SUPPLEMENTARY GROUND INVESTIGATION AND BASEMENT IMPACT ASSESSMENT REPORT

153-163 Broadhurst Gardens
London NW6

Client: Kilburn and District Houses Limited

Engineer: Fluid Structures

J13364A

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GEA Geotechnical & Environmental Associates

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This report is intended as a Ground Investigation Report (GIR) as defined in BS EN1997-2, unless specifically noted otherwise. The report is not a Geotechnical Design Report (GDR) as defined in EN1997-2 and recommendations made within this report are for guidance only.

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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 ground investigation carried out by by Geotechnical and Environmental Associates Limited (GEA) on the instructions of Kilburn and District Houses Ltd, with respect to the redevelopment of the site, which includes the construction of a new four-storey building with a single level basement. The purpose of the investigation has been to confirm the ground conditions and hydrogeology, to assess the extent of any contamination and to provide advice in respect to options for basement construction. The investigation supplements previous work by GEA, which includes a ground investigation undertaken at the site in September 2004 (report ref J04147) into the causes of ongoing movement of the existing buildings. A desk study report has also previously been undertaken for the site by GEA, which included a basement impact assessment (report ref J13364, dated 22 July 2014). The previous findings are discussed herein where appropriate. The information from the previous reports has been used in preparation of an updated and revised report, which includes information required to comply with the London Borough of Camden (LBC) Planning Guidance CPG4, relating to the requirement for a Basement Impact Assessment (BIA) including a ground movement analysis and building damage assessment.

GROUND CONDITIONS

The supplementary investigation has generally confirmed the ground conditions encountered during the previous investigation, in that, beneath a moderate thickness of made ground, the London Clay was proved to the maximum depth investigated of 8.45 m. The made ground extended to depths of between 0.40 m and 1.45 m and generally comprised brown silty sandy clay with rare flint gravel and fragments of brick and ash. The London Clay comprised an initial upper horizon of soft or firm medium strength brown silty clay with varying quantities of flint gravel and extended to depths of between 0.60 m and 2.50 m and may represent naturally reworked soils. The greatest thickness of reworked soils was encountered at the front of the site in No 153 Broadhurst Gardens. Beneath the reworked London Clay, firm becoming stiff medium strength becoming very high strength fissured brown mottled grey silty clay with occasional partings of orange-brown fine sand and silt and selenite crystals was encountered and proved to the maximum depth investigated of 8.45 m. Decayed rootlets were noted in Borehole Nos 101 and 102 at depths of 4.80 m and 4.15 m, respectively. Desiccation was encountered to a depth of 2.50 m during the previous investigation, within the vicinity of the former mature oak tree.

Perched groundwater was encountered from around a claystone. Subsequent groundwater monitoring on three occasions over an 11-week period has recorded water in the pipes. Contamination testing has measured a slightly elevated concentration of lead within a single sample of made ground.

RECOMMENDATIONS

The existing buildings are bearing on made ground, which in turn overlies an upper layer of soft reworked London Clay, found to extend to a maximum depth of 2.50 m at the exploratory locations investigated. The existing building has been moving for a number of years and it is understood that the building is continuing to move, which is being monitored. If the existing building is to remain, in order to prevent further ongoing movements, underpinning of the foundations should be undertaken and will need to bypass the reworked clay horizon.

The proposed new basement will extend to a depth of roughly 3.50 m, including the slab make-up, and on this basis, formation level is likely to be within firm London Clay, which should form a suitable bearing stratum for spread foundations excavated from basement formation level. Significant groundwater inflows into the basement excavation are not anticipated, but perched water may be encountered from within the made ground and reworked clay, but any inflows should be suitably controlled by sump pumping. Consideration could also be given to a piled foundation solution.

BASEMENT IMPACT ASSESSMENT

The BIA has not indicated any concerns with regard to the effects of the proposed basement construction on the site and surrounding area. It has been concluded that the impacts identified can be mitigated by appropriate design and standard construction practice. The GMA has concluded that the range of damage for sensitive structure is acceptable.

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 Kilburn and District Houses Ltd to carry out a supplementary ground investigation at 153–163 Broadhurst Gardens, London NW6 3AU. The structural engineers are Fluid Structures.

The site has been the subject of a number of previous reports produced by GEA, as follows:

- September 2004: Desk Study and Ground investigation Report. (Ref J04147);
- December 2013: Desk Study and Basement Impact Assessment (Ref J13364 report issue 1); and
- July 2014: Desk Study and Basement Impact Assessment (Ref J13364 report issue 2).

An audit of the Basement Impact Assessment has been undertaken by Campbell Reith Consulting Engineers for the London Borough of Camden (Report ref 12466-13, dated November 2016).

The purpose of this work has been to provide supplementary information for the BIA to address points raised by the Campbell Reith audit and includes an updated and revised report following supplementary investigations.In addition, a ground movement analysis and building damage assessment has been completed.

1.1 Proposed Development

It is understood that it is proposed to demolish the existing three-storey terraced building and to subsequently construct a new four-storey building with single level basement.

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

1.2 Purpose of Work

GEA reviewed the BIA audit undertaken by Campbell Reith and it was noted that additional information was required on the following items:

- Confirmation of groundwater level and impact on hydrogeology;
- Structural Engineering Design Strategy and Construction Methodology; and
- Ground Movement Analysis and Damage Assessment.

The ground movement assessment is currently outstanding.

In order to address the above, the principal technical objectives of the work carried out by GEA were as follows:

- to review the previous reports produced by GEA;
- to provide additional information on the ground conditions and their engineering properties;
- to provide additional information on the hydrogeological regime;
- to provide additional information to assist in the design of suitable foundations and retaining walls for the proposed development;
- to undertake contamination testing for waste disposal purposes; and
- to assess the ground movements caused by excavation of the proposed basement and the level of damage to the surrounding structures.

1.3 Scope of Work

In order to meet the above objectives, the scope of work comprised, in summary, the following activities:

- two open-drive sampler boreholes advanced to depths of 8.00 m and 8.45 m;
- Standard Penetration Tests (SPTs), carried out at regular intervals in the open-drive sampler boreholes, to provide additional quantitative data on the strength of the soils;
- a single drive-in window sampler borehole, advanced to a depth of 4.00 m;
- the installation of three standpipes; two installed to depths of 6.00 m and a third pipe installed to a depth of 4.00 m;
- three subsequent groundwater monitoring visits, carried out one week, three weeks and 11 weeks after installation;
- rising head tests at the time of the third monitoring visit in three standpipes to provide an indication of groundwater inflow rates into the proposed basement excavation;
- laboratory testing of selected soil samples for geotechnical and contaminated land purposes;
- a ground movement analysis and building damage assessment; and
- compilation of an updated and revised Basement Impact Assessment report, presenting the findings of the supplementary investigation.

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

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

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.
The methods of investigation adopted have been selected on the basis of the constraints of the site including but not limited to access and space limitations, together with any budgetary or timing constraints. Where it has not been possible to reasonably use an EC7 compliant investigation technique a practical alternative has been adopted to obtain indicative soil parameters and any interpretation is based upon GEA's engineering experience, local precedent where applicable and relevant published information.

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 aim of the work is to provide information on surface water, land stability and groundwater 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.

1.3.2 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.

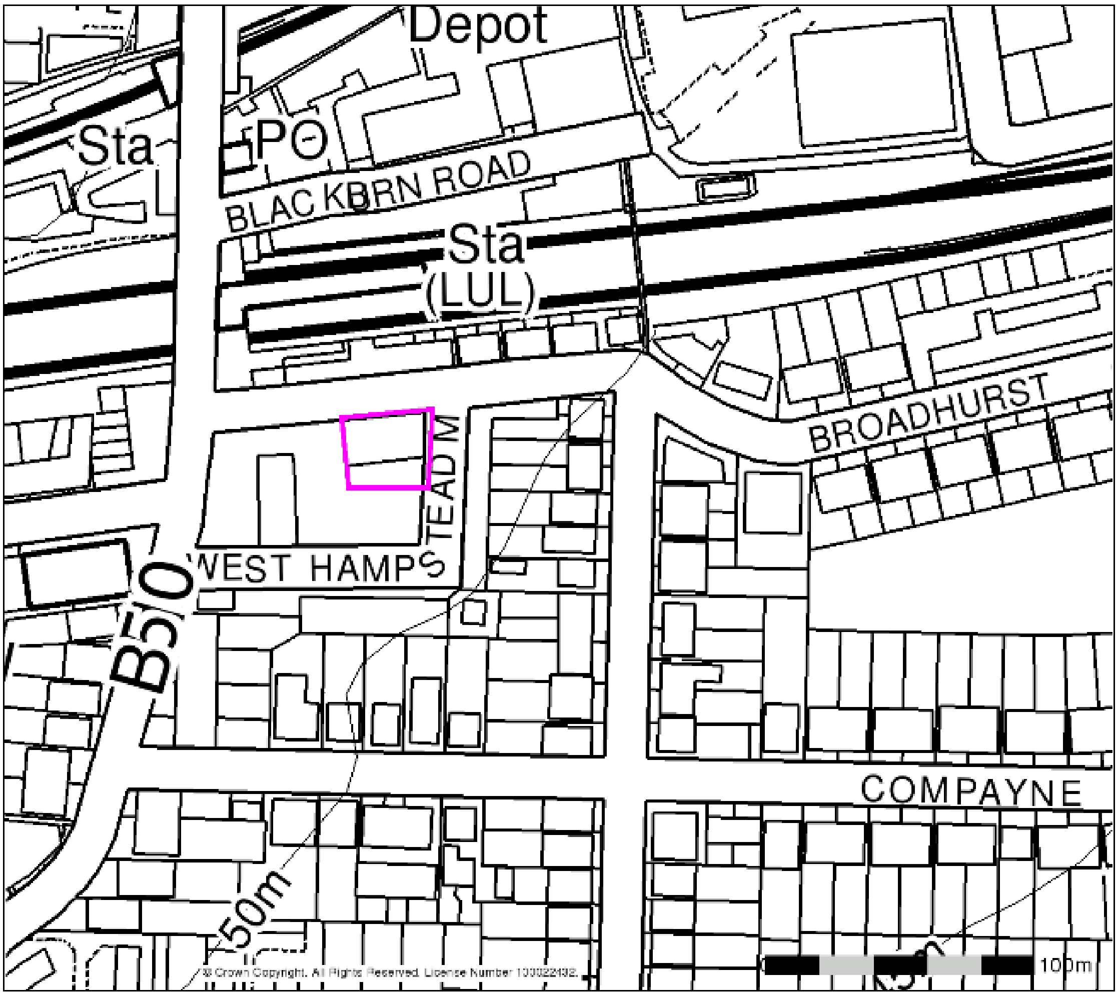
1.4 Limitations

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 and the number of locations where the ground was sampled. 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 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

2.0 THE SITE

2.1 Site Description



The site is located roughly 45 m southeast of West Hampstead Underground Station and 100 m southeast of West Hampstead Overground Station, within a mixed residential and commercial area. It fronts onto Broadhurst Gardens to the north and is bordered to the west by a two-storey building with mansard roof known as Lilian Bayliss House (currently used by English National Opera), West Hampstead Mews to the east, three-storey mixed commercial and residential use buildings to the north, and two-storey commercial use buildings to the south. The site may additionally be located by National Grid Reference 525599, 184591, as shown by the location map above.

A walk-over of the site was undertaken by an engineer from GEA on 30th January 2017 and selected photographs are included overleaf.

Broadhurst Gardens frontage, looking east

Broadhurst Gardens frontage, looking west

Pollarded oak tree at rear

The site measures approximately 20.0 m by 35.0 m at its widest point and is roughly rectangular in shape.The local topography slopes down gently towards the east and the site is on a number of different levels. It is currently occupied by a terrace of three-storey brick buildings with rear extensions and a lower ground floor level beneath part of the building. The ground floor is currently vacant whilst the upper floors are occupied by residential accommodation. To the rear of the buildings are four individual gardens, separated by brick boundary walls. The gardens are mostly paved and located at lower ground floor level.

It is clear that there has been movement to the façade of the existing buildings, with uneven window frames, where some parts of the building have settled relative to other areas. Less evidence of movement was apparent at the rear of the structure.

The site is essentially devoid of vegetation. The mature oak tree that was present in the garden of No 155 Broadhurst Garden at the time of the 2004 investigation has been cut down within the past year to leave an approximately 1.5 m high stump. Evidence of a bowing movement in the garden wall was noted adjacent to the remaining tree stump.

2.2 Site History

Full details of the site history have been reported in the desk study and ground investigation report by GEA and the previous reports should be referred to for full details relating to the site history and contamination issues, although a summary of pertinent information is included.

In summary, the site was first developed with the existing terraced buildings at some time between 1871 and 1896. The site has remained as such to the present day, with the exception of various rectangular buildings, presumably outbuildings, appearing and disappearing in the rear gardens throughout.

The existing buildings have been experiencing ongoing movement for a number of years. Sagging of window sills is evident along the building frontage, although less evidence of movement was noted at the rear. The cause of the movement has previously been investigated by GEA in 2004 and by Fluid Structures in 2010 (report ref 22591, dated August 2012). The most likely cause of the movement is considered to be structural modifications that have been carried out in the past, and in particular as a result of the removal of the load-bearing walls at ground floor level. These modifications would have resulted in an increase in load on the foundation, resulting in additional movements.

2.3 Other Information

Full details of the environmental setting have been reported in the GEA desk study report. In summary the potential risks to site workers, end users, buried structures and groundwater arising from contamination at the development were assessed as being low. Furthermore, a source of hazardous soil gas to be present on or migrating towards the site was not identified.

The London Underground Limited (LUL) Jubilee Line passes through West Hampstead Underground Station 45 m northeast of the site, and the Network Rail line passes through West Hampstead Railway Station 100 m to the northeast.

Reference to the Lost Rivers of London[4] indicates that the River Westbourne flowed in a southeasterly direction approximately 50 m east of the site, through The Serpentine in Hyde Park and into the River Thames approximately 9.4 km to the southeast of the site. Today the Westbourne is entirely covered and culverted and forms part of the surface water sewerage system which discharges into the Thames to the west of Chelsea Bridge.

The British Geological Survey map (Sheet 256) of the area indicates the site to be underlain by London Clay. The previous investigation by GEA in 2004 comprised three drive-in window sampler boreholes advanced to depths of 5.00 m and 6.00 m in the rear gardens, along with three trial pits to determine the configuration of the existing foundations.

The previous boreholes encountered a moderate thickness of made ground, extending to depths of between 0.40 m and 0.80 m, in turn overlying the London Clay, proved to the maximum depth investigated of 6.00 m. Desiccation was noted in the vicinity of a mature oak tree to a depth of 2.50 m. Groundwater was generally not encountered in the investigation, except for seepages within the made ground.

The trial pits found the existing foundations to be bearing on made ground at depths of between 0.60 m and 0.80 m.

3.0 SCREENING

The London Borough of Camden guidance suggests that any development proposal that includes a subterranean basement should be screened to determine whether or not a full Basement Impact Assessment (BIA) is required.

3.1 Screening Assessment

A number of screening tools are included in the Arup report and for the purposes of this report reference has been made to Appendix E which includes a series of questions within a screening flowchart for three categories; groundwater flow; land stability; and surface water flow. Responses to the questions are tabulated on the following pages.

4 Barton, N (1992) *The Lost Rivers of London* Historical Publications Ltd

3.2 Subterranean (groundwater) Screening Assessment

Question	Response for 153-163 Broadhurst Gardens
1a. Is the site located directly above an aquifer?	No. The site is underlain by the London Clay Formation which is designated as an Unproductive Stratum by the Environment Agency.
1b. Will the proposed basement extend beneath the water table surface?	Not known.
2. Is the site within 100 m of a watercourse, well (used/ disused) or potential spring line?	*Yes. The historical River Westbourne flowed in a southeasterly direction approximately 50 m east of the site, although the closest existing surface water feature is over 100 m from the site.*
3. Is the site within the catchment of the pond chains on Hampstead Heath?	No. The area of the proposed basements is already hardstanding.
4. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas?	No. The area of the proposed basements is already 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. There are no local ponds or spring lines present within 100 m of the Site.
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. The site is underlain by the London Clay Formation which is designated as an Unproductive Stratum by the Environment Agency.

The screening exercise has identified the following potential issues which should be assessed:

Q1b The basement may possibly extend below the groundwater level.
Q2 The site is within 100 m of a historical watercourse.

3.3 Stability Screening Assessment

Question	Response for 153-163 Broadhurst Gardens
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?	*Yes*
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?	*Yes. A mature oak tree that was present in the garden of No 155, has been cut down to leave an approximately 1.5 m high stump, which will need to be removed.*
7. Is there a history of seasonal shrink-swell subsidence in the local area and / or evidence of such effects at the site?	*Yes.*
8. Is the site within 100 m of a watercourse or potential spring line?	*Yes. The historical River Westbourne flowed in a southeasterly direction approximately 50 m east of the site, although the closest existing surface water feature is over 100 m from the site.*

Question	Response for 153-163 Broadhurst Gardens
9. Is the site within an area of previously worked ground?	No
10a. Is the site within an aquifer?	No. The site is underlain by the London Clay Formation which is designated as an Unproductive Stratum by the Environment Agency.
10b. Will the proposed basement extend beneath the water table such that dewatering may be required during construction?	No
11. Is the site within 50 m of Hampstead Heath ponds?	*Yes. The site fronts onto a public road.*
12. Is the site within 5 m of a highway or pedestrian right of way?	No. Lilian Bayliss House extends below street level, though total depth is unknown.
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, eg railway lines?	No

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

Q5 London Clay is the shallowest strata on the site.
Q6 A cut down oak tree is located within the footprint of the proposed development.
Q7 The site in an area of seasonal shrink-swell.
Q8 The site is within 100 m of a historical watercourse.
Q12 The site is within 5 m of a public highway on one side.

3.4 Surface Flow and Flooding Screening Assessment

Question	Response for 153-163 Broadhurst Gardens
1. Is the site within the catchment of the pond chains on Hampstead Heath?	No
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
3. Will the proposed basement development result in a change in the proportion of hard surfaced / paved areas?	No. The area of the proposed basements is already hardstanding.
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.
5. Will the proposed basement result in changes to the quality of surface water being received by adjacent properties or downstream watercourses?	No. The area of the proposed basements is already hardstanding.
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 or nearby surface water feature?	Yes.

The surface flow screening exercise has not identified any potential issues.

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.

Potential Impact	Consequence
The proposed basement may extend beneath the water table surface.	This may affect the groundwater flow regime.
The London Clay Formation is the shallowest strata on site and is prone to seasonal shrink / swell (subsidence and heave)	Shrinkage and swelling of the underlying soil may result in structural damage of the buildings.
Site is within 5 m of a highway or pedestrian right of way	Excavation of a basement could lead to damage
Site is within 100 m of watercourse	Changes in groundwater regimes within slopes can affect slope stability. The flow from a watercourse may increase or decrease if the groundwater flow regime which supports that water feature is affected by a proposed basement. If the flow is diverted, it may result in the groundwater flow finding another location to issue from with new springs forming or old springs being reactivated. There may also be an impact on water quality.
A pollarded oak tree is present in the rear garden of No 155 where proposed development will extend.	*An oak tree has been cut down to leave an approximately 1.5 m high stump and the ground is currently heaving locally. The rest of the tree will need to be removed.*
The site is within an area known to be at risk of surface water flooding.	The basement may flood during periods of high intensity rainfall if adequate drainage is not provided.

These potential impacts have been investigated through the site investigation, as detailed in Section 9.0.

5.0 EXPLORATORY WORK

The scope of the works was specified by GEA to provide the additional information requested by the Campbell Reith audit.

In order to meet the objectives discussed in Section 1.2, an additional three boreholes were drilled across the site, in a roughly triangular configuration. These additional boreholes were targeted to confirm the ground and groundwater conditions beneath the site and to allow additional groundwater monitoring. Standard Penetration Tests (SPTs) were undertaken within two of the boreholes to provide quantitative data on the strength of the underlying soil to assist in the soil profile for the ground movement assessment. The boreholes were positioned by GEA, with due respect to the proposed development, whilst avoiding the areas of known services.

Standpipes were installed into the new boreholes (Borehole Nos 101 to 103) to depths of 4.00 m and 6.00 m and monitoring has been undertaken on three occasions to date, roughly one week, three weeks and 11 weeks after installation.

Rising head tests were carried out at the time of the third groundwater monitoring visit to provide an indication of the likely groundwater inflow rates into the proposed basement excavation.

The fieldwork was supervised by an engineer from GEA in full time attendance.

A selection of the samples recovered from the boreholes was submitted to a soil mechanics laboratory for a programme of geotechnical testing and an analytical laboratory for a programme of contamination testing.

The borehole and trial pit records and results of the laboratory analyses are appended, together with a site plan indicating the exploratory positions.

5.1 Sampling Strategy

The borehole locations were agreed at a site meeting by the client and GEA. The boreholes were positioned on site by GEA in accessible areas, whilst avoiding areas of known services.

Three samples of made ground were 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. The soil samples were 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.

A number of samples recovered from the boreholes were submitted to a geotechnical laboratory for a programme of testing that included moisture content and Atterberg limit tests, undrained triaxial compression tests and soluble sulphate and pH level analysis.

6.0 GROUND CONDITIONS

The supplementary investigation has generally confirmed the ground conditions encountered during the previous investigation, in that, beneath a moderate thickness of made ground, the London Clay was proved to the maximum depth investigated of 8.45 m.

6.1 Made Ground

The made ground extended to depths of between 0.50 m and 1.45 m and generally comprised brown silty sandy clay with rare flint gravel and fragments of brick and ash.

