Castlehaven Row Limited

251 – 259 Camden High Street, London

Basement impact assessment – Revision 1

February, 2016

Card Geotechnics Limited
Palatine House, Matford Court,
Sigford Road, Exeter, Devon, EX2 8NL
Telephone: 01392 439905
www.cgl-uk.com

Author	Steve Morgan, Chartered Senior Engineer *MSc BSc (Hons) CGeol FGS*	
Checked	Bryn Jones, Associate Director *BSc (Hons) MSc CGeol EurGeol FGS*	
Approved	Richard Ball, Associate Director *MSc BSc CEng MICE FGS*	

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1. INTRODUCTION

Card Geotechnics Limited (CGL) has been instructed by Castlehaven Row Limited (the Client) to undertake a Basement Impact Assessment (BIA) for the proposed basement development to assess the potential impact on surrounding buildings, infrastructure and hydrological features.

Camden Guidance CPG4[1] requires Basement Impact Assessments to be undertaken for new basements in the borough and sets out 5 stages:

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

This report is intended to address the screening, scoping and impact assessment processes set out in CPG4 and the Camden geological, hydrogeological, and hydrological study (CGHHS)[2]. It identifies key issues relating to land stability, hydrogeology and hydrology as part of the screening process (Stage 1) and also identifies potential impacts of the proposed scheme as part of the scoping process (Stage 2 and Stage 3), and as such the scoping process comprises a summary of the findings of the neighbouring site investigation and derivation of an appropriate ground model and design parameters for the site to allow the ground movement and damage assessment calculations to be undertaken (Stage 4).

[1] Camden Planning Guidance. 2015. *CPG4, Basements and Lightwells*, July 2015.
[2] Ove Arup and Partners Limited. 2010. *London Borough of Camden. Camden geological, hydrogeological and hydrological study. Guidance for subterranean development.* Issue 01, November 2010.

2. SITE CONTEXT

2.1 Site location

The site is located at 251 – 259 Camden High Street in the London Borough of Camden, London. The National Grid Reference for the approximate centre of the site is 528792, 184028. A site location plan is presented as Figure 1.

2.2 Site description

A walkover of the site was undertaken by the CGL engineer as part of the intrusive investigation on the 21st December 2015.

At the time of the investigation the site comprised a row of mixed use, retail and residential properties with three above ground storeys and a single storey reduced height basement. The existing ground floor level is at 27.77 m Ordnance Datum (OD) to 28.07 m OD and the level of the lower ground floor (basement) is between 25.7 m OD, at the front of the property and 26.6 m OD, to the rear of No. 253. To the rear of No. 251, 255, 257 and 259 a courtyard is present (current ground level is at 26.78 m OD to 26.98). At the time of the site visit, the courtyard comprised of hardstanding with localised areas of soft standing with stumps from recently cut vegetation. Detailed plans of the existing buildings on site are included within Appendix A.

The site is bordered by 261 Camden High Street to the north-west, Camden High Street to the north-east, 249 Camden High Street to the south-east and a multi-storey retail and residential development to the south-west.

2.3 Proposed development

The proposed development comprises the refurbishment of the existing buildings at the site and construction of a single storey, full height, basement across the footprint of the site. The proposed lower ground floor level ranges between 24.82 m OD (No. 253 and 255), 24.99 mOD (No. 251 and 257) and 25.14 m OD (No. 259). In addition to this a single storey extension will be constructed to the rear of the property. The proposed ground floor levels are to be between 27.84 m OD and 28.04 mOD. The existing lower ground floor will be reduced in level by approximately 1 m and the rear courtyard by up to 2 m to provide a full height basement with 2.6 m of clearance. Proposed development plans can be found in Appendix A.

This basement impact assessment covers properties, at 251, 253-255, 257, and 259 Camden High Street. The proposals have been submitted as four separate planning applications. The applications have been split for commercial reasons and to allow works to commence as soon as possible. The proposed basement works are however consistent across all sites. A separate BIA has been submitted for each application and it is acknowledged that the proposals could be undertaken separately for each unit.

2.4 Published and unpublished geology

Based on the British Geological Survey (BGS) website[4], the site is underlain by the solid geology of the London Clay Formation. No recent superficial deposits are recorded proximal to the site boundary.

The London Clay Formation is an over consolidated firm to very stiff fissured blue to grey clay of very high plasticity. The upper and lower parts may contain silty or fine-grained sand partings and laminated, structured, and nodular claystone bands. It commonly contains thin courses of carbonate concretions, selenite and disseminated pyrite. Local BGS boreholes indicate the London Clay Formation to be in excess of 40 m thick.

2.5 Historical BGS boreholes

The BGS holds records of a number of historical borehole records within 250 m of the site. Selected logs are summarised in Table 1 and details are included in Appendix B.

Table 1 - Summary of BGS historical borehole records

BH record reference	Distance (m)	Direction	Base of BH (mbgl)	Ground water level (mbgl)	Depth to top of stratum (mbgl)				
					MG	London Clay Formation	Lambeth Group	Thanet Sand Formation	Chalk
TQ28SE5	110	NE	91.4	NR	-	0.0	42	NR	64
TQ28SE26	40	NW	13.7	-	0.0	3.2	-	-	-
TQ28SE2264	50	SW	10.0	-	0.0	0.70	-	-	-
TQ28SE2272	50	SW	1.1	-	0.0	1.08	-	-	-
TQ28SE2270	60	SW	1.8	0.0	0.0	0.38	-	-	-
TQ28SE2269	90	SW	1.8	1.14	0.0	-	-	-	-
TQ28SE2271	90	SW	1.8	1.40	0.0	0.38	-	-	-

[4] http://mapapps2.bgs.ac.uk/geoindex/home.html. Accessed 13.01.2016.

BH record reference	Distance (m)	Direction	Base of BH (mbgl)	Ground water level (mbgl)	Depth to top of stratum (mbgl)				
					MG	London Clay Formation	Lambeth Group	Thanet Sand Formation	Chalk
TQ28SE2265	80	SW	4.0	0.23	0.0	0.25	-	-	-
TQ28SE2268	90	SW	0.5	0.32	0.0	0.58	-	-	-
TQ28SE297	180	SE	8.84	-	0.0	1.83	-	-	-

The historical borehole records generally recorded Made Ground up to 1.8m in thickness overlying the London Clay Formation. Underlying the London Clay Formation , the Lambeth Group was encountered at 42 m bgl and the underlying Chalk was proven at 64 m bgl. Within the exploratory hole record the Thanet Sand Formation, which stratigraphically lies between the Lambeth Group and the Chalk, was not recorded.

The historical borehole records identify shallow water strikes at depths between ground level and 1.4 m bgl. These strikes are considered to be associated with perched water within the Made Ground or sand lenses in the upper London Clay Formation.

2.6 Hydrogeology and hydrology

The Environment Agency (EA)[5] 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 London Clay Formation is classified as an *unproductive stratum*. *These are rock layers or drift deposits with low permeability that has negligible significance for water supply or river base flow.*

The site is not within a Groundwater Source Protection Zone. The nearest significant surface water feature is the *Regent's Canal,* located approximately 100 m to the north of the site at its nearest point.

[5] http://www.environment-agency.gov.uk/wiyby (accessed 13.01.2016)

With reference to Barton's *Lost Rivers of London*[6], a historical watercourse is located approximately 250 m east of the site, flowing broadly north-west to south-east. This was a tributary of the *River Fleet*.

The Environment Agency[7] flood maps indicate that the immediate site area is not at risk of flooding by river or sea, however it is shown to be a low risk of surface water flooding to the immediate west of the site.

2.7 Underground Infrastructure

With reference to CGL's in-house archive and mapping, the London Underground Northern Line is located within Camden High Street to the immediate east of the site, which is aligned north-west to south-east. Based on information for nearby developments it is understood that the tunnel crown of the shallowest LUL tunnel is located approximately 10 m below existing ground level (17.85 mOD), with a tunnel diameter of 3.5 m. The tunnel crown is aligned north-west to south-east 5 m from the front of the site beneath Camden High street.

In addition a deep shelter tunnel, associated with a WWII, is located beneath the site. The tunnel is aligned in a north-west to south-east orientation beneath the site. Based on the drawing provided, the axis of the tunnel is located at a depth of 22 m below existing ground level at a level of 5.85 m OD, the internal diameter of the tunnel is approximately 5 m, therefore, the level of the tunnel crown is approximately at a level of 8.35 m OD (circa 19.5 m bgl). The tunnel is estimated to be located under the site aligned north-west to south-east 7 m from Camden High Street.

Copies of the underground infrastructure information available are included within Appendix C.

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[6] Barton N. (1962) *The Lost Rivers of London.* Historical Publications Limited.

[7] The Environment Agency. (2012) *Risk of Flooding from River and Sea*. Online. Accessed 13.01.2016. Available from http://www.environment-agency.gov.uk

3. SCREENING – STAGE 1

3.1 Introduction

A screening assessment has been undertaken based on structured guidance presented in Camden Borough Council's CPG4, based on the flowcharts presented in that document as a template. 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) flow

This section answers questions posed by Figure 3 of CPG4.

Table 2. Responses to Figure 3 of CPG4

Question	Response	Action Required
1a. Is the site located directly above an aquifer?	No The site is underlain by the London Clay Formation	None
1b. Will the proposed basement extend beneath the water table surface?	No The site is underlain by the impermeable London Clay Formation.	None
2. Is the site within 100m of a watercourse, well, or potential spring line?	Yes The Regent's Canal is located approximately 100 m to the north of the site. The River Fleet which is now culverted underground is located approximately 250m east of the site.	None
3. Is the site within the catchment of the pond chains on Hampstead Heath?	No Hampstead Heath is located approximately 1.8 km to the north of the site.	None
4. Will the proposed basement development result in a change in the proportion of hard surfacing?	Yes The majority of the site is currently covered by hardstanding, however within the rear courtyard areas of soft standing are present. As part of the new development additional drainage will be installed to intercept the surface water.	Assessment
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 All surface water is likely to be discharged to the sewer network through existing connections. An assessment will need to be undertaken to confirm if the existing infrastructure has sufficient capacity to take increased drainage.	Assessment
6. Is the lowest point of the proposed excavation close to, or lower than, the mean water level in any local pond or spring lines?	Yes The basement is likely to be lower than the water level in the canal to the north.	Investigation and assessment

In summary, the site is underlain by the relatively impermeable London Clay Formation. Regional groundwater flow is likely to be to the south-east River Thames, evidenced by the tributary of the River Fleet aligned north-west to south-east shown on Barton's 'Lost Rivers of London'. However, flow rates are considered to be extremely slow within the effectively impermeable London Clay Formation, and there is no water table or general flow that is likely to be affected by basement construction. The presence of groundwater will be confirmed during the intrusive investigation.

There is the potential for localised and small quantities of perched water within the Made Ground or within sandy/silty horizons in the London Clay Formation and groundwater seepage is likely between the Made Ground and London Clay Formation interface.

The proposed development will increase the proportion of impermeable surfaces, however given the site is anticipated to be directly underlain by the London Clay Formation there is likely to be no additional recharge to the ground above that of the existing hydrogeological regime.

3.3 Slope/land stability

This section answers questions posed by Figure 4 of CPG4.

Table 3. Responses to Figure 4 of CPG4

Question	Response	Action required
1. Does the site include slopes, natural or man-made, greater than about 1 in 8?	No The site is relatively flat	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 The topography of the surrounding region is relatively flat	None
5. Is the London Clay Formation the shallowest stratum on site?	Yes The London Clay Formation was encountered directly below a limited thickness of Made Ground during the current site investigation.	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?	No Shrubs were historically located on site however these have been subsequently cleared. Given the proposed development will have a basement across the entire site footprint the foundations will be extended to a depth outside the zone of influence of the former shrubs..	Investigation and assessment

Question	Response	Action required
7. Is there a history of shrink/swell subsidence in the local area and/or evidence of such at the site?	Unknown The London Clay Formation is susceptible to seasonal shrink/swell movements and it is likely that these will occur, particularly in close proximity to high water demand trees. The impact of this on the proposed development and adjacent properties should be assessed. It is noted that trees / shrubs were located on site prior to being removed as part of the site clearance. An assessment of the effects of their removal should be undertaken given the London Clay Formation is susceptible to changes in water content.	Investigation and assessment
8. Is the site within 100m of a watercourse or a potential spring line?	Yes The Regent's Canal is located approximately 100m to the north of the site. The River Fleet which is now culverted underground is located approximately 250m east of the site.	Investigation and assessment
9. Is the site within an area of previously worked ground?	No	None
10. Is the site within an aquifer?	No The London Clay Formation is classified as an 'Unproductive Stratum'.	None
11. Is the site within 50 m of the Hampstead Heath Ponds?	No The site is more than 2 km to the south of the Hampstead Chain Catchment.	None
12. Is the site within 5m of a highway or pedestrian right of way?	Yes The eastern boundary of the site is adjacent to Camden High Street.	Investigation and assessment
13. Will the proposed basement significantly increase the differential depth of foundations relative to neighbouring properties?	Yes The neighbouring properties are likely to have shallow foundations.	Investigation and assessment
14. Is the site over (or within the exclusion zone of) any tunnels?	Yes As stated in Section 2.7 of this report, the site is underlain by a deep shelter tunnel located approximately 19.5 m below the site. In addition The London Underground Limited (LUL) Northern Line tunnels run below Camden High Street.	Investigation and assessment

In summary, an investigation and impact assessment is required to confirm ground conditions within the site and surrounding area and to also assess the magnitude of ground movements that may result from basement excavation and construction as these may have an affect on adjacent structures and infrastructure including the LUL Northern Line tunnel and the deep shelter tunnel located beneath the site.

The impact assessment will determine any likely potential damage that could be caused by ground movements to adjacent structures and infrastructure, and the assessment will recommend measures to mitigate potentially damaging movements.

The impact assessment will focus primarily on the impact of ground movements on the adjacent structures and LUL tunnels beneath Camden High Street.

3.4 Surface flow and flooding.

This section answers questions posed by Figure 5 of CPG4.

