

Highgate School Richard Music Centre Basement Impact Assessment

EXP-REP-427-001

Rev 01



expedition

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1 Executive Summary

A Basement Impact Assessment has been undertaken to evaluate and mitigate potential impacts of the proposed basement of the Highgate School Richards Music Centre development.

The geological and hydrogeological conditions of the site have been investigated through a Desktop Study and site specific investigation. The Geotechnical Assessment has been used to guide the design.

The Ground Movement Assessment has found the impact of the works on the adjacent properties to be limited to the *Category 1 – Very Slight* damage category of the Burland scale when assessed in accordance with guidance in CIRIA C760. This is the case throughout construction as well as in the permanent case.

The impact of the construction has been mitigated through the selection of an embedded piled retaining wall which avoids open excavation and the associated risks to the neighbouring structures.

To further mitigate the risk on adjacent properties throughout the works, this report outlines the proposed movement monitoring strategy.

The cohesive nature of these clay strata/formations indicates that there is likely limited existing ground water movement within these unproductive aquifers underlying the site and within the immediate vicinity.

Hydrological aspects of the proposal are addressed in the Drainage Statement submitted as Part of the Planning Application.

2 Description of the Site and Proposed Development

2.1 Description of the Proposed Development

The site is located within the existing Highgate School campus on the eastern side of Bishopswood Road. There is an existing building on the site which will be demolished as part of the works. The impact of the proposed basement on the existing buildings on neighbouring properties has been mitigated through design.

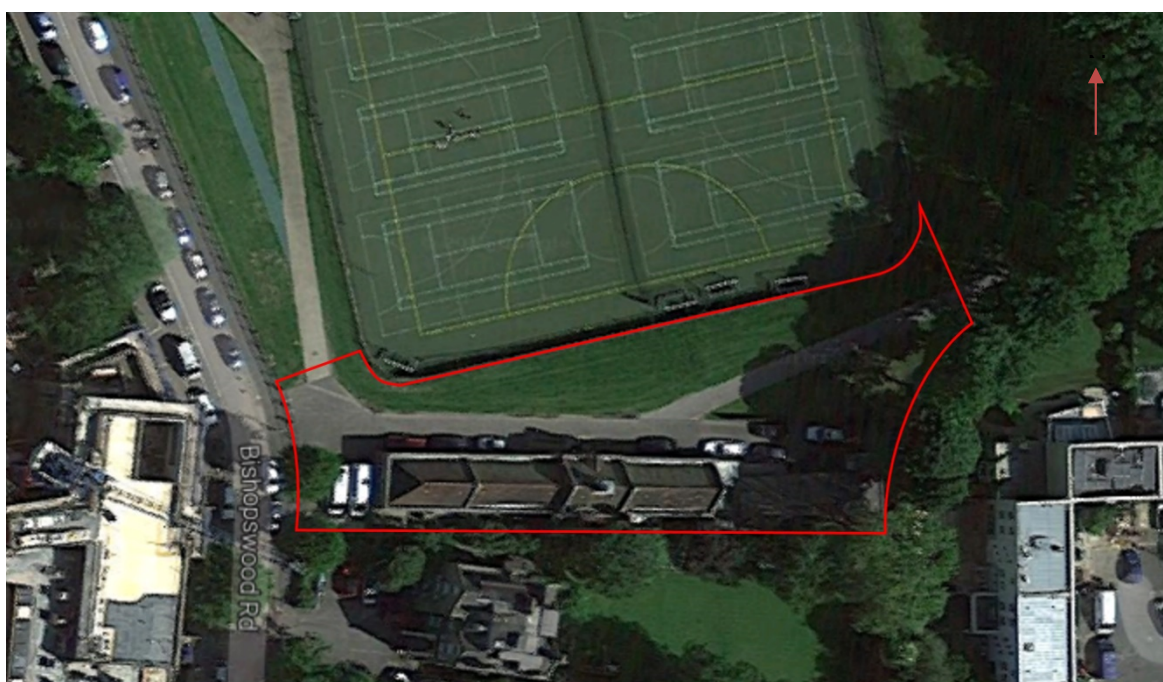


Figure 1: Site Boundary and immediate surrounding area

The proposed building has two storeys above ground level and one basement level. The structure currently generally takes the form of a reinforced concrete frame in combination with timber elements to the superstructure.

The basement retaining wall is a piled wall with an RC capping beam. Predominantly, the foundations are concrete piles. The RC basement slab is to span between internal piles and the piled retaining wall. The basement slab has been designed to resist water pressure uplift and a heave protection mat is to be used underneath to accommodate clay heave.

3 Assessments

3.1 Geological and Hydrogeological Conditions

The Geotechnical Desktop study, Site Specific Investigation and interpretative Geotechnical Assessment are available in Appendix A.

3.2 Consideration of Risks of Land Instability

The Ground Movement Assessment is presented in Appendix B. The proposed development construction operations comprise a series of stages, including demolition of the existing building, excavation for the new basement and loading of the proposed building. The impact of each of these primary stages of construction has been reviewed in a phased fashion.

The results from the analyses of the neighbouring existing buildings indicate maximum tensile strains limited to the *Category 1 – Very Slight* damage category using the Burland Scale for all phases of the analyses. Assessment of the façade/wall elements indicate that the structures concerned are located outside of the anticipated zone of influence of the proposed works.

It is also noted that the predicted ground movements, the associated wall tensile strains and level of damage categorisation are considered to be moderately conservative in view of the relatively cautious ground model assumptions and greenfield nature of the assessment undertaken.

3.3 Consideration of Hydrogeological Risk

The site specific ground investigation documents that clays were encountered within and beneath the superficial soil deposits. The cohesive nature of these clay strata/formations indicates that there is likely limited existing ground water movement within the site and immediate vicinity. The cohesive strata can be classified as unproductive aquifers with limited groundwater yield. This suggests that the construction of the basement will not significantly alter the ground water regime. Due to the anticipated limited impact, further investigation, mitigation or monitoring measures are not considered necessary.

3.4 Consideration of Hydrological Risk

The current hydrological conditions, proposed and mitigation measures are captured in the Drainage Statement submitted as part of the Planning Application.

