From: s22
To: s22
Cc: s22 ; 's22 ; Blewett Richard; s22 ; "s22"
Subject: RE: CSIRO-Geoscience Australia Tranche 2 Report for the Carmichael Coal Project [DLM=For-Official-Use-Only] [SEC=UNCLASSIFIED]
Date: Friday, 22 February 2019 4:42:57 PM
Attachments: image001.png
image002.png
image003.png
image004.png
image005.png

Thanks all!
Chat Monday
s22
s22
T s22 @environment.gov.au

From: s22 ga.gov.au]
Sent: Friday, 22 February 2019 3:58 PM
To: s22
Cc: s22 ; s22 t@csiro.au' ; Blewett Richard ; s22 ;
s22 @csiro.au'
Subject: CSIRO-Geoscience Australia Tranche 2 Report for the Carmichael Coal Project [DLM=For-Official-Use-Only]

Dear s22

Attached is the joint CSIRO/GA submission for Tranche 2 of the DoEE advice request for Carmichael Coal Mine Project. Tranche 2 is a focused review of the draft groundwater management and monitoring plan and draft groundwater dependent ecosystem management plan provided by the proponent, looking at use of groundwater modelling and approaches to monitoring and management. This advice also includes Tranche 1 and pre-Tranche 2 reports.

If the Department has specific questions regarding this submission, please contact s22 s22 @ga.gov.au) for further information.

Kind regards,

Dr s22 | Geologist | Groundwater Advice and Data
Groundwater Branch | Environmental Geoscience Division | Tues – Fri
t +61 2 s22 www.ga.gov.au
cid:image008.png@01D23B50.A4D01B10

------< HPE Content Manager record Information >------
Record Number : D2019-19528
Title : CSIRO-Geoscience Australia Tranche 2 Report

FOI 190417
Document 2

From: s22
To: s22
Subject: RE: EPBC 2010/5736: condition 5 - Updated Groundwater Dependent Ecosystem Management Plan (groundwater data) [SEC=UNCLASSIFIED]
Date: Wednesday, 23 January 2019 11:21:44 AM

Hi s22
I'll grab a copy and ensure the rest of the team is made aware.
We'll eagerly await the whistle blow to start.
Thanks
s22

From: s22
Sent: Wednesday, 23 January 2019 11:04 AM
To: s22
Subject: RE: EPBC 2010/5736: condition 5 - Updated Groundwater Dependent Ecosystem Management Plan (groundwater data) [SEC=UNCLASSIFIED]
Importance: High

Hi s22,
I have just uploaded Rev 5 of the GMMP to Govdex. I'm yet to receive confirmation from DNRME that all water level data has been verified, but understand that the GMMP has been updated with the revised water level data, as per the GDEMP earlier this week.
When we receive confirmation, your review can formally start
s22
s22
T 02 s22 @environment.gov.au
W www.environment.gov.au

From: s22
Sent: Monday, 21 January 2019 3:54 PM
To: s22 @ga.gov.au>
Subject: Re: EPBC 2010/5736: condition 5 - Updated Groundwater Dependent Ecosystem Management Plan (groundwater data) [SEC=UNCLASSIFIED]

It will be after 5 - is that ok?

Sent from my iPhone

On 21 Jan 2019, at 3:00 pm, s22 @ga.gov.au> wrote:

> H s22
> That would be helpful if you could stop in at Symonston and I can get eyes on it immediately.
> Thanks
>
> s22
>
> ---
>
> **From:** s22 [mailto s22 @environment.gov.au]
> **Sent:** Monday, 21 January 2019 2:01 PM
> **To:** s22
> **Cc:** s22; Gregory Manning
> **Subject:** FW: EPBC 2010/5736: condition 5 - Updated Groundwater Dependent Ecosystem Management Plan (groundwater data) [SEC=UNCLASSIFIED]
> **Importance:** High

Hi s22 and s22 ,

I have uploaded a revised GDEMP (v10a) onto Govdex, for your review. The word version with tracked changes is too big for the site – I am happy to drop a USB to Symonston this afternoon if it would help.

I will let you know as soon as we get a revised GMMP including DNRME agreement to the revised water level data and Adani's 'materiality' test for model revisions.

Please let me know there are any questions

s22
s22
T 02 s22 @environment.gov.au
W www.environment.gov.au

From: s47F @adani.com.au]
Sent: Monday, 21 January 2019 11:26 AM
To: Gregory Manning <Gregory.Manning@environment.gov.au>
Cc s22 @environment.gov.au>; s22 @environment.gov.au>; s22 @environment.gov.au>; s22 @environment.gov.au>; s22 @environment.gov.au>; Post Approval <PostApproval@environment.gov.au>; Hamish Manzi <Hamish.Manzi@adani.com.au>
Subject: EPBC 2010/5736: condition 5 - Updated Groundwater Dependent Ecosystem Management Plan (groundwater data)
Importance: High

COMMERCIAL IN CONFIDENCE

Good morning Greg

The purpose of this email is to advise that I will shortly transmit a copy of the *Groundwater Dependent Ecosystem Management Plan (Carmichael Coal Mine Project)* with updated groundwater level and quality data.

For your information, following figures and tables have been updated:

Figures

- Figure 4-2: Hydrogeological conceptual model – pre-mining
- Figure 4-3: Hydrogeological conceptual model – mining & post-mining
- Figure 6-9 a-d Predicted Alluvial aquifer impacts associated with the Carmichael River
- Figure 7-6 a to d: Predicted drawdown to Alluvium aquifer over the life of the project
- Figure 8-10 Hydrogeological conceptual model – pre-mining
- Figure 8-11 Hydrogeological conceptual model – post-mining
- Figure 8-15a-e Groundwater impact contour maps for the Clematis aquifer

- Figure 9-8a-f Predicted groundwater draw down associated with the Mellaluka springs-complex

Tables

- Table 6-7 Groundwater Monitoring locations (from the GMMP), column titled "Monitoring Bores (depth in m)", last two monitoring levels

- Table 8-1 Water level data; columns titled "Ground Surface Elevation (mAHD)" and "Water Level (mAHD)"

- Appendix B - Groundwater drawdown and quality triggers, and all groundwater quality tables, including new information at the start of each table.

I will also transmit a track changed version, highlighting the location of the changes. Could the department please advise when the documents are successfully retrieved?

Regards

s47F [redacted]

Manager, Approvals

Off +s47F [redacted]@adani.com.au | www.adaniaustralia.com

Level 25, 10 Eagle Street, Brisbane, QLD 4000 | GPO Box 2569, Brisbane, QLD, 4001

From: s22
To: s22
Subject: Words on CSIRO [SEC=UNCLASSIFIED]
Date: Wednesday, 20 March 2019 8:41:34 AM
Attachments: image002.jpg

GMMP
The CSIRO and Geoscience Australia review found that the modelling that underpins the approaches in the GMMP is not suitable to ensure the outcomes sought by the EPBC Act conditions are met. A number of limitations were also identified in the proposed monitoring and management approaches indicating they are not sufficiently robust to monitor and minimise impacts to protected environments. Recommendations from the review enable Adani to refine the conceptualisation and improve the robustness of the modelling, monitoring and management over time to address the intended outcomes of the approval conditions. Adani have largely addressed these recommendations, by committing to install additional groundwater and surface water monitoring and fully addressing the modelling limitations at the next model review within two years (refer Attachment X).
GDEMP
The CSIRO and Geoscience Australia review found that the GDEMP systematically addresses the management objectives, performance criteria, adaptive management triggers and corrective actions. Monitoring under the plan is based on the GDE Toolbox approach, and is considered adequate. However, the GDEMP relies heavily on the conceptualisations and modelling outlined in the GMMP and other research plans, and as such is subject to any limitations of these plans. Recommendations from the review of these associated plans enable Adani to refine the conceptualisation and improve the robustness of the modelling, monitoring and management over time to address the intended outcomes of the approval conditions. Adani have largely addressed these recommendations, by committing to install additional groundwater and surface water monitoring and fully addressing the modelling limitations at the next model review within two years (refer Attachment X).
Our assessment to come after coffee!

s22
Assistant Director | Post Approvals Strategies
Environment Standards Division
Department of the Environment and Energy
T 02 s22 @environment.gov.au

Reconciliation%20Email%20Footer

From: s22
To: s22
Cc: s22
Subject: Updated front cover date [SEC=UNCLASSIFIED]
Date: Monday, 25 February 2019 2:32:44 PM
Attachments: image001.png
image002.png
image003.png
image004.png
image005.png
CSIRO-Geoscience Australia Tranche 2 Report.PDF

Dear all,
Please find a revised copy with an amended front cover date.

Thanks

s22
s22, **PhD** | A/g Director
Groundwater Advice and Data | Environmental Geoscience Division
t +61 2s22 | www.ga.gov.au
16-9481 GA Email Signature_social media-04

FOI 190417
Document 4a

Carmichael Coal Mine

Advice on Groundwater Management and Monitoring and Groundwater Dependent Ecosystem Management plans to the Department of the Environment and Energy

FEBRUARY 2019

Executive Summary

The Department of the Environment and Energy requested CSIRO and Geoscience Australia to assess draft research and management plans submitted by Adani Pty Ltd for the Carmichael Coal Project under *Environment Protection and Biodiversity Conservation Act* (1999) approval conditions (EPBC ref: 2010/5736). This advice addresses questions for the Groundwater Dependent Ecosystem Management Plan (version 10a) and the Groundwater Management and Monitoring Plan (version 5).

Modelling underpins the approaches in the management and monitoring plans. The review found that the modelling used is not suitable to ensure the outcomes sought by the EPBC Act conditions are met. A number of limitations were also identified in the proposed monitoring and management approaches indicating they are not sufficiently robust to monitor and minimise impacts to protected environments.

***Q2a**. How appropriate is the numerical model scenario selected by the approval holder to inform the Groundwater Management and Monitoring Plan and Rewan Formation Connectivity Research Plan and for incorporation into the Groundwater Dependent Ecosystem Management Plan as required by the conditions of approval?*

The SEIS model used by the GMMP is the most conservative of the model scenarios as it predicts the greatest impacts from the mine development in all aquifers. However, being the best choice of available model runs does not mean that this model run is considered to be fit-for-purpose. The rationale to support this statement is provided in *Section 2 Numerical modelling scenarios*.

***Q2b**. Are there any other model scenarios put forward by the approval holder that are more appropriate to ensure the outcomes sought by the conditions of approval are met?*

The review of the available model scenarios <u>did not</u> identify any other model scenarios put forward by the approval holder that are considered more appropriate. However, this review has identified a number of limitations, which mean that the model is not suitable to ensure the outcomes sought by the conditions of approval are met. These limitations are detailed in *Section 2.3 Limitations of modelling*.

***Q3.** Are the monitoring and management approaches proposed in the GMMP and GDEMP consistent with the most plausible conceptualisation and sufficiently robust to ensure the outcomes above are met?*

The proposed monitoring and management approaches described are consistent with the most plausible conceptualisation of groundwater source to the Doongmabulla Springs complex. However, limitations identified mean that the proposed monitoring and management approaches are <u>not sufficiently robust</u> to ensure the outcomes set out in 2b are met. These limitations are described in *Section 3 Monitoring and management approaches.*

If the Proponent implements the recommendations in this advice they will be able to refine the conceptualisation and improve the robustness of the modelling, monitoring and management approaches to address the intended outcomes of the approval conditions.

1 Introduction

On 24 January 2019, the Department of the Environment and Energy (DoEE) requested Geoscience Australia and CSIRO to provide groundwater-related advice on draft management plans provided by Adani Mining Pty Ltd (the Proponent) in accordance with *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval conditions for the Carmichael Coal Mine. These plans include the draft Groundwater Management and Monitoring Plan revision 5 dated January 22, 2019 (GMMP) and the draft Groundwater Dependent Ecosystem Management Plan version 10a dated January 21, 2019 (GDEMP). This advice follows earlier advice provided on draft research plans (CSIRO and Geoscience Australia, 2018).

DoEE sought advice specifically on an additional three questions relating to these draft management plans, set out below:

> ***Q2a**. How appropriate is the numerical model scenario selected by the approval holder to inform the GMMP and RFCRP and for incorporation into the GDEMP as required by the conditions of approval?*
>
> ***Q2b**. Are there any other model scenarios put forward by the approval holder that are more appropriate to ensure the outcomes sought by the conditions of approval are met?*
>
> *The relevant outcomes sought by the conditions are to:*
>
> - *monitor and minimise impacts to water resources of the Great Artesian Basin;*
> - *ensure groundwater drawdown at Doongmabulla Springs Complex does not exceed 0.2m and that there is no ecological impact at the springs; and*
> - *monitor and minimise impacts to other groundwater-dependent ecosystems.*
>
> *Note: The conditions require that results of the groundwater flow model re-run inform the GMMP and RFCRP and be incorporated into the GDEMP. The focus of question 2 is on the selection of a numerical modelling scenario from those available, i.e. the options around the general head boundary considered as part of the groundwater model re-run, and previous scenarios, i.e. the SEIS and EIS models.*

Q3. *Are the monitoring and management approaches proposed in the GMMP and GDEMP consistent with the most plausible conceptualisation and sufficiently robust to ensure the outcomes above are met?*

This advice provides an assessment of how these draft plans address the three questions. This assessment relied on the draft plans, and additional information, including studies undertaken since the time of approval and provided by the Proponent. Other references are included as in-text citations and in the reference list provided. Appendix B is that initial advice on some matters raised prior to undertaking this review, Appendix A provides a review of the Proponent's responses to Appendix B. CSIRO and Geoscience Australia (2018), an assessment on draft research plans, is provided for completeness, as Appendix C.

2 Numerical modelling scenarios

2.1 Summary

***Q2a**. How appropriate is the numerical model scenario selected by the approval holder to inform the GMMP and RFCRP and for incorporation into the GDEMP as required by the conditions of approval?*

Of the available numerical modelling scenarios selected by the approval holder to inform the GMMP and RFCRP and for incorporation into the GDEMP as required by the conditions of approval, the Supplementary Environmental Impact Statement (SEIS) model (GHD, 2013) is considered to be the most appropriate. There are still issues with the model scenario including:

1. Comparison of the SEIS model and the two alternate re-run models shows that the location of the western model boundary has little impact on drawdown predictions (refer Section 2.2).
2. The SEIS model includes the most recent calibrated parameter set developed for the Carmichael Coal Mine in 2013. Although, it must be noted that model errors increased from 4.5% RMS error reported for the SEIS model to 7.2% when compared to updated data following resurveying bore locations. This degradation in calibration statistic is equivalent to 0.8 m of groundwater level (refer Section 2.3.2).

***Q2b**. Are there any other model scenarios put forward by the approval holder that are more appropriate to ensure the outcomes sought by the conditions of approval are met?*

The review of the available model scenarios did not identify any other model scenarios put forward by the approval holder that are considered more appropriate to ensure the outcomes sought by the conditions of approval are met. However, this review has identified a number of limitations, which mean that the SEIS model is not suitable to ensure the outcomes sought by the conditions of approval are met. In particular, the SEIS model under-predicts groundwater drawdown arising from mine development for the following reasons:

1. Representation in the model of surface water flows for the Carmichael River over-predicts flows from the river into the groundwater. As a result the groundwater drawdown in the alluvium (Carmichael River GDEs) will be greater than the predicted model (refer Section 2.3.1).
2. Reduced confidence in the ability of the calibrated model parameters to accurately predict groundwater drawdown arising from mine development due to revision of some bore elevations. When model predictions are compared with corrected bore heights scaled RMS error increases from 4.5% to 7.2% (refer Section 2.3.3).
3. Combined effect of revised bore heights and evapotranspiration, in the unconfined parts of the Clematis Sandstone model layer, on the accuracy of the 0.19 m predicted drawdown at the Doongmabulla Springs complex (DSC) by the SEIS model (refer Section 2.3.3).
4. Parameterisation of the Rewan Formation and Clematis Sandstone by the SEIS model. Calibrated hydraulic conductivity values for the Rewan Formation are very low compared with measured values, which minimises vertical water movement, and hydraulic conductivity values for the Clematis Sandstone are high, which increases the lateral transfer of water. In combination these hydraulic conductivity values minimise predicted drawdown at the DSC (refer Section 2.3.4).

2.2 Selection of available numerical model scenarios

The GMMP uses the calibrated SEIS model run as the basis for the calculation of groundwater level thresholds. This model run has been accepted as part of the assessment, conditioning and approval of the proposed action. The report states that the model re-runs have informed the GMMP by adding confidence to the predictions made using the SEIS model. Previous comments on the suitability of numerical models are provided by CSIRO and Geoscience Australia (2018)

The model re-runs differ from the SEIS model in the location of the General Head Boundaries (GHB) on the western edge of the model domain and in the magnitude of the conductance for all GHBs in the model. These changes were made following discussions with DoEE and the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC), reflected in Condition 23 of the EPBC Act approval conditions. This results in three model run choices being available. There is little difference in the drawdown predictions between the SEIS model and the two alternate re-run models. The groundwater flow direction is mostly along the western boundary from the north and south rather than across the boundary from east to west, this is why the location of the boundary has little influence on the predictions. The flow directions predicted by the SEIS model are consistent with the generated piezometric surfaces from field observations. The boundary in the SEIS model on the topographic divide seems appropriate for the predictions being made.

Issue: The re-run models were not calibrated as this was not required by Condition 23, they used the existing parameterisation from the SEIS model. Not having a specific calibration for each of the re-run models has reduced the confidence in the predictions that they make. The re-run models predict less drawdown at the Doongmabulla Springs Complex (DSC) and more baseflow depletion in the Carmichael River than the SEIS model, although these variations are not significant. Comparison of predicted maximum impact for different models shows similar extent and magnitude overall (GMMP Section 2.3.3.1).

Recommendation: A re-calibration is warranted to improve confidence in model predictions.

The SEIS model used by the GMMP is considered to be the most conservative of the available model scenarios as it predicts the greatest impacts from the mine development in all aquifers. However, being the best choice of available model runs for use in the GMMP does not mean that this model run is considered to be fit-for-purpose, as outlined in the following sections.

2.3 Limitations of modelling

Issue: The approach used to model potential impacts to the groundwater system due to mining indicates that the model will under-estimate the amount of drawdown predicted at the DSC and the Carmichael River GDE as a result of model representation of:

- the unrealistically high modelled flow in the Carmichael River,
- error in the bore heights used to calibrate the model, and
- hydraulic conductivity in the Clematis Sandstone and Rewan Formation model layers.

If the predicted drawdown has been underestimated as a result of these factors, then issues with predicted drawdowns are propagated into the GMMP. It is unclear what impact these limitations will have on the timing of impacts on the DSC. The implication is that the thresholds and triggers will be reached sooner than anticipated based on this modelling, which means that relying on the model in its current form may not be an appropriate approach to deriving monitoring and management regimes. Each of the three factors are discussed in more detail below.

2.3.1 Impact of Carmichael River flow on predictions

Issue: The model under predicts drawdown in the Alluvium along the Carmichael River corridor because of the way the model provides a source of water to offset drawdown. The SEIS report (Table 10) shows observed dry season stream-flow percentiles, the 90th percentile is 460 m^3/d at the gauge upstream of the proposed mining area on the western edge of the mine lease and 0 m^3/d at the gauge on the eastern edge of the mine lease, downstream of proposed mining. In contrast, the SEIS model steady-state run shows baseflow in Carmichael River above 4000 m^3/d at the upstream gauge and above 3000 m^3/d at downstream gauge (SEIS Figure 33). Simulated baseflow is an order of magnitude too high and is perennial at the downstream gauge rather than ephemeral, this has the effect of mitigating the drawdown in the alluvium (the Carmichael River GDE). The predicted stream depletion due to mining is ~1000 m^3/d at the downstream gauge (SEIS Figure 39) which is physically impossible from the river (as the river only flows for short periods each year) and will subsequently deplete groundwater, contributing to drawdown.

The observed baseflow in the river was not used as a constraint in model calibration and therefore the baseflow predictions are physically impossible (i.e. too high). This means that predictions in drawdown to the Alluvium along the Carmichael River are unrealistically small.

Recommendation: Carmichael River flow and under-estimated drawdown can be addressed in subsequent model updates. Future updates of the model should also use stream flow as one of the calibration parameters. To facilitate this, ongoing stream flow gauging should be undertaken.

2.3.2 Impact of revised bore heights on calibration

Issue: The revision of the bore heights, resulting from resurveying of collar locations undertaken by the Proponent, has degraded the calibration of the SEIS model. The SEIS report uses the scaled RMS error between 88 observation bores and model predictions as the calibration statistic. This report says that the scaled RMS error is 4.5% for all bores and 5.9% for the 39 Proponent bores and therefore below the threshold for an acceptable model from the MDBC guidelines (Middlemis, 2000) (<5% is acceptable) which is used by the Proponent to justify the model performance. The revision of the bore heights and longer time series of groundwater level data available has degraded the scaled RMS to 7.2% for all bores and 12.2% for the 41 Proponent bores (no explanation is given for the discrepancy in the number of bores). These revised calibration statistics are outside of the nominated threshold from the SEIS report of 5%.

Recommendation: The updated Australian Groundwater Modelling Guidelines (Barnett et al., 2012), and the IESC Explanatory Note *Uncertainty analysis—Guidance for groundwater modelling within a risk management framework* (Middlemis and Peeters, 2018) provide more refined expectations of using uncertainty analysis in modelling, and how this may affect management and monitoring decisions. These should be considered in future model updates.

Issue: The Carmichael Coal Mine - Groundwater level review (Adani, 2019) adopts a value of +/- 7 m as an indication of significant variation in mismatch between calibrated and observed groundwater level. This value is justified as being close to the average RMS error of 6.8 m from the SEIS calibration and the 7.6 m average RMS error calculated from the revised bore heights. There is no analysis given for what this error means for the predicted drawdown. The revised bore heights have degraded the average RMS error of the simulated groundwater levels by 0.8 m. The interim threshold drawdown at the DSC is 0.2 m (EPBC Act approval condition 3.d), and represents a quarter of the degradation in model performance due to the revised bore heights.

As a conclusion from the revision to the bore heights, the Carmichael Coal Mine - Groundwater level review (Adani, 2019) states:

> *"The changes in calibration statistics are not material from a modelling perspective." (page 1)*

This statement is at odds with the clearly degraded model performance of the updated calibration dataset using the whole dataset and in particular, the nominated subset of the Proponent's bores. The 40 bores drilled since the SEIS model calibration could provide an independent validation dataset for the calibrated model but have not been assessed.

The GMMP states there is a continuous improvement to the model as new information becomes available:

> *"Continuous refinement of the models with new data as it becomes available ensures they are robust and defensible for use to accurately predict potential impacts because of the CCP" (page34)*

> *"The numerical model has been refined over time as additional information has become available." (page 81)*

The model run used in the GMMP is from the SEIS report. This has not been updated since 2013. The revised bore heights and the new bores drilled since that time are clearly new information that could improve the model but these have not been part of the continuous refinement process claimed in the GMMP.

Recommendation: The Proponent has committed to updating the groundwater model two years after mining commences. This commitment includes the collection, analysis and use of additional groundwater data to refine conceptualisations (GMMP Section 2.2.9), as well as incorporating groundwater monitoring information and response to dewatering (GMMP Section 6.2 and Section 7.1.1). Model updates should include recalibration, and clearly define bore reference levels, how they have changed over time and how these changes affect model prediction and performance.

2.3.3 Impact of revised bore heights on predictions

Issue: Confined groundwater systems act in a linear fashion so the offset errors associated with the revised bore heights will have little effect on drawdown predictions in the confined aquifers. This is not the case with unconfined groundwater systems which do not act linearly. Bore HD02 is in the unconfined part of the Clematis Sandstone and is the closest bore to the DSC, it has had its elevation revised downward by 4 m. This means that the groundwater level is deeper than the GW model was trying to calibrate to (in the SEIS model); the model is over-predicting the elevation of the groundwater level at this location. In areas with shallow water tables the model is simulating evapotranspiration from the watertable, any predicted drawdown in these areas will capture some of this evapotranspiration. If the simulated water table is too high in the baseline model run then there is potentially more evapotranspiration available to capture and this will result in less drawdown than would otherwise be predicted. With the predicted drawdown from the SEIS model at the DSC being 0.19 m (1 cm less than the acceptable threshold set out in EPBC Act Approval Condition 3.d), a correction to the overestimate of the captured evapotranspiration could be enough to increase the drawdown to greater than 0.2 m.

Recommendation: Future groundwater model updates should incorporate recalibration to the revised bore heights to provide confidence that captured evapotranspiration is not limiting drawdown to the DSC and the Carmichael River GDE.

2.3.4 Impact of model parameterisation on predictions of groundwater drawdown at the Doongmabulla Springs Complex

Issue: Previous reviews have described the hydraulic conductivity used in the modelling for the Rewan Formation as lower than the field measurements on site (this is discussed in more detail in CSIRO and Geoscience Australia, 2018). A previously unidentified issue is that the calibrated hydraulic conductivity of the Clematis Sandstone in the model is too high when compared to field measurement data. The calibrated hydraulic conductivity of the Clematis Sandstone is 1.55 m/d. There is one field measurement of 15 m/d from a shallow bore in the weathered zone and two measurements, from areas where the Clematis Sandstone is confined, of 0.01 m/d (Table 6, GMMP). Data for the China Stone project, immediately to the north of Carmichael, yield hydraulic conductivities of 0.005 m/d and 0.09 m/d (Australasian Groundwater and Environmental Consultants Pty Ltd (AGES), 2015). The Clematis Sandstone is confined by the Moolayember Formation in the vicinity of the DSC.

The calibration undertaken for the SEIS model was a deterministic calibration, i.e. there is only one value of each parameter for the entire model domain. A parameterisation which recognises the spatial heterogeneity in K values and reports confidence intervals of predicted parameters, and importantly, confidence intervals (based on the probability distribution function, pdf) of drawdowns is more robust and in line with international best practice.

Recommendation: Future model updates should use locally appropriate parameterisations.

Issue: The sensitivity analysis undertaken for the groundwater model shows that the high hydraulic conductivity of the Clematis Sandstone acts to limit drawdown at the DSC (SEIS addendum Figure 12). The sensitivity analysis shows that the drawdown is equally sensitive to the hydraulic conductivity of the Clematis Sandstone as it is to the hydraulic conductivity of the Rewan Formation. The SEIS and SEIS addendum are incorrect when discussing the sensitivity of predictions to the hydraulic conductivity of the Clematis Sandstone (e.g. SEIS addendum Section 3.5.1); high conductivity allows the lateral transfer of water and minimises the drawdown, hence the high value adopted in the calibration being a concern.

The sensitivity analysis was of a one-at-a-time type, which does not allow for parameter interaction. One-at-a-time analysis does not enable assessment of parameter sensitivity to simultaneous changes in parameters. This is in contrast to a global sensitivity analysis, such as that used in Peeters et al. (2018), which accounts for simultaneous parameter variation, and enables analysis of sensitivity to parameter interactions. Individually, an order of magnitude change in the hydraulic conductivity of either the Clematis Sandstone or Rewan Formation can produce a drawdown of greater than 0.3 m.

The cumulative effect on drawdown prediction of varying both parameters, were they changed at the same time, is untested.

Recommendation: Sensitivity analysis undertaken for future model updates should seek to assess cumulative sensitivity.

Issue: The hydraulic enhancement after the collapse of the goaf in the long wall panels was not included in the sensitivity analysis. In the SEIS model the hydraulic conductivity was increased by a factor of 50 for 75 m above the long wall panel and by a factor of 10 for between 75 m and 150 m above the long wall panel. Poulsen et al. (2018) and Adhikary and Poulsen (2018) have shown that the hydraulic enhancement can be up to 8 orders of magnitude (a factor of 10^8) immediately above the goaf and decline exponentially with increasing height for up to 500 m (also a smaller hydraulic enhancement below the long wall panels). The recommendations from the SEIS subsidence report for the groundwater modelling include:

> *"Accordingly the expected height of fracturing at the Carmichael Project, is expected to extend from the AB1 seam to the surface over much of the proposed longwall footprint."*

> *"Conservatively adopting 160 metres based on Klenowski (ACARP C5016, 2000) would be considered a reasonable height for preliminary modelling of the height of direct hydraulic connection. Above this height, it is anticipated that there will be increase in the strata permeability due to fracturing through beds and bedding plane dilation, however the likelihood of hydraulic connectivity from the surface to the seam is anticipated to be low given the presence of aquiclude and aquitard materials in the overburden."*

The subsidence report shows there is the possibility for the enhancement of hydraulic conductivity from the coal seams to the surface; this includes the full thickness of the Rewan Formation (averaging 250 m) above the longwall panels.

Recommendation: The way the hydraulic enhancement after the collapse of the goaf has been implemented in the modelling is not conservative (i.e. is likely to underestimate impact) and the omission of the associated parameters from the sensitivity analysis means that the impact these assumptions have on drawdown at the DSC is untested. Future model updates should include analysis of the sensitivity of the model to parameter changes due to underground mining.

3 Monitoring and management approaches

3.1 Summary

***Q3.** Are the monitoring and management approaches proposed in the GMMP and GDEMP consistent with the most plausible conceptualisation and sufficiently robust to ensure the outcomes above are met?*

The proposed monitoring and management approaches described in the GMMP and GDEMP are consistent with a plausible conceptualisation of groundwater source to the Doongmabulla Springs complex (DSC). However, this review has identified a number of limitations, which mean that the proposed monitoring and management approaches are <u>not sufficiently robust</u> to ensure the outcomes sought by the conditions of approval are met:

1. The SEIS model under-predicts groundwater drawdown arising from mine development by up to 0.8 m, which means that the adopted thresholds and triggers will be reached sooner than anticipated and so are not a suitable foundation for the proposed monitoring and management approaches (refer Section 2.2).

2. Available evidence supports the conceptualisation that the Clematis Sandstone is a likely source aquifer for the DSC. However, the proposed monitoring and management approaches do not sufficiently address the uncertainty regarding potential alternative or additional source aquifers (refer Section 3.2 and 3.3).

3. There is a lack of stream flow gauging. Gauging provides critical information on the state of the Carmichael River. This data would assist in and verifying the reliance of Carmichael River GDEs on groundwater along sections with different characteristics (refer Section 3.3). This would also contribute to model calibration.

4. The water level thresholds and triggers chosen are based on predicted drawdown. A large number of bores are predicted to exceed their thresholds as a result of approved mining activities (refer Section 3.4).

5. The chosen definition of thresholds and triggers for hydrogeochemical analytes, as well as definition of contaminant limits, will result in frequent trigger exceedances. No defined workflow for subsequent investigation is provided. In addition, there are different notification mechanisms to DoEE for water level and chemical exceedances, without a rationale as to why this is the case (refer Section 3.5).

6. The GDEMP systematically addresses the management objectives, performance criteria, adaptive management triggers and corrective actions. Monitoring is based on the GDE Toolbox approach, and is considered adequate. The GDEMP relies heavily on the conceptualisations and modelling outlined in the GMMP and other research plans, and as such is subject to any limitations of these plans (refer Section 3.6)

While the Proponent considers comments relating to model updates and refinement out of scope for the GMMP, they are included here to assist DoEE understand the limitations of the GMMP resulting from the model limitations. Issues arising from model performance and predictions is a fundamental underpinning of the approaches set out in the GMMP and GDEMP. They are critical in assessing if measures set out are sufficiently robust to ensure environmental outcomes are met.

3.2 Hydrogeological conceptualisation

Issue: It is plausible and reasonable that the Clematis Sandstone is a major source aquifer for the DSC. This is supported by water level and groundwater flow information presented by the proponent, as well as by other studies (Evans et al., 2018; Fensham et al., 2016; JBT Consulting, 2015), and by some aspects of hydrogeochemistry of the springs and the Clematis Sandstone (Fensham et al., 2016; Webb et al., 2015). It is not plausible and reasonable to state unequivocally that the Clematis Sandstone is *the sole* source aquifer for the DSC, as sufficient uncertainty surrounding hydrogeochemistry, inter-aquifer connectivity and groundwater flow exists (Currell et al., 2017; Lewis et al., 2018; Webb et al., 2015) to necessitate a precautionary approach to the conceptualisation (as ruled by the Land Court of Queensland, 2015).

Documents provided by the Proponent, including the GMMP, support the conceptualisation that the Clematis Sandstone is a source aquifer, but there is enough uncertainty around the information provided, as acknowledged by the Proponent, such as in GDEMP Section 4.3.1, to necessitate a robust assessment of potential alternative or additional source aquifers. The paucity of water level and hydrochemistry data for units other than the Clematis Sandstone in the vicinity of the DSC means that it is not possible to conclusively determine the source aquifer or aquifers for the DSC based on available evidence, and thus the precautionary principle must apply.

As stated in CSIRO and Geoscience Australia (2018), the hydrochemistry information provided does not preclude alternative conceptualisations of the source aquifers for the springs:

1. The GMMP shows only sodium/chloride and chloride/sulfate bivariate plots comparing groundwater in the Permian sediments and Clematis Sandstone with the Joshua Spring vent only.
2. No chemistry data or groundwater pressure data from the Dunda Beds is presented for comparison, nor any data from other spring vents.
3. The bores proposed for groundwater quality monitoring near the DSC are not screened in source aquifers that have been identified in alternative conceptualisations, such as the Dunda Beds.

Consequently, the hydrochemistry data collected to date, and proposed to be collected, will not contribute to the assessment of other or additional potential source aquifers for the DSC below the Clematis Sandstone.

Recommendation: To constrain the source aquifer(s) of the DSC, a more sophisticated statistical analysis of hydrochemistry data is required. This includes assessing a wider variety of groundwater and surface water analytes, as well as appropriate use of isotope hydrochemistry analysis. Further information on potential techniques is provided in (CSIRO and Geoscience Australia, 2018) and other readily available references.

3.3 Water monitoring network design

Early warning monitoring bores need to be located sufficiently close to mining operations to experience measurable drawdowns relatively quickly after mining operations commence. Deviation of this drawdown from predictions can provide a prompt indication that greater than predicted impacts will likely occur in the future, and can be predicted to be observed years in advance of the impacts reaching matters of national environmental significance (MNES) to enable implementation of management and mitigation actions. The use of control bores, as required under EPBC Act conditions, can also assist in this assessment.

Issue: To adequately monitor for the impacts of mining, for the plausible groundwater conceptualisations, monitoring bores should be distributed across all potentially impacted formations within the zone of predicted impact. The GMMP includes abundant monitoring locations on-lease, which is adequate to assess impacts across all units. However, most of the on-lease bores are likely to be affected by surface or mining operations. The GMMP does not define the process for replacing such bores as mining operations progress.

Groundwater-dependent MNES lie to the west of the lease boundary (DSC), as well as within the alluvium of mapped drainage features (Carmichael River GDEs). To adequately monitor potential impacts to these MNES, the monitoring network needs to consider all possible source aquifers, and predicted areas of impact, as well as the use of control bores.

The monitoring network set out in the GMMP is designed to monitor potential impacts to the DSC based on the conceptualisation that the springs are sourced solely from the Clematis Sandstone. The distribution of monitoring bores is not adequate if other units provide a direct source to the DSC, or through the Clematis Sandstone to the DSC, either by transmission through interconnectivity of hydrostratigraphic units or via structural pathways (not limited to geological faults). The GMMP monitoring network does not provide adequate spatial or geological unit coverage to monitor for groundwater impacts if aquifers other than the Clematis Sandstone contribute flow to the DSC. This effectively means that the proposed GMMP monitoring network will only be able to identify potential impacts that may affect the DSC where they are evident in a source aquifer in the Clematis Sandstone.

In the GMMP, there are 54 off-lease monitoring bores (Table 1 and Figure 1 below). The off-lease monitoring bores are primarily designed to monitor the Joe Joe Group and the Clematis Sandstone. These are the source aquifers proposed by the proponent for the Mellaluka Springs and DSC respectively. The monitoring network set out in the GMMP for the Mellaluka Springs appears adequate, given that these are sourced from the Joe Joe Group and Tertiary[1] sediments.

Recommendation: Installation of bores to monitor the groundwater system in the Dunda Beds and Rewan Formation (upper Rewan and lower Rewan) at existing monitoring points in the west of the central zone would allow an assessment of any dewatering impact propagating through the Rewan Formation (in effect, nested monitoring bores). The current monitoring network does not address any contributions to the springs from the Dunda Beds or Rewan Formation, or from deeper units. These potential spring contributions need to be considered and factored into monitoring design. Monitoring these two units is considered a bare-minimum. Ideally all units from outcrop to sub-Joe Joe coal (Jericho Formation) would be monitored. Co-location with existing points would remove any significant access issues, and would enable at least spatially comparable data to be collected.

Recommendation: It is strongly recommended that the monitoring program includes stream flow gauging upstream and downstream of the mine area. Stream gauging similar to that undertaken for the EIS would address this, provided it is part of ongoing monitoring programmes. Stream flow is a critical calibration parameter for the groundwater model. The current model is based on very limited surface water monitoring data and the status of the gauges installed to acquire this data is unknown.

[1] "Tertiary" is a non-standard term used by Adani, and so this use is continued throughout this advice. The standard terms applied to the Geological Timescale are available from the International Commission on Stratigraphy (http://www.stratigraphy.org/index.php/ics-chart-timescale).

Additionally, an improved and re-calibrated flow-discharge relationship for each gauge would improve the accuracy of the data.

Baseflow conditions across the site varies, with the Carmichael River switching from gaining to losing and to gaining again, ongoing. Consequently gauging where the river enters and leaves the lease is necessary to better understand the interactions between surface water and groundwater, and the implications for the Carmichael River GDEs in this area. Gauging data would also address issues with stream flow identified in Section 2.3.1.

Table 1 Number of off-lease monitoring bores by formation.

Formation	Number of bores
Springs	7
Alluvium	3
Tertiary sediments	1
Moolayember Formation	2
Clematis Sandstone	10
Clematis/Dunda	1
Dunda Beds	3
Rewan Formation	5
Bandanna Formation	3
Joe Joe Group	15
Tertiary sediments / Joe Joe Group	4

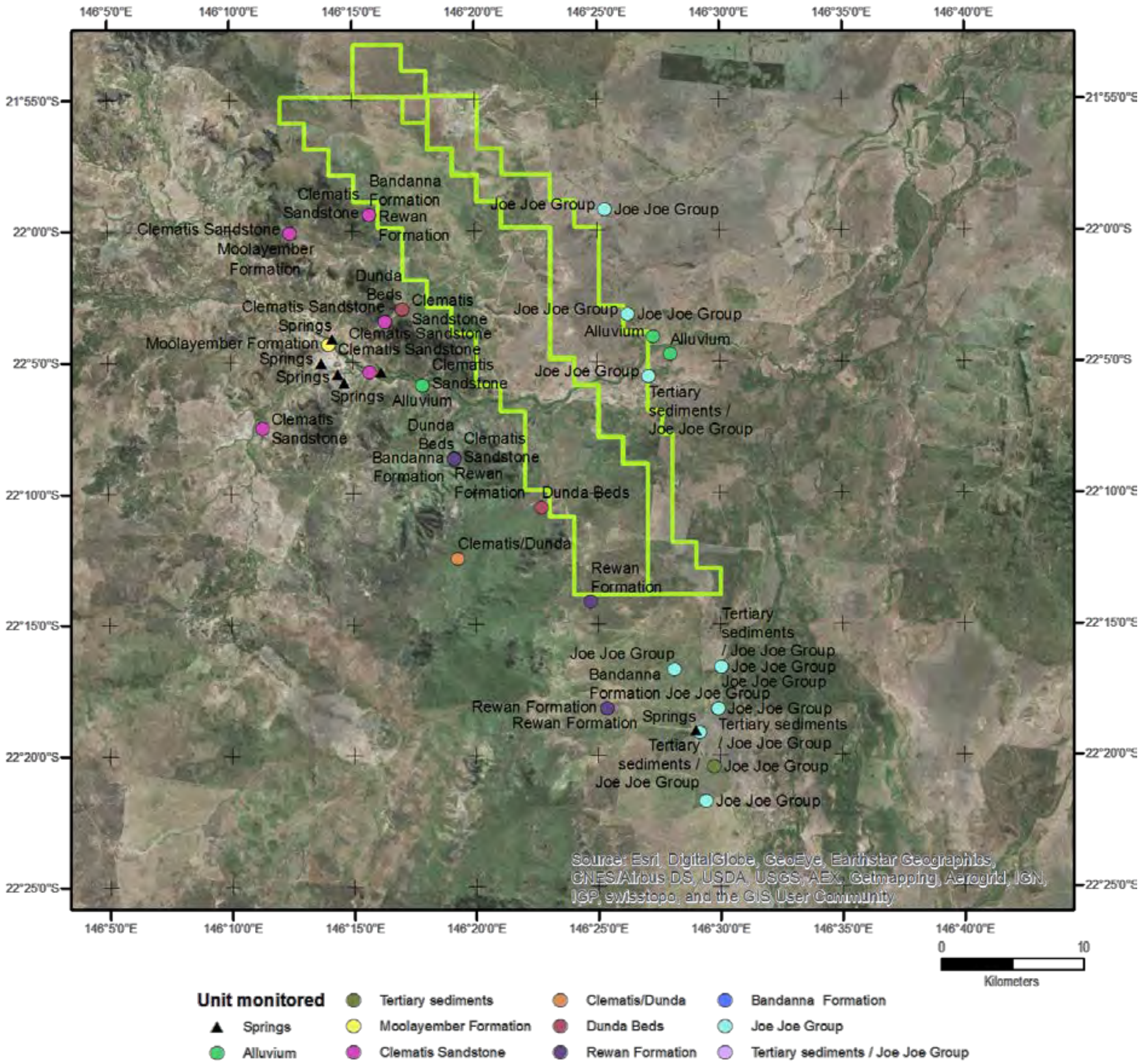

Figure 1. Spatial distribution of off-lease monitoring bores. Note that some locations represent nested bore sites. The green polygon shows the Proponent's mining lease areas.

3.4 Management approaches: water level thresholds and triggers

Issue: The use of drawdown rate triggers for the Rewan Formation and Dunda Beds (GMMP section 5.3.5.2) as part of the groundwater level monitoring and management regime represents a valid, well-considered approach to adaptive management. This approach relies heavily on predicted impacts. Bores C555P1 and C556P1, two of the three bores for which drawdown rate limits have been set, lie within the underground mining footprint. These may be impacted directly by mining activity.

The Proponent presents predicted impact hydrographs based on modelling in Appendix E. The hydrographs presented indicate that the bores listed in Table 2 will exceed nominated threshold levels. These drawdowns are all attributable to "approved mining activities", and most of the Alluvium, Tertiary, Clematis and Dunda bores will experience these exceedances within 40 years of commencement of "approved mining activities". The introduction of drawdown rate limits for selected Rewan Formation and Dunda Beds bores represents a positive approach to adaptive management for early warning of potential impacts. However, these limits do not address the concern that overall groundwater level thresholds will be exceeded by a large number of bores.

Recommendation: All monitoring locations for which water level thresholds are defined should also have drawdown rate limits derived. Evaluation of drawdown rate limits should form part of routine monitoring data assessment and be included in the Impact Threshold Assessment approach outlined in GMMP Section 5.3.5.3 and GMMP Plate 24.

Table 2 Monitoring bores identified as exceeding thresholds during operation

C022P1	C016P2	C025P1	C025P2	C027P2	C029P1
C029P2	C555P1	C556P1	C558VWP1	C848SP	C851VWP2
C968VWP_P2	C968VWP_P5	C9553P1R	C9845SPR	C14004SP	C14006SP
C14008SP	C14011SP	C14012SP	C14013SP	C14015SP	C14016SP
C14020SP	C14021SP	C14023SP	C14024SP	C14028SP	C14029SP
C914030SPR	C14033SP	C14206VWP_1	C180116SP	C180117SP	C180118SP

Issue: The threshold proposed for C025P1 appears inappropriate. It will trigger immediately as the bore has been reported dry for 4 years.

Recommendation: This bore should not be used as a threshold monitoring point until a deeper replacement has been installed. The threshold for the new bore should only be set after the acquisition of sufficient baseline data.

Issue: GMMP Section 5.3.3.1 and Section 5.3.5.1 indicate the processes by which a threshold will be triggered and an investigation initiated, for bores across the monitoring network and early warning trigger bores, respectively. Some of the actions presented are inconsistently applied or poorly defined.

Recommendation: To ensure clarity of management processes and that DoEE are aware that an investigation report is being produced, the Proponent should explicitly state that the Commonwealth regulator will be notified whenever a groundwater level exceedance occurs. The Proponent should commit to a maximum timeframe in which the investigation will be completed (for example three months) in the GMMP.

Issue: Quantification of non-mining influences on water levels (such as other land uses or climatic variability) has proven to be a complex and contentious process for other projects.

Recommendation: It is recommended that the Proponent provide details of how this process will occur during investigation of threshold exceedances, so that an agreed approach is in place before any exceedances occur.

Issue: Mitigation actions are not presented in the GMMP, and a number of references are made to actions presented in the GAB Spring Research Plan (GABSRP) or the Biodiversity Offset Strategy (BOS, out of scope for this advice). CSIRO and Geoscience Australia (2018) provides comments about the mitigation actions described in the GABSRP. EPBC Act approval condition 3.d) indicates that mitigation measures to protect the DSC must be incorporated into the GMMP.

3.5 Management approaches: hydrogeochemical triggers and thresholds

Groundwater quality is a key monitoring attribute for all GDEs in the GDEMP (Table 5-1) and groundwater quality triggers will be used to assess potential impacts on GDEs. The Proponent has established contaminant (groundwater quality) trigger levels and contaminant limits with the Queensland Department of Environment and Science (DES). The trigger levels allow for investigation and implementation of mitigation measures prior to reaching any groundwater quality limits. Contaminant limits (presented in Appendix D of GMMP) will be used to assess the potential for environmental harm, presumably resulting from a trigger exceedance. The GMMP states that triggers and limits may be revised if they are exceeded due to natural conditions.

Issue: As was the case in previous versions of the GMMP, there are trigger levels for up to 38 analytes for bores and hydrostratigraphic units, based on the 85^{th} percentile of background data where more than 12 results are beyond the limit of laboratory detection. This is a sound approach, but does mean trigger levels should be reached 15% of the time for each analyte.

Recommendation: Given the regularity with which exceedances are expected to occur, consideration should be given to:

- the implication of frequent triggering,
- how these exceedances will be investigated,
- how the Proponent will be able to differentiate between a trigger that does not result in environmental harm and one that might,
- ensuring that frequently exceeded triggers do not result in the conclusion that it is always due to natural variability,
- how an investigation into the cause of the exceedance will be undertaken, such as how an exceedance will be evaluated as being due to natural variability or mining activities,
- providing a timeline of how long an investigation will take and what data the Proponent will need to undertake this investigation, such as groundwater use volumes by other users.

There have been some changes to trigger levels compared to previous versions following discussions between the Proponent and the Queensland DES. There is now a “two consecutive exceedances approach” to trigger values, such that an investigation will only be initiated after two consecutive exceedances are detected. This is an appropriate approach. The “two consecutive exceedances approach” results in approximately 6 months passing before an exceedance is identified, based on groundwater monitoring events occurring every 3 months. The GMMP states that DoEE will not be notified when an exceedance occurs; notification will only occur 28 days after completion of the investigation into the cause of the exceedance. Given the length of time this may take (no time frame is provided in the GMMP), DoEE may not be notified of an exceedance until many months after it was first identified.

Recommendation: Consideration should be given to extending the approach to two exceedances within 12 months (~4 sampling events) rather than just consecutive exceedances, to ensure triggers can provide an early warning of potential impacts. The management actions would also be strengthened by providing a maximum time frame for an investigation.

If the investigation finds that the exceedances are due to mining activities, the Proponent commits to undertaking a further investigation to determine if ‘environmental harm’ has occurred. The GMMP states that the contaminant limits are ‘for consideration’ when assessing the potential for environmental harm, however it is not clear how they will be used or if they are enforceable limits. There may also be a time lag between a trigger exceedance and the realisation of ‘environmental harm’.

Issue: Table 45 in the GMMP describes the proposed trigger level methodology and step 4 states that *'all trigger levels derived from the baseline monitoring program (at least eight results greater than LOR) are compared to the ANZECC & ARMCANZ 2000 guideline values per analyte (95th protection and low reliability). In instances where the ANZECC & ARMCANZ 2000 guideline value is higher, this ANZECC value should be adopted as the proposed trigger level.'* In some cases, this results in trigger levels far in excess of baseline conditions (e.g. manganese and boron in bores screened in the Clematis Sandstone). This is contradictory to the principles of the Guidelines, which recommend that the default guideline values are a generic starting point for assessing water quality and specify that there is a distinct advantage in tailoring guideline values to reflect local conditions for the protection of aquatic ecosystems. The triggers and limits appear to be based on data collected in April 2017.

Recommendation: A clear statement regarding whether triggers and limits will be updated when additional pre-operational hydrochemistry data are collected should be included. Some bores may then have the required number of analyses to calculate baseline trigger values at that point, which would be preferable to using generic triggers derived from the ANZECC guidelines.

Issue: The GMMP and GDEMP state that the hydrochemistry triggers are interim for two years. This is generally a good approach for adaptive management, however care will need to be taken to ensure this does not result in triggers creeping up to avoid exceedances that will occur with the triggers set at the 85^{th} percentile of baseline.

Issue: Setting static trigger levels does not account for trends in hydrochemistry that may provide an early indication of impact.

Recommendation: An assessment of trends in the hydrochemistry data following each monitoring event will identify if groundwater quality is changing over time, which may provide an early warning of triggers being approached.

Issue: The GMMP states that monitoring data will be verified and then reviewed on a regular basis and reported to the regulators.

Recommendation: This should include an assessment of hydrochemistry at the site, in addition to presenting raw data.

Issue: Detailed issues with the triggers and limits are as follows:

- The increased number of analytes that have a contaminant limit assigned to them compared to previous versions (including aluminium, cadmium, chromium, lead, molybdenum, selenium, silver, vanadium, mercury and nitrate) is an improvement over previous versions of the GMMP.
- Contaminant limits for "HD03A and C14021SP" and "All other Clematis bores" seem to have been swapped between the current version of the GMMP and previous versions.
- In many cases, the trigger is the same as the contaminant limit or not substantially different (e.g. <5mg/L difference). In these instances, no time is allowed for investigation and required implementation of mitigation measures prior to reaching contaminant limits.

Issue: Previous versions of the GMMP presented contaminant limits recommended by DES for all hydrostratigraphic units. However, Appendix D in the current draft GMMP only presents contaminant limits for bores screened in the Alluvium, Tertiary Sediments and the Clematis Sandstone.

Recommendation: Limits for the Dunda Beds need to be included in Appendix D at a minimum, until alternative conceptualisations for the source aquifer for the DSC has been resolved as the Dunda Beds are likely to be a contributing water source.

Issue: There are instances where the trigger level is higher than the contaminant level in bores screened in the Alluvium and Clematis Sandstone. It is not clear how an investigation into an exceedance would progress in this scenario.

In some cases, the contaminant limit is far in excess of the background conditions at the site. In particular, the limits for boron, manganese and iron are consistently higher than baseline data.

Issue: For Clematis Sandstone bores, many dissolved metals have a no value (NV) contaminant limit. This means that there are not contaminant limits defined for the Proponent's preferred source aquifer for the DSC.

Recommendation: Given that the Proponent considers the Clematis Sandstone as the sole source aquifer for the DSC, contaminant limits for the Clematis Sandstone are required.

3.6 Ecological monitoring

The GDEMP sets out how to minimise and manage the environmental impacts of the Project on the four groundwater-dependent ecosystems listed in the approval conditions, through the combination of specific ecological measurements and links with other research and management plans (GMMP, GABSRP, RFCRP, Receiving Environment Management Plan, BOS, Great Artesian Basin Offset Strategy, Offset Area Management Plans, and MNES Plans). Proposed ecosystem measurements are based on relevant research and management guidelines. However, limitations identified for other management plans, in particular the GMMP, RFCRP and GAPSRP, mean that the proposed groundwater monitoring approaches are not sufficiently robust to ensure the outcomes sought by the conditions of approval are met.

The design of the ecological monitoring approach follows the GDE Toolbox approach and relevant research and management plans, which is considered to be adequate for monitoring potential impacts to GDEs. In the event that trigger levels are exceeded, the GDEMP will investigate the cause and notify the administering authority within 28 days. If mining activities are identified as the cause, the plan will revise monitoring and management approaches, including ecological and/or groundwater triggers; relevant operational constraints to manage groundwater drawdown impacts, such as revised mine planning or associated activities; changes to research priorities and additional mitigation and/or offset measures.

The GDEMP systematically addresses the management objectives, performance criteria, adaptive management triggers and corrective actions for each of the four GDEs identified in the approval conditions:

- Waxy Cabbage Palm (*Livistona lanuginosa*)
- Carmichael River (Carmichael River and its riparian zone between the Doongmabulla springs and the Belyando River)
- The Mellaluka Springs-complex
- Community of native species dependent on discharge from the Great Artesian Basin (Doongmabulla Springs-complex) including the Salt Pipewort *Eriocaulon carsonii*; and the Blue Devil *Eryngium fontanum*.

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Appendix A

A.1 Initial review of GMMP revision 4 water levels, triggers and thresholds

A.1.1 Revised hydrographs

Specific issues relating to water levels and hydrographs have been compiled and are provided in Table 1. The column "contoured" indicates if a bore has been used to derive groundwater contours or not. The column "hydrogeochemistry" indicates if a bore has been sampled and data provided as part of the chemical characterisation of groundwater. For bores C008P1 and C035P1, no data has been provided, however a geochemical trigger value is provided.

A key point identified in this work is that Appendix C and E of GMMP revision 4 show differences between hydrographs for individual bores. Appendix C shows a shorter time series, whereas Appendix E shows a more complete time series, extending further back and including more recent data. In addition, Appendix E appears to contain hydrographs constructed from data which has been corrected in some part as a result of feedback on previous versions of the GMMP. Groundwater level contour maps provided in Appendix C are described as being derived from the average water level for each bore. It is unclear if this is the average water level for data presented in Appendix C, or if it is for the entire time series. The contour maps for the Alluvium, Tertiary Sediments, Dunda Beds, Rewan Formation, Bandanna Formation (AB Seam), Colinlea Seam (D Seam), and Joe Joe Group are derived from "Average Groundwater Elev (mAHD)" according to the legend and statement on each map (Figures F1, F2, F4, F5, F6, F7, F8a and F8b). The groundwater contour map for the Clematis Sandstone is derived from the "April 2018 water level data" according to the legend to Figure F3, although the Notes for the map state that "SWL (mAHD) data is the average water level based on hydrographs by NRC (on behalf of Adani)." These statements are mutually exclusive. The "Notes" to the groundwater level maps appear to be based on a template, whereas the "Legend" is map-specific.

GMMP revision 4 Appendix C and Appendix E both contain observation hydrographs from monitoring bores. There are however inconsistencies between the two appendices, including but not limited to:

1. Discrepancy in hydrographs from the same bore for the same time period:

   HB03B, C027P2, C029P2, C14005SP, C016P2, C555P1

2. Concerns with hydrographs in the alluvium are still not addressed in GMMP revision 4 appendices:

   HD02 (05/2013 to 05/2015), C027P2 (11/2012 to 03/2015), C025P2 (entire record)

3. Unexplained offsets in values between bore water levels which are not related to resurveyed reference elevations:

   C9180124SPR common reference value of 224.29m

4. Unexplained changes, shifts or deletion of logger data and/or manual data:

   C14005SP– removal of manual measurements and changes to hydrograph

   C011P1– removal of period between 03/2013 and 09/2013 as well as shift in manual measurements by approximately 2-3 months.

Additional detailed work on understanding issues with water level data from bore HD02 subsequent to provision of the GMMP revision 4 was provided to Geoscience Australia and CSIRO on 5 December 2018. This work rectified issues identified with this bore's water level data. The new hydrograph accords with the reported hydrogeological setting HD02 is in, and the thorough and detailed explanation put forward for the corrections. The work undertaken shows an appreciation of the importance of robust scientific analysis in this type of work. The new water level work undertaken for HD02 raises further questions:

1. How does this effect the integrated interpretation of data near the springs given there is now a drop of ~0.6m in 4years in GMMP revision 4 as opposed to the 0.2m in the GMMP revision 1 graphs for HD02?
2. Should the trigger values consider this rate of decline (i.e. no increase in rate) as part of the early warning assessment of the 0.2m limit?
3. Why was data only corrected up until 2016?

Rainfall data can be used to help constrain the alluvium and unconfined components of the groundwater system. The same cannot be said for bores screened in confined aquifers. These bores warrant more detailed investigation; however, this diverges from the questions being posed under Tranche 2.

It is unclear why minimum and maximum water levels are calculated from automated logger data for some bores, and from manual water level readings for other bores. Similarly, it is unclear why some bore records have been used to derive water level contours, as opposed to including all bore records available. A significant change between previous versions of the GMMP is the omission in revision 4 of vibrating wire piezometer data. Hydrographs do not report data for 2017 or 2018. Figure F3 from Appendix C states, however, that contours for the Clematis Sandstone are based on April 2018 water level data. As noted in reviews of previous revisions, as well as in peer reviews of the GMMP provided by the Proponent, groundwater contour maps must contain the subcrop or extents of hydrogeological units. For example, Figures F1 through F4 and F8a and 8b do not include mapped extents, whereas Figures F5 through F7 do. Another feature not present on all maps is the location of the interpreted groundwater synform. This feature appears for all units stratigraphically below the Clematis Sandstone, although the axis does not appear to match with the groundwater contours. For example, the synform in Figure F4 trends in a northeasterly direction, whereas the contours would imply such a feature trends in ad easterly direction, coincident with the orientation of the Carmichael River.

A.1.2 Issues relating to revised water level data that relate to modelling and modelled impacts

The numerical groundwater model has not been recalibrated since the SEIS report. When the observation bores were surveyed and the heights updated the model was not recalibrated. The model re-runs changed the western boundary conditions (location, elevation and conductance) but did not recalibrate. There are several issues with the model calibration which makes the drawdown predictions unreliable, including that the model was calibrated to incorrect bore heights; the parameterisation of the Rewan and Clematis are at the extremes of the expected range; and, the river flows were not part of the calibration.

Having the incorrect bore heights in the calibration dataset has forced the model to have the incorrect groundwater levels. Bore HD02 is the closest bore to Doongmabulla Springs and has shifted elevation by 4m. When the springs are potentially sensitive to drawdown of 0.2m an error of 4m is substantial. The drawdown is calculated as the difference between two model runs, if the model behaved in a linear fashion then the 4m offset would not be a problem. However, the model boundary conditions associated with ET and the river are not linear and neither is the flow in the top unconfined layer. We cannot estimate the error in predicted drawdown due to the change in bore elevations without re-calibrating the model.

The hydraulic conductivity of the Rewan formation is extremely low and this minimises the propagation of drawdown into the Clematis. The hydraulic conductivity of the Clematis is at the high end of the expected value which allows the model to draw more water in horizontally and thus minimising the drawdown to Doongmabulla Springs. The sensitivity analysis shows that if either of these parameters were changed to their expected values then the drawdown at the springs would be greater than 0.2m. If both were changed it would be greater again.

The 90th percentile of river flows measured at the upstream gauge was 400 m^3/d but the calibrated baseflow in the model was 4000 m^3/d. The predicted maximum impact on the flow in the river was 1000 m^3/d, which is more than the measured baseflow. In the model the Carmichael River is acting as a source of water that doesn't exist and so drawdown in the Carmichael River GDE is underestimated. The model needs baseflow in the river to be a calibration target to ensure that the predicted drawdown in the target to ensure that the predicted drawdown in the GDE is accurate.

The status of the interaction between baseline water level data, modelled drawdown predictions, revised hydrographs, and triggers and thresholds is not clear from this initial assessment.

A.1.3 Hydrogeochemistry

As stated in Tranche 1 review, the proposed groundwater quality monitoring bores in the vicinity of the Doongmabulla Springs Complex (DSC) are not screened in alternative spring source aquifers such as the Dunda Beds. Consequently, the groundwater chemistry monitoring data that has been collected to date and is proposed to be collected, will not contribute to the assessment of alternative source aquifers for the DSC.

In some cases, groundwater trigger levels have been set for individual bores. In other cases, the trigger level is set for the hydrostratigraphic unit. The Proponent describes the methodology they used to calculate trigger levels, however the results of this methodology are not presented in the GMMP. For example there are no box and whisker plots; there are no piper diagrams to identify why some bores are considered to have different water quality to other bores in the same hydrostratigraphic unit. No clear evidence is presented for why bore C0227P2 in the Dunda Beds has variable groundwater quality compared to other bores in the Dunda Beds. Time series graphs in Appendix D indicate this bore is not consistently different across a range of groundwater quality indicators from other bores in the Dunda Beds.

Other issues associated with the proposed groundwater quality triggers include:

1. Some trigger levels are set far in excess of baseline concentrations. The trigger levels for boron, manganese and iron seem to be consistently higher than baseline data. The Proponent do not provide an explanation for why their proposed triggers differ from those recommended by Queensland Department of Environment and Science (DES).
2. Setting trigger levels does not account for trends in groundwater chemistry that may provide an early indication of impact. Following the recommendation from DES (DES review August 2018), the Proponent state that two consecutive groundwater chemistry results above the trigger value will prompt an investigation. Some assessment of trends in the groundwater chemistry data following each monitoring event to identify if groundwater quality is changing over time should also form part of the monitoring strategy.
3. Few bores are classified as 'sentinel' bores have site-specific groundwater trigger levels set. The trigger levels for these bores defaults to hydrostratigraphic unit-wide trigger levels. Whilst this may be a suitable approach to investigate aquifer-wide changes to groundwater chemistry; the protection of specific receptors requires site-specific triggers to provide early warning of potential impacts to the springs. Individual triggers need to be set for sentinel bores which are "a monitoring point where groundwater level and quality changes can be monitored before changes occur at a receptor (p.32)".

A.1.4 Recommendation

While Geoscience Australia and CSIRO have assessed water levels and associated information provided, this does not constitute the detailed work necessary to address Tranche 2 of the current work program. That work will commence once a decision has been reached by Geoscience Australia, CSIRO and DoEE taking into consideration the information provided here. Geoscience Australia and CSIRO have previously provided DoEE with time lines for completion of Tranche 2 work, factoring in contingencies relating to provision of appropriate documentation by the Proponent. That documentation has been provided. Based on this initial assessment, Geoscience Australia and CSIRO recommend allowing the proponent to reconsider their submission for Tranche 2. Tranche 2 will include the work undertaken in this initial assessment of water levels for GMMP revision 4.

Table 3. Compilation of specific comments relating to hydrographs presented in GMMP revision 4.

Bore ID	Initial Review comments	Contoured	Hydrochemistry
Quaternary Alluvial Deposits			
C025P1	• Used in the contour plot, however has been reported dry since 2015. Since dry, they use a rounded value of terminal depth as the WL. This is not correct. This data point should be discounted and not used in the contour (or in model calibration). - its only value is to indicate maximum possible water level if checking modelled data over the historic period. • This bore is shown in the Tertiary formation in Figure 12	Y	N
C027P1	Value used in contour plot is over 1 metre higher than long term value and most recent reading on hydrograph. A rise of WL of this amount is inconsistent with long term trends.	Y	Y
C029P1	Manual dips diverged from logger data for a few readings. (Logger not being reset at each dip)	Y	Y
HD03B	• RL has shifted >3m. Concern this shift will impact model calibration. • Logger and manual dips divergent, this not explained.	Y	Y
C14027SP	Contour plot uses long term minimum, instead of long term average	Y	N
C14028SP	The hydrograph is characterised by a peak (associated with flooding) in 2012. Then subsides to a significantly lower value that is fairly steady from 2014 to 2017. The average value uses data from the peak and so gives a long term average that is more than a metre higher than the apparent long term average value.	Y	Y
Tertiary Age Sediments			
C025P2	• Outlying data point removed - approximately Jan 2015, no explanation. • Plot in Appendix C still inverted version.	Y	Y

Bore ID	Initial Review comments	Contoured	Hydrochemistry
C029P2	The early manual dip readings are no longer included (from 2011)	Y	Y
C558P1	• Step change in data values still present and not explained. Concern that model calibrated using GHD logger values, whereas long-term dataset is >0.5m higher. • Appears to be 3 manual dip readings between 2014 and early 2015 removed from data set without explanation.	Y	Y
C9180121SPR	No overlap between logger and manual dips, however logger used to calculate max, min and average values.	Y	Y
C9845SPR	nil comment	Y	Y
C971SP (C896G)	no hydrographs presented	N	N
Triassic Age Units (GAB Units)			
Moolayember Formation			
C14020SP	nil comment (not contoured)	N	N
Clematis Sandstone			
HD02	• Values transposed down approximately 4m compared with SEIS hydrograph. This likely to impact validity of model calibration. • Parts of plot appear upside down. If so this would fix the divergence between manual dips and logger data. • Hydrograph does not include any data beyond mid 2016.	Y	Y
HD03A	Manual dips not included on hydrograph	Y	Y
C180118SP	• Hydrograph indicates well is blocked from mid 2015, suggesting value should not be used on contour plot. • Value used on contour plot is >1m lower than last value on hydrograph, not clear if it is now unblocked, but if so value shows a dramatic drop from previously steady readings.	Y	Y

Bore ID	Initial Review comments	Contoured	Hydrochemistry
C14021SP	• This point lies outside the formation boundary for the Clematis (likely Tertiary or Dunda Beds). Thus is used incorrectly on the Clematis contour plot. • Manual dip readings (in Appendix C) not provided on Appendix E hydrograph	Y	Y
C14033SP	nil comment	Y	Y
C14011SP	• Value on contour plot is approximately 1m higher than last value on hydrograph. Given the very steady long-term groundwater levels it is unprecedented for the hydrograph to rise sufficiently to make contour value likely. • Maximum water level on hydrograph appears to be calculated from manual dips, if so value is incorrect.	Y	Y
C14012SP	Value on contour plot is approximately 1m higher than last value on hydrograph. Given the very steady long-term groundwater levels it is unprecedented for the hydrograph to rise sufficiently to make contour value likely	Y	Y
C14013SP	Value on contour plot is approximately 1m higher than last value on hydrograph. Given the very steady long-term groundwater levels it is unprecedented for the hydrograph to rise sufficiently to make contour value likely	Y	Y
C18001SP	new, artesian	Y	N
C18002SP	new	Y	N
C18010SP	new	Y	N
C18011SP	new	Y	N
C18012SP	new	Y	N
C18013SP	new	Y	N
C18014SP	new	Y	N
Dunda Beds			
C022P1	nil comment	Y	Y

Bore ID	Initial Review comments	Contoured	Hydrochemistry
C027P2	• Early manual dip readings appear to have been shifted up 1m in the Appendix E hydrograph Section of the plot is possibly inverted (ie rainfall response) • Manual dip readings in mid 2016 appear to have been omitted (are present in Appendix C data).	Y	Y
C14023SP	nil comment	Y	N
C180117SP	Early manual dip readings (March to November 2014) have not been included in Appendix E hydrograph	Y	Y
Rewan Formation			
C008P1	Manual dip readings in Appendix C and Appendix E do not match - possibly a time shift in the data, or several points omitted.	Y	? Have trigger
C035P1	• Time scale on Appendix E plot has malfunctioned (mid 2013 to 4/2015 missing). • Data ends at 2/2016. • Appears that manual dip points are missing/Plots in appendices C and E very different.	Y	? Have trigger
C555P1	• Approximately 1m jump in water levels in mid 2013 - not explained. • Logger data from approximately 9/2015 in Appendix E appears to be a plotting error (different to App C). • Calculated average water level is incorrect (appears to be 1m higher than correct value - typo?), the incorrect value is used in the contour plot.	Y	N
C556P1	Outlying manual dip reading has been removed - but not mentioned/ discussed/explained.	Y	N

Bore ID	Initial Review comments	Contoured	Hydrochemistry
C9553P1R	• Data ends 7/2016. • Early data (2012 to 7/2013) has two logger plots that don't coincide. No explanation given as to why data is different. • Need to clarify which data was used for the model calibration.	Y	N
C180116SP	Nil comment	Y	N
C9838SPR	Logger and manual dips diverge from mid 2016 - not discussed/explained.	Y	N
Permian Age Units			
Bandanna Formation			
B-C Sandstone			
C006P1	Nil comment	N	N
C018P1	Short period in early part of plot with 2 sets of logger data. Need to clarify which was used in the model calibration	N	N
C847SP	2 outlier manual dips from early 2015 removed in Appendix E without discussion.	N	N
AB Seam			
C007P2	Nil comment	Y	Y

Bore ID	Initial Review comments	Contoured	Hydrochemistry
C008P2	5/2016 outlier manual dip removed - no discussion.	Y	Y
C014P2	Nil comment	Y	Y
C016P2	Appears to be a small vertical shift (<0.5m) downward in data. Difficult to confirm due to variable scales.	Y	Y
C020P2	Nil comment	Y	Y
C032P2	Appears to be a small vertical shift upward of data in 2013/2014 (approximately 0.5m).	Y	Y
C034P1	• Single manual dip - significantly different to logger data - not discussed/ explained. • Logger appear to malfunction from 7/2016 - not discussed/explained.	N	N
C035P2	Nil comment	Y	Y
AB Interburden			

Bore ID	Initial Review comments	Contoured	Hydrochemistry
C011P1	• It appears the elevation of the data has shifted by approximately 1m. This may impact model calibration. • Appendix C and Appendix E are inconsistent, and the issues identified in 2017 have not been addressed.	N	N
C Seam			
C823SP	• Hydrograph behaviour strange (opera house) - either logger error (as indicated in Appendix E) or issues with gw sampling (as indicated in Appendix C) this issued should be clarified and resolved. Has been going since end of 2014. • Plots in Appendix C and E are different (logger coincides with manual dip in E, but not in C).	N	N
C832SP	Divergence of manual readings and logger data in later 2016 not explained	N	N
C Seam interburden			
C9839SPR	2 manual dip outliers (early 2015) removed in Appendix E without discussion	N	N
C844SP	Nil comment	N	N
Other Bandanna Formation			
C018P2	1.5 metre step down in data in approximately 8/2012. Not explained.	N	N

Bore ID	Initial Review comments	Contoured	Hydrochemistry
C034P1	• Single manual dip - significantly different to logger data - not discussed/ explained. • Logger appears to malfunction from 7/2016 - not discussed/explained.	N	N
Colinlea Sandstone			
C-D Sandstone			
C972SP (C897G)	Not included	N	N
C974SP (C899G)	Nil comment	N	N
D Seam			
C006P3R	• Two sets of logger data provided for early (10/11 to 5/13) part of plot. One plot has peaks in the data not present in the other. • The logger plot that continues as the long-term logger appears to be inverted (potential rainfall response falling instead of rising).	Y	Y
C007P3	Nil comment	Y	Y
C011P3	Nil comment	Y	Y
C018P3	Nil comment	Y	Y
C024P3	Nil comment	Y	Y
C034P3	• Logger appears to have failed in late 2015 - no comment/ explanation (however data appears not to be used in calculation of average). • Manual dips shown in Appendix E do not appear to match those in Appendix C.	N	Y

Bore ID	Initial Review comments	Contoured	Hydrochemistry
C180114SP	Nil comment	Y	Y
C833SP	• Logger and manual readings do not match throughout monitoring period. No discussion about why.	Maybe - with typo as C883?	Y
C848SP	Nil comment	Y	Y
C9849SPR	Appendix C includes many more manual readings than Appendix E.	N	Y
C975SP (C900G)	Nil comment	Y	N
D Seam interburden			
C829SP	Outlying manual dip included in Appendix C but not E - no explanation	N	N
D-E Sandstone			
C825SP	Nil comment	N	N
C840SP	Outlying manual dip included in Appendix C but not E - no explanation	N	N
E-F Sandstone			
C180112SP	Outlying manual dip included in Appendix C but not E - no explanation	N	N
Other Colinlea Sandstone			
C827SP	Nil comment	N	N
C834SP	• Appendix C includes manual dips, none are included in Appendix E. • Dips diverge from logger data - no discussion/explanation.	N	N
Joe Joe Group			

Bore ID	Initial Review comments	Contoured	Hydrochemistry
C012P1	Nil comment	Y	Y
C012P2	Nil comment	Y	Y
C180119SP	Manual dips included in appendix C but not appendix E.	Y	Y
C9180124SPR	• Water levels in appendix C are approximately 3 metres lower than Appendix E values. • Appendix C includes manual dips, none are included in Appendix E. • Dips do not coincide with logger data - no discussion/explanation.	Y	Y
C9180125SPR	• Appendix C includes manual dips, none are included in Appendix E. • Dips do not coincide with logger data - no discussion/explanation	Y	Y
C180123SP	Manual dips included in appendix C but appendix E.	Y	Y
C14002SP	Manual readings have shifted vertically from Appendix C to Appendix E.	Y	N
C914001SPR	Nil comment	Y	Y
C14014SP	• Early manual dips in Appendix C and Appendix E do not correspond. • Notes indicate farmer using bore, consequently is the bore suitable as a monitoring point?	Y	Y

Bore ID	Initial Review comments	Contoured	Hydrochemistry
C14032SP	• No hydrograph provided in appendix C. • Step change in water levels in approximately October 2015 (3m down) - not explained/explored. Could it be a resurvey of the monitoring point? (water levels appears relatively steady before and after the step change)	Y	N
C14008SP	Manual dips and logger data do not coincide - not discussed/explained	Y	Y
C14015SP	No manual dip data provided	Y	Y
C14017SP	Manual dips and logger data do not coincide - not discussed/explained	Y	Y
C14006SP	• Manual dip readings not presented in Appendix E. • Dips and logger do not coincide - not discussed/explained	Y	Y
C914030SPR	Manual dips and logger data do not coincide - not discussed/explained	Y	N
C14004SP	Early outlier in Appendix C removed in Appendix E (probably reasonable, but not explained).	Y	N
C14016SP	nil comment	Y	Y
C14003SP	Outlying manual dips from Appendix C not in E.	Y	Y
Composite Sample Points			
C180122SP	• No manual dips included in appendix E. • Manual dips do not coincide with logger data - no explanation	N	N
C180120SP	• No manual dips included in appendix E. • Manual dips diverge from logger data - no explanation	N	N
C973SP (C898G)	Not included in Appendix C	N	N
C14031SP	No manual dips included in appendix E.	N	N

Bore ID	Initial Review comments	Contoured	Hydrochemistry
C14024SP	Not included in Appendix C	N	N
C14005SP	• Plots in Appendix C and Appendix E are very different: several data steps in Appendix C, none in Appendix E. • No manual dips in Appendix E. • Several small downward data spikes not explained. • Logger and manual readings divergent	N	N
C14029SP	Not included in Appendix C	N	N

Appendix B

CSIRO Comment location in App A	CSIRO Comment	Adani Comment response	Location where CSIRO comment to be addressed in GMMP rev 5	GA response post GMMPv5
Paragraph 1, Attachment A (Revised Hydrographs)	For bores C008P1 and C035P1, no data has been provided, however a geochemical trigger value is provided.	No data on Rewan formation is provided in Appendix D. However in GMMP report body, triggers for C008P1 are provided.	Section 5.4.3.4.5 of GMMP (Rev 5)	Adequately addressed and data is now provided in Appendix D: Geochemistry tables
Paragraph 2, Attachment A (Revised Hydrographs)	A key point identified in this work is that Appendix C and E of GMMP revision 4 show differences between hydrographs for individual bores.	Appendix C has been revised to include only groundwater contours; Appendix E includes hydrographs	Refer to Appendix E of the revised GMMP (Rev 5)	
Paragraph 2, Attachment A (Revised Hydrographs)	Groundwater contour figures: notes and legend between Clematis and all other maps are different. The "Notes" to the groundwater level maps appear to be based on a template, whereas the "Legend" is map-specific.	Groundwater contour figures have been updated per action specified in next column	The maps legend has been corrected. Please refer to maps in Appendix C.	
Paragraph 3, Attachment A (Revised Hydrographs)	Inconsistencies between App C and App E	Hydrographs in App C have been removed and App E includes most recent hydrographs accepted by	Refer to Appendix E for hydrographs in revised GMMP	

CSIRO Comment location in App A	CSIRO Comment	Adani Comment response	Location where CSIRO comment to be addressed in GMMP rev 5	GA response post GMMPv5
		DNRME		
Paragraph 4 and subsequent dot points, Attachment A (Revised Hydrographs)	Revised HD02 hydrograph (accounting for DNRME comments) raises questions: 1. How does this effect the integrated interpretation of data near the springs given there is now a drop of ~0.6m in 4years in GMMP revision 4 as opposed to the 0.2m in the GMMP revision 1 graphs for HD02? 2. Should the trigger values consider this rate of decline (i.e. no increase in rate) as part of the early warning assessment of the 0.2m limit? 3. Why was data only corrected up until 2016?	1. The min GWL is 234.07 and max GWL is 234.58, The decline of 0.6m is not observed. The bore is also influenced by flooding of Carmichael River. 2. The rate of decline in HD02 which is a Clematis Sst bore is a naturally occurring phenomena, as this bore is influenced by the flooding of Carmichael River. However mining related impacts are also monitored in units below Clematis by assigning triggers based on a rate of decline and which will occur prior to the impact reaching HD02.	The hydrograph for HD02 has been reviewed, and all inconstancies have been addressed and explanation provided and signed off by DNRME. The hydrograph has been updated up to 2017.	
Paragraph 6 (Revised Hydrographs)	1. It is unclear why minimum and maximum water levels are calculated from automated logger data for some bores, and from manual water level readings for other bores.	1. The GMMP details the dataset utilised to calculate average groundwater elevation for each bore and rationale 2. The GWL data collected by manual dipping and	The GWL statistics has been derived by using the most accurate data. DNRME has agreed with the approach followed in selecting the data sets for	

CSIRO Comment location in App A	CSIRO Comment	Adani Comment response	Location where CSIRO comment to be addressed in GMMP rev 5	GA response post GMMPv5
	2. Similarly, it is unclear why some bore records have been used to derive water level contours, as opposed to including all bore records available.	automated logger for each bore is assessed and as per assessment the most valid data is used for generating the hydrographs. For generating hydrographs, only data within the same horizon/aquifer is considered. 3. As per DNRME advice all VWP data was not considered for generating hydrographs	deriving the GWL stats. See Section 3.4 of the revised GMMP.	
	3. A significant change between previous versions of the GMMP is the omission in revision 4 of vibrating wire piezometer data. Hydrographs do not report data for 2017 or 2018.	4. Figures F1 and F2 are for alluvium and tertiary where extents exist throughout the area. Extents of Clematis SSt and Dunda Beds may be included in Figures F3 and F4 respectively.	See Section 3.3 of GMMP	
	4. As noted in reviews of previous revisions, as well as in peer reviews of the	5. Synform does not extend through all hydrostratigraphic units	The sub crop lines where identified from the geological model are now	

CSIRO Comment location in App A	CSIRO Comment	Adani Comment response	Location where CSIRO comment to be addressed in GMMP rev 5	GA response post GMMPv5
	GMMP provided by the Proponent, groundwater contour maps must contain the subcrop or extents of hydrogeological units. For example, Figures F1 through F4 and F8a and 8b do not include mapped extents, whereas Figures F5 through F7 do. 5. Another feature not present on all maps is the location of the interpreted groundwater synform. This feature appears for all units stratigraphically below the Clematis Sandstone, although the axis does not appear to match with the groundwater contours.		incorporated in the maps. For sub crops not identified in the geological model an indicative sub crop are included. Refer to updated maps in Appendix C.	
Paragraph 1 (Issues relating to….. modelled impacts)	There are several issues with the model calibration which makes the drawdown predictions unreliable, including that the model was calibrated to incorrect bore heights; the parameterisation of the Rewan and Clematis are at the extremes	Model review is outside scope/ objective of GMMP.	See Section 2.2.9	

CSIRO Comment location in App A	CSIRO Comment	Adani Comment response	Location where CSIRO comment to be addressed in GMMP rev 5	GA response post GMMPv5
	of the expected range; and, the river flows were not part of the calibration.			
Paragraph 1 (Issues relating to….. modelled impacts)	…We cannot estimate the error in predicted drawdown due to the change in bore elevations without re-calibrating the model.	Model review is outside scope/ objective of GMMP.	See Section 2.2.9	
Paragraph 2 (Issues relating to….. modelled impacts)	The hydraulic conductivity of the Rewan formation is extremely low and this minimises the propagation of drawdown into the Clematis. The hydraulic conductivity of the Clematis is at the high end of the expected value which allows the model to draw more water in horizontally and thus minimising the drawdown to Doongmabulla Springs. The sensitivity analysis shows that if either of these parameters were changed to their expected values then the drawdown at the springs would be greater than 0.2m. If both were changed it would be greater again.	Model review is outside scope/ objective of GMMP	See Section 2.2.9	

CSIRO Comment location in App A	CSIRO Comment	Adani Comment response	Location where CSIRO comment to be addressed in GMMP rev 5	GA response post GMMPv5
Hydrogeochemistry				
Paragraph 2	The Proponent describes the methodology they used to calculate trigger levels, however the results of this methodology are not presented in the GMMP. For example there are no box and whisker plots; there are no piper diagrams to identify why some bores are considered to have different water quality to other bores in the same hydrostratigraphic unit.	Further information has been detailed with respect to the adopted approach to finalise the trigger levels in consultation with DES	Section 5.4.3.2 and Section 5.4.3.3	Additional information has been provided here. It would be beneficial to provide the results of the assessments of hydrochemistry to see the evidence for why bores within a formation have been differentiated for the purpose of defining trigger levels.
Paragraph 2	No clear evidence is presented for why bore C0227P2 in the Dunda Beds has variable groundwater quality compared to other bores in the Dunda Beds. Time series graphs in Appendix D indicate this bore is not consistently different across a range of groundwater quality indicators from other bores in the Dunda Beds.	As the site is currently a greenfield site, the reported variability is considered to be a representation of the existing (baseline) environment. A conservative approach has been adopted for this bore by the development of bore-specific trigger levels.	Section 5.4.3.4.4	The raw data is now presented in the geochemistry tables in Appendix D. Presenting this information on something like a Piper diagram would be helpful to illustrate that C0227P2 has a different hydrochemistry to other bores in the Dunda Beds.
Other issues associated with the proposed groundwater quality	1. Some trigger levels are set far in excess of baseline concentrations. The trigger levels for boron,	Further information has been detailed with respect to the adopted approach to finalise the trigger levels in consultation	Section 5.4.3.2 and Section 5.4.3.3	Additional information is provided in Table 45. With regards to trigger levels for some analytes being higher

CSIRO Comment location in App A	CSIRO Comment	Adani Comment response	Location where CSIRO comment to be addressed in GMMP rev 5	GA response post GMMPv5
triggers include:	manganese and iron seem to be consistently higher than baseline data. The Proponent do not provide an explanation for why their proposed triggers differ from those recommended by Queensland Department of Environment and Science (DES). 2. Setting trigger levels does not account for trends in groundwater chemistry that may provide an early indication of impact. Following the recommendation from DES (DES review August 2018), the Proponent state that two consecutive groundwater chemistry results above the trigger value will prompt an investigation. Some assessment of trends in the groundwater chemistry data following each monitoring event to	with DES Assignment of site-specific triggers to provide early warning for 'specific receptors' is not related to GMMP, or the objective of GMMP as per EA as this will be for GDEMP to prescribe. But EPBC approval require GMMP to assign triggers for MNES. Therefore, the hydrostratigraphic unit		than baseline data, Table 45 states that in Step 4: '*trigger levels derived from the baseline monitoring program are compared to the ANZECC & ARMCANZ 2000 guideline values per analyte (95th protection and low reliability). In instances where the ANZECC & ARMCANZ 2000 guideline value is higher, this ANZECC value should be adopted as the proposed trigger level.*' GA notes the ANZECC guidelines are only used in preference to the baseline data when they are higher than baseline data, not lower. GA considers that site-specific triggers are preferential to using the ANZECC guideline trigger values.

CSIRO Comment location in App A	CSIRO Comment	Adani Comment response	Location where CSIRO comment to be addressed in GMMP rev 5	GA response post GMMPv5
	identify if groundwater quality is changing over time should also form part of the monitoring strategy. 3. Few bores are classified as 'sentinel' bores have site-specific groundwater trigger levels set. The trigger levels for these bores defaults to hydrostratigraphic unit-wide trigger levels. Whilst this may be a suitable approach to investigate aquifer-wide changes to groundwater chemistry; the protection of specific receptors requires site-specific triggers to provide early warning of potential impacts to the springs. Individual triggers need to be set for sentinel bores which are "a monitoring point where groundwater level and quality changes can be monitored before changes occur at a receptor (p.32)".	which is the source of springs is MNES.		

Appendix C

Carmichael Coal Mine

Advice on draft research plans to the Department of the Environment and Energy

NOVEMBER 2018

CSIRO
Australian Government
Geoscience Australia

1. Introduction

On 25 October 2018, the Department of the Environment and Energy (DoEE) requested Geoscience Australia and CSIRO to provide groundwater-related advice on draft plans provided by Adani Mining Pty Ltd (the Proponent) in accordance with *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval conditions for the Carmichael Coal Mine. These plans include the draft Great Artesian Basin Springs Research Plan (GABSRP) and the draft Rewan Formation Connectivity Research Plan (RFCRP), required under EPBC Act conditions 25 and 26, and 27 and 28, respectively.

The DoEE sought advice specifically on two questions relating to these draft plans:

Q1a. Based on the information currently available, how plausible and reasonable is it that the Clematis Sandstone is the source aquifer for Doongmabulla Springs Complex?

Q1b. How adequately do the methods and techniques put forward in the research plans address uncertainties about:

1. the source of the springs
2. the capacity of the Rewan Formation to prevent impacts to the springs, and
3. methods to prevent, mitigate and remediate ecological impacts to the springs?

These questions were to be based on available information including:

4. the draft GABSRP (Final draft, dated 21 May 2018)
5. the draft RFCRP (Revision L, dated 6 August 2018)
6. a Statement of claims about the springs source and additional information about the conceptualisation provided by the Proponent to DoEE on 12 October 2018 (Supplementary information)
7. the draft Groundwater Management and Monitoring Plan – Carmichael Coal Project Revision 3, dated August 8, 2018 (GMMP).
8. the draft Groundwater Dependent Ecosystem Management Plan – Carmichael Coal Mine Project, Version 9 dated 5 July, 2018 (GDEMP)

This document provides an assessment of how the methodology and rationale for each draft research plan addresses Q1a and Q1b. This assessment relied on the draft plans, the statement of claims about the springs source and additional information about the conceptualisation, including some studies undertaken since the time of approval. Other references are included as in-text citations and in the reference list provided.

a. Advice on the draft research plans

In general, the draft research plans provide approaches to address some data gaps and areas of uncertainty about the source of the Doongmabulla Springs Complex and the hydrogeological characteristics of the Rewan Formation. However, they will not address the differing hydrogeological conceptualisations or potential uncertainties outlined above in the 12 month work programs specified in the plans. The plans provide a number of techniques and methods to address their aims; however they are poorly referenced, and generic in nature. The draft research plans lack the specificity required to assess if the methods are appropriate given the known geological and hydrogeological characteristics of the Carmichael Coal Project area, and the different components of the conceptualisations being tested. Both plans also set out to confirm the proponent's preferred conceptualisation, as opposed to seeking to collect data and information with which to develop and evaluate multiple conceptualisations. Some inconsistencies between the documentation also exist, such as differing maps between plans.

2. Based on the information currently available, how plausible and reasonable is it that the Clematis Sandstone is the source aquifer for Doongmabulla Springs Complex?

It is plausible and reasonable that the Clematis Sandstone is a major source aquifer for the Doongmabulla Springs Complex (DSC). This is supported by water level and groundwater flow information presented by the proponent, as well as by other studies (Evans et al., 2018; Fensham et al., 2016; JBT Consulting, 2015), and by some aspects of hydrogeochemistry of the springs and the Clematis Sandstone (Fensham et al., 2016; Webb et al., 2015). It is not plausible and reasonable to state unequivocally that the Clematis Sandstone is *the* sole source aquifer for the DSC, as sufficient uncertainty surrounding hydrogeochemistry, inter-aquifer connectivity and groundwater flow (Currell et al., 2017; Lewis et al., 2018; Webb et al., 2015) exists to necessitate a precautionary approach to the conceptualisation, as ruled by Land Court of Queensland (2015). Evidence provided in the GABSRP supports the conceptualisation that the Clematis Sandstone is a source aquifer, but there is enough uncertainty around the information provided, as acknowledged by the Proponent, to necessitate a robust assessment of potential alternative or additional source aquifers. In addition, and as summarised below, the body of existing evidence available in the public domain shows that there is ambiguity in the source aquifers of the Doongmabulla Springs Complex (Currell et al., 2017; Evans et al., 2018; Fensham et al., 2016; Land Court of Queensland, 2015; Lewis et al., 2018; Webb et al., 2015; Webb, 2015). Addressing the spring source aquifer question relies mostly on the work proposed under the GABSRP, with locally specific application of the RFCRP also important.

3. How adequately do the methods and techniques put forward in the research plans address uncertainties?

The GABSRP aims to investigate and evaluate the source of water feeding the DSC. The RFCRP aims to evaluate the presence, extent, and influence of various structural and stratigraphic characteristics of Rewan Formation and how these may influence the behaviour of that unit with respect to allowing interconnection between overlying and underlying units. The GABSRP and RFCRP present programs of work that extend over 12 month periods. Some of the data collection has already been undertaken, while some of the work will include collection of new data. The methods and techniques proposed in the GABSRP and the RFCRP include:

9. Geological mapping
10. Geophysical processing and interpretation
11. Reprocessing and reinterpreting historical seismic reflection data
12. Possibly using other existing geophysical data (e.g. regional magnetic data) to inform seismic interpretation

13. Geological data analysis
14. Lithofacies analysis including petrophysical analysis
15. Fault modelling
16. Juxtaposition analysis
17. Shale gouge and fault membrane seal analysis
18. Fault leakage analysis
19. Hydrogeological data analysis
20. Hydrogeological parameter testing and analysis
21. Groundwater level and pressure analysis
22. Hydrochemistry

The methods and techniques proposed will provide information and data to allow for evaluation of the potential for hydrological connectivity pathways to transect the Rewan Formation. The main pathways that the geological and geophysical techniques seek to evaluate are direct interconnection of the Upper Permian units and the Clematis Sandstone via fault offsets. Another model by which the Rewan Formation can provide preferential flow pathways is via physically connected zones of higher permeability materials, such as connected sandstone bodies, small offset faults and fractures, or combinations of these. The methods and techniques proposed in the RFCRP will provide additional data and reduce uncertainty in the understanding and conceptualisation of the hydraulic behaviour of this unit. For the GABSRP, some aspects of the general approach, such as water level mapping, geological mapping and hydrogeochemical analysis are sound, however not enough detail on some methods is provided to adequately assess how these will address uncertainty in the springs conceptualisation. There are areas of both plans that will not provide the necessary information to inform GMMP or Groundwater Dependent Ecosystems Management Plan in a timely manner.

In general, the groundwater monitoring network shown in documents supplied is not well suited to monitor potential mining-related effects to the springs or to determine Rewan Formation connectivity. In order to adequately monitor changes that may result from mining, the Clematis Sandstone requires installation of several additional monitoring bores, in particular south of the Carmichael River along the strike of the tenement and to the west of the springs. Land Court of Queensland (2015) specified that monitoring must be undertaken in all units across and adjacent to the mine site to confirm groundwater flow patterns and monitor drawdown. The bore distribution shown in the GMMP does not meet this requirement, most notably to the west of the mine site. Given that groundwater is interpreted to flow from the west (Appendix C, GMMP; Evans et al., 2018), it is important that monitoring bores be located in all units to the west of the mine. Locating monitoring bores to the west will also allow for data collection pertinent to springs source aquifer identification and characterising the ability of the Rewan Formation to prevent impact propagation to springs.

There is limited groundwater monitoring of the hydrostratigraphic units below the Clematis Sandstone (Dunda Beds, Rewan Formation and Permian units) outside of the tenement. These are the units that are modelled to be most affected by mine dewatering which could pose a potential risk to the springs, in the event that these aquifers contribute discharge or are hydraulically connected to the springs (Land Court of Queensland, 2015).

Ideally, the Clematis Sandstone monitoring sites would include nested monitoring wells for other underlying and overlying units. These sites would provide water level and pressure data and stratigraphic and parameter information to help to calibrate the numerical groundwater model and could also be used as early warning sites for the springs, particularly where groundwater pressure reductions at the monitoring bores exceed modelled drawdown predictions.

Additional monitoring bores below the base of Clematis Sandstone would also help to answer the question about the source(s) of the DSC by providing additional hydrochemistry and water level data to compare with springs values. Additional drilling in the Rewan Formation and underlying Permian units could enable collection and analysis of further information on hydraulic conductivity.

a. Spring source

The GABSRP identifies the source aquifer of the DSC (hypothesis 1) as a key uncertainty associated with preventing predicted ecological impacts to the springs from the Project. The Proponent has assessed the potential risks arising from this uncertainty in the following way:

1. The Clematis Sandstone is the source aquifer for the Doongmabulla Springs Complex – **Medium risk** to the DSC if the source aquifer is below the Rewan Formation under the alternate scenario, which would lead to an increase in impact to the springs (high consequence), but is considered by the Proponent to be unlikely (low likelihood).

The information provided and available in the public domain indicates that it is both plausible and reasonable that units other than the Clematis Sandstone, including below the Rewan Formation may be a source aquifer for the DSC. If these other units are providing flow to the DSC, then this would lead to an increase in impacts to the springs (high consequence) and is considered plausible (medium likelihood) – **High risk**.

The Proponent's conceptualisation of the DSC is that all of the springs from the Moses, Joshua and Little Moses groups are likely to be fed by groundwater sourced solely from the Clematis Sandstone aquifer which, in the case of most of the springs, discharges through the overlying Moolayember Formation and/or Quaternary alluvium. Under this model, the springs associated with outcropping sandstone are conceptualised as gravity-fed outcrop springs. These outcrop springs are located on the Dunda Beds and the Clematis Sandstone to the east of the spring groups covered by the GABSRP. The springs the Proponent includes in the DSC are predominantly interpreted as discharge springs. For the discharge springs to remain active, sufficient artesian head (i.e. pressure) in source aquifers such as the Clematis Sandstone is necessary to provide upward flow through the overlying Moolayember Formation or alluvium, which has been eroded where Carmichael Creek and Bimbah Creek converge (Fensham et al., 2016; Lewis et al., 2018).

An alternative spring source conceptualisation is also plausible based on available evidence. Webb (2015) proposed that the springs are sourced in part from the Colinlea Sandstone, via preferential upward leakage through the Rewan Formation and Dunda Beds. The Colinlea Sandstone is one of the units that will be actively dewatered during mining operations at Carmichael.

The main objective of the GABSRP is to confirm the hypothesis that the DSC is sourced from the Clematis Sandstone. However, previous investigations have concluded that there is ambiguity in the source aquifers based on currently available data. These studies agree that for the springs west of Little Moses (i.e. the discharge springs) the Clematis Sandstone is the likely primary source aquifer, based on the geology and groundwater potentiometry at these springs. However, it is unclear if the Clematis Sandstone is the sole source aquifer for these springs (Currell et al., 2017; Fensham et al., 2016; JBT Consulting, 2015; Lewis et al., 2018; Webb, 2015). For the outcrop springs (including Little Moses), based on descriptions in Fensham et al. (2016) it is more likely that the springs are water table fed, and that local geological units are the source aquifer (the outcropping Clematis Sandstone and Dunda Beds). Despite relying in part on descriptions of the DSC provided by Fensham et al. (2016), the Proponent does not include all of the spring vents mapped in that study within their definition of the DSC. This results in a disparity whereby the GABSRP seeks to assess approximately 80 vents, whereas Fensham et al. (2016) mapped 187 vents forming 160 separate wetlands. The reason for this discrepancy may be due to the updated state of knowledge between the approval of the mine and the work of Fensham et al. (2016). The GABSRP does not propose to investigate outcrop springs. In addition, the hydraulic interplay between the underlying hydrogeological units and the alluvium on the springs needs to be considered. To determine potential impacts on the springs and address requirements for mitigation measures, and given that there are a variety of spring types in the DSC, conceptual models for each spring type need to be developed and tested, and a detailed water balance will also need to be prepared.

An integrated analysis of existing and newly acquired geological, hydrodynamic and hydrochemical data would improve the conceptual understanding of the groundwater sources of the DSC.

Regarding geological interpretations, the Proponent states:

"Based on geological mapping, the source aquifer for the DSC is thought to be the Clematis Sandstone and/or the underlying Dunda Beds….Detailed mapping of faults around the area of the springs has not been undertaken." (GABSRP pg 40)

Regarding hydrodynamic analysis, the Proponent states:

"Although the available data supports the concept of the Clematis Sandstone being the spring source aquifer, there is a lack of groundwater head data in other potential source aquifers beneath the springs, such as the Dunda Beds or even deeper Permian strata, from which to rule other sources out. On the basis of the available head data therefore, it is not possible to categorically rule out other aquifers besides the Clematis Sandstone as potentially contributing to spring discharge at the DSC." (GABSRP pg 41)

Regarding hydrochemical analysis, the Proponent states:

"The studies associated with the EIS and SEIS did not directly compare the groundwater chemistry of the DSC with that of the Clematis Sandstone or other potential source aquifers. As such, based on the current hydrochemistry data, it is not possible to categorically rule out other aquifers besides the Clematis Sandstone as potentially contributing to spring discharge at the DSC." (GABSRP, pg 41)

Based on these three statements and until such time as more data is provided in the research and management plans, the conceptualisation whereby the Clematis Sandstone is recognised as the sole source aquifer is not the only reasonable and plausible conclusion.

To that end, the assessment of the draft plans with respect to addressing uncertainty in the source aquifer of the DSC relies on the commitments within the plan to undertake appropriate geological (including structural geology), hydrodynamic and hydrochemical studies.

The GABSRP sets out a timeline and identifies expertise required to undertake the plan, as well as general subjects to be addressed. However, the GABSRP methods lack the required level of specific detail required to adequately assess how they will address the aims of the plan.

Geological and geophysical mapping

The geological mapping approach described in the GABSRP will provide additional information about the regional geology and hydrogeology. The inclusion of geophysical techniques to map distribution and thickness of the main geological units below surface is warranted, and may create linkages with the RFCRP, and better inform the GMMP. Geophysical data including seismic reflection (original and reprocessed), and airborne magnetics, reveal potential geological complexity at depth which will inform the updated geological knowledge.

More information is required on the extent and scale of mapping, the methods proposed, and the availability of the Proponent’s geological models and mapping to inform this work in order to assess how well-suited the approach is to addressing the goals of the research plans. A specific linkage between this work, the GMMP and the RFCRP would provide more assurance that research plans and management plans are based on the same information and conceptualisations. It is unclear what is planned in the “soils survey” mentioned, as there are a variety of types of soil survey. The particular methods and standards, and how they will address knowledge gaps is not provided in the GABSRP, and is an important oversight. In addition, other landscape surveys including high-resolution elevation models and geomorphology, would allow for a better integration between the geology, hydrogeology and springs typology. The plan would benefit by including discussion on the different geological mapping available to demonstrate how the proposed work would address knowledge gaps and discrepancies, such as the disparity between available local (1:100 000 and finer scale), regional (1:250 000), and state wide (1:500 000 and coarser) geological mapping.

Groundwater pressure

The use of groundwater pressures and head to map flow directions is well supported and is a standard method in hydrogeology at all scales.

Any consideration of groundwater pressure in different aquifers, and associated flows, relies on spatially and temporally representative data. Where a multiple aquifer system is envisaged, as is the case for the DSC, this means that relevant hydrostratigraphic units require representative data. Based on the information supplied in the research plans, no data is being collected or analysed for any units below the Dunda Beds outside the Carmichael mining lease. In addition, no measured groundwater pressure data is available, or planned to be collected west of bore HD03 in units below the Clematis Sandstone. This means that the monitoring bore network is insufficient to resolve potentiometric surfaces in these units up-gradient of the lease, or the DSC. This lack of spatially representative groundwater head data limits scope to reduce the uncertainty of the springs source aquifer or the Rewan Formation connectivity outside of the mining lease. Nested or adjacent bores installed to measure pressure in multiple hydrostratigraphic units are required to adequately assess groundwater pressure as it relates to springs, and also to address data gaps identified in the broader hydrogeological conceptualisation. Based on the information provided, the proposed monitoring network will not be able to provide the required data to improve the evaluation of alternative source aquifer conceptualisations (Currell et al., 2017; Land Court of Queensland, 2015).

A high resolution ground surface elevation model is required to properly assess groundwater pressures in relation to groundwater interaction with the land surface and contributions to and from surface water bodies. Similarly, accurate stream gauging data is required. This also extends to a need for representative spring flow measurements. There is no mention in the draft plans of the elevation model or surveying methods to be used, or whether stream gauging or spring flow measurements will be taken. Bioregional Assessment work (Lewis et al., 2018) has shown the value and utility of using time-series remote sensing data to identify stream reaches that form important components of the springs conceptualisation.

Hydrochemistry

If undertaken appropriately, hydrochemistry investigations can provide strong supporting evidence of spring source formations. It is '*plausible and reasonable*' that the Clematis Sandstone forms the source aquifer for discharge springs in the DSC, but no hydrochemical evidence is presented in the GABSRP to support this conclusion. The GABSRP confirms that it is not currently possible to rule out contributions to DSC flow from other formations. Similarly, hydrochemistry investigations could provide strong supporting evidence of connectivity through the Rewan Formation.

The hydrochemistry investigations described in the Chemical Analysis subsection of Section 5.1.2 of the GABSRP require revision. For example, there are few cited references to existing analytical techniques. There is insufficient information on the analytical suite and research methodology, and the proposed isotope suite may be insufficient to identify spring source formations. Details of sampling and analysis methods (including Quality Assurance and Quality Control components) are also lacking. The GABSRP and RFCRP (and relevant parts of the GMMP) provide limited detail on the methodology of proposed environmental tracer sampling. The RFCRP lists $\delta^{18}O$, $\delta^{2}H$, ^{3}H and ^{14}C as potential tracers to assess connectivity, evaporation, source, recharge conditions, groundwater mixing and mean residence time. These tracers alone do not cover the range of groundwater residence time scales expected in the groundwater systems under investigation, considering that an older formation (the Clematis Sandstone) is currently proposed as the source aquifer of the springs. Processes operating over timeframes beyond those measured by ^{14}C should be considered to aid in determining spring source aquifers and characterising groundwater flow in the Rewan Formation. This needs to consider timescales in the order of 10^5 to 10^6 years. Noble gas tracers which are not influenced by geochemical or water-rock interactions would also aid these assessments by providing valuable information on groundwater flow in and through the Rewan Formation.

The proposed radioactive isotopes are useful in detecting and assessing the processes affecting younger groundwater in a mixed system. However, the draft plans do not consider analysing and assessing older components of groundwater by other radiogenic tracers, such as helium. In a setting such as the DSC, where alternative hypotheses may include groundwater contribution from deeper formations flowing through shallower hydrostratigraphic units via faults and discharging at springs, there is a need to assess the potential mixing of older and younger groundwater. Methane has also been used to successfully identify interaquifer mixing across the Rewan Formation in the Eromanga-Galilee Basin system further to the west (Moya et al., 2016), and is not discussed in the draft plans.

The proposed monitoring bores in the area of the DSC do not include several potential spring source formations. As shown in the GMMP, formation water chemistry can vary spatially. The research plan may therefore not provide data suitable for assessing the source aquifers for the DSC without including monitoring wells in all relevant formations near the spring vent locations.

Although the GABSRP acknowledges that various dissolved species are reactive, there is no commitment to undertake reactive transport modelling or testing of solid formation materials to inform such modelling. While this may not prove necessary, it could be usefully considered. The GABSRP briefly outlines a desktop phase of study that will precede field investigations. It would be useful if this phase was included in the proposed GABSRP to refine the hydrochemistry study components (including the analytical suite, field locations and investigation methods). This would enable review of the hydrochemistry components of the research plan prior to their implementation, as well as identification of key knowledge and data gaps.

Appropriate geochemical characterisation for each potential contributor to spring flow is necessary to identify spring source aquifers. This includes aquifer materials, surface water and groundwater. This type of assessment should consider a broad suite of parameters including but not limited to anions, cations, trace metals, and isotopes with analytical detection limits at trace levels, including parameters that are commonly associated with coal. This analysis and assessment should involve chemical and isotopic measurements of aquifer formations and springs, as well as alluvium and surface water. This is because most of the springs are located within the footprint of the alluvium and near to Carmichael River and Bimbah Creek. The distribution of mapped spring vents within the DSC could indicate the influence of near-surface geological structures (Fensham et al., 2016). This highlights the importance of considering synoptic baseline surveys of the streams for parameters including, but not limited to, major ions, trace elements, ^{222}Rn, He and CH_4 to determine if there is any influence of geological structures in the vicinity of the springs. Geological influence on streams may be identified by anomalies in the distribution of the proposed variables along the stream course, as observed in the Avon River (e.g. Mallants et al., 2018).

Limited groundwater isotopic data are available to support the conceptual model presented in the GABSRP and the GMMP. Any assessment seeking to understand and conceptualise the springs and their aquifer connectivity needs to encompass a wide range of variables to identify which tracers may be useful for long-term monitoring.

Isotope data from the Galilee and Eromanga basins, including $^{87}Sr/^{86}Sr$ data from the hydrostratigraphic units relevant to the Carmichael Coal Project are publically available (Moya et al., 2016). However, these data are not discussed in the documents provided by the Proponent.

b. Rewan Formation

The GABSRP identifies that thickness and hydraulic properties of the Rewan Formation (hypothesis 2) as a key uncertainty associated with preventing predicted ecological impacts to the springs from the Project. The Proponent has assessed the risk to springs due to this uncertainty as:

2. The thickness and hydraulic properties of the Rewan Formation will prevent significant groundwater pressure reduction from mine site dewatering propagating to the Clematis Sandstone at the DSC – **Medium risk** to the DSC if the Rewan vertical hydraulic conductivity is significantly higher than modelled under the alternate scenario, which would lead to an increase in impact to the springs (high consequence), but is considered by the Proponent to be unlikely (low likelihood).

As described below, it is considered plausible that the thickness of the Rewan Formation is more variable and the hydraulic conductivities are higher than modelled, which means that the alternate scenario would lead to an increase in impacts to the springs (high consequence) and is considered plausible (medium likelihood) – **High risk**.

The characterisation of the Rewan Formation as an aquitard relies mainly on the work proposed under the RFCRP. In addition, work undertaken to inform revisions of the GMMP, including pump testing in 2015 and drilling, downhole geophysical logging, and groundwater level and chemistry monitoring in 2016 are not included in the RFCRP. The structure of the RFCRP is poorly organised and appears focused towards a single conceptualisation of the Rewan Formation as a thick, homogenous aquitard rather than considering a range of conceptualisations. Figure 6 of the RFCRP, presented much later in the plan, provides a well-considered representation of the various potential preferential flow pathways through the Rewan Formation. Information provided by the Proponent shows that the intercepted thickness of the Rewan Formation in drilling varies from 263 m to 337 m, although it is unclear whether the Dunda Beds are considered as part of this unit or not in various documents. At one field location, the Rewan Formation is shown to be 234 m and 306 m thick in two co-located bores (C14206VWP and C14204VWP respectively). This suggests that the Rewan Formation may show significant variations in thickness at a local scale.

Hydraulic conductivity values used to model pressure reductions in the Clematis Sandstone at the DSC (hypothesis 3) is another key uncertainty identified in the GABSRP associated with preventing predicted ecological impacts to the springs from the Project:

3. Pressure reductions in the Clematis Sandstone at the DSC will be small – **Medium risk** to the DSC if the pressure reduction at the DSC is greater than model predictions under the alternate scenario, which would lead to an increase in impact to the springs (high consequence), but is considered by the Proponent to be unlikely (low likelihood).

This review indicates that it is considered plausible (medium likelihood) that the low vertical hydraulic conductivity values used to model the Rewan Formation and high hydraulic conductivity values used to model the Clematis Sandstone would lead to an increase in impacts to the springs (high consequence) under the alternate scenario – **High risk**. The proposed uncertainty and sensitivity analysis would improve confidence in the groundwater model parameters.

Previous reviews of the Proponent's numerical groundwater modelling have raised concerns about the appropriateness of the hydraulic parameters assigned to the Rewan Formation, as they are lower by up to 5 orders of magnitude than field measurements from the Carmichael Coal project area, and adjacent projects (Currell et al., 2017; Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, 2013; Webb et al., 2015). In addition, the hydraulic conductivity of the Clematis Sandstone as applied in the groundwater model is potentially too high, based on information provided in the GMMP. The calibrated hydraulic conductivity is 1.55 m/d. The available measured hydraulic conductivities from field tests at two bores where the Clematis Sandstone is confined is 0.01 m/d, and from one field test where the Clematis Sandstone is unconfined is 15 m/d (Table 6, GMMP). The conceptualisation presented in the GABSRP and GMMP for the DSC is that the Clematis Sandstone source aquifer is confined by the Moolayember Formation. Using a higher conductivity in the model than shown by the limited field data allows the lateral transfer of water and minimises the drawdown. The sensitivity analysis of the groundwater modelling by the proponent shows that the high hydraulic conductivity of the Clematis Sandstone limits drawdown at the DSC. This analysis also shows that drawdown is equally sensitive to the conductivity of the Clematis Sandstone as it is to the Rewan Formation. It is unclear how any data or information obtained through the GABSRP or RFCRP will be incorporated into model reviews or updates, despite both plans being linked to the GMMP and GDEMP.

Analysis, interpretation and collation of all existing geological data proposed in the RFCRP are appropriate for this type of study. A good approach to geological analysis includes detailed facies analysis, and explicit commitments to incorporate exploration geological modelling and mapping. The outcome of these work packages is unclear, however a three dimensional geological model, including geological structures and lithofacies variation would provide extremely valuable information to underpin any hydrogeological conceptualisation, including the characteristics of the Rewan Formation. How any detailed site-based geological modelling is extrapolated off site, or incorporated in regional exploration models is not discussed in the RFCRP. The detailed assessment of the material properties and hydraulic behaviour of faults at a localised scale is an appropriate approach, but needs to be further refined to incorporate these findings with the rest of the RFCRP and the GMMP as a whole. Future updates to numerical modelling will include relevant parameters such as updated recharge estimate and hydraulic conductivity values, acquired where not currently available. The specific application of fault seal and shale gouge analysis requires clarification, with reference to relevant applications. Any characterisation of potential connectivity pathways through the Rewan Formation should consider other pathways, such as increased fracturing localised around fold hinges, in addition to pathways via faults. Structural and geological analysis of the kind presented in the draft RFCRP is predicated on the availability of appropriately detailed geological mapping and modelling over the area of interest. It is unclear how the required geological data to do the type of analysis planned is going to be acquired to the west of the mine lease area.

Reprocessing historical seismic reflection data, as proposed, has been previously been undertaken by different parties (Comet Ridge Limited, 2015; QER Pty Ltd, 2013). Both reprocessing efforts reported good outcomes for the target depths, below the Rewan Formation. Reprocessing and reinterpretation was successful for these deeper units, with poor resolution of units above the Permian coal seams. Faulting within the Rewan Formation, and across the Betts Creek Beds was identified on lines 82-23, 25 and 27 (Velseis Processing Pty Ltd, 2010). These lines are proposed to be reprocessed. Velseis Processing Pty Ltd is the nominated geophysical reprocessing company in the RFCRP. Given the difficulties in resolving the early time portion (which equates to the shallower depths) of the historical seismic data, it is unclear how further reprocessing will add value. The orientation of historical seismic lines proposed for reprocessing are optimally oriented to test certain structural geometries, at the expense of testing others. This may bias the structural interpretation due to the potential orientation of some features. The Proponent makes reference to “high quality 2D seismic” data available from within their lease. These data are vital to assessing the facies and structural aspects of the Rewan Formation. Interpretation is limited by the resolution of seismic data used, and it is not apparent what the resolution of the seismic data to be reprocessed will limit this analysis to. Fensham et al. (2016) specifically recommended high resolution seismic reflection surveying adjacent to the Doongmabulla Springs as “…an appropriate technique to reveal structural weakness within the Rewan Formation down to depths of about 500 m”. Figure 3 of Currell et al. (2017) presented part of an interpreted seismic line acquired by the Proponent in 2011, but this is not included in the RFCRP. This line is northeast of the DSC, and on the Carmichael mining lease. It shows a possible fault structure extending from the Colinlea Sandstone upwards through the Rewan Formation into the overlying units. This structure suggests that potential pathways for aquifer connectivity of these hydrogeologic units across the Rewan Formation do exist. Additional seismic data acquisition may be warranted, given the data quality issues that may affect reprocessing historical data outlined above.

There is considerable overlap between the proposed GABSRP and RFCRP approaches to hydrochemical data analysis. More cross-referencing between the two research plans is required. As for the GABSRP, the RFCRP does not include adequate referencing of published material relating to proposed methods. The RFCRP does not stipulate a full analytical suite or fully outline how data will be analysed. Sampling and analysis is not proposed for all formations that may interact with the Rewan Formation. It is unclear why certain formations are not included in the analysis when they may provide useful information on groundwater flows across the Rewan Formation, such as the underlying Permian units in the vicinity of the DSC and off-lease, or the alluvium. The distribution of monitoring bores is particularly important since the GMMP shows that groundwater chemistry can vary spatially within the same hydrostratigraphic unit. The proposed monitoring locations may not supply the required information on connectivity because different formations are monitored in different plan locations. In this instance, assumptions may need to be made on groundwater evolution along flow lines which increases uncertainty. Drilling proposed to test hydraulic connectivity across geological structures needs to be appropriately oriented. If vertical drilling is used, geological structures may not be intersected, or the intersections may not allow adequate testing. Inclined drilling allows structures to be intersected, and hydraulic testing to be undertaken in a more controlled fashion. The draft plans do not specify if any drilling will be non-vertical. Details of sampling and analysis methods (including quality assurance, quality control and field parameter measurements) are lacking.

Whereas the GABSRP includes some discussion of work undertaken since initial drafting (e.g. Fensham et al., 2016), the RFCRP does not. Additional drilling planned for 2014-2015 is mentioned, however not discussed in detail. This work forms the basis of the URS (2016) report, and should be included in the summary of existing work.

4. Ecological impact prevention, mitigation and remediation

The GABSRP identifies three key uncertainties (4a, 4b, 4c) associated with preventing predicted ecological impacts to the springs from the Project. For uncertainty related to water pressure variability in the Clematis Sandstone, the Proponent concludes:

> 4a Natural groundwater pressure fluctuations in the Clematis Sst are greater than the predicted pressure reduction resulting from the Project – Very Low risk to the DSC associated with the natural groundwater pressure fluctuations in the Clematis Sst at the DSC being smaller than the predicted groundwater pressure reduction from the Project, which would lead to a reduction in impact to the springs (low consequence), but is considered by the Proponent to be unlikely (low likelihood).

While this assumption is reasonable in the case of groundwater-dependent terrestrial vegetation that can adapt their rooting depth to accommodate fluctuations in groundwater levels, it is not a reasonable assumption for springs, where the cumulative impacts of natural fluctuations in addition to predicted drawdown may mean that groundwater levels fall below spring vent elevations, leading to springs that stop flowing for extended periods. Therefore, this alternate scenario <u>could</u> lead to an increase in impacts to the springs (medium consequence) that is considered plausible (medium likelihood) – **Medium risk**.

Inconsistent groundwater levels, fluctuations and broken links in this section of the report make it difficult to assess the veracity of the analysis. Of note, maximum groundwater levels in bore C14012SP assigned to the Clematis Sandstone and located nearest to the Joshua Springs is reported as 249.5 mAHD in the text on page 40 and 242.73 mAHD in Table 4.1 of the GABSRP. In comparison, the ground elevation at Joshua Springs is approximately 246 mAHD (page 40). Maximum natural fluctuations reported in Table 4.1 – Groundwater level monitoring summary of the GMMP are 0.5 m, not 1.01 m as cited on page 43. The magnitude of natural fluctuation that can be tolerated is unclear.

The Proponent assesses the level of risk to the DSC from reduced flow (hypothesis 4b) as:

> 4b. Small predicted impacts to source aquifer pressure will result in small fluctuations in the spring wetland water balance – **Low risk** to the DSC associated with the small predicted reductions in aquifer pressure at the DSC resulting in a higher than anticipated effect on the wetland water balance, which <u>could</u> lead to an increase in impact to the springs (medium consequence), but is considered by the Proponent to be unlikely (low likelihood)

Again, the cumulative impacts of natural fluctuations in addition to predicted drawdown may mean that groundwater levels fall below spring vent elevations, leading to springs that stop flowing for extended periods. Therefore, this alternate scenario <u>could</u> lead to an increase in impacts to the springs (medium consequence) and is considered plausible (medium likelihood) – **Medium risk**.

The proposed wetland water balance approach does not consider the special circumstances associated with springs, where the difference between vent elevation and groundwater pressures drives flow into the springs. No details are provided for how to measure these indicators in the field or how field measurements will reduce uncertainty associated with the predicted impacts. A number of copy and paste errors occur in Table 5.1 of the GABSRP. The critical question of spring vent elevation relative to minimum predicted groundwater levels is not addressed. Further, the proposed actions do not look to test or improve the conceptualisation or magnitude of modelled groundwater discharge described on p 48 of the GABSRP.

With regard to the ability of the ecosystem being able to adapt to changed flow conditions in the event of any impact to the wetland water balance for the DSC (hypothesis 4c), the Proponent assessed that:

4c. The Ecological community of the DSC are already adapted to the small fluctuations in the wetland water balance – **Medium risk** to the DSC associated with the ecological community not being able to tolerate small fluctuations in the spring wetland water balance, which would lead to an increase in impact to the springs (high consequence), but is considered by the Proponent to be unlikely (low likelihood)

An alternative assessment based on other information (discussed below) is that the ecological community is unable to tolerate small fluctuations in wetland water balance, which would lead to an increased impact at the springs (high consequence), however ecological resilience research indicates that the alternate scenario is unlikely to occur (low likelihood) – **Medium risk.**

The proposed Baseline springs survey program draws on recent research from Queensland Office of Groundwater Impact Assessment and the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development and is considered adequate. The Species specific study does not explain how the leaf water potential and stable isotope of water measurements will characterise the environmental water requirements and the resilience of the two EPBC Act listed threatened species found within the DSC (*Eriocaulon carsonii* and *Eryngium fontanum*) with respect to changes in the wetland water balance. Further, it is unclear why the Waxy Cabbage Palm (*Livistona lanuginose*) that is known to occur at the Little Moses and Joshua Spring Group wetlands (p 33) is not considered in this section.

The GABSRP considers a number of potential measures to mitigate ecological impacts to the springs, including direct recharge – both surface and sub-surface techniques, and indirect techniques developed for the Surat Basin coal seam gas (CSG) operations. This summary is general in nature and favours offsetting potential impacts to groundwater levels by reducing up gradient groundwater use in the Clematis Sandstone, but does not attempt to quantify its effects. No references to the GDEMP or GMMP are provided to support the general qualitative assumptions supporting potential mitigation measures.

The methods and techniques to address uncertainties about the source of the springs and the capacity of the Rewan Formation to prevent impacts to the springs (described above) will strengthen the conceptual understanding, monitoring bore network, hydrochemical and environmental tracer analyses necessary to adequately assess potential mitigation measures. Measures to mitigate or remediate ecological impacts to the springs are not discussed in the RFCRP.

5. Concluding remarks

The GABSRP relies on a risk assessment approach to address uncertainties associated with the springs. A similar approach is not undertaken in the RFCRP; however given the links between the research plans and management plans, it is instructive to address the questions DoEE posed in the context of the GABSRP risk framework.

In their current form, the GABSRP and RFCRP present approaches that will not comprehensively address the uncertainty surrounding the source aquifers of the springs, or the characterisation of the Rewan Formation as an aquitard or leaky aquitard. In order to more fully address these uncertainties, the plans require more comprehensive discussion of the methods proposed, with better reference to other work seeking to address similar questions.

The plans are set out in order to support the assertion that the Clematis Sandstone is the sole source aquifer for the Doongmabulla Springs Complex. The information provided in both plans, as well as in the public domain is clear that uncertainty still exists in this regard. While the Clematis Sandstone may a principal source aquifer for the springs, based on the information currently available, it is not reasonable to assert that it is the sole source aquifer.

The methods and techniques outlined in the draft plans will provide some information to reduce uncertainty in the source of water feeding the DSC. The methods proposed in the RFCRP will provide some information to evaluate the presence, extent, and influence of various structural and stratigraphic characteristics of the Rewan Formation and how these may influence the behaviour of that unit with respect to allowing interconnection between overlying and underlying units

There may not be enough information available from existing bores to evaluate the potential connectivity across the Rewan Formation, in particular at and adjacent to the springs to the west of the mine lease. Nested bores are required in order to provide the best information on potential inter-aquifer connectivity, as well as to provide additional data to inform refinement of springs and hydrogeological conceptualisation in areas where this information is sparse.

Further information on the specific methods and techniques to be applied to chemically assess the springs source and groundwater flow processes is required for a more detailed assessment to be made. This includes the need to define the analytical suite, quality assurance and quality control methods, and use of a broader range of isotopic and environmental tracers as outlined above. Incorporation of these amendments would provide necessary descriptions of proposed approaches, as well as the data necessary to address the aim of identifying spring source aquifers.

The approach to ecological impact mitigation based on a risk assessment is heavily reliant on the conceptualisation of springs and Rewan Formation connectivity. Therefore, changes to the conceptualisation based on the outcomes of the research plans may necessitate a change in the risk assessment. Any change in risk ratings would mean that the mitigation approaches would need to be revised.

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FOI 190417
Document 5

From: s22
To: s22
Cc: s22
Subject: Review to commence
Date: Thursday, 24 January 2019 1:02:19 PM

Hi s22,

Just confirming the Department requests GA and CSIRO commence review today of the GDEMP and GMMP submitted in the past couple of days.

We understand that the bore water level data QA has been completed and will proceed as such.

Given the time that has elapsed, it might be nice to have a re-inception meeting tomorrow (understand you are on a RDO) or early next week.

Let me know what time might suit or if you have any questions.

s22

Sent from my iPhone

On 23 Jan 2019, at 11:21 am, s22 @ga.gov.au> wrote:

> Hi s22
>
> I'll grab a copy and ensure the rest of the team is made aware.
>
> We'll eagerly await the whistle blow to start.
>
> Thanks
>
> s22
>
> ---
>
> **From:** s22 @environment.gov.au>
> **Sent:** Wednesday, 23 January 2019 11:04 AM
> **To:** s22 @ga.gov.au>; s22 @csiro.au>
> **Subject:** RE: EPBC 2010/5736: condition 5 - Updated Groundwater Dependent Ecosystem Management Plan (groundwater data) [SEC=UNCLASSIFIED]
> **Importance:** High
>
> Hi s22
>
> I have just uploaded Rev 5 of the GMMP to Govdex. I'm yet to receive confirmation from DNRME that all water level data has been verified, but understand that the GMMP has been updated with the revised water level data, as per the GDEMP earlier this week.
>
> When we receive confirmation, your review can formally start
>
> s22
> s22
> **T** 02 s22 @environment.gov.au
> **W** www.environment.gov.au
>
> ---
>
> **From:** s22
> **Sent:** Monday, 21 January 2019 3:54 PM
> **To:** s22 @ga.gov.au>
> **Subject:** Re: EPBC 2010/5736: condition 5 - Updated Groundwater Dependent

Ecosystem Management Plan (groundwater data) [SEC=UNCLASSIFIED]
It will be after 5 - is that ok?

Sent from my iPhone

On 21 Jan 2019, at 3:00 pm, s22 @ga.gov.au> wrote:

> Hi s22
> That would be helpful if you could stop in at Symonston and I can get eyes on it immediately.
> Thanks
>
> s22
>
> ---
>
> **From:** s22 @environment.gov.au]
> **Sent:** Monday, 21 January 2019 2:01 PM
> **To:** s22
> **Cc:** s22 ; Gregory Manning
> **Subject:** FW: EPBC 2010/5736: condition 5 - Updated Groundwater Dependent Ecosystem Management Plan (groundwater data) [SEC=UNCLASSIFIED]
> **Importance:** High
> Hi s22 and s22
> I have uploaded a revised GDEMP (v10a) onto Govdex, for your review. The word version with tracked changes is too big for the site – I am happy to drop a USB to Symonston this afternoon if it would help.
> I will let you know as soon as we get a revised GMMP including DNRME agreement to the revised water level data and Adani's 'materiality' test for model revisions.
> Please let me know there are any questions
> -s22
> s22
> **T** 02 s22 @environment.gov.au
> **W** www.environment.gov.au
>
> ---
>
> **From:** s47F @adani.com.au]
> **Sent:** Monday, 21 January 2019 11:26 AM
> **To:** Gregory Manning <Gregory.Manning@environment.gov.au>
> **Cc:** s22 @environment.gov.au>; s22 @environment.gov.au>; s22 @environment.gov.au>; s22 @environment.gov.au>; s22 @environment.gov.au>; Post Approval <PostApproval@environment.gov.au>; Hamish Manzi <Hamish.Manzi@adani.com.au>
> **Subject:** EPBC 2010/5736: condition 5 - Updated Groundwater Dependent Ecosystem Management Plan (groundwater data)
> **Importance:** High
> **COMMERCIAL IN CONFIDENCE**
> Good morning Greg
> The purpose of this email is to advise that I will shortly transmit a copy

of the *Groundwater Dependent Ecosystem Management Plan (Carmichael Coal Mine Project)* with updated groundwater level and quality data.

For your information, following figures and tables have been updated:

Figures

- Figure 4-2: Hydrogeological conceptual model – pre-mining
- Figure 4-3: Hydrogeological conceptual model – mining & post-mining
- Figure 6-9 a-d Predicted Alluvial aquifer impacts associated with the Carmichael River
- Figure 7-6 a to d: Predicted drawdown to Alluvium aquifer over the life of the project
- Figure 8-10 Hydrogeological conceptual model – pre-mining
- Figure 8-11 Hydrogeological conceptual model – post-mining
- Figure 8-15a-e Groundwater impact contour maps for the Clematis aquifer
- Figure 9-8a-f Predicted groundwater draw down associated with the Mellaluka springs-complex

Tables

- Table 6-7 Groundwater Monitoring locations (from the GMMP), column titled "Monitoring Bores (depth in m)", last two monitoring levels
- Table 8-1 Water level data; columns titled "Ground Surface Elevation (mAHD)" and "Water Level (mAHD)"
- Appendix B - Groundwater drawdown and quality triggers, and all groundwater quality tables, including new information at the start of each table.

I will also transmit a track changed version, highlighting the location of the changes.

Could the department please advise when the documents are successfully retrieved?

Regards

s47F

[redacted]

Manager, Approvals

Off +61 7 3223 4800 | Melinda.bergmann@adani.com.au | www.adaniaustralia.com
Level 25, 10 Eagle Street, Brisbane, QLD 4000 | GPO Box 2569, Brisbane, QLD, 4001

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FOI 190417
Document 6

From: s22
To: "james.johnson@ga.gov.au"; "jane.coram@csiro.au"
Cc: "Stuart Minchin"; "Blewett Richard"; "McDonald, Warwick (L&W, Black Mountain)"; Gregory Manning; s22 ; Dean Knudson
Subject: RE: Revised GMMP [SEC=OFFICIAL]
Date: Friday, 5 April 2019 1:03:46 PM
Attachments: Attachment%20A%20-%20GDEMP%20Final_Part1.pdf
image001.jpg

Hi everyone,

Part one of the GDEMP attached – parts 2 and 3 will follow

s22
s22
T 02 s22 @environment.gov.au
W www.environment.gov.au

From: s22
Sent: Friday, 5 April 2019 12:53 PM
To: 'james.johnson@ga.gov.au' ; 'jane.coram@csiro.au'
Cc: Stuart Minchin ; Blewett Richard ; 'McDonald, Warwick (L&W, Black Mountain)' ; Gregory Manning ;s22 ; Dean Knudson
Subject: Revised GMMP [SEC=OFFICIAL]

Hi James and Jane,

Please find the revised GMMP attached.

The GDEMP will follow

s22
s22
Acting Director | Post Approvals Strategies
Environment Standards Division
Department of the Environment and Energy
T 02 s22 @environment.gov.au

Reconciliation%20Email%20Footer

FOI 190417
Document 6a

Groundwater Dependent Ecosystem Management Plan

Carmichael Coal Mine Project

Prepared for
Adani Mining Pty Ltd

19 March 2019

DOCUMENT TRACKING

Item	Detail
Project Name	Groundwater Dependent Ecosystem Management Plan – Carmichael Mine Project
Project Number	10964
Status	Final
Version Number	11b
Last saved on	19 March 2019
Cover photos	Main picture: Waxy Cabbage Palm *Livistona lanuginosa*; Top right: GAB spring mound at Doongmabulla; Centre right: Carmichael River riparian vegetation; Bottom right: GAB spring wetland

This report should be cited as 'Eco Logical Australia 2019. *Groundwater Dependent Management Plan – Carmichael Coal Mine Project*. Prepared for Adani Mining Pty Ltd.'

ACKNOWLEDGEMENTS

This document has been prepared by Eco Logical Australia Pty Ltd with support from Jacobs.

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Abbreviations

Abbreviation	Description
Adani	Adani Mining Pty Ltd
AusRivAS	Australian River Assessment System
BioCondition	A vegetation condition assessment tool, which provides a measure of how well a terrestrial ecosystem is functioning for the maintenance of biodiversity values at a local or property scale.
Biosecurity Act	Queensland Biosecurity Act 2014
BOS	Biodiversity Offsets Strategy
CEMP	Construction Environmental Management Plan
CG	Coordinator General
CORVEG	Queensland Herbarium database of ground-truthed physical and vegetation features
DBH	Diameter at breast height (of a tree)
DES	Queensland Department of Environment and Science
DoEE	Commonwealth Department of the Environment and Energy
EA	Environmental Authority EPML01470513 – Carmichael Coal Mine
EIS	Environmental Impact Statement
ELA	Eco Logical Australia Pty Ltd
EPBC Act	*Environment* Protection *and Biodiversity Conservation Act 1999* (Commonwealth)
EPBC Approval	Approval granted by the Commonwealth under the EPBC Act (EPBC 2010/5736)
EPP (Water)	*Environmental Protection (Water) Policy 2009*
ER	Environmental Representative
EWR	Environmental Water Requirement
GAB	Great Artesian Basin
GABSRP	Great Artesian Basin Springs Research Program
GDE	Groundwater Dependent Ecosystem
GDEMP	Groundwater Dependent Ecosystem Management Plan
GMMP	Groundwater Management and Monitoring Plan
LEBSA	Lake Eyre Basin Springs Assessment project
MP	Management Plan
MNES	Matters of National Environmental Significance, as defined under the EPBC Act.
NC Act	Queensland *Nature Conservation Act 1992*
OEMP	Operations Environmental Management Plan
REMP	Receiving Environment Monitoring Program
RE	Regional Ecosystem
RFCRP	Rewan Formation Connectivity Research Plan
SDPWO Act	*State Development and Public Works Organisation Act 1971* (Queensland).
SEIS	Supplementary Environmental Impact Statement, prepared in response to comments on the draft EIS.
SMD	Slightly-moderately disturbed
TEC	Threatened Ecological Community as defined under the EPBC Act.

Abbreviation	Description
ToR	Terms of Reference
WoNS	Weed of National Significance under Commonwealth legislation
WQO	Water quality objective

1 Introduction

1.1 Background

Eco Logical Australia (ELA) and Jacobs Group (Australia) Pty Ltd (Jacobs) have been engaged by Adani Mining Pty Ltd (Adani) to develop a groundwater dependent ecosystem (GDE) management plan (GDEMP) for the construction and operation of the Carmichael Coal Mine and Rail Project in the Galilee Basin of central Queensland.

The Carmichael Coal Mine and Rail Project (the Project) has been assessed by the Commonwealth and Queensland governments through an Environmental Impact Statement (EIS) process. Conditional approval of the Project was granted by the Queensland Coordinator-General on 8 May 2014, and the Commonwealth Minister for the Environment gave approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the Project on 14 October 2015 (EPBC 2010/5736 – EPBC Act Approval). An Environmental Authority (EA) for the Project (EPML01470513 – Carmichael Coal Mine) was granted by the Queensland Government on 2 February 2016.

The development of a GDEMP is a requirement under the Coordinator-General's report and EA to protect groundwater dependent ecosystems and minimise impacts associated with the Project. This GDEMP also includes sub-plans specific to some Matters of National Environmental Significance (MNES) that are required under the EPBC Act Approval and EA.

1.2 Purpose of management plan

The purpose of this GDEMP is to minimise and manage the environmental impacts of the Project on listed groundwater dependent species and ecosystems, through the development of mitigation and monitoring measures for implementation prior to construction, during construction, during operations, during offsetting and post operations. This GDEMP is consistent with relevant guidelines and policies on the protection of MNES under the EPBC Act, including the National Recovery Plan for Great Artesian Basin discharge spring wetlands (Fensham et al. 2010).

As required by Conditions 6f) and 6g) of the EPBC Act Approval and Condition I13 of the EA, this GDEMP applies to the following:

- *Livistona lanuginosa* (Waxy Cabbage Palm)
- Carmichael River (Carmichael River and its riparian zone between the Doongmabulla springs and the Belyando River)
- The Mellaluka Springs-complex
- Community of native species dependent on discharge from the Great Artesian Basin (Doongmabulla Springs-complex) including *Eriocaulon carsonii* (Salt Pipewort); and *Eryngium fontanum* (Blue Devil).

Objectives of this GDEMP are as follows:

- Present the assessed and approved impacts and threats to groundwater and ecology for each of the Groundwater Dependent Ecosystems (GDEs)
- Detail the environmental values that have been monitored during baseline phases of the Project
- Identify goals and triggers for each GDE, which will be refined over time as further information becomes available during the pre-impact and impact Project phases

- Detail the monitoring program for both pre-impact and impact phases of the project, including how this monitoring will inform relevant mitigation, management and offset measures
- Describe mitigation and management measures with specific criteria, timing, performance objectives, goals and corrective measures
- Achieve compliance with relevant Commonwealth and Queensland approval conditions to report results and corrective actions for each GDE over the full period of mining activities and for a period of five years post mining rehabilitation.

1.3 Relationship with other management plans and programs

Adani is required to develop and implement a number of other management plans to address the full requirements of approval conditions under both Commonwealth and Queensland legislation (**Table 1-1**). There will be some interaction among the plans during all phases of the Project, as further described in **Sections 1.4 and 10.4** with respect to key linkages across research program outcomes, modelling updates and management plan review, updates and reporting.

Table 1-1 Description of other management plans and linkages with this GDEMP

Management Plan	Description	Link to legislation or approval	Link with GDEMP
Groundwater Management and Monitoring Plan (GMMP)	Identifies monitoring, management and mitigation with respect to approved impacts to groundwater resources	EPBC Approval Conditions 3-4 EA Approval Condition E4	Informs interpretation of ecological triggers, monitoring and management through adaptive processes.
Great Artesian Basin Springs Research Plan (GABSRP)	Investigates, identifies and evaluates methods to prevent, mitigate and remediate ecological impacts on the Doongmabulla Springs-complex	EPBC Approval Conditions 25-26	Informs ecological triggers, monitoring and management through adaptive processes (see Section 1.4 for more details)
Receiving Environment Monitoring Program (REMP)	Monitors, identifies and describes adverse impacts to surface water environmental values, quality and flows associated with authorised mining activities	EA Approval Condition F23	Mine approved discharges are to the Carmichael River, a GDE under this plan
Rewan Formation Connectivity Research Plan (RFCRP)	Characterises the Rewan Formation within the area impacted by the mine	EPBC Approval Conditions 27-28	Informs groundwater triggers, monitoring and management through adaptive processes such as the GMMP

Management Plan	Description	Link to legislation or approval	Link with GDEMP
Biodiversity Offset Strategy (BOS) GAB Offset Strategy Offset Area Management Plans (OAMPs)	Describes required offsets for unavoidable residual impacts to MNES Describes required offsets for indirect impact to Great Artesian Basin (GAB) aquifers Describes specific management actions for properties to be used as offsets under the BOS	EPBC Approval Conditions 8-13 EA Approval Condition I1	The BOS outlines offset requirements for MNES including relevant GDEs The GAB Offset Strategy addresses indirect impacts to GAB aquifers The OAMP includes management of GDE offset areas
MNES management plans (other than GDEs)	Specific management plans for MNES listed in the EPBC Approval	EPBC Approval Conditions 5-7	Ensure consistent monitoring, mitigation and management measures for common threats and impacts
Project Management Plans	Plans to be used for day to day management of generic project matters including: • Erosion and sediment control plan • Pest management plan • Water quality management plan • Dust management plan • Waste management plan • Fire management plan • Rehabilitation management plan	Not all are linked to specific conditions. However, plans assist in meeting the performance requirements of approval conditions. For example, the Rehabilitation management plan is part of Adani's commitment to rehabilitate all areas of MNES habitat to meet Condition 6d(iii) of the EPBC Act approval.	Specific measures from relevant project management plans have been incorporated into this GDEMP to ensure consistency across areas of commonality

This GDEMP has been developed to ensure consistency with the latest groundwater impact predictions as required under Condition 23 of EPBC Act Approval (groundwater flow model revisions, including revision to the GAB conceptualisation). A key document relating to this GDEMP is the GMMP, which provides a framework for the management of groundwater impacts, including defining groundwater trigger levels. The GMMP will facilitate the detection of any mining-related impacts to groundwater (i.e., impacts from establishment and operation of the mine). Triggers from the GMMP, which are related to groundwater dependent ecosystems have also been included in this GDEMP.

The GMMP will be reviewed by an appropriately qualified person within two years from the start of the project and thereon at least every 5 years, with a report provided to the administering authority on the outcome of the review. The report will include an assessment of the GMMP against the monitoring aims, a review of the adequacy of the monitoring locations, a review of monitoring frequency and groundwater quality triggers, and a review of the validity of the groundwater monitoring program results against the groundwater model predictions.

Outcomes of implementing this GDEMP will inform the GAB Springs Research Plan with the aim of supporting research and analysing the effectiveness of mitigation actions. Conversely, research outcomes will directly inform monitoring, management, mitigation and remediation measures presented in this GDEMP.

1.4 Links with research plans and guidelines for management

The GAB is one of the largest underground freshwater reservoirs in the world, and one of the few in the world that has not been over exploited. Water extracted from the GAB is the only reliable water source for communities, industries and landholders in arid and semi-arid parts underlain by the Basin. Strategic planning for the GAB enables management decisions to be responsive to needs and based on reliable information.

A strategic, whole-of-Basin plan for the GAB was released in 2000, with a life of 15 years. A revised draft plan has also been made available for public consultation. The GDEMP has been prepared to be consistent with the GAB Water Resource Plan, particularly in the key policy areas of monitoring the effectiveness of groundwater management, providing an accessible knowledge base and managing quantity (flow and water level), quality and pressure of Basin flows. Future revisions of the GDEMP will consider revisions of the GAB Water Resources Plan, prior to being updated.

There are numerous other guideline documents that have informed the preparation of this GDEMP. These include relevant recovery plans, research findings and monitoring methodology for springs, and national water quality guidelines. Key publications are as follows:

- National Recovery Plan for Great Artesian Basin discharge spring wetlands (Fensham et al. 2010)
    - Relevant recovery plan for the Doongmabulla Springs
    - Sections 3 and 4 of the Recovery Plan informed development of the GDEMP sub-plan for the Doongmabulla Springs, with a focus on threats, impacts and mitigation measures.
    - Concepts were also applied to the Mellaluka Springs sub-plan (while not a GAB spring).
- Lake Eyre Basin Springs Assessment (LEBSA) project
    - The aim of LEBSA is to support the Australian Government's Bioregional Assessment Program in its analysis of the impacts of coal seam gas and large coal mining development on water resources
    - This is a critical data acquisition project that will supply up to date scientific baseline data to be used as part of the bioregional assessment for the Lake Eyre Basin
    - The Galilee Basin is an area of focus for the assessment, with several assessment products released for the Galilee subregion (Commonwealth of Australia 2018)
    - The GDEMP will supply up to date scientific baseline data on spring vents and other groundwater dependent ecosystems and their function within the Lake Eyre Basin
- *Environmental Protection (Water) Policy 2009*; EPP (Water) is subordinate legislation that supports the *Environmental Protection Act 1994* (EP Act).
    - The EPP (Water) provides a framework for the development of environmental values (EVs) and water quality objectives (WQOs) for all Queensland waters, although there are no specific EVs and WQOs for the Burdekin Basin
    - It is a requirement that local WQOs are developed for the sub-catchment

    - Informed development of the Receiving Environment Monitoring Program (REMP) for the project
- Wetland Monitoring Methodology for Springs in the Great Artesian Basin (Fensham & Fairfax, 2009)
    - Queensland Herbarium publication on the design and trial of a procedure to monitor the flow of water from springs in the Great Artesian Basin
    - Sections 2 and 5 of the publication informed the selection of monitoring variables and methodology for the Doongmabulla Springs.
    - Concepts were also applied to the Mellaluka Springs sub-plan (while not a GAB spring)
- Springs in the Surat Cumulative Management Area: A summary report on spring research and knowledge (DNRM 2016a)
    - Summarises knowledge and monitoring approaches to springs in the Surat Basin, subject to coal seam gas development
    - Section 3 of the document informed the design of this GDEMP, with specific reference to the monitoring approach to be implemented for the Doongmabulla Springs-complex and Mellaluka Springs-complex
- Underground Water Impact Report for the Surat Cumulative Management Area (DNRM 2016b)
    - Assessment report on the impacts of coal seam gas on groundwater and associated environmental values
    - Primarily used as a reference document, with Section 9 providing useful management strategies to reduce impacts on springs
    - Where applicable, concepts and findings on the connectivity between springs and aquifers have been applied in the GDEMP.
- Lake Eyre Basin Springs Assessment Project: Hydrogeology, cultural history and biological values of springs in the Barcaldine, Springvale and Flinders River supergroups, Galilee Basin and Tertiary springs of western Queensland (Fensham et al. 2016)
    - Reference document regarding the interaction of groundwater and springs, including biological values, key threats and management
    - Section 8 of the document informed development of the sub-plan for the Doongmabulla springs
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000, 2018).
    - Guideline for the management of water quality in Australia
    - Section 3 of Volume 1 (ANZECC 2000) guided the approach to the derivation of water quality trigger levels and the assessment of change between baseline/pre-impact and impact periods
    - Trigger levels were revised and updated for some water quality parameters in 2018

1.5 Structure of this management plan

This management plan has been structured to address the requirements of relevant approval conditions and documentation approved by Commonwealth and Queensland regulatory agencies. To facilitate practical implementation of management measures, this GDEMP provides for the inclusion of additional information and / or management review outcomes through an adaptive management framework. A summary of key sections of the GDEMP is provided below:

- A contextual description of the Project (**Section 2**)
- Overview of the legislative framework and approval conditions to be addressed within this GDEMP (**Section 3**)

- General description of the existing environmental and hydrological values within the Project area (**Section 4**)
- The approach to the preparation of this GDEMP (**Section 5**)
- Management sub-plans for GDEs listed under Commonwealth and Queensland legislation (**Section 6 to 9**)
- Arrangements for reporting and monitoring compliance with management plan actions (**Section 10**)

Each management sub-plan (**Section 6 to 9**) is structured to provide information in a consistent format on:

- Description of the ecological values of the GDE
- Description of the supporting groundwater resources for the GDE
- Distribution and relationship to the Project area and more broadly
- Relevant conservation advices, recovery plans and matters to be addressed under relevant Commonwealth or State approval conditions
- Description of the baseline monitoring results and relevant studies
- The assessed and approved ecological and groundwater impacts and threats to the GDE
- Proposed monitoring program for the GDE across the pre-impact and impact stages
- Proposed triggers for both groundwater and ecological values of the GDE
- Details of mitigation and management measures to be implemented, including corrective actions

Appendix A provides trigger levels and details of the corresponding flow release regime. **Appendix B** groundwater drawdown and quality limits. **Appendix C** provides a chart showing the timing of all major project elements in relation to each GDE.

For some GDEs, Project impacts are not expected for up to 20 years or more after the commencement of mining activities, due to construction and mining activities being located in parts of the Project area that do not influence the groundwater aquifer associated with the GDE. For other GDEs, project impacts are expected in shorter timeframes. Such issues are discussed in relation to the aquifer source and baseline data sources in each management sub-plan.

1.6 Compliance with approval conditions

Appendix D presents a compliance matrix indicating where approval conditions and commitments relevant to this GDEMP are addressed within this report.

2 Project description

2.1 Overview

The Project involves the construction of a greenfield coal mine, located approximately 160 km northwest of Clermont in the Galilee Basin. The mine site will be located over Mining Lease areas ML 70441, ML 70506 and ML 70505, with coal transported by rail to the Port of Abbot Point for export (**Figure 2-1**).

The mine component of the Project includes:

- Both open cut and underground mining methods
- On mine lease infrastructure
- Associated mine processing facilities
- Off-lease infrastructure including:
    - A worker's accommodation village and associated facilities
    - A permanent airport site
    - Quarries
    - Industrial area.

The mine will cover a total area of approximately 45,400 ha, with an additional 1,850 ha required for off-lease infrastructure. The operational mine life will be approximately 60 years, with a production rate peaking at 60 Mtpa (combined open cut and underground mining). The open cut mine will be operated primarily using truck shovel/excavator methods, and supplemented by draglines and dozers for primary waste removal. A total of 6 open cut pits will be progressively mined, with a capacity of 40 mtpa. During the early stages of developing each mine pit, overburden will be transported to out of pit dumps, where it will be profiled and rehabilitated. A proportion of this material will be used to reprofile the high-wall of the final voids.

The underground mine will operate concurrently with the open cut pits, to provide for coal blending and ensure continuity of production. The underground mine will comprise three independent underground longwall mines, producing 20 Mtpa (product). Each underground mine will be serviced by above ground infrastructure.

All run of mine coal will be transported by truck and/or overland conveyor to a centralised coal handling facility, where the high-ash (greater than 30 per cent ash) portion will be washed for blending with the bypass coal (un-washed coal). Coal will be stockpiled prior to loading on trains for transportation by rail. The channel and riparian zone of the Carmichael River will be preserved and the adjacent pits protected from flooding events by a levee.

All off-lease infrastructure to support the operation of the mine will be located on the Moray Downs property (Lot 662 on SP282172) to the east of the mine. The workers accommodation village will be located approximately 12 km east of the Mine and accessed via the upgraded and realigned Moray-Carmichael Road. The village will accommodate construction and operational workforces for the mine.

The permanent airport will be located approximately 5 km west of the workers accommodation village and will provide access for workers.

Seperately, the rail component of the Project will involve the construction of a 388 km rail development from Carmichael Coal Mine to the Port of Abbot Point (Carmichael Rail Network) in a number of phases. Activities associated with the rail component of the Project are not related to this GDEMP and do not influence the preparation or implementation of commitments under this plan. As impacts to each GDE are linked to the timing of specific mining activities, this plan has been designed to account for and be responsive to any potential changes to production variables, within the context of the approved project description and production outputs.

2.2 Description of Project phases and implementation

This GDEMP describes monitoring, mitigation and management actions for each of the GDEs across the Project phases. Those project phases, timeframes and the activities associated with each project stage, differ in the relationship to, and hence impact on, each individual GDE. This GDEMP also uses available methods, such as the GDE Toolbox (Richardson et al. 2011a, b), and the timing of these methods is also important to understand in the context of this GDEMP and the Project Timing. In doing so, it is important to standardise relevant terms and avoid confusion in the use of terms that have multiple meanings. For example, the GDE toolbox has a phased approach to the management of GDEs, with each phase referred to as a ‘stage’. The mine plan also uses the term ‘stage’ when describing the scheduling of mining activities across the lease.

Therefore, **Table 2-1** below has been included as a reference point to make clear:

- The timing terminology used in the GDEMP across all GDEs with respect to the phases of monitoring and implementation of measures
- Corresponding timing and terminology with respect to the GDE Toolbox (where it has been adopted for use in this GDEMP)
- Broad Project phases and activities.

A graphical illustration of these key terms in relation to project timing is also provided in **Appendix C**.

The management of GDEs is based on the approved impacts under environmental approvals from the Commonwealth and Queensland governments to each GDE, the existing baseline information and the principles of adaptive management applied to forward Project phases and activities. The duration of the pre-impact phase varies according to the GDE and is completed when project-related impacts on the GDE commence. This has been predicted for each GDE environmental value, with impact phase predictions ranging from Year 2 to Year 20 (**Appendix C**).

Baseline information on environmental values, including groundwater, collected during the EIS process (and consequently linked to the approved project impacts) will be supplemented by a comprehensive program of ongoing monitoring. As this information becomes available, mitigation measures to reduce project impacts and triggers for corrective actions will be reviewed and refined (as required). This process of adaptive management is discussed in further detail in **Section 5**.

Following the completion of mining activities, rehabilitation and associated monitoring activities will be carried out.

