardine F.M. (eds) (2001), Building response to tunnelling, case studies from construction of the Jubilee Line Extension London, CIRIA Special Publication 200.

The parameters in Table 8 are unfactored (Serviceability Limit State) and considered to be 'moderately conservative' design values. Groundwater was not encountered during drilling, however for long-term design, a groundwater level of 1.5mbgl (60.3mOD) is recommended.

7. STAGE 3 - CONTAMINATION ASSESSMENT

7.1 Introduction

This section evaluates risks to potential receptors at the site from identified chemical contamination. Potential receptors have been identified with reference to the Part 2A regime and associated DEFRA guidance[10]. As with the Part 2A regime, under the planning regime all receptors (humans, controlled waters, ecology, crops/livestock and buildings) have been considered if there is the potential for them to be adversely affected by exposure to contamination. CGL's approach and rationale to assessment criteria adoption for the site is presented in Appendix J.

7.2 Assessment of ground contamination

7.2.1 Risks to human health (long-term chronic risks)

A total of nine soil samples, including six of Made Ground and three of natural soil (London Clay Formation) were analysed from across the site. The laboratory results have been compared against the published *Soil Guideline Values (SGVs)* for the *"Residential with home-grown produce"* land-use category.

The results of the Made Ground assessment are set out in Table 2 of Appendix J. The results indicate that the concentrations of some contaminants are above the assessment criteria and may pose a risk to human health. These samples are summarised in Table 9.

Table 9. Summary of contaminant exceedances (Made Ground)

Sample location	Sample depth (mbgl)	Stratum	Contaminant	US_{95} (mg/kg)	Measured concentration (mg/kg)	Assessment Criteria[1] (mg/kg)
WS01	1.0	Made Ground	Lead	1248.22	220	200
WS02	0.2	Made Ground	Lead Benzo(a)pyrene	1248.22 7.22	490 8.3	200 3.0
WS03	0.3	Made Ground	Lead Benzo(a)pyrene	1248.22 7.22	550 9.0	200 3.0
WS05	0.8	Made Ground	Lead Benzo(a)pyrene	1248.22 7.22	1,300 4.0	200 3.0
WS06	0.4	Made Ground	Lead	1248.22	220	200

Notes
1. Based on C4SL values

[10] DEFRA (2012) *Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance.*

In addition to the above contaminants, asbestos was detected during laboratory analysis of two Made Ground samples (WS3 and WS5). Quantification testing on these samples recorded concentrations of less than 0.001%.

Inspection of Table 3 of Appendix J indicates that the concentrations of the analysed determinants within the natural ground samples do not exceed their respective assessment criteria values.

The significance of these results in terms of the proposed development is discussed further in Sections 8 and 9.2.

7.2.2 Risks to vegetation and plants

Nine soil samples have been assessed against the British Standard for topsoil[11]. The assessment is presented as Table 4 of Appendix J and the contaminant exceedances are summarised in Table 10 below.

Table 10. Summary of contaminant exceedances

Sample location	Contaminant	Measured concentration (mg/kg)	Assessment Criteria (mg/kg)
WS3	Zinc	350	200
WS5	Zinc	520	200

The significance of these results in terms of the proposed development is discussed further in Sections 8 and 9.2.

7.2.3 Controlled waters assessment

One leachate sample and three groundwater samples were taken for analysis. The results of the testing are presented in Tables 5 and 6 of Appendix J. These show that the concentrations of the contaminants analysed are generally below the freshwater Environmental Quality Standard (EQS) and Drinking Water Value (DWV). Contaminant exceedances against the EQS and DWV are summarised below in Table 11 and Table 12, respectively.

[11] BSI (2007) Specification for topsoil and requirements for use. BS13882. Values taken for pH6-7

Table 11. Summary of contaminant exceedances (EQS)

Sample location	Contaminant	Measured concentration (µg/kg)	Assessment Criteria (EQS) (µg/kg)
Leachate sample			
WS6	Lead	9.9	7.2
Groundwater sample			
BH1	Chromium III	6.1	4.7
	Mercury	0.07	0.05
	Sulfate	3,900.0	400.0
WS2	Naphthalene	2.9	2.4

Table 12. Summary of contaminant exceedances (DWV)

Sample location	Contaminant	Measured concentration (µg/kg)	Assessment Criteria (DWV) (µg/kg)
Groundwater sample			
WS2	TPH	810.0	10.0

The significance of these results in terms of the proposed development is discussed further in Sections 8 and 9.2.

7.3 Ground gas assessment

One ground gas visit was undertaken on 3rd September 2015 during atmospheric pressures of 1006mb. The air pressure was steady at the time of the visit. The monitoring record is presented as Appendix G and the results of the monitoring are summarised below;

- Maximum carbon dioxide concentration: 7.4% v/v
- Maximum methane concentration: <0.1% v/v
- Maximum sustained flow rate: <0.1l/hr (after initial peak value of 28.7l/hr)
- Minimum oxygen concentration: 17.3% v/v

The significance of this monitoring in terms of the proposed development is discussed further in Sections 8 and 9.2. As only one round of monitoring was completed, further monitoring visits may be required to satisfy the Local Authority or building warrantor.

8. STAGE 3 - CONTAMINATION RISK ASSESSMENT

A semi-quantitative risk assessment has been undertaken based on the findings of the Conceptual Site Model and the potential pollutant linkages that may exist at the site in accordance with Contaminated Land Report (CLR) 11[12]. The risks identified are in accordance with the DEFRA and Contaminated Land Report (CLR) 6[13], site prioritisation and categorisation rating system, which is summarised below in Table 13.

Table 13 - Risk Rating Terminology

Risk Rating	Description
High Risk	Contaminants very likely to represent an unacceptable risk to identified targets Site probably not suitable for proposed use Enforcement action possible, Urgent action required
Medium Risk	Contaminants likely to represent an unacceptable risk to identified targets Site probably not suitable for proposed use Action required in the medium term
Low Risk	Contaminants may be present but unlikely to create unacceptable risk to identified targets Site probably suitable for proposed use Action unlikely to be needed whilst site remains in current use
Negligible Risk	If contamination sources are present they are considered to be minor in nature and extent Site suitable for proposed use No further action required

Based on the above terminology an assessment of the risks posed by the potential pollutant linkages at the site are outlined in Table 14. A diagrammatic representation of the conceptual site model is provided in Figure 5.

[12] The Environment Agency (2004) Model Procedures for the Management of Land Contamination. CLR 11.
[13] M.J. Carter Associates (1995) Prioritisation and Categorisation Procedure for Sites which may be Contaminated. Department of Environment. CLR 6.

Table 14. Semi-quantitative risk assessment

Source/Medium	Receptor	Potential Exposure Route	Risk Rating
Made Ground, including ground gases	Future site occupants	Inhalation, direct contact or ingestion, including through home-grown produce. Migration of gases through the surface and via permeable soils.	Medium *(NB gas risk based on one ground gas monitoring visit only)*
	Construction workers	Ingestion, direct contact or inhalation	Medium
	Future buildings and services	Direct contact causing degradation of building materials including concrete and plastics in the ground. Migration of gases through the surface and via permeable soils.	Low to medium
	Vegetation and plants	Root uptake by vegetation/plants	Low to medium
	Controlled waters	Vertical and lateral migration	Negligible

8.1 Risks to human health

Overall, the risks to future site occupants are considered to be medium as the majority of the Made Ground is to be removed from site during excavation of the proposed basements. However, areas of Made Ground are likely to remain outside of the basement perimeter and the site has been classified as Characteristic Situation 2, with respect to ground gas conditions, due to elevated concentrations of carbon dioxide. It is anticipated that these risks may be mitigated through use of a capping layer and gas protection measures at the site. Further ground gas monitoring is also recommended to confirm the ground gas regime at the site.

No elevated contaminant concentrations were encountered in the natural soils. These soils are therefore not considered to present an unacceptable risk to human health

The risk to construction workers is considered to be medium due to the potential for direct contact with contaminated soils during excavation. It is anticipated that this risk may be mitigated through use of appropriate site working practices and PPE.

8.2 Risks to buildings and structures

The risk to future buildings and structures at the site is considered to be low to medium. The risk due to contamination in the Made Ground is considered to be low, however relatively high pH and sulfate conditions were encountered in WS01 and there is therefore a potential risk to concrete at the site. This is discussed further in Section 9.1.4.

8.3 Risks to vegetation and plants

The risk to vegetation and plants is considered to be low to medium due to the exceedances of zinc noted in the Made Ground. It is noted that a capping layer has been recommended to mitigate the risks to human health due to elevated lead and benzo(a)pyrene. It is therefore anticipated that vegetation and plants will be planted within the capping layer, thereby mitigating the potential risk from the Made Ground.

8.4 Risks to controlled waters

Elevated contamination concentrations were encountered in the water samples taken from across the site. However, the London Clay is classified as an unproductive stratum and the site is not close to significant water bodies or within a source protection zone. The risk to groundwater is therefore considered to be negligible. There are no significant surface water bodies adjacent to the site.

9. STAGE 3 - GEOTECHNICAL AND GEOENVIRONMENTAL RECOMMENDATIONS

9.1 Geotechnical recommendations

9.1.1 Excavations

Based on the ground conditions encountered during the intrusive investigation, shallow excavations in the Made Ground material are likely to remain stable in the short term. Battering back or shoring of the Made Ground may be required for excavations which are required to remain open for longer periods of time (i.e. for casting of foundations) or where man entry is required.

Perched groundwater is likely to be encountered during excavations within the Made Ground encountered in the boreholes. Where groundwater ingress is encountered, groundwater control measures, such as a pump and sump dewatering system, should be adopted to keep excavations and formation levels dry.

A retaining wall will be required for the basement excavation. Information from the Structural Engineer (Appendix A) indicates that this will consist of either a secant or contiguous piled wall. Given the limited groundwater encountered during the ground investigation and subsequent monitoring, and the slow recharge noted during the groundwater sampling, it is considered that a contiguous piled wall, with groundwater control measures, would be appropriate for the site. Groundwater disposal should be carried it out in accordance with the recommendations in Section 9.2.2

No operatives should enter unshored or otherwise protected excavations identified as unstable by a competent person, however shallow they are, in accordance with the guidelines presented in CIRIA Report 97[14].

[14] CIRIA (1992). *Trenching Practice (Second Edition).* Construction Industry Research and Information Association Report 97.

9.1.2 Foundations

Subject to settlement calculations and loadings, a raft foundation may be appropriate for the proposed development. Information provided by the structural engineers suggests that this is the preferred option. Alternatively strip or pad foundations may be utilised, designed for an allowable bearing pressure of 100kPa at a depth of 4m below existing ground level and constructed within the main basement excavation.

Continuous flight auger (CFA) piled foundations would be suitable for the proposed development of the site, including for construction of the basement walls. Indicative safe working loads for the site for pile diameters of 0.3m, 0.45m and 0.6m and pile lengths of 5m, 10m and 15m are presented in Table 15 and are shown graphically in Figure 6, based on the geotechnical design parameters given in Table 8 An overall design factor of safety of 2.6 and adhesion factor of 0.5 have been assumed, and the pile cut off level has been taken to be approximately 4m below ground level.

Final pile designs should be provided by the contractor engaged to undertake the piling works and should take into consideration potential obstructions due to the claystone bands encountered in BH01.

Table 15. Indicative pile working loads (kN)

Pile Length (mbgl)	**Safe Working Load (kN) FoS = 2.6**		
	Pile diameter (m)		
	0.3	0.45	0.6
5	15	25	45
10	60	105	155
15	135	220	310

9.1.3 Floor slab design

Should piles or pads be adopted, the basement floor slab may be designed as ground bearing with adequate reinforcement to resist a uniform heave pressure of some 35kPa (approximately 50% of maximum overburden removal, assumed to be a maximum 3.5m excavation to basement level and unit weight of excavated material of 20kN/m^3).

Alternatively the floor slab may be designed as suspended, incorporating appropriate heave protection (Cellcore or similar) to prevent heave pressures from being realised.

9.1.4 Concrete design

Based on the pH and sulfate testing undertaken on samples of Made Ground and London Clay Formation (see Table 7), appropriate concrete design classes have been calculated and are presented in Table 16.

The availability of total potential sulfate (TPS) in pyritic soils, such as the London Clay Formation, is dependent on the extent to which the soils are disturbed, and the level to which the soils may oxidise, resulting in sulfate ions that may reach the concrete. In this regard, BRE SD1 guidance states that *"Concrete in pyritic ground which is initially low in soluble sulfate does not have to be designed to withstand a high potential sulfate class unless it is exposed to ground which has been disturbed to the extent that contained pyrite might oxidise and the resultant sulfate ions reach the concrete. This may prompt redesign of the structure or change to the construction process to avoid ground disturbance; for example, by using precast or cast-in-situ piles instead of constructing a spread footing within an excavation"*.

On this basis, the appropriate DS and ACEC class for the pyritic soils, i.e. based on water soluble sulfate (WSS) or total potential sulfate (TPS), should be adopted dependant on the extent to which the soils will be disturbed during construction.

One of the samples from the London Clay Formation (from WS01 at 4.0mbgl) was found to contain high values of sulphate and sulphur. These values are atypical for the London Clay Formation and it is anticipated that they may be due to selenite crystals within the sample. Based on these values, concrete at this depth should be designed to DS-5 and AC-4s if the London Clay Formation is exposed during construction. A lower categorisation of DS-4 and AC-3s may be used for piled foundations, as these do not expose the London Clay to further oxidation.

Initial DS and ACEC classes are provided in Table 16 below, based on the currently available data. It is recommended that further testing is undertaken to enable a more detailed assessment of the concrete design requirements to be made.

Table 16. Summary of concrete design classes

Strata	DS class	ACEC class
Made Ground	DS-1	AC-1s
London Clay Formation (TPS)[1]	DS-5	AC-4s
London Clay Formation (WSS)[2]	DS-4	AC-3s

Notes
1. Based on TPS – e.g. for open excavations
2. Based on WSS – e.g. for piled foundations

9.1.5 Drainage design

No permeability tests were undertaken during the ground investigation, however bailing out of the boreholes during the groundwater sampling recorded slow recharge, indicating that the soils are of limited permeability.

Given the relative impermeability of the London Clay Formation in this area and the vertically and laterally heterogeneous composition of the Made Ground, soakaway drainage is not considered a viable option at the site.

The drainage strategy for the site has been undertaken by others and is included as Appendix D of this report.

9.1.6 Pavements

A design CBR of 2% is recommended for pavements constructed within the Made Ground, and of 3% is recommended for pavements constructed within the London Clay.

9.2 Geoenvironmental recommendations

9.2.1 Contamination and remediation

No contaminant exceedances were noted within the natural soils on site. However, elevated concentrations of lead and benzo(a)pyrene were noted in the Made Ground across the site. Proposed development plans indicate that the majority of the Made Ground across the site is to be removed during excavation of the basements, removing the source of the contamination and therefore the risk to future occupants in this area will be negated. A capping layer will be required in areas where Made Ground is to remain, such as the northeastern and southwestern parts of the site. This layer should comprise hardstanding or a geotextile membrane underlying a minimum of 450mm cohesive subsoil and 150mm topsoil.

The risk to construction workers is anticipated to be mitigated through appropriate use of PPE during the works.

Exceedances of lead, chromium III, mercury, sulphate and naphthalene (against EQS) and TPH (against DWV) were noted within the groundwater. The source of the TPH contamination is not known. However, based on the carbon ranges of the contamination (Aromatic C8-10, C10-C12 and C12-C16), it is anticipated that this relates to spilt petrol, possibly associated with historical gardening works at the site. As the site is underlain by an unproductive stratum, which will act as an aquitard, and is not within a groundwater source exclusion zone, these exceedances are not considered to pose a risk to human health or controlled waters and remediation is therefore not required.

However, consideration should be given to the safe disposal of impacted groundwater if encountered during the works on site, in particular during the basement excavation. Further chemical testing of inflowing groundwater is recommended and Thames Water should be contacted to confirm that the groundwater may be discharged to the foul sewer. If this is not permitted, disposal of the groundwater via tanker to an appropriate facility may be required.

Based on the single ground gas monitoring visit undertaken, a gas screening value (GSV) of 0.0l/h has been calculated for the site. This GSV indicates that the site conforms to Characteristic Situation 1. However, as sustained concentrations of carbon dioxide were recorded in excess of 5% in two boreholes (BH01 and WS06), it is considered that the site conforms to Characteristic Situation 2 (NHBC 'Amber 1'). Ground gas protection measures will therefore be required for the proposed development. These could comprise a fully tanked basement with a reinforced concrete foundation raft in order to achieve the requisite gas score in accordance with BS 8485[15].

It should be noted that this assessment is based on one round of ground gas monitoring and further rounds of monitoring are recommended to confirm the ground gas regime. Further visits may also be required to satisfy the local authority or building warrantor.

[15] British Standards (2007) *Code of Practice for the characterisation and remediation from ground gas in affected developments*. BS8485:2007

Based on current guidance a minimum of 6 visits are required for residential properties, undertaken over a two month period.

9.2.2 Material management

A preliminary assessment of the Made Ground for waste classification purposes indicates that the Made Ground across the majority of the site may be classified as 'not hazardous' with respect to waste disposal and may be disposed of in an inert or non-hazardous landfill, subject to confirmation by waste acceptance criteria (WAC) testing and agreement with the selected permitted facility.

