Asset Impact Assessment
of TfL Northern Line

in connection with proposed development at

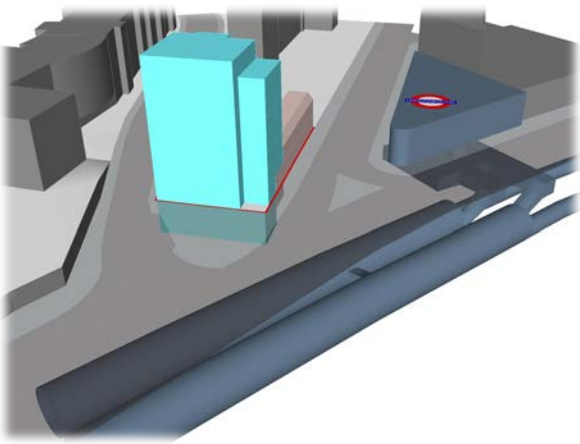
155-157 Regent's Park Road
Camden
London
NW1 8BB

for

Uchaux Ltd

LBH4540aia Ver. 1.0

August 2019



LBH WEMBLEY ENGINEERING

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Foreword-Guidance Notes

GENERAL

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THIRD PARTY INFORMATION

The report may present an opinion based upon information received from third parties. However, no liability can be accepted for any inaccuracies or omissions in that information.

1. Introduction

1.1 Background

Following demolition of the existing building at Nos. 155 – 157 Regent's Park Road, it is proposed to construct an eight storey hotel with a two storey basement extending to an approximate depth of 7m below ground level.

LBH WEMBLEY have previously completed an Interpretive Geotechnical Report (ref: LBH4540GIR ver. 1.0, July 2019) and a Basement Impact Assessment (ref: LBH4540 ver. 1.0, July 2019) in support of the planning application for the proposed development.

The southbound and northbound tunnels of the Northern Line at the Chalk Farm Underground Station lie beneath Haverstock Hill, located to the northeast of the site.

1.2 Brief

LBH WEMBLEY have been appointed by Uchaux Ltd to prepare an Asset Impact Assessment in accordance with Transport for London (TfL) standard guidance to satisfy the London Underground Infrastructure Protection Team that the proposed development will not cause a detrimental impact to their infrastructure.

1.3 Report Structure

Following a description of the site and the established ground conditions, the report proceeds to an analysis of the ground movements that can be expected to occur at the Chalk Farm Underground Station and Northern Line tunnels as a result of the proposed development.

The following Transport for London (TfL) Guidance documents have been followed in preparation of this document.

G0023 Infrastructure Protection: Special Conditions for Outside Parties Working On or Near the Railway

S1050 Civil Engineering: Common Requirements

In accordance with Section 3.3 of TfL G0023, the following items have been addressed in this report:

3.3.3 f) No new support to be taken from LU Land or structures

3.3.3 g) Proximity to LU tunnels or other structures and the effect of works on these structures, including potential temporary or permanent weather proofing

3.3.3 h) Required site investigation, including boreholes, and the proximity of these investigations to tunnels or other structures

3.3.3 i) Direct or indirect (such as that caused by ground movement) changes of existing loading on or from LU structures

1.4 Documents Consulted

The following documents have been consulted in preparation of this report:

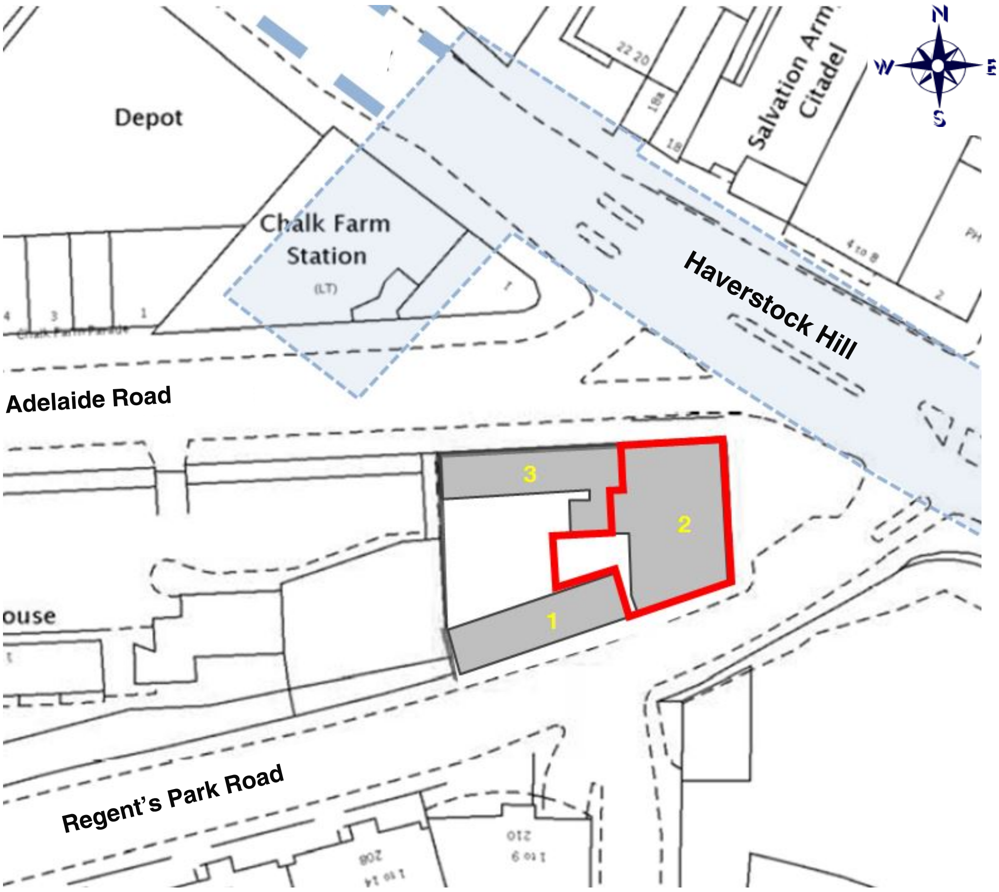
2019 July	Tunnel Correlation Survey by TfL	(Ref: SR19_112)
2019 July	Geotechnical Interpetive Report by LBH WEMBLEY	(Ref: LBH4540gir)
2019 July	Basement Impact Assessment by LBH WEMBLEY	(Ref: LBH4540bia)
2019 July	Flood Risk Assessment & SuDS Strategy by LBH WEMBLEY	(Ref: LBH4540fra)
2018 July	Factual Site Investigation Report by ST Consult	(Ref: JN1143)

2. The Site

2.1 Site Location

The site is situated at the junction of Regent's Park Road, Haverstock Hill and Adelaide Road, approximately 15m to the southeast of Chalk Farm London Underground station.

