Groundwater Dependent Ecosystem Management Plan

Carmichael Coal Mine Project

Prepared for
Adani Mining Pty Ltd

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DOCUMENT TRACKING

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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)	Describes required offsets for unavoidable residual impacts to MNES	EPBC Approval Conditions 8-13 EA Approval Condition I1	The BOS outlines offset requirements for MNES including relevant GDEs
GAB Offset Strategy	Describes required offsets for indirect impact to Great Artesian Basin (GAB) aquifers		The GAB Offset Strategy addresses indirect impacts to GAB aquifers
Offset Area Management Plans (OAMPs)	Describes specific management actions for properties to be used as offsets under the BOS		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 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.

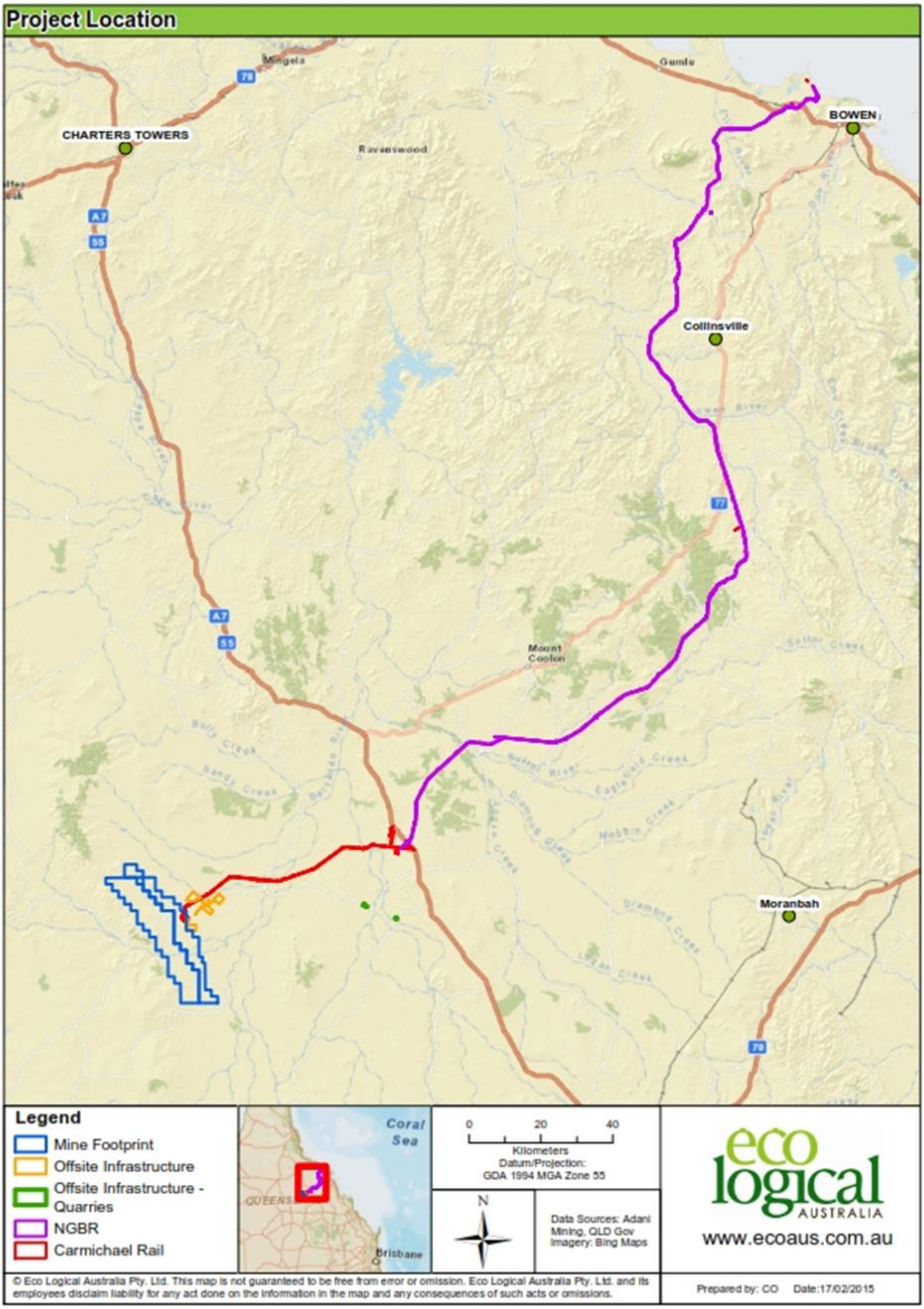


Figure 2-1: Project location.

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.

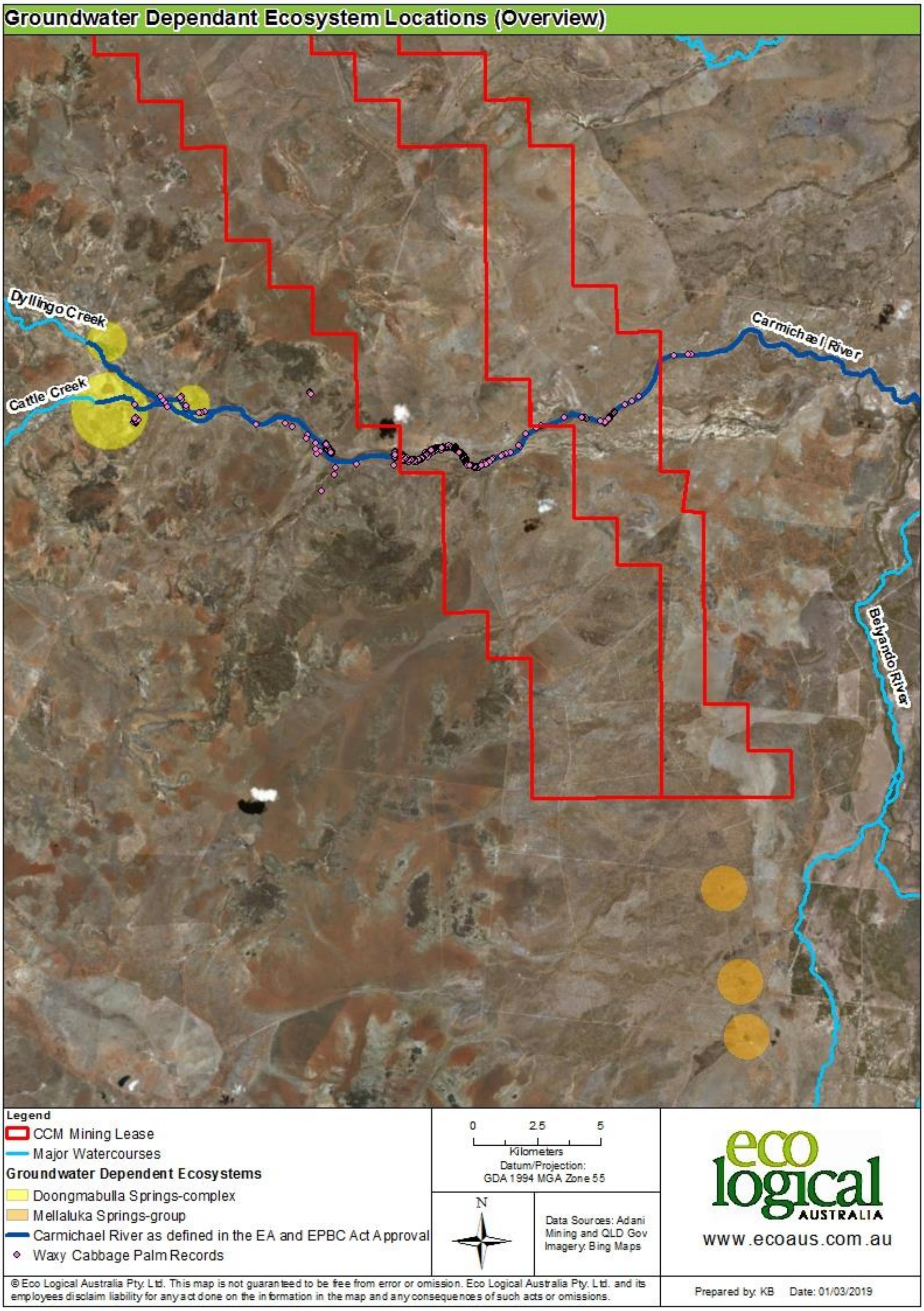


Figure 4-1: Groundwater Dependent Ecosystems in Project area

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 modelling 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.

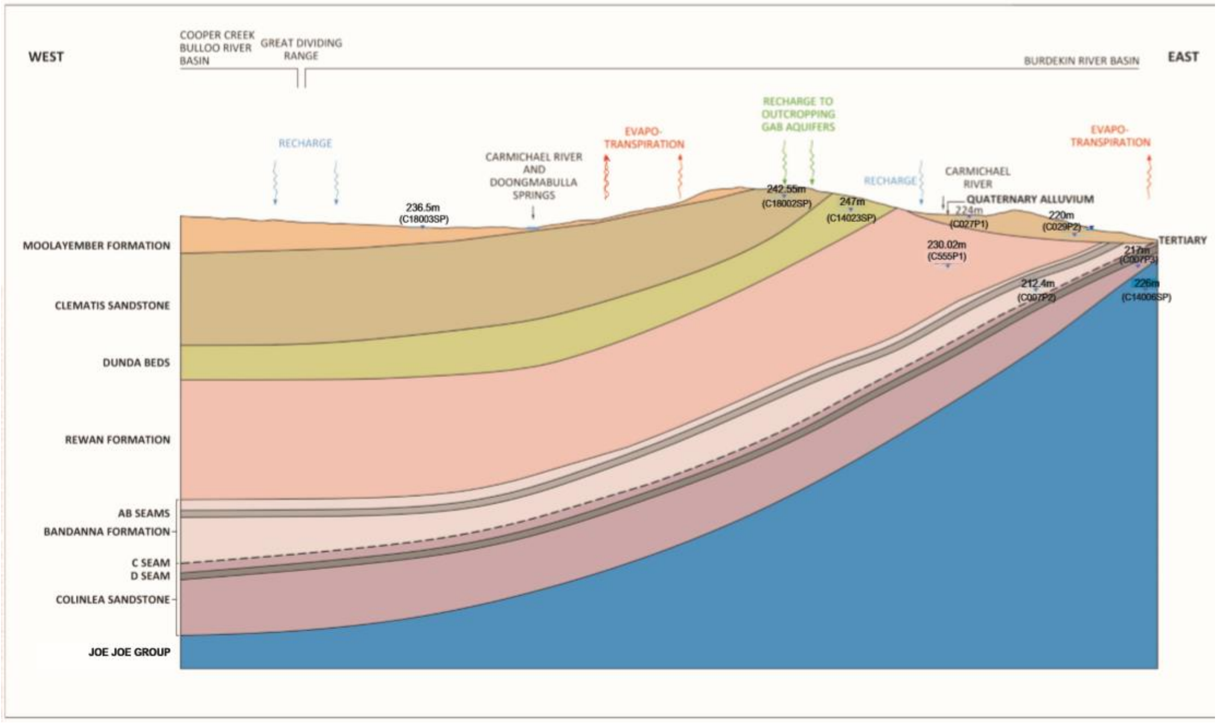


Figure 4-2: Hydrogeological conceptual model – pre-mining

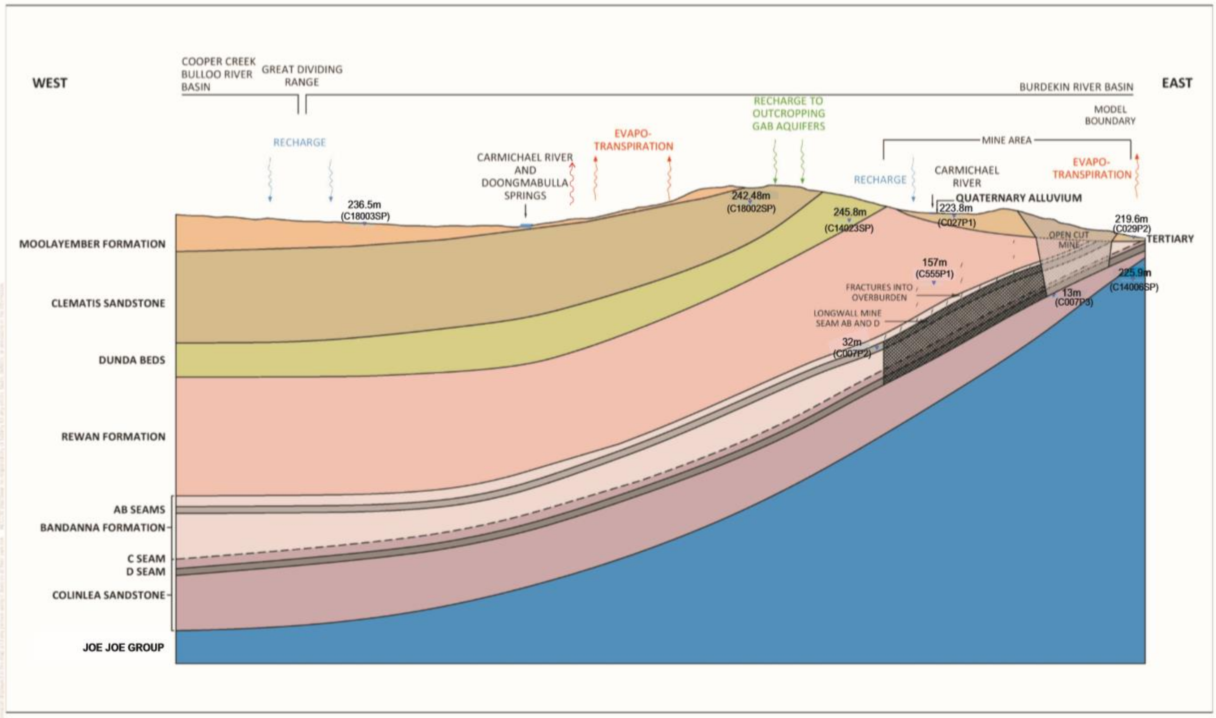


Figure 4-3: Hydrogeological conceptual model – mining & post-mining

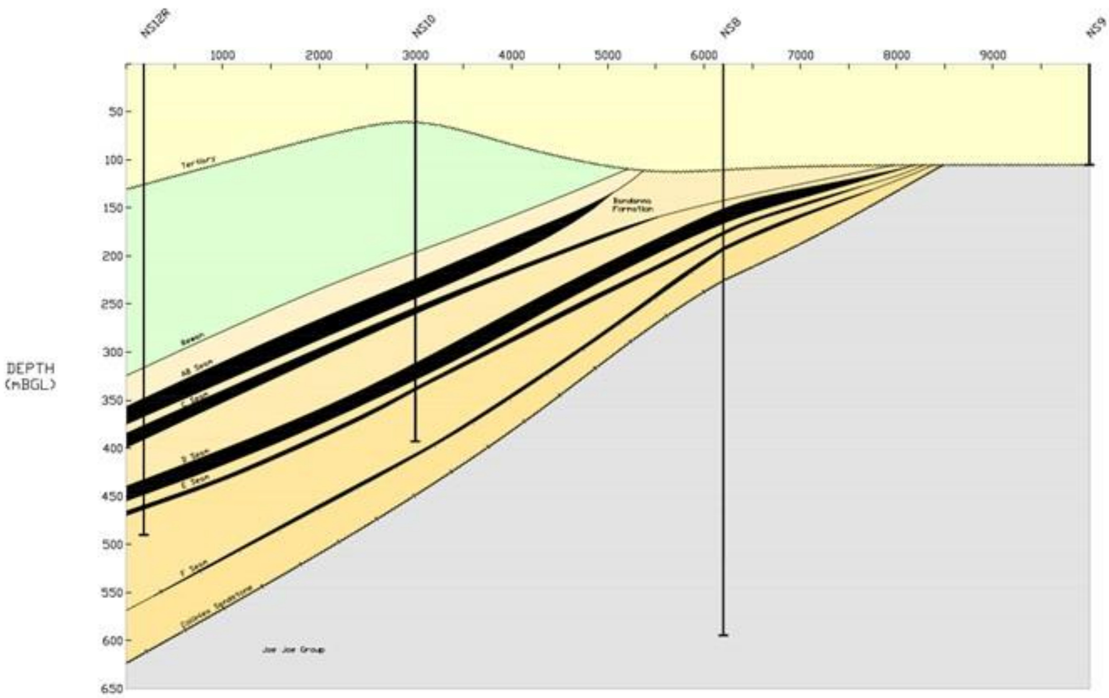


Figure 4-4 Cross section showing Joe Joe Group and Mellaluka Springs-complex – bores shown are government exploration bores (Source: GMMP)

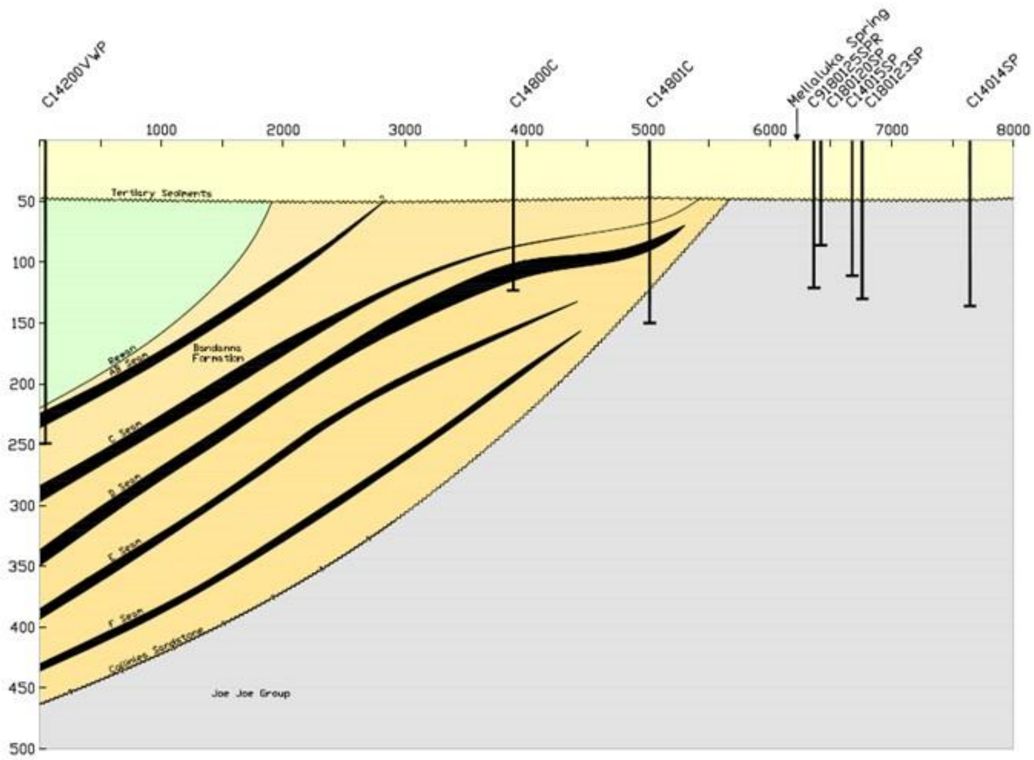


Figure 4-5 Cross section showing Joe Joe Group and Mellaluka Springs-complex. Water levels (Artesian) are: C9180125SPR 243.10 mAHD, C180120SP 243.48 mAHD, C14015SP 239.15 mAHD and C14014SP 239.32 mAHD. Remaining bores are government exploration bores (Source: GMMP)

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		C025P2 (41.00) 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	C027P2 (32.80) C14023SP (165.60)	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.

This GDEMP will be updated with revised triggers for monitoring indicators after a period of 12 months (from the date of approval). New triggers for monitoring indicators that do not yet have a specified trigger will be nominated at this time, based on the findings of pre-impact field surveys. Thereafter, triggers will be reviewed and refined on an annual basis, informed by the collection and analysis of additional information from ongoing field surveys.

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 Monitoring descriptions and indicators

Consistent ecological monitoring descriptions and indicators have been developed in response to the established environmental baseline. These are described in detail in the monitoring section of each GDE Chapter (Section 6 to Section 9). The monitoring of each indicator will allow for an assessment of the condition once impacts 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.

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.

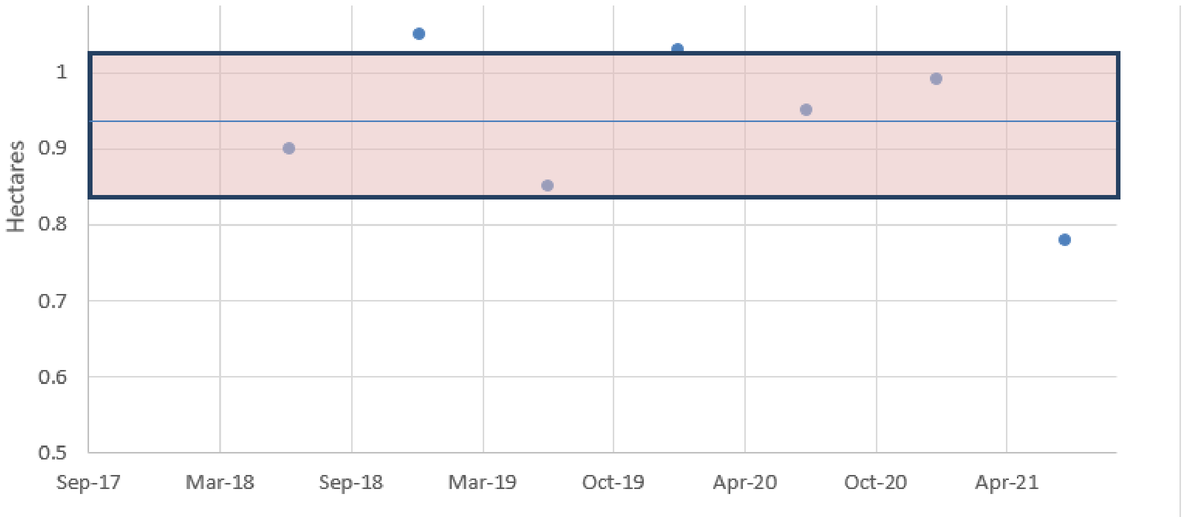


Figure 5-1: Example of application of a control chart to assess changes in ecological variables (mid-line indicates long term mean, with the limits of a statistically significant change shaded in pink)

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. 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).

Ecological triggers will be reviewed and if required, updated upon groundwater model review, when the conceptual understanding (e.g. source aquifer) changes, pre-impact data are collected prior to the impact phase (for each relevant impact) and once Environmental Water Requirements of GDEs are known. The timing of these changes are outlined in **Appendix C**.

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).

5.9 Additional Studies, Research and Model Re-run

Adani commits to undertake and complete studies and additional work sequentially over the first two years for the purpose of refining the groundwater numerical model and the hydrogeological conceptualisation as required by EA Condition E6.

These additional works include:

- Hydrogeochemical analysis across the Doongmabulla springs-complex from groundwater and surface water samples. This includes isotopic analysis and will also include noble and radioactive gases and strontium isotopes where isotopic analysis is not sufficient to significantly improve understanding and reduce uncertainty in relation to source aquifer(s) of the Doongmabulla Springs-complex
- Acquiring, testing and examining any new cores samples generated through new bore holes (dependent on the integrity of these samples)
- As part of the new nested bores committed to be drilled in the GMMP (Section 7), Adani will install one hole below the Rewan in the vicinity of the Doongmabulla Springs-Complex, within the Permian Betts Creek Beds (which includes the Bandanna and Colinlea).

Baseline research on GDEs is provided in sections 6.1, 7.1, 8.1 and 9.1. Future research activities on the wetland composition of the Doongmabulla and Mellaluka Springs-complexes will be undertaken through the GABSRP, summarised in section 5.9.2. Baseline research on source aquifers is presented in sections 6.2, 7.2, 8.4 and 9.4. Future research is noted in the GMMP (Section 1.10) and in the RFCRP and GABSRP. The GMMP (Section 5 and Table 42) provides details on the natural variation of groundwater level and pressure and how this will be monitored over time against the predicted groundwater levels. The ecological response to groundwater level fluctuation is a key component of the GABSRP (Section 5.9.2)

Within two years of commencement of mining activities, the groundwater model is to be reviewed and re-run with the subsequent provision of updated hydrogeological conceptualisation/s and reporting that details the information that was or was not used for this exercise, the supporting reasons for that approach, and detailed findings of this model re-run and revision of the conceptual understanding of the source aquifer(s) and how these will in turn inform the revised GDEMP and GMMP. A key outcome of this exercise is to refine/improve the understanding and decrease the uncertainty surrounding source aquifer/s for each GDE.

The GMMP provide details under section 7, commitment 24 on matters to be included in that model re-run.

Specifically, this will include:

- A comprehensive review of groundwater level and quality data from across the monitoring network
- Hydrochemistry analysis from groundwater and spring samples from different spring groups within each spring complex as conducted through the additional studies
- Inputs from research programs such as the RFCRP and the GABSRP
- Attain a better understanding of the intact hydrostratigraphy to assess and quantify hydraulic properties from geological information gathered from new bores and core samples, geological mapping and research studies
- Incorporate Geoscience Australia airborne Electro-magnetic modelling
- Review of groundwater modelling network and locations for ongoing optimisation.
- Adani commits to systematically consider the sources of uncertainty as they pertain to each source aquifer and modelling limitations and document this consideration
- Inclusion of all relevant parameters in a range of modelled scenarios that encompass the identified uncertainties
- Selection of appropriate model spatial scale to account for local and regional parameters including scale dependent parameters such as hydraulic conductivity
- Uncertainty analysis and estimation in accordance with relevant guidelines
- Revision of groundwater drawdown rates for continuing appropriateness
- Revision of early warning triggers for continuing appropriateness

At the second model re-run (7 years after commencement of box cut), Adani will specifically review both the hydrogeological conceptualisation arising from model review and hydrochemistry analysis and seismic information pertaining to the impacts of underground mining. This mining activity is not scheduled to commence until year 10, and a number of precursors are required before it commences.

At the second model re-run (7 years after commencement of box cut), Adani will specifically review both the following:

- hydrogeological conceptualisation arising from model review and hydrochemistry analysis, consistent with and refined from the first model re-run (2 years after commencement of box cut); and
- seismic information pertaining to the impacts of underground mining. This mining activity is not scheduled to commence until year 10, and a number of precursors are required before it commences.

If this review determines that additional seismic studies are required to determine the source aquifers of the Doongmabulla Springs Complex, these activities will be completed and that information included into revised modelling. Underground mining will not commence until these actions are completed and only if predicted impacts are consistent with approved impacts. Likewise, if the hydrogeological conceptualisation differs from that of the approved project, approval must be sought prior to relevant impact causing activities, if predicted impacts also differ from those approved.

Further, if any groundwater model re-run, or bore monitoring results, determine:

- unauthorised impacts may or have occurred to the Doongmabulla Springs-complex from commencement of dewatering operations into the long term post closure; or
- the unlikely scenario that the Permian is an additional source to the Doongmabulla Springs-complex

the following mitigation measures and corrective actions will be put in place:

- Limiting thickness of extraction of coal seams and reviewing extraction of multiple coal seams for the underground longwall mining in order to minimise drawdown impacts to Doongmabulla Springs-complex
- Freezing mine development at current levels until the completion of investigations and assessments which demonstrate and conclude that further development will not exceed approved impacts
- Assess the water balance / budgets and evaluate losses at the Doongmabulla Springs-complex, in the context of the Permian being a possible additional source of groundwater.

5.9.1 Rewan Formation Research Plan

The Rewan Formation Connectivity Research Plan (RFCRP) is required under EPBC Approval conditions 27 and 28. The purpose of the plan is to characterise the Rewan Formation within the area impacted by the mine. The RFCRP will inform groundwater triggers, monitoring and management through adaptive processes under plans such as the GMMP.

The RFCRP will combine existing monitoring and modelling programs with an initial period of intensive desktop research primarily focussed on characterising the Rewan Formation and the contribution of fracturing, faulting and preferential pathways to connectivity within the area impacted by the mine. This will be followed by ongoing monitoring and further validation as operations commence.

The RFCRP concentrates on a one year intensive period of desktop research to meet specific conditions and provide outcomes which would then be validated and assessed once the mining process provides actual data that can be compared to predicted responses. The RFCRP is subject to Commonwealth Government approval, but it will aim to determine:

- The properties and characteristics that should be used for the Rewan Formation as relevant to groundwater model re-run

- The associated behaviour of fractured Rewan Formation following longwall mining subsidence as relevant to groundwater models
- The associated behaviour of other structures and conduits as relevant to groundwater models
- A revised 3D geological model for future groundwater model revisions.

Specific research packages under the RFCRP include:

1. Review of Data from Supplementary Field Investigations
2. Detailed geological interpretation of Rewan lithofacies from Existing data
3. Conceptualisation of groundwater resources associated with the Rewan
4. Assignment of hydraulic properties from supplementary field work and existing data sources
5. Reprocessing and interpretation of existing historical regional 2D petroleum seismic lines.
6. Mapping and modelling of fault styles, orientations, displacements and densities
7. Juxtaposition analysis
8. Shale Gouge Analysis and Fault membrane seal analysis
9. Assessment of fault leakage potential
10. Assessment of Longwall Mining Subsidence on hydraulic connectivity
11. Fault Zone Analysis
12. Pressure, geochemical and Isotope analysis
13. Literature and benchmarking studies

5.9.2 GAB Springs Research Plan

The Great Artesian Basin Springs Research Plan (GABSRP) will investigate, identify and evaluate methods to prevent, mitigate and remediate ecological impacts on the Doongmabulla Springs-complex as required by EPBC Approval Conditions 25 and 26. It informs ecological triggers, monitoring and management through adaptive processes (see Section 1.4 for more details).

The scope of the GABSRP is focused on the Doongmabulla Springs Complex, however, the aim is to ensure that research outcomes delivered under this plan can be applied to other similar communities of native species dependent on natural discharge of groundwater from the Great Artesian Basin. The GABSRP is subject to Commonwealth Government approval, but it will aim to determine:

- Predicted hydrological changes due to project activities, in terms of magnitude and timing, relative to background trends and influences
- Predicted hydrological changes likely impact the GAB Springs Community in the Galilee Basin
- How ecological impacts to the GAB Springs Community in the Galilee Basin can be prevented or mitigated
- how any ecological impacts to the GAB Springs Community in the Galilee Basin be remediated or offset.

A number of research packages will be implemented under the Plan. Research will be governed through an independent technical review panel, conducted by appropriately experienced researchers, scientists and professionals, implemented over a 5 year period and research findings will be made publicly available as well as being incorporated into the GDEMP and GMMP through annual review processes, through mode re-run processes and through the conclusion of each research package.

The research packages are:

1. Hydrogeology review and monitoring
2. Geochemical survey
3. Geological mapping

4. Spring wetland hydro-geological conceptualisation and water balance
5. Rewan formation connectivity investigations
6. Regional hydrogeology conceptualisation review
7. Ecological survey and monitoring
8. Hydrogeological conceptualisation and assessment of key species
9. Desktop prevent and mitigation study
10. Remediation assessments and trials
11. Remediation and offset strategies

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)

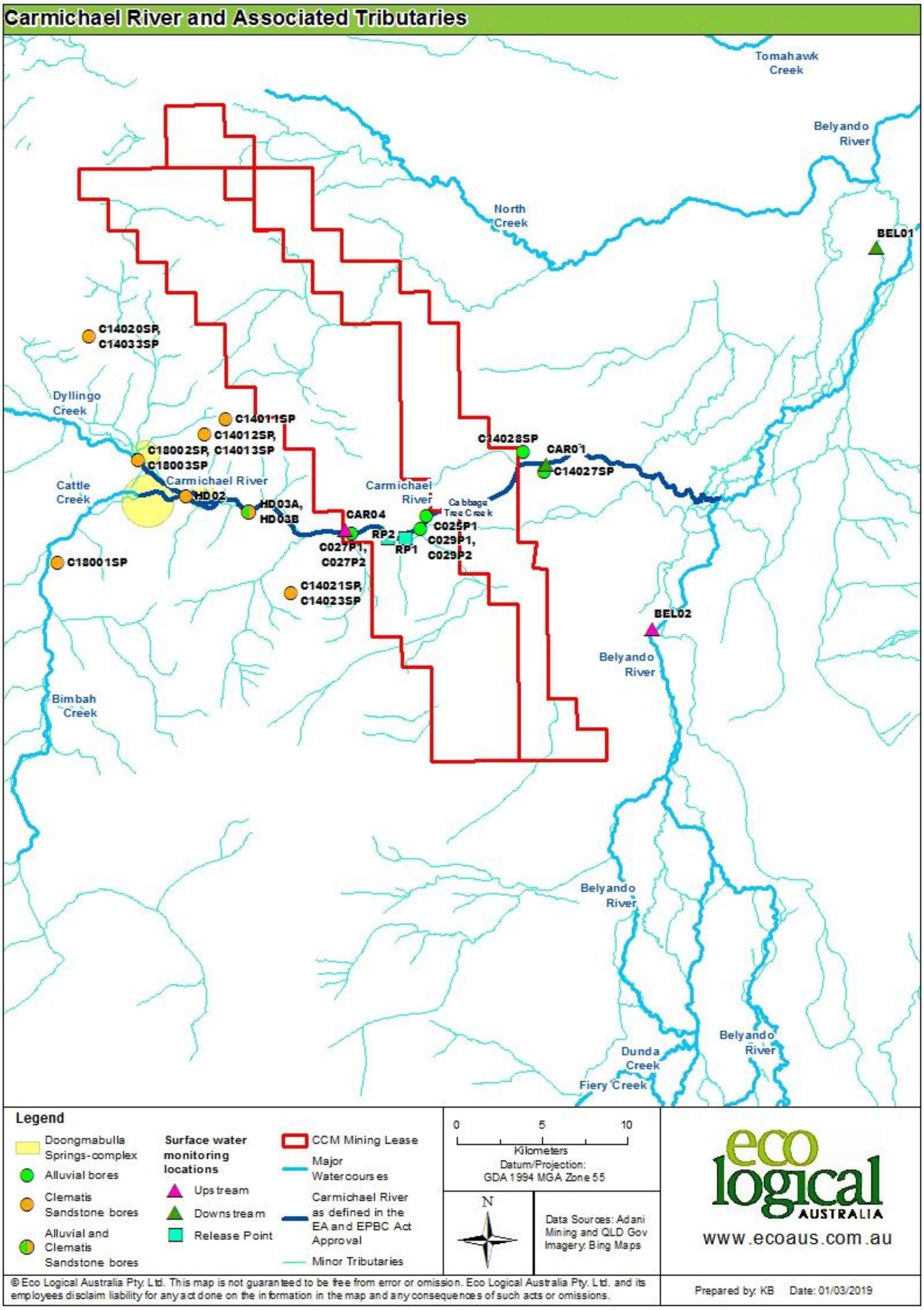


Figure 6-2 Carmichael River and Associated Tributaries

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.

