102
Camley Street, London N1C 4PF

Basement Impact Assessment

June 2014

REGENT RENEWAL LTD

ARUP

Regent Renewal Ltd

102 Camley Street

Basement Impact Assessment

Issue | 23 April 2014

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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1 Introduction

Arup has been appointed by Regent Renewal Ltd to undertake a Basement Impact Assessment (BIA) for the proposed basement development at 102 Camley Street, London, N1C4PF.

102 Camley Street Camden is an existing one storey warehouse that was built in the 1970's. The proposed re-development project involves the demolition of the existing property and the construction of 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.

The objective of the BIA is to assess the potential impact of the development and basement construction on the local surface water and groundwater environment and of possible impacts on structural stability of the building and its neighbours. The BIA is a process of assessing a combination of surface and groundwater conditions, with geotechnical analysis into a comprehensive review.

As recommended by the Guidance for Subterranean Development (Arup, 2010) the BIA methodology comprises the following steps:

1. Initial **Screening** to identify whether there are matters of concern;
2. **Scoping** to further define the matters of concern identified in the screening stage and devise an approach to evaluate the potential impacts;
3. **Site investigation and study** to establish baseline conditions;
4. **Assessment** of the information to determine the impact of the proposed basement on baseline conditions.

The information contained within this BIA has been produced to meet the requirements of a BIA as set out by Camden Planning Guidance – Basements and Lightwells (CPG4) including Camden Development Policies DP27 – Basements and Lightwells (London Borough of Camden, 2013) in order to assist LBC with their decision making process.

A contamination and remediation assessment has been carried out and is reported separately within the Geotechnical Desk Study submitted as part of this application (Arup, 2014). Summaries of relevant information from the desk study are included in this report.

Arup were not commissioned to undertake or supervise the ground investigations at the site. All the factual ground investigation information has been collected by others and it is assumed to be reliable, representative and suitable for the purpose of this assessment.

1.1 Summary of the report

This report includes assessment of the following:

- Surface flow and flooding;
- Groundwater flow; and
- Slope stability.

These are assessed in accordance with the Camden Planning Guidance for relevance to the proposed development and potential impacts that the development may cause.

The available site investigation information is reviewed to assess the existing ground conditions. Using this information the key basement construction impacts which were identified have been investigated. These include:

- Impacts to the groundwater flow caused by the proposed basement; and
- Ground movements due to the proposed basement.

An analysis of the potential groundwater changes due to the basement was carried out in MODFLOW, a 3D finite difference groundwater modelling software package. It was found that potential increase in groundwater level up gradient of the site (to the north) is approximately 0.2 m. On the down-gradient side (to the west and south) water table levels fall by between 0.2 & 0.6 m. It is considered that these potential small changes in water level in the Made Ground are not significant.

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. Analysis of the ground movements due to the deflection of the basement retaining wall was carried out.

The maximum ground settlements for the nearby rail lines were predicted to be less than 5 mm in total and to be approximately 4 mm at the edge of the rail lines. This is expected to be well within allowable limits. Further liaison with Network Rail will be required in order to ensure the ground movements arising from the proposed works are within the allowable limits.

A preliminary assessment of the potential damage of the warehouse to the north was carried out using the damage categories from Burland (Burland, 1997). The conclusion is that damage will be limited to Category I "very slight" in detailed design.

There are other less significant issues that will be addressed at the next design stage during detailed design. These include:

- A detailed examination of net surface water flows and discharges from site. This will be carried out when a more detailed design of the proposed building is available. The detailed design of possible mitigation of surface water, surface water flow storage and other systems will need to demonstrate that the design discharge conditions are, as a minimum, like for like.

- The radius of influence of trees in the vicinity and whether they would cause any adverse impacts in conjunction with the basement; and
- Detailed consideration of the potential risk and impact of the adjacent canal.

A ground investigation is recommended in later stages of the project to inform the design, but is not expected to significantly affect the conclusions of this BIA.

2 Site context

2.1 Location

The existing site is 102 Camley Street, Camden, London N1C 4PF. It is located north of Regent's canal, between Camley Street and land owned by Network Rail, which houses Midland Rail lines. To the north of the site is property with a warehouse. A map and a photograph of the site are shown in Figure 1 and Figure 2.

The site is currently in use as a warehouse for Marigold Health Foods. It is a one storey structure with no basement built in the 1970s. 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 6 m and Network Rail have right to use this access way in order to maintain the substation and access trackside. The Thameslink tunnel runs parallel to the site beneath the CTRL rail lines. It is situated at a distance of about 20m from the site boundary.

