Our ref: STH05/01238/21
Contact: Andrew Lissenden 0418 962 703

18 December 2020

Ernest Dupere
Benedict Industries Pty/Ltd
BY EMAIL: ernest@benedict.com.au

MENANGLE SAND AND SOIL – REQUEST FOR IN PRINCIPLE AGREEMENT TO HOW MATERIAL IS TRANSPORTED WITHIN THE SITE.

Dear Ernest,

Transport for NSW (TfNSW, formerly Roads and Maritime Services) refers to your email dated 4 November 2020, and the subsequent phone discussion had regarding the above.

TfNSW notes that:

- You are looking at amending the currently approved Menangle Quarry development consent (DA85/2865). As such, you are seeking an 'in-principle agreement' with TfNSW so as to enable you to progress a proposed design with some confidence that it is open to the idea;
- The change you are proposing seeks to allow material on the eastern side of the Hume Highway to be transported by heavy vehicles, as opposed to a conveyor belt, to the processing area on the western side of the Hume Highway (i.e. under the Menangle Bridges);
- The Menangle Bridges are a TfNSW asset;
- You have had discussions with TfNSW Area Maintenance Manager (Vincent Boer) who has not objected to the concept subject to additional information being provided; and
- The current development consent will need to be amended (i.e. lodgement of a Section 4.55 application) to allow the proposed change from a conveyor belt system to the use of trucks/heavy vehicles.

Having regard for the above, TfNSW advises that it provides 'in-principle agreement' to the concept of using heavy vehicles to transport material under the Hume Highway/Menangle Bridges being further investigated. This being subject to the requirements outlined in **Attachment 1**.

If you have any questions, please contact Andrew Lissenden on 0418 962 703.

Yours faithfully

Andrew Lissenden
Development Assessment Officer
Community and Place I South Region

Cc: lauren.evans@planning.nsw.gov.au

1. Engineering designs that have been prepared by a suitably qualified person will need to be provided to TfNSW for its approval. These will need to have regard for issues including, but not limited to, the protection of piers and the bridge structure;
2. Further discussions be had with Vincent Boer (TfNSW Area Maintenance Manager) and Dony Castro (TfNSW Bridge Maintenance Planner) during the preparation of engineering designs;
3. The implementation and ongoing maintenance of any design approved by TfNSW will be at the quarry operator/owners own cost;
4. TfNSW will be licenced to use the enhanced access tracks; and
5. An application to amend the existing development consent will be lodged to enable the all relevant environmental and design factors to be considered.

Ground floor 20 Chandos Street
St Leonards NSW 2065
PO Box 21
St Leonards NSW 1590
02 9493 9500
www.emmconsulting.com.au

13 May 2024

Chris Kelly
Senior Operations Officer
Metropolitan South
Environmental Protection Agency
6 Parramatta Square
10 Darcy Street
Parramatta NSW 2150

Re: Menangle Sand and Soil Quarry - proposed management plan updates

Dear Mr Kelly,

1 Project overview

Menangle Sand and Soil Pty Ltd (Menangle Sand and Soil) operates the Menangle Sand and Soil Quarry at 15 Menangle Road, Menangle. The quarry extracts sand and soil along the Nepean River as approved by Development Consent 85/2865 granted by the Minister for Planning in 1989 and as modified in 2020 (MOD1) and 2021 (MOD2). The quarry also operates under Environment Protection Licence (EPL) 3991.

The Consolidated Consent ('the Consent') allows the extraction of sand and soil in the Stage 8 area (about 13 ha) that extends about 2 kilometres (km) along the Nepean River south of the quarry's processing area (the Stage 7 area). The site is accessed from Menangle Road through the site entry compound (the Stage 6 area). The Consent and EPL cover these areas.

More details (including maps) of the approved operations are provided in the quarry's environmental management plans (see below).

The quarry operates in accordance with environmental management plans that were first prepared in 2022 in consultation with various agencies, as required by the Consent. The plans have been approved by the Planning Secretary.

The following plans were prepared in consultation with the Environment Protection Authority (EPA):

- Air Quality Management Plan (AQMP)
- Noise Management Plan (NMP)
- Soil and Water Management Plan (SWMP).

The plans are available on the Major Projects Website:

https://www.planningportal.nsw.gov.au/major-projects/projects/menangle-quarry (see Post Approval tab).

The Consent requires that the quarry periodically reviews, and if required updates, the quarry's environmental management plans. This includes a review within three months of submitting the Annual Review. The *Menangle Sand and Soil, Annual Review, 1 January 2023–31 December 2023* (Benedict Sands Menangle 2024) (the Annual Review) was submitted to Department of Planning, Housing and Infrastructure (DPHI) in March 2024.

As a result of the review, Menangle Sand and Soil seeks to update the AQMP, NMP and SWMP. The proposed changes to these plans are outlined below.

2 Proposed management plan updates

2.1 Air Quality Management Plan

The most recent version of the *Menangle Sand and Soil Quarry Air Quality Management Plan*, version 9, 31 March 2022 (EMM 2022a) was approved by the Planning Secretary on 19 April 2022.

It is proposed to update the air quality monitoring programme as described below.

2.1.1 Air quality monitoring

The ambient air quality monitoring described in Section 6.2 of the AQMP consists of:

- ongoing monitoring using three dust deposition gauges
- two air quality separate four-week monitoring campaigns.

2.1.2 Dust gauges

As reported in Section 3 'Regular Air Quality Monitoring' in the *Annual Review*, one of the dust deposition gauges is located in a grassed area that requires regular maintenance, including mowing, that has contaminated dust deposition samples. It is therefore proposed to move the dust gauge approximately 130 m to the west so that it is no longer surrounded by grass that needs maintenance and is closer to boundary of the site (see Figure 2.1).

Figure 2.1 Proposed relocation of DDG01

The proposed location of DDG01 meets the requirements of *Methods for Sampling and Analysis of Ambient Air, Guide to Siting Air Monitoring Equipment (*AS/NZS 3580.1.1:2016):

- clear sky angle of 120°
- unrestricted air flow of 360° around sample inlet
- 10 m from nearest object or tree dripline
- 5 m from road
- no boiler or incinerator flues nearby.

It is proposed to amend Figure 6.1 'Dust deposition gauge and meteorological station locations' of the AQMP, to show the new location for DDG01.

2.1.3 Ambient air quality monitoring campaigns

Two four-week ambient air quality monitoring campaigns are required by Section 6.2 of the AQMP. These campaigns included real-time monitoring of PM_{10} and $PM_{2.5}$ using two particulate matter monitoring units.

These campaigns have been completed (Photograph 2.1).

Photograph 2.1 AQM01 campaign monitoring location – co-located with DDG1

The results of ambient air quality monitoring campaigns are reported in *Menangle Sand and Soil Quarry Air Quality Monitoring Campaign* (EMM 2024a). This report was appended to the *Annual Review*.

A summary of the monitoring results from the two campaigns are as follows:

- one exceedance of the 24-hour PM_{10} criterion (50 µg/m³) was recorded at the AQM01 monitoring location (adjacent to DDG01) due to the influence of local lawn mowing emissions, no exceedances were recorded at the three other monitoring locations
- no exceedances of the 24-hour average $PM_{2.5}$ criterion (25 µg/m³) were recorded at any of the monitoring locations
- the PM_{10} and $PM_{2.5}$ concentrations recorded at the quarry were generally comparable with the concurrent measurements at the Department of Climate Change, Energy, the Environment and Water (DCCEEW) Campbelltown West and Camden Air Quality Monitoring Station for the two campaign periods, indicating that regional emissions sources are the primary driver of ambient particulate matter concentrations.

As these campaigns have been completed, it is proposed to remove the requirement for ambient air quality monitoring campaigns from the AQMP.

2.2 Noise Management Plan

The most recent version of the *Menangle Sand and Soil Quarry Noise Management Plan*, version 7, 25 February 2022 (EMM 2022b) was approved by the Planning Secretary on 19 April 2022.

It is proposed to update the noise monitoring programme as described below.

2.2.1 Noise monitoring

The noise monitoring described in Section 5 of the NMP consists of quarterly attended monitoring at locations representative of the nearest privately-owned to quarry operations.

2.2.2 Monitoring results

Two rounds of attended quarterly noise monitoring have been completed:

- October 2023 (EMM 2023): monitoring at eight locations
- February 2024 (EMM 2023x): monitoring at six locations.

Monitoring and reporting were completed in accordance with the *Noise Policy for Industry* (EPA 2017) and the *Approved Methods for the Measurement and Analysis of Environmental Noise in NSW* (EPA 2022). Noise levels were monitored at residences during the shoulder period (6 am to 7 am Monday to Saturday) and day period (7 am to 6 pm Monday to Saturday and 8 am to 6 pm Sundays and public holidays).

Consent Condition B4, in conjunction with Consent Appendix 3, specifies the residences where noise criteria apply. Since the Consent was granted, about 90 houses and a playground/park have been built north and south of the quarry's processing area. So while monitoring is required at the locations specified by the Consent, the monitoring does not provide information useful in the managing the quarry. It is not possible to change the monitoring locations without modifying the Consent. However, the frequency of monitoring can be changed with the Planning Secretary's approval.

The site complied with all Consent and EPL noise conditions. Site operations were inaudible at all monitoring locations on all occasions.

The quarry has not received any complaints, including regarding noise.

Given the monitoring results and the ineffective monitoring locations, it is proposed to undertake attended noise monitoring biannually (i.e. once every two years) rather than quarterly.

The Planning Secretary's approval will also be sought for the proposed changed to the monitoring frequency.

2.3 Soil and Water Management Plan

The most recent version of the *Menangle Sand and Soil Quarry Soil and Water Management Plan*, version 3, 25 February 2022 (EMM 2022b) was approved by the Planning Secretary on 25 March 2022.

The approved SWMP covers the first three extraction substages in the Stage 8 area (Substages 8A–8C). The plan is being revised to address all substages (Substages 8A–8M).

It is proposed to amend the SWMP to include:

- recent rainfall and streamflow statistics
- reference to all substages (Substages 8A–8M)
- sediment basin sizes for all substages
- the Ephemeral Creek Management Plan required by Consent Condition B40
- improvements to the Stage 7 water management system
- an updated site water balance.

The previous Stage 7 water management system is shown in Figure 5.5 of the SWMP. The proposed Stage 7 water management system is shown in Figure 2.2 below.

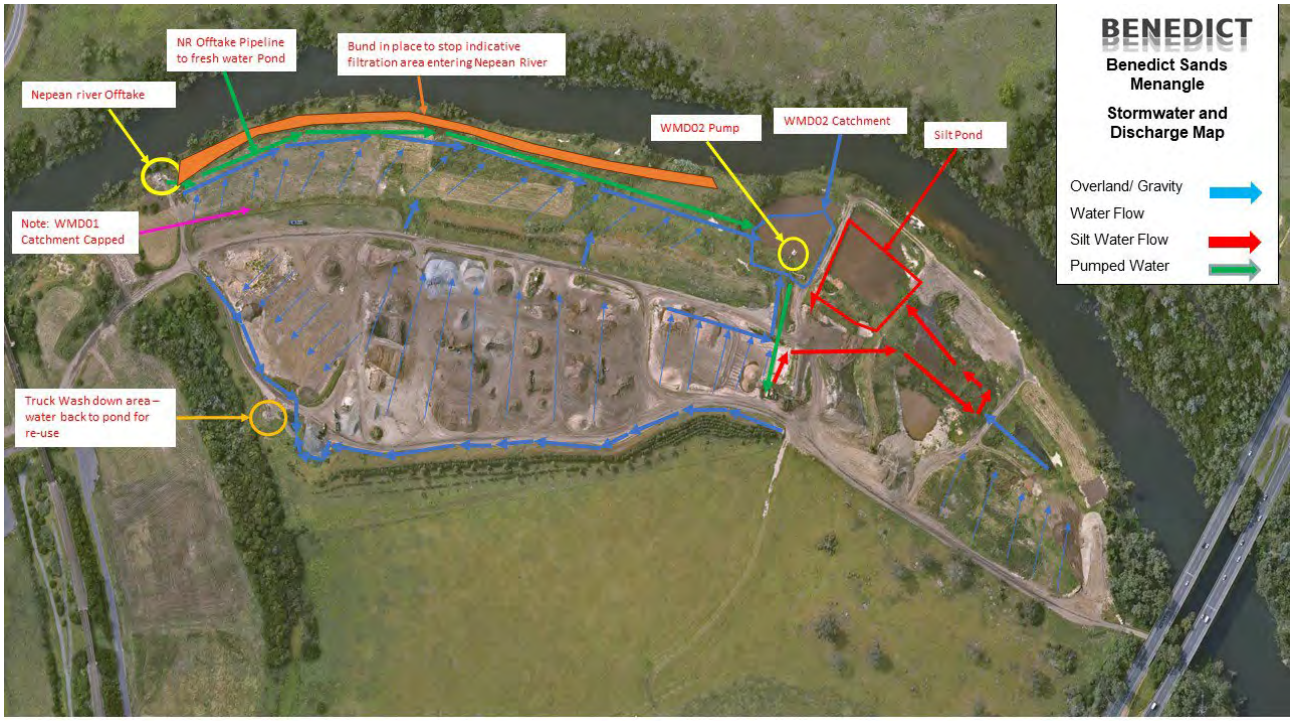

Figure 2.2 Proposed Stage 7 area water management system

2.4 Other updates

The management plans will be reviewed to ensure that they align with current department names and references. The appended consultation correspondence associated with the previous plans will be replaced with consultation correspondence associated with the amendments.

3 Conclusion

Menangle Sand and Soil seeks EPA's comments and/or endorsement of the proposed updates to the management plans.

Please contact me if you have any questions.

Yours sincerely

Dr Philip Towler
Associate Director
ptowler@emmconsulting.com.au

References

Benedict Sands Menangle 2024, *Menangle Sand and Soil, Annual Review, 1 January 2023–31 December 2023*.

EMM 2022a, *Menangle Sand and Soil Quarry Air Quality Management Plan*. Report prepared by EMM Consulting Pty Limited for Menangle Sand and Soil Pty Ltd.

EMM 2022b, *Menangle Sand and Soil Quarry Noise Management Plan*. Report prepared by EMM Consulting Pty Limited for Menangle Sand and Soil Pty Ltd.

EMM 2022c, *Menangle Sand and Soil Quarry Soil and Water Management Plan*. Report prepared by EMM Consulting Pty Limited for Menangle Sand and Soil Pty Ltd.

EMM 2023, *Menangle Sand and Soil Quarry Noise Compliance Assessment*. Report prepared by EMM Consulting Pty Limited for Menangle Sand and Soil Pty Ltd.

EMM 2024a, *Menangle Sand and Soil Quarry Air Quality Monitoring Campaign*. Report prepared by EMM Consulting Pty Limited for Menangle Sand and Soil Pty Ltd.

EMM 2024b, *Menangle Sand and Soil Quarry, Noise Compliance Q1 Assessment*. Report prepared by EMM Consulting Pty Limited for Menangle Sand and Soil Pty Ltd.

EPA 2017, *Noise Policy for Industry*, NSW Environment Protection Authority.

EPA 2022, *Approved Methods for the Measurement and Analysis of Environmental Noise in NSW*, NSW Environment Protection Authority.

Phil Towler

From: Kohben Grech <kohben.grech@epa.nsw.gov.au>
Sent: Thursday, 6 June 2024 9:08 AM
To: Phil Towler
Subject: Menangle Sand and Soil Quarry - proposed management plan updates

Hi Philip,

The NSW EPA is writing to you regarding the proposed management plan updates for Menangle Sand and Soil Quarry (EPL 3991).

The EPA encourages the development of such plans to address approval condition requirements and ensure that proponents have determined how they will meet their statutory obligations and designated environmental objectives. Our role is not to be directly involved with the development of strategies to achieve those objectives. The EPA does however make the following comment(s):

- The EPA do not object to Menangle Sand and Soil Quarry submitting the proposed changes to NSW Planning for review, however the proposal should include more details regarding supporting documentation alongside the written request.

Kind regards,

Kohben Grech
Operations Assistant - Operations
NSW Environment Protection Authority
D 02 4908 6854 **M** 0447 171 195

www.epa.nsw.gov.au @NSW_EPA

The EPA acknowledges the traditional custodians of the land, waters and sky where we work. As part of the world's oldest surviving culture, we pay our respect to Aboriginal elders past and present.

I work on Awabakal Country

Report pollution and environmental incidents 131 555 or +61 2 9995 5555

Appendix B

Plan approval

Ms Alycia Campbell
Environmental Compliance Manager
Benedict Recycling PTY Limited
11 NARABANG WAY
BELROSE NSW 2085

25/03/2022

Dear Ms Campbell

Menangle Quarry (DA 85/2865)
Soil and Water Management Plan - Version 3

I refer to the updated Soil and Water Management Plan - Version 3 which was submitted in accordance with Condition B36 of Schedule 2 of the consent for Menangle Quarry (DA 85/2865).

The Department has carefully reviewed the document and is satisfied that it is satisfied that it generally meets the requirements of the conditions.

Accordingly, the Secretary has approved the Soil and Water Management Plan (Revision 3, dated February 2022). Please ensure that the approved plan is placed on the project website at the earliest convenience.

If you wish to discuss the matter further, please contact Kevin Reid on 0292746209.

Yours sincerely

JEvans

Jessie Evans
Director, Resource Assessments
Resource Assessments

As nominee of the Secretary

Appendix C

Ephemeral creek management plan

TOOKER+ ASSOCIATES

Department of Planning, Housing and Infrastructure
Via Planning Portal

9 September 2024

Dear Sir/Madam,
Re: Menangle Sand and Soil Quarry (DA 85/2865) – Ephemeral Creek Management Plan (ECMP)

Menangle Sand and Soil Pty Ltd operates the Menangle Sand and Soil Quarry at 15 Menangle Road, Menangle. The quarry, located in the Wollondilly and Campbelltown local government areas, extracts sand and soil along the Nepean River as approved by Development Consent 85/2865.

Condition B40(a) of Schedule 2 of the Consolidated Consent requires the preparation on an *Ephemeral Creek Management Plan* by suitably qualified and experienced person/s.

This *Ephemeral Creek Management Plan* (*ECMP*) has been prepared by:
- Mark Tooker, Director, Tooker and Associates: design
- Zac Richards, Director, GRC Hydro: hydrology
- Dr Philip Towler, EMM, Associate Director: management measures.

The location of the ephemeral creek ("creek") which is the subject of the *ECMP* is shown on Figure 1. The creek has a small catchment (1.78 km^2) and only flows in response to heavy local rain. It is located generally near to Menangle township but cannot be viewed from any adjoining property. The lowermost 150m long stretch of the creek (immediately above its confluence with the Nepean River) is within the quarry's extraction area (substages 8E, 8F and 8G). It is proposed to realign this section of the creek to prevent erosion of the creek bed should the creek flow during extraction of these substages. The proposed new location, which is several metres to the north, and the new alignment of the creek and the new creek site-vehicle crossing locations are presented on Figure 2.

The creek crossing and realignment works will occur prior to soil extraction within substage 8E. The realignment works will include provision of a new channel and a culvert bridge.

Creek realignment

Flood modelling by GRC Hydro has estimated the peak flood flow in the creek and used *Manning's Equation,* with a limited flow velocity of 1.2m/s, to properly size the channel's required dimensions (refer Appendix A). The channel dimensions were calculated based on a bank full flow capacity (to the top of the bank) for a 2yr annual return interval (ARI) flood (approximately 2.54% annual exceedance probability (AEP)) which is the typical geomorphological creek bank formation in NSW and will match the existing creek capacity at top of bank. On this basis, a trapezoidal channel with the base at 1.6m wide and side slopes of 1V:3H will be constructed.

The side slopes of the new creek alignment will be protected with a biodegradable mat pinned to the surface and riparian vegetation planted through the mat. The limited velocity (1.2m/s) will minimize the potential for bank erosion as will vegetation installed on this new structure. The new creek will be aligned to join the Nepean River in a downstream alignment and will also be stabilized with a pegged matting and vegetation to minimize the potential for bank erosion and adverse impacts on the downstream receiving environments. The designs for the realigned creek channel and crossing are supported by hydrological modelling and meet the rehabilitation objectives in Table 4.

m 0409 912 631 e mark.tooker@tookerandassociates.com.au a 30 Walworth Avenue, Newport abn 39 619 046 070

The old creek alignment will be filled in and revegetated as part of the quarry's ongoing rehabilitation.

As is normal quarrying practice at Menangle, runoff from the extraction area will be diverted to a sedimentation pond and will not be allowed to run into the new creek alignment or the Nepean River. The erosion and sediment control measures described in Chapter 7 of the *Menangle Sand and Soil Quarry Soil and Water Management Plan* including in Table 7.9 and Table 7.10, will be implemented. These measures will include maintaining the bund formed by leaving the riverbank within the Nepean River Buffer Zone (NRBZ) intact and the use of sediment fence along the realigned creek and Nepean River.

A bund along the upslope (northern) edge of the creek realignment will redirect any surface flow from the extraction area to a sedimentation pond within the extraction area, i.e. within the NRBZ 'bund'.

There will be no loss of flood storage and in fact flood storage across the Quarry development will be increased with the lowering of the natural sand/soil areas in the extraction zones.

Haul road bridge

The proposed location of the culvert bridge for the extraction works is shown in Appendix B. The culvert bridge will have an overall length of 4.8m and an overall width of 6.15m. There will be one box culvert 1.8m width and 0.65m high. The culvert will be supported on a concrete slab and the driving surface for the bridge will also consist of a concrete slab. The culvert will consist of wing walls at either end with rock protection to minimize any erosion of the channel.

GRC Hydro has undertaken a hydrological assessment of the culvert size required for the bank full peak flood flow rate (refer Appendix A). The box culvert size provides a flow area capacity adequate to achieve the required flows as determined by the GRC flood modelling. Large rocks (300-400mm d50) will be placed around the winged sides of the culverts where the culverts meet the banks so as to minimize the potential for flood erosion. Larger floods would overtop the culverts and continue to flow in the channel. There would be no adverse flood impacts as the culverts provide the same flow capacity as the proposed channel.

Compliance with Conditions

The *Consent Condition B40* under the *ECMP* heading has a number of requirements **B40(a)** to **(f)**. These requirements are addressed under each of these sub points:

B40 (a) – *ECMP to be prepared by suitably qualified and experienced persons.*

Details lodged in a separate document and approval of qualified and experienced persons is contained in Appendix C.

B40 (b) – *measures that would be implemented to manage and control soil erosion and bank stabilization and limit the risk of impacts on downstream receiving environments.*

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Detailed measures to manage and control soil erosion and bank stabilization and to limit the risk of impacts on downstream receiving environments are described in the approved *Menangle Sand and Soil Quarry Soil and Water Management Plan*. These measures will be implemented in the areas around the creek realignment.

In addition, the realigned channel banks will be protected by a biodegradable mat until the riparian vegetation has established on the banks. Runoff from disturbed/unrehabilitated extraction area will be managed in a sediment pond and will not be allowed to discharge down the creek/riverbank. The realigned channel will be monitored after any significant rainfall event and any erosion will be repaired immediately.

The creek realignment will be lined so will not introduce additional sediment into the Nepean River.

The creek realignment and crossing will not significantly increase flood levels in the Nepean River upstream or downstream because there will be a significant increase of flood storage due to the Quarry's sand/soil extraction works.

B40 (c) – *methods and timing of extraction to demonstrate that the integrity of the ephemeral creek would be maintained for as long as practicable during operations*.

These works will be undertaken prior to sand extraction in Substages 8E, 8F and 8G and will be maintained for the duration of the Quarry's life.

The realigned channel and creek crossing will be monitored on a weekly basis during operations to check for erosion, vegetation growth, removal of debris or need for any further control measures.

B40 (d) – *provide for construction and stabilization of appropriate diversion channels to divert surface water flows around the disturbance area*.

As described above, surface runoff from disturbed/unrehabilitated extraction area will be diverted to a sediment pond and be prevented from flowing into the realigned creek or Nepean River.

B40 (e) – *provide designs for a road crossing and realigned section of creek that are supported by hydrological modelling and meet with the rehabilitation objectives in Table 4 [of the Consolidated Consent]*:

The realigned channel and road crossing details are provided in Appendix A, including hydrological modelling.

The rehabilitation objectives from Table 4 of the Consolidated Consent are discussed below:

Stage 8 Area – the channel and crossing works have been designed to be safe, hydraulically, geotechnically and geomorphologically stable (see Appendix A) and non-polluting (surface runoff controlled). With rehabilitation of the surrounding extraction area, the realigned creek will integrate into the final landform. While the creek is normally dry, the bridge will negate the need to drive through the creek bed for access along the Nepean River. The realignment will not be visible from the Hume Highway.

m 0409 912 631 e mark.tooker@tookerandassociates.com.au a 30 Walworth Avenue, Newport abn 39 619 046 070

Surface Infrastructure – it is proposed to leave the creek realignment and bridge in place at the end of operations.

Quarry Substages – the creek realignment and bridge will not affect works to establish River-Flat Forest EEC, to progressively landscaped and revegetated the extraction area or to maintain the required batters.

Final Landform – there will be no loss of flood storage compared with the pre development conditions (and in fact a significant net gain in flood storage), and rehabilitation works will incorporate geomorphological features such as mounds to let surface runoff infiltrate to creeks and river and this will minimize sediment laden runoff entering Nepean River. This has been successfully employed during the 40 years of extraction of sands at Menangle.

Water Quality – surface runoff will be controlled as above ensuring that water entering the creek and river are suitable for the ecology and riparian vegetation.

Community – the works will ensure public safety (there is no public access) with incorporation of all of Menangle Sand and Soil P/L's OHS works safety measures.

B40 (f) – *describe the methods and timing for rehabilitation of the final realigned section of creek channel*

Progressive rehabilitation of the area around the realigned creek (all extraction area) will commence as soon as extraction in the active extraction area is complete in accordance with the *Menangle Sand and Soil Quarry Biodiversity and Rehabilitation Management Plan*.

Closing

The proposed creek realignment and creek crossing works will satisfy all of the Conditions related to the ECMP.

Yours Sincerely

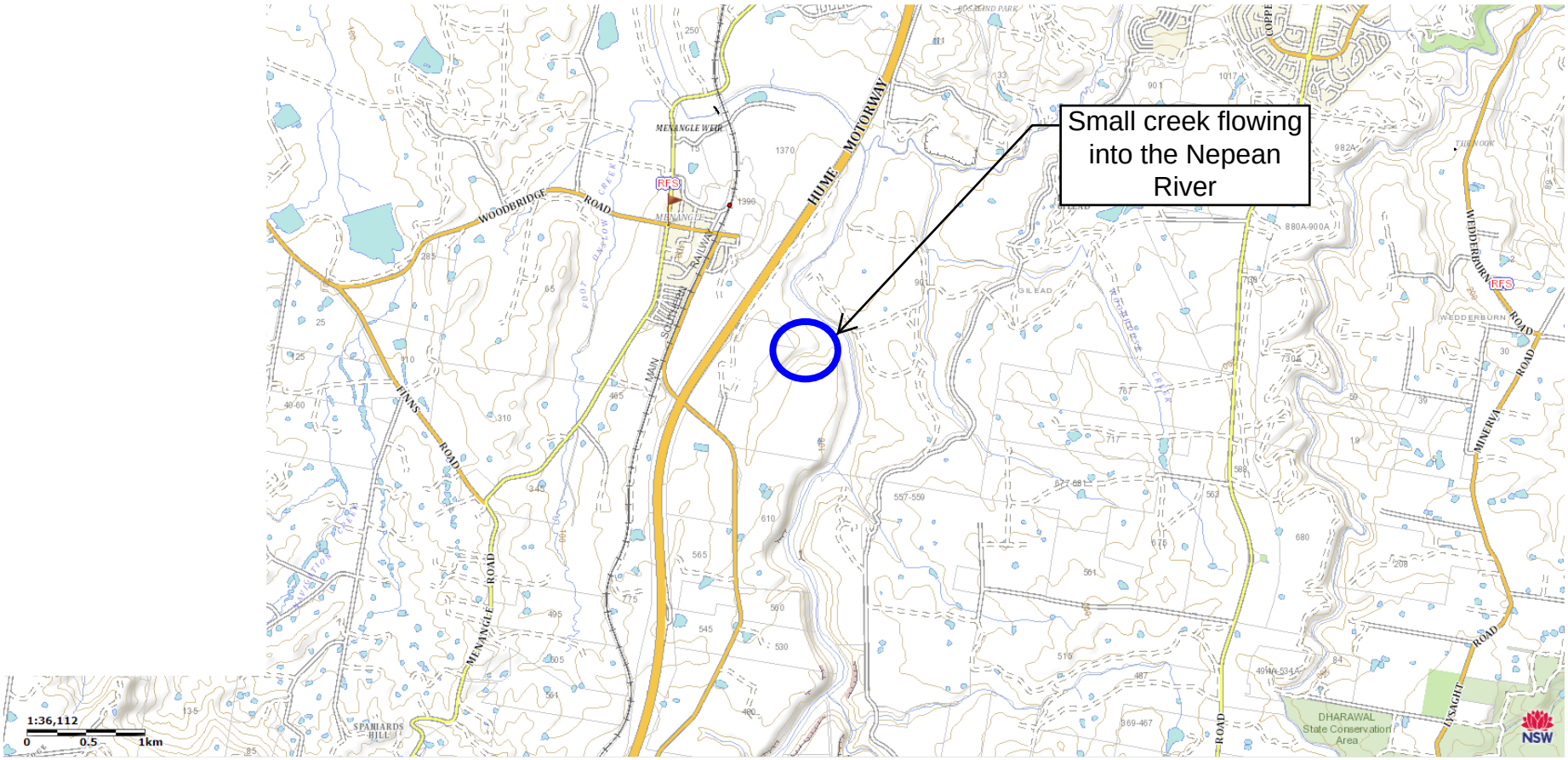
Mark Tooker
Director

m 0409 912 631 e mark.tooker@tookerandassociates.com.au a 30 Walworth Avenue, Newport abn 39 619 046 070

FIGURES

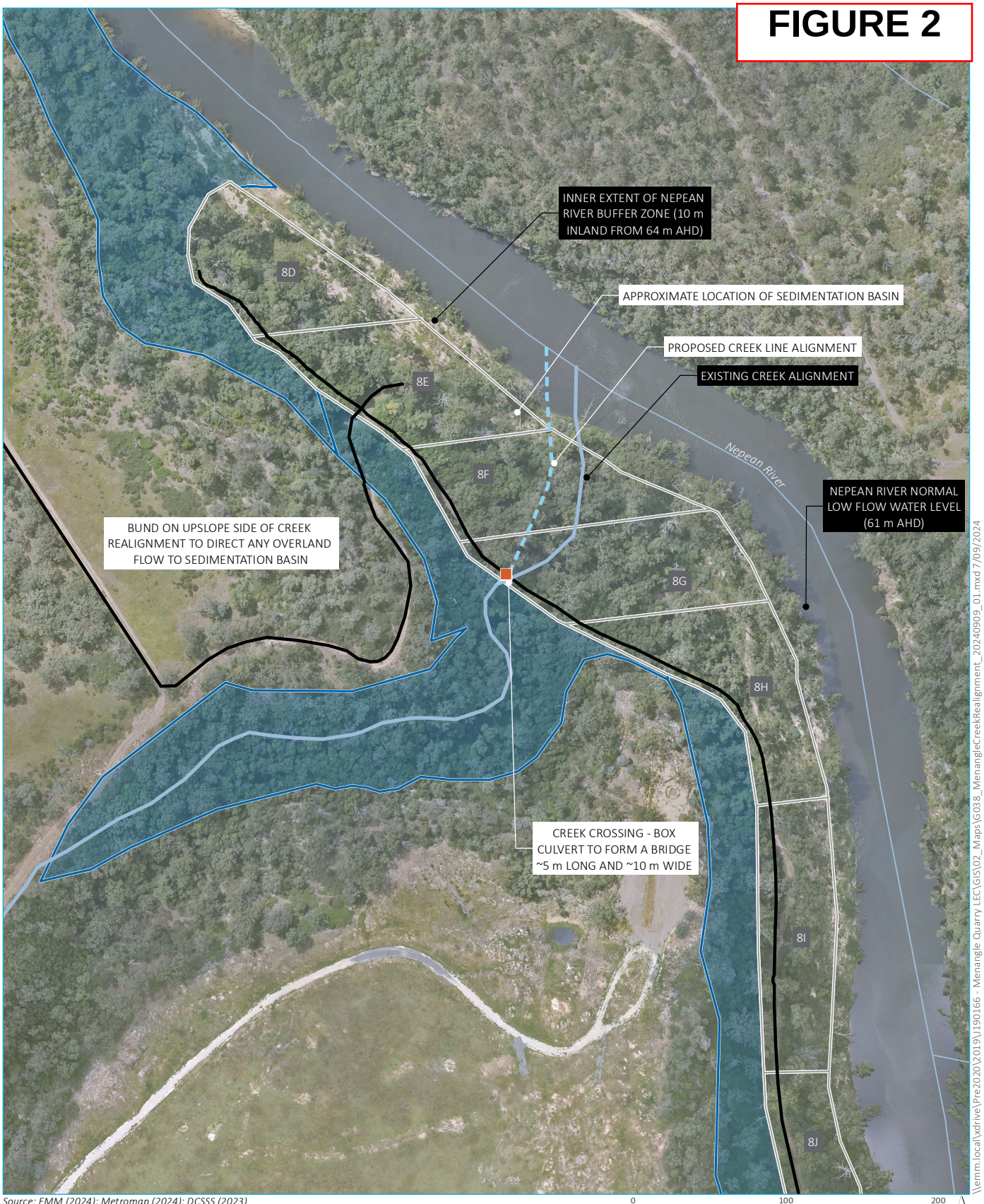
m 0409 912 631 e mark.tooker@tookerandassociates.com.au a 30 Walworth Avenue, Newport abn 39 619 046 070

FIGURE 1



LOCALITY PLAN

FIGURE 2



Source: EMM (2024); Metromap (2024); DCSSS (2023)

0 100 200 m

GDA 1994 MGA Zone 56

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KEY

- Stage 8 - restoration area (no extraction)
- Proposed creek crossing
- Proposed Menangle creek alignment
- Substage 8D-8M haul road

Existing environment

- Watercourse/drainage line
- Menangle creek

Substage boundary

Phase 3 | Sub-stage 8D - 8E
Phase 4 | Sub-stage 8F - 8G
Phase 5 | Sub-stage 8H - 8I
Phase 6 | Sub-stage 8J - 8K

Proposed creek alignment and creek crossing

Menangle Sand and Soil Quarry
Figure 1.1

EMM
creating opportunities

APPENDIX A
GRC Hydro

m 0409 912 631 e mark.tooker@tookerandassociates.com.au a 30 Walworth Avenue, Newport abn 39 619 046 070

Job Number: *240014*
Date: *24 June 2024*

Mark Tooker
Tooker & Associates

GRC Hydro
Level 20, 66 Goulburn Street
Sydney NSW 2000

Tel: +61 432 477 036
www.grchydro.com.au

Dear Mark,

Re: Menangle - Nepean River Sand extraction – Hydrologic and hydraulic

1. Introduction

Tooker & Associates have requested hydrologic and hydraulic estimates to inform construction staging works associated with sand extraction on a tributary of the Nepean River near Menangle. The following analysis was requested:

- Estimation of the 2 year ARI flow;
- Estimation of a channel cross section using the Mannings equation that can convey the 2 year ARI flow assuming grass cover; and
- Sizing of a culvert for a proposed channel crossing.

This analysis has been undertaken by Zac Richards who is Director at GRC Hydro and specialist in hydraulic engineering and floodplain management. Zac's CV in contained in Attachment A.

2. Assumptions and Limitations

This analysis is for proposed construction staging conditions and does not relate to end state conditions for the site. The following assumptions and limitations apply:

- It is understood that the proposed works will not adversely impact adjoining properties. A flood impact assessment is not in the scope of this assessment.
- Flood risk associated with flooding of the site due to the channel capacity being exceeded (by flows exceeding 2 year ARI) will be managed onsite by the contractor through appropriate wet weather contingencies and flood management plans (by others).
- Flood risk associated with Nepean River flooding will be managed through implementation of a flood warning system and flood management plans (by others).
- It is understood that high-level 'hand calculations' are appropriate analysis for the site, based on the site's flood risk profile.

3. Hydrologic Analysis

Design flow estimates have been determined using the Australian Rainfall and Runoff (ARR2019) ARR2019 Regional Flood Frequency Estimation (RFFE) tool. The catchment is generally rural in nature with few developments and the Hume Highway passing through the upper portion of the catchment. It is assumed

that the catchment response is generally consistent with a typical rural catchment and is suitable for assessment using the RFFE model.

Two RFFE versions were used for comparison:

- Version RFFE Model 2016 v1; and
- Version RFFE Model 2021 v2, BETA.

The RFFE outputs are contained in Attachment B, with a summary of flow estimates presented in Image 1 and Image 2.

Image 1: RFFE Model 2016 v1 – flow estimates

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	1.41	0.520	3.78
20	3.32	1.29	8.52
10	5.24	2.04	13.4
5	7.67	2.95	20.0
2	11.8	4.45	31.8
1	15.8	5.83	43.5

Image 2: RFFE Model 2021 v2, BETA – flow estimates

AEP (%)	Expected Value (m^3/s)	Lower Confidence Limit (m^3/s)	Upper Confidence Limit (m^3/s)
50%	1.30	0.30	5.86
20%	4.37	1.38	13.36
10%	7.28	2.32	21.02
5%	10.47	3.16	30.57
2%	14.87	4.00	48.44
1%	18.19	4.44	65.24

The RFFE models output flow estimates are for standard Annual Exceedances Probabilities (AEP) and interpolation was required to determine the 2 year ARI flow which has an AEP of ~ 1 in 2.54 AEP. The interpolation was undertaken in log-normal space and resulted in flow estimates presented in Table 1. RFFE Model 2021 v2 resulted in a higher flow of 2.38 m^3/s and has been used in preference for the ensuing analysis.

Table 1: 2 year ARI flow estimates for the site derived from RFFE

Project	2 year ARI Flow Estimate
RFFE 2016	2.08 m^3/s
RFFE 2019 v2 (BETA)	2.38 m^3/s

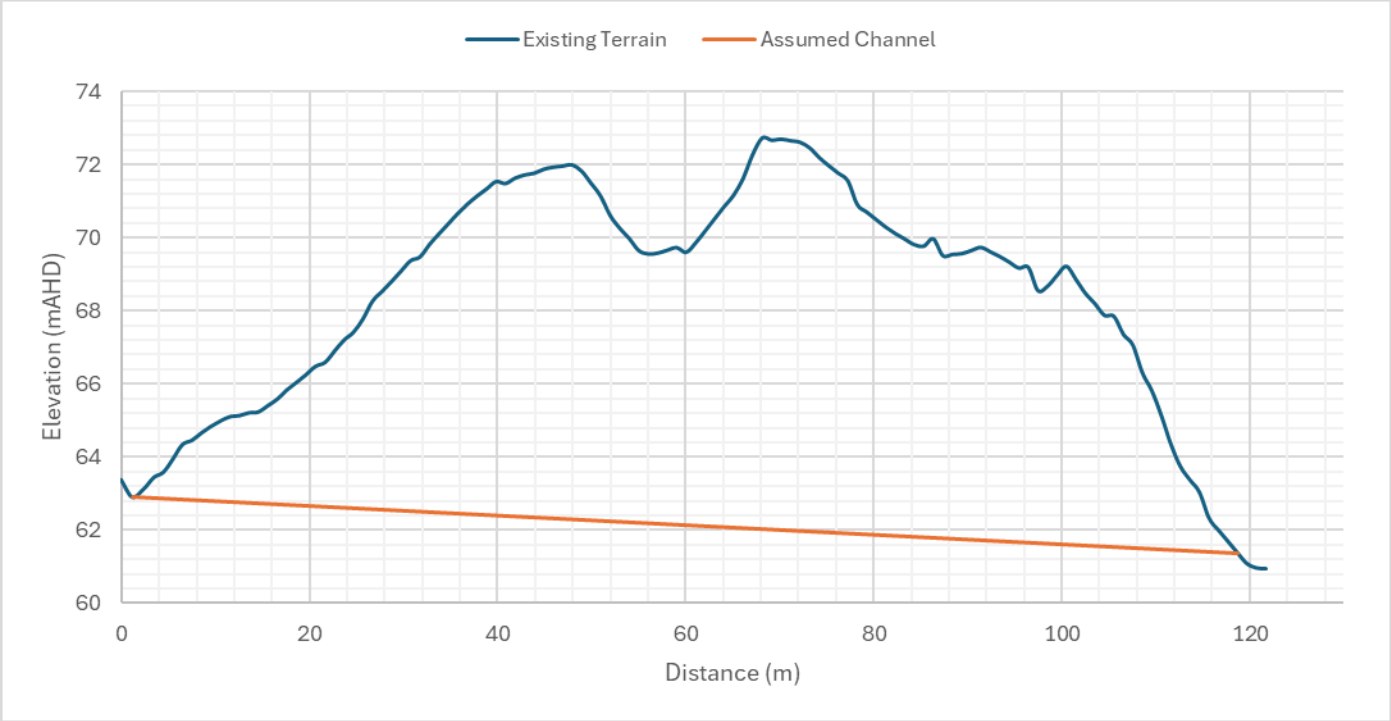
4. Hydraulic Calculations

Using the flow estimate derived in Section 3, a channel cross section and culvert dimension has been estimated. The channel alignment was provided by Tooker & Associates and is contained in Attachment C.

4.1. Channel dimension

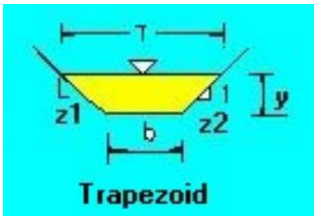
The 'Wollongong_201906_LID1' LiDAR dataset was used to estimate the channel invert to tie-in with existing inverts at the upstream and downstream ends of the provided alignment. A long section is shown in Image 3 and the channel slope was calculated to be 1.3%.

Image 3: Assumed channel invert and existing terrain



Using the calculated channel slope and a Manning's n = 0.05 (consistent with unkept grass), an open channel flow calculator (https://www.eng.auburn.edu/~xzf0001/Handbook/Channels.html) was used to estimate a channel cross section to convey the flow along the proposed channel alignment. The flow calculator results are contained in Attachment D and show that the following channel characteristics can convey a flow of 2.4 m^3/s (velocity of 1.2 m/s) with a flow depth (y) of 0.6 m:

- Trapezoidal channel shape;
- Slope = 1.3%;
- Bottom width (b) = 1.6 m;
- Side slopes (z) = 1 in 3;
- Mannings n = 0.05.



The channel dimensions assume normal flow conditions and that minor energy losses due to bends/expansion/contraction etc. are negligible.

4.2. Culvert dimension

A culvert dimension for a proposed channel crossing has been estimated using the Queensland Urban Drainage Manual (QUDM, fourth edition). The culvert dimension was determined iteratively using Equation 10.7 and 10.8 from Section 10.4.6 which is reproduced below:

$$\Delta H = \left(K_e + \left(\frac{2gLn^2}{R^{4/3}} \right) + K_{exit} \right) \cdot \left(\frac{V^2}{2g} \right) \qquad (10.7)$$

where:

K_e = entrance loss coefficient (assume 0.5 if unknown)

L = length of culvert (m)

n = average Manning's roughness of culvert

R = hydraulic radius of culvert flowing full (m)

K_{exit} = exit loss coefficient (assume 0.8 if unknown) otherwise the exit loss component equals the change in velocity head from within the culvert ($V^2/2g$) to a downstream location where the flow has expanded to approximately full channel width ($V_{d/s}^2/2g$), thus:

$$K_{exit}\,(V^2/2g) = (V^2/2g) - (V_{d/s}^2/2g) \qquad (10.8)$$

In this equation:

- ▲H = the target head loss due to the culvert was assumed to be 0.05 m;
- L = was assumed to be 8 m;
- n = was assumed to be 0.013;
- Vd/s = the downstream channel velocity was as calculated in Section 4.1.

A culvert blockage factor of 0% was applied as calculated by ARR2019. The blockage calculations are contained in Attachment E.

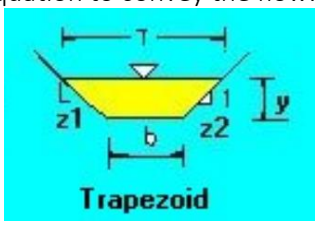
The culvert size that was calculated was a 2 x 1.5 m x 0.6 m box culvert. This achieved an afflux of 0.05 m which was in line with the target afflux.

5. Conclusions

Tooker & Associates requested hydrologic and hydraulic estimates to inform works associated with sand extraction on a tributary of the Nepean River near Menangle.

The 2 year ARI flow estimate was calculated using ARR2019 RFFE model. A channel with the following characteristics was determined using the Mannings equation to convey the flow:

- Trapezoidal channel shape;
- Slope = 1.3%;
- Bottom width (b) = 1.6 m;
- Side slopes (z) = 1 in 3;
- Depth (y) = 0.65 m
- Mannings n = 0.05.



Based on these channel characteristics and the 2 year ARI flow estimate, a flow depth of 0.65 m (0.6 m + 0.05 m afflux due to the culvert) is expected with a velocity of 1.2 m/s. This assumes normal flow conditions and that minor energy losses due to bends/expansion/contraction etc. are negligible.

Culvert dimensions for a proposed channel crossing were estimated using the QUDM. A 2 x 1.5 m x 0.6 m box culvert was calculated to provide conveyance for the 2 year ARI flow estimate with an afflux of 0.05 m.

If you have any questions, please do not hesitate to contact the undersigned.

Yours Sincerely

Zac Richards

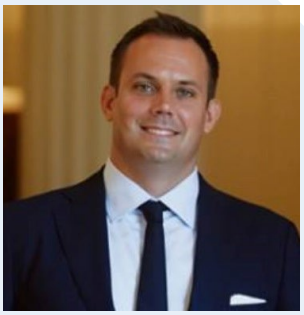
Director

Email: richards@grchydro.com.au

Tel: +61 432 477 036

Attachment A

Zac Richards
Director



Date of Birth:
19 September 1982

Nationality:
Australian

Profession:
Civil Engineer (hydrologist)

Qualifications:
Bachelor of Engineering (Civil) Honours, University of New South Wales, Sydney, 2010

PROFILE

Zac has extensive experience working in the fields of hydrology and hydraulic modelling. He has been involved in a range of major rail and other infrastructure projects as the flooding/hydrology lead, including the Canberra Light Rail, Sydney Metro, Barangaroo Development, and Snowy 2.0 projects. Zac has been involved in various projects in Canberra and the ACT region and has detailed knowledge of local hydrologic and hydraulic characteristics. He is also an accomplished hydraulic modeller and is proficient with various hydraulic modelling packages (TUFLOW, SOBEK, HECRAS). Zac has excellent communication skills developed through client liaison and stakeholder consultation which helps ensure the success of a project.

PROFESSIONAL EXPERIENCE

GRC Hydro (Director) - 2017 and ongoing

- *SMEC/Canberra Metro, Canberra Light Rail Project*
  Hydrologic/hydraulic investigation for proposed Canberra Light Rail using WBNM/TUFLOW. Proposed rail alignment was assessed for various compliance criteria including depth over rail and flood impacts. Zac is the lead modeller and flooding technical advisor on behalf of SMEC.

- *Sydney Metro, Sydney Metro West – Clyde Maintenance and Stabling Facility*
  Hydrologic and hydraulic investigation of a large train stabling and maintenance facility at the confluence of several major watercourses. Zac is the project flooding lead for development of the reference flood model and hydraulic concept design and is currently the Sydney Metro Subject Matter Expert overseeing the detailed design being prepared by the contractor.

- *Sydney Metro, Sydney Metro City and Southwest – Detailed Design*
  Hydraulic investigation of a proposed major trunk drainage deviation is currently being undertaken. Detailed hydraulic modelling is being undertaken to assess hydraulic efficiency of the proposed culvert network. Catchment wide flood impacts are being assessed using TUFLOW. Zac is the project flooding lead on behalf of Sydney Metro.

- *ACT Government, Yarralumla Creek Flood Study review and Mawson mitigation works*
  A WBNM/TUFLOW hydrologic/hydraulic modelling system was derived for Yarralumla Creek at Mawson. The models were calibrated to three historic events and validated to FFA. Design flood modelling was undertaken using ARR2016 methods. Various flood mitigation works were analysed and progress to concept design stage. Zac is the lead modeller and flooding technical advisor on behalf of SMEC.

- *Infrastructure NSW, Barangaroo Precinct – Concept, Reference & Detailed Design*
  Hydraulic investigation for proposed trunk drainage deviation is currently being undertaken using a TUFLOW rainfall on grid model. Design of a trunk stormwater drainage system considering various constraints is required. Zac is the Infrastructure NSW (INSW) nominated hydrologist and flooding lead.

