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ST GILES CIRCUS

LONDON UNDERGROUND CONCEPTUAL DESIGN STATEMENT

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Revision History

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Prepared by:

Clive Fussell
MEngMSt CEng MIStructE
Director Engenuiti

I confirm that professional skill and care has been used in the preparation of this deliverable and it meets the project requirements. I also confirm that this deliverable has been checked for accuracy and compliance by competent persons employing check processes commensurate with the level of risk inherent to the assets and works.

Reviewed by:

Paul Grimes
BEng MSt CEng MICE
Director Engenuiti

I approve this deliverable as the designated technical authority for the relevant engineering discipline and am accredited to do so.

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Senior Engineer Donaldson Associates

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Reviewed by:

Hilary Skinner
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Director Donaldson Associates

I approve this deliverable as the designated technical authority for the relevant engineering discipline and am accredited to do so.

1 EXECUTIVE SUMMARY

1.1.1 This Conceptual Design Statement has been prepared for London Underground Limited (LUL) to demonstrate how the St Giles Circus Development near Tottenham Court Road Underground Station will affect their assets. The proposed development includes the construction of a deep basement above and to the east of the Northern Line Escalator Box (NLEB), refurbishment of existing buildings on Denmark Street and Endell Street and the construction of a single storey basement below the existing buildings at 4 Flitcroft Street and 1 Book Mews.

1.1.2 The principal objective of the document is to demonstrate the following:

- The Demolition and Enabling Works required to construct the project do not adversely affect London Underground assets, so that London Underground can give approval for the Demolition and Enabling Works. The effect of the enabling and demolition works is assessed in sections 9 to 20.
- The construction of a new basement south of Denmark Street between 4 Flitcroft Street and 1 Book Mews does not adversely affect the London Underground assets so that London Underground can give approval for the construction of the new basement between 4 Flitcroft Street and 1 Book Mews.
- Identify a ~~proposed~~ method of construction for the development so that London Underground assets are not prejudiced by the proposed building.
- ~~Identify an intrusive Site Investigation that will be undertaken during the Enabling Works to confirm the ground conditions sufficient for detailed design to be completed.~~
- ~~Identify~~ Present an Analysis Method for undertaking the Conceptual Design Statement for the permanent works.

1.1.3 The effect of the permanent works is assessed in sections 21 to 33.

1.1.4 Part of the site was until recently occupied by London Underground for the upgrading works to Tottenham Court Road Station which included the construction of a new escalator box to provide improved access to the Northern Line. The development is governed by an Agreement between the Secretary of State for Transport and the developer which identifies the construction of a future basement on the site. The site was returned to the developer by London Underground upon completion of the structural works to the escalator box (5th August 2014). The Eastbound Crossrail tunnel has been constructed below the site, but the proposed development is planned to be constructed before the tunnels are fully commissioned.

1.2 Interface with London Underground

1.2.1 The proposed basement is above and adjacent to the Northern Line Escalator Box (NLEB) that has recently been constructed by London Underground and is immediately to the East of the Northern Line Platform tunnels below Charing Cross Road. The Conceptual Design Statement assesses the impact of demolition and enabling works on the London Underground infrastructure and proposes a basement construction method to limit movements of the NLEB and the Northern Line Platform tunnels.

1.2.2 A top down method of basement construction is proposed to both minimise the removal of overburden above the NLEB and provide early, stiff propping to the retaining walls so that lateral movements are minimised. Consideration is given to the control of movements due to drying shrinkage and creep of the concrete basement slabs.

1.2.3 A method of analysis for assessing the ground movements is ~~proposed~~ presented and an ~~preliminary~~ analysis of the construction sequence is included to show that the predicted movements are around the 5mm limits for the escalator supports advised by LUL and that the Northern Line platform tunnels are not adversely affected.

1.2.4 A system of monitoring is then ~~proposed~~ presented to verify that the actual movements are in line with the predicted movements and interventions are suggested if the movements are greater than predicted. The monitoring to the NLEB commenced installation in December 2014 with tiltmeter monitoring ongoing since June 2015. The residual risk to both the travelling public and the operation of the railway is considered to be low.

1.2.5 A second phase of site investigation was undertaken between November 2014 and March 2015 by Concept Consulting to verify the ground conditions on the part of the site previously occupied by LUL. This did not change the soil parameters used in the design.

1.3 Further work

1.3.1 In June 2015 Skanska were appointed under a pre-contract services agreement to provide construction advice and logistics for the development. The construction sequence and methodology has been revised to incorporate their working methods. Detailed design and method statements will then be prepared with their input for all the ground floor and sub-structures for approval by London Underground so that their requirements can be discharged.

2 INTRODUCTION

2.1 Purpose

2.1.1 This Conceptual Design Statement describes the proposed design for the St Giles Circus project and its interface with London Underground. The principal objective of the document is to demonstrate the following:

- The Demolition and Enabling Works required to construct the project do not adversely affect London Underground assets, so that London Underground can give approval for the Demolition and Enabling Works. The effect of the enabling and demolition works is assessed in sections 9 to 20.
- The construction of a new basement between 4 Flitcroft Street and 1 Book Mews does not adversely affect London Underground assets so that London Underground can give approval for the construction of the new basement at 4 Flitcroft Street.

~~2.1.2 The document also outlines the approach to the following that will be used to complete the Conceptual Design Statement for the new basement works to the north of Denmark Street:~~

- Identify a ~~proposed~~ method of construction for the development so that London Underground assets are not adversely impacted by the proposed building.
- Give details of the intrusive Site Investigation that was undertaken during the Enabling Works to confirm the ground conditions sufficient for detailed design to be completed.
- ~~Identify~~ Present an Analysis Method for undertaking the Conceptual Design Statement for the permanent works.

2.1.3 The effect of the permanent works is assessed in sections 21 to 33.

2.1.4 The document includes ~~preliminary~~ results from 2D analysis models through the Northern Line Escalator Box to illustrate that the movements predicted as a result of the permanent works are within the limits identified and that the structural capacity of the NLEB is not exceeded.

~~2.1.5 These movement assessments will be developed further following feedback from the stakeholder review of this Conceptual Design Statement and construction input from the selected Contractor. A final submission of the Conceptual Design Statement will then be made.~~

2.1.6 Titles of this document refer to London Underground specific headers in the Conceptual Design Statement template as LUL_(x).

3 DESIGN ORGANISATION (LUL_1)

3.1 Lead designer

The lead designer for the main site of the St Giles Circus project (North of Denmark Street) is ORMS Designers + Architects Ltd who are responsible for co-ordinating the design. Contact details are:

John McRae
ORMS Designers + Architects Ltd
1 Oliver's Yard,
55-71 City Road,
London. EC1Y 1HQ
Tel 020 7833 8533
Fax 020 7837 7575
www.orms.co.uk
Email: JMcRae@orms.co.uk

3.1.1 The lead designer for the site South of Denmark Street is Ian Chalk Architects Ltd who are responsible for co-ordinating the design. Contact details are:

Ian Chalk
Ian Chalk Architects Ltd
70 Cowcross Street
London EC1M 6EJ
www.ianchalkarchitects.com
Email: ian@ianchalkarchitects.com

3.1.2 The structural engineer for the St Giles Circus project is Engenuiti who are also responsible for compiling the Conceptual Design Statement. Engenuiti are working with geotechnical engineering specialist Donaldson Associates who are advising on the foundation design and ground movements and who are co-authoring the Conceptual Design Statement. Contact details are:

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4 IDENTIFICATION OF STRUCTURE (LUL_2)

4.1 Location

4.1.1 The St Giles Circus project involves the redevelopment of this Central London site adjacent to Tottenham Court Road station and is bounded by Charing Cross Road, Andrew Borde Street (current location of D4 bus diversion), St Giles Circus and Denmark Street. The project also includes the refurbishment of some properties to the south of Denmark Street and the refurbishment of a property on Endell Street. Refer to figure 4.1.1 for a site plan. The development will include Retail, Hotel, Residential, Commercial and Leisure facilities.

4.1.2 The new build part of the site north of Denmark Street (incorporating the basement, buildings A, B, C and D) is referred to as Zone 1. Zone 2 comprises the existing buildings on the north side of Denmark Street (Nos 20 to 28 Denmark Street and No. 59 St Giles High Street)

4.1.3 The development also includes the refurbishment of existing buildings to the south of Denmark Street (Nos 4, 6, 7, 9 and 10 Denmark Street, No 4 Flitcroft Street and No 1 Book Mews) and the creation of a new basement in the courtyard between Book Mews and Denmark Street. This area is referred to as Zone 3.

4.2 Asset Summary

4.2.1 The following London Underground assets that form part of the Tottenham Court Road Station Upgrade interface with the proposed St Giles Circus project:

- The new Escalator Box structure that provides improved access to the Northern Line.
- The new Northern Line Lower Concourse tunnel that connects the Escalator Box to the Northern Line Platform Tunnels.
- The Southbound and Northbound Northern Line tunnels and associated cross passages.

4.2.2 The following Crossrail assets interface with the proposed St Giles Circus project:

- The contract C300 Eastbound running tunnel approximately between chainage points 5050m and 5140m (see Appendix A, Crossrail drawings).
- The contract C300 Westbound running tunnel approximately between chainage points 5050m and 5130m.

4.2.3 The relationship between the St Giles Circus development and the London Underground assets is shown on drawing 029-Z1-S-051.

4.3 Description

4.3.1 Part of the site was until recently occupied by London Underground (LUL) as part of the upgrade works at Tottenham Court Road that include the construction of a new escalator box and associated tunnels for access to the Northern Line beneath the Charing Cross Road frontage of the site. An Agreement is in place between the Secretary of State for Transport and the Project Sponsor that allows LUL to utilise the part of the site and divert Charing Cross

Road across the site during the construction of the escalator box and new ticket hall at Tottenham Court Road station.

4.3.2 The Agreement defines a zone for the future construction of a basement above the escalator box, this CDS describes the construction of the development that includes the basement above the escalator box.

4.3.3 As part of this Agreement LUL installed 7 piles (known as the 'Consolidated Piles') which will support part of the new build element of the St Giles Circus project where it extends above the new escalator box. The Agreement also requires LUL, Crossrail and the Project Sponsor to proactively work together and share information regarding over-site development on the St Giles Circus site.

4.3.4 The scheme for the St Giles Circus project involves the construction of four new buildings on the site (known as Buildings A, B, C and D), the refurbishment of the existing building stock on Denmark Street and the construction of a new basement below Buildings A, B, C and D. Refer to figure 4.3.1 for the extent of the basement.

4.3.5 The project also falls within the Crossrail Safeguarding zone (see Appendix A) and lies directly above the Eastbound Crossrail running tunnel. A separate submission has been made to Crossrail that assesses the impact of the development on their assets.

5 TITLE OF SCHEME (LUL_3)

5.1 St Giles Circus

5.1.1 The scheme is known as 'St Giles Circus' and includes the area of land referred to in the Agreement between Consolidated Developments and the Secretary of State for Transport as the 'Consolidated Site.'

5.1.2 The planning application for the scheme is reference 2012/6858/P and is given the address St.Giles Circus site including: site of 138-148 (even) Charing Cross Road; 4 6 7 9 10 20-28 (inc) Denmark Street; 1-6 (inc) and 16-23 (inc) Denmark Place; 52-59 (inc) St.Giles High Street; 4 Flitcroft Street and 1 Book Mews London WC2.

6 NAME OF SUPPLIER (LUL_4)

6.1 Project Sponsor

6.1.1 The Project Sponsor is Consolidated Developments Ltd. Contact details are:

Laurence Kirschell
Consolidated Developments Limited
26 Soho Square
London W1D 4 NU
Tel 020 7437 4372
Fax 020 7437 3800
www.26sohosq.com

6.2 Crossrail Infrastructure Manager (IM)

6.2.1 Where this Conceptual Design Statement relates to the interface of the St Giles Circus project with the Crossrail Infrastructure below the site it has been developed with the guidance of the Crossrail 3rd Party Developments Manager:

Geoff Rankin, 3rd Party Developments Manager – CRL Chief Engineer's Group
Floor 30/G4/05
Crossrail, 25 Canada Square, Canary Wharf, London, E14 5LQ
Telephone: 0203 229 9600
Mobile: 07540 666 875
Email: geoffrankin@crossrail.co.uk

6.3 London Underground

6.3.1 Where this Conceptual Design Statement relates to the interface of the St Giles Circus project with the London Underground Infrastructure below the site and has been developed with the guidance of London Underground's engineers and project managers for the Northern Line Escalator Box (NLEB), Ticket Hall and Northern Line Lower Concourse tunnels.

William Lau, NLEB and Ticket Hall engineer,
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6.4 Third Party Approvals

6.4.1 Aside from Crossrail and London Underground, the St Giles Circus project will also be obtaining approvals from the following bodies for the basement works:

- London Borough of Camden.
- The Environment Agency.

6.5 Organisation responsible for Detailed Design

6.5.1 The organisations responsible for the detailed design of structures that interface with London Underground are the structural and geotechnical engineers identified in the section 3 'Design Organisation.' Whilst elements of the St Giles Circus project may become Contractor Design, the design of the basement structure above the NLEB ~~will be~~ has been fully designed by the Design Organisation who ~~will~~ have ~~then~~ prepared a performance specification that ~~will~~ identifies the minimum size of structural elements, minimum depth and length of piles, minimum reinforcement requirements, required material properties and all other key performance criteria that affect the Conceptual Design Statement.

7 OUTLINE PROJECT PROGRAMME (LUL_5)

7.1 Enabling Works

7.1.1 Following the handover of the Consolidated Site from LUL (5th August 2014) an Enabling works package of services isolation and soft strip of the existing buildings has been undetaken ~~is planned to commence.~~ The Demolition works ~~are due to~~ commenced on 22nd June 2015 with initial works on site set up and hoarding and are due to finish in June 2016. The current programme is shown in Appendix G. ~~and envisages the Demolition and Enabling works being completed in October 2015.~~

7.2 Permanent Works

7.2.1 The Permanent works are due to commence in June 2016 ~~October 2015~~. The current programme is shown in Appendix G and envisages the permanent works being completed at the end of ~~in early~~ 2018.

8 BRIEF DESCRIPTION OF EXISTING CONDITIONS (LUL_6)

8.1 Site Investigation Reports

8.1.1 The site is located within the London Borough of Camden at National Grid Reference TQ 298 812. The Northern part of the site is bound to the west by the Charing Cross Road, to the south by Denmark Street and to the north and east by St Giles Street. A further portion of the site is located to the south of Denmark Street, at numbers 4, 6, 7, 9 and 10 Denmark Street, number 4 Flitcroft Street and number 1 Book Mews. No. 71 Endell Street is also included within the development.

8.1.2 The site currently comprises several commercial buildings and an area of ground cleared for LUL's works at Tottenham Court Road station. Single level basements are present below a number of the properties that line Denmark Place, Denmark Street and St Giles High Street. The Northern and North-Western part of the site has been cleared of buildings to allow for the construction of the Northern Line Escalator Box.

8.1.3 Existing London Underground Northern Line station tunnels (Northbound and Southbound) are located immediately to the west of the site and lie in a north-south direction. The Southbound Northern Line tunnel is the nearer of the two to the proposed location of the piles. The recently constructed Eastbound Crossrail tunnel runs below the site from west to east.

8.1.4 An initial site investigation has been carried out at the site by STATS Ltd on behalf of Consolidated Developments Ltd. The works were carried out during the period between 8th April and 16th May 2008.

8.1.5 The investigation included the sinking of two cable percussive boreholes (BH) to a depth of 7.6mbgl. BH101 was extended to 63.5mbgl by rotary coring and BH102 was extended to 54.0mbgl using open hole rotary drilling. Nine self-boring pressuremeter tests were carried out within BH102 and further in-situ and laboratory testing was conducted. Four piezometers were installed to depths of 15.0, 24.1, 35.05 and 55.0 metres below ground level (mbgl).

8.1.6 Full details of the Ground Investigation are presented within the STATS Factual Report on Ground Investigation (STATS, 2008), included in Appendix D.

8.1.7 In order to begin preliminary analysis, additional ground investigation information was used from Crossrail boreholes to better define the stratigraphy and geotechnical parameters. These boreholes occasionally recorded a different stratigraphy within the Lambeth Group to that observed within the STATS boreholes. A further site investigation was undertaken by Concept Consulting between November 2014 and March 2015 to confirm the stratigraphy across the site (see Sections 8.5 and 8.6), this did not change the soil parameters in the previous version of this CDS.

8.1.8 The investigations revealed the typical stratigraphy shown in table 8.1.1. Levels are given in metres above tunnel datum (mATD), which is metres above Ordnance datum plus 100m. It is considered more conservative when modelling the effects of heave to consider the Laminated Beds as a clay stratum; ~~this will be the case unless~~ and has been borne out by the additional site investigation ~~shows that the sand layer is continuous across the whole site in which case it will be modelled as a sand stratum~~.

Stratum	Top Of Stratum Level (mATD)	Thickness (m)	Description
Made Ground	125.10	3.90	Clayey GRAVEL comprising brick rubble and ceramic fragments changing with depth to slightly sandy gravely CLAY.
Lynch Hill Gravel	121.20	2.10	Dense to very dense, slightly silty sandy fine to coarse angular to subrounded GRAVEL.
London Clay A3	119.10	13.60	Firm, becoming stiff and very stiff with depth, fissured locally thinly laminated CLAY. Weak mudstone bands present between 112.70 and 103.55mATD.
London Clay A2	105.50	10.90	
Upper Mottled Beds	94.60	10.80	Hard (locally very stiff) closely to extremely closely fissured locally thinly laminated multi-coloured (purple, grey, red brown, orange) CLAY with occasional thin beds to thick laminae of very silty fine sand.
Laminated Beds	83.80	4.20	Within the STATS boreholes the Laminated Beds were recorded as: very dense thinly interlaminated light grey and light brown slightly silty fine SAND. However, the information from the Crossrail boreholes suggests that this sand layer is not continuous across the area. Elsewhere the Laminated Beds are recorded as stiff thickly laminated dark grey black CLAY with laminae of light grey silt.
Lower Mottled Beds	79.60	1.50	Hard indistinctly fissured locally thinly to thickly laminated multi-coloured (mottled green grey, grey green, purple, red brown and orange brown) sandy CLAY with occasional fine sand pockets and partings to 5mm. Sand is fine.
Upnor Formation	78.10	1.80	Very dense thinly interbedded to thinly inter-laminated clayey dark grey mottled dark green fine SAND and light grey silty fine SAND (located on site) and very stiff indistinctly laminated dark greyish brown slightly sandy to sandy CLAY. Occasional partings of light grey silty fine sand, locally greenish grey. Rare rounded fine and medium dark flint gravel (located to the west of the site).
Thanet Sand	76.30	4.60	Very dense silty fine Sand. A 0.7m thick layer of flint cobbled present at the base interface (Bullhead Beds).
Chalk	71.70	Proven to 10.7	Weak to moderately weak, medium density structured Chalk.

Table 8.1.1: Typical stratigraphy for St Giles Circus site

8.1.9 Geotechnical parameters used for each stratum for the ~~preliminary~~ modelling are given in table 8.1.2. The London Clay and Lambeth Group strata, which are closest to the base of excavation and the Crossrail and LUL assets ~~will~~ has been modelled using Hardening Small Strain models (see Appendix P for more details); table 8.1.2 presents the E_{50} stiffness (reference secant stiffness taken from drained triaxial testing) for these strata to provide an indication of the relative stiffness assumed. ~~Other parameters for this constitutive model will be presented in more detail in subsequent stages of reporting~~.

Stratum	γ bulk $[kN/m^3]$	c' [kPa]	ϕ' [deg]	E' [MPa]	E_{50} [MPa]	ν'	K_0
Made Ground	20	3	25	4	-	0.2	0.577
Lynch Hill Gravel	21	3	34	30	-	0.25	0.441
London Clay A3	20	5	25	-	20	0.2	1.2
London Clay A2	20	5	25	-	26.9	0.2	1.2
Upper Mottled Beds	20.6	5	25	-	38.9	0.2	1.2
Laminated Beds	21	5	25	-	38.9	0.2	1.2
Lower Mottled Beds	21	5	25	-	38.9	0.2	1.2
Upnor Formation	21	3	30	90	-	0.2	0.500
Thanet Sand	19	3	35	300	-	0.2	0.426

Table 8.1.2: Geotechnical parameters for ~~preliminary~~ modelling

8.1.10 Groundwater level is assumed to be at 121.0mATD; based on the results of the Concept Site Investigation and the worst case accidental ground water level identified in the 'Tottenham Court Road Station Upgrade Design Statement – Structures' received from London Underground (see Sections 8.5 and 8.6). Groundwater monitoring from the STATS and Concept Consulting investigations confirm that the London Clay and Lambeth Group (intermediate aquifer) in this area are currently under drained (i.e. porewater pressures reduce from hydrostatic) as is typical for central London; this is presented in figure 8.1.1. In the longer term it is expected that generally porewater pressures will increase within the intermediate aquifer ~~back~~ towards hydrostatic, however some under drained profile is likely to remain due to pumping required to prevent water ingress to the tube network.

8.1.11 Prior to demolition of the existing buildings an asbestos refurbishment/demolition survey ~~is being~~ was undertaken and ~~any~~ the asbestos discovered ~~will be~~ removed by an approved specialist contractor to a licenced waste facility.

8.1.12 The planning conditions require that an archaeological investigation is undertaken over part of the site prior to construction of the new basement. MOLA have been appointed to undertake this investigation during the demolition works.

8.2 Environmental Issues

8.2.1 As part of the planning application submitted for the site an Environmental Impact Assessment was prepared by Buro Happold and submitted to Camden, copies can be accessed from the Planning Portal if required.

8.2.2 The new construction in the development is targeting a BREEAM Very Good rating under BREEAM New Construction Shell and Core. This includes a number of surface water control measures such as green or brown roofs, rainwater harvesting and stormwater attenuation tanks to meet the requirements of the London Plan development strategy.

8.2.3 The project does not alter the environmental impact of the existing LUL infrastructure.

8.3 Associated Structural Assessment

8.3.1 The following London Underground assets that form part of the Tottenham Court Road Station Upgrade interface with the proposed St Giles Circus project:

- The new Escalator Box structure that provides improved access to the Northern Line.
- The new Northern Line Lower Concourse tunnel that connects the Escalator Box to the Northern Line Platform Tunnels.
- The Southbound and Northbound Northern Line tunnels and associated cross passages.

8.3.2 The new Northern Line Escalator Box is an insitu reinforced concrete structure constructed between 2010 and 2013. The structure is ground bearing and is also structurally connected to the new Tottenham Court Road ticket hall. A movement joint is provided between the Northern Line Escalator Box and the Northern Line Lower Concourse tunnel. The cross section of the structure is a rectangular tube and as such will act as a deep beam. The structure was constructed 'bottom up' between propped permanent secant piled walls which remain in place and resist the earth pressures in the permanent condition. The top of the box has been backfilled as shown on drawing VBN-TCR-8742-SKC-000273.

8.3.3 The concrete Escalator Box structure is provided with an external waterproof membrane and is designed to resist the hydrostatic pressure. The top and bottom slabs of the box also act as permanent props between the secant piled walls that resist lateral earth pressures and support the weight of the backfill above the Escalator box.

8.3.4 Table 8.3.1 shows the material properties assumed for the Northern Line Escalator Box:

Item	**Assumption**	**Source**
1. Concrete strength	C32/40 giving: f_{ck} = 32MPa. f_{cd} = 18.1MPa. E_{cm} = 33.3GPa $E_{c,eff}$ =11.9GPa.	As built reinforcement drawings.
2. Reinforcement strength	Grade B/Type 2 f_{yk} = 500MPa	As built reinforcement drawings.

Table 8.3.1 material properties assumed for Northern Line Escalator Box

8.3.5 The new Northern Line Lower Concourse tunnel is a sprayed concrete lining tunnel of approximately 9.6m diameter intrados at its maximum extent where an internal floor slab is provided at the junction with the Escalator Box. A 400mm thick cast insitu reinforced concrete permanent lining is provided within the sprayed concrete lining. The tunnel reduces in height to approximately 7.6m as it progresses away from the Escalator box where the tunnel invert is provided with 2.7m of mass concrete fill. Side passages stair access to the escalator void are provided using similar construction. A movement joint is provided between the Escalator Box and the Lower Concourse tunnel. Some water ingress was visible at the junction between the two structures during a site visit in May 2014 and was observed again during the condition survey undertaken on 6th January 2015.

8.3.6 The material properties assumed for the Northern Line Lower Concourse tunnel are shown in table 8.3.2:

Item	Assumption	Source
1. Primary Lining Concrete strength	C28/35 giving: f_{ck} = 28MPa. f_{cd} = 15.9MPa. E_{cm} = 32.3GPa $E_{c,eff}$ =9.8GPa.	HAG-N105-8742-CIV-X-SPE-X-00571_C02
2. Permanent Concrete Lining	C32/40 giving: fck = 32MPa. fcd = 18.1MPa. Ecm = 33.3GPa Ec,eff =11.9GPa.	Table of mix references provided by Chris Barnes 16/4/14.
2. Reinforcement strength	Grade B/Type 2 f_{yk} = 500MPa	As built reinforcement drawings.

Table 8.3.2 material properties assumed for Northern Line Lower Concourse tunnel.

8.3.7 The Southbound and Northbound Northern Line tunnels were constructed in the early years of the 20th Century and are formed of cast iron segments forming a tunnel of approximately 6.5m diameter.

8.3.8 The material properties assumed for the Northern Line platform tunnels are shown in table 8.3.3:

Item	Assumption	Source
1. Cast Iron segments	Grade 10 cast iron giving: Characteristic compressive strength 161MPa. Limit strength for tension 38MPa. Young Modulus E = 103 GPa Shear Modulus G = 41 GPa Poisson ratio υ = 0.26	LU Standards G-055-A1 (Civil Engineering – Deep Tube Tunnels and Shafts, October 2007).

Table 8.3.3 material properties assumed for Northern Line Platform tunnels.

8.4 ~~Proposed~~ Additional Surveys or Investigations

8.4.1 The Northern Line Escalator Box, Northern Line Lower Concourse Tunnel and Ticket Hall box are of new construction and are generally in good condition. During site visits to co-ordinate the proposed monitoring with the existing structures and installations some water ingress and cracking was noted, especially at the junction between the Escalator Box and the Lower Concourse Tunnel, see figure 8.4.1.

