102
Camley Street, London N1C 4PF

Geotechnical Desk Study

June 2014

REGENT RENEWAL LTD

ARUP

Regent Renewal Ltd

102 Camley Street

Geotechnical Desk Study

Issue | 23 April 2014

Job number 234937-00

Ove Arup & Partners Ltd
13 Fitzroy Street
London
W1T 4BQ
United Kingdom
www.arup.com

ARUP

Document Verification

ARUP

Job title	102 Camley Street			**Job number** 234937-00	
Document title	Geotechnical Desk Study			**File reference**	
Document ref					
Revision	**Date**	**Filename**	102CamleySt_DeskStudy_issue.docx		
Issue	23 Apr 2014	**Description**	Issue		
			Prepared by	Checked by	Approved by
		Name	Áine Ní Bhreasail	Hilary Shields	Tim Chapman
		Signature	Áine Ní Bhreasail.	C H Shields.	[signature]
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			

Issue Document Verification with Document ✓

Contents

Appendices

1 Introduction

This geotechnical desk study is the first part of the identification and mitigation of the ground related hazards on the site. Section 2 includes detailed information on the site location and history, an overview of the proposed development and information on Regent's Canal adjacent to the site. Section 3 discusses the ground conditions including the geology and groundwater, and suggests a likely design stratigraphy. A summary of the geotechnical design parameters of the Channel Tunnel Rail Link project in the area is also given. Section 4 & 0 go through the potential ground hazards such as utilities, unexploded ordnance, flood risk and ground contamination. Section 6 discusses geotechnical design required for the development and the possible solutions, followed by the recommendations and scope of a ground investigation in Section 7.

The desk study is limited due to the fact that a site walkover was only around the perimeter. The site itself was not inspected during the visit.

2 The Site

2.1 Site Location

The proposed location of the mixed use development is at 102 Camley Street, Camden, London N1C 4PF. The location is shown in Figure 1. The site is bounded by

- A strip of land to the east;
- Regent's Canal and towpath to the south;
- Camley Street to the west; and
- An adjoining site with warehouse to the north.

To the east of the site there are several railways leading to and from St. Pancras Station including the Channel Tunnel Rail Link and mainline rail in the direction of St. Albans, Leicester and Nottingham. The lines closest to the site are the mainline rail lines. The southern boundary spans the distance between the road bridge and the rail bridge. Camley Street bounds the western edge of the site and access to the site is from here. There is a commercial building on the site to the north. The Ordnance Survey Grid reference for the site is 529800, 183750.

The site is currently in use as a warehouse for Marigold Health Foods. It is a one story structure with no basement built in the 1970s. A recent aerial photograph is shown in Figure 2.

There is a Network Rail substation between the site and the railway lines to the east. Access to the substation is through the northern end of the site. The access way width is 6m and Network Rail have right to use this access way in order to maintain the substation and access trackside.

2.2 Topography

The site is at an elevation of approximately +28m above Ordnance Datum. There is a very gentle slope across the site from northwest to southeast, i.e. it slopes down towards the canal. The maximum and minimum levels vary from +27.2mOD to +28.3mOD, but in general the northwest of the site is at a level of approximately +28.2mOD and the southeast is at +27.8mOD. The site is approximately half a metre lower than the railway lines to the east.

The site to the north, 104 Camley Street, is also approximately 0.5 m lower than 102 Camley Street, as seen in Figure 3 (a). There is a noticeable slope in the access road on the site as seen in Figure 3 (b). The topographical survey shows that the level of the entrance from Camley Street is +27.22 m OD while at the eastern side (next to the gateway leading to the Network Rail substation) the elevation is +28.24 m OD. The exact ground level of the Network Rail substation is unknown at this time but believed to be similar to the ground level near the gateway.

2.3 Proposed development

The proposal for the site is to demolish the existing warehouse and replace it with a mixed use residential development with a small amount of commercial space. The development plan includes a maximum of 12 storeys and a one level basement.

Sketches of the proposed development are seen in Figure 4. The section of the building in the northwest of the site is 8 storeys high. In the east part of the building 12 storeys with a one level basement is proposed. The area in front of the basement includes access to the Regent's Canal towpath. Currently the towpath is not directly accessible from the site. The existing retaining wall between the site and the canal will be removed but the Oblique Bridge retaining wall will be kept in place. Liaison with the Canal and River Trust will be required to implement changes to retaining walls. The courtyard area in the south west of the site will have a sprinkler tank underneath it.

2.4 Site History

Historical maps have been reviewed in order to monitor the development of the site and the changes in site usage. Both Ordnance Survey maps and non-Ordnance Survey maps were reviewed, dating from 1700s to present day.

<u>John Roque Survey of London 1741-1745</u>

This map indicates that the site was undeveloped at the time. An excerpt is shown in Figure 5.

<u>London 1805-1822</u>

This map, reprinted by Ordnance Survey in 2007, shows that there is much more development in the vicinity of the site, particularly to the south. However the site itself remained undeveloped apart from the adjoining Regent's Canal which was constructed in the intervening period. An extract from the map can be seen in Figure 6. Other records from the Canal and River Trust show that the canal was completed in 1820. Given that the site is directly adjacent to the canal, it is likely that it was used during construction for storage or dumping of arisings.

Greenwood's Map of London 1827

Greenwood's map was published in 1827 from a survey of the previous two years. It is hosted online by Bath Spa University and was accessed in November 2013. An excerpt from this map is shown in Figure 7. The Oblique Bridge across the canal has been constructed. The site itself is marked as farmland.

London Map published 1851

This town map indicates that significant development occurred between 1822 and 1851. The site was now crossed by two roads from west to east: Winchester Street and Salisbury Crescent, as shown in Figure 8. No buildings are shown on the site. Regent's Canal is to the south, and the Oblique Bridge (a road bridge) crosses the canal onto Salisbury Street, which is in the same location as the current day Camley Street. Saint Pancras station is to the north of the site, surrounded by the Midlands Counties Railway Goods Depot. To the east is the Great Northern Railway Coal & Goods Depot.

London Map published 1873-1874

This map shows that the site was used as a goods depot for Midlands Railway by 1873. There are no buildings indicated on the site although there are some railways terminating on the eastern side of the site. A rail bridge has been constructed across Regent's Canal adjacent to the Oblique Bridge. An excerpt from this map is shown in Figure 9. It shows that Salisbury Street no longer existed in 1873 and that Camley Street in its current state did not yet exist.

London Map published 1875-1877

A cutting is shown on the southern end of the site next to the canal between the road bridge and the rail bridge.

London Map published 1896

In the 1896 London map the building to the north of the site has been extended right up to the boundary. A Goad insurance plan indicates that this warehouse had wooden girders on stone, brick or concrete columns and the extension had an iron glass roof. It was used to store wine and beer. A new small brick, stone or concrete structure is shown on the western boundary of the site.

London Map published 1916

In the 1916 London map there are additional rail tracks terminating on the site, new structures adjoining the goods depot to the north and a new structure in the southwest of the site. An excerpt from this is shown in Figure 11.

Aerial photograph published 1946

The aerial photograph is shown in Figure 12. This was produced by the Ordnance Survey as an interim measure, pending preparation of conventional mapping, due to post war shortages. The site is mainly unchanged from 1916, except for the removal of the structure seen in the 1916 map in the south east of the site and the addition of a small structure adjoining those structures added by 1916. It appears as though the site is being used for storage containers.

The Goad insurance plans around this time (1942) show that the structures adjoining the main warehouse to the north of the site were being used for van storage, tarpaulin storage and as a mess room. The most eastern structure, i.e. that adjacent to the rail lines, is labelled a "transforming house". It is at the location of the existing Network Rail substation.

Ordnance Survey Map published 1953/1954/1962-1971/1970-1971

There is little to no change indicated in the next few maps available, i.e. the Ordnance Survey maps from 1953, 1954, 1962-1971 and 1970-1971.

Goad insurance plans during this time show the buildings on the north of the site (adjoining the warehouse to the north of the site) were being used as a general and stationary store (1960, 1963), as a garage (1960, 1963 and 1970), as a workshop and for repairs (1960, 1963 and 1970). The transforming house is still labelled as such in all these plans. The warehouse to the north is labelled as a general warehouse storing goods including wood, wool, wine and spirits from 1960-1963. In 1967 and 1970 it is shown to be vacant.

Ordnance Survey Map published 1980-1988

Significant change is shown on the site in the Ordnance Survey 1980-1988 map. The goods depot to the north, and structures adjoining it, have both been demolished and the rail lines terminating on the site have been removed. A new building has been built which is believed to be the current day building as it is the same location and has the same footprint. A structure in the same location as the existing Network Rail substation is shown. Camley Street to the west of the site is also in place in this map. An excerpt from this map is shown in Figure 13.

Ordnance Survey Map published 1992-1994

On the site to the north of 102 Camley Street, i.e. 104 Camley Street, a new building has been constructed. This map represents the layout of the site in the present day.

2.5 Archaeology

An archaeological assessment of the site has not been carried out for this report.

2.6 Regent's Canal

The completion of the canal from the Paddington Basin to the Grand Junction canal in 1801 led to a proposal to build Regent's Canal. It was proposed in order to link the Paddington Basin to the West India Docks on the River Thames.

