Memorandum

ARUP

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Geotechnical Input for D2015/1049 Condition 39 – Department of Primary Industries Conditions

1 Introduction

This memo has been prepared to present the findings of the groundwater assessment and management strategy for the proposed development at 1 Alfred Street, Sydney.

This memo provides:

- Discussion of the groundwater monitoring undertaken during the field investigation in 2015;
- Development of a groundwater model for the site;
- Assessment of likely sources and rates of groundwater inflow to the basement during construction and the long term and confirmation that the resultant inflows can be classified as having a minimal impact according to Section 3.3 of the NSW Aquifer Interference Policy and therefore no Aquifer Interference Approval is required under Section 91 of the Water Management Act 2000;
- A Water Licence is not required as the expected inflows are less than 3ML per year;
- Recommendation for potential management strategies of inflow to the basement during construction and the long term.

2 The site

The site is located at 1 Alfred Street, bounded by George Street, Herald Square and Pitt Street to the west, north and east, respectively. The site has an approximate footprint area of 3,665 m^2, presented in the attached Figure 1.

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The proposed development of the site will comprise the demolition of the existing buildings and the construction of two towers, Tower A (56 levels) and Tower B (23 levels), with a common basement extending to approximately RL -18.5m AHD occupying the footprint of the site. The proposed basement is not proposed to be tanked, however high level concrete walls, socketed into rock, are intended to limit water inflows to seepage from the exposed rock surface.

