Basement Impact Assessment (BIA)

Sandford Road, Dublin 6

Report No. B1694-GEO-R001

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[1] Introduction

[1.1] Background Information

The site for assessment is “Sandford Road” located at the intersection of Milltown Road and Sandford Road in Ranelagh, Dublin 6. The site is primarily a Greenfield site with a small footprint of low-rise buildings occupying its south-eastern section as shown in Figure 1-1 below. The site area is circa 4.26ha in area and is located in the local authority area of Dublin City Council (DCC).

Figure 1-1 Site location and approximate site boundary (Source: Google Earth)

[1.2] Report Objectives

It is intended to lodge an LRD planning application with Dublin City Council in December 2025. At the time of planning this development, planning applications which include a basement are required to carry out a Basement Impact Assessment (BIA) as per Dublin City Development Plan 2022-2028, Appendix 9 Basement Development Guidance.

This report has been prepared by Ayesa on behalf of its client, DBFL Consulting Engineers to assess the impact of the proposed development.

In order to achieve the objectives of the report, the following were undertaken:

1. Desktop study to provide a brief outline on the site particularly focussing on previous site use, nearby basements and its location;
2. Carry out a ground movement assessment and hydrogeological assessment associated with the construction of the basement structure; and
3. Provide recommendation for further works (if required).

[1.3] Proposed Development

The client intends to develop the site as a residential-led mixed use development with underground basement for car parking. The site's existing level around the proposed basement ranges between 17.9mOD and 21.0mOD (Malin Head). The basement finished floor level (FFL) will range between 14.55 to 16.85mOD for the basement, hence the dig level for the basement will vary between 4.0 to 4.8mBGL. The basement will occupy approximately 20% of the full footprint of the site and has been setback by more than 0.5m away in all directions from the red line boundary of the site as shown in Figure 1-2.

Figure 1-2: Basement footprint of the proposed development (Source: O' Mahony Pike Architects)

[1.4] Basement Construction Sequence

The basement is proposed to be constructed and formed using the open cut excavation method. The construction sequence is expected to follow a traditional sequence of:

1. Excavate to the proposed formation level of the basement (c. 4.0 to 4.8m BGL).
2. Construct the permanent works basement substructure in the following sequence:

a) Construct basement floor slab

b) Construct RC liner walls

c) Construct ground floor slab and backfill around the basement as necessary.

[1.5] Education and Experience of author(s)

The report was completed by originally completed by Nick Peters, Associate Director (later revised by David Feeney, Project Engineer). The revised report was revived Nick Peters at a later date.

David Feeney, Project Engineer has 3 years of experience in Engineering and holds a Master of Engineering (Geotechnical) from Camborne School of Mines, University of Exeter, UK. David Also holds a Master of Science (Engineering) from TUS, Ireland.

Nick Peters, Associate Director has 13 years of experience in Geotechnical Engineering and holds a Master of Engineering (Civil) from Heriot Watt University, UK. Nick is also a Chartered Engineer with the Institution of Civil Engineers (ICE) and is a Registered Ground Engineering Professional (RoGEP).

[1.6] Limitations

The conclusions and recommendations made in this report are limited to those that can be made on the basis of the information supplied at the time of writing this report. Any information used have been assumed by Ayesa to be accurate and valid. Ground movement values and hydrogeology findings presented in this report are considered predictions and should be verified and confirmed at detailed design stage following final selection of construction methodologies and details.

[1.7] References

The following is a non-exhaustive list of technical papers and guidance documents referenced in the body of the report and used in the assessment:

CIRIA C760 (formally C580) Guidance on Embedded Retaining Wall Design

Dublin City Development Plan 2022-2028, Appendix 9 Basement Development Guidance https://consult.dublincity.ie/en/system/files/materials/5522/Appendix%209%20-%20Basement%20Impact%20Assessment.pdf

Geological Survey of Ireland's (GSI) online geotechnical map viewer. www.gsi.ie;

Long, M. and C. O. Menkiti (2007). "Geotechnical properties of Dublin Boulder Clay." Geotechnique (57)7: 595-611;

Misstear, B.R., Brown, L., Daly, D., 2009 Hydrogeology Journal, Methodology for making initial estimates of groundwater recharge from groundwater vulnerability mapping;

Metro North Railway Order Application – An Bord Pleanála Further Information Request, Item 19 Groundwater and Hydrogeology, Pages 18-34, 2010.

National Mounments Service Historic Environment Viewer. http://webgis.archaeology.ie/historicenvironment/

National Planning Application Map Viewer. https://housinggovie.maps.arcgis.com/apps/webappviewer/index.html?id=9cf2a09799d74d8e9316a3d3a4d3a8de

Ordnance Survey Ireland Geohive mapviewer. http://map.geohive.ie/mapviewer.html

Skipper, J., B. Follet, et al. (2005). "The engineering geology and characterization of Dublin Boulder Clay." Quarterly Journal of Engineering Geology and Hydrogeology 38: 171 – 187;

[2] Desktop Study

[2.1] Nearby Land Use

The site's surrounding land use is urban. There are no major industrial/manufacturing operations present nearby to the site which might indicate that soil and groundwater contamination might have taken place. Table 2-1 below shows the breakdown of land use surrounding the site.

Table 2-1: Adjacent Land Uses

Boundary	Land Use
North	Residential Properties.
South	Irish Jesuit building, Residential Properties and further 500m south is the River Dodder.
East	Residential Properties and further to the south-east is the Clonskeagh Hospital.
West	Residential and Commercial Properties.

[2.2] Site History

An overview of the site history was obtained through the review of publicly available extracts of historical Ordnance Survey of Ireland (OSI). The years 1837-1842 displayed by the 6" OSI map show the site to be shown as a park as shown in Figure 2-1 below. The 25" Historical maps (1888-1913) show that a chapel have been built in the southern portion while the northern portion also appear to be occupied by a park.

The majority of the site remained undeveloped at least until 2013. A temporary school building, car parking, drop-off/pick up area and external play area were present on site until late 2019. The school building has been removed from site.