- *Snowy Hydro, Snowy 2.0 Main Works – SEARs Assessment*
  Flooding analysis of major river and creek catchments in the Snowy Mountains is being undertaken as part of the Snowy 2.0 Main Works. The analysis requires complex hydrological assessment of gauged and ungauged rural catchment to defined design flood behaviour. Analysis of major reservoirs to assess dam flood levels is also being performed. Zac is the flooding lead for GRC Hydro, on behalf of EMM Consulting.

- *Cooma, Michelago, Bredbo and Berridale Flood Studies and FRMS&P*
  Four Flood Studies and four FRMS&P are currently being undertaken for Snowy Monaro Regional Council. The development of hydrologic and hydraulic models, including detailed model calibration and validation, is currently being undertaken to define flood behaviour for a range of design flood events. Zac is the project manager and technical advisor.

- *Goulburn FRMS&P*
  The Goulburn FRMS&P is currently being undertaken for Goulburn Mulwaree Council. Floodplain Management options are current being assessed and development of flood planning policy is being undertaken. Zac is the project manager and technical advisor.

- *Snowy Hydro, Snowy 2.0 Main Works – EIS*
  Flooding analysis of a major river in the Snowy Mountains was undertaken as part of the Snowy 2.0 Exploratory Works. The analysis required hydrological modelling and FFA to defined design flood behaviour. Zac was the flooding lead for GRC Hydro, on behalf of EMM Consulting.

- *Bango Bridge hydrologic and hydraulic assessment – Yass Valley Council*

- *Yass River bridge crossings (Back Creek, Yass River, Murrumbateman Creek) hydrologic and hydraulic assessment – Yass Valley Council*

- *Ryrie Street bridge, Michelago, hydrologic and hydraulic assessment and detailed design flood modelling – Snowy Monaro Regional Council*

- *Massie Street bridge, Cooma, hydraulic assessment and detailed design flood modelling – Snowy Monaro Regional Council*

- *Deep and Peak Creek bridges, hydrologic and hydraulic assessment – Snowy Monaro Regional Council*

WMAwater (Associate) - 2009 to 2017

- *Gundaroo and Sutton Flood and Floodplain Risk Management Studies*
  Two individual Flood Studies and FRMS&Ps were performed in Yass Valley Council. Hydrologic analysis and calibration was undertaken with WBNM for both riverine and local catchments. Hydraulic modelling was performed using TUFLOW. Cost effective flood mitigation strategies were identified for each town and have been put forward for detailed design. Zac was responsible for day to day running of the study and liaison with the client and sub-consultants.

- *Goulburn Flood Study*

The Goulburn Flood Study defined design flood behaviour for the Wollondilly and Mulwaree Rivers at Goulburn. The achieve this the development of hydrologic (WBNM) and hydraulic (TUFLOW) models was required. Rigorous calibration of these models was undertaken using a large amount of daily read and pluviometer rainfall data as well as numerous stream gauges. The model was calibrated at four stream gauges for three events ensuring a high degree of confidence can be had in the modelling results. Zac was the project manager for the project and was the main point of contact for the client and provided direction advice and quality control for the modelling work.

- *Yass Flood Study*
  The Yass Flood Study defined design flood behaviour for Yass for riverine, creek and major overland flow flooding. Zac determined design Yass River flows via FFA. The analysis was complicated by the poor quality of the high flow rating and required that a rating be built using the hydraulic model. Examination of historic newspaper articles allowed for the analysis to be undertaken for ~180 years of data through use of a Bayesian maximum likelihood approach. Creek and overland flows were determined via hydrologic modelling (DRAINS). Zac was the project manager for the project and was the main point of contact for the client and provided direction advice and quality control for the modelling work.

- *Culcairn, Henty and Holbrook FRMS&P*
  Three individual FRMS&P were performed in Greater Hume Shire. Numerous cost effective flood mitigation strategies were identified for each town and have been put forward for detailed design. The study also had significant focus on planning and worked closely with a specialist planner, Council planners and DoPI. To mitigate flood risk a risk expert was employed to perform analysis. Zac was responsible for day to day running of the study and liaison with the client and sub-consultants.

- *Lockhart Shire Council Voluntary Purchase Feasibility Assessment*
  The Lockhart Shire FRMS&P made a recommendation to undertake a VP feasibility assessment. The study used findings from the Lockhart and The Rock Flood Studies to identify properties eligible for VP and to justify inclusion of these properties in the scheme. A rigorous community consultation process was undertaken with one on one meetings to inform and appease the community. Zac was responsible for day to day running of the study and was the primary contact for the community and Council.

- *Wagga Wagga Detailed Model Revision*
  An existing model was updated for determining design heights for proposed upgrades of the Wagga City and North Wagga Levees. Zac determined design flows through Flood Frequency Analysis and assisted in hydraulic modelling (TUFLOW). Zac also liaised with various parties including surveyors, hydrographers and OEH.

- *Currumbene and Moona Moona Creeks FRMS&P*
  This study required a total revision of the existing flood study for both the hydrologic and hydraulic models. Statistical analysis of pluviometer rainfall data revealed that current ARR87 rainfall for the region was grossly incorrect and that ARR2013 estimates produced better design rainfall intensities for the catchments. Model flows were determined by WBNM. The hydrologic model was calibrated to Flood Frequency Analysis and two hydraulic models (TUFLOW) were constructed for the two creeks. The ensuing FRMS&P largely focused on mitigation of flood risk through emergency response planning as no mitigation works were suitable for the study areas. Zac was responsible for all technical aspects and day to day running of the study.

- *Gundagai Flood Study*
  The Gundagai Flood Study determined design flood behaviour of Jones Creek and the Murrumbidgee River at Gundagai. Zac determined design Murrumbidgee River flows through Flood frequency analysis. The analysis was complicated by the construction of two upstream storages, Burrinjuck and Blowering Dams, during the period of record. The impact of Blowering Dam on the annual series record was shown to be statistically insignificant for events greater than the 0.2 EY which allowed the ensuing analysis to be undertaken with over 90 years of recorded flow data. The pre-Burrinjuck Dam period was then incorporated into the analysis using a Bayesian maximum likelihood approach which extended the record period to 170 years and added robustness to the 1% AEP flow estimate. A Log-Pearson III probability distribution was then fitted to the data which revised existing flow estimates by 10%. Jones Creek flows were determined via hydrologic modelling (WBNM). Two individual hydraulic models (TUFLOW) were constructed for the two water courses and the models were calibrated to the 2012 and 2010 floods.

- *Lockhart and The Rock Flood Studies and FRMS&P*
  Two flood studies were undertaken for the towns of Lockhart and The Rock in Lockhart Shire. Hydrologic analysis was undertaken with WBNM and hydraulic modelling was performed using TUFLOW. Following the flood study a FRMS&P was undertaken with a number of cost effective flood mitigation solutions put forward for detailed costing and design. Flood planning and emergency response also formed a key part of the management study. Rigours community consultation was key to the success of the study. Zac was responsible for hydrologic/hydraulic modelling and reporting and oversaw the day to day running of the project.

- *Greater Hume Shire Council Flood Studies*
  Three flood studies were performed for the townships of Culcairn, Henty and Holbrook situated in GHSC. Hydrologic analysis was undertaken with WBNM for a large region with only minor rainfall and flow data available for calibration. Hydraulic modelling was performed using TUFLOW. Models were calibrated to the October 2010 and March 2012 Floods. Zac was responsible for hydrologic/hydraulic modelling and reporting and oversaw the day to day running of the project.

- *Murrumbidgee River Flooding Data Collection Project 2012*
  During and after the 2012 Murrumbidgee Flood event a field trip was undertaken with the purpose of collecting flood intelligence in affected regions. Flood intelligence was obtained from numerous sources and data was collated into a report that detailed all aspects of the event.

- *Warrell Creek to Urunga Pacific Highway Upgrade – Flood Study*
  Development of a TUFLOW model of the Bellingen / Kalang River system. River inbanks were modelled using both 1D and 2D methods with 1D methods used for the narrower upper reaches and 2D tinning methods employed for wider tidal branches. The model was calibrated and verified using four historical events. Design flood levels and extents were produced for the region. Zac was responsible for hydraulic modelling and reporting.

- *Hawthorne Canal – Flood Study*
  A TUFLOW model was developed of an urbanised catchment with the aim of modelling the local stormwater drainage system. The model was constructed in 1D/2D and was calibrated to historical events. Zac was responsible for hydraulic modelling and reporting.

- *Eastern Creek Catchment – Hydrological Assessment*
  Development of numerous RAFTS models to assess the hydrologic properties of the Eastern Creek Catchment. A number of RAFTS models were created for various variations to proposed development as well as to investigate potential climate change impacts. Generated flows will be used for a future flood study. Zac was responsible for hydrologic modelling and reporting.

- *Murrumbidgee River Flooding Data Collection Project 2010*
  Directly after the 2010 Murrumbidgee Flood event a field trip was undertaken with the purpose of collecting flood data in affected regions. Flood marks were collected at a number of points along the river as well as other regions in the vicinity that were affected by flash flooding as opposed to river flooding. A report was produced that not only included these flood marks but also discussed various details of the 2010 event and comparisons were made to the last significant flood event that occurred during 1974.

- *Wagga LGA, Modelling of the Murrumbidgee River*
  Developed a TUFLOW model of the Murrumbidgee River over the length of the Wagga LGA and calibrated against the 1974 flood event. Design flood levels and extents were produced for the region. Zac was responsible for hydraulic modelling and reporting.

- *Jugiong Flood Study and Floodplain Risk Management Study & Plan (FRMS&P)*
  A Flood Study and FRMS & P were prepared for Jugiong situated on the Murrumbidgee River. Flood Frequency Analysis and extrapolation of flood surface profiles were employed to define design flood levels. Design flood levels and extents were produced for the region.

- *Rose Bay Floodplain Risk Management Study & Plan*
  The catchment of Rose Bay was analysed through a combination of digital and field trip observations to determine potential flood risk areas. Locations of high risk regions and properties were determined from the observations mentioned above. Methods of alleviating these problems were constructed and then modelled in SOBEK to determine flood impacts. Zac was responsible for hydraulic modelling and reporting.

- *Ourimbah Creek FRMSP (Project Manager)*

- *Tuggerah Southern Catchments Flood Studies (Project Manager)*

- *Gundagai FRMSP (Project Manager)*

- *Wagga FRMSP (Project Manager)*

Lyall and Associates (Student) - 2008 to 2009

- *Numerous Flood Studies and Water Engineering Work*
  Duties included data analysis, GIS processing and modelling (HECRAS, DRAINS).

PUBLICATIONS

- Richards, Z, Babister, M and Sharma, A (2012). "*A Methodology for Incorporating*

Orographic Information in Deriving Intensity-Frequency-Duration Relationships", 34th Hydrology and Water Resources Symposium, November 2012.

- Richards, Z.J, Gray, S.D, Varga, C, and M.K. Babister (2012). *"How much time do we have? The variability of riverine flood wave routing speed."* . Proceedings 52st Floodplain Management Association Floodplain Managers Conference Bateman's Bay, February 2012

Attachment B

BETA

Regional Flood Frequency Estimation Model

Release Version of the Regional Flood Frequency Estimation Model for the 4th edition of Australian Rainfall and Runoff.

Australian Rainfall & Rur

Basic

Polygon

Input Data

Outlet Longitude (°)

150.75334

Outlet Latitude (°)

-34.13527

Centroid Longitude (°)

150.7447800

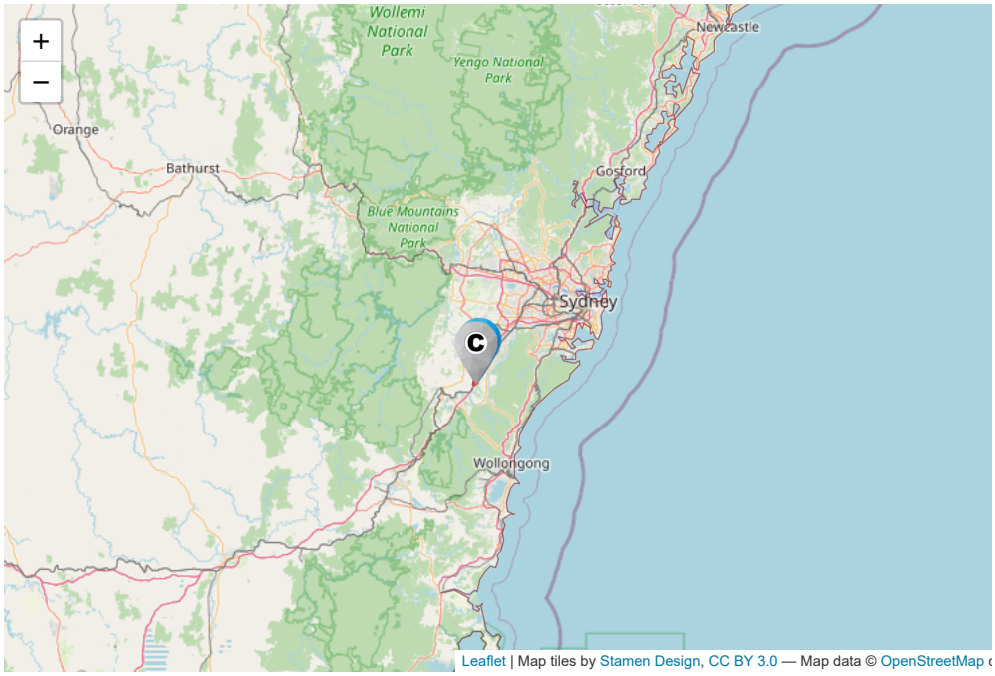
Centroid Latitude (°)

-34.14754117

Catchment Area (km²)

1.778

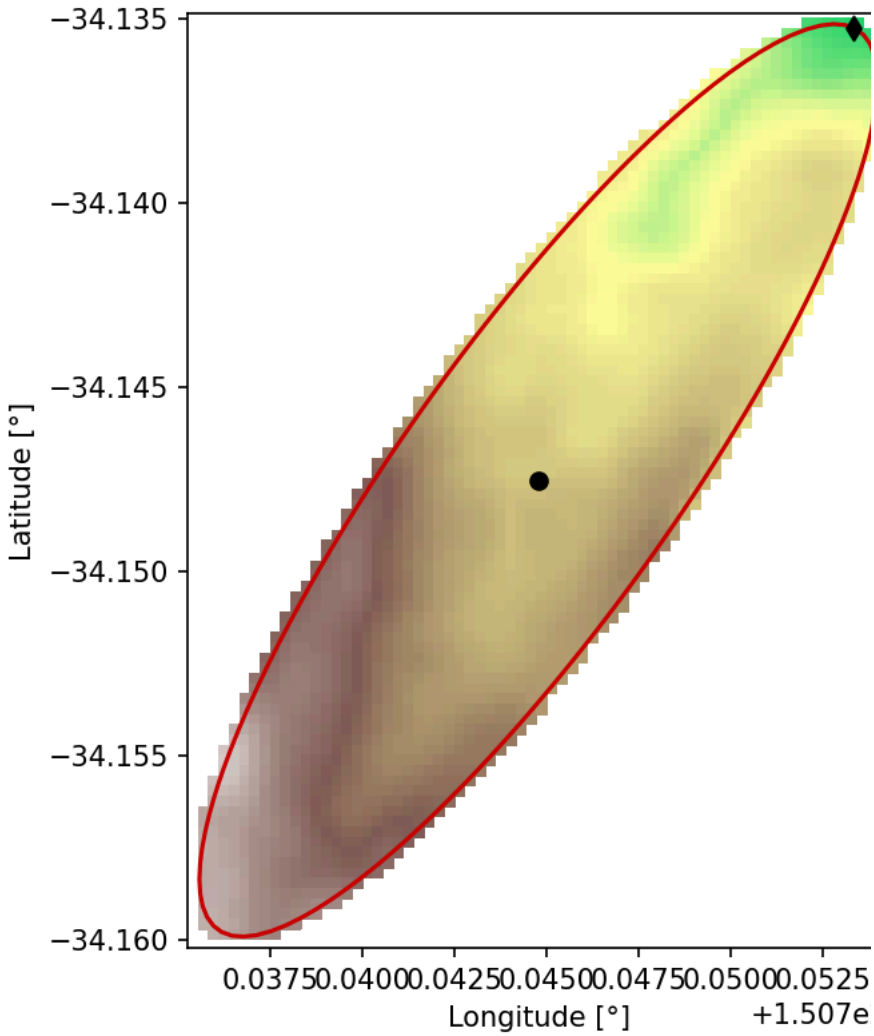
RUN RFFE



Catchment Properties

Date/time	2024-03-25 11:19:16
River Basin	Hawkesbury River
RFFE Region	East Coast
State	NSW
Outlet Lat/Lon	-34.1353, 150.7533
Centroid Lat/Lon	-34.1475, 150.7448
Area (km²)	1.78
Shape Factor (adim.)	1.181
Mean Elevation (m AHD)	120.7
50% AEP 6 Hours Rainfall Intensity (mm/h)	7.9
2% AEP 6 Hours Rainfall Intensity (mm/h)	18.5
RFFE Version	2021a
Rainfall Source	ARR Design Rainfall 2018

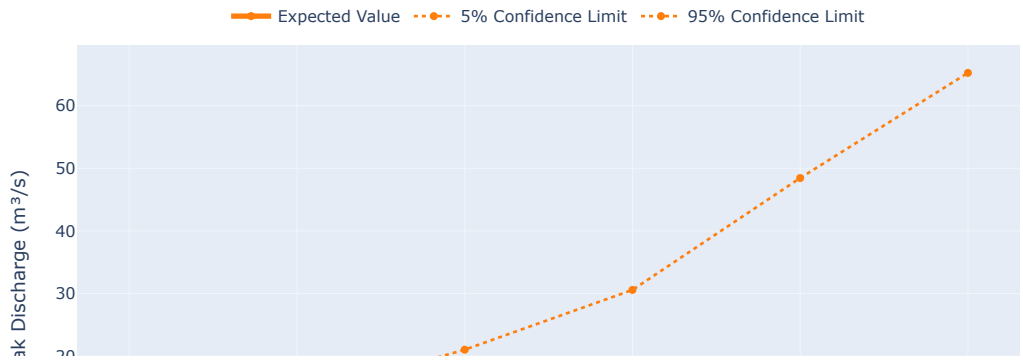
Elevation Map

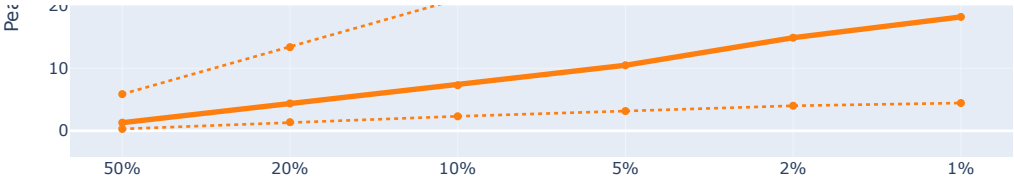


Estimated Flow Quantiles ?

OVERALL | SMALL CATCHMENTS [RECOMMENDED] | AVERAGE | ALL MODELS

Region	Model Type	Regression Type	Fitting Method	Predictors	Min Nearby Stations	Max Nearby Stations
1	Small Catchments [Recommended]	Hybrid	Mean GLS	Mean Area km2, IFD 2% 72.0h, Soil Moisture Mean	Mean 15	Mean 50
			StDev OLS	StDev IFD 50% 72.0h, IFD 2% 72.0h, Soil Moisture Mean	StDev 50	StDev 100
			Skew OLS	Skew IFD 50% 72.0h, IFD 2% 72.0h, Slope Mean	Skew 50	Skew 100





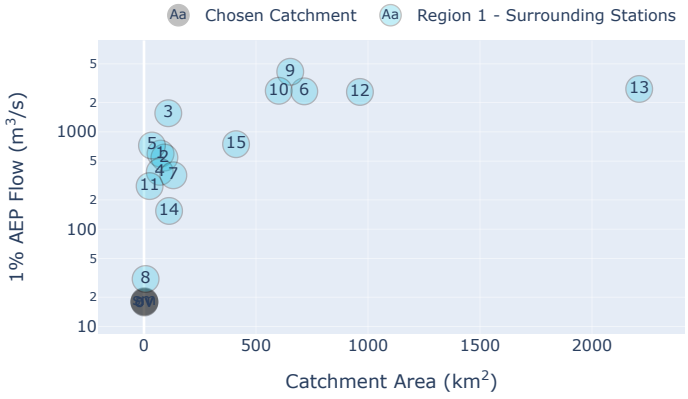
AEP (%)	Expected Value (m³/s)	Lower Confidence Limit (m³/s)	Upper Confidence Limit (m³/s)
50%	1.30	0.30	5.86
20%	4.37	1.38	13.36
10%	7.28	2.32	21.02
5%	10.47	3.16	30.57
2%	14.87	4.00	48.44
1%	18.19	4.44	65.24

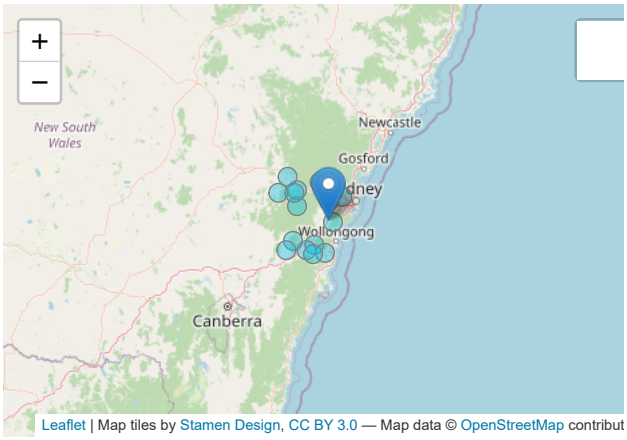
Predictors Data at 15 Closest Stations

Select the flood's AEP

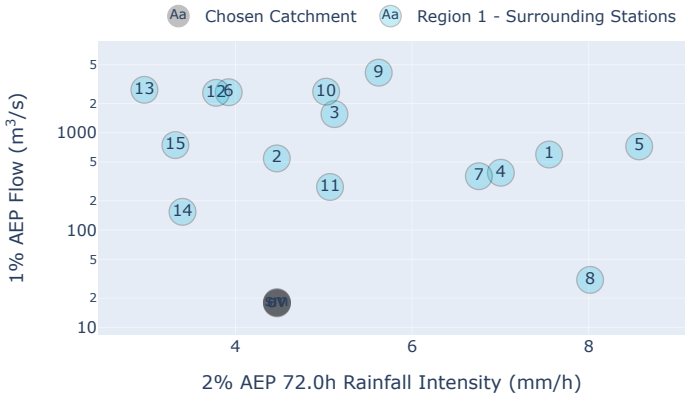
50% AEP | 20% AEP | 10% AEP | 5% AEP | 2% AEP | 1% AEP

1% AEP Flow vs Catchment Area

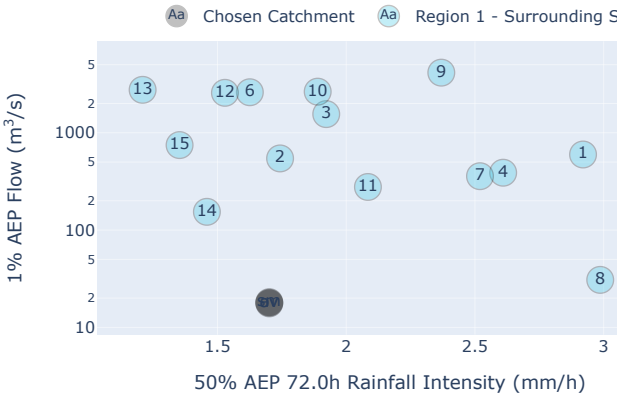


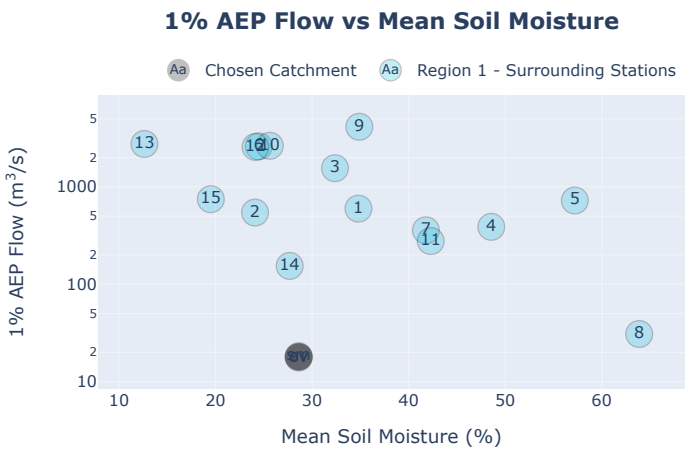


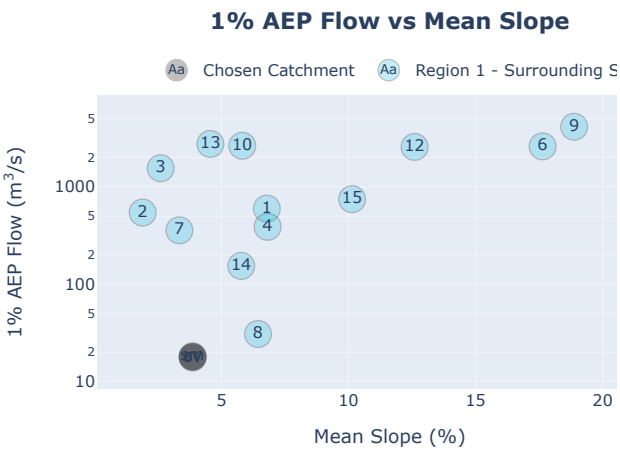
1% AEP Flow vs 2% AEP 72.0h Rainfall Intensity



1% AEP Flow vs 50% AEP 72.0h Rainfall Ir







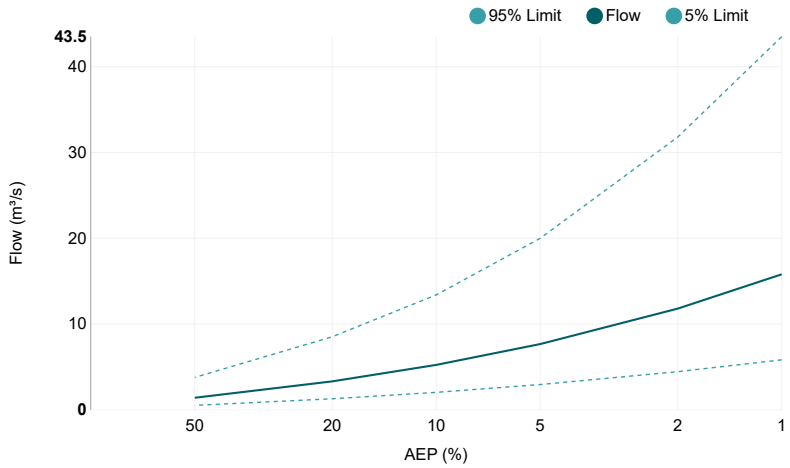
Download RFFE Dataset

Method by Dr Ataur Rahman and Dr Khaled Haddad from Western Sydney University for the Australian Rainfall and Runoff Project. Full description of the project can be found at the project page on the ARR website. Send any questions regarding the method or project here.

ENGINEERS AUSTRALIA

WESTERN SYDNEY UNIVERSITY

Results | Regional Flood Frequency Estimation Model



*The catchment has unusual shape. Results have lower accuracy and may not be directly applicable in practice.

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	1.41	0.520	3.78
20	3.32	1.29	8.52
10	5.24	2.04	13.4
5	7.67	2.95	20.0
2	11.8	4.45	31.8
1	15.8	5.83	43.5

Statistics

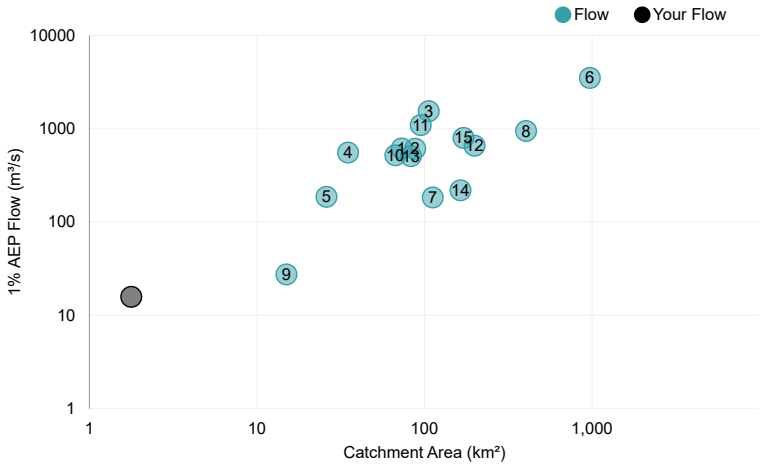
Variable	Value	Standard Dev
Mean	0.361	0.610
Standard Dev	0.995	0.179
Skew	0.077	0.028

Note: These statistics come from the nearest gauged catchment. Details.

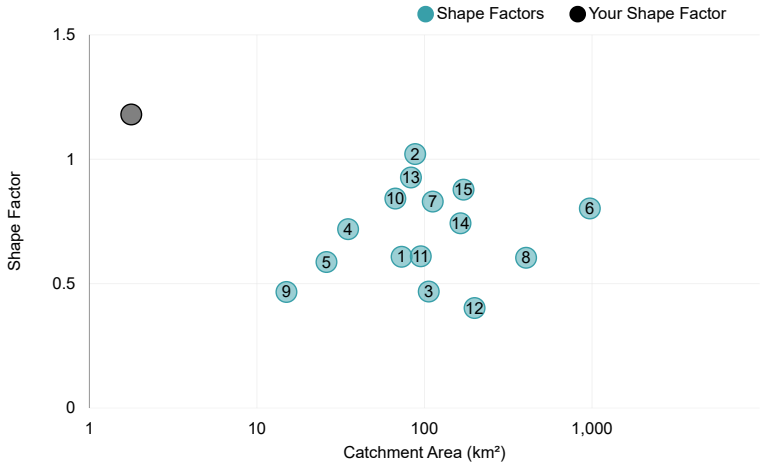
Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

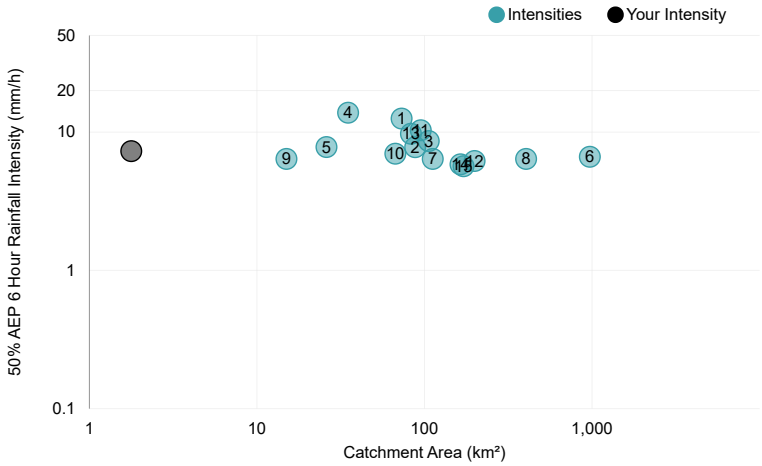
1% AEP Flow vs Catchment Area



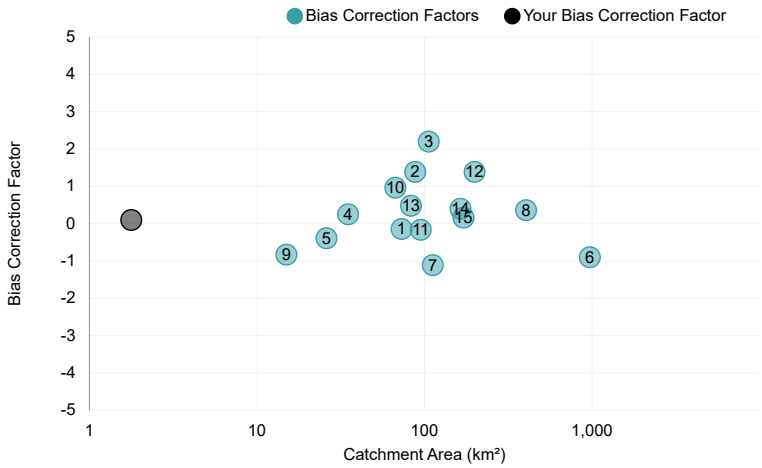
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



Download

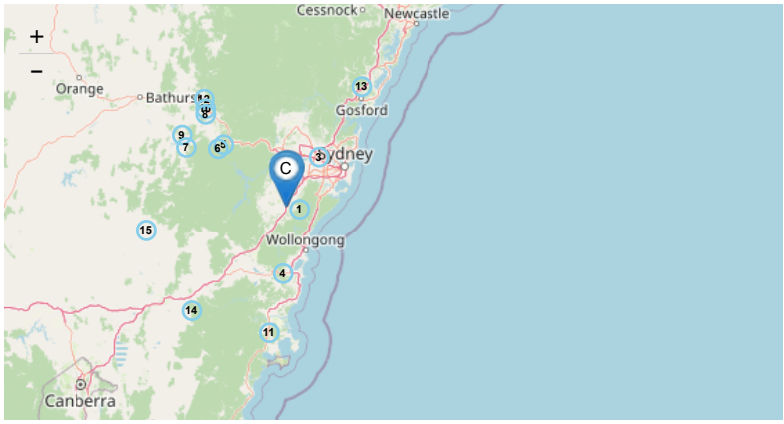
TXT Nearby JSON

Input Data

Date/Time	2024-03-25 11:20

Input Data

Catchment Name	Menangle
Latitude (Outlet)	-34.13527
Longitude (Outlet)	150.75334
Latitude (Centroid)	-34.14754117
Longitude (Centroid)	150.74478
Catchment Area (km^2)	1.778
Distance to Nearest Gauged Catchment (km)	8.42
50% AEP 6 Hour Rainfall Intensity (mm/h)	7.285037
2% AEP 6 Hour Rainfall Intensity (mm/h)	17.018818
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	1.18*
Interpolation Method	Natural Neighbour
Bias Correction Value	0.093



Method by Dr Ataur Rahman and Dr Khaled Haddad from Western Sydney University for the Australian Rainfall and Runoff Project. Full description of the project can be found at the project page (http://arr.ga.gov.au/revision-projects/project-list/projects/project-5) on the ARR website. Send any questions regarding the method or project here (mailto:admin@arr-software.org).

ENGINEERS AUSTRALIA (http://www.engineersaustralia.org.au)

WESTERN SYDNEY UNIVERSITY (http://www.uws.edu.au)

Attachment C

10metres FROM RL 64

BANK OF RIVER

LINE BY SURVEY

This alignment of the creek appears to be controlled by the underlying rock

CH20

I would suggest that this alignment would be easier to control

CENTRE LINE OF CREEK

CH140

CH60

proposed centre line of creek

CH80

CH100

LIMIT OF EXTRACTION

The control of the creek centreline would be the spur of rock which would extend along this ridge line under the sand bank

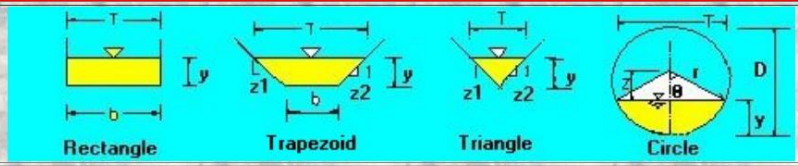
VIEWPORT 1 E=292589.7 N=6220107.6 Scale 1:800 Rotation 325°06'00"

Attachment D

eng.auburn.edu/~xzf0001/Handbook/Channels.html

The open channel flow calculator

Select Channel Type: Trapezoid



Velocity(V)&Discharge(Q) | Select unit system: Meter(m)

Channel slope: 0.013 m/m	Water depth(y): 0.6 m	Bottom width(b) 1.6 m
Flow velocity 1.1925 m/s	LeftSlope (Z_1): 3 z1/y	RightSlope (Z_2): 3 z2/y
Flow discharge 2.4326 m^3/s	Input n value 0.05 or select n	
Calculate!	Status: Calculation finished	Reset
Wetted perimeter 5.39 m	Flow area 2.04 m^2	Top width(T) 5.2 m
Specific energy 0.67 m	Froude number 0.61	Flow status Subcritical flow
Critical depth 0.47 m	Critical slope 0.0367 m/m	Velocity head 0.07 m

Attachment E

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

COMPANY LOGO

Project: Nepean River Sand extraction
Structure/Drawing: Proposed Culvert
Location & LGA: Menangle
Designer/Engineer: ZR
Checked by: ZR
Date: 25/03/2024

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details

Catchment Area:	1.8	ha or km2
Source Area (&Landuse):	rural grazing some urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and fallen tree limbs	
How assessed:	Google Maps	
Inlet Clear Width **(W)**	1.5	(m)
Inlet Clear Height **(D)**	0.6	(m)
Check W/D<=3	2.5	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Coarse gravel and boulders. Limited sand and silt	
How assessed:	Sandy based on project	
D_{50}	2	(mm)
Barrel velocity **(V)**	1.3	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP

Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	M	H	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	MMM	HMM	
1% Debris Potential	MED	MED	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)

Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)

AEP Adjusted Debris Potential At Structure (Inlet)

Control Dimension	High	Med	Low
$W < L_{10}$	100%	50%	25%
$L_{10} <= W <= 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)

Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)

AEP Adjusted Sediment Potential At Structure (barrel)

Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	**Inlet (Debris)**		**Barrel (Sediment)**	
Event AEP(%) [1:yr]	**MED**	**STEP 4**	**MED**	**STEP 6**
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Med	10%	Med	15%
<0.5% [>1:200]	High	20%	High	25%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

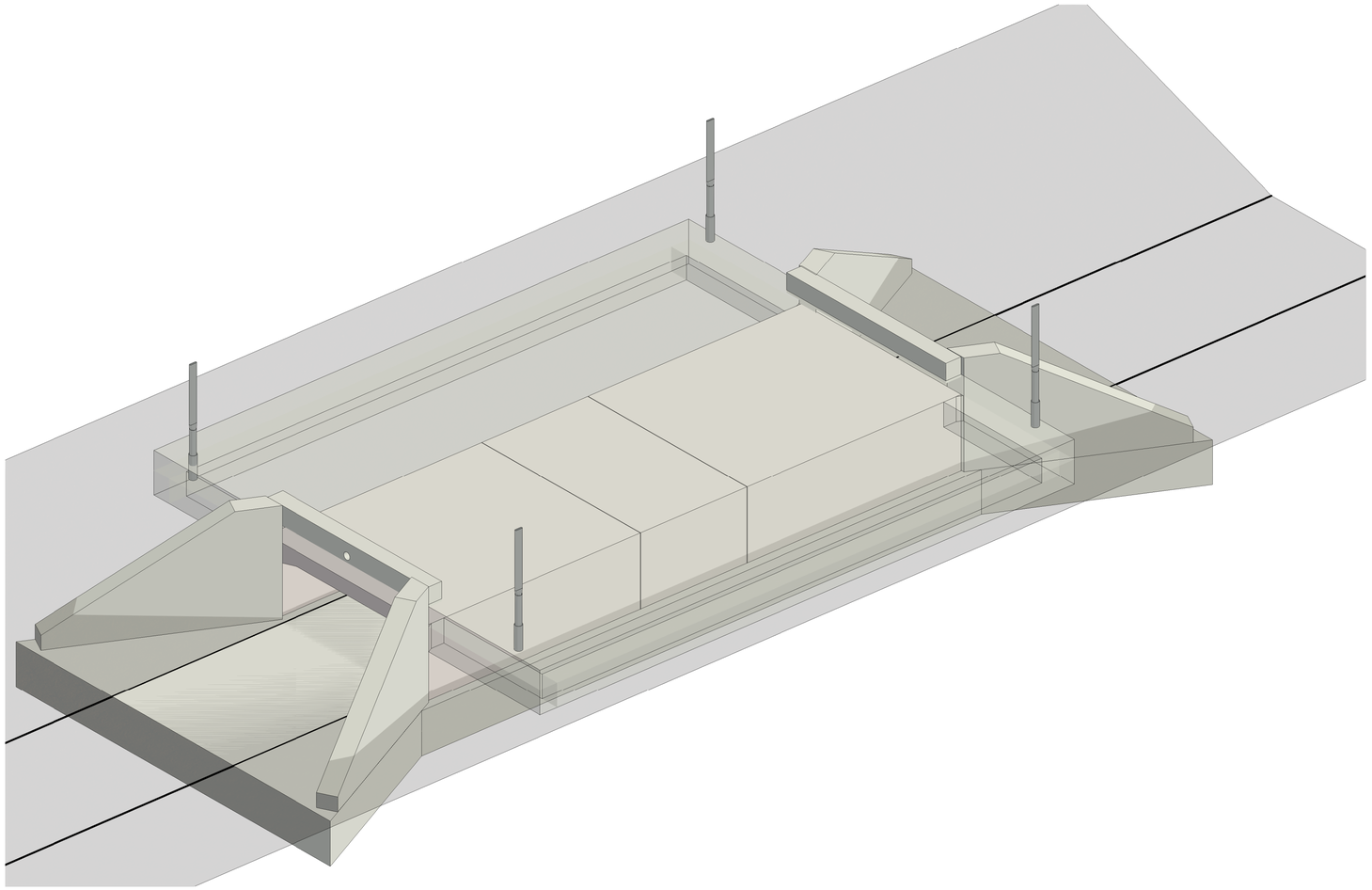
Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

APPENDIX B
Culvert Bridge Design Plans

m 0409 912 631 e mark.tooker@tookerandassociates.com.au a 30 Walworth Avenue, Newport abn 39 619 046 070

MENANGLE QUARRY CULVERTS



DRAWING LIST

NUMBER	SHEET NAME
ST-00-000	COVER SHEET
ST-00-001	GENERAL NOTES
ST-01-001	GENERAL ARRANGEMENT PLANS
ST-01-021	CULVERT SECTIONS AND DETAILS SHEET 01

EPS
ENGINEERING PROJECT SOLUTIONS

STRUCTURAL ENGINEERING
PRELIMINARY
NOT FOR CONSTRUCTION

REV	DESCRIPTION	DATE
A	PRELIMINARY ISSUE	02.09.24

PROJECT
MENANGLE QUARRY CREEK CROSSING
Menangle, NSW

DRAWING TITLE
COVER SHEET

DATE	DRAWN BY	DESIGNED BY	SCALE	NORTH POINT
08/28/24	M.J.S.	P.L.M.		

PROJECT NUMBER	DRAWING NUMBER	REVISION	SHEET SIZE
24127	ST-00-000	A	A1

GENERAL NOTES:

G1 THESE DRAWINGS SHALL BE READ IN CONJUNCTION WITH ALL NDY, ARCHITECTURAL AND OTHER CONSULTANTS DOCUMENTS, SPECIFICATIONS AND OTHER WRITTEN INSTRUCTIONS AS MAY BE ISSUED DURING THE COURSE OF THE CONTRACT.

G2 ANY DISCREPANCY ON THE DRAWINGS OR BETWEEN THE DRAWINGS AND/OR THE SPECIFICATION AND/OR THE SPECIFIED AUSTRALIAN STANDARDS SHALL BE REFERRED TO THE ENGINEER AND A WRITTEN INSTRUCTION RECEIVED PRIOR TO PROCEEDING WITH THE WORK. DURING TENDERING THE TENDERER SHALL ASSUME THE LARGER/GREATER CRITERIA IN TERMS OF COST IN THE ABSENCE OF OTHER INSTRUCTIONS.

G3 ALL MATERIALS AND WORKMANSHIP SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE CURRENT AUSTRALIAN STANDARDS, INCLUDING ALL AMENDMENTS, AND THE BY-LAWS AND ORDINANCES OF THE RELEVANT BUILDING AUTHORITY, EXCEPT WHERE VARIED BY THE PROJECT SPECIFICATION.

G4 THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS RELEVANT TO SETTING OUT AND OFF-SITE WORK ON SITE BEFORE CONSTRUCTION AND FABRICATION. THE ENGINEERS DRAWINGS ARE NOT TO BE SCALED. NO RESPONSIBILITY WILL BE TAKEN BY THE ENGINEER FOR DIMENSIONS OBTAINED BY SCALING THE DRAWINGS.

G5 SUBSTITUTIONS MUST BE APPROVED BY THE ENGINEER AND BE INCLUDED IN ANY TENDER SUBMISSION. ALL SUBSTITUTIONS SHALL ACHIEVE THE REQUIRED DESIGN LIFE FOR THE WORKS.

G6 DURING CONSTRUCTION THE CONTRACTOR SHALL BE RESPONSIBLE FOR MAINTAINING THE STRUCTURE IN A STABLE CONDITION; ENSURING NO PART SHALL BE OVER-STRESSED DURING CONSTRUCTION ACTIVITIES.

G7 THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE DESIGN AND ERECTION OF ALL TEMPORARY WORKS.

G8 THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE DELIVERY, FABRICATION, CONSTRUCTION AND ERECTION OF ALL ELEMENTS OF THE STRUCTURE.

G9 THE STRUCTURAL DRAWINGS DO NOT SHOW ALL DETAILS OF FIXTURES, INSERTS, SLEEVES, OPENINGS, ETC. REQUIRED BY THE VARIOUS TRADES. ALL SUCH DETAILS, INCLUDING OPENINGS FOR CONSTRUCTION PURPOSES, MUST BE APPROVED BY THE ENGINEER BEFORE PROCEEDING WITH CONSTRUCTION. THE CONTRACTOR SHALL ALLOW FOR ADDITIONAL SUPPORT MEMBERS WHERE REQUIRED.

G10 ANY DAMAGED STRUCTURAL MATERIAL SHALL BE REPAIRED OR REPLACED TO THE ENGINEERS SATISFACTION ENSURING THE ORIGINAL DURABILITY STRENGTH AND SERVICEABILITY CHARACTERISTICS ARE MAINTAINED.

G11 SHOULD ADDITIONAL SERVICES OR CHANGES TO THE STRUCTURAL DOCUMENTATION BE REQUESTED BY THE CONTRACTOR, THE CONTRACTOR SHALL BE RESPONSIBLE FOR ALL ASSOCIATED CONSULTANT FEES AND EXPENSES.

G12 THE CONTRACTOR SHALL ALLOW FOR THE PREPARATION AND COST OF DETAILED SHOP DRAWINGS. THE CONTRACTOR SHALL CHECK AND COORDINATE THE SHOP DRAWINGS WITH ALL TRADES, OTHER CONSULTANT DOCUMENTS AND SITE CONDITIONS.

G13 THE STRUCTURAL ENGINEER DOES NOT PROVIDE "AS BUILT" DRAWINGS FOR THE STRUCTURE THAT REFLECT THE AS BUILT CONDITIONS AT THE COMPLETION OF CONSTRUCTION. SHOULD THE CONTRACTOR REQUEST ASSISTANCE FROM THE STRUCTURAL ENGINEER FOR PRODUCTION OF "AS BUILT" DRAWINGS THEY SHALL BE RESPONSIBLE FOR ALL ASSOCIATED CONSULTANT FEES AND EXPENSES.

G14 THE CONTRACTOR SHALL ENGAGE A GEOTECHNICAL ENGINEER FOR THE PURPOSE OF CERTIFYING THE REQUIRED GROUND CONDITIONS AS NOMINATED IN THE DOCUMENTS.

G15 THE CONTRACTOR SHALL ENGAGE AN INDEPENDENT WELDING INSPECTION AND SITE SUPERVISION SERVICE TO CARRY OUT ALL STEELWORK TESTING AND EXAMINATIONS REQUIRED BY AUSTRALIAN STANDARDS. MINIMUM STEEL EXAMINATIONS REQUIRED BY THIS CONTRACT ARE :

- 100% VISUAL WELD INSPECTIONS
- 10% RADIOGRAPHIC OR ULTRASONIC WELD INSPECTIONS
- 100% BOLT TIGHTENING INSPECTION AFTER ERECTION

G16 PRIOR TO COMMENCING SITE WORKS, THE CONTRACTOR SHALL CONFIRM AND LOCATE ALL EXISTING STRUCTURES, SERVICES AND OTHER ASSETS THAT MAY BE AFFECTED BY THE WORKS. THE CONTRACTOR SHALL SEEK DIRECTION FROM THE ENGINEER SHOULD ANY EXISTING STRUCTURES, SERVICES OR ASSETS BE DIFFERENT TO THOSE SHOWN ON THE CONSULTANTS DOCUMENTS.

G17 THE DESIGN LIFE OF THE WORKS SHALL BE 50 YEARS OR AS OTHERWISE AGREED WITH THE CLIENT. ALL MATERIALS AND WORKMANSHIP PROVIDED BY THE CONTRACTOR SHALL ENSURE THAT THE REQUIRED DESIGN LIFE IS ACHIEVED.