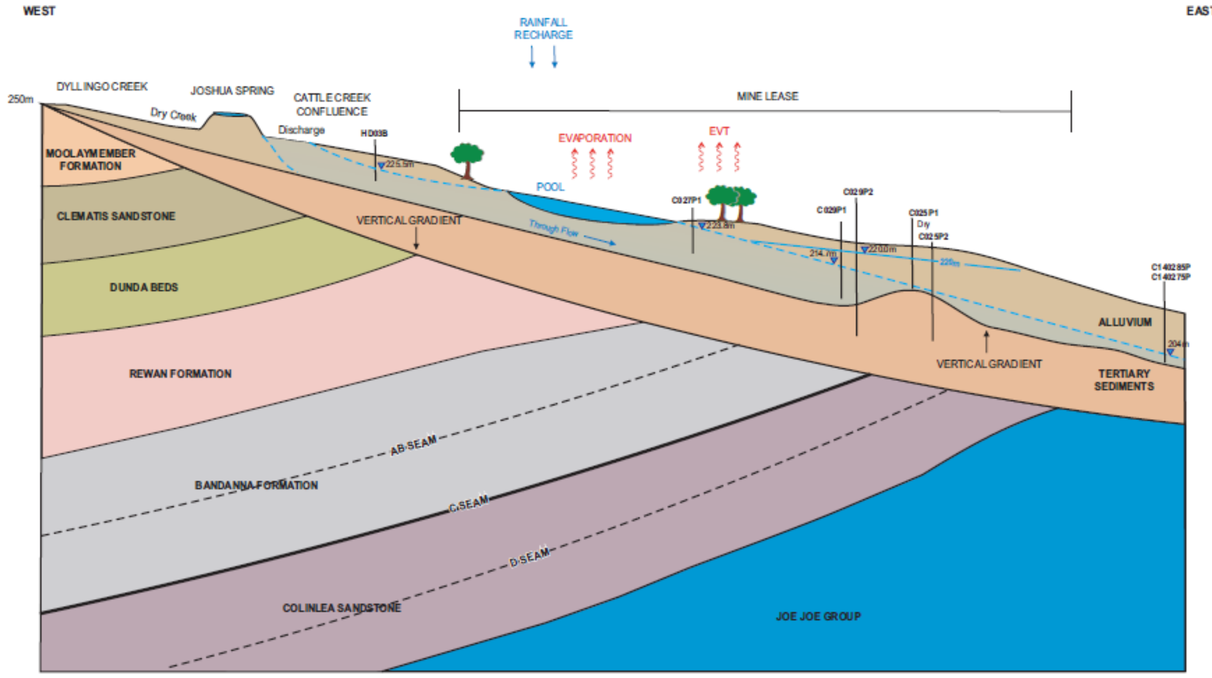


Figure 6-3 Conceptual model of Carmichael River

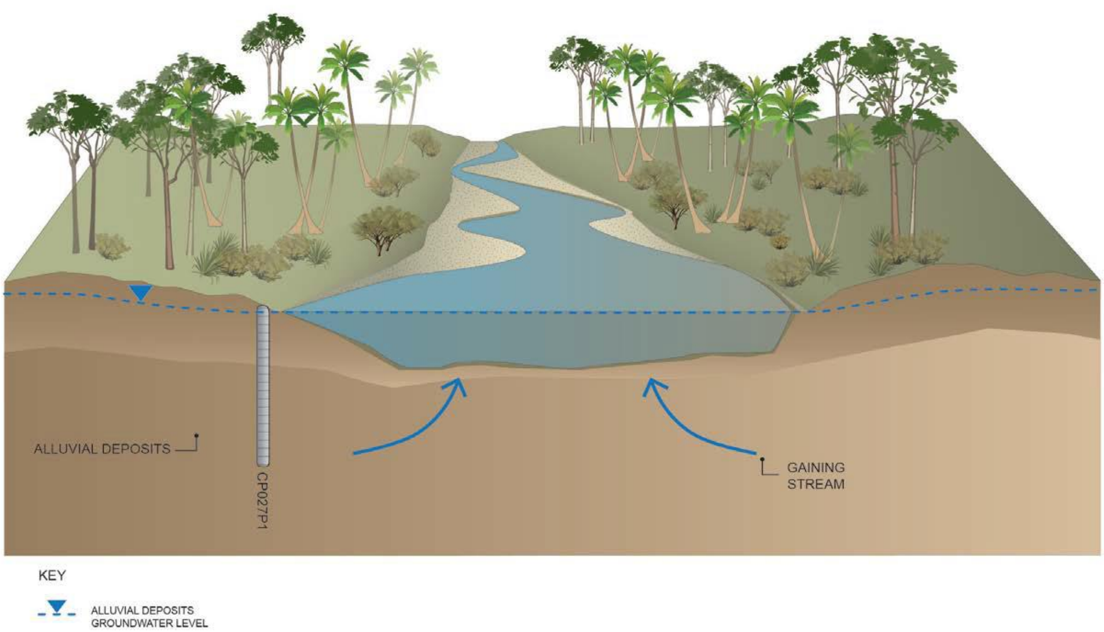


Figure 6-4 Gaining Section of the Carmichael River

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.

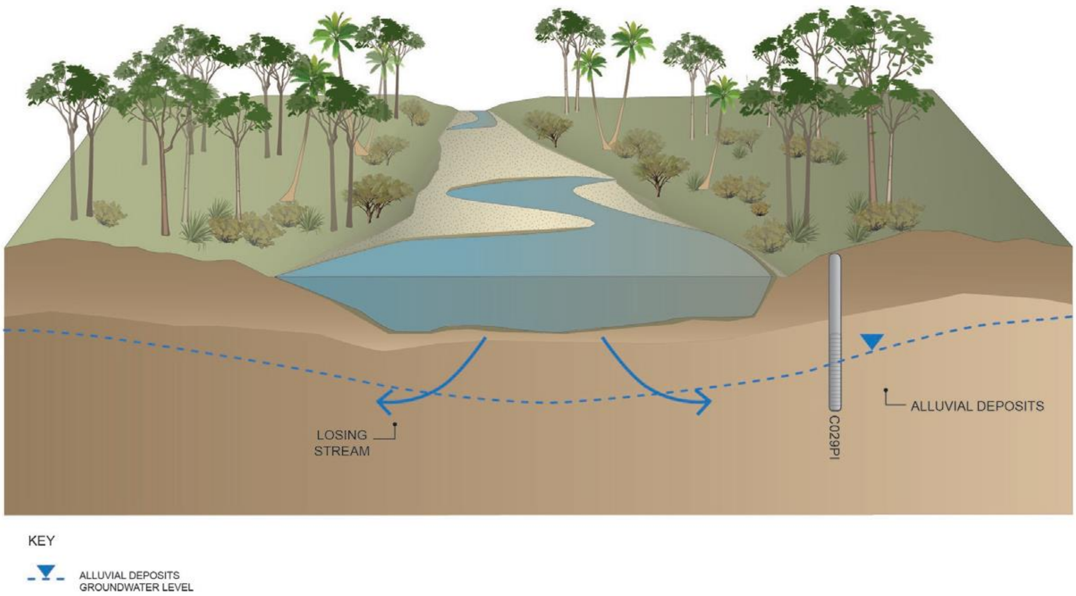


Figure 6-5 Losing Section of the Carmichael River

6.3 Summary of baseline monitoring results

6.3.1 Surface Water

The Carmichael River, designated as a fifth order stream (DERM, 2009c), 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.

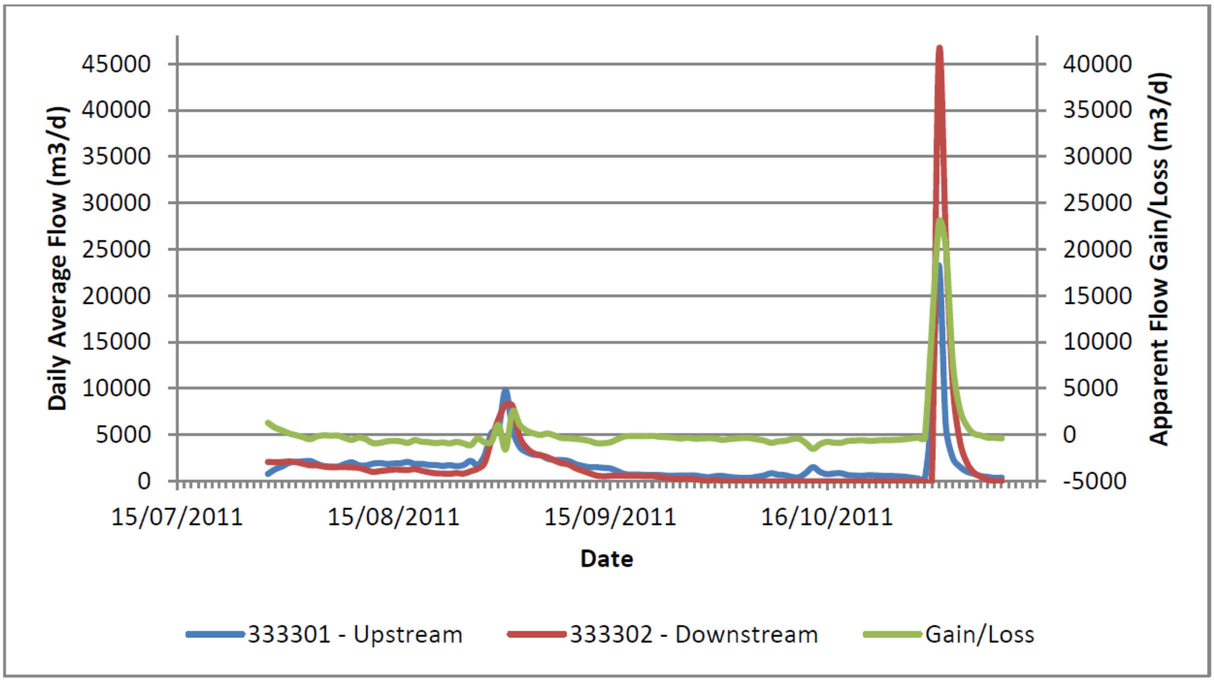


Figure 6-6 Surface water flows and losses in the Carmichael River (EIS)

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

Parameter	Unit	Selected WQO	Source of WQO
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.

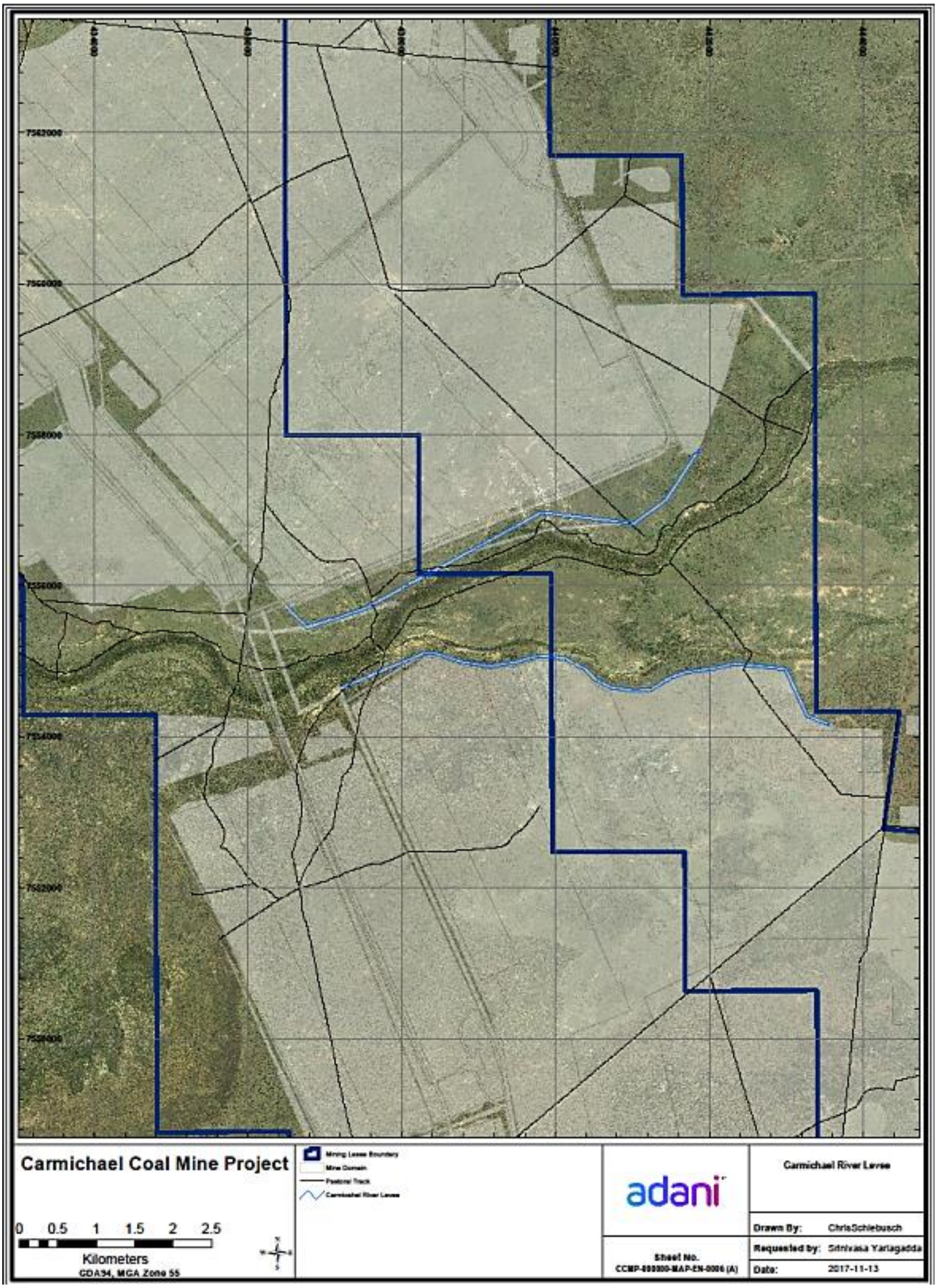


Figure 6-7 Levees to be constructed on the northern and southern sides of the Carmichael River

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	**Table 6-11**
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	
7	Weeds and pest	-	Yes	(c)(ix)	(5)	Pre-construction Construction Operations Rehabilitation	Year 1	
8	Earthworks	-	Yes	(c)(iv)	-	Construction Operations	Year 5	
9	Noise and vibration	-	-	(c)(v)	-	Construction Operations	Unlikely to impact, but may occur from Year 1	
10	Emissions (including dust)	-	Yes	(c)(vi)	-	Construction Operations	Unlikely to impact, but may occur from Year 1	
11	Light spill and other visual impacts	-	-	(c)(vii)	-	Construction Operations	Unlikely to impact, but may occur from Year 1	

#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**).

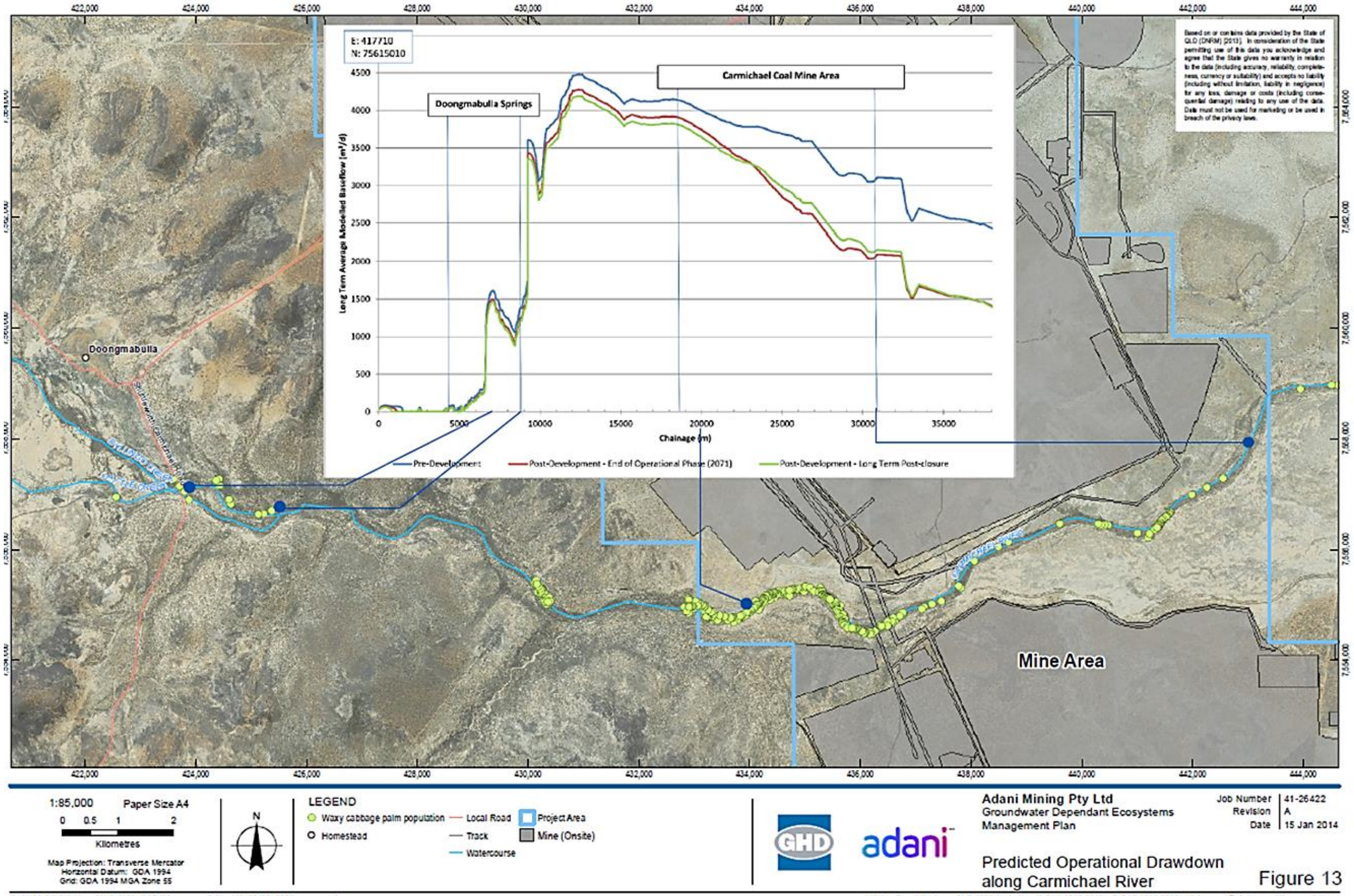


Figure 6-8 Predicted base flow impacts to the Carmichael River

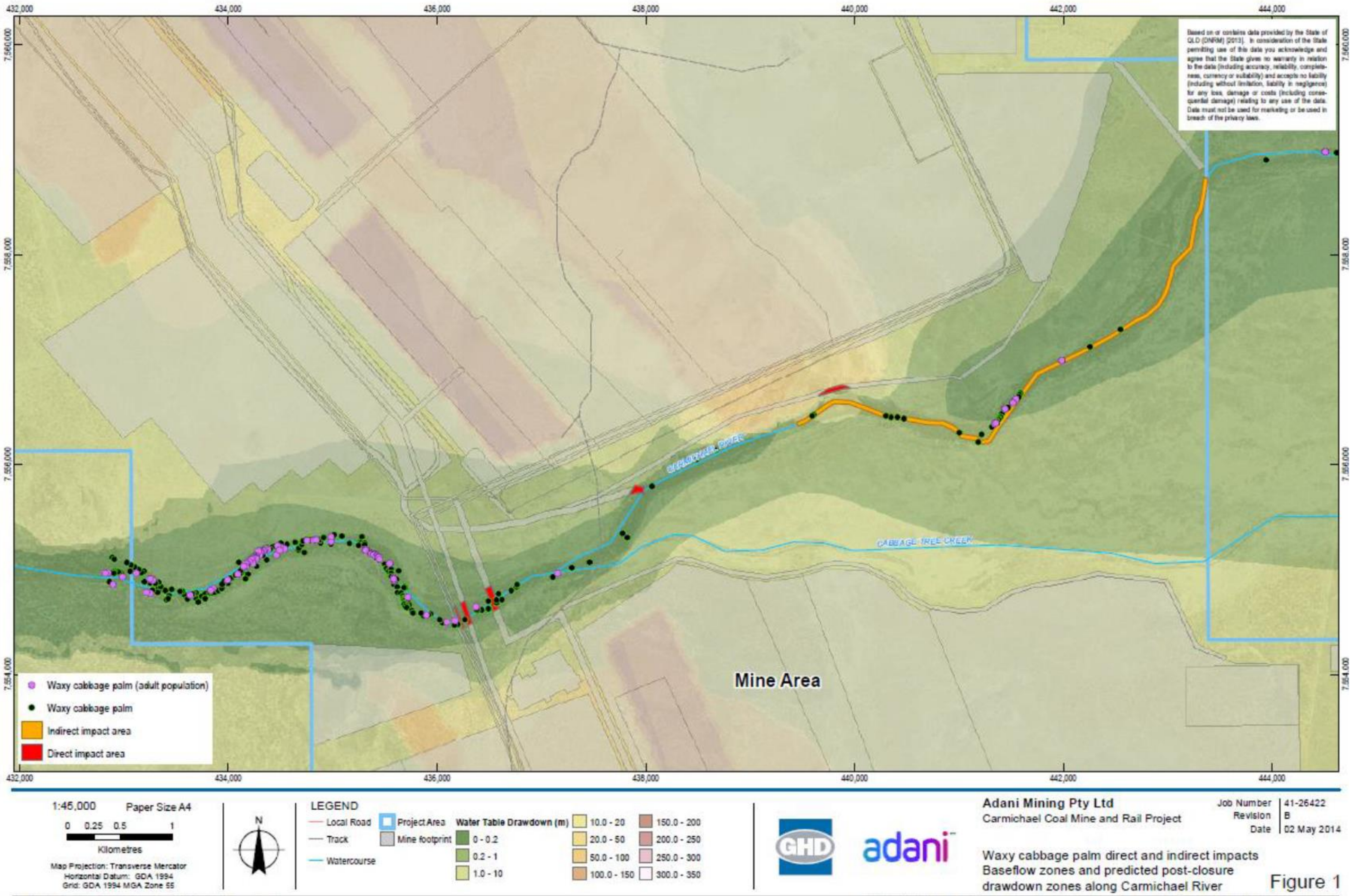
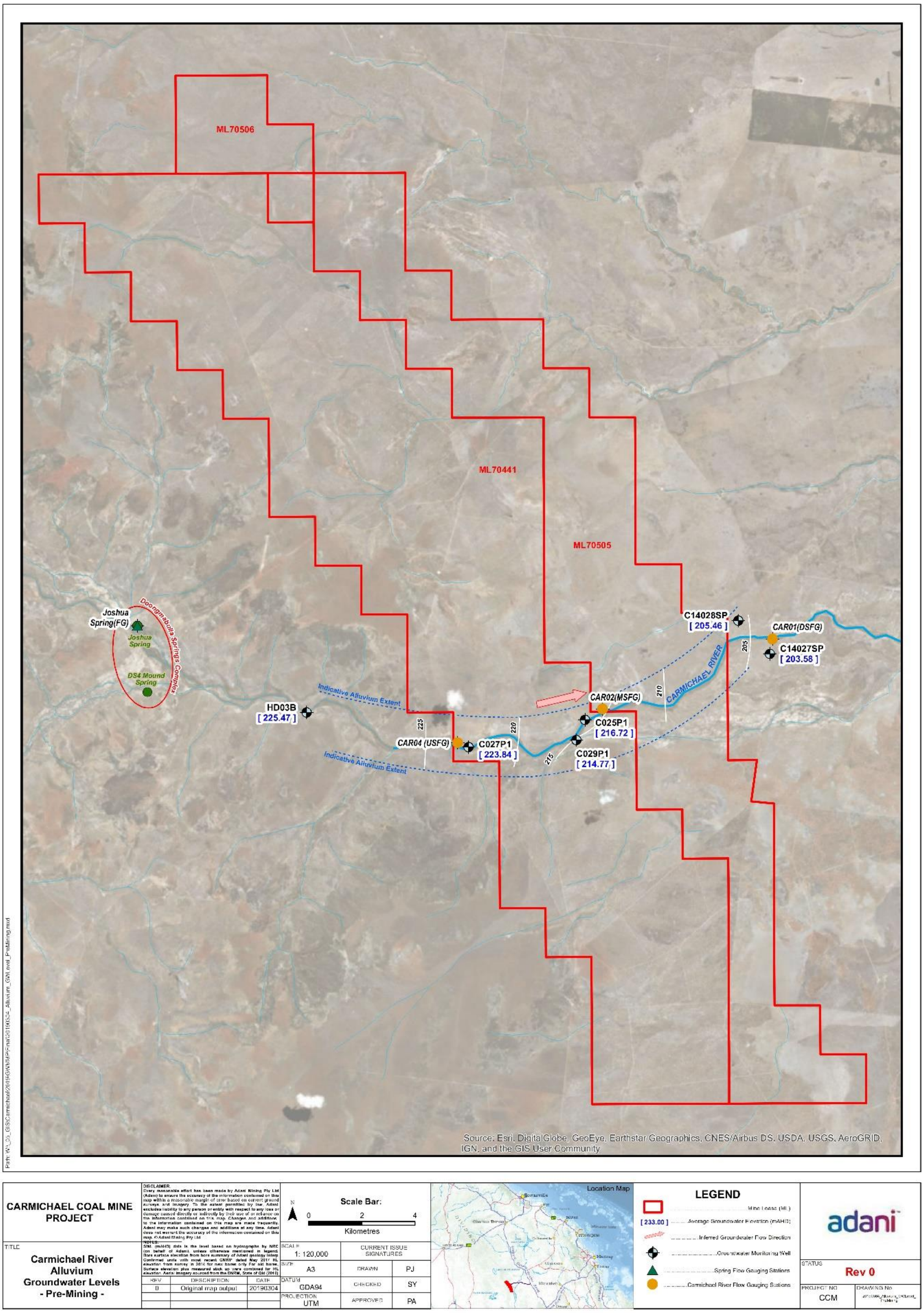


Figure 6-9 Predicted groundwater drawdown impacts to the Carmichael River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CARMICHAEL COAL MINE PROJECT
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Carmichael River Alluvium Groundwater Levels - Pre-Mining -
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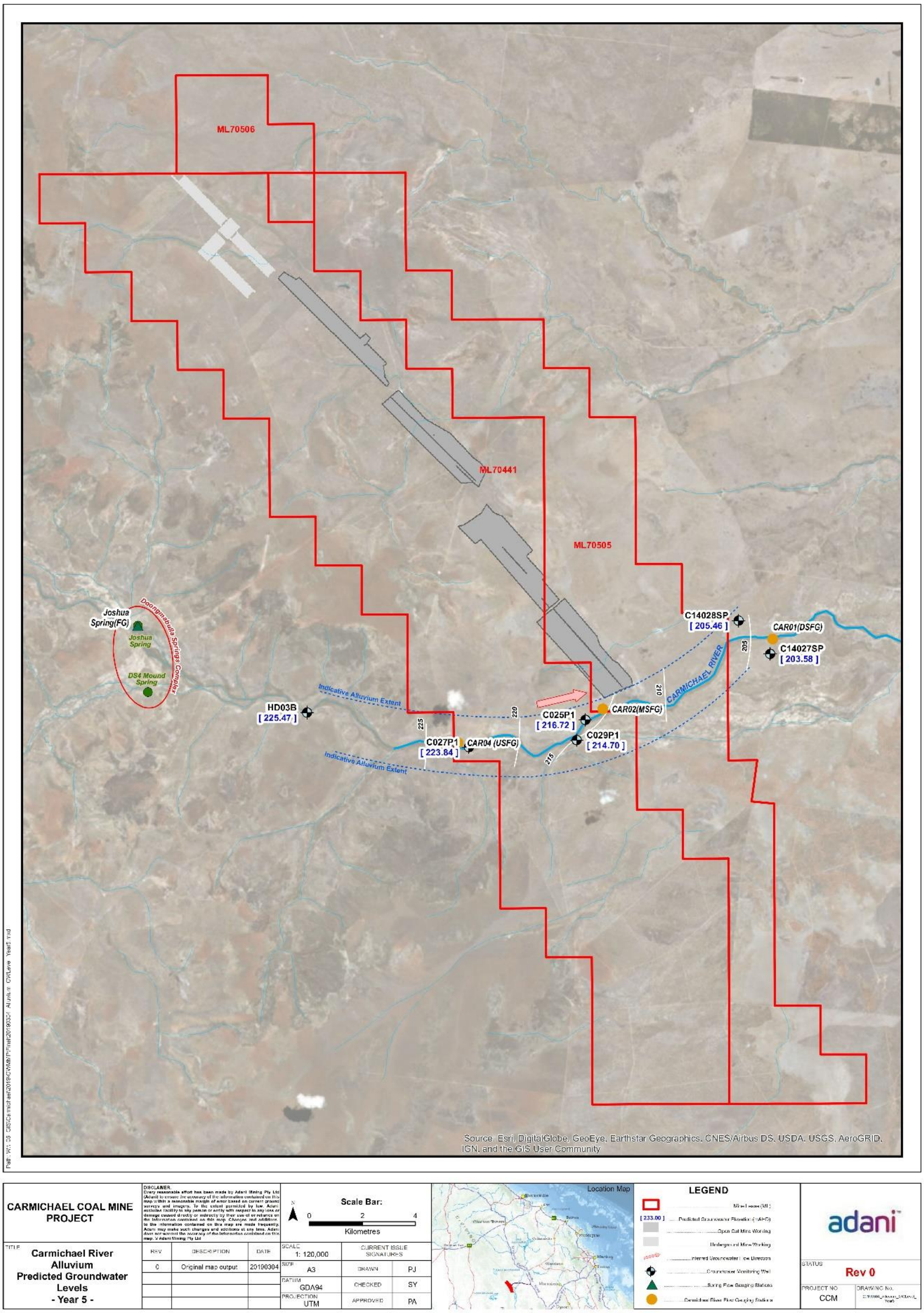
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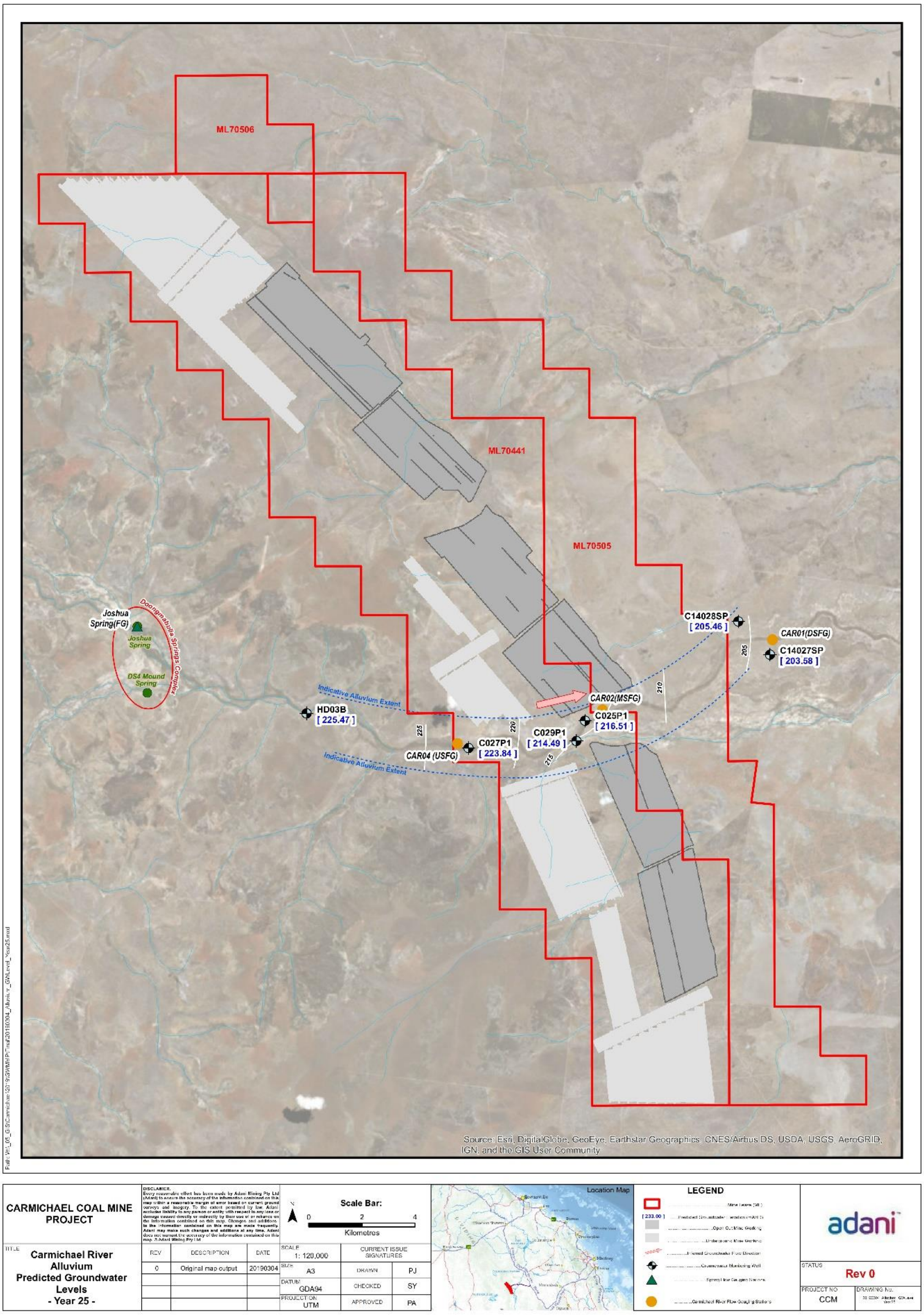
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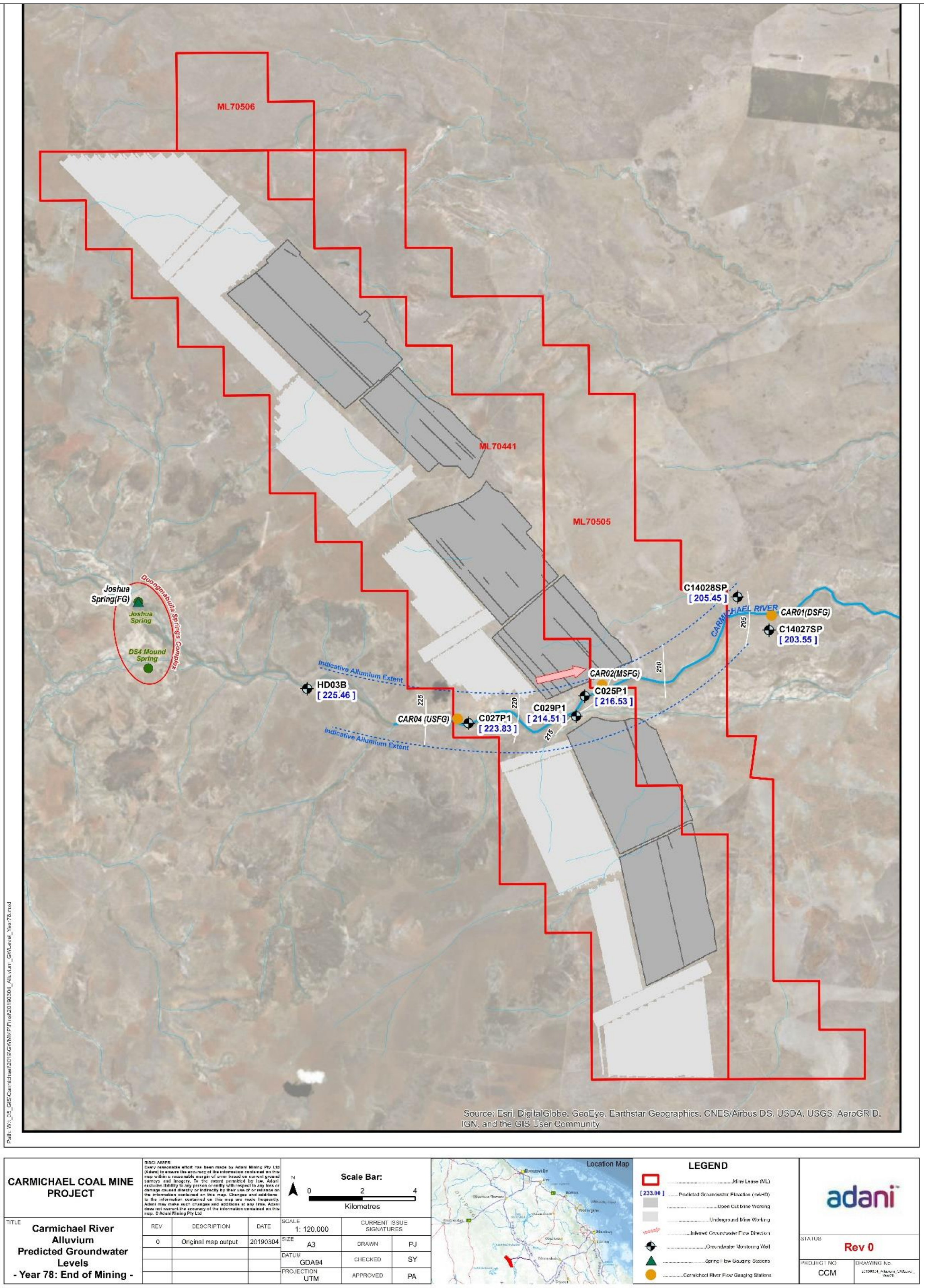


Figure 6-10 a-d Predicted Alluvial aquifer impacts associated with the Carmichael River

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 6-11** 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 6-11** 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.