The site may be located approximately by postcode NW1 8BB or by National Grid Reference 528155, 184380.



Location plan

KEY

Site Boundary

Existing Buildings

Chalk Farm Underground Station Extent

1: Nos. 151 – 153 Regent's Park Road

2: Nos. 155 – 157 Regent's Park Road

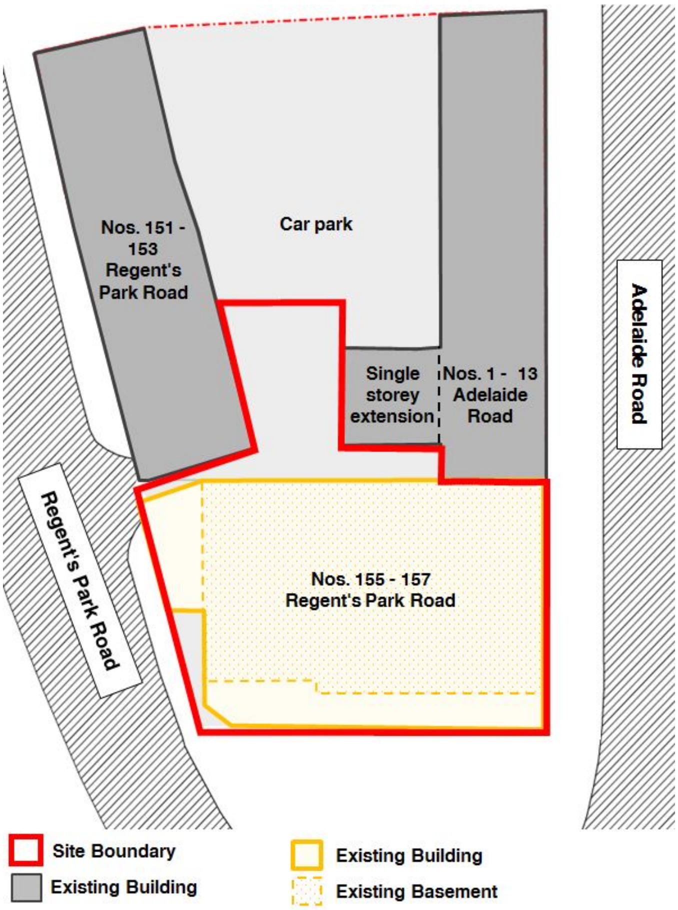
3: Nos. 1 – 13 Adelaide Road

2.2 Site Description

The site is occupied by a four storey terraced building with mansard roof at Nos. 155 – 157 Regent's Park Road.

Street level immediately on the corner of Regent's Park Road and Adelaide Road is situated at approximately +31m OD. The natural ground level appears to rise by some 2m towards the rear end of Nos. 151 – 153.

Nos. 155 – 157 comprises a single storey basement that occupies most of the building footprint. It appears that the basement extends to approximately 3.5m depth below ground level.



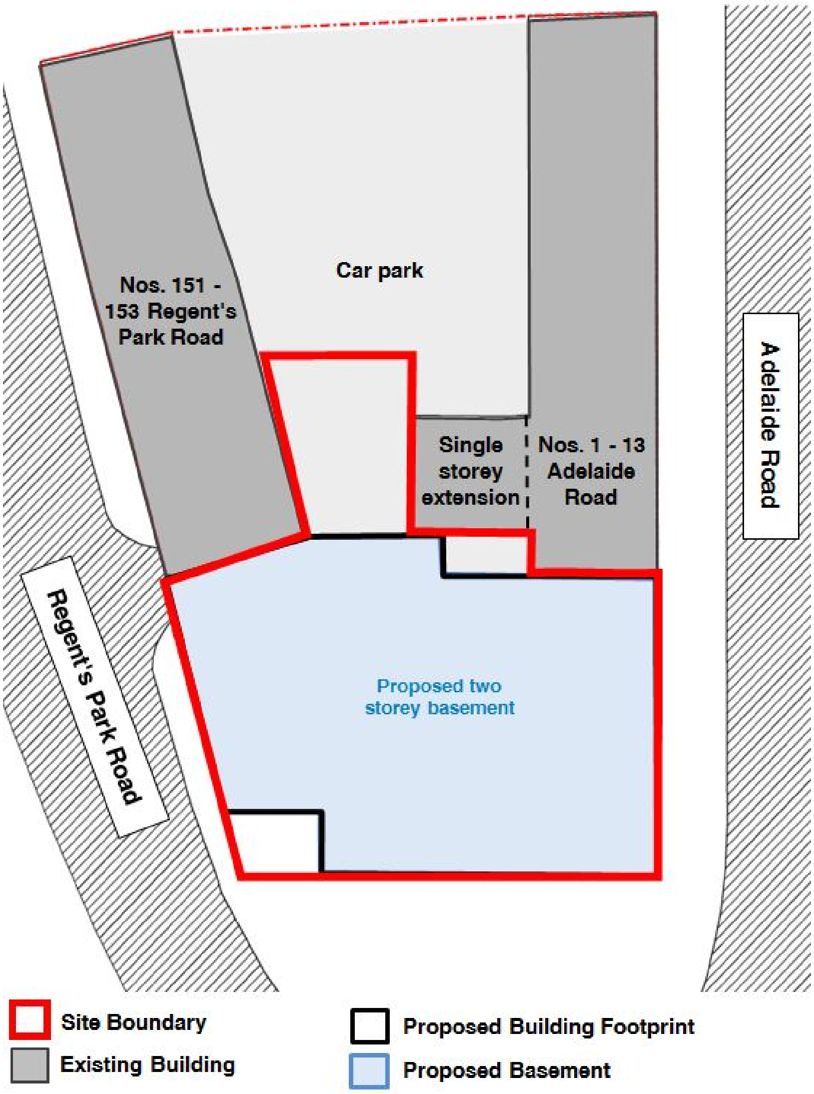
Plan showing existing features

2.3 Proposed Development

It is proposed to construct an eight storey hotel with a double-storey basement.

The proposed redevelopment includes demolition of the existing four storey building at Nos. 155 – 157 Regent's Park Road, followed by an excavation to an approximate depth of 7m (+24m OD) below existing ground level to allow the construction of an additional basement storey. However, one corner of the existing single storey basement will be retained.

The basement excavation will be retained by a contiguous bored pile wall, following which the new hotel will be supported by piled foundations.