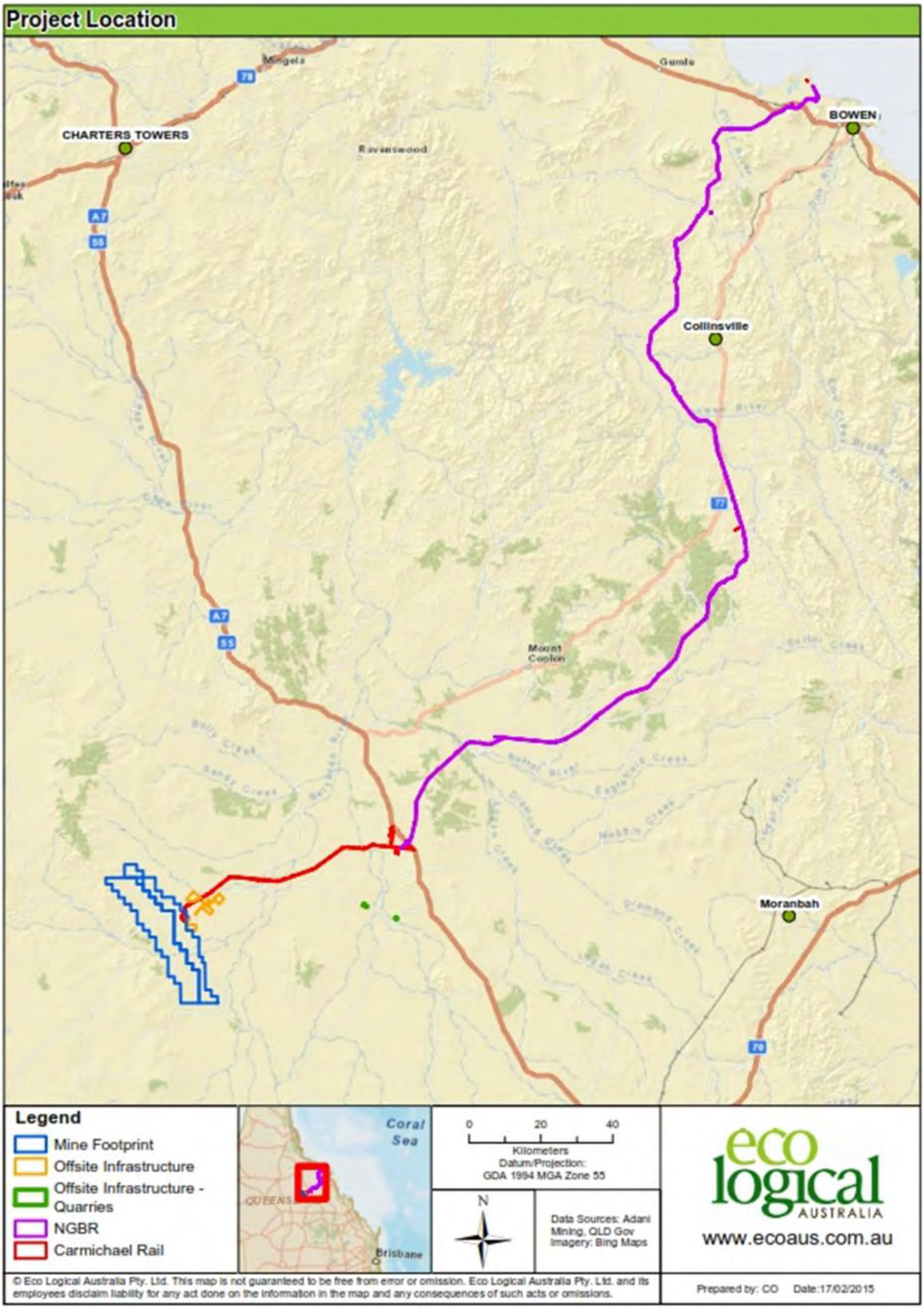


Figure 2-1: Project location.

Table 2-1 GDE Monitoring and Implementation Phases

GDEMP Monitoring & Implementation Phase	Description	Purpose	GDE Toolbox Stage	Relevant Project Phases
Baseline	Beginning at the start of the EIS process (~2010) and finishing in 2018 prior to the approval of this GDEMP. Includes information presented in the EIS, SEIS and additional work post approval within this period. Underpins the approved project impacts.	Describes the environmental values used for impact assessment and approval prior to project construction and the associated threats and impacts (direct and indirect) commencing. Used to establish trigger levels.	Stage 1	Pre-construction phase: EIS and post EIS studies – ecological, geotechnical and hydrogeological investigations (prior to approval of the GDEMP)
Pre-impact	Begins immediately following approval of this GDEMP (2019). Commences with an initial period of two years, coinciding with requirements to update the underpinning groundwater numerical and conceptual models and to then revisit triggers and management plans. Concludes at the time when mining-related activity and impacts will commence for each GDE, noting that this varies for each GDE (as described in relevant sections of this GDEMP) Relates to impacts to relevant source aquifers and/or ecological values.	Provides for the collection of pre-impact information to supplement baseline information. Used to inform future revisions of trigger levels, based on extensive additional data collected during pre-impact monitoring and investigations. Allows consideration of groundwater and ecological changes not attributable to significant groundwater impacts arising from mining activities.	Stage 2	Pre-construction / Construction: Initial development of the Project as described in the EIS, includes surface disturbance and is prior to the commencement of significant groundwater impacting activities. Specific timing of impacts related to groundwater will be specific to each groundwater unit and GDE.
Impact	Begins when project impacts on relevant GDEs commence. Information collected from the commencement of Project-related impacts to the relevant groundwater aquifers and/or ecological values. Draw-down impacts are expected at	Data collected allows validation of observed impacts against predicted and approved impacts. The implementation of mitigation measures and corrective actions is to address potential deviations from approved impacts, noting the implementation	Stage 3	Refers individually and collectively to the full development of the mine where activities influence across a number of groundwater aquifers and to ecological features of GDEs.

GDEMP Monitoring & Implementation Phase	Description	Purpose	GDE Toolbox Stage	Relevant Project Phases
	different times for each GDE. See **Table 6-2, Table 6-3, Table 7-3, Table 7-4, Table 8-5, Table 9-1** and **Appendix C** for more detail regarding potential direct / indirect impacts and key timeframes for drawdown.	timeframes of these measures will vary. Monitoring during this period also ensures that no impacts occur before they were predicted to occur. Allows consideration of groundwater and ecological changes attributable to significant groundwater impacts arising from mining activities.		

3 Legislative and regulatory framework

3.1 Key legislation

Assessment of the Project by the Commonwealth Government occurred through the EIS process under the EPBC Act. This assessment considered potential impacts of the Project on MNES, such as federally-listed threatened ecological communities and species dependent on groundwater as well as water resources in relation to coal seam gas and large coal mining development ('the water trigger').

Assessment of the Project by the Queensland Government occurred through the EIS process under the *State Development and Public Works Organisation Act 1971* (SDPWO Act). This Act provides for the assessment of 'coordinated projects' by the Coordinator-General, while considering other Queensland legislation relevant to the proposed activity, including the:

- EP Act
- *Planning Act 2016*
- *Water Act 2000*
- *Fisheries Act 1994*
- *Nature Conservation Act 1992* (NC Act)
- *Vegetation Management Act 1999* (VM Act)

Adani began formal environmental assessment of the Carmichael Coal Mine and Rail Project in 2010. The Project was declared a 'significant project' under the SDPWO Act requiring an EIS and was assessed to be a 'controlled action' requiring assessment and approval under the EPBC Act.

An EIS was prepared in accordance with the bilateral agreement between the Commonwealth and Queensland Governments, with the objective of avoiding or mitigating potentially adverse impacts on environmental, social and economic values and enhancing positive impacts. Where there were unavoidable residual impacts, offsets were proposed in accordance with Commonwealth and Queensland Government policies.

Adani worked closely with stakeholders and undertook a range of technical, environmental, social and cultural investigations to develop the EIS, which described the current environment, the Project's environmental impacts and ways of avoiding, mitigating or offsetting these impacts.

The EIS was released by the Coordinator-General for public and local, Commonwealth and Queensland Government agency consultation from 15 December 2012 to 11 February 2013. All submissions received during public consultation period were assessed by the Coordinator-General, and Adani was requested to then prepare a Supplementary EIS (SEIS) to address and respond to submissions made during the public consultation of the EIS.

Adani prepared the SEIS in accordance with section 35(2) of the SDPWO Act and the bilateral agreement between the Commonwealth and Queensland Governments. The SEIS provided revised and additional environmental studies undertaken to reflect the amendments made to the Project since the EIS publication and to address matters raised in submissions. It also included revised technical studies, impact assessment and management plans for a range of project issues. Adani also undertook engagement with stakeholders during the development of the SEIS.

The SEIS was released by the Coordinator-General for public, local, Commonwealth and Queensland Government agency consultation from 25 November 2013 to 20 December 2013. The Project was subsequently approved to proceed by the Queensland Coordinator-General on 7 May 2014, subject to conditions. The project was approved by the Commonwealth Government on 14 October 2015, also subject to conditions (EPBC 2010/5736).

3.2 Approval conditions relevant to this GDEMP

The Coordinator-General's report and EPBC Act approval identify that the Project may potentially impact GDEs, and associated threatened species, listed under the EPBC Act and/or the NC Act. Commonwealth approval conditions require the development of management plans for the MNES dependent on groundwater that were considered most likely to be affected by the Project.

For the EPBC Act Approval (2010/5736), Conditions 5 through 7 are relevant and include the following MNES:

- Carmichael River (Carmichael River and its riparian zone between the Doongmabulla springs and the Belyando River)
- *Livistona lanuginosa* (Waxy Cabbage Palm)
- the Mellaluka Springs-complex
- Community of native species dependent on discharge from the Great Artesian Basin (Doongmabulla Springs-complex) including *Eriocaulon carsonii* (Salt Pipewort); and the *Eryngium fontanum* (Blue Devil).

The Environmental Authority (EPML01470513) for the Carmichael Coal Mine requries the development and implementation of a GDEMP as per conditions I11 through I14. The definition of the GDEMP in the Environmental Authority provides additional requirements to be addressed in the GDEMP.

Condition I13 confirms the GDEs to be included in this GDEMP as:

- The Doongmabulla Springs-complex
- The Lignum, Stories and Mellaluka Springs
- The Carmichael River riparian zone (ecosystems associated with the Carmichael River between the Doongmabulla Springs and the Belyando River, including populations of Waxy Cabbage Palm)

An inventory of all relevant Commonwealth and State approval conditions is provided in **Appendix D**, with a description of the location within this report where each condition has been addressed. This GDEMP addresses all matters that have been listed under either Commonwealth and / or State approval conditions, thus satisfying all requirements.

4 Existing environment

This section provides a general description of the ecological values of the Project area, which are relevant to the development of this GDEMP.

4.1 Environmental setting

The Carmichael Coal Mine is located in central Queensland within the Burdekin catchment. It covers the boundary of the Brigalow Belt and Desert Uplands bioregions of Queensland. The Brigalow Belt North and Desert Uplands bioregions are semi-arid, and located in the tropics where summer rainfall dominates, with a distinct wet season between December and April, and a dry season between May and November.

The Brigalow Belt North Bioregion is a large and complex area characterised by clay soils with forests and woodlands dominated by *Acacia harpophylla* (Brigalow), eucalypts and grasslands. The general land types include undulating rugged ranges to alluvial plains (Young et al. 1999, Bastin 2008). The Desert Uplands Bioregion is characterised by sandstone ranges and sand plains, with thick eucalypt and acacia woodlands, often with a spinifex understory (Bastin 2008). Each of these bioregions is further divided into subregions based on land forms.

The Project area is located in the Belyando Downs subregion of the Brigalow Belt North Bioregion, and the Alice Tableland subregion of the Desert Uplands. The dominant vegetation communities in these subregions are *Eucalyptus melanophloia* (Silver-leaved Ironbark) and *E. populnea* (Poplar Box) woodlands on alluvial deposits, and *Acacia shirleyi (*Lancewood) and *A. catenulata* (Bendee) woodlands on rocky hills and sandstone ranges (Sattler and Williams 1999). The Brigalow Belt North Bioregion is also dominated by Brigalow and *A. cambagei* (Gidgee) woodlands on fine soils, and *Dichanthium sericeum* (Queensland Bluegrass) grasslands on alluvial deposits; whilst the northern reaches of the Alice Tablelands are dominated by *E. whitei* (White's Ironbark) and *E. brownii* (Reid River Box) (Sattler and Williams 1999).

The predominant land use of the region is beef cattle grazing, which covers over 90% of the total area (Bastin 2008). Other land uses include conservation and minimal use, forestry, dryland agriculture, horticulture, mining, and urban centres (Dight 2009). There are few major urban centres in the region, with the largest being Bowen, Barcaldine, Collinsville, Alpha, and Pentland (Bastin 2008). The Project area is approximately 320 km west of the coast of central Queensland.

The mine is located within the Carmichael River sub-catchment of the Belyando Basin in the Burdekin Catchment. The Belyando Basin is characterised by generally low relief floodplains drained by braided channels and surrounded by wide alluvial plains (Dight 2009).

4.2 Ecological values of groundwater dependent ecosystems

The following GDEs (incl. threatened species listed under the EPBC and/or NC Acts) occur within the region and are relevant to the Project:

- The population of Waxy Cabbage Palm, listed as vulnerable under the EPBC Act and NC Act
- Carmichael River and its riparian zone between the Doongmabulla springs and Belyando River, as described in the EPBC Act Approval (2010/5736) and Environmental Authority

- The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin (GAB; listed as endangered under the EPBC Act) and other non-GAB springs that occur at the Doongmabulla Springs-complex
- The Mellaluka Springs-complex.

For the purposes of EA Conditions I8 and I9, the GDEs include the affected Carmichael River riparian zone (ecosystems associated with the Carmichael River between Doongmabulla Springs and the Belyando River, including populations of Waxy Cabbage Palm), the Lignum, Stories and Mellaluka springs and the Doongmabulla Springs-complex. These GDEs, and associated habitat values, also support a number of terrestrial and aquatic flora and fauna species.

The Doongmabulla Springs-complex occurs approximately 8 km west of the Project area (**Figure 4-1**), on the Doongmabulla station. It comprises discrete pools and patches of grassland, sedgeland and woodland, created by the outflow of artesian water from a cluster of spring groups (Joshua, Moses and Little Moses) (GHD 2013b). The Doongmabulla Springs-complex is classified as the Threatened Ecological Community (TEC) of native species dependent on natural discharge of groundwater from the GAB (hereafter 'GAB spring wetland community'). As stated above, other non-GAB springs also occur at the Doongmabulla Springs-complex, and the complex as a whole is protected under the water trigger.

The Doongmabulla Springs-complex provides important wetland habitat for flora, birds, mammals, amphibians, reptiles, fish and invertebrate species. *Geophaps scripta scripta* (Squatter Pigeon), which is listed as vulnerable under the NC Act and EPBC Act, has been recorded at Moses Springs. The complex also contains a small population of Waxy Cabbage Palm, six other threatened flora species endemic to GAB spring wetlands, three other spring-endemic flora species and two spring-endemic fauna species.

The Mellaluka Springs-complex (consisting of the Mellaluka, Lignum and Stories springs) is located near the south western corner of the eastern section of the Project area on Mellaluka Station (**Figure 4-1**). This springs-complex consists of several pools (both modified and natural) and seeps which support dense vegetation (GHD 2014). Mellaluka Springs is listed as an MNES (water resource) under the EPBC Approval. However the Mellaluka Springs-complex is not a GAB spring wetland community TEC because it is not a GAB spring. There are no endemic species known to be associated with the complex, yet it is commonly utilised by Squatter Pigeon, which is listed as vulnerable under the NC Act and the EPBC Act.

The Carmichael River flows through the Project area, and reaches its confluence with the Belyando River 20 km downstream from the Project area (**Figure 4-1**). The Carmichael River is the main riverine feature of the area and maintains aquatic habitat throughout the year. The riparian zone of the Carmichael River, which includes fringing *Eucalyptus camaldulensis* and *Melaleuca leucadendra* forests, is listed as an MNES (water resource) under the EPBC Approval. The Carmichael River also supports a large population of Waxy Cabbage Palm and provides habitat for threatened fauna species.

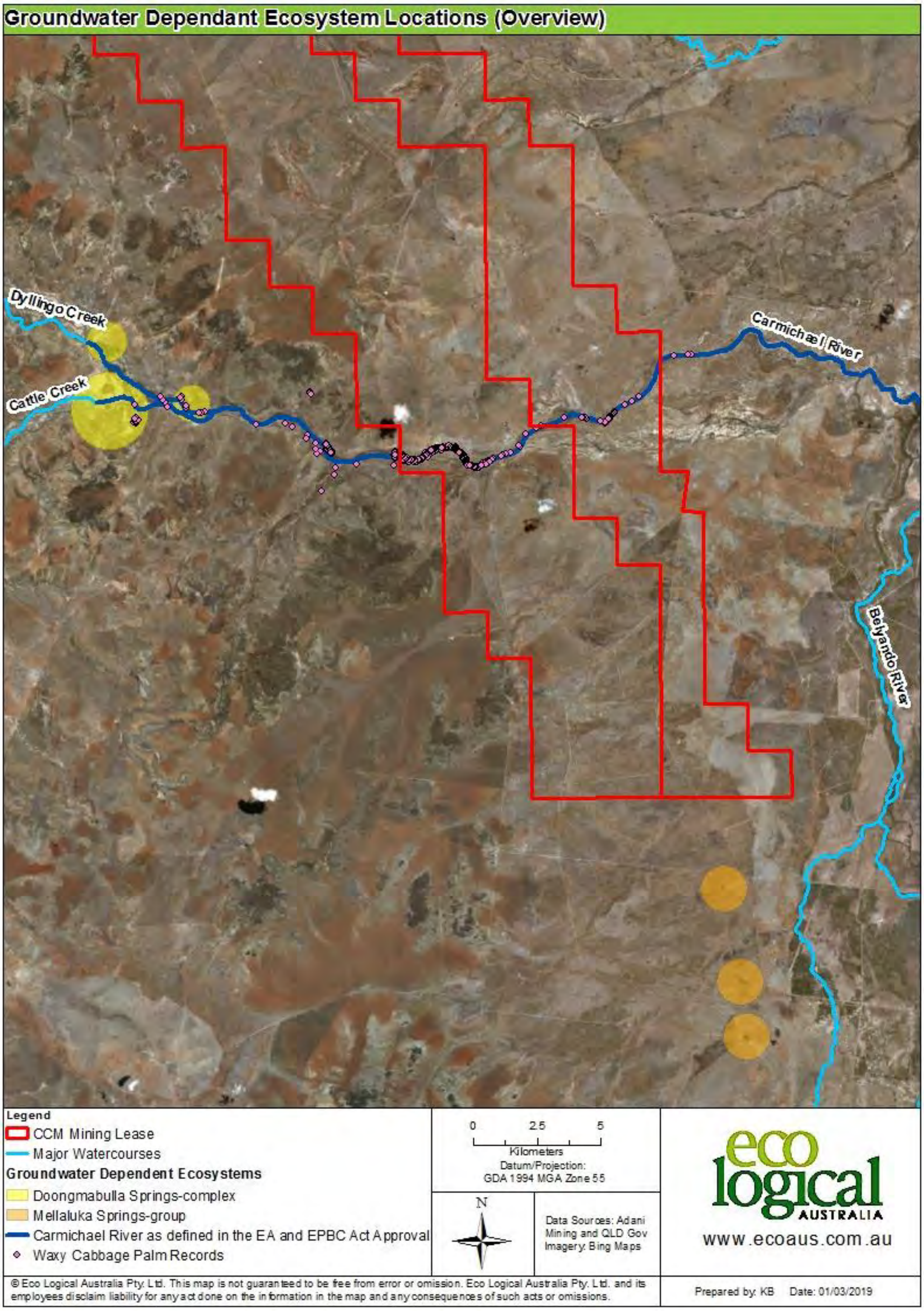


Figure 4-1: Groundwater Dependent Ecosystems in Project area

4.3 Hydrogeology, groundwater resources and relationship to GDEs

Extensive hydrogeological impact analysis and modelling was undertaken through the environmental impact assessment process for the Carmichael Coal Mine and Rail Project. EPBC Act Approval, condition 6 states that Matters of National Environmental Significance management plans, such as this Groundwater Dependent Ecosystem Management Plan, "… must incorporate the results of the groundwater flow model re-run (Condition 23) where relevant…".

Condition 22 of the EPBC Act approval required Adani to "submit to the Minister, within one month of [the] approval a peer review of the adequacy of the current groundwater flow model to characterise groundwater impacts. This review must consider the parameters used into the groundwater flow model, the required additional modeling information and the model re-runs outlined in Condition 23. The peer review must be undertaken by a suitably qualified independent expert. The peer review report should identify any additional information requirements." Condition 23 required Adani to provide a report to the Minister about the re-run of the groundwater flow model. The condition also outlined what the re-run must incorporate in terms of parameters in scenarios and address additional specified information requirements.

The model re-run tested parameters and scenarios of groundwater modelling carried out during the EIS and SEIS. The peer reviewer "did not identify any material weaknesses in the model design, boundary conditions, parameter values or calibration performance. The exploration of model uncertainty in conceptual and parameter value terms is commendable and the results indicated low sensitivity/uncertainty". The reviewer concluded that the model revisions were undertaken "competently, consistent with condition 23, and the revised model design and performance is consistent with guidelines and suitable as is for impact assessment purposes, with future model refinements dependent on monitoring to obtain data for validation".

A peer review of the adequacy of the Groundwater Flow Model, along with the report on the re-run of the Groundwater Flow Model were approved by the Commonwealth Government in March 2016. As described in the GMMP, the results of the model re-run where similar to the SEIS model and the SEIS model was the most conservative. As such, there were no results arising from the groundwater flow model re-run under condition 23 relevant to this GDEMP.

This section provides an overview of the key hydrogeological features and groundwater resources associated with the GDEs described in this report. This material is drawn from across the available environmental impact assessment material and the GMMP and hence is consistent with and complimentary to that work. Further technical detail can be obtained through that material.

4.3.1 Hydrogeological conceptual model

The original conceptual model presented through the EIS process has been refined over time with new information. The current understanding of the site's hydrogeological regime is presented below, which is the result of incorporation of data gathered and assessed since the original model was developed for the EIS/SEIS. This refined conceptual model has been utilised to inform augmentation of the groundwater monitoring network and program and identify data gaps (through various mechanisms such as the GABSRP and the RFCRP), which in turn, will be utilised to update the conceptual understanding for the Project.

Refinement of the groundwater conceptual model indicates the groundwater regime of the Galilee Basin is complex and varied, particularly along the eastern margin, where the Project area is located. A conceptual groundwater model, which formed the basis of the numerical groundwater model, was developed based on existing information and field data collected for the Project and surrounding area.

Figure 4-2 and **Figure 4-3** present the hydrogeological conceptual model for the Carmichael Coal Mine pre- and post-mining. **Figure 4-4** and **Figure 4-5** show a cross section of the hydrogeological conceptual model for the Joe Joe Group and the Mellaluka Springs-complex.

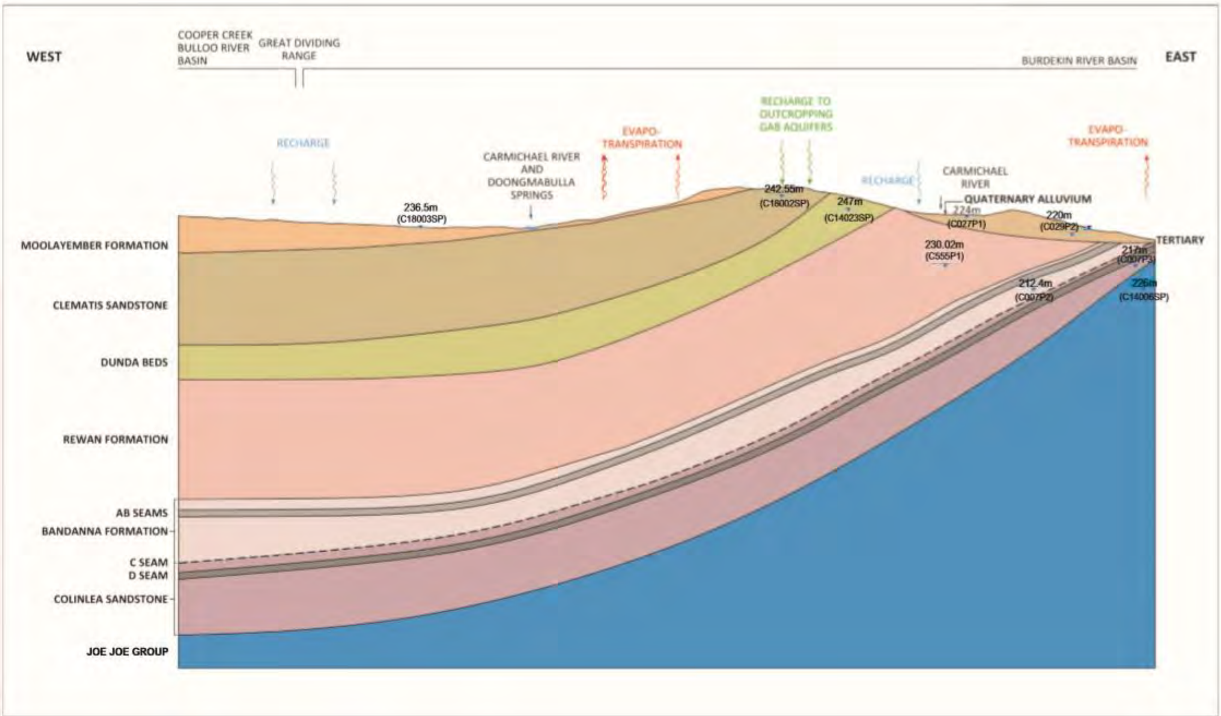


Figure 4-2: Hydrogeological conceptual model – pre-mining

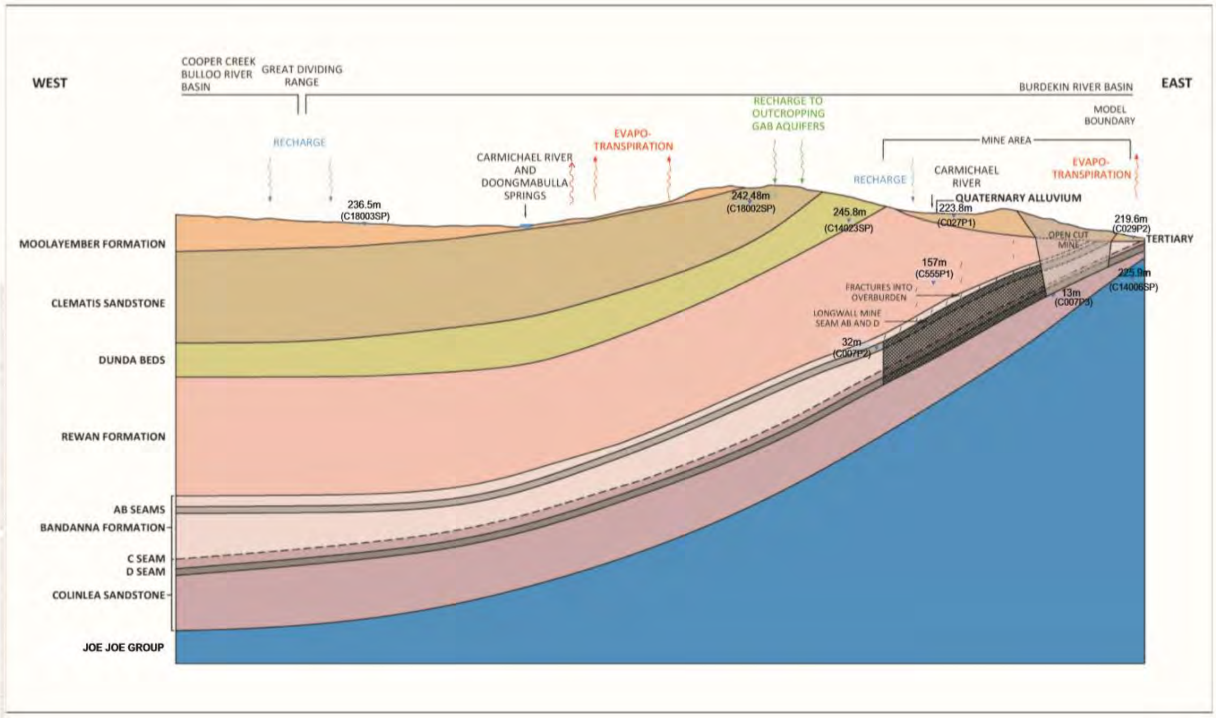


Figure 4-3: Hydrogeological conceptual model – mining & post-mining

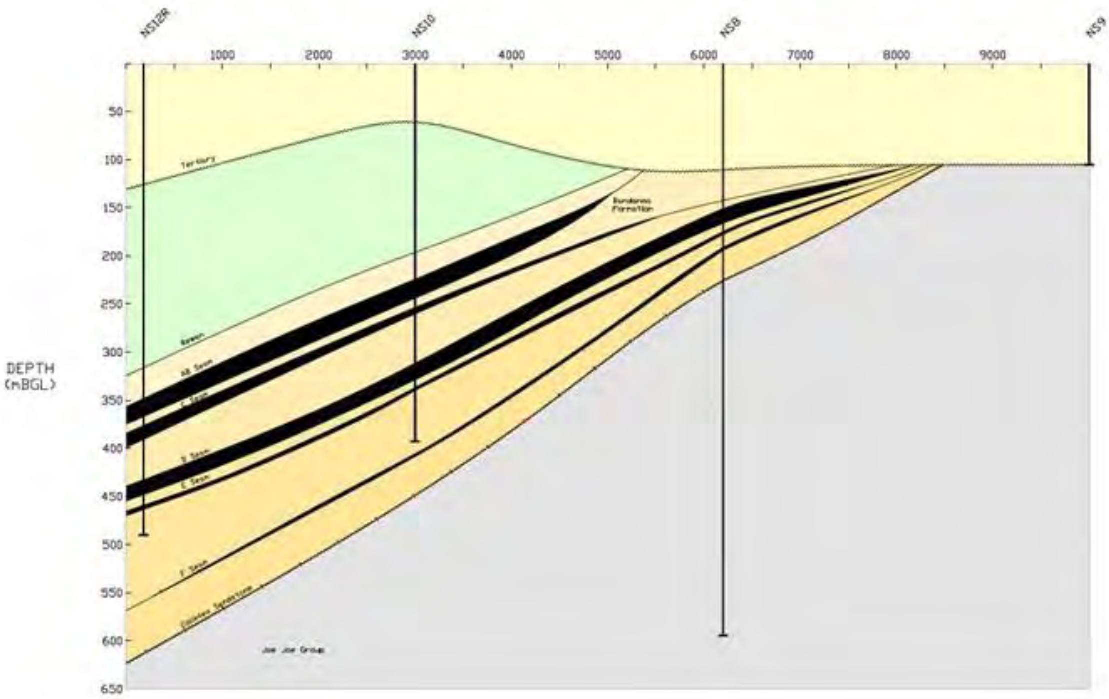


Figure 4-4 Cross section showing Joe Joe Group and Mellaluka Springs-complex – bores shown are government exploration bores (Source: GMMP)

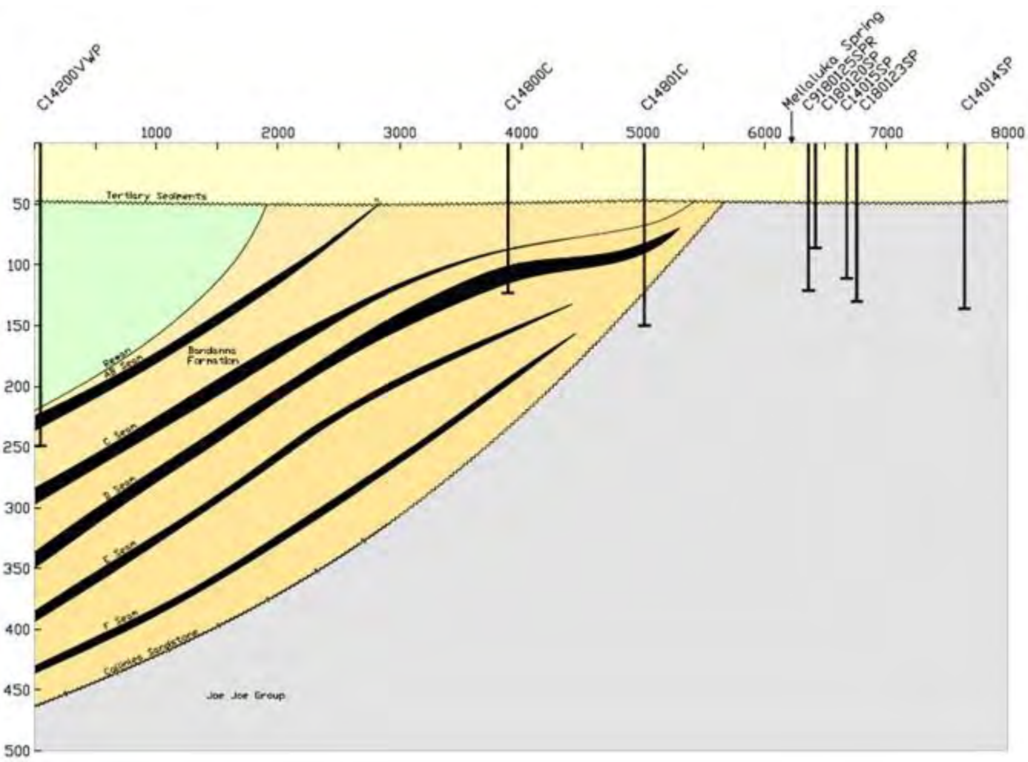


Figure 4-5 Cross section showing Joe Joe Group and Mellaluka Springs-complex. Water levels (Artesian) are: C9180125SPR 243.10 mAHD, C180120SP 243.48 mAHD, C14015SP 239.15 mAHD and C14014SP 239.32 mAHD. Remaining bores are government exploration bores (Source: GMMP)

4.3.2 Hydrogeological units and aquifers

Each of the hydrogeological units and their relevance to GDEs is presented in **Table 4-1**.

In order to inform alternative groundwater conceptualisations, Adani will install additional bores nested at three locations in groundwater units other than the Clematis with respect to predicted groundwater drawdown to the Doongmabulla Springs. This will include bores in the Dunda Beds and Rewan Formations. These bores will be located, installed and monitoring of pre-impact level and quality will commence after approval of the GMMP. This information will be used in the groundwater model re-run that is required within two years of the commencement of mining operations. The GMMP will also adopt interim triggers for these bores prior to the groundwater model re-run.

Table 4-1: Hydrogeological units and aquifers, showing depth of monitoring bores

Hydrogeological Unit	Associated GDEs	GDE Monitoring Bores (depth of bore in m)	Recharge Mechanism	Discharge Mechanism	Description
Alluvium	Carmichael River Waxy Cabbage Palm	C025P1 (11.00) C027P1 (13.00) C029P1 (13.40) HD03B (11.37) C14027SP (21.00) C14028SP (20.00)	Surface water infiltration, particularly from the Carmichael River Direct rainfall infiltration Vertical leakage (upward) from underlying units	Base flow to surface water features (i.e. Carmichael River) Vertical leakage into underlying units Evapotranspiration	Alluvium, along the Carmichael River, is recognised to be recharged through continuous discharge from the Joshua Spring (artesian flow from the Clematis Sandstone), which is discharged into the Dyllingo Creek, which flows into the Carmichael River (GMMP).
Tertiary sediments		C029P2 (46.00)			
Tertiary sediments	Mellaluka Springs-complex	C180122SP (47.00) C9180121SPR (45.00) C14031SP (54.00)	Surface water infiltration, particularly along the eastern portion of the site Rainfall infiltration in outcrop areas Vertical leakage from overlying alluvium	Vertical leakage to overlying alluvium Evapotranspiration Poorly constructed bores resulting in uncontrolled discharge, forming springs	The Tertiary sediments, particularly overlying the Joe Joe Group, are considered to thicken in the eastern area of the site, which results in artesian conditions. Complex multi-storey artesian conditions occur in the Tertiary and

Hydrogeological Unit	Associated GDEs	GDE Monitoring Bores (depth of bore in m)	Recharge Mechanism	Discharge Mechanism	Description
					Joe Joe Group due to interbedded high and low permeable units.
Moolayember Formation	Doongmabulla Springs-complex	C14020SP (136.00) C18003SP (20.00)	Rainfall recharge in outcrop areas (west of the Project area) Vertical leakage from the underlying units	Vertical leakage into overlying Cainozoic sediments and underlying Clematis Sandstone Recharge reject due to low permeability and storage Evapotranspiration	Deep weathering and erosional features around the Doongmabulla Springs-complex indicates limited recharge and high runoff across the Moolayember outcrop.
Clematis Sandstone	Doongmabulla Springs-complex Carmichael River (surface flow) Waxy Cabbage Palm (surface flow)	HD02 (32.00) HD03A (37.00) C14011SP (144.00) C14012SP (168.00) C14013SP (72.00) C14021SP (46.00) C14033SP (200.00) C18001SP (188.00) C18002SP (100.00)	Rainfall recharge in outcrop areas (along western boundary of the CCP area)	Vertical leakage to underlying Dunda Beds and overlying Moolayember Formation (where present) Evapotranspiration in outcrop areas Vertical leakage forming the Doongmabulla Springs-complex Loss through poorly constructed artesian bores	The Clematis Sandstone may be hydraulically connected to Cattle Creek and Dyllingo Creek, which drain across the outcrop.
Dunda Beds	Doongmabulla Springs-complex	HD01 (59.00) C027P2 (32.80)	Rainfall recharge in outcrop areas (along western boundary of the Project area) Vertical leakage from the overlying units.	Vertical leakage to underlying and overlying units Evapotranspiration in the outcrop areas	Alternative conceptualisation is that the Dunda may be a groundwater source of Doongmabulla Springs-complex.
Rewan Formation	Nil	C180116SP (71.00)	Minor recharge at outcrop	Minor through flow due to low permeability	The Rewan Formation is, based on site specific data collected, an

Hydrogeological Unit	Associated GDEs	GDE Monitoring Bores (depth of bore in m)	Recharge Mechanism	Discharge Mechanism	Description
		C14023SP (165.60) C9553P1R (66.00) C555P1 (75.00) C556P1 (83.30)			aquitard where the vertical groundwater gradient above and below the Rewan are upwards above the unit and downwards below the unit Monitoring bores have been noted for this unit as they related to groundwater monitoring of the Rewan Formation in relation to the groundwater model.
Bandanna Formation (AB Seam)	Nil	Nil	Vertical leakage from the underlying units	Vertical leakage to the more permeable underlying units	The coal seams are the most permeable units within the clay-rich Bandanna Formation
Colinlea Sandstone (D Seam)	Nil	Nil	Vertical leakage from the underlying and overlying units	Vertical leakage to the more permeable underlying units Vertical leakage to the overlying units in subcrop areas Vertical leakage to the Mellaluka Springs-complex	The Colinlea Sandstone was initially considered to be the primary source aquifer for the Mellaluka Springs-complex, however, additional drilling indicates complex artesian conditions associated with the Tertiary and Joe Joe Group sediments provide discharge to surface in the area of Mellaluka Springs-complex.
Joe Joe Group	Mellaluka Springs-complex	C180119SP (85.00) C180120SP (86.00) C180123SP (130.00) C9180124SPR (86.00)	Vertical leakage from the overlying units, particularly in subcrop areas	Vertical leakage to the overlying units	Information collected from additional groundwater monitoring bores installed within the Joe Joe Group to the south of Carmichael

Hydrogeological Unit	Associated GDEs	GDE Monitoring Bores (depth of bore in m)	Recharge Mechanism	Discharge Mechanism	Description
		C9180125SPR (121.00) C14032SP (90.00) C14008SP (120.00) C14015SP (144.00) C14017SP (111.00)			River suggests a possible hydraulic connection with the Belyando River (palaeochannels). Artesian pressures observed south of the Carmichael River occur where the Tertiary sediments are thicker and become sub-artesian north of the river.

5 General Approach

5.1 Overview

This GDEMP provides both an overarching framework for the management and monitoring of GDEs in the Project area, and sub-plans, which have been developed for each GDE and describe specific management and monitoring requirements.

The GDEMP has been developed based in the following sequential approach that:

- Establishes an environmental baseline using data collected during and subsequent to the EIS process
- Establishes a suite of trigger levels for each GDE
- Analyses threats and potential impacts (direct and indirect) to each GDE
- Defines management objectives and performance criteria to limit and manage each of the potential impacts
- Provides a comprehensive suite of mitigation and management measures that specifically address the potential impacts to each GDE
- Develops pre-impact monitoring requirements to further develop the environmental baseline prior to the impacts of mining on GDEs
- Develops impact monitoring requirements, the results of which will be compared to trigger levels to determine whether investigations and corrective actions are required
- Provides an adaptive management framework including details of the investigative process and corrective actions that will be implemented.

The approach described above was informed by and is consistent with the GDE Toolbox. This is described in detail in **Section 5.8**.

5.2 Environmental baseline

Adani has gained an understanding of the presence, location and hydrogeological and ecological functions of GDEs within and proximal to the Project area through a range of hydrogeological and ecological studies developed as part of the Project's approvals process (EIS, SEIS and in response to subsequent approval conditions). These baseline studies have been through numerous rounds of peer and regulatory review, and are considered adequate and appropriate to meet the level of rigour required to obtain Project approvals under State and Commonwealth legislation. A range of publications also provide baseline information for the Doongmabulla Springs (e.g. Fensham et al. 2016).

Conditions 6(f) and 6(g) of the EPBC Approval and Condition I10 of the EA require that a comprehensive baseline condition dataset for GDEs is obtained, over and above what would normally be required to obtain State and Commonwealth approvals through an EIS process. This GDEMP therefore details a summary of information derived from surveys that establishes the baseline for each GDE. Baseline data will be complemented by future studies during the pre-impact period before project impacts commence. Results will be used to further refine and develop trigger values. These triggers will provide an early warning for potential impacts that will then warrant further investigation, monitoring and adaptive management measures.

5.3 Threats and potential impacts

Threats and potential impacts to each GDE were collated from relevant policy documents (e.g. Approved Conservation Advices, recovery plans), the Carmichael Coal EIS and approval conditions. For each, an analysis was then undertaken to determine the extent to which each threat and potential impact is relevant to the GDE, including when in the life of the Project the threat / impact becomes relevant. This analysis forms the basis of the management objectives, performance criteria and the comprehensive suite of management and mitigation measures that will be implemented to limit and manage each of the threats / potential impacts.

5.3.1 Management and mitigation measures

Key potential impacts to GDEs stem from groundwater drawdown. The GMMP provides a detailed analysis of the management and mitigation measures that will be implemented to address groundwater specific issues. These are repeated in this GDEMP for each GDE and are related to the groundwater unit which provides the source for each GDE (i.e. management measures for groundwater issues that have no relationship to GDEs are not presented here).

There are also a number of potential impacts to the ecological values of each GDE that are not directly related to groundwater. This GDEMP provides a comprehensive suite of management and mitigation measures that will be implemented to address these.

Each GDE sub-plan identifies specific mitigation and management measures tailored for each GDE potentially impacted by the Project. These measures have been developed to address specific threats from the Project, and the approved sub-plans will be implemented adaptively.

Although the primary potential impact on GDEs from the Project is groundwater drawdown from mining activities, which is generally not expected to occur until 2035 (GHD 2015), direct impacts to some GDEs will occur earlier in the Project. These include the clearing of vegetation for a bridge over the Carmichael River which will remove approximately 5.47 ha of habitat for Waxy Cabbage Palm and five mature individuals (**Figure 7-7**). Mitigation and management measures have been developed for other potential impacts including weeds, feral animals and bushfire.

The results of all mitigation actions will be recorded and reported to the DoEE and DES as specified in approval conditions. Further details of such reporting are provided in **Section 10**.

Due to some uncertainty regarding the ecological water requirements (EWRs), interactions with groundwater, responses to changes and natural variations for GDEs in the Project area, an adaptive management approach will be adopted to ensure impacts are within the approved limits. Assumptions regarding the dependency on groundwater of some GDEs in the Project area have been made utilsing the EIS conceptual groundwater model, relevant literature and baseline monitoring information to develop triggers for both groundwater drawdown and ecological impacts. After completion of pre-impact monitoring (see below), there will be information available on the ecological values of the GDEs to further inform how reliant these GDEs are on groundwater.

Adaptive management for GDEs in the Project area is based on the following steps:

- Linking GDE values with the underpinning groundwater model
- Develop and implement monitoring
- Develop and implement management actions including corrective actions if required
- Evaluate effectiveness of management actions
- Adapt management actions (including mitigation and corrective actions if relevant).

It should be noted that the GDEs described in this management plan are located on several properties under the ownership and control of differing landholders. Therefore, the approach to the management and monitoring of weeds and pests on these properties will need to account for this ownership issue and hence varies among the GDEs. The management of weeds and pests (and associated activities that influence these threats) is outside of Adani's direct control on land owned by others. Adani will engage with those landholders to promote practices consistent with ensuring these threats are reduced and/or minimised.

Where sections of the Carmichael River and assemblages of Waxy Cabbage Palm are located on land under the control of Adani, mitigation measures and monitoring programs for these GDEs will be directly controlled by Adani.

5.4 Monitoring approach

The monitoring program is required to have clear objectives and a rigorous statistical design to achieve the desired outcomes of characterising pre-impact conditions and measuring change in environmental variables. There is also a need for inherent flexibility in the design and application of the monitoring program, to achieve the application of an adaptive management approach.

There are a number of key criteria that must be addressed through the implementation of the monitoring program:

- Incorporate natural variation in environmental variables, including those influenced by wet and dry seasons, by augmenting baseline data with mapping or data from 10 years prior to 10 years post commencement, to capture natural climatic variability influences on GDEs
- Ensuring that monitoring and investigation can distinguish between the influences / impacts of mining and non-mining through the various phases of the project
- Ensure that data are collected over an appropriate time-scale that is relevant to the stressor
- Ensure that the magnitude of change relevant to a trigger is likely to be detectable.

The monitoring methodology described below, and specifically in each GDE Chapter of this plan, is designed to enable the measurement and separation of mining and non-mining influences on the monitoring indicators across the four GDE's. This monitoring method and the investigation process in Section 5.6 enable the effective designation of control and impact site monitoring, and to achieve compliance with these criteria through implementation of the following key steps.

5.4.1 Monitoring design

Team selection

Following approval of this GDEMP, Adani will select a team of suitably qualified persons to implement the monitoring program. Details of the minimum qualifications and experience of the team are provided in **Section 10.4**. The team will be comprised of individuals with skills and experience in ecology, botany and GDEs (including hydrogeology). Selection and engagement of the team will be through Adani's internal procedures. Personnel within the project team will be assigned to relevant aspects of the monitoring program aligned with their skills and experience.

Desktop review

The monitoring team will complete a desktop review of information available on the GDEs, including information presented in this GDEMP, and work completed by Adani during and since completion of the

EIS process (baseline data). Other scientific studies and experience related to the monitoring of GDEs will be considered, to assist in planning and implementation of field surveys.

Field sampling plan

A field sampling plan will be developed for each GDE, which complies with the monitoring requirements specified in this GDEMP. Data collection methods and equipment will be tailored to each environmental variable, and the approach to the selection of sampling sites will be documented. The selection of sampling sites for a long-term monitoring program is always best completed in consideration of issues 'on the ground'. Key aspects of the sampling method are as follows:

- Surveys will be undertaken bi-annually within the wet season and dry seasons, and more frequently (quarterly) for some parameters
- Survey sites are to be clearly marked (e.g. pegged) so that they can be monitored through time, and located in close proximity to groundwater monitoring sites (e.g. bores) to allow interpretation of trends in data
- Monitoring methods will be clear and repeatable
- Data sheets will be developed to allow for the consistent collection, storage and analysis of data
- Survey activities must be safe to implement and avoid significant impact on the environment from conducting the monitoring (e.g. minimise trampling or collection of biological samples, where possible).

A weather station established at the project area will collect relevant meteorological data (e.g. rainfall, temperature) to assist in the interpretation of monitoring data related to water and ecological indicators.

5.4.2 Key monitoring attributes

The key ecological monitoring attributes have been developed in response to the established environmental baseline and are presented in **Table 5-1**. Monitoring attributes for surface water are in the REMP and for groundwater, are described in the GMMP. **Table 5-1** shows the attributes that may be suceptible to potential project impacts and are therefore the values for which triggers have been developed. The monitoring of each parameter will allow for an assessment of the condition once impacts is commence versus the baseline (which will be updated, based on pre-impact monitoring), to determine whether a trigger has been activated and a response is required.

Table 5-1: Key ecological monitoring attributes for each GDE

GDE	Monitoring survey	Monitoring attributes or methods
Carmichael River (**Section 6.6**)	Ecological features map of the Carmichael River	Threatened and endemic flora locations
		Weed and pest locations
		Riparian vegetation composition and health
		Fauna use of riparian habitat
		Areas of connectivity or disconnection with groundwater
		Gaining / losing areas relative to groundwater
		Location of deep pools

GDE	Monitoring survey	Monitoring attributes or methods
		Location of riffles
		Location and size of aquatic macrophyte beds
		Other key aquatic habitat features
	Riparian condition surveys	CORVEG and/or BioCondition surveys
	Aquatic Ecological Surveys	Vertebrate species presence, in particular at remnant pools
		Ecological condition (e.g. using AusRivAS)
		Ecological patterns (macrophytes, fish, invertebrates)
	Groundwater monitoring	Groundwater level and quality
	Surface water monitoring	Surface water level, flow and quality
	Weed and pest surveys	Presence of weed species and extent of coverage
		Presence of pest species and extent of disturbance
Waxy Cabbage Palm (See **Section 7.6**)	Condition and population survey	Presence/absence of the species
		Number and location of individuals, in particular adults
		Age class structure (life stages, primarily depicted by height or form)
		Condition (evidence of poor health, including fire damage or drought stress)
		Habitat condition, in particular threats (presence and abundance, or severity of disturbance from weeds, pests or erosion)
		CORVEG and/or BioCondition data
	Ecological features map of the Carmichael River	Areas of *Cryptostegia grandiflora* (Rubber Vine) infestation
		Riparian composition and health
		CORVEG and/or BioCondition site locations
		Weed and pest locations
		Gaining / losing areas relative to groundwater
	Groundwater data	Groundwater level and quality
	Surface water data	Surface water flow in Carmichael River
	Pre-impact studies	Relationship of individuals and refugia habitats during drought
		Leaf water potential
		Stable isotope studies

GDE	Monitoring survey	Monitoring attributes or methods
		Soil sampling
		Leaf area index
		Sap flow measurements
Doongmabulla Springs-complex (**Section 8.7**)	Springs monitoring	Spring-head pressure
		Flow rate if measurable
	Groundwater monitoring	Groundwater level and quality
	Surface water monitoring	Surface water quality
		Spring wetland extent and water level
	Mound springs data	Mound springs diameter, height and perimeter
		Full floristic species composition and abundances
		Population surveys for spring endemic flora species
		Population surveys for Commonwealth and State listed species
		Photographic references (photo point monitoring)
	Wetland vegetation monitoring	Identify wetland zones and their boundary locations
		Photographic references (photo point monitoring)
		Wetland vegetation species composition
		Wetland vegetation species abundances
	Threatened and endemic flora populations	Targeted surveys for threatened and endemic flora populations at each spring head in the Moses Springs-group and each springs wetland
	Weed and pest surveys	Presence of weed species and extent of coverage
		Presence of pest species and extent of disturbance
	Aquatic invertebrate communities	Characterisation of aquatic macroinvertebrate communities
		Macroinvertebrate genera and species richness
	Stygofauna	Stygofauna presence and endemicity
Mellaluka Springs-complex (**Section 9.8**)	Springs monitoring	Springs head pressure
		Surface water level
		Water quality
	Habitat features survey	Spring wetland extent
		Wetland pool depth
		Wetland vegetation zone
		Native vegetation cover

GDE	Monitoring survey	Monitoring attributes or methods
		Photographic reference (photo point monitoring)
	Aquatic invertebrate communities	Characterisation of aquatic macroinvertebrate communities
		Macroinvertebrate genera and species richness
	Weed and pest surveys	Presence of weed species and extent of coverage
		Presence of pest species and extent of disturbance
	Stygofauna	Stygofauna presence and endemicity
	Groundwater monitoring	Groundwater level and quality
	Surface water monitoring	Surface water quality
	Pre-impact condition report	Ecological condition report for the Mellaluka Springs-complex

5.4.3 Statistical Analysis

There are two key statistical analysis considerations for a monitoring program which aims to detect change:

- Statistical power required to detect a change beyond natural variations
- Level of change that is considered to be significant.

Each of these variables influence the statistical merits of a monitoring program and the degree to which monitoring objectives will be achieved. It is generally accepted that statistical power should be 0.8 or greater, meaning that there is an 80% or greater chance of detecting a change of a given magnitude when one actually occurs.

The number and location of survey sites for various indicators has been nominated where possible, based on previous knowledge of the study site and indicator (baseline studies). A power analysis will be undertaken in the early stages of data collection during the pre-impact monitoring phase, to determine if the proposed number of sites is sufficient to obtain satisfactory statistical power. If, based on the magnitude and variability of the data, more sites are required to gain sufficient statistical power, then these will be included in the pre-impact monitoring program. The timeframe over which change can be detected must be early enough to identify and minimise impacts.

It is important that the analysis of monitoring data is responsive, so that changes, if detected, can be identified early and lead to further investigation of the potential causes, and implementation of additional mitigation measures if necessary, to avoid long term impacts occurring. High replication of data increases statistical power but may also take many years to establish. While an early warning mechanism for detected change is desirable, it is also important to minimise false triggers that indicate a change when one doesn't really exist (Type I error).

In monitoring programs involving repeated measurement of environmental variables, determining the magnitude of change is also important. This GDEMP adopts a threshold of any statistically significant change in baseline and pre-impact conditions for all GDEs. Multivariate ordination analysis will be used to assess change in biological communities, where multiple variables exist.

Control charts provide a robust approach to understanding trends in parameters over time by identifying deviations beyond those that would normally be expected. This is achieved by plotting a measure through time with reference to its expected value (Anderson and Thompson 2004). Control charts have been applied to environmental monitoring for many years and allow a responsive analysis of data with identification of deviations from what would normally be expected. This involves a comparison of environmental variables with their long-term baseline, with a deviation beyond control limits signifying the need for early investigation of the possible causes.

The Queensland Government has published a guideline which illustrates appropriate methods to identify suitable test criteria for control charting (DSITI 2017). While the guideline is based on groundwater quality, the approach is relevant to ecological triggers for GDEs. The guideline notes that a defining element of a control chart is the control limits that can be used to inform or trigger management actions. Control limits need to be appropriate to provide an early warning of change. Point data can be viewed and assessed graphically over time.

An example of the application of the control chart approach is provided in **Figure 5-1**, for illustration purposes only (based on imaginary data). The control chart illustrates the area of a wetland within the Mellaluka Springs-complex. Wetland area in hectares has been calculated through field measurements and application of satellite imagery. There is some natural variation in the wetland area between the wet and dry seasons, and from year to year.

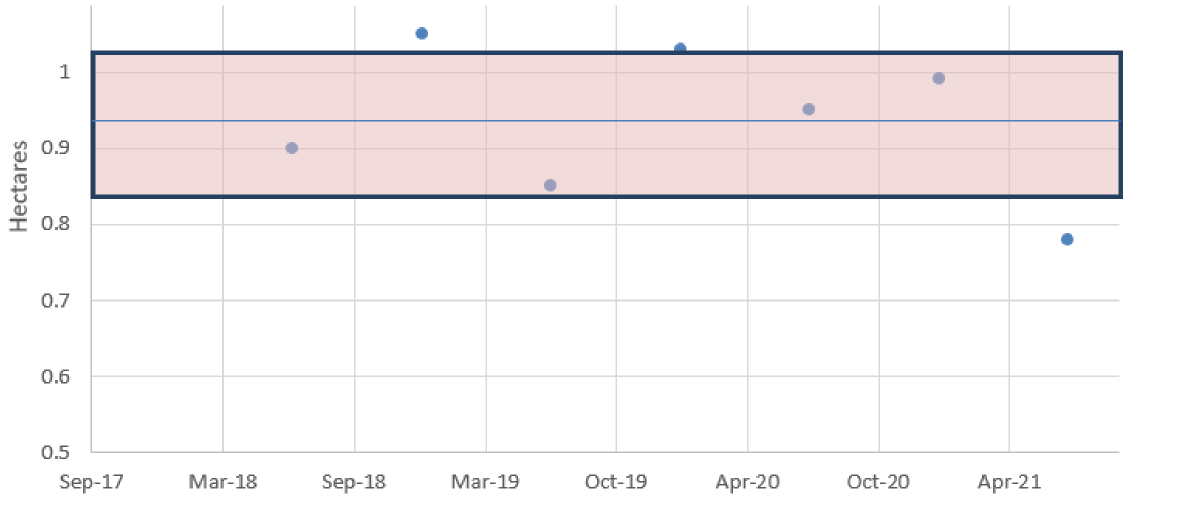


Figure 5-1: Example of application of a control chart to assess changes in ecological variables (mid-line indicates long term mean, with the limits of a statistically significant change shaded in pink)

The approach taken to the establishment of control charts and identification of control limits needs to be tailored to each environmental variable. Many aspects of the data influence the approach that should be taken to analysis, such as whether data points are normally distributed, or if outliers are present. Given that the variability of measures among sites is not necessarily reflected in their mean alone, statistical significance between baseline/pre-impact and impact will also be assessed. For unique variables such as water level or wetland extent, differences will be tested using univariate f-tests to test for homogeneity of group variances, and then t-tests to test for differences in mean values.

For related variables such as water quality or vegetation condition, a multivariate approach will be taken. Multivariate statistical techniques allow for a robust assessment of the parameters that have the greatest influence on changes in the data. They also allow for the combined effects of all variables to be considered. Multidimensional scaling (MDS) plots will be used to visually assess differences between impact and baseline data, with the significance of these differences tested using non-parametric multivariate analysis of variances (PERMANOVA). To understand which of the individual parameters are having the greatest influence on the groupings, Similarity Percentage (SIMPER) tests will be undertaken.

By combining the control charting approach with tests for statistical significance, changes to indicators over time will be effectively assessed in the context of the overall variation across the study area. If changes are noted outside the control limits (difference from baseline/pre-impact conditions) and these are statistically significant, then this is a trigger for further investigation, which would include:

- Review of groundwater data from nearby bore locations, to determine whether the reduction in wetland area is caused by a lowering of the water table
- Review of rainfall records to determine whether the reduction may be related to an unusually dry period (drought).

Details of the hypothesis being tested and statistical test for each monitoring parameter are provided in the sub-plan for each GDE.

5.4.4 Pre-impact monitoring

For the first pre-impact monitoring survey, the field team will collect information on all variables listed in this GDEMP; primarily those outlined in **Table 5-1** and additional items discussed in each GDE section regarding monitoring and management. In the event that some variables are found to be inappropriate for ongoing application (e.g. not present or unable to be collected without impacting the environment), then alternative monitoring variables will be considered. Any proposed alternative monitoring arrangements will be developed in consultation with regulatory agencies (DoEE and DES), with the plan being subsequently updated. Pre-impact monitoring, including any alternative approaches, will be undertaken prior to relevant project impacts occurring. The pre-impact monitoring, combined with completed baseline monitoring, is considered to be adequate for compiling a substantial baseline/pre-impact dataset prior to the commencement of project impacts.

Pre-impact studies will be undertaken for the Doongmabulla Springs-complex, Waxy Cabbage Palm, Carmichael River and Mellaluka Springs-complex GDEs. These studies will build on existing baseline information collected during and post the EIS and evaluate the pre-impact conditions including seasonal variations and existing threats. This monitoring will continue in conjunction with the implementation of detailed studies to characterise the GDEs' reliance on groundwater and develop triggers for impacts.

Pre-impact monitoring will be carried out until the commencement of Project impacts for each GDE. These studies will be undertaken on a seasonal basis (wet and dry season) initially. The location of pre-impact monitoring locations is described in Sections 6 to 9 for each GDE, with maps provided where appropriate. These locations will be updated in future revisions of the plan as pre-impact monitoring is completed.

Following the completion of these pre-impact surveys, the frequency of monitoring will be reviewed and ongoing monitoring data will contribute towards the development of an extended baseline for each GDE to account for temporal variations. At the conclusion of the pre-impact monitoring for each individual GDE, triggers will be reviewed and updated for inclusion in a revised GDEMP to be submitted to DoEE and DES. The conceptual model will also be revised at this time.

5.4.5 Impact monitoring

The monitoring program will continue after activities that may impact GDEs commence.

Results from this impact monitoring will be evaluated at the time of data collection to assess whether there has been any change from baseline conditions i.e. if a trigger has been exceeded. This will typically be every three months for groundwater data and every six months for ecological data. Investigations and corrective actions will be instigated promptly if a trigger is reached or exceeded. This approach will also assist in evaluating the effectiveness of mitigation measures and identify the condition of environmental values in relation to impact trigger levels. In particular, monitoring will aim to establish the EWR and ecological response of each GDE to changes in groundwater (consistent with GDE Toolbox stage 3 – see **Section 5.8** below).

In accordance with EA Condition I8, monitoring of GDEs will be undertaken over the full period of mining activities and continue for a period of five years post mining rehabilitation and for the life of the EPBC Act approval.

5.5 Ecological trigger levels

In accordance with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000, 2018), trigger levels for ecological indicators have been determined for each GDE. These are based on statistical analysis of local reference data, collected during the baseline surveys and to be further monitored during the pre-impact period. Ecological and groundwater triggers aim to provide an early detection of potential impacts prior to ecological disturbance occurring and ensure appropriate management actions to minimise impacts.

Triggers have been adopted for each GDE, based on the results of baseline surveys and condition. These triggers follow the approach outlined in Section 3.2.4.2 of the ANZECC (2000) Guidelines, which seeks to identify a statistically significant deviation from baseline conditions. Triggers will be revised in the future with the approval of the administering authorities, utilising additional monitoring data collected during the pre-impact period for each GDE.

Groundwater quality triggers have been included for each GDE in this plan, and are based on the 85th percentile in accordance with Table E2 of the EA. Triggers will be updated where appropriate at the completion of pre-impact studies and monitoring and where relevant updates are made to the GMMP. A revision of triggers will also occur when information from related management and research plans (as described in **Section 10.4**) becomes available. This GDEMP will be updated upon approval of the revised trigger levels, which will replace the previous triggers. Groundwater drawdown triggers will also provide an ‘early warning’ that changes in the groundwater environment may have occurred and that investigations into potential ecological responses must be undertaken. Surface water quality triggers have been derived from the Environmental Authority for GDEs on a mining lease and from the 80th percentile for GDEs located off-lease, consistent with the ANZECC Guidelines (2000, 2018).

Areas of high conservation value have a lower level of acceptable change arising from Project related impacts, than areas of low conservation value. Whilst a number of the GDEs currently show evidence of disturbance from human activity such as grazing and from pests such as *Sus scrofa* (Feral Pigs), the protection of listed species that depend on this environment (e.g. Waxy Cabbage Palm) should be given a high priority. In this context, the level of acceptable change applied to GDEs in the Project area is consistent with those applied to high environmental values systems (Condition 1 in ANZECC 2000 Guidelines).

Regardless of the ecosystem condition classification that may apply to the GDE, trigger levels for ecological parameters in this plan aim to detect statistically significant change ($p<0.05$) from baseline conditions at which point further investigations will be undertaken and/or corrective actions implemented. This approach recognises the conservation value of the ecosystems being monitored.

In the event that a groundwater quantity or quality trigger is met, then an investigation will be carried out to review the ecological condition of the GDEs. In the case that one or more ecological triggers are exceeded, then an investigation and corrective action process will be carried out. If required, concurrent investigation of groundwater triggers will also be undertaken as per the mechanisms detailed in the GMMP and in this plan. As environmental data is collected, control charts identifying the baseline mean and trigger thresholds will be developed and updated for each variable (see **Section 5.4** for further information).

Triggers will be updated when the conceptual understanding (e.g. source aquifer) changes, pre-impact data are collected prior to the impact haase and once Environmental Water Requirements of GDEs are known. The timing of these changes are outlined in **Appendix C**.

Ecological triggers for the Carmichael River

The following are the ecological triggers for the Carmichael River:

1. Macro-invertebrate sampling using AusRivAS methods - EPT (Ephemeroptera, Plecoptera and Trichoptera) ratios of macroinvertebrates fall below baseline values of 6.7% (Autumn) and 15.8% (Spring)
2. Reduction in riparian forest canopy cover as determined from analysis of aerial photography from period 2010 to 2018.
3. Change in the presence of native flora species recorded at monitoring sites located in the riparian zone of the Carmichael River from ecology surveys completed in Spring and Autumn 2011.
4. Weed species recorded at riparian monitoring sites on the Carmichael River that did not have that weed species recorded during ecology surveys completed in Spring and Autumn 2011.

It is anticipated that following the completion of pre-impact monitoring, additional and/or revised triggers will be derived, including:

1. Riparian community health indicators (CORVEG and BioCondition data) deviate from baseline and pre-impact conditions.
2. New population or area affected by weed or pests
3. Identification of new weed or pest species at any location along the riparian zone of the Carmichael River

Ecological triggers for Waxy Cabbage Palm (*Livistona lanuginosa*)

The following are the ecological triggers for Waxy Cabbage Palm:

1. Waxy Cabbage Palm population structure deviates significantly from following the following baseline conditions:

- Seedlings 60% of individuals
- Sub-adult 28% of individuals

- Adult 12% of individuals

2. Waxy cabbage palm population across the project area declines below a baseline population of 831 individuals.
3. Evidence of dieback or impacts to Waxy Cabbage Palm (e.g. fire damage, erosion, level of discolouration, defoliation and leaf area index)

It is anticipated that following the completion of pre-impact monitoring, additional and/or revised triggers will be derived, including:

1. Deviation in the age class structure or condition of Waxy Cabbage Palm when compared with baseline and pre-impact period
2. Deviation from baseline conditions of riparian community health (CORVEG surveys)
3. Increase in weed cover, pests or pest activity above baseline and pre-impact period (within the transect / survey areas on the mining lease only)
4. Identification of new weed or pest species.

Ecological triggers for the Mellaluka Springs-complex

The following are the ecological triggers for Mellaluka Springs-complex:

1. Reduction in wetland area as determined from analysis of aerial photography from period 2010 to 2018.

It is anticipated that following the completion of pre-impact monitoring, additional and/or revised triggers will be derived, including:

1. Deviation from baseline conditions in wetland pool depth (measured from a specific site in each pool for consistency)
2. Deviation of from baseline conditions in wetland vegetation zone margins (e.g. area of free-standing water, proportion of wetland that is saturated, damp or dry – measured using a soil moisture probe)
3. Deviation from baseline conditions in the cover of native wetland vegetation (area covered by vegetation type).

Ecological triggers for the Doongmabulla Springs-complex

The following are the ecological triggers for Doongmabulla Springs-complex:

1. Absence of GAB spring endemic species observed in Moses Spring in 2012 and 2013 baseline surveys:

- *Eriocaulon carsonii*
- *Eryngium pinnatifidum*
- *Hydrocotyle dipleura*

- *Myriophyllum artesium*
- *Sporobolus pamelae*
- *Sporobolus partimpatens*

2. Reduction in wetland area as determined from analysis of aerial photography from period 2010 to 2018.

It is anticipated that following the completion of pre-impact monitoring, additional and/or revised triggers will be derived, including:

1. Deviation from baseline Spring wetland extent
2. Deviation from baseline conditions of mound springs characteristics (maximum diameter, height, perimeter length, full floristics species composition and abundance, abundance of spring endemic flora species, abundance of threatened species)
3. Deviation from baseline conditions of wetland vegetation characteristics (area of wetland zones, vegetation species composition and vegetation species abundance)
4. Deviation from baseline conditions in the number and abundance of threatened and endemic flora species
5. Deviation from baseline conditions of aquatic invertebrate communities (utilising AusRivAS protocols).

5.6 Investigations and corrective actions

In the event that a trigger is reached or exceeded, an investigation into the potential cause will be initiated within 14 days of the detection. **Sections 6** to **9** provide specific details of the investigation process that will be followed for each GDE and what corrective actions will be taken, should it be found that mining activities have contributed to reaching or exceeding the trigger.

As a guide, the following approach will generally be applied and tailored to the environmental variables of interest:

- Notification of DoEE and/or DES that an exceedance has occurred
- Development of a decision tree model (before any investigation) for the possible effect of mining activities on the measured variable. This will involve developing a conceptual decision tree using all of the information available at the time of the investigation, to identify the potential 'root cause/s' of the observed result
- A detailed review of all existing data relevant to the environmental parameter will be completed, to quantify the nature, magnitude and reliability of the observed result
- Site-specific investigations will be implemented involving the collection and interpretation of additional data
- A review will be completed of relevant data related to potential non-mining causes of variability in environmental variables (e.g. climatic data). This will seek to either identify or rule out the contribution of non-mining activities to the identified trigger exceedance
- A detailed model of relevant environmental variables will be developed
- Expert opinion on the potential for environmental harm will be sought.

Data that will be collected during an investigation, specific to each GDE, is provided in **Sections 6** to **9**. The investigation process should not delay the implementation of corrective actions, once identified, and should be completed as soon as possible, within a maximum period of three months.

If the investigation determines that the exceedance is caused by mining activities, the administering authority will be notified within 28 days of the detection.

Corrective actions have been developed to reduce the effect of any mining related activity, based on the findings of the investigation. Corrective actions are tailored to the particular environmental variables or trigger levels of relevance, and include:

- A review of mitigation measures and the implementation of additional or more effective controls
- Implementation of additional monitoring to assess the effectiveness of mitigation measures and corrective actions
- Actions that prevent the occurrence of impacts beyond those that are approved
- Notification of relevant managing agencies and a revision to the BOS will be proposed if an increased impact cannot be avoided.

5.7 Reporting

Reports will be provided regularly throughout the implementation of this GDEMP and include:

- An annual report of the findings of this GDEMP, including all monitoring results and interpretations (e.g. the results from first year of pre-impact monitoring and proposed amendments to triggers)
- Any investigations and assessments into unexpected impacts, if authorised unavoidable impacts are exceeded or if trigger levels are exceeded as a result of mining activities
- Notification to the Commonwealth and State governments within five business days of identifying any GDE not previously identified and reported in the Project Area and within 20 business days report how the conditions of approval will still be met.

In the event that a new listed species or TEC that is groundwater dependent is found, then DoEE and/or DES will be notified within five business days and Adani will outline how the conditions of the relevant approval will still be met within 20 business days. This will include updating the relevant management plan (e.g. threatened species management plan) for re-assessment, based on the new information. Changes may also be required to the offsets strategy. Endemic species found in areas outside of the direct disturbance area (and therefore subject to potential future impacts from groundwater drawdown) will be included in annual reporting, with recommendations for updates to this plan, to mitigate the impacts of groundwater drawdown.

See **Section 10.3** and each GDE sub-plan for full reporting details. All reports will be made available to the administering authority.

5.8 Consistency with GDE Toolbox approach

The approach described above was informed by and is consistent with the GDE Toolbox, as described below.

5.8.1 GDE Toolbox Stage 1 – GDE location, classification and conceptualisation

GDE Toolbox Stage 1 assessments focus on developing a baseline understanding of where GDEs exist, classification of ecosystem type and conceptualisation of the ecohydrogeologic setting (Richardson et al. 2011a). For this GDEMP, this work was largely completed prior to and after the EIS and includes baseline studies of the Doongmabulla Springs-complex, Mellaluka Springs-complex, Carmichael River and the

Waxy Cabbage Palm. This work will continue through pre-impact stages of the Project and involves the refinement of groundwater models that underpin each GDE and wil be informed and tested through the activities under the GMMP. This work will build upon the studies and models completed during the EIS and include a gap analysis to identify additional survey requirements. These tasks are described in further detail within each sub-plan.

GDE Toolbox Stage 1 assessments aim to determine the reliance of groundwater for Type 2 GDEs by considering the following questions:

- Does a stream / river continue to flow all year, or does a floodplain waterhole remain wet all year in dry periods?
- Does the volume of flow in a stream / river increase downstream in the absence of inflow from a tributary?
- Is the level of water in a wetland maintained during extended dry periods?
- Is groundwater discharged to the surface for significant periods of time each year at critical times during the lifetime of the dominant vegetation type?

For Type 3 GDEs, the following questions are to be considered:

- Is groundwater or the capillary fringe above the water table present within the rooting depth of any vegetation?
- Does a proportion of the vegetation remain green and physiologically active (principally, transpiring and fixing carbon, although stem-diameter growth or leaf growth are also good indicators) during extended dry periods?
- Is the level of water in a wetland maintained during extended dry periods?

This is achieved in the GDEMP by connecting each GDE with the current groundwater conceptual model that will be further informed and tested through the activities under the GMMP.

5.8.2 GDE Toolbox Stage 2 – Characterisation of groundwater reliance

GDE Toolbox Stage 2 assessments aim to characterise potential reliance of the GDE on groundwater. Key questions that need to be considered at this stage are:

- Is groundwater part of the ecosystem?
- How reliant is the system on groundwater (Richardson et al. 2011a)?

To determine the groundwater interactions and dependency for each GDE, collection of time-series data is required to quantify the seasonal use of groundwater. The timing of groundwater use by each of the GDEs is aconsideration in the development of EWRs (Richardson et al. 2011a). A continuous supply of groundwater is essential for the Doongmabulla Springs-complex, and near-continuous groundwater contributions to the Carmichael River base flow are likely to be required. Groundwater contributions to various life-stages for Waxy Cabbage Palm are currently uncertain, however the species is assumed to have some reliance on shallow groundwater sources.

Water balance modelling can also assist in determining whether groundwater is used by vegetation, by providing an understanding of the balance between rainfall, evapotranspiration (ET) and available soil moisture within the root zone. For instance this approach may be particularly beneficial for assessing groundwater dependency for Waxy Cabbage Palm through evidence such as pre-dawn leaf water potential measurements and use of stable isotopes of water analysis, to determine whether a groundwater ‘signature’ exists within the plant xylem (Richardson et al. 2011a).

Additional questions that are to be considered for Type 2 GDEs in Stage 2 assessments include:

- Is the vegetation associated with surface discharge of groundwater different (in terms of species composition, phenological pattern, leaf area index or vegetation structure) to vegetation nearby that is not thought to access groundwater?
- Is the annual rate of water use by the vegetation significantly larger than annual rainfall at the site and the site does not receive overland flow?
- Are plant water relations (especially pre-dawn and midday water potentials and transpiration rates) indicative of lower water stress (potentials close to zero, transpiration rate larger) than for vegetation nearby not accessing groundwater?
- Is occasional (or habitual) groundwater release at the surface associated with key developmental stages of vegetation (such as flowering, germination, seedling establishment)?

For Type 3 GDEs the following questions are to be considered during Stage 2:

- Within a small region (and thus an area having the same rainfall and same temporal pattern of rainfall across its entirety), and in an area that does not receive overland flow and has no access to stream or river water, do some ecosystems show large seasonal changes in leaf area index while others do not?
- Is the vegetation associated with surface discharge of groundwater different (in terms of species composition, phenological pattern, leaf area index or vegetation structure) to vegetation nearby that is not thought to access groundwater?
- Are seasonal changes in groundwater depth larger than can be accounted for by the sum of lateral flows and percolation to depth (that is, is vegetation a significant discharge path for groundwater)?

GDE Toolbox Stage 2 assessments are analagous to the continued development of an extended set of pre-impact data for GDEs . The pre-impact monitoring will aim to quantify the EWRs for each GDE, and will include a review of triggers based on more comprehensive data and knowledge of each of the GDEs.

Concurrent activities through the GMMP will also be undertaken to link changes in groundwater condition (e.g. drawdown of groundwater levels, saline water intrusion) with the driver of the threat (e.g. groundwater abstraction, drought, or land-use change). Modelling approaches should also take into account potential interaction between surface water features and groundwater. It is critical that the scale of groundwater modelling is commensurate with the temporal and spatial scale of occurrence of the GDE, as often the ecohydrogeologic analysis requires greater resolution than is available from many groundwater modelling approaches used to support regional management of groundwater systems. Multiple scales of models may be required to increase confidence (Richardson et al. 2011a).

GDE Toolbox Stage 2 activities (i.e. pre-impact monitoring) will be undertaken from the approval of the GDEMP until the commencement of groundwater drawdown impacts (the timing of which varies depending on each GDE).

5.8.3 GDE Toolbox Stage 3 – Characterisation of ecological response to change

GDE Toolbox Stage 3 involves creating a detailed and quantified understanding of the ecological and biotic responses of GDEs to fluctuations and changes in groundwater. This will be achieved through analysis of monitoring data collected over the duration of this GDEMP, including regular monitoring and research observations. This work will occur both during the pre-impact monitoring (i.e. response to natural varation in groundwater) and impact monitoring (i.e. response to mining related impacts).

Key questions in Stage 3 are:

- What are the threats to the ecosystems and species presented by changes in groundwater?
- How might the ecosystems and species respond as a result of these groundwater changes?
- Is the actual impact as predicted by the groundwater model?
- What is the long-term ecosystem state due to the change (Richardson et al. 2011a)?

GDE Toolbox Stage 3 assessments will include the continued long-term monitoring of GDEs, and will include both the pre-impact monitoring and impact monitoring, which will commence at the anticipated initiation of groundwater drawdown impacts (approximately 20 years after project commencement) and continue for the life of the mine. Monitoring will focus on the biotic responses of GDEs due to changes to groundwater conditions, and the effectiveness of management and mitigation measures (during impact monitoring stage).

6 Carmichael River

6.1 Environmental Values

6.1.1 Description

The Carmichael River is located in the upper reaches of the Belyando Basin of the Burdekin River catchment (**Figure 6-1, Figure 6-2**). The greater Carmichael River forms from the confluence of Dyllingo and Cattle Creeks, approximately 2 km upstream (west) of the mine site. It flows in an easterly direction through the southern portion of the Project area and converges 20 km downstream with the Belyando River. However, for the purposes of the EPBC Act approval, the Carmichael River is defined as the river and its riparian zone between the Doongmabulla Springs-complex and the Belyando River.

The width of the Carmichael River varies, depending on the season and quantity of water. For the purposes and description of management, monitoring and actions under this GDEMP, the width of the Carmichael River (water component) is conservatively assumed to be 20 m in total (10 m each side) from the centre line. The riparian zone, which is included in the definition of the Carmichael River for the GDEMP, is variable in width (minimum of 20 m), depending on the local topography. The area between the outer edge of the riparian zone and the 500 m buffer zone is outside the extent of the Carmichael River.

The Carmichael River is the major surface water resource which runs through the Project (Mine) Area. The flow regime of the Carmichael River is subject to seasonal variability as wet season overland flow drains from the catchment. Late in the dry season the Carmichael River is reduced to a low flow environment, interspersed with deeper pools. The Carmichael River is characterised by a well-established riparian zone that provides extensive shading of the water.

Figure 6-1 Carmichael River in May 2011 and April 2013 (GHD, 2016)

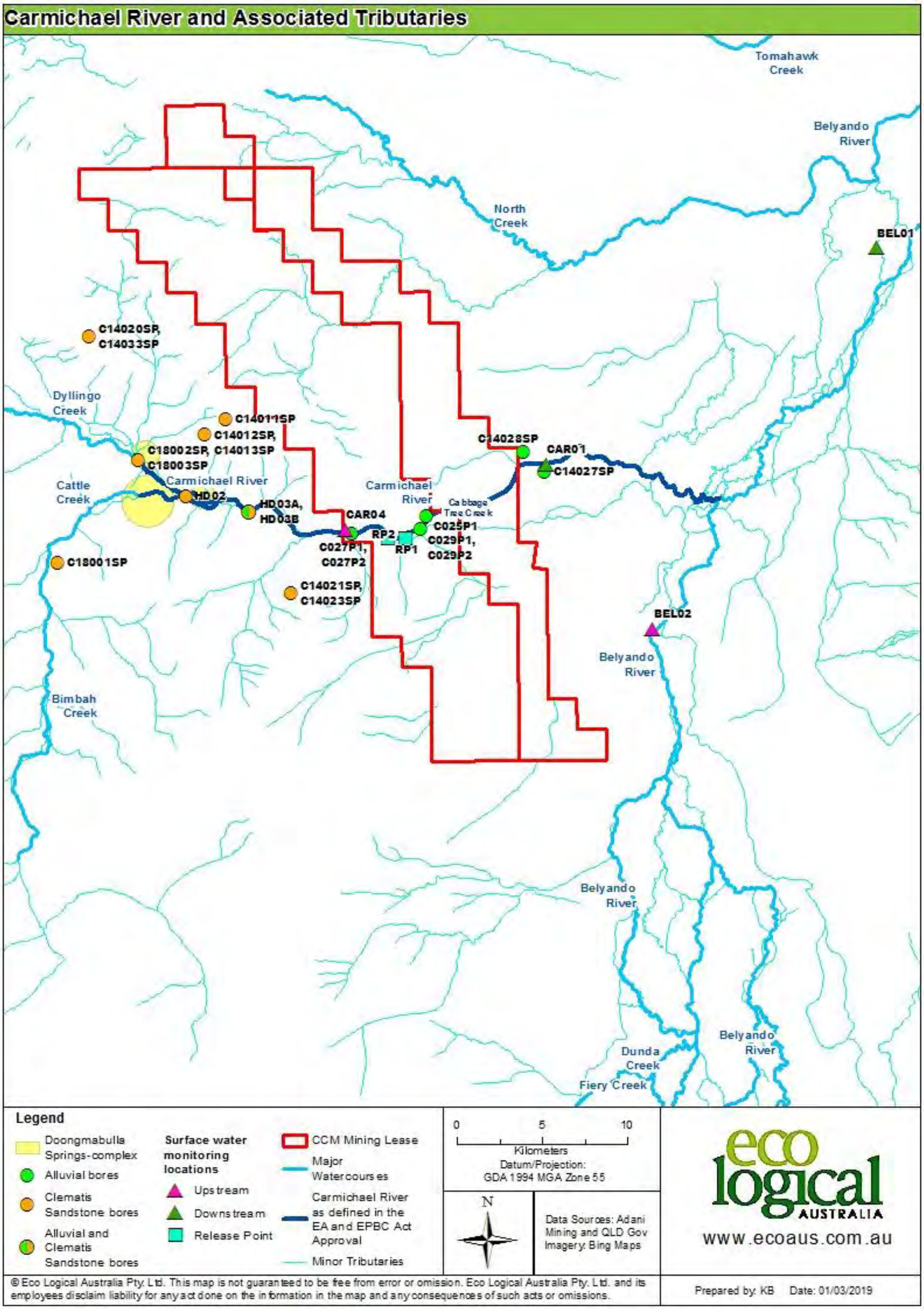


Figure 6-2 Carmichael River and Associated Tributaries

6.1.2 Ecology

The Carmichael River is typical of watercourses within the Belyando Basin, characterised by generally low relief floodplains drained by braided channels and surrounded by wide alluvial plains (GHD 2012b). The river flows through Quaternary-aged floodplain alluvium (i.e. sands, silts, gravels and clays) (URS 2014).

The Carmichael River is characterised by a well-established riparian zone that provides extensive shading of the water (GHD 2014). This riparian zone is dominated by *Eucalyptus camaldulensis* (River Red Gum), *Melaleuca leucadendra* (Weeping Paperbark) and *M. fluviatilis* (Narrow-leaved Paperbark). The Vulnerable Waxy Cabbage Palm is also present within the Carmichael River riparian community (GHD 2014).

The Carmichael River has a high diversity of instream habitat features, although the diversity and abundance of macrophytes is low, which is typical for rivers that have long dry periods interspersed by short periods of intense flow (GHD 2012b). Field assessments have recorded eleven common species of freshwater fish, and 27 families of aquatic macroinvertebrates along the Carmichael River and Cabbage Tree Creek systems in the Project area. The comparatively low macroinvertebrate assemblage recorded in the Project area is influenced by the sandy substrate of the Carmichael River (GHD 2012b).

6.2 Supporting Groundwater resources

Information on observed surface water flows, groundwater levels and a comparison of groundwater and surface water quality data for the Carmichael River demonstrates that flows and/or water levels are at least partly supported by direct groundwater flow from the underlying units (Alluvium) or by discharge from the Doongmabulla Springs-complex (**Figure 6-3**). This suggests that Carmichael River and the associated remnant riparian vegetation are groundwater dependent to a degree and consequently the fauna which are attracted to these areas are also thought likely to be dependent on groundwater, but indirectly.

Flow in the Carmichael River is subject to strong seasonal variability, with the average base flow peaking at around 4,500 m^3/day at a point approximately 7 km upstream of the western boundary of the Project area (GHD 2015). The Carmichael River provides aquatic habitat throughout the year. In the wet season, there can be high overland flows that drain from the catchment, while during the dry season the river becomes a low-flow environment which is characterised by interspersed pools in deeper sections of the stream bed (GHD 2014) that are linked to groundwater from the surrounding alluvium. It is important to note that base flow to the river will naturally vary, is seasonally affected and that current model predictions are effectively long-term averages. It is normal for base flow to fluctuate and for many sections of the river to have periods of zero base flow – for example, late in the dry season, or during droughts. Modelling has shown that zero base flow periods occur approximately 30% of the time in the vicinity of the eastern mine boundary.

Model results suggest the Carmichael River predominantly upstream of the western boundary of the Mine Area is considered to be a ‘gaining’ section (**Figure 6-4**), which is consistent with groundwater level and surface water flow observations at the site.

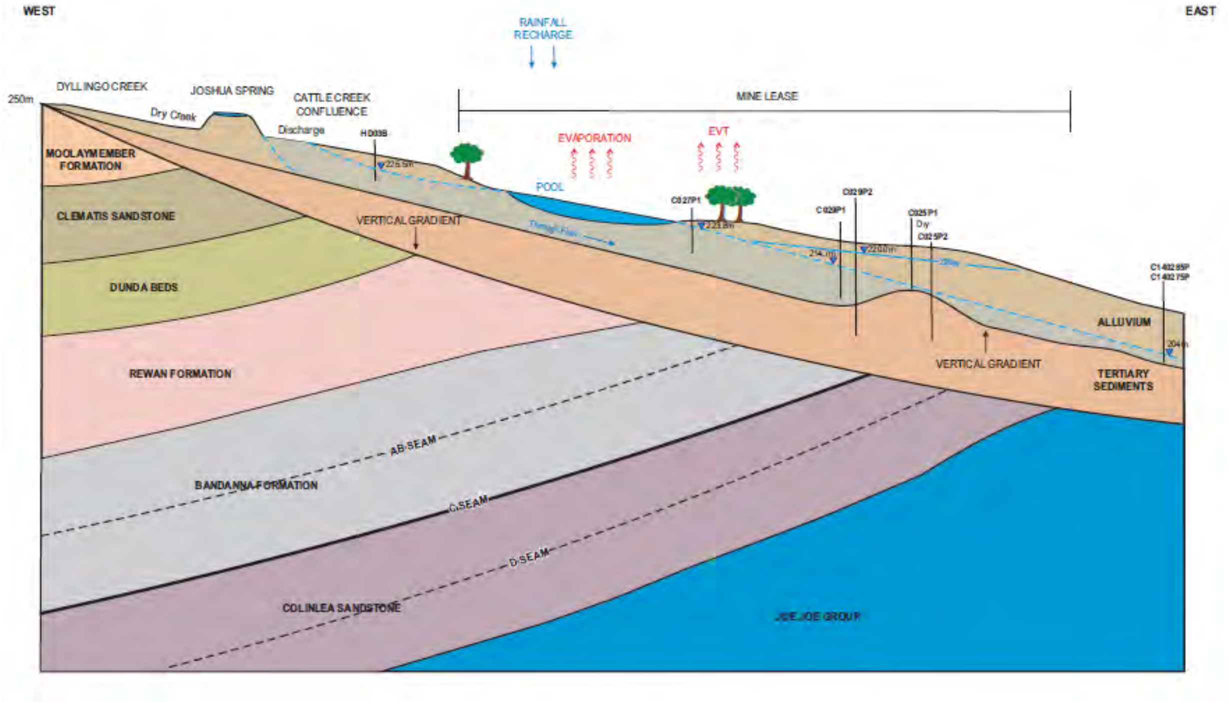


Figure 6-3 Conceptual model of Carmichael River

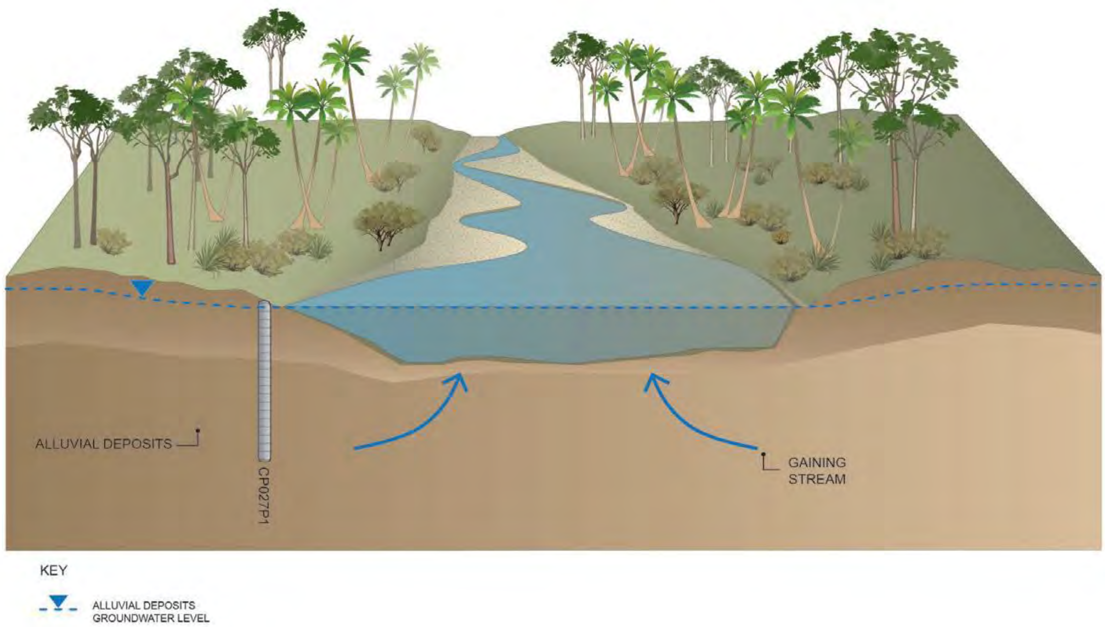


Figure 6-4 Gaining Section of the Carmichael River

Pre-development groundwater flow modelling results suggest that the Carmichael River switches from generally gaining flow to losing flow at a point just east of the western boundary of the Mine Area (**Figure 6-5**). This conclusion is consistent with groundwater level and surface water flow observations at the site. Between that location and the eastern Mine Area boundary, predicted pre-construction long-term average base flow gradually reduces to around 3,150 m^3/day and groundwater levels have been measured around 4.5 m below the channel bed.

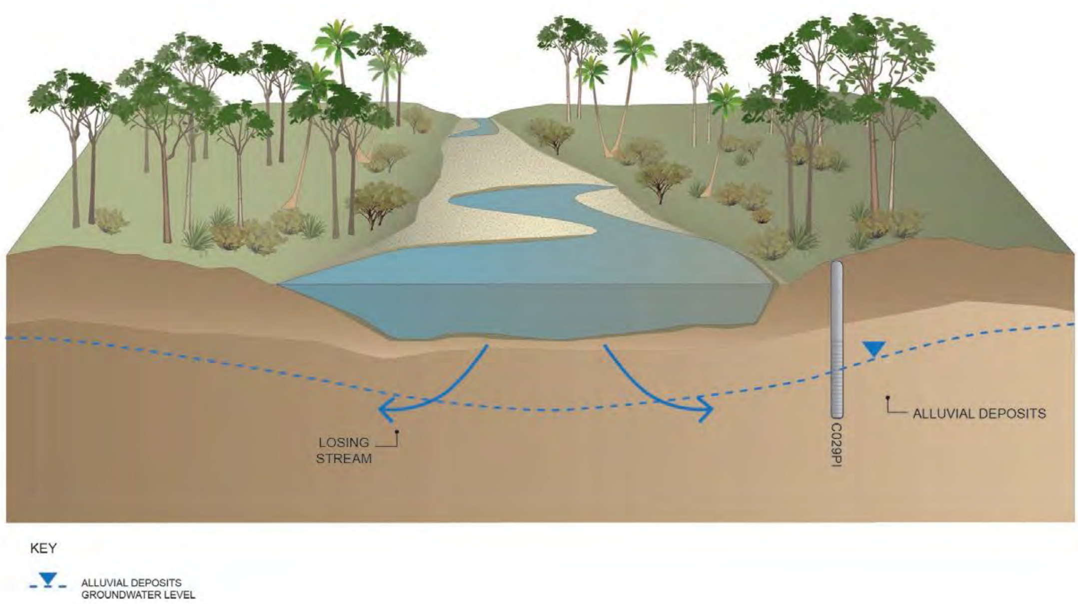


Figure 6-5 Losing Section of the Carmichael River

6.3 Summary of baseline monitoring results

6.3.1 Surface Water

The Carmichael River, designated as a fifth order stream (DERM, 2009c) (Plate 24), is a surface water resource potentially affected by the Project (Mine). The flow regime of the Carmichael River is subject to seasonal variability as wet season overland flow drains from the catchment. Late in the dry season the Carmichael River is reduced to a low flow environment, interspersed with deeper pools. The Carmichael River is characterised by a well-established riparian zone that provides extensive shading of the water.

Flows in the Carmichael River in the vicinity of the mine are understood to be relatively persistent where located within the mining lease. This suggests that Carmichael River and the associated remnant riparian vegetation are groundwater dependent to a degree in the regions upstream of the Project (Mine). Consequently, the fauna which are attracted to these areas are also thought likely to be indirectly dependent on groundwater to a degree.

Information on observed surface water flows, groundwater levels and a comparison of groundwater and surface water quality data for the Carmichael River suggests that flows and/or water levels are at least partly supported by direct groundwater flow from the underlying units and/or by discharge from the Doongmabulla Springs-complex (GHD 2013b).

The Carmichael River is considered to be a slightly-moderately disturbed (SMD) ecosystem under the ANZECC (2000, 2018) Guidelines. The catchment area associated with the description of the Carmichael River as a GDE includes significant grazing and agricultural activity over many years. Additionally, the river is directly used for stock water and has a number of private and public road crossings.

Adani undertook baseline surface water quality and flow monitoring at a number of locations from 2011 through to 2014, documented across the EIS technical reports through to 2014.

No historical stream gauge data existed within the Carmichael River at the time of the EIS. During the EIS, field work was undertaken to support existing technical knowledge. Two surface water monitoring stations were established for the mine project area which recorded water levels and flows at approximately the upstream and downstream boundaries of the study area. These were placed within the mining lease boundary on the Carmichael River.

These monitoring stations commenced monitoring in July 2011, however, during this period limited flows were experienced. Records from December 2011 at the upstream gauge are missing due to equipment failure. Field inspection of downstream gauge from August 2012 indicated that water level and flow were logged incorrectly. A field-based water and in-stream sediment quality assessment was undertaken from April to September 2011 to characterise the quality of the surface water resources within the Study Area.

A hydrograph of the flow data collected to date, 28 July to 10 November 2011, is shown in **Figure 6-6**. It should be noted, however, that the estimates of flow were based on a stage discharge relationship derived from a single flow gauging event. As such, observed flow data for these gauges should be treated with some caution.

Nevertheless, the flow data suggested the following:

- Continuous flow has been observed at the upstream gauge despite rainfall being limited to two events in late August and early November. This suggests that groundwater discharge to the

Carmichael River upstream of the Study Area is occurring and is consistent with the upward gradient observed at a site close to the western margin of the lease

- Apparent flow losses between the upstream and downstream gauges during dry periods. This is consistent with the downward gradient observed from river bed to groundwater at sites close to the eastern margin of the lease.
- An alternative explanation for the observations at that time, which has now been confirmed, is that dry season flows in the Carmichael River are supported primarily by discharges from the Doongmabulla Springs-complex and that direct groundwater discharge to the river itself is negligible.

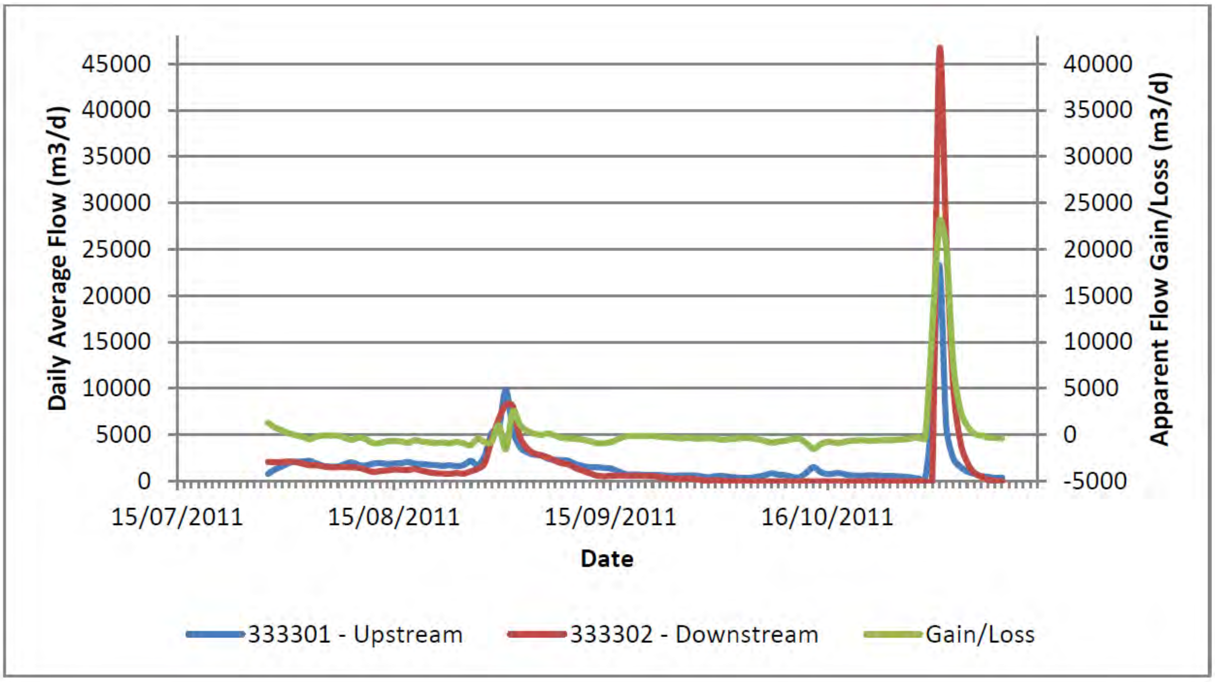


Figure 6-6 Surface water flows and losses in the Carmichael River (EIS)

Local water quality objectives were derived from this data set to inform surface water monitoring requirements under the Environmental Authority (EA) for the project (EMPL01470513 – Carmichael Coal Mine). These have been further developed through the REMP (**Table 6-1**), and any updates to the REMP will also be integrated into this GDEMP to reflect the environmental values of the river.

Table 6-1 Water quality objectives for the Carmichael River (REMP)

Parameter	Unit	Selected WQO	Source of WQO
pH	pH units	6.5-8.5	Queensland Water Quality Guidelines
Electrical Conductivity	µS/cm	1300	Carmichael River 80th percentile
Turbidity	NTU	130	Carmichael River 80th percentile
Total Suspended Solids	mg/L	106	Carmichael River 80th percentile
Ammonia – N	µg/L	900	Environmental Authority
Nitrate	µg/L	1100	Environmental Authority
Total N	µg/L	590	Environmental Authority
Total P	µg/L	200	Environmental Authority
Fluoride	µg/L	2000	Environmental Authority
Sodium	µg/L	232	Carmichael River 80th percentile
Sulphate	µg/L	129	REMP
TPH (C6-9)	µg/L	20	Environmental Authority
TPH (C10-36)	µg/L	100	Environmental Authority
Dissolved metals			
Aluminium	µg/L	212	Carmichael River 80th percentile
Arsenic	µg/L	13	ANZECC (2000, 2018)
Boron	µg/L	370	ANZECC (2000, 2018)
Cadmium	µg/L	0.2	ANZECC (2000, 2018)
Chromium	µg/L	2	Carmichael River 80th percentile
Cobalt	µg/L	90	Environmental Authority
Copper	µg/L	4	Carmichael River 80th percentile
Iron	µg/L	580	Carmichael River 80th percentile
Lead	µg/L	4	Environmental Authority
Manganese	µg/L	1900	ANZECC (2000, 2018)
Mercury	µg/L	0.2	Environmental Authority
Molybdenum	µg/L	34	Environmental Authority
Nickel	µg/L	11	ANZECC (2000, 2018)
Selenium	µg/L	10	Environmental Authority
Silver	µg/L	1	Environmental Authority
Uranium	µg/L	1	Environmental Authority
Vanadium	µg/L	10	Environmental Authority
Zinc	µg/L	8	ANZECC (2000, 2018)

The water quality sampling site locations (see **Section 6.6**) are consistent with Table F6 in the EA. The locations of sites were selected by considering historic data, position in relation to surrounding land uses, representativeness, accessibility, and the QWQG (DEHP 2009) reference site criteria for physio-chemical indicators in freshwater. Further background and rationale is provided in the REMP.

Surface water sampling was initially undertaken in 2009 as part of the EIS studies. In 2012, water sampling commenced on a regular basis in order to achieve a representative dataset of the river system. The ANZECC Guidelines (2000, 2018) and QWQG (DEHP 2009) recommend that for the purpose of collecting data:

a) a minimum of 18 samples and preferably two years of continuous monthly data be collected;
b) data should characterise seasonal variations; and
c) guidelines should be based on dissolved concentrations to allow better estimation of metals in their bioavailable forms.

In the period 2011 to 2014, a water sampling program was implemented. Due to access constraints in wet weather conditions, the majority of samples were collected during no or low flow conditions, creating a data set biased towards standing and low flow conditions characterised by higher electrical conductivity, low turbidity and total suspended solids, and potentially lower metal concentrations due to low TSS. Automatic samplers were installed at several sites to ensure that samples could be collected during medium and high flow conditions.

Parameters analysed as part of the surface water monitoring program displayed both spatial and temporal variations. Spatial patterns were consistently related to the differences between the types of water resources (Carmichael River versus non-flowing environments). Sites sampled along the Carmichael River displayed little spatial variation, indicating that the results obtained from the monitoring program are fairly typical of that stretch of the river. Temporal patterns at the Carmichael River sites were related to seasonal variability associated with the influx of overland flows prior to the start of the monitoring program, and subsequent drying of the water resources as the dry season progressed. All monitoring was undertaken in low-flow conditions.

The Carmichael River displayed high turbidity at the start and end of the monitoring program. This has been attributed to the increase of overland flow input of fine sediments (associated with preceding rainfall events) at the start of the monitoring program, and re-suspension of sediments in shallower waters at the end of the monitoring program. Dissolved oxygen concentrations in the Carmichael River were relatively low throughout the monitoring program. These low values are likely associated with the low flow conditions experienced for the majority of the program. The waters of the Carmichael River displayed an alkaline pH throughout the monitoring program.

6.3.2 Structure and Habitat

The section of the Carmichael River between the western edge of the mining lease and the Doongmabulla Springs-complex is characterised by the following values:

- Meandering river with some braided areas, the width of the channel is from 1 to 8m
- There is evidence of high flows with debris high up in trees
- There is a well-established riparian zone, a minimum of 20 metres wide
- The depth of the river varies from 10cm to 2m
- Generally, the river is highly shaded, and very turbid during wet season flows
- No in-stream vegetation and limited substrate variation (sand)

- Habitat for turtles, fish, crustaceans and macroinvertebrates.

The section of the Carmichael River between the western edge of the mining lease and the eastern edge of the mining lease is characterised by the following values:

- Meandering river with some braided areas, the width of the channel is from 1 to 8m, isolated pools in the dry season
- There is evidence of high flows with debris high up in trees
- There is a well-established riparian zone, a minimum of 20 metres wide
- The depth of the river varies from 10cm to 1m
- Generally, the river is highly shaded, and very turbid during wet season flows
- No in-stream vegetation and limited substrate variation (sand, silt/clay)
- Habitat for turtles, fish, crustaceans and macroinvertebrates

The section of the Carmichael River between the eastern edge of the mining lease and the confluence with the Belyando River is characterised by the following values:

- Meandering river with some braided areas, the width of the channel is from 1 to 8m, isolated pools in the dry season
- There is evidence of high flows with debris high up in trees
- There is a well-established riparian zone, a minimum of 20 metres wide
- The depth of the river varies from 10cm to 2m
- The river is less shaded than upstream
- No in-stream vegetation and limited substrate variation (sand, silt/clay)
- Habitat for turtles, fish, crustaceans and macroinvertebrates.

6.3.3 Flora and Fauna - Aquatic

All of the fish recorded are common freshwater species previously recorded in the upper Burdekin Catchment. No conservation significant species were detected during the field survey. *Ambassis agassizii* (Agassiz's Glassfish) and *Hypseleotris* species 1 (Midgley's Carp Gudgeon) were the most commonly recorded species during field surveys. Other species captured included *Mogurnda adspersa* (Purple-spotted Gudgeon), *Oxyeleotris lineolata* (Sleepy Cod), *Melanotaenia splendida splendida* (Eastern Rainbowfish), *Neosilurus hyrtlii* (Hyrtl's Tandan), *Leiopotherapon unicolor* (Spangled Perch), *Amniataba percoides* (Barred Grunter), *Craterocephalus stercusmuscarum* (Fly-speckled Hardyhead), *Hypseleotris klunzingeri* (Western Carp Gudgeon) and *Nematalosa erebi* (Bony Bream). No pest fish species were detected during field surveys and no previous records were identified within 50 km of the Study Area.

The sandy habitats within the Carmichael River are generally ephemeral or recorded little or no macrophytes. Whilst the river may be suitable habitat for the *Emydura macquarii krefftii* (Krefft's River Turtle), it is not expected to provide habitat for the *Elseya irwini* (Irwin's turtle).

Whilst the Carmichael River provides suitable habitat for *Ornithorhynchus anatinus* (Platypus), they were not observed and the ephemeral nature of the river and lack of suitable permanent water sources suggest that they are unlikely to occur in the river.

Invertebrates were detected during field surveys during fish trapping and as part of the targeted aquatic macroinvertebrate sampling techniques. Trapping (bait traps) during field surveys detected *Cherax* *quadricarinatus* (Redclaw) within the Carmichael River. Macroinvertebrate sampling was undertaken at three locations along the Carmichael River in pre-wet and wet seasons. A total of 230 individuals were collected from 41 families of aquatic macroinvertebrates across the five sites sampled. The highly variable and unpredictable environmental conditions of the river systems represented in the Burdekin Catchment are reflected in the relatively low macroinvertebrate diversity.

The amphibian diversity was dominated by genus *Litoria* (common tree frogs) and genus Cyclorana (burrowing frogs) from the family *Hylidae*, and genera *Limnodynastes*, *Platyplectrum*, *Uperoleia* (ground-dwelling frog)s from the family *Myobatrachidae*. Species diversity was typically higher in those habitats near waterbodies (i.e. Carmichael River, ephemeral waterways, and gilgais). The most abundant species were the *Platyplectrum ornatum* (Ornate Burrowing Frog), *Limnodynastes tasmaniensis* (Spotted Grass Frog) and *Rhinella marina* (Cane Toad).

6.3.4 Flora and Fauna - Terrestrial

The Carmichael River channel is dominated by River Red Gum and Weeping Paperpark (RE 10.3.13) with some smaller patches of regional ecosystem 10.3.14. One threatened plant species has been recorded within the Carmichael River, being the Waxy Cabbage Palm, listed under both the EPBC Act and NC Act. Chapter 7 of this plan describes specific management and monitoring for this species.

The Carmichael River provides notable arboreal mammal habitat where mature River Red Gum trees supportes a relatively large number of hollows of varying sizes. Mammal surveys recorded species in proximity to the Carmichael River including *Aepyprymnus rufescens* (Rufous Bettong) and *Isoodon macrourus* (Northern Brown Bandicoot). This habitat may also be suitable for Koala noting that only one individual was sighted in the proejct area during baseline surveys.

6.3.5 Pests and Weeds

No aquatic pest species were noted during baseline assessments. The Cane Toad was recorded across the mining area.

Aquatic weeds were noted in additional assessments conducted further upstream at the Doongmabulla Springs-complex associated with the Joshua Springs-group.

Terrestrial weeds were noted across the mining lease area, those recorded in proximity to the Carmichael River included:

- *Parthenium hysterophorus* (Parthenium) – Category 3 restricted matter under the Queensland Biosecurity Act 2014 (Biosecurity Act) and Weed of National Significance (WoNS);
- *Opuntia stricta* (Prickly Pear) – Category 3 restricted matter and WoNS;
- *Cryptostegia grandiflora* (Rubber Vine) – Category 3 restricted matter and WoNS;
- *Xanthium pungens* (Noogoora burr).

There is evidence of Feral Pig disturbance along the Carmichael River and bank disturbance associated with cattle accessing the river for drinking.

6.4 Threats and impacts

Threats and potential direct / indirect project impacts that are required to be addressed, as they apply to the Carmichael River on the Project Area are identified via the following:

- EIS (GHD 2012b; GHD 2013a; GHD 2013b; GHD 2014)
- EPBC Approval 5736, condition 6(c)
- Environmental Authority EPML01470513, condition I14 and Appendix 1, definition “GDEMP”, subsection (5).

Also, the Carmichael River is considered a “watercourse” as defined under the *Water Act 2000*, however, the project does not propose to divert the river, and the legislation is not triggered.

The potential impacts on the Carmichael River due to the construction and operation of the mine are:

- a 33% reduction in surface water discharged into the Carmichael River, due to loss of 16,664 ha of the catchment (see EIS for further details)
- changes to surface and groundwater flows into the Carmichael River
- altered stream morphology from scouring and sediment deposition, leading to degradation of aquatic habitat quality
- reduced bank stability due to construction activities and alterations in surface water flows
- degradation of water quality due to sedimentation and changes in river water properties (e.g. pH, dissolved oxygen, turbidity)
- loss, degradation and fragmentation of aquatic and riparian habitat
- potential introduction and / or spread of aquatic and riparian weeds
- potential introduction and / or spread of aquatic and riparian pests such as *Gambusia* spp. (Mosquitofish), Cane Toad, Feral Pigs and *Oryctolagus cuniculus* (Rabbits)
- changes to fire regimes increasing the susceptibility of riparian vegetation to hot and destructive bush fires
- water contamination from chemicals, heavy metals, and nutrients
- potential obstruction of fish passage.

The EIS identified that infrastructure construction works to be undertaken within the Carmichael River floodplain will likely directly impact the Carmichael River. The relevant infrastructure construction works consist of:

- A bridge over the Carmichael River to convey the haul road and conveyors during the construction project phase
- Mine protection flood levees on the northern and southern banks of the River during the construction project phase (**Figure 6-7**).

The EIS idenfitied the following indirect impacts to the Carmichael River as a result of the construction and operation of the Project (Mine) are:

- Alterations to the surface and groundwater regime
- Aquatic habitat degradation
- Water quality degradation
- Introduction or spread of aquatic and terrestrial weed and/or pest species to Project (Mine) Area
- Changes to fire regime.

The EPBC Approval 5736, condition 6(c) requires the following additional potential threats and impacts be addressed by this plan:

i. Vegetation clearing
ii. Subsidence from underground mining
iii. Mine dewatering
iv. Earthworks
v. Noise and vibration
vi. Emissions (including dust)
vii. Light spill and other visual impacts
viii. Stream diversion and flood levees
ix. Weeds and pests.

Environmental Authority EPML01470513, condition I14 and Appendix 1, definition “GDEMP”, subsection (5) requires this plan must include a “description of the potential impact on each GDE from each project stage including impacts from subsidence, mine dewatering of aquifers, water discharge, hydrological changes and weed and pest infestation.

The key threats and potential direct / indirect project impacts identified for the Carmichael River are relevant to the Project and are detailed in the following **Table 6-2** and sections.

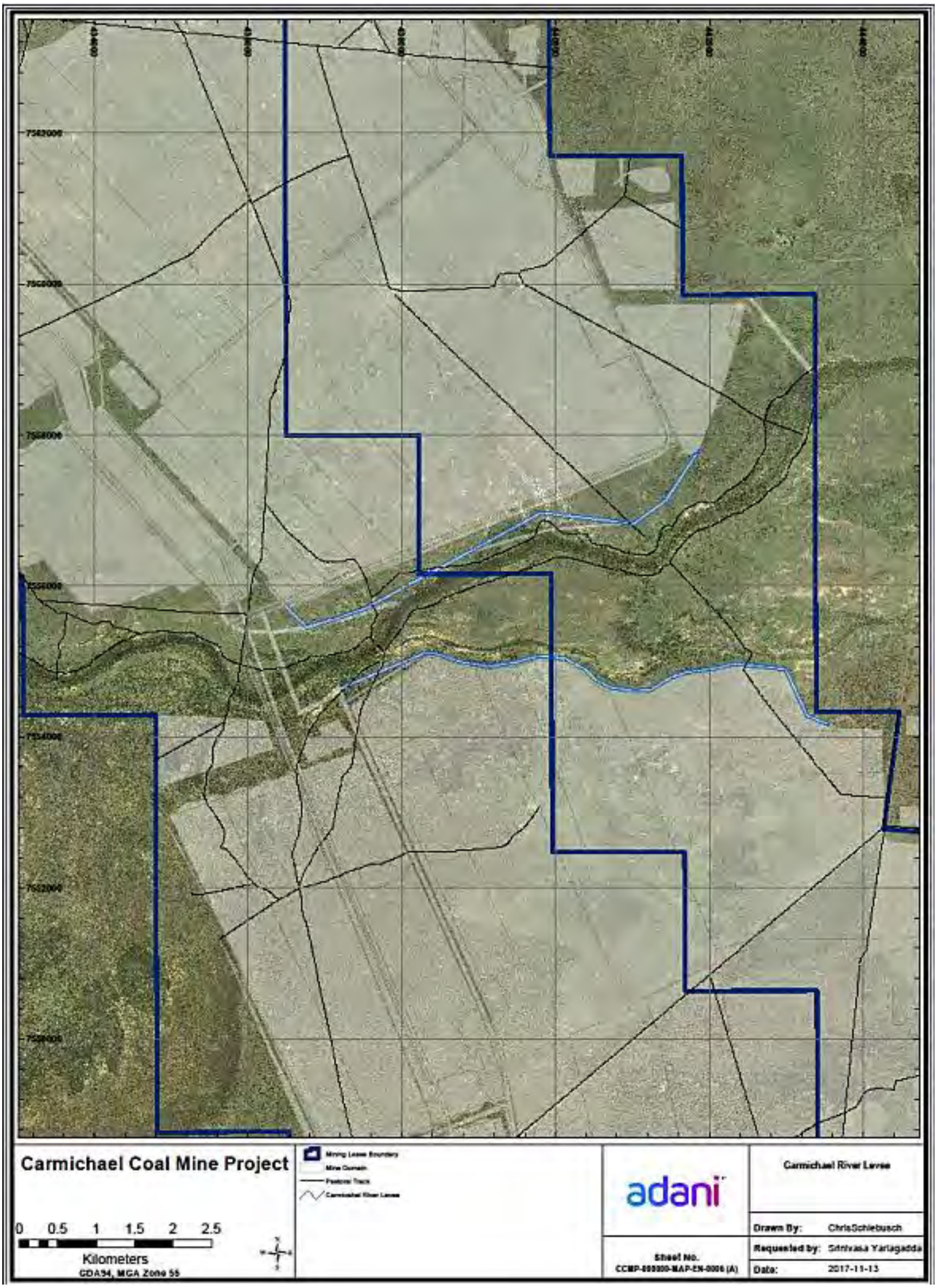


Figure 6-7 Levees to be constructed on the northern and southern sides of the Carmichael River

Table 6-2 Carmichael River threats, potential direct / indirect project impacts and matters required to be addressed by conditions

#	Potential Threat or Impact	Potential direct project impact identified in EIS (GHD, 2014)	Potential indirect threat or impact identified in EIS (GHD, 2014)	EPBC Approval 2010/5736, condition 6	Environmental Authority condition I14 and Appendix 1, Definition of "GDEMP"	Project Phase/s*	Earliest predicted potential impact	Table
1	Groundwater drawdown from mine dewatering	-	Yes	(c)(iii)	(5)	Operations Rehabilitation	Year 15	
2	Subsidence from underground mining	-	-	(c)(ii)	(5)	Operations Rehabilitation	*Not predicted*	
3	Changes to surface water flows and flooding, including water discharge	Yes	Yes	(c)(vii)	(5)	Construction Operations	Year 1	
4	Surface water quality degradation	-	Yes	-	-	Construction Operations	Year 1	
5	Vegetation clearing and habitat loss, of approximately 5 hectares to build a bridge across the Carmichael River	Yes	-	(c)(i)	-	Construction	Year 10	
6	Fire	-	Yes		-	Pre-construction Construction Operations Rehabilitation	Year 1	Table 6-10
7	Weeds and pest	-	Yes	(c)(ix)	(5)	Pre-construction Construction Operations Rehabilitation	Year 1	
8	Earthworks	-	Yes	(c)(iv)	-	Construction Operations	Year 1	
9	Noise and vibration	-	-	(c)(v)	-	Construction Operations	Year 1	
10	Emissions (including dust)	-	Yes	(c)(vi)	-	Construction Operations	Year 1	
11	Light spill and other visual impacts	-	-	(c)(vii)	-	Construction Operations	Year 1	

* Please refer to Section 2.2 for details on GDEMP monitoring and implementation phase; baseline, pre-impact, impact

#1: Groundwater drawdown from mine dewatering

A potential threat for Carmichael River identified through the EIS and required to be addressed by the EPBC Approval 2010/5736, condition 6(c)(iii), is changes in hydrogeology that may stress individuals. The EIS Groundwater modelling results suggest that drawdown from mine dewatering is predicted to occur in the vicinity of the Carmichael River (GHD 2014, 2015). Environmental Authority EPML01470513, condition I14 and Appendix 1, definition “GDEMP”, subsection (5) requires this plan must include a description of the potential impact on each GDE from each project stage including impacts from mine dewatering of aquifers.

The predicted impact of this drawdown is a reduction in the volume of base flow to the Carmichael River. These predicted hydrogeological impacts will be expressed as changes to the hydrology, or flow, of the Carmichael River. Currently, the base flow contribution to river flow extends to a downstream point approximately 25km from the eastern boundary of the mining lease. The impacts to base flow will mean that the base flow contribution to river flow will extend to a downstream point approximately 15km from the eastern boundary of the mine lease (GHD 2014). Output from the calibrated pre-construction steady-state models suggests that long-term average base flow to the Carmichael River peaks at around 7 km upstream of the Mine Area.

Reductions in groundwater discharge due to Project activities are predicted to have an indirect impact on the Carmichael River (URS 2014). Groundwater discharge, including from the Doongmabulla Springs-complex, maintains base flow in the Carmichael River during dry periods. Groundwater modelling indicates that during the operational phase, drawdown of the water table is predicted to reduce base flow into the Carmichael River by 916 m^3/day to 1016 m^3/day, with a total base flow loss of up to 27% of the pre-construction discharge (GHD 2015). The SEIS prediction was a reduction of 954 m^3/day (GHD 2015).

Drawdown of the water table along the Carmichael River is modelled to be greatest (at approximately 4 m) near the middle of the Project area along a stretch of the river approximately 800 m in length. Drawdown of the water table will decrease towards both the western and eastern boundaries to be <0.2 m in other areas. Near the western boundary of the Project area, drawdown will be <0.2 m and zero flow periods will increase from 0% (currently) to approximately 5% of the time. At the eastern Project area boundary, base flow will be reduced by up to 33% during the operational phase, then to approximately 31% after closure. Zero flow periods at the eastern Project area boundary will increase by 30% to 60% of the time during operation and post closure.

Key areas and timeframes for drawdown in the vicinity of the Carmichael River are included in **Table 6-3.**

Table 6-3 Key areas and timeframes for drawdown in the vicinity of the Carmichael River

#	Key areas	Predicted drawdown within vicinity of Carmichael River	When*
1	Near western boundary of mining lease	Approximately <0.2 m and zero flow periods will increase to approximately 5% of the time, from zero per cent currently	During operational project phase From Year 20
2	Carmichael River –towards western and eastern mining lease boundaries	Maximum <0.2 m	During operational project phase From Year 20
3	Carmichael River – 800 m stretch near middle of mine area	Maximum of 4 m	During operational project phase From Year 20
4	Eastern mining lease boundary	Base flow reduced by around 1000 m^3/day (up to 27% of pre-construction base flow)	During operational phase, from Year 20
5		Approximately 950 m^3/day (21% of pre-construction base flow)	Post mine closure, from Year 60
6		Zero flow periods expected to increase in fequency by 30% to 60%	During operation and post mine closure, from Year 60

* Please refer to Section 2.2 for details on GDEMP monitoring & implementation phase; baseline, pre-impact, impact

The residual impact of 6.4 ha of habitat is predicted to be affected by hydrological changes to the Carmichael River (indirect impact zone) during mine dewatering. This indirect impact zone is located in the eastern half of the Project area. Modelled pre-construction long-term data suggest that the Carmichael River switches from generally gaining flow to losing flow approximately 2.5 km downstream of the confluence of Cabbage Tree Creek with Carmichael River. Impacts to base flow are expected to occur 20 years into the operational life of the Mine. Drawdown of 1–4 m of groundwater may occur in the vicinity of some sections of the Carmichael River and groundwater flows into the Carmichael River may be reduced by up to 5%.

Therefore, impacts will be minimal in the western half of the Project area, and the riparian communities are likely to tolerate the predicted changes. In the eastern half of the Project area, groundwater is currently deeper than in the west, so riparian vegetation may be more sensitive to changes in base flows.

These changes to groundwater flow will cause the base flow in the Carmichael River to be reduced to zero, via leakage to the ground in 'losing' sections of the river. This means that the isolated pools, which act as refugia for aquatic fauna during dry periods, will become less frequent and will eventually dry out. These losing sections are predicted to migrate from 25 km downstream of the eastern mining lease boundary pre-construction, to 15 km downstream of the eastern mining lease boundary post development (i.e. a total migration of 10 km upstream). A reduction in groundwater discharge to the Carmichael River has the potential to reduce the temporal and spatial availability of aquatic habitats during dry periods, and may also cause stress and dieback along the riparian vegetation zone, including individuals and habitat of the vulnerable Waxy Cabbage Palm (GHD 2012b; **Figure 6-8**). The loss of isolated pools during dry periods could mean that fish and other aquatic fauna will be removed from the reach of stream impacted by aquifer dewatering (**Figure 6-9** and **Figure 6-10a-d**).

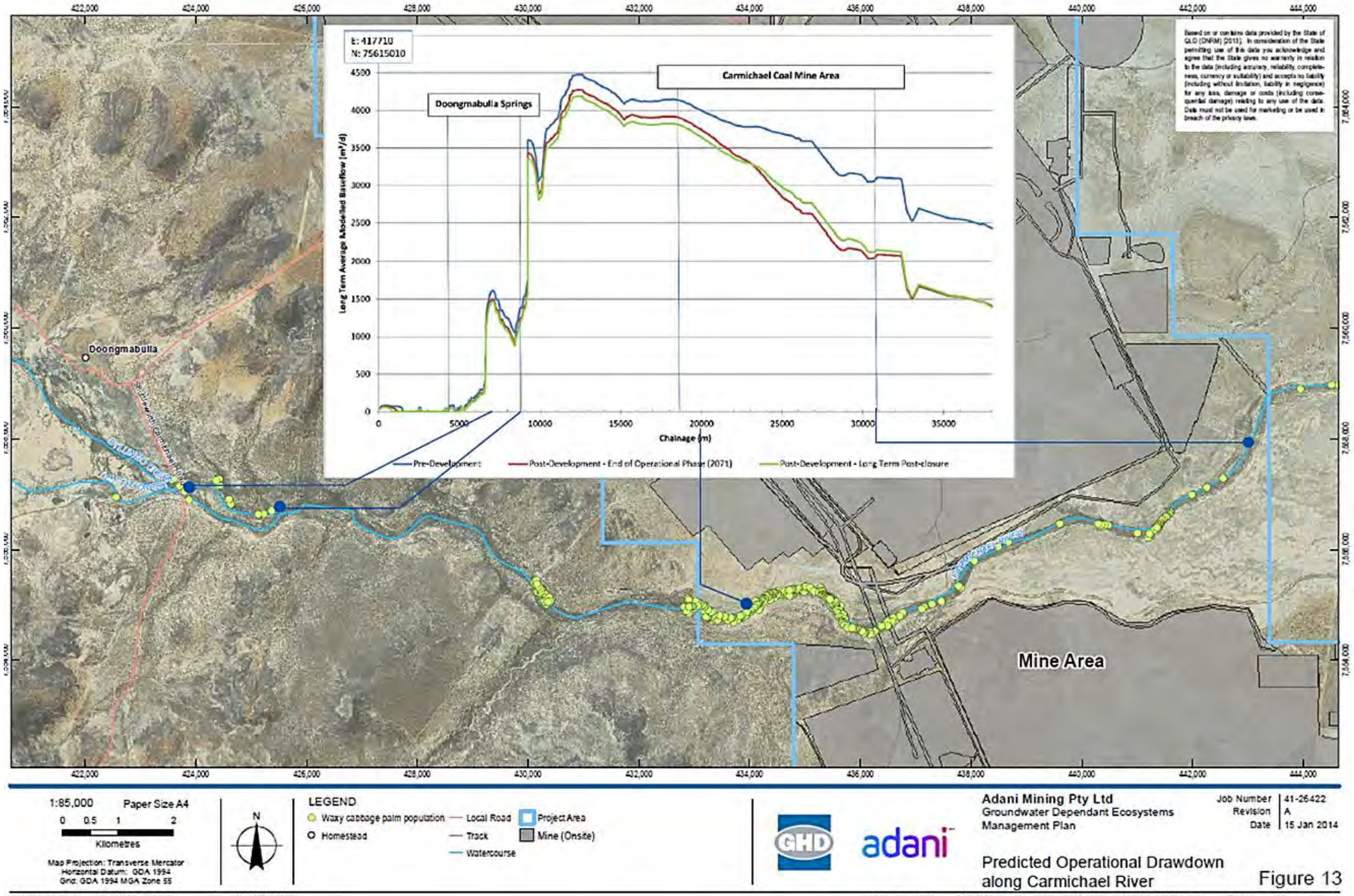


Figure 6-8 Predicted base flow impacts to the Carmichael River

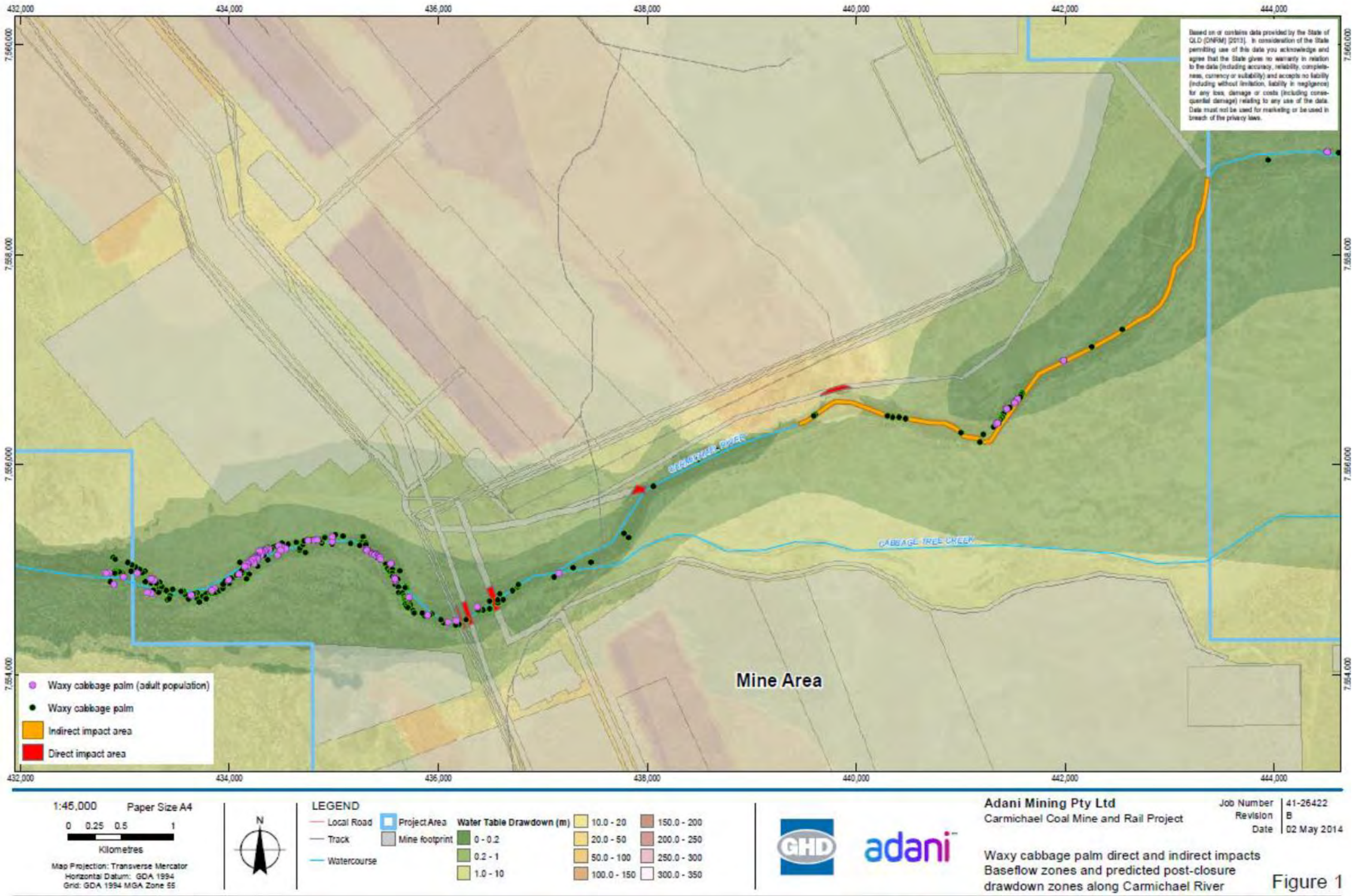
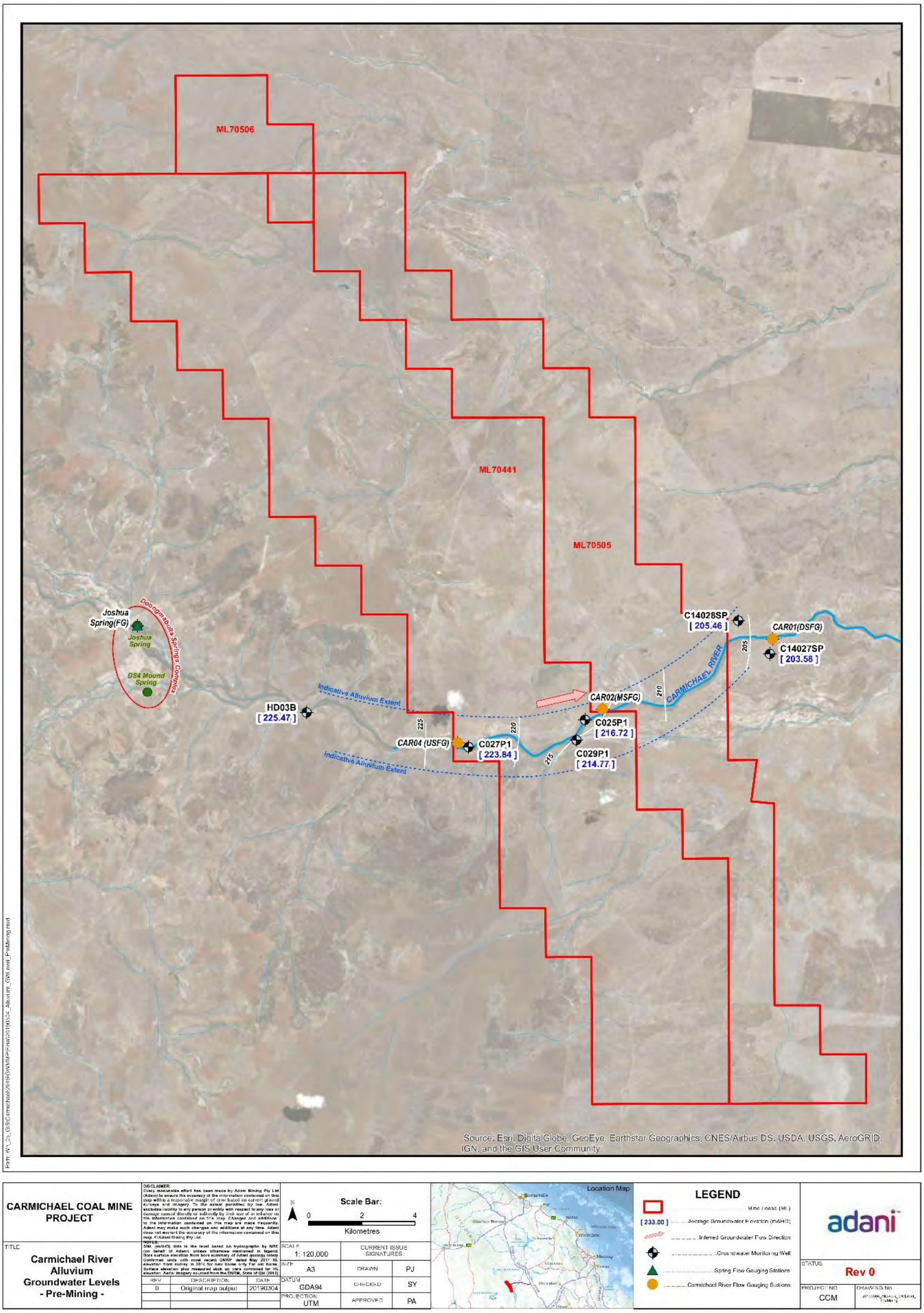


Figure 6-9 Predicted groundwater drawdown impacts to the Carmichael River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ML70441
ML70505
Joshua Spring(FG)
Joshua Spring
DS4 Mound Spring
Doongmabulla Springs Complex
HD03B
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Indicative Alluvium Extent
Indicative Alluvium Extent
CAR04 (USFG)
C027P1
[223.84]
225
220
215
210
205
CAR02(MSFG)
C025P1
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C029P1
[214.77]
CARMICHAEL RIVER
C14028SP
[205.46]
CAR01(DSFG)
C14027SP
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Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
CARMICHAEL COAL MINE PROJECT
TITLE
Carmichael River Alluvium Groundwater Levels - Pre-Mining -
Scale Bar:
0 2 4
Kilometres
SCALE 1: 120,000
SIZE A3
DATUM GDA94
PROJECTION UTM
CURRENT ISSUE SIGNATURES
DRAWN PJ
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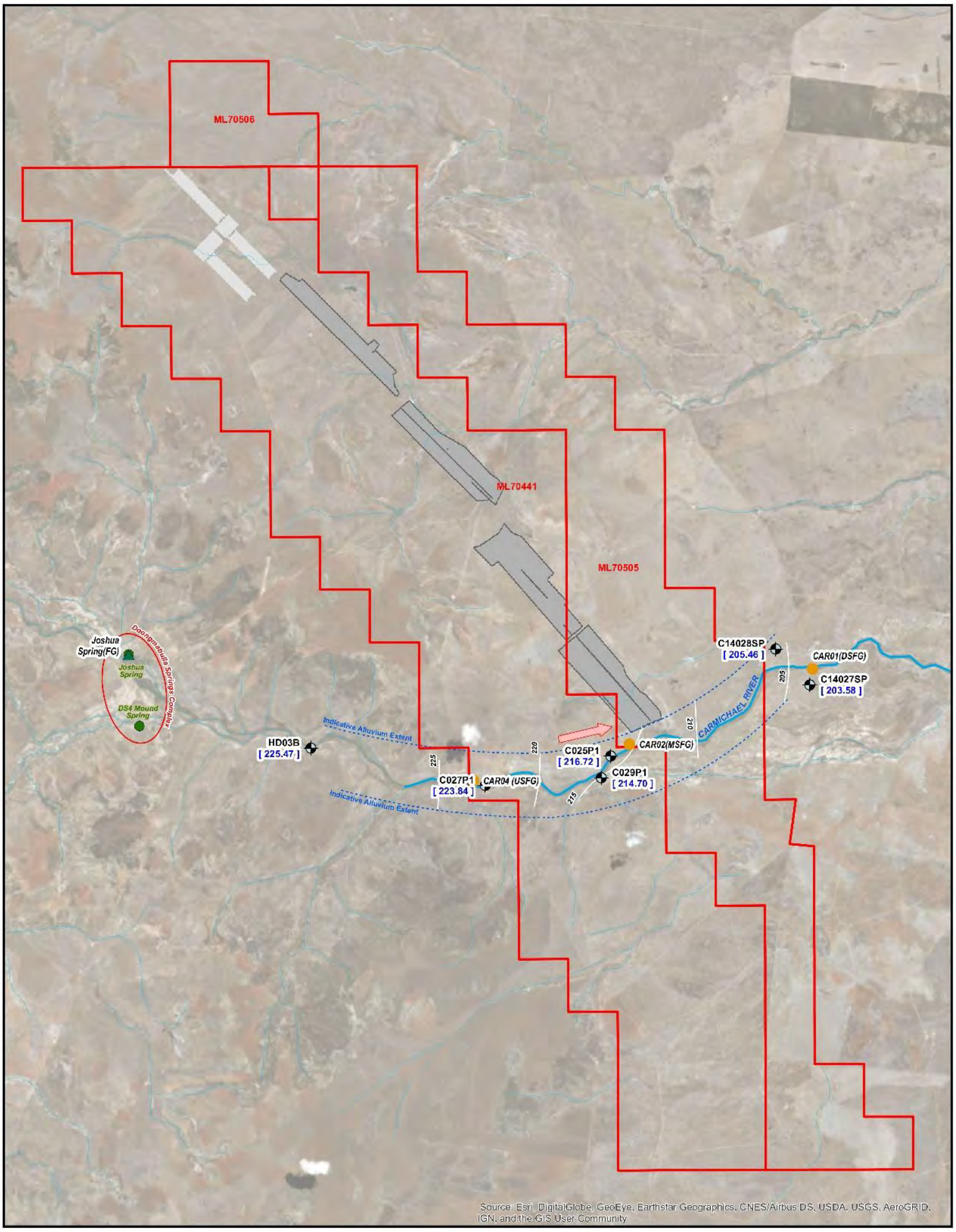
Location Map
LEGEND
Mine Lease (ML)
[233.00] Average Groundwater Elevation (mAHD)
Inferred Groundwater Flow Direction
Groundwater Monitoring Well
Spring Flow Gauging Stations
Carmichael River Flow Gauging Stations
adani
STATUS
Rev 0
PROJECT NO
CCM
DRAWING No



CARMICHAEL COAL MINE PROJECT

TITLE: **Carmichael River Alluvium Predicted Groundwater Levels - Year 5 -**

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Scale Bar: 0 2 4 Kilometres

REV	DESCRIPTION	DATE
0	Original map output	20190304

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SIZE A3	DRAWN	PJ
DATUM GDA94	CHECKED	SY
PROJECTION UTM	APPROVED	PA

Location Map

LEGEND

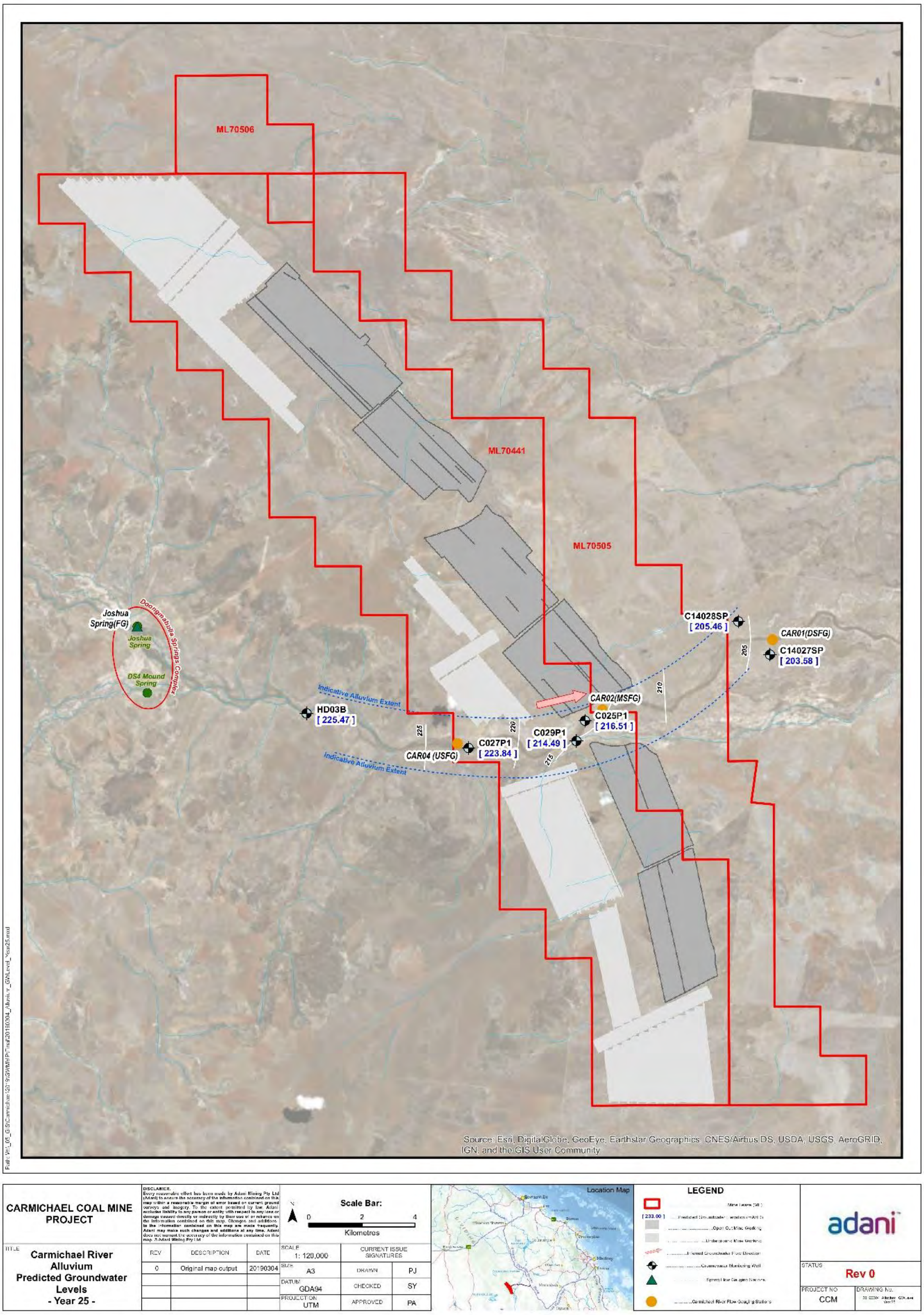
- Mine Lease (ML)
- [233.00] Predicted Groundwater Elevation (mAHD)
- Open Cut Mine Working
- Underground Mine Working
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Spring Flow Gauging Stations
- Carmichael River Flow Gauging Stations

adani

STATUS: **Rev 0**

PROJECT NO: CCM

DRAWING NO.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ML70441
ML70505
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Joshua Spring
DS4 Mound Spring
Doongmabulla Springs Complex
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Indicative Alluvium Extent
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Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
CARMICHAEL COAL MINE PROJECT
TITLE
Carmichael River Alluvium Predicted Groundwater Levels - Year 25 -
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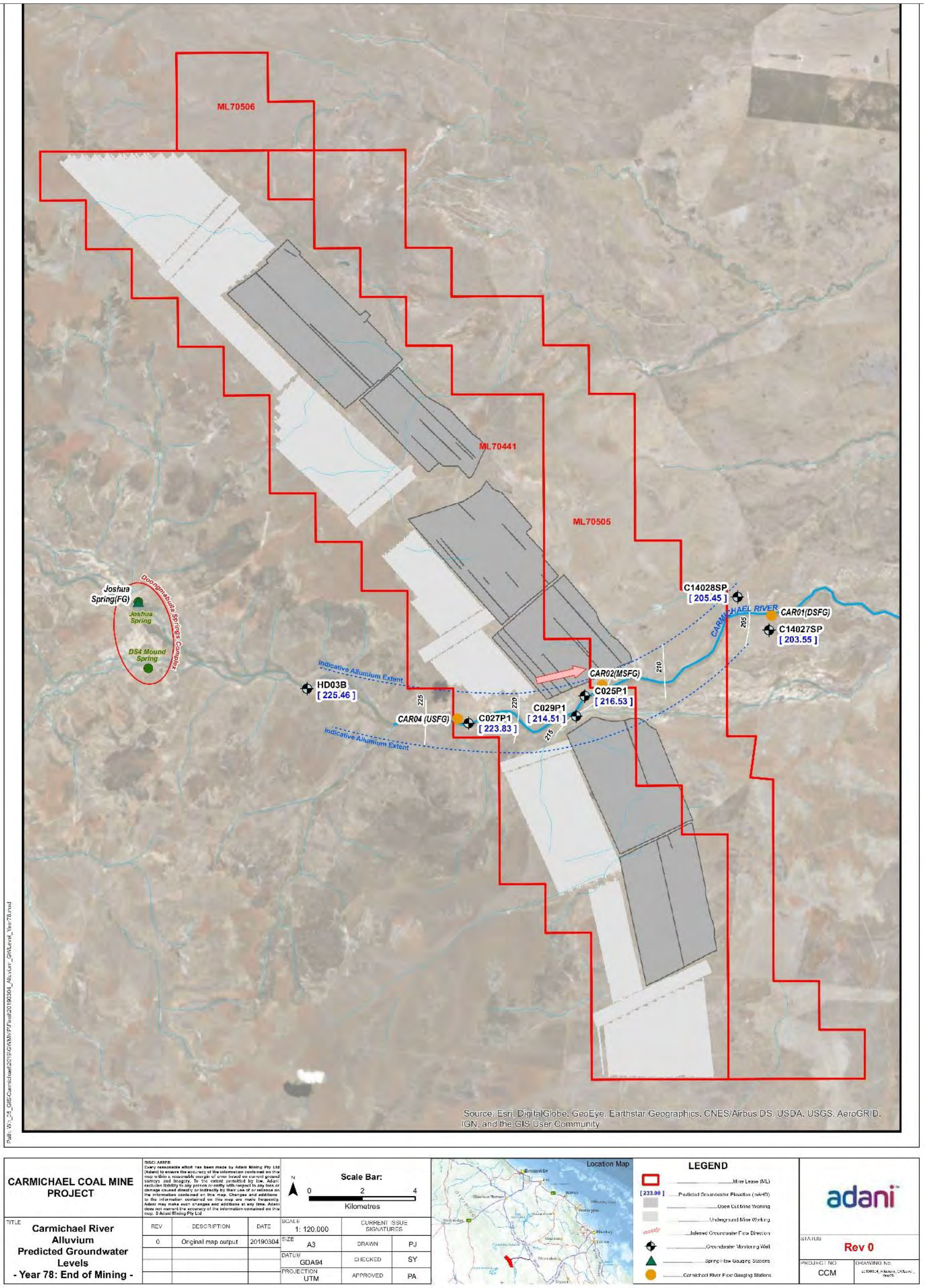


Figure 6-10 a-d Predicted Alluvial aquifer impacts associated with the Carmichael River

The residual groundwater impact to Carmichael River is to be offset through the Biodiversity Offset Strategy. An area of 90 ha has been established on Moray Downs West for this purpose.

The impacts associated with a drawdown of the groundwater table in the vicinity of the river, relate to a reduction in the availability of habitats for aquatic dependent species, both spatially and temporally. Drawdown will result in longer dry periods and the potential loss of a drought refuge in the Carmichael River. However, it is common for many sections of the river, from the mining lease to the east, to have periods of zero base flow, particularly in the late dry season or during droughts.

The Carmichael River provides habitat for native aquatic species during the wet and dry season and removal of sections of this habitat will reduce the availability of aquatic habitat on a local scale as well as reduce the population of aquatic species that recolonise up and downstream habitats during the wet season when isolated pools are connected.

No EPBC Act or NC Act listed threatened aquatic flora species were recorded during field surveys in Study Area or desktop searches (GHD, 2012b). Based on species information, distribution and habitat preferences, no threatened or conservation significant aquatic flora or fauna listed under the EPBC Act or NC Act are considered likely to occur. Generally, the Carmichael River is characterised by relatively low aquatic ecosystem and habitat values being present (GHD, 2012b).

A management objective under this plan is to limit and manage the impact of hydrological changes to the Carmichael River from mine dewatering beyond those approved and offset. **Table 6-10** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#2: Subsidence from underground mining

Subsidence from underground mining is generally not considered to be a potential threat to the Carmichael River identified by EPBC Approval 2010/5736, condition 6(c)(ii). The condition also requires details of potential impacts from subsidence from underground mining, including subsidence induced fracturing and any changes to groundwater or surface water flow, be addressed in this plan. Environmental Authority EPML01470513, condition I14 and Appendix 1, definition “GDEMP”, subsection (5) also requires this plan include a description of the potential impact on each GDE from each project stage, including impacts from subsidence.

No subsidence is predicted to occur near the Carmichael River, as modelled in the EIS for the Project.

Changes to the flow of the Carmichael River, as a result of groundwater flow and surface water diversions and flows, and subsidence beneath catchment areas feeding into the Carmichael River, are addressed in #1 and #3.