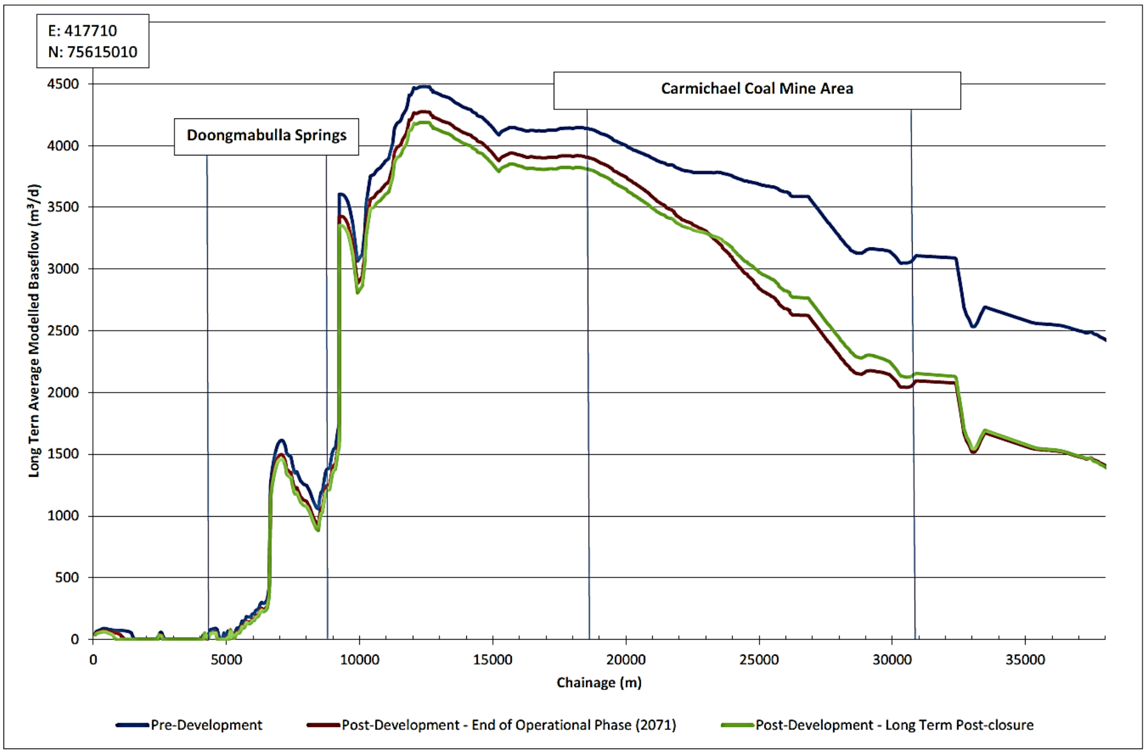
The EIS projected changes to flow rates in the Carmichael River as a result of the following:

- 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**.

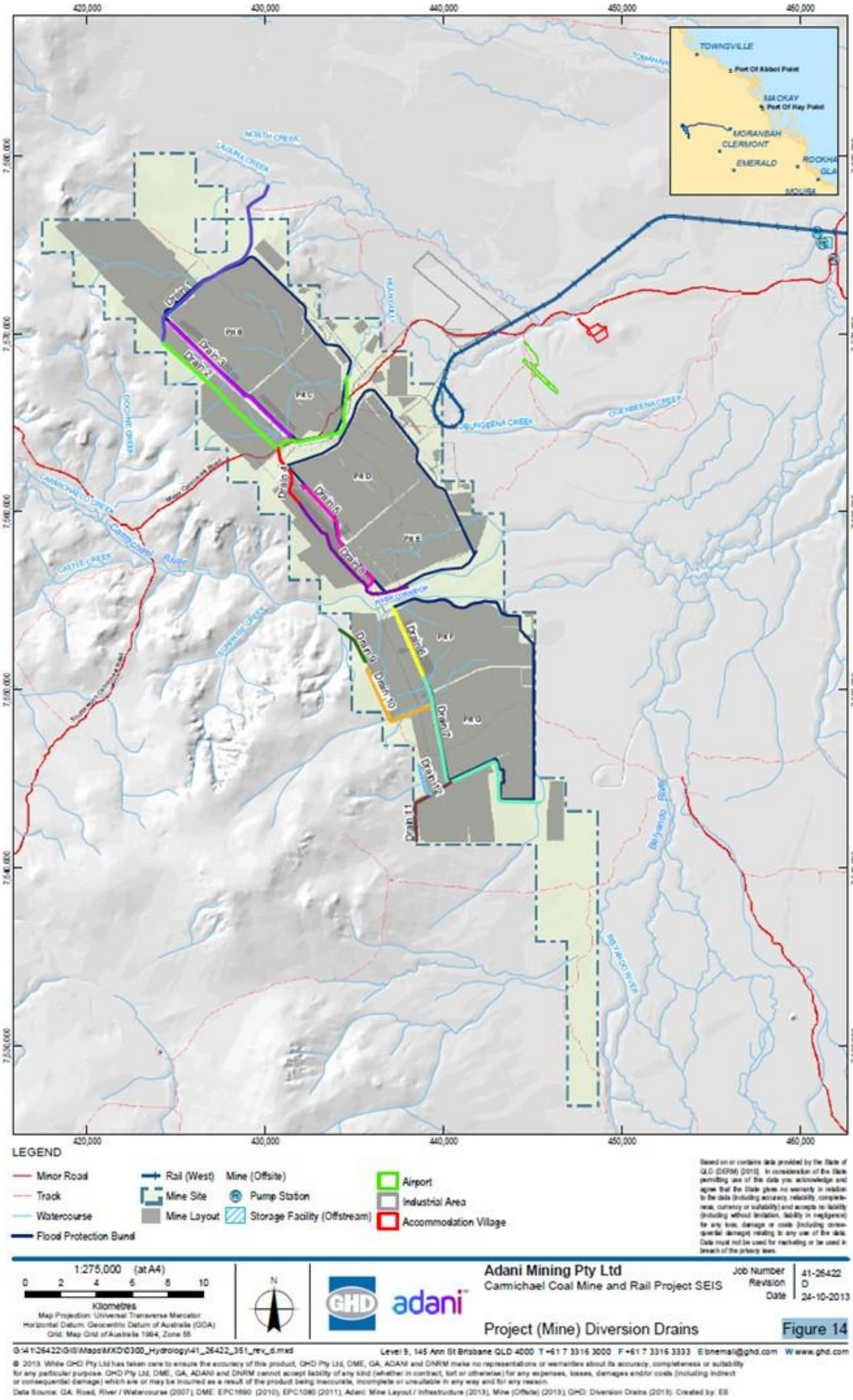


Figure 6-12 Stream diversions and levees

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).

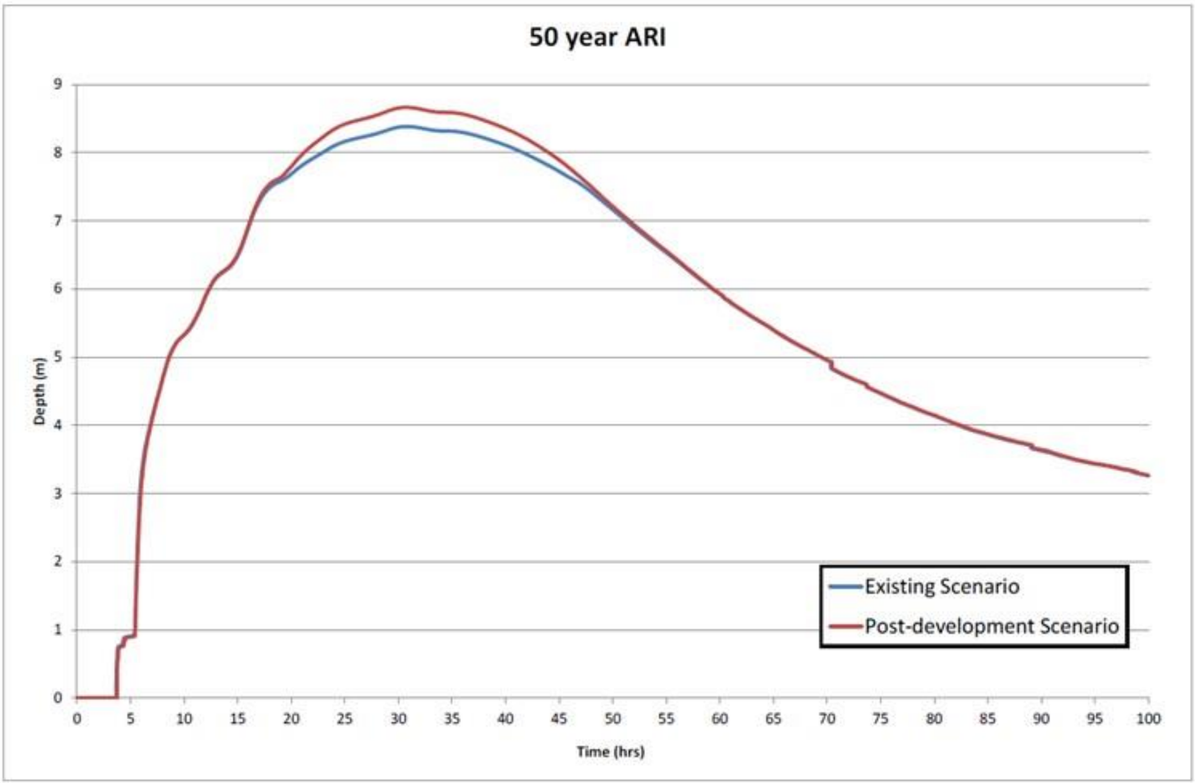


Figure 6-13 50-year ARI depth hydrograph upstream of proposed bridge

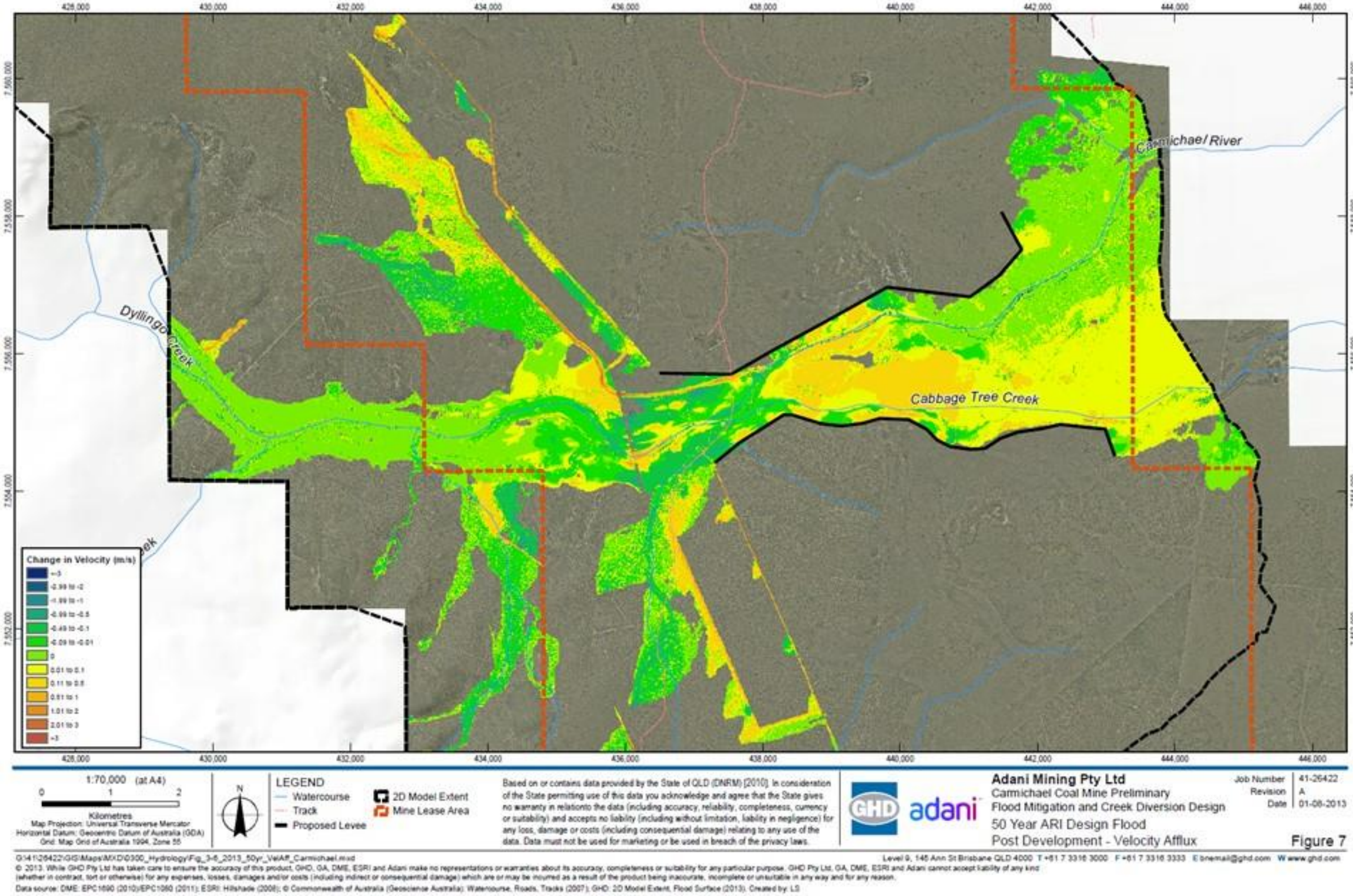


Figure 6-14 50 Year ARI Design Flood – Post Development – Velocity Afflux (GHD, 2013)

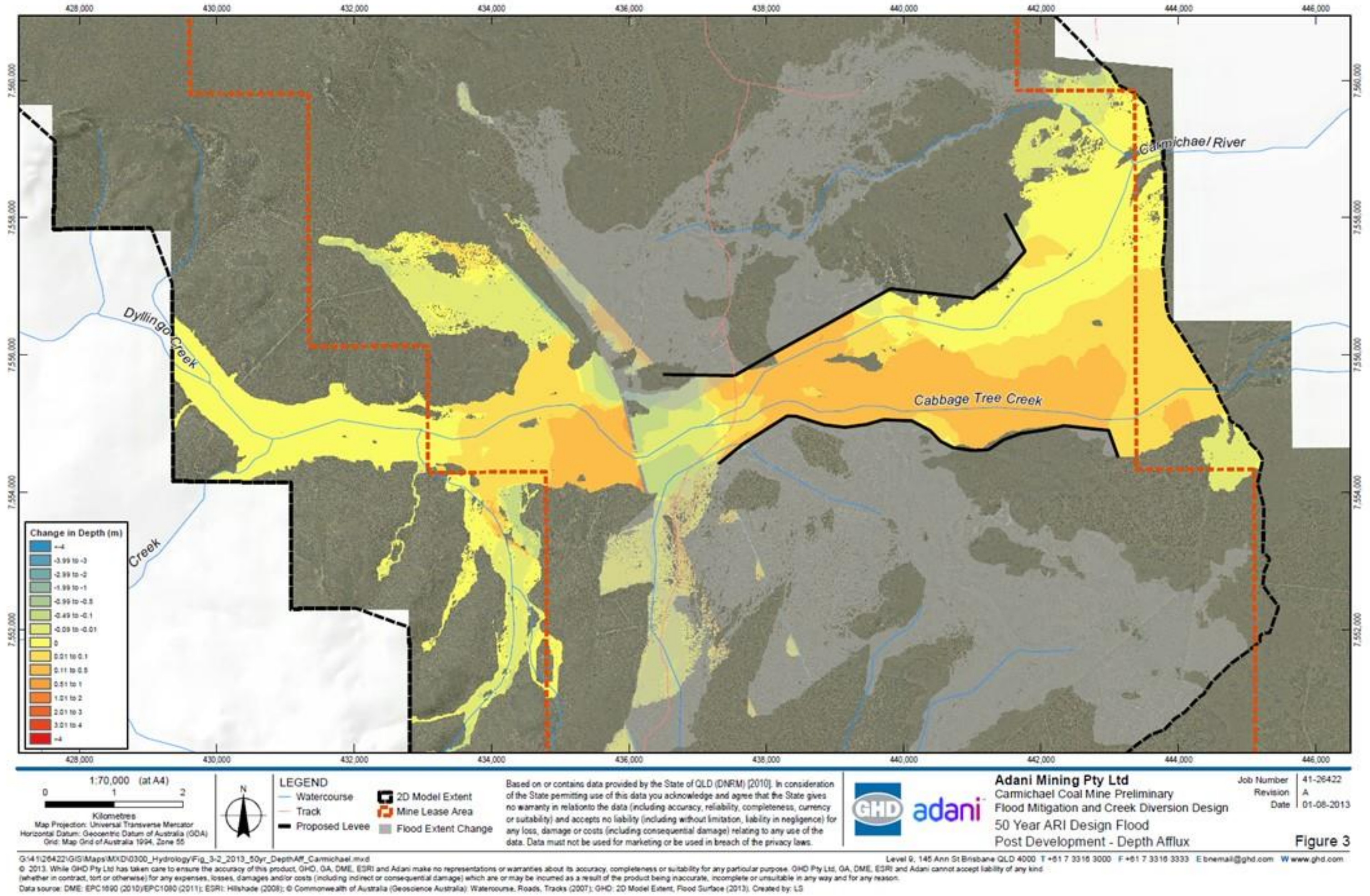


Figure 6-15 50 Year ARI Design Flood – Post Development – Depth Afflux (GHD, 2013)

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 6-11** 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 6-11** 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 6-11** 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 6-11** 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 6-11** 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 6-11** 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 6-11** 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 6-11** 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 6-11** 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 Monitoring Program (surface water).

6.5.2 Receiving Environment Management Program

A Receiving Environment Monitoring Program (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.

Table 6-7 summarises the monitoring frequency, duration, type and indicators for the Carmichael River.

Table 6-7: Carmichael River monitoring frequency, duration, type and indicators

Monitoring Description	Frequency and duration	Monitoring type	Indicators
Ecological features map of the Carmichael River	Within three months of completing the first wet and dry season surveys.	Pre-impact	Riparian vegetation population structure, riparian community health, presence of weed species, extent of weed coverage, presence of feral animals, extent of feral animal disturbance, fauna use of riparian habitat, aquatic flora and fauna population structure.
Pre-clearance surveys	Prior to clearing	Pre-impact	Riparian vegetation population structure
Riparian condition surveys	Annually, until drawdown commences (quarterly thereafter)	Pre-impact Impact	Riparian vegetation population structure, riparian community health, fauna use of riparian habitat, threatened and endemic flora populations.

Monitoring Description	Frequency and duration	Monitoring type	Indicators
Aquatic ecology survey	Twice per year (wet season and dry season), for a period of two years and then annually	Pre-impact Impact	Aquatic ecology condition, aquatic flora and fauna population structure
Groundwater levels (as per GMMP)	12 hourly	Pre-impact Impact	Groundwater level
Surface water flow (as per REMP)	Continuously (daily)	Pre-impact Impact	Surface water level, surface water flow
Groundwater quality (as per GMMP)	Every two months	Pre-impact Impact	Groundwater quality
Surface water quality (as per REMP)	As per REMP		surface water quality
Weeds and pest surveys (as per Pest Management Plan)	Prior to construction and operations, during high and low water conditions	Pre-impact Impact	Presence of weed species, extent of weed coverage, presence of feral animals, extent of feral animal disturbance.
Rehabilitated riparian zone survey	Annually once rehabilitation has commenced	Post Impact?	Riparian vegetation population structure, riparian community health, fauna use of riparian habitat, threatened and endemic flora populations.

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

6.6.1 Pre-impact Monitoring

Pre-impact monitoring will be carried out prior to each project phase, as summarised in **Table 6-9** A pre-impact monitoring report will be prepared per impact, before the impact occurs (e.g. 1, 5, 10 and 15 years as predicted in Table 6-2).

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 feral animal locations and extent.

Indicators: Riparian vegetation population structure, presence of weed species, extent of weed coverage, presence of feral animals, extent of feral animal disturbance, riparian community health, aquatic flora and fauna population structure.

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. Groundwater level data (m AHD) 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.

Indicators: Riparian vegetation population structure, riparian community health, 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 aquatic 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.

Indicators: Aquatic ecology condition, aquatic flora and fauna population structure.

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 6-8** 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 6-8 Groundwater Monitoring locations (from the GMMP)

Aquifer / Resource	Monitoring Bores (depth in m AHD)
Alluvium	• C025P1 (11.00) • 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 6-9**, 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 6-9**).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 6-9 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

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

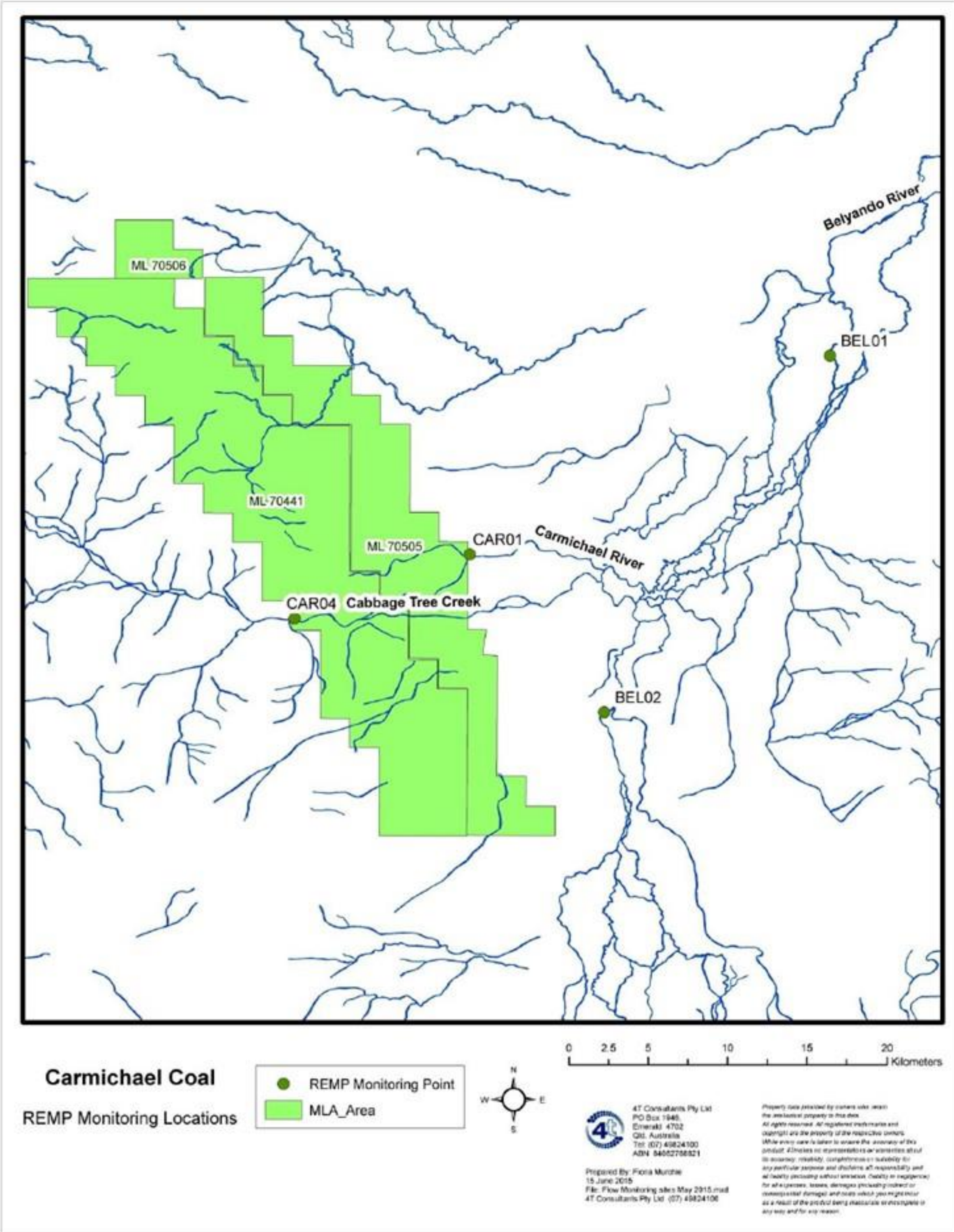


Figure 6-16 Surface Water Monitoring locations (from the REMP)

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.

Pre-clearance surveys

Pre-clearance surveys will be undertaken by a suitably qualified ecologist(s) where potential habitat will be cleared for the Carmichael River crossing and bridge.

Indicator: riparian vegetation population structure.

Weed and Pest Survey

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 feral animals, extent of feral animal disturbance.

6.6.2 Impact Monitoring

Riparian Condition Survey

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.

Indicators: Riparian vegetation population structure, fauna use of riparian habitat.

Carmichael River Aquatic Ecological Surveys

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 aquatic 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.

Indicators: Aquatic ecology condition, aquatic flora and fauna population structure.

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 C025P1, C027P1, C029P1, HD03 B, C14027SP, C14028SP 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

Weed and Pest Survey

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 feral animals will also be monitored through surveys.

Indicators: presence of weed species, extent of weed coverage, presence of feral animals, extent of feral animal 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.

<u>Indicators:</u> Riparian vegetation population structure, presence of weed species, extent of weed coverage, presence of feral animals, extent of feral animal disturbance, riparian community health, fauna use of riparian habitat, threatened and endemic flora populations.

Other monitoring

Other impact monitoring will be carried out for the Carmichael River 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 Monitoring Program (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.

Details of the statistical approach for Carmichael River triggers and monitoring are provided in **Table 6-10**.

Table 6-10: 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 vegetation population structure Threatened and endemic flora populations	Riparian community health, Riparian vegetation population, threatened and endemic flora population 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 Reduction in riparian forest canopy cover as determined from analysis of aerial photography.	Structural formation, canopy cover, density of shrub layers, 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
Aquatic ecology condition Aquatic flora and fauna population structure	Macroinvertebrates - EPT (Ephemeroptera, Plecoptera and Trichoptera) ratios of macroinvertebrates fall below baseline values of 6.7% (Autumn) and 15.8% (Spring) Aquatic flora and fauna population deviate by more than statistically significant change from baseline conditions.	Macroinvertebrate sampling using AusRivAS methods. Sampling for aquatic flora (macrophytes) Fish trapping	Macroinvertebrate genera and species richness Ecological patterns (macrophytes, fish, invertebrates) Vertebrate species presence, in particular at remnant pools	EPT (Ephemeroptera, Plecoptera and Trichoptera) ratios. MDS graphs to show relative spread of aquatic flora and fauna composition and abundance. Follow up SIMPER tests to detect the main indicators driving the patterns in the data.
Presence of weed species Extent of weed coverage Presence of feral animals Extent of feral animal disturbance (within areas controlled by Adani)	Statistically significant increase in weed cover, pests or pest activity above baseline. Identification of new weed or feral animal.	Weed and pest surveys undertaken at COREVEG / BioCondition plots, surveyed annually.	Inventory of all weed and feral animals present. Identify spatial extent of weeds, especially Rubber Vine, along the Carmichael River. Identify areas of Riparian habitat subject to pig damage and cattle 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 feral animal 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.

Indicator	Relevant triggers	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
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.
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
- Statistically significant reduction in aquatic ecology health from baseline conditions
- Significant increase in weed cover, pests or pest activity above baseline.
- Identification of new weed or feral animal.
- 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.

Aquatic ecology

Triggers for aquatic ecology are Macroinvertebrates - EPT (*Ephemeroptera, Plecoptera* and *Trichoptera*) ratios of macroinvertebrates fall below baseline values of 6.7% (Autumn) and 15.8% (Spring); and aquatic flora and fauna population deviate by more than statistically significant change from baseline conditions.

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 85^{th} 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 6-11**. 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 6-11** and **Table 6-10** (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

Table 6-11: 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 Minimise the impacts of water drawdown on the Carmichael River	No impact greater than that approved to the Carmichael River from mine dewatering Project impacts are less than or equal to approved impacts at the equivalent stage of the mine life	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.
2	Subsidence 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	Surface water flow and level Tilt, strain and displacement exceeding predictions at monitoring locations under the Subsidence Management Plan	• Measurable evidence of tilt in the vicinity of the Carmichael River attributable to Subsidence. • 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.	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 Surface water 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.

#	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.	Surface water 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: ○ 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 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:** Erosion and Sediment Management Plan.	Surface water quality	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 • Removal of grazing (watering of stock at Carmichael River) in order to increase water pool life span from Year 20.

#	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 Carmichael River Aquatic Ecological Survey **Impact monitoring:** Receiving Environment Management Program that includes monitoring requirements before, during and after a discharge event. Carmichael River Aquatic Ecological Survey	Surface water quality Aquatic ecology condition Aquatic flora and fauna population structure	Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded.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) Aquatic flora and fauna population deviate by more than statistically significant change from baseline conditions.	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 • 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:** 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.