4 Proposed Construction and Monitoring Methods

4.1 Proposed Construction

Piles are to be used to construct the basement retaining walls. This method avoids open excavation and the associated risks to neighbouring structures. Temporary propping will be installed during the construction stage to minimise movement. In the permanent case, the ground floor slab will provide propping to the pile capping beam for most the basement perimeter. In the limited zone where the ground floor slab does not extend to the basement perimeter, a wide capping beam will be used to restrain the top of the piles.

4.2 Proposed Monitoring Strategy

In parallel with the ongoing design development of the Richards Music Centre scheme and corresponding Ground Movement Assessment efforts, the project team will develop a suitable project specific ground movement monitoring strategy. This will comprise the preparation of a monitoring specification, which will be developed in coordination with an Action Plan. The monitoring specification will detail the proposed means of verification of ground movements and impact on surrounding structures. This will be performed by means of installation of strategically positioned survey targets on primary facades/walls within the zone of influence of the proposed site redevelopment works. The target arrays will enable the measurement of translational and rotational mechanisms. The frequency of monitoring will be adapted to the site activity zoning and schedule. The Action Plan will detail an array of movement/performance trigger levels at given stages of the construction process, alongside appropriate means of data management and mitigation measures (should any incremental or absolute trigger levels be approached and/or exceeded throughout construction operations).

It is noted that an outline condition survey of the surrounding buildings/structures within the zone of influence of the proposed works will be undertaken in advance of any site operations. This exercise will be repeated upon completion of the works, as agreed with the relevant Party Wall representatives.

Appendix A. Site Investigation Report

SITE INVESTIGATION REPORT

**RICHARDS MUSIC CENTRE, HIGHGATE SCHOOL
BISHOPSWOOD ROAD, LONDON N6 4PR**



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SITE INVESTIGATION REPORT

RICHARDS MUSIC CENTRE, HIGHGATE SCHOOL BISHOPSWOOD ROAD, LONDON N6 4PR

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APPENDIX A

Fieldwork, in-situ testing and monitoring

- ✚ Cable percussive borehole records
- ✚ Standard Penetration Test results
- ✚ SPT hammer energy rating certificate
- ✚ Window sample records
- ✚ Trial pit records
- ✚ Trial pit soakage test records
- ✚ Monitoring records (observation pipe and vibrating wire piezometer)

Laboratory test results

- ✚ Index property tests
- ✚ Plasticity charts
- ✚ Unconsolidated undrained triaxial tests
- ✚ Consolidated undrained triaxial tests (K4 Soils Laboratory)
- ✚ Oedometer tests (K4 Soils Laboratory)

Contamination and chemical testing

QTS Environmental Ltd Reports:

- ✚ 16-41198 (03/03/16)
- ✚ 16-41460 (10/03/16)

Ground profiles

- ✚ Plot of SPT 'N' and undrained cohesion versus depth
- ✚ Schematic cross section

Plans & drawings

- ✚ Development scheme drawings
- ✚ Photographs
- ✚ Site Plan
- ✚ Location Plan

APPENDIX B

Envirocheck report (79759257, 12/02/16)

1.0 INTRODUCTION

Consideration is being given to the redevelopment of this site with the construction of a new music centre. In connection with the proposed works, Soil Consultants Ltd (SCL) were commissioned by Expedition Engineering to carry out a site investigation to include the following elements:

-  Desk Study to identify site history and potential contaminative uses
-  Identification of ground sequence, groundwater levels and geotechnical parameters
-  Recommendations for spread/raft/piled foundation design
-  Contamination appraisal, risk assessment and conceptual model

This report describes the investigation undertaken, gives a summary of the ground conditions encountered and then provides recommendations for the design of foundations and retaining walls. An environmental appraisal is then provided together with a site specific risk assessment and conceptual model.

2.0 SITE DESCRIPTION

The existing Richards Music Centre is located within the existing Highgate School campus on the eastern side of Bishopswood Road in Highgate, north London. The centre is a narrow, single-storey building, measuring about 7m x 60m with its centre at approximate NGR 528025E 187600N. To the south of the site is a 3-storey detached house (No 2 Bishopswood Road) and grounds, whilst to the east are the rear gardens of residential properties which front onto Highgate Close. An access road and open green area are present to the north, with an artificially surfaced sports pitch beyond. Bishopswood Road forms the western site boundary.

The ground surface slopes down very gently to the north, from about +113.5mOD on the southern boundary to about +112.75mOD at its northern extent; these levels are shown on the Highgate School drawing 'DH Options Studies' (HGS/101, Sept 15). The artificial pitch to the north is cut into the slope with an RC retaining wall, about 1.7m high delineating it from the site. Numerous mature and semi-mature deciduous trees are present to the south, east and west of the existing building. These include Lime and Sycamore trees which are up to approximately 15m in height.

The current site features are shown on the site plan and photographs which are included in Appendix A and the aerial photograph on the front cover.

3.0 GEO-ENVIRONMENTAL DESK STUDY

3.1 Envirocheck historical map pack and reports

An historical map and environmental database search was commissioned from Envirocheck to ascertain the site history/usage and surrounding land usage. An indication of the gradual development of the site over the years can be gained by a study of the historical maps (shown in Appendix B). The following table contains a summary of the site development obtained from the source maps provided in the Envirocheck historical maps.

Historical development of site and surrounding area		
Map date	The site and immediate surrounding areas	Significant development / features in surrounding area (generally within 250m)
1864-1879	- The site is shown to be an open undeveloped area - The area which includes the site and the slope to the north is delineated into discrete sections; possibly landscaping features or terracing	- General area appears to be residential - The National School is present to the north-east - A cricket ground is present about 50m-100m to the east 'The Parsonage' is present about 100m to the south-east - Several ponds within about 100m/120m radius and what appears to be a ditch draining the fields just to the north, into the ponds - Waterworks about 200m to the south-east
1896-1920	- The site is still undeveloped with no significant changes - Bishopswood Road is now present on the western boundary and Sussex House is identified immediately to the south (now No 2 Bishopswood Road) - In 1915 a small unidentified building is present within the south-eastern part of the site	- Field House and School House are present on the western side of Bishopswood Road - Some excavations/terracing appear to have taken place within the grounds of the National School to the east – presumably this was to provide level playing fields - A pond is identified about 180m to the north-east - The area to the north is identified as a cricket ground on the 1915 map

Historical development of site and surrounding area		
Map date	The site and immediate surrounding areas	Significant development / features in surrounding area (generally within 250m)
1935-present day	The present-day building is now present, identified as 'Pavilions'	- The property immediately to the south is now identified as Mansfield House - The landscaped/levelled area to the north-east is identified as a sports ground, becoming tennis courts from about 1952 (later identified as Highgate Lawn Tennis Club) - Highgate Close is present to the south-east from 1970 onwards

The relevant historical maps are included in Appendix B of this report.

