TECHNICAL NOTE – FINAL version 1.2
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Project No:	**30422**
Project:	**Maple Cross**
Document Ref:	**30422TN1 Maple Cross GW Flow Calculations**
Version:	**1.2**
Date:	**24/03/2020**
Status	**FINAL**

1 INTRODUCTION

A planning application for warehouse construction at a site on the western edge of Maple Cross Industrial Estate was refused, partly due to concerns over potential impacts on local public water supply (PWS) groundwater abstractions including:

- that piling could cause blocking of groundwater flow paths, thereby reducing flow to the PWS and creating an increase in drawdown at the PWS; or
- that piling could increase turbidity in fractures which could be transported to the PWS
- that dewatering at the site could affect drawdown or flows at the PWS

This technical note presents the results of preliminary calculations regarding groundwater flow, potential impacts of piling and dewatering, and effects of dilution at the PWS.

This draft document is intended to support discussions between Affinity Water and the applicant (and its agents and consultants) regarding the potential impact of piling on PWS abstractions and possible mitigation measures. The assumptions and conclusions within this document may change as more information comes to light. H Fraser Consulting Ltd has been contracted by Tier Consult Ltd on behalf of the applicant.

The following documents have been reviewed

- Mott MacDonald, 2014. Mid Colne and Lakes AMP5 National Environment Programme Final Report
- Vivendi Water Partnership, 2001. Downhole Inspection Report [redacted] Pumping Station Borehole Nos. 1, 2 and 3.
- Information has also been derived from third party site investigation reports in and around the application site, most notably ESI 2014 'Maple Lodge' (ref 62409D1).

1.1 Background

The site is located in the valley of the River Colne, an area heavily utilised for groundwater abstraction for public water supply (PWS). The valley is occupied by several lakes which were artificially created by gravel extraction, and also by the Grand Union Canal. Recovery tests have shown that the surface water and groundwater systems are linked, with surface water bodies variously showing responses to pumping/recovery from PWS boreholes.

The site location is shown in

Figure 1.1. The site lies approximately [redacted] from the [redacted], on the south-eastern edge of Springwell Lake.

[redacted]

Figure 1.1 Site location

Table 1.1 shows the geology in the environs of the site (ESI, 2014).

Table 1.1 Site Geology

Strata	Description
Topsoil	Typically 0.3 m thick
Made Ground	c.0.5 m thick, variably present
Alluvium	Typically <1 m thick although locally deeper, predominantly sand and gravel which with variable clay and peat
River Terrace deposits	Typically c.3 m thick and encountered between 0.5 m and 4.8 m bgl and comprised of medium dense to dense sand and gravel
Chalk bedrock	Encountered at depths below 2.8 m bgl and completely weathered to structureless putty in the upper sections (Dm grade) at depths up to circa 6 m bgl becoming weathered and clast supported (Dc grade) to depths of circa 11 m bgl with structured grade Chalk at greater depths.

Assuming a ground elevation of c. 42.62 m aOD (ESI, 2014), the surface of the putty chalk is at c. 39.82 m aOD, the surface of the weathered Chalk at c. 36.62 m aOD, and the surface of the structured Chalk at 31.62 m aOD.

Groundwater elevations at the site were estimated by ESI (2014) as around 42.05 m aOD.

Figure 1.2 shows the location of local PWS abstraction boreholes, and groundwater contours with flow directions superimposed. Groundwater flow below the site is to the southeast. Groundwater contours indicate that the [redacted] PWS is the only PWS in the flow path from the site. A branch of the River Colne and Springwell Lake lie between the site and the PWS. The groundwater gradient is estimated as 0.0029.

Groundwater flow in the Chalk aquifer is predominantly along fractures and fissures, with minimal movement of water through the porous matrix of the rock. The piling zone will be predominantly through superficial materials, putty chalk and unstructured chalk where flow features are likely to be far less developed, if at all. The superficial materials will transmit groundwater via primary permeability, and putty chalk is likely to be relatively impermeable.

[redacted]

[redacted]

1.2 Development plan and piling methods

The development plan is shown in Figure 1.3. The proposal is for two warehouse buildings with car parking and soft landscaping.

Figure 1.3 Development plan

There are two potential piling methods considered for the site:

- Displacement piles – a precast concrete rod (250 mm x 250 mm square) with a point driven with a hammer into the ground until the ground provides a certain resistance, which is determined by the number of hammer blows. The soils intercepted by the piles are pushed to the side. This is the preferred piling method.

- Continuous flight auger (CFA) pile – a hole is augered to a pre-set depth using hollow stem flight auger. Wet concrete is placed through the hollow stem as the auger is withdrawn. The soils intercepted by the augur are brought to surface by the auger flights.

Piles will be on an approximate 2.5 m to 3 m grid across the footprint of the buildings. There will also be clusters of 3 or 4 piles at between 7.5 m and 8 m centres along the edges of the buildings (the foundation lines).

The piles will be driven to between 12 m depth. Assuming a site datum of 42.62 m aOD gives the maximum depth of piling as 30.62 m aOD.

