BASEMENT IMPACT ASSESSMENT REPORT

12-14 Greville Street
London EC1

Client: Workspace Management

Engineer: Price & Myers

J15340A

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Document Control

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EXECUTIVE SUMMARY

This executive summary contains an overview of the key findings and conclusions. No reliance should be placed on any part of the executive summary until the whole of the report has been read. Other sections of the report may contain information that puts into context the findings that are summarised in the executive summary.

BRIEF

This report describes the findings of a site investigation carried out by Geotechnical and Environmental Associates Limited (GEA) on the instructions of Price & Myers, on behalf of Workspace Management, with respect to the redevelopment of the site by the construction of a five-storey building with a single level basement. The purpose of the investigation has been to research the history of the site with respect to possible contaminative uses, to determine the ground conditions and hydrogeology, to assess the extent of any contamination and to provide information to assist with the design of suitable foundations and retaining walls for the proposed development. An assessment of ground movements resulting from excavation of the proposed basement is also included in this report. A desk study and BIA was previously carried out for this site by GEA (ref J15340 Report issue 3, dated 23 August 2016) and the findings of the desk study are incorporated herein.

DESK STUDY FINDINGS

John Rocque's 1746 Map of London shows the site to be developed with Grevil Street present and running east-west from Leather Lane to Brook Street, whilst to the east it became Cross Street, where it joined with Saffron Hill. At that time a stable yard was shown leading from Cross Street to the east of the site and a park area that appeared to belong to a chapel is shown in the south. The map dated 1878 shows the site to be occupied by a number of buildings that adjoin one another around a central courtyard. By 1916 the cluster of buildings had apparently been demolished and replaced with one large building that occupied the entire site, with the exception of the northwestern quarter of the site, that was occupied by a public house. The insurance plan dated 1922 indicates the site was occupied by a cluster of two-storey and four-storey buildings, including a public house in the northwest, with a small rear courtyard and a printer rollers and surgical instrument facility in the east. By 1953 Charles Street had been renamed to be a continuation of Greville Street, while the public house was no longer annotated as such and was indicated to be Nos 12 and 13. The site has since remained largely unchanged.

GROUND CONDITIONS

Below a moderate thickness of made ground, the Hackney Gravel was encountered over London Clay, which extended to the maximum depth of the investigation, of 2.10 m (12.18 m OD) below basement level. The Hackney Gravel comprised brown very gravelly coarse sand and extended to depths of between 1.70 m (12.58 m OD) and 1.80 m (12.48 m OD) below basement level. Groundwater was encountered within the Hackney Gravel at a depth of about 1.50 m (12.78 m OD) below basement level.

Contamination testing of a single sample of the made ground indicated no elevated concentrations of contamination.

RECOMMENDATIONS

The Hackney Gravel should be suitable for the support of a moderately loaded raft foundation, although only a limited thickness of gravel will remain above the London Clay at formation level. A check on the likely settlement of the raft has been carried out as part of the GMA and confirms that the London Clay will not be overstressed. No additional analysis is required in this respect. In addition, consideration will need to be given the presence of the deeper basement along the southern boundary. In order to ensure that additional load is not placed on the foundations of the adjacent structure to the south, the raft will not extend to the southern boundary.

GROUND MOVEMENT ASSESSMENT

The analysis has predicted that the proposed installation of the retaining wall underpins and excavation of the proposed basement are likely to result in the building damage for sensitive structures being Category 0 (negligible). The CPG4 document indicates that where possible all building damage should be restricted to a maximum of Category 1, as set out in CIRIA Report 760, and as a result, the predictions are in line with Camden's requirements.

Part 1: INVESTIGATION REPORT

This section of the report details the objectives of the investigation, the work that has been carried out to meet these objectives and the results of the investigation. Interpretation of the findings is presented in Part 2.

1.0 INTRODUCTION

Geotechnical and Environmental Associates Limited (GEA) has been commissioned by Price & Myers, on behalf of Workspace Management, to carry out a ground investigation at 12–14 Greville Street, London EC1N 8SB. This report also forms part of a Basement Impact Assessment (BIA), which has been carried out in accordance with guidelines from the London Borough of Camden in support of a planning application.

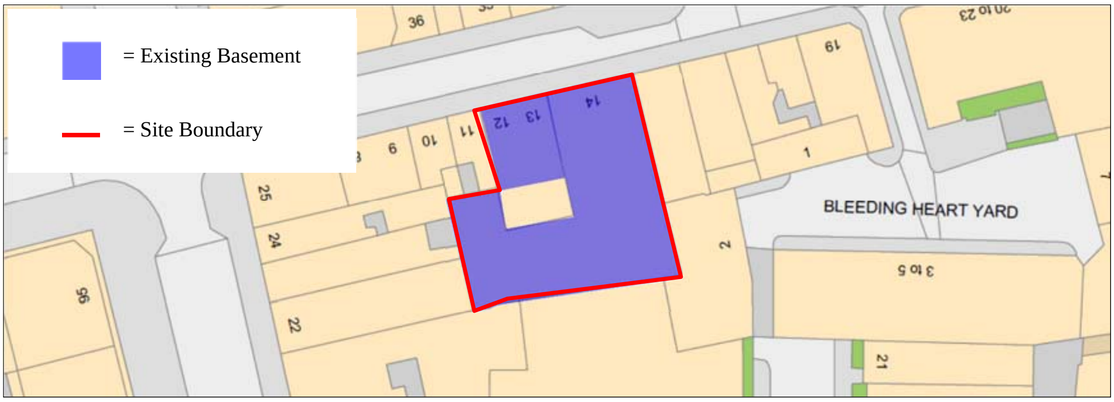
The report has been updated following a review of the BIA by Campbell Reith and additional work to satisfy the requirements of the BIA audit.

A desk study and BIA was previously carried out for this site by GEA (ref J15340 Report issue 3, dated 23 August 2016) and the findings of the desk study are incorporated herein.

1.1 Proposed Development

It is understood that it is proposed to demolish the two existing five-storey buildings, Nos 12 to 13 and No 14 Greville Street, and subsequently construct a single five-storey building with a single level basement that will be supported by means of a new concrete raft foundation. The proposed development is designed to protect a Crossrail tunnel approximately 25 m below the site.

The new single level basement is proposed to be deepened by up to 1.0 m to a new slab level of 14.28 m OD across the entire footprint, such that formation level will be at 13.48 m OD. The existing basement does not occupy the entire footprint of the building in that there is a central area without a basement which is surrounded on all sides by the existing basement, as shown in the plan below and referred to as an 'island' in this report. As part of the basement construction, the 'island' of material will be removed such that the existing basement will extend beneath the entire footprint. The surface above the existing 'island' is hardstanding.



This report is specific to the proposed development and the advice herein should be reviewed if the proposals are amended.

1.2 Purpose of Work

The principal technical objectives of the work carried out were as follows:

- to check the history of the site with respect to previous contaminative uses;
- to determine the ground conditions and their engineering properties;
- to assess the possible impact of the proposed development on the local hydrogeology and surrounding structures;
- to provide advice with respect to the design of suitable foundations and retaining walls;
- to provide an indication of the degree of soil contamination present; and
- to assess the risk that any such contamination may pose to the proposed development, its users or the wider environment.

1.3 Scope of Work

In the light of the previous desk study, an intrusive ground investigation was carried out in two phases and comprised, in summary, the following activities:

- eight hand held window sampler boreholes advanced to a maximum depth of 3.0 m;
- laboratory testing of selected soil samples for the presence of contamination; and
- provision of a report presenting and interpreting the above data, together with our advice and recommendations with respect to the proposed development.

Trial pit records detailing the existing foundations at the boundary walls have also been provided by the consulting engineers and are discussed in this report.

The report includes a contaminated land assessment which has been undertaken in accordance with the methodology presented in Contaminated Land Report (CLR) 11[1] and involves identifying, making decisions on, and taking appropriate action to deal with, land contamination in a way that is consistent with government policies and legislation within the United Kingdom. The risk assessment is thus divided into three stages comprising Preliminary Risk Assessment, Generic Quantitative Risk Assessment, and Site-Specific Risk Assessment.

1.3.1 Basement Impact Assessment

The work carried out also includes a Hydrological and Hydrogeological Assessment and Land Stability Assessment (also referred to as Slope Stability Assessment), all of which form part of the BIA procedure specified in the London Borough of Camden (LBC) Planning Guidance CPG4[2] and their Guidance for Subterranean Development[3] prepared by Arup ('the Arup Report'). The aim of the work is to provide information on surface water, groundwater and land stability and in particular to assess whether the development will affect neighbouring properties or groundwater movements and whether any identified impacts can be appropriately mitigated by the design of the development.

1 *Model Procedures for the Management of Land Contamination* issued jointly by the Environment Agency and the Department for Environment, Food and Rural Affairs (DEFRA) Sept 2004
2 London Borough of Camden Planning Guidance CPG4 *Basements and lightwells*
3 Ove Arup & Partners (2010) *Camden geological, hydrogeological and hydrological study. Guidance for Subterranean Development.* For London Borough of Camden November 2010

1.3.2 Qualifications

The land stability element of the Basement Impact Assessment (BIA) has been carried out by Martin Cooper, a BEng in Civil Engineering, a chartered engineer (CEng), member of the Institution of Civil Engineers (MICE), and Fellow of the Geological Society (FGS) who has over 25 years' specialist experience in ground engineering. The subterranean (groundwater) flow assessment has been carried out by John Evans, MSc in Hydrogeology, Chartered Geologist (CGeol) and Fellow of the Geological Society of London (FGS). The surface water and flooding assessment has been carried out by Rupert Evans, a hydrologist with more than ten years consultancy experience in flood risk assessment, surface water drainage schemes and hydrology / hydraulic modelling. Rupert Evans is a Chartered Environmentalist, Chartered Water and Environmental Manager and a Member of CIWEM.

The assessments have been made in conjunction with Steve Branch, a BSc in Engineering Geology and Geotechnics, MSc in Geotechnical Engineering, a Chartered Geologist (CGeol) and Fellow of the Geological Society (FGS) with some 30 years' experience in geotechnical engineering and engineering geology.

All assessors meet the qualification requirements of the Council guidance.