The Envirocheck Report includes information from a database of local activities encompassing a range of subjects related to land use, pollution, and geological/hydrological conditions. A summary of contaminative uses and other environmental issues covered by the desk study within the site and its immediate surroundings (250m unless otherwise stated) is as follows:

AGENCY & HYDROLOGICAL

- Discharge consents: none within 250m. Nearest is 379m SE, trade effluent
- Local authority pollution prevention and controls: petrol filling station, 236m E
- Nearest surface water feature: 253m SW, issues (spring) flowing southwards
- Pollution incidents to controlled waters: none within 250m. Nearest is 364m SW, Cat 2 significant incident (oils)
- Groundwater vulnerability: soils of high leaching potential on site
- Drift deposits: none
- Bedrock aquifer designation: Secondary Aquifer – A
- Flooding: no risks identified
- Detailed river network lines: 253m SW, secondary river ('issues' discussed above)

WASTE

- Local authority landfill coverage: no data

GEOLOGICAL

- ✚ Solid geology: Thames Group
- ✚ BGS estimated/measured soil chemistry: no data for site
- ✚ Ground stability hazards: 'moderate' hazard potential for shrinking swelling clay on site. All other risks are low to negligible
- ✚ Radon potential: no radon protective measures required, <1% homes above action level

INDUSTRIAL LAND USE

- ✚ Contemporary trade directory entries: no entries within 200m. Nearest is 210m SW, hospital (inactive)
- ✚ Fuel station entries: 245m E, open petrol station

SENSITIVE LAND USE

- ✚ Local nature reserves and SSSIs: none within 250m

3.2 Walk-over survey

Our site walkover survey was undertaken on 31st March 2016. The development site (which comprised the Richards Music Centre and immediate surrounding area) was generally found to be in a clean and tidy state, with the exception of some building waste (including scrap plasterboard, metal etc), which was stored at the rear of the building. No fuel tanks or chemical containers were visibly obvious within the vicinity of the site. The immediate surrounding areas (within 250m) which included an artificial sports pitch to the north, residential buildings/gardens to the east and south and Highgate School buildings to the west, were also noted to be in a well-maintained and tidy state, as far as observed.

Overall, we have not identified any particular features (such as fuel tanks), materials (such as chemical containers) or land use within the site or in its immediate vicinity which are likely to give rise to significant contamination risks and we thus have no particular concerns in this regard. Photographs of the site taken during the walkover survey are presented in Appendix A.

4.0 EXPLORATORY WORK

The scope of the investigation was specified by Expedition/A-Squared Studio and the fieldwork was carried out in two phases in February and April 2016. The investigation comprised the following elements:

Cable percussive boreholes

Three cable percussive boreholes as follows:

Hole ID	Coordinates	Ground level	Total depth (below ground level)	Installations and notes
BH1	527997E 187610N	+112.70mOD	20m	 50mm ID pipe installed to 7.00m depth  SPT hammer $E_r = 76\%$
BH2	528028E 187615N	+112.80mOD	30m	 50mm ID pipe installed to 6.50m depth  Vibrating wire piezometers installed at 8.00m, 12.00m and 18.00m depth  SPT hammer $E_r = 73\%$
BH3	528049E 187610N	+112.90mOD	20m	 50mm ID pipe installed to 8.00m depth  SPT hammer $E_r = 73\%$

Sampling and in-situ testing (SPT) were carried out at regular intervals.

Trial pits

A summary of the trial pits is as follows:

Hole ID	Coordinates	Ground level	Depth (below ground level)	Notes
TP1	527995E 187603N	+112.9mOD	1.00m	 Hand excavated  To expose foundation of existing music centre
TP2				 To be completed
TP3	528011E 187613N	+112.85mOD	1.90m	 Machine excavated  To expose retaining wall heel
TP4	528047E 187622N	+112.75mOD	2.00m	 Machine excavated  To expose retaining wall heel
TP5	528024E 187610N	+112.75mOD	2.00m	 Machine excavated  To expose general ground sequence
TPS1	527990E 187603N	+113.0mOD	1.80m	 Soakage test generally in accordance with BRE Digest 365
TPS2	528058E 187613N	+112.90mOD	1.80m	 Soakage test generally in accordance with BRE Digest 365

Window sample boreholes

Three window sample boreholes were completed using hand-held/operated equipment under the supervision of a geotechnical engineer. A summary of the boreholes is as follows:

Hole ID	Coordinates	Ground level	Depth (below ground level)	Notes
WS1	527994E 187597N	+113.2mOD	4.00m	Monitoring pipe installed to base (35mmID)
WS2	528016E 187595N	+113.2mOD	4.00m	Monitoring pipe installed to base (35mmID)
WS3	528038E 187594N	+113.7mOD	4.00m	Monitoring pipe installed to base (35mmID)

Geotechnical laboratory testing

The following geotechnical laboratory testing was completed:

- Natural Moisture Content and index properties tests
- Unconsolidated, undrained triaxial tests
- Oedometer tests (K4 Soils Laboratory)
- Consolidated, undrained (CUP) triaxial compression tests (K4 Soils Laboratory)

The oedometer and CUP tests were scheduled by A-Squared Studio.

Contamination and chemical testing

Selected soil and groundwater samples were delivered to a specialist laboratory (QTS Environmental Ltd) and the following testing was carried out:

- General soil suite - 10no samples
- Waste Acceptance Criterion (WAC) - 2no samples
- Soluble sulphate/pH - 11no samples

The engineering logs of the exploratory holes and the geotechnical laboratory testing results are included in Appendix A. The ground levels at the exploratory locations have been interpolated from the Highgate School drawing HGS/101 (Sept 2015).