2.2 Site history

A review of historical maps in the desk study (Arup, 2014) showed that the site was undeveloped until the 19^{th} Century. Regent's Canal on the southern boundary was completed in 1820. It is likely that the site was used during construction of the canal for storage or dumping of arisings. The first Oblique Bridge, a road bridge, was built around this time.

A map published in 1851 showed the first recorded development on the site: two roads that crossed the site from west to east. The original Saint Pancras station is shown to the north of the site, surrounded by the Midlands Counties Railway Goods Depot.

A later map published in 1873-74 marks the land as a goods depot for Midland Railway. In the following 100 years the site was used for this purpose with Goad insurance maps indicating that the warehouse on the northern part of the site was used to store wine and beer, as well as later for van storage. The rail bridge was first built in 1867. There are now two adjacent rail bridges southwest of the site: one for Midland Main Line and another for the Channel Tunnel Rail Link.

Detailed consideration of historical maps and other records of the site is given in the desk study.

2.3 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 results of a topographical survey are shown in Figure 3.

The site to the north, 104 Camley Street, is approximately 0.5 m lower than 102 Camley Street, as seen in Figure 4 (a). There is a noticeable slope in the access road on the site as seen in Figure 4 (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.

There is a significant slope behind the retaining wall between the site and the towpath (see Section 2.4 for details of the wall itself). The ground is indicated to have a slope of over 7° in Figure 16 of the Guidance for subterranean development (Arup, 2010). During a site walkover it was observed that the ground did not behind come up to the top of the wall.

2.4 Existing site structures

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 5. The bridge retaining wall is a concrete and brick structure approximately 1.8 m high measured from the Oblique Bridge, (i.e. not from the tow path level).

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 6.

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 7. The wall was visually judged to be approximately 0.7 m wide at the top and increases in width towards the ground, but it was not possible to estimate 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. It appears to be made mainly out of the same material.

2.5 Geology

The preliminary design stratigraphy has been outlined in Section 3.4 of the Desk Study (Arup, 2014) and is summarised in the following table.

Table 1. Summary of preliminary design stratigraphy beneath the site

Stratum	Approximate Thickness (m)	Top of Stratum (mOD)	Description
Made Ground	2.6 to 5.1	+28.4 to +23.8	sandy clay, clayey sand, silty sandy gravel very varied
London Clay	22 to 28*	+22.75	stiff to very stiff sandy clay
Lambeth Group	12 to 18*	-2 to -8	very stiff to hard fissured clay with laminations and occasional thin layers of silty fine sand

*from the CTRL ground investigation

2.5.1 Previous ground investigations

Extensive ground investigations have been carried out in the areas bordering the site and within the vicinity. There has been no intrusive investigation on site to date but recommendations for such an investigation are included in Arup desk study (Arup, 2014).

The nearby ground investigations include that carried out for the CTRL investigations and for 103 Camley Street. Ten boreholes in close proximity to the site, shown in Figure 9, were drilled into the London Clay. In addition trial pits and made ground only boreholes in the vicinity are shown in Figure 10. These investigations provided extensive information, the findings of which are presented in Section 7.1.

2.6 Hydrology

2.6.1 Rainfall and runoff

Rainfall in the area averages about 610 mm (Mayes, 1997), significantly less than the national annual average of about 900 mm. Rainfall in London is split almost equally over the seasons, with the winter months experiencing only marginally higher rainfall than summer months. However, the rainfall in summer months will often occur in a smaller number of intense rainfall events leading to peaks which can lead to flash flooding and overloading of sewer systems. Climate change predictions indicate that future winters may be wetter and summers drier, but that rainfall patterns may become more intense and the summer storms will become more frequent. Over time the standard of protection of existing sewers is likely to reduce leading to an increase in localised flooding incidents.

Evapotranspiration is typically about 450 mm/yr resulting in about 160 mm per year as “hydrologically effective” rainfall which is available to infiltrate into the ground or runoff as surface water flow.

The site lies within the catchment of the River Fleet which shapes the eastern boundary of LB Camden.

The area around the site, in central London, is highly developed with more than 80% of the surface covered with hard standing. Most of the rainfall in the area will runoff hard surface areas and be collected by the local sewer network.

2.6.2 Drainage

Surface drainage from the site appears to be directed three ways:

- The majority of the hard standing areas and rook drainage is directed to storm-water sewers under Camley Street. There appears to be drainage from the roof on the Camley Street side.
- There are drainage pipes in the retaining wall along the towpath of Regents Canal. It is possible that the Made Ground drains onto the towpath.
- The southern part of the site has soft landscaping, some of the rainfall in this area can infiltrate and recharge to groundwater.

2.6.3 Flood risk

Although Camden missed the serious national floods of 2007 & 2012 it is known that Camden is at risk of flooding because of the significant floods in 1975 and 2002 (Halcrow, 2011).

