soiltechnics

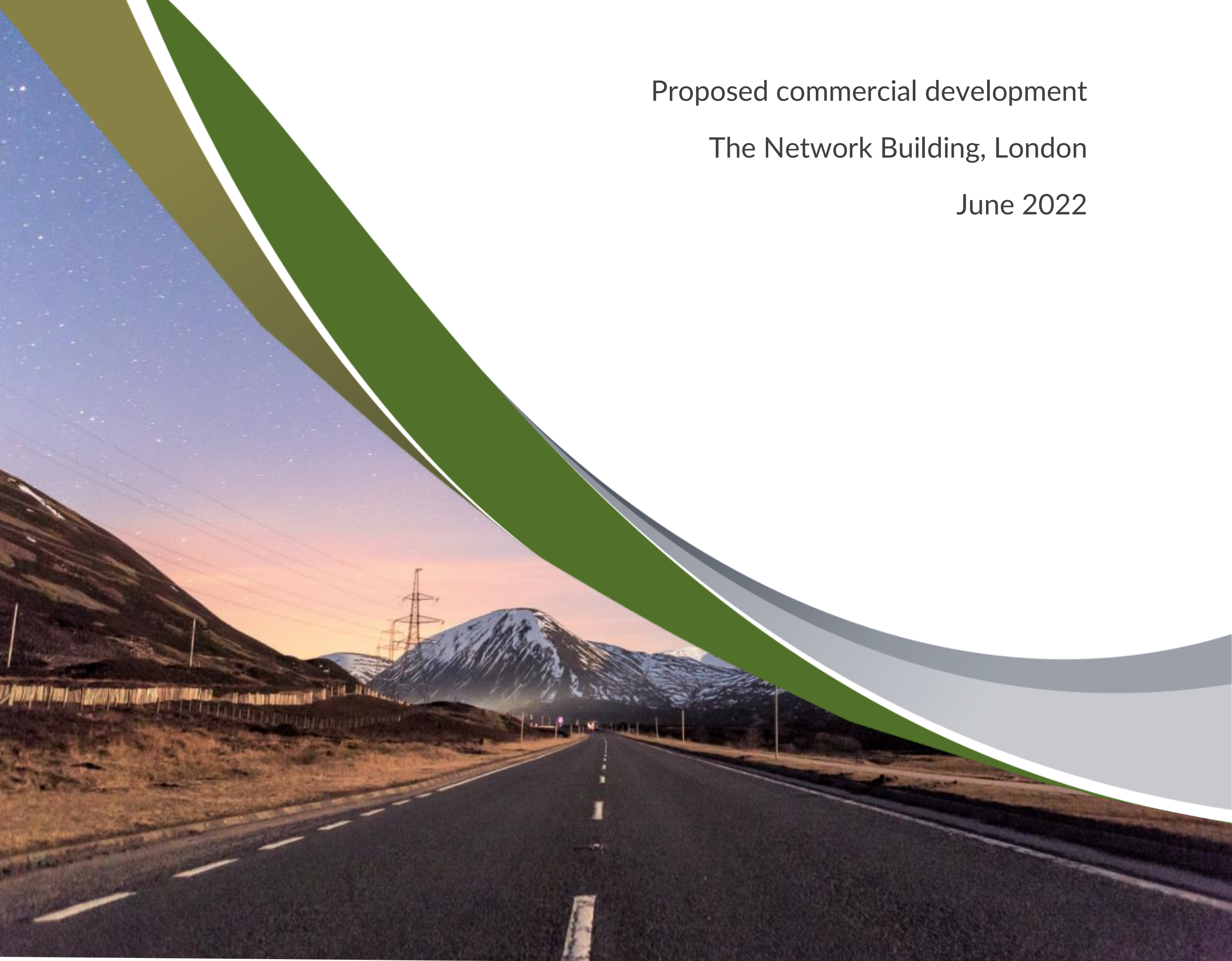
environmental ▪ geotechnical ▪ building fabric

Northern Line Tunnel Impact Assessment

Proposed commercial development

The Network Building, London

June 2022



soiltechnics
environmental ▪ geotechnical ▪ building fabric

Project Details

Site: The Network Building, London

Document Title: Northern Line Tunnel Impact Assessment

Document no.: STT5532-R02 Rev C

Date: June 2022

Client: The Thornton Partnership

Issuing office: Soiltechnics Ltd
Cedar Barn, White Lodge, Walgrave, Northampton. NN6 9PY
Tel: 01604 781 877 E-mail: mail@soiltechnics.net

Document history and status

Revision	Date	Description	Author	Reviewer
A	Feb 2022	First Issue	AW	ID
B	Mar 2022	Revision to proposed load changes	AW	ID
C	Jun 2022	Revision following comments from TfL	AW	MH

Table of Contents

Appendix A Drawings

Title	Produced by	Date	Reference
Exploratory hole layout	Soiltechnics	Feb 2022	D-STT5532-01
Site Constraints Plan 2	Elliott Wood	Apr 2020	2170754-EWP-ZZ-XX-SK-S-SK
Home Office Deep Shelter Tunnels	Elliott Wood	Mar 2022	2170754-EWP-ZZ-XX-SK-S-0046
Correlation Survey	Socotec	May 2022	SOC 1877-01 01 Rev0

List of Tables

List of Figures

1 Introduction

1.1 Site Location

1.1.1 The site is located within the London Borough of Camden and comprises the southern portion of the block bounded by Tottenham Court Road to the east, Howland Street to the south, Whitfield Street to the west and Maple street to the north. A pedestrian street (Cypress place) orientated north-south bisects the site.

1.1.2 Two tunnels that carry the Northern Line are present beneath Tottenham Court Road and therefore within relatively close proximity of the site. Drawings have been provided by the Client that indicate that the crown level of the tunnels is circa 3.1 – 3.5m AOD.

1.2 Scheme Outline

1.2.1 The scheme comprises the demolition of an existing six storey building followed by the construction of a nine storey building plus single storey basement.