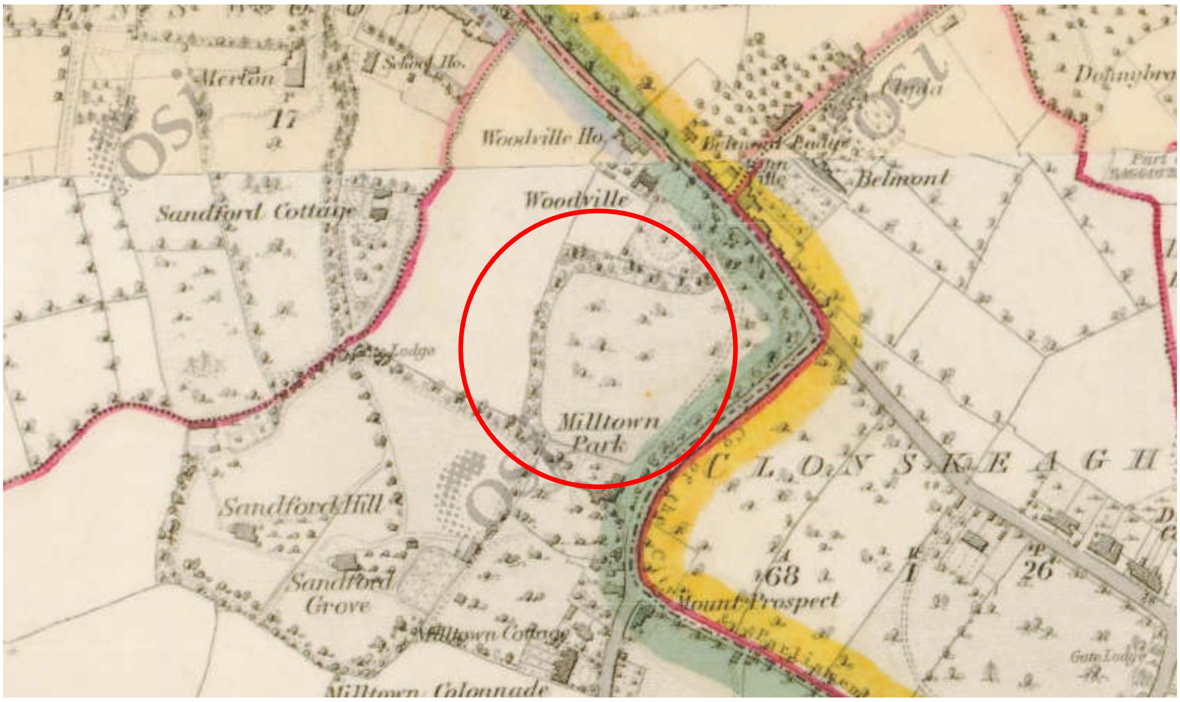

Figure 2-1: Approximate location of the site on the1888-1913 25 inch OS Map (Source: Ordnance Survey Ireland)

[2.3] Protected Structures

DCC's current Record of Protected Structures (Volume 4 of the 2022-2028 Dublin City Development Plan) came into force on the 14th December 2022. The record was accessed to identify nearby protected structures. The nearest protected structures are 4No. houses located at the East of the intersection of Belmont Avenue and Sandford Road to the north-east of the site, 2No. houses (No. 87 & No. 89 Sandford Road) to the north of the site and properties located on Clonskeagh Road (St James' Tce) to the East of the site (No. 2 – No.24 Clonskeagh Road). The site does not directly abut any protected structure and the proposed basement is at least 90m away from any protected structure. Some houses along Anna Villa, Sandford Road, Milltown Road, Clonskeagh Road and Beechwood Road are also protected structures.

[2.4] Nearby basements

As required by the DCC basement guidance, Ayesa investigated the presence of existing nearby basements of which none were identified. The DCC planning application map viewer was accessed to identify permitted development with basements which might interact with the proposed basement. The nearby planning applications to the site are shown in Figure 2-2 below, the site is highlighted in yellow. Upon querying the planning applications surround the site, all of the other approved planning permissions comprises of prefabricated classrooms addition to existing schools, refurbishment, minor extensions and/or change of use. The interaction between the proposed basements is further discussed in Section 4.4 of this report.

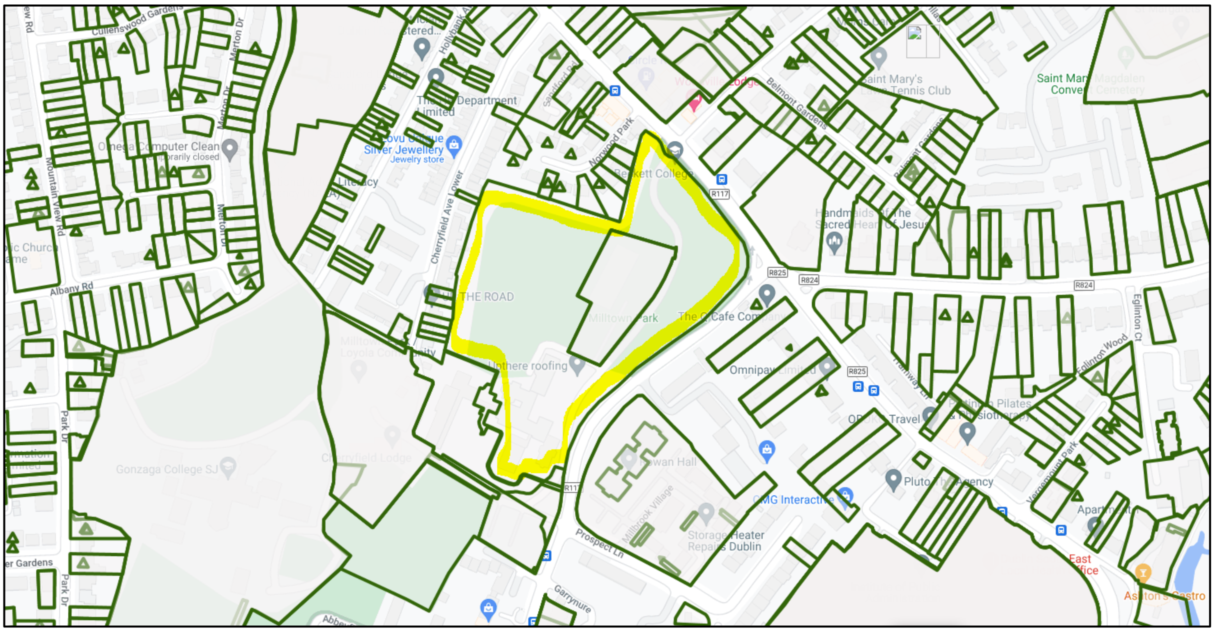

Figure 2-2: Nearby Permitted Developments (Source: DCC Planning Portal)

[2.5] Geology and Nearby Ground Investigations (GI)

The Geological Survey of Ireland (GSI) mapviewer shows the site to be underlain by Calp Limestone which is described as dark-grey to black, fine-grained, occasionally cherty, micritic limestones that weather paler, usually to pale grey. There are rare dark coarser grained calcarenitic limestones, sometimes graded, and interbedded dark-grey calcar.