Table 4. Responses to Figure 5 of CPG4

Question	Response	Action required
1. Is the site within the catchment of the pond chains on Hampstead Heath?	No Hampstead Heath is located approximately 1.8 km to the north of the site.	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?	No It is understood all surface water will be discharged to the sewer network through existing connections. An assessment will need to be undertaken to confirm existing infrastructure has sufficient capacity to take increased drainage.	None
3. Will the proposed development result in a change in the proportion of hard surfaced/paved external areas?	Yes The majority of the site is currently covered by hardstanding, however within the rear courtyard areas of soft standing are present. However given the site is likely to be directly underlain by the London Clay Formation it is not considered likely to impact on surface water flows.	Investigation and assessment
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	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 The site is not in a Flood Risk Zone. The Environment Agency website identifies a low risk of surface water flooding to the immediate west of the site.	None

In summary, the proposed development will increase the proportion of impermeable surfaces, however given the site is anticipated to be directly underlain by the impermeable London Clay Formation it is not anticipated to impact surface water flow. In addition, the site is not known to be at risk from flooding.

3.5 Conclusions

The items summarised below in Table 5 were identified as part of the Stage 1 screening process.

Table 5. Summary of Basement Impact Assessment requirements

Item	Description
1.	Subterranean (Groundwater flow) Assess the potential impact on the Regent Canal located 100m north of the site
1. 2.	Slope and land stability Assessment of potential movements associated with construction in the London Clay Formation, including short and long term heave movements, settlement associated with retaining wall deflections, and ground movements around the basement perimeter. Shrink/swell behaviour is a possibility. An assessment of the impact the proposed excavation and basement installation could have on neighbouring structures and their foundations. An assessment of the impact the proposed excavation and basement installation could have on tunnels located beneath and proximal to the site.
1.	Surface flow and flooding Proposed development does not affect surface flow and flooding.

4. SCOPING – STAGE 2

4.1 Introduction

This section of the report covers the scoping process (Stage 2) of the BIA, which is used to identify potential impacts of the proposed scheme and establish a conceptual site model. The scoping stage also informs the scope of the site investigation. The site covers an area of approximately 450m^2 and the basements may be considered to present a limited impact in the local area.

Based on the output of the screening process (Table 5), the site investigation should comprise the following:

- Due to the unknown thickness of the potential Made Ground and London Clay Formation, a minimum of one borehole to a depth of 5 m below depth of the proposed basement foundations to provide details on ground conditions and stratum levels. Soil and groundwater observations should be logged by an appropriately qualified geotechnical engineer;
- In-situ geotechnical testing and laboratory testing to provide adequate information to derive geotechnical design parameters and develop a conceptual site model. This will inform the retaining wall and foundation design and subsequent impact on adjacent structures, and should include alternate U100s (to allow for triaxial testing) and Standard Penetration Tests (SPTs) at regular intervals; and
- Installation of standpipes within the boreholes and subsequent groundwater monitoring to confirm the hydrogeological regime beneath the site.

5. GROUND INVESTIGATION (STAGE 3)

5.1 Current site investigation

An intrusive investigation was undertaken by CGL from 21st to 23rd December 2015. The investigation comprised a single cable percussion borehole (BH01) to 11 m bgl and three foundation inspection pits (FTP01 to FTP03 inclusive). Within the boreholes, in-situ Standard Penetration Testing (SPT) was undertaken throughout, along with the extraction of both undisturbed and disturbed samples for geotechnical laboratory testing. The exploratory holes were logged by a suitably experienced CGL engineer. Upon completion, the borehole was installed with a monitoring well with a response zone in the London Clay Formation.

An exploratory hole location plan is provided as Figure 2 and records of the borehole logs are provided in Appendix D.

A single return ground gas and groundwater monitoring visit was undertaken on 7th January 2016. The monitoring record is included in Appendix E.

5.2 Geotechnical laboratory analysis

Selected soil samples were submitted to Albury SI (UKAS Accredited) for geotechnical laboratory testing and i2 Analytical (a UKAS and MCerts Accredited) for chemical laboratory testing including the following:

- Quick undrained triaxial test;
- Atterberg Limit tests;
- Moisture content; and
- BRE analysis in accordance with BRE SD1.

The geotechnical and chemical test results are included in Appendix F.

6. GROUND AND GROUNDWATER CONDITIONS (STAGE 3)

6.1 Summary

The ground conditions encountered during the intrusive investigation are generally consistent with those of the published geological maps with the exception of alluvium. The alluvium is likely to be associated with an unmapped tributary of the nearby River Fleet located approximately 250 m to the east of the site. The existing ground level in the courtyard at the rear of the site is in the region of 26.85mOD. The ground conditions are summarised in Table 6 below

Table 6: Summary of ground conditions

Stratum	**Depth to top of stratum (m bgl)** **[m OD]**	**Typical thickness (m)**
MADE GROUND (All exploratory holes)	Ground level [26.85 to 26.98]	0.5 - 1.4
REWORKED ALLUVIUM (BH01 and FTP02 only)	0.5 – 0.6 [26.2 to 26.35]	0.5 – 0.7
ALLUVIUM (BH01, FTP01 and FTP03 only)	0.9 – 1.4 [25.58 to 25.9]	0.2* - 1.0
WEATHERED LONDON CLAY FORMATION (BH01 and FTP02 only)	1.3 – 2.0 [24.85 to 25.5]	1.0* - 7.0
LONDON CLAY FORMATION (BH01 only)	9.0 [17.85]	Proven to 11m depth

Notes: * base not encountered

The ground conditions are discussed in the following sections together with the results of the in-situ and laboratory geotechnical tests. A plot of Standard Penetration Test (SPT) 'N' value against depth profile is presented in Figure 3. A plot of undrained shear strength against level is presented in Figure 4. A Plasticity Index Chart is presented in Figure 5.

6.2 Made Ground

Made Ground was encountered in all exploratory holes across the site to a maximum depth of 1.4m bgl (FTP03) in the west of the site. The Made Ground generally comprised granular deposits of a loose sandy gravel or gravelly sand with varying proportions of clay and silt. Occasionally the Made Ground was encountered as a soft to firm silty clay with varying proportions of sand and gravel. The gravel fraction comprised brick, flint and concrete.

No in-situ testing was undertaken within the Made Ground, the density and strengths are based on field observations[8].

6.3 Reworked Alluvium

Reworked Alluvium was encountered within exploratory holes FTP02 and BH01 only, to a maximum depth of 1.3 m bgl (FTP02) in the north of the site. The Reworked Alluvium comprised a soft dark brown, black silty clay with varying proportions of sand and gravel. The gravel fraction comprised brick, flint and concrete. No in-situ SPT 'N' values were recorded within the Reworked Alluvium.

6.4 Alluvium

Alluvium was recorded within all exploratory holes except FTP02 to a maximum depth of 2.0 m bgl (BH01) in the centre of the site. The Alluvium comprised soft dark blue, black, silty clay with varying proportions of sand and an organic odour. Within borehole BH01 a slight organic odour was recorded at 1.5 m bgl.

A single SPT was undertaken within the cohesive Alluvium which recorded an 'N' value of 5 which correlates to an undrained shear strength of 22 (based on f_1 = 4.5[13]).

6.5 London Clay Formation

The London Clay Formation was encountered beneath the Reworked Alluvium and Alluvium across the site. The London Clay Formation was found to have a weathered upper surface grading from a light orange brown to dark grey brown, soft to firm becoming stiff consistency, silty clay with close fissures, and occasional selenite crystals.

SPT 'N' values within the London Clay Formation stratum were found to show an increase with depth from 16 near the top of the stratum to 22 at 11 m bgl, corresponding to

[8] BS 5930:2015 +A2, Code of practice for site investigations

undrained shear strength (c_u) values in the order of 72 kPa to 100 kPa (based on f_1 = 4.5[13]). Three quick undrained triaxial tests recorded undrained shear strength values between 95kPa to 190kPa, which indicates that clay to be high to very high strength. The testing was undertaken on three samples extracted between 3.0 m bgl and 9.0 m bgl and the undrained shear strength values recorded from the laboratory testing are generally higher than the correlated values from in-situ tests. It is considered likely that the correlation is slightly conservative in this location.

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

- Moisture Contents between 29% and 32%;
- Liquid Limits between 77% and 82%;
- Plastic Limits between 28% and 30%; and
- Plasticity Indices between 48% and 52%.

Based on laboratory testing and established correlations for the London Clay Formation[9], the following design shear strength lines are recommended for the London Clay Formation:

$$c_u = 70 + 5z \text{ (kPa)}$$

Where 'z' indicates the depth below the surface of the London Clay Formation, as indicated on Figure 4.

6.6 Groundwater

Shallow perched groundwater ingress was noted within the Made Ground at depths of 0.5 m bgl (26.48 mOD) and 0.6 m bgl (26.25 m OD). A deeper perched water seepage was recorded at a depth of 6.5 m bgl within the London Clay Formation in borehole BH01. During the subsequent groundwater monitoring visit, the standing water was recorded in the installation at a depth of 3.50 m bgl, the well was then emptied down to a depth of 6.92 m bgl.

Further monitoring after this showed the water level in the well rose to a depth of 6.75 m bgl after 15 minutes and 6.73 m bgl after 60 minutes upon completion of the monitoring.

[9] 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).

The slow recharge rates recorded during the monitoring visit, once the well had been purged, are consistent with the perched water strike recorded at 6.5 m bgl during the intrusive investigation. This is likely to be associated with a sandy lens within the London Clay Formation.

The results of the single groundwater monitoring visit are presented within Appendix E.

6.7 Geotechnical design parameters

Geotechnical design parameters for the proposed development are summarised in Table 7 below, these are based on the results of laboratory and in-situ testing and published data for the well-studied London Geology.

Table 7: Geotechnical design parameters

Stratum	Design Level mbgl [mOD]	Bulk Unit Weight γ_b (kN/m³)	Undrained Cohesion c_u (kPa) [c']	Friction Angle ϕ' (°)	Young's Modulus E_u (MPa) [E']
Made Ground	0 [26.85]	18	-	30[b]	[5]
Reworked Alluvium	0.5 [26.35]	19	20 [0]	25[a]	[5]
Alluvium	1.0 [25.85]	18	20 [0]	25[a]	[5]
London Clay Formation	2.0 [24.85]	20	70 + 5z[c] [2][f]	20[a]	42 + 5z[d] [31.5 + 3.75z][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 lower surface of the London Clay Formation*
d. *Based on 600c_u - 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.*
f. *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 7 are unfactored (Serviceability Limit State) and considered to be 'moderately conservative' design values.

6.8 Buried concrete

The availability of total potential sulfate (TPS) in pyritic soils 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.

Where open excavations will be required into the London Clay (i.e. during basement excavations), the soils may be disturbed to the extent that contained pyrite might oxidise and allow the resultant sulfate ions to reach the concrete, and as such the TPS DS and ACEC classes should be adopted. However, where the soils are undisturbed (i.e. where cast-in-situ piles are utilised), the lower WSS DS and ACEC classes may be adopted.

It is considered that the London Clay Formation acts as an aquiclude preventing the downward migration of water at the site, therefore it is considered to be static. The concrete classifications, based on the above and the concentration obtained from laboratory testing are summarised in Table 8.

Table 8. Summary of DS and ACEC classes.

Stratum	Worst case soil values		Total potential sulfate (Pyritic soil)	
	DS class	ACEC Class	DS class	ACEC Class
London Clay Formation	DS-4 (3,300)[a]	[AC-3s] (7.8)[b]	DS-4 (1.89)[c]	AC-3s (7.8)[b]

a. Characteristic value soil (mg/l)
b. Characteristic value pH
c. Characteristic value total potential sulfate

On this basis, and in accordance with BRE SD1[10], a Design Sulfate Class of DS 4 with an ACEC of AC-3s would apply for buried concrete.

[10] British Research Establishment. 2005. *Concrete in aggressive ground.*

6.9 Potential contamination

No significant olfactory or visual evidence of gross contamination was noted during the intrusive works.

7. BASEMENT IMPACT (STAGE 4)

7.1 Subterranean (groundwater) Flow

7.1.1 Introduction

This section addresses outstanding issues raised by the screening process regarding groundwater flow.

7.1.2 Impact on groundwater flow

During the intrusive investigation shallow groundwater strikes were encountered within the Made Ground and Reworked Alluvium above the surface of the London Clay. The source of the water is known to be a damaged sewer on an adjacent site and therefore the water does not indicate the presence of a regional shallow groundwater table that might be affected by a new basement.

In addition, groundwater was recorded within the deep borehole, at a depth of some 6.5m bgl (20.35 m OD). This level is some 4.5 m below the proposed basement level and therefore does not have an effect on the proposed development, which, conversely, will also not affect water levels in this stratum.

It is considered that the limited volumes of water likely to be encountered within the Made Ground will be adequately accommodated with pumping from locally excavated sumps.

7.2 Surface flow and flooding

It is understood that surface waters will join the existing drainage infrastructure (albeit via basement pumping if a gravity fed solution is not feasible), with no significant changes in peak drainage outflows anticipated from the site. In addition the site lies outside of any EA designated Flood Zone for rivers or the sea. Based on the above, it is considered that the development will have a negligible impact on surface water flow and flooding. In addition, the basement is likely to provide enhanced attenuation given its requirement to be drained in accordance with Building Regulations.

8. BIA STAGE 4 - GROUND MOVEMENT ASSESSMENT

8.1 Introduction

This section describes calculations undertaken to assess ground movements that may result from the construction of the proposed basement and to assess how these may affect the adjacent structures and infrastructure.

A sacrificial sheet pile wall will be installed around the basement perimeter in the south and west of the site before a reinforced concrete wall is constructed. All other areas of the site will be underpinned using a traditional 'hit and miss 'sequence.

8.2 Conceptual Site Model and critical sections

A conceptual site model (CSM) of the proposed site conditions has been developed based on the available data to illustrate the conceptual understanding of the ground model, and is presented in Figures 6a and 6b in section and plan view respectively. Details of the critical sections to be analysed as part of this assessment are discussed below.

8.2.1 Section adjacent to London Underground tube tunnels

Two LUL Northern Line tunnels run below Camden High Street aligned in a north-west to south east orientation along the north-eastern boundary of the site. A preliminary assessment has been undertaken based on proximal sites, the nearest tunnel crown is located at 10 m bgl (17.85 mOD) and is positioned 5 m from the boundary of the site. Based on this an assessment has been undertaken to determine the effects of ground movements from the basement excavation and construction on the tunnel.

