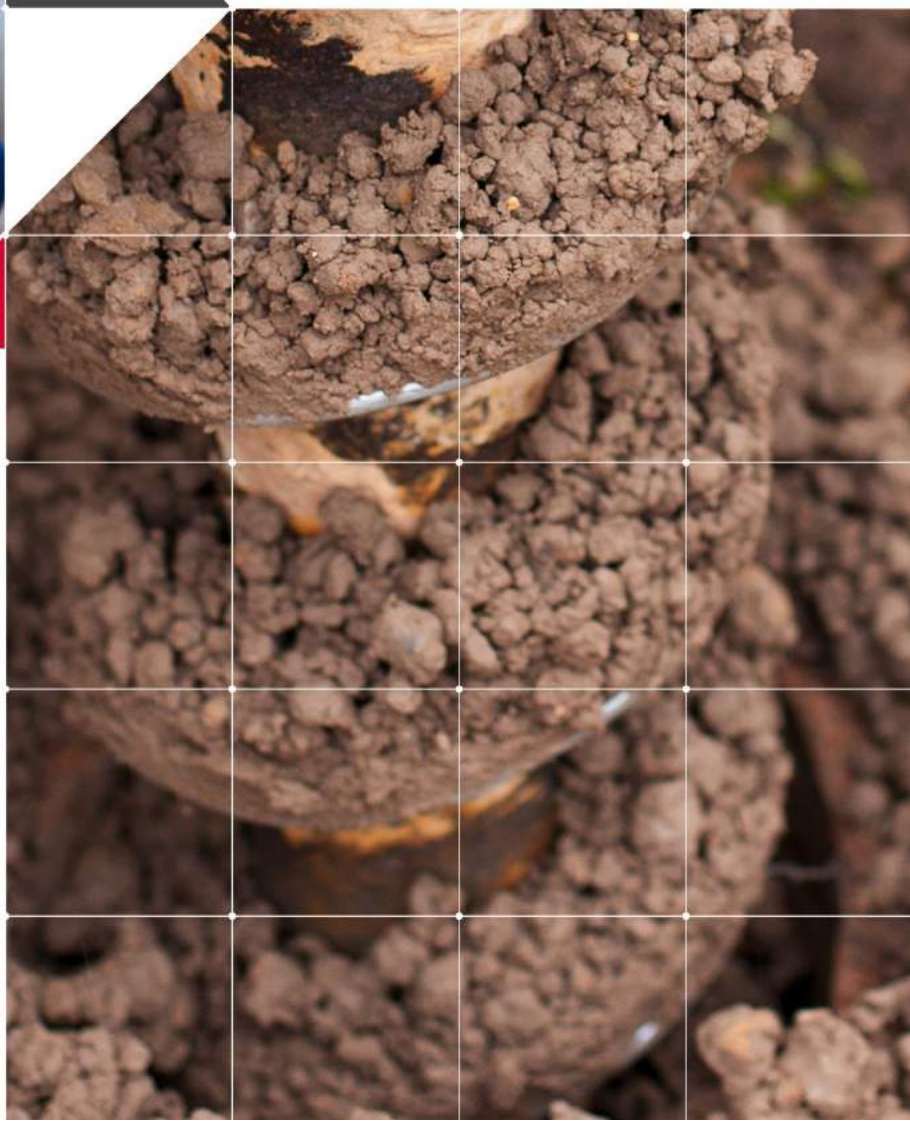
McMahon EARTH SCIENCE



PROPOSED SOLID WASTE LANDFILL

GROUNDWATER IMPACT ASSESSMENT

TUMBLONG RESERVE ROAD TUMBLONG NSW 2729

NOVEMBER 2019

REPORT NO. 5985

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Executive summary

DM McMahon Pty Ltd (McMahon) was commissioned by MH Earthmoving Pty Ltd (MHE) to undertake a groundwater impact assessment on a quarry located at Tumblong NSW that is nearing the end of its operational life.

MHE intend to develop the final excavated quarry void as a waste disposal facility (landfill) receiving up to 60,000 tonnes per annum (tpa) of general solid (non-putrescible) waste materials from Visy Pulp and Paper (Visy) located in Tumut, NSW.

McMahon conducted research and enquiries of the hydrogeological conditions underneath and surrounding the site as well as undertaking physical investigations and measurements by:

- Drilling five bores in the base of the quarry to a depth of 21.6 metres.
- Drilling six nested monitoring bores around the quarry to depths between 19 and 75 metres
- Conducting slug testing on all bores to determine the near well aquifer characteristics and is used to determine the hydraulic conductivity of the material near the bore.
- Undertaking chemical analysis on groundwater encountered.

The results returned the following findings:

- The underlying geology has a hydraulic conductivity of between 4.4×10^{-6} m/sec and 8.2×10^{-8} m/sec, which compares favourably to a minimum hydraulic conductivity of a compacted clay liner of 1×10^{-9} m/sec as defined by the NSW EPA Environmental Guidelines for solid waste landfills (2016).
- Groundwater was encountered in only one bore (BH5D).
- The groundwater in BH5D is 58 metres below the existing ground surface at an elevation of 209.47 mAHD.
- The groundwater in BH5D is part of low yielding intermediate to regional groundwater flow system that is hydraulically disconnected from the overlying surface water system.
- The analysis of the water sampled from BH5D identified that the water is NOT suitable for human consumption due to manganese and nickel concentrations exceeding the health guidelines values. Long term exposure to nickel concentrations above the guideline value may result in toxic effects to the kidney and nickel compounds are carcinogenic to humans.

In summary, McMahon assesses that the site is suitable for the development of the proposed land fill with low risk to the underlying groundwater system owing to:

- The low hydraulic conductivity of underlying geology that will act as a natural barrier (in addition to the engineered liner) that will significantly reduce the likelihood of potential contamination of groundwater from the proposed landfill.
- The deep depth to groundwater beneath the site.
- The groundwater is not suitable for drinking water, therefore is unlikely to be used as a resource for such.

Based on the above and adoption of the recommendations for the groundwater management plan, the site is assessed to be suitable for the proposed landfill development with low risk to groundwater.

Report type

Groundwater Impact Assessment

Site address

Lot 7004 and Lot 7300
Tumblong Reserve Road
Tumblong NSW 2729

Report number

5985

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Contents

1.0 Introduction

This report presents the details and results of a groundwater impact assessment of the quarry site at Lot 7004 and Lot 7300, Tumblong Reserve Road. The site is presently used as a quarry nearing the end of its operational life.

It is proposed to use the final excavated quarry void as a waste disposal facility (landfill) receiving up to 60,000 tonnes per annum (tpa) of general solid (non-putrescible) waste materials from Visy Pulp and Paper (Visy) located in Tumut, NSW. The Visy manufacturing facility produces kraft linerboard from plantation grown radiata pine and recycled paper. During the manufacturing process, by-products are generated which require landfilling in the absence of other resource recovery options.

The surrounding land use includes a travelling stock reserve, a decommissioned land fill to the south west and grazing and cropping farmland encompassing the entirety of the site**.**

This assessment is of the potential groundwater impacts of the use of the site as a waste management facility (landfill) consistent with the siting restrictions as outlined in Environmental Guidelines: Solid Waste Landfills (NSW EPA, 2016) and the environmental suitability of the landfill in relation to the Gundagai Local Environment Plan (2011) and to address the NSW Planning & Environment Planning Secretary's Environmental Assessment Requirements (SEARs) 1321.

1.1 Site identification

The site identification details can be seen as follows, **Table 1**.

Table 1: *Site identification*

Identifier	Details
Address	Lot 7004 and Lot 7300 Tumblong Reserve Road, Tumblong NSW 2729
Real property description	Lot 7004 DP 1028797 Lot 7300 DP 1149008
Centre co-ordinate	589059E 6113435N MGA GDA z55
Property size	Approximately 4.4ha
Owner	Cootamundra- Gundagai Regional Council (Lot 7004 DP 1028797) Crown Land (Lot 7300 DP 1149008)
Local Government Area	Cootamundra- Gundagai Regional Council
Present use	Quarry
Present zoning	RU1 – Primary Production (Gundagai LEP, 2012)

A small proportion of the adjacent DP 702858 also forms part of the development, albeit for the temporary storage of excavated quarry resource used for ongoing Council commitments and for rehabilitation soils post closure.

1.2 Ownership

The National Library of Australia: Trove Database and the Historical Land Records Viewer database was investigated for historical land use, ownership history, previous owner occupations and other notes of interest, **Table 2**. There are some gaps in the data due to the incomplete nature of historical documents, but the data demonstrates lot sizes and identification are maintained throughout the ownership, which indicates congruency of land use.

Table 2: *Historical land ownership*

Year	Data	Address	Owner	Notes/Details
1896	HLRV: Parish Map	**Lots 7300 & 7004**	Crown Land	*"TSR 10947. Not^{d} 15.3.1890"*
1912	HLRV: Parish Map	**Lots 7300 & 7004**	Crown Land	*"TSR 10947. Not^{d} 15.3.1890"*
1921	HLRV: Parish Map	**Lots 7300 & 7004**	Crown Land	*"TSR 10947. Not^{d} 15.3.1890"* TSR has decreased in size.
1931	HLRV: Parish Map	**Lots 7300 & 7004**	Crown Land	*"TSR 10947. Not^{d} 15.3.1890"* TSR has again decreased in size.
1946	HLRV: Parish Map	**Lots 7300 & 7004**	Crown Land	*"Under pastures protection board control, Gaz 17th March 1933 (NW)", "Landfill area – R.85.349 for rubbish depot. Not^{d} 4.6.65"*
1966	HLRV: Charting Map	**Lots 7300 & 7004**	-	*"R.89508 for Quarry Not^{d} 18.7.75", "abt 3.5ha"*

Ownership details from 1966 were not available at the time of reporting, however, Cootamundra-Gundagai Regional Council manage the site.

The review of the available aerial photography from 1961 to 2016 supports the historical data, with the quarry formed sometime before 1961. The aerial photography also supports the observation of no improvements being made on site. A review is summarised in **Table 3**.

Table 3: *Observations from historical aerial photography*

Year	Subject site	Surrounding land
1961	The site appears to be a quarry occupying the majority of surface area.	One rural property can be seen to the east of the quarry. Surrounding areas are predominantly agricultural.
1980	The site remains a quarry with more incised pit.	An open landfill cell can be seen around 300m to the south west of the site and the rural property to the east has been demolished. A new house has been built further to the south east.
1995	The site remains a quarry with some stockpiles of red clay.	No significant development has taken place in surrounding areas
2009	The site remains a quarry with stockpiled material within.	No significant development has taken place in surrounding areas
2013	The site remains a quarry.	Two further houses have been built to the south east. The landfill cell to the south west is capped. Surrounding land is agricultural.
2016	The site remains a quarry.	No significant development has taken place in surrounding areas

1.3 EPA records

The site is not declared to be significantly contaminated as defined by the CLM Act and not registered on the NSW EPA Contaminated land register nor have any nearby properties.

1.4 Council records

Council have not identified any matters being prescribed by Section 59 (2) of the Contaminated Land Management Act 1997 as additional matters to be specified in a planning certificate.

1.5 SafeWork search

A SafeWork NSW Hazardous Chemicals on Premises search was undertaken for the subject site. A search of the records held by SafeWork NSW has not located any records pertaining to the subject site.

2.0 Proposed development

The proposal seeks to utilise the final excavated quarry void as a waste disposal facility (landfill) receiving up to 60,000 tpa of general solid (non-putrescible) waste materials from Visy Pulp and Paper (Visy) located in Tumut, NSW. The Visy manufacturing facility produces kraft linerboard from plantation grown radiata pine and recycled paper. During the manufacturing process, by-products are generated which require landfilling in the absence of other resource recovery options.

The construction of the waste disposal facility at the site will require bulk excavation of the quarry to the required subgrade levels, formation of the waste cells to incorporate a composite lined leachate barrier system, a full leachate collection and extraction system, lining and construction of leachate control facilities and construction of stormwater management infrastructure. The landfill design and associated infrastructure shall be in full accordance with the NSW EPA Environmental Guidelines: Solid Waste Landfills Second Edition (2016).

The proposal is designed to include two waste cells which are formed around the current quarry void footprint (the gravel pit). Additional excavation of the pit would be required to form both waste cells (Cell 1 & Cell 2) and this activity is proposed to be performed in two stages. Excavated materials would be used to construct the perimeter bunds, Cell 1/Cell 2 intercell bund and minimum 200mm thick basal sub-base layer consistent with NSW EPA Guidelines, with the remainder stored in Cell 2 and temporarily within the adjacent lot owned by the proponent.

A 1 metre high engineered bund will be constructed on the northern and western boundary of the landfill, utilising compacted clay fill, these bunds, side slopes and floor will be subsequently covered with geosynthetic clay liner (GCL), high density polyethylene (HDPE) geomembrane and protection geotextile. A sump area for leachate collection and extraction will be constructed within Cell 1 and Cell 2. A series of slotted HDPE pipes laid within a minimum 300mm aggregate leachate drainage blanket will also be installed on the base of the landfill to collect and direct leachate into the two separate sump areas. Leachate will be pumped from the two landfill sumps via 400mm ID HDPE side riser where it will be carried via surface laid pipework to the clay, GCL and HDPE lined leachate storage dam. The leachate storage dam has been designed to meet the requirements of the NSW EPA Environmental Guidelines: Solid Waste Landfills (2016).

