APPENDIX E

GEOTECHNICAL CONSULTING GROUP HYDROGEOLOGICAL REVIEW APRIL 2012
WJ GROUNDWATER LIMITED REPORT DATED APRIL 2012

For and on behalf of
GEOTECHNICAL CONSULTING GROUP

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KARWANA LTD

29 NEW END, LONDON NW3

Hydrogeological Review

April 2012

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Introduction

It is proposed to construct 17 private residential apartments on the existing site of the former Nurses accomodation at 29 New End, London NW3 1JD. This comprises the construction of a six level structure with a basement which is a single level at the front of the site. GCG has received an instruction from the developer, Karwana Ltd to undertake a review of the local hydrogeological conditions and the impact that the proposed basement may have on the flow of groundwater across the area.

This report reviews the available information about the site and the current scheme and sets down an outline of the design requirements for the development such that the property remains well-drained and that there would be no detrimental influence on neighbouring properties in respect of ground water.

GCG have been supplied with information by the Structural Engineering Consultant, Taylor Whalley Spyra (TWS).

This report has been prepared for Karwana Ltd in connection with the 29 New End project, taking into account particular instructions and requirements. It is not intended for, and should not be relied upon by, any third party.

The property and the proposed re-development

The site is located on the north side of New End, London NW3 (Fig. 1). It occupies a total area of approximately 40 metres by 60 metres, the longer axis being orientated south-north. An examination of historical maps shows that the existing building was constructed in the first half of the last century on ground that originally belonged to Christ Church, which is adjacent to the site to the north. On the other sides the site is bounded by New End to the south, 27 New End at the south west corner with Lawn House directly up hill of it and Christ Church passage to the east. Christchurch is situated at the north end of the site.

The ground levels fall across the site from around +120 mOD at the north end of the site to around +112 mOD on New End. The site lies on the SE side of the hill that is topped by Whitestone Pond at an elevation of around +132 mOD. The ground continues to fall towards the lower part of the Heath.

The current property on site comprises a "T-shaped" six-storied building at the front of the site. It steps up northwards following the ground level, and, as the ground rises, the site and Christchurch passage overlook the properties to the east. The ground floor level is +116.2 mOD at the front of the existing building.

Fig 2 shows a plan of the proposed basement and a section through the site from north to south. The proposed lower ground floor level is +110.03 mOD, with a ground floor level of +113.43m OD. This requires the retention of around 10 metres of ground at the rear of the site and 3 metres at the front. The current proposal is to construct the basement within a propped bored pile retaining wall.

Topography and geology

As described above, the site is on a gently sloping hillside.

The geology of the area is shown on the British Geological Survey 1:10560 sheet TQ28NE (Fig. 3a). The site is underlain by Bagshot Formation Sand overlaying Claygate Member and London Clay. A section through Hampstead Heath suggests that the base of the Bagshot Formation slopes down northwards (Fig.3b). In a record borehole located in close vicinity to the site (BH8 in Fig 3) the Bagshot Formation sand was found to be about 20 metres thick and the Claygate Member was found about 27 metres thick. The thickness of the London Clay underneath the Claygate Member was not proved, but the London Clay is shown to extend to at least about 62.5 metres below ground level.

The Bagshot Formation thins southwards and eastwards and the Claygate Member outcrops at about 800 metres to the east of the site. The level at which the Claygate Member outcrops, scaled from the geological maps appears to be at about +105 mOD. As the base of the Bagshot Formation deepens northwards, the level of the top of the Claygate Member at the site can be expected to be a few metres deeper.

The soils of the Lambeth Group underlay the London Clay at about -20 mOD and it is probably about 20 metres thick. About 10-15 meters of Thanet Sand underlay the Lambeth Group and Chalk is thought to be present at about -40 mOD.

A site investigation was carried out under instructions from TWS by MRH geotechnical. This comprised three boreholes to 20 metres and trial pits to expose existing foundations. A standpipe was installed in each of the boreholes to below the level of the observed water table. The location of the two boreholes is shown in Fig 4 and Fig 5 gives a marked up section through the two boreholes giving the descriptions of the soils encountered. Based on this it appears that the top of the Claygate Member is at around +100 mOD, i.e. some 10 metres below the base of the excavation.

Hydrogeological conditions and Geohazards

The area around Hampstead is surrounded by numerous springs, as shown in Figs 6 and 7 which have been taken from Barton (1962) and the 1922 British Geological Survey map. Springs of the Westbourne River are to the west, springs of the Tyburn River to the south, spring of the River Brent to the north and springs of the Fleet River run through Hampstead Heath to the east. Fig 7 shows a tributary of the Fleet River which runs approximately up Willow Road to below the site. These springs emanate from the spring line formed at the top of the Claygate Beds. There is no evidence of any streams near or across the site and none would be expected in the Bagshot

Formation.

The groundwater from this area drains into the catchment of the Fleet River, long since lost in its upper reaches, into which the water from the Hampstead Ponds drains. Thus it is not within the catchment of the Hampstead Ponds.

The London Clay acts as a barrier to flow between the lower (Chalk) aquifer and superficial groundwater. The water head in the Chalk was about -40 mOD in 1965, and has been rising since as the demand for water abstraction began to diminish after 1965; in 2010, the water level in the Chalk in the area of the site was approximately -10 mOD (see Figs. 8 and 9). The current policy, implemented by the Environment Agency, is to maintain water levels in the Chalk at about their present levels. Thus, the property is unlikely to be influenced directly by groundwater levels in the Chalk, even in the long-term. There are no known underground structures in the vicinity of the site that might indirectly induce local changes of water pressures in the London Clay, which could affect the development.

The geology of the area would suggests that there would be a perched groundwater level in the Bagshot Formation. This is confirmed by the observations in the standpipes as well as the presence of the wells and springs along the line of the postulated boundary between the Bagshot Formation and the Claygate Member below the site. It is noted that properties to the east of Christchurch passage, which are at a lower level, do not show signs of springs or seepage of groundwater. Some horizontal water flow is also expected to occur within the silt and sand lenses of the Claygate Member, although these should be well below the proposed basement level and therefore unaffected by the proposed development.

Taking the levels from the BGS map and the section it appears that the surface of the Claygate Member dips to the north, but this cannot be relied on. Water falling on the hill above the site clearly does accumulate in the Bagshot Formation and flows out to the south of the site. The water levels observed in the standpipes (at approximately +113 and +109 mOD) confirm that this is the case. However the levels are higher than would be expected and could be a result of water being trapped in local areas. It must be assumed however, that water is likely to be flowing across the site above the level of excavation

The proposed project includes the construction of a new basement under the front section of the site. The formation level of the new basement will be approximately +110 mOD, so it is possible that the basement will intercept the water currently flowing across the site. The basement will be wholly within the Bagshot Formation.