8.2.2 Deep shelter tunnels

A deep shelter tunnel is located beneath the site associated with WWII. The tunnel is aligned in a north-west to south-east orientation. Based on the drawing provided, the axis of the tunnel is at a depth of 22 m bgl (circa 73 ft) or at a level of 5.85 m OD. The internal diameter of the tunnel is estimated to be 5 m, therefore the level of the tunnel crown is approximately at a depth of 8.35 m OD (circa 19.5 m bgl). The tunnel is estimated to be located under the site aligned north-west to south-east 7 m from Camden High Street.

8.2.3 Existing party walls

From the drawings provided and the findings of the intrusive investigation, the party wall of No. 261 Camden High Street is understood to have an existing underpins installed to a level of 24.68 mOD (2.3 m bgl) in foundation inspection pit FTP02. In addition, an investigation of the party wall of No. 249 Camden High Street was not possible, although it is understood to have existing underpins.

To the rear of the property where the sacrificial sheet pile wall is proposed between the site and a boundary wall, the foundation inspection pit (FTP03) recorded a 600mm thick foundation on to the reworked Alluvium with no underpin present.

8.3 Basement construction sequence

It is understood that beneath the existing building the new basement is to be constructed using 'hit and miss' underpinning techniques excavated in a sequence of bays with a maximum 1.2 m width.

In the area of the courtyard a sheet piled wall will be initially installed around the perimeter to allow for the excavation of the basement before a permeant concrete retaining wall is constructed.

Appropriate lateral propping should be provided during construction to limit potential for lateral movement and associated settlement.

8.4 Ground movements arising from basement excavation

A ground movement assessment has been undertaken using OASYS Limited *PDISP* (*Pressure Induced Soil Displacements*) analysis software version 19.3. *PDISP* 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 by the user. The analysis calculates total settlement, including both short term and long term movements.

The proposed development will increase the loadings on the existing foundations at the front of the property and additional loadings will be added at the rear of the property where new foundations are proposed. The geometry of the foundations for the model has been taken from drawings provided by the Architect, Barr Gazetas, and included in Appendix A.

As part of the construction works to build the new basements the ground level of the existing half height basement will be reduced by up to 1.04 m (25.86 m OD to 24.82 m OD), which would generate an approximate unloading of 20kPa (assuming an overburden bulk unit weight of 19 kN/m^3). In the west of the site the ground level will be reduced by up to 1.99 m (26.98 m OD to 25.14 m OD) which would generate an approximate unloading of 38kPa (assuming an overburden bulk unit weight of 19kN/m^3).

The new foundations for the structure have been designed for a Design Action, provided by the structural engineer Walsh, of 150kPa at this stage. The net loading conditions are summarised below in Table 9.

Table 9: Net loading conditions

Current ground level	Stress relief from overburden (kPa)	Gross bearing pressure (kPa)	Net load beneath underpins (kPa)
25.86	-20	150	130
26.98	-38	150	112

For the purposes of the assessment it has been assumed that the foundations will be formed in the London Clay Formation at a depth of 0.6m bgl (24.2 mOD) beneath the proposed lower ground floor level based on information provided by the structural engineer. It has been assumed in the analysis that the additional loadings will be applied instantaneously across the whole structure.

8.4.1 Ground movement during construction – basement formation level

Short term heave at basement formation level is calculated to be of the order of some 2 to 5 mm in the south of the site in the centre of the excavation. Along the north-eastern boundary (adjacent to Camden High Street) up to 5 mm of settlement is anticipated. These movements will occur during construction as superstructure loads are transferred through the new foundations and underpins to the underlying London Clay Formation. A contour plot showing short term movement at basement formation level is presented in Figure 7.

8.4.2 Long term ground movement – basement formation level

Long term movement is governed by net loadings at formation level as outlined in Table 9 and develop as a result of pore pressure recovery within the London Clay. The results indicate the movements to be similar to those calculated in the undrained condition, with maximum heave movements of up to5 mm in the south of the site in the centre of the excavation at basement formation level. Along the north-eastern boundary (adjacent to

Camden High Street) up to 10 mm of settlement is anticipated. A contour plot showing long term movement at basement formation level is presented in Figure 8.

8.4.3 Summary

Based on the short and long term ground movements discussed above up to 10 mm of heave is calculated in the south of the site and up to 15 mm of settlement is calculated in the north east of the site. The increased settlement in the north-east of the site is associated with the width of the existing foundations and the proposed underpins in this area.

8.5 Underpin settlement – workmanship

In CGL's experience, settlement caused by the construction of underpinning is typically of the order of 5 mm with good workmanship. This makes allowance for compression of the dry pack concrete on the underside of the foundation as loads are taken up on the new foundations.

A 5 mm settlement has been incorporated in the building damage assessment assuming high quality workmanship is adopted in addition to those calculated using the Pdisp assessment.

8.6 Underpin Walls – Lateral Movements

Lateral ground movement during construction will be primarily dependent on the quality of workmanship of the contractor, particularly in the provision of temporary excavation support for the underpin drive, use of sacrificial trench sheeting to the rear face of the underpin excavation, dry-packing and timely and accurate installation of temporary propping during construction. Temporary propping of the top, middle and bottom of each underpin section during construction will be crucial in controlling horizontal deflection and rotation of the underpins. The detailing and construction of any reinforcement and connections/curing joints between underpin sections and basement slab will also be critical in controlling deflections.

For the purpose of this assessment the maximum deflection ratio of the wall will be determined from the critical ground movement profiles calculated for the adjacent property. This value will be used to determine the critical allowable lateral deflection of the wall to restrict movements such that predicted Damage Category 1 (very slight damage) is not exceeded. Where the Damage Category 1 limits are exceeded, limiting lateral deflection to restrict wall movements so that they do not exceed Damage Category 2 (slight damage) have been modelled.

8.7 Building damage assessment

The calculated ground movements have been used to assess potential 'damage categories' that may apply to neighbouring properties/infrastructure due to the proposed basement construction. The methodology proposed by Burland and Wroth[11] and later supplemented by the work of Boscardin and Cording[12] has been used, as described in *CIRIA Special Publication 200*[13] and *CIRIA C580*[14].

General damage categories are summarised in Table 10 below:

Table 10. 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).

For the neighbouring party wall sections the combined impact of short and long term heave and settlement due to workmanship have been combined to determine the deflection ratio for the adjacent properties. These values will then be used to establish the limiting

[11] 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

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

[13] 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.

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

horizontal strain allowed for the adjacent properties to ensure the damage category is confined within Category 1 'very slight' damage. The horizontal strain is a function of the lateral deflection of the wall which should be controlled during construction by a combination of regular propping and monitoring of the underpins.

For the critical perimeter basement wall section (neighbouring walls with 249 and 261 Camden High Street to the south-east and north-west respectively) the combined impact of undrained and drained ground movement and assumed settlement due to workmanship have been combined to determine the overall ground movements due to the construction of the basement. Maximum combined vertical movements have been predicted to be approximately 5.5 mm of heave below 261 Camden High Street and 5.5 mm below 249 Camden High Street foundations in addition to the 5mm of settlement associated with the installation of the underpins. Any minor settlements induced through construction should serve to reduce net heave movements. The combined movements for No. 248 Camden High Street and 261 Camden High Street are presented in Figure 9a and 9b respectively.

Table 11 summaries the calculation of damage category parameters, namely the deflection ratio and horizontal strain. The method of establishing an appropriate deflection ratio for the neighbouring structure is illustrated graphically in Figure 10.

The span between the footings of the adjacent party wall properties has been assumed from development plans to be approximately 5m. This span distance is taken perpendicular and not parallel to the basement footprint.

Table 11. Summary of ground movements and corresponding damage category

Critical Section	Limiting Horizontal movement [c] (mm)	Calculated Maximum deflection (mm)	Limiting horizontal Strain εh [a] (%)	Deflection ratio Δ/L [b] (%)	Damage category
249 Camden High Street Party Wall	0.5	3.5	0.01	0.07	1 - very slight
261 Camden High Street Party Wall	0.5	4	0.01	0.08	2 - slight

a. See Figure 2.18 (a) CIRIA C580 (2003) Embedded retaining walls guidance for economic design. (L = length of adjacent structure in metres, perpendicular to basement; Δ = relative deflection)

b. See Box 2.5 (v) CIRIA C580 (2003) Embedded retaining walls guidance for economic design. (δ_h = horizontal movement in metres

c. Maximum horizontal movement allowed to ensure Category 1 Damage is not exceeded

For 249 Camden High Street, based on the calculated maximum deflection of 3.5 mm, a maximum limiting value of 0.5 mm for the horizontal deflection of the underpins has been calculated to restricted the damage category of adjacent properties to within Category 1 'very slight' damage.

For 261 Camden High Street, based on the calculated maximum deflection of 4 mm, a maximum limiting value of 0.5 mm for the horizontal deflection of the underpins has been calculated to be on the boundary of Category 1 'very slight' and Category 2 'slight' damage.

The limiting horizontal movement and the deflection ratio are controlled by the distance between the foundations, which is assumed to be 5 m and a height of the building which is assumed to be 11 m, with a L/H ratio of 0.45.

8.8 Impact Assessment – London Underground tube tunnels

The potential impacts resulting from ground movements from the basement construction on the LUL tunnel and tracks located beneath Camden High Street have been assessed in accordance with LUL Guidelines[15], [16].

The movements associated with basement excavation will be generally uniform, and predominantly downwards associated with the loading resulting from the construction of the new development. The nature of such movements is that they form gentle curves on a relatively long-scale, which are relatively uniform along the length of the tunnel and therefore unlikely to have an effect on localised measures of track quality such as 2m twist and 10m twist which could be affected by very localised causes such as, say, the collapse of a duct causing localised track settlement. With this in mind, movements have been reviewed to assess the potential changes in track cant and vertical alignment as an indication of how much the new basement might affect broad maintenance targets. It should be noted that the current condition of the track is not known, therefore results have been compared to the Maintenance Limit (ML), Maintenance Target (MT) and the Safety Standard (SS)

The anticipated ground movements at the crown of the shallowest LUL tunnel have been assessed and are shown on Figure 11, the maximum differential movements associated with the basement construction have been calculated a 5 m centres with maximum movements of <0.4 mm/5m. The MT for a Category A track is 5 mm/5 m therefore the anticipated movements are well within the MT criteria based on the track being in a good condition. If the existing track is in a poor condition a change in the vertical profile of between 2 mm is required to change the MT and a further change of 3 mm is required to

[15] London Underground. 2014. *Civil Engineering – Deep Tube Tunnels and Shafts*. Ref: S1055
[16] London Underground. 2013. *Track – Dimensions and Tolerances*. Ref: S1159

reach the SS in accordance with the maintenance schedule. Along the length of the tunnel the cumulative movements are within the MT.

Three sections, X, Y and Z, the locations of these are presented on Figures 7 and 8, have been used to determine the change in cant between the track gauge (1.435 m wide) based on the track level at 15.15 mOD. A schematic of the dimensions of the tunnel used for the assessment is presented on Figure 12. This level is based on the tunnel crown at 17.85 mOD and approximate diameter of the tunnel of 3.5 m and the track 2.7 m below the tunnel crown. Figure 13 shows the maximum combined differential movements for section X, Y and Z from the basement excavation on the track are calculated as being between <0.2 mm across its width, this lies within the cant tolerance for a MT for a Category A track of +/- 10 mm, the anticipated movements are well within the MT criteria based on the track being in a good condition. If the existing track is in a poor condition a change in cant of between 5 mm is required to reach the MT and a further change of 15 mm is required to reach the SS in accordance with the maintenance schedule.

Lateral movement would be taken to be as a proportion of vertical and would not be expected to affect the vertical alignment of the tunnels. Similarly, with track being relatively straight adjacent to the tunnel, and the movements being very low, no effect on clearances would be expected.

The results of the VDISP analysis indicate that the proposed basement construction will cause a maximum stress increase of 8kPa on the nearest LUL tunnel running below Camden High Street. This corresponds to a stress increase of <5 % assuming the shallowest tunnel is at 10 m bgl and the weight of the overburden material is 19 kN/m^3. The predicted combined short and long term stress change profile along the crown of the tunnel are presented within Figure 14.

8.9 Impact assessment - Deep shelter tunnel

The results of the VDISP analysis indicate that the proposed basement construction will cause a maximum stress change of 1 kPa on the deep shelter tunnel located beneath the site. This corresponds to a stress increase of <0.3 % assuming the shallowest tunnel is at 19.5 m bgl and the weight of the overburden material is 19 kN/m^3. The predicted combined short and long term stress change profile along the crown of the tunnel are presented within Figure 15.

The anticipated ground movements at the crown of the deep shelter tunnel have been assessed and are shown on Figure 16, the maximum differential movements associated with the basement construction have been calculated a 5 m centres with maximum movements of 0.03 mm/5m.

A schematic of the dimensions of the deep shelter tunnel used for the assessment is presented on Figure 12.

9. MONITORING STRATEGY

9.1 Party wall structures

The results of the ground movement analysis suggest that with good construction control, damage to adjacent structures generated by the assumed construction methods and sequence are likely to be within Category 2 ('slight'). To ensure movements do not start to fall outside of those predicted, it is recommended that a formal monitoring strategy is implemented on site in order to observe and control ground movements during construction.

The monitoring system should operate broadly in accordance with the 'Observational Method' as defined in CIRIA Report 185[17]. Monitoring can be undertaken by using positional surveys compared to baseline values established before any excavation work is undertaken onsite. Regular monitoring of these positions will determine if any horizontal translation, tilt or differential settlement of the neighbouring structure is occurring as the construction progresses. Monitoring data should be checked against predefined trigger limits and can also be further analysed to assess and manage the damage category of the adjacent buildings as construction progresses.

As discussed previously, the horizontal deflection/translation of the underpins during construction should be limited to less than 4.5 mm, between the site and 261 Camden High Street, for the underpinned sections to restrict the damage category for the adjacent critical properties to within Category 2 'slight'. The horizontal deflection/translation of the underpins during construction should be limited to less than 0.5 mm, between the site and 249 Camden High Street, for the underpinned sections to restrict the damage category for the adjacent critical properties to within Category 1 'very slight' and 5.5 mm to keep within damage Category 2 'slight'. This value should form the basis of the 'traffic light' trigger levels established prior to underpinning and piling works commencing onsite. 'Trigger levels' should be discussed and agreed with the party wall surveyor.