8.4.2 The Northern Line platform tunnels are of cast iron segment construction and have recently been modified locally for the installation of cross passages to the new exit stairs.

8.4.3 Prior to the demolition works commencing a condition survey of the existing structures was undertaken jointly with LUL to record the condition and any defects prior to the St Giles Circus demolition works. The results of the condition survey are presented in the report 'Schedule of Condition Of those parts of the new escalator access at Tottenham Court Road station in the vicinity of the development site at St Giles Circus. London WC2, Revision A' and have been agreed with LUL. Drawings of the existing structures provided by LUL are shown in Appendix A.

8.5 Additional site investigation

8.5.1 An additional site investigation was required to confirm the stratigraphy and soil parameters across the remainder of the Zone 1 site, as access constraints meant that the original site investigation undertaken by STATS (see Appendix D) was only able to cover the western part of the site near the NLEB. Concept Consulting undertook additional boreholes PB1 and PB2 between November 2014 and March 2015. PB3 will be sunk after demolition of the buildings on Denmark Place that are preventing access.

8.5.2 The STATS investigation showed a sand channel within the Lambeth Group in one part of the site; the additional ground investigation undertaken by Concept Consulting has not identified this in either PB1 or PB2. The additional ground investigation also confirmed general strength and stiffness parameters across the site following laboratory testing to confirm specific soil parameters required for finite element analysis.

8.5.3 The location of boreholes PB1, PB2 and PB3 are shown in figure 8.5.1. The general position of the boreholes has been reviewed and agreed with the Crossrail and LUL teams; the exact position of PB3 may be updated in order to meet access constraints.

8.5.4 The depth and drilling technique for the three boreholes are summarised in table 8.5.1.

Boreholes	Depth [m]	Drilling technique
PB1	55.00	Cable percussive from ground level to the London Clay and rotary coring thereafter
PB2	55.00	Cable percussive from ground level to the London Clay and rotary coring thereafter
PB3	55.00	Cable percussive from ground level to the London Clay and rotary coring thereafter

Table 8.5.1 Zone 1 boreholes ~~proposed~~ for additional site investigation.

8.5.5 The stratigraphy of the London Clay and Lambeth Group are of particular importance to the project. The Lambeth Group was logged using the most up-to-date nomenclature (see for example Page and Skipper, 2000 and Hight et al., 2004).

8.5.6 The following field testing and sampling was undertaken on PB1 and PB2, and will be undertaken on PB3:

- Ground level to 4.4mbgl: Small and bulk disturbed samples shall be taken at every change in strata. In addition SPT tests should be conducted every metre starting 0.5m below inspection pit.
- 4.4mbgl to London clay: SPT test at 1.0m intervals. Small disturbed samples at every change in strata.
- Below London clay: Alternate U100 / OS-TK/W samples and SPT tests at 1.5m intervals. Small disturbed samples at every change in strata.
- Size of U100 to be a minimum of 100mm diameter. Size of undisturbed samples to be a minimum of 76mm diameter.

8.5.7 In addition, 9 No. self-bored pressuremeter tests (SBPM) were conducted in PB01.

8.5.8 The following laboratory testing were conducted on PB1 and PB2 and will be undertaken on PB3:

- Atterberg limits
- Moisture content.
- Particle size distribution (PSD)
- Oedometer and swelling test
- Unconsolidated Undrained triaxial test (UU)
- Consolidated Undrained triaxial test (CU)
- Stress path triaxial test
- Chemical testing (in accordance with BRE Special Digest 1:2005, Appendix C1)
- Waste Acceptance Criteria (WAC) testing

8.5.9 A multiple level vibrating wire piezometer was installed within PB01 to monitor the groundwater level within the superficial deposits. If feasible, given the demolition sequence, piezometers will be installed within the PB03 borehole to confirm the porewater pressure profile within the London Clay and confirm that the design assumptions are suitable.

8.5.10 The results of the Concept Consulting site investigation are presented in Appendix O.

8.6 Additional site investigation South of Denmark Street

8.6.1 A site investigation was required to confirm the stratigraphy and soil parameters for the design of piles in the Zone 3 site.

8.6.2 Two further boreholes we sunk by Concept Consulting between November 2014 and March 2015 in the Zone 3 site located as shown in figure 8.6.1. The general position of the boreholes was reviewed and agreed with the Crossrail and LUL teams.

8.6.3 The depth and drilling technique for the Zone 3 boreholes are summarised in table 8.6.1. The results for the Concept Consulting site investigation are presented in Appendix O.

Boreholes	Depth [m]	Drilling technique
PB4	30.00	Cable percussive
PB5	30.00	Cable percussive

Table 8.6.1 Zone 3 boreholes ~~proposed~~ for additional site investigation.

ENABLING WORKS (SECTIONS 9 TO 20)

9 DESCRIPTION OF DEMOLITION WORKS AND METHOD OF DEMOLITION (LUL_7)

9.1 Previous Demolition Works

9.1.1 As part of the Tottenham Court Road Station Upgrade works the north part of the site that is currently occupied by LUL has already had the existing buildings demolished in advance of the NLEB construction. It is understood that these buildings have been demolished down to basement level and outside the footprint of the NLEB they have been backfilled. Refer to drawing HAG-N105-8742-CON-D-PLN-X-06902 Rev 05 in Appendix A.

9.1.2 A temporary road (bus diversion D3) has been formed across the site which is to be removed as part of the demolition package.

9.2 Demolition Works

9.2.1 The site encompasses a range of different buildings with varying levels of demolition required (see figure 9.2.1), these include:

Denmark Street

9.2.2 Removal of the rear sections of the building facing onto Denmark Place to No. 21, 22, 23, 24 & 25 (which form No.'s 17, 18, 19, 20 & 21 Denmark Place respectively).

St Giles High Street

9.2.3 Façade retention to the York & Clifton mansions elevation from No. 52 to 58 and the demolition of the 5 storey building over basement behind.

9.2.4 The ground floor passageway walls leading to Denmark Place and the sections of external walls above are to be carefully dismantled to allow for future reinstatement.

9.2.5 The rear elevation of buildings No. 56, 57 & 58 are to be carefully dismantled to allow for future reinstatement.

Denmark Place

9.2.6 Removal of buildings No. 1, 2, 3, 4, 5 & 6.

9.2.7 The front facade of buildings No. 1, 2 & 3 are to be dismantled and replaced with a facsimile restrained by the new building B. ~~carefully retained and moved to the edge of site (location TBC by Architect) to allow for future reinstatement.~~

9.2.8 The elevations of buildings No. 17, 19, 20 & 21 are to be carefully recorded and dismantled to allow for future reinstatement.

9.2.9 Refer to the Architects demolition drawings in Appendix H to confirm full extent of the demolition works. Refer to section 9.4 for the sequence of works.

9.3 Site Investigation

9.3.1 As part of the Enabling works an intrusive site investigation ~~will be~~ was undertaken to confirm the ground conditions in advance of the final design. Sections 8.5 and 8.6 identify the scope of the investigation.

9.4 Sequence of Works

9.4.1 The following sequence of works is proposed:

9.4.2 Inspect and survey façades that are to be retained as part of the works.

9.4.3 Divert existing services to the occupied and adjoining properties that cross the areas ~~proposed~~ for demolition.

9.4.4 Install dividing walls as per drawings between the occupied properties and the portion of the buildings to be demolished.

9.4.5 Disable all incoming services to the properties that are to be demolished and cap redundant drainage runs.

9.4.6 Undertake a soft strip of the properties that are to be demolished.

9.4.7 Fill the vaults under the street at 52 to 58 St Giles High Street in accordance with the drawings.

9.4.8 Install façade retention system.

9.4.9 Demolish the buildings to existing ground level using rubble from masonry and concrete structures to fill existing basements to a level 1.0m below existing ground level.

9.4.10 Remove other demolition rubble/debris from site to a licenced waste disposal facility.

9.4.11 ARCHAEOLGICAL INVESTIGATION to be undertaken by others, excavating areas outside basement footprints to a depth of approximately 2.5m below existing ground level.

9.4.12 Upon release of the site from the Archaeological Investigation breakout remaining basement structures including retaining walls, footings, concrete or masonry ground slabs and drainage runs.

9.4.13 Rubble from concrete and masonry structures to be used to level the site to approximately 24.0mAOD

9.4.14 Remove other demolition rubble/debris from site to a licensed waste disposal facility.

9.5 Movement and Storage of Materials during demolition

9.5.1 In order to control the effect on ground movements that the demolitions could have, it is proposed to use the masonry and concrete rubble from the demolished buildings to fill the existing basements below the buildings. As figure 9.5.1 shows this will be done in a sequential manner so that the only material removed from the site during the demolition is the soft strip material and organic matter such as the timber floor structures.

9.5.2 Any surplus rubble that results from the demolition of the above ground floor structures will be stored on the northern area of the site so that it is away from the archaeological investigations that are required by the planners. Stock piles of demolition rubble or other materials will be limited to a maximum height of 2.0m above surrounding ground level so that the loading from the stored materials does not exceed 40kPa. This is within the 50kPa allowance above existing ground level that the Crossrail tunnels are designed for. The demolition specification prohibits the storage of materials above the NLEB. A minimum clear distance of 1.0m must be maintained between the outside of the NLEB and the material storage area as identified on demolition drawing Z1-D-404

9.5.3 Once the archaeological investigations are completed the remaining basement walls, basement slabs and footings will be broken out. This will require the temporary excavation of the rubble fill to the basements. So that the effect of this temporary excavation on the Crossrail tunnel below is limited, the demolition specification requires the excavation of rubble and basement material to be under taken in "hit and miss" areas of no more than 100m2 prior to backfill. See figure 9.5.2.

9.5.4 The footprint of the basements are then backfilled to 24mAOD (124m to LUL datum) using the compacted rubble from the site so that the enabling works conclude with a level site that is approximately 1.0m below existing ground level. The effect of this change in level is considered in section 15.

10 BRIEF DESCRIPTION OF OTHER STRUCTURAL FORMS CONSIDERED (LUL_8)

10.1.1 Initially conventional demolition to existing lower ground floor level and removal of demolition rubble was considered. The effects of removing the weight of the existing buildings over the Crossrail tunnel was assessed and it was decided that a staged demolition method that retained the demolition rubble as fill would reduce the movements experienced during demolition by both the Crossrail Tunnel and the LUL infrastructure.

10.1.2 The staged demolition method also facilitates the construction of retaining walls to protect the existing buildings around the site and the archaeological investigation.

11 DESIGN CRITERIA (LUL_9)

11.1 Northern Line Escalator Box

11.1.1 London Underground (William Lau, Lead Civil Engineer) advised on 26 November 2012 that escalators 7, 8 and 9 can 'tolerate movements of about 5mm'. The main concerns are twisting and differential movement.

11.1.2 The key design criteria for the NLEB is therefore that the cumulative movements that result from the demolition works and the permanent works do not exceed this 5mm limit.

11.1.3 As the demolition works result in the removal of a small amount of material to the east of the NLEB the effect of removing upto 1.0m of the existing overburden during demolition ~~will be~~ has been assessed.

11.1.4 The changes in stress in the NLEB that result from both the demolition works and the permanent works have been assessed and the worst case stresses checked against the capacity of the concrete structure in accordance with the design standards and material properties identified in this report. In its current condition the most critical part of the NLEB structure is the reinforcement to the inside of 750mm thick walls. These are assessed as being at a maximum of 80% utilisation (combination of bending and axial forces) currently and during demolition. Based on conservative assumptions about the earth and water pressures during construction the assessment shows a 97.5% utilisation of this wall during construction of the basement that reduces to 73.6% in the long term.

11.2 Northern Line Lower Concourse Tunnel

11.2.1 London Underground have been asked for the movement limits that the lower concourse cladding is designed for. To date these have not been available, therefore it is conservatively proposed to limit movement of the Lower Concourse Tunnel as a result of the development to the same 5mm movement in any direction that the NLEB is designed for.

11.2.2 The changes in stress in the tunnel linings that result from both the demolition works and the permanent works ~~will~~ have been assessed and the worst case stresses checked against the capacity of the tunnel wall in accordance with the design standards and material properties identified in this report.

11.3 Northern Line Platform Tunnels

11.3.1 Following meetings with London Underground in February and April 2014, it is understood that a kinetic envelope survey is planned for the Northern Line platform tunnels once the Crossrail works are complete, this will form a baseline for future works. In advance of this survey tunnel movements ~~will~~ have been assessed against limits that were defined in The Monitoring Implementation Plan for the Northern Line Works (VBN-TCR-8742-MIP-000001).

11.3.2 Section 4.4 of VBN-TCR-8742-MIP-000001 identifies that gauge clearances are currently substandard in the Northern Line Platform tunnels adjacent to Lift Shaft 4, close to the northern headwall and tail wall or both platforms. The proposed St Giles Circus basement works are located adjacent to the centre of the Northern Line platforms, approximately 30m away from the areas of sub-standard gauge clearance noted above. The ~~preliminary~~ assessment is therefore based on the understanding that the platform tunnels adjacent to the site are outside the Kinetic Limit.

11.3.3 The key design criteria for the Northern Line Platform tunnels is that demolition and permanent works do not result in movements that infringe on the Kinetic Limit in the tunnels.

11.3.4 The changes in stress in the tunnel cast iron tunnel segments that result from both the demolition works and the permanent works ~~will~~ have been assessed and the worst case stresses checked against the capacity of the tunnel wall in accordance with the design standards and material properties identified in this report.

11.4 Collision Loads

11.4.1 The demolition and proposed basement works are sufficiently far away from the platform tunnel that train collision loads do not need to be considered.

11.4.2 The loading limit on the existing road slab over the NLEB has been communicated to the soft strip contractor and has been included in the tender documents for the Demolition Works and the Main Contractor along with the Health & Safety File produced by LUL at handover of the site.

12 METHOD OF STRUCTURAL ANALYSIS (LUL_10)

12.1 Analysis Method

12.1.1 A geotechnical overview was conducted to assess the impact of site re-grading on LUL assets. Various sections were sketched to demonstrate qualitatively what stress changes and movements LUL assets would experience during the enabling works.

12.1.2 The results from the overview were then verified by 2D Plaxis models of the Northern Line Escalator Box and the Northern Line Platform tunnels that considered the effect of demolishing the buildings at 1-6 Denmark Place and St Giles High Street, and then subsequently reducing levels on the area to the east of the Northern Line Escalator Box to +124.0m.

13 STANDARDS AND CODES OF PRACTICE TO BE USED IN THE DESIGN (LUL_11)

13.1 Design Standards

13.1.1 The detailed design of each element, sized to ensure that LUL assets are not adversely impacted, ~~will be~~ has been undertaken according to the relevant Eurocodes listed in table 13.1.1. The design ~~will be~~ is in accordance with the Construction (Design & Management Regulations) 2015.

Element	Design codes	Anticipated methodology
General	BSEN 1990:2004 BSEN 1991:2009	Basis of structural design. Actions on structures.
Basement wall	BSEN 1997-1 BSEN 1992	Identification of internal stresses and allowable ground movements from finite element analysis or retaining wall design software.
Ground floor slab, Basement slab	BSEN 1997-1 BSEN 1992	Identification of temporary case prop requirements from finite element or retaining wall design software. Permanent works loads from structural load requirement and permanent heave loading from finite element analysis.
Heave restraint walls and slabs	BSEN 1997-1 BSEN 1992	Identification of internal stresses and allowable ground movements from finite element analysis.
~~Timber headings for adits~~	~~BS EN 1995 1-1~~	~~Outline design of timber member sizes to ensure buildability.~~
~~Tunnelled adit beams~~	~~BSEN 1997-1~~ ~~BSEN 1992~~	~~Permanent works beams, loads identified by finite element analysis and structural modelling.~~

Table 13.1.1: Design Standards used for Design of St Giles Circus.

13.1.2 In all cases the UK National Annex shall be used.

13.1.3 The design ~~will be~~ is in accordance with the LUL and Network Rail (NR) standards listed in table 13.1.2.

Author	Standard	Title	Purpose
Network Rail	NR/L2/TRK/001/CO1	Level 2 module inspection and maintenance of permanent way – geometry gauge and clearance	Check that Crossrail track geometry does not suffer undue movement or distortion.
LUL	LUL Standard 1-538	Category 1 Standard S1538 Assurance	Produce compliant design.
LUL	LUL Standard 1-050	Civil Engineering – Common Requirements	Produce compliant design.
LUL	LUL Standard 1-055	Category 1 Standard S1055 Civil Engineering – Deep Tube Tunnels and Shafts	Produce compliant design.

LUL	LUL Standard 1-156	Gauging and Clearances	Check that LUL track geometry does not suffer undue movement or distortion.
Crossrail		Crossrail Safeguarding Guide: Information for Developers	Produce compliant design.
Crossrail		Addendum to the Crossrail Safeguarding Guide: Information for Developers. Additional considerations for complex development close to Crossrail assets completed or under Construction	Produce compliant design.
Secretary of State for Transport		Agreement Relating to the Crossrail project and proposed works at Charing Cross Road London WC2	Produce compliant design.

Table 13.1.2: LUL and Crossrail standards used in the design.

14 SAFETY CONSIDERATIONS (LUL_12)

14.1 Key safety issues

14.1.1 The key safety issues that affect the London Underground infrastructure are:

- Ground movement of the Escalator Box causing the escalator to stop suddenly.
- Ground movement of the Northern Line platform tunnels causing the infringement of the kinematic envelope leading to possible train strike
- Ground movement of the Escalator Box, Northern Line platform tunnels, or Northern Line Lower Concourse tunnel causing cladding or other finishes to fall off the tunnel and injuring users/staff.
- Ground movement resulting in stress changes that overload the Escalator Box structure leading to collapse.
- Ground movement resulting in stress changes that overload the Northern Line platform tunnels leading to collapse.
- Ground movement resulting in stress changes that overload the Northern Line Lower Concourse tunnels leading to collapse.
- Construction activities that could overload the temporary road slab above the Escalator Box or the Escalator Box itself.
- Construction activities that could remove the permanent overburden above the Escalator Box.

14.1.2 The effect of ground movement on the London Underground infrastructure is considered in detail in section 15 where the magnitude of the predicted movement is identified, it's impact assessed, mitigation measures considered, monitoring requirements identified to confirm that the actual movement is as predicted and trigger levels proposed to enact an emergency response if movements are beyond those predicted.

14.1.3 Stress changes in the London Underground infrastructure are also considered in section 15.

14.1.4 The temporary road slab above the Escalator Box will remain in place during the enabling and demolition works before ultimately being removed during the permanent works. The slab has been designed to support combined HA and HB loading in accordance with BD37/0, however there are loading restrictions around openings that are identified on drawing HAG-N105-8742-STR-D-PLN-1-02005 (reference Health & Safety File Section 3 – Consolidated Developments, VBN-TCR-8742-HSF-000003). The above Health & Safety File and drawing have been provided to the demolition contractor and the specific loading restrictions requirements highlighted to the Contractor in the tender documents and on the drawings.

14.2 Operational Hazards

14.2.1 The following section considers the risk of ground movement resulting in disruption to train services due to track movement or impact on kinematic envelope. This hazard is mitigated by sequencing the demolition works to control the movements to significantly less than the limits. The hazard is controlled by real time monitoring of tunnel movements during demolition works and for a period after completion of the demolition works to give early warning as soon as any movements are larger than predicted. Should the movements be larger than predicted there is sufficient margin between the predicted movements and the acceptable movement limit for remedial measures to be undertaken. These remedial measures are identified in the Emergency Preparedness Plan.

14.2.2 Based on the LU standard on customer safety (5-534, A1) the risk of injury to the travelling public has been assessed as follows:

	Extremely likely	Very likely	Likely	Unlikely	Very Unlikely
Fatal	Very High	High	High	High	Medium
Severe	High	High	High	Medium	Medium
Major	High	High	Medium	Medium	Low
Serious	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Low	Low	Very Low

14.2.3 Extreme movement of the tunnel lining (many times beyond that predicted) could cause line-side equipment or station platforms to enter the kinetic envelope which a train could then strike leading to major injury. Extreme movement could also cause cladding or other finishes to fall onto users/staff.

14.2.4 The risk of damage to the tunnel or disruption to service has been ~~preliminary~~ assessed as follows:

	Extremely likely	Very likely	Likely	Unlikely	Very Unlikely
Collapse	Very High	High	High	High	Medium
Extended Closure	High	High	High	Medium	Medium
Major disruption	High	High	Medium	Medium	Low
Some disruption	High	Medium	Medium	Low	Low
Minor disruption	Medium	Medium	Low	Low	Very Low

14.2.5 Extreme movement of the tunnel lining (many times beyond that predicted) could cause speed restrictions and the need for adjustment of line-side equipment to be moved outside the kinematic envelope resulting in major disruption while adjustments are made during engineering hours. Extreme movement of the Escalator Box (many times beyond that predicted) could require the escalator to be taken out of use whilst adjustments are made. Major disruption to access to the Northern Line platforms would be caused by taking the escalators out of use.

14.3 Consideration of Railway Safety Principles and Guidance

14.3.1 The requirements of the Construction (Design and Management) Regulations 2015 have been addressed through the review of the demolition proposal. The ~~proposed~~ demolition sequence has been developed taking into account the need to minimise movements of the adjacent structures. A design interface Hazard Log and Risk Register is presented in Appendix L and ~~will be~~ has been maintained and updated as the design develops so that hazards are recorded and eliminated as far as reasonably practical.

14.4 Safety Critical Structures

14.4.1 The structures that interface with the London Underground infrastructure are routine and do not involve innovative design, structures or materials and do not provide direct support to any track, lift, escalator or moving walkway.

15 MOVEMENTS, CLEARANCES AND STRESSES IN SUB-SURFACE STRUCTURES (LUL_13)

15.1 Introduction to Zone 1 Analysis Results

15.1.1 The following sections summarise the stresses and movements that result from the demolition works in Zone 1 and are based on the Ground Movement Impact Assessment presented in Appendix P.

15.2 Northern Line Escalator Box Stresses

15.2.1 As discussed previously, the site will be re-graded and lowered by approximately one metre after demolition of existing buildings resulting in stress changes in the ground. The re-graded area is adjacent to the Northern Line Escalator Box (NLEB) as shown on Figure 15.1.1. The two sections shown on Figure 15.1.1 show that the box is heavily propped along the escalator and hence negligible change in stresses would occur in this structure. The existing road slab that currently caps the excavation over the NLEB will also be left in place.

15.2.2 ~~Preliminary~~ Modelling indicates changes in bending moment, shear force and axial force of less than 5% due to the demolition and re-grading works.

15.3 Northern Line Platform Tunnel Stresses

15.3.1 The Northern Line Platform is located deeper than the Escalator Box and is further from the re-grading works hence it is expected to experience negligible change in stress.

15.3.2 For both the northbound and southbound platform tunnels, ~~preliminary~~ modelling indicates changes in bending moment, shear force and axial force of less than 1.0% due to the demolition and re-grading works.

15.4 Northern Line Low Level Concourse Stresses

15.4.1 It is expected that due to the demolition and re-grading works, the Low Level Concourse tunnel will experience stress changes of a similar magnitude to those predicted for the NLEB.

15.5 Movements in Northern Line Escalator Box

15.5.1 It was assessed in section 15.2 that very negligible stress changes would occur in the structure due to site re-grading, hence movements will also be negligible. ~~Preliminary~~ Modelling confirms this, indicating movements of less than 1mm of the NLEB during demolition and re-grading.

15.6 Movements in Northern Line Platform Tunnel

15.6.1 It was assessed in section 15.3 that negligible stress changes would occur in the structure due to site re-grading hence movements will also be negligible. ~~Preliminary~~ Modelling confirms this, indicating movements of less than 0.5mm of both the southbound and northbound northern line platform tunnels.

15.7 Movements in Northern Line Low Level Concourse

15.7.1 It is expected that due to the demolition and re-grading works, the Low Level Concourse tunnel will experience movements of a similar magnitude to those predicted for the NLEB.

15.8 Escalator Movements

15.8.1 London Underground (William Lau, Lead Civil Engineer) advised on 26 November 2012 that escalators 7, 8 and 9 can 'tolerate movements of about 5mm'. The main concerns are twisting and differential movement.

15.8.2 The predicted movement of the NLEB during the enabling and demolition works is much less than this, therefore the risk of exceeding the movement limits is considered to be very low. In order to further mitigate this risk ~~it is proposed to install~~ an escalator box and escalator truss monitoring system is being installed to confirm that the movements during the enabling and demolition works are within predicted limits.

15.9 Minimum Gauge Clearance

15.9.1 Following meetings with London Underground in February and April 2014, it is understood that a kinetic envelope survey is planned for the Northern Line platform tunnels once the Crossrail works are complete, this will form a baseline for future works. In advance of this survey tunnel movements ~~will~~ have been assessed against limits that were defined in The Monitoring Implementation Plan for the Northern Line Works (VBN-TCR-8742-MIP-000001).

15.9.2 Section 4.4 of VBN-TCR-8742-MIP-000001 identifies that gauge clearances are currently substandard in the Northern Line Platform tunnels adjacent to Lift Shaft 4, close to the northern headwall and tail wall of both platforms. The ~~proposed~~ St Giles Circus demolition and enabling works are located adjacent to the centre of the Northern Line platforms, approximately 30m away from the areas of sub-standard gauge clearance noted above. The ~~preliminary~~ assessment is therefore based on the understanding that the platform tunnels adjacent to the site are outside the Kinetic Limit.

15.9.3 The ~~preliminary~~ analysis completed to date suggests that the movement of the Northern Line Platform tunnel will increase the clearance between the tunnel wall and the kinetic envelope so it is envisaged that the basement construction will not adversely affect the Minimum Gauge Clearance.

16 FUNCTIONAL REQUIREMENTS (LUL_14)

16.1 Purpose of the Demolition and Enabling Works

16.1.1 The works clear the site of the Zone 1 basement of existing buildings, basements, foundations and other buried obstructions in advance of the proposed permanent works.

16.1.2 In order that the secant bored pile wall may be installed around the perimeter of the basement, the lower ground floor of the existing buildings that are to remain on the south side of the Zone 1 basement will be protected with ~~an in-situ~~ a pre-cast concrete retaining wall that will support the backfill and the surcharge from the piling rig.