As no subsidence is predicted to occur, the management objective is to monitor to ensure there is no habitat alteration through subsidence. **Table 6-10** describes how the management objective will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#3: Changes to surface water flows and flooding

Changes to the surface water flows and flooding of the Project Area, during the construction and operational project phases, are potential impacts to the Carmichael River. These were identified in the EIS and required to be addressed by EPBC Approval 2010/5736, condition 6(c)(viii). In particular, the condition requires details of potential impacts from stream diversions and flood levees, be addressed in this plan.

Environmental Authority EPML01470513, condition I14 and Appendix 1, definition “GDEMP”, subsection (5) also requires this plan include a description of the potential impact on each GDE from each project stage, including impacts from water discharge and hydrological changes.

Surface water is highly susceptible to changes in hydrology and quality caused by construction and operational activities. Alterations to surface topography due to vegetation clearing, watercourse diversion works, subsidence and earthworks cause changes in drainage patterns and overland flows. In turn, this can increase scouring, erosion, and sedimentation, which affects flood levels, water quality, and riparian vegetation and aquatic habitat.

Changes to the surface water flows and flooding of the Project Area are:

- Change in flow rates in the Carmichael River
- Impact of stream diversions and flood levees across the project site to the Carmichael River.

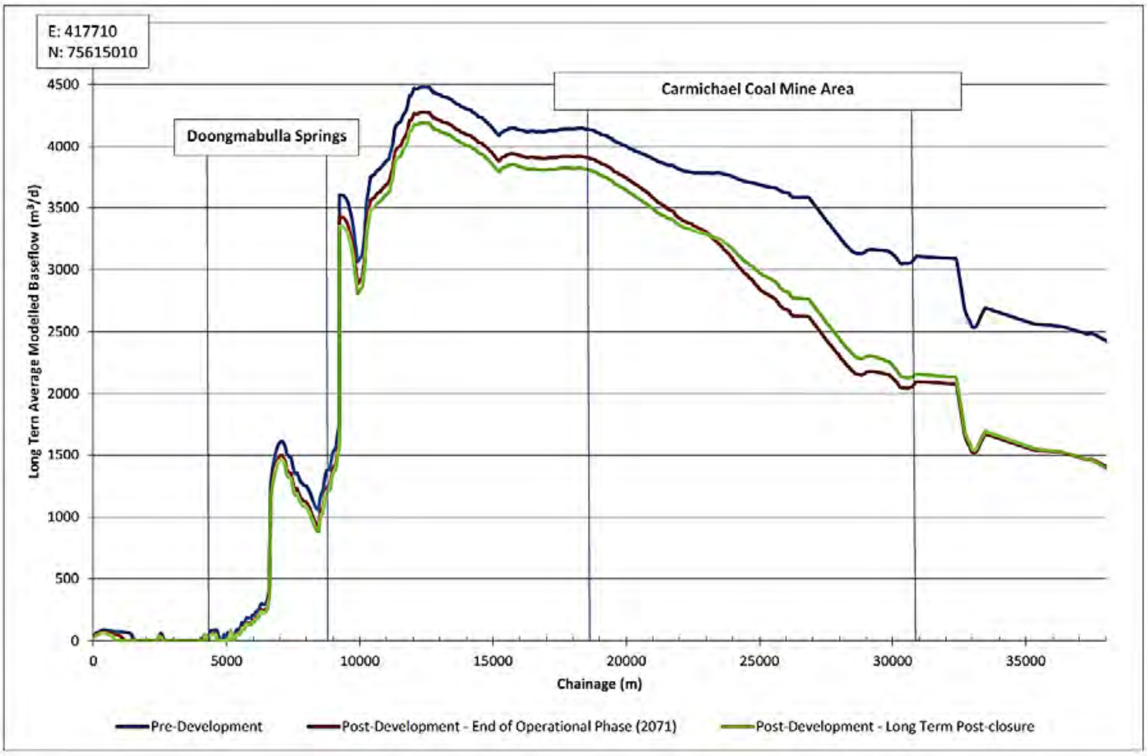
The EIS projected changes to flow rates in the Carmichael River as a result of the following:

- Stream diversions and flood levees
- Reductions in groundwater (examined in other sections of this plan).

The mine area will remove 16,664 ha (25 percent) of the Carmichael River catchment (GHD, 2013c). The mine will also result in loss and disturbance of aquatic habitats and fauna and the disconnection of the floodplain (loss of connectivity between the river and the floodplain). This may result in minor impacts on aquatic fauna species that utilise floods for migration or breeding.

Over staged development of the Mine, the local availability of surface water discharged from the Mine Area will be reduced by 33 percent (GHD, 2013d). This reduction is due to the reduced catchment area and subsidence ponding.

Figure 6-11 describes the predicted Carmichael River base flow changes over time.



Source: GHD, 2013c

Figure 6-11 Predicted Carmichael River base flow changes

Impact of stream diversions and flood levees across the project site to the Carmichael River

The EIS identified the indirect hydrological impacts to the Carmichael River as a result of the construction and operation phases of the mine. The mine site will become inundated during flood events. Therefore, the mine site requires flood protection in order to operate and some method of stormwater management on-site to minimise the impact of the site on overland flow. The necessary flood protection and stormwater management infrastructure identified includes the following:

- Levees to protect the adjacent pits from flooding by the Carmichael River
- Diversion drains to allow local waterways to pass through the site without causing flooding and also redirect overland flow around operational areas
- Changed flow velocities, increased erosion and subquent changes in bed and bank stability as a result of works within or adjacent to watercourses (GHD, 2016)

The EIS identified that infrastructure works during the construction and operational project phases within the Carmichael River floodplain will likely directly impact the Carmichael River. Mine protection flood levees on the northern and southern banks of the River will be constructed during the construction project phase. The mine protection flood levees are located 500 m from the Carmichael River, and will be constructed in sequence with the mine. As the Carmichael River width is considered, for the purposes of this GDEMP, to be 20 m from the centre line, with the addition of a riparian zone of varying width but less than 500 m, the construction of the levees at 500 m, are not considered to be a direct impact on the Carmichael River. However, the mine protection flood levees will create changes to surface water flows and flooding, that are considered in this section.

Stream diversions and levees are shown in **Figure 6-12**.

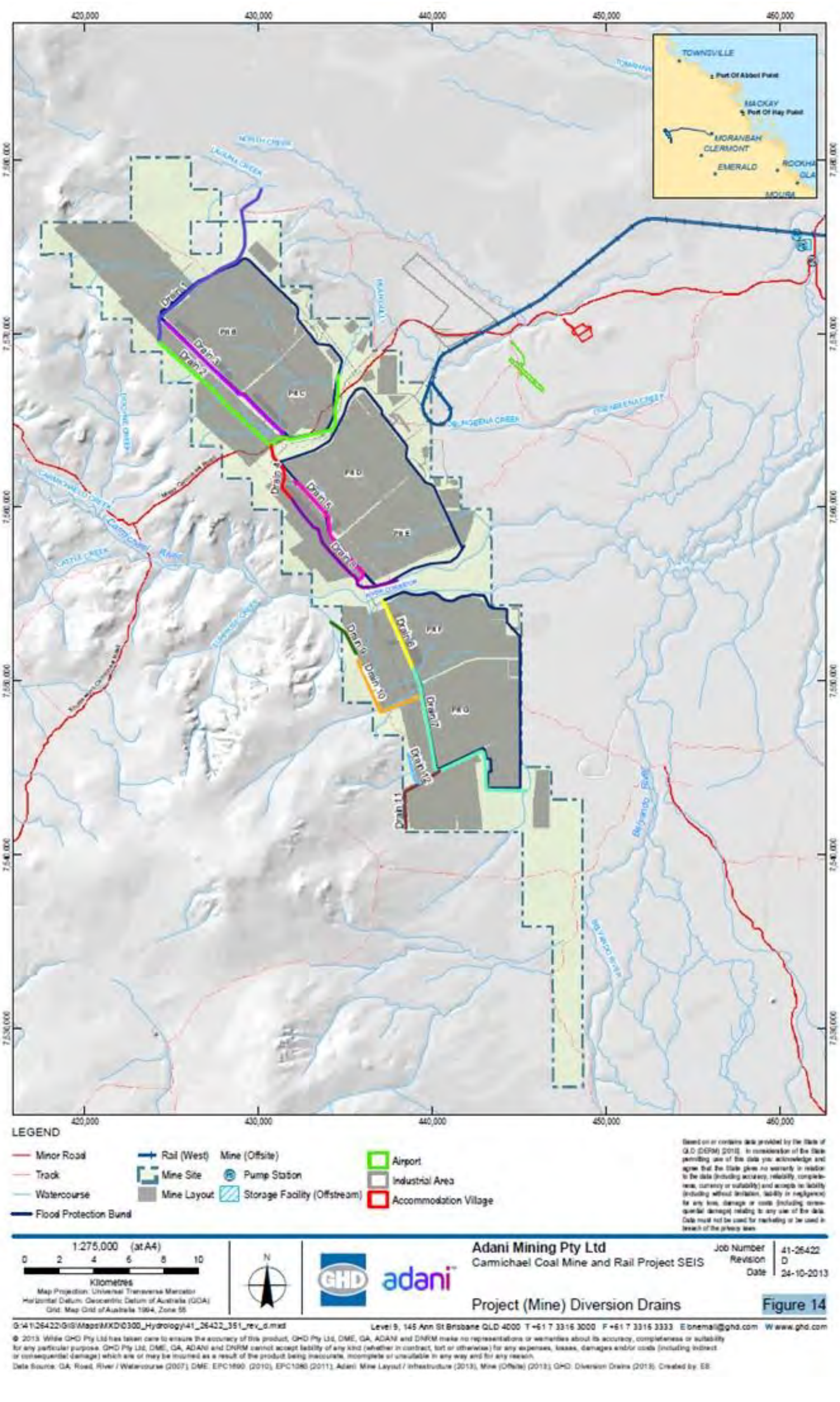


Figure 6-12 Stream diversions and levees

Proposed flood mitigation infrastructure will cause afflux within the mine area. This is considered to be due to the combined effect of minor increased inflows from some of the diverted waterways, reduced runoff coming from the developed mine areas and hydraulic constriction by the flood protection levees, haul road and conveyor crossing.

Upstream of the haul road crossing afflux was modelled to peak at 0.98 m for the 1 in 1,000-year ARI event, but at the downstream eastern boundary this had already reduced to peak at 0.09 m adjacent to the Carmichael River. These values are reduced in smaller events, with afflux at the Mine area boundaries generally being relatively insignificant (0 – 0.09 m; **Table 6-4**).

Table 6-4 Projected afflux from proposed development at selected locations (GHD, 2013)

Location	Description	Afflux (m) for Average Recurrence Interval (ARI)			
		10 year	50 year	100 year	1,000 year
1	Carmichael River Model Inflow Boundary	0.001	0.00	0.00	0.00
2	2 km Downstream of Carmichael River Model Inflow	0.02	0.00	0.00	0.01
3	Western Project (Mine) area Boundary	0.02	0.01	0.01	0.06
4	Upstream of Haul Road Crossing	0.11	0.19	0.23	0.98
5	Downstream of Haul Road Crossing	0.03	-0.04	-0.08	0.31
6	Upstream Cabbage Tree Creek	0.04	0.16	0.23	0.70
7	Midway through Project (Mine) area	0.02	0.14	0.21	0.59
8	Eastern Project (Mine) area Boundary	0.01	0.00	0.01	0.07
9	Downstream Cabbage Tree Creek	0.01	0.07	0.09	0.17

The SEIS, Updated Mine Hydrology report provides detail for the 10, 50, 100 and 1,000 yearly ARI. The following **Figure 6-13** to **Figure 6-15** show the 50 year ARI for the Carmichael River. The modelling determined the full first half of the area confined by the Carmichael River levees experiences between 0.1 and 0.2 afflux (GHD, 2013).

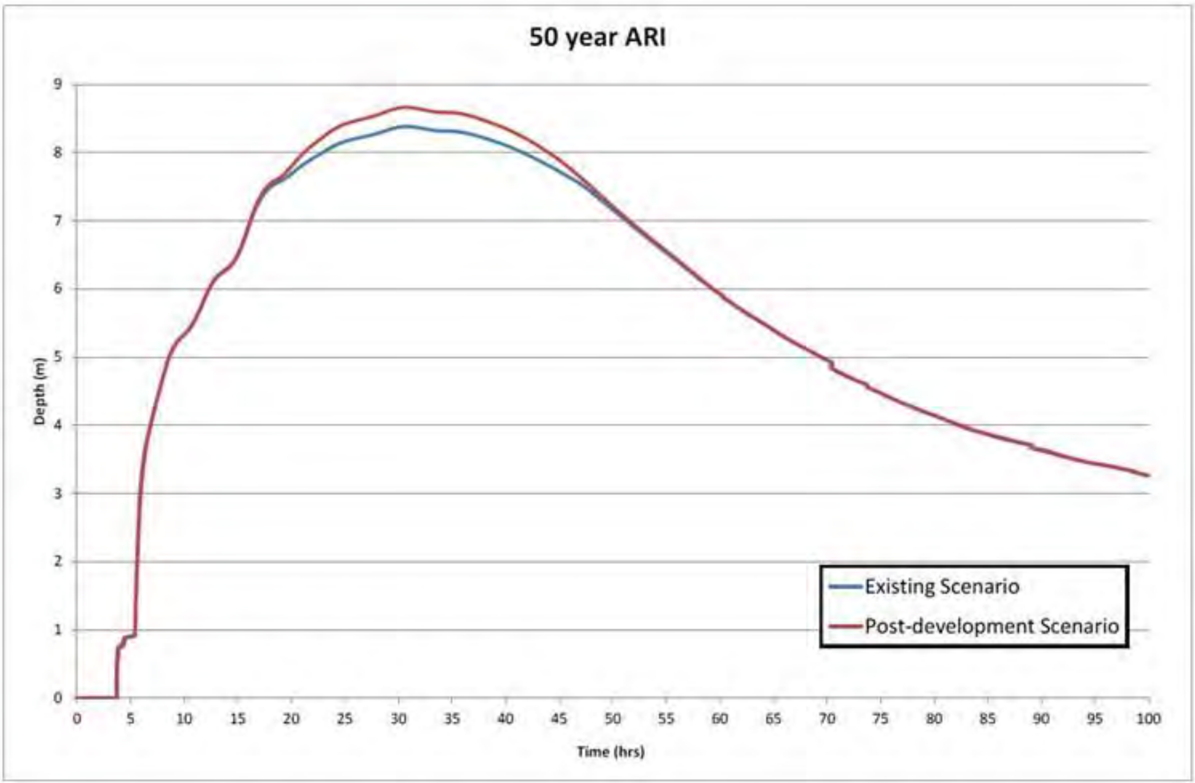


Figure 6-13 50-year ARI depth hydrograph upstream of proposed bridge

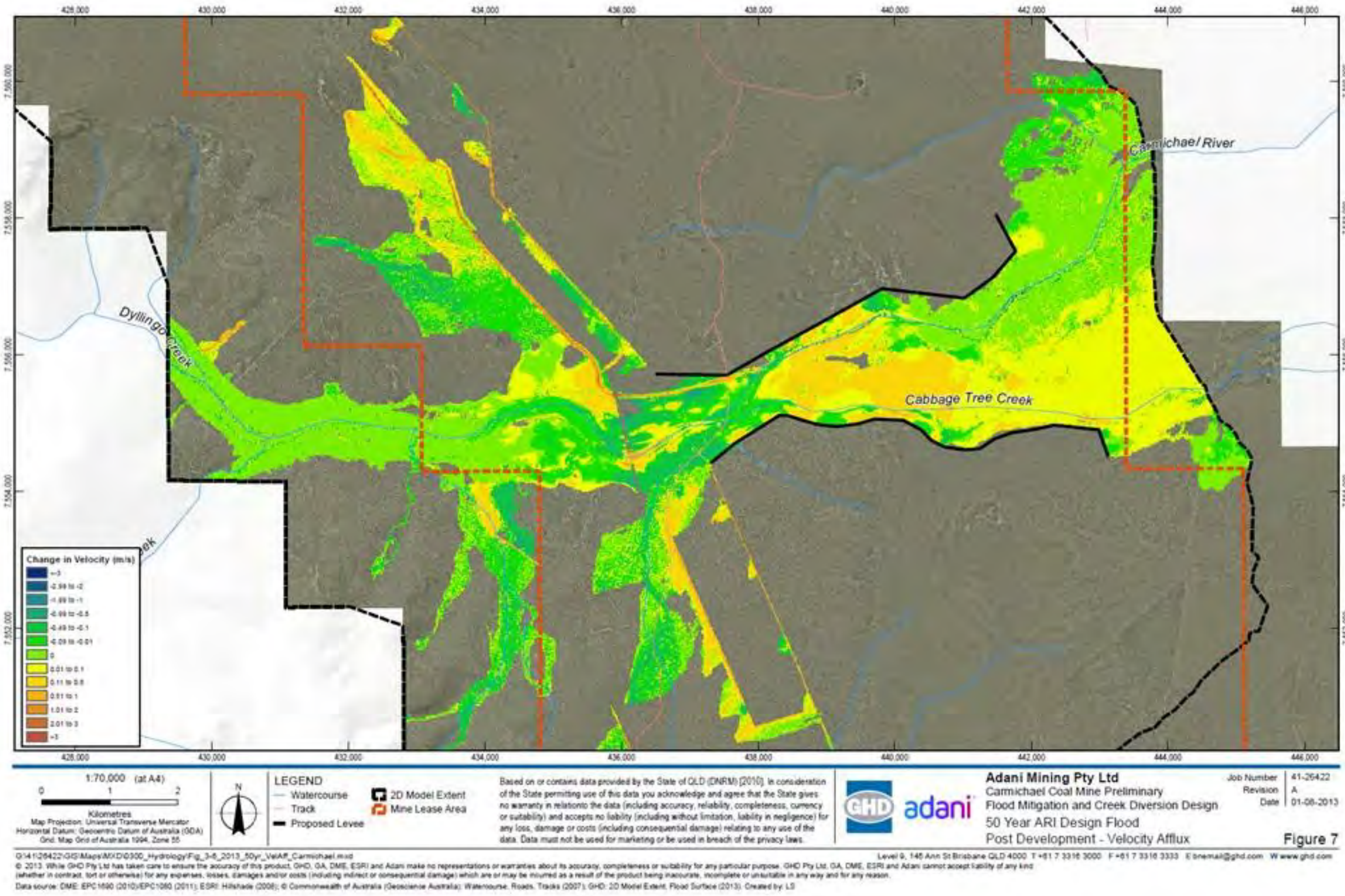


Figure 6-14 50 Year ARI Design Flood – Post Development – Velocity Afflux (GHD, 2013)

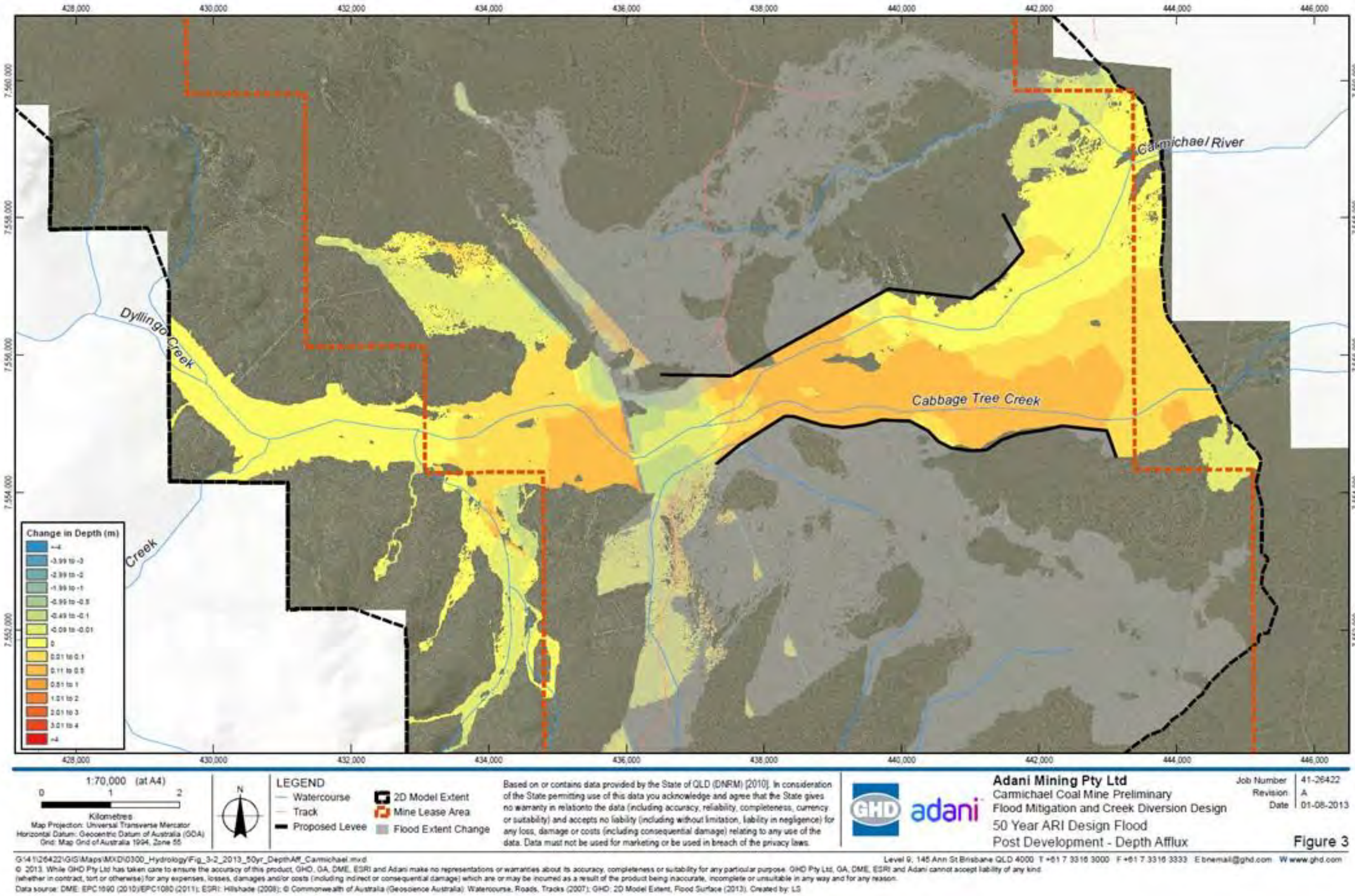


Figure 6-15 50 Year ARI Design Flood – Post Development – Depth Afflux (GHD, 2013)

Changes in the direction or volume of runoff flows to watercourses has the potential to change watercourse geomorphology as a result of scour and deposition (GHD, 2012b). Physical changes can reduce habitat suitability for existing aquatic communities and remove microhabitats to which the community has adapted. During construction, the change from open grazing land with relatively permeable soils, to compacted developed areas within the Project footprint will increase potential for runoff of rainfall as the permeability of soils is reduced (GHD, 2012b).

No impact to surface water flows in the Carmichael River is predicted as a result of the construction of the transport corridor. Design of the bridge crossing for the transport corridor will consider fish passage requirements. The crossing will not be physically within the watercourse bed or banks (and will not affect flows).

A management objective under this plan is to minimise changes to surface water flows and flooding. **Table 6-10** describes how the management objective will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#4: Surface water quality degradation

All drainage run-off from the disturbed areas of the mine site will be treated as mine affected water. To ensure no adverse impacts occur in surrounding waterways as a result of MAW contamination, water management structures and systems will be installed during the construction phase of the project.

Schedule F of the EA permits the release of water from the mine site, with strict specified release limits and monitoring requirements. These conditions ensure any water leaving the mine site will not affect water quality values in the Carmichael River. For release of water from the mine site to the Carmichael River, Conditions F2, F5 and F10 provide sources, release points, maximum release rates, receiving waters, monitoring points and trigger levels. These are described in **Table 6-5**.

Table 6-5 Mine Affected Water Release Points, Sources and Receiving Waters

Release point	Easting (GDA94-Zone 55K)	Northing (GDA94-Zone 55K)	Contaminant Source and Location	Monitoring Point	Receiving Waters Description
RP1-Central MAW North	441709.44	7558984.92	Mine Affected Water Dam Central - North	Outlet works to Carmichael River	Carmichael River
RP1-Central MAW South	435539.56	7553979.62	Mine Affected Water Dam Central - South	Outlet works to Carmichael River	Carmichael River

The conditions also ensure that releases of water to the Carmichael River are undertaken in a manner that does not cause erosion of the bed and banks of receiving waters or cause increased sedimentation.

Condition F4 of the EA states that water collected from across the mine area and released to the Carmichael must not exceed those limits stated in the table when measured at the monitoring points. The release limits are described in **Table 6-6**.

Table 6-6 Mine affected water release limits

Quality characteristic	Release limit	Monitoring frequency
Electrical conductivity	Release limits specified in the EA, Table F4 for mine affected water release during flow events	Continuous
pH (or pH unit)	6.5 (minimum) 9.0 (maximum)	Continuous
Turbidity (NT)	500*	Continuous

*Turbidity release limits will be reviewed once sufficient monitoring data is available to adequately characterise the baseline turbidity in the Carmichael River – including consideration of natural spatial and temporal variability.

The release of water to the Carmichael River must meet the quality and flow requirements of the river (Appendix A, REMP), and will supplement dry flow periods. The discharge of water is not predicted to negatively impact the Carmichael River.

The EIS also identified the following indirect impacts to water quality of the Carmichael River :

- Temporary increased surface runoff as a result of vegetation clearance, topsoil removal and soil compaction on land adjacent to watercourses
- Impacts to surface water quality, including downstream impacts may occur where the geomorphology of waterways is altered, where sediment and/or contaminants are mobilised during construction activities and enter waterways during and after rainfall or where an increase in localised flow may cause increased erosion and scouring
- Increases in salinity and / or contamination of surface water or groundwater may occur from large spills of environmentally hazardous material, discharge of saline groundwater during dewatering, discharge of mine affected water. Contamination of the Carmichael River by saline water, hydrocarbons, metals and waste materials may reduce the quality of downstream aquatic habitats.
- Improper treatment of wastewater may enable nutrients, pathogens and other contaminants to be released into downstream waters.

Physical changes in water quality may reduce the suitability of the aquatic environment for some aquatic flora and fauna species. The main sources of potential water quality changes relate to mobilisation of sediments and pollutants (GHD, 2012b). Operational activities have the potential to impact on water quality via discharge of contaminants to the environment (GHD, 2014).

The source of most suspended particulates (and in turn increase in turbidity), nutrients and other contaminants attached to particulates in waterways is mobilisation of soils through surface runoff, stream bank erosion and dust. Although aquatic ecosystems in ephemeral systems such as the Carmichael River are likely to be adapted to peaks in turbidity during periods of high flow, an increase in the magnitude and number of these peaks may have a detrimental impact on aquatic ecosystems.

Construction activities within or adjacent to watercourses may disturb bed and bank substrates and lead to localised erosion and sediment transport to downstream habitats (GHD, 2012b). Suspended particulates in the water column can reduce light penetration and therefore primary production of aquatic macrophytes, as well as affecting gill function of fish. When sediments settle they can smother aquatic organisms and their habitats (ANZECC 2000).

Potential loss of the large trees growing in banks and channel bars will result in increased instability of those banks and channel bars. High flow events in future will result in increasing bank and channel erosion, and bank slumping. Increased erosion leads to increased sedimentation downstream, with consequent declines in water quality, and reduction in the quality of habitat for aquatic dependent species.

Movement of sediment can also mobilise nutrients to aquatic habitats that have leached from soils in exposed areas. Nutrient pollution has the potential to impact upon aquatic ecosystems through the stimulation of growth of nuisance plants and cyanobacteria (ANZECC 2000). Growth of these plants and cyanobacteria can lead to changes in community composition and influence aspects of water quality such as dissolved oxygen concentrations which can impact on aquatic fauna community health (GHD, 2012b).

There is a risk of contaminating surface water or groundwater from large spills of environmentally hazardous material, discharge of mine affected water, or leaching of improper irrigation of treated wastewater. The loss of surface vegetation, and changes to drainage patterns and flows across landscapes can also increase salinity levels in surface water, which can then seep and drain into major river systems (GHD 2013).

A management objective under this plan is to maintain surface water quality. **Table 6-10** describes how the management objective will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#5: Vegetation clearing and habitat loss

The EIS identified that infrastructure works during the construction and operational project phases within the Carmichael River floodplain will likely directly impact the Carmichael River. The relevant infrastructure is the construction of a bridge over the Carmichael River to convey the haul road and conveyors during the construction project phase.

EPBC Approval 2010/5736, condition 6(c)(i) also requires details of potential impacts from vegetation clearing be addressed in this plan. Clearing in the Carmichael River of approximately 5 hectares was identified as a direct impact to the Waxy Cabbage Palm in the Carmichael River in the EIS. Impacts to Waxy Cabbage Palm are addressed in section 7.

Broadly, impacts to native plants and vegetation communities the Carmichael River are also predicted as a result of the following matters that are considered in other threats and impacts in this section:

- Degradation of adjacent habitat due to dust deposition, changes in overland flow regimes, exposure of edges to sunlight and increased predation
- Proliferation of weeds and pests
- Release of sediments to water through erosive processes.

A 500m wide buffer zone on each side of the Carmichael River will not be cleared of vegetation, thus protecting riparian habitat. No in channel works will be required, aside from construction of a transport infrastructure corridor with a bridge crossing the river. Design and layout of the crossing will incorporate a bridge design that spans the watercourse bed and avoids construction within the banks as much as possible. Spanning the watercourse will avoid the removal of aquatic habitat, avoid installation of a barrier to movement by aquatic fauna and avoid alteration of hydrological flows locally. It is likely however that during construction vehicles may require access to the bed of the river; hence a temporary loss of habitat will result (GHD, 2012b).

Management objectives about the threat and impacts include enhancing the ecological values of riparian zones within a 500 m buffer either side of the centreline of the Carmichael River within the Project area and minimising impacts to the Carmichael River. **Table 6-10** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#6: Fire

The threat of fire for the Carmichael River exists during the pre-construction (baseline and pre-impact), construction, operational and rehabilitation project phases.

Fire is inevitable in the grassy woodlands of central Queensland and a natural component of these ecosystems. Historically, ignition sources include lightning-strike, low intensity wet season fires, or under traditional indigenous management. Inappropriate fire regimes leading to intense bushfires that result in death of individuals, reduced recruitment from damaged adults and burning of seeds and bare ground. Bare ground is susceptible to erosion and degradation from Feral Pigs, further impacting the banks of the Carmichael River.

Fires in woodlands of the type that occur in the Project Area are fuelled principally by grass biomass rather than by woody material. Fire intensity will be greater with high fuel biomass, continuity of the fuel layer, a high degree of curing (drying) of the grassy fuel and ambient conditions, including high temperatures, low humidity and high wind speeds. Lower intensity fires will occur when fuel biomass is low and / or discontinuous, fuel moisture levels are high, ambient temperatures and wind speeds are low and atmospheric humidity is high.

Fire frequency, scale and intensity may also impact on vegetation in the Carmichael River through numerous mechanisms. Large uncontrolled wildfires have the potential to destroy large areas of the Carmichael River with consequential long recovery times. Fire frequency can also effect vegetation in the Carmichael River with inappropriate fire regimes impacting on the quality by affecting the production of seeds.

Management objectives under this plan are to reduce the risk of bushfire ignition, maintain a mosaic of fire history in the Carmichael River and reduce the risk of bushfire spread. **Table 6-10** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#7: Weeds and pests

EPBC Approval 2010/5736, condition 6(c)(ix), requires details of potential impacts, including area of impact on the Carmichael River from weeds and pests through direct competition or habitat degradation to be addressed by this plan. Environmental Authority EPML01470513, condition I14 and Appendix 1, definition "GDEMP", subsection (5) also requires this plan include a description of the potential impact on each GDE from each project stage, including impacts from weed and pest infestation.

The EIS noted that Rubber Vine and Parthenium are established within the Project area.

The threat of weeds and pests will occur during pre-construction (baseline and pre-impact), construction, operational and rehabilitation project phases.

Aquatic weed species can impact on native aquatic ecosystems by shading out native plants, reducing the quality of habitat for aquatic fauna communities and degrading water quality (DERM, 2011).

Terrestrial weed species may manifest in riparian areas when loss of open forest canopy will let in more light, favouring weeds and shrubs. If not controlled, Rubber Vine infestations currently in the Carmichael River within the Mine Area may increase in height, area and density, with the capability to render the watercourse inaccessible to humans and large animals. Other weeds such as *Parkinsonia aculeata* (Parkinsonia) may also flourish. However, as there is a 500m wide buffer zone each side of the Carmichael River, in which no vegetation will be cleared, the likelihood of further weed invasion and spread is reduced (GHD, 2012b).

Any increase in weed levels will increase the quantity of seed moved downstream to other sections of the Carmichael and Belyando Rivers. In addition, weed infestations provide habitat for Feral Pigs which exacerbate erosion and bank degradation and damage native vegetation.

Increased weed levels reduce species diversity and ecosystem complexity, reducing the ability of the watercourse to host a diverse range of species and life forms.

A management objective under this plan is to reduce weed competition and habitat degradation from grazing by introduced herbivores within the Carmichael River. **Table 6-10** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#8: Earthworks

The EIS identified that infrastructure works during the construction and operational project phases within the Carmichael River floodplain will likely directly impact the Carmichael River. Earthworks are required to construct a bridge over the Carmichael River to convey the haul road and conveyors.

EPBC Approval 2010/5736, condition 6(c)(iv) requires details of potential impacts from earthworks be addressed in this plan. Earthworks carried out as a part of mine construction and operation will lead to increased risk and exposure to light, noise, dust, vehicles and people (Adani 2012). Dust, noise, vibration and light spill are described in following sections.

A transport infrastructure corridor will be established with a bridge crossing the river. The crossing infrastructure will be designed such that no infrastructure will be placed in the bed of the Carmichael River. It is likely however that during construction, vehicles may require access to the bed of the river; hence a temporary loss of habitat will result. Installation of the infrastructure across this watercourse will potentially result in a small loss of aquatic habitat, create a barrier to movement for native aquatic fauna species and/or alter hydrological flow (GHD, 2012b). These effects will however be temporary during construction and unlikely to have any medium or long-term effects. No significant impact on aquatic dependent species is predicted.

A management objective under this plan is to minimise impacts from earthworks in the Carmichael River. **Table 6-10** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#9: Noise and vibration

EPBC Approval 2010/5736, condition 6(c)(v) requires details of potential impacts from noise and vibration be addressed in this plan.

During the construction project phase, standard construction equipment, general trade equipment and specialised equipment will be used as required. Noise and vibration from construction activities (particularly the construction of the Carmichael River haul road crossing) and operations, may reduce the amount and quality of habitat for aquatic and riparian fauna. However, it is not anticipated noise and vibration will significantly impact the Carmichael River.

A management objective under this plan is to minimise habitat modification as a result of noise and vibration. **Table 6-10** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#10: Emissions (including dust)

EPBC Approval 2010/5736, condition 6(c)(v) requires details of potential impacts from emissions (including dust) be addressed in this plan.

Earthworks during the construction and operational project phase will result in dust emissions. Excessive dust settling on vegetation could also suppress vegetation growth by limiting the photosynthesis potential of plants in close proximity to the construction area (Nanos and Ilias 2007). As such, particulate emissions may reduce photosynthetic ability of species located in the bed and banks of the Carmichael River.

Dust deposition associated with earthwork activities will generally occur relatively close to areas of disturbance and hence, plants within 50 m to 100 m of construction activities may be affected by dust. As there is a 500m buffer zone surrounding the Carmichael River, emissions and dust from construction activities and temporary, dust impacts are unlikely and any effects will be short lived, and rainfall will generally remove dust from plants (Adani 2012).

As there is a 500m wide buffer zone each side of the Carmichael River, and dust impacts are assessed as being unlikely, no significant impact on aquatic dependent species is predicted.

A management objective under this plan is to minimise emissions, particularly dusts. **Table 6-10** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#11: Light spill and other visual impacts

EPBC Approval 2010/5736, condition 6(c)(viii) requires details of potential impacts from light spill and other visual impacts be addressed in this plan.

During the construction project phase, lighting for safety and security of operations will be installed as the mine will operate 24 hours per day. Impacts from lighting will involve static floodlights associated with mine operations, lighting around the mine infrastructure area, workshops and ancillary buildings, vehicle lights moving around the site. Artificial night lighting levels within the Carmichael River are expected to be very low, if present at all, and this is considered to be a potential impact of minor significance (GHD, 2012).

Shading of the Carmichael River by the haul road bridge may lead to reduced fish movements across this visual barrier.

Whilst there are no predicted impacts to the Carmichael River associated with light spill and visual impacts. A management objective under this plan is to minimise light spill and other visual impacts. **Table** 6-**10** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

6.5 Mitigation and management measures for the Carmichael River

6.5.1 General management

Activities will be managed, and impacts mitigated for the Carmichael River under the Environmental Management System and Plan for the project. Other plans that also form part of the system include:

- Erosion and Sediment Control Plan
- Dust Management Plan
- Fire Management Plan
- Pest Management Plan (including weed management)
- Grazing management
- Receiving Environment Management Plan (surface water).

6.5.2 Receiving Environment Management Program

A REMP will be implemented by a suitably qualified person to monitor, identify and describe any adverse impacts to surface water quality from mining activities. The program will include, but is not limited to:

- water quality parameters specified in Table F5 of the EA - Receiving waters contaminant trigger levels
- monitoring at locations specified in Table F6 of the EA - Receiving water upstream background sites and downstream monitoring points
- monitor daily during release
- meeting the water quality parameters specified in the sub-catchment plan for the Belyando-Suttor Basin
- identification of any sensitive receiving waters or environmental values downstream of the authorised mining activity that will potentially be directly affected by an authorised release of mine affected water
- additional water quality parameters that focus on possible contaminants and saline intrusion
- control and impact monitoring locations
- monitoring frequency and timeframe (including scientific rationale)
- data analysis and reporting requirements
- reporting will be provided annually

6.5.3 Fire management

Fire and grazing can be considered competitors of one another for the available grass fuel / forage. Cattle grazing will be used to manipulate the grass fuel load and distribution.

The existing network of roads and tracks will be used to manage fire, rather than establishing additional firebreaks. This will help reduce the risk of weed incursion through movement of traffic into intact understorey. The numerous existing tracks that were created during mine exploration and development provide firebreaks that can help ensure that prescribed fires are not extensive. The value of maintaining these tracks as firebreaks needs to be weighed up against the value of minimising the risk they present in terms of weed incursion.

6.5.4 Weed and pest management

Weed and pest management is addressed in a project specific Pest Management Plan, which covers weeds and feral animals (pests). The Pest Management Plan has an overarching strategy, as follows:

- Identification of current and potential pest animals and plants for the area, and current locations of populations of pest animals and plants
- Avoidance of travel through or establishing infrastructure in areas of known pest plant infestation
- Prevention of the introduction of new weed and pest animal species to the area
- Minimisation of the increase in distribution and abundance of currently present pest plants or animals
- Control of identified weeds and pest animals to contain, reduce or eradicate pest populations.

Actions associated with weed management align with this strategy.

6.5.5 Grazing management

The existing cattle grazing practices were not identified by the EIS or EPBC Approval 2010/5736 as a potential threat or impact to the Carmichael River, hence grazing will be carefully used in the Project Area as a management tool to manage specific threats to the Carmichael River riparian zone. Grazing will be used to decrease the abundance and presence of weeds, such as *Cenchrus ciliaris* (Buffel Grass) and other exotic pasture grasses, and control fuel loads so as to reduce the risk of an uncontrolled fire.

The management of grazing within non-mined areas will be based on existing pastoral management practices under land agistment agreements, pastoral holding lease conditions and associated legislation. Sustainable grazing guides such as the 'Sustainable management of the Burdekin grazing lands' (McIvor 2012) will also guide the management of grazing activities. The following actions will be delivered under the legislation, agreements and conditions:

- Adani will complete annual habitat vegetation assessments to maintain and where possible enhance the Carmichael River
- Corrective actions will include additional fencing or spelling of paddocks to control grazing in order to prevent impacts whilst maintaining biomass levels for fire management.

Management objectives are:

- the strategic use of grazing to manipulate the grass layer and manage fire by reducing fuel loads and therefore fire intensity
- do not allow grazing itself to become a threat.

Management actions will be to:

- Maintain, and where possible, enhance the Carmichael River
- Manage grass loads to reduce fire risk
- Ensure grazing does not become an impact to grass layers and grass composition

The management of grazing along the Carmichael River will be based on existing pastoral management practices under land agistment agreements, pastoral holding lease conditions and associated legislation. Monitoring of the habitat will be carried out annually, and if there are demonstrated impacts to the

Carmichael River as a result of the grazing, the appropriate corrective actions will be implemented and will include:

- Additional fencing
- Spelling of paddocks to control grazing
- Additional controlled grazing to reduce biomass levels
- Additional pest controls
- Further fire management.

6.5.6 Erosion and sediment management

A total of 19 soil types have been identified within the project area based on geology, landform, native vegetation and soil profile features. It is important to reduce soil loss from the site for the management environmental values relating to both soil and water. Vegetation clearing, topsoil stripping, earthworks, and stockpiling will result in disturbance and exposure of soils to erosive forces from either overland flows of water or wind action. Soil loss reduces soil productivity and removes nutrients and organic matter. Sediment mobilised by overland flow can affect adjacent watercourses through increased turbidity, deposition of sediment on aquatic ecosystems, geomorphological changes and reduced water quality for other water users.

Management of erosion and sedimentation will be undertaken in accordance with the Erosion and Sediment Control Plan. This plan will identify all practices to be implemented prior to, during, and post-construction to minimise the potential for erosion to occur, including (but not limited to) timing of clearing activities, sediment and erosion control measures to be implemented, performance criteria and corrective actions. Monitoring and reporting protocols are to be detailed within this plan, and responsible parties for implementing the plan’s actions identified.

Controls include the following activities:

- Preparation of detailed erosion and sediment control plans for each aspect of the project
- Design stormwater systems to include sediment retention basins
- Locate infrastructure away from drainage lines and steep slopes, where ever practicable
- Where practical, schedule works to avoid wet conditions, or if in streams, outside times of flow
- Minimise the areas to be disturbed
- All disturbed areas to be revegetated or protected from erosion using suitable control measure

Monitoring activities will include the inspection of sediment control devices and stormwater systems, including diversion drains and outlets.

6.6 Monitoring of the Carmichael River

To adequately address approval conditions, and to determine that adequate mitigation and management measures are implemented, a detailed monitoring program has been developed for the Carmichael River. This work will build upon the significant studies completed during the EIS.

This section summarises the monitoring program for the Carmichael River. Some tasks will overlap with monitoring requirements for other GDEs, in particular with regard to the Waxy Cabbage Palm. Monitoring programs will be implemented following approval of this GDEMP.

The EA has detailed requirements in relation to the management and disposal of mine affected water

6.6.1 Pre-impact Monitoring

Ecological Features Map

A detailed 'ecological features' map will be prepared for the Carmichael River to assist in dieback and river health monitoring. The map will draw upon the results of baseline and pre-impact monitoring and be completed within three months of completing the first wet and dry season surveys. The map will be constructed using GIS and ground-truthing, and will identify priority management areas including:

- the locations of Waxy Cabbage Palm
- Rubber Vine infestations
- riparian vegetation composition and health
- areas of connectivity / disconnection with the groundwater, based on modelling
- gaining / losing sections of the river relative to the groundwater
- the location of deep pools that become isolated during periods of low and act as refugia for aquatic fauna
- the location of riffles
- the location and size of aquatic macrophyte beds
- other key aquatic habitat features (e.g. natural flow obstructions such as bedrock constrictions, log jams; lateral and mid-stream gravel and sand bars; undercut banks)
- weed and pest species locations and extent.

Indicators: Population structure, community condition, weeds and pests, riparian community health, fauna use of riparian habitat, canopy cover.

Riparian Condition Surveys

The aim of the riparian survey is to assess the relationship between groundwater level, base flow and the existing health of riparian communities. This survey will involve the establishment of permanent CORVEG / BioCondition monitoring plots on the northern and southern banks of the Carmichael River. These plots will be located within 200 m of the Carmichael River, focusing on remnant riparian vegetation communities dominated by River Red Gum, Weeping Paperbark, Narrow-leaved Paperbark, and Waxy Cabbage Palm. Monitoring will require a minimum of two CORVEG / BioCondition monitoring plots per 50 ha of remnant riparian vegetation within 200 m north and south of the Carmichael River, within the Project area. At least half the monitoring plots will incorporate the Carmichael River bank.

Monitoring of the CORVEG / BioCondition plots will be undertaken twice annually, reflecting high flow / low flow variability in the Carmichael River. The pre-impact monitoring will be undertaken over one year and begin from approval of this plan, and prior to the commencement of excavation of the first box cut. Depth-to-groundwater data will be incorporated into the riparian vegetation monitoring schedule.

The CORVEG / BioCondition surveys will be undertaken as per the 'Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland' (Neldner et al. 2012) and the 'Method for the Establishment and Survey of Reference Sites for BioCondition' (Eyre et al. 2011).

The following information will be collected at each monitoring site during surveys:

- location
- structural formation
- leaf litter cover
- rock cover
- bare ground
- cryptogram cover
- crown cover
- species composition and cover (by species and by stratum)
- height of each strata
- cover of coarse woody debris
- number of large trees (eucalypt and non-eucalypt)
- diameter at breast height (DBH) of eucalypt and non-eucalypt trees
- weed cover
- erosion and severity
- disturbances and severity
- stem count for woody vegetation
- basal area.

<u>Indicators:</u> Population structure, community condition, weed cover and pests, riparian community health, fauna use of riparian habitat, wetland vegetation, canopy cover, threatened and endemic flora populations.

Carmichael River Aquatic Ecological Surveys

Prior to the commencement of dewatering impacts, ecological surveys will be conducted along the reach of the Carmichael River GDE. Permanent waterholes upstream of the Carmichael River as defined in the EPBC Act (i.e., upstream of Dylingo Creek) will also be surveyed, as these are likely sources for recolonisation after periods of no flow.

The surveys will determine the following:

- which vertebrate species are using remnant pools as refugia
- overall ecological condition of each site (e.g. using AusRivAS protocol)
- ecological patterns (macrophytes, fish, invertebrates) that occur through time as the river moves through drying and wetting phases.

Sampling will be undertaken over two years. In each year, sampling will be undertaken during a dry period, when pools become isolated and the degree of groundwater dependence is likely to be greatest, a wet period, when pools are connected with continuous flow and surface water is the dominant moderator of ecological processes.

Monitoring activities do not include an assessment of stygofauna communities, as the predicted groundwater drawdown along the Carmichael River is generally <0.2 m, except in two sections of the river closest to the mine approximately 800 m in length.

<u>Indicators:</u> Population structure, community condition, weeds and pests, riparian community health, fauna use of riparian habitat, spring wetland extent, wetland vegetation, threatened and endemic flora populations.

Carmichael River Groundwater Levels and Surface Water Flow

To further understand variability in groundwater levels and surface water flows and to inform groundwater and surface water models, detailed monitoring of groundwater levels and surface water flows in the Carmichael River will be undertaken prior to construction and during the first phase of construction and operations (during the pre-impact phase). Carmichael River groundwater level monitoring will be undertaken continuously from the bores and locations as identified in **Table 6-7** and surface water flow monitoring will be undertaken upstream, downstream and within the Project area.

Groundwater levels will be assessed using a series of bores from the bores and locations as identified in **Table 6-7** containing loggers that track changes in water level at least every 12 hours. The locations for these monitoring bores will correspond to ecological features shown in the ecological features map, once developed, (i.e. deep pools, Waxy Cabbage Palm riparian communities, areas of connectivity / disconnection with the groundwater, and gaining / losing sections of the river) to enable meaningful interpretation of potential direct interactions between groundwater conditions and these features.

Table 6-7 Groundwater Monitoring locations (from the GMMP)

Aquifer / Resource	Monitoring Bores (depth in m)
Alluvium	• C025P1 (11.00) • C027P1 (13.00) • C029P1 (13.40) • HD03B (11.37) • C14027SP (21.00) • C14028SP (20.00)
Clematis Sandstone (contributing to surface flow from the Doongmabulla Springs-complex)	• HD02 (32.00) • HD03A (37.00) • C14011SP (144.00) • C14012SP (168.00) • C14013SP (72.00) • C14021SP (46.00) • C14033SP (200.00) • C18001SP (197.00) • C18002SP (100.00)

Surface water flow will be monitored daily and analysed monthly (through all project phases) at the existing monitoring locations noted in **Table 6-8**, at a minimum of three sites (at least one upstream, one downstream and one in the area where drawdown is greatest) along the Carmichael River (**Figure 6-16**) and at control sites on the Belyando River (**Figure 6-16**). Adani will also install two additional stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease, the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence. The final gauging station locations will be determined based on factors such as ease of access, suitability and long term viability. Once determined, locations will be included in the updated versions of this plan.

At each site, the surface water flow rate will be assessed in accordance with the REMP. Monitoring will target pools that persist for long periods of time during drying phases (**Table 6-8**).To ensure gauged data are accurate, the channel cross-sections will be re-surveyed at stream gauging locations to maintain accurate height-flow-discharge relationships.

Gaining / losing sections of the river, relative to the groundwater, will be identified in the field using mini piezometers.

Stream flow in the Carmichael River is influenced by groundwater base flow (subsurface), upstream surface flow from a number of springs in the Doongmabulla Springs-Complex and surface water. The groundwater model re-run that is required within two years of commencement of mining operations will utilise baseline and pre-impact data to determine stream flow triggers and early-warning indicators to ensure impacts are consistent with those predicted and approved.

Table 6-8 Surface Water Monitoring locations (from the REMP)

Monitoring Points Receiving Waters	Receiving Waters Location Description	Latitude (decimal degree, GDA94)	Longitude (decimal degree, GDA94)
Upstream Background Monitoring Points			
CAR04	Carmichael River at US GS	-22.1087960	+146.3527180
BEL02	Belyando River at Bygana Waterhole	-22.1620320	+146.5285470
Downstream Monitoring Points			
CAR01	Carmichael River far DS mining lease	-22.0740740	+146.4675990
BEL01	Belyando River at Carmichael/Moray Rd	-21.9594600	+146.6568190

<u>Indicators:</u> Groundwater level, surface water level, surface water flow.

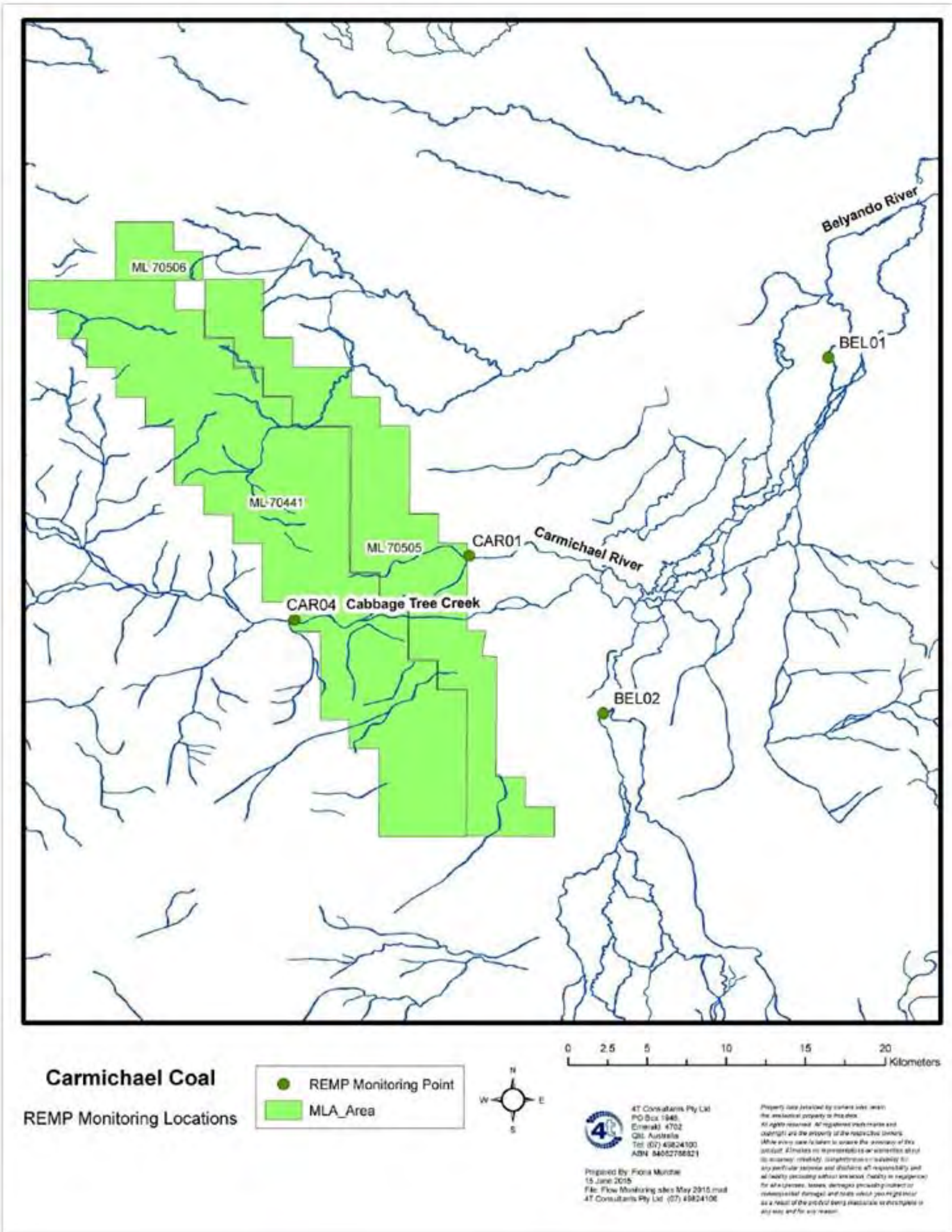


Figure 6-16 Surface Water Monitoring locations (from the REMP)

Carmichael River Groundwater and Surface Water Quality

Surveys of groundwater quality along the Carmichael River will include at least 12 sampling events that are no more than 2 months apart, over a 2 year period, as outlined in conditions E3 and E4 of the EA. Groundwater quality will be assessed using the same series of bores as described for monitoring groundwater levels. Surveys will identify groundwater hydrochemistry values for 36 chemical and physical water quality parameters, including major anions and cations, dissolved metals, nutrients, hydrocarbons and physio-chemical parameters (see Table E2 of the EA).

Surface water quality will be monitored at a series of sites along the Carmichael River (within the Project area and downstream) and at control sites in the Belyando River in accordance with the REMP. Background variation in surface water quality will be assessed using a series of additional surveys targeting low-flow areas.

Monitoring of surface water quality for the Carmichael River GDEMP will be implemented under the REMP and include the establishment of background and impact monitoring locations for water quality, determination of water quality trigger levels, continuous monitoring of key parameters that indicate mine-related impacts, and procedures for checking results against trigger levels and implementing corrective actions, if trigger levels are detected.

Indicators: Groundwater quality, surface water quality

Weeds and Pests

GPS mapping will occur of the location and extent ofinfestations within the riparian and aquatic habitats along the length of the Carmichael River, in the Project area, prior to construction and operations. This includes Rubber Vine, Parthenium, Hymenachne amplexicaulis (Olive Hymenachne) and other declared weed species.

Feral Pig disturbance area, and Rabbit, Cane Toad, and Mosquitofish densities will be surveyed in riparian and aquatic habitats of the Carmichael River, prior to construction and operations. Surveys will be undertaken during high and low water conditions, and target shallow pools for Feral Pigs, Cane Toads, and Mosquitofish, and river banks for Rabbits.

Indicators: presence of weed species, extent of weed coverage, presence of pest species, extent of pest disturbance.

6.6.2 Impact Monitoring

Riparian Condition

Monitoring of the CORVEG / BioCondition plots will continue to be undertaken during the operation of the mine. Monitoring frequency will continue to be annually and will increase to quarterly once drawdown commences. Depth-to-groundwater data will be monitored 12 hourly in accordance with the GMMP.

Indicators: riparian community health, fauna use of riparian habitat, groundwater levels.

Carmichael River Groundwater Levels and Surface Water Flow

Ongoing monitoring of groundwater levels and surface water flows will continue at the monitoring locations during operations, and post-operations, in and adjacent to the Carmichael River, upstream, downstream and within the Project area, as specified in the GMMP and REMP. Surface water flow data will be collected daily and analysed monthly.

Groundwater triggers for the Carmichael River were determined during development of the GMMP. It is to be noted that in the GMMP the groundwater level drawdown triggers are referred to as 'impact thresholds'. Hence any groundwater level triggers mentioned in this plan will be equivalent to groundwater impact thresholds in the GMMP.

The groundwater drawdown triggers for the Carmichael River is specified in the GMMP and also **Appendix B**, and relates to drawdown of alluvial aquifers according to EA threshold limits. This trigger will be updated when additional monitoring data is collected to accurately define the EWR. The groundwater trigger level will be applied to the minimum groundwater level (as this is the critical value for GDEs) and will account for seasonal fluctuations determined by the studies.

Groundwater monitoring bores C027P1, C029P1, HD03 B, C14027, C14028 and C0259P1 will be used to monitor groundwater drawdown in relation to trigger levels.

Detailed monitoring of groundwater levels will be undertaken 12 hourly in accordance with the GMMP. An ongoing surface water flow monitoring program will assess flow rates in the Carmichael River at the same time as groundwater level and riparian vegetation condition surveys. This information will feed into the conceptual model for ground and surface water flow along the Carmichael River.

Indicators: Groundwater level, surface water level, surface water flow.

Carmichael River Groundwater and Surface Water Quality

Ongoing surveys of Carmichael River groundwater and surface water quality will enable early detection (should it occur) of Carmichael River contamination by raised levels of hydrocarbons, nutrients, waste materials, and / or saline intrusion. A water quality monitoring program will be implemented as outlined in the REMP and include seasonal and event-based (following flooding and large rainfall events) monitoring, with samples collected after high flow events once flow has returned to normal levels. Surface and groundwater monitoring will be undertaken in conjunction with MAW water quality surveys to ensure water quality trigger exceedances can be clearly attributable, or not attributable, to mining activities. Contaminant trigger levels for releases are provided in Table F3 of the EA, with trigger levels for receicing waters provided in Table F5 of the EA.

Indicators: Groundwater quality, surface water quality

Weeds and Pests

Surveys for pest aquatic and riparian plants along the Carmichael River will be used to assess changes in densities of pest species, and increases in their range inside the Project area. Changes in the densities and range of pest fauna will also be monitored through surveys.

Indicators: presence of weed species, extent of weed coverage, presence of pest species, extent of pest disturbance.

Rehabilitated Riparian Zone

To monitor the rehabilitated riparian vegetation condition, BioCondition monitoring plots will be established within the rehabilitated riparian zone 500 m north and south of the Carmichael River. The purpose of these plots is to monitor the effectiveness of the 500 m buffer from the Carmichael River on the condition of riparian vegetation (see **Section 6.4**). Two riparian rehabilitation BioCondition monitoring plots will be established in every 50 ha of rehabilitated habitat, evenly distributed within the riparian zone. The condition of rehabilitated areas will be compared to benchmark values for the pre-clearing Regional Ecosystem at each monitoring plot. Once rehabilitation has commenced, these plots will be surveyed annually.

The BioCondition surveys will be undertaken as per the 'Method for the Establishment and Survey of Reference Sites for BioCondition' (Eyre et al. 2011). The following information will be collected at each monitoring site:

- location
- native species richness
- weed cover
- coarse woody debris cover
- native perennial grass cover
- organic litter cover
- tree species richness
- canopy height(s)
- recruitment of woody perennial species

- number of large trees
- tree canopy cover and shrub canopy cover

Surveys of rehabilitated areas will include an annual survey of bank stability in rehabilitated riparian areas adjoining the Carmichael River.

Indicators: Population structure, community condition, weed cover and pests, riparian community health, fauna use of riparian habitat, wetland vegetation, threatened and endemic flora populations,

Details of the statistical approach for Carmichael River triggers and monitoring are provided in **Table 6-9**.

Table 6-9: Statistical approach for Carmichael River triggers and monitoring

Indicator	Relevant triggers	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
Riparian community health	Riparian community health indicators deviate by more than statistically significant change from baseline conditions. Statistically significant change in health indicators compared to baseline conditions.	COREVEG / BioCondition plots to be surveyed Biannually (wet and dry season). A minimum of two plots per 50 ha of remnant vegetation within 200m north and south of the Carmichael River, within the project area	Structural formation, leaf litter cover, rock cover, bare ground, cryptogram cover, crown cover, species composition and cover (by species and by stratum), height of each strata, cover of coarse woody debris, number of large trees (eucalypt and non-eucalypt), diameter at breast height (DBH) of eucalypt and non-eucalypt trees, weed cover, erosion and severity, disturbances and severity, stem count for woody vegetation, basal area.	Descriptive comparison of mean health indicators across plots between the current sampling time and baseline. MDS graphs to show relative spread of plots based on community health indicators. Multivariate PERMANOVA test on health indicators to detect significant differences in the community health of the riparian zones sampling time and baseline. Follow up SIMPER tests to detect the main indicators driving the patterns in the data.
Fauna use of riparian habitat	Remnant riparian habitat use by fauna reduces by more than statistically significant change from baseline conditions. Statistically significant reduction in fauna observations compared to baseline.	Remote cameras and targeted fauna surveys (trapping).	Abundance of key species.	Descriptive comparison of mean use indicators across plots between the current sampling time and baseline. MDS graphs to show relative spread of plots based on fauna use indicators. Multivariate PERMANOVA test on use indicators to detect significant differences in fauna use between sampling time and baseline. Follow up SIMPER tests to detect the main indicators driving the patterns in the data.

Indicator	Relevant triggers	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
Weed and pests (within areas controlled by Adani)	Statistically significant increase in weed cover, pests or pest activity above baseline. Identification of new weed or pest species.	Weed and pest surveys undertaken at COREVEG / BioCondition plots, surveyed annually.	Inventory of all weed and pest species present. Identify spatial extent of weeds, especially Rubber Vine, along the Carmichael River. Identify areas of Riparian habitat subject to pig damage.	Descriptive comparison of mean weed cover, pest abundance, and area of pest damage at time of sampling to baseline conditions. Log the occurrence of new weed or pest species compared to baseline.
Groundwater Level	Groundwater level drawdown thresholds as outlined in the GMMP, Appendix B and Table E3 in the EA.	Monitoring at the bores listed in Table 6-7. Monitored 12 hourly as per GMMP	Groundwater level.	Univariate comparison between groundwater level at time of sampling and groundwater level threshold.
Groundwater Quality	Groundwater Quality Trigger levels as outlined in the GMMP and Table E2 in the EA.	Monitoring at the bores listed in Table 6-7. Monitored quarterly as per GMMP	Water quality parameters as outlined in GMMP.	Descriptive comparison with defined groundwater quality trigger levels.
Surface Water Flow (periods of flow) Surface Water Level (periods of no flow)	20th percentile of baseline surface water flow.	Monitor flow daily (analyse data monthly) during seasonal river flows prior to construction, during operation and post operation at monitoirng locations in Table 6-8.	River discharge Surface Water Level (periods of no flow)	Descriptive comparison of daily discharge at each month with the 20th percentile of baseline flow.

Indicator	Relevant triggers	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
Surface Water Quality	Surface water quality trigger levels in Table F3 and F5 of the EA.	Monitor in accordance with the REMP at monitoirng locations in Table 6-8.	Water quality parameters as outlined in REMP.	Descriptive comparison with defined surface water quality trigger levels.

6.7 Triggers for adaptive management or corrective actions

The GMMP identifies groundwater early warning triggers and drawdown level thresholds that have been also included in **Appendix B** for monitoring the impacts to the Carmichael River based on updated groundwater and surface water modelling. Ecological triggers for the Carmichael River GDE have been established and will be reviewed following the completion of the pre-impact surveys. Triggers are based on a statistically significant deviation in baseline and pre-impact conditions (as relevant). Water quality contaminant triggers will be set as the 85th percentile of baseline scores in accordance with Table E2 of the EA and Section 5.3.1 of the GMMP. Triggers for the following characteristics of the Carmichael River are specified in **Table 6-10** and include:

- Changes in groundwater level
- Statistically significant reduction in riparian community health indicators (CORVEG and BioCondition data) from baseline conditions
- Significant increase in weed cover, pests or pest activity above baseline.
- Identification of new weed or pest species.
- Water quality contaminant guidelines for groundwater and surface water
- Surface water flows
- Riparian zone rehabilitation

If a trigger is exceeded, an investigation will be conducted to determine whether the detected result is caused by mining activities. The investigation will follow the broad approach outlined in Section 3.3 of the ANZECC (2000) Guidelines, and will involve:

- Development of a decision tree model for the possible effect of mining activities on the measured variable
- Site-specific investigations involving the collection and interpretation of additional data
- A review of relevant data related to potential non-mining causes of variability in environmental variables (e.g. climatic data)
- Development of a detailed model of relevant environmental variables
- Expert opinion on the potential for environmental harm

Groundwater Level

Thresholds have been developed within the GMMP for both the level and rate of decline of the water table. When level thresholds are exceeded, an investigation and review of groundwater modelling will be instigated within 14 days of detection. Trigger (threshold) levels must be reviewed by a suitably qualified person every five years after the issue of the EA.

Riparian Community Health

Triggers for riparian community health are based on CORVEG / BioCondition indicators and scores as well as the dieback in trees.

Surface Water Flows

Triggers for surface water flow will be developed during the implementation of the surface water quality monitoring program as well as updated modelling predictions from the GMMP. Triggers will be based on the reduction of base flow, determined from monitoring the output of springs, alluvial bores and stream flow rates. Triggers will also be based on the potential subsequent changes to both water quality and the aquatic and riparian ecological community.

Ground and Surface Water Quality

Ground and surface water quality triggers for the Carmichael River will be 85th percentile of baseline values as mentioned in GMMP and REMP. Trigger levels for the contaminant points of receiving waters are identified in Table F3 and F5 of the EA.

Rehabilitated Riparian Zone

Triggers for these areas will be developed during the development of the riparian Rehabilitation Management Plan and will include:

- Tree height
- Canopy cover
- Species diversity
- Weed cover
- BioCondition Benchmark scores.

6.8 Adaptive management

An adaptive management framework will be employed to mitigate impacts from the Project and will include a review of trigger levels for the Carmichael River during the course of the Project and particularly in response to long term monitoring and studies undertaken during each assessment and monitoring stage.

The effectiveness of management and mitigation measures will be reviewed and assessed at the completion of each assessment and monitoring stage. If monitoring identifies that managemernt measures are ineffective, the GDEMP and GMMP will be updated with improved management measures.

In accordance with Conditions E13 and E14 of the EA, the following process will be initiated:

- an investigation will be instigated within 14 days of detection to determine whether the fluctuations are the result of mining activities, pumping from licensed bores, seasonal variation or neighbouring land use
- if the investigation determines that the exceedance is caused by mining activities, the following tasks will be undertaken
  - determine whether impacts to the Carmichael River have occurred or are likely to occur
  - identify long-term mitigation and management measures to address the impact
  - identify corrective actions
  - notify the administering authority within 28 days of the detection
- undertake an assessment of the associated impacts to the Carmichael River
- update the GDEMP if required

When adaptive management and corrective actions are triggered, the first step is to investigate the cause of the trigger. Such investigations will involve a review of available data (including groundwater levels), consideration of the potential influence of mining and non-mining activities or fluctuations in the area that may have contributed to the result, and the input of specialist advice. The specific details of the investigation will be tailored to identify the root cause or best available solution to the identified issue.

In accordance with Conditions I3, I4 and I5 of the EA, if the investigation indicates that there is a risk of impacting the Carmichael River, the BOS will be reviewed and a report prepared within 3 months to identify the actual impact to the Carmichael River riparian corridor from the mining activities. If the assessment finds that the actual areas of disturbance to the Carmichael River differs from the area of disturbance as detailed in the BOS, the BOS will be amended within 30 days, from when tiggered, and the amended offset delivered within 12 months.

If a trigger is exceeded, an investigation will be conducted to determine whether the detected result has been caused by mining activities. The investigation will include consideration of groundwater monitoring data, surface water flow and quality data and ecological data collected on the Carmichael River riparian corridor. The investigation will focus on determining whether an observed decline in the Carmichael River is caused by the project, and will involve:

- A review of groundwater monitoring data to determine the potential for drawdown to be impacting the Carmichael River
- Site-specific investigations involving the collection and interpretation of additional data
- A review of relevant data related to potential non-mining causes of variability in environmental variables (e.g. climatic data)
- Developing a detailed model of relevant environmental variables
- Expert opinion on the potential for environmental harm

6.9 Management objectives, performance criteria, adaptive management triggers and corrective actions

The threats to the Carmichael River relevant to the Project and potential project impacts and actions minimising impacts to the Carmichael River are summarised in **Table 6-10**. The tables address the following:

- management objectives
- performance criteria
- management actions
- monitoring
- triggers for adaptive management and corrective actions
- specific, measurable and time-bound corrective actions.

The relevant statistical analyses outlined in section 5.4.3 support the specific performance criteria for the Carmichael River. Table 6-10 and Table 6-9 (Statistical approach for Carmichael River triggers and monitoring) will be used to assess the success of management measures against goals, triggers, implementation of corrective actions if the criteria are not met within specified timeframes.

At the conclusion of pre-impact monitoring, the performance criteria, monitoring and triggers will be reviewed, and updated, as required, via the review and adaptive management process detailed in sections 10.2 (Pre-impact studies, reporting and updates), 10.3 (Annual and compliance reporting) and 10.4 (Reporting and monitoring of related management plans and programs).

The objectives apply for the life of the approvals, and the life of this plan, subject to updates via reviews and adaptive management process detailed in sections 10.2 to 10.4

Groundwater Dependent Ecosystem Management Plan

Table 6-10 Management objectives, performance criteria, adaptive management triggers and corrective actions for the Carmichael River

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Trigger for adaptive management and corrective actions	Corrective actions
1	Groundwater drawdown from mine dewatering	Prevent any changes to groundwater / surface water flow interactions over approved impacts	No impact greater than that approved to the Carmichael River from mine dewatering	Implement groundwater monitoring and management program as per the GMMP and undertake review of conceptual model as per EA and EPBC Conditions to inform impact predictions. Incorporate research outcomes from the Great Artesian Basin Springs Research Program and Rewan Formation Research Program in relation to the GMMP implementation.	**Pre-impact monitoring:** Groundwater Management and Monitoring Program, Receiving Environment Monitoring Program **Impact monitoring:** Groundwater Management and Monitoring Program, Receiving Environment Monitoring Program	Groundwater level Groundwater quality Surface water quality Surface water flow and level	• Groundwater level drawdown thresholds as outlined in the GMMP, Appendix B and Table E3 in the EA are exceeded. • Groundwater quality trigger levels as outlined in the GMMP and Table E2 in the EA are exceeded. • Changes to groundwater modelling and predicted drawdowns. Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded. Statistically significant change in condition metrics compared to baseline/pre-impact conditions as per Section 6.3	The appropriate corrective actions will be implemented and will include: • Immediately limiting mining activities to current activities, until monitoring indicates the trigger level(s) are no longer being exceeded, or at further risk of being exceeded. • If the investigation indicates that there is a risk of impacts to the Carmichael River beyond that approved, monitoring will be reviewed and a report prepared within 3 months to identify the actual impact from the mining activities. • If the investigation finds that the actual areas of impact to the Carmichael River differs from the area of impact as detailed in the BOS, the BOS will be amended within 30 days and the amended offset delivered within 12 months.
		Minimise the impacts of water drawdown on the Carmichael River	Project impacts are less than or equal to approved impacts at the equivalent stage of the mine life					
2	Subsidence impacts from underground mining	Ensure no habitat alteration through subsidence	No subsidence impacts to the Carmichael River	Implement the subsidence management plan Changes to the flow of the Carmichael River, as a result of groundwater flow and surface water diversions and flows, are addressed in #1 and #3.	**Pre-impact and impact monitoring:** Subsidence Management Plan	Early warning signs of subsidence, such as tilt, strain and displacement exceeding predictions at monitoring locations. Observations of cracking or ponding in the Carmichael River.	• Measurable evidence of tilt in the vicinity of the Carmichael River attributable to Subsidence.	The appropriate corrective actions will be implemented and may include: • Rectifying impacts (e.g. pumping out ponds) • Re designing and implementing and water diversions. • No expansion of underground mining until investigations complete.
3	Changes to surface water levels and flows	Minimise changes to surface flows and flooding. Reduce the impact of stream diversion and flood levees Minimise the loss of catchment area and impacts of subsidence on catchment runoff	No hydrological changes to the Carmichael River greater than those approved as a result of catchment loss, stream diversions and flood.	Undertake further modelling prior to construction of the final levee location and the final bridge design to demonstrate that the impact due to increased flood inundation duration is minimised to protect riparian vegetation. No water for the Project will be sourced directly from the Carmichael River within the reach of ML area. Implement the Receiving Environment Management Program and Erosion and Sediment Management Plan	**Pre-impact monitoring:** , Receiving Environment Management Program **Impact monitoring:** , Receiving Environment Management Program	Surface water flow (and level (periods of no flow)	• Flooding / inundation is greater than predicted • Decreases in water flows within the Carmichael River due to loss of catchment area, diversions and levees exceed those predicted from hydrological modelling during the EIS phase of the project. • Water is sourced from the Carmichael River	The appropriate corrective actions will be implemented and may include: • If water is sourced from the river, immediately ceasing the activity • Informing the administering authority within 30 days of incident. An investigation into potential impacts within 14 days of detection. • If it is determined that impact to the Carmichael River have resulted, the administering authority will be notified within 28 days and mitigation measures implemented. • Supplementing water flow with additional water from the mine site, via the approved discharge locations • Rehabilitation activities to be undertaken in areas of temporary disturbance.

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#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Trigger for adaptive management and corrective actions	Corrective actions

		No greater impact than approved to the Carmichael River from the quality or quantity of water released from the project area.	Water from the project area released into the Carmichael River meets quantity and quality conditions in EA.	Notify the administering authority prior to, and at the cease of, water release events.
				
				Monitoring of released water quantity must be undertaken by an appropriately qualified person in accordance with specified frequencies and trigger investigation levels.
				
				Review optimal location for discharge to the Carmichael River that considers ability to achieve high volume discharge by gravity.
				
				Stream flow gauging stations installed, operated and maintained to determine and record stream flows at locations and flow recording frequency specified in Table F4 of the EA
				
				Release of water to the Carmichael River from the project area in accordance with condition F2 of the EA about the maximum release rate for combined release point flows for each receiving water flow criterion specified in Table F4 of the EA.
					Pre-impact monitoring:
					Receiving Environment Monitoring Program
					
					Impact monitoring:
					Receiving Environment Monitoring Program as per Table F5 and F6 in the EA that includes monitoring requirements before, during and after a discharge event.
					
					Release point water quality
					Receiving Environment Management Program
						Surface water flow (periods of flow)
						Surface water level (periods of no flow)
						Surface water quality
							Mine affected water release limits in Table F2 and F4 of the EA are exceeded.	The appropriate corrective actions will be implemented and will include:
								• During a release event, comparing the downstream results to the upstream results in the receiving waters will be undertaken and:
								  o if the downstream result is the same or a lower value than the upstream value for the quality characteristic then no action will be taken; or
								  o if the downstream results exceed the upstream results complete an investigation into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining the details of the investigations carried out; and actions taken to prevent environmental harm
								• release limits will be reviewed once sufficient monitoring data is available to adequately characterise the baseline turbidity in the Carmichael River – including consideration of natural spatial and temporal variability
								• If there is potential for environmental harm identified, implementing management actions targeted at correcting the water quality parameter for which an exceedance occurred (e.g. changes to the discharge of mine affected water to achieve compliance).

		Minimise impacts on geomorphology	Water release flow rates into the Carmichael River meet conditions in the EA to prevent geomorphology impacts	An Erosion and Sediment Management Plan will be developed for the water discharge locations approved under the EA	**Impact monitoring:** Regular site inspections in accordance with the Erosion and Sediment Management Plan and Environmental Management System.	Visual record pH Turbidity	Evidence of erosion and / or sedimentation within the vicinity and immediately downstream of discharge locations	The appropriate corrective actions will be implemented and may include • Reviewing erosion and / or sedimentation controls • Stabilising river bank / bed • Undertaking targeted weekly inspections of erosion and sediment controls for the following month to review effectiveness.

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#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Trigger for adaptive management and corrective actions	Corrective actions
4	Surface water quality degradation	Maintain surface water quality in accordance with Table F3 and F5 of the EA. Protection of environmental values within waterways of the receiving environment.	Water quality is not impacted from mining operations and associated activities other than that approved through discharges associated with the EA	Vegetation clearing near, or within ephemeral waterways will be avoided when rain is falling, or imminent. Management of erosion and sedimentation will be undertaken in accordance with the Erosion and Sediment Management Plan. This plan will identify all practices to be implemented prior to, during, and post-construction to minimise the potential for erosion to occur, including (but not limited to) timing of clearing activities, sediment and erosion control measures to be implemented, performance criteria and corrective actions. Review optimal location for discharge to the Carmichael River, that considers availability of sufficient dilution flows to control salinity and ability to achieve high volume discharge by gravity. Compliance with additional management actions included in the Receiving Environment Management Program and Erosion and Sediment Management Plan	**Pre-impact monitoring:** Receiving Environment Management Program **Impact monitoring:** Receiving Environment Management Program that includes monitoring requirements before, during and after a discharge event.	Surface water quality	• Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded. •	The appropriate corrective actions will be implemented and may include: • During a release event, comparing the downstream results to the upstream results in the receiving waters will be undertaken and: o if the downstream result is the same or a lower value than the upstream value for the quality characteristic then no action will be taken; or o if the downstream results exceed the upstream results complete an investigation into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining the details of the investigations carried out; and actions taken to prevent environmental harm • Pumping water from significant subsidence areas into waterways that will flow into the Carmichael River, and complete earthworks to allow water ponding in subsidence areas to flow into the Carmichael River via connecting creek systems and diversion drains • If there is potential for environmental harm identified, implementing management actions targeted at correcting the water quality parameter for which an exceedance occurred (e.g. implement changes to the discharge of mine affected water to achieve compliance).
		Reduce and minimise the risk of contamination of the Carmichael River from mine affected water or from chemicals, fuel, heavy metals etc.	Water from the project area released into the Carmichael River meets quantity and quality conditions in EA	Any sites used for chemical and fuel storage will be located a safe distance away from the Carmichael River, with bunding or other raised barrier, resistant to normal flood events, between chemicals and habitat. All vehicles and machinery will be cleaned and maintained to minimise the introduction of contaminants such as oil and fuel. Compliance with management actions included in the Receiving Environment Management Program	**Impact monitoring:** Water Management Plan Erosion and sediment control Groundwater Management and Monitoring Program Receiving Environment Management Program	Surface water quality Groundwater quality	• Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded. • Groundwater quality trigger levels as outlined in the GMMP and Table E2 in the EA are exceeded. • Pollution of the Carmichael River by contaminants.	The appropriate corrective actions will be implemented and will include: • Minimising immediate impacts and rectifying through clean-up actions • Reporting to DES as per statutory and project requirements where incidents trigger reporting thresholds.

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#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Trigger for adaptive management and corrective actions	Corrective actions

5	Vegetation clearing and habitat loss	Minimise vegetation loss in the Carmichael River	No unapproved clearing or disturbance to vegetation.	Prior to the commencement of site works, the limits of clearing and exclusion areas will be clearly marked.
				See also management actions included in section 7 for the Waxy Cabbage Palm.
					Pre-impact monitoring
					Ecological features map
					Riparian condition survey
					Carmichael River Aquatic Ecological Survey
					Receiving Environment Management Program
					
					Close out report for the Permit to Disturb process includes check for compliance with:
					• clearing only in the approved footprint
					• no clearing in the no-go zone/s.
					
					Regular site inspections in accordance with the Environmental Management Plan and System.
						CORVEG attributes
						Canopy cover
						Vidual evidence of disturbance or clearing
							Trampling or clearing in the Carmichael River:
							• outside approved clearing footprint
							• in no-go zone/s
							• without a Permit to Disturb issued
								The appropriate corrective actions will be implemented and will include:
								• When clearing outside approved clearing footprint, no go zones or without a "Permit to Disturb Permit" issued,
								  o Environment Manager ensure that all clearing activities cease immediately
								  o Area assessed by a suitably qualified ecologist/person within 15 business days of investigation
								  o additional barricading to be installed
								  o Reviewing and modifying Permit to Disturb process and no-go zone identification and communication protocols
								  o Implement remediation measures within 1 month to promote revegetation
								
								If mitigation is unsuccessful, the provision of offsets, as an overarching corrective action to achieve the objective of minimising habitat loss.

		Minimise disturbance to significant riparian and aquatic ecological features	No unapproved disturbance to significant riparian and aquatic ecological features	Define ecological features on an ecological features map (see Section 7.6.1).
				The construction footprint for the road across the Carmichael River will avoid aquatic flora, waterholes, watercourse junctions and watercourse with steep banks.
				
				The Carmichael River bridge will span the main channel of the Carmichael River with no pylons or supports within the low flow channel.
				
				The location of the Carmichael River road will use an existing track, if present.
				
				Construction of the Carmichael River road will be undertaken in dry conditions as far as practicable.
				
				The Carmichael River road construction activities will comply with government guidelines for carrying out activities in a watercourse. Clearing slopes leading to the river will be delayed, where possible, until construction of the crossing of the Carmichael River is imminent.
				
				Prior to the commencement of site works, any conditions listed in the Permit to Disturb must be implemented (e.g. clearing extents clearly marked, trees/areas requiring protection clearly marked).
					Pre-impact monitoring:
					Ecological features map
					Riparian condition survey
					
					Impact monitoring:
					Pre-clearance surveys
					
					Close out report for the Permit to Disturb process includes check for compliance with:
					• clearing only in the approved footprint
					• no clearing in the no-go zone/s.
					
					Regular site inspections in accordance with the Environmental Management Plan and System.
						Ecological survey indicators
						Visual evidence of clearing or disturbance
							Disturbance outside areas of construction for the Carmichael River road	The appropriate corrective actions will be implemented and will include:
								• When clearing outside approved clearing footprint, no go zones or without a "Permit to Disturb Permit" issued,
								  o Environment Manager ensure that all clearing activities cease immediately
								  o Area assessed by a suitably qualified ecologist/person within 15 business days of investigation
								  o additional barricading to be installed
								  o Reviewing and modifying Permit to Disturb process and no-go zone identification and communication protocols
								• Supplementing water flow with additional water from the mine site, via the approved discharge locations
								
								The provision of offsets, as an overarching corrective action to achieve the objective of minimising habitat loss.

Groundwater Dependent Ecosystem Management Plan

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Trigger for adaptive management and corrective actions	Corrective actions
			Clearing of the Carmichael River does not exceed 5.47 ha of Waxy Cabbage Palm habitat as an unavoidable impact, as approved in EIS and referral documentation	Prior to site entry, all relevant site personnel including contractors shall be appropriately trained about the Carmichael River. All people on site who have not completed induction will be excluded from the site until the induction has been completed. Prior to the commencement of site works, any conditions listed in the Permit to Disturb must be implemented (e.g. clearing extents clearly marked, trees/areas requiring protection clearly marked).	**Pre-impact monitoring:** Ecological features map Riparian condition survey **Impact monitoring:** Monitoring of vegetation proposed to be cleared by the Environmental Manager, via the Permit to Disturb process. Receiving Environment Management Program Ongoing monitoring and reporting on clearing in the Carmichael River annually, and predicted to be cleared.	Area cleared	• Reach 75% of the clearing approved in the Carmichael River • Evidence of dieback or impacts to vegetation in the Carmichael River	The trigger of reaching 75% of clearing in the Carmichael River does not require correction as the clearing is approved to be carried out, however the following actions will be triggered: • Contacting the nominated representatives from compliance teams of DoEE and DES under the EPBC and Environmental Protection Acts when clearing reaches 75% of approved area for stage 1 • Providing maps and data showing clearing in approved impact areas, and calculations showing quantity of approved clearing • Providing advice demonstrating how the clearing will not exceed approved limits. When clearing outside approved clearing footprint, no go zones or without a "Permit to Disturb Permit" issued, • Environment Manager ensuring that all clearing activities cease immediately • Assessing the area by a suitably qualified ecologist/person within 15 business days of investigation • additional barricading to be installed • Reviewing and modifying Permit to Disturb process and no-go zone identification and communication protocols
		Enhance ecological values of riparian zones within a 500 m buffer either side of the centreline of the Carmichael River, within the Project area	Evaluation of the extent and condition of riparian vegetation within the riparian zone	Evaluate the extent and condition of riparian vegetation prior to the commencement of mine construction and operations.	**Pre-impact monitoring:** Ecological features map. Riparian condition survey. **Impact monitoring:** Riparian condition survey.	Population structure Community condition Riparian community health Fauna use of riparian habitat Wetland vegetation Threatened and endemic flora populations Canopy cover	• Failure to evaluate the extent and condition of riparian vegetation in the riparian zone prior to the commencement of construction and operations • Riparian health indicators (CORVEG and BioCondition data) statistically significant difference from pre-impact monitoring	The appropriate corrective actions will be implemented and may include revising and implementing an updated plan for riparian zone rehabilitation and management within 30 days.
		Minimise habitat fragmentation	Manage offset areas to maintain and improve the condition of the Carmichael River.	Management and monitoring of the offset area on Moray Downs West to occur in accordance with the Offset Area Management Plan (OAMP).				
		Carmichael River crossing area is rehabilitated	Rehabilitation success as per the EA criteria (quality and time)	Rehabilitation of the Carmichael River crossing will be undertaken at the completion of the construction and once temporary construction areas are no longer required. Rehabilitation will focus on the reinstatement of ground cover to stabilise the creek banks.	**Pre-impact monitoring:** Ecological features map Riparian condition survey **Impact monitoring:** Riparian condition Rehabilitated Riparian Zone	Rehabilitation success parameters as listed in Appendix 2 of the EA (native fauna species, plant regeneration, weed abundance, pest abundance), erosion Event monitoring for: pH Turbidity	Rehabilitation not meeting success criteria under EA for parameters such as vegetation cover, evidence of erosion within relevant EA timeframes.	The appropriate corrective actions will be implemented and will include: • Installing additional erosion and / or sedimentation in accordance with Erosion and Sediment Management Plan. • Stabilising the river bank / bed in accordance with Erosion and Sediment Management Plan • Reviewing the process for temporary disturbance and monitoring to improve response time • Rehabilitation activities to be undertaken in areas of temporary disturbance.

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#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Trigger for adaptive management and corrective actions	Corrective actions
6	Fire	Maintain a mosaic of fire history in the Carmichael River. Reduce the risk of bushfire spread	No uncontrolled fires (bushfires) in the Project Area. Fire management is conducted within an approved planning regime	The fire regime will be managed to utilise a patchwork of areas of different fire frequencies and times but biased toward low intensity fires. This regime would also help to reduce the risk of widespread hot fires by reducing fuel loading at the landscape scale. The existing network of roads and tracks will be used to manage fire, rather than establishing additional firebreaks. This will help reduce the risk of weed incursion through movement of traffic.	**Impact monitoring:** Fire Management Plan.	Fuel load levels and ground composition.	• Dense shrub layers forming due to fire promoted germination. • Incidence of uncontrolled bushfire	The appropriate corrective actions will be implemented and will include: • Reviewing fire regime based on monitoring results and aim to achieve appropriate balance of groundcover/shrub layer management • Amending the strategic grazing regime • Reviewing effectiveness of firebreaks, and establishment of additional fire breaks • Modifying the timing and/or intensity of controlled burns.
		Reduce the risk of bushfire ignition	No bushfires sparked by project activities.	Prior to site entry, all relevant site personnel, including contractors, will be made aware of fire safety and risks, including compliance with the Fire Management Plan. Bushfire mitigation measures will be outlined in the Bushfire Management Plan and will include, but not limited to: • Monitoring of weather conditions to identify high fire risk days, with controls to be upgraded on these days • Restrictions on vehicles being left idling with the exhaust in contact with dry grass • Designation of smoking areas • Development of bushfire fuel management practices in the Project Area • Minimise the residency time of accumulated coal around coal handling facilities to reduce the risk of spontaneous combustion • Ensure all crews are equipped to deal with fires. This includes both fire-fighting equipment and training • Monitor pasture biomass at the beginning of the wet season • Work sites will be provided with adequate fire-fighting equipment (water cart) and training • Implement actions to prevent and suppress the spread of fire, should bushfire be ignited.	**Impact monitoring:** Monitoring of fuel load levels and ground composition. To be assessed at least annually against the baseline and pre-impact data. Additional monitoring actions as per the Fire Management Plan.	Fuel load levels and ground composition.	Bushfire sparked by project activities.	The appropriate corrective actions will be implemented and will include: • Mitigating the established source, arising from the investigation, as to why and how the bushfire was sparked by project activities • Reviewing the existing Bushfire Management Plan, ensuring consideration of ecological values and Rural Fire Service recommendations • Increasing monitoring of adherence to fire management measures • Amending the strategic grazing regime • Modifying timing and/or intensity of controlled burns • Re-training of site team members • Assessing the benefits of strategic burning prior to the storm season to address pasture biomass.

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#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Trigger for adaptive management and corrective actions	Corrective actions
7	Weeds and pest plants through direct competition or habitat degradation	Reduce weed competition	No introduction of pest plants, invasive understorey species within the Carmichael River. Prevent the spread of weeds across the Project Area and into / from adjacent habitat.	Weed control, as part of the pest management plan, will focus on managing declared pest plants and invasive species during construction and operations. Weed hygiene controls, including the use of weed wash down stations, will be implemented in accordance with the pest management plan to prevent the introduction and spread of declared pest plants and other invasive weeds. Weed free areas within in the Carmichael River will be identified and mapped with strict weed control requirements for entering weed free areas. The establishment of new tracks through the Carmichael River outside of the clearing areas will be minimised to prevent transport of weed seeds into in Waxy Cabbage Palm management areas.	**Pre-impact and Impact monitoring:** Monitoring of weeds will be conducted yearly (including photo monitoring) or as per the project pest management plan. Weed and pest surveys will be undertaken along the Carmichael River and riparian area to: • identify the extent of weeds, especially Rubber Vine, along the Carmichael River • identify areas of the Carmichael River habitat subject to pig damage.	Presence of weed species Extent of weed coverage	• Introduction or establishment of declared pest plants, and invasive species into previously unaffected areas. • Results of weed monitoring indicate a degradation of the Carmichael River, due to a proliferation of weeds. • A significant increase in the abundance of weeds, or pests or identification of new infestations.	The appropriate corrective actions will be implemented and will include: • Eliminating potential sources or reasons that may have attributed to an increase in species richness and/or relative abundance of weeds • Amending weed hygiene restrictions within 1 week of concluding the investigation • Providing additional educational awareness training for all staff and contractors to ensure weed hygiene restrictions are adhered to • Revising weed control methods in accordance with the *Biosecurity Act 2014* • Increasing the frequency and intensity of weed controls for the following 12 months • Updating weed control methods in targeted weed control programs and plans.
	Feral animal impacts	Reduce habitat degradation by introduced herbivores Minimise predation risk by invasive mammals	No measured increase in feral animal numbers in the Project Area.	Adaptive management of pest controls to minimise threats to the Carmichael River. A project pest management plan will be developed and implemented prior to construction and operations, including measures for controlling rabbits, goats, foxes and cats. The project pest management plan will be developed in conjunction with neighbouring land owners, and will focus on tracks, waterways and habitat edges. Domestic animals other than cattle (horses and dogs may also be required e.g. during mustering) will not be permitted into the Project Area.	**Impact monitoring:** Monitor the presence and population abundance of invasive fauna to be yearly as per the project pest management plan. Regular site inspections in accordance with the Environmental Management Plan and System.	Presence of feral animals Extent of damage from feral animals	• Significant increase in the population of any invasive predator species from baseline and pre-impact scores. • Observed bed and bank degradation of the Carmichael River attributed to feral animals • Domestic animals not permitted are observed in the Project Area	The appropriate corrective actions will be implemented and may include: • Increasing the frequency and intensity of feral animal control. • Revising methods of pest animal control in accordance with Queensland Department of Agriculture and Fisheries (DAF) guidelines, and coordinate with neighbouring land owners to ensure a consistent approach • Reviewing actions and methods included in the project pest management plan • Updating feral animal control methods in targeted pest animal control programs • Increasing feral herbivore management efforts, in conjunction with neighbouring land owners • Communication with personnel involved and across all site team members (for example, via toolbox meetings).
8	Earthworks	Minimise damage from vehicles and machinery during earthworks and operations to the Carmichael River	Vehicles only drive on designated access tracks	Disturbance areas on either side of the road crossing the Carmichael River kept minimal and stabilised as soon as possible. Laydown, storage areas and parking outside of Carmichael River area. Vehicles and plant will drive on pre-determined roads only, and adhere to all speed limits, which will be clearly communicated.	**Impact monitoring:** Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Visual observation and records	Vehicles observed driving outside designated areas	The appropriate corrective actions will be implemented and may include: • Reviewing of mapping and access routes • Rectifying impacts • Reviewing and re-designing to avoid reoccurrence • Communicating with personnel involved and across all site team members (for example, via toolbox meetings).

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#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Trigger for adaptive management and corrective actions	Corrective actions
		Minimise impacts on geomorphology from earthworks	Prevent impacts known to the Carmichael River from erosion and sediment	An Erosion and Sediment Management Plan will be developed and implemented for the Carmichael River bridge construction by a suitably qualified person.	**Impact monitoring:** Regular site inspections in accordance with the Erosion and Sediment Management Plan and Environmental Management System.	Event monitoring for: pH Turbidity	Evidence of erosion and / or sedimentation within the vicinity of construction activities or caused by construction activities	The appropriate corrective actions will be implemented and may include • Stabilising the river bank / bed. • Reviewing erosion and/or sedimentation controls within 5 days of investigation conclusion • Implementation of revised controls prior to earthworks re-commencing • Undertaking targeted weekly inspections of erosion and sediment controls for the following month to review effectiveness
9	Noise and vibration	Minimise modification to the Carmichael River as a result of noise and vibration	No death to species within in the Carmichael River due to noise or vibration disturbance	Disturbance areas on either side of the road crossing the Carmichael River kept minimal and stabilised as soon as possible. Laydown, storage areas and parking outside of Carmichael River area. Plant and equipment are serviced and maintained to minimise machinery noise and v bration. Project impacts like noise, dust and lighting will be minimised by the implementation of the Environment Management Plan.	**Impact monitoring:** Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Event monitoring for: dB(A) peak particle velocity (PPV)	Dieback of vegetation in the Carmichael River likely to have been caused by noise or vibration.	The appropriate corrective actions will be implemented and may include: • Determining the root and contributing causes as being likely caused by noise or vibration • Reviewing and re-designing to avoid reoccurrence and address actual cause • Communicating with personnel involved where appropriate and across all site team members (for example, via toolbox meetings).
10	Emissions (including dust)	Minimise emissions (dusts)	Prevent disturbance from emissions (dust) on photosynthetic species within the Carmichael River.	Regular watering of project areas in accordance with procedures under the Environmental Management Plan. Vehicles are to be cleaned regularly and are not to be overloaded. Disturbance areas on either side of the road crossing the Carmichael River kept minimal and stabilised as soon as possible. Laydown, storage areas and parking outside of Carmichael River area. Coal dust to be managed in accordance with the Environmental Management Plan.	**Impact monitoring:** Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Event monitoring for: Total suspended particulate matter	Growth of vegetation known in, and adjacent to, the Carmichael River are inhibited due to dust emissions.	The appropriate corrective actions will be implemented and will include: • Where monitoring shows a reduction in habitat condition due to dust, mitigate source of dust • Reviewing and re-designing to avoid reoccurrence and reduce dust emissions impacts on habitat. • Communicating with personnel involved and across all site team members (for example, via toolbox meetings).
11	Light spill and other visual impacts	Minimise light spill	Prevent light disturbance in species within the Carmichael River, adjacent to works.	Install light controlling devices to deflect lighting away from adjacent habitats. Avoid using unnecessary lighting.	**Impact monitoring:** Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Observations of amount of light falling on Carmichael River	Direct light spill >100 m into the Carmichael River	The appropriate corrective actions will be implemented and will include: • Reviewing and re-designing light controlling devices, or adjust location of light, to reduce light spill and lighting levels • Communicating with personnel involved and across all site team members (for example, via toolbox meetings).

7 Waxy Cabbage Palm (*Livistona lanuginosa*)

7.1 Environmental Values

7.1.1 Status and description

Waxy Cabbage Palm is listed as vulnerable under both the EPBC Act and NC Act. Waxy Cabbage Palm is described as a stout single-trunked, fan-leaved palm that grows to 20 m in height (DoE 2015). It has abundant woolly scales on the leaf stalks and large brownish fruits that are diagnostic for the species.

7.1.2 Distribution

Waxy Cabbage Palm was previously listed as endemic to tributaries of the Burdekin River in the Burdekin-Ravenswood-Cape River area (Jones 1984). Dowe (2007) had described the main population as occurring on the lower Cape River and associated tributaries, listing the following as areas with the most intact and least impacted populations:

- Campaspe River, upstream from Muckinbulla Waterhole at Nosnillor Station
- Homestead Creek at Trafalgar Station
- Deep Creek at Dandenong Park Station.

Thompson and Turpin (2001) identified a small population of three to four individuals at Doongmabulla, near the Carmichael River. A larger population of Waxy Cabbage Palm has since been recorded along the Carmichael River near Doongmabulla including within the Project area (GHD 2012a; ELA 2014). The Carmichael River population is the most southerly known occurrence of the species (**Figure 7-1**). The population at Doongmabulla is addressed separately in **Section 8**, along with other listed species at that Springs-complex. This section focusses on the population along the Carmichael River.

In known areas, populations of Waxy Cabbage Palm are generally comprised of scattered individuals along the stream, rarely forming dense congregations (TSSC 2008). A detailed survey of eight sites within the Burdekin-Ravenswood-Cape River area by Pettit and Dowe (2004) recorded a total of 5,179 individuals, including 510 reproductive adults.

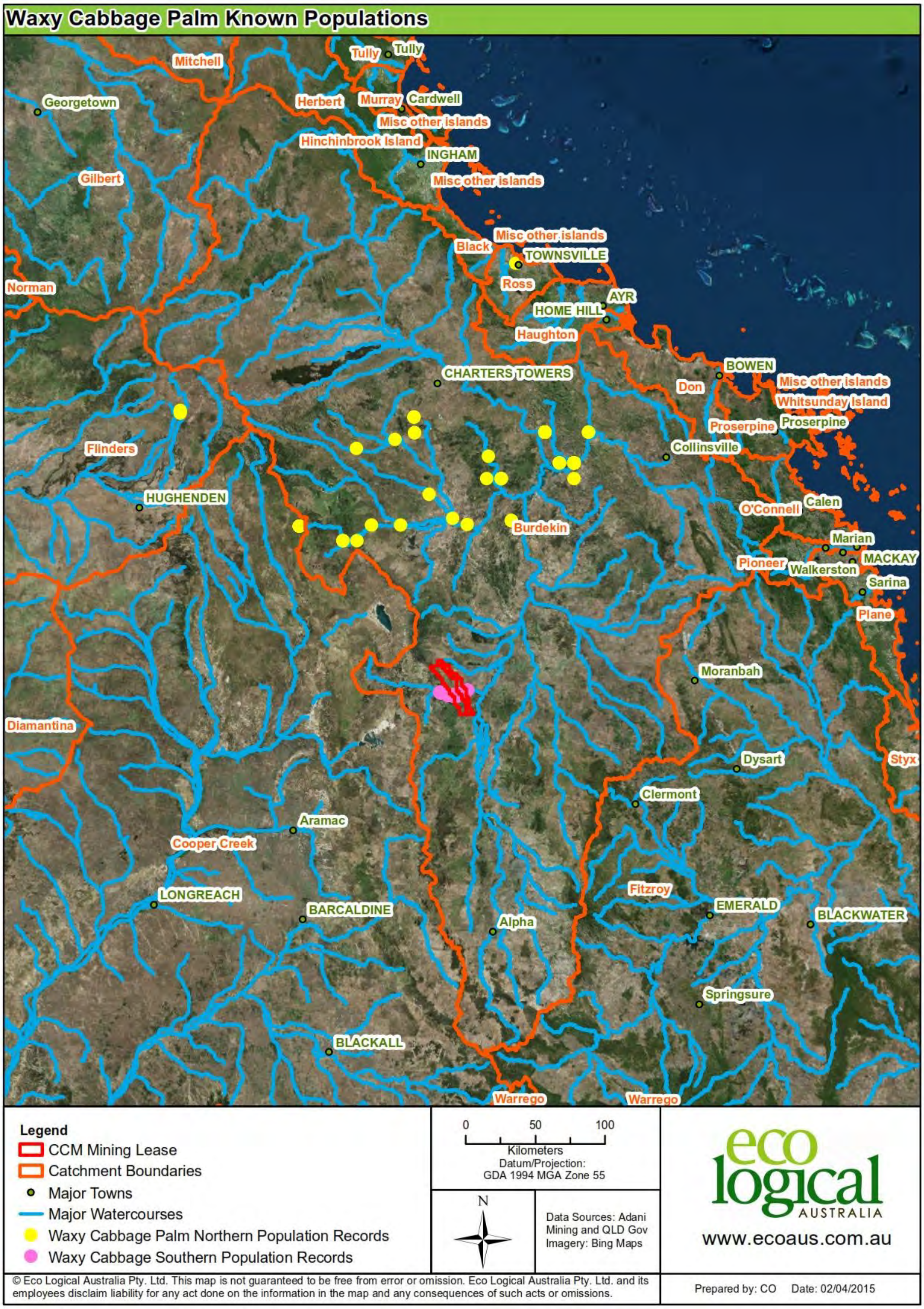


Figure 7-1: Known populations of Waxy Cabbage Palm

7.1.3 Ecology

Dowe (2007) has described appropriate Waxy Cabbage Palm riparian habitat as braided and anastomosed (multiple channel) permanent pools that flow for only part of the year and occur adjacent to floodplains in sandy alluvial soils derived from granite.

Climatic conditions of the Burdekin River system are typical of a semi-arid tropical environment with an average summer rainfall of 600-700 mm and extreme temperature range of 5-45°C (DoE 2015). This area also has extreme climatic conditions as rainfall can be influenced by unreliable monsoons or periodic severe droughts.

Suitable habitat for Waxy Cabbage Palm is present in Regional Ecosystems 10.3.13, 10.3.14, 10.3.6 and 11.3.4 (BAAM 2011). Associated tree species have been identified as *Corymbia brachycarpa*, River Red Gum, Weeping Paperbark and *Pandanus* sp. (DoE 2015).

Waxy Cabbage Palm flowers during spring, the driest part of the year, and flowers are bisexual (Rodd 1998; DoE 2015). Fruits will develop 4 – 6 months after flowering, which coincides with summer rains. The germination type for Waxy Cabbage Palm is remote ligular, with the growing point relatively deep below the soil surface, and germination usually takes place 2 – 3 months later. Successful recruitment is likely to be associated with several factors, including wet season flooding, and Waxy Cabbage Palm seeds are well adapted for water dispersal (Rodd 1998).

Waxy Cabbage Palm is thought to have episodic recruitment, which usually leads to populations of palms dominated by seedlings. Tomlinson (1990) described seven life-stages for Waxy Cabbage Palm (**Figure 7-2** and **Table 7-1**). The studies by Pettit and Dowe (2004) and GHD (2013a) showed that most populations of Waxy Cabbage Palm conformed to a population structure with a lower proportion of later life stages. This is expected due to a generally higher plant mortality rate in younger life stages, and a long time span inherent in maturity (Dowe, 2010). Variation in life stage proportions may also be the result of different habitat conditions across the sites. Pettit and Dowe (2014) also suggested that large numbers of seedlings are expected where there are sufficient reproductive adults and moist conditions for germination.

Table 7-1: Life-stage categories of Waxy Cabbage Palm based on Pettit and Dowe (2004)

Terminology for GDEMP	Life stage	Expected height (m)
Seedling/Juvenile (0.1-1.5m)	Seedling Undivided	0.1 m
	Fan	0.25 m
	Rosette	1.5 m
Sub-adult (1.5-5m)	Established	2.2 m
	Sub-adult	4 m
Adult (Non-reproducing) (5-8m)	Non-reproducing reproductive adult	>5 m
Adult (Reproducing) (8m+)	Reproducing Reproductive adult	>8 m


Seedling Undivided


Fan


Rosette


Established


Sub-adult


Non-reproducing adult

Reproducing adult

Figure 7-2 Life-stage categories of Waxy Cabbage Palm

Waxy Cabbage Palm is considered likely to be dependent on a seasonal recharging of soil water, which includes pockets and lenses that store water and which palms in arid watercourses often rely upon (Paul Forster, Queensland Herbarium, pers. comm. Sept 2012). The Waxy Cabbage Palm population on the Carmichael River has been identified as a GDE because individuals are usually located adjacent to sandy alluvial riverine channels and are associated with a high water table (GHD 2013a). The species is likely to require moist conditions for all life stages and is shallow rooted (Pettit and Dowe 2004). Although it is reasonable to conclude a dependency on groundwater from the correlation between the palm and water table (Eamus 2009) the detailed physiological requirements, including groundwater dependence, of this species have not been confirmed.

7.2 Supporting Groundwater resources

The groundwater resources supporting the Waxy Cabbage Palm are a combination of base flow from upstream sources (Doongmabulla Springs surface and subsurface flow) and closer to the mine area, alluvial groundwater resources.

For around 3 km upstream of the western boundary of the Mine Area, the predicted pre-construction modelled long-term average base flow is approximately 4,150 m^3/day. Model results suggest the Carmichael River predominantly upstream of the western boundary of the Mine Area is considered to be a ‘gaining’ section (**Figure 7-3**), which is consistent with groundwater level and surface water flow observations at the site. This section of the river corresponds to the location of a dense cluster of Waxy Cabbage Palms.

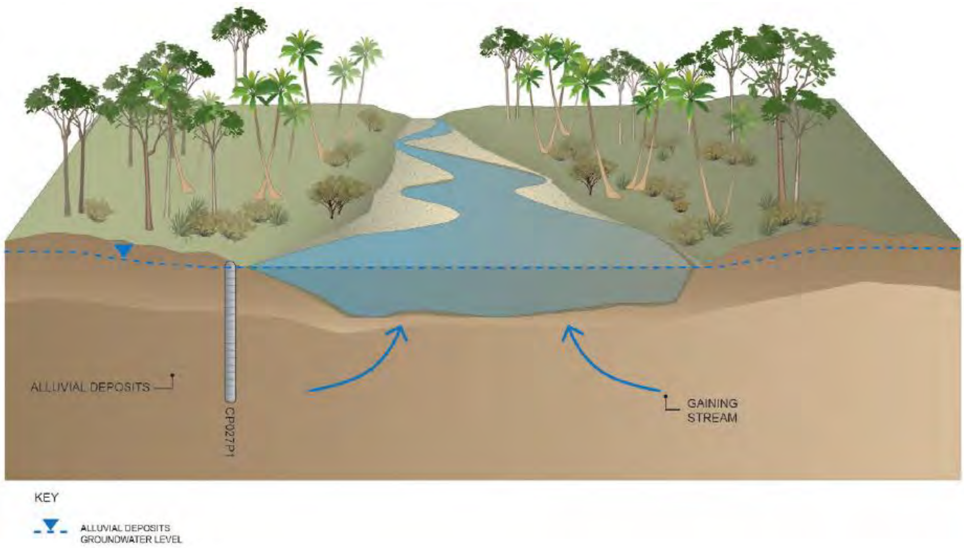


Figure 7-3 Gaining section of the Carmichael River (GHD 2014)

From a point a few hundred metres east of the western boundary of the Mine Area, pre-construction groundwater flow modelling results suggest that the Carmichael River switches from generally gaining flow to losing flow (**Figure 7-4**), which is consistent with groundwater level and surface water flow observations at the site. Between that location and the eastern Mine Area boundary, predicted pre-construction long-term average base flow gradually reduces to around 3,150 m^3/day and groundwater levels have been measured around 4.5 m below the channel bed.

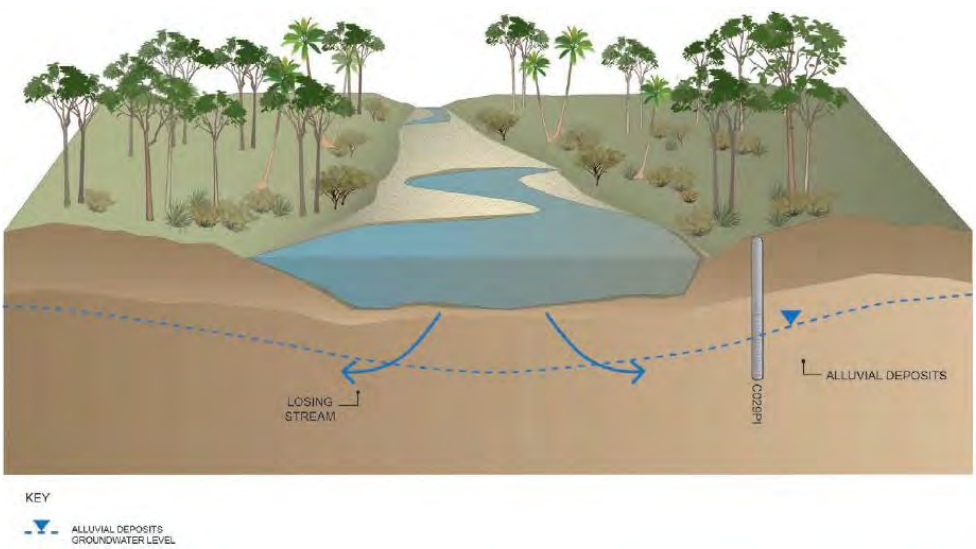


Figure 7-4 Losing section of the Carmichael River (GHD 2014)

Waxy Cabbage Palms are present along the Carmichael River and become progressively less common from west to east. However, apart from the reduced presence of Waxy Cabbage Palms, there is no discernible difference in riparian vegetation along the river.

It is important to note that base flow to the river will naturally vary, is seasonally affected and that current model predictions are effectively long-term averages. It is normal for base flow to fluctuate and for many sections of the river to have periods of zero base flow – for example, late in the dry season, or during droughts. Zero base flow periods pre-construction are predicted to occur approximately 30 percent of the time at the eastern Mine Area boundary.

7.3 Summary of baseline monitoring results

A targeted search of several reaches of the Carmichael River and Moses Springs-group during the EIS studies identified 831 palms, with adult palms comprising 12 per cent of the population (comprised of both non-reproductive and reproductive adults) (GHD 2014). Further ecological surveys have identified the species in additional areas along minor tributaries and within the alluvial plains (ELA 2014). In 2003, Pettit and Dowe estimated a population of fewer than 1000 individuals. It is important to note that this was estimated when the population was thought to be endemic only to the Burdekin River catchment. Known Waxy Cabbage Palm locations are shown in **Figure 7-5a-d**.

Waxy Cabbage Palm occurs along the Carmichael River in the Project area, and is primarily recorded in River Red Gum woodlands (GHD 2013a). This riverine ecosystem is described as an open-forest with the canopy occasionally dominated, or co-dominated, by Weeping Paperbark and Narrow-leaved Paperbark, and a dense ground layer.

Waxy Cabbage Palm populations along the Carmichael River are not evenly dispersed, with a 3 km long cluster inside the western boundary of the Project area, upstream of the confluence of Carmichael River with Cabbage Tree Creek. The habitat of this area is described as sandy alluvial soil on channel benches, scroll plains, channel bars, and in the bed of the Carmichael River, where the groundwater is closest to the surface (GHD 2014).

The Carmichael River changes from a 'gaining' to a 'losing' stream near the western boundary of the Project area. This means at the western boundary the water table is on average 0.5 m above the bed of the river channel, and drops to an average of 4 m below the river bed approximately half way across the Project area. Correspondingly the distribution of Waxy Cabbage Palm in the eastern half of the mine lease is sparse (GHD 2013).

Twenty-five individuals are known from the Moses Springs-group. These individuals are mostly located at the boundary of *Sporobolus pamelae* grassland, and River Red Gum and Weeping Paperbark woodland / open woodland (GHD 2014). The group of palms at the Moses Springs-group is the only known occurrence of a Waxy Cabbage Palm-GAB spring wetland association. **Table 7-2** lists all Regional Ecosystems where this species has been recorded within the Project area and surrounds.

Table 7-2 Regional Ecosystems associated with the Carmichael River population of Waxy Cabbage Palm

Regional Ecosystem	Description	Biodiversity Status	VM Act Status
10.3.12a	*Corymbia plena* dominates the canopy, usually with *C. dallachiana* co-dominant on sandy alluvial terraces. Scattered small trees, and a sparse ground layer.	No concern at present	Least Concern
10.3.13a	Riverine wetland or fringing riverine wetland, along watercourses. *Eucalyptus camaldulensis* dominates the very sparse to sparse canopy.	Of Concern	Least Concern

Regional Ecosystem	Description	Biodiversity Status	VM Act Status
10.3.14	*Eucalyptus camaldulensis* and / or *E. coolabah* open woodland along channels and on floodplains	Of Concern	Least Concern
10.3.6a	*Eucalyptus brownii* open woodland on alluvial plains	No concern at present	Least Concern
11.3.25	*Eucalyptus camaldulensis* woodland to open forest fringing channels and on adjacent bench plains.	Of Concern	Least Concern

Figure 7-5a: Known population of Waxy Cabbage Palm locations within Doongmabulla Springs-complex

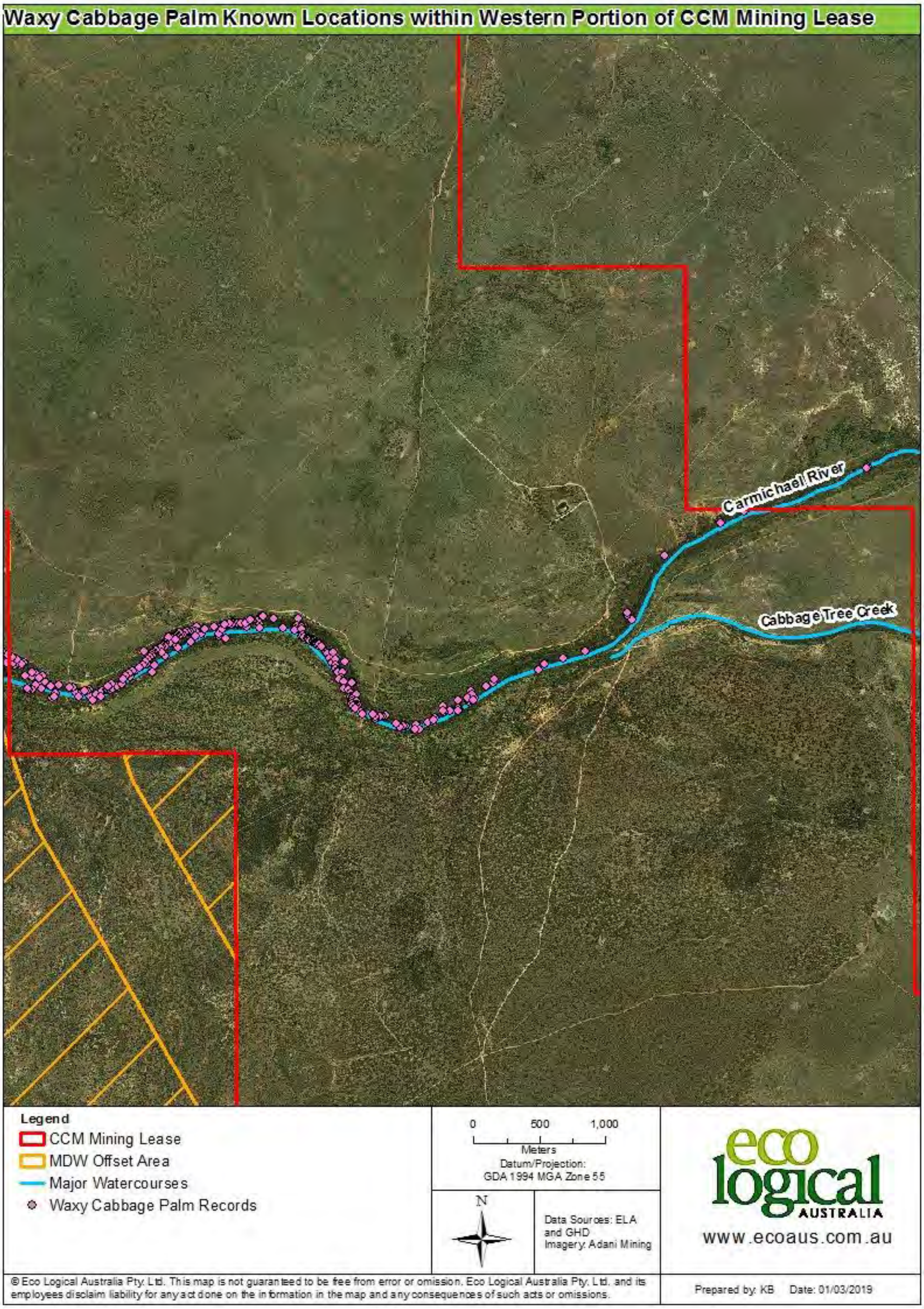


Figure 7-5b: Known population of Waxy Cabbage Palm in Project area

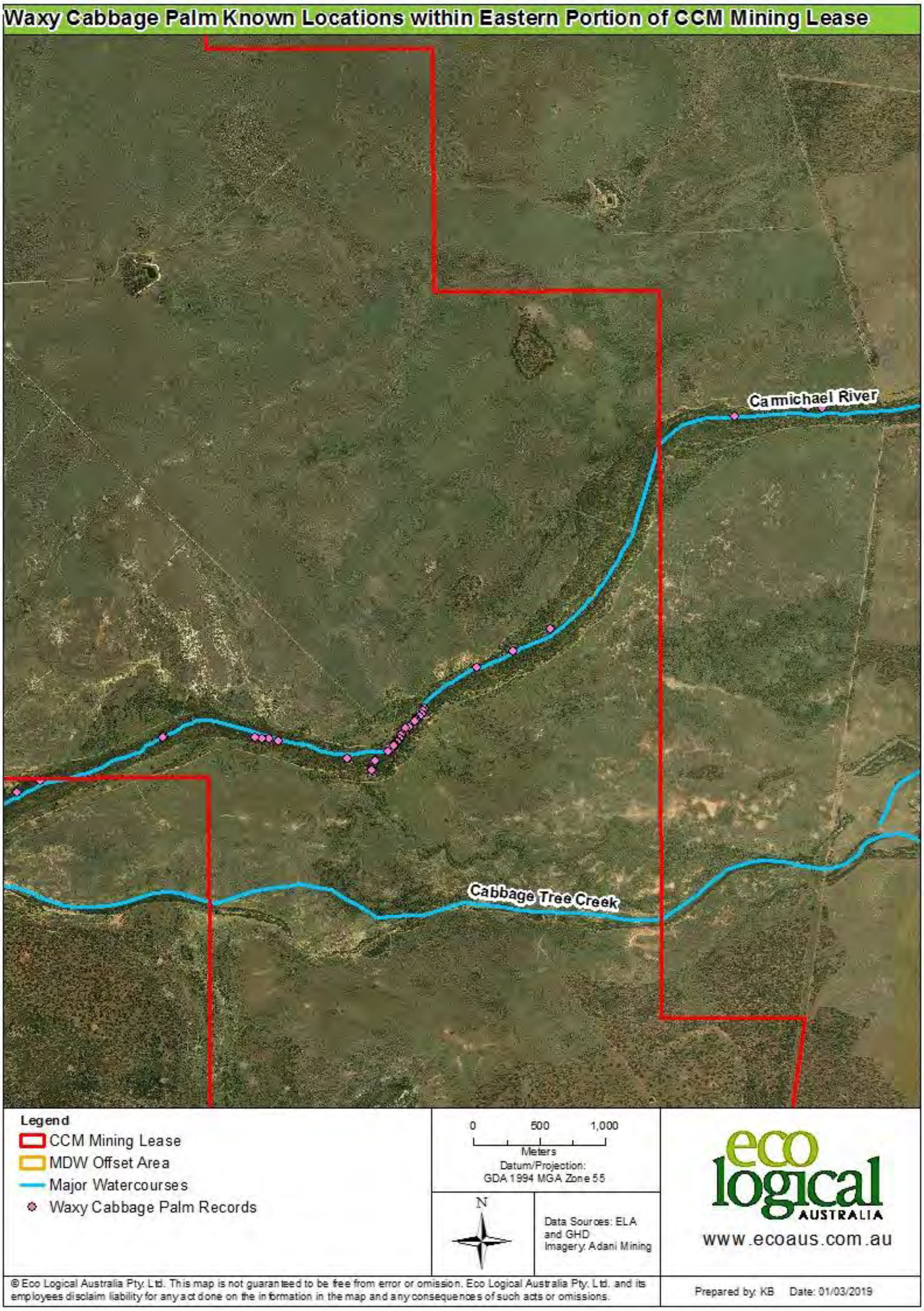


Figure 7-5c. Known population of Waxy Cabbage Palm in Project area

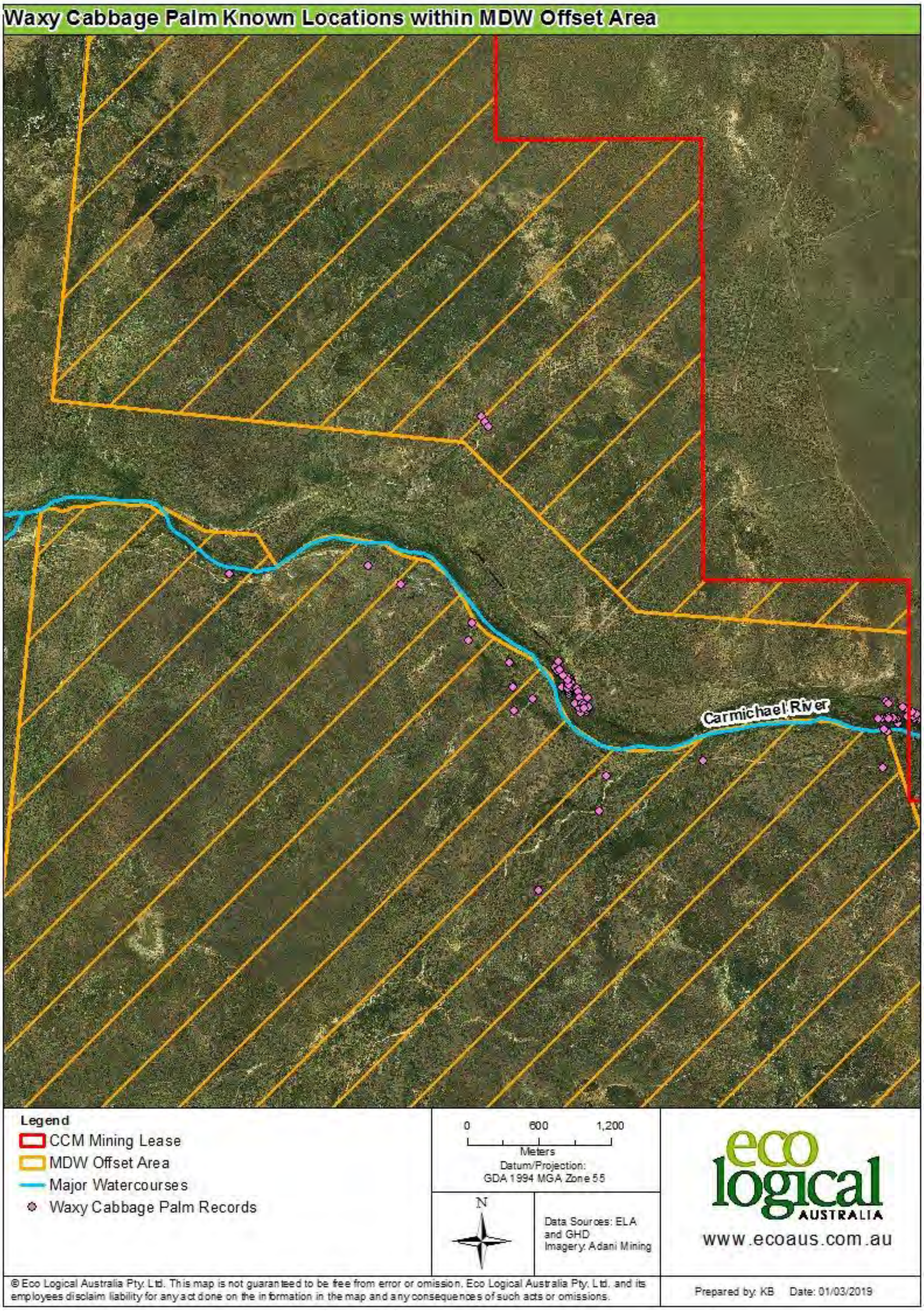


Figure 7-5d. Known population of Waxy Cabbage Palm in Project area

7.4 Threats and impacts

Threats and potential direct / indirect project impacts that are required to be addressed, as they apply to the Waxy Cabbage Palm on the Project Area are identified via the following:

- the Commonwealth *Approved Conservation Advice for Livistonia lanuginosa (Waxy Cabbage Palm)* (Department of the Environment, Water, Heritage and the Arts (DEWHA), 2008)
- Carmichael Coal EIS (GHD 2012b; GHD 2013a; GHD 2013b; GHD 2014)
- EPBC Approval 2010/5736, condition 6(c).

The Commonwealth *Approved Conservation Advice for Livistonia lanuginosa (Waxy Cabbage Palm)* identified the Waxy Cabbage Palm is believed to be somewhat fire resistant (Pettit and Dowe, 2003; Dowe, 2010). However, frequent fires combined with continuous grazing may overcome this resistance (Pettit and Dowe, 2003). Pettit and Dowe (2003) stressed the threats to the species from frequent fires, heavy weed infestations, and grazing (mostly associated with trampling, not just of seedlings but also through damage to riverbeds and banks, which form habitat for the species). These authors considered that these threats together with 'its limited geographic range and the small isolated population size makes it vulnerable to rapid decline given unfavourable natural conditions such as extended drought periods' (Pettit and Dowe, 2003).

The EIS (GHD 2014) identified the only direct impact as being 5.72 ha clearance of potential Waxy Cabbage Palm habitat, containing five individuals, to enable a bridge crossing of the Carmichael River for construction of the mine to the south of the river. These impacts are not estimated to commence until at least Year 10 of the project.

The EIS (GHD 2014) also identified the following potential indirect impacts of the project, including:

- Groundwater drawdown from mine dewatering, and changes to hydrogeology that may stress individuals. Groundwater modelling results suggest that groundwater drawdown from mine dewatering is predicted to occur in the vicinity of the Carmichael River, with the majority of impacts predicted to be less than 0.2 m, and a maximum predicted impact at operations of 4 m for 800 m in the middle of the River (GHD 2014, 2015);
- Changes to hydrology in the Project Area, such as stream diversions and flood levees and potential degradation of surface water quality, commencing from approximately Year 1 during construction; and
- Potential increase in weed competition as a result of increased traffic in the project area, commencing Year 1 during construction.

Inundation of Waxy Cabbage Palm is not an anticipated impact of the project.

The key threats and potential direct / indirect project impacts identified for Waxy Cabbage Palm relevant to the Project are detailed in **Table 7-3** and the following sections.

Table 7-3 Waxy Cabbage Palm Threats, potential direct / indirect project impacts and matters required to be addressed by conditions

#	Potential Threat or Impact	Identified in Conservation Advice as threat (DEWHA, 2008)	Potential direct project impact identified in EIS (GHD, 2014)	Potential indirect threat or impact identified in EIS (GHD, 2014)	EPBC Approval 2010/5736, condition 6	Environmental Authority condition I14 and Appendix 1, Definition of "GDEMP"	Project Phase/s*	Earliest predicted potential impact of the project	Impact addressed
1	Groundwater drawdown from mine dewatering	-	-	Yes	(c)(iii)	(5)	Operations Rehabilitation	Year 20	Table 7-6
2	Subsidence from underground mining	Yes	-	-	(c)(ii)	(5)	Operations Rehabilitation	*Not predicted*	
3	Changes to hydrology, including stream diversion and flood levees and degradation of surface water quality	Yes	-	Yes	(c)(vii)	(5)	Construction Operations	Year 1	
4	Fire	Yes	-	-	-	-	Pre-construction Construction Operations Rehabilitation	Year 1	
5	Weeds and pests through direct competition or habitat degradation	-	-	Yes	(c)(ix)	(5)	Pre-construction Construction Operations Rehabilitation	Year 1	
6	Grazing pressures, including stock browsing seedling leaves and trampling seedlings	Yes	-	-	-	-	Pre-construction Construction Operations Rehabilitation	Year 1	
7	Vegetation clearing / habitat loss	Yes	Yes	-	(c)(i)	-	Construction	Year 10	
8	Restricted geographic distribution	Yes	-	-	-	-	*Not applicable*	*Not applicable*	
9	Clearing and fragmentation for agriculture	Yes	-	-	-	-	*Not applicable*	*Not applicable*	
10	Earthworks	-	-	Yes	(c)(iv)	-	Construction Operations	Year 1	
11	Noise and vibration	-	-	-	(c)(v)	-	Construction Operations	Year 1	
12	Emissions (including dust)	-	-	Yes	(c)(vi)	-	Construction Operations	Year 1	
13	Light spill and other visual impacts	-	-	-	(c)(vii)	-	Construction Operations	Year 1	

* Please refer to Section 2.2 for details on GDEMP monitoring & implementation phase; baseline, pre-impact, impact

#1: Groundwater drawdown from mine dewatering

A potential threat for Waxy Cabbage Palm identified through the EIS and required to be addressed by the EPBC Approval 2010/5736, condition 6(c)(iii), is changes in hydrogeology that may stress individuals. Environmental Authority condition I14 and Appendix 1, Definition of "GDEMP" (5) requires potential impacts from mine dewatering of aquifers to be addressed in this plan.

The EIS Groundwater modelling results suggest that drawdown from mine dewatering is predicted to occur in the vicinity of the Carmichael River (GHD 2014, 2015).The predicted drawdown in the Alluvium aquifer is shown below in a series of figures across the life of the Mine (**Figure 7-6a-d**).

The predicted impact of this drawdown is a reduction in the volume of base flow to the Carmichael River. These predicted hydrological changes will cause the point at which base flow in the Carmichael River is reduced to zero (through leakage to the ground in 'losing' sections of the river) to migrate upstream, in the Carmichael River, downstream of the eastern edge of the Project area (GHD 2014). Output from the calibrated pre-construction steady-state models suggests that long-term average base flow to the Carmichael River peaks at around 7 km upstream of the Mine Area. Modelled total base flow loss from the groundwater model rerun (compared to the pre-construction conditions) is predicted to range between 916 m^3/day and 1,016 m^3/day, with the SEIS predictions positioned at 954 m^3/day (GHD 2015).

Waxy Cabbage Palm has a shallow root structure and the indicative source aquifer for the species is the alluvium. However, further information on the water sources associated with the Carmichael River will be collected during surveys, which will assist with management and monitoring of project impacts.

Key areas and timeframes for drawdown in the vicinity of the Carmichael River are included in **Table 7-4.**

Table 7-4 Key areas and timeframes for drawdown in the vicinity of the Carmichael River

<table>
<tr><th>#</th><th>Key areas</th><th>Predicted drawdown within vicinity of Carmichael River</th><th>When during operational project phase*</th></tr>
<tr><td>1</td><td>Near western boundary of mining lease</td><td>Approximately <0.2 m and zero flow periods will increase to approximately 5 % of the time, from zero per cent currently</td><td>From Year 20</td></tr>
<tr><td>2</td><td>Carmichael River – towards western and eastern mining lease boundaries</td><td>Maximum <0.2 m</td><td>From Year 20</td></tr>
<tr><td>3</td><td>Carmichael River – 800 m stretch near middle of mine area</td><td>Maximum of 4 m</td><td>From Year 20</td></tr>
<tr><td>4</td><td rowspan="2">Eastern mining lease boundary</td><td>Base flow reduced by around 1000 m³/day (up to 27 % of pre-construction base flow),</td><td>During operational phase, from Year 20</td></tr>
<tr><td>5</td><td>Approximately 950 m³/day (21 % of pre-construction base flow)</td><td>Post mine closure, from Year 60</td></tr>
</table>

#	Key areas	Predicted drawdown within vicinity of Carmichael River	When during operational project phase*
6		zero flow periods expected to increase by 30% to 60% of the time	During operation and post mine closure, from Year 60

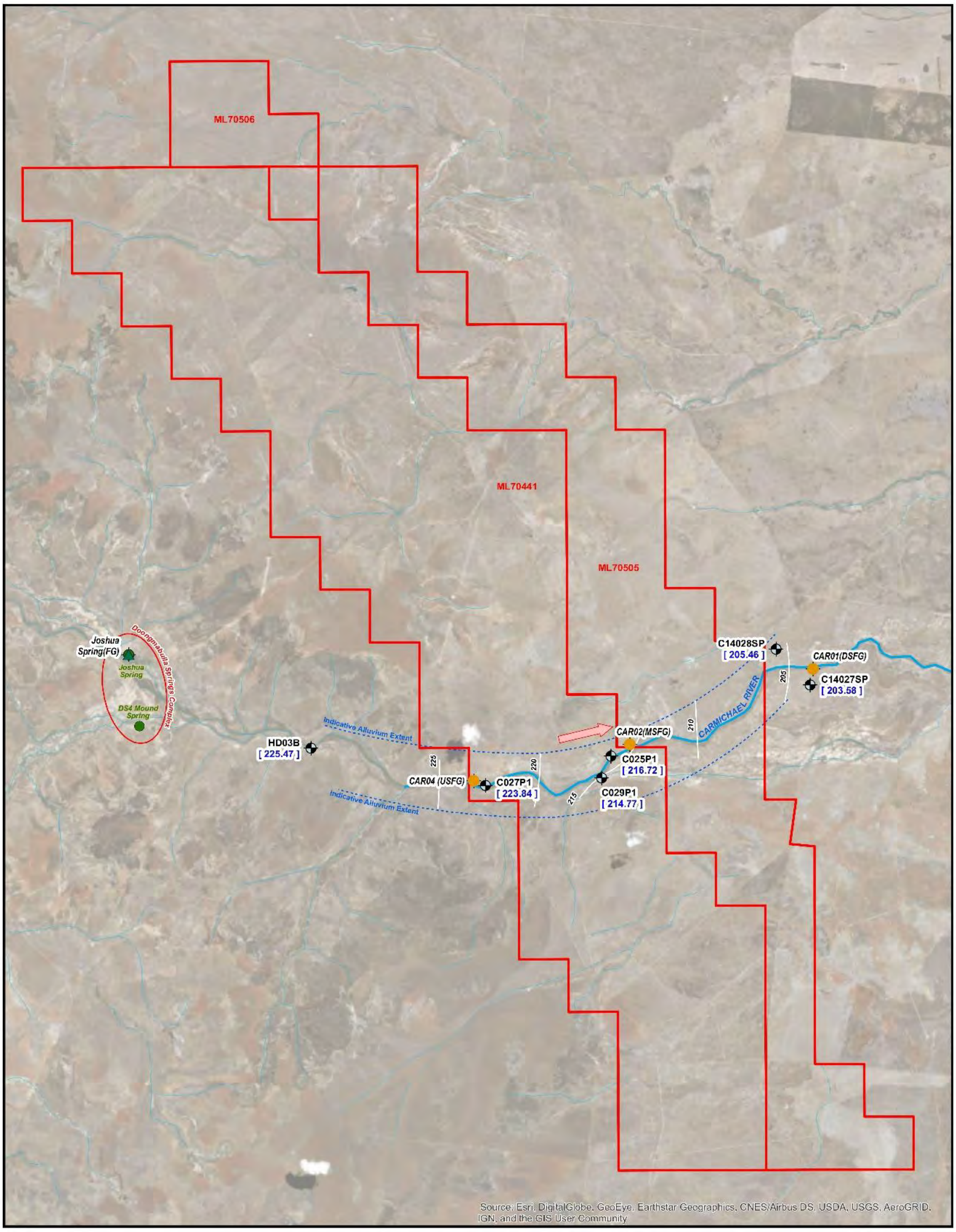
* Please refer to Section 2.2 for details on GDEMP monitoring & implementation phase; baseline, pre-impact, impact

Drawdown may impact dominant riparian species (River Red Gum and Paperbarks) and therefore result in loss of open forest canopy. Loss of open forest canopy may in turn impact Waxy Cabbage Palm.

The residual impact of 21.7 ha of habitat is predicted to be affected by hydrological changes to the Carmichael River (indirect impact zone) during mine dewatering. This indirect impact zone is located in the eastern half of the Project area where 9 adults and 160 juveniles have previously been recorded. Modelled pre-construction long-term data suggest that the Carmichael River switches from generally gaining flow to losing flow approximately 2.5 km downstream of the confluence of Cabbage Tree Creek with Carmichael River. Impacts to base flow are expected to occur 20 years into the operational life of the Mine. Drawdown of 1–4 m of groundwater may occur in the vicinity of some sections of the Carmichael River and groundwater flows into the Carmichael River may be reduced by up to 5%.

The residual groundwater impact to Waxy Cabbage Palm is shown in **Figure 7-7**. This residual impact was required to be offset through the Biodiversity Offset Strategy. An area of 90 ha has been established on Moray Downs West for this purpose (**Figure 7-8**).

A management objective under this plan is to limit and manage the impact of hydrological changes in Waxy Cabbage Palm habitat from mine dewatering beyond those approved and offset. **Table 7-6** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.



CARMICHAEL COAL MINE PROJECT

TITLE

Carmichael River Alluvium Groundwater Levels - Pre-Mining -

DISCLAIMER:
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NOTES:
SWL (mAHD) data is the level based on hydrographs by KRC (on behalf of Adani), unless otherwise mentioned in legend. Bore surface elevation from bore summary of Adani geology interp Confirmed units with most recent GMMP dated May 2017 RL elevation from survey in 2014 for new bores only. For old bores, Surface elevation plus measured stick up were combined for RL elevation. Aerial imagery sourced from the DNRM, State of Qld (2016)

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DATUM GDA94	CHECKED	SY
PROJECTION UTM	APPROVED	PA

LEGEND

- Mine Lease (ML)
- [233.00] Average Groundwater Elevation (mAHD)
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Spring Flow Gauging Stations
- Carmichael River Flow Gauging Stations

adani

STATUS: **Rev 0**

PROJECT NO: CCM

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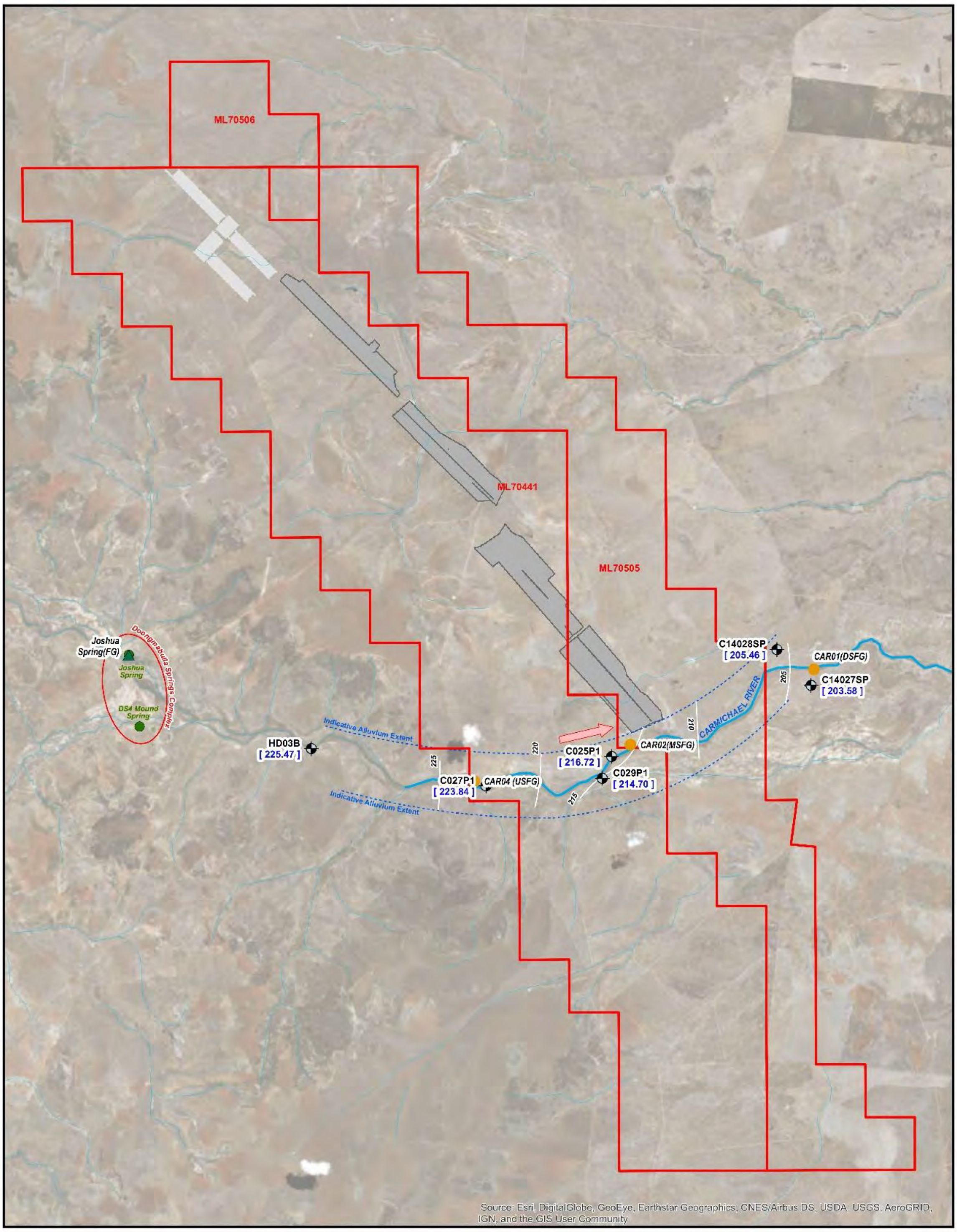

CARMICHAEL COAL MINE PROJECT

TITLE: **Carmichael River Alluvium Predicted Groundwater Levels - Year 5 -**

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DATUM GDA94	CHECKED	SY
PROJECTION UTM	APPROVED	PA

Location Map

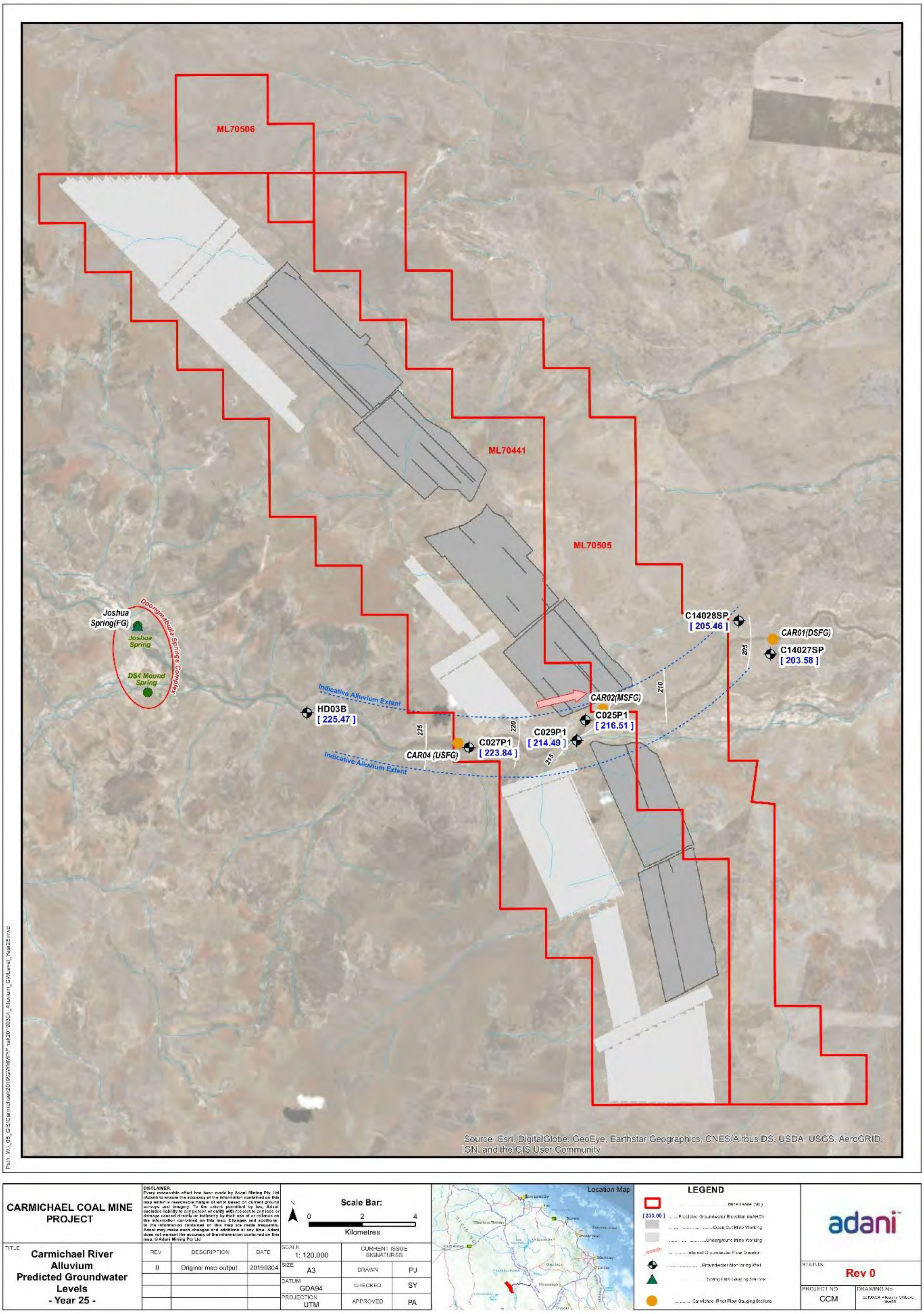
LEGEND

- Mine Lease (ML)
- [233.00] Predicted Groundwater Elevation (mAHD)
- Open Cut Mine Working
- Underground Mine Working
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Spring Flow Gauging Stations
- Carmichael River Flow Gauging Stations

adani

STATUS: **Rev 0**

PROJECT NO: CCM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ML70441
ML70505
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Joshua Spring
DS4 Mound Spring
Doongmabulla Springs Complex
Indicative Alluvium Extent
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C027P1
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Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
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Underground Mine Working
Inferred Groundwater Flow Direction
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Carmichael River Flow Gauging Stations
adani
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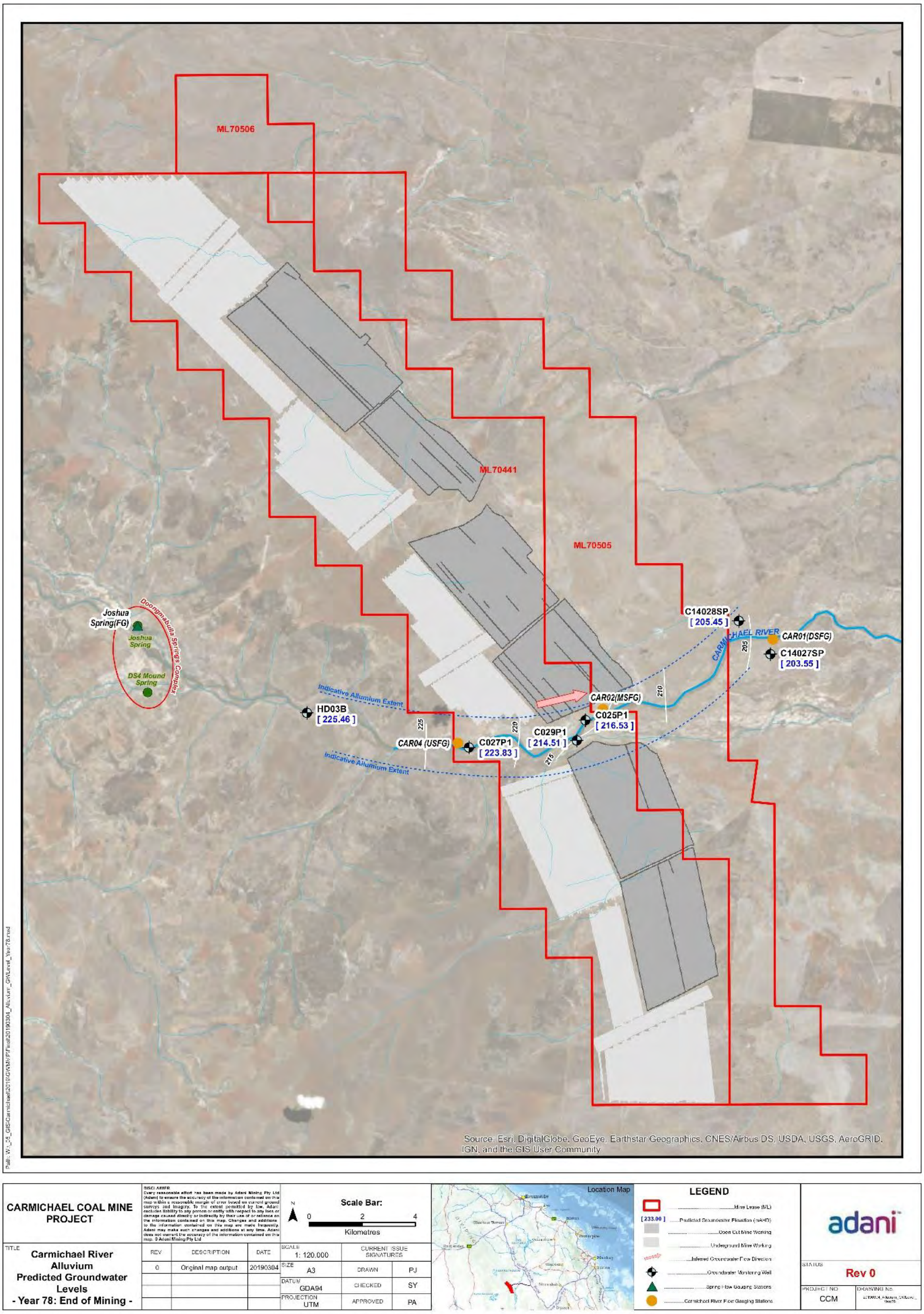

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STATUS Rev 0 | PROJECT NO CCM

Figure 7-6 a to d: Predicted drawdown to Alluvium aquifer over the life of the project

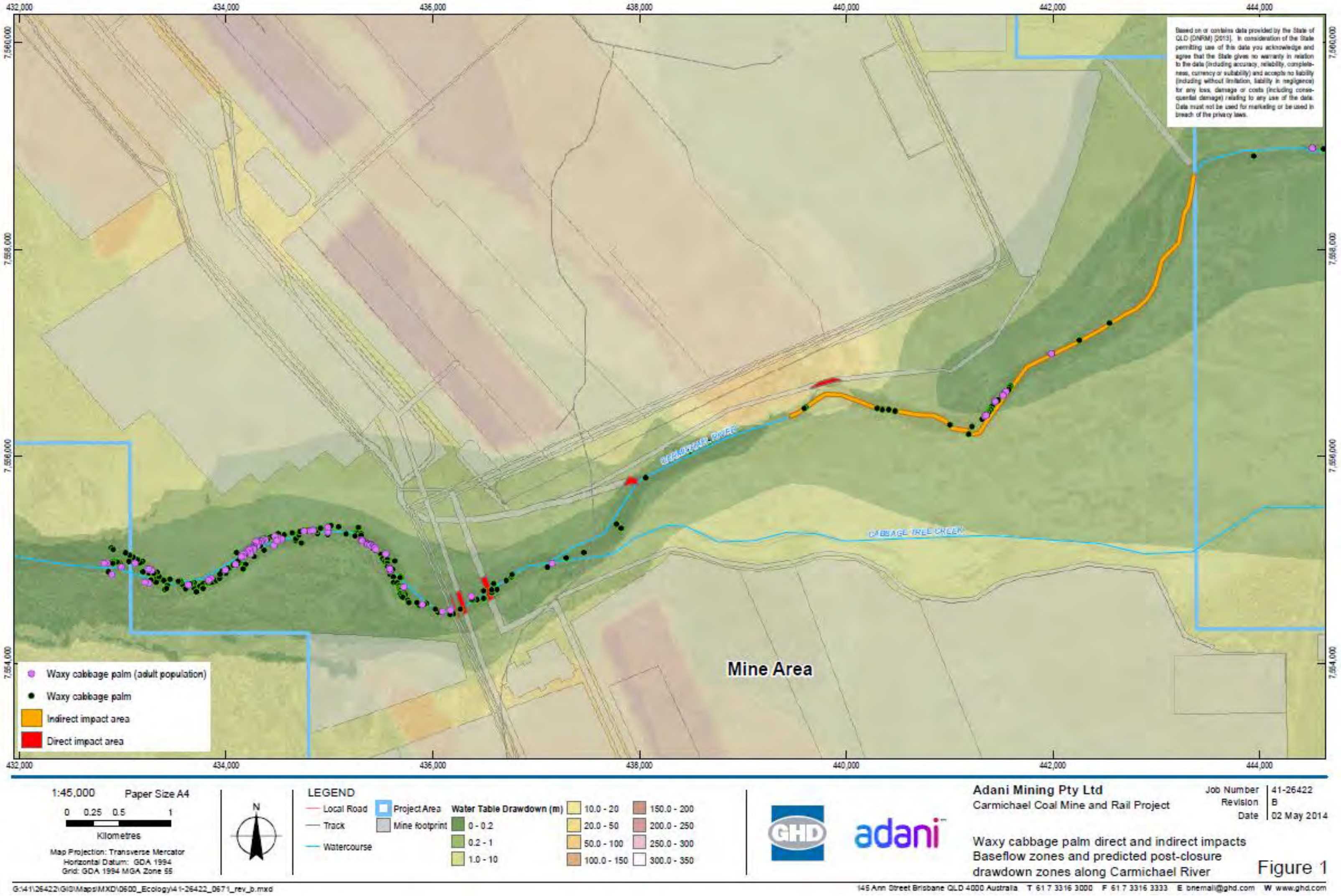

Figure 7-7 Location of residual groundwater and surface disturbance impacts on Waxy Cabbage Palm

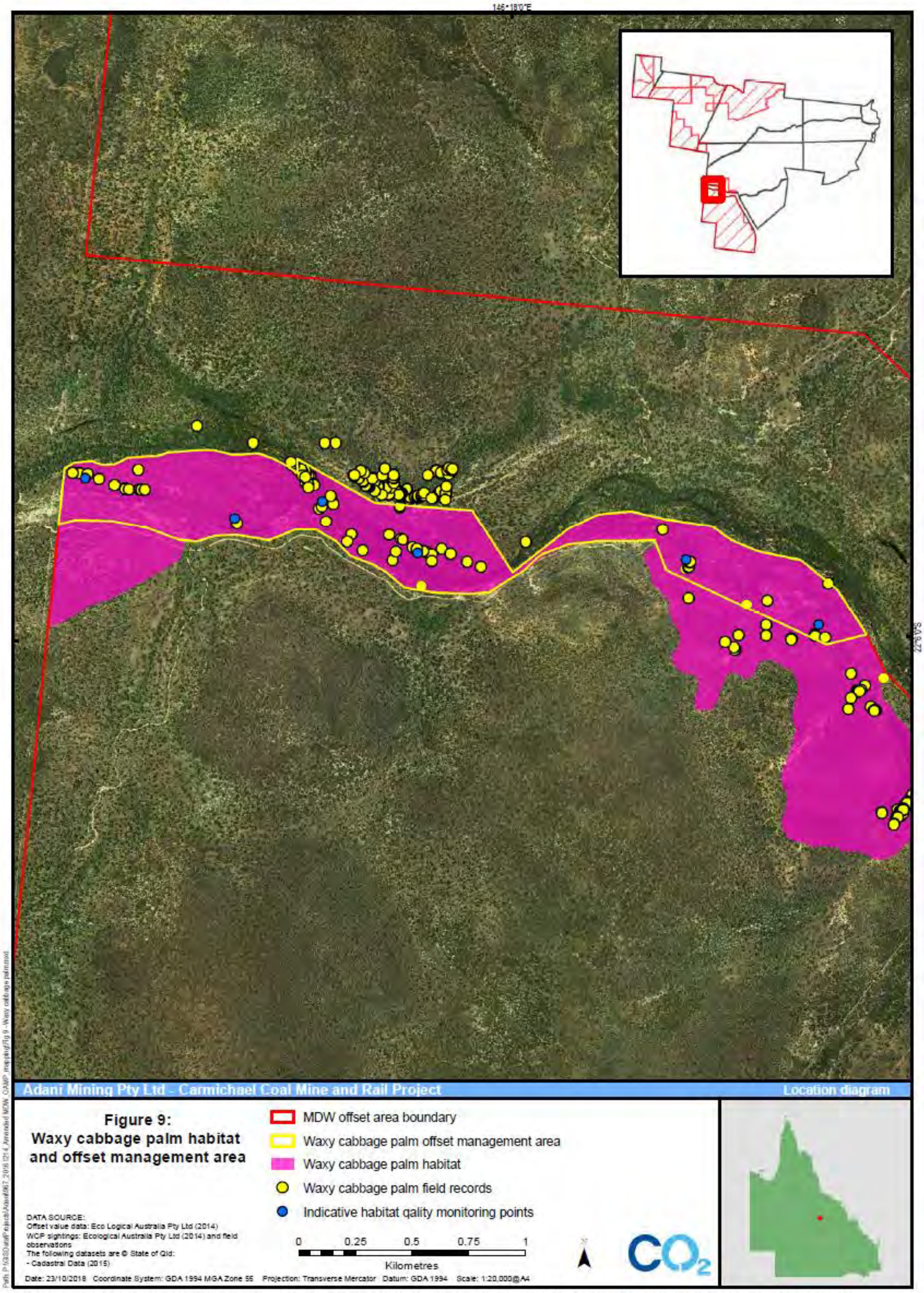

Figure 7-8 Waxy Cabbage Palm Offset Area (from approved Biodiversity Offsets Strategy)

#2: Subsidence from underground mining

Subsidence impacts (direct and indirect) from underground mining is generally not considered to be a potential or significant impact to the Waxy Cabbage Palm identified by the Conservation Advice (DEWHA, 2008). EPBC Approval 2010/5736, condition 6(c)(ii) also requires details of potential impacts from subsidence from underground mining, including subsidence induced fracturing and any changes to groundwater or surface water flow, be addressed in this plan.