5.0 GROUND CONDITIONS

Reference to published BGS data indicates that the site is underlain by the Claygate Member resting upon the London Clay. Beneath variable made ground/superficial soils the investigation encountered an upper layer of essentially brown/grey mottled silty clay overlying dark grey clay silty sandy clay. For the purposes of this discussion we have identified the upper mottled clay layer as the Claygate Member and the underlying darker clay as the London Clay. In fact both of these sub-units are incorporated under the parent unit of the London Clay Formation. This sequence is illustrated on the appended cross section through the cable percussive boreholes.

5.1 Made ground

Either topsoil (300mm to 1000mm thick) or asphalt/concrete hard surfacing (up to 250mm thick) were generally present at the borehole and trial pit positions. The underlying made ground generally comprised brown/orange, light grey/brown, brown or grey silty sandy clay or clayey sand with variable amounts of gravel, brick/concrete fragments, clinker and occasional metal fragments. The clay soils were assessed as being of a firm, locally soft consistency.

Remote from the retaining wall along the northern boundary, the made ground generally extended to depths of <1.00m below ground level. In the vicinity of the wall, significantly greater thicknesses of made ground were present, with a maximum of 2.20m in BH2.

5.2 Superficial clay

Localised deposits of superficial clays were encountered, generally in the window sample boreholes located in the southern part of the site (WS2 and WS3). These deposits comprised soft or firm grey, light brown/grey and brown/orange mottled gravelly clay.

5.3 Claygate Member

This unit comprised variable weathered brown, brown/orange, light grey, dark brown and locally red/brown clay which was generally slightly silty to very silty and locally sandy; occasional silt parting were observed. Where its full thickness was proven, this stratum extended to depths of between 3.90m and 4.50m (ie between about +108mOD to +109mOD).

Plasticity tests indicate that the soils classify as High Plasticity (CH) in the BS5930 scheme, with a 'medium' to 'high' volume change potential in the NHBC scheme. Laboratory triaxial tests and SPT N values indicate the clay to be generally of medium to high strength.

5.4 London Clay

This formation was only encountered in the cable percussive boreholes and was met at depths of between 3.90m and 4.50m (approximately +108mOD to +109mOD). The formation comprised dark grey clay with a variable silt and sand content and with occasional to frequent silt/sand partings and scattered shell fragments. The upper parts may be representative of the unweathered Claygate Member but due to its gradational nature of the boundary is not easily identified. Below about 21.50m depth (BH1) the clay became dark greyish brown in colour with a lower silt/sand content

In-situ SPT and laboratory triaxial tests indicate the clay to be locally medium strength in its upper levels (BH1), becoming high strength then very high strength with depth. Index property testing indicated an intermediate to high plasticity classification using the BS scheme. This formation was present to the full 30m depth investigated.

5.5 Groundwater

During the drilling of the boreholes, slow groundwater inflows were recorded at various depths within the London Clay, the shallowest being at about 5m depth. A minor seepage occurred within made ground in TP4, resulting in a small pocket of accumulated water at the base of the pit. In the soakage test, TPS2, the water level rose slightly due to a slow inflow.

Observation pipes (35mm or 50mm ID) were installed in all boreholes to depths of between 4.00m and 7.00m, with response zones from 1.00m depth and the base of the pipe. Monitoring visits were carried out on three occasions and these indicated highly variable water levels, ranging between 0.61m and 2.41m depth. This range in water levels probably reflects the variability in silt/sand content in the predominantly clay soils and thus a variability in the permeability. The silt/sand partings within the clay, particularly below about 4m/5m depth will almost certainly be fully charged with groundwater with a relatively high horizontal permeability.

Vibrating wire piezometers were installed within BH2 at 8.00m, 12.00m and 18.00m depth below ground level. Monitoring of the piezometers was carried out by ITM Monitoring on three occasions (including the initial installation readings) on 17th February, 2nd March and 10th March 2016; the results are included in Appendix A. The piezometric levels on the latest visit varied between +109.97mOD and +110.45mOD, equivalent to between 2.35m and 2.83m depth below ground level. This relatively small range in piezometric levels suggests a probable hydrostatic distribution with hydraulic continuity from the surface to the deepest installation.

5.6 Environmental observations

No visual or olfactory evidence of significant contamination was observed in the exploratory holes.

5.7 Foundation trial pits

A summary of the exposed foundations is as follows:

Ref	Location	Observations
TP1	NW corner of existing building	 Concrete foundation at 0.80m depth  Supported by natural firm clay
TP2	Northern central part of existing building	 Cancelled
TP3	Retaining wall	 Upper surface of heel at 1.90m depth  Unable to establish base/depth of heel due to concrete obstructions
TP4	Retaining wall	 Upper surface of heel at 1.90m depth  Unable to establish base/depth of heel

6.0 GEOTECHNICAL ASSESSMENT

The proposed development scheme involves the demolition of the existing music centre and construction of a new 2-storey building to accommodate classrooms, theatre, library and offices. The current proposals envisage a single level basement at about 4m depth which will accommodate further classrooms, a rifle range, offices and plant areas. We understand that an alternative scheme which incorporates a 2-level basement may also be considered.

Expedition advise that the columns will be arranged on a grid of approximately 8m x 7m, and that loads of approximately 2750kN and 1800kN (DL+LL) are anticipated for internal and perimeter columns respectively.

The investigation has indicated that beneath a generally small thickness of made ground, the natural Claygate Member is present overlying the London Clay. Larger thicknesses of made ground were present near to the RC retaining wall along the northern boundary. Groundwater was measured at shallow depths in the monitoring installations, locally at <1m below ground level as shown on the appended cross section through the cable-percussion boreholes. It is perhaps not surprising that shallow groundwater conditions predominate when considering the evidence from old maps that there were a number of ponds nearby and the area to the north was drained by a ditch into ponds. This general area of relatively high ground also drains southwards (issues about 250m SW) into the Highgate Ponds.

For construction of the proposed basement we consider that an embedded retaining wall would present the best solution. For the single basement level option, consideration could possibly be given to the construction of a new RC basement wall in sequential open excavation. However, there would be significant attendant problems with this approach and these are discussed below. For a 2-level basement, we consider that an embedded wall will almost certainly be required.

Foundations for the new structure will depend upon the structural loads and configuration. In our opinion, piled foundations will present the optimum type. The individual column loads are considered to be too high for individual pad foundations, although we understand that consideration is also being given to the use of an RC raft basement level.