Regent's Canal began construction 1812. The section from Paddington Basin to Camden Lock was completed by 1815, when there was a pause in construction due to financial reasons and disputes with land owners. The route was largely determined as a result of these conflicts with land owners. The section of the canal adjacent to the present day 102 Camley Street is between Camden Lock to the west and York Way to the east. This section began construction in 1818 after a series of court cases with the original land owner William Agar. The extent of his land (marked as farmland) is shown in Figure 7. The canal was opened in 1820.

The canal was used for trade and by the 1830s was carrying 0.5m tons of goods per annum, including goods such as coal, bricks, glass, grain, cheese, chemicals and beer. The trade rose to 1m tons per annum by the 1850s, and was maintained between these two levels until after the Second World War when the canal business went into irreversible decline. The last of the commercial traffic passed on the canal in the mid-1960s, after which it was used for leisure purposes only.

The canal is a broad canal up to 5m in width. It originally had earth banks but these were lined with rag stone walls in 1832. These are still in place in some locations but have been replaced by steel caissons with concrete copings in other locations. A towpath present alongside the canal was used for horses, and subsequently barrow tractors, to tow the canal boats. A 400 kV electrical cable passes under the towpath (see Section 4.1.1 for details). The trough coverings of this cable make the towpath foot path.

The canal is under the ownership of the Canal and River Trust which was formerly known as British Waterways.

2.7 Retaining walls

There are two main retaining walls on the site: one at the southern end of the site at the boundary to the towpath and one at the south-eastern end between the site and the Oblique Bridge. The bridge retaining wall is shown in Figure 15. The bridge retaining wall is a concrete and brick structure approximately 1.8 m high measured from the Oblique Bridge.

The towpath retaining wall at the southern end of the site is a red brick structure measuring 2.2 m high at the east side and 2.13 m high at the west side of the site. Photographs of the structure are shown in Figure 16. The ground behind does not appear to come up to the top of the wall.

The site across Camley Street, i.e. 103 Camley Street, was undergoing major construction at the time of the site walkover (November 2013). This included new entrances onto the towpath from the site itself, necessitating new openings in the retaining wall. These are shown in Figure 17. The wall is approximately 0.7 m at the top and increases in width towards the ground, but it was not possible to ascertain the width at the base. The height of the wall is greater than at the east side of the Oblique Bridge adjoining the 102 Camley Street but appears to be made mainly out of the same material.

2.8 Oblique Bridge

The Oblique Bridge, shown in Figure 18, was originally built to carry the drive to Mr. Agar’s house sometime between the construction of the canal (starting in 1818) and the first appearance on maps in 1827. It was rebuilt in the 1840s with cast iron girders and then rebuilt again 1980 retaining the earlier abutments which have gritstone dressings.

The deck is made of pre-stressed concrete beams and in situ concrete reinforced concrete slab. The loads are passed through concrete bearing shelves onto reinforced concrete piled foundations. A drawing of the Oblique Bridge is shown in Figure 19.

The piled foundations of the bridge extend approximately 1.6 m behind the bridge retaining wall. The piles are indicated to be 500 mm and 600 mm diameter in Figure 19. The pile cap is typically 1000 mm depth.

2.9 St. Pancras Station Mainline Railway Bridge

There are two bridges on at the south-eastern boundary of the site: one for the Midland Main Line and one for CTRL, see Figure 20 (a) which is a photograph looking to the east from the Oblique Bridge. The original wrought iron edge girders from the Midland Railway Bridge of 1867 are reused as screens to the new concrete structure as seen in Figure 20 (b).

2.10 Thameslink Tunnel

The Thameslink tunnel runs parallel to the site beneath the CTRL rail lines. The location of the tunnel is shown in Figure 21. It is situated at a distance of about 20m from the site boundary. A cross section through the tunnel at a location further south than the site is shown in Figure 22. This cross section also shows the Thameslink Canal Tunnels that run parallel to the Thameslink tunnel at that point. Further information on the tunnel construction and elevation as it passes the site location will be sought in discussions with Network Rail.

3 Ground Conditions and Geology

3.1 Geological Mapping

An excerpt from the geological map of North London – England and Wales Sheet 256 at a scale of 1:50000 (NERC 1994) is shown in Figure 23. The stratigraphy of the site is as follows: London Clay overlying the Lambeth group, which in turn overlies the fine grained Thanet sand and then chalk. The Lambeth group (previously known as the Woolwich & Reading beds) consists of mottled clay with sand and pebble stones.

3.2 Proximity to Natural Watercourses

The nearest river course is The River Fleet which is now channelled in a sewer. The location of this is shown in Figure 24. It is at the other side of the Regents Canal and is approximately 200 m away. At this distance it is considered unlikely that there would be disturbance to the top of the London Clay as a result of river action.

3.3 BGS Borehole Logs

Logs of thirty boreholes, held in the British Geological Survey (BGS) archive, were reviewed as part of this desk study. All of these were from the Channel Tunnel Rail Link ground investigation. Eight of the boreholes were reported to have reached the London Clay while the other twenty-two examined the Made Ground only and did not reach the London Clay stratum. Reference should be made to Figure 30 to see the location of the boreholes that recorded the top of the London Clay. Figure 31 shows the boreholes in the vicinity that examined the Made Ground only.

The boreholes that did reach London Clay all transitioned directly from Made Ground to the London Clay without coming across any other strata such as River Terrace Deposits or Alluvium. The Made Ground was described as varying from Tarmacadam, reinforced concrete, concrete and brick gravel to dense, brown, silty sandy clay. The London Clay was described as firm to stiff, brown mottled grey clay, and also as brown, closely fissured clay. The level of the top of the strata and associated thickness found in these boreholes are summarised in the following table.

Table 1. Stratigraphy in BGS borehole logs.

Stratum	Approximate Thickness (m)	Top of Stratum (mOD)
Made Ground	2.6 to 5.1	28.4 to 23.8
London Clay	5.2 to unproven	20 to 24.2

3.4 Previous Investigations

Information from previous ground investigations carried out in the vicinity of the site was also reviewed as part of this desk study.

3.4.1 Channel Tunnel Rail Link

Construction of the Channel Tunnel Rail Link began in 1998. An extensive ground investigation took place at the time which included several boreholes within the site boundaries. The stratigraphy found in St. Pancras and Railway Lands area (known as area 100) is shown in the table below.

Table 2. Design stratigraphy from CTRL ground investigation

Stratum	Thickness (m)
Made Ground	1 to 15
Alluvium/Brickearth	0 to 2
London Clay	15 to 37
Lambeth Group (Woolwich and Reading): - Upper Mottled Clay - Laminated Beds - Lower Mottled Beds	5 to 8 0 to 2 7 to 8
Upnor Formation	4 to 5
Thanet Sand	2 to 4
Bullhead Bed	< 1
Upper Chalk	Not proven

The area considered is bounded by Euston Road to the south, the North London Line (NLL) to the north, to the east by the East Coast Main Line and York Way, and to the West by Pancras Road, Midland Road and the Midland Main Line. The site of 102 Camley Street is immediately west of the Midland Main Line. Geotechnical design parameters used in the CTRL project were determined for the Made Ground, the London Clay, Lambeth Group, the Upnor Formation and the Thanet Sand. Presented below are those parameters for the Made Ground, London Clay and the Lambeth Group.

London Clay depth varies significantly across the site from 15m in the south under St. Pancras Station and increasing to 30m in the north of the site and to 35m immediately north of the NLL. The base of the London Clay is recorded as dipping north eastwards across the site, falling from -2mOD in the south west below St. Pancras to -8mOD in the northeast at the junction between the East Coast Mainline and the NLL. Locally the base was found to be depressed due to aggregate piles, but these were not present on 102 Camley Street. The site lies approximately to the west of the most northern quarter of the site. Thus it would be expected that the base of London Clay would lie between these -2mOD and -8mOD on 102 Camley Street.

3.4.1.1 Made Ground

The Made Ground varies in thickness across the site but in the area nearest to 102 Camley Street it was generally less than 2m. It includes sandy clay, clayey sand and very silty sandy gravel confirmed by PSD analyses showing a wide range of gradings. The unit weight is approximately 19 kN/m^3.

The Made Ground varies substantially over the CTRL St. Pancras site and so it was recommended to consult local boreholes in order to determine the bearing capacity and other properties as was necessary for local design cases. The strength of a heterogeneous material such as Made Ground will vary enormously and should be used with caution in design analysis.

3.4.1.2 London Clay

The London Clay is described as stiff to very stiff very closely to extremely closely fissured silty or slightly sandy clay, generally with an overlying mantle of firm to stiff weathered material. Atterberg limits show it to be an inorganic clay of high to very high plasticity. The natural moisture content is generally found to be below the plastic limit, confirming that the clay is of very stiff consistency. The average unit weight is 19 kN/m^3.

The undrained shear strength was determined by carrying out unconsolidated undrained triaxial tests. The distributions for design were selected to be the following:

$c_u = 50 + 15\,z$ kN/m^2 above 3m depth;

$c_u = 75 + 6.5\,z$ kN/m^2 below 3m depth; and

maximum $c_u = 200$ kN/m^2

where z = depth in metres below the top of the London Clay.

