ATTACHMENT 10 – HYDROGEOLOGICAL ASSESSMENT

Planning Proposal – SP20018 – Croft Developments (November 2021)

DM McMahon Pty Ltd
6 Jones St (PO Box 6118)
Wagga Wagga NSW 2650
t (02) **6931 0510**
www.dmmcmahon.com.au

16 November 2021

Attention: Kyan Hyde
Salvestro Planning
PO Box 783
Wagga Wagga NSW 2650
kyan@salvestroplanning.com.au
BY EMAIL

Dear Kyan

Re: Information request – Aged Care Facility Hely Avenue Turvey Park NSW

I refer to your email dated 15 November 2021 requesting further information around tree removal, monitoring bores and irrigation at the proposed Aged Care Facility located at Hely Avenue Turvey Park NSW. The intended recipient of this letter is yourself and Wagga Wagga City Council in response to the request for information numbered 12) and 13) that is further to our Hydrogeological Assessment report dated February 2020 (Our reference 6723).

12) The report needs to consider the effect of removing several deep-rooted trees in an area historically fragile in terms of highly saline and shallow ground water conditions.

We don't have a copy of the Tree Management Plan & Hydraulic Analysis, or the Aqueduct Works so can't provide comment. But our report did assess that there would be minimal use of groundwater by the trees to be removed and the change to recharge would likely not be measurable, however we did recommend that the use of trees on site should be optimised i.e., more plantings.

13) The report recognises the following:

1. High ground water tables in the north western side of the site (Bore 7: 0.37m below surface in 2016) and proposes adding fill over the site to ensure the groundwater always remains at 2.5m below the natural surface elevation. Also, the addition of 2 monitoring bores be installed prior to commencement of onsite construction works to monitor ground water levels at the site given Bore 7 will be removed.

2. Large irrigated areas are to be kept to the eastern side of the site to mitigate recharge in the western, higher ground water area of the site and that irrigation water management estimates be calculated so as not to exceed pre- developed levels of recharge.

The proposal needs to identify how these will be implemented and the design impacts from fill and dedicated irrigation areas.

1. We have not been involved in the supervision of the earthworks so cannot provide comment around the filling of the site. Also, the monitoring bores can be installed at any time during development given they are not compromised during construction.

2. Irrigation should be done on a best practice basis and incorporate the following:

When irrigation is taking place, scheduling is reviewed daily considering weather conditions, available soil moisture, and the plant growth and development stage. Irrigation monitoring resources should include:

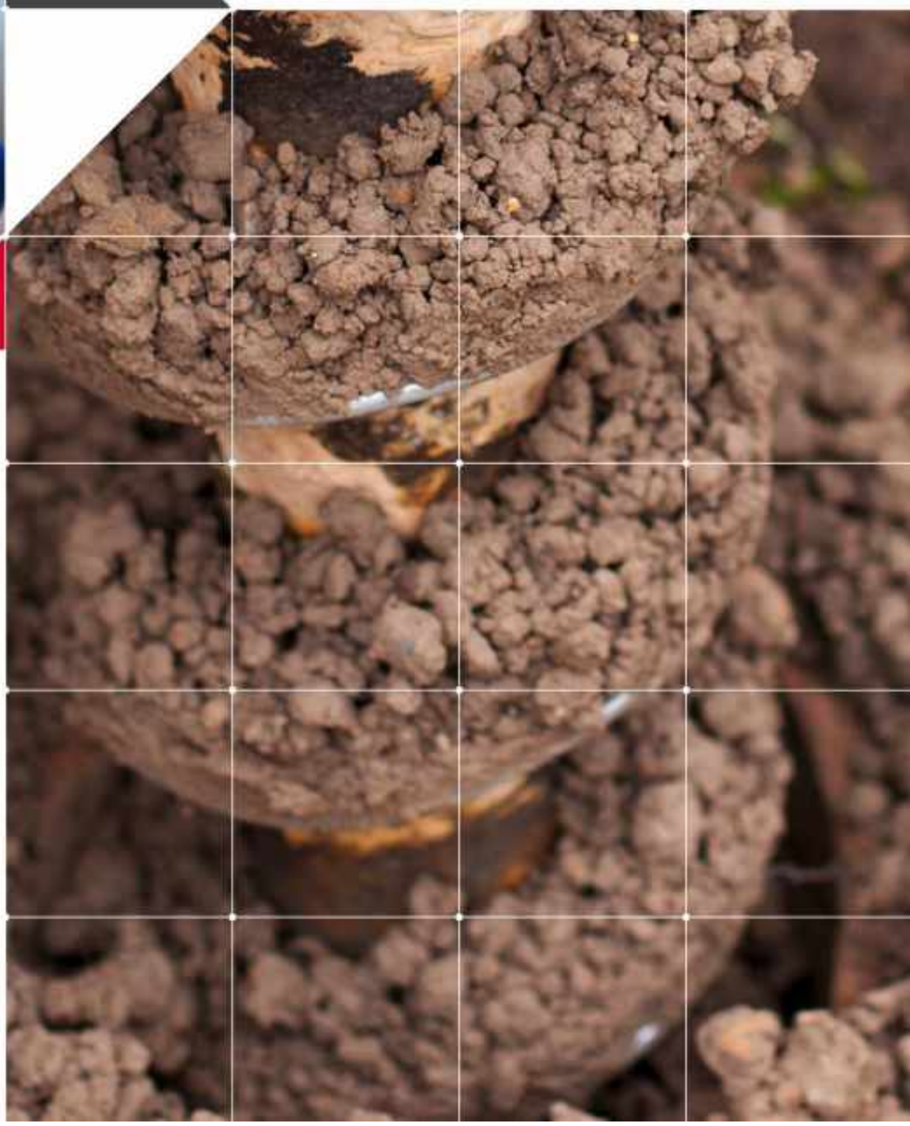
- Soil moisture probes within the irrigation area.
- Weather data from an onsite weather station or online resource.
- Irrigation scheduling and application records.

If you have any queries about the contents of this letter, please contact the undersigned.

Yours sincerely

David McMahon CEnvP SC
BAppSc SA
GradDip WRM
MEnvMgmt
MALGA MEIANZ MSSA

McMahon
EARTH SCIENCE



121 FERNLEIGH ROAD TURVEY PARK NSW

HYDROGEOLOGICAL ASSESSMENT

MAY 2020

REPORT NO. 6722

DM McMahon Pty Ltd
6 Jones St (PO Box 6118)
Wagga Wagga NSW 2650
t (02) **6931 0510** www.dmmcmahon.com.au

Hydrogeological Assessment
121 Fernleigh Road
Turvey Park NSW 2650

Report number
6722

Prepared for
Croft Developments Pty Ltd
59 Wangara Road
Cheltenham, Melbourne VIC 3192
Tel: 0269 218 333
Email: reception@croft.com

Prepared by
DM McMahon Pty Ltd
6 Jones Street (PO Box 6118)
Wagga Wagga NSW 2650
Tel: 0269 310 510
Email: admin@dmmcmahon.com.au

Document Control

Compiled by	Signed	Date	Revision Number
Mark Mitchell Hydrogeologist BAppSc Geology (hons) MEnvMgmt		13/05/20	00
Reviewed by			
David McMahon CEnvP BAppSc SA GradDip WRM MEnvMgmt		13/05/20	00

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1.0 Report brief

The objective of this report is to:

- Place the development in the context of the urban salinity environment.
- Provide information of the groundwater levels at and in the vicinity of the site.
- Define the potential impact of the proposed change in land use on groundwater levels on and off site.
- Identify factors that will need to be considered in building on the site to mitigate potential salinity impacts to buildings.
- Develop a groundwater management plan for the site.

2.0 Site identification

Details of the site identification can be seen as follows, **Table 1**.

Table 1: *Site identification*

Identifier	Details
Address	121 Fernleigh Road Turvey Park NSW 2650
Real property description	Lot 1 DP1254451
Centre co-ordinate	531685E 6112445N - MGA GDA z55H
Development footprint	1.8 hectares (approx.)
Owner(s)	Charles Sturt University
Local Government Area	Wagga Wagga
Present use	Infrastructure
Proposed use	Aged care facility
Development Application Reference	Not known

3.0 Introduction

3.1 Development area

The former Charles Sturt University (CSU) South Campus in Turvey Park NSW is proposed to be developed as an Aged Care Facility by Croft Developments Pty Ltd. 121 Fernleigh Road, the subject site, is an expansion of the proposed development. As part of the Aged Care Facility development, 121 Fernleigh Road (the subject site) is proposed to be an extension of the independent living residential lots on the former CSU South Campus.

The highest point of this site is about 206 mAHD in the south-east fronting Fernleigh Road. The site generally slopes to the north-west with the lowest point being about 197 mAHD in the north-western corner. The subject site lies to the north and eastern boundaries of the Ambulance Station, the southern boundary of the Saint Mary MacKillop Colleges, and the western boundary of the Aged Care Facility Development (Stages 1 & 2), see **Figure 1**.

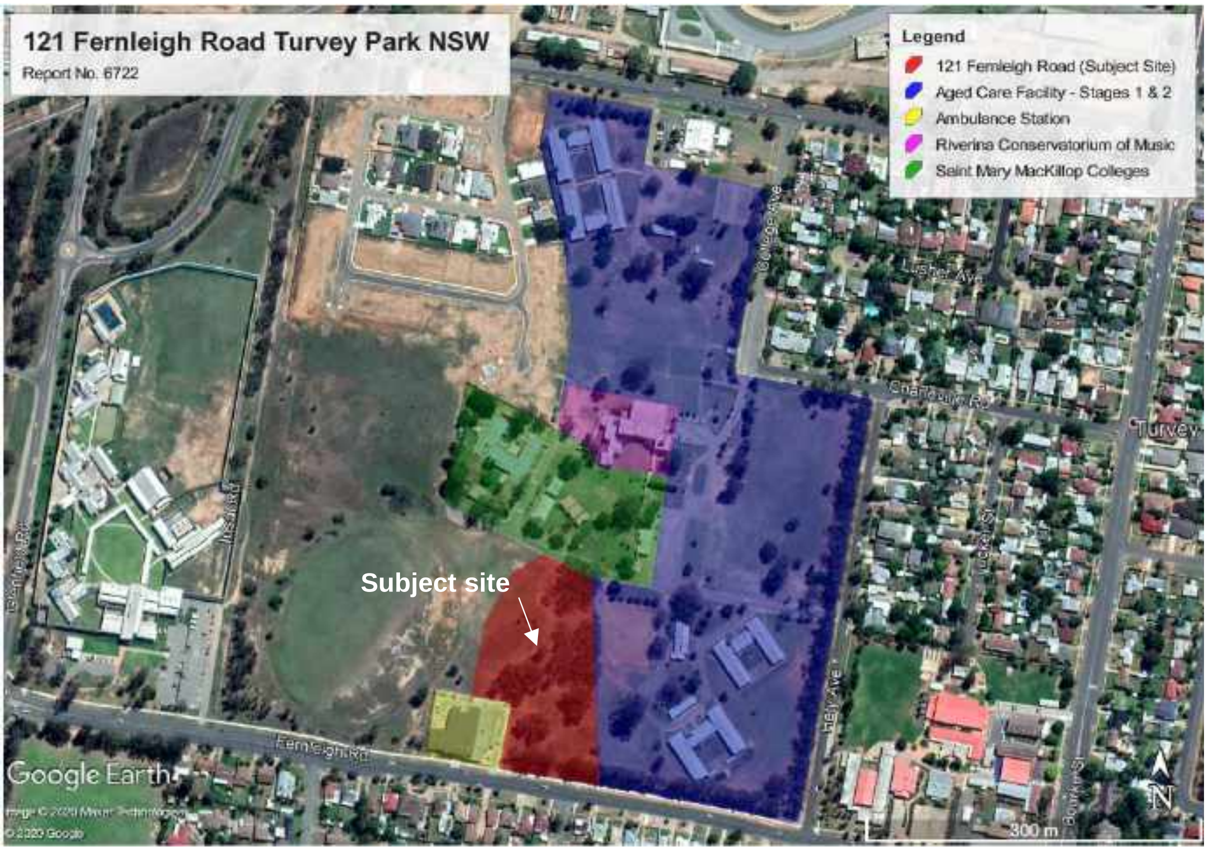

Figure 1: *Subject site – 121 Fernleigh Road*

The assessment has been requested in response to a planning approval request. The development approval by Wagga Wagga City Council required the applicant to ensure that all built infrastructure was more than 2.5m above the water table level and a groundwater management plan was developed for the site. This assessment evaluates the suitability of the proposed development to meet this requirement.

3.2 Wagga Wagga urban salinity

Wagga Wagga is recognised as being impacted by urban salinity. Wagga Wagga City Council (WWCC) has undertaken a substantial amount of investigation, monitoring and engineering works over the past 30 years to manage and mitigate urban salinity. About 30 years ago WWCC developed an urban salinity management plan (Hamilton, 1995). The study included investigations into recharge processes, strategies to reduce recharge and management options for the rehabilitation of urban discharge areas.

The action taken by WWCC includes engineering works to remove rear yard rubble pits, the installation of a dewatering bore field in the Calvary Hospital precinct, the revegetation of recharge areas and the installation and ongoing monitoring of an urban salinity monitoring network.

The cause of the urban salinity is associated with the hydrogeology of the area and the increase of groundwater recharge above that experienced under **natural (pre-urbanisation) conditions**. The groundwater system has a low hydraulic conductivity, which limits the ability of the system to accommodate additional recharge without causing a significant change in the water table level.

The urbanisation of the area has caused additional recharge above that experienced from rainfall due to factors such as urban irrigation and pipe leakage. This has caused the water table levels to rise, especially in the lower areas with a lower hydraulic gradient.

The proposed development site is located in the urban catchment west of Willans Hill. This catchment is coincidentally the area that is most severely affected by urban salinity, see **Figure 2**.

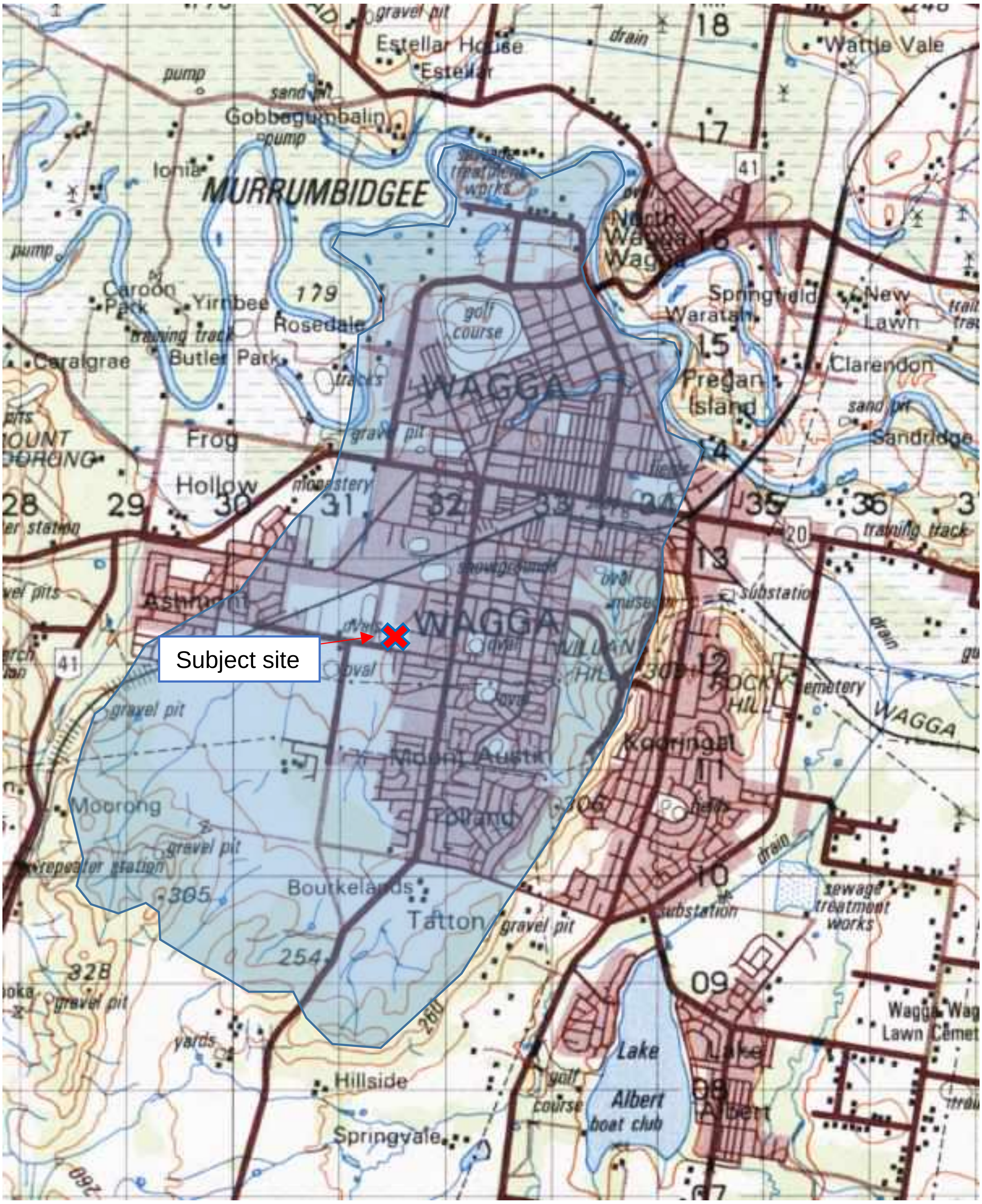

Figure 2: *Western urban salinity catchment*

The depth to groundwater contour map from the Wagga Wagga Urban Salinity Technical Report 2017/2018 (WWCC, 2018) shows that in the western catchment, the shallowest groundwater levels occur in the lower elevation areas, see **Figure 3**.