Excavated aggregate and fill temporarily stored in the adjacent lot will be progressively removed by Council requiring the material for its ongoing construction needs with the remainder being used for rehabilitation involving the installation of a minimum of 1m upon an engineered capping layer.

A small office and associated infrastructure will be constructed on site for administration purposes.

3.0 Present use and proposed development

The quarry site is presently operated by Cootamundra-Gundagai Regional Council, which, after the proposed excavation to design levels, will be nearing the end of its operational life. It is proposed to change the land use to a waste management facility (landfill). The surrounding land use involves a travelling stock reserve, a decommissioned putrescible landfill 300m to the south west, a waste transfer station 900m to the south and grazing and cropping farmland encompassing the entirety of the site**.** The closest residence to the site is approximately 820m to the south-east of the site.

3.1 Topography

The NSW SIX Maps: e-Topo mapping platform indicates that the subject site lies at an elevation of approximately 265-290m AHD. The site is located on a western spur of a ridgeline that trends north-north west to the east of the site. The ridgeline curves around to the west to the north of the site. The subject site is an open quarry pit with a flat quarry floor and near vertical cut faces.

The spur that the site is located on creates a drainage divide for two first order catchments that commence to the east of the site, both of these drainages do not flow into the proposed landfill site.

The first order drainage to the east of the site terminates at a dam to the east of the site. The other first order drainage commences to the west of the site, commencing about 100 metres west of the Tumblong Reserve Road and forming a second order drainage 900m further west. A landscape depression to the south of the site likely captures runoff from beneath the dam to the east of the site, with it flowing towards the dam to the west of the site.

Located to the north-east of the site are two first order drainages that join to create a second order drainage about 200 metres to the north of the site, this drainage continues to flow to the west away from the site

The surrounding landform pattern has a low relief with a gentle to very steep modal, slopes with fixed erosional and closely spaced drainages forming a non-directional and interrupted tributary pattern. The geomorphological processes are continuously active, driven by precipitation agents to form an eroded mode of geomorphological activity including sheet flow, sheet wash and surface wash from precipitation, **Figure 1**.

3.2 Hydrology

The subject site is part of the Murrumbidgee Central (Burrinjuck to Gogeldrie) Water Source under the *Water Sharing Plan for the Murrumbidgee Unregulated and Alluvial Water Sources 2012*. Runoff water from the site flows to the north west due to local aspect with no natural drainages on site. A first order drainage forms 100m below the site which moves into a second order drainage 900m west of the site. This drainage line develops into third and fourth order lines 2km and 2.8km north west of the site before draining into the Murrumbidgee River. In the wider locale the site is part of a widely to closely spaced, non-directional/convergent incipient stream channel network. The channel network is rapidly migrating and tributary to non-tributary in pattern. Surface waters not consumed by evaporation, evapotranspiration or deep drainage drain to the Murrumbidgee via surface flow and interflow. The Murrumbidgee River flows west as a major tributary of the Murray River within the Murray–Darling basin.

There is limited run-on water to the subject site from neighbouring blocks owing to the spur that the site is located on creating a drainage divide, **Figure 1**.

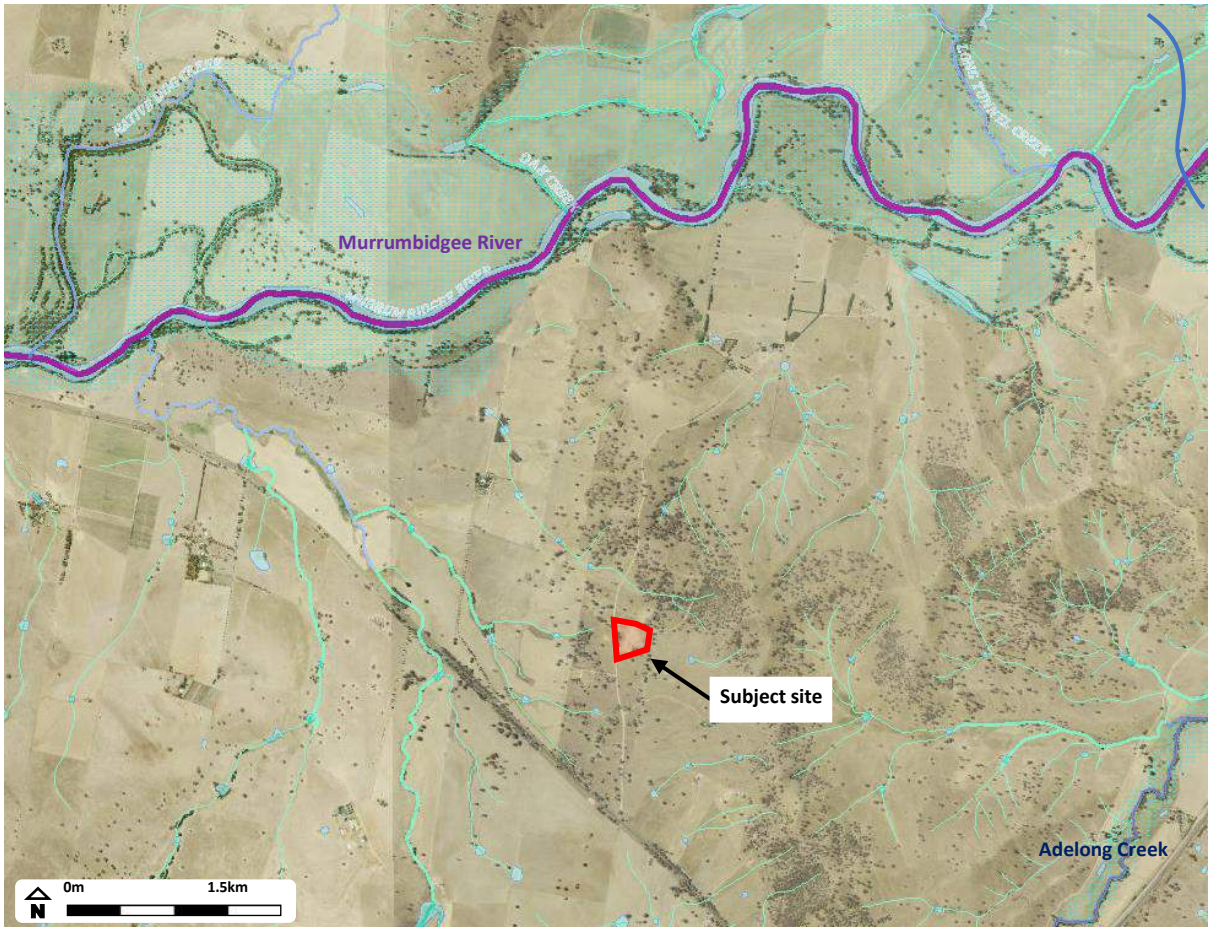

Figure 1**:** *Hydrology map*

4.0 Regional setting

4.1 Climate

The climate data is from SILO data drill for the coordinates of the site -34.09S and 148.00E, (Queensland Government, 2019). It is a mathematical interpolation technique to infill gaps in time series and construct spatial grids. SILO climatic data was used rather than Bureau of Meteorology weather station data due to the proximity of weather stations not being representative of the site and the duration of climatic data available at the nearest sites.

The region experiences hot dry summers with cool to cold winters, **Figure 2**. Rainfall is winter and spring dominant, with an annual average of 655 mm, **Figure 3**. Evaporation exceeds rainfall except May through to August, with an annual average evaporation of 1471 mm, **Figure 4**.

The long term annual residual mass rainfall curve shows that for the first half of the 20th century that rainfall was below average, whilst the second half of the 20th century was above average, **Figure 5**. In the millennium drought (2000 to 2009) rainfall was below average. Since then rainfall has been above average in 2010 to 2012, 2016 and 2017. Since 2018 there has been below average rainfall.