16.1.3 Where the existing buildings do not have a lower ground floor, the walls adjacent to the Zone 1 basement will be underpinned to reduce the risk of differential movement between the existing buildings.

16.1.4 Pile probing will be undertaken to ensure that there are no obstructions in the proposed pile locations for the permanent works.

17 MAINTENANCE REQUIREMENTS (LUL_15)

17.1.1 The demolition and enabling works do not require any special operational or maintenance requirements beyond routine maintenance of the monitoring equipment both within the LUL infrastructure and elsewhere on the site.

19 DESIGN CHECK CERTIFICATE FOR ENABLING WORKS (LUL_16)

19.1.1 ~~It is proposed that~~ A Category 1 check~~ing~~ of the Conceptual Design Statement has been ~~will be~~ undertaken for the enabling and demolition works.

20 MOVEMENT MONITORING PLAN

20.1 LUL Infrastructure

20.1.1 The ~~proposed~~ LUL Monitoring Plan is presented in Appendix M. As the enabling and demolition works ~~are proposed to~~ commenced in advance of the final submission for the permanent works, the Monitoring Plan has been designed to cover both the enabling and permanent works. The Monitoring plan ~~will be~~ has been updated to reflect the predicted movements of the NLEB and LUL tunnels as they are refined by the site investigation results and updated ground movement modelling.

20.1.2 Site Engineering Services Ltd (SES) have been appointed to undertake the monitoring within the LUL Infrastructure for the St Giles Circus project. ~~Based on the scope of the Monitoring Plan they are developing their detailed design and monitoring methodology.~~ Method Statements for installation of the monitoring ~~will then be~~ have been submitted to and approved by LUL.. ~~for approval~~.

20.1.3 It was originally proposed to install the monitoring in December 2014 in order to obtain baseline readings before demolition commenced in February 2015, this would also enable the monitoring to be installed in the NLEB prior to the ~~proposed~~ public opening of the NLEB on 12 January 2015. ~~Hard demolition has now been delayed to July 2015 and the completed monitoring installation has been delayed by power, data and installation co-ordination issues~~. In the event tiltmeter monitoring for the escalator trusses was commissioned in June 2015 with demolition commencing in August 2015. The commissioning of the prism monitoring required for the permanent works has been delayed due to problems with the installation of the power and data connection and is awaiting final resolution of problems with the BT phone line.

20.2 Crossrail Infrastructure

20.2.1 The ~~proposed~~ Crossrail Monitoring plan is presented in Appendix K. As the enabling and demolition works ~~are proposed to~~ commenced in advance of the final submission for the permanent works, the Monitoring Plan has been designed to cover both the enabling and permanent works. The Monitoring plan ~~will~~ has been updated to reflect the predicted movements of the tunnel as ~~they are~~ refined by the site investigation results and updated ground movement modelling.

20.3 Above Ground Infrastructure

20.3.1 In addition to the monitoring of the Crossrail and LUL infrastructure ~~it is proposed to monitor~~ the position of the existing buildings on the North and South side of Denmark Street is being monitored for movement associated with the basement construction. The scope of the ~~proposed~~ monitoring is also presented in Appendix M.

20.3.2 Site Engineering Services Ltd (SES) have also been appointed to undertake the above ground monitoring. This included ~~the~~ taking over ~~of~~ prisms, bracketry and cabling from LUL monitoring points C13, C14, C15 and C16 once they ~~are~~ were decommissioned by LUL and purchased by Consolidated Developments.

PERMANENT WORKS (SECTIONS 21 TO 33)

21 DESCRIPTION OF PROPOSED PERMANENT WORKS (LUL_7)

21.1 Zone 1 Building A:

21.1.1 Building A comprises a 7 storey steel framed structure that houses a mixed use development that could include retail, hotel, office and leisure facilities, see figure 21.1.1. Steel is used as the framing system to minimise the weight of the structure that is imposed on the transfer structures and the foundations. The floor structure is formed of composite metal deck slabs which act compositely with steel beams. A main feature of the building is the 4 storey high covered Urban Gallery on the Andrew Borde Street and Charing Cross Road sides of the building. Above the Urban Gallery is a 3 storey leisure facility that is supported on long span transfer trusses that transfer the gravity loads to a limited number of columns on the building's facade. On the Charing Cross Road facade these columns are supported by the existing Consolidated Piles.

21.1.2 Around the Urban Gallery a moveable facade is provided that enables the area to be screened off from the surrounding streets for certain events. This moveable facade is supported at the top by the structure of the leisure facility and restrained approximately 4m above ground level by a horizontal beam or transom that spans between the main facade columns. At the corner of Charing Cross Road and Andrew Borde Street a 'dummy column' is provided which is actually hung from the leisure facility above. This dummy column supports and restrains the corner of the moveable facade rail without imposing vertical foundation loads at its base. This is because the dummy column is located too close to the Escalator Box, Crossrail Tunnel and new Tottenham Court Road ticket hall to enable an independent foundation to be constructed.

21.1.3 To the south side of the Plaza is a 4 storey mixed use building which provides vertical circulation and stability to the leisure facility above. Stability is provided by the diaphragm action of the floor plates transferring horizontal loads back to the stability cores where concrete shear walls around the stairs, lifts and risers transfer the horizontal loads to the ground floor slab which is itself restrained by the retaining walls of the basement box.

21.1.4 The positions of the columns at ground floor have been co-ordinated with the below ground infrastructure to avoid the footprint of the Eastbound Crossrail tunnel and the exclusion zone around it identified in the Agreement between Consolidated Developments and the Secretary of State for Transport.

21.2 Zone 1 Building B:

21.2.1 Building B is a 5 storey mixed use building that is similar in form and construction to Building A, see figure 21.2.1. A single storey covered Plaza is formed at ground floor with two stories of office use and two stories of restaurant use above. Steel transfer structures span between the main supporting columns on the west and east sides of the building and also over the basement Events Gallery.

21.2.2 A top hung moveable facade runs along the Andrew Borde Street side of the building and is restrained by a transom approximately 4m above ground level. The transom spans between the superstructure columns.

21.2.3 Stability is provided by concrete shear walls around the lift core. The transfer trusses and superstructure columns on the west side of the Plaza also contribute to the stability system of the building. At ground floor level the horizontal loads are transferred by the ground floor slab to the basement retaining walls.

21.2.4 At the third floor level an interconnecting bridge is provided between buildings A and B, it is proposed that a movement joint is provided between the buildings to keep the stability systems separate and control differential movements.

21.2.5 The footprint of the building is clear of the Escalator box, however the Eastbound Crossrail tunnel runs diagonally across the building. Column positions at ground floor level have been planned to avoid landing on the Crossrail tunnels and exclusion zones as far as possible, however some columns land close to the exclusion zone and are transferred around it by the ~~adit beams~~ Crossrail heave retention slab at B1 level.

21.3 Zone 1 Building C:

21.3.1 The 4 storey building C provides office accommodation, with plant on the roof structure. The regular arrangement of the structure and spans of up to 8m allow for the use a concrete flat slab structure that minimises the depth of the structural zone and allows for the horizontal distribution of services. See figure 21.3.1.

21.3.2 Stability is provided by concrete shear walls that go to the ground floor where horizontal loads are transferred by the ground floor slab to the basement retaining walls.

21.3.3 Building C is outside the footprint of the NLEB and London Underground tunnels and is supported by piles.

21.4 Zone 1 Building D:

21.4.1 Building D is a 4 storey concrete framed structure that houses two stories of residential use and the building services plant that serves the majority of the project. A concrete flat slab structure spanning up to 7m between columns is utilised to provide the maximum clear height for the residences and the services and provide a robust structure with sufficient mass to provide acoustic separation between spaces. See figure 21.4.1.

21.4.2 The concrete structure also restrains the retained facade on St Giles High Street. Stability is provided by a combination of concrete shear walls around the lift shafts and a concrete shear wall that is shared with the adjacent building B. Closely spaced columns are provided behind the existing facade.

21.4.3 Building D is largely above the Crossrail tunnel and utilises a raft slab to distribute the superstructure loads over the Crossrail tunnel. As the superstructure loads are less than the weight of the overburden removed, a heave retention slab at B1 level and perimeter retaining walls are used to stiffen the basement structure and transfer the net heave forces back to the tension piles either side of the Crossrail tunnel.

21.5 Zone 1 Basement Box:

21.5.1 A new basement is proposed beneath buildings A, B, C and D which will form an Events Gallery, see figure 21.5.1. The central part of the Events Gallery is a column free space of approximately 18m x30m with the maximum clear height possible. A mezzanine is provided around the Events Gallery to accommodate bars and ancillary activities.

21.5.2 Either side of the Crossrail Tunnel exclusion zone the depth of the basement is increased to accommodate the plant rooms, lift pits and sprinkler tanks. These areas of deeper basement are clear of both Crossrail and the Escalator Box.

21.5.3 The footprint of the basement is constrained by the Escalator Box and Charing Cross Road to the West, Andrew Borde Street to the North, the retained facade on St Giles High Street to the East and retained (some listed) buildings to the South on Denmark Place.

21.5.4 As the Event Gallery is located directly above the Eastbound Crossrail tunnel the depth of the basement is constrained by the exclusion zone around the Tunnel as detailed in the Crossrail Information for Developers (February 2008) which puts a 6.0m clearance between the outside of the tunnel and the development above. The Crossrail Information for Developers also allows for an 'Alignment adjustment zone' of 3.0 m above and to the sides of the tunnel, however at the site location the tunnel is constrained by passing under the Escalator Box so its position is fixed at this location. As part of the Agreement between the Secretary of State for Transport and the Project Sponsor, it was agreed that the exclusion zone between the Crossrail tunnel and the oversite development could be reduced to a minimum of 1.0m at the Escalator Box, increasing to 3.0m where the centre of the tunnel alignment crosses the Eastern boundary of the site. Furthermore the drawings in the Agreement note that 'the exclusion zone shown on this drawing allows for the development of the Crossrail alignment to the East of the safeguarding tunnel. Subject to agreement with Crossrail, piling may be permitted in this zone once the alignment is fixed. However, no piles closer than 1.0m clear from outside of tunnel will be allowed, and no piles within the exclusion zone may be closer than the pile diameter from the tunnel.'

21.5.5 The design for the basement has therefore been progressed on the basis that no foundation structures will be allowed closer than 1.0m clear (including allowances for construction tolerances) from the outside of the tunnel, and that the basement structure should be 6m above the tunnel crown. After consideration of the construction method (see section 22) a minimum dimension of 2.0m between the outside of the pile and the outside of the tunnel is proposed. The minimum dimension allows for pile construction tolerances.

21.5.6 As a significant amount of the existing overburden above the Eastbound Crossrail tunnel will be removed by the basement excavation, a design for the basement structure has been developed that will restrain the ground movements, particularly heave, caused by the removal of the overburden. The design involves the installation of tension piles either side of the Eastbound Crossrail tunnel and the construction of a heave retention slab that spans between the tension piles at B1 level. ~~'adit' beams between the tension piles prior to the basement excavation above the tunnel~~. This system of ~~'adit' beams~~ heave retention slab and tension piles is designed to resist the heave forces generated by the basement excavation and therefore control the movements experienced by the Eastbound Crossrail tunnel. The principle was initially discussed with Crossrail in meetings in 2011 and was presented to them in the Conceptual Design Statement (029-S-REP-001 Revision 01, December 2012). Following review by Arup (original designers of the Crossrail tunnel) and construction methodology input from Skanska the adit beams were replaced with a heave retention slab at B1 level. This approach was presented to and accepted in principle by Crossrail in November 2015. ~~This Conceptual Design Statement updates the preliminary assessment of the heave retention system to the current design.~~

21.5.7 The basement structure above the Escalator Box is supported by the Consolidated Piles so that it does not rely on either the Escalator Box structure or the LUL secant piled wall that was used to enable construction of the escalator. A new basement retaining wall spans between the Consolidated Piles and supports the basement floor slabs.

21.5.8 There is no piling directly above the NLEB or the Northern Line platform tunnels, however the basement above the Northern Line Lower Concourse (NLLC) tunnel is proposed to be constructed within secant piled walls with a toe level no lower than +113.500m (see drawings Z1-S-031 and Z1-S-032 in Appendix N). The top of the extrados of the NLLC tunnel is at approx. +105.5m giving 8.0m clear between the pile toe and the tunnel. This exceeds the 6.0m exclusion zone identified in figure 1 of LUL Standard 1-050. Furthermore these secant piled walls are not designed to support vertical loads with all column and floor loads supported by the Consolidated piles and other piles shown on drawing Z1-S-031.

21.5.9 The basement and ground floor slabs prop the retaining walls across the footprint of the basement site to resist earth pressures and therefore control lateral movements of the retaining wall and the Escalator Box.

21.5.10 The depth of the basement over the Escalator Box is limited to +114m as part of the Agreement between the Secretary of State for Transport and the Developer. This Agreement also requires at least 2m of overburden to be maintained above the Escalator Box to control heave and uplift, therefore the footprint of the basement structure reduces from Lower Ground Floor Level to Basement Mezzanine Level to Main Basement Level to maintain this clearance.

21.5.11 Given the relative proximity of the Events Gallery to both Crossrail and the Northern Line, an acoustic assessment of the noise from the trains has been made and is included in Appendix F. This has resulted in the adoption of a 'box in box' structure around the Events Gallery.

21.5.12 The inner structure of the 'box in box' is formed by a braced steel framed structure that sits on acoustic isolation bearings at main basement level. The structure is separated from the surrounding concrete basement structures at all other levels.

21.6 Zone 2 Nos 22 and 23 Denmark Place

21.6.1 No 22 Denmark Place (at the rear of 26 Denmark Street) is a single storey masonry building with a timber framed roof. It is known as the 'Smithy' as it was formerly a forge. Although No 26 Denmark Street is grade II listed this building is not included within the description, but is considered to be locally significant by Camden. Part of the building sits above the Eastbound Crossrail tunnel. Constructing the basement around this building would create a discontinuity in the heave restraint system described above and also results in significant movements due to both the basement construction and the Crossrail tunnelling.

21.6.2 As a result it is proposed to extend the basement and heave protection system under No. 22 Denmark Place in order to maintain a consistent heave restraint system. In order to mitigate the effects of movement it is proposed to support the existing building on a concrete raft slab that will itself be ultimately supported on the piled basement structure. As access for piling within the building footprint is difficult it is proposed to temporarily move the Smithy during the piling works so that a consistent interface with the Crossrail Tunnel can be maintained across the basement footprint. Once the piling works are complete the Smithy will be returned to its original location and suppported by the piled foundations over the basement construction. Abbey Pynford have been engaged to develop the methodology for moving the Smithy and propose to cast a raft slab under the building and lift the building and raft slab together. ~~construct the tension piles for the adit beams within the footprint of the adjacent No 23 Denmark Place~~.

~~21.6.3~~ No 23 Denmark Place is a 3 storey former Victorian warehouse of masonry construction with timber floors. It is in poor condition, has experienced recent movement and would require extensive repair and underpinning to stabilise and protect it. After consultation with Camden Heritage officers and Historic England it is proposed to dismantle No 23 Denmark Place to facilitate the protection and temporary movement of No 22 Denmark Place. ~~By temporarily removing the first floor of No 23 and the cill below the window it is possible to gain access for a specialist piling rig to install the adit tension piles within No 23 Denmark Place. Adit~~

~~'transfer' beams are then constructed below No 22 and 23 Denmark Place to connect the tension piles to the Crossrail adit beams.~~

21.7 Zone 2 Nos. 21 to 25 Denmark Street:

21.7.1 These existing buildings are to be retained and refurbished as part of the development. The principle structural alterations are the addition of a new floor with a mansard roof. In order to minimise the change in foundation loads associated with the new floor it is proposed to replace the existing roof construction with a lightweight steel and timber floor construction and form the mansard roof out of similar lightweight construction.

21.7.2 The existing first floor structure at No. 21 Denmark Street will also be removed to improve access to the development from Denmark Street. Steel frames will be provided between ground and second floor at No. 21 to restrain the party walls and support the lightwell above.

21.8 Zone 3 No. 4 Flitcroft Street and No.1 Book Mews:

21.8.1 These existing buildings are to be refurbished as part of the development. The existing lower ground floor in 4 Flitcroft Street will be lowered to connect to a new basement below the existing yard and No. 1 Book Mews. Underpinning of existing party wall footings is proposed to form the perimeter retaining walls to the basement and a new basement slab supported on bored piles will be constructed between the retaining walls to support the internal column loads. Tension piles will be utilised to resist water pressure under the centre of the slab, and heave due to removal of the overburden.

21.8.2 Under and adjacent to 1 Book Mews the basement will be constructed within a secant piled wall adjacent to the existing boundary walls. In this area the basement will be two stories deep with internal tension piles to resist heave and water pressure.

21.8.3 The existing upper ground floor in 4 Flitcroft Street will be removed and reconstructed at street level to prop the top of the retaining wall and align with the level of adjacent properties.

21.8.4 The basement excavation to formation level is proposed to be approximately 5m below ground in 4 Flitcroft Street and 9m below ground in 1 Book Mews. The closest part of the basement to the Crossrail works is approximately 10m from the centreline of the Westbound running tunnel.

21.8.5 An acoustic assessment of noise and vibration from the Crossrail trains below this basement has been made and is included in Appendix F.

21.9 Zone 3 Nos. 6, 7, 9, 10 Denmark Street:

21.9.1 The structural refurbishment of these buildings is limited to change of use from commercial to residential, some internal modifications to create new openings in load bearing walls and replacement of the existing mansard roof at No. 10. As this refurbishment does not materially affect the existing loads supported by the foundations, no impact is anticipated on the London Underground infrastructure or the Crossrail tunnels.

21.10 Zone 3 No. 4 Denmark Street:

21.10.1 This existing buildings is to be retained and refurbished as part of the development. The principle structural alteration is the addition of a new floor with a mansard roof. In order to minimise the change in foundation loads associated with the new floor it is proposed to replace the existing roof construction with a lightweight steel and timber floor construction and form the mansard roof out of similar lightweight construction.

21.11 Nos. 126 to 136 Charing Cross Road, Nos. 18 to 20, 26 to 28 Denmark Street, No. 59 St Giles High Street:

21.11.1 No significant structural alterations are proposed to these buildings.

21.12 No 71 Endell Street

21.12.1 This existing buildings is to be retained and refurbished as part of the development. The existing roof structure is to be replaced and some internal alterations are proposed to load bearing walls.

22 PROPOSED METHOD OF CONSTRUCTION (LUL_7)

22.1 Zone 1 Main Basement above Eastbound Crossrail Tunnel

~~22.1.1~~ The following description outlines the ~~proposed~~ Construction Method Statement for the purposes of identifying the modelling strategy for the basement construction. ~~at this preliminary stage.~~

22.1.2 Since the preliminary issue of the CDS the basement construction methodology has been reviewed and developed by Skanska and is shown in more detail in Appendix J.

22.1.3 The interface with the NLEB structure has not changed significantly, the principle change to the basement construction methodology relates to the heave retention system for Crossrail Tunnel.

22.1.4 The overall construction sequence can be described as follows:

On Handover from demolition contractor:

Site is clear and level. All services and buildings have been removed.

The facade retention to St Giles High Street will be in place.

No. 22 Denmark Place (the Smithy) will have been relocated.

The reinforced concrete wall to the rear of Denmark Street will be in place.

Piling:

Install Piling Mat.

Site set up and installation of bentonite plant.

Construct guide wall.

Commence piling - retaining walls to south and east of NLEB constructed first, then other retaining walls, tension piles, plunge columns.

Pile testing actioned and completed.

Return No. 22 Denmark Place (the Smithy) to original position.

During pile installation commence basement construction over NLEB (refer to 029-Z1-SK174 in Appendix J):

Prop existing NLEB piled walls between capping beams below road slab.

Remove road slab.

Construct new capping beam on Charing Cross Road frontage, supported by Consolidated piles.

Construct new Ground Floor slab between capping beam on Charing Cross Road frontage and new retaining walls to south and east of NLEB.

Remove props between NLEB capping beams once new Ground Floor slab over NLEB has achieved design strength. At this point ground floor construction can commence to the east of NLEB.

Excavate between NLEB and new retaining walls to south and east of NLEB to Basement Mezzanine level (approximately coincidental with existing backfill level below NLEB).

Construct Basement Mezzanine slab and lining wall above NLEB. Fix to Consolidated piles.

Construct Lower Ground Floor slab and lining wall above NLEB. Fix to Consolidated piles.

Install Ground Floor Slab to the east of NLEB:

Install capping beams.

Cast Lower Ground walls / lift pits to link plunge columns.

Layout long span beams to plunge column or temporary support points.

Layout transfer structures for buildings over until excavation beneath allows final columns installed over Crossrail.

Connect to Smithy support structure.

Cast Ground Floor slab leaving mole holes.

Superstructure construction (detailed bottom) can commence at this point.

Excavate Basement to the east of NLEB: Note this may only commence once BM and LGF slabs and lining walls over NLEB have been completed.

Excavate top down through mole holes to Basement Mezzanine level.

Construct Basement Mezzanine floor slab as permanent whaling/ring beam to prop retaining wall.

Link Basement Mezzanine slab above NLEB to remaining slab at this level.

Complete ring beam at Basement Mezzanine level with insertion of steel struts to north side of excavation.

Excavate top down through mole holes to Basement B1 level. Note this includes the B1 basement above the NLEB

Construct Basement B1 floor slab as permanent propping to retaining wall.

Install reinforced concrete walls and Lower Ground Floor slab as access becomes available.

Excavate top down through mole holes to Basement B2 level.

Construct Basement B2 floor slab as permanent propping to retaining wall.

Complete basement lining walls, core walls and slab at lower ground floor.

Remove temporary plunge columns and temporary props.

Superstructure construction (can commence once ground floor complete):

Building A Superstructure:

Cast Cores Building A

Install steel structure to floor plates and rentrant steel deck up to level 4 on south of building fixing back to core.

Cast floors.

Install trusses all round on temporary supports at 4th floor level.

Insall longspan steel structure to remaining floor plates and rentrant steel deck to top floors of building.

Cast floors.

Install steel structure to roof level bar.

Building B Superstructure:

Cast Cores Building B

Install first floor truss on Grid B2. Found on central temporary support point.

Install truss to west facade. Found on temporary support point to south.

Install longspan steel structure to floor plates and rentrant steel deck.

Cast floors, connect to retained facade as construction progresses.

Continue to roof level.

Install steel structure to roof level bar and steel portal frame to roof behind St Giles High Street.

Building D Superstructure:

Cast reinforced concrete walls and columns then construct reinforced concrete floor above.

Repeat until top floor is reached.

Connect to retained facade as construction progresses.

Install large containerised plant units.

Install steel portal frame structure to roof.

Once the superstructure for Buildings B and D is complete and connected to the retained façade the temporary façade retention to St Giles High Street may be removed.

Building C Superstructure

Cast reinforced concrete walls and columns then construct reinforced concrete floor above.

Repeat until top floor is reached.

Install large containerised plant units.

Install acoustic wall to open plant enclosure.

~~22.1.5 The fundamental principle of the basement construction method is that the tension piles and adit beams of the heave retention system must be installed prior to any bulk excavation above the Eastbound Crossrail Tunnel. The method statement will be further developed with involvement from Skanska at the detailed design stage before a final submission is made.~~

~~22.1.6 Primary Sequence~~

~~**On Handover:**~~
~~Site is clear and level. All services and buildings have been removed.~~

~~The facade retention to St Giles High Street will be in place.~~
~~The facade of 3 to 6 Denmark Place will have been relocated.~~
~~The reinforced concrete protection box to the Smithy and protection wall to the rear of Denmark Street will be in place.~~

~~**Piling:**~~
~~Install Piling Mat.~~
~~Site set up and installation of bentonite plant.~~
~~Construct guide wall.~~
~~Commence piling – retaining walls, tension piles. Crossrail tension piles cast to ground level to maintain overburden over Crossrail during basement construction until adits installed/~~
~~Commence piling – plunge columns.~~
~~Commence piling - restricted access piling behind Smithy.~~
~~Pile testing actioned and completed.~~

~~**Install basement over NLEB (refer to drawings Z1-S-206, Z1-S-805 and Z1-S-806 in Appendix N):**~~
~~Cut new access in to void above NLEB at southern end.~~
~~Install formwork in void for Lower Ground slab.~~
~~Install Lower Ground slab - fix through eastern pile wall with stub beams for later connection. Leave mole hole to Basement Mezz.~~
~~Install walls around Lower Ground basement. Fix to Consolidated piles.~~
~~Excavate to Basement Mezz level, continue sequence down to Basement Level.~~

~~**Install Ground Floor Slab:**~~
~~Cast Lower Ground walls / lift pits to link plunge columns.~~
~~Install capping beams.~~
~~Layout long span beams to plunge column or temporary support points.~~
~~Layout transfer structures for buildings over until excavation beneath allows final columns installed over Crossrail.~~
~~Connect to Smithy support structure.~~
~~Cast Ground Floor slab leaving mole holes.~~
~~Leave joint with NLEB to allow jacking between NLEB and Ground Slab to alleviate NLEB movement / concrete shrinkage.~~

~~**Superstructure construction (detailed bottom) can commence at this point.**~~
-
~~**Excavate North and South Basements:**~~
~~Excavate top down through mole holes.~~
~~Install floor slabs as permanent props as excavation progresses.~~
~~Install reinforced concrete walls as excavation progresses.~~
~~Leave Jacking Strip between slabs to allow jacking between NLEB and Ground Slab to alleviate NLEB movement / concrete shrinkage.~~

~~Connect through to NLEB basement slabs as excavation progresses.~~
~~Cast B1 slab leaving mole holes for B2 excavation.~~
~~Cut down piles not used temporary support as excavation progresses.~~
~~Excavate to B2 and install B2 slab.~~
~~Install permanent columns through basement where possible.~~

~~**Excavate and Cast Adit Beams**~~
~~Install "Picture Frame" to transfer loads around adit beam.~~
~~Breakthrough piled wall local to adit beams.~~
~~Excavate between basements using timber headers.~~
~~Concrete base of adit as excavation progresses.~~
~~Install reinforcement cage to adit.~~
~~Cast concrete for adit beams.~~
~~Install lining wall to B2 basement acting as deep beam to link tension piles and adit beams.~~

~~**Excavate Central Basement**~~
~~Excavate central basement through mole holes.~~
~~Break down piles not used for support.~~

~~Install slab over Crossrail tunnel fixing to adit beams.~~
~~Install final permanent columns over Crossrail tunnel.~~
~~Break down final temporary piles used as support.~~
~~Install lining walls to basement all round.~~

~~**Buildings above ground can commence construction as excavation progresses beneath.**~~

~~**Cast Cores Buildings A B C D**~~
~~Building off plunge columns progress lift cores and shear walls.~~

~~**Building D Superstructure**~~
~~Cast reinforced columns and slabs fixing to lift cores and shear walls to plant room slab level.~~
~~Connect to retained facade as construction progresses.~~
~~Install large containerised plant units.~~
~~Install steel portal frame structure to roof.~~

~~**Building C Superstructure**~~
~~Cast reinforced columns and slabs fixing to lift cores and shear walls to roof level.~~
~~Install large containerised plant units.~~
~~Install acoustic wall to open plant enclosure.~~

~~**Building B Superstructure**~~
~~Install ground floor truss on Grid B2. Found on central temporary support point.~~
~~Install truss to west facade. Found on temporary support point to south.~~
~~Insall longspan steel structure to floor plates and rentrant steel deck.~~
~~Cast floors, connect to retained facade as construction progresses.~~
~~Continue to roof level.~~
~~Install steel structure to roof level bar and steel portal frame to roof behind St Giles High Street.~~

~~**Building A Superstructure**~~
~~Install longspan steel structure to floor plates and rentrant steel deck to south of building fixing back to core.~~
~~Cast floors.~~
~~Install crash deck over road.~~
~~Install trusses all round on temporary supports at 4th floor level.~~
~~Insall longspan steel structure to floor plates and rentrant steel deck to top floors of building.~~
~~Cast floors.~~
~~Install steel structure to roof level bar.~~
~~After closure of D4 diversion and return of Andrew Borde Street Frontage, install North West corner windpost and transom.~~

23 ALTERNATIVE OPTIONS (LUL_8)

23.1 Building over NLEB

23.1.1 During the stage 3 design process alternative construction methods for building the basement over and alongside the NLEB have been considered.