Uncontaminated natural soils, as encountered at the site, can be disposed to an inert landfill as listed inert waste.

It should be noted that in May/June 2012 HMR&C issued Briefs 15/12 and 18/12 clarifying how construction spoil and excess soils will be assessed for landfill tax purposes. Detailed accurate descriptions of waste are required for all wastes to support the landfill tax assessment. Uncontaminated naturally occurring soils will remain inert by default and eligible for the lower rate of landfill tax. Similarly 'reworked soils' and demolition 'stone' comprising ONLY materials listed in the Schedule of the Landfill Tax (Qualifying Material) Order 2011 (SI 2011/1017) will also be eligible for the lower rate of landfill tax. However, Made Ground containing soil and foreign objects such as timber, plastic, rubber, metal, paper, plasterboard, asbestos, etc., regardless of the results of chemical analysis for waste classification purposes, will be eligible for the standard (higher) rate of landfill tax. Therefore, to maximise eligibility for lower rate landfill tax on waste construction spoil/ reworked ground, careful waste segregation and controls are necessary.

All material intended for offsite disposal should be transported and disposed in accordance with the Environmental Protection (Duty of Care) Regulations, 1991 and the Landfill (England and Wales) Regulations, 2002 (as amended). Waste legislation stipulates that hazardous and not hazardous waste should be pre-treated prior to disposal. Pre-treatment can be undertaken either at the site of origin or may be carried out at a licensed off-site facility and can include selective segregation of soils conducted on site.

The suitability of the impacted groundwater for discharge to the local sewer system should be confirmed with Thames Water prior to discharge. If discharge to the sewer is not permitted due to contaminant exceedances, the groundwater may require treatment or off-site disposal at an appropriate facility.

9.2.3 Buried services

Based on the measured concentrations of contaminates within the Made Ground, it is anticipated that PE or PVC pipes will be suitable for use at the site. However, it is recommended that the water supply company is contacted to confirm this recommendation is acceptable to them.

9.2.4 Health and safety

Precautions should be taken to minimise exposure of workers and the general public to any potentially harmful substances during earthworks.

The risks to construction workers can be controlled through the implementation of site safety procedures and the use of suitable personal protective equipment (PPE). Attention should also be paid to restricting possible off-site nuisance such as dust and odour emissions. All work should be carried out in accordance with the Contractor's Construction Health and Safety Plan.

Precautions will include but not be limited to:

- Personal hygiene, washing and changing procedures.
- Adequate personal protective equipment.
- Dust and vapour suppression methods, including damping down, minimising the working face exposed and covering stockpiles, where required.
- Regular cleaning of all site roads, access roads and the public highway.
- Safe storage of fuel and other potentially polluting liquids and the provision of spill control and clean up facilities.
- Positive collection and disposal of on-site run-off.

10. STAGE 4 - BASEMENT IMPACT ASSESSMENT

10.1 Conceptual site model

A conceptual site model (CSM), relating to potential ground movement, has been developed based on the available data. The CSM comprises a section (Figure 7) and a plan (Figure 8) indicating the basement construction and the location of neighbouring properties in relation to the proposed development.

The figures highlight the locations of the two critical sections through Nos. 30 and 34 Glenilla Road. These have been taken at the areas of the neighbouring properties closest to the proposed basement and are considered to represent 'worst-case' conditions.

10.2 Groundwater

Groundwater was encountered during the intrusive investigation and subsequent monitoring visit at between 1.88mbgl and 5.8mbgl (56mOD to 59.81mOD), within the Made Ground and upper parts of the London Clay Formation. It is anticipated that the groundwater encountered within the London Clay Formation is perched water within the claystone band and is not representative of a groundwater table. The claystone bands are located below the base of the proposed basement and groundwater ingress through these bands will therefore not impact the basement excavation.

The shallow perched water encountered in the Made Ground is likely to result in groundwater ingress into the basement excavation. However, given the limited groundwater, and poor recharge noted during the groundwater monitoring visit, it is anticipated that inflows during the basement excavation will be easily controlled in the with groundwater control measures such as sump pumping. For long-term design, a groundwater level of 1.5mbgl (60.3mOD) is recommended, based on the groundwater levels recorded during the groundwater monitoring visit.

As discussed in Section 6.2, the ground conditions encountered on site indicate that the historical *River Tyburn* does not flow through the site, as previously thought, based on historical information for the area.

It is understood that the neighbouring properties do not have basements and groundwater within the Made Ground will therefore be diverted around the proposed basement and the basement would therefore not be expected to obstruct groundwater flow or generate a rise in groundwater levels.

10.3 Land/slope stability

10.3.1 Introduction

This section provides calculations to determine ground movements that may result from the construction of the basement and to assess how these may affect the adjacent boundary walls and structures. It is assumed that a contiguous piled wall will be adopted to form the new basement walls, with the imposed loads from the proposed structures taken by the basement slab, which has been modelled as a raft.

Ground movements are derived from:

- Heave movements: The London Clay is susceptible to short term heave and time dependant swelling on unloading, which will occur as a result of lower ground floor excavation, generating upward ground movements.
- Long term ground movement: The net loading on formation soils will generate ground movement, which could affect adjacent foundations. This takes into account existing stress conditions, additional loads from the basement structure and the weight of soil removed.
- Piled wall installation: Ground disturbance during pile installation may cause ground settlement.
- Piled wall deflection: Deflection of the piled wall during excavation may cause settlement behind the wall, which could impact the neighbouring properties.

10.3.2 Ground movements arising from basement excavation

The soils at formation level will be subject to stress relief during excavation, as overburden is removed to form the basement. This is likely to give rise to a degree of elastic heave over the short term and potential heave or settlement over the longer term as pore pressures recover in the London Clay. The magnitude of these movements has been assessed using OASYS Limited *VDISP* (***V**ertical **DISP**lacement*) analysis software. *VDISP* assumes that the ground behaves as an elastic material under loading, with movements calculated based on the applied loads and the soil stiffness (E_u and E') for each stratum input.

The proposed development gives rise to a net unloading of the underlying strata, both during construction and over the long term, of some 20kPa. This value assumes that some 3.5m of soil will be removed during the basement excavation, at a typical bulk unit weight of 20kN/m^3 (i.e. a removed load of 70kPa), with an imposed load due to the proposed buildings of some 50kPa, acting across the raft. The combined effects of both the immediate undrained unloading and the long-term drained recovery of pore pressures have been analysed.

The maximum short term heave due to excavation to basement level is predicted to be of the order of 2.5mm, occurring in the central part of the excavation. This movement decreases to an average of 1.0mm of heave around the basement perimeter.

Maximum long term heave within the basement is predicted to be some 6.5mm in the central part of the excavation, decreasing to an average of 2.5mm of heave around the excavation perimeter.

Contour plots showing the variation of both short and long term heave for the whole basement are presented in Figure 9.

The result of the settlement analysis along the northwestern and southeastern boundary walls with Nos. 30 and 34 Glenilla Road, respectively are summarised in Table 17.

Table 17. Summary of underpin displacements

Location	Predicted vertical displacement[a] (mm)		
	Short term conditions	Long term conditions	Total displacement (mm)
No.30 Glenilla Road	-0.25	-1.0	-1.25
No.34 Glenilla Road	-0.5	-1.75	-2.25

a. A positive number denotes settlement and a negative number denotes heave

10.4 Ground movement due to retaining wall installation

With reference to CIRIA C580[16], vertical and horizontal surface movements due to installation of a contiguous piled wall are generally in the region of 0.04% of the wall depth, dissipating linearly with distance from the wall. However, assuming a 'hit and miss' piling method is adopted, in combination with an excellent standard of workmanship, the predicted amount of vertical and horizontal ground movement may be reduced to 0.02% of the wall depth. For the purpose of design, a value of 0.04% has been used in the analysis.

An indicative pile length of 10m has been assumed for use in the analysis. Maximum vertical and horizontal ground displacements due to installation of these piles is estimated to be approximately 4mm, occurring at the pile head during installation.

Detailed pile design should be undertaken by the piling contractor ultimately awarded the works.

10.5 Ground movement due to retaining wall deflection

10.5.1 Introduction

Analysis of the piled retaining wall has been undertaken using GeoSolve WALLAP embedded retaining wall analysis software. WALLAP provides soil/structure interaction analysis, modelling the soil as a series of springs to provide bending moments, shear forces, and deflections within a user defined structural element. Forces in the wall are derived from soil parameters, as set out in Section 6.5 of this report.

With regard to indicative wall displacements that may be expected during excavation, it should be noted that WALLAP uses a Winkler spring analysis to determine the wall displacements. In a Winkler medium, springs are used to represent a continuum and there is no transfer of shear stresses between the springs. In general, the application of this concept leads to an overestimation of structural deformations; hence the resulting wall displacements and corresponding impact on the nearby building and infrastructure may be over-predicted by the WALLAP program.

Full WALLAP output for the analysis can be provided upon request.

[16] CIRIA C580 (2003) *Embedded Retaining Walls – guidance for economic design*

10.5.2 WALLAP model assumptions

The WALLAP analysis assumes that:

- A contiguous piled wall of 450mm diameter at 600mm spacing will be installed to retain the soil during excavation.
- The piles will be bored to a minimum of 51.8mOD (10mbgl)

10.5.3 Piled wall WALLAP construction sequence

The proposed construction sequence for the critical cross section is summarised below;

1. Install contiguous piled retaining wall from ground level (61.8mOD);
2. Excavate to 61mOD and install temporary prop at 61.3mOD;
3. Excavate to 58.3mOD and cast basement slab at 58.55mOD and ground floor slab at 61.8mOD, removing the temporary prop at 61.3mOD;

10.5.4 Results of analysis

The result of the WALLAP analysis indicates a long-term deflection of some 2mm to 6mm along the Critical Sections, with the maximum deflection anticipated to occur between 55.2mOD and 59.0mOD. This deflection is dependent on the level of propping of the piled wall during the excavation. The contractor should ensure that sufficient props are installed to resist movements during excavation.

It should be noted that where the basement wall is required to carry vertical columns, the pile embedment will be governed by these loads. Final detailed pile design should be undertaken by the piling contractor.

10.6 Effect of trees

Existing trees are to be removed as part of the proposed development. With reference to the current NHBC guidance[17], and assuming that neighbouring buildings are founded a minimum of 1.0mbgl, it is considered that the proposed removal of trees as part of the development will not have an adverse effect on neighbouring properties.

[17] NHBC (2013) *Standards 2013: 4.2 Building near trees.*

11. STAGE 4 - DAMAGE CATEGORY ASSESSMENT

11.1 Introduction

The calculated ground movements have been used to assess potential 'damage categories' that may apply to neighbouring properties due to the proposed lower ground floor construction. The methodology proposed by Burland and Wroth[18] and later supplemented by the work of Boscardin and Cording[19] has been used, as described in *CIRIA Special Publication 200*[20] and *CIRIA C580*[21].

General damage categories are summarised in Table 18 below:

Table 18. Classification of damage visible to walls (reproduction of Table 2.5, CIRIA C580)

Category	Description
0 (Negligible)	Negligible – hairline cracks
1 (Very slight)	Fine cracks that can easily be treated during normal decoration (crack width <1mm)
2 (Slight)	Cracks easily filled, redecoration probably required. Some repointing may be required externally (crack width <5mm).
3 (Moderate)	The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced (crack width 5 to 15mm or a number of cracks > 3mm).
4 (Severe)	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows (crack width 15mm to 25mm but also depends on number of cracks).
5 (Very Severe)	This requires a major repair involving partial or complete re-building (crack width usually >25mm but depends on number of cracks).

[18] Burland, J.B., and Wroth, C.P. (1974). *Settlement of buildings and associated damage*, State of the art review. Conf on Settlement of Structures, Cambridge, Pentech Press, London, pp611-654

[19] Boscardin, M.D., and Cording, E.G., (1989). *Building response to excavation induced settlement*. J Geotech Eng, ASCE, 115 (1); pp 1-21.

[20] Burland, Standing J.R., and Jardine F.M. (eds) (2001), *Building response to tunnelling, case studies from construction of the Jubilee Line Extension London*, CIRIA Special Publication 200.

[21] CIRIA C580 (2003) *Embedded Retaining Walls – guidance for economic design*

11.2 Damage assessment of boundary walls

The results of the predicted ground movement below Nos. 30 and 34 Glenilla Road due to the proposed basement development have been compiled to determine the overall lateral deflection and vertical deflection of the structure.

Figure 10 shows the combined lateral movement of the piled wall due to pile installation and deflection adjacent to both Nos. 30 and 34 Glenilla Road. The maximum deflection of the piled wall is predicted to be some 6mm and the corresponding ground settlement is predicted to be a maximum of 3mm, occurring between 3m and 6m from the piled wall.

The maximum deflection ratio and horizontal strain of the neighbouring boundary walls of Nos. 30 and 34 Glenilla Road, as derived from the ground movement assessment, are summarised in Table 19.

The methods for calculating the deflection ratios for the boundary walls are presented graphically in Figure 11 and Figure 12. The deflection ratio is calculated by combining the ground movement profiles from heave due to excavation and settlement due to pile installation.

Table 19. Summary of ground movements and corresponding damage category

Critical Section	Predicted horizontal movement at level of foundation (mm)	Calculated Maximum deflection (mm)	Horizontal Strain ε_h (%)	Deflection ratio Δ/L (%)	Damage category
No.30 Glenilla Road	4.0	1.7	0.04	0.017	Category 0 (Negligible damage)
No.34 Glenilla Road	3.0	3.0	0.029	0.029	Category 0 (Negligible damage

The results of the ground movement assessment indicate that the predicted damage category imposed on the neighbouring properties due to the proposed development, assuming a good standard of workmanship controlling the horizontal and vertical displacements, can be controlled to within Category 0, corresponding to 'negligible' damage.

The building interaction chart is presented as Figure 13.

12. STAGE 4 - SUBTERRANEAN (GROUNDWATER) FLOW

12.1 Introduction

This section provides a qualitative assessment of the effect the basement will have on the local hydrogeological regime and whether this will affect adjacent properties.

12.2 Groundwater conditions

During the intrusive investigation and subsequent monitoring visit, groundwater was encountered at between 1.88mbgl and 5.8mbgl (56mOD to 59.81mOD), within the Made Ground and upper parts of the London Clay Formation. It is anticipated that the groundwater encountered within the London Clay Formation is perched water within the claystone band and is not representative of a groundwater table.

12.3 Impact on local groundwater conditions

Based on the available information, the single groundwater monitoring visit and CGL's experience of groundwater conditions in the area, groundwater is likely to be perched water and the basement formation level is therefore unlikely to be constructed below a consistent groundwater table. Because of a lack of regional groundwater, the basement would not be expected to obstruct groundwater flow or generate a rise in groundwater levels.

12.4 Recommendations for groundwater control

Given that perched groundwater is likely to be encountered in the Made Ground during excavation of the basement, provision of groundwater control measures should be allowed for in order to maintain excavation stability. Sump pumping may be utilised in the initial stages of the excavation (i.e. during construction of the party wall underpins) until the contiguous piled wall is installed around the perimeter of the site. Observations on groundwater should be carefully recorded during excavation and appropriate mitigation strategies put in place in case of previously unidentified significant inflows.

13. STAGE 4 - MONITORING STRATEGY

The results of the ground movement analysis suggest that with good construction control, damage to adjacent boundary walls generated by the assumed construction methods and sequence are likely to not exceed Category 0 (negligible). A formal monitoring strategy should be implemented on site in order to observe and control ground movements during construction, and in particular movements of the adjacent properties.

The system should operate broadly in accordance with the 'Observational Method' as defined in CIRIA Report 185[22]. Monitoring can be undertaken by installing survey targets to the top of the wall and face of the adjacent buildings. Baseline values should be established prior to commencement of works. Monitoring of these targets should be carried out at regular time intervals and the results should be analysed to determine if any horizontal translation of the wall or tilt/settlement of the neighbouring walls is occurring. Regular monitoring of these targets will allow ground movement trends to be detected in a timely manner such that mitigation strategies may be implemented if required.

Monitoring data should be checked against predefined trigger limits and reviewed regularly to assess and manage the damage category of the adjacent buildings as construction progresses.

It is recommended that a condition survey is undertaken on all adjacent walls and property facades prior to the works commencing and ideally when monitoring baseline values are established. Existing cracks or structural defects should be carefully recorded, documented and regularly inspected as construction progresses.

[22] Nicholson, D., Tse, Che-Ming., Penny, C., The Observational Method in ground engineering: principles and applications, CIRIA report R185, 1999.

14. CONCLUSIONS AND RECOMMENDATIONS

14.1 Conclusions of basement impact analysis

The findings of this report are informed by site investigation data and information regarding construction methods, sequence and loading provided by the Structural Engineer. The analysis is undertaken on the assumption of high quality workmanship during the construction of the basement.