No visual or olfactory evidence of contamination was noted during the investigation, apart from extraneous fragments. As a precaution and for confirmatory analysis, three samples of made ground were sent for contamination testing and the results are summarised in Section 4.4.

The previous boreholes and trial pits by GEA in the rear garden, found the made ground to extend to depths of between 0.40 m and 0.80 m.

6.2 London Clay Formation

The London Clay comprised an initial upper horizon of soft orange-brown clay with rare to occasional flint gravel, which extended to depths of between 1.45 m and 2.50 m and may represent Head Deposits. The greatest thickness of the soft horizon was encountered in Borehole No 102, located within the footprint of No 153 Broadhurst Gardens.

The underlying soils comprised typically weathered London Clay composed of firm becoming stiff brown mottled grey silty fissured clay with occasional partings of orange-brown fine sand and silt, selenite crystals and was proved to the maximum depth investigated of 8.45 m.

Decayed rootlets were noted in Borehole Nos 101 and 102 at depths of 4.80 m and 4.15 m, respectively, although no evidence of desiccation was noted during the supplementary investigation at the locations investigated, which has been confirmed through laboratory testing.

Laboratory undrained triaxial compression tests were carried out on a number of samples recovered from the open-drive sampler boreholes. The results are included in the appendix and indicate the clay to be of medium strength becoming very high strength with depth. However, in view of the need to reduce the sampled diameter as drilling progressed, the tests on samples below about 5 m have been carried out on samples of smaller diameter than would normally be the case. The strengths obtained from these tests are higher than expected and do not correlate well with the SPT N-values; it is therefore considered that any design should be based on the results of the SPTs alone.

Laboratory plasticity index tests were carried out on five samples of London Clay indicated the clay to be of high volume change potential.

These soils were observed to be free of any visual or olfactory evidence of soil contamination.

The previous boreholes also encountered an initial upper horizon of clay containing occasional flint gravel which extended to depths of between 0.60 m and 1.40 m. The flint gravel may represent naturally reworked soils or Head Deposits.

6.3 Groundwater

Groundwater was not encountered in Borehole Nos 101 or 102 during drilling, but perched groundwater was encountered in Borehole No 103 at a depth of 3.00 m from around a claystone, with the water level rising to 2.15 m after 20 minutes.

During the previous investigation, groundwater was only encountered as perched water strikes from within the made ground. The results of the three monitoring visits are shown in the table below.

Borehole No	Standpipe depth (m)	Depth to groundwater in m		
		13/03/2017	22/03/2017	17/05/2017
101	6.00	DRY	5.34	2.49
102	6.00	DRY	5.70	4.33
103	4.00	0.78	0.76	0.84

At the time of the third groundwater monitoring visit, rising head tests were undertaken in Borehole Nos 101, 102 and 103 to give a preliminary assessment of groundwater inflows into the basement excavation. The results of these tests are appended. The testing indicated inflow rates of 3.79 x 10^{-6} m/s and 1.47 x 10^{-6} m/s in Borehole Nos 101 and 103, respectively, but no inflow was measured in Borehole No 102.

6.4 Soil Contamination

The following table sets out the values measured within three samples of made ground analysed. All concentrations are in mg/kg unless otherwise stated.

Determinant	BH101: 0.60 m	BH102: 1.20 m	BH103: 0.30 m
pH	8.1	7.1	7.9
Arsenic	18	17	19
Cadmium	<0.20	<0.20	<0.20
Chromium	26	30	34
Copper	53	45	46
Lead	**250**	98	140
Mercury	1.8	<0.30	1.7
Nickel	17	17	19
Selenium	<1.00	<1.00	<1.00
Zinc	71	57	89
Total Cyanide	<1.00	<1.00	<1.00
Total Phenols	<1.00	<1.00	<1.00
Total PAH	<1.60	<1.60	<1.60
Sulphide	<1.00	<1.00	<1.00
Benzo(a)pyrene	<0.10	<0.10	<0.10
Naphthalene	<0.05	<0.05	<0.05
TPH	<10	<10	350
Total Organic Carbon (%)	1.4	1.5	1.4

Note: Figure in bold indicates concentration in excess of risk-based soil guideline values, as discussed in Part 2 of this report

6.4.1 Generic Quantitative Risk Assessment

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. 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 residential end use with plant uptake, or is based on the DEFRA Category 4 Screening values[7]. The key generic assumptions for this end use are as follows:

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 (CL|EA)* 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

- that groundwater will not be a critical risk receptor;
- that the critical receptor for human health will be young female children aged zero to six years old;
- that the exposure duration will be six years;
- that the critical exposure pathways will be direct soil and indoor dust ingestion, consumption of homegrown produce, consumption of soil adhering to homegrown produce, skin contact with soils and indoor dust, and inhalation of indoor and outdoor dust and vapours; and
- that the building type equates to a two-storey small terraced house.

It is considered that these assumptions are acceptable for this generic assessment of this site albeit conservative as the proposed development will comprise a mixed residential and commercial end use. 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 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.

This assessment is based upon the potential for risk to human health, which at this site is considered to be the critical risk receptor.

When comparing the results from the contamination testing to those in the Soil Guideline Values and Generic Guideline Values, the analyses have revealed a marginally elevated concentration of lead within a single sample of made ground.

The significance of these results is considered further in Part 2 of the report.

Report SP1010 and DEFRA (2014) *Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination* Policy Companion Document SP1010

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 basement excavation and the potential impact on the hydrogeology.

7.0 INTRODUCTION

The current proposal is to redevelop the site, through the demolition of the existing three-storey terraced building and subsequent construction of a new four-storey building with single level basement.

8.0 GROUND MODEL

The previous desk study revealed that the site does not have a significant contaminative history, having been occupied by the existing terraced building since at least 1896; the building was used for commercial purposes on the ground floor with residential accommodation on the upper floors. On the basis of the supplementary fieldwork and previous investigation, the ground conditions at this site can be characterised as follows:

- beneath a moderate thickness of made ground, the London Clay is present and has been proved to the maximum depth investigated of 8.45 m;
- the made ground extends to depths of between 0.40 m and 1.45 m and generally comprises brown silty sandy clay with rare flint gravel and fragments of brick and ash;
- the London Clay comprises an initial upper horizon of soft or firm brown silty clay with varying proportions of flint gravel and extends to depths of between 0.60 m and 2.50 m and these soils may represent Head Deposits;
- the greatest thickness of reworked soils was encountered at the front of the site in No 153 Broadhurst Gardens;
- beneath the reworked London Clay, firm becoming stiff brown mottled grey silty fissured clay with occasional partings of orange-brown fine sand and silt and selenite crystals was encountered and proved to the maximum depth investigated of 8.45 m;
- triaxial tests on recovered 'undistrubed' soils have indicated medium strength becoming very high strength clay with depth;
- decayed rootlets were noted in Borehole Nos 101 and 102 at depths of 4.80 m and 4.15 m, respectively;
- desiccation was encountered to a depth of 2.50 m during the previous investigation, within the vicinity of the former mature oak tree, which has since been cut down to a 1.5 m high stump;
- perched groundwater was encountered from within the made ground and around a claystone;

- subsequent groundwater monitoring has recorded two standpipes to be dry on the first monitoring visit, with water measured at depths of between 2.49 m and 5.70 m on the second and third visits, and in the third pipe groundwater has been measured at depths of between 0.76 m and 0.84 m on three occasions;

- rising head tests have measured permeability in the order of 10^{-6} m/s in Borehole Nos 101 and 103; and

- contamination testing has measured a slightly elevated concentration of lead within a single sample of made ground.

9.0 ADVICE AND RECOMMENDATIONS

The client is aware that the existing building has been moving for a number of years and it is understood that the building is continuing to move. The cause of the movements has been attributed to the existing foundations bearing on made ground and the past removal of load bearing walls at ground floor level.

In order to prevent further ongoing movements, underpinning of the existing foundations should be undertaken, if the existing building is to remain. In view of the findings from the supplementary investigation, foundations will need to be deepened to bypass any soft clays to prevent ongoing movements.

It is understood that a single level basement is being considered for the site. On this basis, it is assumed that any underpins or new foundations will extend to a depth of roughly 3.00 m, or 3.50 m including the slab make-up and formation level is likely to be within firm London Clay. Significant groundwater inflows are not anticipated but perched water may be encountered from within the made ground. Perched water may also encountered around any claystones and from within any siltier or sandier horizons, but any inflows should be suitably controlled by sump pumping.

9.1 Basement Construction

The proposed single level basement, extending to a depth of approximately 3.50 m will bypass the made ground and upper reworked clay.

Two of the standpipes were recorded to be dry at the time of the first groundwater monitoring visit and on the second and third visits water was present at depths of between 2.49 m and 5.70 m, and in the third pipe groundwater has been measured at depths of between 0.76 m and 0.84 m on three occasions. Groundwater was encountered during drilling in Borehole No 103 from around a claystone and the water measured within the pipe is likely to represent water that has drained from around the claystone and is trapped within the pipe surround by low permeability clay soils.

Whilst groundwater monitoring should be continued, it is not possible to draw entirely meaningful conclusions from the measurements made in the standpipes, as the level of the water is not necessarily as significant as the volume of water that may flow into the excavation. For example, a high level of water measured in a standpipe may not be significant if this represents only a small volume of water. The London Clay encountered on the site, included partings of fine sand and silt and the occurrence of groundwater into the basement may be controlled by such, along with claystones. This water should only be perched and it is expected that sump pumping will be adequate to maintain a dry excavation.

Shallow inflows of perched water may also be encountered from within the made ground, particularly within the vicinity of existing foundations, although such inflows are also unlikely to be significant.

The results of the simple rising head tests carried out in the standpipes installed in Borehole Nos 101 and 103, indicated inflow rates of 3.79×10^{-6} m/s and 1.47×10^{-6} m/s and whilst this preliminary information indicates that there is a replenishable source of groundwater, it does not indicate that high rates of inflow will occur. It would however be prudent to excavate trial pits to the maximum depth of the proposed basement and if groundwater is encountered, pumping tests should be carried out, in order to assess the groundwater inflow rates. The trial pits will be over a larger area than investigated by the boreholes, and provide additional information to supplement the findings to date.

The design of basement support in the temporary and permanent conditions needs to take account of the need to maintain the stability of the excavation and surrounding structures, and to protect against groundwater inflows.

It may be possible to form the retaining walls by underpinning of the existing foundations, using a traditional 'hit and miss' approach, which should be feasible on the basis of the groundwater monitoring results to date. Good workmanship will be required to ensure that movement of the surrounding structures does not arise during underpinning of the existing foundations, but this method will have the benefit of minimising the plant required and maximising usable space in the new basement. The contractor should have a contingency in place to deal with any groundwater inflows that are more significant than anticipated.

A bored pile retaining wall is likely to be the most appropriate means of supporting the basement excavation for the new building and it would have the advantage of being incorporated into the permanent works and being able to provide support for structural loads for the proposed new four-storey building. On the assumption that limited groundwater inflows will be encountered, it should be possible to adopt a contiguous bored pile wall, with the use of localised grouting and / or sump pumping if necessary.

The ground movements associated with the basement excavation will depend on the method of excavation and support and the overall stiffness of the basement structure in the temporary condition. Thus, a suitable amount of propping will be required to provide the necessary rigidity. In this respect, the timing of the provision of support to the wall will have an important effect on movements.

A ground movement analysis and building damage assessment is underway and the findings will be reported in due course.

9.1.1 Retaining Walls

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

Stratum	Bulk Density (kg/m³)	Effective Cohesion (c' – kN/m²)	Effective Friction Angle (Φ' – degrees)
Made Ground	1800	Zero	20
London Clay	1950	Zero	23

At this stage it is recommended that a design water level of 1.00 m below ground level is adopted. The advice in BS8102:2009[8] should be followed in this respect and with regard to the provision of suitable waterproofing.

9.1.2 Basement Heave

The formation level of the 3.50 m basement is likely to be within the London Clay and will result in net unloading of approximately 70 kN/m². This will result in an elastic heave and long term swelling of the London Clay. The effects of the longer term swelling movement will be mitigated to some extent by the load applied by the existing or new foundations. Further consideration will be given to heave movements within the ground movement analysis, included in Part 3 of this report.

9.2 Spread Foundations

All new foundations should bypass the made ground and any soft clay to bear within the firm clay which was present below a depth of 2.50 m. Moderate width pad or strip foundations including underpins bearing on the firm London Clay below basement level may be designed to apply a net allowable bearing pressure of 120 kN/m^2.

Foundations will need to be deepened in the vicinity of existing and proposed trees and National House Building Council (NHBC) guidelines should be followed in this respect. High shrinkability clays should be assumed. Where trees are to be removed the required founding depth should be determined on the basis of the existing tree height if it is less than 50% of the mature height and on the basis of full mature height if the current height is more than 50% of the mature height. Where a tree is to be retained the final mature height should be adopted. Notwithstanding NHBC guidelines, all foundations should extend beyond the zone of desiccation. In this respect, all foundation excavations should be inspected by a suitably experienced engineer.

The requirement for compressible material alongside foundations should be determined by reference to the NHBC guidelines.

If the proposed loads are high or the required founding depths become uneconomic piled foundations would provide a suitable alternative foundation option.

9.3 Piled Foundations

In view of the sensitive nature of the surrounding buildings it is considered bored piles installed by means of a continuous flight auger (cfa) are the most suitable as this will negate the requirement for temporary casing to protect against instability or water ingress.

The following table of ultimate coefficients may be used for the preliminary design of bored piles, based on the measured SPT and cohesion / depth graph in the appendix. A relationship of 5.0 x N has been adopted.

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

Stratum	Depth (m)	kN / m^2
Ultimate Skin Friction		
Basement	All soil above 3.00	Ignore
London Clay	3.00 to 8.45	Increasing linearly from 30 to 50
Ultimate End Bearing		
London Clay	3.00 to 8.45	Increasing linearly from 540 to 935

In the absence of pile tests, guidance from the London District Surveyors Association (LDSA)[9] suggests that a factor of safety of 2.6 should be applied to the above coefficients in the computation of safe theoretical working loads.

On the basis of the above coefficients, the following pile capacities have been estimated.

Pile Diameter mm	Pile length m (Depth below basement level m)	Safe Working Load kN
300	8.00 (5.00)	105
450	8.00 (5.00)	175

The above examples are not intended to constitute any form of recommendation with regard to pile size or type, but merely serve to illustrate the use of the above coefficients. Specialist piling contractors should be consulted with regard to the design of an appropriate piling scheme and their attention should be drawn to potential groundwater inflows within the made ground and from within silt and sand partings and claystones within the London Clay.

Piles may be subject to uplift as the clay heaves from the basement unloading. Consideration will need to be given to potential basement heave and pile tension when the final pile layout and loads are known.

9.4 Basement Floor Slab

Following the excavation of the single level basement, it is likely that the floor slab will need to be suspended over a void or layer of compressible material to accommodate the anticipated heave and any potential uplift forces from groundwater pressures, unless the slab can be suitably reinforced to cope with these movements. This should be reviewed once the levels and loads are known.

9.5 Shallow Excavations

On the basis of the borehole findings it is anticipated that shallow excavations for services terminating within the made ground should remain generally stable in the short term, although some instability may occur, particularly if perched water is present within the made ground. Sump pumping should be sufficient for dealing with any such occurrences as permeability results indicate inflows in the region of .79 x 10^{-6} m/s and 1.47 x 10^{-6} m/s.

10 Environment Agency 2015. *Guidance on the classification and assessment of waste.* Technical Guidance WM3 First Edition

However, if deeper excavations are required, or if excavations are to remain open for prolonged periods it is recommended that provision be made for battered side slopes or lateral support. Where personnel are required to enter excavations, a risk assessment should be carried out and temporary lateral support or battering of the excavation sides considered in order to comply with normal safety requirements.

9.6 Effect of Sulphates

Chemical analyses carried out on a total of five samples; including three samples of made ground and two samples of London Clay have revealed concentrations of soluble sulphate in accordance with Class DS-1 to DS-3 conditions of Table C2 of BRE Special Digest 1 Part C (2005). The measured pH value of the samples shows that an ACEC class of AC-2s would be appropriate for the site, assuming static water at the site. The guidelines contained in the above digest should be followed in the design of foundation concrete.

9.7 Site Specific Risk Assessment

The desk study has not indicated the site or immediate surrounding area to have had potentially contaminative history, having been occupied by the existing terraced house for over 130 years.

The contamination results have revealed a slightly elevated concentration of lead within a single sample of the made ground from Borehole No 101 at a depth of 0.60 m. The lead concentration was measured at 250 mg/kg, above the screening value of 200 mg/kg.

The source of the lead is likely to be extraneous fragments of ash noted within the sample. Given the depth of the samples tested, no pathway to end users in soft landscaped areas exists and no remedial measures are deemed to be required.

The lead is considered to be non-volatile or of a low volatility and does not thus present a significant vapour risk. In addition, the compounds are considered likely to be of low solubility and a plausible risk to groundwater has therefore not been identified.

Currently end users are isolated from direct contact with the identified contaminants by the extent of buildings and areas of external hardstanding. It is understood that no new pathways will be created, with the exception of site workers. Site workers will be protected from any contamination in the soils through adherence to normal high standards of site safety.

9.8 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[10] states that landfill WAC analysis, specifically leaching test results, must not be used for waste classification purposes.

10 Environment Agency 2015. *Guidance on the classification and assessment of waste.* Technical Guidance WM3 First Edition

Any spoil arising from excavations or landscaping works, which is not to be re-used in accordance with the CL:AIRE[11] 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 nine chemical analyses carried out on samples of made ground, 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	
London Clay	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[12] 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.

11 CL:AIRE March 2011. *The Definition of Waste: Development Industry Code of Practice* Version 2

12 Environment Agency 23 Oct 2007 *Regulatory Position Statement Treating non-hazardous waste for landfill - Enforcing the new requirement*

Part 3: GROUND MOVEMENT ANALYSIS

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.

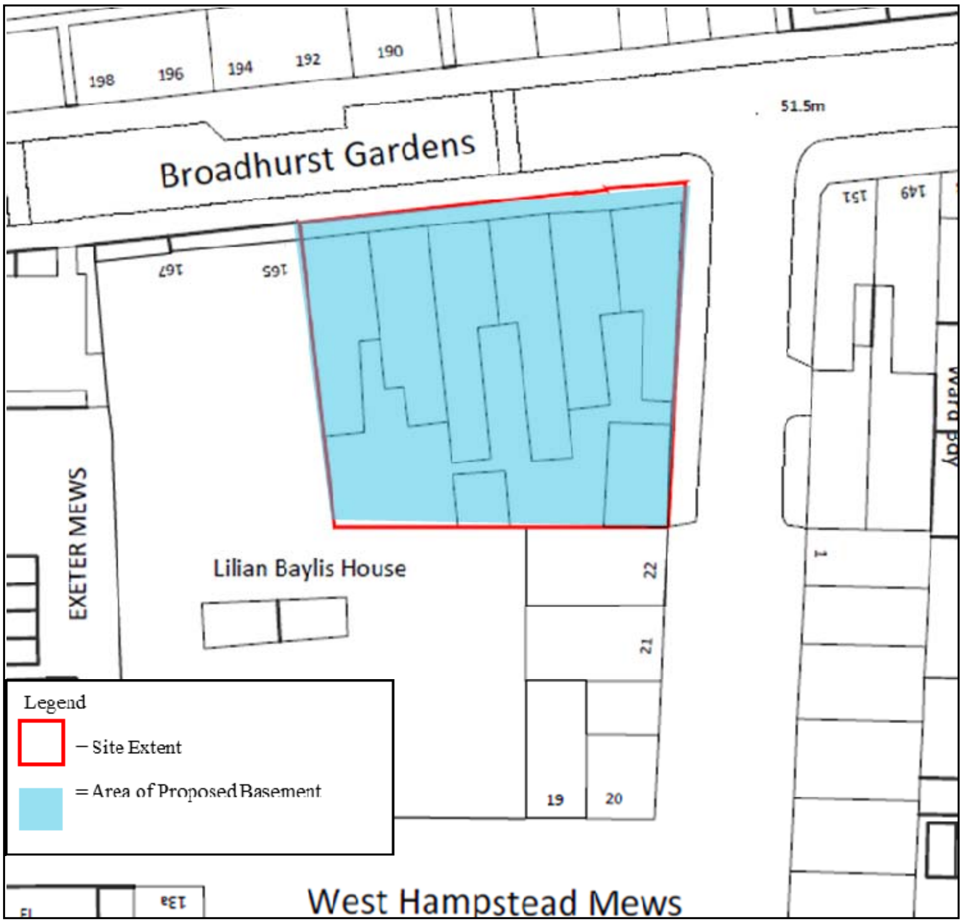
10.0 INTRODUCTION

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 piling, and the efficiency or stiffness of any support structures used.

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.

10.1 Basis of Ground Movement Assessment

A plan showing the nearby sensitive structures is shown below.