The lead local flood authority (LLFA) and local planning authority is the London Borough of Camden (LBC). The recommendations from the LBC Preliminary Flood Risk Assessment (PFRA) have been reviewed in undertaking this assessment. The LBC Local Flood risk Management Strategy (LFRMS) was approved in June 2013 (London Borough of Camden, 2013). LBC has also produced a strategic flood risk assessment (SFRA) in conjunction with a number of surrounding local planning authorities (Mouchel, 2008).

Review of these documents show that potential flooding risks in LBC are primarily from surface water flooding, when the intensity of rainfall can overwhelm sewers and drainage systems. There is also a small risk of groundwater flooding (which occurs when the water table rises to ground level); from inundation due to reservoir failure (e.g. Hampstead Ponds); or from overtopping the Regents Canal. The impact of basements on each of these types of flooding is considered in the surface flow and flooding scoping section of the BIA.

2.6.4 River or tidal flooding

Because the site is elevated well above the flood plain of the River Thames at about 28.0mOD, it is shown as being outside Flood Zone as defined on the Environment Agency Flood Zone maps (Environment Agency).

2.6.5 Surface water flooding

Camden's flood risk management strategy (London Borough of Camden, 2013) describes how, in highly developed areas, such as London, surface water flooding occurs when intense rainfall is unable to soak into the ground or enter drainage systems, because of failure of the pipes or where drainage capacity has been exceeded. It concludes that the risk of surface water flooding in Camden South is much lower than in the north of the borough.

Surface water runoff from the area drains to the former Fleet River, which has now been fully incorporated into the Fleet sewer (London Borough of Camden, 2013). A hydraulic assessment of the catchment investigated which areas are at the highest risk from surface water flooding. 102 Camley Street is not near to any of these 'Critical Surface Water Flood Locations' and the risks of surface water flooding at the site are therefore considered low.

In addition the site is not located near any of the areas that were flooded in 1975 or 2002 or identified as areas with the potential to be at risk of surface flooding as shown in Figure 5.1 of the LFRMS (London Borough of Camden, 2013).

2.6.6 Sewer flooding

Most of Camden is served by combined sewers which receive foul water, water from roofs, hard standing and sometimes highways. Many of these combined sewers were designed by Sir Joseph Bazalgette in the 1860's. During periods of heavy rain the sewers fill up and can overflow. Sewer flooding events are a London wide issue. Thames Water holds details of incidents of sewer flooding for individual properties in a Sewer Flood database. This database has not been interrogated as part of this assessment but it is understood that very few properties have experienced flooding from sewers in the N1 post code area.

Sewer systems in the Borough are often very old. These older sewers were sometimes designed to convey storms of relatively low return periods, typically a 1 in 10 year rainfall event. Even new surface water systems are designed to a minimum standard of 1 in 30 years, much less than the 1 in 100 year standard of protection expected from fluvial flooding. As a result sewer flooding events, where they occur, can often be frequent, although the scale of impact is generally smaller than those associated with fluvial flooding.

The London Regional Flood Risk Appraisal (2009) advises that foul sewer flooding is most likely to occur where properties are connected to the sewer system at a level below the hydraulic level of the sewage flow, which in general are often basement flats or premises in low lying areas. Although there is no record of sewer flooding having occurred at 102 Camley Street the proposed basement is deeper than its neighbours and as such may be at risk of sewer flooding.

2.6.7 Groundwater flooding

Groundwater flooding most commonly occurs in low lying areas which are underlain by permeable rock (aquifers) or may be localised sands or river gravels in valley bottoms underlain by less permeable rocks. Flooding occurs when the local water table rises up from the permeable rocks to the ground surface, flooding low lying areas or occurring as intermittent springs. Flooding is most likely to occur after prolonged periods of rainfall when a greater volume of rain will percolate into the ground, causing the groundwater table to rise above its usual level.

The site is underlain by the London Clay formation which fully confines the underlying Chalk aquifer at depth and therefore the risk of groundwater flooding is considered negligible.

2.6.8 Flooding from canals, water features and water mains

In Camden this type of flooding is most likely to result from burst water mains or from infrastructure failure in an artificial watercourse or water bodies, i.e. canals or other water features. Many of the water mains in the area date from Victorian times. Detailed records of the exact locations and incidents are held by Thames Water.

Desk study review has confirmed that the site is located alongside the Regents canal. The risk of surface flooding or overtopping of the canal is not currently known.

2.7 Hydrogeology

Typically in central London, there is a ‘shallow’ aquifer usually consisting of sand and gravel River Terrace Deposits or more silty alluvium and a ‘deeper’ aquifer contained within the Thanet Sand and Upper Chalk Formations. The two aquifers are separated by the impermeable London Clay which is classed as a non-aquifer.