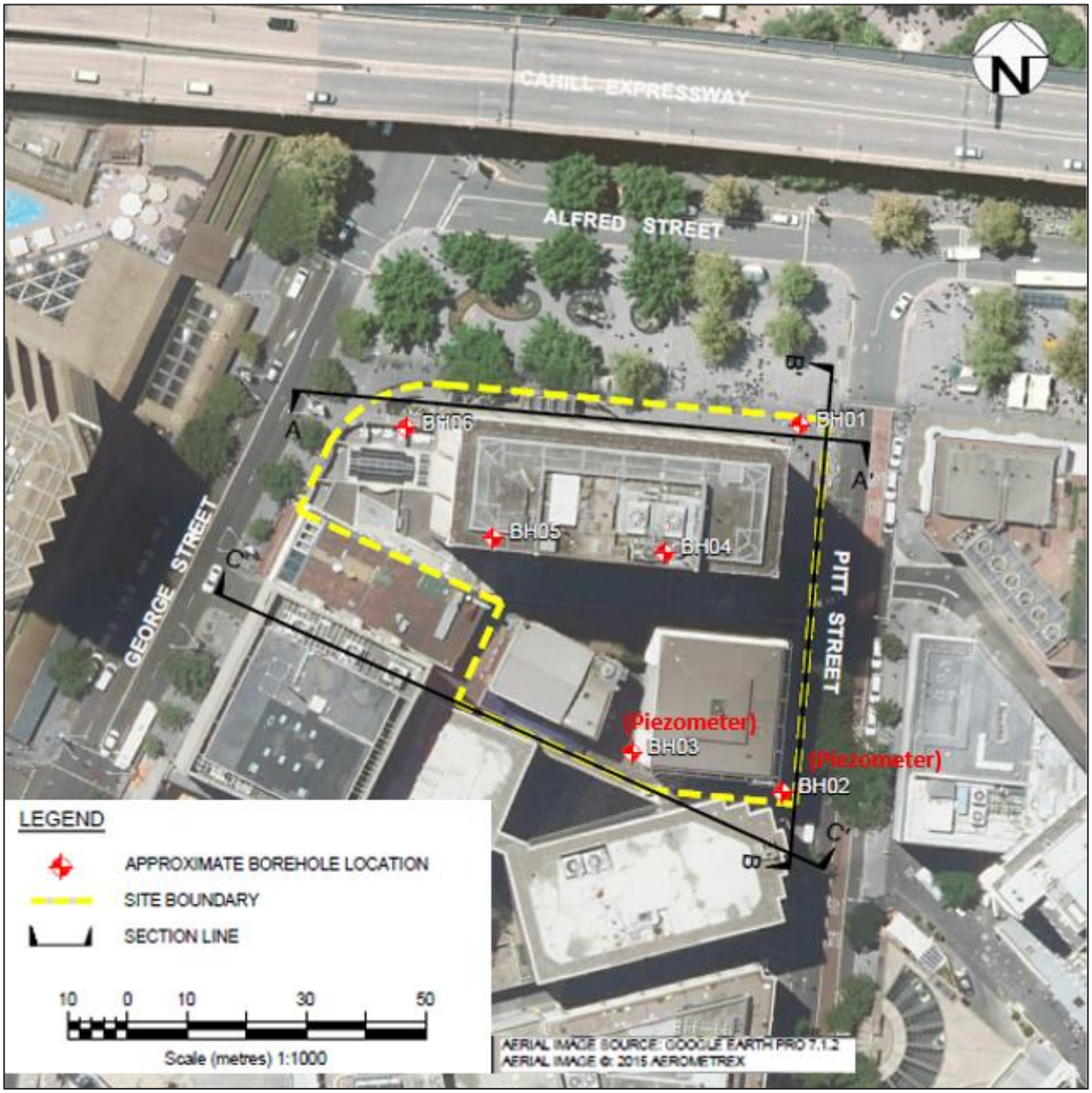

Figure 1 Site plan (sourced from Coffey Report GEOTLCOV24001AF-AB)

3 Fieldwork

3.1 Piezometer installation

Previous geotechnical fieldwork was undertaken by Coffey in August 2015 which included the installation and development of monitoring piezometers (BH02 and BH03) at the site. The locations of the piezometers are shown in Figure 1.

The detailed borehole logs and piezometer installation records are presented in Geotechnical Investigation Report by Coffey (document reference GEOTLCOV24001AF-AB dated 2 October 2015). The piezometer completion details are provided in Table 1.

Table 1 Piezometer completion details

Monitoring Well ID	Approximate Elevation of Top of Casing (m AHD)	Total Depth (mbtc)	Screen Interval (mbtc)
BH02	2.4	25	11 to 20
BH03	2.4	16	5 to 16

Note – mbtc: metres below top of well casing

3.2 Groundwater level monitoring

Down hole data loggers were installed in piezometers BH02 and BH03 to collect water level information over a three month period between September and December 2015. Monitored groundwater levels are presented in Figure 2.

Both piezometers screened in the Sandstone, with data logger level at -17.4m AHD in BH02 and -13.4m AHD in BH03.

The rainfall data was based on readings at Sydney Observatory (Station Number 066062) – Bureau of Meteorology.

Figure 2 Groundwater monitoring results (sourced from Coffey Report GEOTLCOV24001AF-AB)

The groundwater level at BH02 and BH03 lie consistently at approximately -3.0m AHD and -6.5m AHD, respectively.

Groundwater levels do not show significant response to rainfall events, but show minor response to harbour tides (less than 0.05m).

3.3 Perched groundwater table

Observations during drilling (BH01 to BH03) indicated the presence of a perched water table within the fill/alluvium, above a separate water table within the sandstone. This is typical of groundwater conditions in the vicinity of basements within the Sydney CBD.

The perched groundwater table encountered in the fill varies from 0.4m AHD (BH02) to 1.6m AHD (BH03) and 0.1m AHD in the alluvium (BH01).

Reference was also made to the groundwater monitoring results at the adjacent site at 33-35 Pitt Street. The observed perched water table within the fill/alluvium at 33-35 Pitt Street was between -0.4m AHD and 0.2m AHD. This is considered to be generally consistent with the perched water table encountered at 1 Alfred Street.

From the above observations, it is believed that the perched water table at and in the vicinity of the site generally lie between 0 to 1.5m AHD.

3.4 Permeability testing

In situ permeability tests were conducted at select sandstone horizons in boreholes below:

Table 2 Summary of in situ permeability tests

Borehole / Piezometer	Depth Interval tested Below Ground Level (m)	Material	Interpreted Hydraulic Conductivity (m/day)
BH03 – Packer Test	6 to 13	Sandstone, predominantly fresh, no defects observed	0.003
BH02 – Rising Head Test	11 to 20	Sandstone and minor siltstone, predominantly fresh	0.003
BH03 – Rising Head Test	5 to 16	Sandstone, predominantly fresh	0.002

The hydraulic conductivity of the sandstone is approximately 0.003 m/day at the test locations. The interpreted hydraulic conductivities of the sandstone at the site fall within the typical range of rock mass permeability of Class III to Class I sandstone in published data for Sydney Sandstone (Bertuzzi & Pells 2002).

3.5 Groundwater sampling and testing

Groundwater was sampled from piezometers in BH02 and BH03 on 11 September 2015 and tested in a NATA accredited laboratory.