The GSI's Geotechnical viewer which contain records for nearby ground investigations (GI) carried out across Ireland was consulted. The most relevant GI is Milltown Road (20m south to the site) as shown in Figure 2-3 which included the drilling of 3 No. cable percussion boreholes. The boreholes showed that the ground comprised of 0.3-1.2m of made ground which is underlain by glacial till described as Sandy Gravelly Clay (Dublin Boulder Clay). The boulder clay thickness ranged between 5.9-7.4m, the upper 2m of the boulder clay was noted to be brown and had lower Standard Penetration Test (SPT) N value than deeper black layer. All 3No. boreholes terminated at depth of around 6.5-7.5mBGL.

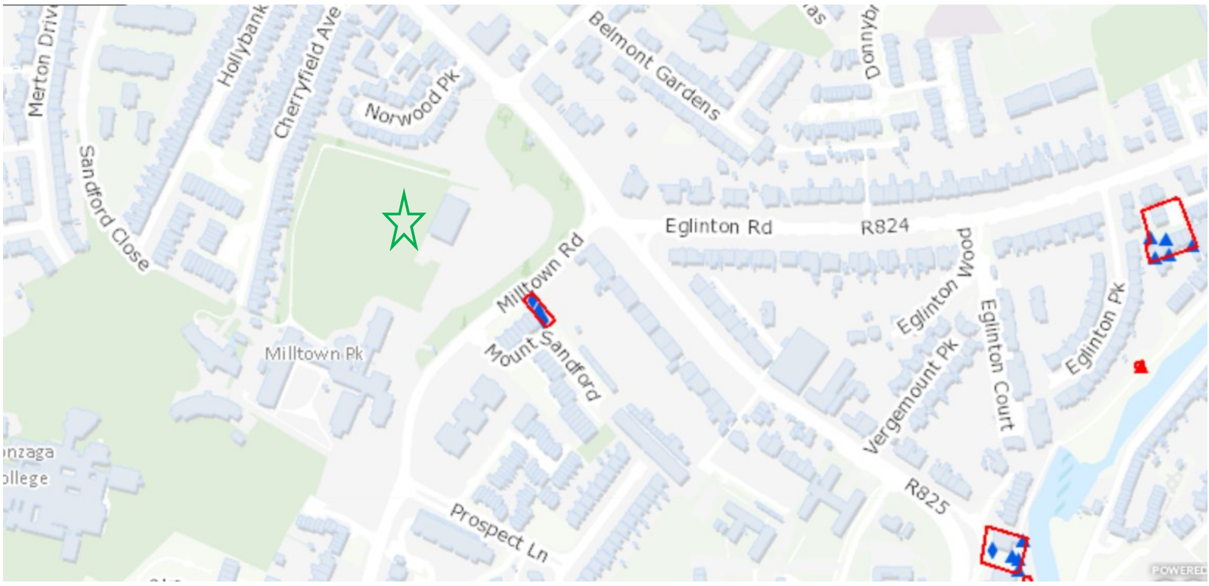

Figure 2-3: Nearby ground investigations to the site (Source: GSI Geotechnical viewer)

[3] Ground Conditions

[3.1] Ground Investigation

A ground investigation was carried out throughout January to October 2020 and comprised of the following:

- 16No. Cable Percussion boreholes to a maximum depth of 8m;
- 5No. rotary follow on boreholes on the cable percussion boreholes to a maximum depth of 20mBGL;
- 14No. window sample boreholes;
- 11No. trial/foundation pits to determine existing foundation details;
- 3No. soakaway pits;
- 13No. Dynamic probes; And
- 9No. Plate Load tests to determine CBR value.

[3.2] Ground Profile

The geology of the site based on intrusive investigations carried out across the site were as follows:

- TOPSOIL;
- In some locations, a thin layer of Made Ground comprising of 'brown sandy gravelly CLAY with construction and demolition waste namely concrete and plastic fragments'. The maximum thickness of Made Ground during the investigation was 1.0m and the minimum thickness was 0.1m;
- Underneath the Made Ground, a glacial till layer is present and it can be described as 'Soft to Stiff light brown mottled grey sandy gravelly CLAY with occasional cobbles (Dublin Boulder Clay)'. This layer was encountered from depths of 0.5mBGL to 2.2mBGL during the investigation; and
- Underneath the brown sandy gravelly CLAY is 'very stiff grey to dark grey sandy gravelly CLAY with occasional boulders' (Dublin Boulder Clay). This layer was encountered from minimum depth of 2.2 and a maximum depth of 2.6mBGL; And
- Bedrock is LIMESTONE. The rotary core follow on boreholes encountered top of rock at a minimum depth of 9.0mBGL and a maximum depth of 18.5mBGL.

[3.3] Ground Model & Characteristic Soil Parameters

The table below presents the ground model adopted for the purposes of this assessment. This is considered a site-wide model which is a best representative model of the whole site and is considered appropriate for the type of assessment completed.

Table 3-1: Design Ground / Ground Model

Strata	Depth to Top (m)	Elevation to Top (m)	Thickness (m)
Made Ground	0	+ 20.8-18.2	0.5
Firm to Stiff Sandy Gravelly CLAY	0.5	+ 20.3-17.7	1.7
Stiff to Very Stiff Sandy Gravelly CLAY	2.2-2.6	+ 18.6-18.2	7-17
Bedrock	Expected circa 9.0 to 18.45	+11.45 -/+ 1.2	-

More detailed ground models may be used at detailed design stage and following the completion of the rotary core drilling (e.g. specific ground models and stratigraphy levels for wall design at a given elevation).

As noted above, for undertaking a ground movement assessment, the most important properties of the soil are vertical stiffness (E', E_u). A number of authors and publications present correlations relating stiffness of overconsolidated clays to undrained shear strength. CIRIA C760 presents correlations for drained and undrained stiffness modules with Jamiolkowski et al. (1979) and Stroud & Butler (1975) also proposing relationships of Eu/Cu and E'/Cu to Plasticity Index.