1.2.2 Scheme drawings are presented as Appendix A.

1.2.3 The report is based on the project proposals and information outlined above; should the scheme change then it will be necessary to review the conclusions and recommendations presented in this report.

1.3 Brief

1.3.1 In view of the scheme proposals, there is a potential for a change in stress at the tunnel horizon that may lead to movement of the tunnel and therefore the rail track. On this basis Soiltechnics have been commissioned by the Client, acting on instructions from the structural engineer, Elliot Wood, to:

i) Undertake a ground investigation at the site to characterise ground and groundwater conditions.
ii) Undertake geotechnical modelling to assess the potential impact of the proposed scheme on an existing underground tunnel.

1.4 Limitations

1.4.1 Soiltechnics disclaims any responsibility to our Client and others in respect of any matters outside the scope of this report. This report has been prepared with reasonable skill, care and diligence in accordance with the terms of our contract, taking account of the manpower, resources, investigations and testing devoted to it by agreement with our Client. This report is confidential to our Client and Soiltechnics accepts no responsibility of whatsoever nature to third parties to whom this report or any part thereof is made known. Any such party relies upon the report at their own risk.

soiltechnics
environmental ▪ geotechnical ▪ building fabric

1.5 Revision B

1.5.1 This report has been revised following comments received from Transport for London (TfL). The comments are summarised as follows:

- What is the radius of curvature of the tunnels based on the estimated movements?
- What is the impact, if any, to a pair of Home Office deep shelter tunnels that traverse under Tottenham Court Road.

soiltechnics
environmental ▪ geotechnical ▪ building fabric

2 Ground Conditions

2.1 Investigation works

2.1.1 A ground investigation was undertaken by Card Geotechnics Limited (CGL) between 10 August and 03 September 2020. That investigation comprised

- Two boreholes drilled using cable percussive techniques to depths of 10m and 30m.
- Three trial pits hand excavated to a maximum depth of 2.3m.

2.1.2 The findings of the investigation are presented in the corresponding Geotechnical and Geo-environmental Interpretative Report (reference CGL/09528 Rev 0, October 2020).

2.1.3 A supplementary ground investigation was undertaken by Soiltechnics between 16th December 2021 and 28th January 2022. This investigation comprised:

- Three boreholes drilled using cable percussive techniques to a maximum depth of 24.5m
- Attempted dynamic windowless sampling (aborted due to concrete obstructions)
- Foundation investigations in three areas

2.1.4 The findings of this investigation are presented in a separate Ground Investigation Report and reference should be made to that document for full details (Reference STT5532-R01 Rev B).

2.2 Ground Model

2.2.1 A site ground model has been derived based on the combined dataset of both ground investigations described above. The following ground model has been adopted:

Stratum	Summary Description	Level at top of stratum (m AOD)
Made Ground	Mix of clayey sand and gravel or gravelly clay.	Ground level
Lynch Hill Gravel	Medium dense to dense sand and gravel.	24.10
London Clay – Upper	Firm becoming stiff brown becoming grey clay.	22.30
London Clay – Lower	Stiff to very stiff dark grey clay with occasional bands of mudstone.	13.30
Lambeth Group – cohesive	Very stiff bluish grey mottled dark orange Clay.	4.30
Lambeth Group – granular	Dense sand and pebbles (from historic borehole records)	-4.90

Table 2-A: Adopted ground model

2.2.2 The London Clay Formation improves with depth in terms of strength, stiffness and compressibility. On this basis an upper and lower London Clay Formation has been modelled.

2.2.3 Geotechnical parameters have been derived based on material descriptions, in situ and laboratory testing from both ground investigations. Industry publications and wider literature has also been referenced to validate parameters.

2.2.4 Table 2-B summarises the parameters adopted in the analysis. Given the level of the tunnel (crown level ~3.5m AOD) it is the London Clay and Lambeth Group parameters that are critical; however, the parameters adopted for the other strata are included for completeness.

Parameter / variable	Value adopted
Unit weight, γ (kN/m³)	
Made Ground	18
Lynch Hill Gravel	19
London Clay	20
Lambeth Group – cohesive	20
Lambeth Group – granular	20
Coefficient of volume compressibility, m_v (m²/MN)	
Made Ground	N/A
Lynch Hill Gravel	N/A
London Clay	0.15 (upper) and 0.10 (lower)
Lambeth Group – cohesive	0.1
Lambeth Group – granular	N/A
Coefficient of consolidation, c_v (m²/yr)	
Made Ground	N/A
Lynch Hill Gravel	N/A
London Clay	1
Lambeth Group – cohesive	1
Lambeth Group – granular	N/A
Undrained modulus, E_u (MN/m²)	
Made Ground	50
Lynch Hill Gravel	75
London Clay	25.5 + 3.78z where z = depth below 22.30m AOD
Lambeth Group – cohesive	90
Lambeth Group – granular	90

Table 2-B: Adopted geotechnical parameters

2.2.5 It should be noted that the coefficient of volume compressibility values detailed above do not include a geological factor, μ_g, which is typically adopted in consolidation settlement calculations. A factor of 0.5 has been adopted for the London Clay and Lambeth Group – cohesive units.

2.3 Groundwater

2.3.1 Groundwater is interpreted to be present within the Lynch Hill Gravel unit at a level of 23.7m AOD. A hydrostatic groundwater pressure profile has been adopted.

3 Geotechnical Modelling

3.1 Geotechnical Category

3.1.1 In accordance with BS EN1997-1:2004 + A1:2013 (Eurocode 7), the project is designated as Geotechnical Category 2. This category includes projects with *conventional types of structures and foundations with no exceptional risk, or difficult ground or loading conditions*. Furthermore, *routine design procedures* are appropriate.

3.1.2 It should be noted that this Report does not constitute a Geotechnical Design Report (GDR) as defined in Eurocode 7. Accordingly, a GDR should be prepared by the designer during the detailed design phase.

3.2 Proposed Loadings

3.2.1 The proposed loadings are based on the preliminary assessment undertaken by the structural engineer, Elliott Wood. That assessment has considered the existing loading and the proposed loading on the building foundations.