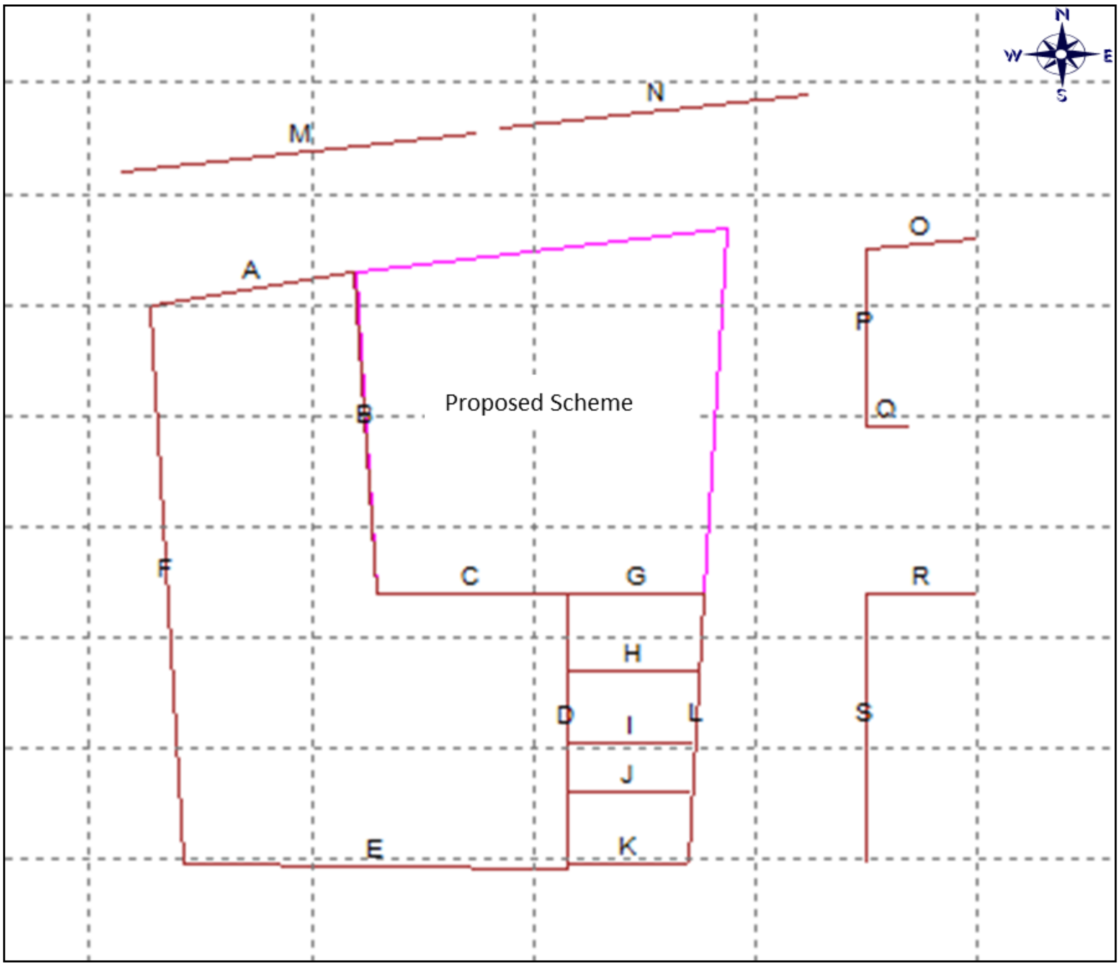


Sensitive structures relevant to this assessment include Lilian Baylis House, Nos 19, 20, 21 and 22 West Hampstead Mews, the front elevations of 1a to 4a West Hampstead Mews, Nos 152 and 149 Broadhurst Gardens, and the front elevations of 186 to 194 Broadhurst Gardens opposite to site. Garden and boundary walls have not been included in this assessment..

The building heights for the nearby sensitive structures have been derived from site observations and sections presented within the CMS. The locations of the neighbouring buildings have been determined using the map extract on page 43 of the CMS, as supplied by the consulting engineer. The perimeter foundations for the neighbouring Lylian Baylis House (Lines A –F) were measured at their shallowest at 0.65 m depth during site investigation, whilst the other surrounding properties have been assumed at 0.595 m, as per an internal pit excavated within 163 Broadhurst Gardens, which appears to be of a similar age.

Sensitive Structure	Structure Reference	Depth below existing ground level of foundations (m)	Height of building above ground level (m)
Lilian Baylis House	A to F	0.65	10.0
Nos 19, 20, 21 and 22 West Hampstead Mews	G to L	0.595	7.0
186 to 194 Broadhurst Gardens	M and N	0.595	13
152 and 149 Broadhurst Gardens	O to Q	0.595	13
1a to 4a West Hampstead Mews	R and S	0.595	7.0

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



11.0 CONSTRUCTION SEQUENCE

For the purposes of the ground movement assessment, ground level has been taken as the proposed ground floor level, at an arbitrary level of zero. It is proposed to construct a basement from this level to a depth of 3.5 m across the entire footprint of the proposed structure. It is understood that the proposed basement walls will be supported by a combination of mass concrete underpinning and contiguous bored piles. The bored piled walls are assumed to be founded at a depth of 8.25 m, whilst the underpins are assumed to be founded at a depth of 3.5 m. A plan of the proposed underpin and piling schemes is provided overleaf.

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. Underpin neighbouring structure;

2. construct contiguous piled walls;

3. excavate new basement to capping beam level and construct new capping beam. Once cured and if required, install a temporary propping regime;

4. excavate remaining basement and form concrete blinding to ensure sub-grade integrity;

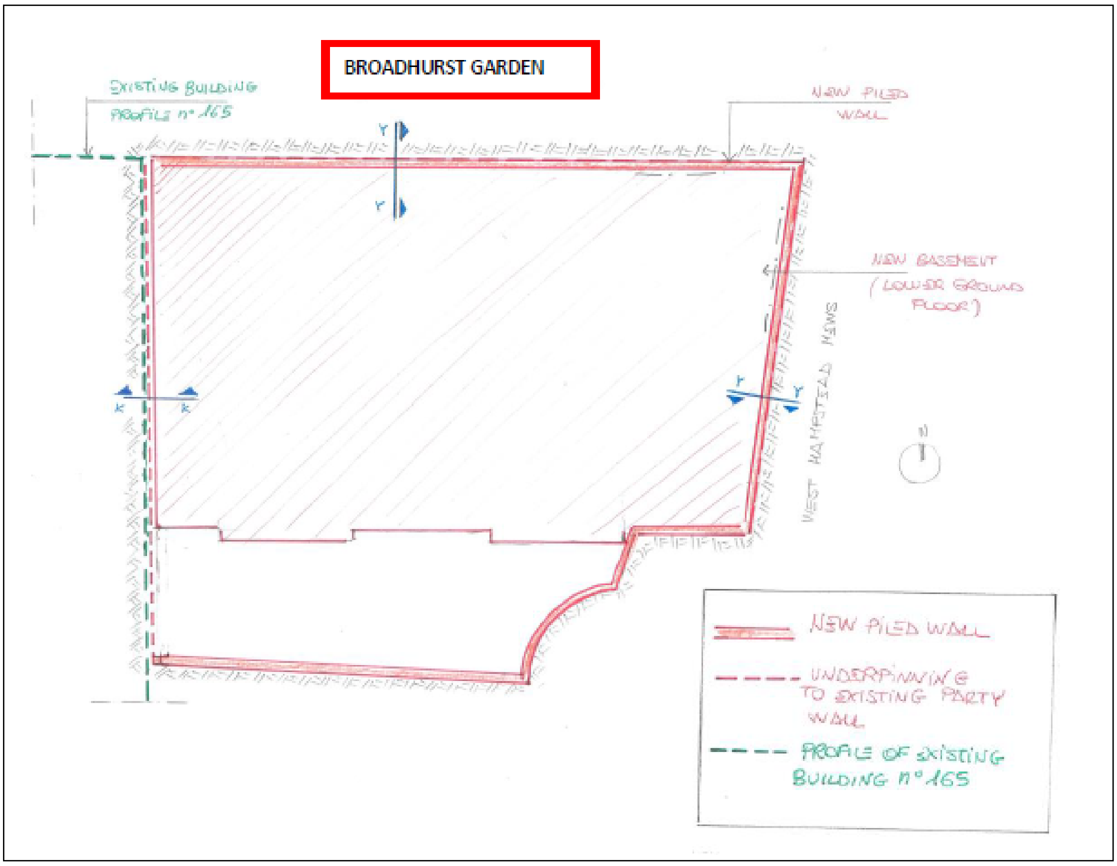
5. construct basement floor slab; and

6. construct ground floor slab

The Construction Method Statement (CMS) provided by the consulting engineers shows that the corners of the excavation will be supported by cross-bracing or similar and that the new retaining walls adjacent to neighbouring structures will not be cantilevered at any stage during the construction process. The contour plots appended show the wall installation phase, as well as the combined effect of the wall installation and basement excavation.

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 piling contractor.

When the final excavation depths have been reached the permanent works will be formed. Reinforced concrete should be used for the floor slabs and it is anticipated that heave protection may be installed beneath the basement slab. Following this, the floor slab will be constructed at basement depth and the temporary props will be removed.



12.0 GROUND MOVEMENTS

An assessment of ground movements within and surrounding the excavation has been undertaken using the P-Disp and X-Disp computer programs licensed from the OASYS suite of geotechnical modelling software from Arup. These programs are commonly used within the ground engineering industry and are considered to be appropriate tools for this analysis. The P-Disp software has been used to model the ground movements behind the underpinned retaining walls resulting from the wall installation, as well as movements within the proposed basement as a result of the excavation. The X-Disp software has been used to model the ground movements behind the piled retaining wall due to installation and the subsequent excavation. Due to the different construction methods the ground movements have been analysed within two different models. However the resulting movements from both models have been combined in order to give the Building Damage Assessment described in Section 13.0.

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[13], although this approach is considered to be conservative. A manual approach has therefore been adopted in conjunction with the results of a P-Disp analysis to assess the effects of construction of underpinned retaining walls and subsequent excavation in cohesive soils and is based on the assumption that the soils behave elastically, which provides a reasonable approximation to soil behaviour at small strains.

13 Gaba, A, Hardy, S, Powrie, W, Doughty, L and Selemetas, D (2017) *Embedded retaining walls – guidance for economic design* CIRIA Report C760

The X-Disp program has been used to predict ground movements likely to arise from the construction of the proposed piled walls and excavation of the basement. This includes the settlement of the ground (vertical movement) and the lateral movement of soil behind the proposed retaining walls (horizontal movement).

12.1 Models Used

Unloading of the London Clay below the basement excavation will take place as a result of the basement excavation, and 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. Drained parameters have been used to provide an estimate of the total long-term movement.

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[14] and Butler[15] and more recently by O'Brien and Sharp[16]. Relationships of $E_u = 500\ C_u$ and $E' = 300\ C_u$ for the cohesive soils and 2000 x SPT 'N' for granular soils have been used to obtain values of Young's modulus. More recent published data[17] indicates stiffness values of 750 x Cu for the London Clay and a ratio of E' to Eu of 0.75, but it is considered that the use of the more conservative values provides a sensible approach for this stage in the design.

The strength parameters used in this assessment were extrapolated from the SPT 'N' data presented in the YE Ground Investigation report and are tabulated below.

Stratum	Depth range (m)	Eu (MPa)	E' (MPa)
Made Ground	G/L to 1.0	5.0 to 20.0	3.0 to 12.0
London Clay	2.0 to 80.0	20.0 to 200.0	12.0 to 120.0

A rigid boundary for the analysis has been set at a depth of 80 m below existing ground level, which nearby BGS records indicate to be the minimum depth to the base of the London Clay. The proposed basement excavation will result in a net unloading of around 70 kN/m^2 which is assumed to act at a maximum excavation depth of 3.5 m below existing ground floor level. The proposed loads are unknown and it is assumed that the underpinning will apply a pressure of 120 kN/m^2, also assuming a proposed underpin width of 1.0 m.

For the purpose of these analyses, the corners have been defined by x and y coordinates. In the X-Disp and P- Disp analyses the x-direction is roughly parallel with the orientation east-west, whilst the y-direction is roughly parallel with the orientation of north-south. Vertical movement is in the z-direction. The sensitive structures were located using drawings supplied by the consulting structural engineers and have been modelled in the analysis as a set of displacement lines. Each displacement line represents a wall of the building and is given

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

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

16 O'Brien AS and Sharp P (2001) *Settlement and heave of overconsolidated clays - a simplified non-linear method.* Part Two, Ground Engineering, Nov 2001, 48-53

17 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

structural characteristics, such as height, length and its construction type, eg masonry, steel framed, concrete framed. The displacement lines have been modelled as 1.0 m long structural elements if the wall is less than 10 m long, or as 2.0 m long structural elements if the wall is greater than 10 m long. The full outputs of all the analyses can be provided on request and samples of the output movement contour plots are included within the appendix.

12.2 Ground Movements – Wall Installation

12.2.1 Underpin Wall Installation

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

Table 6.3 of CIRIA C760 indicates that for a planar diagram 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 and for a 3.5 m wall this equates to a zone of influence of 5.25 m. Sensitive Structure A falls within this 5.25 m distance and Table 6.1 indicates that maximum horizontal and vertical movements of 0.05 % of the retained height may arise immediately behind the wall, which for a 3.5 m deep basement gives a movement of 1.5 mm. Whilst this is considered to be a reasonable approximation of the likely movement, the horizontal and vertical movements will be sensitive to the quality of workmanship and appropriate sequencing during the underpin construction.

12.2.2 Piled Wall installation

Settlement of soil behind the piled retaining wall will occur due to the displacement of soil caused during installation. The predicted movements are based on the worst case of the individually analysed segments of ‘hogging’ and ‘sagging’ and these are summarised in the tables overleaf. It should be noted that the combined effect of segments acting together typically improves the resultant movements and the values below are therefore deemed to be conservative.

The movements predicted by X-Disp model are summarised in the table below.

Phase of Works	Wall Movement (mm)	
	Vertical Settlement	Horizontal Movement
Installation of contiguous bored piled retaining walls	0-4	0-4

The analysis has indicated that the maximum vertical and horizontal settlements that will result from wall installation are likely to be less than 5 mm.

12.3 Ground Movements – Following Excavation

12.3.1 Ground Movements behind Underpin Section

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, although for an underpinned wall this movement is likely to be small due to the existing building effectively acting as additional support at ground level. Furthermore, due to the construction sequence, the excavation phase will occur after the piled walls, capping beam and temporary props have been installed, which are also likely to reduce movements. 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.

Given the relatively short time difference between underpin installation and basement excavation, the combined ground movements are expected to act together. P-Disp has been used to predict the effect of potential heave movements at the foundation depth of nearby sensitive Structure Lines A and B (Lilian Baylis House) 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 Table 6.3 of CIRIA C760. This 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 3½ and 4 times the retained height. For this assessment these distances are around 12 m and 14 m for vertical and horizontal movements respectively and any structures beyond these points are assumed to be unaffected.

The results of the P-Disp analysis are tabulated below, which in the worst case are from the total movement model, and have been presented to the degree of accuracy required to allow predicted variations in ground movements around the structure(s) to be illustrated, but may not reflect the anticipated accuracy of the predictions.

Structure	Elevation	Maximum Vertical heave (mm)
Lilian Baylis House	A	8
Lilian Baylis House	B	10

12.3.2 Ground Movements behind Piled Wall Sections

Following the piled wall installation and basement excavation, settlement of the soil behind the new piled retaining wall may occur due to the excavation in front of the wall causing the wall to deflect. Unlike the underpins, the piled retaining walls are unlikely to be loaded for a period of time and thus this settlement is more likely to be realised. Given the relatively short time difference between piled wall installation and basement excavation, the combined ground movements are expected to act together. Below are the predicted combined ground movements resulting from the piled wall installation and basement excavation.

Phase of Works	Wall Movement (mm)	
	Vertical Settlement	Horizontal Movement
Combined Retaining Wall and Excavation Movements	0-6	0-9

The maximum movements arising from the combined wall installation and excavation phases are likely to be about 6 mm of vertical settlement, whilst the maximum horizontal movements are anticipated to be about 9 mm.

The estimated movements are considered to represent a worst case scenario, particularly as they do not take account of the increased stiffness due to lining walls, propping at floor levels and the overall completed structure.

12.3.3 Movements within the Excavation (Heave)

Using the same P-Disp model used to assess the underpins, the proposed excavation of the new basement will result in a net unloading of approximately 70 kN/m². The P-Disp analysis indicates that, by the time the basement construction is complete, around 10 to 11 mm of heave is likely to have taken place at the centre of the proposed excavation, while around 5 mm to 7 mm of settlement will occur at the edges. Beneath the underpins, around 3 mm of heave is predicted.

An additional 12 to 14 mm of long term heave may theoretically occur at the centre of the proposed excavation following construction, while an additional 5 mm to 7 mm of heave may occur at the edges of the excavation. Beneath the underpins, around another 4 mm of heave may theoretically take place.

The results of the P-Disp analysis can be used to indicate the likely impact of the proposed basement construction beyond the site boundaries; about 5 m away from the excavation a total movement of about 5 mm is predicted. Movements outside the excavation will be further constrained to a certain extent by the presence of the new retaining walls.

13.0 DAMAGE ASSESSMENT

In addition to the above assessment, some of the neighbouring structures are considered to be sensitive structures and have been subject to a Building Damage Assessment, on the basis of the classification given in Table 6.4 of CIRIA report C760[18].

In order to determine the Damage Category for sensitive structures lines A and B, as a result of the underpinning and excavation phase, P-Disp was used to estimate the differential movement along the length of each sensitive structure and the results have been used in a manual assessment. As noted previously in Section 12.2.2, structures greater than 14 m from the proposed basement are assumed to have a damage category of zero – Negligible. The results of the building damage assessment are shown in the table below. For the assessment of the underpinning, the plot for horizontal wall movements as a result of the excavation in front of a wall in stiff clay in CIRIA C760 (Fig 6.16) has been adapted to reflect a trend line that assumes a movement of 5 mm immediately behind the wall, with movement that diminishes with distance from the wall according to the trend line set by a wall within a high stiffness clay. As the construction of the contiguous bored pile wall is likely to take place shortly after the underpinning, the movements generated by X-Disp in the combined piled wall and excavation model have also been considered in this part of the Damage Assessment. This approach is considered to be conservative and the results for the analysis are shown in the table overleaf.

All structures are shown on the plan in Section 12.1.

13.1 Damage to Neighbouring Structures

The results for both analyses are summarised in the table below.

For clarity, where the analysis has indicated that the structure is unlikely to experience damage of higher than Category 0 – Negligible, they have not been included within the table below. Furthermore, where the analysis indicated that the structure is predicted to experience damage of higher than Category 1 (Very Slight), further analysis was carried out in order to determine the upper limit of vertical or horizontal movement required to maintain the Damage Category at an acceptable level.

18 Gaba, A, Hardy, S, Powrie, W, Doughty, L and Selemetas, D (2017) *Embedded retaining walls – guidance for economic design* CIRIA Report C760.

Building Damage Assessment		
Construction Phase	Elevation	Category of Damage*
Combined underpin and piled wall installation and excavation	D	1 (Very slight)
	L	1 (Very Slight)

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

The analysis has predicted that the proposed installation of the retaining walls and excavation of the proposed basement will generally result in a building damage for sensitive structures of Category 0 (negligible) and Category 1 (Very Slight), which fall within the range of damage that is considered to be aesthetic and not structural.

The Camden Planning Guidance notes that '*The Council…..will expect BIAs to provide mitigation measures where any risk of damage is identified of Burland category 1 'very slight' or higher. Following inclusion of mitigation measures into the proposed scheme the changes in attributes are to be re-evaluated and new net consequences determined.'* Additional consideration has therefore been given to the walls with damage categories of Very Slight, as discussed below.

The table below shows the maximum allowable horizontal and vertical movement for each sensitive structure in order to achieve a building damage category[19] of Category 0 – Negligible.

Sensitive Structure	Reference	Maximum Allowable Vertical Movement at Foundation Depth to Achieve Category 0 – Negligible (mm)	Maximum Allowable Horizontal Movement at Ground Level to Achieve Category 0 – Negligible (mm)
Lilian Baylis House	D	5 to 6	3 to 4
Nos 19, 20, 21 and 22 West Hampstead Mews	L	5 to 6	3 to 4

The limiting values of movements listed in the table above are considered to be feasible maximum limits with respect to basement construction.

In practice, the underpinning, installation of contiguous piled walls and the subsequent excavation of the proposed basement will be staged processes and will take place over a number of weeks. This will provide an opportunity for the ground movements during and immediately after the installation of the retaining walls to be measured and the data acquired can be fed back into the design and compared with the predicted values. Such a comparison will allow the ground model to be reviewed and the predicted wall movements to be reassessed prior to the main excavation taking place so that propping arrangements can be adjusted if required.

13.2 Monitoring of Ground Movements and Mitigation

The predictions of ground movement based on the ground movement analysis should be checked by monitoring of the adjacent properties and structures. The structures to be monitored during the construction stages should include the neighbouring structures. Condition surveys of the above 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.

14.0 CONCLUSIONS

The analysis has predicted that the proposed installation of the retaining walls and excavation of the proposed basement may generally result in a building damage for sensitive structures of Category 0 (negligible) and Category 1 (Very Slight), thus falling within the range of damage that is considered to be aesthetic and not structural.

The separate phases of work will in practice be separated by a number of weeks during which time construction of permanent supports, basement slab and retaining wall curing will take place. This will provide an opportunity for the ground movements during and immediately after retaining wall construction to be measured and the data acquired can be fed back into the design and compared with the predicted values. Such a comparison will allow the ground model to be reviewed and the predicted wall movements to be reassessed prior to the main excavation taking place so that propping arrangements can be adjusted if required.

Part 4: BASEMENT IMPACT ASSESSMENT

15.0 BASEMENT IMPACT ASSESSMENT

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.

It is understood that the proposed redevelopment of the site with four-storey buildings includes the excavation of the ground to accommodate a single level basement, which are anticipated to extend to a depth of roughly 3.00 m. Formation level of basement will be within the London Clay, which has been proved to the maximum depth investigated of 8.45 m.