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

9.2 Tunnels

Predicted displacements on the tunnels are effectively negligible and it is not proposed to monitor the tunnels.

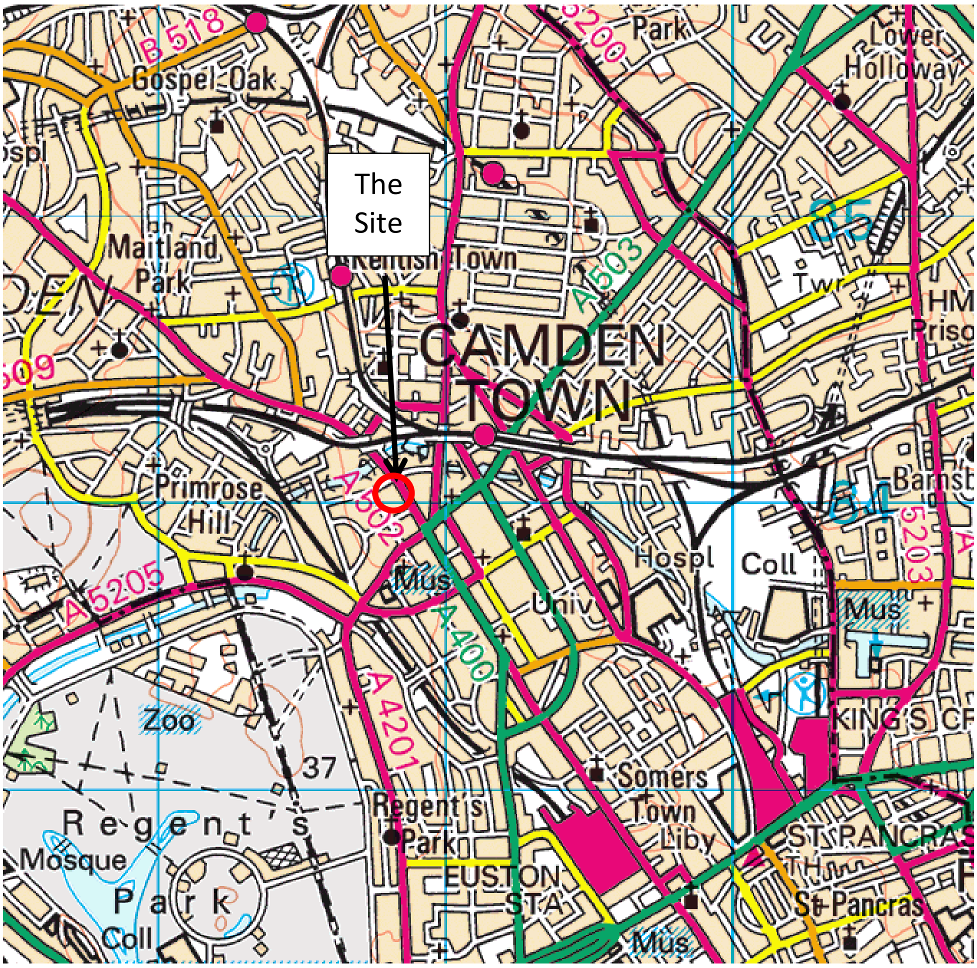
10. NON-TECHNICAL SUMMARY

The results of this Ground Movement Report are informed by ground investigation data available for the site and BGS borehole records. The analysis is also informed by drawings and loadings provided by the architect and structural engineer respectively for the project.

- Based on a numerical assessment ground movements are anticipated to be of low magnitude in the locale of the adjacent structures and can be mitigated in the structural and temporary works design. The design should also take account of the adequacy of embedment.
- Assuming high quality workmanship and appropriate contingencies for groundwater control, it is considered that the calculated ground movement would limit building damage categories to the Category 1'very slight' and Category 2 'slight' damage boundary. It should be noted that good workmanship will be critical in controlling ground movements during construction. Reference should be made to the Association of Specialist Underpinning Contractors guidance[19] in this respect.
- Additionally, ground movements predicted along the line of the LUL tunnel fall below maintenance standards and the ground movements are unlikely to significantly impact the deep shelter tunnel located directly under the site.
- In order to control ground movements to within the predicted range, it is recommended that a formal monitoring strategy is implemented on site in order to observe and control ground movements during construction.
- The long term impact of the basement on the local hydrogeological regime is expected to be negligible.

[19] ASUC (October 2013) *Guidelines on safe and efficient basement construction directly below or near to existing structures.*

FIGURES



N

Client	Project	Job No
Castlehaven Row Limited	**251 – 259 Camden High Street, London**	**CG/18648**
CGL	Title **Site location plan**	**Figure 1**

KEY

Borehole Location. CGL. December 2015.

Foundation exposure pit location. CGL. December 2015.

Notes:

Exploratory holes locations for indicative purposed only.

Do not scale from drawing.

Site layout drawing provided by The Client.

Rev	Date	Comments
*	*	*

CGL
Card Geotechnics Ltd
4 Godalming Business Centre
Woolsack Way
Godalming
Surrey
GU7 1XW
T: 01483 310600

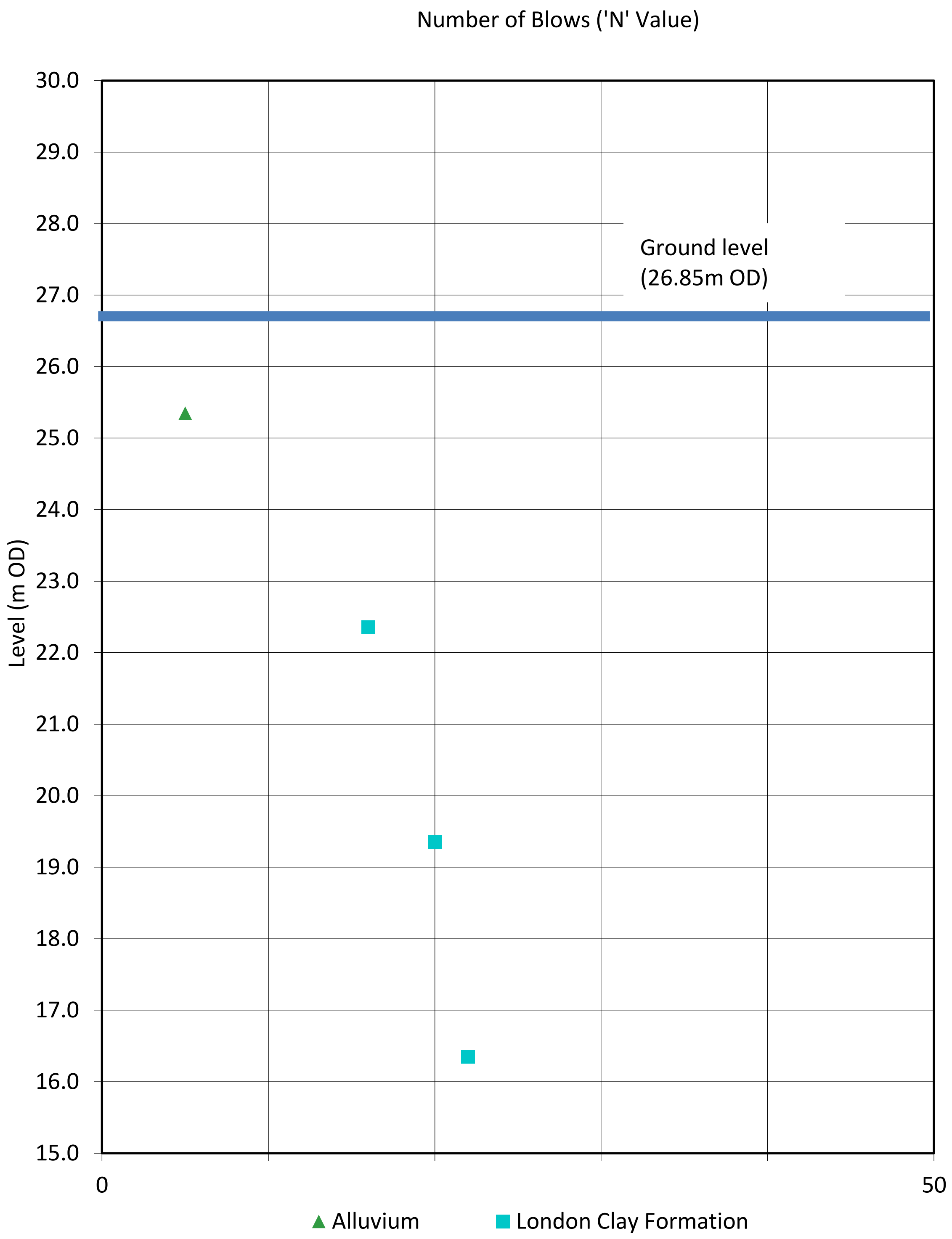
Project: **251-259 Camden High Street**

Client: **Castlehaven Row Ltd**

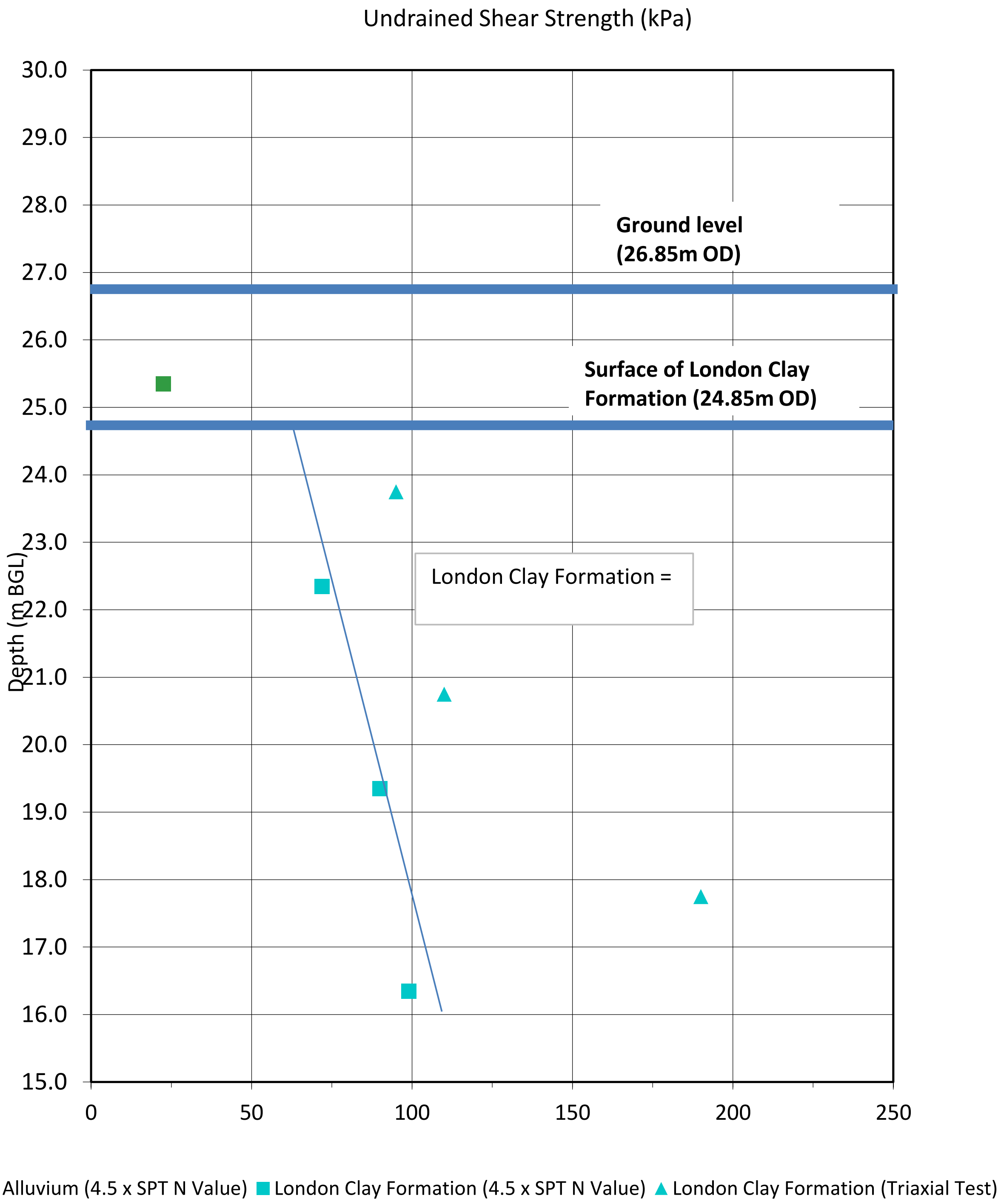
Drawing title: **Figure 2 - Exploratory Hole Location Plan**