G18 SHOULD THE CONTRACTOR REQUIRE NDY TO PARTICIPATE IN AN ONLINE CENTRALIZED DATA MANAGEMENT SYSTEM (SUCH AS PROJECTWEB, ACONEX, PROJECT CENTRE AND OPTUS INCITE), THE CONTRACTOR SHALL ALLOW TO PAY ALL ASSOCIATED PARTICIPATION FEES REQUIRED BY THE SERVICE OPERATOR IN THEIR TENDER PRICE. THE CONTRACTOR SHALL NOTIFY NDY IN WRITING OF THIS REQUIREMENT DURING TENDERING OF THE PROJECT.

WITHIN THREE (3) MONTHS OF PRACTICAL COMPLETION OF THE PROJECT, THE CONTRACTOR SHALL FURNISH FREE OF CHARGE TO NDY A COMPLETE RECORD OF ALL DATA THAT NDY WERE ABLE TO ACCESS ON THE SYSTEM DURING THE PROJECT. SUCH DATA SHALL BE FURNISHED IN A COMMON READABLE AND SEARCHABLE FORMAT AND BE RECORDED ON CD, DVD OR SIMILAR MEDIA.

FOUNDATION NOTES:

F1 THE MINIMUM SAFE BEARING CAPACITY OF THE FOUNDATION MATERIAL IS TO BE: ASSUMED ***200*** kPa (IN NATURAL STIFF CLAY)

PRELIMINARY GEOTECHNICAL REPORT NOT CURRENTLY PROVIDED

F2 BEFORE ANY REINFORCEMENT OR CONCRETE IS PLACED, THE SAFE BEARING CAPACITY OF THE GROUND IS TO BE VERIFIED BY THE GEOTECHNICAL ENGINEER. EXCAVATION SHALL CONTINUE UNTIL THE REQUIRED BEARING CAPACITY IS FOUND. ANY OVER-EXCAVATION SHALL BE BACKFILLED WITH 15 MPa BLINDING CONCRETE TO THE UNDERSIDE OF THE WORKS.

F3 THE DEPTHS TO UNDERSIDE OF ALL FOOTINGS ARE PROVISIONAL ONLY. AFTER EXCAVATION APPROVAL SHALL BE OBTAINED FROM THE ENGINEER FOR THE LEVELS IF NECESSARY PRIOR TO FURTHER WORK.

F4 ALL FOOTINGS TO BE FOUNDED A MINIMUM OF 100mm INTO THE FOUNDING MATERIAL. REFER TO THE GEOTECHNICAL REPORT FOR FURTHER DETAILS.

F5 CONCRETE BLINDING SHALL BE PLACED WITHIN 24HRS OF EXCAVATION ONCE APPROVAL HAS BEEN GIVEN BY GEOTECHNICAL ENGINEER.

F6 THE FOUNDATION EXCAVATION IS TO BE KEPT FREE OF WATER AT ALL TIMES BY BAILING AND PUMPING IF NECESSARY, PARTICULARLY PRIOR TO CONCRETING. CONCRETE SHALL NOT BE PLACED IN WATER.

CONCRETE NOTES:

C1 ALL WORKMANSHIP AND MATERIALS SHALL BE IN ACCORDANCE WITH AS3600 AND THE SPECIFICATION.

C2 CONCRETE SIZES SHOWN DO NOT INCLUDE FINISH AND MUST NOT BE REDUCED WITHOUT THE ENGINEERS APPROVAL. DEPTHS OF BEAMS ARE GIVEN FIRST AND INCLUDE SLAB THICKNESS. SLABS AND BEAMS ARE TO BE POURED TOGETHER.

C3 CONSTRUCTION JOINTS SHALL BE PROPERLY FORMED AND USED ONLY WHERE SHOWN OR SPECIFICALLY APPROVED BY THE ENGINEER.

C4 ALL CONCRETE SHALL BE GRADE N32, NORMAL DENSITY UNLESS NOTED OTHERWISE. MAXIMUM AGGREGATE SIZE 20mm. ADMIXTURES SHALL NOT BE USED WITHOUT THE PRIOR APPROVAL OF THE ENGINEER. MAXIMUM BASIC SHRINKAGE AT 56 DAYS SHALL BE 650 MICROSTRAIN.

C5 ALL CEMENT IS TO BE "GP" GENERAL PURPOSE PORTLAND CEMENT OR "GB" GENERAL PURPOSE BLENDED CEMENT OR TYPE "SR" SULPHATE-RESISTING CEMENT AS REQUIRED COMPLYING WITH AS3972 UNLESS NOTED OTHERWISE ON THE DRAWINGS. EXTRA RAPID HARDENING SUPERSULPHATED AND HIGH ALUMINA CEMENTS SHALL NOT BE USED. THE USE OF FLY ASH AND/OR SILICA FUME AS A CEMENT SUBSTITUTE, OTHER THAN THAT PROPORTION ALLOWED AS PART OF THE "GB" CEMENT CONTENT WILL ONLY BE PERMITTED AS PART OF A DESIGNED CONCRETE MIX WHICH HAS BEEN APPROVED IN WRITING BY THE ENGINEER.

C6 EXTERNAL CONCRETE ELEMENTS SHALL BE MINIMUM GRADE S32 MEETING THE FOLLOWING REQUIREMENTS:
(a) MINIMUM PORTLAND CEMENT CONTENT 400kg/m (NO FLY ASH TO BE USED)
(b) MAXIMUM WATER/CEMENT RATIO 0.5
(c) SHRINKAGE LIMIT 650 MICROSTRAIN AFTER 56 DAYS
(d) CHLORIDE CONTENT TO BE RESTRICTED AS PER CLAUSE 4.9 OF AS 3600
(e) NO SALT SHALL BE ADDED

EXTERNAL ELEMENTS ARE THOSE EXPOSED TO WEATHER OR WATER PENETRATION, AS3600 EXPOSURE CLASSIFICATION B1 UNLESS NOTED OTHERWISE.

C7 CONCRETE SLUMP SHALL BE A MAXIMUM OF 80mm UNLESS NOTED OTHERWISE ON THE DRAWINGS.

C8 FREE DROPPING OF CONCRETE FROM A HEIGHT GREATER THAN 1000mm IS NOT PERMITTED.

C9 CAMBER TO SUSPENDED SLABS AND BEAMS SHALL BE AS NOTED ON THE DRAWINGS. NO CAMBER IS REQUIRED TO POST-TENSIONED SLABS AND BEAMS UNLESS NOTED ON THE DOCUMENTS.

C10 ALL EXPOSED CONCRETE CORNERS TO HAVE 15mm CHAMFER UNLESS NOTED OTHERWISE.

C11 NO HOLES, CHASES OR EMBEDMENT OF PIPES OTHER THAN THOSE SHOWN ON THE STRUCTURAL DRAWINGS SHALL BE MADE IN THE CONCRETE MEMBERS WITHOUT THE PRIOR APPROVAL OF THE ENGINEER.

C12 ALL STEEL EMBEDMENTS SHALL BE HOT DIP GALVANIZED.

C13 CONCRETE MUST BE CURED BY AN APPROVED METHOD IN ACCORDANCE WITH THE SPECIFICATION FOR SEVEN DAYS AFTER POURING.

C14 CONCRETE SHALL BE SEPARATED FROM SUPPORTING MASONRY BY TWO LAYERS OF MALTHOID (OR AN APPROVED EQUIVALENT). VERTICAL FACES OF CONCRETE SHALL BE KEPT FREE OF ADJOINING SURFACES BY 10mm THICKNESS OF ABLEFLEX (OR AN APPROVED EQIVALENT). ALL NON-LOADBEARING WALLS SHALL BE KEPT CLEAR OF THE UNDERSIDE OF SLABS AND BEAMS BY 20mm UNLESS NOTED OTHERWISE.

C15 BRICKWORK MUST NOT BE BUILT ON CONCRETE SLABS OR BEAMS UNTIL FORMWORK SUPPORTING IT HAS BEEN REMOVED.

C16 HIGH FREQUENCY VIBRATORS SHALL BE USED TO COMPACT ALL CONCRETE.

C17 SURFACES RECEIVING GROUT SHALL BE LEFT ROUGH AND FREE OF LAITANCE.

C18 REINFORCEMENT IS REPRESENTED DIAGRAMMATICALLY AND NOT NECESSARILY SHOWN IN TRUE PROJECTION.

C19 COVER TO REINFORCEMENT AND CONCRETE GRADE SHALL BE AS SCHEDULE BELOW UNLESS NOTED OTHERWISE.
(a) COVER IS THE CLEAR DISTANCE BETWEEN ANY REINFORCING (INCLUDING FITMENTS) AND THE FACE OF THE STRUCTURAL ELEMENT
(b) ALL COVERS SHALL BE MAINTAINED USING APPROVED BAR CHAIRS. IN SLABS BAR CHAIRS SHALL BE AT 1000x1000 mm MIN. CTS. BAR CHAIRS SHALL BE PROVIDED ALONG THE EDGES OF ALL CONSTRUCTION JOINTS. STOP ENDS SHALL NOT BE USED TO MAINTAIN COVERS.
(c) FOR ALL EXTERNAL SURFACES, PROVIDE FULLY PLASTIC BAR CHAIRS. TIE WIRE SHALL NOT BE NAILED TO THE FORMS. REINFORCING BARS SHALL NOT BE USED TO KEEP FORMS APART. THROUGH TIE SYSTEM SHALL BE USED TO TIE FORMS.
(d) PROVIDE AN APPROVED VAPOUR BARRIER FOR SLABS, BEAMS AND THICKENINGS CAST AGAINST THE GROUND.

C20 REINFORCEMENT NOTATIONS:
N DENOTES DEFORMED BARS GRADE 500N TO AS/NZS 4671
R DENOTES PLAIN ROUND BARS GRADE 250N TO AS/NZS 4671
SL, RL DENOTES HARD-DRAWN WIRE REINFORCING FABRIC GRADE 500L TO AS/NZS 4671.

THE NUMBER IMMEDIATELY FOLLOWING THE BAR GRADE SYMBOL REPRESENTS THE NOMINAL BAR DIAMETER IN MILLIMETRES. THE FIGURE FOLLOWING THE FABRIC SYMBOL IS THE REFERENCE NUMBER. SUBSTITUTION OF 500N REINFORCING BY 500L MESH IS NOT PERMITED.

C21 SPLICES IN REINFORCEMENT SHALL BE MADE IN THE POSITIONS SHOWN OR AS OTHERWISE APPROVED BY THE ENGINEER. GRADE 500N BARS SHALL BE LAPPED IN ACCORDANCE WITH THE GENERAL LAPS AND DEVELOPMENT LENGTHS TABLE BELOW, UNLESS NOTED OTHERWISE ON THE DRAWINGS. MINIMUM LAP FOR ALL FABRICS SHALL BE THE SPACING OF TWO TRANSVERSE WIRES PLUS 25mm.

C22 WELDING OF REINFORCEMENT SHALL NOT BE PERMITTED WITHOUT THE WRITTEN APPROVAL OF ENGINEER.

C23 ALL REINFORCEMENT SHALL BE SUPPORTED IN ITS CORRECT POSITION ON APPROVED BAR CHAIRS AT 1000mm MAXIMUM CENTRES BOTH WAYS, SO AS NOT TO BE DISPLACED DURING CONCRETING. WHERE REQUIRED PROVIDE N16 SUPPORT BARS AT 1000mm CENTRES.

C24 UNLESS OTHERWISE SHOWN, PROVIDE N12-300 TOP & BOTTOM BOTH WAYS MINIMUM TYING STEEL WHERE REQUIRED, LAPPED 300mm AT SPLICES.

C25 2N12 DIAGONAL CORNER BARS 1000mm LONG ARE REQUIRED AT ALL RE-ENTRANT CORNERS IN SLABS AND WALLS (ONE EACH FACE).

C26 REINFORCEMENT SET-OUT DIMENSIONS ARE RELATED TO COLUMN CENTRELINES, QUARTER SPAN POINTS AND BEAM EDGES UNLESS NOTED OTHERWISE.

C27 REINFORCEMENT LENGTHS INDICATED ARE IN MILLIMETRES AND ARE PLAN LENGTH ONLY. TURN DOWNS AND CRANKS ARE NOT INCLUDED IN THE DIMENSION.

C28 BARS SHOWN STAGGERED ON PLAN SHALL BE PLACED ALTERNATELY.

C29 BARS SHALL BE EVENLY DISTRIBUTED OVER THE WIDTH NOMINATED UNLESS NOTED OTHERWISE.

C30 REINFORCEMENT SHALL NOT BE CUT OR WELDED ON SITE UNLESS APPROVED BY THE ENGINEER. BARS CONFLICTING WITH SMALL HOLES AND OTHER MINOR PENETRATIONS LESS THAN 300mm LONG MAY BE DISPLACED LATERALLY.

C31 FORMWORK SHALL BE DESIGNED AND CONSTRUCTED IN ACCORDANCE WITH AS 3610. NO CONCRETE SHALL BE PLACED UNTIL THE FORMWORK IS INSPECTED AND CERTIFIED BY THE FORMWORK ENGINEER AT THE CONTRACTOR'S EXPENSE.

C32 THE CLASS AND COLOUR OF THE CONCRETE SURFACE FINISH SHALL BE AS SPECIFIED ON THE ARCHITECTURAL DRAWINGS AND/OR THE SPECIFICATION. APPROVAL OF THE CONCRETE MIX DOES NOT ABSOLVE THE CONTRACTOR OF THE NEED TO COMPLY WITH THE REQUIRED CONCRETE COLOUR REQUIREMENTS.

C33 BACKPROPPING OR AN UNDISTURBED FORMWORK SHALL BE USED. RESHORING SYSTEMS ARE NOT PERMITED.

CONCRETE NOTES CONTINUED:

C34 MINIMUM FORMWORK STRIPPING TIMES ARE AS A GUIDE IN AMBIENT TEMPERATURES BETWEEN 12°C AND 20°C AS FOLLOWS, PROVIDED THE TARGET CONCRETE STRENGTH IS ACHIVED:
(a) VERTICAL SURFACES 2 DAYS (fcm = 5 MPa)
(b) SOFFITS OF BEAMS AND SLABS 6 DAYS (fcm = 22 MPa)
(c) FLOOR BACKPROPPING 18 DAYS (fcm = 28 MPa)
fcm IS THE TARGET CONCRETE STRENGTH AT THE TIME UNLESS NOTED OTHERWISE.

C35 MINIMUM OF 3 LEVELS OF FORMWORK AND/OR BACKPROP SUPPORTS ARE REQUIRED, UNLESS NOTED OTHERWISE.

C36 HORIZONTAL LOADS ON FORMWORK ARE TO BE RESISTED BY THE FORMWORK BRACING. STRUTTING OF THE FORMWORK FROM THE PERMANENT STRUCTURE TO RESIST HORIZONTAL LOADS IS NOT PERMITTED.

C37 CREATION OF ANY PENETRATIONS INTO CONCRETE (INCLUDING FOR THE INSTALLATION OF FIXINGS AND ANCHORS) SHALL ONLY BE CARRIED OUT VIA THE USE OF EQUIPMENT, PROCEDURES AND MATERIALS THAT DO NOT DAMAGE THE EMBEDDED STEELWORK INCLUDING REINFORCEMENT AND / OR POST-TENSIONING CABLES.

REINFORCEMENT COVER AND CONCRETE STRENGTH SCHEDULE

ELEMENT		COVER		MINIMUM CONCRETE GRADE (MPa)
		SURFACES CAST AGAINST GROUND	FORMED OR FINISHED SURFACES	
FOOTING / PILES / PILECAPS		75	50	S32
WALLS	INTERNAL	50	30	N40
	EXTERNAL	50	40	S40

GENERAL LAPS AND DEVELOPMENT LENGTHS (mm)

BAR TYPE AND SIZE	VERTICAL BAR	HORIZONTAL BARS		90°, 135° OR 180° COG LENGTH *
		MORE THAN 300mm OF CONC. BELOW BAR	OTHER LOCATIONS	
N12	450	500	300	210
N16	700	800	500	250
N20	1000	1150	750	300
N24	1200	1350	850	360
N28	1400	1600	1000	410
N32	1550	1750	1100	470
N36	1700	1950	1200	530

* COG LENGTH MEASURED FROM START OF BEND.

NOTES FOR TABLE:
- LAP LENGTHS INDICATED ARE BASED ON A MINIMUM CONCRETE STRENGTH OF f'c = 25 MPa. MINIMUM COVER TO REINFORCEMENT IS NOT TO BE LESS THAN THE DIAMETER OF THE BAR UNDER CONSIDERATION, OR 20mm, WICHEVER IS THE GREATER.
- PIN DIAMETER FOR BENDS SHALL BE 5 BAR DIAMETERS.
- MINIMUM CLEAR DISTANCE BETWEEN BARS SHALL BE 150mm.
- ANY VARIATION TO THE ABOVE SHALL BE REFERRED TO THE ENGINEER.

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A	PRELIMINARY ISSUE	02.09.24

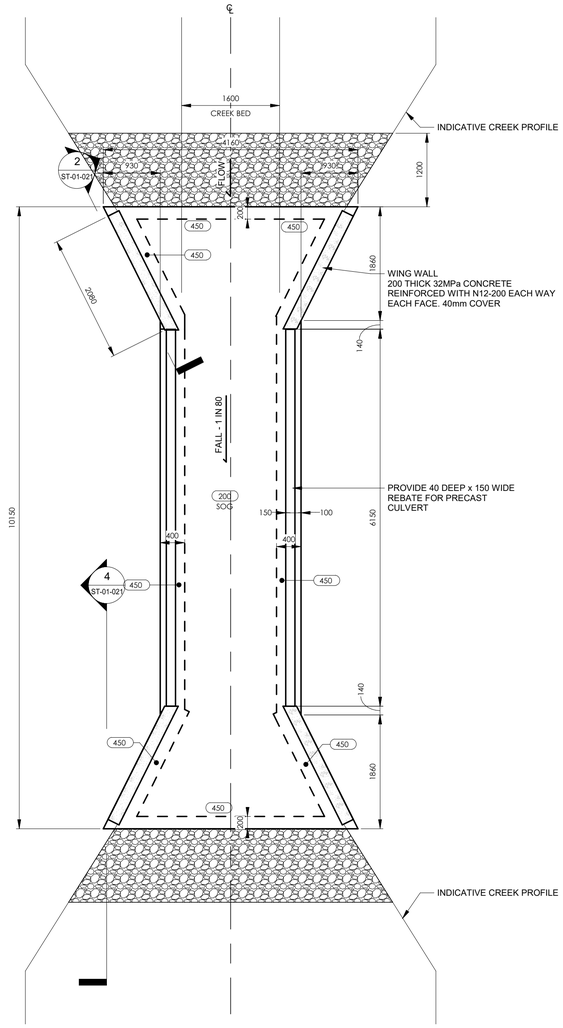
PROJECT
MENANGLE QUARRY CREEK CROSSING
Menangle, NSW

DRAWING TITLE
GENERAL NOTES

DATE	DRAWN BY	DESIGNED BY	SCALE	NORTH POINT
08/28/24	M.J.S.	P.L.M.	1 : 1	

PROJECT NUMBER	DRAWING NUMBER	REVISION	SHEET SIZE
24127	ST-00-001	A	A1

A1



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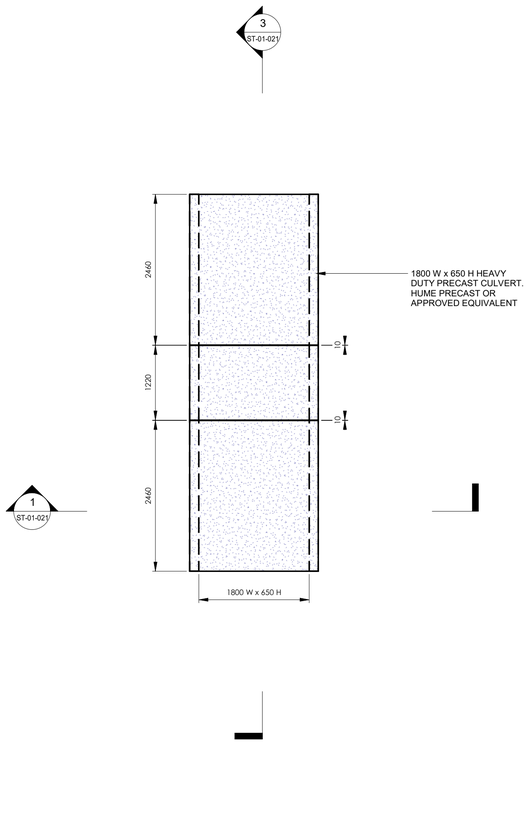

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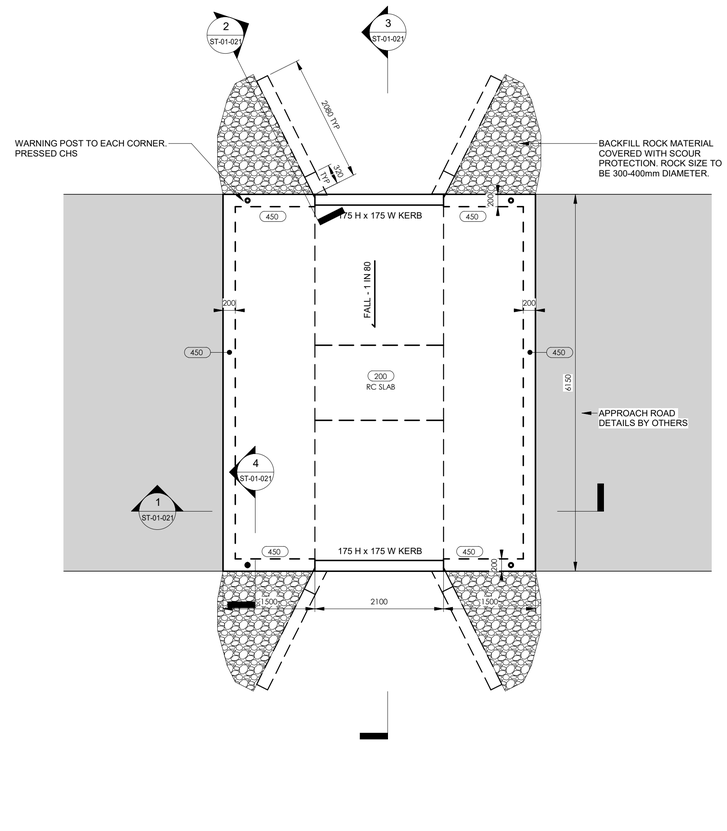

3 UPPER DECK PLAN

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PROJECT

MENANGLE QUARRY CREEK CROSSING

Menangle, NSW

DRAWING TITLE

GENERAL ARRANGEMENT PLANS

DATE	DRAWN BY	DESIGNED BY	SCALE	NORTH POINT
08/28/24	M.J.S.	P.L.M.	1 : 50	

PROJECT NUMBER	DRAWING NUMBER	REVISION	SHEET SIZE
24127	ST-01-001	A	A1

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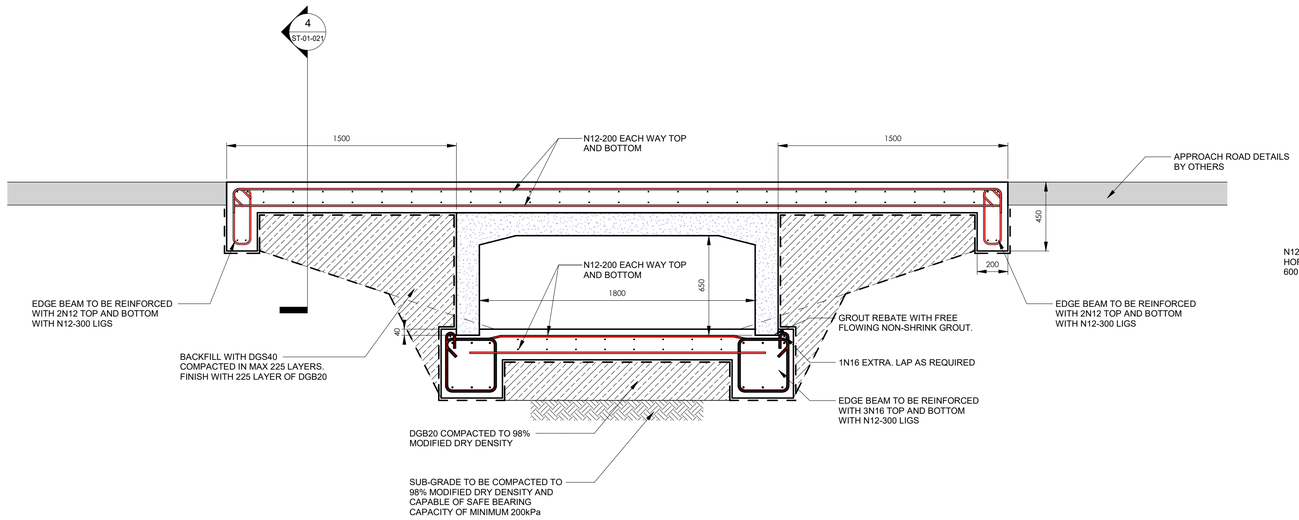

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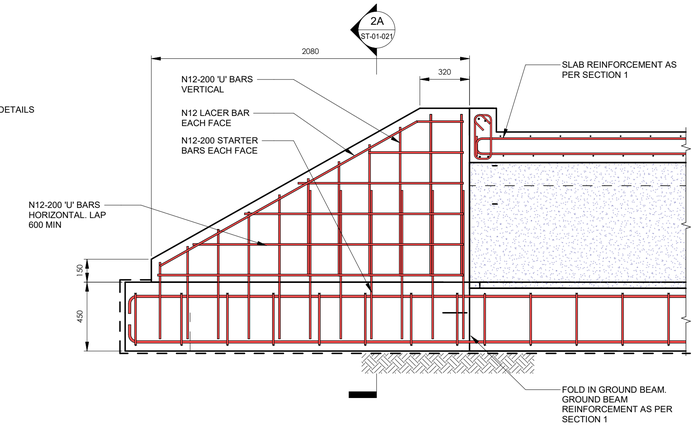

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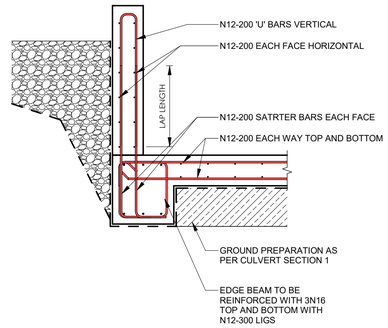

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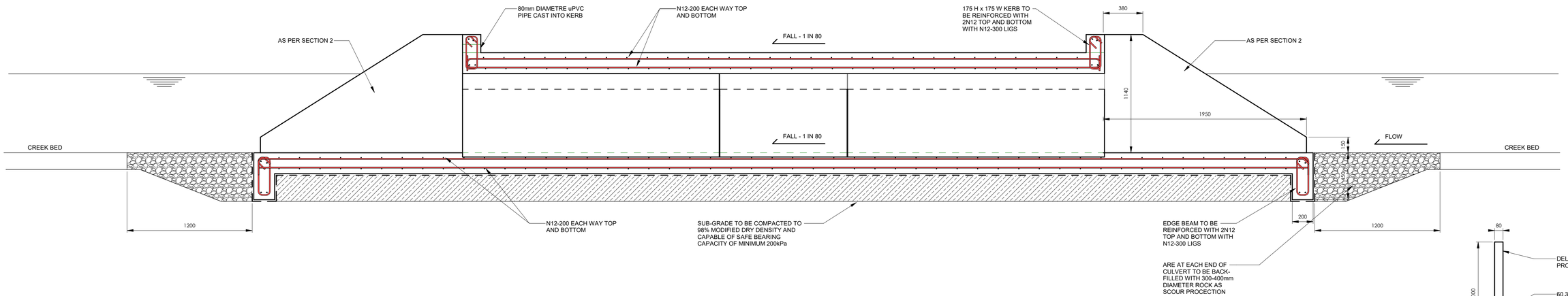

3 ST-01-001 **CULVERT SECTION 2**

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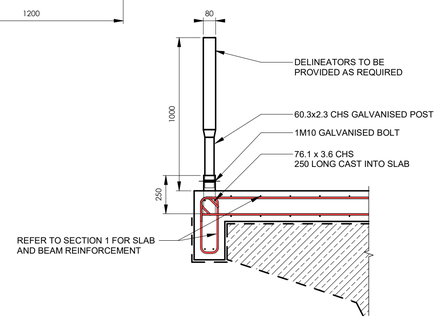

4 ST-01-001 **ROAD EDGE GUIDE POST DETAIL**

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PROJECT
MENANGLE QUARRY CREEK CROSSING
Menangle, NSW

DRAWING TITLE
CULVERT SECTIONS AND DETAILS SHEET 01

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PROJECT NUMBER	DRAWING NUMBER	REVISION	SHEET SIZE
24127	ST-01-021	A	A1

A1

APPENDIX C
Approval of qualified and experienced persons

m 0409 912 631 e mark.tooker@tookerandassociates.com.au a 30 Walworth Avenue, Newport abn 39 619 046 070

Department of Planning, Housing and Infrastructure

NSW Planning ref: DA85/2865-PA-39

Ewen McKenzie
Acting Environmental Compliance Manager
BENEDICT RECYCLING PTY LIMITED
11 NARABANG WAY
BELROSE New South Wales 2085
17/06/2024

Sent via the Major Projects Portal only

Subject: Menangle Quarry – Approval of Authors for Ephemeral Creek Management Plan

Dear Mr McKenzie

Reference is made to your post approval matter, DA85/2865-PA-39, requesting the Planning Secretary's approval of suitably qualified and experienced person/s to prepare the Menangle Quarry – Ephemeral Creek Management Plan.

I have reviewed the Curricula vitae of Mr Mark Tooker, Mr Zac Richards and Dr Phil Towler and consider that they are suitably experienced and qualified to prepare the plan in accordance with condition of consent, B40(a). Consequently, as nominee of the Planning Secretary, I approve their appointment.

Should you wish to discuss the matter further, you may contact me on email carl.dumpleton@planning.nsw.gov.au

Yours sincerely

Carl Dumpleton
Team Leader
Resource Assessments

As nominee of the Planning Secretary

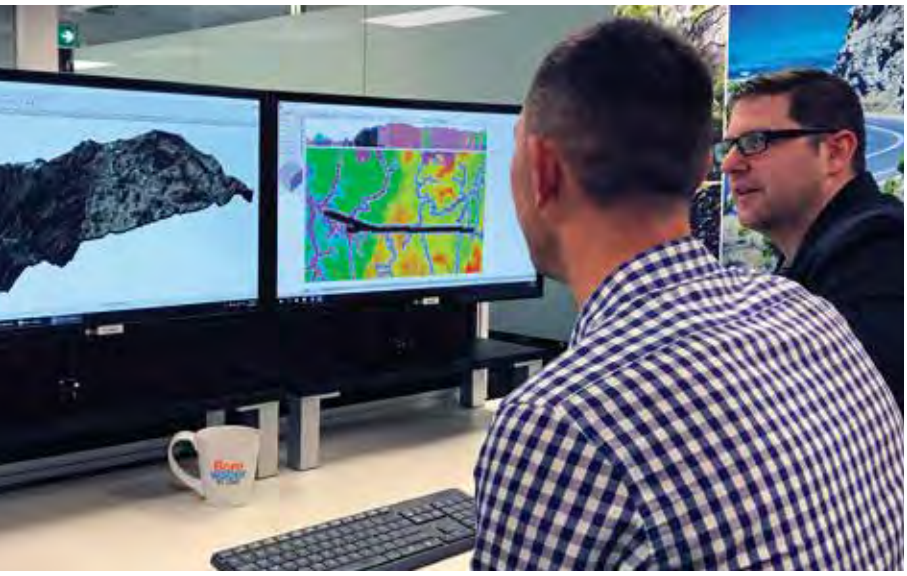
Appendix D

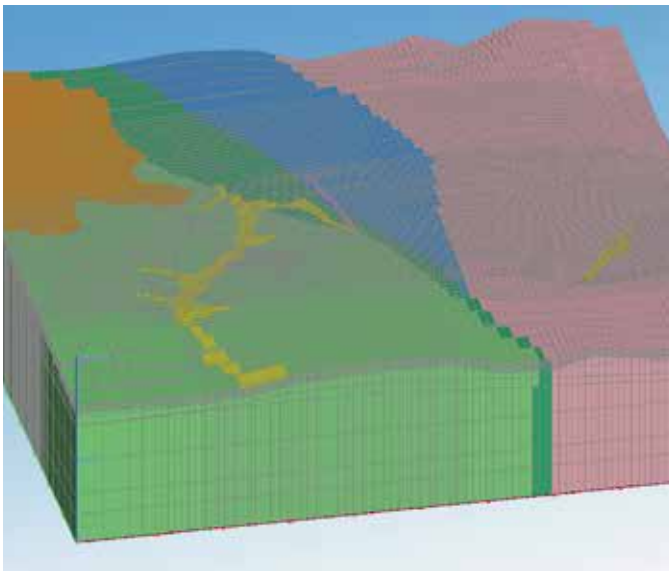
Menangle Quarry - Groundwater Model Report

Menangle Quarry

Groundwater model report

Prepared for Menangle Sand and Soil Pty Ltd
March 2021





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PO Box 9148
Deakin ACT 2600

Menangle Quarry

Groundwater model report

Report Number

J190166 RP32

Client

Menangle Sand and Soil Pty Ltd

Date

4 March 2021

Version

v2 Final

Prepared by

Jeff Whitter
Associate Hydrogeologist / Modeller
4 March 2021

Approved by

Dr Doug Weatherill
Associate Groundwater Modeller
4 March 2021

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Appendices

Tables

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1 Introduction

Menangle Sand and Soil Pty Ltd (Menangle Sand and Soil) operates the Menangle Sand and Soil Quarry at 15 Menangle Road Menangle. In September 2020, the NSW Land and Environment Court (LEC) approved Menangle Quarry Extension – Modification 1 (MOD1). This allows the extraction of sand and soil in a new area, the Stage 8 area, that is about 13 hectares (ha) in area and extends about 2 kilometres (km) along the Nepean River.

Preliminary groundwater modelling has been conducted to quantify the groundwater licence volume required from the Sydney Basin Nepean Groundwater Source (Management Zone 2) to allow for temporary interception of groundwater by quarrying in the Stage 8 area. The modelling was informed by approximately three months of groundwater monitoring data, proposed quarrying operations and expected conditions at the site (water levels in the Nepean River and adjacent groundwater system are largely controlled by the Menangle Weir with only short duration rises above this long-term average level).

1.1 Background

The Menangle Quarry Extension – Modification 1 (MOD1) conditions of approval (CoA) require that:

- B24. The Applicant must develop a groundwater model using a variant of MODFLOW standard software, or equivalent software, to quantify the progressive takes from water sources during Quarrying Operations in the Stage 8 area.
- B25. The Applicant must:
  - (a) initially construct the groundwater model required under condition B24 of Schedule 2 using the first three months of groundwater monitoring data collected from 17 June 2020 to 16 September 2020;
  - (b) update the groundwater model following collection of the first 12 months of data collected from 17 June 2020 to 16 June 2021; and
  - (c) incorporate the outputs of the groundwater model into the Site Water Balance as required under condition B36(c)(i) of Schedule 2.
- B28. When making an application for any necessary Water Access Licence, the Applicant must specify the annual take of water from each affected water source, as estimated by the groundwater model required under condition B24 of Schedule 2.

This report describes the preliminary modelling results based on history matching to the first three months of groundwater monitoring data. As required under condition B25(b), once 12 months of monitoring data have been collected, the groundwater model will be updated utilising the extended groundwater monitoring record and the licence volume requirement updated in line with any changes to model predictions.

1.2 Water affecting activities

The quarry does not plan to excavate below the long-term average watertable elevation. However, during short-duration flooding in the Nepean River, the watertable in the adjacent alluvial water table is expected to rise. If the Nepean River water level increase is of sufficient magnitude and duration, the alluvial water table may rise above the base of the quarry and, hence, shallow alluvial groundwater will be intercepted. Quarrying ceases during such periods of inundation and intercepted groundwater will not be abstracted from the quarry area (eg by pumping) and water in the base will be allowed to infiltrate back into the base of the quarry. However, the NSW Aquifer Interference Policy (NSW AIP) requires intercepted water to be licensed.

1.3 Modelling objectives

The broad objective of the Menangle Sand and Soil Quarry groundwater modelling is to quantify the necessary groundwater volume to be licensed for the project. The modelling is being undertaken in two stages.

In Stage 1, a groundwater model has been built and undergone a ~3.5 month history-matching process using groundwater monitoring data from 3 June 2020 up to 23 September 2020. Initial predictions of groundwater interception will inform groundwater licensing.

The tasks in Stage 1 of the groundwater modelling are as follows:

- build a numerical groundwater flow model based on the conceptual model;
- calibrate/history-match the model using groundwater monitoring data from 3 June 2020 to 23 September 2020;
- simulate the proposed quarrying activities; and
- quantify groundwater potentially intercepted by the excavation voids (via indicative scenarios).

In Stage 2, the groundwater model will be reviewed and updated using a full year of groundwater monitoring data for history-matching. Predictive scenarios will be rerun and the required groundwater licence volume reassessed in line with the updated model.

1.4 Model confidence classification

The Australian Groundwater Modelling Guidelines (Barnett et al 2012) provide a framework from which to define a target “model confidence level”. Model class is closely linked to model history-matching, with reference to the historical stresses in comparison to the stresses (both magnitude and duration) in the predictions. The groundwater model is best described as a class 1 model at present. EMM expects that stage 2 of the modelling will be described as a class 1 model, with some class 2 attributes. Given the anticipated low groundwater risk of the project due to the expected relatively small groundwater interception, both in terms of duration and volume, a model of class 1 to class 2 categorisation is considered to be adequate.

2 Conceptual model

2.1 Geology and hydrostratigraphy

The following provides a summary of the site geology, taken from the joint expert report on groundwater (Merrick and Webb 2020). More detail is presented in monitoring bore installation and testing program report (EMM 2020a).

There are two geological units at the site:

- Thin alluvial Quaternary sand and alluvial deposits exist immediately adjacent to and underlying the Nepean River. Alluvial deposits contain discontinuous, unconfined local groundwater systems in direct connection with the Nepean River (Merrick and Webb 2020).

- The Hawkesbury Sandstone (HBSS) forms an extensive confined to semi-confined regional groundwater system within the Sydney Geological Basin with permeability from both the rock mass itself and fractures within the rock mass (ie dual permeability system) (Merrick and Webb 2020).

In the Stage 8 area, the HBSS is thick. At Bore GW105339, approximately 1.5 km south of the southern extent of Stage 8, the Bald Hill Claystone beneath the HBSS was intercepted at 238 m below ground level.

The alluvium deposit overlies HBSS, and the excavation will not intrude into the sandstone. The resource will be extracted so that the base of the quarry will be at least 1 m above the low flow water level in the Nepean River, as controlled by Menangle Weir downstream of the Stage 8 area. As the quarry will not excavate below the long-term average watertable elevation, and will not excavate into the HBSS, the project is considered to have very low potential to impact the regional HBSS aquifer.

The alluvial deposits and HBSS are two distinct hydrostratigraphic units (HSUs) at the quarry (Merrick and Webb 2020). These HSUs are managed as one groundwater source under the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*. The groundwater source is the Sydney Basin Nepean Groundwater Source (Management Zone 2).

HSUs of relevance to the project area are presented with additional details in Table 2.1.

Table 2.1 Hydrostratigraphy summary

HSU name	HSU type	HSU typical thickness	Description
Alluvial sediments (Sand)	Disconnected, unconfined aquifer	~9 m	Shallow, disconnected and often unsaturated alluvial sediments.
Ashfield Shale	Aquitard	Up to ~150 m	The presence of this unit is limited to the west of the model domain and is inferred to act as a confining unit, consistent with observations in the greater Sydney basin. It is not mapped at the project site.
Hawkesbury Sandstone	Aquifer	Up to 238# m	This unit forms a major regional aquifer in the Sydney basin and has been mapped and studied in the extensive detail. The Hawkesbury Sandstone is a sedimentary fractured rock aquifer with some primary porosity.

1. # value taken from Statement of Evidence by Dr. Noel Merrick (2020).

Surfaces for the top/bottom of the HSUs were developed using the regional hydrogeological understanding and drill hole data (sourced from Menangle Sand and Soil, WaterNSW and MinView drill hole databases). Figure 2.1 to Figure 2.3 show the locations of the data points used to generate HSU surfaces. The MinView database was used to download both exploration and groundwater drill hole databases. The orange points show the exploration drill hole database, while the red points are based on the groundwater drill hole database. The site-specific data (blue points) were included in the generation of the surfaces. In the figures, the quarry location is indicated as a pink area near the Nepean River. ELVIS topography data was used to define ground surface.

The joint expert report on groundwater (Merrick and Webb 2020) presented local-scale conceptual cross sections through the project area, aligned with the groundwater monitoring bores drilled for the project. These are reproduced as Figure 2.4 and Figure 2.5.

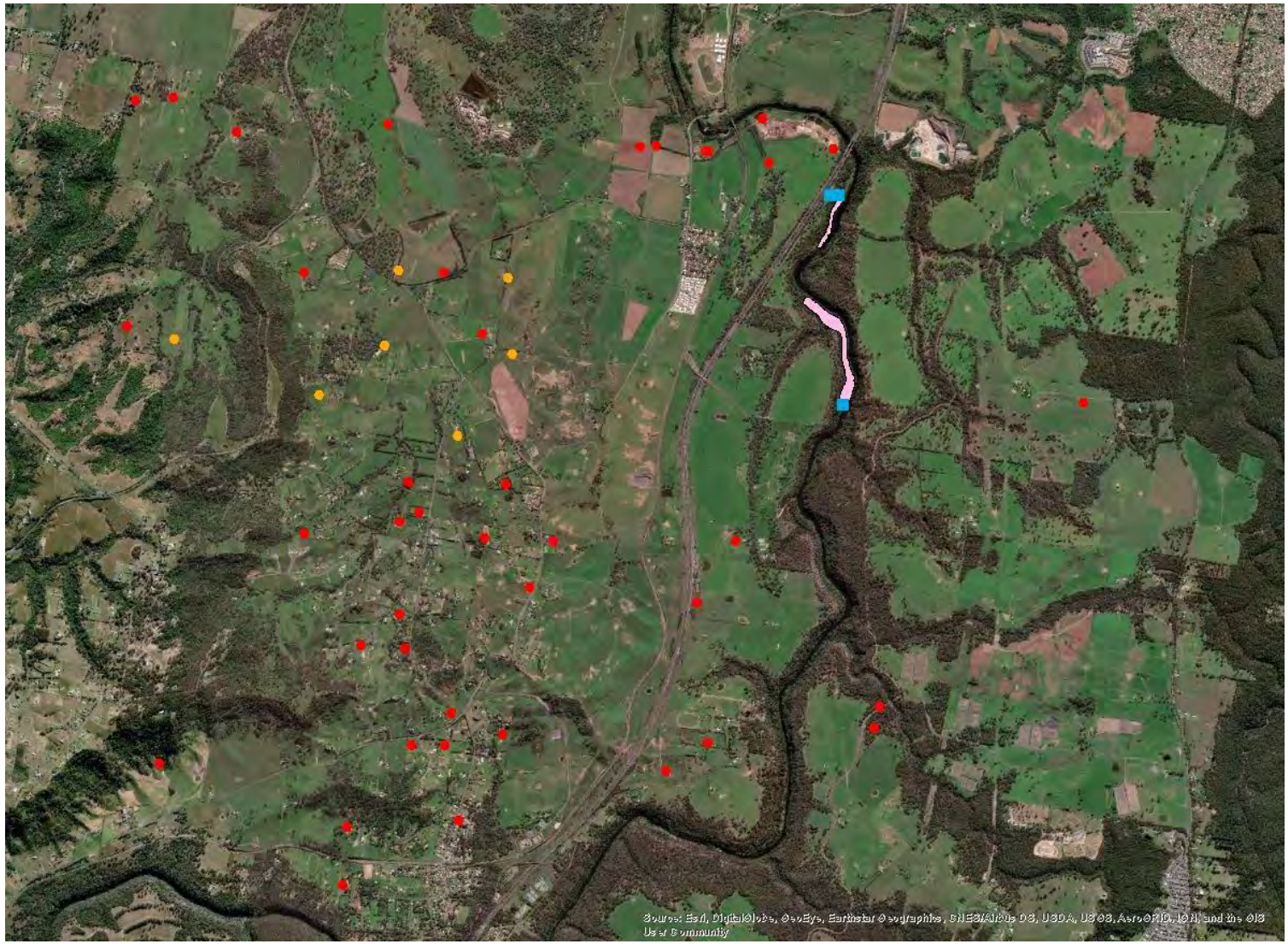


Figure 2.1 Alluvium data locations

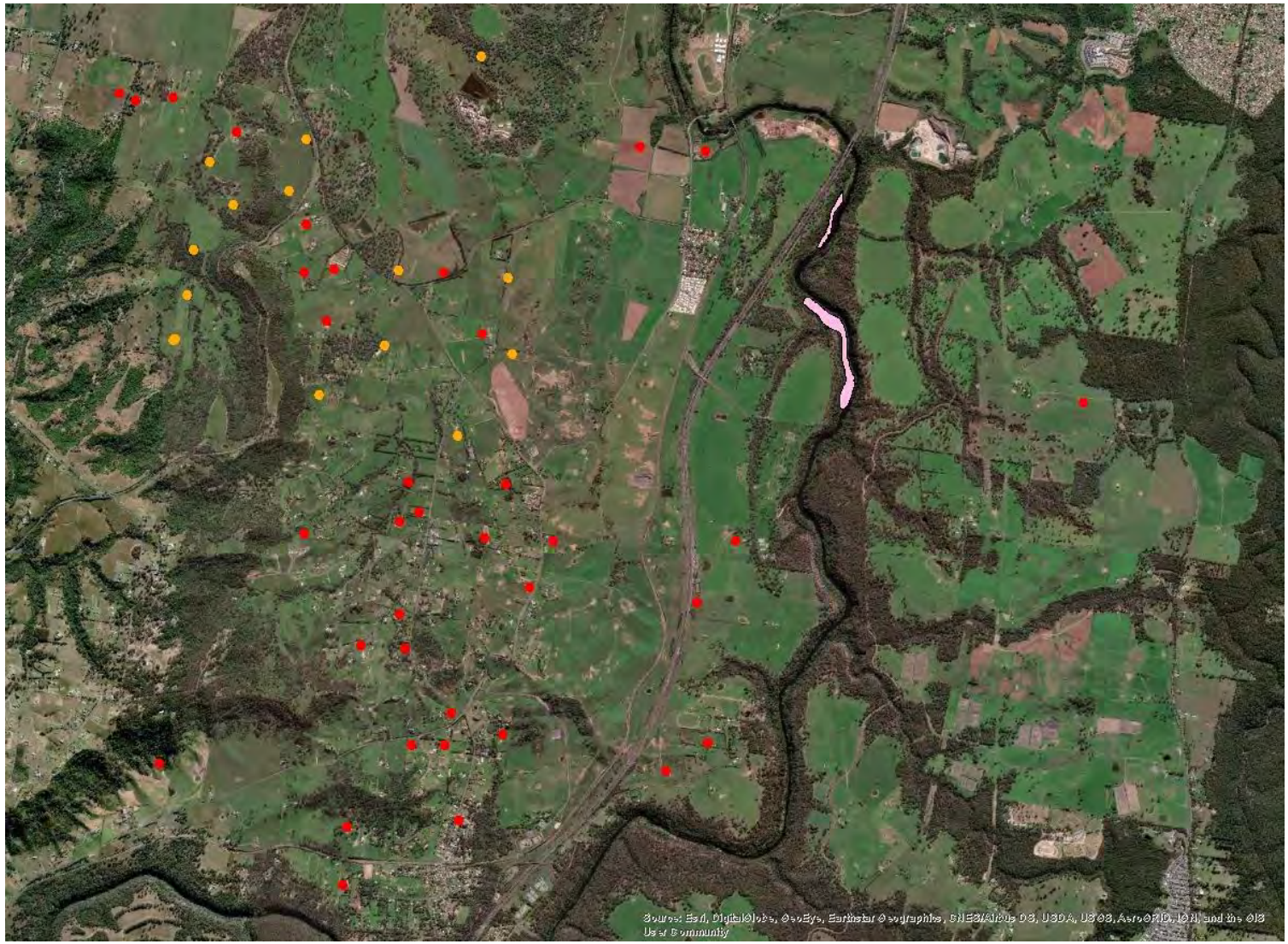


Figure 2.2 Ashfield Shale data locations

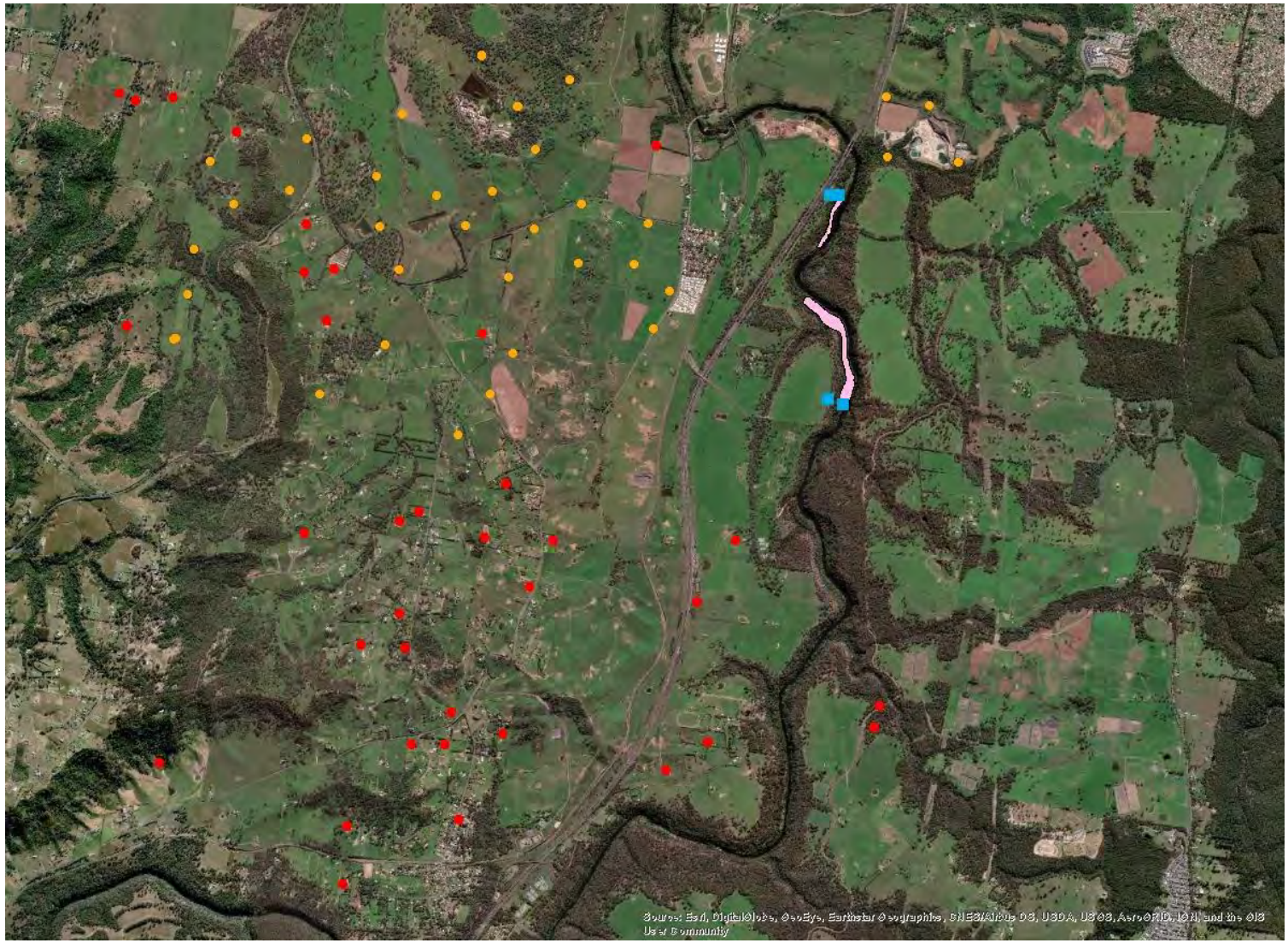
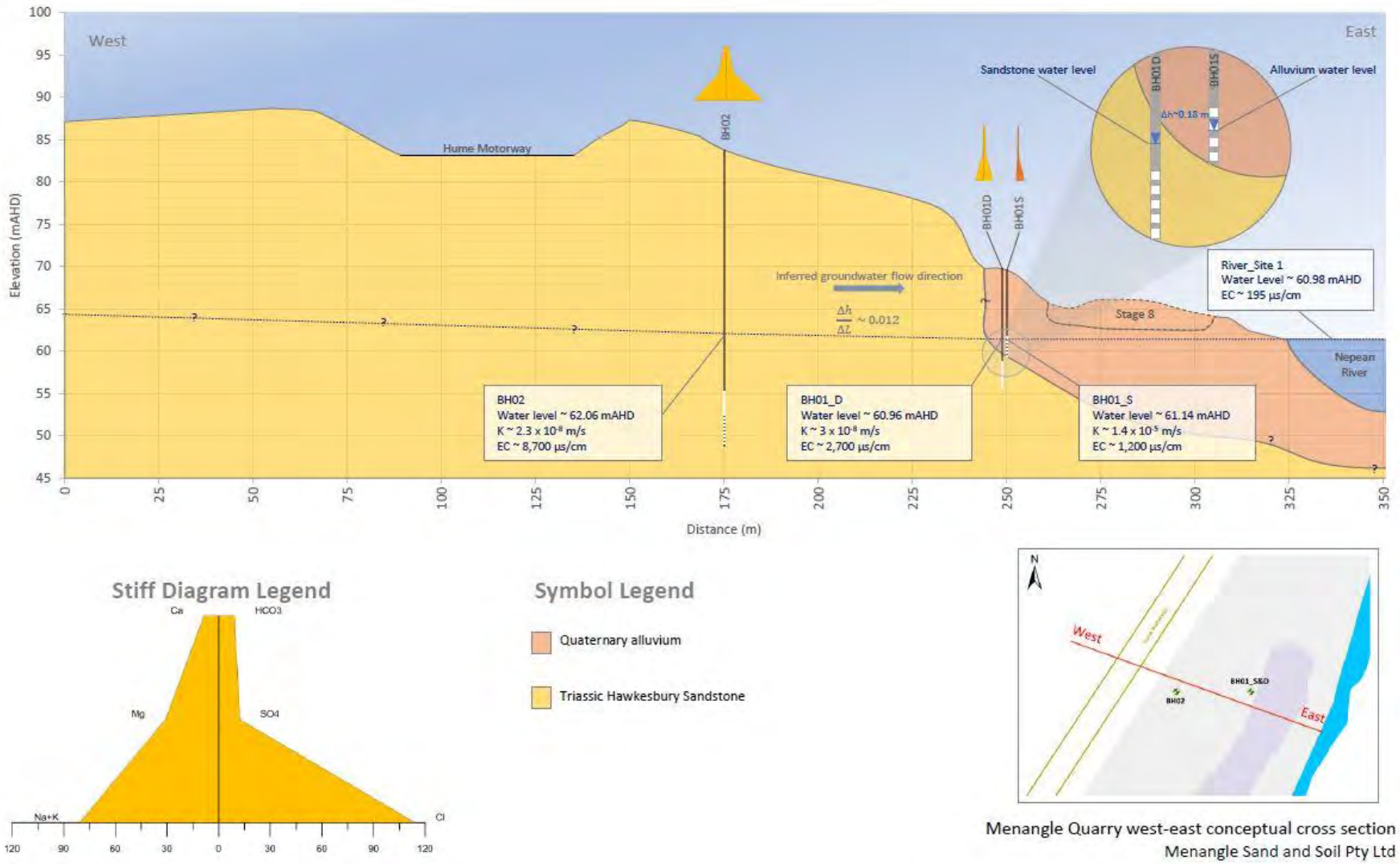