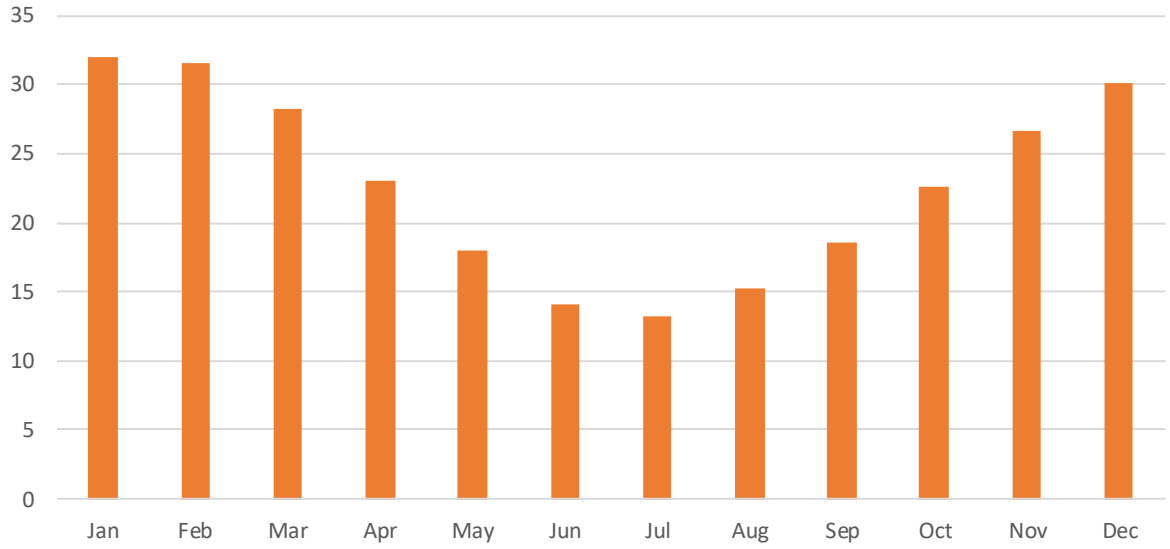

Figure 2: *Average monthly maximum temperature*

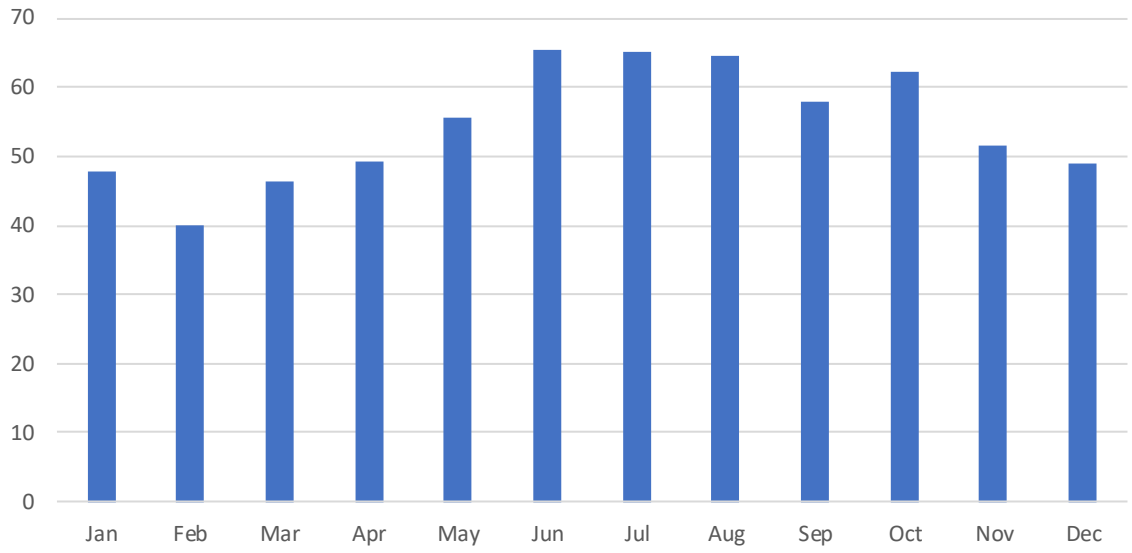

Figure 3: *Average monthly rainfall*

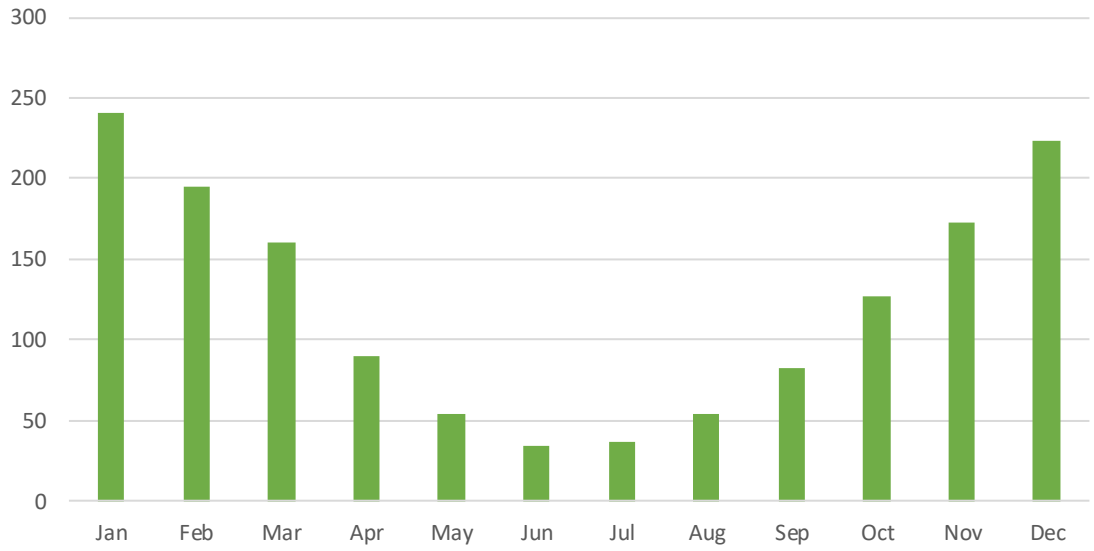

Figure 4: *Average monthly evaporation*

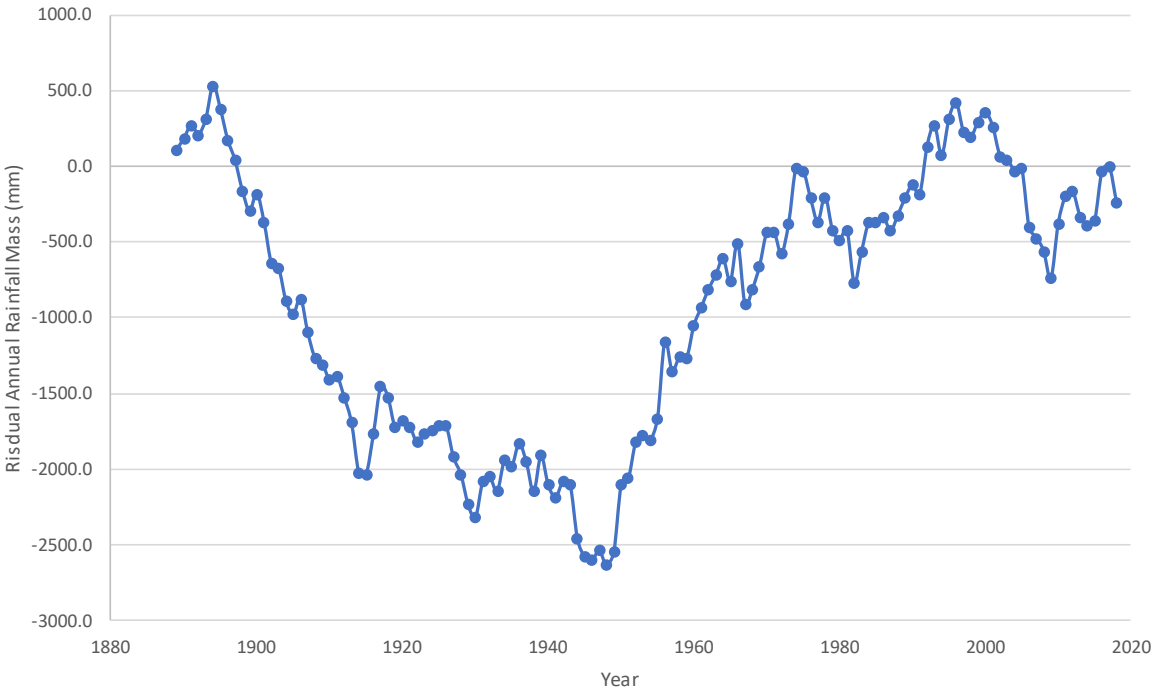

Figure 5: *Annual residual rainfall mass curve*

4.2 Landscape

The site lies within the mapping unit Qb7 from the Digital Atlas of Australian Soil (BRS, 1991). The map unit Qb7 is described as:

Landscape: Hilly with some steep hilly to rugged areas and narrow valleys. Some small areas are of conical hills which are towards the mountains.

Soils: Chief soils are hard neutral and acidic red soils (Dr2.22, Dr2.42, and Dr2.21), sometimes of very shallow depth, with (Um4.1), (Dy3.4), and shallow (Gn2.15) soils. Associated are some undulating areas of (Dy3.42) soils; narrow valleys of unit Va15; and (Dd3.12), (Ug5.13). (Db3.12). (Dr4.12) soils on steep, sometimes bouldery, slopes of serpentine rock.

The NSW modified great soil grouping provides a similar classification defining the surrounds as being Red Earths - less fertile (granites and metasediments) and the surrounding landscape as Red Podzolic Soils - less fertile (granites and metasediments).

Site conditions are synonymous with Qb7 from the site inspection. No serpentine rock was noted on site but is known to exist in geology closer to Gundagai.

Landscape capability mapping of the surrounding landscape defines the broad agricultural land uses most physically suited to an area. It is based on the inherent physical capacity of the land to sustain these land uses and management practices that in the long term will not cause degradation to soil, land, air and water resources (see Dent and Young 1981; Emery 1986; Sonter and Lawrie 2007). It is a function of landscape features and processes and is influenced by terrain, soil and climatic attributes and their interactions.

NSW landscape capability mapping identifies that site as being Class 4 and the surrounding area as Class 5 and the ridgelines to the east of the site as Class 7. The definition of these classes are:

Class 4: Moderate capability land: Land has moderate to high limitations for high-impact land uses. Will restrict land management options for regular high-impact land uses such as cropping, high-intensity grazing and horticulture. These limitations can only be managed by specialised management practices with a high level of knowledge, expertise, inputs, investment and technology.

Class 5: Moderate–low capability land: Land has high limitations for high-impact land uses. Will largely restrict land use to grazing, some horticulture (orchards), forestry and nature conservation. The limitations need to be carefully managed to prevent long-term degradation.

Class 7: Very low capability land: Land has severe limitations that restrict most land uses and generally cannot be overcome. On-site and off-site impacts of land management practices can be extremely severe if limitations not managed. There should be minimal disturbance of native vegetation.

4.3 Geology

The site is in Silurian aged weathered and fractured rocks of the eastern Lachlan Fold Belt, **Figure 6**. The regional geological map (Wagga Wagga 1:250,000) describes the geology in the region of the site as conglomerate, sandstone, siltstone and minor volcanics. The Tumut 1:100,000 geological map which covers the area to the west of the site and contains the continuation of the geological unit (Su) at the site identifies it as quartz rich shale/slate siltstone and fine sandstone of the Bumbolee Creek Formation. The fine-grained siltstone and sandstone are defined as fined grained and predominantly quartz arenites.

The Tumut 1:100,000 does not include a detailed structural study of the formation. The fine-grained beds have a strong foliation. The siltstone and sandstone beds generally have blocky jointing than foliation. Small scale folding (metres) is common and difficult in outcrop to find consistent strike and dip across the structure (Barsden 1990).

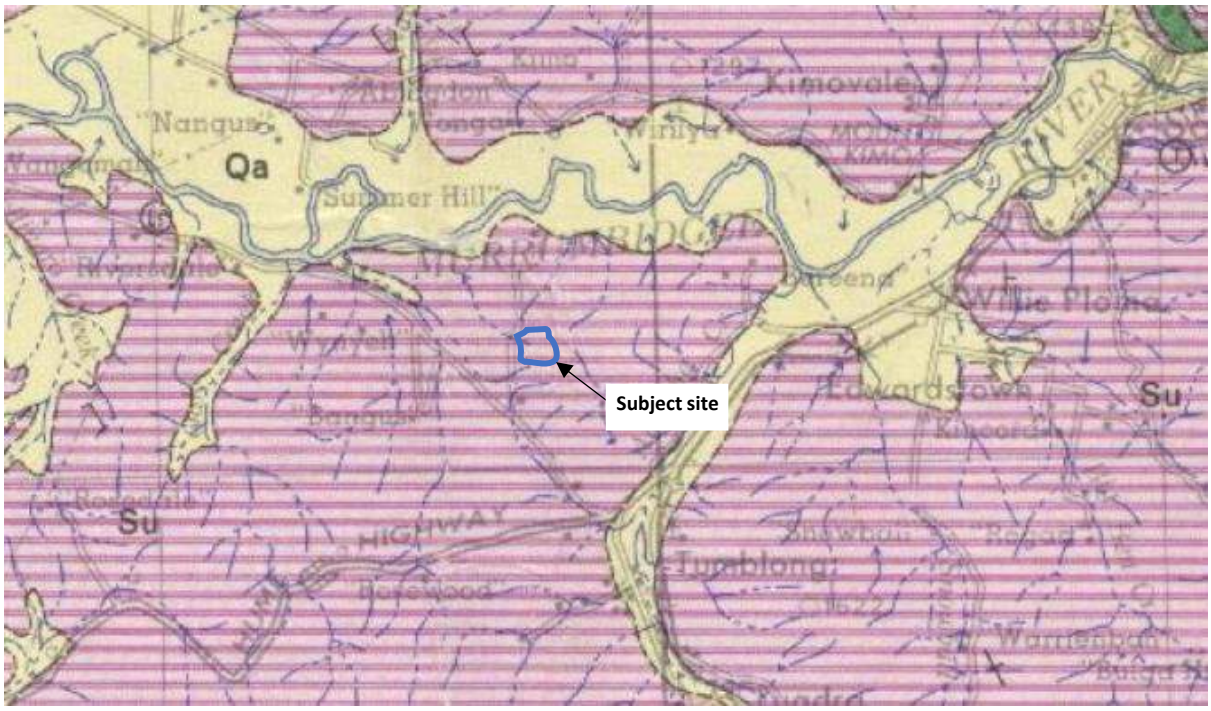

Figure 6: *Regional Geology (Wagga Wagga 1:250,000 geological map sheet)*

4.4 Hydrogeology

4.4.1 Regional

The hydrogeology at the site and the surrounding region is a low yielding fractured rock aquifer system within the Silurian quartz rich shale/slate siltstone and fine sandstone of the Bumbolee Creek Formation.

About 2 kilometres to the north of the site, contiguous with the Murrumbidgee River is the unconsolidated alluvial Cowra Formation. This alluvial aquifer is no more than approximately 30 metres in depth in this reach of the river and highly connected to the Murrumbidgee River (Mitchell 2009).

Table 4 is a summary of the bores in the vicinity of the site and their locations are shown in **Figure 7**. The depth of the water bearing zones in the bores in the region is generally greater than 37 metres below ground level, with recorded standing water levels at the time of construction being between 18 and 34 metres below ground level. Yields of 0.46 L/s and 1 L/s at GW014960 and GW403222 respectively is the only available information on bore yields.

The exception being at GW405001 (4.3 kilometres to the west) where a water bearing zone is documented as occurring at a depth of between 15 and 30 metres depth below ground level. There is insufficient information available on this bore to indicate the groundwater depth or yield from the bore. The distance of the bore from the site mitigates any likelihood of any adverse impacts form the proposed development.

The depth of the water bearing zones of the bores in the region of the site coincides with the contact zone between the weathered and unweathered shale.

An initial site investigation drilled five bores in the base of the quarry to a depth of 21.6 metres. The bore logs for these sites define the material as weathered siltstone, **Attachment A**. The sites did not intersect any water bearing zones. The information from this drilling program informed the siting and design of the monitoring bores constructed during this investigation.

In addition, six nested monitoring sites were constructed during this investigation to depths between 19 and 75 metres, **Table 5** and **Figure 9.**

At the proposed landfill site, BH5D was drilled to a depth of 75 metres, **Table 5**. The contact zone between the weathered and unweathered slate/shale siltstone occurs at a depth of approximately 60 metres. A low permeability water bearing zone was intersected in the vicinity of the contact between the weathered and unweathered rock. At the time of construction, a groundwater level was not able to be measured within BH5D due to the low permeability of the water bearing zone. A groundwater level was later measured at the site of 58 metres below ground level (209.47 mAHD).

The depth of the low permeability water bearing zone in the fractured rock aquifer system and the standing groundwater level indicates that in the vicinity of the Murrumbidgee River that it would not be hydraulically connected to the alluvial Cowra aquifer adjacent to the Murrumbidgee River

4.4.2 Conceptual model

The groundwater data from the site investigations and the construction details from the bores in the region show that groundwater is generally present at the contact between the weathered and unweathered rock and is low yielding.

Based on the bore construction details and regional geology, it has been interpreted that there is an intermediate to regional groundwater flow system in the region of the site. This is based on the location of the low permeability water bearing zone being at the contact between the

weathered and unweathered slate/shale siltstone and this contact being at depth of greater than 39 metres below ground level. The hydraulic head above the water bearing zone is well below ground level, being recorded at greater than 28 metres below ground level in the region and greater than 57 metres below ground level at the proposed landfill site.

This groundwater flow system would be influenced by the local topography and the regional elevation decreasing from east to west and preferential flow paths through factures, joints, faults, bedding plains and contacts between the geological units.

The groundwater depth shows that there is no upward hydraulic gradient from the regional to intermediated fractured rock system to the unconsolidated alluvial aquifer system adjacent to the Murrumbidgee River.