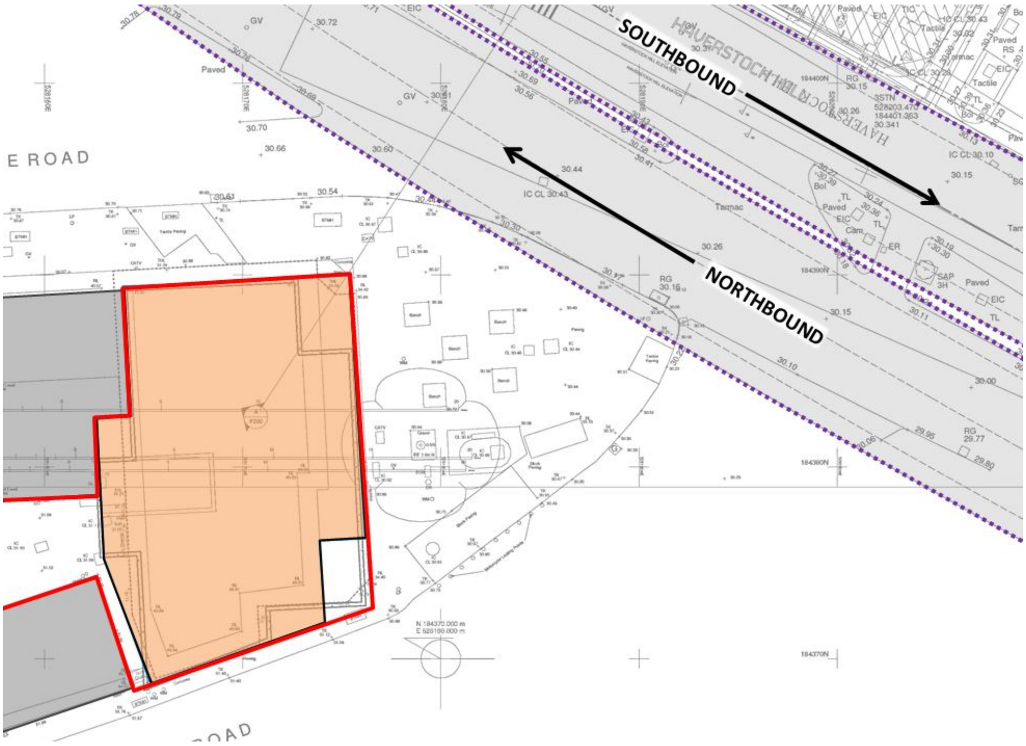
Plan showing proposed development

2.4 LUL Infrastructure

Chalk Farm Station on the LUL Northern Line tunnels is present to the northeast of the development, running approximately parallel to Haverstock Hill.

The location and levels of the tunnels underneath Haverstock Hill have been obtained from a TfL correlation survey which relates the position and depth of the tunnels with the location and levels of Haverstock Hill. This survey has been related to the site position and the location of the proposed development.

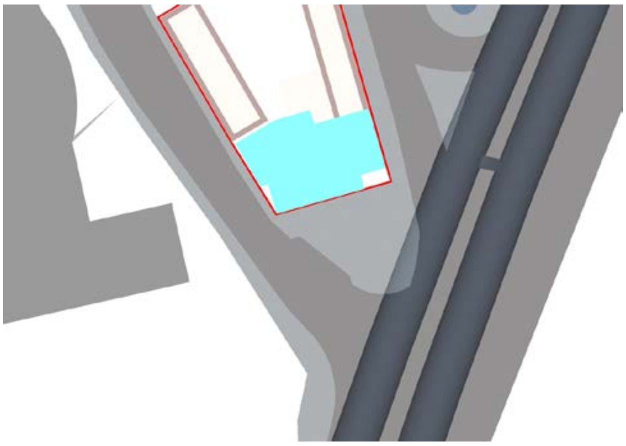
The Northern Line tunnels measure approximately 3.5m in internal diameter and comprise cast iron segmental lining. The tunnels at the station, however, are understood to be bored to a larger diameter to house station platforms and are expected to measure approximately 7m in diameter.

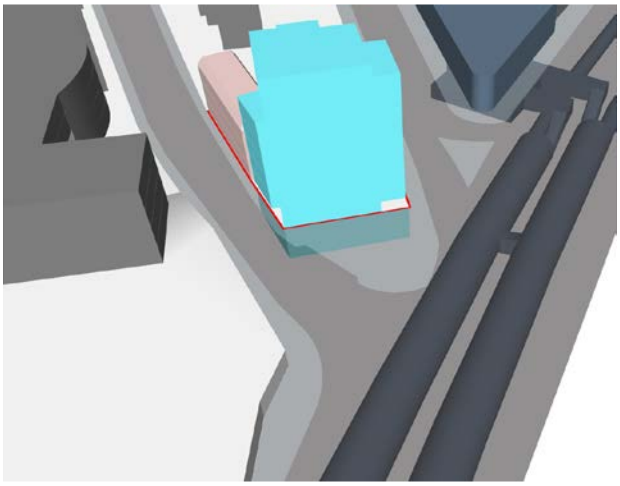


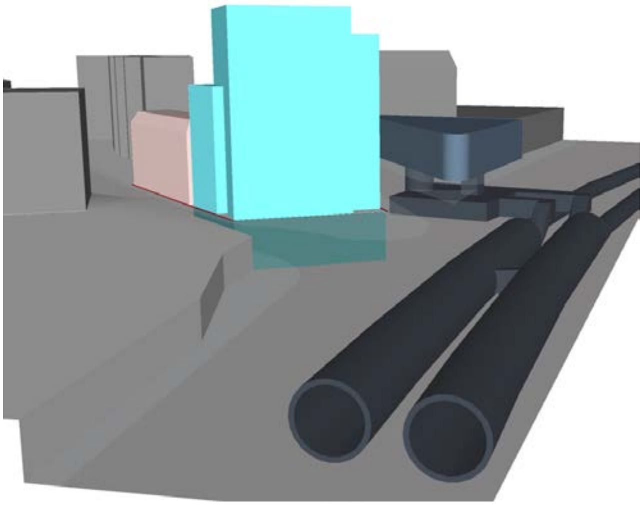
Proposed basement location (shaded orange) in relation to the LUL Chalk Farm station Tunnels