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
Seasonal shrink-swell can result in foundation movements	Plasticity index tests generally indicated the London Clay to be of medium and high volume change potential at the site. Shrinkable clay is present within a depth that can be affected by tree roots and the soil was indicated to be desiccated to a depth of 2.50 m in the vicinity of a mature oak tree at No 155 in 2004, which was pollarded in the last 12 months.
Location of public highway – excavation of basement could lead to damage	The highway is located within 5 m of the site. It is anticipated that the basement will extend under the footprint of the new building and as such will be within 5 m of the highway.
Site is within 100 m of watercourse	The site is underlain by low permeability London Clay, which cannot store and transmit significant quantities of groundwater and does not support flow to water courses. Any water flows associated with the former course of the River Westbourne are, therefore, unlikely to be affected by the proposed development. The River Westbourne no longer exists as a surface watercourse and is not considered likely to be affected, or have any effect on, the proposed development.
The basement will extend below the groundwater table – this may affect the groundwater flow regime	Groundwater was not encountered in Borehole Nos 101 or 102 during drilling, but perched groundwater was encountered in Borehole No 103 from around a claystone. During the previous investigation, groundwater was not encountered, apart from as perched water strikes from within the made ground. Subsequent groundwater monitoring has recorded two standpipes to be dry on the first monitoring visit, with water measured at depths of between 2.49 m and 5.70 m on the second and third visits, and in the third pipe groundwater has been measured at depths of 0.76 m and 0.84 m on three occasions.

Potential Impact	Site Investigation Conclusions
Trees within the rear garden may be affected by the new development – the basement is located at the site of a former mature oak tree, which has been pollarded in the last 12 months.	The laboratory testing indicated the soil to be desiccated to a depth of 2.50 m in the vicinity of the mature oak tree in the 2004 investigation, which has since been pollarded.
The site is within an area known to be at risk of surface water flooding.	N/A

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

Shrink / swell potential of London Clay

Shrinkable clay is present within a depth that can be affected by tree roots and laboratory tests indicated the soil to be desiccated to a depth of 2.50 m in the vicinity of an oak tree, which has recently been pollarded. However, the basement is anticipated to extend to a depth of 3.00 m. Once the final levels are known, the depth of founding should be checked to ensure that it provides sufficient protection against the elastic rebound of the soil and it is recommended that the basement excavation is inspected by a qualified and experienced geotechnical engineer to ensure that no desiccation remains at formation level.

Trees within the rear garden may be affected by the new development

It is anticipated that the new development will extend over the site of an existing oak tree at No 155. Following removal of any vegetation, allowance should be made for the increase in moisture content of the desiccated soils which may cause heave of the soil. The effects of the longer term swelling movement will be mitigated to some extent by the load applied by the new foundations. It is recommended that the basement slab is suitably reinforced to withstand heave or that a void is incorporated below the slab to allow the movement to take place. It would be prudent to conduct a detailed analysis of these movements once the basement design has been finalised.

Location of public highway

The proposed basement is anticipated to extend under the footprint of the new buildings in the redevelopment, which front onto Broadhurst Gardens to the north, and West Hampstead Mews to the east. The design of the basements and the method of construction should mitigate for any movement of the soil that may cause damage to the highway. The efficiency of the various support systems employed during the excavation and the efficiency or stiffness of any support frames used will be important.

Proposed basement structure may extend below groundwater table

Shallow monitored groundwater levels within standpipes is a common feature of low permeability clay strata and is not necessarily indicative of a consistent water table as would be the case within a permeable water bearing strata. Thus, although the basement may extend below the monitored water levels in standpipes it is not the case that it extends below a general and continuous groundwater table. As such, is not considered that the proposed basement would result in a significant change to the groundwater flow regime in the vicinity of the proposal.

The site is within 100 m of the historical River Westbourne

The River Westbourne no longer exists as a surface watercourse and is not considered likely to be affected, or have any effect on, the proposed development.

The site is within an area known to be at risk of surface water flooding

Broadhurst Gardens suffered from severe flooding during a storm in 1975 which caused considerable damage to properties and disruption of public services. It is recommended that a Flood Risk Assessment is carried out by a specialist.

15.1 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.

15.1.1 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?	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?	A site walkover and existing plans of the site have confirmed the proportions of hardstanding and soft landscaping, which have been compared to the proposed drawings to determine the changes in the proportions.
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?	As above.
5. Will the proposed basement result in changes to the quantity of surface water being received by adjacent properties or downstream watercourses?	
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 subterranean (groundwater flow) 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?	Previous GEA investigation from 2004.
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 and soft landscaping, 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 subterranean (groundwater flow) screening questions.

Question	Evidence
1. Does the existing site include slopes, natural or manmade, greater than 7°?	Site survey drawing and Figures 16 and 17 of the Arup report and confirmed during a site walkover
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 and confirmed during a site walkover
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?	A site walkover confirmed that there are trees on site. An arboriculturist should be consulted if any trees are to be removed from the site.
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 was used to make an assessment of this, in addition to a visual inspection of the buildings carried out during the site walkover
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
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.

Question	Evidence
12. Is the site within 5 m of a highway or pedestrian right of way?	Site plans and the site walkover.
13. Will the proposed basement significantly increase the differential depth of foundations relative to neighbouring properties?	Camden planning portal and the site walkover confirmed the position of the proposed basement relative the 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.

15.1.2 Scoping and Site Investigation

The questions in the screening stage that required further assessment, 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. The findings of the investigation are discussed in Section 5.0 of this report and summarised in both Section 7.0 and the Executive Summary.

15.1.3 Impact Assessment

Section 15.0 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 9.0 of this report also provides recommendations for the design of the proposed development, whilst Section 10.0 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.

16.0 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.

Groundwater monitoring should be continued and trial excavations should be considered to the full depth of the proposed basement to assess the extent of inflows to be expected from within the London Clay over a larger area than has been previously investigated.

If during ground works any visual or olfactory evidence of contamination is identified further investigation should be carried out and the risk assessment reviewed.

These items 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.

APPENDIX

Borehole Records

Trial Pit Records

Geotechnical Laboratory Test Results

SPT & Cu / Depth Plot

Chemical Analysis (Soil)

Generic Risk Based Screening Values

GROUND MOVEMENT ASSESSMENT

X-DISP ANALYSIS:

Wall Installation

Contour Plots of Vertical Movements and Horizontal Movements

Wall Installation and Basement Excavation combined

Contour Plots of Combined Vertical Movements and Horizontal Movements

Tabular Outputs

P-DISP ANALYSIS

Short Term Movement Contour Plots

Total Movement Contour Plots

Structure A and B Manual Calculation Sheets

Site Plan

Geotechnical & Environmental Associates

Widbury Barn
Widbury Hill
Ware,Herts
SG12 7QE

Site	Number
153-163 Broadhurst Gardens, West Hampstead, NW6 3AU	BH101

Excavation Method	Dimensions	Ground Level (mOD)	Client	Job Number
Open-drive sampler		51.09	Kilburn and District Homes Ltd	J13364A
	Location	**Dates**	**Engineer**	**Sheet**
		27/02/2017	Fluid Structures	1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.33)	MADE GROUND (brick, 100 mm thick, over 70 mm of concrete, overlying brick, 160 mm thick)		
0.30	D1			50.76	0.33			
				50.69	0.40	MADE GROUND (brown sand with brick and ash)		
					(0.40)	MADE GROUND (brown silty sandy clay with rare flint gravel and fragments of brick and ash)		
0.60	D2							
				50.29	0.80			
1.00	D3				(0.65)	Soft becoming firm orange-brown mottled grey silty CLAY with rare partings of orange-brown fine sand, medium subangular to subrounded flint gravel, carbonaceous material and fine rootlets. Selenite crystals encountered at a depth of 1.20 m		
1.20-1.65	SPT N60=7		0,1/1,2,2,2					
1.20-1.65	D4		(PP) 1.25	49.64	1.45			
1.30	D5							
1.65-2.00	U6				(1.05)	Firm medium strength brown mottled grey silty CLAY with abundant selenite crystals and occasional partings of orange-brown fine sand and silt. Fine rootlets noted at a depth of 2.00 m		
2.00	D8		(PP) 1.75					
2.00-2.45	SPT N60=11		2,2/2,3,3,3					
2.00-2.45	D7							
2.40	D9			48.59	2.50			
			(PP) 1.75			Firm high strength fissured brown mottled grey silty CLAY with abundant selenite crystals and occasional partings of orange-brown fine sand and silt		
2.80	D10							
			(PP) 1.75					
3.00-3.45	SPT N60=13		2,2/3,3,3,4					
3.30	D11		(PP) 1.75					
3.50-4.00	U12		(PP) 2.00		(2.00)			
4.00-4.45	D13		(PP) 2.25					
4.00-4.45	SPT N60=15		2,3/3,3,4,5					
4.20	D14		(PP) 3.00					
4.50	D15			46.59	4.50	Stiff fissured brown mottled grey silty CLAY with occasional partings of orange-brown fine sand and silt, shell fragments and selenite crystals. Decayed rootlets noted at a depth of 4.80 m.		
			(PP) 3.00		(0.80)			
4.90	D16		(PP) 3.50					
5.00-5.45	SPT N60=16		2,3/3,3,5,5					
5.00-5.45	D17							
5.30	D18			45.79	5.30	Stiff very high strength fissured brown silty CLAY with rare partings of orange-brown fine sand and silt, shell fragments and selenite crystals		
5.60	D19							
5.90	D20							
6.00-6.45	SPT N60=19		2,3/4,4,5,6					
6.00-6.45	D21							
6.20	D22							
6.50-7.00	U23							
7.00-7.45	SPT N60=19		3,3/4,4,5,6		(3.15)			
7.00-7.45	D24							
7.50-8.00	U25							
8.00-8.45	SPT N60=23		3,4/5,5,6,7					
				42.64	8.45	Complete at 8.45m		

Remarks
Hand-dug starter pit to a depth of 1.20 m
Groundwater not encountered during drilling
PP denotes pocket penetrometer reading
Standpipe (50 mm diameter) installed to a depth of 6 m - response zone from 1.00 m to 6.00 m
Standpipe recorded to be dry on 28/02/2017
Groundwater measured at depths of 5.34 m on 22/03/2017 and 2.49 m on 22/03/2017

Scale (approx)	Logged By
1:50	HD

Figure No. J13364A.BH101

GEA Geotechnical & Environmental Associates

Widbury Barn
Widbury Hill
Ware,Herts
SG12 7QE

Site	Number
153-163 Broadhurst Gardens, West Hampstead, NW6 3AU	BH102

Excavation Method	Dimensions	Ground Level (mOD)	Client	Job Number
Open-drive sampler		51.74	Kilburn and District Homes Ltd	J13364A
	Location	**Dates**	**Engineer**	**Sheet**
		28/02/2017	Fluid Structures	1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.57)	MADE GROUND (tile over adhesive, 15 mm thick, over 50 mm of concrete, underlain by 200 mm of concrete, over red brick, 300 m thick)		
				51.17	0.57 (0.23)	MADE GROUND (brown sand with brick) - poor recovery		
0.80	D1			50.94	0.80	MADE GROUND (brown mottled orange-brown silty sandy clay with rare pockets of orange-brown sand, flint gravel and fragments of brick and ash)		
1.00-1.45	SPT N60=7		0,0/1,2,2,2		(0.65)			
1.00-1.45	D2							
1.20	D3							
				50.29	1.45	Soft medium strength orange-brown silty CLAY with carbonaceous material		
1.50-2.00	U4				(0.55)			
				49.74	2.00	Soft brown silty CLAY with rare fine claystones - naturally reworked?		
			(PP) 1.00		(0.50)			
2.20	D5		(PP) 1.50					
				49.24	2.50	Firm medium strength brown mottled grey silty CLAY		
2.50-3.00	U6				(0.50)			
				48.74	3.00	Firm high strength fissured brown mottled grey silty CLAY. From a depth of 3.20 m, rare partings of orange-brown fine sand and silt and selenite crystals		
3.00-3.45	SPT N60=11		2,3/2,3,3,3					
3.00-3.45	D8		(PP) 1.75					
3.20	D7		(PP) 2.00		(1.00)			
3.50-4.00	U9							
				47.74	4.00	Stiff high strength becoming very high strength fissured brown mottled grey silty CLAY with rare selenite crystals and partings of orange-brown fine sand and silt. Decayed rootlets noted from a depth of 4.15 m to 4.60 m		
			(PP) 2.75					
4.20	D10		(PP) 2.75					
4.60	D11		(PP) 3.00					
4.90	D12							
5.00-5.45	SPT N60=17		2,3/3,4,4,6					
5.00-5.45	D13							
5.30	D14		(PP) 3.00					
5.50-6.00	U15		(PP) 3.00					
					(4.00)			
			(PP) 3.75					
6.20	D16		(PP) 4.00					
6.50-7.00	U17							
7.00-7.45	SPT N60=20		2,3/4,4,6,6					
7.00-7.45	D18							
7.50-8.00	U19							
				43.74	8.00	Complete at 8.00m		

Remarks
Floor cored in 150 mm diameter using a concrete coring attachment on the rig
PP denotes pocket penetrometer reading
Groundwater not encountered during drilling
Standpipe (50 mm diameter) installed to a depth of 6.00 m - response zone from 1.50 m to 6.00 m
Standpipe recorded to be dry on 28/02/2017
Groundwater measured at depths of 5.70 m on 22/03/2017 and 4.33 m on 17/05/2017

Scale (approx)	Logged By
1:50	HD

Figure No. J13364A.BH102

Geotechnical & Environmental Associates	Widbury Barn Widbury Hill Ware,Herts SG12 7QE	Site 153-163 Broadhurst Gardens, West Hampstead, NW6 3AU	Number **BH103**

Excavation Method	Dimensions	Ground Level (mOD)	Client	Job Number
Drive-in Windowless Sampler		51.73	Kilburn and District Homes Ltd	J13364A
	Location	**Dates**	**Engineer**	**Sheet**
		28/02/2017	Fluid Structures	1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
0.30	D1				(0.50)	MADE GROUND (concrete paving slab, 50 mm thick overlying brown mottled orange-brown silty sandy clay with rare flint gravel and fragments of brick, burnt coal, ash and pottery)		
				51.23	0.50			
0.60	D2		(PP) 1.00 (PP) 1.00		(0.50)	Soft orange-brown mottled grey silty CLAY with rootlets		
1.00	D3			50.73	1.00			
					(0.50)	Soft brown mottled grey silty CLAY		
1.50	D4		(PP) 1.00	50.23	1.50			
2.00	D5				(1.50)	Firm brown mottled grey silty CLAY with rare partings of orange-brown fine sand and silt. Claystone encountered at a depth of 2.50 m		▼1
2.50	D6		(PP) 1.50					
3.00	D7		Water strike(1) at 3.00m, rose to 2.15m in 20 mins. (PP) 2.00	48.73	3.00			∇1
					(0.50)	Firm fissured brown mottled grey silty CLAY with rare partings of orange-brown fine sand and silt. Claystone encountered at a depth of 3.20 m		
3.50	D8		(PP) 2.50	48.23	3.50			
					(0.50)	Stiff fissured brown mottled grey silty CLAY with rare partings of orange-brown fine sand and silt		
4.00	D9		(PP) 3.25	47.73	4.00			
						Terminated at 4.00m		

Remarks
PP denotes pocket penetrometer reading
Standpipe (19 mm diameter) installed to a depth of 4.00 m - response zone from 1.00 m to 4.00
Groundwater measured at depths of 0.78 m on 13/03/2017, 0.76 m on 22/03/2017 and 0.84 m on 17/05/2017

Scale (approx)	Logged By
1:50	HD

Figure No. J13364A.BH103

Geotechnical & Environmental Associates

Widbury Barn
Widbury Hill
Ware,Herts
SG12 7QE

Standard Penetration Test Results

Site : 153-163 Broadhurst Gardens, West Hampstead, NW6 3AU

Client : Kilburn and District Homes Ltd

Engineer : Fluid Structures

Job Number J13364A

Sheet 1 / 1

Borehole Number	Base of Borehole (m)	End of Seating Drive (m)	End of Test Drive (m)	Test Type	Seating Blows per 75mm		Blows for each 75mm penetration				Result	Comments
					1	2	1	2	3	4		
BH101	1.20	1.35	1.65	SPT	0	1	1	2	2	2	N60=7	
BH101	2.00	2.15	2.45	SPT	2	2	2	3	3	3	N60=11	
BH101	3.00	3.15	3.45	SPT	2	2	3	3	3	4	N60=13	
BH101	4.00	4.15	4.45	SPT	2	3	3	3	4	5	N60=15	
BH101	5.00	5.15	5.45	SPT	2	3	3	3	5	5	N60=16	
BH101	6.00	6.15	6.45	SPT	2	3	4	4	5	6	N60=19	
BH101	7.00	7.15	7.45	SPT	3	3	4	4	5	6	N60=19	
BH101	8.00	8.15	8.45	SPT	3	4	5	5	6	7	N60=23	
BH102	1.00	1.15	1.45	SPT	0	0	1	2	2	2	N60=7	
BH102	3.00	3.15	3.45	SPT	2	3	2	3	3	3	N60=11	
BH102	5.00	5.15	5.45	SPT	2	3	3	4	4	6	N60=17	
BH102	7.00	7.15	7.45	SPT	2	3	4	4	6	6	N60=20	

Summary of Natural Moisture Content, Liquid Limit and Plastic Limit Results

Job No.	Project Name	Programme	
22451	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU	Samples received	28/02/2017
		Schedule received	09/03/2017
Project No.	Client	Project started	10/03/2017
J13364A	GEA	Testing Started	18/03/2017

Hole No.	Sample Ref	Sample Top	Sample Base	Sample Type	Soil Description	NMC %	Passing 425µm %	LL %	PL %	PI %	Remarks
BH101	4	1.20	-	D	Brown and occasional pale grey silty CLAY with occasional selenite crystals and traces of fine brick fragments	29	99	75	25	50	
BH101	7	2.00	-	D	Brown slightly mottled pale grey silty CLAY with pale yellow sand pockets	30	100	74	26	48	
BH101	15	4.50	-	D	Brown and occasional pale grey silty CLAY	31	100	77	26	51	
BH102	10	4.20	-	D	Brown and occasional bluish grey silty CLAY with traces of selenite crystals	30	100	73	25	48	
BH103	3	1.00	-	D	Brown silty CLAY	33	100	78	24	54	

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Test Methods: BS1377: Part 2: 1990:
Natural Moisture Content : clause 3.2
Atterberg Limits: clause 4.3 and 5.0

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MSF-5-R1(b)

Sulphate Content (Gravimetric Method) for 2:1 Soil: Water Extract and pH Value - Summary of Results
Tested in accordance with BS1377 : Part 3 : 1990, clause 5.3 and clause 9

Job No.	Project Name	Programme	
22451	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU	Samples received	28/02/2017
		Schedule received	09/03/2017
Project No.	Client	Project started	10/03/2017
J13364A	GEA	Testing Started	16/03/2017

Hole No.	Sample Ref	Sample Top	Sample Base	Sample Type	Soil description	Dry Mass passing 2mm %	SO3 Content g/l	SO4 Content g/l	pH	Remarks
BH101	10	2.80	-	D	Brown slightly sandy silty CLAY with scattered traces of selenite	100	2.32	2.79	7.83	
BH103	3	1.00	-	D	Brown silty CLAY	100	0.31	0.37	7.98	

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MSF-5-R29

Unconsolidated Undrained Triaxial Compression tests without measurement of pore pressure
Summary of Results

Tests carried out in accordance with BS1377:Part 7 : 1990 clause 8 or 9 as appropriate to test

Job No.	Project Name	Programme	
22451	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU	Samples received	28/02/2017
		Schedule received	09/03/2017
Project No.	Client	Project started	12/04/1900
J13364A	GEA	Testing Started	22/03/2017

Hole No.	Sample Ref	Sample Top	Sample Base	Sample Type	Soil Description	Test Type	Density bulk Mg/m3	Density dry Mg/m3	w %	Length mm	Diameter mm	σ3 kPa	At failure Axial strain %	At failure σ1 - σ3 kPa	At failure cu kPa	Mode	Remarks
BH101	6	1.50	2.00	U	Medium strength brown slightly bluish grey mottled silty CLAY with scattered selenite crystals	UU	1.81	1.35	34	200	100	30	7.5	82	41	B	
BH101	12	3.50	4.00	U	High strength slightly fissured brown silty CLAY	UU	1.86	1.42	31	170	85	70	6.2	193	97	B	
BH101	23	6.50	7.00	U	Very high strength slightly fissured brown silty CLAY with orangish brown silty sand partings	UU	2.04	1.58	29	120	60	130	6.3	331	166	B	
BH101	25	7.50	8.00	U	Very high strength slightly fissured brown silty CLAY with rare selenite crystals	UU	1.92	1.51	27	100	50	150	7.5	374	187	B	
BH102	4	1.50	2.00	U	Medium strength brown and orangish brown mottled silty CLAY	UU	1.70	1.25	36	200	100	30	9.5	89	45	C	
BH102	6	2.50	3.00	U	Medium strength fissured brown slightly mottled bluish grey silty CLAY	UU	2.04	1.59	29	160	80	50	7.0	147	73	B	
BH102	9	3.50	4.00	U	High strength slightly fissured brown slightly mottled bluish grey silty CLAY	UU	1.94	1.48	31	170	85	70	4.4	192	96	B	
BH102	15	5.50	6.00	U	High strength fissured brown silty CLAY with rare selenite crystals	UU	1.95	1.52	28	120	60	110	6.9	290	145	B	
BH102	17	6.50	7.00	U	Very high strength fissured brown silty CLAY	UU	2.02	1.58	28	100	50	130	7.5	367	183	B	
BH102	19	7.50	8.00	U	Very high strength fissured brown and bluish grey mottled silty CLAY with rare selenite crystals	UU	2.08	1.63	28	100	50	150	8.3	338	169	B	

Legend
UU - single stage test (single and multiple specimens) — σ3 Cell pressure — Mode of failure ; B - Brittle
UUM - Multistage test on a single specimen — σ1 - σ3 Maximum corrected deviator stress — P - Plastic
suffix R - remoulded or recompacted — cu Undrained shear strength, ½ (σ1 - σ3) — C - Compound