#	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 **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.	Riparian community health Riparian vegetation population structure Threatened and endemic flora populations	Visual 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, ○ Environment Manager ensure that all clearing activities cease immediately ○ Area assessed 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 ○ 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	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 Carmichael River Aquatic Ecological Survey **Impact monitoring:** Pre-clearance surveys Carmichael River Aquatic Ecological Survey 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.	Riparian community health Riparian vegetation population structure Threatened and endemic flora populations Aquatic ecology condition Aquatic flora and fauna population structure	Visual evidence of clearing or disturbance Clearing in the Carmichael River: • outside approved clearing footprint • in no-go zone/s (such as, outside areas of construction for the Carmichael River road) • without a Permit to Disturb issued 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)	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, ○ Environment Manager ensure that all clearing activities cease immediately ○ Area assessed 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 • 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.

#	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:** 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.	Riparian community health Riparian vegetation population structure Threatened and endemic flora populations	Reach 75% of the clearing approved in the Carmichael River Visual evidence of clearing or disturbance Clearing in the Carmichael River: • outside approved clearing footprint • in no-go zone/s (such as, outside areas of construction for the Carmichael River road) • without a Permit to Disturb issued	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. Carmichael River Aquatic Ecological Survey Weed and pest survey **Impact monitoring:** Riparian condition survey Rehabilitated Riparian Zone Weed and pest survey Carmichael River Aquatic Ecological Survey Regular site inspections in accordance with the Environmental Management Plan and System.	Riparian vegetation population structure Riparian community health Fauna use of riparian habitat Threatened and endemic flora populations Aquatic ecology condition Presence of weed species Extent of weed coverage Presence of feral animals Extent of damage from feral animals	• Statistically significant change in indicators compared to baseline / pre-impact conditions • Failure to evaluate the extent and condition of riparian vegetation in the riparian zone prior to the commencement of construction and operations • Evidence of dieback or impacts to vegetation in the Carmichael River • 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) • 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 •	The appropriate corrective actions will be implemented and may include: • Removal of grazing (watering of stock at Carmichael River) in order to increase water pool life span from Year 20 • Revising and implementing an updated plan for riparian zone rehabilitation and management within 30 days • The corrective actions for project impacts as a result of groundwater drawdown from mine dewatering (#1) • The corrective actions for project impacts as a result of weed and pest plans through direct competition or habitat degradation (#7).
		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).				

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Trigger for adaptive management and corrective actions	Corrective actions
		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 Carmichael River Aquatic Ecological Survey **Impact monitoring:** Riparian condition Rehabilitated Riparian Zone Carmichael River Aquatic Ecological Survey Receiving Environment Monitoring Program Erosion and Sediment Management Plan	Rehabilitation success parameters as listed in Appendix 2 of the EA (native fauna species, plant regeneration, weed abundance, pest abundance), erosion Surface water quality Aquatic ecology condition	• Rehabilitation not meeting success criteria under EA for parameters such as vegetation cover, evidence of erosion within relevant EA timeframes. • Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded. • Pollution of the Carmichael River by contaminants.	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.
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.	**Pre-impact monitoring:** Ecological features map Riparian condition survey Carmichael River Aquatic Ecological Survey **Impact monitoring:** Fire Management Plan. Riparian condition survey Rehabilitated Riparian Zone Regular site inspections in accordance with the Environmental Management Plan and System.	Riparian vegetation population Community condition Riparian community health Fauna use of riparian habitat Threatened and endemic flora populations Fuel load levels as described in the Fire Management Plan	• 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.

#	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 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.	**Pre-impact monitoring:** Ecological features map Riparian condition survey Carmichael River Aquatic Ecological Survey **Impact monitoring:** Fire Management Plan. Riparian condition survey Rehabilitated Riparian Zone Regular site inspections in accordance with the Environmental Management Plan and System.	Riparian vegetation population Community condition Riparian community health Fauna use of riparian habitat Threatened and endemic flora populations Fuel load levels as described in the Fire Management Plan	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.
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 monitoring:** Ecological features map Riparian condition survey Carmichael River Aquatic Ecological Survey Weed and pest survey **Impact monitoring:** Riparian condition survey Weed and pest survey Carmichael River Aquatic Ecological Survey Rehabilitated riparian zone	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. • 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	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.

#	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 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.	**Pre-impact monitoring:** Ecological features map Riparian condition survey Carmichael River Aquatic Ecological Survey Weed and pest survey **Impact monitoring:** Riparian condition survey Weed and pest survey Rehabilitated riparian zone Carmichael River Aquatic Ecological Survey Weed and pest survey	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.	**Pre-impact monitoring:** Ecological features map Riparian condition survey Carmichael River Aquatic Ecological Survey Weed and pest survey **Impact monitoring:** Riparian condition survey Carmichael River Aquatic Ecological Survey 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).
		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.	**Pre-impact monitoring:** Ecological features map Riparian condition survey Carmichael River Aquatic Ecological Survey **Impact monitoring:** Riparian condition survey Carmichael River Aquatic Ecological Survey Regular site inspections in accordance with the Erosion and Sediment Management Plan and Environmental Management System.	Surface water quality	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

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Trigger for adaptive management and corrective actions	Corrective actions
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 vibration. Project impacts like noise, dust and lighting will be minimised by the implementation of the Environment Management Plan.	**Pre-impact monitoring:** Ecological features map Riparian condition survey Carmichael River Aquatic Ecological Survey **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)	• Statistically significant change in indicators compared to baseline / pre-impact conditions • Dieback of vegetation in the Carmichael River	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.	**Pre-impact monitoring:** Ecological features map Riparian condition survey Carmichael River Aquatic Ecological Survey **Impact monitoring:** Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Event monitoring for: Total suspended particulate matter	• Statistically significant change in indicators compared to baseline / pre-impact conditions • 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.	**Pre-impact monitoring:** Ecological features map Riparian condition survey Carmichael River Aquatic Ecological Survey **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	• Statistically significant change in indicators compared to baseline / pre-impact conditions • 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.

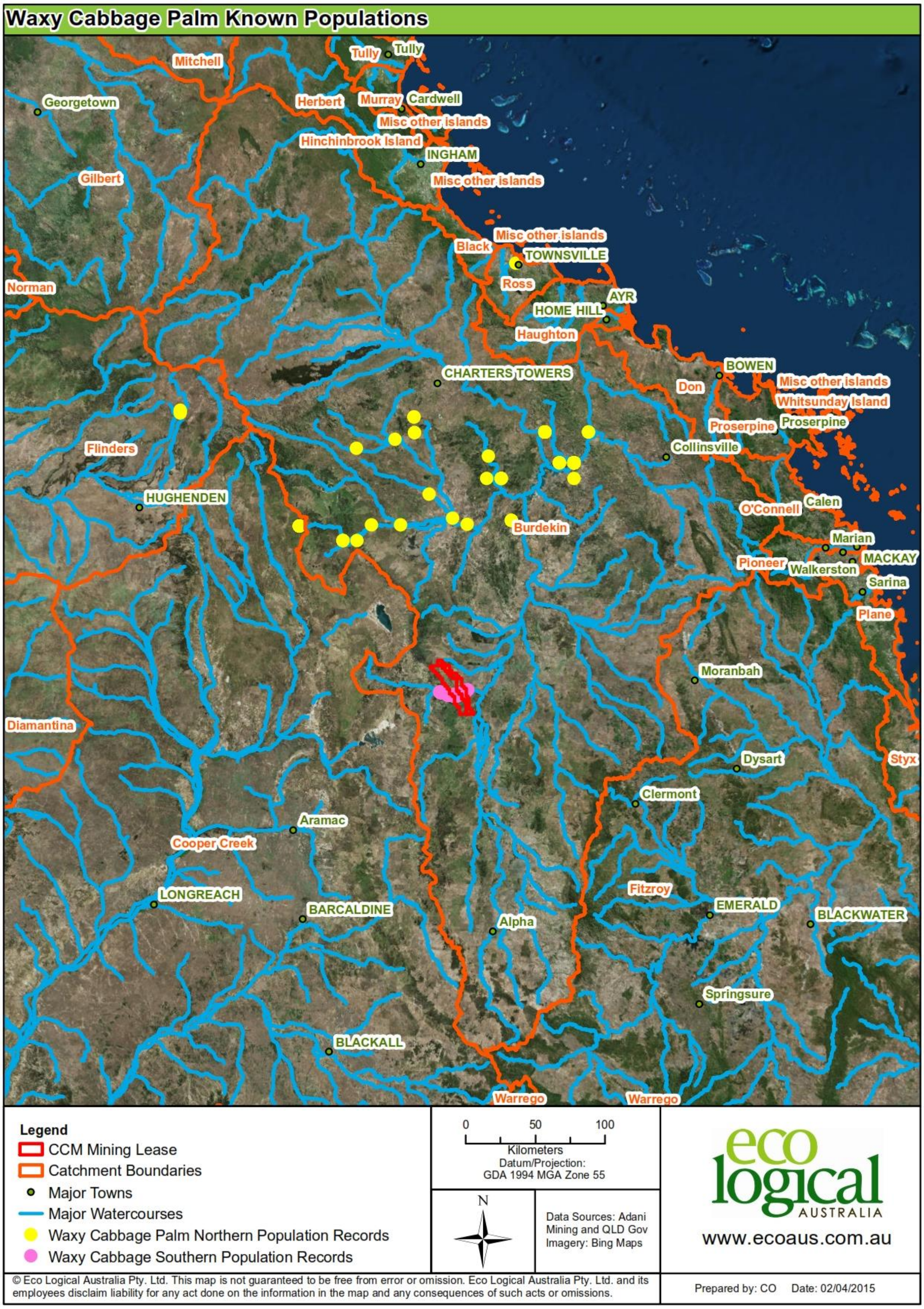


Figure 7-1: Known populations of Waxy Cabbage Palm

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.

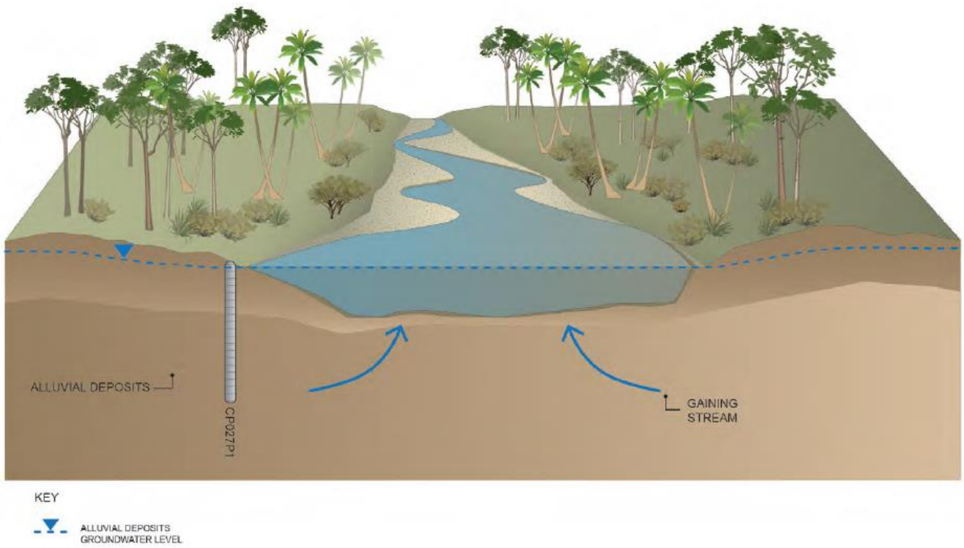


Figure 7-3 Gaining section of the Carmichael River (GHD 2014)

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.

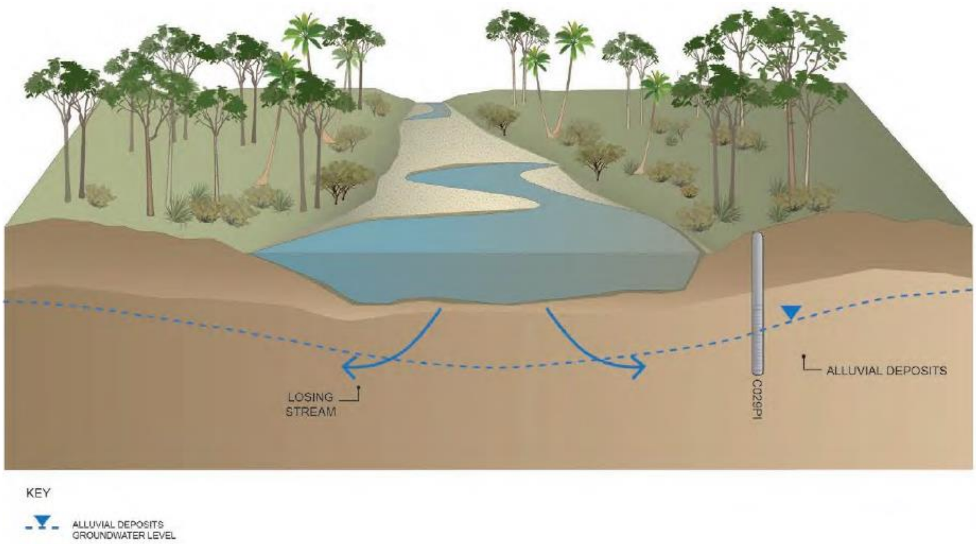


Figure 7-4 Losing section of the Carmichael River (GHD 2014)

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

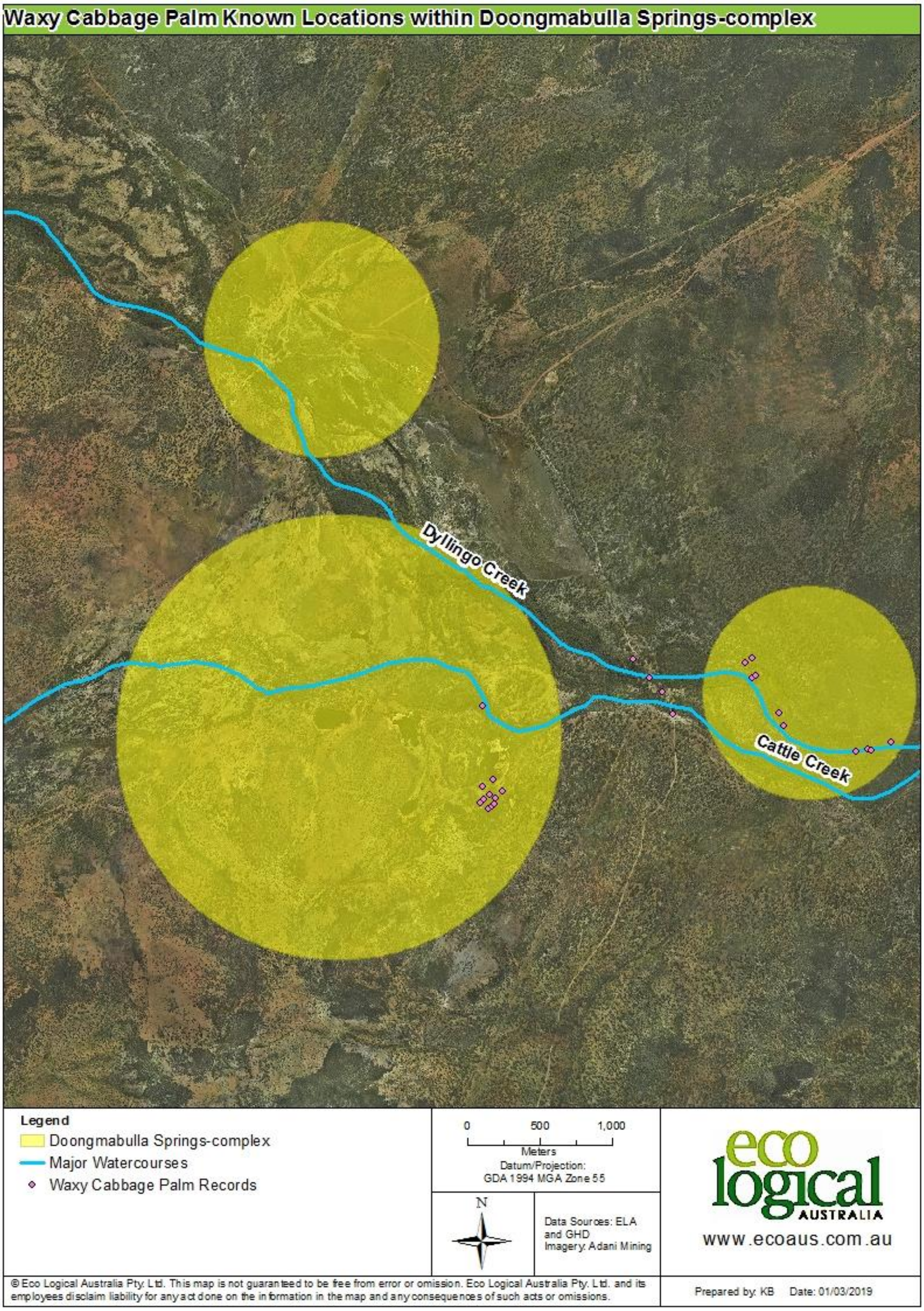


Figure 7-5a: Known population of Waxy Cabbage Palm locations within Doongmabulla Springs-complex

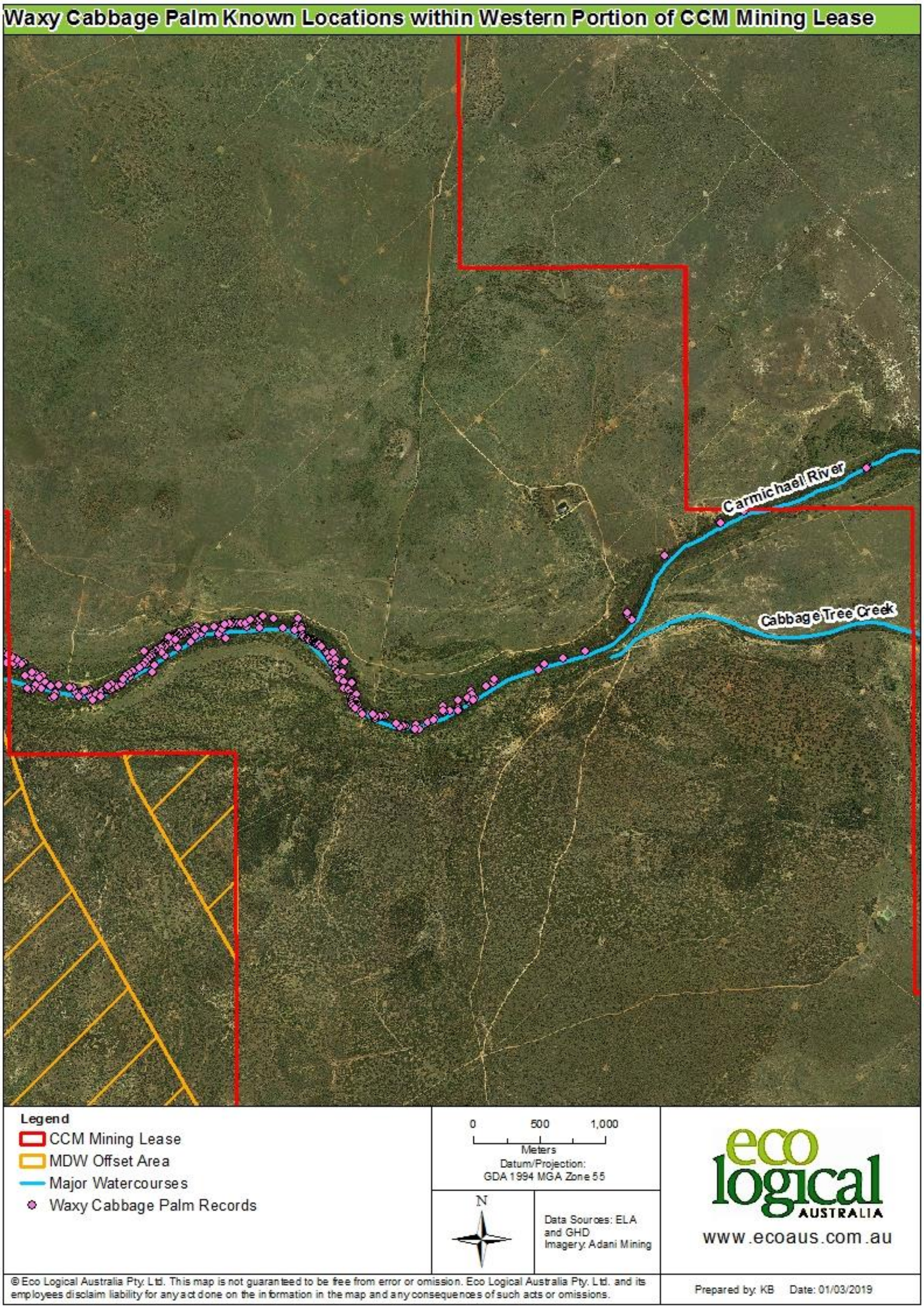


Figure 7-5b: Known population of Waxy Cabbage Palm in Project area

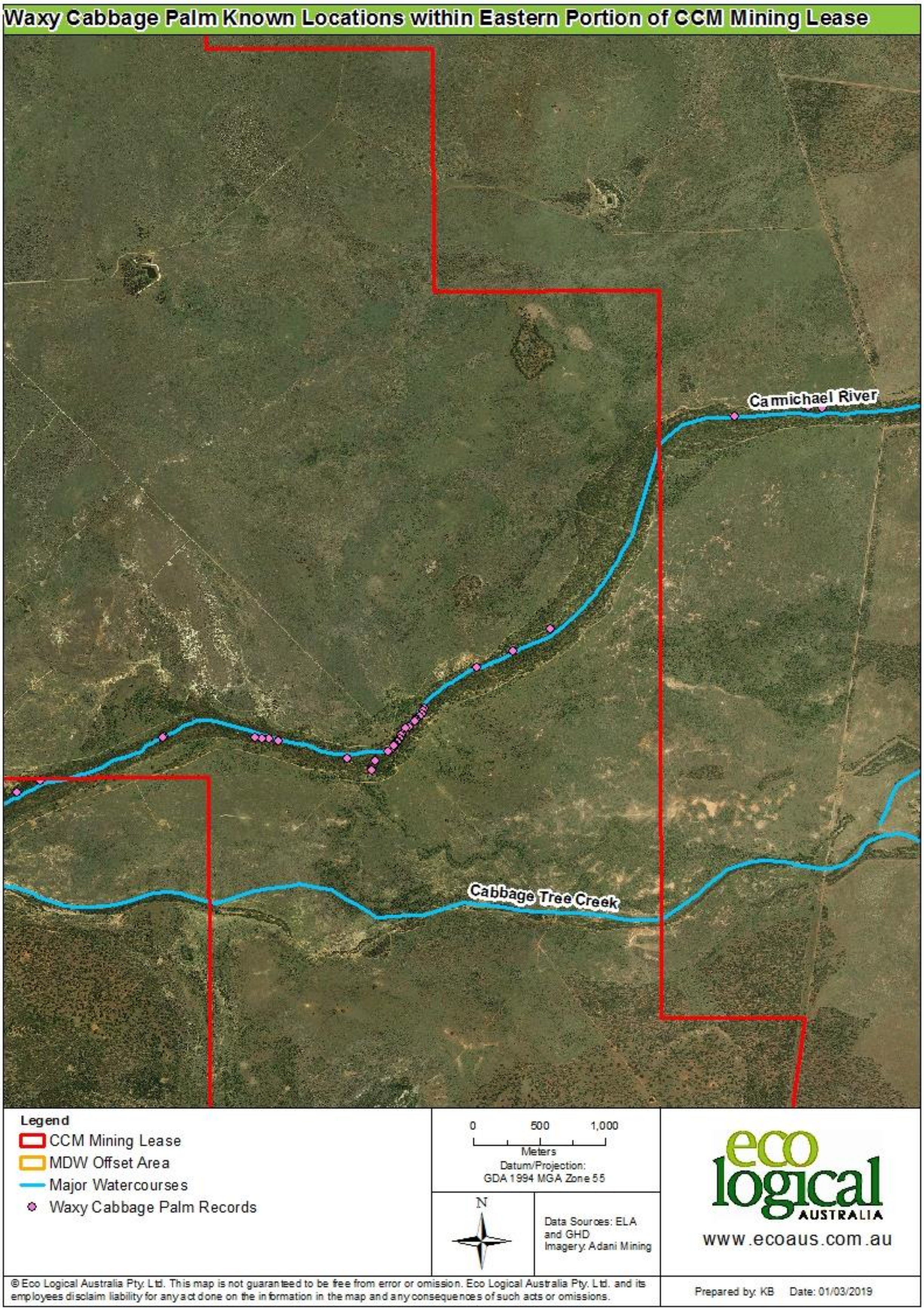


Figure 7-5c. Known population of Waxy Cabbage Palm in Project area

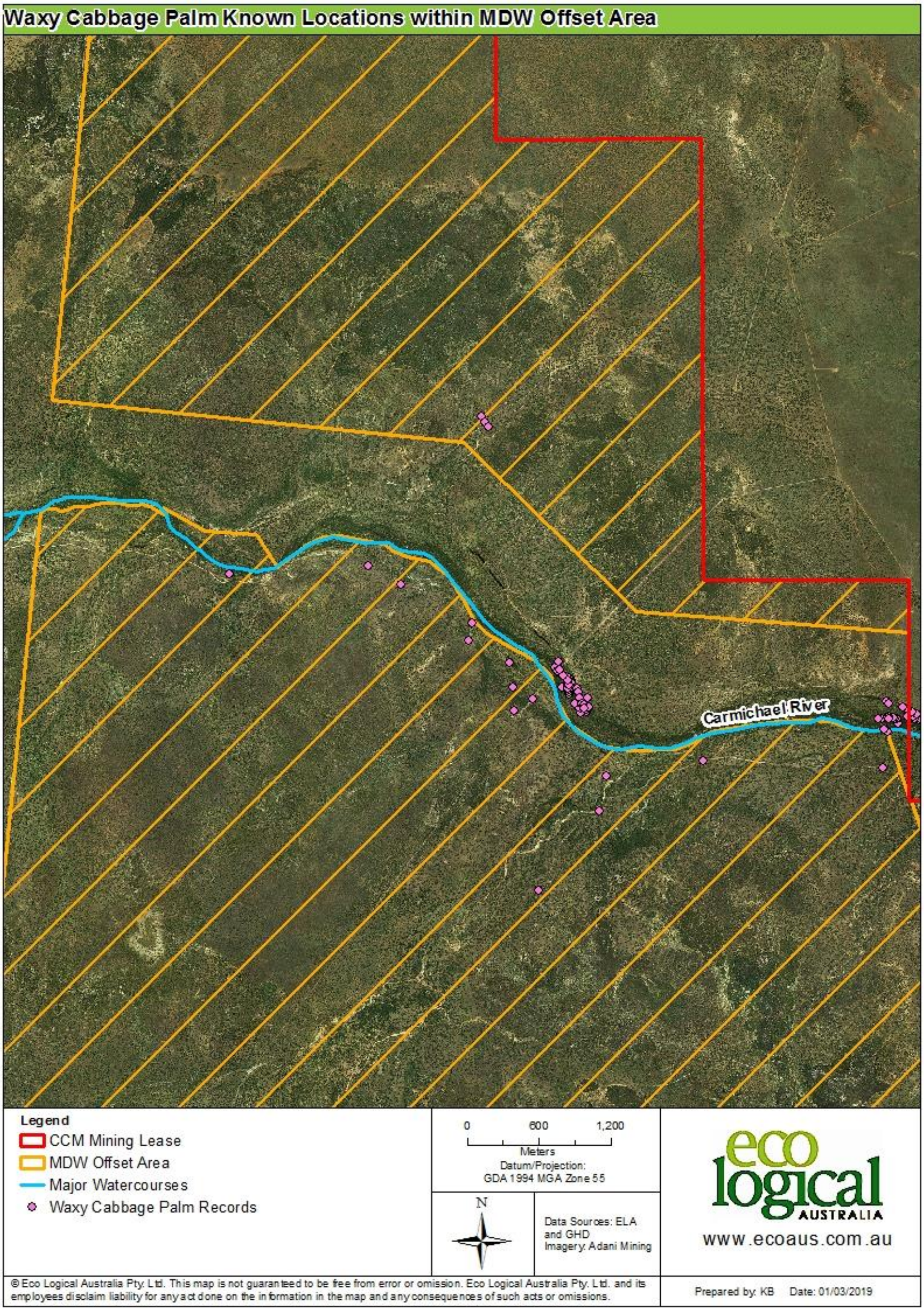


Figure 7-5d. Known population of Waxy Cabbage Palm in Project area

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 7-7
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	Unlikely to impact, but may occur from Year 1	
11	Noise and vibration	-	-	-	(c)(v)	-	Construction Operations	Unlikely to impact, but may occur from Year 1	
12	Emissions (including dust)	-	-	Yes	(c)(vi)	-	Construction Operations	Unlikely to impact, but may occur from Year 1	
13	Light spill and other visual impacts	-	-	-	(c)(vii)	-	Construction Operations	Unlikely to impact, but may occur from Year 1	

#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

#	Key areas	Predicted drawdown within vicinity of Carmichael River	When during operational project phase*****
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	From Year 20
2	Carmichael River –towards western and eastern mining lease boundaries	Maximum <0.2 m	From Year 20
3	Carmichael River – 800 m stretch near middle of mine area	Maximum of 4 m	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 by 30% to 60% of the time	During operation and post mine closure, from Year 60

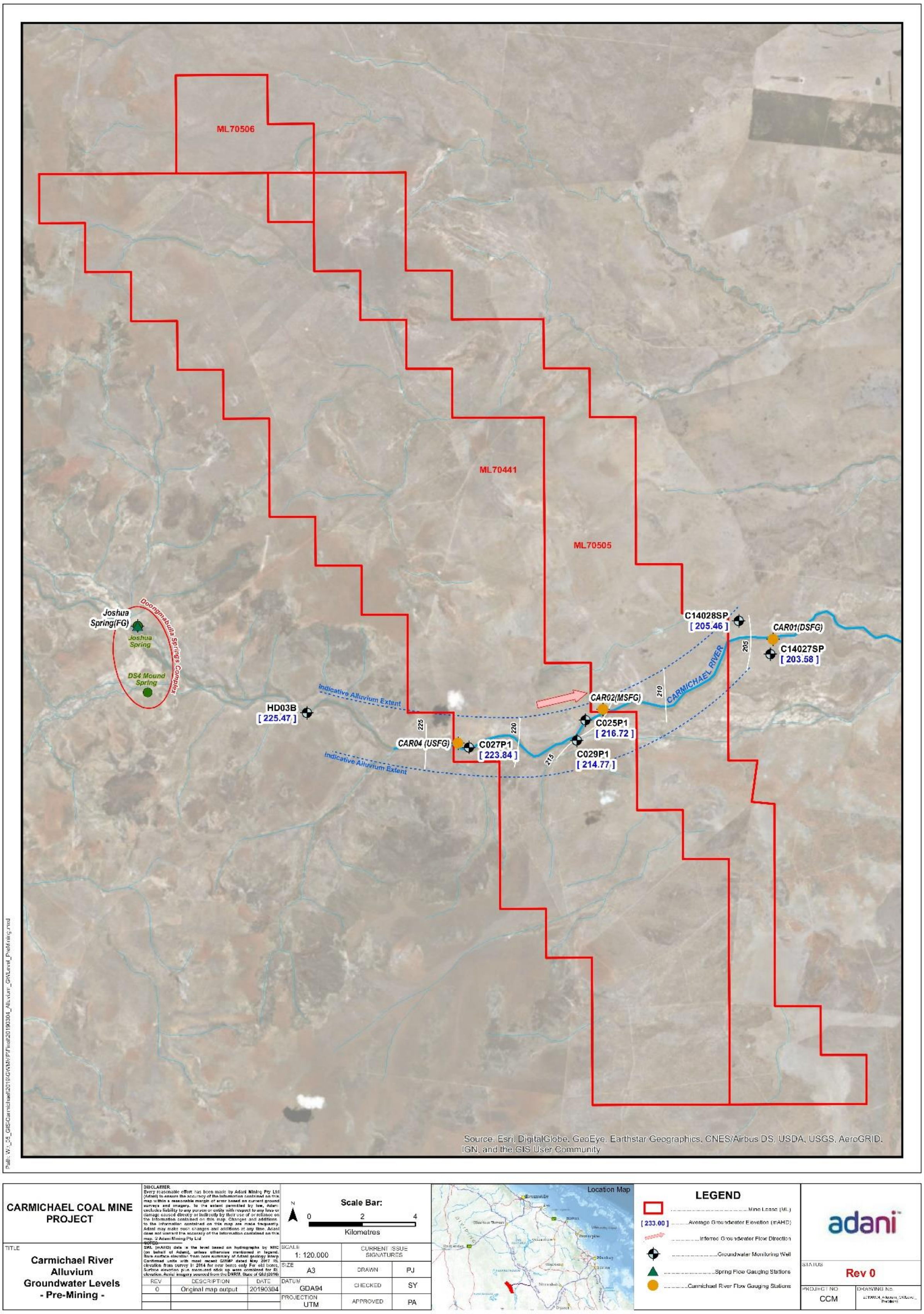
* Please refer to Section 2.2 for details on GDEMP monitoring & implementation phase; baseline, pre-impact, impact