Environmental Authority condition I14 and Appendix 1, Definition of "GDEMP" (5) requires potential impacts from subsidence to be addressed in this plan.

No surface subsidence is predicted to occur within Waxy Cabbage Palm habitat, as modelled in the EIS for the Project. Changes to the catchment area of the Carmichael River are expected in relation to the development footprint of the mine. Clean water diversions will be installed on the perimeter of mining operations and mine affected water will be released only under relevant conditions in the Environmental Authority (see **Appendix A**). Changes to groundwater flow and surface water flows are addressed separately in this plan.

As no subsidence is predicted to occur, the management objective is to monitor to ensure there is no habitat alteration through subsidence. **Table 7-6** describes how the management objective will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#3: Changes to hydrology and surface water quality

Changes to hydrology is a potential threat to the Waxy Cabbage Palm and identified by the Conservation Advice (DEWHA, 2008). EPBC Approval 2010/5736, condition 6(c)(viii) requires details of potential impacts from stream diversions and flood levees, be addressed in this plan. Changes to the hydrology of the Project Area, during the construction and operational project phases, were also identified in the EIS as an indirect impact on Waxy Cabbage Palm habitat. Details are also provided in **Section 6.4**, in relation to the Carmichael River.

Environmental Authority condition I14 and Appendix 1, Definition of "GDEMP" (5) requires potential impacts from water discharges and hydrological changes to be addressed in this plan. Changes to hydrology indirectly impacting Waxy Cabbage Palm may include potential stream diversions, flood levees and contamination of surface waters (GHD 2014). Changes to the catchment area of the Carmichael River are expected in relation to the development footprint of the mine. Clean water diversions will be installed on the perimeter of mining operations and mine affected water will be released only under relevant conditions in the Environmental Authority (see **Appendix A**). These activities are likely to commence from construction, in Year 1.

A management objective under this plan is to maintain surface water flow and quality. **Table 7-6** describes how the management objective will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#4: Fire

Fire is identified as a potential threat to the Waxy Cabbage Palm by the Conservation Advice (DEWHA, 2008). The threat of fire will occur during pre-construction, construction, operational and rehabilitation project phases.

Fire is inevitable in the grassy woodlands of central Queensland and a natural component of these ecosystems. Historically, ignition sources include lightning-strike, low intensity wet season fires, or under traditional indigenous management. Inappropriate fire regimes leading to intense bushfires that result in death of individuals, reduced recruitment from damaged adults and burning of seeds and bare ground. Bare ground is susceptible to erosion and degradation from Feral Pigs, further impacting Waxy Cabbage Palm habitat.

Fires in woodlands of the type that occur in the Project Area are fuelled principally by grass biomass rather than by woody material. Fire intensity will be greater with high fuel biomass, continuity of the fuel layer, a high degree of curing (drying) of the grassy fuel and ambient conditions, including high temperatures, low humidity and high wind speeds. Lower intensity fires may occur when fuel biomass is low and / or discontinuous, fuel moisture levels are high, ambient temperatures and wind speeds are low and atmospheric humidity is high.

Fire frequency, scale and intensity may also impact on Waxy Cabbage Palms through numerous mechanisms. Large uncontrolled wildfires have the potential to destroy large areas of Waxy Cabbage Palms with consequential long recovery times. Fire frequency can also affect Waxy Cabbage Palm populations with inappropriate fire regimes impacting on the quality by affecting the production of seeds.

Management objectives under this plan are to reduce the risk of bushfire ignition, maintain a mosaic of fire history in Waxy Cabbage Palm habitat and reduce the risk of bushfire spread. **Table 7-6** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#5: Weeds and pests through direct competition or habitat degradation

EPBC Approval 2010/5736, condition 6(c)(ix), requires details of potential impacts, including area of impact on Waxy Cabbage Palm from weeds and pests through direct competition or habitat degradation to be addressed by this plan.

Environmental Authority condition I14 and Appendix 1, Definition of “GDEMP” (5) requires potential impacts from weed and pest infestation to be addressed in this plan.

The threat of weeds and pests will occur during pre-construction, construction, operational and rehabilitation project phases.

The EIS (GHD 2014) also identified the following potential impacts to Waxy Cabbage Palm associated with the project:

- ongoing spread and dispersal of Rubber Vine by vehicles and machinery, which is already established along the Carmichael River, throughout the Project area
- introduction and dispersal of new weed species
- introduction or spread of aquatic weeds i.e. Olive Hymenachne
- trampling or eating of seedlings or seeds by pigs, particularly during mass germination events
- degradation of riparian habitat by rabbits may reduce recruitment and potentially lead to a senescent population.

A management objective under this plan is to reduce weed competition and habitat degradation from grazing by introduced herbivores within Waxy Cabbage Palm habitat. **Table 7-6** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#6: Grazing pressures

Grazing pressures, including stock browsing seedling leaves, trampling seedlings are potential threats to the Waxy Cabbage Palm identified by the Conservation Advice (DEWHA, 2008).

Domestic cattle grazing may lead to impacts on the Waxy Cabbage Palm in that stock will browse seedling leaves, trample seedlings and disturb the hydrology for the palm.

The grazing regime influences the composition and structure of the herbaceous layer of vegetation. Currently, the Project Area is being predominantly used for cattle grazing. The Project activities do not specifically include grazing, however, parts of the mining leases not being used for the construction and operation of the mine will be used for grazing.

Particular cattle grazing regimes can also be used to manipulate the grass layer and manage fire by reducing fuel loads and therefore fire intensity. Grazing by cattle can be used strategically to reduce fuel loads in order to reduce the risk of hot extensive fires.

Sustainable grazing practices will be used in the Project Area as a management tool to manage threats to the Waxy Cabbage Palm. For example, grazing will be used to decrease the abundance and presence of weeds, such as Buffel Grass and other exotic pasture grasses, and control fuel loads so as to reduce the risk of an uncontrolled fire.. This will be achieved by managing stocking densities and access to parts of the Project Area. The use of stock is not the only management tool and the effectiveness of this tool will be monitored.

A management objective under this plan is to use strategic and sustainable grazing to manipulate the grass layer and manage fire by reducing fuel loads and therefore fire intensity. However, the objective is to also ensure grazing itself does not become a threat. **Table 7-6** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#7: Vegetation clearing / habitat loss

Clearing of Waxy Cabbage Palm is a potential threat to the Waxy Cabbage Palm identified by the Conservation Advice (DEWHA, 2008). EPBC Approval 2010/5736, condition 6(c)(i) requires details of potential impacts from vegetation clearing be addressed in this plan.

Vegetation clearing and habitat loss for the Waxy Cabbage Palm will occur during the construction project phase. The EIS identified that clearing of 5.47 ha Waxy Cabbage Palm habitat and the removal of five individuals for the construction of the haul road across the Carmichael River as the only direct impact of the project. The location of these impacts are shown in **Figure 7-7**.

However, there are other identified potential threats and indirect impacts, such as trampling from cattle and people, unapproved clearing, reduced dispersal of propagules downstream during floods and habitat fragmentation. These impacts are to be avoided, minimised and offset by protecting and improving the existing condition of offset areas.

Management objectives about the threat and impacts include minimising habitat loss and habitat restoration of disturbed areas. **Table 7-6** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#8: Restricted geographic distribution

Restricted geographic distribution is not an identified threat or impact from project activities, however, it is an identified threat under the Conservation Advice (DEWHA, 2008) and has been included in this plan for completeness. As such, no management objectives, performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions are required.

#9: Clearing and fragmentation for agriculture

Clearing and fragmentation for agriculture does not form part of the project activities, however, it is an identified threat under the Conservation Advice (DEWHA, 2008) and has been included in this plan for completeness. As clearing and fragmentation of the Waxy Cabbage Palm for agriculture are not proposed, no management objectives, performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions are required.

#10: Earthworks

EPBC Approval 2010/5736, condition 6(c)(iv) requires details of potential impacts from earthworks be addressed in this plan. Earthworks carried out as a part of mine construction will lead to increased risk and exposure of the Waxy Cabbage Palm to light, noise, dust, vehicles and people (Adani 2012). Dust, noise, vibration and light spill are described in following sections. However, it is not anticipated other activities carried out under earthworks will likely impact the Waxy Cabbage Palm.

A management objective under this plan is to minimise the risk of light vehicle and machinery strike during earthworks and operations. **Table 7-6** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#11: Noise and vibration

EPBC Approval 2010/5736, condition 6(c)(v) requires details of potential impacts from noise and vibration be addressed in this plan.

During the construction project phase, standard construction equipment, general trade equipment and specialised equipment will be used as required. Some blasting will be required to prepare overburden for removal and also coal extraction (Adani 2012), however, it is not anticipated noise and vibration will likely impact the Waxy Cabbage Palm.

A management objective under this plan is to minimise habitat modification as a result of noise and vibration. **Table 7-6** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#12: Emissions (including dust)

EPBC Approval 2010/5736, condition 6(c)(vi) requires details of potential impacts from emissions (including dust) be addressed in this plan.

Earthworks during the construction project phase will result in dust emissions. Excessive dust settling on vegetation could also suppress vegetation growth by limiting the photosynthesis potential of plants in close proximity to the construction area (Nanos and Ilias, 2007). As such, particulate emissions may reduce photosynthetic ability of Waxy Cabbage Palm.

Dust deposition associated with earthwork activities will generally occur relatively close to areas of disturbance and hence, plants within 50 m to 100 m of construction activities may be affected by dust. As the location of the Waxy Cabbage Palm are far (within the 500m buffer zone surrounding the Carmichael River) from construction activities and temporary, dust impacts are unlikely, and any effects will be short lived, and rainfall will generally remove dust from plants (Adani 2012).

A management objective under this plan is to minimise emissions, particularly dusts. **Table 7-6** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#13: Light spill and other visual impacts

EPBC Approval 2010/5736, condition 6(c)(vii) requires details of potential impacts from emissions (including dust) be addressed in this plan.

During the construction project phase, lighting for safety and security of operations will be installed as the mine will operate 24 hours per day. Impacts from lighting will involve static floodlights associated with mine operations, lighting around the mine infrastructure area, workshops and ancillary buildings, vehicle lights moving around the site. Artificial night lighting levels are expected to be very low indeed, if present at all, and this is considered to be a potential impact of minor significance (Adani 2012).

Whilst there are no predicted impacts to the Waxy Cabbage Palm associated with light spill and visual impacts, a management objective under this plan is to minimise light spill and other visual impacts. **Table 7-6** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

7.5 Mitigation and management measures for the Waxy Cabbage Palm

A suite of mitigation and management measures will be implemented to address impacts to Waxy Cabbage Palm. These are detailed below.

7.5.1 Grazing management

Grazing will be carefully used in the Project Area as a management tool to manage specific threats to Waxy Cabbage Palm habitat. For example, grazing will be used to decrease the abundance and presence of weeds, such as Buffel Grass and other exotic pasture grasses, and control fuel loads so as to reduce the risk of an uncontrolled fire.

The management of grazing within non-mined areas of the mining lease will be based on existing pastoral management practices under land agistment agreements, pastoral holding lease conditions and associated legislation. Sustainable grazing guides such as the ‘Sustainable management of the Burdekin grazing lands’ (McIvor 2012) will also guide the management of grazing activities. The following actions will be delivered under the legislation, agreements and conditions:

- Adani will complete annual habitat vegetation assessments to maintain and where possible enhance Waxy Cabbage Palm habitat
- Corrective actions will include additional fencing or spelling of paddocks to manage stocking densities and access, in order to prevent impacts whilst maintaining biomass levels for fire management.
- Maintaining access and condition of existing off-stream watering points that are not likely to be directly impacted by mining operations.

7.5.2 Fire management

Fire and grazing can be considered competitors of one another for the available grass fuel / forage. In considering the use of cattle grazing to manipulate the grass fuel load and distribution it is also important to address other aspects of the herbaceous layer that will be affected by grazing.

The existing network of roads and tracks will be used to manage fire, rather than establishing additional firebreaks. This will help reduce the risk of weed incursion through movement of traffic into intact understorey. The numerous existing tracks that were created during mine exploration and development provide firebreaks that can help ensure that prescribed fires are not extensive. The value of maintaining tracks as firebreaks will be balanced with minimising the risk they present in terms of weed incursion.

7.5.3 Weed and pest management

Weed and pest management is addressed in a project specific Pest Management Plan, which covers weeds and feral animals (pests). The Pest Management Plan has an overarching strategy, as follows:

- Identification of current and potential pest animals and plants for the area, and current locations of populations of pest animals and plants
- Avoidance of travel through or establishing infrastructure in areas of known pest plant infestation
- Prevention of the introduction of new weed and pest animal species to the area
- Minimisation of the increase in distribution and abundance of currently present pest plants or animals
- Control of identified weeds and pest animals to contain, reduce or eradicate pest populations.

Actions associated with weed management align with this strategy.

7.6 Monitoring of Waxy Cabbage Palm

To adequately address approval conditions, and to determine that adequate mitigation and management measures are implemented, a detailed monitoring program has been developed for Waxy Cabbage Palm. This work will build upon the significant studies completed during the EIS.

This section summarises the monitoring program for Waxy Cabbage Palm. Some tasks will overlap with monitoring requirements for other GDEs, in particular the Carmichael River. The approach to statistical analysis is summarised in **Table 7-5**. Monitoring programs will be implemented following approval of this GDEMP.

7.6.1 Pre-impact monitoring of the Waxy Cabbage Palm

Waxy Cabbage Palm condition and population survey

To determine the current size and condition of the Waxy Cabbage Palm Carmichael River population, a comprehensive population survey and condition assessment will be undertaken over 1 year following project commencement.

Population surveys will be carried out between Doongmabulla station and Belyando River (including all tributaries of the Carmichael River) to further build on the EIS baseline studies and confirm the following characteristics of the Waxy Cabbage Palm population, prior to any predicted impact:

- spatial extent of the local population, within and adjacent, to the Project area
- presence / absence
- population structure (life form stages)
- condition status

The location of all individuals will be recorded using differential GPS and mapped, with all sub-adult and older individuals tagged with photographs taken. These sub-adults will be monitored throughout the life of the project.

Condition surveys will involve targeted searches over the wet and dry seasons across five transect areas between the Doongmabulla Springs-complex and the Belyando River confluence. The surveys will build on the extensive information collected by Adani during the EIS process. As there are no survey guidelines for Waxy Cabbage Palm, the proposed survey method is based on Pettit and Dowe (2004):

- actively search all suitable habitats within the survey area, defined as both main banks, instream channels, and adjacent pools. The search area will extend out from the alluvial bank until no individuals can be found
- note the key attributes where Waxy Cabbage Palm are encountered:
  - spatial location using differential GPS
  - life-stage category (**Table 7-1**)
  - average number of individuals (in that life-form) within 5 m radius
  - height (m)
- note key features of habitat condition i.e. weeds, pests, erosion.

During the pre-impact population survey, each individual within each transect will be marked using a differential GPS, and older life forms (sub-adult and older) will be permanently tagged and monitored throughout the life of the project.

Information from the population surveys will be used to inform the spatial variation of monitoring sites for the ongoing monitoring of population health. This monitoring will be based on a BACI design (Before, After, Control and Impact). The spatial extent of sites will enable identification of the extent of downstream impacts i.e. where potential or actual Waxy Cabbage Palm habitat is affected by reduced base flows, and the spatial and temporal variation of available water within the root zone of the palms.

At least five monitoring sites will be located within three key zones: upstream of predicted impact (control site), in the area of predicted groundwater impact area and downstream from the predicted groundwater impact (**Figure 7-9**). Monitoring sites will be closely co-located with existing groundwater monitoring bores such as C027P1, C029P1, HD03 B, C14027, C14028 and C025P1 (**Figure 7-9**).

At least one control site will be located within sub-populations upstream of the Project area (such as the Moray Downs West offset area) where predicted groundwater drawdown is minimal (verified by bore C027P1 which is not predicted to be impacted from water table drawdown). Three monitoring sites will be located within the dense sub-populations in the western portion of the mining lease where groundwater drawdown and base flow reductions are predicted to occur. One of these sites will be located at the eastern (downstream) extent of the dense sub-population. At least one monitoring site will be located downstream from the predicted impact.

The exact location of monitoring sites will be finalised during the survey and establishment of gauging stations for the groundwater monitoring and surface water monitoring programs. A minimum of two impact sites will be associated with gauging stations, to allow interpretation of health with groundwater depth and surface water and groundwater interactions.

This approach will allow a monitoring design that selects representative assemblages of Waxy Cabbage Palm in control and impact locations where complementary data on groundwater from alluvium bores and surface water flows are available.

At each monitoring site, two permanent transects of 100 x 20 m will be established parallel with the river in representative Waxy Cabbage Palm areas. Transect A will be immediately adjacent to the river and Transect B will be at the extent of the population, furthest from the main channel. Within each transect key attributes of Waxy Cabbage Palm will be noted:

- number of individuals classified by life-stages (**Table 7-1**)
- height (m)
- condition of individuals (evidence of poor health including evidence of fire damage, erosion or drought stress)
- habitat condition (presence and abundance of weeds and evidence of pests)
- CORVEG and BioCondition data

Indicators: number of Waxy Cabbage Palm individuals, age class structure, height, evidence of fire damage/erosion/drought, presence of weed species, extent of weed coverage, presence of pest species, extent of pest disturbance.

Ecological features map of the Carmichael River

Within three months of completing the first wet and dry season surveys, an ecological features map of the Carmichael River will be developed and include the following information relevant to Waxy Cabbage Palm:

- locations of Waxy Cabbage Palm
- areas of Rubber Vine infestations
- riparian composition and health
- gaining / losing areas relative to groundwater
- areas of low / high impact from subsidence

Waxy Cabbage Palm community health surveys

Waxy Cabbage Palm community health surveys will commence prior to any predicted impact. Permanent CORVEG survey sites will be located at regular intervals along the Carmichael River. A Waxy Cabbage Palm community health survey will be carried out biannually (wet and dry season), for two years, and then the frequency will be reviewed.

Indicators: Waxy Cabbage Palm community health indicators per CORVEG methodology

Weed and pest surveys

Weed and pest surveys will be undertaken yearly along the Carmichael River to:

- identify the extent of weeds, especially Rubber Vine, along the Carmichael River
- identify areas of Waxy Cabbage Palm habitat subject to pig damage
- identify areas for weed and pest management activities in accordance with the OAMP.

Indicators: presence of weed species, extent of weed coverage, presence of pest species, extent of pest disturbance

Groundwater Monitoring

Groundwater monitoring will coincide with the five population monitoring sites located within three key zones; upstream of predicted impact (control site), in the area of predicted groundwater impact area and downstream from the predicted groundwater impact. However, it is noted that matching groundwater monitoring sites to Waxy Cabbage Palm population monitoring sites may not always be possible. The frequency of groundwater monitoring will be 12 hourly for water levels, and at least quarterly for water quality (as per the GMMP). Monitoring locations are noted on **Figures 7-6a**-**d**.

Indicators: groundwater level, groundwater quality

Surface Water Monitoring

Surface water quality monitoring at the Carmichael River will be carried out monthly, in accordance with the REMP. Flow data will be collected daily and analysed monthly prior to construction, during operation and post operation. Monitoring locations are noted in **Figure 6-2**.

Indicator: surface water quality, surface water flow, surface water level (periods of no flow)

Pre-clearance surveys

Pre-clearance surveys for Waxy Cabbage Palm will be undertaken by a suitably qualified ecologist(s) where potential habitat will be cleared for the Carmichael River crossing and bridge. Any other individuals that are to be cleared will be marked, photographed and mapped.

Assessment and calculation of Waxy Cabbage Palm habitat disturbance and monitoring against the maximum disturbance limit balance will be undertaken by suitably qualified ecologist(s) quarterly.

Environmental Water Requirement assessment

An Environmental Water Requirement assessment program will be developed to align with other monitoring activities and will include a combination of the following tasks:

- determining if Waxy Cabbage Palm are likely to persist in drier conditions, addressing the relationship of individuals with the persistence of refugia habitats and ‘permanent soaks’ in drought conditions. This can include flow monitoring and measurements of groundwater depth changes at a minimum of three locations along riverine habitat with adult Waxy Cabbage Palm.
- developing an understanding of the indicators of population health, particularly stress in adult life-forms
- measurements and monitoring of leaf water potential
- stable isotope studies to determine depth of soil water absorbed by Waxy Cabbage Palm and to determine whether a groundwater ‘signature’ exists within the plant xylem
- soil sampling to determine the root depth
- leaf area index measurements and monitoring (may include remote sensing)
- sap flow measurements to determine water use

The Environmental Water Requirement assessment will be carried out biannually (wet and dry season), for two years, and then the frequency will be reviewed.

7.6.2 Impact monitoring of the Waxy Cabbage Palm

The approach to pre-impact monitoring will be continued during the impact period, with data on Waxy Cabbage Palm indicators collected at control and impact sites. This will be complemented with data on groundwater from alluvial bores and stream flow gauging stations.

Condition monitoring

Population surveys will continue annually at the control and impact sites (two 100 m x 20 m transects) established during the baseline survey to collect the following data:

- number of individuals classified by life-stages (**Table 7-1**)
- height (m) of each individual
- condition of individuals (evidence of poor health including evidence of fire damage, erosion or drought stress)
- habitat condition (presence and abundance of weeds and evidence of pests)
- CORVEG and BioCondition data

Indicators: number of Waxy Cabbage Palm individuals, age class structure, height, evidence of fire damage/erosion/drought, presence of weed species, extent of weed coverage, presence of pest species, extent of pest disturbance

Groundwater Monitoring

Groundwater monitoring will coincide with the five population monitoring sites located within three key zones: upstream of predicted impact (control site), in the area of predicted groundwater impact area and downstream from the predicted groundwater impact. The frequency of groundwater monitoring will be 12 hourly for water levels, and at least quarterly for water quality (as per the GMMP).

Indicators: groundwater level, groundwater quality

Surface Water Monitoring

Surface Water Monitoring at the Carmichael River will be carried out monthly, in accordance with the REMP. Flow data will be collected daily and analysed monthly prior to construction, during operation and post operation.

Indicator: surface water quality, surface water flow, surface water level (periods of no flow)

Other monitoring

Other impact monitoring will be carried out for the Waxy Cabbage Palm as a part of other management plans, under the Environmental Management Plan and System. These are:

- Erosion and Sediment Control Plan
- Dust Management Plan
- Fire Management Plan
- Pest Management Plan
- Receiving Environment Management Plan (surface water).

A REMP will be implemented by a suitably qualified person to monitor, identify and describe any adverse impacts to surface water quality from mining activities. The program will include, but is not limited to:

- meeting the water quality parameters specified in the sub-catchment plan for the Belyando-Suttor Basin
- additional water quality parameters that focus on possible contaminants and saline intrusion

- control and impact monitoring locations
- monitoring frequency and timeframe (including scientific rationale)
- data analysis and reporting requirements.

Table 7-5 Statistical approach for Waxy Cabbage Palm triggers and monitoring

Indicator	Relevant triggers	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
Population structure	A statistically significant difference in the population of older (established to reproducing adult) life forms when compared with baseline conditions. Statistically significant change in the age class structure compared to baseline conditions.	Transects at a minimum of 5 sites located in 3 key zones. Monitored Bi-annually (wet and dry season) for baseline/pre-impact survey then annually	Spatial extent Number of individuals Population structure (life form stages)	Descriptive comparison of mean number of older life forms between current sampling time and baseline/pre-impact. MDS plots, Multivariate PERMANOVA test on life form data to detect significant differences in the number of individuals in each life form between sampling time and baseline/pre-impact period. Follow up SIMPER tests to detect the main life form driving the patterns in the data.
Community condition	Statistically significant change in condition metrics compared to baseline/pre-impact conditions	Transects at a minimum of 5 sites located in 3 key zones. Monitored Bi-annually (wet and dry season) for pre-impact survey then annually	Condition of individuals (evidence of poor health including evidence of fire damage, erosion or drought stress). Habitat condition (presence and abundance of weeds and evidence of pests). CORVEG and BioCondition data	MDS plots, Multivariate PERMANOVA test on condition metrics to detect significant differences between sampling time and baseline/pre-impact. Follow up SIMPER tests to detect the main condition metrics driving these patterns. From SIMPER results, compare dominant condition metrics to assess statistically significant change compared to baseline/pre-impact conditions.
Weed and pest surveys (within areas controlled by Adani)	Significant Increase in weed cover, pests or pest activity above baseline/pre-impact period. Identification of new weed or pest species. Identification of new Weeds of National Significance.	Weeds: Transects at a minimum of 5 sites located in 3 key zones. Pests: Pest surveys undertaken at a minimum of 5 sites in 3 key zones. Monitored annually for pre-impact surveys then biannually	Inventory of all weed and pest species present. Identify spatial extent of weeds, especially Rubber Vine, along the Carmichael River. Identify areas of Waxy Cabbage Palm habitat subject to pig damage.	Descriptive comparison of mean weed cover, pest abundance, and area of pest damage at time of sampling to baseline/pre-impact conditions. Log the occurrence of new weed or pest species compared to baseline/pre-impact period.

Indicator	Relevant triggers	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
Groundwater Level	Groundwater level drawdown thresholds as outlined in the GMMP, Appendix B and Table E3 in the EA.	Monitoring at the bores listed in **Figures 7-6a - d**. Monitored 12 hourly as per GMMP.	Groundwater level.	Univariate comparison between groundwater level at time of sampling and groundwater level threshold.
Groundwater Quality	Groundwater Quality Trigger levels as outlined in the GMMP and Table E2 in the EA.	Monitoring at the bores listed in **Figures 7-6a - d**. Monitored quarterly as per GMMP	Water quality parameters as outlined in GMMP.	Descriptive comparison with defined groundwater quality trigger levels.
Surface Water Flow (periods of flow) and Level (periods of no flow)	20th percentile of baseline/pre-impact surface water flow	Monitor flow daily and report monthly during seasonal river flows prior to construction, during operation and post operation at monitoirng locations in **Figure 6-2**. In addition, measure surface water level, in particular when there is no flow.	River discharge	Descriptive comparison of daily discharge at each month to the 20th percentile of baseline flow.
Surface Water Quality	Surface water quality trigger levels in Table F3 and F5 of the EA.	Monitor in accordance with the REMP at monitoirng locations in **Figure 6-2**.	Water quality parameters as outlined in REMP.	Descriptive comparison with defined surface water quality trigger levels.

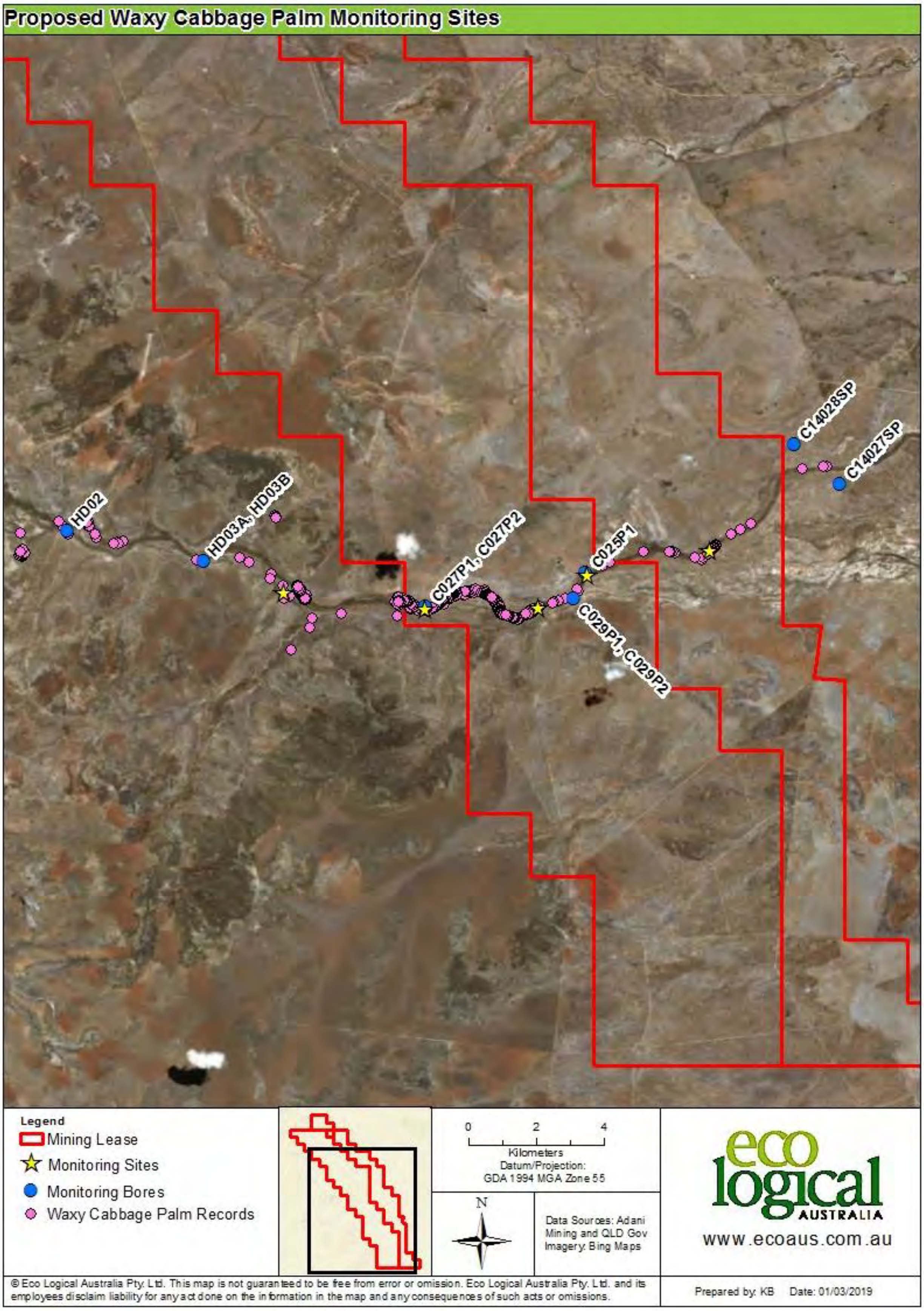

Figure 7-9 Waxy Cabbage Palm monitoring locations

7.7 Triggers for adaptive management or corrective actions

Triggers will be focussed on detecting changes in the population of Waxy Cabbage Palm and investigating potential mining-related causes.

7.7.1 Groundwater triggers

Groundwater drawdown and quality triggers for Waxy Cabbage Palm have been developed for the GMMP and will be reviewed once the EWR for the species has been confirmed during studies and monitoring. These triggers are provided in **Appendix B**. It is to be noted that in the GMMP the groundwater level drawdown triggers are referred to as 'impact thresholds'. Hence any groundwater level triggers mentioned in this report will be equivalent to groundwater impact thresholds in the GMMP.

The groundwater drawdown triggers for Waxy Cabbage Palm is specified in the GMMP, and primarily relates to drawdown of alluvial aquifers according to EA threshold limits, with inclusion of the bore HDO3B located in the Clematis Sandstone aquifer. These triggers will be updated once sufficient monitoring data are collected under studies to accurately define the EWR. This trigger level has been chosen as it is the lower limit that is detectable in the SEIS modelling, and is small relative to the current depth to the water table associated with Waxy Cabbage Palm populations. The groundwater trigger level will be applied to the minimum groundwater level (as this is the critical value for GDEs) and will account for seasonal fluctuations determined by the studies.

Groundwater monitoring bores C027P1, C029P1, HD03 B, C14027, C14028 and C0259P1 will be used to monitor groundwater drawdown in relation to trigger levels. Additional monitoring bores may also be required to coincide with Waxy Cabbage Palm monitoring sites to identify potential groundwater impacts. The reliability of groundwater data from monitoring bore HD03 B is uncertain, and attempts will be made to cleanout and recondition the bore and a replacement bore will be installed if required to assist in detecting trigger level exceedances for Waxy Cabbage Palm. Corrective actions and adaptive management strategies are provided in **Section 7.9** in the event that groundwater triggers are exceeded.

7.7.2 Ecological triggers

Monitoring of the Carmichael River Waxy Cabbage Palm population will aim to identify potential impacts from the Project and ensuing responses to groundwater changes. Control sites will be established in reaches of the Carmichael River upstream of modelled drawdown areas and where Waxy Cabbage Palm occurs. This will include at least one monitoring site within the proposed offset area in Moray Downs West (**9**).

The following are the ecological triggers for Waxy Cabbage Palm:

1. Waxy Cabbage Palm population structure deviates significantly from following the following baseline conditions:

- Seedlings 60% of individuals
- Sub-adult 28% of individuals
- Adult 12% of individuals

2. Waxy cabbage palm population across the project area declines below a baseline population of 831 individuals.
3. Evidence of dieback or impacts to Waxy Cabbage Palm *(*e.g. fire damage, erosion, level of discolouration, defoliation and leaf area index)

It is anticipated that following the completion of pre-impact monitoring, additional and/or revised triggers will be derived, including:

1. Deviation in the age class structure or condition of Waxy Cabbage Palm when compared with baseline and pre-impact period
2. Deviation from baseline conditions of riparian community health (CORVEG surveys)
3. Increase in weed cover, pests or pest activity above baseline and pre-impact period (within the transect / survey areas on the mining lease only)
4. Identification of new weed or pest species.

7.8 Adaptive management

An adaptive management framework will be employed to mitigate impacts from the Project and will include a review of trigger levels for Waxy Cabbage Palm during the course of the Project and particularly in response to long term monitoring and studies undertaken during each assessment and monitoring stage.

The effectiveness of management and mitigation measures will be reviewed and assessed at the completion of each assessment and monitoring stage as increased knowledge and data of the EWR and response to groundwater changes is developed during long term monitoring of Waxy Cabbage Palm. If monitoring and / or greater understanding of the species relationship with groundwater identifies that management measures are ineffective, the GDEMP and GMMP will be updated with improved management measures.

In the event that trigger levels for Waxy Cabbage Palm are exceeded, in accordance with Conditions E13 and E14 of the EA, the following process will be initiated:

- an investigation will be instigated within 14 days of detection to determine whether the fluctuations are the result of mining activities, pumping from licensed bores, seasonal variation or neighbouring land use
- if the investigation determines that the exceedance is caused by mining activities, the following tasks will be undertaken
    - determine whether impacts to Waxy Cabbage Palm populations have occurred or likely to occur
    - identify long-term mitigation and management measures to address the impact
    - identify corrective actions
    - notify the administering authority within 28 days of the detection
- undertake an assessment of the associated impacts to Waxy Cabbage Palm
- update the GDEMP if required.

The investigation will focus on determining whether an observed decline in Waxy Cabbage Palm is caused by the project, and will involve:

- A review of groundwater monitoring data to determine the potential for drawdown to be impacting Waxy Cabbage Palm
- Site-specific investigations involving the collection and interpretation of additional data
- Consideration of groundwater monitoring data and the population distribution across all life stages: seedling, sub-adult and adult, against baseline and pre-impact distribution information

- A review of relevant data related to potential non-mining causes of variability in environmental variables (e.g. climatic data)
- Developing a detailed model of relevant environmental variables
- Expert opinion on the potential for environmental harm

If ongoing population health declines are detected an investigation into the cause will be undertaken and the administering authority notified within 28 days of the detection. If the investigation identifies mining activities as the cause, an assessment into the known or likely impacts will be undertaken and mitigation measures identified. If the investigation indicates that there is a risk of impacting Waxy Cabbage Palm, the Biodiversity Offset Strategy will be reviewed, and a report prepared within 3 months to identify the actual impact to Waxy Cabbage Palm habitat from the mining activities.

In accordance with Conditions I3, I4 and I5 of the EA, if the investigation indicates that there is an unmitigated risk of impacting Waxy Cabbage Palm, the BOS will be reviewed, and a report prepared and submitted to DoEE and DES within 3 months of detection to identify the actual impact to Waxy Cabbage Palm habitat from the mining activities. If the assessment finds that the actual areas of disturbance to Waxy Cabbage Palm differs from the area of disturbance as detailed in the BOS, the BOS will be amended within 30 days of submission of the report and the amended offset delivered within 12 months of submission of the report.

7.9 Management objectives, performance criteria, adaptive management triggers and corrective actions

The threats to the Waxy Cabbage Palm relevant to the Project and potential project impacts and actions minimising impacts to the Waxy Cabbage Palm are summarised in **Table 7-6**. The tables address the following:

- management objectives
- performance criteria
- management actions
- monitoring
- triggers for adaptive management and corrective actions
- specific, measurable and time-bound corrective actions.

The relevant statistical analyses outlined in section 5.4.3 support the specific performance criteria for the Waxy Cabbage Palm. Table 7-6 and Table 7-5 (Statistical approach for Waxy Cabbage Palm triggers and monitoring) will be used to assess the success of management measures against goals, triggers, implementation of corrective actions if the criteria are not met within specified timeframes.

At the conclusion of pre-impact monitoring, the performance criteria, monitoring and triggers will be reviewed, and updated, as required, via the review and adaptive management process detailed in sections 10.2 (Pre-impact studies, reporting and updates), 10.3 (Annual and compliance reporting) and 10.4 (Reporting and monitoring of related management plans and programs).

The objectives apply for the life of the approvals, and the life of this plan, subject to updates via reviews and adaptive management process detailed in sections 10.2 to 10.4

Table 7-6 Management objectives, performance criteria, adaptive management triggers and corrective actions for Waxy Cabbage Palm

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions
1	Groundwater drawdown from mine dewatering	Prevent any changes to groundwater / surface water flow interactions over approved impacts	No impact, greater than that approved, to Waxy Cabbage Palms from mine dewatering	Implement groundwater monitoring and management program as per the GMMP and undertake review of conceptual model as per EA and EPBC Conditions to inform impact predictions. Incorporate research outcomes from the Great Artesian Basin Springs Research Program and Rewan Formation Research Program in relation to the GMMP implementation	**Pre-impact monitoring:** Groundwater Management and Monitoring Program Receiving Environment Monitoring Program **Impact monitoring:** Groundwater Management and Monitoring Program Receiving Environment Monitoring Program Conduct annual monitoring of the condition of Waxy Cabbage Palm in accordance with Sections 7.6.1 and 7.6.2.	Groundwater level Groundwater quality Surface water quality Number of Waxy Cabbage Palm individuals Age class structure and height CORVEG indicators	• Groundwater level drawdown thresholds as outlined in the GMMP, Appendix B and Table E3 in the EA are exceeded • Groundwater quality trigger levels as outlined in the GMMP and Table E2 in the EA are exceeded • Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded. • Statistically significant change in the population of, age class structure or health condition of Waxy Cabbage Palm when compared with baseline & pre-impact.	The appropriate corrective actions will be implemented and may include: • Supplementary introduction of surface water to the channel near the upstream Mine Area boundary through controlled discharges • Translocating individual plants (if deemed viable), seed collection and planting programs • Population monitoring be reviewed and a report prepared within 3 months to determine the impact to Waxy Cabbage Palm • If the assessment finds that the actual areas of impact to Waxy Cabbage Palm differs from the area of impact as detailed in the BOS, the BOS will be amended within 30 days and the amended offset delivered within 12 months.
2	Subsidence impacts from underground mining	. Minimise alteration through subsidence	No impacts, such as ponding and cracking in subsidence areas (not predicted for any GDE	Changes to the flow of groundwater to Waxy Cabbage Palm and surface water diversions are addressed in #1 and #3.	**Impact monitoring:** Subsidence Management Plan	Early warning signs of subsidence, such as ponding or cracking	Impacts to Waxy Cabbage Palm such as ponding and cracking as a result of subsidence	The appropriate corrective actions will be implemented and may include: • Rectifying impacts (e.g. pumping out ponds) • Re designing and implementing water diversions.
3	Changes to hydrology, surface water level or flow or quality degradation	Minimise impacts to surface water levels or flow, other than that approved	No impact, greater than that approved, to Waxy Cabbage Palms from changes to water levels or flow No impacts to Carmichael River from any changes to hydrology other than approved.	Implement surface water monitoring and management as per the Receiving Environment Monitoring Program	**Pre-impact monitoring:** Receiving Environment Monitoring Program **Impact monitoring:** Receiving Environment Monitoring Program Conduct annual monitoring of the condition of Waxy Cabbage Palm in accordance with Sections 7.6.1 and 7.6.2.	Surface water levels and flow Number of Waxy Cabbage Palm individuals Age class structure and height CORVEG indicators	Detection of potential changes to surface water as a source for the Waxy Cabbage Palm by: • Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded. • Statistically significant change in the population of, age class structure or health condition of Waxy Cabbage Palm when compared with baseline & pre-impact.	The appropriate corrective actions will be implemented and may include: • Supplementary introduction of surface water to the channel near the upstream Mine Area boundary through controlled discharges • Translocating individual plants (if deemed viable), seed collection and planting programs • Population monitoring be reviewed and a report prepared within 3 months to determine the impact to Waxy Cabbage Palm If the assessment finds that the actual areas of impact to Waxy Cabbage Palm differs from the area of impact as detailed in the BOS, the BOS will be amended within 30 days and the amended offset delivered within 12 months.

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions

		Maintain surface water quality
		
		Protection of environmental values within waterways of the receiving environment.
		
		Minimise siltation of water resources
			Surface water not impacted by other disturbing processes than otherwise approved.
			
			See also #12 (Emissions – dust)
				Vegetation clearing near, or within ephemeral waterways will be avoided when rain is falling, or imminent.
				
				Management of erosion and sedimentation will be undertaken in accordance with an Erosion and Sediment Management Plan. This plan will identify all practices to be implemented prior to, during, and post-construction to minimise the potential for erosion to occur, including (but not limited to) timing of clearing activities, sediment and erosion control measures to be implemented, performance criteria and corrective actions.
					Pre-impact and impact monitoring, as per the:
					Receiving Environment Management Plan
					Erosion and Sediment Management Plan (sections 7.6.1 and 7.6.2)
					Release point water quality
					Receiving Environment Monitoring Program as per Table F5 and F6 in the EA that includes monitoring requirements before, during and after a discharge event.
					Regular site inspections in accordance with the Environmental Management Plan and System.
						Surface water quality
						
						Number of Waxy Cabbage Palm individuals
						
						Age class structure and height
						
						CORVEG indicators
							Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded.
							
							Mine affected water release limits in Table F2 and F4 of the EA are exceeded.
								The appropriate corrective actions will be implemented and may include:
								• During a release event, a comparison of the downstream results to the upstream results in the receiving waters will be undertaken and:
								  ○ if the downstream result is the same or a lower value than the upstream value for the quality characteristic then no action will be taken; or
								  ○ if the downstream results exceed the upstream results complete an investigation into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining the details of the investigations carried out; and actions taken to prevent environmental harm
								• If there is potential for environmental harm identified, Adani will implement management actions targeted at correcting the water quality parameter for which an exceedance occurred (e.g. implement changes to the discharge of mine affected water to achieve compliance).

		Reduce the impact of stream diversion and flood levees	No impacts on Waxy Cabbage Palm of stream diversion and flood levees, than otherwise approved.	Undertake further modelling prior to construction of the final levee location and the final bridge design to ensure that the impact due to increased flood inundation duration is minimised to protect riparian vegetation and Waxy Cabbage Palm. No water for the project will be sourced directly from the Carmichael River in the reach of the ML area. Compliance with additional management actions include in the Receiving Environment Monitoring Program and Erosion and Sediment Management Plan	**Pre-impact and impact monitoring:** Receiving Environment Monitoring Program Waxy Cabbage Palm community health baseline and pre-impact survey, as outlined in sections 7.6.1 and 7.6.2	Number of Waxy Cabbage Palm individuals Age class structure and height CORVEG indicators Surface water flow and level	Evidence of dieback or impacts to Waxy Cabbage Palm near area of impact for a stream diversion or flood levee Surface water quality triggers as per the EA	The appropriate corrective actions will be implemented and may include: • review and re design of stream diversions of flood levees to avoid reoccurrence and address actual cause. • Reinstatement / removal of any flood debris impacting waxy cabbage palms and potential channel restoration • If mitigation is unsuccessful, the provision of offsets, as an overarching corrective action to achieve the objective of minimising loss.

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions

		No greater impact than approved to the Carmichael River from the quantity of water released from the project area.	Water from the project area released into the Carmichael River meets quantity and quality conditions in EA.	Notify the administering authority prior to, and at the cease of, water release events.
				
				Monitoring of released various water quality characteristics must be undertaken by an appropriately qualified person in accordance with specified frequencies and trigger investigation levels.
				
				Review optimal location for discharge to the Carmichael River that considers ability to achieve high volume discharge by gravity.
				
				Stream flow gauging stations installed, operated and maintained to determine and record stream flows at locations and flow recording frequency specified in Table F4 of the EA
					Pre-impact monitoring:
					Receiving Environment Monitoring Program
					
					Impact monitoring:
					Receiving Environment Monitoring Program as per Table F5 and F6 in the EA that includes monitoring requirements before, during and after a discharge event.
					
					Release point water quality
					
					Receiving Environment Management Program
						Surface water flow (periods of flow) and level (periods of no flow)	Mine affected water release limits in Table F2 and F4 of the EA are exceeded.	The appropriate corrective actions will be implemented and may include:
								• During a release event, comparing the downstream results to the upstream results in the receiving waters will be undertaken and:
								  ○ if the downstream result is the same or a lower value than the upstream value for the quality characteristic then no action will be taken; or
								  ○ if the downstream results exceed the upstream results complete an investigation into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining the details of the investigations carried out; and actions taken to prevent environmental harm
								• release limits may be reviewed once sufficient monitoring data is available to adequately characterise the baseline turbidity in the Carmichael River – including consideration of natural spatial and temporal variability
								• Pumping water from significant subsidence areas into waterways that will flow into the Carmichael River, and complete earthworks to allow water ponding in subsidence areas to flow into the Carmichael River via connecting creek systems and diversion drains
								• If there is potential for environmental harm identified, implementing management actions targeted at correcting the water quality parameter for which an exceedance occurred (e.g. changes to the discharge of mine affected water to achieve compliance).

		Reduce the risk of contamination of Waxy Cabbage Palm by chemicals, fuel, heavy metals etc.	No pollution of Waxy Cabbage Palms by contaminants (e.g. chemicals, fuel etc.)	Any sites used for chemical and fuel storage will be located a safe distance away from Waxy Cabbage Palm, with bunding or other raised barrier, resistant to normal flood events, between chemicals and. All vehicles and machinery will be cleaned and maintained to minimise the introduction of contaminants such as oil and fuel.	**Impact monitoring:** Water Management Plan Erosion and sediment control (section 7.6.2) Receiving Environment Monitoring Program Regular site inspections in accordance with the Environmental Management Plan and System.	Surface water quality Groundwater quality	Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded. Groundwater quality trigger levels as outlined in the GMMP and Table E2 in the EA are exceeded. Pollution of Waxy Cabbage Palm by decreased water quality.	The appropriate corrective actions will be implemented and may include: • Minimising immediate impacts and rectifying through clean-up actions • Reporting to DES as per statutory and project requirements where incidents trigger reporting thresholds.

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions
4	Fire	Maintain a mosaic of fire history in Waxy Cabbage Palm. Reduce the risk of bushfire spread	No uncontrolled fires (bushfires) in the Project Area. Fire management is conducted within an appropriate planning regime	The fire regime will be managed to utilise a patchwork of areas of different fire frequencies and times but biased toward low intensity fires. This regime would also help to reduce the risk of widespread hot fires by reducing fuel loading at the landscape scale. The existing network of roads and tracks will be used to manage fire, rather than establishing additional firebreaks. This will help reduce the risk of weed incursion through movement of traffic.	**Impact monitoring:** Fire Management Plan.	Fuel load and ground composition	• Dense shrub layers forming due to fire promoted germination. • Incidence of uncontrolled bushfire	The appropriate corrective actions will be implemented and may include: • Review of fire regime based on monitoring results and aim to achieve appropriate balance of groundcover/shrub layer management • Amending the strategic grazing regime • Reviewing effectiveness of firebreaks, and establishment of additional fire breaks • Modifying the timing and/or intensity of controlled burns.

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions
		Reduce the risk of bushfire ignition	No bushfires sparked by project activities.	Prior to site entry, all relevant site personnel, including contractors, will be made aware of fire safety and risks, including compliance with the Fire Management Plan. Bushfire mitigation measures will be outlined in the Bushfire Management Plan and will include, but not be limited to: • Monitoring of weather conditions to identify high fire risk days, with controls to be upgraded on these days • Restrictions on vehicles being left idling with the exhaust in contact with dry grass • Designation of smoking areas • Development of bushfire fuel management practices in the Project Area • Minimise the residency time of accumulated coal around coal handling facilities to reduce the risk of spontaneous combustion • Ensure all crews are equipped to deal with fires. This includes both fire-fighting equipment and training • Monitor pasture biomass at the beginning of the wet season • Work sites will be provided with adequate fire-fighting equipment (water cart) and training • Implement actions to prevent and suppress the spread of fire, should bushfire be ignited.	**Impact monitoring:** Monitoring of fuel load levels and ground composition. To be assessed at least annually against the baseline and pre-impact data. Additional monitoring actions as per the Fire Management Plan.	Fuel load levels and ground composition.	Bushfire sparked by project activities.	The appropriate corrective actions will be implemented and may include: • Mitigate the established source, arising from the investigation, as to why and how the bushfire was sparked by project activities • Review existing Bushfire Management Plan, ensuring consideration of ecological values and Rural Fire Service recommendations • Greater monitoring of adherence to fire management measures • Amending the strategic grazing regime • Modifying the timing and/or intensity of controlled burns • Re-training of site team members • Assess the benefits of strategic burning prior to the storm season to address pasture biomass.

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions
5	Weeds and pest plants through direct competition or degradation	Reduce weed competition	No new introduction of pest plants, invasive understorey species near Waxy Cabbage Palm individuals. Minimise the spread of weeds across the Project Area and into / from adjacent	Weed control, as part of the pest management plan, will focus on managing declared pest plants and invasive species during construction and operations. Weed hygiene controls, including the use of weed wash down stations, will be implemented in accordance with the pest management plan to prevent the introduction and spread of declared pest plants and other invasive weeds. Weed free areas around Waxy Cabbage Palms will be identified and mapped with strict weed control requirements for entering weed free areas. The establishment of new tracks through the Carmichael River outside of the clearing areas will be minimised to prevent transport of weed seeds into in Waxy Cabbage Palm management areas. .	**Pre-impact and Impact monitoring:** Monitoring of weeds will be conducted yearly (including photo monitoring) or as per the project pest management plan. Weed and pest surveys will be undertaken prior to construction along the Carmichael River to: • identify the extent of weeds, especially Rubber Vine, along the Carmichael River • identify areas near Waxy Cabbage Palm individuals subject to pig damage.	Presence of weed species Extent of weed coverage Presence of pest species Extent of damage from pest species	• Introduction or establishment of declared pest plants, and invasive species into previously unaffected areas • Results of weed monitoring indicate a degradation of Waxy Cabbage Palm, due to a proliferation of weeds • A significant increase in the abundance of weeds, or pests or identification of new infestations • Infestation of new weed species.	The appropriate corrective actions will be implemented and may include: • Eliminating potential sources or reasons that may have contributed to an increase in weed species richness and/or relative abundance of weeds • Amending weed hygiene restrictions within 1 week of concluding the investigation • Providing additional educational awareness training for all staff and contractors to ensure weed hygiene restrictions are adhered to • Revising weed control methods in accordance with the *Biosecurity Act 2014* • Increasing the frequency and intensity of weed controls for the following 12 months • Updating weed control methods in targeted weed control programs and plans.

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions
	Feral animal impacts	Reduce degradation to Waxy Cabbage Palms from introduced herbivores. Minimise predation risk by invasive animals	No measured increase in feral animal numbers in the Project Area	Adaptive management of pest controls to minimise threats to Waxy Cabbage Palm. A project pest management plan will be developed and implemented prior to construction and operations, including measures for controlling rabbits, goats, foxes and cats. The project pest management plan will be developed in conjunction with neighbouring land owners, and will focus on tracks, waterways and habitat edges. Domestic animals other than cattle (horses and dogs may also be required e.g. during mustering) will not be permitted into the Project Area.	**Impact monitoring:** Monitor the presence and population abundance of invasive fauna to be yearly as per the project pest management plan. Regular site inspections in accordance with the Environmental Management Plan and System.	Presence of feral animals Extent of damage from feral animals	Significant increase in the population of any invasive predator species from baseline & pre-impact scores. Observed degradation of Waxy Cabbage Palms attributed to threatening feral animals Domestic animals not permitted are observed in the Project Area	The appropriate corrective actions will be implemented and may include: • Increasing the frequency and intensity of feral animal control. • Revising methods of feral animal control in accordance with Queensland Department of Agriculture and Fisheries (DAF) guidelines, and coordinate with neighbouring land owners to ensure a consistent approach • Reviewing actions and methods included in the project pest management plan • Updating feral animal control methods in targeted pest animal control programs • Increase feral herbivore management efforts, in conjunction with neighbouring land owners • Communication with personnel involved and across all site team members (for example, via toolbox meetings).
6	Grazing pressures	Strategic use of grazing to manipulate the grass layer and manage fire by reducing fuel loads and therefore fire intensity across the ML area Ensure grazing does not become an impact to grass layers and grass composition	No significant impacts to Waxy Cabbage Palm as a result of grazing activities.	The management of grazing along the Carmichael River will be based on existing pastoral management practices under land agistment agreements, pastoral holding lease conditions and associated legislation. Maintain, and where possible, enhance Waxy Cabbage Palm populations Manage grass loads to reduce fire risk	**Impact monitoring:** Annual Waxy Cabbage Palm vegetation assessments Regular site inspections in accordance with the Environmental Management Plan and System.	CORVEG attributes Grazing practices (density, locations) as per management plan and agreements.	Annual vegetation assessment demonstrates evidence of grazing impact to Waxy Cabbage Palm Regular site inspections reveal evidence of grazing impact to Waxy Cabbage Palm	The appropriate corrective actions will be implemented and may include: • Immediately spelling of paddocks to control grazing • Completing a review of grazing practices with respect to duration, location, watering, access etc. within 4 weeks of investigation being concluded • Installing additional fencing / fencing repairs of required within 2 weeks of being confirmed as an issue. • Changing the management of grazing density and access • Adding pest controls • Revising fire management planning and practices if grazing is to be reduced as a fuel load control, review and update plan within 3 months.

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions

7	Vegetation clearing / habitat loss	Minimise Waxy Cabbage Palm loss	No mortality or damage associated with project related disturbance or unapproved clearing	Prior to the commencement of site works in areas with known populations of Waxy Cabbage Palm, the limits of clearing and exclusion areas will be clearly marked. Temporary fencing, such as barricade webbing, wire fencing or similar, will be used to prevent over clearing.
				
				Individual Waxy Cabbage Palm to be cleared will be clearly marked.
				
				Pre-start meetings for work in the Carmichael River will include discussions regarding Waxy Cabbage Palm including education on its appearance at various life forms.
				
				No-go zones for vegetation clearance and machinery to be developed for Waxy Cabbage Palm outside of the clearing footprint and to be depicted on site plans and maps to restrict access and prevent unapproved clearing.
					Pre-impact monitoring:
					Population surveys
					Ecological features map
					Riparian condition survey
					
					Impact monitoring:
					
					Pre-clearance surveys
					Close out report for the Permit to Disturb process includes check for compliance with:
					• clearing only in the approved footprint
					• no clearing in the no-go zone/s.
					
					Regular site inspections in accordance with the Environmental Management Plan and System.
						CORVEG attributes
						Visual evidence of damage or mortality
							Disturbance., trampling or clearing of Waxy Cabbage Palm:
							• outside approved clearing footprint
							• in no-go zone/s
							• without a "Permit to Disturb" issued
								The appropriate corrective actions will be implemented and may include:
								• When clearing outside approved clearing footprint, no go zones or without a "Permit to Disturb Permit" issued,
								  o Environment Manager ensure that all clearing activities cease immediately
								  o Area assessed by a suitably qualified ecologist/person within 15 business days of investigation
								  o additional barricading to be installed
								  o Reviewing and modifying "Permit to Disturb" process and no-go zone identification and communication protocols
								  o Implementing remediation measures within 1 month to promote regenerations
								• If mitigation is unsuccessful, the provision of offsets, as an overarching corrective action to achieve the objective of minimising loss.

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions
		Minimise Waxy Cabbage Palm loss	Clearing of Waxy Cabbage Palm does not exceed 5.47 ha of unavoidable impact, as approved	Prior to site entry, all relevant site personnel including contractors shall be appropriately trained in the identification of Waxy Cabbage Palm at all life stages and made aware of the sensitive environments (i.e. riverine areas) in which they will be working, including the extent of works and the extent of Waxy Cabbage Palm. Prior to the commencement of site works, any conditions listed in the "Permit to Disturb" must be implemented (e.g. clearing extents clearly marked, trees/areas requiring protection clearly marked).	**Pre-impact monitoring:** Population surveys Ecological features map Riparian condition survey **Impact monitoring:** Close out report for the Permit to Disturb process includes check for compliance with: • Clearing only in the approved footprint • No clearing in no-go zone/s. Ongoing monitoring and reporting on the amount of Waxy Cabbage Palm cleared annually, and predicted to be cleared.	Area cleared	Reach 75% of clearing of Waxy Cabbage Palms in approved areas	The trigger of reaching 75% of clearing of Waxy Cabbage Palm does not require correction as the clearing is approved to be carried out, however the following actions will be triggered: • Contact with nominated representatives from compliance teams of DoEE and DES under the EPBC and Environmental Protection Acts when clearing reaches 75% of approved area for stage 1 • Provision of maps and data showing clearing in approved impact areas, and calculations showing quantity of approved clearing • Provide advice demonstrating how the clearing will not exceed approved limits.
		Minimise fragmentation	Manage offset areas to maintain and improve the condition of the Carmichael River	Management and monitoring of the Waxy Cabbage Palm offset area on Moray Downs West to occur in accordance with the Offset Area Management Plan (OAMP).				
		Carmichael River crossing area is rehabilitated	Rehabilitation success as per the EA criteria (quality and time)	Rehabilitation of the Carmichael River crossing will be undertaken at the completion of the construction and once temporary construction areas are no longer required. Rehabilitation will focus on the reinstatement of ground cover to stabilise the creek banks.	**Impact monitoring:** Population surveys Ecological features map Riparian condition survey	Rehabilitation success parameters as listed in Appendix 2 of the EA (native fauna species, plant regeneration, weed abundance, pest abundance) Event monitoring for: pH Turbidity	\ Rehabilitation not meeting success criteria under EA for parameters such as vegetation cover, evidence of erosion within relevant EA timeframes.	The appropriate corrective actions and may include: • Installing additional erosion and / or sedimentation in accordance with Erosion and Sediment Management Plan. • Reviewing Waxy Cabbage Palm mapping and access routes within 1 week to determine if impacts were avoidable. • Rectifying direct impacts through review within 5 days • Reviewing activities and making improvements to rehabilitation methods.
8	Restricted geographic distribution	*Not applicable / included for completeness – see **section 7.4.***						
9	Clearing and fragmentation for agriculture	*Not applicable / included for completeness – see **section 7.4.***						

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions
10	Earthworks	No damage to Waxy Cabbage Palm attributable to vehicle movements.	Vehicles and machinery only drive on designated access tracks	All relevant site personnel, including contractors, will be made aware of the locations of Waxy Cabbage Palm populations. Vehicles and machinery only drive on pre-determined roads only, and adhere to all speed limits, which will be clearly communicated.	**Impact monitoring:** Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Visual record of damage	• Damage to Waxy Cabbage Palm attributable to vehicle movements • Vehicles observed driving outside designated tracks or areas	The appropriate corrective actions will be implemented and may include: • Review of Waxy Cabbage Palm mapping and access routes • Rectifying direct impacts within 5 days • Communication with personnel involved and across all site team members (for example, via toolbox meetings).
		Minimise impacts on geomorphology	No impacts to known Waxy Cabbage Palm from erosion and sediment other than otherwise approved.	An Erosion and Sediment Management Plan will be developed and implemented for the Carmichael River bridge construction by a suitably qualified person.	**Impact monitoring:** Regular site inspections in accordance with the Erosion and Sediment Management Plan and Environmental Management System.	Event monitoring for: pH Turbidity	Evidence of erosion and / or sedimentation within the vicinity of construction activities or caused by construction activities that has impacted Waxy Cabbage Palm.	The appropriate corrective actions will be implemented and may include • Remediation of plants that have been impacted by sedimentation within 2 weeks of investigation conclusion • Review erosion and / or sedimentation controls and plan within 5 days of investigation conclusion. • Implementation of revised controls prior to earthworks recommencing. • Undertake targeted weekly inspection of erosion and sediment controls for the following month to review effectiveness.
11	Noise and vibration	Minimise impacts to Waxy Cabbage Palm as a result of noise and vibration	No Waxy Cabbage Palms deaths due to noise or vibration disturbance.	Project impacts like noise, dust and lighting will be minimised by the implementation of the Environment Management Plan Disturbance areas on either side of the road crossing the Carmichael River kept minimal and stabilised as soon as possible. Laydown, storage areas and parking outside the Carmichael River area. Machinery are serviced and maintained to minimise machinery noise and vibration.	**Impact monitoring:** Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Event monitoring for: dB(A) peak particle velocity (PPV)	Dieback of Waxy Cabbage Palm likely to have been caused by noise or vibration.	The appropriate corrective actions will be implemented and may include: • Assessment to determine the root and contributing causes as being likely caused by noise or vibration • Review and re design to avoid reoccurrence and address actual cause • Communication with personnel involved where appropriate and across all site team members (for example, via toolbox meetings).

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions
12	Emissions (including dust)	Minimise emissions (dusts)	No disturbance from emissions (dust) on photosynthetic ability of grasses in Waxy Cabbage Palm.	Regular watering of project areas in accordance with procedures under the Environmental Management Plan. Vehicles are to be cleaned regularly and are not to be overloaded. Disturbance areas on either side of the road crossing the Carmichael River kept minimal and stabilised as soon as possible. Laydown, storage areas and parking outside the Carmichael River area. Coal dust to be managed in accordance with the Environmental Management Plan.	**Impact monitoring:** Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Event monitoring for: Total suspended particulate matter	Growth of Waxy Cabbage Palm in, and adjacent to, the Project Area are inhibited due to dust emissions.	The appropriate corrective actions will be implemented and may include: • Where monitoring shows a reduction in condition due to dust, mitigate source of dust • Review and re design to avoid reoccurrence and reduce dust emissions impacts • Communication with personnel involved and across all site team members (for example, via toolbox meetings).

		Maintain surface water quality
		
		Protection of environmental values within waterways of the receiving environment.
		
		Minimise siltation of water resources
			Emissions (i.e. dust, coal and heavy metals) do not degrade water source quality in Waxy Cabbage Palm.	Vegetation clearing near, or within ephemeral waterways will be avoided when rain is falling, or imminent.
				
				Management of erosion and sedimentation will be undertaken in accordance with an Erosion and Sediment Management Plan. This plan will identify all practices to be implemented prior to, during, and post-construction to minimise the potential for erosion to occur, including (but not limited to) timing of clearing activities, sediment and erosion control measures to be implemented, performance criteria and corrective actions.
				
				Implement dust control measures, as per the environmental management plan and systems.
					Pre-impact and impact monitoring, as per the:
					Receiving Environment Management Plan
					Erosion and Sediment Management Plan (sections 7.6.1 and 7.6.2)
					Release point water quality
					Receiving Environment Monitoring Program as per Table F5 and F6 in the EA that includes monitoring requirements before, during and after a discharge event.
					Regular site inspections in accordance with the Environmental Management Plan and System.
						Surface water quality	Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded.
							Physical evidence of dust degradation to water sources outside active mining areas.
							Mine affected water release limits in Table F2 and F4 of the EA are exceeded.
								The appropriate corrective actions will be implemented and may include:
								• During a release event, a comparison of the downstream results to the upstream results in the receiving waters will be undertaken and:
								  ○ if the downstream result is the same or a lower value than the upstream value for the quality characteristic then no action will be taken; or
								  ○ if the downstream results exceed the upstream results complete an investigation into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining the details of the investigations carried out; and actions taken to prevent environmental harm
								• If there is potential for environmental harm identified, Adani will implement management actions targeted at correcting the water quality parameter for which an exceedance occurred (e.g. implement changes to the discharge of mine affected water to achieve compliance).

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions
13	Light spill and other visual impacts	Minimise light spill	No light disturbance to Waxy Cabbage Palms	Install light controlling devices to deflect lighting away from adjacent Waxy Cabbage Palms. Avoid using unnecessary lighting.	**Impact monitoring:** Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Observations of amount of light falling near Waxy Cabbage Palms	Direct light spill measured >100 m from Waxy Cabbage Palms	The appropriate corrective actions will be implemented and may include: • Review and re design of light controlling devices, or adjust location of light, to reduce light spill and lighting • Communication with personnel involved and across all site team members (for example, via toolbox meetings).

8 Doongmabulla Springs-complex

8.1 Status and description

The Doongmabulla Springs-complex is recognised as a 'community of native species dependent on natural discharge of groundwater from the Great Artesian Basin' (hereafter 'GAB spring wetland community') Threatened Ecological Community (TEC). The GAB spring wetland community TEC is listed as endangered under the EPBC Act.

The Doongmabulla Springs-complex is mapped as a Great Barrier Reef Wetland Protection Area (GBR WPA) under State Planning Policy 4/11: Protecting Wetlands of High Ecological Significance in Great Barrier Reef Catchments.

The Doongmabulla Springs-complex is listed under the Queensland *Nature Conservation (Protected Areas) Regulation 1994* as a Nature Refuge, the listing noted as "Doongmabulla Mound Springs Nature Refuge".

The Doongmabulla Springs-complex is located approximately 8 km from the western edge of the Carmichael Mine lease boundary (**Figure 8-1**). It is situated near the confluence of three third order creek systems (Cattle Creek, Dyllingo Creek and Carmichael Creek). These creeks join downstream to form the Carmichael River within the upper reaches of the Burdekin River catchment.

The Doongmabulla Springs-complex has been included within the Barcaldine Supergroup, but unlike the other springs in this supergroup, they are associated with the Galilee Basin rather than the Eromanga Basin (Fensham et al. 2016).

The Doongmabulla Springs-complex includes incipient mound springs, small artesian seeps, non-mounding artesian springs, mound springs, and a modified high flow spring (GHD 2014). They include relatively large spring wetlands and consist of 187 vents forming 160 separate wetlands varying in size from small clumps of wetland vegetation fed by miniscule discharge to a spring wetland of about 8.7 ha in area (Fensham et al. 2016).

The Doongmabulla Springs-complex consists of three primary Springs-groups:

- Moses Springs-group – a cluster of at least 65 mounding and non-mounding artesian springs and large wetland areas, spread over a 2.5 km radius, within close proximity (north and south) to Cattle Creek.
- Little Moses Springs-group – a small number of incipient non-mounding springs, located approximately 2 km east of the Moses Springs-group, which drain into a relict channel of Dyllingo Creek
- Joshua Springs-group – a single large and very active spring, located 2 km north of the Moses Springs-group, now modified into a turkey's nest dam with associated overflow dams.

From: Coram, Jane (L&W, Black Mountain)
To: s22
Subject: Re: Summary available on website [SEC=OFFICIAL]
Date: Thursday, 11 April 2019 2:36:28 PM
Attachments: image001.gif
image002.gif
image003.gif
image004.gif

Thanks s22

With regards, Jane.

On 11 Apr 2019, at 2:22 pm, s22 @environment.gov.au> wrote:

Hi Jane,
You may have heard through other means, but I wanted to let you know the summary of your advice is now at the web link below
s22
s22
T 02 s22 @environment.gov.au
W www.environment.gov.au

From: s22
Sent: Thursday, 11 April 2019 2:02 PM
To: s22 @environment.gov.au>; s22 @environment.gov.au>
Cc: Gregory Manning <Gregory.Manning@environment.gov.au>; s22 @environment.gov.au>; s22 @environment.gov.au>
Subject: RE: Web updates [SEC=OFFICIAL]

Thanks s22
Now live:
https://www.environment.gov.au/protection/assessments/key-assessments
Sorry for the to and fro.
Kind regards
s22

Web Designer
Department of the Environment and Energy
s22
www.environment.gov.au
Please note: I work Mon/Tues/Thurs/Fri 9.30am-4.30pm

From: s22
To: s22
Cc: s22
Subject: RE: Tranche 2 on track for delivery tomorrow before CoB [SEC=UNCLASSIFIED]
Date: Thursday, 21 February 2019 4:56:25 PM
Attachments: image001.png
image002.png
image003.png
image004.png
image005.png

Sounds good to me. I'll book a room and a teleconference number, just in case.
You should get an invite soon!
s22

T 02 s22 @environment.gov.au
W www.environment.gov.au

From: s22 @ga.gov.au]
Sent: Thursday, 21 February 2019 4:49 PM
To: s22
Cc: s22
Subject: RE: Tranche 2 on track for delivery tomorrow before CoB [SEC=UNCLASSIFIED]

Hi s22
Who would you want from the team?
s22 and I will be available, I'm not sure if s22 are free to dial in.
12:30 (Canberra), 12:00 (Adelaide) – Works best for GA people, happy to come to you (Allara St)

From: s22 @environment.gov.au>
Sent: Thursday, 21 February 2019 4:40 PM
To: s22 @ga.gov.au>
Cc: s22 @ga.gov.au>; s22 @ga.gov.au>; s22 @csiro.au>
Subject: RE: Tranche 2 on track for delivery tomorrow before CoB [SEC=UNCLASSIFIED]

Excellent. We're only available at odd times, sorry:
9:30am (here), 12:30pm (here) or 4pm (here or at GA)
s22

T 02 s22 @environment.gov.au
W www.environment.gov.au

From: s22 @ga.gov.au]
Sent: Thursday, 21 February 2019 4:32 PM
To: s22 @environment.gov.au>
Cc: s22 r@ga.gov.au>; s22 @ga.gov.au>; s22 @csiro.au>
Subject: RE: Tranche 2 on track for delivery tomorrow before CoB [SEC=UNCLASSIFIED]

We are at your disposal on Monday. What time suits?

From: s22 @environment.gov.au>
Sent: Thursday, 21 February 2019 4:31 PM
To: s22 @ga.gov.au>
Cc: s22 @ga.gov.au>; s22 @ga.gov.au>; s22 @csiro.au>

Subject: RE: Tranche 2 on track for delivery tomorrow before CoB [SEC=UNCLASSIFIED]

Hi s22

Good to hear! Very keen to get it.

Is it possible to chat as soon as you can – i.e. Monday?

s22

[redacted]

T 02 s22 @environment.gov.au

W www.environment.gov.au

From: s22 @ga.gov.au]

Sent: Thursday, 21 February 2019 4:27 PM

To: s22 @environment.gov.au>

Cc: s22 @ga.gov.au>; s22 @ga.gov.au>; s22 @csiro.au>

Subject: Tranche 2 on track for delivery tomorrow before CoB [SEC=UNCLASSIFIED]

Hi s22

Welcome back from your break. To let you know, Tranche 2 work is on track for delivery, we are doing the last of GA clearances tomorrow morning.

It would be good to arrange a meeting next week to discuss our submission once you have had time to ingest it. We have primed the GA and CSIRO media teams to hold the line and direct all enquiries to DoEE media.

I will be on an RDO tomorrow, so please direct any queries to s22 or s22

Speak to you next week.

Thanks

s22

[redacted] **, PhD |** A/g Director

Groundwater Advice and Data **|** Environmental Geoscience Division

t +61 2 s22 **|** www.ga.gov.au

16-9481 GA Email Signature_social media-04

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FOI 190417
Document 9

From: s22
To: s22 "
Subject: RE: Updated front cover date [SEC=UNCLASSIFIED]
Date: Monday, 25 February 2019 5:15:59 PM
Attachments: image001.png
image002.png
image003.png
image004.png
image005.png

Thanks s22

T 02 s22 @environment.gov.au
W www.environment.gov.au

From: s22 @ga.gov.au]
Sent: Monday, 25 February 2019 2:33 PM
To: s22
Cc: s22
Subject: Updated front cover date [SEC=UNCLASSIFIED]

Dear all,

Please find a revised copy with an amended front cover date.

Thanks

s22
, PhD | A/g Director
Groundwater Advice and Data **|** Environmental Geoscience Division
t +61 2 s22 **|** www.ga.gov.au

16-9481 GA Email Signature_social media-04

From: s22
To: 's22 (CorpAffairs, Dutton Park)"
Subject: RE: URGENT [SEC=OFFICIAL]
Date: Thursday, 11 April 2019 12:48:01 PM

Thanks s22
s22
T 02 s22 @environment.gov.au
W www.environment.gov.au

From: s22 (CorpAffairs, Dutton Park) [mailto:s22 @csiro.au]
Sent: Thursday, 11 April 2019 12:44 PM
To: s22
Subject: FW: URGENT

Dear s22 , for your information below is an updated version of the CSIRO statement on the advice provided regarding the Carmichael project.

In late 2018 and early 2019 CSIRO and Geoscience Australia wrote two reports for the federal government on specific questions on groundwater monitoring, management and modelling planned by Adani Pty Ltd for its Carmichael mine proposal in central Queensland.

This advice was limited to answering discrete inquiries on whether elements of Adani's proposed plans would be adequate to protect nationally significant environmental assets.

CSIRO identified inadequacies in the plans and was subsequently asked to review Adani's response to the recommendations CSIRO made to address the issues we raised, as summarised by the Department of the Environment and Energy. Adani had committed to address the modelling limitations identified by the CSIRO and GA review in a groundwater model re-run to be undertaken within two years.

CSIRO considered that this commitment satisfied our recommendations, while also acknowledging that there are still some issues that need to be addressed in future approvals, particularly confirming the source of the ecologically-important Doongmabulla Springs.

CSIRO has provided robust, peer-reviewed science on specific groundwater modelling-related questions about the plans. CSIRO's role is to provide scientific advice to inform approval processes, but it does not have any role in making approval decisions.

Kind regards, s22
s22
Communication Manager
CSIRO Land & Water
E s22 @csiro.au **P** s22
Ecosciences Precinct
41 Boggo Road Dutton Park QLD 4102
GPO Box 2583 Brisbane QLD 4001 Australia
www.csiro.au | Facebook | Twitter

CSIRO acknowledges the Traditional Owners of the lands that we live and work on across Australia and pays its respect to Elders past and present.

From: Coram, Jane (L&W, Black Mountain)
Sent: Thursday, 11 April 2019 11:43 AM
To: s22 (CorpAffairs, Black Mountain) <s22 @csiro.au>; s22 (CorpAffairs, Dutton Park) <s22 @csiro.au>; Mayfield, Peter (Executive, Newcastle)

<Peter.Mayfield@csiro.au>; McDonald, Warwick (L&W, Black Mountain) <Warwick.Mcdonald@csiro.au>
Cc: s22 (CorpAffairs, Dutton Park) s22 @csiro.au>; s22 (Executive, Black Mountain) s22 @csiro.au>; s22 (CorpAffairs, Adelaide K. Ave) <s22 @csiro.au>
Subject: RE: URGENT

Further refinements (in blue).

Thank you; Jane.

From: Coram, Jane (L&W, Black Mountain)
Sent: Thursday, 11 April 2019 11:26 AM
To: s22 (CorpAffairs, Black Mountain) <s22 @csiro.au>; s22 (CorpAffairs, Dutton Park) s22 @csiro.au>; Mayfield, Peter (Executive, Newcastle) <Peter.Mayfield@csiro.au>; McDonald, Warwick (L&W, Black Mountain) <Warwick.Mcdonald@csiro.au>
Cc: s22 (CorpAffairs, Dutton Park) s22 @csiro.au>; s22 (Executive, Black Mountain) s22 @csiro.au>; s22 (CorpAffairs, Adelaide K. Ave) s22 @csiro.au>
Subject: RE: URGENT

Hi all,

A few tweaks in green and also two points needing clarification in the last line:

(i) CSIRO has provided robust, peer-reviewed scientific advice on specific questions about the plan. While our advice was based on understanding developed through other peer-reviewed work, there was no external peer review process involved in the advice. Is this statement misleading and should we leave off the "peer-reviewed"?

(ii) CSIRO does will not play a role in approval processes around developments. Can we say this – we may be asked to provide further advice to inform the approvals of the subsequent research plan. Suggest alternate wording: CSIRO's role is to provide independent scientific advice to inform approvals processes, but it does not have any role in making approvals decisions. Or is this also too defensive?

With regards, Jane.

From: s22 (CorpAffairs, Black Mountain)
Sent: Thursday, 11 April 2019 10:46 AM
To: s22 (CorpAffairs, Dutton Park) s22 @csiro.au>; Mayfield, Peter (Executive, Newcastle) <Peter.Mayfield@csiro.au>; Coram, Jane (L&W, Black Mountain) <Jane.Coram@csiro.au>
Cc: s22 (CorpAffairs, Dutton Park) s22 @csiro.au>; s22 (Executive, Black Mountain) s22 @csiro.au>; s22 (CorpAffairs, Adelaide K. Ave) s22 @csiro.au>
Subject: RE: URGENT

Looks good, just a couple of small suggestions to make it slightly less defensive..

s22 CSIRO
E s22 @csiro.au T 02 s22

From: s22 (CorpAffairs, Dutton Park)
Sent: Thursday, 11 April 2019 10:26 AM
To: Mayfield, Peter (Executive, Newcastle) <Peter.Mayfield@csiro.au>; Coram, Jane (L&W, Black Mountain) <Jane.Coram@csiro.au>
Cc: s22 (CorpAffairs, Dutton Park) s22 @csiro.au>; s22 (Executive, Black Mountain) s22 @csiro.au>; s22 (CorpAffairs, Adelaide K.

Ave) s22 @csiro.au>; s22 (CorpAffairs, Black Mountain)
s22 @csiro.au>
Subject: URGENT

s22

Further to earlier email below is the written response for APPROVAL.

Deadline is tight at 12 noon. We will need to advise DoEE & GA of this development.

Thanks

s22

Karen Middleton, The Saturday Paper - **Have all the conditions been met in Adani's proposal?**

RESPONSE

In late 2018 and early 2019 CSIRO and Geoscience Australia wrote two reports for the federal government on specific questions on groundwater monitoring, management and modelling planned by Adani Pty Ltd for its Carmichael mine proposal in central Queensland.

This advice was limited to answering discrete inquiries on whether elements of Adani's proposed plans would be adequate to protect nationally significant environmental assets.

CSIRO identified inadequacies in the plans and was ~~later~~subsequently asked to review Adani's response to the recommendations CSIRO made to address the issues we raised, whereby Adani committed to address the modelling limitations identified by the CSIRO and GA review in a groundwater model re-run to be undertaken within 2 years.

CSIRO considered that this ~~found that the~~ commitment~~s made to revise the groundwater modelling plans sh~~would satisfy our recommendations, whilst also acknowledging that there are still some issues that need to be addressed in future approvals~~, including confirming the source of the ecologically-important Doongmabulla Springs~~.

CSIRO has provided robust, peer-reviewed scientific advice on specific groundwater modelling-related questions about the plans. CSIRO does ~~will~~ not play a role in approval processes around developments.

FOI 190417
Document 11

From: s22
To: "james.johnson@ga.gov.au"
Cc: "Stuart Minchin"; "Blewett Richard"
Subject: RE: Revised GMMP [SEC=OFFICIAL]
Date: Friday, 5 April 2019 1:01:17 PM
Attachments: Attachment%20A%20-%20GMMP%20Final_Part1.pdf
image001.jpg

Hi James,
Sorry – I've had to split into two parts to get to your inbox. This does not include the appendices, happy to provide these separately if required.
s22

T 02 s22 @environment.gov.au
W www.environment.gov.au

From: s22
Sent: Friday, 5 April 2019 12:53 PM
To: 'james.johnson@ga.gov.au' ; 'jane.coram@csiro.au'
Cc: Stuart Minchin ; Blewett Richard ; 'McDonald, Warwick (L&W, Black Mountain)' ; Gregory Manning ; s22 Dean Knudson
Subject: Revised GMMP [SEC=OFFICIAL]

Hi James and Jane,
Please find the revised GMMP attached.
The GDEMP will follow
s22

Acting Director | Post Approvals Strategies
Environment Standards Division
Department of the Environment and Energy
T 02 s22 @environment.gov.au

Reconciliation%20Email%20Footer

AECOM Imagine it. Delivered.

Adani Mining Pty Ltd
15-Mar-2019

FOI 190417
Document 11a

DRAFT

FOR REVIEW

Groundwater Management and Monitoring Program

Carmichael Coal Project

D R A F T

Groundwater Management and Monitoring Program

Carmichael Coal Project

Client: Adani Mining Pty Ltd

ABN: 27 145 455 205

Prepared by

AECOM Services Pty Ltd
Level 8, 540 Wickham Street, PO Box 1307, Fortitude Valley QLD 4006, Australia
T +61 7 3553 2000 F +61 7 3553 2050 www.aecom.com
ABN 46 000 691 690

15-Mar-2019

Job No.: 60451774

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Quality Information

Document	Groundwater Management and Monitoring Program
Ref	60451774
Date	15-Mar-2019
Prepared by	Krystle L. Nichols
Reviewed by	Mark Stewart

Revision History

Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
0	28-Jul-2017	For Issue	Mark Stewart Associate Director - Environment	
1	08-May-2018	Address regulator comments / data requests	Mark Stewart Technical Director - Hydrogeology	
2	26-Jul-2018	Triggers and Thresholds	Mark Stewart Technical Director - Hydrogeology	
3	08-Aug-2018	Draft for Submission	Mark Stewart Technical Director - Hydrogeology	
4	28-Nov-2018	Draft for Review	Mark Stewart Technical Director - Hydrogeology	
5	22-Jan-2019	Draft	Mark Stewart Technical Director - Hydrogeology	
6	07-Mar-2019	Draft for Review	Mark Stewart Technical Director - Hydrogeology	
7	15-Mar-2019	Draft DoEE Comments	Mark Stewart Technical Director - Hydrogeology	

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Abbreviations

Abbreviation	Description
Adani	Adani Mining Pty Ltd
AECOM	AECOM Services Pty Ltd (formerly URS Australia Pty Ltd)
AEIS	Addendum to the SEIS
AWL	Associated water licence
BTEX	Benzene, toluene, ethylbenzene, xylene
CCP	Carmichael Coal Project
CG's Report	The Coordinator-General's evaluation report
DERM	Department of Environment and Resources Management
DEHP	Department of Environment and Heritage Protection
DES	Department of Environment and Science
DNRM	Department of Natural Resources and Mines
DNRME	Department of Natural Resources, Mines and Energy
DO	Dissolved oxygen
DoE	Department of the Environment
DoEE	Department of the Environment and Energy
DotE	Department of the Environment
EA	Environmental Authority
EC	Electrical conductivity
EIS	Environmental Impact Statement
EHP	Department of Environment and Heritage Protection (now DES)
EMP	Environmental Management Plan
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPC	Exploration permit for coal
EPP (Water)	Environmental Protection (Water) Policy 2009
EVs	Environmental Values
Fm	Formation
GAB	Great Artesian Basin
GABSRP	GAB Springs Research Plan
GDEs	Groundwater Dependent Ecosystems
GDEMP	Groundwater Dependent Ecosystems Management Plan
GHBs	General head boundaries
GME	Groundwater monitoring event
GMMP	Groundwater Management and Monitoring Program / Plan
LOR	Limit of reporting
L/s	Litre per second

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Abbreviation	Description
m/day or m/d	metres per day
3332m^3/day	metres cubed per day
µS/cm	microSiemens per centimetre
mg/L	milligrams per litres
mAHD	meters Australian Height Datum
MAW	Mine affected water storage dams
MIA	Mine infrastructure area
MLs	Mine Leases
MNES	Matters of National Environmental Significance
MSES	Matters of State Environmental Significance
Mtpa	Million tonnes per annum
NF	Natural fluctuation
NRM	Department of Natural Resources and Mines
RFCRP	Rewan Formation Connectivity Research Plan
RL	Reference Level (in mAHD)
SDWPO Act	State Development and Public Works Organisation Act 1971
SEIS	Supplemental Environmental Impact Statement
TDS	Total dissolved solids
TPH	Total petroleum hydrocarbons
UG	Underground mine
UWMP	Underground Water Monitoring Program
VWPs	Vibrating wire piezometers
WQIP	Water Quality Improvement Plan 2016
WQGs	Water quality guidelines

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1.0 Introduction

1.1 Overview

Adani Mining Pty Ltd (Adani) propose to develop a 60 million tonne (product) per annum (Mtpa) thermal coal mine in the geological Galilee Basin, approximately 160 kilometres (km) north-west of Clermont, Central Queensland, Australia as presented in **Figure 1** below.

The Carmichael Coal Project (CCP), the mining component of the overall Carmichael Coal Mine and Rail project (the Project), includes a greenfield coal mine within mining leases (MLs) 70441, 70505, and 70506. The CCP proposes to comprise both open cut and underground mining methods, mine infrastructure and associated mine processing facilities, and ancillary mine infrastructure including a worker's accommodation village and associated facilities, a permanent airport, a mine industrial area, and water supply infrastructure.

The Queensland's Coordinator-General approved the overall Project subject to an extensive set of environmental and social conditions. These approval conditions include the development and approval of a Groundwater Management and Monitoring Program (GMMP) for the CCP component of the Project; the GMMP-specific conditions are included in the approvals as follows:

- Coordinator-General's evaluation report on the environmental impact statement (EIS) for the Carmichael Coal Mine and Rail project, dated May 2014 (CG's Report), and includes a stated condition of approval to develop a suitable Groundwater Management and Monitoring Program (Stated Condition E4)
- Environmental Authority (EA), issued by the Department of Environment and Heritage Protection (DEHP), on 5 June 2017 (now the Department of Environment and Science [DES]) requires a GMMP to be developed to address all phases of mining operations approved under the EA inclusive of the pre-mining or baseline phase
- Baseline (pre-mining) groundwater monitoring program must result in a groundwater dataset provided to the administering authority at least 30 days prior to commencement of any mining activities associated with box cut excavation
- Approval condition for the CCP issued by the Australian Government Department of the Environment (DotE), on 14 October 2015, with respect to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) requires the submission of a suitable Groundwater Management and Monitoring Plan[1] three months prior to the commencement of the first box cut excavation.

This document, the GMMP, has been prepared for the CCP to address both the Commonwealth and Queensland State environmental approval conditions, inclusive of proposed groundwater quality triggers (chemistry) and groundwater level thresholds. The GMMP has been compiled by Mark Stewart, Technical Director – Groundwater at AECOM Australia Pty Ltd and reviewed by John Bradley of JBT Consulting. Both are appropriately qualified persons (hydrogeologists) as required in the approvals.

This GMMP has been developed to characterise the baseline groundwater conditions (pre-mining) and to provide groundwater monitoring locations for all approved phases of mining operations, consistent with Project approval condition requirements to inform long term monitoring of groundwater resources. Further, the groundwater monitoring network presented herein is considered suitable to evaluate potential impacts which may result from the proposed CCP on: local groundwater resources, local landholder bores, aquifers of the Great Artesian Basin (GAB), groundwater dependent ecosystems (GDEs), overlying alluvium and Tertiary sediments groundwater resources, and surface water resources (Carmichael River baseflow, Doongmabulla Springs Complex, and Mellaluka Springs Complex).

[1] Based on the nature of the approval conditions it is noted that the required Groundwater Management and Monitoring Program (EA Condition E4) and the Groundwater Management and Monitoring Plan (EPBC Act condition) are the same document, abbreviated as GMMP in this document.

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Figure 1 **Location of the overall Project and CCP tenements**

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1.2 Groundwater Management Framework

To ensure this GMMP is suitable to inform long term groundwater monitoring, and identification of potential impacts on groundwater resources, an adaptive management framework for performance assessment has been adopted.

Adaptive management is a structured, iterative process of robust decision-making with a focus on reducing uncertainty over time via systems monitoring and continuous improvement to achieve the desired environmental and operational outcomes of the project.

There are five primary principles to the adaptive management and continuous improvement process: Plan, Develop, Evaluate, Implement, and Monitor. These principles are centred around a continuous feedback loop (the improvement cycle) and presented in **Figure 2.**

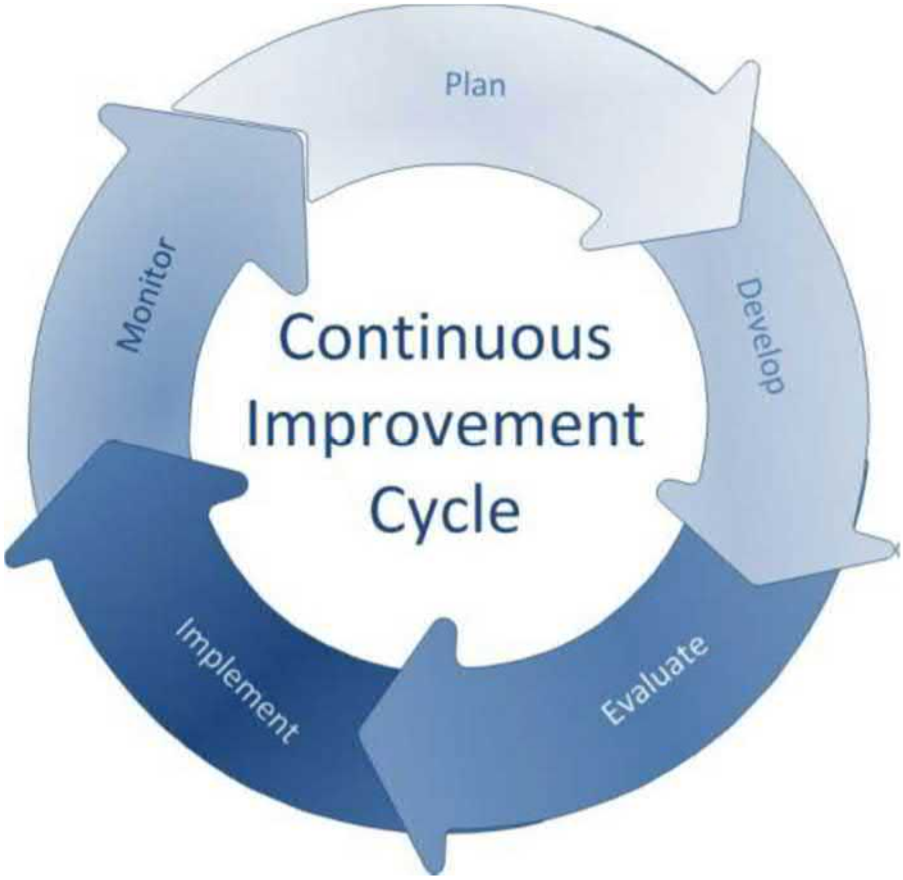

Figure 2 Adaptive management framework and continuous improvement process

Monitoring, evaluation, and reporting are required to ensure operational and environmental outcomes are being achieved for the CCP. If not, a feedback loop into management actions addresses the issues which prevent the desired outcomes. The elements associated with the adaptive management framework for the CCP are detailed in **Table 1** below.

Adaptive management principles allow for adjustments in outcomes, indicators and limits, as well as associated monitoring and reporting approaches to improve the long-term management outcomes.

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Table 1 Elements of the Adaptive Management Framework for the CCP

Element	Description
Outcomes	The environmental state to be achieved. Outcomes reflect project requirements, regulatory requirements, and societal values and perceptions. Outcomes are pragmatic, realistic and measurable (using relevant indicators).
Parameter	A measured variable or state of resource condition used to verify that established outcomes are being achieved.
Trigger (contaminant trigger or water level threshold)	A desired condition or range for a given parameter to be maintained below, above, or within. The value(s) selected consider natural variability and ambient (background) conditions for an aquifer with respect to both quality and quantity.
Limit	A value not to be exceeded, such that the aquifer's health and associated resources may be maintained. That is, significant exceedance of the established natural variability at a given location or an agreed-upon published criterion can impact on the aquifer's condition.
Receptor	A natural discharge point (spring / watercourse) or user (landholder) of an environment or health value which is interconnected to the groundwater system and influenced by changes to aquifer's physical and / or chemical characteristics.

The adaptive management approach allows for inclusion of new groundwater quality and quantity data into models as it is collected and promotes adaptation of water management decisions. The groundwater levels and quality data collected for the EIS assessments, after EIS assessments (as a part of baseline data collection required for EA condition E3), and further data collected to date has been used for development of the GMMP, water quality triggers, and groundwater level drawdown thresholds. In addition to the monitoring bores installed for the EIS additional monitoring bores have been installed to collect data adjacent to identified GDEs and within the GAB hydrostratigraphic units. Further details of data collected and how it has been utilised is furnished in **Section 3.0**.

Development of groundwater quality triggers and groundwater level thresholds, used to instigate investigation into groundwater resource impacts, is discussed further in **Section 5.0**.

In compliance with the Coordinator-General's stated condition E6 of the EA this GMMP is to be reviewed within two years of commencement of mining activities and at least every five (5) years thereafter, and a report prepared which presents the outcomes of the GMMP review and provided to the administering authority for approval.

1.3 Groundwater Management and Monitoring Program – Baseline (Pre-Mining Phase) Monitoring

Adani has prepared this GMMP to address the CCP regulatory approval conditions specific to address all phases of mining, inclusive of the pre-mining (baseline) phase. The baseline monitoring program developed and presented in this GMMP includes the following:

- Details of the baseline groundwater monitoring program which comprises a bore network of monitoring points designed and constructed to collect representative ambient (background) data from each hydrostratigraphic unit (aquifer or aquitard) identified to potentially be impacted by the approved mining activities of the CCP. The identified hydrostratigraphic units with potential to be impacted are:
    - Quaternary aged alluvium
    - Tertiary sediments
    - Triassic aged Clematis Sandstone
    - Triassic aged Dunda Beds
    - Triassic aged Rewan Formation

- Permian aged Bandanna Formation
- Permian aged Colinlea Sandstone
- Early Permian aged Joe Joe Group.

- The groundwater monitoring bore network, designed and constructed to provide sufficient spatial distribution across the MLs of the individual hydrostratigraphic units (listed above), allows for compilation of representative background groundwater quality and water level data
- Baseline groundwater quality and water level data from at least twelve (12) monitoring events
- Identification of natural groundwater level trends
- Calculated groundwater quality trigger levels (85^{th} percentiles)
- Proposed groundwater level thresholds to allow for verification of predictions and assessment of potential impacts on groundwater resources.

1.4 Groundwater Management and Monitoring Program – Objectives

This inaugural version of the GMMP was developed to meet the objectives below:

- Ensure compilation of adequate groundwater monitoring data to allow for validation of the predictive groundwater numerical model, including boundary and recharge conditions, and assessment of the accuracy of groundwater impact predictions
- Ensure compilation of spatial and transient groundwater monitoring data to allow for refinement of the groundwater numerical model, as required, for accurate groundwater impact predictions
- Allow for a suitable groundwater monitoring bore network which promotes accurate groundwater level monitoring in all identified hydrostratigraphic units that may potentially be impacted by the approved mining activities
- Ensure collection of groundwater level data to confirm groundwater flow patterns for all identified hydrostratigraphic units that may potentially be impacted by the approved mining activities and to refine the conceptual models regarding recharge, groundwater flow, and discharge
- Allow for a suitable groundwater monitoring bore network which promotes monitoring of potential groundwater level drawdown impacts in all identified geological units that may potentially be impacted by the approved mining activities (this was the main rationale for developing the groundwater monitoring bore network across and adjacent to the CCP MLs)
- Utilisation of the existing predictive groundwater model(s) to develop proposed groundwater level thresholds and allow for assessment of possible impacts from the approved mining activities on identified GDEs, inclusive of spring complexes and the Carmichael River alluvium
- Ensure a groundwater monitoring bore network and program are established to suitably monitor the hydrostratigraphic units associated with the Mellaluka Springs Complex, located southeast of the MLs
- Ensure a suitable groundwater monitoring bore network and program are established so that representative groundwater monitoring data can be collected to facilitate refinement of the potential impact predictions on groundwater levels within hydrostratigraphic units of the Great Artesian Basin (GAB), inclusive of the Clematis Sandstone and Dunda Beds units
- Ensure compilation of groundwater level data to refine current estimations, using the existing numerical groundwater model, of groundwater ingress into mine workings and assessment of potential surface water ingress to mine workings because of flood events
- Allow for a suitable groundwater monitoring bore network and program to monitor possible source aquifers with potential to be utilised for alternative water supplies relevant to any approval issued under the *Water Act 2000* for the CCP

- The GMMP must allow for monitoring of hydrostratigraphic units throughout all phases of the CCP mine life, inclusive of the period post-closure (refer to Appendix 1, Section 1, Attachment B: Rehabilitation Requirements of the Coordinator- General's Assessment Report [**Appendix A**])
- Ensure the identification of groundwater monitoring bores which may require replacement over time due to the proposed mining activities
- Ensure a suitable groundwater monitoring bore network and program to identify all potential impacts on groundwater from mine dewatering activities and mine water and waste storage facilities (artificial recharge) are established and allow for potential mitigation measures to be monitored.

In addition to these objectives, the GMMP includes groundwater quality monitoring objectives, which:

- Ensure a suitable groundwater monitoring bore network that:
  - allows for the collection of representative and repeatable groundwater quality data
  - facilitates the monitoring of potential groundwater quality impacts in all identified hydrostratigraphic units that may potentially be impacted by the approved mining activities.
- Ensure a suitable groundwater monitoring bore network to assess possible artificial recharge at mine water and waste storage facilities and evaluate any corrective actions (if required).

1.5 Groundwater Management and Monitoring Program – EA Approval Conditions

Preparation of the GMMP included consideration of the applicable groundwater-related EA Conditions (**Appendix A**). The groundwater-related EA Conditions include the following:

- Groundwater quality and water level monitoring to be performed by appropriately qualified person(s)
- The provision of groundwater management and monitoring records to facilitate the regular GMMP review, which is to include:
  - an assessment of the groundwater management and monitoring program against the objectives (**Section 1.4** and EA Condition E4 **Appendix A**)
  - a review of the adequacy of the groundwater monitoring locations, monitoring program frequencies, groundwater level thresholds (EA Condition Table E3 [**Section 5.3** of this GMMP] and the adopted groundwater quality triggers (EA Condition Tables E1 and E2 [**Appendix A**] [**Section 5.4** of this GMMP])
  - a review of the validity of the GMMP against the regular model predictions.
- The GMMP will facilitate the collection and compilation of accurate and representative groundwater monitoring data across all the identified geological units within and adjacent to the mine, which in conjunction with measured mine dewatering volumes, will be utilised to undertake regular reviews of the groundwater model
- The development of a suitable groundwater monitoring bore network and program to ensure the detection of potential impacts of the mine operations on groundwater quality
- The development of a suitable groundwater monitoring bore network capable of detecting:
  - groundwater level and pressure drawdown caused by the mining operation (and for comparison to the prediction in the numerical model)
  - the potential impacts of mine related groundwater alteration on State significant biodiversity values.
- Details of the groundwater monitoring program, approved by the administering authority, and groundwater quality and water level monitoring frequencies at the approved monitoring locations (**Appendix A**, EA Condition Table E1 [**Table 35** of this GMMP])

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- The compilation of baseline groundwater quality data, allowing for the (statistical) calculation of contaminant trigger levels (**Appendix A**, EA Conditions E8 and E9 Table E2)
- If groundwater quality monitoring results reach any of the trigger levels stated in EA Condition Table E2 – Groundwater quality trigger levels, an investigation must be undertaken to determine if the exceedance is because of:
  - authorised mining activities
  - natural variation or
  - neighbouring land use resulting in groundwater impacts.
- Propose groundwater level thresholds for detecting impacts on groundwater levels (**Appendix A**, EA Conditions E8 and E13 Table)
- If groundwater monitoring results reach any of the groundwater level thresholds stated in EA Conditions E8 and E13 Table E3 – Groundwater level thresholds, an investigation must be undertaken to determine if the fluctuations are as a result of:
  - authorised mining activities
  - pumping from licensed bores
  - seasonal variation or
  - neighbouring land use resulting in groundwater impacts.
- The provision of the groundwater monitoring data collected in compliance with the EA Conditions and submitted to the administering authority in the format and at the frequency specified by the administering authority
- Construct, maintain, and manage the groundwater monitoring bores in a manner that prevents or minimises impacts to the environment and ensures the integrity of the bores to obtain accurate groundwater monitoring results.

1.6 Groundwater Management and Monitoring Program – *EPBC Act* Approval Conditions

Preparation of the GMMP included consideration of EPBC 2010/5736 Conditions dated 14 October 2015, (**Appendix A**). Specifically, the GMMP-related Approval Conditions, which include:

a. Details of a groundwater monitoring network that includes:
   - control monitoring sites
   - sufficient bores to monitor potential impacts on the GAB aquifers (whether inside or outside the Project Area)
   - a rationale for the design of the monitoring network with respect to the nature of potential impacts and the location and occurrence of Matters of National Environmental Significance (MNES) (whether inside or outside the CCP mine lease) [**Section 3.8**].

b. Baseline monitoring data

c. Details of proposed trigger values for detecting impacts on groundwater levels and a description of how and when these values will be finalised and subsequently reviewed in accordance with state approvals

d. Details of groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex (GMMP **Section 5.3**), informed by groundwater modelling and corrective actions and/or mitigation measures to be taken if the triggers are exceeded where caused by mining operations, to ensure that groundwater drawdown as a result of the project does not exceed an interim drawdown threshold of 0.2 metres at the Doongmabulla Springs Complex:
   i. The Early warning triggers and Impact thresholds (GMMP **Section 5.3**) must be informed by groundwater modelling in accordance with Conditions 3e) i, 22, 23, and 24 and the relevant

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requirements of the environmental authority held under the *Environmental Protection Act (1994)* OLD (in particular requirements arising in response to the conditions at Appendix 1, Section 1, Schedule E of the Coordinator- General's Assessment Report)

ii. The interim drawdown threshold required under condition 3d) may be replaced with a new drawdown threshold, if the approval holder applies to the Minister for approval to change it, and submits further evidence supported by groundwater modelling and other scientific investigations (such as those required in conditions 25 and 27), that a new drawdown threshold will ensure the protection and long-term viability of the Doongmabulla Springs Complex.

e. Details of the timeframe for a regular review of the GMMP in accordance with the requirements of the environmental authority issued under the *Environmental Protection Act 1994* (Qld), and subsequent update of the GMMP, including how each of the outcomes of the following will be incorporated:

- independent review and update of the groundwater conceptual model, as well as the numerical groundwater model and water balance calculations as necessary, to incorporate monitoring data
- future baseline research required by the Queensland Coordinator-General into the Mellaluka Springs Complex (Appendix 1, Section 3, Condition 1 of the Coordinator-General's Assessment Report)
- the GAB Springs Research Plan (Conditions 25 and 26)
- the Rewan Formation Connectivity Research Plan (Conditions 27 and 28).

f. Provisions to make monitoring data available to the Department and Queensland Government authorities (if required) on a six-monthly basis for inclusion in any cumulative impact assessment, regional water balance model, bioregional assessment or relevant research required by the Bioregional Assessment of the Galilee Basin sub-region and the Lake Eyre Basin and any subsequent iterations

g. Provisions to make monitoring results publicly available on the approval holder's website for the life of the project

h. A peer review by a suitably qualified independent expert and a table of changes made in response to the peer review.

1.7 Groundwater Management and Monitoring Program – Additional Approval Conditions

In addition, to further achieve compliance with the stated, recommended, and imposed EA conditions (**Appendix A**), this GMMP was developed to assist with the following:

- Development of a Groundwater Dependent Ecosystems Management Plan (GDEMP), to manage potentially affected GDEs, to include the monitoring of groundwater level fluctuations in proximity to GDEs
- Identification of groundwater level thresholds, ensuring the capture of groundwater level monitoring data across and adjacent to the mine site to allow for the comparison to groundwater level thresholds, assessment of mine dewatering impacts on groundwater dependent ecosystems (GDEs) and implementation of corrective measures for each GDE and/or the provision of offsets
- Provision of groundwater quality data for inclusion in the Subsidence Management Plan and allow for monitoring of potential impacts on groundwater due to longwall mining-induced subsidence
- Provision of site specific data for inclusion in the Rewan Formation Connectivity Research Plan (RFCRP) and GAB Spring Research Plan
- Monitor and evaluate potential for groundwater take from the GAB to ensure compliance with the CCP Associated Water Licence (ref. 617264, dated 29 March 2017 [**Appendix A**])

- Collection of data that identifies natural groundwater level trends, as per EA Conditions E3 and E4 (**Appendix A**), which will facilitate the assessment of groundwater level impacts on authorised groundwater users (land holders) and the compilation of a report to each potentially unduly affected authorised groundwater user and the administering authority
- Development of groundwater quality objectives and model water conditions for coal mines and coal seam gas projects in the Galilee Basin and any other related decisions the administering authority under the *Environmental Protection Act 1994* may be required to make in relation to cumulative impacts on water quality
- Development of an ongoing regional groundwater monitoring and assessment program with reference to existing water users and maintenance of environmental values
- The GMMP will assist in addressing imposed conditions, under section 54B of the *State Development and Public Works Organisation Act 1971* (SDWPO Act), which includes:
  - a groundwater and surface water monitoring and reporting program that takes into account requirements of any regional groundwater and surface water monitoring and assessment program developed in accordance with Recommendation 3, Appendix 1, Section 2, Part B (CG's Report)
  - provision of the monitoring results in the format and at intervals specified in the protocol for co-ordination of regional groundwater and surface water monitoring data to the lead agency for the surface water monitoring and assessment program (Recommendation 3, Appendix 1, Section 2 (CG’s Report))
  - a contribution to the on-going operation of the regional groundwater and surface water monitoring and assessment program in Recommendation 3, Appendix 1, Section 2, Part B (CG’s Report).

1.8 Considerations included in the GMMP

Consideration of discussions with the administering authority, during the compilation of the EA Conditions, was given such that the GMMP allows for:

- Identification of potential groundwater impacts from the approved mining activities with sufficient time to implement management (i.e. make-good agreements) and/or mitigation measures
- Detection of long-term groundwater trends and potential cumulative effects from the mine and other future coal mining operations in the eastern Galilee Basin
- Recording of dewatering volume(s) data to assist in numerical/ predictive modelling revisions and water balance assessments
- Assistance in assessment of source aquifers which could be utilised for alternative water supplies
- Ensuring the capture of groundwater level data across and adjacent to the mine site to compile pre-mining groundwater flow patterns (including the groundwater “low” located to the north of Carmichael River)
- Assisting in the assessment of geological structures and their influence on groundwater flow patterns and mine dewatering predictions
- Monitoring of hydrostatic pressures in artesian bores to assess possible mine dewatering impacts.

1.8.1 EPBC Recommendations Included in Compilation of the GMMP

- Federal approval conditions regarding the CCP (EPBC 2010/5736) include requirements for an independent peer review, revision, and re-run of the numerical groundwater model (Carmichael Coal Project Groundwater Flow Model Independent Review (RE: Approval Conditions 22 and 23). These requirements have been completed and resulted in several recommendations

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- Recommendations because of the independent peer review and revised numerical groundwater model reports, relevant to the groundwater monitoring program and network, were considered for the GMMP. The relevant recommendations include the following:
  - separate the D-seam from the underlying Joe Joe Group basement (as included in the conceptualisation, based on site-specific data, in **Section 2.2** of this GMMP)
  - investigate aquifer connectivity at Mellaluka Springs via data from monitoring bores in the area
  - application of recent groundwater monitoring data for the model validation process and to investigate episodic recharge processes
  - assess Rewan Formation aquitard parameters.

The recommendations of the groundwater model re-run and groundwater water model peer review will be addressed in the first groundwater model refinement to be conducted after two years as per EA conditions.

It is noted that, in line with these recommendations, the GMMP includes information from the preliminary assessment of the Mellaluka Springs, using geological and groundwater data compiled post-EIS and SEIS. The ongoing compilation and assessment of data will be used in future refinement of the groundwater modelling (refinement of conceptualisation) and iterations of the GMMP.

1.8.2 Carmichael Coal Project Response to Federal Approval Conditions – Groundwater Flow Model (GHD, 2015)

GHD conducted the required modelling revisions and re-run and considered that while the groundwater model is considered appropriate for the current stage of the project, the model should be updated in the future as the hydrogeological understanding of the Project and surrounding area continues to evolve.

GHD compiled recommendations as a guide for future investigations and modelling studies. These include:

- Update calibration targets based upon subsequent groundwater level data collected over the model domain, particularly within the GAB units to the west of the mine
- Re-calibrate the model, inclusive of transient calibration, with operational and regional monitoring data
- Incorporation of the weathered zone into the model
- Review of recharge parameters, particularly in the GAB units.

1.8.3 GMMP Considerations

This GMMP allows for the collection of transient groundwater level data across the current groundwater model domain, both spatially and with depth. These data will allow for the re-calibration and revised predictions of the current groundwater model.

Additional geological information will be available, from the detailed geological data collected during drilling and construction of monitoring bores on and adjacent to the mine lease since the model was constructed, for the next model refinement event.

The new bores (post-EIS) have allowed for the preliminary evaluation of geology and groundwater resources in the Doongmabulla and Mellaluka Springs areas. Additional data collection and assessment will be used to validate the existing conceptualisation, and will be used in future refinement of the predictive groundwater model. The refined groundwater model will aid in assessing and updating the GMMP. This approach is in line with the approval conditions, which include:

- The GMMP must be reviewed by an appropriately qualified person at least every 5 years with a report provided on the outcome of the review to the administering authority by 2nd February 2021 and then no later than 1 July every 5 years following (EA Condition E5)
- The EPBC Act approval conditions for regular reviews of the GMMP and subsequent updates to the GMMP.

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Groundwater and geological data collected and compiled under the GMMP and other groundwater related data collected for GDEs under the GDEMP and other research plans will be considered and included in future iterations of the GMMP, where appropriate. A Flow Chart **(Figure 3)**has been compiled indicating the interaction between the research plans and the GMMP.

The interaction flow chart **(Figure 3)** represents the implementation of the adaptive framework approach. The GMMP's primary function is the collecting of groundwater data through monitoring and updating impact predictions based on periodical model reviews. Any new information that has been collected via the research plans will assist in updating and refining the predictive groundwater model, allowing for addressing model uncertainties. These data will also be used to update the GMMP, including revising the monitoring regime, update the triggers, and formulating optimum mitigation measures. This will ultimately result in better management of GDEs that exist within the mining impacted zone.

It is also to be noted that the other management plans required under approval conditions such as the GDEMP, Rewan Formation Research Plan, and the GAB Spring Research Plan will also be informed from the results of the groundwater modelling, concepts and predictions as presented in the GMMP and also from any updates made to GMMP in future revisions

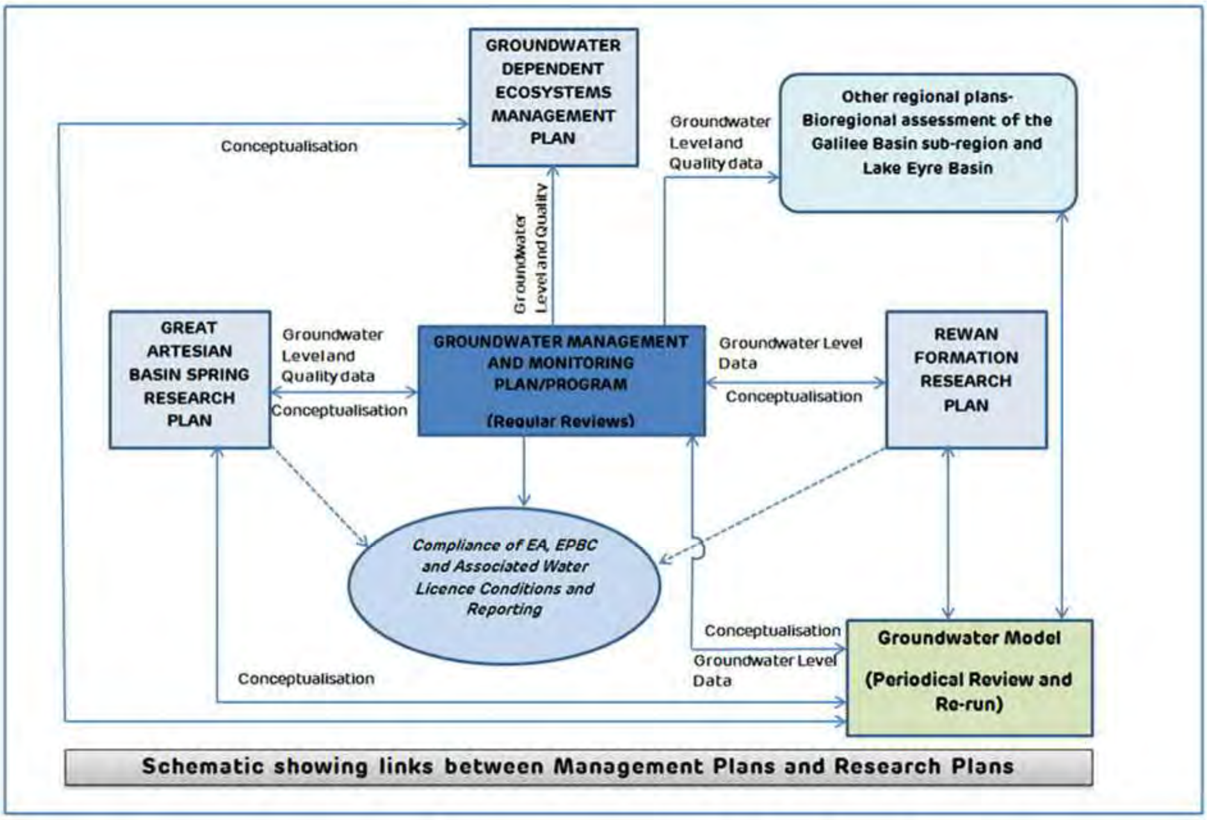

Figure 3 Interaction flow chart between Management Plans and Research Plans

Adani are required to develop and implement a number of other management plans to address the full requirements of approval conditions under both Commonwealth and Queensland legislation (**Table 2**). There will be some interaction among the plans during all phases of the Project, with respect to key linkages across research program outcomes, modelling updates and management plan review, update and reporting (**Table 3**).

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Table 2 Description of other management plans and linkages with this GMMP

Management Plan	Description	Link to legislation or approval	Link with GMMMP
Groundwater Dependent Ecosystem Management Plan (GDEMP)	To detail the management of threats to defined environmental values and to report results and corrective actions for each GDE over the full period of mining activities and for a period of five years post mining rehabilitation.	EPBC Approval Conditions 5-6 EA Approval Condition I11- I14	Informs ecological triggers, monitoring and management through adaptive processes
Great Artesian Basin Springs Research Plan (GABSRP)	Investigates, identifies and evaluates methods to prevent, mitigate and remediate ecological impacts on the Doongmabulla Springs-complex	EPBC Approval Conditions 25-26	Informs ecological triggers, monitoring and management through adaptive processes
Receiving Environment Monitoring Program (REMP)	Monitors, identifies and describes adverse impacts to surface water environmental values, quality and flows associated with authorised mining activities	EA Approval Condition F23	Mine approved discharges are to the Carmichael River, a GDE under this plan
Rewan Formation Connectivity Research Plan (RFCRP)	Characterises the Rewan Formation within the area impacted by the mine	EPBC Approval Conditions 27-28	Informs groundwater triggers, monitoring and management through adaptive processes such as the GMMP
Biodiversity Offset Strategy (BOS) GAB Offset Strategy Offset Area Management Plans (OAMPs)	Describes required offsets for unavoidable residual impacts to MNES Describes required offsets for indirect impact to Great Artesian Basin (GAB) aquifers Describes specific management actions for properties to be used as offsets under the BOS	EPBC Approval Conditions 8-13 EA Approval Condition I1	The BOS outlines offset requirements for MNES including relevant GDEs The GAB Offset Strategy addresses indirect impacts to GAB aquifers The OAMP includes management of GDE offset areas
MNES management plans (other than GDEs)	Specific management plans for MNES listed in the EPBC Approval	EPBC Approval Conditions 5-7	Ensure consistent monitoring, mitigation and management measures for common threats and impacts
Project Management Plans	Plans to be used for day to day management of generic project matters including:	Not linked to specific conditions	Specific measures from relevant project management plans have been incorporated into

Management Plan	Description	Link to legislation or approval	Link with GMMMP
	• Sediment and erosion and control management plan • Pest management plan • Water quality management plan • Dust management plan • Waste management plan • Fire management plan • Rehabilitation management plan		this GDEMP to ensure consistency across areas of commonality

This GMMP has been developed to ensure consistency with the latest groundwater impact predictions as required under Condition 23 of EPBC Act Approval (groundwater flow model revisions, including revision to the GAB conceptualisation). The GMMP will facilitate the detection of any mining related impacts to groundwater (i.e., impacts from establishment and operation of the mine). Triggers from the GMMP, which are related to groundwater dependent ecosystems will be included in GDEMP.

Outcomes of implementing this GMMP will inform GDEMP, Rewan formation connectivity Research Plan and GAB Springs Research Plan with the aim of supporting research and analysing the effectiveness of mitigation actions. Conversely, research outcomes will directly inform monitoring, management, prevention mitigation and remediation measures presented in this GMMP

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Table 3 Reporting requirements of other management plans with linkages to this GMMP

Management Plan	Description	Internal Review Frequency	External Review Frequency	Reporting Frequency	Linkage to GMMP and triggers/corrective actions
Groundwater Dependent Ecosystem Management Plan (GDEMP)EPBC Approval Condition 5-6 EA Approval Conditions I11-I14	The GDEMP identifies monitoring, management and mitigation with respect to approved impacts to MNES The GDEMP includes details of for monitoring GAB aquifers, GDEs (Springs, Carmichael River and Waxy Cabbage Palms) during all phases of the project including baseline, operations, and post-closure.	In compliance with EA approval conditions (EA Condition I11-14 (Appendix A)),	EA Annual Compliance Report to be prepared by Third Party.	Annual – EPBC Compliance Reporting – Condition 31 Annual - EA Compliance Reporting – Condition A13	The GDEMP provides a framework for the management of groundwater impacts, including defining trigger levels, and MNESMPs for other threatened species and ecological communities. Relevant triggers from the GMMP (those that are related to groundwater dependent ecosystems) will be included in GDEMP.
Receiving Environment Monitoring Program (REMP) EA Approval Conditions F23 to F25	The aim of the REMP is to monitor, identify and describe and provide early warning indicators for any adverse impacts to surface water environmental values, quality and flows due to the authorised mining activity. For the purposes of the REMP, the receiving environment is the waters of the Carmichael River and connected or	Annual monitoring and findings report to be prepared and provided.		Annual - EA Compliance Reporting – Condition A13 Annual implementation report - EA condition F25	Surface water monitoring results will be used in relation to monitoring and management for the Carmichael River GDE, within the context of approved mine discharges to the River.

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Management Plan	Description	Internal Review Frequency	External Review Frequency	Reporting Frequency	Linkage to GMMP and triggers/corrective actions
	surrounding waterways within 12 km downstream from the release point. This includes the Belyando River, which is immediately downstream of the confluence with the Carmichael River.				
GAB Springs Research Plan (GABSRP) EPBC Approval Condition 25	The GABSRP investigates, identifies and evaluates methods to prevent, mitigate and remediate ecological impacts on the EPBC Act listed community of native species dependent on natural discharge of groundwater from the Great Artesian Basin, including the Doongmabulla Springs-complex, in the Galilee Basin.	Annually and as directed through the outcomes of discrete research packages. *Note: this plan requires separate approval and hence review frequency will be determined and approved through that mechanism.*		Annual – EPBC Compliance Reporting – Condition 31 Annual Implementation Report	The GABSRP informs ecological triggers, monitoring and management through adaptive processes. Both the GMMP and GDEMP will define groundwater and (related) ecological trigger levels and management and mitigation measures, which will inform research programs undertaken under the GAB. GMMP will provide information to the GAB Springs Research Plan with the aim of supporting research and analysing the effectiveness of mitigation actions. Research outcomes will directly inform monitoring, management, prevention mitigation and remediation. Both the baseline springs survey and the specific species study (part of the GABSRP), will be undertaken as specified in this GMMP.

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Management Plan	Description	Internal Review Frequency	External Review Frequency	Reporting Frequency	Linkage to GMMP and triggers/corrective actions
Rewan Formation Connectivity Research Plan (RFCRP) EPBC Approval Conditions 27 and 28	The RFCRP characterises the Rewan Formation within the area impacted by the mine. The Rewan Formation has been identified as an area where further information needs to be collected and additional studies need to be conducted to negate uncertainties, especially with effect of faulting and potential subsidence induced	Within 1 year of approval of the RFCRP Adani will provide a report on research outcomes, *Note: this plan requires separate approval and hence review frequency will be determined and approved through that mechanism.*		Annual – EPBC Compliance Reporting – Condition 31	The RFCRP informs groundwater triggers, monitoring and management through adaptive processes as described in the GMMP. Details have been included in the GMMP regarding how the Rewan Formation monitoring allows for: 1). The development of early warning monitoring points (with regards to potential impacts on the GAB units); 2). The establishment of groundwater level threshold levels (which if reached instigate investigation into the cause of potential environmental harm); 3). The interaction of the Rewan Research Plan (groundwater component) with the GAB Spring Research Plan, offset, subsidence, and GDEMP; and 4). Links to the Geoscience Australia regional Galilee Basin numerical groundwater model

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1.9 Compliance with Approval Conditions – Groundwater

A summary of the groundwater approval condition requirements and cross-reference to the location of the details within the GMMP is presented in **Table 4** below. The table aims to ensure Adani's GMMP is compliant with all the state government and EPBC Act groundwater-related approval conditions.

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Table 4 Conditions for Approval – Reference Table

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
1	A5	Monitoring records or reports must be kept for a period of no less than 5 years.	Section 1.5 Section 4.6 Section 4.8	The compilation of groundwater monitoring reports will provide validation of environmental protection performance; long term trends will be established using historic datasets and used for comparison to assess potential impacts.
1	E1	The EA holder must not release contaminants to groundwater.	Section 1.13 Section 4.0 Section 5.0	The GMMP aims at assessing groundwater quality overtime and validating management / mitigation measures employed to ensure contaminants are not released offsite within the groundwater.
1	E2	All determination of groundwater quality, groundwater monitoring and biological monitoring must be performed by appropriately qualified person/s.	Section 7.0 Appendix A (AECOM Letter)	Adani employs specialist groundwater monitoring contractors and consultants to develop and maintain their groundwater monitoring network including the collection of representative groundwater monitoring data.
1	E3	A baseline groundwater monitoring program must be developed and certified by an appropriate qualified person and implemented by the EA holder no later than the 2nd June 2016.	Appendix A(AECOM Letter)	AECOM (formerly URS Australia Pty Ltd) provided a review and assessment of the baseline groundwater monitoring, including confirmation of implementation prior to 2 June 2016. Included in **Appendix A**.
		The baseline groundwater monitoring program must result in the holder of this EA finalising a groundwater dataset that must be provided to the administering authority at least 30 days prior to commencing any mining activities associated with box cut excavation.	Section 1.3 Section 1.13 Section 3.1 Appendix C Appendix D Appendix E	This GMMP includes the baseline groundwater data, compiled to meet the criteria under EA Condition E3, prior to any mining activities associated with box cut excavation.

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		The groundwater dataset must: Contain representative groundwater quality samples from the geological units identified as potentially affected by mining activities including Quaternary age alluvium, Tertiary sediments, Bandanna Formation, Colinlea Sandstone, Clematis Sandstone, Rewan Formation, Dunda Beds, and Early Permian sediments.	Section 3.0 Appendix D	Representative baseline groundwater data has been compiled for all the units included in the EA condition, E3.
		The groundwater dataset must: Include at least 12 sampling events that are no more than 2 months apart over a 2-year period, to determine background quality.	Section 3.1 Appendix D Section 5.4	Baseline data, included in the GMMP, consists of data that has been compiled since the EIS / SEIS phase from 2011-2014, data obtained from baseline monitoring carried out from 2014-2016 as per EA Condition E3, and data obtained from further monitoring carried out until April 2017. All the available data from September 2011 through April 2017 has been compiled to form the 'final' baseline monitoring dataset.
		The groundwater dataset must: Include background groundwater quality in hydraulically isolated background bore(s).	Section 3.1 Figure 19 Table 23 Section 5.4 Appendix B Appendix D	Baseline data, included in the GMMP, consists of data that has been compiled since the EIS / SEIS phase from 2011-2014, data obtained from baseline monitoring carried out from 2014-2016 as per EA Condition E3, and data obtained from further monitoring carried out until 2017. All the available data from September 2011 through April 2017 has been compiled to form the 'final' baseline monitoring dataset. Maps included in **Appendix B** indicate the baseline groundwater monitoring bore network to collect background water quality, as no mining has occurred on or adjacent to the CCP. All bores are constructed according to the applicable standards and currently (pre-mining) provide representative ambient groundwater monitoring data for all hydrostratigraphic units included in EA Condition E3.

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		The groundwater dataset must: Allow for the identification of natural groundwater level trends and groundwater contaminant trigger levels.	Section 3.1 Figure 19 Table 23 Section 5.0 Section 5.3 Section 5.4 Appendix C and E Appendix D	Groundwater levels have been compiled from manual water level measurements, automated water level loggers. These datasets have been assessed to determine natural fluctuation and seasonal trends. Groundwater quality trigger levels have been determined and included in the GMMP (as per EA Condition E9 Table E2).
1	E4	A Groundwater Management and Monitoring Program must be developed and certified by an appropriately qualified person which addresses all phases of mining operation approved under this EA.	Section 1.1 Appendix F Appendix G	Mark Stewart, Technical Director – Groundwater at AECOM, has compiled the GMMP. The GMMP has been reviewed and revised after a review by John Bradley of JBT Consulting. Both are appropriately qualified persons (hydrogeologists). The GMMP includes for the baseline, construction, operational, and post-closure phases of mining.
		The GMMP must be provided to the administering authority for approval with the baseline monitoring program in condition E3.	This document	Data and details required for the baseline monitoring program, as detailed above, is included in this draft GMMP for approval.
		GMMP objectives: Validation of groundwater numerical model to refine and confirm accuracy of groundwater impacts predicted.	Section 1.2 Section 1.4 Section 1.8.3 Section 1.10.1 Section 2.4 Section 2.7.4 Section 4.7.1 Section 5.3.5.3 Section 6.2	Using adaptive management, as new groundwater quality and quantity knowledge is generated, models will be updated and water management decisions adapted accordingly; the compilation of groundwater monitoring data to allow for the validation and refinement of the groundwater numerical model (including boundary and recharge conditions) and assess accuracy of predicted groundwater impacts; the GMMP also allows for the recording of dewatering volume(s) data to assist in the modelling revisions. The numerical model re-run works and subsequent changes to the predicted impacts on groundwater have been included.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		GMMP objectives: Groundwater level monitoring in all identified geological units present across and adjacent to the mine site to confirm existing groundwater flow patterns and monitor drawdown impacts.	Section 1.4 Section 1.5 Section 1.7 Section 1.8 Section 0 Section 2.2.3 Section 2.2.5 Section 2.2.8 Section 2.2.10 Section 2.3.6 Section 5.2 Section 5.3.3.1 Section 5.3.5 Appendix C	Representative baseline groundwater data has been compiled for all the units included in the EA condition, E3. Groundwater contours are included in **Appendix C**. Conceptualisation of groundwater flow is included in **Section 2.2**.
		GMMP objectives: Identification of groundwater drawdown level thresholds for monitoring the impacts to GDEs (including spring complexes and Carmichael River alluvium).	Section 1.4 Section 1.6 Section 0 Section 1.13 Section 2.2.5 Section 2.2.6 Section 2.3.3 Section 2.3.6 Section 2.7.2 Section 2.7.4 Section 3.4 Section 5.3	Groundwater drawdown predictions, from the predictive model, were used to develop groundwater level thresholds in locations included in EA Table E3 to assess model predictions, evaluate drawdown impacts, instigate investigations, and implement mitigation measures (as required). Details of the GDE monitoring bores are included in **Table 57**.

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
			Section 5.6 Section 6.2	
		GMMP objectives: Monitoring of aquifers in the area to the south of the mining lease that may affect the Mellaluka springs.	Section 1.4 Section 1.8.1 Section 1.8.3 Section 2.1.3 Section 2.2.5.8 Section 2.2.6.3 Section 2.7.4.2 Section 5.3 Section 5.3.4 Section 5.4 Section 5.5 Section 7.1.1	Details of the GDE monitoring bores are included in **Table 57**, including units intersected in the Mellaluka Springs area.
		GMMP objectives: Identify and refine potential impacts on groundwater levels in the GAB Clematis Sandstone and Dunda Beds geological units.	Section 1.4 Section 1.7 Section 0 Section 2.1.3 Section 2.7 Section 2.2.10.1 Section 3.0 Section 5.3 Section 6.2	Groundwater drawdown predictions, from the predictive modelling, were used to develop groundwater level thresholds to monitor potential impacts in the GAB Clematis Sandstone and Dunda Beds geological units. GAB monitoring bores are presented in **Table 23**.

Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		GMMP objectives: Estimation of groundwater inflow to mine workings and surface water ingress to groundwater from flooding events using the groundwater model.	Section 1.4 Section 1.10.1 Section 2.2.7 Section 2.2.7.1 Section 2.3.6	Model refinement will occur using groundwater monitoring data compiled using the monitoring program included in the GMMP. The numerical groundwater model will be reviewed, using the GMMP data plus measured mine dewatering volumes, within two (2) years of the box cut excavation, and then at least every 5 years afterwards. In addition to measured mine dewatering volumes, other methods may be utilised (inclusive but not limited to): compilation of rainfall and evaporation data, records of water extracted from the pit, and estimates of catchment (runoff) capture, and conditions included in AWL (**Appendix A**) for the CCP. These data will aid with the water balance model, where the compilation of groundwater level data from units above and below the target coal seams will facilitate the revision of model water budgets and allow for the estimates of groundwater ingress from surrounding units. Surface water – groundwater interaction is included in the model and will be refined overtime, based on groundwater and surface water monitoring data.
		GMMP objectives: Monitoring in any identified source aquifers for alternative water supplies, relevant to any approval issued under the *Water Act 2000* for the project.	Section 1.4 Section 1.8 Section 2.1.3 Section 3.5.3 Section 4.5 Section 6.2	All geological units identified as potentially affected by mining activities including Quaternary aged alluvium, Tertiary sediments, Bandanna Formation, Colinlea Sandstone, Clematis Sandstone, Rewan Formation, Dunda Beds, and Early Permian sediments, are included in the GMMP. Additional bores are planned to facilitate the model refinement and to better assess the sub-E sediments. These bores will provide information regarding the groundwater potential within the sub-E coal seam sediments, which could be used as Make-Good groundwater supplies.
		GMMP objectives: Monitoring of geological units throughout all phases of project life including for the period post-closure in accordance with EA Approval Conditions Appendix 1.	Section 5.0 Section 6.1 Section 6.2 Section 6.3	Monitoring recommendations and commitments have been compiled for all phases of mine life, including baseline, construction, operations, and post-closure (inclusive of project stage 1 and project stage 2, as per Appendix 1 of the EA conditions).

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		GMMP objectives: Identifying monitoring bores that will be replaced due to mining activities.	Section 3.5 Section 6.1 Section 6.2 Table 55	The GMMP includes the commitment to augment and alter the groundwater monitoring bore network in line with the mine plan and activities. Bores identified in the GMMP for Operational Phase are based on the first five years of mining, after the review and refinement of modelling at this approval condition timeframe, the Operational Monitoring network will be revised (if required). It is noted that not all bores lost during mining will be replaced based on the nature of the open cut and underground mining. Alternative monitoring bores, within the same target geological units, will be included based on the objectives of the GMMP.
		GMMP objectives: To ensure all potential groundwater impacts from mine dewatering and mine water and waste storage facilities are identified, mitigated and monitored.	Section 1.13 Section 2.2.7 Section 2.7.9 Section 3.5 Section 5.4.1 Section 6.1 Section 6.2 Section 7.0	The GMMP allows for the compilation of sufficient, spatially and geological unit-wise, groundwater monitoring data to adequately assess potential impacts from mine-dewatering and mine water and waste storage facilities are identified, mitigated, and monitored.
1	E5	The GMMP must be reviewed by an appropriately qualified person at least every 5 years with a report provided on the outcome of the review to the administering authority by 2nd February 2021 and then no later than 1 July every 5 years following.	Section 1.5 Section 1.6 Section 1.8.3 Section 1.10.1 Section 2.3.6 Table 35 Section 4.7.2 Section 5.3.5.3 Section 7.0	The GMMP includes for a review of the current GMMP and future versions, every 5 years. The commitment includes the details of the review requirements included under EA condition E5.

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
			Appendix F Appendix G	
1	E6	Groundwater Model Review.	Section 1.8.3 Section 2.2.6.2 Section 2.2.6.4 Section 2.2.9	The GMMP includes a summary of the predictive model review and re-run, as per approval conditions. The compilation of groundwater monitoring data, under the GMMP, will allow for the validation and refinement of the groundwater numerical model (including boundary and recharge conditions) and assess accuracy of groundwater impacts predictions.
1	E7	Groundwater Model Review Report.	Appendix A	The Carmichael Coal Project numerical groundwater flow model developed by GHD (as described in **Section 2.3**) was independently peer reviewed by Hugh Middlemis. The report is attached in **Appendix A**. To be conducted in the future based on GMMP input.
1	E8	Based on monitoring data collected in Condition E3 the EA holder must provide the following: • A proposed groundwater monitoring network for detecting potential impacts of the mine operations on groundwater quality.	Section 3.8 Section 4.0 Section 5.0 Section 6.0	Details regarding groundwater monitoring locations and sampling frequency (EA Condition Table E1) and groundwater quality trigger levels (EA Condition Table E2) are included in baseline groundwater monitoring tables, presented in this GMMP.
		Based on monitoring data collected in Condition E3 the EA holder must provide the following: • A groundwater monitoring network for detecting if: - Drawdown caused by the mining operation may exceed predictions in the numerical model referred to in condition E6.	Section 5.3	Groundwater level thresholds have been developed for assessing excess drawdown (compared to model predictions) and impacts on MSES (and MNES), as detailed in EA Condition Table E3. The groundwater monitoring network for detecting if drawdown caused by the mining operation may exceed predictions and MNES may be impacted is included in **Table 46** and **Table 57**.

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		- Matters of State Environmental Significance may be impacted (Table E3).		
1	E9	Groundwater quality and level monitoring.	Section 3.0 Section 4.0 Appendix C Appendix D	Groundwater monitoring locations and frequency as required under EA Condition E9 has been developed and included in this GMMP. See GMMP **Table 46** which represents EA Condition E9 Table E1 providing monitoring bore details, location and elevation data.
1	E10 E11 E12	Groundwater quality trigger level investigation.	Section 1.5 Section 1.10 Section 1.12 Section 1.13 Section 4.7 Section 5.4 Section 6.0	The investigation and response processes to be adopted in case of trigger levels being exceeded are detailed in **Section 4.7.2** in compliance with EA conditions E10, E11, and E12.
1	E13 E14	Groundwater (water levels).	Section 1.5 Section 1.14.1 Section 3.4 Section 4.7 Section 5.3 Section 6.1 Section 6.2	The investigation and response processes to be adopted in case of groundwater thresholds being exceeded are detailed in GMMP **Section 4.7.2.2, Section 5.3.3.1,** and **Section 5.3.5.1** in compliance with EA conditions E13 and E14.
1	E15	Monitoring data submission.	Section 4.6.2 Section 4.8	Data reporting details are included in the GMMP in **Section 4.8**, which considers all State and Federal reporting / data requests, committed to be compiled and submitted annually.

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
1	E16	Bore construction, maintenance and decommissioning of groundwater bores.	Section 3.4.6 Section 7.0	**Section 3.5.1** and **Section 3.5.2** of this GMMP includes details of bore designs and drilling for bores to be constructed to augment the existing bore network. Adani is committed to maintaining and the decommission of bores, according to industry standards, to ensure the management of groundwater resources and obtaining representative groundwater monitoring data.
2	EPBC Act Condition 3a	Groundwater management and monitoring plan. At least three months prior to commencing excavation of the first box cut, the approval holder must submit to the Minister for approval a Groundwater Management and Monitoring Plan (GMMP).	This document	As per EA Condition E4 above, data and details required for the baseline monitoring program, as detailed above, is included in the GMMP for approval. The GMMP includes all requirements of the EPBC conditioned Groundwater Management and Monitoring Plan. It is noted that the EA Conditions refer to a Groundwater Management and Monitoring Program, which is considered to be the same as the EPBC Act approvals Groundwater Management and Monitoring Plan. The abbreviation GMMP throughout the document is considered to adhere to both approval requirements.
		The GMMP must contain the following: *Control monitoring sites.*	Section 1.6 Section 0 Section 1.14.1 Section 3.1.3 Table 22 Section 5.3 Section 5.5 Table 56	Control monitoring points have been located (within and adjacent to the mine lease) and constructed as hydraulically isolated background bores to obtain representative groundwater data within each hydrostratigraphic unit that could be impacted by the proposed mining activities. The selected control monitoring bores are included in **Section 5.4.4** are located in areas which allow these bores to be utilised during all phases of the mine allowing for monitoring and comparison to the proposed quality triggers and groundwater level thresholds (it is noted that these bores were included in the bores utilised to develop the thresholds and quality triggers).

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		The GMMP must contain the following: *Sufficient bores to monitor potential impacts on the GAB aquifers (whether inside or outside the Project Area).*	Section 1.4 Section 1.6 Section 0 Section 1.12 Section 2.0 Section 3.1 Table 22 Section 3.5 Section 3.7 Section 5.3 Section 5.6 Section 6.2	Groundwater monitoring bores are located adjacent (to the west) of the CCP within the GAB aquifers to allow for the assessment of potential induced drawdown impacts on GAB aquifers. Bores identified in EA Condition E9 (groundwater quality monitoring within hydrostratigraphic units including the GAB aquifers) and EA Condition E13 (groundwater level thresholds in GAB units to the west of mine lease) address both approval requirements. Groundwater drawdown predictions, from the predictive modelling, were used to develop groundwater level thresholds to monitor potential impacts in the GAB Clematis Sandstone and Dunda Beds geological units. GAB monitoring bores are presented in **Table 23**.
		The GMMP must contain the following: *A rationale for the design of the monitoring network with respect to the nature of potential impacts and the location and occurrence of MNES (whether inside or outside the Project Area).*	Section 1.6 Section 1.12 Section 3.7 Section 5.0 Table 22 Table 33 Table 56	This document provides the details of the existing baseline groundwater monitoring program and rationale for the design and implementation for groundwater monitoring, for all approved phases of mining operations, in line with the EPBC approval condition requirements. Groundwater monitoring bores are located adjacent to the Carmichael River, spring complexes, and within the GAB aquifers to allow for the assessment of potential impacts on groundwater related MNES.
2	3b	The GMMP must contain the following: *Baseline monitoring data.*	Section 1.3 Section 1.6 Section 1.10 Section 3.1 Table 23 Section 3.7	Baseline groundwater monitoring data for all groundwater monitoring events, between the EIS studies in 2011 and April 2017 are included in the GMMP.

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
			Table 35 Section 4.4.3.1 Section 4.6.1 Section 5.0 Table 46 Section 6.0 Appendix B Appendix C Appendix D Appendix E	
2	3c	The GMMP must contain the following: *Details of proposed trigger values for detecting impacts on groundwater levels and a description of how and when they will be finalised and subsequently reviewed in accordance with state approvals.*	Section 5.3 Section 5.3.5 Section 5.3.5.3	Groundwater trigger values are referred to as groundwater level thresholds in the GMMP (noting that State approval conditions refer to triggers for water quality). These are discussed in compliance with State approvals in the GMMP, see EA Condition E13. **Section 5.3** includes details of how the proposed groundwater level thresholds were derived and have been submitted to DES for approval / comment.
2	3d	The GMMP must contain: *Details of groundwater level early warning triggers and impact thresholds for the Doongmabulla Springs Complex, informed by groundwater modelling and corrective actions and/or mitigation measures to be taken if the triggers are exceeded where caused by mining operations, to ensure that groundwater drawdown as a result of the project does not exceed an interim threshold of 0.2 meters at the Doongmabulla Springs Complex.*	Section 5.3 Section 5.3.5 Section 5.3.5.1	Groundwater level thresholds have been derived based on predictive modelling and an assessment of natural fluctuation, this approach has been compiled for the GAB units underlying the Doongmabulla Springs Complex. Selected bores between the MLs and the springs have low (Early warning triggers) and high (Impact thresholds) groundwater level drawdown thresholds as agreed with State regulators to meet the AWL conditions. **Section 5.3** includes details of how the proposed drawdown thresholds were derived, including Early warning triggers and Impact thresholds for the GAB units.