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UKAS TESTING 2519

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Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen

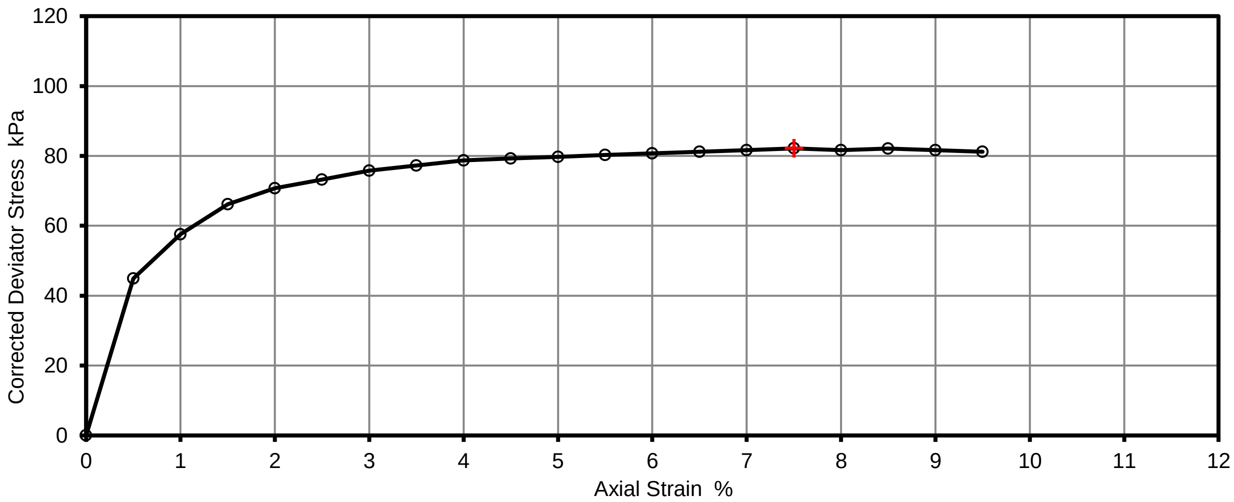
Job Ref	22451				
Borehole/Pit No.	BH101				
Site Name	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU			Sample No.	6
Project No.	J13364A	Client	GEA	Depth	1.50 m
Soil Description	Medium strength brown slightly bluish grey mottled silty CLAY with scattered selenite crystals			Sample Type	U
				Samples received	28/02/2017
				Schedules received	09/03/2017
Test Method	BS1377 : Part 7 : 1990, clause 8, single specimen			Date of test	22/03/2017

Remarks

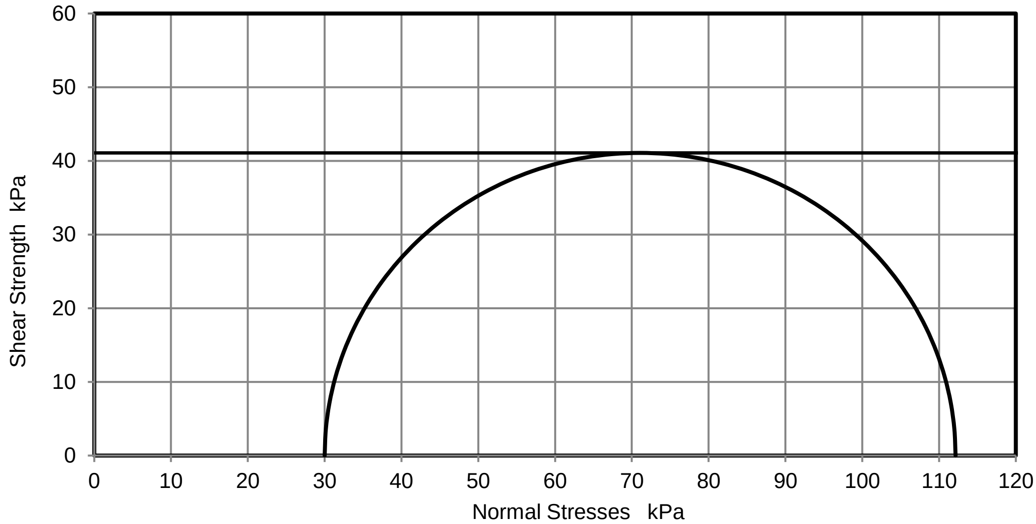
Position within sample

Test Number	1	
Length	200.0	mm
Diameter	100.0	mm
Bulk Density	1.81	Mg/m3
Moisture Content	34	%
Dry Density	1.35	Mg/m3
Rate of Strain	2.0	%/min
Cell Pressure	30	kPa
Axial Strain	7.5	%
Deviator Stress, (σ1 - σ3)f	82	kPa
Undrained Shear Strength, cu	41	kPa ½(σ1 - σ3)f
Mode of Failure	Brittle	

Deviator Stress v Axial Strain



Mohr Circles



Deviator stress corrected for area change and membrane effects

Mohr circles and their interpretation is not covered by BS1377. This is provided for information only.

UKAS TESTING 2519

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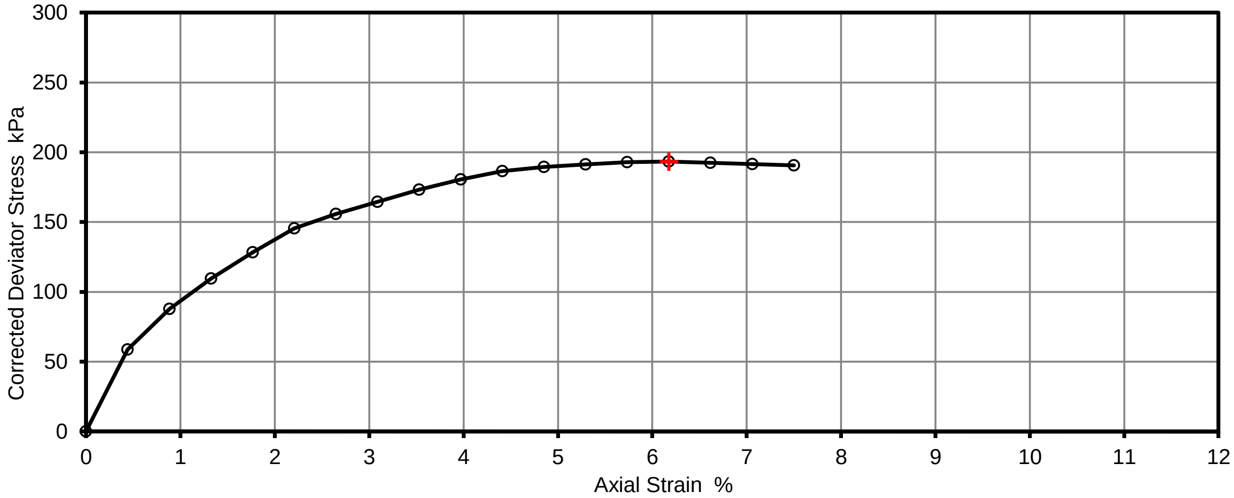
Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen			Job Ref	22451	
			Borehole/Pit No.	BH101	
Site Name	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU		Sample No.	12	
Project No.	J13364A	Client GEA	Depth	3.50	m
Soil Description	High strength slightly fissured brown silty CLAY		Sample Type	U	
			Samples received	28/02/2017	
			Schedules received	09/03/2017	
Test Method	BS1377 : Part 7 : 1990, clause 8, single specimen		Date of test	22/03/2017	

Remarks

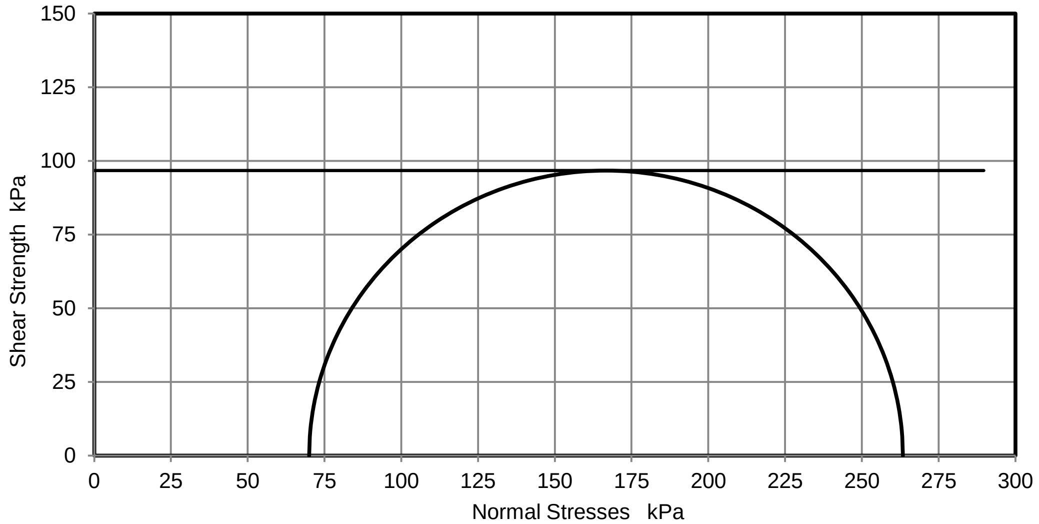
Position within sample

Test Number	1	
Length	170.0	mm
Diameter	85.0	mm
Bulk Density	1.86	Mg/m3
Moisture Content	30	%
Dry Density	1.42	Mg/m3
Rate of Strain	2.0	%/min
Cell Pressure	70	kPa
Axial Strain	6.2	%
Deviator Stress, (σ1 - σ3)f	193	kPa
Undrained Shear Strength, cu	97	kPa ½(σ1 - σ3)f
Mode of Failure	Brittle	

Deviator Stress v Axial Strain



Mohr Circles



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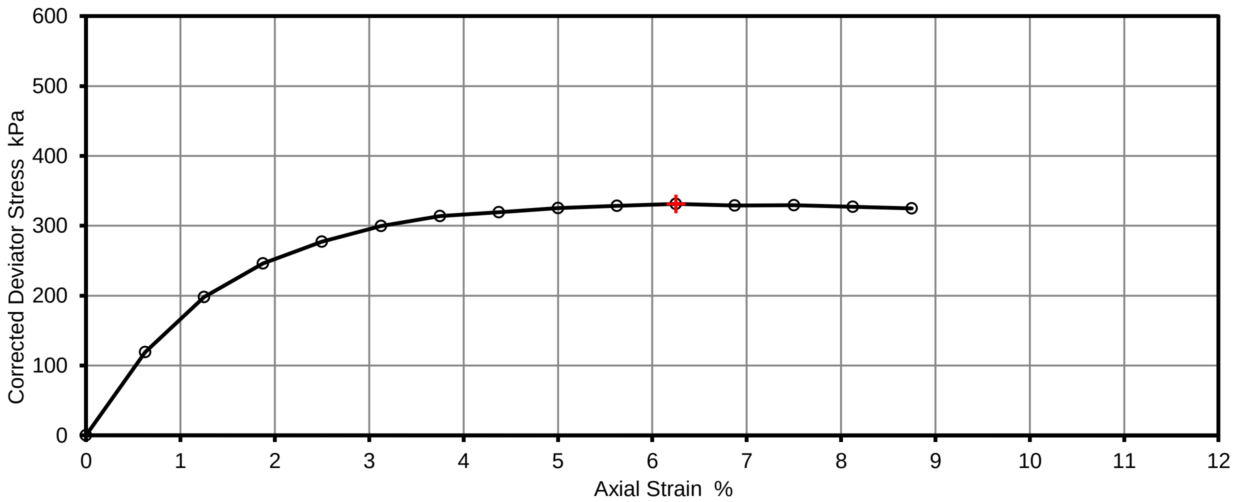
K4 SOILS	**Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen**			Job Ref	22451	
				Borehole/Pit No.	BH101	
Site Name	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU			Sample No.	23	
Project No.	J13364A	Client	GEA	Depth	6.50	m
Soil Description	Very high strength slightly fissured brown silty CLAY with orangish brown silty sand partings			Sample Type	U	
				Samples received	28/02/2017	
				Schedules received	09/03/2017	
Test Method	BS1377 : Part 7 : 1990, clause 8, single specimen			Date of test	22/03/2017	

Remarks

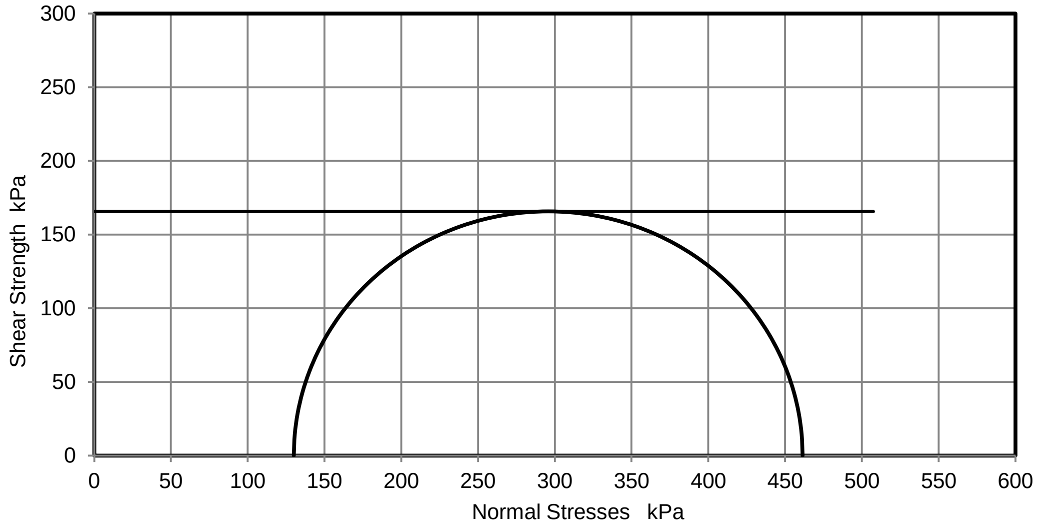
Position within sample

Test Number	1	
Length	120.0	mm
Diameter	60.0	mm
Bulk Density	2.04	Mg/m3
Moisture Content	29	%
Dry Density	1.58	Mg/m3
Rate of Strain	2.0	%/min
Cell Pressure	130	kPa
Axial Strain	6.3	%
Deviator Stress, (σ1 - σ3)f	331	kPa
Undrained Shear Strength, cu	166	kPa ½(σ1 - σ3)f
Mode of Failure	Brittle	

Deviator Stress v Axial Strain



Mohr Circles



Deviator stress corrected for area change and membrane effects

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MSF-5 R7

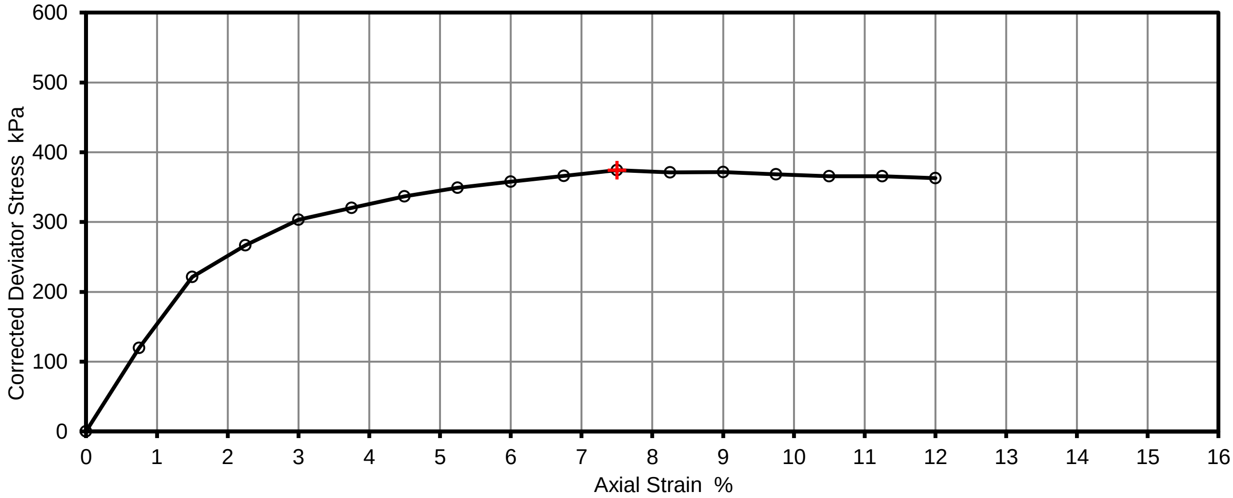
	Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen			Job Ref	22451	
				Borehole/Pit No.	BH101	
Site Name	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU			Sample No.	25	
Project No.	J13364A	Client	GEA	Depth	7.50	m
Soil Description	Very high strength slightly fissured brown silty CLAY with rare selenite crystals			Sample Type	U	
				Samples received	28/02/2017	
				Schedules received	09/03/2017	
Test Method	BS1377 : Part 7 : 1990, clause 8, single specimen			Date of test	22/03/2017	

Remarks

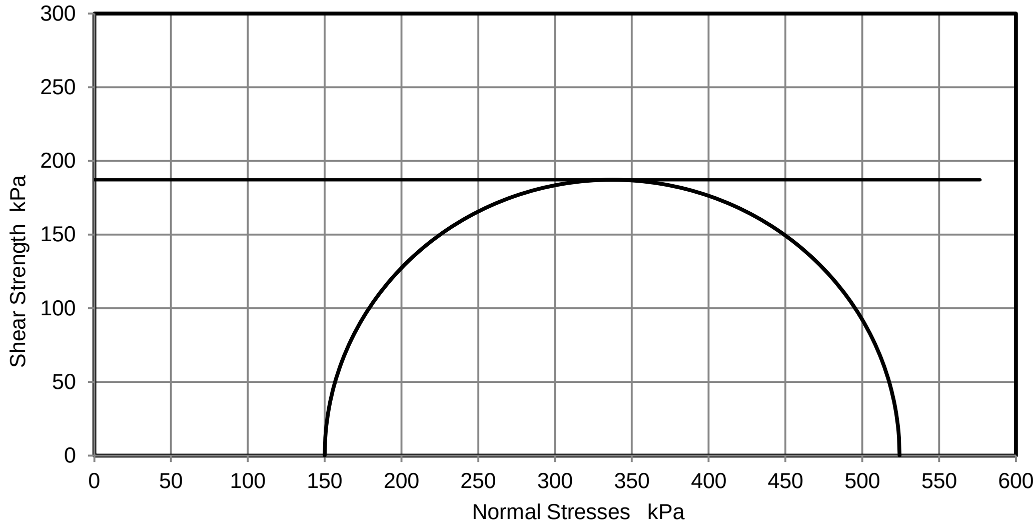
Position within sample

Test Number	1	
Length	100.0	mm
Diameter	50.0	mm
Bulk Density	1.92	Mg/m3
Moisture Content	27	%
Dry Density	1.51	Mg/m3
Rate of Strain	2.0	%/min
Cell Pressure	150	kPa
Axial Strain	7.5	%
Deviator Stress, (σ1 - σ3)f	374	kPa
Undrained Shear Strength, cu	187	kPa ½(σ1 - σ3)f
Mode of Failure	Brittle	

Deviator Stress v Axial Strain



Mohr Circles



Deviator stress corrected for area change and membrane effects

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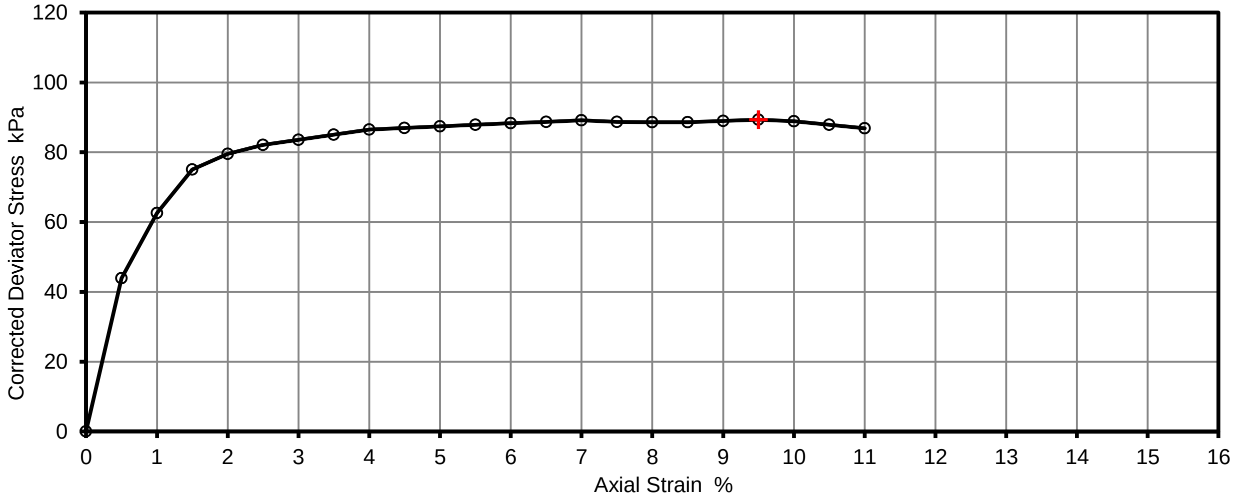
	Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen			Job Ref	22451	
				Borehole/Pit No.	BH102	
Site Name	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU			Sample No.	4	
Project No.	J13364A	Client	GEA	Depth	1.50	m
Soil Description	Medium strength brown and orangish brown mottled silty CLAY			Sample Type	U	
				Samples received	28/02/2017	
				Schedules received	09/03/2017	
Test Method	BS1377 : Part 7 : 1990, clause 8, single specimen			Date of test	22/03/2017	