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 7-7** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.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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
Indicative Alluvium Extent
CAR04 (USFG)
C027P1
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CAR02(MSFG)
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Inferred Groundwater Flow Direction
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Spring Flow Gauging Stations
Carmichael River Flow Gauging Stations
adani
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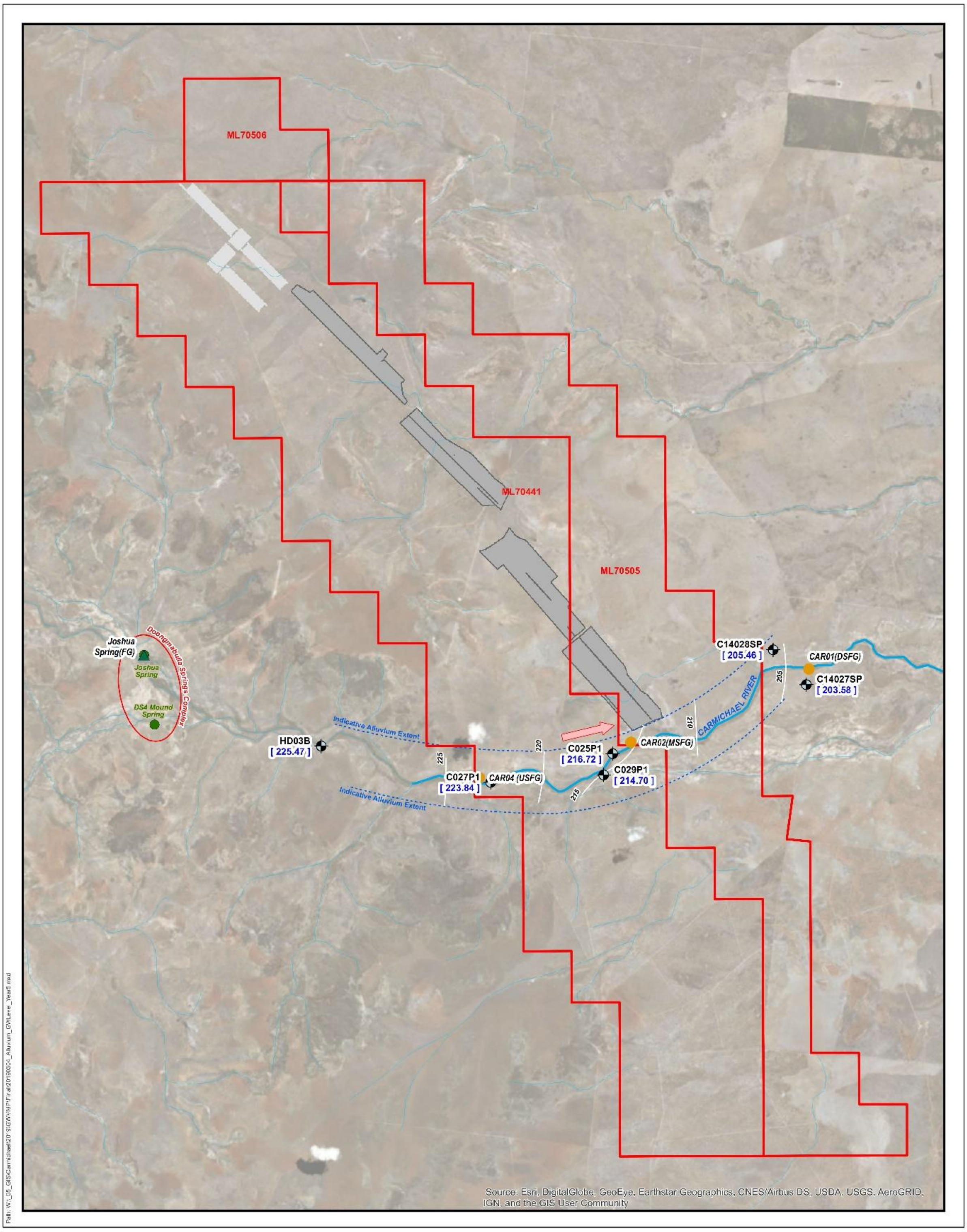

CARMICHAEL COAL MINE PROJECT

TITLE
Carmichael River Alluvium Predicted Groundwater Levels - Year 5 -

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Location Map

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- 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**

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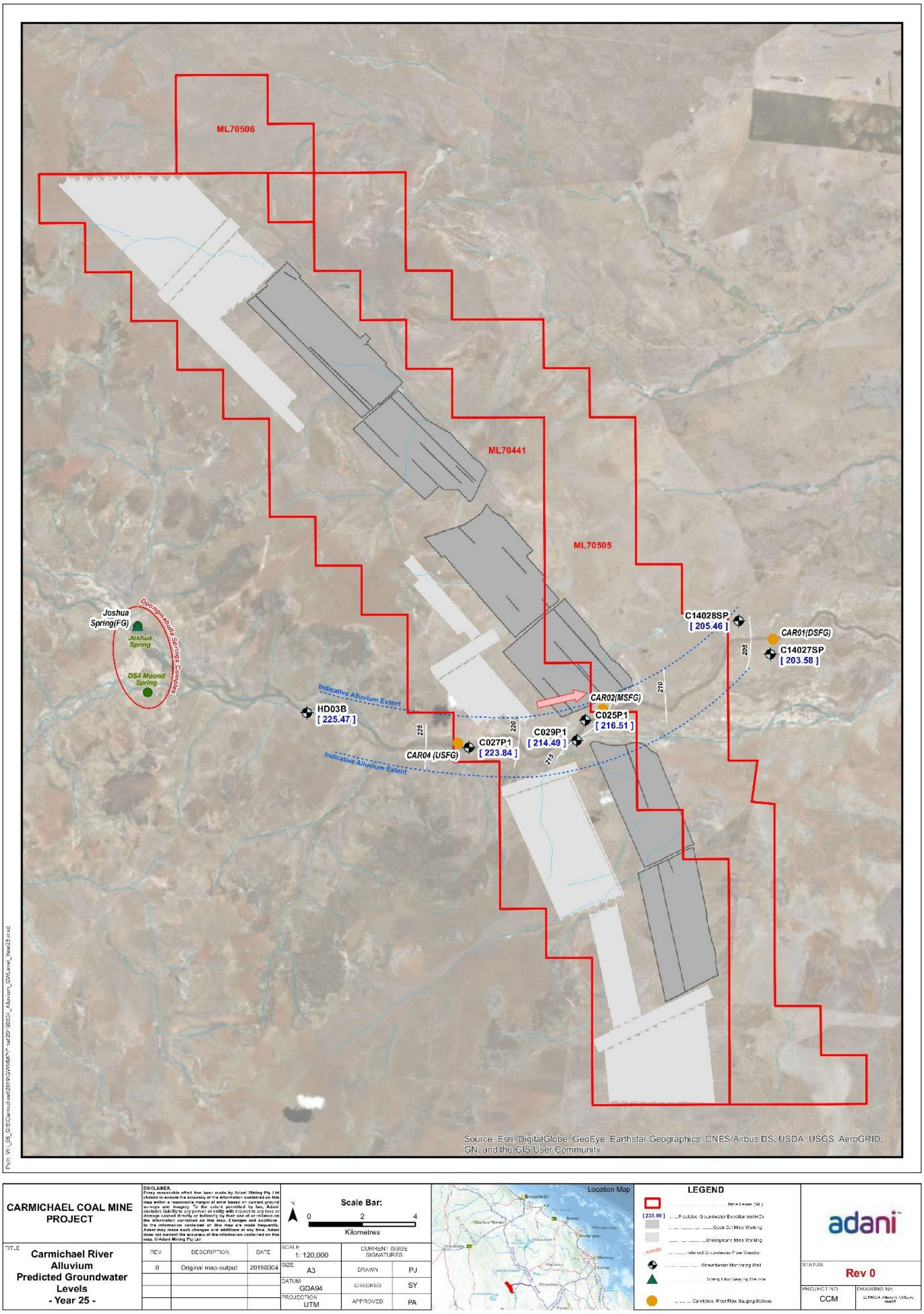
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Joshua Spring
DS4 Mound Spring
Doongmabulla Springs Complex
Indicative Alluvium Extent
Indicative Alluvium Extent
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Open Cut Mine Working
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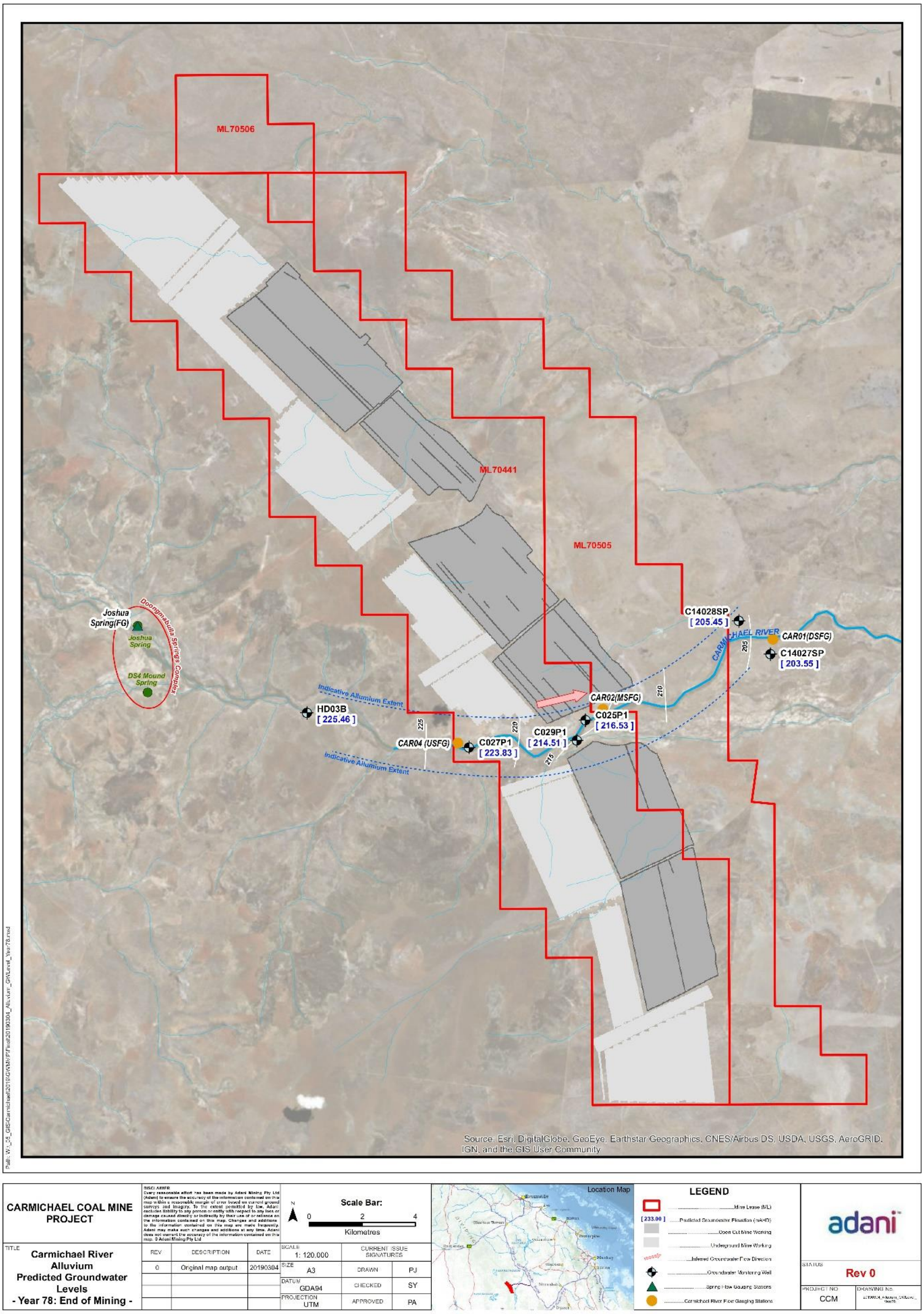


Figure 7-6 a to d: Predicted drawdown to Alluvium aquifer over the life of the project

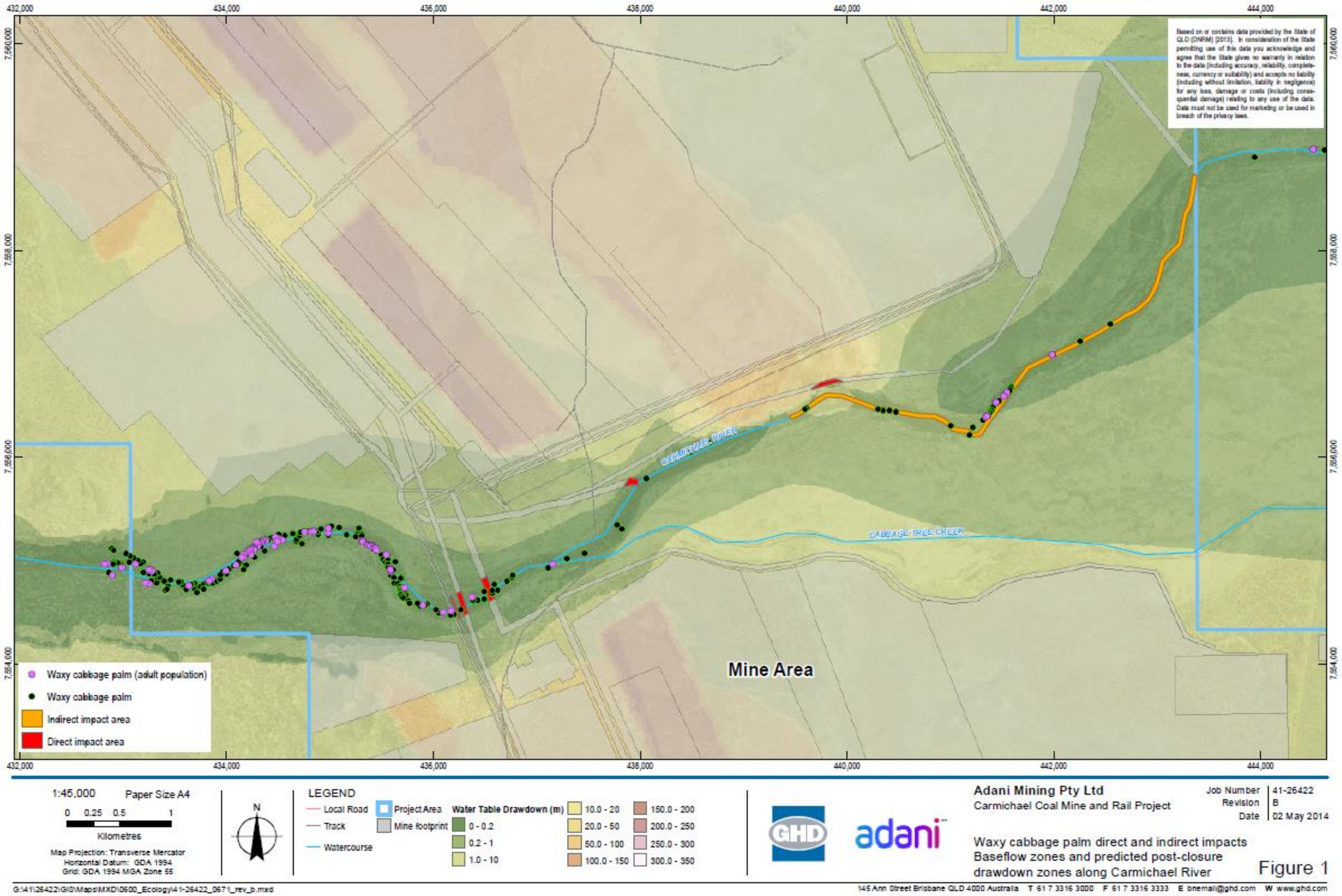


Figure 7-7 Location of residual groundwater and surface disturbance impacts on Waxy Cabbage Palm

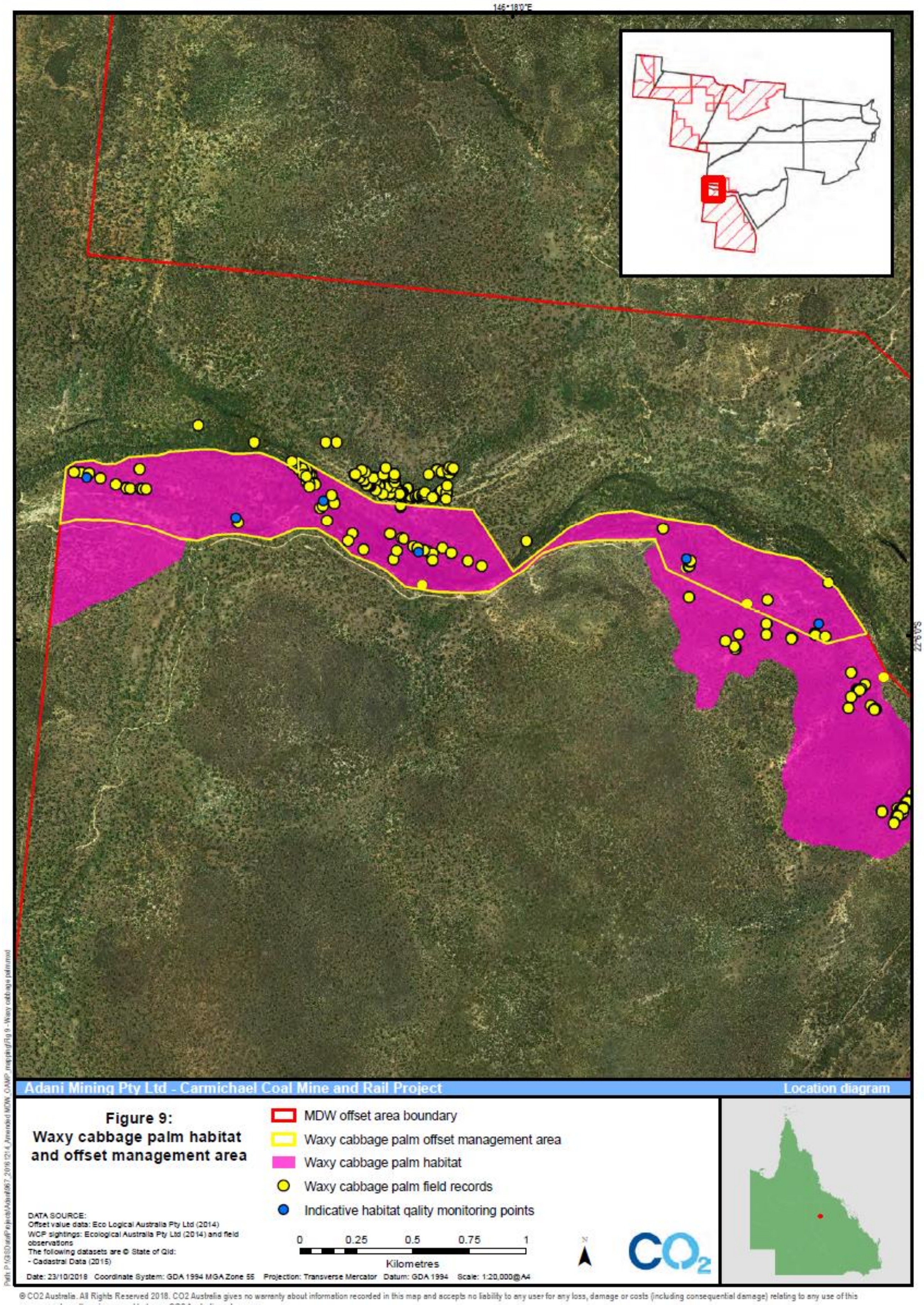


Figure 7-8 Waxy Cabbage Palm Offset Area (from approved Biodiversity Offsets Strategy)

#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 7-7** 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 7-7** 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 7-7** 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 7-7** 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 7-7** 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 7-7** 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 7-7** 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 7-7** 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 7-7** 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 7-7** 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. Stock access for grazing and stocking rates at locations containing Waxy Cabbage Palm will be strategically managed through the use of fencing and access gates. This approach is consistent with priority actions in the Waxy Cabbage Palm Conservation Advice, which seek to prevent grazing pressure at known Waxy Cabbage Palm sites on leased crown land. 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

- Stock access for grazing and stocking rates at locations containing Waxy Cabbage Palm will be strategically managed through the use of fencing, access gates and preferential non-stream watering of stock
- 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 7-6**. Monitoring programs will be implemented following approval of this GDEMP.

Table 7-5 summarises the monitoring frequency, duration, type and indicators for the Waxy Cabbage Palm.

Table 7-5 Waxy Cabbage Palm monitoring frequency, duration, type and indicators

Monitoring Description	Frequency and duration	Monitoring type	Indicators
Ecological features map of the Carmichael River	Within three months of completing the first wet and dry season surveys.	Pre-impact	Riparian vegetation population structure, riparian community health, presence of weed species, extent of weed coverage, presence of feral animals, extent of feral animal disturbance, aquatic flora and fauna population structure.
Pre-clearance surveys	Prior to clearing	Pre-impact	Location of Waxy Cabbage Palms, calculation of habitat disturbance
WCP condition and population survey	Twice per year (wet and dry season) for two years. Annually thereafter	Pre-impact Impact	Waxy cabbage palm population structure, Waxy Cabbage Palm community condition,
Weed and pest surveys	Annually	Pre-impact Impact	Presence of weed species, extent of weed coverage, presence of feral animals, extent of feral animal disturbance
Groundwater monitoring (as per GMMP)	12 hourly (level) Quarterly (quality)	Pre-impact Impact	Groundwater level, groundwater quality
Surface water monitoring (as per REMP)	Continuously (daily; flow) Monthly (quality)	Pre-impact Impact	Surface water flow, surface water level (periods of no flow), surface water quality
Environmental Water Requirement Assessment	Twice per year (wet and dry season) for two years. Frequency reviewed thereafter.	Pre-impact Impact	Waxy Cabbage Palm Community condition

7.6.1 Pre-impact monitoring of the Waxy Cabbage Palm

Pre-impact monitoring will be carried out prior to each project phase, as described in **Table 7-5.** A pre-impact monitoring report will be prepared per impact, before the impact occurs (as per **Table 7-3**).

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.

Waxy Cabbage Palm community condition 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 condition will be carried out biannually (wet and dry season), for two years, and then the frequency will be reviewed.

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

<u>Indicators</u>: Waxy Cabbage Palm population structure, Waxy Cabbage Palm community condition.

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

<u>Indicators:</u> Riparian vegetation population structure (including Waxy cabbage Palms), riparian community health, Waxy Cabbge Palm community condition, presence of weed species, extent of weed coverage,.

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 feral animals, extent of feral animal 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.

Indicator: Location of Waxy Cabbage Palms, calculation of habitat disturbance

Environmental Water Requirement assessment

An Environmental Water Requirement assessment 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.

Indicator: Waxy Cabbage Palm community condition.

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.

Waxy Cabbage Palm condition and population survey

Population surveys will continue annually at the control and impact sites (two 100 m x 20 m transects) established during the pre-impact 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: Waxy Cabbage Palm population structure, Waxy Cabbage Palm community condition, presence of weed species, extent of weed coverage, presence of feral animals, extent of feral animal and cattle disturbance.

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 feral animals, extent of feral animal 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 Monitoring 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:

- 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.

Details of the statistical approach for Waxy Cabbage Palm triggers and monitoring are provided in **Table 7-6**.

Table 7-6 Statistical approach for Waxy Cabbage Palm triggers and monitoring

Indicator	Relevant triggers	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
Waxy Cabbage Palm 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 and location of individuals Population structure (life form stages)Height	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.

Indicator	Relevant triggers	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
Waxy Cabbage Palms 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 Environmental water requirement measures: • Leaf water potential • Depth of soil water absorbed by Waxy Cabbage Palm • Soil sampling to determine the root depth • stable isotope to determine depth of soil water absorbed by Waxy Cabbage Palm and to determine whether a groundwater 'signature' exists within the plant xylem • leaf area index measurements and monitoring • sap flow measurements to determine water use.	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. Determine environmental water requirements
Presence of weed species Extent of weed coverage Presence of feral animals Extent of feral animal disturbance (within areas controlled by Adani)	Significant Increase in weed cover, pests or pest activity above baseline/pre-impact period. Identification of new weed or feral animal. 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 feral animals present. Identify spatial extent of weeds, especially Rubber Vine, along the Carmichael River. Identify areas of Waxy Cabbage Palm habitat subject to pig damage and cattle damage.	Descriptive comparison of mean weed cover, pest abundance, and area of pest damage and cattle damage at time of sampling to baseline/pre-impact conditions. Log the occurrence of new weed or feral animals 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)	20^{th} 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 20^{th} 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.

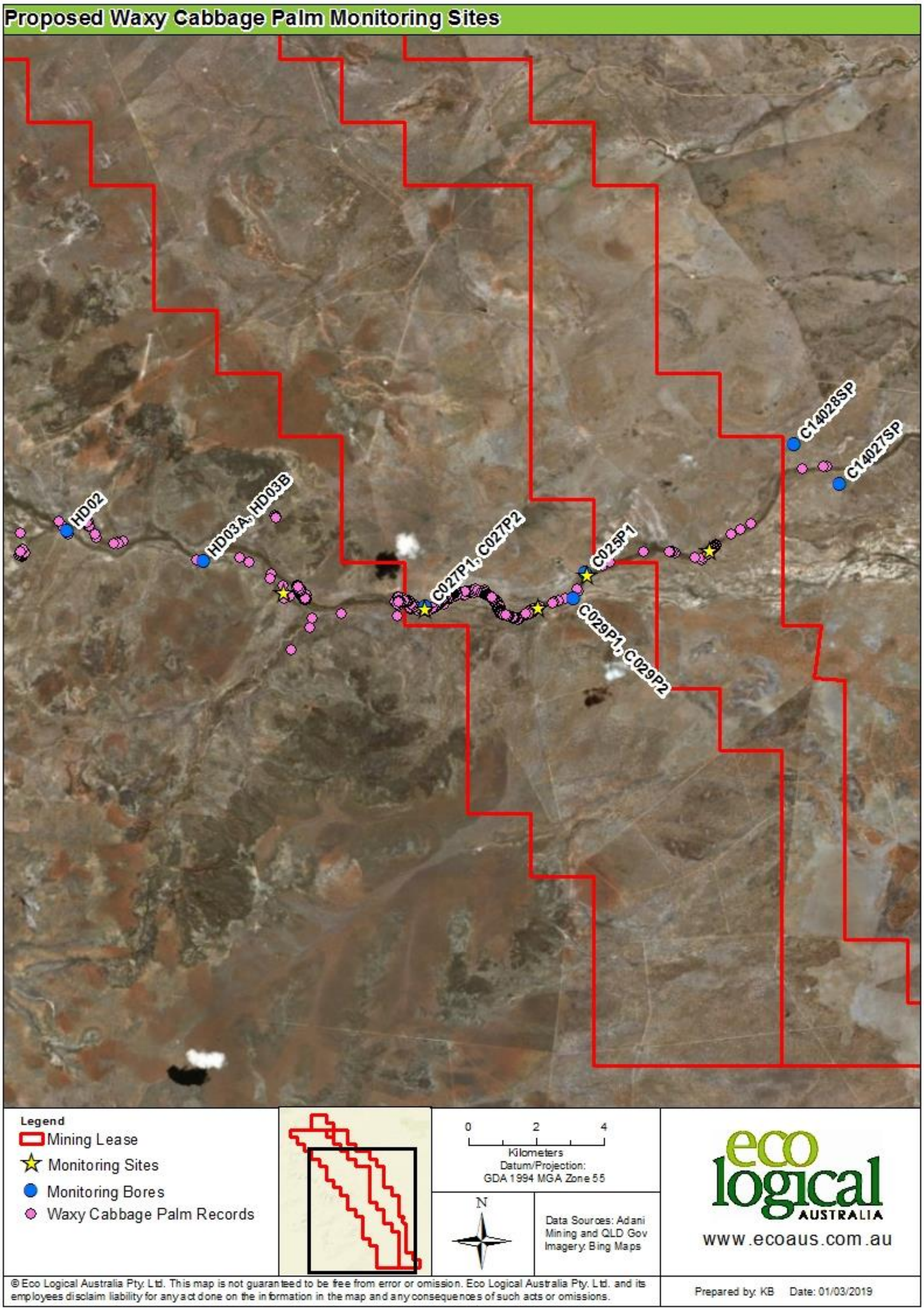


Figure 7-9 Waxy Cabbage Palm monitoring locations

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 feral animals.

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 7-7**. 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 7-7** and **Table 7-6** (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 7-7 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 Waxy Cabbage Palm condition and population survey Ecological Features Map **Impact monitoring:** Groundwater Management and Monitoring Program Receiving Environment Monitoring Program Waxy Cabbage Palm condition and population survey	Groundwater level Groundwater quality Surface water quality Waxy Cabbage Palm population structure Waxy Cabbage Palm community condition	• 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 indicators compared to baseline / pre-impact conditions	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 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 Receiving Environment Monitoring Program	Surface water flow and level Tilt, strain and displacement exceeding predictions at monitoring locations under the Subsidence Management Plan	• Impacts to Waxy Cabbage Palm such as ponding and cracking as a result of subsidence • Measurable evidence of tilt in the vicinity of the Carmichael River attributable to Subsidence. • Early warning signs of subsidence, such as tilt, strain and displacement exceeding predictions at monitoring locations.	The appropriate corrective actions will be implemented and may include: • Rectifying impacts (e.g. pumping out ponds) • Re designing and implementing water diversions.

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions
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 Waxy Cabbage Palm condition and population survey Ecological Features Map **Impact monitoring:** Receiving Environment Monitoring Program Waxy Cabbage Palm condition and population survey	Surface water levels and flow Waxy Cabbage Palm population structure Waxy Cabbage Palm community condition	• Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded. • Statistically significant change in indicators compared to baseline / pre-impact conditions	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 • Removal of grazing (watering of stock at Carmichael River) in order to increase water pool life span from Year 20 • 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.
		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 monitoring:** Receiving Environment Monitoring Program Waxy Cabbage Palm condition and population survey Ecological Features Map **Impact monitoring:** Receiving Environment Monitoring Program Waxy Cabbage Palm condition and population survey Erosion and Sediment Control Plan Regular site inspections in accordance with the Environmental Management Plan and System.	Surface water quality Waxy Cabbage Palm population structure Waxy Cabbage Palm community condition	• 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. • Statistically significant change in indicators compared to baseline / pre-impact conditions	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: 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 • 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
		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 monitoring:** Receiving Environment Monitoring Program Waxy Cabbage Palm condition and population survey Ecological Features Map **Impact monitoring:** Receiving Environment Monitoring Program Waxy Cabbage Palm condition and population survey Erosion and Sediment Control Plan Regular site inspections in accordance with the Environmental Management Plan and System.	Surface water flow and level Waxy Cabbage Palm population structure Waxy Cabbage Palm community condition	• 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. • Statistically significant change in indicators compared to baseline / pre-impact conditions	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	Surface water flow (periods of flow) Surface water 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:** Erosion and Sediment Control Plan Receiving Environment Monitoring Program Groundwater Management and 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.	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.	**Pre-impact monitoring:** Ecological features map Waxy Cabbage Palm condition and population survey **Impact monitoring:** Fire Management Plan. Waxy Cabbage Palm condition and population survey Regular site inspections in accordance with the Environmental Management Plan and System.	Waxy Cabbage Palm population structure Waxy Cabbage Palm community condition Fuel load levels as described in the Fire Management Plan	• 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.	**Pre-impact monitoring:** Ecological features map Waxy Cabbage Palm condition and population survey **Impact monitoring:** Fire Management Plan. Waxy Cabbage Palm condition and population survey Regular site inspections in accordance with the Environmental Management Plan and System.	Waxy Cabbage Palm population structure Waxy Cabbage Palm community condition Threatened and endemic flora populations Fuel load levels as described in the Fire Management Plan	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 monitoring:** Ecological features map Waxy Cabbage Palm condition and population survey Weed and pest survey **Impact monitoring:** Waxy Cabbage Palm condition and population survey Weed and pest survey	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 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.	**Pre-impact monitoring:** Ecological features map Waxy Cabbage Palm condition and population survey Weed and pest survey **Impact monitoring:** Waxy Cabbage Palm condition and population survey Weed and pest survey	Presence of feral animals Extent of feral animal disturbance	• 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	**Pre-impact monitoring:** Ecological features map Waxy Cabbage Palm condition and population survey Weed and pest survey **Impact monitoring:** Waxy Cabbage Palm condition and population survey Waxy Cabbage Palm community health survey Weed and pest survey Regular site inspections in accordance with the Environmental Management Plan and System.	Waxy Cabbage Palm community condition Grazing practices (density, locations) as per management plan and agreements Extent of feral animal disturbance	• Statistically significant change in community condition indicator compared to baseline / pre-impact conditions • 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:
					Ecological features map
					Waxy Cabbage Palm condition and population survey
					
					Impact monitoring:
					Pre-clearance surveys
					Waxy Cabbage Palm condition and population survey
					
					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.
						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,
								  ○ Environment Manager ensure that all clearing activities cease immediately
								  ○ Area assessed 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
								  ○ 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:** Ecological features map Waxy Cabbage Palm condition and population survey **Impact monitoring:** Waxy Cabbage Palm condition and population survey Pre-clearance survey 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. Regular site inspections in accordance with the Environmental Management Plan and System.	Waxy Cabbage Palm population structure Waxy Cabbage Palm community condition	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.	**Pre-impact monitoring:** Ecological features map Waxy Cabbage Palm condition and population survey Receiving Environment Monitoring Program **Impact monitoring:** Waxy Cabbage Palm condition and population survey Receiving Environment Monitoring Program	Rehabilitation success parameters as listed in Appendix 2 of the EA (native fauna species, plant regeneration, weed abundance, pest abundance) Surface water quality	• Rehabilitation not meeting success criteria under EA for parameters such as vegetation cover, evidence of erosion within relevant EA timeframes. • Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded.	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.

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions
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.***						
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.	**Pre-impact monitoring:** Ecological features map Waxy Cabbage Palm condition and population survey **Impact monitoring:** Waxy Cabbage Palm condition and population survey Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Visual observations	• 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.	**Pre-impact monitoring:** Ecological features map Waxy Cabbage Palm condition and population survey Receiving Environment Monitoring Program **Impact monitoring:** Waxy Cabbage Palm condition and population survey Receiving Environment Monitoring Program Regular site inspections in accordance with the Erosion and Sediment Management Plan and Environmental Management System.	Surface water quality	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.