At the upper end of the site the current ground water levels suggest that the new basement will be some 4 to 5 metres below the level of the ground water if the water is flowing in the direction of the maximum gradient of the ground surface. At the front of the site the water level appears to be below the level of the basement. The installation of a bored pile wall will impede the flow of water across the site and may result in a rise in water level of the back of the wall unless measures are taken in both the short and long term to prevent this and lead the water back down below the basement at the front.

In order to excavate in the dry it will be necessary to provide a combination of measures to prevent water flow through the walls and pumping. It is currently envisaged that over the top half of the site a hard soft secant pile wall will be constructed with the soft piles extending sufficiently far to provide a flow restriction. Well pointing will be used inside the site to maintain a water level below the excavation level, or wells will be installed within the wall. At the front of the site the soft piles will only extend to the excavation level. Observation wells will be installed on the uphill side of the site in order to monitor the ground water levels and if necessary additional recharge or abstraction wells will be installed on the uphill side of the wall.

In the finished condition, depending on the observed behaviour during the construction, a long term ground water control system will be put in place to ensure that water continues to flow freely across the site.

Both the temporary and the permanent works issues with regard to the groundwater control are discussed in the attached report prepared by Dr.T. Roberts of WJ Groundwater Engineering and his comments on concerns raised by local residents. Work carried out recently by GCG, TWS and WJGE on nearby sites at Witanhurst and 5 Cannon Lane where ground conditions are almost identical and groundwater has been an issue have given confidence that groundwater can readily be controlled.

It is proposed to carry out further observations of ground water levels and perform permeability tests as part of the final design. However, it should be emphasised that it is highly unlikely that the potential changes in water levels both in the permanent and temporary condition will put any of the surrounding properties at risk due to increased moisture, stability or settlement. A further assessment will be carried out as part of the design development.

Land Drainage design requirements

Fig. 10 shows a section of the proposed basement showing the current proposals for the provision of a permanent drainage system behind and under the basement structure. This should provide adequate drainage to allow the re-establishment of the natural groundwater flow down-slope, to ensure that the property is well drained and to prevent any potential effects of water pressure on adjacent structures.

Summary and Conclusions

- The principal issue of concern is the presence of ground water within the upper sandy soils of the Bagshot Formation.
- The water flowing across the site is not in streams but is groundwater within the Bagshot Formation. Sufficient site investigation has been carried out on the site to establish the ground and groundwater conditions.
- The site is above the spring line which is seen at the base of the Bagshot Formation some 10 metres elevation below the site.
- The nearest recorded stream is the head of the Fleet River (long since lost) which is shown on old maps as more than 100 metres from the site. This river runs below the Hampstead Ponds and therefore the site is not within the catchment of the ponds.
- It will be necessary to control the flow of groundwater across the site in both temporary and permanent conditions. This can be safely achieved using well established methods. The design of the groundwater control system will be the subject of further testing to

establish the flow conditions and detailed design. Careful monitoring of groundwater will be carried out during construction.

- Recent work on comparable sites by the design team has increased knowledge and understanding of the groundwater conditions in these particular soils.

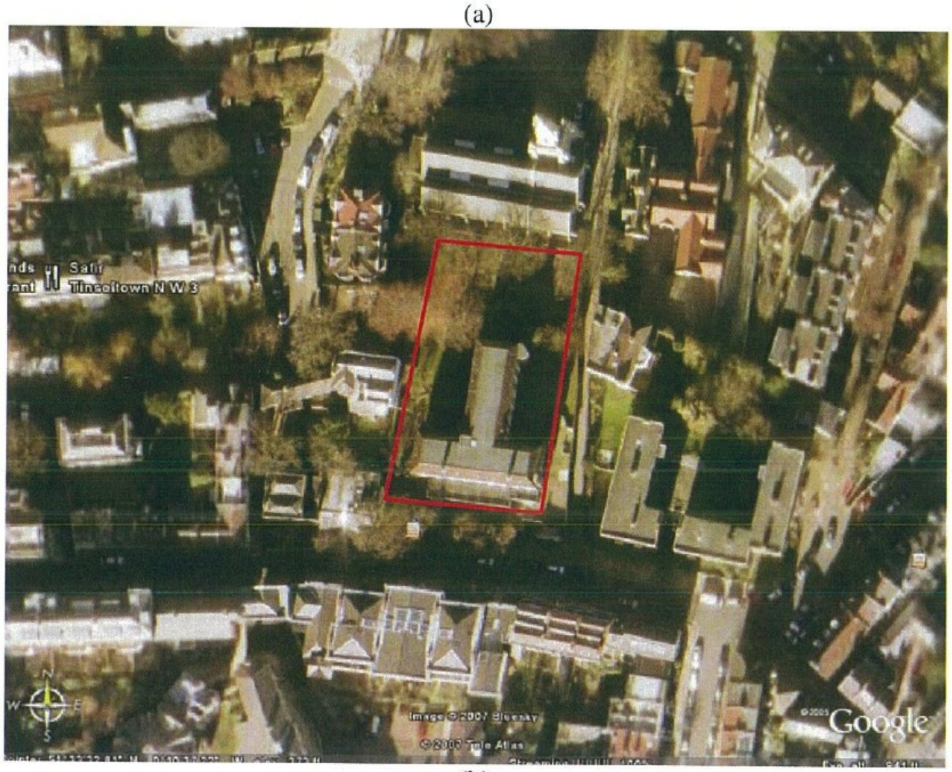
References :

Barton N. (1962): The Lost Rivers of London. Historical Publications Ltd

CIRIA Special Publication 69 (1989). The engineering implications of rising groundwater levels in the deep aquifer beneath London