SPTs were carried out in during the ground investigation and these were found to be in reasonable agreement with the proposed design distributions above when the correlation by Stroud and Butler (1975) is used. The factor used is based on the plasticity of the soil and was 4.5 in this case. The SPT data best fit line is plotted in Figure 32 alongside the design line above and laboratory test results.

The effective stress parameters were found from results of consolidated undrained triaxial tests. The design values were set as the following:

$c' = 2$ kN/m^2

$\phi' = 25°$

The critical state angle of shearing resistance was assessed using Table 2 of BS8002:1994 as the following:

$\phi'_{cv} = 20°$

The value of K_0 was evaluated from the results of triaxial tests, filter paper suction tests and pressuremeter tests as well as being estimated from supposed geological history, which gave the following value for preliminary design:

$K_0 = 1.4$

The stiffness of London Clay was investigated and the following parameters were chosen for design:

Table 3. Stiffness parameters in the London Clay from CTRL Technical Report 100-RUP-LCEEH-00024-AA.

Stiffness Type	Value
Small Strain undrained (retaining walls)	$E_u = 750\ c_u$ (isotropic) $E_{uv} = 500\ c_u$
Intermediate Strain undrained (foundation settlement)	$E_{uv} = 400\ c_u$ (deep) $E_{uv} = 300\ c_u$ (shallow)
Drained (foundation settlement)	$E'_v = 300\ c_u$ (deep) $E'_v = 220\ c_u$ (shallow)

3.4.1.3 Lambeth Group

The Lambeth Group is described as a very stiff to hard fissured clay with laminations and occasional thin layers of silty fine sand. The units of engineering significance present are the Upper Mottled Clay and the Lower Mottled Beds. Atterberg limits show that the clay is of intermediate to high plasticity and the natural moisture content is generally below the plastic limit as in the London Clay, confirming the stiff to hard consistency. The materials are graded as silty clays, except in the sand layers. The average unit weight was found to be 20 kN/m^2.

The undrained shear strength distribution for design was selected to be:

$c_u = 160 + 5\ z\ kN/m^2$

where z = depth in metres below the top of the Lambeth Group.

The laboratory measurements are plotted in Figure 33 alongside the design line and SPT best fit line. The factor used was 4.5. In this case the SPT best fit data indicated a higher strength than the laboratory test data but the above design line based on the laboratory data was selected for design.

The effective strength parameters were found to have unexpectedly low strength but similar results were found in previous investigations at the British Library site. Thus the adopted parameters were:

$c' = 0\ kN/m^2$

$\phi' = 20°$

The critical state angle of shearing resistance was assessed using Table 2 of BS8002:1994 as the following:

$\phi'_{cv} = 20°$

It was recommended that the design overconsolidation ratio to be 3 and the in situ horizontal stress to be:

$K_0 = 1.0$

The stiffness parameters recommended for use are summarised in the following table.

Table 4. Stiffness parameters in the Lambeth Group from CTRL Technical Report 100-RUP-LCEEH-00024-AA.

Stiffness Type	Value
Small Strain undrained (retaining walls)	$E_u = 1000\ c_u$ (isotropic)
Intermediate Strain undrained (foundation settlement)	$E_{uv} = 450\ c_u$ (deep)
Drained (foundation settlement)	$E'_v = 350\ c_u$ (deep)

3.4.2 103 Camley Street

103 Camley Street is northwest of 102 Camley Street and is a triangular shaped site that also borders Regent's Canal. A ground investigation was undertaken on this site in 2000 by Albury SI and it comprised of two boreholes to 10m and eight trial pits to depths of between 1.2m and 3.8m. The ground level in relation to Ordnance Datum for these is not provided.

The boreholes, shown in Figure 30, found that the Made Ground extended to a maximum of 6.3 mbgl. Below that there was a defined layer of brown silty clay, possibly representing canal excavation arisings, of thickness 0.5 m – 0.6 m. Regent's Canal was completed in 1820, see Section 2.6 for details. Beneath the suspected arisings brown fissured very silty clay with veins of grey clay (i.e. London Clay) was found in the boreholes. The location of the eight trial pits are shown in Figure 31. None of the trial pits reached as far the London Clay stratum.

There are no available geotechnical design parameters for this project.

Table 5. Table of stratigraphy found in the ground investigation of 103 Camley Street.

Stratum	Approximate Thickness (m)	Top of Stratum (mOD)
Made Ground	5.5 - 6.3	unknown
London Clay	4.5 to unproven	unknown

3.5 Likely Stratigraphy

The closest boreholes to the site are SA7375A and SA7376 from the CTRL investigation and BHA and BHB from 103 Camley Street as shown in Figure 30. They were of depths 4.8 m, 4.4 m, 10 m and 10 m respectively. The stratigraphy of these boreholes is given in Table 6. Scanned copies of the borehole logs are in Appendix A.

Table 6. Stratigraphy of the closest boreholes to the site.

Borehole	Made Ground thickness (m)	Made Ground top of stratum (mOD)	London Clay thickness (m)	London Clay top of stratum (mOD)
SA7375A	4.2	+27.74	0.6 - unproven	+23.54
SA7376	3.9	+28.42	0.5 - unproven	+24.52
BHB	6.3	Unknown	3.7 - unproven	Unknown
BHA	5.5	Unknown	4.5 - unproven	Unknown

A summary of the preliminary design stratigraphy is presented in the following table. The thickness of the Made Ground and the tops of the Made Ground and the London Clay are taken from the boreholes presented in Figure 30. The thickness of London Clay was estimated given the base of the stratum was found to lie between -2 and -8mOD in the CTRL ground investigation.

Table 7. Recommended preliminary design stratigraphy.

Stratum	Approximate Thickness (m)	Top of Stratum (mOD)
Made Ground	2.6 to 5.1	+28.4 to +23.8
London Clay	22 to 28*	+22.75
Lambeth Group	12 to 18*	-2 to -8*

*from the CTRL ground investigation

3.6 Groundwater

The following aquifers are typically present below London, and are separated by the impermeable London Clay:

- A ‘shallow’ aquifer contained within the sand and gravel of the River Terrace Deposits; and
- A ‘deep’ aquifer contained within the Thanet Sand and Upper Chalk Formations.

Previous investigations on site and in the vicinity have indicated that the River Terrace Deposits are not present on the site and a shallow aquifer is deemed unlikely to be present. However, there may be localised pockets of perched groundwater in the Made Ground.

Groundwater level (GWL) readings were taken during the CTRL GI in boreholes SA7375A and SA7376 marked in Figure 30. These were monitored weekly for a period of three months after installation. The GWL varied between 2.2 and 3.91mbgl in SA7375A and between 3.09 and 4.11mbgl in SA7376. These readings were all taken between June and September 1997.

The railway lines to the east of the site are likely to have had extensive drainage installed during the construction of CTRL and this would have aided drainage in the vicinity of the site.

Groundwater levels in the boreholes on the 103 Camley Street ground investigation were also monitored. Both BHA and BHB (see Figure 30 for locations) were dry during installation on 27/11/00 and 24/11/00 respectively. On 27/11/00 both measured groundwater. The GWL was 4.5mbgl in BHA and 6mbgl in BHB. No monitoring was recorded after this.

Referring to the deep aquifer, information obtained from the Environment Agency in 2010 suggests that the piezometric level was at approximately -32mOD. Investigations and foundations for the proposed structure are not expected to penetrate into the deep aquifer at this location.

4 Potential Ground Hazards

4.1 Underground structures

Underground structures exist at the location of 102 Camley Street, including the foundations of the existing building. Other underground structures such as utilities are also known to be present. Unknown underground obstructions to building works may be present, and ground investigation is required to locate these.

4.1.1 Utilities

4.1.1.1 Thames Water

There is a 200mm Distribution Main, including a general purpose valve, on the Camley Street boundary of the site. This was laid in 1979-1980. There are other water mains including a foul and a surface water mains in the centre of Camley Street, but these are approximately 4m or more from the site boundary.

4.1.1.2 National Grid

An underground electricity cable runs along the Regent's Canal towpath. This is a 400 kV three phase cable that has ancillary cooling equipment. In places the cables and the boxes with cooling equipment measure approximately 2m by 1.2m in area. A smaller electricity cable of 300mm diameter runs along the opposite side of Camley Street to the site.

4.1.1.3 BT

There is a BT distribution point containing a joint box on the southwestern corner of the site. One cable from this box is indicated as traversing the road away from the site and the other as traveling inside the boundary along the orientation of Camley Street, terminating prior to the cutting that leads to the Regent's Canal towpath.

4.1.1.4 BskyB

BskyB telecommunications have indicated that the site is affected by one of their routes, but did not provide a map indicating where this was.

4.1.1.5 Instalcom

Instalcom covers several companies including Level 3, Global Crossing and Fibernet. Two of these are in close proximity to the site. One is along the rail lines to the east of the site and the other follows the same path as the National Grid electricity cable under the towpath to the south of the site.

4.1.1.6 Network Rail

Network Rail have utility assets on the rail line to the east of the site. There is a Network Rail substation between the site and the railway lines to the east and it is possible that some cables accidentally cross the site, although no indication of this is given in the utilities records.

4.1.1.7 UK Power Networks

UK Power Networks have high voltage electricity cables running alongside the western boundary of the site on Camley Street that continue over the Oblique Bridge.