The subject site is partially within a 2 - 4m depth to groundwater area. Once the site is fully developed the depth to groundwater will be greater than 2.5m due to clean fill being used to level the site and to ensure that the groundwater level beneath the site is greater than 2.5m.

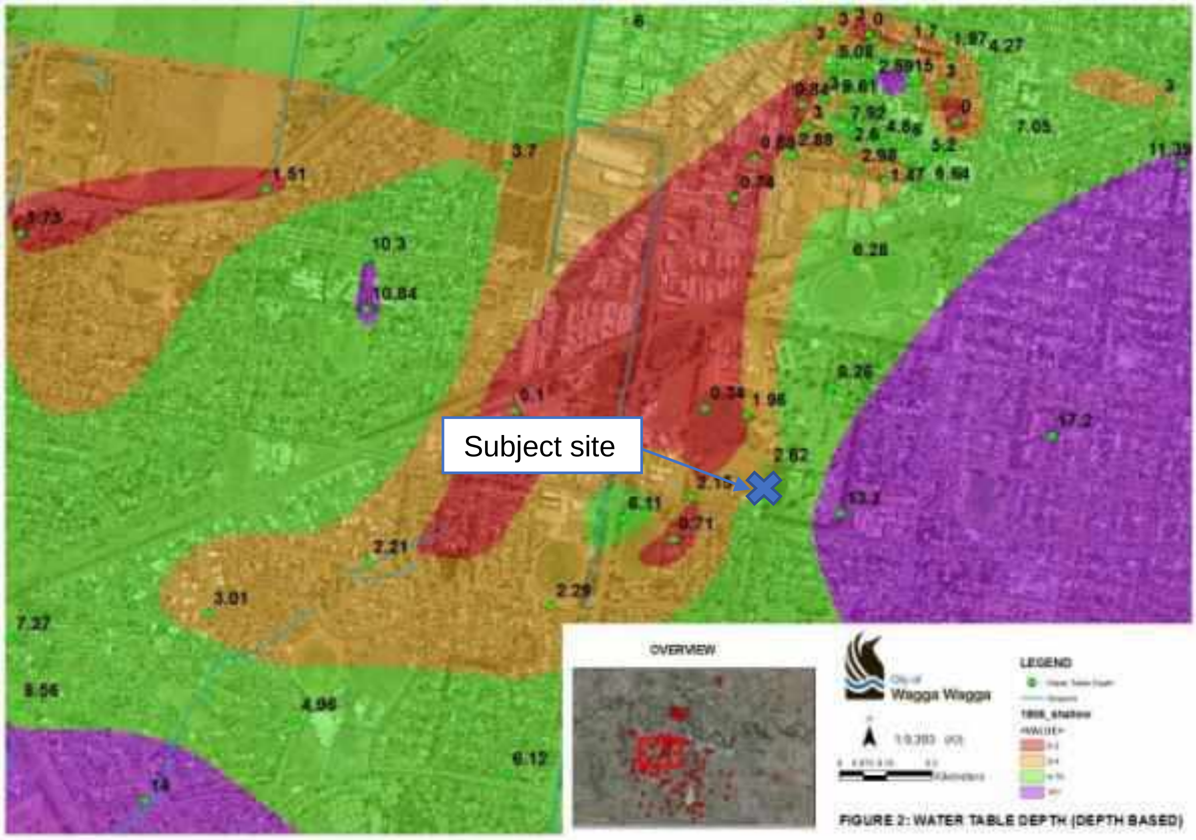

Figure 3*: Water table levels in the western Wagga Wagga catchment (WWCC 2018)*

4.0 Regional setting

4.1 Climate

The climate based on weather station 72150 at Wagga Wagga Airport shows that the area has hot dry summers with cool to cold winters (**Figure 4*Figure 4***). Rainfall is winter and spring dominant, with an annual average of 556 mm (**Figure 5**). Evaporation exceeds rainfall throughout the year except in June and July, with an annual average evaporation of 1749 mm (**Figure 6*Figure 6***).

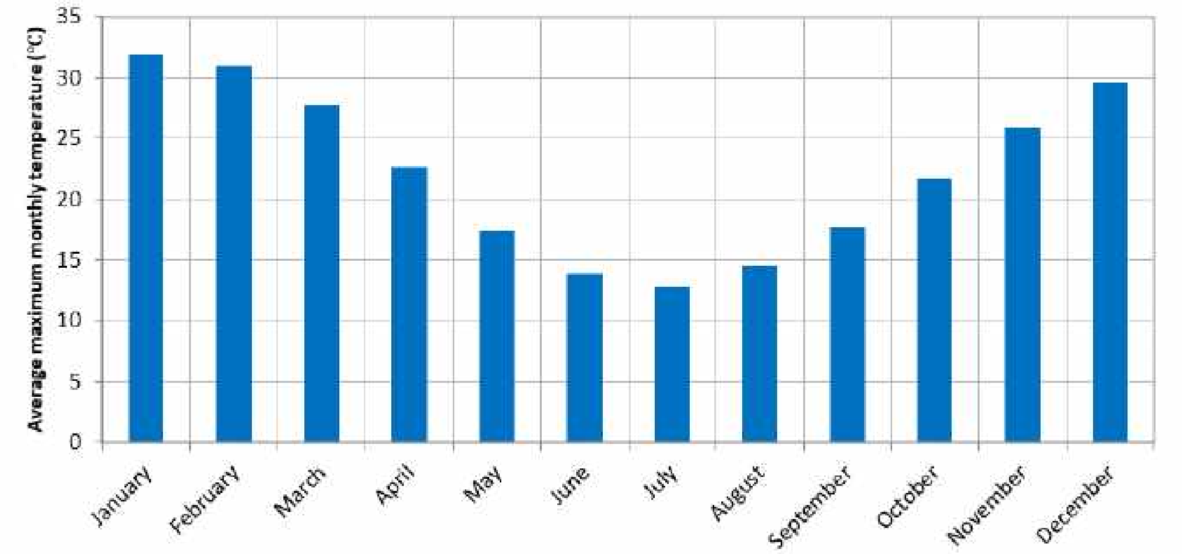

Figure 4: *Wagga Wagga average maximum monthly temperature*

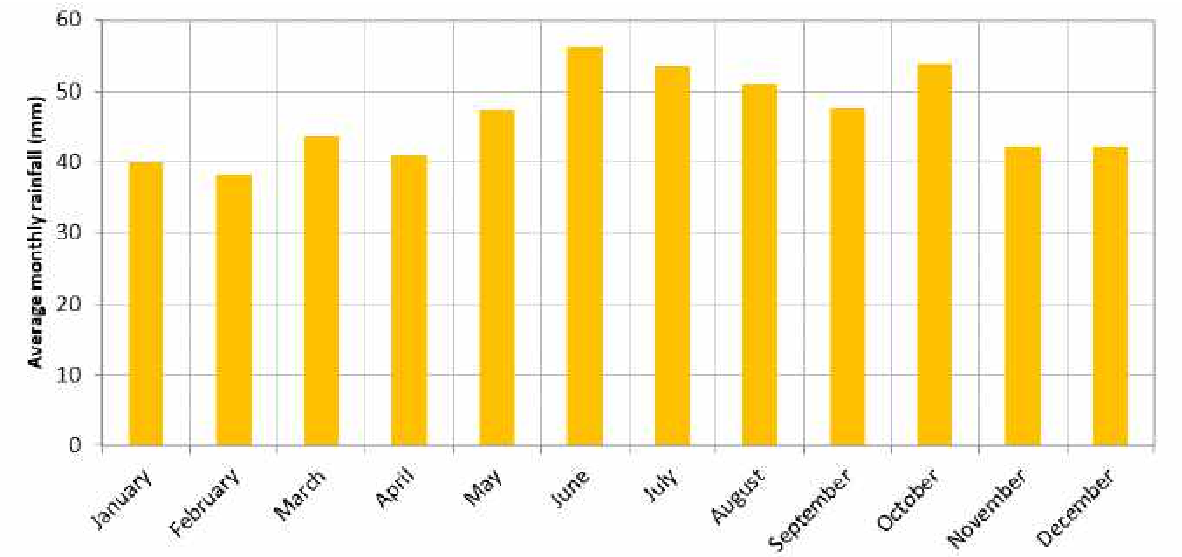

Figure 5*:* *Wagga Wagga annual average rainfall*

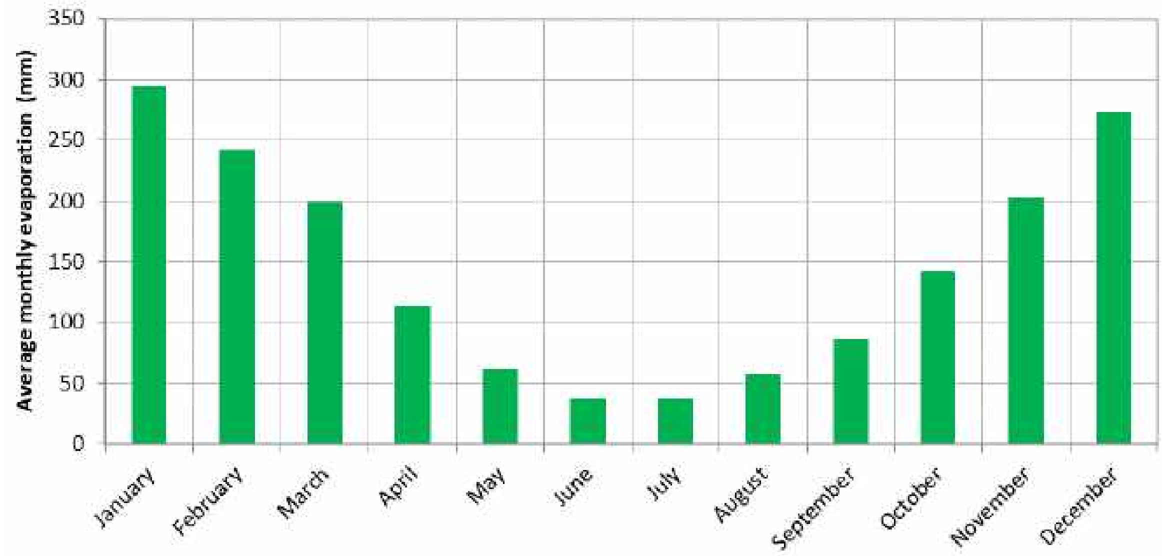

Figure 6: *Wagga Wagga annual average evaporation*

4.2 Landscape

The Wagga Wagga Soil Landscapes 1:100,000 map series (Chen & McKane, 1997) shows the Becks Lane (bk) and Pulletop (pu) soil landscapes occurring on the site. The Becks Lane soil landscape is present in the western margins of the site and in the lower lying areas of the catchment, whilst the Pulletop soil landscape occurs over the majority of the site including mid and upper slopes of the western urbanised area of Wagga Wagga, see **Figure 7**.

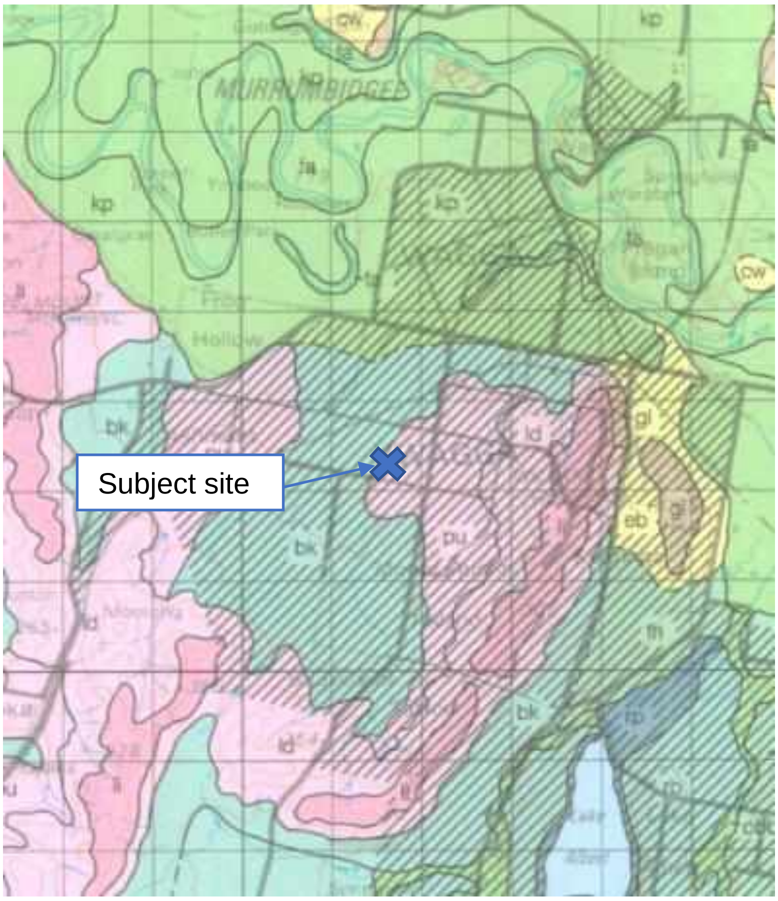

Figure 7: *Wagga Wagga soil landscapes*

The Becks Lane soils landscape is associated with slope gradients of 2 to 4 percent and parallel to shallow drainage lines. Soils are bleached brown and mottled Dermosols up to 150 cm deep.

Underlying regolith is generally greater than 2 m thick, consisting of slope-washed and alluvial-colluvial sands, clays and gravels, mostly derived from the surrounding Ordovician metasedimentary rocks.

The Pulletop soil landscape, which occurs in the mid and upper slopes in the western catchment and over the majority of the site, is associated with slope gradients of 3 to 10 percent with broad crests and ridges.

The soil landscape is associated with Mesotrophic Red Chromosols up to 1m in thickness on crests, ridges and upper slopes, bleached and Haplic Chromosols on the mid to lower slopes up to 150 cm in thickness. Soil on site is likely associated with the bleached and Haplic Chromosols of the mid and lower slopes.

The underlying geology is weathered Ordovician metasedimentary rocks, with usually greater than 2m thick slope wash and alluvial clayey sediments occurring on the lower slopes and drainage depressions. The western catchment of Wagga Wagga is synonymous with the Becks Lane soil landscape.

4.3 Geology

The Wagga Wagga region is located on the eastern highland front of the Murray Geological Basin, with the surrounding and underlying geology being the Lachlan Fold Belt facture rock complex.

The unconsolidated alluvial sediments of the Murrumbidgee River floodplain are the Tertiary Lachlan Formation and the overlying Quaternary Cowra Formation. These sediments are up to 100 m thick in the Wagga Wagga area.