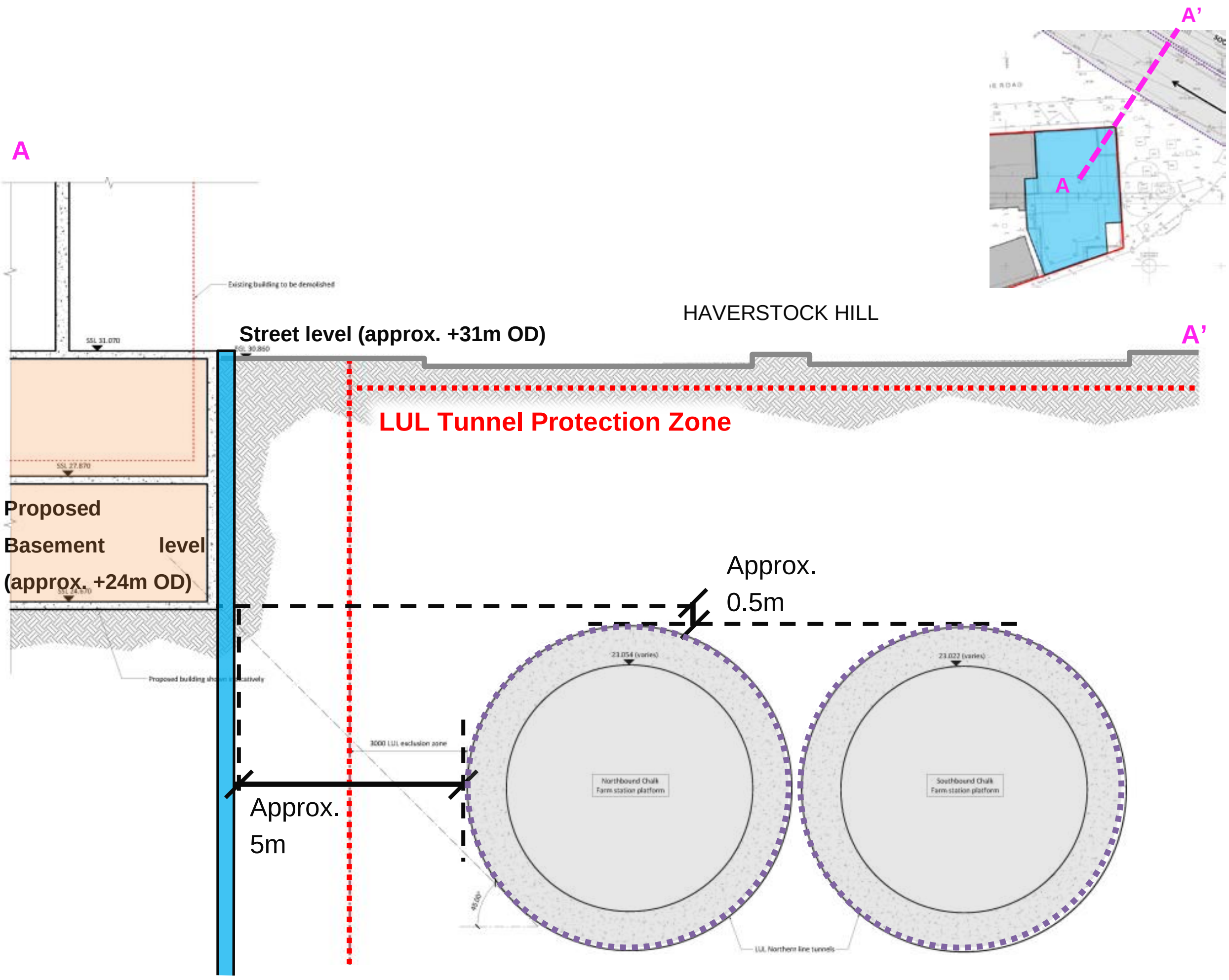
The internal crowns of the southbound and northbound tunnels of the Northern Line beneath Haverstock Hill are situated at a similar level of approximately +23m OD (+123m London Underground Datum). The closest edge of the proposed basement will be placed approximately 5m laterally to the northeast of the edge of the Northern Line northbound station tunnel and some 1m above the crown of this tunnel.

Any works associated with the proposed development will not intrude into the Tunnel Protection Zone, which extends to 6m above the crown and 3m horizontally from the sides of the tunnel.









Section drawing showing the location of the LUL Northern Line tunnels in relation with the proposed development (shaded blue) at the closest point, together with an indicative perimeter pile location

3. Ground Conditions

A ground model has been developed on the basis of an intrusive site investigation undertaken in July 2018 by ST Consult and from other nearby archive information.

3.1 Made Ground

There appears to be approximately 1m of made ground beneath the car park, consisting of dark brown sandy clay with extraneous fragments of brick and concrete.

3.2 London Clay Formation

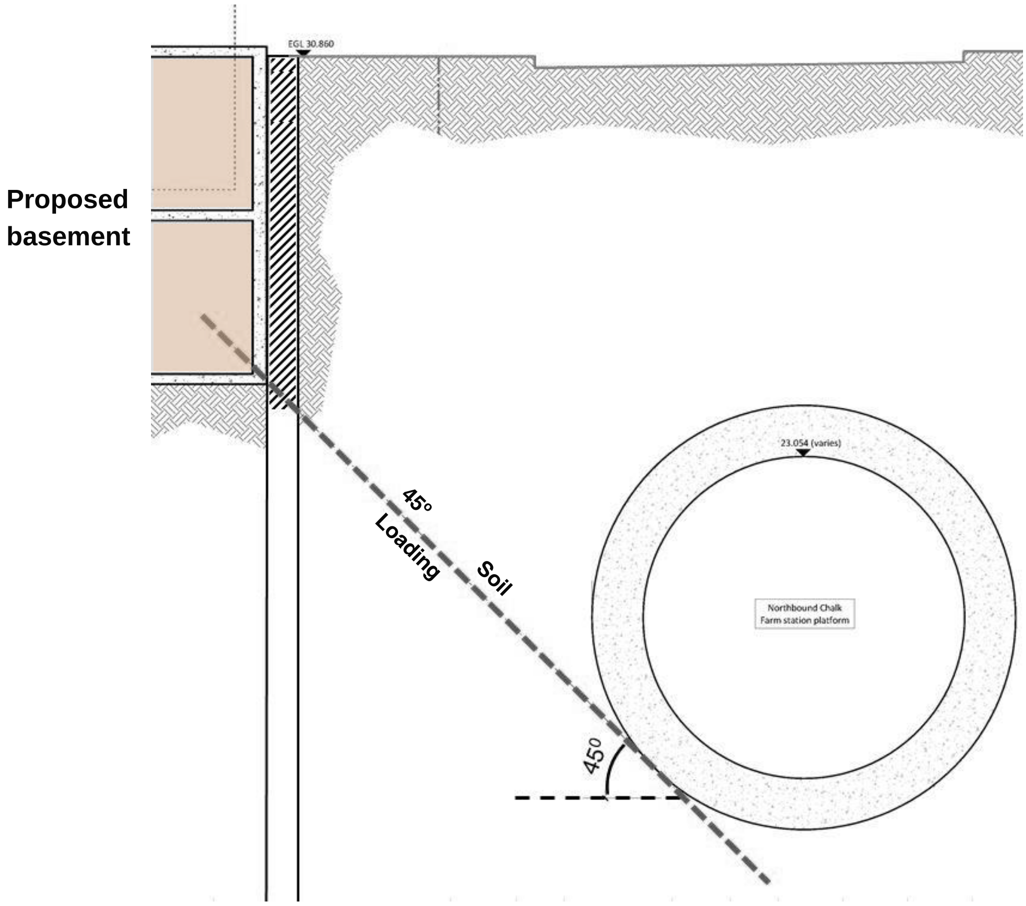
The London Clay underlies the made ground and consists of typical firm becoming stiff, grey fissured silty clay with occasional claystones.