Remarks

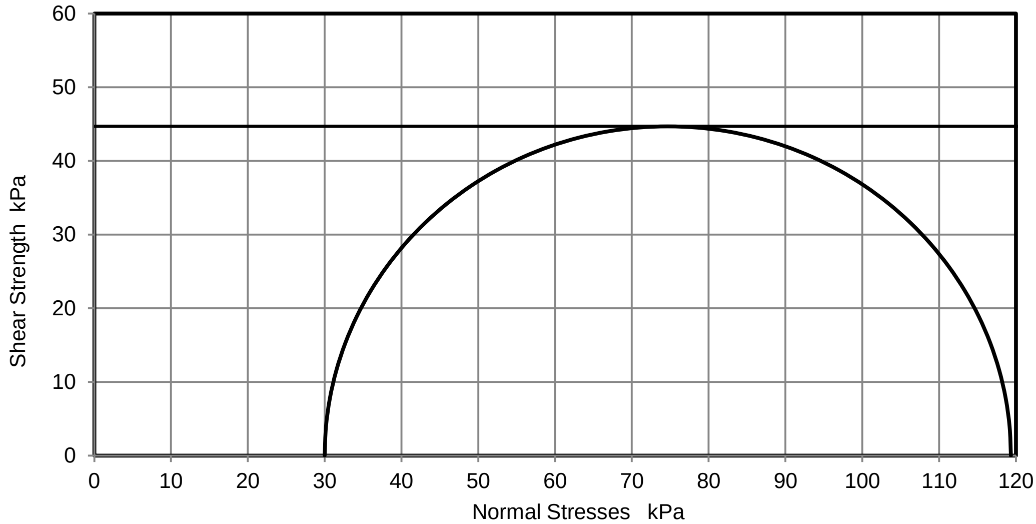
Position within sample

Test Number	1	
Length	200.0	mm
Diameter	100.0	mm
Bulk Density	1.70	Mg/m3
Moisture Content	36	%
Dry Density	1.25	Mg/m3
Rate of Strain	2.0	%/min
Cell Pressure	30	kPa
Axial Strain	9.5	%
Deviator Stress, (σ1 - σ3)f	89	kPa
Undrained Shear Strength, cu	45	kPa ½(σ1 - σ3)f
Mode of Failure	Compound	

Deviator Stress v Axial Strain



Mohr Circles



Deviator stress corrected for area change and membrane effects

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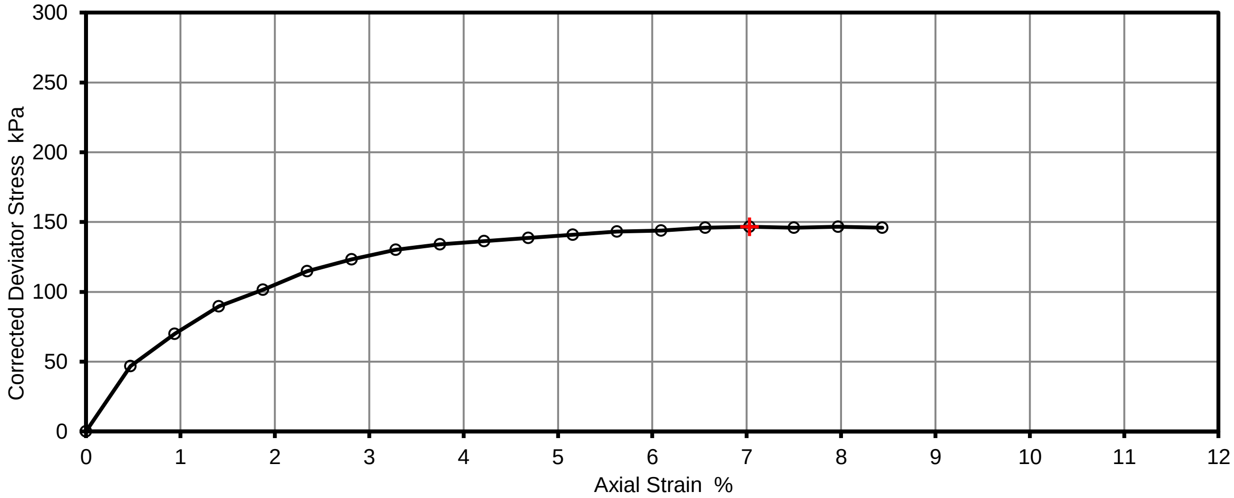
K4 SOILS	**Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen**			Job Ref	22451	
				Borehole/Pit No.	BH102	
Site Name	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU			Sample No.	6	
Project No.	J13364A	Client	GEA	Depth	2.50	m
Soil Description	Medium strength fissured brown slightly mottled bluish grey silty CLAY			Sample Type	U	
				Samples received	28/02/2017	
				Schedules received	09/03/2017	
Test Method	BS1377 : Part 7 : 1990, clause 8, single specimen			Date of test	22/03/2017	

Remarks

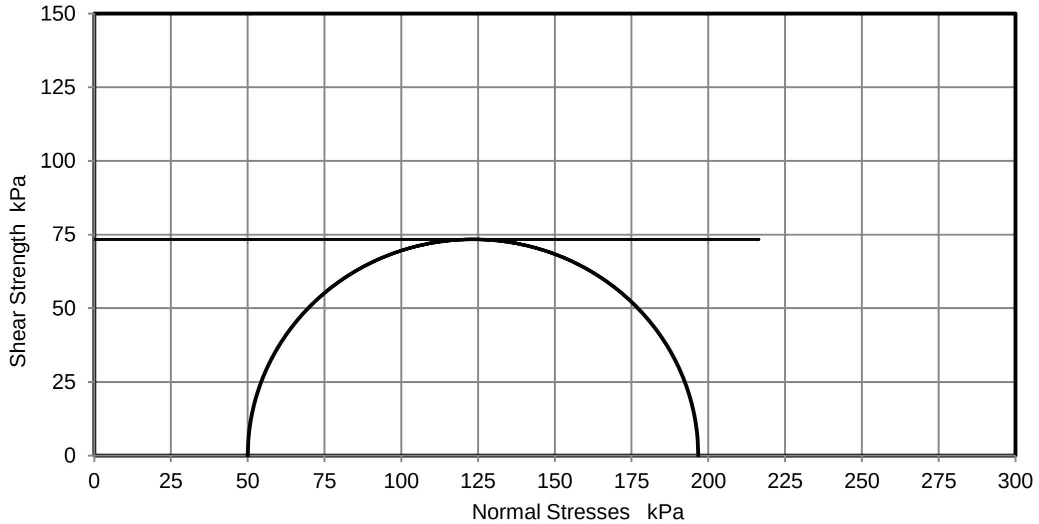
Position within sample

Test Number	1	
Length	160.0	mm
Diameter	80.0	mm
Bulk Density	2.04	Mg/m3
Moisture Content	29	%
Dry Density	1.59	Mg/m3
Rate of Strain	2.0	%/min
Cell Pressure	50	kPa
Axial Strain	7.0	%
Deviator Stress, (σ1 - σ3)f	147	kPa
Undrained Shear Strength, cu	73	kPa ½(σ1 - σ3)f
Mode of Failure	Brittle	

Deviator Stress v Axial Strain



Mohr Circles



Deviator stress corrected for area change and membrane effects

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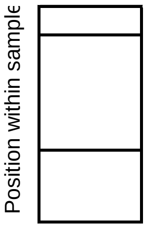
Date 24/03/2017

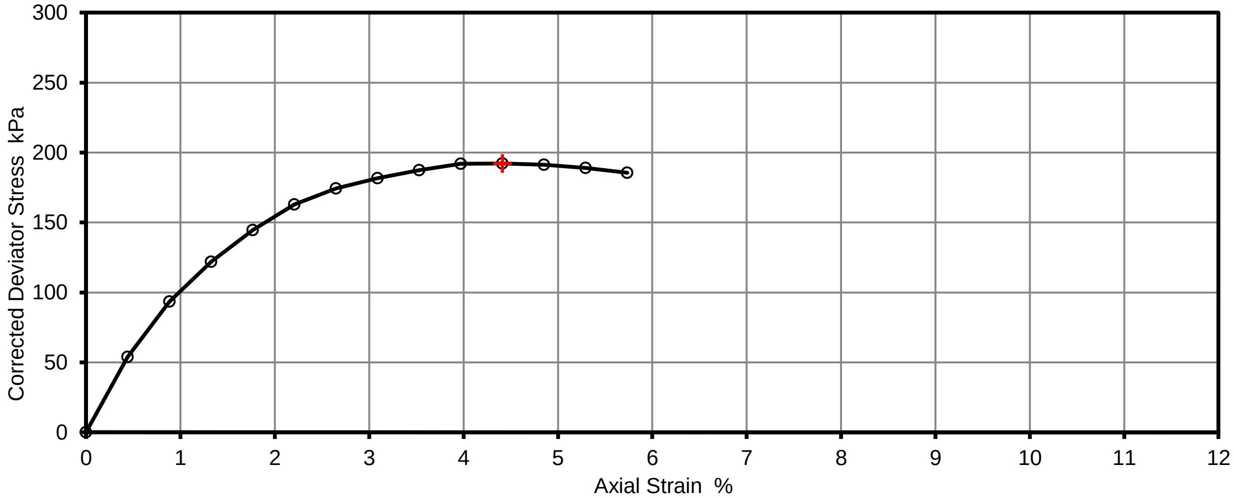
K4 SOILS	**Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen**			Job Ref	22451	
				Borehole/Pit No.	BH102	
Site Name	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU			Sample No.	9	
Project No.	J13364A	Client	GEA	Depth	3.50	m
Soil Description	High strength slightly fissured brown slightly mottled bluish grey silty CLAY			Sample Type	U	
				Samples received	28/02/2017	
				Schedules received	09/03/2017	
Test Method	BS1377 : Part 7 : 1990, clause 8, single specimen			Date of test	22/03/2017	

Remarks

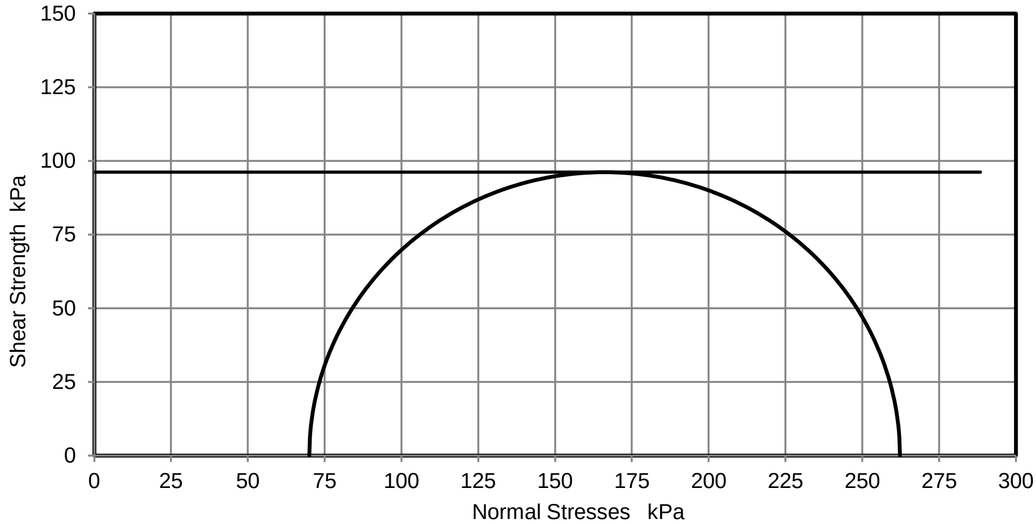


Test Number	1	
Length	170.0	mm
Diameter	85.0	mm
Bulk Density	1.94	Mg/m3
Moisture Content	31	%
Dry Density	1.48	Mg/m3
Rate of Strain	2.0	%/min
Cell Pressure	70	kPa
Axial Strain	4.4	%
Deviator Stress, (σ1 - σ3)f	192	kPa
Undrained Shear Strength, cu	96	kPa ½(σ1 - σ3)f
Mode of Failure	Brittle	

Deviator Stress v Axial Strain



Mohr Circles



Deviator stress corrected for area change and membrane effects

Mohr circles and their interpretation is not covered by BS1377. This is provided for information only.

Test Report by K4 SOILS LABORATORY
Unit 8 Olds Close Olds Approach
Watford Herts WD18 9RU
Tel: 01923 711 288
Email: James@k4soils.com

UKAS TESTING 2519

Approved Signatories: K.Phaure (Tech.Mgr) J.Phaure (Lab.Mgr)

Checked and Approved
Initials: J.P
Date 24/03/2017

MSF-5 R7

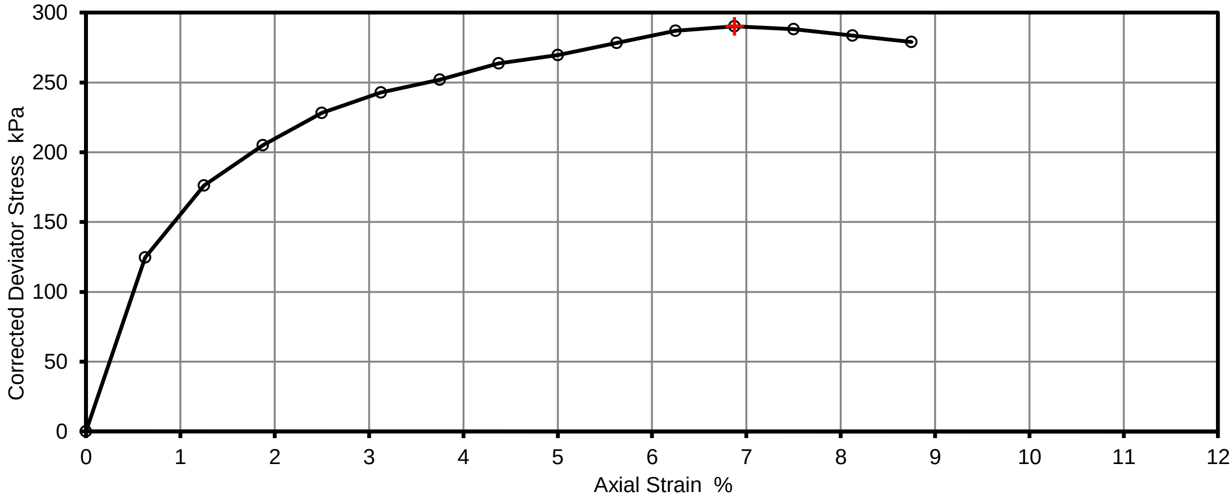
	Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen			Job Ref	22451	
				Borehole/Pit No.	BH102	
Site Name	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU			Sample No.	15	
Project No.	J13364A	Client	GEA	Depth	5.50	m
Soil Description	High strength fissured brown silty CLAY with rare selenite crystals			Sample Type	U	
				Samples received	28/02/2017	
				Schedules received	09/03/2017	
Test Method	BS1377 : Part 7 : 1990, clause 8, single specimen			Date of test	22/03/2017	

Remarks

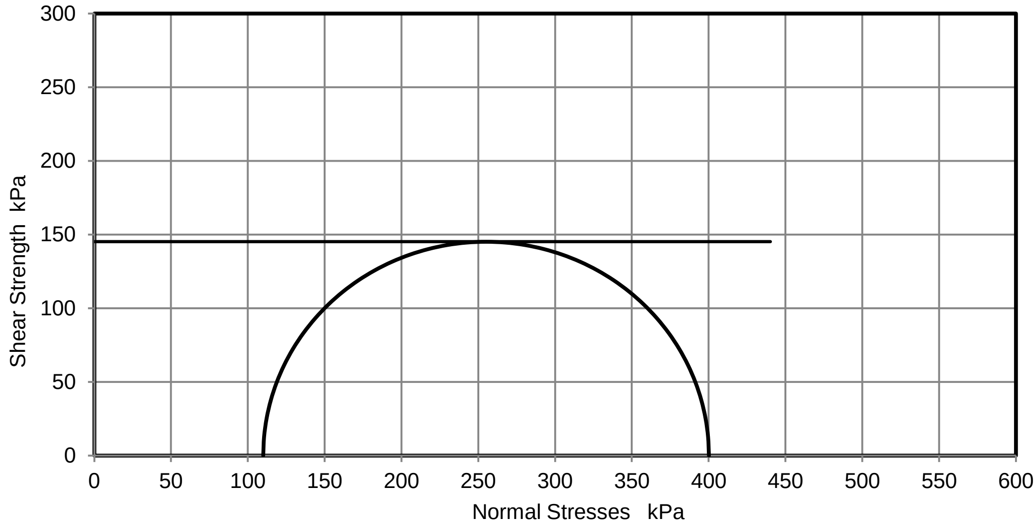
Position within sample

Test Number	1	
Length	120.0	mm
Diameter	60.0	mm
Bulk Density	1.95	Mg/m3
Moisture Content	28	%
Dry Density	1.52	Mg/m3
Rate of Strain	2.0	%/min
Cell Pressure	110	kPa
Axial Strain	6.9	%
Deviator Stress, (σ1 - σ3)f	290	kPa
Undrained Shear Strength, cu	145	kPa ½(σ1 - σ3)f
Mode of Failure	Brittle	

Deviator Stress v Axial Strain



Mohr Circles



Deviator stress corrected for area change and membrane effects

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Date 24/03/2017

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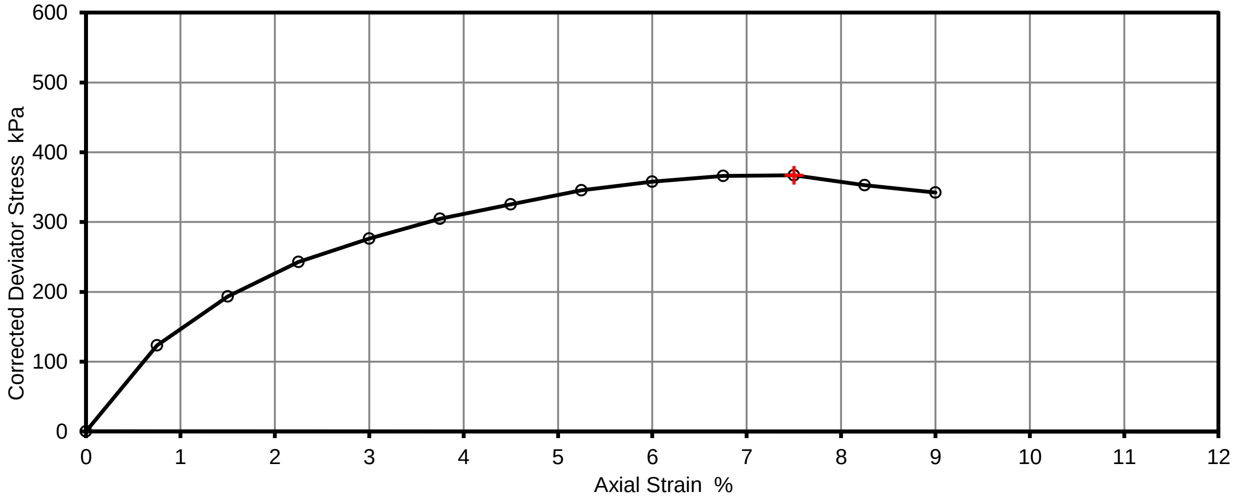
	Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen			Job Ref	22451	
				Borehole/Pit No.	BH102	
Site Name	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU			Sample No.	17	
Project No.	J13364A	Client	GEA	Depth	6.50	m
Soil Description	Very high strength fissured brown silty CLAY			Sample Type	U	
				Samples received	28/02/2017	
				Schedules received	09/03/2017	
Test Method	BS1377 : Part 7 : 1990, clause 8, single specimen			Date of test	22/03/2017	

Remarks

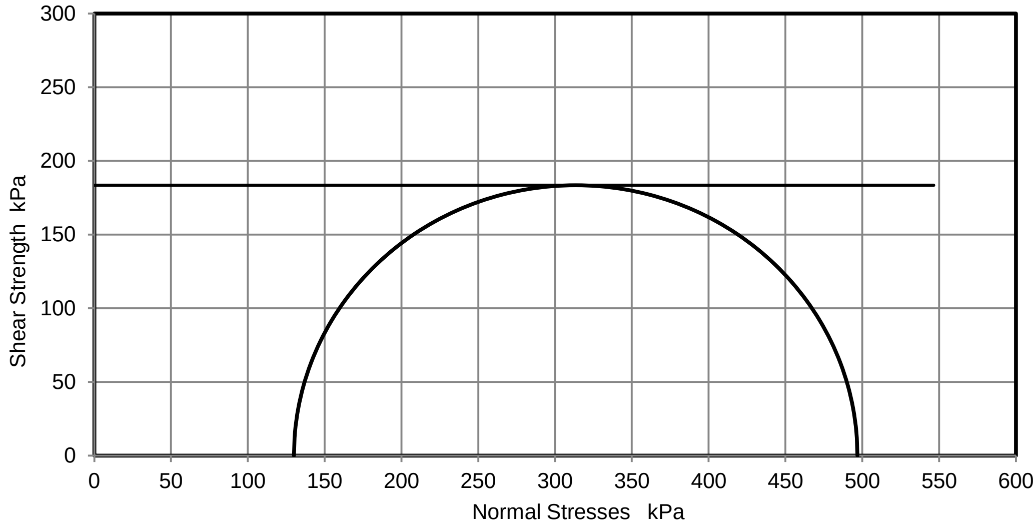
Position within sample

Test Number	1	
Length	100.0	mm
Diameter	50.0	mm
Bulk Density	2.02	Mg/m3
Moisture Content	28	%
Dry Density	1.58	Mg/m3
Rate of Strain	2.0	%/min
Cell Pressure	130	kPa
Axial Strain	7.5	%
Deviator Stress, (σ1 - σ3)f	367	kPa
Undrained Shear Strength, cu	183	kPa ½(σ1 - σ3)f
Mode of Failure	Brittle	