#	Potential direct and indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring indicators	Trigger for adaptive management and corrective actions	Corrective actions
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.	**Pre-impact monitoring:** Ecological features map Waxy Cabbage Palm condition and population survey **Impact monitoring:** Waxy Cabbage Palm condition and population survey Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Event monitoring for: dB(A) peak particle velocity (PPV)	• Statistically significant change in indicators compared to baseline / pre-impact conditions • 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).
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.	**Pre-impact monitoring:** Ecological features map Waxy Cabbage Palm condition and population survey **Impact monitoring:** Waxy Cabbage Palm condition and population survey Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Event monitoring for: Total suspended particulate matter	• Statistically significant change in indicators compared to baseline / pre-impact conditions • 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).

#	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	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 monitoring:** Receiving Environment Monitoring Program Waxy Cabbage Palm condition and population survey **Impact monitoring:** Receiving Environment Monitoring Program Erosion and Sediment Management Plan Waxy Cabbage Palm condition and population survey 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).
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.	**Pre-impact monitoring:** Waxy Cabbage Palm condition and population survey **Impact monitoring:** Waxy Cabbage Palm condition and population survey Regular site inspections in accordance with the Project Environmental Management Plan and Management System.	Observations of amount of light falling near Waxy Cabbage Palms	• Statistically significant change in indicators compared to baseline / pre-impact conditions 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.

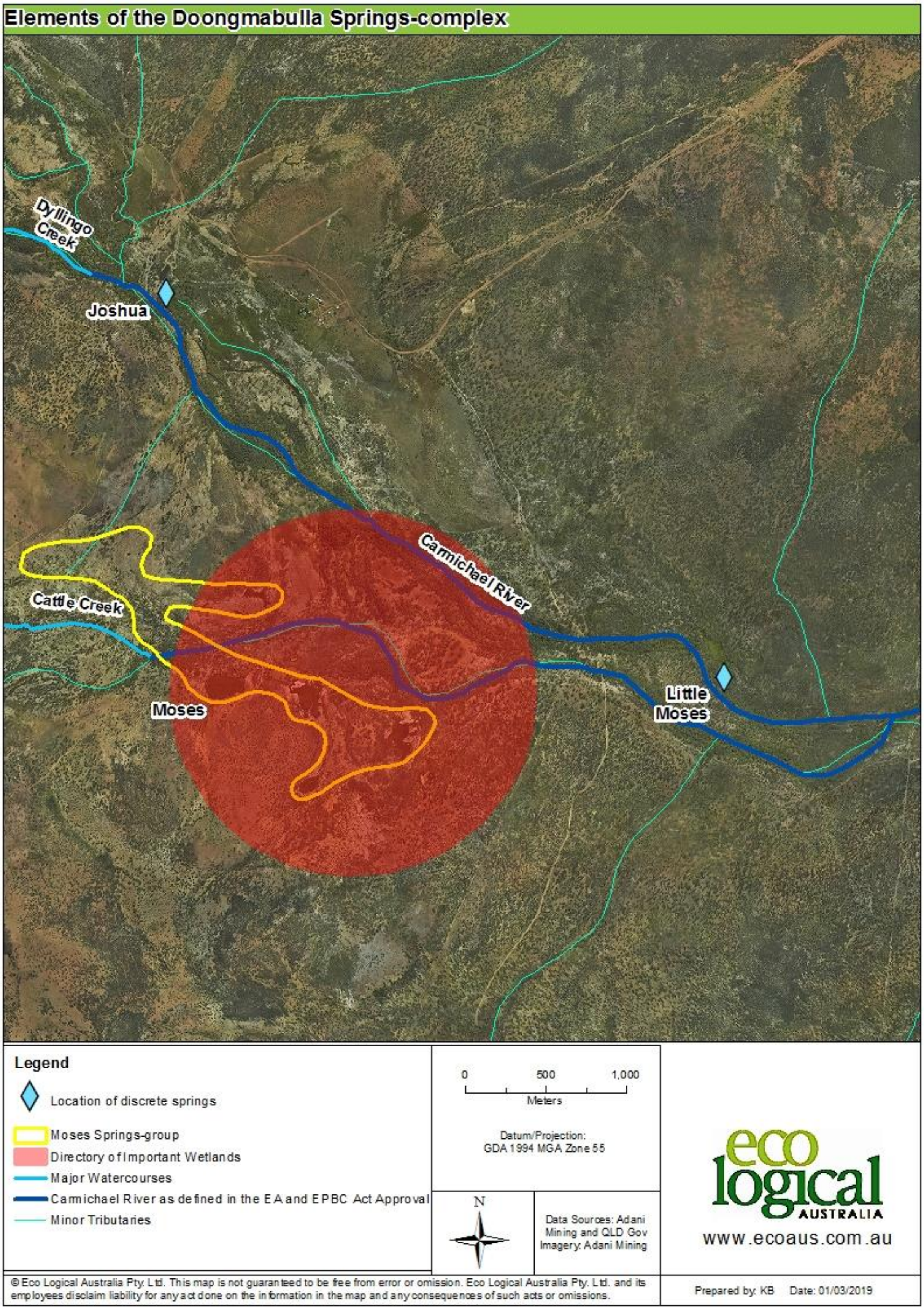


Figure 8-1 Location of the elements of the Doongmabulla Springs-complex

Recent studies of the Doongmabulla Springs-complex (Fensham et al. 2016) have described the following features (a map showing their location is available in Fensham et al. 2016):

- A cluster of eight small to medium sized springs known as Home Springs are located within the Joshua Springs-group, approximately 580 m south-east of the Joshua spring. The outflow from the Joshua Spring and House Springs converge to form the main discharge feeding the Carmichael River for a distance of 20 km.
- Bonanza Springs-group – a small number of non-mounding springs, located on the southern banks of Dyllingo Creek, immediately north of the Mouldy Crumpet springs.
- Within the Moses Spring-group, the following springs have been identified
    - Mouldy Crumpet Springs-group – a cluster of numerous small mounded springs (82 vents), located on the scalded plain between Dyllingo Creek and Cattle Creek.
    - Camaldulensis Spring, Greschlechin Spring, and Bush Pig Trap Spring – non-mounding springs located on the eastern edge of the Moses Springs-group.
- Yukunna Kumoo Springs – one large recharging spring and vents on the edge of the wetland, located 1.8 km downstream of the Little Moses Springs-complex.
- Dusk springs – a small cluster of outcrop springs, located north of the Carmichael River, 2.3 km downstream of the Yukunna Kumoo Springs.
- Surprise Spring – an outcrop spring which has formed a short gully from an ill-defined sources in colluvial material on the edge of Surprise Creek which enters the Carmichael River.
- There are some scalded areas around House Springs and Camp Springs, but *Trianthema* sp. is the only scald endemic occurring in these areas

While features do not form part of the statutory description of the Doongmabulla Springs-complex, they have been included for reference, and may form part of future statutory descriptions. The features are discussed in further detail within the following sections.

8.1.1 Moses Springs-group

The Moses Springs-group consists of at least 65 springs spread over an area 2.5 km long by 1.3 km wide, located in the Doongmabulla Mound Springs Nature Refuge, approximately 9 km west of the Project area (**Figure 8-5** and **Figure 8-6**). The Moses Springs-group includes the Moses Springs, Keelback Springs, Geschlichen Spring, Mouldy Crumpet Springs and Camp Spring.

Most of the discharge areas in the Moses Springs-group are mound springs ranging in height from 20 - 50 cm, and often supporting central pools (GHD 2014). The highest mound is 1.5 m tall, which suggests that the existing pressure head is up to 1.5 m above ground level (GHD 2014). Seepage springs are also present. The size of the vents, in conjunction with the scalded areas, suggests groundwater is fed by artesian pressure through a vertical conduit, features characteristic of discharge springs elsewhere (Fensham et al. 2016).

All of the springs have a wetted area, with five springs supporting wetland areas larger than 0.5 ha. In four locations the mound springs have contributed water to broad shallow pools (often only a few centimetres deep), forming wetlands of approximately 3.5 ha in total area (GHD 2014). Elsewhere, mounds have occasionally formed localised shallow pools up to 20 m in diameter (GHD 2014) and aggregations of wetland vegetation <4 m in diameter. The large wetlands at the Moses Springs-group wetlands, together with the Keelback Springs flow into permanent open ponds and channels within the bed of Cattle Creek, however during periods of drought, evaporation reduces moisture in the regolith and these channels do not discharge into the Carmichael River (Fensham et al. 2016).

The condition of the Moses Springs-group is rated as 1a on a scale of 1-5 with 1 being the best condition, 4 being the poorest condition, and 5 being extinct (Fensham et al. 2010). However, Rod Fensham suggests that the Moses Springs-group would be unlikely to achieve the highest overall score if the ranking exercise were to be undertaken again, due to degradation, and the discovery of a formerly endemic plant species at another Springs-complex nearby (GHD 2012a).

Despite this, the Moses Springs-group does have exceptional biological value, with two fauna species found only within this springs-group, seven GAB spring endemic flora species including one that is only known from two springs-groups and of which six are listed as threatened under the EPBC Act and / or NC Act (**Section 8.2** and **Figure 8-3**).

The GAB endemic and threatened species associated with the wetland areas at Doongmabulla Springs-complex are all found in the Moses Springs-group. These species were generally present on or immediately adjacent to mounds, seeps or pools, with the majority of species located within the wetland areas fed by seepage from the springs. Most mounds (and associated wetlands) are generally heavily vegetated with a characteristic suite of species that identify them from a distance, in particular the grass *Sporobolus pamelae*, which only occurs in association with GAB mound springs (GHD 2014).

Scalded, pale soils, and extensive grasslands and sedgelands at the Moses Springs-group reflect altered soil chemistry, likely due to the high salinity content of GAB groundwater discharge, which has resulted in a specialised community of salt-tolerant and endemic flora (GHD 2012a). These soil and vegetation characteristics indicate the Moses Springs-group wetland community is mature and has probably been in place for a long time (GHD 2012a).

8.1.2 Little Moses Springs-group

The Little Moses Springs-group is immediately adjacent to Dyllingo Creek, approximately 7 km from the western edge of the Project area boundary (**Figure 8-7**).

The Little Moses Springs-group is a series of seepages (no mounds) from the side of a slope and one large pool (GHD 2012a). The spring is a tear-shaped sedgeland/wetland with an open pond in the centre. The spring is approximately 200 m long and 50 m wide.

Waxy Cabbage Palm has been recorded at the Little Moses Springs-group (GHD 2012a), although it occurs in non-wetland vegetation where the surface is not permanently wet. No GAB endemic flora or fauna species are known to occur at this spring.

Grasslands are absent from the Little Moses Springs-group and the soil is dark brown to black and of a heavier nature. These observations, combined with a lack of surface water and GAB springs flora and fauna endemics, have led to the postulation that Little Moses may be a very young springs-group (GHD 2014).

8.1.3 Joshua Springs-group

The Joshua Springs-group is located approximately 10 km directly west of the mine area boundary (**Figure 8-8**). The Joshua Springs-group consists of one spring mound ('Joshua Spring') that has been modified into an artificial turkey's nest dam (GHD 2012a). It is a high flow spring with a strong pressure head, which rises at least 1 m above the surrounding plain (GHD 2014). The daily flow of Joshua Spring is approximately 4.32 to 8.64 ML (GHD 2014). The water flows out of the mound spring and into an adjacent shallow wetland of approximately 2 ha in area, and then drains to Dyllingo Creek, where it is believed to contribute a significant proportion of the Carmichael River's base flow (GHD 2014).

The Joshua Spring is considered to be high value habitat for aquatic fauna (GHD 2012a). Given the depth and permanency of this spring, it is likely that fish, amphibian, turtle and aquatic invertebrate species use it, especially during the dry season (GHD 2012a). The wetland contains two threatened flora species:

- *Myriophyllum artesium* (listed as Endangered under the NC Act)
- *Sporobolus partimpatens* (listed as Near Threatened under the NC Act).

The Joshua Spring wetlands harbour a Category 3 restricted matter and WoNS Olive Hymenachne, with the outflow channel of the modified spring mound dam choked with this exotic grass.

Scalded earth was not observed at this site, and it is speculated that this spring may have been similar to the Little Moses spring seepages, prior to modification, only with a much larger flow (GHD 2012a).

8.2 Ecology

As well as being a GAB springs wetland TEC, the Doongmabulla Springs-complex and associated wetlands are listed as being of national significance in the Directory of Important Wetlands because: 1) they are a good example of a wetland type occurring within a biogeographic region in Australia, and 2) the wetlands are important habitat for animal species at vulnerable stages in their life cycles, or provide a refuge when adverse conditions such as drought prevail (DoE 2015).

8.2.1 Vegetation Communities

The open vegetation areas of the Doongmabulla Springs-complex wetlands include (**Figure 8-2**):

- bare scalded clay pans with sparse grass and herb cover, including the Near Threatened grass *Sporobolus partimpatens* and low chenopod shrubs.
- grasslands dominated by the Endangered *Sporobolus pamelae*, growing in or close to the saturated zone (within RE 10.3.31). This vegetation community is considered to be obligate groundwater dependent.
- mixed-species sedgelands in the wetter areas, dominated by *Cyperus laevigatus, C. polystachyos, C. difformis, Eleocharis cylindrostachys*, and *Fuirena umbellata*. Some of these sedgelands contain a small population of the Vulnerable Waxy Cabbage Palm.

These vegetation communities are all included in RE 10.3.31, which is an Of Concern RE that is part of the GAB springs wetland TEC ecological community.

Wooded vegetation communities within the Doongmabulla Springs-complex and wetland areas include *Eucalyptus coolabah* (Coolibah) / River Red Gum woodland and open woodland, Weeping Paperbark forest, *E. persistens* (Peppermint Box) open woodland, and Reid River Box woodland (GHD 2012a).

Sporobolus pamelae grassland

Mixed Sedglands

Weeping Paperbark forest

Peppermint Box open woodland

Figure 8-2 Vegetation communities

8.2.2 Flora of the Doongmabulla Springs-complex

The wetland areas and mound springs of the Doongmabulla Springs-complex are known to contain six threatened flora species (**Figure 8-3**, **Figure 8-4**):

- *Eryngium fontanum* (Blue Devil) – Endangered under the EPBC Act and NC Act, and is only known from two springs-groups
- *Eriocaulon carsonii* (Salt Pipewort)– Endangered under the EPBC Act NC Act
- *Hydrocotyle dipleura* – Vulnerable under the NC Act
- *Myriophyllum artesium* - Endangered under the NC Act
- *Sporobolus pamelae* – Endangered under the NC Act
- *Sporobolus partimpatens* - Near Threatened under the NC Act
- Waxy Cabbage Palm - Vulnerable under the NC Act and the EPBC Act

Habitat for these occurs at the wetlands of Moses, Keelback, Geshlichen, Camp, Stepphing Sone and Mouldy Crumpet Springs. *Sporobolus partimpatens* is a scald endemic found in scalded areas around the Moses and Mouldy Crumpet Springs (Fensham et al. 2016).

Six other spring endemic flora species have been recorded at the complex:

- *Isotoma* sp. (R.J. Fensham 3883)

- *Peplidium* sp. (R.J. Fensham 3880)
- *Chloris* sp. (Edgbaston R.J. Fensham 5694)
- *Panicum* sp. (Doongmabulla RJ Fensham 6555)
- *Utricularia fenshamii* (Fensham et al. 2016)
- *Fimbristylis blakei* (Fensham et al. 2016)

Salt Pipewort

Blue Devil

Hydrocotyle dipleura

Waxy Cabbage Palm

Myriophyllum artesium

Sporobolus pamelae

Figure 8-3 Threatened flora

8.2.3 Fauna of the Doongmabulla Springs-complex

Squatter Pigeon, which is listed as Vulnerable under the EPBC Act and NC Act, has been recorded in open woodlands associated with the Doongmabulla Springs-complex (GHD 2012a). *Denisonia maculata* (Ornamental Snake), *Egernia rugosa* (Yakka Skink), *Phascolarctos cinereus* (Koala), *Poephila cincta cincta* (Black-throated Finch) and the *Rostratula australis* (Australian Painted Snipe) are threatened vertebrates that are considered likely to occur within the Doongmabulla Springs-complex (GHD 2012a).

The Doongmabulla Springs-complex also contains two spring endemic fauna species:

- *Gabbia rotunda* (a mollusc)
- *Mamersella* sp. AMS KS 85341 (an invertebrate)

8.2.4 Habitat Values

The Doongmabulla Springs-complex and associated wetlands provide habitat for many non-threatened fauna, including nesting habitat for birds, permanent pools for fish and aquatic reptiles, sedgeland habitat for frogs, and aquatic habitat for invertebrates such as mussels, crayfish, freshwater crabs and insects. A total of 18 fish species are predicted to occur in the surface waters of the Doongmabulla Springs-complex, including rainbowfish and spangled perch (GHD 2012a).

The Doongmabulla wetland was also used for bird nesting. Mud nests were especially common, highlighting the importance of this site as a resource for nest building materials, particularly during dry periods when mud may be scarce. Stick nests were also frequently observed within the Doongmabulla wetland.

Hollows are plentiful on the periphery of the wetland and surrounds, so it is very likely that a number of arboreal species will be present at the wetland. Woody debris was typically abundant in forested areas, but was (as would be expected) absent from the grasslands and wetlands. Leaf litter was dense in much of the forested parts of the wetland, particularly under the stands of Weeping Paperbark. Logs, lifted or fallen bark and fallen timber was common, and was confirmed to provide habitat for skinks, geckos and dragons. The Doongmabulla Springs-complex is fringed by rocky rises, some with short but abrupt escarpments, populated by a grassy open woodland of peppermint gum with porcupine grass and soft spinifex. The rock mosaic and spinifex provide ideal habitat for reptiles. It is likely that this diverse habitat within the Doongmabulla wetland would support a diverse and abundant range of reptiles.

The Doongmabulla Springs-complex, and in particular the Moses Springs-group, provide abundant, suitable habitat for frogs in the region. The density of vegetation and abundance of perennial water makes the Doongmabulla Springs-complex and associated wetlands an important amphibian habitat in an otherwise arid environment.

While the springs themselves may provide a relatively small area of habitat for fish, the value of these springs is in providing surface flows which in some areas drained directly into the neighbouring waterways. Doongmabulla Springs-complex also provides a diverse range of habitat for aquatic invertebrates, including freshwater mussels, crayfish, freshwater crabs and various insects.

The diversity and abundance of aquatic invertebrates is largely determined by the habitat structure and type (for example clay substrates with root masses) and the availability of foraging material (for example leaf litter and other organic detritus). Suitable habitat was observed within the springs themselves, within the wetlands, and also in adjacent waterways. Substrates ranged from sand (suitable for freshwater mussels) to clays (preferred by many aquatic insects), and were mostly provided with abundant organic matter utilised by invertebrates for shelter and as a food source.

8.2.5 Disturbance

In general, the habitats present within the Doongmabulla Springs-complex are intact and in good ecological condition. The wetland is exposed to introduced wildlife and stock, with cattle trampling observed particularly at the Moses Springs-group (GHD 2012a). The Doongmabulla Springs-complex is currently (and was historically) used for watering livestock, which directly impacts the springs through trampling, pugging, fouling of water and compaction (GHD 2012a). The greatest damage to the wetlands was caused by Feral Pigs, with parts of some wetlands highly disturbed by pig wallowing and foraging (GHD 2012a).

Outside of the wetland, Rubber vine is present along Cattle Creek, which is a Category 3 restricted matter under the Queensland *Biosecurity Act 2014*, and is a Weed of National Significance (WoNS) under Commonwealth legislation. This weed was growing in very low densities, as scattered individuals. However, it is growing near mound springs within the Moses Springs-group and is a potential future threat. The overflow channel for the Joshua spring is infested with Olive Hymenachne, a Category 3 restricted matter under the Biosecurity Act 2014 and a WoNS species.

The Joshua Springs-group is the most impacted and is completely altered from its natural state. It now consists of an upper turkey's nest dam and a more recently constructed lower turkeys nest dam. Given the depth of the turkey's nest dam and the permanency and high flow rate of this spring, it is predicted that the Joshua Spring provides potential habitat for fish, amphibians, turtles and invertebrate species, especially during the dry season.

Maps of the key wetland areas are provided in **Figure 8-5** to **Figure 8-8**.

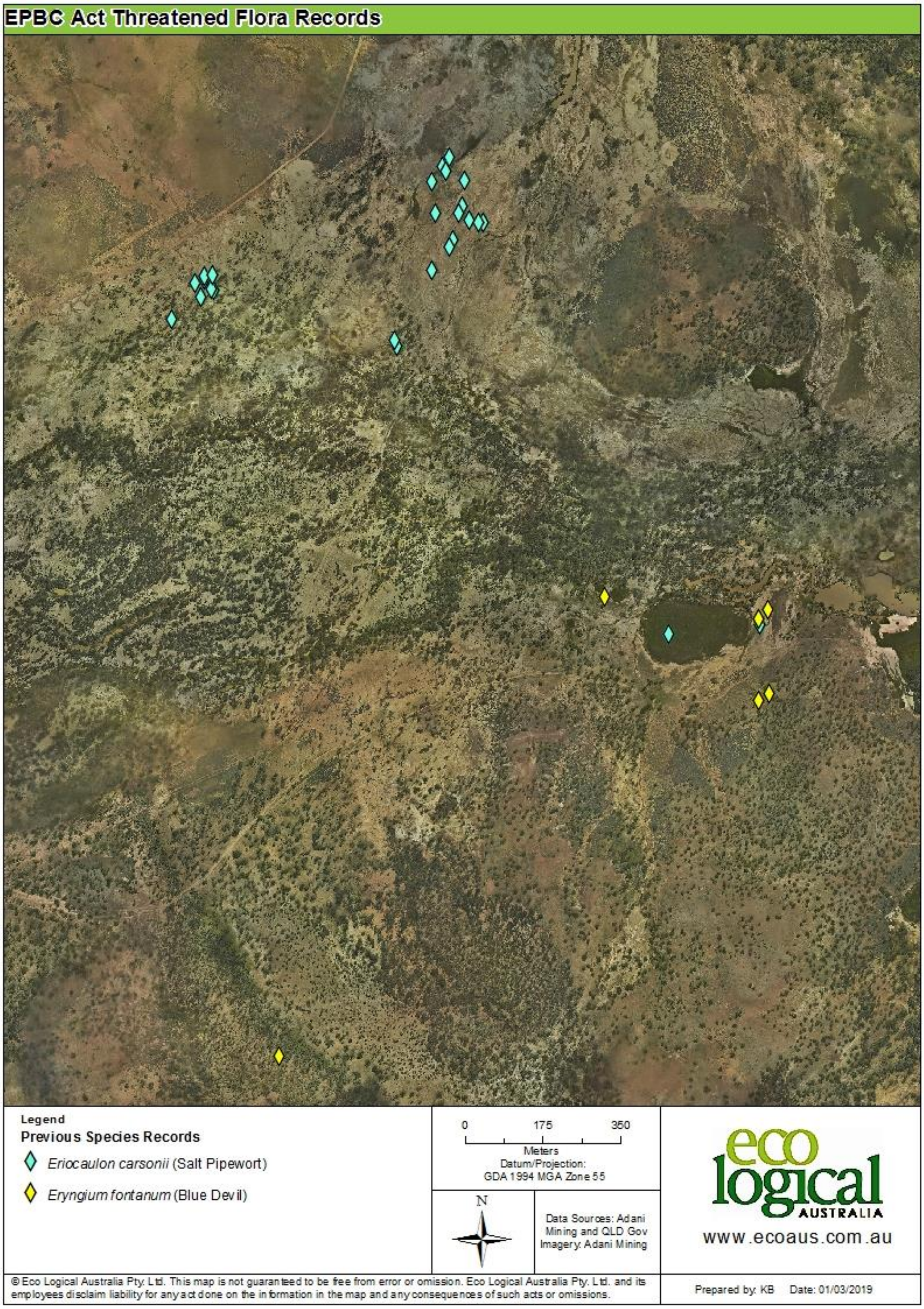


Figure 8-4 *Eriocaulon carsonii* and *Eryngium fontanum* records

Figure 8-5 Moses Springs-group wetland areas

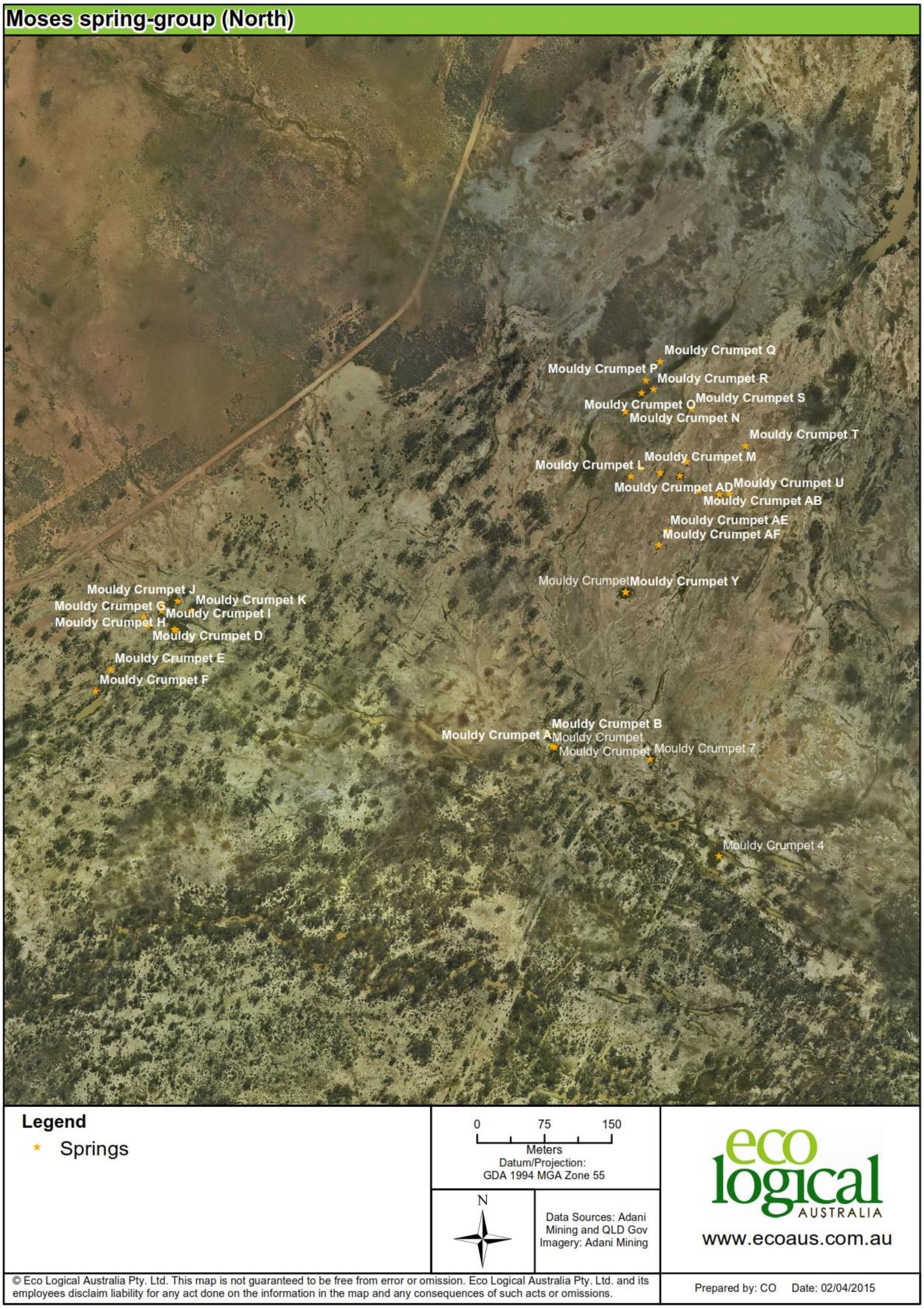


Figure 8-6 Moses Springs-group mound springs

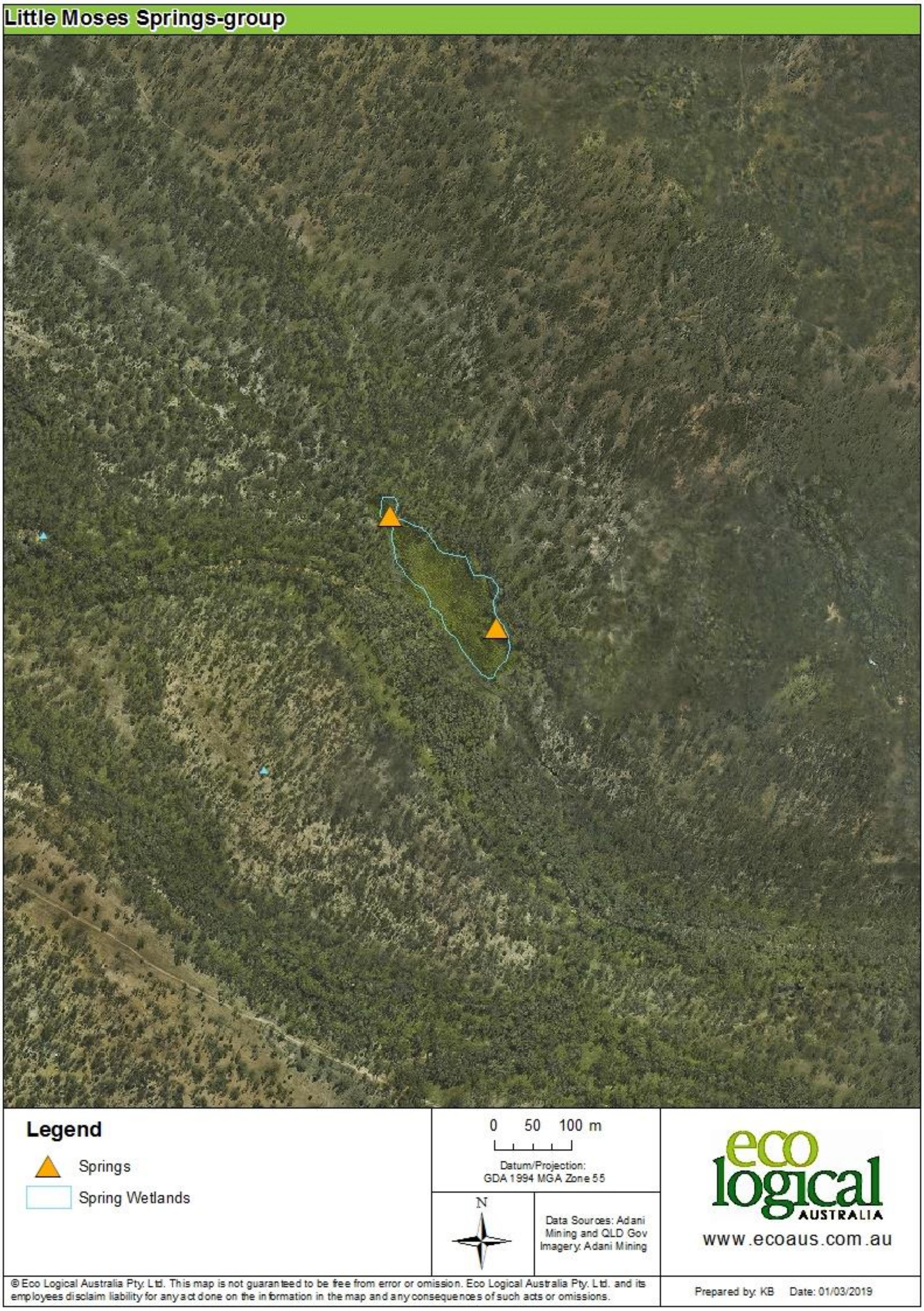


Figure 8-7 Little Moses Springs-group

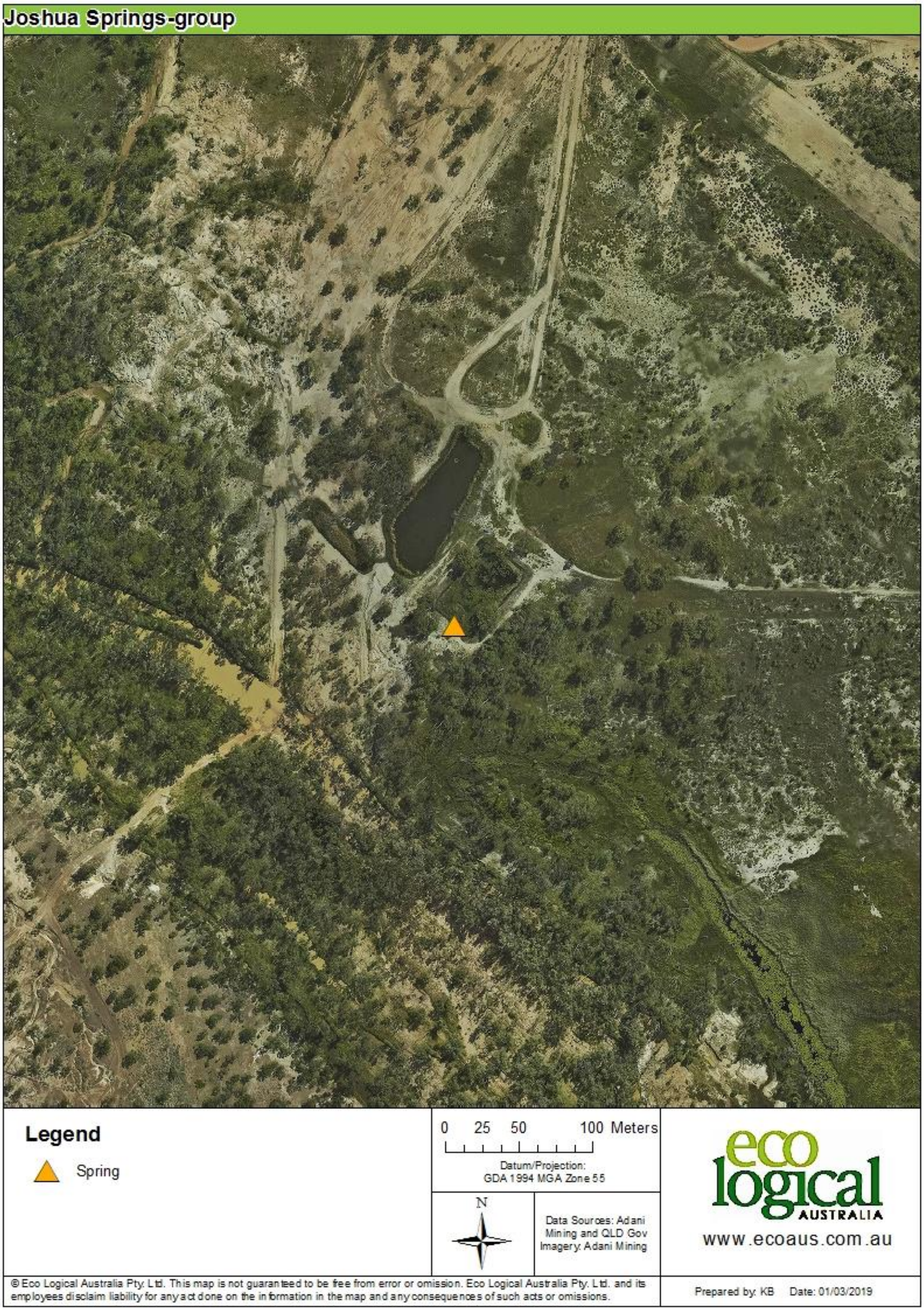


Figure 8-8 Joshua Springs-group

8.3 Supporting Groundwater resources

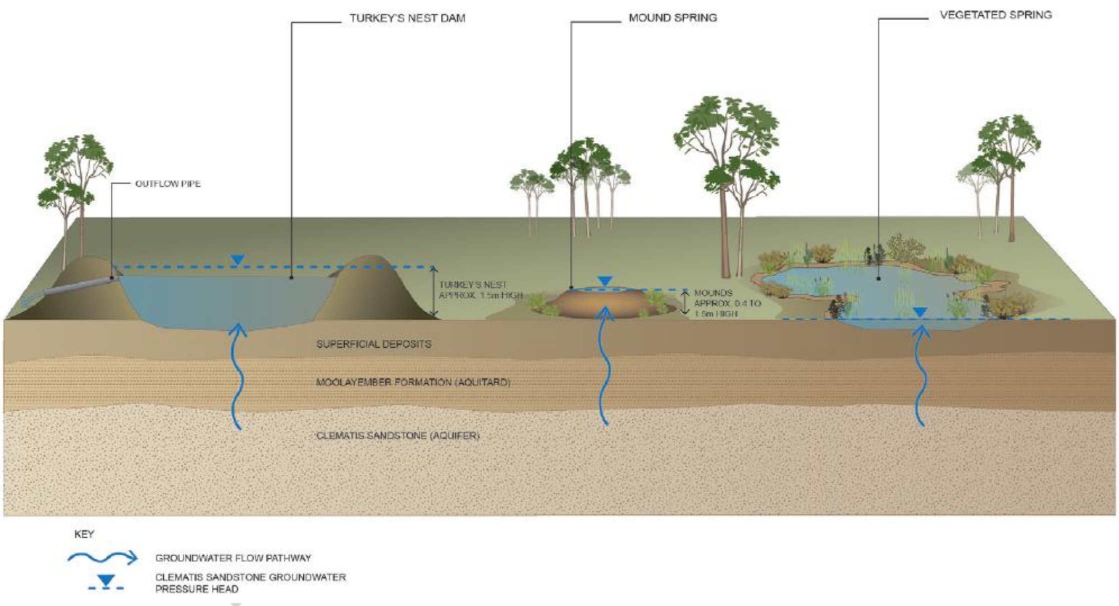
8.3.1 Conceptual groundwater model

The Doongmabulla Springs-complex comprises a series of mound (wetland) springs approximately 8 km to the west of the mine leases, as depicted in **Figure 8-1**.