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		i. *The early warning triggers and impact thresholds must be informed by groundwater modelling in accordance with Conditions3e)I, 22, 23, and 24 and the relevant requirements of the environmental authority held under the Environmental Protection Act (1994) Qld (in particular requirements arising in response to the conditions at Appendix 1, Section 1, Schedule E of the Coordinator-General's Assessment Report)* ii. *The interim drawdown threshold required under condition 3d) may be replaced with a new drawdown threshold, if the approval holder applies to the Minister for approval to change it, and submits further evidence supported by further groundwater modelling and other scientific investigations (such as those required in conditions 25 and 27), that a new drawdown thresholds will ensure the protection and long-term viability of the Doongmabulla Springs Complex.*		
	3e	The GMMP must contain the following: *Details of the timeframe for a regular review of the GMMP in accordance with the requirements of the EA.*	Section 1.5 Section 1.6 Section 1.8.3 Section 1.10.1	GMMP is a document which will aim at continual improvement subject to refinement based on adaptive management, **Section 1.10.1** includes details of the GMMP review, intervals and details.

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
			Section 2.3.6 Table 35 Section 4.7.2 Section 5.3.5.3 Section 7.0 Appendix F Appendix G	
		In subsequent updates of the GMMP, how each of the outcomes of the following will be incorporated: *Independent review and update of the groundwater conceptual model, as well as the numerical groundwater model and water balance calculations.*	Section 1.8.1 Section 1.10 Section 1.11 Section 2.2.9 Section 2.3 Section 2.4 Section 7.0	**Section 1.10.1** includes details of the GMMP review process including these requirements. Details regarding the independent peer review and revision of the numerical groundwater model are included in **Section 1.8.1.**
		In subsequent updates of the GMMP, how each of the outcomes of the following will be incorporated: *Future baseline research required by the Queensland Coordinator-General into the Mellaluka Springs Complex.*	Section 1.4 Section 1.8.1 Section 1.8.3 Section 2.1.3 Section 2.2.5.8 Figure 3 Section 2.2.6.3 Section 2.7.4.2 Table 33 Section 5.3.4 Section 7.1.1	Details regarding how the GMMP data compilation and assessment will aid with the various research programs are included. Extensive drilling and groundwater data collection, conducted during 2014 and 2015, around the Mellaluka Springs are included in the GMMP. Drilling and aquifer assessments post model construction have, as included in **Section 2.2.6.3**, resulted in a more detailed conceptualisation, which will be included in future model refinement.

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
		In subsequent updates of the GMMP, how each of the outcomes of the following will be incorporated: *The GAB Springs Research Plan.*	Section 1.7 Section 1.8.3 Figure 3 Section 1.10.2 Section 2.0 Section 2.2 Section 2.2.6 Section 2.3 Section 7.1.1	Details regarding how the GMMP data compilation and assessment will aid with the various research programs are included. Extensive drilling and groundwater data collection, conducted during 2014, 2015, and 2018 to the west of the CCP mine lease. Re-run of the model (**Section 2.3**) in line with approval conditions, allowed for the further assessment of potential impacts on the GAB springs because of approved mining.
		In subsequent updates of the GMMP, how each of the outcomes of the following will be incorporated: *The Rewan Formation Connectivity Research Plan.*	Section 1.7 Section 1.8.3 Figure 3 Section 1.10.2 Section 2.0 Section 2.2 Section 2.2.9 Section 7.1.1	Details regarding how the GMMP data compilation and assessment will aid with the various research programs are included. Extensive drilling, core sample analysis, and groundwater data collection, conducted during 2014 and 2015, to the west of the CCP mine lease.
2	3f	Provisions to make monitoring data available to the Department and Queensland Government authorities (if requested) on a six-monthly basis for inclusion in any cumulative impact assessment, regional water balance model, bioregional assessment of relevant research required by the Bioregional Assessment.	Section 1.6 Section 4.6.2 Section 4.8 Section 7.0	Adani has committed to providing groundwater monitoring data on a regular basis to the administering authorities. **Section 4.8** provides details of the groundwater monitoring data dissemination and frequency.

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Ref	Condition	Condition Requirement	Plan Reference	Demonstration / Commitments Plan Addresses Requirements
2	3g	Provisions to make monitoring results publicly available on the approval holder's website for the life of the project.	Section 4.6.2 Section 4.8	Adani will make the groundwater data, collected throughout the monitoring life, available for the public through posting data on a webpage dedicated to sharing monitoring information in its website.
2	3h	A peer review by a suitably qualified independent expert approved by the Minister in writing, and a table of changes made in response to the peer review.	Section 1.11 Section 2.3.5 Section 2.4 Appendix F Appendix G	**Section 1.11** includes the details of the independent peer review process, **Appendix F** includes the review details and **Appendix G** includes the table of changes.
2	4	The approval holder must not commence excavation of the first box cut until the GMMP has been approved by the Minister in writing. The approved GMMP must be implemented.	n/a	This draft GMMP document will be submitted for approval. The GMMP is a combined document prepared to address both state government and EPBC Act approval conditions.

NOTE:
Section 1.5 (EA Approvals), **Section 1.6** (EPBC Act Approvals), and **Section 1.7** (additional approval conditions) include details of how the GMMP will aid in addressing the various groundwater related conditions and achieve compliance with stated, recommended and imposed approval conditions.

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Table 2 References:

- Approval Carmichael Coal Mine and Rail Infrastructure Project, Queensland (EPBC 2010/5736), dated 10 October 2015
- Environmental Authority EPML01470513 – Carmichael Coal Mine dated 5 June 2017
- Department of Natural Resources and Mines (now DNRME) Associated Water Licence Reference 617264, dated 29 March 2017
- Carmichael Coal and Rail Project (project number 2010/5736) Department of Environment and Energy (DoEE) comments Groundwater Management and Monitoring Plan (informed by Geoscience Australia, and the Department of Agriculture and Water) dated 18 October 2017
- EHP (now DES) response to the GMMP for the Carmichael Coal Mine Project, email dated 8 November 2017, minutes of the clarification meeting with DES on 22 November 2017, and EHP comments on GMMP baseline dataset, email dated 8 December 2017
- DoEE comments sent 6 November 2018 based on Teleconference 12 September 2018 (conceptualisation), Workshop on 16 October 2018, and Teleconference 24 October 2018
- DES comments on draft GMMP submitted on 10 August 2018

1.10 GMMP Development

Establishment and implementation of the groundwater monitoring program promotes adaptive management principles, presented in **Section 1.2**, to allow for evolution and response to the various stages of the mining project (i.e. the groundwater monitoring program will adapt to the different phases of mining including baseline, construction, operations, and post closure).

To develop an optimal GMMP, Adani have adopted a phased approach to allow for the correct scientific development of the GMMP and allow for variation over time to suit the different mining stages.

The GMMP includes procedures and processes to assess the baseline hydrogeological regime(s), allowing for the development of groundwater quality triggers and groundwater level thresholds. The baseline data, derived from hydraulically isolated monitoring bores, will be used for comparison purposes to aid in assessing potential groundwater impacts of approved mining operations and to inform investigations and mitigation measures consistent with the EA Conditions (**Appendix A**). The majority of these hydraulically isolated control monitoring bores, located outside the mine footprint, have been recognised as control points (**Section 5.4.4**).

Compilation and compliance with approval conditions of the GMMP involved:

- Development of a groundwater management and monitoring program / plan (GMMP), EA Condition E4 and EPBC Act approval condition 3 (**Appendix A**)
- Obtaining approval of this GMMP from the administering authorities, which included development of a baseline monitoring program (EA Condition E3) and control monitoring sites (EPBC Act approval condition 3) (**Appendix A**)
- Independent peer review of this GMMP (EA Condition E7 and EPBC Act approval condition 3h) (**Appendix A**)
- Compilation of representative groundwater quality samples from each hydrostratigraphic unit identified with potential to be impacted (directly and/or indirectly) by the approved mining activities (EA Condition E9 and EPBC Act approval condition 3b)(**Appendix A**)
- Compilation of a representative baseline groundwater level dataset prior to mine activities, identification of trends and natural fluctuation, including groundwater flow patterns (EA Condition E13 and EPBC Act approval condition 3b) **(Appendix A**)
- Determination of groundwater quality triggers prior to commencement of coal mining activities ((EA Condition E9 and EPBC Act approval condition 3b)(**Appendix A**)

- Development of groundwater monitoring network, in specific representative hydrostratigraphic units, which will act to detect water quality triggers (prior to reaching the predicted impacts of groundwater quantity) and drawdown thresholds , which when exceeded has a potential to result in environmental harm to GDEs (including spring complexes and the Carmichael River alluvium) and/or groundwater supply reduction in neighbouring landholder bores and GAB (Clematis Sandstone and Dunda Beds) units (EA Conditions E13 and E14 and EPBC Act approval condition 3a (ii), 3c, and 3d [**Appendix A**]).

The GMMP includes recommendations and considerations for remaining phases of mining to be implemented through revision of the GMMP and approval from the administering authority over time.

1.10.1 GMMP Review

The GMMP must be reviewed by an appropriately qualified person at the first instance before July 2020 and thereafter at regular five-year intervals, per EA Condition E5 and EPBC Act approval condition 3e (**Appendix A**). A report summarising the outcome of the review will be submitted to the administering authorities, which will include:

- An assessment of the GMMP to satisfy the objectives in EA Condition E5 (as presented in **Section 1.4** above)
- A review of the adequacy of the groundwater monitoring locations, frequencies, and groundwater quality triggers specified in **Table E1**, **E2**, and **E3** (**Appendix A** and **Section 5.4** in the GMMP) and in EPBC Act approval condition 3e
- A review of the validity of the groundwater monitoring program against the regular model predictions (EPBC Act approval condition 3e(i) and EA Condition E6) (EPBC Act approval condition 3e(i) and EA Condition E6) (**Appendix A**).

Upon evaluation of the five-year GMMP review report and included results, the administering authority may consider an amendment of the required review timeframe from at least five-year intervals to at least ten-year intervals, per Note under EA Condition E5 (**Appendix A)**

Preparation of the GMMP considered the required regular reviews will allow for the:

- Update of the groundwater conceptual model with (post-EIS) bore logs, groundwater level data (vertical gradients, interaction, and hydraulic connectivity), and groundwater chemistry data (recharge, discharge, and hydraulic connection) (EPBC Act approval condition 3e(i) and EA Condition E6(a, d, and f) (**Appendix A**)
- Verification and validation of the predictive numerical groundwater model with transient groundwater level data and mine dewatering data (volumes) (EPBC Act approval condition 3e(i) and EA Condition E6(b, e, and h) (**Appendix A**)
- Indirect assistance with the water balance model, where compilation of groundwater level data from units above and below the target coal seams will facilitate the revision of model water budgets (estimates of groundwater ingress from surrounding units) (EPBC Act approval condition 3e(i) and EA Condition E6(c) (**Appendix A**)

In compliance with EA approval conditions (EA Condition E6 (**Appendix A**)), the numerical groundwater model is to be reviewed, using the GMMP data and measured mine dewatering volumes, within two (2) years of the initial box cut excavation and then at least every five years afterwards. This is in line with the EPBC Act approval condition (3e), which requires a regular review of the GMMP, including the numerical groundwater model.

1.10.2 GMMP and Research

The GMMP bore network (spatial and with depth) was designed for compilation of extensive baseline groundwater levels and hydrochemistry data over time in all the hydraulically isolated geological formation that exist within and adjacent to the mine lease area. These data will allow for the assessment of potential impacts on groundwater resources and reassessment of groundwater alteration, due to stress (mine dewatering), over prolonged periods of mining.

Such data, inclusive of the envisaged change in groundwater levels, induced groundwater movement towards the dewatered and depressurised target coal seams, and groundwater chemistry (mixing) changes, will be captured in the groundwater monitoring.

The groundwater monitoring data will, through accurate evaluation and assessment, allow for input into:

- Evaluation of compliance with groundwater quality triggers
- Evaluation of groundwater level thresholds (including EPBC Act specific approval condition Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex)
- Development of the GDEMP (EA Approval Condition I11)
- The Carmichael Coal Project Biodiversity Offset Strategy
- The GAB Springs Research Plan (EPBC Act approval condition 3e(iii))
- The RFCRP (EPBC Act approval condition 3e(iv))
- Regional cumulative impact assessment(s) (EPBC Act approval condition 3f)
- Regional water balance model (EPBC Act approval condition 3f)
- Bioregional assessment and research for the Bioregional Assessment of the Galilee Basin sub-region and the Lake Eyre Basin (EPBC Act approval condition 3f).

All relevant data collected for the various research plans mentioned above (e.g. the GABSRP) will be considered in the subsequent iterations of the GMMP and groundwater model re-run(s).

In addition to groundwater level and quality data, augmentation of the GMMP bore network in response to mining allows for the provision of additional site specific geological data and aquifer hydraulic parameter estimations (modelling and aquifer testing) for the various research programs.

The dewatering volume records (to be maintained as per Associated Water Licence conditions), groundwater level changes (in response to mine dewatering), and hydrochemistry data will be available for consideration in the CCP Subsidence Management Plan (EA approval condition J2). These data will facilitate assessment of potential impacts and management processes associated with longwall mining impacts, such as subsidence.

Section 1.8.1 includes details of the GMMP – Research plan interaction.

1.11 GMMP Peer Review

For the GMMP to comply with EPBC Act approval conditions, a peer review of the GMMP is required (EPBC Act approval condition 3h).

Adani, in agreement with the DotE, appointed JBT Consulting (an independent specialist hydrogeological consultancy) to undertake an independent review of the draft GMMP.

Comments and recommendations which resulted from the initial independent review of the draft are presented in **Appendix F**. A record of changes and modifications to this GMMP, in response to the independent review, are included in **Appendix G**.

The initial GMMP was then reviewed by DES and DotE, leading to this revision of the GMMP. The current version of the GMMP has been updated to address the regulator comments and recommendations.

1.12 Current Groundwater Monitoring Network

Adani developed and constructed a baseline groundwater monitoring network, detailed in **Section 3.0** which provided ambient groundwater level and quality data from all identified hydrostratigraphic units within, and adjacent to, the mine leases as per EA Condition E3(a).

Groundwater monitoring locations, on and off the mine leases, were initially drilled and constructed as a component of the EIS process, utilising existing larger diameter core / exploration bores. The EIS groundwater monitoring network was augmented post-EIS; both efforts were developed in consultation with the Queensland Department of Natural Resources, Mines and Energy (DNRME).

The resultant groundwater monitoring network, presented in **Appendix B**, is considered suitable to monitor potential impacts on groundwater resources as a result of the approved mining operations. The current groundwater monitoring network (monitoring rationale as requested in EPBC Act approval condition 3a(iii)) included the following:

- Installation of monitoring points along strike and down dip using existing exploration bores, specifically designed and constructed groundwater monitoring bores in the GAB units off lease, vibrating wire piezometers, and correctly designed (bore construction and wellheads) artesian bores. The bores all monitor hydraulically isolated units to provide groundwater level and groundwater quality data for each of the hydrostratigraphic units on and adjacent to the mine leases. The bores are located spatially across the mine footprint, providing data from subcrop to down-dip, as well as off lease adjacent to MNES, sensitive water resources, neighbouring groundwater users, and GDEs
- Collection of regular (~ 2-month intervals) baseline monitoring data (groundwater levels and quality) from all hydrostratigraphic units (potentially directly or indirectly impacted by mining), as described in this GMMP
- Identification of natural (seasonal) or anthropogenic fluctuations of groundwater levels and chemistry prior to mining (particularly the alluvium aquifers which are artificially recharged in the west due to discharge from the Joshua Spring / uncontrolled artesian flow and are non-perennial downstream, which results in changes in groundwater chemistry (no first flush changes in the west compared to the east)
- Identification of groundwater chemistry changes down-dip within hydrostratigraphic units (to assess differences based on recharge at subcrop and natural alteration down dip)
- Development of representative (site-specific) groundwater quality triggers and groundwater level thresholds.

Groundwater level data is recorded at 12-hour intervals via automated water level loggers. The groundwater level data, upon commencement of mining operations, will be compared to groundwater level thresholds derived from model predictions and assessment of natural fluctuation (**Section 5.3**).

1.13 Monitoring Performance Indicators

The adaptive management framework allows for, and promotes, assessment of management and mitigation measures for potential impacts on groundwater resources because of approved mining operations. To assess the effectiveness of such measures, to be employed by Adani during the life of mine (as compiled in the CCP Environmental Management Plan), performance criteria (to be assessed using this GMMP) has been developed such that:

- There will be no migration of mine-related poor quality seepage, within groundwater, into the surface water bodies
- There is compliance with groundwater quality triggers, and groundwater level thresholds (including the groundwater level Early warning triggers and Impact thresholds specific to the Doongmabulla Springs Complex) and the validation of corrective actions and/or mitigation measures to be taken if the triggers or thresholds are exceeded
- All landholder concerns over impacts on their groundwater supplies are to be addressed in a timely and prompt manner
- The compilation of annual groundwater monitoring reports, annually by 1 July (EA Condition E15), will provide validation of environmental protection performance
- Rehabilitated final voids to remain after mining will be managed and maintained appropriately.

The robust baseline groundwater dataset will be utilised for comparison during the life of mine and post-closure, to allow for assessment of mining operations on groundwater resources.

All monitoring data, compiled during the different phases of mine life (baseline, construction, operation, and post-closure) will be maintained for the life of the project.

1.14 Clarifications

Approval conditions include for a Groundwater Management and Monitoring Program (EA Condition E4), a Groundwater Management and Monitoring Plan (EPBC Act condition), and an Underground Water management Program (UWMP) under the AWL conditions (*Water Act 2000*). The different approvals, Commonwealth and State, have similar requirements to be included in the GMMP, which leads to some confusion when compiling a single GMMP.

A glossary of terms has been included to allow for clarification regarding terms which mean different meanings depending on the source of the approval condition, i.e. triggers for the State approvals relates to groundwater chemistry, whereas triggers for the Commonwealth approvals relate to groundwater levels. The glossary provides details of the terms and their meanings as included in this GMMP.

1.14.1 Glossary

- Trigger values – a groundwater quality value, which if exceeded will lead to an assessment of the water quality parameter and possibly lead to (trigger) an investigation into potential for environmental harm

  Note: the groundwater level trigger values included in the EPBC Act approvals are referred to as groundwater level thresholds in this GMMP.

- Early warning bores – the use of the term early warning bores, in the initial iterations of the GMMP, has been recognised to cause confusion. The term was used to describe groundwater monitoring bores located between the mine activities and an identified receptor (GDE, landholder bore, etc.), providing a monitoring point where groundwater level and quality changes can be monitored before changes would occur at the receptor.

  Confusion was recognised as regulators / GMMP reviewers related early warning to be time related rather than spatial. To avoid this confusion the bores are now referred to as sentinel bores in this GMMP.

- Early warning triggers – the EPBC Act approvals includes for the details of groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Spring Complex. These investigation triggers have developed to ensure that groundwater drawdown as a result of approved mining activities does not result in groundwater level decline by 0.2 m (the approval condition interim drawdown threshold for the Doongmabulla Spring Complex.

  The Early warning triggers in the GMMP are the same as the EA approval condition for groundwater level thresholds, a level of decline in water level which:

  - allows for the assessment of drawdown so it does not exceed the maximum predicted drawdown in the selected monitoring bore and hydrostratigraphic unit
  - validates predictive modelling
  - provides an early warning regarding the changes to groundwater levels if different (drawdown extent and/or rate of drawdown) to the predicted changes
  - instigates an investigation

- Interim threshold – EPBC Act approval condition 3(d) includes for Early warning triggers and Impact thresholds to be detailed in the GMMP so as to ensure that the groundwater drawdown as a result of the approved mining activities does not exceed 0.2 m, an interim drawdown threshold at the Doongmabulla Spring Complex.

  The interim drawdown threshold (0.2 m) may be replaced with a new drawdown threshold if further evidence can be provided which proves that a new drawdown threshold will ensure the protection and long-term viability of the Doongmabulla Spring Complex.

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- Impact threshold – the EPBC Act approvals includes for the details of groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Spring Complex. This drawdown threshold limit, selected to be less than the maximum predicted drawdown, ensures an investigation into groundwater drawdown, a revision of the predictive modelling, and the determination of mitigation measures to ensure that drawdown does not exceed 0.2 m, the interim drawdown threshold at the Doongmabulla Spring Complex.

  These impact threshold (drawdown limits for the DSC) are not the same as the States' groundwater level thresholds.

- High and low impact threshold levels - the Adani Associated Water Licence (AWL) condition 57 required the recommendations for low impact and high impact threshold levels in the Dunda Beds and Clematis Sandstone aquifers. The low impact and high impact threshold levels, derived for the AWL conditions, are the same as the Early warning triggers and Impact thresholds required for the Doongmabulla Springs Complex to meet the requirements of EPBC approval condition 3(d).

  To avoid confusion regarding groundwater level thresholds, the following is noted:

  - Early warning triggers (EPBC 2010/5736 Approval) are equivalent to the low impact threshold levels (AWL Condition 57) and groundwater level thresholds.
  - Impact thresholds (EPBC 2010/5736) are equivalent to the high impact threshold levels (AWL Condition 57).

- Control bores - control monitoring sites are a subset of the baseline hydraulically isolated groundwater monitoring bores. These monitoring bores are located adjacent to the mine lease and are constructed as hydraulically isolated background bores.

  The DotE considers that control bores are to be located outside the zone of potential impact. For groundwater this is impractical as the groundwater monitoring bores would have to be located outside the mine lease (due to the extent of drawdown extending beyond the mine lease boundaries) and long-term access cannot be assured. Discussions with Geoscience Australia indicated that the control bores can be where uninterrupted data can be provided during and after the life of the mine.

  Where possible Adani has identified control bores within areas where Adani has written approval for access these bores, and where little or no drawdown is predicted (beyond natural fluctuation). Although these bores, to the west of the mine lease, are not predicted to be impacted by mine related dewatering these bores are located on other landholders properties and as such there is no guarantee that these bores will not be impacted by groundwater extraction in the future.

  It is noted that Adani also has a series of sentinel bores between the mine lease and sensitive receptors (such as the Doongmabulla Spring Complex and neighbouring landholder bores). These bores will not be directly impacted by approved mining activities and as such will provide uninterrupted data can be provided during and after the life of the mine.

- Reference bores – control bores are technically reference bores, where natural groundwater level and chemistry changes can be monitored (then compared to the mine monitoring bore network to aid in assessing if change is due to approved mining or natural fluctuations) .

2.0 Hydrogeological Regime

Understanding the site's hydrogeological system was essential to identify groundwater resources with potential to be impacted by the approved mining operations, including their magnitude and significance. To develop a fundamental comprehension of these systems at the CCP, several studies have been undertaken by Adani; the results of which have informed this GMMP.

The approvals process for the CCP allowed for compilation of geologic and hydrogeologic information from literature reviews, drilling and construction of groundwater monitoring wells, and groundwater assessments (groundwater quality and levels) conducted across and adjacent to the MLs. These datasets were utilised to develop initial groundwater, conceptual and numerical, models for the Environmental Impact Statement (EIS) (GHD, 2010), refinement in the Supplemental Environmental Impact Statement (SEIS) Mine Hydrogeology Report (GHD, 2013), and Addendum to the SEIS (AEIS) (GHD, 2013a).

This report was prepared to be read as a standalone document; however, should additional information regarding project geology and/or hydrogeology be required, reference should be made to the SEIS and AEIS reports referenced above.

To comprehensively understand the groundwater regime, review and assessment of the conceptual and numerical groundwater models were undertaken to identify potential data gaps. Continuous refinement of the models with new data as it becomes available ensures they are robust and defensible for use to accurately predict potential impacts because of the CCP. The groundwater model reviews, investigations undertaken, and requirements of future studies incorporated into this GMMP include:

- Carmichael Coal Mine and Rail Project SEIS Report for Mine Hydrogeology Report (GHD, 2013)
- Carmichael Coal Project Numerical Groundwater Model Peer Review (URS, 2013)
- Carmichael Coal Mine and Rail Project SEIS Mine Hydrogeology Report Addendum (GHD, 2013a)
- Carmichael Coal Project Groundwater Model Peer Review Final Comments (GHD, 2013b)
- Carmichael Coal Mine and Rail Project: Coordinator-General's evaluation report on the environmental impact statement (State of Queensland, 2014)
- Carmichael Coal Project Response to IESC Advise (GHD, 2014)
- Transient model verification memo (GHD, 2014a)
- Carmichael Coal Project Groundwater Model Independent Review (Hydrogeologic, 2014)
- Joint Groundwater Experts Report prepared for the Land Court of Queensland (Webb, et al., 2015)
- Adani - Carmichael Coal Project: Assessment of Potential Reduction in Spring Flow (Hydrosimulations, 2015)
- Land Court of Queensland judgement - Adani Mining Pty Ltd v Land Services of Coast and Country Inc. & Ors [2015] QLC 48
- Approval, Carmichael Coal Mine and Rail Infrastructure Project, Queensland (EPBC 2010/5736) (DotE, 2015)
- Response to Federal Approval Conditions - Groundwater Flow Model (GHD, 2015)
- Carmichael Coal Mine 2015 Hydrogeological Pumping Tests: Factual Report (AECOM, 2016)
- Environmental Authority Permit – Carmichael Coal Mine (EHP, 2016)
- Geological and Groundwater Assessment of the Rewan Formation (URS, 2016)
- Associated Water Licence 617264 Department of Natural Resources and Mines March 2017.

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The numerical groundwater modelling in the SEIS and AEIS reports will be reviewed to incorporate groundwater monitoring data and measured mine dewatering volumes (from this GMMP) per EA Condition E6 (groundwater model review) within two years of commencement of any mining activities associated with box cut excavation and at least every five years after that. An accurate understanding of the impacts of approved mining operations on the groundwater regime(s) at the CCP is critical for appropriate refinement of this GMMP.

The subsections below present the current understanding of the groundwater regime(s), limitations, identified data gaps, studies undertaken to address known data gaps, and how future studies can incorporate remaining and/or future identified gaps in the groundwater conceptual understanding. It is recognised that at least one study has been planned to characterise the Rewan Formation within and adjacent to the mine leases, which will aid in finalising the current groundwater conceptual model.

Studies have been designed to satisfy the purposes of the RFCRP and GAB Springs Research Plan (GABSRP) and are currently in the planning stage. Objectives of the studies include further drilling and monitoring well installation to inform the source aquifer(s) for the Doongmabulla Spring Complex, located west of the CCP area. Results of these studies will be incorporated into the next iterations of the GMMP and numerical model review and update.

The current hydrogeological understanding has been used to inform this GMMP and the groundwater monitoring bore network, throughout the various stages of mining, spatially and temporarily.

2.1 Geology

2.1.1 Regional Geology

The CCP is situated along the eastern edge of the northern Galilee Basin, an intracratonic sedimentary basin comprised of Late Carboniferous to Middle Triassic sedimentary strata of predominantly fluvial depositional origin. The central Galilee Basin overlies the Devonian Adavale Basin, the Late Devonian-Early Carboniferous Drummond Basin, and Early Palaeozoic basement (Moya, et al., 2014). The Galilee Basin itself is overlain by the Jurassic-Cretaceous Eromanga Basin, a component of the GAB.

The principal tectonic elements of the Galilee Basin include the east-west trending Barcaldine Ridge which subdivides the basin into northern and southern components. The northern component of the basin is subdivided by the Maneroo Platform and the Beryl Ridge, which resulted in the development of the western depression termed the Lovelle Depression and the eastern depression termed the Koburra Trough; the CCP area occupies a position on the eastern margin of the Koburra Trough which corresponds with the basin margin, as depicted on **Plate 1** below.

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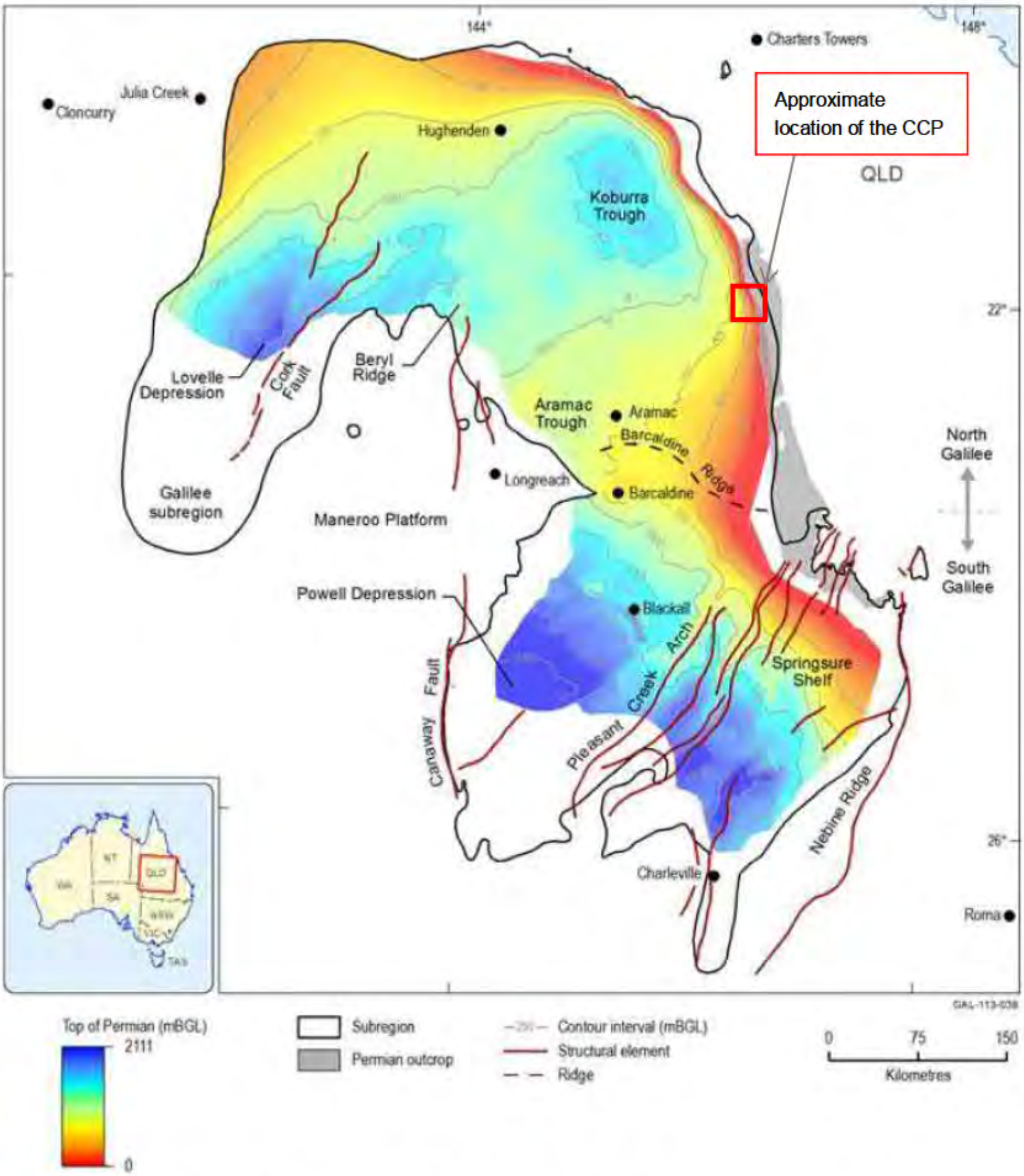

Plate 1 Structures of the Galilee Basin (after Bradshaw et al., 2009)

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Mineable coal seam targets occur in the Bandanna Formation (A and B seam) and the Colinlea Sandstone (C and D seams). The coal seams vary in thickness from 1 to 13 m across the mine leases and converge and diverge or split to distances that vary between 5 to 70 m. Together, these Late Permian coal measures are referred to as the Betts Creek Beds, which unconformably overlay the Early Permian Aramac Coal measures and Joe Joe Group. The Aramac Coal Measures do not occur in the CCP area; however, the Early Permian aged Joe Joe Group unconformably underlies the Colinlea Sandstone in the CCP area and is considered the basal unit of the Galilee Basin. **Plate 2** below presents the Galilee Basin stratigraphy by proximity to major structural feature and relationship to the adjacent Eromanga and Drummond basins. **Plate 3** depicts the relationship to the adjacent Eromanga Basin along the eastern margin of the Galilee Basin.

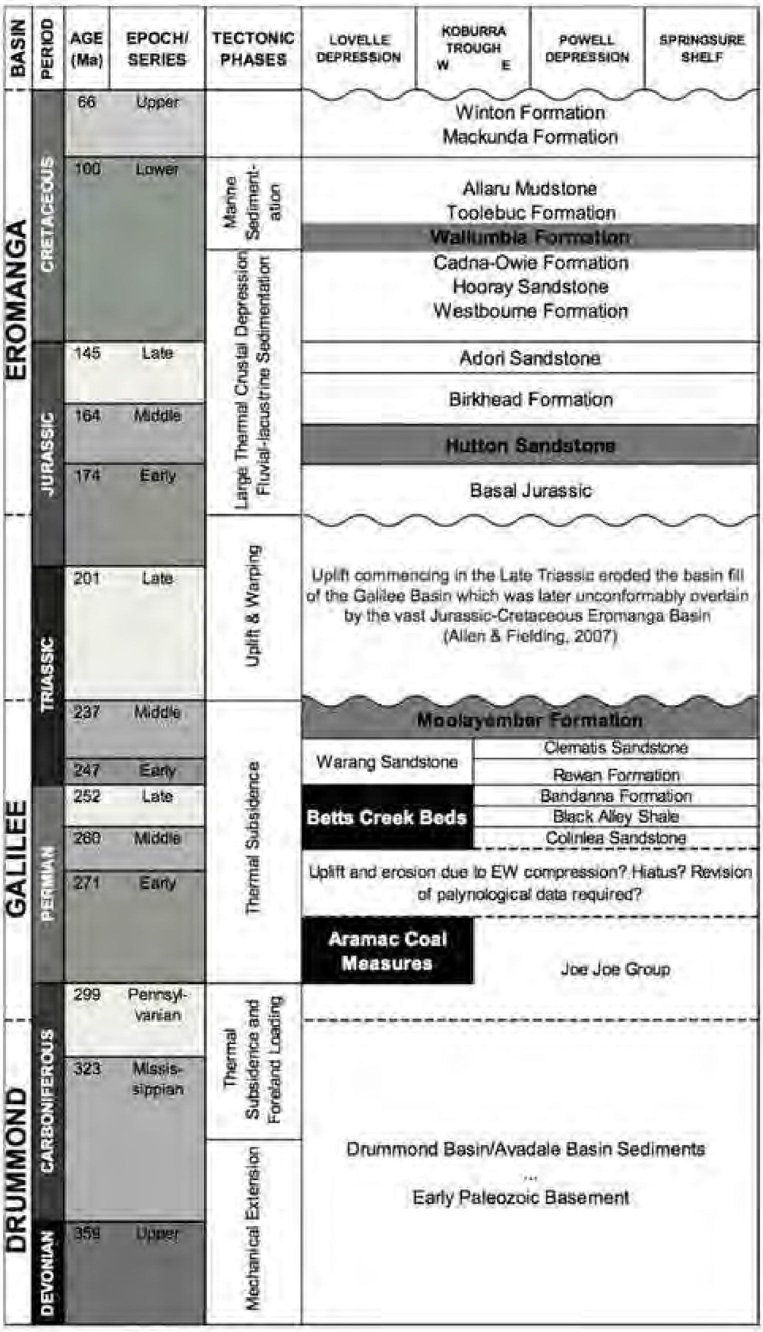

Plate 2 **Galilee Basin Stratigraphy and Relationship to adjacent basins (Modified from Scott et al. [1995] and van Heeswijck [2010])**

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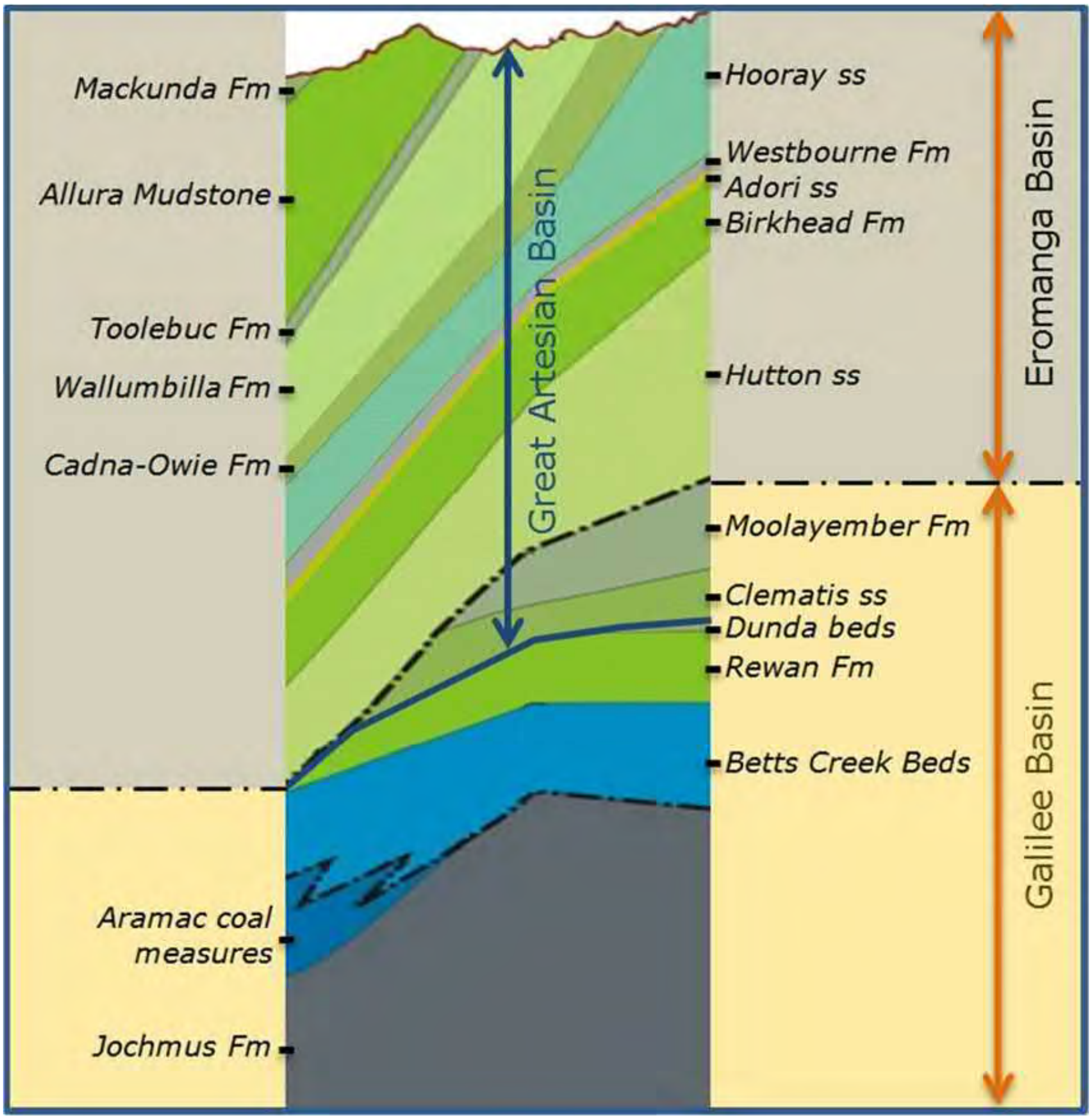

Plate 3 Galilee Basin – Eromanga Basin geology (source: Galilee Basin Operators Forum)

The stratigraphy of the CCP area is characterised by the Jochmus Formation of the Early Permian aged Joe Joe Group, the vertical extent of exploration, and overlying strata. Above the Jochmus Formation consists of the coal-bearing Colinlea Sandstone and Bandanna Formation, which are divided roughly by northwest-southeast trending geological outcrops, located west of the CCP area, comprised of the Moolayember Formation, Clematis Sandstone, and Dunda Beds. **Figure 4** below depicts the CCP tenements and surface geology which presents the location and proximity of these outcrops. The Rewan Formation subcrops in this area and is underlain by the Late Permian to Triassic-aged coal-bearing units which overlie the Joe Joe Group.

East of the outcrop alignment, the depth to the Early Permian Joe Joe Group (Jochmus Formation) is limited and an unconformable and variable veneer of Tertiary sediments and Quaternary aged alluvium overlies the Early Permian aged sediments. The Joe Joe Group (Jochmus Formation) is considered the geological basement within the eastern portion of the CCP area and indicates the edge of the geological Galilee Basin.

Plate 4 below depicts the stratigraphy of the coal measures in the CCP area (modified from Allen & Fielding, 2007).

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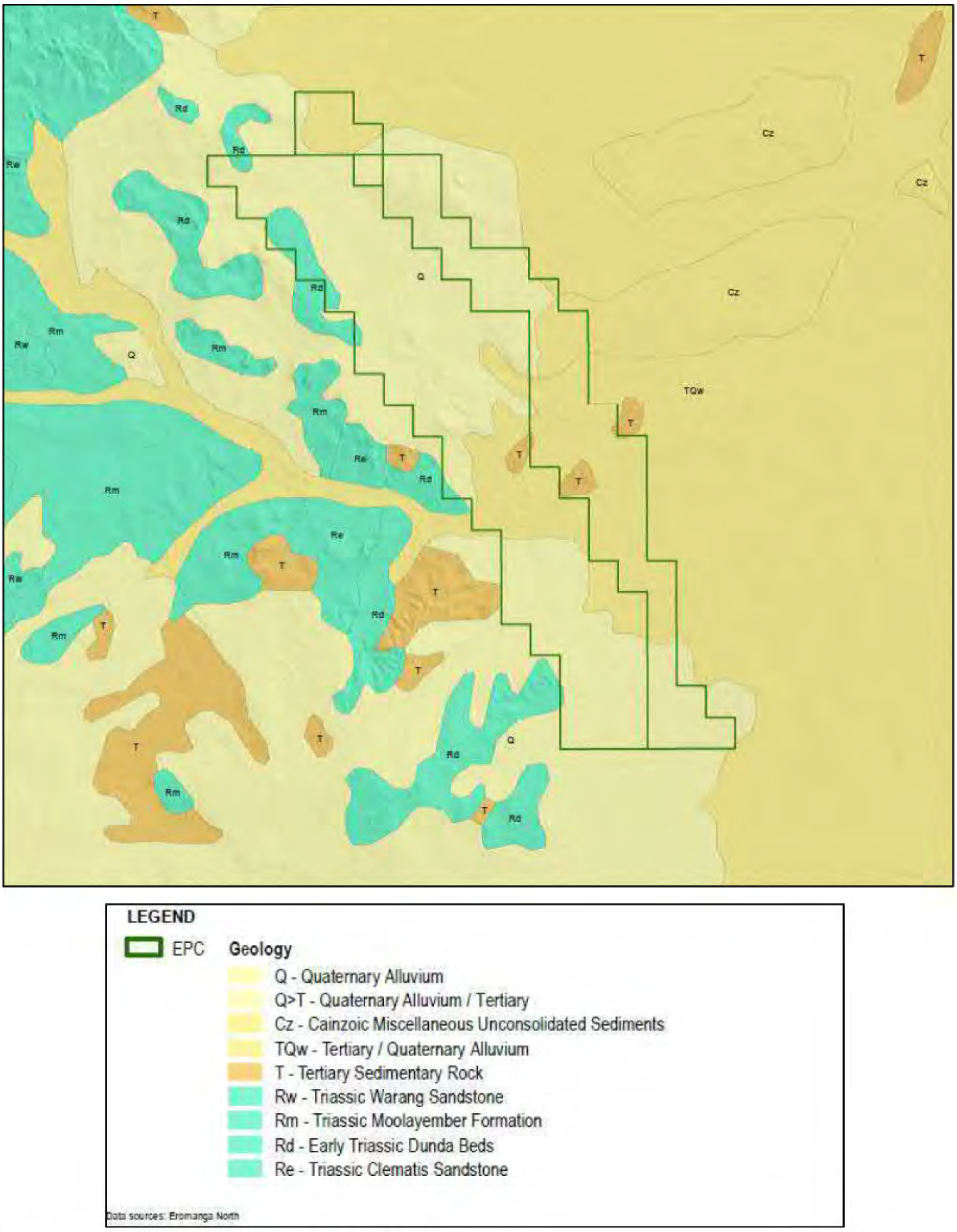

Figure 4 Regional Surface Geology and CCP Mine leases

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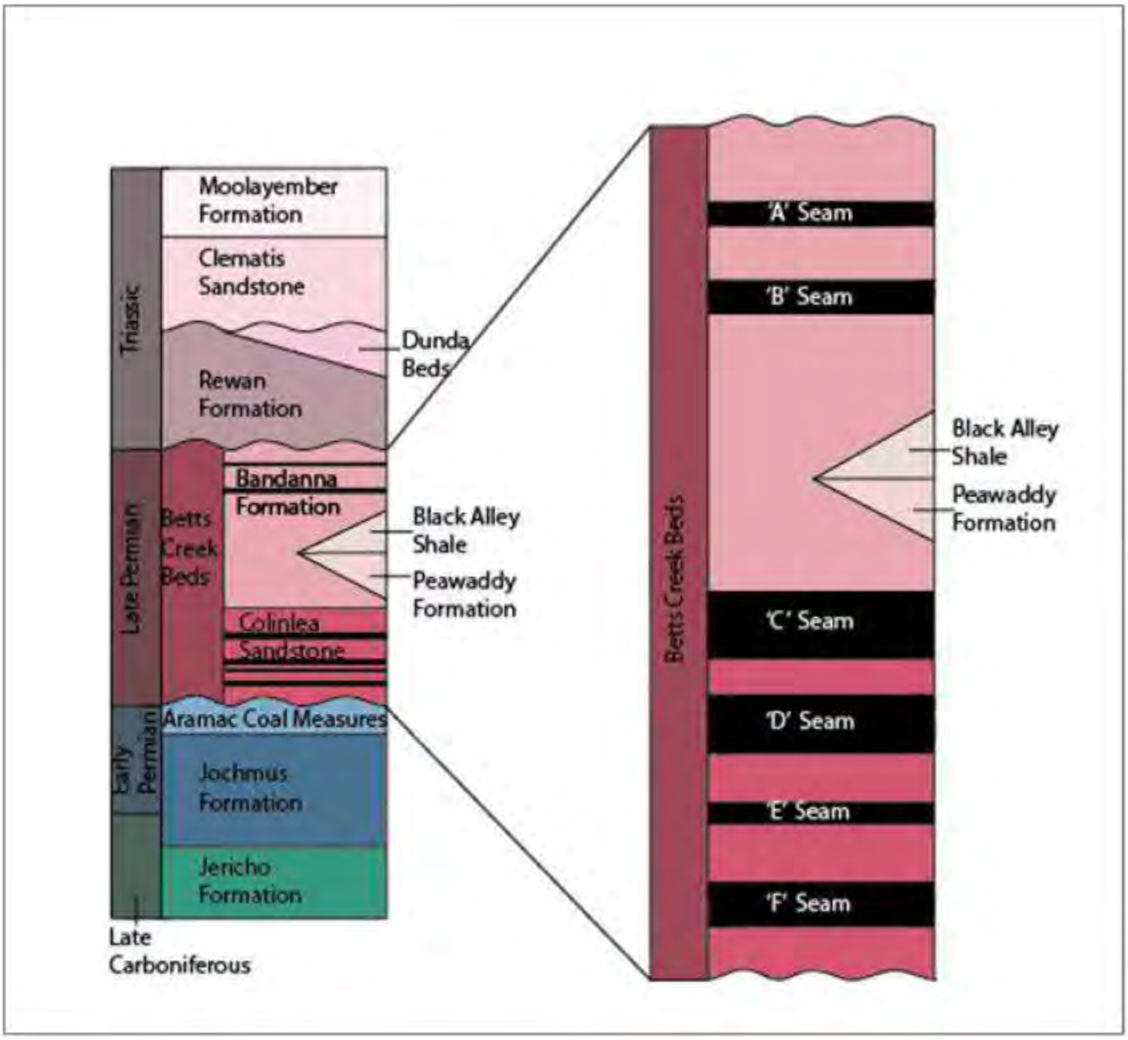

Plate 4 Galilee Basin Coal Stratigraphy

Cainozoic Cover

A sequence of sand, fine gravel and minor clay horizons (Tertiary sediments) covers the CCP mine lease areas. With an average thickness of 40 m, the Tertiary sediments are thickest in the eastern and central regions (~ 60 m thick) and thins towards the elevated areas in the west (< 5 m thick). Lateritic horizons (laterisation process of Permian aged sediments during the Tertiary period) are recorded along with mottled clay paleosols.

Floodplain alluvium sediments comprised of generally sands, silts, gravels, and clays are located along the Carmichael River and much of the Belyando River system east of the CCP area. The Tertiary sediments are overlain by alluvium in these areas. The alluvium sediments are laterally and vertically limited to the major surface water features.

The Cainozoic sediments unconformably overlie the Triassic aged Rewan Group (Dunda Beds and Rewan Formation), the Permian aged Bandanna Formation and Colinlea Sandstone, and the Early Permian aged Joe Joe Group units on the mine leases.

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Moolayember Formation

West of the CCP area, the Middle Triassic Moolayember Formation outcrops and predominantly comprises sandstone and siltstone. The Moolayember Formation is a recognised aquitard of the hydrogeological GAB and is the uppermost unit of the Galilee Basin, which is unconformably overlain by the sediments of the Eromanga Basin west of the Mine Leases (see **Plate 2** above). In proximity to the CCP, this unit dips to the west and is not present within the Mine Lease; unconfined at areas of outcrop the Moolayember Formation becomes confined westwards where the Eromanga Basin overlies the Galilee Basin.

It is noted that the Moolayember Formation, west of the CCP leases, is absent south of the Carmichael River and becomes thicker to the north. The Moolayember Formation, weathered to clay, outcrops across the Doongmabulla Springs Complex area.

Clematis Sandstone

The Clematis Sandstone, a recognised major GAB aquifer, is observed at outcrop west of the CCP mine lease boundary. Comprised of quartz-rich coarse-grained sandstone, minor siltstone, and mudstone this unit is located along the western boundary of the CCP area. Considered unconfined at outcrop, the Clematis Sandstone dips westwards and becomes confined where it underlies the Moolayember Formation west of the CCP leases.

Drilling to the west of the CCP mine leases indicates artesian conditions exist within the Clematis Sandstone within the low-lying flood plains of the Carmichael River, where overlain by clay-rich Moolayember Formation sediments.

The Clematis Sandstone outcrop west of the CCP area is recognised as the recharge zone of the larger GAB.

Rewan Group

The Rewan Group sediments include the Dunda Beds and underlying Rewan Formation and comprise a massive sequence (~300 m thick) of multi-coloured argillaceous sediments which are regionally extensive.

The Dunda Beds, predominantly sandstone, form an angular unconformity with the overlying Tertiary aged strata and outcrop along the western margins of the mine leases.

The Rewan Formation underlies the Dunda Beds and comprises typical green to brownish purple siltstone and minor fine-grained sandstone which form a thick sequence of very low permeability strata (i.e. a regional aquitard) that separates recognised aquifers of the GAB from underlying Galilee Basin sediments, inclusive of the Permian coal-bearing sequences of the Bandanna Formation and Colinlea Sandstone. The base of the Rewan Formation is located some 30 to 50 m above the uppermost Bandanna Formation A seam coal ply.

Within the mining leases, the Rewan Formation is dominated by thick (~ 250 m) clays and mudstones with some interbedded sandstone strata. Drilling through the entire Rewan Group profile, to the west of the mine leases, intersected swelling clay resulted in difficult drilling conditions and abandonment of monitoring well construction. The Rewan Formation aquitard effectively separates the CCP coal resource within the underlying Permian-age strata from the stratigraphically younger Dunda Beds and Clematis Sandstone to the west.

Permian Sediments

Permian sedimentary deposits at site, which underlie the Rewan Group, comprise the Bandanna Formation and underlying Colinlea Sandstone, collectively known as the Betts Creek Beds. These Permian units contain both economic and sub-economic coal seams. The coal seams are named alphabetically A through to F, where the A seam is the uppermost unit.

Geologically, the boundary between the Bandanna Formation and Colinlea Sandstone is, in the absence of the Black Alley Shale and Peawaddy formations in the CCP area, an interval below the C coal seam where the sedimentation grades from argillaceous to increasingly arenaceous sediments. Thus, the Bandanna Formation hosts the A and B coal seams (and C where present) in clay-rich sediments, while the Colinlea Sandstone hosts the target D coal seam and coal seams E and F (where present) in more coarse-grained sandstone beds.

D R A F T

A layer of tuff has been observed below the CCP area within the interburden between the C3 and D1 coal seams.

Bandanna Formation

The Bandanna Formation comprises calcareous, lithic sandstone, siltstone and a number of low rank sub-bituminous and sub-hydrous coal seams. This sequence represents fluvial deposition with sandy braided channel and flood plain deposits associated with mire (marsh) and coal seam development.

Three coal seams, namely seams A, B, and C, are laterally continuous and correlated regionally.

Colinlea Sandstone

The Colinlea Sandstone, an arenaceous sequence, comprises primarily quartz sandstone and conglomerate with minor shale and a number of low rank sub-bituminous and sub-hydrous coal seams. The sequence represents fluvial deposition with sandy braided channel and flood plain deposits associated with coal seam development. Three coal seams, namely seams D, E, and F are laterally persistent and correlated regionally.

Joe Joe Group

The Colinlea Sandstone is unconformably underlain by sediments of the late Carboniferous to Early Permian aged Joe Joe Group, comprised of four formations within the Galilee Basin. From oldest to youngest the Lake Galilee Sandstone, Jericho Formation, Jochmus Formation, and the Aramac Coal Measures; the Aramac Coal Measures are absent within the CCP area and the Lake Galilee Sandstone is restricted to the Trough axis. Thus, the upper Jochmus Formation is identified as the bottom confining unit of the Colinlea Sandstone aquifers and vertical extent of investigation for the CCP.

The Joe Joe Group in the project area consists of entirely non-marine sediments inclusive of mudstone, labile sandstone, siltstone, shale.

2.1.2 Site Geology

Tertiary sediments (sandstone, mudstone, laterite, and conglomerate) are mapped at outcrop over much of the CCP area and typically range from 20 to 60 m thick. Along the Carmichael River and over much of the Belyando River system to the east of MLs, these strata are mapped to be overlain by Quaternary aged alluvium (i.e. sands, silts, gravels, and clays).

Beneath the mine leases, an unconformity defines the boundary between the Tertiary sediments and the underlying Late Permian-age coal bearing strata (a sequence of siltstone, mudstone, sandstone, shale, and coal of the Bandanna Formation and Colinlea Sandstone).

The Late Permian-age strata typically dip at approximately 2 to 4 degrees to the west, which steepen slightly in the southern half of the lease. Monitoring well drilling indicates a synform within the MLs, which corresponds to the groundwater level lows monitored onsite (**Section 2.2.5**).

Along the western margins of the CCP area, a sequence of Triassic-age strata forms an angular unconformity with the overlying Tertiary sediments and is mapped at outcrop as the Dunda Beds (predominantly fine grained feldspathic sandstone). The Rewan Formation (mudstone and minor sandstone) underlies the Dunda Beds and overlies the Late Permian age coal bearing strata.

The lithostratigraphy along the eastern margin of the Galilee Basin is presented in **Table 5** below.

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Table 5 Lithostratigraphy of the Eastern Limb of the Galilee Basin (source: CCP drilling and Alpha Bulk Sample Pit)

Age	Geological unit		Lithology	Thickness	Comment
Quaternary			Alluvium	< 20 m	Unconfined aquifer along rivers
Tertiary			Argillaceous saprolite, laterite, and clay sediments	20 to 60 m	Unconfined aquifer, altered Permian units during the Tertiary period
Triassic	Moolayember Formation		Moolayember Formation (sandstone and siltstone)	25 to 50 m near Doongmabulla Springs Complex; and >100 m further west	Outcrops to the west of CCP
	Clematis Sandstone		Quartz sandstone, minor siltstone and mudstone	~100 m near Doongmabulla Springs Complex; and >100 m further west	Unconfined at outcrop and confined to the west of the site, major GAB aquifer
	Rewan Group	Dunda Beds	Sandstone, siltstone, mudstone	Up to 100 m on CCP	Confining unit, basal unit of the GAB, Rewan Formation grades into Dunda Beds
		Rewan Formation	Grey-green mudstone, siltstone, and sandstone	~ 250 m on CCP	
Late Permian (Betts Creek Beds)	Bandanna Formation		Sandstone		Permian 90 to 180 m to base of target coals
			Coal - AB Seam	12 – 18 m	Resource target
			Sandstone / siltstone	10 m	Aquitard
			Coal – B splits	1 – 2 m	Coal
			Siltstone / mudstone	60 – 70 m	Aquitard
			Coal – C Seam	3 – 4 m	Carbonaceous
	Colinlea Sandstone		Siltstone / sandstone	2 – 20 m	
			Coal – D1 Seam	4 – 6 m	Resource target
			Sandstone	5 – 30 m	
			Coal – D2/D3 Seam	8 – 10 m	Resource seam
			Siltstone / mudstone	10 – 20 m	
			Coal – E Seam	1 – 3 m	Resource seam
			Sandstone / siltstone	5 – 10 m	
			Coal – F Seam	1 – 5 m	Resource seam

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Age	Geological unit	Lithology	Thickness	Comment
Early Permian	Joe Joe Group (Jochmus Formation)	Bedrock Mudstone, labile sandstone, siltstone, shale and thin carbonaceous beds		Low permeable unit

2.1.3 Site Hydrogeology

Based on the current understanding of the geology for the mine site the hydrogeological units considered of relevance to CCP include the:

- Quaternary aged unconsolidated alluvium associated with the Carmichael River and other local water courses
- Tertiary aged clay-rich saprolite and laterite (altered Permian units during the Tertiary period)
- Triassic aged units which form part of the GAB including the Moolayember Formation, Clematis Sandstone, Dunda Beds, and Rewan Formation
- Permian aged siltstone, mudstone, sandstone and coal seams of the Bandanna Formation and the Colinlea Sandstone which form the target of the proposed mining operations (not mapped at outcrop), also known as the Betts Creek Beds when these two units are combined together
- Early Permian aged Joe Joe Group (Jochmus Formation) weathered and fresh bedrock: mudstone, labile sandstone, siltstone, shale.

Alluvium

Unconsolidated alluvium typically forms the uppermost hydrogeological unit within and adjacent to the CCP leases. Along the Carmichael River these strata include sand, gravel and clay-dominated layers of variable thickness and limited lateral extent. These sediments form an unconfined aquifer, indicated to be approximately 20 m thick with variable saturation (seasonal) and from west to east where the Carmichael River is gaining (in the west because of continuous artesian discharge from Joshua Spring) to become a losing stream further east (downstream).

The permeability of these units is governed primarily by the proportion of sand and gravels and the connectivity of the strata, which vary both laterally and vertically. Bore yields recorded on site are < 1 L/s.

Tertiary Sediments

Clay, sandstone, and siltstone of Tertiary age are mapped on surface and underlie the younger unconsolidated deposits over much of the CCP tenures. Lithological logging of bores within the Tertiary sediments suggest a typical profile which includes around 16 m of clay that overlies a maximum thickness of 60 m of sandstone and often highly weathered siltstone (saprolite) and includes significant clay-dominated material. This saprolite is considered to be Permian-age strata weathered during the Tertiary period.

Variable (falling) head test results from the Tertiary sediments suggest hydraulic conductivity values as low as 2.1×10^{-4} m/day for the Tertiary age clay-rich strata. The Tertiary sediments are not considered to represent a locally important groundwater resource.

This unit does form an aquitard, a confining layer, that separates the alluvium and underlying Early Permian aged Joe Joe Group in the eastern area of the CCP are, in the area containing the Mellaluka Springs. Here the palaeochannel deposits within the Tertiary sediments and underlying Joe Joe Group are under artesian conditions.

Triassic GAB units

Triassic-age GAB units comprise the Rewan Formation, Dunda Beds, Clematis Sandstone, and Moolayember Formation, which lie within and to the west of CCP. The Rewan Group (Rewan Formation and Dunda Beds) is recognised as the regional basal confining unit (aquitard) of the GAB. Within the CCP area, the Rewan Formation is logged to be dominated by claystone and mudstone

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(which form swelling clays due to the presence of the expansive smectite clay) with some inter-beds of sand.

Analysis of core drilling samples across all bores drilled from north to south, west of the CCP mine leases, indicate the Rewan Formation comprises an aquitard. The triaxial permeability tests performed on the Rewan Formation core samples indicate permeability values that range from 1.1×10^{-03} to 7×10^{-05} m/day (bore C14025VWP) and 2.0×10^{-04} to 7.0×10^{-04} m/day (bore C14204VWP hole).

The Rewan Formation (a regional aquitard) is recognised to be continuous (~250 m thick) across and adjacent to the MLs. **Table 6** below presents the measured thickness of the Rewan Formation from bore logs, which have top and bottom contact depth data for the Rewan Formation.

Table 6 Thickness of Rewan Formation

Bore	Thickness (m)	Top (mAHD)	Bottom (mAHD)
C14204VWP	294	165	459
Shoemaker-1[2]	337.1	199.7	536.8
C14205VWP	234	375	609
C865G	254	79	333
C864G	249	166	415
C039	273	46	319
C039CR	284	46	330
C037	285	50.5	335.5
C037C	284	49	333
C866G	275	153	428
C048	273	65	338
C860G	280	48	328
C047	284	176	460
C861G	283	92	375
C015	263	60	323
C022	268	84	352
C003	270	48	318
C053	269	130	399
C065	286	54	340
C065C	282	57	339
C010	290	89	379
C044C	270	56	326

The locations of these bores are presented on **Figure 5** below.

[2] Shoemaker-1 coal seam gas well drilled on Comet Ridge ATP744P (Comet Ridge, 2010)

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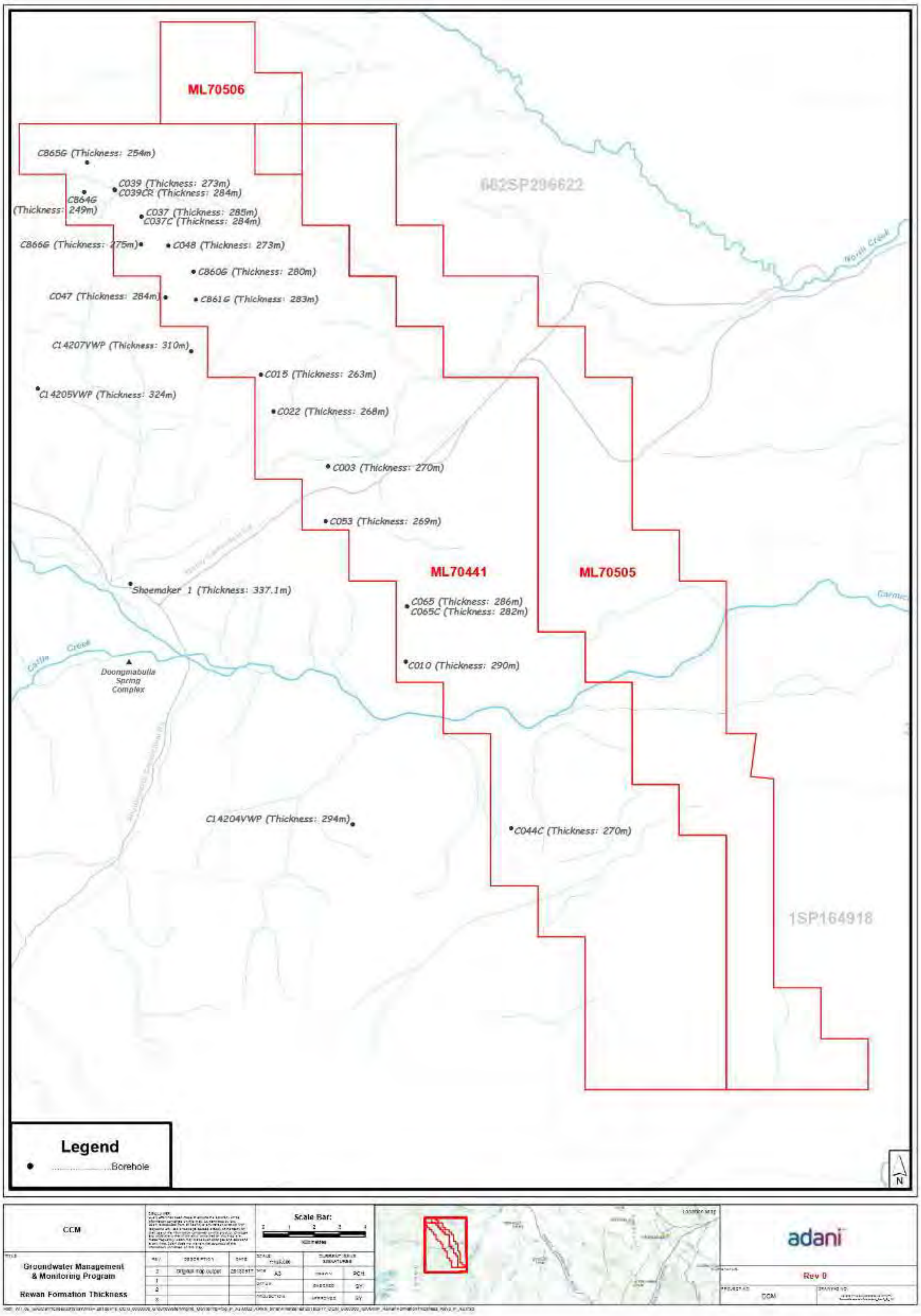

Figure 5 Rewan Formation Bores (with top and bottom Rewan Formation contacts recorded)

The Rewan Formation, continuous in all bores to the west of the mine leases, separates the Permian target coal seams from the stratigraphically younger Dunda Beds and Clematis Sandstone (recognised GAB aquifer) to the west.
Near the CCP area, generally along the western boundary of the mine, permeability of the Dunda Beds sandstone unit is variable and dependent on the degree of weathering, cementing, and/or grain sizes. Available drilling records indicate the variability in permeability as available well yield data indicate a range from as low as 0.1 L/s to as high as 4 L/s

Permian Coal Measures

The target coal seams lie within the Late Permian age Bandanna Formation and Colinlea Sandstone units which dip from east to west across the CCP tenure. Thus, the coal seams subcrop directly beneath the Tertiary sediments in the eastern portion of the CCP area. Conversely, the Triassic-age sandstone and mudstone of the Rewan Group overlie the coal seams in the west. Both the Triassic and Permian age strata typically dip with a shallow gradient (2 to 4°) towards the west across the mine lease and are unconformably overlain by Tertiary sediments and Quaternary aged alluvium. An assessment of the geology and groundwater (potentiometric heads) levels, resulting in flow patterns towards the centre of the lease, indicate a local scale synform (**Section 2.2**).

From a groundwater perspective, major hydrostratigraphic boundaries occur within the CCP area at the base of weathering, beyond which groundwater is encountered under confined conditions in the A-B, B-C, and C-D sandstones and AB and D coal seams. Adani intend to drill and construct additional groundwater monitoring bores, south of the MLs, within the strata below the E seam (Sub-E) to assess and monitor potential alternative source aquifer supplies. These additional Sub-E bores are proposed to be drilled and constructed to the south of the MLs to inform potential aquifer suitability.

The Bandanna Formation typically comprises a varied sequence of sandstone, siltstone, mudstone, and coal. Primary porosity and permeability are typically low and, hence, yields are generally governed by the degree to which secondary porosity and permeability have developed. Experience at locations within the Galilee Basin suggests that coal seams within the Bandanna Formation argillaceous sediments are often the highest yielding and most permeable part of the sequence. This likely reflects the relatively low strength and high fracture potential of the coal seams in comparison to other units present.

Yield estimates from short period airlift tests (1 to 2 hours in length) conducted across CCP, from groundwater monitoring bores installed in the coal seams, ranged from <0.1 to 1.0 L/s (with a mean of 0.2 L/s and median of 0.12 L/s) which suggests low sustainable yields.

The Colinlea Sandstone comprises predominantly arenaceous sandstone between the coal seams. These sandstone units, becoming more coarse-grained with depth, are recognised to have good groundwater potential. Drilling results indicate yields in the coal of ~ 1 L/s and within the sandstone of 3 to 10 L/s. The Sub-E sandstone has been identified as possible sources of make-good groundwater supplies along the eastern margin of the Galilee Basin.

Joe Joe Group

The Jochmus Formation of the Joe Joe Group is identified to be low permeable strata and the bottom confining unit of the Colinlea Sandstone aquifers and geological basement in the CCP area. A heterogenic clay-rich unit, the Joe Joe Group sediments are understood to be variable but generally considered to have limited groundwater potential.

Drilling undertaken within the Joe Joe Group in the southern area of the CCP and south of the Mine Lease (near Mellaluka Spring Complex) indicate three distinct artesian zones:

- The contact between the Tertiary sediments and Joe Joe Group
- A more permeable sand-rich weathered layer within the Joe Joe Group
- The base of weathering in the Joe Joe Group.

Results of aquifer tests performed from groundwater monitoring wells, inclusive of high potentiometric pressures (artesian conditions), identified variable yield ranges (0.5 to 3.0 L/s) and indicate there is a low permeability hydraulic connection between the three artesian zones within the Joe Joe Group. It is conceptualised, based on location, drilling results, and chemistry (see **Section 2.2.6.3**), that the artesian conditions exist locally and are considered associated with the Belyando River palaeochannels. . The aquifer tests indicate that, with yields of up to 3 l/s, that the Joe Joe Group may be considered as alternate water supply source (in instances of make-good).

Further the first groundwater model revision (to be conducted within 2 years of the box cut excavation) will include Joe Joe Group site specific data as well as the revision of the model layers below the D seam and to the east (as conceptualised in **Section 2.2.6.3**). The refined model will be used to assist in evaluating the suitability of aquifers within the weathered Joe-Joe Group for providing alternative water supplies, relevant to any approval issued under the *Water Act 2000*.

2.2 Hydrogeological Conceptual Model

A conceptual groundwater model is a representation of the behaviour of the groundwater system and its interactions with surface water within the catchment. Development of a conceptual model requires the compilation of detailed information on the geology, water quality, recharge/discharge mechanisms, rivers, springs, water levels, hydraulic parameters, and groundwater usage. The key elements in a conceptual model are:

- The definition of the extent and hydraulic properties of the aquifers and aquitards
- An understanding of the groundwater recharge and discharge processes
- An understanding the groundwater flow directions.

A conceptual groundwater model, which formed the basis of the numerical groundwater model, was developed based on existing information and field data collected for the CCP and surrounding area. These data were utilised as the basis to develop the groundwater monitoring network for the project which has been and will continue to be augmented over time via the adaptive management framework presented in **Section 1.2**.

The original conceptual model has been refined over time with new information. The current understanding of the site's hydrogeological regime is presented in the subsections below which are the result of incorporation of data gathered and assessed since the original model was developed for the EIS/SEIS. This refined conceptual model has been utilised to inform augmentation of the groundwater monitoring network and program and identify data gaps (through various mechanisms such as the GABSRP and the RFCRP) which in turn, will be utilised to update the conceptual understanding for the CCP.

Refinement of the groundwater conceptual model indicates the groundwater regime of the Galilee Basin is complex and varied, particularly along the eastern margin, where the CCP area is located.

2.2.1 Geometry and Structures

Structural features of the Galilee Basin are located primarily along the eastern and western boundaries of the Basin. The Mingobar Monocline and Koburra Trough are in the north-eastern area of the Basin and a series of faults, monoclines, and ridges where the Galilee and Drummond basins intersect.

Geometry of the geological Betts Creek Beds (Triassic aged Bandanna Formation and Colinlea Sandstone) is understood to reflect a series of monoclines and synforms at the basin's western and eastern boundaries. The westernmost extent of these units ends at the Maneroo Platform (metamorphic basement and granitic intrusions) and are pinched out between the contact of the Drummond Basin and the GAB, below the Hulton-Rand Monocline.

On the eastern margin of the basin, where the CCP is located, the stratigraphic units outcrop and subcrop within and adjacent to the MLs. The Dunda Beds and Clematis Sandstone outcrop along the western boundary of the CCP area. The Rewan Formation, Bandanna Formation, Colinlea Sandstone, and Joe Joe Group subcrop within the CCP area. The geometry of the subcrops and outcrops reflect a synform, as depicted in **Plate 5**.

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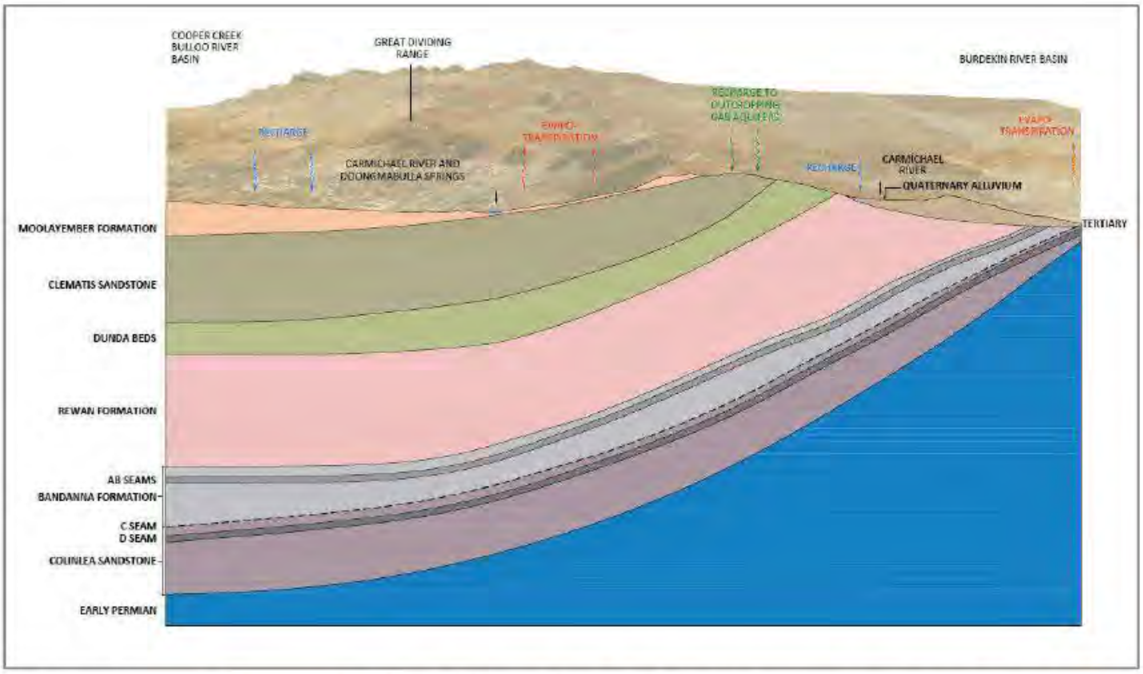

Plate 5 Conceptual Cross-section of the CCP area (Note: Early Permian aged sediments are the Joe Joe Group)

Structurally, there is a general absence of any significant regional faults in the area (Biggs, 2014). There are only four minor faults interpreted within the coal strata, with vertical throws between 20 and 40 m, which trend in a general east-west direction across the CCP area. The four minor faults were recognised because of exploration from a 2-D seismic investigation in 2011 and additional drilling works in 2013 across the project area. These minor faults were limited to the coal strata and not mapped to impact on the overlying units or act as a preferential pathway or compartmentalise the groundwater regime within the CCP area.

An assessment of available groundwater monitoring bore logs and screen depths indicates folding within the CCP footprint where a synform is recognised. The groundwater elevations associated with the deepest installed screens within the different hydrostratigraphic units monitored on site indicate a groundwater 'low' in the centre of the CCP area (as depicted in the groundwater contour figures in **Appendix C**). The axial plane of the synform, based on bore locations, screen depths, and associated groundwater level data, has a northeast to southwest strike. Due to this geometry, the units which overlie the Betts Creeks Beds are similarly influenced, inclusive of the Rewan Group units (Rewan Formation and Dunda Beds) but not the younger Clematis Sandstone (where no similar groundwater low is present). This groundwater 'low' can be observed on the groundwater contour maps (**Appendix C**); groundwater flow direction across the CCP site is observed to flow south/southeast north of the Carmichael River and flow towards the northwest from areas south of the Carmichael River.

While the geometry of the CCP area is considered to influence groundwater elevations onsite, the regional (basin-wide groundwater flow direction for these units) is understood to mirror the dip of the strata from northeast to southwest (except for the Clematis Sandstone), as depicted in the groundwater modelling (GHD, March 2015).

Overall, the hydrostratigraphic heads of each unit influence the groundwater flow direction within the CCP tenements where flow is towards the lowest hydraulic point associated with the deepest portion of the unit (groundwater elevation low observed onsite).

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2.2.2 Groundwater Recharge and Discharge

Each geologic unit's inferred recharge and discharge mechanisms are presented in **Table 7** below.

Table 7 Groundwater Recharge and Discharge Mechanisms

Stratigraphic Unit	Primary Recharge Mechanism	Primary Discharge Mechanism	Comment
Alluvium	• Surface water infiltration, particularly from the Carmichael River • Direct rainfall infiltration • Vertical leakage (upward) from underlying units	• Baseflow to surface water features (i.e. Carmichael River) • Vertical leakage into underlying units • Evapotranspiration	Alluvium, along the Carmichael River, is recognised to be artificially recharged through continuous discharge from the Joshua Spring (artesian flow from the Clematis Sandstone), which is discharged into the Dyllingo Creek, which flows into the Carmichael River.
Tertiary sediments	• Surface water infiltration, particularly along the eastern portion of the site • Rainfall infiltration in outcrop areas • Vertical leakage from overlying alluvium	• Vertical leakage to overlying alluvium • Evapotranspiration • Poorly constructed bores resulting in uncontrolled discharge, forming springs	The Tertiary sediments, particularly overlying the Joe Joe Group, are considered to thicken in the eastern area of the site which results in artesian conditions. Complex multi-storey artesian conditions occur in the Tertiary sediments and Joe Joe Group due to interbedded high and low permeable units.
Moolayember Formation	• Rainfall recharge in outcrop areas (west of the CCP area) • Vertical leakage from the underlying units	• Vertical leakage into overlying Cainozoic sediments and underlying Clematis Sandstone • Recharge reject due to low permeability and storage • Evapotranspiration	Deep weathering and erosional features around the Doongmabulla Springs Complex indicates limited recharge and high runoff across the Moolayember Formation outcrop.
Clematis Sandstone	• Rainfall recharge in outcrop areas (along western boundary of the CCP area)	• Vertical leakage to underlying Dunda Beds and overlying Moolayember Formation (where present) • Evapotranspiration in outcrop areas • Vertical leakage forming the Doongmabulla Spring Complex • Loss through poorly constructed artesian bores	The Clematis Sandstone may be hydraulically connected to Cattle Creek and Dyllingo Creek, which drain across the outcrop.

Stratigraphic Unit	Primary Recharge Mechanism	Primary Discharge Mechanism	Comment
Dunda Beds	• Rainfall recharge in outcrop areas (along western boundary of the CCP area) • Vertical leakage from the overlying units.	• Vertical leakage to underlying and overlying units • Evapotranspiration in the outcrop areas	An alternative conceptualisation is that the Dunda Beds may be a groundwater source of Doongmabulla Spring Complex. This is presented in **Section 2.2.6.2**.
Rewan Formation	• Minor recharge at outcrop	• Minor through flow due to low permeability	The Rewan Formation is, based on site specific data collected, an aquitard where the vertical groundwater gradient above and below the Rewan Formation are upwards above the unit and downwards below the unit (**Section 2.1.3**).
Bandanna Formation (AB Seam)	• Vertical leakage from the underlying units	• Vertical leakage to the more permeable underlying units	The coal seams are the most permeable units within the clay-rich Bandanna Formation.
Colinlea Sandstone (D Seam)	• Vertical leakage from the underlying and overlying units	• Vertical leakage to the more permeable underlying units • Vertical leakage to the overlying units in subcrop areas • Vertical leakage to the Mellaluka Spring Complex	The Colinlea Sandstone was initially considered to be the primary source aquifer for the Mellaluka Spring Complex ; however, additional drilling indicates complex artesian conditions associated with the Tertiary sediments and Joe Joe Group provide discharge to surface around the Mellaluka Spring Complex.
Joe Joe Group	• Vertical leakage from the overlying units, particularly in subcrop areas	• Vertical leakage to the overlying units	Information collected from additional groundwater monitoring bores installed within the Joe Joe Group to the south of Carmichael River suggests a possible hydraulic connection with the Belyando River (palaeochannels). Artesian pressures observed south of the Carmichael River occur where the Tertiary sediments are thicker become sub-artesian north of the river.

Note: The Bandanna Formation and Colinlea Sandstone are referenced as to include the AB Seam (Bandanna Formation) and D Seam (Colinlea Sandstone), the two target coal seams for mining. These coal seams are to be mined and as such will be the most altered (mined and dewatered) during mining, and as such are used as units to assess the potential groundwater impacts of these two Permian aged coal bearing hydrostratigraphic units in the GMMP.

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2.2.3 Regional Groundwater Flow

Subcrops of the Joe Joe Group (Jochmus Formation) and Colinlea Sandstone (in the higher elevation outcrops south of the town of Alpha), along the eastern margin of the Galilee Basin are recognised on a regional scale to result in the regional groundwater flow direction as northwards.

Figure 6 depicts the groundwater flow patterns within the Colinlea Sandstone of the eastern edge of the Galilee Basin.

2.2.4 Aquifer Hydraulic Properties

Multiple groundwater investigations have been undertaken within and near the CCP area from 2011 through 2018 to characterise the hydraulic regime of the site. Outcomes of each investigation were utilised to inform the augmentation of the groundwater monitoring network.

Hydraulic parameters were estimated from various investigations onsite via packer tests, aquifer pump tests, and falling head tests, in addition to air lift yields during new monitoring bore development. The results of these investigations were compiled to assist in estimating site-specific hydraulic properties, which are applied in the numerical groundwater model. The aquifer hydraulic conductivity data plus summary of studies are presented in **Table 8** below.

Comments on the original model were considered and resulted in expansion of the numerical model domain towards the west of the hydraulic divide (**Plate 12**, **Section 2.3**), to incorporate a portion of the Lake Galilee catchment; the model was then re-run to understand any potential impacts on the GAB units from the CCP. Details of the revised model are included in the AEIS (GHD, 2013a), and the Response to Federal Approval Conditions - Groundwater Flow Model (GHD, 2015). While summarised in this GMMP (**Section 2.3**), it is recommended to review the reports referenced above for further information in this regard.

The model re-run (GHD, 2015) adopted the hydraulic values from those included in the SEIS and AEIS apart from the expanded model domain, west of the CCP area to incorporate a portion of the Lake Galilee catchment. Further information in regard to the model re-run works is presented in **Section 2.3** below.

Aquifer hydraulic tests were undertaken by AECOM in 2015 to gain an understanding of the potential for groundwater sources for construction purposes within the Tertiary sediments and underlying Early Permian aged Joe Joe Group to the east and south of the CCP. Results of the aquifer hydraulic tests indicate limited hydraulic connectivity between the Tertiary sediments and underlying Joe Joe Group. It is noted that to the south of the Carmichael River artesian conditions are observed.

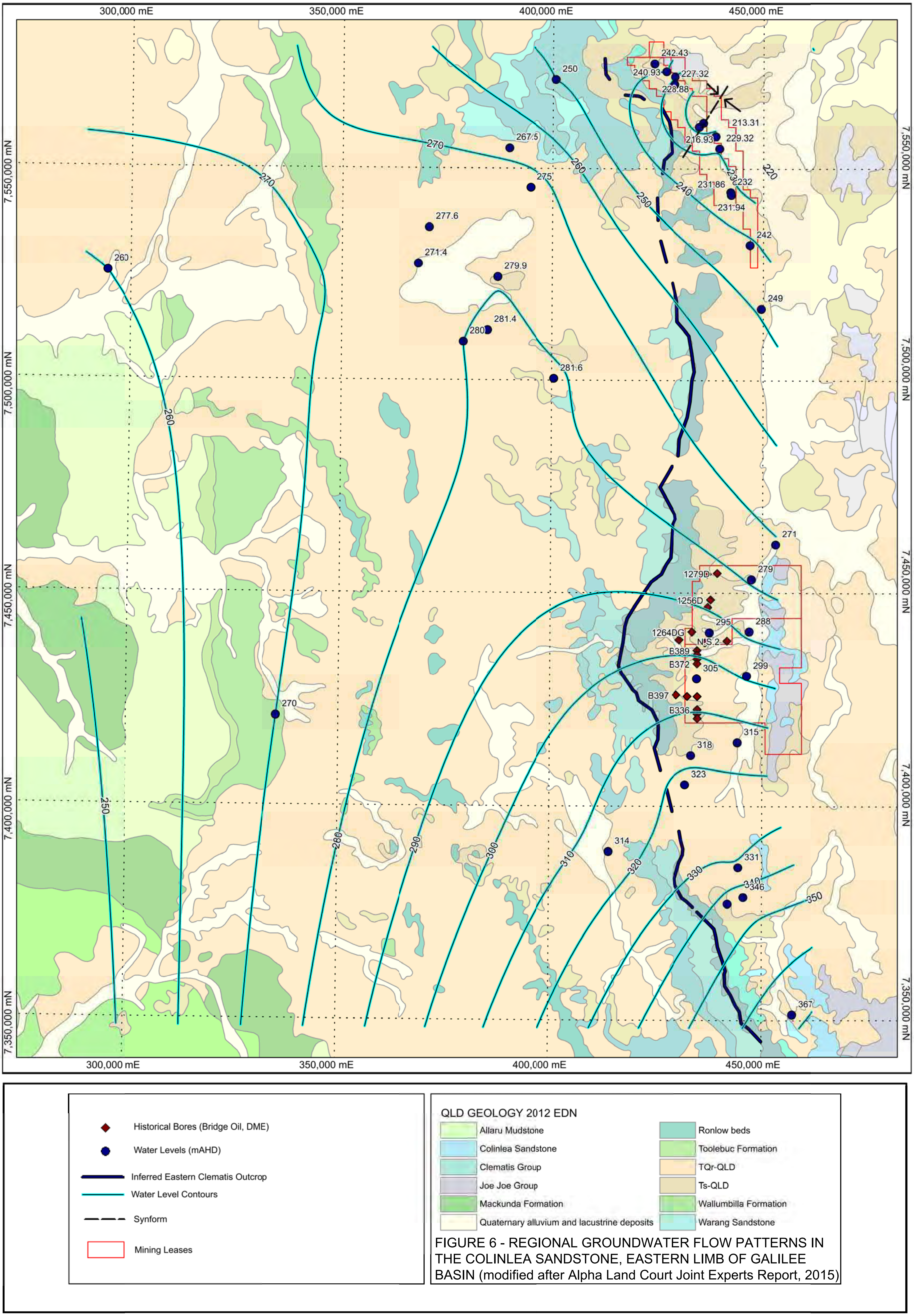

FIGURE 6 - REGIONAL GROUNDWATER FLOW PATTERNS IN THE COLINLEA SANDSTONE, EASTERN LIMB OF GALILEE BASIN (modified after Alpha Land Court Joint Experts Report, 2015)

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Table 8 Estimates of Hydraulic Properties of Aquifers within the CCP Area

Hydrostratigraphic Unit	Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
Alluvium	C027P1	Alluvium (sand with gravel)	SEIS	2.5×10^{-02}	Slug test result
	C029P1	Alluvium (sand and clayey sand)	SEIS	1.4×10^{-01}	Slug test result
	HD03B	Alluvium (clay)	SEIS	1.1 x 10	Slug test result
	Layer 1	Quaternary	AEIS	$2.0 \times 10^{+01}$	Calibrated value for numerical model (result from sensitivity analysis)
Tertiary sediments	C025P2	Tertiary sediments (leached, fine grained rock)	SEIS	1.7×10^{-01}	Slug test result
	C029P2	Tertiary sediments (ferricrete / laterite)	SEIS	5.3×10^{-02}	Slug test result
	C558P1	Tertiary sediments and Permian aged overburden (sandy clay)	SEIS	2.1×10^{-04}	Slug test result
	Layer 2	Tertiary sediments	AEIS	1.0×10^{-02}	Calibrated value for numerical model (result from sensitivity analysis)
	Layer 2	Tertiary aged deposits and older Quaternary aged deposits	Model re-run	1×10^{-02}	Western model region (Lake Galilee catchment expansion to numerical model)
Moolayember Formation	Layer 3	Moolayember Formation	Model re-run	5.18×10^{-02}	Western model region (Lake Galilee catchment expansion to numerical model)
	Layer 3	Moolayember Formation	AEIS	5.18×10^{-02}	Calibrated value for numerical model (result from sensitivity analysis)

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Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
Clematis Sandstone		HD02	Clematis Sandstone	SEIS	$1.5 \times 10^{+01}$	Slug test result
		Layer 4	Clematis Sandstone	AEIS	1.6×10^{0}	Calibrated value for numerical model (result from sensitivity analysis)
		Layer 4	Clematis Sandstone	Model re-run	1.55×10^{0}	Western model region (Lake Galilee catchment expansion to numerical model)
		C14201VWP	Clematis Sandstone	Groundwater monitoring network expansion 2014	1.0×10^{-02}	Packer test result (median value)
		C14205VWP	Clematis Sandstone	Groundwater monitoring network expansion 2014	1.0×10^{-02}	Packer test result
Rewan Group	Dunda Beds	C022P1	Dunda Beds (weathered sandstone)	SEIS	3.0×10^{0}	Slug test result
	Dunda Beds	C027P2	Dunda Beds (ferricrete)	SEIS	2.5×10^{-01}	Slug test result
	Dunda Beds	C9553P1R	Dunda Beds (clayey sand)	SEIS	2.2×10^{-03}	Slug test result
	Dunda Beds	Layer 5	Dunda Beds	Model re-run	7.9×10^{-02}	Western model region (Lake Galilee catchment expansion to numerical model)
	Dunda Beds	Layer 5	Dunda Beds	AEIS	7.9×10^{-2}	Calibrated value for numerical model (result from sensitivity analysis)
	Rewan Group	C035P1	Rewan Group (weathered sandstone)	SEIS	2.3×10^{-02}	Slug test result

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Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
	Rewan Group	C555P1	Rewan Group (sandy clay)	SEIS	1.0×10^{-01}	Slug test result
	Rewan Group	C556P1	Rewan Group (sandy clay)	AEIS	2.9×10^{-01}	Slug test result
	Rewan Group	Layers 6/7	Rewan Group	AEIS	7.4×10^{-05}	Calibrated value for numerical model (result from sensitivity analysis)
	Rewan Group	C008P1	Rewan Group (weathered siltstone)	SEIS	2.3×10^{-03}	Slug test result
	Rewan Group	C842VWP	Rewan Group - interbedded siltstone and sandstone	Packer test 2013	9.50×10^{-5}	Packer test result
	Rewan Group	C836VWP	Rewan Group - Siltstone/ mudstone below base of weathering	Packer test 2013	3.72×10^{-4}	Packer test result
	Rewan Group	C836VWP	Rewan Group - siltstone (below base of weathering- no sandstone)	Packer test 2013	2.42×10^{-4}	Packer test result
	Rewan Group	C056 Test 9	Base of Rewan Group (siltstone, fractured)	SEIS	1.7×10^{-04}	Packer test result
	Rewan Group	C9556PR Test 6	Rewan Group (sandstone and siltstone)	SEIS	2.3×10^{-04}	Packer test result
	Rewan Group	C842VWP Test 5	Rewan Group (sandstone and siltstone)	SEIS	9.5×10^{-05}	Packer test result
	Rewan Group	C836VWP Test 5	Rewan Group (siltstone and mudstone)	SEIS	3.7×10^{-04}	Packer test result
	Rewan Group	C836VWP Test 6	Rewan Group (siltstone and mudstone)	SEIS	2.4×10^{-04}	Packer test result

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Hydrostratigraphic Unit	Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
Rewan Fm	C14202VWP (Site 17 Rewan #3)	Rewan Formation	Groundwater monitoring network expansion 2014	4.0×10^{-04}	Packer test result (median value from 16 3-minute tests)
Rewan Fm	C14202VWP (Site 17 Rewan #2)	Rewan Formation	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result (median value from 18 3-minute tests)
Rewan Fm	C14202VWP (Site 17 Rewan #1)	Rewan Formation	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result (median value from 18 3-minute tests)
Rewan Fm	C14201VWP (Site 18 Rewan #1)	Rewan Formation	Groundwater monitoring network expansion 2014	1.0×10^{-03}	Packer test result (median value from 26 2-minute tests)
Rewan Fm	C14201VWP (Site 18 Rewan #2)	Rewan Formation	Groundwater monitoring network expansion 2014	3.0×10^{-04}	Packer test result (median value from 18 3-minute tests)
Rewan Fm	C14201VWP (Site 18 Rewan #3)	Rewan Formation	Groundwater monitoring network expansion 2014	7.0×10^{-05}	Packer test result (median value from 17 3-minute tests)
Rewan Fm	C14201VWP (Site 18 Rewan #4)	Rewan Formation	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result (median value from 20 3-minute tests)

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Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
	Rewan Fm	C14201VWP (Site 18 Rewan #5)	Rewan Formation	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result (median value from 18 3-minute tests)
	Rewan Fm	C14205VWP (Site 18)	Rewan Formation – claystone and minor siltstone (top of Rewan Formation)	Groundwater monitoring network expansion 2014	1.1×10^{-03}	Packer test result
	Rewan Fm	C14205VWP (Site 18)	Rewan Formation – interbedded fine-grained sandstone and claystone (upper section of Rewan Formation)	Groundwater monitoring network expansion 2014	3.0×10^{-04}	Packer test result
	Rewan Fm	C14205VWP (Site 18)	Rewan Formation –claystone (middle section of Rewan Formation)	Groundwater monitoring network expansion 2014	7.0×10^{-05}	Packer test result
	Rewan Fm	C14205VWP (Site 18)	Rewan Formation – siltstone with minor claystone (lower section of Rewan Formation)	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result
	Rewan Fm	C14204VWP (Site 17)	Rewan Formation – interbedded siltstone and claystone (top section of Rewan Formation)	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result
	Rewan Fm	C14204VWP (Site 17)	Rewan Formation – claystone with minor siltstone (top section of Rewan Formation)	Groundwater monitoring network expansion 2014	2.0×10^{-04}	Packer test result

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Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
	Rewan Fm	C14204VWP (Site 17)	Rewan Formation –siltstone (middle section of Rewan Formation)	Groundwater monitoring network expansion 2014	4.0×10^{-04}	Packer test result
	Rewan Fm	C14204VWP (Site 17)	Rewan Formation –siltstone (top section of Rewan Formation)	Groundwater monitoring network expansion 2014	7.0×10^{-04}	Packer test result
	Rewan Fm	Lake Galilee catchment	Rewan Formation	Model re-run	7.38×10^{-5}	-
Betts Creek Beds	Bandanna Fm (AB Seam)	C007P2	AB Seam	SEIS	5.6×10^{-02}	Slug test result
		C016P2	AB Seam (coal and carbonaceous siltstone)	SEIS	4.0×10^{-03}	Slug test result
		C056 Test 1	AB1/AB2 coal seams	SEIS	1.7×10^{-02}	Packer test result
		C056 Test 2	AB3 coal seam	SEIS	1.2×10^{-02}	Packer test result
		C039 Test 1	AB3 seam lower split (coal)	SEIS	5.4×10^{-04}	Packer test result
		C039 Test 2	AB3 seam upper split (coal)	SEIS	1.4×10^{-04}	Packer test result
		C558P Test 6	AB2/AB3 seams (coal)	SEIS	1.4×10^{-02}	Packer test result
		C555P Test 4	AB Seam (coal)	SEIS	1.2×10^{-03}	Packer test result
		C9556PR Test 4	AB Seam (coal)	SEIS	1.5×10^{-04}	Packer test result
		C842VWP Test 2	AB1 to AB3 (coal)	SEIS	2.8×10^{-03}	Packer test result
		C836VWP Test 3	AB2/AB3 (coal)	SEIS	4.8×10^{-02}	Packer test result
		C035[1]	AB Seam	SEIS	3.5 x 10	Slug test results

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Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
		Layer 9	AB coal seam	AEIS	1.9×10^{-03}	Calibrated value for numerical model (result from sensitivity analysis)
		Layer 9	AB Seam coal	Model re-run	1.0×10^{-04}	Western model region (Lake Galilee catchment expansion to numerical model)
	Colinlea Sandstone (D Seam)	C558P Test 2	D Seam (coal)	SEIS	1.6×10^{-02}	Packer test result
		C558P Test 3	D Seam and below D Seam (coal and sandstone)	SEIS	8.7×10^{-03}	Packer test result
		C007P3	D Seam (coal with siltstone)	SEIS	6.9×10^{-02}	Slug test result
		C056 Test 4	D Seam and interburden (coal, siltstone, sandstone)	SEIS	5.6×10^{-03}	Packer test result
		C555P Test 2	D1/D2 seams (coal and siltstone)	SEIS	2.8×10^{-03}	Packer test result
		C9556PR Test 2	D Seam (coal)	SEIS	1.3×10^{-04}	Packer test result
		C9556PR Test 3	Interburden to below D Seam (sandstone and coal)	SEIS	1.3×10^{-03}	Packer test result
		C851VWP Test 4	D Seam (coal)	SEIS	9.5×10^{-03}	Packer test result
		C006[2]	D Seam	SEIS	2.0×10^{-01}	Pump test results
		C018[3]	D Seam	SEIS	1.0×10^{-01}	Pump test results
		Layer 11	D Coal Seams	AEIS	3.1×10^{-03}	Calibrated value for numerical model (result from sensitivity analysis)
		Layer 11	D Seam coal and interburden	Model re-run	1.0×10^{-04}	Western model region (Lake Galilee catchment expansion to numerical model)

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Hydrostratigraphic Unit		Monitoring Point	Lithology description	Investigation type and period	Estimated horizontal hydraulic conductivity (m/day)	Comments
Joe Joe Group	Jochmus Fm	C012P1	Joe Joe Group (weathered sandstone and siltstone)	SEIS	4.1×10^{-01}	Slug test result
		C012P2	Joe Joe Group (weathered sandstone)	SEIS	2.5×10^{-03}	Slug test result
		C9556PR Test 5	Permian overburden (sandstone)	SEIS	2.3×10^{-04}	Packer test result
		C842VWP Test 3	Permian overburden (sandstone and siltstone)	SEIS	3.5×10^{-03}	Packer test result
		C842VWP Test 4	Permian overburden (sandstone)	SEIS	4.8×10^{-04}	Packer test result
		C836VWP Test 4	Permian overburden (sandstone)	SEIS	9.5×10^{-04}	Packer test result
		Layer 12	Older Permian units	AEIS	3.6×10^{-04}	Calibrated value for numerical model (result from sensitivity analysis)

Notes:
[1] The estimated storativity for C035 is 0.005 and transmissivity is 60 m^2/day
[2] The estimated storativity for C006 is 0.005 and transmissivity is 12 m^2/day
[3] The estimated storativity for C018 is 0.001 and transmissivity is 9 m^2/day

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2.2.5 Local (site-specific) Groundwater Flow Patterns

The groundwater monitoring results indicate complex groundwater flow patterns within the different hydrostratigraphic units across and adjacent to the CCP MLs. The groundwater flow patterns have been interpreted, as discussed above (see **Section 2.2.1**), to include a groundwater low, corresponding with the deepest portions of the hydrostratigraphic units of the CCP area, where the synform axial plane trends from northeast to southwest across the CCP footprint. The units observed to be influenced by the synform observed in the groundwater flow patterns include Dunda Beds, Rewan Formation, Permian sediments of the Colinlea Sandstone (D Seam), and the Early Permian aged Joe Joe Group. The younger Clematis Sandstone does not indicate the same fold influence on groundwater flow in this unit. No monitoring bore intersecting the Bandanna Formation AB seam is located within the synform.

In addition to the localised (CCP scale) groundwater flow in line with the synform, groundwater flow direction is also considered to:

- Either flow to the southwest (down dip) mimicking the regional basin-scale flow from subcrop in the northeast down dip to the southwest, or
- Discharge into overlying / underlying units (depending on vertical gradients) and discharge to the northeast, as is possible when considering the regional and local Colinlea Sandstone contours in **Figure 6**.

It is noted that additional flow trend analysis off lease is required to assess larger basin scale flow.

The local pre-mining inferred groundwater flow directions are depicted by unit on Figures F1 through F8 (**Appendix C**) and discussed below.

NOTES:

The groundwater contours generated utilised groundwater levels measured within the stand pipe monitoring bores only. No vibrating wire piezometer (VWP) data was used as the VWP sensors provide total pressure (formation, water, and [possible] gas) at a single point (sensor point) within the selected unit. VWP data is used for assessing predicted groundwater level (drawdown) trends as discussed in **Section 5.3** (thresholds).

The AB Seam and the D Seam units of the Bandanna Formation and Colinlea Sandstone, respectively have been selected to represent these Permian aged coal bearing units. This is done as the target coals have a good spatial spread of groundwater monitoring bores (along strike and down dip) and as target coal seams will be directly impacted by mining (allowing for assessment in the compilation of the GMMP).

Groundwater contours were created by Adani using krigging and edited by AECOM based on geological extent and subcrops.

2.2.5.1 Alluvium

Average groundwater level data (**Table 9**) were used to generate the groundwater contours within the alluvium. Groundwater flow in this surficial unit mimics topography and surface water and flows from west to east across CCP (**Figure F1 Appendix C**).

Table 9 Average Alluvium Groundwater Levels

Bore ID	Average groundwater level (mAHD)
C025P1	216.72
C027P1	223.84
C029P1	214.77
C14027SP	203.58
C14028SP	205.46
HD03B	225.47

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2.2.5.2 Tertiary Sediments

Groundwater flow within the Tertiary sediments across the CCP is from south to north (**Figure F2 Appendix C**), based on the average groundwater level data included in **Table 10**.

Table 10 Average Groundwater Levels in the Tertiary Sediments

Bore	Average Groundwater Level (mAHD)
C025P2	217.62
C029P2	220.00
C558P1	216.02
C9845SPR	234.91
C9180121SPR	244.47

2.2.5.3 Clematis Sandstone

The groundwater flow pattern, using groundwater level data from the new (September 2018) monitoring bores in the Clematis Sandstone around the Doongmabulla Spring Complex, indicates complex groundwater flow (**Figure F3 Appendix C**).

Table 11 includes the groundwater levels measured in September 2018 after several additional groundwater monitoring bores had been constructed around the Doongmabulla Spring Complex.

The groundwater flow patterns are towards HD02, which indicates discharge at the springs and as baseflow in this area.

Table 11 Clematis Sandstone Groundwater Levels (September 2018)[3]

Bore ID	Water Level (mAHD)	Comment
C14033SP	250.52	
C180118SP	250.17	Note: last reading measured before blocked bore
C14011SP	242.77	
C14012SP	242.53	
C14013SP	242.46	
C18002SP	242.55	
Joshua Spring	241.20 (243.26)	Floor of spring (top of turkey's nest)
C14021SP	245.93	
C18001SP	249.77	
DS4 Mound Spring	241 (EIS survey)	Elevation of specific spring DS4
HD02	233.88	Average groundwater level is 234.28 mAHD
HD03A	231.76	Artesian average potentiometric level is 232.03 mAHD

2.2.5.4 Dunda Beds

Groundwater flow within the Dunda Beds, on and adjacent to the CCP mine leases, is considered to be influenced by the synform. Groundwater flow is from south to north and north to south towards C027P2, located within the synform (**Figure F4 Appendix C**).

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[3] Only one groundwater level reading is available for all the new 2018 monitoring bores, such that average groundwater levels were not used for Clematis Sandstone

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Average groundwater levels for the Dunda Beds, obtained from hydrographs in **Appendix E**, are included in **Table 12**.

Table 12 Average Groundwater Levels for the Dunda Beds

Bore	Average Groundwater Levels (mAHD)
C022P1	246.66
C027P2	226.90
C14023SP	247.26
C180117SP	251.02

2.2.5.5 Rewan Formation

Average groundwater level data, **Table 13**, was used to generate groundwater contours for the Rewan Formation across the CCP. Groundwater flow in this unit is influenced by the synform, where groundwater flow from north to south and south to north occurs towards C008P1 (**Figure F5 Appendix C**).

Table 13 Average Groundwater Levels for the Rewan Formation

Bore	Average Groundwater Levels (mAHD)
C008P1	211.80
C035P1	231.89
C555P1	230.02
C556P1	234.84
C9553P1R	252.26
C9838SPR	228.74
C180116SP	239.12

It is noted that bore C035P1 has a slightly lower than expected average groundwater level when considering the other bores in the southern area of CCP. Groundwater level data, since 2013, is recognised to have declined overtime (resulting in the lower than envisaged average groundwater level). This declining trend has influenced groundwater levels in this area. It is currently considered that this trend is related to local groundwater abstraction (south of Carmichael River on the Lignum property) or as a result of groundwater sampling (extraction) over time with little or no recharge in the low permeable Rewan Formation. It is noted that this bore is located in the southern portion of the mine lease and away from the synform recognised to the north of the Carmichael River, which is recognised to influence groundwater levels and flow patterns.

Data from monitoring bore C555P1 is considered based on the resultant hydrograph to be inconsistent with the groundwater flow pattern. This is considered to occur due to erratic logger data recorded since July 2016 (**Appendix E**). The logger will be replaced as per the approval conditions (EA Condition E16), which relates to the maintenance of the groundwater monitoring network.

It is noted that Adani is committed to maintaining and the decommission of bores, according to industry standards, to ensure the management of groundwater resources and obtaining representative groundwater monitoring data.

2.2.5.6 Bandanna Formation (AB Seam)

Average groundwater level data, as compiled in **Appendix E** hydrographs, were used to generate average groundwater flow patterns of the target AB Seam within the CCP mine leases. **Figure F6** (**Appendix C**) presents the result groundwater contours for the data included in **Table 14**.

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Table 14 Bandanna Formation AB Seam Average Groundwater Levels

Bore ID	Average groundwater level (mAHD)
C007P2	212.38
C008P2	213.40
C014P2	209.21
C016P2	248.50
C020P2	220.92
C032P2	233.27
C035P2	232.68

The lowest measured groundwater level within the Bandanna Formation AB seam is located at C014P2, where groundwater flow is from the south and from the north towards the groundwater low. It is noted that bore C014P2 is not within the recognised synform included on **Figure F6** (**Appendix C**), this may be as a result of undulating coal seams within the Bandanna Formation and the absence of an AB seam groundwater monitoring bore along the synform axis.

2.2.5.7 Colinlea Sandstone (D Seam)

Groundwater level contours within the target D Seam across the CCP are influenced by the recognised synform, where groundwater flow is towards monitoring bore C006P3R. Groundwater monitoring bore C006P3R intersects a hydraulic low within the D Seam (**Figure F7 Appendix C**).

Average groundwater levels, used to contour the groundwater flow patterns with the Colinlea Sandstone D Seam, are included in **Table 15**.

Table 15 Colinlea Sandstone D Seam Average Groundwater Levels

Bore ID	Average Groundwater Level (mAHD)
C006P3R	213.28
C007P3	216.93
C011P3	227.32
C018P3	242.43
C024P3	228.88
C833SP	228.28
C848SP	231.91
C975SP	240.99
C9849SPR	231.88
C180114SP	223.00

Groundwater flow, from north and south with the CCP MLs, is recognised as per the regional flow patterns in **Figure 6**. It is noted that the synform, influencing the local groundwater flow does not coincide with the Doongmabulla Springs Complex, which indicates that Permian sediments are not readily recognisable as a source of flow to the springs based on groundwater flow patterns.

2.2.5.8 Joe Joe Group

Groundwater flow contours across the CCP mine leases were generated using the average groundwater levels from the monitoring bores included in **Table 16**.

Table 16 Average Groundwater Levels for the Joe Joe Group at CCP

Bore	Average Groundwater Levels (mAHD)
C012P1	221.33
C012P2	221.32
C14002SP	218.75
C14003SP	209.37
C14004SP	209.44
C14006SP	226.03
C14008SP	228.34
C14016SP	234.13
C914001SPR	218.47

Groundwater flow is recognised to be influenced by the synform across the CCP footprint, where groundwater within the Joe Joe Group flows towards monitoring bores C14003SP and C14004SP, as depicted in **Figure F8a** (**Appendix C**).

Additional assessment of artesian groundwater potentiometric levels was conducted, where several groundwater monitoring bores were installed around the Mellaluka Springs Complex. The average groundwater levels within this area are included in **Table 17** below and presented along with corresponding monitoring locations on **Figure F8b** (**Appendix C**).

Table 17 Average Groundwater Levels for the Joe Joe Group at Mellaluka Springs Complex

Bore	Average Groundwater Levels (mAHD)
C14014SP	”239.32” – landholder is utilising this monitoring bore
C14015SP	239.15
C14017SP	248.26
C14032SP	233.69
C914030SPR	230.25
C180119SP	238.21
C180123SP	246.35
C9180124SPR	235.31
C9180125SPR	243.10
Mellaluka Spring	228 (surface elevation)

Groundwater flow within the Joe Joe Group is from south to north along the eastern edge of the Galilee Basin, the flow is recognised in **Figure F8b (Appendix C)**, except for the local change in flow pattern because of discharge at the Mellaluka Spring.

Continuous discharge at the Mellaluka Spring plus extraction at the Mellaluka homestead (**Section 3.5.4**) is recognised to have influenced regional south to north flow at the Mellaluka Spring.

2.2.5.9 Observations and Discussion

In the area east of the mine leases and to the south of the Carmichael River, where the Tertiary sediments thicken above the Joe Joe Group, a multi-storey artesian aquifer system is inferred. In this area, the Tertiary sediments increase in thickness and directly overlie the Joe Joe Group.

This artesian system, based on measured piezometeric pressures and interbedded aquifers and aquitards, is considered to dictate the vertical groundwater flow direction within these units, as

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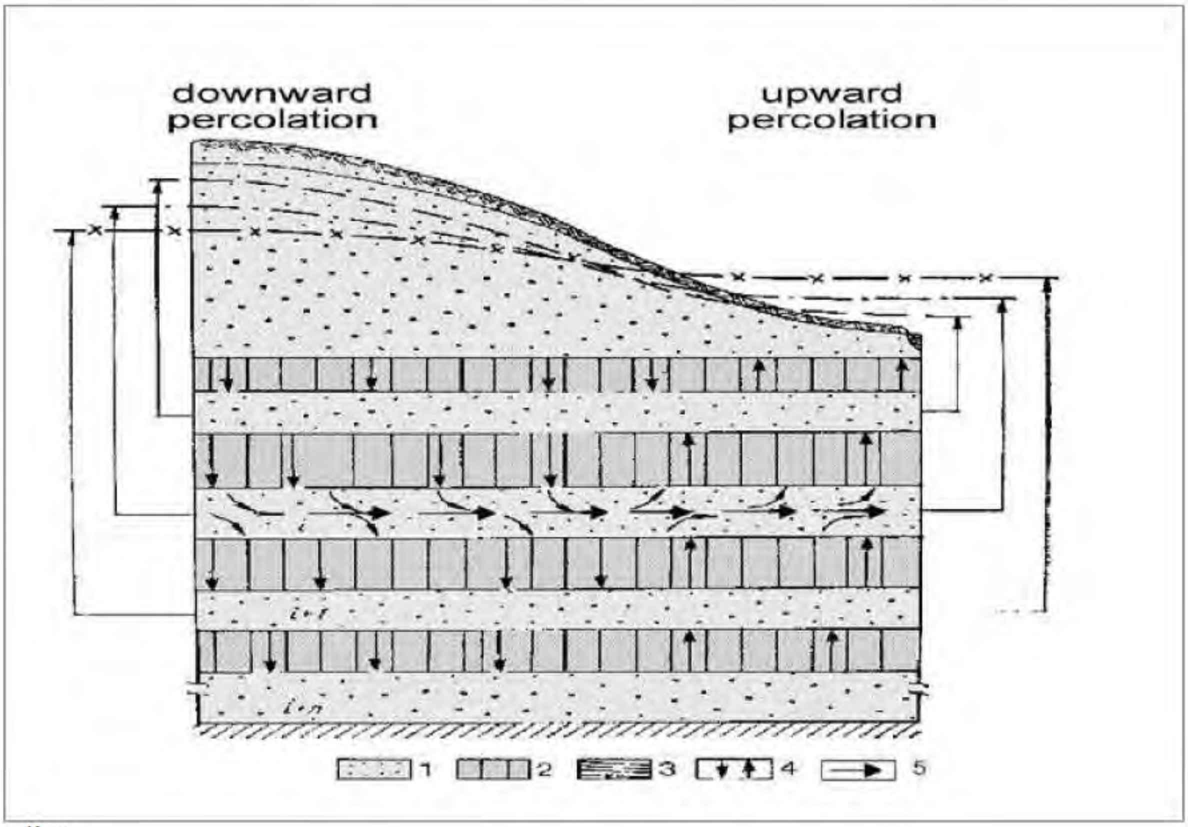
depicted in **Plate 6** below (i.e. in the various nested monitoring bores constructed around the Mellaluka Spring vertical gradients are recognised as both upward and downward in this area).



Key:
1 = aquifers
2 = confining bed
3 = potentiometric levels of the aquifers
4 = directions of transverse groundwater flow
5 = directions of lateral flow

Plate 6 Example of multi-storey artesian aquifer system and resultant flow patterns (from Shestopalov, 1989)

It is noted that artesian conditions only occur south of the Carmichael River in the Tertiary sediments and Joe Joe Group, as sub-artesian conditions have been measured north of the Carmichael River. The extent of connectivity between the Tertiary sediments, Joe Joe Group, and the Belyando River are not yet fully understood.

The groundwater within Quaternary aged alluvium across the CCP area is observed to flow from west to east (seasonally dependent), along the Carmichael River. The continuous discharge from Joshua Spring into the Dyllingo Creek, which flows into the Carmichael River, results in flow from west to east. Flow in the Carmichael River is non-perennial with distance from the spring source, as surface water discharges to groundwater. Groundwater levels (and chemistry) are more seasonally varied to the east.

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2.2.6 Springs

Two recognised spring complexes are located within proximity to the CCP MLs; details of each are presented in the subsections below.

2.2.6.1 Doongmabulla Spring Complex

The Doongmabulla Springs Complex (DSC) comprises a series of mound (wetland) springs approximately eight (8) km to the west of the mine leases, as depicted in **Figure 7** below. Drilling results and Clematis Sandstone groundwater level contours (**Figure F3**, **Appendix C**) indicate the source of the mound springs is discharge from the artesian Clematis Sandstone through weathered Moolayember Formation.

Table 11 (Section 2.2.5.3) above provides a summary of Clematis Sandstone monitoring bores and groundwater level data used to develop the conceptualisation.

Groundwater levels in the Clematis Sandstone groundwater monitoring bores HD02 and HD03A are considered to be influenced by Clematis Sandstone baseflow into the Carmichael River and discharge from the springs (i.e. these bores are down gradient of the springs (**Figure F3 Appendix C**)).

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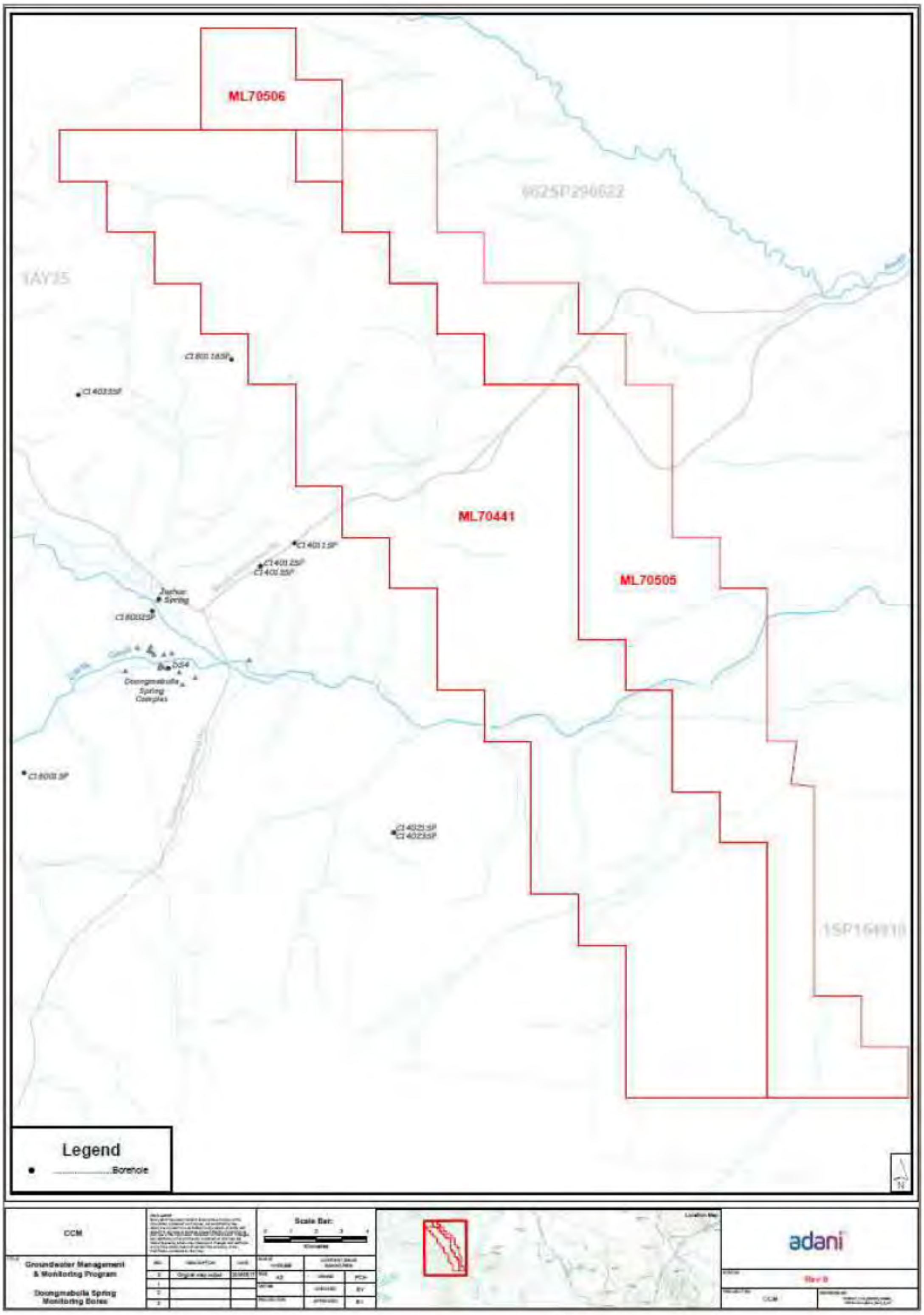

Figure 7 Doongmabulla Springs Complex in proximity to the CCP

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The data **Table 11 (Section 2.2.5.3)** indicates groundwater levels in the Clematis Sandstone, measured adjacent (west) of the MLs, are consistently above 243 mAHD away from the Carmichael River. Where weathered (thinning and more porous) Moolayember Formation cover is present at elevations lower than 243 mAHD, the spring discharges are observed.

Figure 8 presents the conceptualisation of the Doongmabulla Springs Complex, like the wetlands springs of the Surat Basin. In this conceptualisation, the Moolayember Formation is represented by the confining layer and the Clematis Sandstone is represented by the sandstone aquifer in **Figure 8.**

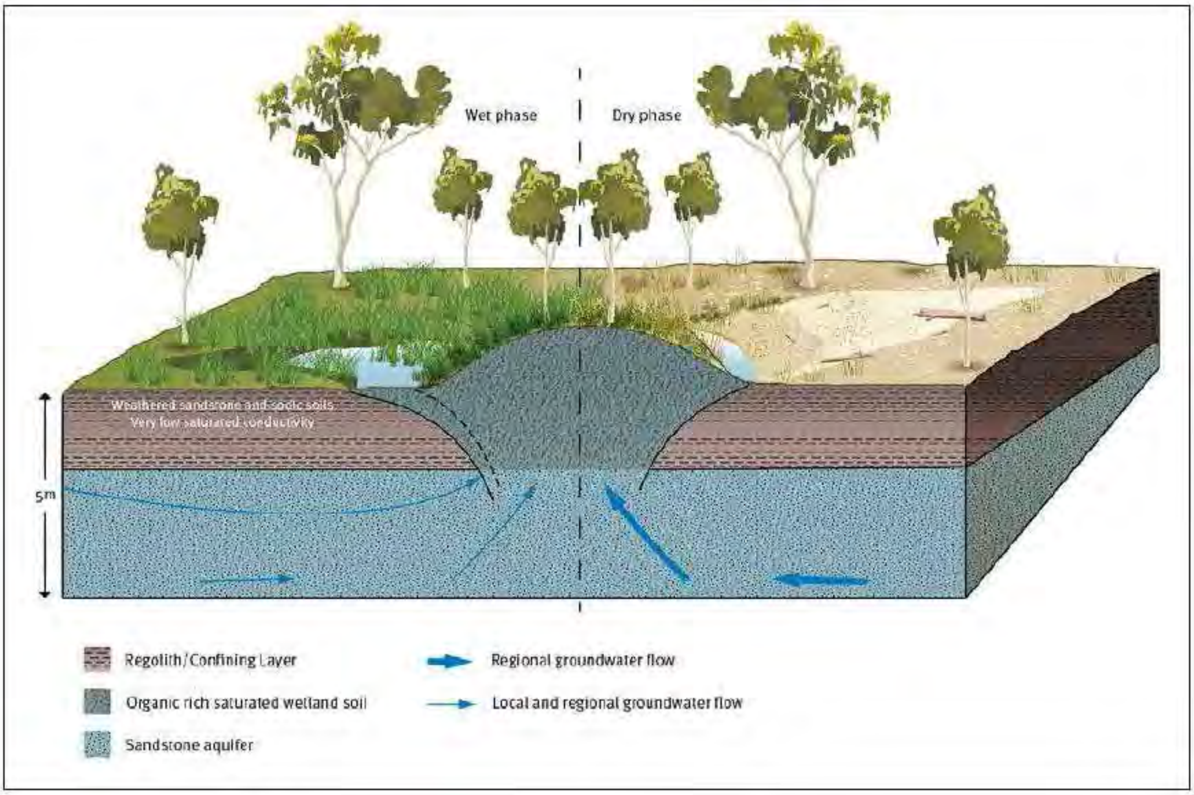

Figure 8 Conceptualisation of the Doongmabulla Springs Complex (source: DNRM Springs of the Surat CMA, 2016)

It is noted that, from drilling in 2014 along a south to north traverse parallel to the CCP MLs western boundary, the Moolayember Formation is absent to the south of the springs. The unit increases in thickness with distance to the north (refer to Section 1 on **Plate 7** below), where:

- C14204SP does not intersect Moolayember Formation (intersecting Dunda Beds close to surface surface)
- Former location C14024VWP (now C14206VWP) intersects a thin veneer of Clematis Sandstone (~ 47 m)
- Schoemaker-1 exploration bore intersects 78 m of Moolayember Formation and 119 m of Clematis Sandstone
- C14025VWP (collapsed)[4] intersected 142 m of Moolayember Formation and 218 m of Clematis Sandstone.

The springs occur where the Moolayember Formation is sufficient thick and (low) permeable to act as a confining layer yet sufficiently thin to facilitate discharge. The absence to the south and thickness to the north result in reducing the extent or development of the Doongmabulla Springs Complex springs.

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[4] See Section 2.1.1 for detail on swelling clays.

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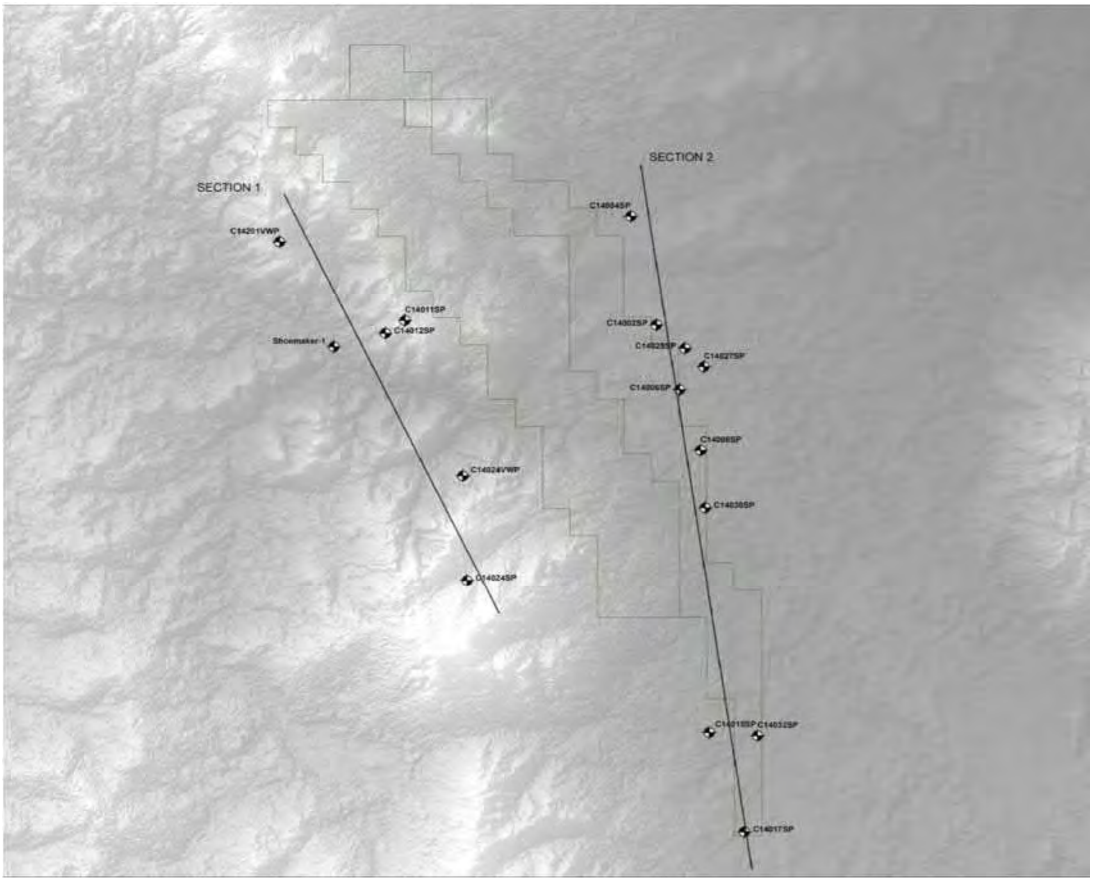

Plate 7 Geological traverse (bores drilled in 2014)

2.2.6.2 Alternative Conceptualisation for the Doongmabulla Spring Complex

The source aquifer for the DSC is, based on groundwater quality (salinity), geology (confining layers), and groundwater level data, was identified as the Clematis Sandstone. This has been included in the EIS documents, predictive modelling, and validated during the Land Court proceedings (independent model reviews). However, alternative sources for the springs have been offered, including:

- Alternative water source aquifers for the DSC, discussed in the Land Court of Queensland was "either the Clematis or the Colinlea may be the source".
- The Lake Eyre Basin Springs Assessment (LEBSA) Project (The Department of Science, Information Technology and Innovation, 2016), has considered an alternative source aquifer for DSC being the Permian sediments. This alternative scenario was suggested by Dr John Webb during the land court proceedings that groundwater from the Permian provides discharge, via a fault or fracture through the Rewan Formation and Dunda Beds, as springs on surface.

Consideration of drilling results, vertical groundwater gradients, and water quality data allowed for assessment of the alternative source (Permian age) conceptualisation.

Considerations included:

- Drilling results, including the difficulties in construction of the standpipe groundwater monitoring bores within the Rewan Formation due to swelling clays (smectite), along with aquifer test results (**Table 8** above), indicate that the potential for faults to occur and remain open within the approximately 250 m thick Rewan Formation are negligible.
- Surface outcrop adjacent to the mound springs comprises multi-coloured (white and purple-rust) clay-rich weathered Moolayember Formation sediments; no marked changes in elevation (fault throw) or outcrop is apparent in the springs area, as presented in **Plate 8** below.

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- Groundwater levels indicate that the vertical groundwater gradients are upward above the Rewan Formation and downward below the Rewan Formation (see **Table 18** below which provides a summary based on groundwater contour data); this indicates the source of the Doongmabulla Springs Complex is above the Rewan Formation.

Plate 8 Weathered Moolayember Formation outcrop near the Doongmabulla mound springs

Table 18 Groundwater Level Elevation Data (North, Mid, and South across the CCP area)

Hydrostratigraphic Unit	North (mAHD)	Mid (mAHD)	South (mAHD)
Moolayember Formation	252.43	236.50	ND
Clematis Sandstone	250.75	242	247.22
Dunda Beds	246.73	247	250.94
Rewan Formation	252.26	230	239.47
Bandanna Formation (AB Seam)	248.55	212	233.00
Colinlea Sandstone (D Seam)	242.43	217	231.94
Joe Joe Group	221.39	226	234.13

Notes:
ND – Not determined

- Groundwater quality at Joshua Spring is fresh, recently recharged groundwater, where electrical conductivity (EC) is measured at 558 microSiemens per centimetre (µS/cm) in September 2018, albeit this location is a pond/dam where water quality is influenced by rainfall, evaporation, and evapotranspiration.

  Spearpoints installed in September adjacent to several DSC springs (see **Section 6.2**) indicate EC values between 532 and 681 µS/cm.

  Groundwater from the Clematis Sandstone outcrop (bores C14012SP and C14013SP) ranges from 410 to 490 µS/cm. Groundwater quality down dip of the outcrop increases slightly in salinity, where EC is measured at 630 to 720 µS/cm in Clematis Sandstone bores HD02 and HD03A. The 85th percentiles for EC for the other hydrostratigraphic units at CCP are presented in **Table 19** below.

Table 19 Groundwater Salinity Data Summary (Electrical Conductivity in µS/cm)

Hydrostratigraphic Unit	85th Percentiles
Alluvium	42,250 (east) / 900 (west)
Tertiary sediments	14,000
Moolayember Formation[5]	572
Clematis Sandstone	640
Dunda Beds	772
Rewan Formation	3,723
Bandanna Formation (AB Seam)	1,896
Colinlea Sandstone (D Seam)	2,000
Joe Joe Group	15,900

Spring Chemistry

Major anion and cation concentrations obtained from the Joshua Spring water samples, have been used for comparison to the major anion and cation data for all the samples from the groundwater monitoring bores installed into the Permian aged Bandanna Formation (AB Seam) and the Colinlea Sandstone (D Seam). The composition (water types) for the Joshua Spring and the Bandanna Formation (AB Seam) and the Colinlea Sandstone (D Seam) are markedly different (**Plate 9**).

For comparison the Joshua Spring major anion and cation concentrations are compared to all the major anion and cation results derived from the groundwater bores in the Clematis Sandstone (**Plate 10**).

Conclusions

Conclusions with respect to consideration of the alternative conceptualisation for the Doongmabulla Spring Complex include:

- The available site-specific information negates the concept that a groundwater source, below the Rewan Formation, discharges at the Doongmabulla Springs Complex.
- Groundwater discharge from units below the Clematis Sandstone is considered unlikely based on quality data and vertical groundwater gradients. In addition, the clay-rich Dunda Beds sediments (interbedded claystone, mudstone and sandstone with minor siltstone) reduce the potential for this unit to provide continuous recently recharged groundwater at the springs.

[5] C18003SP was sampled in September 2018

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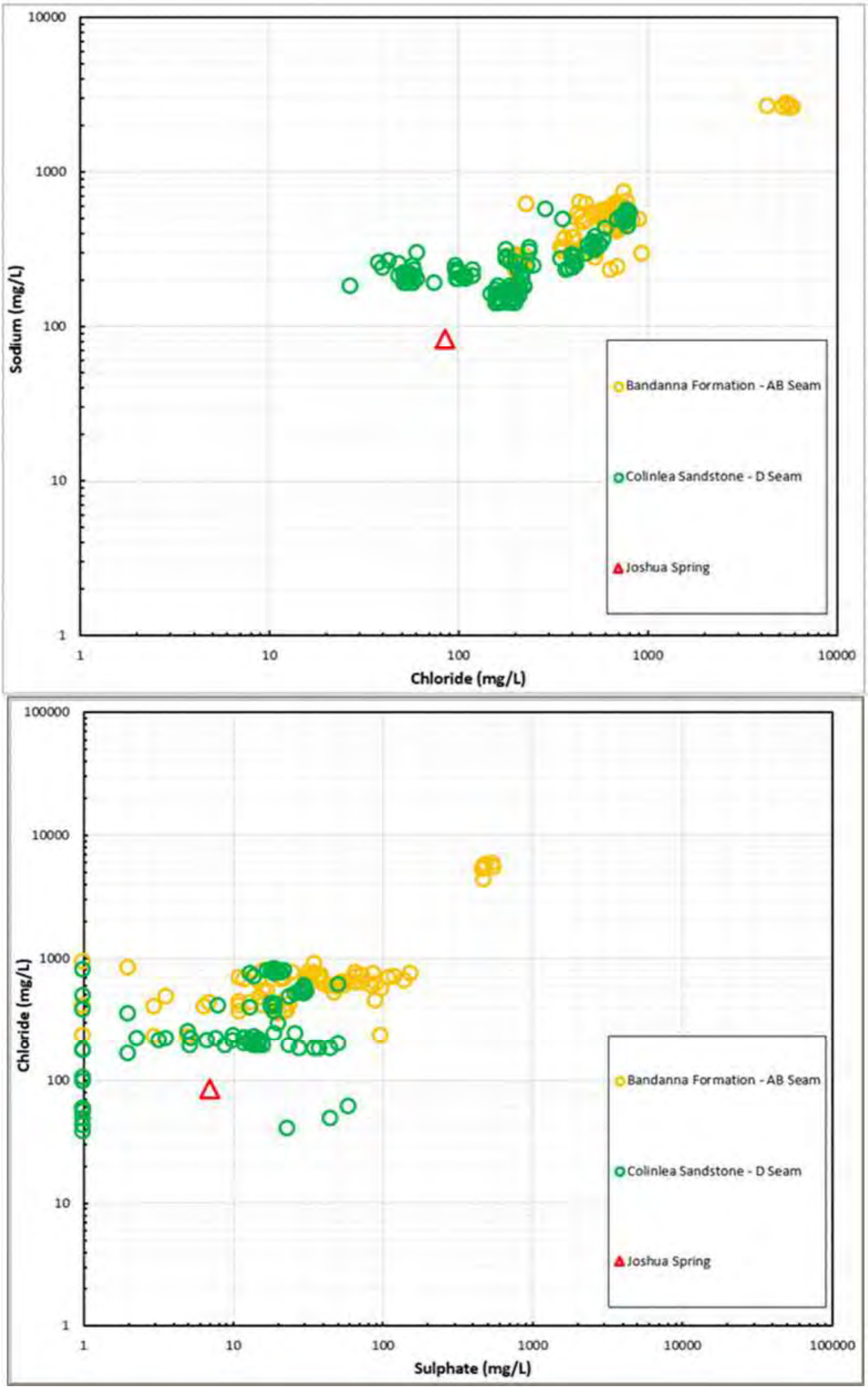

Plate 9 Major anion and cation concentrations comparison Joshua Spring and Betts Creek Beds

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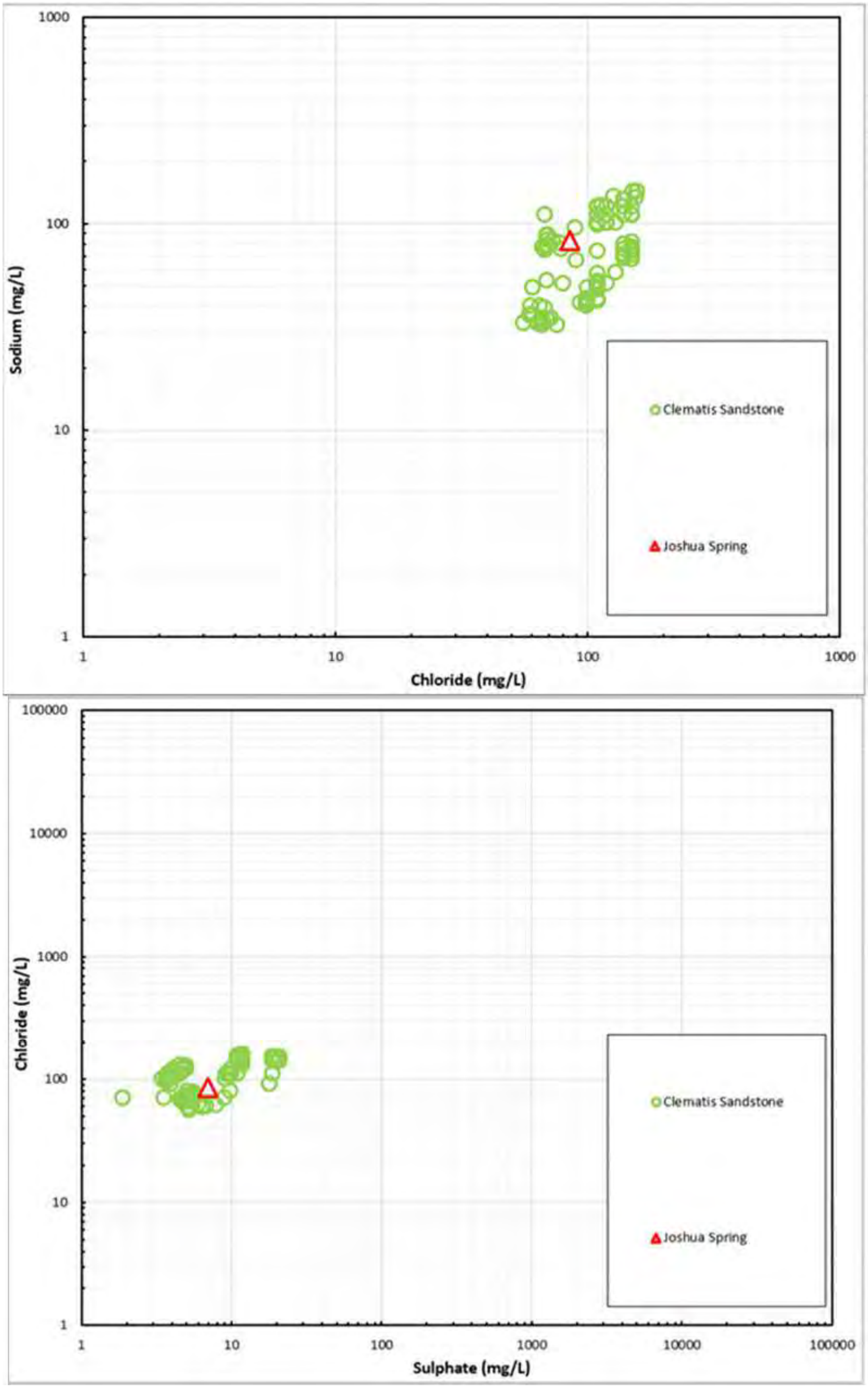

Plate 10 Major anion and cation concentrations comparison Joshua Spring and Clematis Sandstone

- Groundwater flow patterns (**Section 2.2.3** and **Section 2.2.5.7**), influenced by a synform, do not correspond with the springs such that discharge at the springs are not the reason for the complex Permian units flow patterns on CCP.

The groundwater heads in the DSC correlate well with monitoring data collected from the Clematis Sandstone monitoring bores, which confirms the conceptualisation of DSC used in impact assessment studies. Further additional field investigations into Rewan Formation confirms thickness and extent of Rewan Formation that separates source aquifers of DSC from the coal bearing Betts Creek Beds. Hence the groundwater drawdown thresholds (including Early warning thresholds and Impact thresholds) developed using the groundwater level data collected to date will meet the requirements and objectives of the approvals.

NOTE: The compilation of groundwater monitoring data during mining operations plus the results of research plans (EPBC Act approval conditions as detailed in **Section 1.6**) will allow for the refinement of the groundwater conceptualisation over time. This includes the current conceptualisation for the Doongmabulla Springs Complex.

The refinement of predictive modelling will allow for the reassessment of the potential impacts on groundwater levels, across all hydrostratigraphic units, and the revision of groundwater level Early warning and Impact thresholds for the DSC (as detailed in **Section 5.3**) as well as the interim threshold of 0.2 m at the DSC springs..

2.2.6.3 Mellaluka Springs Complex

Additional geological / exploration bores and monitoring bores were constructed to assess groundwater resources, associated with the Tertiary sediments and the Joe Joe Group's Jochmus Formation, for mine construction purposes. The drilling also allowed for a preliminary assessment of underlying geological and hydrogeological regimes around the Mellaluka Springs Complex. The locations of these bores are presented in **Figure 9** below.

As discussed in **Section 2.2.5** (and depicted in **Plate 6**) the drilling in this area indicates a complex (multi-storey) groundwater system within the Tertiary sediments and Joe Joe Group in this area.

The conceptualisation and understanding of the groundwater resources will be refined over time for inclusion in the future iterations of the predictive groundwater model and the GMMP, in line with the approval conditions EA Conditions E4, E5, and E6 and EPBC Act condition 3e .

Cross-sections through Sections A1 - B1 and A2 - B2, as indicated in **Figure 10** below, allowed for the assessment of the contact between the Colinlea Sandstone and the Joe Joe Group. This contact is depicted in **Figure 10** and **Figure 11** below.

The Mellaluka Springs Complex is located immediately adjacent to groundwater monitoring bore C9180124SPR, logged to be underlain by Tertiary sediments and Joe Joe Group.

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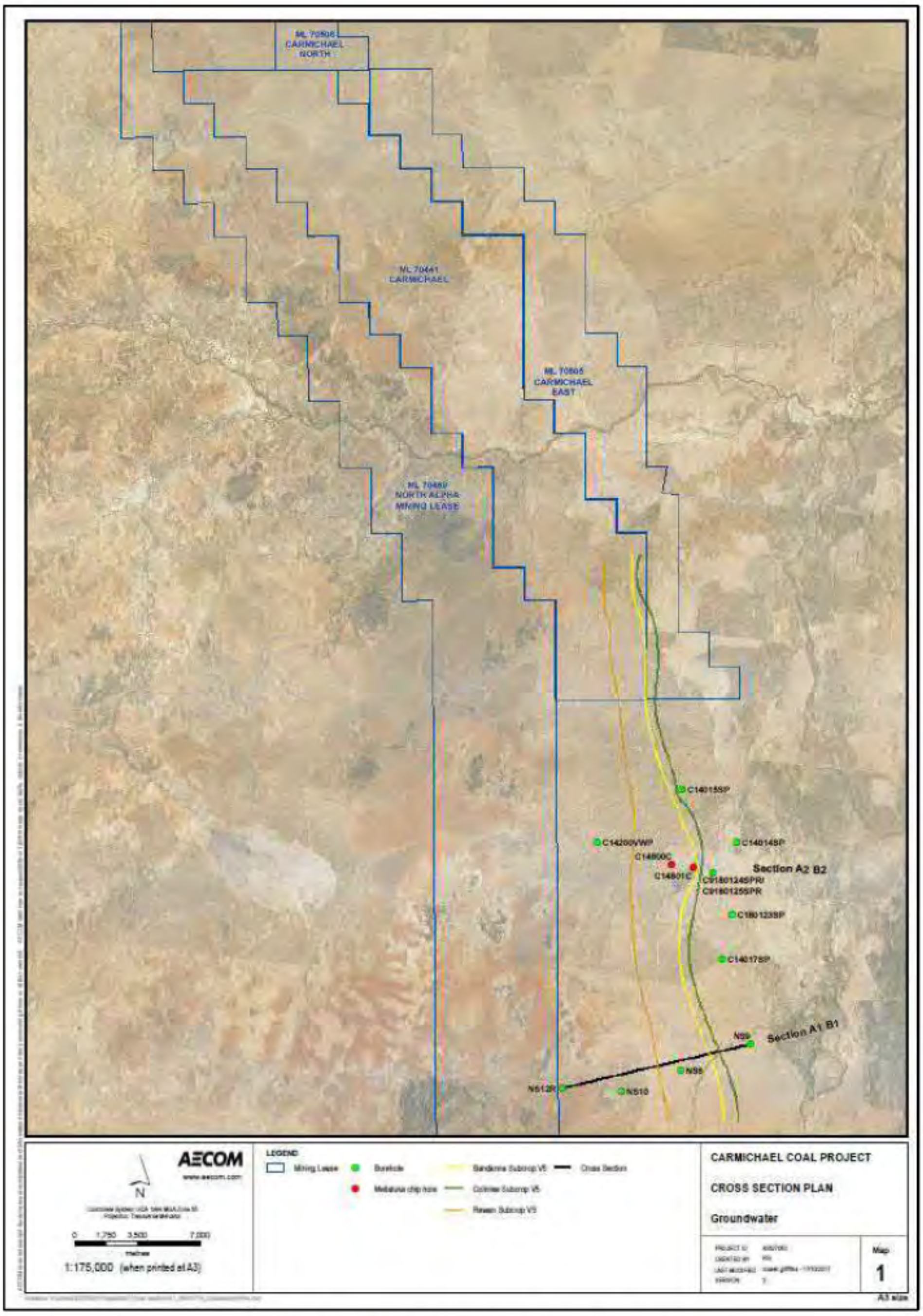

Figure 9 Bores located within the Mellaluka Springs Complex area

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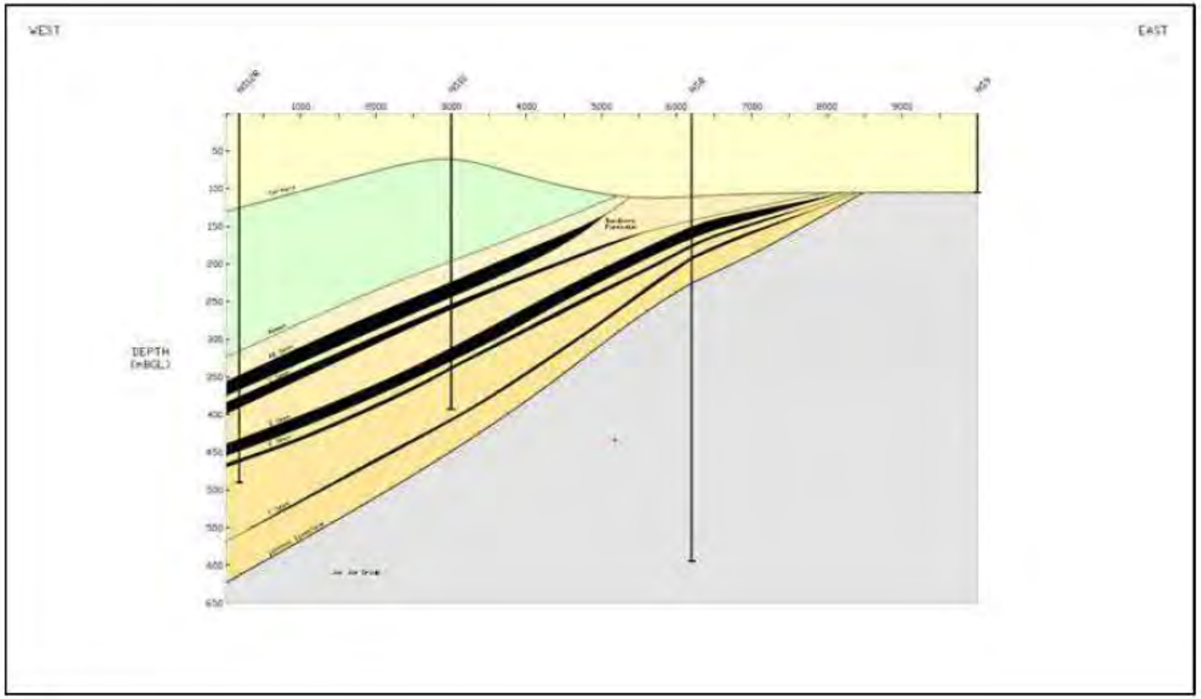

Figure 10 Cross-section A1 - B1

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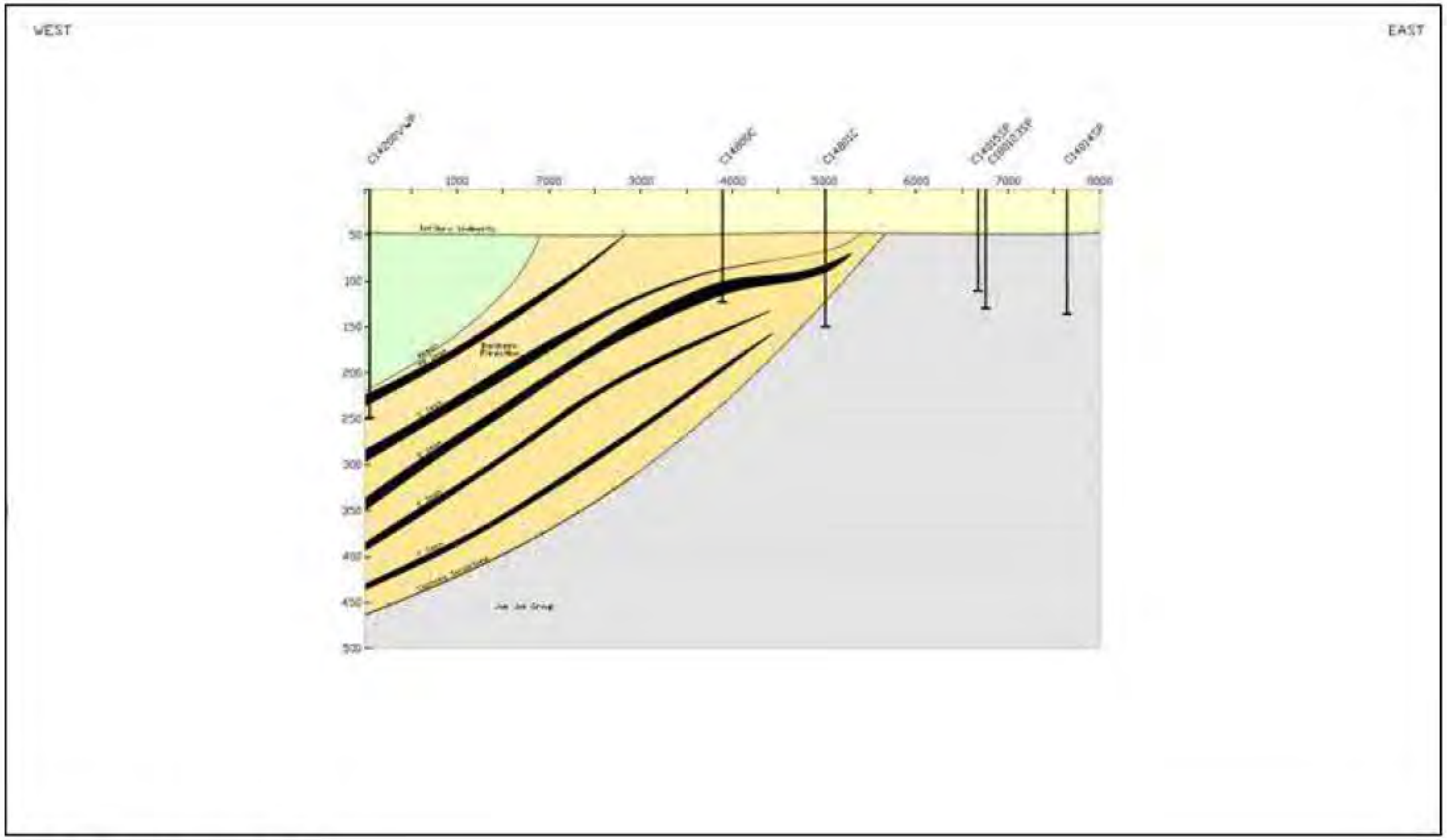

Figure 11 Cross-section A2 - B2

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2.2.6.3.1 Preliminary Assessment of Mellaluka Springs

The groundwater quality within the Mellaluka Springs Complex area includes the following:

- Mellaluka Spring salinity ranges from 800 to 3,200 µS/cm
- Bore C180123SP salinity ranges from 790 to 830 µS/cm (Joe Joe Group), C9180124SPR salinity ranges from 420 to 460 µS/cm (Joe Joe Group), C14014SP salinity ranges from 490 to 520 µS/cm (Joe Joe Group), and C180123SP salinity ranges from 790 to 830 µS/cm (Joe Joe Group)
- Tertiary sediments groundwater salinity, bore C9180121SPR, ranges from 3,600 to 3,700 µS/cm
- Blended groundwater quality from bores screened across both the Tertiary sediments and Joe Joe Group, such as bore C180120SP (6,500 to 8,700 µS/cm) and bore C180122SP (6,800 to 7,600 µS/cm).