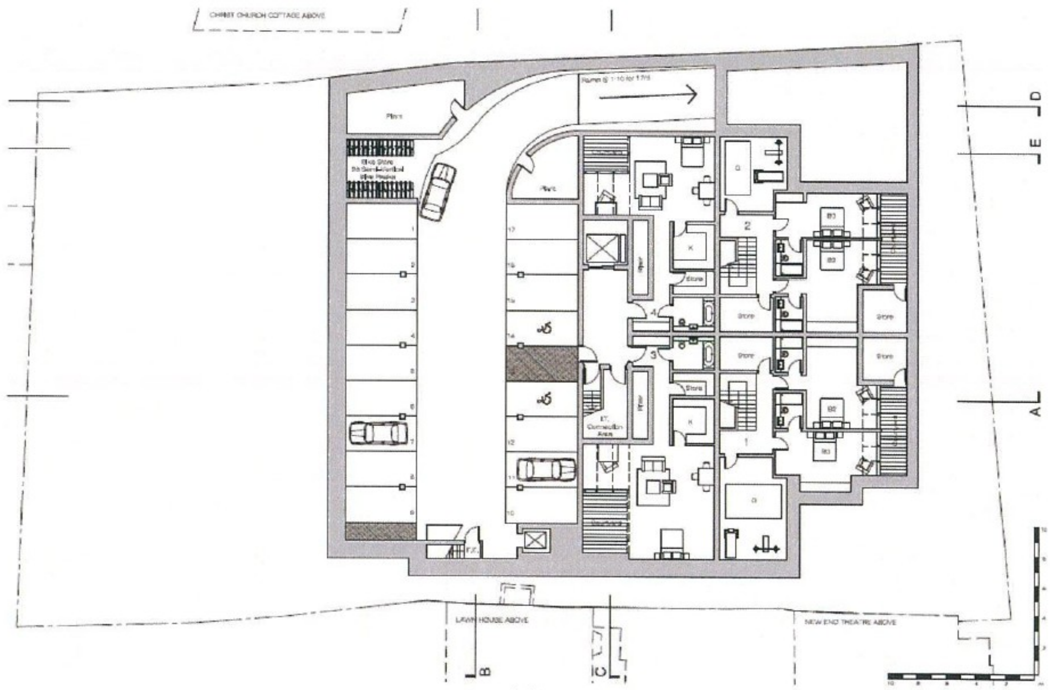
Environment Agency (2010): Management of the London Basin Chalk Aquifer.

(a)

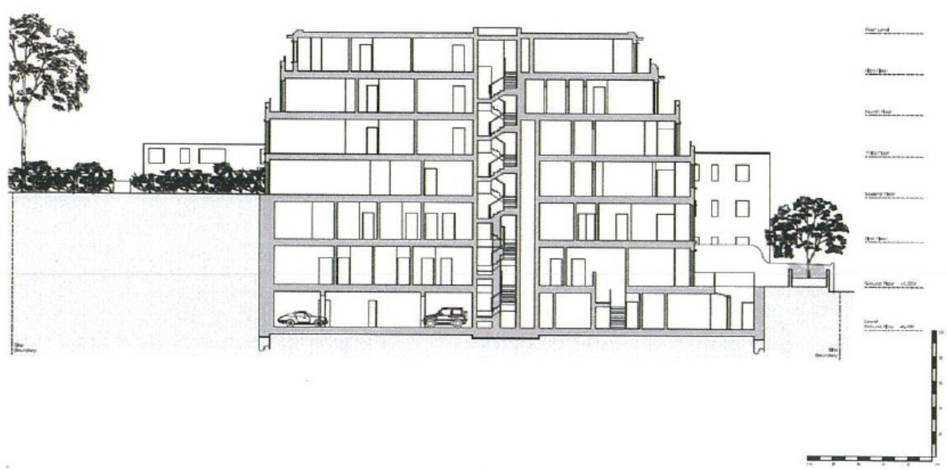


(b)

Figure 1: Site location, (a) street and (b) aerial view



(a)



(b)

Figure 2: Proposed basement: a) Plan b) North-South section

(a)

(b)

Figure 3: Geology of the area (a) extract from the British Geological Survey 1:10560 sheet TQ28NW; (b) section through Hempstead Heath