3.2.2 The proposed basement excavation will unload the soils. This is greatest where there is no existing basement. The geotechnical modelling undertaken has modelled the effect caused by the *change* in overall loading.

3.3 Tunnels

3.3.1 The centre line of the Northern Line tunnels has been assumed based on drawings provided by the structural engineer, Elliot Wood. Tunnel crown levels have been interpolated between the levels at known locations as indicated on the drawing. A tunnel diameter of 12’ 6” has been assumed.

3.3.2 The centre lines and crown levels of the Home Office tunnels have also been assumed based on details provided by Elliot Wood; a diameter of 5.5m has been assumed.

3.4 Potential impacts to the existing tunnels

3.4.1 The proposed development will change the stress regime in the soil and thereby have the potential to directly impact the tunnels or indirectly by causing settlement in the soil beneath the tunnel. On this basis the following elements have been considered within the modelling:

i) Change in stress at tunnel crown level
ii) Potential settlement at crown level
iii) Potential settlement beneath tunnel
iv) Change in curvature of the longitudinal axis of the tunnel

3.5 PDisp Model

3.5.1 The ground modelling has been undertaken with the aid of computer software package PDisp Version 20.1, developed by OASYS. The software program calculates the displacements and stresses within a soil mass arising from uniform pressures applied to loaded planes. The software models the loading as three dimensional stress bulbs. The Boussinesq method has been adopted as this allows consolidation settlement to also be computed.

3.5.2 PDisp computes the settlement at discrete horizons within the soil by dividing each soil stratum below the point of interest into several sub layers. Total settlement is determined by summing the immediate and consolidation settlement within each of the sub layers below the point on interest.

3.5.3 The interpolated undrained modulus of each sub layer is utilised to compute the immediate settlement of that sub layer. The immediate settlements for each sub layer are then summed together to provide the total immediate settlement at the point of interest.

3.5.4 Consolidation settlement is determined in a similar fashion using the m_v method, also known as the oedometer method. The stress change at the mid-point of each sub layer is computed using Boussinesq theory and then multiplied by the coefficient of volume compressibility, m_v, and sub layer thickness to determine the theoretical consolidation settlement in that sub layer. The degree of consolidation is accounted for within the software calculations based on the coefficient of consolidation, c_v, and time period. A time period of 60 years has been assumed. Total consolidation settlement at the point of interest is calculated by summing the consolidation settlement within each sub layer.

3.5.5 Figure 3-A and Figure 3-B provides a plan outline and isometric view of the model:

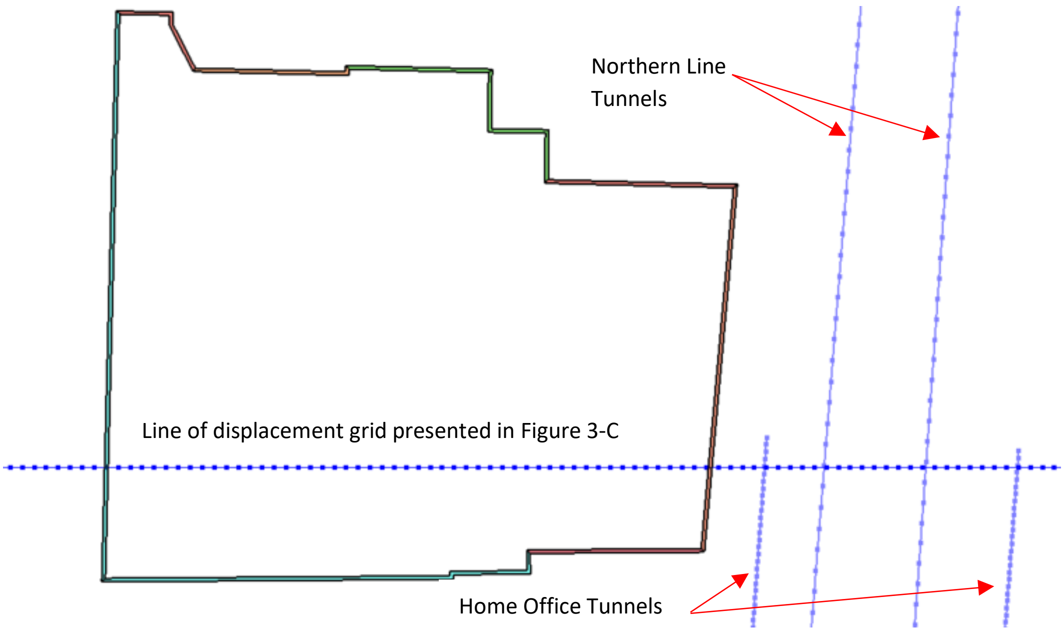


Figure 3-A: Plan view of PDisp model illustrating the outline of the proposed building and tunnel centre lines.

soiltechnics
environmental ▪ geotechnical ▪ building fabric

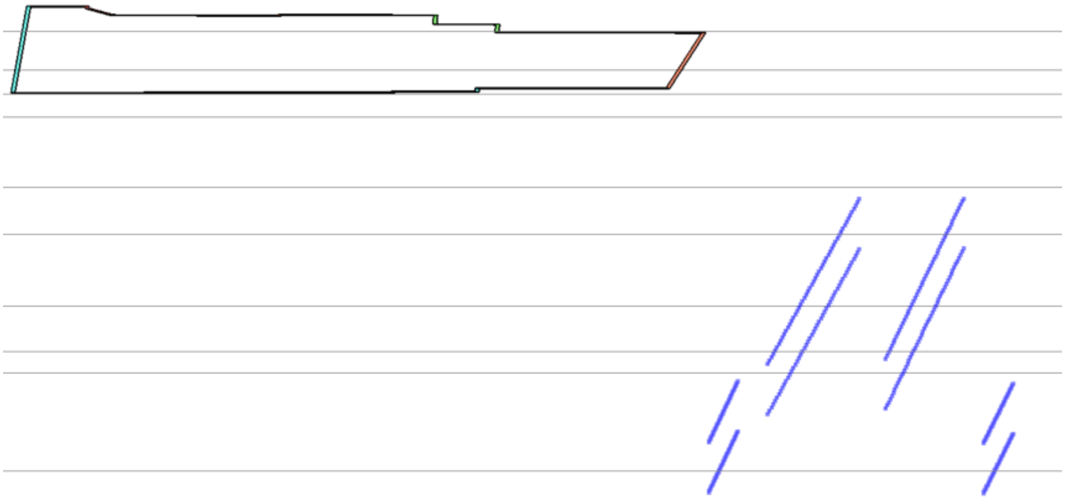


Figure 3-B: Isometric view of the PDisp model illustrating the tunnel crown and invert levels relative to the proposed development.