Relationships of E_u = 500-600 C_u have been used for undrained modulus with the drained modulus (E') taken as 60% of this value. For soils with PI less than 30, the E_u/C_u relationship can be as high as 1000. E_u = 500 C_u has been taken here as a conservative approach. E' = 2N (MPA) is typically considered for granular soils and has been attributed for the GRAVEL.

In addition to the standard correlations above, a number of papers, namely '*Retaining Walls in Dublin Boulder Clay, Ireland*' by Long, Brangan, Menkiti, Looby and Casey in which a detailed study of retaining walls in Dublin Boulder Clay was conducted (2013) and *'Geotechnical properties of Dublin Boulder Clay'* by Long and Menkiti (2007) were consulted in the selection of parameters for the firm to stiff Clays. Based on the above, the following characteristic soil parameters have been chosen for the various strata.

Table 3.2 Characteristic Soil Parameters

Strata	γ (kN/m^3)	SPT N Value	C_u (kPa)	E' (MPa)	E_u (MPa)
Made Ground	18	10	-	20	-
Soft/Firm to Stiff Sandy Gravelly CLAY	19	6-27	100	40	60
Very Stiff Sandy Gravelly CLAY	19	33-50	225	90	135

For the purposes of the ground movement analysis, rock has been considered incompressible.

[4] Hydrogeology

[4.1] Geology and Hydrogeology of Dublin

Limestone bedrock from the Carboniferous age (365-325 million years ago) underlie circa 65% of the island of Ireland. This part of Dublin city is underlain by the Lucan formation which is classified by the GSI as a Locally Important (LI) aquifer which is moderately productive in local zones only as shown in Figure 4-1 below. In general, permeability in the Lucan Formation is low (1m/day). The flow of groundwater in rock aquifers is dependent on the network of fractures and its properties such as density of fracture, direction, length, width and the connectivity between the network of fractures, Fractures length can vary accordingly from a few metres to hundreds of metres (Comte et al., 2012). When fractures are present in rocks it will change the flow pattern of groundwater because the water is trapped inside the fractures and hence it moves along the direction of the fracture and also fractured rock aquifer characteristics such as transmissivity and storage will differ greatly depending on the length and width of the fracture.

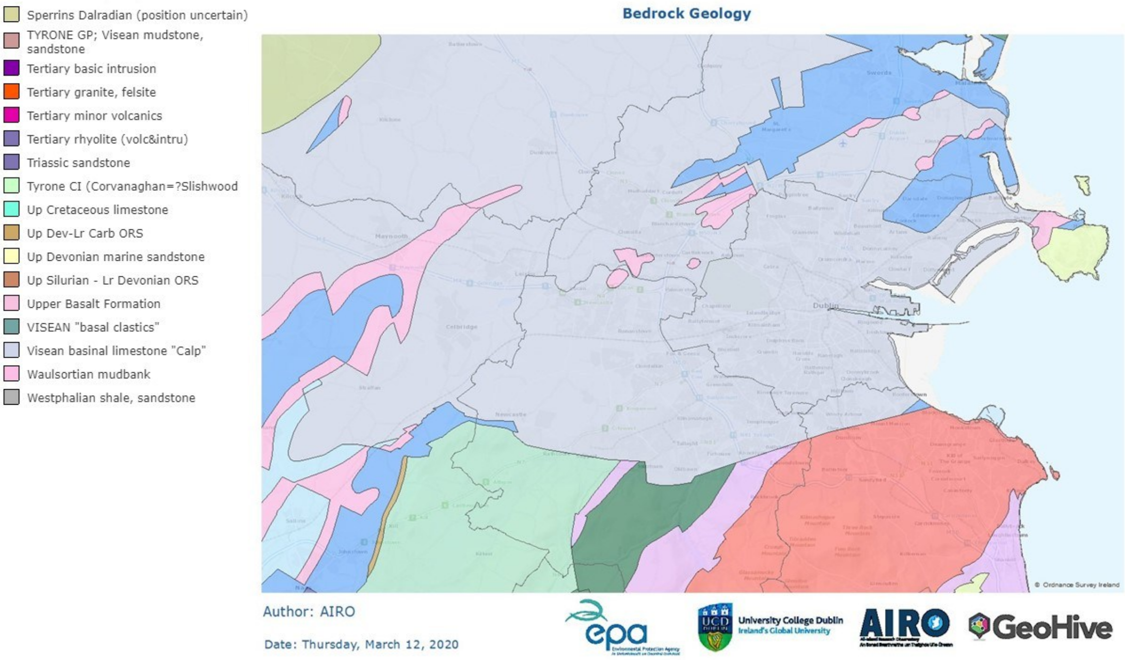

Figure 4-1: Bedrock Geology (Source: Geological Survey of Ireland)

Some 10,000 years ago, when a layer of ice of 1km thickness covered majority of the Leinster region, a low permeability lodgement till was formed at the base of this ice sheet due to the grinding action of the ice sheet on the bedrock. This layer of low permeability sandy gravelly clay (Dublin Boulder Clay) is present almost everywhere in the Dublin region and can range in thickness from 20m in some parts to being absent near the Heuston Station and Smithfield area. A layer of glacial-fluvial Sand and Gravel can be found in Dublin city along the channels/floodplains of the River Liffey, Dodder and Camac. In addition, some unconnected Sand and Gravel lenses can be found within the boulder clay, their lateral and vertical extent is also limited.

Groundwater flow in the bedrock is confined (artesian to semi-artesian) by the layer of low permeability clay present above it in the Dublin region. The boulder clay hence acts as a protective layer to the bedrock from surface activities such as contamination and oil spills and also limits the amount of rainfall that can end up recharging the groundwater in the bedrock (Misstear, Brown and Daly, 2009).