Table 4: *Summary of bore details (WaterNSW 2019)*

Bore ID	Date constructed	Drilled depth (m)	Water bearing zone from (m)	Water bearing zone from (m)	SWL (m)	Yield (L/s)	Geology Water Bearing Zone	AHD (m)*	Purpose	Salinity (ppm)	Zone	Easting	Northing
GW014960	1/11/1963	47.2	39	47.2	33.7	0.46	Slate	280	Stock	1001-3000	55	590306	6114358
GW403222	1/02/2002	90	75	90	18	1	Shale	N/A	Irrigation	N/A	55	585916	6113095
GW405001	4/05/2004	65	15	30	N/A	N/A	Shale	280	Stock & Domestic	N/A	55	585191	6111704
GW416166	12/02/2010	85.2	52	75	28.0	N/A	Shale	260	Stock & Domestic	N/A	55	589573	6111969
GW018388	1/01/1911	5.5	N/A	N/A	N/A	N/A	N/A	N/A	Stock & Domestic	N/A	55	588191	6115550

**Estimated from topographic map*

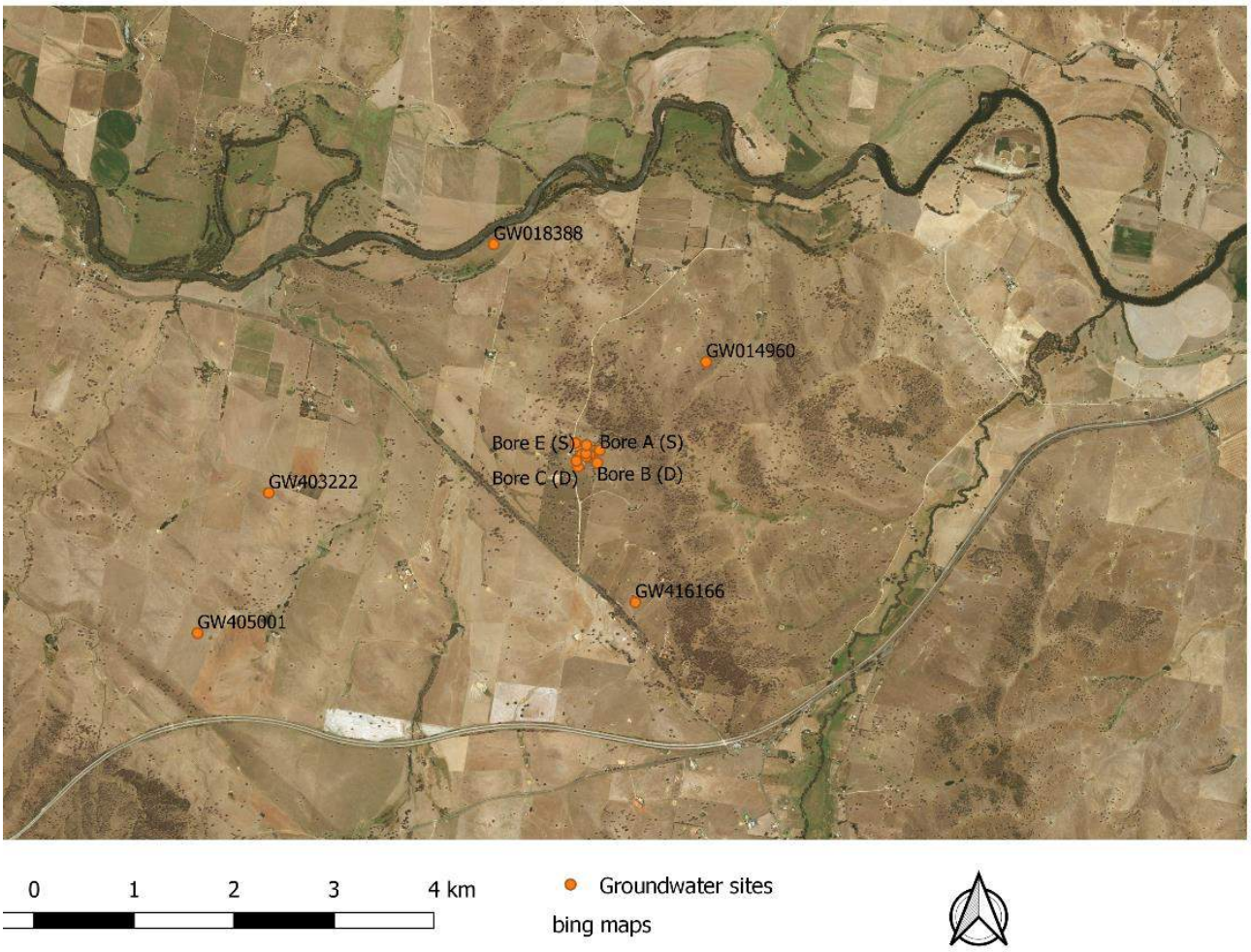

Figure 7: *Bore locations*

4.4.3 Groundwater dependent ecosystems

The National Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology 2019) does not identify any aquatic, terrestrial or souterrain groundwater dependent ecosystems at or in the region of the site.

4.4.4 Groundwater use

The location of bores in the region of the site are shown in **Figure 7**. There is minimal groundwater use in the region of the propose landfill site, with five bores within 4.3 kilometres. The closest bore (GW014960) is a stock and domestic bore 1.5 kilometres to the north-east of the site. Four of the five bores are licenced either for stock or stock and domestic use, while GW403222 is classified as being for irrigation.

The distance of these bores from the site and the low yields from these bores would indicate that negligible or low risk of these bores being impacted by this proposed landfill facility.

5.0 Assessment

5.1 Desktop assessment

An initial desktop assessment of the region and the site was completed prior to conducting site investigations. This assessment provided an initial assessment of the history of land use and ownership at the site, the hydrology, geology, hydrogeology, vegetation and climate of the region.

5.2 First phase drilling program

An initial groundwater site investigation constructed five investigation bores to a depth of 21.6 metres in the base of the quarry site (Bore 1 to Bore 5), see **Figure 9** and **Attachment A**. These bores did not intersect any water bearing zones and have remained dry since being constructed in February 2019.

5.3 Site investigation

Results of the initial drilling led to the siting of an additional six nested shallow and deep monitoring bores around the proposed landfill facility. Each bore was constructed with a 6-metre screen surrounded with gravel and an overlying bentonite seal. A conceptual diagram of the bore construction is shown in **Figure 8**.

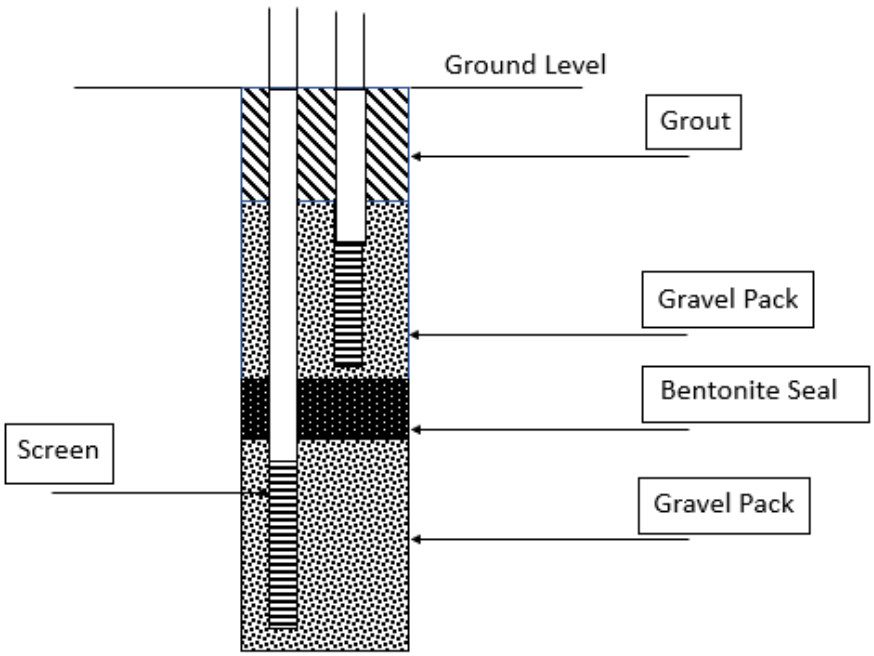

Figure 8: *Bore construction diagram*

The shallow monitoring bores are designed to monitor any shallow lateral flow up and down gradient of the site. The purpose of BH4S is to monitor the profile down gradient from the proposed leachate pond.

The deep monitoring bores are designed to monitor the presence of any groundwater below the base of the landfill. BH5D was drilled to a depth of 75 metres to identify the depth of any water bearing zones and the groundwater depth beneath the site. A low permeability water bearing zone was intersected at about 60 metres depth.

Only one low permeability water bearing zone was intersected during the construction of the monitoring bores, this being BH5D. At the time of drilling, a standing water level measurement was not possible at BH5D as there was insufficient flow into the bore. A later measurement of the standing water level at the site recorded a standing water level of 58 metres below ground level (209.47 mAHD). The construction details for the monitoring bores is summarised in **Table 5** and the bore logs can be seen in **Attachment B**.

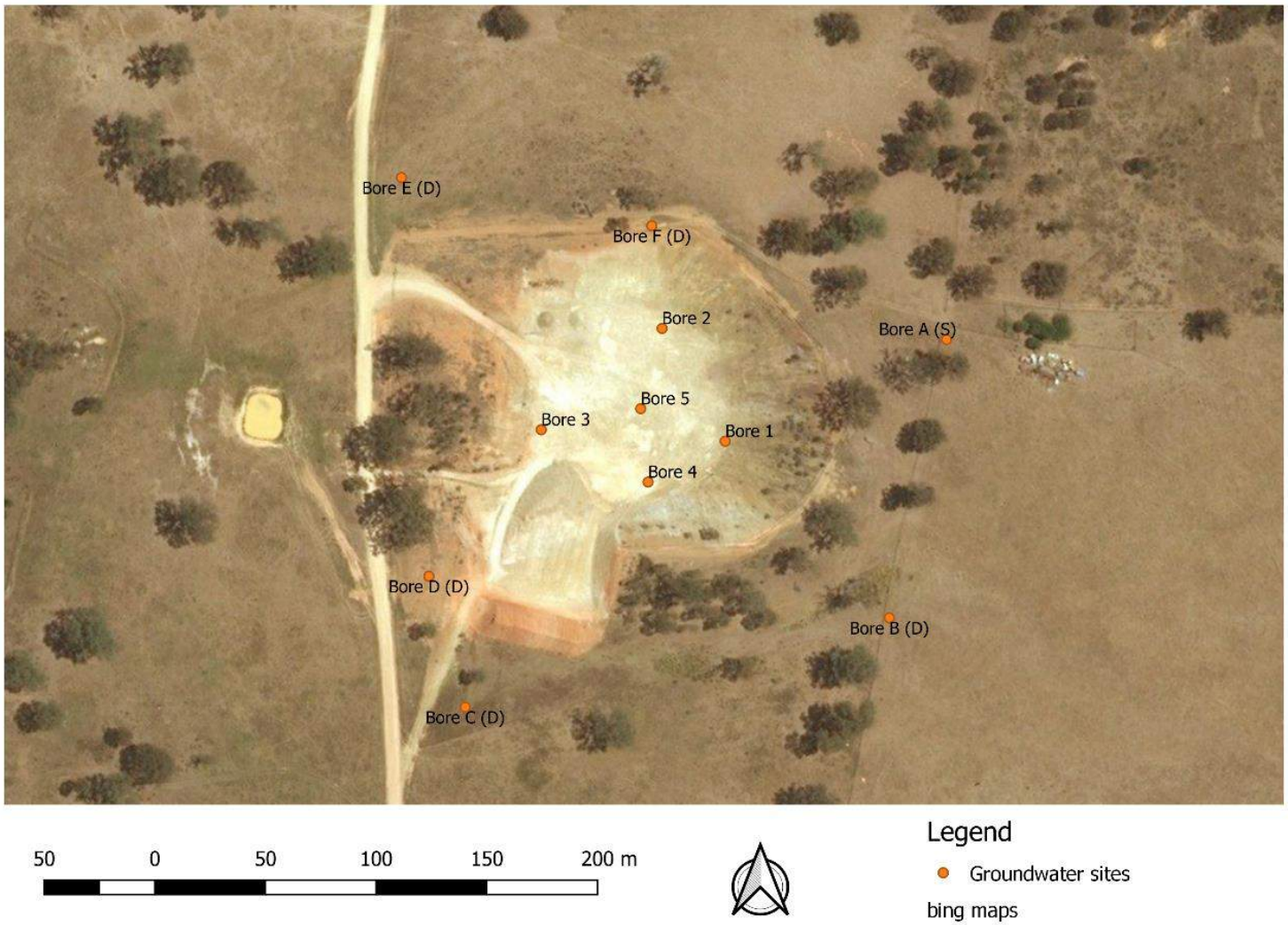

Figure 9: *Location of site investigation and monitoring bores*

Table 5: *Site investigation and monitoring bores*

Bore ID	Date constructed	Drilled depth (m)	Screen from (m)	Screen from (m)	SWL (m)	Yield (L/s)	Geology at screen	AHD	Purpose	Salinity (ppm)	Zone	Easting	Northing
Bore 1	18/02/2019	21.6	N/A	N/A	N/A	N/A	Siltstone	269.7	Investigation	N/A	55	589132	6113443
Bore 2	18/02/2019	21.6	N/A	N/A	N/A	N/A	Siltstone	269.4	Investigation	N/A	55	589104	6113494
Bore 3	18/02/2019	21.6	N/A	N/A	N/A	N/A	Siltstone	268.5	Investigation	N/A	55	589049	6113449
Bore 4	18/02/2019	21.6	N/A	N/A	N/A	N/A	Siltstone	269.2	Investigation	N/A	55	589097	6113425
Bore 5	18/02/2019	21.6	N/A	N/A	N/A	N/A	Siltstone	268.1	Investigation	N/A	55	589094	6113458
BH1S	2/09/2019	35.2	22	25	N/A	N/A	Weathered Shale	287.18	Site monitoring	N/A	55	589232.4	6113487.8
BH1D	2/09/2019	35.2	29	35	N/A	N/A	Weathered Shale	287.18	Site monitoring	N/A	55	589232.4	6113487.8
BH2S	3/09/2019	25.6	12	15.6	N/A	N/A	Weathered Shale	277.63	Site monitoring	N/A	55	589205.3	6113362.9
BH2D	3/09/2019	25.6	19.6	25.6	N/A	N/A	Weathered Shale	277.63	Site monitoring	N/A	55	589205.3	6113362.9
BH3S	3/09/2019	19	5	8	N/A	N/A	Weathered Shale	270.45	Site monitoring	N/A	55	589013.4	6113324.7
BH3D	3/09/2019	19	12	18	N/A	N/A	Weathered Shale	270.45	Site monitoring	N/A	55	589013.4	6113324.7
BH4S	4/09/2019	19	5.4	8.4	N/A	N/A	Weathered clay	271.05	Site monitoring	N/A	55	588997.6	6113383.7
BH4D	4/09/2019	19	12.4	18.4	N/A	N/A	Weathered clay	271.05	Site monitoring	N/A	55	588997.6	6113383.7
BH5S	4/09/2019	75	2.5	5.5	N/A	N/A	Weathered shale	267.47	Site monitoring	N/A	55	588987.0	6113562.9
BH5D	4/09/2019	75	69	75	58	N/A	Granite	267.47	Site monitoring	1,200	55	588987.0	6113562.9
BH6S	2/09/2019	24.9	12.9	15.9	N/A	N/A	Weathered shale	276.88	Site monitoring	N/A	55	589099.8	6113540.2
Bh6D	2/09/2019	24.9	18.9	24.9	N/A	N/A	Weathered shale	276.88	Site monitoring	N/A	55	589099.8	6113540.2

5.4 Slug tests

A slug test determines the near well aquifer characteristics and is used to determine the hydraulic conductivity of the material near the bore. Falling head slug tests were conducted and analysed using the Bouwer Rice method. A falling head test is where the bore is filled with water and measurements are taken of the water level depth at set intervals. The rate that the water level declines in the bore is used to calculate the hydraulic conductivity of the material adjacent to the bore.