3.5.6 Figure 3-C shows the stress change along the displacement grid shown in Figure 3-A and thereby demonstrating that the software models the third dimension. The tunnels are shown to the right of the figure and are oblique to the section. The change in stress at tunnel crown level is less +10 kN/m^2 and is considered negligible.

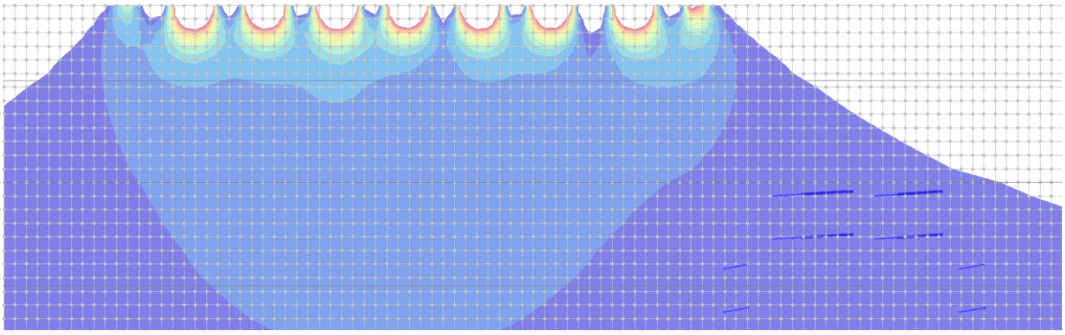


Figure 3-C: Extract from PDisp illustrating change in stress beneath the proposed development. The dark blue represents a stress change of 0-10kN/m^2

3.5.7 The settlement of the tunnel crowns has been computed by estimating the settlement of the soil at this level and assuming that this is transferred entirely to the tunnel. This is a conservative assumption as it assumes that the tunnels have no structural stiffness. In order to estimate this settlement it is assumed that the tunnel is absent, and that soil is present instead, which is susceptible to settlement; this is also considered to be a conservative assumption.

3.6 Northern Line Tunnels

3.6.1 Figure 3-D shows the total settlement of the western Northern Line tunnel crown against the tunnel chainage. Ch42 is approximately level in plan with the proposed core. As would be expected, this displacement line is the worst case and shows the maximum settlement; circa 1.6mm. In contrast the eastern tunnel crown shows ~1mm. The western and eastern inverts show <0.5mm.

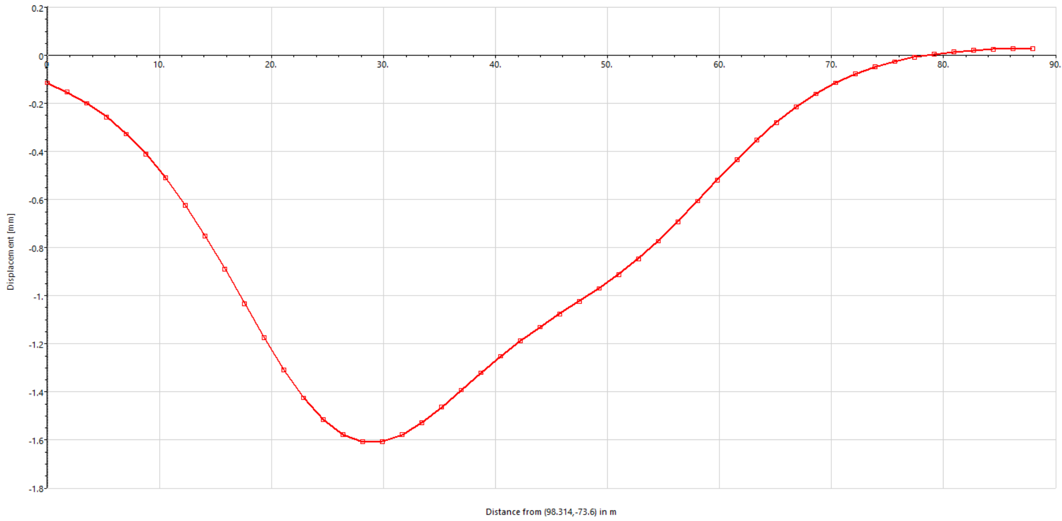


Figure 3-D: Extract from PDisp modelling showing displacement versus chainage along western Northern Line tunnel crown.

3.6.2 The radius of curvature has been calculated using trigonometry assuming a chord length of 23m (Ch19 – Ch42) and maximum relative displacement of 0.4mm. The calculated radius of curvature is 165,000m.

3.7 Home Office Tunnels

3.7.1 Figure 3-E shows the total settlement of the western Home Office tunnel crown against the tunnel chainage. The maximum settlement is predicted to be ~0.6mm at Ch25 – 30 which corresponds to the northern end of the tunnel (closest to the core). The eastern tunnel crown, and both tunnel inverts indicate even less settlement.