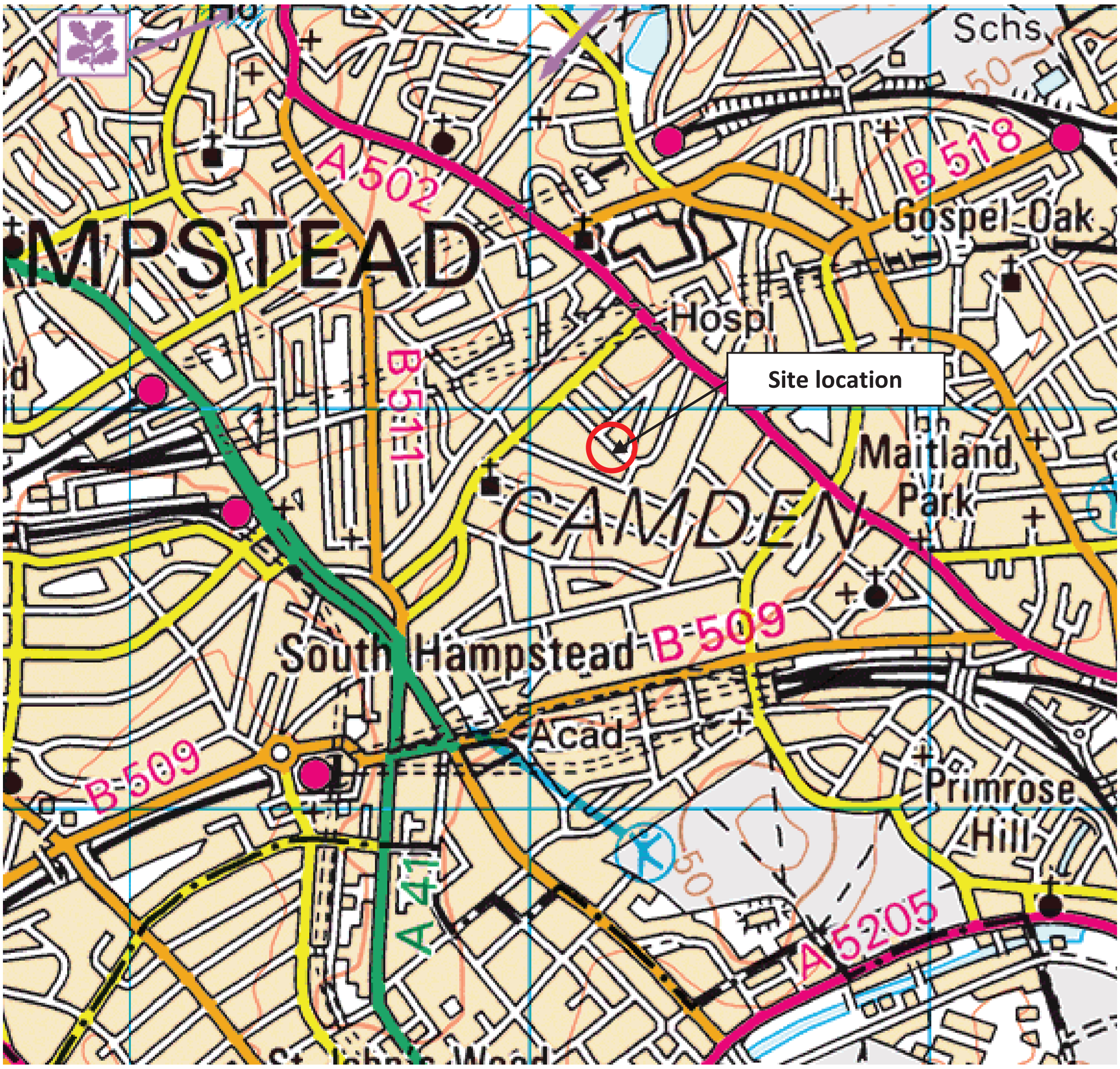
The construction of the basements will generate ground movements due to a variety of causes including heave, settlement, pile construction and piled wall deflection during and after excavation. Calculations indicate that these will give rise to a damage category within 'Category 0' ('negligible) for the adjacent properties of Nos. 30 and 34 Glenilla Road. The above assumes a good standard of workmanship during construction.

It is recommended that a condition survey is undertaken and an appropriate monitoring regime is adopted to manage risk and potential damage to the neighbouring structures as construction progresses onsite.

The remaining neighbouring buildings and infrastructure surrounding the site are sufficiently distant from the basement development to not be considered to be susceptible to ground movements due to pile installation, deflection and heave due to excavation, assuming a typical 45^{o} load spread from the proposed development.

Groundwater was encountered during the site investigation within the Made Ground and in claystone bands or bands of silty sand within the London Clay Formation. It is anticipated that groundwater within the Made Ground will be diverted around the basement and will continue to flow downslope towards the historical *River Tyburn*. The claystone bands and bands of silty sand within the London Clay Formation and not consistent across the site and groundwater within these bands may be considered to be isolated and not representative of a groundwater table. The impact of the proposed basement on this water is therefore considered to be negligible.

FIGURES



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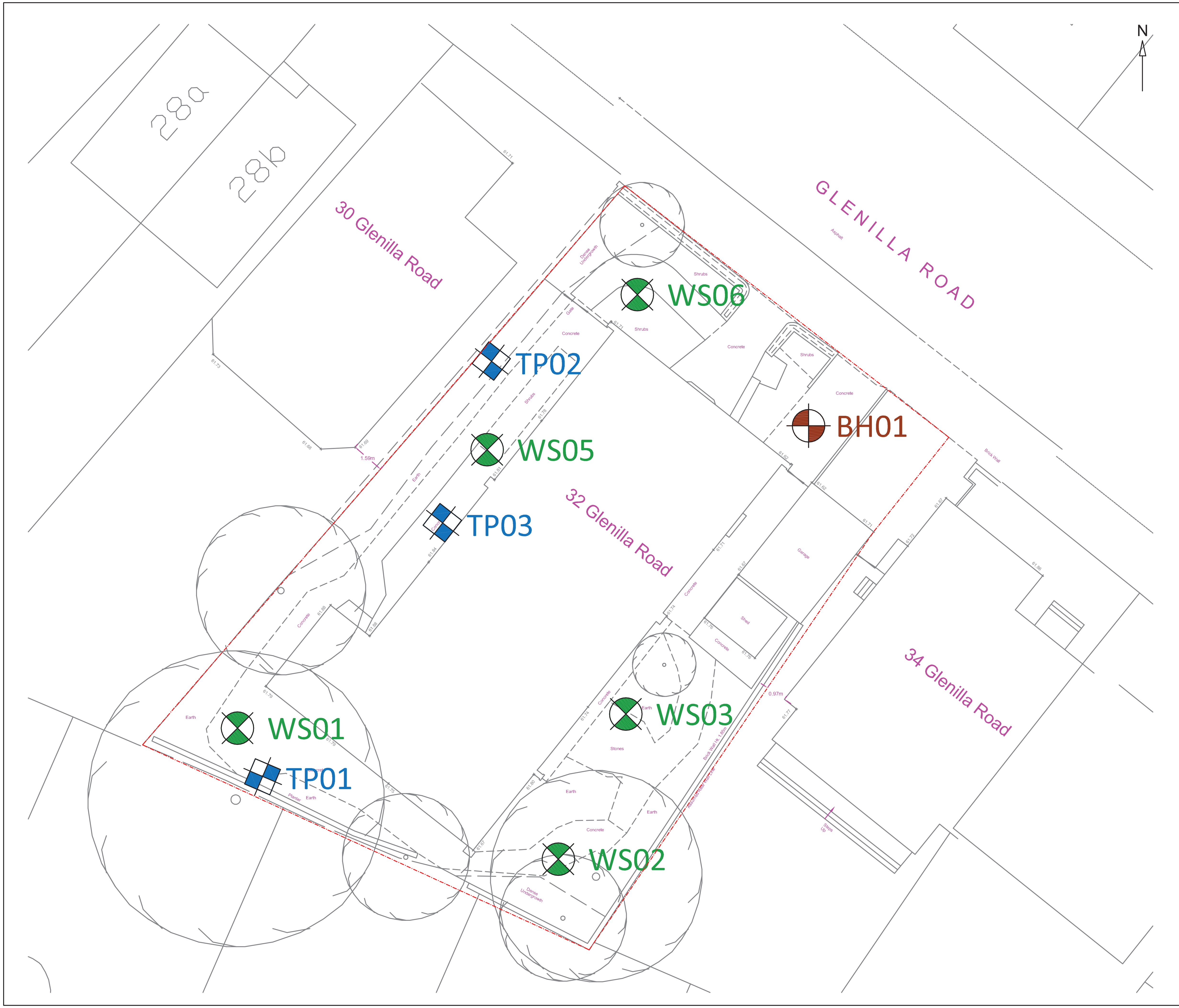
N

Client	Project	Job No
Mr & Mrs Gausen and Mr de Botton	32 Glenilla Road, London	CG/18516
CGL	Title Site location plan	Figure 1



KEY

BH01	Borehole
WS01	Window Sample
TP01	Trial Pit

Rev	Date	Comments
*	*	*

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4 Godalming Business Centre
Woolsack Way
Godalming
Surrey
GU7 1XW
T: 01483 310600

Project: **32 Glenilla Road, London**

Client: **Mr & Mrs Gausen and Mr de Botton**

Drawing title: **Site layout and exploratory hole location plan**

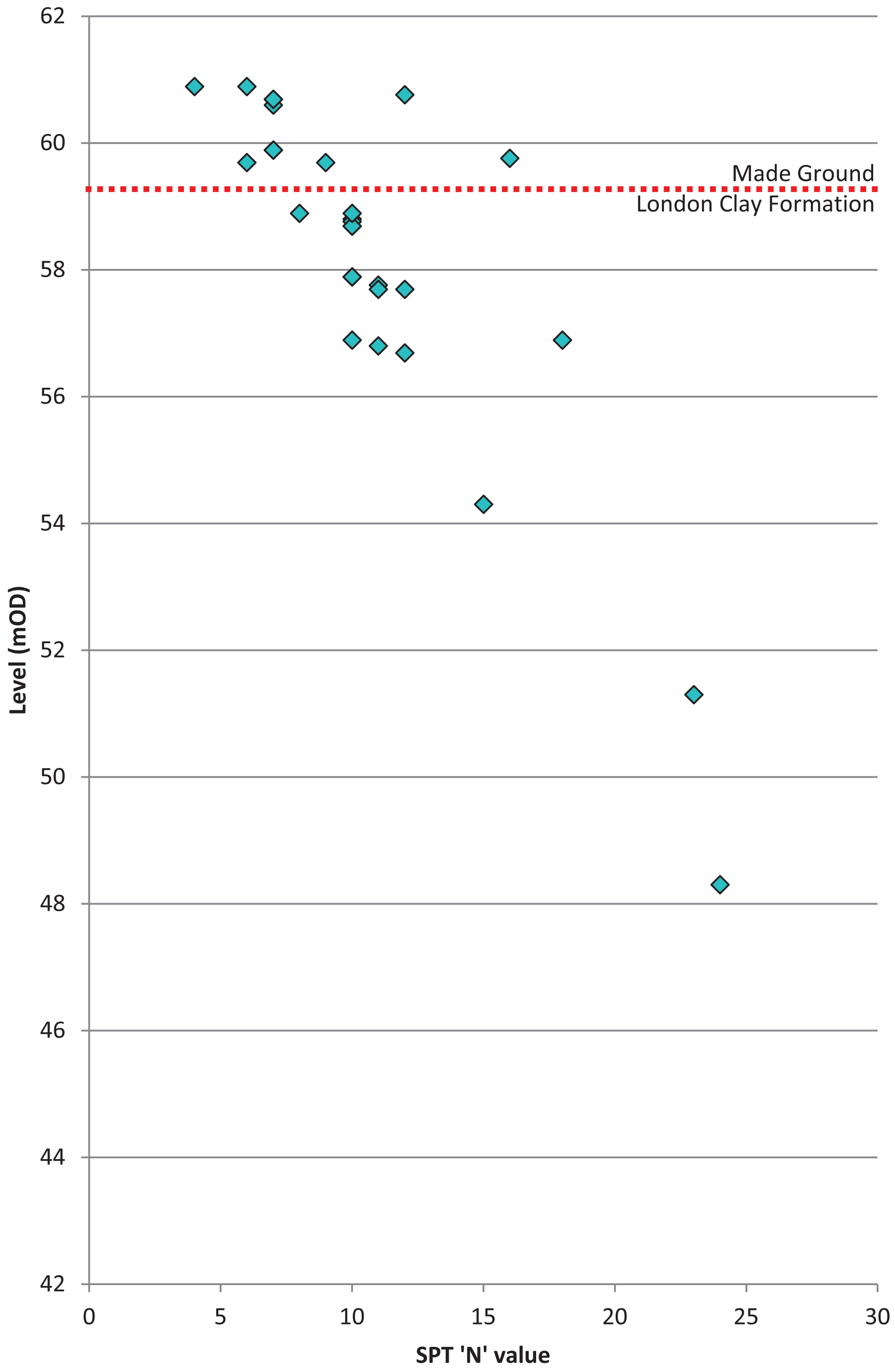
Scale(s): **NTS**

Job No.: **CG/18516**

Drawn	JJM	05/10/15
Checked	RJB	15/10/15
Approved	IMM	20/10/15

Dwg No.: **Figure 2**

Rev.: *



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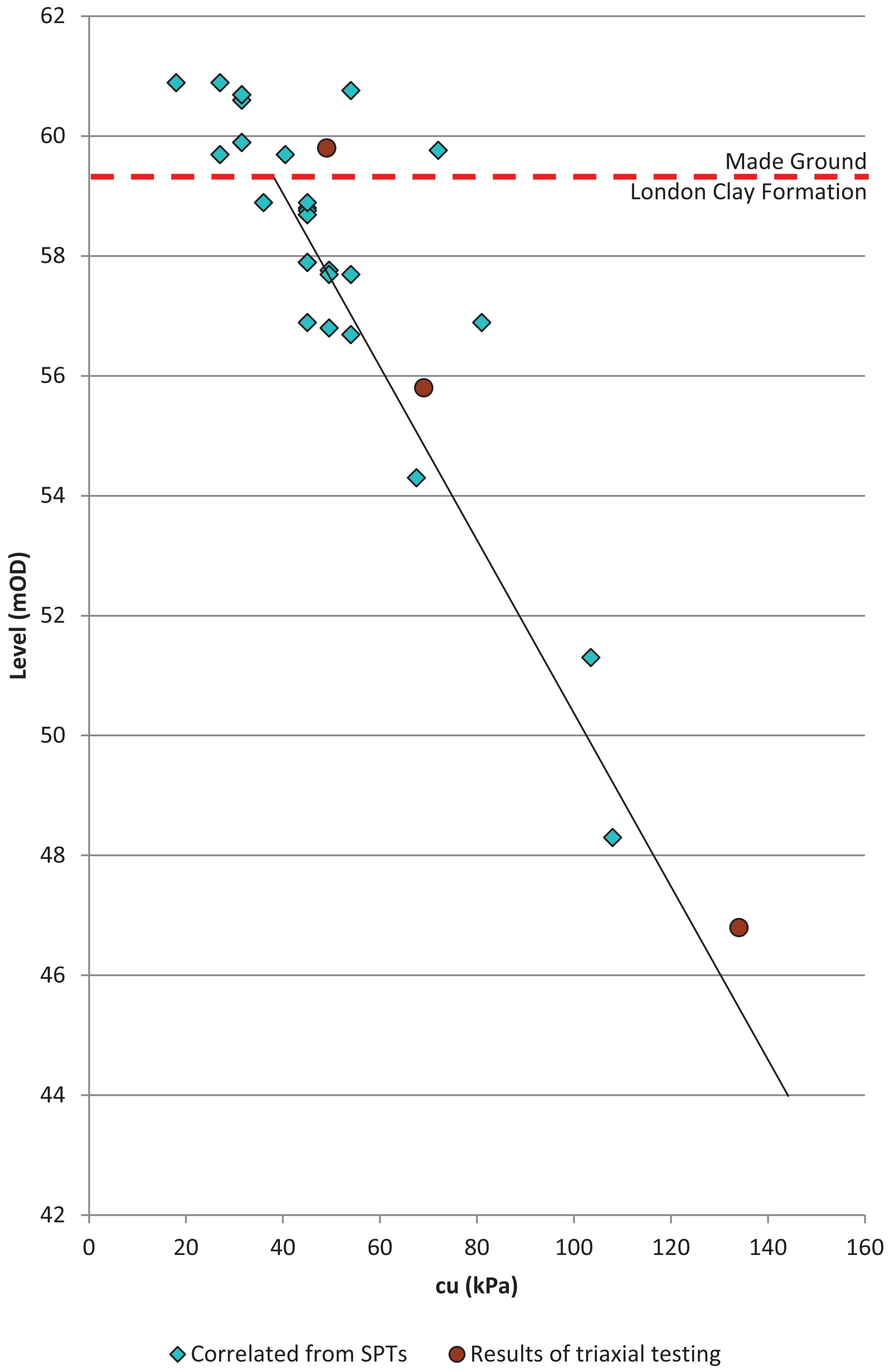
Mr & Mrs Gausen and Mr de Botton	32 Glenilla Road, London	CG/18516
CGL	Title Plot of SPT 'N' value against level	Figure 3