Slug tests were conducted on 4 of the 5 investigation bores and 11 of nested monitoring bores, **Figure 9**. The tests were conducted to gain an insight into the hydraulic conductivity at the site and the rate that any leachate may migrate from the landfill cell if it was to permeate through the liner.

The five investigation bores are all open holes, the hydraulic conductivity of these bores represents the whole profile as the tests were conducted following the bores being fully filled with water. The hydraulic conductivity of these holes had minimal variation ranging between 1.2 X 10^{-7} m/sec to 8.2 X 10^{-8} m/sec and a median of 1.1 X 10^{-7}, **Table 6**.

The hydraulic conductivity of the 12 monitoring bores represent the screened interval. The hydraulic conductivity of these bores had minimal variation ranging from 4.4 X 10^{-6} to 2.2 X 10^{-7} and a median of 4.3 X 10^{-7}, **Table 6.**

The values for the investigation bores are within the lower range for sandstone (Freeze & Cherry 1979). This is not unexpected with the geology of the region being fine grained slate/shale siltstone and sandstone and these bores being constructed with weathered shale likely to be fine grained siltstone.

The slug tests prove that the geology beneath the proposed landfill and the water bearing zone in BH5D have a low permeability.

Table 6: *Slug test hydraulic conductivity*

Bore	K m/sec
Bore 1	8.2 X10^{-8}
Bore 2	1.2 X10^{-7}
Bore 3	Not tested
Bore 4	9.6 X10^{-8}
Bore 5	1.3 X10^{-7}
BH1S	4.4 X10^{-6}
BH1D	2.2 X10^{-7}
BH2S	4.4 X10^{-7}
BH2D	2.5 X10^{-7}
BH3S	4.9 X10^{-7}
BH3D	2.8 X10^{-7}
BH4S	4.3 X10^{-7}
BH4D	9.3 X10^{-7}
BH5D	3.9 X10^{-7}
BH6S	4.9 X10^{-7}
BH6D	3.0 X10^{-7}

5.5 Water quality

One water quality sample was collected from BH5D, the only site with an observed low permeability water bearing zone. The bore could not be fully developed due to its low permeability. Following development of the bore, a water sample was collected. Due to the low yield characteristics of the water bearing zone, the bore could not be purged prior to sampling and the high TDS reflects that the bore was not able to be fully developed. The water quality sample therefore reflects that standing water within the bore.

The results of analysis conducted by ALS Environmental at Smithfield NSW are shown in **Table 7** and can be seen in **Attachment D**. An attempt to collect a second sample following the falling head test was not successful. Due to the low permeability of the water bearing zone, it was not possible to obtain a representative sample of the groundwater from the water bearing zone.

The dominant water composition of the major cations and anions are sodium and bicarbonate ($NaHCO_3$) based on a piper plot analysis, **Figure 10**.

The ALS Environmental test results show that the groundwater sample tested has parameters that exceed the Australian Drinking Water Guidelines, rendering it not fit for human consumption, these are as follows:

- Turbidity - Turbidity likely reflects that the bore not being fully developed prior to sampling. This is due to the low yielding nature of the water bearing zone
- Aluminium – This can be as high as 18 mg/L in the Murray River. The value measured is likely associated with the presence of clay minerals (aluminosilicates) in the weathered shales.
- Manganese – Based on aesthetic considerations, the concentration of manganese in drinking water should not exceed 0.1 mg/L. Manganese is a health consideration when concentration exceeded 0.5 mg/L.

  Laboratory animals have shown no adverse effects other than a change in appetite and a reduction in the metabolism of iron in haemoglobin synthesis. No firm evidence identifies manganese as being carcinogenic. Some in vitro studies using mammalian and bacterial cells have reported that manganese acts as a mutagen.

  Manganese is commonly found in groundwater as it is commonly associated with soil and rock weathering. The high concentration may indicate anoxic conditions (depleted of dissolved oxygen) which could be associated with restricted water exchange. This would be associated with an intermediate to regional groundwater flow system as identified in the groundwater flow process in the region of the site.

- Nickel - Long-term exposure may result in toxic effects to the kidney and nickel compounds are carcinogenic to humans.

Table 7: *BH5D water quality*

Parameter	Limit of reporting	Unit	Result	ADWG* value	
				Aesthetic	Health
pH value	0.01	pH unit	7.69		6.5 – 8.5
Electrical conductivity @ 25°C	1	µS/cm	1630	1400-1875 (TDS conversion factor of 0.64) poor palatability	
Total Dissolved Solids @ 180°C	10	mg/L	1200	900-1200	

				Poor palatability	
Colour (True)	1	PCU	<1	<15	
pH colour	.01	pH unit	7.22		
Turbidity	0.1	NTU	85.2	<0.2	
Total Hardness as $CaCO^3$	1	mg/L	416	200–500 mg/L (increasing scaling problems)	
Hydroxide Alkalinity as $CaCO^3$	1	mg/L	<1		
Carbonate Alkalinity as $CaCO^3$	1	mg/L	<1		
Bicarbonate Alkalinity as $CaCO^3$	1	mg/L	514		
Total Alkalinity as $CaCO^3$	1	mg/L	514		
Sulphate as SO^4	1	mg/L	36	250	
Chloride	1	mg/L	158	250	
Calcium	1	mg/L	61		
Magnesium	1	mg/L	64		
Sodium	1	mg/L	191	180	
Potassium	1	mg/L	8		
Aluminium	0.01	mg/L	1.16	0.2	
Silver	0.001	mg/L	<0.001		0.1
Arsenic	0.001	mg/L	0.001		0.01
Boron	0.05	mg/L	<0.05		4
Barium	0.001	mg/L	0.199		2
Cadmium	0.0001	mg/L	0.0005		0.002
Chromium	0.001	mg/L	0.006		0.05
Copper	0.001	mg/L	0.012		2
Manganese	0.001	mg/L	2.23	0.1	0.5
Molybdenum	0.001	mg/L	0.004		0.05
Nickel	0.001	mg/L	0.045		0.02
Lead	0.001	mg/L	0.003		0.01
Antimony	0.001	mg/L	<0.001		0.003
Selenium	0.01	mg/L	<0.01		0.01
Zinc	0.005	mg/L	0.049		3
Iron	0.05	mg/L	2.68	0.3	
Mercury	0.0001	mg/L	<0.0001		0.001
Total Cyanide	0.004	mg/L	<0.004		0.08
Fluoride	0.1	mg/L	0.2		1.5
Ammonia as N	0.01	mg/L	0.15	0.5 (as NH_3)	
Nitrite as N	0.01	mg/L	<0.01		3
Nitrate as N	0.01	mg/L	0.03		50
Nitrite + Nitrate as N	0.01	mg/L	0.03		
Total Cations	0.01	meq/L	15.5		
Total Anions	0.01	meq/L	16.8		
Ionic Balance	0.01	%	4.17		

**NHMRC, NRMMC (2011)*

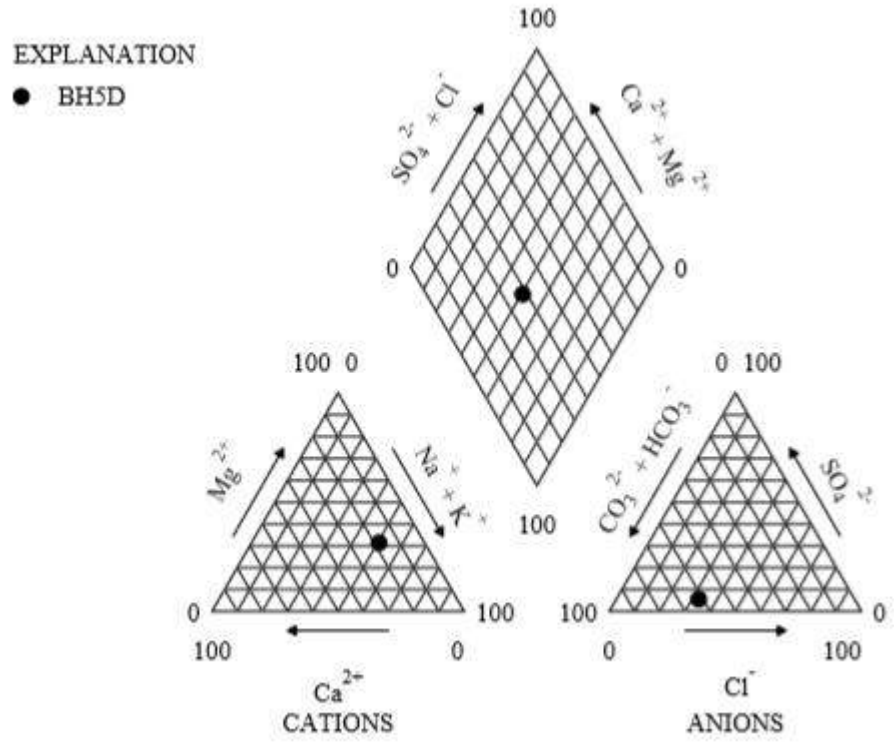

Figure 10: *Piper plot BH5D*

6.0 NSW EPA Environmental Guidelines: Solid Waste Landfills – 2nd Ed. 2016

The proposed landfill site with respect to groundwater meets the siting restrictions as outlined in the Environmental Guidelines: Solid Waste Landfills (NSW EPA, 2016). Below are the listed siting restrictions in italics and comments on the suitability of the site for the proposed landfill cell.

• *within 250 metres (or other protection zone) of an area of significant environmental or conservation value identified under relevant legislation or environmental planning instruments, including national parks, historic and heritage areas, conservation areas, wilderness areas, wetlands, littoral rainforests, critical habitats, scenic areas, scientific areas and cultural areas*

The site is not within any of the above areas of significant environmental or conservation value.

• *within specially reserved drinking water catchments, such as special areas identified by the Sydney Catchment Authority, Sydney Water and local water supply authorities;*

The site is not within any of the above drinking water catchments

• *within 250 metres of a residential zone or dwelling, school or hospital not associated with the facility;*

The site is not within 250 metres of a residential zone or dwelling, school or hospital.

• *in or within 40 metres of a permanent or intermittent water body or in an area overlying an aquifer that contains drinking water quality groundwater that is vulnerable to pollution;*

As outlined in the risk assessment the groundwater on site is not suitable to be used for drinking water supply. The groundwater is not vulnerable to pollution owing to the depth of the groundwater beneath the proposed landfill being 209.47 mAHD, in excess of 50 metres below the base of the landfill (RL of the sump in the deepest Cell 2 is 262.09m). The onsite investigation and a review of the surrounding bores did not identify any shallow groundwater. The shallowest water bearing zone within a fractured rock aquifer is at GW405001 about 6.5 kilometres east of the site. The shallowest water bearing zone near the site was at GW014960 at 39 metres depth. This site is 2.7 kilometres north east of the site and within an adjacent catchment. In addition, the landfill is designed to have an engineered landfill liner with a suitable leachate management system as outlined in the Environmental Guidelines: Solid Waste Landfills (NSW EPA 2016).

• *within a karst region or with substrata that are prone to land slip or subsidence*

The site is not within a karst region or with substrata prone to land slip or subsidence.

• *within a floodway that may be subject to washout during a major flood event (a 1-in-100-year event).*

Not relevant to the groundwater assessment.

7.0 Gundagai Local Environmental Plan 2011

Gundagai Local Environmental Plan (2011) Clause 6.3 water protection has an objective of maintaining the hydrological functions of riparian land, waterways and aquifers, including protecting the water quality, natural water flows, the stability of the bed and banks of waterways, and groundwater systems.