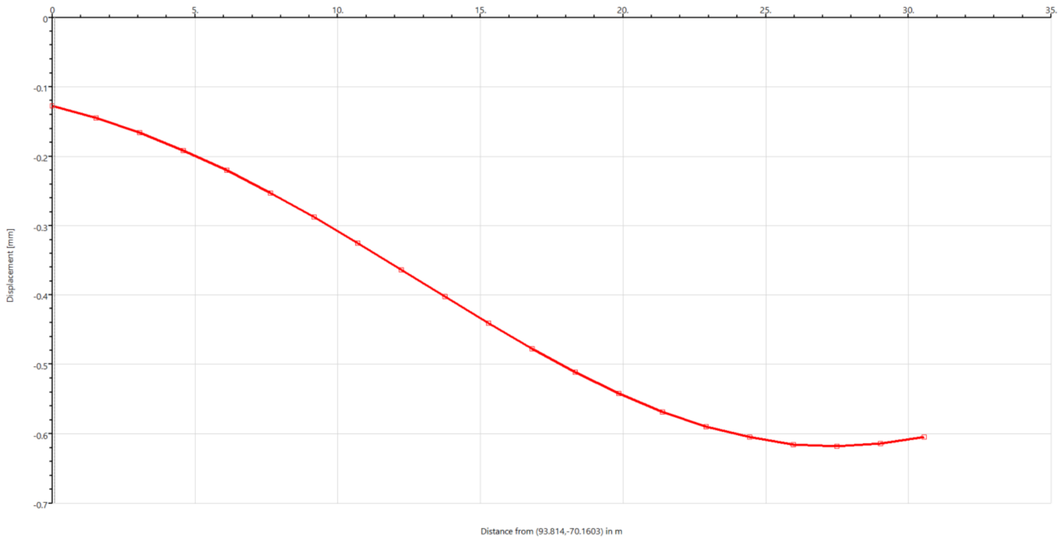


Figure 3-E: Extract from PDisp modelling showing displacement versus chainage along western Home Office tunnel crown.

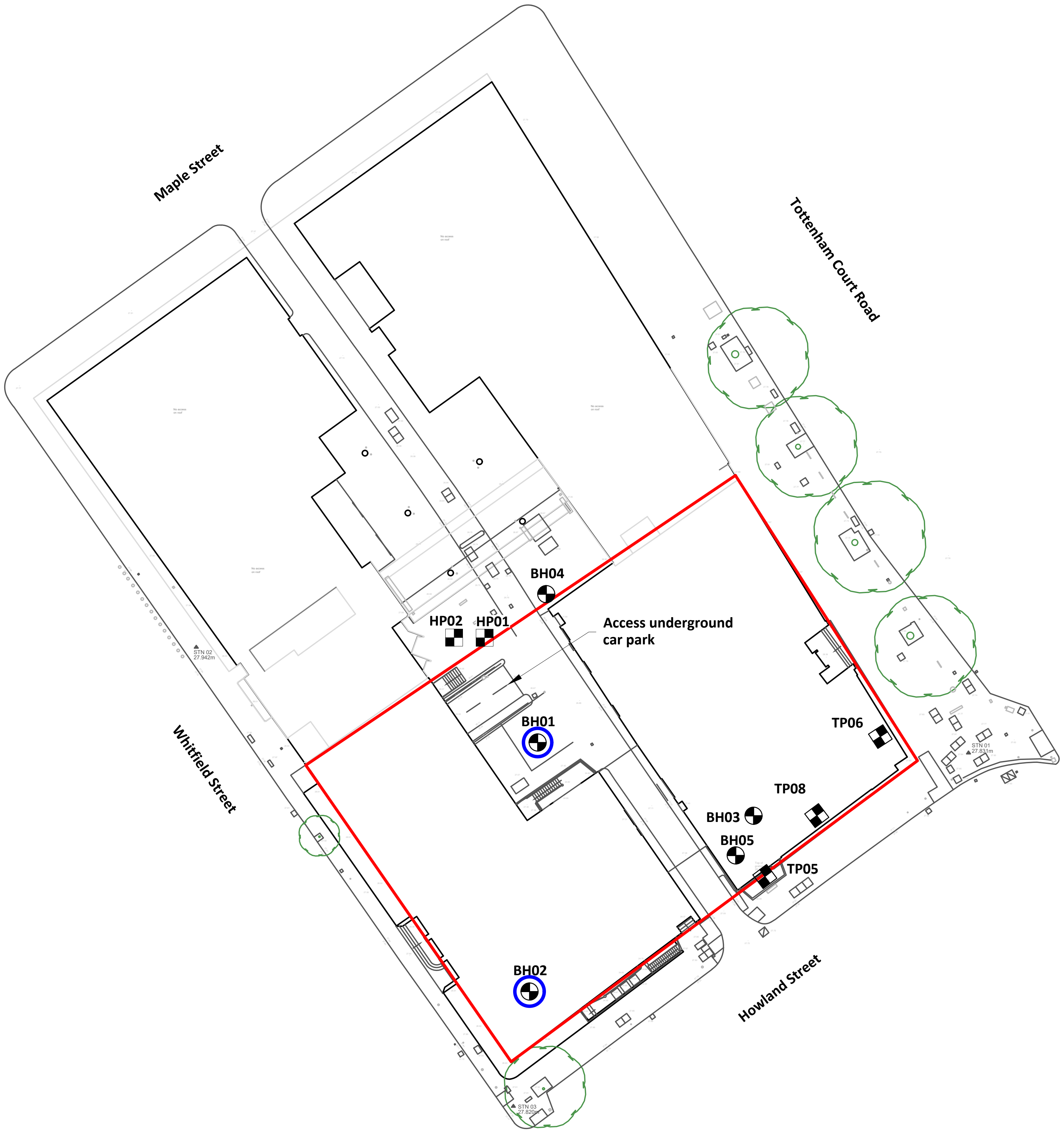
soiltechnics
environmental ▪ geotechnical ▪ building fabric

4 Conclusion

4.1.1 Ground modelling has been undertaken with the aid of computer software package, PDisp, which is widely accepted in the industry. Conservative assumptions have been made throughout the modelling ranging from selection of parameters to modelling methodology.

4.1.2 The modelling demonstrates that the change in stress at crown level of the Northern Line and Home Office tunnels is less than +10kN/m^2. The modelling further predicts that settlement of the tunnel crowns and inverts will be negligible.