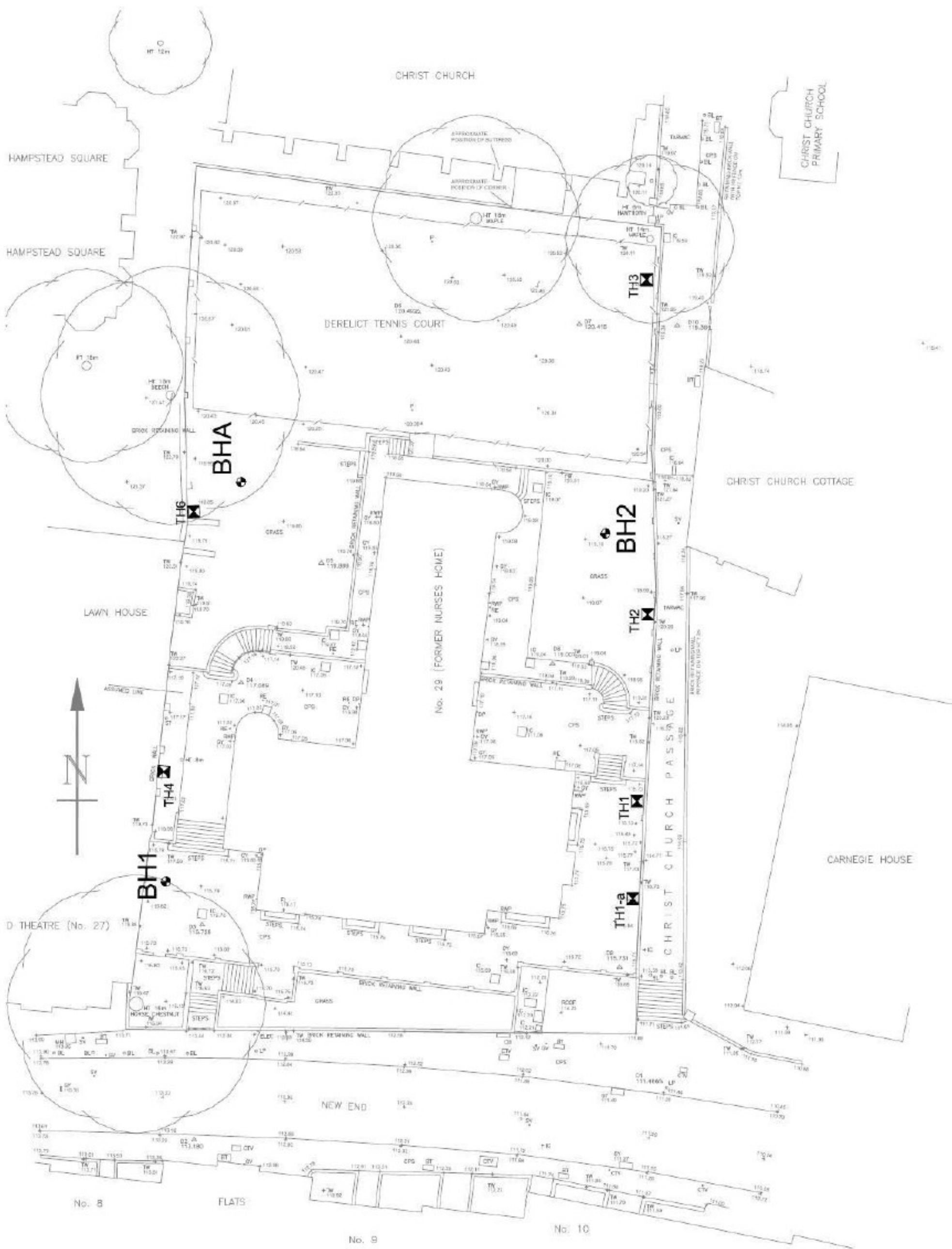


Fig 4: Site Investigation Plan, showing borehole locations

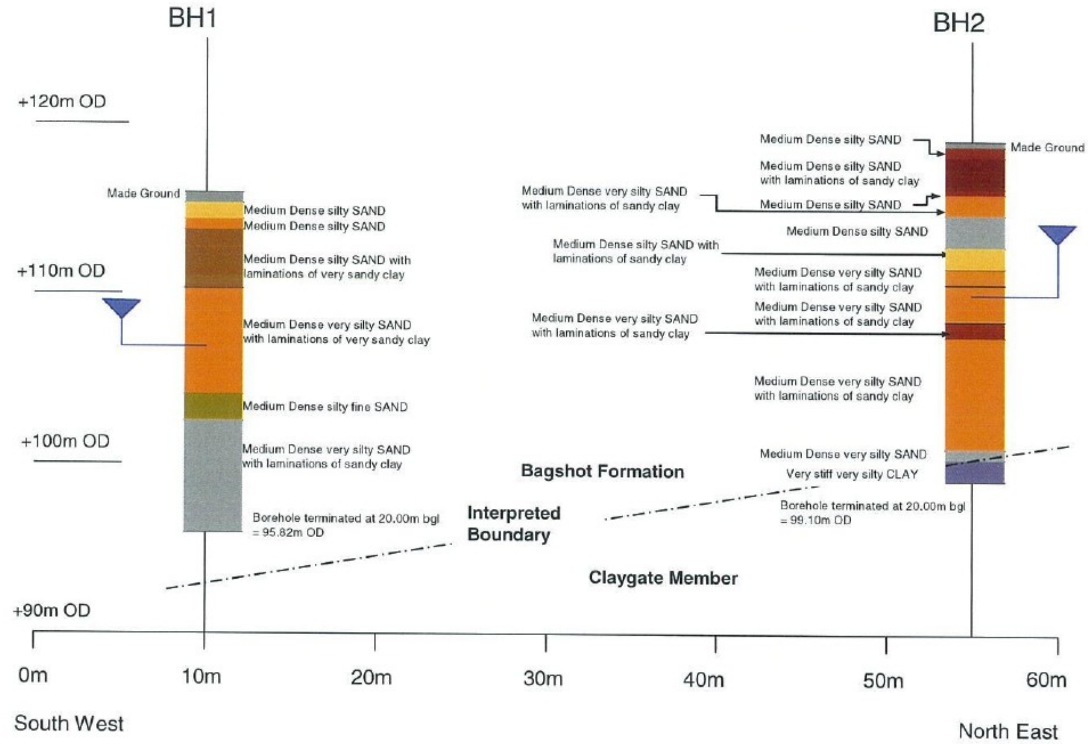


Figure 5: Section through SI boreholes

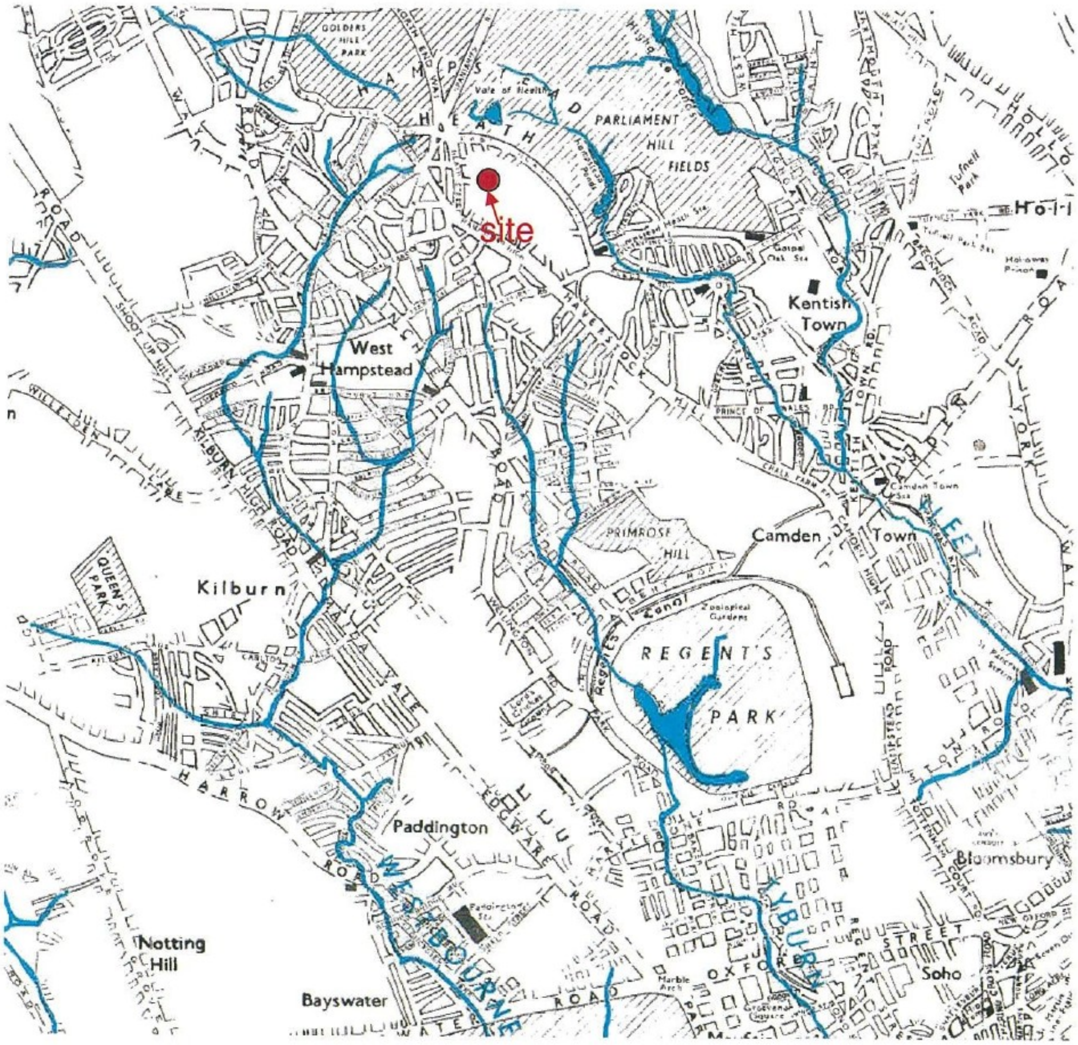


Figure 6: Extract from The Lost Rivers of London Map (Burton N., 1962)