In considering the application, the consent authority must consider any adverse impact from the proposed development on the water quality of receiving waters, the natural flow regime, the natural flow paths of waterways, the stability of the bed, shore and banks of waterways, and the flows, capacity and quality of groundwater systems.

The proposed landfill facility site does not intersect any natural drainage line or depression and there are sufficient stormwater management controls to prevent run-off from the site.

The proposed landfill will avoid any adverse environmental impact to the flows, capacity and quality of groundwater by the design being consistent with the construction standards specified by the NSW EPA, (2016). Any impact will be further avoided due to the groundwater quality not being drinking water quality, the depth of the aquifer being more than 50 metres below the base of the landfill (RL of the sump in the deepest Cell 2 is 262.09m), being disconnected from the surface water system and the low hydraulic conductivity of the weather slate/shale siltstone leading to physical and chemical attenuation of any leachate that breaches the landfill lining.

8.0 Water quality objectives

The NSW Water Quality Objectives are the agreed environmental values and long-term goals for NSW's surface waters. The Objectives are consistent with the agreed national framework for assessing water quality set out in the Australian and New Zealand guidelines (here in the guideline) for fresh and marine water quality (2018). They provide a framework for the conservation of the ambient water quality in rivers, lakes, estuaries and marine waters. The core concept of the guidelines is managing water quality for environmental values. The environmental values are those values or uses of water that the community believes are important for a healthy ecosystem for public benefit, welfare, safety and health. The guideline identifies particular water quality characteristics or indicators that are used to assess whether the condition of the water supports that value.

The NSW Water Quality Objectives (WQO) establish for each catchment environmental values and long-term goals for consideration when assessing and managing the likely impact of activities on water waterways.

The WQO provide goals that help in the selection of the most appropriate management options. The guiding principles are that:

- Where the environmental values are being achieved in a waterway, they should be protected, and
- Where the environmental values are not being achieved in a waterway, all activities should work towards their achievement over time.

The guidelines specify three levels of protection, corresponding to whether the condition of the particular ecosystem is:

- Of high conservation value,
- Slightly to moderately disturbed, or
- Highly disturbed.

The NSW policy is that the level of protection applied to most waterways is for slightly to moderately disturbed ecosystems. In areas that are relatively undisturbed such as national parks and World Heritage areas, or wetlands of outstanding ecological significance are designated as high conservation value.

In high disturbed waterways, a reduced level of protection maybe appropriate with the goal being to eventually restore it to the status of a slightly to moderately disturbed.

The WQO for the uncontrolled streams in the Murrumbidgee River and Lake George catchment are (DEC 2006):

- Aquatic ecosystems;
- Visual amenity;
- Primary and secondary contact recreation;
- Livestock, irrigation, and homestead water supply;
- Drinking water at point of supply; and
- Aquatic foods.

There are no surface water drainage lines that intercept the proposed landfill site. The drainage lines to the north and south and east of the site are all ephemeral first order stream and will not be impacted or influenced by the proposed works on site.

The proposed leachate pond has been designed to ensure that there is sufficient freeboard for a 1:25 ARI, 24-hour storm. Hence, it is anticipated that the leachate pond will not have any adverse impact on the WQO.

The site investigation sampled monitoring bore BH5D, the only site that intersected a low permeability water bearing zone.

The parameters analysed and the analysis results are shown in **Table 7**. The key points of the sampling are:

- Aluminium – Exceeds the Australian Drinking Guidelines. The value measured is likely associated with the presence of clay minerals (aluminosilicates) in the weathered shales.

- Manganese – Based on aesthetic considerations, the concentration of manganese in drinking water should not exceed 0.1 mg/L. Manganese is a health consideration when concentration exceeded 0.5 mg/L.

  Laboratory animals have shown no adverse effects other than a change in appetite and a reduction in the metabolism of iron in haemoglobin synthesis. No firm evidence identifies manganese as being carcinogenic. Some in vitro studies using mammalian and bacterial cells have reported that manganese acts as a mutagen.

  Manganese is commonly found in groundwater as it is commonly associated with soil and rock weathering. The high concentration may indicate anoxic conditions (depleted of dissolved oxygen) which could be associated with restricted water exchange. This would be associated with an intermediate to regional groundwater flow system as identified in the groundwater flow process in the region of the site.

- Nickel - Long-term exposure may result in toxic effects to the kidney and nickel compounds are carcinogenic to humans.

The water quality of BH5D shows that the groundwater has high levels of sodium and bicarbonate and concentrations of manganese, aluminium and nickel that exceed the Australian Drinking Water Guidelines values. The water is regarded as being of not suitable for drinking water without further treatment (NHMRC, 2011).

The review of the National Groundwater Dependent Ecosystems Atlas did not identify any dependent ecosystems within the site or the region, BOM (2019).

The conceptual groundwater flow model shows that the groundwater flow system in the region is an intermediate to regional system, with a low hydraulic head that would not cause any interaction with the overlying alluvial aquifer system in the Cowra Formation associated with the Murrumbidgee River flood plain. The high concentration of manganese may also indicate anoxic conditions in the groundwater which would align with the groundwater system being an intermediate to regional groundwater flow system.

The proposed works will cause minimal change to the surface runoff and therefore cause no to minimal impact to the aquatic ecosystem, visual amenity and the use of the surface water downstream of the site for livestock and homestead water supply.

The groundwater quality objectives are to maintain the existing environmental values which would be livestock water supply and maintenance of aquatic ecosystems compared to the reference water quality conditions.

9.0 Site and regional hydrogeology assessment

The assessment shows that the aquifer system is part of low yielding intermediate to regional groundwater flow system that occurs at the contact between the weathered and unweathered shale/slate siltstones.

The site assessment has identified a low permeability water bearing zone at the contact between the weathered and unweathered shale/slate siltstone at a depth of approximately 60 metres from ground surface. The standing water level at the time of construction was measured at 58 metres below natural surface and this depth has been maintained through subsequent monitoring. The depth of the aquifer is 209.47 mAHD and the level of the sump within proposed Cell 2 is 262.09 mAHD, greater than 50 metres below the base of the landfill.

The falling head slug tests found that the shallow and deep monitoring bores have hydraulic conductivity of between 4.4×10^{-6} m/sec and 8.2×10^{-8} m/sec. This compares favourably to a minimum hydraulic conductivity of a compacted clay liner of 1×10^{-9} m/sec as defined by the NSW EPA Environmental Guidelines for solid waste landfills (2016).

The analysis of the water sampled from BH5D identified that the water is NOT suitable for human consumption due to nickel concentrations exceeding the health guidelines values. Long term exposure to concentrations above the guideline value may result in toxic effects to the kidney and nickel compounds are carcinogenic to humans.

The high concentrations of manganese suggest that the aquifer is anoxic and therefore hydraulically disconnected from the overlying surface water system.

These multiple lines of evidence show that the aquifer beneath the site is at depth (greater than 50m) and is not suitable as a drinking water source. This aquifer is part of an intermediate to regional groundwater system that is hydraulically disconnected from the overlying surface water system, with the overlying weathered shale having a low hydraulic conductivity.

In the highly unlikely circumstance that leachate was to leach below the base of the landfill liner, it is likely that physical and chemical attenuation and the low hydraulic conductivity of the weathered shale would significantly reduce the likelihood of contamination of the aquifer. This aquifer has also been identified as not suitable as a drinking water source as defined by the Australian Drinking Water Guidelines (2011).

10.0 Groundwater management plan

10.1 Aquifer interference policy

Aquifer interference policy does not apply to this development as it does not intercept or cause any aquifer interference.

10.2 Monitoring

The monitoring network established as part of this assessment has identified a single water bearing zone at BH5D at a depth of approximately 60 metres.

Quarterly monitoring should be conducted of the monitoring installations and if groundwater is observed, it should be measured and recorded. Any observation of groundwater should trigger the collection of a groundwater quality sample via micro-purge sampling. The purpose of the sampling would be to identify if the water has a surface or groundwater origin. A surface water origin of the water could indicate surface infiltration in the vicinity of the bore.

A rainwater sample should be collected and analysed annually to serve as a background sample to validate any groundwater samples collected.

A micro-purge water quality sample should be collected from BH5D initially every three months and reported on following the first 12 months of monitoring. The observation of a stable water quality would lead to sampling being extended to either six (6) or twelve (12) monthly.

10.3 Trigger action response plan

Based on the initial water quality monitoring of BH5D, a suitable trigger value should be established for additional actions to be undertaken should the water quality vary beyond the established acceptable variation. This should be consistent with or a higher standard than identified in the NSW EPA operating licence.

An exceedance of the acceptable variation would instigate further investigations. The significance of these investigations would be subject to the degree that the water quality has exceeded that acceptable variation. An exceedance would trigger the following:

- collection of a secondary sample to verify the exceedance.
- a confirmed exceedance would trigger further investigations into field sampling and laboratory analysis practices to identify if these are the source.
- Following validation of these practices, the likelihood of the landfill as being the point source should be investigated.
- Further investigations or actions should be event specific and conducted in consultation with the EPA.

The identification of the presence of water at any of the other monitoring installations would trigger the collection of a water sample through micro-purging. The results of this sampling should be compared to the baseline rainwater quality and the leachate. The outcome of the assessment may trigger one of the following:

- A relationship to rainwater would instigate further investigations into the integrity of the monitoring bore as the results would indicate failure of the bentonite seal overlying the gravel pack surrounding the screened interval.
- No relationship to rainwater or leachate should lead to a re-evaluation of the hydrogeological setting in the surrounding area of the site.
- A relationship to the leachate should lead to investigations to identify the source or potential sources. Further investigations or actions should be event specific and conducted in consultation with the NSW EPA.

11.0 References

ANZG (2018) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

Basden, H., (1990) Geology of the Tumut 1:100,000 Sheet 8527. 275 pp. New South Wales Geological Survey, Sydney.

Bureau of Meteorology (2019) Groundwater Dependent Ecosystem Atlas. http://www.bom.gov.au/water/groundwater/gde/map.shtml

Dent D. and Young A., (1981) Soil Survey and Land Evaluation. Georg Allen and Unwin Publishers, London.

Emery K.A., (1986) Rural land capability mapping. Soil Conservation Service of NSW, Sydney.

Freeze R.A & Cherry J.A., (1979) Groundwater, Prentice-Hall.

Mitchell, M., 2009, Mid Murrumbidgee Alluvium. Groundwater Management Area 013: Gundagai to Narrandera. Groundwater Resources Status Report – 2007, NSW Department of Water and Energy, Sydney

NSW EPA (2016) Environmental Guidelines Solid Waste Landfills 2nd ed. Sydney

NSW Water Quality and River Flow Objectives (DEC 2006) https://www.environment.nsw.gov.au/ieo/Murrumbidgee/report-02.htm#P393_43912

NHMRC, NRMMC (2011) Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.

Queensland Government (2019) SILO – Australian Climatic Data from 1889 to 2019. https://www.longpaddock.qld.gov.au/silo/point-data/

Sonter R.O., and Lawrie J.W,, (2007) Soils and rural land capability, in Soils: Their properties and management, 3rd edition, PEV Charman and BW Murphy (eds). Oxford University Press, Melbourne.

Wagga Wagga 1:250000 geological map https://search.geoscience.nsw.gov.au/product/200

WaterNSW (2019) https://realtimedata.waternsw.com.au/

12.0 Attachments

Attachment	Details
A. Bore logs – 18/02/19	2 pages
B. Bore logs – 2-4/09/19	1 page
C. Slug test analysis	8 pages
D. Laboratory results	4 pages

McMahon EARTH SCIENCE

DOCUMENT ATTACHMENTS

REPORT 5985

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Attachment A : *Bore logs - 18/02/19*

McMahon EARTH SCIENCE

Job No:	5803	**Landform:**	Pit floor
Client:	MH Earthmoving Pty Ltd	**Slope:**	Level
Site:	Bangus Quarry	**Vegetation/Surface:**	Rock
Date:	18/02/2019	**Logged By:**	DM

Sheet: 'Geotech Field Sheet_rev2'

Sampling Method: AS1289.1.2.1-1998: cl. [ ] 6.5.1 - Hand Excavated [ ] 6.5.2 - Hand Auger [ ] 6.5.3 - Power Auger [ ] 6.5.4 - Machine Excavated Other: 87mm DTH Hammer

Site Identity	Sample	Co-ordinates MGA GDA94 z55	Depth to Top of Layer (m)	Depth to Bottom of Layer (m)	Classification (AS1726:2017 Table 20)	Name (BLOCK LETTERS)	Grain Size (Fine / Coarse)	Primary Colour	Weathering Colour	Plasticity	Strength	Relative Density (Non-cohesive)	Moisture	Origin	Comments (Coarse Fragments, Size, %, Structure (Zoning, Defects, Cementing etc.))
1	-	589132E	0.0	3.6	XM	Siltstone	Fine	Y	R	Low	VL	-	D	Silurian	-
	-	6113443N	3.6	7.2	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		7.2	10.8	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		10.8	14.4	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
	-		14.4	18.0	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
			18.0	21.6	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
2	-	589104E	0.0	3.6	XM	Siltstone	Fine	Y	R	Low	VL	-	D	Silurian	Some rounded fragments
	-	6113494N	3.6	7.2	HW	Siltstone	Fine	G	-	Non	L	-	D	Silurian	-
	-		7.2	10.8	HW	Siltstone	Fine	G	-	Non	L	-	D	Silurian	-
	-		10.8	14.4	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
	-		14.4	18.0	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
			18.0	21.6	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
3	-	589049E	0.0	3.6	XM	Siltstone	Fine	Y	R	Low	VL	-	D	Silurian	-
	-	6113449N	3.6	7.2	XM	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		7.2	10.8	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		10.8	14.4	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
	-		14.4	18.0	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
			18.0	21.6	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-