[4.2] Findings of Detailed Assessment For Former Metro North Station Boxes on Groundwater Levels

The impact of deep basements construction within the city centre of Dublin has not been studied/investigated thoroughly, however, a small number of major developments such as the former Metro North (also known as MetroLink today) were requested by An Bord Pleanala (ABP) to appoint a hydrogeologist to carry out a study on the potential impact of its proposed underground station boxes on surrounding groundwater flow and/or levels. The former alignment of Metro North passes within areas which had low permeability geology (Made Ground over Dublin Boulder Clay over Limestone bedrock) and it also crosses areas where there are layers of alluvial deposits above the Dublin Boulder Clay such as in Parnell Square area. The proposed underground station boxes for the Metro North had an average dimension of 25m deep, 30m wide and 165m long. Professor William Powrie from University of Southampton, UK was appointed to carry out the study and his conclusions were as follows:

1. Where basements are founded in Low permeability tills such as Sandy Gravelly CLAY (Dublin Boulder Clay), there are no impact on groundwater regime since it is evident that there is very little water flow in these low permeability horizons regardless of their porosity;

[4.3] Impact of the proposed development on the groundwater regime

The proposed basement is approximately 150m in length and 120m in width, the finished floor level for the basement of the development will be at circa 14.55-16.88mOD for the basement, the basement will be founded within the boulder clay. The construction of the basement will result in the excavation of the thin layers of Topsoil and Made Ground and about 3-4m of boulder clay. The boulder clay has very limited ability to transmit groundwater due to its low permeability characteristic and is an aquitard/aquiclude rather than an aquifer. Throughout the ground investigation, the vast majority of the cable percussion boreholes did not encounter groundwater strikes and where encountered it was within the boundary of the brown and dark grey boulder clay which is a known occurrence in the Dublin boulder clay.

The proposed basement is not likely to impede/block groundwater flow as it will be founded within the boulder clay

[4.4] Cumulative Impact of Nearby Basements

There are no new basements proposed within the immediate vicinity of the site. It is therefore concluded that groundwater flow impediment scenarios C1 and D1 illustrated in the DCC guidance document (see Figure 4-2) are not applicable and the likely scenario for this proposed basement is B1.

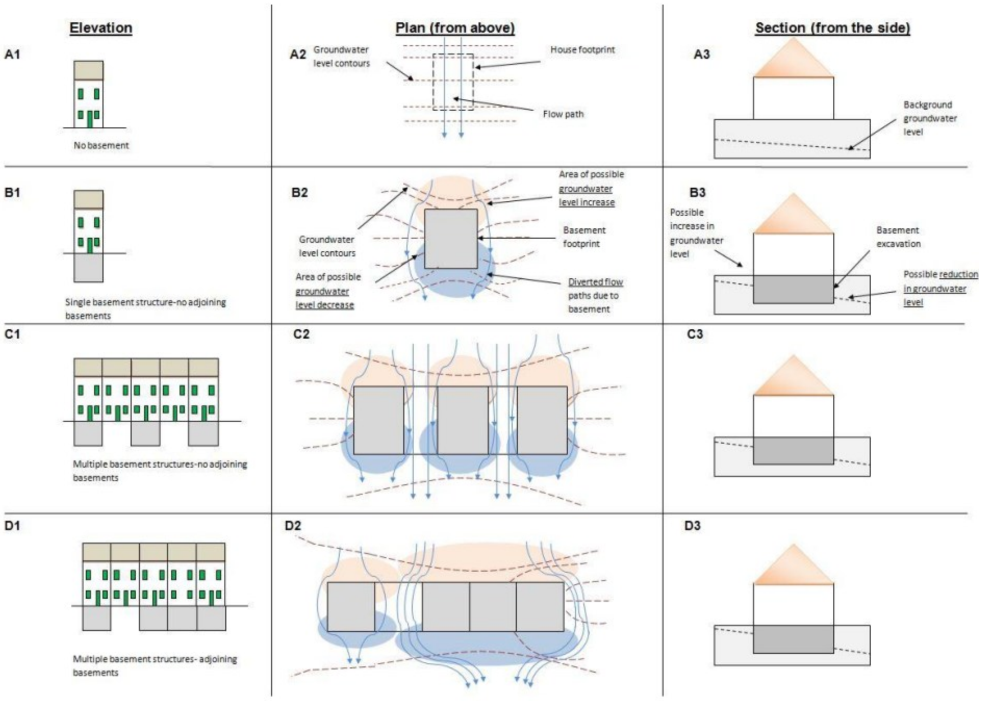

Figure 4-2: cumulative effects of basement construction on groundwater

[4.5] Temporary Groundwater control

During the basement excavation, pumping of water might be required to keep the excavation dry. The source of water will likely be surface water runoff accumulating within the excavation footprint, minimal pumping arrangement will suffice.

[5] Ground Movement Assessment

[5.1] Basis of Assessment

[5.1.1] Mechanisms Explored

Ayesa have completed a preliminary ground movement assessment associated with the proposed basement structure. The basement will be excavated to approx. 4.8m deep and will be formed on the stiff to very stiff CLAY strata. This assessment is considered preliminary. The following mechanisms of movements have been assessed:

1. <u>Ground Movements within Basement (Heave & Settlement)</u>

   The ground movements within the basement are as a result of the unloading on the formation soils that will generate ground movement, which could affect adjacent foundations. Stress relief will initially cause short-term heave following which the soils will be subject to structural loading from the substructure. This mechanism considers the existing stress conditions, stress and weight of soil removed and design loads from new structural slab and pad/strip foundations. Short-term movements (i.e. heave) are associated with undrained conditions. The long-term movements are associated with drained conditions.

2. <u>Ground Movements surrounding Basement</u>

   It is proposed to construct the basement using open cut excavation techniques. Ayesa have carried out an assessment of ground movements based on ground movements caused by the lateral deflection of an embedded retaining wall which are based on default values within CIRIA C760, which were derived from a number of historic case studies. No ground movements caused by the installation of the embedded retaining wall have been included in the assessment. As it is proposed to construct the basement using open cut techniques, the assessment is considered conservative. Around critical wall sections embedded retaining walls will be required. Along these elevations, ground movements from embedded retaining wall installation have also been included.

[5.1.2] Software Used

The assessment of ground movements within and surrounding the excavation has been undertaken using the X-Disp and P-Disp computer programs licensed from the OASYS suite of geotechnical modelling software. These programs are commonly used within the ground engineering industry and are considered to be appropriate tools for this analysis.

The analysis of potential ground movements within the excavation, as a result of unloading of the underlying soils, has been carried out using the Oasys P-Disp software package and is based on the assumption that the soils behave elastically, which provides a reasonable approximation to soil behaviour at small strains.