1.4 Limitations

The conclusions and recommendations made in this report are limited to those that can be made on the basis of the investigation. The results of the work should be viewed in the context of the range of data sources consulted, the number of locations where the ground was sampled and the number of soil, gas or groundwater samples tested; no liability can be accepted for information in other data sources or conditions not revealed by the sampling or testing. Any comments made on the basis of information obtained from the client or other third parties are given in good faith on the assumption that the information is accurate; no independent validation of such information has been made by GEA.

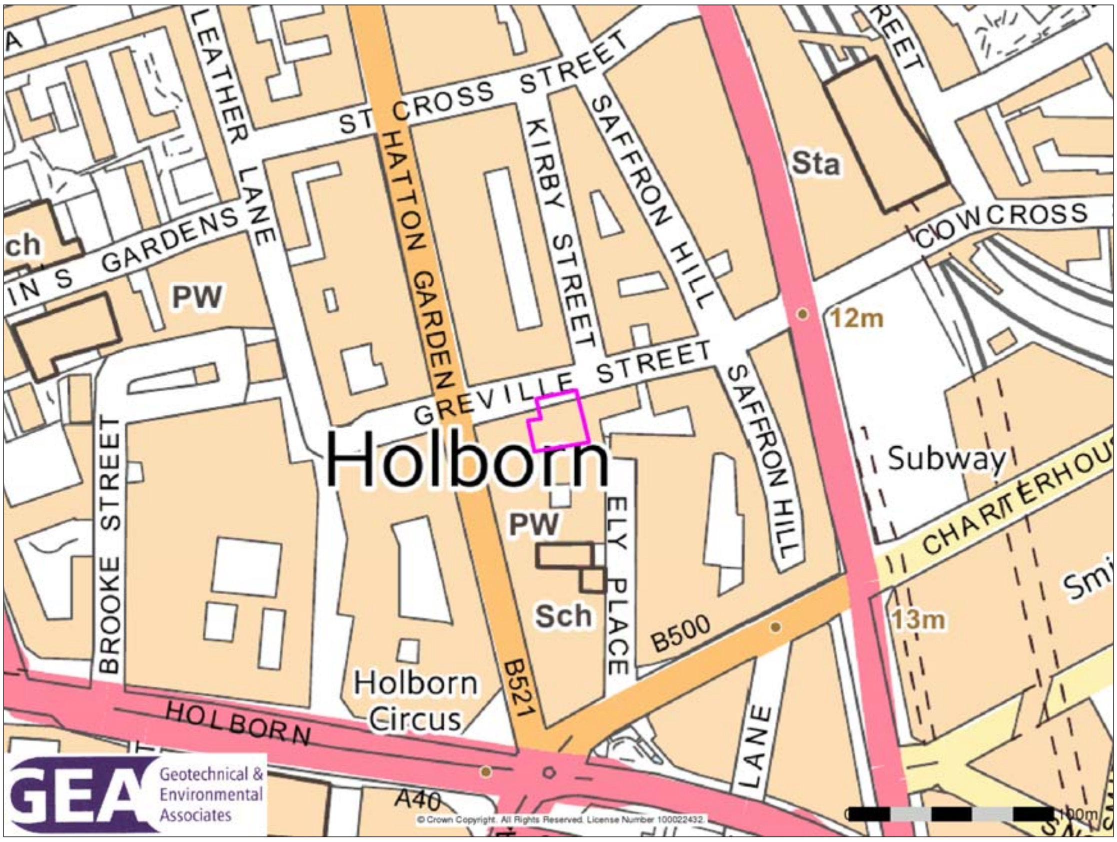
2.0 THE SITE

2.1 Site Description

The site is located in the London Borough of Camden, roughly 200 m southwest of Farringdon Station and 310 m northeast of Chancery Lane London Underground Station. It is roughly rectangular in shape, measuring approximately 25 m north-south by 20 m east-west. The site fronts on to Greville Street to the north and is adjoined by four-storey buildings that also front onto Greville Street to the east and west and by a building that fronts on to Ely Place to the south. The building to the west, 11 Greville Street, is Grade II Listed. The site may additionally be located by National Grid Reference 531397, 181742 and is shown on the map extract overleaf.

The site is entirely occupied by Nos 12 to 14 Greville Street, which form two adjoining five-storey buildings with a single level basement beneath the majority of the site, with the exception of the northwestern corner and a central section of the site.

At the time of the fieldwork the building was in use as offices, with a café present in the northwestern corner of the site. The site is at a range of levels, from 17.55 m OD in the central courtyard, where no basement is present, to 14.83 m OD in Nos 12 & 13 Greville Street and with two levels in No 14, of 15.86 m OD and 14.28 m OD.



2.2 Site History

The history of the site and surrounding area has been researched by reference to historical Ordnance Survey (OS) maps sourced from the Envirocheck database.

John Rocque's 1746 Map of London shows the site to be developed with Grevil Street present and running east-west from Leather Lane to Brook Street, whilst to the east it became Cross Street, beyond Saffron Hill. At that time a stable yard was shown to the east of the site, leading from Cross Street. A park area that appeared to belong to a chapel is also shown to the southeast. By the time of Greenwood's Map of London, dated 1827, Grevil Street is shown as Greville Street, while Cross Street was named Charles Street. The map dated 1878 shows the site to be occupied by a number of buildings that adjoin one another around a central courtyard. The park area to the south had also been developed as part of the buildings that fronted on to Ely Mews to the south. By 1916 the cluster of buildings had apparently been demolished and replaced with one large building that occupied the entire site, with the exception of the northwestern quarter of the site, that was occupied by a public house. The insurance plan dated 1922 indicates the site was occupied by a cluster of two-storey and four-storey buildings, including a public house in the northwest, with a small rear courtyard and a printer rollers and surgical instrument facility in the east. By 1948 the building was also used as a picture engraver. By 1953 Charles Street had been renamed to be a continuation of Greville Street, while the public house was no longer annotated as such and was indicated to be Nos 12 and 13. The site has since remained largely unchanged.

2.3 Other Information

A search of public registers and databases has been made via the Envirocheck database and relevant extracts from the search are appended. Full results of the search can be provided if required.

The search has revealed that there are no landfills, waste management, transfer, treatment or disposal sites within 500 m of the site. There have been no pollution incidents to controlled waters within 500 m of the site.

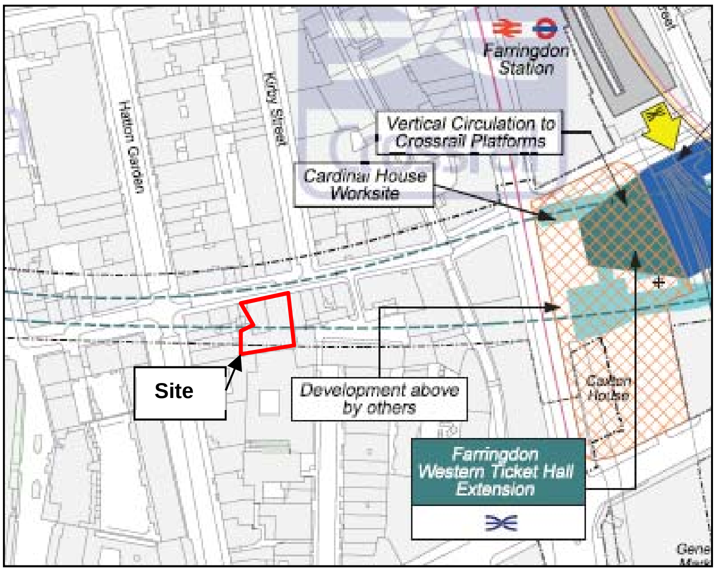
The search has indicated that the site is located in an area where less than 1% of homes are affected by radon emissions; which is the lowest classification given by the Health Protection Agency (HPA) and therefore no radon protective measures will be necessary.

The site is not located within a nitrate vulnerable zone or any other sensitive land use.

The results of a search of the Camden Planning Portal for planning applications relating to the properties surrounding the site to determine those with basements are highlighted on the map below.

No 11 Greville Street has a basement, which has previously been used as an iron monger and silver plating and gilding company (application ref 629 dated 1959). No 15 Greville Street has a single level basement (application ref 30676, dated 1980). No 2 Bleeding Heart Yard has no evidence of a basement on the London Borough of Camden (LBC) planning portal, although there is evidence of a basement or lower ground floor in the form of pavement lights adjacent to the building at pavement level. Nos 16 to 20 Ely Place, also known as Audrey House, has a sub-basement extending to a level of approximately 10.0 m OD. Nos 19 to 22 and No 25 Hatton Gardens have no evidence of basements on the LBC planning portal, although there is evidence of a basement or lower ground floor in the form of possible lightwells at the front of the

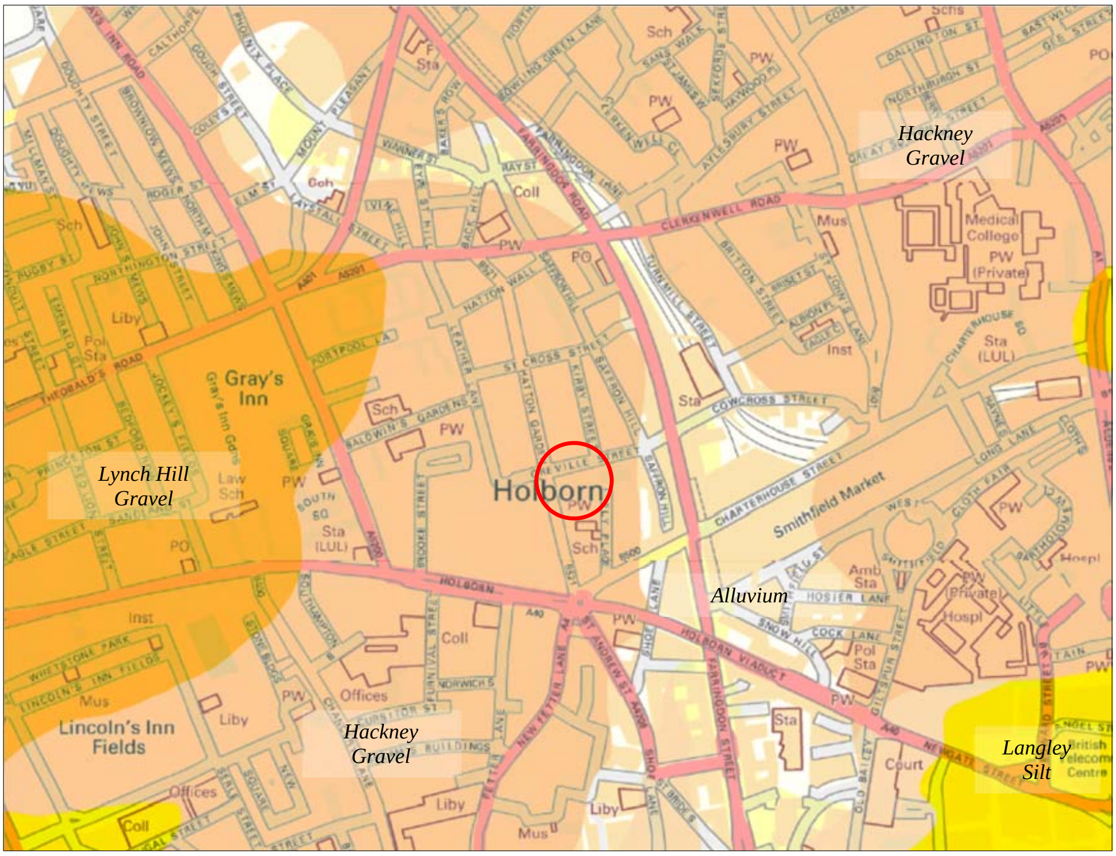
building. There are no records of basement structures beneath Nos 23 to 24 Hatton Garden on the LBC planning portal or insurance plans, nor is there evidence to the front of the buildings. There is evidence of basements on the LBC planning portal at Nos 8 to 10 Greville Street.