3.3 Groundwater

No shallow groundwater table is present beneath the site.

4. Direct Loading of the Tunnel

A key factor for the proposed development is the need to avoid any undue loading of the existing LUL tunnel. The proposed perimeter piled foundations will need to be designed to transfer the structural loading to the soil at depth and to not shed any appreciable load within the zones of soil that might transfer this loading to the tunnel. As a first approximation, these zones may be assessed as that soil lying above a line rising at 45 degrees (green line) away from the edge of the tunnel.



The tunnel is at a depth of approximately 7m, meaning that the theoretical 45 degree exclusion line would extend approximately 7m out from the tunnel edge on the ground surface. The proposed perimeter piled foundations will therefore extend into the zone of influence of the soils associated with the closest tunnel.

However, provided that the piles in this section are designed to only shed loading to the soil through shaft friction below the approximate location of the 45 degree exclusion line, it is considered that no discernible load will be shed upon the structure of the tunnel.

In order to achieve this, the perimeter piles should be designed to shed load from approximately 8m depth below ground level (approx. +23m OD).

5. Ground Movement Assessment

5.1 Analysis

Excavation of the basement will result in unloading of the clay which will in turn lead to theoretical short-term heave movement of the underlying soil. Analyses have been carried out for both a short-term excavation phase with no re-loading of the soil and a long term post-construction phase where the application of the proposed hotel structure loading will to some extent counteract the heave and induce settlements. Analysis of the settlements induced by the perimeter piled foundations following loading is also undertaken.

The assessment considers the potential impact of the proposed development on the southbound and northbound LUL Northern Line tunnels.

5.2 Modelled Ground Conditions

The soil model used for the analysis is detailed in the table below, as devised from the results of ground investigation and the Geotechnical Interpretive Report.

Stratum	Upper Boundary Level	Undrained Elastic Modulus Eu (kN/m^2)	Drained Elastic Modulus E' (kN/m^2)
London Clay Formation	Proposed new excavation level	79,500kN/m^2 at existing basement level increasing linearly to 259,500kN/m^2 at 30m depth	53,000kN/m^2 at existing basement level increasing linearly to 173,000kN/m^2 at 30m depth

The analysis uses classic modified Boussinesq elastic theory, assuming a fully flexible foundation applying a uniform loading/unloading to a semi-infinite elastic half-space, using the above parameters for stratified homogeneity.

Poisson's Ratios of 0.5 and 0.1 have been used for short term (undrained) and long term (drained) conditions respectively.

5.3 Modelled Construction Stages

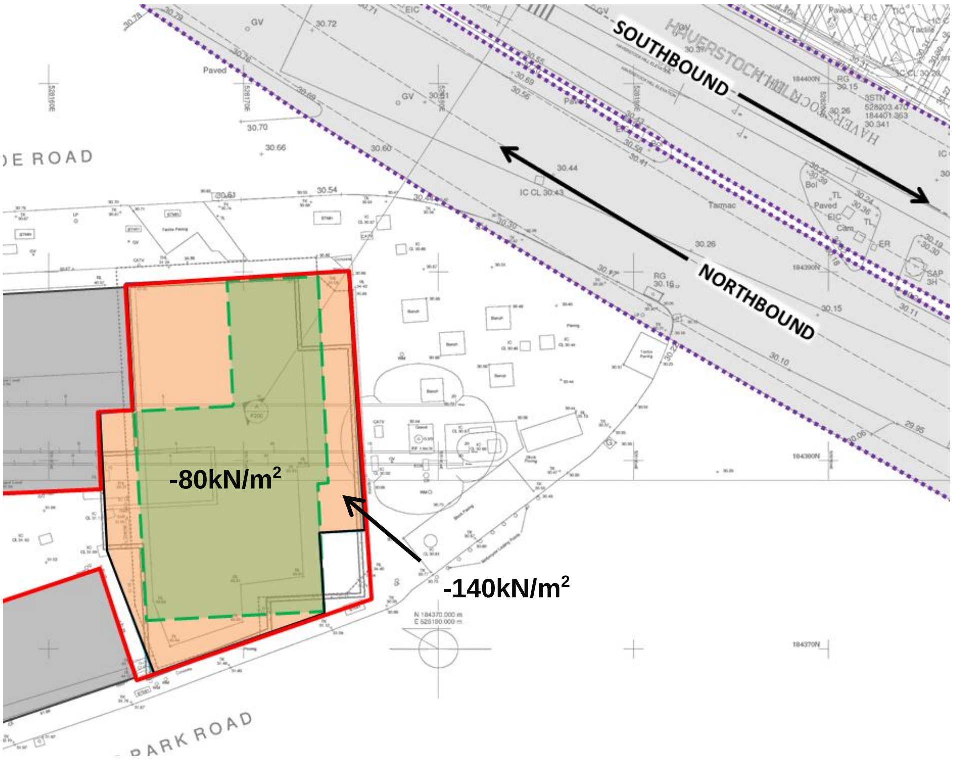
Vertical displacements at the crown of the nearest Northern Line tunnel (northbound) have been modelled for the following loading/unloading conditions occurring as construction stages:

1. Unloading due to demolition of the existing structure and excavation of the basement (short term)
2. Loading of the piled foundations due to proposed construction (long term)

5.3.1 Existing Structure Demolition and Basement Excavation (Stage 1)

Unloading has been applied across the area of the proposed basement to reflect the effects of demolition of the existing building and soil excavation.

The unloading due to soil removal is modelled as -80kN/m^2 in the central area of the building footprint, beneath the existing basement, increasing to -140kN/m^2 in the surrounding excavation area



Plan showing the areas of modelled unloading due to basement excavation

In addition, unloading of up to -200kN/m^2 has been applied on the areas corresponding to shallow strip foundations below the perimeter of the existing building in order to model the demolition of the existing structure.