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

[5.2] Ground Movements within Basement (Heave)

[5.2.1] Input Information

The soils at formation level of the basement will be subject to stress relief during excavation, as approximately 4.8m of overburden is to be removed from the basement excavation. It is envisaged that the reduction in vertical stress in the short term will cause heave or elastic rebound to take place. Undrained soil parameters have been used to estimate the potential short-term movements, which include the “immediate” or elastic movements as a result of the basement excavation.

The subsequent reloading of the soils due to structural loading applied from pad/strip foundations is likely to give rise to potential settlement over the longer term. Drained parameters have been used to provide an estimate of the total long term movement.

As noted above, a vertical movement assessment has been undertaken using OASYS Limited PDisp analysis software. P-Disp assumes that the ground behaves as an elastic material under loading, with movements calculated based on the applied loads and the soil stiffness (E_u and E’) for each stratum.

P-Disp assumes perfectly flexible loaded areas and as such tends to overestimate movements in the centre of loaded areas and underestimate movements around the perimeter.

The following loading has been considered for the basement:

- As above the proposed excavation of the new basement will result in a maximum unloading stress reduction of approximately 96kN/m². An unloading value of 96kN/m² was taken as a representative to assess effects of short-term heave.
- To simplify the model a UDL of 350kN/m^2 has been applied across the full basement footprint, this has been derived from DBFL drawings which have outlined a column layout for a section of the building only. Based on this, the net pressure (i.e. loading minus uplift pressure) has been applied as 254kN/m^2.

For the purpose of this analyses, the basement ha been assumed as a box with the extremity corners defined by x and y coordinates.

[5.2.2] Results

The P-Disp (internal displacement) results have been summarised below for the long and short-term conditions.

<u>Short-term Conditions</u>

A contour plot showing the variation of short-term movement due to unloading across the basement footprint is presented in the figure below.

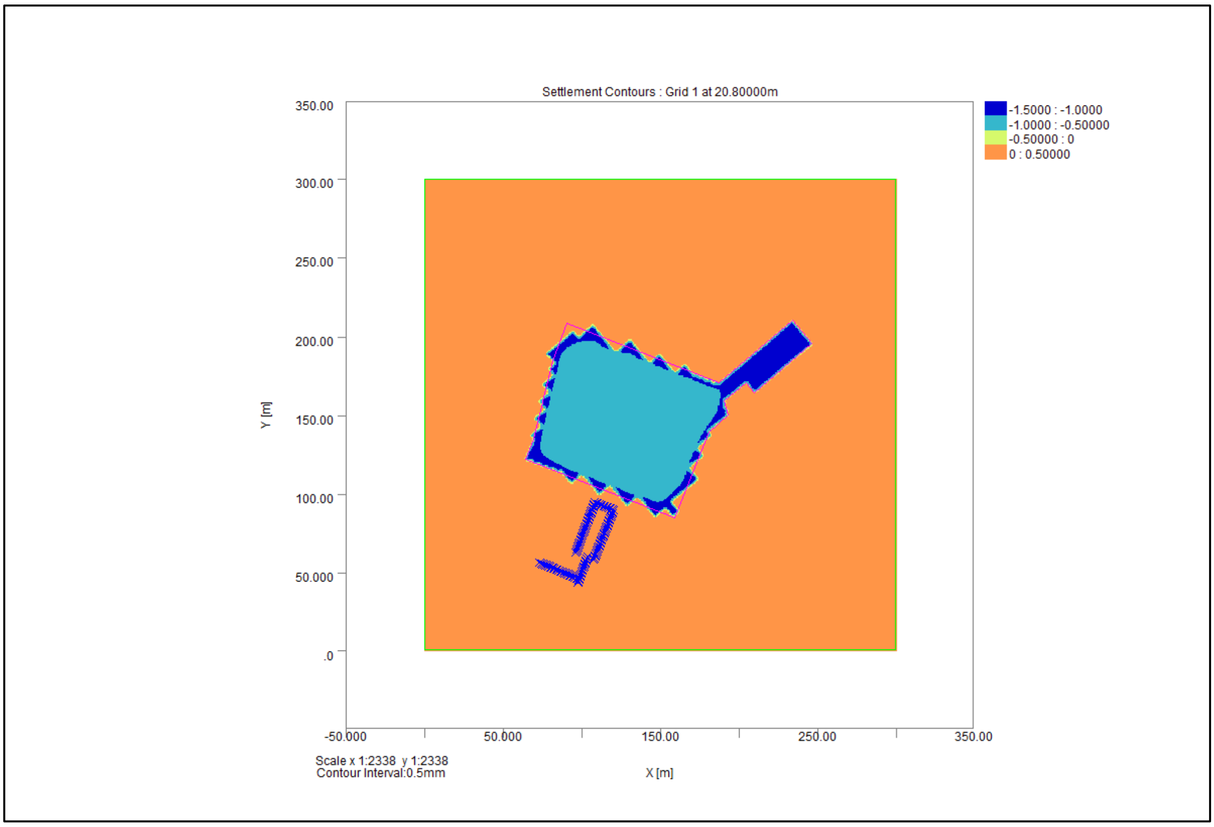

Figure 5-1: Short-term Ground Movement Contour Plot (Internal Movements)

The P-Disp analysis indicates that approximately up to 1.5mm of heave is likely to take place in the basement.

Long Term Conditions

For long term conditions, a net loading has been applied (i.e. unloading plus structural loading) with drained conditions. The results are shown in the Figure below.