Deviator Stress v Axial Strain



Mohr Circles



Deviator stress corrected for area change and membrane effects

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Checked and Approved
Initials: J.P
Date 24/03/2017

MSF-5 R7

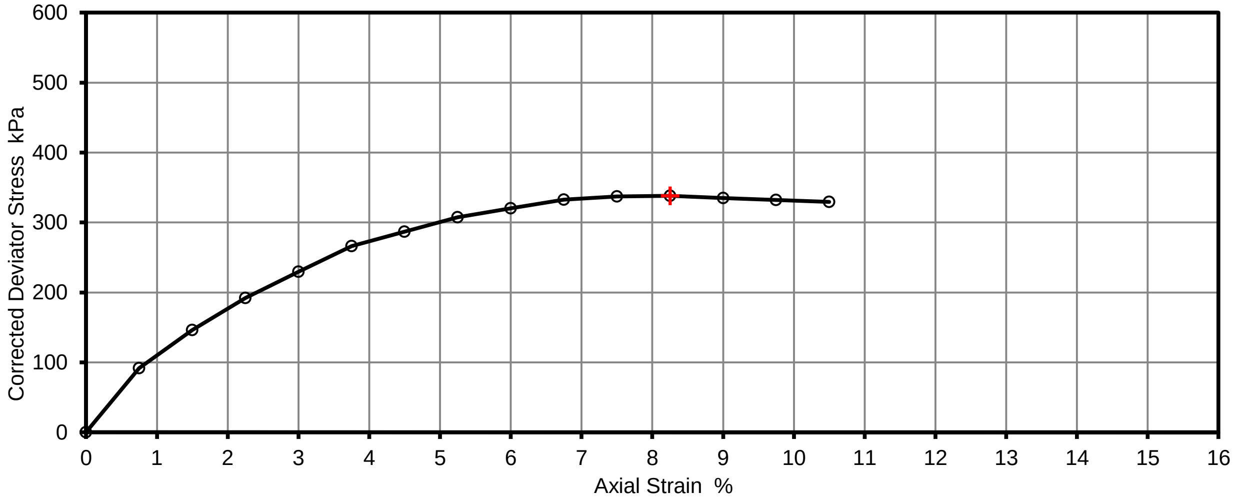
	Unconsolidated Undrained Triaxial Compression Test without measurement of pore pressure - single specimen			Job Ref	22451	
				Borehole/Pit No.	BH102	
Site Name	153-163 Broadhurst Gardens, West Hampstead, London NW6 3AU			Sample No.	19	
Project No.	J13364A	Client	GEA	Depth	7.50	m
Soil Description	Very high strength fissured brown and bluish grey mottled silty CLAY with rare selenite crystals			Sample Type	U	
				Samples received	28/02/2017	
				Schedules received	09/03/2017	
Test Method	BS1377 : Part 7 : 1990, clause 8, single specimen			Date of test	22/03/2017	

Remarks

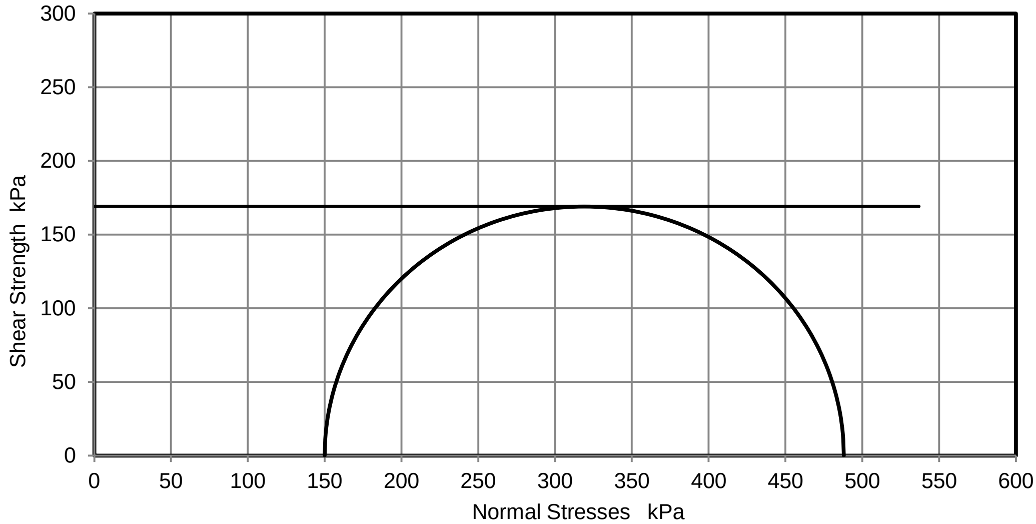
Position within sample

Test Number	1	
Length	100.0	mm
Diameter	50.0	mm
Bulk Density	2.08	Mg/m3
Moisture Content	28	%
Dry Density	1.63	Mg/m3
Rate of Strain	2.0	%/min
Cell Pressure	150	kPa
Axial Strain	8.3	%
Deviator Stress, (σ1 - σ3)f	338	kPa
Undrained Shear Strength, cu	169	kPa ½(σ1 - σ3)f
Mode of Failure	Brittle	

Deviator Stress v Axial Strain



Mohr Circles



Deviator stress corrected for area change and membrane effects

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Checked and Approved
Initials: J.P
Date 24/03/2017

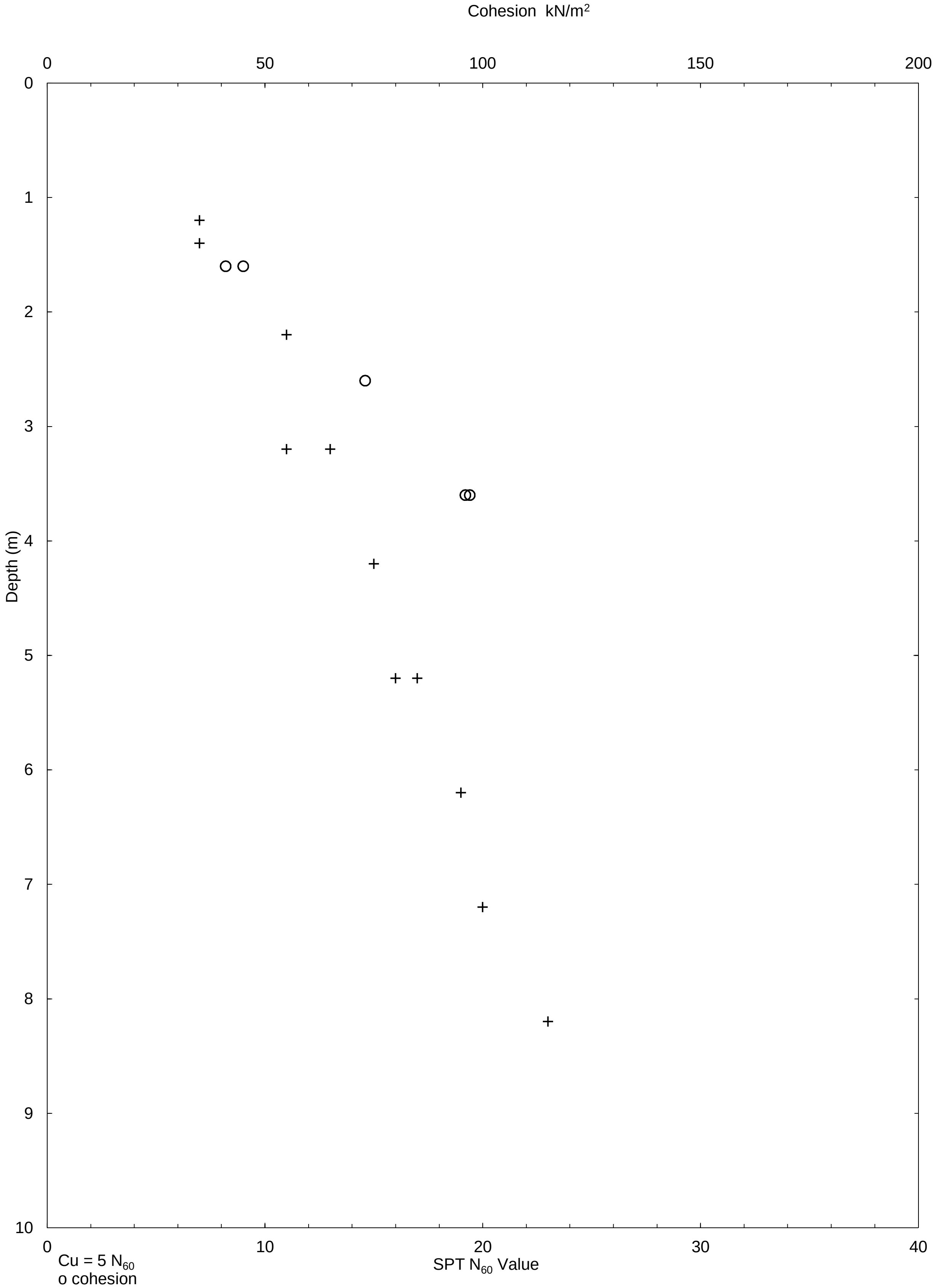
Approved Signatories: K.Phaure (Tech.Mgr) J.Phaure (Lab.Mgr)

GEA Geotechnical & Environmental Associates

Widbury Barn
Widbury Hill
Ware
Herts SG12 7QE

SPT & Cohesion / Depth Graph

Site	153-163 Broadhurst Gardens, London, NW6 3AU	**Job Number** J13364A
Client	Kilburn and District Homes Ltd	**Sheet** 1 / 1
Engineer	Fluid Structures	



Cu = 5 N_{60}
o cohesion
+ SPT N Value

Analytical Report Number: 17-42752

Project / Site name: 153-163 Broadhurst Gardens
Your Order No: J13364A

Lab Sample Number				718238	718239	718240		
Sample Reference				BH101	BH102	BH103		
Sample Number				None Supplied	None Supplied	None Supplied		
Depth (m)				0.60	1.20	0.30		
Date Sampled				27/02/2017	28/02/2017	28/02/2017		
Time Taken				None Supplied	None Supplied	None Supplied		
Analytical Parameter (Soil Analysis)	**Units**	**Limit of detection**	**Accreditation Status**					
Stone Content	%	0.1	NONE	< 0.1	< 0.1	< 0.1		
Moisture Content	%	N/A	NONE	19	16	21		
Total mass of sample received	kg	0.001	NONE	1.2	1.1	0.89		
General Inorganics								
pH - Automated	pH Units	N/A	MCERTS	8.1	7.1	7.9		
Total Cyanide	mg/kg	1	MCERTS	< 1	< 1	< 1		
Total Sulphate as SO_4	mg/kg	50	MCERTS	870	800	420		
Water Soluble SO4 16hr extraction (2:1 Leachate Equivalent)	g/l	0.00125	MCERTS	0.14	0.21	0.045		
Sulphide	mg/kg	1	MCERTS	< 1.0	< 1.0	< 1.0		
Water Soluble Chloride (2:1)	mg/kg	1	MCERTS	9.6	130	3.5		
Total Organic Carbon (TOC)	%	0.1	MCERTS	1.4	1.5	1.4		
Total Phenols								
Total Phenols (monohydric)	mg/kg	1	MCERTS	< 1.0	< 1.0	< 1.0		
Speciated PAHs								
Naphthalene	mg/kg	0.05	MCERTS	< 0.05	< 0.05	< 0.05		
Acenaphthylene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Acenaphthene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Fluorene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Phenanthrene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Anthracene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Fluoranthene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Pyrene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Benzo(a)anthracene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Chrysene	mg/kg	0.05	MCERTS	< 0.05	< 0.05	< 0.05		
Benzo(b)fluoranthene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Benzo(k)fluoranthene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Benzo(a)pyrene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Indeno(1,2,3-cd)pyrene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Dibenz(a,h)anthracene	mg/kg	0.1	MCERTS	< 0.10	< 0.10	< 0.10		
Benzo(ghi)perylene	mg/kg	0.05	MCERTS	< 0.05	< 0.05	< 0.05		
Total PAH								
Speciated Total EPA-16 PAHs	mg/kg	1.6	MCERTS	< 1.60	< 1.60	< 1.60		
Heavy Metals / Metalloids								
Arsenic (aqua regia extractable)	mg/kg	1	MCERTS	18	17	19		
Cadmium (aqua regia extractable)	mg/kg	0.2	MCERTS	< 0.2	< 0.2	< 0.2		
Chromium (aqua regia extractable)	mg/kg	1	MCERTS	26	30	34		
Copper (aqua regia extractable)	mg/kg	1	MCERTS	53	45	46		
Lead (aqua regia extractable)	mg/kg	1	MCERTS	250	98	140		
Mercury (aqua regia extractable)	mg/kg	0.3	MCERTS	1.8	< 0.3	1.7		
Nickel (aqua regia extractable)	mg/kg	1	MCERTS	17	17	19		
Selenium (aqua regia extractable)	mg/kg	1	MCERTS	< 1.0	< 1.0	< 1.0		
Zinc (aqua regia extractable)	mg/kg	1	MCERTS	71	57	89		
Petroleum Hydrocarbons								
TPH C10 - C40	mg/kg	10	MCERTS	< 10	< 10	350		
TPH (C8 - C10)	mg/kg	0.1	NONE	< 0.1	< 0.1	< 0.1		
TPH (C10 - C12)	mg/kg	2	MCERTS	< 2.0	< 2.0	< 2.0		
TPH (C12 - C16)	mg/kg	4	MCERTS	< 4.0	< 4.0	7.9		
TPH (C16 - C21)	mg/kg	1	MCERTS	< 1.0	< 1.0	27		
TPH (C21 - C35)	mg/kg	1	MCERTS	< 1.0	< 1.0	280		

Geotechnical & Environmental Associates

Widbury Barn
Widbury Hill
Ware
Herts SG12 7QE

Generic Risk-Based Soil Screening Values

Site	153-163 Broadhurst Gardens, London, NW6 3AU	**Job Number** J13364A
Client	Kilburn and District Homes Ltd	**Sheet** 1 / 1
Engineer	Fluid Structures	

Proposed End Use Residential with plant uptake

Soil pH 8

Soil Organic Matter content % 2.5

Contaminant	Screening Value mg/kg	Data Source
Metals		
Arsenic	37	C4SL
Cadmium	26	C4SL
Chromium (III)	3000	LQM/CIEH
Chromium (VI)	21	C4SL
Copper	2,330	LQM/CIEH
Lead	200	C4SL
Elemental Mercury	1	SGV
Inorganic Mercury	170	SGV
Nickel	97	LQM/CIEH
Selenium	350	SGV
Zinc	3,750	LQM/CIEH
Hydrocarbons		
Benzene	0.34	C4SL
Toluene	320	SGV
Ethyl Benzene	180	SGV
Xylene	120	SGV
Aliphatic C5-C6	55	LQM/CIEH
Aliphatic C6-C8	160	LQM/CIEH
Aliphatic C8-C10	46	LQM/CIEH
Aliphatic C10-C12	230	LQM/CIEH
Aliphatic C12-C16	1700	LQM/CIEH
Aliphatic C16-C35	64,000	LQM/CIEH
Aromatic C6-C7	See Benzene	LQM/CIEH
Aromatic C7-C8	See Toluene	LQM/CIEH
Aromatic C8-C10	65	LQM/CIEH
Aromatic C10-C12	160	LQM/CIEH
Aromatic C12-C16	310	LQM/CIEH
Aromatic C16-C21	480	LQM/CIEH
Aromatic C21-C35	1100	LQM/CIEH
PRO (C_5 –C_{10})	646	Calc
DRO (C_{12} –C_{28})	66,490	Calc
Lube Oil (C_{28} –C_{44})	65,100	Calc
TPH	**1000**	Trigger for speciated testing

Contaminant	Screening Value mg/kg	Data Source
Anions		
Soluble Sulphate	500 mg/l	Structures
Sulphide	50	Structures
Chloride	400	Structures
Others		
Organic Carbon (%)	6	Methanogenic potential
Total Cyanide	140	WRAS
Total Mono Phenols	290	SGV
PAH		
Naphthalene	5.30	C4SL exp & LQM/CIEH
Acenaphthylene	400	LQM/CIEH
Acenaphthene	480	LQM/CIEH
Fluorene	380	LQM/CIEH
Phenanthrene	200	LQM/CIEH
Anthracene	4,900	LQM/CIEH
Fluoranthene	460	LQM/CIEH
Pyrene	1,000	LQM/CIEH
Benzo(a) Anthracene	6.7	C4SL exp & LQM/CIEH
Chrysene	11	C4SL exp & LQM/CIEH
Benzo(b) Fluoranthene	9.5	C4SL exp & LQM/CIEH
Benzo(k) Fluoranthene	14.1	C4SL exp & LQM/CIEH
Benzo(a) pyrene	4.40	C4SL
Indeno(1 2 3 cd) Pyrene	5.6	C4SL exp & LQM/CIEH
Dibenzo(a h) Anthracene	1.27	C4SL exp & LQM/CIEH
Benzo (g h i) Perylene	69	C4SL exp & LQM/CIEH
Screening value for PAH	**62.9**	B(a)P / 0.15
Chlorinated Solvents		
1,1,1 trichloroethane (TCA)	27.2	LQM/CIEH
tetrachloroethane (PCA)	1.25	LQM/CIEH
tetrachloroethene (PCE)	2.32	LQM/CIEH
trichloroethene (TCE)	0.308	LQM/CIEH
1,2-dichloroethane (DCA)	0.008	LQM/CIEH
vinyl chloride (Chloroethene)	0.000184	LQM/CIEH
tetrachloromethane (Carbon tetra	0.039	LQM/CIEH
trichloromethane (Chloroform)	1.99	LQM/CIEH

Notes

Concentrations measured below the above values may be considered to represent 'uncontaminated conditions' which pose 'LOW' risk to human health. Concentrations measured in excess of these values indicate a potential risk which require further, site specific risk assessment.

SGV - Soil Guideline Value, derived from the CLEA model and published by Environment Agency 2009

LQM/CIEH - Generic Assessment Criteria for Human Health Risk Assessment 2nd edition (2009)derived using CLEA 1.04 model 2009

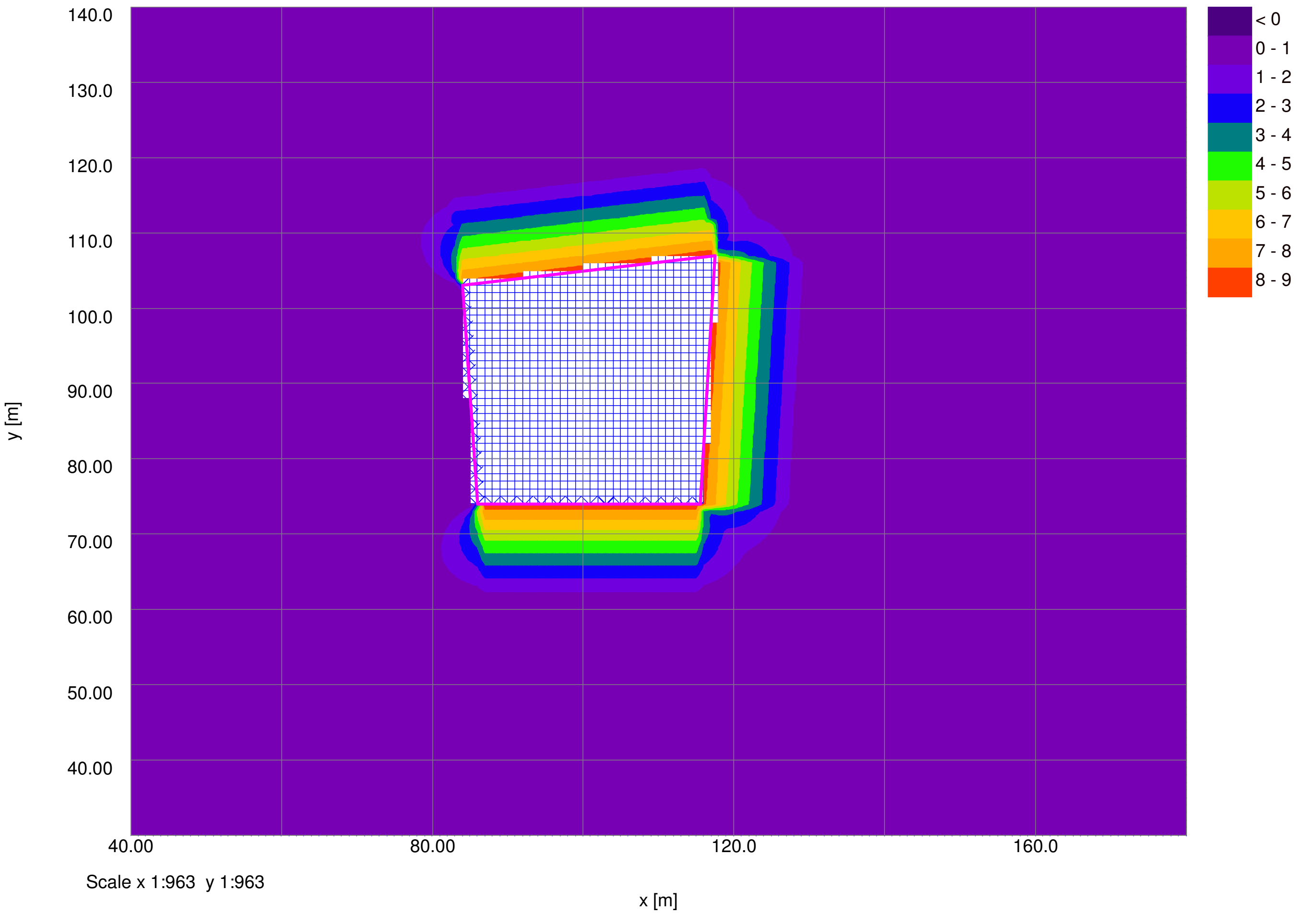
C4SL - Defra Category 4 Screening value based on Low Level of Toxicological Risk