The desk study and previous investigations in the vicinity of the site have indicated that the River Terrace Deposits are not present and no shallow aquifer is deemed to be present although there may be localised pockets of perched groundwater within the deposits of Made Ground.

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 and the influence of and risks to the deeper Chalk aquifer are not considered further.

As far as the “shallow” aquifer is concerned; groundwater level (GWL) readings were taken during the CTRL GI in boreholes SA7375A and SA7376. These were monitored weekly for a period of three months after installation between June and September 1997. The GWL varied between 2.2 and 3.91mbgl in SA7375A and between 3.09 and 4.11mbgl in SA7376. The response zones of the standpipes were mostly within the Made Ground, with a small portion of each within the London Clay.

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 were dry on installation but both did measure groundwater a few days later. The GWL was 4.5mbgl in BHA and 6mbgl in BHB. No monitoring was recorded after this.

From the limited information available it appears that the Made Ground deposits above the London Clay may support some groundwater flows or may form a continuous perched aquifer. The deposits are 2.6 - 5.1 meters thick and are extensively modified by artificial drainage, such as that along existing roads, railways etc.

3 The proposed development

3.1 Description

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, 3.5 m deep basement.

A sketch of the proposed development is shown in Figure 11. The section of the building in the northwest of the site is 8 storeys high with a one level basement. In the east part of the building 12 storeys with a one level basement is proposed. The area south of the one level basement includes a courtyard with access to the Regent's Canal towpath, as seen in a sketch in Figure 12. Currently the tow path is not directly accessible from the site. For the proposed development it is planned that a substantial amount of the made ground will be removed in order for the basement to be open to the Canal at the towpath level. This means that the basement will not be fully underground until some distance back from the towpath. The approximate extents of the basement are shown in Figure 13.

The existing retaining wall between the site and the canal will be removed but the Oblique Bridge retaining wall will be kept in place. The courtyard area in the south west of the site will have a sprinkler tank underneath it with a depth the same as the rest of the basement. It is included in the basement outline in Figure 13. At the northern end of the site the basement extent is at least 5 m from the boundary (to allow Network Rail access to the substation on the adjoining site to the east).

3.2 Construction methodology

The proposed methodology for retaining the ground around the basement includes a permanent contiguous or secant piled wall constructed from the general ground level of the site. This will be sufficiently stiff to limit ground movements to the Network Rail lines to acceptable levels and damage to neighbouring structures to "very slight". Where the ground slopes down towards the towpath, between the bridge abutments, temporary propping measures to the abutments will be adopted if required whilst the ground is excavated and the reinforced concrete retaining wall is built in situ.

A preliminary design of the basement retaining wall has been undertaken for a hard-soft secant piled wall with 600 mm diameter piles at 750 mm centres. The toe has been taken to extend 3.25 m below the basement level, which is itself 3.5 m deep. To allow for the slab depth it has been modelled as 3.75 m deep. A sketch of the analysed retaining wall is shown in Figure 14.

4 Surface flow and flooding

The impact of the proposed development on the surface water environment and need for flood risk assessment is considered here.

4.1 Stage 1: Initial screening

The first stage in assessing the impact of any proposed basement development is to recognise what issues are relevant to the proposed site and to identify the matters of concern which should be investigated further. This is done by using the screening flowchart and guidance found in Appendix E of the Arup guidance for Subterranean Development [3] and in the Camden Planning Guidance – Basements and Lightwells (CPG4) including Camden Development Policies DP27 – Basements and Lightwells [4].

4.1.1 Table 1: Surface flow and flooding screening

No.	Screening Question	Impact	Source/Comment
1.	Is the site within the catchment of the pond chains on Hampstead Heath?	No	The site lies well outside the Hampstead Heath surface water catchment area as defined by Figure 14 of LBC guidance [3] and there are no other equivalent sensitive water features in the vicinity of the site.
2.	**As part of the proposed site drainage, will surface water flows (e.g. volume of rainfall and peak run-off) be materially changed from the existing route?**	**Yes**	**Surface water mainly discharges to the local storm water sewer, although there appear to be some discharges to drains along the canal towpath. It is unlikely that the discharges to cross the canal towpath will be permitted in the long term and modifications to the site wide site drainage will need to be considered.**
3	**Will the proposed basement development result in a change in the proportion of hard surfaced / paved external areas?**	**Yes**	**About two thirds of the existing site is either roofed or hard standing. It is likely that there will be an increase in the footprint of the building and an increase in the amount of paved surface in relation to the total site on completion of the development. The total difference is likely to be small but will need to be quantified.**