The site lies to the west of Farringdon station which is the easternmost end of the western tunnel drive of Crossrail between Royal Oak and Farringdon, at a depth of roughly 25 m below the site. It comprises two 6.8 km rail tunnels, constructed by boring machines. The tunnels were completed in October 2013 and January 2014, with the northernmost tunnel running below Greville Street and the southernmost tunnel running beneath the central-southern part of the site.

2.4 Geology

The British Geological Survey (BGS) map of the area (Sheet 256) indicates the site to be underlain by the Hackney Gravel over the London Clay Formation. A digital map sourced from FIND maps is included below, indicating the location of the site with respect to the geological boundaries.



According to the BGS memoir, the Hackney Gravel predominantly comprises sand and gravel, with localised lenses of clay and silt and is characteristically free-draining. The London Clay Formation is homogenous, slightly calcareous silty clay to very silty clay, with some beds of clayey silt grading to silty fine grained sand.

A historical BGS borehole drilled roughly 50 m southwest of the site encountered gravel to a depth of 2.7 m over London Clay to a depth of 18.4 m. Below this the Lambeth Group was encountered.

2.5 Hydrology and Hydrogeology

The Hackney Gravel is classified as a Secondary 'A' Aquifer, which refers to strata that contain permeable layers capable of supporting water supply at a local level and in some cases may form an important source of base flow for local rivers, as defined by the Environment Agency (EA). The underlying London Clay is classified as a Non-Aquifer and Unproductive Stratum, which refers to a soil or rock with low permeability that has a negligible effect on local water supply or river base flow.

There are no EA designated Source Protection Zones (SPZs) on the site. The Envirocheck report indicates that the nearest surface water feature is located 381 m south of the site. The site is not located in an area at risk of flooding from rivers or sea, as defined by the EA.

Reference to the Lost Rivers of London[4] indicates that a tributary of the River Fleet flowed along Farringdon Road in a southerly direction, approximately 130 m to the east of the site. The direction of groundwater flow beneath the site is likely to be in a southerly direction, downslope towards the River Thames.

4 Nicholas Barton (2000) *London's Lost Rivers.* Historical Publications Ltd

Any surface water runoff that infiltrates the shallow made ground and Hackney Gravel above the London Clay is likely to flow southwards along the surface of the London Clay towards the River Thames which is located roughly 920 m to the south.

The permeability of the Hackney Gravel is expected to range between about 1 x 10^{-6} m/s and 1 x 10^{-4} m/s, whereas in contrast, any groundwater flow within the London Clay will be at a very slow rate, due to its negligible permeability. Published data for the permeability of the London Clay indicates the horizontal permeability to generally range between 1 x 10^{-10} m/s and 1 x 10^{-8} m/s, with an even lower vertical permeability. The London Clay cannot therefore support groundwater flow and as such does not support a "water table" or continuous piezometric surface. Boreholes constructed within clays do fill with water due to the often high water content of shallow clays; however, this is not reflective of groundwater flow in a porous and permeable saturated stratum.

Subsequent monitoring at the site along Gray's Inn Road measured groundwater at levels of between 14.64 m OD and 15.27 m OD in the Hackney Gravel. Deeper groundwater has been encountered at levels of between 10.80 m OD and 14.83 m OD in the London Clay and at levels of between 9.29 m OD and 9.55 m OD in the Lambeth Group.

2.6 Preliminary Risk Assessment

Part IIA of the Environmental Protection Act 1990, which was inserted into that Act by Section 57 of the Environment Act 1995, provides the main regulatory regime for the identification and remediation of contaminated land. The determination of contaminated sites is based on a "suitable for use" approach which involves managing the risks posed by contaminated land by making risk-based decisions. This risk assessment is carried out on the basis of a source-pathway-receptor approach.

2.6.1 Source

The desk study research has indicated that the site has only been occupied by the existing building for its entire developed history, with known site uses comprising a public house in the northwest, a printer rollers, surgical instrument facility and picture engraver in the east The site is therefore not considered to have had a contaminative history.

2.6.2 Receptor

The future end users of the commercial building will represent high sensitivity receptors. The site is underlain by a Secondary 'A' Aquifer and therefore groundwater is considered to be a relatively sensitive receptor. Similarly, perched water may also exist in the made ground or in the vicinity of existing foundations. Buried services are likely to come into contact with any contaminants present within the soils through which they pass and site workers are likely to come into contact with any contaminants present during demolition and construction works.

2.6.3 Pathway

The new building will cover the entire footprint of the site and it is likely that this will effectively form a barrier between any contaminants within the near-surface soils and end-users or infiltration of surface water. Furthermore it is understood that areas of soft landscaping will not form part of the proposed development.

Buried services will be exposed to any contaminants present within the soil through direct contact and site workers will come into contact with the soils during construction works. There is thus considered to be very low potential for a contaminant pathway to be present between any potential contaminant source and a target for the particular contaminant.

2.6.4 Preliminary Risk Appraisal

On the basis of the above it is considered that there is a low risk of there being a significant contaminant linkage at this site, which would result in a requirement for major remediation work. Furthermore as there is no evidence of filled ground within the vicinity, there is not considered to be a significant potential for hazardous soil gas to be present on or migrating towards the site; there should thus be no need to consider soil gas exclusion systems.

3.0 SCREENING

The LBC guidance suggests that any development proposal that includes a subterranean basement should be screened to determine whether or not a full BIA is required.

3.1 Screening Assessment

A number of screening tools are included in the Arup document and for the purposes of this report reference has been made to Appendices E1, E2 and E3 which include a series of questions within screening flowcharts for surface flow and flooding, subterranean (groundwater) flow and land stability. The flowchart questions and responses to these questions are tabulated below.

3.1.1 Subterranean (groundwater) Screening Assessment

Question	Response for 12-14 Greville Street
1a. Is the site located directly above an aquifer?	*Yes. The site is located above a Secondary 'A' Aquifer as designated by the EA.*
1b. Will the proposed basement extend beneath the water table surface?	*Possibly. The Hackney Gravel has been found to be present beneath the existing basement and groundwater is anticipated to be present within the Hackney Gravel The deepest excavations are understood to extend below the site to a level of 13.28 m OD and thus it is possible that the Hackney Gravel will be fully excavated as part of the proposed basement construction and that any potential groundwater within the Hackney Gravel is cut-off as a result of the basement deepening.*
2. Is the site within 100 m of a watercourse, well (used/ disused) or potential spring line?	No. The site is located 130 m to the west of the former River Fleet and 920 m to the north of the River Thames.
3. Is the site within the catchment of the pond chains on Hampstead Heath?	No.
4. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas?	No, the area of the removal of the central 'island' already has hardstanding above it and there will be no change in the proportion of hardstanding
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 soakaways and/or SUDS)?	No. Site drainage will continue to be directed to public sewer, as per the existing situation.
6. Is the lowest point of the proposed 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?	No. There are no local ponds or spring lines

The above assessment has identified the following potential issues that need to be assessed:

Q1a The site is located directly above an aquifer.
Q1b The proposed basement could extend beneath the water table.

3.1.2 Stability Screening Assessment

Question	Response for 12-14 Greville Street
1. Does the existing site include slopes, natural or manmade, greater than 7°?	No.
2. Will the proposed re-profiling of landscaping at the site change slopes at the property boundary to more than 7°?	No.
3. Does the development neighbour land, including railway cuttings and the like, with a slope greater than 7°?	No.
4. Is the site within a wider hillside setting in which the general slope is greater than 7°?	No.
5. Is the London Clay the shallowest strata at the site?	No.
6. Will any trees 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?	No.
7. Is there a history of seasonal shrink-swell subsidence in the local area and / or evidence of such effects at the site?	No.
8. Is the site within 100 m of a watercourse or potential spring line?	No.
9. Is the site within an area of previously worked ground?	No.
10. Is the site within an aquifer?	*Yes a Secondary 'A' Aquifer.*
11. Is the site within 50 m of Hampstead Heath ponds?	No.
12. Is the site within 5 m of a highway or pedestrian right of way?	*Yes. Greville Street and the associated footway are parallel to the northern boundary.*
13. Will the proposed basement significantly increase the differential depth of foundations relative to neighbouring properties?	No.
14. Is the site over (or within the exclusion zone of) any tunnels, e.g. railway lines?	Yes a Crossrail tunnel is at a depth of approximately 25 m below the site.

The above assessment has identified the following potential issues that need to be assessed:

Q10 The site is located within the Secondary 'A' Aquifer of the Hackney Gravel.
Q12 Greville Street runs parallel to the northern boundary of the site.
Q14 There is a Crossrail Tunnel around 25 m below the site.

3.1.3 Surface Flow and Flooding Screening Assessment

Question	Response for 12 to 14 Greville St
1. Is the site within the catchment of the pond chains on Hampstead Heath?	No. Figure 14 of the Arup report confirms that the site is not located within this catchment area.
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?	No. There will not be an increase in impermeable area across the ground surface above the basement, so the surface water flow regime will be unchanged. There will be no surface expression of the basement development, so the surface water flow regime will be unchanged.