The Cowra Formation includes brown to yellow polymictic sediments of sands, gravel, silts, and clay. The polymictic nature of the formation suggests mechanical weathering was dominant. The climate during the Quaternary was much drier than during the Tertiary, and the sediments in this layer reflect the typical flood/drought cycle of streams from a semi-arid environment (Woolley, 1972).

The formation extends from ground surface down to varying depths. The formation increases in thickness from Gundagai in the east, where it extends to a depth of about 25m, to about 40m around Narrandera. The main poorly sorted gravel zones of the formation typically extend from about 2m to 24m below ground surface. The gravel layers are inter-layered with clay and silt.

Lachlan Formation sediments are commonly clean grey quartz sands and gravels, with intermittent layers of grey clay. The clay lenses are remnants of floodplain and/or wetland environments and were deposited in an environment of high rainfall and humidity (Woolley 1972). The formation commences from near Oura east of Wagga Wagga and increases in thickness to about 120m at Narrandera (37m to 160m below ground surface).

The majority of the urban area of Wagga Wagga overlies Ordovician to Silurian metamorphic sediments, granites and volcanic bedrock of the Lachlan Fold Belt, with these units outcropping on the surrounding hills.

The Silurian Wantabadagery Granite occurs midway between Nangus and Wantabadgery to Wagga Wagga. The western contact between the granite and the metamorphic sediments and volcanics is the prominent north-south ridge line of Willans Hill, which runs through the southern suburbs of Wagga Wagga. These two units form the bedrock and outcrops on the adjacent hills

The granite intrusion is thought to have occurred during the Late Ordovician to Early Silurian Benambran Orogeny. The granite displays a structure that is mainly concordant with the regional structure and commonly displays north-westerly trending shear and brittle zones (Warren et al 1994).

The granites are generally medium grained rock of fairly massive appearance with roughly euhedral biotite flakes and an absence of hornblende. Hydrothermal alteration occurs near the contact margins (Warren et al 1994).

The area west of Willans Hill is underlain by the Ordovician metasediments, which are the predominant unit in the area. It consists of fine grained inter-bedded sediments which have been subject to low grade regional metamorphism. They have been altered to phyllite, shale, and schists as well as micaceous sandstone and quartzite. The rocks are moderately folded with a strongly developed regional cleavage trending about north-south. They are generally well fractured in outcrops. Drilling data indicates that both the granite and metasediments have a thick weathered zone.

The catchment that is the focus of this report where the proposed development is located consists of Ordovician metasediments. Overlying the weathered zone are colluvial clayey sediments, especially in the lower elevation areas of the catchment.

4.4 Hydrogeology

The hydrogeology in the western urban catchment of Wagga Wagga is controlled by the soil landscapes and the underlying geology. The groundwater unit of interest for the site and surrounds is the Ordovician metasediments, with the groundwater electrical conductivity ranging between 4,000 and 7,000 µS/cm (Cook et al. 2001).

The groundwater flow in the western catchment is from south to north, discharging into the unconsolidated alluvial sediment of the Murrumbidgee River floodplain. The lower permeability clays in the lower catchment and the lower hydraulic gradient in the northern part of the lower lying areas of the catchment restrict drainage and cause water tables to approach the land surface.

Cook et al 2001, identified in the western catchment that the groundwater level would have been close to the land surface (<5m) in the lower elevation areas, under natural conditions and that with even a small increase in recharge under dryland agricultural landuse groundwater levels may have been close to the ground surface. Therefore, only a small increase in recharge above natural conditions would have been required to maintain shallow groundwater levels in the lower lying areas of the catchment. Therefore, the urbanisation of the catchment means that groundwater levels will remain shallow in the lower lying areas.

5.0 Groundwater hydrographs

The groundwater depth varies from greater than 10m on the mid and upper slopes to less than 1m in the lower lying areas of the catchment. The monitoring bores located in the lower lying areas that are associated with the Becks Lane soil landscapes generally have shallow groundwater levels of less than 3m. Groundwater level monitoring has remained relatively steady, with variations associated with seasonal conditions, with an overarching long-term trend corresponding with the monthly rainfall residual mass curve. This is demonstrated by comparing sites 7 and 10 which are in the lower lying area and the longer-term monthly rainfall residual mass curve, see **Figure 8**, **Figure 9,** and **Figure 10**. Site 7 is located in the northern area of the subject site and is constructed to a depth of 4.1m. Site 10 is to the north-west of the subject site and is constructed to a depth of 3.9m. Like many of the bores in the lower lying area it is screened in clay or sandy clay.

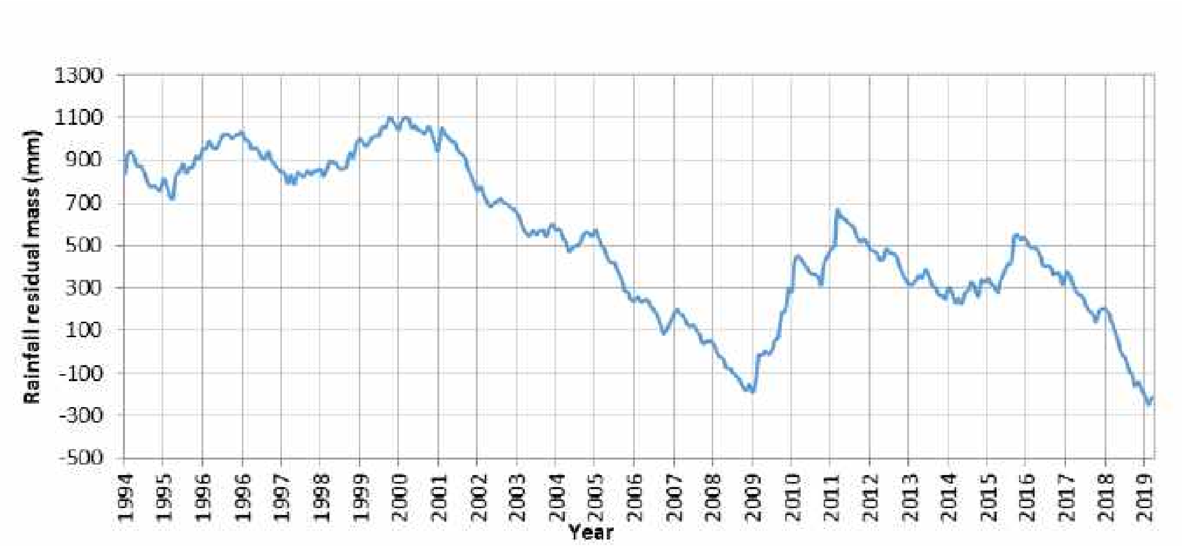

Figure 8: *Wagga Wagga monthly rainfall residual mass curve @ station 72150 (1994 -2018)*

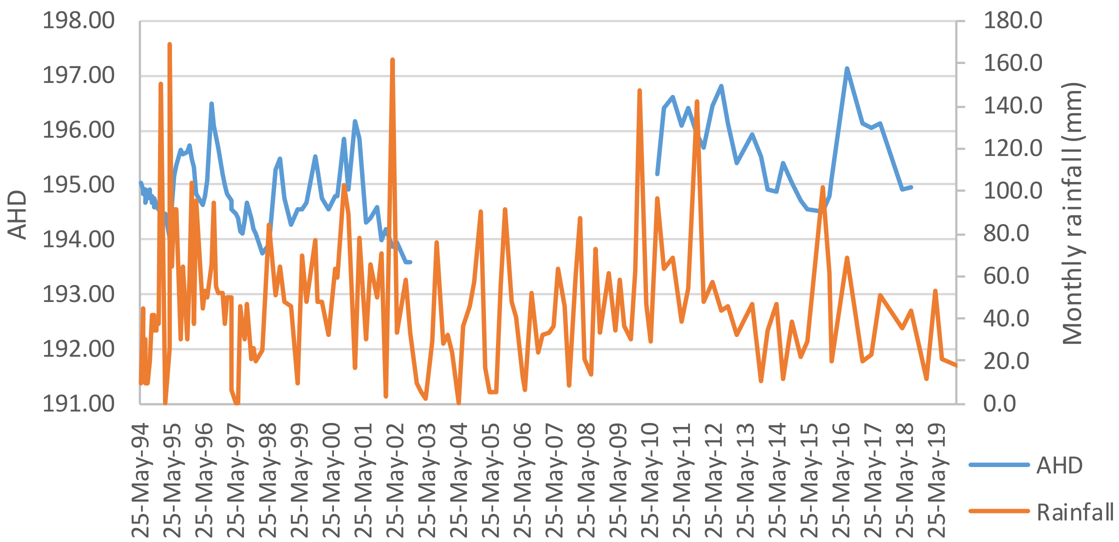

Figure 9: *Groundwater hydrograph of Wagga Wagga City Council monitoring bore 7– Ground level 198 mAHD*

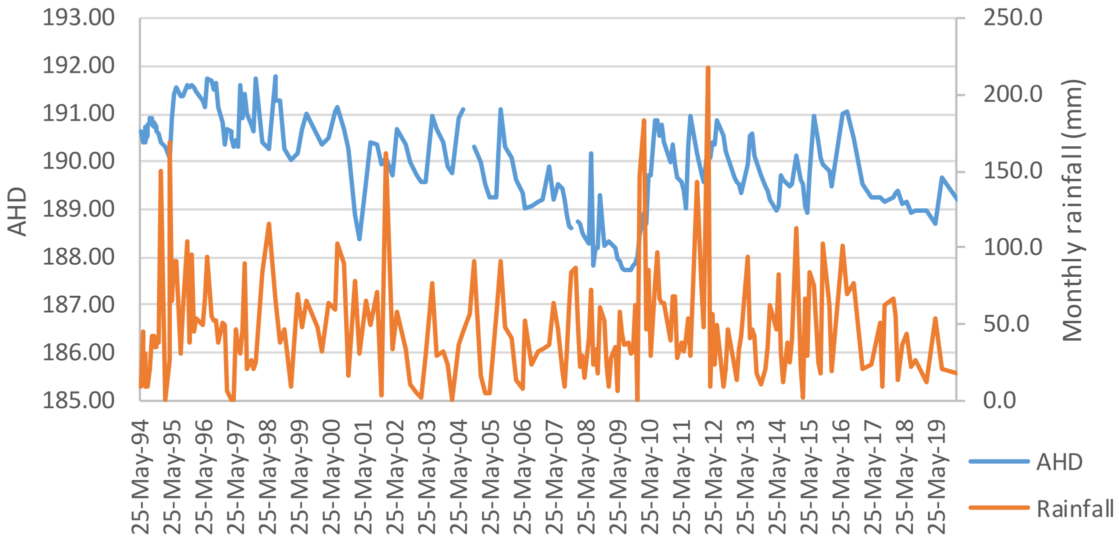

Figure 10*: Groundwater hydrograph of Wagga Wagga City Council monitoring bore 10– Ground level 192 mAHD*

The groundwater levels at site 7 ranged between less than 1m to more than 3m below ground level since the millennium drought. Site 7 was dry at the time of this assessment and has historically experienced prolonged dry periods including 2003-2009. The groundwater levels at the site are highly influenced by the climatic conditions, especially rainfall. The groundwater level rose to less than 1m during 2016, which is a period when rainfall was considerably higher than the long-term average, see **Figure 9**.

The groundwater levels at site 7 are likely higher than those prior to the millennium drought due to rainfall being considerably above the long-term average and greater than any exceedance of the long-term average between 1994 and the millennium drought. An extended period of above average rainfall in the future may led to groundwater levels at site 7 being less than 1m below natural surface.

Site 7 is located on the northern boundary of the subject site. The proposed mitigation measures to ensure that the groundwater level remains greater than 2.5m below ground level in the extended area is discussed in **Section 9.0.**

The WWCC monitoring bore (site 6 – GW400446) located to the east of the subject site is constructed to a depth of 13.2m. Based on the available information from the driller's log, it is assumed to be screened from a depth of 12m to 13m in the metasediments. The site was constructed in 1994 and has maintained a standing water level of greater than 10 m and since 2002 the bore has been dry. The groundwater levels at this site show some influence of monthly rainfall but are more influenced by the long-term rainfall trends, see **Figure 11**.

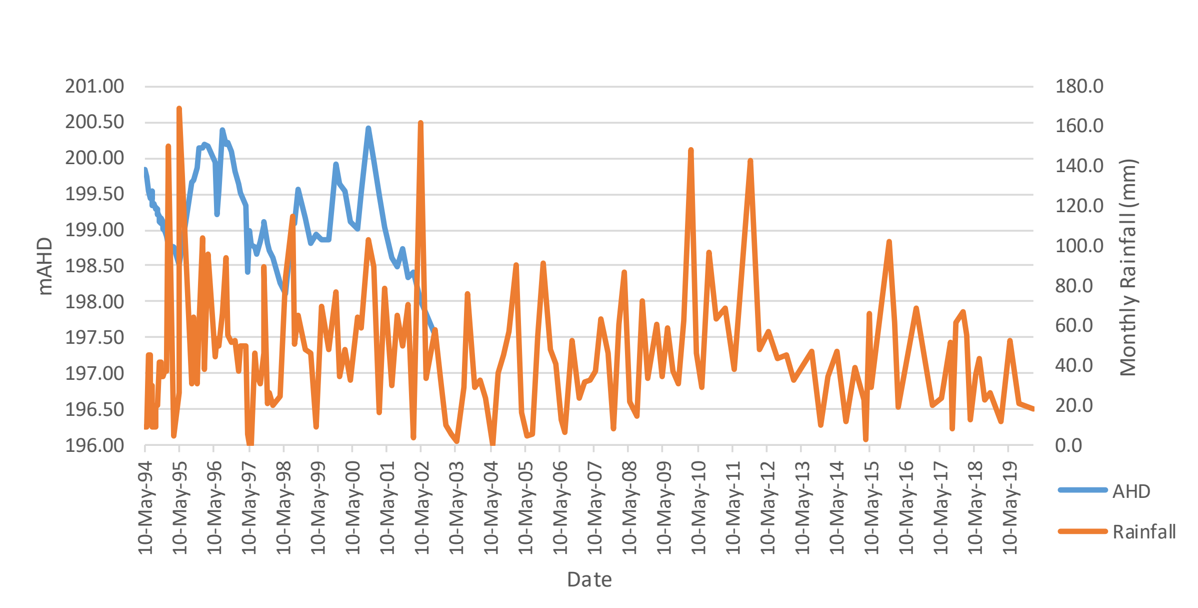

Figure 11*: Groundwater hydrograph of Wagga Wagga City Council monitoring bore 6 (south-east corner of site) – ground level 211 mAHD*

Sites 5 and 128 to the north of the subject site are constructed to depths of 9.7m and 10.2m respectively. No information is available on the material that these bores are screened. Based on the geology and soil landscapes mapping it is assumed that they are screened in weathered metasediments similar to Site 6.

Site 5 has been blocked since 2014 and had been dry from 2004, see **Figure 12**. Site 128 has maintained a groundwater level greater than 4m below ground level. The groundwater level remained at about 188 mAHD from 2007 to 2009 due to the groundwater level being at the base or below the depth of the bore, see **Figure 13**.