Figure 2.3 Hawkesbury Sandstone data locations



Menangle Quarry west-east conceptual cross section
Menangle Sand and Soil Pty Ltd

Figure 2.4 Conceptual cross section near BH01 and BH02

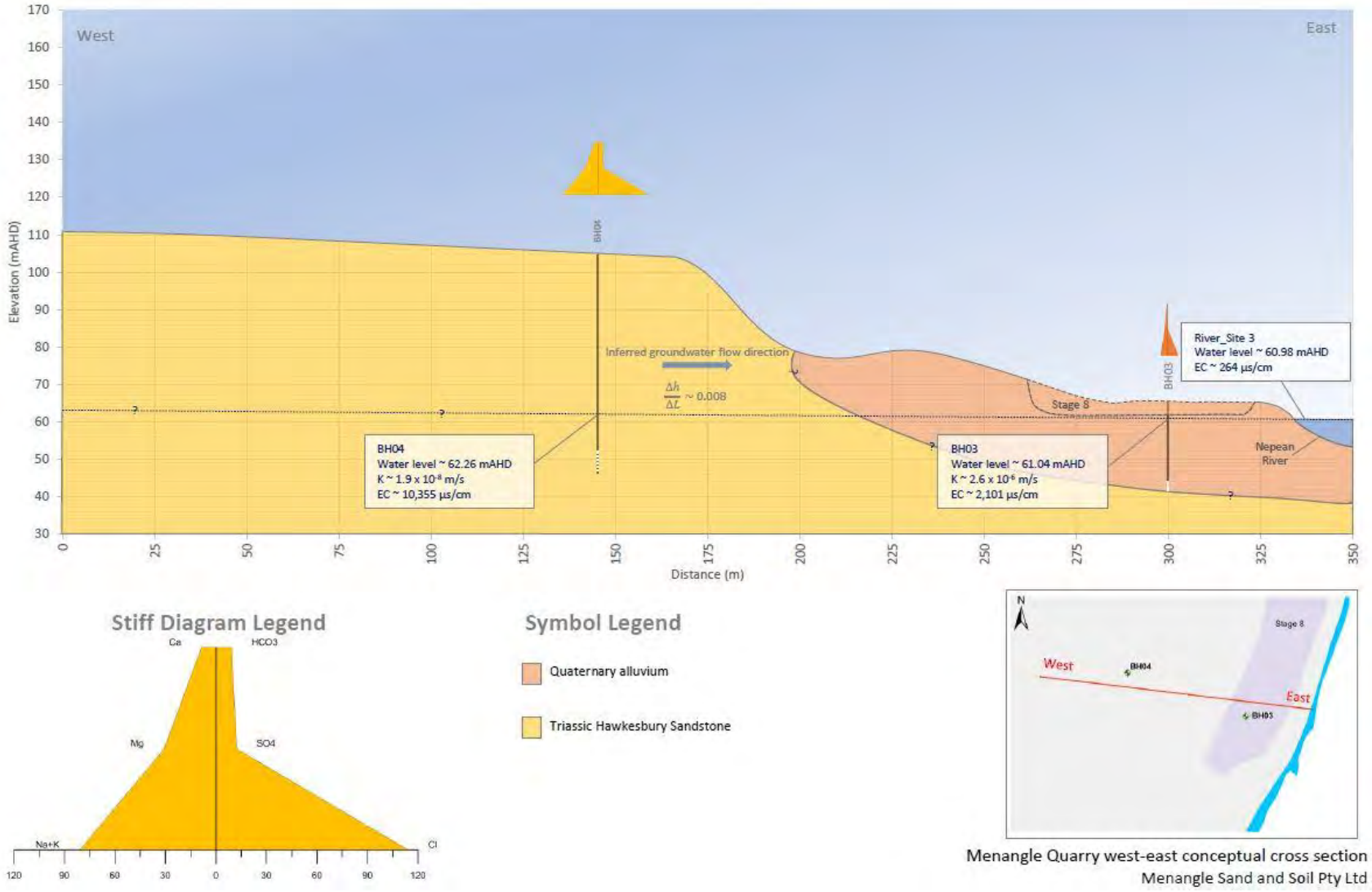


Figure 2.5 **Conceptual cross section near BH03 and BH04**

2.1.1 Groundwater levels and flow directions

Local-scale transient groundwater monitoring data are available for the groundwater monitoring bores installed for the project. Hydraulic heads are measured via pressure transducer every 6 hours at each of the 5 locations. Appendix A contains the data collected at the five monitoring locations until 23 September 2020. Of note from the joint experts report on groundwater (Merrick and Webb 2020) is that the alluvial groundwater level is observed by site operators to be controlled by the level in the Nepean River.

Two distinct groundwater behaviours are observed from the site hydrographs, bores BH01-S, BH01-D and BH03 can be grouped with similar behaviour, while bores BH02 and BH04 exhibit similar behaviour. The hydraulic head responses are associated with the bores being screened in either the alluvium or HBSS. The bore log for BH01-D suggests it is screened in the very top of the HBSS unit and monitoring data shows the characteristic changes associated with the alluvium watertable.

Monitoring data for the water table (ie alluvium bores) indicate that it is located at approximately 61 mAHD for the majority (>98%) of the time (based on river level data) (Merrick and Webb 2020). This level has been confirmed by the recent EMM bore installation and testing program (2020a) where the two alluvial bores having levels of 61.14 mAHD for BH01S, and 61.04 mAHD for BH03.

Available groundwater level data (Appendix A) show that the vertical hydraulic gradient in this area is upward from the regional HBSS aquifer towards the alluvium and the river. This supports the discussion in the joint experts report (Merrick and Webb 2020) that the head in the HBSS would generally be higher than that in the alluvium, from which groundwater discharges to the usually gaining Nepean River as baseflow.

The regional groundwater flow direction is from west to east on the western side of the Nepean River (refer Appendix A).

2.1.2 Nepean River

Hourly monitoring of Nepean River level is conducted by WaterNSW (Menangle weir station #212238). From the EMM joint experts report (Merrick and Webb 2020), it was agreed that the normal low flow level of the river in the Stage 8 area is approximately 61 mAHD. The river observation data are provided in Appendix A and show a strong correlation between river water level and alluvium groundwater levels at the local monitoring bores. It was agreed that 61 mAHD is the best estimate of the “average alluvial watertable level” (Merrick and Webb 2020).

Previous reporting (Merrick and Webb 2020) indicated the river level has exceeded 62 mAHD (the nominal base of quarry excavations) 1.0% of the time from 1990 to 2013, and 0.7% of the time from 1990 to 2020. The river level has also exceeded 64 mAHD, the height at which bank overtopping generally occurs, approximately 0.3% of the time, or 1.2 days per year, on average since ‘consent was granted’ (Merrick and Webb 2020).

The hydraulic gradient of the Nepean River is low, at approximately 1.9 cm/km, measured between Menangle Weir (60.84 mAHD) and Douglas Park Weir (61.10 mAHD) over a distance of approximately 14 km (Merrick and Webb 2020). Over the length of the Stage 8 corridor, the normal river levels are expected to range from 60.87 mAHD at the northern end to 60.92 mAHD at the southern end. Therefore, the adoption of 61 mAHD as the normal river level is appropriate.

The Nepean River is gaining the majority of the time in the project area, with gradient reversals during high flow events. In such events river water is expected to flow into the near-river alluvial aquifer, potentially being intercepted (but not extracted from) by quarry pits. When the river level declines this water is expected to flow back from the aquifer into the river, with the alluvium acting as a river bank storage. During overtopping events (ie when the river rises to 64 mAHD or higher) water will flow directly across the land surface and may flood pits from above, in addition to groundwater rising from the pit floor.

2.1.3 Rainfall

Daily rainfall in excess of 100 mm has occurred on only 0.06% of days since 1889 (31 days in 130 years), and the highest ever daily rainfall recorded in the location of the quarry was 235 mm (Merrick and Webb 2020). Therefore, rainfall is not considered a major contribution to the shallow groundwater system and is not considered an issue for site water management.

The joint experts report (Merrick and Webb 2020) agreed that the river flow is likely to be more affected by rainfall in the headwaters of the catchment, rather than rainfall at the project site due to the presence of significant weirs that would temper the variations in river levels. Hydrographs (Appendix A) show that site rainfall events have little to no influence on the groundwater levels and that the stage of the Nepean River has the greatest influence on the groundwater levels.

2.2 Aquifer properties

The permeability of the alluvial sediments associated with the Nepean River is known to be variable and dependent on the sediments, with sand and gravel deposits having high permeabilities, while clay lenses have a much lower permeability (Merrick and Webb 2020). The permeability of the HBSS rock mass itself (primary permeability) can be low relative to the overlying alluvium. However, the HBSS is a dual permeability system, and in areas of high density of interconnected fractures and faults the 'secondary permeability' can result in moderate to high permeabilities if intercepted (Merrick and Webb 2020).

Hydraulic testing (slug tests) of the recently installed site monitoring bores provided estimates of hydraulic conductivity. The results confirm that the hydraulic conductivity of the alluvium is approximately two orders of magnitude higher than the underlying HBSS. The hydraulic property ranges reported in the Drilling completion report (EMM 2020a) are reproduced in Table 2.2 for ease of reference.

Table 2.2 Summary of measured hydraulic conductivity

HSU	Area	Test type	Hydraulic conductivity (m/day)		
			Min	Max	Mean
Alluvium	Menangle Quarry	Rising head tests (2 tests)	0.2	1.2	0.7
HBSS	Menangle Quarry	Rising head tests (3 tests) and Development recovery (2 tests)	1.0×10^{-3}	3.5×10^{-3}	2.1×10^{-3}

The Sydney Basin bioregional assessment (Heron et al 2018) reports 370 packer tests conducted in the HBSS around the Sydney metropolitan area. The scaled geometric mean hydraulic conductivity of the HBSS ranges from 0.5 m/day at the surface to 0.01 m/day at 50 m depth (Heron et al 2018). The conceptual understanding that the hydraulic conductivity of the HBSS unit decreases with depth is commonly simulated. Hume Coal (EMM 2018) presented values of the HBSS ranging between 5×10^{-3} to 6×10^{-1} m/d.

In the Sydney Basin bioregional assessment (Heron et al 2018), the Ashfield shale unit is reported to vary between 3 and 10 m in thickness, with hydraulic conductivities between 0.01 and 0.08 m/day, and behave as an aquitard.

Based on EMM's experience in the Sydney Basin geological environment, and from other regional modelling work, values of hydraulic conductivity and storage properties were used to guide the values applied in the model (EMM 2020b, EMM 2020c).

Due to the method of the hydraulic testing (slug tests) in the bore installation and testing program, site specific storage properties could not be estimated. Rau et al (2018) specifies plausible ranges for specific storage as between 2.3×10^{-7} and 1.3×10^{-5} m^{-1}.

3 Numerical modelling

3.1 Model design

3.1.1 Software

A numerical groundwater flow model was developed using MODFLOW-USG (Panday et al 2013). This code contains additional capabilities over previous releases of MODFLOW. The formulation allows for the development of an unstructured, highly refined model mesh over areas of interest and larger, less computationally-demanding, model cells further away. In addition, MODFLOW-USG contains an optional Newton-Raphson formulation which improves model stability for processes involving the drying and rewetting of model cells.

The Groundwater Vistas 7 (ESI 2017) graphical user interface (GUI) was used to build and run the model, and to conduct some components of post-processing of the simulation results.

3.1.2 Equivalent porous medium

The model assumes an equivalent porous medium (EPM) approach for each HSU. This approach is commonly used in regional groundwater modelling of fractured rock hydrogeological environments. The EPM method assigns bulk hydraulic properties for a HSU and treats the rock (and pathways) as if it were a single porosity medium such as a granular aquifer (Anderson and Woessner 1991). This approach was adopted for the following reasons:

- in order to replicate regional hydraulic gradients, a simplified regional model was needed; and
- dual porosity models require significant detail on fracture/joint orientations, spacing and apertures. These details are not available for the geology in the model domain.

3.1.3 Model domain and spatial discretisation

The groundwater model domain was selected based on size of the quarry, publicly available groundwater level data, and the assumption that the Nepean River is a gaining river in the area of interest. The domain extends approximately 1.5 km to the west of the project. To the east, the model is bounded by the Nepean River. The model domain to the north and south uses the natural curves of the Nepean River and no flow boundaries perpendicular to the river, consistent with groundwater flow toward a gaining river. Groundwater monitoring data indicate that the Nepean River is lower than groundwater levels in the regional groundwater system on both sides of the river and, hence, groundwater converges at the river. Therefore, the river is typically gaining and groundwater beneath the river flows vertically upward, not across the river, making this an ideal model boundary. The model domain covers an area that is approximately 21.8 km^2. The domain is adequately large enough to:

- encompass all of the Stage 8 quarry areas;
- include the inferred hydrogeological boundary conditions influencing groundwater flow; and
- encompass changes to the groundwater system in relation to quarrying and site operation.

AlgoMesh, with default ‘high’ quality settings, was used to create a Voronoi polygon mesh incorporating relevant site features and locations. This discretisation method is numerically efficient and can handle complex geometries. The resultant mesh has approximately 32,000 cells per layer. Regional cells have a maximum size of approximately 250 m across, with cell sizes refined down to approximately 2 m to 3 m in areas of refinement, specifically between the Stage 8 quarry and the Nepean River. The model mesh has progressive refinement from large regional cells to small cells around the area of interest. The model domain and mesh are presented in Figure 3.1 to Figure 3.4.

Figure 3.1 **Groundwater model domain with Voronoi cells**

Figure 3.2 **Stage 8 area with Voronoi cells (northern area)**

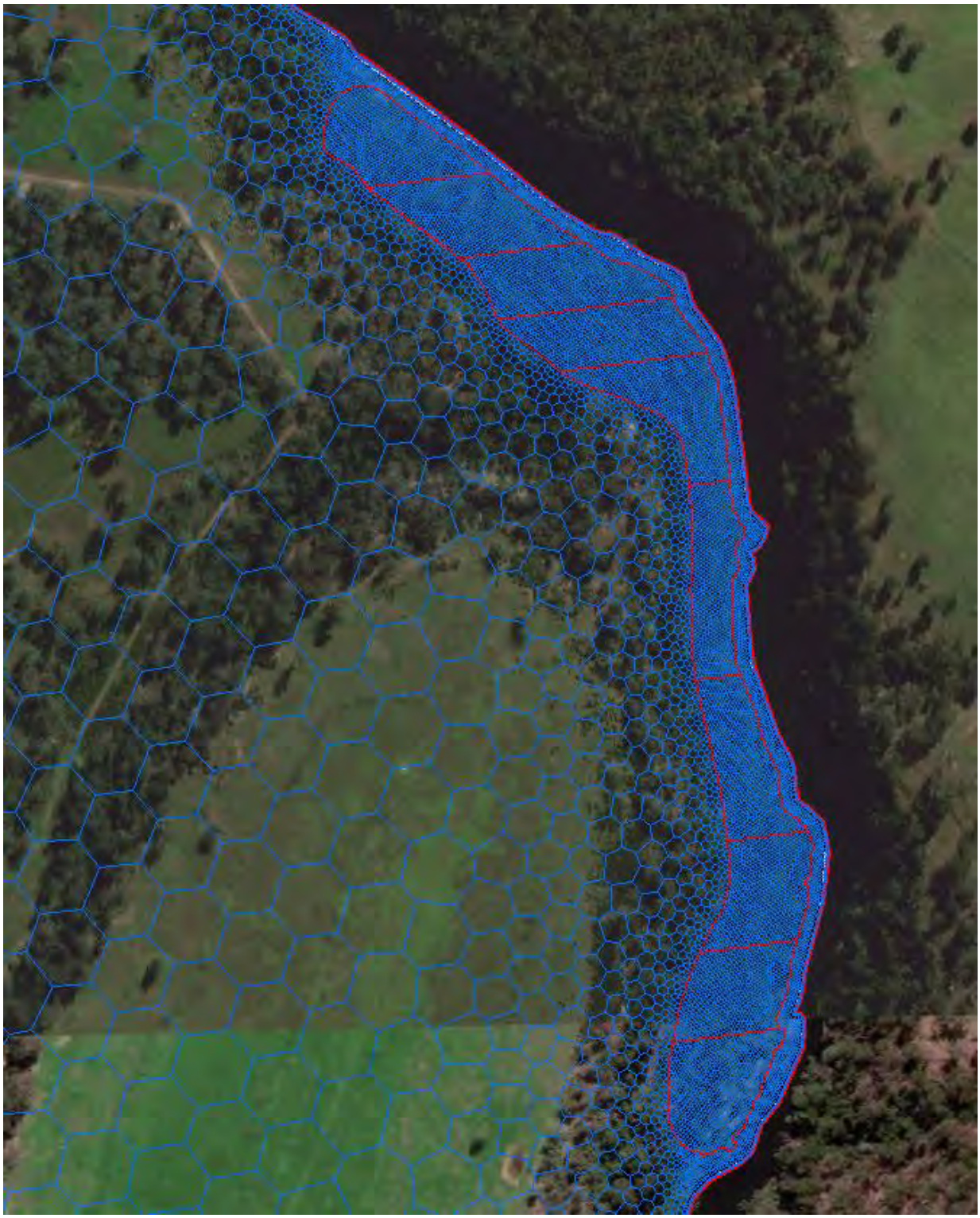


Figure 3.3 Stage 8 area with Voronoi cells (southern area)

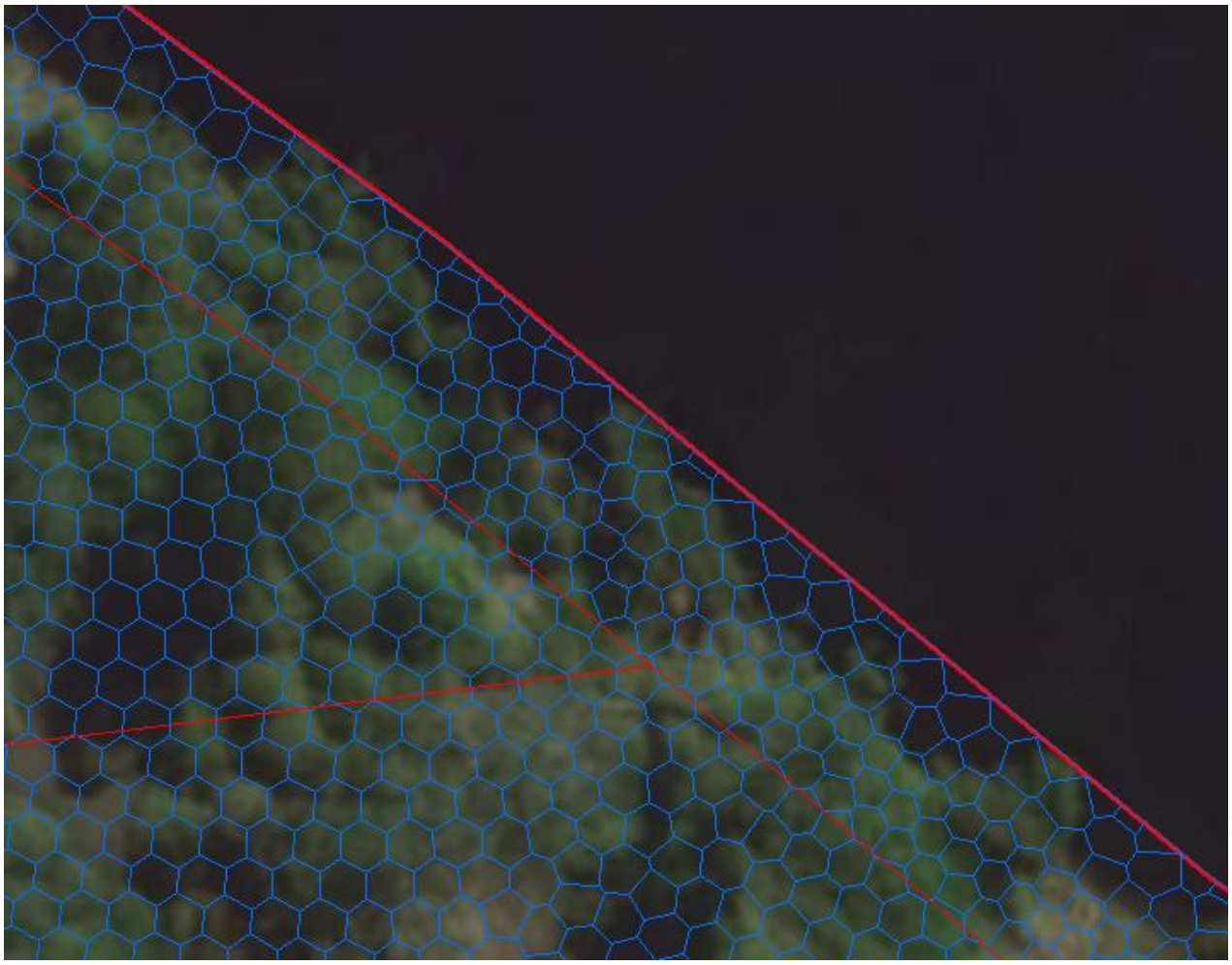


Figure 3.4 Voronoi cells between Nepean River and Quarry area

3.1.4 Model layers

Four model layers were employed to represent the HSUs and quarry operations (Table 3.1).

Table 3.1 HSUs and model layers

HSU Name	Groundwater model layer#	Comments	Quarry Infrastructure
Alluvium (above base of quarry)	Layer 1 – unconfined aquifer	As the area of interest is based on the removal of alluvium sediments, layer 1 of the groundwater model simulates quarry pits.	Present
Alluvium (below base of quarry)	Layer 2 – unconfined aquifer	Present over the entire model domain in various thicknesses- main conduit to water affecting activities.	Not included
Ashfield Shale	Layer 3 – aquitard	Present in the western area of the model domain.	Not included
Hawkesbury Sandstone	Layer 4 – aquifer	Regionally extensive.	Not included

# denotes model layer near Quarry area – groundwater model layers may be combined regionally based on HSUs and available information.

Model layer elevations were developed using drill hole data sourced from Menangle Sand and Soil and publicly available drill hole databases. The top of the model is set at topography using the ELVIS 1 second (~30 m) dataset from Geoscience Australia and the base of the model is set 150 m below the generated top of HBSS surface.

MODFLOW-USG allows model layers to pinch out and be deactivated. The alluvium is divided into two layers to represent the alluvium above the base of the quarry pits (62 mAHD) and the alluvium below the base of the pits. These layers pinch out a) where alluvium is not present and/or b) where the alluvium is not present below the proposed base of excavation. The Ashfield Shale layer pinches out towards the Nepean River, where it is mapped as not being present.

The base of the active extraction area is proposed as 62 mAHD and therefore 1 m above the long-term average watertable elevation in the alluvium (during the normal low flow level of the river). For most of the time (>98% of the time when normal river flow conditions occur), the excavations will be 1 m above the watertable and will not intercept groundwater.

3.1.5 Temporal discretisation

Stress periods used for history matching period are outlined in Table 3.2. The model employs an initial steady state stress period followed by a series of transient stress periods over which the Nepean River stage is varied in line with measured stage over the history matching period. River stage is the only time-varying stress in the history matching period and, hence, is the driver for design of stress periods. Figure 3.5 illustrates measured Nepean River level, the defined stress periods and modelled Nepean River boundary condition elevation.

Table 3.2 Model stress periods

Stress period	Duration	Description	Dates	River stage (mAHD)
1	Steady state (1 day)	Develops initial pre-project conditions in response to modelled hydraulic parameters and boundary conditions.	Prior to recording of any data	Constant at 61.009
2	53 days	History matching period, steady river levels	from 3 June 2020 to 26 July 2020 (12:00)	Use average river value of 61.009 over period
3-5	0.6667 days each	History matching period, increasing river levels	from 26 July 2020 (12:00) to 28 July 2020 (12:00)	Use average river value over stress period times (gradual increase 61.053, 61.194, 61.428)
6	12 hours total – 0.5 day	History matching period, steady river levels (peak)	from 28 July 2020 (12:00) to 28 July 2020 (24:00)	Use average river value over stress period times (steady value 61.538)
7-9	1 day each	History matching period, decreasing river levels	from 28 July 2020 (24:00) to 31 July 2020 (24:00)	Use average river value over stress period times (gradual decrease 61.405, 61.271, 61.185)
10	7.25 Days	History matching period, steady river levels	from 31 July 2020 (24:00) to 8 August 2020 (06:00)	Use average river value of 61.165 mAHD over period
11-13	0.708 day each	History matching period, increasing river levels	from 8 August 2020 (06:00) to 10 August 2020 (12:00)	Use average river value over stress period times (gradual increase 61.203, 61.4, 62.359)
14	0.1667 day	History matching period, steady river levels (peak)	from 10 August 2020 (12:00) to 10 August 2020 (14:00)	Use average river value over stress period times (steady value 63.118)
15-17	1.333 days each	History matching period, quickly decreasing river levels	from 10 August 2020 (14:00) to 14 August 2020 (14:00)	Use average river value over stress period times (gradual decrease 62.373, 61.614, 61.465)
18-19	7 days each	History matching period, gradually decreasing river levels	from 14 August 2020 (14:00) to 28 August 2020 (14:00)	Use average river value over stress period times (gradual decrease 61.318, 61.109)
20	26.25 days	History matching period, steady river levels	from 28 August 2020 (14:00) to 23 September 2020 (14:00)	Use average river value over stress period times (steady value 61.034)

The ATS package is used to adaptively adjust time step lengths within each stress period. An initial time step of 1 x 10^{-6} days was defined. The maximum timestep length was 2.5 days in stress period 20.

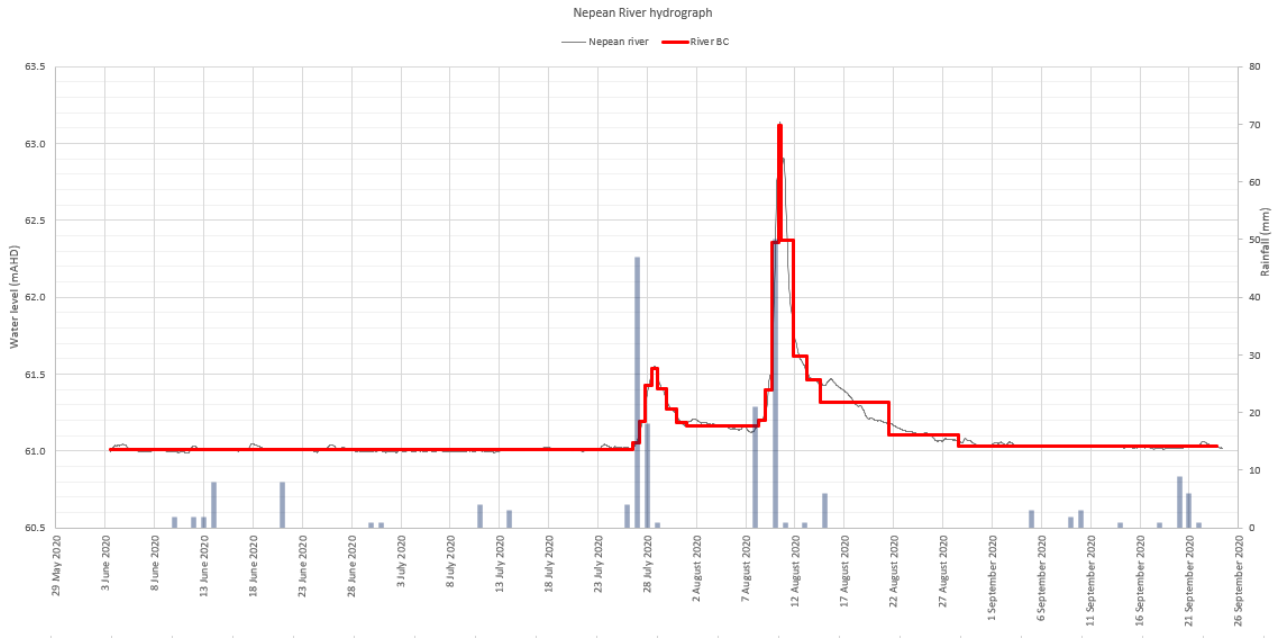


Figure 3.5 Measured and modelled Nepean River stage

3.1.6 Boundary conditions

a General head boundary condition

The General Head Boundary (GHB) package was employed to assigned boundary conditions to model cells along the western edge of the model domain in the HBSS layer to represent regional groundwater inflow to the model domain. Hydraulic head was set to 75 mAHD in line with measured groundwater elevations in the HBSS (see Figure 3.6). A sufficiently high conductance value was assigned such that it would not act as a limit to flow in and out of the model domain, effectively acting as a constant head boundary condition.

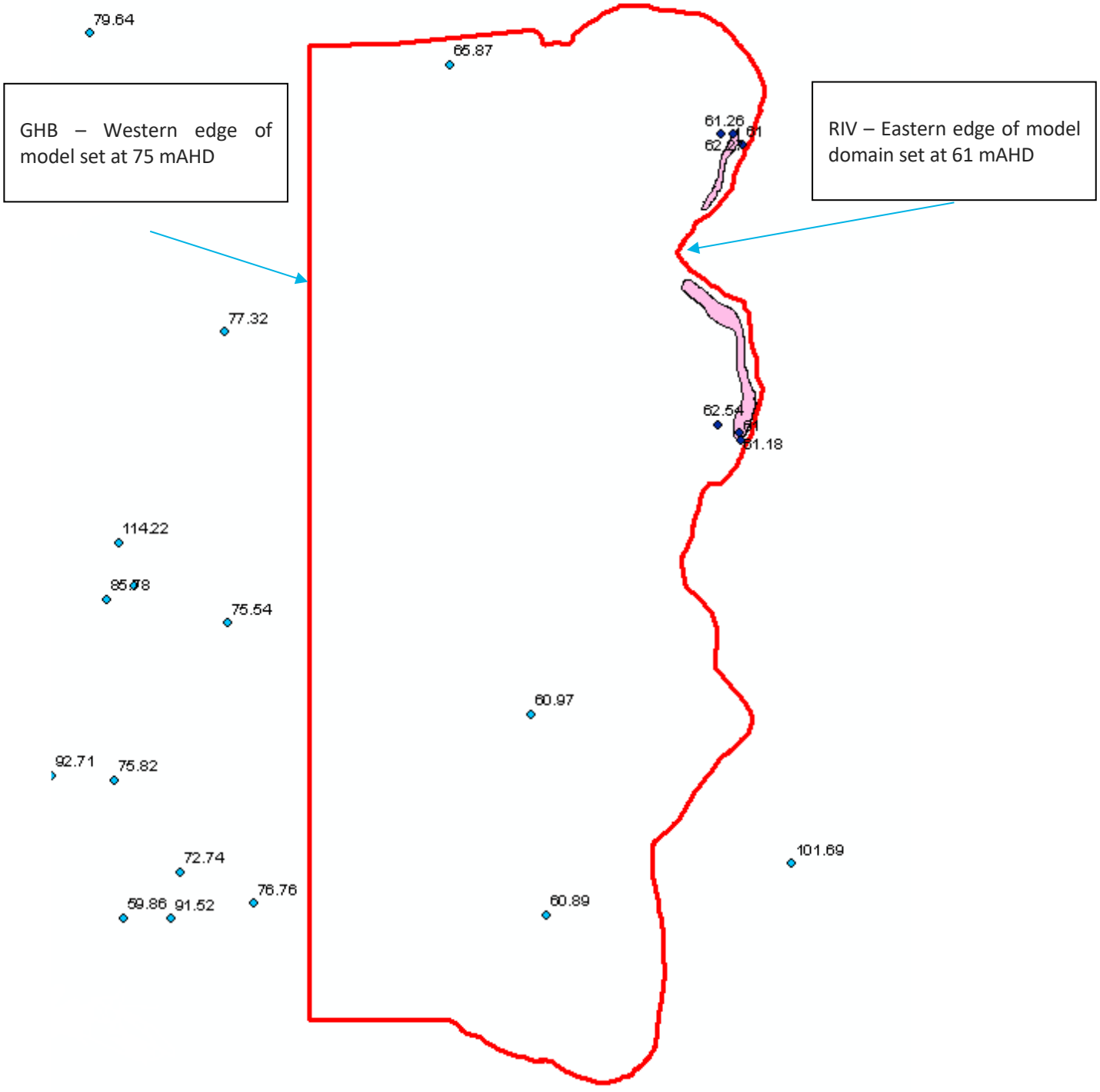


Figure 3.6 **Model boundary conditions and regional groundwater levels**

b River boundary condition

The River (RIV) package was used to simulate the Nepean River in model layers 1 and 2. The assigned river stage and timing are presented in Table 3.2. River conductance was assigned a value of 80 m^2/d, based on an approximate river width of 40 m, the average cell length parallel to the river of 2 m and riverbed thickness of 1 m and a vertical hydraulic conductivity of 1 m/d. Figure 3.5 shows the modelled river stage and the measured water levels of the Nepean River over the history-matching period.

c Evapotranspiration and recharge

As shown in site groundwater level hydrographs in Appendix A, periods of local rainfall do not significantly affect the groundwater levels at the site. Therefore, climate interaction via evapotranspiration and recharge from rainfall are not simulated.

4 History matching and sensitivity analysis

4.1 Approach

The numerical groundwater flow model was calibrated in two modes. The initial steady state stress period was used to calibrate the model to regional groundwater levels. A single indicative average unimpacted hydraulic head value for each observation location was used to quantify model performance. Following the initial steady state stress period, transient stress periods were used to calibrate the model to the key process of interest: the response of groundwater levels near the quarry to changes in Nepean River level. No measurements of groundwater fluxes to or from the Nepean River were available to inform calibration and, hence, history-matching was to hydraulic head data only.

4.2 Hydraulic properties

Hydraulic conductivity property ranges were guided by the ranges measured at the project site (refer Section 2.2) and from other projects in similar geological environments.

In the groundwater model, the hydraulic properties of the Ashfield Shale were not modified from a horizontal hydraulic conductivity of $1x10^{-4}$ m/d and $1x10^{-5}$ m/d for a vertical hydraulic conductivity. The adopted values are lower than reported in the bioregional assessment (Heron et al 2018), however the values are consistent with the conceptual understanding and with other reported (modelled) values in the region.

Site storage properties were not evaluated during the EMM drilling completion report, as these can only be calculated during aquifer pumping tests where data from observation bores are available. Representative values from literature were used. Specific storage values were constrained between the physical limits presented by Rau et al (2018) of 2.3×10^{-7} m^{-1} to 1.3×10^{-5} m^{-1}. A value of 5×10^{-6} m^{-1} was adopted. Specific yield values for assigned similarly, with sand typically around 20%; the Ashfield Shale is approximately 1%; and the HBSS is typically slightly lower at 0.5 to 0.8% (EMM 2018).

During the history-matching process, an additional model layer was added to aid the matching of the data observed at BH01-D. The HBSS was divided into an upper and lower system, where the upper layer was denoted as the upper 10 m of the HBSS unit.

During the automated history-matching process it was observed that some hydraulic parameters were trending towards values outside of their conceptual range. However, the parameters were constrained to plausible limits. The calibrated hydraulic parameter values are presented in Table 4.1.

Table 4.1 Calibrated hydraulic parameter values

Layer	Geological Unit	Hydraulic conductivity - horizontal	Hydraulic conductivity - vertical	Specific yield
1	Alluvium	5 m/d	0.1 m/d	0.05
2	Alluvium	5 m/d	0.1m/d	0.05
3	Ashfield Shale#	$1x10^{-4}$ m/d	$1x10^{-5}$ m/d	0.01
4	Upper Hawkesbury Sandstone	5 m/d	0.1 m/d	0.001
5	Lower Hawkesbury Sandstone	0.1 m/d	0.07 m/d	0.001

- denotes that parameters were not adjusted during history matching process.

4.3 History-matching performance

Calibration performance was evaluated in several ways. Modelled regional groundwater contours and scaled root mean square (SRMS) error were used to evaluate the history-matching performance, in addition to the mounding of the watertable observed at the site bores (in response to high river flow events).

Modelled and measured hydrographs at the selected monitoring bores were used to quantify the ability of the model to replicate responses to changes in Nepean River level. Given that change in groundwater level is the key aspect of transient calibration, SRMS error was quantified for hydraulic head relative to steady state modelled head at each of the bores. The transient response to the changes in river levels was evaluated at the five project monitoring bores.

The history-matching performance of the groundwater model was evaluated for the transient response to the measured Nepean River level at the Menangle weir over approximately 3 months of monitoring. Figure 4.1 shows modelled and measured hydraulic head at the site-specific monitoring bores (BH01 to BH04). Figure 4.2 shows modelled and measured mounding of groundwater levels relative to the pseudo steady state period over the first ~1.5 months of measurements.

The calculated hydraulic head SRMS for the history-matching model is 22.7%. Figure 4.3 shows a scatter plot of modelled versus measured hydraulic head. Modelled heads are typically below the measured heads. It is expected that an improved match to measured groundwater behaviour will be achieved when the model is updated when 12 months of monitoring data are available.