Question	Response for 12 to 14 Greville St
	The basement will entirely be beneath the footprint of the existing building footprint and hardstanding areas, therefore the 1m distance between the roof of the basement and ground surface as recommended by the Arup report and para 2.16 of the CPG4 does not apply.
3. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas?	No. There will not be an increase in impermeable area across the ground surface above the basement. There will be no surface expression of the basement development.
4. Will the proposed basement development result in changes to the profile of the inflows (instantaneous and long term) of surface water being received by adjacent properties or downstream watercourses?	No. There will not be an increase in impermeable area across the ground surface above the basement, so the surface water flow regime will be unchanged. There will be no surface expression of the basement development, so the surface water flow regime will be unchanged. The basement will entirely be beneath the footprint of the existing building footprint/existing hardstanding areas, therefore the 1m distance between the roof of the basement and ground surface as recommended by the Arup report and para 2.16 of the CPG4 does not apply.
5. Will the proposed basement result in changes to the quality of surface water being received by adjacent properties or downstream watercourses?	No. The proposed basement is very unlikely to result in any changes to the quality of surface water being received by adjacent properties or downstream watercourses as the surface water drainage regime will be unchanged.
6. Is the site in an area identified to have surface water flood risk according to either the Local Flood Risk Management Strategy or the Strategic Flood Risk Assessment or is it at risk of flooding, for example because the proposed basement is below the static water level of a nearby surface water feature?	No. The Camden Flood Risk Management Strategy dated 2013, together with Figures 3i, 4e, 5a and 5b of the SFRA dated 2014, and Environment Agency online flood maps show that the site has a very low flooding risk from surface water, sewers, reservoirs (and other artificial sources), groundwater and fluvial/tidal watercourses. In accordance with paragraph 5.11 of the CPG a positive pumped device will be installed in the basement in order to further protect the site from sewer flooding. The site is located within the Critical Drainage Area number GROUP3-003, but is not in a Local Flood Risk Zone, as identified in the Camden SWMP and Updated SFRA Figure 6/Rev 2.

The above assessment has identified no potential issues that need to be assessed.

4.0 SCOPING AND SITE INVESTIGATION

The purpose of scoping is to assess in more detail the factors to be investigated in the impact assessment. Potential impacts are assessed for each of the identified potential impact factors.

4.1 Potential Impacts

The following potential impacts have been identified by the screening process

Potential Impact	Consequence
The site is located directly above an aquifer	The site is underlain by the Hackney Gravel, which is classified as a Secondary 'A' Aquifer. This has the potential of being able to support local water supplies as well as forming an important source of base flow for local rivers. There is the potential for the hydrogeological setting to be affected by a basement development.

Potential Impact	Consequence
The proposed basement may extend beneath the water table surface	As stated above, groundwater would be expected to be encountered within the Hackney Gravel and therefore it is possible that the basement excavation will extend below the water table. The deepest excavations are understood to extend to a level of 13.28 m OD and thus it is possible that the Hackney Gravel will be fully excavated as part of the proposed basement construction, which may have an effect on local groundwater movements. This in turn has the potential to affect the local hydrogeology and any adjacent structures.
It is possible that the basement will be constructed within a perched groundwater table.	Water-proofing and tanking of the basement construction is likely to reduce the risk to acceptable levels.
Is the site located within 5 m of a public highway or pedestrian right of way?	The public walkway of Greville Street borders the site to the north and the excavation of a basement can cause instability of such structures. However the proposed basement excavation is actually over 5 m away from the footway.
There is a Crossrail Tunnel about 25 m below the site	Any ground movements from the installation of new retaining walls and/or excavations may affect the underlying tunnel.

These potential impacts have been investigated through the site investigation, as detailed below.

4.2 Exploratory Work

The basement is accessed through the front of the building and via a staircase and lift from upper ground floor level. Therefore, in order to meet the objectives described in Section 1.2, as far as possible within the access restrictions, eight hand held window sampler boreholes were drilled from basement level.

All of the above work was carried out under the supervision of a geotechnical engineer from GEA.

A number of trial pits were also excavated by others to investigate the existing foundations; trial pit records have been provided and are included in the appendix.

Following the initial investigation, additional fieldwork was carried out, once access became available, to confirm the ground conditions in the east and west of the site and to satisfy the requirements of the BIA audit.

The borehole records and results of the laboratory testing are enclosed, together with a site plan indicating the exploratory positions. The Ordnance Datum (OD) levels shown on the borehole and trial pit records have been interpolated from spot heights shown on a Frost Architects drawing (ref 15229/20/D0, dated 11 August 2015), which was provided by the consulting engineers.

4.3 Sampling Strategy

The scope of the works was specified by the consulting engineers, with input from GEA. The borehole positions were positioned on site by GEA with due regard to the proposed development, whilst avoiding areas of known services.

A single sample of the made ground was subjected to analysis for a range of common industrial contaminants and contamination indicative parameters. For this investigation the analytical suite for the soil included a range of metals, speciation of total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH), total cyanide and monohydric phenols for the purposes of general coverage. The soil sample was selected to provide a general view of the chemical conditions of the soils that are likely to be involved in a human exposure or groundwater pathway and to provide advice in respect of re-use or for waste disposal classification.

The contamination analyses were carried out at an MCERTs accredited laboratory with the majority of the testing suite accredited to MCERTS standards. Details of the MCERTs accreditation and test methods are included in the Appendix together with the analytical results.

5.0 GROUND CONDITIONS

The investigation has encountered a limited thickness of made ground over the Hackney Gravel, which was in turn underlain by the London Clay to the maximum depth of the investigation, of 3.00 m below basement level.

5.1 Made Ground

Beneath a layer of concrete of between 100 mm and 400 mm in thickness, made ground generally comprising dark greyish brown sandy clay with gravel, large fragments of brick and concrete with occasional charcoal was encountered to depths of between 0.30 m (13.98 m OD) and 0.60 m (13.68 m OD). In Borehole No 1, a void was encountered beneath the initial concrete floor slab with a second layer of concrete at 1.7 m (14.16 m OD) where this borehole was terminated.

Beneath a 50 mm layer of screed, Borehole Nos 5, 5A and 5B encountered dry lean concrete reinforced with 15 mm diameter rebar to depths of between 0.30 m and 0.50 m. Borehole Nos 5 and 5B were terminated on obstructions at 0.50 m depth and 0.30 m depth respectively.

Apart from the presence of fragments of extraneous material noted above, no visual or olfactory evidence of contamination was observed during the fieldwork. A single sample of the made ground was tested for the presence of contamination and the results are detailed within Section 4.5.

5.2 Hackney Gravel

This stratum generally comprised brown, greyish brown or yellowish brown very gravelly fine to coarse sand and extended to depths of between 1.70 m (12.58 m OD) and 1.80 m (12.48 m OD) below existing basement level.

5.3 London Clay

The London Clay generally comprised firm orange-brown becoming grey fissured silty clay and was proved to the maximum depth of the investigation, of 3.00 m (11.28 m OD) below existing basement level.

5.4 Groundwater

Groundwater was encountered during drilling at depths of between 1.40 m (12.88 m OD) and 1.75 m (12.53 m OD) in Borehole Nos 6 and 4 respectively. The granular soils were also noted to be damp from 1.00 m (13.28 m OD) in Borehole No 4, which is likely to represent seepage of perched water from the made ground above, whilst the gravels were noted to be damp from a depth of 1.50 m (12.78 m OD) in Borehole No 2 and from a depth of 1.70 m (12.58 m OD) in Borehole No 3, both observations are thought to represent the groundwater table.

Standpipes were installed in Borehole Nos 3, 4 and 6 to depths of between 1.35 m and 2.20 m. Groundwater was monitored at a depth of 1.60 m in Borehole No 4 on completion of the installation, however the standpipe appeared to have silted up during the next monitoring visit and was subsequently cleared and groundwater was monitored at 1.54 m seven weeks after the date of its original installation. Groundwater was monitored at a depth of 1.48 m in Borehole No 6 on completion of the standpipe installation.

The standpipe installed in Borehole No 3 was disturbed during excavation of Trial Pit No 8, although later monitoring of groundwater at a depth of 1.98 m within the pipe indicates that it may have silted up and therefore this measurement has been discounted.

Groundwater was also encountered in a number of the trial pit excavations at a depth of approximately 1.50 m.

5.5 Soil Contamination

A single sample of made ground was tested for a range of common industrial contaminants and the results of the analysis are discussed below.

The use of a risk-based approach has been adopted to provide an initial screening of the test results to assess the need for subsequent site-specific risk assessments. To this end contaminants of concern are those that have values in excess of a generic human health risk based guideline values which are either that of the CLEA[5] Soil Guideline Value where available, or is a Generic Screening Value calculated using the CLEA UK Version 1.06[6] software assuming a commercial end use, or is based on the DEFRA Category 4 Screening values[7]. The key generic assumptions for this end use are as follows;

- that groundwater will not be a critical risk receptor;
- that the critical receptor for human health will be a working female aged 16 to 65 years;
- that the exposure duration will be 49 years;
- that the critical exposure pathways will be direct soil and indoor dust ingestion, skin contact with soils and dust, and inhalation of dust and vapours; and
- that the building type equates to a three-storey office.

It is considered that these assumptions are acceptable, albeit conservative, for this generic assessment of this site. The tables of generic screening values derived by GEA and an explanation of how each value has been derived are included in the Appendix.

Where contaminant concentrations are measured at concentrations below the generic screening value it is considered that they pose an acceptable level of risk and thus further consideration of these contaminant concentrations is not required. However, where concentrations are measured in excess of these generic screening values there is considered to be a potential that

5 *Updated Technical Background to the CLEA Model (Science Report SC050021/SR3) Jan 2009* and Soil Guideline Value reports for specific contaminants; all DEFRA and Environment Agency.

6 Contaminated Land Exposure Assessment (CLEA) Software Version 1.06 Environment Agency 2009

7 CL:AIRE (2013) *Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination* Final Project Report SP1010 and DEFRA (2014) *Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination* Policy Companion Document SP1010

they could pose an unacceptable risk and thus further action will be required which could include;

- additional testing to zone the extent of the contaminated material and thus reduce the uncertainty with regard to its potential risk;
- site specific risk assessment to refine the assessment criteria and allow an assessment to be made as to whether the concentration present would pose an unacceptable risk at this site; or
- soil remediation or risk management to mitigate the risk posed by the contaminant to a degree that it poses an acceptable risk.