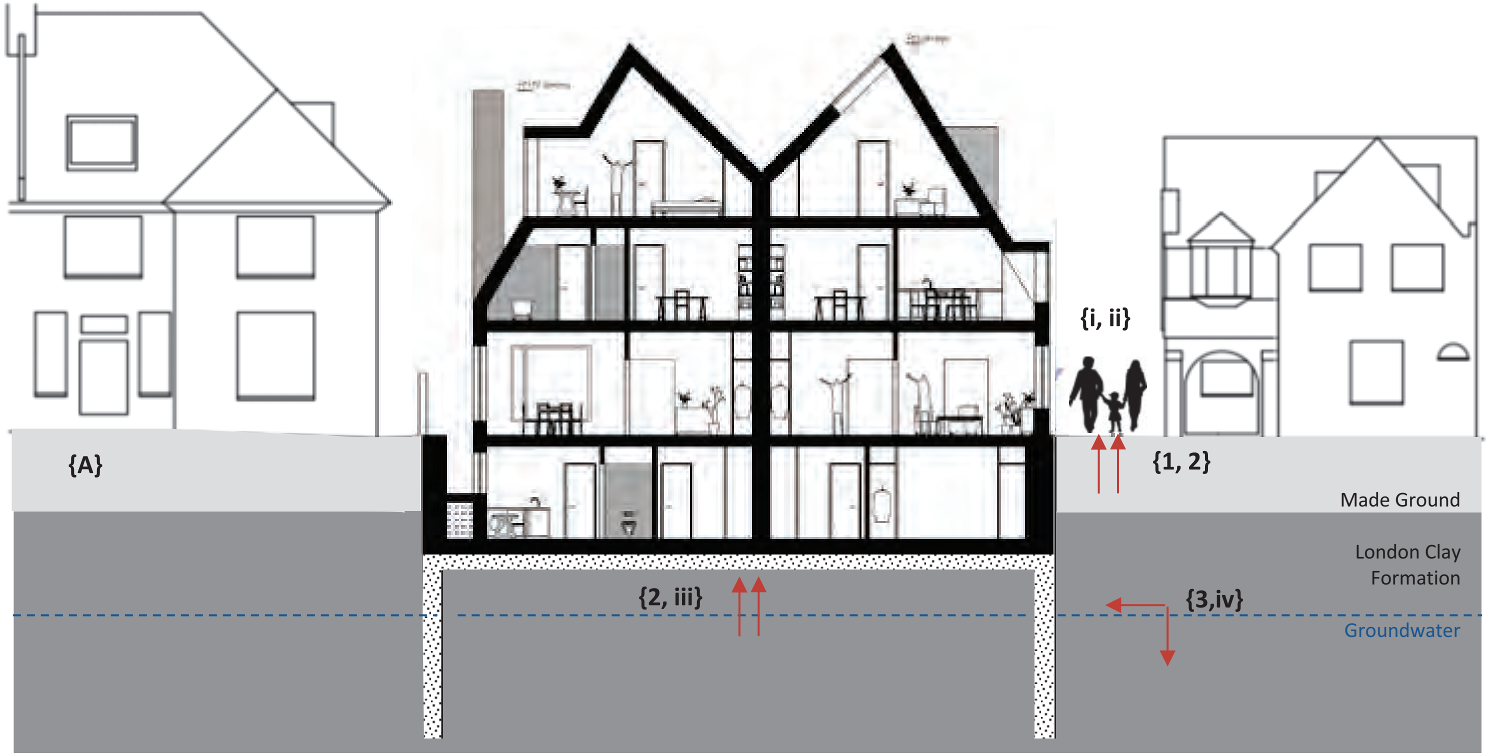


Client	Project	Job No
Mr & Mrs Gausen and Mr de Botton	**32 Glenilla Road, London**	**CG/18516**
CGL	Title **Plot of c_u against level**	**Figure 4**

Sources
A. Contamination and ground gas within Made Ground

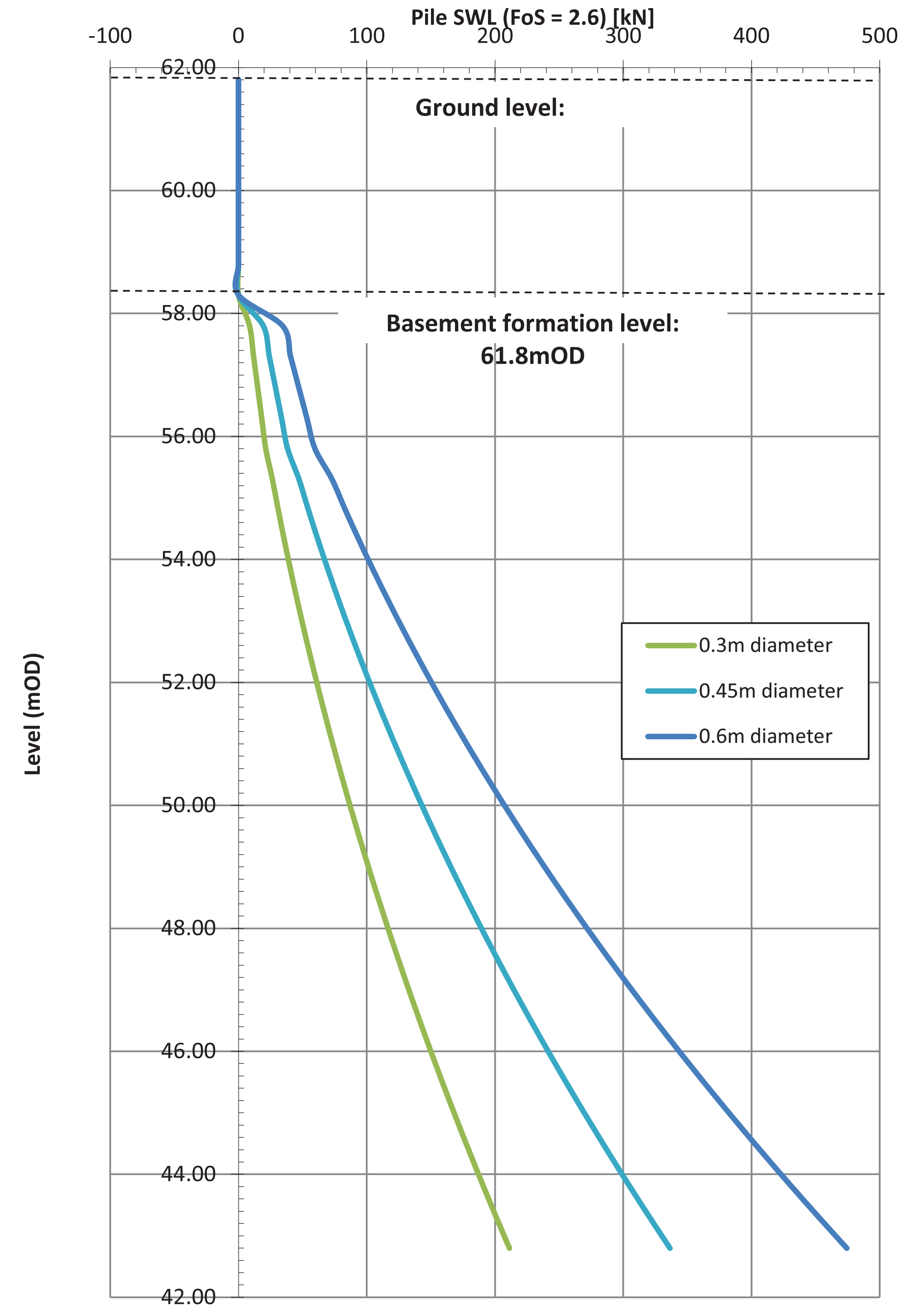
Pathways
1. Ingestion or inhalation
2. Direct contact
3. Vertical and lateral migration

Receptors
i. Current and future site occupants
ii. Construction workers
iii. Current and future buildings and services
iv. Groundwater

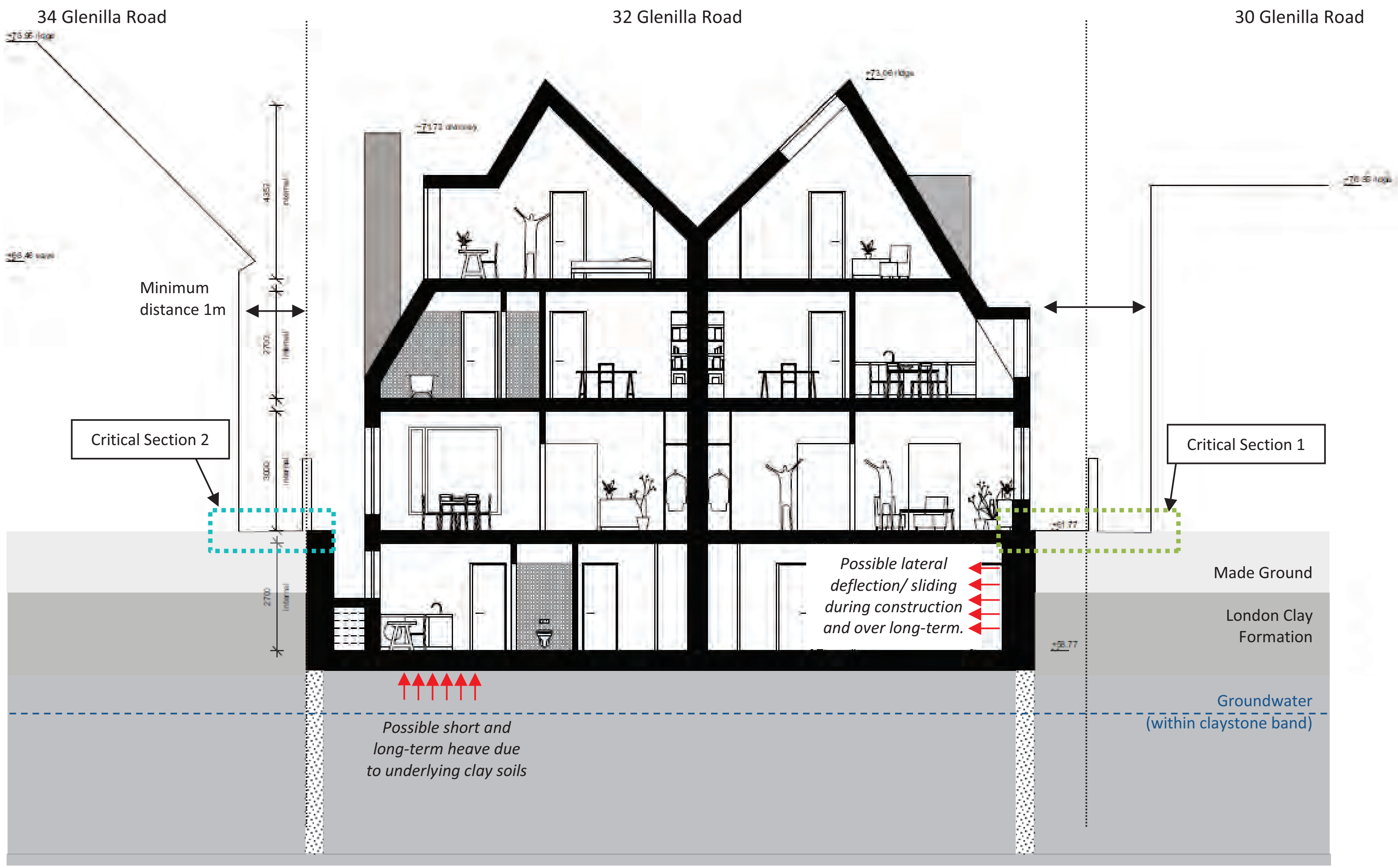


N
Not to scale

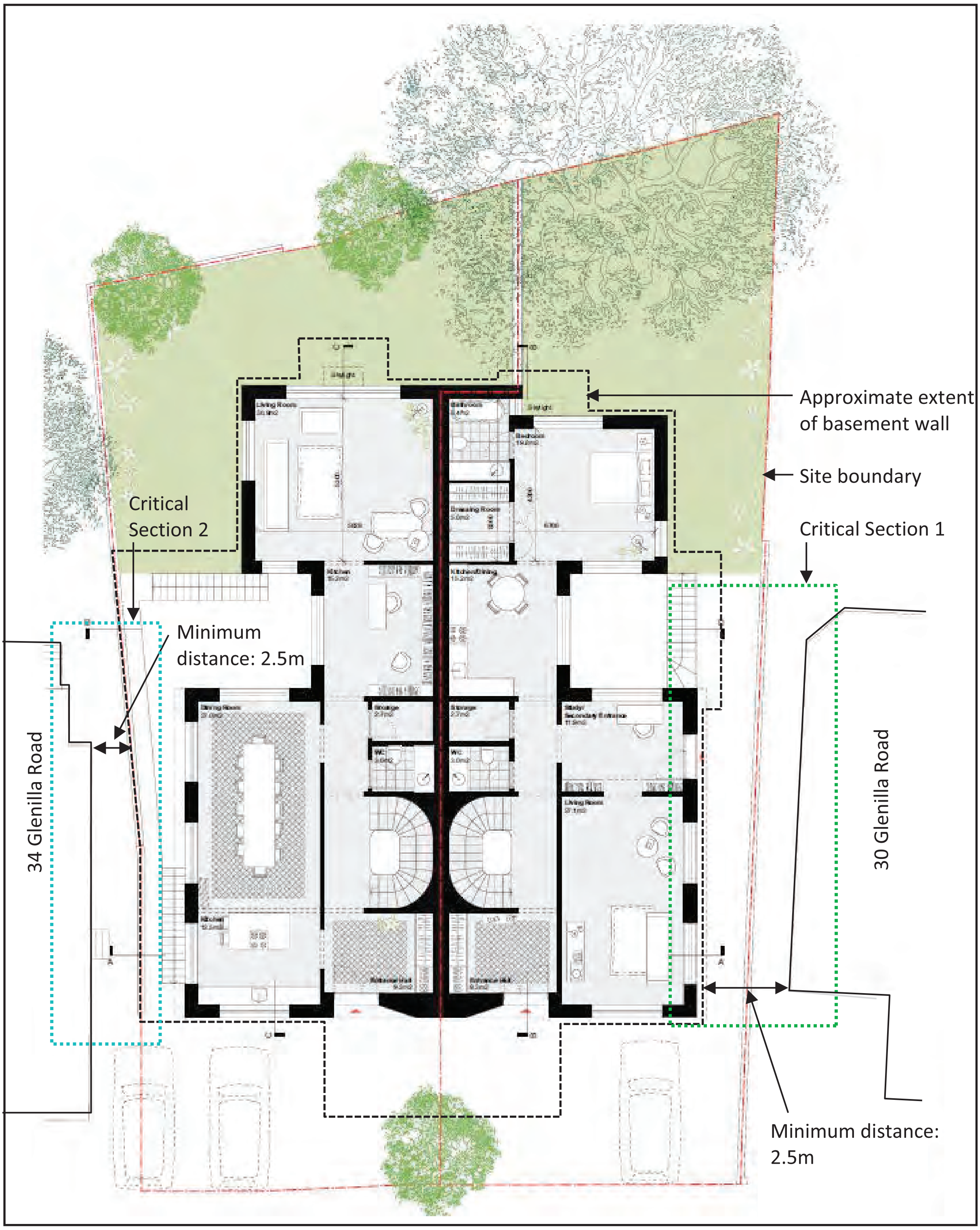
Client	Project	Job No
Mr & Mrs Gausen and Mr de Botton	**32 Glenilla Road, London**	**CG/18516**
CGL	Title **Conceptual site model – contamination risk assessment**	**Figure 5**



Client	Project	Job No
Mr & Mrs Gausen and Mr de Botton	**32 Glenilla Road, London**	**CG/18516**
CGL	Title **Pile SWL vs. Toe Level**	**Figure 6**