McMahon EARTH SCIENCE

Job No:	5803	**Landform:**	Pit floor
Client:	MH Earthmoving Pty Ltd	**Slope:**	Level
Site:	Bangus Quarry	**Vegetation/Surface:**	Rock
Date:	18/02/2019	**Logged By:**	DM

Sheet: 'Geotech Field Sheet_rev2'

Sampling Method: AS1289.1.2.1-1998: cl. [ ] 6.5.1 - Hand Excavated [ ] 6.5.2 - Hand Auger [ ] 6.5.3 - Power Auger [ ] 6.5.4 - Machine Excavated Other: 87mm DTH Hammer

Site Identity	Sample	Co-ordinates MGA GDA94 z55	Depth to Top of Layer (m)	Depth to Bottom of Layer (m)	Classification (AS1726:2017 Table 20)	Name (BLOCK LETTERS)	Grain Size (Fine / Coarse)	Primary Colour	Weathering Colour	Plasticity	Strength	Relative Density (Non-cohesive)	Moisture	Origin	Comments (Coarse Fragments, Size, %, Structure (Zoning, Defects, Cementing etc.))
4	-	589097E	0.0	3.6	ML	CLAY	Fine	R	Y	Low	VL	-	D	Residual	-
	-	6113425N	3.6	7.2	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		7.2	10.8	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		10.8	14.4	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
	-		14.4	18.0	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
			18.0	21.6	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
5	-	589094E	0.0	3.6	ML	CLAY	Fine	R	Y	Low	VL	-	D	Residual	-
	-	6113458N	3.6	7.2	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		7.2	10.8	HW	Siltstone	Fine	G	Y	Non	L	-	D	Silurian	-
	-		10.8	14.4	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
	-		14.4	18.0	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-
			18.0	21.6	MW	Siltstone	Fine	G	-	Non	M	-	D	Silurian	-

Attachment B : *Bore logs - 2-4/09/19*

AS1726:2017 Bore Log

McMahon EARTH SCIENCE

Job No:	5985	**Landform:**	Simple slope
Client:	MH Earthmoving Pty Ltd	**Slope:**	Moderatley inclined
Site:	Bangus Quarry	**Vegetation/Surface:**	Sparse native grasses and topsoil
Date:	2-4/09/2019	**Logged By:**	ZB

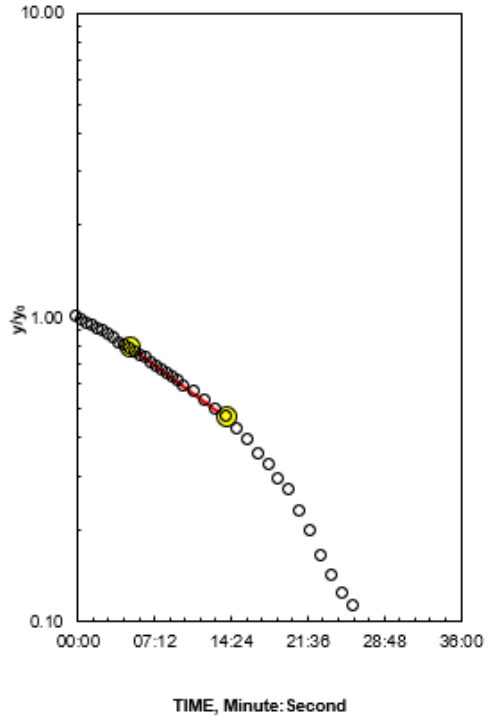
Sheet: 'Geotech Field Sheet_rev2'

Sampling Method: AS1289.1.2.1-1998: cl. [ ] 6.5.1 - Hand Excavated [ ] 6.5.2 - Hand Auger [ ] 6.5.3 - Power Auger [ ] 6.5.4 - Machine Excavated Other: 87mm DTH Hammer

Site Identity	Sample	Co-ordinates MGA GDA94 z55	Depth to Top of Layer (m)	Depth to Bottom of Layer (m)	Classification (AS1726:2017 Table 20)	Name (BLOCK LETTERS)	Grain Size (Fine / Coarse)	Primary Colour	Weathering Colour	Plasticity	Strength	Relative Density (Non-cohesive)	Moisture	Origin	Comments (Coarse Fragments, Size, %, Structure (Zoning, Defects, Cementing etc.))
A	-	589232E	0.0	0.3	CL	Silt CLAY	Fine	B	-	Low	L	-	D	Colluvial	Trace sand
	-	6113487N	0.3	0.6	CL	CLAY	Fine	G	Y	Med	H	-	D	Residual	-
	-		0.6	36.0	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
B	-	589205E	0.0	26.0	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
	-	6113362N													-
C	-	589013E	0.0	19.0	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
	-	6113324N													
D	-	588997E	0.0	0.3	CL	Silt CLAY	Fine	B	-	Low	L	-	D	Colluvial	Trace sand
	-	6113383N	0.3	1.0	CL	CLAY	Fine	G	Y	Med	H	-	D	Residual	-
	-		1.0	19.0	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
E	-	588987E	0.0	0.3	CL	Silt CLAY	Fine	B	-	Low	L	-	D	Colluvial	Trace sand
	-	6113562N	0.3	2.0	CL	CLAY	Fine	G	Y	Med	H	-	D	Residual	-
	-		2.0	60.0	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-
			60.0	78.0	SW	Granite	Fine	W	R	Non	H	-	D	Silurian	Damp spot at contact zone
F	-	588997E	0.0	0.3	CL	Silt CLAY	Fine	B	-	Low	L	-	D	Colluvial	Trace sand
	-	6113383N	0.3	1.0	CL	CLAY	Fine	G	Y	Med	H	-	D	Residual	-
	-		1.0	26.0	MW	Siltstone	Fine	G	Y	Non	M	-	D	Silurian	-

Attachment C : *Slug test analysis*

Bore 1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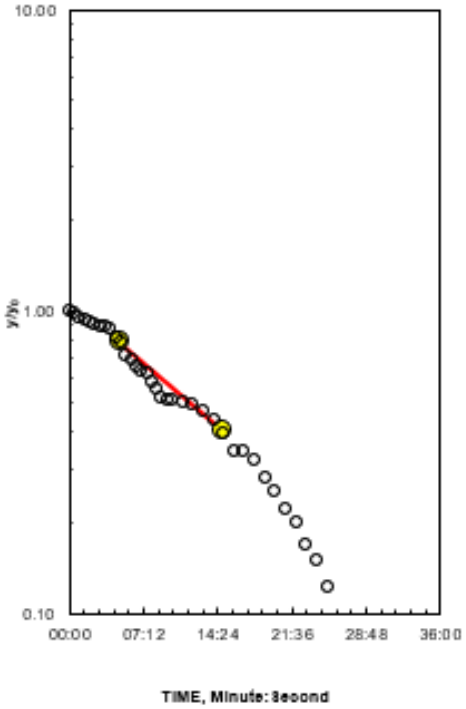
TIME, Minute: Second

Bore 4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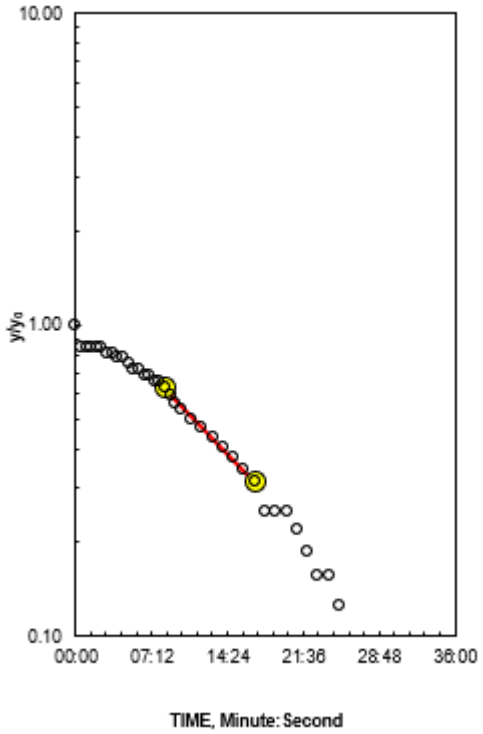
Bore 2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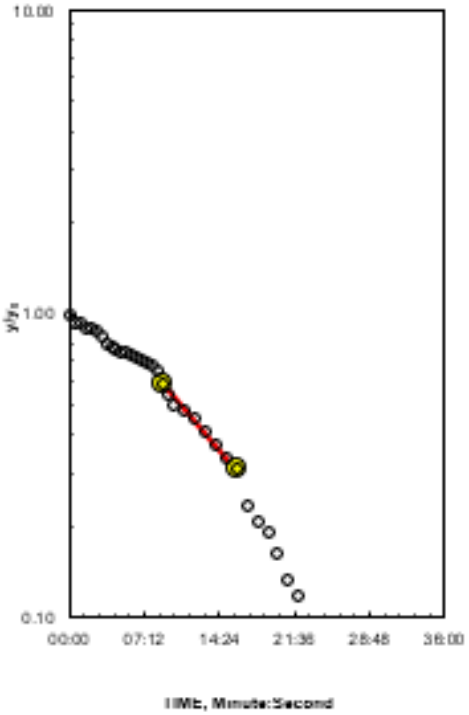
TIME, Minute: Second

Bore 5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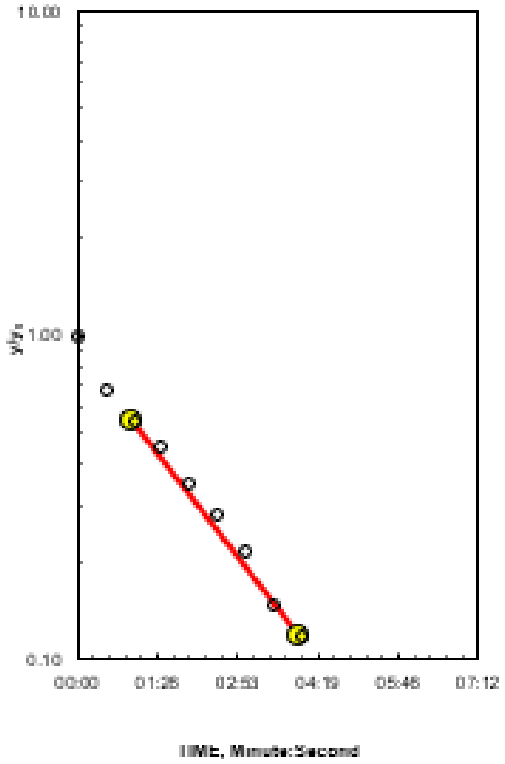
BH1S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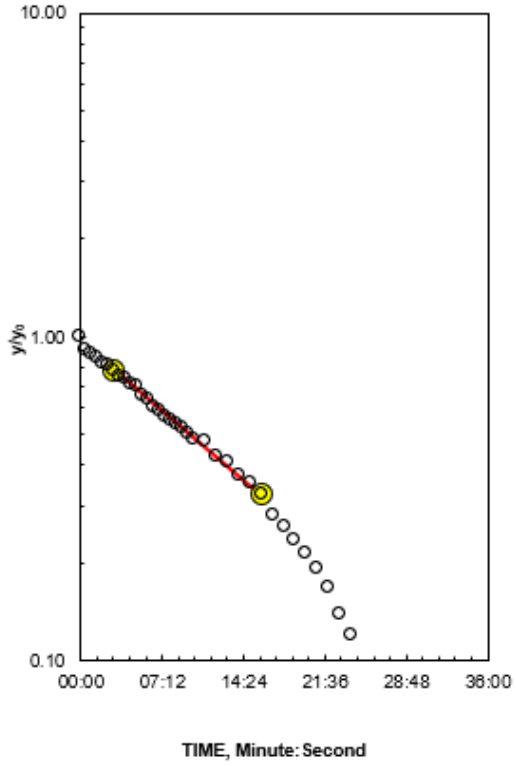
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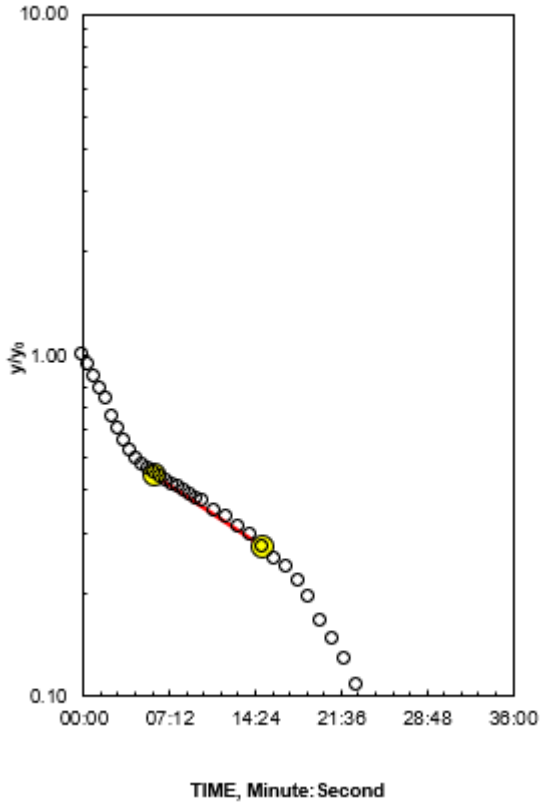
BH1D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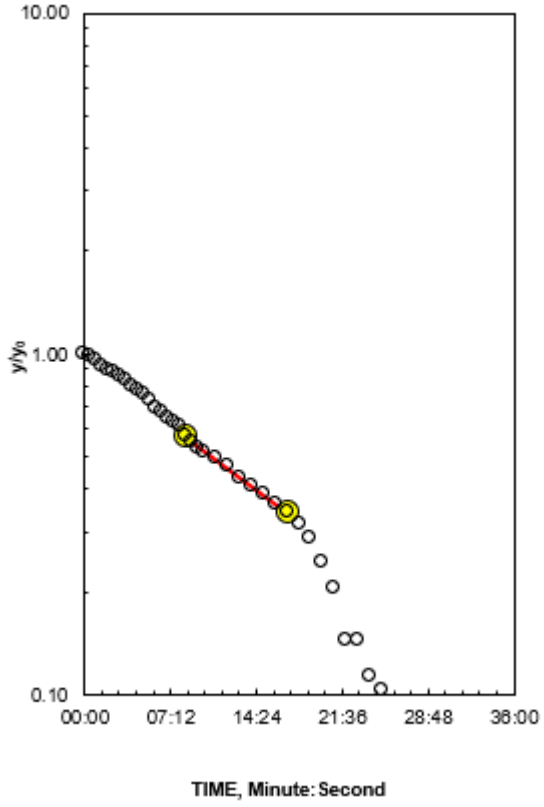
BH2D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TIME, Minute: Second