Scale(s)	Job No.
NTS	**CG/18648**

			Dwg No.	Rev.
Drawn	TSB	11/01/15	**CG/18648-001**	*
Checked				
Approved				



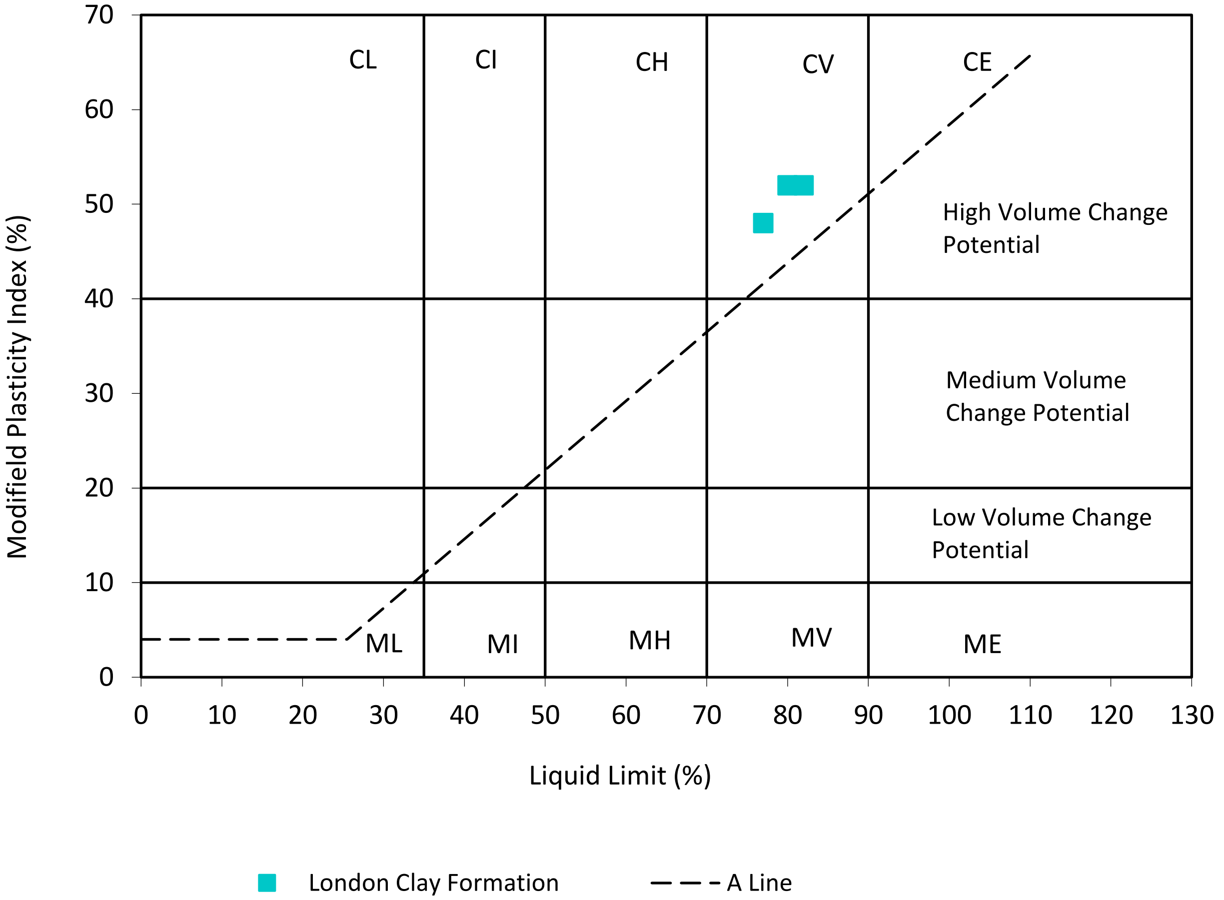
Client	Project	Job No.
Castlehaven Row Limited	**251 - 259 Camden High Street, London**	**CG/18648**
CGL	Title **SPT 'N' value versus level**	**Figure 3**



Client	Project	Job No.
Castlehaven Row Limited	**251 - 259 Camden High Street, London**	**CG/18648**
CGL	Title **Undrained shear strength versus level**	**Figure 4**

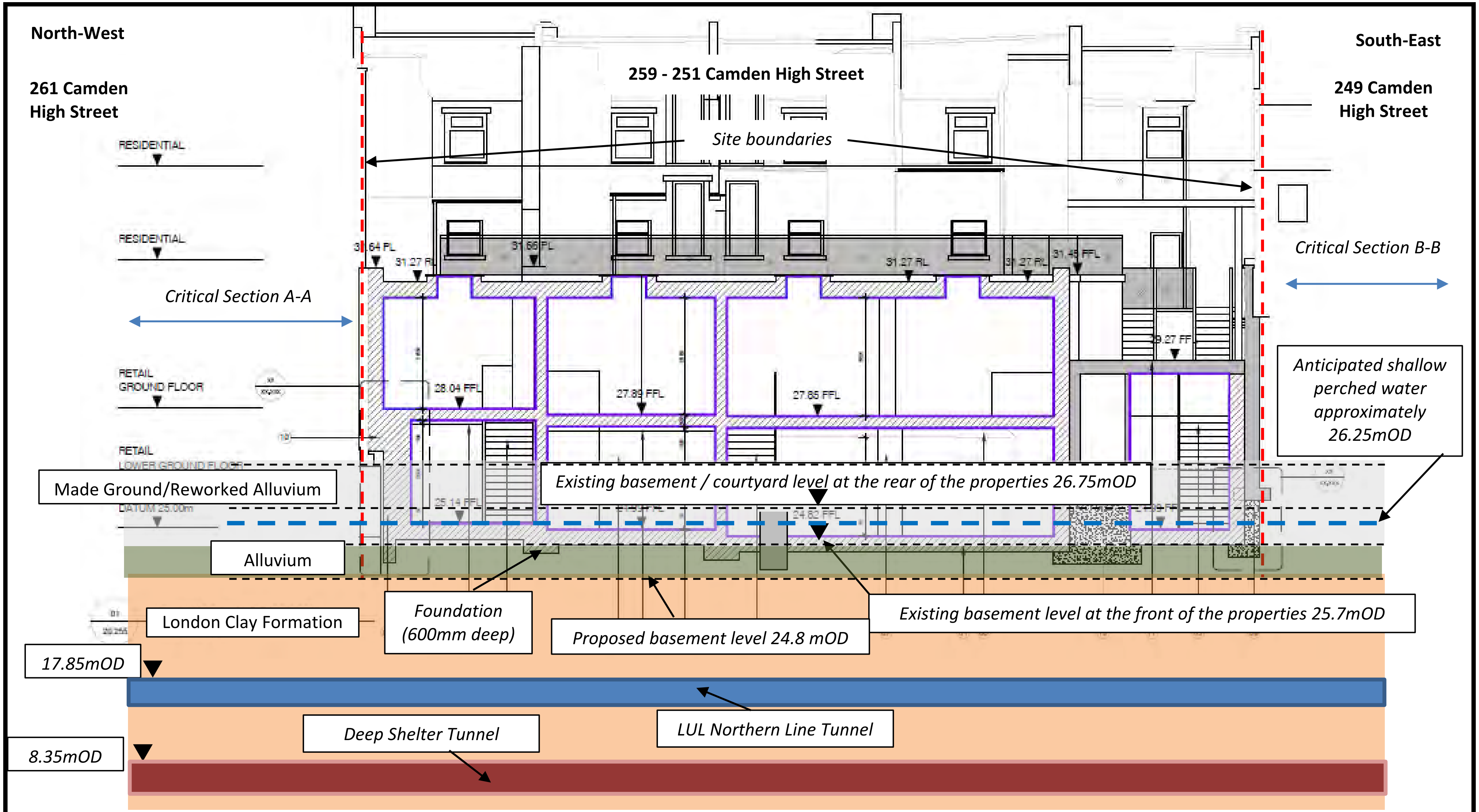
Key:
C Clay M Silt

L Low plasticity
I Intermediate plasticity
H High plasticity
V Very high plasticity
E Extremely high plasticity

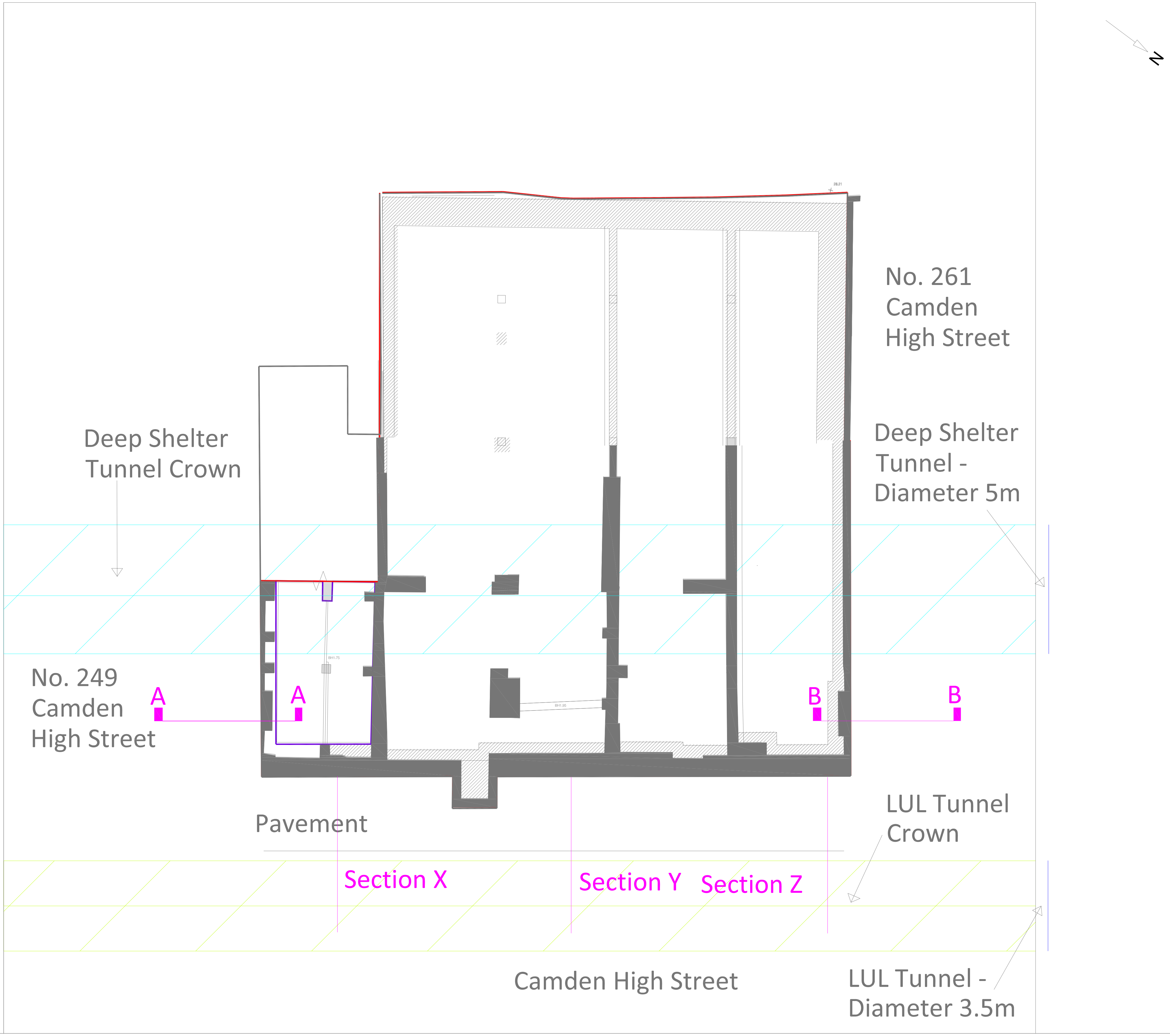


Notes. Volume change potential based on NHBC 4.2 : 2013 : Building near trees. Plasticity of the soils is based on BS 5930 : 1999 : Code of practice for site investigations. British Standards Institution, London.

Client	Project	Job No.
Castlehaven Row Limited	**251 - 259 Camden High Street, London**	**CG/18648**
CGL	Title **Plasticity chart**	**Figure 5**



Client	Project	Job No
Castlehaven Row Limited	**251 – 259 Camden High Street, London**	**CG/18648**
CGL	Title **Conceptual site model section (Not to scale)**	**Figure 6a**



Key:

A — A Critical section

LUL tunnel.

Deep shelter tunnel

Notes

Do not scale from drawing

Rev	Date	Comments
*	*	*

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

Project: 251-259 Camden High Street, London

Client: Castlehaven Row Limited

Drawing title: Figure 6b - Conceptual side model plan view

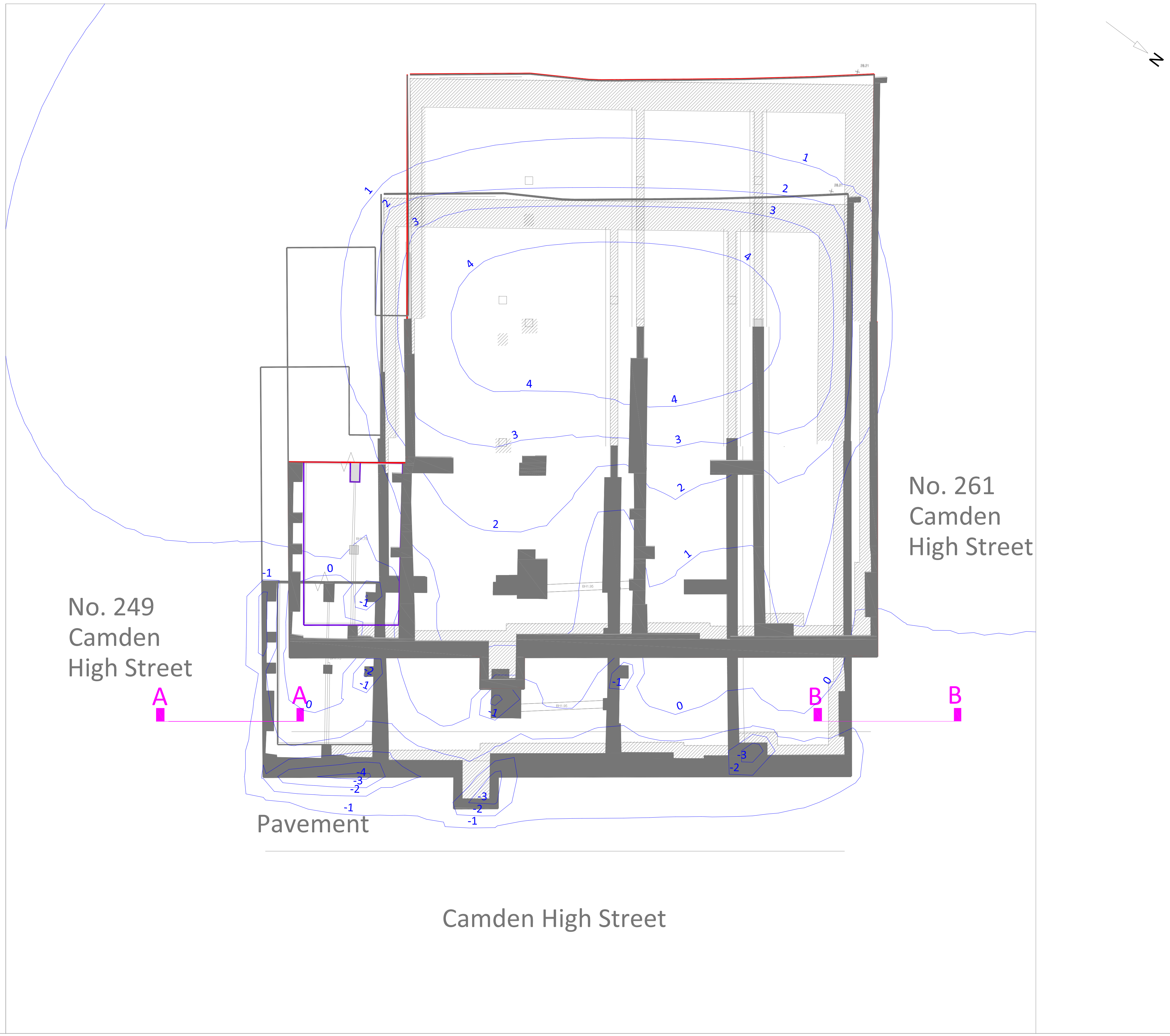
Scale(s): NTS

Job No.: CG/18648

Drawn	SJM	11/02/16
Checked	RJB	12/02/16
Approved	RJB	12/02/16

Dwg No.: CG/18648-001

Rev.: *



A ———— A Critical section.