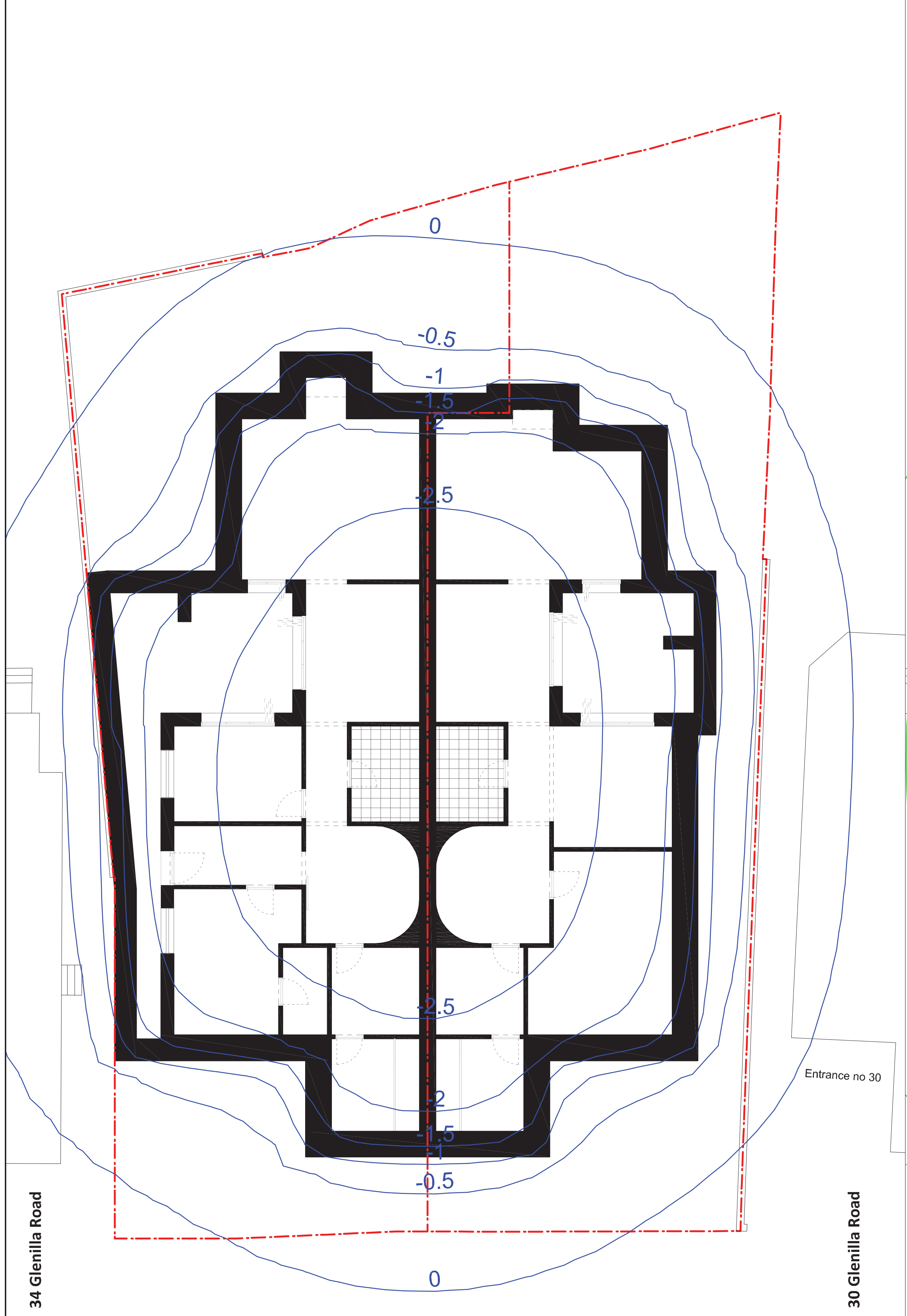


Client	Project	Job No
Mr & Mrs Gausen and Mr de Botton	**32 Glenilla Road, London**	**CG/18516**
CGL	Title: **Conceptual site model (section) – basement impact assessment**	**Figure 7**

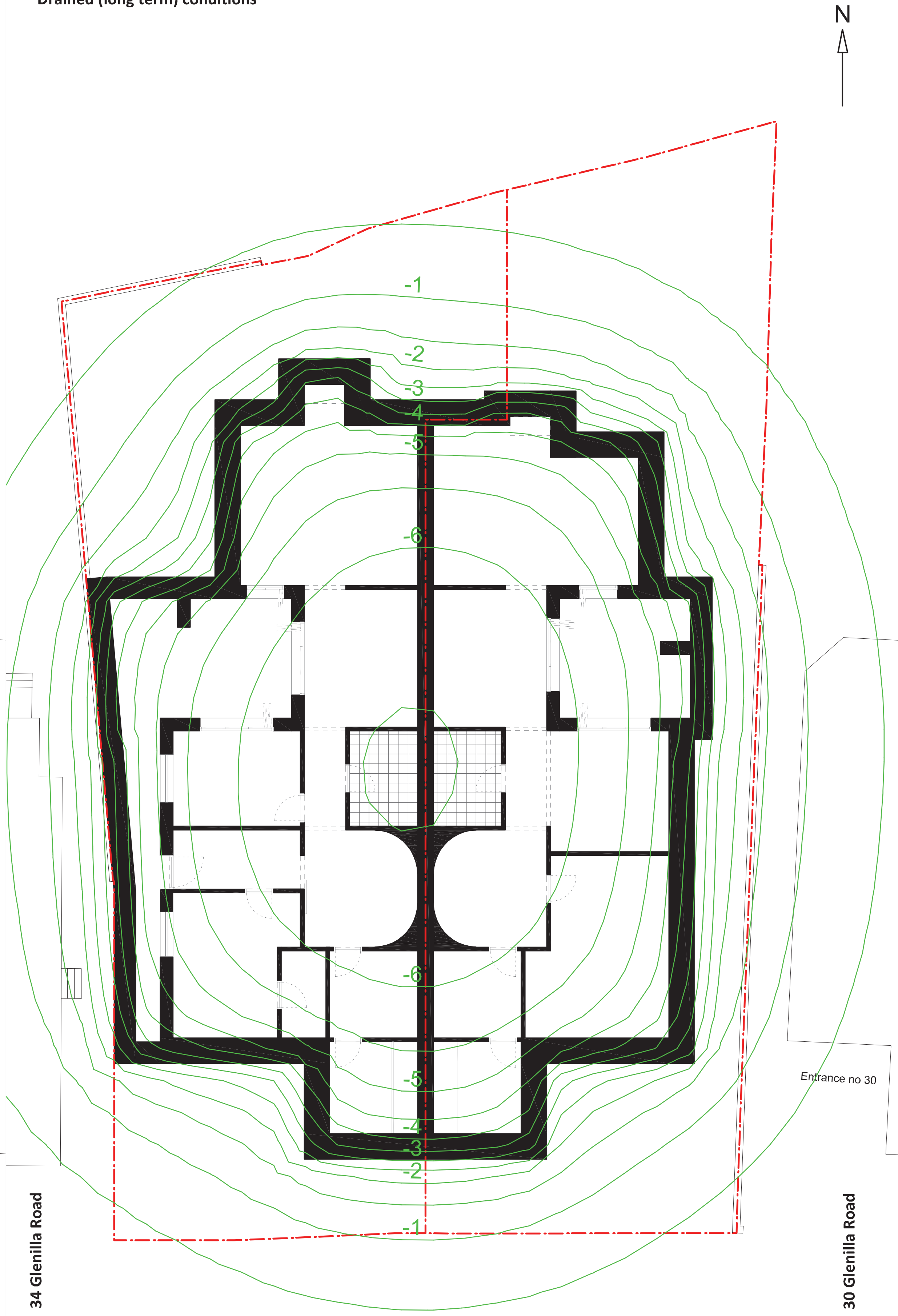


Client	Project	Job No
Mr & Mrs Gausen and Mr de Botton	32 Glenilla Road, London	CG/18516
CGL	Title: Conceptual site model (plan view)	Figure 8

Undrained (short term) conditions



Drained (long term) conditions



KEY

Rev	Date	Comments
*	*	*

Card Geotechnics Ltd
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Godalming
Surrey
GU7 1XW
T: 01483 310600

Project: **30 Glenilla Road, London**

Client: **Mr & Mrs Gausen and Mr de Botton**

Drawing title: **Contour plots of vertical displacements**

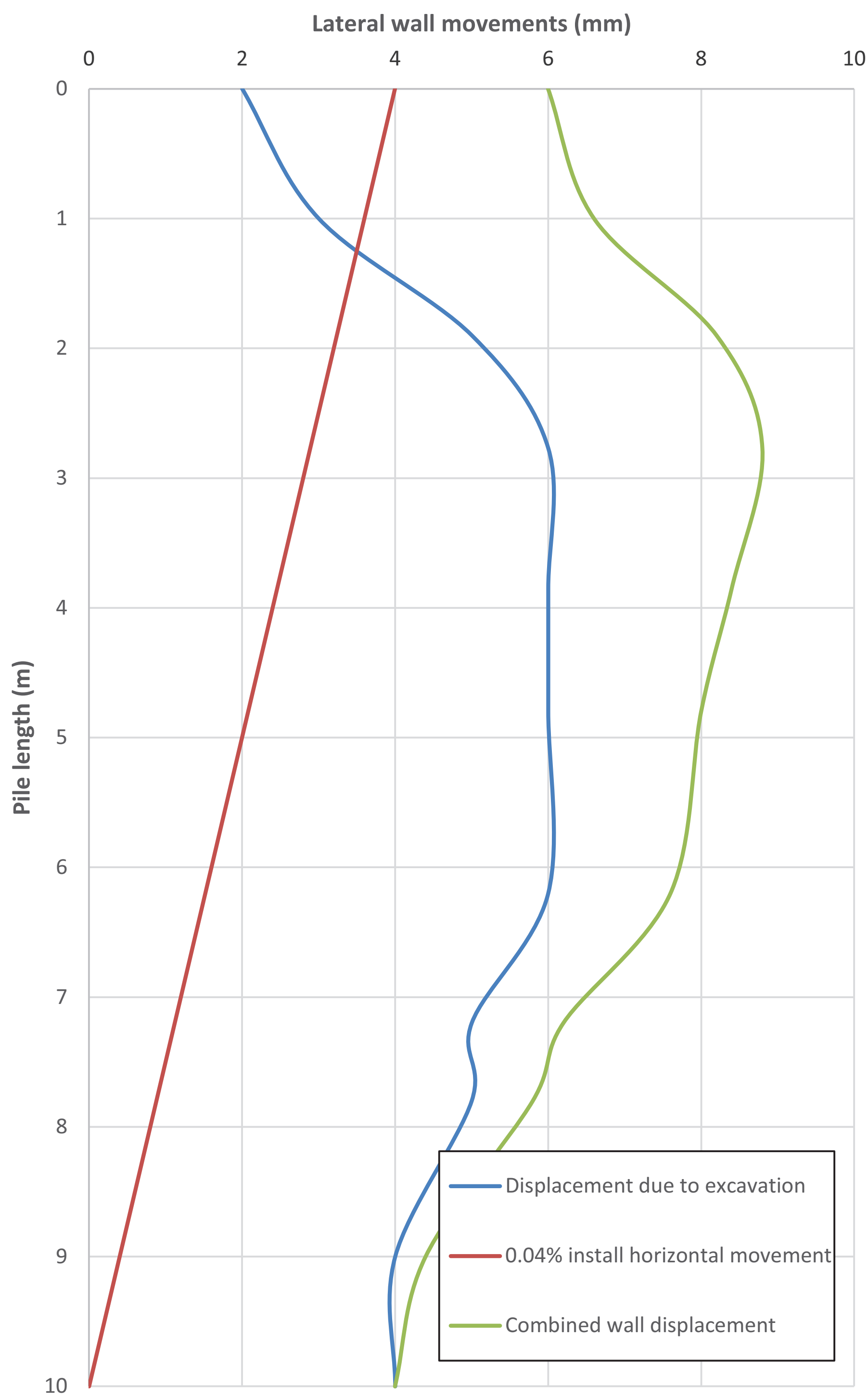
Scale(s): **NTS**

Job No.: **CG/18516**

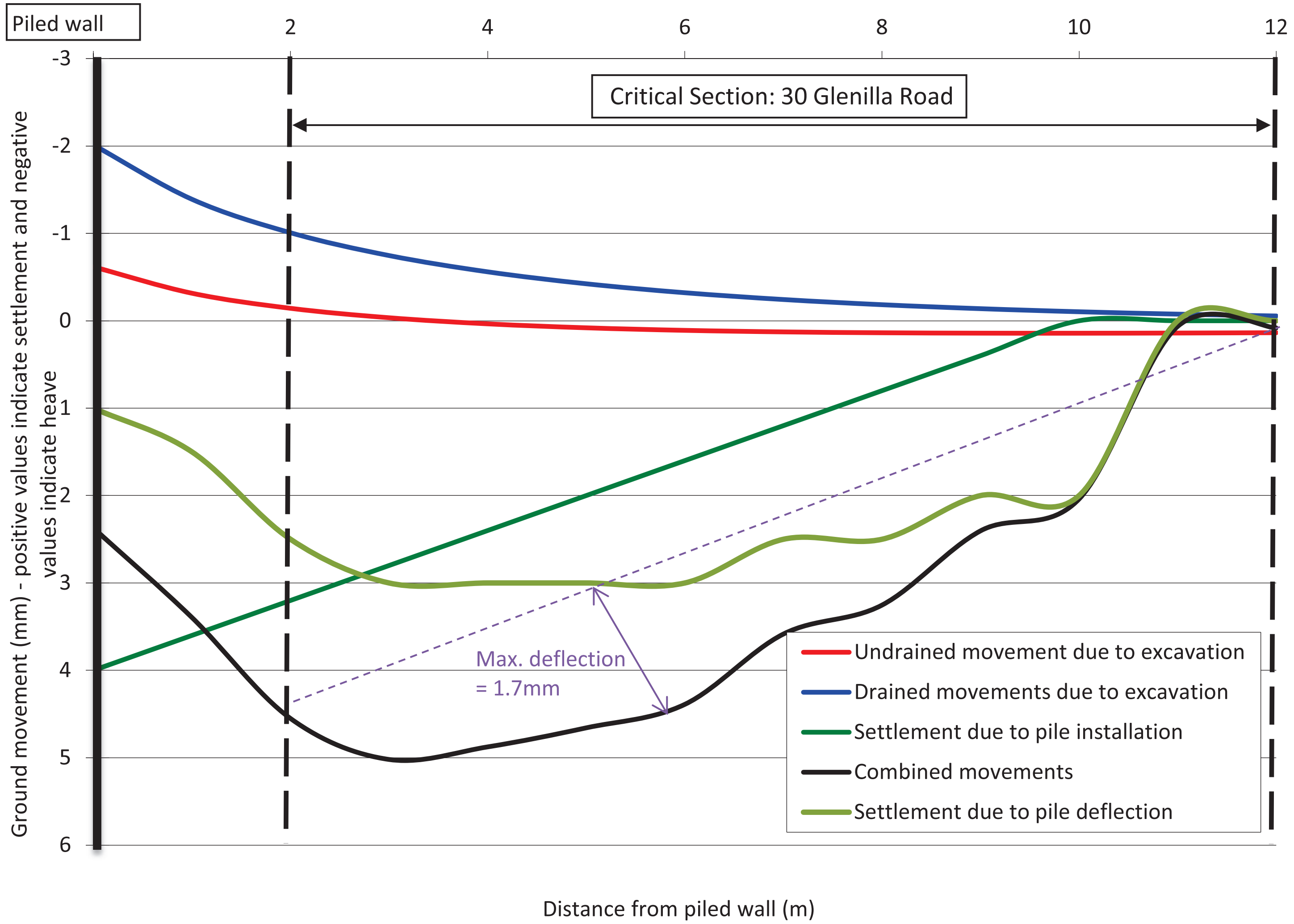
Drawn: JJM 15/11/16
Checked:
Approved:

Dwg No.: **Figure 9**

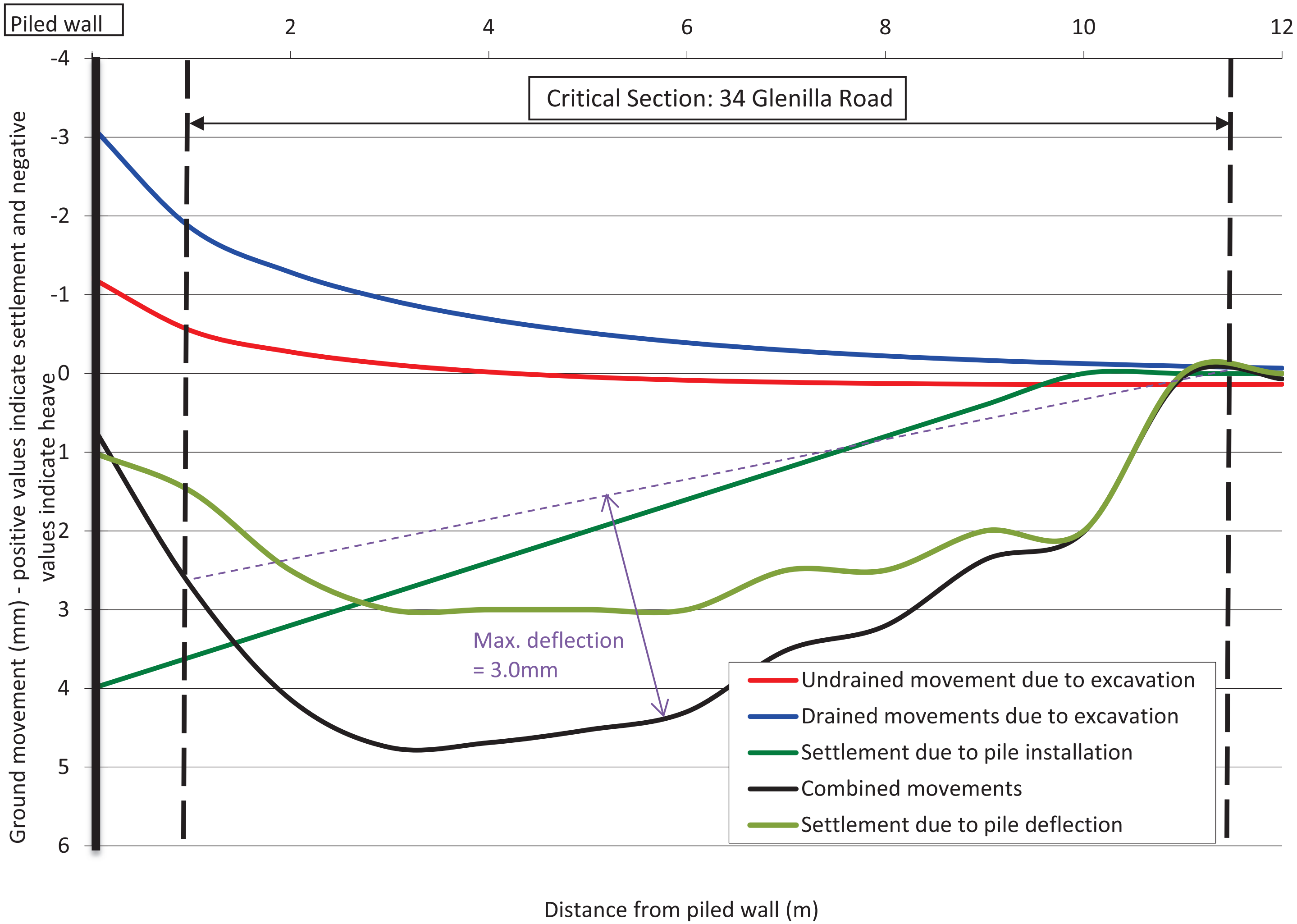
Rev.: *



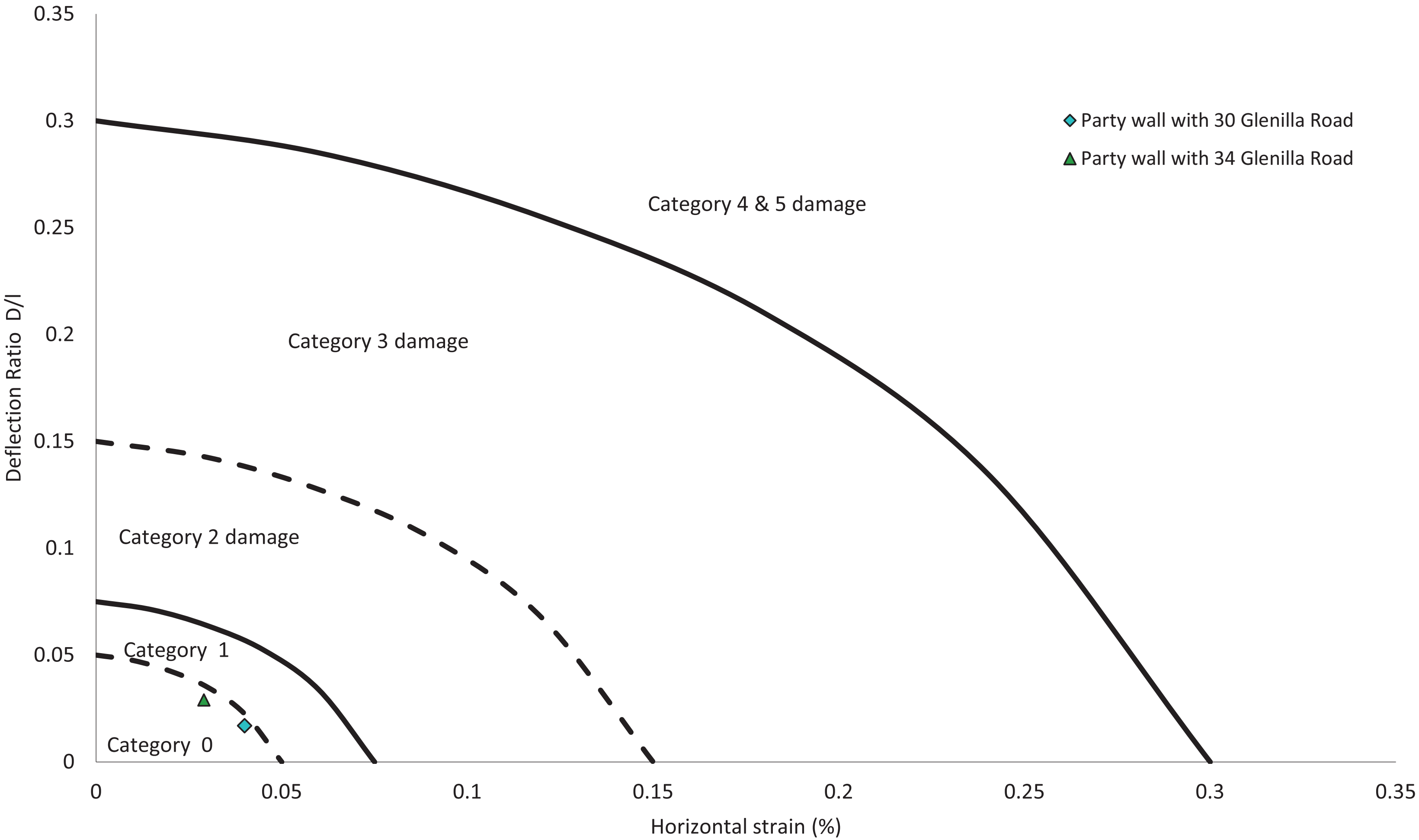
Client	Project	Job No
Mr & Mrs Gausen and Mr de Botton	**32 Glenilla Road, London**	**CG/18516**
CGL	Title **Combined lateral ground movements**	**Figure 10**



Client	Project	Job No
Mr & Mrs Gausen and Mr de Botten	**32 Glenilla Road, London**	**CG/18516**
CGL	Title **Combined vertical ground movements – 30 Glenilla Road**	**Figure 11**



Client	Project	Job No
Mr & Mrs Gausen and Mr de Botton	**32 Glenilla Road, London**	**CG/18516**
CGL	Title **Combined vertical ground movements – 34 Glenilla Road**	**Figure 12**



Client	Project	Job No
Mr & Mrs Gausen and Mr de Botton	**32 Glenilla Road, London**	**CG/18516**
CGL	Title **Building interaction chart**	**Figure 13**

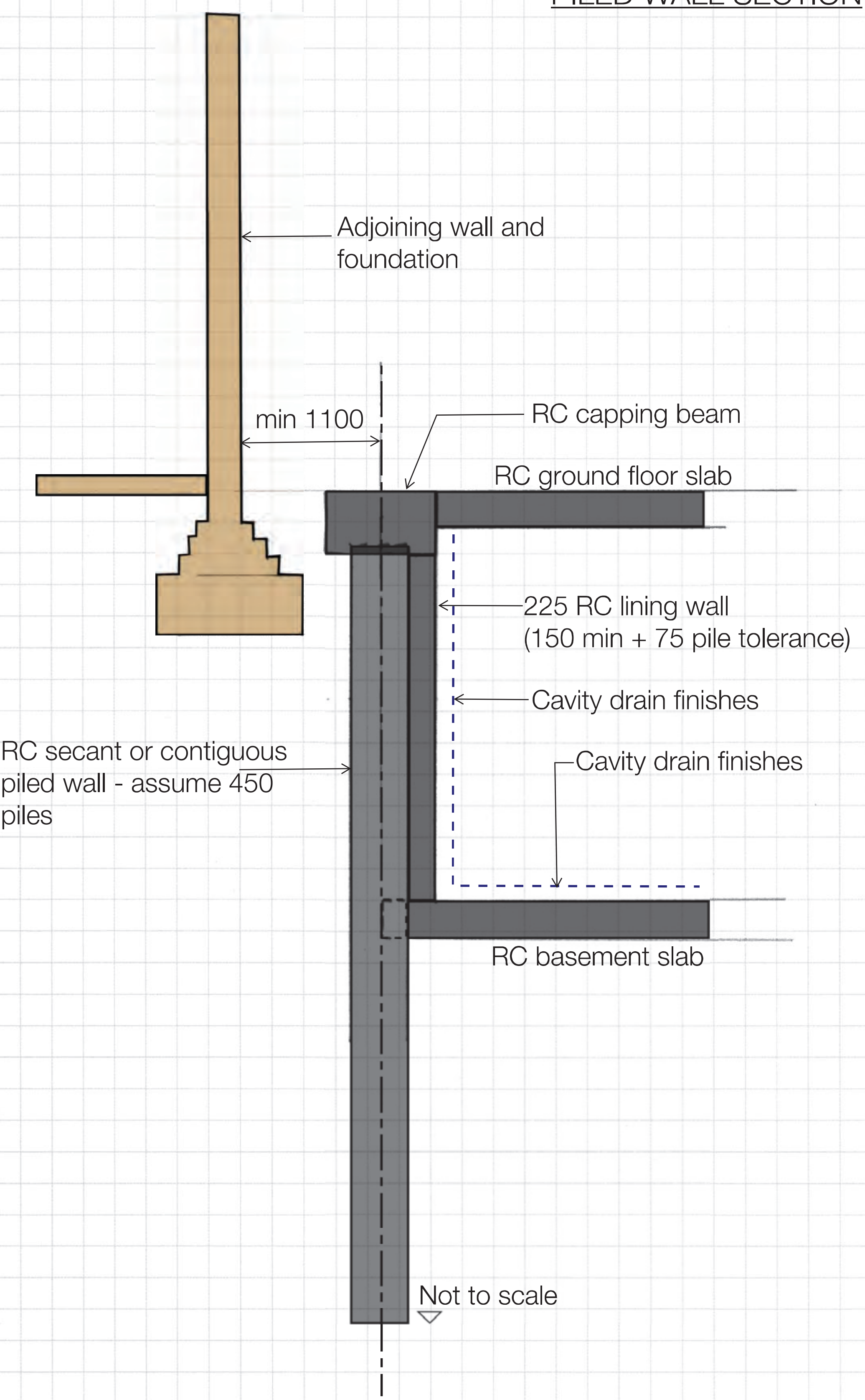
APPENDIX A

Information from the Structural Engineer

PRICE&MYERS
Consulting Engineers

Job No	24357	Page	SK1	Rev	1
Date	07/15	Eng	JH	Chd	
Job	Glenilla Road				

PILED WALL SECTION



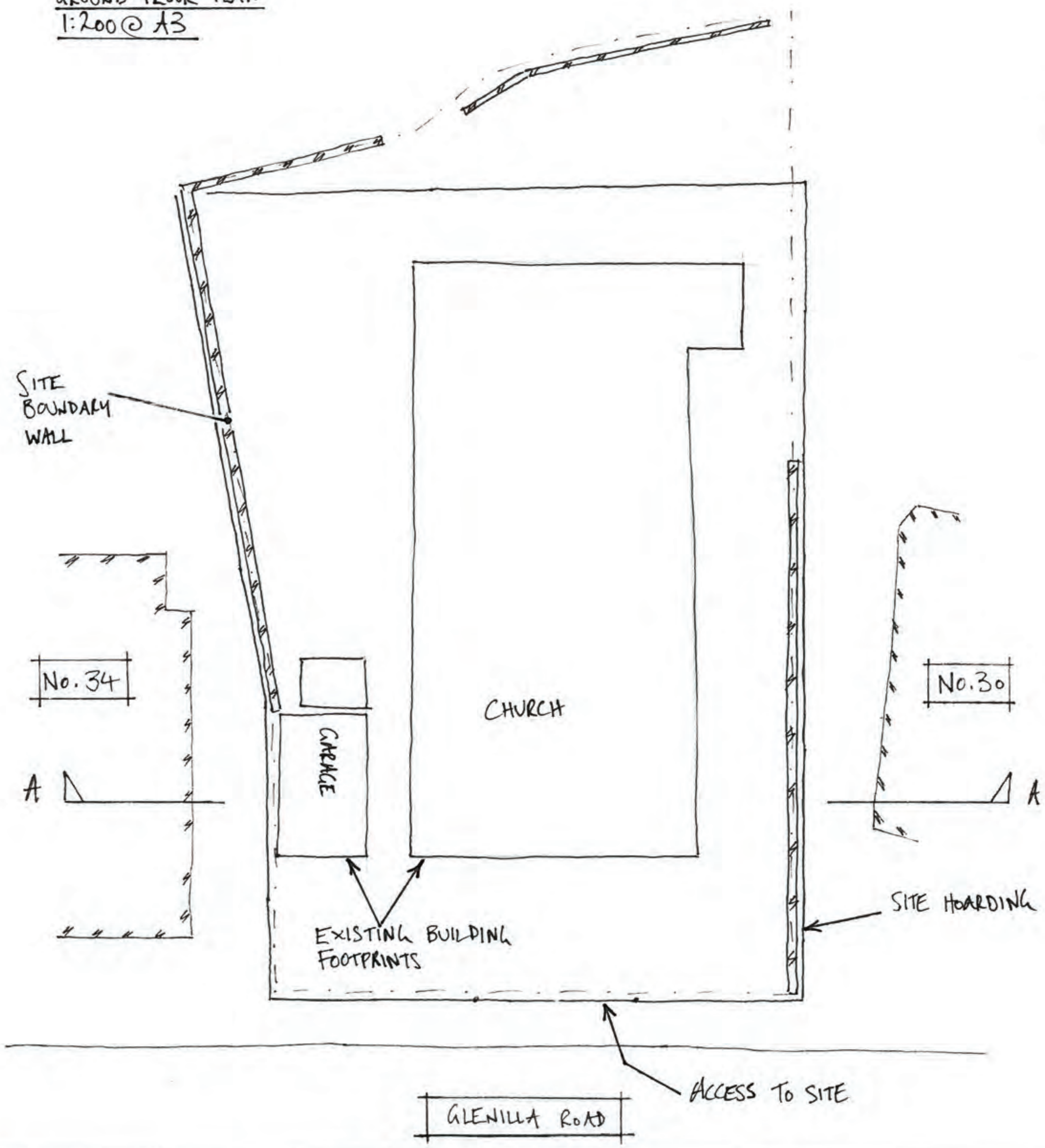
PRICE & MYERS
Consulting Engineers

ASSUMED CONSTRUCTION SEQUENCE.

Job No 24357 Page Sk006 Rev
Date 17.11.16 Eng DF Chd JE
Job 32, GLENILLA ROAD, NW3