Parameter	Options considered	Risk	Recommendation
Timing of basement construction over NLEB	Before main basement excavation. During main basement excavation. After main basement excavation	Early substructure works requires mobilisation of sub-contractor in advance of main excavation. Can assess heave due to excavation above NLEB in advance of main excavation. Requires interface with LUL temporary works secant wall. Quicker construction method and easier site access. Likely to result in heave and horizontal movements occurring at same time. Does not take benefit of stiffer permanent structure above NLEB Prolongs programme and delays installation of superstructure, does not take benefit of stiffer permanent structure above NLEB and temporary structure around Crossrail tunnels.	Construct basement above NLEB before main basement excavation so that vertical and horizontal movements of NLEB can be linked to specific construction activities, advantage is taken of stiffer permanent structure above NLEB and temporary structure around Crossrail tunnels to reduce lateral movements, programme effects mitigated by undertaking main basement piling during construction over NLEB.
Basement excavation method	Top down Bottom up	Top down construction utilises the existing NLEB road slab as a temporary prop during excavation and reduces movement and cost associated with temporary propping. Relatively small size of basement gives constrained working zone. Bottom up construction requires open excavation over the basement footprint, requires significant temporary propping to control movements and is likely to result in increased overall movements due to load transfer between the props and the permanent structure.	Top down is preferred as the ground floor slab will improve access to an otherwise constrained site and reduce ground movements due to earlier and stiffer propping of retaining walls. It will also reduce short term heave associated with removal of the overburden as the floor slabs will be constructed earlier.
Interface between basement slab and fill above NLEB	Provide heave protection layer	Heave protection layer will isolate new basement structure from permanent fill above NLEB, limiting load transfer to a defined limit. Increased heave of NLEB is	Following a study of heave resulting from the construction of the basement above the NLEB (see section 28.2) it is recommended that the basement slab is cast against

	Cast slab against blinding on fill.	likely. Casting base slab of basement against fill will enable earth pressure resulting from heave to be partially resisted by the self-weight of the new basement above reducing overall movement of the NLEB. The basement structure will still be designed to be entirely suspended from the Consolidated Piles.	the fill above the NLEB to reduce the movement experienced by the NLEB. The 950mm thick basement slab is designed to both resist the heave and uplift pressures and also to act as a suspended slab supporting the gravity loads above. In the event that the building is demolished the lowest level of basement slab would need to be left in place and the basement backfilled to the existing level.

24 DESIGN CRITERIA (LUL_9)

24.1 London Underground Infrastructure

24.1.1 The design criteria for the London Underground Infrastructure are the same as for the Enabling Works identified above. The cumulative effect of the demolition and permanent works must not exceed these criteria.

24.2 Proposed Development

24.2.1 The structural loading criteria for the proposed development are summarised on the loading drawings presented in Appendix N. These loads are based on the Eurocodes listed in table 13.1.1 with enhancements where required by the client. All safety factors used in the design are based on the codes in table 13.1.1.

24.2.2 The proposed basement development will be provided with 120mins fire resistance (REI), this will be achieved by providing sufficient cover to the concrete structures and either sprayed, intumescent or fire boarded protection to the steel structures. Full details of the structural design criteria for Zone 1 basement and superstructure are provided in the Zone 1 Structural Design Criteria report 029-S-Z1-REP-006 which can be provided for information to London Underground if required.

24.3 Material Properties

24.3.1 The concrete grades used for design are listed in below:

Concrete Grade:
Grade C32/40 (f_{ck} = 32 N/mm2) For all vertical elements including columns, walls, piles

Grade C32/40 (f_{ck} = 32 N/mm2) All horizontal elements, including floor slabs,
~~adit beam~~ and heave retention slabs

Concrete Material Properties:
Material Property Grade C32/40
Young's Modulus, E = 33.35 kN/mm^2
Poisson's Ratio, v = 0.2
Co-efficient of thermal expansion, 1.0 x 10^{-5} per ^oK
Shear Modulus, G = 13.9 kN/mm^2
Concrete in contact with the ground is to have sulphate design class DS-3

24.4 Collision Loads

24.4.1 The proposed basement works are sufficiently far away from the platform tunnel that train collision loads do not need to be considered.

24.4.2 The loading limit on the existing road slab over the NLEB has been included in the tender documents for the Main Contractor along with the Health & Safety File produced by LUL at handover of the site so that the slab does not become overloaded during the works.

24.4.3 The sub and superstructure has been designed against progressive collapse so that the loss of an element (e.g. a column through vehicle strike) will not cause collapse of the building.

25 METHOD OF STRUCTURAL ANALYSIS (LUL_10)

25.1 Zone 1 Analysis Method

25.1.1 Finite element analysis ~~is to~~ has been undertaken to assess the impact of the construction on the LUL assets in the vicinity of the site. ~~It is proposed that~~ Four plane strain (2D) sections ~~will be~~ have been analysed using Plaxis in order that the complex geometrical interaction between the LUL assets and the new basement is sufficiently well modelled. Figure 25.1.1 presents the location of these sections in plan and Figure 25.1.2 presents the section cuts relative to the NLEB. One key objective of the modelling is to allow a construction sequence to be developed which does not adversely affect LUL assets; this is presented in more detail in table 25.1.1 Another key objective of the modelling is to obtain a sufficient understanding of ground movements so that reasonable trigger values can be adopted for monitoring purposes. ~~Preliminary~~ Results from the analysis are presented in Appendix P.

Section	***Assets Modelled***	***Objectives of Modelling***
1	• *NLEB along full length.* • *Northern Line Lower Concourse tunnel.*	• *Predict additional movements along length of NLEB allowing comparison to be made with Sections 2 to 4.* • *Predict movements along lower concourse tunnel and identify whether differential settlement is acceptable.*
2	• *NLEB (through single storey new basement)* • *Northern Line platform tunnels*	• *Predict additional stress in secant pile box and assess whether acceptable.* • *Predict additional stress in NLEB and assess whether acceptable.* • *Predict additional stress in Northern Line platform tunnel lining and assess whether acceptable; including effects of any squatting or elongation.* • *Predict movements along length of escalator box and assess whether differential settlement along escalators is acceptable.* • *Predict movements along length of escalator box and assess whether any twist occurs and if is acceptable.* • *Predict movements along Northern Line platform tunnel and identify whether differential settlement is acceptable.* • *Use predicted movements to derive trigger levels for monitoring.*
3	• *NLEB (through two storey new basement)* • *Northern Line platform tunnels*	
4	• *NLEB (through three storey new basement)* • *Northern Line platform tunnels*	

Table 25.1.1: LUL assets ~~to be~~ modelled and objectives of modelling

25.1.2 The following assumptions have been made with regards the modelling:

- The effects of the enabling works (archaeological dig and surcharge storage) do not influence any LUL assets and hence ~~will~~ have not be included within the analysis.
- The existing LUL infrastructure has been wished into place i.e. the effects of its construction are not explicitly modelled; however, periods of consolidation are modelled to allow heave to develop due to the reduction in total stress caused by installing the box. A period of 3 years post construction of the NLEB (and prior to any demolition works on the St Giles Site) has been modelled to assess the amount of movement that will take place prior to demolition on the St Giles site. A separate period of 120 years post construction of NLEB (no St Giles basement works) has been used to identify NLEB-only movements and modelling loads which would develop in the long term if the proposed St Giles basement were not constructed.
- The short term results (presented in sections 28.3 and 28.4) are for movements immediately post St Giles basement construction.
- The long term results (presented in sections 28.3 and 28.4) are for movements 120 years after St Giles basement construction
- Consolidation following construction of the new basement ~~will be~~ has been modelled in order to develop a schedule of monitoring for during and after the works.
- The NLEB is built into the ticket hall box with reinforcement tying the structures together. The NLEB butts against the Northern Line Lower Concourse tunnel with a movement joint between them. The NLEB will in effect act as a concrete beam that spans between the ticket hall and Low Level Concourse. For section 1 it is assumed that the Northern Line Lower Concourse tunnel provides a pinned point at the south of the NLEB.

25.1.3 Those soil parameters for the modelling required for the Mohr Coulomb models are summarised in Section 8.1. A hardening small strain soil model ~~will be~~ has been adopted for the London Clay and Lambeth Group that allows the effects of small strain and unloading/reloading behaviour to be modelled. Soil parameters ~~will be further developed~~ for these models ~~from~~ were validated against the results of the additional site investigation ~~to be~~ undertaken (see Section 8.5) and will be reviewed once the results of PB3 become available.

25.1.4 In both the short and long term a porewater profile hydrostatic from 121.0mATD ~~will~~ has been used for modelling. It is considered that this is slightly conservative; however, monitoring data from the STATS and Crossrail site investigations suggests that at critical ground levels for the models (i.e. to B2 level) an under-drained porewater profile is not fully developed and limited benefit would therefore be seen from adopting an under-drained profile.

25.1.5 An assessment of the structural capacity of the NLEB structure before, during and after the St Giles Circus basement construction using Rankin earth pressures is presented in Appendix Q.

25.2 Zone 2 Analysis Method

25.2.1 The refurbishment works in Zone 2 (described above) are minor in nature, will not significantly alter the loadings on either the structures or the foundations and are away from the LUL infrastructure, therefore it is not proposed to undertake any detailed analysis of the effect of the refurbishment on the LUL infrastructure.

25.3 Zone 3 Analysis Method

25.3.1 A hand calculation has been undertaken to assess the effect of deepening and extending the basement at 4 Flitcroft Street, close to the Crossrail westbound running tunnel (see figures 25.3.1 and 25.3.2). The change of stress at tunnel crown level was calculated (with reference to Newmark, 1942) beneath the corner of the basement closest to the Crossrail tunnel (approx. 8m away). These works are approximately 40m away from the nearest LUL asset.

26 STANDARDS AND CODES OF PRACTICE TO BE USED IN THE DESIGN (LUL_11)

26.1 Design Standards

26.1.1 The same Design Standards and codes of practice are used for the Permanent Works as were used for the Enabling Works, refer to the earlier section in the Enabling Works part of the CDS for details.

27 SAFETY CONSIDERATIONS (LUL_12)

27.1 Key safety issues

27.1.1 The key safety issues that affect the London Underground infrastructure are:

- Ground movement of the Escalator Box causing the escalator to stop suddenly.
- Ground movement of the Northern Line platform tunnels causing the infringement of the kinematic envelope leading to possible train strike
- Ground movement of the Escalator Box, Northern Line platform tunnels, or Northern Line Lower Concourse tunnel causing cladding or other finishes to fall off the tunnel and injuring users/staff.
- Ground movement resulting in stress changes that overload the Escalator Box structure leading to collapse.
- Ground movement resulting in stress changes that overload the Northern Line platform tunnels leading to collapse.
- Ground movement resulting in stress changes that overload the Northern Line Lower Concourse tunnels leading to collapse.
- Construction activities that could overload the temporary road slab above the Escalator Box or the Escalator Box itself.
- Construction activities that could remove the permanent overburden above the Escalator Box.

27.1.2 The effect of ground movement on the London Underground infrastructure is considered in detail in section 28 where the magnitude of the predicted movement is identified, it's impact assessed, mitigation measures considered, monitoring requirements identified to confirm that the actual movement is as predicted and trigger levels proposed to enact an emergency response if movements are beyond those predicted.

27.1.3 Stress changes in the London Underground infrastructure are also considered in section 28.

27.1.4 The temporary road slab above the Escalator Box will remain in place during a significant part of the construction works before ultimately being demolished and replaced with the permanent ground floor slab. The slab has been designed to support combined HA and HB loading in accordance with BD37/0, however there are loading restrictions around openings that are identified on drawing HAG-N105-8742-STR-D-PLN-1-02005 (reference Health & Safety File Section 3 – Consolidated Developments, VBN-TCR-8742-HSF-000003). The above Health & Safety File and drawing ~~will~~ have been provided to the principal contractor and the specific loading restrictions requirements highlighted to the Contractor in the tender documents and on the drawings.

27.1.5 In order to prevent overload of the Escalator Box structure during the construction ~~it is proposed to limit~~ any construction load that could be applied to the overburden above the escalator box has been limited to 50kPa as measured at the top of the Escalator Box plus the weight of temporary overburden that has been removed during the construction. The maximum extent of temporary overburden installed is shown on drawing VBN-TCR-8742-SKC-000273 Rev 01 (see figure 27.1.1). Overburden below the 'Marker Layer (Orange Netlon Fencing)' shown on this drawing is permanent and may not be removed. Note that the design of the Escalator Box slab allowed for the void above the box to be backfilled up to the underside of the road slab, therefore the allowance above is significantly less than the design capacity of the roof slab to the Escalator Box.

27.2 Operational Hazards

27.2.1 The following section considers the risk of ground movement resulting in disruption to train services due to track movement or impact on kinematic envelope. This hazard is mitigated by designing the structure to control the movements to significantly less than the limits. The hazard is controlled by real time monitoring of tunnel movements during construction of the basement and for a period after completion of the structural works to give early warning as soon as any movements are larger than predicted. Should the movements be larger than predicted there is sufficient margin between the predicted movements and the acceptable movement limit for remedial measures to be undertaken. These remedial measures are identified in the Emergency Preparedness Plan.

27.2.2 Based on the LU standard on customer safety (5-534, A1) the risk of injury to the travelling public has been assessed as follows:

	Extremely likely	Very likely	Likely	Unlikely	Very Unlikely
Fatal	Very High	High	High	High	Medium
Severe	High	High	High	Medium	Medium
Major	High	High	Medium	Medium	Low
Serious	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Low	Low	Very Low

27.2.3 Extreme movement of the tunnel lining (several times beyond that predicted) could cause line-side equipment or station platforms to enter the kinetic envelope which a train could then strike leading to major injury. Extreme movement could also cause cladding or other finishes to fall onto users/staff.

27.2.4 The risk of damage to the tunnel or disruption to service has been assessed as follows:

	Extremely likely	Very likely	Likely	Unlikely	Very Unlikely
Collapse	Very High	High	High	High	Medium
Extended Closure	High	High	High	Medium	Medium
Major disruption	High	High	Medium	Medium	Low
Some	High	Medium	Medium	Low	Low

disruption					
Minor disruption	Medium	Medium	Low	Low	Very Low

27.2.5 Extreme movement of the tunnel lining (several times beyond that predicted) could cause speed restrictions and the need for adjustment of line-side equipment to be moved outside the kinematic envelope resulting in major disruption while adjustments are made during engineering hours. Extreme movement of the Escalator Box (beyond that predicted) could require the escalator to be taken out of use whilst adjustments are made. Major disruption to access to the Northern Line platforms would be caused by taking the escalators out of use.

27.3 Consideration of Railway Safety Principles and Guidance

27.3.1 The requirements of the Construction (Design and Management) Regulations 2015 have been addressed through the review of the design proposal and the consideration of alternative methods of construction. The buildability of the proposed basement box has been reviewed within the Consultant team and with specialist contractors such as Bauer, Balfour Beatty Ground Engineering, Keltbray, Martello Piling, Joseph Gallagher, Cementation and Skanska. The ~~proposed~~ construction sequence has been developed taking into account the need to minimise movements of the adjacent structures. A design interface Hazard Log and Risk Register is presented in Appendix L and ~~will be~~ has been maintained and updated as the design develops so that hazards are recorded and eliminated as far as reasonably practical.

27.4 Safety Critical Structures

27.4.1 The structures that interface with the London Underground infrastructure are routine and do not involve innovative design, structures or materials and do not provide direct support to any track, lift, escalator or moving walkway.

28 MOVEMENTS, CLEARANCES AND STRESSES IN SUB-SURFACE STRUCTURES (LUL_13)

28.1 NLEB 2D modelling results

28.1.1 ~~Initial~~ Analysis of movements of the NLEB have been made based on sections 1 - 4 in table 25.1.1. These fully replicated the construction methodology. The modelling of sections ~~will be~~ has been reviewed ~~when~~ to incorporate the results of the further SI ~~has been undertaken~~. The following sections present a summary of the results of the 2D Plaxis models that are presented in Appendix P. Whilst in section 1 a movement joint exists between the NLEB and the passenger concourse, this has not been modelled as the additional restraint to the basement from the adjacent secant piles and Consolidated piles has also been omitted. The assessment is conservative as it does not take account of the following:

- Crossrail ~~Adit~~ tension piles.
- Superstructure loads.
- Crosswalls and bending stiffness of basement slabs above NLEB.
- Consolidated piles.
- Loads from machinery etc. within NLEB.

28.1.2 The effect of these is considered below.

28.1.3 A simple bending deflection calculation based on the cross-section of the NLEB, simply supported restraints at either end, and a change in load equivalent to removing 4m of overburden over the whole length and width of the NLEB shows that the escalator box would deflect approximately 4mm over its 35m length (this in broad agreement with the model of Section 1). Therefore the bending stiffness of the box is likely to halve the deflections predicted by the 2D Plaxis model. In Appendix Q a more detailed assessment of the effect of ~~the final submission~~ the varying earth pressures at each modelling section of the NLEB ~~will be~~ has been modelled and applied to a structural model of the NLEB to give a more refined assessment of the movements that the structure will be subjected to during the basement construction.

~~28.1.4~~ The assessment does not take account of the restraining effect of the Crossrail tension piles either side of the Crossrail heave retention slab ~~adit beams. These temporary secant walls will prop the existing road slab and the new basement slabs above the NLEB against horizontal movements during excavation of the main basement.~~

28.1.5 The assessment does not take account of the self-weight of the superstructure above ground floor level. These loads are supported by the Consolidated piles and the new piles installed within the new basement and will reduce the predicted heave under the new basement and therefore will reduce the movement of the NLEB towards the new basement.

28.1.6 The 2D Plaxis model does not include the east-west internal and end retaining walls within the basement above the NLEB and does not take account of any continuity of the basement slabs between these walls. As a result the horizontal movements will be less than predicted.

~~28.1.7 These movement assessments will be developed further following the results of the Site Investigation, feedback from the stakeholder review of this Conceptual Design Statement and construction input from the selected Contractor. A final submission of the Conceptual Design Statement will then be made.~~

28.1.8 A conservative assessment of the structural capacity of the NLEB using Rankin Earth Pressures has also been made. The following key stages were considered: Existing Condition; Post Dig above NLEB (effectively reversing the backfilling operation to a level of 114mATD); Post Main Basement Dig Short Term; and Post Main Basement Dig Long Term.

28.1.9 It is noted that as the NLEB was not backfilled to existing ground level as originally intended the Existing Condition may be less heavily loaded than the original design intent.

28.1.10 As the concrete section and reinforcement detailing of the NLEB varies with depth, five different 2D sections have been taken through the NLEB structure to model and identify the most critical conditions, these are labelled sections A to E and are identified in Appendix Q, also see figure 28.1.1.

28.1.11 Sections A to D are taken perpendicular to the top slab of the NLEB as this is the shortest and therefore stiffest span of the structure. Section E is taken vertically where the top slab is horizontal as this results in the longest span of the wall and is therefore critical for the wall design.

28.1.12 As per the 'Tottenham Court Road Station Upgrade Design Statement - Structures' report the secant piled wall is considered as permanent works that resists earth pressures (and surcharge loads) with the NLEB concrete structure resisting water pressure. The top and bottom slabs of the NLEB also prop the piled wall. In the Existing and Post NLEB Dig conditions the piles are continuous and modelled as moment fixed at the prop locations, during basement construction the piles on the East side are broken down to the formation level of the St Giles Circus basement and are therefore modelled as pinned at the top prop.

28.2 Review of Heave Protection Layer above NLEB

28.2.1 The effect of installing a heave protection layer to isolate the new basement structure from the permanent fill above the NLEB was reviewed using a preliminary model similar to section 4 (table 25.1.1). The heave protection was modelled by leaving a small void between the slab and the permanent fill. The full construction sequence and long term consolidation were modelled in a model containing the heave protection layer and a model without it. It was observed within this model that the heave protection layer allowed increased movement of the box by approximately 10% here (movements are largely upwards). This reflects the fact that constructing the new basement unloads the NLEB resulting in upwards heave movements that add to the long term heave of the NLEB in isolation. If the new basement is in contact with the permanent fill it reduces the amount that the NLEB is unloaded and hence the amount of heave. A similar proportion is expected to be observed for the other sections.

28.3 Northern Line Escalator Box, Stress Assessment

28.3.1 Beam elements were included within the Plaxis model along the inside of the top slab and base slab (which were both modelled as a continuum) in order to obtain the change of stress within the NLEB. Table 28.3.1 shows the short term stresses in NLEB elements immediately after construction of the St Giles basement divided by the original stresses in the NLEB before St Giles basement construction. The assessed utilisation (axial and bending) of the NLEB top slab in the existing condition is 29.9% (source Appendix Q section D), therefore stresses at 179% of existing would result in a worst case utilisation of 53.5%. The assessed utilisation (axial and bending) of the NLEB bottom slab in the existing condition is 44.9% (source Appendix Q section C), therefore stresses at 151% of existing would result in a worst case utilisation of 67.8%.

28.3.2 Tables 28.3.2 shows the long term stresses in NLEB elements 120 years after construction of the St Giles basement divided by the original stresses in the NLEB before St Giles basement construction. Note stresses in NLEB 120 year post NLEB construction were lower than these original stresses, so the maximum was used.

28.3.3 Whilst these stresses may not reflect actual design stresses, as they are highly dependent on the modelling assumptions e.g. fixity, they can be compared with those predicted when constructing the NLEB only. As reinforcement drawings indicate top and bottom reinforcement is the same for each section, only the maximum absolute value has been used for comparison.

Quantity	Sect	Top Slab		Base Slab	
		Maximum	**Minimum**	**Maximum**	**Minimum**
Bending Moment kNm/m	2	76%	-31%	25%	-64%
	3	91%	-32%	6%	-96%
	4	169%	-47%	61%	-151%
Axial Force kN/m	2	22%	-74%	21%	-78%
	3	23%	-79%	6%	-84%
	4	40%	-179%	41%	-147%
Shear Force kN/m	2	74%	-87%	58%	-66%
	3	89%	-60%	105%	-26%
	4	166%	-37%	148%	-107%

Table 28.3.1: Stress due to Basement Construction as a percentage of Stress in existing condition (Short Term – after basement construction) – Plaxis Model.

Quantity	Sect	Top Slab		Base Slab	
		Maximum	Minimum	Maximum	Minimum
Bending Moment kNm/m	2	28%	-13%	14%	-31%
	3	43%	-7%	1%	-38%
	4	98%	-45%	59%	-130%
Axial Force kN/m	2	11%	-25%	11%	-28%
	3	3%	-41%	-1%	-34%
	4	37%	-109%	42%	-124%
Shear Force kN/m	2	30%	-21%	30%	-16%
	3	37%	-14%	40%	-18%
	4	110%	-86%	96%	-135%

Table 28.3.2: Stress due to Basement Construction as a percentage of Stress in existing condition (Long Term) – Plaxis Model

28.3.4 The forces in general do not exceed the maximum experienced when constructing the NLEB alone. In all cases the maximae are experienced at the corners of the box, in which the model may not perfectly represent the real conditions. This is illustrated in figure 28.3.1 below. In practice, within the accuracy of the modelling, the forces are similar or less than the maximum experienced when constructing the NLEB alone.

28.3.5 The capacity of the NLEB structure has also been assessed using the Rankin Earth pressures applied to 2D finite element cross-sections of the NLEB at critical locations where the cross-section of the box changes or the loading conditions are most onerous. Out of balance earth and water pressures caused by the basement excavation are applied to a longitudinal section that assesses the bending in the NLEB.

28.3.6 Table 28.3.3 presents a summary of the bending stress results under Rankin earth pressures for the Existing Condition; after excavation to B1 level (Stage 5A); after completion of the basement structure in the short term (Stage 5B); and in the Long Term case when pore water pressures have equalised. Table 28.3.4 presents a summary of the shear check results under

Rankin earth pressures. More detailed results are presented in Appendix Q. The results show that based on a conservative assessment of the earth pressures (Rankin K_0), the proposed construction of the St Giles Circus basement does not overstress the existing NLEB box structure or the secant piled wall during either construction or long term usage.