No.	Screening Question	Impact	Source/Comment
4	**Will the proposed basement result in changes to the profile of the inflows (instantaneous & long-term) of surface water being received by adjacent properties or downstream water-courses?**	**Yes**	**Currently much of the site consists of hard-standing or roofed areas and all surface water flows are routed, at present to the Thames Water storm-water sewers under Camley Street or onto the towpath along Regents Canal.** **It is likely that there will be an increase in the footprint of the building and an increase in the amount of paved surface in relation to the total site on completion of the development. The net difference in flow is likely to be small, but will need to be quantified.**
5	Will the proposed basement result in changes to the quality of surface water being received by adjacent properties or downstream water courses?	No	The surface water quality will not be affected by the development. During construction a Construction Management Plan (CMP) will be followed to minimize the risk of excess runoff and contamination of surface water. After completion, runoff will be derived from roof hard landscaping or collected from beneath the landscaping layer over the basement and will be the same as the existing situation.
6	**Is the site in an area known to be at risk from surface water flooding, such as South Hampstead, West Hampstead, Gospel Oak and King's Cross, or is it at risk from flooding, for example because the proposed basement is below the static water level of a nearby surface water feature?**	**Yes**	**The site is not at risk of surface flooding. However the lowest part of the excavation will be close to the static water level of the nearby Regents Canal during construction.** **Note that the canal is manmade, i.e. it was excavated into London Clay and is likely to be fully lined and isolated. In addition the water level in the canal is controlled by locks.**

4.2 Surface flow and flooding, matters to be carried forward

The following impacts have been identified during screening:

- The existing surface water drainage system will need to be modified as part of the proposal;
- The proposal may increase total surface water flows, as a result of a possible increase in hard landscaping across the site.

4.3 Stage 2 Scoping

The potential impacts which will need to be considered include:

- More detailed examination of net surface water flows and discharges from site. This will require:
    - A more detailed description of the existing and proposed future drainage design,
    - Estimate of total area of hard surface/paved or roofed areas;
    - Estimate of net runoff and consideration in detailed design of how net runoff will remain the same as at present, for example by incorporation of SUDS into the design.
- Consideration of the potential risk and impact of the adjacent canal: This will require:
    - Further assessment of seepage and flood risk arising from the canal.

The above issues will need to be covered in detailed design.

The detailed design of possible mitigation of surface water, surface water flow storage and other systems should be completed during the next design stage; however it will be necessary to demonstrate that the design discharge conditions are, as a minimum, like for like.

5 Subterranean (groundwater) flow

5.1 Stage 1: Initial screening

The impact of the proposed development on groundwater flows and levels is considered here.

5.1.1 Table 2: Subterranean (groundwater) flow screening flowchart

No.	Screening Question	Impact	Source/Comment
1a.	**Is the site located directly above an aquifer?**	**Yes**	**The Geotechnical desk study** (Arup, 2014) **shows that the superficial Made Ground deposits across the site could form a perched aquifer, which may or may not be continuous.**
1b.	**Will the proposed basement extend beneath the water table surface?**	**Yes**	**Local groundwater levels appear to range between 2.2 and 6.0mbgl within both the Made Ground and the London Clay. The proposed basement floor level is 3.5mbgl.**
2.	**Is the site within 100m of a watercourse, well (open/disused) or potential spring line?**	**Yes**	**The closest water feature is the Regents canal which forms the western boundary of the site. It is likely that the canal is fully lined and isolated and no impacts on flow volumes or water quality are anticipated. There are no recorded spring lines or groundwater features in the area.**
3	Is the site within the catchment of the pond chains on Hampstead Heath?	No	The site lies well outside the Hampstead Heath surface water catchment areas and there are no other equivalent sensitive water features in the vicinity of the site.
4	**Will the proposed basement development result in a change in the proportion of hard-surfaced/paved areas?**	**Yes**	**The surface permeability will be affected by a slight increase in the building footprint and small increase in the amount of paved surface in relation to the total site. Natural recharge of groundwater through the site is likely to be slightly reduced.**

No.	Screening Question	Impact	Source/Comment
5	As part of the site drainage, will more surface water (e.g. rainfall and run-off) than at present be discharged to the ground (e.g. via soak-away and/or SUDS)?	No	Because the overall extent of hard-standing is slightly greater than at present the quantity of surface water and runoff could be higher than at present unless mitigation, by on site storage or attenuation is installed.
6	**Is the lowest point of the excavation (allowing for any drainage and foundation space under the basement floor) close to, or lower than, the mean water level in any local pond or spring line?**	**Yes**	**The lowest part of the excavation will be close to the static water level of the nearby Regents Canal.** **Note that the canal is manmade, i.e. it was excavated into London Clay and is likely to be fully lined and isolated. In addition the water level in the canal is controlled by locks.**

5.2 Subterranean flow, matters to be carried forward

The following possible impacts on groundwater have been identified during screening:

- The proposed basement is located close to the Regents canal and the lowest part of the excavation will be at a similar level to the static water level.
- The site may have a perched aquifer in the Made Ground and the basement level is likely to be below the water level of this aquifer.
- The proposed basement development is likely to result in a change in the proportion of hard-surfaced/paved areas and create a net reduction in groundwater recharge across the site.
- The flow path of any water in the Made Ground will be diverted around the basement.