Appendix A Drawings



Key

	TP	Trial pit
	BH	Cable percussive borehole
	HP	Hand dug trial pit
		Approximate position of borehole (previous investigation)
		Site boundary

Notes

1. Base drawing provided by Client
2. Exploratory locations are approximate

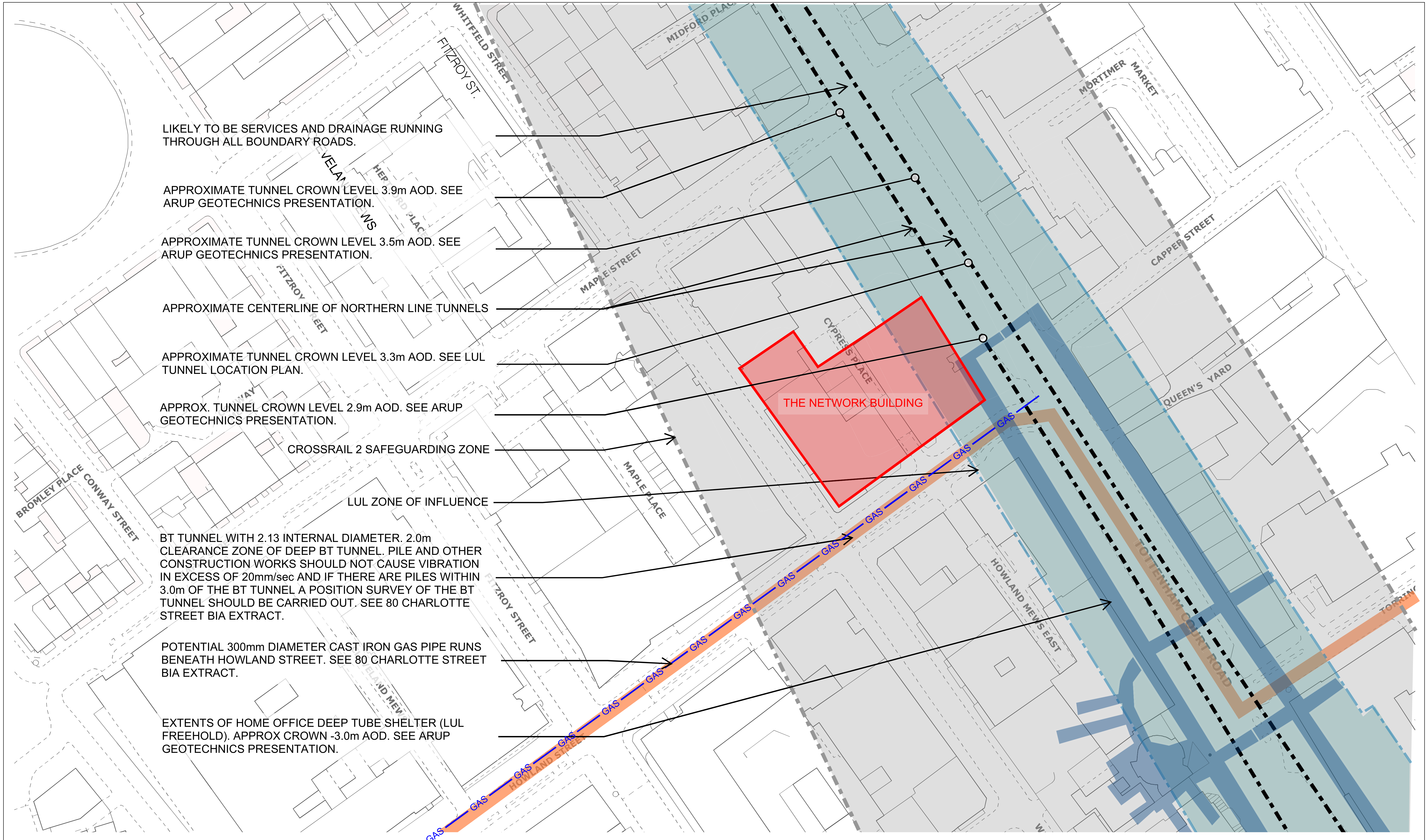
REV	DESCRIPTION	PREP	CHKD	APPD	DATE
A	First issue	SA	VJ	ID	28.02.2022

soiltechnics
environmental ▪ geotechnical ▪ building fabric

PROJECT
The Network Building, London

TITLE
Exploratory hole plan (current layout)

PROJECT NO.	SCALE AT A3	DRAWING NO.
STT5532	1:500	01



This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

Do not scale from this drawing.