28.3.7 In its current condition the most critical part of the NLEB structure under bending and axial load is the reinforcement to the inside of 750mm thick walls. These are assessed as being at a maximum of 80% utilisation (combination of bending and axial forces) currently and during demolition. The revised basement construction sequence no longer removes the overburden above the NLEB before lowering the water table and excavating on the east side of the NLEB, therefore there is less moment redistribution in the wall from hogging to sagging than under the previous construction sequence. The wall utilisation reduces to 73.6% in the long term.

28.3.8 The results from Appendix Q show that the most critical section under shear is the walls of Section E. This is significantly worse than Section D because the wall is much taller and is therefore subject to larger sagging moments and shears than the wall in Section D. In the long term case shear in wall E is assessed at 99.6% of capacity, compared to 91.9% in the existing condition. This is largely due to the increased water pressure that results from a rising water table above the NLEB and is less onerous than the 108.5% utilisation that would occur if the basement was not built and the NLEB was backfilled as originally envisaged.

28.3.9 It is also noted that if in the future the basement is demolished and the NLEB is backfilled to street level (+125m ATD) then there is a risk that the resulting increase in earth pressures could exceed the design shear capacity of both the base slab and the wall in section E. The concrete backfill that was placed immediately above the NLEB top slab will go some way to mitigate this risk.

28.3.10 The results of the Rankin earth pressure checks are considered to be conservative during and after basement construction, because no account has been made of the reduction in net horizontal earth pressures that would occur as the NLEB deflects (developing active pressures on the west side and passive pressures on the east side).

Section	Max Utilisation (bending stress)			
	Existing Condition	Stage 5A	Stage 5B	Long Term
A	0.279	Less onerous	Less onerous	0.354
B	0.328	Less onerous	Less onerous	0.340
C	0.450	Less onerous	Less onerous	0.582
D	0.378	Less onerous	Less onerous	0.446
E	0.799	0.805	Less onerous	0.736
Long section	NA	0.653	NA	0.785
Piles	0.750	Less onerous	Less onerous	Less onerous

Table 28.3.3: Stress due to Basement Construction (Long Term) – Rankin Earth Pressure Model.

Section	Max Utilisation (shear)			
	Existing Condition	Stage 5A	Long Term	Backfilled, no basement
750 thk wall	0.919	Less onerous	0.996	1.085
1100 thk top	Less onerous	Less onerous	0.370	0.602
1650 thk base	Less onerous	Less onerous	0.914	1.423
1100 thk base	Less onerous	Less onerous	0.796	NA
Long section	NA	0.053	0.109	Less onerous
Piles	Less onerous	Less onerous	0.995	Less onerous

Table 28.3.4: Shear checks – Rankin Earth Pressure Model.

28.4 Northern Line Escalator Box, Movement Assessment

28.4.1 Based on the 2D sections in the Plaxis model without longitudinal bending stiffness, the modelling suggests that the NLEB will move by the amounts summarised in table 28.4.1 in the long term.

U	Sect	Maximum (mm)	Minimum (mm)	Average (mm)	Differential
Top Slab	2	11.7	9.2	10.5	2.5
	3	8.4	7.0	7.7	1.5
	4	15.8	7.2	11.5	8.5
Base Slab	2	9.2	6.4	7.8	2.8
	3	7.2	5.9	6.5	1.3
	4	14.2	4.3	9.2	9.9

Table 28.4.1: Movements due to Basement Construction (Long Term)

Ux	Sect	Maximum (mm)	Minimum (mm)	Transverse differential across box	Maximum longitudinal differential between sections
Top Slab	2	4.8-8.4	4.1-7.7	-	-
	3	7.9-3.7	7.6-3.3	-	-
	4	5.4-6.2	4.7-5.6	-	-
Base Slab	2	7.2-3.8	6.8-3.5	0.4-0.3	1.5 – 4.0
	3	5.9-0.7	5.8-0.3	0.1-0.3	

Ux	Sect	Maximum (mm)	Minimum (mm)	Transverse differential across box	Maximum longitudinal differential between sections
					0.4 – 0.3
	4	-4.0-1.2	-4.1-0.9	0.1-0.3	

Table 28.4.2: Horizontal movements due to Basement Construction (Short-Long Term)

Uy	Sect	Maximum (mm)	Minimum (mm)	Transverse differential across box	Maximum longitudinal differential between sections
Top Slab	2	-1.8-8.2	-4.4- 5.0	-	-
	3	-0.8- -4.5	-4.9- -14.5	-	-
	4	1.3-7.7	0.6-6.0	-	-
Base Slab	2	-1.4- 8.4	-3.3-5.2	1.9- 3.2	2.5 – 4.5
	3	1.4-7.1	0.7-5.8	0.6-1.3	
	4	1.1-14.2	-4.8- -4.2	5.9-10.0	0.7 – 2.4

Table 28.4.3: Vertical movements due to Basement Construction (Short-Long Term)

28.4.2 In the absence of the basement, construction of the NLEB alone is predicted to result in up to 11mm vertical long term movement in section 2. The construction of the basement has little impact on the vertical movement, but does cause an increase in horizontal movement. In practice the vertical movement is likely to be significantly over predicted in the absence of the longitudinal bending stiffness of the box, to illustrate this, the movements of the box prior to the construction of the St Giles basement at each section location have been extracted from the model of Section 1 (Model 1) (see table 25.1.1) and compared with each transverse model (for Section 2, 3 and 4) at the same stage. Figures 28.4.1 and 28.4.2 show the vertical movements predicted by Model 1 in Appendix P.

Uy	Sect	Result from Model 1 (mm)	Maximum from each model (mm)
Top Slab	2	1.5	14.0
	3	1.7	9.7
	4	1.6	6.2

Table 28.4.4: Vertical movements of the NLEB after box construction

28.4.3 The horizontal movements in the above tables have been used to make a conservative assessment of the spring stiffness of the ground adjacent to the top and bottom slabs of the escalator box under lateral pressure. This has been input into the Rankin Earth pressure model of the longitudinal section of the escalator box (see Appendix Q) to both assess the longitudinal bending in the box (see table 28.3.2) and make a conservative prediction of the horizontal displacement of the box by combining the effects of ground movement and bending of the concrete box along its length. These predict a lateral movement of the base slab that supports the escalator of between 5.3mm distributed over the 35m length of the escalator box. This represents a very small differential movement along the length of the escalator. Figures 28.4.3 and 28.4.4 show the lateral movements predicted in Appendix Q.

28.5 Northern Line Platform Tunnel, Movement Assessment

28.5.1 The modelling of the various sections predict movements of the platform tunnel of up to 2.5mm, with no change in maximum and minimum bending moments or axial forces within the lining.

28.5.2 As the movements predicted within the southbound Northern Line platform tunnel are small (only just above the 2.0mm typical accuracy of manual survey prism monitoring) and the residual capacity of the cast iron tunnel ring is not near the limit (refer to assessment in Appendix P) it is proposed to reduce the movement monitoring scope to the Northern Line Platform tunnels to manual monitoring of the southbound platform only. The scope with include stick on targets on arrays at approximately 10m centres along the length of the tunnel in the zone of influence of the St Giles Circus basement, it is proposed that the arrays will include targets on the tunnel structure at 3 points. For further details refer to Appendix M. It is recommended that a condition survey is undertaken of the southbound platform tunnel before and after the completion of the basement permanent works.

28.5.3 It is not proposed to monitor or undertake a condition survey of the northbound platform tunnel as the predicted movements caused by the St Giles Circus development are less than 1.0mm.

28.5.4 The scope of the proposed condition survey is also shown in Appendix M.

28.6 Northern Line Low Level Concourse, Movement Assessment

28.6.1 The modelling of the long section suggests that the Northern Line Low Level Concourse will move by the amounts summarised in table 28.6.1 in the long term. These movements are accompanied by small stress changes.

	Maximum (mm)	Minimum (mm)	Average (mm)	Differential
Crown	2.5	0.0	1.3	2.5
Invert	0.7	0.0	0.4	0.7

Table 28.6.1: Movements due to Basement Construction (Long Term)

28.7 Escalator Movements, assessment

28.7.1 London Underground (William Lau, Lead Civil Engineer) advised on 26 November 2012 that escalators 7, 8 and 9 can 'tolerate movements of about 5mm'. The main concerns are twisting and differential movement.

28.7.2 Following completion of the further SI the total and differential movements along the escalator will be reviewed.

28.7.3 In order to ensure that the NLEB behaves within predicted limits ~~it is proposed to install~~ an escalator box and escalator truss monitoring system is being installed to confirm that the movements during the works are within predicted limits.

28.8 Minimum Gauge Clearance, ~~preliminary~~ assessment

28.8.1 ~~Following meetings with London Underground in February and April 2014, it is understood that a~~ A kinetic envelope survey ~~is planned~~ for the Northern Line platform tunnels was undertaken in late 2014 (reference UIP8742-SCA-TRK-N104-001-02 for the southbound tunnel; UIP8742-SCA-TRK-N106-001-02 for the northbound tunnel) ~~once the Crossrail works are complete, this will~~ these form a baseline for future works. The survey is shown in Appendix S.

~~28.8.2~~ At the south end of the southbound platform tunnel the clearance between the kinematic envelope and the tunnel wall is reduced to -14mm in two locations (N105/NSBLO/87.5 and N105/NSBLO/90.0). This is well within the 50mm limit before mandated action is required. ~~In advance of this survey tunnel movements will be assessed against limits that were defined in The Monitoring Implementation Plan for the Northern Line Works (VBN-TCR-8742-MIP-000001).~~

28.8.3 Similarly on the northbound platform tunnel the clearance between the kinematic envelope and the tunnel wall is reduced to upto -29mm in several locations between N105/NNBLO/25.0 and N105/NNBLO/52.5, although again this is well within the 50mm limit before mandated action is required.

28.8.4 For both north and southbound tunnels the clearance between the platform and the kinematic envelope is much tighter, with -49mm clearance on the northbound platform and -50mm clearance on the southbound platform.

~~28.8.5 Section 4.4 of VBN-TCR-8742-MIP-000001 identifies that gauge clearances are currently substandard in the Northern Line Platform tunnels adjacent to Lift Shaft 4, close to the northern headwall and tail wall or both platforms. The proposed St Giles Circus basement works are located adjacent to the centre of the Northern Line platforms, approximately 30m away from the areas of sub-standard gauge clearance noted above. The assessment is therefore based on the understanding that the platform tunnels adjacent to the site are outside the Kinetic Limit.~~

28.8.6 The movement analysis completed to date suggests that the movement of the Northern Line Platform tunnel will very slightly increase the clearance between the tunnel wall and the kinetic envelope; and between the platform and the kinematic envelope, so it is envisaged that the basement construction will not adversely affect the Minimum Gauge Clearance.

28.8.7 In view of the above it is proposed to set amber trigger levels at the lesser of predicted movement inwards plus 100% of monitoring accuracy or 50% of the kinematic limit if greater. Red trigger levels are proposed to be set at twice the predicted movement inwards or at the kinematic limit if greater. Black trigger levels are proposed to be set at the kinematic limit plus 10mm.

28.9 Zone 3 basement.

28.9.1 The basement at 4 Flitcroft Street is planned to be extended as per Figure 25.3.1. A conservative calculation (shown in Figure 25.3.2) was undertaken to assess the stress changes in the ground at westbound Crossrail tunnel crown level. It was found that the excavation of the basement would result in a change of ground stress of 7%. Hence stress changes in the westbound Crossrail tunnel to the side of the site are expected to be negligible.

28.9.2 As the LUL infrastructure (Northern Line) is more than 40m away from the Zone 3 basement it is not anticipated that the construction of the basement will significantly affect LUL infrastructure.

29 FUNCTIONAL REQUIREMENTS (LUL_14)

29.1 Purpose of the Works

29.1.1 The purpose of the works is to provide a new mixed use development on the site incorporating a large basement Events Gallery and a ground floor Urban Gallery. A full description of the use and serviceability requirements of the development can be found in the Zone 1 Stage 4 report which can be issued to LUL if required.

29.1.2 The development is designed to comply with the requirements of the Planning Act, Building Regulations and the CDM Regulations.

30 MAINTENANCE REQUIREMENTS (LUL_15)

30.1 Basement above Northern Line Escalator Box

30.1.1 The proposed St Giles Circus development does not require any ongoing maintenance requirement to the London Underground infrastructure below and to the side of the site.

30.1.2 The basement above the NLEB is structurally independent of the NLEB as it is supported by the Consolidated Piles. The design life of the structural works is 60 years. The basement is constructed in reinforced concrete with inherent durability requirements provided by the cover to the reinforcement and the classification of the concrete mix design. Beyond routine inspection and maintenance of the basement cavity drainage system no special maintenance requirements are envisaged.

30.1.3 In the event that the future demolition of the St Giles Circus structure is proposed, the basement slabs could be demolished and the basement backfilled with suitable fill material that replaces the overburden removed during the basement construction. Alternatively the Consolidated Piles and lowest level of suspended basement slab could be incorporated into a new basement structure. As the building is above and adjacent to London Underground infrastructure any proposals to significantly alter the structure and how it interfaces with London Underground will require planning and London Underground Infrastructure protection approval.

31 DESIGN CHECK CERTIFICATE (LUL_16)

31.1 LUL

31.1.1 ~~It is proposed that a~~ A Category 3 check will be undertaken following issue of this ~~preparation of the final submission of the~~ Conceptual Design Statement to LUL. A-Squared Studio have been appointed by the Developer to undertake the check.

32 MOVEMENT MONITORING PLAN

32.1 LUL Infrastructure

32.1.1 The ~~proposed~~ LUL Monitoring plan is presented in Appendix M. The Monitoring plan ~~will be updated in the final submission~~ has been updated to reflect the predicted movements of the NLEB and the London Underground tunnels as they are refined by the site investigation results and updated ground movement modelling.

32.1.2 Site Engineering Services Ltd (SES) have been appointed to undertake the monitoring within the LUL Infrastructure for the St Giles Circus project. ~~Based on the scope of the Monitoring Plan they are developing their detailed design and monitoring methodology.~~ Method Statements for installation of the monitoring ~~will then be~~ have been submitted to and approved by LUL..~~ for approval~~.

32.1.3 It was originally proposed to install the monitoring in December 2014 in order to obtain baseline readings before demolition commenced in February 2015, this would also enable the monitoring to be installed in the NLEB prior to the~~ proposed~~ public opening of the NLEB on 12 January 2015. ~~Hard demolition has now been delayed to July 2015 and the completed monitoring installation has been delayed by power, data and installation co-ordination issues~~. In the event tiltmeter monitoring for the escalator trusses was commissioned in June 2015 with demolition commencing in August 2015. The commissioning of the prism monitoring required for the permanent works has been delayed due to problems with the installation of the power and data connection and is awaiting final resolution of problems with the BT phone line.

32.2 Crossrail Infrastructure

32.2.1 The ~~proposed~~ Crossrail Monitoring plan is presented in Appendix K. The Monitoring plan ~~will be~~ has been updated ~~in the final submission~~ to reflect the predicted movements of the tunnel as ~~they are~~ refined by the site investigation results and updated ground movement modelling.

32.3 Above Ground Infrastructure

32.3.1 In addition to the monitoring of the Crossrail and LUL infrastructure ~~it is proposed to monitor~~ the position of the existing buildings on the North and South side of Denmark Street is being monitored for movement associated with the basement construction. The scope of the ~~proposed~~ monitoring is also presented in Appendix M.

32.3.2 Site Engineering Services Ltd (SES) have also been appointed to undertake the above ground monitoring. This included ~~the~~ taking over ~~of~~ prisms, bracketry and cabling from LUL monitoring points C13, C14, C15 and C16 once they ~~are~~ were decommissioned by LUL and purchased by Consolidated Developments.

33 MONITORING CLOSE-OUT REPORT

33.1 Completion of the Permanent Works

33.1.1 Upon completion of the Permanent Works a Monitoring Close out report will be prepared which will record the predicted movements during the Works and compare them against the actual movements recorded by the monitoring system. The report will record any instances where Amber trigger levels were exceeded and identify any corrective actions that were undertaken.

34 FIGURES

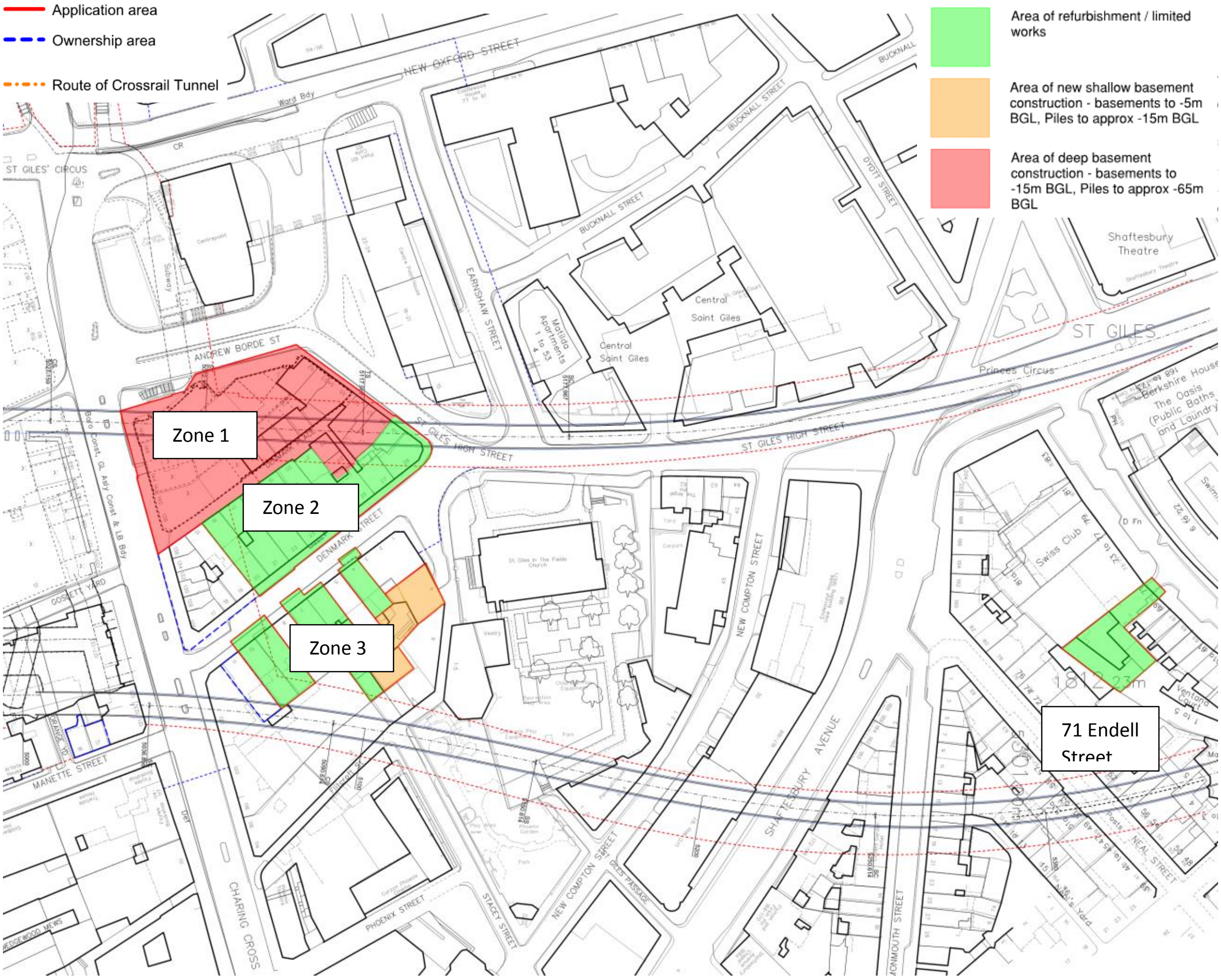


Figure 4.1.1: Site Plan

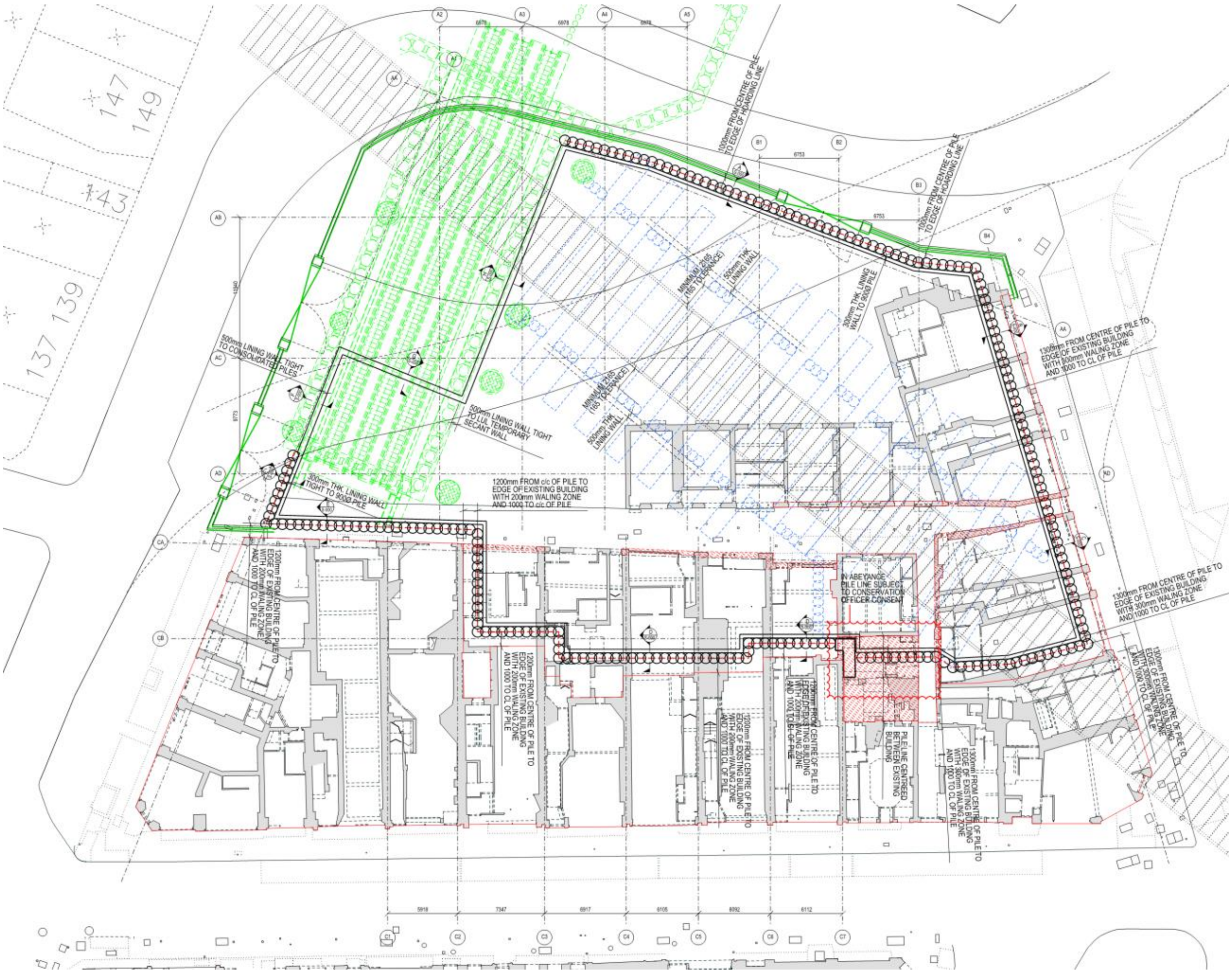


Figure 4.3.1: Extent of Basement

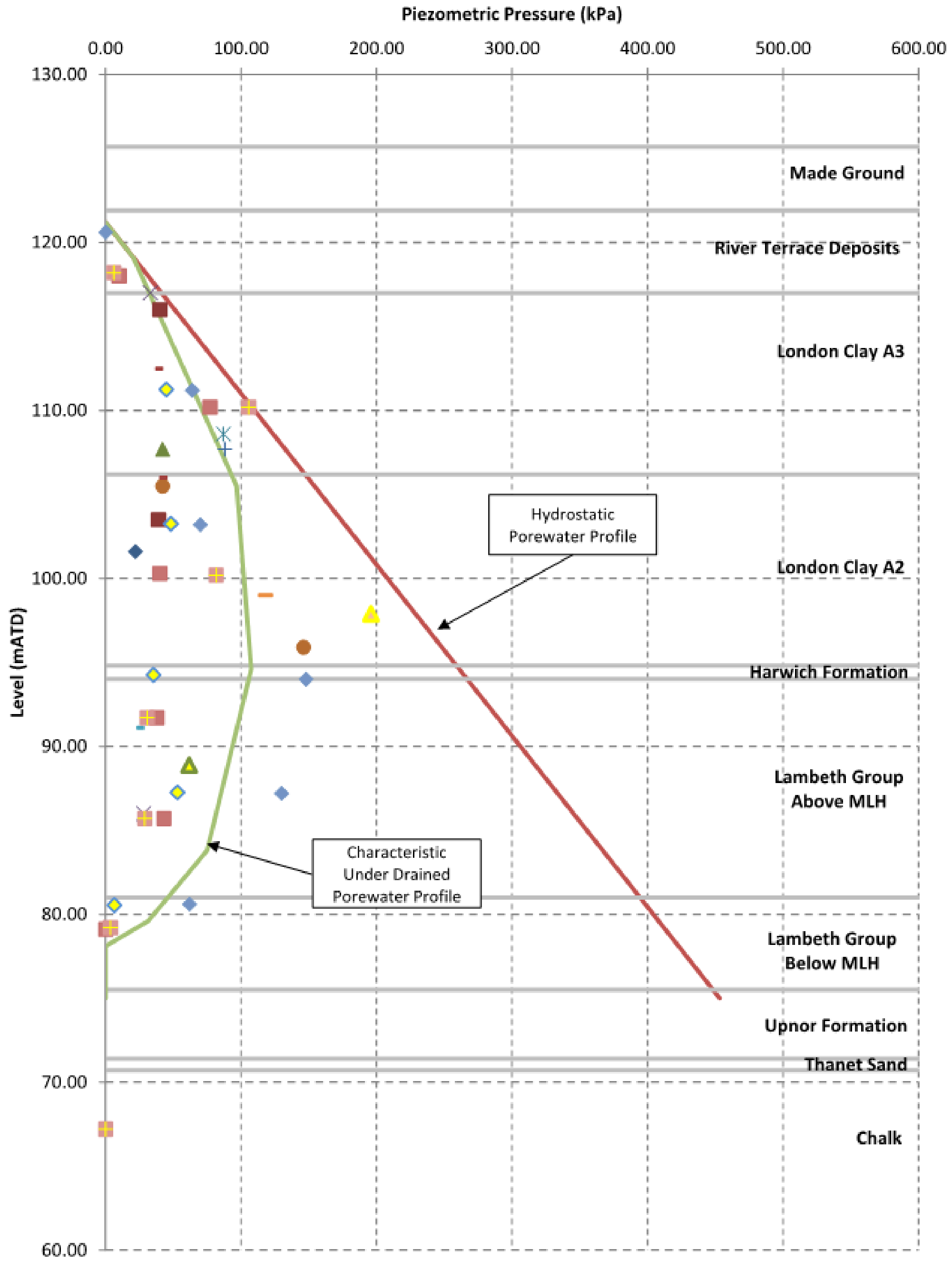


Figure 8.1.1: Characteristic Porewater Profile

Figure 8.4.1: Water ingress recorded at junction between NLEB and Northern Line Lower Concourse Tunnel (West wall).