4.1.1.8 Unaffected Utilities

As part of this desk study a request was made to utility service providers via Groundwise Searches Ltd for information on existing services at the site including plant, pipes and cables. The following utilities were not found to be affected:

- Electricity cables including SSE, Energetics, Colt, London Underground cables;
- Communications including Interoute, Airwave, T-mobile, Orange, O2 UK, Network Rail, Vodafone, 3, Verizon and Zayo;
- Gas pipelines including ESP Connections (formerly British Gas Connections) and Fulcrum Pipelines Limited;
- Others such as Transport for London traffic control equipment, Ministry of Defence Estates, Tata and KCOM Group.

This list is not exhaustive as not all utility companies responded prior to completion of this study. These companies may or may not have assets within the site boundaries.

4.1.2 Old Foundations

During a site walkover in November 2013 concrete footings were seen on the Camley Street site of the warehouse. Photographs of these are seen in Figure 25. They are possibly the old foundations of some small structures that appear on the 1896 map on the western boundary of the site.

4.2 Contamination

Refer to Section 5 for details of the contamination ground hazards.

4.3 Unexploded Ordnance

London was heavily bombed during World War II and as shown in Figure 26 there was a high density of bombs dropped in the south of the Borough of Camden, i.e. the area the site is located in. There are also detailed bomb damage maps for London that indicate the building by building damage that occurred. It must be noted that not all damage was recorded on these maps, including damage to rail stations, and therefore more significant damage than is indicated by the maps may have occurred. An excerpt from these maps is shown in Figure 27. It shows that there was no damage recorded on the site itself, but that within the vicinity there were buildings that were damaged beyond repair (purple coloured) and buildings with general blast damage (orange coloured).

Given the bombing in the area, it is possible that unexploded bombs (UXO) remain present on the site. Unreported UXO is ordnance that penetrated the ground but failed to explode and went unnoticed or unreported. It is relatively rare in urban areas but a potential risk in uninhabited areas or over water.

A preliminary UXO risk assessment should be undertaken in advance of any intrusive works. This risk assessment should be based on data obtained in a desktop review of the site location, site history, wartime bombing records and other data. This is presented in the table below.

Table 8. Assessment criteria and hazard potential of UXO at this site

Assessment Criteria	Hazard Potential
Site location	The site is located on Camley Street near Regent's Canal in the Borough of Camden, London.
Proximity of site to potential targets	The site is located in close proximity to the King's Cross and St Pancras railway stations as well as being adjacent to Regent's Canal. As such the site would have been considered as a priority bomb target by enemy aircraft.
Local bombing history	Central London was heavily bombed by enemy bombs during World War II, with significant damage to buildings in the vicinity as discussed above.
Mitigating factors	A warehouse was constructed on the site in the 1970s and no UXO was discovered. However the current proposals would likely have deeper foundations than the existing building.

Having considered the assessment criteria and hazard potential above, there is sufficient potential for UXO present at the site to warrant a further risk assessment.

4.4 Flood Risk

The Environment Agency's Flood Data Map is reproduced in Figure 28. It shows that there is very little risk of flooding on this site. This is despite the location of a canal on the site boundary. The water level in the canal is at least 4.5m below ground level on the site.

The River Thames is at a distance of approximately 3 km to the south and the site is 24m above the elevation vulnerable to flooding and so the River Thames is not considered to be at risk of flooding the site.

In addition there is no history of flooding on the site. RMS data with a return period of 1000 years indicates that there is no susceptibility to pluvial or minor river flooding as shown in Figure 29.

In correspondence the Environment Agency have said that they do not deal with any consents for the canal or hold any data for it as Regent's Canal is not designated as a main river by Defra. They indicated that it is not considered a flood risk.

4.5 Archaeology

An archaeological assessment of the site has not been carried out for this report.

5 Preliminary ground contamination assessment

5.1 Introduction

Land contamination is regulated under several regimes including environmental protection, pollution prevention and control, waste management, planning and development control, and health and safety.

The National Planning Policy Framework (NPPF) places responsibility on the developer of the land for ensuring that development is safe and suitable for use for the purpose for which it is intended which will include dealing with historic contamination of the ground to the satisfaction of the local authority and Environment Agency. The NPPF defines site investigation information as including a risk assessment of land potentially affected by contamination. It states that all investigations of land potentially affected by contamination should be carried out in accordance with established procedures.

The UK framework for the assessment of contaminated land endorses the principle of a "suitable for use" approach to contaminated land, where remedial action is only required if there are unacceptable risks to health or the environment, taking into account the use of the land and its environmental setting. For land to be determined as contaminated and require remediation (or possibly a change to less sensitive use), all three elements of a source, pathway and receptor (SPR) 'plausible pollutant linkage' (PPL) must be present.

An appraisal of the site sensitivity and historic potentially contaminative activities has been carried out on the basis of a review of an Envirocheck report, Goad insurance plans, the London Borough of Camden records and information provided by the Environment Agency.

The risk characterisations provided in this section have been assessed in a scale from very high/ high/ moderate/ low to very low. If a particular PPL is absent or not applicable then the risk has been assessed as negligible.

5.2 Site setting

5.3 General

As detailed in Section 2.1 the site is currently in commercial use and occupied by a warehouse, located in an area of mixed commercial and residential use. A building up to 12 storeys and a one level basement is proposed to be developed on site. This will be for mixed use, with plant equipment based in the basement and ground floor, commercial activities in the basement up to the first floor, and residential apartments from the first floor upwards. A soft landscaped grassed area with trees is proposed to the west of the building, but the basement extends beneath this area.

5.3.1 Environmental permits, controls and designated areas

The Envirocheck report identifies three discharge consents within 1km. Two are located 758m southeast, for the release of cooling water via boreholes into the ground. The other, 797m east, is for the discharge of cooling water into the Grand Union Canal.

The closest local authority pollution prevention and control permit is held 345m north east, for cement blending, packing, loading and use. Eight dry cleaners are located within 1km and the closest is located 349m south west.

Two pollution prevention and control enforcements are within 1km. These relate to dust emissions from the Kings Cross depot and British Rail goods yard, located 377m and 413m north east, respectively.

Nine minor (category 3) pollution incidents are recorded in the Envirocheck report within 1km, all pre-1999. The closest incident involved a 'natural' pollutant 108m south in August 1998. Oils were noted to have been released 280m east in February 1998. Kings Cross goods yard (530m east) were fined for emitting cement dust in October 1998. Environment Agency records show seven further pollution incidents within 500m of the site, between 2001 and 2011. These incidents had a minor to no impact (category 3 to 4). The seven incidents were between 240m and 470m from the site. The incidents involved either fire fighting run-off, oil or fuel, construction and demolition materials, smoke or spillage of contaminated water. The oil or fuel release had no impact (category 4) to air, land or water.

The nearest registered radioactive substances is at the Royal Veterinary College (240m west).

Kings Cross Goods Depot (87m east) was a permitted waste management facility; the permit has now been surrendered. The Environment Agency have confirmed that seven waste management licences have been found within 500m of the site, but all of these have now been surrendered or are no longer operational. Transco (492m south east) holds a notification of installations handling hazardous substances.

Contemporary trade directories show an inactive motor garage 10m north west. The closet petrol filling station is 452m east and is obsolete. The nearest active petrol filling station is located 855m north.

No radon protective measures are necessary in the construction of new dwellings/ extensions as less than 1% of homes are above the action level.

A local nature reserve, Camley Street Nature Park, is 187m south east.

5.4 Ground conditions

The ground conditions are described in detail in Section 3, with the likely stratigraphy found on site summarised in Table 6. There is likely to be 2.6m to 5.1m of Made Ground across the site. The bedrock geology consists of London Clay, Lambeth Group, Thanet Sands and Chalk. The London Clay is reported to be between 22 to 28m thick.

Perched water may be present within the Made Ground. The Made Ground is underlain by a significant thickness of the unproductive London Clay. The Lambeth Group is a secondary aquifer and chalk is a principal aquifer. The closest source protection zone is 761m east of the site.

The nearest surface water feature is Regent's Canal, 7m south of the site boundary. The river quality (based on a general quality assessment) of the canal 50m south west of the site was recorded as grade C (fairly good) in 2000.

Water is abstracted from the Grand Union Canal 117m south for the purpose of non-remedial river/ wetland support. The closest groundwater abstraction point is 274m north and used by Kings Cross Concrete Plant with a licence to abstract 33,400 cubic metres per year. The borehole is118m deep and abstracts from the Chalk aquifer.

5.5 Site history and potential contamination sources

An appraisal of the site history has been carried out on the basis of a review of historical map extracts and records. The site history is described in detail in Section 2.4. Developments relevant to the potential for contamination at the site are considered below.