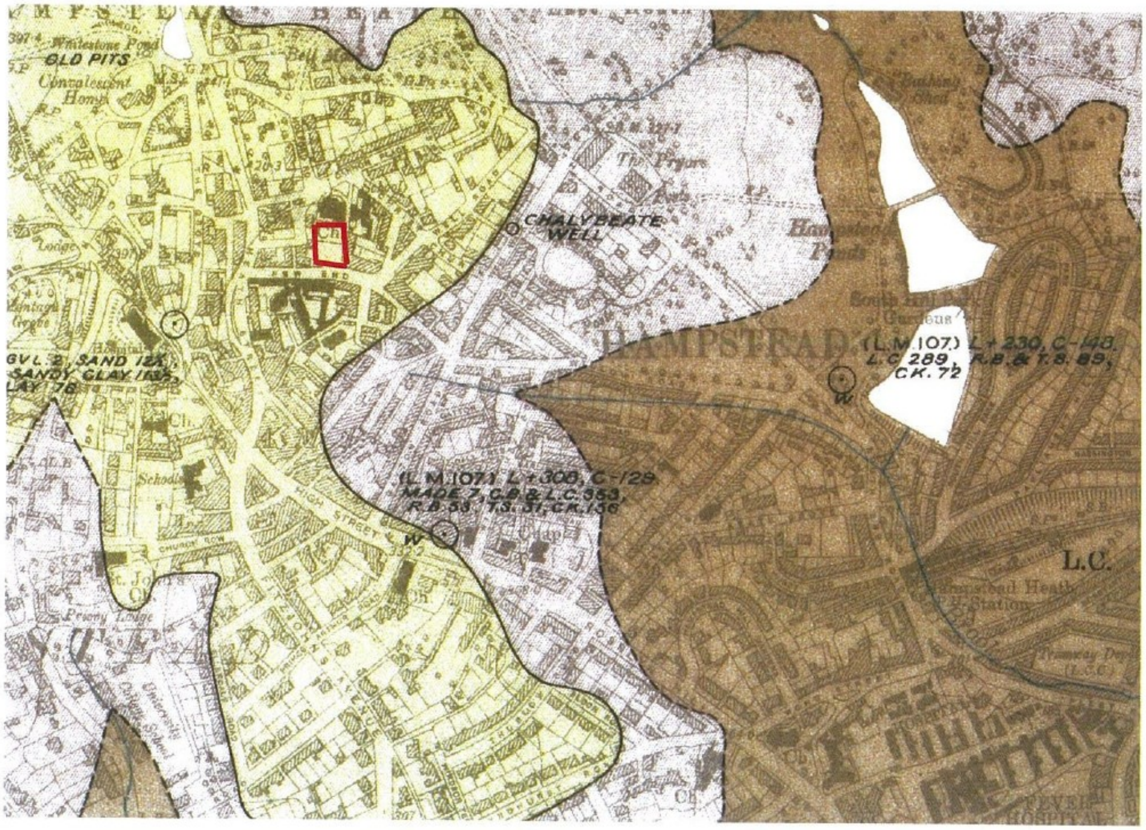


Figure 7: Extract from 1922 Geological map, showing spring rising from west of junction between New Road and Willow Road

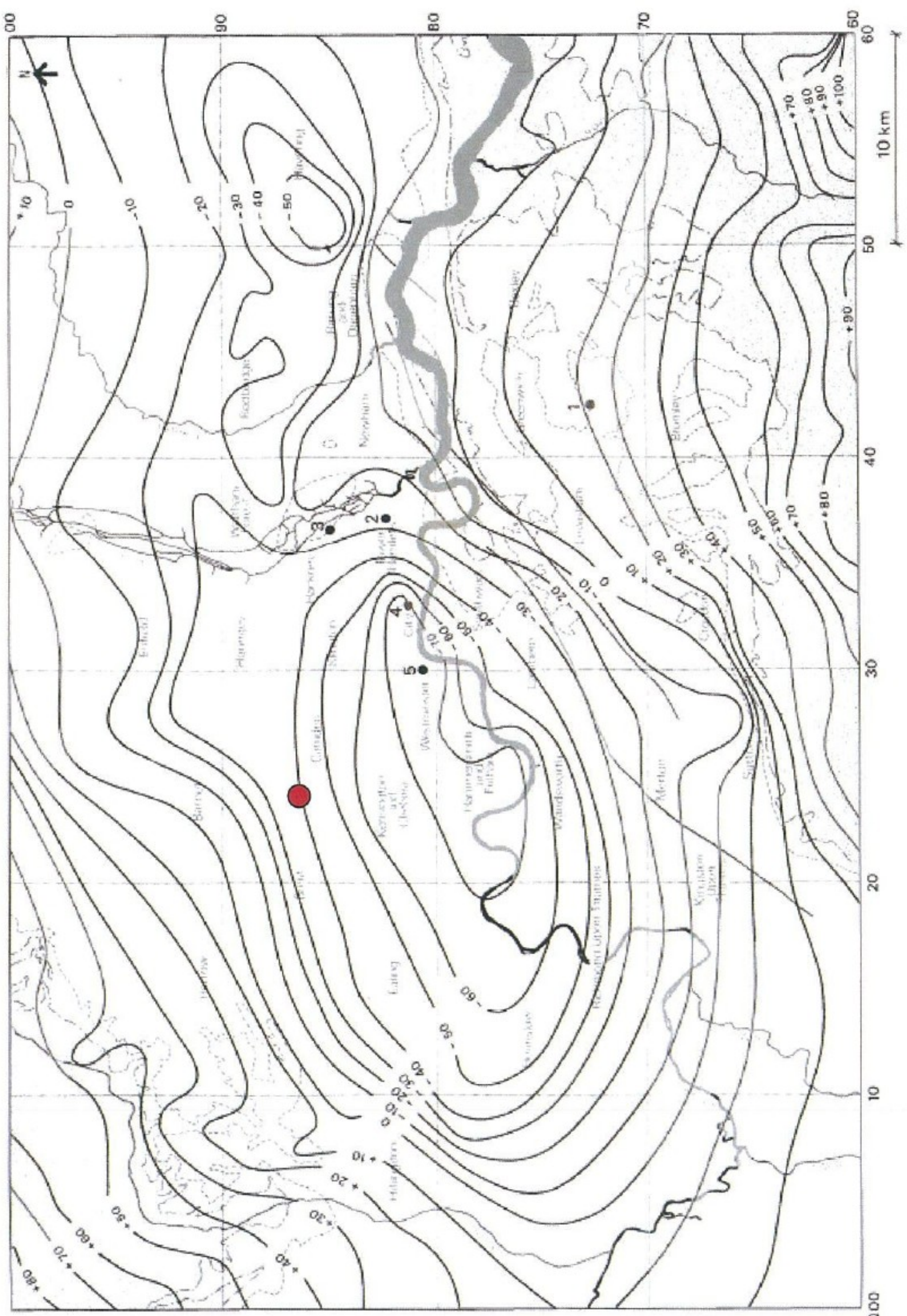


Figure 8: Groundwater levels in the deep aquifer in 1965 (CIRIA, 1989)