Groundwater quality indicates mixing / blending of groundwater measured at Mellaluka Springs, when considering the salinity of Tertiary sediments and Joe Joe Group data. It is further considered that, based on mapped palaeochannels, the area likely includes groundwater associated with the Belyando River which may provide, or contribute to, the artesian pressures. **Plate 11** below depicts the mapped Belyando River, drainage pattern within a wide flood plain, and location of the Mellaluka Springs Complex.

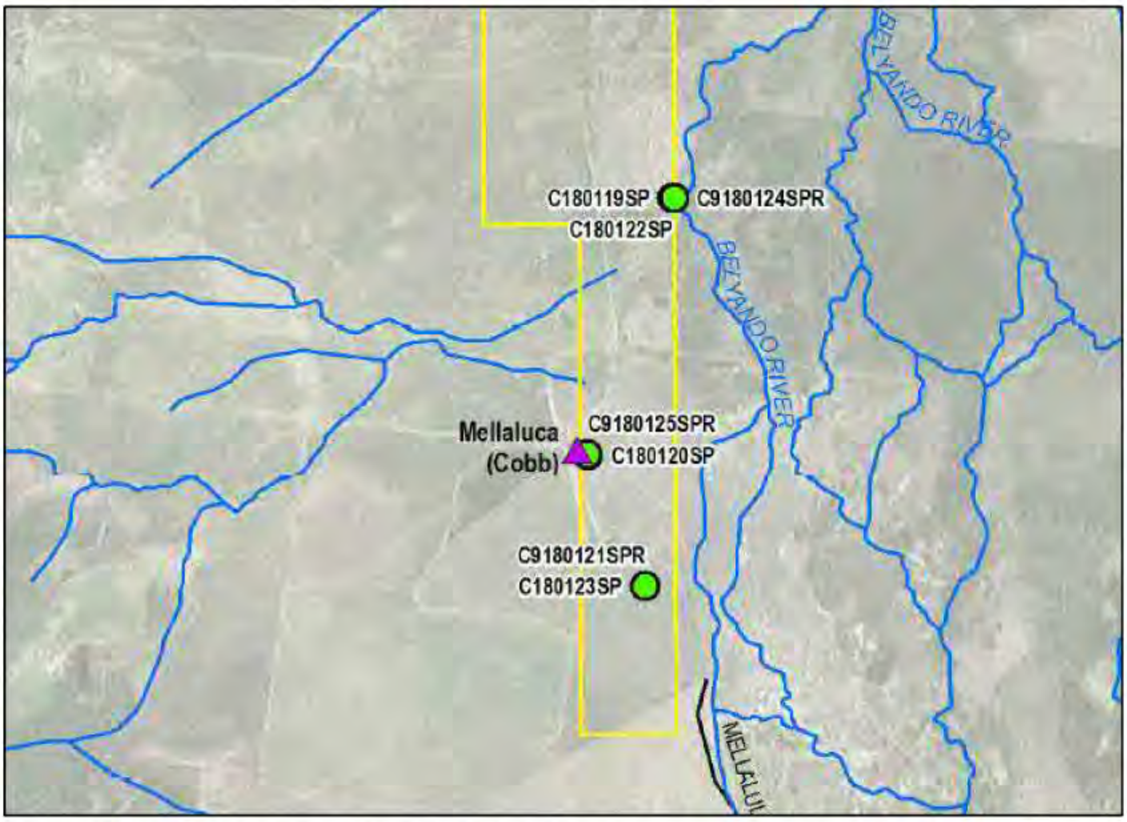

Plate 11 Belyando River proximity to Mellaluka Springs Complex

2.2.6.4 Considerations regarding Mellaluka Springs Complex

Based on the drilling results (re-assessment of site-specific geology) , mapping of coal seam subcrop, and the available groundwater quality, the groundwater associated with the Mellaluka Springs Complex is sourced from artesian Tertiary sediments and Joe Joe Group. The predicted groundwater level impacts, considering the alternate conceptualisation that Tertiary sediments and Joe Joe Group are the source of the Mellaluka springs, will be markedly less than those predicted for the Colinlea Sandstone source, as predicted in SEIS studies.

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It is noted that the groundwater level drawdown thresholds for the Mellaluka Springs area are based on the conservative SEIS model approach, which assumes the Colinlea Sandstone is the source of the springs, i.e. the bottom model layer is the coal bearing Colinlea Sandstone. Thus, the groundwater level drawdown thresholds for the Mellaluka Springs are developed based on worst case impacts considering the Mellaluka springs are sourced from Colinlea Sandstone (which is directly impacted by mine dewatering). The alternate conceptualisation will be tested during the first model review which is scheduled to be conducted within two years of commencement of any mining activities associated with box cut excavation.

This conceptualisation, based on conditions within the area, will be refined overtime as additional groundwater data is compiled and the groundwater model is revised. The model revision will include the inclusion of the Joe Joe Group and calibration of the model to the artesian conditions in the Joe Joe Group based on the additional drilling (which was conducted to assess groundwater potential for construction purposes to the east of the MLs). Further results of groundwater testing carried out to estimate aquifer parameters will be included in the model to aid in the refinement of the model construction and layer properties.

It is to be noted that predictions of drawdown are not considered to increase because of the revised conceptualisation in model refinement. The GMMP will be revised, as required, in response to modelling refinement.

2.2.7 Model Water Balance

The numerical groundwater model has been refined over time as additional information has become available. As a result, the calibrated steady state pre-development water balance has been updated; the most current balance is presented in **Table 20** below. As can be observed, this table compares the model water balance with the SEIS model completed in 2013, both undertaken by GHD.

The groundwater model was revised and re-run in 2014 to review potential impacts on the GAB groundwater resources, as per the EPBC Act approval condition (Condition 23). The model re-run aimed to address the additional information requirements from the Commonwealth.

The model revision incorporated the required updates for the revised General Head Boundary (GHB) arrangements and included:

- The best fit GHB elevation of 275 m (Option 1)
- An 'alternative conceptualisation' GHB elevation of 250 m (Option 2).

As a primary driver of the model revision was to review potential impacts on the GAB units, the best fit elevation was reduced by 25 m to maximise the westerly flow of groundwater into the GAB units (Option 1 did not result in a high groundwater flow or a net westerly flow across the western GHB within the central region of the model).

Further information in regard to the model re-run is included in **Section 2.3** below.

Table 20 Model Water Balance (Source: GHD, 2015)

Component	SEIS model			Option 1 (275m) GHB model			Option 2 (250m) GHB model		
	Flow IN (m^3/d)	Flow OUT (m^3/d)	IN – OUT (m^3/d)	Flow IN (m^3/d)	Flow OUT (m^3/d)	IN – OUT (m^3/d)	Flow IN (m^3/d)	Flow OUT (m^3/d)	IN – OUT (m^3/d)
Recharge	2,533	0	2,533	2,940	0	2,940	2,941	0	2,941
Evapotranspiration	0	4,001	-4,001	0	4,060	-4,060	0	3,961	-3,961
Discharge from/to Adjoining Areas	44,680	41,466	3,214	84,933	77,758	7,175	80,272	76,917	3,355
Groundwater Extraction	0	152	-152	0	153	-153	0	151	-151
Carmichael River Leakage	6,662	7,084	-421	6,549	9,648	-3,099	6,889	7,931	-1,041
Discharge to Other Water Courses	0	1,200	-1,200	0	2,826	-2,826	0	1,162	-1,162
TOTAL	53,876	53,904	-28 (-0.05%)	94,422	94,446	-24 (-0.03%)	90,102	90,122	-20 (-0.02%)

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The model water balance, as presented in **Table 20**, indicates:

- Minor uniform groundwater recharge, due to clay-rich over burden (Tertiary sediments) across the model domain
- Evapotranspiration (EVT) is double the recharge across the model domain
- Groundwater through-flow into the CCP area is higher than outflow, due to loss to surface water bodies as evident in the Carmichael River where the river is a gaining river to the west
- Surface water losses are included in the water balance, where rivers and creeks are losing systems, such as Carmichael River to the east
- Minor local groundwater extraction is included in the model
- Influx and Outflow in the model, for all scenarios, are well balanced.

All future revisions of groundwater model will compare the initial and refined model water balance(s) with the actual measurements obtained through operational monitoring (i.e., actual dewatering volumes). The methods used for estimation of recharge and evapotranspiration will be updated based on annual rainfall measurements. The actual measured pit inflows and dewatering volumes will be used to compare the predicted dewatering volumes and update the groundwater flow model periodically.

2.2.7.1 EA Condition E4 f

The EA Approval Condition E4 f) Estimation of groundwater inflow to mine workings and surface water ingress to groundwater from flooding events using the groundwater model, was discussed with the regulators during a meeting held on 7 November 2018.

It was discussed that the groundwater model only includes for groundwater inflows into pits and through rainfall directly falling onto the active mining areas but not surface water flood inundation, as the mine includes for levees along the Carmichael River. The levees will be built to provide immunity from a 1 : 1000 year ARI design flood event on either sides of the Carmichael River.

It was agreed that the surface water ingress to groundwater from flooding events would not be required from the groundwater modelling based on the flood immunity.

The regularly updated groundwater model, initially after 2 years and then every 5 years, will be used to provide estimations of groundwater inflow and will include the model water balance (with the components as included in **Table 21**).

2.2.8 Surface water – Groundwater Interaction

The surface water – groundwater interaction within the surficial sediments (alluvium and Tertiary sediments) is complex across the CCP footprint. Spring discharge from Joshua Spring (into the Dyllingo Creek) and the DSC springs (into Cattle Creek) are recognised to facilitate perennial surface water within the Carmichael River to the west and within the western portion of the mine lease.

The Dyllingo Creek is non-perennial upstream of Joshua Spring, and then flowing as a result of continuous discharge from the turkey's nest dam constructed around Joshua Spring. The groundwater level, on average, within the alluvium monitoring bore HD03B is some 5 m below surface (225.47 mAHD). Surface water levels are considered to be at a similar elevation, exposed within the deeper river channel.

The groundwater level remains close to surface at alluvium monitoring bore C027P1 (223.8 mAHD, ~ 4 m below surface) near the water pool on the Carmichael River within the western boundary of the mine lease. Here the river channel is deeper and wider corresponding with the a change in topography.

Downstream of the permanent pool the groundwater levels start to decline markedly, corresponding to the Carmichael River being non-perennial as it drains eastwards. The groundwater discharges as throughflow in the alluvium, mimicking surface water flow, due to the limited effective storage of the more coarse-grained permeable alluvium.

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Two surface water flow monitoring stations located upstream (CAR04) and downstream (CAR01) locations to gauge flow of the Carmichael River will be serviced to make them operational. A third location, CAR02, is located centrally and is adjacent to alluvium monitoring bore C025P1. These surface water monitoring locations will allow for identification of impacts on the Carmichael River and associated riparian MNES / GDEs. A flow meter has been installed at Joshua Spring to monitoring possible impacts of flow from the spring into the Dyllingo and Carmichael rivers .

Groundwater levels in the alluvium, to the east of the mine lease, at monitoring bore C14028SP is some 15 m below surface (204 mAHD).

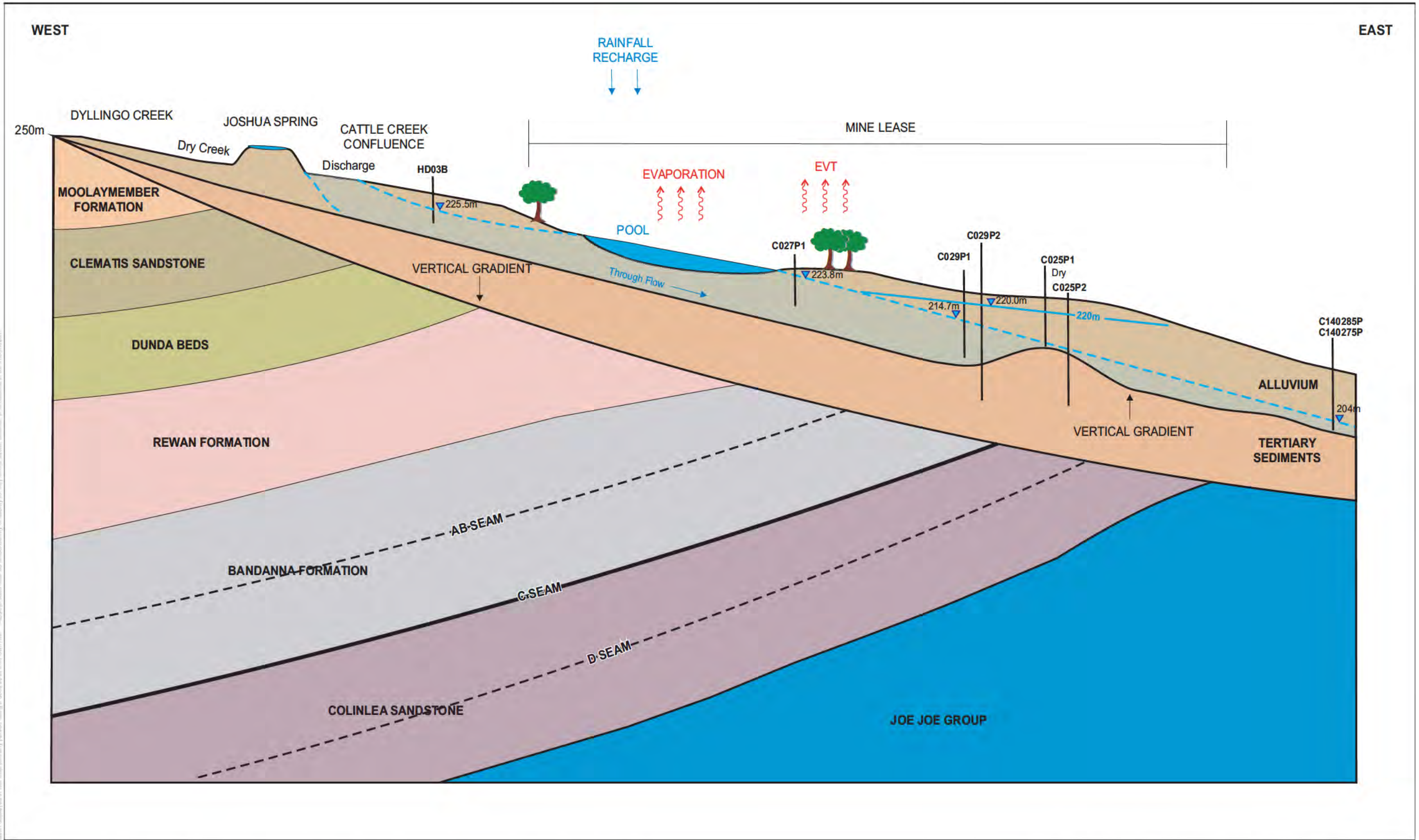
Groundwater level data for the underlying (up to 60 m thick) low permeable clay-rich Tertiary sediments directly below the alluvium is limited. The two monitoring bores (C029P2 and C025P2) along the Carmichael River within the mine lease indicate potentiometric groundwater levels of 220 mAHD. This groundwater level is contoured to occur below the Carmichael River (see **Figure F2**, **Appendix C**).

A review of the vertical groundwater level gradients, between the alluvium and the Tertiary sediments, indicates the gradient is downward where spring recharge (perennial conditions) occurs and upward to the east. Thus, groundwater is more readily discharged as throughflow than vertical downward flow in the eastern portion of the Carmichael River. It is noted that the confined hydrostratigraphic units, overlain by the Tertiary sediments (220 mAHD) and alluvium (225.5 to 204 mAHD) in the Carmichael River area, have the following average groundwater levels:

- Moolayember Formation, 236.50 mAHD (C18003SP)
- Clematis Sandstone, 242.55 mAHD (C18002SP)
- Dunda Beds, 247.26 mAHD (C14023SP)
- Rewan Formation, 230.029 (C555P1)
- Bandanna Formation (AB seam), 212.4 mAHD (bore C007P2)
- Colinlea Sandstone (D seam), 217 mAHD (bore C007P3)
- Joe Joe Group, 226.03 mAHD (C14006SP).

The groundwater gradients above the Rewan Formation (as discussed in **Section 2.2.6.2**) are upwards, restricting vertical groundwater loss from the alluvium in the areas where the alluvium overlie these units.

Figure 12 shows the conceptual model along the Carmichael River, illustrating geology, groundwater levels and recharge/discharge mechanisms with the alluvium, as well as the potentiometric level associated with the Tertiary sediments.



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TERTIARY SEDIMENTS POTENTIOMETRIC LEVEL - 220 mAHD ALONG WEST - EAST FLOW OF CARMICHAEL RIVER

NOT TO SCALE

Numbers in mAHD

FIGURE 12

CARMICHAEL COAL PROJECT

SURFACE WATER - GROUND WATER INTERACTION CONCEPTUAL MODEL

Groundwater

PROJECT ID:	60541774
CREATED BY:	WW
LAST MODIFIED:	WW 14 JAN 2019
VERSION:	4

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Flow impacts

The predictive modelling indicates the estimated average baseflow (upstream where perennial flow is measured in the Carmichael River) to be approximately 4,500 m^3/day. Model predictions indicate a possible decrease to 4,300 m^3/day at the end of mining; a possible reduction of 200 m^3/day (~4.4% of daily flow).

This “losing” of surface water to groundwater indicates that groundwater levels would need to reduce sufficiently to allow for a steeper vertical gradient between the alluvium and the target coal seam Permian age units so as to increase vertical groundwater flow (rather than horizontal throughflow).

The model predicts a decrease in the potentiometric level at the Joshua Spring of 0.19 m (**Section 2.7.4.1**), which is insufficient to alter the artesian conditions (the discharge from the turkey’s nest occurs at some 2 m above the base of the dam) but could reduce the flow rate from the turkey’s nest dam into the Dyllingo Creek.

No other change in DSC spring flow into the perennial portion of the Carmichael River is predicted.

2.2.9 Refinement of the Current Groundwater Conceptual Model

After reassessment of the data collected since commencement of investigations across and adjacent to the CCP, the revised groundwater conceptual model has addressed the data gaps identified in previous iterations. However, additional data gaps have been identified and include:

- Identification of artesian conditions evident between the Tertiary sediments and Joe Joe Group in the Mellaluka Springs Complex area
- The assessment of the changing artesian conditions within the Tertiary sediments and Joe Joe Group (south and north of the Carmichael River) including consideration of the Belyando River palaeochannels influence on potentiometric pressures (only mapped to the south of the Carmichael River)
- Moolayember Formation groundwater quality
- Verification / validation of the aquitard nature of the Rewan Formation
- Further explore hydraulic connectivity of the units
- Further explore groundwater flow directions
- Refine estimate of baseflow from the Carmichael River.

Adani propose to address the data gaps above to refine the current conceptual understanding of the groundwater regime and ensure the predictive capacity of the numerical model is robust. This GMMP includes for the collection of additional groundwater data to aid in refining conceptualisations for future iterations of the GMMP and numerical model updates.

Additional investigation(s) within and adjacent to the CCP area will be undertaken through the project’s EPBC conditioned requirements to undertake a RFCRP and a GABSRP. Alternative conceptualisations may be developed and explored as the data from the studies required above are assessed and compiled.

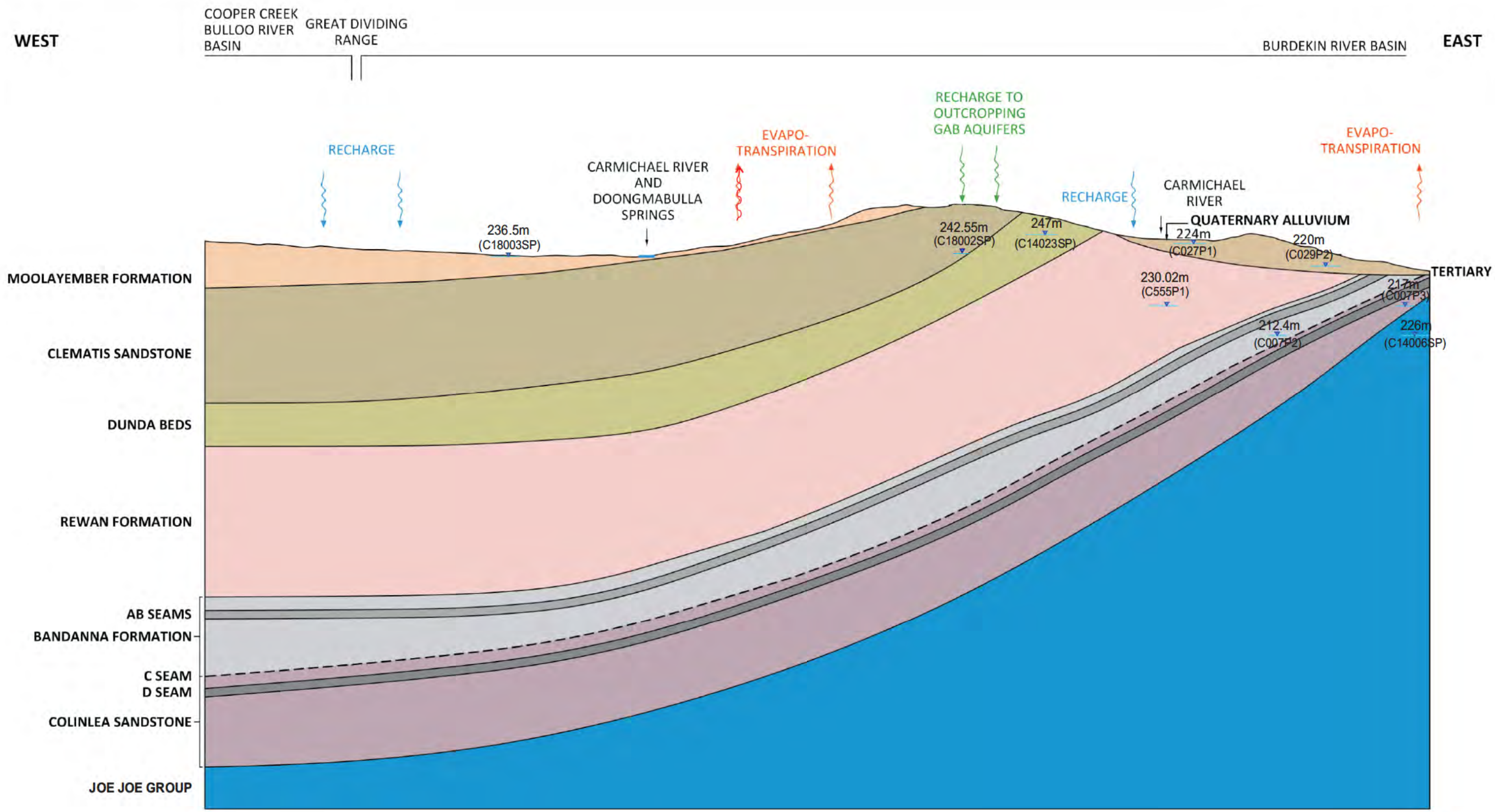
The results of these studies, with respect to the groundwater conceptual understanding, are proposed to inform EA condition E6 numerical modelling review and updates (after two years then every five years). This approach promotes continued and increased accuracy of the groundwater numerical model simulations to predict potential impacts on the groundwater resources of the site over the life of mine. The model reviews, updates, and revised predictions will be provided to both the State and Commonwealth regulators for review, as well as an independent auditor (see **Section 7.0**).

2.2.10 Hydrogeological Conceptual Model Summary

The groundwater conceptual model(s) has been refined to include the results of continued investigations onsite. It is considered the key elements of the groundwater system in the CCP area include:

- Geometry of each unit
- Groundwater levels and influences on these levels (e.g. artesian conditions south of Carmichael River)
- Inter-aquifer connectivity
- Groundwater flow directions
- Recharge and discharge mechanisms.

The current understanding of these key elements has allowed for the development of pre- and post-mining conceptualisations presented in **Figure 13** and **Figure 14** below.



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236.5m Standing Water Level (SWL) (mAHD)

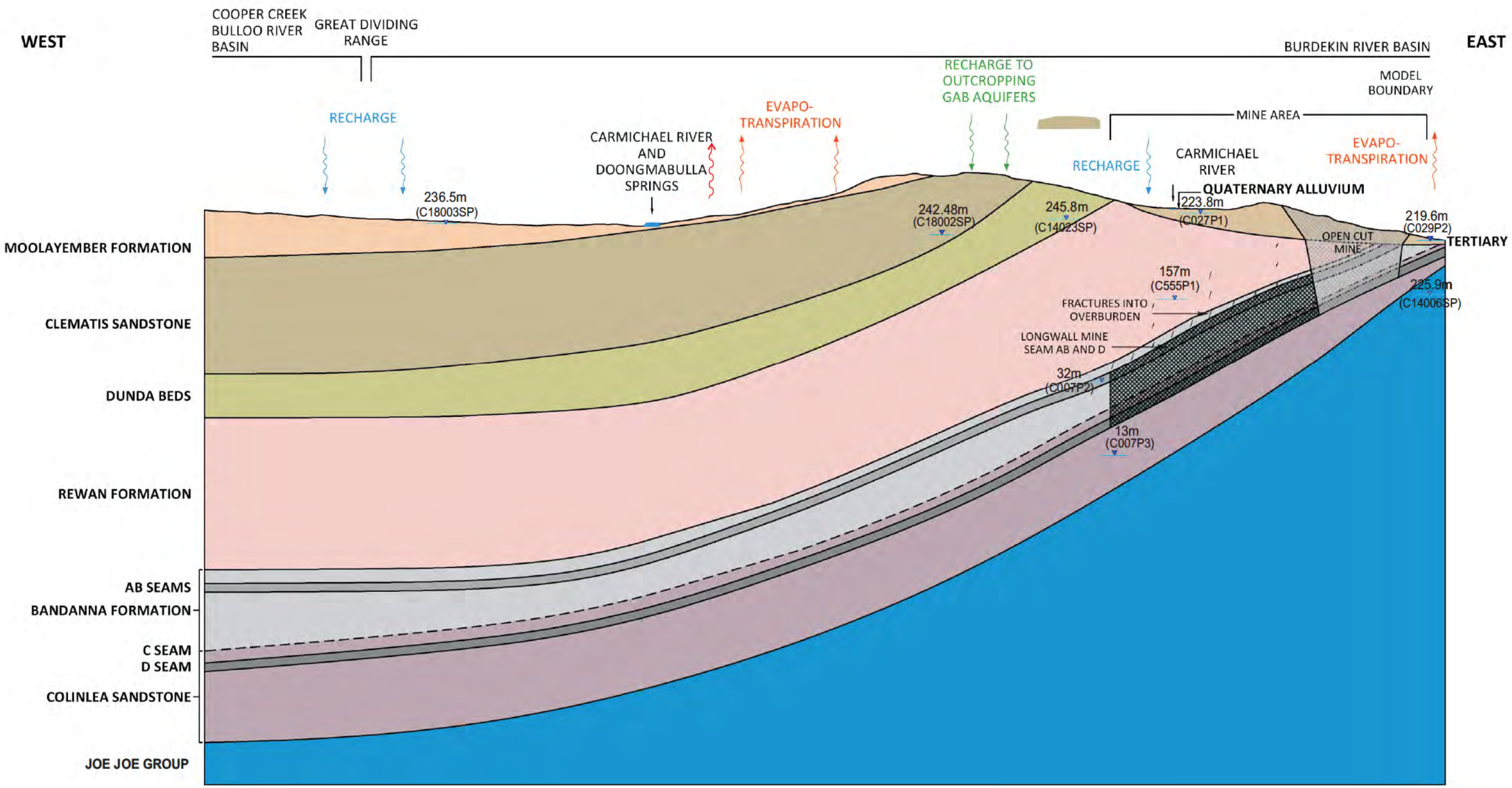
FIGURE 13

CARMICHAEL COAL PROJECT

PRE MINING CONCEPTUAL MODEL

Groundwater

PROJECT ID:	60451774
CREATED BY:	RG
LAST MODIFIED:	WW 26 NOV 2018
VERSION:	3



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NOT TO SCALE

236.5m Standing Water Level (SWL) (mAHD)

FIGURE 14

CARMICHAEL COAL PROJECT

END OF MINING CONCEPTUAL MODEL - 78 YEARS

Groundwater

PROJECT ID:	60451774
CREATED BY:	RG
LAST MODIFIED:	WW 26 NOV 2018
VERSION:	3

2.2.10.1 Predicted Changes in Groundwater Levels

Groundwater levels included in the conceptualisations are included in **Table 21**, which provide an indication of groundwater levels per hydrostratigraphic unit before and at the end of mining within the middle of the MLs.

Table 21 Groundwater Level Data for Conceptual Models

Hydrostratigraphic Unit	Average Groundwater Level (middle of CCP) [mAHD]	Projected Groundwater Level (middle of CCP) [mAHD]
Alluvium	224	224
Tertiary Sediments	220	219.6
Moolayember Formation	236.5	236.5
Clematis Sandstone	243	242.5
Dunda Beds	247	245.8
Rewan Formation	230	157
Bandanna Formation (AB Seam)	212	32
Colinlea Sandstone (D Seam)	217	13
Early Permian aged Joe Joe Group	226	225.6

The predicted groundwater level changes, because of approved mining operations, indicates limited potential for induced flow based on hydraulic properties of the hydrostratigraphic units.

Groundwater level change, per hydrostratigraphic unit, using the SEIS predictive groundwater model allowed for the compilation of groundwater level drawdown at the end of mining. These contours are included in **Appendix C**, and allow for evaluation of groundwater flow pattern changes (pre-mining and end of mining (78 years).

2.2.10.2 Final Void Influence

The post-mining hydrogeological conceptualisation is an important consideration for the development and augmentation of this GMMP. The long-term groundwater regime(s) are altered, post-mining, due to:

- Open cut mining, where backfill increases groundwater recharge
- Long wall mining (goaf), which results in increased vertical hydraulic conductivity and secondary permeability
- Final void(s), where groundwater rebound occurs within the underground workings to the base of the final voids.

The final voids will act as groundwater “sinks” in perpetuity, where the pseudo-steady state water levels within the final voids will be governed by:

- Direct rainfall
- Increased recharge through the backfill
- Evaporation (decreasing with depth and shade)
- Groundwater ingress
- Surface water runoff (directed into the voids until rehabilitation facilitates suitable water quality for discharge off site).

It is predicted that the final voids will result in long term alteration to localised groundwater flow patterns within the hydrostratigraphic units directly impacted by the open cut workings (i.e. the units intersected within the final voids), where groundwater flow will be into the final voids. This flow pattern

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will be considered when developing long term groundwater monitoring programs (bore network and sampling requirements).

The groundwater levels will reach a pseudo-steady state (these will be below current pre-mining groundwater levels), governed by permeability, such that groundwater drawdown cones facilitate flow towards the final voids, within the mine leases (and extend to the radius of influence as discussed in **Section 2.7.3**). This resultant groundwater flow directions into the final voids prevents contaminants within groundwater from migrating off-site.

Groundwater monitoring will be required to validate final void flow patterns and pseudo-steady state groundwater levels, and to verify groundwater quality into and off the MLs.

2.3 Model Re-Run

As part of the environmental approvals process for the CCP, the project was assessed to be a controlled action under sections 75 and 87 of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Commonwealth approval of the project was issued subject to a series of conditions, documented within *Approval Carmichael Coal Mine and Rail Infrastructure Project, Queensland (EPBC 2010/5736)* (**Appendix A**). The EPBC Act Condition 23 required a re-run of the groundwater flow model, based on the independent expert review as per EPBC Act Condition 22.

Condition 23 includes:

The model revisions and re-runs must incorporate the following parameters in the scenarios and address the following additional information requirements:

a. *Re-define the current General Head Boundary (GHB) arrangement, as agreed by the Department in writing including the following:*
    i. *Remove the GHB from its current location in all layers to the western edge of the model domain*
    ii. *Review and justify the GHB conductance values used in the model to reflect the differences between aquifers and aquitards and also between aquifers (e.g. Clematis and Colinlea Sandstones), and modify if required;*
    iii. *GHB cell elevations to be re-set using data as agreed by the Department in writing*
    iv. *Report on the impacts on groundwater levels and net flows between the model domain for the revised GHB boundaries and compare with previous modelling results.*
b. *Review and justify the recharge parameters for the Clematis Sandstone to represent the flux into the recharge beds of the Great Artesian Basin, and modify if required;*
c. *Document outflow mechanisms used in the model for the Doongmabulla Springs Complex and individual model layers, using maps to show the spatial distribution of model discharges*
d. *Document and incorporate known licensed groundwater extractions within the model domain*
e. *Document and justify any other charges made as part of the model re-runs that are not outlined above*
f. *As per the IESC information guidelines provide an assessment of the quality of, and risks and uncertainty inherent in, the data used in the background data and modelling, particularly with respect to predicted model scenarios*
g. *Provide adequate data (spatially and geographically representative) to justify the conceptualisation of topographically driven flow from south to north (and west to east) in both shallow and deep aquifers.*

As a result of Condition 23, GHD undertook the model re-run which is documented in detail in the report *Carmichael Coal Project Response to Federal Approval Conditions- Groundwater Flow Model* (GHD, 2015) which should be read in conjunction with the SEIS (GHD, 2013) to enable a

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comprehensive understanding of the hydrogeology of the mine and surrounding area. The model re-run was completed based on the data within the SEIS report.

A technical memorandum, prepared in accordance with Condition 23 a)(iii) was submitted to the Department of the Environment (DotE) which outlined the approach to address conditions 23 a) (i)-(iii); Adani received notification from the Department on 3 November 2014 which confirmed that these conditions have been met.

It is noted that the Commonwealth Approval Condition 3 and Condition 24, related to the Groundwater management and monitoring plan, includes the provision that the GMMP must be informed by the results of the groundwater flow model re-run. The details of the groundwater network with respect to MNES and *EPBC Act* approvals, using the results of the predictive groundwater modelling, are included in **Section 3.0** of this GMMP.

2.3.1 Changes to the Numerical Model

Requirements of Condition 23 included the extension of the model domain westwards. The western boundary in the SEIS model was defined as the surface water divide associated with the Belyando River (including the Diamond Creek, Dyllingo Creek, Dunda Creek catchments). To satisfy Condition 23 (a) the western model boundary was moved to the western extent of the model domain, which resulted in a portion of the Lake Galilee catchment being included within the active extent of the model, as depicted in **Plate 12**.

The extension of the western model boundary involved modification of several boundary conditions associated with the SEIS model, which included:

- All general head boundaries (GHBs) were removed from the western extent of the SEIS model
- The no-flow cells in the western region of the model (Lake Galilee area) were activated
- A new series of GHBs were assigned along the revised western model boundary to allow for shallow groundwater discharge in the Lake Galilee area and deep through flow to the west
- A small section of GHBs were removed from the north-western corner of the model as the revised western GHB locations and elevations encouraged westerly flow in this region, with head contours orthogonal to the northern model boundary
- River boundaries were applied within the expanded western area of the model
- The GHB conductance values were revised for all GHB cells (previously these were set to 1000 m^2/d for all GHB cells)
- All other boundary conditions remain unchanged from the SEIS model.

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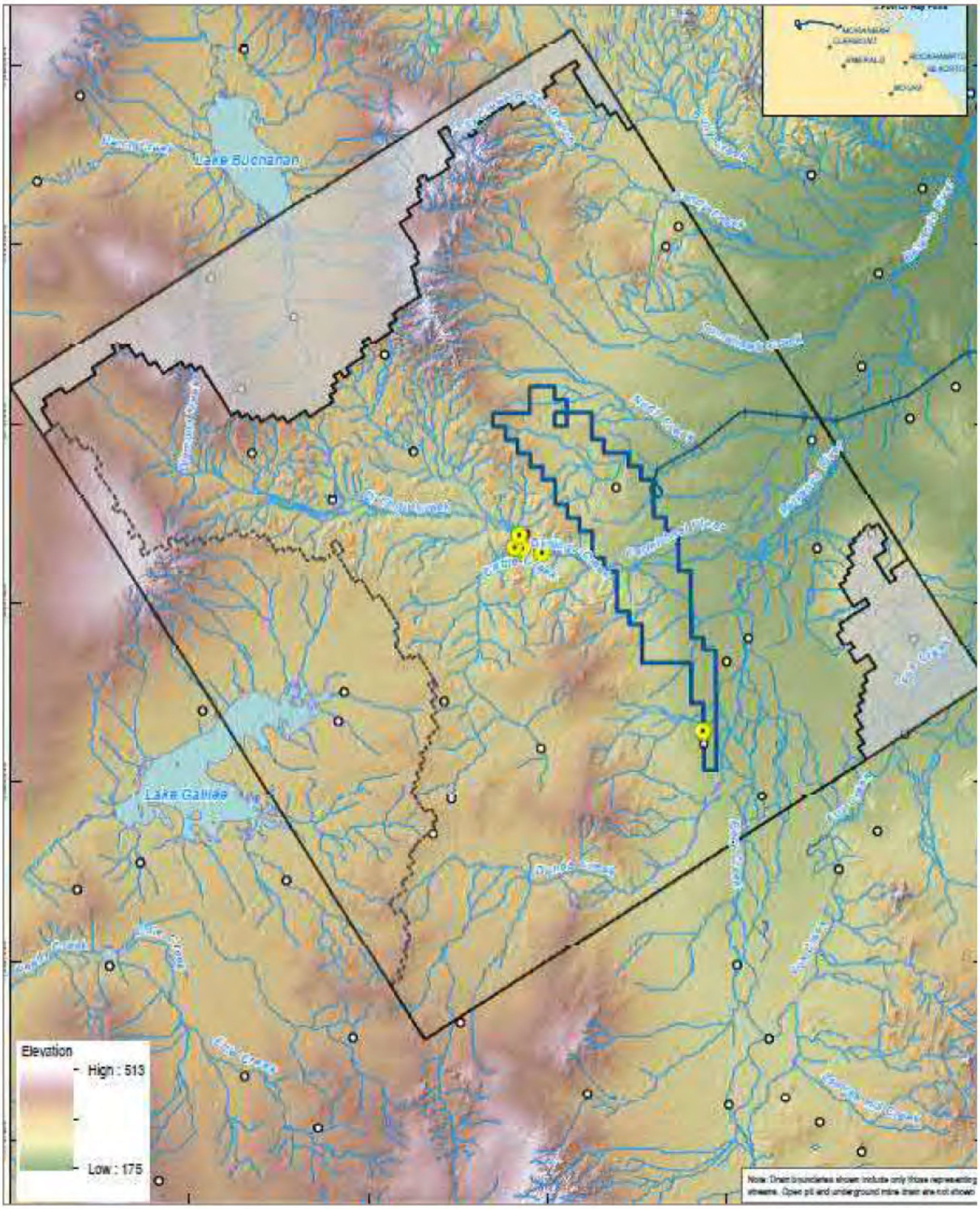

Plate 12 Model boundaries (Portion of Figure 4 from GHD 2015)

During preliminary model runs, it was noted that limited westerly groundwater flow was achieved through the western model boundary. To promote additional westerly flow, a second GHB configuration ("Option 2 [250m]") was adopted throughout this assessment, which utilised lower GHB elevations along the western boundary. The adoption of the Option 2 (250m) model was, therefore, included to further assess the model sensitivity and reduce the uncertainty in model predictions.

2.3.2 Re-Run Model Input into GMMP

The model changes, through discussions and agreement with DotE, and reassessment of model parameters (head values, conductance, etc.) addressed the EPBC Act Condition 23 requirements.

The resultant re-run model predictions and uncertainty analyses were used to aid in compiling this GMMP, particularly the selection of the operational monitoring bore network, groundwater level thresholds, and assessment of potential impacts on MNES.

The re-run of the model allowed for:

- Configuration of model boundaries and justification for each model layer
- Assignment of conductance based on calibrated hydraulic conductivity values and cell geometry (thickness and width)
- Inclusion of licensed groundwater abstraction, approximately 73 ML/year within the revised model domain for nineteen (19) licensed stock bores and six (6) licensed irrigation bores
- Rainfall recharge assessment which indicates that the recharge used in the model are appropriate, supported by literature, verified by site specific data, and were derived during model calibration. Sensitivity analysis indicate that recharge has a low impact on model predictions
- An assessment of model layer hydraulic parameters, hydraulic conductivity, and storage are consistent for the model re-run (compared to the SEIS model), based on model calibration
- Calibration statistics for the SEIS model and the re-run model (both GHB options [250 m and 275 m]), are all acceptable calibration statistics and indicate little change in the scaled root-mean-square values
- Evaluation of outflow at the western model boundary
- Evaluation of the model water balance for the SEIS and re-run model options, which considered:
    - modelled recharge is higher in the re-run models due to increased model domain
    - evapotranspiration is relatively constant across all models
    - groundwater discharge from/to adjoining areas increases in the re-run models due to differences in the western boundary (hydraulic divide in SEIS model)
    - groundwater discharge to rivers is highest in re-run model option1 (275 m) due to higher heads in the upper reaches of the Carmichael River tributaries.
- Water level validation using additional measured groundwater levels in the expanded model domain.

On examining the impact predictions from the SEIS predictive groundwater model and re-run model scenarios (differing model boundaries) at important receptors it is evident that the impacts are similar but higher in case of SEIS model. The GMMP compilation include a review of the available models and a conservative approach was taken to use the SEIS model (i.e. base the GMMP on the highest predicted impacts). The SEIS model predicts the highest magnitude of impacts and hence the results from the SEIS model have been used for all assessments and development of water quality triggers and water level thresholds included in GMMP.

2.3.3 Model Predictions – Operational Phase

The predictive modelling allowed for an assessment of operational phase impacts on the groundwater resources, which were considered when compiling this GMMP.

2.3.3.1 Water Table Impacts

Maximum predicted water table impacts due to the approved open cut and underground mining have been predicted for the SEIS and re-run models. The model outputs allowed for identification of the maximum predicted drawdown irrespective of model layer and timing due to transient mining operations which resulted in maximum drawdown in different units at different times.

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Groundwater drawdown is deepest in the coal measures within the mine leases, approximately 300 m below surface. Drawdown outside the mine leases reach 20 to 50 m, related to depressurisation of the coal down-dip of mining. It is noted that this depressurisation, estimated to be 500 m and greater than 8 km away from the GAB Doongmabulla Springs Complex reduce the potential for induced flow impacts on neighbouring groundwater resources, including the springs.

Comparison of maximum drawdown predictions for the different models is similar with limited differences in the extent of the maximum drawdown contours (smaller in the larger model domain models).

The 0.2 m drawdown contour, in both re-run model options, does not extent as far west as the SEIS model predictions, which is estimated to extend some 1 km closer than the re-run models.

The groundwater level predictions, using hydrographs from the predictive modelling, were used to develop groundwater level thresholds (**Section 5.3**), which allow for the instigation of further assessment to ensure management and mitigation of potential impacts on MNES and neighbouring bores (as required in EA approval Condition E13 (Table E3) and EPBC Act Condition 3d).

2.3.3.2 Spring Impacts

The assessment of potential impacts on the springs is included in **Section 2.7.3.1**, where model prediction hydrographs at the Doongmabulla and Mellaluka spring complexes have been assessed.

These hydrographs plus the model predictions for bores between the mine leases and the springs have been used to determine groundwater level thresholds, as detailed in **Section 5.3**.

2.3.3.3 Neighbouring Bores

Little or no impact is predicted, in all three models, at the 20 bore locations within the SEIS model domain. Maximum predicted drawdown includes:

- 0.05 m in 10 of the 20 bore locations
- < 0.2 m in a further 9 bores
- 0.8 m drawdown in RN90255 (despite being near the northern MLs boundary).

Predicted maximum groundwater level impacts at 15 registered groundwater within ten (10) km of the CCP are less than 1 m. Registered bores within the mine footprint are to be decommissioned (lost) due to mining operations.

Despite the model predictions indicating little or no groundwater level decline in the registered bores, sentinel bores have been included in the GMMP between the mine leases and the neighbouring bores to allow for the validation of model predictions, as detailed in **Section 5.3**.

2.3.3.4 Carmichael River

Reduction of groundwater baseflow and discharge from the Doongmabulla Springs Complex were considered in the modelling. Pre-mining steady-state modelling estimates average baseflow (upstream where perennial flow is measured in the Carmichael River) to be approximately 4,500 m^3/day. Model predictions indicate a possible decrease to 4,300 m^3/day at the end of mining; a possible reduction of 200 m^3/day.

In the area where the Carmichael River is a losing system (non-perennial flow) within the mine lease, pre-mining groundwater flow from surface water to groundwater is estimated to be 1,000 m^3/day. Predictive modelling estimates this contribution will increase to around 1,800 m^3/day at the end of mining.

Groundwater monitoring bores (**Table 57, Section 5.3**), along the Carmichael River (as included in EA approval condition E13 [**Table E3**]), have been identified and groundwater level thresholds have been developed for these bores to allow for the validation of groundwater level changes (considered to be associated in part to increased surface water losses).

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2.3.3.5 GAB Impacts

Pre-mining steady-state modelling estimates around 100 m^3/day of net vertical leakage from the lowest GAB unit (the Rewan Formation) to the underlying Permian units (conceptualisation and assessment of vertical gradients indicates this could occur, **Section 2.2.6.1**).

It is noted that this 100 m^3/day over the entire Rewan Formation model layer within the 10,044 km^2 model domain (re-run model), is a very low flow rate as associated with an aquitard.

Model predictions, at the end of mining, estimate vertical leakage to increase to 2,200 m^3/day due to mine dewatering /depressurisation of coal which facilitates induced flow.

The groundwater level predictions, using hydrographs from the predictive modelling for all available bores to the west of the mine leases, were used to develop groundwater level thresholds (GMMP **Section 5.3**), which allow for the instigation of further assessment to ensure management and mitigation of potential impacts on GAB units (as required in EA approval Condition E13 (Table E3) and EPBC Act Condition 3d).

2.3.4 Model Predictions – Post-Closure

The predictive modelling also allowed for an assessment of post-mining impacts on the groundwater resources. It is noted that, in compliance with approval conditions, these potential impacts will be assessed and revised as additional monitoring and refinement of modelling takes place during mining operations. These predictions were, however, considered when compiling the GMMP (i.e. if marked changes between operational impacts and post-mining impacts were identified the GMMP bore network was assessed to determine suitability for long-term groundwater impact monitoring).

2.3.4.1 Long-term Water Table Impacts

Long term 0.2 m drawdown contours are predicted to extend to west over time, south of the Carmichael River.

The 0.2 m drawdown, for all three models, is not predicted to extend into the Doongmabulla Springs Complex area.

2.3.4.2 Long-term Springs Impacts

The long-term impacts on the Doongmabulla Springs Complex are predicted to be less than or equivalent to the operational impacts. Maximum post-closure drawdown is predicted at 0.09 m (Option 1) and 0.13 m (Option 2) compared to the operational phase drawdown predictions 0.11 m (Option 1) and 0.13 m (Option 2).

For the Mellaluka Springs Complex, based on the conservative conceptualisation that the sub-D Permian sediments underlie the springs (see **Section 2.7.3.1**), the model predictions are considered to increase over time.

Refined modelling, using additional geological data, will be conducted as per the approval conditions. This refinement will allow for the more accurate assessment of drawdown in the Mellaluka Springs area.

2.3.4.3 Long-term Neighbouring Bore Impacts

Long term predictions are considered unlikely to materially affect neighbouring bores, i.e. groundwater levels are not predicted to exceed 5 m in confined aquifers.

2.3.4.4 Post-closure Baseflow Impacts

Pre-mining steady-state modelling estimates baseflow (upstream where perennial flow is measured in the Carmichael River) at:

- A maximum flow of 4,479 m^3/day, which will reduce to 4,189 m^3/day in the long-term (SEIS model)
- A maximum flow of 7,103 m^3/day, which will reduce to 6,850 m^3/day in the long-term (re-run Option 1 275 m) model)
- A maximum flow of 5,105 m^3/day, which will reduce to 4,752 m^3/day in the long-term (re-run Option 2 250 m) model).

Long-term modelling predicts a 4 to 7% reduction in groundwater contribution to baseflow in the Carmichael River, compared to the 4.4% during mining operations.

In the area where the Carmichael River is a losing system (non-perennial flow) within the mine lease, pre-mining groundwater flow from surface water to groundwater is estimated at 1,000 m^3/day. Post-closure predictions suggest that this flow (loss) from surface water would increase to 1,650 m^3/day (less than the 1,800 m^3/day predicted at the end of mining).

2.3.4.5 Post-Closure GAB Impacts

Long term groundwater flow from the GAB was simulated in the model, considering flow within the model. Long-term flow indicates a range from 104 to 229 m^3/day, markedly less than the end-of-mining flow predictions.

2.3.5 Numerical Model Confidence

The groundwater model re-run was undertaken in accordance with Australian modelling guidelines, published by the National Water Commission (Barnett et all, 2012) and with reference to the Murray Darling Basin Commission (Middlemis et al, 2001). These guidelines provided a mechanism for characterising model objectives and confidence.

To provide sufficient confidence in model predictions, conservative, long-term steady state post-closure predictions were incorporated and flow data from the Carmichael River was used to benchmark groundwater/surface water interactions. Modelled results at receptors beyond the mine leases typically predict low levels of impact, which provides additional confidence in the level of stress observed at receptors versus calibration data (GHD, 2015).

A detailed sensitivity analysis has also been completed, which enabled the impact of uncertainty in the model inputs to be characterised.

According to the Australian modelling guidelines, the current groundwater model is a confidence level: Class 1—2, based on the data utilised to date (for modelling). The level of confidence in the model is expected to increase once mining starts and model validation can be undertaken.

This is to say, steady-state calibration is acceptable for mine dewatering predictions as there is no additional data available. However, model validation can be undertaken to assist prediction once additional observations are available after the start of mining. Regular modelling updates are to be undertaken, as per approval conditions, including after 2 years of mining, which will be the first review of the model and the GMMP.

An independent review (see **Section 2.4** below) of the groundwater model has been conducted. The peer review process identified that the model design, software, extent, layers, cell size and boundaries described in detail in various reports are consistent with best practice.

2.3.5.1 Summary

The three models, using different boundary conditions, conductance, and conceptualisations, allow for a suitable range of predictions which can be used for developing the GMMP.

2.3.6 Predictive Modelling and Groundwater Level Thresholds

The GMMP includes a groundwater monitoring network that can detect drawdown caused by the approved mining operations and allow for the comparison of actual drawdown to the predicted drawdown of groundwater levels. The monitoring bore network also allows for the assessment of drawdown prior to reaching the maximum drawdowns (irrespective of model layer and timing due to transient mining operations).

While the GMMP is primarily developed to manage and monitor groundwater resources to meet all groundwater related approval conditions, the ongoing management of water during mine operations will be done through the water management plan. The important features of the water management plan will be to promote water conservation, water recycling, water reuse, and also to meet water quality objectives of the intended purpose of use or discharge. The water management plan also have management actions to measure quantity of water leaving a particular application or destination to ensure it is appropriate for the next application or destination, including, for example, release into the environment . The volume of water taken by carrying out the authorised activity under the mining lease

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(i.e., the water entering the pits or groundwater pumped out in advance from mining areas) will be measured and reported as required under section 334ZP of the Mineral Resources Act 1989 and sections 31A and 31B of the Mineral Resources Regulation 2013.

The compilation of groundwater ingress volume records during mining, based on mine dewatering schemes (pump flow meters), allows for addressing model uncertainty and model refinement (i.e. using actual dewatering results and changes in monitoring bore water levels to recalibrate the model) at regular intervals as per the EA conditions.

To undertake this assessment during mining operations groundwater level thresholds have been developed, in line with EA approval condition E13, to detect if drawdown caused by the mine operations may exceed predictions in the numerical model and sensitive ecosystems may be impacted. Apart from setting out and monitoring to detect for exceedances of groundwater level drawdown thresholds, it is noted that there are other monitoring and reporting mechanisms required under other project approval conditions. These details were discussed in monitoring and reporting in **Section 4.0**.

Section 5.3 provides details of the groundwater level thresholds, including the EPBC Act (EPBC 2010/5736) approval condition which includes for the details of groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex.

The selection of groundwater level thresholds was based on predictive model groundwater level projections, which allowed for the prediction of groundwater level change over time in different units across and adjacent to the MLs. It is noted that, to allow for model uncertainty (which will be improved with transient groundwater level and ingress / dewatering records during mining), that the groundwater drawdown thresholds include the following:

- Allow for the assessment of drawdown so it does not exceed the maximum predicted drawdown
- Validate predictive modelling
- Allow for the assessment of decline trends through the compilation of groundwater level hydrographs, to be updated after each groundwater monitoring event. This will allow for the evaluation of the rate of groundwater level decline as well as the actual drawdown
- Implementation of a rate of groundwater level decline trigger, as well as the groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex. This is to ensure the drawdown does not exceed the interim drawdown threshold of 0.2 m at the Doongmabulla Springs Complex.

The groundwater level thresholds (and groundwater level Early warning triggers for the Doongmabulla Springs Complex) are as follows:

- If groundwater levels vary by 50% of the predicted drawdown, above natural fluctuation, in unconfined aquifers
- If groundwater levels / potentiometric levels vary by 75% of the predicted drawdown, above natural fluctuation, in the confined aquifers
- For bores where groundwater levels are predicted to decline by > 10 m, as a direct result of coal mining, the impact threshold levels are 90% of the predicted maximum drawdown levels
- In cases where the predicted drawdown is markedly lower than the natural fluctuation, the predicted drawdown plus natural fluctuation is taken as the impact threshold.

Should groundwater level monitoring indicate variations in groundwater levels by more than 50% (unconfined) or 75% (confined) groundwater level fluctuations or > 90% of the predicted maximum drawdown levels (in bores where drawdown is predicted to > 10 m) on two consecutive groundwater monitoring events (quarterly) then the following will occur:

- An investigation must be instigated within 14 days of detection
- Notify the regulator within 30 days as per condition 59 of the Associated Water Licence
- Assess the cause of the groundwater level fluctuation considering:

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  - dry / drought conditions
  - groundwater extraction from neighbouring user(s)
  - groundwater level trends in multiple bores within the same unit
  - long term recharge / discharge trends
  - mining operations and dewatering volumes.

A report into the investigation will be made available to the State and Commonwealth regulators on request with findings and recommendations.

Impact thresholds for the Doongmabulla Springs Complex have been compiled to assess potential mining impacts on MNES. The Impact thresholds are defined as the following:

- 90% of the predicted maximum drawdown levels:
  - **NOTE:** For bore C14033SP, were the drawdown is predicted to be close to the natural fluctuations, the natural fluctuation variation (i.e. 90% of natural fluctuation in the reference data set) is the impact threshold
  - **NOTE:** For bores where the 90% of the predicted maximum drawdown levels is less than the selected groundwater level thresholds (determined based on natural fluctuation), the impact thresholds are determined using Natural Fluctuation plus 90% of predicted drawdown.
- Timing of groundwater level drawdown, such that if groundwater levels start to decline before the predicted impacts (as predicted in model hydrographs (**Section 5.3**))
- Rate of groundwater level decline change which exceeds the rate of groundwater level decline trigger in key hydrostratigraphic units (included in **Section 5.3.5**).

Should any or all these Impact threshold levels be realised, through the assessment of groundwater monitoring data and comparison to model predictions, then an appropriately qualified person will complete an investigation and will provide a written report to the State and Commonwealth regulators within 60 days.

The investigation will also perform refinement and re-run of predictive model if required along with increased monitoring through additional bores and evaluation of induced flow due to mining impacts. If the investigation concludes that the exceedance of Impact thresholds is a result of mining activities, then the following will occur:

- Review of the latest numerical groundwater model, comparing with the monitoring results and revising as required
- Update the predictions using the revised numerical model to check if the revised predictions exceed the interim threshold or not
- Review of mine plan including sequencing of mining
- Review of Underground Water Monitoring program
- Investigate and implement potential mitigation activities including those identified from the GAB Spring Research Plan.

2.4 Groundwater Model Independent Review

As per the requirements of the Conditions 22 and 23 of the EPBC Approval (EPBC 2010/5736) the Carmichael Coal Project numerical groundwater flow model developed by GHD (as described in **Section 2.3** above) was independently peer reviewed by Hugh Middlemis.

The peer review process identified that the model design, software, extent, layers, cell size, and boundaries described in detail in various reports are consistent with best practice. In fact, the investigation of an alternative conceptualisation is not common practice and should be considered a leading practice method of addressing the key area of conceptual model uncertainty. The report is attached in **Appendix A**.

The summary of the peer review is set out below:

> *The review process did not identify any material weaknesses in the model design, boundary conditions, parameter values or calibration performance. The exploration of model uncertainty in conceptual and parameter value terms is commendable and the results indicate low sensitivity/uncertainty. It is my professional opinion that the model revisions have been undertaken competently, consistent with Condition 23, and the revised model design and performance is consistent with guidelines and suitable as is for impact assessment purposes, with future model refinements dependent on monitoring to obtain data for validation.*

2.5 Environmental Values

2.5.1 Environmental Protection (Water) Policy 2009

The Environmental Protection (Water) Policy 2009 (EPP [Water]) applies to all waters within Queensland which include rivers, streams, wetlands, lakes, estuaries, coastal areas, and groundwater aquifers. Based on the intent of the Environmental Protection Act 1994 (EP Act), groundwater quality is an EV with intrinsic value that is to be protected, with the groundwater quality maintained within the range of natural quality variations established through baseline characterisation to ensure that no adverse effect on groundwater quality occurs from the operation of the activity. The EPP (Water) achieves the objectives of the EP Act with a framework that includes identification of environmental values (EVs) which define the uses of the water by aquatic ecosystems and for human use (e.g. drinking water, irrigation, aquaculture, and recreation). Water quality objectives (WQOs) define objectives for the physical, chemical, and biological characteristics of the water (e.g. dissolved oxygen, turbidity, toxicants, fish); WQOs are being progressively determined for areas of Queensland to enhance or protect the environmental values identified for waters (DES, 2018).

The CCP is located within the Belyando Catchment of the Burdekin River Basin, where draft EVs and WQOs have been established and are included in the Water Quality Improvement Plan 2016 (WQIP) for the Burdekin Dry Tropics Natural Resource Management (NRM) region (NQ Dry Tropics, 2016).

For aquatic EVs, ecosystems are typically subdivided into three levels of protection related to their current condition, which include High Ecological Value, Slightly to Moderately Disturbed and Highly Disturbed ecosystems.

The Belyando Catchment is further divided into seven sub-catchments; the CCP is located within the Carmichael River sub-catchment. EVs considered applicable to the CCP to be particularly enhanced or protected under the EPP (Water), indicated as draft EVs in the WQIP for the Carmichael River sub-catchment, include (both surface and groundwaters):

- Biological integrity of an aquatic ecosystem (including the Waxy Cabbage Palm tree communities)
- Primary industries (water for farm use [fruit packing or milking shed] and stock watering)
- Primary recreation (swimming)
- The cultural and spiritual values of the water
- Drinking water (groundwater).

2.5.2 *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act)

The EPBC Act focuses on Australian Government interests on the protection of mattes of national environmental significance (MNES), separate from the states and territories which have responsibility for matters of state and local significance. The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places which define the MNES.

In 2013, the EPBC Act was amended to include a 'Water Trigger' to include water resources as a MNES, in relation to coal seam gas and large coal mining developments (DoEE, 2013). Such developments likely to have a significant impact on water resources are required to be referred under the EPBC Act.

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The EVs considered applicable to the CCP to be particularly enhanced or protected under the EPBC Act include:

- The Great Artesian Basin spring system close to Doongmabulla around eight kilometres west of the mine lease western boundary
- The (non-GAB) springs mapped adjacent to Mellaluka around 10 km south-southeast of the approved mining
- Groundwater dependent ecology along Carmichael River, as identified in the GDE Management Plan
- Existing extraction bores and registered bores within the mine-related drawdown extent predicted adjacent to the CCP
- Recharge zones of the Clematis Sandstone (a major aquifer within the GAB).

2.5.3 Burdekin, Don, and Haughton River Basins

The CCP is located within the Burdekin Basin. Draft environmental values and water quality objectives (WQOs) have been compiled in a draft report for consultation to include for groundwaters of the Burdekin, Don, and Haughton River Basins (State of Queensland, 2017). The mine site is, based on the draft report, located within "Earlier sedimentary basins underlying the GAB", which comprise Clematis Sandstone, Dunda Beds, Rewan Group, and Moolayember Formation. The Permian coal bearing units are not included and the Joe Joe Group is considered within a Palaeozoic sedimentary basin.

The Environmental Values of the Earlier sedimentary basins underlying the GAB include:

- Aquatic ecosystems (waterways and waterholes)
- Stock watering
- Visual recreation
- Drinking water supply
- Cultural, spiritual and ceremonial values.

Water Quality Objectives have been drafted for groundwater zones within the Burdekin Basin, based on available DNRME water quality databases. The CCP is recognised to be located within the following groundwater (chemistry) zones:

- Suttor Alluvium Zone
- Saline Tertiary sediments
- Central Galilee Clematis
- Western Galilee Clematis.

It is noted that these groundwater zones are based on chemistry and differ from the geological descriptions / zones (Earlier sedimentary basins underlying the GAB) used to assess Environmental Values. These zones, once finalised and updated with additional data (currently only represent mid-range levels), are used to identify outlying sites and sudden or rapid changes. The draft WQO are included in **Table 23**.

It is considered that Adani has a more robust and site-specific (greenfield data) hydrochemistry dataset, which can be used to inform the draft report. These data have been used (**Section 5.4**) to identify outlying data and allow for chemical trend analysis to identify sudden or rapid changes.

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Table 22 Draft water quality objectives for groundwaters of Burdekin, Don and Haughton River Basins

Zone [1,2]	Percentile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	RAH	eH
		mgL-1	%	mgL-1	%	mgL-1	%	mgL-1	%	mgL-1	%	mgL-1	%	mgL-1	%	µScm-1	mgL-1		mgL-1	mgL-1	mgL-1	mgL-1	mgL-1	mgL-1	mgL-1	meqL-1	meqL-1	mV
3 - Suttor	Samples	68	68	68	68	67	67	65	64	67	67	65	64	57	56	154	68	71	65	49	68	24	20	10	9	67	65	0
	10th	102	63	6	2	3	4	26	0	44	17	11	2	0.0	0.0	639	28	6.8	25.0	17.0	0.0	0.0	0.0	0.0	0.0	4.7	-106.6	0.0
	20th	141	65	11	4	6	5	46	1	95	33	21	3	0.0	0.0	823	46	7.0	40.0	19.6	0.1	0.0	0.0	0.0	0.0	8.1	-50.3	0.0
	50th	800	72	44	12	71	16	134	7	1150	86	92	6	0.5	0.0	6500	436	7.5	125.0	34.0	0.4	0.0	0.1	0.1	0.0	14.6	-2.6	0.0
	80th	3156	90	437	17	410	19	399	55	6318	93	622	9	1.6	0.2	21140	2612	8.1	349.0	49.4	0.8	0.8	0.6	0.5	0.3	29.6	3.7	0.0
	90th	5203	94	824	19	845	21	554	72	10996	94	850	11	6.4	0.7	31000	5505	8.3	540.0	59.2	2.6	2.7	2.4	0.7	0.6	33.2	4.9	0.0
6 - Saline Tertiary Sediments	Samples	156	156	155	155	155	155	143	143	156	156	151	151	107	107	245	156	173	156	76	141	85	77	34	35	154	141	0
	10th	147	57	6	2	5	3	55	2	142	56	0	0	0.0	0.0	580	32	6.8	6.1	14.1	0.0	0.0	0.0	0.0	0.0	6.4	-36.2	0.0
	20th	253	65	11	3	10	6	130	4	321	64	7	1	0.0	0.0	1015	80	7.1	55.7	15.0	0.1	0.0	0.0	0.0	0.0	7.8	-24.4	0.0
	50th	685	78	54	7	68	14	285	10	975	85	51	4	0.4	0.0	3613	455	7.8	223.0	26.5	0.3	0.0	0.0	0.0	0.0	15.6	-2.4	0.0
	80th	1804	91	203	13	220	23	494	34	3667	92	191	7	2.4	0.1	12330	1456	8.2	405.0	56.0	0.6	0.2	0.1	0.0	0.0	28.4	2.4	0.0
	90th	2897	94	367	18	312	30	686	43	5556	94	528	9	5.0	0.5	16100	2066	8.3	553.8	77.5	0.9	0.5	0.3	0.1	0.0	33.9	5.8	0.0
1 - Central Galilee Coal Measures	Samples	51	51	51	51	50	50	49	49	50	50	51	50	42	41	75	51	54	48	23	43	25	18	7	5	50	48	0
	10th	58	45	4	3	3	2	39	2	73	31	6	2	0.0	0.0	400	27	6.5	35.3	9.8	0.1	0.0	0.0	0.0	0.0	2.3	-23.6	0.0
	20th	87	65	16	4	5	6	69	4	110	38	18	2	0.0	0.0	725	67	7.1	69.6	13.0	0.2	0.0	0.0	0.0	0.0	4.4	-10.4	0.0
	50th	293	76	38	10	30	11	205	19	327	69	90	7	0.0	0.0	1530	236	7.7	178.5	18.0	0.3	0.0	0.1	0.0	0.0	10.7	-1.0	0.0
	80th	1179	87	127	18	112	22	413	40	1938	86	255	18	3.0	0.4	4460	769	8.1	339.5	25.9	1.0	0.3	0.2	0.4	0.0	22.4	1.9	0.0
	90th	2060	90	166	28	180	26	687	58	3595	89	452	27	6.3	0.6	9030	1448	8.2	566.4	47.4	1.4	0.5	0.7	2.6	0.0	34.8	4.3	0.0
3 - Western	Samples	27	27	26	26	26	26	27	27	27	27	27	27	21	21	42	26	36	26	17	25	19	18	4	1	26	26	0
Galilee Clematis	10th	35	73	1	1	2	2	18	4	52	64	0	0	0.0	0.0	204	10	6.6	20.6	10.0	0.1	0.0	0.0	0.0		3.7	-14.7	0.0
	20th	52	78	1	1	3	2	31	9	58	68	1	0	0.2	0.0	283	14	7.0	30.0	10.9	0.1	0.0	0.0	0.0		4.6	-4.7	0.0
	50th	239	88	7	3	6	9	116	15	275	80	4	2	0.8	0.1	1244	44	7.5	98.5	15.0	0.3	0.1	0.0	0.0		14.8	0.2	0.0
	80th	630	95	55	8	36	16	157	28	1110	88	57	7	1.3	0.4	3752	395	7.9	131.6	22.4	1.2	0.5	0.0	0.1		20.2	1.3	0.0
	90th	979	97	147	14	137	17	219	33	1429	92	132	8	2.6	0.7	5301	870	8.1	183.5	46.0	2.4	0.8	0.3	0.2		21.9	2.3	0.0

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2.6 CCP Mine Activities

The proposed CCP mine comprises a greenfield coal mine over Mine Lease areas, ML 70441, ML 70505, and ML 70506, for both open cut and underground mine operations. The approved mine plan includes for six open cut pits and five multi-seam underground mines to produce up to 74 Mtpa of raw coal, which equates to approximately 60 Mtpa of thermal coal over the 60 year mine life.

The mine footprint is over 200 km^2 and includes mine infrastructure, associated mine processing facilities, and offsite infrastructure (a worker's accommodation village and associated facilities, a permanent airport site, a mine industrial area and water supply and storage infrastructure). The mine layout is presented in **Figure 15** below.

The geological characteristics of the CCP mine define the location of open cut and underground mining operations. This in turn determines the optimal location of mine infrastructure and associated interdependencies which include site access, services, and other infrastructure required to access offsite infrastructure and third-party service providers. The layout of the infrastructure has subsequently been designed and located to minimise the likelihood of resource sterilisation.

The main infrastructure area is located east of the target coal subcrops. The out-of-pit dumps are located to minimise handling of material and to avoid the sterilisation of coal resources.

The approved mining and associated mine infrastructure was reviewed to allow for identification of mine infrastructure which may potentially impact on groundwater, these include:

- Mine areas
- Fuel supply and storage
- Mine water supply and management
- Mine waste management
- Waste disposal facilities.

Mine phasing for the first five years (initial development phase) has been prepared and the location of the Year 5 mine footprint is included on the operational groundwater monitoring bore network figures (**Appendix B**). The Year 5 mine footprint inclusive of box cut works, and associated mine infrastructure re depicted on the operational bore network maps in **Appendix B**.

The nature of activities to be undertaken within the first five years of operations include:

- Water truck filling stations
- Power reticulation
- Telecommunications
- Warehouse
- Light vehicle workshop
- Administration facilities and bathhouses
- Carparking for light, medium and delivery vehicles
- Fire Services
- Rail loop
- Airstrip
- Accommodation village
- Explosive storage
- Heavy Workshop areas including:
  - Repair bays
  - Tyre changing facility

- Washdown bays
- Services areas
- Fuel and lubrication storage and refuelling facilities
- Battery and gas storage area
- Crib rooms and offices

- Open cut operations
- Mine services and infrastructure
- Potable water treatment plant and storage
- Sewerage treatment plant and storage
- Raw water, mine affected water and sediment water storages
- Process water storage
- Water management infrastructure including levees and creek diversions, and
- Coal handling and processing plant.

From Year 5 onwards, mining will progress to other pits north and south of the initial development.

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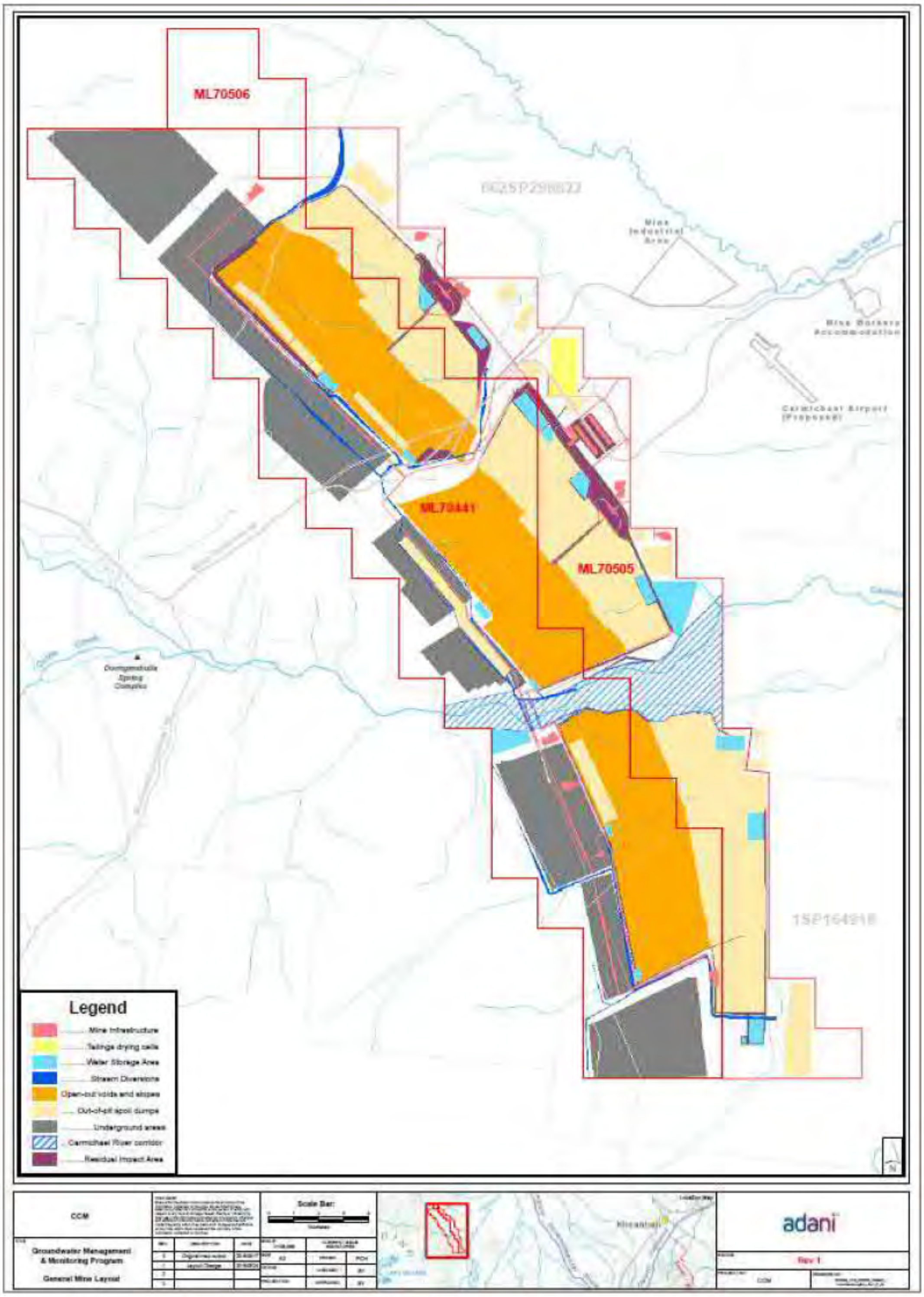

Figure 15 Proposed Mine Layout and Associated Infrastructure

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2.7 Potential Impacts on the Hydrogeological Regime

A summary of potential impacts of mining activities on the groundwater resources has been compiled and are based on the EIS and post-EIS groundwater studies, summarised below.

2.7.1 Construction

The principal activities during the construction phase of the mine, which may impact groundwater resources, are:

- Possible temporary dewatering of foundations for proposed infrastructure
- Degradation of groundwater quality due to spills and leaks of hazardous materials such as oil and diesel or mismanagement of wastewater.

Dewatering

Temporary dewatering is unlikely to be required for construction of foundations for infrastructure (including the village and airport) or for the construction of a general waste landfill, given that depth to groundwater is at least 20 m below ground surface away from the Carmichael River (i.e. near the Mine Infrastructure Area (MIA) where the majority of construction is proposed).

Temporary dewatering is also considered unlikely to be required for construction of minor creek crossings, given that the minor surface watercourses in the mine area are ephemeral and located in areas where groundwater is anticipated to be at least 20 m below ground surface.

Spills

Construction vehicles and equipment will use diesel and oil, which will be stored at the MIA and off-site infrastructure area. Other potentially environmentally hazardous materials include waste oils and sewage.

As the depth to groundwater in these areas is typically greater than 20 m below the clayey Tertiary sediments encountered across the site, the nature of these clays is considered to provide significant attenuation of any contaminants from leaks and spills before they reach the groundwater table.

2.7.2 Operations

The principal activities during the operational phase of the mine, which may impact groundwater resources, include:

- Dewatering of open cut pits and underground mine workings
- Spoil and tailings disposal to pits, out-of-pit spoil dumps, and/or tailings cells
- Mine affected water (MAW) storage dams
- Operation of processing and storage facilities and plant
- The diversion of minor ephemeral creeks along the western boundary of the mine lease area
- Longwall mining of the underground workings.

Mine Dewatering

Dewatering will be required to lower groundwater levels to the base of the proposed workings for safe and efficient operation of the open cut and the underground mines. As a result, groundwater levels will be drawn down during the operational phase.

The sandstone unit directly below the D coal seam and above the E coal seam (D-E sandstone), the overlying sandstone (AB-D sandstone interburden layers), and the AB and D coal seams will require to be locally dewatered for safe mining to occur.

Dewatering has the potential to reduce groundwater levels in existing groundwater bores that fall within the cone of influence of the proposed mine and hence has the potential to impact on existing groundwater supplies.

Predictive groundwater modelling was conducted as presented in the SEIS (GHD, 2013a) and reassessed, considering different model boundaries, in the Carmichael Coal Project Response to

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Federal Approval Conditions- Groundwater Flow Model report (GHD, 2015). This predictive modelling, using conservative geological model layers (such as the Colinlea Sandstone extending to the east) and a conservative hydraulic conductivity of 10^{-5} m/day for the Rewan Formation (which can be as low as 10^{-7} m/day), is used to allow for the evaluation of potential impacts on groundwater levels.

Figure 16 is the model output figure of maximum predicted groundwater drawdown (using the SEIS model), which indicates the predicted extent of drawdown (the 0.2 m below initial groundwater level). These drawdown predictions were used to evaluate possible impacts on groundwater resources and associated environmental values, as detailed below. The SEIS model-predicted drawdown for each unit except Rewan and Dunda Beds , at various times throughout the life of mine, have been included in Appendix C and are part of the SEIS assessments included in the report *Appendix K6 Mine Hydrogeology Report Addendum*.

The dewatering impacts, outside the mine lease, have been considered (**Appendix E** hydrographs and **Section 5.0**). The GMMP includes for the validation and assessment of model predictions based on mine dewatering over time. The use of sentinel bores and groundwater level thresholds (in bores between the mine and sensitive groundwater reliant systems), on the mine lease boundaries, allows for assessment of dewatering and the instigation of investigations (into potential for environmental harm and/or make-good).

2.7.3 Indirect Impacts

No direct impacts on groundwater resources associated with the GAB Clematis Sandstone aquifer will occur because of approved mining. Longwall mining will, as a result of goaf, result in alteration of the overlying (above the target coal seams) Rewan Formation, the basal GAB aquitard.

Groundwater modelling results suggest the potential for indirect dewatering impacts via induced flow. Induced flow can occur due to the dewatering and depressurisation of the target coal seams, such that:

- Drawdown in the near-surface Tertiary sediments and Quaternary-age alluvium which are present throughout much of the modelled area can occur
- Induced flow from the overlying GAB Clematis Sandstone aquifer through the Rewan Group (Dunda Beds and Rewan Formation) to the depressurised target coal seams.

It is noted that the greatest potential for induced flow is where the coal is most dewatered / depressurised and induced flow would be vertically from over and underlying hydrostratigraphic units (extent dependent on vertical permeability, thickness of aquitards, and proximity to the target coal). The effects of depressurisation down dip of the mined coal will reduce exponentially such that the change in head (some 8 km from the mine lease) would be limited below the DSC. This possible depressurisation (if measurable) would have limited potential for induced flow (particularly through the Rewan Formation (the regional aquitard) and Bandanna Formation). As the coal seams are some 600 m below the DSC there is little or no potential for induced flow as indicated in the predictive modelling.

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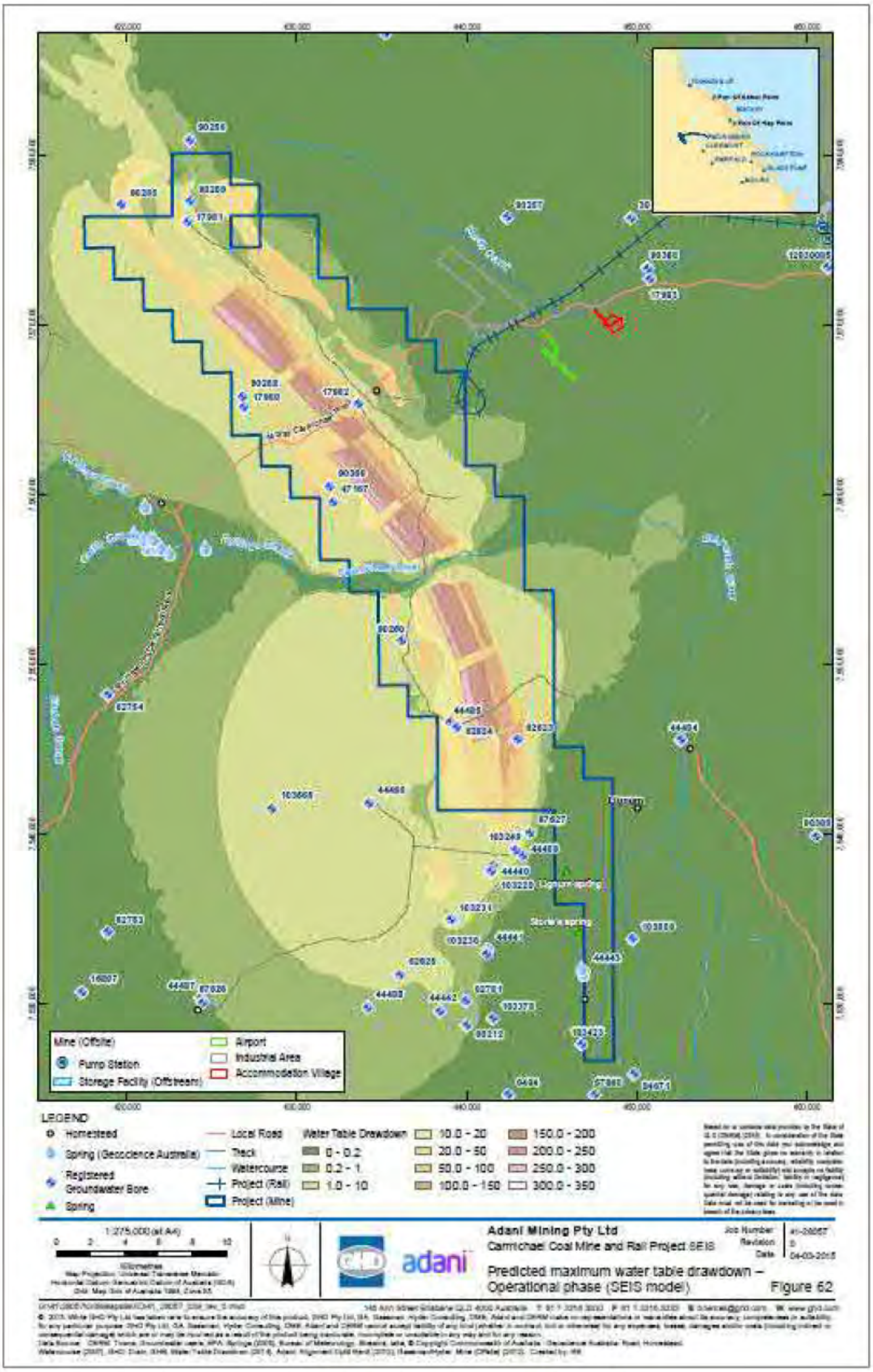

Figure 16 Predicted maximum water table drawdown (SEIS model, GHD, 2015)

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2.7.3.1 Cross-section along strike

The potential for induced flow from the GAB units is based on the change in head (increase in vertical gradient) between the depressurised target coal seams and the overlying hydrostratigraphic units as well as the hydraulic conductivity of the hydrostratigraphic units.

The dewatering and coal depressurisation will be greatest at the mine workings (dewatering required to allow for safe mining conditions) decreasing exponentially down dip away from the mine workings (**Plate 11**)

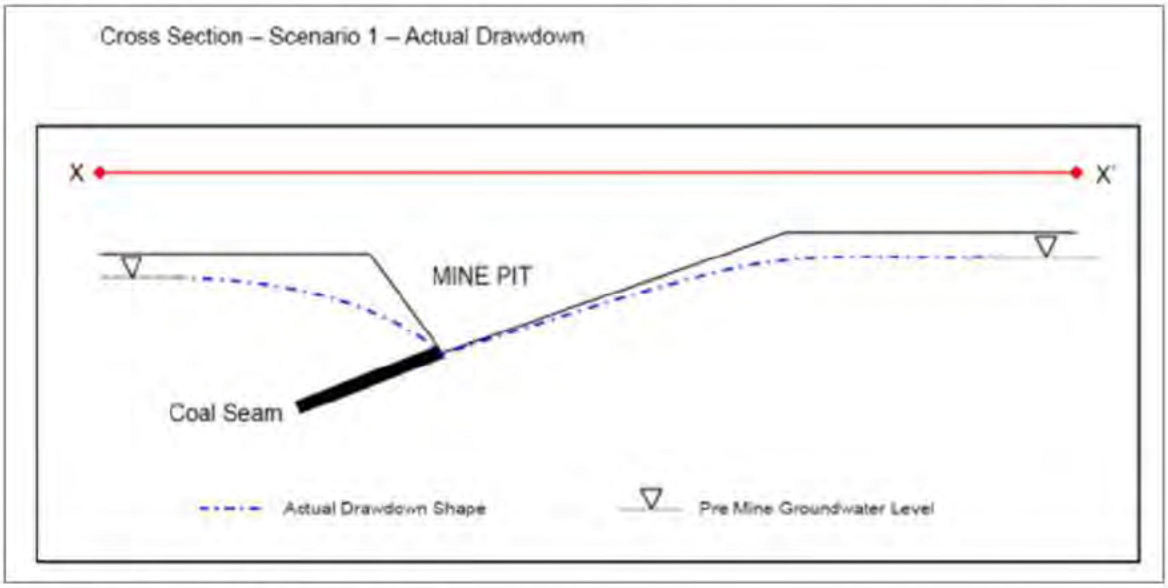

Plate 13 Mine dewatering drawdown curves

The zone of influence due to mine dewatering is the distance to negligible drawdown, as recognised in the Thiem-Dupuit stead-state equation (equation 1), such that the influence of dewatering (the depressurisation of the coal seams) reduces to zero with distance.

Equation 1

$$Q = \frac{\pi k(h_o^2 - h_w^2)}{\ln(R / r_e)}$$

Where:

Q = inflow (m^3/day),

k = hydraulic conductivity (m/day)

h_o = head at distance R from centre of pit (m),

h_w = head at distance re (m) at pit face (seepage face)

R = radius of "influence" or distance to negligible drawdown (m)

r_e = radius of "well" (m)

(Kruseman & de Ridder 1991[6])

A cross-section (**Figure 17**) has been compiled along geological strike along the western boundary of the mine lease. This cross-section allows for the illustration of the underlying geology, initial pre-mining groundwater levels (heads) and the predicted groundwater levels (post-mining heads), which indicates the predicted influence of direct mine dewatering on the coal seams and Rewan Formation as well as

[6] Kruseman G.P. and N.A. de Ridder. 1991. Analysis and Evaluation of Pumping Test Data. 2nd Edition. International Institute For Land Reclamation and Improvement. Wageningen. The Netherlands.

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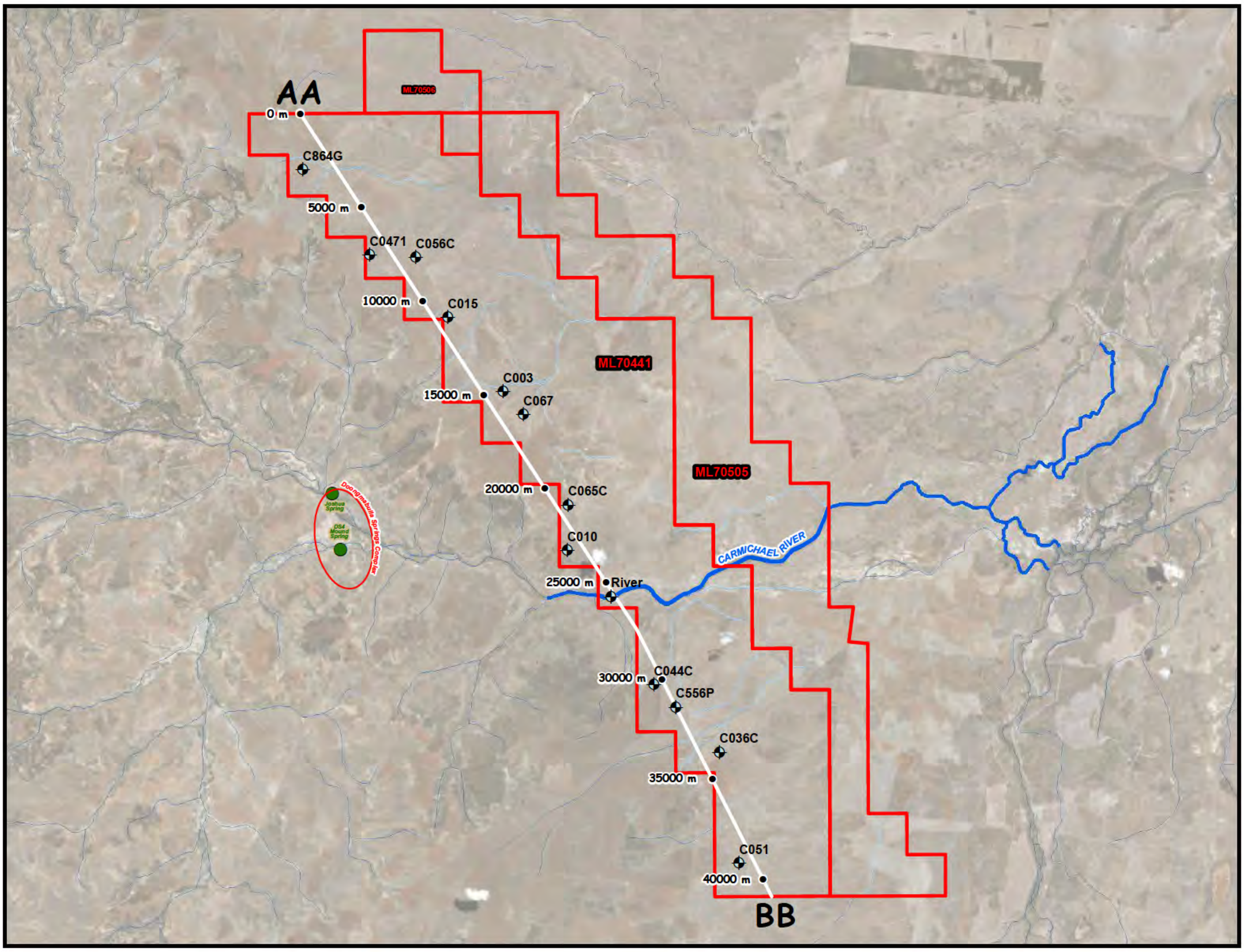
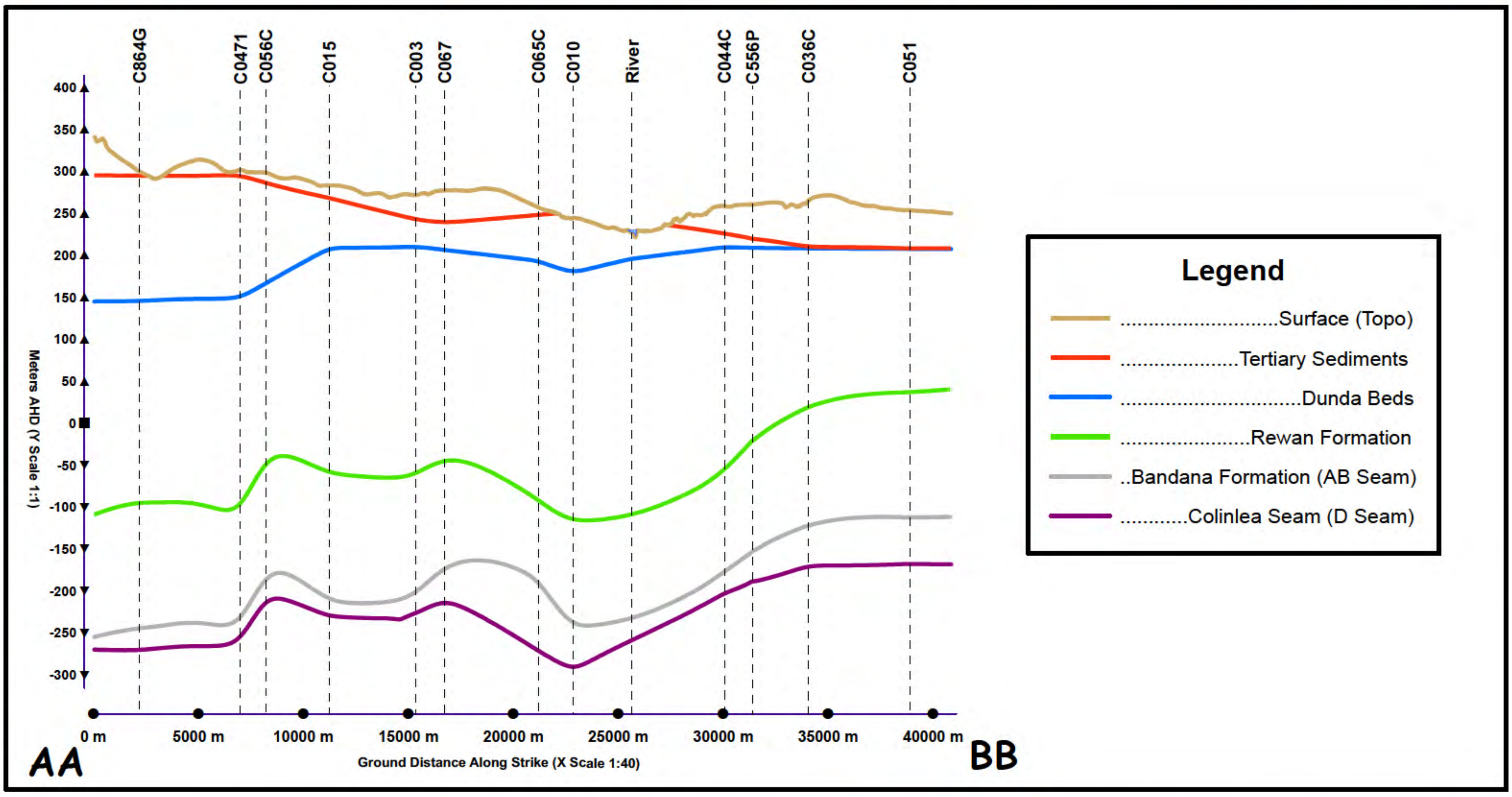
the predicted induced flow from the Dunda Beds and Clematis Sandstone above the Rewan Formation aquitard.

NOTE: The pre- and post-mining groundwater levels, derived from the hydrographs and predicted drawdown contours over time (**Appendix E**), have been included on the strike cross-section, as requested by the regulators. These groundwater levels are included in **Appendix C**.

The following conclusions have been compiled based on the predicted groundwater levels, along the western boundary of the MLs:

- Induced flow from the alluvium will result in centimetre alteration in the alluvium monitoring bores, on the cross-section bore C027P1 is predicted to vary from 223.84 mAHD to 223.82 mAHD (0.02 m) post closure
- The potentiometric levels across the Tertiary Sediments , where groundwater flow is from south to north pre-mining, indicate little or no change to groundwater flow patterns (south to north) at the end of mining
- Unsaturated Clematis Sandstone is only mapped in the northwest corner of the MLs so not included on the cross-section. **Appendix C** drawdown contours over time indicate minor (< 0.2 m) drawdown predictions at the end of mining across the DSC area
- Groundwater flow in the Dunda Beds remains towards the synform, around C027P2 throughout the life of mine
- Rewan Formation groundwater flow patterns are towards C008P1, at the synform, before and at the end of mining
- Groundwater flow patterns, towards the synform at C008P2 and C007P2, remains over the life of mine within the target AB seam
- Groundwater flow patterns, towards the synform at C007P3 and C006P3R, remains over the life of mine within the target D seam
- Groundwater flow in the Joe Joe Group is always towards the synform at bores C14004SP and C14003SP
- Transient mining across a large (~ 45 km strike) over a long period results in groundwater level fluctuation (dewatering, depressurisation, and rebound) resulting in the difference in groundwater levels within the same hydrostratigraphic units during mining and post-mining
- Marked drawdown as a result of direct mine dewatering does not result in marked changes in groundwater levels in overlying hydrostratigraphic units (via induced flow) due to the aquitard (poor groundwater potential) of the sediments within the CCP.





Path: W:_05_GIS\Carmichael\2018\GWMMP\20181004_CCM_0000000_GroundWaterDrawDownMappingSeries\MXD_APRX_other\LongSection\LongSection_MapFigure.mxd

CARMICHAEL COAL MINE PROJECT

TITLE

Cross Section Along Strike - Figure 17 -

DISCLAIMER.
Every reasonable effort has been made by Adani Mining Pty Ltd (Adani) to ensure the accuracy of the information contained on this map within a reasonable margin of error based on current ground surveys and imagery. To the extent permitted by law, Adani excludes liability to any person or entity with respect to any loss or damage caused directly or indirectly by their use of or reliance on the information contained on this map. Changes and additions to the information contained on this map are made frequently. Adani may make such changes and additions at any time. Adani does not warrant the accuracy of the information contained on this map. © Adani Mining Pty Ltd

NOTES.
SWL (mAHD) data is the average water level based on hydrographs by NRC (on behalf of Adani). Bore surface elevation from Bore Summary of Adani Geology Interp Confirmed units with most recent GWMMP dated May 2017 RL elevation from survey in 2014 for new bores only For old bores, Surface elevation plus measured stick up were combined for RL elevation. Aerial imagery sourced from the DNRM, State of Qld (2018)

REV	DESCRIPTION	DATE
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Scale Bar:
0 2 4 6
Kilometres

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SIZE	A3	DRAWN	PCH
DATUM	GDA94	CHECKED	SY
PROJECTION	UTM	APPROVED	LL

LEGEND
..............................Mine Lease (ML)
............Groundwater Monitoring Well

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STATUS	Rev 0
PROJECT NO CCM	DRAWING No. Figure F6

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2.7.4 Spring Impacts

The spring water balance (**Figure 18**) requires alteration to impact on springs. Based on the location of the mine operations, away from the identified springs adjacent to CCP, no alteration of surface water flow, precipitation, or evapotranspiration will occur because of the mining activities. The only possible alteration is the reduction in groundwater flux.

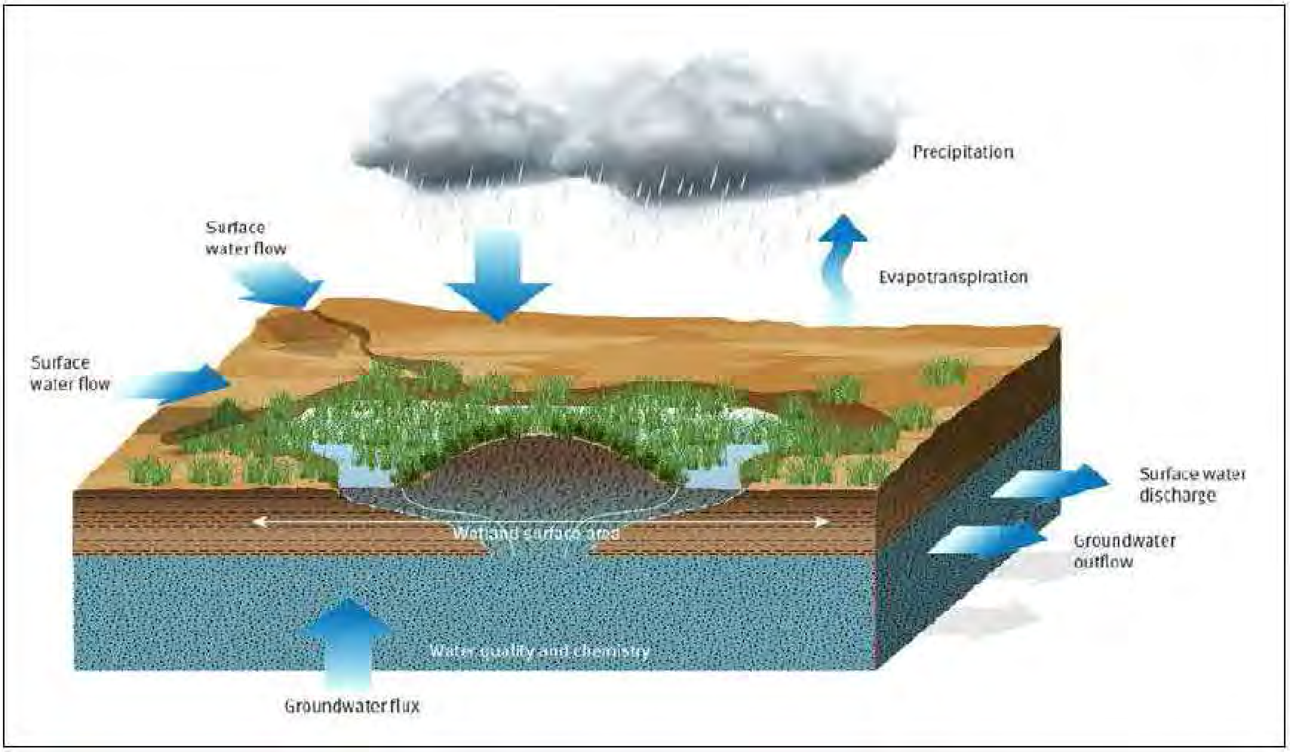

Figure 18 Spring Water Balance (Source: DNRM Springs of the Surat CMA, 2016)

2.7.4.1 Doongmabulla Springs Complex

In the EIS, the source aquifer for the Doongmabulla Spring Complex was identified as the Clematis Sandstone. Post-EIS drilling and groundwater monitoring indicates that recharge to the Clematis Sandstone discharges through the overlying Moolayember Formation (confining layer) to form the required artesian head for the spring to discharge, only where the Moolayember Formation is sufficiently thick to cause artesian conditions but thin/permeable enough to facilitate discharge as springs.

The SEIS predictive model (**Figure 16**) indicate limited predicted drawdown impacts on groundwater levels within the Clematis Sandstone to the west of the mine site in the area containing the Doongmabulla Springs Complex (GHD, 2015).

Model predictions compiled during the SEIS and EPBC Act approval condition modelling (GHD, 2015) indicates:

- Drawdown of 0.2 m extending to Doongmabulla homestead (Predicted maximum water table drawdown – Operation phase SEIS model)
- Drawdown of 0.2 m does not extend to Doongmabulla homestead (Predicted maximum water table drawdown – Operation phase Option 2 (250 m) re-run model)
- Drawdown of 0.2 m does not extend to Doongmabulla homestead (Predicted maximum water table drawdown – Operation phase Option 1 (275 m) re-run model).

The largest predicted drawdown within the Doongmabulla Springs Complex area is at Joshua Spring, where the maximum predicted drawdown includes:

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- SEIS model drawdown of 0.19 m in mine year 95
- Option 1 (275 m) model drawdown of 0.11 m in mine year 85
- Option 2 (250 m) model drawdown of 0.13 m in mine year 91.

Groundwater monitoring between the Doongmabulla Spring Complex and the mine operations, will allow for the validation of the predictions and the reassessment of the potential for induced flow (from the GAB units to the depressurised coal seams).

2.7.4.2 Mellaluka Springs Complex

Predictive groundwater modelling conducted for the Mellaluka Springs Complex is based on a conservative conceptualisation by GHD, due to limited understanding / drilling in the area around the Mellaluka Springs Complex. The predictive groundwater model, constructed and calibrated for the SEIS and approval re-runs, considers the Colinlea Sandstone extends to the east; that is, no Early Permian Joe Joe Group contact or sediments are included in the model. Thus, the predictive modelling considers the springs to be sourced from sub-D coal seam Colinlea Sandstone sediments.

Drilling and aquifer assessments post model construction have, as included in **Section 2.2.6** above, resulted in a more detailed conceptualisation, which will be included in future model refinement.

Approval of mining operations was provided based on a possible worst-case scenario, where these springs are sourced from Colinlea Sandstone, directly impacted by mining operations. Model predictions[7] of groundwater level drawdown include:

- 8.2 m at Lignum Spring
- 2.3 m at Stories' Spring
- 1.1 m at Mellaluka Spring.

2.7.5 River Impacts

Mine dewatering is predicted to result in drawdown of the coal seam potentiometric surface, extending beneath the Carmichael River. Given that groundwater discharge to the Carmichael River upstream of the site maintains flow in the river during dry periods (discharge from Joshua Spring); surface water flows in the river may decline because of possible induced flow from the surface water to the groundwater, in response to the reduction in groundwater levels along the river.

Groundwater modelling results suggest that groundwater discharges to the Carmichael River upstream of the mine site, could be reduced by up to 200 m^3/day or 5 per cent of pre-development discharge during the operational phase.

This assessment, considering additional drilling, assessment of vertical groundwater gradients (particularly the nature of flow above and below the Rewan Formation) (**Section 2.2.5**), and the collection of mine dewatering data, will be updated and refined based on information compiled using the GMMP.

No groundwater drawdown, and thus potential from induced flow impacts, is predicted under the North Creek, as shown in **Figure 16.** The existing groundwater monitoring bore network and program, during operations, allows for the validation of model predictions within the Tertiary sediments, alluvium, and Joe Joe Group to the east of the mine lease.

2.7.6 Riparian Impacts

Direct groundwater discharge to the Quaternary aged alluvium underlying the river and discharge from the Joshua Spring is conceptualised to provide water to the stands of the mature River Red Gum, Paper Bark and Waxy Cabbage Palm tree communities along the river, particularly during dry periods.

Any marked reduction in groundwater levels and/or surface water flows in the Carmichael River during dry periods have the potential to impact the ecological health of these communities.

It is considered this GMMP will provide data for input into the GDE Management Plan to aid with assessment of the project on GDEs.

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[7] All modelling provide the same predictions as no refinement of the model in this area has been done

2.7.7 Other impacts

The construction and operation of the mine also require establishment of associated infrastructure such as tailings dams, water storage facilities, and mine-affected water (MAW) storage areas. As described in **Section 2.5** the groundwater quality is an intrinsic environmental value, which highlights the need to identify those EVs specific to each environment in order to provide the appropriate levels of protection. Therefore adequate groundwater monitoring points have to be identified for baseline characterisation so as to maintain the groundwater quality within the range of natural quality variations and that no adverse effect on groundwater quality occurs from the operation of the above mentioned facilities. The proposed monitoring arrangements to track the likelihood of groundwater contamination are described in **Section 6**. Below is the summary of potential impacts due to these facilities.

2.7.7.1 Tailings

Mining activities generate waste during processing and washing of coal. This waste (tailings) will be stored temporarily in tailings drying cells before disposal. There is a potential for the seepage from the drying cells into the ground and could impact shallow groundwater resources.

Mine waste will be managed through a combination of in-pit disposal (overburden, interburden, coarse reject, tailings, and slimes) and out-of-pit disposal (overburden, interburden, and coarse reject).

The seepage from these out-of-pit or in-pit waste disposal facilities can potentially impact on shallow groundwater resources.

2.7.7.2 Waste Storage Facilities

If disposal of tailings and spoil are not managed effectively at the operational stage there is potential for these wastes to be sources of long term contamination of groundwater post closure of the mine, both within and down gradient of the mine lease.

Similarly if other waste generated from equipment maintenance, such as used oils, tyres and metallurgical waste, has the potential to contaminate shallow groundwater resources in the vicinity of these storage facilities.

2.7.7.3 MAW Storage Facilities

Water pumped out from the pits and underground dewatering operations will be treated as mine affected water. Mine affected water will be stored in (MAW) dams exclusively constructed for the purpose to re-use and recycling. Where the re-use will be used to meet mine dust suppression and process water requirements.

There is potential for seepage of mine affected water to seep and contaminate the shallow groundwater resources.

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3.0 Groundwater Monitoring Bore Network

The long-term objective of the groundwater monitoring bore network is to monitor potential effects of the approved mining operations on the groundwater resources within the CCP area, as recognised in **Section 2.0**, such that informed and adaptive management decisions can be made.

The baseline groundwater monitoring bore network considers the hydrogeological regimes and groundwater resources, to collect representative ambient (pre-mining) data. The existing groundwater monitoring bore network provides lateral and vertical coverage such that potentially impacted groundwater resources can be assessed during mining (operational monitoring bore network).

The monitoring network also includes bores located strategically to allow for early warning of potential impacts on groundwater resources, where groundwater level decline differs from predicted drawdown, so that timely intervention can be implemented to ensure water security to landholders and reduce potential environmental harm.

In the instance groundwater monitoring in a bore indicates an alteration in water quality (using triggers), sample validation (re-sampling) and sampling of additional monitoring bores in other hydrostratigraphic units located in the vicinity of the bore will be undertaken. This will allow for an assessment of possible causes of the water quality changes and the extent of change. This is done as groundwater quality can alter due to blending, which can happen when induced flow from over- and under-lying hydrostratigraphic unit occurs.

3.1 Baseline Monitoring Bores

The baseline (pre-mining) groundwater monitoring bore network was designed to collect representative ambient (background) groundwater level and quality data from all hydrostratigraphic units within the CCP area prior to commencement of mining activities. Locations of each bore within baseline groundwater monitoring network were identified after consideration of the following:

- Exploration boreholes that allowed access to all potentially impacted units within the CCP area
- GAB units outside of the CCP tenure
- Discussions with DES (formerly DEHP)
- Predicted groundwater impacts from the EIS, SEIS, and AEIS
- Identified environmentally sensitive areas (spring complexes and the Carmichael River corridor)
- Existing landholder bores (groundwater extraction).

A summary of the baseline groundwater monitoring network is presented, per monitoring unit, in **Table 23** below. **Figure 19** below presents the comprehensive baseline groundwater monitoring bore network while **Appendix B** provides locality figures depicting all baseline bore locations with respect to the MLs for each of the hydrostratigraphic units.

3.1.1 Initial Monitoring Network

Groundwater monitoring commenced in late 2011 as a component of the EIS process for the collection of representative groundwater monitoring data from all potentially affected hydrostratigraphic units within and adjacent to the CCP mine leases. As there are currently no coal mining activities on or adjacent to the CCP, many of the monitoring locations are located within the CCP tenements and were exploration-phase bores converted to groundwater monitoring bores fit for purpose.

Hydrochemistry and water levels were collected from the initial monitoring network to characterise the groundwater regime below the CCP area. While not performed on a regular basis, a total of five monitoring events were completed during the EIS, SEIS, AEIS programs, as follows:

- September 2011
- October / November 2011
- May / June 2012

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- September / October 2012
- May / June 2013.

The initial monitoring network consisted of thirty-seven (37) locations which were assessed during this period and included bores from the following hydrostratigraphic units:

- Alluvium
- Tertiary Sediments
- Dunda Beds
- Rewan Formation
- AB Seam (Bandanna Formation)
- Bandanna Formation inter- and over-burden
- D Seam (Colinlea Sandstone)
- Colinlea Sandstone inter- and over-burden
- Joe Joe Group.

In addition, composite monitoring points have been included to aid with groundwater resource assessments, groundwater conceptualisations, and predictive groundwater modelling.

These bores were surveyed upon verification of suitability (screened interval, geology) to ensure accurate groundwater level data was procured. The Wilson Survey Group completed the survey of the initial monitoring network and reported the following data for each location:

- Easting / Northing (GDA94 – Zone 55)
- Ground level elevation (mAHD)
- Top of casing (Reference Level [RL]) elevation (mAHD).

The monitoring event in May/ June 2012 also included collection of field physio-chemical measurements from the Doongmabulla Springs Complex, Cattle Creek, and Dyllingo Creek. Six locations within the Mellaluka Springs Complex were sampled and analysed in April 2013 for cations/anions, metals and alkalinity. These data are the initial data for characterisation of water quality from the spring complexes within the CCP area.

At this time, a formal program of analytes was not established which resulted in groundwater quality data gaps with inconsistent monitoring across the events.

3.1.2 Baseline Monitoring Program

Between 2013 and 2014, the groundwater monitoring network was expanded to include 68 monitoring locations and a formal baseline groundwater monitoring program was developed to address EA Condition E3 (**Appendix A**).

In order to satisfy EA Condition E3 (**Appendix A**), Adani developed and undertook a regular (~every two months) groundwater monitoring program where events were conducted, and data collected, in:

- April, May, July, September, and November 2014
- February, March, May, July, September, and November 2015
- February, April, July, and November 2016
- April 2017.

The groundwater monitoring network was again expanded in 2014 and 2015 to allow for groundwater quality and level data from gaps identified.

The additional bores installed during this timeframe were surveyed upon completion. The Gassman Development Perspectives survey company completed the survey of the expanded network and reported the following data for each location:

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- Easting / Northing (GDA94 – Zone 55)
- Ground level elevation (mAHD)
- Top of casing (RL elevation as mAHD).

The groundwater monitoring data collected from September 2011 through April 2017 was utilised to establish background groundwater quality, to identify natural groundwater level trends, and draft groundwater contaminant trigger levels and groundwater thresholds for the groundwater resources.

The baseline groundwater level and chemistry data are included in the following appendices:

- **Appendix C** - Groundwater level contour figures
- **Appendix D** - Groundwater quality
- **Appendix E** - Water level information (hydrographs generated from automated data loggers and manual readings, and vibrating wire piezometers [VWPs]) and groundwater level threshold hydrographs.

For the purposes of developing reference groundwater data for the project, all the available data from September 2011 through April 2017 has been compiled to form the 'final' baseline monitoring dataset.

3.1.3 Summary of Bore Network and Groundwater Data included in GMMP

For clarity regarding the data points (monitoring bores), groundwater assessments, and data assessed for the compilation of the GMMP, the following sequence of events is presented (as requested by the Commonwealth regulators):

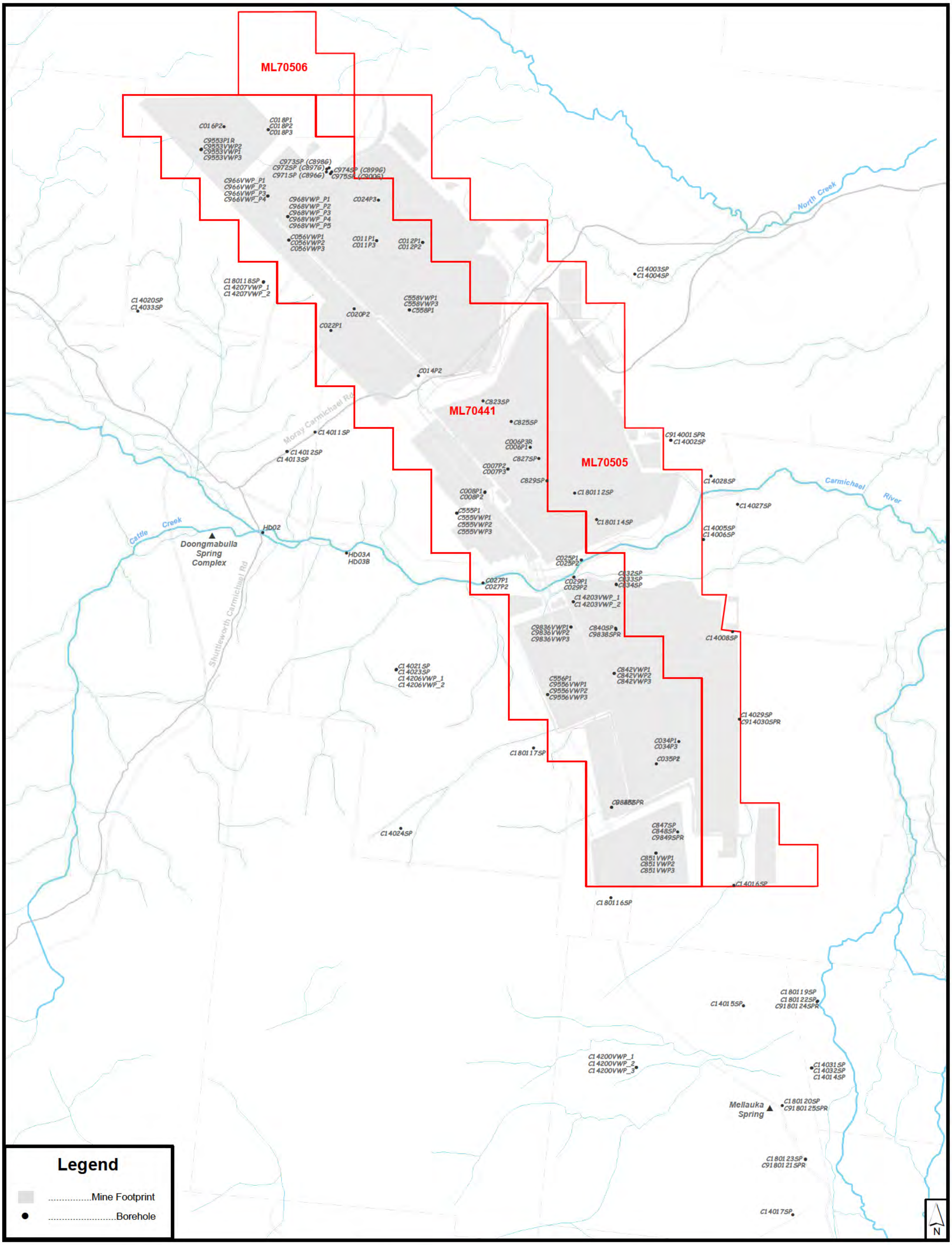
- All bores with the prefix C0 (such as C025P1 in **Table 23**) are exploration bores which were converted to groundwater monitoring bores during the compilation of the EIS and SEIS (circa 2011)
- The bores with the prefix HD were installed as groundwater monitoring bores during the compilation of the EIS and SEIS (circa 2011)
- The bores starting with C180, were installed as groundwater monitoring bores during the compilation of the EIS and SEIS (2011-2013)
- The bores C971SP (C896G), C972SP (C897G), C974SP (C899G), and C975SP (C900G) were geotechnical bores which were converted to groundwater monitoring bores within the box cut area in 2013
- The bores starting with C140 were drilled during 2014 for the collection and assessment of geology and groundwater data to the east (additional assessment of the Mellaluka Springs and Tertiary sediments) and west (Rewan Formation and Clematis Sandstone)
- Bores C18001SP to C18003SP were installed in 2018 as monitoring bores immediately adjacent to the DSC
- Bores C18001 to C18009 are shallow seepage monitoring bores adjacent to the mine water and waste storage facilities.

Note bores starting with C9 are redrills, i.e. C9180124SPR is a redrill of C180124SP, where the original bores could not readily be converted to groundwater monitoring bores.

The groundwater bores installed for the EIS and SEIS, associated aquifer testing, and groundwater level datasets, were used to undertake the predictive groundwater modelling. These model predictions were used to inform this GMMP.

Post EIS and SEIS drilling and bore construction, undertaken to assess groundwater resources and augment the groundwater monitoring network, were used (with the EIS and SEIS bore data) to describe the baseline groundwater conditions, develop groundwater quality triggers and groundwater drawdown thresholds.

Drilling from 2013 onwards, was used to assess and update groundwater conceptualisations at the Doongmabulla and Mellaluka spring complexes. Alternative conceptualisations were also considered using the entire geological and groundwater datasets. All available groundwater monitoring bores were considered when developing the baseline, construction, operational, control, and sentinel bore networks.



CCM	DISCLAIMER: Every effort has been made to ensure the accuracy of the information contained on this map. As permitted by law, Adani is excluded from all liability to any person or entity with respect to any loss or damage caused directly or indirectly by their use of the information contained on this product. Changes and additions to the information contained on this map are made frequently. Adani may make such changes and additions at any time. Adani does not warrant the accuracy of the information contained on this map.

Scale Bar: 0 1 2 3 4 Kilometres

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TITLE: Groundwater Management & Monitoring Program
Baseline Monitoring Bores (All Formations)

REV	DESCRIPTION	DATE
0	Original map output	20180517
1	Layout Change	20180808
2		
3		

SCALE	1:160,000	CURRENT ISSUE SIGNATURES	
SIZE	A3	DRAWN	PCH
DATUM		CHECKED	SY
PROJECTION		APPROVED	SY

STATUS: Rev 1
PROJECT NO: CCM
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Table 23 Baseline Groundwater Monitoring Bore Network

Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
Quaternary aged Alluvium						
C025P1	438015.54	7555845.80	7 to 11	11.00	Sandy clay	Assess Carmichael River and GDEs Control bore
C027P1	433643.08	7554818.39	6 to 12	13.00	Mostly clay	Assess Carmichael River and GDEs
C029P1	437691.19	7555082.39	8 to 13	13.40	Fine and medium grained sand	Assess Carmichael River and GDEs Control bore
HD03B	427559.00	7556120.00	6 to 11	11.37	Pale grey clay	Assess perennially saturated alluvium Control bore
C14027SP	444964.65	7558330.02	9 to 21	21.00	Gravelly sand and clay	Assess alluvium downstream of MLs Control bore
C14028SP	443775.64	7559581.18	12 to 18	20.00	Clayey sand, very salty water	Assess alluvium downstream of MLs Control bore
Tertiary Sediments						
C025P2	438010.34	7555844.69	31 to 41	41.00	Clay	Assess induced flow within MLs, possible impacts on river and GDEs
C029P2	437687.63	7555080.91	37.8 to 41	46.00	Ferricrete and sand	Assess induced flow within MLs, possible impacts on river and GDEs
C558P1	430311.55	7566903.06	29 to 41.4	41.40	Tertiary sediments to 42.96 m	Baseline description of Tertiary sediments within planned open cut
C9180121SPR	448085.12	7529363.93	36 to 45	45.00	Tertiary sediments to 52 m	Baseline description of Tertiary sediments south of mine
C9845SPR	439410.87	7544903.28	36 to 45	45.00	Tertiary sediments to 58 m	Baseline description of Tertiary sediments within planned open cut Sentinel bore for long term monitoring on southwestern portion of MLs

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Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C971SP (C896G)[8]	426590.06	7572994.56	14 to 20	86.97	Tertiary sediments to 34 m	Groundwater ingress assessment bore for box cut
Triassic Age Units (GAB Units)						
Moolayember Formation						
C14020SP	418230.28	7566782.35	105 to 117	136.00	Moolayember Formation to 140 m	Control bore at DSC Sentinel bore
C18003SP	420944.04	7558963.70	12 to 18	20.00	Moolayember Formation subcrop	Control bore at DSC
Clematis Sandstone						
HD02	423822.04	7557008.25	26 to 32	32.00	Sand, micaceous conglomerate	Control bore at DSC
HD03A	427562.00	7556132.00	29 to 37	37.00	Sand, artesian	Control bore at DSC
C180118SP	423796.76	7568090.93	117 to 123	126.00		Assess recharge in Clematis Sandstone subcrop outside western MLs boundary
C14021SP	429796.76	7550966.33	33 to 39	46.00	Coarse sandstone 32 – 39m	Assess Clematis Sandstone outside western MLs boundary
C14033SP	418210.22	7566775.83	188 to 200	200.00		Control bore at DSC
C14011SP	426130.96	7561454.81	90 to 96	144.00		Clematis Sandstone bores between MLs and DSC
C14012SP	424896.07	7560596.18	156 to 168	168.00	Sampled below base of weathering	
C14013SP	424895.49	7560591.10	57 to 69	72.00		
C18001SP	416311.5	7553052	176 – 188	197.00	Artesian bore	Control bore at DSC
C18002SP	420948	7558952	82 – 94	215.00	Backfilled to 100 m	Control bore at DSC

[8] Bore at box cut is dry and not used as a monitoring bore

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Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
Dunda Beds						
HD01[9]	426146.04	7561467.86	48 to 59	59.00	Silty clay	Drilled dry – geology only
C022P1	426812.52	7565961.84	61 to 67	67.00	Med to fine sandstone	Dunda Beds subcrop on western MLs boundary
C027P2	433648.21	7554818.54	28 to 32	32.80	Fine sandstone	Assessment of Dunda Beds below Tertiary sediments on river
C14023SP	429801.74	7550968.73	124 to 130	165.60	Dunda Beds / Rewan Fm gradational contact	Control bore, assess possible induced flow through Rewan Formation
C180117SP	435915.16	7547522.16	73 to 79	81.00	Dunda Beds to 79 m	Assessment of Dunda Beds on western MLs boundary, verify induced flow through Rewan Formation Sentinel bore
Rewan Formation						
C008P1	433712.50	7558833.75	47 to 57.50	57.50	Rewan Formation to 253 m	Groundwater quality assessment bore
C035P1	441403.59	7546823.81	52 to 62	62.00	Base at 91 m	Assess Rewan Formation within open pit area south of Carmichael River
C555P1	432461.38	7557892.99	65 to 75	75.00	Rewan Formation from 37 to 336 m	Monitoring bores in upper Rewan Formation at edge of mining, to assess possible induced flow through thick Rewan Formation above target coal
C556P1	436524.08	7549881.55	70 to 82	83.30	Rewan Formation from 47 to 348 m	
C9553P1R	421010.11	7573974.87	54 to 66	66.00	Clayey sand	
C180116SP	439392.91	7540908.81	40 to 51	71.00	Tertiary sediments to 39.71 m	Sentinel bore south of MLs
C9838SPR	439557.91	7552811.73	85 to 96	98.00	Base of Rewan Formation	Assess Rewan Formation within open pit area south of Carmichael River

[9] HD01 was drilled dry and not used as a monitoring point

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Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C056VWP3	424923.62	7569971.65	240	486.07		VWPs to aid with assessing vertical groundwater gradients and modelling
C9553VWP3	420992.73	7573965.33	265.4	485.00		
C555VWP2	432461.38	7557892.99	260.5	473.78		
C555VWP3	432461.38	7557892.99	166	473.78		
C9556VWP3	436542.64	7549884.87	216	444.00	Rewan Formation base 261.2	
C842VWP3	439505.09	7550840.30	130	247.65	Rewan Formation base 160.88m	
C851VWP3	441384.00	7542877.33	103.7	261.00	Rewan Formation base 136.06m	
C9836VWP3	437562.93	7552868.05	130	299.39	Rewan Formation base 216.66m	
C966VWP_P3	423982.89	7571921.15	260	286.00	Rewan Formation base 264.80m	
C966VWP_P4	423982.89	7571921.15	240	286.00	Rewan Formation base 264.80m	
C14200VWP_2	440547.49	7533418.60	199	249.00	Rewan Formation base 219m	
C14200VWP_3	440547.49	7533418.60	101	249.00	Rewan Formation base 219m	
C14203VWP_2	437658.90	7553984.34	77	273.00	Rewan Formation base 181m	
C14206VWP_2	429783.15	7550956.80	355	477.46	Rewan Formation base 458m	
C14207VWP_2	423806.63	7568105.26	400	525.36	Rewan Formation base 498m	
Permian Age Units						
Bandanna Formation						
B-C Sandstone						
C006P1	435726.23	7560833.15	36 to 42	47.30	Interburden above C seam	Assessment of interburden between B and C coal seams in Bandanna Formation, aided in model construction
C018P1	423981.83	7574849.86	44 to 52	53.00	Weathered Permian between the AB and C seams	

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Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C847SP	442354.86	7543817.19	78 to 87	87.00	Weathered Permian interburden between AB and C seams	
AB Seam						
C007P2	434728.01	7559861.98	163 to 173	179.50	AB1 and AB2 seams	Assessment of baseline data for target coal seams
C008P2	433710.27	7558830.28	260 to 271.50	271.38	AB1, AB2 and AB3 seams	
C014P2	430731.00	7563976.07	194 to 205	205.00	AB1 and AB2 seams	
C016P2	422017.38	7574974.58	218 to 227	233.00	AB1, AB2 and AB3 seams	Sentinel bore in northwest corner of MLs
C020P2	427845.47	7566931.73	255 to 262	267.00	AB1 and AB2 seams	Assessment of baseline data for target coal seams
C032P2	439404.36	7544896.02	250 to 262	263.00	AB1, AB2 and AB3 seams	
C035P2	441401.68	7546827.75	98 to 110	110.00	AB1, AB2 and AB3 seams	
C056VWP2	424923.62	7569971.65	312	468.07	AB3 seam	VWPs to aid with groundwater modelling
C9553VWP2	420992.73	7573965.33	348	485.00	AB1 seam	
C555VWP1	432461.38	7557892.99	346	473.78	AB1 seam	
C9556VWP2	436542.64	7549884.87	316	444.00	AB1 seam	
C558VWP3	430311.51	7566903.01	73	222.00	AB1 seam	
C842VWP2	439505.09	7550840.30	177.5	247.65	AB3 seam	
C851VWP2	441384.00	7542877.33	145.7	261.00	AB3 seam	
C9836VWP2	437562.93	7552868.05	237	299.39	AB3 seam	
C966VWP_P2	423982.89	7571921.15	268	286.00	AB1 seam	
C968VWP_P5	424873.59	7570989.17	244	375.00	AB1 seam	
C14200VWP_1	440547.49	7533418.60	224	249.00	AB1 seam	

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Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C14206VWP_1	429783.15	7550956.80	464	477.46	AB1 seam	
C14207VWP_1	423806.63	7568105.26	504	525.36	AB1_2 seam	
AB Interburden						
C011P1	428842.59	7569952.89	48 to 54	55.00	Weathered interburden between the AB3_3 and AB3_4 seams	Assessment of Bandanna Formation interburden between A and B seams, included in modelling
C966VWP_P1	423982.89	7571921.15	278	286.00	Interburden between the AB3_3 and AB3_4	
C968VWP_P4	424873.59	7570989.17	258	375.00	Interburden between the AB3_3 and AB3_4	
C Seam						
C823SP	433605.00	7562864.00	103 to 111	111.00	C1, C2 and C3 seams	Geological information for Bandanna Formation and Colinlea Sandstone contact (bottom of C seam)
C832SP	439569.61	7554787.07	89 to 100	102.00	C1_2 and C2 seams	
C968VWP_P3	424873.59	7570989.17	302.5	375.00	C1 seam	
C Seam Interburden						
C9839SPR	439565.48	7552795.94	162 to 168	173.00	Interburden between C2 and C3 seams	Geological and groundwater level data for Bandanna Formation in modelling
C844SP	441389.94	7546839.28	172 to 179	179.00	Interburden between C2 and C3 seams	
C558VWP2	430311.51	7566903.01	120	222.00	Interburden between the C0 and C1 seams	
C842VWP1	439505.09	7550840.30	235	247.65	Interburden between the C2 and C3 seams	
Other Bandanna Formation						
C018P2	423988.18	7574849.11	81 to 89	90.00	AB3_5, C0, C1_1 seams	Geological and groundwater level data

Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C034P1	442385.59	7547815.69	59 to 67	67.00	Weathered Permian between AB and D, No C seam	for Bandanna Formation in modelling
Colinlea Sandstone						
C-D Sandstone						
C851VWP1	441384.00	7542877.33	209.7	261.00	Interburden between C and D seams	Assessment of interburden above the target D seam
C9836VWP1	437562.93	7552868.05	296	299.39	Interburden between C and D seams	
C972SP (C897G)[10]	426601.16	7573122.06	57 to 63	86.10	Interburden above D seam	
C974SP (C899G)	426765.59	7572907.73	48 to 60	86.47	Interburden above the D1 seam	
C14203VWP_1	437658.90	7553984.34	247	273	D seam overburden	
D Seam						
C006P3R	435727.00	7560835.00	108 to 118	118	D seam	Geological thickness and extent for model construction, aquifer hydraulic properties for baseline description
C007P3	434726.28	7559864.39	252 to 259	259.20	D2 and D3 seams	
C011P3	428845.58	7569954.89	94 to 104	105.00	D1 seam	
C018P3	423977.57	7574853.06	139 to 145	161.00	D2_5, D3_1 and D3_2 seams	
C024P3	428909.10	7571761.09	44 to 49	49.00	D3 seam	
C034P3	442388.72	7547813.99	94 to 107	113.00	D2 and D3 seams with 6 m of Permian underlying D3 seam	
C180114SP	438684.80	7557646.88	62 to 71	120.00	D1, D2 and D3 seams	
C833SP	439559.68	7554777.43	120 to 132	134.00	D1, D2 and D3 seams	

[10] Bore C972SP, due its close proximity to C974SP, was discontinued as a monitoring point

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Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C848SP	442363.39	7543815.03	129 to 140	140.00	D0 and D1 seams	
C9849SPR	442383.73	7543808.29	157 to 169	170.00	D3_1 seam and interburden between the D3_1 and D3_2 seams	
C056VWP1	424923.62	7569971.65	412	468.07	D2 seam	
C9553VWP1	420992.73	7573965.33	467	485.00	D1 seam	
C9556VWP1	436542.64	7549884.87	410	444.00	D3 seam	
C558VWP1	430311.51	7566903.01	178	222.00	D3 seam	
C968VWP_P2	424873.59	7570989.17	348.5	375.00	D1 seam	
C975SP (C900G)	426824.24	7573002.03	48 to 60	86.73	Highly weathered D1 and D2 seams	
D Seam interburden						
C829SP	436459.73	7559355.44	137 to 147	147.00	Interburden between the D1_2 and D1_3 seams	Additional geological information for modelling
C968VWP_P1	424873.59	7570989.17	355	375.00	Interburden between the D2_1 and D2_2 seams	
D-E Sandstone						
C825SP	434867.57	7561957.63	125 to 132	134.00	Interburden between D3 and E seams	Assessment of sub-D sandstone
C840SP	439545.55	7552837.74	205 to 210	212.00	Interburden between D3 and E seams	
E-F Sandstone						
C180112SP	437712.17	7558819.50	92 to 97	120.00	Between E and F seams	Assessment of sub-D sandstone
Other Colinlea Sandstone						
C827SP	436100.74	7560332.12	130 to 138	138.00	D-E Sandstone, E seam, E-F Sandstone	Assessment of sub-D sandstone
C834SP	439575.77	7554763.53	140 to 150	151.00	E seam and interburden to F1 seam	

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Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
Joe Joe Group						
C012P1	430887.52	7569874.40	35 to 40	40.00	Jochmus Formation	Assessment of Joe Joe Group subcrop on lease
C012P2	430887.34	7569876.76	52 to 58	59.00	Jochmus Formation	
C180119SP	448587.45	7536355.38	58 to 61	85.00	Weathered Jochmus Formation (JoeJoe)	Control bore in Mellaluka Springs area
C9180124SPR	448600.00	7536357.00	74 to 86	86.00	Weathered Jochmus Formation (JoeJoe)	Control monitoring bore at Mellaluka Springs area
C9180125SPR	447039.74	7531738.83	90 to 100	121.00	Jochmus Formation	Control monitoring bore at Mellaluka Springs area
C180123SP	448077.54	7529357.50	102 to 112	130.00	Weathered Jochmus Formation (JoeJoe)	Control monitoring bore at Mellaluka Springs area
C14002SP	441977.77	7561157.53	96 to 108	113.80	Jochmus Formation	Assess groundwater potential off lease
C914001SPR	441973.49	7561149.58	50 to 56	57.00	Tertiary sediments to 44.77m	
C14014SP	448343.76	7533407.48	108 to 120	136.00	Weathered Jochmus Formation (JoeJoe)	Assessment of groundwater resources adjacent to Mellaluka Spring
C14032SP	448355.77	7533400.67	78 to 89	90.00	Tertiary sediments to 50m	
C14008SP	444760.74	7552697.83	93 to 105	120.00	Weathered Jochmus Formation (JoeJoe)	Sentinel bore east of the MLs
C14015SP	445301.98	7536138.69	110 to 122	144.00	Weathered Jochmus Formation (JoeJoe)	Sentinel bore between MLs and Mellaluka Springs
C14017SP	447525.30	7526907.00	78 to 84	111.00	Weathered Jochmus Formation (JoeJoe)	Southern most monitoring bore (before MLs relinquishment)
C14006SP	443446.61	7556785.07	96 to 108	115.40	Weathered Jochmus Formation (JoeJoe)	Assess groundwater potential off lease
C914030SPR / C14030SP	445072.27	7548821.00	95 to 107	114.00	Weathered Jochmus Formation (JoeJoe)	Sentinel bore east of MLs
C14004SP	440355.93	7568513.34	91 to 103	103.00	Weathered Jochmus Formation (JoeJoe)	Sentinel bore east of MLs

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Bore ID	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Screened Interval (mbgl)	Total Depth	Geology / Comment	Purpose
C14016SP	444852.34	7541471.06	114 to 126	129.00	Weathered Jochmus Formation (JoeJoe)	Sentinel bore on southern MLs boundary
C14003SP	440350.80	7568518.85	54 to 66	70.00	Tertiary sediments to 39.23m	Sentinel bore east of MLs
Composite Sample Points						
C180122SP (Tertiary / Jochmus Fm)	448579.21	7536348.70	33 to 47	47.00	Laterite and weathered Jochmus Formation	Control monitoring bore at Mellaluka Springs area
C180120SP (Tertiary / Jochmus Fm)	447056.56	7531729.89	38 to 48	86.00	Tertiary sediments and weathered Joe Joe Group	Control monitoring bore at Mellaluka Springs area
C973SP (C898G) (Tertiary / Colinlea Sandstone)	426707.25	7573188.29	31 to 37	86.97	Tertiary sediments and highly weathered D1 and D2 seams	Groundwater assessment at box cut
C14031SP (Tertiary / Jochmus Fm)	448331.34	7533407.27	40 to 52	54.00	Tertiary sediments to 47.64 m	Groundwater assessment at Mellaluka Spring area
C14005SP (Tertiary / Jochmus Fm)	443452.50	7556775.91	40 to 60	67.00	Tertiary sediments to 52 m	Assess groundwater potential off lease
C14029SP (Tertiary / Jochmus Fm)	445059.11	7548820.621	44 to 56	56.00	Tertiary sediments to 49.44 m	Sentinel bore to east of MLs
C14024SP (Clematis Sandstone / Dunda Beds)	430036.80	7543917.13	140 to 152	162.00	Weathered Clematis Sandstone and Dunda Beds	Sentinel bore in Clematis Sandstone subcrop

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3.2 Static Water Level Data – Automated Pressure Transducers

Groundwater level measurements were and continue to be collected both manually (during each sample event) and automatically from monitoring wells located across the site. Manual readings are procured during each monitoring event (prior to any sampling); automated readings via dedicated water level loggers are downloaded from all baseline monitoring bores each monitoring event. These loggers are programmed to collect a static water level (SWL) measurement in the form of a pressure reading at least every 12 hours. At the commencement of the Baseline Monitoring Program, loggers were included in these bores only; however, all groundwater monitoring bores are now equipped with automated water level loggers.

The automatic groundwater level loggers measure the total pressure acting on a transducer at their zero point/sensor. The total pressure is a combination of the column of water lying above the logger pressure sensor (i.e. height of water column) and the atmospheric (barometric) pressure acting on the water surface. The groundwater level logger data is barometrically, and temperature compensated to obtain true height of water column measurements. All groundwater level logger data is converted to groundwater elevations in mAHD, utilising the measured depth of deployment of the logger, the recorded water column level and the (manual) measured depth to water below well casing.

Each automated level logger dataset is converted from a pressure reading to a water level by correlation to the manual measurements collected during installation. The logger readings are correlated to the manual reading nearest to the installation date of the logger to capture the longest timeframe of readings available. The loggers are then corrected for barometric pressure from the closest of three (3) dedicated barometric loggers across the site (north, central, and southern portions of the CCP footprint); the barometric pressure logger and groundwater level logger are corrected via software from the logger manufacturer.

The loggers are downloaded regularly (not more than 6 months apart) to ensure data collection and identify any faulty loggers. Faulty loggers are replaced as part of the groundwater monitoring program. Loggers where downloads are difficult / faulty loggers are sent to the manufacturers to try and retrieve missing data (where possible).

3.3 Vibrating Wire Piezometers

The groundwater monitoring bore network includes 17 vibrating wire piezometers (VWPs) fully grouted into fourteen (14) bores in separate locations (**Appendix B** figures). The VWPs, installed on steel cable and measured tremmie pipes, are laid out on surface to collect calibration data and ensure sensors are grouted into the identified hydrostratigraphic units.

The total pressure readings (formation, water, and [possibly] gas), recorded at least at 12-hour intervals to a data logger, are downloaded every six months. The total pressure readings are converted to a relative water level (in mAHD) using calibration data. Each VWP sensor has its own calibration values, at surface readings (collected during installation), and calibration factors (supplier specific), which are used to convert the downhole (fully grouted) pressure readings.

Typically, there are multiple sensors installed in one bore, which allows for the collection of data from serval separate hydrostratigraphic units at one location on site versus standpipe monitoring bores which allow only one hydrostratigraphic unit to be monitored per bore.

The data collected at the VWP sites provides relative groundwater level measurements over time, which is used to assess groundwater level trends within the hydrostratigraphic units. The total pressure readings are noted to vary over time with curing of cement grout but in some cases do not stabilise and cannot be used for comparison or trend analysis during and post-mining. This can occur if air bubbles form between the VWP sensor and the grout, which does not readily allow the transfer of (accurate) pressure from the hydrostratigraphic unit to the sensor.

NOTE: Currently, quality of the VWP data is unproven but may prove useful for trend analysis in the future.

The VWP sensor depths, units, and (possible) suitability for use for trend analysis are included in **Table 24**. The relative water level hydrographs are included in **Appendix E**.

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Table 24 Summary of VWP Data

VWP ID	Unit	Sensor Depth (mbgl / mAHD)	Relative groundwater level (mAHD)	Trend	Monitoring Period	Comment
C966VWP_P1	AB Seam interburden	355 / -66.3	215	Flat	01/2014 to 02/2016	Can be used for assessing depressurisation due to mine dewatering
C966VWP_P2	AB Seam	348.5 / -59.8	222	Flat with time		
C966VWP_P3	Rewan Formation	302.5 / -13.8	258.5	Flat with time		
C966VWP_P4	Rewan Formation	258 / 30.7	251	Flat with time		
C056VWP1	D Seam	408 / -124.14	154	Stabilisation of pore pressure readings with time	10/2012 to 02/2017	Can be used for assessing depressurisation due to mine dewatering
C056VWP2	AB Seam	312 / -28.14	227			
C056VWP3	Rewan Formation	240 / 43.86	239			
C555VWP1	***AB Seam***	***346 / -104.85***	***Unstable***	***Unstable***	***09/2012 to 11/2016***	***Failed read-out unit*** ***Unstable readings – unsuitable for trend analysis***
C555VWP2	***Rewan***	***260.5 / -19.35***				
C555VWP3	***Rewan Formation***	***166 / 75.15***				
C558VWP1	D Seam	178 / 72.05	212	Flat with time	09/2012 to 04/2017	Can be used for assessing depressurisation due to mine dewatering
C558VWP2	C Seam interburden	120 / 130.05	214	Flat with time		
C558VWP3	***AB Seam***	**73 / 177.05**	**168.5**	***Failed***		***Unsuitable***
C842VWP1	C Seam interburden	235 / 3.84	**Unstable**	**Unstable**	07/2013 to 04/2017	Currently unsuitable but may stabilise going forward
C842VWP2	AB Seam	177.5 / 61.39				
C842VWP3	Rewan Formation	130 / 108.89				
C851VWP1	C-D Sandstone	209.7 / 34.97	226	Flat with time	06/2013 to 04/2017	Can be used for assessing depressurisation due to mine dewatering
C851VWP2	AB Seam	145.7 / 98.97	228.7	Flat with time		
C851VWP3	Rewan Formation	103.7 / 140.97	229.5	Flat with time		

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VWP ID	Unit	Sensor Depth (mbgl / mAHD)	Relative groundwater level (mAHD)	Trend	Monitoring Period	Comment
C968VWP_P1	D Seam interburden	355 / -75.82	380 (above ground)	Flat	01/2014 to 04/2017	Can be used for assessing depressurisation due to mine dewatering
C968VWP_P2	D Seam	348.5 / -69.32	355 (above ground)	Flat		
C968VWP_P3	C Seam	302.5 / -23.32	**275**	Flat		Possible issue – VWP3 water level should be 215 to 220 mAHD, VWP4 and VWP5 are lower than surrounds Flat trend – can be used for assessing depressurisation
C968VWP_P4	AB Interburden	258 / 21.28	**201**	Flat		
C968VWP_P5	AB Seam	244 / 35.18	**192.8**	Flat		
C9553VWP1	D Seam	467.43 / -172.87	**Unstable**	**Unstable**	08/2012 to 02/2016	Currently unsuitable but may stabilise going forward
C9553VWP2	AB Seam	348.43 / -53.87	**Unstable**	**Unstable**		
C9553VWP3	Rewan	265.43 / 29.13	219.7	Flat with time		Can be used for assessing depressurisation due to mine dewatering
C9556VWP1	***D Seam***	***410 / -149.6***	***Failed***	***Failed***	***10/2012 to 04/2017***	***Unstable readings – unsuitable for trend analysis***
C9556VWP2	***AB Seam***	***316 / -55.6***	***Failed***	***Failed***		
C9556VWP3	***Rewan Formation***	***216 / 44.4***	***Unstable***	***Unstable***		
C9836VWP1	C-D Sandstone	296 / NA	220	Flat with time	07/2013 to 04/2017	Can be used for assessing depressurisation due to mine dewatering
C9836VWP2	AB Seam	237 / NA	214	Flat with time		
C9836VWP3	Rewan Formation	130 / NA	223	Flat with time		

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VWP ID	Unit	Sensor Depth (mbgl / mAHD)	Relative groundwater level (mAHD)	Trend	Monitoring Period	Comment
C14200VWP_1	AB Seam	224 / 23.08	235	Flat with time	11/2014 to 04/2017	Failed read-out unit Suitable for trend analysis
C14200VWP_2	Rewan Formation	199 / 48.08	234	Flat with time		
C14200VWP_3	Rewan Formation	101 / 146.08	245	Flat with time		
C14203VWP_1	C-D Seam	247 / -16.45	225	Flat	10/2014 to 04/2017	Failed read-out unit Suitable for trend analysis
C14203VWP_2	***Rewan Formation***	***77 / 153.55***	***Unstable***	***Unstable***		***Unsuitable***
C14206VWP_1	AB Seam	464 / -186.85	224	Flat with time	03/2015 to 04/2017	Can be used for assessing depressurisation due to mine dewatering
C14206VWP_2	Rewan Formation	355 / -77.85	237	Flat with time		
C14207VWP_1	***AB Seam***	***504 / -198.83***	***Unstable***	***Unstable***	***03/2015 to 04/2017***	***Unsuitable***
C14207VWP_2	***Rewan Formation***	***400 / -94.83***	***Unstable***	***Unstable***		

3.4 Hydrographs

The transient groundwater level data collected by automated water level loggers, manual readings, and artesian pressure measurements for each bore was compiled and further reviewed and assessed by DNRME. The DNRME review has resulted in identification of most accurate and valid data sets for development of hydrographs and to derive groundwater level statistics. For example, in some bores the more consistent manual data was selected as there are issues with logger-generated data due to failures, logger drift, tangling of loggers inside bores, etc. In some cases the more accurate logger data was used. Further, for hydrograph generation, only data within the same horizon/aquifer was considered. The hydrographs are included in **Appendix E**.

An assessment of these hydrographs, used for conceptualising groundwater flow patterns and proposing thresholds, was conducted to allow for the selection of the most suitable / representative data to be used in the GMMP.

As detailed in **Section 3.3**, a review of the suitability of VWP data was conducted, allowing for the selection of VWP sensors and units which can be utilised for verifying / validating dewatering trends. VWP data was not utilised for the development of groundwater flow patterns, as detailed in **Section 2.2.5** but several have been included in the proposed thresholds and monitoring. These VWPs allow for an assessment of drawdown predictions (**Section 5.3**).

All VWP hydrographs have been included in **Appendix E** for completeness.

3.4.1 Alluvium

Six baseline groundwater monitoring bores are installed into the alluvium across and adjacent to the CCP MLs. The bores, average groundwater levels, and comments on transient data are included in **Table 25**.