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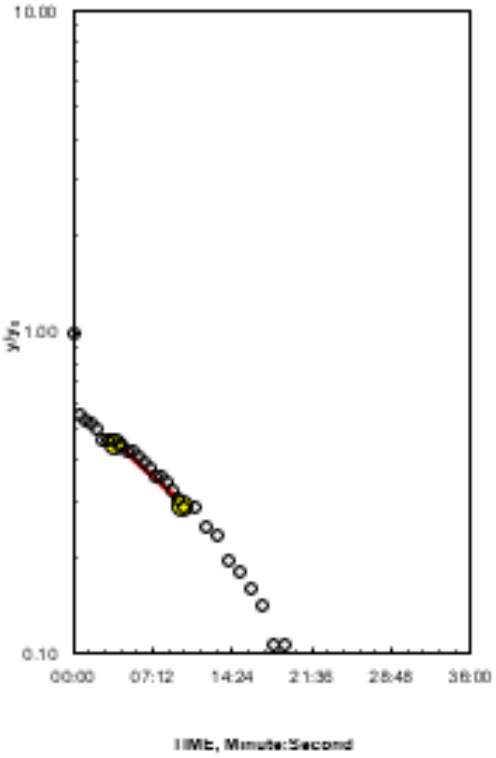
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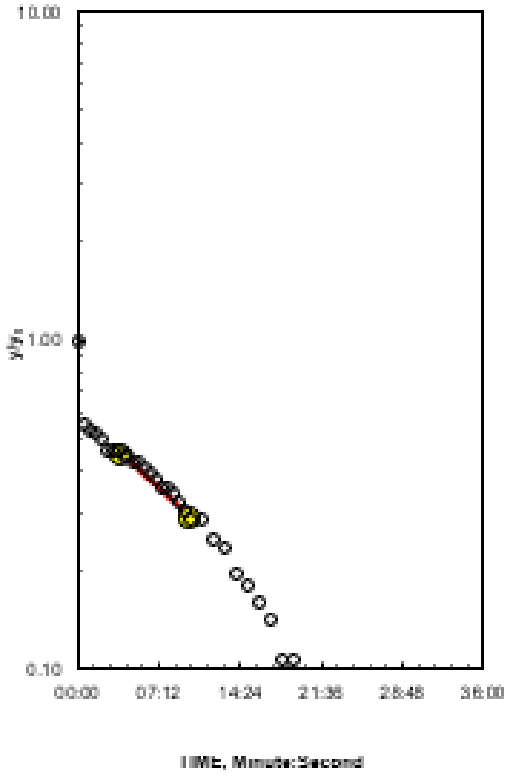
Time, Minute:Second

BH4S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Time, Minute:Second

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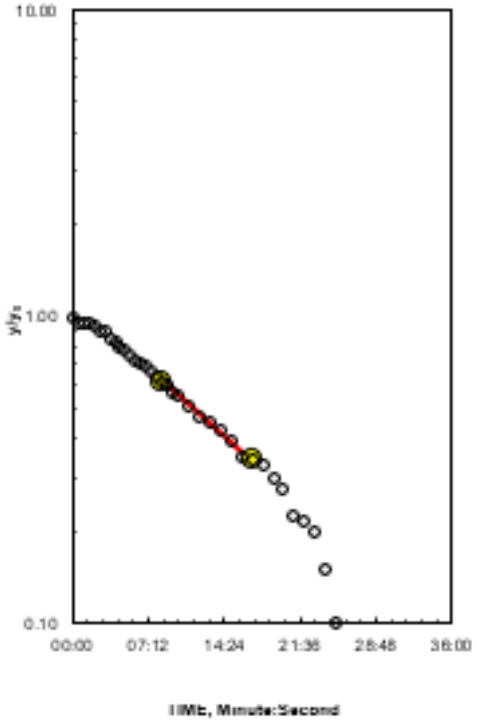
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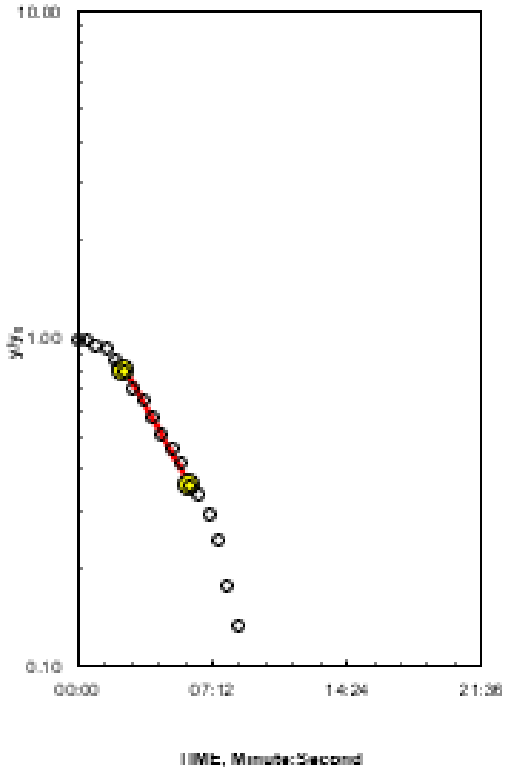
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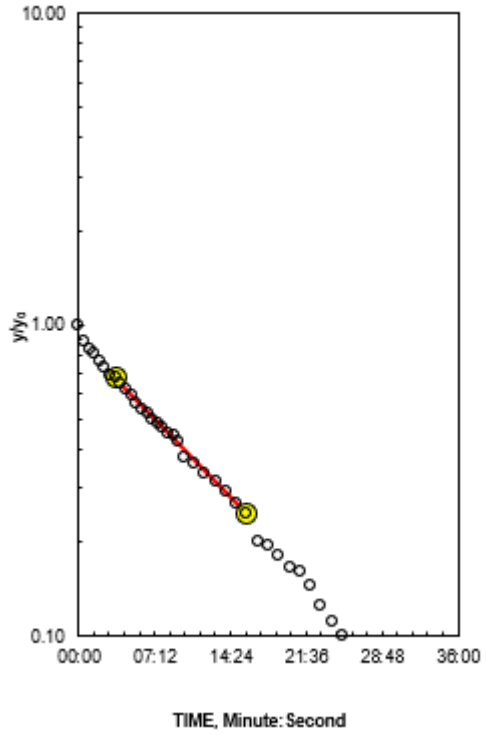
Time, Minute:Second

BH5D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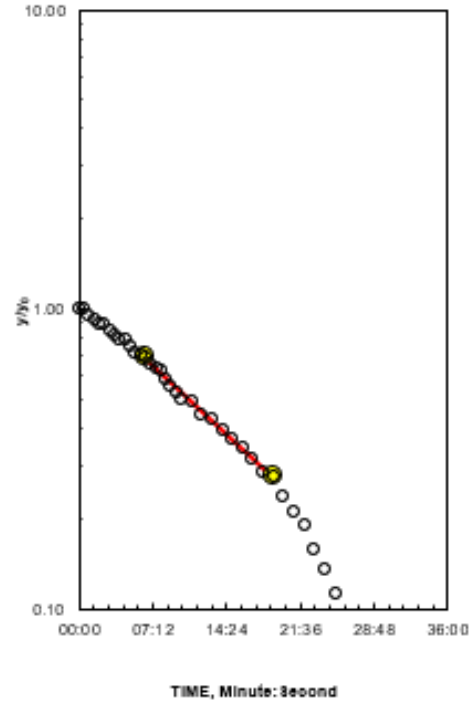
TIME, Minute: Second

BH6D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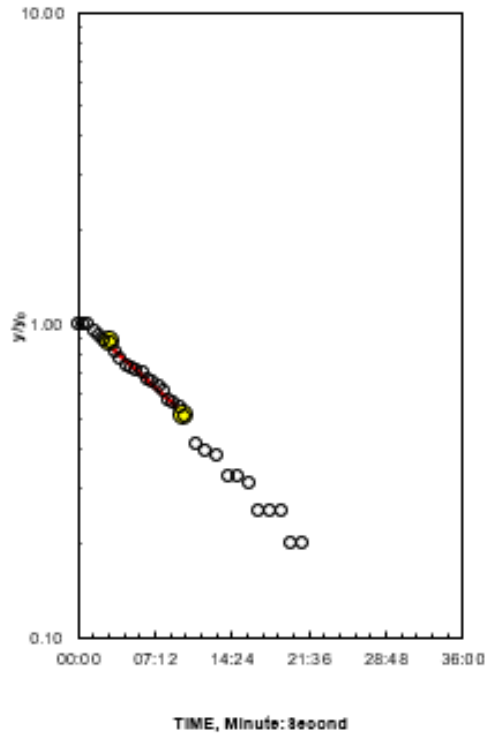
TIME, Minute: Second

BH6S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36:00
TIME, Minute:Second

Attachment D : *Laboratory results*

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1930730**	Page	: 1 of 4
Client	: **DM MCMAHON PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: ZACH	Contact	: Customer Services ES
Address	: 6 JONES ST Wagga Wagga NSW, AUSTRALIA 2650	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: MH Bangus	Date Samples Received	: 23-Sep-2019 13:30
Order number	: 5985	Date Analysis Commenced	: 23-Sep-2019
C-O-C number	: ----	Issue Date	: 27-Sep-2019 12:51
Sampler	: Zach Bradley		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 1		
No. of samples analysed	: 1		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BH5	----	----	----	----
			Client sampling date / time	20-Sep-2019 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	ES1930730-001	--------	--------	--------	--------
				Result	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.69**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**1630**	----	----	----	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**1200**	----	----	----	----
EA041: Colour (True)								
Colour (True)	----	1	PCU	<1	----	----	----	----
pH Colour	----	0.01	pH Unit	**7.22**	----	----	----	----
EA045: Turbidity								
Turbidity	----	0.1	NTU	**85.2**	----	----	----	----
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	**416**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**514**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**514**	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**36**	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**158**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**61**	----	----	----	----
Magnesium	7439-95-4	1	mg/L	**64**	----	----	----	----
Sodium	7440-23-5	1	mg/L	**191**	----	----	----	----
Potassium	7440-09-7	1	mg/L	**8**	----	----	----	----
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**1.16**	----	----	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.001**	----	----	----	----
Boron	7440-42-8	0.05	mg/L	<0.05	----	----	----	----
Barium	7440-39-3	0.001	mg/L	**0.199**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0005**	----	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	BH5	----	----	----	----
				Client sampling date / time	20-Sep-2019 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit		ES1930730-001	--------	--------	--------	--------
					Result	----	----	----	----
EG020T: Total Metals by ICP-MS - Continued									
Chromium	7440-47-3	0.001	mg/L		**0.006**	----	----	----	----
Copper	7440-50-8	0.001	mg/L		**0.012**	----	----	----	----
Manganese	7439-96-5	0.001	mg/L		**2.23**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L		**0.004**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L		**0.045**	----	----	----	----
Lead	7439-92-1	0.001	mg/L		**0.003**	----	----	----	----
Antimony	7440-36-0	0.001	mg/L		<0.001	----	----	----	----
Selenium	7782-49-2	0.01	mg/L		<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L		**0.049**	----	----	----	----
Iron	7439-89-6	0.05	mg/L		**2.68**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	----	----	----	----
EK025G: Free cyanide by Discrete Analyser									
Total Cyanide	57-12-5	0.004	mg/L		<0.004	----	----	----	----
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.2**	----	----	----	----
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**0.15**	----	----	----	----
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	14797-65-0	0.01	mg/L		<0.01	----	----	----	----
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N	14797-55-8	0.01	mg/L		**0.03**	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**0.03**	----	----	----	----
EN055: Ionic Balance									
ø Total Anions	----	0.01	meq/L		**15.5**	----	----	----	----
ø Total Cations	----	0.01	meq/L		**16.8**	----	----	----	----
ø Ionic Balance	----	0.01	%		**4.17**	----	----	----	----