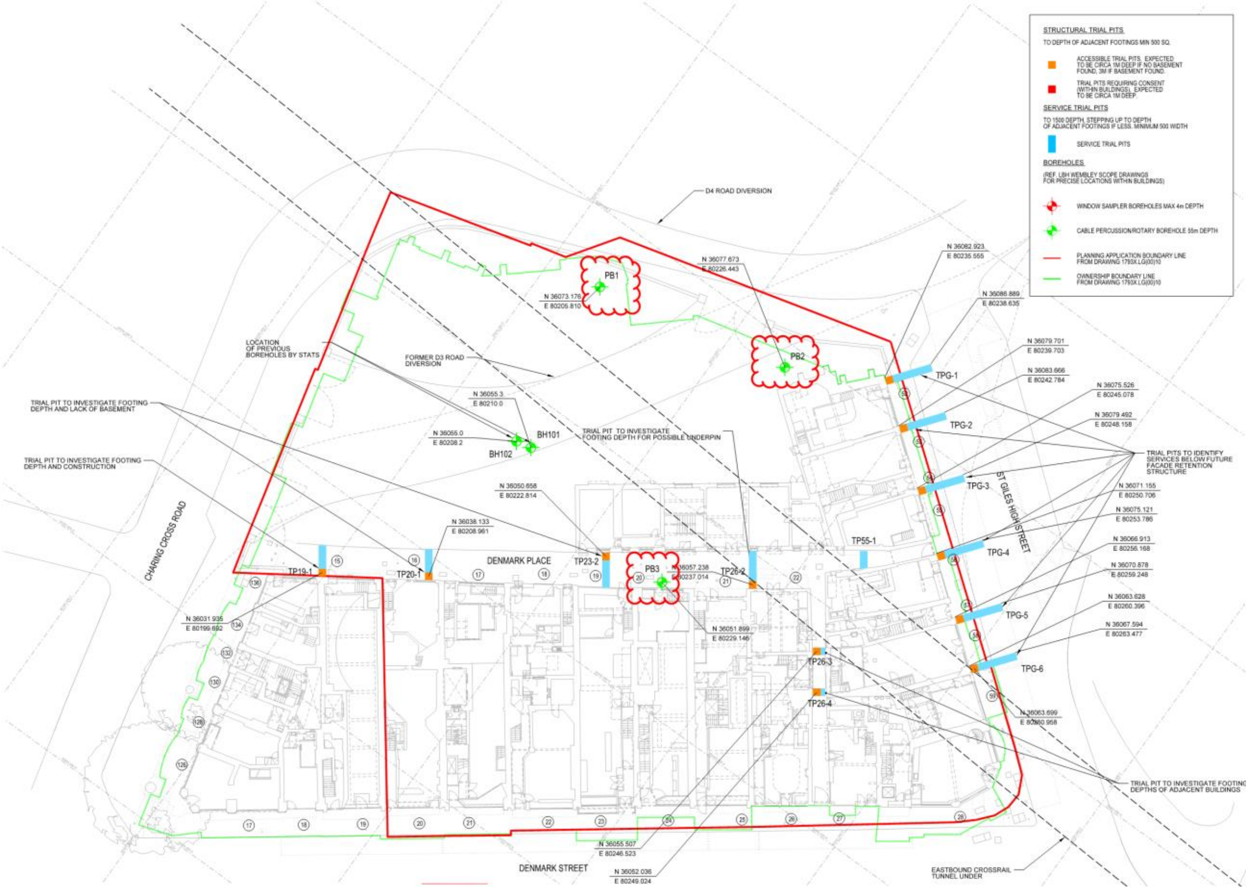


Figure 8.5.1: Zone 1 Additional Site Investigation (PB01, PB02 and PB03).

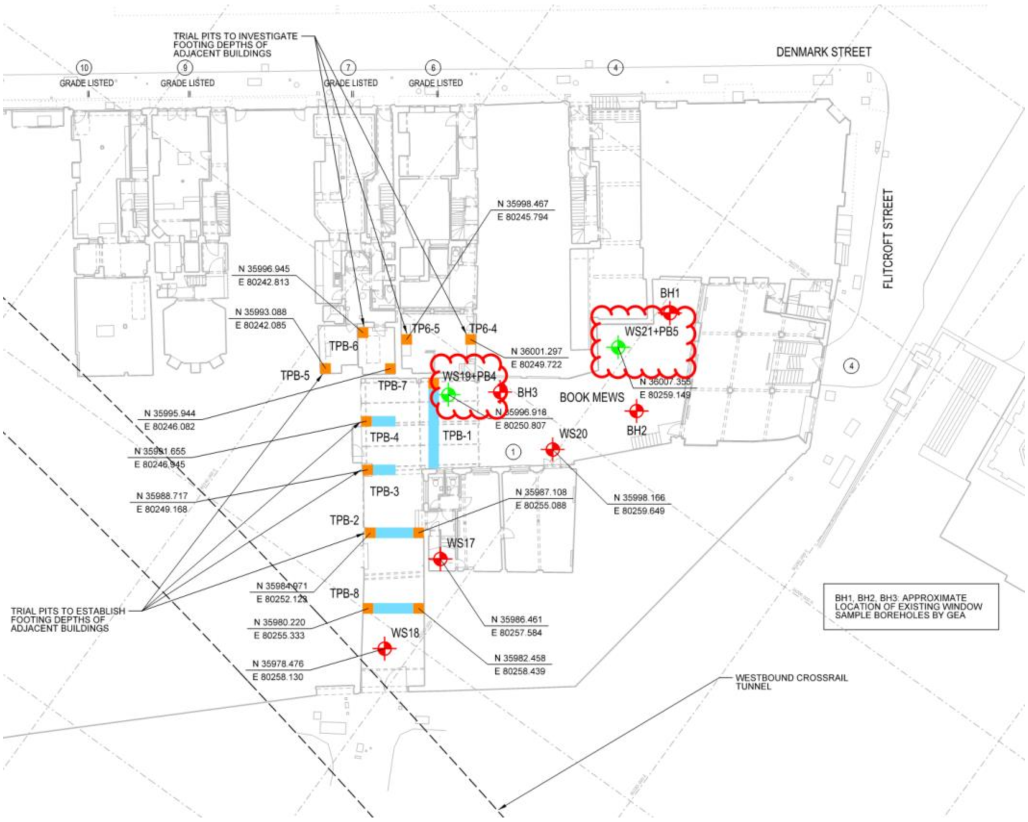


Figure 8.6.1: Zone 3 Additional Site Investigation (PB4 and PB5).

Figure 9.2.1: Extent of ~~proposed~~ demolitions.

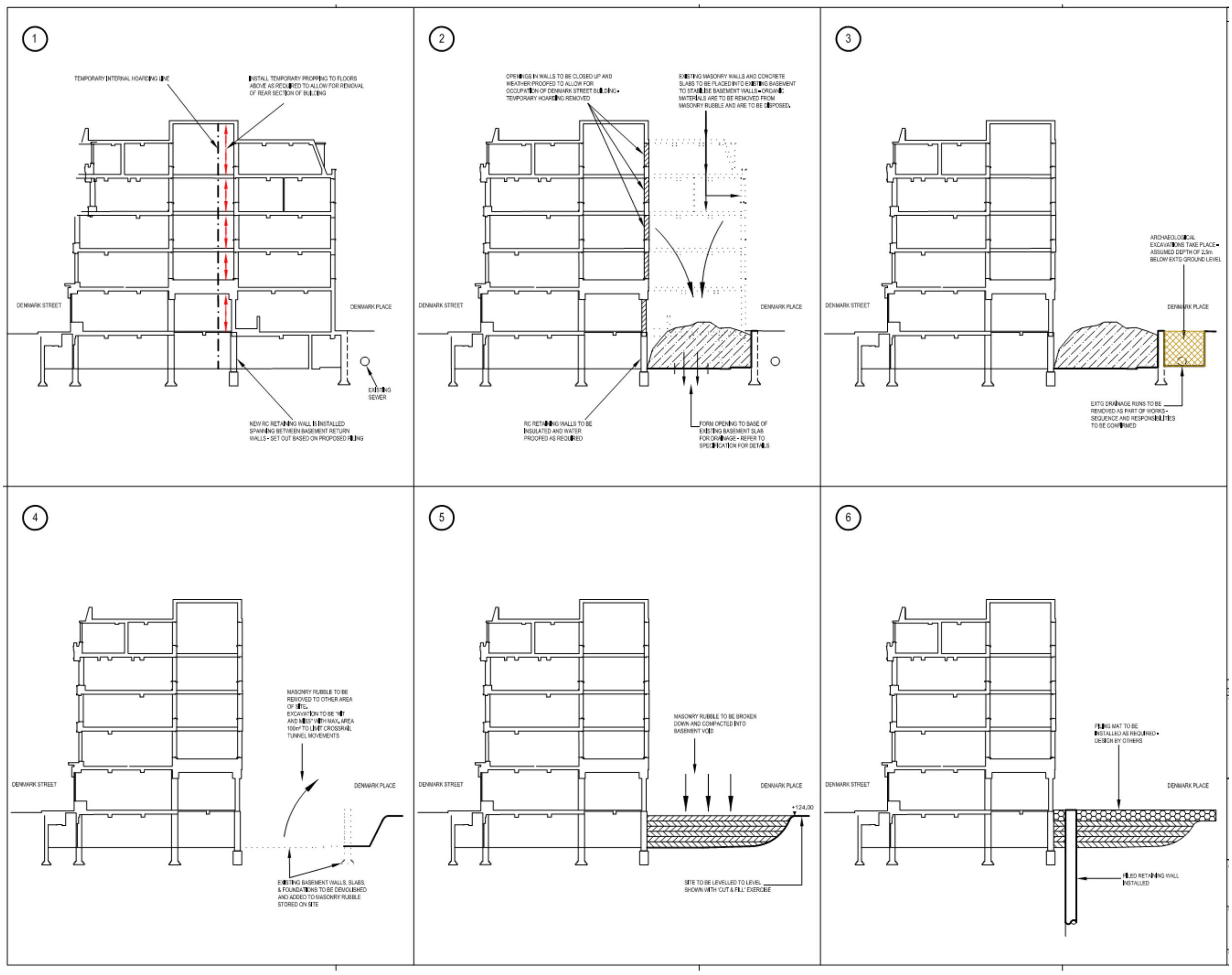


Figure 9.5.1: Sequence of demolition to control ground movements.

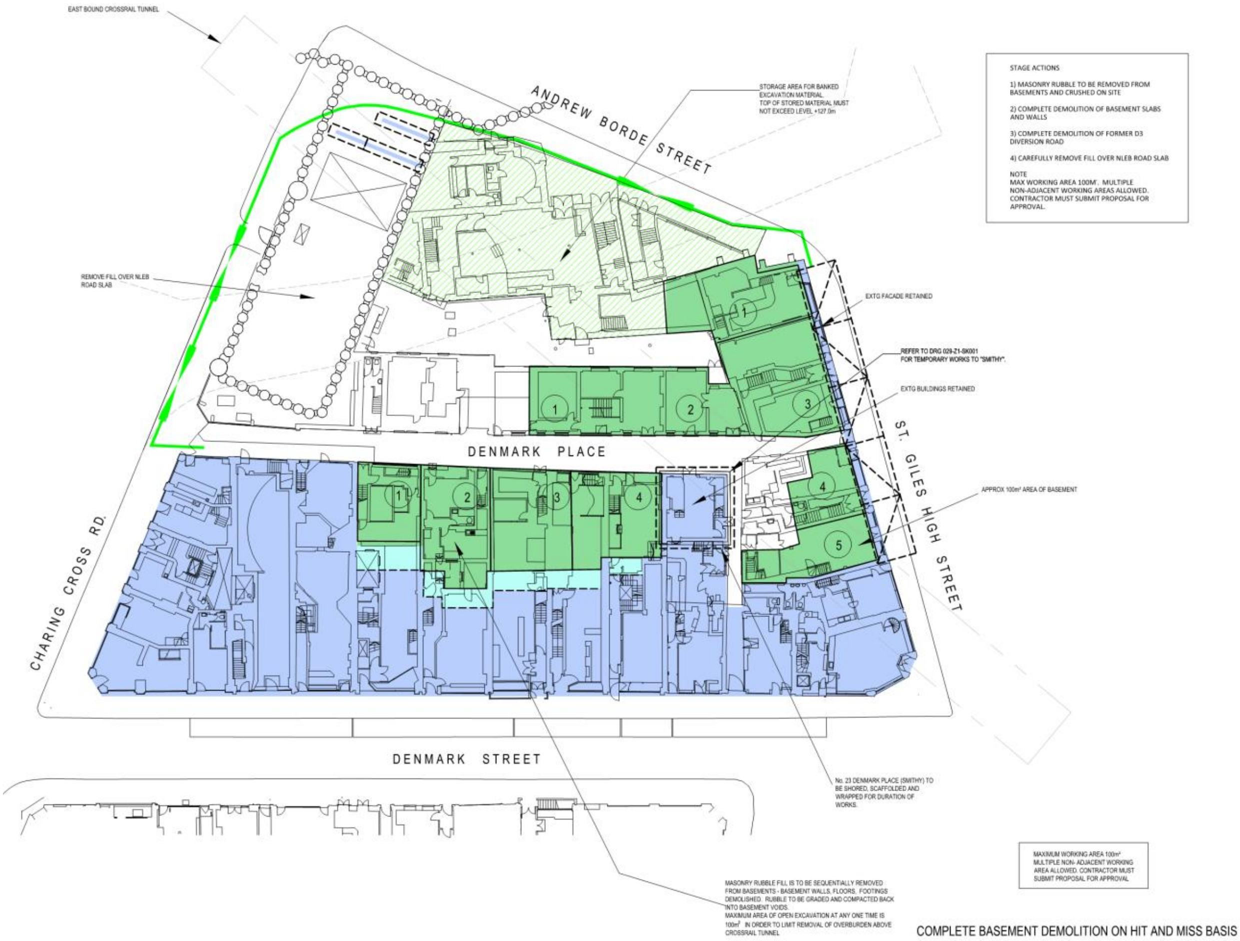


Figure 9.5.2: Breaking out of basements to be conducted in hit and miss arrangement.

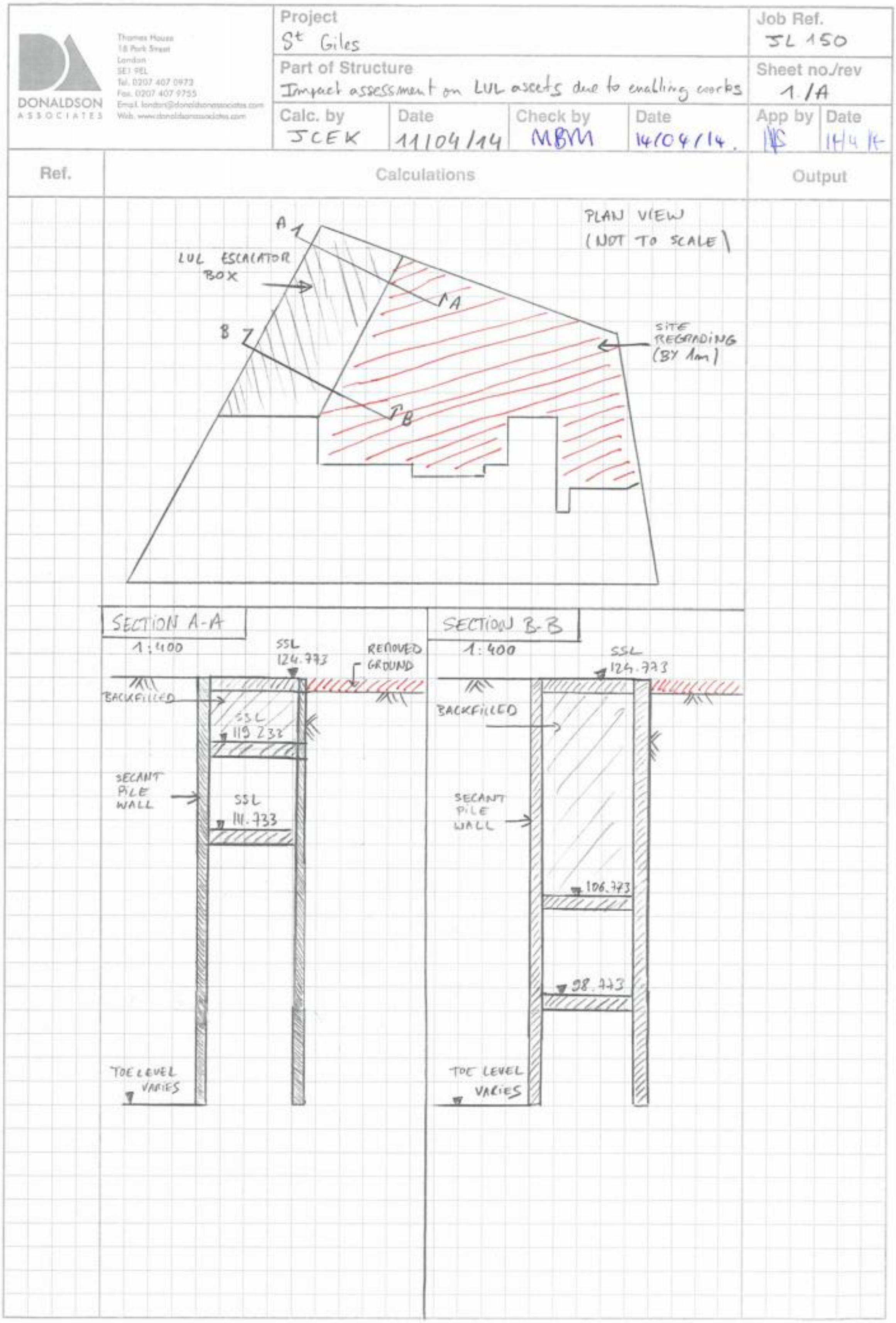
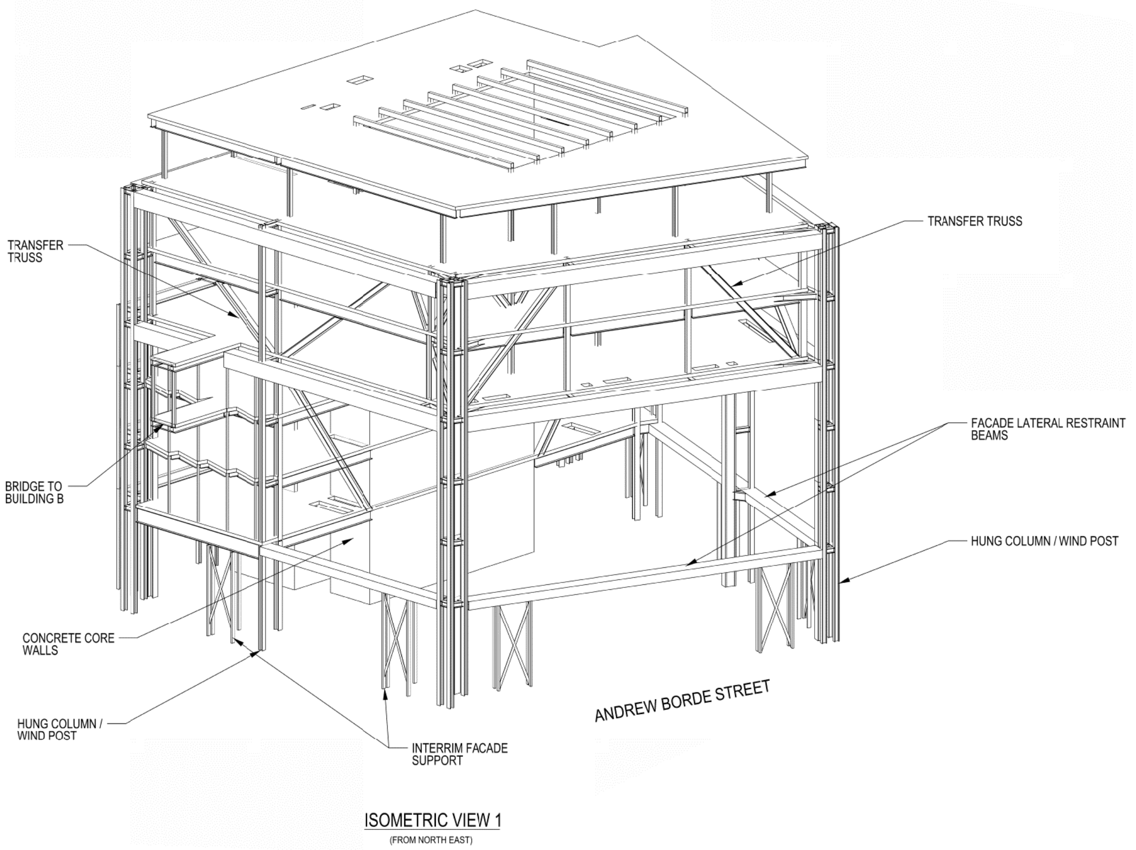


Figure 15.1.1: Relationship between NLEB and Demolition and Enabling Works



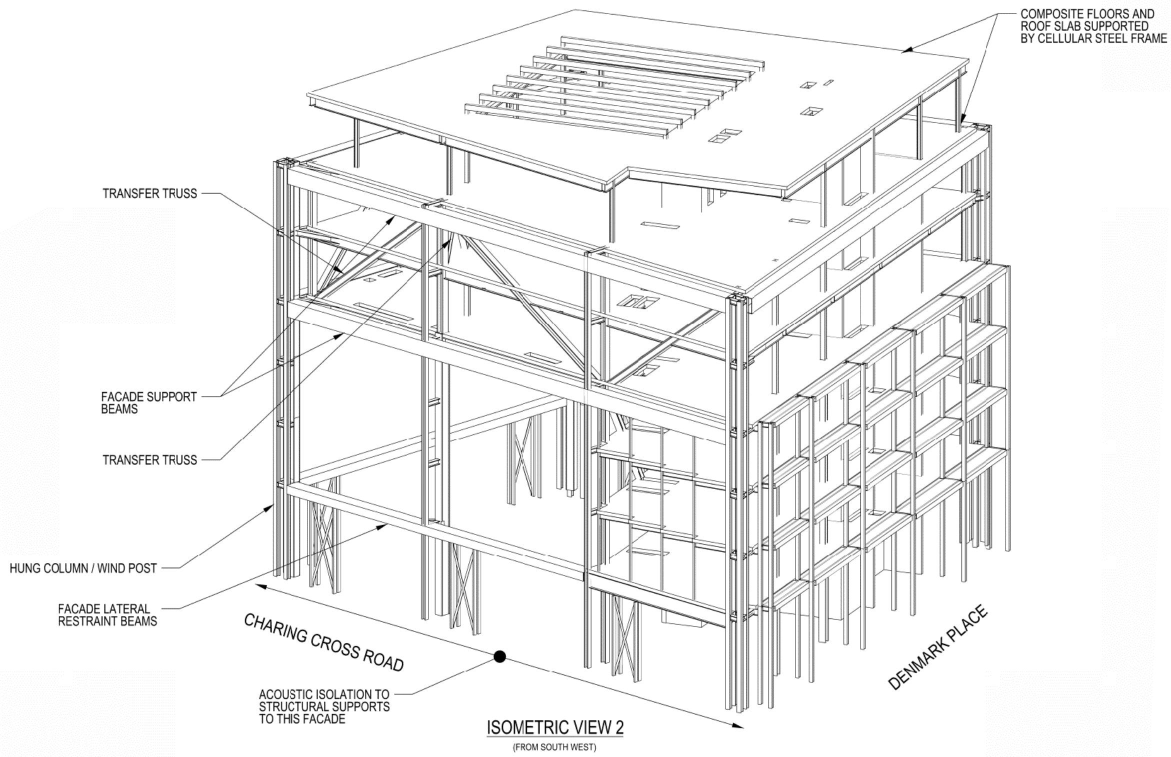
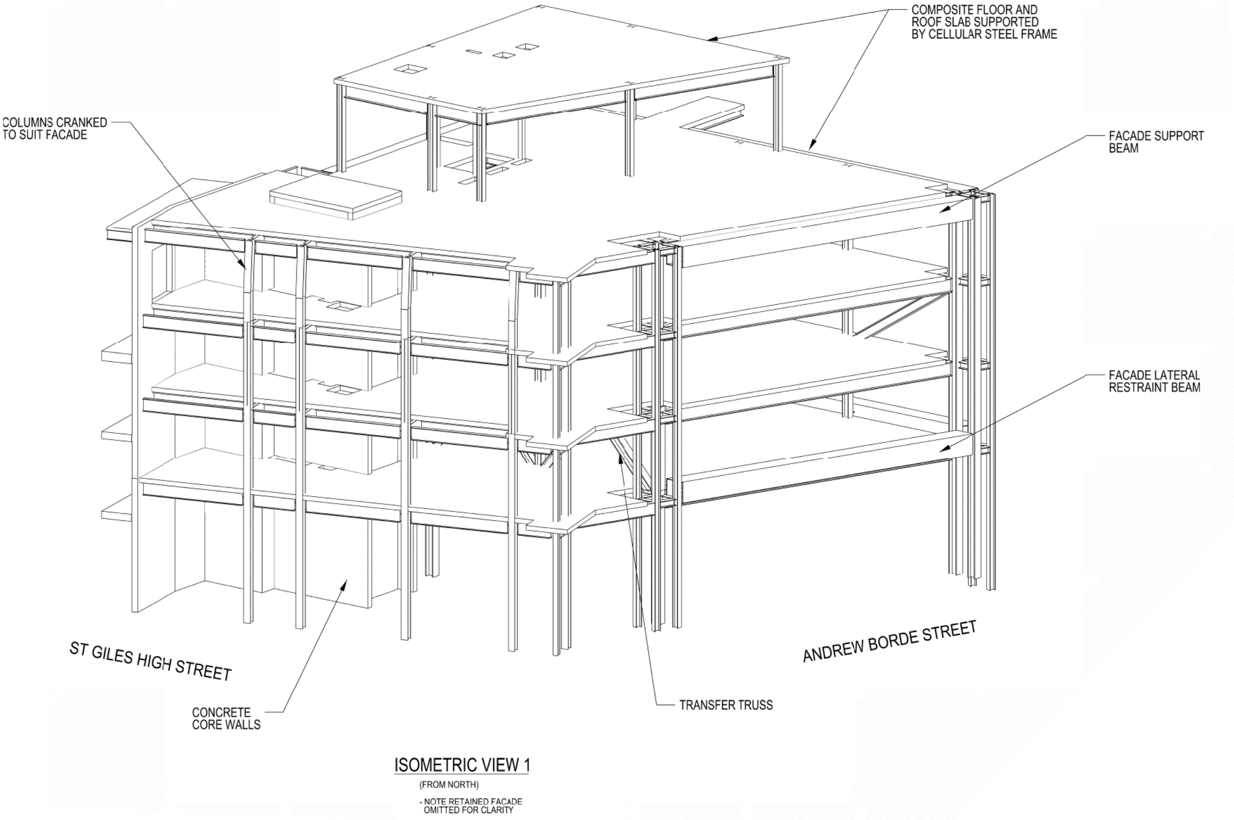