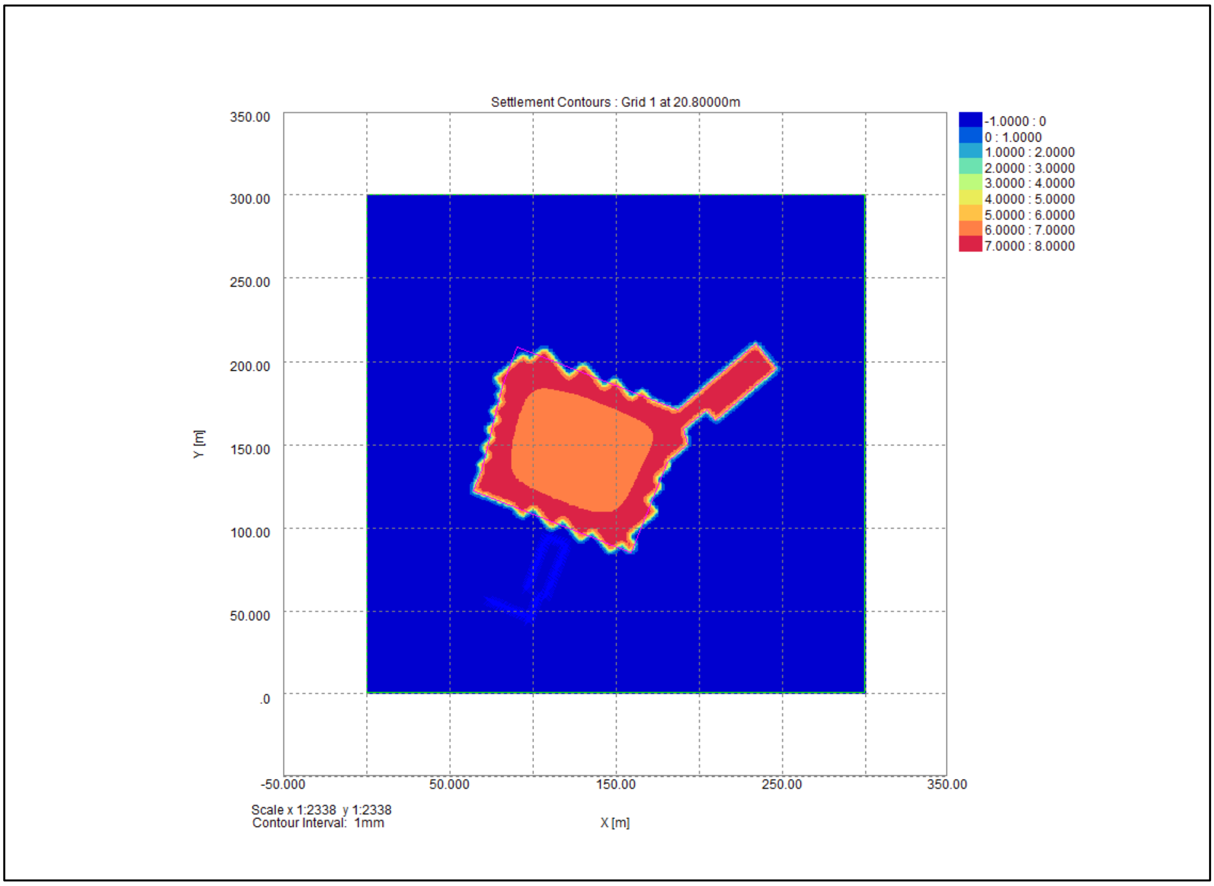

Figure 5-2: Long-term Ground Movement Contour Plot (Internal Movements)

As per the Figure above, the maximum predicted vertical settlement has been calculated as up to 8mm in the centre of the basement.

Ground movement associated with the basement excavation externally to the basement itself has been assessed in the section below.

[5.3] Ground Movements Surrounding Basement

[5.3.1] Input Information

For the X-Disp analysis, the ground movements used are the default values within CIRIA C760, which were derived from a number of historic case studies. Although, an open cut excavation is proposed to construct the basement, the ground movements curves for 'excavations in front of a low stiffness wall in stiff clay' have conservatively been used, as referenced in CIRIA C760. A number of sections have been modelled as an embedded retaining wall due to the proximity of adjacent buildings. The nearest adjacent structures assessed in the analysis are:

- Tabor House (Denoted Structure 'A')

All other nearby structures are considered outside the zone of influence from the site (i.e. a sufficient distance for the movements as a result of the proposed basement construction to reduce to negligible values) and as such, have not been included in the assessment.

The structures outlined above have been modelled as lines in the analysis and are the lines along which the damage assessment has been undertaken. These lines are expected to be sensitive at their foundation level, which have been taken as 0.55m bgl. The height of the structures has been estimated.

[5.3.2] Results

The ground movements used in the assessment are summarised in the table below which in turn have been used to complete a Damage Impact Assessment of the adjacent properties. As an open cut excavation is proposed to form the basement, the movements detailed in the table below are considered conservative.

The movements detailed in the table below are extreme values and occurred immediately behind the embedded retaining wall. It is important to note that they are not settlement or movement values at specific foundation locations. Movements generally decrease away from the embedded retaining wall with extrapolated values used for the Damage Impact Assessment (see Section 5.4).

Table 5.5-1: Results of Ground Movement Analysis

Phase of Works		Max Ground Surface Movement Immediately Adjacent to Wall	
		Vertical Movement (mm)	Horizontal Movement (mm)
Excavation Movements – Main Basement	Low Stiffness System*	17	19

** Movements have been based on CIRIA C760 Figure 6.15.*

A Damage Impact Assessment for the above movements with respect to the surrounding structures has been completed in the next section.

[5.4] Damage Impact Assessment

In addition to the above assessment of the likely movements that will result from the proposed development, a Damage Impact Assessment of the neighbouring structures has been completed based on the classifications given in Table of 6.4 of CIRIA report C760 (formally C580).

These classifications, which have been extracted and shown in the table below, are based on method of damage assessment outlined by Burland et al (1977), Boscardin and Cording (1989) and Burland (2001).

Table 5-2: Table 6.4 of CIRIA C760: Classification of visible damage to walls (after Burland et al, 1977, Boscardin and Cording, 1989, and Burland, 2001.

Category of damage	Description of typical damage (ease of repair is underlined)	Approximate crack width (mm)	Limiting tensile strain, ε_{lim} (%)
0 Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible	<0.1	0.0 to 0.05
1 Very slight	**Fine cracks that can easily be treated during normal decoration.** Perhaps isolated slight fracture in building. Cracks in external brickwork visible on inspection	<1	0.05 to 0.075
2 Slight	**Cracks easily filled. Redecoration probably required.** Several slight fractures showing inside of building. Cracks are visible externally and **some repointing may be required externally** to ensure weathertightness. Doors and windows may stick slightly.	<5	0.075 to 0.15
3 Moderate	**The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable lining. Repointing of external brickwork and possibly a small amount of brickwork to be replaced.** Doors and windows sticking. Service pipes may fracture. Weathertightness often impaired.	5 to 15 or a number of cracks >3	0.15 to 0.3
4 Severe	**Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows.** Windows and frames distorted, floor sloping noticeably. Walls leaning or bulging noticeably, some loss of bearing in beams. Services pipes disrupted.	15 to 25, but also depends on number of cracks	>0.3
5 Very severe	**This requires a major repair, involving partial or complete rebuilding.** Beams lose bearings, walls lean badly and require shoring. Windows broken with distortion. Danger of instability.	Usually >25, but depends on numbers of cracks	

The cumulative movements (Short Term Unloading and Excavation Movement) is shown in Figure 5-3.