6.1 Retaining wall and basement excavation

The basement excavation will encounter made ground, localised superficial clay, clay of the Claygate Member and the London Clay. Groundwater was generally not observed at shallow levels when undertaking the boreholes and trial pits, but these were of relatively short duration with the inflows clearly taking some time to develop; subsequent monitoring of the borehole installations measured shallow standing levels at between 0.61m and 2.41m depth.

As discussed above, an embedded retaining structure such as a secant bored pile or steel sheet pile wall is considered to be the optimum type. A properly designed and dimensioned wall would provide an effective cut-off to groundwater and ensure stability of the excavation.

Consideration could possibly be given to the use of an RC panel wall, constructed in open excavation but this would depend crucially on the potential groundwater inflow and stability. Such a structure would need to be constructed sequentially with temporary support probably being necessary. Little groundwater was observed during the actual execution of the boreholes and trial pits, at least above 5m depth, and if short term inflows are very slow then there may be some merit in this type of construction. However, the influence of groundwater would clearly be critical in determining the feasibility of this approach. Whilst the soils are generally cohesive, those at basement level contain sand/silt horizons and some degree of groundwater inflow would be expected. In order to assess the viability of this approach, we would recommend advance trial excavations to the full basement depth by an experienced groundworks contractor and that these are left open for a reasonable period; this would allow an assessment of the groundwater conditions and the potential stability of the excavations.

Careful selection of design parameters, both temporary and long term will be needed to ensure overall stability of the new basement wall, incorporating allowances for factors such as the presence of high groundwater and the probability of soil softening. Deflection of the wall is unlikely to be critical expect in the vicinity of No 2 Bishopswood Road and the residential building to the east. The key to controlling ground movements outside the excavation will be to adopt a well-designed, robust arrangement of temporary bracings/props during construction. Of course, in the permanent condition, lateral support will be provided by the new basement and ground floor slabs.

The following table of coefficients may be used for the preliminary design of the basement retaining wall:

Stratum	Bulk density [Mg/m ³]	Effective cohesion, c' [kN/m ²]	Effective friction angle, ϕ' [degrees]
Made ground	1.80	0	22
Superficial clay	1.80	0	23
Claygate Member	2.00	0	22
London Clay			
<5m below basement slab	2.00	0	21
>5m below basement slab	2.00	5	21

The above preliminary parameters may be regarded as being 'moderately-conservative' estimates which in our experience are appropriate for these strata. Effective stress testing has been undertaken as part of this investigation (scheduled by A-Squared Studio) and the results may be used by a specialist designer to inform their own assessment of appropriate parameters.

The wall designer should use the parameters to derive the active and passive earth pressure coefficients, K_a and K_p . The determination of appropriate earth pressure coefficients, together with factors such as the pattern of earth pressure distribution, will depend upon the type/geometry of the wall and the overall design approach. Piled walls may of course also be used to provide vertical load capacity if required subject to the necessary allowance being made for interaction effects.

It is noted that a significant number of trees are present along the southern and western boundaries. The clay soils will be shrinkable and due consideration will need to be given to potential shrink/swell effects on the retaining wall. These could include either the incorporation of a compressible layer if appropriate or modification of the design parameters.

A specialist contractor should be consulted to confirm the most appropriate type of wall and to provide the final wall design.

6.2 Piled foundations

Piled foundations would transfer the structural loads to the London Clay at depth. For the ground and groundwater conditions encountered, with frequent seepages/inflows within the London Clay, we consider that Continuous-flight Auger-injected piles (CFA) are likely to be the most appropriate type. The following table of coefficients may be used for the preliminary design of CFA piles and, based upon the measured strength profile.

Shaft adhesion

Stratum	Depth	Undrained cohesion (from strength profile)	Ultimate unit shaft adhesion ' q_s '
All soils above basement level	Above say 5m depth (allow for pile cap)	N/A	Ignore
London Clay	Below 5m depth (about +108mOD)	Increases linearly from 70kPa at a rate of 8kPa/m	Increases linearly from 35kPa at a rate of 4kPa/m (incorporates $\alpha = 0.50$)

Notes:

- Unit shaft adhesion ' q_s ' = $\alpha \times c_u$ (where $\alpha = 0.50$ and c_u is the undrained cohesion from the design line)
- The α value of 0.5 is based upon 102mm diameter triaxial tests and this should not be varied
- The average shaft adhesion over the pile length should be limited to 110kN/m²
- The maximum value for unit shaft adhesion should be limited to 140kN/m²

End bearing

Stratum	Depth/level	Undrained cohesion (from strength profile)	Ultimate unit base resistance 'q _b '
London Clay	Below 15m depth (about +98mOD)	Increases linearly from 150kPa at a rate of 8kPa/m	Increases linearly from 1,350kPa at a rate of 72kPa/m (incorporates N _c = 9)

Notes:

- a) Unit base resistance in clay 'q_b' = N_c x c_u (where N_c = 9 and c_u is the equivalent undrained cohesion from the design line)

An overall Factor of Safety of 2.6 should be appropriate when applied to these ultimate parameters, in accordance with LDSA guidelines. As a preliminary guide to the use of the coefficients, we have calculated the capacities of single piles with a range of diameters terminating at various depths.

Pile diameter (mm)	Pile toe depth – note c (mbgl)	Pile toe level – note c (mOD)	Working load (kN)
300	15	+98	235
	20	+93	400
	25	+88	600
450	15	+98	380
	20	+93	635
	25	+88	940
600	15	+98	545
	20	+93	895
	25	+88	1315

Notes:

- a) Working load is calculated using F_{shaft} and F_{base} = 2.6
b) Concrete stress should be considered in the final design
c) Relative to assumed PPL at +113mOD
d) Ignores the contribution of all soils to 5m depth

The above examples are not recommendations for pile diameter/length but are intended to illustrate the use of the shaft and base parameters.

Eurocode 7 adopts a different approach, applying partial factors to the ultimate pile capacity. The pile resistance is calculated using the above parameters in accordance with EC7 (BS EN 1997-1:2004 and UK National Annex) for the ultimate limit state GEO Design Approach 1, Combinations 1 and 2. The following partial factors, as recommended in the UK National Annex, are applied:

- a] Model Factor, γ_{Rd} = 1.4 (Combinations 1 and 2)
b] Factor on shaft resistance, γ_s = 1.6 (Combination 2)
c] Factor on base resistance, γ_b = 2.0 (Combination 2)

The design engineer must ensure that the correct comparisons are made between the Design Actions and Design Resistances and that SLS checks are made.