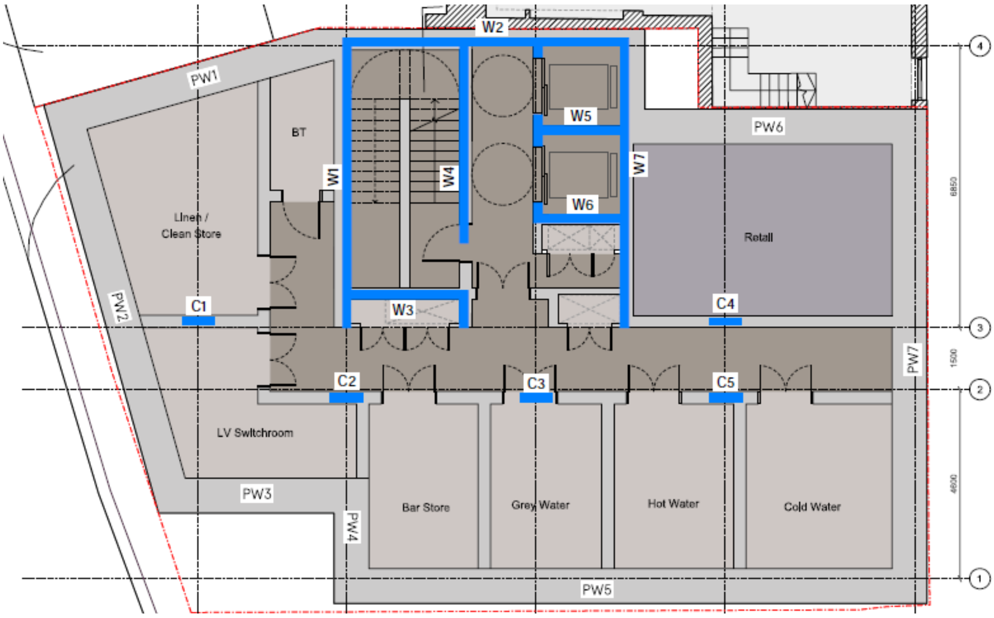
The demolition and excavation unloading will also result in a negative change in stress in the underlying ground. This is assessed in section 6.4 of this report in terms of potential impact on the LUL Northern Line tunnels.

5.3.2 Proposed Construction Loading (Stage 2)

5.3.2.1 Structural Loading

Loading information has been provided by HTS, in the form of column and wall loading at the proposed basement level. This was provided by means of the following drawing and load schedule:

- 1872-SK21-P1 – Proposed Structural GA, dated June 2019
- 2170-Sheet 1-P1 – Column & Wall Load Summary, dated June 2019



Proposed lower basement plan showing the column and wall loads references

Column Schedule

Ref	Bearing Level	Description	Self Weight (kN)	SDL (kN)	Live (kN)	Live % Red (kN)	Total G (kN)	Total Q (kN)
C1	B2	Column Total Load	784	162	518	311	946	311
C2	B2	Column Total Load	735	224	451	271	959	271
C3	B2	Column Total Load	923	209	627	376	1132	376
C4	B2	Column Total Load	764	166	498	299	930	299
C5	B2	Column Total Load	959	218	656	394	1177	394
C6	Piled Wall	Column Total Load	226	455	97	58	681	58
C7	Piled Wall	Column Total Load	314	518	161	97	832	97
C8	Piled Wall	Column Total Load	301	505	152	91	806	91
C9	Piled Wall	Column Total Load	416	412	232	139	829	139
C10	Piled Wall	Column Total Load	171	233	52	31	404	31
C11	Piled Wall	Column Total Load	163	293	59	35	456	35
C12	Piled Wall	Column Total Load	385	626	198	119	1011	119
C13	Piled Wall	Column Total Load	667	740	397	238	1407	238
C14	Piled Wall	Column Total Load	469	548	279	168	1017	168
C15	Piled Wall	Column Total Load	581	737	366	219	1318	219
C16	Piled Wall	Column Total Load	338	670	179	108	1009	108
C17	Piled Wall	Column Total Load	424	522	245	147	946	147
C18	Piled Wall	Column Total Load	424	522	245	147	946	147
C19	Piled Wall	Column Total Load	343	711	183	110	1054	110
Total		**Total Column Loads**	**9386**	**8473**	**5596**	**3358**	**17859**	**3358**

Wall Schedule

Ref	Bearing Level	Description	Length (m)	Self Weight (kN)	SDL (kN)	Live (kN)	Live % Red (kN)	Total G (kN/m)	Total Q (kN/m)
W1	B2	Column Total Load	6.9	2326	549	850	510	417	74
W2	B2	Column Total Load	7	1946	900	238	143	407	20
W3	B2	Column Total Load	2.8	720	59	178	107	278	38
W4	B2	Column Total Load	6.9	2370	306	921	553	388	80
W5	B2	Column Total Load	2.1	738	53	167	100	376	48
W6	B2	Column Total Load	2.1	738	53	167	100	376	48
W7	B2	Column Total Load	6.9	2055	677	672	403	396	58
Total		**Total Wall Load**	**35**	**10892**	**2597**	**3193**	**1916**	**2638**	**366**

Piled Wall Schedule

Ref	Bearing Level	Description	Length (m)	Self Weight (kN)	SDL (kN)	Live (kN)	Live % Red (kN)	Total G (kN/m)	Total Q (kN/m)
PW1	B2	B1 + B2 + Columns	6.9	1128	903	422	253	294	37
PW2	B2	B1 + B2 + Columns	10.3	1100	1020	352	211	206	20
PW3	B2	B1 + B2 + Columns	4.6	553	557	168	101	241	22
PW4	B2	B1 + B2 + Columns	2.2	312	319	118	71	287	32
PW5	B2	B1 + B2 + Columns	14.4	2477	2203	1127	676	650	94
PW6	B2	B1 + B2 + Columns	7.2	1033	905	433	260	269	36
PW7	B2	B1 + B2 + Columns	12	1862	1775	788	473	303	39
Total		**Total Piled Wall Load**	**58**	**8464**	**7682**	**3408**	**2045**	**2250**	**281**

Total

Ref	Bearing Level	Description	Self Weight (kN)	SDL (kN)	Live (kN)	Live % Red (kN)	Total G (kN)	Total Q (kN)
Total	B2	Total Column Loads	23521	11258	9353	5612	34779	5612
							40391	

Schedule of structural loads by HTS, reproduced

5.3.2.2 Perimeter Piled Foundations

The modelled loading condition in stage 2 provides a movement prediction of cumulative effects of excavation and demolition soil unloading combined with re-loading following construction.

The loads associated with the proposed building will be supported by perimeter and internal piled foundations.

A conventional equivalent raft approach of assessing settlement of pile groups in clay soils has been adopted for the piled foundations. The equivalent raft is considered to induce the collective pile loading over an area determined by assumed load shedding slope at two thirds of an average pile depth.