5.3 Stage 2 Scoping

The potential impacts which will need to be considered include:

- More detailed examination of net surface water flows and discharges from site. This will be dealt with during detailed design (see Section 4.3 for details). This will require:
    - A more detailed description of the existing and proposed future drainage design,
    - Estimate of total area of hard surface/paved or roofed areas;
    - An assessment of whether the surface permeability of the site will be affected by the works, and consideration of what measures can be used to mitigate against the impact of this.
    - Estimate of net runoff and consideration in detailed design of how net runoff will remain the same as at present, for example by incorporation of SUDS into the design.
- Consideration of the potential risk and impact of the adjacent canal. This will be considered further during detailed design. This will require:
    - Further assessment of the groundwater seepage and flood risk arising from the canal;
- Consideration of any impacts of the basement acting as an impermeable barrier to water flow. This is addressed in the impact assessment in Section 8.1 of this report.

6 Slope stability

6.1 Stage 1: Initial screening

6.1.1 Table 3: Slope stability screening flowchart

No.	Screening Question	Impact	Source/Comment
1.	Does the existing site include slopes, natural or manmade, greater than 7°? (approximately 1 in 8)	No	The site is includes a slope over 7° on the southern boundary next to the towpath. This slope is to be entirely removed as part of the proposed development and thus no further investigation of the effect of the basement on the stability of this slope is needed.
2.	Will the proposed re-profiling of landscaping at site change slopes at the property boundary to more than 7°? (approximately 1 in 8)	No	The proposed development has a cycle path from the tow path up into the site with an approximate slope of 1in10.
3.	**Does the development neighbour land, including railway cuttings and the like, with a slope greater than 7°? (approximately 1 in 8)**	**Yes**	**The Midland Rail Line to the east has an embankment approximately 0.5 m high, slope unconfirmed. Ground movements affecting the embankment need to be assessed.**
4.	Is the site within a wider hillside setting in which the general slope is greater than 7°? (approximately 1 in 8)	No	The site is not located within a wider hillside setting and there are no slopes adjacent to the property boundary.
5.	**Is the London Clay the shallowest strata at the site?**	**Yes**	**London Clay is overlain by Made Ground.**
6.	**Will any tree/s be felled as part of the proposed development and/or are any works proposed within any tree protection zones where trees are to be retained? (Note that consent is required from LB Camden to undertake work to any tree/s protected by a Tree Protection Order or to tree/s in a Conservation Area if the tree is over certain dimensions).**	**Yes**	**Trees in the south part of the site (adjacent to the boundary wall) and the east of the site, (adjacent to the rail lines) will be removed.**
7.	Is there a history of seasonal shrink-swell subsidence in the local area (Claygate Beds), and/or evidence of such effects at the site?	No	We are not aware of the area having a history of shrink-swell subsidence. The effects of shrink-swell subsidence are not evident at the site.

No.	Screening Question	Impact	Source/Comment
8.	**Is the site within 100m of a watercourse or a potential spring line?**	**Yes**	**The towpath of Regent's Canal is directly adjacent to the site. However this is a man-made watercourse in London Clay and is likely to be isolated from flow from or to the surrounding ground.**
9.	Is the site within an area of previously worked ground?	No	Made Ground and fill above original ground level is present across the site. This is considered to be stable and will be completely supported during the excavation.
10.	Is the site within an aquifer? If so, will the proposed basement extend beneath the water table such that dewatering may be required during construction?	No	The site is not expected to be within an aquifer, although there may be perched water within the Made Ground.
11.	Is the site within 50m of the Hampstead Heath ponds?	No	-
12.	**Is the site within 5m of a highway or pedestrian right of way?**	**Yes**	**Camley Street to the west of the site.**
13.	**Will the proposed basement significantly increase the differential depth of foundations relative to neighbouring properties?**	**Likely**	**Ground movements related to deflection of basement retaining walls may affect surrounding properties.**
14.	Is the site over (or within the exclusion zone of) any tunnels, e.g. railway lines?	No	-

6.2 Slope stability, matters to be carried forward

A number of potential impacts have been identified in the screening process and these must be evaluated and assessed. The issues are summarised below.