Table 9 Summary of site history and significant potentially contaminative uses and activities

Map	Description
1741-1745	In the earliest available illustration, John Roque Survey of London, the site is shown to be undeveloped. An excerpt is shown in Figure 5.
1805-1822	The site remains undeveloped. To the south Regent's Canal has been developed (completed around 1820). Given the site is directly adjacent to the canal, it is likely that it was used for the storage of materials e.g. arisings. An extract from the map can be seen in Figure 6.
1827	The site is marked as farmland. The Oblique Bridge across the canal has been constructed. An excerpt from this map is shown in Figure 7.
1851	The site is now crossed (from west to east) by two roads named Winchester Street and Salisbury Crescent. There are no buildings noted on site. Significant development in the surrounding area has occurred. Saint Pancras station is approximately 100m to the north of the site, surrounded by the Midlands Counties Railway Goods Depot. Approximately 60m to the east is the Great Northern Railway Coal & Goods Depot.
1873-1874	The site forms part of the goods depot for Midlands Railway (by 1873). There are no buildings indicated on site although railway lines terminate in the eastern part. Immediately east are a number of railway lines passing from north to south. A rail bridge has been constructed across Regent's Canal adjacent to the Oblique Bridge. Other features, associated with the goods depot include a train repairing shed (60m north east), train cleaning shed (100m north east) and coaling sheds (120m north east). An excerpt from this map is shown in Figure 9.
1875-1877	A cutting is shown on the southern end of the site next to the canal between the road bridge and the rail bridge.
1891-1895	The building to the north, part of the goods depot, has extended up to the northern boundary of the site. The Goad insurance plans (from 1891) show the goods depot to store beer and wine in the single basement. A small structure is shown on the western boundary.
1916	Additional rail tracks terminate on site. There are three new structures on site with two adjacent to the goods depot (immediately north) and a structure in the southern part. An extract is shown in Figure 11.
1942 and 1946	Goad insurance maps show the structures adjoining the main warehouse to the north of the site were being used for van storage, tarpaulin storage and as a mess room. The most eastern structure is labelled as an electrical substation. It is at the location of the existing Network Rail substation.

Map	Description
1951	Central London was heavily bombed by enemy bombs during WWII. The site is situated in close proximity to King's Cross and St Pancras railway stations as well as being adjacent to Regent's Canal. As such the site would have been considered as a priority bomb target by enemy aircraft. Historical building plans show the closest area cleared due to enemy action was 173m south west. This was discussed in detail in Section 4.3. The 1946 aerial photo shows the site may have been used for the storage and possibly maintenance of rail related infrastructure and equipment, possibly rain wagons.
1953	A large building 30m south is noted to be in ruin, which is considered to be due to bomb damage from WWII.
1954	Saint Pancras Hospital is located approximately 60m to the west.
1960-1971	Camley Street has been constructed immediately to the west. On the opposite side of Camley Street and Regent's Canal, 20m west of the site, a vehicle park is noted. Asbestos in the building fabric 52m north in Goad insurance plans. A diesel depot (as labelled on Envirocheck maps) is noted 72m east with ten oil tanks marked on Goad insurance plans with a pump house. The railway tracks branch off the main line and meet the cluster of tanks, considered to be for refuelling activities. An electrical substation is nearby the tanks (60m east of the site).
1980-1988	A new building has been built which is believed to be the current day building as it is the same location and has the same footprint. As detailed in Section 2.1 this building is single storey with no basement. A structure in the same location as the existing Network Rail substation is shown. An additional electrical substation is approximately 20m to the west. The goods depot to the north, and structures adjoining it, have both been demolished and the rail lines terminating on the site have been removed. A smaller depot is shown approximately 40m north with an associated tank (at the south eastern corner of the depot building). An extract is shown in Figure 13.
1991	Immediately north of the boundary 104 Camley Street is noted. This map is relatively representative of the current layout of the site.
2013	The warehouse on site is currently occupied by Marigold Health Foods.

5.6 Consultation

Arup submitted requests for an environmental search to both the local authority and Environment Agency to inform this desk study. The information has been incorporated into the table above and additional data is described below.

The Environment Agency stated that their records do not contain information on past investigation or remediation activities at the site. The local authority has not determined the site area as 'contaminated land' under Part 2A of the Environment Protection Act 1990. The sustainable places team (part of the Environment Agency formerly known as planning liaison) are not aware of any fuel tanks on site.

The Environment Agency has recorded a ground investigation within a 500m radius. The application to redevelop the southern part of Kings Cross Central (500m south of the site) for mixed development (railway land, commercial and residential) was received in 2004. Formerly this Kings Cross site was occupied by gasworks, a series of gasholders and an engine house. The environment statement from May 2004 stated that the Kings Cross had contamination in the Made Ground, and in the perched groundwater above the London Clay. This included areas of high concentrations of metals (particularly copper, lead, zinc and cadmium) and moderate concentrations of hydrocarbons potentially from refuelling activities. Remediation comprised of 'hot spot' removal, on site treatment in certain areas and cement stabilisation to reduce the combustibility and mobility of coal rich material.

5.7 Potential for contamination

In summary potential contaminative sources include:

1. The site is likely to include Made Ground of unknown origin, although this may partly comprise arisings from excavating the Regent's Canal, demolition waste and materials associated with the railway. It is not unusual for such material to include ash and clinker, along with building rubble and sometimes industrial waste. Contaminants may include metals, hydrocarbons and asbestos.
2. Electrical substation on site from the 1940's is likely to have included oils containing polychlorinated biphenyls (PCBs).
3. The site formed part of a rail depot and may have been used for rail maintenance. A range of contaminants are associated with such activities, particularly fuels, oil and asbestos.
4. Bomb damage off site may have resulted in the distribution of asbestos (for instance in building rubble) and leaks of stored fuels and oils. There is a potential for UXO on site. The proposed development foundations will be deeper than the existing building on site built in the 1980's.
5. Railway line immediately east from 1850's with associated depot and cluster of oil tanks. East of the site may be a source of contaminants including metals, hydrocarbons, PCBs, solvents, detergents and herbicides.
6. The existing or previous buildings on site may have included fuel and oil tanks which may have leaked.

No heavy industry has been located on site such as gasworks or fuel depots etc. The site formed part of a rail depot for many years and aerial photographs suggest related equipment, possible goods wagons or other rail vehicles, may have been stored or even maintained on site. Rail users, and particularly maintenance, may often results in contamination of the ground due to leaks and spills of oils or other hydrocarbons and asbestos. The site has noted to be occupied by a vehicle store and electrical substation until it was developed for the modern commercial building in the 1980's. Some contamination may have been removed during the development of the commercial building although this is not known. There is a potential for some residual contamination within the Made Ground and perched groundwater. The potential for significant contamination on site due to its history of being part of railway land is considered to be low to moderate.

The potential for significant contamination affecting the site due to off-site sources is considered to be low, as neighbouring sources were similar in nature (rail use). More significant gasworks and other heavy industry were located in the vicinity but were considerable distances considering the ground conditions (London Clay). Key sources include the railway immediately east and associated rail activities including potential refuelling at the cluster of oil tanks, along with engine cleaning/ repair, coaling sheds and depots.

5.8 Potential receptors

The following potential receptors have been identified during the construction and operation phases of the development:

- construction workers (particularly groundworkers) and neighbours during construction (occupants of adjacent residences, employees of adjacent businesses and general public);
- site users after development including workers, adult/ child residents and visitors;
- maintenance/utility workers after development;
- deep groundwater in the chalk aquifer during and after development;
- surface waters, in particular the nearest feature being Regent's Canal (7m south), although this is unlikely to be linked;
- plants and vegetation after development; and
- building materials and services in contact with aggressive ground conditions.

5.9 Plausible pollutant linkages (PPL)

A consideration of the PPL associated with the potential sources of contamination, as defined by the desk study report is outlined in Table 10. The associated risk classifications are shown in Table 9. The assessment takes into consideration the proposed development and the linkages that may be present during the construction and operational phases.

Table 10 Risk classifications

Risk classification	Description of risk
Very high	There is a high probability that severe harm could arise to a receptor from an identified hazard, or there is evidence that severe harm to a designated receptor is currently happening. The risk, if realised, is likely to result in substantial liability. Remediation is likely to be required.
High	Harm is likely to arise to a receptor from an identified hazard. Realisation of the risk is likely to present a substation liability. Remedial works may be necessary.
Moderate	It is possible that harm could arise to a receptor from an identified hazard. However, it is either relatively unlikely that any such harm could occur, or if any harm were to occur it is more likely that the harm would be relatively mild. Some remedial works or preventative measures may be required.
Low	It is possible that harm could arise to a receptor from an identified hazard but it likely that this harm, if realised, would typically be mild. Some preventative measures to further reduce the risk may be required.
Very low	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised the consequence would at worst normally be mild or not noticed. Remediation and/ or mitigation is unlikely to be required.
Negligible	No conceptual link between a potential source and receptor identified.