Summary of the laboratory testing is provided below:

- The pH, and sulphate and chloride concentrations of groundwater indicate that the groundwater would be classified as “non-aggressive” in accordance with Australian Standard AS 2159-2009.
- The field and laboratory test pH of the groundwater samples ranged from 5.6 to 6.6.
- Potential acid sulfate soils were identified in the fill and alluvial soil samples from the site.
- The results for PAH, OCP, chlorinated hydrocarbons, polychlorinated biphenyls and phenols were all below the laboratory Limit of Reporting.
- TRH were identified in groundwater from monitoring well BH02, but not in BH03. Monitoring well BH02 lies close the Pitt Street and it is possible that this result is associated with petroleum hydrocarbons derived from vehicles/runoff on Pitt Street.
- Total cobalt, iron, manganese, nickel and zinc concentrations lie above the (low reliability) ANZECC (2000) trigger values. Concentrations of these metals in exceedance of ANZECC (2000) is not uncommon in disturbed settings within Sydney.

4 Groundwater model

Groundwater monitoring results suggest the presence of the following two separate aquifers at the site:

- Shallow groundwater within the fill and alluvium, perched on top of the bedrock
- Deeper groundwater system within the sandstone bedrock.

This dual aquifer system is typical of environments in the vicinity of deep building basements within the Sydney CBD.

The proposed basement excavations will extend below the groundwater table. As-built drawings suggest the current Gold Fields House basement walls perform as a cut off structure to groundwater within the fill and alluvial soils. It is anticipated that the existing Gold Fields House northern and eastern retaining walls will be retained and extended to the lower basement levels.

The southern basement walls are likely to be removed, with new retention structures installed close to the site boundaries. The new retention walls will be installed into the underlying sandstone as a cut off structure to groundwater within the fill and alluvial soils.

Extensive dewatering of the near surface fill and alluvial materials is therefore not anticipated.

Groundwater inflows may occur within the underlying rock mass, either through the mass itself, along defects, or at the base of the retaining walls. Bedrock seepage in sandstone bedrock could be assumed as typically flowing downwards toward local drainage lines or regional water table, along horizontal bedding planes and sub-vertical joints.

5 Groundwater inflow and associated impacts

5.1 Groundwater inflow and drawdown

Groundwater levels observed in the sandstone and the fill/alluvium soils are above the proposed basement floor level.

With adequate cut-off of the fill/alluvium materials mentioned in Section 4, groundwater ingress will be significant reduced by being limited to seepage through the sandstone.

An assessment of the long-term inflow to the developed basement from the sandstone stratum was undertaken. The assessment assumes:

- Radial drawdown from an extensive aquifer under steady state flow conditions
- Groundwater flow to the basement through the sandstone only (the fill and alluvium is cut-off)
- The excavation/basement footprint is some 3,665m^2 and the lowest basement floor level is -18.5m AHD. The basement is assumed to be under-drained to approximately -18.8m AHD, some 0.3m below finished floor level
- The pre-development groundwater table elevation in the sandstone is -3m AHD according to the groundwater monitoring results
- A hydraulic conductivity of 0.003m/day for the sandstone
- Surface water does not enter the excavations
- The absence of significant water bearing features within the sandstone
- The aquifer contributing to inflow extends to -30m AHD

- Infiltration of 2% (typical of urban settings) of mean annual rainfall of 1.21 m (the 157-year mean for Bureau of Meteorology Station at Observatory Hill).

Based on these assumptions, a long term inflow of approximately 2 ML per year (5.5m^3/day) through the sandstone stratum only to the drained basement may occur post construction. Inflows may be close to this value following periods of high rainfall, but are expected to typically be less than this.

With groundwater cut-off from entering the basement through the fill and alluvium, drawdown of the groundwater table within the fill/alluvium will be insignificant. Drawdown of the groundwater table within the sandstone immediately adjacent to the proposed basement walls may be up to 16 m (i.e. full depth of excavation in rock) during construction and operation, with that drawdown reducing to a 10% drop of the rock mass water table approximately 70 m from the basement excavation. This distance will be less in the northerly direction due to the presence of the harbour water source.

This assessment is based on limited data collected from discrete locations. Ground conditions are variable and it is possible sandstone at the site has features that transmit significant groundwater flow. Construction planning shall include a contingency to manage the presence of rock with significant defects (through which significant groundwater inflow might take place).

Groundwater flows during excavation within the bedrock may be able to be managed by a sump and drainage system. Appropriate treatment of joints or other defects in the sandstone near the base of the existing basement walls that may provide hydraulic connection to the groundwater within the fill/alluvium shall be provided. Where unacceptable groundwater inflows occur in the rock mass, which exceeds the predicted inflow rate above or the acceptable inflow rate approved by Sydney Water, targeted grouting shall be carried out to reduce inflows from the rock defects to the basement both during construction and over the longer term.