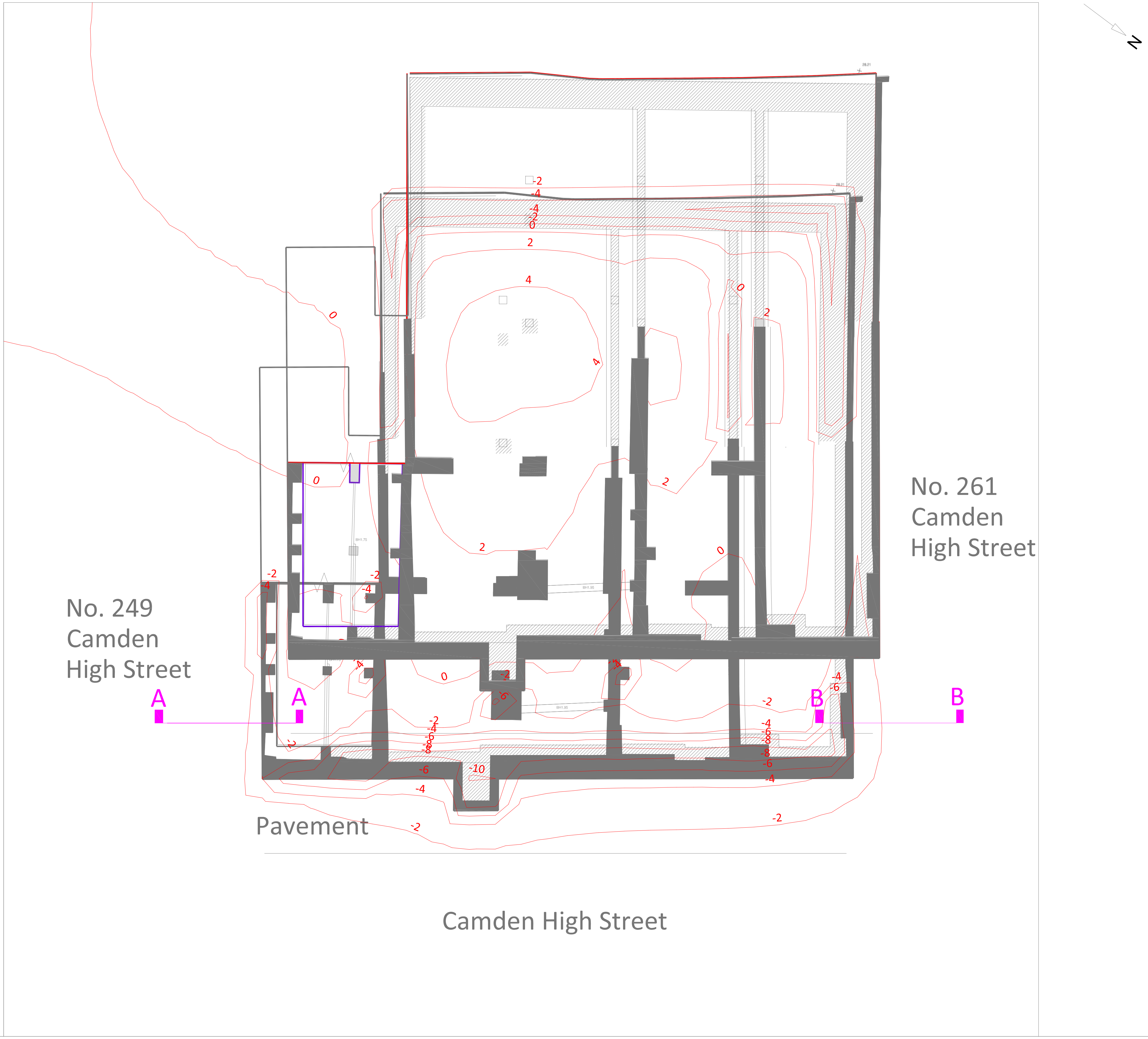
Note
Contour levels are in mm
Positive numbers = heave
Negative numbers - settlement

Rev	Date	Comments
*	*	*

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

Project	**251-259 Camden High Street, London**
Client	**Castlehaven Row Limited**
Drawing title	**Figure 7 - Short term ground movement contour plot at basement level**
Scale(s) **NTS**	Job No. **CG/18648**

Drawn	TSB	11/02/16	Dwg No. **CG/18648-001**	Rev. *
Checked	RJB	12/02/16		
Approved	RJB	12/02/16		



A —— A Critical section.

Note
Contour levels are in mm
Positive numbers = heave
Negative numbers - settlement

Rev	Date	Comments
*	*	*

CGL
Card Geotechnics Ltd
4 Godalming Business Centre
Woolsack Way
Godalming
Surrey
GU7 1XW
T: 01483 310600

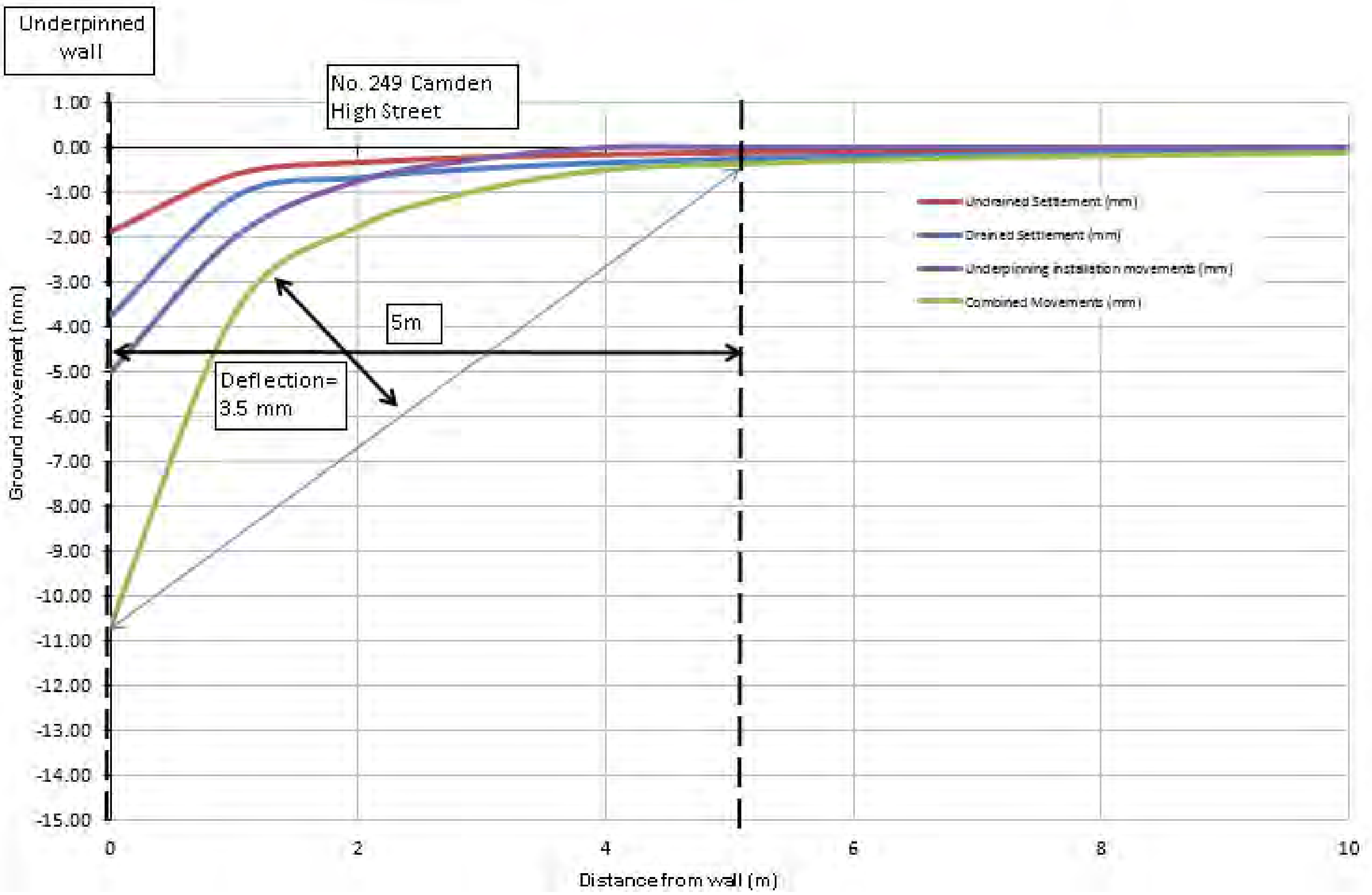
Project: **251-259 Camden High Street, London**

Client: **Castlehaven Row Limited**

Drawing title: **Figure 8 - Long term ground movement contour plot basement level**

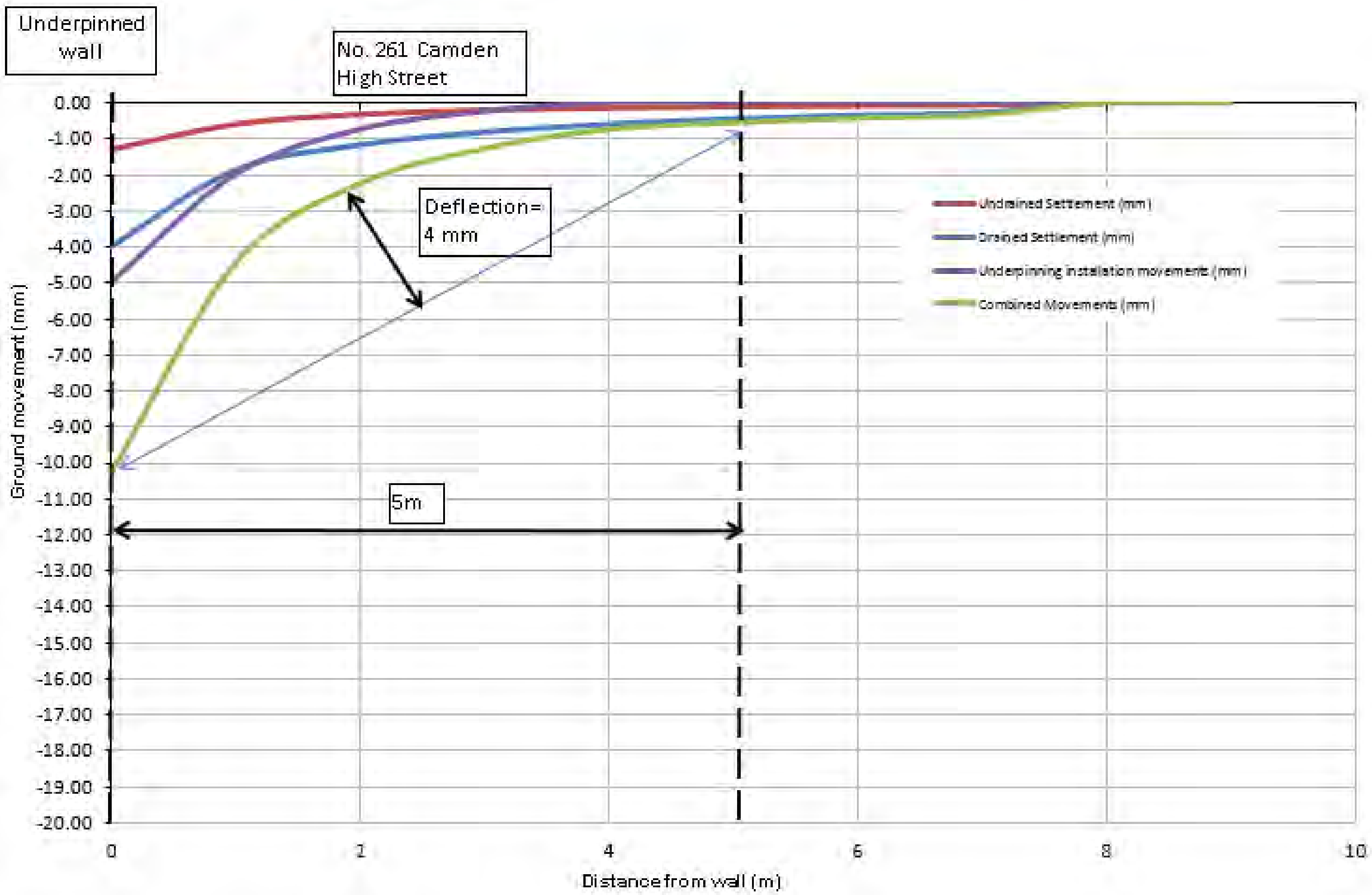
Scale(s)	Job No.
NTS	CG/18648

			Dwg No.	Rev.
Drawn	TSB	11/02/16	CG/18648-001	*
Checked	RJB	12/02/16		
Approved	RJB	12/02/16		