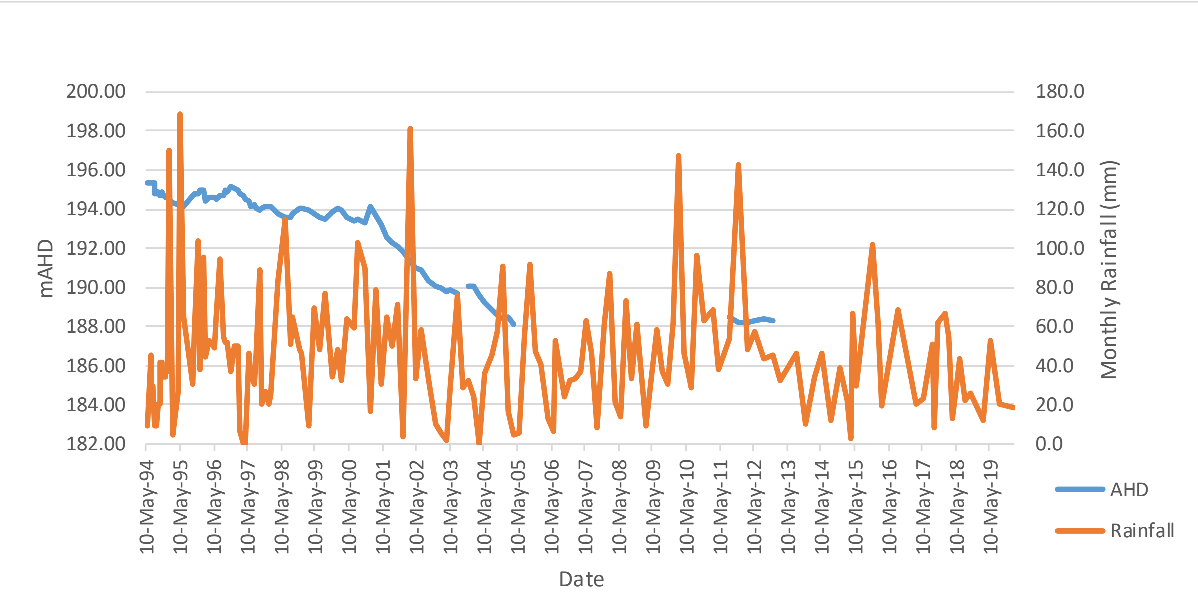

Figure 12*: Groundwater hydrograph of Wagga Wagga City Council monitoring bore 5 (Showgrounds, north of Lusher Avenue) – ground level 199 mAHD*

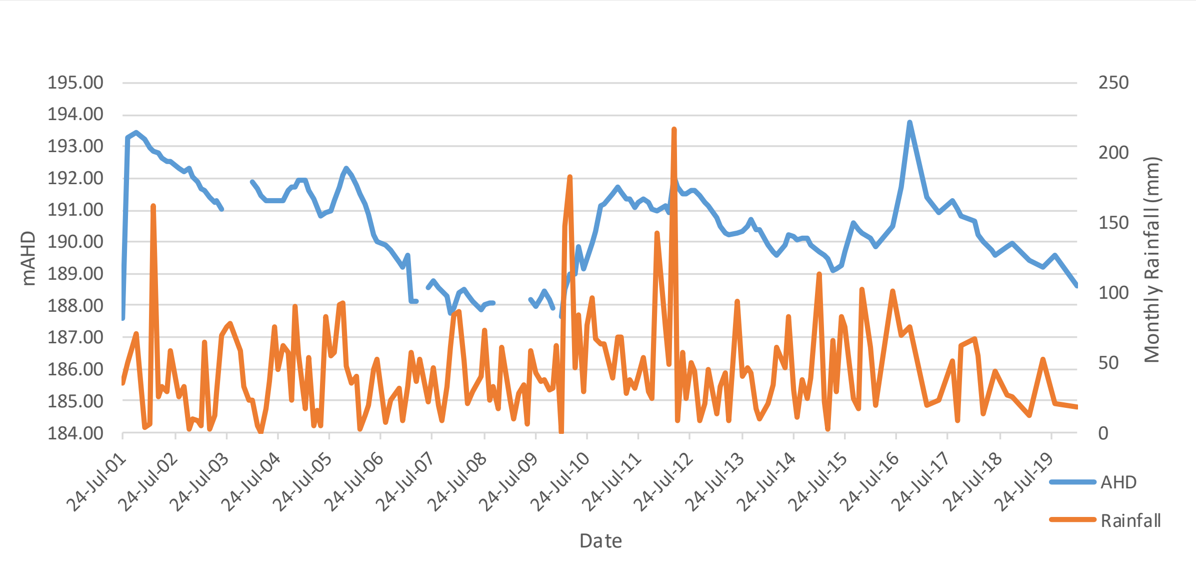

Figure 13: *Groundwater hydrograph of Wagga Wagga City Council monitoring bore 128 (College Avenue) – ground level 198 mAHD*

Site 42 at the southern end of Maher Oval is 12.6m deep and has been monitored since April 1997. This site provides an indication of the groundwater levels prior and post the millennium drought in a deeper bore. The groundwater level was about 2m to 2.5m below ground level prior to the millennium drought, decreasing to greater than 3.5m during the millennium drought and rising to 2.5m to 3m below ground level following the drought, see **Figure 14**. This shows that groundwater levels have generally not fully returned to pre-millennium drought levels. This trend is seen throughout the southern Murray Darling Basin.

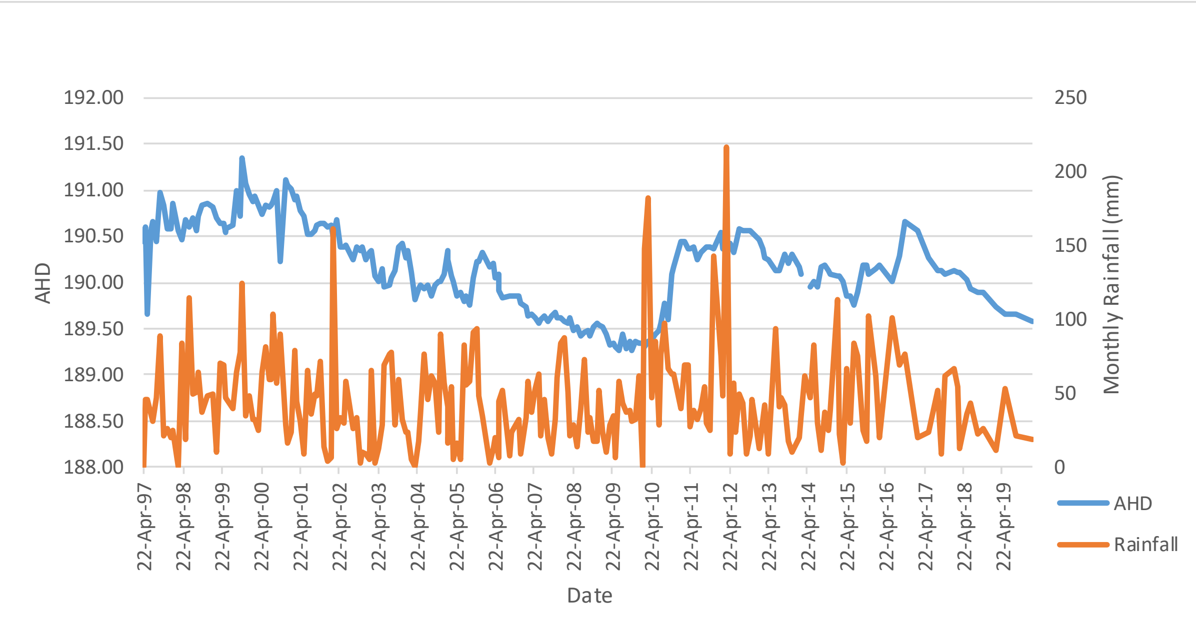

Figure 14: *Groundwater hydrograph of Wagga Wagga City Council monitoring bore 42 (Maher Oval) – ground level 193 mAHD*

The long-term groundwater level trend at site 5, 128 and 42 corresponds with monthly rainfall residual mass curve for Wagga Wagga at weather station 72150 which has recorded rainfall since 1942.

Sites 5 and 6 have either been dry or blocked for an extended period of time. It is assumed based on comparing the groundwater hydrographs that it is likely that the long-term groundwater level trend corresponds with the monthly rainfall residual mass curve.

6.0 Hydrogeological conceptual model

It was noted by Cook et al. 2001 that groundwater levels in the western catchment had likely established a new steady state condition. This trend has continued with it likely that at least in the lower lying areas of the western catchment that this steady state condition remains.

Cook et al 2001 defined the shallow groundwater system as anything where the bore depth was less than 12m. They found that chloride concentrations were higher in the shallow groundwater system and was likely associated with evaporative concentration or a source of salt in the shallow soils that has been mobilised by the rising groundwater levels. Although, it would be expected that urban recharge would reduce chloride concentrations.

The shallow groundwater levels had stable isotopes ^{2}H and ^{18}O to the right of the local meteoric water line, likely indicating evaporative enrichment. While the deep groundwater and reticulated water supply are on the local meteoric water line and have measurable lower ^{2}H and ^{18}O concentrations.

Based on the monitoring data from the WWCC groundwater monitoring network and the work by Cook et al. 2001. A conceptual model of the western catchment has been developed to place the proposed development within the catchment.

The southern, eastern, and western margin of the catchment consist of elevated areas, creating a drainage basin that drains to the north towards the Murrumbidgee River and the alluvial floodplain. The central and northern areas of the basin are flat with a slight gradient.

The central and northern areas of the catchment consist of colluvial and alluvial clays and fine sands. These clays and fine sand are possibly up to 10m in thickness. In the nearby WWCC Works Depot a bore (GW416216) intersected sands and clays to a depth of 8.5m, see **Attachment A**. These clays and fine sands would overlay weathered Ordovician metamorphic sediments.

The colluvial and alluvial clays thin out as the elevation increases on the eastern, western and southern margins of the basin. This material and the contact margin with the underlying weathered metamorphic sediments likely contain a shallow water table. This shallow water table would be due to increased recharge under the urban environment and as identified by Cook et al. 2001 would have likely been shallow prior to urbanisation.

Underlying this shallow water table aquifer would be an intermediate to localised groundwater flow system associated with the Ordovician metasediments. The system would receive recharge from the ranges surrounding the catchment and potentially leakage from the overlying water table. In the lower catchment, the pressure head of the metamorphic sediment aquifer is likely to be similar to the water table level.

The potential relationship between the water table and the groundwater level in the metamorphic sediments is shown in the conceptual south-north and east-west cross section in **Figure 15** and **Figure 16**. The location of the conceptual sections in the western catchment is shown in **Figure 17**.

The investigation site is conceptually on the eastern margin of the east-west cross section in **Figure 17**. The western boundary of the site is likely located near the margin of the colluvial material, while the majority of the site would be underlain by Ordovician metamorphic sediments.

The local to intermediate groundwater flow system would underlie the site, with the shallowest groundwater levels assumed to occur in the lower elevation areas in the north-west of the site.

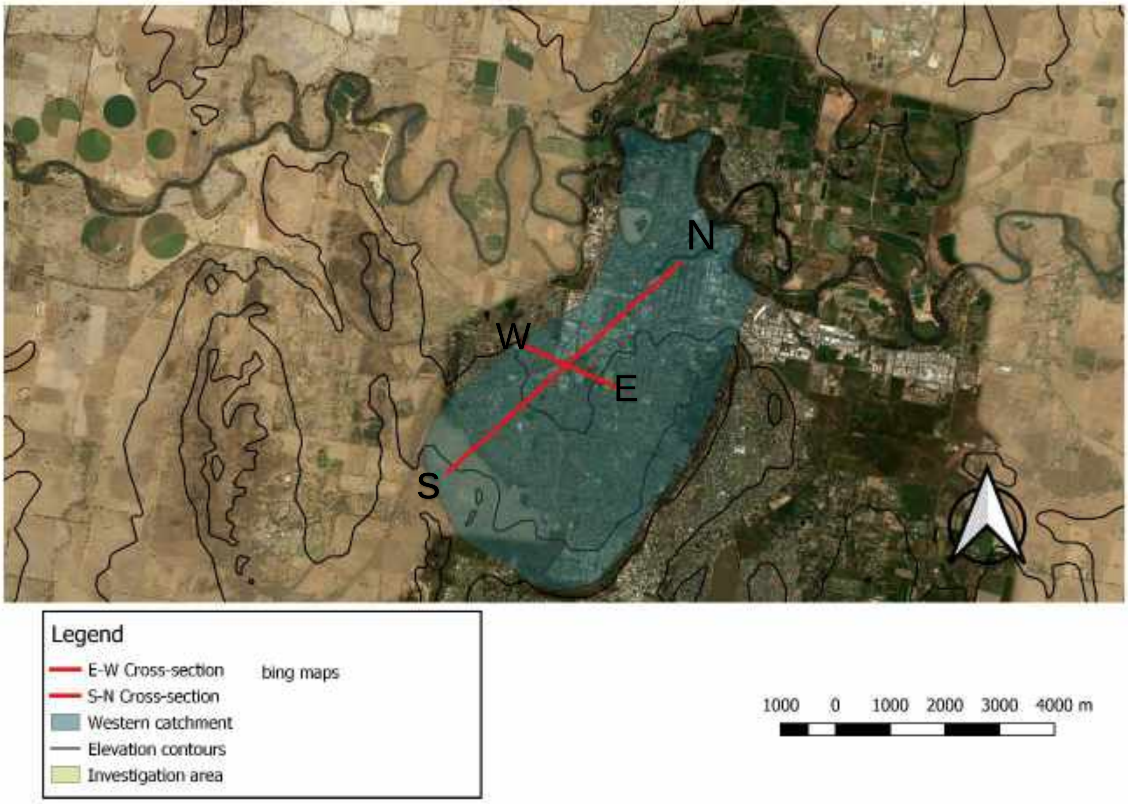

Figure 15: *Location of conceptual cross sections in western catchment*

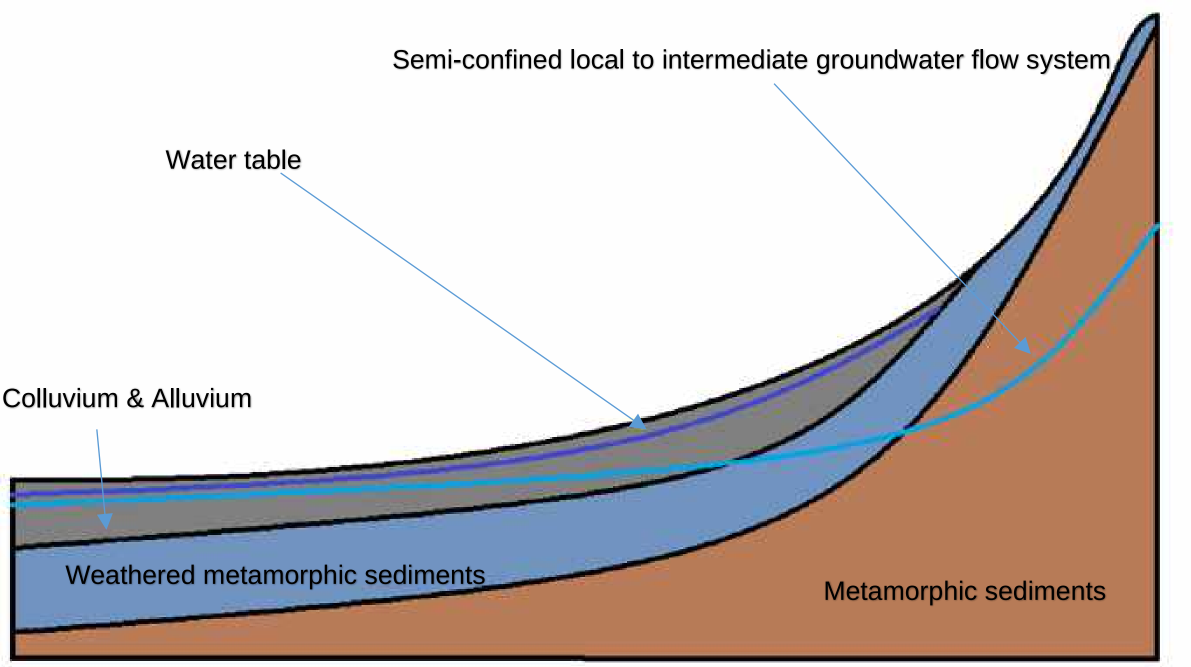

Figure 16: *South to North cross section of the western catchment*

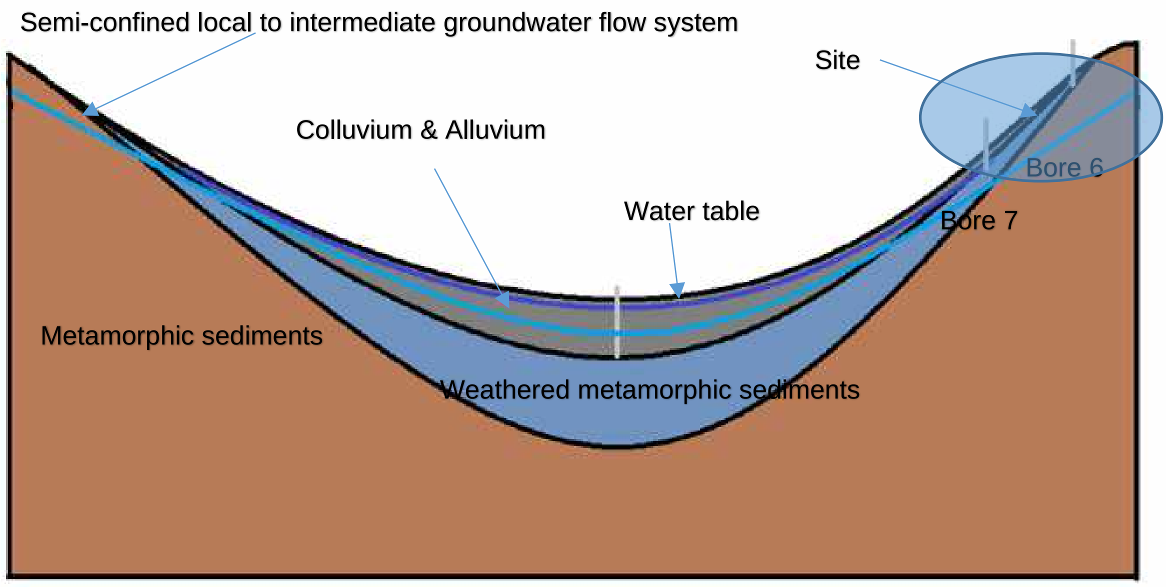

Figure 17: *East-West cross section of the western catchment*

7.0 Current land use and groundwater recharge

The subject site was previously used as recreation/open space as part of the CSU South Campus, with the land being covered mainly with annual grasses and scattered trees.