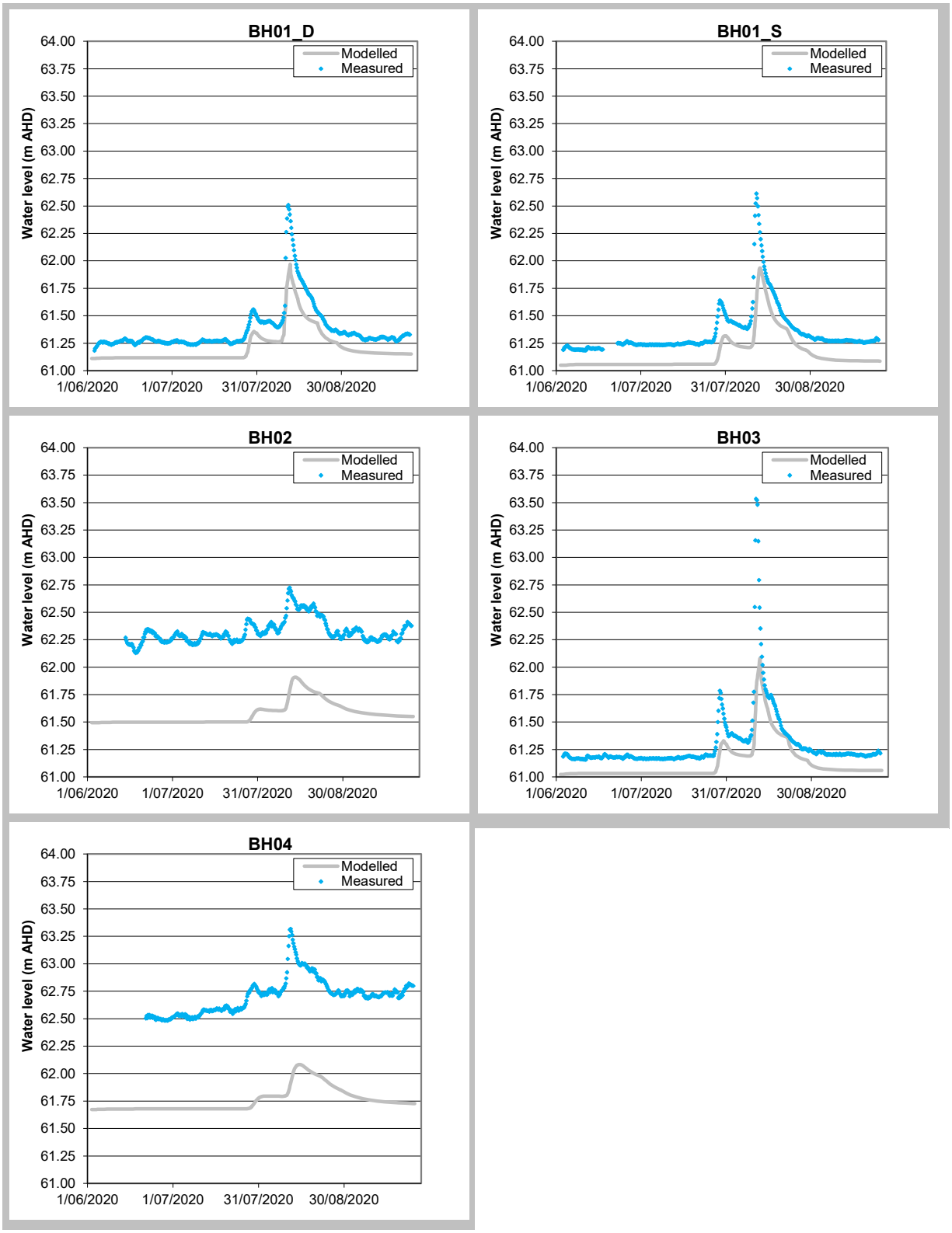


Figure 4.1 - Modelled and measured hydrographs (History Matching)

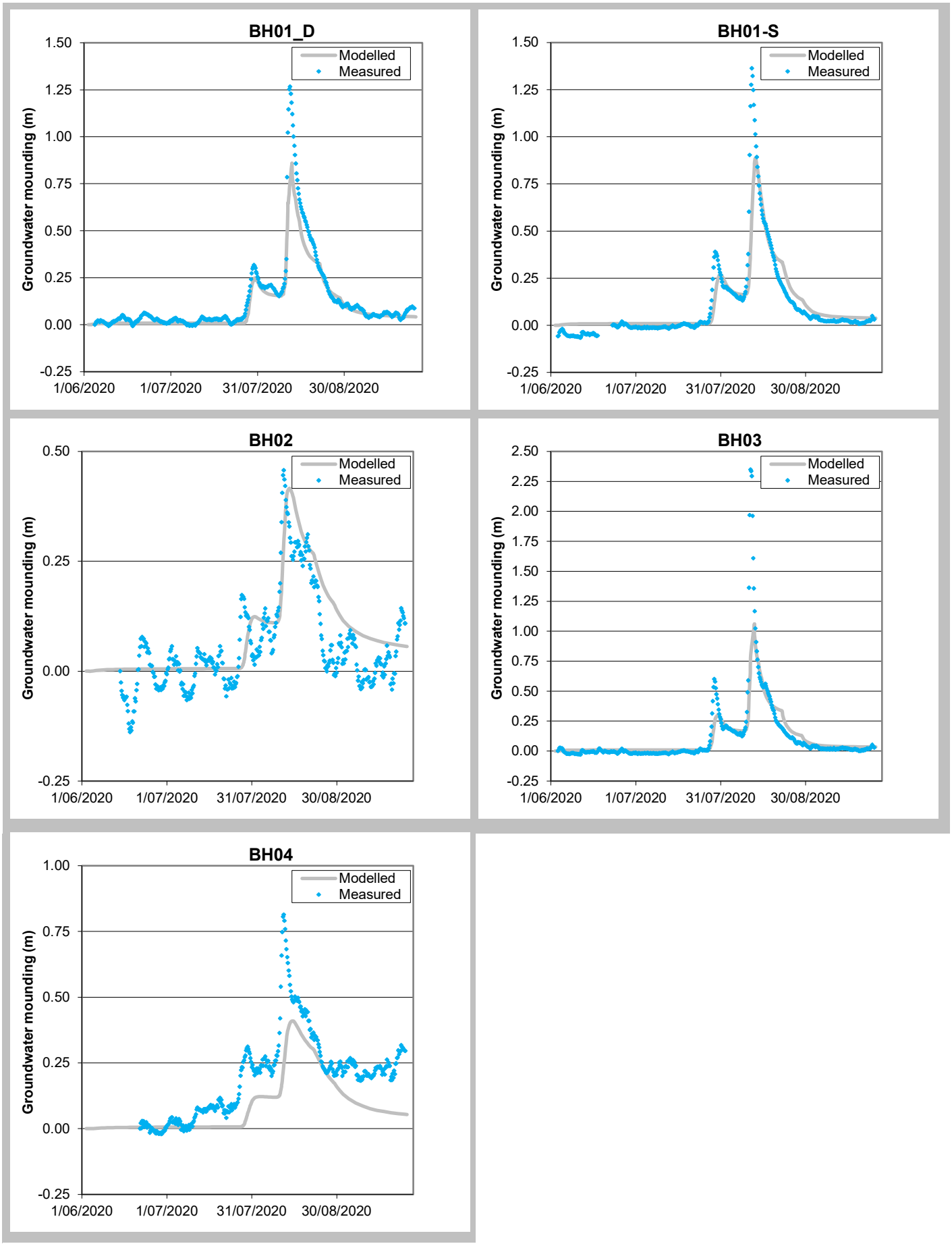


Figure 4.2 - Modelled and measured mounding hydrographs (History Matching)

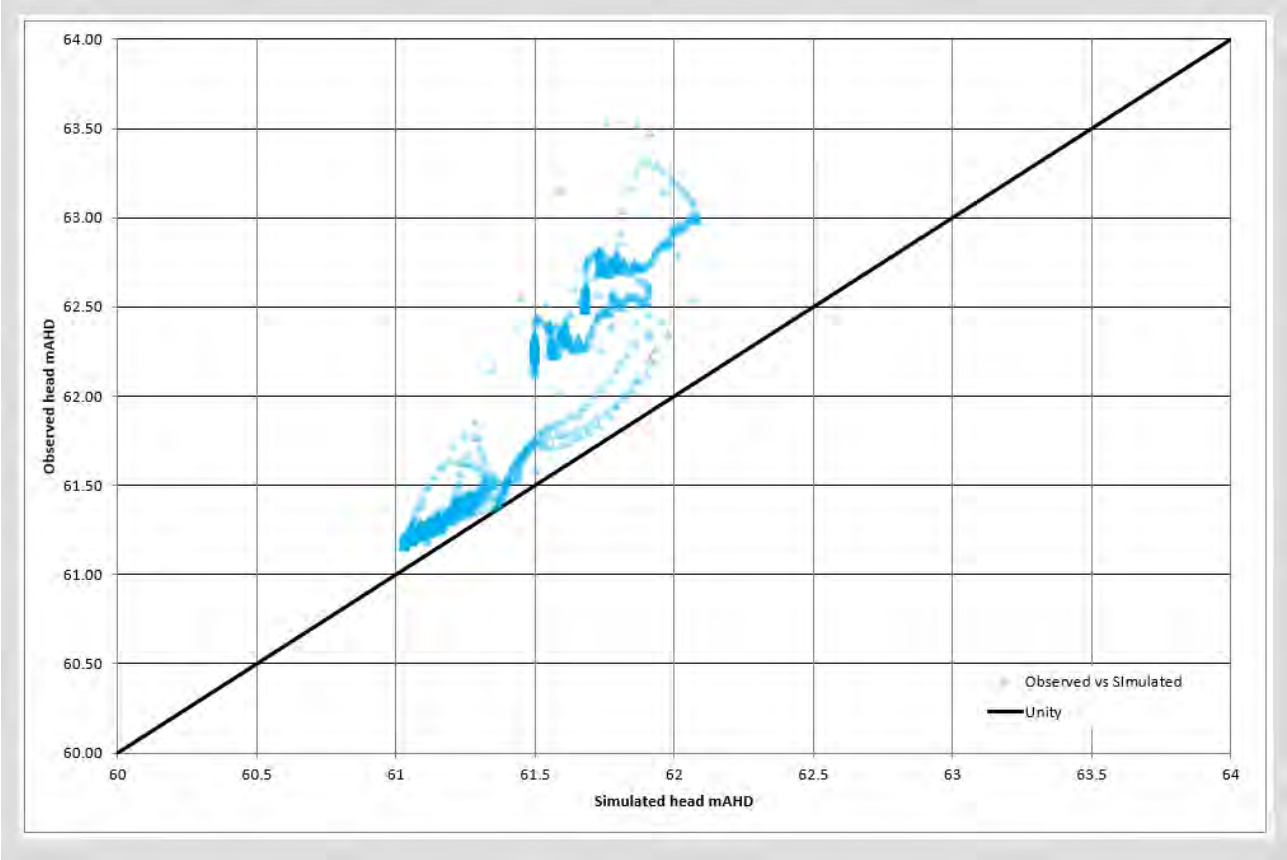


Figure 4.3 Scatter plot of modelled versus measured hydraulic head

4.4 Sensitivity analysis

A relative composite sensitivity analysis was performed on the calibrated model and the results show that the model is most sensitive to horizontal hydraulic conductivity (model layers 2, 4 and 5) and specific yield of layer 2 (alluvium). Figure 4.4 shows the relative values of the composite sensitivity. The sensitivity of the history-matched model is based on the hydraulic head targets at the site monitoring bores.

As there are no measurements in model layer 1, the sensitivity shows a low relative sensitivity to the parameters of layer 1.

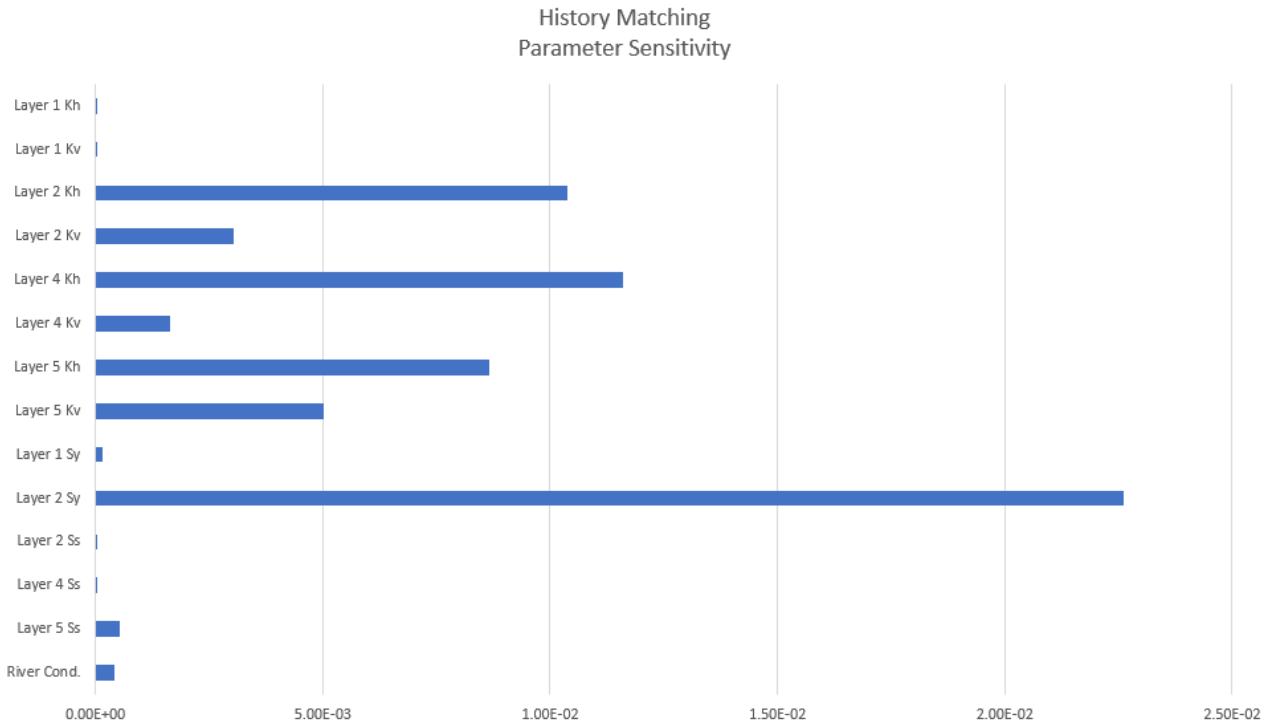


Figure 4.4 Relative composite sensitivity of the history-matched model

5 Predictive scenarios

5.1 Predictive modelling

a Quarry void material properties used in predictive modelling

For the predictive modelling of the proposed project, the following material properties were implemented:

- Hydraulic conductivity: a significant increase in the horizontal and vertical hydraulic conductivity was used to represent void space. A value of 1,000 m/d was assigned to layer 1 in the quarry void areas.
- Specific yield: specific yield was increased to 100% in quarry void areas of model layer 1.

b Boundary conditions

The Nepean River boundary condition simulated a synthetic high flow event, designed to represent the maximum driving head that can cause groundwater interception by the quarry. River level was raised over time to just below the overtopping level of the river banks, at an elevation of 64 mAHD. The base of the proposed quarry was set at an elevation of 62 mAHD, which is 1 m above the long-term average watertable. When river levels are above 64 mAHD, the river overtops the banks and any water captured by the quarry is considered surface water. Therefore, simulation of a river stage higher than modelled would not represent an event requiring licensing of groundwater.

A synthetic river flood event was constructed from a review of measured Nepean River historic high flow events. River level measurements since 1990 indicate that 13 high flow events occurred where the maximum river level was below 64 mAHD. A synthetic flood event was created where the rise and fall of the Nepean River was designed to be consistent with typical historical events, particularly the duration of river level above the base of the quarry floor (62 mAHD). Figure 5.1 shows measured river levels during high flow events, and the synthetic event assigned to the Nepean River boundary condition in the predictive modelling. It was observed that since the end of the Millennium drought (2010), 12 high flow events (with river levels above 62 mAHD but not greater than 64 mAHD) have occurred. Therefore, a high flow event occurred on average 1.2 times per year. As the predictive scenario only simulates one high flow event, rather than an annual duration, the model results have been multiplied by 1.2 to annualise them.

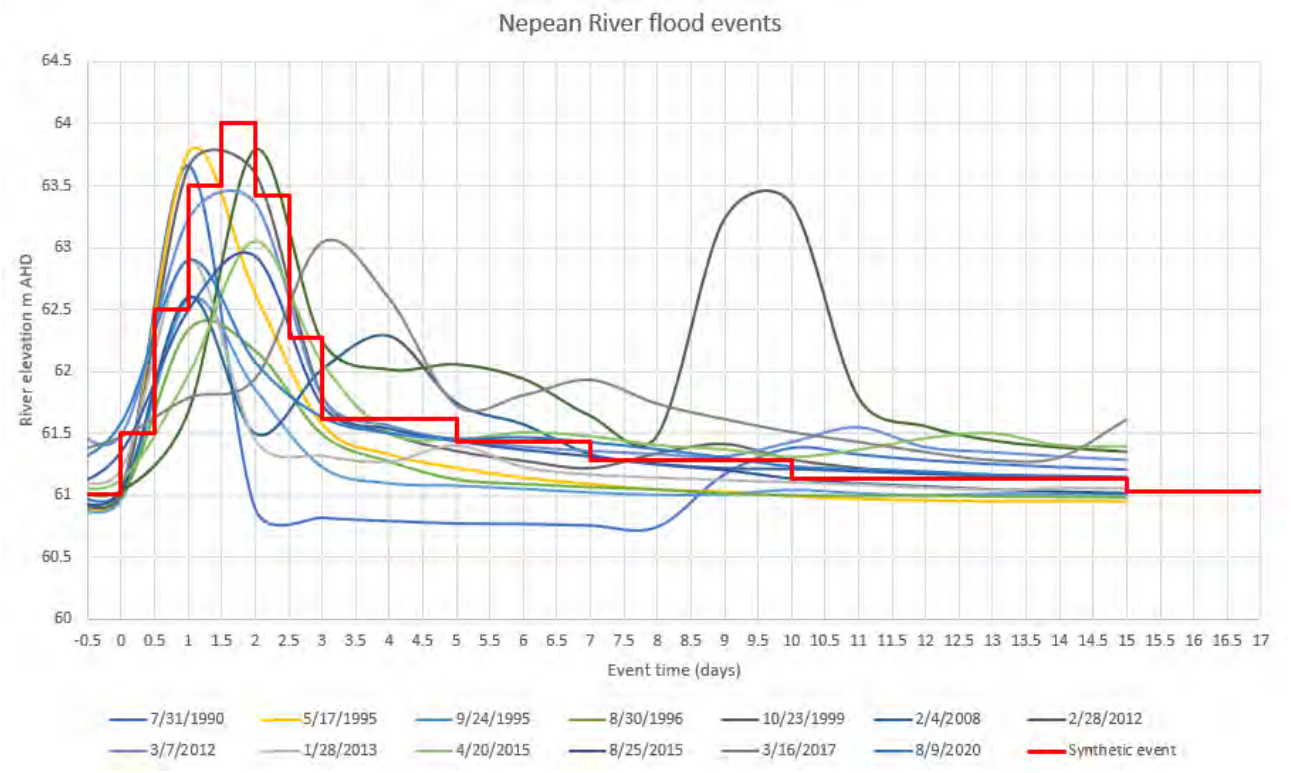


Figure 5.1 Nepean River high flow events since 1990 and the modelled synthetic scenario

c Predictive scenarios

The quarry plan will minimise the open quarry area and active face that is exposed at any one time with progressive backfill of the quarried areas. The project quarry areas (substages 8A to 8M) were subdivided into four sections (1, 2, 3 and 4) that represent areas of quarry that are active at any time and to represent the open area of the quarry consistent with the progressive backfilling approach. For example, area 8A is subdivided into A-1, A-2, A-3 and A-4. All simulated quarry areas have the same pit floor elevation (62 mAHD).

EMM initially selected four predictive scenarios to allow estimates of a range of inflows to the quarry based on active quarry area:

- Scenario 1: quarrying from the subdivision area longest parallel to the Nepean River (Area 8B-4, refer Figure 5.2);
- Scenario 2: quarrying from the largest of the subdivided areas (Area 8F-4, refer Figure 5.2);
- Scenario 3: quarrying from the smallest of the subdivided areas (Area 8C-4, refer Figure 5.2); and
- Scenario 4: quarrying from the subdivided area shortest parallel to the Nepean River (Area 8G-3, refer Figure 5.2).

Figure 5.2 shows the locations of the simulated quarry area for the various predictive modelling scenarios. While reviewing the total inflow data, it was observed that location 8C-4 (Scenario 3), the smallest of the subdivided area, showed the highest inflow volumes. The reason for this may relate to the location of the quarry area relative to the river, where the quarry allows a longer interaction length (eastern and southern faces of the quarry) between the quarry and river. As such, four additional scenarios were simulated as part of the predictive modelling:

- Scenario 5: the northern cell in the north section of the quarry (Area 8A-1, refer Figure 5.2);
- Scenario 6: the northern cell in the southern section of the quarry (Area 8D-1, refer Figure 5.2);
- Scenario 7: the southern cell in the southern section of the quarry (Area 8M-4, refer Figure 5.2); and
- Scenario 8: a quarry cell that is closest to the mean size of all subdivided areas (Area 8K-2, refer Figure 5.2).

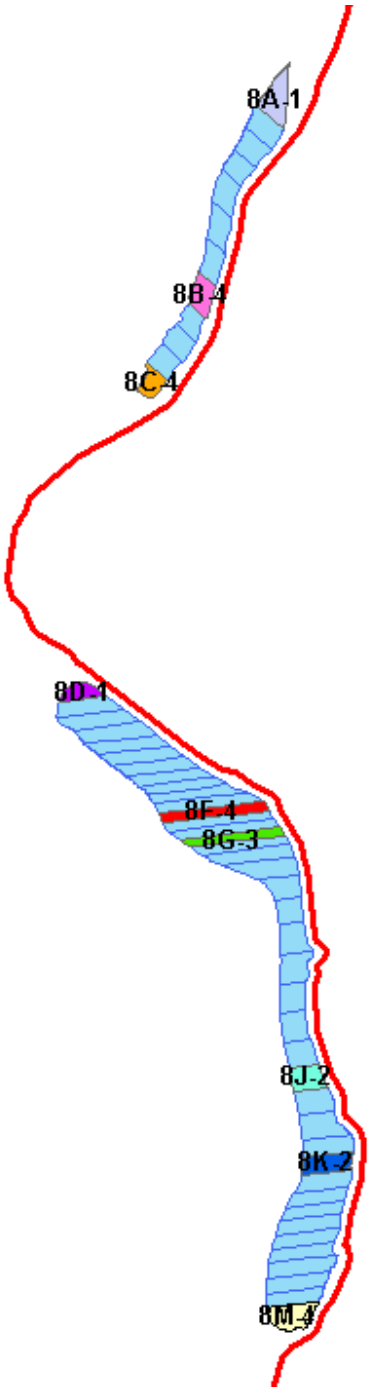


Figure 5.2 Quarry pit locations simulated in predictive modelling

5.2 Predictive uncertainty analysis

A single 'true' model cannot be constructed due to the inherent uncertainty that exists within hydrogeological systems, which is introduced by effects of error in field measurements, conceptual, spatial and temporal simplifications (Barnett et al 2012). To better understand how the prediction results may vary due to uncertainty within the system, a simple uncertainty analysis has been carried out. This is in the form of 'scenario analysis with subjective probability' as defined by the IESC explanatory note on Uncertainty Analysis (Middlemis and Peeters 2018). The main advantage of this kind of 'what-if' analysis is that it is straight forward to implement and communicate to stakeholders, and it is less computationally demanding compared to some other approaches. This approach is viewed as appropriate for this low-risk project.

The following uncertainty analysis was performed, which was guided by the relative composite sensitivity analysis that was performed on the history matching model (Section 4.4). The predictive uncertainty analysis was performed on the quarry cell that showed the highest predicted inflow during the simulated flood event.

Five predictive uncertainty models were generated based on the following changes to hydraulic parameters:

- Uncertainty 1 – increase the hydraulic conductivity in the alluvium by 25%;
- Uncertainty 2 – reduce the hydraulic conductivity in the alluvium by 25%;
- Uncertainty 3 – increase the specific yield to 10% (twice the history-matched value);
- Uncertainty 4 – reduce the specific yield to 2.5% (half the history-matched value); and
- Uncertainty 5 – a combination of #1 and #4 above.

6 Results

The model predicted inflow volumes are presented in Table 6.1. The modelled inflow volumes are calculated from the change in storage of Layer 1 (quarry layer) over the quarry area for each simulation. As the predictive model duration only covers one flood event, rather than an annual period, the model results have been multiplied by 1.2 to represent an indicative annual inflow amount, consistent with the requirement for licensing.

The scaled modelled inflow volumes range from 4 kL/yr to 408 kL/yr (up to 0.4 ML/yr).

Table 6.1 Model predicted inflow volumes

Scenario	Quarry area	Modelled inflow volumes (kL)	Scaled inflow volumes (kL/yr)
1	8B-4 – longest along Nepean River	97	116
2	8F-4 – largest area	55	66
3	8C-4 – smallest area and southern end of southern area	214	257
4	8G-3 – shortest along Nepean River	26	31
5	8A-1 – Northern end of northern area	38	46
6	8D-1 – Northern end of southern area	28	34
7	8M-4 – Southern end of southern area	340	408
8	8K-2 – average area	3	4

The predictive uncertainty analysis was conducted on Scenario 7 (Area 8M-4), as it has the highest predicted inflow during the simulated high flow event. Table 6.2 shows the results of the predictive uncertainty analysis.

Table 6.2 Predictive uncertainty analysis – Area 8M-4 predicted inflow volumes

Uncertainty run #	Model changes	Modelled results (kL)	Scaled volumes (kL/yr)
1	Increase alluvium hydraulic conductivity by 25%	460	552
2	Decrease alluvium hydraulic conductivity by 25%	220	264
3	Increase specific yield to 10%	191	229
4	Decrease specific yield to 2.5%	463	556
5	Alluvium K values up by 25% and Sy down to 2.5%	592	710

The model results show a large range in the predicted inflow volumes, with the predicted inflow volumes for Area 8M-4 ranging from 229 kL/yr to 710 kL/yr, compared to the base case (ie using history-matched parameter values) of 408 kL/yr. For example, a 25% increase in alluvium hydraulic conductivity results in a 35% increase in predicted inflows.

7 Summary

The groundwater model was constructed based on limited regional data, and was history matched on the 3 months of available hydraulic site data. The model will be updated following the collection of 12 months of monitoring data, in June 2021.

Based on preliminary Stage 1 modelling, the project will require an annual licence allocation to cover the peak predicted inflow volume of 410 kL/yr (0.4 ML/yr) for a high flow event (river level up to 64 mAHD). However, based on the uncertainty of the hydraulic conductivities in the area, and potential uncertainty in the geological surfaces used in the model (see below), the inflow volumes may reach 710 kL/yr (0.7 ML/yr).

8 Limitations

Numerical simulation of the hydrogeological regime at the Menangle Sand and Soil Quarry area has limitations that reflect the complexity of the groundwater systems, the influence of the adjacent Nepean River, the scope and timing of the project, data availability and the restrictions imposed by the software. The main limitations are as follows:

- Any faults, bedding planes and fracture/joint planes have not been represented as discrete features due to limitations of available detailed structural and/or hydraulic information related to these potential features. This simplification means that the influence of these heterogeneities (preferential pathways or secondary porosities) is not be captured, which may be locally important in controlling flux distribution.

- Any local mining operations (BHP, South32 and others) are not explicitly simulated. In reality, mine planning and associated dewatering and depressurisation may have changed, which could influence predictions for the Menangle Quarry area.

- The model layers represent the hydrostratigraphy in the area of the Menangle Quarry. These data were collected from the WaterNSW and MinView databases for water drill points and for mine drill data, respectively.

- Model history-matching included site-specific hydraulic head data at Menangle and publicly available data from WaterNSW for the Nepean River weir at Menangle. However, there are information gaps related to bore construction and screened lithological unit for some publicly available data, as such these data are not vetted in terms of accuracy of groundwater elevations.

- The model does not consider backfill operations, however it is planned that the pits will be backfilled to an elevation of 64 mAHD such that they will no longer intercept groundwater during times of high river levels.

- The groundwater model does not simulate the removal of water from the excavation of alluvium material.

- The groundwater model did not simulate all quarry areas, a representative sampling of quarry areas was used to generate a range of potential inflow volumes.

- Potential density-dependent flow is assumed to be negligible in the model. The salinity levels at the site do not warrant that their effects to be simulated.

- Contaminant fate and transport modelling are not part of the modelling scope.

- Simulation of quarry water management is limited to reporting of the amount of the groundwater intercepted from the rise of the Nepean River in active quarrying areas.

- Waste stockpiles and other stockpiles were not simulated.

- Quantification of baseflow or river leakage will not be included as part of history-matching or the modelling of the proposed project.

- Impacts of local climatic or weather variations were not modelled.

- Topography used in the groundwater model is based on a 1 second (~30 m) digital elevation model (DEM) dataset from Geoscience Australia based on Shuttle Radar Topography Mission (SRTM).

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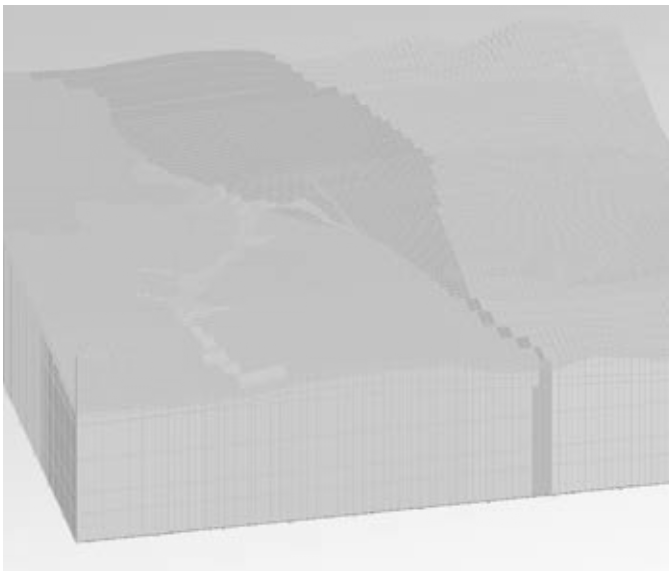
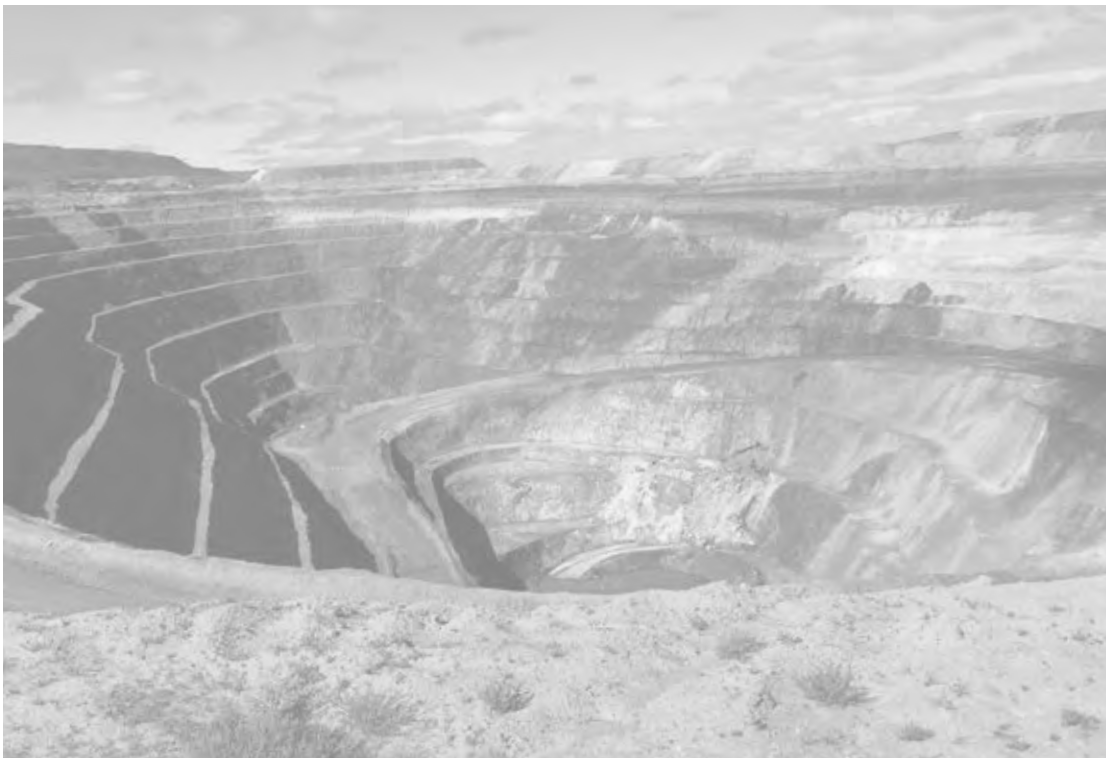
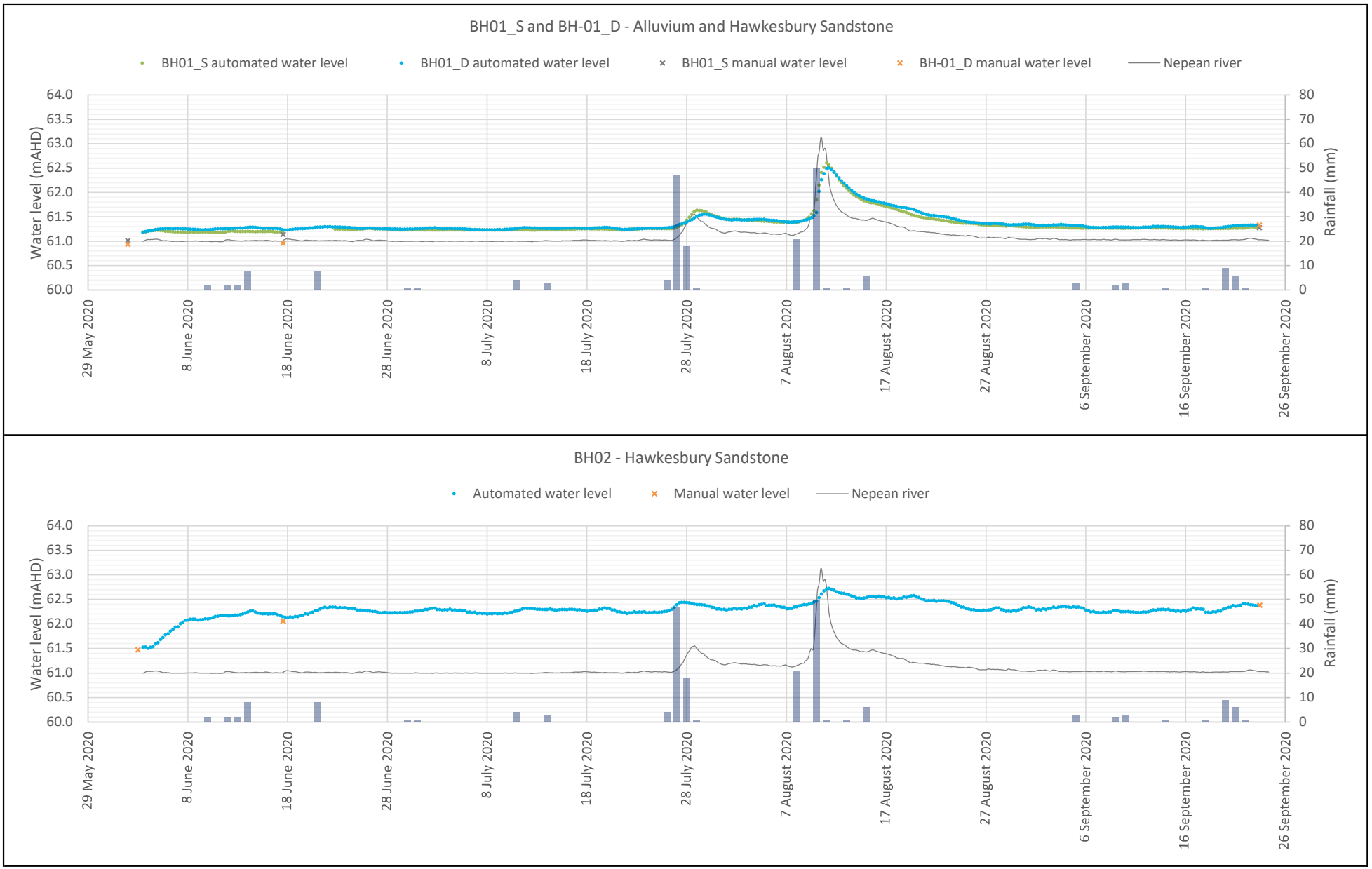
Appendix A

Hydrographs







Notes

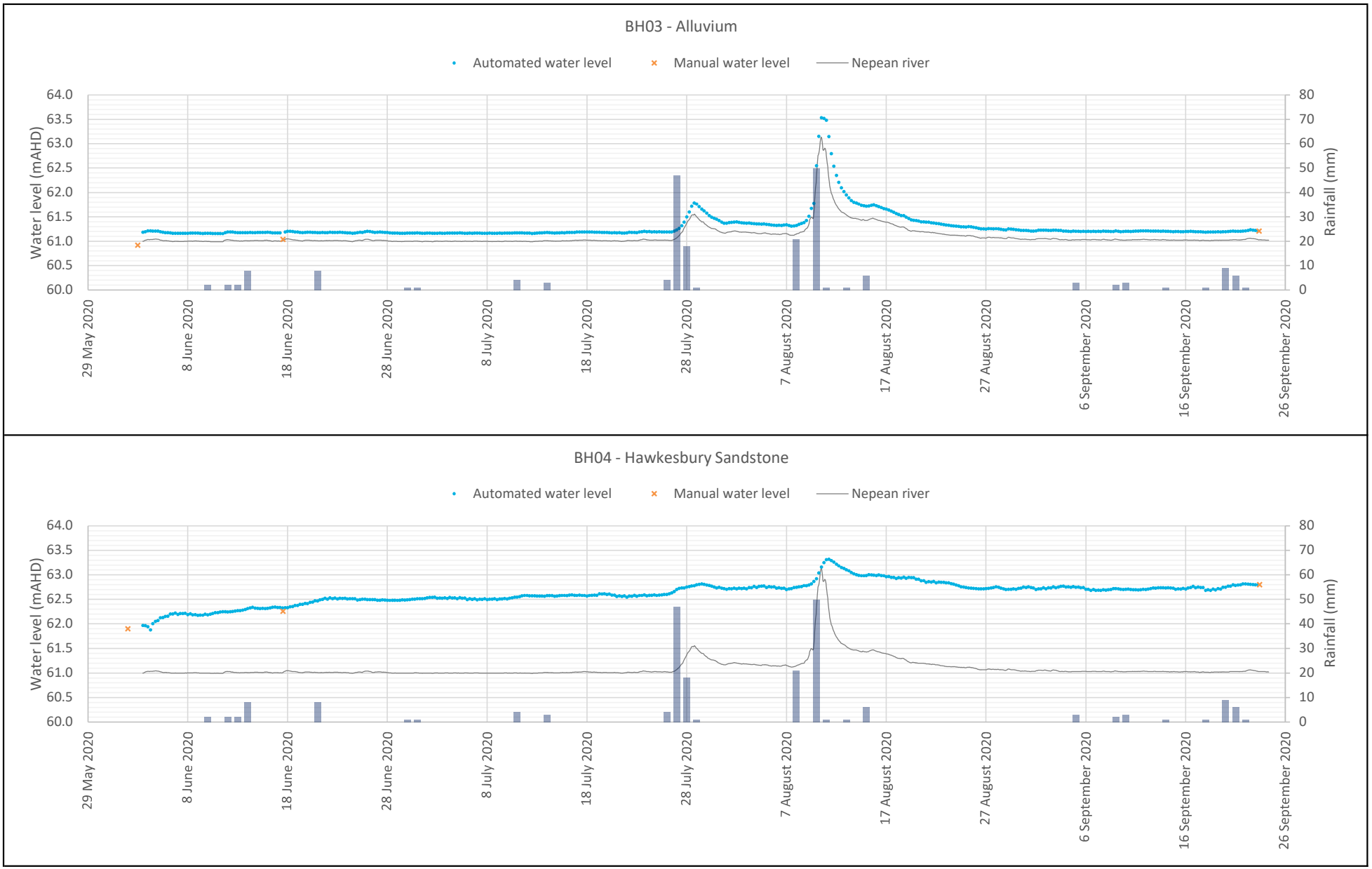
Average hourly river height data accessed from Menangle Weir gauging station, WaterNSW station reference 212238 (https://realtimedata.waternsw.com.au/)

Daily rainfall data accessed from Menangle Bridge monitoring station, BoM reference 68216. (http://www.bom.gov.au/climate/data/)

Water level hydrographs - BH01_S, BH01_D and BH02

Menangle Sand and Soil Pty Ltd

Figure A.1



Notes

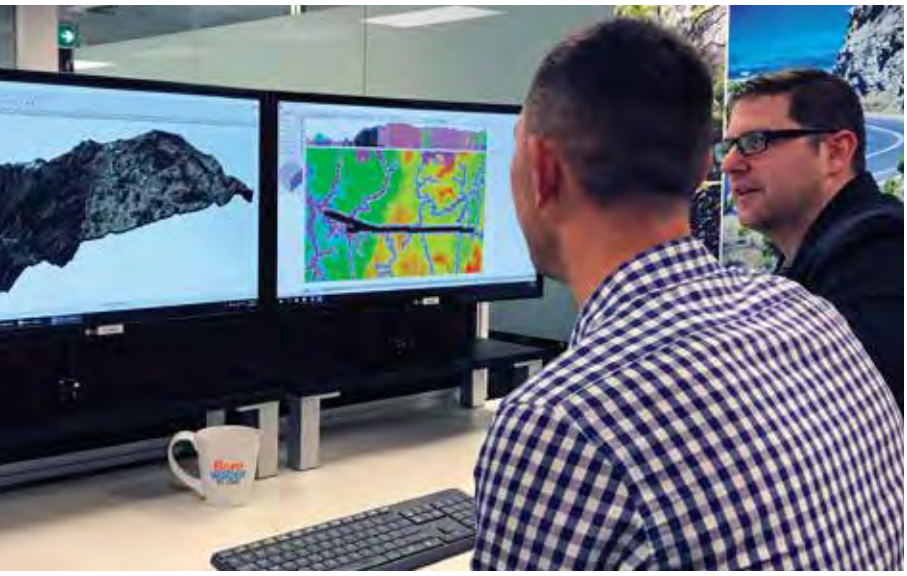
Average hourly river height data accessed from Menangle Weir gauging station, WaterNSW station reference 212238 (https://realtimedata.waternsw.com.au/)

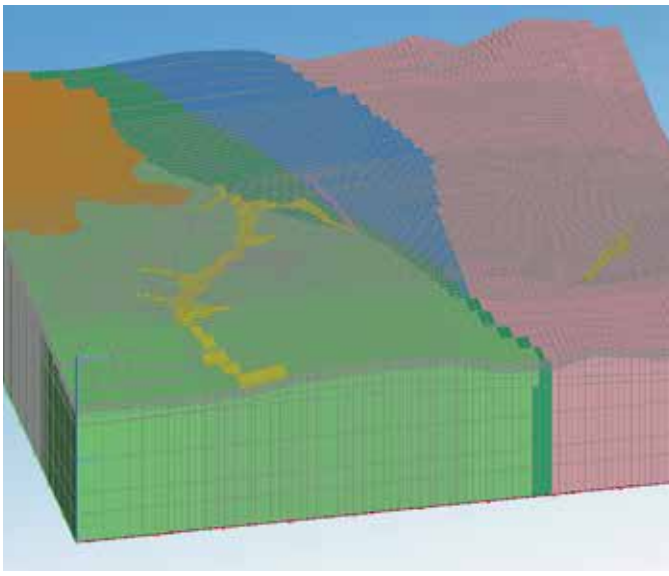
Daily rainfall data accessed from Menangle Bridge monitoring station, BoM reference 68216. (http://www.bom.gov.au/climate/data/)

Water level hydrographs - BH03 and BH04

Menangle Sand and Soil Pty Ltd

Figure A.2





Appendix E

Groundwater Monitoring and Modelling Update - July 2021

Memorandum

23 September 2021

To: Ernest Dupere
Director
Benedict Industries Pty Ltd
From: Henry Noakes
Subject: Groundwater monitoring and modelling update - July 2021

Dear Ernest,

1 Introduction

Menangle Sand and Soil Quarry (the quarry) is located at 15 Menangle Road, Menangle NSW (refer Figure 2.1). The quarry extracts sand and soil along the Nepean River as approved by Development Consent 85/2865 (the Consent), granted by the Minister for Planning on 15 November 1989, and as modified (Modification 1) by the NSW Land and Environment Court in September 2020.

This memorandum presents the June 2021 groundwater monitoring results and subsequent groundwater model/site water balance update. It has been prepared for Menangle Sand and Soil Pty Ltd by EMM Consulting Pty Limited (EMM). It addresses monitoring requirements of the *Menangle Sand and Soil Quarry Soil and Water Management Plan* (SWMP) (EMM 2021a) and conditions B25(b) and B25(c) of the Consent that require Menangle Sand and Soil to:

- update the groundwater model following collection of the first 12 months of data collected from 17 June 2020 to 16 June 2021; and
- incorporate the outputs of the groundwater model into the Site Water Balance as required under condition B36(c)(i) of Schedule 2 [within the conditions].

2 Monitoring

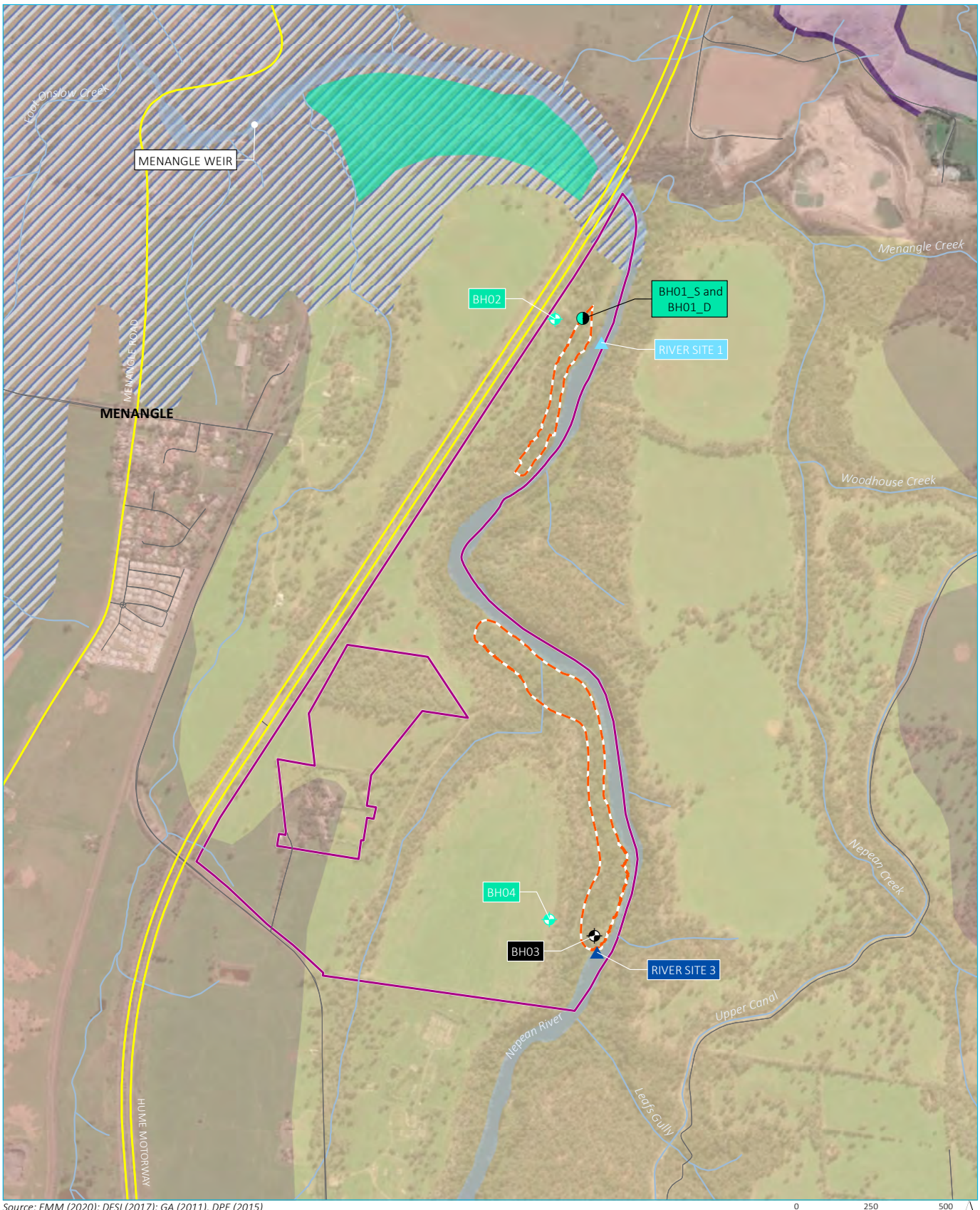
2.1 Fieldwork

The following fieldwork was undertaken on 18 June 2021 in accordance with the SWMP, Section 6: Groundwater management (refer Figure 2.1):

- manual groundwater level measurement (dip) and download of automated groundwater level loggers (loggers) at five groundwater monitoring bores (BH01_S, BH01_D, BH02, BH03 and BH04);
- collection of water samples in five bores (BH01_S, BH01_D, BH02, BH03 and BH04) and two surface water sites, within the adjacent Nepean River (River site 1 and River site 3) to:
    - assess physico-chemical parameters (temperature, pH, electrical conductivity, total dissolved solids, reduction potential and dissolved oxygen) using a calibrated YSI water quality meter; and
    - submit to a NATA accredited laboratory for analytical testing suites, comprising:

- general water quality (pH, electrical conductivity[EC], total dissolved solids, hardness and alkalinity); and
- major ions (calcium, chloride, fluoride, sodium, magnesium, potassium, sulfate and an ionic balance).

At the time of the fieldworks (18 June 2021), quarrying activities had not begun within the Stage 8 extraction area (refer Figure 2.1).



Source: EMM (2020); DFSI (2017); GA (2011), DPE (2015)

0 250 500 m

GDA 1994 MGA Zone 56

N

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KEY

- Study area
- Menangle Quarry - Stage 7
- Proposed extraction area
- Main road
- Local road
- Watercourse/drainage line
- Named waterbody

Location Type

- Borehole - alluvium
- Borehole - sandstone
- Borehole - alluvium & sandstone
- Surface water quality
- Surface water quality and level

Surface geology

- Alluvium
- Ashfield shale
- Bringelly shale
- Hawkesbury sandstone
- Minchinbury sandstone

Monitoring bore locations

Menangle Quarry Extension
Groundwater monitoring and modelling update - July 2021
Figure 2.1

EMM creating opportunities

2.2 Groundwater level

A summary of groundwater dips and groundwater level trigger values (EMM 2021a) is provided in Table 2.1. Time series data of the groundwater level in each bore is provided in Figure 2.2–Figure 2.3.