A specialist piling contractor should be consulted to confirm the most appropriate piling technique and to provide the final pile design.

6.3 Raft foundation at basement level

Either the Claygate Member or the London Clay will be exposed at the proposed basement level. In their undisturbed state, these are expected to be relatively competent strata capable of supporting moderate structural loads. It must be noted however that these strata will be highly sensitive in the presence of groundwater with an appreciable risk of softening; this is discussed further below.

If the excavation can be carried out successfully without leading to softening of the foundation soils then consideration could be given to the use of an RC raft foundation to support the new building. No loadings have been provided but we would expect the new building to generate a UDL over the probable raft footprint of approximately 40kPa, which would be well within the capabilities of the natural soils. However, the feasibility of a raft will of course need to be verified and this will depend upon the structural arrangements of the new columns and the distribution/concentration of the loads. Due consideration would need to be given to potential soil heave and hydrostatic pressures and these are discussed further in Section 6.4 of this report. The depth of such foundations would be beyond the expected zone of influence of the nearby trees and no special precautions would be required in this respect.

The soils at formation level will be highly susceptible to softening and are likely to rapidly lose strength and become almost unworkable in the presence of significant groundwater. If a water-tight, deeply embedded retaining wall is adopted the risk would be lower although good construction techniques, such as the immediate placing of a blinding layer would still be required. It may simply be possible to undertake local deepening if softened material is present, to ensure that the foundations are supported by the stiff natural clay. This emphasises the need for full depth trial excavations, as recommended in the previous section, to allow an assessment of the likely response of the stress-relieved soils, the influence of groundwater and appropriate water control measures. Of course, such trial excavations could indicate that this approach is not practical and a piled foundation solution would then certainly be required throughout.

6.4 Basement excavation and soil heave

The proposed works will result in the removal of approximately 4m of soil for the single level basement. When taking into account the existing building, this could be equivalent to an unloading of approximately 100kPa (assume a 20kPa UDL for the building), potentially resulting in short and long term heave in the London Clay. Factors such as the length of the construction programme, the restraining effects of the retaining wall piles and the basement slab/raft stiffness will generally determine the amount of heave which could occur.

The basement slab could either be designed as a suspended structure, incorporating a void to accommodate potential heave, or as a ground-bearing slab designed to resist potential heave forces. A raft foundation

may result in a net unloading and potential ground movements would need to be assessed for this option. We understand that a ground movement analysis is to be carried out by A-Squared Studio to address soil heave in relation to basement slab or raft design and the potential differential movements which could occur if a mixed pile/raft solution is adopted.

It will be necessary to consider potential uplift of the slab due to potential hydrostatic pressures and in this respect the guidelines incorporated in BS8102:2009 should be followed. We recommend that a water level at say 1m depth is adopted for design. This would result in minimum uplift pressures of about 30kPa for the single level basement.

6.5 Foundation concrete

Low concentrations of soluble sulphates (2:1 soil/water extract) were measured in selected soil samples with near neutral pH values. The results fall into Site Design Class DS-1 of Table C2 given in BRE Special Digest 1 (2005) and with a 'mobile' ground water classification, this would result in buried concrete being designed in accordance with ACEC Site Class AC-1. However, the results suggest that pyrite is probably present with a significant number of samples (40% of those tested) containing oxidisable sulphides >0.3%. With the proposed excavation into the London Clay, we consider that there is a theoretical risk of oxidation occurring and therefore, as recommended by the BRE digest, determination of the characteristic value of Total Potential Sulphate (TPS) has been carried out. Using all of the results, this procedure results in a more onerous classification of ACEC Site Class AC-4. This classification should be used for concrete which could be exposed to disturbed ground which might be vulnerable to oxidation, for example any slab, raft or pile caps constructed at basement level.

7.0 ENVIRONMENTAL ASSESSMENT

This appraisal adopts the current UK practice which uses the Source-Pathway-Receptor methodology to assess contamination risks. For a site to be designated as contaminated a plausible linkage between any identified sources and receptors must be identified, ie whether significant pollution linkages (SPLs) are present. In considering the potential for contamination to cause a significant effect, the extent and nature of the potential source are assessed and pathways/receptors identified; without an SPL there is theoretically no risk to the receptors from contamination. The assessed risks to the various potential receptors are summarised in the tabulated Conceptual Site Model which forms Section 7.6 of this report.

7.1 Environmental setting and context

The Envirocheck report indicates a Bedrock Aquifer Designation of 'Secondary A'. No groundwater abstraction points or source protection zones are identified within the search buffer. The site is assessed as being of **low** Environmental Sensitivity.

7.2 Potential contamination sources (on-site and off-site)

The desk study has not identified any significant potential contamination sources within the site or its immediate surroundings. Some ground workings were identified to the east of the site but these appear to be associated with a levelling exercise to provide a sports area. We assess there to be a **low** risk of potential contaminative sources which could affect the site.

7.3 Contamination testing

In order to identify whether known or unknown sources within (and outside) the site have caused contamination, we have carried out testing on a series of soil and groundwater samples. The desk study has indicated that the main risk to the site and potential receptors is likely to be only the limited thickness of made ground present. Testing for a general range of contaminants was therefore initially undertaken.

The results were assessed where relevant against the DEFRA Soil Guideline Values (SGV) and the LQM/CIEH Generic Assessment Criteria (GAC) for Human Health Risk Assessment in which LQM/CIEH have derived additional SGVs from the current CLEA Model (2nd Edition, 2009). There are currently no published SGV's or GAC's for Extractable/Total Petroleum Hydrocarbons and the results were compared with the frequently used EA remedial target of 1,000mg/kg. The SGV for lead contamination has been withdrawn but Category 4 Screening Levels (C4SLs) recently introduced by DEFRA can be useful values for comparison with recorded results. C4SLs have also been useful for comparison with several other contaminants.

The contamination testing was carried out specifically for the purpose of providing a general guidance evaluation for the proposed development. Reference should be made to the foreword to the appended contamination test results in order to fully understand the context in which this discussion should be viewed.

There are no specific published guidelines for school use and we therefore assessed the results against the criteria for residential development.