Studies undertaken during and post EIS indicate that the source aquifer of the Doongmabulla Springs-complex is discharge from the artesian Clematis Sandstone through weathered Moolayember Formation.

A conceptual groundwater model (**Figure 8-9**), which formed the basis of the numerical groundwater model, was developed based on existing information and field data collected for the Carmichael Coal Mine EIS process. This original conceptual model has been refined over time with new information since completion of the EIS. This model was independently peer reviewed through the EIS process by Adani and by the Queensland Government, reviewed by the Independent Expert Scientific Committee (IESC), further developed and subsequently approved through the Queensland Coordinator General's Evaluation Report and the EPBC Approval. Subsequent work included the groundwater flow model review conducted as per conditions 22 and 23 of the EPBC Approval which was peer reviewed by an independent expert and the results of which further informed the conceptual groundwater model.

The current understanding of the site's hydrogeological regime is presented in detail in the GMMP, with relevant material from the GMMP also provided in this GDEMP. This refined conceptual model has also 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 model. For further information, reference should be made to *Research Study Report - Source Aquifer to Doongmabulla Springs* (Adani 2018).



Source: GHD 2013b

Figure 8-9 Conceptual groundwater model for the Doongmabulla Springs-complex GDE

The groundwater conceptual model has been subsequently refined to include the results of continued investigations. It is considered the key elements of the groundwater system in the 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 8-10** and **Figure 8-11**. The groundwater contour impact mapping in **Section 8.5** is presented on the basis of this hydrogeological conceptual model.

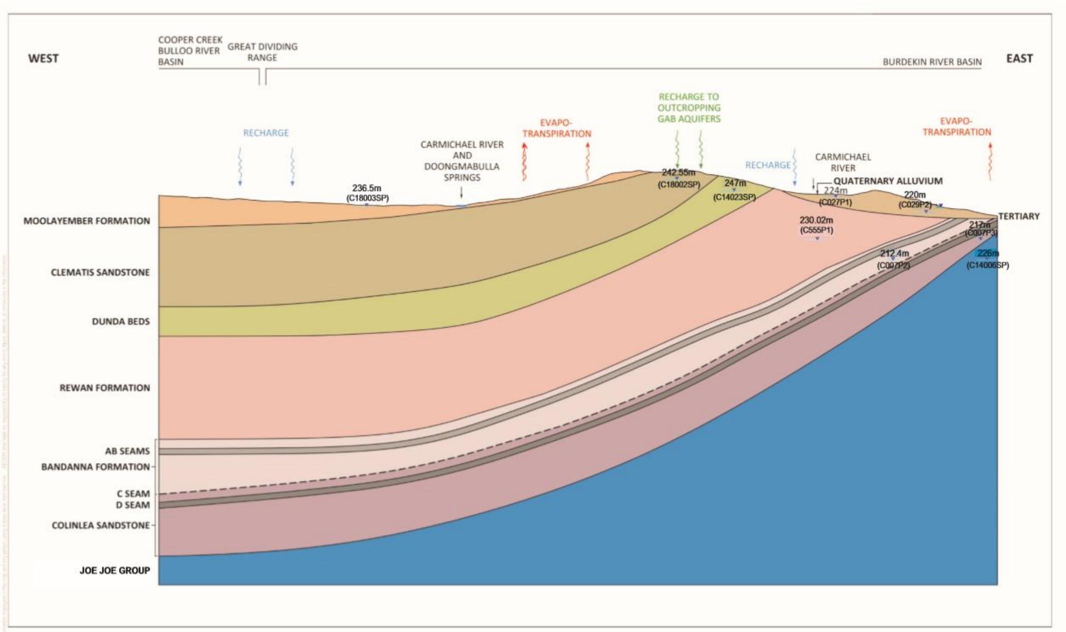


Figure 8-10 Hydrogeological conceptual model – pre-mining

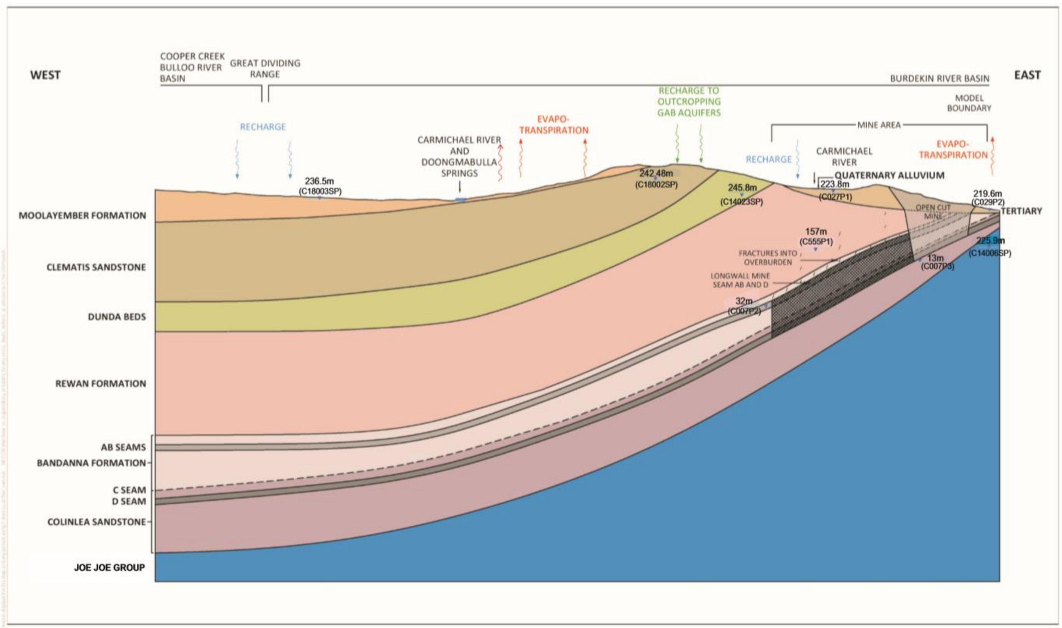


Figure 8-11 Hydrogeological conceptual model – post-mining

The groundwater model conceptualisation is supported through the following baseline studies, investigations and information, each of which is provided in further detail below, and additionally in the GMMP:

- Additional borehole Information
- Water Level data
- Water Quality data
- Regional geological interpretation
- The properties of the Rewan Formation

8.3.2 Additional Borehole Information

Project approvals are based on EIS (2012) and SEIS (2013) Groundwater modelling and Impact assessment studies. The hydrogeological conceptualisation generated by these studies is summarised below;

- The hydrogeological model has been developed based on the exploratory drilling within the ML area (from 2011 to 2014)
- The spatial extent of geological units within the Project area is extrapolated to areas outside the Project area for modelling purposes and cross checked with publicly available regional geological data
- The conceptualisation (based on mapped geology) determined that the Doongmabulla Springs-complex are likely fed by groundwater from the Clematis Sandstone aquifer through the overlying Moolayember Formation and/or Quaternary alluvium
- Three monitoring bores (HD02, HD03 A and HD03B) are installed between the Project area and the Doongmabulla Springs-complex in this conceptualisation
- It was identified through the approvals process that the collection of additional geological/hydrogeological information close to the Doongmabulla Springs-complex would be necessary.
- This need was also identified in the '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' report (2016) which states on page 194:

"Drilling of new monitoring bores in the vicinity of the springs, …A high-resolution survey of spring elevations would also improve the accuracy of predictions relating to spring flows and the potentiometric surface of potential aquifers."

Further work has been undertaken by Adani since 2014 to address recommendations/requirements:

- Three (3) additional deep core bores were drilled and logged (outside the Project area and in between the Project area and the Doongmabulla Springs-complex), through the Rewan Formation and into the coal seams below the Rewan formation
- Field and Laboratory investigations were conducted to determine the hydraulic properties of the Rewan formation;
- Several additional monitoring bores were drilled outside the Project area and in between the Project area and the Doongmabulla Springs-complex into the aquifers conceptualised to be the source of the springs
    - 8 bores in the Clematis Sandstone

    - 2 bores in the Moolayember Formation
- Shallow spear point wells (5) were installed in close vicinity to mound springs and discharge springs within the Doongmabulla Springs-complex
- Monitoring of groundwater levels and chemistry in the new monitoring bores was completed, and measurement of vertical groundwater gradients in the different hydro-stratigraphic formations
- Accurate survey of the springs and spring mounds to measure groundwater levels for comparison with that of source aquifers
- An assessment of the drilling conditions in the west of the Project area whilst drilling through the Rewan Formation and associated laboratory testing of the physical properties of the Rewan Formation;

8.3.3 Water Level Data

Hydrostatic pressure was measured at various locations within the springs, and compared with groundwater levels from the network of monitoring bores installed into the same source aquifer of the springs to provide a means for testing and correlating the source aquifer (**Table 8-1**).

Table 8-1 Water level data

Bore ID	Easting	Northing	Ground Surface Elevation (mAHD)	Water Level (mAHD)	Comment
C14033SP	418230.3	7566782.4	296.47	250.62	
C180118SP	423796.8	7568090.9	306.63	250.17#	
C14011SP	426131.0	7561454.8	311.67	242.80	
C14012SP	424895.5	7560591.1	286.37	242.62	
C14013SP	424895.5	7560591.1	286.46	242.49	
C18002SP	420948.1	7558952.3	248.30	242.55	
Joshua Spring	421201.8	7559387.6	241.20	241.20 (243.26)	Floor of spring (Top of Turkey's nest) - From Survey data
C14021SP	429796.3	7550966.3	277.59	245.54	
C18001SP	416311.5	7553052.0	246.97	249.77	
DS4	421571.0	7556883.0	241 to 243	243*	Mound Springs
C 18010 SP**	421610.099	7556860.735	237.84	237.837	Moses Springs Group- Doongmabulla Springs-complex
C 18011 SP**	422044.827	7556285.962	240.11	239.908	Moses Group (Camaldulensis Spring)- Doongmabulla Springs-complex
C 18012 SP**	420424.313	7557642.007	239.03	239.03	Mouldy Crumpet Spring- Doongmabulla Springs-complex
C 18013 SP**	420427.749	7557636.776	238.66	238.663	Mouldy Crumpet Springs- Doongmabulla Springs-complex
C 18014 SP**	424639.569	7557046.462	235.48	235.475	Little Moses Spring – Doongmabulla Springs-complex

Note-*: As measured during 2013 SEIS studies
**: Installed in September 2018

Bore ID	Easting	Northing	Ground Surface Elevation (mAHD)	Water Level (mAHD)	Comment
#- Last reading before blocked (new bore will be installed)					

Key findings from the review of water level data:

- The groundwater levels in the mound springs are generally in agreement with that of Clematis Sandstone in the vicinity of the springs;
- Groundwater level in C 18002 SP (screened into the Clematis Sandstone) is 243.67 (April 2018) m AHD and is considered to be the prevailing potentiometric hydrostatic heads in Clematis Sandstone in the vicinity of springs;
- It is observed that Joshua Spring (modified turkeys nest dam) top of mound level is 243.26 m AHD is matching to the groundwater level of C 18002 SP;
- Further assessment of groundwater levels of C 18002 SP and Joshua Spring is summarised below:
  - Bore C 18002 SP is screened in coarsest Clematis Sandstone at around 70m deep;
  - It is observed that the water level at the Joshua Spring turkeys nest dam is matching with that of bore C 18002 SP, and to support this observation there must exist a clear conduit or passage way for discharge of water at the Turkeys nest dam;
  - This observation is at odds with the other discharge springs/mound springs where the ground water potentiometric heads are found to be less than 240m AHD
  - With the above it is likely that Joshua Spring must be a very old uncontrolled water bore, having been converted into a turkeys nest dam to make use of the water head (albeit there is a drop in head at Joshua Spring by 0.40 m when compared to C 18002 SP bore, possibly be due to accumulation of sand, clay and vegetation around the bore over a period of time)
- Groundwater potentiometric heads within the mounds of Moses Springs-group (Moses Spring, Camaldulensis Spring and Mouldy Crumpet Spring) are within the range of 237 m to 239 m AHD;
- Comparing the hydro-stratigraphic potentiometric heads of the Clematis Sandstone aquifer as measured form C 18002 SP, with that of mound springs, it is observed that most of the pressure heads are lost in finding the way through to the surface through weak /thin unconfined Moolayember Formation. This validates the scenario discussed in the LEBSA Report 2016: *“Under this scenario sufficient artesian head in the Clematis Sandstone is required to provide discharge to the surface through a thin layer of the Moolayember Formation and/or surface alluvium thinned by erosion around the confluence of Carmichael Creek and Bimbah Creek”*
- The springs occur where the Moolayember Formation is of sufficient thickness and (low) permeability to act as a confining layer, yet sufficiently thin to facilitate discharge. This is evident from the surface outcrop adjacent to the mound springs comprises multi-coloured (white and purple-rust) clay-rich weathered Moolayember Formation sediments; as presented in **Figure 8-12**.

Figure 8-12 Moolayember Formation outcrop

8.3.4 Water Quality Data

Water quality results from across the project area (**Table 8-2**) from EIS studies and data reported through the Environmental Authority and additionally presented in the GMMP demonstrates the following:

- Groundwater quality at Joshua Spring is fresh, recently recharged groundwater, where electrical conductivity (EC) is measured at 940 micro Siemens per centimetre (µS/cm), albeit this location is a pond/dam where water quality is influenced by evaporation/ evapotranspiration.
- 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.

Table 8-2: Electrical conductivity (µS/cm) in each hydrogeological unit

Hydrogeological Unit	85th Percentile of Electrical conductivity (µS/cm)
Alluvium	42,250 (east) / 900 (west)
Tertiary	14,000
Moolayember Formation	572
Clematis Sandstone	640
Dunda Beds	772
Rewan Formation	3,723
Bandanna Formation	1,896
Colinlea Sandstone	2,000
Joe Joe Group	15,900

8.3.5 Regional Geology Interpretation

Adani commissioned an investigation of the interaction of mine-scale faulting at the Carmichael Coal Project (as identified from field mapping, exploration drilling and a high resolution 2D seismic survey and interpretation undertaken in 2011), with regional trends identified from the eastern margin of the Galilee Basin.

The report briefly examined the relationship between regional structure of the eastern Galilee Basin and the local structure identified at the mine site, with reference to the effect of faulting on any aquifers present in the target sequence and the overlying strata.

There is no evidence in the geological data set of any faults with sufficient throw to bring the Clematis Sandstone into contact with the underlying Permian-age units on the other side of a faulted contact. Given that the Rewan Group is around 250 m thick at the western boundary of the proposed Mine Area, a throw of 40 m would still result in an effective aquitard thickness of 210 m.

Additionally, local field mapping, exploration drilling and 2D seismic surveying has, to date, only revealed normal faulting with throws to a maximum of forty (40) metres in the planned mine area.

Considering the current documented fault regime and based on independent geological opinion, it is not considered scientifically possible that aquifers within the coal measures (mostly coal seams) would impact on groundwater flow processes in aquifers identified in the overlying Triassic aged Dunda beds and Clematis Sandstone.

8.3.6 Properties of the Rewan Formation

Rewan Thickness

Adani has conducted extensive drilling investigations into the Rewan Formation as presented in **Table 8-3** and **Figure 8-13** which demonstrates a minimum thickness of 249m and a maximum thickness of 337.1 m and an average thickness of 277 m.

Furthermore, the Rewan Formation is found to be extending to the west of the mine leases consistently, which also separates the Permian target coal seams from the stratigraphically younger Dunda Beds and Clematis Sandstone (recognised GAB aquifer) to the west. Hence it can be concluded that the consistency of the Rewan Formation thickness to the west of the Project area up to the Doongmabulla Springs-complex further confirms the hydrogeological conceptualisation.

Table 8-3 Rewan thickness

Bore	Thickness (m)	Top of Formation (mAHD)	Bottom of Formation (mAHD)
C003	270	48	318
C010	290	89	379
C015	263	60	323
C022	268	84	352
C037	285	50.5	335.5
C037C	284	49	333
C039	273	46	319
C039CR	284	46	330
C044C	270	56	326
C047	284	176	460
C048	273	65	338

Bore	Thickness (m)	Top of Formation (mAHD)	Bottom of Formation (mAHD)
C053	269	130	399
C065	286	54	340
C065C	282	57	339
C14204VWP	306	127	433
C14205VWP	302	375	609
C14207 VWP	333	166	499
C860G	280	48	328
C861G	283	92	375
C864G	249	166	415
C865G	254	79	333
C866G	275	153	428
Shoemaker-1	279	246	526.8

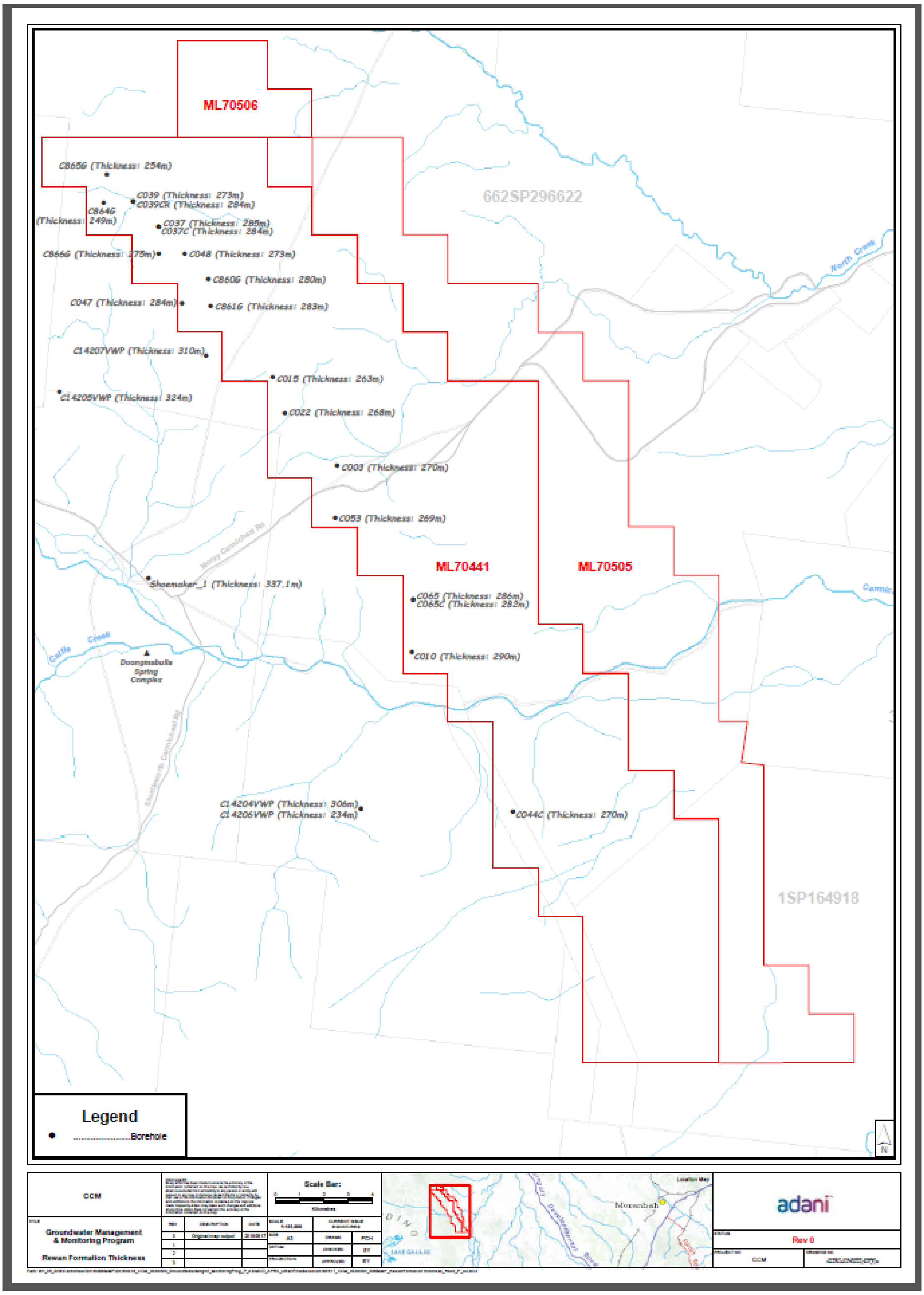


Figure 8-13 Rewan Formation boreholes

Rewan Formation Permeability

The primary permeability of the upper claystone sequence of the Rewan Formation was measured as consistently low, based on the laboratory analysis of sampled cores. In the predominant claystone strata, both vertical and horizontal hydraulic conductivity ranged from 10^{-6} to 10^{-5} m/day. In the interbedded siltstone strata, permeability was measured as low, but slightly more permeable than the surrounding claystone at 10^{-4} m/day.

The primary (formation) permeability of the lower siltstone sequence of the Rewan Formation measured as low to very low, but more variable than the upper sequence (10^{-7} to 10^{-4} m/day), likely as the result of the variance in grainsize within the predominant siltstone and the larger amount of defects.

Self-sealing Properties of Rewan Formation: Shale Gouge ratio (SGR)

To determine the SGR of interpreted faults a number of individual borehole logs extending from within the Project area towards the west (including the Shoemaker hole close to the Doongmabulla Springs-complex), were examined and the thickness of clay and shale dominated sequences within relevant logged units was quantified. Clay and shale sequences were determined from both core logging and geophysical logs for calculation of SGR for each of the relevant sequences based on anticipated fault displacements of 10 m (most frequent lower order displacement) and 50 m (maximum anticipated displacement of interpreted faults in the CCMP. Note that a SGR of 15% – 20%, is considered as the threshold above which the faults will selfheal.

- The highest SGR's are calculated as expected in the Rewan (recognised aquitard) Formation, with the lowest SGR's in the Clematis Sandstone
- For the Tertiary, Moolayember and Rewan Formations, calculated SGR's are well in excess of the limiting threshold (20%), indicating that 10 m and 50 m displacement faults would consistently form an impermeable seal in these instances
- Calculated SGR's for the Rewan Formation are consistently greater than 431% for 10 m displacement faults, and consistently greater than 86% for 50 m displacement faults. This is so far in excess of SGR of 20% derived from multiple international case study examples, that it is considered scientifically impossible for faults of this magnitude to provide connectivity through and within the interpreted Rewan Formation sequences.

8.3.7 Alternative Groundwater Conceptualisation/s

A number of alternative groundwater conceptualisations for the Doongmabulla Springs-complex have been considered in the project assessment or post project assessment and will be further investigated through the collection of additional information and the subsequent review of the groundwater numerical model within two years of mining commencement.

These alternative conceptualisations include:

- Groundwater from below the Rewan Formation, namely the Colinlea formation;
- Multiple source aquifers from above the Rewan Formation; and
- A combination of source aquifers from above and below the Rewan Formation.

The primary alternative conceptualisation for the Doongmabulla Springs-complex is that the source of the mound springs is a result of the presence of faults, which facilitate groundwater flow from a deeper source aquifer (the Colinlea) below the Clematis Sandstone and the Rewan formation (**Figure 8-14**).

Consideration of drilling results, vertical groundwater gradients, and water quality data allowed for assessment of the suitability of this conceptualisation.

A key line of evidence to test this scenario was to compare the hydraulic head for all the aquifers considered to be source(s). Data from relevant bores in each hydro geological unit was used to examine the possibility of an alternate scenario.

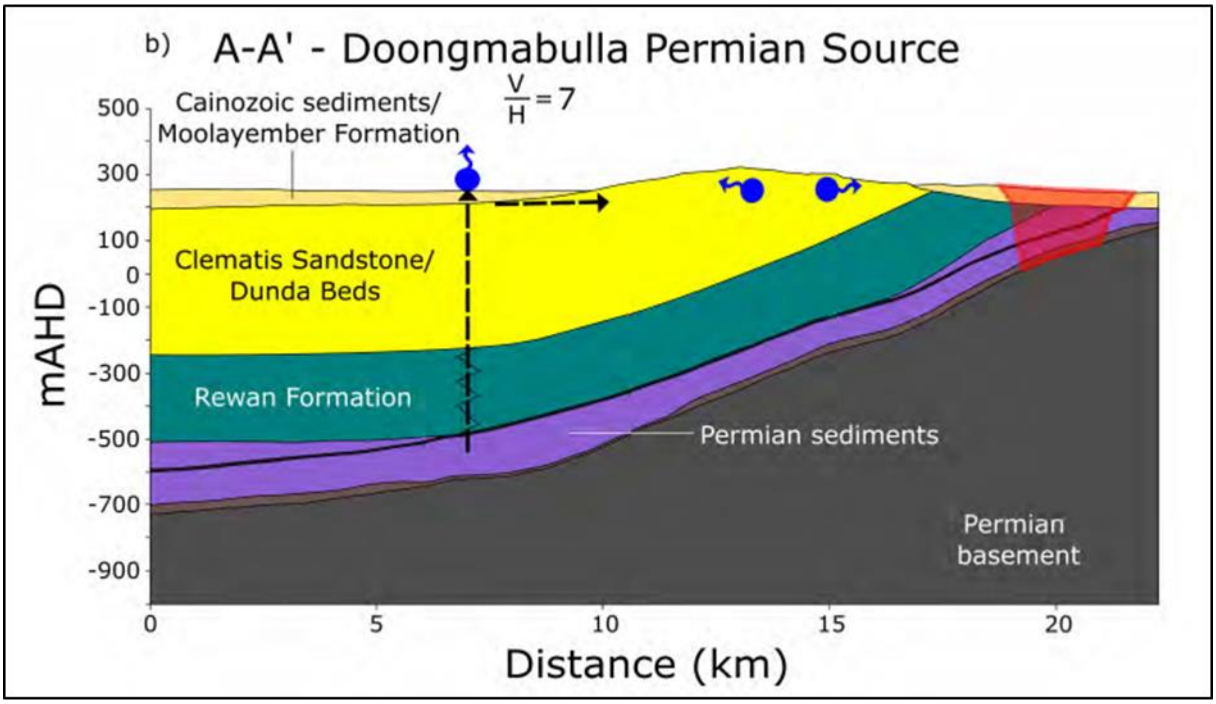


Figure 8-14 Alternative conceptual model representing the Permian Scenario (LEBSA 2016)

However groundwater levels indicate that the vertical groundwater gradients are upward above the Rewan Formation and downward below the Rewan Formation (see **Table 8-4** below which provides a summary based on groundwater contour data); this indicates the source of the Doongmabulla Springs-complex is above the Rewan Formation.

Table 8-4 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	243.67	247.22
Dunda Beds	246.73	227.18	250.94
Rewan Formation	252.26	211.83	239.47
Bandanna Formation	248.55	209.32	233.00
Colinlea Sandstone	242.43	213.31	231.94
Joe Joe Group	221.39	209.44	234.13

ND – Not determined

The findings from these considerations included:

- Drilling results, including the difficulties in construction of the standpipe groundwater monitoring bores within the Rewan Formation due to swelling clays, along with aquifer test results 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.
- Groundwater levels indicate that the vertical groundwater gradients are upward above the Rewan Formation and downward below the Rewan Formation this indicates the source of the Doongmabulla Springs-complex is above the Rewan Formation.
- Groundwater quality at Joshua Spring is fresh, recently recharged groundwater, where electrical conductivity (EC) is measured at 940 μS/cm, albeit this location is a pond/dam where water quality is influenced by evaporation/evapotranspiration. 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.

8.4 Summary of baseline monitoring findings

Baseline surveys of the Doongmabulla Springs-complex, described in **Section 8.2**, identified the following key features (GHD 2012a, 2014), summarised below.

- The Moses Springs-group is almost entirely intact, with the exception of impacts from cattle and pigs. It straddles Cattle Creek, comprises approximately 65 vents or springs, spread over 2.5 km, and forms a wetland of approximately 3.5 hectares (GHD, 2014).
- The Little Moses Springs-group is located to the east of the Moses Springs-group. Little Moses differs from the main Moses Springs-group in being much smaller (it has approximately two vents) and located within a woodland with different soils (GHD, 2014).
- The Joshua Springs-group was the most impacted, and is completely altered from its natural state. It now consists of a single turkey's nest dam and two associated scrapes. The overflow channel for the Joshua Spring (which carries a significant volume of water) is infested with the Grass Olive, a Category 3 restricted matter and WoNS (GHD, 2014).

The greatest habitat values of the Doongmabulla Springs-complex is the permanency of water, and the connectivity of the wetland to the nearby waterways, and the surrounding region. The reliable water supply provides an important resource for both flora and fauna during dry periods, but it is the habitat connectivity that provides the means for fauna to access the springs. Generally, the Doongmabulla Springs-complex and adjacent areas consisted of a diverse range of habitats. All strata of terrestrial vegetation were present, from native grasses and herbs through to mature trees.

The Doongmabulla Springs-complex contains a comparatively high number of flora species endemic to GAB spring wetlands, including:

- Salt Pipewort – listed as endangered under both the NC Act and the EPBC Act, observed at Moses Spring during the 2012 and 2013 field surveys.
- Blue Devil – listed as endangered under the NC Act and the EPBC Act, observed at Moses Spring during the 2012 and 2013 field surveys.

- *Hydrocotyle dipleura* – listed as vulnerable under the NC Act, observed confirmed at Moses Spring during the 2012 and 2013 field surveys.
- Waxy Cabbage Palm – listed as vulnerable under the NC Act and the EPBC Act, observed at Moses and Little Moses springs during the 2012 and 2013 field surveys.
- *Myriophyllum artesium* – listed as endangered under the NC Act, observed at Moses and Joshua springs during the 2012 and 2013 field surveys.
- *Sporobolus pamelae* – listed as endangered under the NC Act, observed at Moses Spring during the 2012 and 2013 field surveys.
- *Sporobolus partimpatens* – listed as near threatened under the NC Act, observed at Moses Spring during the 2012 and 2013 field surveys and Joshua Spring during the 2013 field survey.