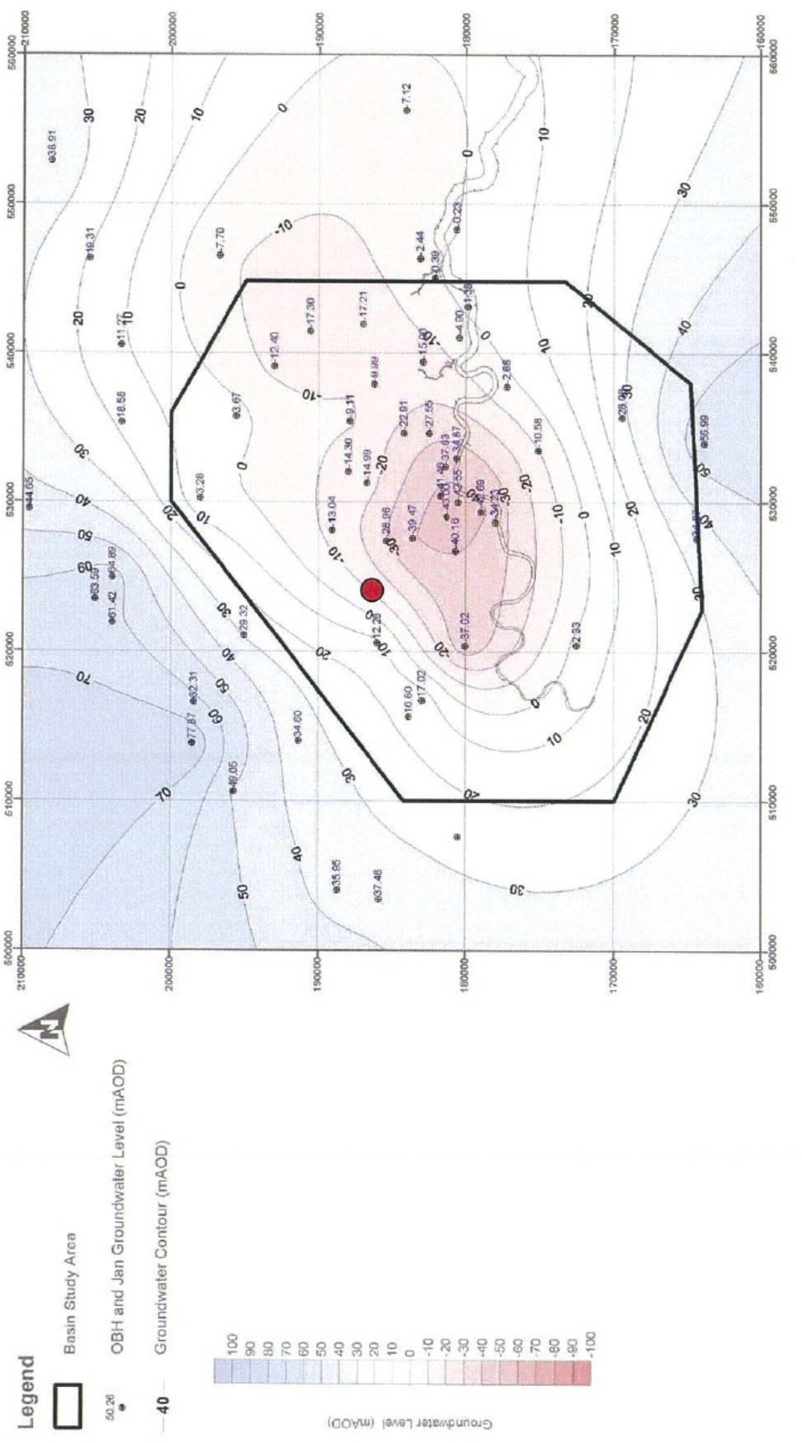


Figure 9: Groundwater levels in the deep aquifer in 2010 (Environment Agency)