rev	date	by	chk	description
P1	xx/xx/18	By	Chk	Preliminary

Drawing title
Site Constraints Plan 2

Scale	Date	Drawn
1:1000@ A3	April 2020	GCa

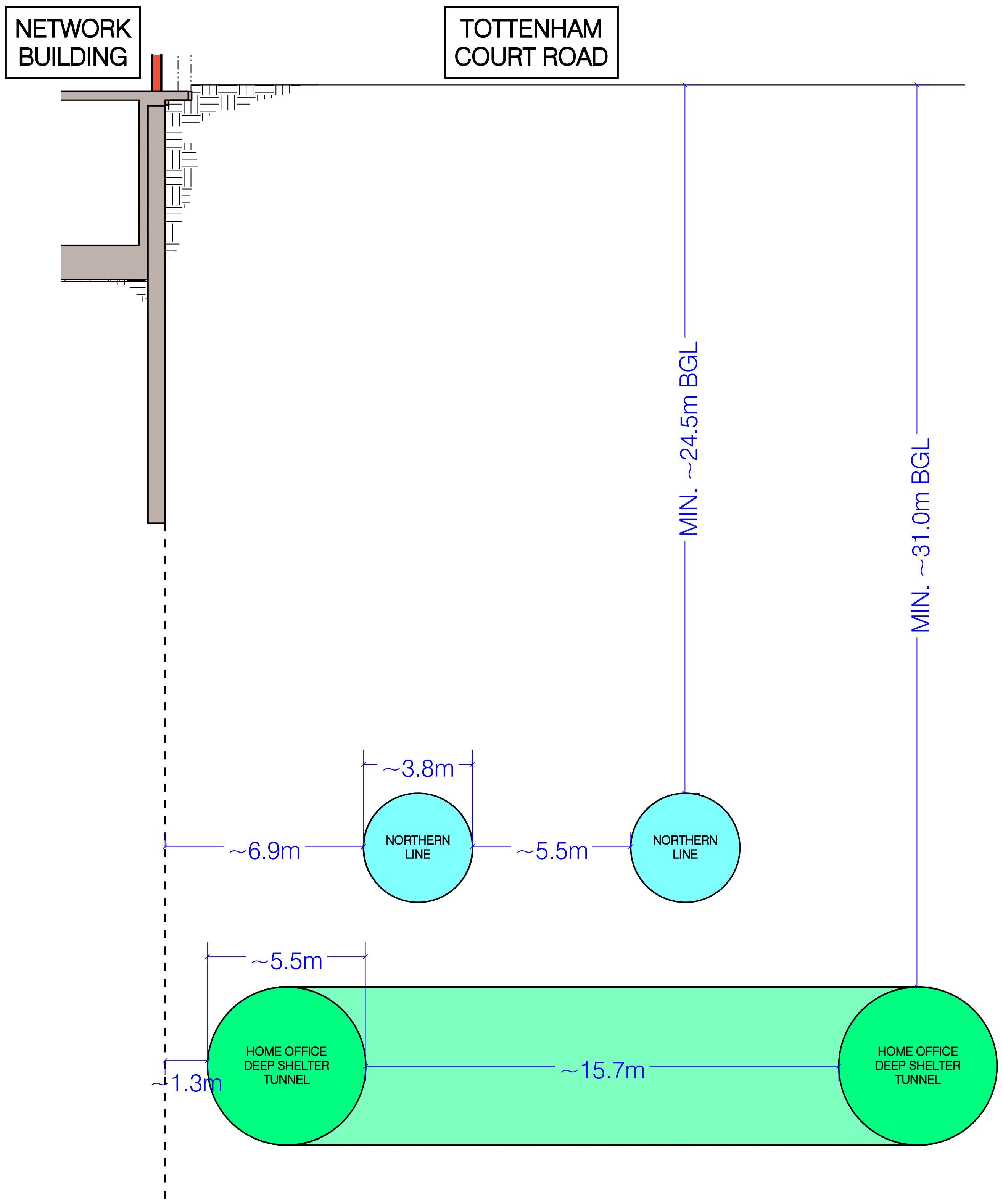
elliottwood | engineering a better society

Elliott Wood Partnership Ltd
Central London • Wimbledon • Nottingham
Consulting Structural and Civil Engineers
(020) 7499 5888 • elliottwood.co.uk

Project
The Network Building

Drawing status	Status	Revision
Preliminary	S2	P1

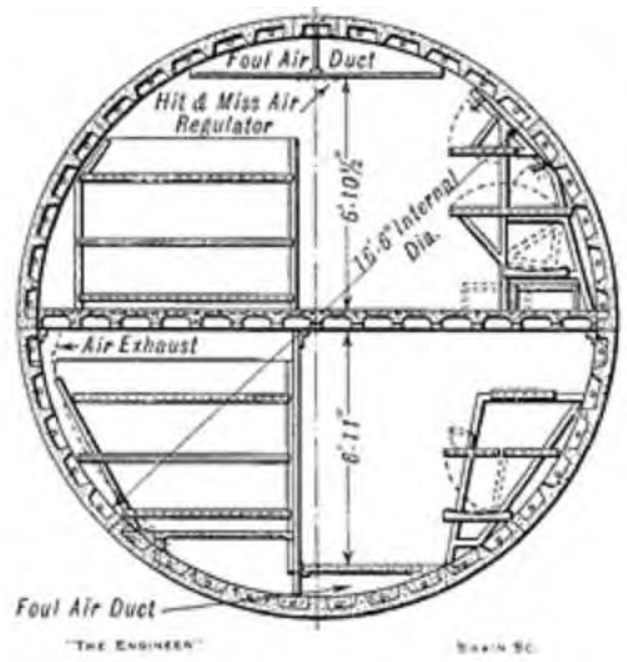
Project no. Originator Zone Level Type Role drg no.
2170754 - EWP - ZZ - XX - SK - S - SK



NOTES

CROWN LEVEL, PLAN POSITION, AND DIAMETER OF NORTHERN LINE RUNNING TUNNELS TAKEN FROM TfL PROVIDED DRAWING "SR22_017".

CROWN LEVEL, PLAN POSITION, AND DIAMETER OF HOME OFFICE DEEP SHELTER TUNNELS TAKEN FROM SOCOTEC SURVEY DRAWING "SOC 1877-01 01". WIDTH OF TUNNEL WALLS ASSUMED TO BE APPROX. 200mm.



This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

Do not scale from this drawing.

rev	date	by	chk	description
P2	08/06/22	SCa	JHi	Updated based on survey
P1	02/03/22	SCa	JHi	Preliminary

elliottwood | engineering a better society

Elliott Wood Partnership Ltd
Central London • Wimbledon • Nottingham
Consulting Structural and Civil Engineers
(020) 7499 5888 • elliottwood.co.uk