Figure 21.1.1: Building A superstructure



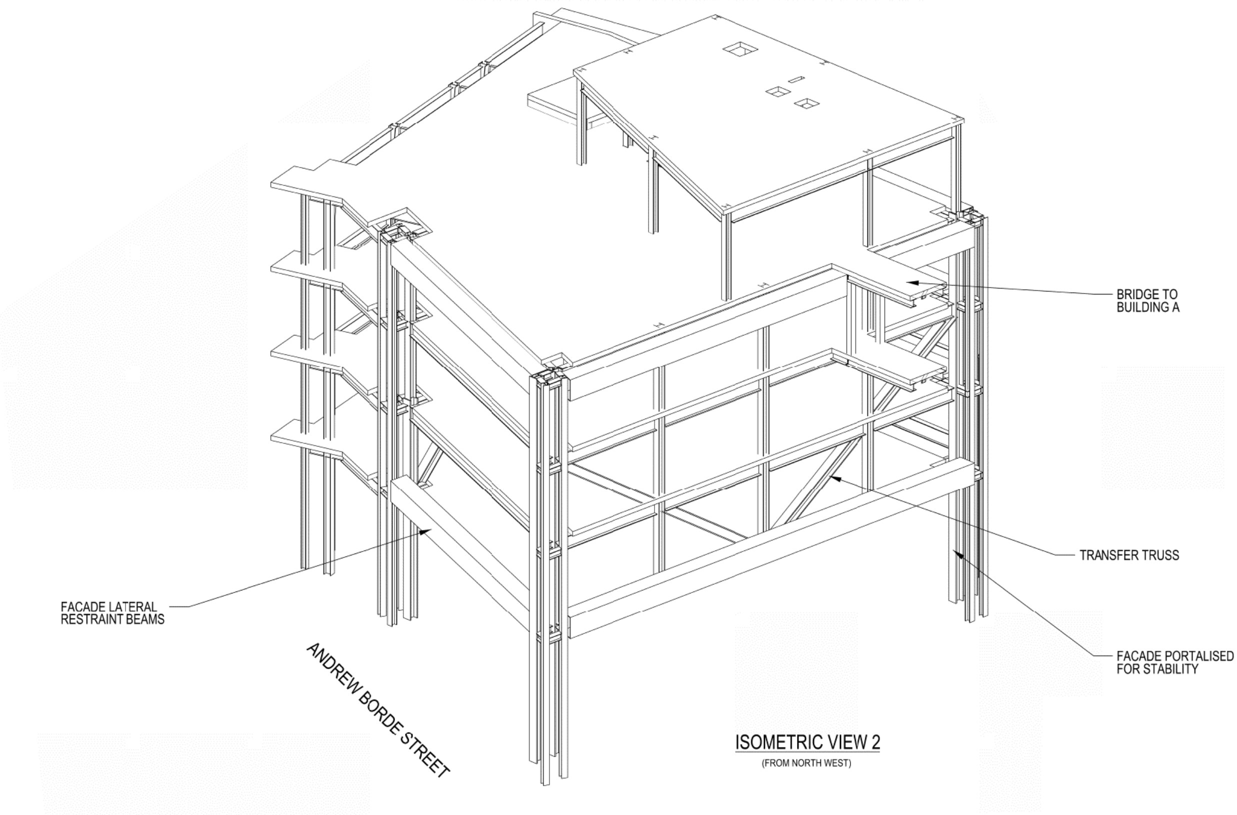


Figure 21.2.1: Building B superstructure

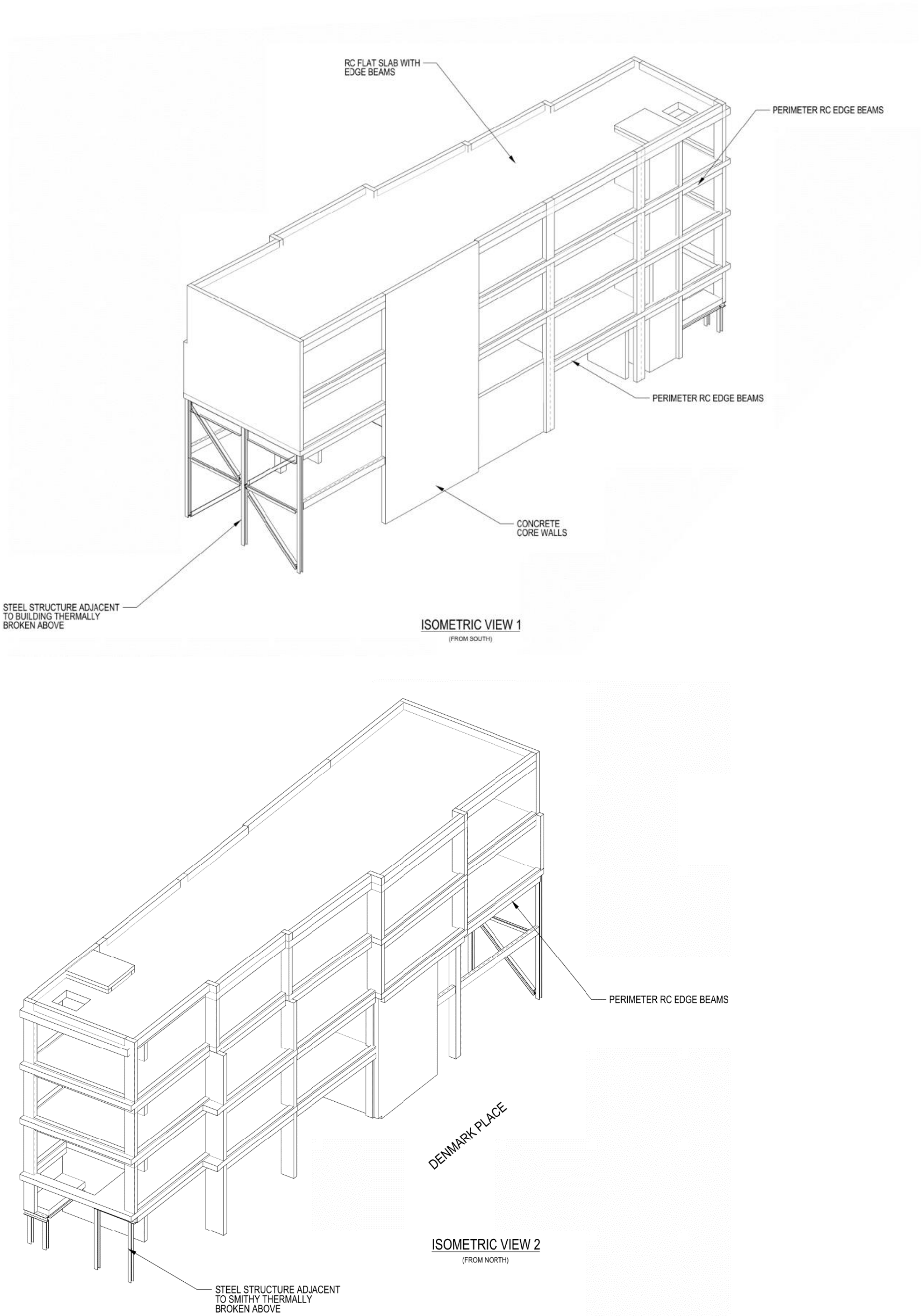
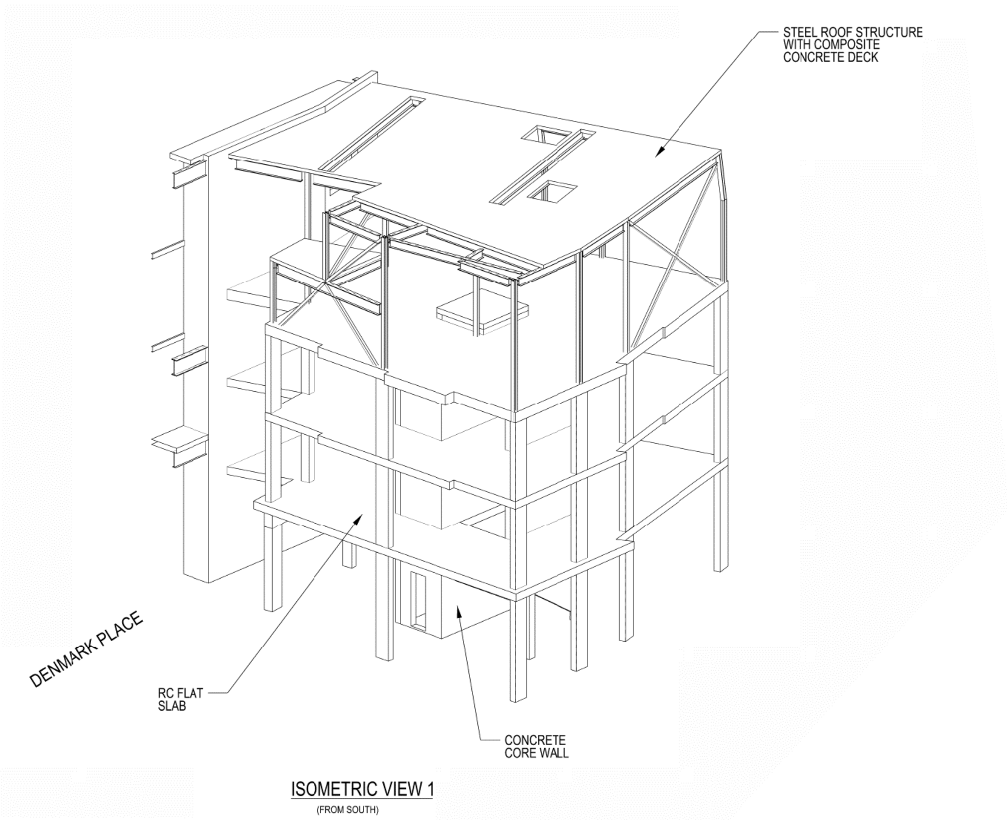


Figure 21.3.1: Building C superstructure



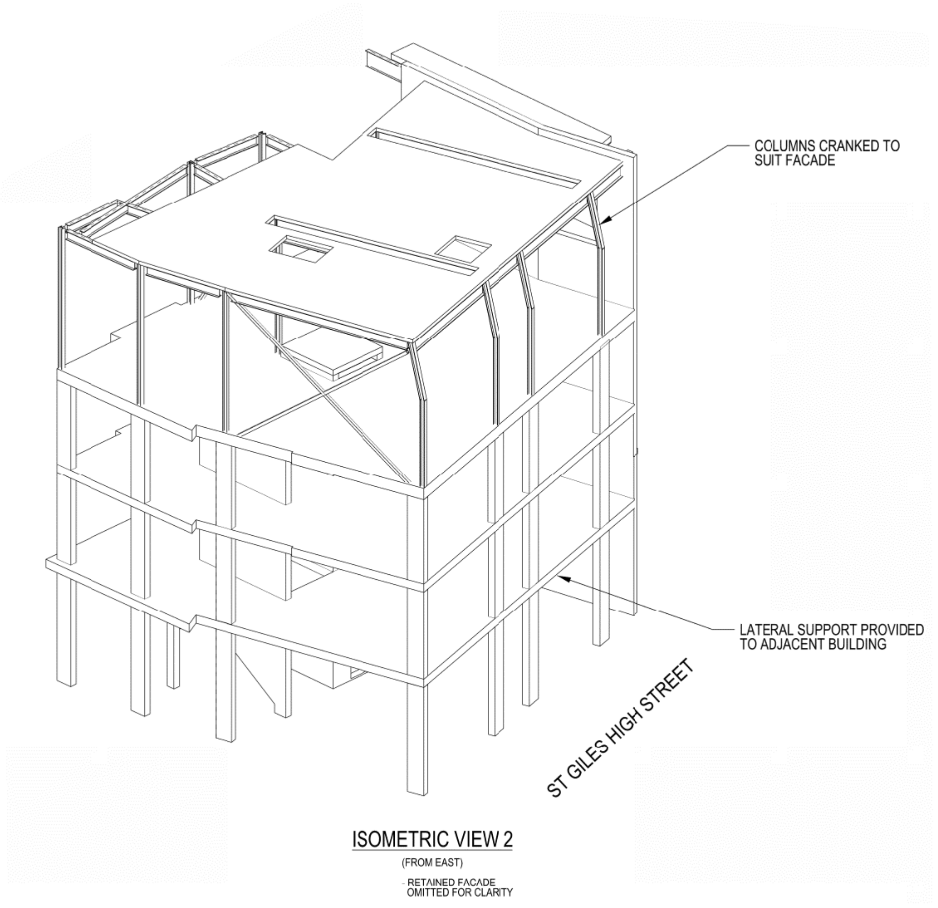


Figure 21.4.1: Building D superstructure

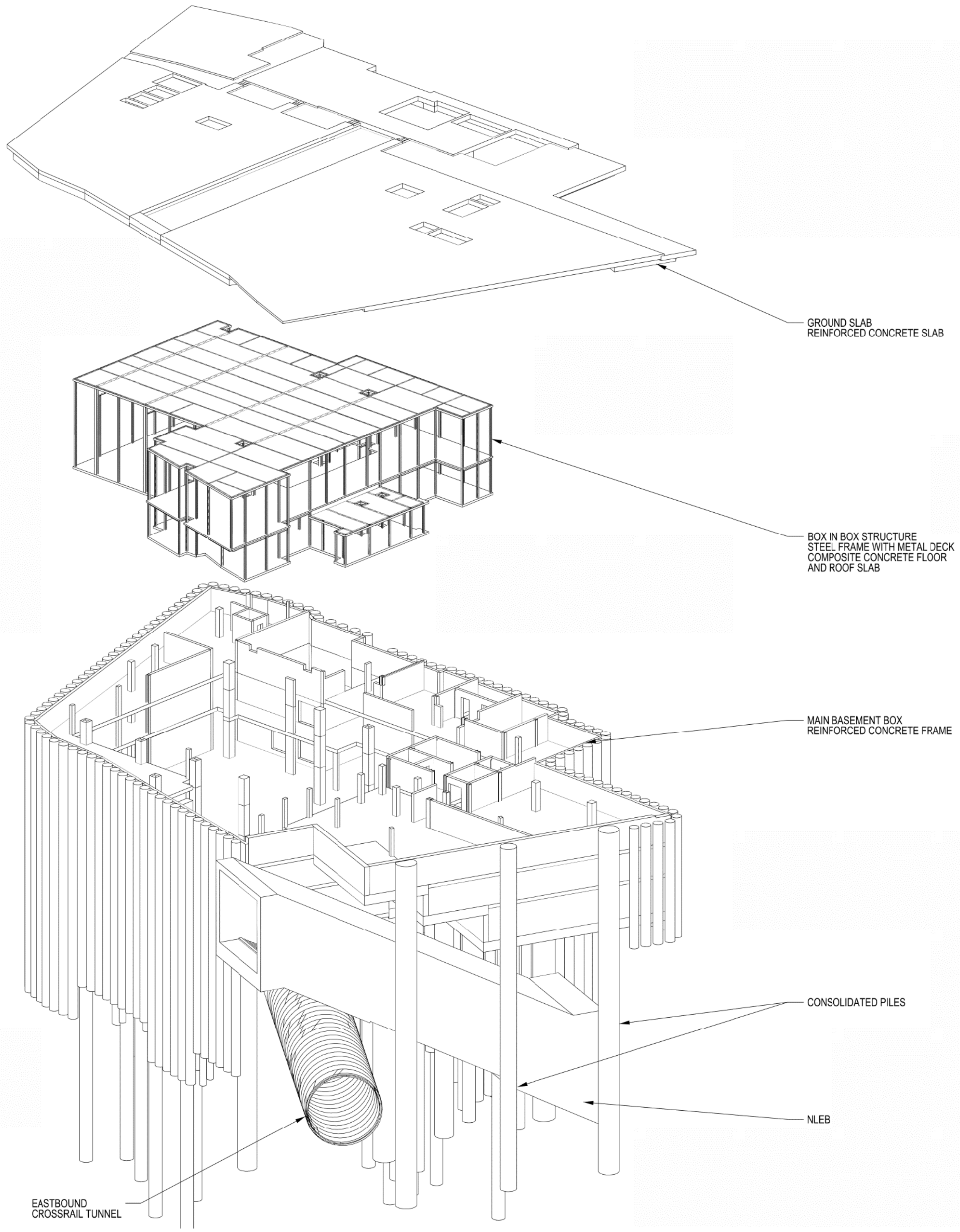


Figure 21.5.1: Basement structure

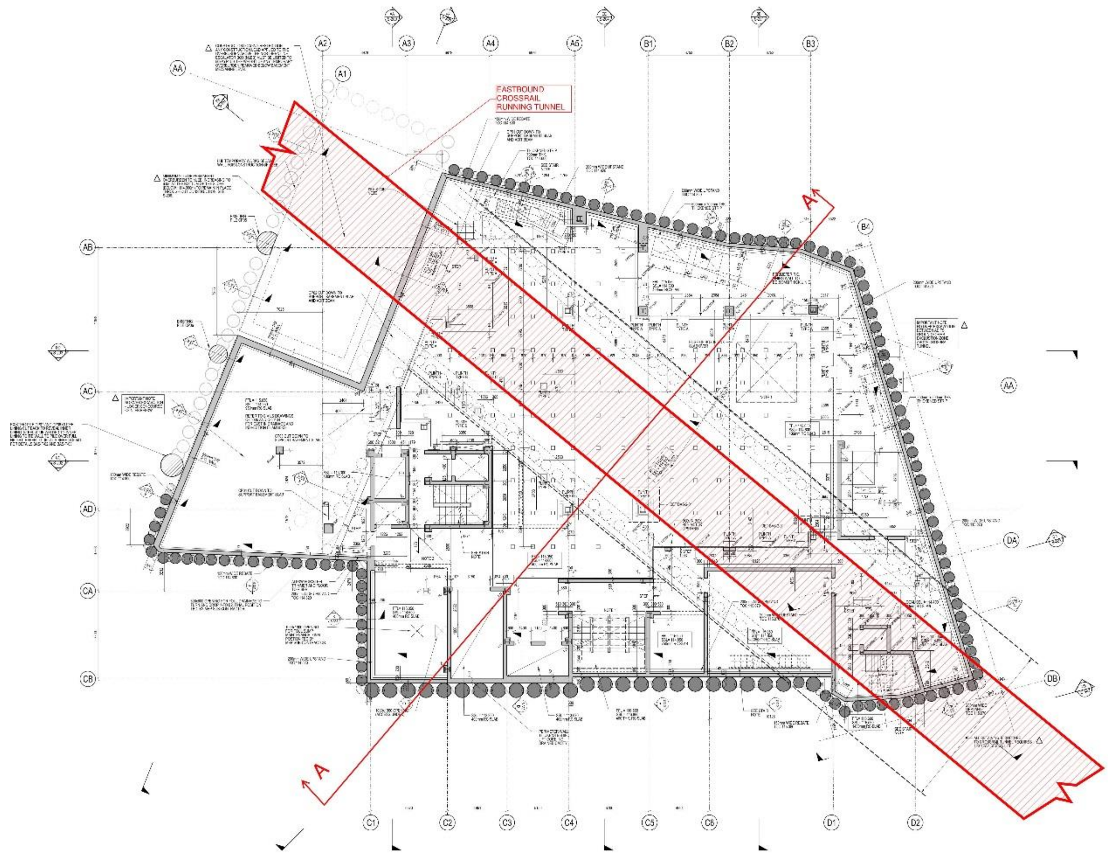


Figure 23.1.1: Plan of Modelling Sections through Crossrail.

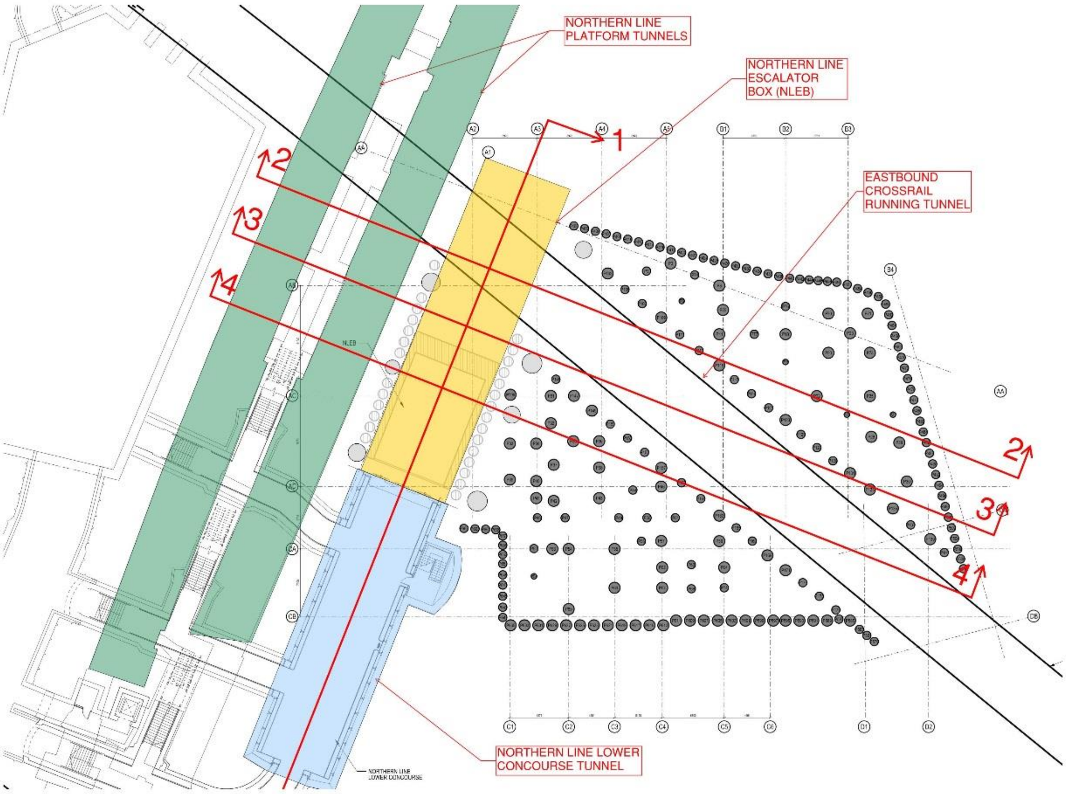


Figure 25.1.1: Plan of modelling sections through NLEB (Appendix P)

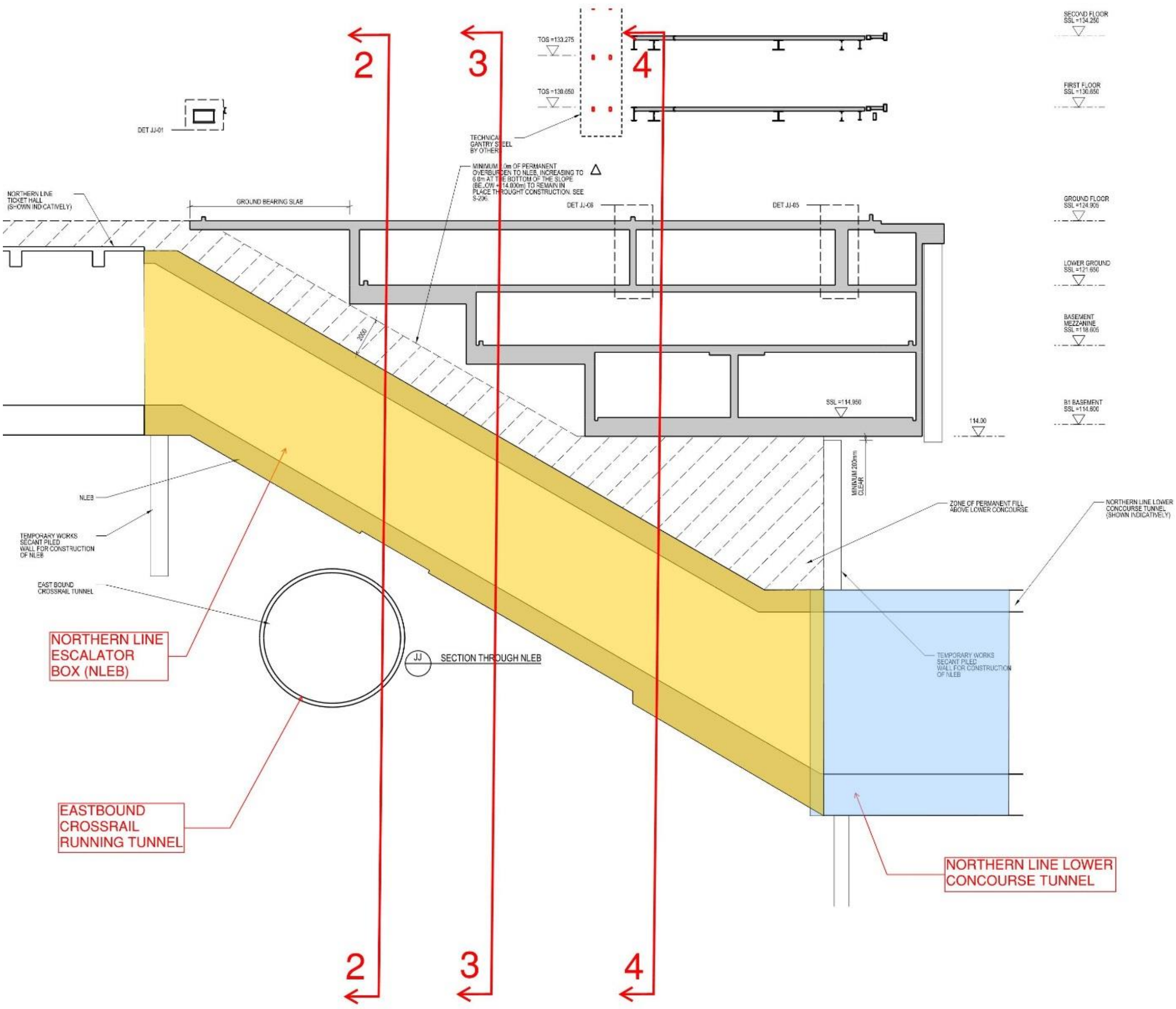


Figure 25.1.2: Elevation of modelling sections through NLEB (Appendix P).