C4SL exp & LQM/CIEH calculated using C4SL revisions to exposure assessment but LQM/CIEH health criteria values

Calc - sum of nearest available carbon range specified including BTEX for PRO fraction

B(a)P / 0.15 - GEA experience indicates that Benzo(a) pyrene (one of the most common and most carcinogenic of the PAHs) rarely exceeds 15% of the total PAH concentration, hence this Total PAH threshold is regarded as being conservative

Horizontal Displacement Contours: Grid 1 (level 0.000m) Interval 1mm



Scale x 1:963 y 1:963

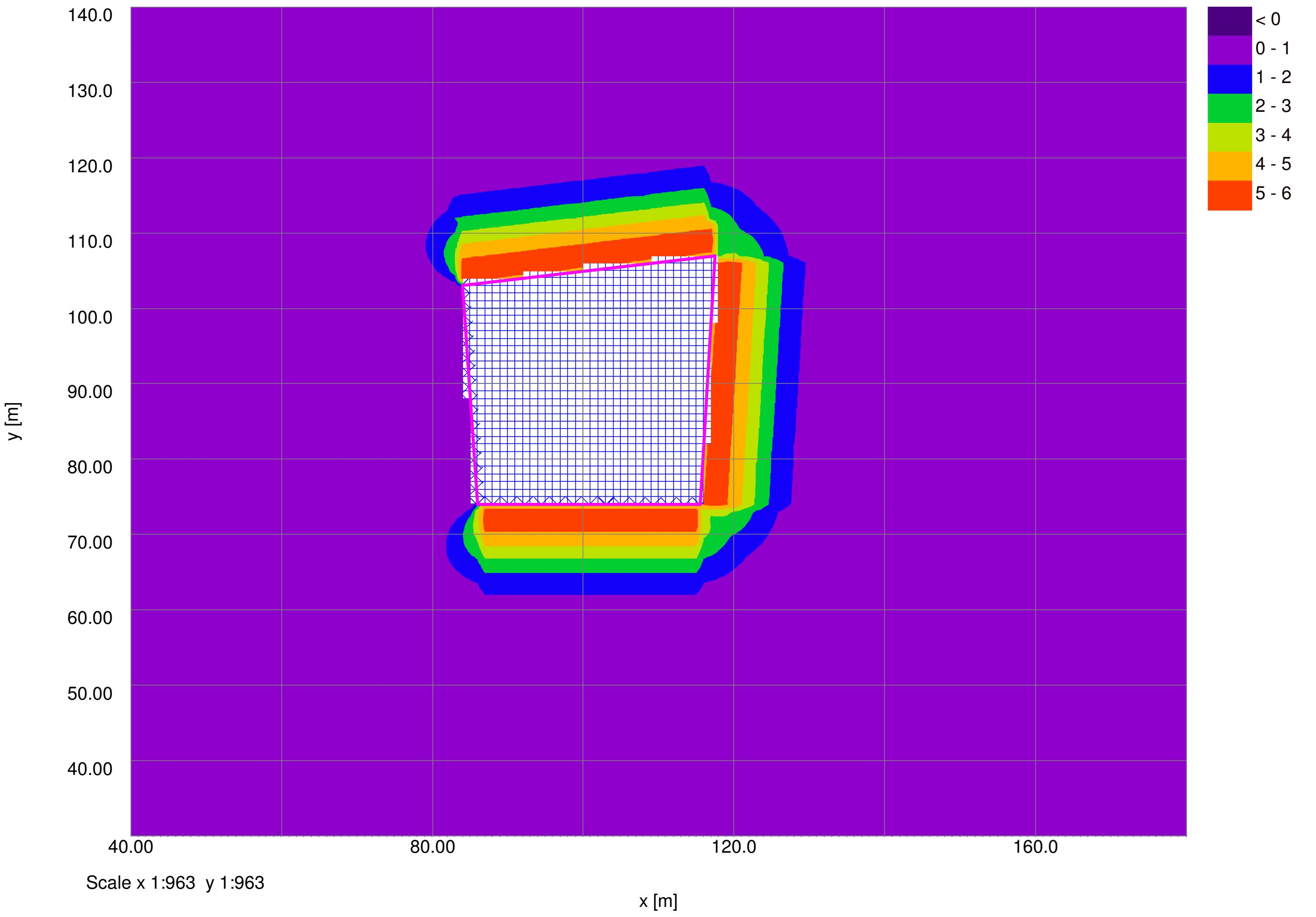
Oasys

Piled Wall Installation

GEA LIMITED
(GEOTECHNICAL &ENV ASSOC)

Job No.	Sheet No.	Rev.
J13364A		
Drg. Ref.		
Made by JD	Date 23-Jun-2017	Checked

Vertical Settlement Contours: Grid 1 (level 0.000m) (Interval 1mm)



Scale x 1:963 y 1:963

Oasys
Piled Wall Installation

GEA LIMITED
(GEOTECHNICAL &ENV ASSOC)

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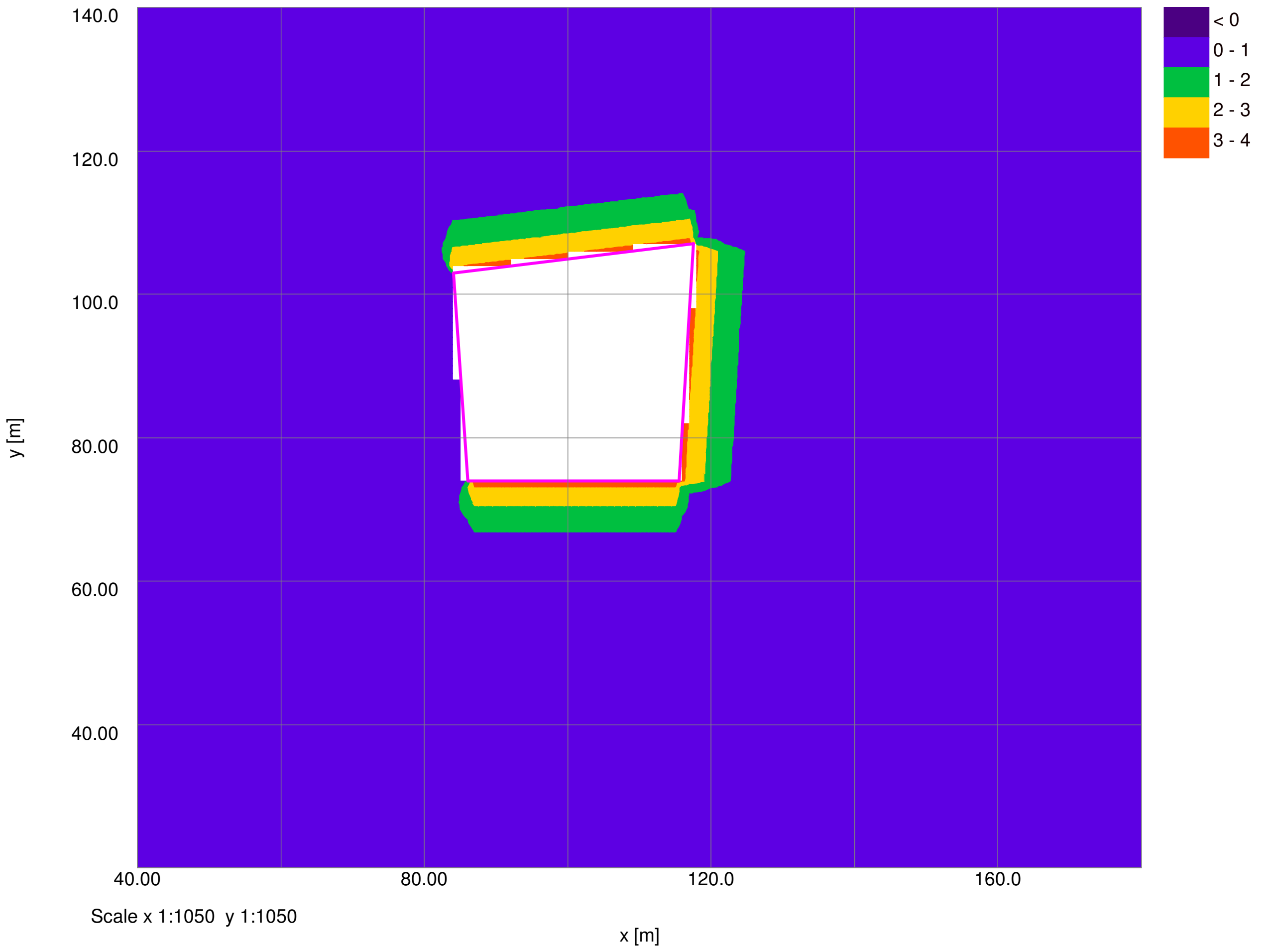
Horizontal Displacement Contours: Grid 1 (level 0.000m) Interval 1mm



Scale x 1:1050 y 1:1050

Oasys
Piled Wall Installation

GEA LIMITED
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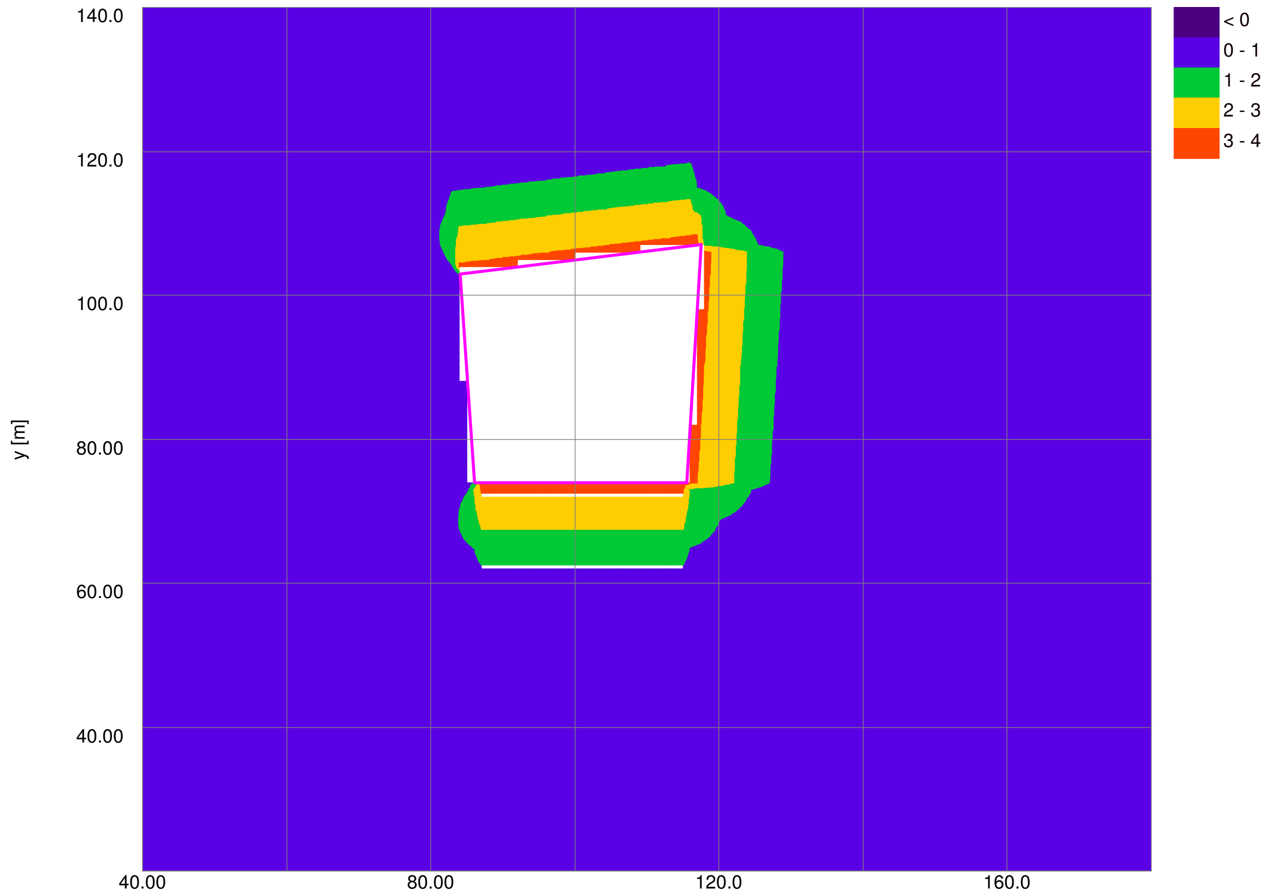
Job No.	Sheet No.	Rev.
J13364A		
Drg. Ref.		
Made by JD	Date 23-Jun-2017	Checked

Vertical Settlement Contours: Grid 1 (level 0.000m) (Interval 1mm)



Scale x 1:1050 y 1:1050

x [m]

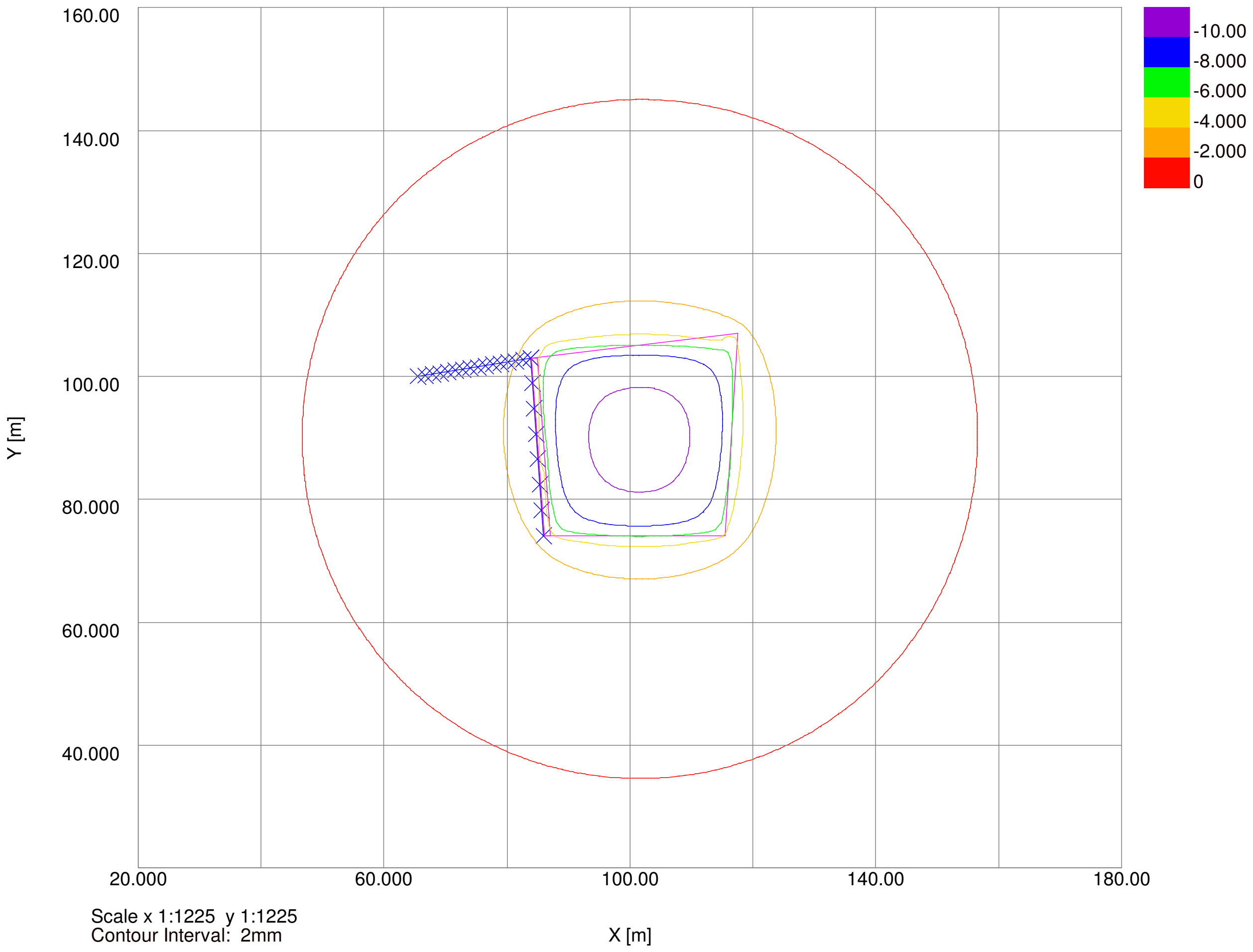
Oasys

GEA LIMITED
(GEOTECHNICAL &ENV ASSOC)

153-163 Broadhurst Gardens
Short Term

Job No.	Sheet No.	Rev.
J13364A		
Drg. Ref.		
Made by JD	Date	Checked

Settlement Contours : Grid 1 at -3.5000m



Scale x 1:1225 y 1:1225
Contour Interval: 2mm

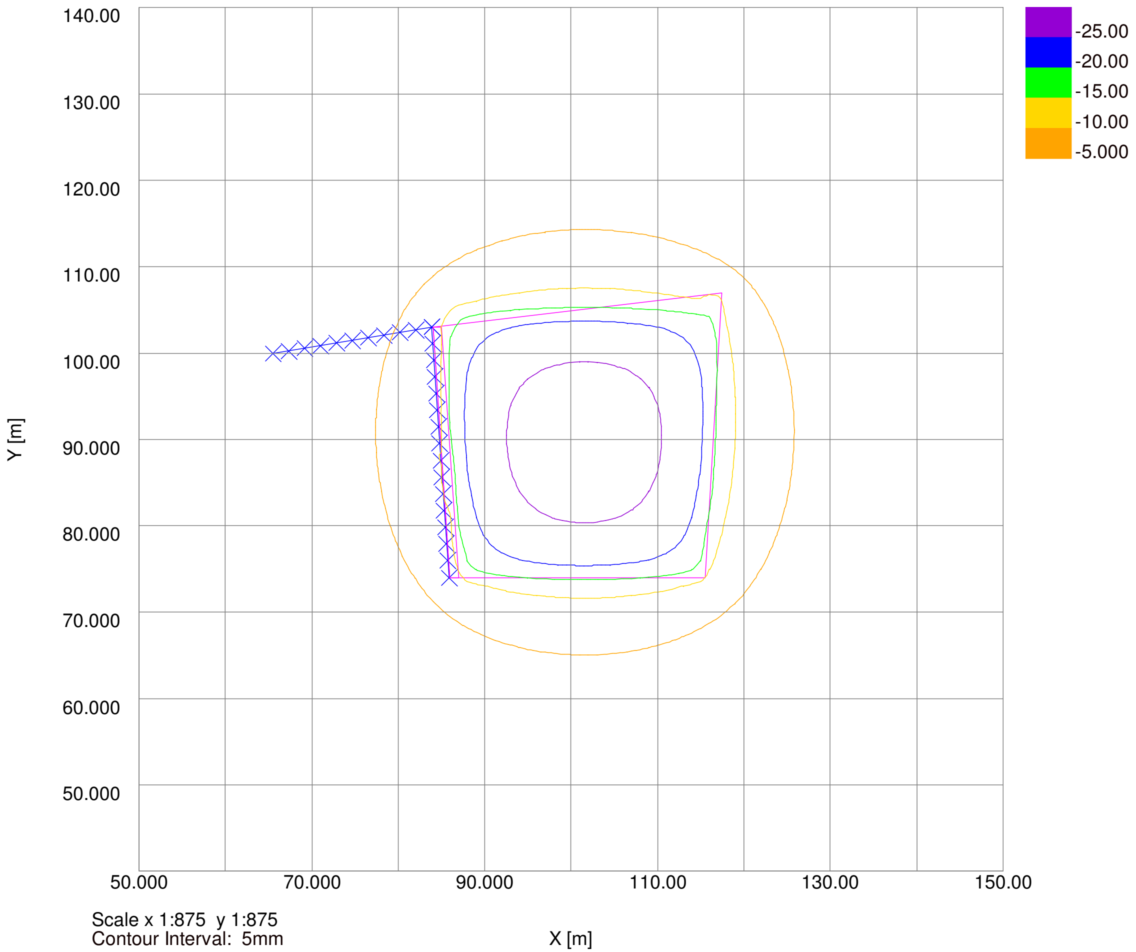
Oasys

Broadhurst Gardens
Total Movement

GEA LIMITED
(GEOTECHNICAL &ENV ASSOC)

Job No.	Sheet No.	Rev.
J1364a		
Drg. Ref.		
Made by JD	Date	Checked

Settlement Contours : Grid 1 at -3.5000m



Scale x 1:875 y 1:875
Contour Interval: 5mm

Geotechnical & Environmental Associates

Widbury Barn
Widbury Hill
Ware
Herts SG12 7QE

Site Plan

Site	153 - 163 Broadhurst Gardens, London, NW6 3AU	**Job Number** J13364A
Client	Kilburn and District Homes Ltd	**Sheet** 1 / 1
Engineer	Fluid Structures	

0 5 10 15

Approximate Scale in metres

Geotechnical & Environmental Associates (GEA)
is an engineer-led and client-focused independent specialist providing a complete range of geotechnical and contaminated land investigation, analytical and consultancy services to the property and construction industries.

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Enquiries can also be made on-line at

www.gea-ltd.co.uk

where information can be found on all of the services that we offer.

GEA Geotechnical & Environmental Associates