Table 25 Alluvium Hydrograph Data

Bore	Average Groundwater Level (mAHD)	Duration of Hydrograph	Comments
C025P1	216.72	4 years 10 months	Dry well for most of the monitoring period
C027P1	223.84	5 years 5 months	High water levels after 2011 floods
C029P1	214.77	5 years 5 months	Faulty logger replaced, logger data more reliable than manual readings
C14027SP	203.58	2 years 1 month	Fault logger replaced, logger and manual readings good match
C14028SP	205.46	2 years 5 months	Logger and manual readings good match
HD03B	225.47	3 years 11 months (manual only)	No correlation between initial logger results, correlation between logger and manual readings poor becoming better since 04/16 Influenced by discharge from springs and runoff

3.4.2 Tertiary Sediments

Five of the six Tertiary monitoring bores have transient groundwater level data; bore C971 (located around the proposed box cut) is dry. **Table 26** provides details of the Tertiary sediments hydrographs.

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Table 26 Tertiary Sediments Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C025P2	217.62	4 years 10 months	Good correlation between loggers and manual readings
C029P2	220.00	5 years 8 months (manual)	Spikes in logger data due to sampling Consistent manual data used as logger data gaps
C558P1	216.02	4 years 6 months	Good correlation between loggers and manual readings Issue with set-up elevation of initial logger
C9845SPR	234.91	2 years 5 months	Good correlation between loggers and manual readings
C9180121SPR (artesian)	244.46	2 years 5 months	Conversion of manual pressure gauge readings inaccurate, logger provides consistent data

3.4.3 Moolayember Formation

A single hydrograph has been compiled for monitoring bore C14020SP, constructed in 2014.

The average groundwater level is 252.43 mAHD, where logger and manual readings correlate well over 31 months.

3.4.4 Clematis Sandstone

Eight groundwater monitoring bores constructed in the Clematis Sandstone have transient groundwater level data. **Table 27** provides details of the Clematis Sandstone hydrographs.

Table 27 Clematis Sandstone Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C14011SP	242.80	22 months	Good correlation between loggers and manual readings
C14012SP	242.62	23 months	Good correlation between loggers and manual readings
C14013SP	242.49	23 months	Good correlation between loggers and manual readings
C14021SP	246.54	23 months	Conservative approach – use manual readings only in the unconfined Clematis Sandstone outcrop
C14033SP	250.62	15 months	Good correlation between loggers and manual readings
C180118SP	250.17	2 years	Good correlation between loggers and manual readings Blocked – needs replacing
HD02	234.28	3 years 7 months	Good correlation between loggers Good correlation between manual readings and unconfined fluctuations in logger readings
HD03A (artesian)	233.03	3 years 8 months	Logger readings only in confined Clematis Sandstone below alluvium

3.4.5 Dunda Beds

Four of the five Dunda Beds monitoring bores have transient groundwater level data; bore HD01 has always been dry. **Table 28** provides details of the Dunda Beds hydrographs.

Table 28 Dunda Beds Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C022P1	246.66	5 years 5 months	Good correlation between loggers and manual readings
C027P2	226.90	5 years 6 months	Good correlation between loggers and manual readings after initial logger issues
C14023SP	247.26	2 years 5 months	Good correlation between loggers and manual readings
C180117SP	251.02	2 years 5 months	Good correlation between loggers and manual readings

3.4.6 Rewan Formation

Hydrographs have been compiled for all seven Rewan Formation groundwater monitoring bores with transient groundwater level data, as presented in **Table 29**.

Table 29 Rewan Formation Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C008P1	211.80	4 years 8 months (manual)	Water level / logger response issues after sampling in 2015 Used consistent manual readings
C035P1	231.89	5 years 6 months	Logger and manual readings declining since 2013, possibly due to extraction at Lignum property Not used in contouring or thresholds
C555P1	230.02	35 months (manual)	Logger data issues since 2015 Initial GHD logger offset possibly due to reference level error Not included in contours
C556P1	234.84	4 year 6 months	Good correlation between loggers and manual readings after initial logger issues
C9553P1R	252.26	2 years 11 months (manual)	Good correlation between loggers and manual readings after correcting logger install issues Logger reinstallation issues, after sampling events, noted Initial GHD logger offset possibly due to reference level error

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C9838SPR	228.74	3 years 1 month (manual)	Logger reinstallation in July 2016 different to previous reference level Used consistent manual data for contours
C180116SP	239.12	2 years 5 months	Good correlation between loggers and manual readings

Based on a review of the hydrographs several of the Rewan Formation monitoring bores will have replacement / faulty loggers repaired, as per EA Condition E16 which requires the maintenance of the groundwater monitoring network (including monitoring equipment) to ensure the compilation of representative groundwater monitoring data.

3.4.7 Bandanna Formation

Seventeen (17) groundwater level monitoring bores are installed in the Bandanna Formation across the CCP MLs (**Table 23**). These bores, located in various sediments included in the Bandanna Formation (as included in **Table 30**), are equipped with automated water level loggers which will remain and downloaded at least every 6 months to aid with model updates and refinement (as detailed in **Section 6.2** Operational GMMP).

Table 30 Bandanna Formation Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
AB Seam			
C016P2	248.50	3 years 1 month	Logger issues in 2012 / 2013; consistent manual readings from March 2014 to April 2017 applied
C020P2	220.92	5 years 5 months	Good correlation between loggers and manual readings
C014P2	209.21	4 years 5 months	Good correlation between loggers Good correlation between manual readings Logger to be reinstalled to correct depth
C007P2	212.38	years 10 months	Good correlation between loggers and manual readings
C008P2	213.40	5 years 8 months	Good correlation between loggers and manual readings
C035P2	232.68	3 years 11 months	Gap in logger data; manual dataset utilised. The average groundwater elevation calculation excludes erroneous measurement from November 2016
C032P2	233.27	20 months	Good correlation between loggers and manual readings after logger issues
AB Interburden			
C011P1	229.72	4 years 10 months	High variation, logger possibly affected by sampling
C Seam			
C823SP	209.30	36 months (manual)	Manual readings used as logger influenced by sampling / low recovery

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C832SP (artesian)	229.20	2 years 6 months	Conversion of manual pressure gauge readings inaccurate, logger provides consistent data
B-C Sandstone			
C006P1	211.25	5 years 5 months	Good correlation between loggers and manual readings
C018P1	244.98	5 years 5 months	Good correlation between loggers and manual readings after initial logger issues
C847SP	232.43	3 years 1 month	Good correlation between loggers and manual readings Manual measurement dataset used for calculation of average groundwater elevation due to longer monitoring period (more data points)
C Seam Interburden			
C844SP	231.00	37 months	Good correlation between loggers and manual readings
C9839SPR	228.13	37 months	Good correlation between loggers and manual readings
Other Bandanna Formation			
C018P2	242.47	54 months	AB3_5, C0, C1_1 seams Good correlation between loggers and manual readings after logger issues
C034P1 (artesian)	230.95	2 years 11 months	Weathered Permian between AB and D, No C seam Logger data only, faulty logger needs replacing

The AB Seam was selected for use for developing groundwater quality triggers, groundwater level thresholds, and groundwater contours for the Bandanna Formation. This was done as the AB Seam is a target coal seam for mining and is the most impacted unit (by approved mining operations) of the Bandanna Formation.

3.4.8 Colinlea Sandstone

Eighteen (18) groundwater level monitoring bores are installed in the Colinlea Sandstone across the CCP MLs (**Table 23**). These bores, located in various sediments included in the Colinlea Sandstone (as included in **Table 31**), are equipped with automated water level loggers which will remain and downloaded at least every six-months to aid with model updates and refinement (as detailed in **Section 6.2** Operational GMMP).

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Table 31 Colinlea Sandstone Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C-D Sandstone			
C974SP	240.96	37 months	Good correlation between loggers and manual readings
C972SP	-	-	No logger, removed from monitoring program
D Seam			
C018P3	242.43	5 years 5 months	Good correlation between logger and manual readings
C975SP	240.99	3 years 1 month	Good correlation between logger and manual readings
C024P3	228.88	5 years 8 months	Good correlation between logger and manual readings
C011P3	227.32	5 years 9 months	Good correlation between logger and manual readings
C006P3R	213.28	5 years 9 months	Good correlation between logger and manual readings, logger influenced by sampling / low recovery
C007P3	216.93	5 years 8 months	Logger malfunction after November 2014 GME; logger replaced in September 2015.
C180114SP	223.00	2 years 5 months	Good correlation between logger and manual readings
C833SP (artesian)	228.28	2 years 5 months	Conversion of manual pressure gauge readings inaccurate, logger provides consistent data
C848SP	231.91	3 years 1 month	Good correlation between logger and manual readings
C9849SPR	231.88	3 years 1 month	Logger data only
C034P3 (artesian)	231.07	2 years 5 months	Erratic data from logger, not used in contours
D Seam Interburden			
C829SP	214.56	3 years 1 month	Good correlation between logger and manual readings
D-E Sandstone			
C825SP	211.82	2 years 5 months	Good correlation between logger and manual readings
C840SP	228.01	2 years 5 months	Good correlation between logger and manual readings
E-F Sandstone			
C180112SP	219.20	37 months	Good correlation between logger and manual readings
Other Colinlea Sandstone			
C827SP	212.86	2 years 4 months	D-E Sandstone, E seam, E-F Sandstone Good correlation between logger and manual readings
C834SP (artesian)	227.50	2 years 5 months	E seam and interburden to F1 seam Logger data only

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The D Seam was selected for use for developing groundwater quality triggers, groundwater level thresholds, and groundwater contours for the Colinlea Sandstone. This was done as the D Seam is a target coal seam for mining and is the most impacted unit (by approved mining operations) of the Colinlea Sandstone.

3.4.9 Joe Joe Group

All eighteen (18) groundwater monitoring bores within the Joe Joe Group sediments have transient groundwater level data. The summary of the resultant hydrographs is included in **Table 32**.

Table 32 Joe Joe Group Hydrograph Data

Bore	Average Groundwater level (mAHD)	Duration of Hydrograph	Comments
C012P1	221.33	4 years 10 months	Good correlation between logger and manual readings
C012P2	221.32	4 years 10 months	Good correlation between logger and manual readings
C14003SP	209.37	2 years 8 months	Good correlation between logger and manual readings
C14004SP	209.44	2 years 4 months	Good correlation between logger and manual readings
C914001SPR	218.47	2 years 5 months	Good correlation between logger and manual readings
C14002SP	218.75	2 years 5 months	Good correlation between logger and manual readings
C14006SP (artesian)	226.03	10 months	Logger readings stable since 09/2015
C14008SP (artesian)	228.34	1 year 7 months	Conversion of manual pressure gauge readings inaccurate, logger provides consistent data
C14016SP (artesian)	234.13	1 year 9 months	Good correlation between logger and pressure gauge readings
C14015SP (artesian)	239.15	9 months	Erratic logger data after April 2016; data used to calculate average groundwater elevation is from July 2015 to April 2016
C180119SP (artesian)	238.21	1 year 10 months	Consistent logger data since mid-April 2015
C9180124SPR (artesian)	235.31	2 years	Consistent logger data since April 2015
C14032SP (artesian)	233.69	1 year 5 months	Pressure gauge readings only, to be equipped with logger and digital pressure gauge
C9180125SPR	243.10	2 years 1 month	Consistent logger data since December 2014
C180123SP	246.35	2 years 4 months	Consistent logger data
C14017SP	248.26	1 year 7 months	Consistent logger data
C14014SP (artesian)	239.32	-	Not used for contours as landholder utilises bore for water supply
C914030SPR (artesian)	230.25	1 year 8 months	Consistent logger data

3.4.10 Composite Bores

Seven (7) standpipe groundwater monitoring bores have been installed where the screened intervals, after construction, have been identified as intersecting two hydrostratigraphic units. These bores occur predominantly where the sediments are similar (initial logging records changed only after an assessment of down-hole geophysics) and/or where difficult drilling conditions (high potentiometric pressures and multiple artesian zones) were encountered.

Hydrographs of the groundwater level data from these bores will be compiled for future use for dewatering trend analysis (mine dewatering) and were not used to generate groundwater contours or thresholds.

3.5 Augmentations to the Groundwater Monitoring Network

The groundwater monitoring network has been augmented since 2011 to ensure the following:

- Collection of additional baseline groundwater levels across all the hydrogeological units that are likely to be impacted by approved mining operations
- The determination of groundwater level responses to mine activities. The comparison of water level decline to selected thresholds (**Section 5.3**) will allow for the identification of groundwater resources which may be unduly affected by mine dewatering, where unduly affected is where drawdown is projected to be greater than the groundwater level thresholds
- The extent and magnitude of drawdown in each aquifer is adequately monitored for comparison to modelled projections over time, which considers the envisaged alteration of the geological units above the coal seam units in response to longwall mining, particularly the intervening aquitards (Rewan Formation) which control projected drawdown (induced flow) from the Clematis Sandstone
- The identification and management of any potential impacts on surface water – groundwater interaction.

Examples of augmentations made to the network and baseline groundwater monitoring program include:

- Expansion of the groundwater monitoring network within and outside the MLs to include GAB units for the baseline groundwater monitoring program (quality and water levels) and for use as long term sentinel monitoring sites
- Identification of additional areas with artesian pressures and information on gradients between different strata south of the Carmichael River
- Collection of data from the vicinity of the Mellaluka Spring Complex
- Collection of aquifer hydraulic data through completion of packer tests, pump out tests, slug-in (falling head) tests and groundwater yield estimations from standpipe piezometer development within and outside the MLs
- Collection of hydraulic data from the Rewan Group, Joe Joe Group, and Tertiary sediments
- Collection of data from the Doongmabulla Springs Complex.

The groundwater monitoring bore network will, during operations, act as an early warning system should actual drawdown differ from predicted drawdown and to allow for the instigation of investigation in to changes in groundwater quality should chemistry triggers be exceeded.

These potential impacts could impact current groundwater use or have potential environmental harm. Therefore, the groundwater monitoring network will be modified as mining extends to the west (down dip) and south of the Carmichael River over time. The monitoring network augmentation will ensure the replacement of monitoring points that are lost during mining, and the groundwater monitoring program will be modified in response to mine activities change (i.e. operations or closure).

Additional monitoring bores (post-EIS) have been constructed in optimum locations considering the proposed mine activities, groundwater resources, MNES, and local landholder groundwater extraction.

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These new monitoring points between the mine and the existing landholder extraction allow for an assessment of the groundwater resource(s) away from pumping effects.

Further monitoring bores have been constructed on neighbouring properties near the Doongmabulla Springs Complex. These nested bores, comprising standpipe bores about ten metres apart, are constructed within the Clematis Sandstone and overlying confining Moolayember Formation adjacent to the Doongmabulla Springs Complex.

Adani has also installed six additional shallow (installed into the clay-rich base of weathering within the Tertiary sediments) seepage monitoring bores adjacent to the mine affected water and waste storage facilities. These seepage monitoring bores were installed as per Adani's commitment that these bores would be installed at least six months prior to utilisation of these mine facilities.

The shallow seepage bores will be sampled every two months during the construction phase to establish the baseline water quality and levels (if any). Groundwater levels and water quality (if water is encountered) data will be compiled prior to operations for comparison purposes. These six bores are also included in the operational monitoring program. Groundwater level thresholds and water quality triggers will be established for these bores prior to commissioning of the mine affected water and waste storage facilities.

The monitoring bores installed within and outside the existing monitoring bores since 2013 are tabulated in **Table 33** below and **Figure 20**.

Table 33 Summary of Augmentation Monitoring Bores

Bore ID	Easting	Northing	Formation	Comments
C971SP (C896G)	426590	7572995	Tertiary sediments	Drilled in 2013 for the assessment of possible groundwater ingress into the box cut
C972SP (C897G)	426601	7573122	Colinlea Sandstone	Drilled in 2013 for the assessment of possible groundwater ingress into the box cut from overburden above D seam
C974SP (C899G)	426766	7572908	Colinlea Sandstone	Drilled in 2013 for the assessment of possible groundwater ingress into the box cut from overburden above D seam
C975SP (C900G)	426824	7573002	Colinlea Sandstone	Drilled in 2013 for the assessment of possible groundwater ingress into the box cut from weathered D seam
C14003SP	440351	7569519	Joe Joe Group	Drilled in 2014 to assess groundwater potential of the Tertiary sediments east of the mine lease (north of Carmichael River)
C14004SP	440361	7568516	Joe Joe Group	
C914001SPR	441974	7561154	Joe Joe Group	
C14002SP	441973	7561154	Joe Joe Group	
C14028SP	443780	7559582	Alluvium	Drilled in 2014 augmentation to baseline monitoring network to include bores downstream of the mine lease on each side of the Carmichael River
C14027SP	444968	7558335	Alluvium	
C14005SP	443452	7556779	Tertiary sediments / Joe Joe Group	Drilled in 2014 to assess groundwater potential of the Tertiary sediments east of the mine lease (south of Carmichael River)
C14006SP	443440	7556788	Joe Joe Group	
C14008SP	444762	7552705	Joe Joe Group	
C914030SPR	445072	7548821	Joe Joe Group	
C14029SP	445059	7548820	Tertiary sediments / Joe Joe Group	

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Bore ID	Easting	Northing	Formation	Comments
C14016SP	444852	7541471	Joe Joe Group	Drilled in 2014 augmentation to baseline monitoring network on southern mine lease boundary, assessing geology to determine Colinlea Sandstone / Joe Joe Group contact
C14015SP	445301	7536138	Joe Joe Group	Drilled in 2014 augmentation to baseline monitoring network around Mellaluka Spring and assess underlying geology Colinlea Sandstone or Joe Joe Group Assess artesian conditions in the Tertiary sediments and Joe Joe Group
C14014SP	448344	7533410	Joe Joe Group	
C14031SP	448331	7533407	Composite Bore	
C14032SP	448355	7533400	Joe Joe Group	
C14200VWP	440547	7533419	VWP1 – AB Seam (224 mbgl) VWP2 – Rewan Fm (199 mbgl) VWP3 – Rewan Fm (101 mbgl)	Drilled in 2014 to assess geology west of Mellaluka Spring, augment baseline monitoring network and provide monitoring along strike of mining
C14017SP	447525	7526905	Joe Joe Group	Drilled in 2014 to augment the baseline monitoring network on southern mine lease boundary, which has now been relinquished
C14011SP	426140	7561447	Clematis Sandstone	Drilled in 2014 in a north – south transverse between the mine lease and the DSC, to assess GAB units, depth of cover to Permian coal seams Assess Rewan Formation, Moolayember Formation thickness leading to confining of Clematis Sandstone Assessment of aquifer hydraulic properties Increase groundwater monitoring network
C14012SP	424891	7560589	Clematis Sandstone	
C14013SP	424897	7560590	Clematis Sandstone	
C14024SP	430033	7543915	Clematis Sandstone/ Rewan Group	
C14020SP	418233	7566780	Moolayember Formation	
C14023SP	429803	7550970	Dunda Beds	
C14033SP	418210.	7566775	Clematis Sandstone	
C14021SP	429801	7550972	Clematis Sandstone	
C14203VWP	437658	7553983	VWP1 – D Seam overburden (247 mbgl) VWP2 – Rewan Fm (77 mbgl)	Drilled in 2014 adjacent to a pump test well, used as an observation bore when assessing groundwater resources in the mine pit area to the south of Carmichael River
C18001SP	416311	7553052	Clematis Sandstone	Installed in 2018 to augment the existing groundwater monitoring network, control bores at the DSC
C18002SP	420948	7558952	Clematis Sandstone	
C18003SP	420944	7558964	Moolayember Formation	
C18004	437013	7565647	Weathered Tertiary sediments	Seepage monitoring bores installed in 2018
C18005	438966	7564569	Weathered Tertiary sediments	
C18006	439882	7562704	Weathered Tertiary sediments	

Bore ID	Easting	Northing	Formation	Comments
C18007	434334	7563940	Weathered Tertiary sediments	
C18008	433753	7565451	Weathered Tertiary sediments	
C18009	436933	7567302	Weathered Tertiary sediments	

Notes:
mbgl - metres below ground level

NOTE: **Section 3.1.3** includes a timeline of which bores were installed and for what purpose. The section includes comments on what data was used for the different groundwater inputs into the GMMP, such as modelling baseline descriptions, and monitoring networks.

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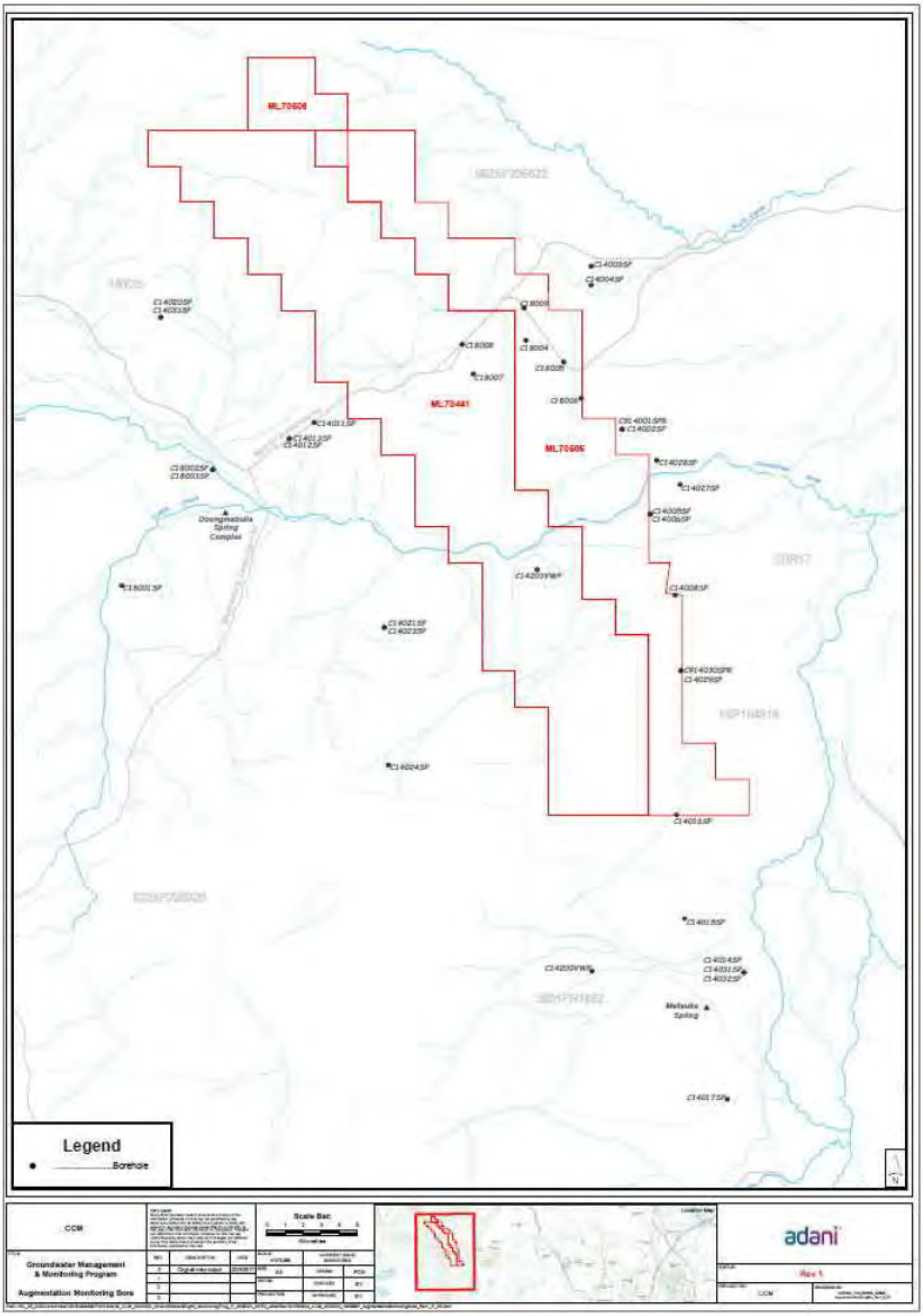

Figure 20 Augmentation Bores

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3.5.1 Bore Design Drilling

All monitoring bores were drilled using a water bore drilling rig, using mud-rotary or air-percussion techniques. VWPs and bores which intersect the Rewan Formation were constructed with a core rig to facilitate sample recovery. The groundwater standpipe monitoring bores have been designed in accordance with the Minimum Construction Requirements for Water Bores in Australia, 3rd Edition (NWC, 2012) and the Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (NRM, 2013a). All future groundwater monitoring bores will adopt the water bore regulations (noting that these have or may be updated in the future).

Consideration was given to casing and annular seal requirements to ensure that no pathway is provided for the movement of water between aquifers.

Each standpipe monitoring bore was installed with 50 mm diameter uPVC casing, machine slotted screen and fitted with a lockable monument cover. The bore annulus of the screened interval was filled with washed two mm diameter silica sand, sealed with a bentonite plug and grouted to surface with a cement-bentonite grout mix. Each bore was developed by airlifting.

Each group of VWPs was installed on steel cable (sensor and wiring attached using cable ties through the cable) and grouted into place using dedicated tremmie pipes with bentonite-cement grout.

3.5.2 Artesian Bores

In areas with potential artesian conditions, the bore design, drilling, and construction were and need to be conducted in accordance with the requirements for artesian bores, inclusive of the requirement to use a Class 3 driller, as detailed in the following guidelines:

- Minimum standards for the construction and reconditioning of the water bores that intersect the sediments of artesian basins in Queensland (NRM, 2013a)
- Minimum Construction Requirements for Water Bores in Australia, 3rd Edition (DNRM, 2012)
- Water bore driller's licensing handbook (NRM, 2013b).

It is noted that updated versions of the guidelines have been released since the artesian bores were installed (Version 1.02 dated 2017). In the instance further bores are to be constructed in areas with potential for artesian conditions, the most recent version of applicable guidelines will be utilised.

The artesian bores include pressure gauges to allow for the measurement of the shut-in pressure. The pressure, typically measured in pounds per square inch (psi), is then converted to equivalent hydrostatic head in meters where 1 psi (6.9 kPa) of pressure measured has an equivalent water rise of 0.7 m above the gauge. In addition to pressure gauges, automated groundwater level loggers installed in the artesian bores provide additional water level data to the manual pressure readings.

An example of potentiometric level estimates for artesian bores, where the pressure readings were measured as pressure (either with an automated water level logger or manually read off a pressure gauge), where:

- pressure in psi or kPa was converted to meters of water column
- 1 mH_2O = 9,806.65 Pa
- 1 psi = 6,894.76 Pa
- mH_2O value x 9,806.65 Pa = psi value x 6,894.74 Pa
- mH_2O value = psi value x 0.70307
- e.g. 20 psi = 14.0614 m.

The hydrostatic head data, taking into consideration the height of the gauge above ground level, allow for the assessment of potential mine dewatering impacts on the springs.

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NOTE: Several comparisons between automated water level logger results and manual pressure readings (and conversion) show marked differences. It is considered the automated water level loggers provide more accurate data compared to the manual readings off the available pressure gauges, as is observed on hydrographs generated for groundwater level assessment (**Appendix E**).

This approach and design requirements were adopted for the artesian groundwater monitoring bores constructed adjacent to the Mellaluka Springs Complex and within the Tertiary sediments to the east of the mine leases (**Appendix B**). **Figure 21** below shows the current artesian bore headworks constructed on site, adjacent to the Mellaluka Springs Complex (within the Tertiary sediments and Joe Joe Group), comprising two gate valves and an access bolt (for the collection of water level readings, groundwater samples when hydrostratigraphic pressures are below headworks, and a pressure gauge.

Figure 21 Artesian Monitoring Bore Headworks

3.5.3 Sub-E Permian Bores

Adani, after discussions with the administering authorities and in compliance with their EA conditions, will be refining the current predictive groundwater model on a regular basis (after two years and then at five-year intervals). The refined model is to include additional model layers and parameters for the sub-E sediments of the Colinlea Sandstone unit (consistent with the drilling results around the Mellaluka Springs Complex, **Section 2.2.6.3**). This is also consistent with the recommendations of DNRME during the EIS assessment to include additional modelling layer below D seam.

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To facilitate the model refinement and to better assess the unconformable contact between the Tertiary sediments, the Joe Joe Group (as recognised in the Mellaluka Springs Complex area), and the Colinlea Sandstone, additional groundwater monitoring bores are to be constructed prior to mine operations. These proposed sub-E bores are indicated on **Figure 22**, denoted as CSSTMB1 and CSSTMB2. These locations have been approved by DNRME as a part of the associated water licence Condition 47.

The data from these sub-E bores will be used to refine the groundwater model by adding additional model layers within and below the Colinlea Sandstone. The revision of model with additional layers will also provide impact predictions on sub-E aquifers due to the approved mining. It is expected that impacts due to mining on sub-E aquifers will be not significant as mining operations will be carried out above this aquifer, and this supports a suggestion that these aquifers could serve the purpose of providing alternative water supplies, relevant to any approval issued under the *Water Act 2000*, especially for other water resource users in the impacted area. Further these bores will be used to monitor the possible impacts on sub-E aquifers due to mining, which provides a pathway for assessing the suitability of these aquifers in terms of quality and quantity to provide alternate water supply sources.

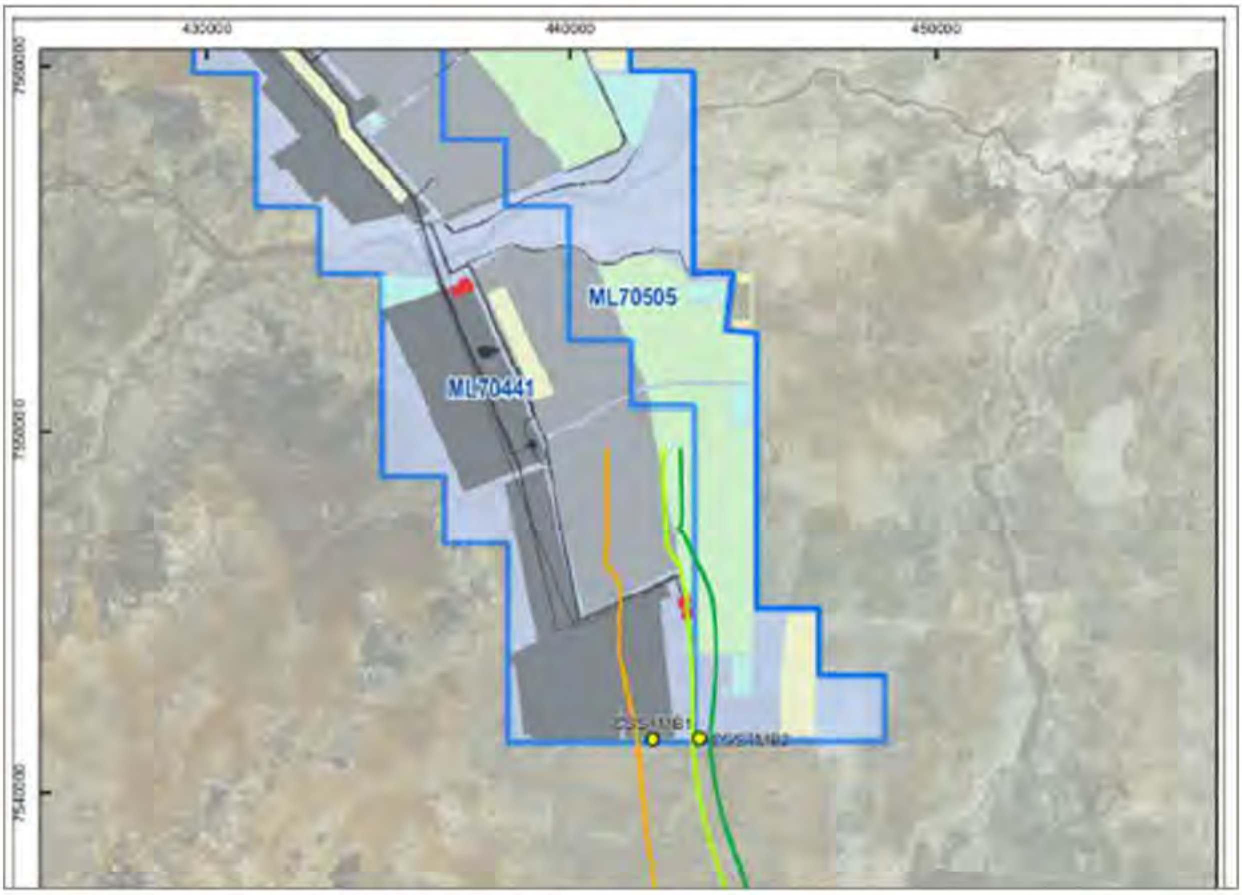

Figure 22 Proposed locations of Sub-E Permian Bores

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3.5.4 Doongmabulla Spring Complex

To augment the monitoring network Adani commits to installing additional monitoring bores into the Dunda Beds and the Rewan Formation to the west of Mining lease in between the Mining lease and DSC and is included in section 7.0 As far as practicable, these additional bores will be co-located with the existing bores, HD02, HD03A, and C14011SP, as nested monitoring bores in consultation with DNRME of Queensland.

These bores, once installed, will be added to the operational groundwater monitoring program and will allow for the collection of additional spatially comparable groundwater level and quality data between the Mining lease and DSC. The additional monitoring points will assist in further evaluation of the predicted groundwater impacts associated with the mining activities and will also assist in validating the predicted timing of impacts.

These bores once installed will be added to the operational groundwater monitoring program and will enable to collect spatially comparable groundwater level and quality data in between the Mining lease and DSC for the purpose of additional data collection prior to the occurrence of predicted impacts associated with project activities and timing (see **Section 2.6**). The additional groundwater (bore construction and monitoring) data will be used in the groundwater model rerun for the prediction of impacts, which will then be used to develop additional Early Warning groundwater level and Impact thresholds (as compiled in **Section 5.3**) for inclusion in the next GMMP.

Further, Adani will investigate drilling into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information if required under relevant research programs.

From: Coram, Jane (L&W, Black Mountain)
To: s22
Subject: Re: Revised GMMP [SEC=OFFICIAL]
Date: Friday, 5 April 2019 1:00:39 PM
Attachments: image002.jpg

Thanks s22

With regards, s22

On 5 Apr 2019, at 12:54 pm, s22 @environment.gov.au> wrote:

> Hi James and Jane,
> Please find the revised GMMP attached.
> The GDEMP will follow
> -s22
>
> Acting Director | Post Approvals Strategies
> Environment Standards Division
> **Department of the Environment and Energy**
> **T** 02 s22 @environment.gov.au
>
> Reconciliation%20Email%20Footer

From: s22
To: "james.johnson@ga.gov.au"
Cc: "Stuart Minchin"; "Blewett Richard"
Subject: RE: Revised GMMP [SEC=OFFICIAL]
Date: Friday, 5 April 2019 1:01:43 PM
Attachments: Attachment%20A%20-%20GMMP%20Final_Part2.pdf
image001.jpg

Part two
Thanks
s22

T 02 s22 @environment.gov.au
W www.environment.gov.au

From: s22
Sent: Friday, 5 April 2019 1:01 PM
To: 'james.johnson@ga.gov.au'
Cc: 'Stuart Minchin' ; 'Blewett Richard'
Subject: RE: Revised GMMP [SEC=OFFICIAL]

Hi James,
Sorry – I've had to split into two parts to get to your inbox. This does not include the appendices, happy to provide these separately if required.
s22

T 02 s22 @environment.gov.au
W www.environment.gov.au

From: s22
Sent: Friday, 5 April 2019 12:53 PM
To: 'james.johnson@ga.gov.au' <james.johnson@ga.gov.au>; 'jane.coram@csiro.au' <jane.coram@csiro.au>
Cc: Stuart Minchin <stuart.minchin@ga.gov.au>; Blewett Richard <Richard.Blewett@ga.gov.au>; 'McDonald, Warwick (L&W, Black Mountain)' <Warwick.Mcdonald@csiro.au>; Gregory Manning <Gregory.Manning@environment.gov.au>; s22 @environment.gov.au>; Dean Knudson <Dean.Knudson@environment.gov.au>
Subject: Revised GMMP [SEC=OFFICIAL]

Hi James and Jane,
Please find the revised GMMP attached.
The GDEMP will follow
s22

Acting Director | Post Approvals Strategies
Environment Standards Division
Department of the Environment and Energy
T 02 s22 @environment.gov.au

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Document 13a

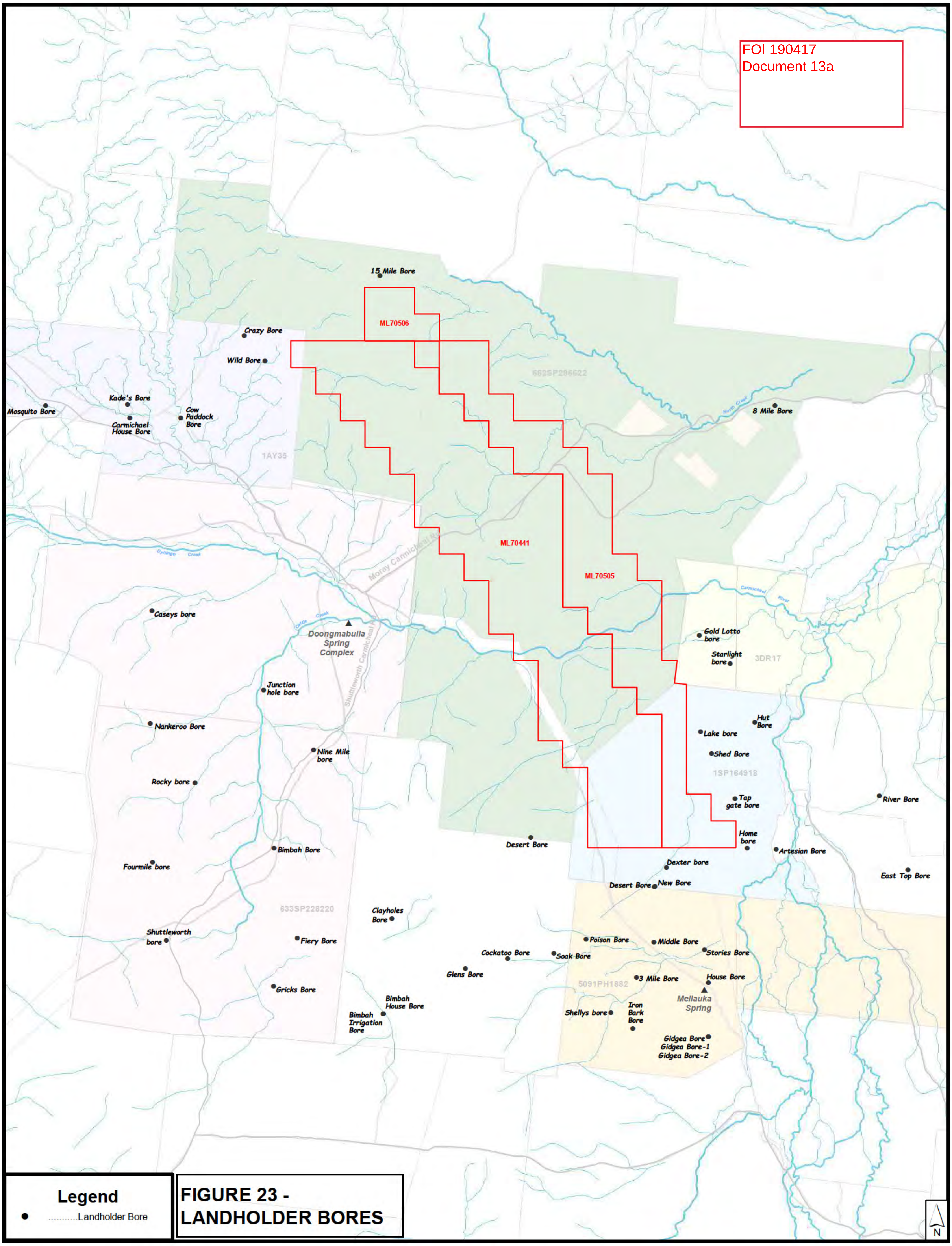

FIGURE 23 - LANDHOLDER BORES

CCM	DISCLAMER Every effort has been made to ensure the accuracy of the information contained on this map. As permitted by law, Adani is excluded from all liability to any person or entity with respect to any loss or damage caused directly or indirectly by their use of the information contained on this product. Changes and additions to the information contained on this map are made frequently. Adani may make such changes and additions at any time. Adani does not warrant the accuracy of the information contained on this map.	Scale Bar: 0 1.5 3 4.5 6 7.5 Kilometres		
TITLE Groundwater Management & Monitoring Program Landholder Bores	REV / DESCRIPTON / DATE	SCALE 1:250,000	CURRENT ISSUE SIGNATURES	
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	1 / Layout Change / 20180524	DATUM	CHECKED	SY
	2			
	3	PROJECTION	APPROVED	SY

adani

STATUS	
Rev 1	
PROJECT NO CCM	DRAWING NO 2018052_CCM_0000000_GWMMP_LandHolderMonitoringBores_Rev1_P_A3

Path W:_05_GIS\Carmichael\2018\GWMMP\20180418_CCM_0000000_GroundWaterMngmt_MonitoringProg_P_A3\MXD_APRX_other\Rev1\20180524_CCM_0000000_GWMMP_LandHolderMonitoringBores_Rev1_P_A3.mxd

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Table 34 **Landholder Bore Summary**

Property name	Bore name	Number	Type / Use	Easting	Northing	Depth (m)	Aquifer
Lignum	Lake bore	158001	Stock & Domestic	446122	7549419	93	Unconsolidated alluvium / Tertiary sediments
	Hut Bore		Stock & Domestic	449869	7550061	TBD	Unconsolidated alluvium / Tertiary sediments
	Tap gate bore		Stock & Domestic	448517	7544827	85	Unconsolidated alluvium / Tertiary sediments
	Home bore	158471	Stock & Domestic	449378	7541377	93	Unconsolidated alluvium / Tertiary sediments
	Dexter bore	67627	Stock & Domestic	4456773	7540047	104	Tertiary sediments / Permian aged Sandstone
	New Bore	103249	Stock & Domestic	442972	7538727	46	Tertiary sediments /Permian aged Sandstone
	Shed Bore		Stock & Domestic	446876	7547938	TBD	Unconsolidated alluvium / Tertiary sediments
Albinia	Starlight bore	158649	Stock & Domestic	448149	7554152	90	Unconsolidated alluvium / Tertiary sediments
	Gold Lotto bore		Stock & Domestic	446002	7556100	TBD	Unconsolidated alluvium / Tertiary sediments
Bimbah East	Desert Bore	44486	Stock & Domestic	434344	7542064	91	Dunda Beds
	Clayholes Bore	103565	Stock & Domestic	424733	7536432	88	Clematis Sandstone (to be verified)
	Bimbah House Bore	44487	Stock & Domestic	424155	7529828	47	Clematis Sandstone
	Bimbah Irrigation Bore	67626	Irrigation	424155	7529828	137	Clematis Sandstone
	Glens Bore		Stock & Domestic	429833	7532978	~100	Dunda Beds (to be verified)
	Cockatoo Bore	44488	Stock & Domestic	432768	7533696	25	Dunda Beds
	Soak Bore	62625	Stock & Domestic	435979	7534079	85	Dunda beds
Mellaluka	Gidgea Bore	132959	Stock & Domestic	446731	7528369	97	Interburden in Joe Joe Group
	Gidgea Bore-1	103423	Stock & Domestic	446731	7528369	100	Interburden in Joe Joe Group
	Gidgea Bore-2	132960	Stock & Domestic	446731	7528369	140	Interburden in Joe Joe Group
	Iron Bark Bore	103378	Stock & Domestic	441486	7528898	96	Interburden in Joe Joe Group
	3 Mile Bore	103230	Stock & Domestic	441722	7532437	88	Interburden in Joe Joe Group
	Desert Bore	103229	Stock & Domestic	442930	7538681	47.85	Interburden in Joe Joe Group

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Property name	Bore name	Number	Type / Use	Easting	Northing	Depth (m)	Aquifer
	Middle Bore	132961	Stock & Domestic	442929	7534861	140	Interburden in Joe Joe Group
	Poison Bore	103231	Stock & Domestic	438212	7535068	97.4	Interburden in Joe Joe Group
	Stories Bore	103559	Stock & Domestic	446437	7534364	73.15	Tertiary sediments / Joe Joe Group
	Shellys bore	90212	Stock & Domestic	439949	7529980	84	Interburden in early Permian
	House Bore	44443	Stock & Domestic	446729	7532074	42	Tertiary sediments / Joe Joe Group
Bygana	River Bore	158678	Stock & Domestic	458554	7545051	168	Mount Hall Formation (Drummond Basin)
East Top	Artesian Bore	158631	Stock & Domestic	451402	7541297	100	Tertiary sediments / Joe Joe Group
Moray Downs	15 Mile Bore	90256	Stock & Domestic	423671	7580878	117	Tertiary sediments / Joe Joe Group
	8 Mile Bore	90368	Stock & Domestic	451221	7572005	100	Tertiary sediments / Joe Joe Group
Carmichael East	Carmichael House Bore		Stock & Domestic	406312	7570944	48.8	Moolayember Formation or Warang sandstone
	Kade's Bore		Stock & Domestic	406128	7571872	70.8	Moolayember Formation or Warang sandstone
	Cow Paddock Bore		Stock & Domestic	409855	7570961	57.6	Moolayember Formation or Dunda beds
	Crazy Bore		Stock & Domestic	414230	7576676	160	Base of Dunda beds
	Wild Bore		Stock & Domestic	415707	7574934	100	Dunda Beds
	Mosquito Bore	96545	Stock & Domestic	400432	7571736	234	Moolayember Formation or Warang sandstone
Doongmabulla	Caseys bore	16896	Stock & Domestic	407919	7557603	123.44	Moolayember Formation
	Junction hole bore		Stock & Domestic	415716	7552192	TBD	Clematis Sandstone
	Rocky bore	62750	Stock & Domestic	410986	7545753	168	Clematis Sandstone
	Fourmile bore	62751	Stock & Domestic	408065	7540229	221	Clematis Sandstone
	Nankeroo Bore	16895	Stock & Domestic	407851	7549824	97.5	Moolayember Formation
	Nine Mile bore	62754	Stock & Domestic	419215	7548049	91.4	Clematis Sandstone
	Bimbah Bore	165169	Stock & Domestic	416514	7541230	TBD	Dunda Beds
	Fiery Bore	62753	Stock & Domestic	418153	7535046	161	Dunda Beds

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Property name	Bore name	Number	Type / Use	Easting	Northing	Depth (m)	Aquifer
	Gricks Bore	16897	Stock & Domestic	416510	7531718	231	Clematis Sandstone
	Shuttleworth bore	62752	Stock & Domestic	409061	7534843	250	Clematis Sandstone

Notes:

TBD – To be determined

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3.7 Landholder Bores

During the compilation of the EIS several landholder bores, located on and adjacent to the CCP tenements, have been identified and a summary of the data compiled is included in **Figure 23.**

These bores are currently subject to bore assessments and discussions regarding make-good agreements. To assist with the assessment of potential impacts of approved mining activities on groundwater resources outside of the mine area and potentially on current groundwater users, sentinel bores have been identified between the mine and the local groundwater users, as discussed in **Section 5.3.1** (which includes groundwater level thresholds for the bores between the mine and the landholder bores).

Groundwater levels will be monitored in these sentinel monitoring bores, including in **Table 39.**

Groundwater levels will be compared to model predictions and the proposed groundwater level thresholds (**Section 5.3**).

3.8 Groundwater Monitoring Network Rationale

Groundwater monitoring bores were constructed within large diameter exploration bores across the CCP during the compilation of the EIS. The selection of exploration bores, along strike and down-dip, allowed for the construction of monitoring bores within the major hydrostratigraphic units intersected within the CCP mine leases.

Bore construction, including an assessment of lithology and down-hole geophysics, allowed for screened section of the bores (and installation of VWPs), which provided groundwater data for over-, inter-, and under-burden as well as the coal seams. Groundwater monitoring, quality and levels, allowed for the compilation and assessment of groundwater resources, groundwater flow and gradients, plus ambient hydrochemistry.

Discussions with the then DNRM (now DNRME) allowed for the compilation of baseline geological and groundwater data, which was used in the EIS / SEIS to:

- Describe the groundwater resources of the coal seams and surrounding aquifers
- Detail the ambient hydrochemistry
- Detail the geology / lithostratigraphy
- Assess aquifer types and groundwater levels and flow patterns
- Aquifer hydraulic parameter assessments
- Assessment of groundwater environmental values
- Conceptual groundwater model(s), including assessment of recharge / discharge mechanisms and surface water – groundwater interaction
- GAB resource evaluation and inter-aquifer connectivity
- Construct and calibrate a numerical groundwater model (and undertake impact assessments).

Additional drilling and monitoring bore network augmentation occurred post SEIS to aid with further understanding of groundwater regimes, providing baseline data, and assessing groundwater resource potential in the hydrostratigraphic units east and west (off lease) of the CCP mine leases.

The areas of additional assessment (geology and groundwater) through the drilling, down-hole geophysics, bore construction, and aquifer assessment (quantity and quality) included:

- The proposed box cut (monitoring bores and VWPs) in the AB Seam subcrop
- Bores installed and tested in the Tertiary sediments and Joe Joe Group to the east and southeast of the MLs, including an assessment of the Mellaluka Springs area

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- Deep drilling some 5 km west of the MLs to allow for an assessment of the Clematis Sandstone (dip, groundwater resources, and monitoring network augmentation), the Dunda Beds and Rewan Formation (aquitard evaluation), Bandanna Formation and Colinlea Sandstone VWPs
- Moolayember Formation and Clematis Sandstone bores adjacent and to the west of the Doongmabulla Springs.

The development of the large, > 100 bores, groundwater monitoring network allowed for the compilation of representative (and repeatable) groundwater monitoring data which allowed for the compilation of the GMMP and addressing approval conditions, such as groundwater quality triggers and groundwater impact levels.

The phased approach, allowing for the scientific development of the groundwater assessment, allowed for the development of a network of groundwater monitoring bores, which satisfactorily monitor groundwater resources (before, during and after mining) and obtain accurate groundwater information.

Section 3.5 provides the rationale / reasons for the bores installed since 2013.

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4.0 Monitoring Requirements

This section describes the groundwater monitoring that, at a minimum, is undertaken and will be conducted before, during, and after the approved mining activities. In accordance with the adaptive management approach, these monitoring requirements will be modified on an on-going basis to ensure optimal understanding of the groundwater regimes and assessment of the predicted mining impacts.

4.1 Parameters

Optimum parameter selection allows for the measure of the cause and effect relationship between mining activities and the environmental response to those activities. Suitable indicators include those:

- Commonly found in the environment
- Relatively easy to measure
- Sensitive to environmental change
- Specific to disturbance impacts.

The selected parameters, as included in the EA Condition E9 (**Appendix A**), allow for the description of the groundwater resource, the physical, chemical and biological aspects of the groundwater system. The parameters also allow for assessment of possible alteration of groundwater related to anthropogenic activities.

The groundwater monitoring program allows for the evaluation of both groundwater quantity (levels) and quality parameters.

4.2 Dewatering Volumes

The monitoring of groundwater volumes extracted during mining is an additional groundwater monitoring requirements to be met under the Associated Water Licence (AWL) issued for the project. Under the AWL conditions the volume of associated water taken, under the authority of the AWL licence, must be measured and reported in accordance with requirements prescribed in section 334ZP of the *Mineral Resources Act 1989* and sections 31A and 31B of the Mineral Resources Regulation 2013.

In addition to measurement of water quantities there is a requirement to provide an annual monitoring report. Further details are provided in **Section 4.7**.

4.3 Groundwater Level Monitoring

Groundwater level monitoring is the key parameter for assessing changes to the groundwater regime, particularly as the 'make-good' agreements with the landholders is predicated on a water level change.

4.3.1 Frequency and Duration

Groundwater level monitoring is ongoing to allow for characterisation and identification of natural fluctuation (seasonal variation) prior to commencement of mining activities.

Based on approval conditions (**Section 4.3**) groundwater levels within the baseline groundwater monitoring network are to be reviewed at least every six months. All groundwater monitoring locations have dedicated automated groundwater level loggers. The loggers compile water level data at a minimum 12-hour interval, with the data being downloaded (at a frequency of not more than six months) and assessed on a regular basis as per reporting requirements.

Groundwater level monitoring will continue through construction, operations, and post-closure at selected representative groundwater monitoring points to provide representative assessment of groundwater level changes in the various groundwater units and adjacent to MNES, Carmichael River GDEs, and neighbouring groundwater use.

During post-closure it is envisaged that the groundwater level data will provide recovery data (long-term pseudo-steady groundwater levels), which will be compared to long-term model predictions.

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Details of groundwater level monitoring frequency for each of the mine phases are included in **Table 35**.

Table 35 Mining Phases and Monitoring Details

Mining Phase	Groundwater Level	Frequency	Groundwater Quality	Frequency	Monitoring points
Baseline	Automated loggers	12-hour intervals	Every 2 months	For a minimum of 24 months	As per GMMP Table 46
Construction	Automated loggers	12-hour intervals	Every 2 months	During construction	As per GMMP Table 46, plus shallow bores adjacent to mine water and waste facilities six months prior to construction.
Operations	Automated loggers	12-hour intervals Life of Mine	Every 2 or 3 months[11] (subject to regulatory confirmation)	Life of Mine (possible revision of frequency after 10 years depending on chemistry trends)	As per GMMP **Section 6.2**
Post closure	Automated loggers	12-hour intervals Post-closure duration to be determined in closure plan	Every 3 months	Samples every 3 months for a minimum of 5 years[12] - frequency to be determined in the long term, depending on chemistry trends	Post closure monitoring points to be determined at least five years prior to cessation of mining operations.

4.3.2 Instrumentation and Control

Groundwater levels are measured manually with an electronic water level meter each time a bore is visited. The probe is decontaminated between bores.

Hydrostatic pressure readings are and will be collected from the artesian bores, both manually (reading PSI gauges) and from automated pressure loggers (**Section 3.5.2**).

Permanent automated water level measuring devices have been installed in all monitoring bores (**Section 5.0**), comprised of a pressure transducer or vibrating wire piezometer for water level measurement, and data loggers for recording the measurements.

Barometric pressure loggers are included across the large mine lease and are in each geographic region of the CCP tenements, three barometric loggers are located within the north, central, and southern sections of the MLs. The barometric pressure loggers are downloaded, and the data collected each sampling event to allow for barometric correction of water level data recorded over time.

[11] To be confirmed by DES during the GMMP approval process

[12] Adani will appoint a suitably qualified hydrogeologist to assess post-mining groundwater monitoring to assess long term trends.

4.3.3 Groundwater Level Indicators

Changes in quantity of groundwater (or availability of groundwater), flow volumes in aquifers, and interaction between groundwater and surface water features are primarily determined based on groundwater level/pressure levels and related changes to these levels.

Natural fluctuation in groundwater levels occur (dependant on aquifer type, depth, etc.) in response to daily, seasonal, and long-term climate cycles. The duration of these fluctuations can range from short-term (for example, shallow monitoring bores in unconfined aquifers responding to individual precipitation events) to long-term (multi-year variations in climate and basin water balance).

Mining-induced changes in groundwater levels can be caused by removal of groundwater from an aquifer, changes in groundwater balances (due to land cover changes including construction of ponds, dumps, etc.) and pressure effects due to depressurisation of aquifers.

Localised effects on groundwater levels can occur in the form of artificial recharge because of leakage from mine waste or mine water storage facilities which result in an increase of groundwater level(s).

The primary indicator for groundwater quantity is, therefore, defined as the temporal change to groundwater level (hydrostratigraphic pressure) in a defined aquifer interval at an established monitoring location.

As a result, groundwater levels at established locations are and will continue to be monitored to compare and assess future trends. Characterisation of expected natural fluctuations in groundwater elevation in each monitored hydrostratigraphic unit has been compiled to establish baseline conditions and variability. The identified baseline conditions and natural fluctuation (variability) were utilised to assess and categorize groundwater level thresholds and will be used to assess for mine-related influences on groundwater levels going forward.

4.4 Groundwater Quality Monitoring

Groundwater samples have and will be obtained from representative groundwater monitoring bores within each monitored hydrostratigraphic unit. The baseline groundwater quality monitoring undertaken to date was used to establish representative groundwater chemistry trigger levels, as required in EA Condition E9 (**Appendix A**).

The hydrostratigraphic units monitored on site, based on the potential for mine activities to impact on groundwater resources, include:

- Unconfined alluvium sediments
- Tertiary sediments
- Clematis Sandstone
- Dunda Beds
- Rewan Formation
- Bandanna Formation (AB Seam)
- Colinlea Sandstone (D Seam)
- Joe Joe Group.

4.4.1 Groundwater Quality Indicators

Ambient groundwater quality data for each hydrostratigraphic unit was collected as a component of the baseline monitoring program. This included analyses of a wide range of parameters to gain an understanding of specific hydrochemistry and variation within each unit.

Review of these baseline data resulted in identification of representative chemistry parameters for each unit. The established representative data allow for identification of conditions outside of the range of natural variability / baseline conditions and potential impacts on groundwater quality.

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It is noted that baseline parameters (i.e. large suite of analytes) were collected until sufficient measurements were available to statistically demonstrate the range of natural variability within the each hydrostratigraphic unit.

The baseline hydrochemistry datasets will be used for comparison to future groundwater quality samples.

4.4.2 Methods

Groundwater quality sampling techniques were selected to minimise purge water volumes to be managed that ensure groundwater samples collected are representative and repeatable for the hydrostratigraphic unit.

Quality samples are collected via low-flow methods with dedicated tubing for each monitoring bore. Groundwater is purged until aquifer field parameters, measured via flowthrough cell, have stabilised per **Table 36** below. Groundwater quality samples are then collected after confirmation of aquifer parameter stabilisation.

Table 36 Field Parameter Stabilisation Criteria Prior to Sample Collection

Measurement	Variability	Recording
pH	± 0.1 pH unit	Continuous readings until stabilised, i.e. three to five consecutive readings within the variability range.
Temperature	± 0.2°C	
Electrical Conductivity	± 3%	
Dissolved oxygen	± 0.3 mg/L	
Redox potential (Eh)	± 5%	

4.4.2.1 Groundwater Sampling

Groundwater monitoring and sample collection is undertaken in accordance with the most recent edition of the EHP (DES) Water Quality Sampling Manual, which outlines guidelines and approaches for the collection of repeatable and representative groundwater data.

4.4.2.2 Springs Sampling

For sample procurement purposes all springs sampled are treated similarly to a bore, except for two differences. Firstly, as the spring flows are continuous no purging is required. The second difference relates to quality: special care is made to not allow contamination of the representative flowing water with standing water during sampling (especially where cattle have access to spring discharge).

Adani's approach to reduce contamination is to obtain grab samples from the flowing water as close to the spring outlet as possible (where identifiable). Field parameters are measured and recorded, and after rinsing the sample bottles samples are collected as for a bore. Electrode measurements are made from little pools close to the spring outflow where the water velocity is not too great to cause distortion of the electrode readings.

In addition to the grab samples collected from the DSC springs, the samples to be collected at the Joshua Spring are obtained from the discharge pipe installed within the turkey's nest dam wall. This flowing water allows for the collection of a representative grab sample of the Joshua Spring.

The Mellaluka Springs Complex comprises a wetland and dam, with no readily discernible spring discharge point(s). Sampling from the wetland inundation requires additional consideration to ensure representative water samples.

Adani has, after discussions with the landholder, installed a spearpoint within an accessible portion of the permanently saturated section of the Mellaluka Springs Complex to facilitate the sample collection. These sample points were selected and constructed so to ensure the limitation of damage to sensitive ecosystems (groundwater dependent ecosystems, vegetation communities) that are associated with springs which could be damaged by long-term / ongoing sampling (walking to and working around springs can cause damage).

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Spearpoints

In September 2018 Adani installed five (5) spearpoints into springs within the Doongmabulla Spring Complex, to facilitate sampling. The spearpoints are included in the operational groundwater monitoring network (**Section 6.2**) to allow for the collection and assessment of groundwater data within the DSC.

A summary of the wellpoints is included in **Table 37**.

Table 37 Spearpoints at DSC

Spearpoint	Easting	Northing	Depth (mbgl)	Screen (mbgl)	Water level (mbgl)
C18010SP	421610.10	7556860.74	2.82	1.27 – 2.67	Blocked[13]
C18011SP	422044.83	7556285.96	0.56	0.08 – 0.51	0.22
C18012SP	420424.31	7557642.01	2.40	0.40 – 2.40	At surface
C18013SP	420427.75	7557636.78	2.52	0.50 – 2.52	0.18
C18014SP	424639.57	7557046.47	4.10	2.50 – 3.95	3.22

4.4.3 Parameters

4.4.3.1 Baseline Monitoring

The pre-mining groundwater quality monitoring, required to determine ambient hydrochemistry, includes the following:

- Field parameters: dissolved oxygen (DO), pH, temperature, and electrical conductivity (EC) - calculated total dissolved solids (TDS)
- Major cations and ions: calcium, magnesium, potassium, sodium, chloride, sulphate, alkalinity (carbonate and bi-carbonate), sulphide, and fluoride
- Dissolved[14] Metals/metalloids: aluminium, arsenic, boron, cadmium, chromium[15], cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc, and mercury
- Nutrients: Ammonia (as N), nitrate (as N), nitrite (as N), and total phosphorous (as P)
- Total Petroleum Hydrocarbons[16] (TPH) (C_6 –C_{40}) and BTEX (benzene, toluene, xylene, ethylbenzene).

These parameters were selected to obtain a large encompassing suite of analyses to ensure accurate evaluation of ambient hydrochemistry, allowing for comparison with groundwater quality data compiled during mining.

NOTE: The baseline groundwater parameter suite, as included in EA Condition E9 (developed to allow for the determining baseline groundwater quality), will be adopted during the current ongoing monitoring (between GMMP draft and construction), during construction, and during the initial operational phases of mining. This list will then be assessed in future iterations of the GMMP and discussed with the regulators to develop a more site specific (indicator) list, as discussed in **Section 4.4.1**.

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[13] Screen clogged with clay, to be developed
[14] Dissolved concentrations will be analysed as this is representative of the water that flows through the aquifer, rather than analysis of total concentrations which may be affected by bore conditions.
[15] Total chromium and not hexavalent chrome is included in the suite. Should elevated chromium results be recorded then speciation of chrome will be investigated.
[16] It is noted and has been discussed with DES that since the amendment of the NEPM NATA accredited laboratories provide their TPH concentrations at Total Recoverable Hydrocarbons, allowing for more definitive reporting. Adani will provide the most accurate hydrocarbon concentration results, i.e. the TRH results understanding that this addresses this EA approval requirement

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4.4.3.2 EA Condition Monitoring

The baseline monitoring suite detailed in **Section 4.4.3.1** has been adopted in EA Condition E9 Table E1 (**Appendix A**). These data will allow for comparison during and post-mining, should queries arise.

It is noted this baseline suite will continue to be collected during construction and initially when mining operations start. It is considered this parameter list may be reduced in the long term through discussions with regulators.

4.4.4 Quality Assurance / Quality Control Sampling

Field monitoring equipment, such as electrical conductivity and pH meters, are to be calibrated daily during groundwater monitoring events (GMEs) using appropriately ranged and preserved calibration solutions.

Quality assurance/quality control laboratory samples are collected at a rate of one duplicate sample for every ten groundwater samples collected, or if less than ten samples in a sampling event, one duplicate sample per batch. The duplicate sample is sent to the primary analytical laboratory.

NOTE: the duplicate results were included in the ambient groundwater quality dataset which was utilised to develop groundwater quality triggers (**Section 5.4**).

Duplicate groundwater samples are analysed for the full suite of parameters as the primary sample.

Collected samples are transported under chilled conditions to the laboratory without compromising the sample hold time limits.

4.5 Monitoring Requirements under the AWL

The AWL obtained for the project require development of Underground Water Monitoring Program (UWMP) with the following objectives-

(a) to assess the effects of the take of underground water authorised under this licence, including:
- *(i) to provide for the monitoring of impacts on springs and watercourses dependent on underground water flow (Doongmabulla Spring Complex, Mellaluka Spring Complex and Carmichael River alluvium and baseflow);*
- *(ii) to provide for the monitoring of impacts on other underground water users;*
- *(iii) to provide for underground water level monitoring in all identified geological units across and adjacent to the mine site;*
- *(iv) to monitor impacts on the Dunda Beds and Clematis Sandstone aquifers;*
- *(v) to monitor source aquifers identified as potential alternative water supplies for owners of bores with predicted impaired capacity;*
- *(vi) to estimate underground water inflow to, and take from mine workings;*

(b) to provide for the refinement and validation of the numerical underground water model used to assess impacts; and

(c) to take into account requirements of any regional underground water monitoring and assessment program developed to address potential cumulative impacts.

Note: the requirements of the Underground Water Monitoring Program may be incorporated within monitoring programs as required under Federal or State Government approvals

It is to be noted that the GMMP meets above required objectives of the UWMP, as the above objectives are consistent with that of mentioned under EA and EPBC approval conditions.

4.6 Data Management

4.6.1 Data Collation

All groundwater hydrochemistry data, compiled during the baseline project phase, is currently stored in a CCP-specific Excel workbook and in an ESdat database, which is directly updated using laboratory Certificates of Analysis (COA) reports.

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It is planned that all groundwater data (chemistry and water levels), collected and compiled as part of this GMMP, will be stored and managed in a CCP-specific groundwater database. This database is planned to include:

- Bore location details, aquifer and equipment details (including pumping infrastructure and instrumentation)
- Groundwater level and chemistry data
- Projected groundwater level variations based on predictive groundwater modelling
- Geological logs
- Bore construction details.

4.6.2 Data Dissemination

Reports

Interpreted data will be disseminated through the agreed (EA Condition E15 (**Appendix A**)) reporting requirements (**Section 4.8**). These data will be provided on a six-monthly basis, in line with the approval conditions.

Geological logs and construction details of monitoring bores constructed on site (existing and in future) will be provided for inclusion in the groundwater database and provided in reporting as required (**Appendix A** - EA Condition E15).

Website Information

Verified (Quality Assurance / Quality Control) groundwater monitoring data will be made available to the public through the Adani website, these publicly available data will include:

- All groundwater quality monitoring data
- All groundwater level data
- Figures showing the groundwater monitoring points
- Site rainfall data.

The will be uploaded to the website within 4 weeks of the finalisation of the 6 monthly reports.

4.7 Data Analysis

4.7.1 Data Analysis Process

Adani has, in discussion with DES, proposed groundwater quality triggers and groundwater level thresholds.

The groundwater quality triggers (EA Condition E9 Table E2 (**Appendix A**)), are based on statistics, against which future monitoring data is to be assessed. Different methods exist for the assessment of groundwater monitoring data, one of which is the use of statistical tests for the development of indicator parameter limits. It is recognised that alternative methods exist, however, statistics honour natural data variability and facilitate tracking of quality and quantity trends.

The groundwater level thresholds (EA Condition E13 Table E3 (**Appendix A**)), including low and high impact threshold levels for the Dunda Beds and Clematis Sandstone (Recommended Condition 5 Great Artesian Basin aquifer threshold levels and condition 57 Associated Water License Ref 617264), and Early warning triggers and Impact thresholds in accordance with EPBC Act conditions 3e)i, 22, 23, and 24, have been proposed in **Section 5.3**. These thresholds, in response to the conditions at Appendix 1, Section 1, Schedule E of the CG's Report, have been based on predictive groundwater modelling.

4.7.1.1 Hydrochemistry Data

A sufficient (statistical) groundwater dataset is available (a minimum of 12 sample events over a two-year period) to assess and identify representative hydrochemistry data for each hydrostratigraphic unit being monitored (GMMP **Section 5.4**).

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The sufficient groundwater quality data (from a statistical perspective) has allowed for the proposition of groundwater quality trigger levels. These trigger levels are based on the conditioned 85th percentile values for each measured parameter (in EA Condition E9 Table E2) in each hydrostratigraphic unit, possibly impacted by mine operations, as detailed in EA Condition E9 Table E1 (**Appendix A**).

Trends can be identified, and follow-up investigations initiated (when trigger levels are exceeded) per the established approach outlined in **Section 4.7.2**. The intent of the investigative follow-up is to identify natural exceptions to established trigger levels and facilitate revision of the triggers as per the adaptive management approach (i.e. an assessment of potential for environmental harm will be conducted and if it is found that the trigger levels are exceeded due to natural conditions (not mine related) then the limits are to be re-evaluated).

4.7.1.2 Groundwater Level Data

It is recognised that drawdown, because of mine dewatering and/or depressurisation, can materially impact on groundwater yields (e.g. reduced available drawdown) and potentially cause environmental harm (e.g. water table decline below root depths).

To identify potential drawdown impacts before they can impact on sensitive receptors (springs, river, neighbouring bores, etc.), the groundwater monitoring at CCP allows for several of the monitoring points to act as early warning and model prediction validation points, when assessing mine dewatering drawdown.

Groundwater level thresholds in units between the mine and the sensitive ecosystems (GDEs, spring complexes, and riparian vegetation) and landholder supply bores have been proposed based on predictive modelling (GMMP **Section 5.3**).

Once monitoring indicates that these groundwater level thresholds (including Early warning triggers and Impact thresholds) have been reached then investigations and response processes will be instigated, as detailed in GMMP **Section 4.7.2**.

The proposed groundwater level thresholds have been adopted for monitoring points in areas as defined in EA Condition E13 Table E3 (**Appendix A**), and include:

- Adjacent to the Carmichael River
- To the west of the mine lease in and below the GAB units and adjacent to the Doongmabulla Springs Complex
- Adjacent to the Mellaluka Springs Complex to the southeast of the mine leases.

These monitoring points on the mine lease boundary and outside the mine lease, between the mine operations and current groundwater users, are sentinel bores which allow for the validation of groundwater level and chemistry change before these possible groundwater impacts occur at the sensitive receptors .

It is noted that the groundwater level thresholds will be revised over time, based on model refinement conducted using site specific monitoring data (every two years for first ten years and then every five years).

4.7.2 Investigation and Response Processes

4.7.2.1 Hydrochemistry

First Step

In compliance with EA Condition E10, should any groundwater quality triggers (as detailed in EA Condition E9 Table E2) be exceeded in two consecutive monitoring events, an investigation will be undertaken within 14 days of detection (after chemistry results are received from the second groundwater monitoring event) to determine if the exceedance is a result of:

- Mining activities authorised under this environmental authority, or
- Natural variation, or

Neighbouring land use resulting in groundwater impacts.

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Second Step

If the investigation determines that the exceedance was the result of the approved mining operations, then investigations will be undertaken to establish whether environmental harm has occurred or may occur (EA Condition E11).

Third Step

In compliance with EA Condition E12, if the investigation determines that environmental harm has or may occur, then the following will occur:

- Implement immediate measures to reduce the potential for environmental harm
- Develop long-term mitigation measures to address any existing groundwater contamination and prevent recurrence of contamination.

Fourth Step

Adani will provide details of the measures implemented to reduce the potential for environmental harm as well as the long-term mitigation measures to the administering authority within 28 days after completing the investigation.

NOTE: This stepped approach will be implemented for trigger exceedances, which allows for investigation and implementation of mitigation measures prior to reaching any groundwater quality limits. **Section 5.4.4** includes recommended Contaminant Limits, derived by DES, for consideration when assessing potential for environmental harm.

4.7.2.2 Groundwater Levels

If groundwater levels fluctuate more than the groundwater level thresholds (Early warning and low impact thresholds), defined through predictive modelling, an investigation will be instigated within fourteen (14) days of detection.

The investigation will aim at determining if the fluctuations in groundwater levels are a result of CCP activities or outside influences. Potential sources of impact may include:

- Mining activities authorised under this environmental authority
- Pumping from licensed bores
- Seasonal variation / climatic events such as prolonged drought
- Neighbouring land use resulting in groundwater impacts; or
- Nearby projects.

To identify if the fluctuation in groundwater level(s) are resultant from non-CCP activities, Adani will undertake investigation as follows:

- Investigate equipment condition / placement (e.g. water level logger malfunction, logger replaced in a different location – stuck on side of bore, animal disturbance, etc.)
- Review and assess at least the most recent twelve (12) months of groundwater level data (hydrographs) to identify and assess trends
- Compare the hydrograph to climate data (rainfall and evaporation rates) over the same timeframe
- Review hydrographs for nearby bores to identify the scale of fluctuation and area of influence (local vs regional)
- Compare the location of other local projects (e.g. projects not related to CCP such as road / rail improvements where groundwater is sourced for construction activities)
- Assess the potential for the fluctuation to be a cumulative impact (extreme drought coupled with local landholder's groundwater extraction rates/frequency increased due to extreme drought).

If the groundwater level thresholds exceedance is because of authorised mining activities, the investigation will be prioritised and, depending on the nature of the impact, completed within three

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months. Adani will notify the administering authority within 28 days of the completion of the investigation and provide the following:

- Details of whether actual environmental harm has occurred or is likely to occur
- Any proposed long-term mitigation measures required to address the affected groundwater resource
- An assessment into the known or likely impacts will be undertaken and mitigation measures identified
- A review of mitigation measures and the implementation of additional or more effective controls
- Implementation of additional monitoring to assess the effectiveness of mitigation measures and corrective actions
- Prescribe actions that prevent the occurrence of impacts beyond those that are approved
- Proposed actions to reduce the potential for environmental harm (as dictated per the GAB Spring Research Plan).

In addition, Adani will undertake an assessment of the associated impacts to matters of state environmental significance (MSES) and MNES values as per conditions i3, i4, and i5 of the EA (**Appendix A**). The investigation reports must be prepared within 3 months (of the completion of the investigation) by an appropriately qualified person. The investigation will include consideration of:

- Notification of relevant managing agencies and a revision to the Biodiversity Offset Strategy (BOS) will be proposed if an increased impact cannot be avoided
- Update/revise the numerical groundwater model with the monitoring results
- Implementation of relevant operational constraints in relation to groundwater drawdown impacts such as review of the mine plan (including sequencing of mining)
- Update the model predictions using the refined model and evaluation of the interim threshold level
- Directing research priorities under the GABSRP and/or RFCRP in relation to mitigation strategies and offset requirements
- If impacts are predicted to be beyond those allowed in the project approvals, commence planning of further mitigation activities with regards to water availability at the springs which may include
  - limiting thickness of extraction of coal seams and reviewing extraction of multiple coal seams for the underground longwall mining.

freezing mine development at current levels until the completion of investigations and assessments which conclude that further development will not exceed approved impacts.**NOTE**: The administering authority will be notified when an investigation is to be instigated for both groundwater quality and levels.

4.8 Data Reporting

EA Condition E15 Requirements

Monitoring results, both groundwater levels and groundwater quality, are verified and stored in a CCP-specific monitoring database. Review of these data will be undertaken on a regular basis and will be reported to the relevant regulator on an agreed-upon basis (i.e. annual environmental returns), as per EA Condition E15.

EPBC Act Requirements

The approval conditions for the CCP under the EPBC Act (EPBC 2010/5736 dated 14 October 2015) include for the provision to make monitoring data available to the Department of the Environment (DotE) (and Queensland Government authorities if requested) on a six-monthly basis. The provision of this data, considering the requirements of the EA approval condition (**Appendix A,** Condition E15), will be provided in a format specified by the administrating authority.

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Reports will be prepared and provided at least every six months, as required. It is envisaged that, subject to agreement with the administering authority, the 6-monthly monitoring data packages/reports for the DotE will include:

- Details regarding any changes to the existing monitoring network from the previous report (for example, new monitoring bores coming online)
- The most recent monitoring results in comparison with groundwater quality triggers and groundwater level thresholds
- Histories of complaints regarding groundwater level drawdown or groundwater chemistry in private water bores
- The results of any investigation(s) into potential environmental harm, details of mitigation and / or rehabilitation plans, and results (if applicable)
- The most recent monitoring results in comparison with groundwater quality triggers and groundwater level thresholds
- Groundwater level hydrographs, and trend analysis, will be updated and included in the reports
- Long term trends in the groundwater quality data will also be assessed and included in the report.

<u>AWL Condition 51 Requirements</u>

Under condition 53 of AWL , Adani will provide the Annual Monitoring Report within three months after the end of the relevant water year which includes:

a) the underground water levels in the monitoring bores of the approved UWMP
b) any changes in water quality (Table 3 of AWL Condition 45) in the monitoring bores
c) quarterly monitoring information relating to springs and watercourses dependent on underground water flow by application of Tables 1 and 2 listed in Condition 45 of AWL
d) an estimate of spring flows for each of the spring groups including details of the method used to estimate the spring flows
e) maps showing the actual water level drawdown contours caused by the take of associated water for each aquifer
f) details of any review undertaken of the numerical underground water model since the previous Annual Monitoring Report, as required under AWL conditions 55 or 56
g) an assessment of any differences between the actual water level impact and the impact predicted for the same period in the most current numerical underground water model
h) details of any bores which are predicted by the most current numerical underground water model to be located in the affected area; and
i) raw data provided in a format as requested by the chief executive.

<u>Reporting</u>

Commitments in regard to groundwater monitoring data submission includes the following:

- Data collected under the groundwater monitoring program will be sent to the administering authority on a 6-monthly basis within 30 business days of the end of each six-monthly period and compiled in a motioning report in a format approved by the administering authority
- Adani will undertake an assessment of the impacts of approved mining operations on groundwater after the first 12 months of dewatering commencing and thereafter every subsequent calendar year
- The monitoring reports will include an assessment of impacts, any mitigation strategies as well as any recommendations for changes to the approved monitoring program.

Adani will submit the six-monthly groundwater data in compliance with the EPBC Act Conditions and provide an annual report (EA Condition E15). Groundwater level data and groundwater quality data,

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detailed in the Associated Water Licence (AWL) (**Appendix A**), will be provided with the following timeframes:

- For water level data, within 10 business days from the measurements
- For water quality data, within 40 business days from measurement.

Adani will also make the groundwater data, collected throughout the monitoring life, available for the public through posting data on a webpage dedicated to sharing monitoring information on its website (www.adaniaustralia.com.au) as per AWL Condition 51.

All groundwater monitoring data, factual and interpretative reports will be kept in the Adani database (beyond the minimum five-year EA requirements) for comparison and identification of trends.

For completeness the groundwater monitoring data, factual and interpretative reports (including any possible investigations as a result of triggers / thresholds) will be provided to the Commonwealth regulators as well as the State regulators.

As detailed in **Section 4.6.2** the groundwater monitoring data will be made available to the public through the Adani website, which will be uploaded to the website within 4 weeks of the finalisation of the 6 monthly reports. The groundwater monitoring data dashboard on the website will be operational within three months of approval of the GMMP. Commonwealth-conditioned monitoring results will be publicly available on Adani's website for the life of the CCP.

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5.0 Monitoring Data Presentation and Compliance with Approval Conditions

The baseline data, compiled and presented in the previous sections, have been assessed and interrogated to allow for the compilation of approval conditions, for inclusion in the GMMP. These post approval assessments, to comply with regulatory requirements of the GMMP, include:

- Proposed groundwater level thresholds, which instigate investigations and validation of model predictions with regards to groundwater level changes over time
- Groundwater quality triggers, based on the large baseline groundwater monitoring data set for each hydrostratigraphic unit, which allows for the instigation of investigations into groundwater quality changes over time.

The site-specific GMMP includes detailed procedures which were undertaken to develop a robust baseline groundwater dataset. The baseline monitoring was and continues to be compiled before the commencement of mining activities to ensure representative data (from geologically isolated bores) is collected for comparison during the later stages of mine activities.

The monitoring data presented in this GMMP used to characterise the groundwater resources includes the groundwater monitoring period discussed in **Section 3.0**. Adani continue to collect ambient groundwater, at regular intervals to capture wet and dry season conditions (to provide continuity of data), until mining activities start.

5.1 Overview

The current GMMP allowed for the compilation of baseline data for identified hydrostratigraphic units (as stated above) that may be directly or indirectly impacted by the approved mining activities. The compilation of sufficient (from a statistical and approval perspective) hydrochemistry and water level baseline data allowed for the assessment of natural fluctuations (seasonal variation) of hydrostatic pressures and ambient groundwater quality, which will be used for comparative and assessment purposes over the life of mine and post-mining.

5.2 Groundwater Level Contours

Average groundwater levels using the hydrographs compiled for all available groundwater level data (**Appendix E**) have been contoured to provide an indication of baseline groundwater flow patterns, in each hydrostratigraphic unit, and gradients prior to mining.

The groundwater level contours and flow patterns are included in **Appendix C**.

5.3 Proposed Threshold Limits

5.3.1 Groundwater Level Data

The groundwater monitoring bores network for the monitoring locations, as included in the EA Condition E13, allowed for the collection of background / reference groundwater level data both north, central, and south across the mining lease area. A summary of these bores is presented in **Table 38** below and their locations in relation to the mine leases are present in **Appendix B** (Figures).

The bores selected for assignment of groundwater level thresholds, as required in Table E3 of EA Condition E13, included the following:

- Carmichael River Location - bores adjacent to the Carmichael River, west, within, and east of the Mining Lease, were selected to allow for the assessment of potential environmental harm to Groundwater Dependent Ecosystems (GDEs) associated with the river. Bores intersecting shallow groundwater resources within the surficial geology (Dunda Beds, Alluvium, Tertiary sediments, and Joe Joe Group) were selected for groundwater level thresholds monitoring
- Great Artesian Basin to West of Mining Lease - Bores constructed within the Rewan Formation, Dunda Beds, and Clematis Sandstone were selected as required in Table E3. The bores were

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selected, from north to south, to the west of the mining lease for groundwater level thresholds and will also serve as control bores, which will remain for the life of the project and post-closure

- Doongmabulla West of Mining Lease – In addition to the bores identified for the Great Artesian Basin to West of Mining Lease above, the EA Condition E13 included the requirement to compile groundwater level thresholds for the target coal seams D seam and AB seam. It is noted that these units are > 600 m below the Doongmabulla Springs Complex to the west of the MLs and thus, in the absence of very deep coal seam standpipe monitoring bores, selected VWPs have been included to assess potential drawdown between the MLs and the western Doongmabulla Springs Complex area

  In addition, groundwater level thresholds have been proposed for bores within the Rewan Group sediments, the confining aquitard, between the target coal seams and the overlying GAB units

- Mellaluka Springs Complex south of the MLs – Bores to the southeast of the mine lease within the Tertiary sediments and Joe Joe Group were selected to assess potential impacts on groundwater levels adjacent to the Mellaluka Springs Complex. Two bores were included for groundwater level thresholds monitoring in the area in the Permian sediments which pinch out adjacent to the springs. The evaluation of groundwater levels in this area will allow for the assessment of possible induced flow and hydraulic connection within the Tertiary sediments

- Sentinel Bores – In addition to the bores selected above, additional bores that intersect the Joe Joe Groups within and outside the MLs were selected as sentinel bores. These bores are located between the mine and the neighbouring landholder bores and will remain for the life of the project and post-closure:

  - additional sentinel bores, not intersecting the Joe Joe Group, were included to provide long term monitoring bores between the mine lease and the areas of interest, including the Carmichael River, Doongmabulla and Mellaluka Spring complexes, and the neighbouring land holder bores.

The transient groundwater level data was collected using both manual methods (water level dip meter) and using automated water level loggers (In-situ level trolls with accuracy of ±0.1% of full scale, i.e. ± 0.34 m at full scale of 340 m). It is noted that groundwater levels are predicted to decline by up to 200 m (see **Plate 11** to **Plate 19** in **Section 5.3.2**), such that the accuracy of the level loggers will be adequate (within the full scale range of the loggers) to measure the change in groundwater levels.

As barometric pressure changes can effect groundwater level data the data from the non-vented loggers are corrected (compensated) for barometric pressure (**Section 3.2**).

The groundwater level measurements allowed for the identification of natural fluctuations within these units, as included in **Table 38**. The groundwater level hydrographs are included in **Appendix E**. The hydrographs allowed for the identification of natural fluctuation over the total monitoring period from installation to April 2017.

NOTE: Groundwater level measurements have been conducted prior to any mining activities. The fluctuation of groundwater levels is assumed to be representative of pre-mining conditions, however, existing extraction at neighbouring pastoral bores and/or regular sampling may result in groundwater level variation. Alteration associated with sampling has been edited where evident. The groundwater level data is referred to as natural fluctuation (NF) within this section.

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Table 38 Groundwater Level Data Summary

Bore ID	Maximum (mAHD)	Average (mAHD)	Minimum (mAHD)	Natural Fluctuation (monitoring period)	Trend / Comments
Carmichael River Location					
HD03B	226.28	225.47	225.02	1.26 m (47 months)	High variability in unconfined alluvium.
C027P2	227.35	226.90	226.64	0.72 m (66 months)	Stable water level within confined Dunda Beds after initial logger issues, no influence of wet/dry seasons or recharge / discharge evident.
C029P1	215.38	214.77	214.37	1.01 m (65 months)	Seasonal variation within unconfined alluvium.
C029P2	220.23	220.00	219.75	0.47 m (68 months)	Initial logger data issues, confined limited response in Tertiary sediments.
C025P1	217.05	216.72	216.54 (dry)	0.51 m (58 months)	Often dry downstream alluvium.
C025P2	218.56	217.62	217.36	1.20 m (58 months)	Unconfined to semi-confined Tertiary sediments.
C14028SP	205.60	205.46	205.29	0.31 m (29 months)	Minor fluctuations in response to seasonal changes.
C14027SP	203.72	203.58	203.50	0.22 m (25 months)	Initial logger data issues, confined limited response in alluvium.
C14006SP (Artesian)	226.61	226.03	225.67	0.94 m (10 months)	Stable logger data after 09/2015. Average potentiometric level some 6 m above surface.
Great Artesian Basin to West of Mine Lease					
C180118SP	250.28	250.17	250.05	0.23 m (24 years)	BLOCKED to be repaired. Stable water level within confined Clematis Sandstone, no influence of wet/dry seasons or recharge / discharge evident.
C14033SP	250.75	250.62	250.49	0.26 m (15 months)	Minor fluctuations in response in Clematis Sandstone to seasonal changes.
C14011SP	242.92	242.80	242.69	0.23 m (22 months)	
C14012SP	242.73	242.62	242.50	0.23 m (23 months)	
C14013SP	242.62	242.49	242.33	0.29 m (23 months)	

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Bore ID	Maximum (mAHD)	Average (mAHD)	Minimum (mAHD)	Natural Fluctuation (monitoring period)	Trend / Comments
HD02	234.58	234.28	234.12	0.46 m (43 months)	Unconfined Clematis Sandstone bore, slight variations due to dry / wet seasons (highest water levels in February).
HD03A (Artesian)	232.50	232.03	231.48	1.02 m (44 months)	Average potentiometric level in Clematis Sandstone artesian bore, ~ 3 m above surface.
C14021SP	247.30	246.54	246.21	1.09 m (23 months)	Manual readings within unconfined Clematis Sandstone bore indicate variability. difference in manual readings from logger readings due to unconfined conditions.
C022P1	246.88	246.66	246.46	0.42 m (65 months)	Stable water level within confined Dunda Beds, no influence of wet/dry seasons or recharge / discharge evident.
C027P2	227.35	226.90	226.64	0.72 m (66 months)	Stable water level within confined Dunda Beds after initial logger issues, no influence of wet/dry seasons or recharge / discharge evident.
C14023SP	247.47	247.26	247.16	0.30 m (29 months)	Stable water level within confined Dunda Beds, no influence of wet/dry seasons or recharge / discharge evident.
C180117SP	251.16	251.02	250.78	0.38 m (29 months)	Stable water level within confined Dunda Beds, no influence of wet/dry seasons or recharge / discharge evident.
C9553P1R	252.35	252.26	252.20	0.15 m (35 months)	Minor fluctuations within confined Rewan Formation.
C556P1	235.10	234.84	234.52	0.58 m (54 months)	Logger data matching manual data since 05/2014, slight decline in confined water level trend in Rewan Formation.
C555P1	230.14	230.02	229.79	0.35 m (35 months)	Logger issues, manual readings indicate slight response to wet/dry seasons. GHD data datum incorrect.
Doongmabulla to West of Mine Lease					
HD02	234.58	234.28	234.12	0.46 m (43 months)	Unconfined Clematis Sandstone bore, slight variations due to dry / wet seasons (highest water levels in February).
HD03A (Artesian)	232.50	232.03	231.48	1.02 m (44 months)	Average potentiometric level in Clematis Sandstone artesian bore, ~ 3 m above surface.

Bore ID	Maximum (mAHD)	Average (mAHD)	Minimum (mAHD)	Natural Fluctuation (monitoring period)	Trend / Comments
C14013SP	242.62	242.49	242.33	0.29 m (23 months)	Stable water level within confined Clematis Sandstone, no influence of wet/dry seasons or recharge / discharge evident.
C022P1	246.88	246.66	246.46	0.42 (65 months)	Stable water level within confined Dunda Beds, no influence of wet/dry seasons or recharge / discharge evident.
C14012SP	242.73	242.62	242.50	0.23 m (23 months)	Stable water level within confined Clematis Sandstone, no influence of wet/dry seasons or recharge / discharge evident.
C14021SP	247.30	246.54	246.21	1.09 m (13 months)	Manual readings within unconfined Clematis Sandstone bore indicates variability, difference in manual readings from logger readings due to unconfined conditions.
C14206VWP_1	-	237.3	-	Stable since 11/2016	Hydrostatic plus pore pressure stable within AB seam VWP sensor used to assess dewatering / depressurisation trends.
C558VWP1	-	211.6	-	Stable since install 2012	Hydrostatic plus pore pressure stable within D seam VWP sensor used to assess dewatering / depressurisation trends.
C968VWP_P2	-	355	-	Stable since install 2014	Hydrostatic plus pore pressure stable within D seam VWP sensor used to assess dewatering / depressurisation trends.
C968VWP_P5	-	192.8	-	Stable since install 2014	Hydrostatic plus pore pressure stable within AB seam VWP sensor used to assess dewatering / depressurisation trends.
C848SP	232.52	231.91	231.52	1.00 m (37 months)	D Seam coal seam fluctuations.
Mellaluka Springs to the southeast of Mine Lease					
C180120SP (Artesian)	244.15	243.48	241.62	2.53 m (29 months)	Average potentiometric level in artesian bore, ~ 18.5 m above reference level. Composite Tertiary sediments / Joe Joe Group potentiometric pressure Possible sampling influence on potentiometric level.

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Bore ID	Maximum (mAHD)	Average (mAHD)	Minimum (mAHD)	Natural Fluctuation (monitoring period)	Trend / Comments
C180122SP (Artesian)	236.66	236.46	235.91	0.75 m (29 months)	Average potentiometric level in artesian bore, ~ 11.5 m above reference level. Composite Tertiary sediments / Joe Joe Group potentiometric pressure Possible sampling influence on potentiometric level.
C851VWP2	-	229	-	Stable since 12/2014	Hydrostatic plus pore pressure stable within AB seam. VWP sensor used to assess dewatering / depressurisation trends.
C180119SP (Artesian)	238.43	238.21	237.94	0.49 m (22 months)	Initially aquifer undergoing stabilisation after drilling and monitoring well installation. Average potentiometric level in artesian bore since 04/2015, ~ 14 m above reference level.
C180123SP (Artesian)	246.52	246.35	245.85	0.67 m (28 months)	Average potentiometric level in artesian bore since 11/2014, ~ 18.5 m above reference level.
C9180124SPR (Artesian)	235.54	235.31	234.99	0.55 m (24 months)	Initially aquifer undergoing stabilisation after drilling and monitoring well installation. Average potentiometric level in artesian bore since 04/2015, ~ 11 m above reference level.
C9180125SPR (Artesian)	243.42	243.10	242.35	1.07 m (25 months)	Initially aquifer undergoing stabilisation after drilling and monitoring well installation. Average potentiometric level in artesian bore since February 2015, ~ 19 m above reference level.
Sentinel Bores					
C14016SP (Artesian)	235.52	234.13	233.39	2.13 m (21 months)	Logger installed 07/2015, average potentiometric level measured on logger is ~11.5 m above surface.
C9845SPR	235.02	234.91	234.74	0.28 m (29 months)	Confined Tertiary sediments.
C14029SP (Artesian)	251.22	251.07	250.75	0.47 m (20 months)	Average potentiometric level in artesian bore, ~ 12 m above reference level. Composite Tertiary sediments / Joe Joe Group potentiometric pressure.
C14003SP	209.52	209.37	209.25	0.27 m (32 months)	Confined Joe Joe Group

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Bore ID	Maximum (mAHD)	Average (mAHD)	Minimum (mAHD)	Natural Fluctuation (monitoring period)	Trend / Comments
C14030SP (Artesian)	230.86	230.25	229.58	1.29 m (20 months)	Confined Joe Joe Group Average potentiometric level is approximately 12 m above the reference elevation. Alternate bore name: C914030SPR.
C14015SP (Artesian)	239.26	239.15	238.70	0.55 m (9 months)	Average potentiometric level is approximately 10 m above the reference elevation.
C016P2	248.56	248.46	248.37	0.19 m (66 months)	Relatively stable manual water levels since 02/2014.
C14004SP	209.65	209.44	209.13	0.52 m (28 months)	Confined Joe Joe Group
C14008SP (Artesian)	228.73	228.34	227.35	1.38 m (19 months)	Logger data used, average potentiometric level some 7.6 m above reference level. Manual readings erratic due to pressure gauge inaccuracies.
C180116SP	239.24	239.12	239.01	0.23 m (29 months)	Confined Rewan Formation sediments.
C14024SP	262.80	262.71	262.62	0.18 m (24 months)	Confined groundwater level for bore screened in Clematis Sandstone / Rewan Group.
C14020SP	252.62	252.43	252.31	0.31 m (31 months)	Confined Moolayember Formation sediments.

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5.3.2 Projected Groundwater Levels

During the pre- and post-approval process the groundwater flow model has been subjected to several revisions. On examining the impact prediction results of SEIS model (GHD, 2013) and re-run modelling (GHD, 2015) at sensitive receptors it is learnt that the impacts are similar but higher in case of SEIS model. For the GMMP a review has been made on all the available model predictions and a conservative approach has been taken to use the model which predicts the highest Impacts. The SEIS model predicts the highest magnitude of impacts and hence the results from the SEIS model have been used for all assessments and development of water quality and water level thresholds included in the GMMP.

Predictive groundwater modelling, compiled during the approval process and in response to approval conditions, allowed for the projection of groundwater levels within the bores included in **Table 23** and **Table 38** above. These projected drawdown levels within these bores are based on the approved mining operations. To better represent when and by how much each hydrostratigraphic unit may be altered (by mine dewatering) and the resultant changes in groundwater flow patterns a series of maps have been developed to depict groundwater flow patterns pre-mining and for different stages of mining (including post closure) have been compiled. The map series are provided in (**Appendix C**).

The projected changes in groundwater levels within the groundwater monitoring bores are included in **Plate 14** through **Plate 22** below, which present projected groundwater level hydrographs from the predictive groundwater modelling. The groundwater level change, within bores on and adjacent to the mine lease, are presented in semi-log scale. This is due to the large scale difference in the impacts (direct or indirect) of the mine dewatering. As discussed in **Section 2.7.3.1**, the scale of drawdown is dependent on the distance from the mine and the hydraulic conductivity properties of the hydrostratigraphic units. The bores, hydrostratigraphic units, locations, and predicted drawdown for the bores included in **Plate 12** to **Plate 19** are summarised and discussed in **Table 40**.

Table 39 Summary of predicted drawdown

Bore	Units	Location	Maximum Predicted Drawdown (m)	Mine year	Comment
Carmichael River Location					
HD03B	Alluvium	West of MLs	0.004	64	Shallow intersection of coal (drawdown in C832SP is predicted to be 21 m in the C seam and 37 m in C833SP the D seam) plus the thick low permeable clay-rich Tertiary sands overlying the target coal seams reduces the extent of induced drawdown within the area where the Carmichael River cross the mine lease
C029P1	Alluvium	Centre of MLs	0.33	50	
C025P1	Alluvium	Centre of MLs	1.87	59	
C14028SP	Alluvium	East of MLs	0.075	500	
C14027SP	Alluvium	East of MLs	0.018	500	
C029P2	Tertiary sediments	Centre of MLs	0.42	58	
C025P2	Tertiary sediments	Centre of MLs	1.20	60	
C027P2	Dunda Beds	Western boundary of MLs	1.11	65	
C14006SP	Joe Joe Group	Eastern boundary of MLs	0.42	500	
Great Artesian Basin to West of Mine Lease					
HD02	Clematis Sandstone	West of MLs	0.03	90	Drawdown > 70 m within the Rewan Formation,

Bore	Units	Location	Maximum Predicted Drawdown (m)	Mine year	Comment
HD03A	Clematis Sandstone	West of MLs	0.18	87	within the mine lease, is predicted to result in induced flow from the overlying Dunda Beds by < 5 m (one order of magnitude less), and drawdown in the Clematis Sandstone of ~ 0.5 m some 5 km from the mine lease (a further order of magnitude less), indicating the depressurisation impacts are reduced to the west with distance, thickness, and permeability of overlying units
C14021SP	Clematis Sandstone	West of MLs	1.66	500	
C14011SP	Clematis Sandstone	West of MLs	0.62	81	
C14012SP	Clematis Sandstone	West of MLs	0.38	83	
C14013SP	Clematis Sandstone	West of MLs	0.38	82	
C14033SP	Clematis Sandstone	West of MLs	0.25	500	
C180118SP	Clematis Sandstone	On western boundary of MLs	2.61	80	
C022P1	Dunda Beds	On western boundary of MLs	3.86	81	
C027P2	Dunda Beds	Western boundary of MLs	1.11	65	
C14023SP	Dunda Beds	West of MLs	0.32	500	
C180117SP	Dunda Beds	On western boundary of MLs	4.83	586	
C9553P1R	Rewan Formation	Northwest corner of MLs	4.5	586	
C556P1	Rewan Formation	West portion of MLs	84.5	50	
C555P1	Rewan Formation	West portion of MLs	73	90	
Doongmabulla to West of Mine Lease					
HD02	Clematis Sandstone	West of MLs	0.03	90	Similar to the GAB units above, drawdown within the D seam on site is predicted to be >120 m, whereas the drawdown within the monitoring bore HD02 some 1 km from the DSC (between the springs and the mine) is predicted to only vary by up to 0.03 m. The low permeable interbeds, above the AB
HD03A	Clematis Sandstone	West of MLs	0.18	87	
C14013SP	Clematis Sandstone	West of MLs	0.38	82	
C14012SP	Clematis Sandstone	West of MLs	0.38	83	
C14021SP	Clematis Sandstone	West of MLs	1.66	500	

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Bore	Units	Location	Maximum Predicted Drawdown (m)	Mine year	Comment
C022P1	Dunda Beds	On western boundary of MLs	3.86	81	seams in the Bandanna Formation, the Rewan Formation, and the Dunda Beds reduce the impacts on the Clematis Sandstone groundwater levels
C848SP	D Seam	Within MLs	128	586	
Mellaluka Springs to the southeast of Mine Lease					
C180120SP	Tertiary sediments and Joe Joe Group	At the Mellaluka Spring	0.02	586	Groundwater drawdown in the Tertiary and Joe Joe Group sediments are not predicted to result in the loss of artesian pressures (> 10 m) in the Mellaluka Springs area
C180122SP	Tertiary sediments and Joe Joe Group	North of Mellaluka Spring	0.05	586	
C180119SP	Joe Joe Group	North of Mellaluka Spring	0.04	586	
C180123SP	Joe Joe Group	South of Mellaluka Spring	0.007	586	
C9180124SPR	Joe Joe Group	North of Mellaluka Spring	0.045	586	
C9180125SPR	Joe Joe Group	At the Mellaluka Spring	0.02	586	

These projected groundwater level hydrographs were used to assist in developing groundwater level thresholds, as per the approval requirements detailed in EA Condition E13, Condition 5 of the CG's Report, and condition 58 of Associated Water Licence.

In addition, Early warning and Impact threshold levels are required for the Dunda Beds and Clematis Sandstone (GAB) aquifers (EPBC Approvals).

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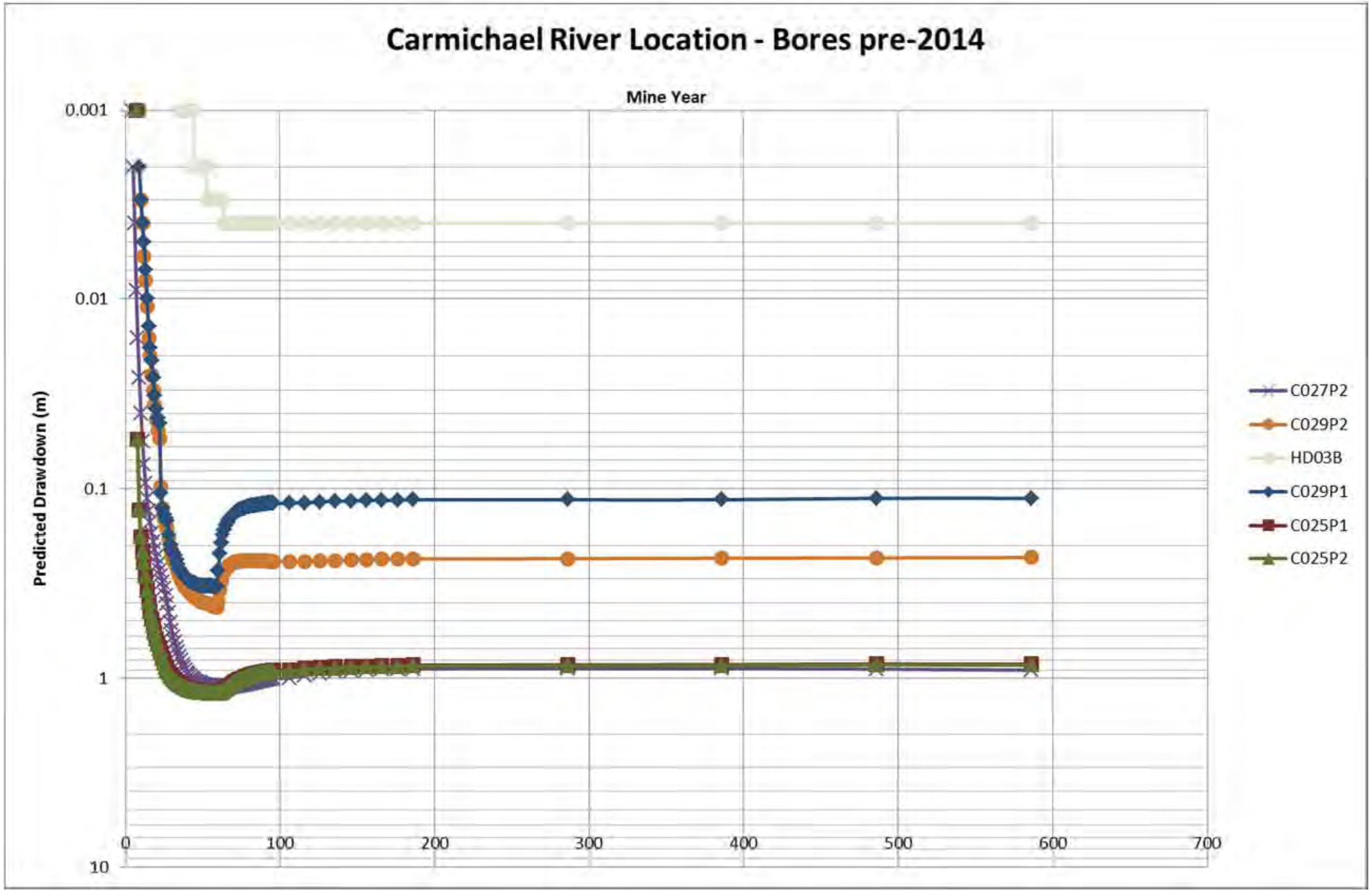

Plate 14 **Carmichael River Location (modelled drawdown)**

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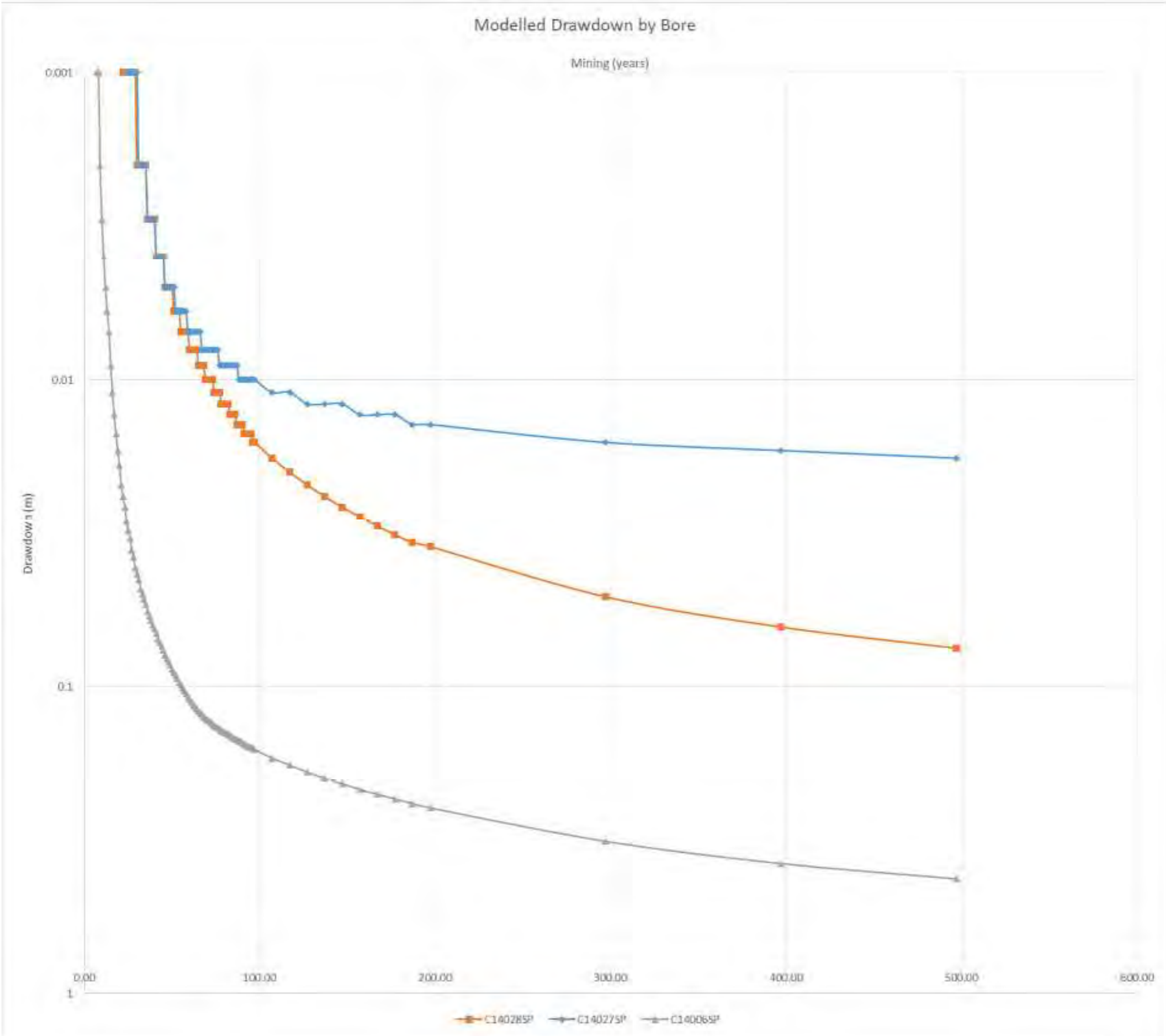

Plate 15 Carmichael River Area (2014 bores)

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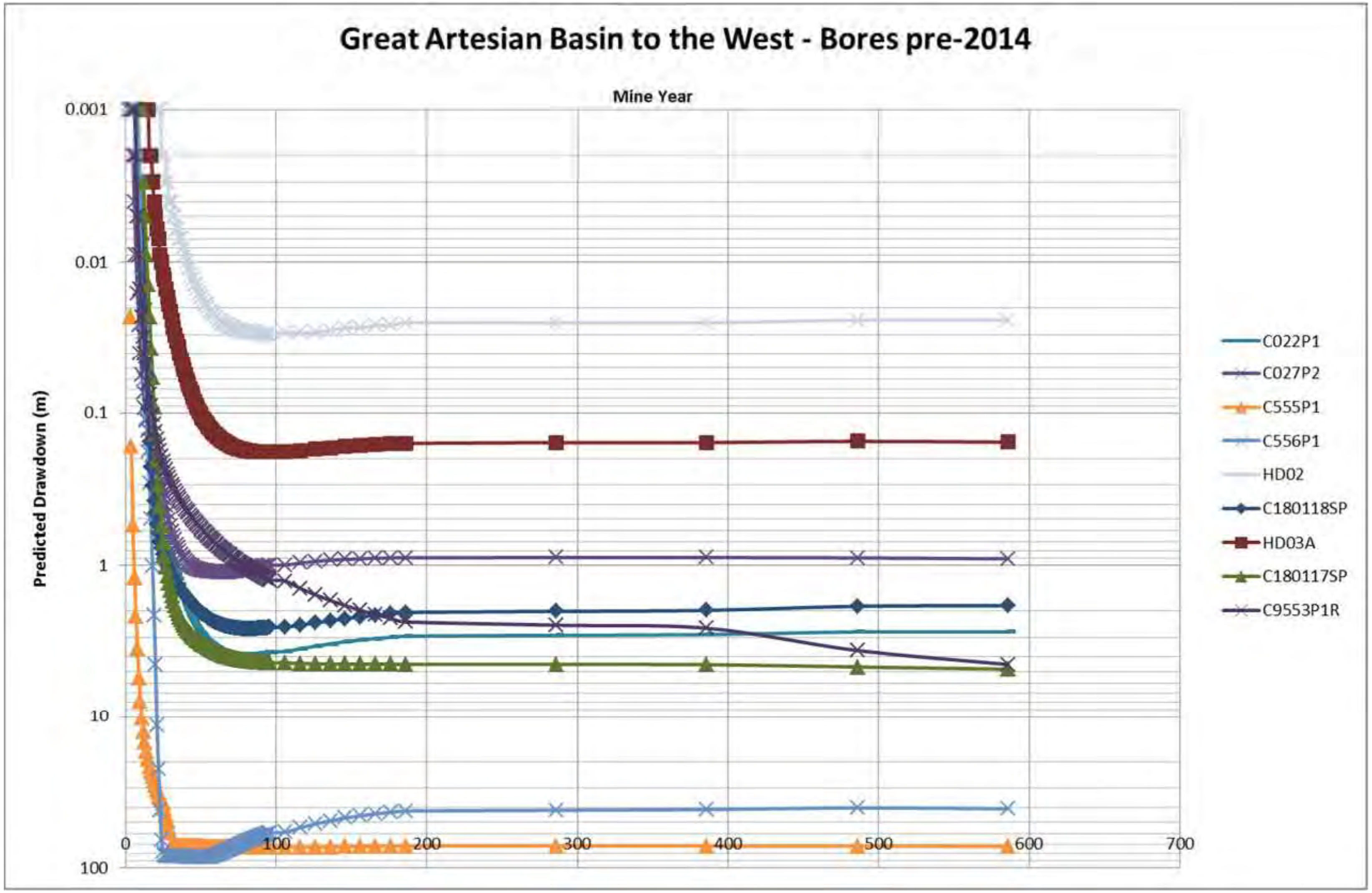

Plate 16 **Great Artesian Basin west of the Mine Leases**

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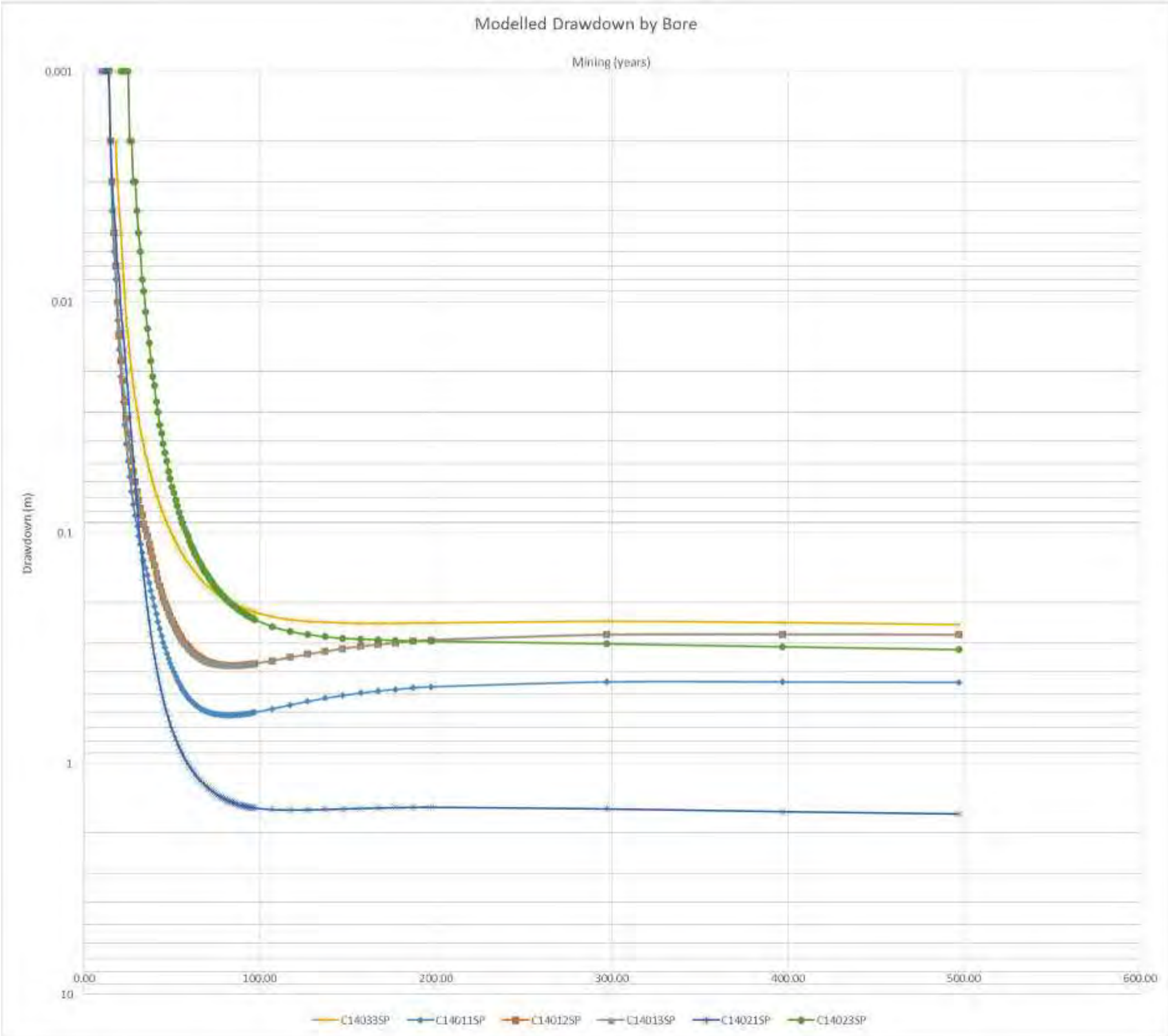

Plate 17 Great Artesian Basin west of the Mine Leases (2014 bores)

D R A F T

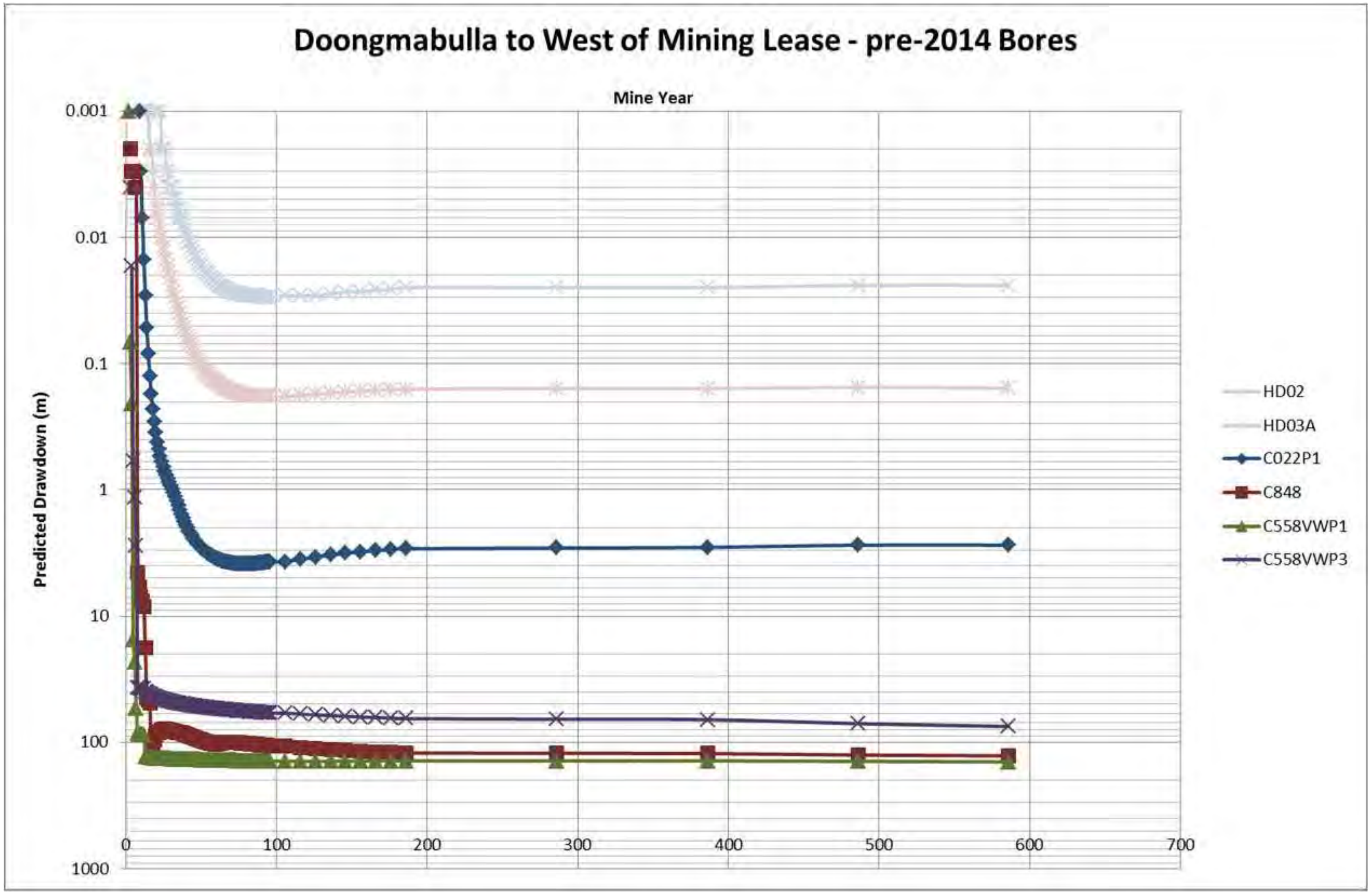

Plate 18 **Doongmabulla Spring Complex west of the Mine Leases**

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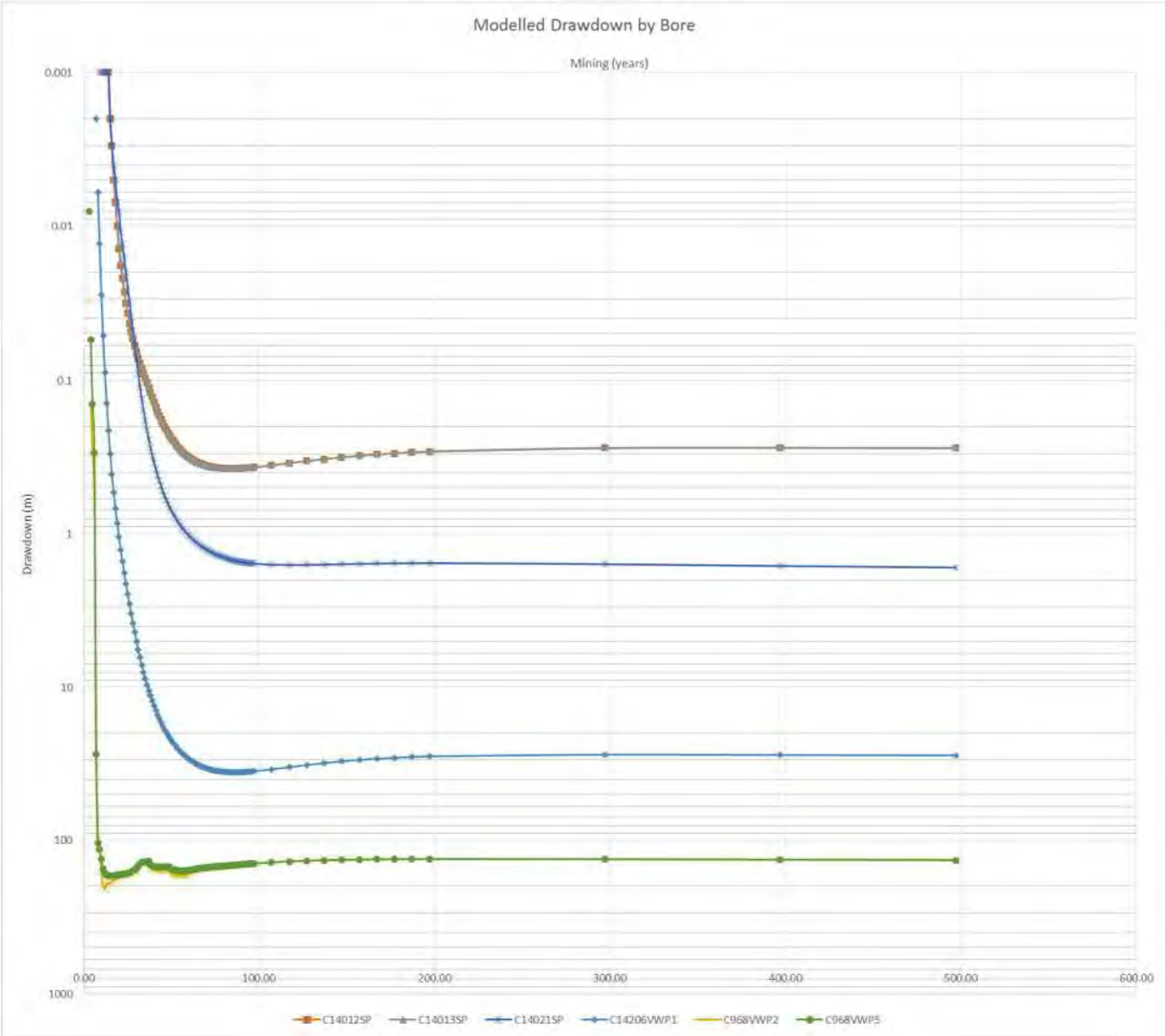

Plate 19 **Doongmabulla Spring Complex west of the Mine Leases (2014 bores)**

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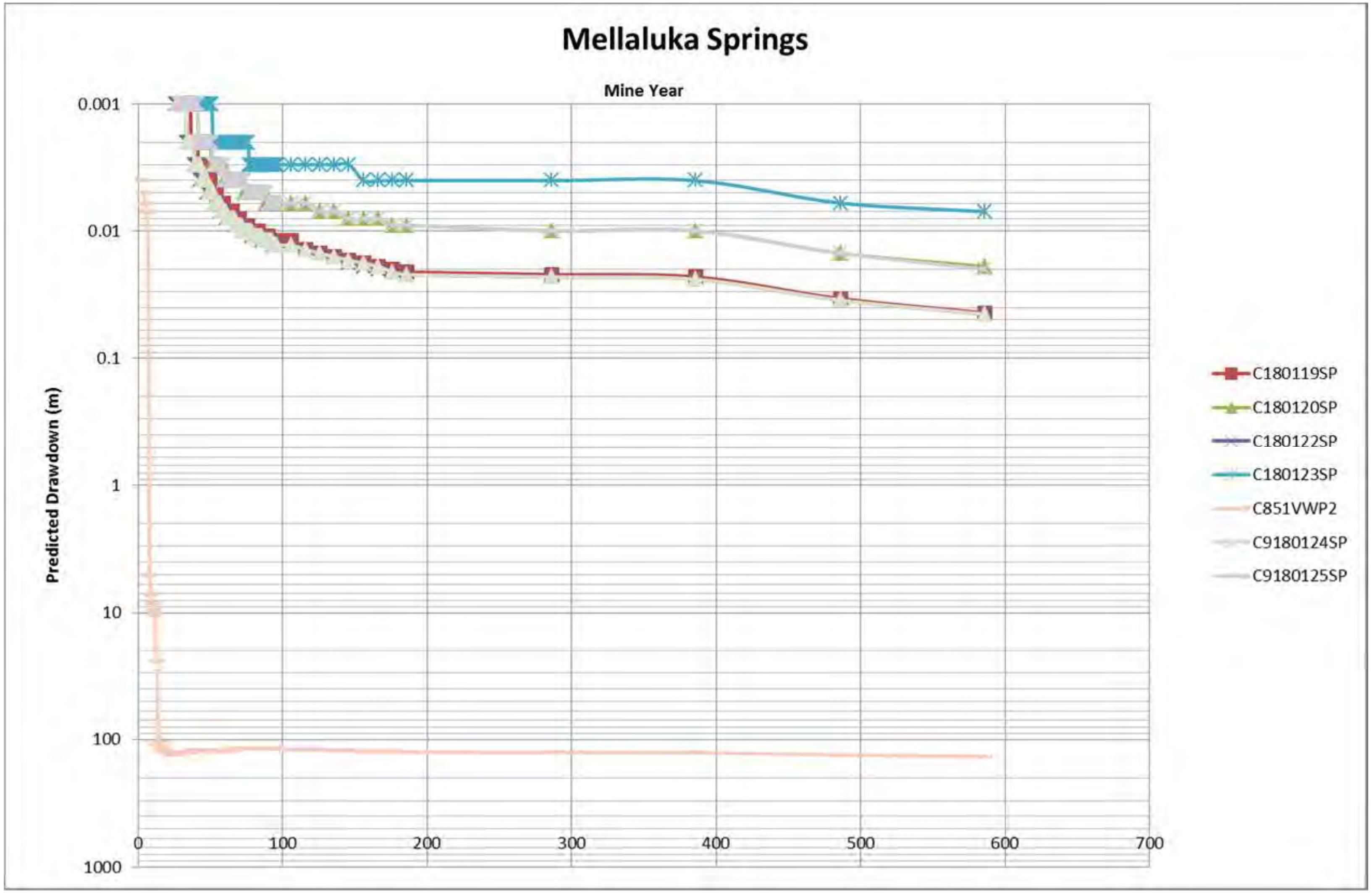

Plate 20 Mellaluka Springs Complex (southeast of the MLs)

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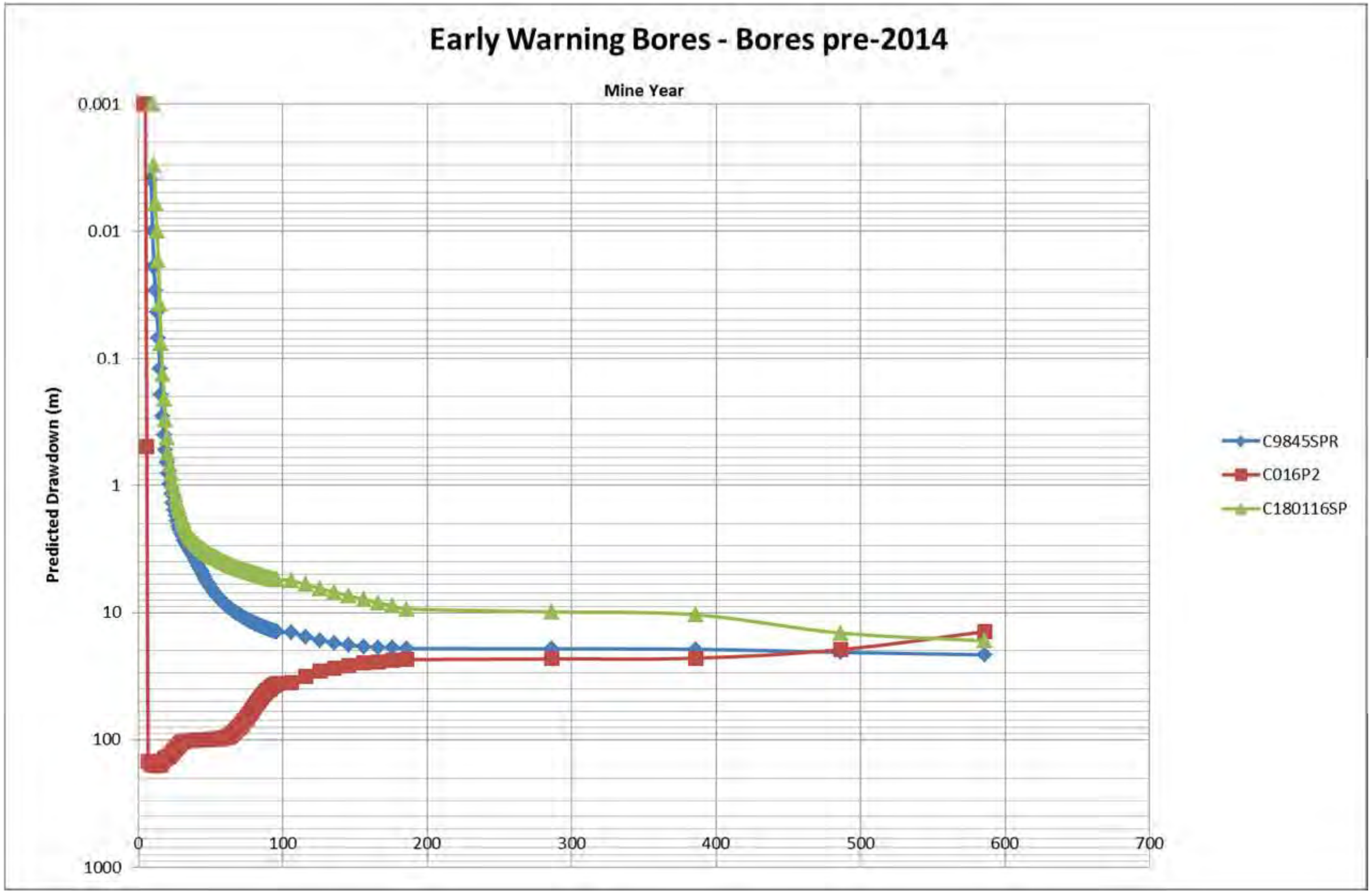

Plate 21 Sentinel Bores

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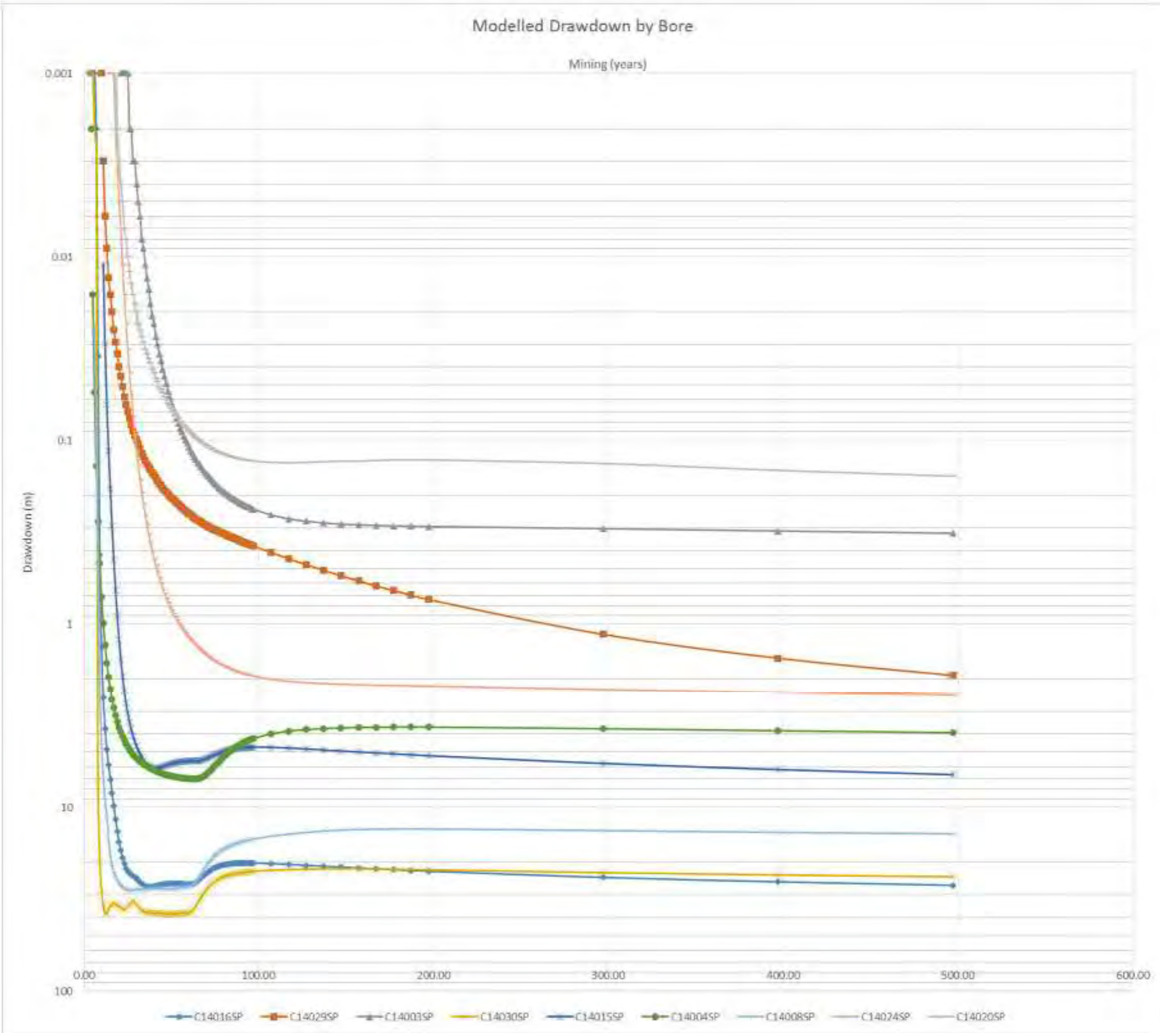

Plate 22 Sentinel Bores (2014 bores)

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The predicted drawdown (below modelled steady-state water level) and timing is summarised in **Table 40**.

Table 40 Drawdown Predictions

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur[17]	Natural fluctuation (monitoring period)	Comments
Carmichael River Location				
HD03B	0.004 m	64	1.26 m (47 months)	Not predicted to drawdown more than natural fluctuation
C027P2	1.11 m	65	0.72 m (66 months)	Groundwater level predicted to recover and reach a post-mining level
C029P1	0.33 m	50	1.01 m (65 months)	Recovery to a post-mining level
C029P2	0.42 m	58	0.47 m (68 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C025P1	1.87 m	59	0.51 m (58 months)	Recovery to a post-mining level
C025P2	1.20 m	60	1.20 m (58 months)	Recovery to a post-mining level
C14028SP	0.075 m	500	0.31 m (29 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C14027SP	0.018 m	500	0.22 m (25 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C14006SP	0.42 m	500	0.94 m (10 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
Great Artesian Basin to West of Mine Lease				
C180118SP	2.61 m	80	0.23 m (24 months)	Groundwater level predicted to recover over time
C14033SP	0.25 m	500	0.26 m (15 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C14011SP	0.62 m	81	0.23 m (22 months)	Recovery to a post-mining level

[17] Time since the commencement of mining in years

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Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur[17]	Natural fluctuation (monitoring period)	Comments
C14012SP	0.38 m	83	0.23 m (23 months)	Recovery to a post-mining level
C14013SP	0.38 m	82	0.29 m (23 months)	Recovery to a post-mining level
HD02	0.03 m	90	0.46 m (43 months)	Not predicted to drawdown more than natural fluctuation
HD03A	0.18 m	87	1.02 m (44 months)	Recovery to a post-mining level
C14021SP	1.66 m	500	1.09 m (23 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C022P1	3.86 m	81	0.42 m (65 months)	Groundwater level predicted to recover and reach a post-mining level
C027P2	1.11 m	65	0.72 m (66 months)	Groundwater level predicted to recover and reach a post-mining level
C14023SP	0.32 m	500	0.30 m (29 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C180117SP	4.83 m	586	0.38 m (29 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C9553P1R	4.5 m	586	0.15 m (35 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C556P1	84.5 m	50	0.58 m (54 months)	Groundwater level predicted to recover and reach a post-mining level
C555P1	73 m	90	0.35 m (35 months)	Groundwater level not predicted to recover
Doongmabulla to West of Mine Lease				
HD02	0.03 m	90	0.49 m (43 months)	Not predicted to drawdown more than natural fluctuation
HD03A	0.18 m	87	1.02 m (44 months)	Recovery to a post-mining level
C14013SP	0.38 m	82	0.29 m (23 months)	Groundwater level predicted to recover over time

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Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur[17]	Natural fluctuation (monitoring period)	Comments
C022P1	3.86 m	79	0.42 m (65 months)	Groundwater level predicted to recover and reach a post-mining level
C14012SP	0.38 m	83	0.23 m (23 months)	Recovery to a post-mining level
C14021SP	1.66 m	500	1.09 m (23 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
C14206VWP_1	36 m	84	Stable at 237.3 since 11/2016	Recovery to a post-mining level
C558VWP1	143 m	586	Stable since 2012	Drawdown predicted to reach deepest drawdown at end of model simulation
C968VWP_P2	206 m	12	Stable since 2014	Recovery to a post-mining level
C968VWP_P5	171 m	15	Stable since 2014	Recovery to a post-mining level
C848SP	128	586	1.00 m (37 months)	Drawdown predicted to reach deepest drawdown at end of model simulation
Mellaluka Springs to the southeast of Mine Lease				
C180120SP	0.02 m	586	2.53 m (29 months)	Not predicted to drawdown more than natural fluctuation
C180122SP	0.05 m	586	0.75 m (29 months)	Not predicted to drawdown more than natural fluctuation
C851VWP2	136 m	586	Stable since 2014	VWP for trend analysis
C180119SP	0.04 m	586	0.49 m (22 months)	Not predicted to drawdown more than natural fluctuation
C180123SP	0.007 m	586	0.67 m (28 months)	Not predicted to drawdown more than natural fluctuation
C9180124SPR	0.045 m	586	0.55 m (24 months)	Not predicted to drawdown more than natural fluctuation
C9180125SPR	0.02 m	586	1.07 m (25 months)	Not predicted to drawdown more than natural fluctuation

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Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur[17]	Natural fluctuation (monitoring period)	Comments
Sentinel Bores				
C14016SP (Artesian)	27 m	37	2.13 m (21 months)	Groundwater level predicted to recover and reach a post-mining level
C9845SPR	21.5 m	586	0.28 m (29 months)	Groundwater level declining over entire prediction period
C14029SP (Artesian)	1.90 m	500	0.47 m (20 months)	Groundwater level declining over entire prediction period
C14003SP	0.09 m	500	0.27 m (32 months)	Groundwater level declining over entire prediction period
C14030SP (Artesian)	1.90 m	500	1.29 m (20 months)	Not predicted to drawdown more than natural fluctuation
C14015SP (Artesian)	6.65 m	500	0.55 m (9 months)	Groundwater recovery followed by decline predicted
C016P2	160 m	14	0.19 m (48 months)	Groundwater level predicted to recover and reach a post-mining level
C14004SP	7 m	63	0.52 m (28 months)	Groundwater level predicted to recover and reach a post-mining level
C14008SP	1.18 m	500	1.38 m (19 months)	Groundwater level declining over entire prediction period
C180116SP	17 m	586	0.23 m (29 months)	Groundwater level declining over entire prediction period
C14024SP	2.44 m	500	0.18 m (24 months)	Groundwater level declining over entire prediction period
C14020SP	0.16 m	500	0.31 m (31 months)	Groundwater recovery followed by decline predicted

5.3.3 Development of Groundwater Level Thresholds

Based on the assessment of natural fluctuations in groundwater levels, both unconfined and confined aquifers, and the model predictions, groundwater level thresholds have been compiled for the bores in the areas included in EA Condition E13.

The aim of the groundwater level thresholds is to provide an alert regarding possible deviation from the predicted dewatered / depressurisation impacts during mining.

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The groundwater level thresholds also aim to validate induced flow predictions, confirming water take from the GAB units (where present), and validating predicted groundwater level drawdown.

NOTE: It is noted that, due to distance from the approved mining and thick low vertical hydraulic conductivity sediments (Rewan Group and Bandanna Formation) between the target coal and overlying units, several bores are predicted to have limited drawdown because of possible induced flow (i.e. groundwater flow from the overlying units to the depressurised coal seams). These predicted induced flow impacts are recognised to be below the natural fluctuation, resulting in the need to develop several different approaches to setting groundwater level thresholds, as detailed below.

5.3.3.1 Groundwater Level Thresholds

The groundwater level threshold levels (referred to as low impact thresholds (for AWL) and Early warning (EPBC Act)), as required in the EA Condition E13, have been selected based on the possible change in groundwater levels as included in **Table 40**. The assessment of groundwater level data, compiled during mining operations, will allow for the compilation of groundwater level hydrographs (up dated after every groundwater monitoring event) allowing for the evaluation of groundwater level trends.

The groundwater level thresholds proposed for the Carmichael Coal Mine are as follows:

- If groundwater levels vary by 50% of the predicted drawdown, above natural fluctuation[18], in unconfined aquifers
- If groundwater levels / potentiometric levels vary by 75% of the predicted drawdown, above natural fluctuation, in the confined aquifers
- For bores where groundwater levels are predicted to decline by > 10 m, as a direct result of coal mining, the groundwater level thresholds are 90% of the predicted maximum drawdown levels plus half of the natural fluctuation (for comparison to the average groundwater level as a reference level)
- In cases where the predicted drawdown is lower than the natural fluctuation, the highest predicted drawdown plus half of natural fluctuation is taken as the groundwater level thresholds
- Water level readings in C025P1 indicating continuous prolonged dry / no water level readings longer than 6 months (or 1.19 m in a newly constructed alluvium bore).

Should groundwater level monitoring indicate variations in groundwater levels by more than 50% (unconfined) or 75% (confined) groundwater level fluctuations or > 90% of the predicted maximum drawdown levels (in bores where drawdown is predicted to > 10 m) on two consecutive groundwater monitoring events (quarterly) then the following will occur[19]:

- An investigation must be instigated within 14 days of detection.
- The investigation is to determine the cause of the groundwater level fluctuation considering:
  - mining activities authorised under the EA
  - pumping from licensed bores
  - seasonal variation
  - neighbouring land use resulting in groundwater impacts.

A report into the investigation will be made available to the regulator, via WaTERS, within 28 days of completing the investigation. **Plate 23** provides a decision tree in the event an investigation is instigated due to exceedance of groundwater level thresholds.

Table 41 presents a summary of the proposed groundwater level thresholds for the selected monitoring bores plus a summary of the selection criteria.

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[18] Using the average groundwater levels from the hydrographs, the groundwater levels can vary by half the natural fluctuation before mining operations are considered to influence the groundwater level
[19] Prolonged dry conditions in C025P1 (alluvium bore) will trigger these investigations

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Table 41 includes a reference datum, the average groundwater level data from the baseline monitoring, to allow for the evaluation of groundwater change to the groundwater level thresholds. In doing so the groundwater level thresholds include for half of the natural fluctuation (i.e. the average groundwater can vary up and down by half the recognised natural fluctuation before the potential impacts of approved mining is recognised).

The predicted groundwater level hydrographs and associated groundwater level thresholds are included in **Appendix E**.

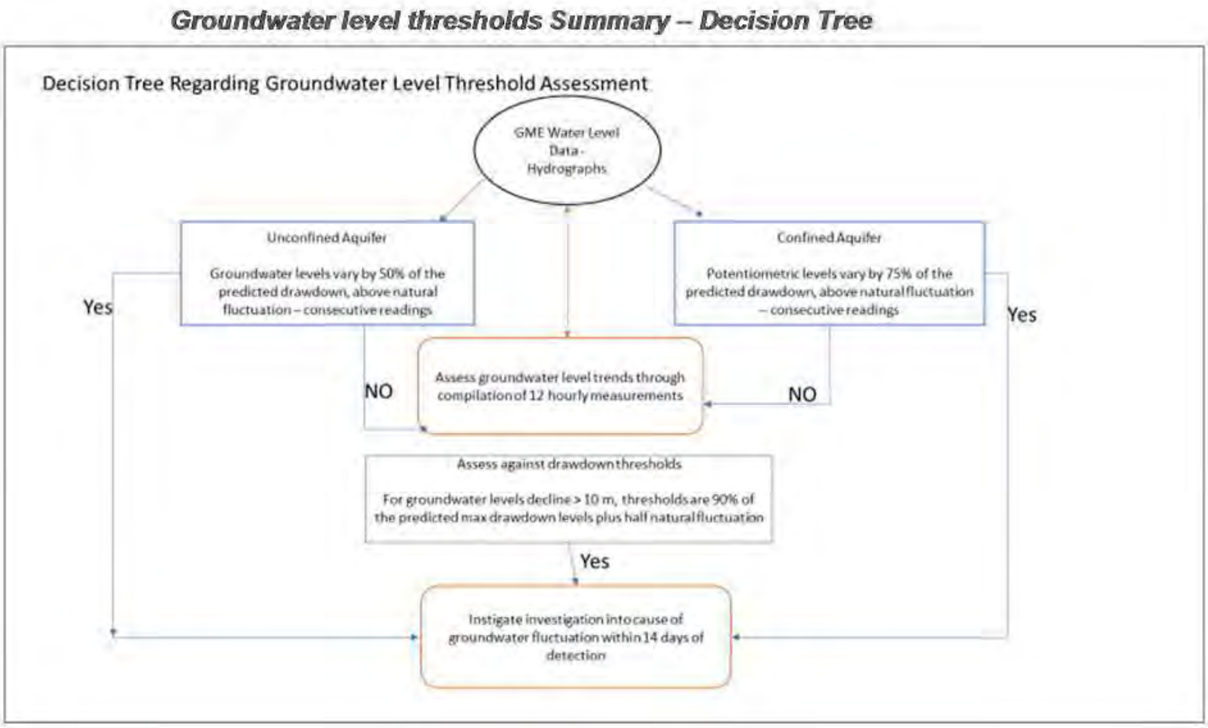

Plate 23 Groundwater level drawdown threshold decision tree

Note: The use of the groundwater level thresholds, including for alluvium along the Carmichael River, included in **Table 43** addresses the EPBC Act approval condition 3 c) for detecting impacts on groundwater levels, which will be finalised and reviewed as per the EA Condition E13 approvals.

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Table 41 Groundwater Level Thresholds Summary

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[20])	Comment / Reference Level
Carmichael River Location						
HD03B	0.004 m	64	1.26 m (47 months)	0.63 m (Prediction plus ½NF)	0.634 m	Predicted drawdown, due to distance from mining and vertical hydraulic conductivity, is limited. The groundwater level threshold is suggested as the prediction plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time). 225.47 mAHD average groundwater level
C027P2	1.11 m	65	0.72 m (66 months)	1.19 m (½NF + 75% of prediction)	1.47 m	Induced flow from GAB unit, Dunda Beds, adjacent to river. 226.90 mAHD average groundwater level
C029P1	0.33 m	50	1.01 m (65 months)	0.67 m (½NF + 50% of prediction)	0.835 m	Induced flow from GAB unit, Dunda Beds, adjacent to river impacting on alluvium. 214.77 mAHD average groundwater level
C029P2	0.42 m	58	0.47 m (35 months)	0.55 m (½NF + 75% of prediction)	0.655 m	Induced flow from Tertiary sediments adjacent to river. 220.00 mAHD average groundwater level
C025P1	1.87 m	59	0.51 m (58 months)	1.19 m (½NF + 50% of prediction)	2.13 m	The hydrograph for this bore indicates this bore is often dry. In addition, this bore is predicted to be impacted by induced flow from alluvium adjacent to river. The groundwater level threshold for this bore

[20] The total change in groundwater level, relative to the average groundwater level (**Appendix E**), comprises the maximum predicted drawdown plus half of the natural fluctuation.