Table 11 Plausible pollutant linkages

Receptors	Pathways	PPL	Risk classification
Human health			
Site workers (during construction)	Ingestion of soils, dust and/or groundwater. Dermal contact with soils, dust and/or groundwater. Inhalation of dust, fibres and/or vapour.	Yes Workers are likely to come into direct contact with the soil (considered to be Made Ground over London Clay) and potentially perched water when carrying out groundworks, particularly during the basement excavation. Workers may be exposed to gases and vapours when working in confined spaces.	Moderate Reducing to very low following investigation, assessment and remediation or mitigation as necessary.
Visitors (during construction)		Yes Soil may be exposed during visits.	Low Can be reduced to very low (as above).
Neighbours (during construction)	Inhalation of dust. Dermal contact with dust.	Yes Neighbours may be exposed to fugitive dust and fibres.	Low (assuming normal good construction practice) Can be reduced to very low (as above).
Future site users, including residents and visitors (during operation)	Ingestion of, and dermal contact with soils and dust, and inhalation of dust (outdoor). Inhalation of, and dermal contact with dust (tracked back to buildings).	Yes A significant amount of the Made Ground will be excavated during the basement excavation, although some is likely to remain. Landscaped area is proposed.	Low. It is assumed there will be limited contact with residual made ground. Reducing to very low (as above).
	Inhalation of ground gases and vapours.	Yes Potential vapour and gas sources may remain on site in the Made Ground and around the edge of the construction.	Low Reducing to very low as above and appropriate gas protection if required.
Future maintenance workers (during operation)	Ingestion of soils, dust and/or groundwater. Dermal contact with soils and/or groundwater. Inhalation of dust, fibres and/or vapour.	Yes Landscaped area proposed and some Made Ground is likely to remain.	Low to moderate Reducing to very low (as above).
Controlled waters			
Surface water (Canal) Assumed to have limited contact with groundwater	Lateral and vertical migration of non-aqueous phase liquids (NAPL).	Yes (but unlikely) Some Made Ground will remain with the potential of perched water. However water level in canal is higher and unlikely to be	Very Low Investigation to confirm the ground conditions.

Receptors	Pathways	PPL	Risk classification
and likely higher water level		connected.	
	Leaching of unsaturated zone and dissolved phase migration	Yes (but unlikely) Same as above.	
Deeper Chalk principal aquifer	Vertical migration of NAPL or dissolved phase contamination to Chalk	No The underlying London Clay (considered to be 22 to 28m thick). All piles terminate in the London Clay.	Negligible
Buildings and services			
Below-ground building materials and services	Direct contact with soils and groundwater. Vertical migration of dissolved phase contamination.	Yes Made Ground will remain and potential for contamination (if present, in particular from off-site sources) to affect building materials and services.	Low Assuming contamination is investigated and remediated (if found), and appropriate service materials are used then this risk can be reduced to very low.

5.10 Summary

The risk classifications for the site are summarised in Table 11 below.

Table 12 Summary of risk classification

Risk Description	Risk Classification
Potential for contamination on site	Low to moderate (potential for asbestos)
Potential for contamination from off-site sources	Low (limited by ground conditions)
Site sensitivity	Very low (underlain with London Clay, canalised surface water, commercial urban setting)
Risk of harm to human health during development	Moderate (without mitigation) reducing to very low
Risk of harm to human health during operation	Low (without mitigation) reducing to very low
Risk of pollution of groundwater	Negligible
Risk of pollution of surface water	Very low
Risk of damage to building materials and services	Low (without mitigation) reducing to very low

5.11 Recommendations

It will be necessary to undertake a detailed ground investigation and subsequent contamination assessment to inform the development and satisfy typical planning requirements. The local authority confirmed a condition would be included on the planning consent. The following scope of the works is recommended:

- Initial site reconnaissance to investigate remaining potential contaminative sources, access and surface conditions on site.
- Recover environmental samples from boreholes and trial pits. Chemical analysis of soil, groundwater and gas/ vapour. Testing would include a suite of metals, total petroleum hydrocarbons (TPH), polyaromatic hydrocarbons (PAH), benzene/ toluene/ ethylbenzene/ xylenes (BTEX), polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs), herbicides, pH and asbestos in Made Ground soil samples.
- Waste materials, including those excavated for the basement would require waste acceptance criteria testing (leachability testing included in suite above).
- Boreholes will be installed across the site to allow for groundwater and gas/ vapour monitoring over a set period. It may be necessary to undertake the ground investigation in phases with return visits to the site to monitor installed locations.
- The investigations should include boreholes and standpipes on the boundary of the site to monitor for off-site contamination.

The planning consent condition may require agreement of the scope of the investigation. On completion of the ground investigation, the risk assessment presented above will be updated with a quantitative assessment in accordance with UK framework.

Previous site development may have reduced/ or locally removed historic contamination (if it was present). The inclusion of a basement in the proposed development may further expose and reduce historic contamination. Excavation for the basement will remove a significant amount of the Made Ground, although some is likely to remain as the basement becomes subterranean only in the northern part (due to the current slope towards the canal). Disposal costs of the excavated soil will increase if found to be impacted by contamination.

If contamination is identified the local authority will expect to agree and approve a remediation strategy and verification strategy, and once that remediation is complete a verification report to be submitted. If the groundwater is found to be contaminated then specific clean up may be required depending on the quantitative risk assessment. Early consultation with the local authority is usually beneficial.

Surplus soils arising from the excavations requiring disposal should be disposed of in accordance with the current waste management regulations and guidance, or sent to off-site treatment/recycling centres. It is necessary to carry out waste classification and compliance testing in line with current regulations prior to export from site. It is now a legal requirement to treat wastes before disposal. Treatment may occur on site or alternatively off site treatment facilities may be utilised. This may also minimise the amount of hazardous waste and maximise the quality of inert waste for disposal.

The Contaminated Land Officers (CLO) at the Local Authority should be notified prior to the start of each phase of ground investigation and assessment. They will be consulted on the findings of the reports and the updated risk assessment and remediation strategy will be submitted and agreed in accordance with the planning conditions.

6 Geotechnical Design

The main geotechnical elements that need designing are:

- The retaining structure for the basement; and
- The foundations of the structure.

There will also be temporary works considerations in relation to maintaining the lateral support for the bridges and the railway.

6.1 Shallow Foundations

Due to the heavy loading of the 12 storey sections of the proposed development it is unlikely that shallow foundations alone will be sufficient under these parts of the site. Site investigation is needed to determine if shallow foundations would be suitable elsewhere. Due to the potential variability and limited capacity of the Made Ground it is likely that any significant building on the site will need to be founded on the London Clay. Any necessary roads, paths etc. may be founded at shallow depths, but only if the engineering behaviour of the locally occurring Made Ground is understood fully.

6.2 Piled Foundations

Where shallow foundations are not practical piles may be required to support any heavier structures. Types of piles are assessed below for suitability.

6.2.1 Rotary Bored Piles

Large diameter rotary bored piles may be considered where large foundation loads are anticipated. During construction bored piles have the advantage of producing little vibration with only the noise of a rig power pack.

6.2.2 Continuous Flight Augered (CFA) Piles

Construction of CFA piles has the advantage of having little vibration and is comparatively quiet. Their length will typically be limited to 30 m for the largest available equipment, and 26 m for commonly available equipment. Further ground investigation will be required in order to understand whether casings would be required in the Made Ground.

6.3 Preliminary foundation design

A preliminary pile design chart for a range of diameters from 600 mm to 1200 mm has been prepared in accordance with the LDSA guidance 2009.

Ultimate Shaft Capacity

$\mathbf{Q_{su}}$ = $\alpha\, c_u\, \pi\, D\, L$

Q_{su} = Ultimate shaft capacity, kN;

c_u = Average undrained shear strength over the pile shaft:

50 + 15 z kPa (z above 3 m depth)

75 + 6.5 z kPa (z below 3 m depth)

(where z is depth below top of stratum);

α = Average shaft adhesion factor = 0.5;

D = Pile diameter, m;

L = Pile length in London Clay, m.

Limit α c_u = 110 kPa

Ultimate Base Capacity

$\mathbf{Q_{bu}}$ = $N_c C_u A_b$ **-** (ultimate base capacity), kN

$\mathbf{C_{ubase}}$ = Undrained Shear Strength at pile toe level, kPa;

N_c = Bearing Capacity Factor = 9 (Characteristic value used in the London Clay);

A_b = Pile base area, m^2.

Based on the guidance of the LDSA (2009) an overall factor of safety of 2.6 and factor of safety on shaft alone of 1.2 has been assumed for the design of the piles with no preliminary pile testing.

The Allowable (Safe Working) Load in compression is therefore defined as:

$\mathbf{Q_w}$ **=** Lesser of $(Q_{su} + Q_{bu})/F_g$ or Q_{su} / F_s

Q_w = Design working capacity (total stress), kN;

Q_{su} = Ultimate shaft capacity, kN;

Q_{bu} = Ultimate base capacity, kN;

F_s = Factor of safety on Shaft = 1.2;

F_g = Global factor of safety = 2.6.

The pile design chart is presented in Figure 34. A preliminary pile design has been considered based on an assumed column grid with spacing of 7.5 m by 7.5 m and a loading of 8 MN/column.

A range of pile diameters from 600-1200 mm were considered in order to get a suitable working capacity. The length of the piles is limited by the thickness of the London Clay. In this location the thickness is approximately 22 m to 28 m, see Section 3.5 for details. It is advisable to ensure that the piles do not penetrate into the 3 m closest to the base of the London Clay as it may have sandy inclusions. This constraint has been indicated by a line at +1mOD on the pile capacity chart. This depth should be confirmed in the site specific ground investigation.

Based on a column load of approximately 8 MN it is considered that 4 No. 750 mm diameter piles per column at a toe level at +1mOD or 4 No. 900 mm diameter piles with a higher toe level are potential appropriate solutions. 2 No. 1200 mm diameter piles per column is also a potential solution but would involve a bigger piling rig.