5.2 Existing groundwater users and groundwater dependent ecosystems

To assess the potential impact of the development on existing groundwater users, a search of Department of Primary Industries-registered groundwater bores was conducted by Coffey on 29 September 2015 during previous ground investigation. No registered bores were identified within 500 m of the site.

Groundwater drawdown is not expected to impact existing registered groundwater bore users.

The Bureau of Meteorology Atlas of Groundwater Dependent Ecosystem does not indicate the presence of groundwater dependent ecosystems in the vicinity of potential drawdown expected to be induced by the development. Therefore, there is assessed to be no impact to groundwater depend ecosystem due to the development.

5.3 Groundwater flow

The existing groundwater flow regime within the sandstone is expected to be influenced by the basement. The proposed basement will be one of the deepest basements in the area, and groundwater within the immediate vicinity of the basement is expected to be preferentially drawn

towards the basement. Beyond a distance of 70m from the excavation site, less than a 10% drop in the water table will occur within the rock mass.

Based on the absence of a high priority groundwater dependent ecosystem, or a high priority culturally significant site in the rock mass within this 70m radius, the resultant inflows can be classified as having a minimal impact according to Section 3.3 of the NSW Aquifer Interference Policy and therefore an Aquifer Interference Approval is not required under Section 91 of the Water Management Act 2000.

A Water License will be required where the volume of water removal from a site is more than 3 ML per year.

As discussed in Section 5.1, high level retention system will cut-off water seepage from the fill/alluvium, and target grouting proposed at the defects of the rock mass will limit groundwater inflows through the sandstone. A long term inflow of approximately 2 ML per year to the drained basement is anticipated post construction.

As the anticipated volume of groundwater removal at the site is less than the 3 ML threshold, a Water License is not required for the anticipated long term inflows of approximately 2 ML per year.

5.4 Groundwater quality

The drained basement will form a groundwater sink that may cause changes to groundwater quality via preferential migration of groundwater solutes towards the basement. The salinity of groundwater within the sandstone between Circular Quay and the development may increase due to the development drawing water from the harbour. We have not identified any adverse implication of this potential increase in salinity.

6 Discharge of basement seepage water

Groundwater collected within the basement will be pumped to the stormwater drainage system, ultimately discharging to the estuarine environment of Sydney Harbour. Based on the field data presented in the geotechnical report, the groundwater at the site is fresh and slightly acidic which is below the pH range (7 to 8.5) set in the ANZECC (2000). In addition, TRH and metals were identified in the groundwater as well with the metal concentrations in exceedance of ANZECC (2000) which is not uncommon in distributed settings within Sydney.

Groundwater treatment is required to meet the ANZECC (2000) guidelines prior to discharging to the external stormwater main. This can be achieved by increasing the pH value and reducing the concentration of the metals and TRH via the use of a groundwater treatment plant, i.e. Gravity Clarification (GS) system.

Gravity Clarification is the process of clarifying water by using a flocculent to coagulate the suspended solids into heavier particles which then settle to the bottom of a tank/ clarifier. Different contaminants can have different settling times so Gravity Clarification Systems are designed to suit specific flow rates and factor in parameters such as types of contaminants, volume and surface area.

Acid Sulfate Soils Management Plan will also be developed by other environmental consultant to manage the potential impacts of excavation and dewatering on acid sulfate soils.

7 Groundwater monitoring

7.1 Groundwater level

It is proposed that groundwater monitoring piezometers are to be installed at the outside of the excavation to observe the groundwater response within the fill/alluvium and the sandstone. The location of the proposed groundwater monitoring piezometers shall be selected at the existing structures which are sensitive to the ground movement induced by groundwater drawdown.

Three groundwater monitoring piezometers are proposed:

- Tank Stream – at the north and south extents of the site
- Jacksons on George – at the west extent of the site

Baseline reading shall be established at a minimum of two weeks prior to the commencement of excavation and dewatering. During construction, reading of the groundwater levels in the piezometers shall be taken every 2m of excavation or weekly whichever occurs first. The groundwater monitoring reading shall be continued after the completion of the permanent structures or until a steady groundwater level has been observed.

Trigger levels and response actions shall be established and agreed prior to construction as part of the groundwater management plan.

7.2 Water quality

During excavation and construction of the basement, the groundwater inflows into the basement will be treated, tested and managed by the Contractor prior to discharge to the stormwater drainage system. It is the responsibility of the Contractor to develop the construction and water management plan which will need to be approved by Sydney Water and relevant authorities.

For the operation, the groundwater treatment plant (Section 6) shall be maintained at least six month intervals or as per the manufacturer's recommendations to ensure the treated water quality meets the requirement of the ANZECC (2000) guidelines prior to discharging to the external stormwater main.