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[20])	Comment / Reference Level
						is considered to relate to the duration of dry measurements within the bore, such that if the bore is consistently dry for 6 continuous months (no response to wet season or show recovery) then an investigation will be triggered. An additional alluvium monitoring bore, installed in deeper saturated alluvium, will be constructed adjacent to C025P1 to assess the groundwater level threshold for this location. 216.72 mAHD (average groundwater level)
C025P2	1.2 m	60	1.20 m (58 months)	1.50 m (½NF + 75% of prediction)	1.80 m	Induced flow from Tertiary sediments adjacent to river. 217.62 mAHD average groundwater level
C14028SP	0.075 m	500	0.31 m (29 months)	0.23 m (Prediction plus ½NF)	0.23 m	Predicted drawdown, due to distance from mining and vertical hydraulic conductivity, is limited. Groundwater level thresholds are suggested for prediction plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time).
C14027SP	0.018 m	500	0.22 m (25 months)	0.13 m (Prediction plus ½NF)	0.13 m	
C14006SP	0.42 m	500	0.94 m (10 months)	0.79 m (½NF + 75% of prediction)	0.89 m	Induced flow from artesian Joe Joe Group unit adjacent to river 226.03 mAHD average groundwater level
Great Artesian Basin to West of Mine Lease						
C180118SP	2.61 m	80	0.23 m (24 months)	2.07 m (½NF + 75% of prediction)	2.73 m	Clematis Sandstone sentinel bore, close to mining lease. 250.17 mAHD average groundwater level

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Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[20])	Comment / Reference Level
C14033SP	0.25 m	500	0.26 m (15 months)	0.32 m (½NF + 75% of prediction)	0.38 m	Clematis Sandstone bore, west of mining lease. 250.62 mAHD average groundwater level
C14011SP	0.62 m	81	0.23 m (22 months)	0.58 m (½NF + 75% of prediction)	0.74 m	Clematis Sandstone bore, west of mining lease. 242.80 mAHD average groundwater level
C14012SP	0.38 m	83	0.23 m (23 months)	0.40 m (½NF + 75% of prediction)	0.50 m	Clematis Sandstone bore, west of mining lease. 242.62 mAHD average groundwater level
C14013SP	0.38 m	82	0.29 m (23 months)	0.43 m (½NF + 75% of prediction)	0.53 m	Clematis Sandstone bore, west of mining lease. 242.49 mAHD average groundwater level
HD02	0.03 m	90	0.46 m (43 months)	0.26 m (Prediction plus ½NF)	0. 26 m	Predicted drawdown, due to distance from mining and vertical hydraulic conductivity, is limited. Groundwater level thresholds are suggested for prediction plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time). HD02 – 234.28 mAHD HD03A – 232.03 mAHD
HD03A	0.18 m	87	1.02 m (44 months)	0.69 m (Prediction plus ½NF)	0.69 m	
C14021SP	1.66 m	500	1.09 m (23 months)	1.37 m (½NF + 50% of prediction)	2.2 m	Unconfined GAB Clematis Sandstone bore. 246.54 mAHD (average manual groundwater level)
C022P1	3.86 m	81	0.42 m (65 months)	3.10 m (½NF + 75% of prediction)	4.07 m	Confined Dunda Beds monitoring bore. 246.66 mAHD average groundwater level
C027P2	1.11 m	65	0.72 m (66 months)	1.19 m (½NF + 75% of prediction)	1.47 m	Induced flow from GAB unit, Dunda Beds. 226.90 mAHD average groundwater level

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Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[20])	Comment / Reference Level
C14023SP	0.32 m	500	0.30 m (29 months)	0.39 m (½NF + 75% of prediction)	0.47 m	Dunda Beds / Rewan Formation contact. 247.26 mAHD average groundwater level
C180117SP	4.83 m	586	0.38 m (29 months)	3.81 m (½NF + 75% of prediction)	5.02 m	Confined bore within GAB Dunda Beds. 251.02 mAHD average groundwater level
C9553P1R	4.5 m	586	0.15 m (35 months)	3.45 m (½NF + 75% of prediction)	4.58 m	Confined bore within Rewan Formation. 252.26 mAHD average groundwater level
C556P1	84.5 m	50	0.58 m (54 months)	76.34 m (½NF + 90% of prediction)	84.79 m	Induced flow from Rewan Formation to depressurised coal 234.84 mAHD average groundwater level
C555P1	73 m	90	0.35 m (35 months)	65.88 m (½NF + 90% of prediction)	73.18 m	Induced flow from Rewan Formation to depressurised coal 231.89 mAHD
Doongmabulla to West of Mine Lease						
HD02	0.03 m	90	0.46 m (44 months)	0.26 m (Prediction plus ½NF)	0.26 m	Groundwater level thresholds are suggested for prediction plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time). HD02 – 234.28 mAHD HD03A – 232.03 mAHD
HD03A	0.18 m	87	1.02 m (44 months)	0.69 m (Prediction plus ½NF)	0.69 m	
C14013SP	0.38 m	82	0.29 m (23 months)	0.43 m (½NF + 75% of prediction)	0.53 m	Clematis Sandstone bore, west of mining lease. 242.49 mAHD average groundwater level
C022P1	3.86 m	81	0.42 m (65 months)	3.10 m (½NF + 75% of prediction)	4.07 m	Confined Dunda Beds monitoring bore. 246.66 mAHD average groundwater level
C14012SP	0.38 m	83	0.23 m (23 months)	0.40 m (½NF + 75% of prediction)	0.50 m	Clematis Sandstone bore, west of mining lease. 242.62 mAHD average groundwater level

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Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[20])	Comment / Reference Level
C14021SP	1.66 m	500	1.09 m (23 months)	1.37 m (½NF + 50% of prediction)	2.2 m	Unconfined GAB Clematis Sandstone bore. 246.54 mAHD (average manual groundwater level)
C14206VWP_1	36 m	84	-	32.4 m (90% of max drawdown predicted)	-	AB Seam. 224.00 mAHD
C558VWP1	143.05 m	586	-	129 m (90% of max drawdown predicted)	-	D seam. 212.00 mAHD
C968VWP_P2	206.2 m	12	-	186 m (90% of max drawdown predicted)	-	D seam. 355.00 mAHD
C968VWP_P5	170.72 m	15	-	154 m (90% of max drawdown predicted)	-	AB seam. 192.80 mAHD
C848SP	127.96 m	586	1.00 m (37 months)	115.70 m (½NF + 90% of prediction)	128.46 m	Bore within target D Seam, southern portion of lease. 231.91 mAHD average groundwater level
Mellaluka Springs to the southeast of Mine Lease						
C851VWP2	136 m	586	-	122.40 m (90% of max drawdown predicted)	-	AB Seam target. 228.70 mAHD
C180120SP	0.02 m	586	2.53 m (29 months)	1.29 m (Prediction plus ½NF)	1.29 m	Predicted drawdown, due to distance from mining and vertical hydraulic conductivity, is limited. Groundwater level thresholds are suggested
C180122SP	0.045 m	586	0.75 m (29 months)	0.42 m (Prediction plus ½NF)	0.42 m	

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Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[20])	Comment / Reference Level
C180119SP	0.045 m	586	0.49 m (22 months)	0.29 m (Prediction plus ½NF)	0.29 m	for prediction plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time).
C180123SP	0.007 m	586	0.67 m (28 months)	0.34 m (Prediction plus ½NF)	0.34 m	
C9180124SPR	0.045 m	586	0.55 m (24 months)	0.32 m (Prediction plus ½NF)	0.32 m	
C9180125SPR	0.02 m	586	1.07 m (25 months)	0.56 m (Prediction plus ½NF)	0.56 m	
Sentinel Bores						
C14016SP	27.23 m	37	2.13 m (21 months)	25.57 m (½NF + 90% of prediction)	28.30 m	Artesian bore in Joe Joe Group on southern lease boundary. 234.13 mAHD
C9845SPR	21.49 m	586	0.28 m (29 months)	19.48 m (½NF + 90% of prediction)	21.63 m	Tertiary sediments bore, south west portion of lease. 234.91 mAHD average groundwater level
C14029SP	1.90 m	500	0.47 m (20 months)	1.66 m (½NF + 75% of prediction)	2.14 m	Artesian bore across Tertiary sediments and Joe Joe Group, east of lease. 251.08 mAHD
C14003SP	0.09 m	500	0.27 m (32 months)	0.23 m (Prediction plus ½NF)	0.23 m	Joe Joe Group. Groundwater level threshold is suggested as prediction plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time). 209.37 mAHD average groundwater level
C14030SP / C914030SPR	1.90 m	500	1.29 m (20 months)	2.07 m (½NF + 75% of prediction)	2.55 m	Confined Joe Joe Group bore to the east of the lease. 230.25 mAHD average groundwater level

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Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Groundwater Level Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[20])	Comment / Reference Level
C14015SP	6.65 m	500	0.55 m (9 months)	5.26 m (½NF + 75% of prediction)	6.93 m	Confined Joe Joe Group bore to the east of the lease near Lignum. 239.15 mAHD average groundwater level
C016P2	159.64 m	14	0.19 m (486 months)	143.77 m (½NF + 90% of prediction)	159.83 m	AB seam north portion of lease. 248.46 mAHD average groundwater level
C14004SP	7.01 m	63	0.52 m (28 months)	5.52 m (½NF + 75% of prediction)	7.27 m	Confined Joe Joe Group bore to the east of the lease near Moray Carmichael road. 209.44 mAHD average groundwater level
C14008SP	1.18 m	500	1.38 m (19 months)	1.58 m (½NF + 75% of prediction)	1.87 m	Joe Joe Group northeast of the mine lease. 228.34 mAHD average groundwater level
C180116SP	16.69 m	586	0.23 m (29 months)	15.14 m (½NF + 90% of prediction)	16.81 m	Confined Rewan Formation bore south / along strike of lease. 239.12 mAHD average groundwater level
C14024SP	2.44 m	500	0.18 m (24 months)	1.92 m (½NF + 75% of prediction)	2.53 m	Confined Clematis Sandstone / Rewan Group bore. 262.71 mAHD average groundwater level
C14020SP	0.157 m	500	0.31 m (31 months)	0.27 m (½NF + 75% of prediction)	0.31 m	Confined Moolayember Formation bore. 252.43 mAHD average groundwater level

Notes:
NF – natural fluctuation

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A summary of the groundwater level thresholds (drawdown), for inclusion in EA Condition E13, is compiled in **Table 42**.

Table 42 Groundwater Level Thresholds - Drawdown (EA Condition E13)

Monitoring Location	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Groundwater Level Threshold Drawdown (m)
Carmichael River Location				
HD03B	Alluvium	427559.00	7556120.00	0.63
C027P2	Dunda Beds	433648.21	7554818.54	1.19
C029P1	Alluvium	437691.19	7555082.39	0.67
C029P2	Tertiary sediments	437687.63	7555080.91	0.55
C025P1	Alluvium	438015.54	7555845.80	6 months dry / no water level readings 1.19 (in a new bore to be installed, in deep alluvium, adjacent to C025P1)
C025P2	Tertiary sediments	438010.34	7555844.69	1.50
C14028SP	Alluvium	443775.64	7559581.18	0.23
C14027SP	Alluvium	444964.65	7558330.02	0.13
C14006SP	Joe Joe Group	443446.61	7556785.07	0.79
Great Artesian Basin to West of Mine Lease				
C180118SP	Clematis Sandstone	423796.76	7568090.93	2.07
C14033SP	Clematis Sandstone	418210.8	7566775.83	0.32
C14011SP	Clematis Sandstone	426130.96	7561454.81	0.58
C14012SP	Clematis Sandstone	424896.07	7560596.18	0.40
C14013SP	Clematis Sandstone	424895.49	7560591.10	0.43
HD02	Clematis Sandstone	423822.04	7557008.25	0.26
HD03A	Clematis Sandstone	427562.00	7556132.00	0.69
C14021SP	Clematis Sandstone	429796.25	7550966.33	1.37
C022P1	Dunda Beds	426812.52	7565961.84	3.10
C027P2	Dunda Beds	433648.21	7554818.54	1.19
C14023SP	Dunda Beds	429801.74	7550968.73	0.39
C180117SP	Dunda Beds	435915.16	7547522.16	3.81
C9553P1R	Rewan Formation	421010.11	7573974.87	3.45
C556P1	Rewan Formation	436524.08	7549881.55	76.34
C555P1	Rewan Formation	432461.38	7557892.99	65.88
Doongmabulla to West of Mine Lease				
HD02	Clematis Sandstone	423822.04	7557008.25	0.26
HD03A	Clematis Sandstone	427562.00	7556132.00	0.69

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Monitoring Location	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Groundwater Level Threshold Drawdown (m)
C14013SP	Clematis Sandstone	424895.49	7560591.10	0.43
C022P1	Dunda Beds	426812.52	7565961.84	3.10
C14012SP	Clematis Sandstone	424896.07	7560596.18	0.40
C14021SP	Clematis Sandstone	429796.76	7550966.33	1.37
C14206VWP_1	AB seam	429783.15	7550956.80	32.4[21]
C558VWP1	D seam	430311.51	7566903.01	129
C968VWP_P2	D seam	424873.59	7570989.17	186
C968VWP_P5	AB seam	424873.59	7570989.17	154
C848SP	D seam	442363.39	7543815.03	115.7
Mellaluka Springs to the southeast of Mine Lease				
C851VWP2	AB Seam	441384.00	7542877.33	122.4
C180120SP	Tertiary sediments / Joe Joe Group	447056.56	7531729.89	1.29
C180122SP	Tertiary sediments / Joe Joe Group	448579.21	7536348.70	0.42
C180119SP	Joe Joe Group	448587.45	7536355.38	0.29
C180123SP	Joe Joe Group	448077.54	7529357.50	0.34
C9180124SPR	Joe Joe Group	448600.00	7536357.00	0.32
C9180125SPR	Joe Joe Group	447039.74	7531738.83	0.56
Sentinel Bores				
C14016SP	Joe Joe Group	444852.34	7541471.06	25.57
C9845SPR	Tertiary sediments	439410.87	7544903.28	19.48
C14029SP	Tertiary sediments / Joe Joe Group	445059.11	7548820.62	1.66
C14003SP	Joe Joe Group	440350.8	7568518.85	0.23
C14030SP	Joe Joe Group	445072.27	7548821	2.07
C14015SP	Joe Joe Group	445301.98	7536138.69	5.26
C016P2	AB seam	422017.38	7574974.58	143.77
C14004SP	Joe Joe Group	440355.93	7568513.34	5.52
C14008SP	Joe Joe Group	444760.74	7552697.83	1.58
C180116SP	Rewan Formation	439392.91	7540908.81	15.14
C14024SP	Clematis Sandstone / Rewan Group	430036.80	7543917.13	1.92
C14020SP	Moolayember	418230.28	7566782.35	0.27

[21] Due to the discrepancies between the total pressure readings, converted to relative groundwater levels, and actual static water level readings in stand pipe monitoring bores in the same unit, an assessment of predicted pressure changes in the VWP have been assessed in key (and suitable) VWPs so as to allow for model validation and dewatering / depressurisation trends. The red VWP triggers are for assessing depressurisation impacts due to mine dewatering only.

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Monitoring Location	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Groundwater Level Threshold Drawdown (m)
	Formation			

5.3.4 Mellaluka Springs Thresholds

Groundwater drawdown predictions in the Mellaluka Springs area, as detailed above, indicate that should the source of the Mellaluka Springs be the Permian aged Colinlea Sandstone (which contains the target coal seams) then the water levels could decrease by 1 to 8 m (depending on the spring). This approach, due to paucity of data during the EIS /SEIS modelling, is considered a "worst-case" scenario.

The latest drilling and conceptualisation of the geology and groundwater resources in the Mellaluka Springs area, detailed in **Section 2.2.6.3**, indicates that the source of the springs in the Mellaluka Springs area are the Tertiary sediments and Joe Joe Group. The drawdown within these footwall units, to the east of the mining, would be markedly less than the target coal seam bearing Colinlea Sandstone. This will be assessed in the next refinement of the groundwater model and as part of the baseline research into the Mellaluka Springs Complex.

The groundwater monitoring bores, with long-term baseline hydrostatic / potentiometric level data, are included in **Table 43**, which also includes the source aquifer and the proposed triggers.

Table 43 Mellaluka Springs area monitoring bores and thresholds

Bore	Unit	Easting	Northing	Average artesian potentiometric level (m above ground level)	Natural Fluctuation (m)	Threshold (m)
C180119SP	Joe Joe Group	448587.45	7536355.38	~14	0.49	0.29
C180123SP	Joe Joe Group	448077.54	7529357.50	~18.5	0.67	0.34
C9180124SPR	Joe Joe Group	448600.00	7536357.00	~11	0.55	0.32
C9180125SPR	Joe Joe Group	447039.74	7531738.83	`19	1.07	0.56
Non-artesian sentinel monitoring bores between the MLs and the Mellaluka Springs Complex**						
C180116SP	Rewan Formation	439392.91	7540908.81	239.12 mAHD	0.23	15.14
C14015SP	Joe Joe Group	445301.98	7536138.69	239.15 mAHD	0.55	5.26

** - These bores indicate the predicted drawdown within the sediments in sentinel bores, which will provide assessment of drawdown predictions before the drawdown extends to the Mellaluka Springs Complex.

Section 3.4 discusses the hydrographs for the groundwater monitoring bores included for threshold assessments, as depicted on **Appendix B** figures. The groundwater level data for these bores, as included in **Table 38**, **Section 5.3.1**, indicates all these bores are artesian, with groundwater levels in excess of 10 m above ground.

It is, therefore, considered that the thresholds (~ 1 m) in these bores would mean that the bores will remain artesian, which reduces the risk of discontinuous flow at the springs occurring, i.e. the thresholds are looking at changes in the potentiometric pressure which will remain artesian.

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These thresholds are considered suitable even for the model predictions, which indicate groundwater level decrease up to 8 m. Based on the artesian groundwater data a decline of 8 m would still allow for the bores to be artesian, such that flow at surface would continue to occur.

5.3.5 Early Warning Triggers and Impact Thresholds for Doongmabulla Springs Complex

With regards to the DoEE Approval (EPBC 2010/5736, dated 14/10/2015), it is noted that the approval includes for the details of groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex, based on groundwater modelling, plus the details of corrective actions and/or mitigation measured to be taken if the triggers are because of mining operations.

The Early warning triggers and Impact thresholds are aimed at ensuring that groundwater drawdown because of the project does not exceed the interim drawdown threshold of 0.2 m at the Doongmabulla Springs Complex.

In addition, the Adani AWL condition 57 required the recommendations for low impact and high impact threshold levels in the Dunda Beds and Clematis Sandstone aquifers, where the Licensee must:

a. provide recommendations for low impact and high impact threshold levels for the Dunda Beds and Clematis Sandstone aquifers
b. include an assessment of natural seasonal variation in the Dunda Beds and Clematis Sandstone aquifers
c. outline the investigation protocol when low impact and high impact threshold levels are exceeded:
    i. including any requirements for additional modelling or monitoring required
    ii. including how impacts attributed to the mining operations will be determined.

The low impact and high impact threshold levels, derived for the AWL conditions, are the same as the Early warning triggers and Impact thresholds required for the Doongmabulla Springs Complex to meet the requirements of EPBC approval condition 3(d). These early warning / low impact groundwater trigger levels allow for the assessment of drawdown during mining before the predicted groundwater drawdown is reached.

To avoid confusion regarding groundwater level thresholds, the following is noted:

- Early warning triggers (EPBC 2010/5736 Approval) are equivalent to the low impact threshold levels (AWL Condition 57) and groundwater level thresholds (included in **Table 41**) as discussed above
- Impact thresholds (EPBC 2010/5736) are equivalent to the high impact threshold levels (AWL Condition 57).

The low and high impact thresholds for monitoring bores within the GAB units containing the Doongmabulla Springs Complex (Dunda Beds and Clematis Sandstone) have been selected based on the groundwater model predictions, which have been used to assess potential mining impacts during the approvals process.

Compliance with Approvals

It is noted that the groundwater level variations to be monitored as verification / assessment of potential impact to groundwater resources adjacent to the mine lease have been assessed and thresholds compiled in line with the relevant requirements of the environmental authority under the *Environmental Protection Act 1994 Queensland* in particular the requirements included in Appendix 1, Section 1, Schedule E of the Coordinator-General's Assessment Report.

5.3.5.1 Early Warning Triggers and Impact Thresholds

Based on the assessment of natural fluctuations in groundwater levels, both unconfined and confined aquifers, and the model predictions, Early warning triggers and Impact thresholds have been compiled for the Clematis Sandstone and Dunda Beds.

The aim of the Early Warning triggers and Impact thresholds is to provide early warning regarding the predicted induced flow from the GAB units, the Clematis Sandstone and the Dunda Beds, towards the dewatered / depressurised coal seams targeted during mining.

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The Early warning triggers and Impact thresholds also aim at validating induce flow predictions, confirming water take from the GAB units, validating predicted groundwater level drawdown, and ensuring drawdown does not exceed 0.2 m (interim drawdown threshold) at the Doongmabulla Springs Complex.

The predicted induced flow impacts are recognised to be below the natural fluctuation, resulting in these bores having Early warning triggers (Groundwater Level thresholds in **Table 41**) proposed to be the maximum predicted drawdown (plus half of the natural fluctuation to allow for the assessment of groundwater levels over time against the reference average groundwater level). Thus, the groundwater level thresholds for these bores are the same as the Early warning triggers.

Early Warning Triggers

The Early warning triggers have been selected based on the possible change in groundwater levels beyond the recorded natural groundwater level fluctuations (as included in **Table 45** below). The assessment of groundwater level data, compiled during mining operations, will allow for the evaluation of groundwater level trends. The Early warning triggers proposed for the CCP are as follows:

- If groundwater levels vary by 50% than those recorded for the natural fluctuation in the unconfined Clematis Sandstone bore, C14021SP[22]
- If groundwater levels / potentiometric levels vary by 75% than those recorded for the natural fluctuation in the confined Clematis Sandstone and Dunda Beds bores[23]

Should groundwater level monitoring indicate variations in groundwater levels by more than 50% (unconfined) or 75% (confined) groundwater level fluctuations on two consecutive groundwater monitoring events then the following will occur:

- Notify the regulator within 30 days as per condition 59 of the Associated Water Licence
- Assess the cause of the groundwater level fluctuation considering:
  - dry / drought conditions
  - groundwater extraction from neighbouring user(s)
  - groundwater level trends in multiple bores within the same unit
  - long term recharge / discharge trends
  - mining operations and dewatering volumes.

A report into the investigation will be made available to the regulator on request with findings and recommendations.

Commitments

If the investigation identifies the cause of an exceedance of the Early warning trigger(s) is due to approved mining operations, Adani will (in addition to the commitments included in **Section 4.7.2.2**):

- Install additional monitoring bores in GAB aquifers and Permian aquifers
- Undertake more frequent monitoring of health of GDEs.

Impact Thresholds

[22] Where groundwater level fluctuations are measured to be in excess of the reference natural fluctuations by 50% or more in the unconfined aquifers

[23] Where groundwater level fluctuations are measured to be in excess of the reference natural fluctuations by 75% or more in the confined aquifers

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The Impact thresholds have been selected based on the groundwater model predictions, which have been used to assess potential mining impacts during the approvals process. The use of Impact thresholds will:

- Allow for the assessment of drawdown so it does not exceed the maximum predicted drawdown
- Validate predictive modelling
- Allow for the assessment of decline trends through the compilation of groundwater level hydrographs, to be updated after each groundwater monitoring event. This will allow for the evaluation of the rate of groundwater level decline as well as the actual drawdown
- Implementation of a rate of groundwater level decline trigger, as well as the groundwater level Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex. This is to ensure the drawdown does not exceed the interim drawdown threshold of 0.2 m at the Doongmabulla Springs Complex.

The Impact thresholds are defined as the following:

- 90% of the predicted maximum drawdown levels, as included in **Table 45**
- Timing of groundwater level drawdown, such that if groundwater levels start to decline before the predicted impacts (as shown in **Plate 14** to **Plate 22**)
- An investigation will be instigated if the rate of groundwater level decline change exceeds the rate of groundwater level decline trigger in key hydrostratigraphic units (**Section 5.3.5.2**).

5.3.5.2 Rate of Groundwater Level Decline

The large mine footprint, long life of mine, and transient nature of the mine plan it is recognised that potential indirect impacts on groundwater resources above the target coal seams, particularly the GAB units, are predicted to be less than natural fluctuation and will only occur after a considerable period of time. This reduced indirect impact is related to the nature of the aquitards between the target coal seams and the GAB units.

In order to allow for a regular assessment of groundwater level decline compared to predictions plus the validation of the aquitard nature of the Rewan Formation between the target coal seams and the GAB units, a rate of groundwater level decline trigger is recommended. This trigger will allow for the evaluation of the aquitard nature and regular assessment of the potential for induced flow.

The rate of decline will be assessed against bores in the Rewan Formation and Dunda Beds, where drawdown is measurable (above natural fluctuation) and is predicted to occur in the early part of mining. The bores are located between the mine workings and the DSC. The selected bores in the Rewan Formation and the Dunda Beds are compared to the Clematis Sandstone bore (C180118SP) which is located adjacent to the western boundary of the MLs. **Figure 24** and **Figure 25** shows the groundwater level hydrograph of the selected decline rate assessment bores.

Note: the hydrograph indicates the maximum predicted drawdown will occur within 100 years and then groundwater level recovery or a pseudo-steady post mining groundwater level will be reached.

To allow for regular assessment of the groundwater level change in the Rewan Formation and Dunda Beds bores, it is planned that the groundwater level hydrographs (updated after every groundwater monitoring event) will be compared to the predicted drawdown from the modelling. The assessment will coincide with the review of the GMMP and groundwater model, that is within 2 years after the box cut excavation and then every 5 years. The predicted change in groundwater levels at these intervals and the proposed interim decline rate triggers are included in **Table 45**.

Allowing for uncertainty in the model and possible water level measurement errors, the drawdown at the regular review periods is not to exceed 20% of the drawdown when predicted drawdown is less than 1m, and not to exceed 10% when predicted drawdown is greater than 1 m.

As the proposed threshold values are reliant on predictions from the numerical groundwater model, to be updated within two years of the box cut excavation then every five years subsequently, Adani will compare the actual measured groundwater level data to predicted drawdown to assess the rate of change. In the instance the drawdown rate of the actual data is steeper/ faster than the predicted rate,

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an investigation will be commenced into the cause of the drawdown rate change (see **Section 4.7.2.2**).

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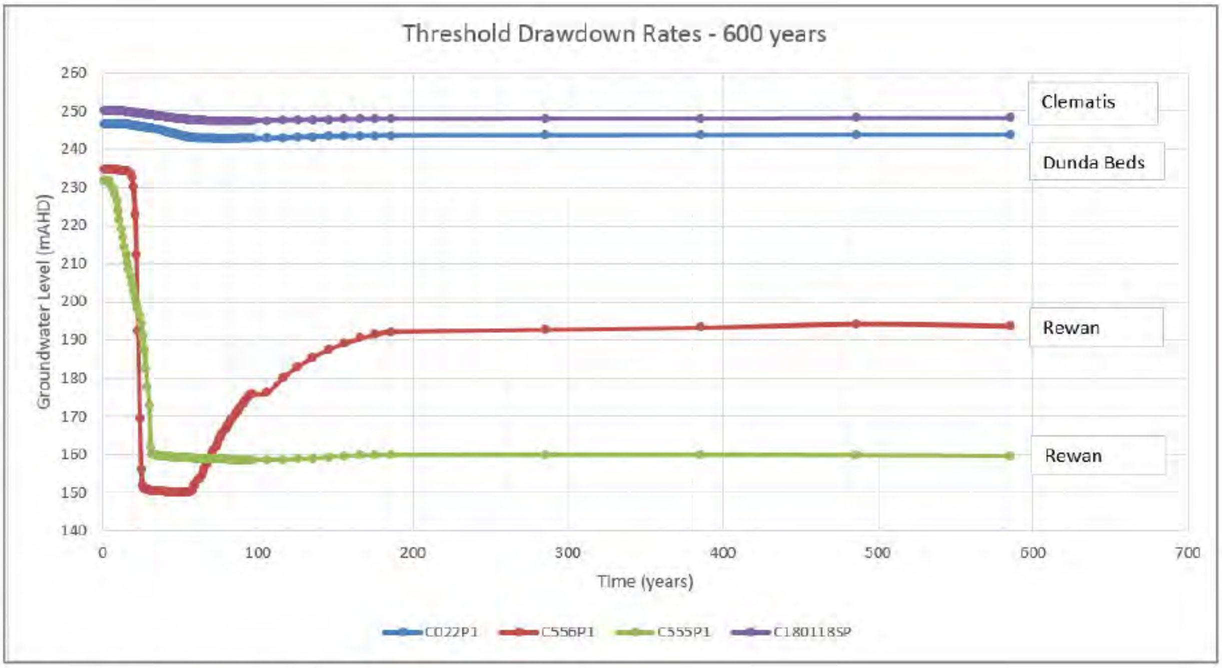

Figure 24 Selected bores for decline rate assessment

The rate of change predicted in the model, for the first 20 years, is included in **Figure 25.**

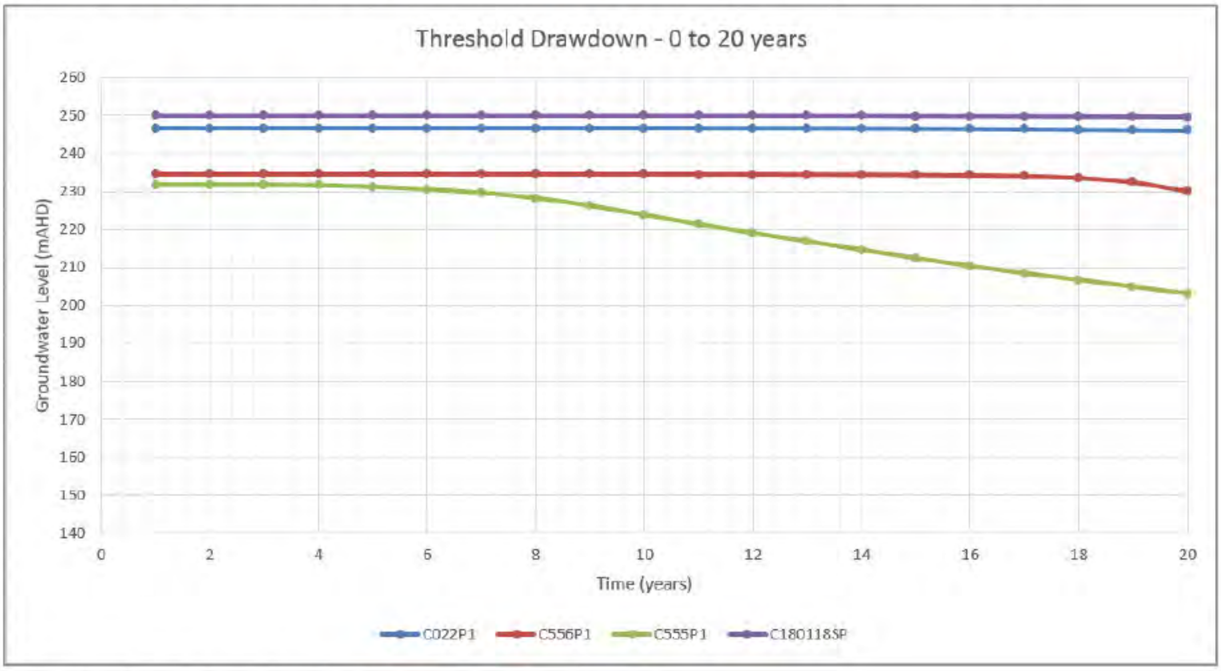

Figure 25 Selected bores for decline rate assessment – 20 years

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Table 44 Interim drawdown rate triggers

Mine Years / Period of Drawdown	Hydrostratigraphic unit	Predicted drawdown (m below average groundwater level)	Drawdown rate trigger (m below average groundwater level)
C022P1			
0 - 2	Dunda Beds	0	0
3 - 7		0	0.01 (0.002 m/year)
8 - 12		0.015	0.018 (0.004 m/year)
13 -17		0.18	0.22 (0.044 m/year)
18 - 22		0.48	0.58 (0.12 m/year)
C555P1			
0 - 2	Rewan Formation	0	0
3 - 7		2.17	2.4 (0.48 m/year)
8 - 12		12.75	14 (2.8 m/year)
13 -17		23.31	26 (5 m/year)
18 - 22		32.11	35 (7 m/year)
C556P1			
0 - 2	Rewan Formation	0	0
3 - 7		0	0.01 (0.002 m/year)
8 - 12		0.03	0.04 (0.008 m/year)
13 -17		0.5	0.6 (0.12 m/year)
18 - 22		22.33	24.6 (5 m/year)

It is considered that the drawdown rate trigger can be assessed after 22 years to determine ongoing assessment criteria for the rate of decline. It is noted that the model will be revised / refined over time and that groundwater level drawdown predictions will be projected during the regular model updates.

5.3.5.3 Impact Thresholds and Exceedance

Should any or all the proposed Impact thresholds be realised and attributed to CCP activities, through the assessment of groundwater monitoring data and comparison to model predictions, then an appropriately qualified person will complete an investigation and will provide a written report to the regulator within 60 days.

The investigation will also perform refinement and re-run of predictive model if required along with increased monitoring through additional bores and evaluation of induced flow due to mining impacts. If the investigation concludes that the exceedance of Impact thresholds is a result of mining activities, then the following will occur (**Plate 24** provides a decision tree in the event an investigation is instigated due to exceedance of Impact thresholds):

- Review of the latest numerical groundwater model and estimate the predicted take of water from the Dunda Beds and/or the Clematis Sandstone hydrostratigraphic units for the balance term of the project. The take is to consider for the approved level of impact, which currently (interim) limits the drawdown to 0.2 m at the Doongmabulla Spring Complex
- Review of the mine plan including sequencing of mining

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- Review of the GMMP (outside of the regulated frequency as required)[24]
- Implement of recommendations /outcomes of the GABSRP for the management, prevention and remediation of impacts on Doongmabulla Springs Complex.

Table 45 presents a summary of the selected Early warning triggers and Impact thresholds for the selected GAB monitoring bores in the Doongmabulla Springs Complex area, plus a summary of the selection criteria.

The reference levels for assessing the thresholds are included in **Table 41**. **Appendix E** includes the individual hydrographs with the projected changes in groundwater levels, as predicted in the groundwater modelling, plus the Early warning triggers and Impact thresholds.

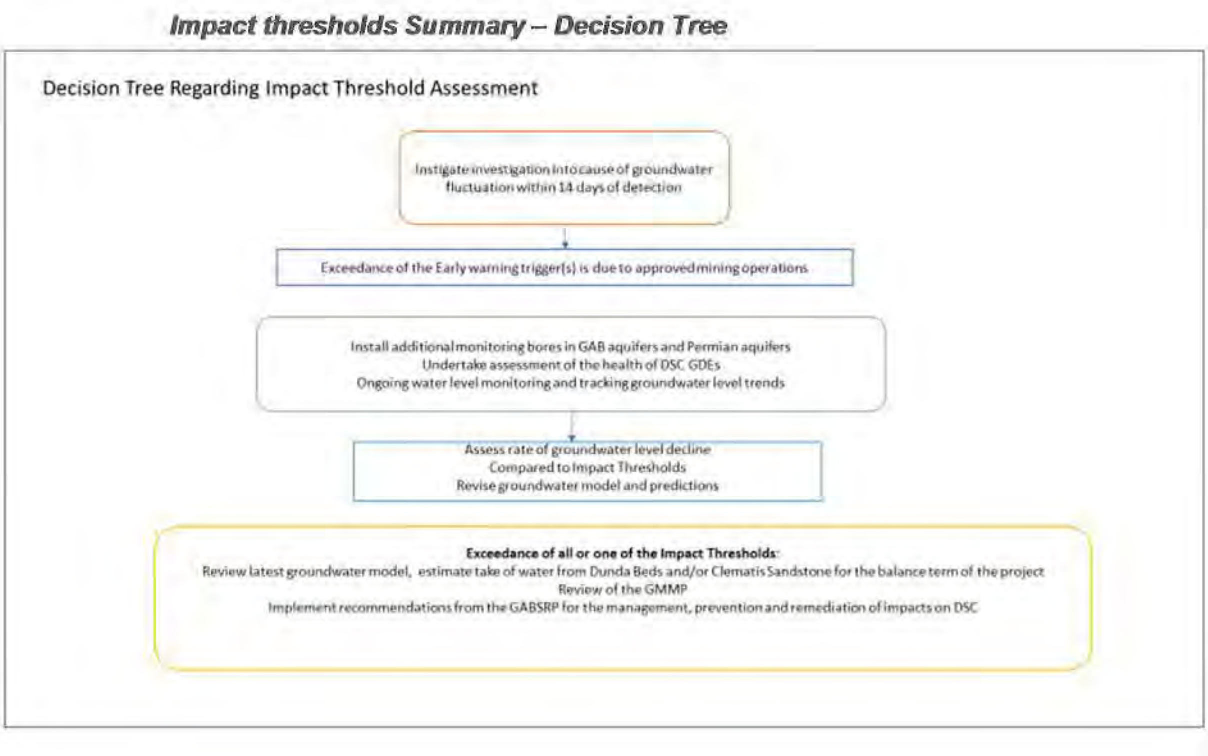

Plate 24 Impact thresholds exceedance decision tree

[24] It is noted that the AWL requires a review of the Underground Water Monitoring Program, which is recognised to be equivalent to the GMMP

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Table 45 Early warning triggers and Impact thresholds for the Doongmabulla Springs Complex

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Early Warning Level (criteria)	(High) Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions)	Comment
Clematis Sandstone							
HD02	0.03 m	90	0.46 m (44 months)	0.25 m (90% Prediction plus ½NF)	0.26 m (Prediction plus ½NF)	0.26 m	Early warning triggers are suggested as 90% of predicted drawdown plus half of the natural fluctuations (for comparison to the average groundwater level reference level over time).
HD03A	0.18 m	87	1.02 m (44 months)	0.67 m (90% Prediction plus ½NF)	0.69 m (Prediction plus ½NF)	0.69 m	
C180118SP	2.61 m	80	0.23 m (245 months)	2.07 m (½NF + 75% of prediction)	2.46 m (½NF + 90% of prediction)	2.73 m	Clematis Sandstone sentinel bore, close to mining lease.
C14021SP	1.66 m	500	1.09 m (23 months)	1.37 m (½NF + 50% of prediction)	2.03 m (½NF + 90% of prediction)	2.20 m	Unconfined GAB Clematis Sandstone bore.
C14033SP	0.25 m	500	0.26 m (15 months)	0.32 m (½NF + 75% of prediction)	0.36 m (½NF + 90% of prediction)	0.38 m	Clematis Sandstone bore, west of mining lease.
C14011SP	0.62 m	81	0.23 m (22 months)	0.58 m (½NF + 75% of prediction)	0.67 m (½NF + 90% of prediction)	0.74 m	Clematis Sandstone bore, west of mining lease

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Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Early Warning Level (criteria)	(High) Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions)	Comment
C14012SP	0.38 m	83	0.23 m (23 months)	0.40 m (½NF + 75% of prediction)	0.46 m (½NF + 90% of prediction)	0.50 m	Clematis Sandstone bore, west of mining lease. 90% of predicted drawdown is less than the low threshold, suggests NF + 90% as high threshold value.
C14013SP	0.38 m	82	0.29 m (23 months)	0.43 m (½NF + 75% of prediction)	0.49 m (½NF + 90% of prediction)	0.53 m	Clematis Sandstone bore, west of mining lease.
Dunda Beds							
C022P1	3.86 m	81	0.42 m (65 months)	3.10 m (½NF + 75% of prediction)	3.68 m (½NF + 90% of prediction)	4.07 m	Confined Dunda Beds monitoring bore.
C027P2	1.11 m	65	0.72 m (66 months)	1.19 m (½NF + 75% of prediction)	1.36 m (½NF + 90% of prediction)	1.47 m	Induced flow from GAB unit, Dunda Beds.
C14023SP	0.32 m	500	0.30 m (29 months)	0.39 m (½NF + 75% of prediction)	0.44 m (½NF + 90% of prediction)	0.47 m	Dunda Beds / Rewan Formation contact.
C180117SP	4.83 m	586	0.38 m (29 months)	3.81 m (½NF + 75% of prediction)	4.54 m (½NF + 90% of prediction)	5.02 m	Confined bore within GAB Dunda Beds

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5.4 Development of Quality Triggers

5.4.1 Conceptualisation Regarding Groundwater Quality Alteration

During mining operations, groundwater quality within aquifers surrounding the site is not expected to change from pre-mining conditions. This would be a result of all CCP water and waste storage facilities infrastructure being designed, constructed, and managed to ensure little or no potential of seepage.

If groundwater contamination did occur contaminant migration off site in the groundwater will not occur. Any potential contaminant plumes would not leave site in the groundwater as during mining operations, groundwater will be continually extracted from bores or sumps in the underground workings to ensure a safe working environment. This abstraction of groundwater will create a depression in the potentiometric surface around the workings such that the net movement of groundwater is towards the workings during mine operation. This drawdown and alteration in groundwater flow effectively limits the potential for contaminant plumes to migrate off site via groundwater. However in case of mine-affected water storage dams, tailings storage facilities, and overburden storage areas there is a potential for the contaminants to migrate off site through seepage via shallow alluvium / Tertiary formations. Adani will install additional monitoring bores located up and down gradient of potential sources of contamination (e.g. mine infrastructure, waste dumps, and tailings facilities) to monitor for seepage from these surficial storage areas.

Upon finalisation of the footprints for these surficial storage areas, the seepage monitoring bores will be installed six months before construction of the infrastructure and monitored for groundwater quality (when there is sufficient water in the bores). In the instance quality data can be procured, it will be used to identify potential impacts in the form of seepage to groundwater by comparison of monitoring data from construction and operation stages to the pre-construction data.

Groundwater quality away from the influence of the mine dewatering will not deteriorate as these resources will continue to receive recharge via the same processes that occurred pre-mining.

Groundwater quality data (with respect to major anions and cations and dissolved metals) indicate that groundwater in the Clematis Sandstone, Dunda Beds, and Rewan Formation similar or better quality when compared to the Permian coal seam aquifers. Hence, any inadvertent mixing of groundwater during and post mining by induced downward movement from the upper to lower aquifers is unlikely to result in a deterioration of groundwater quality in the Permian aquifers.

The Tertiary sediments are recognised to have elevated dissolved solids, compared to the coal seams. Induced flow in areas where Tertiary sediments directly overlies the coal seams can result in marked water quality changes within the mine.

Groundwater monitoring (see **Section 6.2** Operational GMMP) network and triggers, allow for the assessment of the possible blending / alteration of groundwater due to dewatering.

5.4.2 Quality Triggers

The groundwater monitoring program (monitoring points and hydrostratigraphic units) compiled for collecting data prior to being disturbed by mining activities is included in **Table 46** below. The bores in **Table 46** were selected for the compilation of groundwater quality, in hydraulically isolated groundwater monitoring bores, which (after review of hydrochemical data (**Section 5.4.3.2**) allowed for the development of groundwater quality triggers.

Table 46 is recognised to be compliant with the requirements of EA Condition E9 Table E1 (**Appendix A**). **Appendix B** presents the location of these bores.

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Table 46 Baseline Groundwater Monitoring Network Bores

Monitoring Point	Location		Surface Elevation (mAHD)
	Easting (GDA94-Zone 55)	Nothing (GDA94-Zone 55)	
Alluvium			
C027P1	433643.08	7554818.39	226.95
C029P1	437691.19	7555082.39	225.438
HD03B	427559.00	7556120.00	229.41
C14028SP	443775.64	7559581.18	218.86
Tertiary Sediments			
C025P2	438010.34	7555844.69	227.48
C029P2	437687.63	7555080.91	225.37
C558P1	430311.55	7566903.06	250.07
C9180121SPR	448085.12	7529363.93	226.46
C9845SPR	439410.87	7544903.28	255.41
Clematis Sandstone			
C180118SP[25]	423796.76	7568090.93	306.63
C14021SP	429796.76	7550966.33	277.59
C14033SP	418210.22	7566775.83	296.47
C14011SP	426130.96	7561454.81	311.66
C14012SP	424896.07	7560596.18	286.37
C14013SP	424895.49	7560591.10	286.46
HD02	423822.04	7557008.25	236.353
HD03A	427562.00	7556132.00	229.41
Dunda Beds			
C022P1	426812.52	7565961.84	273.76
C027P2	433648.21	7554818.54	227.58
C180117SP	435915.16	7547522.16	279.59
Rewan Formation			
C008P1	433712.50	7558833.75	238.14
C035P1	441403.59	7546823.81	236.31
C555P1	432461.38	7557892.99	241.15
C556P1	436524.08	7549881.55	260.63
C9553P1R	421010.11	7573974.87	294.114
C9838SPR	439557.91	7552811.73	228.81
Bandanna Formation (AB Seam)			
C007P2	434728.01	7559861.98	238.11
C008P2	433710.27	7558830.28	238.12

[25] Blocked bore to be replaced

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Monitoring Point	Location		Surface Elevation (mAHD)
	Easting (GDA94-Zone 55)	Nothing (GDA94-Zone 55)	
C014P2	430731.00	7563976.07	255.99
C016P2	422017.38	7574974.58	294.45
C020P2	427845.47	7566931.73	263.06
C032P2	439404.36	7544896.02	256.32
C035P2	441401.68	7546827.75	236.24
Colinlea Sandstone (D Seam)			
C006P3r	435727.00	7560835.00	233.86
C007P3	434726.28	7559864.39	237.99
C011P3	428845.58	7569954.89	254.54
C018P3	423977.57	7574853.06	281.36
C024P3	428909.10	7571761.09	258.62
C034P3	442388.72	7547813.99	227.38
C180114SP	438684.80	7557646.88	224.92
C833SP	439559.68	7554777.43	223.30
C848SP	442363.39	7543815.03	237.03
C9849SPR	442383.73	7543808.29	236.69
Joe Joe Group			
C012P1	430887.52	7569874.40	247.333
C012P2	430887.34	7569876.76	247.252
C180119SP	448587.45	7536355.38	223.13
C9180124SPR	448600.00	7536357.00	223.19
C9180125SPR	447039.74	7531738.83	222.50
C180123SP	448077.54	7529357.50	226.47
C914001SPR	441973.49	7561149.58	226.146
C14014SP	448343.76	7533407.48	221.05
C14008SP	444760.74	7552697.83	219.54
C14017SP	447525.30	7526907.00	229.228
C14006SP	443446.61	7556785.07	218.98
C14016SP	444852.34	7541471.06	221.75
C14003SP	440350.80	7568518.85	217.967
C14015SP	445301.98	7536138.69	228.22

Notes: * - Reference Levels are the top of casing / measurement point for each monitoring point.

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5.4.3 Baseline Trigger Levels

Groundwater quality trigger levels have been proposed based on a statistical analysis of the baseline data (**Appendix D**), as per the requirements of EA Condition E9 Table E2 (**Appendix A**). The trigger levels are based on the 85th percentile of the background data.

As per Condition E8 of the EA, Adani must establish a groundwater monitoring network for detecting potential impacts of the mine operations on groundwater quality.

5.4.3.1 Approach

Adani has been undertaking groundwater monitoring during various stages in the Project's approvals process. The compiled dataset used for assigning the trigger values includes groundwater monitoring data, collected by multiple entities, from the following timeframes and project stages:

1. September and October 2011 (GHD): for the purposes of the EIS and associated numerical predictive groundwater model
2. May 2013 (GHD): for the purposes of the SEIS and update assessments based on the revised Mine Plan
3. April and May 2014 (4T Consultants Pty Ltd): for the purposes of baseline groundwater monitoring, under Condition E3 of EA
4. June 2014 – April 2017 (NRC): for the purposes of baseline groundwater monitoring under Condition E3 of EA.

It is recognised that not all monitoring bores were utilised to collect groundwater (hydrochemistry) analyses. Bores were selected for groundwater quality monitoring, per unit, based on the spatial distribution (along strike and down-dip) of the bores across the CCP. That is, a number of bores per hydrostratigraphic unit were identified for groundwater quality analyses, and subsequent trigger level development, to represent the hydrostratigraphic units (EA conditions, as included in **Section 5.4.3.2**) across the MLs.

5.4.3.2 Trigger Level Methodology

In order to populate Table E2, EA Condition E9, the baseline data was interrogated and assessed through an iterative process and correspondence with the Queensland Department of Environment and Science (DES) regarding the proposed trigger levels for the Carmichael Coal Project (CCP) Groundwater Management and Monitoring Program (GMMP) as detailed in documents included in **Appendix A.**

The assessment of hydrochemistry allowed for the development of groundwater quality triggers (trigger levels) for the hydrostratigraphic units included in the EA conditions, including:

- Alluvium
- Tertiary Sediments
- Clematis Sandstone
- Dunda Beds
- Rewan Formation
- Bandanna Formation (AB Seam)
- Colinlea Sandstone (D Seam)
- Joe Joe Group.

AECOM developed a methodology for assessing groundwater quality data (suitability for use) and to assign trigger levels for the different groundwater quality parameters in each hydrostratigraphic unit with consideration to comments from DES (formerly DEHP).

5.4.3.2.1 Summary of Methodology

The methodology adopted for assigning the initial proposed trigger levels, following extensive consultation and agreement between Adani and DES is outlined in **Table 47** below. The methodology

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represents the development of several approaches aimed at identifying triggers that will reduce the potential impact to groundwater quality. The approach is outlined below.

Table 47 Proposed Trigger Level Methodology

Step	Aim	Approach
1	Establish baseline groundwater information.	Baseline monitoring program (2014-2016)
		Historic and continuing monitoring (2011-present)
2	Assign groundwater to hydrostratigraphic units and / or subdivide into bore-specific baseline groundwater.	Compare time series plots of all analytes to look for similarities/variations in groundwater from bores in each hydrostratigraphic unit.
		Compare bore groundwater major ions to determine groundwater types (e.g,. Piper plots) and identify key differences within hydrostratigraphic units (if present). Bores assessed to potentially represent different water types within a hydrostratigraphic unit are separated and bore-specific triggers are calculated for these.
3	Identify and remove outliers.	Plot groundwater data as time series for all analytes in each hydrostratigraphic unit and visually compare outputs, noting obvious outliers.
		Refer data entries to field notes and laboratory Certificates of Analysis (CoA) to provide information on whether visual outliers represent true outliers or natural variations.
		Use major ion and total dissolved solids (TDS) box and whisker plots for each hydrostratigraphic unit and/or bore-specific units to identify data outliers
		Remove values that are beyond the mean + 4xSD for each analyte in each hydrostratigraphic unit/bore specific groundwater.
4	Calculate trigger values.	Calculate 85th percentiles for all hydrostratigraphic (and/or bore-specific) units with at least eight (8) results greater than the laboratory limit of report (LOR).
		Where there are less than eight results per analyte per hydrostratigraphic (and/or bore-specific) unit greater than the LOR, the ANZG 2018 guidelines (formerly ANZECC & ARMCANZ 2000 [ANZECC 2000] guidelines 95th protection (freshwater) trigger value from Table 3.4.1) of the guideline should be adopted.
		Where there is no 95th protection (freshwater) trigger value, and less than eight results above LOR, the low reliability (freshwater) trigger values from Section 8.3.7 of the ANZG 2018 guidelines (formerly ANZECC & ARMCANZ 2000 guidelines [ANZECC, 2000]) should be adopted.
		All trigger levels derived from the baseline monitoring program (at least eight results greater than LOR) are compared to the ANZG 2018 guidelines (formerly ANZECC & ARMCANZ 2000 guidelines [ANZECC, 2000]) guideline values per analyte (95th protection and low reliability). In instances where the ANZG 2018 guideline value is higher, this ANZG value should be adopted as the proposed trigger level.
5	Additional data quality steps.	Certain trigger values have been revised, based on agreement between DES and Adani, to provide additional levels of conservatism and the potential for a greater level of environmental protection. This has involved additional passes to remove potential individual analyte outliers.
		A 'consecutive exceedances' approach has been taken to validate the groundwater quality monitoring results. This approach requires two consecutive groundwater quality analytical results to be reported above a

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Step	Aim	Approach
		given parameter trigger value prior to the commencement of any investigations into the exceedance; a single trigger exceedance will not be cause for investigations into groundwater quality results.
		Consecutive sampling relates to two consecutive groundwater monitoring events, some two or three months apart.
		There remain some parameters, with no published guideline value, with reported concentrations above LOR, but less than eight. Where appropriate, a value has been be derived from all relevant data, which may include WQOs from the Burdekin, Don and Haughton River Basins (DEHP, 2017).

5.4.3.2.2 Initial Proposed Trigger Levels

Trigger levels were proposed for each hydrostratigraphic unit as required in the Environmental Approval (EA) dated 5 June 2017. Initially, trigger levels were calculated from the baseline groundwater quality dataset, which included monitoring from 2014 through to 2016. The approach adopted for management and application of analyte concentrations not detected above the laboratory's limit of reporting (LOR) was to apply an industry-standard approach for analytes with which was to apply half of the LOR value (e.g., where the resultant concentration for an analyte was <50 µg/L, a value of 25 µg/L was applied in the trigger level calculation.

After review and assessment of the results, it was decided that it would be more accurate and representative of site conditions to calculate the 85th percentile trigger levels for analytes with at least 50% of the results were reported above the LOR. For analytes with less than 50% of resultant concentrations reported above the LOR for analytes, the National Environment Protection Council (NEPC) National Environment Protection Measure (NEPM) groundwater investigation levels (GILs) for freshwater were adopted, where available. The NEPM guideline values were considered appropriate to supplement site-specific trigger levels as the objective of the NEPM is to provide adequate protection of human health and the environment where site contamination has occurred.

This approach was based on Adani's understanding that the objective of the trigger levels is to protect human health and the environment from contamination because of the approved mining activities; therefore, application of the NEPM was adopted to supplement site –specific trigger levels.

Where a freshwater GIL was not provided in the guideline, the more conservative drinking water GILs and/or marine water GILs were adopted, depending on the water quality of the hydrostratigraphic unit (salinity concentrations). The proposed trigger levels resultant of this methodology were included in the draft GMMP and submitted to DES for approval.

5.4.3.2.3 Associated Water Licence (AWL) and Resultant Augmentation of the Dataset

As a component of the AWL data request by the Department of Natural Resources and Mines (now the Department of Natural Resources, Mines, and Environment [DNRME]), the comprehensive groundwater quality dataset was provided which included data from the EIS and post-EIS monitoring (from 2011 - 2016).

Adani had been undertaking additional groundwater monitoring (events in 2016 - 2017) since the completion of the formal baseline groundwater monitoring program (12 events over two years, 2014 - 2016); DNRME then requested this additional data be incorporated into the baseline groundwater dataset (now incorporates all groundwater quality data from 2011 through April 2017).

This expanded dataset was utilised to recalculate the proposed 85th percentile trigger levels (for analytes with 50% of results above the LOR).

5.4.3.2.4 Further Development of Trigger Levels and Groundwater Chemistry

Trigger Levels

As a development of the above approach, and following the draft GMMP review, it was advised that trigger levels for each analyte (per hydrostratigraphic unit) should be calculated when at least eight (8) concentrations were reported above the LOR and that eight results is considered sufficient and statistically representative of the groundwater quality regardless of the total number of samples analysed, as outlined in the Department of Science, Information Technology and Innovation (DSITI) groundwater guideline *Using monitoring data to assess groundwater quality and potential environmental impacts* (2017), to calculate site-specific limits (DES, November / December 2017 review of the draft GMMP).

In addition, it was recommended that the 85th percentile trigger levels should be compared to the ANZG 2018 guidelines (formerly ANZECC & ARMCANZ 2000 aquatic ecosystem guideline) values and the least stringent of the two values be applied. In instances where less than eight results were above the LOR in the baseline groundwater dataset, the ANZG 2018 aquatic ecosystem guideline values and the low reliability freshwater trigger levels should be applied (DES, November 2017).

Groundwater Chemistry

To take into account potential variations in concentrations and proposed trigger levels (85th percentiles) between bores within the hydrostratigraphic units, it was advised that 'a characterisation of the water quality within each bore should be undertaken to determine if groundwater bores can be grouped together' (DES, November 2017). This involved preparation of piper plots of the groundwater chemistry to classify and compare water quality types based on the ionic composition of different groundwater samples. Additionally, box plots for each bore within an aquifer group for each parameter were assessed to provide a visualisation of differences in water quality between bores.

The methodology to calculate trigger levels for each hydrostratigraphic unit specified in the EA, inclusive of non-detected concentrations, implemented by Adani was a staged approach, as outlined below.

1. Compiled all like analytes in the comprehensive dataset (2011 - 2017) for aquifer monitoring suitability analysis (carbonate, fluoride, etc.)
2. Prepared piper (trilinear) diagrams per hydrostratigraphic unit
3. Assessment of trilinear diagrams to identify potential data outliers and/or monitoring well outliers (from the overall hydrostratigraphic unit)
4. Prepared box and whisker plots per hydrostratigraphic unit to assess major ions and total dissolved solids (TDS) as a representative analyte to identify data outliers:
    a. Median and mean values per well per unit were identified

       NOTE: The box plots summarise the data distribution, displaying the median, interquartile range (IQR), skewness, and potential outlier values. Box plots were constructed as follows: a box is drawn from the 25th percentile (Q1) to the 75th percentile (Q3). The distance between the upper Q3 and lower Q1 lines of the box is equal to the IQR (Q3-Q1). The median (Q2) of the data falls between Q1 and Q3 and is depicted as a line within the interior of the box. The average or mean value were determined and included. The error bars (called whiskers) represents data points farthest from the box but within the maximum or minimum point within that range. Potential outliers (depicted as 'closed circle' symbol) are those that are three (3) times the IQR from Q1 or Q3.

    b. Outliers were then identified using the box and whisker plots (3 x IQR or more below the first quartile or above the third quartile) to be removed from dataset, per **Plate 25** below:

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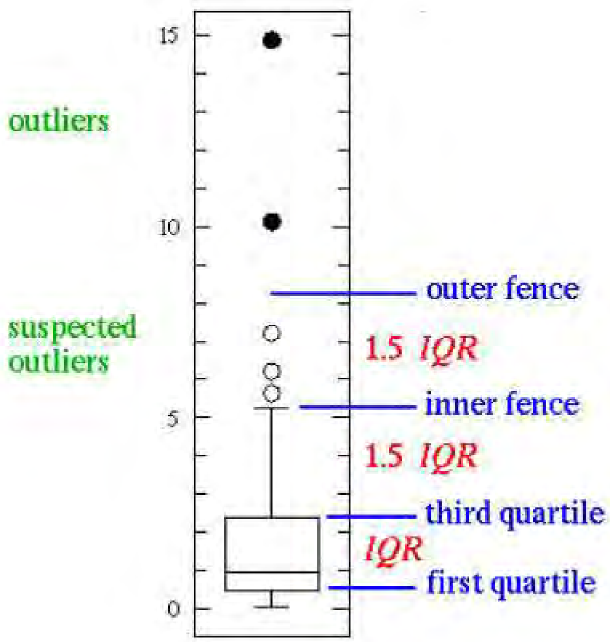

Plate 25 Outlier Identification Methodology

5. Outliers (bores or single sample results) identified were removed per monitoring well per unit
6. The trigger levels were then recalculated after the assessment and removal of identified outliers and resubmitted to DES on 26 March 2018.

Further comments from DES were received in May 2018 which included additional quality assurance (QA) measures for the baseline dataset, namely:

5.4.3.2.5 Additional Quality Assurance Measures

Additional quality assurance (QA) measures for the baseline dataset have been implemented (DES review, May 2018), including:

- Compilation of time-series graphs of all analytes per hydrostratigraphic unit over time to allow for visual identification of possible outliers (i.e. results markedly higher than the rest of the hydrographs)
- Assessment of potential outlier by review of all laboratory reports and field notes/ sheets to ensure the "outlier" was not a transcription error
- Assessing samples that fall outside of the mean and four(4) times the standard deviation (SD).
  - The DSITI (2017) guideline suggests that extreme values in a data set may be represented by measurements that lie outside the mean + 4*SD. However, a visual identification of outliers is also important. USEPA (2009) recommends the use of visual methods of assessment as the starting point for outlier assessment and the human eye remains singularly efficient at observing non-normal distributed data, trends and outliers.
  - The mean + 4*SD was calculated for each bore group (geological unit) and parameter. If outliers were identified that were less than the ANZG 2018 trigger level for 95% protection level for freshwater aquatic ecosystems they were not removed from the dataset. Values greater than mean + 4*SD were removed and the percentiles recalculated. Additional outliers

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were also identified which were considered an extreme value in the data set using a visual assessment, even if they were less than the mean + 4*SD.

- In addition, some 'outlier' bores were recommended to have bore-specific trigger levels.

Adani considered these recommendations and have undertaken the additional QA measures to allow for a robust dataset prior to trigger level calculation. An example of the time-series graphs prepared is presented in **Plate 26** where the zinc concentrations, after removal of data outliers from Piper and Box and Whisker plots, for the Rewan Formation are detailed.

The visually identified "outlier" results were then checked against the laboratory reports and all field sheets prior to removal to determine if the "outlier" was a possible transcript or unit error.

In the instance the elevated concentration, after review of laboratory and field reports, is an outlier, the data was removed from the set. Where the laboratory and field reports did not indicate any errors, the data point remained in the set for further quality assurance assessment (e.g. to confirm the data point is in exceedance of four (4) times the standard deviation of the complete dataset.

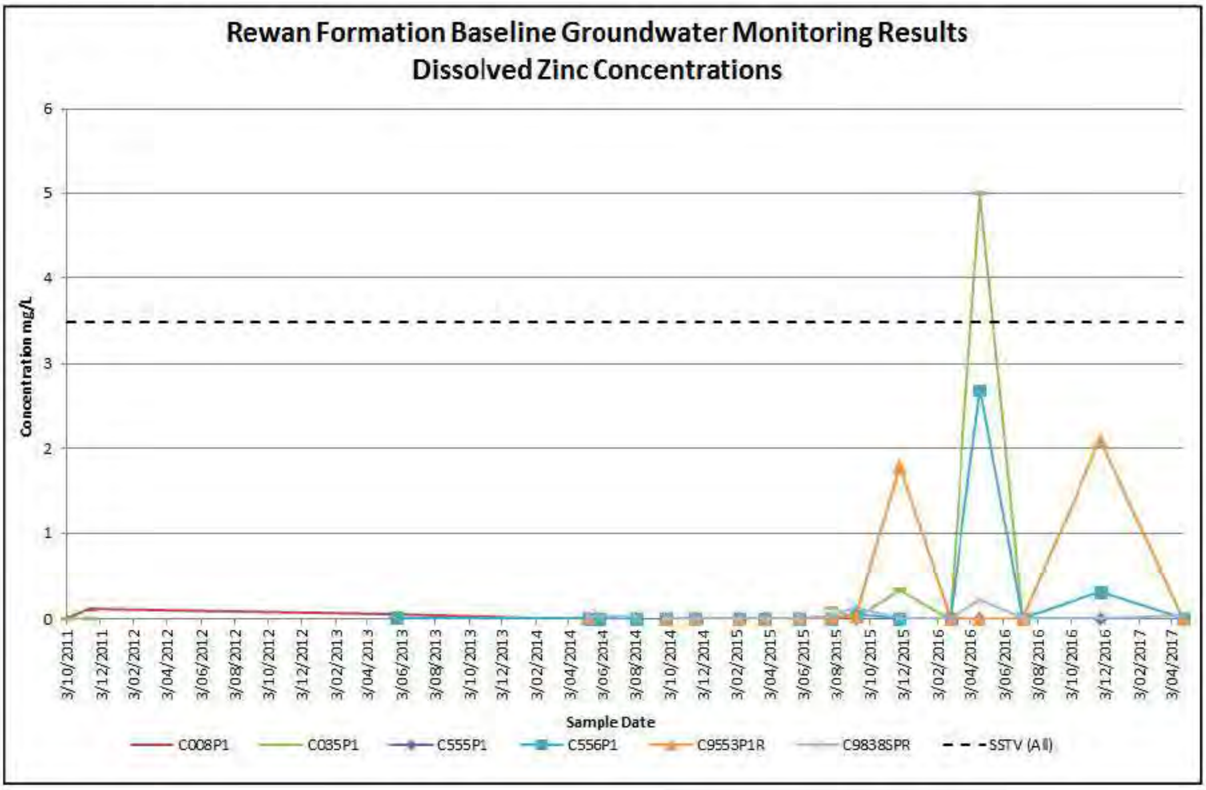

Plate 26 Example of time-series graph for baseline dataset QA

Site-Specific Trigger Values

Site-specific trigger values were determined following removal of outlier data (outside the mean + 4*SD) and calculation of the 85th percentiles of the resultant datasets.

Adani further examined these statistical outliers by referring to and review of the field sampling records. In the case of the example for zinc (**Plate 26**), the field notes revealed that there was a sulphurous odour observed at the time of sampling (see **Plate 27** below).

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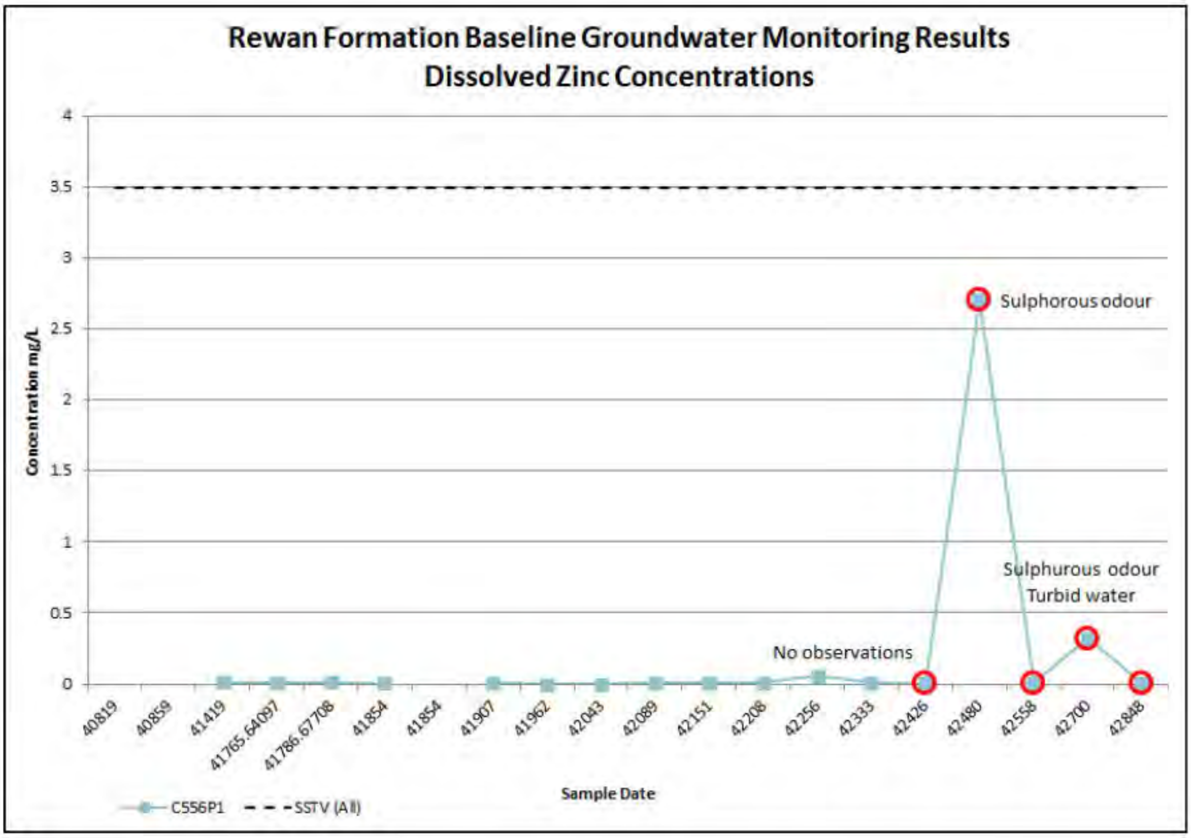

Plate 27 Field Observation correlation

In addition, the laboratory certificates of analysis (COA) were reviewed for any analysis issues, for example reported laboratory quality control outliers; none were noted, with analysis of lab blanks consistently reporting values below limits of detection.

As well as field observations, the time-series output has been compared to BOM rainfall records (collected at Bulliwallah station). Although the correlation is by no means definitive, there does appear to be some agreement between periods of recorded high rainfall and (in this case) increases in zinc concentration, as is depicted in **Plate 28** below.

This suggests that "outliers" may result from a 'flush' in the hydrostratigraphic unit, as there are corresponding increases in concentrations of iron, lead (possibly), copper, etc. in 2016 (although not necessarily in the same bores and again the correlation is not definitive). It is therefore considered that the 'spikes' may be natural and would benefit from being monitored further. Nevertheless, it was recommended that these 'spikes' were removed to provide additional levels of conservatism following further review rounds (see below).

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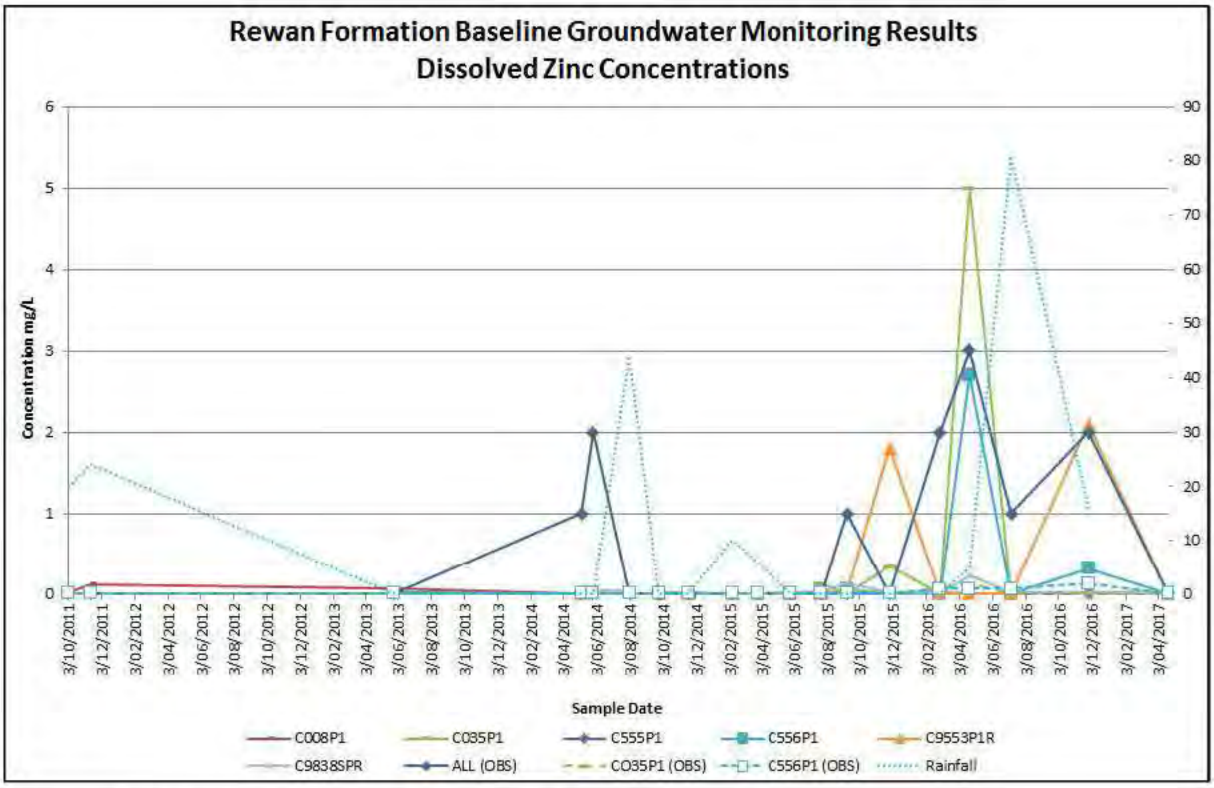

Plate 28 Rainfall vs Dissolved Zinc concentrations - Rewan Formation

Upon completion of the extensive QA assessment of the baseline dataset, and outlier assessment and removal, the trigger levels were calculated as follows:

1. 85th percentiles were then calculated for all hydrostratigraphic units with at least eight (8) results greater than the laboratory limit of report (LOR)
2. Where there were less than eight results per analyte per hydrostratigraphic unit greater than the LOR, the ANZECC & ARMCANZ 2000 guidelines 95th protection (freshwater) trigger value was adopted from Table 3.4.1 of the guideline (ANZECC, 2000)
3. Where there was no 95th protection (freshwater) trigger value (dot point above), and less than eight results above LOR, the low reliability (freshwater) trigger values were adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (ANZECC, 2000)
4. All trigger levels derived from the baseline monitoring program (at least eight results greater than LOR) were compared to the ANZECC & ARMCANZ 2000 guideline values per analyte (95th protection and low reliability). In instances where the ANZECC & ARMCANZ 2000 guideline value was higher, this ANZECC value was adopted as the proposed trigger level(DES review, November 2017)
5. There remain some parameters, with no published guideline value, with reported concentrations above LOR, but less than eight. These analytes (per unit) are to be considered for further discussion with respect to the appropriateness of the analyte in context of the Project for removal from compliance monitoring.

There remain some analytes which do not have established guideline values and variable LOR concentrations, namely total recoverable hydrocarbons (TRH C_6-C_{40}) and monocyclic aromatic hydrocarbons inclusive of benzene, toluene, ethylbenzene, and xylene isomers, collectively known as BTEX. There have been limited reported concentrations above LOR for some of the units; however, typically less than eight results above LOR.

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It is noted the ANZECC 2000 guidelines have been replaced with the Australian and New Zealand guidelines for fresh and marine water quality (ANZG 2018) during finalisation of this plan. The ANZG 2018 guidelines will be applied going forward until which time these are superseded.

It is considered the TRH fractions C_6-C_9 and >C_{10}-C_{40} (sum) are to be monitored and assessed as separate triggers due to limitations of analyses and reporting by laboratories which report TRH fractions in this manner (no total TRH concentration [C_6-C_{40}] reporting is available).

5.4.3.3 Reviews August - December 2018

Following additional review rounds and workshops, it was agreed to increase a greater degree of conservatism into the trigger values, with the aim of increasing EV protection. These include:

1. Adopting additional conservatism in the proposed values, which may offer a greater level of environmental protection.
2. Application of a 'consecutive exceedances' approach to validate the groundwater quality monitoring results. This approach requires two consecutive groundwater quality analytical results to be reported above a given parameter trigger value prior to the commencement of any investigations into the exceedance; a single trigger exceedance will not be cause for investigations into groundwater quality results. The consecutive sampling relates to two consecutive groundwater monitoring events, some two or three months apart.
3. The 'consecutive exceedances' approach has been adopted for the trigger values (**Section 5.4.3.4**) with the following exceptions:
    - High variability in the water quality from the Alluvium East subset of the alluvium trigger values makes assigning trigger values problematic. It was therefore agreed to calculate trigger values based on the bore-specific water qualities of each of the three Alluvium East bores, at least initially, to avoid erroneous triggers.
    - The ANZECC (2000) freshwater 99% species protection value of 5 µg/L was recommended as the trigger value for selenium (Tertiary sediments). It was noted, however, that the analytical laboratory's limits of reporting (LOR) for selenium concentrations were typically above this value. This means a typical analytical laboratory is incapable of identifying and reporting selenium at such a low concentration with a level of confidence. It is, thus, suggested that the ANZECC (2000) freshwater 95% species protection value, 11 µg/L Se, be adopted.
4. After the review and discussions the following were agreed:
    - On acceptance of the proposed trigger values, these values will be interim levels for two years
    - The table of trigger levels resulting from a meeting with DES (November, 2018) will replace Table E2 under Condition E9 of the Environmental Authority (EA)
    - A table of the groundwater monitoring locations of the bores utilise to develop the trigger levels will replace Table E1 of the EA (Condition 9).
5. Additional reviews in December 2018 have recommended minor adjustments to the proposed trigger levels (based on statistical analysis and comparisons between hydrostatic units), and are designed to provided additional levels of protection (DES review, December 2018).
    - For bore-specific triggers, a number of parameters may be represented below 8 recorded values. To provide values that may be included in the EA, these 'NV' (no value) entries have been compared to the hydrostratigraphic data as a whole, and values have been revised to provide appropriate representation (DES review, December 2018).

5.4.3.4 Proposed Triggers

Based on the methodology above, proposed trigger levels have been assigned to each of the water quality parameters for all the formations mentioned above. Proposed triggers, as discussed with DES, have been compiled for each of the hydrostratigraphic units potentially (directly or indirectly) impacted by the proposed mining activities, as identified in the EA are presented in **Table 48** to **Table 55** below

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and were derived for each of the groundwater units based on statistical evaluation of existing datasets, and following additional recommendations by DES.

5.4.3.4.1 Alluvium Triggers

The results of the groundwater quality assessment undertaken to ensure the monitoring bores for each unit are suitable to detect impacts from the approved mining operations has resulted in the proposed separation of the alluvial aquifer into eastern and western monitoring zones. The groundwater quality of the alluvial aquifer is spatially varied and considered the result of the Carmichael River across the CCP area, which is considered to be a losing river to the east and gaining in the west, where groundwater continuously discharges from the Joshua Spring (**Section 2.1.3**).

This is demonstrated as groundwater quality in the eastern area contains high levels of chloride, electrical conductivity (EC) and total dissolved solids (TDS) concentrations an order of magnitude higher than the groundwater quality from the western CCP area, which is considered fresh to slightly brackish. This occurs because of “first-flush”, the mobilisation and addition of evaporitic salts in the non-perennial alluvium during the wet season.

Based on the variation in the alluvium, due to differing levels of saturation and parent material, bore specific triggers were developed for this unit.

Table 48 Alluvium Proposed Trigger Levels

Parameter	Units	Eastern Area (C14028SP) Contaminant Trigger Levels (85th Percentiles)	Eastern Area (C029P1) Contaminant Trigger Levels (85th Percentiles)	Eastern Area (C027P1) Contaminant Trigger Levels (85th Percentiles)	Western Area (HD03A) Contaminant Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	**800**	**68**	**27**	**2.1**
Magnesium	mg/L Mg	**1,000**	**360**	**140**	**2.7**
Potassium	mg/L K	**204**	**397**	**100**	**21**
Sodium	mg/L Na	**8,305**	6,583	**1,209**	**175**
Chloride	mg/L Cl	**16,000**	10,750	**2,000**	**191**
Sulphate	mg/L SO_4	**1,900**	**1,100**	450	**14**
Alkalinity	mg/L $CaCO_3$	**404**	**2,400**	**355**	**150**
Sulphide	mg/L S_2	NV	**1.5**	NV	NV
Fluoride	mg/L F	1.4	**1.6**	**0.6**	**0.49**
Aluminium	µg/L Al	**55**	**55**	**55**	**55**
Arsenic	µg/L As	**13**	**13**	**13**	**13**
Boron	µg/L B	**3,170**	5,275	**845**	**370**
Cadmium	µg/L Cd	**0.2**	**0.2**	**0.2**	*0.2*
Chromium	µg/L Cr	**1.0**	**1.0**	**1.0**	*1.0*
Cobalt	µg/L Co	**23**	**12**	**8**	1.4
Copper	µg/L Cu	**7**	69	**157**	*1.4*
Iron	µg/L Fe	**652**	954	16,095	**530**
Lead	µg/L Pb	**3.4**	**3.4**	**3.4**	*3.4*
Manganese	µg/L Mn	**8,670**	**1,900**	3,750	**2,080**
Molybdenum	µg/L Mo	35(5)	35(5)	34*	34*

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Parameter	Units	Eastern Area (C14028SP) Contaminant Trigger Levels (85th Percentiles)	Eastern Area (C029P1) Contaminant Trigger Levels (85th Percentiles)	Eastern Area (C027P1) Contaminant Trigger Levels (85th Percentiles)	Western Area (HD03A) Contaminant Trigger Levels (85th Percentiles)
Nickel	µg/L Ni	**11**	20	**17**	*11*
Selenium	µg/L Se	**11**	**11**	**11**	*11*
Silver	µg/L Ag	**0.05**	**0.05**	**0.05**	*0.05*
Uranium	µg/L U	**74**	**149**	0.5*	0.5
Vanadium	µg/L V	6*	**27**	6*	**6.0**
Zinc	µg/L Zn	**26**	**56**	48	*8.0*
Mercury	µg/L Hg	***0.06***	***0.06***	***0.06***	***0.06***
Ammonia	mg/L N	**0.9**	**0.9**	**0.9**	0.9
Nitrate	mg/L N	**0.7**	**0.7**	**0.7**	0.7
Nitrite	mg/L N	NV	NV	NV	NV
T. Phosphorous	mg/L P	0.1	**0.3**	**0.1**	**0.1**
Total Recoverable Hydrocarbons	ppb ($C_6 – C_9$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_6 – C_{10}$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_{10} – C_{40}$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
pH**	pH units	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 - 9.0**
Electrical Conductivity	µS/cm	**44,000**	32,000	7,200	**900**
Total Dissolved Solids	mg/L	**26,000**	**20,000**	**4,400**	**580**

Notes:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th).

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- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value).
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program.
- NV - no published guideline value; however, there were results above LOR (less than 8).
- * - trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available.
- ** - pH trigger levels recommended by DES.
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems.
- *Grey* text denotes trigger values refined by DES

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5.4.3.4.2 Tertiary Sediments

As a result of the extensive assessment and QA of the baseline dataset, the trigger levels for Tertiary sediments monitoring bores have been identified as three groups, which include:

- C558P1 (bore specific / outlier bore)
- C025P2 and C029P2
- C9180121SPR and C9845SPR.

Notes for **Table 49** below include:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85^{th} and 99^{th})
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95^{th} reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value)
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program
- NV - no published guideline value; however, there were results above LOR (less than 8)
- * trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available
- ** - pH trigger levels recommended by DES
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems
- *Grey* text denotes trigger values refined by DES.

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Table 49 Tertiary Sediments Proposed Trigger Levels

Parameter	Units	Bore C558P1 Contaminant Trigger Levels (85th Percentiles)	Bores C025P2 and C029P2 Contaminant Trigger Levels (85th Percentiles)	All other Tertiary Bores Contaminant Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	**80**	**120**	**35**
Magnesium	mg/L Mg	**215**	**120**	**50**
Potassium	mg/L K	**49**	**100**	**15**
Sodium	mg/L Na	**1,540**	**2,900**	**575**
Chloride	mg/L Cl	**2,900**	**4,500**	**1,100**
Sulphate	mg/L SO_4	240	**430**	**98**
Alkalinity	mg/L $CaCO_3$	**240**	**420**	**60**
Sulphide	mg/L S_2	NV	NV	NV
Fluoride	mg/L F	**0.4**	**0.6**	**0.3**
Aluminium	µg/L Al	**55** (20)	**55**	**55**
Arsenic	µg/L As	**13**	**13**	**13**
Boron	µg/L B	**840**	**1,600**	307
Cadmium	µg/L Cd	**0.2**	**0.2**	**0.2**
Chromium	µg/L Cr	**1**	**1**	**2**
Cobalt	µg/L Co	**4**	1.4*	1.4*
Copper	µg/L Cu	405	**26**	**180**
Iron	µg/L Fe	**430**	2,750	**350**
Lead	µg/L Pb	**3.4**	**3.4**	**3.4** (2)
Manganese	µg/L Mn	**1,900** (265)	**2,600**	**1,900** (19)
Molybdenum	µg/L Mo	34*	34 (2)	34*

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Parameter	Units	Bore C558P1 Contaminant Trigger Levels (85th Percentiles)	Bores C025P2 and C029P2 Contaminant Trigger Levels (85th Percentiles)	All other Tertiary Bores Contaminant Trigger Levels (85th Percentiles)
Nickel	µg/L Ni	**34**	**11** (7)	**11** (4)
Selenium	µg/L Se	**11**	**11**	**11** (5)
Silver	µg/L Ag	**0.05**	**0.05**	**0.05**
Uranium	µg/L U	**2**	**1.1**	0.5*
Vanadium	µg/L V	**11**	**10**	6*
Zinc	µg/L Zn	46	**15**	**950**
Mercury	µg/L Hg	***0.06***	***0.06***	***0.06***
Ammonia	mg/L N	**0.9** (0.7)	**0.9** (0.7)	**0.9** (0.013)
Nitrate	mg/L N	**0.7** (0.3)	0.7 (0.02)	**0.7** (0.22)
Nitrite	mg/L N	NV	NV	NV
T. Phosphorous	mg/L P	**0.03**	**0.19**	**0.09**
Total Recoverable Hydrocarbons	ppb ($C_6 – C_9$)	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_6 – C_{10}$)	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_{10} – C_{40}$)	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR
pH**	pH units	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 – 9.0**
Electrical Conductivity	µS/cm	**9,360**	**14,000**	3,700
Total Dissolved Solids	mg/L	**5,600**	**8,660**	**2,300**

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5.4.3.4.3 Clematis Sandstone

Assessment of analytical concentrations for the Clematis Sandstone bores has resulted in subdivision of the hydrostratigraphic unit based on chemistry. There are two groups, as follows:

- HD03A and C14021SP
- All other Clematis Sandstone bores (C14011SP, C14012SP, C14013SP, C14033SP, C180118SP, HD02).

Table 50 below presents the trigger levels for the Clematis Sandstone.

Table 50 Clematis Sandstone Trigger Levels

Parameter	Units	Bores HD03A and C14021SP Contaminant Trigger Levels (85th Percentiles)	All other Clematis Bores Contaminant Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	**5**	**3**
Magnesium	mg/L Mg	**11**	**9**
Potassium	mg/L K	**18**	**15**
Sodium	mg/L Na	**130**	**100**
Chloride	mg/L Cl	**150**	**110**
Sulphate	mg/L SO_4	**19**	**9**
Alkalinity	mg/L $CaCO_3$	**120**	**130**
Sulphide	mg/L S_2	NV	NV
Fluoride	mg/L F	**0.3**	**0.4**
Aluminium	µg/L Al	**55**	**55** (18)
Arsenic	µg/L As	**13**	**13** (8)
Boron	µg/L B	**370** (130)	**370** (110)
Cadmium	µg/L Cd	**0.2**	**0.2**
Chromium	µg/L Cr	**1.0**	**1.0**
Cobalt	µg/L Co	1.4*	**4**
Copper	µg/L Cu	**13**	**16**
Iron	µg/L Fe	**505**	**55**
Lead	µg/L Pb	**3.4**	**3.4**
Manganese	µg/L Mn	**1,900** (425)	**1,900** (120)
Molybdenum	µg/L Mo	34*	34*
Nickel	µg/L Ni	**11**	**11** (10)
Selenium	µg/L Se	**11**	**11**
Silver	µg/L Ag	**0.05**	**0.05**
Uranium	µg/L U	0.5*	0.5*

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Parameter	Units	Bores HD03A and C14021SP Contaminant Trigger Levels (85th Percentiles)	All other Clematis Bores Contaminant Trigger Levels (85th Percentiles)
Vanadium	µg/L V	6*	6*
Zinc	µg/L Zn	33	**54**
Mercury	µg/L Hg	***0.06***	***0.06***
Ammonia	mg/L N	**0.9** (0.2)	**0.9** (0.15)
Nitrate	mg/L N	**0.7** (0.17)	**0.7** (0.67)
Nitrite	mg/L N	NV	NV
T. Phosphorous	mg/L P	**0.1**	**0.18**
Total Recoverable Hydrocarbons	ppb ($C_6 - C_9$)	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_6 - C_{10}$)	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_{10} - C_{40}$)	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR
pH**	pH units	**6.0 – 9.0**	**6.0 – 9.0**
Electrical Conductivity	µS/cm	**720**	607
Total Dissolved Solids	mg/L	**430**	**380**

Notes:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th).
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values.
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value).
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program.
- NV - no published guideline value; however, there were results above LOR (less than 8).
- *- trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available.
- ** - pH trigger levels recommended by DES.
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems.
- *Grey* text denotes trigger values refined by DES

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5.4.3.4.4 Dunda Beds

Bore C027P2 was identified to have variable groundwater quality from the remaining bores in the unit and therefore, Adani have developed bore-specific triggers for this monitoring well.

Table 51 presents the trigger levels for the Dunda Beds.

Notes for **Table 51** include:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th)
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value)
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program
- NV - no published guideline value; however, there were results above LOR (less than 8)
- *- trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available
- ** - pH trigger levels recommended by DES
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems
- *Grey* text denotes trigger values refined by DES.

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Table 51 Dunda Beds Trigger Levels

Parameter	Units	Bore C027P2 Contaminant Trigger Levels (85th Percentiles)	All other Dunda Beds Bores Contaminant Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	**1.1**	**3.5**
Magnesium	mg/L Mg	4.2	**3.8**
Potassium	mg/L K	**10**	**3.8**
Sodium	mg/L Na	**160**	**57**
Chloride	mg/L Cl	**212**	**69**
Sulphate	mg/L SO_4	**24**	**16**
Alkalinity	mg/L $CaCO_3$	162	80
Sulphide	mg/L S_2	NV	NV
Fluoride	mg/L F	**0.3**	**0.7**
Aluminium	µg/L Al	**55**	**56**
Arsenic	µg/L As	**13** (7)	**13**
Boron	µg/L B	**370** (210)	**370** (126)
Cadmium	µg/L Cd	**0.2**	**0.2**
Chromium	µg/L Cr	**1.0**	**1.0**
Cobalt	µg/L Co	**3**	**53**
Copper	µg/L Cu	**3**	**100**
Iron	µg/L Fe	**1,325**	**790**
Lead	µg/L Pb	**3.4** (2)	**3.4**
Manganese	µg/L Mn	**1,900** (220)	**1,900** (28.8)
Molybdenum	µg/L Mo	34*	34*

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Parameter	Units	Bore C027P2 Contaminant Trigger Levels (85th Percentiles)	All other Dunda Beds Bores Contaminant Trigger Levels (85th Percentiles)
Nickel	µg/L Ni	**11** (3.8)	12
Selenium	µg/L Se	**11**	**11**
Silver	µg/L Ag	**0.05**	**0.05**
Uranium	µg/L U	0.5*	0.5*
Vanadium	µg/L V	6*	6*
Zinc	µg/L Zn	**28**	**42**
Mercury	µg/L Hg	***0.06***	***0.06***
Ammonia	mg/L N	**0.9** (0.16)	**0.9** (0.25)
Nitrate	mg/L N	**0.7** (0.09)	**0.7** (0.22)
Nitrite	mg/L N	Detect above LOR	NV
T. Phosphorous	mg/L P	**0.03**	**0.06**
Total Recoverable Hydrocarbons	ppb ($C_6 – C_9$)	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_6 – C_{10}$)	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_{10} – C_{40}$)	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR
pH**	pH units	**6.0 – 9.0**	**6.0 – 9.0**
Electrical Conductivity	µS/cm	**850**	350
Total Dissolved Solids	mg/L	**523**	**220**

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5.4.3.4.5 Rewan Formation

Assessment of analytical concentrations for the Rewan Formation bores has resulted in subdivision of the hydrostratigraphic unit into three components with trigger levels being applied to the groupings as follows:

- C008P1
- C035P1
- All other Rewan Formation bores (C555P1, C556P1, C9553P1R, C9838SPR).

Bore C008P1 was identified as an outlier bore within the Rewan Formation. The baseline groundwater quality data for this bore, due to its proximity to C555P1, was discontinued as a monitoring point in 2014. Analysis during the trigger assessment indicates this bore, drilled and screened within the Rewan Formation indicates a different groundwater type to the other Rewan Formation bores. As such, this bore has been reinstated as a groundwater quality monitoring point and will have bore-specific triggers developed.

Due to the paucity of groundwater chemistry data for C008P1, the concentrations included in **Table 52** for bore C008P1 are considered to be interim trigger levels for the first two years of the GMMP in lieu of sufficient data.

Notes for **Table 52** include:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th)
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value)
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program
- NV - no published guideline value; however, there were results above LOR (less than 8)
- *- trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available
- ** - pH trigger levels recommended by DES
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems
- *Grey* text denotes trigger values refined by DES.

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Table 52 Rewan Formation Trigger Levels

Parameter	Units	Bore C008P1 Contaminant Trigger Levels (85th Percentiles)	Bore C035P1 Contaminant Trigger Levels (85th Percentiles)	All other Rewan Formation Bores Contaminant Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	NV	**18.5**	**6**
Magnesium	mg/L Mg	NV	**17**	**8**
Potassium	mg/L K	NV	**7.6**	**8**
Sodium	mg/L Na	NV	**755**	**130**
Chloride	mg/L Cl	NV	**1,100**	**170**
Sulphate	mg/L SO_4	280	57	**50**
Alkalinity	mg/L $CaCO_3$	NV	**171**	**140**
Sulphide	mg/L S_2	NV	NV	NV
Fluoride	mg/L F	0.7	**0.7**	**0.7**
Aluminium	µg/L Al	**55**	**55**	54
Arsenic	µg/L As	**13**	**13** (4)	**13** (4)
Boron	µg/L B	**370**	**710**	**370** (240)
Cadmium	µg/L Cd	**0.2**	**0.2**	**0.2**
Chromium	µg/L Cr	**1**	**1.0**	**1.0**
Cobalt	µg/L Co	1.4*	1.4*	**4**
Copper	µg/L Cu	**1.4**	**1.4**	**23**
Iron	µg/L Fe	800	800	**1,635**
Lead	µg/L Pb	**3.4**	**3.4**	**3.4**
Manganese	µg/L Mn	**1,900**	**1,900** (171)	**1,900** (488)
Molybdenum	µg/L Mo	34*	34*	34*
Nickel	µg/L Ni	**11**	**11**	**11** (5)
Selenium	µg/L Se	**11**	**11**	**11**

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Parameter	Units	Bore C008P1 Contaminant Trigger Levels (85th Percentiles)	Bore C035P1 Contaminant Trigger Levels (85th Percentiles)	All other Rewan Formation Bores Contaminant Trigger Levels (85th Percentiles)
Silver	µg/L Ag	**0.05**	**0.05**	**0.05**
Uranium	µg/L U	0.5*	0.5*	0.5*
Vanadium	µg/L V	6*	6*	6*
Zinc	µg/L Zn	**8**	**151**	**38**
Mercury	µg/L Hg	***0.06***	***0.06***	***0.06***
Ammonia	mg/L N	**0.9**	**0.9** (0.08)	**0.9** (0.4)
Nitrate	mg/L N	**0.7**	**0.7**	**0.7** (0.2)
Nitrite	mg/L N	NV	NV	NV
T. Phosphorous	mg/L P	0.14	**0.14**	**0.26**
Total Recoverable Hydrocarbons	ppb ($C_6 – C_9$)	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_6 – C_{10}$)	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_{10} – C_{40}$)	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR
pH**	pH units	**6.0-9.0**	**6.0 – 9.0**	**6.0 – 9.0**
Electrical Conductivity	µS/cm	21,140	**4,000**	800
Total Dissolved Solids	mg/L	NV	**2,465**	**490**

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5.4.3.4.6 Bandanna Formation (AB Seam)

As with the Rewan Formation bore C008P1, bore C007P2 was to have a water type markedly different to the AB Seam baseline groundwater quality data.

Bore C007P2 was identified as an outlier bore within the AB Seam. The baseline groundwater quality data for this bore, due to its proximity to C008P2, was discontinued as a monitoring point in 2014. Analysis during the trigger assessment indicates this bore, drilled and screened within the AB Seam indicates a different groundwater type to the other AB Seam bores. As such, this bore has been reinstated as a groundwater quality monitoring point and will have bore-specific triggers developed.

Due to the paucity of groundwater chemistry data for C007P2, the concentrations included in **Table 53** for bore C007P2 are considered to be interim trigger levels for the first two years of the GMMP in lieu of sufficient data.

The remaining AB Seam bores include C008P2, C014P2, C016P2, C020P2, C032P2, and C035P2.

Table 53 below presents the trigger levels for the AB Seam; notes for **Table 53** include:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85th and 99th)
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95th reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value)
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program
- NV - no published guideline value; however, there were results above LOR (less than 8)
- *- trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available
- ** - pH trigger levels recommended by DES
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems
- *Grey* text denotes trigger values refined by DES.

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Table 53 Bandanna Formation (AB Seam) Trigger Levels

Parameter	Units	Bore C007P2 Contaminant Trigger Levels (85th Percentiles)	All other Bandanna Formation Bores Contaminant Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	32	**32**
Magnesium	mg/L Mg	16	**16**
Potassium	mg/L K	49	**49**
Sodium	mg/L Na	570	**570**
Chloride	mg/L Cl	723	**723**
Sulphate	mg/L SO_4	74	**74**
Alkalinity	mg/L $CaCO_3$	NV	**480**
Sulphide	mg/L S_2	NV	**10**
Fluoride	mg/L F	1	**1**
Aluminium	µg/L Al	**55**	**400**
Arsenic	µg/L As	**13**	**13** (9)
Boron	µg/L B	**370**	**370**
Cadmium	µg/L Cd	**0.2**	**0.2** (0.2)
Chromium	µg/L Cr	**1**	**1**
Cobalt	µg/L Co	1.4*	1.4*
Copper	µg/L Cu	**1.4**	**2**
Iron	µg/L Fe	138	**138**
Lead	µg/L Pb	**3.4**	**3.4**
Manganese	µg/L Mn	**1,900**	**1,900** (108)
Molybdenum	µg/L Mo	34*	**38**

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Parameter	Units	Bore C007P2 Contaminant Trigger Levels (85th Percentiles)	All other Bandanna Formation Bores Contaminant Trigger Levels (85th Percentiles)
Nickel	µg/L Ni	**11**	**15**
Selenium	µg/L Se	**11**	11
Silver	µg/L Ag	**0.05**	0.05
Uranium	µg/L U	0.5*	0.5*
Vanadium	µg/L V	6*	6*
Zinc	µg/L Zn	**8**	**15**
Mercury	µg/L Hg	***0.06***	**0.06**
Ammonia	mg/L N	**0.9**	**2.8**
Nitrate	mg/L N	**0.7**	**0.7** (0.03)
Nitrite	mg/L N	NV	NV
T. Phosphorous	mg/L P	0.13	**0.13**
Total Recoverable Hydrocarbons+	ppb ($C_6 – C_9$)	Detect above LOR	**61**
Total Recoverable Hydrocarbons+	ppb ($C_6 – C_{10}$)	Detect above LOR	**126**
Total Recoverable Hydrocarbons+	ppb ($C_{10} – C_{40}$)	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR
pH**	pH units	**6.0 – 9.0**	**7.0 – 11.5**
Electrical Conductivity	µS/cm	NV	**3,000**
Total Dissolved Solids	mg/L	NV	**1,800**

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5.4.3.4.7 Colinlea Sandstone (D Seam)

As a result of the extensive assessment and QA of the baseline dataset, bore specific triggers have been developed for:

- C833SP
- C848SP
- C034P3
- C024P3.

The remaining D Seam bores have remained in one group and include C006P3R, C007P3, C011P3, C018P3, C180114SP, and C9849SPR. These are considered to represent the unit specific triggers.

Trigger levels and contaminant limits for the D Seam bores are presented in **Table 54** below; notes for the table include:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85^{th} and 99^{th})
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95^{th} reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value)
- ‘Detect above LOR’ – no guideline values available, no results above LORs reported during baseline monitoring program
- NV - no published guideline value; however, there were results above LOR (less than 8)
- *- trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available
- ** - pH trigger levels recommended by DES
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems
- *Grey* text denotes trigger values refined by DES.

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Table 54 Colinlea Sandstone (D Seam) trigger levels

Parameter	Units	Bore C833SP Trigger Levels (85th Percentiles)	Bore C848SP Trigger Levels (85th Percentiles)	Bore C034P3 Trigger Levels (85th Percentiles)	Bore C024P3 Trigger Levels (85th Percentiles)	All other Colinlea Sandstone Bores Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	**19**	**29**	**28**	25	**25**
Magnesium	mg/L Mg	**7**	**23**	**12**	6	**6**
Potassium	mg/L K	**55**	**27**	**16**	11	**11**
Sodium	mg/L Na	**270**	**540**	**355**	220	220
Chloride	mg/L Cl	**220**	**790**	**560**	200	**200**
Sulphate	mg/L SO_4	**37**	**20**	**30**	15	**15**
Alkalinity	mg/L $CaCO_3$	322	**240**	**115**	NV	**440**
Sulphide	mg/L S_2	**2**	NV	NV	NV	**1.3**
Fluoride	mg/L F	**1.9**	**0.4**	**0.3**	6.2	**6.2**
Aluminium	µg/L Al	**55**	**55**	**55**	**55**	**121**
Arsenic	µg/L As	**13**	**13**	**13**	**13**	**13** (4)
Boron	µg/L B	**370** (190)	**370** (190)	**370** (254)	**370** (300)	**410**
Cadmium	µg/L Cd	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Chromium	µg/L Cr	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
Cobalt	µg/L Co	1.4*	1.4*	1.4*	1.4*	1.4*
Copper	µg/L Cu	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**
Iron	µg/L Fe	**46**	1,345	**2,030**	410	410
Lead	µg/L Pb	**3.4**	**3.4**	**3.4**	**3.4**	**3.4**
Manganese	µg/L Mn	**1,900** (126)	**1,900** (330)	**1,900** (245)	**1,900** (240)	**1,900** (55)
Molybdenum	µg/L Mo	**16**	34*	34*	34*	**2**

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Parameter	Units	Bore C833SP Trigger Levels (85th Percentiles)	Bore C848SP Trigger Levels (85th Percentiles)	Bore C034P3 Trigger Levels (85th Percentiles)	Bore C024P3 Trigger Levels (85th Percentiles)	All other Colinlea Sandstone Bores Trigger Levels (85th Percentiles)
Nickel	µg/L Ni	**11**	**11**	**11**	**11**	**11** (5)
Selenium	µg/L Se	**11**	**11**	**11**	**11**	**11**
Silver	µg/L Ag	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
Uranium	µg/L U	0.5*	0.5*	0.5*	0.5*	0.5*
Vanadium	µg/L V	6*	6*	6*	6*	6*
Zinc	µg/L Zn	**88**	24	**8**	**8**	25
Mercury	µg/L Hg	***0.06***	***0.06***	***0.06***	***0.06***	***0.06***
Ammonia	mg/L N	**1.0**	**0.9** (0.12)	**0.9** (0.12)	**0.9** (0.6)	**0.9** (0.3)
Nitrate	mg/L N	**0.7**	**0.7**	**0.7**	**0.7**	**0.7** (0.02)
Nitrite	mg/L N	NV	NV	NV	NV	NV
T. Phosphorous	mg/L P	**0.02**	**0.03**	**0.07**	0.08	**0.08**
Total Recoverable Hydrocarbons+	ppb ($C_6 – C_9$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons+	ppb ($C_6 – C_{10}$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons+	ppb ($C_{10} – C_{40}$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
pH**	pH units	6.0 – 9.0	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 – 9.0**
Electrical Conductivity	µS/cm	1,210	**3,000**	1,935	1,030	1,030
Total Dissolved Solids	mg/L	**1,100**	**1,800**	**1,215**	639	639

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5.4.3.4.8 Joe Joe Group

Bores C14003SP and C914001SPR were identified to have variable groundwater quality from the remaining bores in the unit and therefore, Adani have developed bore-specific triggers for these locations. Bores C14017SP and C14006SP were also variable, but similar to each other, and have been grouped together.

The remaining bores have been grouped together for trigger levels and include C012P1, C012P2, C14008SP, C14014SP, C14015SP, C14016SP, C180119SP, C180123SP, C9180124SPR, and C9180125SPR. **Table 55** presents the trigger levels for the Joe Joe Group bores; notes for **Table 55** include:

- **Bold** – at least eight (8) results from the baseline groundwater monitoring program were reported above LORs and utilised to calculate trigger and contaminant levels (85^{th} and 99^{th})
- **Bold** - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC & ARMCANZ 2000 guidelines were applied where <8 results above LORs were available from the baseline groundwater monitoring program (XX) – calculated values
- Not bold or **Bold** – ANZECC 95^{th} reliability (freshwater) trigger value or low reliability trigger level from Section 8.3.7 was adopted over baseline calculated value (85% baseline is less than ANZECC value)
- 'Detect above LOR' – no guideline values available, no results above LORs reported during baseline monitoring program
- NV - no published guideline value; however, there were results above LOR (less than 8)
- *- trigger level adopted from Section 8.3.7 of the ANZECC & ARMCANZ 2000 guidelines (low reliability trigger levels) where there were no 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 of the ANZECC & ARMCANZ 2000 guidelines and where <8 results above LORs were available
- ** - pH trigger levels recommended by DES
- *0.06* µg/L Hg adopted, which is the ANZECC & ARMCANZ 2000 guidelines 99% protection trigger levels for freshwater aquatic ecosystems
- *Grey* text denotes trigger values refined by DES.

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Table 55 Joe Joe Group Trigger Levels

Parameter	Units	Bore C14003SP Trigger Levels (85th Percentiles)	Bore C914001SPR Trigger Levels (85th Percentiles)	Bores C14017SP and C14006SP Trigger Levels (85th Percentiles)	All other Joe Joe Group Bores Trigger Levels (85th Percentiles)
Calcium	mg/L Ca	**2,620**	**880**	180	**76**
Magnesium	mg/L Mg	**1,600**	**435**	**84**	**28**
Potassium	mg/L K	**52**	**124**	**39**	**15**
Sodium	mg/L Na	**8,000**	3,800	**1,500**	**426**
Chloride	mg/L Cl	**21,000**	**7,070**	2,545	**630**
Sulphate	mg/L SO_4	2,710	**1,600**	206	**54**
Alkalinity	mg/L $CaCO_3$	48	210	240	**290**
Sulphide	mg/L S_2	NV	NV	NV	**1.4**
Fluoride	mg/L F	**0.2**	0.7	**1.0**	**0.7**
Aluminium	µg/L Al	**55**	**55**	**55**	**55** (39)
Arsenic	µg/L As	**13**	**13 (2)**	**13 (4)**	**13** (6)
Boron	µg/L B	**4,000**	**2,035**	**720**	**425**
Cadmium	µg/L Cd	**0.2**	**0.2**	**0.2**	**0.2**
Chromium	µg/L Cr	**1**	**1**	**1**	**4**
Cobalt	µg/L Co	**29**	1.4*	**3**	**6**
Copper	µg/L Cu	**670**	**1.4**	**1.4**	**19**
Iron	µg/L Fe	**1,300**	**9,445**	1,870	**765**
Lead	µg/L Pb	**3.4**	**3.4**	**3.4**	**7**
Manganese	µg/L Mn	**2,620**	**1,900** (994)	**1900** (1006)	**1,900** (407)
Molybdenum	µg/L Mo	34*	34*	**4**	**4**

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Parameter	Units	Bore C14003SP Trigger Levels (85th Percentiles)	Bore C914001SPR Trigger Levels (85th Percentiles)	Bores C14017SP and C14006SP Trigger Levels (85th Percentiles)	All other Joe Joe Group Bores Trigger Levels (85th Percentiles)
Nickel	µg/L Ni	**33**	**11** (3.5)	**11** (7)	**11** (9.6)
Selenium	µg/L Se	**11** (3.5)	**11**	**11**	**11**
Silver	µg/L Ag	**0.05**	**0.05**	**0.05**	**0.05**
Uranium	µg/L U	0.5*	3.4	0.5*	**1**
Vanadium	µg/L V	6*	6*	6*	6*
Zinc	µg/L Zn	**69**	60	**297**	**260**
Mercury	µg/L Hg	***0.06***	***0.06***	***0.06***	***0.06***
Ammonia	mg/L N	**0.9** (0.67)	**0.9** (0.47)	**0.9** (0.47)	**0.9** (0.18)
Nitrate	mg/L N	**0.7**	**0.7**	**0.7**	**0.7** (0.2)
Nitrite	mg/L N	NV	NV	NV	NV
T. Phosphorous	mg/L P	0.05	0.05	**0.03**	**0.05**
Total Recoverable Hydrocarbons	ppb ($C_6 – C_9$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_6 – C_{10}$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb ($C_{10} – C_{40}$)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
BTEX	ppb	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
pH**	pH units	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 – 9.0**	**6.0 – 9.0**
Electrical Conductivity	µS/cm	**53,000**	**21,000**	**8,600**	**2,600**
Total Dissolved Solids	mg/L	**32,000**	**13,000**	**5,100**	**1,600**

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5.4.4 Groundwater Quality Trigger Assessment

As detailed in **Section 4.7.2,** a stepped approach will be implemented for trigger exceedances. These steps are summarised in the Trigger Assessment decision tree in **Plate 29**.

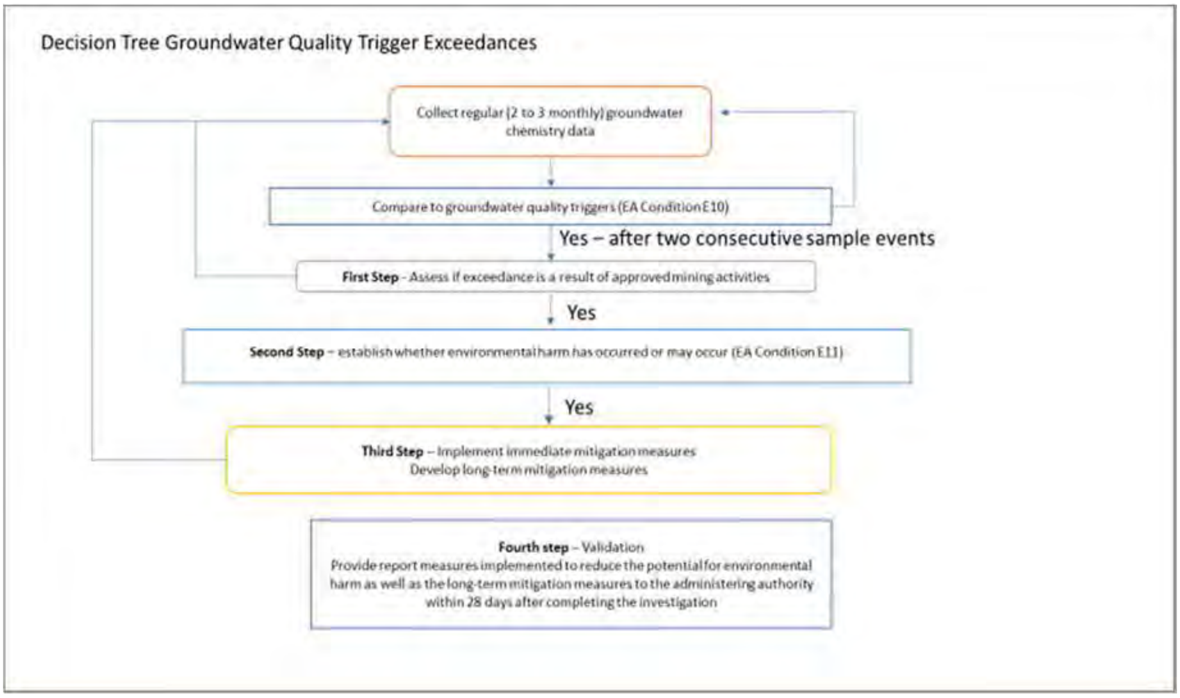

Plate 29 Trigger exceedance decision tree

This stepped approach will be implemented for trigger exceedances.

5.4.5 Contaminant Limits

EA Approval Condition E9 Table E2 (5 June 2017 version) includes for contaminant trigger levels based on the statistical assessment as detailed above. DES have recommended that contaminant limits be considered when assessing for potential for environmental.

The suggested contaminant limits, compiled by AECOM using the baseline chemistry dataset, available guidelines, and outlier identification, and then reviewed and edited by DES, are included in **Appendix D.**

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5.5 Control Monitoring Bores

As detailed in **Section 1.6**, the EPBC Act approval Condition 3a(i) include the requirement to include details of the control monitoring sites, which form part of the groundwater monitoring network.

The Commonwealth regulators considers that control bores are to be located outside the zone of potential impact. For groundwater this is not always possible as the groundwater monitoring bores would have to be located outside the mine lease (due to the extent of drawdown extending beyond the mine lease boundaries) and long-term access cannot be assured.

Where possible Adani has identified control bores within areas where Adani has written approval for access these bores, and where little or no drawdown is predicted (beyond natural fluctuation). Although these bores, to the west of the mine lease, are not predicted to be impacted by mine related dewatering these bores are located on other landholders properties and as such there is no guarantee that these bores will not be impacted by groundwater extraction in the future.

The selected control monitoring bores are in areas which allow these bores to be utilised during all phases of the mine where natural groundwater level and chemistry changes can be monitored (then compared to the mine monitoring bore network to aid in assessing if change is due to approved mining or natural fluctuations).

It is noted that Adani also has a series of sentinel bores (**Section 5.3**) between the mine lease and sensitive receptors (such as the Doongmabulla Spring Complex and neighbouring landholder bores). These bores will not be directly impacted by approved mining activities and as such will provide uninterrupted data can be provided during and after the life of the mine.

To inform impacts on control and sentinel monitoring bores, due to non-CCP works (e.g. landholder extraction of groundwater, in most cases from shallow aquifer units), a trend assessment on water levels will be undertaken. Non-CCP groundwater impacts are likely to be limited in extent and localised and therefore, identifiable via trend analysis. As such, this method is considered suitable to identify and separate out other users' influences on groundwater levels.

Control monitoring bores are presented in **Figure 26** below and in **Table 56** below, by hydrostratigraphic unit. **NOTE**: Bores with a maximum predicted drawdown below natural fluctuation are considered suitable for control bores.

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Table 56 Control Monitoring Bores

Bore ID	Unit Monitoring	Monitoring Target	Predicted Drawdown (m)	Objectives
C025P1	Alluvium	Carmichael River alluvium and associated GDEs	Dry	Allows for monitoring of naturally occurring dry period in the alluvium within the Mine Lease Monitoring of natural change in alluvium required for comparison to other alluvium bores
C029P1	Alluvium		0.33 m	Allows for monitoring of natural fluctuation of groundwater within the alluvium within the mine lease, monitor for changes in vertical groundwater gradients, recharge and discharge in the middle of the mine lease Predicted drawdown is below natural fluctuation of 1.01 m
HD03B	Alluvium		0.004 m	Provides assessment of perennially saturated alluvium, due to spring discharge. Observation of natural fluctuation in the upstream portion of the alluvium
C14027SP	Alluvium		0.018 m	Allows for monitoring of natural fluctuation of groundwater within the alluvium downstream of the mine lease, monitor recharge and discharge in the alluvium. Predicted drawdown is below natural fluctuation of 0.22 m
C14028SP	Alluvium		0.075 m	Allows for monitoring of natural fluctuation of groundwater within the alluvium downstream the mine lease. Monitor recharge and discharge in the alluvium. Predicted drawdown is below natural fluctuation of 0.31 m
HD02	Clematis Sandstone	Doongmabulla Springs Complex (interim threshold of 0.2 m drawdown in spring water table)	0.03 m	Monitor unconfined Clematis Sandstone aquifer down gradient of the DSC discharge Natural fluctuation is 0.46 m

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Bore ID	Unit Monitoring	Monitoring Target	Predicted Drawdown (m)	Objectives
HD03A	Clematis Sandstone		0.18 m	Monitor confined Clematis Sandstone aquifer down gradient of the DSC discharge Natural fluctuation is 1.02 m
C14033SP	Clematis Sandstone		0.25 m	Monitor Clematis Sandstone confined by Moolayember Formation, recharge and discharge Natural fluctuation is 0.26 m
C14020SP	Moolayember Formation		0.16 m	Monitor recharge, vertical groundwater gradients with Clematis Sandstone (C14033SP) Natural fluctuation is 0.31 m
C18001SP	Clematis Sandstone		0	Control bores outside the predicted impact of approved mining activities Provide groundwater flow patterns from west of DSC
C18002SP	Clematis Sandstone		0	
C18003SP	Moolayember Formation		0	
C14023SP	Dunda Beds	Dunda Beds – responses to potential induced flow west of the mine lease	0.32 m	Monitor groundwater levels at Dunda Beds / Rewan Formation contact, evaluate induced flow potential also recharge Natural fluctuation is 0.30 m
C180119SP	Joe Joe Group	Mellaluka Springs Complex – associated GDEs and artesian conditions	0.04 m	All bores to be used to assess groundwater recharge, flow patterns, artesian conditions, and vertical gradients in the MSC area Natural fluctuation is 0.49 m
C180120SP	Tertiary sediments and Joe Joe Group		0.02 m	Natural fluctuation is 2.53 m
C180122SP	Tertiary sediments and Joe Joe Group		0.05 m	Natural fluctuation is 0.75 m

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Bore ID	Unit Monitoring	Monitoring Target	Predicted Drawdown (m)	Objectives
C180123SP	Joe Joe Group		0.007 m	Natural fluctuation is 0.67 m
C9180124SPR	Joe Joe Group		0.045 m	Natural fluctuation is 0.55 m
C9180125SPR	Joe Joe Group		0.02 m	Natural fluctuation is 1.07 m

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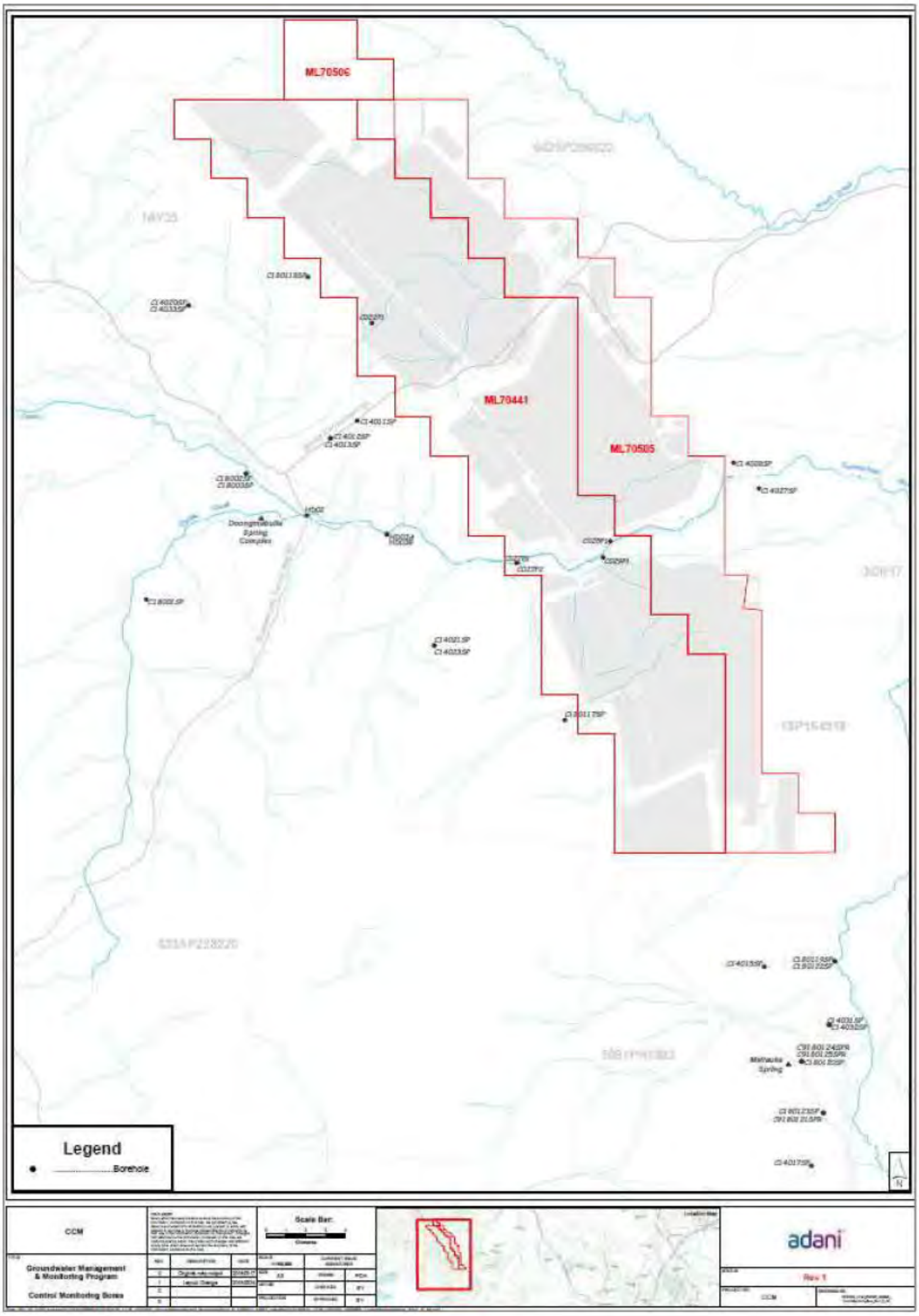

Figure 26 Control Monitoring Bores

5.6 Monitoring Program for Sensitive Ecosystems

In compliance with EA Conditions E4 and E8 plus EPBC Act condition 3a, a number of groundwater monitoring bores have been installed across and adjacent to the CCP MLs to ensure the potential impacts of approved mining are assessed adjacent to the identified groundwater related MNES and state significant biodiversity values (as detailed in **Section 2.5**).

Groundwater monitoring bores, installed to monitor potential impacts on groundwater reliant and sensitive ecosystems, allow for the monitoring of groundwater level response in the following areas:

- The Doongmabulla Spring Complex
- Carmichael River GDEs (such as the Waxy Cabbage Palm tree communities)
- The Great Artesian Basin units and possible induced flow from these units to the mine workings
- The non-GAB Mellaluka Springs Complex.

It is noted that other groundwater environmental values, such as stock watering, are included in the monitoring program for the sentinel bores (**Section 2.5**).

Table 57 provides a summary of the GDE monitoring points and **Figure 27** provides the location of these bores across and adjacent to the MLs.

Table 57 Summary of GDE Monitoring Points

Bore ID	Monitoring Unit	Area	Objective
C027P1	Alluvium	Carmichael River bank	Asses impacts on river and GDEs
C027P2	Dunda Beds	Carmichael River	Verify modelled induced flow, reduction in groundwater levels and influence on river and GDEs
C029P1	Alluvium	Carmichael River bank	Asses impacts on river and GDEs Control bore
C029P2	Tertiary sediments	Carmichael River	Verify predicted induced flow < 0.5 m, evaluate influence on river and GDEs
C180119SP	Joe Joe Group	Mellaluka North	Assess possible induced flow from Joe Joe Group between MLs and Mellaluka Spring GDEs Control bore
C180120SP	Tertiary sediments and Joe Joe Group	Mellaluka Middle	Assess possible induced flow at Mellaluka Spring GDEs Control bore
C180122SP	Tertiary sediments and Joe Joe Group	Mellaluka North	Assess possible induced flow from Joe Joe Group between MLs and Mellaluka Spring GDEs Control bore
C180123SP	Joe Joe Group	Mellaluka South	Control monitoring bore at Mellaluka Springs area

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Bore ID	Monitoring Unit	Area	Objective
C9180121SPR	Tertiary sediments	Mellaluka South	Assess groundwater flow from south within Tertiary sediments upgradient of Mellaluka Spring GDEs
C9180124SPR	Joe Joe Group	Mellaluka North	Assess possible induced flow from Joe Joe Group between MLs and Mellaluka Spring GDEs Control bore
C9180125SPR	Joe Joe Group	Mellaluka Middle	Control monitoring bore at Mellaluka Springs area
HD02	Clematis Sandstone	Doongmabulla Springs Complex /Carmichael River	Control bore
HD03A	Clematis Sandstone	Doongmabulla Springs Complex /Carmichael River	Control bore
HD03B	Alluvium	Carmichael River bank	Control bore
Mellaluka Spring	Tertiary sediments / Joe Joe Group	Mellaluka	Monitoring point for GDEs
Joshua Spring	Clematis Sandstone	Doongmabulla Springs Complex	Monitoring point for GDEs
C14028SP	Alluvium	Carmichael River bank	Assess alluvium GDEs downstream of MLs Control bore
C14027SP	Alluvium	Carmichael River bank	Assess alluvium GDEs downstream of MLs Control bore
C14031SP	Tertiary sediments and Joe Joe Group	Mellaluka	Assess possible induced flow from Joe Joe Group between MLs and Mellaluka Spring GDEs
C14032SP	Joe Joe Group	Mellaluka	
C14008SP	Joe Joe Group	Mellaluka	Sentinel bore
C14015SP	Joe Joe Group	Mellaluka	Sentinel bore
C14017SP	Joe Joe Group	Mellaluka	Assess groundwater flow from south within Tertiary sediments upgradient of Mellaluka Spring GDEs
C14033SP	Clematis Sandstone	Doongmabulla Springs Complex	Control bore
C14020SP	Moolayember Formation	Doongmabulla Springs Complex	Control bore
C14011SP	Clematis Sandstone	Doongmabulla Springs Complex	Assess groundwater level changes between MLs and DSC in Clematis Sandstone, early warning
C14012SP	Clematis Sandstone	Doongmabulla Springs Complex	

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Bore ID	Monitoring Unit	Area	Objective
C14013SP	Clematis Sandstone	Doongmabulla Springs Complex	for GDEs
C025P1	Alluvium	Carmichael River bank	Control bore
C14021SP	Clematis Sandstone	Doongmabulla Springs Complex	Assess groundwater level changes between MLs and DSC in Clematis Sandstone, early warning for GDEs
C14023SP	Dunda Beds	Doongmabulla Springs Complex	Control bore
C18001SP	Clematis Sandstone	Doongmabulla Springs Complex	Control bore
C18002SP	Clematis Sandstone	Doongmabulla Springs Complex	Control bore
C18003SP	Moolayember Formation	Doongmabulla Springs Complex	Control bore

In addition to these bores, Adani will install new wells west of the mine lease, to be co-located as far as practicable within 500 m of existing locations HD02, C14011SP, and HD03A. These bores will be installed to monitor the Dunda Beds and Rewan Formation to assess for any dewatering impact propagation through the Rewan Formation to the GAB. Further, these bores will inform the current understanding of the vertical groundwater gradients above and within the Rewan Formation. Adani will also consider drilling into deeper Permian age units for monitoring purposes if there is a need to do so identified in the relevant research programs.

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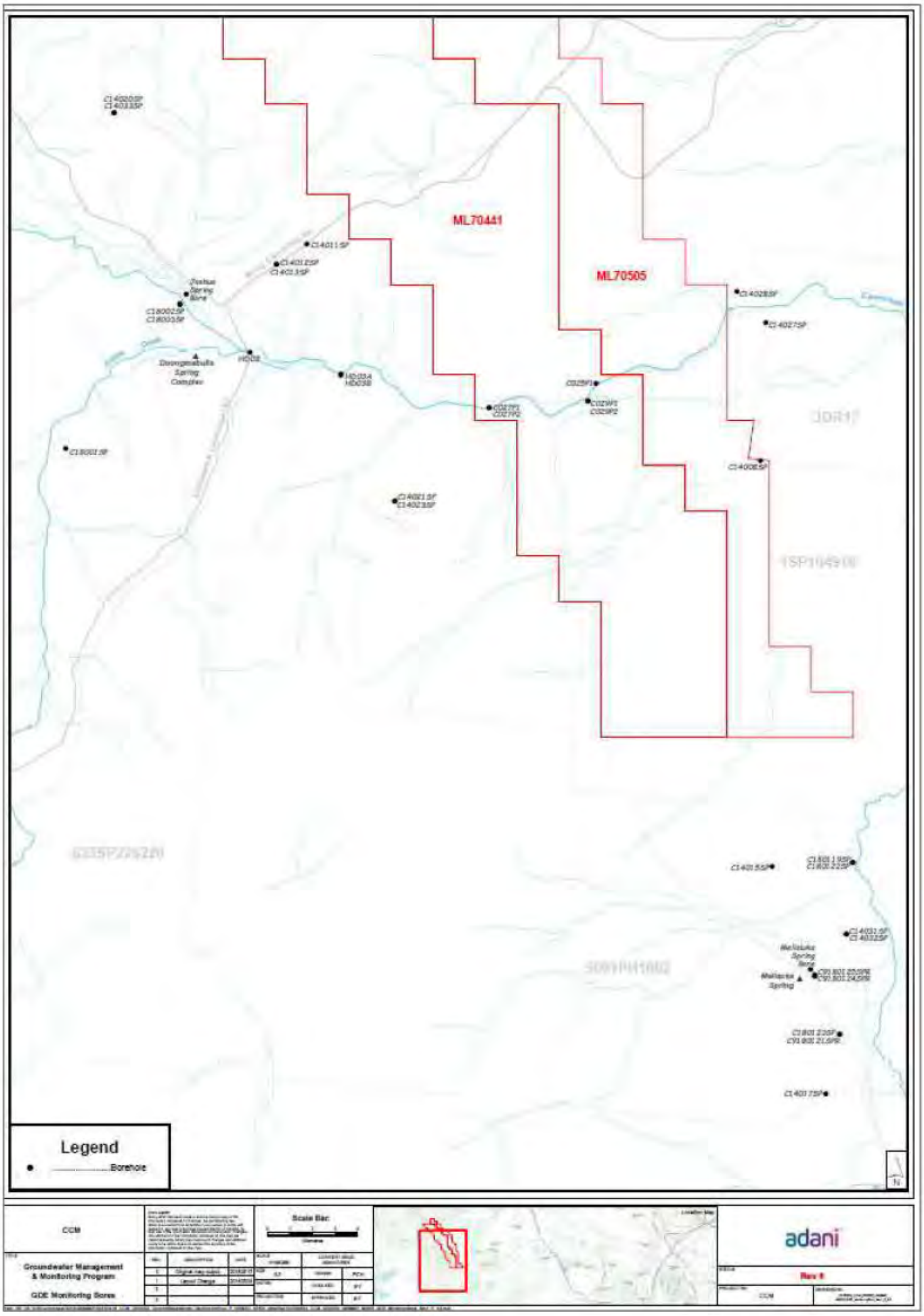

Figure 27 GDE Bores

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6.0 Development of Approval Groundwater Monitoring Programs

6.1 Construction GMMP

A groundwater monitoring program specific to the construction phase has been compiled as different activities, compared to mining, will be involved. This includes monitoring of the shallow groundwater units (Alluvium, Tertiary sediments, and Permian aged subcrop) to ensure fuel, oil, and possibly chemical storage and handling will not impact negatively on site.

The existing baseline groundwater monitoring network has been augmented to allow for the monitoring of groundwater level and quality and any departures from natural fluctuations, such as potential seepage adjacent (down gradient) of the mine affected water and waste storage facilities.

Shallow bores (within the weathered Tertiary sediments) have been constructed so that at least six (6) months of baseline data can be compiled prior to construction of the mine affected water and waste storage facilities. This will allow for the compilation of baseline groundwater quality prior to use, should perched or permanent groundwater is intersected in these bores over at least six months.

These shallow (seepage) monitoring bores provide indication of possible groundwater (saturated or unsaturated conditions prior to construction and use of possible sources of seepage) levels. Where shallow groundwater is intersected, groundwater level data will be compiled for comparison during operations to assess any potential impacts of these facilities on the recharge and shallow groundwater flow (i.e. ponding or compaction impacts) as well as possible artificial recharge (seepage).

The six (6) shallow bores installed adjacent to the mine affected water and waste storage facilities are to be sampled every two months during the construction phase, and are located in proximity to the storage facilities as depicted on **Figure 28**.

Groundwater levels and water quality data (the same set of parameters as included in **Section 4.4.3**) will be compiled prior to operations for comparison purposes. The water quality and water levels, if monitored over at least a six month period, will be used to develop groundwater level (rising) thresholds and water quality triggers.

The GMMP will be updated to include the location of additional seepage monitoring bores that will be installed at least six months prior to construction of other possible sources of artificial recharge, including MAW water storage dams, tailings storage/ drying cells, and out-of-pit spoil dumps where tailings will be co disposed. These bores cannot yet be included in the GMMP as they need to be located once the final footprint of these mine water and waste storage facilities has been finalised, i.e. the location of the seepage monitoring bore network can only be finalised after the footprints of these facilities has been finalised and surveyed on site.

Thus the construction monitoring network is the baseline groundwater monitoring network plus the additional seepage monitoring bores.

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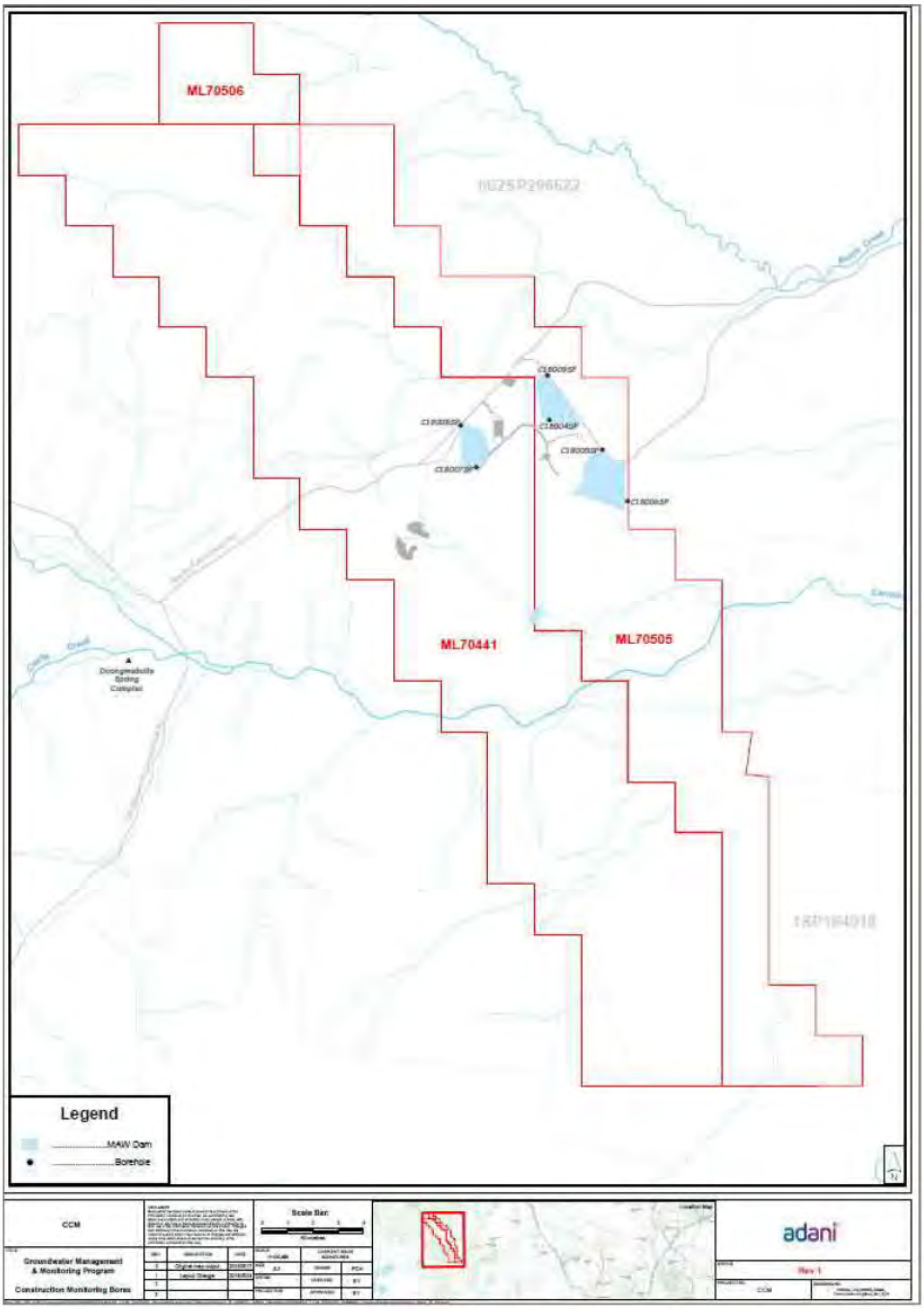

Figure 28 Seepage Bore locations and proximity to mine water infrastructure facilities

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6.2 Operational GMMP

A preliminary validation monitoring program has been designed for inclusion in this initial GMMP, for the first five (5) years of mine life (after which the GMMP is to be reviewed and modified as per the Approval Conditions). This initial Operation GMMP considers the SEIS mine plan and predicted drawdown impacts (model re-run). It is considered this initial operational GMMP groundwater monitoring network will alter with time as mine activities extend to the west and to the south to allow for the monitoring bore network to be augmented (bore replacement) over time.

During the GMMP review process the adequacy of the monitoring bore network, with regard to the active mining areas, will be assessed to ensure the impacts due to mining will be monitored and assessed. The review process also allows for the identification of when and which of the monitoring bores will be lost to mining and will require replacing (using the short term mine plans). The bores identified to be replaced will be drilled in alternate locations which will be representative of bores (i.e. same hydrostratigraphic units) that are being replaced. It is to be noted that identification of replacement bores will depend on progress of mining areas and mining schedules.

The Operational GMMP bores, selected for comparison and prediction evaluation, are based on the 5 year mine plan and schedule (the short term mine plan is considered the most accurate based on the most detailed mine planning). The Operational GMMP bores are included in **Table 58** below and presented on **Figure 29** below. These bores allow for the monitoring of potential groundwater impacts at or adjacent to GDEs, identified landholder bores, and GAB units. The Operational bore network was selected to address and ensure compliance with all approval conditions.

Additional bores will be installed to monitor potential seepage from tailing drying cells, water storage areas, and out-of-pit spoil dumps which are located to the east of mining areas. These monitoring bores will be installed around the perimeter of the tailings cells, water storage areas, and out-of-pit spoil dumps. Facilities will be monitored for surface seepage expressions following standard management practices. The current and operational monitoring bore network does not include the monitoring bores required for the above mentioned purpose but will be installed once the location of these facilities is finalised. The location and timing for installation of these bores will be done before construction and utilisation of these facilities and will be dictated by the mine planning process and progress of mining activities.

To augment the monitoring network Adani commits to installing additional monitoring bores into the Dunda Beds and the Rewan Formation to the west of Mining lease in between the Mining lease and DSC and is included in **Section 7.0** As far as practicable, these additional bores will be co-located with the existing bores, HD02, HD03A, and C14011SP, as nested monitoring bores in consultation with DNRME of Queensland.

These bores, once installed, will be added to the operational groundwater monitoring program and will allow for the collection of additional spatially comparable groundwater level and quality data between the Mining lease and DSC. The additional monitoring points will assist in further evaluation of the predicted groundwater impacts associated with the mining activities and will also assist in validating the predicted timing of impacts.

The additional groundwater (bore construction and monitoring) data will be used in the groundwater model rerun for the prediction of impacts, which will then be used to develop additional Early warning groundwater level and Impact thresholds (as compiled in **Section 5.3**) for inclusion in the next GMMP.

Further, Adani will investigate drilling into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information if required under relevant research programs.

Construction and box cut activities will be progressed during this time, along the eastern boundary of the mine lease, as groundwater level impacts west of the mine lease near the DSC are not anticipated for several years.

Predicted drawdown contours will be used at regular intervals (five years) to show the groundwater monitoring locations and units over time. These data will be used to validate and update the predictive groundwater model as well as the operational monitoring bore network. It is noted that consideration of cumulative drawdown (with neighbouring projects) changes in groundwater flow direction over time will be given when locating additional operational monitoring points.

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During operations the groundwater monitoring network, which includes VWPs to west of the mine leases, allows for the assessment of groundwater level decline over time, as predicted by the SEIS groundwater model.

Groundwater level drawdown thresholds proposed based on predictive modelling, will provide early warning before groundwater levels decline within the hydrostratigraphic units, such that potential impact on the vegetation (sensitive and groundwater dependent ecosystems) can be assessed.

In addition, groundwater level thresholds are proposed for units which are utilised by neighbouring groundwater users (within sentinel monitoring bores [**Section 5.3.5**]). Groundwater levels in these monitoring bores, located between the mine and existing bores will be compiled and assessed. Should groundwater levels within the various confined hydrostratigraphic units (Rewan Group, Bandanna Formation AB seam, and Colinlea Sandstone D seam) be recorded to vary by more than the groundwater level thresholds and natural fluctuation (baseline data) then an assessment of any adjacent “at-risk’ bores will be undertaken as per the make-good commitments and agreements. This will allow for the planning and provision of an alternative water source to replace water supply from the ‘at-risk’ bore, as required.

Operational groundwater monitoring bores are to be sampled for parameters included in **Section 4.4.3** at the frequency included in **Table 58** (as per approval conditions). Groundwater level measurements will be collected with automated water level loggers, VWPs, and manually during GMEs. Quality assurance and quality control (QA / QC) procedures, as detailed in **Section 4.4.4**, will be adopted.

All of the monitoring bores in the current baseline monitoring bore network (**Table 23**) are equipped with automated water level loggers. These loggers will be downloaded every 6 months to allow for assistance with groundwater impact assessment and model refinement (particularly the over-and inter-burden layers). The purpose of the bores are detailed in **Table 23**. The bores included in the Operational GMMP were selected, from these baseline monitoring network, to validate predictive groundwater modelling and ensuring groundwater alteration is measured and monitored (for comparison to groundwater quality triggers and groundwater drawdown level thresholds) in the hydrostratigraphic units predicted to be impacted by mining. The spatial extent of the Operational bore network across and adjacent to the mine leases is indicated in **Figure 29**.

Appendix B includes a series of maps which depict the operational monitoring network by unit to be monitored and in relation to the Year 5 mine plan.

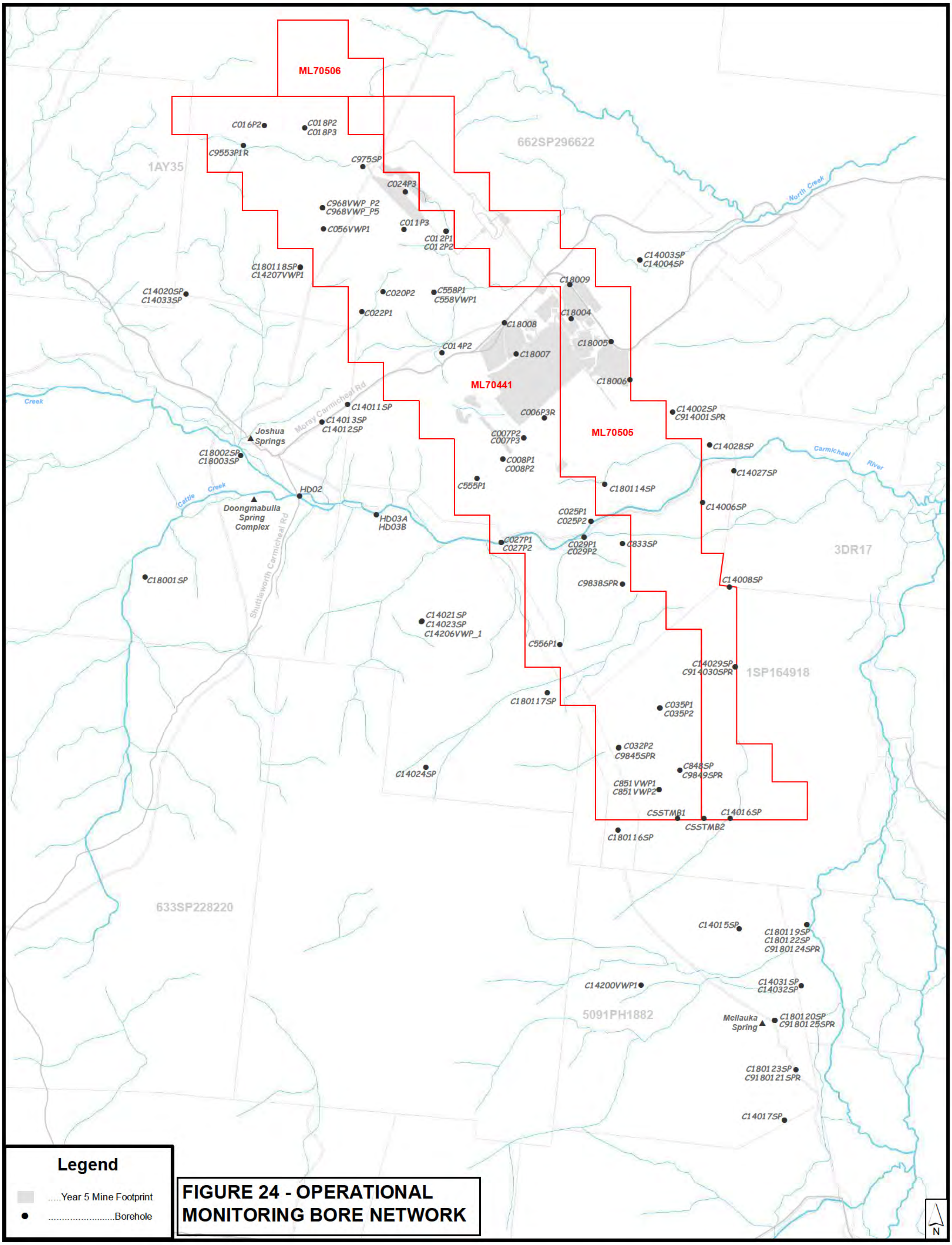

FIGURE 24 - OPERATIONAL MONITORING BORE NETWORK

CCM

DISCLAIMER: Every effort has been made to ensure the accuracy of the information contained on this map. As permitted by law, Adani is excluded from all liability to any person or entity with respect to any loss or damage caused directly or indirectly by their use of the information contained on this product. Changes and additions to the information contained on this map are made frequently. Adani may make such changes and additions at any time. Adani does not warrant the accuracy of the information contained on this map.

Scale Bar: 0 1 2 3 4 Kilometres

Location Map

adani

TITLE

Groundwater Management & Monitoring Program

Operational Monitoring Bores

REV	DESCRIPTION	DATE
0	Original map output	20180516
1	Layout Change	20180530
2		
3		

SCALE	1:175,000	CURRENT ISSUE SIGNATURES	
SIZE	A3	DRAWN	PCH
DATUM		CHECKED	SY
PROJECTION		APPROVED	SY

STATUS: Rev 1

PROJECT NO: CCM

DRAWING NO: 20180530_CCM_0000000_GWMMP_MonitoringBore_Rev1_P_A3

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Table 58 Groundwater monitoring locations and frequency for the Operational GMMP

Monitoring Point[26]	Monitoring	Location		Surface RL (mAHD)[27]	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)			
Alluvium						
HD03B	Water level and quality	427559.00	7556120.00	229.41	At least 2 to 3 monthly	Triggers for west – always saturated alluvium due to spring discharge into creek
C029P1	Water level and quality	437691.19	7555082.39	225.438		Bore specific triggers for non-perennial bores to the east
C025P1 (and new bore adjacent to C025P1)	Water level only	438015.54	7555845.80	227.54		
C14028SP	Water level and quality	443775.64	7559581.18	218.86		
C14027SP	Water level only	444964.65	7558330.02	217.56		
C027P1	Water level and quality	433643.08	7554818.39	226.95		
Tertiary Sediments						
C029P2	Water level and quality	437687.63	7555080.91	225.37	At least 2 to 3 monthly	Triggers for C029P2 +C025P2 (same water type)
C025P2	Water level and quality	438010.34	7555844.69	227.48		
C558P1*	Water level and quality	430311.55	7566903.06	250.07		Bore specific triggers
C9180121SPR	Water level and quality	448085.12	7529363.93	226.46		Unit specific triggers
C9845SPR	Water level and quality	439410.87	7544903.28	255.41		

[26] Monitoring is not required where a bore has been removed as a direct result of the mining activity.
[27] Locations, monitoring frequency and surface RL to be finalised based on information provided to the administering authority under condition E8 (a)

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Monitoring Point[26]	Monitoring	Location		Surface RL (mAHD)[27]	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)			
Clematis Sandstone						
C180118SP	Water level and quality	423796.76	7568090.93	306.63	At least 2 to 3 monthly Bore C180118SP is reported to be blocked; this bore is to be replaced	Unit specific triggers
C14033SP	Water level and quality	418210.80	7566775.83	296.47		
C14011SP	Water level and quality	426130.96	7561454.81	311.66		
C14012SP	Water level and quality	424896.07	7560596.18	286.37		
C14013SP	Water level and quality	424895.49	7560591.10	286.46		
HD02	Water level and quality	423822.04	7557008.25	236.35		
C18001SP (new bore no dataset yet)	Water level and quality	416311.50	7553052.04	246.97		
C18002SP (new bore no dataset yet)	Water level and quality	420948.12	7558952.34	248.30		
HD03A	Water level and quality	427562.00	7556132.00	229.41		Triggers for HD03A and C14021SP – based on Cl and geology, Moolayember Formation cover thin or non-existing
C14021SP	Water level and quality	429796.25	7550966.33	277.59		
Dunda Beds						
C027P2	Water level and quality	433648.21	7554818.54	227.58	At least 2 to 3 monthly	Bore specific triggers – outlier bore
C022P1	Water level and quality	426812.52	7565961.84	273.76		Unit specific triggers
C14023SP	Water level only	429801.74	7550968.73	277.67		
C180117SP	Water level and quality	435915.16	7547522.16	279.59		

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Monitoring Point[26]	Monitoring	Location		Surface RL (mAHD)[27]	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)			
Rewan Formation						
C556P1	Water level and quality	436524.08	7549881.55	260.63	At least 2 to 3 monthly	Unit specific triggers
C555P1	Water level and quality	432461.38	7557892.99	241.15		
C180116SP	Water level only	439392.91	7540908.81	260.82		
C9838SPR	Water level and quality	439557.91	7552811.73	228.81		
C9553P1R	Water level and quality	421010.11	7573974.87	294.114		
C035P1	Water level and quality	441403.59	7546823.81	236.31		Bore specific triggers – outlier bore
C008P1	Water level and quality	433712.50	7558833.75	238.14		Bore specific triggers – outlier bore Bore C008P1 was not included in baseline monitoring program due to proximity to C555P1 – reinstated for operational monitoring due to difference to other bores in Rewan Formation

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Monitoring Point[26]	Monitoring	Location		Surface RL (mAHD)[27]	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)			
Bandanna Formation (AB Seam)						
C007P2*	Water level and quality	434728.01	7559861.98	238.11	At least 2 to 3 monthly	Bore specific triggers – outlier bore Bore C007P2 was not included in baseline monitoring program (2014 – 2016) due to proximity to C008P2 – reinstated for operational monitoring due to difference to other bores in AB Seam bores
C14206VWP_1	VWP – assessment of depressurisation trends only	429783.15	7550956.80	227.15		No quality triggers
C14207VWP1		423806.63	7568105.26	305.17		
C14200VWP1		440547.49	7533418.60	247.08		
C968VWP_P5*		424873.59	7570989.17	279.18		
C851VWP1*		441384.00	7542877.33	244.67		
C851VWP2*		441384.00	7542877.33	244.75		
C016P2	Water level and quality	422017.38	7574974.58	294.45		Unit specific triggers
C032P2*	Water level and quality	439404.36	7544896.02	256.32		
C008P2*	Water level and quality	433710.27	7558830.28	238.12		
C014P2*	Water level and quality	430731.00	7563976.07	255.99		
C020P2*	Water level and quality	427845.47	7566931.73	263.06		
C035P2*	Water level and quality	441401.68	7546827.75	236.24		