The results of the chemical analyses have indicated no elevated concentrations of contaminants within the made ground.

5.6 Existing Foundations

A summary of the findings of the trial pits is tabulated below and the trial pit records are included in the Appendix.

Trial Pit No	Structure	Foundation detail	Bearing Stratum
1	Eastern boundary	Brick corbels and concrete extending to at least 1.0 m, base not proved.	Unconfirmed
2	Southern boundary	Brick corbels resting on 200mm thick concrete slab	Unconfirmed
3	Southwestern Corner	Concrete strip bearing at a depth of 1.25 m	Sand
4	Southern boundary adjacent to Audrey House Corner	Concrete underpin extending to at least 2.32 m	Assumed to be London Clay
5	Southeastern corner	Brick corbels and concrete extending to approximately 1 m	Gravel
5 & 6	Southeastern corner (below column)	Concrete pad extending to a depth of 1.55 m	Gravel
7 A-A’	Eastern boundary adjacent to No 2 Bleeding Heart Yard	Brick corbels and concrete extending to 1.30 m	Sand
7 B-B’	Southern boundary adjacent to No 2 Bleeding Heart Yard	Brick corbels and concrete extending to 1.28 m	Sand
8	Northeastern wall of central pavement vault	Brick corbels and concrete extending to 1.71 m	Clay
11 A-A’	Western boundary	Concrete extending to 0.80 m	Gravel
11 B-B’	Northern boundary adjacent to lightwell to the rear of No 10 Greville St	Brick corbels over concrete extending to 1.00 m	Gravel

The trial pitting and on site observations have indicated the presence of a sub-basement at Audrey House which borders the site to the south. The adjacent basement level is understood to extend to a depth of about 10.08 m OD (assumed formation level), bearing in London Clay.

Part 2: DESIGN BASIS REPORT

This section of the report provides an interpretation of the findings detailed in Part 1, in the form of a ground model, and then provides advice and recommendations with respect to the proposed development.

6.0 INTRODUCTION

Consideration is being given to the redevelopment of the site by the construction of a new five-storey building with a single level basement beneath the entire footprint of the site. The new building will be supported by a raft foundation with a finished slab level at 14.28 m OD and a formation level at 13.48 m OD. The uniform distributed load on the raft is understood to be approximately 72 kN/m^2. The raft will not extend to the southern boundary where there will be a ‘no loading zone’ to prevent overstressing of the sub-basement of the adjoining building, Audrey House.

7.0 GROUND MODEL

The desk study has revealed that the site has not had a potentially contaminative history on the basis that it has been occupied by the existing building for its entire developed history. On the basis of the fieldwork, the ground conditions at this site can be characterised as follows:

- below a moderate thickness of made ground, the Hackney Gravel was encountered over London Clay, which was found to extend to the maximum depth of the investigation, of 3.00 m (11.28 m OD);
- the Hackney Gravel generally comprises brown very gravelly fine to coarse sand and extends to a depth of 1.80 m (12.48 m OD);
- the London Clay comprises soft becoming firm or firm orange-brown becoming grey fissured silty clay and extends to the full depth investigated, of 3.00 m (11.28 m OD);
- groundwater is present within the Hackney Gravel at a typical depth of 1.50 m (12.74 m OD); and
- contamination testing of a single sample of the made ground indicated no elevated concentrations of contaminants.

8.0 ADVICE AND RECOMMENDATIONS

The proposed loads are anticipated to be moderate and in view of the underlying tunnels the structure will be supported by a raft foundation in order to limit the increase in stress at tunnel level. Groundwater is expected to be at a depth of 0.70 m (12.74 m OD) below formation level. Localised underpinning will be required along the boundary walls.

8.1 Spread Foundations

Underpins bearing on the gravelly sand of the Hackney Gravel may be designed to apply a net allowable bearing pressure of 225 kN/m^2. This value incorporates an adequate factor of safety against bearing capacity failure and should ensure that settlement remains within normal tolerable limits.

It is understood that the present underpinning design along the western boundary is based on a maximum net allowable bearing pressure of 225 kN/m^2. Assuming a strip footing approximately 0.6 m wide at this location, with a 800 mm thickness of gravel below the underpin, the resultant pressure on underlying London Clay has been estimated to be around 100 kN/m^2, which will be acceptable on firm clay.

8.2 Basement Excavation

The proposed basement excavation will extend to a level of 13.48 m OD resulting in formation level in the Hackney Gravel; the depth of excavation will generally be about 0.8 m increasing to roughly 3.6 m in the centre of the site where no basement is currently present. Based on the groundwater observations to date, with slow inflows noted in the borehole and trial pits at 12.78 m OD, groundwater is unlikely to be encountered within the main excavation.

The design of basement support in the temporary and permanent conditions needs to take account of the requirement to maintain the stability of the excavation and surrounding structures and to protect against potential groundwater inflows. There are a number of methods by which the sides of the basement excavations could be supported in the temporary and permanent conditions. It is understood that the preferred method will be to form the retaining walls by underpinning the existing party walls using a traditional ‘hit and miss’ approach. Careful workmanship will be required to ensure that movement of the surrounding structures is restricted while excavating in the underlying granular material. Consideration must be given to the stability of excavations to form the underpins within the made ground and gravel, which should be assessed by a temporary works specialist and a watching brief should be maintained throughout the excavation phase of works.

A ground movement assessment to predict the likely movements as a result of the proposed basement construction is included in Part 3.

8.2.1 Basement Retaining Walls

The parameters below are suggested for the design of the permanent basement retaining walls.

Stratum	Bulk Density (kg/m^3)	Effective Cohesion (c′ – kN/m^2)	Effective Friction Angle (ϕ′ – degrees)
Made ground	1700	Zero	27
Hackney Gravel	1800	Zero	33
London Clay	1900	Zero	24

Groundwater is expected to be present below the anticipated level of the proposed basement excavation, although monitoring should be continued to establish equilibrium levels.

On the basis that the Hackney Gravel comprises an essentially free draining material, it is unlikely to be a requirement to design for water pressure above basement slab level. However, the advice in BS8102:2009[1] should be followed in this respect and it is likely that drainage will need to be provided behind the walls to prevent water collecting within the made ground or within any disturbed ground behind the walls. If an effective drainage system cannot be ensured, then a water level of two-thirds of the basement depth should be assumed.

[1] BS8102 (2009) *Code of practice for protection of below ground structures against water from the ground*

8.3 Raft Foundation

The Hackney Gravel should be suitable for the support of a moderately loaded raft foundation, although only a limited thickness of gravel will remain above the London Clay at formation level. A check on the likely settlement of the raft has been carried out as part of the GMA and confirms that the London Clay will not be overstressed. No additional analysis is required in this respect. In consideration to the deeper basement along the southern boundary, to ensure that additional load is not placed on the foundations of the adjacent structure to the south, the raft will not extend to the southern boundary. An assessment of the ground movements resulting from the construction is provided in Part 3 of this report.

8.4 Shallow Excavations

On the basis of the trial pit findings, it is considered likely that it will be feasible to form relatively shallow excavations that extend into the underlying made ground without the requirement for lateral support, although localised instabilities may occur. Instabilities are likely to occur in excavations within the underlying Hackney Gravel, particularly where perched groundwater is encountered. Underpinning on the western side of the site will extend to a depth to match the underside of the proposed raft at 13.5 m, whilst groundwater is expected to be present at around 12.8 m OD, hence, groundwater inflows from the gravel are unlikely. Where personnel are required to enter excavations, a risk assessment should be carried out and temporary lateral support or battering of the excavation sides will be required in order to comply with normal safety requirements.

8.5 Effect of Sulphates

Chemical analysis has revealed a low concentration of soluble sulphate and slightly alkaline pH in accordance with Class DS-1 conditions of Table C2 of BRE Special Digest 1:SD Third Edition (2005). This assumes a mobile water condition at the site. The guidelines contained in the digest should be followed in the design of foundation concrete.

8.6 Contamination Risk Assessment

The desk study findings have not indicated that the site has a potentially contaminative history. The results of the chemical analyses have indicated no elevated concentrations of contaminants within the made ground tested.

8.6.1 Site Workers

Site workers should be made aware of the presence of potential contamination, and a programme of working should be identified to protect workers handling any soil. The method of site working should be in accordance with guidelines set out by HSE and CIRIA and the requirements of the Local Authority Environmental Health Officer. A watching brief should also be maintained during the groundwork, and if suspicious soils are encountered then a suitably qualified engineer should inspect the soils and further testing should be carried out if required.

8.7 Waste Disposal

Under the European Waste Directive, waste is classified as being either Hazardous or Non-Hazardous and landfills receiving waste are classified as accepting hazardous or non-hazardous wastes or the non-hazardous sub-category of inert waste in accordance with the Waste Directive. Waste classification is a staged process and this investigation represents the preliminary sampling exercise of that process. Once the extent and location of the waste that is to be removed has been defined, further sampling and testing may be necessary. The results from this ground investigation should be used to help define the sampling plan for such further testing, which could include WAC leaching tests where the totals analysis indicates the soil to be a hazardous waste or inert waste from a contaminated site. It should however be noted that the Environment Agency guidance WM3[8] states that landfill WAC analysis, specifically leaching test results, must not be used for waste classification purposes.

Any spoil arising from excavations or landscaping works, which is not to be re-used in accordance with the CL:AIRE[9] guidance, will need to be disposed of to a licensed tip. Waste going to landfill is subject to landfill tax at either the standard rate of £86.10 per tonne (about £155 per m^3) or at the lower rate of £2.70 per tonne (roughly £5 per m^3). However, the classifications for tax purposes and disposal purposes differ and currently all made ground and topsoil is taxable at the 'standard' rate and only naturally occurring soil and stones, which are accurately described as such in terms of the 2011 Order, would qualify for the 'lower rate' of landfill tax.

Based upon on the technical guidance provided by the Environment Agency it is considered likely that the soils encountered during this ground investigation, as represented by the two chemical analyses carried out, would be generally classified as follows;

Soil Type	Waste Classification (Waste Code)	WAC Testing Required Prior to Landfill Disposal?	Comments
Made ground	Non-hazardous (17 05 04)	No	-
Natural soils	Inert (17 05 04)	Should not be required but confirm with receiving landfill	-

Under the requirements of the European Waste Directive all waste needs to be pre-treated prior to disposal. The pre-treatment process must be physical, thermal, chemical or biological, including sorting. It must change the characteristics of the waste in order to reduce its volume, hazardous nature, facilitate handling or enhance recovery. The waste producer can carry out the treatment but they will need to provide documentation to prove that this has been carried out. Alternatively, the treatment can be carried out by an approved contractor. The Environment Agency has issued a position paper[10] which states that in certain circumstances, segregation at source may be considered as pre-treatment and thus excavated material may not have to be treated prior to landfilling if the soils can be segregated onsite prior to excavation by sufficiently characterising the soils insitu prior to excavation.