Historical irrigation of the subject site whilst being used as recreation/open space as part of the CSU South Campus is assumed to have been limited as there is no evidence of irrigation infrastructure. The subject site could therefore be considered as being equivalent to dryland pasture.

Various studies have been completed to estimate groundwater recharge in the Wagga Wagga urban environment. A study by Cook et al 2001 estimated groundwater recharge would be about 15 mm/yr under agricultural land use, which was based on other studies in the Murray Darling Basin. This is about 3% of the annual average rainfall for Wagga Wagga. Groundwater recharge under an urban environment was estimated to be 42 mm/yr. This consisted of:

- Rainfall – 11 mm/yr.
- Irrigation – 2 mm/yr.
- Rubble pits – 12 mm/yr.
- Pipe leakage water mains – 13 mm/yr.
- Pipe leakage sewer – 4 mm/yr.

These figures assumed that 32% of the urban environment is paved or rooved, which explains the irrigation and rainfall component being less than recharge under agricultural land use. Irrigation was assumed to be 240 mm/yr for domestic gardens and 660 mm/yr for public recreation areas.

In any new development area, there will be no rubble pits and pipe leakage should not occur. Therefore, groundwater recharge in a new development area with a 32% paved or rooved area would be about 13 mm/yr.

A study of the Lloyd development modelled urban irrigation as being 429 mm/yr (EA systems 2009). This report supported this value based on a study by Riverina Water County Council that estimated urban irrigation in the Lloyd area being between 383 mm to 468 mm/yr.

EA Systems modelled urban irrigation recharge as being 226 mm/yr and 37 mm/yr under an agricultural environment. Under an agricultural environment this is equivalent to about 7% of Wagga Wagga's average annual rainfall. The modelled urban irrigation recharge of 226 mm/yr is believed to be an over estimate. The recharge estimate from Cook et al. 2001 has been adapted as being representative of urban recharge. The estimated groundwater recharge at the site is 17 mm/yr or 3% of the annual average rainfall.

8.0 Methodology

The assessment of the approved development considered multiple factors to identify the groundwater system and potential for salinity impacts on and off site. The combination of these multiple information sources provides evidence of the groundwater processes in the catchment and the site.

The components of the assessment included:

- A review of the geophysical survey at the CSU South Campus for the associated Aged Care Development.
- Geotechnical sampling of the site.
- Existing mapping of soils, geology and topography.
- Geological logs from the Wagga Wagga City Council groundwater monitoring network.
- Groundwater level monitoring from the Wagga Wagga City Council groundwater monitoring network.
- Slug testing of new investigation bores and the Wagga Wagga City Council groundwater monitoring network.

8.1 Review of geophysical survey

The electromagnetic survey (EM31) on the CSU South Campus site of the proposed Aged Care Development site provides information on the top 6m, with the proportional response being from depths of less than 3 m.

An electromagnetic survey measures the soil apparent electrical conductivity. This is influenced by several soil factors including porosity, soil moisture, the concentration of dissolved electrolytes and the amount and type of clay. Since the electrical conductivity readings are influenced by multiple factors that only provide an indication of the site conditions and on-site field investigations are required to validate the results. Field investigations may include soil surveys to gain additional detailed information on soil structure, texture and chemical composition. Where there are shallow groundwater levels analysis of the groundwater quality and levels to identify their influence on the apparent electrical conductivity.

Differences in the apparent electrical conductivity could be due to any of the following factors:

- Accumulation of salts.
- A greater quantity of soil moisture.
- Variation in the soil clay content and composition and the underlying geology.

The EM 31 survey was conducted to determine spatial variation in the soil clay content, depth of soils and the potential presence or absence of groundwater. The results of the EM 31 survey are shown in **Figure 18**.

An evaluation of field investigations for the subject site identified that the extension of the EM31 survey onto the subject site was not warranted. As the information from the CSU South Campus investigation shows that the survey would likely show the variability in the soil profile rather than indicate the presence of shallow groundwater. It was deemed that sufficient site information could be obtained through the construction of on-site investigation bores.

The lowest electrical conductivity on the CSU South Campus site is shown in red and the highest in green. Most of the site had a low electrical conductivity. The highest conductivity responses were associated with the land along Urana Street, the buildings at the central western area indicating influences other than the soil profile.

These results assisted in refining the location of the geotechnical investigation sites for the original investigation of potential shallow groundwater, saline groundwater and saline soils.

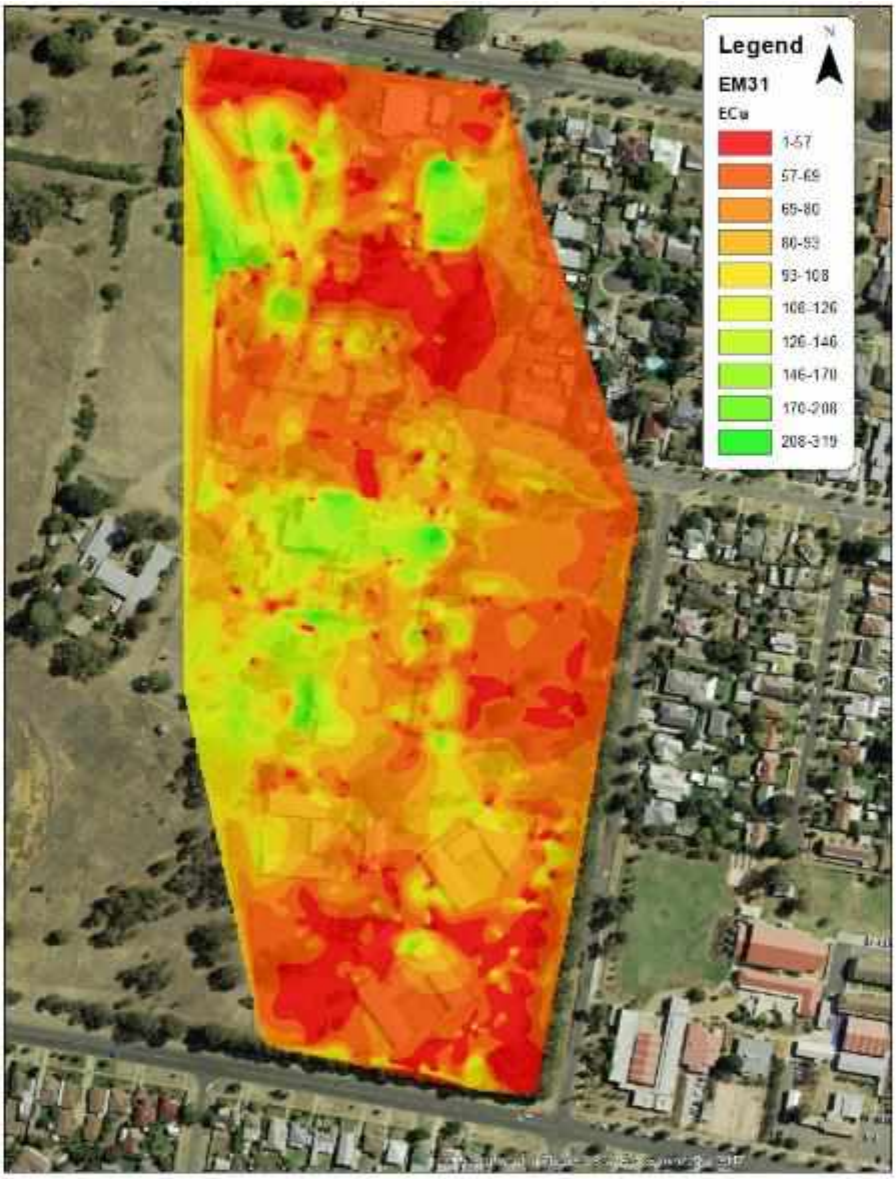

Figure 18: *EM 31 survey response*

8.2 Soil sampling

The assessment of the site included six geotechnical soil sample sites to capture sufficient data of the potential site variability (Report 6705. McMahon, 2020). The sites are located in a loose grid across the subject site, see **Figure 19**.

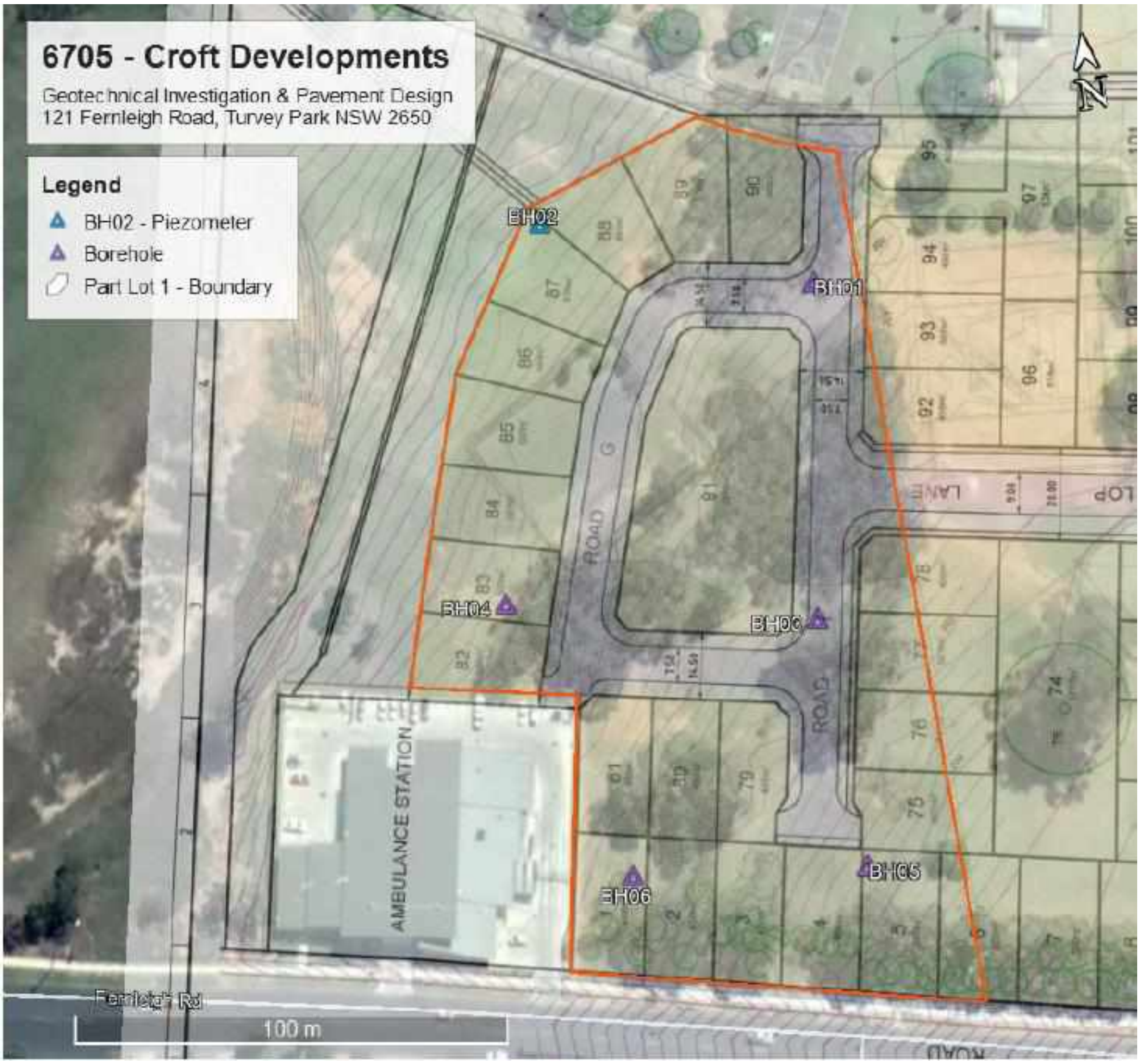

Figure 19:*Location of geotechnical sampling sites*

From geotechnical investigation, the majority of the sites were drilled to a depth of 1.5m, with one drilled to a depth of 6m (BH02). The only site where moist material was intersected was BH02 from 2.7m to 6m below ground level. The groundwater level was measured post drilling at BH02 at 5.7m below natural surface. The presence of moist material above the standing water level of 5.7m would likely be associated with capillary rise.

The material across the site consisted of yellowish to reddish brown, clay to silty clay with a medium to high plasticity. Subsurface conditions encountered across the site were generally consistent with the landscape forming processes, presenting thin colluvial topsoils overlying thick residual clays derived from parent materials. Investigation locations generally presented fine grained inorganic clay subsoils varying from low to high plasticity. All soil salinity analysis conducted on 1:5 soil/water samples found low salinity soils that ranged between 169 µS/cm to 695 µS/cm with a median of 252 µS/cm, see **Attachment B**. These results show no influence of evapoconcentration of saline groundwater has likely occurred on the site and therefore it is unlikely that there have ever been saline shallow groundwater levels beneath the site.

As previously discussed, an additional site (BH02) was constructed during this investigation. During the site investigation, three additional sites (MB02, MB03 and MB04) were located at the site in addition to Wagga Wagga City Council Site 7. **Figure 20** shows the location of the existing sites (Site 7, MB02, MB03 and MB04) and the new site BH02.