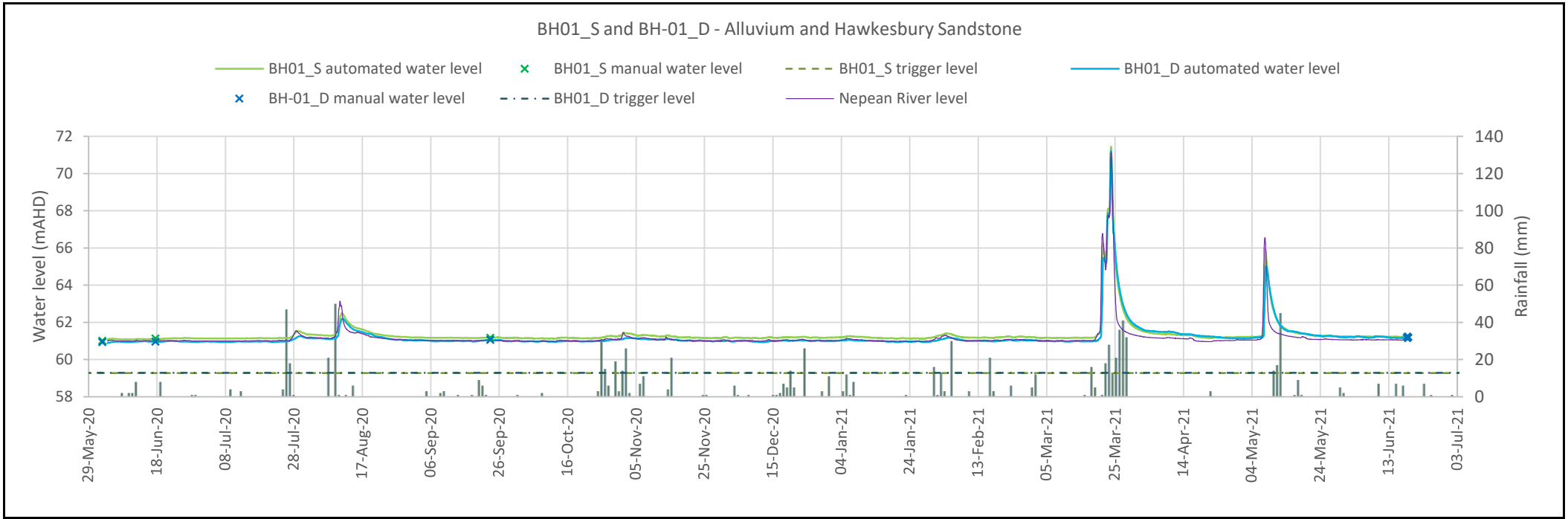
Table 2.1 Groundwater levels

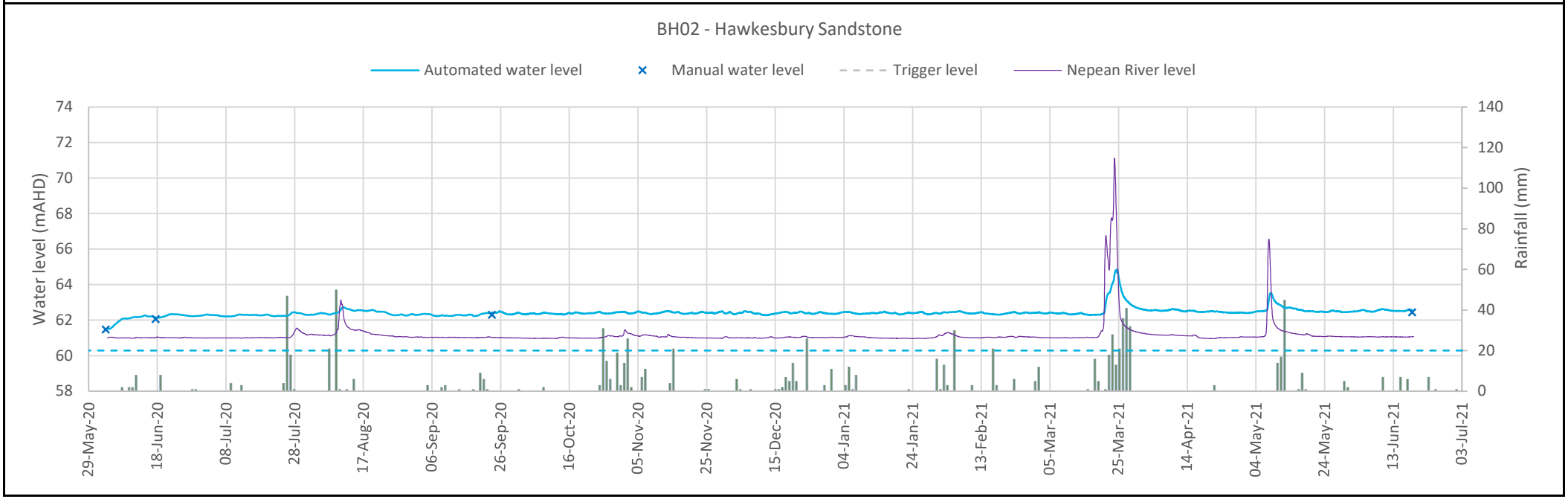
Bore ID	Screened lithology	Groundwater level (18 June 2021)		[3]Groundwater low level trigger value	Exceedance
		[1]mbtoc	[2]mAHD	[2]mAHD	
BH01_S	Alluvium	5.52	61.22	59.27	No
BH01_D	Hawkesbury Sandstone	5.84	61.20	59.29	No
BH02	Hawkesbury Sandstone	25.18	62.44	60.29	No
BH03	Alluvium	4.56	61.15	59.2	No
BH04	Hawkesbury Sandstone	42.70	63.22	60.7	No

1. metres below top of casing (mbtoc);
2. metres above Australian Height Datum;
3. (EMM 2021b)

There was a flood event on 23 March 2021 (to a maximum level of 71.122 m at Menangle Weir). It appears that the barometric data logger (barologger) was inundated from 22 to 24 March 2021. Evidence of flooding above the barologger was noted by field staff (flood debris, fallen timber, rubbish, sediment build-up and broken foliage). Barometric data during this period is considered unreliable and has been inferred from historical data. The barologger appears to be fully functioning following 24 March 2021.

No groundwater level exceedances were observed over the monitoring period (3 June 2020–18 June 2021).





Notes

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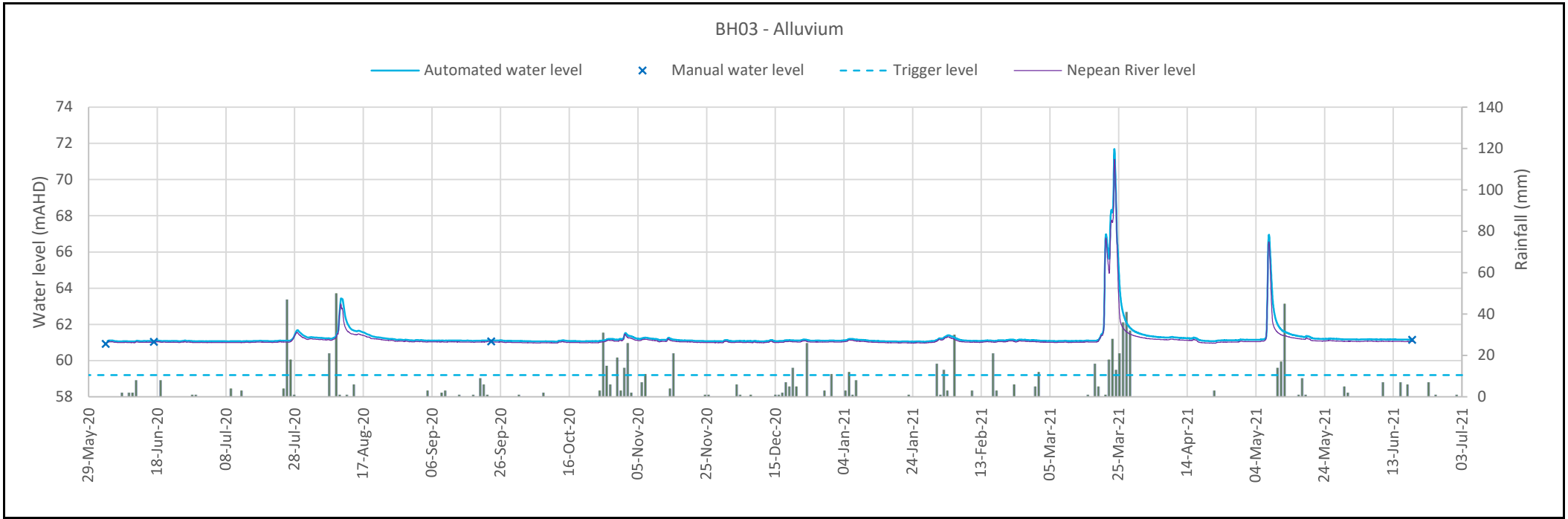
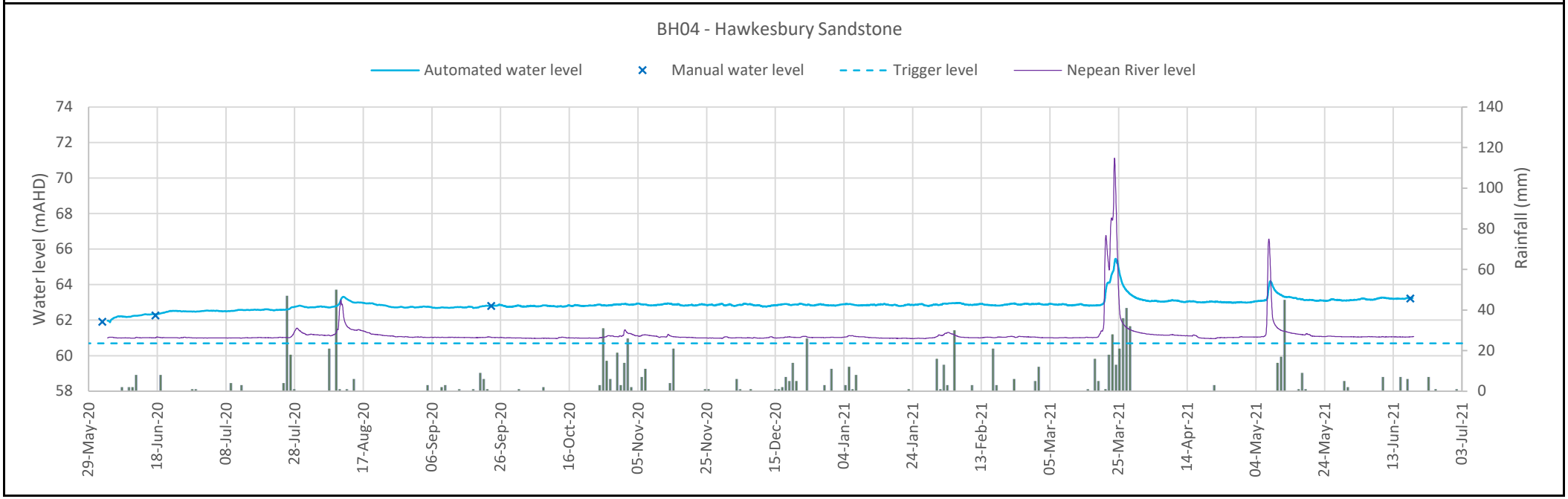
Daily rainfall data accessed from Menangle Bridge monitoring station, BoM reference 68216. (http://www.bom.gov.au/climate/data/)

Time series data - BH01_S, BH01_D and BH02

Menangle Sand and Soil Pty Ltd

Figure 2.2





Notes

Average hourly river height data accessed from Menangle Weir gauging station, WaterNSW station reference 212238 (https://realtimedata.waternsw.com.au/)

Daily rainfall data accessed from Menangle Bridge monitoring station, BoM reference 68216. (http://www.bom.gov.au/climate/data/)

Time series data - BH03 and BH04

Menangle Sand and Soil Pty Ltd

Figure 2.3

2.3 Groundwater sampling

Groundwater sampling was undertaken by a suitably qualified and experienced EMM hydrogeologist, using either a 'Micro-purge' low flow bladder pump (BH01_S and BH01_D) or stainless-steel bailer (BH02, BH03 and BH04). Sampling was undertaken in general accordance with:

- Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (DEC 2004); and
- Australia/New Zealand Standard AS/NZS 5667.11:1998 Water Quality – Sampling, Part 11: Guidance on Sampling of Groundwaters (Standards Australia 1998).

A summary of groundwater pH and EC is provided in Table 2.2 with associated trigger values (EMM 2021a), exceedances have been highlighted. Laboratory certificates of analysis are attached as Appendix B. Field sampling records are attached as Appendix C.

Table 2.2 Groundwater pH and EC summary (including trigger values)

Site ID	Screened lithology	EC trigger value[1] (µS/cm)		EC June 2021 (µS/cm)		pH trigger value		pH June 2021	
		Lower limit	Upper limit	Field	Laboratory	Lower limit	Upper limit	Field	Laboratory
BH01_S	Alluvium	125	2,500	227.2	218.0	6.5	8.0	**5.23**	**6.03**
BH01_D	Hawkesbury Sandstone	125	3,000	1,217.0	1,310.0	6.5	8.0	6.62	7.35
BH02	Hawkesbury Sandstone	125	10,000	7,091.0	8,230.0	6.5	8.5	**5.80**	6.61
BH03	Alluvium	125	2,500	314.1	141.0	6.5	8.0	**5.73**	**5.90**
BH04	Hawkesbury Sandstone	125	12,000	6,864.0	8,460.0	6.5	8.5	6.52	7.42

Notes: 1. (EMM 2021a)

Results indicate groundwater is typically acidic (with the exception of laboratory pH results at BH01_D [pH 7.35] and BH04 [pH 7.42]). Field pH results in BH01_S, BH02 and BH03 were below the lower limit trigger level. Laboratory pH results exceeded lower trigger values in BH01_S and BH03 however, did not exceed in BH02. In accordance with Table 6.6 of the SWMP (EMM 2021a), groundwater quality data will continue to be monitored and assessed.

Higher EC is noted in the Hawkesbury Sandstone (marginal salinity in BH01_D to slightly saline in BH04) compared to the alluvium (fresh in both BH01_S and BH03). No EC trigger value exceedances were recorded in the June 2021 monitoring event.

An obstruction was encountered in BH03, approximately 7 metres below top of casing (mbTOC). A groundwater sample could not be obtained from within the screen interval at BH03 (20–23 mbTOC), in accordance with recommendations provided by *Water quality - Sampling, Part 11: Guidance on Sampling of Groundwaters* Standards Australia (1998). A grab sample was recovered from approximately 6–7 mbTOC and is considered representative; however, BH03 will be assessed during the next site visit using smaller diameter sample equipment.

A summary of groundwater major ion results is provided in Table 2.2. Additional water sampling results are attached as Appendix A. Laboratory certificates of analysis are attached as Appendix B.

Table 2.3 Groundwater major ion summary

Site ID	Screened lithology	Hardness (mg/L)	Alkalinity (mg/L)	Calcium (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Sodium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sulfate (mg/L)	Cations (meq/L)	Anions (meq/L)	Ionic balance (%)
BH01_S	Alluvium	38	30	7	29	<0.1	28	5	<1	30	1.98	2.04	-
BH01_D	Hawkesbury Sandstone	130	322	34	172	0.4	210	11	6	120	11.9	13.8	7.38
BH02	Hawkesbury Sandstone	1,140	392	151	2,700	0.6	1,200	185	12	389	75.3	92.1	10.0
BH03	Alluvium	40	8	11	24	<0.1	16	3	2	17	1.54	1.19	-
BH04	Hawkesbury Sandstone	1,180	454	110	2,700	0.4	1,160	219	32	300	74.8	91.5	10.0

3 Groundwater model update

3.1 Groundwater model and site water balance update

A preliminary groundwater model was constructed in March 2021 (EMM 2021b) in accordance with conditions B24 and B25(a) of the Consent:

- using a variant of MODFLOW standard software, or equivalent software, to quantify the progressive takes from water sources during Quarrying Operations in the Stage 8 area (Figure 2.1); and
- using the first three months of groundwater monitoring data.

The initial modelling, employing a subjective uncertainty analysis approach, predicted annual groundwater interception to range up to 0.7 ML/year from within the Sydney Basin Nepean Groundwater Source (Management Zone 2).

In order to perform a validation of the existing numerical groundwater model, built using MODFLOW-USG (Panday et al 2013) and Groundwater Vistas 7 (ESI 2017), an extension to the history-matching period was made. The extended model stress period setup and stages assigned to the River (RIV) package boundary conditions used to simulate the Nepean River (based on Menangle Weir station 212238) are presented in Table 3.1 and Figure 3.1.

Table 3.1 Stress periods and river representation

Stress period/s	Date range	Duration (d)	River stage (mAHD)	Description
1	n/a	Steady state	61.009	Initialisation
2	3 Jun 2020 (12:00) to 26 Jul 2020 (12:00)	53	61.009	Steady river
3–5	26 Jul 2020 (12:00) to 28 Jul 2020 (12:00)	0.6667 (each)	61.053, 61.194, 61.428	Rising river
6	28 Jul 2020 (12:00) to 28 Jul 2020 (24:00)	0.5	61.538	Steady river (peak)
7-9	28 Jul 2020 (24:00) to 31 Jul 2020 (24:00)	1 (each)	61.405, 61.271, 61.185	Falling river
10	31 Jul 2020 (24:00) to 8 Aug 2020 (06:00)	7.25	61.165	Steady river
11–13	8 Aug 2020 (06:00) to 10 Aug 2020 (12:00)	0.708 (each)	61.203, 61.4, 62.359	Rising river
14	10 Aug 2020 (12:00) to 10 Aug 2020 (14:00)	0.1667	63.118	Steady river (peak)
15–17	10 Aug 2020 (14:00) to 14 Aug 2020 (14:00)	1.333 (each)	62.373, 61.614, 61.465	Rapidly falling river
18–19	14 Aug 2020 (14:00) to 28 Aug 2020 (14:00)	7 (each)	61.318, 61.109	Slowly falling river
20	28 Aug 2020 (14:00) to 23 Sep 2020 (14:00)	26.25	61.034	Steady river
21	23 Sep 2020 (19:00) to 23 Oct 2020 (19:00)	30	60.996	Steady river
22	23 Oct 2020 (19:00) to 28 Oct 2020 (19:00)	5	61.059	Rising river
23	28 Oct 2020 (19:00) to 31 Oct 2020 (19:00)	3	61.092	Rising river
24-25	31 Oct 2020 (19:00) to 2 Nov 2020 (19:00)	1 (each)	61.370, 61.261	Steady river (peak)
26	2 Nov 2020 (19:00) to 4 Nov 2020 (19:00)	2	61.170	Falling river
27	4 Nov 2020 (19:00) to 7 Nov 2020 (19:00)	3	61.142	Falling river
28	7 Nov 2020 (19:00) to 11 Nov 2020 (19:00)	4	61.100	Falling river
29	11 Nov 2020 (19:00) to 16 Nov 2020 (19:00)	5	61.083	Steady river
30	16 Nov 2020 (19:00) to 26 Nov 2020 (19:00)	10	61.014	Steady river
31	26 Nov 2020 (19:00) to 26 Dec 2020 (19:00)	30	61.018	Steady river
32	26 Dec 2020 (19:00) to 15 Jan 2021 (19:00)	20	61.040	Steady river

Table 3.1 Stress periods and river representation

Stress period/s	Date range	Duration (d)	River stage (mAHD)	Description
33	15 Jan 2021 (19:00) to 30 Jan 2021 (19:00)	15	60.984	Steady river
34-35	30 Jan 2021 (19:00) to 3 Feb 2021 (19:00)	2 (each)	61.128, 61.258	Rising river
36	3 Feb 2021 (19:00) to 4 Feb 2021 (19:00)	1	61.236	Steady river (peak)
37-38	4 Feb 2021 (19:00) to 8 Feb 2021 (19:00)	2 (each)	61.119, 61.035	Falling river
39	8 Feb 2021 (19:00) to 13 Feb 2021 (19:00)	5	61.015	Steady river
40	13 Feb 2021 (19:00) to 28 Feb 2021 (19:00)	15	61.051	Steady river
41	28 Feb 2021 (19:00) to 17 Mar 2021 (19:00)	17	61.015	Steady river
42	17 Mar 2021 (19:00) to 19 Mar 2021 (19:00)	2	61.089	Steady river
43	19 Mar 2021 (19:00) to 20 Mar 2021 (19:00)	1	61.542	Rising river
44–46	20 Mar 2021 (19:00) to 21 Mar 2021 (13:00)	0.25 (each)	64.441, 66.491, 66.560	Rising river
47–54	21 Mar 2021 (13:00) to 25 Mar 2021 (13:00)	0.5 (each)	65.639, 65.206, 67.475, 67.866, 70.559, 68.148,64.671, 62.582	Rising river, falling river
55	25 Mar 2021 (13:00) to 26 Mar 2021 (13:00)	1	61.896	Falling river
56	26 Mar 2021 (13:00) to 28 Mar 2021 (13:00)	2	61.564	Falling river
57	28 Mar 2021 (13:00) to 2 Apr 2021 (13:00)	5	61.309	Falling river
58	2 Apr 2021 (13:00) to 12 Apr 2021 (13:00)	10	61.167	Steady river
59	12 Apr 2021 (13:00) to 6 May 2021 (13:00)	24	61.041	Steady river
60	6 May 2021 (13:00) to 7 May 2021 (01:00)	0.5	61.202	Rising river
61–69	7 May 2021 (01:00) to 9 May 2021 (07:00)	0.25 (each)	62.281, 64.731, 66.435, 66.217, 65.023, 63.652, 62.577, 62.067, 61.892	Rising river, falling river
70	9 May 2021 (07:00) to 9 May 2021 (19:00)	0.5	61.742	Falling river
71	9 May 2021 (19:00) to 10 May 2021 (19:00)	1	61.564	Falling river
72	10 May 2021 (19:00) to 12 May 2021 (19:00)	2	61.404	Falling river
73	12 May 2021 (19:00) to 17 May 2021 (19:00)	5	61.248	Falling river
74	17 May 2021 (19:00) to 27 May 2021 (19:00)	10	61.113	Steady river
75	27 May 2021 (19:00) to 16 Jun 2021 (19:00)	20	61.061	Steady river

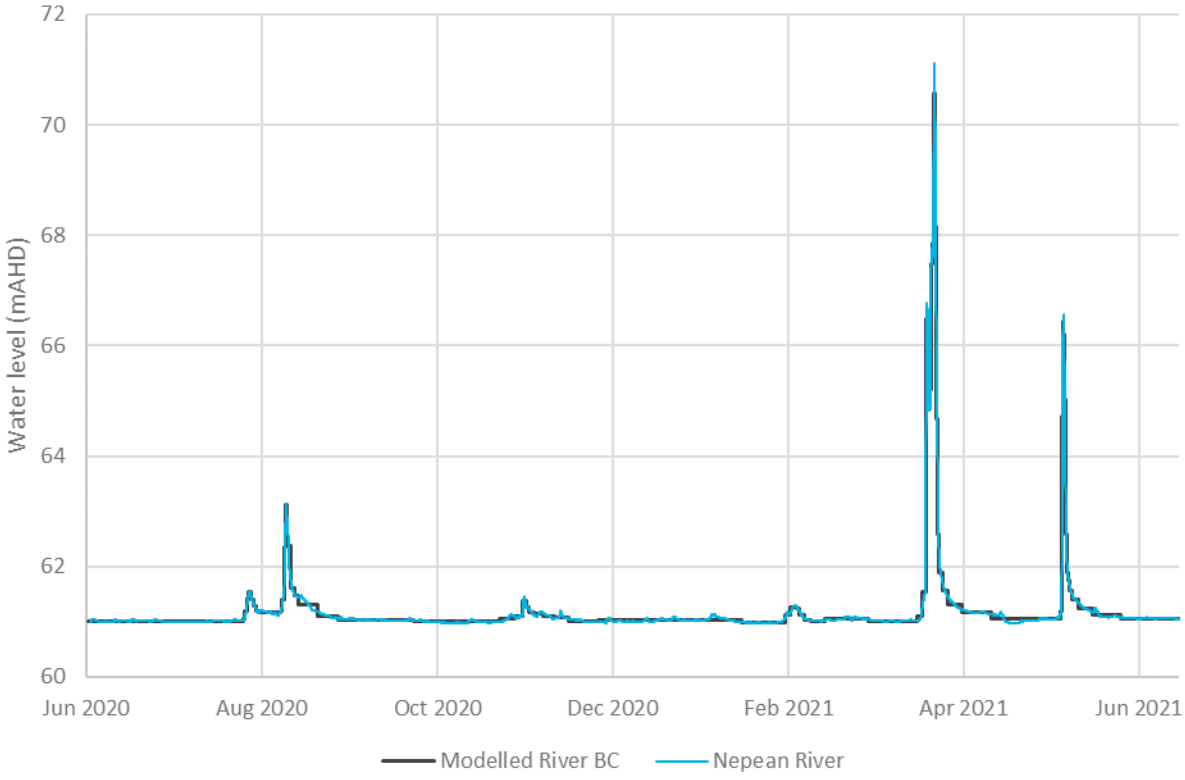


Figure 3.1 Modelled and measured Nepean River stage

3.2 Validation Performance

The history-matching performance of the groundwater model over the extended historical validation period was evaluated statistically and by comparing dynamic trends of modelled and measured groundwater responses.

Statistical measures of the match between modelled and measured groundwater responses over the initial calibration periods (~3.5 months of groundwater monitoring) and the extended validation period (~12 months of groundwater monitoring) are provided in Table 3.2.

Figure 3.2 presents modelled and measured hydraulic head at the site groundwater monitoring bores (BH01–BH04). Figure 3.3 illustrates these same data when converted to drawdown relative to the pseudo steady state period, inferred from the first ~1.5 months of groundwater monitoring, during which there were no significant rises in Nepean River level.

Overall, history-matching to the extended 12-month historical dataset is similar to the performance of the initial calibration over 3.5 months. The very high river level events of early 2021 did lead to an increase in the largest residuals between modelled and measured values, but these events likely involved overtopping of the river-bank which is not represented by the model. Normalised statistical measures of performance for both head and drawdown are improved with the 12-month dataset relative to the first 3.5 months. The trends in modelled responses to high river level events, presented in the hydrographs in Figure 3.2 and Figure 3.3, closely match those measured.

Table 3.2 History-matching statistics

Measure	~3.5 months of monitoring	~12 months of monitoring
SRMS (head)	22.7%	7.5%
SRMS (drawdown)	4.6%	3.0%
Average residual (head)	0.42 m	0.51 m
Average absolute residual (head)	0.42 m	0.55 m
Average residual (drawdown)	0.017 m	0.006 m
Average absolute residual (drawdown)	0.058 m	0.134 m

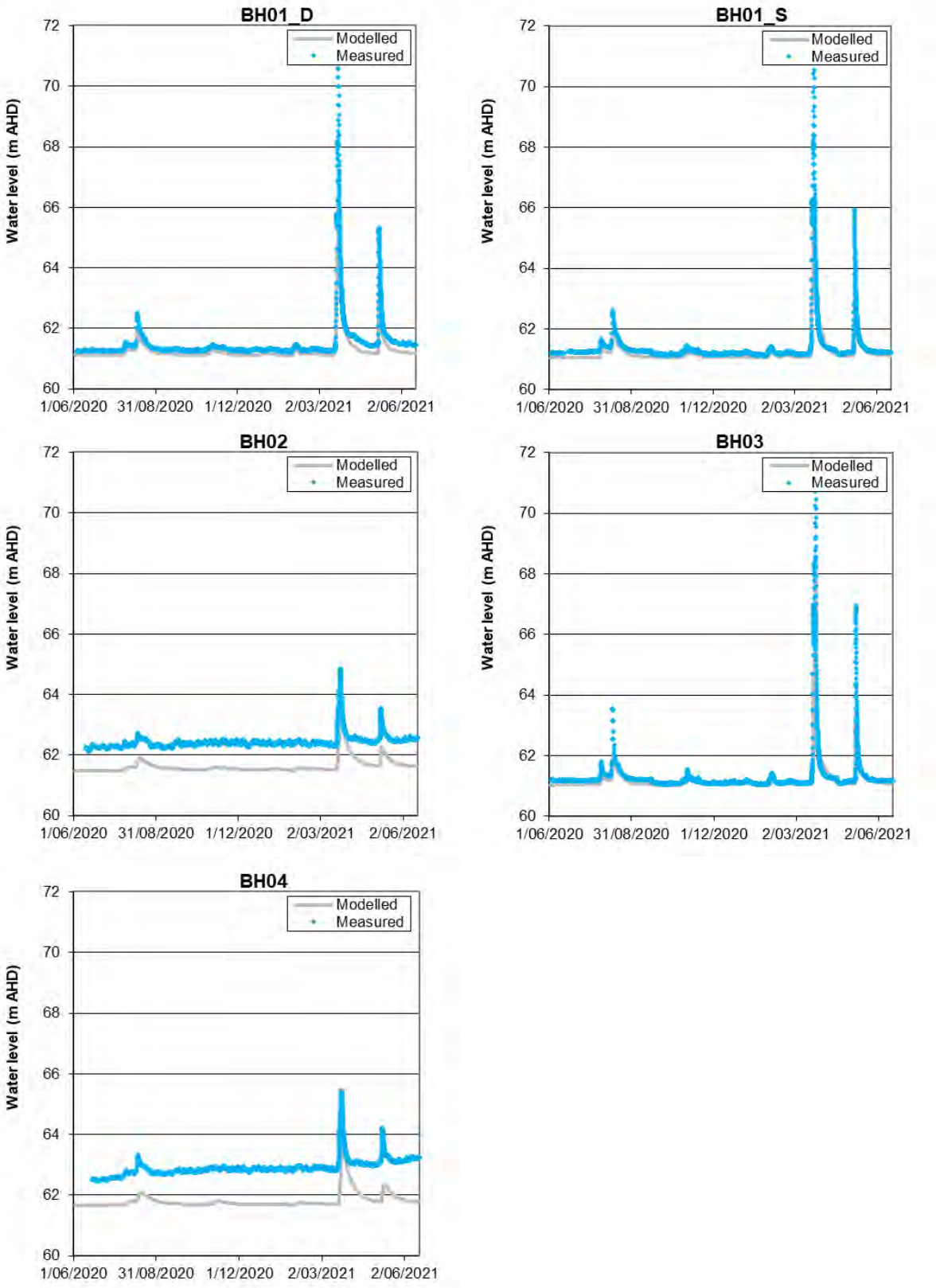


Figure 3.2 **Modelled and measured hydraulic head over the history-matching period**

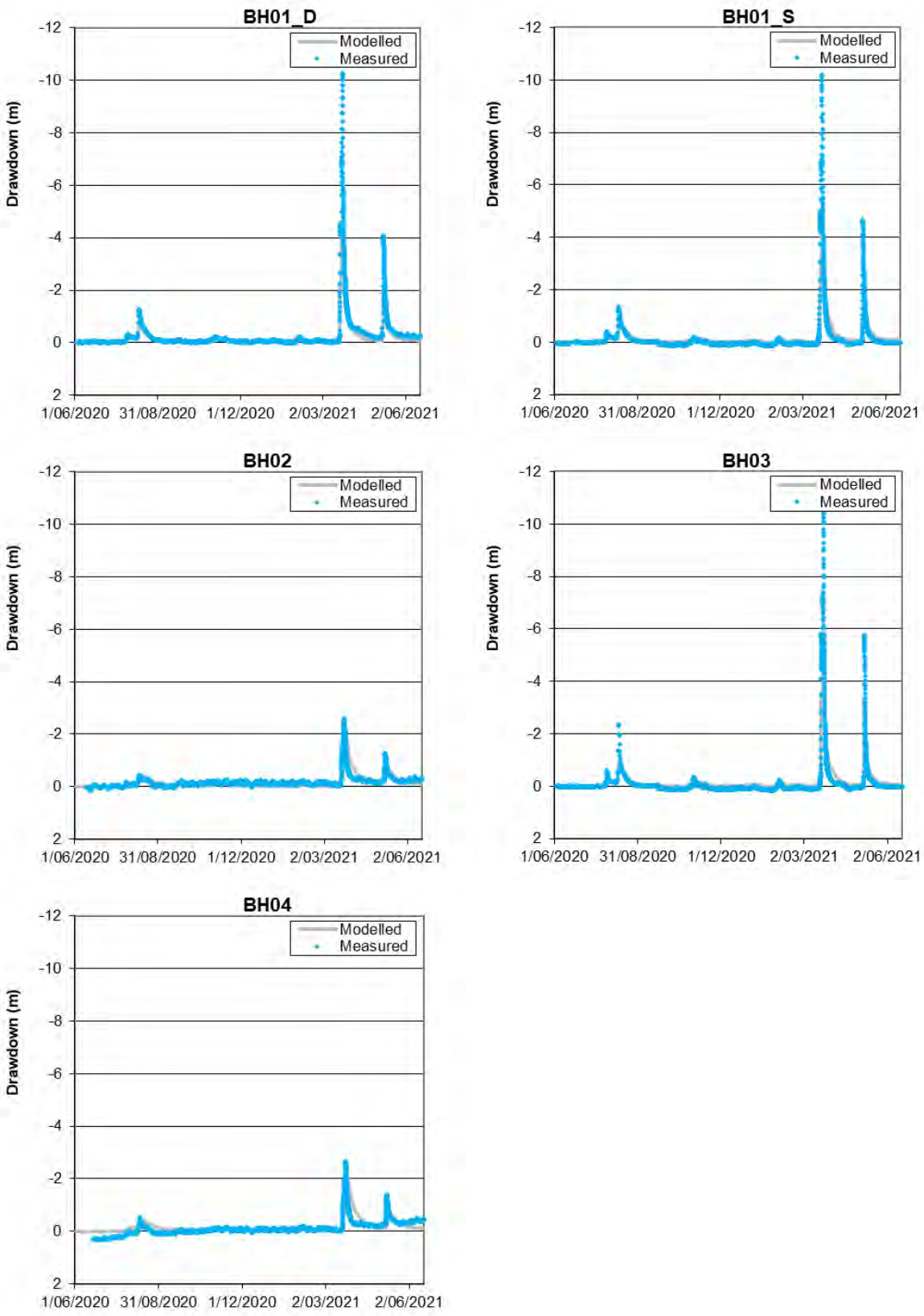


Figure 3.3 **Modelled and measured groundwater drawdown over the history-matching period**

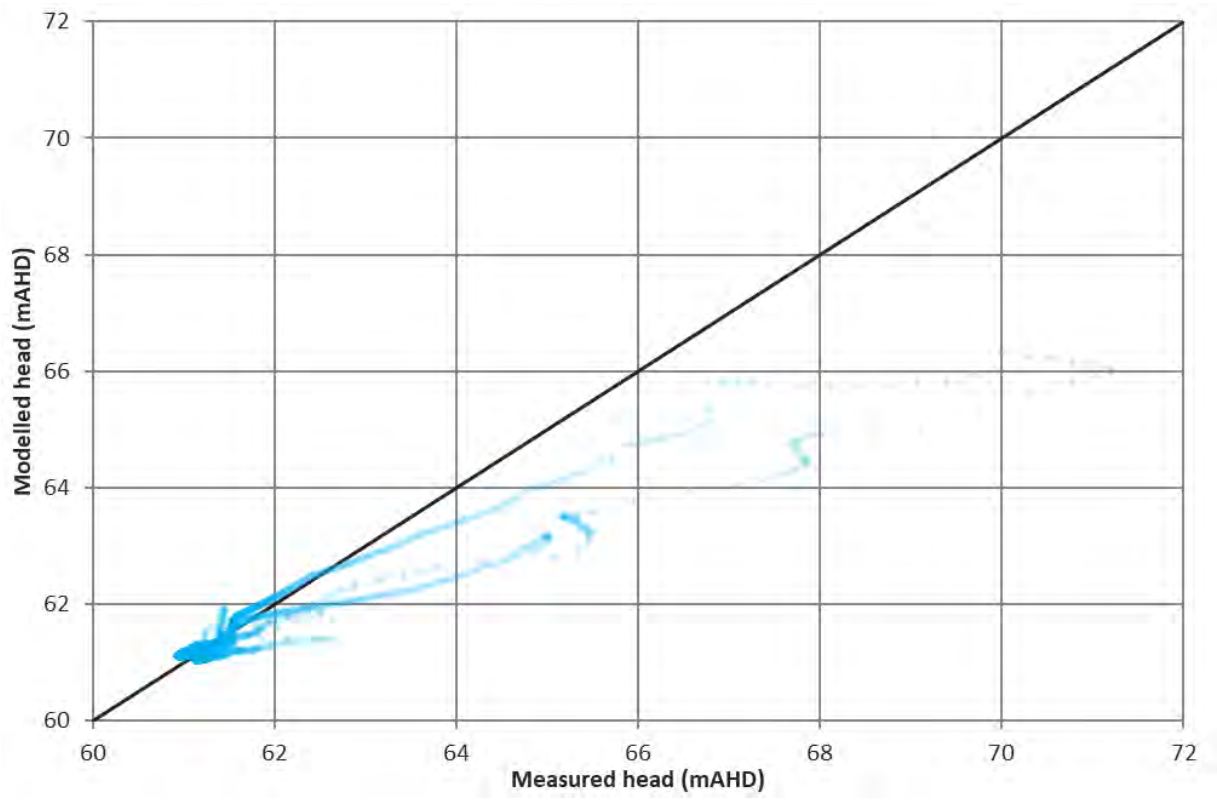


Figure 3.4 Scatter plot of modelled versus measured hydraulic head

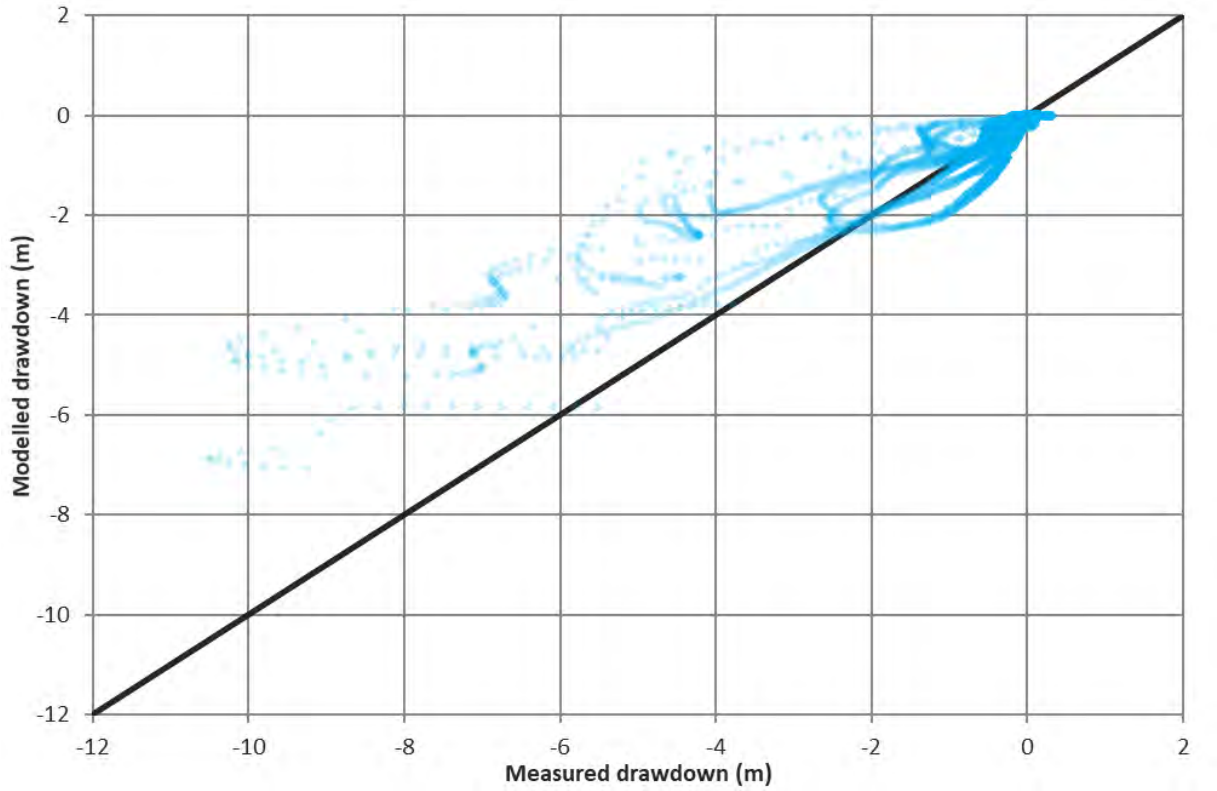


Figure 3.5 Scatter plot of modelled versus measured drawdown

3.3 Summary

The initial 3.5-month groundwater monitoring dataset from five monitoring locations used to calibrate the numerical groundwater model has been extended to 12 months. Extension of the numerical model simulation period and comparison of model results against measured groundwater responses over the 12 months of groundwater monitoring have validated the model. Therefore, the modelling presented in EMM (2021), including maximum predicted groundwater interception of 0.4 ML/yr for the base case and 0.7 ML/yr from the uncertainty analysis, are deemed to be valid. Given the performance of the model over the extended monitoring period, and its inclusion of high river levels relevant to the objective of licensing groundwater interception by pit voids, no further update to the modelling is recommended.

4 Site water balance model update

As summarised in Section 3.3, the modelled groundwater inflows presented in Section 5.3 of the SWMP are considered applicable and no update to the 'Groundwater inflow to Stage 8 area' component of site water balance model is required. The relevant site water balance model is re-produced from the SWMP in Table 4.1.

Table 4.1 Summary of site water balance results

Water management component	Typical dry year (ML/year)	Median rainfall year (ML/year)	Typical wet year (ML/year)
Annual rainfall (mm/year)	443	730	916
Inputs			
Direct rainfall onto storages and catchment runoff	27	49	73
Nepean River water supply	116	90	82
Groundwater inflow to Stage 8 area	0.7	0.7	0.7
Total inputs	**144**	**140**	**156**
Outputs			
Evaporation	16	13	14
Infiltration (infiltration area, seepage from Stage 8 area)	10	19	28
Process water (dust suppression, timber plant, truck washdown)	86	76[1]	77
Water lost in product (wash water)	33	33[2]	33
Overflows from processing area	0	0	2
Total outputs	**145**	**141**	**154**
Change is storage	-1	-1	2
Balance (inputs – outputs – change in storage)	**0**	**0**	**0**

1. See Table 5.3 (EMM 2021a): dust suppression + timber plant + truck washdown = 77 ML/year, with rounding difference
2. See Table 5.3 (EMM 2021a): washing = 33 ML/year

5 Closing

This letter describes updates to the groundwater model following collection of the first 12 months of data collected and the site water balance, thereby addressing the requirements of Conditions B25(b) and B25(c) of the Consent. The predicted groundwater interception is unchanged and no changes to the site water balance are required.

Yours sincerely

Henry Noakes
Senior Hydrogeologist
hnoakes@emmconsulting.com.au

6 References

Australia/New Zealand Standard AS/NZS 5667.11:1998 *Water Quality – Sampling – Part 11, Guidance on Sampling of Groundwaters* (1998).

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Appendix A

Groundwater quality results

				Location Code	BH01_D		BH01_S		BH02		BH03		BH04		River Site 1		River Site 3	
				Date	2/06/2020	18/06/2021	29/05/2020	18/06/2021	29/05/2020	18/06/2021	2/06/2020	18/06/2021	29/05/2020	18/06/2021	29/05/2020	18/06/2021	29/05/2020	18/06/2021
				Lab Report Number	ES2019091	ES2123005	ES2018927	ES2123005	ES2018927	ES2123005	ES2019091	ES2123005	ES2018927	ES2123005	ES2018927	-	ES2018927	-
		Units	LOR	Water type (GW / SW)	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	SW	SW	SW	SW
Analytical results – general	Temperature (Field)	(°C)	1		17.0	18.2	18.5	18.3	15.2	18.7	15.0	17.8	14.3	17.1	15.5	11.6	14.8	11.9
	Hardness as $CaCO_3$ (filtered)	mg/L	1		260	130	278	38	1,180	1,140	383	40	1,970	1,180	26	-	33	-
	Electrical Conductivity (Field)	(µs/cm)	-		2150.0	1217.0	1137.0	227.2	8732.0	7091.0	2101.0	314.1	10355.0	6864.0	195.2	165.8	264.9	160.5
	Electrical Conductivity (Lab)	µS/cm	1		2,730	1,310	1,370	218	9,840	8,230	2,640	141	12,000	8,460	228	-	308	-
	pH (Field)	-	-		6.90	6.62	6.72	5.23	8.38	5.80	7.32	5.73	8.43	6.52	7.25	8.01	7.22	6.36
	pH (Lab)	-	0.01		6.85	7.35	6.45	6.03	8.04	6.61	7.65	5.90	8.11	7.42	7.79	-	7.88	-
	Dissolved oxygen (% saturation - Field)	mg/L	-		51.1	6.9	92.4	4.5	165.9	15.8	126.7	55.1	143.2	32.6	112.0	93.4	127.6	99.0
	Oxidation reduction potential (Field)	mg/L	-		153.1	-84.4	39.9	30.0	50.2	-78.0	135.7	30.4	94.5	-64.7	25.6	-37.7	74.8	23.6
	Total Dissolved Solids (Field)	mg/L	-		-	793.00	-	147.55	-	4608.50	-	204.10	-	4465.50	-	107.90	-	104.00
	Total Dissolved Solids (Calc.)	mg/L	1		1,770	852	890	142	6,400	5,350	1,720	92	7,800	5,500	148	-	200	-
Analytical results – alkalinity	Alkalinity (Bicarbonate as $CaCO_3$)	mg/L	1		228	322	8	30	318	392	32	8	567	454	52	-	82	-
	Alkalinity (Carbonate as $CaCO_3$)	mg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	<1	-
	Alkalinity (Hydroxide) as $CaCO_3$	mg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	<1	-
	Alkalinity (total) as $CaCO_3$	mg/L	1		228	322	8	30	318	392	32	8	567	454	52	-	82	-
Inorganics	Calcium (filtered)	mg/L	1		43	34	42	7	142	151	20	11	172	110	4	-	5	-
	Chloride	mg/L	1		732	172	462	29	2,880	2,700	893	24	4,050	2,700	35	-	43	-
	Fluoride	mg/L	0.1		<0.1	0.4	<0.1	<0.1	0.8	0.6	0.1	<0.1	0.6	0.4	<0.1	-	<0.1	-
	Sodium (filtered)	mg/L	1		450	210	138	28	1,650	1,200	348	16	1,840	1,160	34	-	47	-
	Magnesium (filtered)	mg/L	1		37	11	42	5	201	185	81	3	374	219	4	-	5	-
	Potassium (filtered)	mg/L	1		5	6	2	<1	15	12	3	2	31	32	3	-	4	-
	Anions Total	meq/L	0.01		29.7	13.8	13.4	2.04	104	92.1	26.8	1.19	138	91.5	2.15	-	3.08	-
	Ionic Balance	%	0.01		8.77	7.38	7.33	-	3.93	10.0	7.99	-	6.82	10.0	-	-	-	-
	Cations Total	meq/L	0.01		24.9	11.9	11.6	1.98	95.8	75.3	22.9	1.54	120	74.8	2.08	-	2.81	-
	Sulfate as SO_4 - Turbidimetric (filtered)	mg/L	1		215	120	12	30	770	389	49	17	587	300	6	-	11	-
Metals	Arsenic (filtered)	mg/L	0.001		<0.001	-	<0.001	-	0.001	-	<0.001	-	0.003	-	<0.001	-	<0.001	-
	Cadmium (filtered)	mg/L	0.0001		<0.0001	-	<0.0001	-	<0.0001	-	<0.0001	-	<0.0001	-	<0.0001	-	<0.0001	-
	Chromium (III+VI) (filtered)	mg/L	0.001		<0.001	-	<0.001	-	<0.001	-	<0.001	-	<0.001	-	<0.001	-	<0.001	-
	Copper (filtered)	mg/L	0.001		<0.001	-	<0.001	-	0.004	-	<0.001	-	0.006	-	0.017	-	<0.001	-
	Iron (filtered)	mg/L	0.05		<0.05	-	<0.05	-	<0.05	-	<0.05	-	<0.05	-	0.38	-	0.25	-
	Lead (filtered)	mg/L	0.001		<0.001	-	<0.001	-	<0.001	-	<0.001	-	<0.001	-	<0.001	-	<0.001	-
	Nickel (filtered)	mg/L	0.001		0.006	-	0.003	-	0.020	-	0.013	-	0.023	-	0.006	-	0.003	-
	Zinc (filtered)	mg/L	0.005		0.116	-	0.074	-	0.041	-	0.017	-	0.109	-	0.033	-	<0.005	-

Appendix B

Laboratory certificates of analysis

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES2018927**	Page	: 1 of 4
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: HENRY NOAKES	Contact	: Customer Services ES
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: J190166 - Menangle Quarry	Date Samples Received	: 01-Jun-2020 19:00
Order number	: J190166	Date Analysis Commenced	: 01-Jun-2020
C-O-C number	: ----	Issue Date	: 03-Jun-2020 20:31
Sampler	: KAITLYN BRODIE		
Site	: ----		
Quote number	: ----		
No. of samples received	: 5		
No. of samples analysed	: 5		

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
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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.