The above opinion with regard to the classification of the excavated soils is provided for guidance only and should be confirmed by the receiving landfill once the soils to be discarded have been identified.

The local waste regulation department of the Environment Agency (EA) should be contacted to obtain details of tips that are licensed to accept the soil represented by the test results. The tips will be able to provide costs for disposing of this material but may require further testing.

8 Environment Agency 2015. *Guidance on the classification and assessment of waste.* Technical Guidance WM3 First Edition
9 CL:AIRE March 2011. *The Definition of Waste: Development Industry Code of Practice* Version 2
10 Environment Agency 23 Oct 2007 *Regulatory Position Statement Treating non-hazardous waste for landfill - Enforcing the new requirement*

Part 3: GROUND MOVEMENT ASSESSMENT

This section of the report comprises an analysis of the ground movements arising from the proposed basement and foundation scheme discussed in Part 2 and the information obtained from the investigation, presented in Part 1 of the report.

9.0 INTRODUCTION

The sides of a basement excavation will move to some extent regardless of how they are supported. The movement will typically be both horizontal and vertical and will be influenced by the engineering properties of the ground, groundwater level and flow, the efficiency of the various support systems employed during underpinning and the efficiency or stiffness of any support structures used to form the basement.

An analysis has been carried out of the likely movements arising from the proposed basement excavation and the results of this analysis have been used to predict the effect of these movements on surrounding structures.

9.1 Construction Sequence

For the purposes of the ground movement assessment the depth of foundations and heights of sensitive structures have been measured from ground level. The foundations of the adjacent structures have been assumed on the basis of the information obtained from the Camden Planning Portal which is detailed in Section 2.3, along with the trial pit information. Where basements are considered to be present a basement depth of 4.00 m has been assumed and where a lower ground floor level is considered to present a formation level at a depth of 2.50 m below ground level has been assumed. In each case, the footings are considered to be constructed at assumed basement or lower ground floor level to provide a conservative estimate. A basement depth of 4.00 m would indicate that where a basement is present beneath a nearby structure, the footings of those structures will be below the depth of the basement at a level of 13.00 m OD. These foundations are considered unlikely to be affected by the proposed redevelopment of the site but have been included within the analysis to provide a conservative assessment.

It is proposed to deepen the existing basement using traditional reinforced concrete underpinning methods to a maximum depth of around 1m at the Party wall between 11 and 12 Greville Street, to a level of 13.50 m OD. The only areas of net excavation are in 12 and 13 Greville Street, which will be lowered by approximately 600 mm, coupled with the removal of the central "island" at the rear of 12 and 13 GS, where excavation is 4.07m.

The following sequence of operations has been assumed to enable analysis of the ground movements around the proposed basement both during and after construction.

1. Demolish the existing buildings to ground level;

2. construct underpinned retaining walls. The underpins are commonly formed in a ‘hit and miss’ sequence using a trench box excavation, commonly sheet lined, shored and strutted; all temporary shoring and propping to be inspected by a suitably qualified person; and

3. excavate basement extension and temporarily retain and strengthen, with sufficient propping and walling beams, the new retaining walls. Construct new ground slab. As part of the basement excavation, the existing central pad foundations within the footprint of the building will also be removed.

The underpins will be adequately laterally propped and sufficiently dowelled together, and the concrete will be cast and adequately cured prior to lowering the floor level to form the raft, and removal of the formwork and supports. It is assumed that the corners of the excavation will be locally stiffened by cross-bracing or similar and that the new retaining walls will not be cantilevered at any stage during the construction process.

The detail of the support provided to adjacent walls is beyond the scope of this report at this stage and the structural engineer will be best placed to agree a methodology with the underpinning contractor once appointed.

A reinforced concrete raft slab foundation is to be adopted and following construction of the raft slab the temporary props will be removed. The raft will extend to the northern, eastern and western boundaries, but will stop short of the southern boundary to avoid applying increased lateral pressure to the underpins of Audrey House.

9.2 Ground Movements

An assessment of ground movements within and surrounding the excavation has been undertaken using the P-Disp Version 19.3 – Build 12 package licensed from the OASYS suite of geotechnical modelling software from Arup. This program is commonly used within the ground engineering industry and is considered to be an appropriate tool for the analysis of an underpinned retained wall.

Published data for ground movements associated with underpinned retaining walls and subsequent excavation of a new basement is limited compared to other types of retaining wall. It is possible to use the well-documented predictions and movement curves for embedded retaining walls contained within CIRIA C760[11], although this approach is considered to be unnecessarily conservative. A manual approach has therefore been adopted in conjunction with the results of a P-Disp analysis to assess the effects of the construction of the proposed underpinned retaining walls and the subsequent excavation of the new basement in granular soils.

9.3 P-Disp Model

At this site, unloading of the London Clay will take place as a result of the installation of the proposed underpinned retaining walls and excavation of the basement extension, such that the reduction in vertical stress in the short term will cause heave to take place. Undrained soil parameters have been used to estimate the potential short term movements, which include the "immediate" or elastic movements as a result of the basement excavation. The model is based on the assumption that the soils behave elastically, which provides a reasonable approximation to soil behaviour at small strains. Drained parameters have been used to provide an estimate of the total movement, which includes long term swelling that will continue for a number of years.

The elastic analysis requires values of soil stiffness at various levels to calculate displacements. Values of stiffness for the soils at this site are readily available from published data and we have used a well-established method to provide our estimates. This relates values of E_u and E', the drained and undrained stiffness respectively, to values of undrained cohesion, as described by Padfield and Sharrock[12] and Butler[13] and more recently by O'Brien and Sharp[14].

[11] Gaba A, Hardy S, Doughty L, Powrie W and Selemetas D (2017) *Guidance on Embedded Retaining Wall Design*, CIRIA report C760

[12] Padfield CJ and Sharrock MJ (1983) *Settlement of structures on clay soils*. CIRIA Special Publication 27

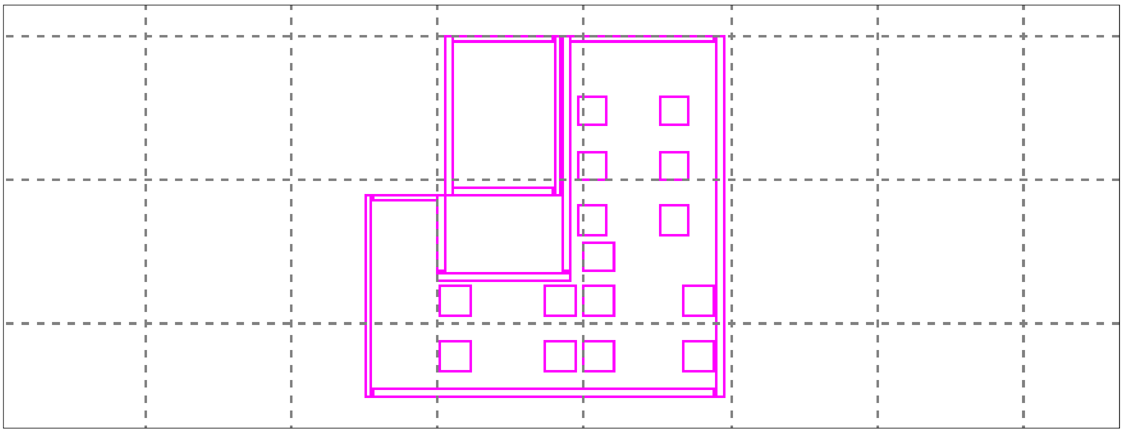
[13] Butler FG (1974) *Heavily overconsolidated clays: a state of the art review*. Proc Conf Settlement of Structures, Cambridge, 531-578, Pentech Press, Lond

[14] O'Brien AS and Sharp P (2001) *Settlement and heave of overconsolidated clays - a simplified non-linear method.* Part Two,

Relationships of $E_u = 500 C_u$ and $E' = 300 C_u$ for the cohesive soils have been used to obtain values of Young's modulus. More recent published data[15] indicates stiffness values of 750 x Cu for the London Clay and a ratio of E' to Eu of 0.75, and it is considered that the use of the more conservative values provides a sensible approach for this stage in the design.

For the purpose of this analysis, the corners have been defined by x and y coordinates, with the x-direction parallel with the orientation of Greville Street, whilst the y-direction is parallel with the orientation of Hatton Garden. Vertical movement is in the z-direction. All of the walls analysed have been modelled as 1 m long structural elements. The full outputs of all the analyses and P-Disp movement contour plots are included within the appendix.

The proposed demolition and excavation will result in a short term unloading of between 13.5 kN/m^2 and 72.9 kN/m^2. The greatest of which is assumed to act at a maximum excavation depth of 3.00 m (13.50 m OD) below existing ground level, beneath the central island only. In addition, as a result of the demolition of the building an unloading of about 35 kN/m^2 will occur beneath the existing foundations. The below plan shows the location of the existing foundations.



The consulting engineers have provided an assessment of the likely loading of the proposed raft foundation, which will generally apply a uniform distributed load in the order of 72 kN/m^2. The raft slab will not extend to the southern boundary in order to avoid applying additional stress to the basement of Audrey House.