Figure 25.3.1: Proposed basement at 4 Flitcroft Street.

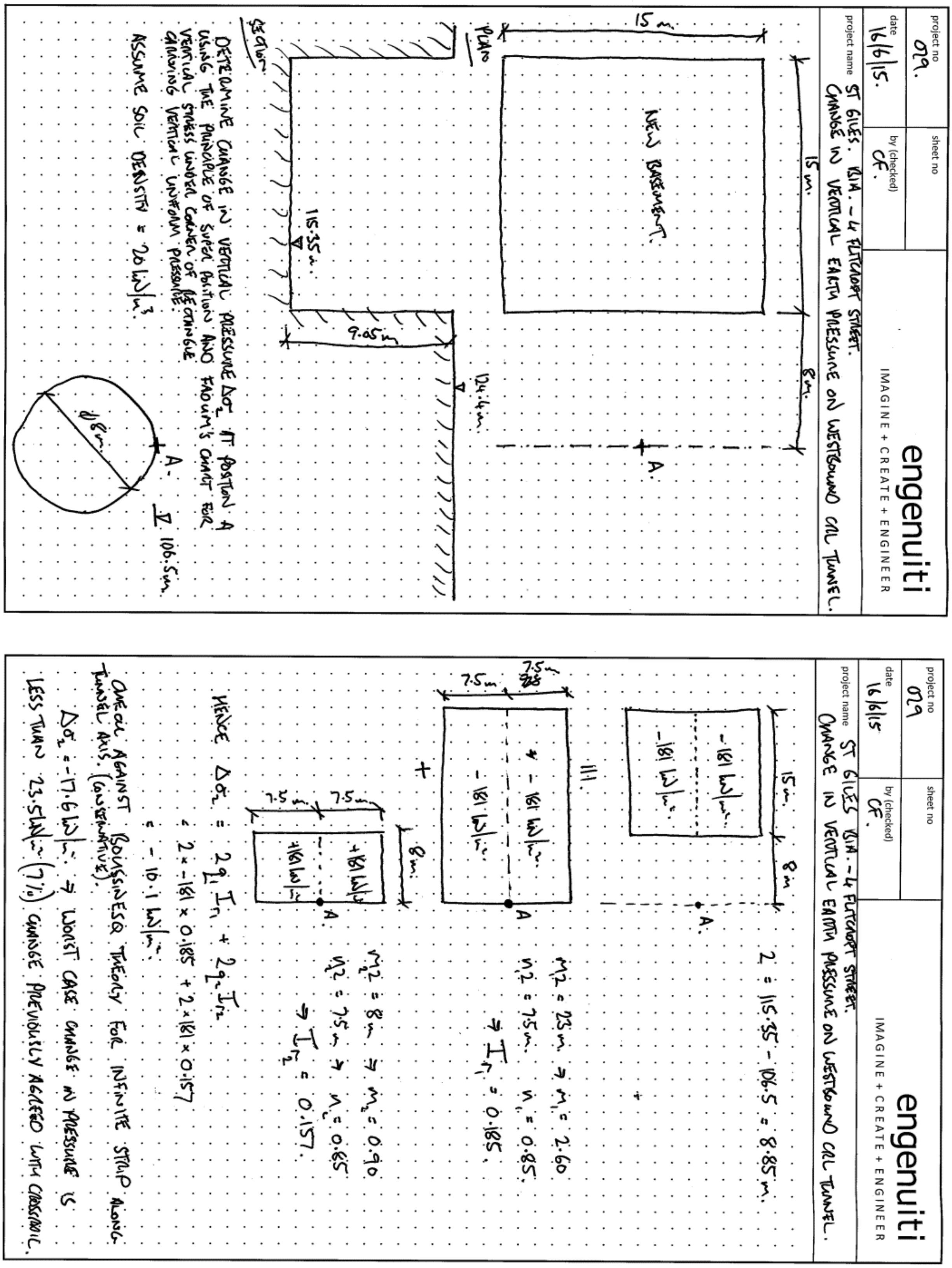


Figure 25.3.2: Conservative ground movement assessment on Westbound Crossrail tunnel as a result of proposed basement at 4 Flitcroft Street

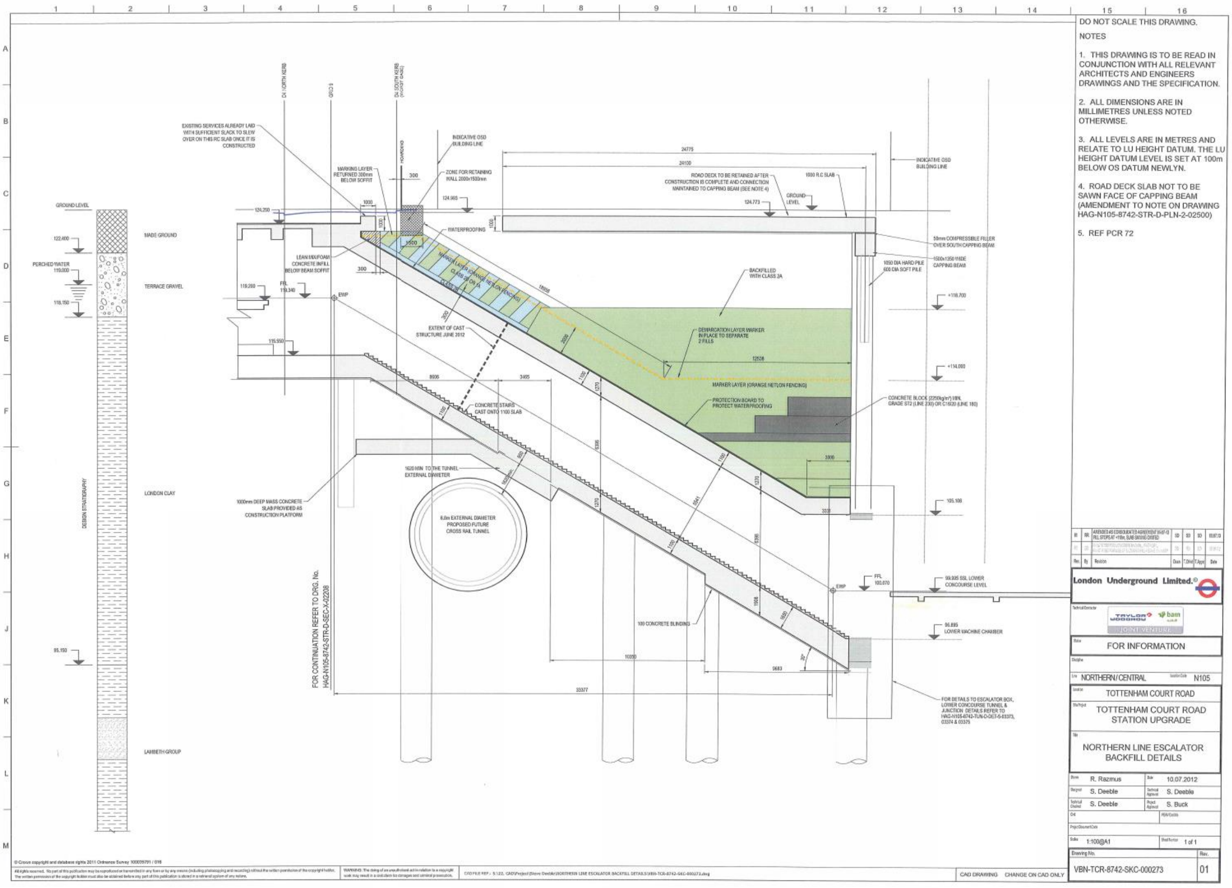


Figure 27.1.1: NLEB backfill details

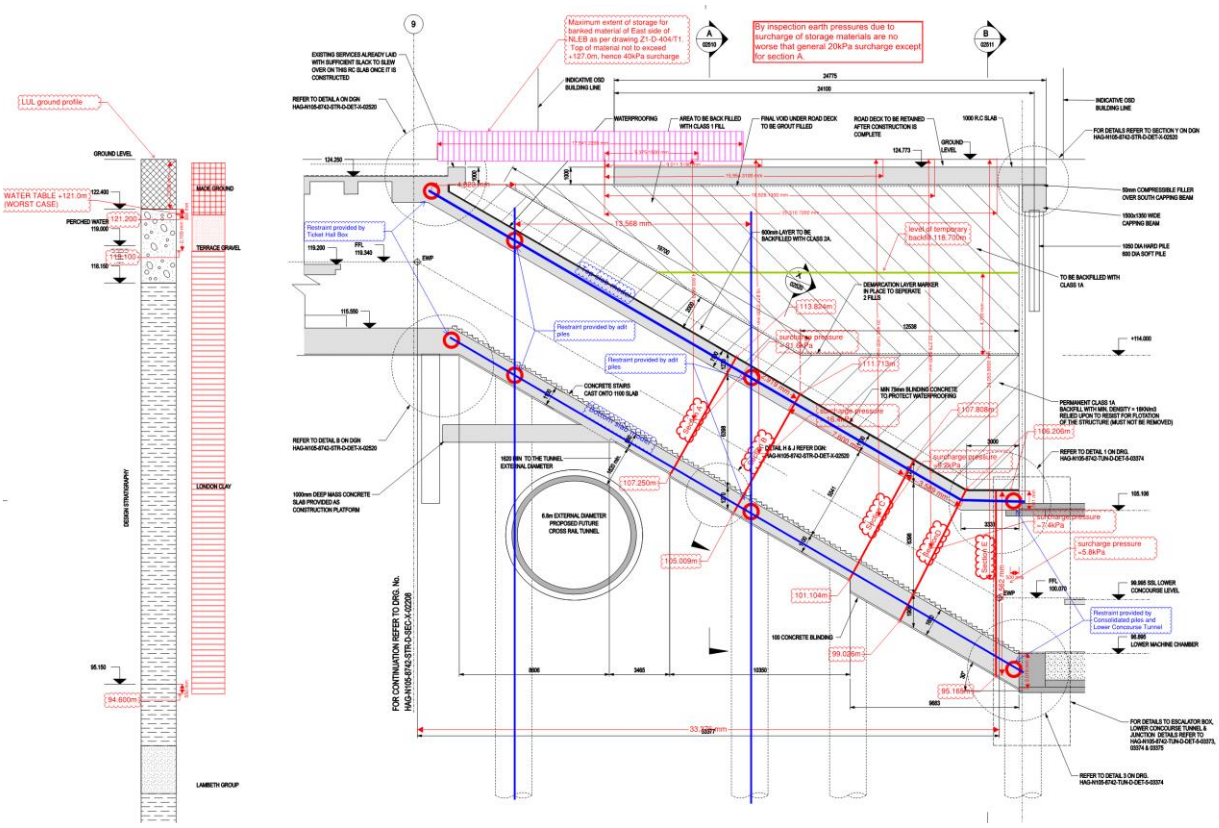


Figure 28.1.1: Modelling sections A to E inclusive from Appendix Q.

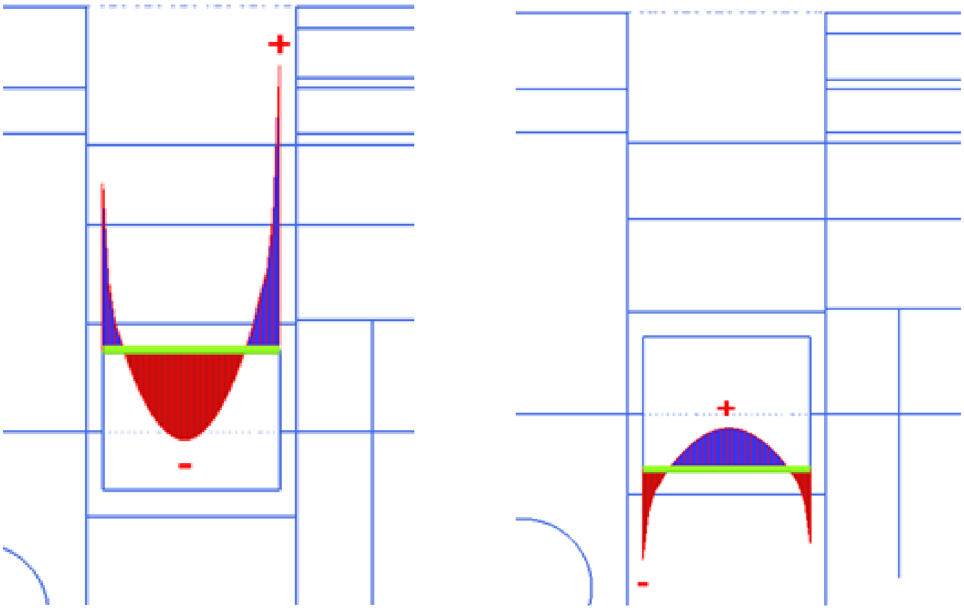


Figure 28.3.1: High moments are corners of NLEB from Plaxis results

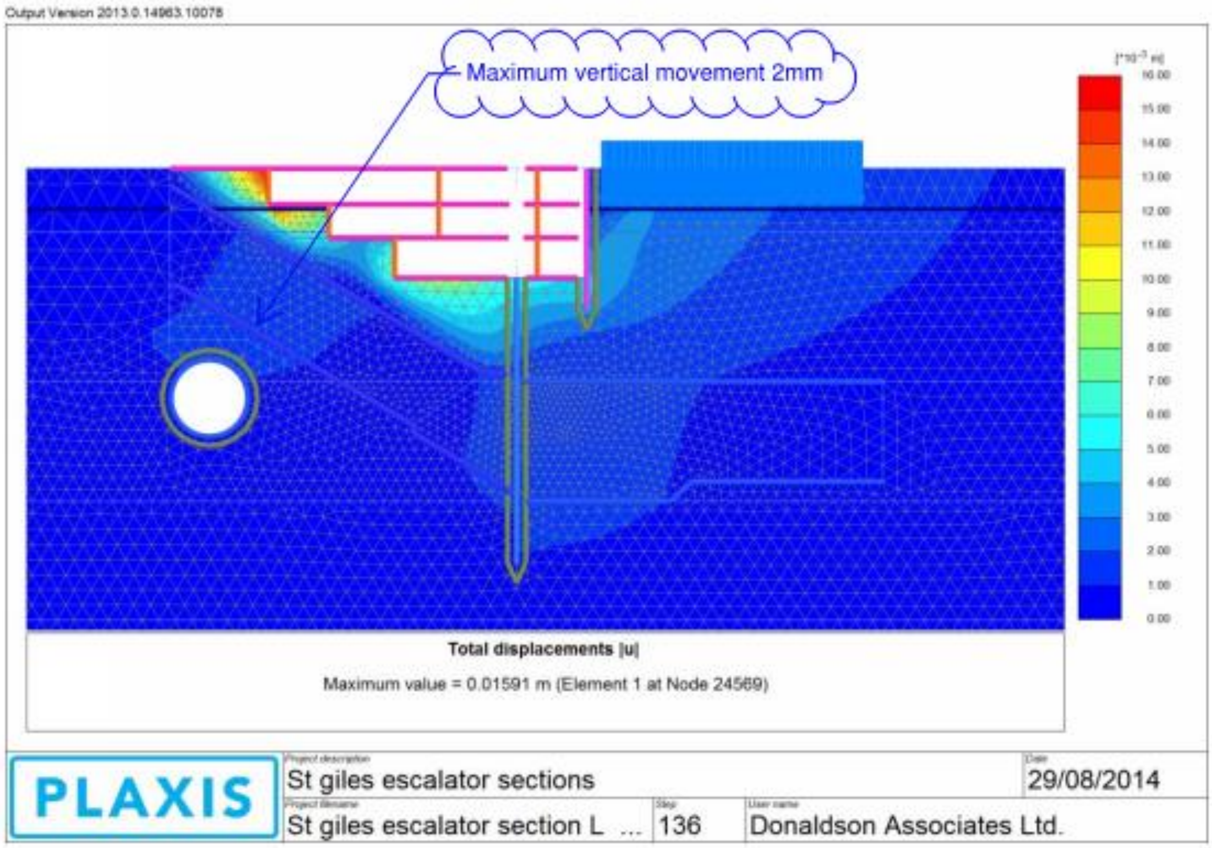


Figure 28.4.1: Predicted vertical movement of NLEB in the short term (post basement construction) from Appendix P.

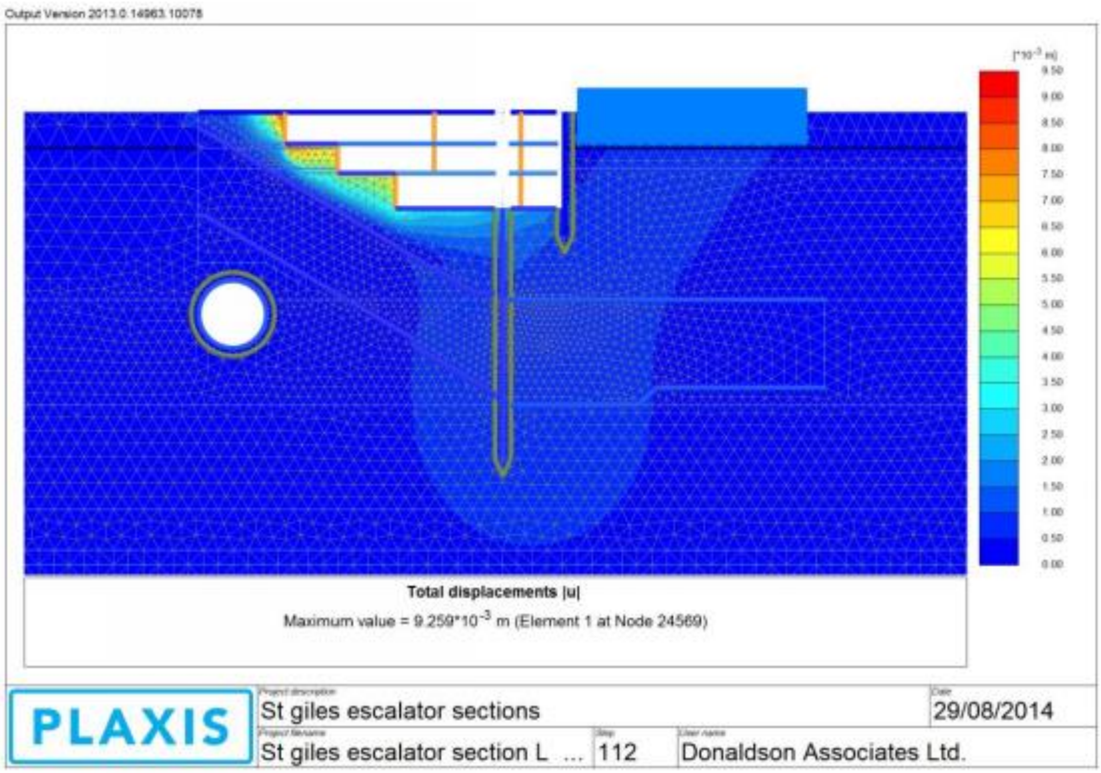


Figure 28.4.2: Predicted vertical movement of NLEB in the long term (post consolidation) from Appendix P.

Predicted lateral movements of NLEB
- Short Term

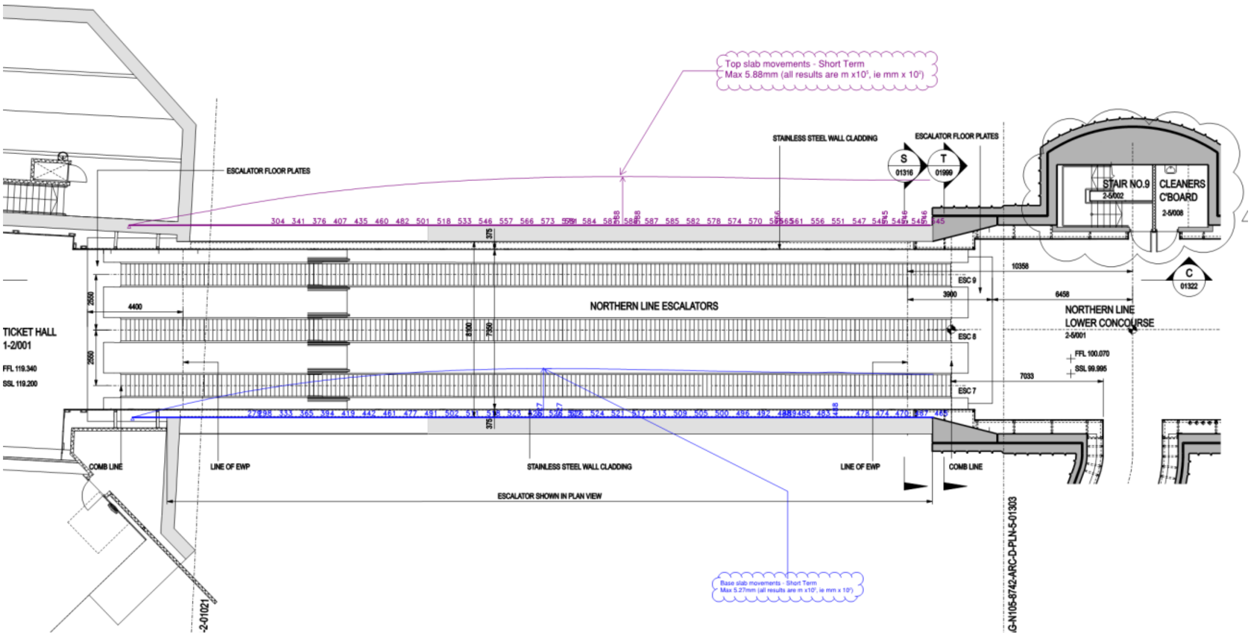


Figure 28.4.3: Predicted lateral movement of NLEB under short term loads from Appendix Q.

Predicted lateral movements of NLEB
- Long Term

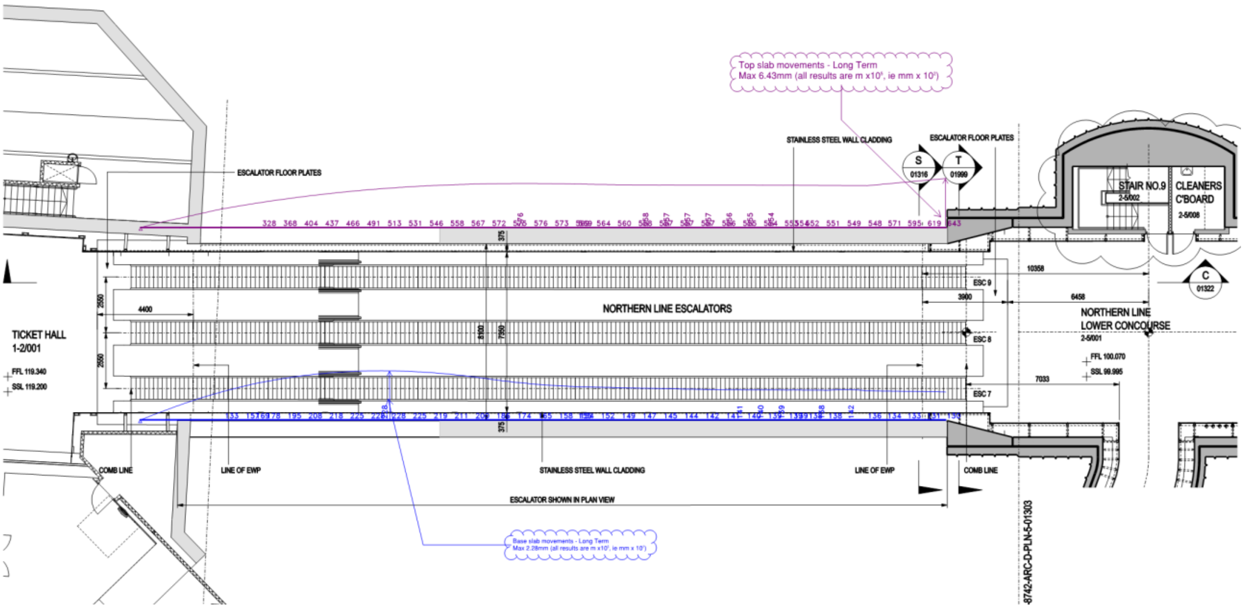


Figure 28.4.4: Predicted lateral movement of NLEB under long term loads from Appendix Q.