The underside of the basement is expected to be at approximately the level of the top of the London Clay. In this case, a piled raft solution may provide a viable foundation design, in which the contribution from a raft foundation could be optimised. The basement is a single story with a height of 3.5 m. The following assumptions have been made in the design:

- A 1 m thick slab;
- A 3.5 m excavation;
- An average c_u over the 2/3 base of 83 kPa;
- Square foundation with no inclination of load or foundation.

The gross bearing capacity is found using this formula:

$$q_{fgross} = 5.14\, c_u\, b_c\, s_c\, i_c + q$$ from EC7 Annex D

where b_c is a factor for the inclination of the base (1 in this case)

s_c is a factor for the shape of the foundation (1.2 in this case)

i_c is a factor for the inclination of the load (1 in this case)

q is the overburden (85.5 kPa in this case)

The gross bearing capacity is found to be 597 kPa. The gross working stress is 166 kPa from the building above. The factor of safety is the net bearing capacity divided by the net working load and is found to be 6.3.

Therefore there would be sufficient bearing capacity and the issues would be adequate design of the raft to support heavy column loads and considerations of settlement. In this case piles could be included as settlement reducing piles to reduce load and differential settlement. These piles would operate with a factor of safety close to 1 and so could reduce the piling requirements significantly from the fully piled solution.

6.4 Basement Options

The one level basement will have a floor level approximately 3.5 m below ground level which is above the water level in the canal. The topographical survey indicated that the water level in the canal was at +23.12 mOD, i.e. 4.58 m below the current site level of +27.7 mOD. A contiguous or secant piled retaining wall, depending on the water conditions found during the ground investigation, will be installed in order to support the basement.

6.4.1 Preliminary retaining wall design

A preliminary design of a retaining wall was carried out for this site in order to understand potential wall movements and impact on adjacent structures and infrastructure. The wall type chosen for this preliminary analysis was a hard-soft secant piled retaining wall with 600 mm diameter piles at 750 mm centres.

Contiguous piles should also be assessed for suitability. The Oasys software for retaining walls FREW was used to model a 2D section of the retaining wall on this site.

The wall was modelled to be 6.5 m deep, i.e. extending 3 m below a 3.5 m deep basement. The wall at the eastern side of the site was modelled as the loading from the railway was considered to be the worst case. The position of the retaining wall considered is shown in Figure 35. Although the wall will not be exactly on the boundary of the site it was modelled as such, which is conservative, because the exact position of the retaining wall is not yet confirmed. The distance from the lines was thus modelled as 3 m, although in the majority of the site it is much further from the rail lines.

The software allows the construction stages to be modelled. The following stages were used:

Stage	Description
1	Initial conditions
2	Wall installation
3	Excavation of 0.75 m
4	Installation of prop at the top
5	Excavation to formation level (+23.75 m OD)
6	Installation of base slab
7	Installation of the ground floor slab and prop removal
8	Wall relaxation
9	Long term conditions

The soil parameters used were the design parameters found in previous investigations such as the CTRL GI. The parameters for London Clay used were given in Section 3.4.1.2. The other stratum relevant for the model was the Made Ground. The parameters for this stratum included a lower stiffness than the London Clay (i.e. 5000 kN/m^3), K_0 = 1 and ϕ' = 25°.

The groundwater was modelled as the maximum found during in monitoring (i.e. +25.54 m OD) with an additional 0.5 m. The water table was modelled below the excavation where relevant.

For the high stiffness support construction sequence modelled, maximum wall deflection and maximum ultimate limit state bending moments can be reasonably accommodated in 600 mm diameter piles. Analysis of the ground movements due to the deflection of the basement retaining wall was carried out. Using the method from CIRIA C580 the deflection of the wall as calculated by FREW was used to find the ground surface settlements. The maximum ground settlements for the nearby rail lines were predicted to be approximately 4 mm. This is considered to be the worst case analysis using this design and is expected to be well within allowable limits. The predicted movements behind the wall, alongside the deflection over the depth of the wall are shown in Figure 36.

The retaining wall design presented here is just one of several options. For example a contiguous piled wall could be considered if the water pressures in the ground were understood better. A site specific ground investigation would aid this understanding. Additionally, taking into consideration construction constraints, an option of a stiffer retaining wall not propped at the top could also be considered provided that movements remain within acceptable limits.

A preliminary assessment of the potential damage to the nearest neighbouring building to the north (a warehouse) was carried out using the damage categories from Burland (1997). The maximum ground movement found due to the deflection of the wall was much less than 10 mm. This threshold, alongside a building slope of less than 1/500, was reported by Burland (1997) to have negligible risk of damage.

Further liaison with Network Rail will be required in order to ensure ground movements arising from the proposed works are within the allowable limits.

7 Recommendations for ground investigation

It is recommended that a full site visit be carried out prior to a ground investigation. In addition this report should be augmented should anything be found during this site visit. A UXO risk assessment should also be carried out prior to ground investigation.

Although this review provides design parameters these should be supplemented with a site specific ground investigation in order to determine:

- The thickness of the Made Ground;
- The thickness of the London Clay;
- Details of buried obstructions such as the foundations of the existing building;
- Design parameters for the materials underlying the site;
- If any part of the ground is contaminated; and
- The ground water level.

This information will inform the design of the basement and building foundations. This document has an associated basement impact assessment prepared for the London Borough of Camden.

8 References

Bath Spa University, accessed November 2013. Greenwood's Map.

Bing Maps, published 2013.

British Geological Survey, published 1994. North London England and Wales Sheet 256, 1:50000 Series.

Burland, J.B.; Assessment of risk of damage to buildings due to tunnelling and excavation. Earthquake Geotechnical Engineering, Isihara (ed.), Rotterdam, 1997.

Card Geotechnics, produced September 2011. Contamination and Remediation Assessment of 103 Camley Street.

Envirocheck, produced October 2013. Commissioned report on 102 Camley Street.

Groundwise, produced October 2013. Commissioned report on 102 Camley Street.

London and Continental Engineering, produced 1997. Channel Tunnel Rail Link Technical Report No. 100-RUP-LCEEH-00024-AA.

London Topographical Society, published 2005. London County Council Bomb Damage Maps 1939-1945.

Zetica, downloaded October 2013. London (East Central) unexploded Bomb Risk Map.