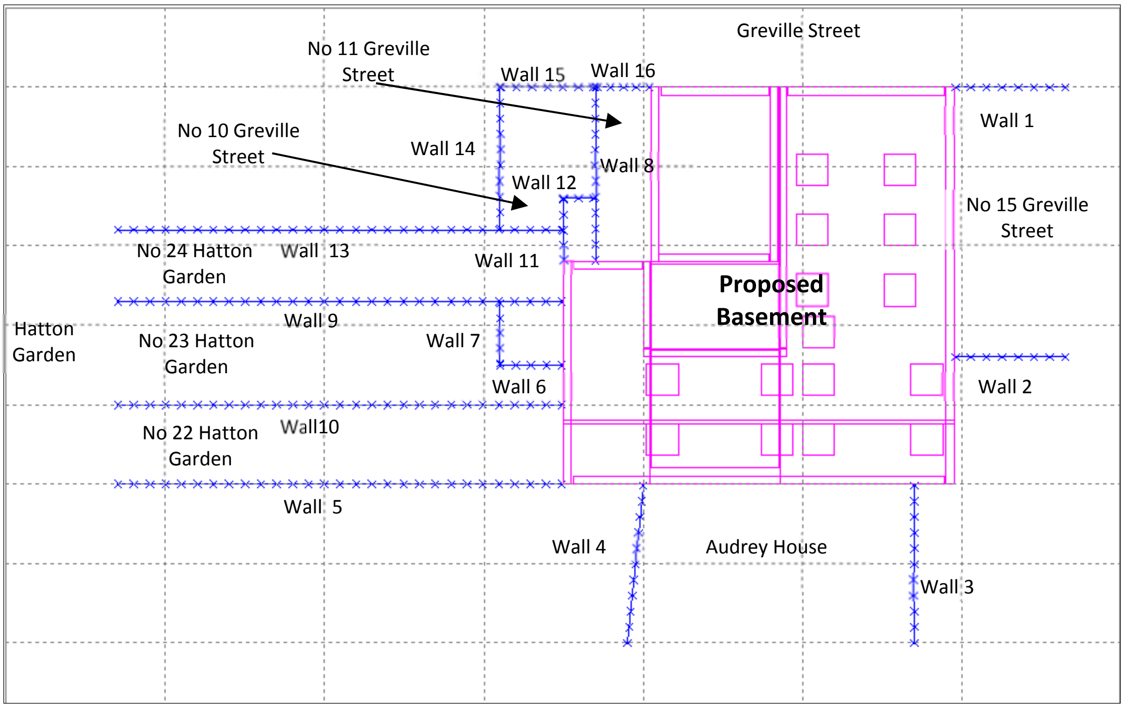
The diagram overleaf details the sensitive structures in relation to the proposed excavation.

The soil parameters used in this assessment have been interpolated from the results of a ground investigation carried out at approximately 240 m to the east of the site and are tabulated below.

15 Ground Engineering, Nov 2001, 48-53
Burland JB, Standing JR, and Jardine FM (2001) *Building response to tunnelling, case studies from construction of the Jubilee Line Extension* CIRIA Special Publication 200

Stratum	Depth range (m) [m OD]	Eu (MPa)		E' (MPa)	
		Top	Bottom	Top	Bottom
Made Ground	GL to 2.0 [16.5 to 14.5]	12000	12000	12000	12000
Hackney Gravel	2.0 to 4.2 [14.5 to 12.3]	68000	68000	68000	68000
London Clay	4.2 to 21.0 [12.3 to -4.5]	25000	175000	15000	105000

A rigid boundary for the analysis has been set at a depth of 21.0 m below ground level (-4.5 m OD), which nearby archive boreholes indicate to be the depth of the boundary between the London Clay and underlying Lambeth Group, below which significant movements would not be expected.



9.4 Ground Movements – Surrounding the Basement

Wall Installation

As noted previously, predictions of the vertical and horizontal ground movements behind the wall, as a result of wall installation, can be based on case study information from CIRIA for a planar diaphragm wall installed into stiff clay. There are no data sets available for the installation of an underpinned wall in granular material and the predicted movements for a wall in clay are considered to be a conservative approach.

Underpinned walls are unlikely to move horizontally to any significant degree as they are subject to a continued vertical loading from the structures above. The use of datasets derived from case studies of embedded retaining walls will therefore be expected to overestimate horizontal movements for these walls, but will provide an indication of the pattern of possible horizontal and vertical movements.

Table 6.1 of CIRIA C760 indicates that for a planar diaphragm wall installed into stiff clay, predicted vertical and horizontal movements behind the wall will be in the region of 1.5 times the retained height. In general the retained height of the new basement will be less than 1 m which equates to a zone of influence of less than 1.50 m. Table 6.1 also indicates that maximum horizontal and vertical movements of 0.05 % of the retained height may arise immediately behind the wall, which for a 1.0 m deep basement gives a movement of 0.5 mm. Whilst this is considered to be a reasonable approximation of the likely movement, the horizontal and vertical movements are likely to be most sensitive to the quality of workmanship and appropriate sequencing during the underpin construction.

Following Excavation

There is a wealth of experience with respect to the construction of underpinned retaining walls, which suggests that overall horizontal ground movements should remain typically within the range of 2 mm to 5 mm following completion of the works, provided that they are installed by a reputable and experienced contractor in accordance with the guidelines published by the Association of Specialist Underpinning Contractors[16].

Settlement of the soil behind the new retaining wall may occur due to the excavation in front of the wall causing the wall to deflect. Again, the magnitude of the settlement will be controlled to a large extent by the quality of workmanship of the underpins and by the existing building that is likely to provide additional rigidity.

P-Disp has been used to predict the effect of potential heave movements at the foundation depth of nearby sensitive structures, as a result of the unloading of the underlying soils following the proposed basement excavation. In order to assess which structures are likely to be affected by the excavation, reference has been made to CIRIA C760, which indicates that for a high support stiffness embedded retaining wall constructed within a high stiffness clay, vertical and horizontal ground surface movements following the basement excavation are likely to be negligible beyond 3.5 and 4 times the retained height respectfully, which for this assessment is around 10.5 m and 12.0 m for vertical and horizontal movements respectively.

9.5 Movements within the Excavation

Results

Using the same P-Disp model, the analysis indicates that, by the time the demolition and basement excavation is complete, around 1 mm to 3 mm of heave is likely to have taken place across the proposed basement, rising to up to 7 mm where the basement is to be excavated from existing ground level. The heave movement generally reduces to less than 2 mm along the edges of the basement and reduces further to less than 1 mm in the corners. Once the proposed building has been constructed, short term settlements are predicted to be in the order of 4 mm to 6 mm in the centre of the site, reducing to between 2 mm and 3 mm at the edges and less than 1 mm in the corners.

In the overall term, total settlement of between 8 mm and 13 mm is anticipated across the footprint of the proposed building, reducing to between 4 mm and 8 mm at the edges and about 4 mm in the corners.

In the south of the site, where the raft slab is not going to be present, between 1 mm and 2 mm of heave are predicted in both the short and overall terms.

A void or layer of compressible material may need to be incorporated into the design to accommodate these potential long term movements in the south of the site where the raft foundation will be offset from the southern boundary wall. If a compressible material is used beneath the floor slab, it will need to be designed to be able to resist the potential uplift forces generated by the ground movements. In this respect potential heave pressures are typically taken to equate to around 30 % to 40 % of the total unloading pressure.

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16 Haslam S, O'Connor L (2013) *Guidelines on safe and efficient basement construction directly below or near to existing structures* ASUC

10.0 BUILDING DAMAGE ASSESSMENT

In addition to the above assessment of the likely movements that will result from the proposed development, the neighbouring buildings are considered to be sensitive structures, requiring Building Damage Assessments, on the basis of the classification given in Table 6.4 of C760[1].

The results above have been used to manually predict the building damage category for each sensitive structure and these are shown in Section 10.1 below. A summary page showing the individual results for each sensitive structure is appended.

All structures are shown on the plan in Section 9.3.

10.1 Damage to Neighbouring Structures

P-Disp has been used to estimate the differential movement along the length of each sensitive structure and the results have been used in a manual assessment to predict the building damage category for each sensitive structure. The results of the building damage assessment are shown in the table below.

The plot for horizontal wall movements as a result of the excavation in front of a wall in stiff clay in CIRIA C760 (Fig 6.15a) has been adapted to reflect a trend line that assumes a movement of 1 mm immediately behind the wall in view of the limited depth of the proposed excavation. The trend line is set such that the predicted movement diminishes with distance from the wall according to the trend line set by a wall within a high stiffness clay. In addition, where the existing structures are founded at depths below the proposed excavation, horizontal movements are not considered to have an effect and have therefore been taken to be zero. The horizontal movements arising from the varying excavation depths have been analysed separately with respect to damage classification and the worst case included within the table.

Structure	Wall Reference	Preliminary Assessment of Damage Category*
No 15 Greville Street	Wall 1	Category 0 - Negligible
	Wall 2	Category 0 - Negligible
Audrey House	Wall 3	Category 0 - Negligible
	Wall 4	Category 0 - Negligible
22 Hatton Garden	Wall 5	Category 0 - Negligible
	Wall 10	Category 0 - Negligible
23 Hatton Garden	Wall 6	Category 0 - Negligible
	Wall 7	Category 0 - Negligible
	Wall 9	Category 0 - Negligible
24 Hatton Garden	Wall 11	Category 0 - Negligible
	Wall 13	Category 0 - Negligible

Structure	Wall Reference	Preliminary Assessment of Damage Category*
10 Greville Street	Wall 12	Category 0 - Negligible
	Wall 14	Category 0 - Negligible
	Wall 15	Category 0 - Negligible
11 Greville Street	Wall 8	Category 0 - Negligible
	Wall 16	Category 0 - Negligible

From Table 6.4 of C760[1]: Classification of visible damage to walls.

The analysis has predicted that the proposed installation of the retaining wall underpins and excavation of the proposed basement are likely to result in the building damage for sensitive structures being Category 0 (negligible).

The CPG4 document indicates that where possible all building damage should be restricted to a maximum of Category 1, as set out in CIRIA Report 760, and as a result, the development is considered to be in line with Camden's requirements.

10.2 Monitoring of Ground Movements

The predictions of ground movement based on the ground movement analysis should be checked by monitoring of adjacent properties and structures, especially those which are to be underpinned. The structures to be monitored during the construction stages should include the existing facade and neighbouring structures. Condition surveys of the existing structures should be carried out before and after the proposed works.

The precise monitoring strategy will be developed at a later stage and it will be subject to discussions and agreements with the owners of the adjacent properties and structures. Contingency measures will be implemented if movements of the adjacent structures exceed predefined trigger levels. Both contingency measures and trigger levels will need to be developed within a future monitoring specification for the works. At present the Construction Method Statement (ref 23327, Issue 3, February 2016) recommends weekly monitoring during demolition and foundation construction, and for two months after completion of the ground floor slab.