Basement excavation and superstructure loading have the potential to cause ground movements in the surrounding property including:

- the rail embankment to the east;
- the building to the north; and
- the public highway Camley Street.

The building on 103 Camley Street is assessed to be outside of the zone of influence. The ground movements and their impacts are addressed in this report in Section 8.2.

The site is within 100 m of a watercourse – Regent's Canal. The canal is expected to be isolated from flow to or from the surrounding ground. However further assessment of the risk of any seepage from the canal is required. This will be considered in detailed design.

6.3 Scoping

Matter carried forward	**Scope of investigation and data collection defined**
The development is adjacent to land with a railway embankment likely to be 0.5 m high situated on it.	Analysis at this location of the ground movements caused by the excavation of the basement shall be carried out. Confirmation of the slope dimensions is to be made.
Trees will be felled as part of the proposed development. 1. In the south of the site 2. In the east of the site	The trees in the south (most likely London plane trees) are currently located on a slope that is to be removed completely. These require no further consideration with regard to slope stability. There are 6 cypress trees and 1 ash tree to the east of the site. The cypress trees are located approximately 5 m from the railway embankment, while the ash tree is approximately 12 m from the lines. The radius of influence of the trees needs to be considered further.
A number of neighbouring properties must be taken into account: the public highway Camley Street, Midland Railway rail lines and a light industrial building to the north.	Analysis at these locations of the ground movements caused by the excavation of the basement shall be carried out.
The site is located within a few metres of a watercourse: Regent's Canal.	Further assessment of the risk of any potential seepage from the canal and any impact on ground stability is required.

7 Stage 3: Site Investigation

Arup were not commissioned to undertake or supervise the ground investigations at the site. All the factual ground investigation information has been collected by others and it is assumed to be reliable, representative and suitable for the purpose of this assessment.

A ground investigation is recommended in later stages of the project to inform the design, but is not expected to significantly affect the conclusions of this BIA.

7.1 Ground investigation information

7.1.1 Channel Tunnel Rail Link

Construction of the Channel Tunnel Rail Link began in 1998. An extensive ground investigation took place in the years prior to this and it included several boreholes in the vicinity of the site. The stratigraphy found in St. Pancras and Railway Lands area (known as area 100) is shown in the table below.

Table 1. 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: - 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 15 m in the south under St. Pancras Station and increasing to 30m in the north of the site and to 35 m immediately north of the NLL. The base of the London Clay is recorded as dipping north eastwards across the site, falling from -2 mOD in the south west below St. Pancras to -8 mOD 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 -2 mOD and -8 mOD on 102 Camley Street. The stratigraphy found during the CTRL investigation is shown in Figure 8.

The following descriptions of the strata underlying the site are from the design basis for CTRL.

7.1.1.1 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 2 m. 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.

7.1.1.2 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/m3.

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

$c_u = 50 + 15\ z\ kN/m^2$ above 3 m 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.

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 2. Stiffness parameters in the London Clay from a CTRL Technical Report.

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)

7.1.1.3 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/m2.

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

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

where z = depth in metres below the top of the Woolwich and Reading Formation.

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 3. Stiffness parameters in the Lambeth Group from a CTRL Technical Report.

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)

7.1.2 103 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 9, 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 the Desk Study (Arup, 2014) for details. Beneath the suspected arisings brown fissured very silty clay with veins of grey clay (which was described in the ground investigation as London Clay) was found in the boreholes.

The location of the eight trial pits are shown in Figure 10. None of the trial pits reached as far the London Clay stratum.

There are no available geotechnical design parameters for this project.

Table 4. 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

7.1.3 Conclusions

7.1.3.1 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 9. 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 5. Scanned copies of the borehole logs are in Appendix A i.e. the Desk Study.

Table 5. 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 9. 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 6. 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

7.1.3.2 Soil Parameters

The soil parameters from the CTRL investigation are considered to be representative of the parameters on the site.

7.1.3.3 Groundwater

Available information on groundwater has been described in Section 2.7. The preliminary proposed design groundwater level is given as the maximum found during in monitoring of previous site investigations (i.e. +25.54 m OD) with an additional 0.5 m.

8 Stage 4: Impact Assessment

The key issues highlighted in Sections 5.3 and 6.3 for which the impacts are considered here are:

- the basement acting as an impermeable barrier to potential water flow
- the ground movements and their impacts on the rail embankment to the east, the warehouse to the north and the public highway Camley Street.

A groundwater flow assessment in Section 8.1 addresses the former and a ground movement assessment in Section 8.2 addresses the latter.