9 Figures

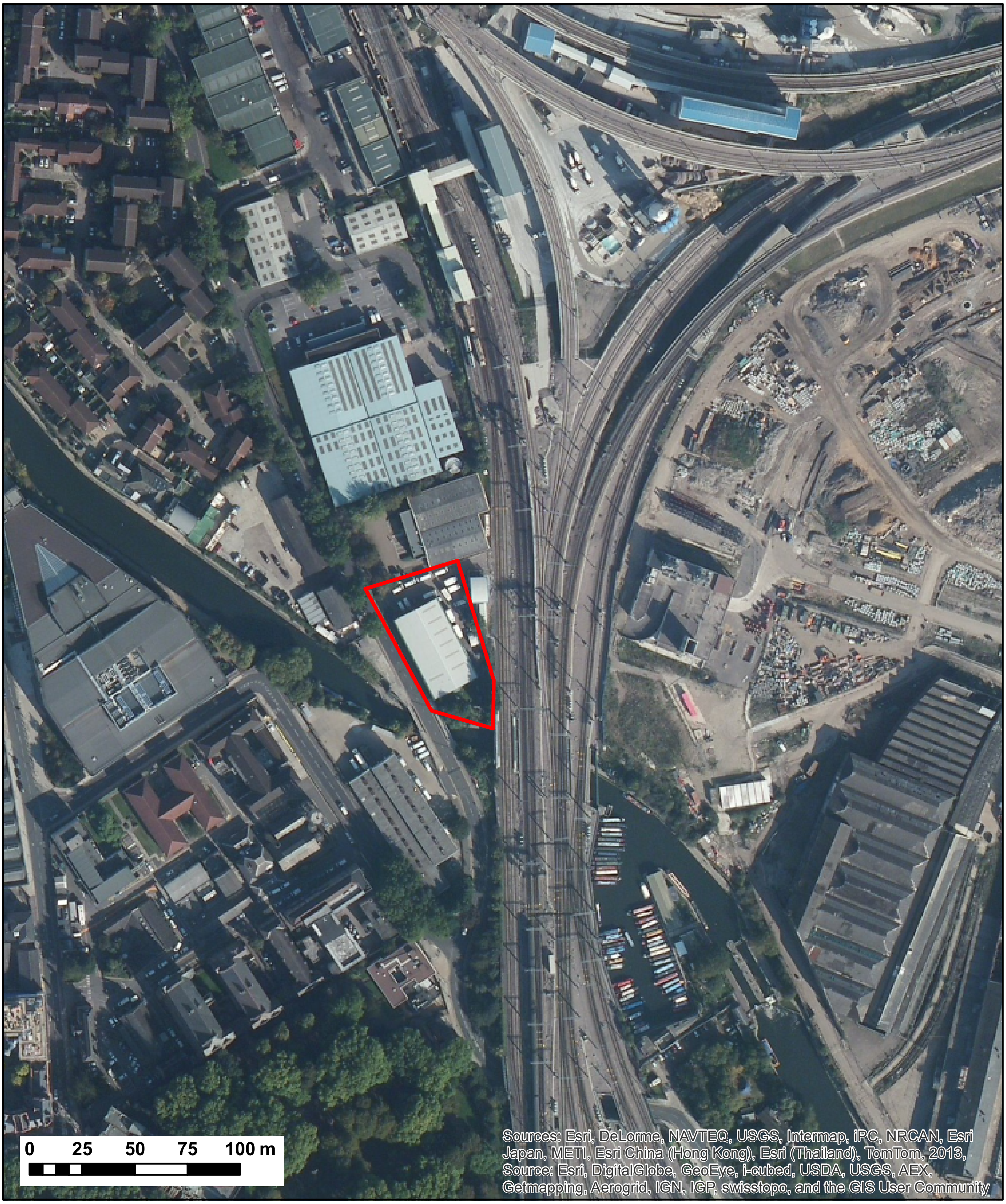
Scale 1:5,000

102 CAMLEY STREET
SITE LOCATION

ARUP

234937-00

FIGURE 1

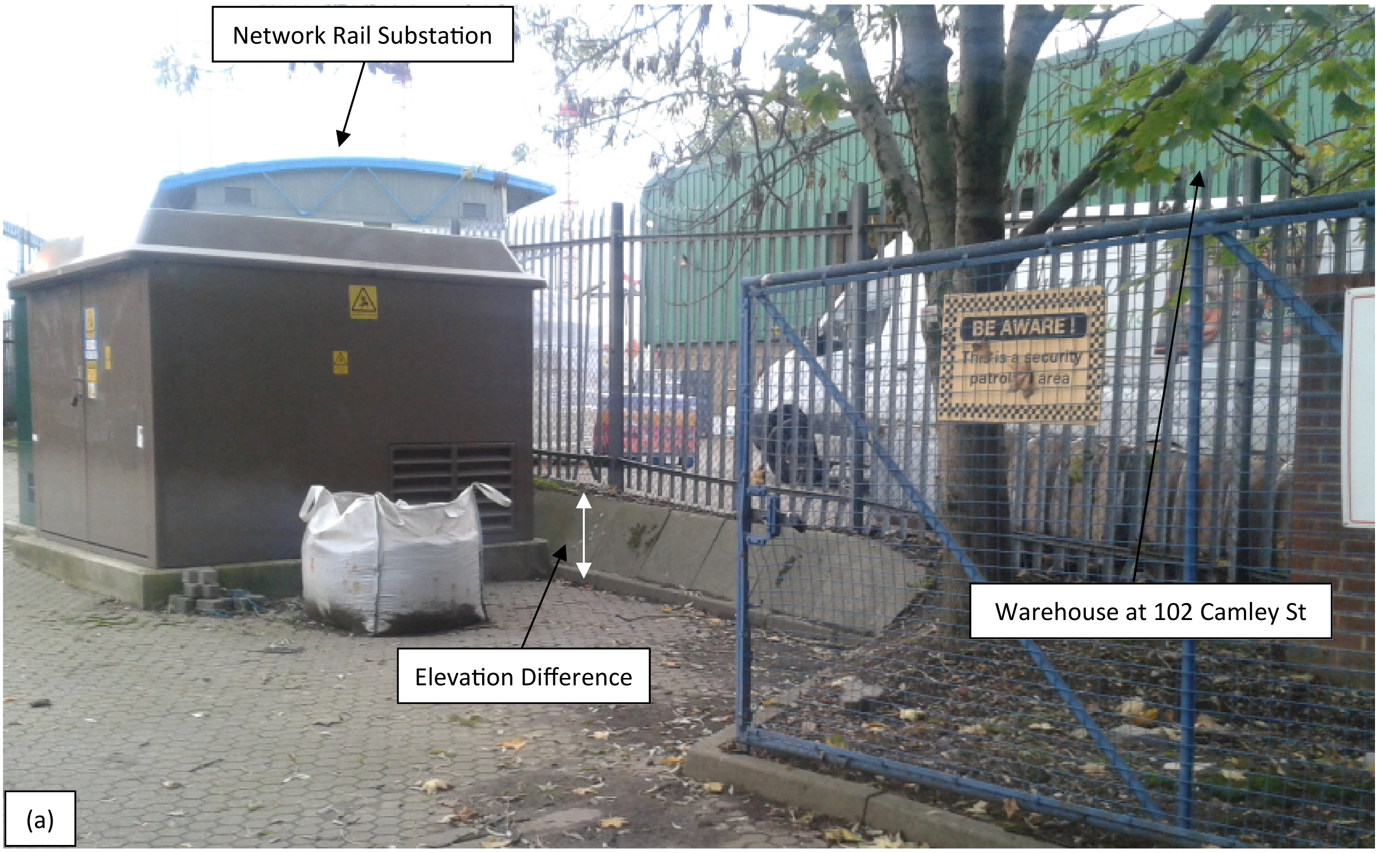


Scale 1:2,500

102 CAMLEY STREET AERIAL PHOTOGRAPH

ARUP

234937-00 FIGURE **2**

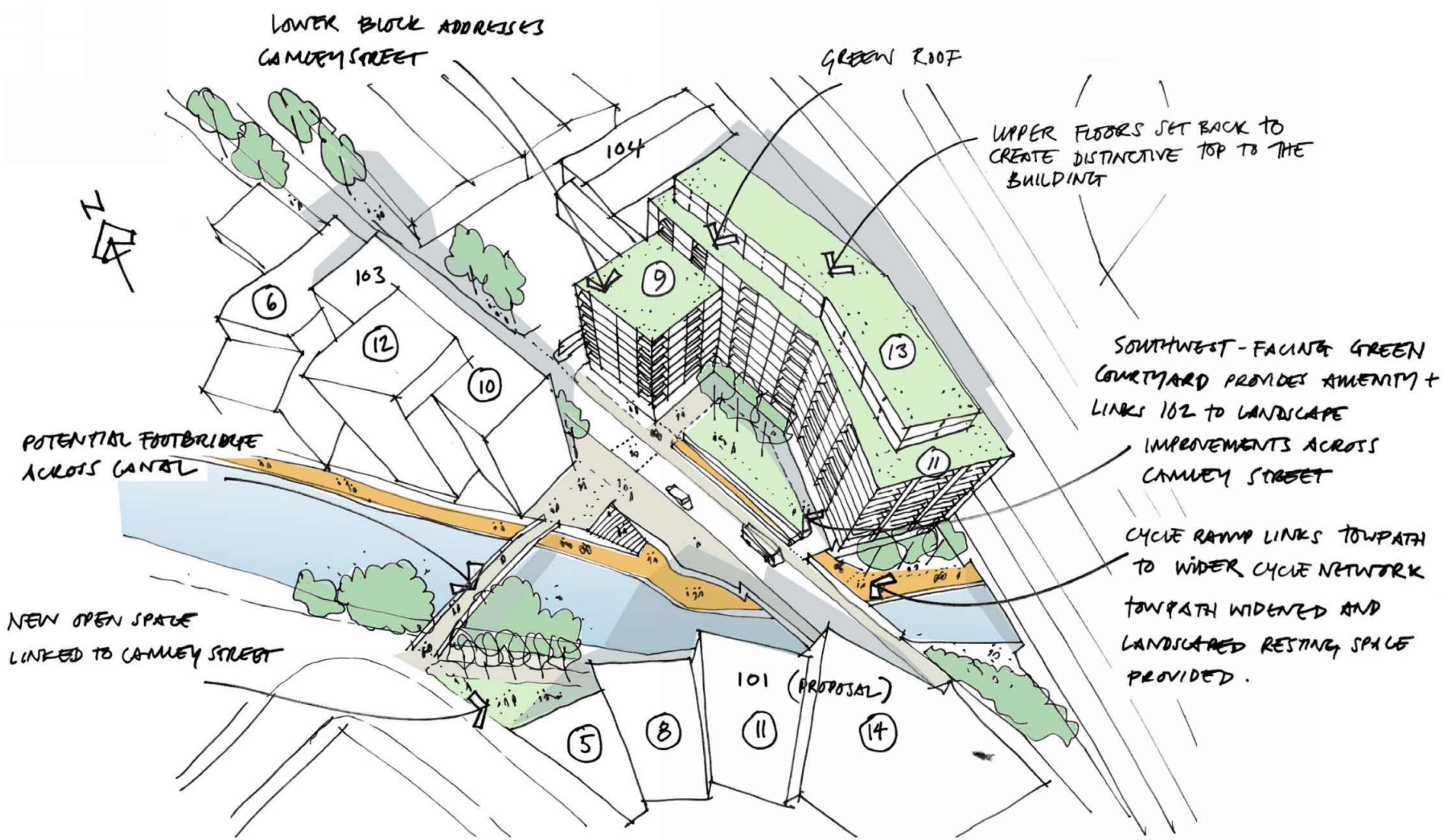


ARUP

102 CAMLEY STREET

PHOTOGRAPHS OF TOPOGRAPHY OF 102 AND 104 CAMLEY STREET

234937-00 **FIGURE 3**



102 CAMLEY STREET

SKETCH OF THE PROPOSED DEVELOPMENT

234937-00 FIGURE 4

ARUP