- EA016: Calculated TDS is determined from Electrical conductivity using a conversion factor of 0.65.
- 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	Site_1_S	Site 2	Site 4	River_Site 1	River_Site 3
			Client sampling date / time	29-May-2020 00:00	29-May-2020 00:00	29-May-2020 00:00	29-May-2020 00:00	29-May-2020 00:00
Compound	CAS Number	LOR	Unit	ES2018927-001	ES2018927-002	ES2018927-003	ES2018927-004	ES2018927-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	6.45	8.04	8.11	7.79	7.88
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	1370	9840	12000	228	308
EA016: Calculated TDS (from Electrical Conductivity)								
Total Dissolved Solids (Calc.)	----	1	mg/L	890	6400	7800	148	200
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	278	1180	1970	26	33
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	8	318	567	52	82
Total Alkalinity as CaCO3	----	1	mg/L	8	318	567	52	82
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	12	770	587	6	11
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	462	2880	4050	35	43
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	42	142	172	4	5
Magnesium	7439-95-4	1	mg/L	42	201	374	4	5
Sodium	7440-23-5	1	mg/L	138	1650	1840	34	47
Potassium	7440-09-7	1	mg/L	2	15	31	3	4
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.001	0.001	0.003	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	0.004	0.006	0.017	<0.001
Nickel	7440-02-0	0.001	mg/L	0.003	0.020	0.023	0.006	0.003
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	0.074	0.041	0.109	0.033	<0.005
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	<0.05	0.38	0.25
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	0.8	0.6	<0.1	<0.1
EN055: Ionic Balance								

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	Site_1_S	Site 2	Site 4	River_Site 1	River_Site 3
				Client sampling date / time	29-May-2020 00:00	29-May-2020 00:00	29-May-2020 00:00	29-May-2020 00:00	29-May-2020 00:00
Compound	CAS Number	LOR	Unit		ES2018927-001	ES2018927-002	ES2018927-003	ES2018927-004	ES2018927-005
					Result	Result	Result	Result	Result
EN055: Ionic Balance - Continued									
ø **Total Anions**	----	0.01	meq/L		**13.4**	**104**	**138**	**2.15**	**3.08**
ø **Total Cations**	----	0.01	meq/L		**11.6**	**95.8**	**120**	**2.08**	**2.81**
ø **Ionic Balance**	----	0.01	%		**7.33**	**3.93**	**6.82**	**----**	**----**

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **ES2018927**	Page	: 1 of 5
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: HENRY NOAKES	Contact	: Customer Services ES
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: J190166 - Menangle Quarry	Date Samples Received	: 01-Jun-2020
Order number	: J190166	Date Analysis Commenced	: 01-Jun-2020
C-O-C number	: ----	Issue Date	: 03-Jun-2020
Sampler	: KAITLYN BRODIE		
Site	: ----		
Quote number	: ----		
No. of samples received	: 5		
No. of samples analysed	: 5		

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 Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

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
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
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
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EA005P: pH by PC Titrator (QC Lot: 3053496)									
ES2018890-001	Anonymous	EA005-P: pH Value	----	0.01	pH Unit	6.14	5.79	5.87	0% - 20%
ES2018927-004	River_Site 1	EA005-P: pH Value	----	0.01	pH Unit	7.79	7.66	1.68	0% - 20%
EA010P: Conductivity by PC Titrator (QC Lot: 3053497)									
EW2002521-001	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	194	194	0.00	0% - 20%
ES2018890-001	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	272	280	3.14	0% - 20%
ED037P: Alkalinity by PC Titrator (QC Lot: 3053493)									
ES2018843-002	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	64	58	9.32	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	64	58	9.32	0% - 20%
ES2018883-001	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	87	84	3.36	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	87	84	3.36	0% - 20%
ED037P: Alkalinity by PC Titrator (QC Lot: 3053498)									
EW2002533-001	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	1	<1	0.00	No Limit
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	1	<1	0.00	No Limit
ES2018927-004	River_Site 1	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	52	53	0.00	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	52	53	0.00	0% - 20%
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QC Lot: 3053456)									

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QC Lot: 3053456) - continued									
ES2018927-001	Site_1_S	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	12	12	0.00	0% - 50%
ED045G: Chloride by Discrete Analyser (QC Lot: 3053457)									
ES2018927-001	Site_1_S	ED045G: Chloride	16887-00-6	1	mg/L	462	460	0.355	0% - 20%
ED093F: Dissolved Major Cations (QC Lot: 3053790)									
ES2018856-002	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	14	14	0.00	0% - 50%
		ED093F: Magnesium	7439-95-4	1	mg/L	22	22	0.00	0% - 20%
		ED093F: Sodium	7440-23-5	1	mg/L	138	141	1.92	0% - 20%
		ED093F: Potassium	7440-09-7	1	mg/L	36	36	0.00	0% - 20%
EG020F: Dissolved Metals by ICP-MS (QC Lot: 3053788)									
ES2018927-005	River_Site 3	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	0.003	0.003	0.00	No Limit
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	0.00	No Limit
		EG020A-F: Iron	7439-89-6	0.05	mg/L	0.25	0.25	0.00	No Limit
ES2018856-002	Anonymous	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	0.008	0.008	0.00	No Limit
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	0.016	0.016	0.00	No Limit
		EG020A-F: Iron	7439-89-6	0.05	mg/L	0.08	0.07	0.00	No Limit
EK040P: Fluoride by PC Titrator (QC Lot: 3053490)									
ES2018620-001	Anonymous	EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	<0.1	0.00	No Limit
ES2018927-004	River_Site 1	EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	<0.1	0.00	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA005P: pH by PC Titrator (QCLot: 3053496)								
EA005-P: pH Value	----	----	pH Unit	----	4 pH Unit	101	98.0	102
				----	7 pH Unit	99.7	98.0	102
EA010P: Conductivity by PC Titrator (QCLot: 3053497)								
EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	<1	2100 µS/cm	108	95.0	113
ED037P: Alkalinity by PC Titrator (QCLot: 3053493)								
ED037-P: Total Alkalinity as CaCO3	----	----	mg/L	----	200 mg/L	99.5	81.0	111
				----	50 mg/L	113	70.0	130
ED037P: Alkalinity by PC Titrator (QCLot: 3053498)								
ED037-P: Total Alkalinity as CaCO3	----	----	mg/L	----	200 mg/L	101	81.0	111
				----	50 mg/L	108	70.0	130
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 3053456)								
ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	25 mg/L	115	82.0	122
				<1	500 mg/L	92.2	82.0	122
ED045G: Chloride by Discrete Analyser (QCLot: 3053457)								
ED045G: Chloride	16887-00-6	1	mg/L	<1	10 mg/L	108	80.9	127
				<1	1000 mg/L	115	80.9	127
ED093F: Dissolved Major Cations (QCLot: 3053790)								
ED093F: Calcium	7440-70-2	1	mg/L	<1	50 mg/L	99.1	80.0	114
ED093F: Magnesium	7439-95-4	1	mg/L	<1	50 mg/L	97.8	90.0	116
ED093F: Sodium	7440-23-5	1	mg/L	<1	50 mg/L	95.1	82.0	120
ED093F: Potassium	7440-09-7	1	mg/L	<1	50 mg/L	95.6	85.0	113
EG020F: Dissolved Metals by ICP-MS (QCLot: 3053788)								
EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.1 mg/L	92.8	85.0	114
EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.1 mg/L	92.6	84.0	110
EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	0.1 mg/L	91.5	85.0	111
EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	0.1 mg/L	90.8	81.0	111
EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	0.1 mg/L	92.4	83.0	111
EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	0.1 mg/L	89.8	82.0	112
EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	0.1 mg/L	93.7	81.0	117
EG020A-F: Iron	7439-89-6	0.05	mg/L	<0.05	0.5 mg/L	101	82.0	112
EK040P: Fluoride by PC Titrator (QCLot: 3053490)								
EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	5 mg/L	105	82.0	116

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 3053456)							
ES2018927-001	Site_1_S	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	10 mg/L	109	70.0	130
ED045G: Chloride by Discrete Analyser (QCLot: 3053457)							
ES2018927-001	Site_1_S	ED045G: Chloride	16887-00-6	250 mg/L	108	70.0	130
EG020F: Dissolved Metals by ICP-MS (QCLot: 3053788)							
ES2018856-003	Anonymous	EG020A-F: Arsenic	7440-38-2	1 mg/L	96.4	70.0	130
		EG020A-F: Cadmium	7440-43-9	0.25 mg/L	94.0	70.0	130
		EG020A-F: Chromium	7440-47-3	1 mg/L	81.0	70.0	130
		EG020A-F: Copper	7440-50-8	1 mg/L	91.5	70.0	130
		EG020A-F: Lead	7439-92-1	1 mg/L	101	70.0	130
		EG020A-F: Nickel	7440-02-0	1 mg/L	93.8	70.0	130
		EG020A-F: Zinc	7440-66-6	1 mg/L	97.0	70.0	130
EK040P: Fluoride by PC Titrator (QCLot: 3053490)							
ES2018620-001	Anonymous	EK040P: Fluoride	16984-48-8	5 mg/L	105	70.0	130

ALS Environmental

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **ES2018927**	Page	: 1 of 5
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: HENRY NOAKES	Telephone	: +61-2-8784 8555
Project	: J190166 - Menangle Quarry	Date Samples Received	: 01-Jun-2020
Site	: ----	Issue Date	: 03-Jun-2020
Sampler	: KAITLYN BRODIE	No. of samples received	: 5
Order number	: J190166	No. of samples analysed	: 5

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **Analysis Holding Time Outliers exist - please see following pages for full details.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Outliers : Analysis Holding Time Compliance

Matrix: **WATER**

Method / Container / Client Sample ID(s)	Extraction / Preparation			Analysis		
	Date extracted	Due for extraction	Days overdue	Date analysed	Due for analysis	Days overdue
EA005P: pH by PC Titrator						
Clear Plastic Bottle - Natural						
Site_1_S, Site 2, Site 4, River_Site 1, River_Site 3	----	----	----	01-Jun-2020	29-May-2020	**3**

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)	Sample Date	Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA005P: pH by PC Titrator							
Clear Plastic Bottle - Natural (EA005-P)							
Site_1_S, Site 2, Site 4, River_Site 1, River_Site 3	**29-May-2020**	**----**	----	----	**01-Jun-2020**	29-May-2020	×
EA010P: Conductivity by PC Titrator							
Clear Plastic Bottle - Natural (EA010-P)							
Site_1_S, Site 2, Site 4, River_Site 1, River_Site 3	**29-May-2020**	**----**	----	----	**01-Jun-2020**	26-Jun-2020	✓
EA065: Total Hardness as CaCO3							
Clear Plastic Bottle - Natural (ED093F)							
Site_1_S	**29-May-2020**	**----**	----	----	**02-Jun-2020**	05-Jun-2020	✓
Clear Plastic Bottle - Nitric Acid; Filtered (ED093F)							
Site 2, Site 4, River_Site 1, River_Site 3	**29-May-2020**	**----**	----	----	**02-Jun-2020**	26-Jun-2020	✓
ED037P: Alkalinity by PC Titrator							
Clear Plastic Bottle - Natural (ED037-P)							
Site_1_S, Site 2, Site 4, River_Site 1, River_Site 3	**29-May-2020**	**----**	----	----	**01-Jun-2020**	12-Jun-2020	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)	Sample Date	Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA							
Clear Plastic Bottle - Natural (ED041G)							
Site_1_S, Site 2, Site 4, River_Site 1, River_Site 3	**29-May-2020**	**----**	----	----	**01-Jun-2020**	26-Jun-2020	✓
ED045G: Chloride by Discrete Analyser							
Clear Plastic Bottle - Natural (ED045G)							
Site_1_S, Site 2, Site 4, River_Site 1, River_Site 3	**29-May-2020**	**----**	----	----	**01-Jun-2020**	26-Jun-2020	✓
ED093F: Dissolved Major Cations							
Clear Plastic Bottle - Natural (ED093F)							
Site_1_S	**29-May-2020**	**----**	----	----	**02-Jun-2020**	05-Jun-2020	✓
Clear Plastic Bottle - Nitric Acid; Filtered (ED093F)							
Site 2, Site 4, River_Site 1, River_Site 3	**29-May-2020**	**----**	----	----	**02-Jun-2020**	26-Jun-2020	✓
EG020F: Dissolved Metals by ICP-MS							
Clear Plastic Bottle - Natural (EG020A-F)							
Site_1_S	**29-May-2020**	**----**	----	----	**02-Jun-2020**	25-Nov-2020	✓
Clear Plastic Bottle - Nitric Acid; Filtered (EG020A-F)							
Site 2, Site 4, River_Site 1, River_Site 3	**29-May-2020**	**----**	----	----	**02-Jun-2020**	25-Nov-2020	✓
EK040P: Fluoride by PC Titrator							
Clear Plastic Bottle - Natural (EK040P)							
Site_1_S, Site 2, Site 4, River_Site 1, River_Site 3	**29-May-2020**	**----**	----	----	**01-Jun-2020**	26-Jun-2020	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Alkalinity by PC Titrator	ED037-P	4	24	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	1	5	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	2	10	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	2	15	**13.33**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	2	12	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
pH by PC Titrator	EA005-P	2	13	**15.38**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	5	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Alkalinity by PC Titrator	ED037-P	4	24	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	2	5	**40.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	15	**6.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	12	**8.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
pH by PC Titrator	EA005-P	2	13	**15.38**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	5	**40.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Chloride by Discrete Analyser	ED045G	1	5	**20.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	15	**6.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	12	**8.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	5	**20.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Chloride by Discrete Analyser	ED045G	1	5	**20.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	15	**6.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	12	**8.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	5	**20.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
pH by PC Titrator	EA005-P	WATER	In house: Referenced to APHA 4500 H+ B. This procedure determines pH of water samples by automated ISE. This method is compliant with NEPM (2013) Schedule B(3)
Conductivity by PC Titrator	EA010-P	WATER	In house: Referenced to APHA 2510 B. This procedure determines conductivity by automated ISE. This method is compliant with NEPM (2013) Schedule B(3)
Calculated TDS (from Electrical Conductivity)	EA016	WATER	In house: Calculation from Electrical Conductivity (APHA 2510 B) using a conversion factor specified in the analytical report. This method is compliant with NEPM (2013) Schedule B(3)
Alkalinity by PC Titrator	ED037-P	WATER	In house: Referenced to APHA 2320 B This procedure determines alkalinity by automated measurement (e.g. PC Titrate) using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM (2013) Schedule B(3)
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	WATER	In house: Referenced to APHA 4500-SO4. Dissolved sulfate is determined in a 0.45um filtered sample. Sulfate ions are converted to a barium sulfate suspension in an acetic acid medium with barium chloride. Light absorbance of the BaSO4 suspension is measured by a photometer and the SO4-2 concentration is determined by comparison of the reading with a standard curve. This method is compliant with NEPM (2013) Schedule B(3)
Chloride by Discrete Analyser	ED045G	WATER	In house: Referenced to APHA 4500 Cl - G.The thiocyanate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form non-ionised mercuric chloride.in the presence of ferric ions the librated thiocynate forms highly-coloured ferric thiocynate which is measured at 480 nm APHA 21st edition seal method 2 017-1-L april 2003
Major Cations - Dissolved	ED093F	WATER	In house: Referenced to APHA 3120 and 3125; USEPA SW 846 - 6010 and 6020; Cations are determined by either ICP-AES or ICP-MS techniques. This method is compliant with NEPM (2013) Schedule B(3) Sodium Adsorption Ratio is calculated from Ca, Mg and Na which determined by ALS in house method QWI-EN/ED093F. This method is compliant with NEPM (2013) Schedule B(3) Hardness parameters are calculated based on APHA 2340 B. This method is compliant with NEPM (2013) Schedule B(3)
Dissolved Metals by ICP-MS - Suite A	EG020A-F	WATER	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. Samples are 0.45µm filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Fluoride by PC Titrator	EK040P	WATER	In house: Referenced to APHA 4500-F C: CDTA is added to the sample to provide a uniform ionic strength background, adjust pH, and break up complexes. Fluoride concentration is determined by either manual or automatic ISE measurement. This method is compliant with NEPM (2013) Schedule B(3)
Ionic Balance by PCT DA and Turbi SO4 DA	* EN055 - PG	WATER	In house: Referenced to APHA 1030F. This method is compliant with NEPM (2013) Schedule B(3)

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order : **ES2018927**

Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: HENRY NOAKES	Contact	: Customer Services ES
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: hnoakes@emmconsulting.com.au	E-mail	: ALSEnviro.Sydney@ALSGlobal.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: J190166 - Menangle Quarry	Page	: 1 of 2
Order number	: J190166	Quote number	: ----
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: ----		
Sampler	: KAITLYN BRODIE		

Dates

Date Samples Received	: 01-Jun-2020 19:00	Issue Date	: 01-Jun-2020
Client Requested Due Date	: 04-Jun-2020	Scheduled Reporting Date	: **04-Jun-2020**

Delivery Details

Mode of Delivery	: Undefined	Security Seal	: Not Available
No. of coolers/boxes	: 1	Temperature	: 6.6' C - Ice Bricks present
Receipt Detail	:	No. of samples received / analysed	: 5 / 5

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **Sample "Site 1_D" not received**
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- Please direct any queries you have regarding this work order to the above ALS laboratory contact.
- Analytical work for this work order will be conducted at ALS Sydney.
- Sample Disposal - Aqueous (3 weeks), Solid (2 months ± 1 week) from receipt of samples.
- Please be aware that APHA/NEPM recommends water and soil samples be chilled to less than or equal to 6°C for chemical analysis, and less than or equal to 10°C but unfrozen for Microbiological analysis. Where samples are received above this temperature, it should be taken into consideration when interpreting results. Refer to ALS EnviroMail 85 for ALS recommendations of the best practice for chilling samples after sampling and for maintaining a cool temperature during transit.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

Method Client sample ID	Sample Container Received	Preferred Sample Container for Analysis
Dissolved Metals by ICP-MS - Suite A : EG020A-F		
Site_1_S	- Clear Plastic Bottle - Natural	- Clear Plastic Bottle - Nitric Acid; Filtered

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.
If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **WATER**

Laboratory sample ID	Client sampling date / time	Client sample ID	WATER - EG020F Dissolved Metals by ICP/MS	WATER - NT-12 General Water Suite	WATER - W-01 7 Metals
ES2018927-001	29-May-2020 00:00	Site_1_S	✓	✓	✓
ES2018927-002	29-May-2020 00:00	Site 2	✓	✓	✓
ES2018927-003	29-May-2020 00:00	Site 4	✓	✓	✓
ES2018927-004	29-May-2020 00:00	River_Site 1	✓	✓	✓
ES2018927-005	29-May-2020 00:00	River_Site 3	✓	✓	✓

Proactive Holding Time Report

The following table summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory.

Matrix: **WATER** Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method Client Sample ID(s)	Container	Due for extraction	Due for analysis	Samples Received		Instructions Received	
				Date	Evaluation	Date	Evaluation
EA005-P: pH by PC Titrator							
River_Site 1	Clear Plastic Bottle - Natural	----	29-May-2020	01-Jun-2020	×	----	----
River_Site 3	Clear Plastic Bottle - Natural	----	29-May-2020	01-Jun-2020	×	----	----
Site 2	Clear Plastic Bottle - Natural	----	29-May-2020	01-Jun-2020	×	----	----
Site 4	Clear Plastic Bottle - Natural	----	29-May-2020	01-Jun-2020	×	----	----
Site_1_S	Clear Plastic Bottle - Natural	----	29-May-2020	01-Jun-2020	×	----	----

Requested Deliverables

ALL INVOICES

- A4 - AU Tax Invoice (INV)	Email	finance@emmconsulting.com.au

HENRY NOAKES

- *AU Certificate of Analysis - NATA (COA)	Email	hnoakes@emmconsulting.com.au
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	hnoakes@emmconsulting.com.au
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	hnoakes@emmconsulting.com.au
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	hnoakes@emmconsulting.com.au
- Chain of Custody (CoC) (COC)	Email	hnoakes@emmconsulting.com.au
- EDI Format - ESDAT (ESDAT)	Email	hnoakes@emmconsulting.com.au
- EDI Format - XTab (XTAB)	Email	hnoakes@emmconsulting.com.au

Katharine Bond

- A4 - AU Tax Invoice (INV)	Email	kbond@emmconsulting.com.au

CHAIN OF CUSTODY

ALS Environmental

ALS Laboratory: please tick →

☐ADELAIDE 21 Burma Road Pooraka SA 5095 Ph: 08 8359 0890 E: adelaide@alsglobal.com

☐BRISBANE 32 Shand Street Stafford QLD 4053 Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com

☐GLADSTONE 46 Callemondah Drive Clinton QLD 4680 Ph: 07 7471 5600 E: gladstone@alsglobal.com

☐MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay@alsglobal.com

☐MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com

☐MUDGEE 27 Sydney Road Mudgee NSW 2850 Ph: 02 6372 6735 E: mudgee.mail@alsglobal.com

☐NEWCASTLE 5/585 Maitland Rd Mayfield West NSW 2304 Ph: 02 4014 2500 E: samples.newcastle@alsglobal.com

☐NOWRA 4/13 Geary Place North Nowra NSW 2541 Ph: 024423 2063 E: nowra@alsglobal.com

☐PERTH 10 Hod Way Malaga WA 6090 Ph: 08 9209 7655 E: samples.perth@alsglobal.com

☐SYDNEY 277-289 Woodpark Road Smithfield NSW 2164 Ph: 02 8784 8555 E: samples.sydney@alsglobal.com

☐TOWNSVILLE 14-15 Desma Court Bohle QLD 4818 Ph: 07 4796 0600 E: townsville.environmental@alsglobal.com

☐WOLLONGONG 99 Kenny Street Wollongong NSW 2500 Ph: 02 4225 3125 E: portkembla@alsglobal.com

CLIENT: EMM Consulting Pty Ltd	**TURNAROUND REQUIREMENTS :** (Standard TAT may be longer for some tests e.g.. Ultra Trace Organics)	☐ Standard TAT **(List due date):**	**FOR LABORATORY USE ONLY (Circle)**
OFFICE: Sydney		☒ Non Standard or urgent TAT **(List due date): 2 day turnaroud**	Custody Seal Intact? Yes No N/A
PROJECT: J190166 - Menangle Quarry	**ALS QUOTE NO.:**	**COC SEQUENCE NUMBER (Circle)**	Preserved / Received on Ice? Yes No N/A
ORDER NUMBER: J190166		COC: 1 2 3 4 5 6 7	Cooling Method: Ice Gel Ice Pack None
PROJECT MANAGER: Katharine Bond / Henry Noakes	**CONTACT PH: 0439 604 035 / 0448 772 835**	OF: 1 2 3 4 5 6 7	Sample Temperature on Receipt: °C
SAMPLER: Kailtyn Brodie	**SAMPLER MOBILE: 0401 881 447**		Other comments:

RELINQUISHED BY:	RECEIVED BY:	RELINQUISHED BY:	RECEIVED BY:
DATE/TIME:	DATE/TIME: 1/6/20 1900	DATE/TIME:	DATE/TIME:

COC emailed to ALS? (YES / NO) **EDD FORMAT (or default):**

Email Reports to (will default to PM if no other addresses are listed): **hnoakes@emmconsulting.com.au**

Email Invoice to (will default to PM if no other addresses are listed): **kbond@emmconsulting.com.au**

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

ALS USE ONLY	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).							Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	General water suite NT-12	Dissolved Metals Suite W-1 PLUS IRON (Fe)						
1	Site 1_S	29/05/2020	W	2 x P	2	x	x						Please lab filter from unpreserved bottle for metals.
SM12	Site 1_D	29/05/2020	W	1 x P & 1 x N	2	x	x						
2	Site 2	29/05/2020	W	1 x P & 1 x N	2	x	x						
3	Site 4	29/05/2020	W	1 x P & 1 x N	2	x	x						
4	River_Site 1	29/05/2020	W	1 x P & 1 x N	2	x	x						
5	River_Site 3	29/05/2020	W	1 x P & 1 x N	2	x	x						
				TOTAL	12	6	6						

Environmental Division Sydney
Work Order Reference
ES2018927

Telephone : +61-2-8784 8555

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES2019091**	Page	: 1 of 4
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: HENRY NOAKES	Contact	: Customer Services ES
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: J190166 - Menangle Quarry	Date Samples Received	: 02-Jun-2020 19:00
Order number	: J190166	Date Analysis Commenced	: 02-Jun-2020
C-O-C number	: ----	Issue Date	: 04-Jun-2020 11:47
Sampler	: KAITLYN BRODIE		
Site	: ----		
Quote number	: EN/112/18 - Primary work only		
No. of samples received	: 2		
No. of samples analysed	: 2		

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
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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.

- EA016: Calculated TDS is determined from Electrical conductivity using a conversion factor of 0.65.
- 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	Site 3	Site 1_D	----	----	----
			Client sampling date / time	02-Jun-2020 00:00	02-Jun-2020 00:00	----	----	----
Compound	CAS Number	LOR	Unit	ES2019091-001	ES2019091-002	--------	--------	--------
				Result	Result	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.65**	**6.85**	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**2640**	**2730**	----	----	----
EA016: Calculated TDS (from Electrical Conductivity)								
Total Dissolved Solids (Calc.)	----	1	mg/L	**1720**	**1770**	----	----	----
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	**383**	**260**	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**32**	**228**	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**32**	**228**	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**49**	**215**	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**893**	**732**	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**20**	**43**	----	----	----
Magnesium	7439-95-4	1	mg/L	**81**	**37**	----	----	----
Sodium	7440-23-5	1	mg/L	**348**	**450**	----	----	----
Potassium	7440-09-7	1	mg/L	**3**	**5**	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.013**	**0.006**	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.017**	**0.116**	----	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.1**	<0.1	----	----	----
EN055: Ionic Balance								

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)				Client sample ID	**Site 3**	**Site 1_D**	**----**	**----**	**----**
				Client sampling date / time	02-Jun-2020 00:00	02-Jun-2020 00:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*		**ES2019091-001**	**ES2019091-002**	**--------**	**--------**	**--------**
					Result	Result	----	----	----
EN055: Ionic Balance - Continued									
ø **Total Anions**	----	0.01	meq/L		**26.8**	**29.7**	**----**	**----**	**----**
ø **Total Cations**	----	0.01	meq/L		**22.9**	**24.9**	**----**	**----**	**----**
ø **Ionic Balance**	----	0.01	%		**7.99**	**8.77**	**----**	**----**	**----**

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **ES2019091**	Page	: 1 of 5
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: HENRY NOAKES	Contact	: Customer Services ES
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: J190166 - Menangle Quarry	Date Samples Received	: 02-Jun-2020
Order number	: J190166	Date Analysis Commenced	: 02-Jun-2020
C-O-C number	: ----	Issue Date	: 04-Jun-2020
Sampler	: KAITLYN BRODIE		
Site	: ----		
Quote number	: EN/112/18 - Primary work only		
No. of samples received	: 2		
No. of samples analysed	: 2		

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 Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

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
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
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
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EA005P: pH by PC Titrator (QC Lot: 3056122)									
ES2019014-001	Anonymous	EA005-P: pH Value	----	0.01	pH Unit	7.49	7.49	0.00	0% - 20%
ES2019017-004	Anonymous	EA005-P: pH Value	----	0.01	pH Unit	11.4	11.4	0.0875	0% - 20%
EA010P: Conductivity by PC Titrator (QC Lot: 3056119)									
ES2018934-001	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	3.36 mS/cm	3340	0.664	0% - 20%
ES2019017-004	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	2230	2230	0.00	0% - 20%
ED037P: Alkalinity by PC Titrator (QC Lot: 3056121)									
ES2018934-001	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	848	931	9.24	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	848	931	9.24	0% - 20%
ES2019017-004	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	265	257	3.02	0% - 20%
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	186	169	9.64	0% - 20%
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	452	426	5.70	0% - 20%
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QC Lot: 3056140)									
ES2019075-008	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	7	7	0.00	No Limit
ES2018934-001	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	202	201	0.00	0% - 20%
ED045G: Chloride by Discrete Analyser (QC Lot: 3056137)									
ES2019072-003	Anonymous	ED045G: Chloride	16887-00-6	1	mg/L	14	14	0.00	0% - 50%
ES2018934-001	Anonymous	ED045G: Chloride	16887-00-6	1	mg/L	548	549	0.233	0% - 20%
ED045G: Chloride by Discrete Analyser (QC Lot: 3056143)									
ES2019091-002	Site 1_D	ED045G: Chloride	16887-00-6	1	mg/L	732	736	0.524	0% - 20%
ED093F: Dissolved Major Cations (QC Lot: 3055986)									
ES2019091-001	Site 3	ED093F: Calcium	7440-70-2	1	mg/L	20	20	0.00	0% - 20%

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
ED093F: Dissolved Major Cations (QC Lot: 3055986) - continued									
ES2019091-001	Site 3	ED093F: Magnesium	7439-95-4	1	mg/L	81	82	1.50	0% - 20%
		ED093F: Sodium	7440-23-5	1	mg/L	348	355	1.89	0% - 20%
		ED093F: Potassium	7440-09-7	1	mg/L	3	3	0.00	No Limit
EG020F: Dissolved Metals by ICP-MS (QC Lot: 3055987)									
ES2019091-001	Site 3	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	0.013	0.013	0.00	0% - 50%
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	0.017	0.016	0.00	No Limit
		EG020A-F: Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	0.00	No Limit
EK040P: Fluoride by PC Titrator (QC Lot: 3056120)									
ES2018934-001	Anonymous	EK040P: Fluoride	16984-48-8	0.1	mg/L	0.6	0.6	0.00	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA005P: pH by PC Titrator (QCLot: 3056122)								
EA005-P: pH Value	----	----	pH Unit	----	4 pH Unit	101	98.0	102
				----	7 pH Unit	99.7	98.0	102
EA010P: Conductivity by PC Titrator (QCLot: 3056119)								
EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	<1	2100 µS/cm	106	95.0	113
ED037P: Alkalinity by PC Titrator (QCLot: 3056121)								
ED037-P: Total Alkalinity as CaCO3	----	----	mg/L	----	200 mg/L	93.0	81.0	111
				----	50 mg/L	105	70.0	130
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 3056140)								
ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	25 mg/L	106	82.0	122
				<1	500 mg/L	103	82.0	122
ED045G: Chloride by Discrete Analyser (QCLot: 3056137)								
ED045G: Chloride	16887-00-6	1	mg/L	<1	10 mg/L	106	80.9	127
				<1	1000 mg/L	112	80.9	127
ED045G: Chloride by Discrete Analyser (QCLot: 3056143)								
ED045G: Chloride	16887-00-6	1	mg/L	<1	10 mg/L	107	80.9	127
				<1	1000 mg/L	117	80.9	127
ED093F: Dissolved Major Cations (QCLot: 3055986)								
ED093F: Calcium	7440-70-2	1	mg/L	<1	50 mg/L	102	80.0	114
ED093F: Magnesium	7439-95-4	1	mg/L	<1	50 mg/L	99.2	90.0	116
ED093F: Sodium	7440-23-5	1	mg/L	<1	50 mg/L	98.0	82.0	120
ED093F: Potassium	7440-09-7	1	mg/L	<1	50 mg/L	98.9	85.0	113
EG020F: Dissolved Metals by ICP-MS (QCLot: 3055987)								
EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.1 mg/L	94.9	85.0	114
EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.1 mg/L	98.1	84.0	110
EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	0.1 mg/L	96.7	85.0	111
EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	0.1 mg/L	93.8	81.0	111
EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	0.1 mg/L	93.2	83.0	111
EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	0.1 mg/L	90.8	82.0	112
EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	0.1 mg/L	93.4	81.0	117
EG020A-F: Iron	7439-89-6	0.05	mg/L	<0.05	0.5 mg/L	102	82.0	112
EK040P: Fluoride by PC Titrator (QCLot: 3056120)								
EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	5 mg/L	98.4	82.0	116

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 3056140)							
ES2018934-001	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	10 mg/L	# Not Determined	70.0	130
ED045G: Chloride by Discrete Analyser (QCLot: 3056137)							
ES2018934-001	Anonymous	ED045G: Chloride	16887-00-6	250 mg/L	102	70.0	130
ED045G: Chloride by Discrete Analyser (QCLot: 3056143)							
ES2019091-002	Site 1_D	ED045G: Chloride	16887-00-6	250 mg/L	95.9	70.0	130
EG020F: Dissolved Metals by ICP-MS (QCLot: 3055987)							
ES2019091-002	Site 1_D	EG020A-F: Arsenic	7440-38-2	1 mg/L	95.1	70.0	130
		EG020A-F: Cadmium	7440-43-9	0.25 mg/L	98.3	70.0	130
		EG020A-F: Chromium	7440-47-3	1 mg/L	97.2	70.0	130
		EG020A-F: Copper	7440-50-8	1 mg/L	93.5	70.0	130
		EG020A-F: Lead	7439-92-1	1 mg/L	105	70.0	130
		EG020A-F: Nickel	7440-02-0	1 mg/L	93.6	70.0	130
		EG020A-F: Zinc	7440-66-6	1 mg/L	102	70.0	130
EK040P: Fluoride by PC Titrator (QCLot: 3056120)							
ES2018934-001	Anonymous	EK040P: Fluoride	16984-48-8	5 mg/L	120	70.0	130

ALS Environmental

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **ES2019091**	Page	: 1 of 5
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: HENRY NOAKES	Telephone	: +61-2-8784 8555
Project	: J190166 - Menangle Quarry	Date Samples Received	: 02-Jun-2020
Site	: ----	Issue Date	: 04-Jun-2020
Sampler	: KAITLYN BRODIE	No. of samples received	: 2
Order number	: J190166	No. of samples analysed	: 2

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **Matrix Spike outliers exist - please see following pages for full details.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **NO Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Outliers : Quality Control Samples

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: **WATER**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Matrix Spike (MS) Recoveries							
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA	ES2018934--001	Anonymous	**Sulfate as SO4 - Turbidimetric**	14808-79-8	Not Determined	----	**MS recovery not determined, background level greater than or equal to 4x spike level.**

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / ***Container*** / Client Sample ID(s)	***Sample Date***	Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Evaluation	***Date analysed***	Due for analysis	Evaluation
EA005P: pH by PC Titrator							
Clear Plastic Bottle - Natural (EA005-P)							
Site 3, Site 1_D	**02-Jun-2020**	**----**	----	----	**02-Jun-2020**	02-Jun-2020	✓
EA010P: Conductivity by PC Titrator							
Clear Plastic Bottle - Natural (EA010-P)							
Site 3, Site 1_D	**02-Jun-2020**	**----**	----	----	**02-Jun-2020**	30-Jun-2020	✓
EA065: Total Hardness as CaCO3							
Clear Plastic Bottle - Natural (ED093F)							
Site 3, Site 1_D	**02-Jun-2020**	**----**	----	----	**02-Jun-2020**	09-Jun-2020	✓
ED037P: Alkalinity by PC Titrator							
Clear Plastic Bottle - Natural (ED037-P)							
Site 3, Site 1_D	**02-Jun-2020**	**----**	----	----	**02-Jun-2020**	16-Jun-2020	✓
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA							
Clear Plastic Bottle - Natural (ED041G)							
Site 3, Site 1_D	**02-Jun-2020**	**----**	----	----	**02-Jun-2020**	30-Jun-2020	✓
ED045G: Chloride by Discrete Analyser							
Clear Plastic Bottle - Natural (ED045G)							
Site 3, Site 1_D	**02-Jun-2020**	**----**	----	----	**02-Jun-2020**	30-Jun-2020	✓
ED093F: Dissolved Major Cations							
Clear Plastic Bottle - Natural (ED093F)							
Site 3, Site 1_D	**02-Jun-2020**	**----**	----	----	**02-Jun-2020**	09-Jun-2020	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)	Sample Date	Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EG020F: Dissolved Metals by ICP-MS							
Clear Plastic Bottle - Natural (EG020A-F)							
Site 3, Site 1_D	**02-Jun-2020**	**----**	----	----	**02-Jun-2020**	29-Nov-2020	✓
EK040P: Fluoride by PC Titrator							
Clear Plastic Bottle - Natural (EK040P)							
Site 3, Site 1_D	**02-Jun-2020**	**----**	----	----	**02-Jun-2020**	30-Jun-2020	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Alkalinity by PC Titrator	ED037-P	2	16	**12.50**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	3	21	**14.29**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	2	19	**10.53**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	2	**50.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	7	**14.29**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	2	**50.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
pH by PC Titrator	EA005-P	2	19	**10.53**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	19	**10.53**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Alkalinity by PC Titrator	ED037-P	2	16	**12.50**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	4	21	**19.05**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	1	19	**5.26**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	2	**50.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	7	**14.29**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	2	**50.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
pH by PC Titrator	EA005-P	2	19	**10.53**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	19	**10.53**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Chloride by Discrete Analyser	ED045G	2	21	**9.52**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	1	19	**5.26**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	2	**50.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	7	**14.29**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	2	**50.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	19	**5.26**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Chloride by Discrete Analyser	ED045G	2	21	**9.52**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	2	**50.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	7	**14.29**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	19	**5.26**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
pH by PC Titrator	EA005-P	WATER	In house: Referenced to APHA 4500 H+ B. This procedure determines pH of water samples by automated ISE. This method is compliant with NEPM (2013) Schedule B(3)
Conductivity by PC Titrator	EA010-P	WATER	In house: Referenced to APHA 2510 B. This procedure determines conductivity by automated ISE. This method is compliant with NEPM (2013) Schedule B(3)
Calculated TDS (from Electrical Conductivity)	EA016	WATER	In house: Calculation from Electrical Conductivity (APHA 2510 B) using a conversion factor specified in the analytical report. This method is compliant with NEPM (2013) Schedule B(3)
Alkalinity by PC Titrator	ED037-P	WATER	In house: Referenced to APHA 2320 B This procedure determines alkalinity by automated measurement (e.g. PC Titrate) using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM (2013) Schedule B(3)
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	WATER	In house: Referenced to APHA 4500-SO4. Dissolved sulfate is determined in a 0.45um filtered sample. Sulfate ions are converted to a barium sulfate suspension in an acetic acid medium with barium chloride. Light absorbance of the BaSO4 suspension is measured by a photometer and the SO4-2 concentration is determined by comparison of the reading with a standard curve. This method is compliant with NEPM (2013) Schedule B(3)
Chloride by Discrete Analyser	ED045G	WATER	In house: Referenced to APHA 4500 Cl - G.The thiocyanate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form non-ionised mercuric chloride.in the presence of ferric ions the librated thiocynate forms highly-coloured ferric thiocynate which is measured at 480 nm APHA 21st edition seal method 2 017-1-L april 2003
Major Cations - Dissolved	ED093F	WATER	In house: Referenced to APHA 3120 and 3125; USEPA SW 846 - 6010 and 6020; Cations are determined by either ICP-AES or ICP-MS techniques. This method is compliant with NEPM (2013) Schedule B(3) Sodium Adsorption Ratio is calculated from Ca, Mg and Na which determined by ALS in house method QWI-EN/ED093F. This method is compliant with NEPM (2013) Schedule B(3) Hardness parameters are calculated based on APHA 2340 B. This method is compliant with NEPM (2013) Schedule B(3)
Dissolved Metals by ICP-MS - Suite A	EG020A-F	WATER	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. Samples are 0.45µm filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Fluoride by PC Titrator	EK040P	WATER	In house: Referenced to APHA 4500-F C: CDTA is added to the sample to provide a uniform ionic strength background, adjust pH, and break up complexes. Fluoride concentration is determined by either manual or automatic ISE measurement. This method is compliant with NEPM (2013) Schedule B(3)
Ionic Balance by PCT DA and Turbi SO4 DA	* EN055 - PG	WATER	In house: Referenced to APHA 1030F. This method is compliant with NEPM (2013) Schedule B(3)

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order : **ES2019091**

Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: HENRY NOAKES	Contact	: Customer Services ES
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: hnoakes@emmconsulting.com.au	E-mail	: ALSEnviro.Sydney@ALSGlobal.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: J190166 - Menangle Quarry	Page	: 1 of 2
Order number	: J190166	Quote number	: ----
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: ----		
Sampler	: KAITLYN BRODIE		

Dates

Date Samples Received	: 02-Jun-2020 19:00	Issue Date	: 02-Jun-2020
Client Requested Due Date	: 03-Jun-2020	Scheduled Reporting Date	: **04-Jun-2020**

Delivery Details

Mode of Delivery	: Undefined	Security Seal	: Not Available
No. of coolers/boxes	: 1	Temperature	: 10.1' C - Ice Bricks present
Receipt Detail	:	No. of samples received / analysed	: 2 / 2

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- Please direct any queries you have regarding this work order to the above ALS laboratory contact.
- Analytical work for this work order will be conducted at ALS Sydney.
- Sample Disposal - Aqueous (3 weeks), Solid (2 months ± 1 week) from receipt of samples.
- Please be aware that APHA/NEPM recommends water and soil samples be chilled to less than or equal to 6°C for chemical analysis, and less than or equal to 10°C but unfrozen for Microbiological analysis. Where samples are received above this temperature, it should be taken into consideration when interpreting results. Refer to ALS EnviroMail 85 for ALS recommendations of the best practice for chilling samples after sampling and for maintaining a cool temperature during transit.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

Method / Client sample ID	Sample Container Received	Preferred Sample Container for Analysis
Dissolved Metals by ICP-MS - Suite A : EG020A-F		
Site 3	- Clear Plastic Bottle - Natural	- Clear Plastic Bottle - Nitric Acid; Filtered
Site 1_D	- Clear Plastic Bottle - Natural	- Clear Plastic Bottle - Nitric Acid; Filtered

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.
If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **WATER**

Laboratory sample ID	Client sampling date / time	Client sample ID	WATER - EG020F Dissolved Metals by ICP/MS	WATER - NT-12 General Water Suite	WATER - W-01 7 Metals
ES2019091-001	02-Jun-2020 00:00	Site 3	✓	✓	✓
ES2019091-002	02-Jun-2020 00:00	Site 1_D	✓	✓	✓

Proactive Holding Time Report

Sample(s) have been received within the recommended holding times for the requested analysis.

Requested Deliverables

ALL INVOICES

- A4 - AU Tax Invoice (INV)	Email	finance@emmconsulting.com.au

HENRY NOAKES

- *AU Certificate of Analysis - NATA (COA)	Email	hnoakes@emmconsulting.com.au
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	hnoakes@emmconsulting.com.au
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	hnoakes@emmconsulting.com.au
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	hnoakes@emmconsulting.com.au
- Chain of Custody (CoC) (COC)	Email	hnoakes@emmconsulting.com.au
- EDI Format - ESDAT (ESDAT)	Email	hnoakes@emmconsulting.com.au
- EDI Format - XTab (XTAB)	Email	hnoakes@emmconsulting.com.au

Katharine Bond

- A4 - AU Tax Invoice (INV)	Email	kbond@emmconsulting.com.au

4/6/20

CHAIN OF CUSTODY

ALS Environmental

ALS Laboratory: please tick →

☐ADELAIDE 21 Burma Road Pooraka SA 5095 Ph: 08 8359 0890 E: adelaide@alsglobal.com

☐BRISBANE 32 Shand Street Stafford QLD 4053 Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com

☐GLADSTONE 46 Callemondah Drive Clinton QLD 4680 Ph: 07 7471 5600 E: gladstone@alsglobal.com

☐MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay@alsglobal.com

☐MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com

☐MUDGEE 27 Sydney Road Mudgee NSW 2850 Ph: 02 6372 6735 E: mudgee.mail@alsglobal.com

☐NEWCASTLE 5/585 Maitland Rd Mayfield West NSW 2304 Ph: 02 4014 2500 E: samples.newcastle@alsglobal.com

☐NOWRA 4/13 Geary Place North Nowra NSW 2541 Ph: 024423 2063 E: nowra@alsglobal.com

☐PERTH 10 Hod Way Malaga WA 6090 Ph: 08 9209 7655 E: samples.perth@alsglobal.com

☐SYDNEY 277-289 Woodpark Road Smithfield NSW 2164 Ph: 02 8784 8555 E: samples.sydney@alsglobal.com

☐TOWNSVILLE 14-16 Desma Court Bohle QLD 4818 Ph: 07 4796 0600 E: townsville.environmental@alsglobal.com

☐WOLLONGONG 99 Kenny Street Wollongong NSW 2500 Ph: 02 4225 3125 E: portkembla@alsglobal.com

CLIENT: EMM Consulting Pty Ltd	**TURNAROUND REQUIREMENTS :** (Standard TAT may be longer for some tests e.g. Ultra Trace Organics)	☐ Standard TAT (List due date):
OFFICE: Sydney		☒ Non Standard or urgent TAT (List due date): Due by COB 3/6/2020
PROJECT: J190166 - Menangle Quarry	**ALS QUOTE NO.:**	
ORDER NUMBER: J190166		
PROJECT MANAGER: Katharine Bond / Henry Noakes	**CONTACT PH:** 0439 604 035 / 0448 772 835	
SAMPLER: Kailtyn Brodie	**SAMPLER MOBILE:** 0401 881 447	
COC emailed to ALS? (YES / NO)	**EDD FORMAT (or default):**	
Email Reports to (will default to PM if no other addresses are listed): **hnoakes@emmconsulting.com.au**		
Email Invoice to (will default to PM if no other addresses are listed): **kbond@emmconsulting.com.au**		

COC SEQUENCE NUMBER (Circle)

COC: 1 2 3 4 5 6 7

OF: 1 2 3 4 5 6 7

FOR LABORATORY USE ONLY (Circle)

Custody Seal Intact? Yes No N/A

Free ice / frozen ice bricks present upon receipt? Yes No N/A

Random Sample Temperature on Receipt: 10.1 °C

Other comment:

RELINQUISHED BY:	RECEIVED BY:	RELINQUISHED BY:	RECEIVED BY:
DATE/TIME:	James D. DATE/TIME: 2/6/20 1900	DATE/TIME:	DATE/TIME:

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).								Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	General water suite NT-12	Dissolved Metals Suite W-1 PLUS IRON (Fe)							
1	Site 3	2/06/2020	W	1 x P & 1 x N	2	x	x							
2	Site 1_D	2/06/2020	W	1 x P & 1 x N	2	x	x							This site appeared on COC sent on 01/06/2020 accidentally.
				TOTAL	4	2	2							

TAT

TAT

Environmental Division Sydney

Work Order Reference

ES2019091

Telephone : +61-2-8784 8555

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES2123005**	Page	: 1 of 3
Amendment	: **1**		
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: HENRY NOAKES	Contact	: Sepan Mahamad
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61 2 8784 8555
Project	: J190166 - Menangle Quarry	Date Samples Received	: 21-Jun-2021 18:45
Order number	: J190166	Date Analysis Commenced	: 21-Jun-2021
C-O-C number	: ----	Issue Date	: 01-Jul-2021 18:24
Sampler	: STEVE ROCKS		
Site	: ----		
Quote number	: EN/112/20 Primary work		
No. of samples received	: 5		
No. of samples analysed	: 5		

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, unless the sampling was conducted by ALS. 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
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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.