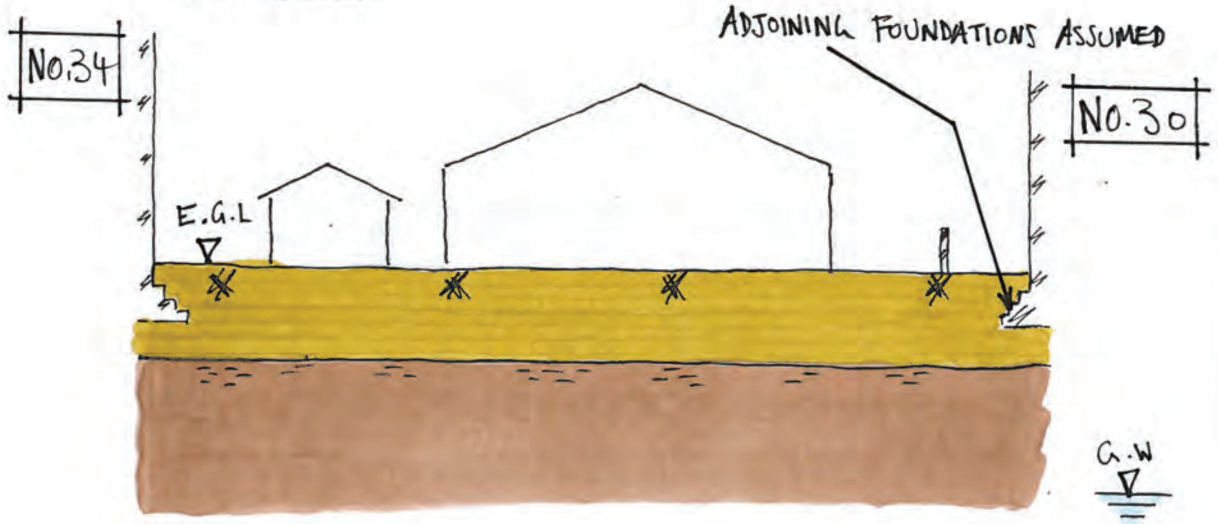
1.
EXISTING SITE LAYOUT

GROUND FLOOR PLAN
1:200 @ A3



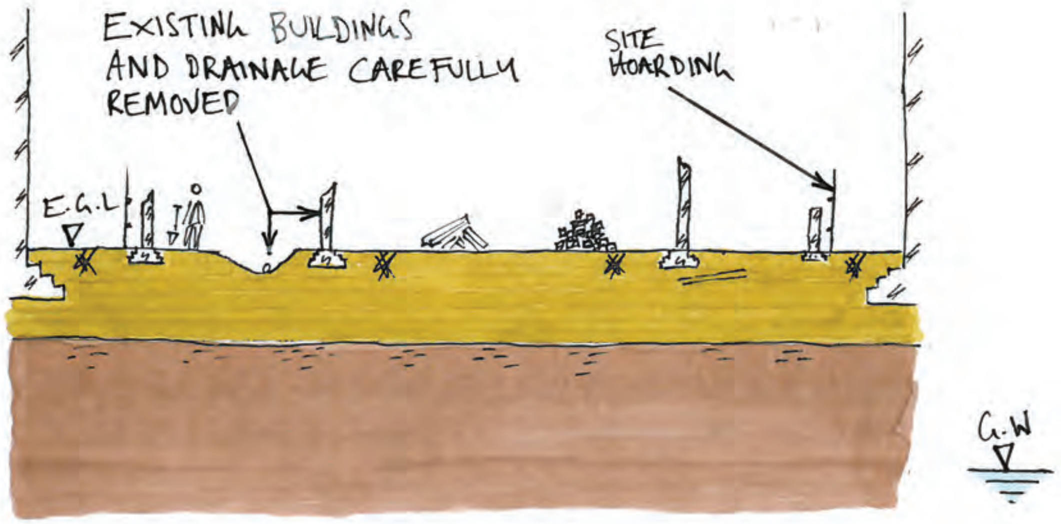
1a.
EXISTING STRUCTURES

SECTION A-A
1:200 @ A3



1b.
REMOVE EXISTING STRUCTURES, AND BELOW GROUND OBSTRUCTIONS

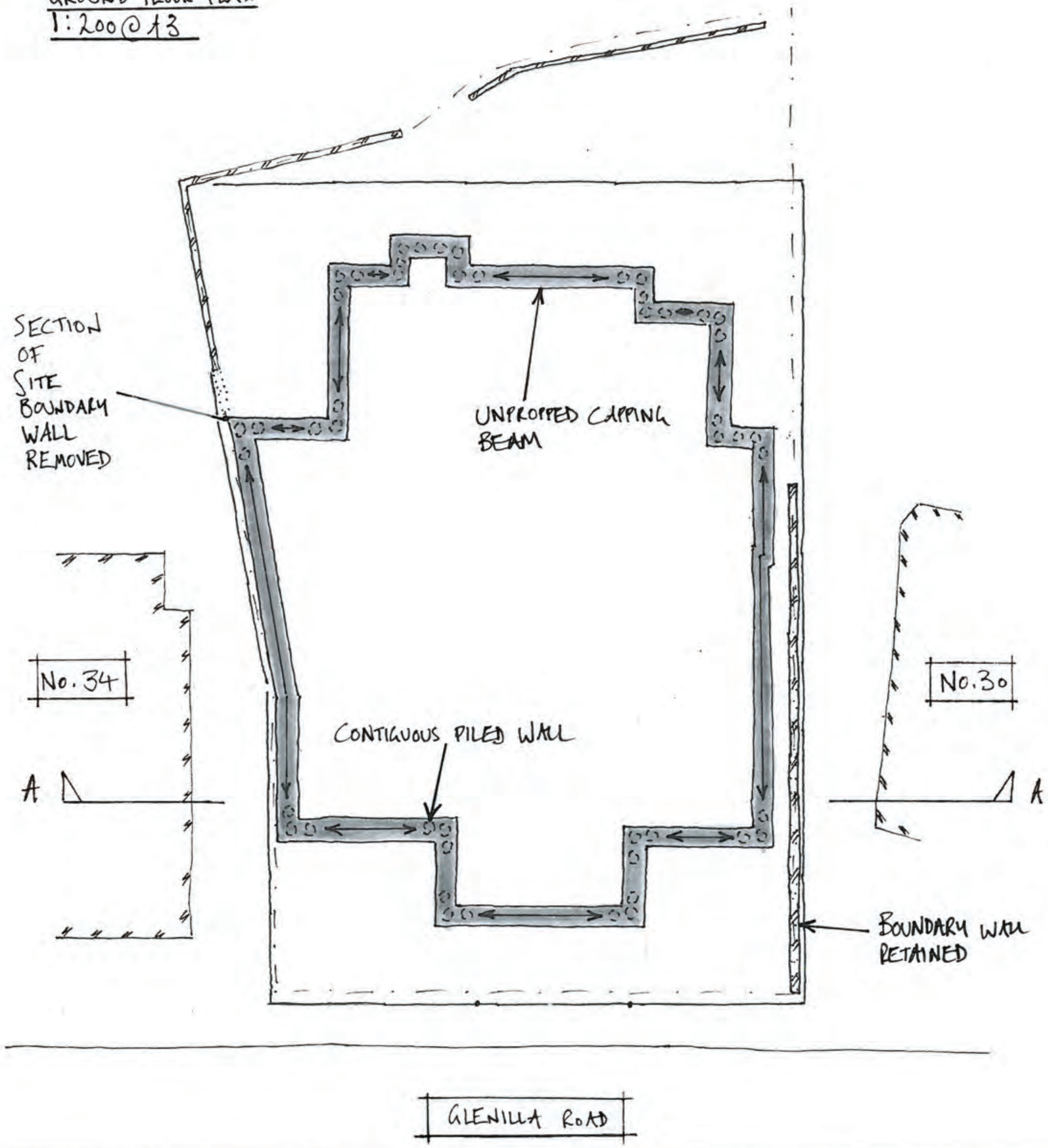
SECTION A-A
1:200 @ A3



2.

INSTALL PILE WALL AND PILE CAP

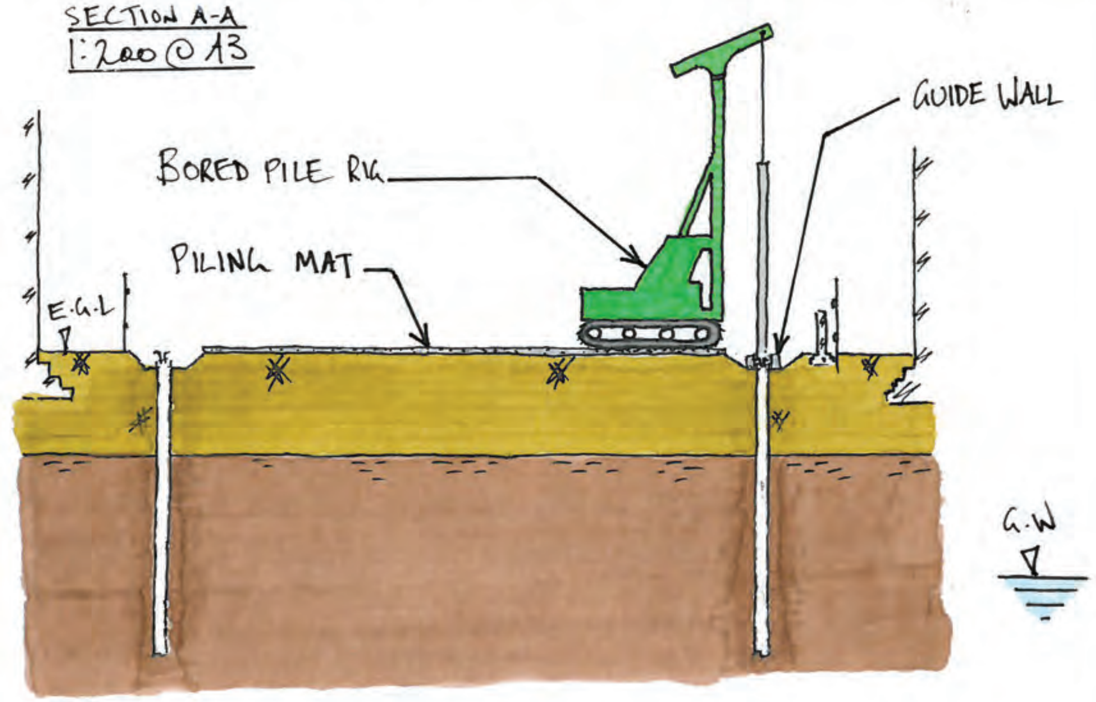
GROUND FLOOR PLAN
1:200@A3



2 a.

INSTALL PILING MAT, EXCAVATE AND INSTALL CONTIGUOUS PILED WALL

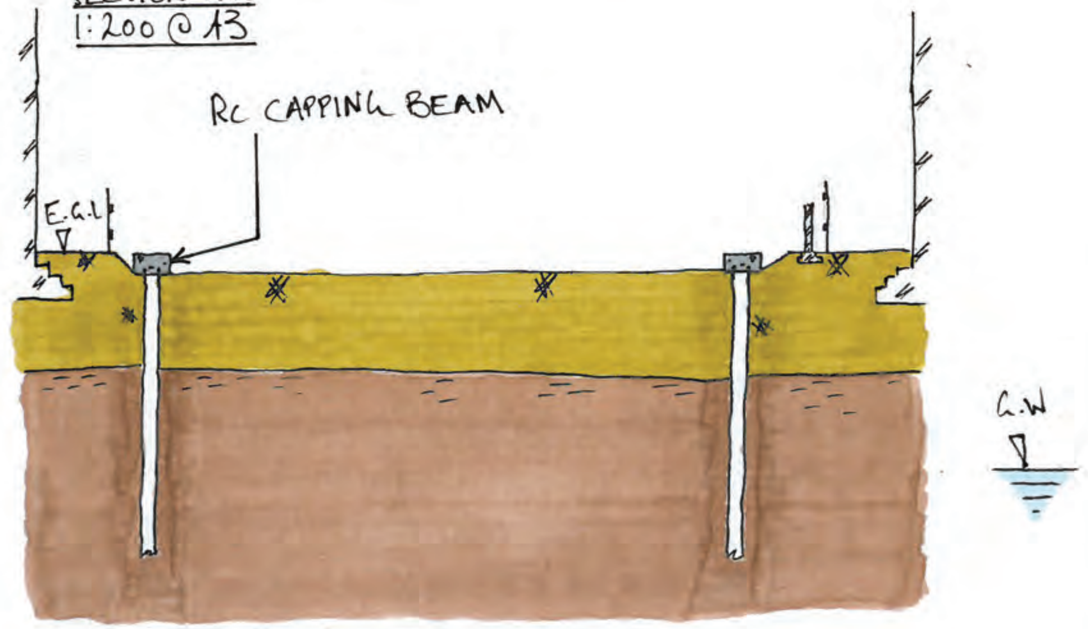
SECTION A-A
1:200@A3



2 b.

EXCAVATE AND INSTALL PILE CAP

SECTION A-A
1:200@A3



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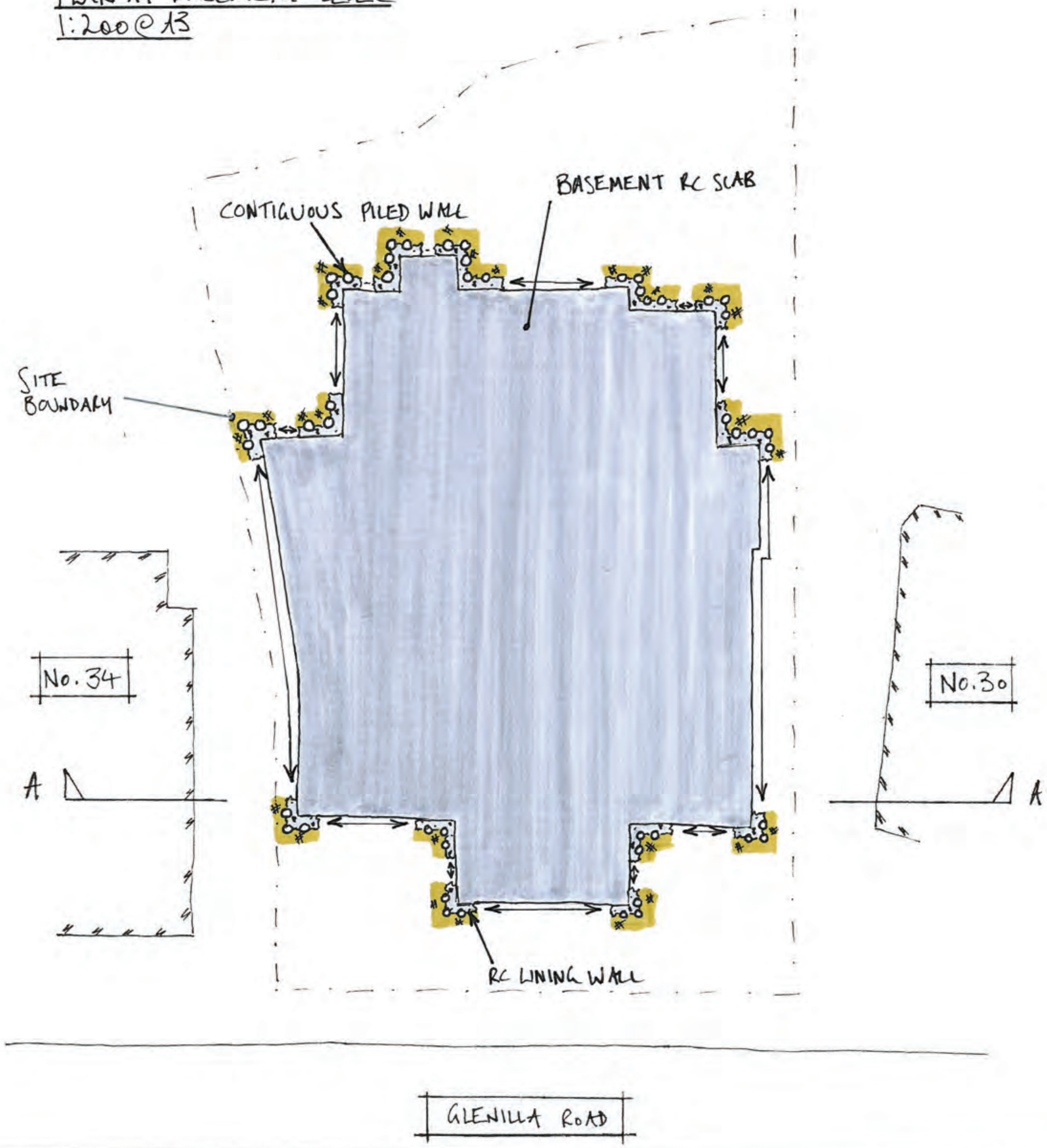
Job No 24357 Page SK008 Rev
Date 17.11.16 Eng DF Chd JE
Job 32, GLENILLA ROAD, NW3

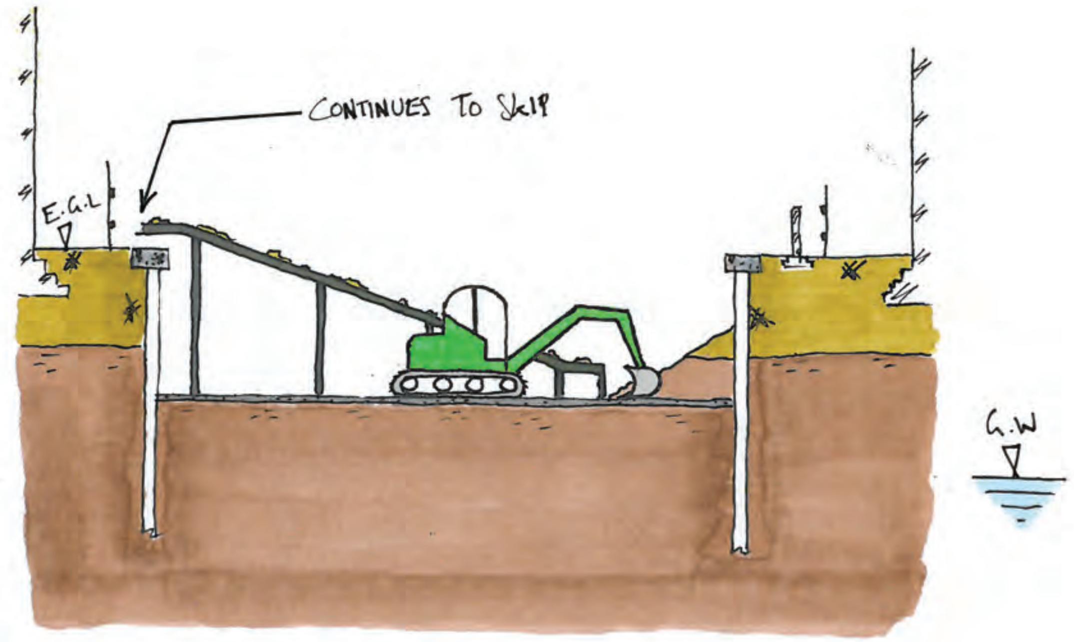
3.
BULK EXCAVATION AND INSTALL BASEMENT 'BOX'