1.3 [redacted] PWS abstractions

The [redacted] PWS comprises three boreholes. Figure 1.4 shows the pumping record from June 2017 until August 2019 at [redacted] PWS. It can be seen that pumping rates are variable, between [redacted] The periods of sustained high pumping rates are in the summer months, with lower or zero pumping rates during winter months. The average daily abstraction during the period was [redacted]

[redacted]

Figure 1.4 Pumping at [redacted] PWS

The [redacted] report presents borehole logging information [redacted] Key features from CCTV surveys are presented in Table 1.2 below.

Table 1.2 Depth and elevation of key flow features in boreholes

Borehole	Depth (m)	Elevation (m OD)	Feature
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]			
	[redacted]		
	[redacted]	[redacted]	[redacted]

Borehole	Depth (m)	Elevation (m OD)	Feature
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]

*n.b. piling zone depth is 12 m bgl and 30.62 m aOD

It is noted that:

- The boreholes are cased to between [redacted].
- [redacted]

1.4 Dewatering

Dewatering will not be required for most of the construction elements of the project. However, dewatering will be required to excavate a void for a storm water drainage tank. The maximum depth of dewatering will be 3.5 m, and it is thought unlikely to impact significantly on the PWS. Further work can be done to quantify this, but in any case mitigation could easily be achieved by minimising dewatering drawdown methods (e.g. sheet piling) and/or re-injection of effluent.

1.5 Turbidity

Turbidity is the opacity of water due to suspended solids. It is measured using a nephelometer, which measures how much light is scattered as it passes through a sample. Figure 1.5 shows samples of water with known turbidity. The drinking water standard is 1 NTU (Nephelometric Turbidity Unit). It is understood that the Affinity Water PWS abstractions have automatic turbidity sensors, and that the abstractions automatically shut off if turbidity is measured at 1 NTU. The treatment for turbidity is to pump the borehole to waste until turbidity reduces, or in cases where turbidity is persistent, to cease abstraction for a period of time.

Figure 1.5 Turbidity standards of 5, 50 and 500 NTU (from Wikipedia).

1.6 Groundwater flow calculations

Groundwater flow through ground affected by piling at the site (Q_{site} in m^3/d) has been roughly estimated as follows:

Transmissivity (*T*) over 60 m depth of aquifer is 2654 m^2/d (Mott MacDonald, 2014) giving a permeability (*K*) of 44 m/d. The hydraulic gradient (*i*) is estimated as 1 in 350 or 0.0029, and the cross-sectional area of piled ground (*A*) through which groundwater flows is estimated as 12 m (depth) by 201 m (width perpendicular to groundwater flow direction), or 2412 m^2.

$$Q_{site} = KiA$$

$$= 44*0.0029*2412$$

$$= 305\ m^3/d$$

The average daily abstraction (ADA) at [redacted] PWS was [redacted] for the period shown in Figure 1.4. The maximum daily abstraction (MDA) for this period was [redacted]. The flow through the piled ground is therefore estimated as 4.5 % of the recent average daily abstraction, or 1.8 % of the recent MDA (n.b. not all of the groundwater flowing through the site may be captured by the PWS, depending on pumping rates and the connectivity of fracture networks).

1.7 Potential impacts of piling on groundwater flow

For the displacement piles, it is estimated that 10% of the cross-sectional area for groundwater flow through the piled area is replaced with concrete. This might mean that [redacted] of groundwater flow ([redacted] Ml/d) would be diverted around the subsurface structures, taking longer to reach the PWS. This represents [redacted] of the ADA and [redacted] of the MDA. This volume would not be derogated from the supply, but slowed down compared to the unpiled scenario. The impact on drawdown in the PWS boreholes is likely to be negligible.

It is unclear to what extent the upper unstructured chalk contributes to flow in the boreholes, which is likely to be dominated by horizontal and sub horizontal flow features at depths below the piling zone depth. If it is assumed that only 20% of the flow from the piling zone is abstracted from the PWS boreholes, then the quantity of flow from the site to the borehole that is slowed down due to piling is estimated as between [redacted] of the PWS abstraction. (It is noted that this is a simplistic assumption, but raises the question of to what extent flow to the boreholes is dominated by deeper features such as the adits).

If CFA piles were used, this could result in wet concrete escaping to fractures in the chalk. The effect on permeability reduction is likely to be more marked than for displacement piles. Potential effects are more difficult to predict than for displacement piles, as they would depend on the geometry of concrete escape through fractures, and the extent to which fractures were blocked. Based on the above calculations, and assuming an effect double that for displacement piles, a ballpark estimate of the volume of groundwater flow slowed down by piling is between [redacted] from the piling zone is abstracted at the PWS, and [redacted] if all the flow from the piling zone is captured at the PWS).