The size of the equivalent raft underneath the piles was determined assuming load shedding at a depth/offset ratio of 2:1, as shown to the right.

On the basis of an assumed average pile depth of 25m from ground level, and taking into account that the top 8m will be design not to shed load, the raft is modelled at approximately 12m depth below the basement (+12m OD) (11m below the crown of the Northern Line tunnels).

Therefore the area occupied by the raft at this level is modelled to be equivalent to an enlarged projection of the entire footprint of the proposed building, which is treated as a single pile group for the purposes of the model.

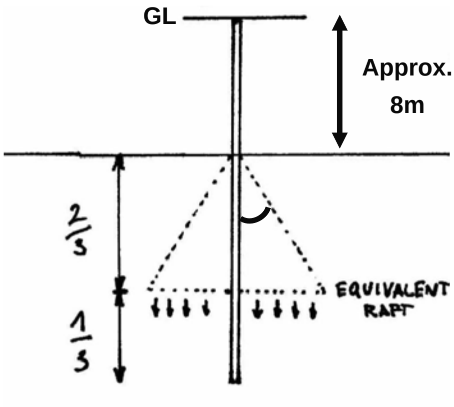


Illustration showing the equivalent raft convention for a representative single pile

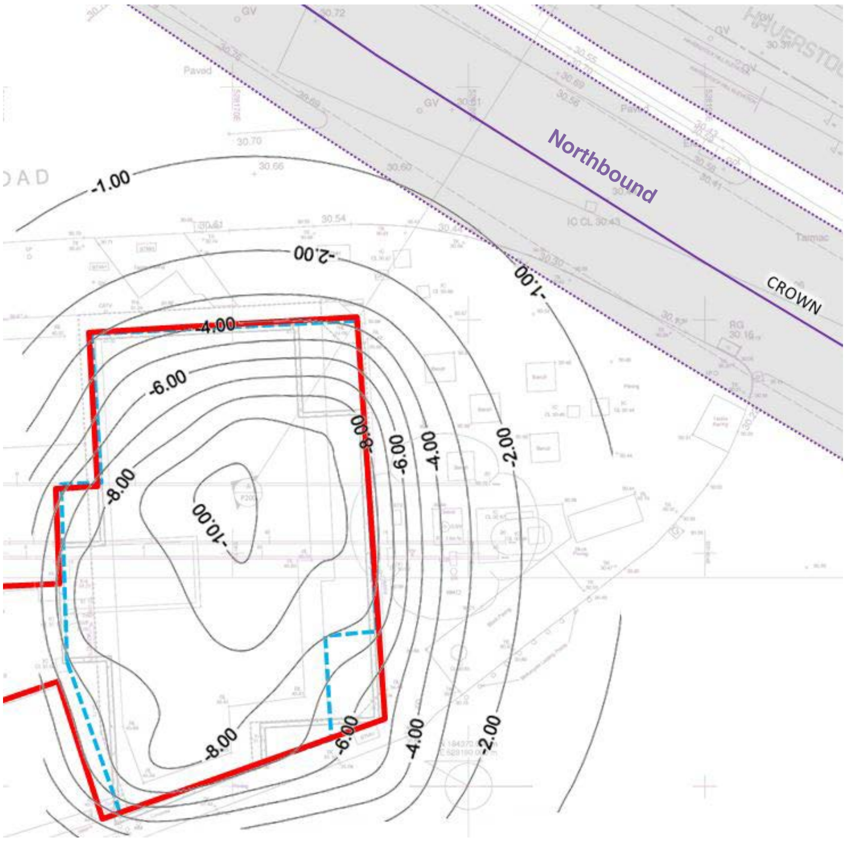
It should be noted that any movement of the tunnel induced by pile settlement would be due to compression entirely within the strata underlying the tunnel. Hence, no increase in vertical stress will be experienced by structure of the tunnel as a result of this loading.

5.4 Impact on the LUL Northern Line

5.4.1 Basement Excavation (Stage 1)

5.4.1.1 Short Term Heave

Numerical analysis of the potential effect of basement excavations in terms of unloading-induced heave suggests that these will lead to less than 1mm of movement in the short term, as calculated at the levels of the crowns of both the southbound and northbound tunnels of the LUL Northern Line.



Theoretical predicted short term heave at the level of the Northern Line tunnel crowns (approx. +23m OD /+123m LU Datum)

(displacement values in mm)

(Proposed basement extent shown by dashed blue line)

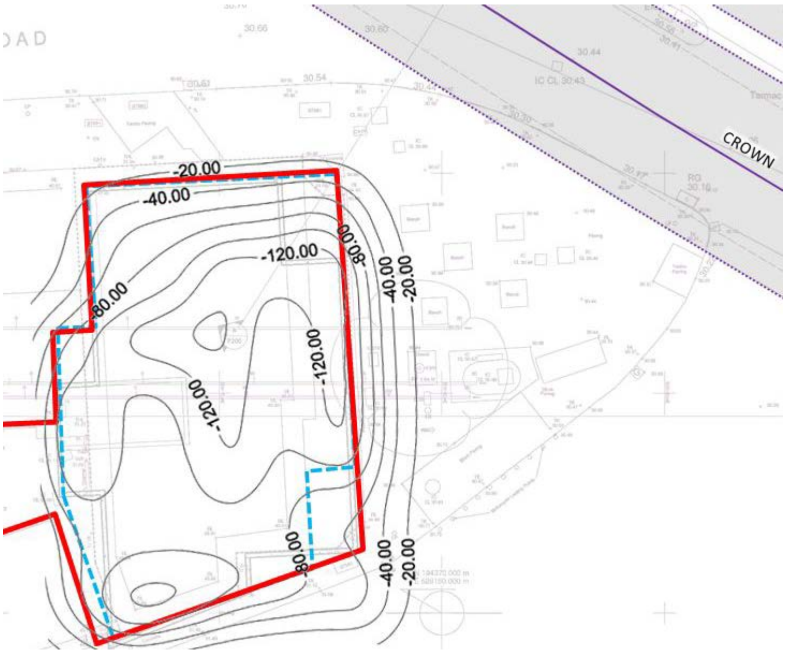
The predicted heave movement at the depth and location of the crown of the northbound tunnel is limited to no more than 1mm.

Negligible movement is predicted at the location of the southbound tunnel crown.

The above predicted ground movements will result in a deformation of the tunnel section (δ) of substantially less than 1%, where δ = (predicted radius – design radius).

5.4.1.2 Change in applied vertical stress

Unloading of the soil at proposed basement level due to demolition and subsequent excavation will result in reduction of vertical stress, with the predicted pattern of this at the level of the Northern Line tunnel crowns presented below.