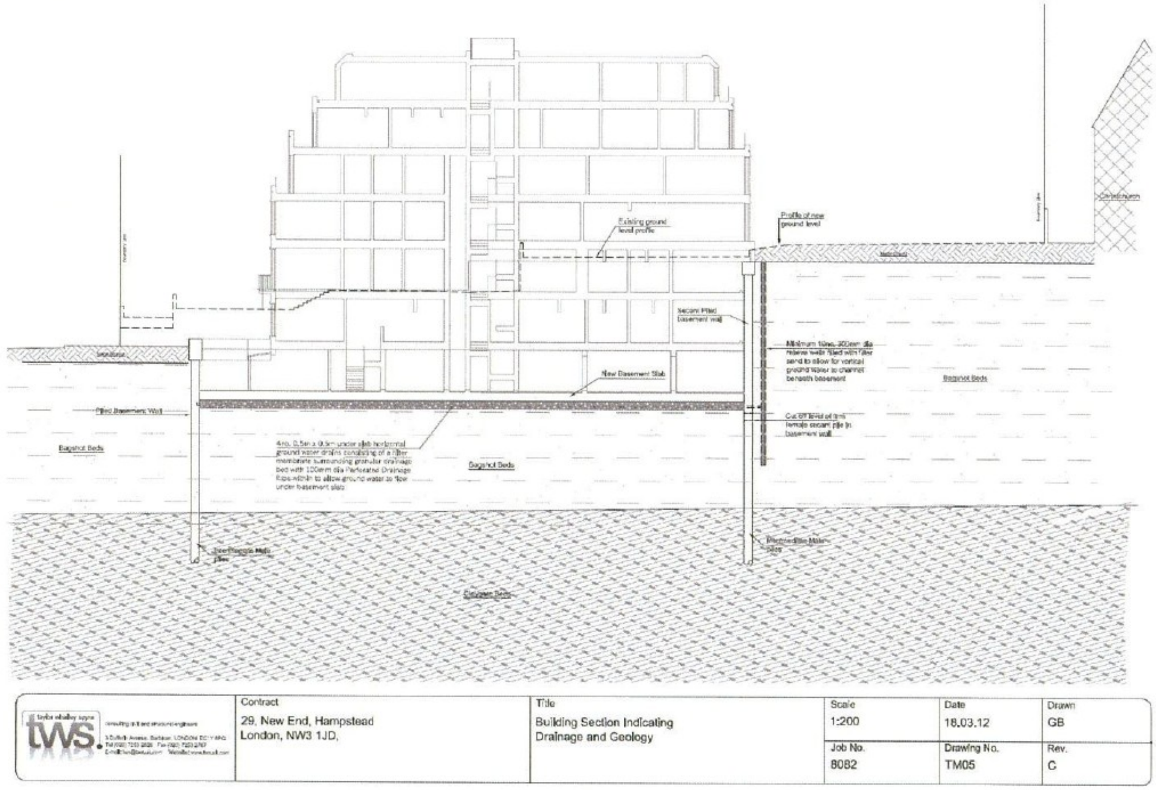


Figure 10: Section through basement, showing geology

WJ GROUNDWATER LIMITED

Groundwater control
Geotechnical instrumentation
Geothermal systems
Groundwater remediation
Pumping tests
Well drilling
Siphon drains for slope stability

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Re: **29 New End, Hampstead, London – Groundwater Management**

1. Background

The proposed redevelopment of 29 New End, Hampstead, London NW3 includes provision of a basement. There is a single basement at the front of the site with a retained height of 3 to 4 m but the site slopes significantly so that the retained height at the back of the basement is of the order of 10 m. Borehole and groundwater monitoring records indicate that the excavation for the basement will extend to below the standing groundwater level. This note considers the arrangements required for temporary control of groundwater levels during basement construction as well as the need for any groundwater flow mitigation measures for the permanent works. This note is based on the information listed in Section 7 below.

This note is concerned with the groundwater in the Bagshot Formation present at about 6 to 7 m below ground level. Groundwater is also present at depth in the lower aquifer (Thanet Sand and Chalk) below the London Clay but at a level well below the proposed works such that it will not impact the basement construction and is therefore not considered further in this note.

2. The Basement Works

The main contract works involves construction of a basement of approximate plan size 40 m by 35 m. Existing ground level slopes up from road level at 113 mOD at the front of the site to 120.5 mOD at the back of the site. The basement excavation formation level is at approximately 109 mOD (4 to 11.5 m depth). Side support will be provided by a pile retaining wall. Along the road front where the retained height is low and standing groundwater level is at or below dig level, side support will be provided by contiguous piles with a gap of approximately 150 mm between piles (assumed to be 600 mm diameter). For the upslope area a hard/soft secant pile retaining wall will be used which will provide a groundwater cut-off down to approximately 1 m below formation level (108 mOD). This level has been deliberately selected to minimise the impact of the permanent works on the groundwater flow below the basement. The hard piles will extend for several metres below this level (down to about 104 mOD).

3. Ground and Groundwater Conditions

Three boreholes have been undertaken at the site by MRH Geotechnical in July 2010 (BH1 and BH2) and January 2011 (BHA). Below superficial topsoil and made ground the boreholes indicate natural ground comprising silty sand with sandy clay laminations typical of the Bagshot Formation. One of the boreholes proved stiff clay at 18.8 m (about 100 mOD) which was interpreted to be the top of the underlying Claygate Member.

A standpipe piezometer was installed in each of the boreholes drilled at the site. Standing groundwater levels have been monitored as follows;

	BH1	BH2	BHA
Depth to groundwater	7.36 m July 2010	5.85 m July 2010	5.9 m January 2011
Ground Level	115.8 mOD	119.1 mOD	119.8 mOD
Groundwater level	108.4 mOD	113.3 mOD	113.9 mOD

We understand that recent groundwater monitoring has indicated that the groundwater levels indicated above are virtually unchanged. This implies relatively little seasonal fluctuation which is not unexpected in an urban setting such as Hampstead where infiltration from precipitation is curtailed by the combination of covering by housing, roads and pavement together with mains drainage. Leakage from water mains and to a lesser extent, sewers, has been found to be a significant source of infiltration in urban areas and these are less sensitive to seasonal effects. Also sewers below the standing groundwater level can act as drains and these together with shallow land drain measures which may be present in the area, can act to limit a rise in groundwater levels

BH2 and BHA are located close to the back of the basement and BH1 is at the front of the site near New End road. The above results indicate that the groundwater level falls across the basement from 113.9 at the back of the site down to below 108.5 mOD at the front of the site. The slope of the groundwater table roughly follows the original natural ground slope which is not perfectly aligned with the proposed basement being roughly 10 to 15 degrees West of North to East of South,

Based on the soil description and experience of works in similar conditions the horizontal permeability of the Bagshot Formation is likely to be in the range 10^{-5} to 10^{-6} m/s. The presence of the sandy clay laminations means that the vertical permeability is likely to be at least one order of magnitude lower than the horizontal permeability.

4. Temporary Groundwater Control

Groundwater levels will need to be lowered temporarily during basement construction to provide stable working conditions. The amount of reduction in the groundwater level varies from approximately 5.5 m where groundwater levels are highest at the back of the site, to no requirement where standing groundwater level is below basement dig level at the front of the site. Given the amount of drawdown required, the fine sandy nature of the substrata with potentially low vertical permeability, the need to preserve the integrity of the exposed formation and the importance of avoiding pumping of fines (which could otherwise lead to ground loss and settlement) some form of pumped well scheme will be required. This should be designed in accordance with the guidance given in CIRIA C515 (2000). Possible approaches include;

- Internal wellpoint scheme: Since the required drawdown is at or above the upper drawdown limit that can be achieved with a wellpoint scheme careful consideration will need to be given to the precise header main level. Also since the system will be installed within the foot print of the basement careful consideration will need to be given to the procedures for accommodating and sealing the wells through the base slab.
- External ejector well scheme: A wellpoint system has limited lift and so cannot be used externally because ground level is too high for such an arrangement to be viable. An alternative approach would be to use an ejector well system which does not have the same limitation on lift. However access for well installation to the sides of the site are constrained by the site boundary which will probably render this option non viable.

In practice dewatering should only be necessary along the back and sides of site as no reduction in groundwater level is required at the front of the site along New End. Permissions and consents will be required from the Environment Agency for temporary groundwater abstraction for dewatering and from the local sewer authority for discharge of the groundwater. Discharge from the dewatering system should be passed through a suitable tank to check that there is no evidence of persistent pumping of fines. This is likely to be a requirement for discharge consent in any case.