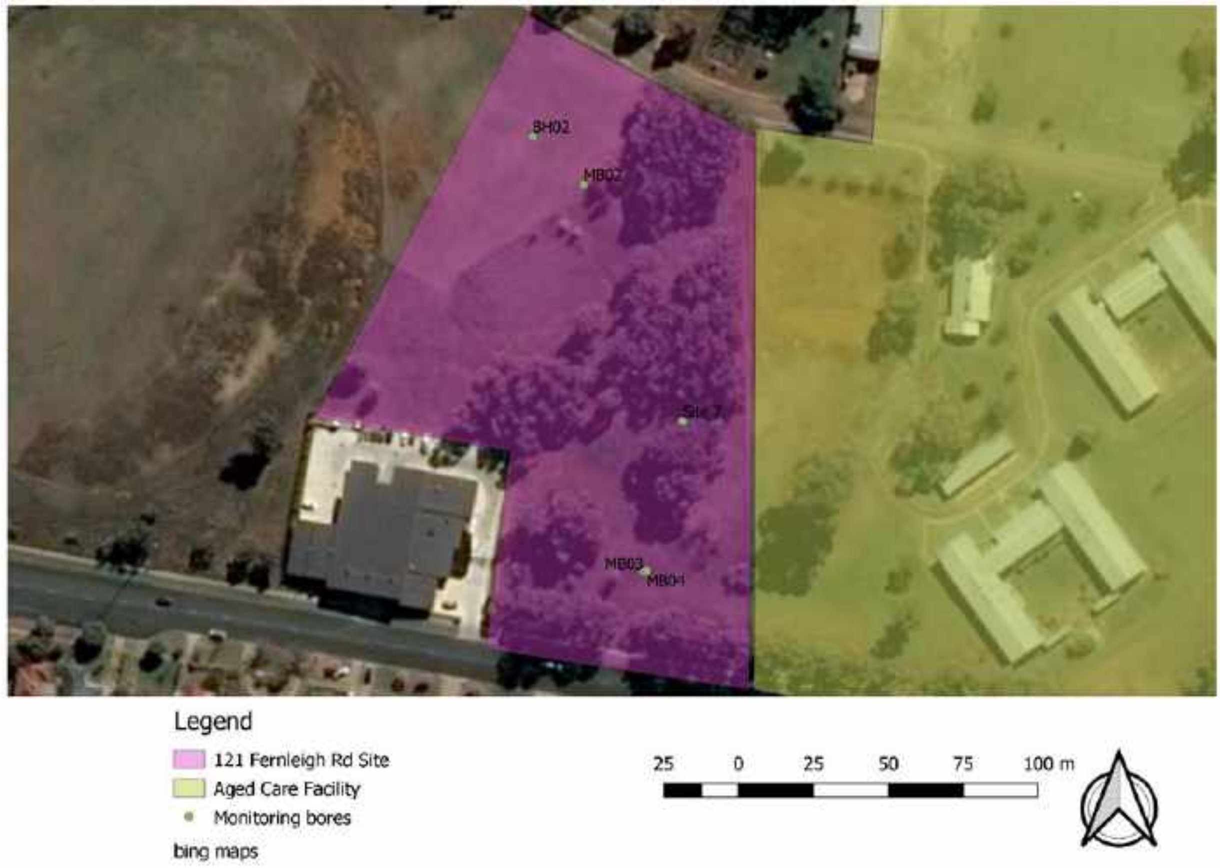

Figure 20: *Site monitoring bores*

Slug tests were completed at each site, with the co-ordinates and depth details for the sites shown in **Table 2**. The construction details for BH02 is in **Attachment C**.

The BH02 1:5 soil salinity is generally low (less than 300 µS/cm) and alkaline (9 pH units), see **Table 3**. Consistent with the soil salinity results from the original assessment the result shows no influence of evapoconcentration.

Table 2: *Sample site details*

Bore ID	Easting	Northing	Depth (m)	Standing Water Level (m) (Ground level)
Site 7	531738	6112406	4.10	Dry
BH02	531688	6112501	5.79	2.29
MB02	531705	6112485	3.32	Dry
MB03	531725	6112356	8.92	7.66
MB04	531726	6112356	2.31	Dry

Table 3: *BH02 Soil salinity 1:5*

Depth (m)	Salinity (µS/cm)	pH units
1	695	9.8
2	276	9.3
3	169	8.8
4	199	8.6
5	228	8.7
6	275	8.7

At the time of conducting the slug tests, groundwater was observed at BH02 and MB03, the two deeper sites. At BH02, located in the north-west corner of the site, groundwater was intersected at 5.7m beneath ground level and rose to a standing water level of 2.29m. Showing that there is an upward pressure gradient at this location. At MB03 the groundwater level was measured at 7.66m beneath ground level.

8.3 Slug test

A slug test determines the near well aquifer characteristics and is used to determine the transmissivity and hydraulic conductivity and storativity of the material near the bore.

During the assessment, slug tests were conducted on the four groundwater level monitoring bores, the three existing bores on site (MB02, MB03 and MB04), and the recently installed BH02, see **Figure 20**. At the time the tests were conducted MB02 and MB04 were dry. The tests were conducted to gain an insight into the transmissivity and hydraulic conductivity in the catchment and the potential rate of movement of any recharge from the site.

The slug test results were analysed using the Bouwer Rice method due to the unconfined nature of the bores tested. The hydraulic conductivity results ranged between 0.0081 and 0.15 m/d, with a median of 0.023 m/d, see **Table 4**. This is equivalent to the value anticipated for a silt (Freeze & Cherry 1979). This is not unexpected with these sites being constructed in clay to silty clay.

Table 4: *Slug test analysis*

Site	Hydraulic Conductivity (K m/d)	Standing Water Level (m) ground level
Site 7*	0.039	Dry
BH02	0.0081	2.29
MB02	0.0083	Dry
MB03	0.023	7.66
MB04	0.15	Dry

* Site 7 was tested as part of the CSU South Campus aged care facility investigation.

The hydraulic conductivity at BH02 and MB02 is significantly lower than that previously measured at Site 7 (Report 6723. McMahon, 2020). This shows that in this area any water that infiltrates or is moving through this area would be moving very slowly and would likely lead to a rise in the groundwater level. The low hydraulic conductivity likely aligns with the presence of water at MB01 and the significant difference in groundwater levels between MB01 and MB03.

8.4 Groundwater monitoring

Wagga Wagga City Council has an urban salinity piezometer network of 214 sites across the city, ranging in depth from 2.6 m to 61 m with 16 of the sites being damaged and no longer used and monthly measurement records from 1994.

This investigation included 30 sites from the western catchment that are either in the vicinity or provide information on the groundwater system in the broader surrounding area of the subject site, see **Table 5** and **Figure 21**.

Table 5: *WWCC groundwater monitoring sites included in this investigation*

Site	Depth	Elevation mAHD	Date Drilled	Easting	Northing
2	10.3	198.36	June 1994	530396	6113170
3	7.4	185.58	May 1994	531432	6113072
5	9.7	198.76	May 1994	532101	6112910
6	13.2	211.33	May 1994	531938	6112342
7	4.1	198.13	March 1994	531704	6112485
9	4.3	189.58	March 1994	531497	6112686
10	4.1	192.12	March 1994	531632	6112662
11	7.1	200.29	May 1994	530856	6111497
14	9.9	216.86	May 1994	532214	6111264
15	9.9	208.80	May 1994	532061	6111761
17	13.7	183.51	June 1995	530854	6113472
20	14.9	182.72	June 1995	533049	6113478
34	24	208.72	June 1995	532061	6111764
38	15	207.43	May 1996	530170	6111671
39	49	216.63	May 1996	533201	6113001
40	25.77	195.19	April 1997	530398	6113009
42	12.6	193.12	April 1997	530998	6112040
43	9.5	212.46	June 2007	531762	6110707
44	22.54	216.95	April 1997	532216	6111264
55	3	182.17	Nov. 1997	530768	6113888
56	6	178.15	June 2007	531252	6113894
57	3	179.95	Nov. 1997	531595	6113369
128	10.2	197.86	May 2007	531911	6112754
147	3.3	192.30	N/A	531455	6112394
173	8	206.01	June 2008	530483	6111212
178	7.3	189.65	June 2010	531233	6112324
179	7.5	191.01	June 2010	531394	6112257
196	14.6	191.88	June 2010	531962	6113149
208	7.5	193.83	June 2013	530403	6112184
209	5	206.57	June 2013	529884	6112018

Figure 21*: WWCC groundwater monitoring sites included in this investigation*

The shallow groundwater system was defined by Cook et al. 2001 as anything where the bore depth was less than 12m. They found that chloride concentrations were higher in the shallow groundwater system and was likely associated with evaporative concentration or a source of salt in the shallow soils that has been mobilised by the rising groundwater levels.

In the assessment conducted for the approved development, the shallow groundwater system is defined as anything where the bore depth was less than 7m. This was based on the groundwater levels in bores at a depth less than 7m being influenced by seasonal variations in rainfall, whilst those below this demonstrated a trend of the rainfall residual mass curve.

8.5 Piezometric contours

The 30 WWCC sites included in this assessment included 22 sites defined as being associated with a deep groundwater system and 8 with a shallow groundwater system. Seven of the deep sites were either damaged or have no groundwater present, whilst 3 of the 8 shallow sites were either dry or damaged.

Piezometric contours were prepared for the shallow and deep groundwater systems along with a groundwater depth map.

This assessment is for 121 Fernleigh Road which is an extension of the independent living lots proposed as part of the CSU South Campus aged care facility development. To ensure consistency in assessment between the sites, the groundwater contours are based on May 2018. In addition, since this assessment the groundwater levels have further declined associated with the drought conditions during this time.

Figure 22 shows the groundwater depth map for May 2018. The map includes the location of sites where no groundwater level information was available due to the bore being dry or damaged and the data from these sites was excluded. The bores that were dry or damaged are in **Table 6**.

Table 6*: Damaged or dry WWCC sites in January 2020*

Site	Depth	Shallow/Deep	Dry/Damaged
2	10.3	Deep	Dry
3	7.4	Deep	Damaged
5	9.7	Deep	Dry
6	13.2	Deep	Dry
7	4.1	Shallow	Dry
14	9.9	Deep	Dry
15	9.9	Deep	Dry
55	3	Shallow	Damaged
56	6	Shallow	Dry
173	8	Deep	Dry

Figure 22 shows the groundwater depth beneath the land that is the focus of this assessment is greater than 2m and likely greater than 2.5m.

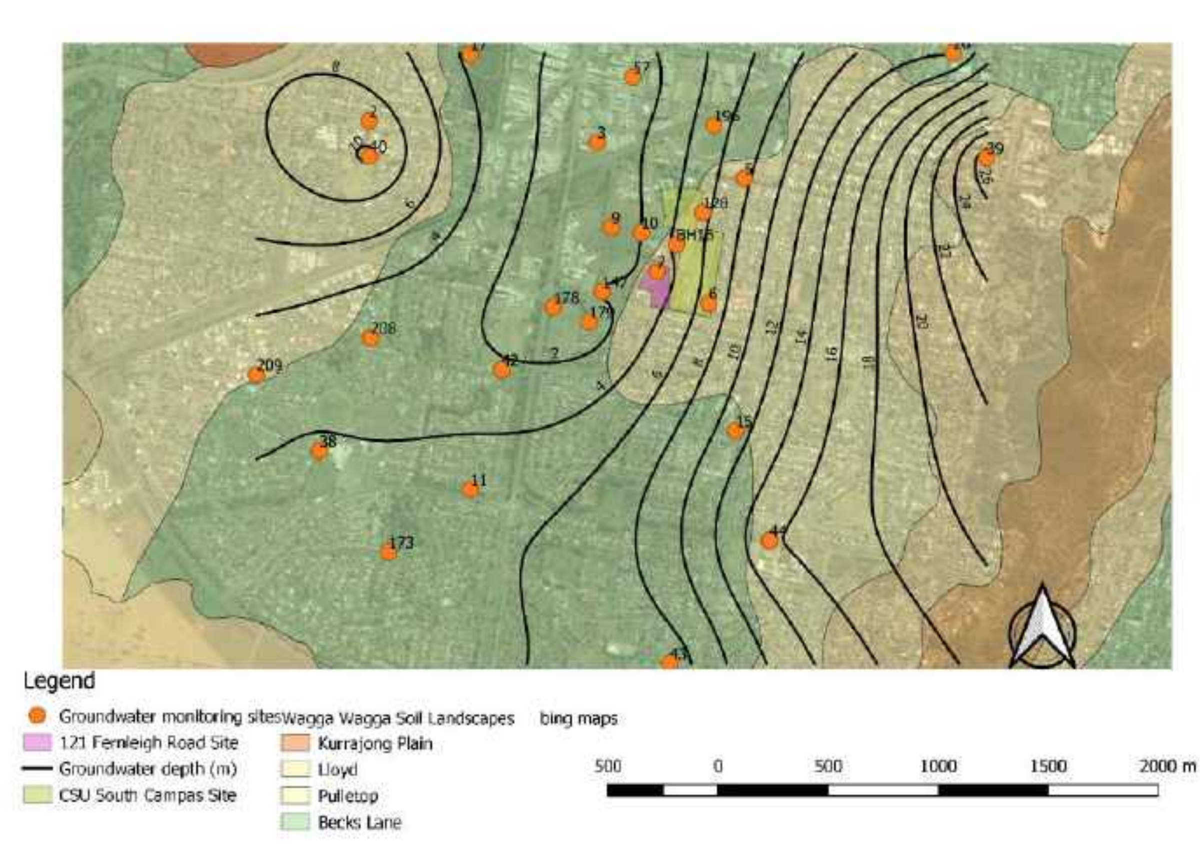

Figure 22: *Groundwater depth contours*

The shallow piezometric contours show that the groundwater flow is from north to south and predominantly within the Becks Lane soils landscape. At the subject site, the shallow groundwater flow is from east to west. In the vicinity of the Juvenile Justice Centre they then head towards the north, consistent with the flow direction of the catchment. A map of the shallow piezometric contours can be seen in **Figure 23**.

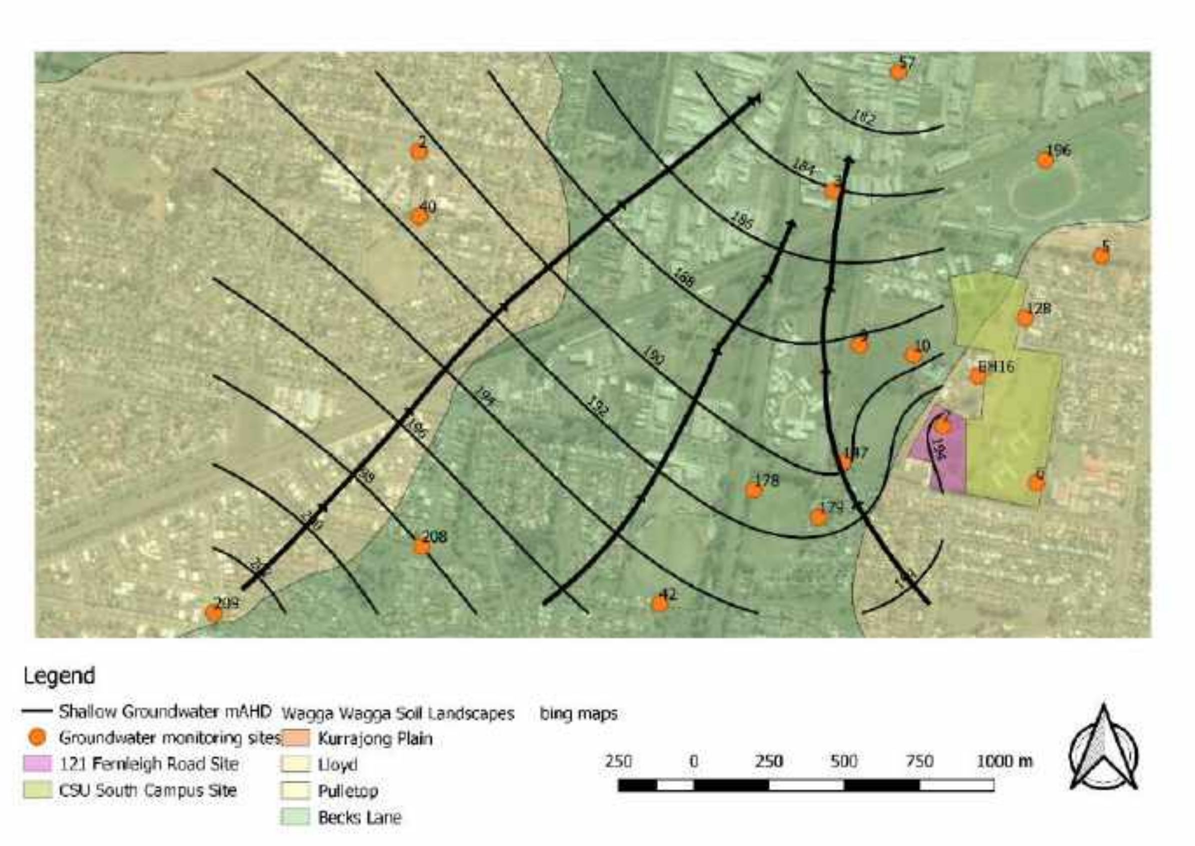

Figure 23*: Shallow piezometric contours*

The deep piezometric contours also mimic the topography with the groundwater flow generally south to north from areas of higher to lower topographic elevation, see **Figure 24**. At the subject site the groundwater flow is from the south-east to the north-east. The surface elevation at site 7 is 199 mAHD, based on the deep piezometric contours, the groundwater at this location is about 8 m below ground level. The ground elevation at site 128, on College Street near the northern area of the investigation site, is 198 mAHD with the groundwater level being 8.11 m below ground level.