Theoretical predicted vertical stress change at the level of the Northern Line tunnel crowns (approx. +23m OD /+123m LU Datum)

(values in kN/m^2)

(Proposed basement extent shown by dashed blue line)

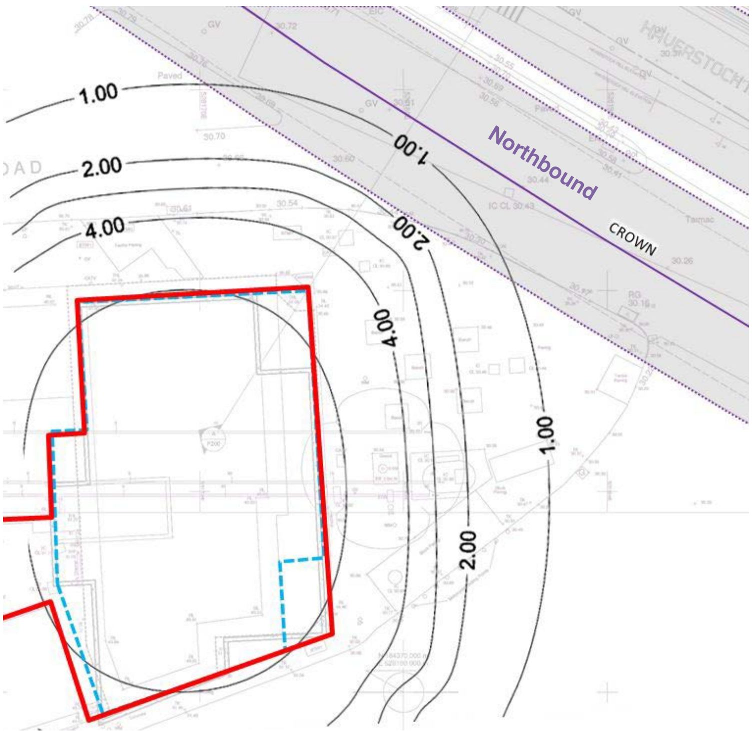
It is predicted that negligible changes in stress (<10) will be exerted on the Northern Line Tunnels due to this stage of development.

The piled foundations will be designed to not shed loading on the tunnels, hence it is assessed that no changes in vertical stress will be applied directly to the tunnel as a result of the development as a whole.

5.4.2 Proposed Construction (Stage 2)

The potential cumulative, post construction impact of basement excavation and subsequent construction of the proposed building has been analysed below, with an equivalent raft method used to theoretically predict the settlements induced by the piled foundations.

5.4.2.1 Settlement due to loading of the Piled Foundations using Equivalent Raft approach



Theoretical predicted post construction ground movement at the level of the Northern Line tunnel crowns (approx. +23m OD /+123m LU Datum)

(displacement values in mm)

(Proposed basement extent shown by dashed blue line)

In this case, at the location of the northbound tunnel crown, post construction settlement of less than 1mm is predicted to occur.

Negligible movement is predicted at the location of the southbound tunnel crown.

The overall post construction impact of the development on the Northern Line tunnels is therefore predicted to be negligible.

5.4.3 Movement due to the perimeter retaining wall

5.4.3.1 Settlement due to Installation of Piles

The ground movements arising from the installation of the bored pile retaining wall may be estimated using CIRIA report C760.

The amount of predicted movement is related to pile depth and the analysis suggests that as a result of pile installation, no more than 1mm of settlement may occur as a result of the piling operation, along the edge of the tunnel.

5.4.3.2 Pile Wall Yielding

The ground surface movements arising from the excavation in front of the bored pile retaining wall and consequent yielding of the wall may also be estimated using default values contained within CIRIA report C760.

The CIRIA model predicts surface settlement and horizontal strain due to lateral yielding of the piled wall. However, as Chalk Farm Underground Station has a tunnel crown level below the proposed basement excavation depth, no settlement due to yielding of piles is predicted and no horizontal strain is predicted at this level.

6. Sensitivity Analysis

While there is a degree of confidence in the adopted parameters for this assessment, separate analyses were undertaken in order to test the influence of changing the various conditions of the ground model, tunnel location and loading conditions. A summary of these follows.

6.1 Ground Conditions

Due to the known presence of London Clay directly underneath the site and the fact that it is known that the Northern Line tunnels were constructed within the London Clay Formation, no variance in ground profile should be expected.

A confirmatory analysis was, however, undertaken using reduced strength parameters for the clay in order to verify that the expected impact will remain negligible.

The analysis indicates that a 50% reduction of the assumed stiffness of the London Clay resulted in an approximately 1mm increase in the predicted movement at the crown of the northbound tunnel.

It can therefore be seen that a relatively large reduction applied to the assumed parameters would still result in negligible damage to the tunnel, thus the risk of underestimated movements based on soil parameter inaccuracy is very low.

6.2 Load Distribution

The equivalent raft settlement prediction method used in the analysis assumes a load shedding for the purposes of load application at a gradient of 2:1. With the theoretical load application area located below the tunnels, it is considered informative to carry out a sensitivity analysis assuming a less likely shallower angle of load shedding of 45°. This would signify a larger projected equivalent raft area is being loaded directly below the assessed tunnels.

However, in line with this approach, the overall loading on the piles is distributed over a larger area, reducing the intensity of loading per unit area.

The analysis of settlement predicted to be induced by this equivalent raft at the location of the tunnels is estimated to amount to up to approximately 3mm. While larger than the prediction made in Section 6, this amount of settlement would still induce negligible impact on the structure of the tunnels, with potential relative displacement between the tunnel crown and invert of far less than 1%.

6.3 Location of the tunnels

Due to the correlation survey information used for this report the margin of error in the location of the tunnels adopted by the analyses is expected to be low.

Based on the results of the ground movement analysis, in order for the tunnels to be significantly affected by the heave or settlement induced by the development the inaccuracy of the lateral location adopted would have to amount to more than 5m towards the development.

Similarly, even though tunnels may be predicted to experience some load application if they are located deeper, the error required for appreciable structural impact is highly unlikely due to the available survey data.

6.4 Magnitude of unloading

For sensitivity analysis purposes, an assumption of higher unloading was tested, theoretically increasing the depth of excavation.

While some degree of over excavation may happen during the works, the analysis indicated that a more than twofold increase in excavation depth would be needed in order to generate heave movements in excess of 1mm at the location of the tunnel crowns, which would still indicate negligible impact.

6.5 Conclusion

It may be concluded the risk of increased impact on the tunnels due to variability of the adopted values is very unlikely given the avoidance of significant movement of the tunnel even if assuming considerable changes in the parameters explored in this section.

7. Conclusion

No detrimental impact is expected to occur to the LUL infrastructure as a result of the proposed development at No. 155 – 157 Regent's Park Road.