There are other less significant issues identified in Sections 4.3 and 5.3 that will be addressed at the next design stage during detailed design. These include:

- A detailed examination of net surface water flows and discharges from site. This will be carried out when a more detailed design of the proposed building is available. The detailed design of possible mitigation of surface water, surface water flow storage and other systems will need to demonstrate that the design discharge conditions are, as a minimum, like for like.
- The radius of influence of trees in the vicinity and whether they would cause any adverse impacts in conjunction with the basement; and
- Detailed consideration of the potential risk and impact of the adjacent canal.

8.1 Groundwater flow assessment

An analysis of the groundwater changes due to the basement was carried out in MODFLOW, a 3D finite difference groundwater modelling software package. A very simple model, with a single horizontal layer, fixed boundaries and a range of conservative hydraulic conductivities was created to give an approximate estimate of the likely impact of the proposed basement excavation.

The model set up was a 200 x 200 m grid with evenly spaced rows and columns 5m width, focused on a proposed basement excavation near the centre of the model area. A single horizontal layer was used to represent the Made Ground, with the top at +27.5 mOD and the bottom at +23.25 mOD on the top of assumed impermeable London Clay. Two permeability values were used for sensitivity analysis: 1x 10^{-5} m/s and 1x 10^{-7} m/s. Permeability was isotropic.

A constant head was set along each side of the domain. The top constant head was set at +26.05 m OD to represent mean local water table level. The lower constant head of +23.30 m OD was set along the foot of the retaining wall along the canal tow path. A plan of the boundaries is shown in Figure 15.

The current state of the groundwater is shown in Figure 16 which includes a plan and a north-south elevation of the groundwater. The excavation assumed to fully penetrate the Made Ground into the underlying London Clay is then added to the model. It will act as a barrier, with groundwater ponding against the up-gradient side and falling on the down gradient side.

The post excavation groundwater levels are shown in Figure 17 and Figure 18 for a permeability of 1x 10^{-5} m/s and 1x 10^{-7} m/s respectively. The grey cells represent inactive areas. The draw down is shown as positive and the draw up as negative. When k = 1x 10^{-5} m/s the water table level rise on the up-gradient side (to the north & east) is approximately 0.2 m over a radius of 20 m - 40 m. On the down-gradient side (to the west and south) water table levels fall over a radius of ~20m by between 0.2 & 0.6 m.

The head distribution of the 1x 10^{-7} m/s model shown in Figure 18 is almost identical to the 1x 10^{-5} m/s simulation. This is not surprising given steady state and identical boundaries. The results show that the water table level rise on the up gradient side extends slightly further to the east by approximately 0.2 m over a radius of ~100m. On the down gradient side (to the west and south) water table levels fall over a radius of ~20m by up to 0.6 m.

These potential small changes in water level in the Made Ground are not considered significant.

8.2 Ground movement assessment

8.2.1 Retaining wall analysis

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 was a hard-soft secant piled retaining wall with 600 mm diameter piles at 750 mm centres. The Oasys software for retaining walls Frew was used to model a 2D section of the retaining wall on this site.

Details of the Frew analysis are given in Appendix B. The maximum bending moment is predicted to be 165 kNm/m and to occur following installation of the base slab. The maximum wall deflection was less than 10 mm for all stages. For the high stiffness support construction sequence modelled the maximum wall deflection and maximum ultimate limit state bending moments can be reasonably accommodated in 600 mm diameter piles.

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 (refer to Section 3.2).

8.2.2 Prediction of ground movements

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.

8.2.2.1 Network Rail

The predicted movements behind the wall, alongside the predicted wall deflection over the depth are shown in Figure 18. The maximum ground settlements for the nearby rail lines were predicted to be less than 5 mm in total and to be approximately 4 mm at the edge of the rail lines. This is expected to be well within allowable limits.

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

8.2.2.2 Neighbouring buildings

A preliminary assessment of the potential damage of the warehouse to the north was carried out using the damage categories from Burland (Burland, 1997). It is the closest building to the proposed development. 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.

A damage assessment chart is shown in Figure 20. Predicted damage arising from the excavation support system analysed is negligible. Given that in detailed design there may be some variation in stiffness of the retaining system from that analysed here, the conclusion is that the damage will be limited to Category I "very slight".

9 Figures

10 References

Works Cited

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Appendix A

Desk Study

Appendix B

Frew Analysis

B1

The wall is expected to be about 7 m deep, i.e. extending 3.25 m below a 3.75 m deep basement (3.5 m plus 0.25 m slab depth). The wall at the eastern side of the site was modelled since the loading from the railway was considered to be the worst case. 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, see Figure 13 for a sketch showing the basement extents and the nearby rail lines. The surcharge assumed was 50kPa.

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 the desk study (see Appendices). 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 $\phi' = 25°$.

The groundwater level was modelled at +25.5m OD, as given in the conclusions in Section 7.1.3.3. The water table was modelled below the excavation where relevant.