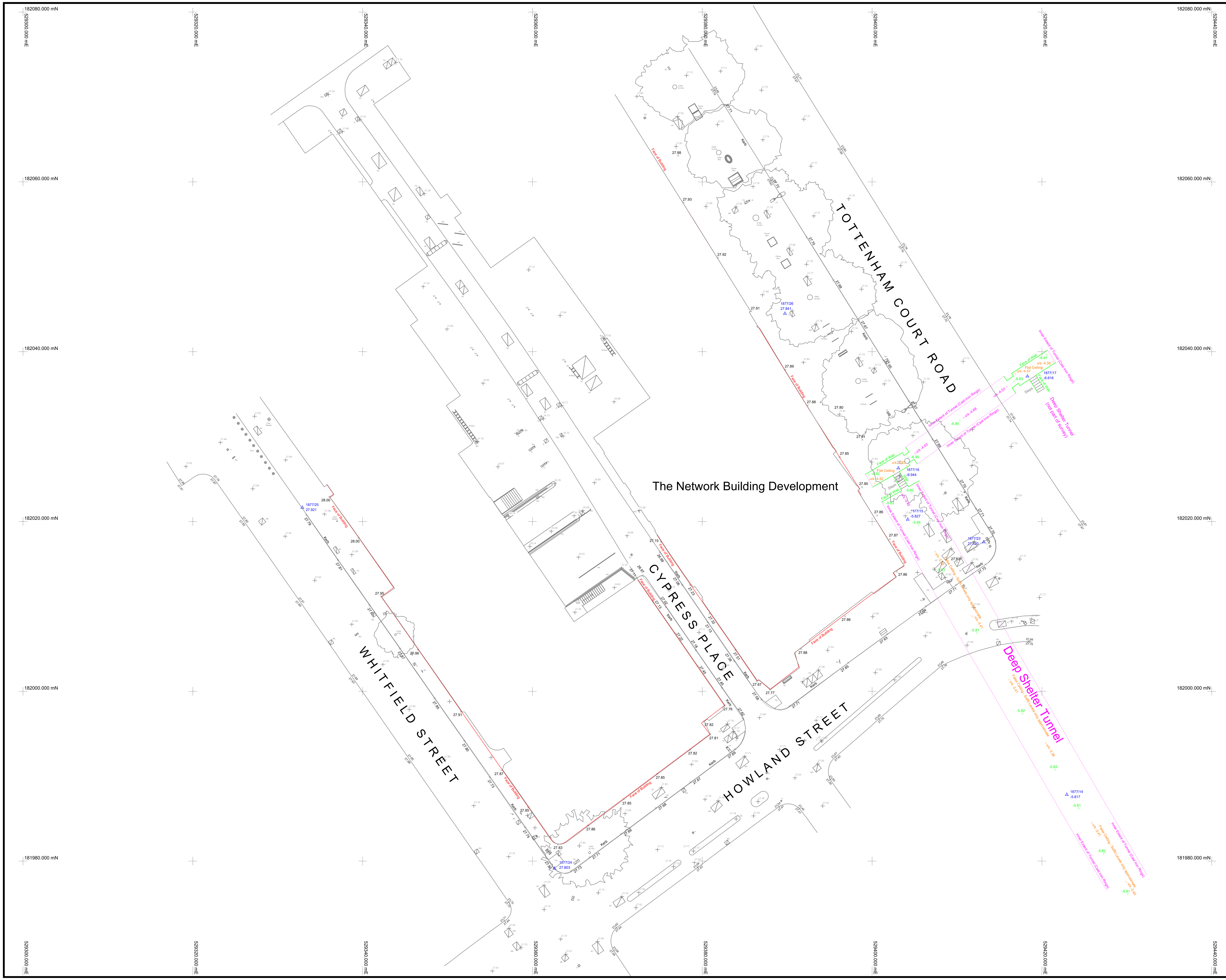
Project
The Network Building

Drawing title
Home Office Deep Shelter Tunnels

Scale	Date	Drawn
NTS	March 2022	SCa

Drawing status	Status	Revision
Preliminary	S2	P2

Project no. Originator Zone Level Type Role drg no.
2180000 - EWP - ZZ - 00 - SK - S - 0046



SOCOTEC Monitoring UK Limited
Bell Lane, Uckfield, East Sussex TN22 1QL
Telephone: 01825 701 801
Visit us @ www.socotec.co.uk/monitoring

SOCOTEC

Grid North

N

Notes

1. This drawing is to Site Grid and Datum. As no original site control points were found at the time of survey, the survey therefore has been graphically matched using the "Best mean fit method" using hard detail features such as corners of buildings and kerb lines to establish survey grid and datum system.

2. This is a digital survey and is only accurate at the scale which is specified.Please exercise extreme care if used at a larger scale.

3. This survey shows the top half of the closest Deep Shelter tunnel and cross passage overlaid on the client supplied topographic survey on the surface. Lower part of the tunnel was not accessed and is not part of the survey.

4. In all cases survey readings have been taken to the internal faces / finishes. Allowances must be made when determining the external position of the tunnels.

5. Soffit levels which have been prefixed with u/s text represent the inner levels on the soffit.

6. The coordination of the subsurface tunnels relative to the surface development was completed by undertaking a closed loop traverse from the development site, towards entrance shaft at Cheniest Street, down the shaft to tunnel level, through tunnels to the exit shaft at Tottenham Court Road and up the spiral staircase returning to the original points on the surface. This ensures the accurate coordination between the surface development and Deep Shelter tunnels.

7. Topographic Data in layer "Client Supplied Data" has been supplied by client and has not been check or verified by Socotec Monitoring UK Ltd. This is for diagrammatic purposes only and should not be used for any other purpose. Client supplied source drawing ref: LS1618_T_220222.dwg.

8. Critical clearance dimensions, levels and invert levels should be checked prior to design and construction.

9. Socotec Job Reference is SOC 1877-01.

10. Survey undertaken for and on behalf of Blackburn & Co.

Control Stations (Site Grid)

Name	Easting [m]	Northing [m]	Level [m]
1877/14	529422.929	181987.829	-5.817
1877/15	529404.192	182020.244	-5.827
1877/16	529403.086	182026.278	-6.944
1877/17	529418.292	182037.106	-6.616
1877/23	529413.157	182017.576	27.820
1877/24	529362.600	181979.128	27.803
1877/25	529332.903	182021.638	27.921
1877/26	529389.735	182044.489	27.841

No.	Date	Description
0	25-05-22	Original Correlation Survey

Revisions

Client :
Blackburn & Co.
No.1 Clink Street
London
SE1 9DG

Project :
The Network Building
London

Scale : 1 : 200	Sheet Size : A1
Date of Survey : May 2022	
Project No : 1877-01	Drawn By : JK
Sheet : 1 of 1	Checked By : NY

Title :
Correlation Survey

Sheet :
SOC 1877-01 01 Rev0