PLAN AT BASEMENT LEVEL
1:200 @ A3



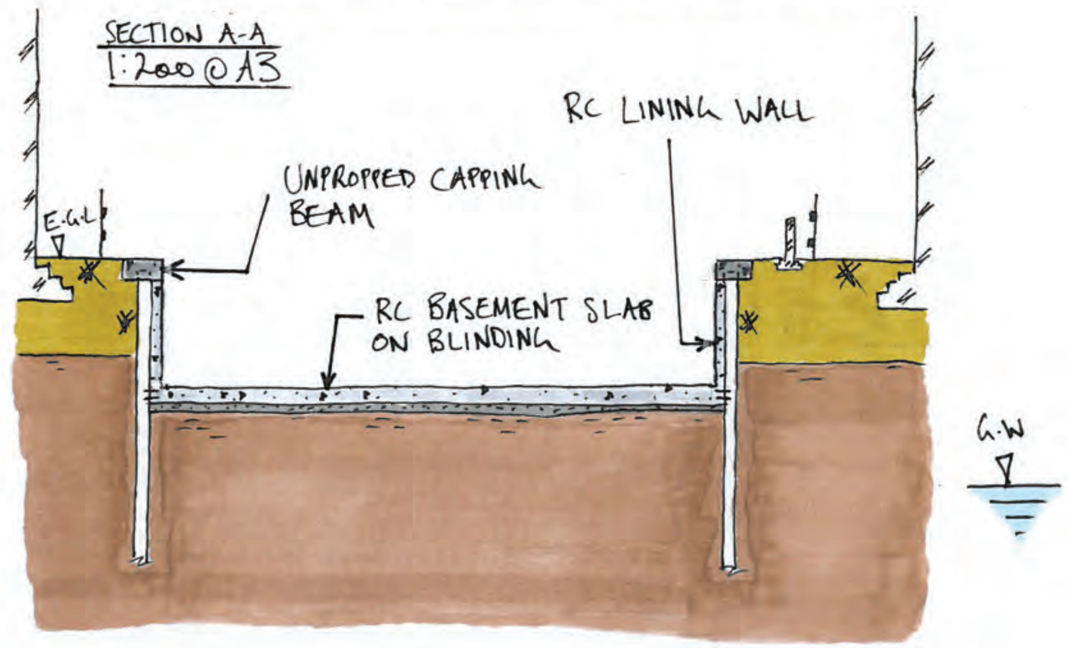
3a.
EXCAVATE TO BASEMENT FOUNDING LEVEL AND INSTALL DRAINAGE AND BLINDING

SECTION A-A
1:200 @ A3



3b.
INSTALL BASEMENT RC SLAB AND RC WALLS

SECTION A-A
1:200 @ A3



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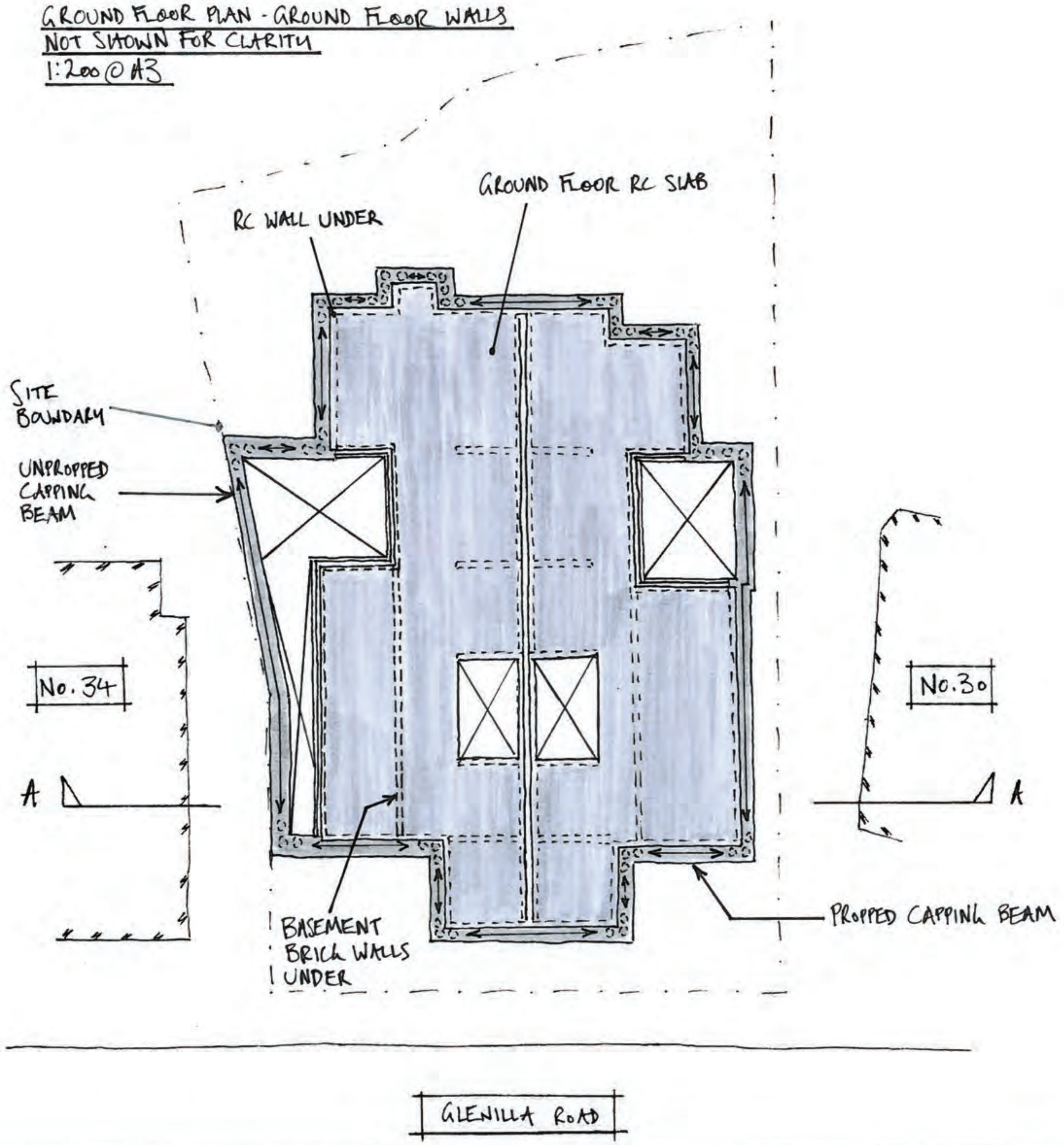
Job No 24357 Page Sk009 Rev
Date 17.11.16 Eng DF Chd JE
Job 32, GLENILLA ROAD, NW3

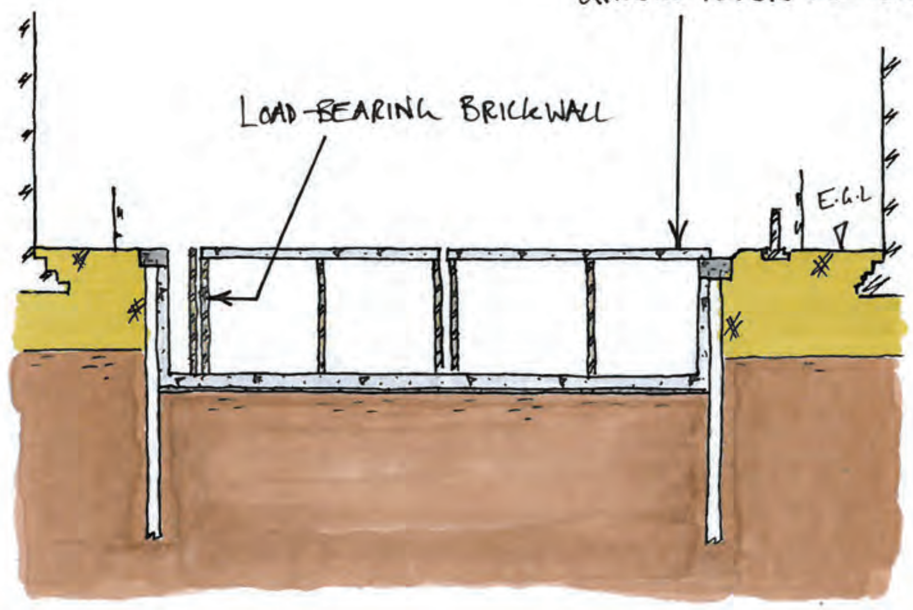
4.
INSTALL SUPERSTRUCTURE

GROUND FLOOR PLAN - GROUND FLOOR WALLS NOT SHOWN FOR CLARITY
1:200 @ A3



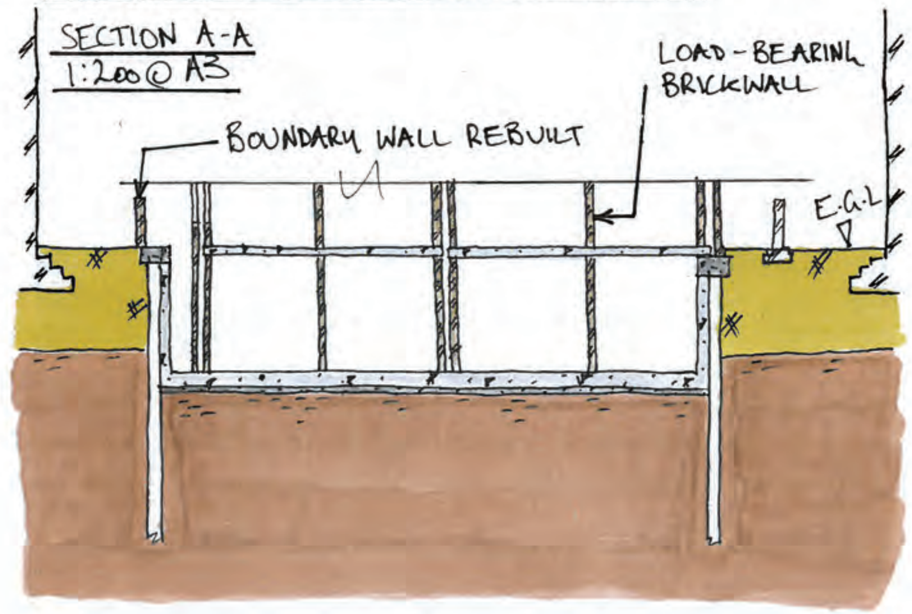
4a.
INSTALL BASEMENT LOAD-BEARING MASONRY WALLS AND GROUND FLOOR RC SLAB

SECTION A-A
1:200 @ A3



4b.
INSTALL SUPERSTRUCTURE AND CAVITY DRAIN

SECTION A-A
1:200 @ A3



PRICE&MYERS

Consulting Engineers

37 Alfred Place London WC1E 7DP T 020 7631 5128

Job No	24357	Page	SK010	Ver	
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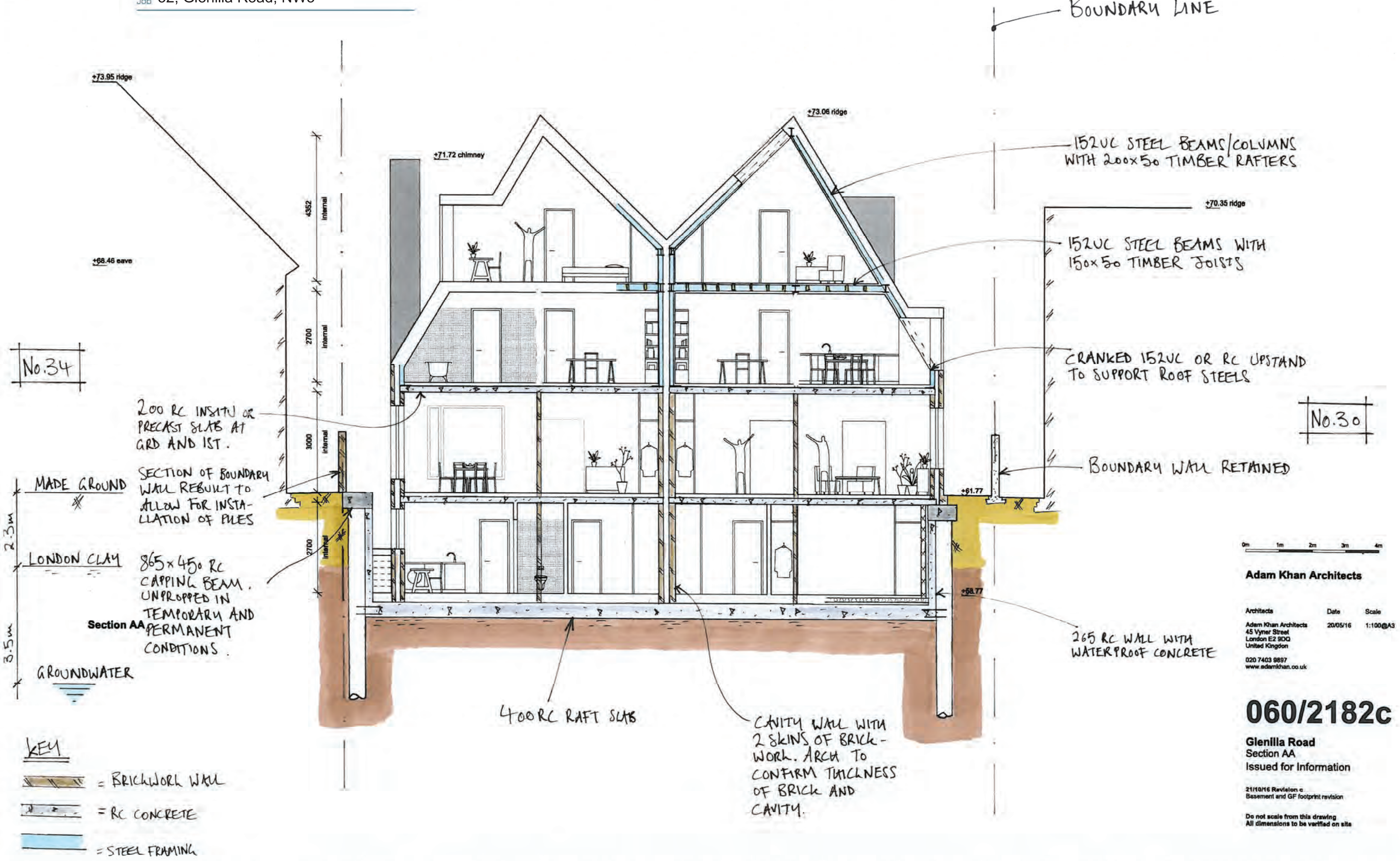
Job	32, Glenilla Road, NW3				



PRICE&MYERS

Consulting Engineers

37 Alfred Place London WC1E 7DP T 020 7631 5128

Job No	24357	Page	SK011	Ver	
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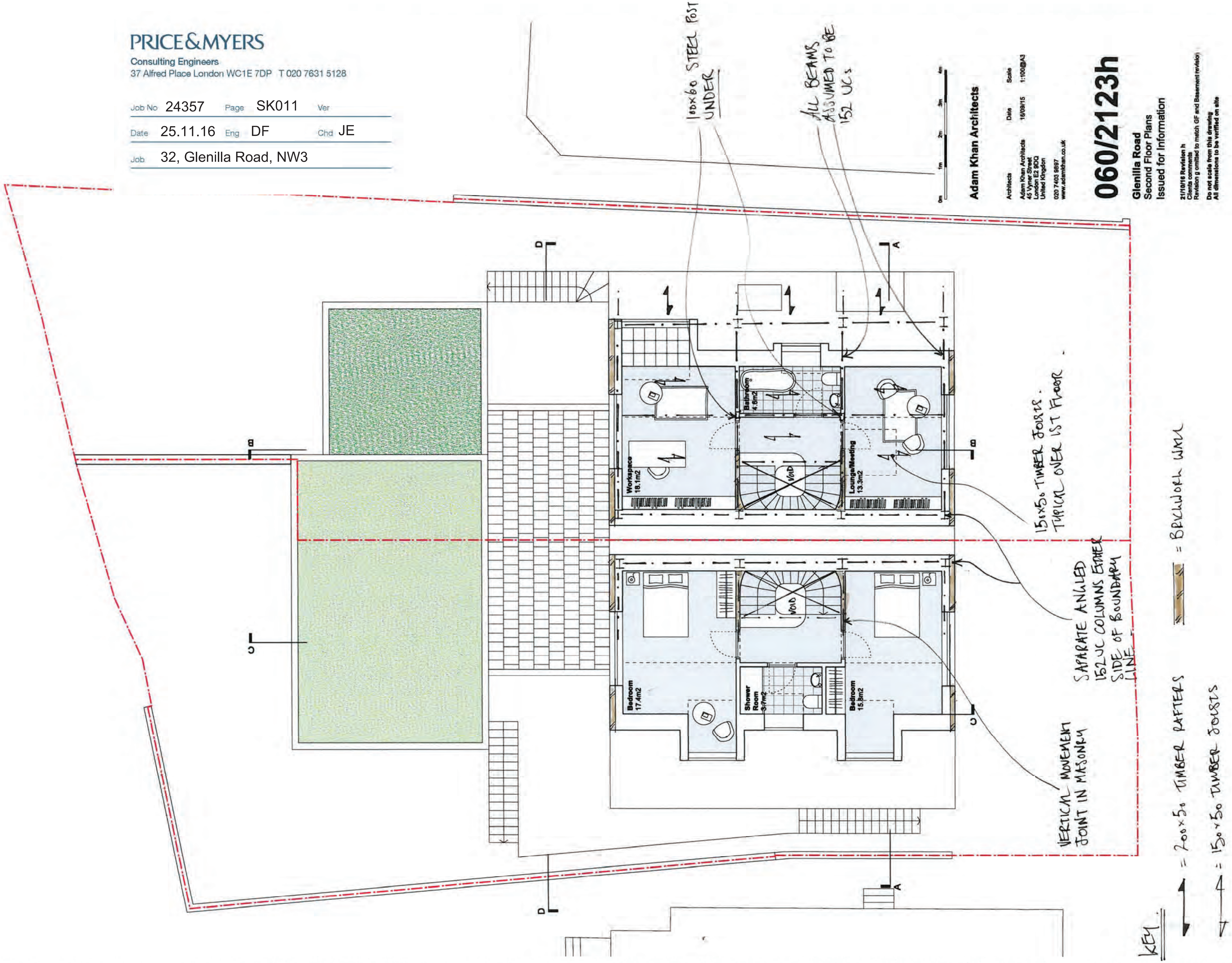
Job	32, Glenilla Road, NW3				



PRICE&MYERS

Consulting Engineers
37 Alfred Place London WC1E 7DP T 020 7631 5128

Job No	24357	Page	SK012	Ver	
Date	25.11.16	Eng	DF	Chd	JE
Job	32, Glenilla Road, NW3