Using these criteria the following results are of note:

-  **Lead:** one of the samples exhibited an elevated Lead concentration (2,950mg/kg) in relation to the DEFRA Cat 4 threshold of 310mg/kg
-  **Petroleum hydrocarbons:** generally low in all samples
-  **Polycyclic Aromatic Hydrocarbons:** generally low in all samples
-  **Asbestos:** loose fibres (crocidolite) detected in one sample of made ground

The results of the testing suggest that there is no widespread contamination present at the borehole positions. However, a localised high lead concentration has been measured and asbestos was identified in one sample. It should be noted of course that there may of course be pockets of undetected contamination between exploratory points. The implications of the contamination results are discussed below.

7.4 Disposal of excavated soils

A rigorous hazard assessment of the results was not within the scope of our investigation, but our preliminary conclusion from the contamination testing and WAC testing is that the made ground will probably classify as either 'inert' or 'non-hazardous industrial' waste with an 'inert' classification for natural soils. The presence of a localised elevated concentration of lead and the presence of asbestos will affect the classification for some of the soils and additional testing is likely to be required during excavation to confirm the disposal classification. Early consultations must be made with appropriate waste facilities or regulators to confirm the requirements for off-site disposal and any additional testing which may be required.

7.5 Ground gas

No significant ground gas risk was identified by the desk study and no degradable soils were observed during the investigation. Gas monitoring was undertaken and the results are included in Appendix A. The concentrations of methane, carbon monoxide and hydrogen sulphide were very low to negligible and we consider that the risk with respect to these gases is relatively low. However, the concentration on carbon dioxide was locally elevated with concentrations of >5% in a number of instances.

Whilst 100% of the made ground is likely to be removed from within the building footprint during basement excavation, there will be a residual risk of lateral gas migration into the basement void. In view of the proposed usage, ie theatre, offices and classrooms, we consider that there will be some risk to the end-user. We therefore consider that it would be advisable to incorporate gas protection measures into the basement wall structure to mitigate this risk. On the basis of the monitoring carried out to date, we consider that Characteristic Situation 2 should be adopted (as described in CIRIA C665 "Assessing risks posed by hazardous ground gases to buildings", 2007) and appropriate protection measures designed. Further monitoring should be carried out and we would recommend that at least three additional visits are made. The risk level should be revised if required following additional monitoring.

7.6 Risk Assessment and Conceptual Model

Taking into account the above discussion, the assessed risks to potential receptors are summarised as follows:

Source/ hazard	Pathway	Receptor	Mitigation measures/explanation	Assessed Risk level
Contaminated soil: on-site and off-site sources	Ingestion/contact	End user and construction workers	The desk study has identified no significant potential contamination sources within the site or its vicinity Whilst a localised elevated concentration of lead was measured, together with one occurrence of fibrous asbestos, the whole of the made ground, which is likely to be the only probable source of contamination, will be removed during basement excavation. Therefore there will be no SPL and no risk to the end-user Appropriate PPE must be worn by construction workers and the site H&S manual should specifically address the potential localised presence of asbestos and lead	LOW
Contaminated soil: on-site sources	Migration of contaminated ground water and/or surface run-off through contaminated fill into aquifer	Aquifer and surface water	A Secondary-A aquifer designation applies to the 'bedrock' No surface/groundwater abstraction points or source protection zones were identified The desk study has identified no significant potential contamination sources within the site or its vicinity Whilst a localised elevated concentration of lead was measured, together with one occurrence of fibrous asbestos, the whole of the made ground, which is likely to be the only probable source of contamination, will be removed during basement excavation. Therefore there will be no SPL and no risk to the surface or groundwater	LOW

In conclusion, based upon the information reviewed and the results of the investigation, our assessment is that the residual risks to potential receptors should be **LOW** provided appropriate remedial measures are adopted. It is self-evident that there may be zones of contamination within the site which were not encountered in our boreholes. A careful watching brief should be kept during construction and if obvious or suspected contamination is encountered this should be dealt with prescriptively; a suitable contingency should be in place in this regard.



GENERAL INFORMATION, LIMITATIONS AND EXCEPTIONS

Unless otherwise stated, our Report should be construed as being a Ground Investigation Report (GIR) as defined in BS EN1997-2. Our Report is not intended to be and should not be viewed or treated as a Geotechnical Design Report (GDR) as defined in EN1997-2. Any 'design' recommendations which are provided are for guidance only and are intended to allow the designer to assess the results and implications of our investigation/testing and to permit preliminary design of relevant elements of the proposed scheme.

The methods of investigation used have been chosen taking into account the constraints of the site including but not limited to access and space limitations. Where it has not been possible to reasonably use an EC7 compliant investigation technique we have adopted a practical technique to obtain indicative soil parameters and any interpretation is based upon our engineering experience and relevant published information.

The Report is issued on the condition that Soil Consultants Ltd will under no circumstances be liable for any loss arising directly or indirectly from ground conditions between the exploratory points which differ from those identified during our investigation. In addition Soil Consultants Ltd will not be liable for any loss arising directly or indirectly from any opinion given on the possible configuration of strata both between the exploratory points and/or below the maximum depth of the investigation; such opinions, where given, are for guidance only and no liability can be accepted as to their accuracy. The results of any measurements taken may vary spatially or with time and further confirmatory measurements should be made after any significant delay in using this Report.

Comments made relating to ground-water or ground-gas are based upon observations made during our investigation unless otherwise stated. Ground-water and ground-gas conditions may vary with time from those reported due to factors such as seasonal effects, atmospheric effects and and/or tidal conditions. We recommend that if monitoring installations have been included as part of our investigation, continued monitoring should be carried out to maximise the information gained.

Specific geotechnical features/hazards such as (but not limited to) areas of root-related desiccation and dissolution features in chalk/soluble rock can exist in discrete localised areas - there can be no certainty that any or all of such features/hazards have been located, sampled or identified. Where a risk is identified the designer should provide appropriate contingencies to mitigate the risk through additional exploratory work and/or an engineered solution.

Where a specific risk of ground dissolution features has been identified in our Report (anything above a 'low' risk rating), reference should be made to the local building control to establish whether there are any specific local requirements for foundation design and appropriate allowances should be incorporated into the design. If such a risk assessment was not within the scope of our investigation and where it is deemed that the ground sequence may give rise to such a risk (for example near-surface chalk strata) it is recommended that an appropriate assessment should be undertaken prior to design of foundations.