11.0 TUNNEL MOVEMENTS

The site is located directly above the recently constructed westbound tunnel of Crossrail, with the eastbound tunnel located in close proximity to the north of the site, beneath Greville Road. The exact locations, crown and invert levels and dimensions of the tunnels is currently unknown, although information obtained by the consulting engineers has indicated the tunnel to be at a depth of 25 m. An analysis of ground movements arising from the proposed development has been carried out using the Oasys P-Disp software and due to the ambiguity with respect to the tunnels, the tunnels themselves could not be accurately modelled at this stage. In order to provide an indication of the anticipated settlements at the depth of the tunnel the potential movements have been calculated for a column of soil beneath the area of maximum anticipated heave in the short term and the area of maximum anticipated settlement in the overall term and graphs displaying the results are included within the appendix.

For the purposes of this analysis a threshold figure of 0.30 mm of movement has been adopted, below which the effects of the movements on the tunnels are considered to be negligible. The results of the analysis have indicated that in the short term, movements of less than 0.30 mm will occur below a depth of 18.50 m (-1.00 m OD) which is 6.50 m above the anticipated depth of the tunnel. In the overall term movements of less than 0.30 mm will occur below a depth of about 20.00 m (-2.50 m OD), some 5.00 m above the anticipated level of the tunnels. As a result, the movements resulting from the development are considered to have a negligible effect on the Crossrail tunnels.

Part 4: BASEMENT IMPACT ASSESSMENT

This section of the report evaluates the direct and indirect implications of the proposed project, based on the findings of the previous screening and scoping, site investigation and ground movement assessment.

12.0 INTRODUCTION

The screening identified a number of potential impacts. The desk study and ground investigation information has been used below to review the potential impacts, to assess the likelihood of them occurring and the scope for reasonable engineering mitigation.

12.1 Potential Impacts

The table below summarises the previously identified potential impacts and the additional information that is now available from the site investigation in consideration of each impact.

Potential Impact	Site Investigation Conclusions
The site is located directly above an aquifer.	The investigation has confirmed the presence of Hackney Gravel, a secondary aquifer below the site.
The proposed basement may extend beneath the water table surface.	The basement extends to a depth of 0.80 m (13.48 m OD), whilst groundwater has been measured at an average depth of 1.50 m (12.74 m OD) and the base of the Hackney Gravel has been proved at an average depth of 1.74 m (12.52 m OD), leaving 0.71 m of dry gravel below the new slab. The deepest excavations are understood to extend below the site to a level of 13.28 m OD and therefore will not intersect the groundwater table. In addition, groundwater flow is expected to be towards the south and southeast and the building to the south already has a basement toe-ing into the London Clay and as such a cut-off already exists.
Is the site located within 5 m of a public highway or pedestrian right of way?	The investigation has not indicated any specific problems, such as weak or unstable ground, voids or a high water table that would make working within 5 m of public infrastructure particularly problematic at this site.
There is a Crossrail Tunnel about 25 m below the site	The investigation has not indicated any specific problems, such as weak or unstable ground, voids or a high water table that would make working above a tunnel problem.

The results of the site investigation have therefore been used below to review the remaining potential impacts, to assess the likelihood of them occurring and the scope for reasonable engineering mitigation.

The site is underlain by a Secondary 'A' Aquifer / the proposed basement could extend beneath the water table.

Groundwater is likely to be encountered within the underlying Hackney Gravel and the extension of the existing basement to include the area of the island may extend into the groundwater and Secondary Aquifer.

The basement extends to a depth of 0.80 m (13.48 m OD), whilst groundwater has been measured at an average depth of 1.50 m (12.74 m OD) and the base of the Hackney Gravel has been proved at an average depth of 1.74 m (12.52 m OD), leaving 0.71 m of dry gravel below the new slab. The deepest excavations are understood to extend below the site to a level of 13.28 m OD and therefore will not intersect the groundwater table. Any groundwater flow is likely to travel in a southerly / southeasterly direction towards the River Thames, although the basement of the building to the south already forms a cut-off to the south.

The proposed development should incorporate sufficient drainage as part of the retaining wall design, which will allow perched water from behind the wall to drain to the existing drainage, preventing any effect on neighbouring properties.

On the basis of all of the above, it is concluded that the proposed development will not have an impact on the hydrogeological setting.

Location of public highway

A retention system will be adopted that maintains the stability of the excavation at all times. In any case part of the existing basement extends between the 'island' and Greville Street and the area of new basement is not within 5 m.

Crossrail Tunnel about 25 m below the site

It is understood that discussions about the proposed development have taken place with Crossrail and approval will be required prior to any construction commencing. Given the depth of the tunnel and the relatively minor excavation that is proposed, it is considered unlikely that there will be any impact from resultant ground movements on the tunnel below.

13.0 NON-TECHNICAL SUMMARY OF EVIDENCE

This section provides a short summary of the evidence acquired and used to form the conclusions made within the BIA.

13.1 Screening

The following table provides the evidence used to answer the surface water flow and flooding screening questions.

Question	Evidence
1. Is the site within the catchment of the pond chains on Hampstead Heath?	Topographical maps acquired as part of the desk study and Figures 12 and 14 of the Arup report
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?	Review of aerial maps of the site, which have been compared to the proposals to work out any proposed changes in hardstanding.
3. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas?	
4. Will the proposed basement development result in changes to the profile of the inflows (instantaneous and long term) of surface water being received by adjacent properties or downstream watercourses?	
5. Will the proposed basement result in changes to the quantity of surface water being received by adjacent properties or downstream watercourses?	

Question	Evidence
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 Kings Cross, or is it at risk of flooding because the proposed basement is below the static water level of a nearby surface water feature?	Flood risk maps acquired from the Environment Agency as part of the desk study, Figure 15 of the Arup report, the Camden Flood Risk Management Strategy dated 2013 and the North London Strategic Flood Risk Assessment dated 2008.

The following table provides the evidence used to answer the groundwater screening questions.

Question	Evidence
1a. Is the site located directly above an aquifer?	Aquifer designation maps acquired from the Environment Agency as part of the desk study and Figures 3, 5 and 8 of the Arup report.
1b. Will the proposed basement extend beneath the water table surface?	Ground investigation data.
2. Is the site within 100 m of a watercourse, well (used/ disused) or potential spring line?	Historical maps acquired as part of the desk study and Figures 11 and 12 of the Arup report.
3. Is the site within the catchment of the pond chains on Hampstead Heath?	Figures 12 and 14 of the Arup report.
4. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas?	A site walkover and existing plans of the site have confirmed the proportions of hardstanding which have been compared to the proposed drawings to determine the changes in the proportions.
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 soakaways and/or SUDS)?	The details of the proposed development do not indicate the use of soakaway drainage.
6. Is the lowest point of the proposed 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?	Topographical maps acquired as part of the desk study and Figures 11 and 12 of the Arup report.

The following table provides the evidence used to answer the land stability screening questions.

Question	Evidence
1. Does the existing site include slopes, natural or manmade, greater than 7°?	Topographical maps and Figures 16 and 17 of the Arup report.
2. Will the proposed re-profiling of landscaping at the site change slopes at the property boundary to more than 7°?	The details of the proposed development provided do not include the re-profiling of the site to create new slopes
3. Does the development neighbour land, including railway cuttings and the like, with a slope greater than 7°?	Topographical maps and Figures 16 and 17 of the Arup report.
4. Is the site within a wider hillside setting in which the general slope is greater than 7°?	
5. Is the London Clay the shallowest strata at the site?	Geological maps and Figures 3, 5 and 8 of the Arup report
6. Will any trees 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?	The proposals provided by the consulting engineers
7. Is there a history of seasonal shrink-swell subsidence in the local area and / or evidence of such effects at the site?	Knowledge on the ground conditions of the area were used to make an assessment of this.
8. Is the site within 100 m of a watercourse or potential spring line?	Topographical maps acquired as part of the desk study and Figures 11 and 12 of the Arup report

Question	Evidence
9. Is the site within an area of previously worked ground?	Geological maps and Figures 3, 5 and 8 of the Arup report
10. Is the site within an aquifer?	Aquifer designation maps acquired from the Environment Agency as part of the desk study and Figures 3, 5 and 8 of the Arup report.
11. Is the site within 50 m of Hampstead Heath ponds?	Topographical maps acquired as part of the desk study and Figures 12 and 14 of the Arup report.
12. Is the site within 5 m of a highway or pedestrian right of way?	Aerial photography and site plans confirmed that the site is within 5 m of Greville Street.
13. Will the proposed basement significantly increase the differential depth of foundations relative to neighbouring properties?	Records held on the Camden Planning Portal of basements being present below neighbouring properties.
14. Is the site over (or within the exclusion zone of) any tunnels, e.g. railway lines?	Maps and plans of infrastructure tunnels were reviewed, in addition to online infrastructure maps, showing exclusions zones, made available by Transport for London, as shown in Section 2.3 of this report.

The questions in the screening stage that there were answered ‘yes’, were taken forward to a scoping stage and the potential impacts discussed in Section 4.0 of this report, with reference to the possible impacts outlined in the Arup report.

A ground investigation was carried out, which has allowed an assessment of the potential impacts of the basement development on the various receptors identified from the screening and scoping stages. Principally the investigation aimed to establish the ground conditions, including the groundwater level, the engineering properties of the underlying soils to enable suitable design of the basement development and the configuration of existing party wall foundations. The findings of the investigation are discussed in Section 5.0 of this report and summarized in both Section 7.0 and the Executive Summary.

13.2 Impact Assessment

Section 9.0 of this report summarises whether or not, on the basis of the findings of the investigation, the potential impacts still need to be given consideration and identifies ongoing risks that will require suitable engineering mitigation. Section 8.0 of this report also provides recommendations for the design of the proposed development, whilst Section 9.0 provides the outcomes of a ground movement analysis and building damage assessment, which has also been used to provide a conclusion on any potential impacts from the proposed basement development.

14.0 OUTSTANDING RISKS AND ISSUES

This section of the report aims to highlight areas where further work is required as a result of limitations on the scope of this investigation, or where issues have been identified by this investigation that warrant further consideration. The scope of risks and issues discussed in this section is by no means exhaustive, but covers the main areas where additional work is considered to be required.

The ground is a heterogeneous natural material and variations will inevitably arise between the locations at which it is investigated. This report provides an assessment of the ground conditions based on the discrete points at which the ground was sampled, but the ground conditions should be subject to review as the work proceeds to ensure that any variations from the Ground Model are properly assessed by a suitably qualified person.

These areas of doubt should be drawn to the attention of prospective contractors and further investigation will be required or sufficient contingency should be provided to cover the outstanding risk.