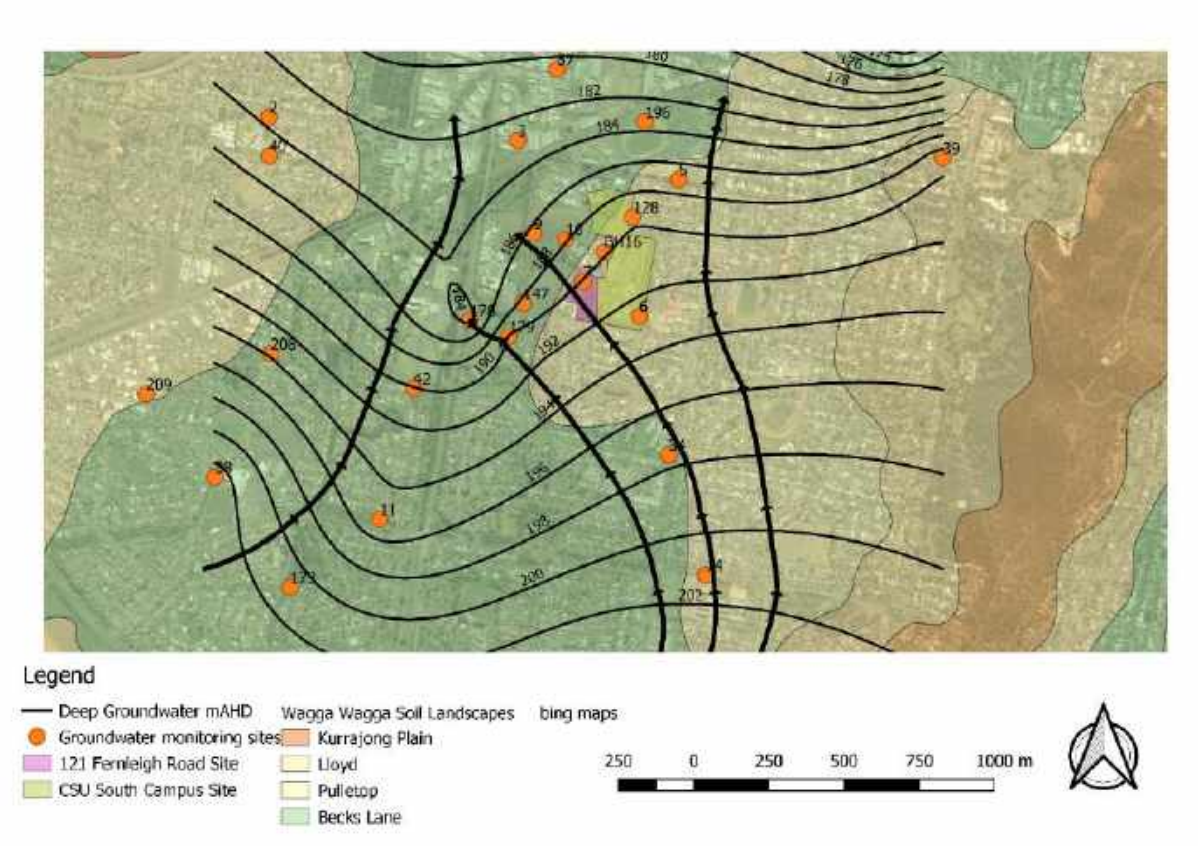

Figure 24*: Deep piezometric contours*

The assessment showed that the groundwater levels beneath the site were at least 2.29m below ground level, with the shallowest groundwater level observed at BH02 at the lowest elevation.

The current climatic conditions have seen a period of below average rainfall, with the rainfall residual mass curve since early 2016 showing below average rainfall. The cumulative deviation is at a similar level to those seen during the millennium drought, see **Figure 8**. A period of average or above average rainfall would lead to a rise in groundwater levels in the area of the investigation site. Groundwater levels at Site 7 on site would likely not rise higher than previously recorded due to the influence of evapotranspiration.

Groundwater levels in the Wagga Wagga groundwater salinity monitoring network declined during the millennium drought. Post the millennium drought they rose to within about 0.5m to 1m of their pre-millennium drought levels but have declined since 2016 due to the below average rainfall.

The available groundwater level information supports the conceptual model of there being a shallow groundwater system generally associated with the lower lying areas and the Becks Land soil landscape and adjacent highly weathered metamorphic sediments. The groundwater system beneath the investigation site is likely associated with the deep groundwater system, which is consistent with the conceptual model in **Figure 16** and **Figure 17**.

8.6 Wet year assessment

To assess the potential impact of a wet year on groundwater levels the following assessment was conducted.

Climatic data from the weather station 72150 – Wagga Wagga AMO was used to define a wet year. This assessment defines a wet year as the decile 9 (90^{th} percentile) for annual rainfall. The decile 9 annual rainfall for this site is 762mm, based on a climatic record of 76 years (1942 - 2018).

A review of the annual rainfall record identifies that since the end of the millennium drought in 2009 there have been two years that have exceeded the decile 9 (2010, 2016) and one that has exceeded the decile 8.5 (2011).

The assessment of a wet year has been based on 2016. This is due to 2010 and 2011 proceeding the millennium drought, which saw groundwater levels across the southern Murray Darling Basin significantly decline. The period between 2011 and 2018 represented a period of median rainfall (553 mm) close to the long-term median (566 mm).

The assessment of the possible site conditions and constraints posed by groundwater during a wet year, was conducted by assessing the shallow and deep groundwater levels in 2016 at monitoring sites identified in the hydrogeological assessment. This was to ensure consistency with the adjacent aged care facility (Report 6723, McMahon 2020) that this assessment is a seeking an extension of the area of individual living lots.

The assessment included the preparation of:

- Shallow piezometric contours.
- Deep piezometric contours.
- Groundwater depth contours.

The assessment has identified that the groundwater levels in 2016 were higher than those observed in 2018 (Annual rainfall in 2017 and 2018 was less than decile 2).

The 2016 shallow and deep piezometric contours have a steeper gradient and groundwater levels were between 1m to 2m higher relative to 2018, with the levels being about 2m higher immediately west of the site, **Figure 25,** and **Figure 26**.

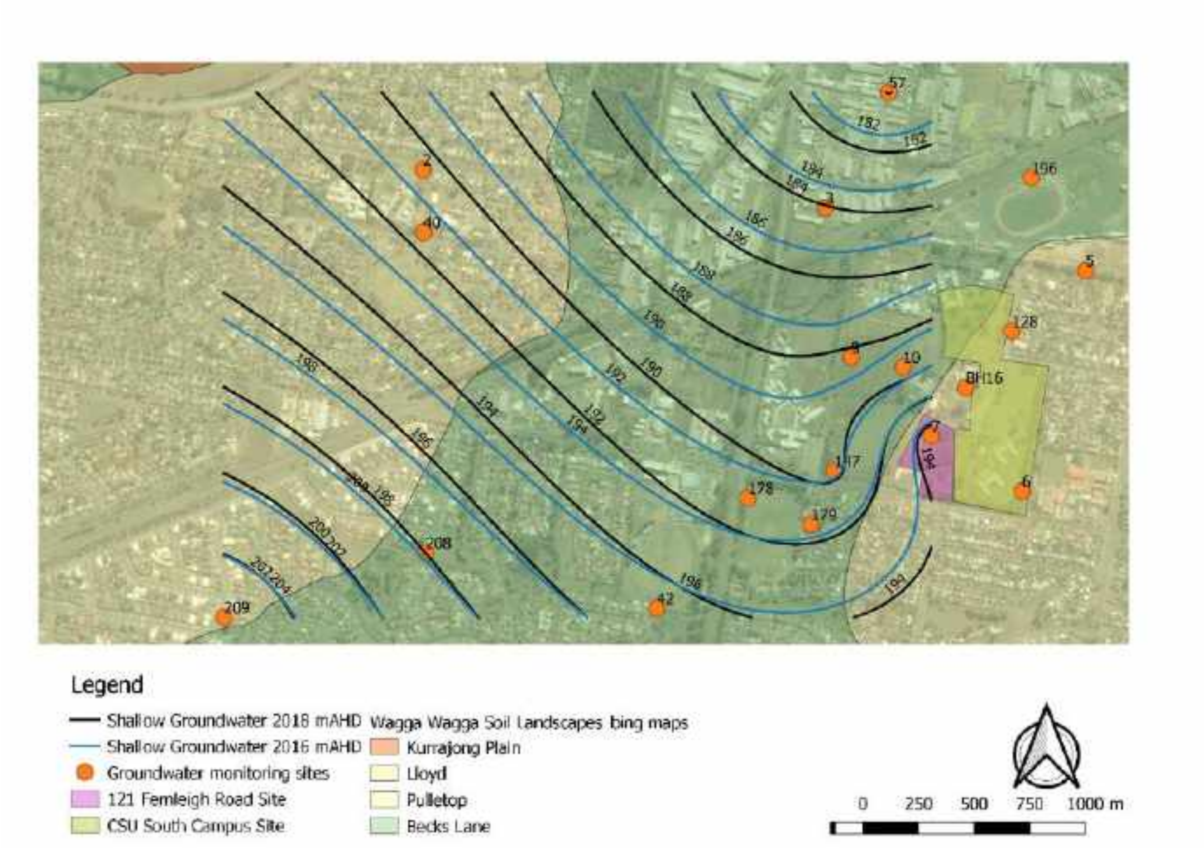

Figure 25*: 2016 shallow piezometric contours*

The 2016 groundwater depth contours (**Figure 25**) show that the groundwater levels were greater than 3m over the majority of the development site. The groundwater level beneath the majority of the area subject to this assessment was less than 1m below the groundsurface.

Shallow groundwater levels are generally not experienced for an extended period and are assocaited with periods when rainfall considerably exceeds the long term average. Once rainfall is average or less the groundwater level varies with climatic conditions and is generally greater than 2m below ground level.

Average rainfall conditions were observed from 2012 to 2015, see **Figure 8**. During this period the groundwater level at site 7, varied between 1m and 3m below ground level.

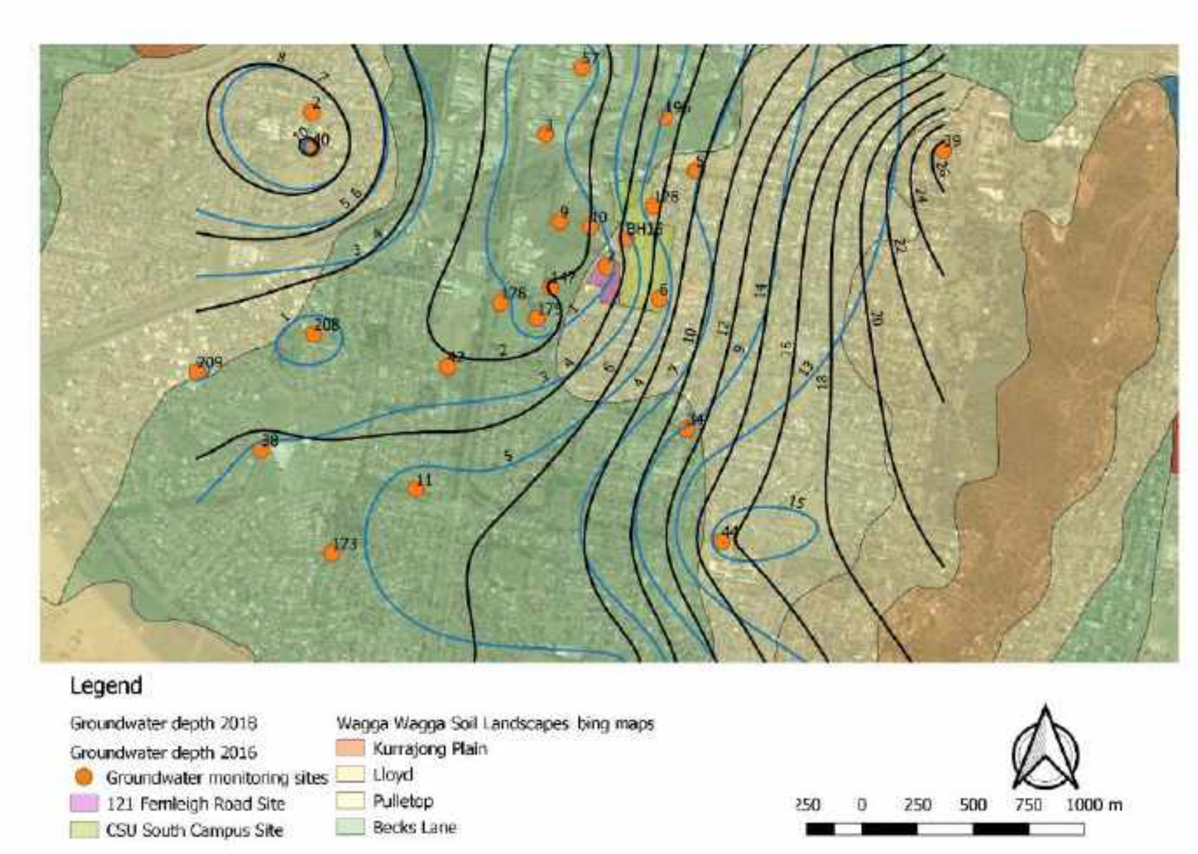

Figure 26*: 2016 deep piezometric contours*

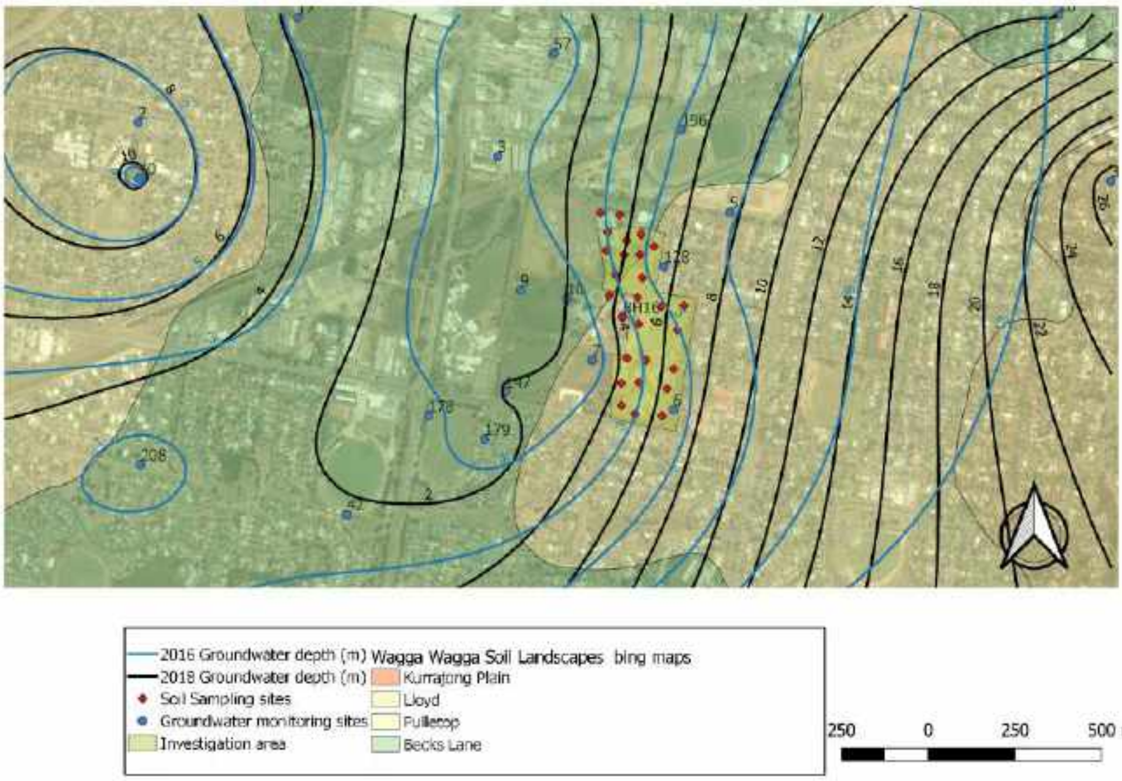

Figure 27*: 2016 groundwater depth contours*

8.7 Wet year site conditions and constraints

The construction of the monitoring sites during this investigation has identified the presence of shallow groundwater (2.29m below the existing ground level) in the north-west corner of the site at MB01 (screened from 3m to 5.8m). At the time of construction, the groundwater was intersected at a depth about 5.7m below the existing ground level. MB02 which is constructed to a depth of 3.3m depth was dry.