Where spread foundations are used, we recommend that all excavations are inspected and approved by suitably experienced personnel; appropriate inspection records should be kept. This should also apply to any structures which are in direct contact with the soil where the soil could have a detrimental effect on performance or integrity of the structure.

Ground contamination often exists in small discrete areas - there can be no certainty that any or all such areas have been located, sampled or identified.

The findings and opinions conveyed in this Report may be based on information from a variety of sources such as previous desk studies, investigations or chemical analyses. Soil Consultants Limited cannot and does not provide any guarantee as to the authenticity, accuracy or reliability of such information from third parties; such information has not been independently verified unless stated in our Report.

Our Report is written in the context of an agreed scope of work between Soil Consultants Ltd and the Client and should not be used in any different context. In light of additional information becoming available, improved practices and changes in legislation, amendment or re-interpretation of the assessment or the Report in part or in whole may be necessary after its original publication.

Unless otherwise stated our investigation does not include an arboricultural survey, asbestos survey, ecological survey or flood risk assessment and these should be deemed to be outside the scope of our investigation.

(Rev_1_08_03_2013)

APPENDIX A

Fieldwork, in-situ testing and monitoring

-  Cable percussive borehole records
-  Standard Penetration Test results
-  SPT hammer energy rating certificate
-  Window sample records
-  Trial pit records
-  Trial pit soakage test records
-  Monitoring records (observation pipe and vibrating wire piezometer)

Appendices are available on request

Appendix B. Ground Movement Assessment



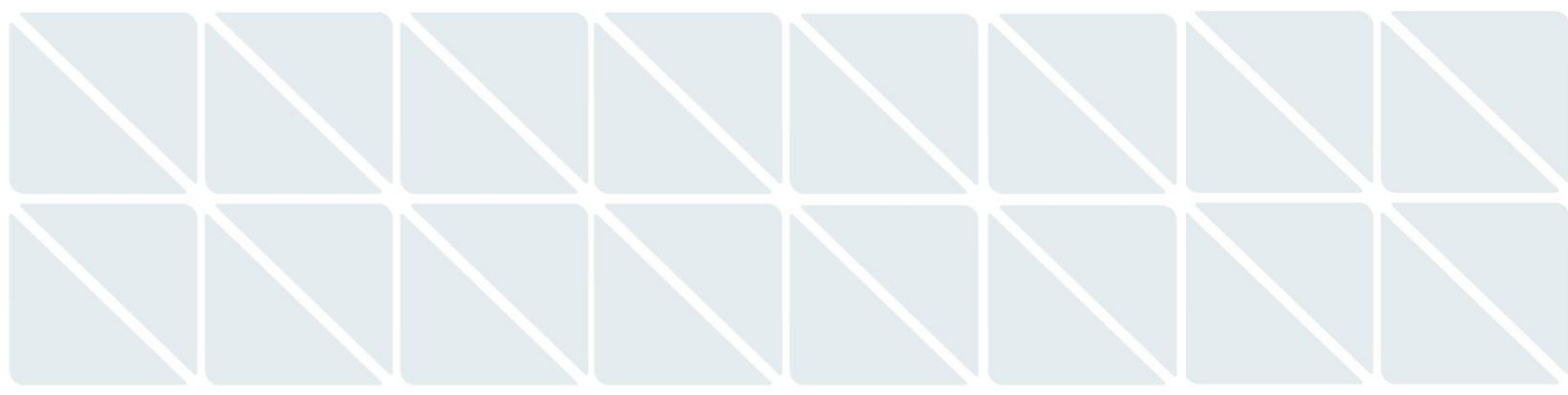
A-squared Studio

Highgate School - Richards Music Centre Site

Ground Movement Assessment Report

December 2019

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1. Introduction

A-squared Studio Engineers Ltd (A-squared) has been appointed by Expedition Engineering Ltd (Expedition) to undertake a Ground Movement Assessment (GMA) for the Richards Music Centre development in Highgate, London.

The A-squared scope comprises an assessment of the potential impact of the proposed redevelopment works on the various neighbouring properties.

1.1. Study Aims & Objectives

A ground movement and impact assessment has been carried out in order to estimate the potential damage induced by the proposed redevelopment at the Richards Music Centre of Highgate School on the neighbouring properties.

The scheme includes the demolition of the existing Richards Music Centre, excavation of a one-level basement, and construction of the proposed two-storey structure. Piled retaining walls have been selected by the project team at this stage as the ground retention system for the entire excavation.

The assessment encompasses properties located within the zone of influence of the proposed scheme. The GMA assessment is based on *greenfield* ground movements which are unlikely to be exceeded. The adopted assessment methodology provides a robust and conservative assessment representative of current industry best practice, as detailed in Section 4.

The assessment carried out and described herein aims to:

- Assess the impact on ground movements induced by the proposed works on properties adjacent to the development under consideration.
- Provide performance criteria and inform aspects of substructure construction and design.

This report provides a detailed description of the:

- Site and proposed development.
- Modelling parameters and input.
- Analyses and results.



2. The Site

2.1. Site Location and Proposed Development

The proposed development is located at the Richards Music Centre, Highgate School, Bishopswood Road, London, N6 4PR, as shown in Figure 2.1. The site is located at British National Grid coordinates 528020E, 187601N and falls within the administrative boundaries of the London Borough of Haringey. Highgate Underground Station is located approximately 800m northeast of the site.

The site slopes very gently from south to north, with elevations ranging from approximately +113.1mOD to +112.75mOD. For this assessment, the site elevation is taken as approximately +113.0mOD.



Figure 2.1 Richards Music School development location

The existing structure occupying the site is the one-storey Richards Music Centre. An approximately 1.8m high reinforced concrete retaining wall can also be found along the northern boundary of the site supporting a sports pitch. The existing Richards Music Centre building will be demolished, along with a portion of the retaining wall that forms the northwest boundary of the site. A two-storey structure has been proposed, including the excavation of a single level basement with a depth to formation level of approximately 4.85mBGL (+108.15mOD).

It is understood that the main structure will be supported by pile foundations, as specified in the *RMC II – Stage 2 Report* prepared by Expedition in October 2018. The report also specifies that the excavation will be supported by piled retaining walls along the entire perimeter. The proposed basement footprint is shown in Figure 2.2.