- Amendment (01/07/2021): This report has been amended and re-released to allow a change in sampling date to 18/06/2021 for samples 001-005. All analysis results are as per the previous report.
- EA016: Calculated TDS is determined from Electrical conductivity using a conversion factor of 0.65.
- 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)			Sample ID	BH01_D	BH01_S	BH02	BH03	BH04
			Sampling date / time	18-Jun-2021 11:30	18-Jun-2021 12:15	18-Jun-2021 13:30	18-Jun-2021 15:00	18-Jun-2021 15:30
Compound	CAS Number	LOR	Unit	ES2123005-001	ES2123005-002	ES2123005-003	ES2123005-004	ES2123005-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.35	6.03	6.61	5.90	7.42
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	1310	218	8230	141	8460
EA016: Calculated TDS (from Electrical Conductivity)								
Total Dissolved Solids (Calc.)	----	1	mg/L	852	142	5350	92	5500
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	130	38	1140	40	1180
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	322	30	392	8	454
Total Alkalinity as CaCO3	----	1	mg/L	322	30	392	8	454
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	120	30	389	17	300
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	172	29	2700	24	2700
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	34	7	151	11	110
Magnesium	7439-95-4	1	mg/L	11	5	185	3	219
Sodium	7440-23-5	1	mg/L	210	28	1200	16	1160
Potassium	7440-09-7	1	mg/L	6	<1	12	2	32
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.4	<0.1	0.6	<0.1	0.4
EN055: Ionic Balance								
ø Total Anions	----	0.01	meq/L	13.8	2.04	92.1	1.19	91.5
ø Total Cations	----	0.01	meq/L	11.9	1.98	75.3	1.54	74.8
ø Ionic Balance	----	0.01	%	7.38	----	10.0	----	10.0

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **ES2123005**	Page	: 1 of 5
Amendment	: **1**		
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: HENRY NOAKES	Contact	: Sepan Mahamad
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61 2 8784 8555
Project	: J190166 - Menangle Quarry	Date Samples Received	: 21-Jun-2021
Order number	: J190166	Date Analysis Commenced	: 21-Jun-2021
C-O-C number	: ----	Issue Date	: 01-Jul-2021
Sampler	: STEVE ROCKS		
Site	: ----		
Quote number	: EN/112/20 Primary work		
No. of samples received	: 5		
No. of samples analysed	: 5		

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, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

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
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
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
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	Sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Acceptable RPD (%)
EA005P: pH by PC Titrator (QC Lot: 3748449)									
ES2122916-001	Anonymous	EA005-P: pH Value	----	0.01	pH Unit	6.71	6.67	0.6	0% - 20%
ES2122988-002	Anonymous	EA005-P: pH Value	----	0.01	pH Unit	7.84	7.85	0.1	0% - 20%
EA010P: Conductivity by PC Titrator (QC Lot: 3748448)									
ES2123005-003	BH02	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	8230	8310	0.9	0% - 20%
ES2122916-001	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	1250	1250	0.0	0% - 20%
ES2123022-002	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	1020	1020	0.2	0% - 20%
ES2122988-002	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	46500	46800	0.7	0% - 20%
ED037P: Alkalinity by PC Titrator (QC Lot: 3748450)									
ES2122916-001	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	25	24	4.3	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	25	24	4.3	0% - 20%
ES2122988-002	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	115	118	1.8	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	115	118	1.8	0% - 20%
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QC Lot: 3749782)									
ES2123005-001	BH01_D	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	120	119	1.5	0% - 20%
EW2102711-004	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	8	8	0.0	No Limit
ED045G: Chloride by Discrete Analyser (QC Lot: 3749783)									
ES2123005-001	BH01_D	ED045G: Chloride	16887-00-6	1	mg/L	172	173	0.6	0% - 20%
EW2102711-004	Anonymous	ED045G: Chloride	16887-00-6	1	mg/L	39	39	0.0	0% - 20%
ED093F: Dissolved Major Cations (QC Lot: 3754213)									
ES2122543-001	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	79	75	5.6	0% - 20%

Sub-Matrix: **WATER**

Laboratory sample ID	Sample ID	Method: Compound	CAS Number	Laboratory Duplicate (DUP) Report					
				LOR	Unit	Original Result	Duplicate Result	RPD (%)	Acceptable RPD (%)
ED093F: Dissolved Major Cations (QC Lot: 3754213) - continued									
ES2122543-001	Anonymous	ED093F: Magnesium	7439-95-4	1	mg/L	29	31	6.5	0% - 20%
		ED093F: Sodium	7440-23-5	1	mg/L	5	5	0.0	No Limit
		ED093F: Potassium	7440-09-7	1	mg/L	<1	<1	0.0	No Limit
ES2122976-007	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	4	4	0.0	No Limit
		ED093F: Magnesium	7439-95-4	1	mg/L	3	2	0.0	No Limit
		ED093F: Sodium	7440-23-5	1	mg/L	18	18	0.0	0% - 50%
		ED093F: Potassium	7440-09-7	1	mg/L	5	2	81.9	No Limit
EK040P: Fluoride by PC Titrator (QC Lot: 3748451)									
ES2123005-003	BH02	EK040P: Fluoride	16984-48-8	0.1	mg/L	0.6	0.5	0.0	No Limit
ES2122988-002	Anonymous	EK040P: Fluoride	16984-48-8	0.1	mg/L	1.1	1.1	0.0	0% - 50%

Method Blank (MB) and Laboratory Control Sample (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Acceptable Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA005P: pH by PC Titrator (QCLot: 3748449)								
EA005-P: pH Value	----	----	pH Unit	----	4 pH Unit	99.0	98.8	101
				----	7 pH Unit	100	99.2	101
EA010P: Conductivity by PC Titrator (QCLot: 3748448)								
EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	<1	220 µS/cm	99.6	91.1	107
				<1	2100 µS/cm	98.7	93.2	108
ED037P: Alkalinity by PC Titrator (QCLot: 3748450)								
ED037-P: Total Alkalinity as CaCO3	----	----	mg/L	----	200 mg/L	99.2	81.0	111
				----	50 mg/L	103	80.0	120
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 3749782)								
ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	25 mg/L	103	82.0	122
				<1	500 mg/L	103	82.0	122
ED045G: Chloride by Discrete Analyser (QCLot: 3749783)								
ED045G: Chloride	16887-00-6	1	mg/L	<1	50 mg/L	106	80.9	127
				<1	1000 mg/L	103	80.9	127
ED093F: Dissolved Major Cations (QCLot: 3754213)								
ED093F: Calcium	7440-70-2	1	mg/L	<1	50 mg/L	106	80.0	114
ED093F: Magnesium	7439-95-4	1	mg/L	<1	50 mg/L	99.1	90.0	116
ED093F: Sodium	7440-23-5	1	mg/L	<1	50 mg/L	106	82.0	120
ED093F: Potassium	7440-09-7	1	mg/L	<1	50 mg/L	93.9	85.0	113
EK040P: Fluoride by PC Titrator (QCLot: 3748451)								
EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	5 mg/L	88.4	82.0	116

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Acceptable Limits (%)	
Laboratory sample ID	Sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 3749782)							
ES2123005-001	BH01_D	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	10 mg/L	# Not Determined	70.0	130
ED045G: Chloride by Discrete Analyser (QCLot: 3749783)							

Sub-Matrix: **WATER**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Acceptable Limits (%)	
Laboratory sample ID	*Sample ID*	*Method: Compound*	*CAS Number*	*Concentration*	*MS*	*Low*	*High*
ED045G: Chloride by Discrete Analyser (QCLot: 3749783) - continued							
ES2123005-001	BH01_D	ED045G: Chloride	16887-00-6	50 mg/L	109	70.0	130
EK040P: Fluoride by PC Titrator (QCLot: 3748451)							
ES2122972-001	Anonymous	EK040P: Fluoride	16984-48-8	5 mg/L	90.6	70.0	130

ALS Environmental

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **ES2123005**	Page	: 1 of 5
Amendment	: **1**		
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: HENRY NOAKES	Telephone	: +61 2 8784 8555
Project	: J190166 - Menangle Quarry	Date Samples Received	: 21-Jun-2021
Site	: ----	Issue Date	: 01-Jul-2021
Sampler	: STEVE ROCKS	No. of samples received	: 5
Order number	: J190166	No. of samples analysed	: 5

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **Matrix Spike outliers exist - please see following pages for full details.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **Analysis Holding Time Outliers exist - please see following pages for full details.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Outliers : Quality Control Samples

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: **WATER**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Matrix Spike (MS) Recoveries							
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA	ES2123005--001	BH01_D	**Sulfate as SO4 - Turbidimetric**	14808-79-8	Not Determined	----	**MS recovery not determined, background level greater than or equal to 4x spike level.**

Outliers : Analysis Holding Time Compliance

Matrix: **WATER**

Method / Container / Client Sample ID(s)	Extraction / Preparation: Date extracted	Extraction / Preparation: Due for extraction	Extraction / Preparation: Days overdue	Analysis: Date analysed	Analysis: Due for analysis	Analysis: Days overdue
EA005P: pH by PC Titrator						
Clear Plastic Bottle - Natural						
BH01_D, BH01_S, BH02, BH03, BH04	----	----	----	21-Jun-2021	18-Jun-2021	**3**

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)	Sample Date	Extraction / Preparation: Date extracted	Extraction / Preparation: Due for extraction	Extraction / Preparation: Evaluation	Analysis: Date analysed	Analysis: Due for analysis	Analysis: Evaluation
EA005P: pH by PC Titrator							
Clear Plastic Bottle - Natural (EA005-P)							
BH01_D, BH01_S, BH02, BH03, BH04	**18-Jun-2021**	**----**	----	----	**21-Jun-2021**	18-Jun-2021	×
EA010P: Conductivity by PC Titrator							
Clear Plastic Bottle - Natural (EA010-P)							
BH01_D, BH01_S, BH02, BH03, BH04	**18-Jun-2021**	**----**	----	----	**21-Jun-2021**	16-Jul-2021	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)	Sample Date	Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA065: Total Hardness as CaCO3							
Clear Plastic Bottle - Natural (ED093F)							
BH01_D, BH01_S, BH02, BH03, BH04	**18-Jun-2021**	**----**	----	----	**24-Jun-2021**	25-Jun-2021	✓
ED037P: Alkalinity by PC Titrator							
Clear Plastic Bottle - Natural (ED037-P)							
BH01_D, BH01_S, BH02, BH03, BH04	**18-Jun-2021**	**----**	----	----	**21-Jun-2021**	02-Jul-2021	✓
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA							
Clear Plastic Bottle - Natural (ED041G)							
BH01_D, BH01_S, BH02, BH03, BH04	**18-Jun-2021**	**----**	----	----	**22-Jun-2021**	16-Jul-2021	✓
ED045G: Chloride by Discrete Analyser							
Clear Plastic Bottle - Natural (ED045G)							
BH01_D, BH01_S, BH02, BH03, BH04	**18-Jun-2021**	**----**	----	----	**22-Jun-2021**	16-Jul-2021	✓
ED093F: Dissolved Major Cations							
Clear Plastic Bottle - Natural (ED093F)							
BH01_D, BH01_S, BH02, BH03, BH04	**18-Jun-2021**	**----**	----	----	**24-Jun-2021**	25-Jun-2021	✓
EK040P: Fluoride by PC Titrator							
Clear Plastic Bottle - Natural (EK040P)							
BH01_D, BH01_S, BH02, BH03, BH04	**18-Jun-2021**	**----**	----	----	**21-Jun-2021**	16-Jul-2021	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Alkalinity by PC Titrator	ED037-P	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	4	36	**11.11**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	2	15	**13.33**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
pH by PC Titrator	EA005-P	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Alkalinity by PC Titrator	ED037-P	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	3	36	**8.33**	**8.33**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	15	**6.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
pH by PC Titrator	EA005-P	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Chloride by Discrete Analyser	ED045G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	1	36	**2.78**	**1.67**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	15	**6.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Chloride by Discrete Analyser	ED045G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	15	**6.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
pH by PC Titrator	EA005-P	WATER	In house: Referenced to APHA 4500 H+ B. This procedure determines pH of water samples by automated ISE. This method is compliant with NEPM Schedule B(3)
Conductivity by PC Titrator	EA010-P	WATER	In house: Referenced to APHA 2510 B. This procedure determines conductivity by automated ISE. This method is compliant with NEPM Schedule B(3)
Calculated TDS (from Electrical Conductivity)	EA016	WATER	In house: Calculation from Electrical Conductivity (APHA 2510 B) using a conversion factor specified in the analytical report. This method is compliant with NEPM Schedule B(3)
Alkalinity by PC Titrator	ED037-P	WATER	In house: Referenced to APHA 2320 B This procedure determines alkalinity by automated measurement (e.g. PC Titrate) on a settled supernatant aliquot of the sample using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM Schedule B(3)
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	WATER	In house: Referenced to APHA 4500-SO4. Dissolved sulfate is determined in a 0.45um filtered sample. Sulfate ions are converted to a barium sulfate suspension in an acetic acid medium with barium chloride. Light absorbance of the BaSO4 suspension is measured by a photometer and the SO4-2 concentration is determined by comparison of the reading with a standard curve. This method is compliant with NEPM Schedule B(3)
Chloride by Discrete Analyser	ED045G	WATER	In house: Referenced to APHA 4500 Cl - G.The thiocyanate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form non-ionised mercuric chloride.in the presence of ferric ions the librated thiocynate forms highly-coloured ferric thiocynate which is measured at 480 nm APHA seal method 2 017-1-L
Major Cations - Dissolved	ED093F	WATER	In house: Referenced to APHA 3120 and 3125; USEPA SW 846 - 6010 and 6020; Cations are determined by either ICP-AES or ICP-MS techniques. This method is compliant with NEPM Schedule B(3) Sodium Adsorption Ratio is calculated from Ca, Mg and Na which determined by ALS in house method QWI-EN/ED093F. This method is compliant with NEPM Schedule B(3) Hardness parameters are calculated based on APHA 2340 B. This method is compliant with NEPM Schedule B(3)
Fluoride by PC Titrator	EK040P	WATER	In house: Referenced to APHA 4500-F C: CDTA is added to the sample to provide a uniform ionic strength background, adjust pH, and break up complexes. Fluoride concentration is determined by either manual or automatic ISE measurement. This method is compliant with NEPM Schedule B(3)
Ionic Balance by PCT DA and Turbi SO4 DA	* EN055 - PG	WATER	In house: Referenced to APHA 1030F. This method is compliant with NEPM Schedule B(3)

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order	: **ES2123005**		
Amendment	: **1**		
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: HENRY NOAKES	Contact	: Sepan Mahamad
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
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Telephone	: ----	Telephone	: +61 2 8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: J190166 - Menangle Quarry	Page	: 1 of 2
Order number	: J190166	Quote number	: ES2020EMGAMM0004 (EN/112/20 Primary work)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: ----		
Sampler	: STEVE ROCKS		

Dates

Date Samples Received	: 21-Jun-2021 18:45	Issue Date	: 01-Jul-2021
Client Requested Due Date	: 29-Jun-2021	Scheduled Reporting Date	: **29-Jun-2021**

Delivery Details

Mode of Delivery	: Client Drop Off	Security Seal	: Intact.
No. of coolers/boxes	: 1	Temperature	: 6.2'C - Ice Bricks present
Receipt Detail	: large esky	No. of samples received / analysed	: 5 / 5

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **(01/07/2021) This is an updated SRN which reflects a change in sampling date to 18/06/2021 for samples 001-005.**
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- Please direct any queries you have regarding this work order to the above ALS laboratory contact.
- Analytical work for this work order will be conducted at ALS Sydney.
- Sample Disposal - Aqueous (3 weeks), Solid (2 months ± 1 week) from receipt of samples.
- Please be aware that APHA/NEPM recommends water and soil samples be chilled to less than or equal to 6°C for chemical analysis, and less than or equal to 10°C but unfrozen for Microbiological analysis. Where samples are received above this temperature, it should be taken into consideration when interpreting results. Refer to ALS EnviroMail 85 for ALS recommendations of the best practice for chilling samples after sampling and for maintaining a cool temperature during transit.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exists.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.
If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **WATER**

Laboratory sample ID	Sampling date / time	Sample ID	WATER - NT-12 General Water Suite
ES2123005-001	18-Jun-2021 11:30	BH01_D	✓
ES2123005-002	18-Jun-2021 12:15	BH01_S	✓
ES2123005-003	18-Jun-2021 13:30	BH02	✓
ES2123005-004	18-Jun-2021 15:00	BH03	✓
ES2123005-005	18-Jun-2021 15:30	BH04	✓

Proactive Holding Time Report

The following table summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory.

Matrix: **WATER** Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Client Sample ID(s)	Container	Due for extraction	Due for analysis	Samples Received		Instructions Received	
				Date	Evaluation	Date	Evaluation
EA005-P: pH by PC Titrator							
BH01_D	Clear Plastic Bottle - Natural	----	18-Jun-2021	21-Jun-2021	✘	----	----
BH01_S	Clear Plastic Bottle - Natural	----	18-Jun-2021	21-Jun-2021	✘	----	----
BH02	Clear Plastic Bottle - Natural	----	18-Jun-2021	21-Jun-2021	✘	----	----
BH03	Clear Plastic Bottle - Natural	----	18-Jun-2021	21-Jun-2021	✘	----	----
BH04	Clear Plastic Bottle - Natural	----	18-Jun-2021	21-Jun-2021	✘	----	----

Requested Deliverables

ALL ESDAT REPORTS
- EDI Format - ESDAT (ESDAT) Email emmconsulting@esdat.net

ALL INVOICES
- A4 - AU Tax Invoice (INV) Email finance@emmconsulting.com.au

HENRY NOAKES
- *AU Certificate of Analysis - NATA (COA) Email hnoakes@emmconsulting.com.au
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI) Email hnoakes@emmconsulting.com.au
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC) Email hnoakes@emmconsulting.com.au
- A4 - AU Sample Receipt Notification - Environmental HT (SRN) Email hnoakes@emmconsulting.com.au
- Chain of Custody (CoC) (COC) Email hnoakes@emmconsulting.com.au
- EDI Format - ENMRG (ENMRG) Email hnoakes@emmconsulting.com.au
- EDI Format - ESDAT (ESDAT) Email hnoakes@emmconsulting.com.au

Katharine Bond
- A4 - AU Tax Invoice (INV) Email kbond@emmconsulting.com.au

CHAIN OF CUSTODY

ALS Laboratory: please tick →

☐ADELAIDE 21 Burma Road Pooraka SA 5095 Ph: 08 8359 0890 E: adelaide@alsglobal.com
☐BRISBANE 32 Shand Street Stafford QLD 4053 Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com
☐GLADSTONE 46 Callemondah Drive Clinton QLD 4680 Ph: 07 7471 5600 E: gladstone@alsglobal.com
☐MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay@alsglobal.com
☐MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com
☐MUDGEE 27 Sydney Road Mudgee NSW 2850 Ph: 02 6372 6735 E: mudgee.mail@alsglobal.com
☐NEWCASTLE 5/585 Maitland Rd Mayfield West NSW 2304 Ph: 02 4014 2500 E: samples.newcastle@alsglobal.com
☐NOWRA 4/13 Geary Place North Nowra NSW 2541 Ph: 024423 2063 E: nowra@alsglobal.com
☐PERTH 10 Hod Way Malaga WA 6090 Ph: 08 9209 7655 E: samples.perth@alsglobal.com
☐SYDNEY 277-289 Woodpark Road Smithfield NSW 2164 Ph: 02 8784 8555 E: samples.sydney@alsglobal.com
☐TOWNSVILLE 14-15 Desma Court Bohle QLD 4818 Ph: 07 4796 0600 E: townsville.environmental@alsglobal.com
☐WOLLONGONG 99 Kenny Street Wollongong NSW 2500 Ph: 02 4225 3125 E: portkembla@alsglobal.com

CLIENT: EMM Consulting Pty Ltd	TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g., Ultra Trace Organics)	☑ Standard TAT (List due date):
OFFICE: Sydney		☒ Non Standard or urgent TAT (List due date): 2 day turnaround
PROJECT: J190166 - Menangle Quarry	ALS QUOTE NO.:	
ORDER NUMBER: J190166		COC SEQUENCE NUMBER (Circle) COC: 1 2 3 4 5 6 7 OF: 1 2 3 4 5 6 7
PROJECT MANAGER: Katharine Bond / Henry Noakes	CONTACT PH: 0439 604 035 / 0448 772 835	
SAMPLER: Steve Rocks	SAMPLER MOBILE: 0414 776 988	
COC emailed to ALS? (YES / NO)	EDD FORMAT (or default):	
Email Reports to (will default to PM if no other addresses are listed): hnoakes@emmconsulting.com.au		
Email Invoice to (will default to PM if no other addresses are listed): kbond@emmconsutling.com.au		

FOR LABORATORY USE ONLY (Circle)

Custody Seal Intact?	Yes	No	N/A
Free ice / frozen ice bricks present upon receipt?	Yes	No	N/A
Random Sample Temperature on Receipt:	6.2 °C		
Other comment:			

RELINQUISHED BY:	RECEIVED BY: James	RELINQUISHED BY:	RECEIVED BY: SGS/Alex SGS
DATE/TIME:	DATE/TIME: 21/6 2.10pm	DATE/TIME:	DATE/TIME: 21/6/21 1845

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).							Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	General water suite NT-12							
1	BH01_D	21/06/2021 11:30	W		1	x							Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
2	BH01_S	21/06/2021 12:15	W		1	x							Please lab filter from unpreserved bottle for metals.
3	BH02	21/06/2021 13:30:00 PM	W		1	x							
4	BH03	21/06/2021 15:00:00 PM	W		1	x							
5	BH04	21/06/2021 15:30:00 PM	W		1	x							
				TOTAL	5	5							

TAT

Environmental Division
Sydney
Work Order Reference
ES2123005

Telephone : + 61-2-8784 8555

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP = Airfreight Unpreserved Pl
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulf
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

...maldehyde Preserved Glass;

Appendix C

Groundwater sampling forms

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Low Flow Sampling Record

I.D: BH01_D (SANDSTONE)

Date start / finish	18/6/2021	Well diameter (mm)	50	Sample method	BLADDER PUMP
Project	J190166 - MENANGLE QUARRY	Stickup (magl)	#	Water quality meter	YSI PRO
Project number	~~J190166~~ J190166	Intial time	11:00	Calibration date	18/06/21
Client	MENANGLE SAND/SOIL (BENEDICT INDUSTRIES)	Initial SWL (mbtoc)	6.332 mbTOC	Final SWL (mbtoc)	10.25
Field staff	SR	Intial TD (mbtoc)		Sample time	11:35
Weather	CLEAR.	Well volume (L)		Logger installed ?	Y

Time	Volume	Yield	Temp	pH	EC	TDS	DO		Redox	Observations / olfactory
	L	L/s	°C ~±0.1	~±0.05	µs/cm ~±5%	mg/L ~±5%	%	mg/L	mV ~±5%	(Colour, turbidity, odour)
17:12	1		18.6	6.43	1375	890.50	8.6	0.81	-81.8	YELLOW BROWN, SLIGHT METALLIC ODOUR
11:20	2		18.6	6.60	1278	832.0	7.7	0.72	-90.2	" " "
11:23	3		18.6	6.59	1241	806.0	8.7	0.81	-84.2	" " "
11:29	4		18.3	6.62	1216	793.0	7.5	0.70	-84.1	" " "
11:31	5		18.3	6.62	1219	793.0	7.1	0.66	-84.4	"
11:35	6		18.2	6.62	1217	793.0	6.9	0.65	-84.4	" " "
SAMPLED ↑										

Additional notes # SLOW RECOVERY - DRAW DOWN UNAVOIDABLE.

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Low Flow Sampling Record

I.D: BH01_S (ALLUVIUM)

Date start / finish	18/06/21	Well diameter (mm)	50	Sample method	LOW FLOW BLADDER
Project	MENANGLE PARK SAND & SOIL	Stickup (magl)		Water quality meter	YSI PRO
Project number	J190166	Intial time		Calibration date	18/6/21
Client	BENEDICT INDUSTRIES	Initial SWL (mbtoc)	6.165	Final SWL (mbtoc)	
Field staff	SR	Intial TD (mbtoc)		Sample time	
Weather	CLEAR	Well volume (L)		Logger installed ?	YES

Time	Volume	Yield	Temp	pH	EC	TDS	DO		Redox	Observations / olfactory
	L	L/s	°C ~±0.1	~±0.05	µs/cm ~±5%	mg/L ~±5%	%	mg/L	mV ~±5%	(Colour, turbidity, odour)
12:06	2		18.1	4.91	~~2265~~	~~146.30~~	9.3	0.87	60.6	DIRTY BROWN/ORANGE
12:08	4		18.2	5.05	222.8	144.30	7.4	0.69	48.6	" "
12:10	5		18.3	5.17	219.4	142.35	5.4	0.5	330	" "
12:12	6		18.3	5.20	222	144.30	4.4	0.41	27.6	" "
12:14	7		18.3	5.22	224	145.6	4.3	0.41	28.1	GETING CLEARER / NO ODOUR
12:16	8		18.3	5.23	227.2	147.55	4.5	0.43	30.0	" "
SAMPLED ↑										

Additional notes * CLEARER THAN FIRST PURGE, STILL SLIGHT GREY.

Low Flow Sampling Record

I.D: BH02

Date start / finish	18/06/21	Well diameter (mm)	50	Sample method	BLADDER
Project	J190166 MENANGLE PARK	Stickup (magl)		Water quality meter	YSI PRO
Project number	J190166	Intial time	13:00	Calibration date	18/06/21
Client	BENEDICT INDUSTRIES MENANGLE PARK SAND & SOIL.	Initial SWL (mbtoc)	25.862	Final SWL (mbtoc)	
Field staff	SR	Intial TD (mbtoc)		Sample time	14:10
Weather	CLEAR	Well volume (L)		Logger installed ?	✓

SCREEN = 33.0 – 39.0 mbGL

Time	Volume	Yield	Temp	pH	EC	TDS	DO		Redox	Observations / olfactory
	L	L/s	°C ~±0.1	~±0.05	µs/cm ~±5%	mg/L ~±5%	%	mg/L	mV ~±5%	(Colour, turbidity, odour)
13:00 *	—	—								
	18.7	1	18.7	5.86	7091	4608.5	15.8	1.44	-78.0	GREY, CLOUDY, SULPHUROUS ODOUR
										SAND/SILT PARTICLES
** SAMPLED @ 13:00 WITH SS BAILER										

Additional notes * ISSUES WITH BLADDER PUMP, SANDY BOREHOLE CLOGGING PUMP. USED BAILER INSTEAD.

** SAMPLE RECOVERED FROM SCREENED INTERVAL @ APPROX. 36-37 mbTOC

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Low Flow Sampling Record

I.D: BH03

Date start / finish	18/06/21	Well diameter (mm)	50	Sample method	BAILER (STAINLESS STEEL)
Project	MENANGLE PARK SAND & SOIL	Stickup (magl)		Water quality meter	YSI PRO
Project number	J190166	Intial time		Calibration date	18/6/21
Client	BENEDICT INDUSTRIES	Initial SWL (mbtoc)	5.170	Final SWL (mbtoc)	
Field staff	SR	Intial TD (mbtoc)		Sample time	15:00
Weather	CLEAR	Well volume (L)		Logger installed ?	Y

Time	Volume	Yield	Temp	pH	EC	TDS	DO		Redox	Observations / olfactory
	L	L/s	°C ~±0.1	~±0.05	µs/cm ~±5%	mg/L ~±5%	%	mg/L	mV ~±5%	(Colour, turbidity, odour)
15:00	2		17.8	5.73	314.1	204.10	55.1	5.23	30.4	GREY - CLEAR, NO ODOUR
* SAMPLED USING SS BAILER @ 15:00										

Additional notes * BAILED DUE TO ISSUES WITH BLADDER PUMP. * 6-7 mbgl THE BAILER STOPPED DUE TO POSSIBLE OBSTRUCTION OF BORE, POSSIBLY AFTER FLOODS. ** SAMPLE RECOVERED FROM APPROX. 6-7m bTOC

Low Flow Sampling Record

I.D: BH04

Date start / finish	18/06/21	Well diameter (mm)	50	Sample method	BAILER (STAINLESS)
Project	MENANGLE PARK	Stickup (magl)		Water quality meter	YSI PRO
Project number	J190166	Intial time		Calibration date	18/6/21
Client	BENEDICT INDUSTRIES	Initial SWL (mbtoc)	43.462	Final SWL (mbtoc)	
Field staff	SR	Intial TD (mbtoc)		Sample time	15:30
Weather	CLEAR	Well volume (L)		Logger installed ?	Y

SCREENED @ 54.0 - 60.0 mbgl

Time	Volume	Yield	Temp	pH	EC	TDS	DO		Redox	Observations / olfactory
	L	L/s	°C ~±0.1	~±0.05	µs/cm ~±5%	mg/L ~±5%	%	mg/L	mV ~±5%	(Colour, turbidity, odour)
*15:30	1		17.1	6.52	6864	4465.5	32.6	3.07	-64.7	GREY/YELLOW SLIGHTLY CLOUDY, SLIGHT
**SAMPLED										SULPHUROUS ODOUR
WITH SS BAILER										

Additional notes: SAMPLED USING BAILER. BAILED FROM WITHIN SCREENED INTERVAL APPROX. 57 mbTOC

Appendix F

Flood scour risk and remedial response TARP

Flood scour risk and remedial response TARP

Trigger	Action required	Timing	Follow up actions	Reporting*
Prior to extraction within substage				
Sand and soil extraction in the Stage 8 area.	Flood modelling to predict the peak flow velocities in potential extraction areas. Survey the extent of the exclusion zones – defined in the Consent as areas where predicted the peak flow velocity is >4 m/s during a 1% AEP flood.	Prior to extraction in each substage. Modelling for Substages 8A–8C has been completed. Exclusion zones associated with substages 8A–8C have been surveyed by a registered surveyor in accordance with Development Consent 85/2865 (the Consent) Condition A22.	Should scour occur that results in the loss of trees in the lower riverbank or Nepean River Buffer Zone: • review, and if required, update flood modelling; and • prepare Incident Report.	Incident Report: findings of flood/scour model review/update. Annual report: progress of actions arising from incident report.
Ongoing during extraction				
Sand and soil extraction within an area that may be inundated by flooding of the Nepean River with a predicted peak flow velocity of ≤4 m/s during a 1% AEP flood.	Quarry design to meet the requirements specified in: • the Consent (including Conditions A10, B32, B71 and B72); • the *Applicant's Description of Amended Project* (EMM 2019); and • the environmental management plans. Inspections to review compliance against the quarry design. The base of the active extraction area is to remain 1 m above the water table in accordance with Consent Condition B22.	Ongoing implementation of quarry design. Weekly inspections.	If the quarry does not meet the design requirements (eg batter angles are too steep), undertake earthmoving operations to ensure that quarry design conforms with the approved design. If any extraction is identified outside of the surveyed extraction area or within the exclusion zone: • cease work in this area immediately; • report as an incident/non-compliance as described in Section 8 of the *Menangle Sand and Soil Quarry Environmental*	Incident Report: providing details of non-compliance and corrective/remedial actions. Annual report: • progress of actions arising from incident report; and • summary of compliance with the Consent, design and environmental management plans relevant this TARP.

Flood scour risk and remedial response TARP

Trigger	Action required	Timing	Follow up actions	Reporting*
	The maximum length of the riverside batter that has a slope between 1:1 and 1:5 will be restricted to 30-m long so that it can be returned to a 1:5 batter within 12 hours if flooding is predicted. The riverside batter will have a slope of no more than 1:5 in the final landform.		*Management Strategy* (EMS) and prepare Incident Report; and • rehabilitate the area in accordance with the *Menangle Sand and Soil Quarry Biodiversity and Rehabilitation Management Plan* (BRMP).	
	Commence rehabilitation of completed extraction area as soon as practicable, always ensuring that the active extraction area is no more than 0.33 ha, in accordance with Consent Condition B72.	Ongoing implementation of quarry design. Weekly inspections of active quarry area, including installation of pegs/flagging to mark the exclusion zone. Monthly review of active quarry area using most recent NearMap (or equivalent) images.	If any extraction is identified outside of the surveyed extraction area or within the exclusion zone: • cordon off part of the extraction area such that the active extraction area is ≤0.33 ha; • commence rehabilitation as described in the BRMP in the cordoned off area; and • report as an incident/non-compliance as described in Section 8 of the EMS and prepare Incident Report.	Incident Report: providing details of non-compliance and corrective/remedial actions. Annual Report: • progress of actions arising from incident report; and • summary of weekly inspections and monthly reviews.
	Install woody debris in rehabilitation area (as required by Consent Condition B78) and in restoration area as described in BRMP Section 7.5. Woody debris should be used to pin brush or mesh surface cover.	Ongoing.	Annual monitoring to confirm that woody debris meets the requirements of Consent Condition B78 (see BRMP Section 8.4).	Report woody debris installation over the last 12 months in the Rehabilitation and Restoration Site Annual Progress Report as described in BRMP Section 8.8.

Flood scour risk and remedial response TARP

Trigger	Action required	Timing	Follow up actions	Reporting*
Sand and soil extraction within an area that may be inundated by flooding of the Nepean River with a predicted peak flow velocity of >4 m/s during a 1% AEP flood.	Do not extract sand and soil within the exclusion zone, where predicted the peak flow velocity is >4 m/s during a 1% AEP flood as provided in Appendix 2 of the Consent. As described in Section 2.3.3 of the *Applicant's Description of Amended Project*, a qualified surveyor has undertaken the following: • mark the boundary of the extraction area closest to the river as defined by the 64 m AHD contour; • mark the extent of the 10-m wide horizontal setback area; • mark all living native trees with their trunk within the 10-m wide horizontal setback area; • place a peg 7.5 m horizontally landward of each tree within the 10-m wide horizontal setback area – marking the extent to which the existing bank will be retained, ie forming the 10-m to 17.5-m wide horizontal setback area; • mark all other boundaries of the extraction area; and • mark the boundaries of the adjacent restoration (no resource extraction) area. Sand and soil is not to be extracted from outside of the marked extraction area.	Each extraction area (8A–8C) is to be marked prior to extraction within the substage.	If any extraction is identified outside of the surveyed extraction area or within the exclusion zone: • cordon off part of the extraction area such that the active extraction area is ≤0.33 ha; • commence rehabilitation as described in the BRMP in the cordoned off area; and • report as an incident/non-compliance as described in Section 8 of the EMS and prepare Incident Report.	Incident Report: providing details of non-compliance and corrective/remedial actions. Annual report: • progress of actions arising from incident report; and • summary of compliance with quarry design.

Flood scour risk and remedial response TARP

Trigger	Action required	Timing	Follow up actions	Reporting*
Prior to flooding (Flood Management TARP actions relevant to substages 8A–8C)				
Stand-by: Bureau of Meteorology (BoM) issues 'flood watch' for Nepean River catchment. 'Flood watch' generally issued up to four days in advance of the expected onset of flooding but maybe as short as 12 hours.	Inform quarry personnel that flooding may impact the quarry in the coming days. Continue to monitor rainfall and flood watch advice.	Immediately following the 'flood watch' notification being received by the quarry.	Inform quarry personnel if BoM updates 'flood watch' so that flooding is no longer expected.	-
Risk level to be advised: BoM issues 'flood warning' for Nepean River catchment in vicinity of the quarry.	Inform quarry personnel that flooding within the Nepean River may inundate quarrying areas. Monitor rainfall and flood warning advice hourly.	Immediately following the 'flood warning' notification being received by the quarry	Continue to monitor BoM flood severity for updates. Proceed to next level of TARP if flood severity classed as 'minor'.	-
Minor: Nepean River flooding adjacent to the quarry is predicted to exceed 64 mAHD (ie a predicted Menangle Weir level of 63.5 mAHD).	Prepare the Stage 8 extraction area for potential flood inundation as described in the FMP, including: • Backfill the active Stage 8 extraction area to achieve a maximum batter slope of 1:5 adjacent to the riverside batter. • Flatten exposed batters and the base of the active extraction area to remove isolated highpoints that may be susceptible to scour. • Smooth all exposed sand and soil in the extraction area so that there are no rapid	Immediately (if safe to do so) following the prediction that flood levels will exceed 64 mAHD.	Continue to monitor BoM flood severity for updates. Proceed to next level of TARP if flood severity classed as 'moderate'. Proceed to 'event over' when flood warning removed.	-

Flood scour risk and remedial response TARP

Trigger	Action required	Timing	Follow up actions	Reporting*
	changes in slopes, particularly at the intersections of different batters. • Move all plant and infrastructure from the active extraction area to higher ground (above predicted maximum flood level). Sand face stabilisation and installation of pinning mesh or brush on potential erosion areas with particular focus in low areas where concentrated flood flows may enter or leave the extraction area.			
Moderate: Nepean River flooding adjacent to the quarry is predicted to exceed 66 mAHD – access road between site entry and operations area becomes inundated.	Move all plant to higher ground (above predicted maximum predicted flood level).	Immediately (if safe to do so) following the prediction that flood levels will exceed 66 mAHD.	Continue to monitor BoM flood severity for updates. Proceed to next level of TARP if flood severity classed as 'major'. Proceed to 'event over' when flood warning removed.	-
Major: Nepean River flooding adjacent to the quarry is predicted to exceed 74 mAHD – entire site inundated	Evacuate personnel from the site.	Immediately (if safe to do so) following the prediction that flood levels will exceed 74 m AHD.	Continue to monitor BoM flood severity for updates. Proceed to 'event over' when flood warning removed.	-
Event over: The SES issue safe to return or flood levels have receded below 64 m AHD.	Assess and report any damage to the active extraction area and operations area. Remediate areas of damage, including clearing of debris and areas undergoing rehabilitation at the time of the flood event. Recommence quarrying activities.	Within 5 days or as soon as practical following the 'event over' trigger is actioned.	Debrief all key personnel and update/modify the FMP as necessary.	-

Flood scour risk and remedial response TARP

Trigger	Action required	Timing	Follow up actions	Reporting*
Post-flood event				
Following a minor, moderate or major flood event.	Inspect the following areas that have been inundated: • lower riverbank and NRBZ adjacent to substages 8A–8C; • rehabilitation area; and • active extraction area.	Within 24 hours of floodwater receding.	Implement corrective actions for other triggers as required (see below).	Annual Report: summary of floods in preceding 12 months.
Any tree, major roots have been exposed, the roots have tilted or the tree appears to be unstable.	Inspect tree health and vulnerability.	Within 24 hours of floodwater receding.	If, for any tree, major roots have been exposed, the roots have tilted or the tree appears to be unstable: • the tree is to be inspected by an arborist and remedial actions implemented; and • report as an incident/non-compliance as described in Section 8 of the EMS and prepare Incident Report.	Incident Report: arborist findings and proposed remedial actions. Annual Report: progress of actions arising from incident report.
Rehabilitation areas have been scoured such that they are below the final landform level (approximately 64 m AHD).	Infill the scoured area with sand and soil to restore the final landform level.	Within 1 week of the flood event.	Monitor rehabilitation in accordance with the BRMP. Review revegetation performance and evaluate for flood hazard reduction and scour protection for the rehabilitated landform. Revegetate (see below).	Annual Report: • report any occurrences; • if scouring occurs, summarise revegetation performance for flood hazard reduction; and • present remedial actions.

Flood scour risk and remedial response TARP

Trigger	Action required	Timing	Follow up actions	Reporting*
Vegetation in post-extraction rehabilitation areas has been swept away.	Rehabilitate the area in accordance with the BRMP including: • addition of soil ameliorants if required; • placement of woody debris if density no longer meets the requirements of Consent Condition B78; and • infill seeding or planting.	Within 1 month of re-establishing the final landform.	Monitor rehabilitation in accordance with the BRMP.	Annual Report: report any occurrences and remedial actions.
Woody debris placed in post-extraction rehabilitation areas has been washed away.	Felled habitat trees and woody debris will be preserved for rehabilitation and restoration purposes. Woody debris will be placed over the ground in rehabilitation areas and pressed in or tracked-rolled to ensure intimate contact with soil to minimise the potential for erosion under the woody debris. Woody debris should be used to pin brush or mesh surface cover.	Within 1 week of the flood event.	Monitor woody debris placement in accordance with the BRMP Section 8.4.	Report woody debris installation over the last 12 months in the Rehabilitation and Restoration Site Annual Progress Report as described in BRMP Section 8.8.
Batters in extraction area have been scoured such that they are too steep and no longer meet the maximum batter angle requirements.	Infill scoured batters with sand and soil to ensure that they meet the maximum batter angle requirements.	Within 1 week of the flood event.	Review batter angles as part of weekly site inspections to ensure that quarry design conforms with the approved design. Undertake further rectification earthworks if required.	Annual Report: report any occurrences and remedial actions.

Flood scour risk and remedial response TARP

Trigger	Action required	Timing	Follow up actions	Reporting*
The base of the active extraction area has been scoured such that it is with 1 m of the normal water table.	Infill the base of the active extraction with sand and soil to ensure that it is not below the maximum depth (within 1 m of the normal water table). Reinstall bores in the base of the extraction area in accordance with the *Menangle Sand and Soil Quarry Soil and Water Management Plan* (SWMP).	Within 1 week of the flood event.	Measure the depth to groundwater using the bores in the active extraction area. Undertake further rectification earthworks if required.	Annual Report: report any occurrences and remedial actions.
Trees in the lower riverbank or NRBZ adjacent to the active extraction area or rehabilitation area have been uprooted. And/or Remnant native vegetation in floodplain strips immediately upstream or downstream of the active extraction area has been swept away.	If roots of the tree are no longer providing bank stability, install measures, eg coir matting, large rocks or rip rap, around the previous root area to prevent erosion. If part of the roots remain in the soil, leave in situ to allow the roots to continue to provide bank stability. Remove the upper part of the tree (chainsaw) to reduce the risk of the tree being washed away in subsequent flooding. If required, install measures to prevent erosion. Bank stabilisation and installation of pinning mesh or brush on potential erosion areas.	Within 2 weeks of the flood event.	Inspect area as part of the drainage, erosion and sediment control inspections (see SWMP Section 8): • weekly during normal operations; • daily during periods of rainfall; and • within 12 hours of the cessation of a rainfall event (greater than 10 mm) causing runoff to occur on, or from, the quarry. Undertake further stabilisation works if required. Should scour occur that results in the loss of trees: • review, and if required, update scour flood model; and • prepare Incident Report.	Incident Report: description of tree loss and proposed remedial actions. Annual Report: progress of actions arising from incident report.

Flood scour risk and remedial response TARP

Trigger	Action required	Timing	Follow up actions	Reporting*
The lower riverbank and NRBZ adjacent to the active extraction area or rehabilitation area is scoured such that the top of the lower riverbank is reduced to less than 64 mAHD or the bank becomes unstable.	Install measures, eg coir matting, large rocks or rip rap, in and around the scour area to prevent erosion. Rehabilitate and revegetate area.	Within 1 week of the flood event.	Inspect area as part of the drainage, erosion and sediment control inspections: • weekly during normal operations; • daily during periods of rainfall; and • within 12 hours of the cessation of a rainfall event (greater than 10 mm) causing runoff to occur on, or from, the quarry. Undertake further stabilisation works if required. Report as an incident/non-compliance as described in Section 8 of the EMS.	Incident Report: report on extent of bank loss and proposed remedial actions. Annual Report: progress of actions arising from incident report.
Sediment from the Stage 8 area deposits in the Nepean River such that river flow is impeded.	Inspection by an appropriately qualified geomorphologist to assess the potential impacts of the deposited sediment on river flow, bank stability and flooding and to determine the rate at which the deposited sediment is likely to be removed by river flow. Inspection by an appropriately qualified aquatic ecologist to determine if the changed flow conditions are likely to cause impacts to aquatic biodiversity. If significant impacts are predicted, prepare and implement a plan to remove the sediment. The sediment will be returned to the Stage 8 area.	Inspections within 1 month of the flood event. Plan preparation within 2 months of the inspection. Required works within 2 months of plan finalisation.	To be determined as part of the sediment removal plan. Report as an incident/non-compliance as described in Section 8 of the EMS.	Incident Report: • report on extent of incident; • geomorphologist report on impacts and proposed remedial actions; and • aquatic ecologist report on impacts and proposed remedial actions. Annual Report: progress of actions arising from incident report.

* See Menangle Sand and Soil Flood Management Plan.

Appendix G

Vegetation management and site stabilisation TARP

Vegetation management and site stabilisation TARP

Trigger	Action required	Timing	Follow-up actions	Reporting*
Controlling threats				
Livestock incursions, or evidence thereof (trampling, grazing, scats) Undesirable access to the property by people, or evidence thereof (litter, vandalism).	Ongoing incidental observations.	Ongoing	Repair damage; inspect and repair fence-lines. Reseed, replant tube stock as required.	Annual Report: report any occurrences and remedial actions.
Increased feral pest sightings within Stage 8 area.	Ongoing incidental observations.	Ongoing	Baiting and trapping programs, if there is an increasing trend in feral animal sightings.	Annual Report: report any occurrences and remedial actions.
Bushfire within Stage 8 area.	Bushfire hazards are managed. Control uncontrolled burns on site as soon as possible.	Incident based	In a fire occurs: • investigate cause of burn and if any preventative measures can be taken; • review erosion and sediment control measures in the burn area; • observe recovery of vegetation; and • undertake additional seeding/in-fill planting as required.	Annual Report: report any bushfires and investigation outcomes.
Active rill, gully or tunnel erosion.	Drainage, erosion and sediment control inspections (see *Menangle Sand and Soil Quarry Soil and Water Management Plan* (SWMP) Section 8).	Weekly inspections (see SWMP Section 8.2)	Ameliorate to stop erosion as per methods in the SWMP.	Annual Report: summary of weekly inspections and remedial actions required.
Physical conditions				
Growth medium development unsuitable	Collect and analyse soil samples at selected floristic monitoring plots (see BRMP Table 8.6).	Annual	Ameliorate soil if outside desired range and is impacting plant growth and condition.	Report landform establishment and stability assessment (including growth medium development) over the last 12 months in the Rehabilitation and Restoration Site Annual Progress Report as described in the *Menangle Sand and Soil Quarry Biodiversity and Rehabilitation Management Plan* (BRMP) Section 8.8.

Vegetation management and site stabilisation TARP

Trigger	Action required	Timing	Follow-up actions	Reporting*
Species composition				
Native trees: total foliage cover of species allocated to Tree (TG) growth form is not trending towards the benchmark range of 27.5–32.5.	Implement revegetation of rehabilitation area as described in BRMP Chapters 4–6. Biodiversity monitoring (see BRMP Section 8.4).	Progressive revegetation Annual monitoring	If foliage cover is not trending towards target value (ie by 5 years post-establishment), increase species cover and abundance via infill seeding and/or planting.	Report floristic monitoring over the last 12 months in the Rehabilitation and Restoration Site Annual Progress Report as described in BRMP Section 8.8.
Native shrubs: total foliage cover of species allocated to Shrub (SG) growth form is not trending towards the benchmark range of 21–31.	Implement revegetation of rehabilitation area as described in BRMP Chapters 4–6. Biodiversity monitoring (see BRMP Section 8.4).	Progressive revegetation Annual monitoring	If foliage cover is not trending towards target value (ie by 5 years post-establishment), increase species cover and abundance via infill seeding and/or planting.	Report floristic monitoring over the last 12 months in the Rehabilitation and Restoration Site Annual Progress Report as described in BRMP Section 8.8.
Native grasses (or grasslike): total foliage cover of species allocated to Grass and Grasslike (GG) growth form is not trending towards the benchmark range of 24.45–30.45.	Implement revegetation of rehabilitation area as described in BRMP Chapters 4–6. Biodiversity monitoring (see BRMP Section 8.4).	Progressive revegetation Annual monitoring	If target value is not being met, increase species cover and abundance as early as possible (ie 2 years post-establishment). This should be achieved by planting, hydro-mulching, etc., depending upon conditions.	Report floristic monitoring over the last 12 months in the Rehabilitation and Restoration Site Annual Progress Report as described in BRMP Section 8.8.
Native forbs: total foliage cover of species allocated to Forb (FG) growth form is not trending towards the benchmark range of 24.45–30.45.	Implement revegetation of rehabilitation area as described in BRMP Chapters 4–6. Biodiversity monitoring (see BRMP Section 8.4).	Progressive revegetation Annual monitoring	If target value is not being met, increase species cover and abundance as early as possible (ie 2 years post-establishment). This should be achieved by planting, soil amelioration, hydro-mulching, etc. depending upon conditions.	Report floristic monitoring over the last 12 months in the Rehabilitation and Restoration Site Annual Progress Report as described in BRMP Section 8.8.
Species diversity: after 5 years of management in a given area, at least 24 species characteristic of River-flat Eucalypt Forest are not present.	Implement revegetation of rehabilitation area as described in BRMP Chapters 4–6. Biodiversity monitoring (see BRMP Section 8.4).	Progressive revegetation Annual monitoring	Undertake in-fill planting of additional species from BRMP Table 5.1 that are not growing adequately or that have died. This should be done as soon as possible (ie 2 years post-establishment).	Report floristic monitoring over the last 12 months in the Rehabilitation and Restoration Site Annual Progress Report as described in BRMP Section 8.8.

Vegetation management and site stabilisation TARP

Trigger	Action required	Timing	Follow-up actions	Reporting*
Weed cover in the rehabilitation and restoration areas is not decreasing based on annual monitoring.	Weed control as described in BRMP Section 5.5. Given the very high weed current loads, it is expected that it will take some time for weed growth to be brought under control and will require ongoing maintenance with the objective to eventually achieve a sum foliage cover of species identified as 'high threat exotic' under the Biodiversity Assessment Method (BAM) and 'priority weeds' as identified by the Local Land Services (LLS) in the relevant strategic weed management plan for the region is no more than 2%. Biodiversity monitoring (see BRMP Section 8.4).	Ongoing weed control. Annual monitoring.	Evaluate weed management methods. Consider trialling different weed management techniques. Increase intensity of weed control.	Report the results of weed mapping in the Rehabilitation and Restoration Site Annual Progress Report as described in BRMP Section 8.8.
Ecosystem function				
Plant species not regenerating after disturbance event.	Implement revegetation of rehabilitation area as described in BRMP Chapters 4–6. Biodiversity monitoring (see BRMP Section 8.4).	Incident based, including inundation.	Infill seeding/planting as required.	Report floristic monitoring over the last 12 months in the Rehabilitation and Restoration Site Annual Progress Report as described in BRMP Section 8.8.
Litter is not increasing towards the target value of 40% cover.	Biodiversity monitoring (see BRMP Section 8.4).	Annual monitoring.	If litter cover is not increasing after 5–10 years post-establishment, additional canopy species will need to be planted.	Report litter as part of floristic monitoring over the last 12 months in the Rehabilitation and Restoration Site Annual Progress Report as described in BRMP Section 8.8.
Nest boxes are missing or are not suitable for use by the target species (see BRMP Table 7.2).	Install 106 nest boxes will be (see BRMP Section 7.5.1).	Install nest boxes prior to extraction in the Stage 8 area. Annual monitoring (see BRMP Section 8.4).	Repair damaged nest boxes. Install the deficit number of nest boxes.	Report results of nest box survey in the Rehabilitation and Restoration Site Annual Progress Report as described in BRMP Section 8.8.

Vegetation management and site stabilisation TARP

Trigger	Action required	Timing	Follow-up actions	Reporting*
Woody debris is not installed in accordance with Consent Condition B78: • at least 400 m/ha of woody debris (ie. logs > 10 cm diam, >0.5 m long); and • at least 100 m/ha of large woody debris (ie. logs >50cm diam, >0.5 m long).	Woody debris will be placed over the ground in rehabilitation areas and pressed in or tracked-rolled to ensure intimate contact with soil to minimise the potential for erosion under the woody debris (see BRMP Section 7.5.2). Woody debris should be used to pin brush or mesh surface cover.	Once within 18 months of commencing extraction of each substage. Annual monitoring (see BRMP Section 8.4).	Install the deficit amount of woody debris. Report as an incident/non-compliance as described in Section 8 of the EMS.	Report results of woody debris survey in the Rehabilitation and Restoration Site Annual Progress Report as described in BRMP Section 8.8.

* Annual report: summarising any triggers that have been exceeded in the last 12 months and the actions taken in response; and providing a list of any incident reports in the last 12 months and reporting on the progress of follow up actions arising from each incident report.

Significant incidents in relation to this TARP are to be reported to NRAR immediately in accordance with Consent Condition D7.


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