Note that lowering the groundwater level for the works will lead to a reduction in groundwater levels below adjacent property. The cut-off provided by the secant pile wall below dig level is limited and for the purposes of assessment of settlement it should be assumed that no cut-off is present. A conservative estimate of the amount of settlement can be determined by assuming that the full target reduction in groundwater level at the site is achieved below adjacent property. In practice the amount of drawdown will diminish with distance from the site and the guidance from CIRIA C515 (2000) suggests that the drawdown is likely to be negligible beyond 35 m of the basement works. The main area of drawdown is to either side and beyond the back of the basement where the maximum reduction in groundwater level is required.

5. Long Term Groundwater Management

The permanent basement structure extends into the groundwater table potentially providing a local barrier to the groundwater flow. The hydraulic gradient at the site is evidence of flow down hill from the back of the site towards New End road at the front of the site. In the absence of any mitigation measures there is the potential for groundwater levels to rise locally at the back of the site with a corresponding reduction in groundwater levels at the front of the site along New End. The basement and secant piles provide a reduction in the Bagshot Formation aquifer area across the width of the basement of over 50%. However in practice the rise in groundwater levels would be modest (almost certainly less than 1 m) because groundwater can readily flow around the new basement structure i.e. the cross sectional area reduction in the Bagshot Formation across the width of the hill side is relatively modest. Any rise in groundwater levels can be further mitigated by incorporating drainage measures around and below the basement to replace some of the blocked Bagshot Formation aquifer capacity. Horizontal drains can be installed below the base slab and vertical drains may be installed immediately up gradient of the basement. If we assume that the permeability of the drains is two orders of magnitude greater than the permeability of the formation then the required drain cross sectional area will need to be two orders of magnitude less than the area of aquifer blocked by the basement. The horizontal area blocked by the basement and piles can be estimated as follows;

- Basement width: 38 m
- Depth from groundwater level to base of soft secant pile cut-off: 113 to 108 mOD = 5 m
- Area reduction for soft secant piles: 190 m^2
- Hard secant piles below 108 mOD assumed to be 600 mm diameter at 750 mm centres with toe level at 104 mOD giving area reduction of 121.6 m^2.

- Total area reduction 312 m^2.

The cross sectional area of drains below the base slab (assuming drain permeability is 100 x Bagshot Formation Permeability) to give the same groundwater transmission capacity is then about 3.1 m^2. This would be equivalent to an 80 mm thick drainage blanket under the base slab across the whole basement. It may prove more practical to provide the capacity using under slab drains which incorporate a drainage pipe (to increase flow capacity) connected to cross drains at the back and front of the site (to promote good aquifer contact for inflow and outflow). A possible arrangement would then be 4 No. 0.5 by 0.5 drains incorporating a 100 mm perforated drainage pipe running from the back to the front of the site. These would connect to cross drains of the same size located at the front and back of the basement. The drains or drainage blanket should comprise free draining granular material surrounded by a geotextile filter. Providing connection between the internal wellpoint bores used for temporary groundwater control and the under slab permanent works drainage network would further improve aquifer connection capacity.

In addition to impeding horizontal groundwater flow the presence of the basement will also impede vertical flow to some extent. Assessing the area over which vertical flow is impeded is more subjective as the thickness of disrupted aquifer reduces appreciably down gradient. As a rough guide it would be reasonable to consider an area of half the basement or approximately 700 m^2. The vertical permeability of the Bagshot Beds is an order of magnitude less than the horizontal permeability and as much as three orders of magnitude less permeable than vertical borehole sand drains. This implies a need for a vertical drain cross sectional area of 0.7 m^2 or 10 No. 300 mm diameter boreholes. These should be installed along the up gradient end of the basement immediately outside the secant pile wall. The bores need to extend to approximately 5 m below the underside of the base slab (i.e. toe level at 104 mOD) to ensure effective inflow and outflow connection to the aquifer. The drains should comprise open bores filled with a suitable filter sand. It is essential that the bores are washed clear with clean water prior to filling with sand.

The flow rate through the soil area which will be occupied by the basement structure can be estimated using the equation Q = A k i (Darcy's law) where,

- A, is the cross sectional area of the basement structure which has been assessed as 312 m^2,
- k, is the permeability which has been estimated to be in the range 10^{-5} to 10^{-6} m/s'
- i, is the hydraulic gradient = distance/change in groundwater level from front to back of site; this is approximately 0.2 (from the change in water level and distance between the boreholes).

The computed flow rate is then in the range 0.22 to 2.2 m3/hr (3.7 to 37 l/min). This low rate of flow is a reflection of the low permeability of the Bagshot Beds and is well within the capacity of the proposed measures.

The detailed design for this scheme will require some further development in particular to consider the need for providing cross link connections between the under-slab drainage and the external vertical sand drains. The under-slab drainage is cut-off around the perimeter by the soft secant piles which extends to 1 m below formation level. The permeability of the natural ground may be sufficient but this would be investigated by undertaking a programme of numerical modelling. If the modelling indicated that there was a need for improving the cross link then this could be provided by one or both of the following;

- Connection of the temporary internal wellpoints into the under-slab drainage layer which would reduce reliance on the potentially low vertical permeability of the natural ground immediately below the under-slab drainage.
- Installation of near horizontal connection drains drilled through the cut-off wall at base slab level which link the vertical drains directly to the under slab drainage.

Any cross connections required would be installed during the period of temporary dewatering prior to base slab construction.

6. Conclusions

The proposed basement works will involve excavation below the standing groundwater level. A temporary groundwater control scheme will be required to reduce groundwater levels during construction. It is recommended that this is achieved with an internal wellpoint system. A correctly designed and installed wellpoint scheme will not pump fines which is important to avoid risk of ground loss and settlement. Consideration will need to be given to the impact of groundwater lowering below adjacent property which is in close proximity to each side of the proposed basement.

Once complete the basement structure will locally impede both horizontal and vertical groundwater flow. In the absence of mitigation measures this will result in a rise in groundwater levels up gradient and a fall in groundwater levels down gradient. The amount of rise will be modest (almost certainly less than 1 m) because groundwater can flow around the basement. Measures are proposed to mitigate against changes in groundwater level due to the presence of the basement. The proposed measures comprise under slab drainage and up gradient vertical sand drains.

7. Sources of Information

This report is based on the following information:

1. GCG Report, *29 New End Hampstead London NW3: Hydrogeological Review*, dated December 2010.
2. TWS drawings, *Construction Sequence of works: Stages 1 to 7*, ref 8082 CSW 01 to 07 dated 18 December 2010.
3. MRH Geotechnical Report, *Ground Investigation for 29 New End Hampstead London NW3 1JD*, ref 101206 dated July 2010.
4. MRH Geotechnical Report, *Ground Investigation for 29 New End Hampstead London NW3 1JD*, ref 101206/A dated January 2011.

8. References

1. CIRIA C515 (2000), *Groundwater Control: design and Practice*, Report Ref C515, CIRIA, London.

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WJ GROUNDWATER LTD