1.8 Groundwater velocities and travel times for contaminants

Using a hydraulic conductivity (*K*) of 44 m/d and a hydraulic gradient of 0.0029, the Darcy velocity is calculated as

$$q = Ki$$

$$=0.13 \text{ m/d}$$

Conservatively assuming a porosity (ϕ) of 0.1%, the contaminant velocity (v) is calculated as

$$v = q/\phi$$

$$=1.3 \text{ m/d}$$

The distance (*x*) from the site to the PWS is 450 m. The travel time from the site to the PWS is calculated as

$$t = x/v$$

$$=356 \text{ days}$$

$$=\text{c. 1 year}$$

It is acknowledged that flow on high velocity fractures may be significantly quicker, however, it is unlikely that the piling zone, which is dominated by superficial materials, putty chalk and unstructured chalk, will be dominated by such features.

1.9 Dilution factors

The flow from the site that contributes to the PWS abstraction (Q_{site}) has been estimated as between [redacted] Ml/d (if only 20 % of flow through the piling zone is captured by the PWS) and [redacted] (if all flow through the piling zone is captured by the PWS). The abstraction rate at the PWS (Q_{abs})is estimated as between the average daily abstraction ([redacted] Ml/d) and the peak licenced volume ([redacted] Ml/d). A dilution factor DF can be calculated as

$$DF = Q_{abs}/Q_{site}$$

Using the range of Q_{abs} and Q_{site} discussed above gives a range of dilution factors between [redacted] and [redacted]. If it is considered that a small proportion of the piling zone will be piled at any one time, and the effects are likely to be short-lived, Q_{site} might be considered to be a tenth of these estimates, and the dilution factor would then be between [redacted] and [redacted].

1.10 Potential impacts on turbidity

There is little quantitative information on the effects of piling on turbidity in the Chalk aquifer. Conceptually, it is recognised that piling might induce turbidity by the action of disturbing the chalk matrix and creating a suspension of fine sediment in the groundwater, however it is not clear whether this would create a measurable effect at distance from the site.

In terms of whether one piling method might create more turbidity than another, CFA piling is perhaps more aggressive in moving the chalk solids, but displacement piling pushes chalk solids into the surrounding matrix rather than removing them from the aquifer.

Whichever method is used, the creation of turbidity would be mitigated as follows:

- The piles are predominantly pushed through superficial materials, putty chalk and unstructured chalk which will not have the well-developed open fractures of the structured chalk; turbidity created is less likely therefore to be entrained in the active fast flow fracture network connected to the PWS

- The effects of turbidity creation would be temporary, although how long turbidity might persist for is not known at present
- Only a fraction of the piling zone will be actively piled at any one time, and the quantity of flow through the piling zone that is affected by turbidity is likely to be far less than the Q_{site} estimated above
- The travel time from the site to the PWS boreholes may not be particularly quick, particularly in the unstructured chalk and overlying material
- Dilution at the borehole is likely to be significant
- The timing of the piling operation could be arranged to a period when the PWS was not actively pumping to minimise capture of groundwater from the site, or at a time of the highest pumping rates to promote dilution at the borehole.

2 CONCLUSIONS

The following conclusions are drawn from this preliminary assessment:

- [redacted] PWS has been identified as the primary receptor of concern. Other PWS may become receptors when [redacted] PWS is inactive, and further consideration will be given to this in due course
- [redacted] PWS is known to have connectivity with the surface water system, indicating that there are other sources of potentially significant turbidity within the local system. Background turbidity and the range of turbidity at the PWS is not known at this point
- The effects of dewatering to 3.5 m bgl during construction are considered likely to be minimal and/or easily mitigated. Further work will be undertaken to quantify this.
- Groundwater flow from the piling zone is estimated as [redacted] Ml/d which is [redacted] % of average daily abstraction and [redacted] of maximum daily abstraction (2017 – present).
- The effects of displacement piling on flow might be to divert [redacted] Ml/d around the subsurface structures, which is [redacted] % of the ADA and [redacted] % of the MDA. The impact on drawdown in the PWS boreholes is likely to be negligible. CFA piling carries higher risks of permeability reduction due to placement of wet concrete in potential fractures.
- Travel times between the site and the PWS have been estimated at around 1 year. Travel times may be much quicker on fast flowing fractures, but these are thought unlikely to dominate the piling zone which is predominantly unstructured chalk.
- Dilution factors have been calculated as between [redacted] and [redacted], but are likely to be significantly higher if the effects of turbidity can be shown to be short lived and the active piling area small.
- If groundwater flow to the PWS is dominated by flow on deep horizontal flow features below the piling zone, as suggested by borehole logs, then impacts on flow and turbidity are likely to be minimal.
- The timing of the piling operation could be arranged to beneficially coincide with a period of zero pumping at the PWS, to minimise capture of groundwater from the site, or high pumping rates to maximise dilution.

The following further information would be useful to further inform the assessment:

- Literature search on piling and turbidity on Chalk aquifers
- SPZ reports from the Environment Agency
- Quantification of the contribution of surface water to the [redacted] PWS
- Background turbidity and range of turbidity in the [redacted] PWS abstractions.

- Consideration of whether turbidity caused by piling could be distinguished from turbidity from other sources
- The drawdown in the PWS boreholes during pumping
- The proportion of flow from deeper flow features such as the adits
- The groundwater flow characteristics of the unstructured chalk and the connectivity with the PWS boreholes
- The likely longevity of turbidity

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