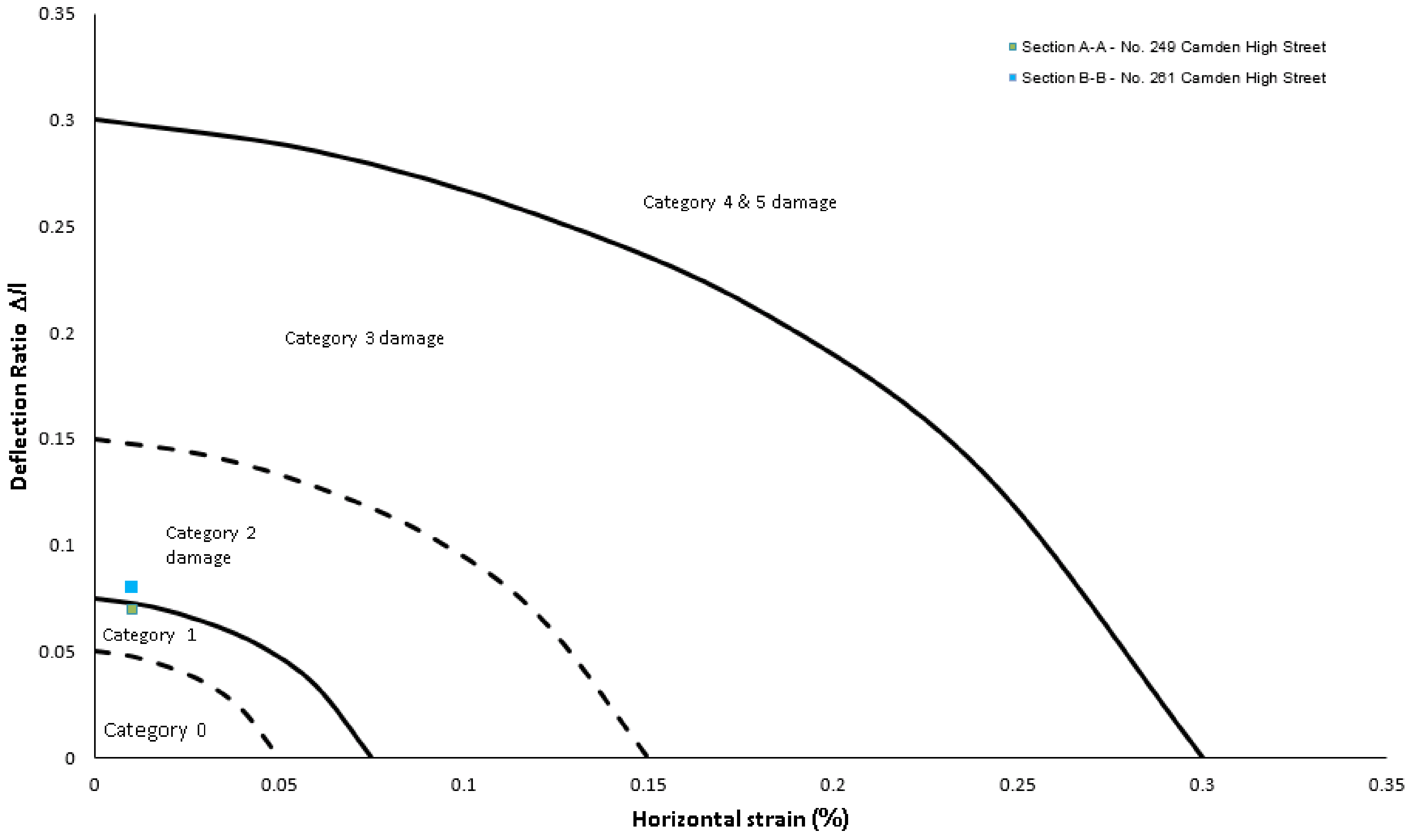
Notes:
Positive number equal heave and negative numbers equal settlement.

Client	Project	Job No
Castlehaven Row Limited	**251 -259 Camden High Street, London**	**CG/18648**
CGL	Title: **Combined vertical movement below 249 Camden High Street**	**Figure 9a**

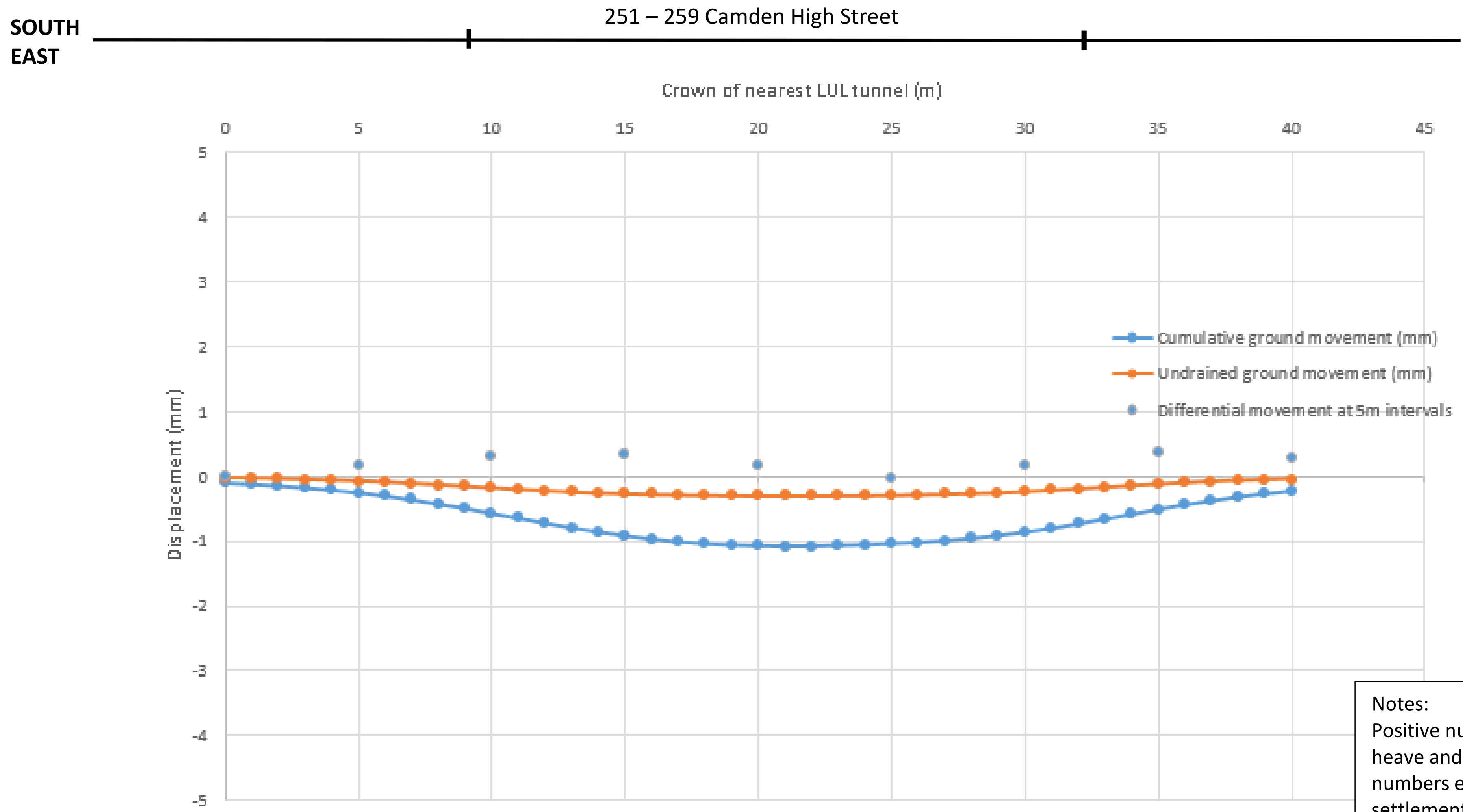


Notes:
Positive number equal heave and negative numbers equal settlement.

Client	Project	Job No
Castlehaven Row Limited	**251 -259 Camden High Street, London**	**CG/18648**
CGL	Title **Combined vertical movement below 261 Camden High Street**	**Figure 9b**

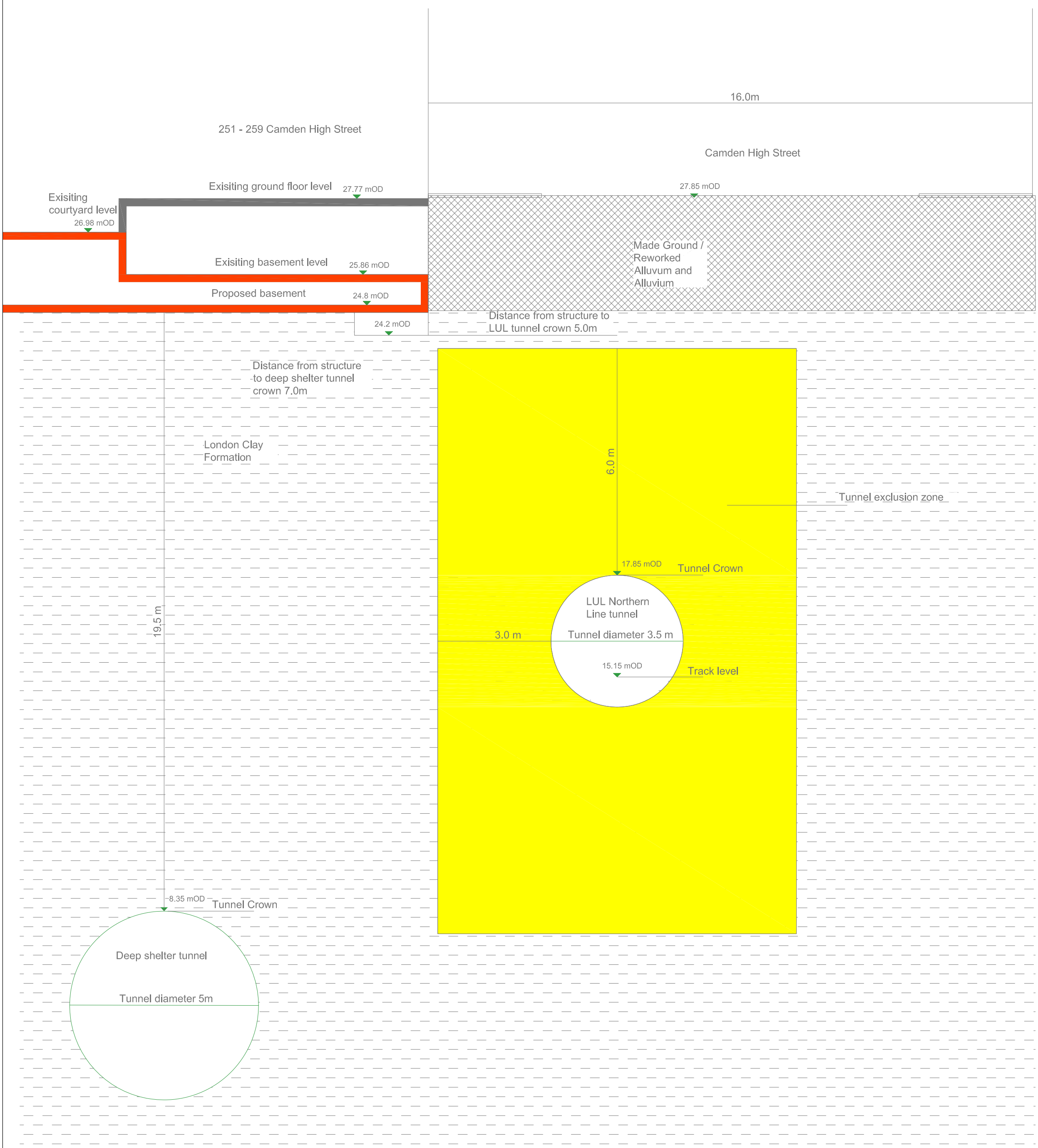


Client **Castlehaven Row Limited**	Project **251 – 259 Camden High Street, London**	Job No **CG/18648**
CGL	Title **Damage category assessment**	**Figure 10**

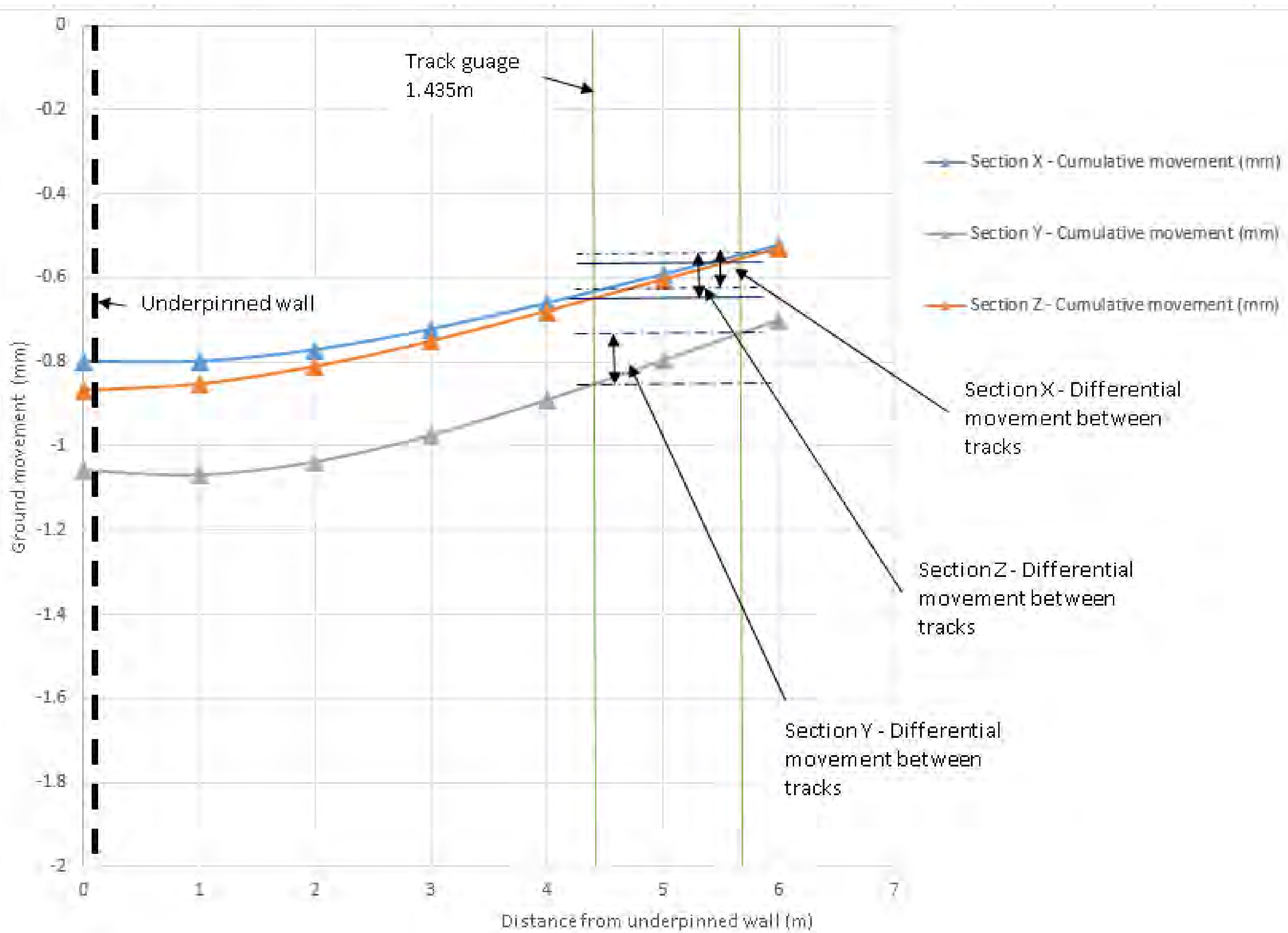


Notes:
Positive number equal heave and negative numbers equal settlement.