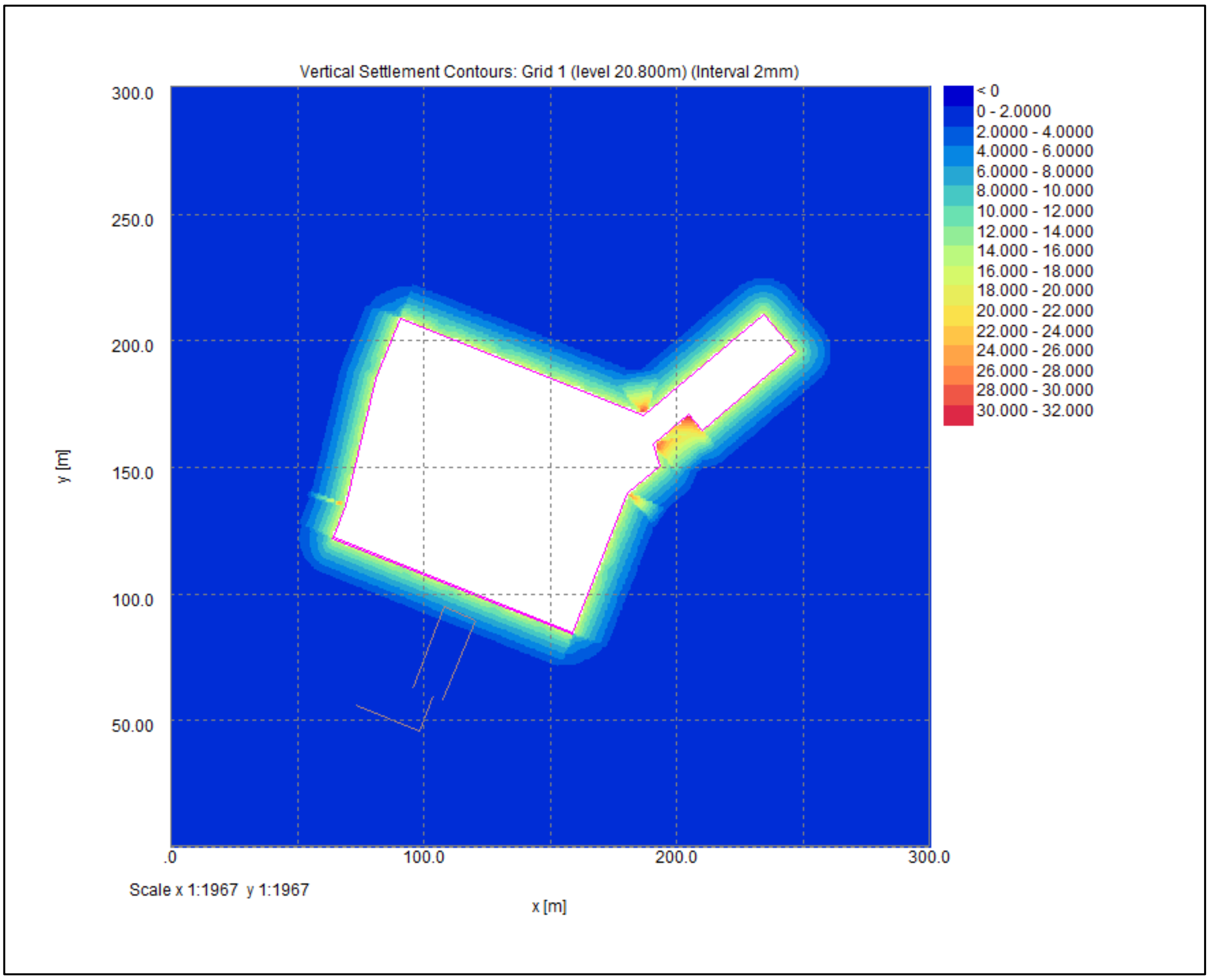

Figure 5-3: Cumulative Vertical Movement

The movements resulting from the excavation have been calculated using the X-Disp modelling software to carry out an assessment of the likely damage to adjacent structures and the results are summarised for the combined wall installation and basement excavation in the table below.

Table 5-3: Results of Damage Impact Assessment

Structure Ref	Structure Description	Elevation / Line	Category of Damage (Table 5.1 above)
A	Tabor House 1	A1	Category 2 – Slight.
	Tabor House 2	A2	Category 0 – Negligible.
	Tabor House 3	A3	Category 2 – Slight.

As shown in the table, Tabor House falls within a Category 2 – Slight Damage Category which, as per Table 5-3, equates to damage that is considered to be aesthetic and non structural.

This may be reduced to a Category 0 - Negligible should a localised high stiffness (propped) embedded retaining wall be constructed along this section. Due to the proximity of Tabor House, required working space and excavation depth at this section a temporary retaining wall may be required.

Alternatively, a monitoring programme may be implemented whereby target points are installed on Tabor House, with movements monitored and contingency measures implemented should movements exceed trigger levels.

[6] Conclusion

Ayesa have carried out a ground movement analysis to assess the impact of ground movements formed by the basement construction on adjacent structures. The only buildings considered within the zone of influence of the basement's construction is Tabor House to the south of the basement, which is a building located within the development. Based on the movements caused by the unloading of the formation soils, permanent structural loading and the excavation works, a damage category of slight has been calculated for Tabor House. The empirical ground movement curves have been based on 'excavations in front of a low stiffness wall in stiff clay'. This may be reduced to a damage category of negligible should a localised high stiffness (propped) embedded wall be constructed along this section. Alternatively, a monitoring programme may be implemented whereby movements are monitored and contingency measures implemented should movements exceed trigger levels.

Ayesa have also assessed the impact of the basement excavation and construction on the groundwater regime beneath and surrounding the site. The basement will be formed using the open cut excavation method (no embedded piled retaining wall needed) and will be founded within the boulder clay. The method of basement construction in conjunction with the geology within which it is to be founded indicate that the impact on groundwater will be negligible.