This is a pressure head water level rather than a water table level. If it was a water table level the groundwater would have been intersected at a depth comparable to the water level in MB01.

The standing water level at MB01 as an Australian height datum is 192.62 mAHD, which aligns closely with the shallow piezometric contours in **Figure 23**. At this location when the piezometric standing water level is compared to a wet year scenario such as shown in **Figure 25**, it is likely to be near the existing ground surface.

It is estimated that the piezometric standing water level at MB02 would be between 1m and 1.5m below the existing ground level during a wet period, when compared to the shallow piezometric contours (**Figure 25**) and the groundwater depth contours in **Figure 27**.

It is likely that during periods of above average rainfall that the piezometric groundwater levels could be less than 1.5m below the existing ground surface beneath a significant proportion of the subject site. The actual groundwater system would also be in close proximity to the existing ground surface.

The subject site will have additional clean fill added to ensure that it is terraced to ensure a minimal change in gradient across the site. The addition fill will need to ensure that during a wet period that the groundwater system is at least 2.5m below ground level. The actual minimal amount of additional clean fill required across the site will need to be evaluated once a detailed surface elevation survey of the site has been completed.

8.8 Future land use and groundwater recharge

The proposed development layout will incorporate a 70:30 hardstand ratio. An example of the style of hard stand development is illustrated in the assessment report for the approved development, with there being minimal turfed and garden area. As identified in the assessment report for the approved development, recharge at the site is estimated to be less than is presently occurring due to the significant increase in hardstand area.

8.9 Land use change

The development of the site will require the removal of a number of existing trees within the development area.

As outlined in the assessment for the aged care development the impact of the removal of the trees in intercepting groundwater should be offset by the reduced amount of rainfall recharge to the groundwater system, due to seventy percent of the area being hardstand.

9.0 Groundwater management plan

Groundwater levels in the north-western area of the site are presently about 2.3m beneath ground surface and would be deeper in the areas of the site with a higher surface elevation.

Previous rainfall and groundwater level data for Site 7 and the wet scenario groundwater level contours, indicates that during periods of above average rainfall the groundwater levels would be less than 2.5m below ground level over an extended area of the site.

The site is sloped, and it is proposed to increase the ground level with fill to ensure that it is terraced and a minimal gradient change across the total development area. The addition of fill across the site to ensure that the groundwater level is a minimum of 2.5m below ground level during periods of above average rainfall, will ensure that the site is sufficiently above the groundwater system to not impact on any infrastructure.

9.1 Hardstand and rooved area

The development should aim to maximise the amount of hardstand and rooved areas and minimise the area irrigated. The use of lawn, grasses, small, medium and large plant species and trees will assist with minimising recharge in irrigated areas. The larger plant species and trees will require irrigation to become established but in the longer term should require minimal to no irrigation. This needs to be balanced to ensure that the development is an attractive and welcoming environment as well as minimising the amount of reflected heat from the hardstand areas.

The Guide to Urban Cooling Strategies by the low carbon living CRC (Osmond and Sharifi 2017) may assist in designing an environment that reduces that amount of reflected heat during summer, whilst balancing the need to be aware of the need to minimise the amount of groundwater recharge.

9.2 Landscaping

The landscaping of the area should integrate the use of lawn, grasses, small, medium and large plants, shrubs and tree species of differing watering needs to establish an attractive and welcoming environment that also assists with shading and cooling the environment during summer.

As many as practical of the existing trees on site should be retained to assist with shading and cooling of the site as well as assisting in reducing rainfall recharge in the area and potentially accessing groundwater to assist in the management of the high saline water levels lower in the catchment.

Any large irrigated areas should be located as far as practical in the higher elevation areas in the eastern and south-eastern areas of the site. This will mitigate the likelihood of recharge to the shallow groundwater system to the west of the site.

The establishment of the plants and trees in the initial years will require irrigation to assist them in becoming established, with irrigation water use likely to be higher in the initial years but declining as the plants become established.

The long-term water use should aim to achieve leakage past the root zone that is equivalent or less than long term annual average rainfall recharge to the groundwater system at the current site.

9.3 Water management

The site should be managed to ensure that rainfall plus irrigation onsite does not exceed the equivalent of 17 mm per year or about 3% of the long term annual average rainfall recharge to the groundwater system from the current site.

To monitor this, onsite or Bureau of Meteorology rainfall data should be collected along with either direct metered irrigation usage or estimate irrigation usage annually. Additionally, soil moisture monitoring can be conducted across the site to ensure the efficient use of irrigation water and to minimise the amount of water passing the root zone. On site irrigation usage and additional monitoring that demonstrates efficiency of water use within the root zone should be reported annually to provide evidence that the long-term irrigation usage and rainfall do not exceed the estimated pre-development long term annual average recharge.

The installation of two additional monitoring bores to the Wagga Wagga urban salinity groundwater monitoring network in the north-western area and the south eastern area of the subject site prior to commencement of onsite construction works will assist in monitoring groundwater levels in the area. These two sites would mitigate the removal of Site 7, which likely will be removed during site works.

The long-term groundwater level trends observed at these sites will not be able to be directly associated with the site but will assist in building an understanding of groundwater levels in the area.

10.0 Disclaimer

The information contained in this report has been extracted from field and laboratory sources believed to be reliable and accurate. DM McMahon Pty Ltd will not assume any responsibility for the misinterpretation of information supplied in this report. The accuracy and reliability of recommendations identified in this report need to be evaluated with due care according to individual circumstances. It should be noted that the recommendations and findings in this report are based solely upon the said site location and the ground level conditions at the time of testing. The results of the said investigations undertaken are an overall representation of the conditions encountered. The properties of the soil within the location may change due to variations in ground conditions outside of the tested area. The author has no control or liability over site variability that may warrant further investigation that may lead to significant design changes.

11.0 Notice of Copyright

12.0 References

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13.0 Attachments

Attachment	Details
A. Bore log GW416216	2 pages
B. Laboratory report	2 pages
C. MB01 bore log	1 page

McMahon
EARTH SCIENCE

DOCUMENT ATTACHMENTS

REPORT 6722

DM McMahon Pty Ltd
6 Jones Street, (PO Box 6118)
Wagga Wagga NSW 2650

t (02) 6931 0510
www.dmmcmahon.com.au

Attachment A : *Bore log GW416216*

NSW Office of Water
Work Summary

GW416216

Licence: 40BL192568

Licence Status: ACTIVE

Authorised Purpose(s): MONITORING BORE
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Equipped
Construct.Method:
Owner Type: Local Govt

Commenced Date:
Completion Date: 15/03/2011

Final Depth: 9.50 m
Drilled Depth: 9.50 m

Contractor Name: COFFEY GEOTECHNICS
Driller:
Assistant Driller:

Property: COUNCIL WORKS DEPOT 155 FERNEIGH ROAD WAGGA WAGGA 2650
GWMA:
GW Zone:

Standing Water Level: 8.500
Salinity:
Yield:

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	WYNYA	WYNYA.38	5//632012
Licensed:			

Region: 40 - Murrumbidgee
River Basin: - Unknown
Area/District:

CMA Map:
Grid Zone:

Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Source: Unknown

Northing: 6112651.0
Easting: 530885.0

Latitude: 35°07'42.7"S
Longitude: 147°20'20.4"E

GS Map: -

MGA Zone: 0

Coordinate Source: GPS - Global Positioning System

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	9.50	100			Unknown
1	1	Casing		0.00	3.50	100			
1	1	Opening	Screen	3.50	8.50	100		1	
1	1	Casing		8.50	9.50	100			

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)

Geologists Log
Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	0.20	0.20	gravel, clayey sandy, sand fine to coarse grained, gravel fine to medium grained, low plasticity, orange	Gravel	
0.20	0.50	0.30	gravel, clayey sandy, sand fine to coarse grained, gravel fine to medium grained, low plasticity, yellow	Gravel	
0.50	0.70	0.20	clayey sand, sand fine to medium grained, low plasticity, grey yellow	Clayey Sand	
0.70	1.80	1.10	clay, medium to high plasticity, yellow orange grey, traces of fine to medium grained sand	Clay	
1.80	7.00	5.20	clay, medium to high plasticity, yellow grey with traces of fine to medium grained sandy	Clay	
7.00	8.50	1.50	sandy clay, medium plasticity, grey yellow, sand fine to coarse grained	Sandy Clay	
8.50	9.50	1.00	shale, fine to medium grained, grey white yellow	Shale	

Remarks

15/03/2011: Form A Remarks:
Helen Lester: Coordinates are taken from charted licence location.
MW3
Information taken from Consultants Log

*** End of GW416216 ***

Attachment B : *Laboratory report*

ENVIRONMENTAL AND ANALYTICAL LABORATORIES

Locked Bag 588
Wagga Wagga NSW 2678

Tel: +61 2 6933 2849
Fax: +61 2 6933 2477
Email: eal@csu.edu.au
www.csu.edu.au/faculty/science/eal

DM McMahon Pty Ltd

PO Box 6118 6 Jones Street

Wagga Wagga NSW 2650

Attention: David McMahon

Monday, March 9, 2020

NATA Accredited Laboratory Number: 9597

Accredited for compliance with ISO/IEC 17025 - Testing

LABORATORY ANALYSIS REPORT

Report Number:2002-0134

For all enquiries related to this report please quote document number: 2002-0134

Facility:

Order # 6705

Sample Type	**Collected By**	**Date Received**
Soil	A. Rudd	28-February-2020

EAL ID	Client ID. Date/Time sample taken	Test	Result	(units)	Method Reference	Limit of Reporting
20Feb-0415	**BH02-1.0m** 26.02.20					
		Conductivity (1:5 soil/water)	**695**	µS/cm	LTM-S-003	1
		pH (1:5 soil/water)	**9.8**	pH units	LTM-S-004	
20Feb-0416	**BH02-2.0m** 26.02.20					
		Conductivity (1:5 soil/water)	**276**	µS/cm	LTM-S-003	1
		pH (1:5 soil/water)	**9.3**	pH units	LTM-S-004	
20Feb-0417	**BH02-3.0m** 26.02.20					
		Conductivity (1:5 soil/water)	**169**	µS/cm	LTM-S-003	1
		pH (1:5 soil/water)	**8.8**	pH units	LTM-S-004	
20Feb-0418	**BH02-4.0m** 26.02.20					
		Conductivity (1:5 soil/water)	**199**	µS/cm	LTM-S-003	1
		pH (1:5 soil/water)	**8.6**	pH units	LTM-S-004	
20Feb-0419	**BH02-5.0m** 26.02.20					
		Conductivity (1:5 soil/water)	**228**	µS/cm	LTM-S-003	1
		pH (1:5 soil/water)	**8.7**	pH units	LTM-S-004	
20Feb-0420	**BH02-6.0m** 26.02.20					
		Conductivity (1:5 soil/water)	**275**	µS/cm	LTM-S-003	1
		pH (1:5 soil/water)	**8.7**	pH units	LTM-S-004	

Note:

**** NATA Accreditation does not cover the performance of this service.***

Charles Sturt University

ENVIRONMENTAL AND ANALYTICAL LABORATORIES

Locked Bag 588
Wagga Wagga NSW 2678

Tel: +61 2 6933 2849
Fax: +61 2 6933 2477
Email: eal@csu.edu.au
www.csu.edu.au/faculty/science/eal

DM McMahon Pty Ltd
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Attention: David McMahon

Monday, March 9, 2020

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LABORATORY ANALYSIS REPORT

Report Number:2002-0134

For all enquiries related to this report please quote document number: 2002-0134

Facility:

Order # 6705

Sample Type	Collected By	Date Received
Soil	A. Rudd	28-February-2020

EAL ID	Client ID. Date/Time sample taken	Test	Result (units)	Method Reference	Limit of Reporting

Signed .... Michael Glazier, Laboratory Manager.

All samples analysed as received.
All soil results are reported on a dry basis.
The EAL takes no responsibility for the end use of results within this report.
This report shall not be reproduced except in full.
This report replaces any previously issued report

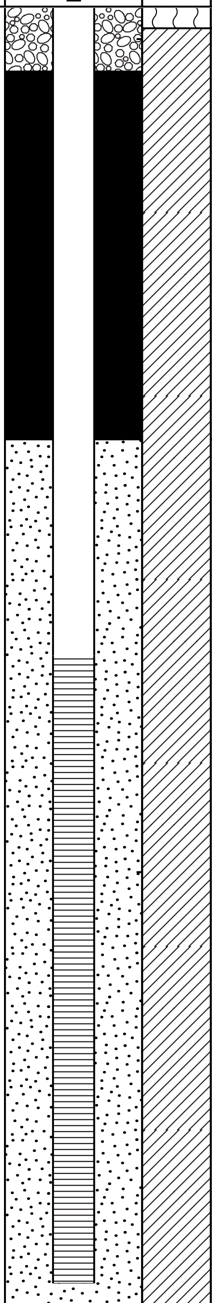
Attachment C : *MB01 bore log*

ENVIRONMENTAL WELL BH02 (MB01)

PROJECT NUMBER 6705	**DRILLING COMPANY** McMahon Earth Science	**COORDINATES**
PROJECT NAME	**DRILLER** Mr. David McMahon	**COORD SYS** MGA94 z55H
CLIENT Croft Developments Pty Ltd	**DRILLLERS LICENCE** DL1770	**SURFACE ELEVATION** ~197.2m
ADDRESS 121 Fernleigh Road, Turvey Park	**DRILLING METHOD** Augering Solid Flight	**WELL TOC** 6.0m
ADDRESS NSW 2650	**TOTAL DEPTH** 6m	**LOGGED BY** AR & LN
DRILLING DATE 26/02/2020	**DIAMETER** 100mm	**CHECKED BY** A. Rudd
COMPLETION 26/02/2020	**CASING** uPVC -50mm Class 12	**SCREEN** uPVC -50mm Class 12 Slotted

COMMENTS North west corner of proposed lot 87. Piezo installed to existing ground height. Elevation has been approximated from survey data.

Depth (m)	Elevation (m)	Samples	Is Analysed?	Water	Piezometer Installation (Piezo)	Graphic Log	Classification (AS1726:2017)	Material Description	Moisture	Consistency
0.0–0.1	197						OL	TOPSOIL: Dark brown silty clay, organic, dry, firm consistency.	D	F
0.1–0.5		6705/2.1 6705/CBR	LS CBR				C I	SILTY SANDY CLAY: Colluvial, reddish brown, low plasticity, firm consistency, Dry.		
0.5–1.5	196.5, 196	6705-1.0m	pH & EC					SANDY CLAY: Residual, reddish yellow, low to moderate plasticity, stiff consistency, Dry.		ST
1.5–2.0	195.5	6705-2.0m	pH & EC					SANDY CLAY: Residual, yellow, low to moderate plasticity, very stiff consistency, Dry.		VST
2.0–2.7	195, 194.5						CH	CLAY: Residual, yellow, low to moderate plasticity, stiff consistency, moderately moist. traces of silt and fine sand present. Minor white mottling from chemically weathered parent material. No structure or fabric of parent material corestones present.	T	ST
2.7–4.0	194, 193.5	6705-3.0m 6705-4.0m	pH & EC pH & EC					SILTY CLAY: Residual brownish yellow, low to moderate plasticity, stiff consistency, moderately moist. Coarse fragments of Ordovician Metasedimentary rocks present (5-10%) up to 20mm. Silt present on surface of chemically weathered coarse fragments and throughout. White mottling present from completely weathered OM, presents as saprolite.		
4.0–5.5	193, 192.5, 192	6705-5.0m	pH & EC					SILTY CLAY: Residual, brownish red, low to moderate plasticity, stiff consistency, moderately moist to 5.5m, wet from 5.5 to termination depth of 6.0m. Residual material derived from Ordovician Metasedimentary parent material		
5.5–6.0	191.5	6705-6.0m	pH & EC	∇					W	VF
6.0	191							Termination at target depth: 6.0 m		



Disclaimer This bore log is intended for environmental not geotechnical purposes.