Client	Project	Job No
Castlehaven Row Limited	**251 – 259 Camden High Street, London**	**CG/18648**
CGL	Title **Displacement change profile along crown of LUL tunnel**	**Figure 11**

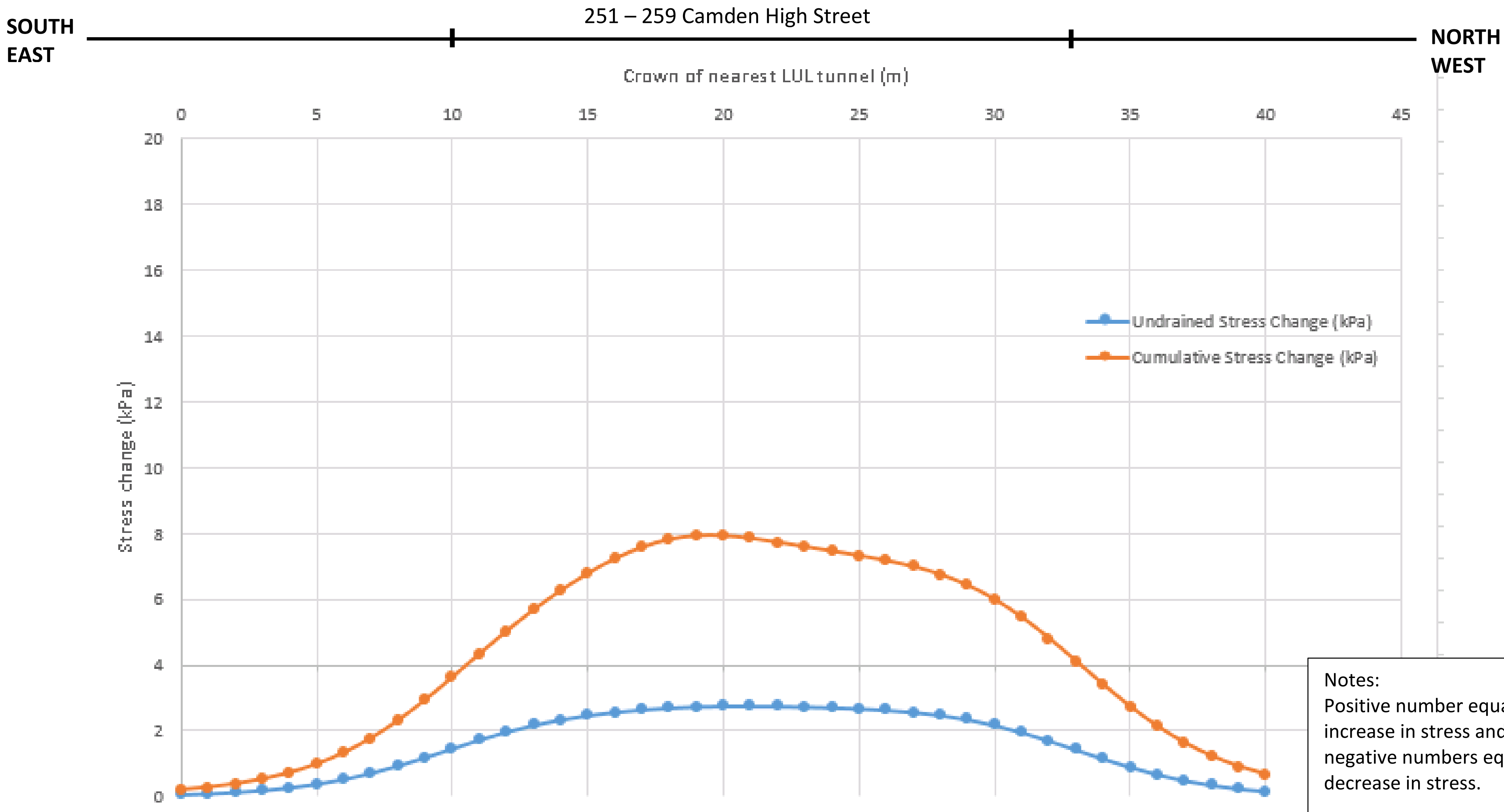


Client	Project	Job No
Castlehaven Row Limited	**251 - 259 Camden High Street, London**	**CG/18648**
CGL	Title: **Schematic of LUL and deep shelter tunnels**	Drawn by: SJM Checked by: RJB Approved by: RJB
		Figure 12



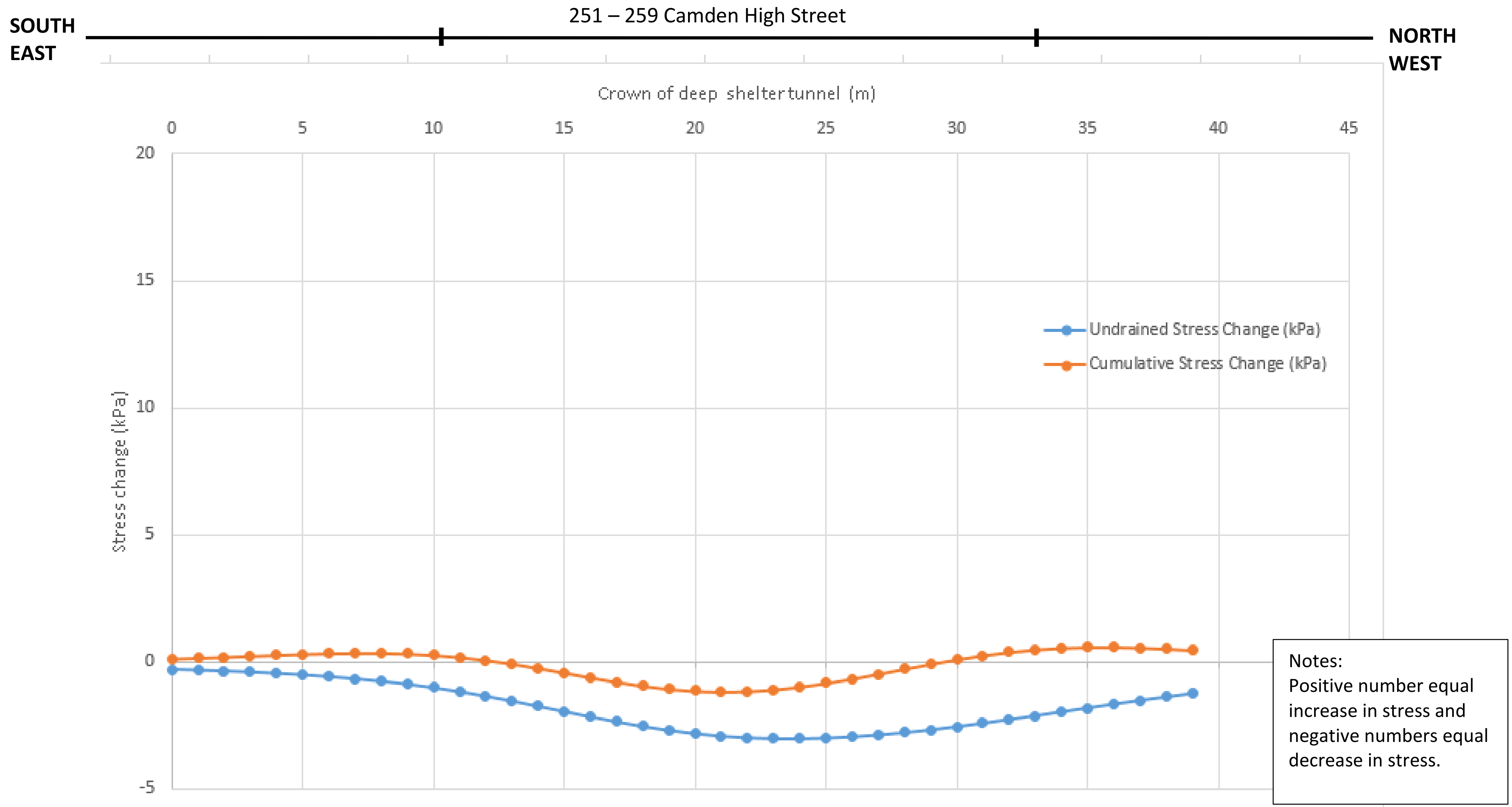
Notes:
1. Cumulative ground movements are calculated.
2.Negative numbers show settlement and positive numbers show heave.
3. Nearest point of the track is located approximately 4.3m from underpinned wall.

Client	Project	Job No
Castlehaven Row Limited	**251 – 259 Camden High Street, London**	**CG/18648**
CGL	Title **LUL Section X, Y and Z**	**Figure 13**



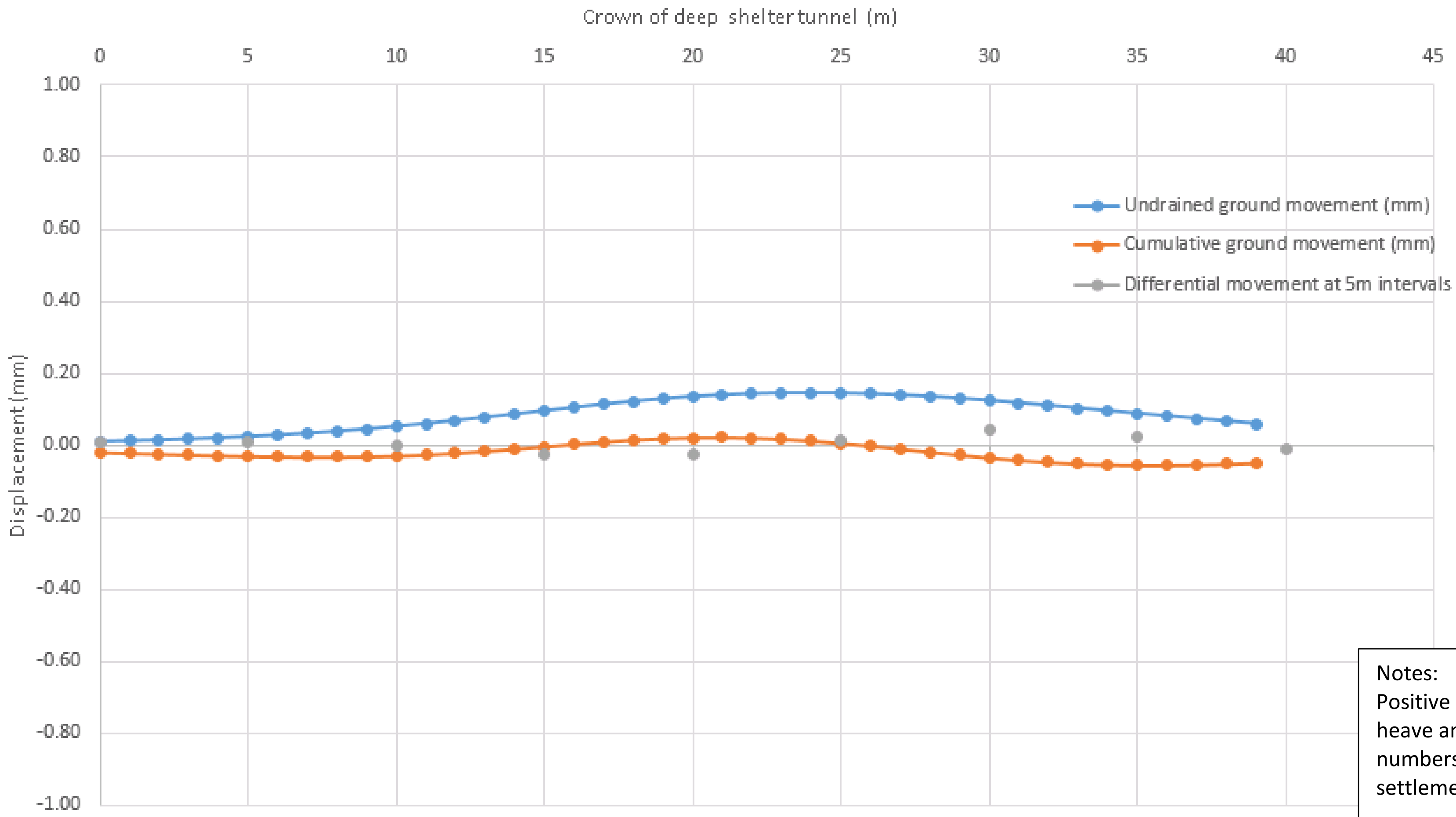
Notes:
Positive number equal increase in stress and negative numbers equal decrease in stress.

Client	Project	Job No
Castlehaven Row Limited	**251 – 259 Camden High Street, London**	**CG/18648**
CGL	Title: **Stress change profile along crown of LUL tunnel**	**Figure 14**



Client	Project	Job No
Castlehaven Row Limited	**251 – 259 Camden High Street, London**	**CG/18648**
CGL	Title **Stress change profile along the crown of the deep shelter tunnel**	**Figure 15**

SOUTH EAST — 251 – 259 Camden High Street — NORTH WEST



Notes:
Positive number equal heave and negative numbers equal settlement.

Client	Project	Job No
Castlehaven Row Limited	**251 – 259 Camden High Street, London**	**CG/18648**
CGL	Title **Displacement change profile along crown of the deep shelter tunnel**	**Figure 16**