A number of active searches were made during the 2012 and 2013 surveys in a variety of habitats during which only the Squatter Pigeon was observed.

8.5 Threats and impacts

Threats and potential direct / indirect project impacts that are required to be addressed as they apply to the Doongmabulla Springs-complex are:

- Direct and indirect project impacts outlined in the EIS (GHD 2012a; Adani 2012) Carmichael Coal Mine and Rail Project – Groundwater Dependent Ecosystems Management Plan (11 February 2014).
- Matters outlined in Condition 6(c) require details for impacts and threats MNES to be included in this plan.

The key threats and potential direct / indirect project impacts identified for Doongmabulla Springs-complex that are relevant to the Project are identified in **Table 8-5** and **Section 8.5**. It should be noted that the Doongmabulla Springs-complex is located a minimum of approximately 8 km from the Project's western boundary, and will therefore not be subject to direct impacts.

It should be noted that the Doongmabulla Springs-complex is on land not owned by Adani, and therefore potentially subject to impacts beyond Adani's control (e.g. grazing, clearing). Indirect impacts described in the following sections primarily relate to threats unrelated to Project activities.

Table 8-5 Doongmabulla Springs-complex threats, potential direct / indirect project impacts and matters required to be addressed by conditions

#	Potential Threat or Impact	Potential indirect threat or impact identified in EIS (GHD, 2014)	EPBC Approval, condition 6	Environmental Authority condition I14 and Appendix 1, Definition of "GDEMP"	National Recovery Plan for the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin	Project Phase/s	Earliest predicted potential impact	Table
1	Groundwater drawdown from mine dewatering	Yes	(c)(iii)	(5)	Yes	Operations Rehabilitation	Year 20	Table 8-12
2	Subsidence from underground mining	-	(c)(ii)	(5)	-	Operations Rehabilitation	Not applicable	
3	Changes to hydrology including: stream diversion and flood levees other alterations to surface water regime degradation of surface water quality	Yes	(c)(vii)	(5)	Yes	Construction Operations	Year 1	
4	Weeds and pests through direct competition or habitat degradation	Yes	(c)(ix)	(5)	Yes	Operations	Year 20	
5	Grazing pressures including browsing and trampling vegetation and disturbing hydrology	-	-		Yes	*Not applicable*	*Not applicable*	
6	Vegetation clearing / habitat loss	-	(c)(i)	-	Yes	*Not applicable*	*Not applicable*	
7	Earthworks	Yes	(c)(iv)	-	Yes	Construction	*Not applicable*	
8	Noise and vibration	-	(c)(v)	-	-	Construction Operations	*Not applicable*	
9	Emissions (including dust)	Yes	(c)(vi)	-	-	Construction Operations	*Not applicable*	
10	Light spill and other visual impacts	-	(c)(vii)	-	-	Construction	*Not applicable*	

#1: Groundwater drawdown from mine dewatering

EPBC Approval 2010/5736, condition 6(c)(iii) requires details of potential impacts from groundwater drawdown of aquifers be addressed in this plan.

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.

Aquifer drawdown is listed as a key threat in the Recovery plan for the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin (Queensland Government, 2010). Drilling of bores for the pastoral industry since the nineteenth century has created thousands of free-flowing artesian bores throughout the GAB. This has resulted in pressure head declines of up to 120 m, and spring flows in the discharge areas of the GAB have declined dramatically as a result of aquifer pressure decline from artificial extraction (Queensland Government, 2010).

EPBC Approval 2010/5736, condition 6(c)(iii) requires details of potential impacts from mine dewatering be addressed in this plan.

Groundwater modelling results indicate mine dewatering will influence groundwater pressure within the Doongmabulla Springs-complex during the operational and post-operational phases (GHD 2015). The maximum predicted reduction in pressure for each spring during these phases is presented in **Table 8-6** and **Table 8-7**. Disturbance from local cattle grazing is a significant existing threat to the GAB springs wetland communities.

Table 8-6 Modelling predictions for aquifer springhead pressure reductions in springs-groups associated with the Doongmabulla Springs-complex – Operational Phase (GHD 2015)

Spring number and name	Spring system	Sub-system	Peak predicted drawdown in source aquifer (m) SEIS model
1031_Moses4*	Doongmabulla	Moses	<0.05
1032_Moses3*	Doongmabulla	Moses	<0.05
1033_Moses2*	Doongmabulla	Moses	0.08
1034_Littmose*	Doongmabulla	Little Moses	<0.05
1035_Moses1*	Doongmabulla	Moses	0.06
1036_75E*	Doongmabulla	Moses	0.09
1037_75A*	Doongmabulla	Moses	0.08
1038_75D*	Doongmabulla	Moses	0.07
1039_75B*	Doongmabulla	Moses	0.12
1040_75C*	Doongmabulla	Moses	0.12
1041_Doongma*	Doongmabulla	Joshua	0.19

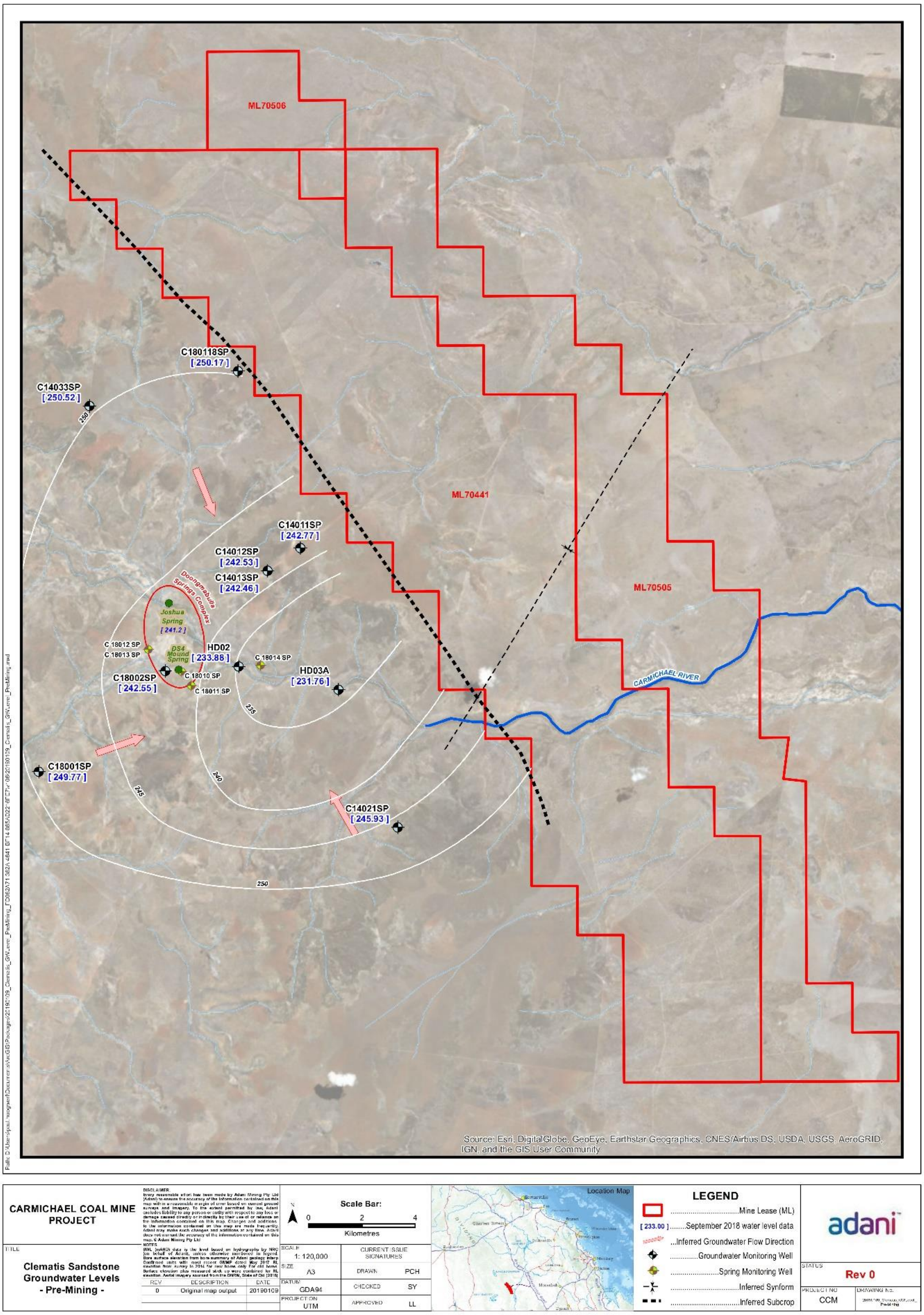
* predicted drawdown in the Clematis Sandstone

Table 8-7 Modelling predictions for aquifer springhead pressure reductions in springs-groups associated with the Doongmabulla Springs-complex – post-closure phase (GHD 2015)

Spring number and name	Spring system	Sub-system	Peak predicted drawdown in source aquifer (m) SEIS model
1031_Moses4*	Doongmabulla	Moses	<0.05
1032_Moses3*	Doongmabulla	Moses	0.05
1033_Moses2*	Doongmabulla	Moses	0.08
1034_Littmose*	Doongmabulla	Little Moses	<0.05
1035_Moses1*	Doongmabulla	Moses	0.06
1036_75E*	Doongmabulla	Moses	0.09
1037_75A*	Doongmabulla	Moses	0.07
1038_75D*	Doongmabulla	Moses	0.07
1039_75B*	Doongmabulla	Moses	0.11
1040_75C*	Doongmabulla	Moses	0.11
1041_Doongma*	Doongmabulla	Joshua	0.16

* predicted drawdown in the Clematis Sandstone

Groundwater contour maps representing the predicted drawdown from pre-mining to post-closure are presented in **Figure 8-15a-e**.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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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CHECKED SY
APPROVED LL
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DATE 20190109
Location Map
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Spring Monitoring Well
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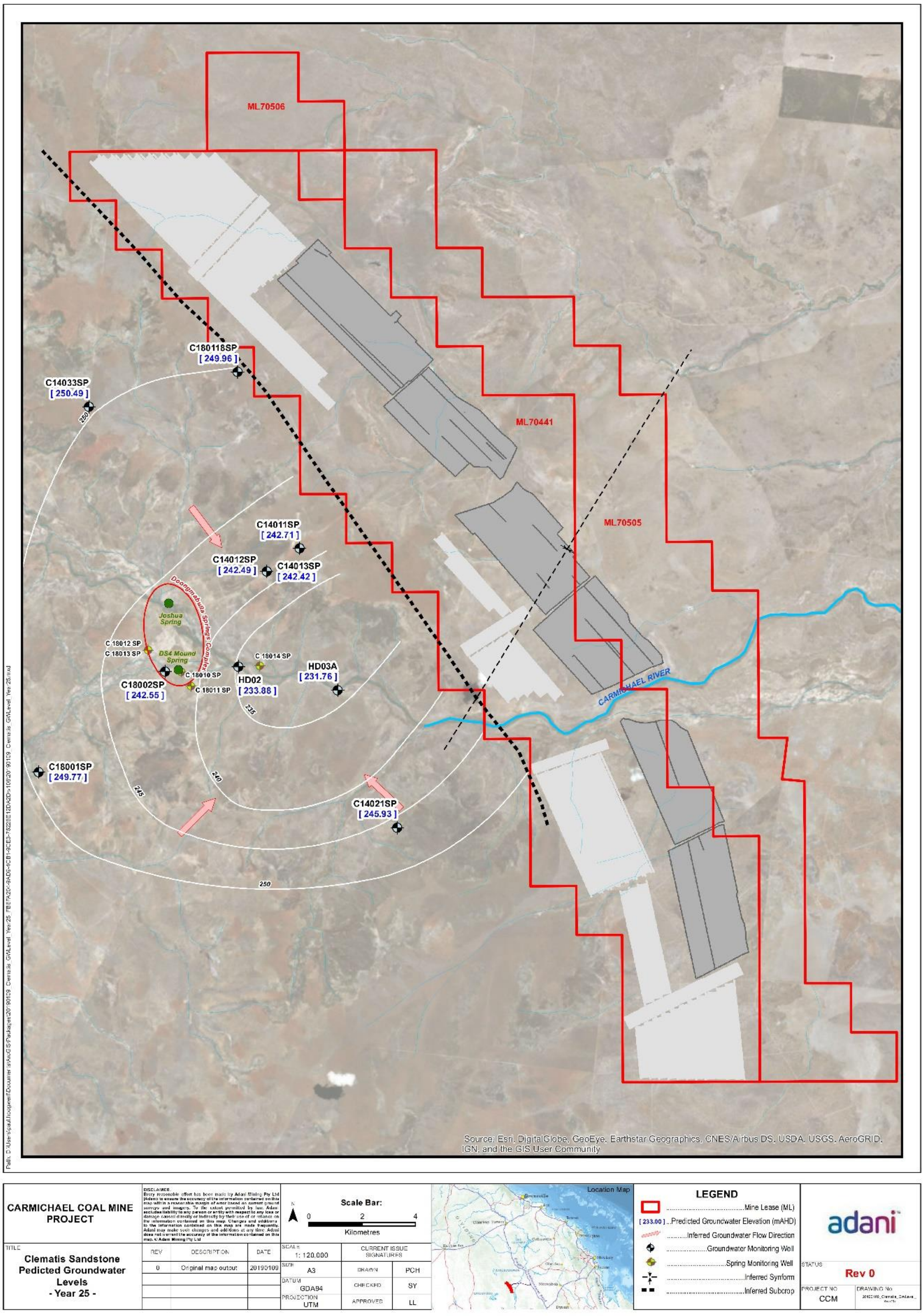
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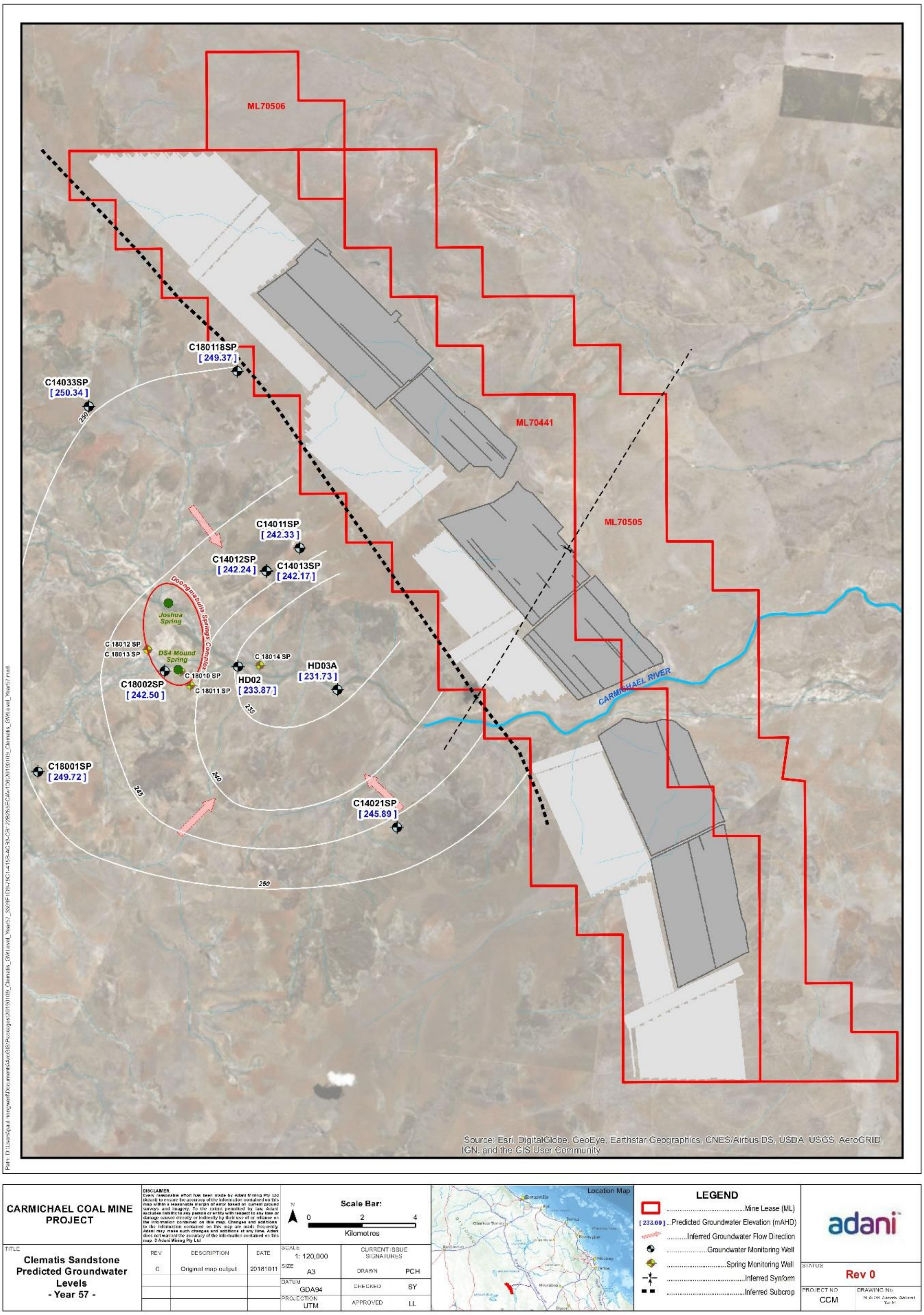

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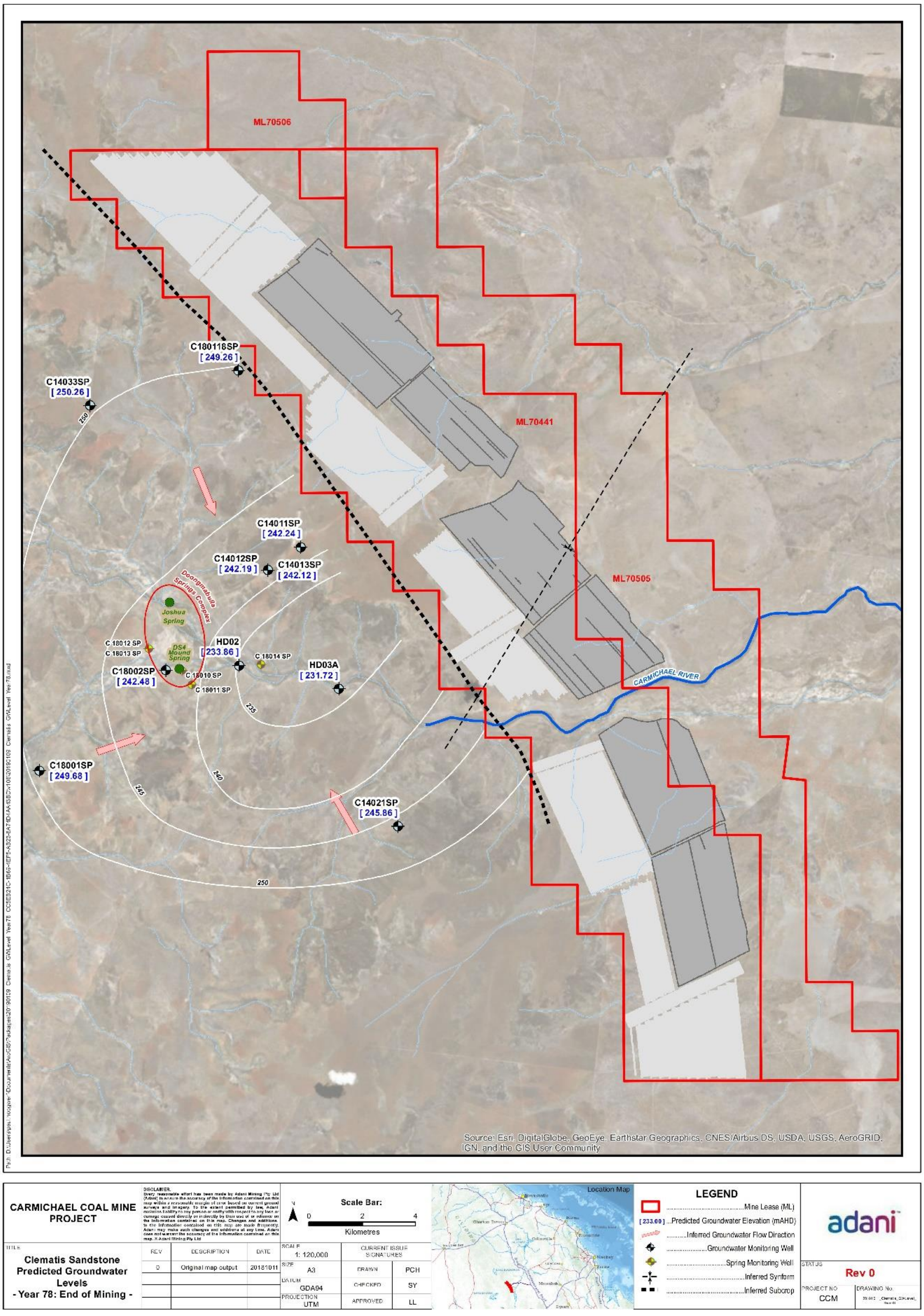
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CARMICHAEL RIVER
250
245
240
235
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
CARMICHAEL COAL MINE PROJECT
TITLE
Clematis Sandstone Predicted Groundwater Levels
- Year 78: End of Mining -
REV
DESCRIPTION
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PROJECTION
UTM
CURRENT ISSUE SIGNATURES
DRAWN
PCH
CHECKED
SY
APPROVED
LL
Location Map
LEGEND
Mine Lease (ML)
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Inferred Groundwater Flow Direction
Groundwater Monitoring Well
Spring Monitoring Well
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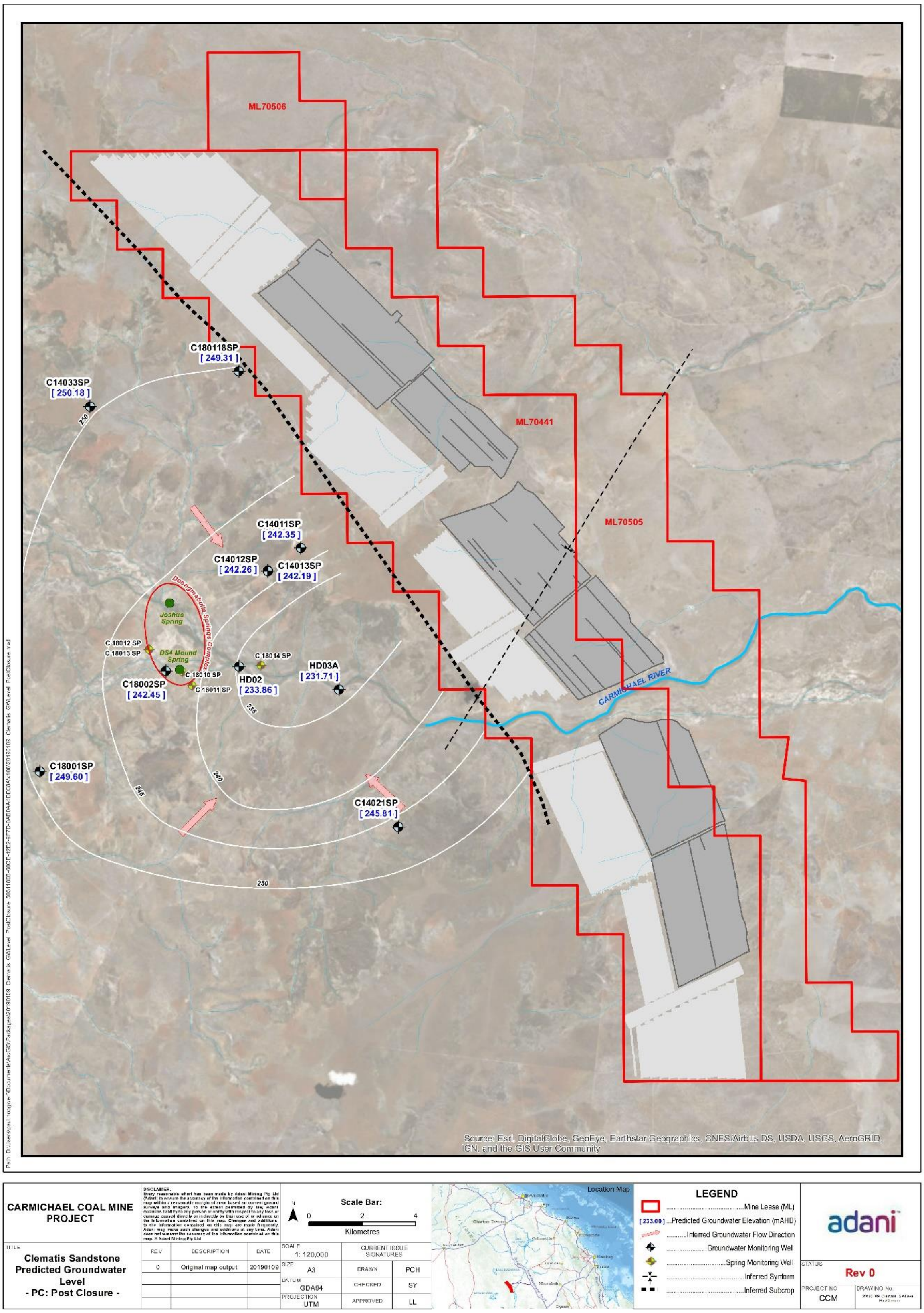


Figure 8-15a-e Groundwater impact contour maps for the Clematis aquifer

Twelve mounds at Moses Springs are less than 20 cm high, 24 mounds are 20 to 50 cm high, and 20 mounds are >50 cm high. The tallest mounds are approximately 1 to 1.5 m high (GHD 2014). The reduction in pressure at the Moses Springs-group is predicted to be between <0.05 and 0.11 m (**Table 8-6** and **Table 8-7**), with the predicted reduction in pressure for the majority of the Moses spring heads being <0.08 m (GHD 2014). This predicted pressure drop falls within the natural range of seasonal fluctuations in spring flow to which the Moses Springs-group wetland communities are already adapted. Therefore, it is thought that the reduction in flow will be within a tolerable range (GHD 2014). The threatened species associated with the Moses Springs-group are generally present on or immediately adjacent to the mounds, seeps or pools. Most mounds are separated from other mounds by bare sections of plain. The majority of the population of endemic and/or threatened species at Moses Springs-group are located within wetland areas fed by seepage from the springs. These wetlands generally form sedgeland or grassland, rarely with trees (Weeping Paperbark clumps or individual Waxy Cabbage Palms).

The predicted reduction in pressure at the Little Moses Springs-group will be <0.05 m, which is predicted to result in a negligible impact on the spring wetland communities (GHD 2014).

Joshua Spring is a high flow spring that rises at least 1 m above the surrounding plain (GHD 2014). The predicted reduction in pressure of up to 0.19 m at Joshua Spring is expected be a minor impact, with no major impact on associated threatened flora (GHD 2014). The threatened species found at the Joshua Spring wetland, *Myriophyllum artesium* and *Sporobolus partimpatens*, are unlikely to be impacted, as the water supply to the wetland in which they occur is not likely to be reduced to an extent that will affect these species.

The reduction in pressure of the aquifers is expected after approximately 20 years from the commencement of mining operations (GHD 2014).

The levels of reductions (generally less than 5 percent at Moses Springs and within the range of natural seasonal fluctuations) are likely to have negligible adverse impacts at Moses Springs and, at most, negligible adverse impacts to Joshua and Little Moses Springs.

No significant impacts to the GAB discharge spring wetlands TEC will occur, as the Project (Mine) will not:

- Reduce the extent of, fragment, or increase fragmentation of the ecological community
- Adversely affect habitat critical to the survival of the ecological community, or destroy or modify factors necessary for the survival of the community
- Cause substantial changes or reductions in species compositions, quality or integrity.

Localised and direct threats to GAB springs wetland communities include excavation of springs, exotic plants, stock and feral animal disturbance, exotic aquatic animal invasion, tourist access, and impoundments (Fensham et al. 2010). Due to the location of the Doongmabulla Springs-complex being outside the mining footprint, and about 8 km from the Project boundary, mining activities are generally not expected to introduce or exacerbate direct threats to the integrity of the Doongmabulla Springs-complex wetlands TEC, such as excavation and impoundments.

A management objective under this plan is to manage the impacts of mine dewatering and limit impact of hydrological changes on the Doongmabulla Springs-complex from mine dewatering. **Table 8-12** 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

EPBC Approval 2010/5736, condition 6(c)(ii) requires details of potential impacts from subsidence be addressed in this plan.

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.

No direct or indirect impacts associated with subsidence are predicted to occur within the vicinity of the Doongmabulla Springs-complex.

As no subsidence is predicted to occur, the management objective is to monitor to ensure there is no habitat alteration through subsidence. **Table 8-12** 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

EPBC Approval 2010/5736, condition 6(c)(viii) requires details of potential impacts from stream diversions and flood levees, be addressed in this plan.

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.

In addition, impoundments which may inundate GAB discharge springs are listed as a threat in the Recovery plan for the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin (Queensland Government, 2010).

The Doongmabulla Springs-complex 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 Springs-complex is located upstream of the Project area. There is no predicted significant impact to flooding conditions associated with the construction of levees on either side of the Carmichael River (**Figure 8-16**). **Figure 8-16** shows no increase to flooding at the western edge of the mining lease, noting that the Doongmabulla Springs-complex is upstream from this location. The focus for this threat is therefore to maintain existing surface water quality of the Doongmabulla Springs-complex.

A management objective under this plan is to maintain surface water level and quality. **Table 8-12** describes how the management objective will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

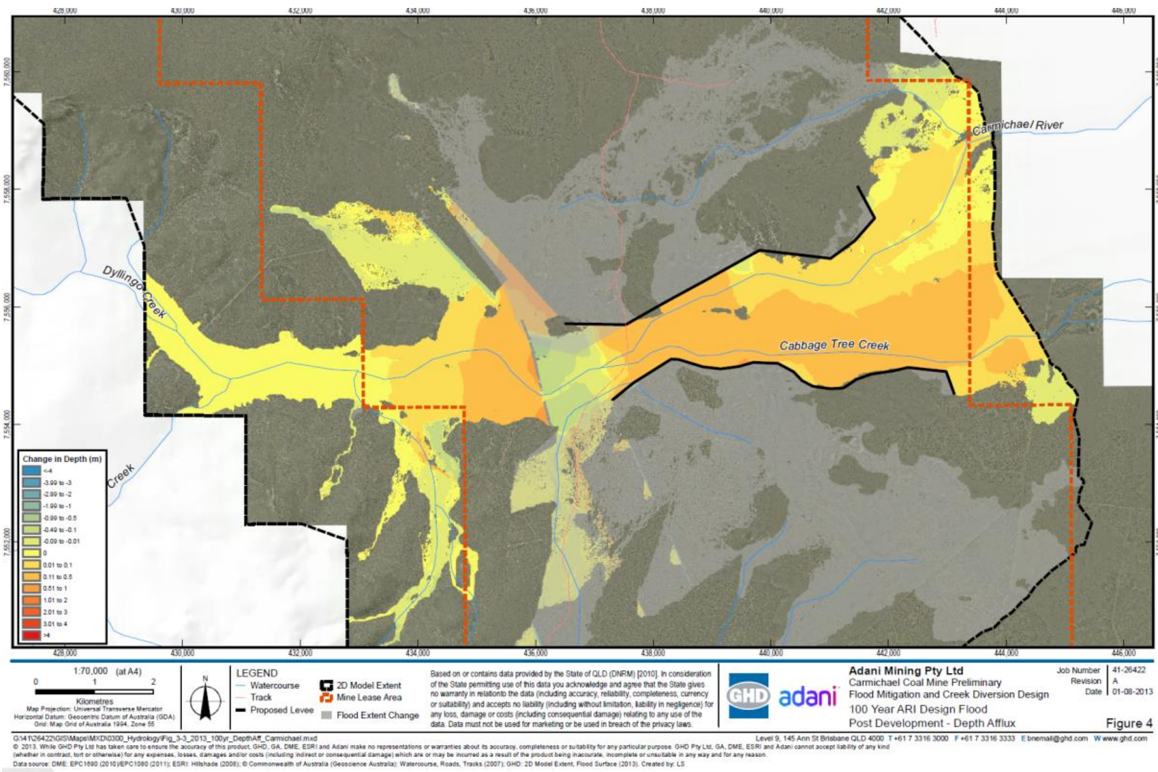


Figure 8-16 Predicted flood impacts on Carmichael River: 100-year ARI event (SEIS, Appendix K5)

#4: Weeds and pests through direct competition or habitat degradation

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

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.

Weeds and pests are listed as an impact under the “National Recovery Plan for the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin”.

Exotic plant incursion (e.g. ponded pasture species such as Olive Hymenachne), and introduction of exotic animals (e.g. Mosquitofish and Cane Toads) are listed as threats in the Recovery plan for the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin (Queensland Government, 2010).

Project-related impacts on the Doongmabulla Springs-complex through drawdown may exacerbate existing impacts from weeds and pests, by reducing the resilience of the wetland communities and impacting sensitive native flora species. However, drawdown impacts have been modelled to be negligible (see #1) and no exacerbation of impacts from weeds and pests are predicted as a result of drawdown. The Doongmabulla Springs-complex currently experiences impacts in the form of pugging from cattle and pigs. Impacts from cattle grazing are not under the direct control of Adani, as the Doongmabulla Springs-complex is located on land not owned by Adani. However, Adani commits to engaging where possible with the landholder at the Doongmabulla property regarding weed and pest management practices. While there are potential impacts from increased human traffic to and from the Springs-complex for research and monitoring purposes, the risks and magnitude of such impacts are low.

A management objective under this plan is to reduce weed competition and habitat degradation from Project-related activities within the Doongmabulla Springs-complex. **Table 8-12** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions. It should be noted that the Doongmabulla Springs-complex is located on land that is not owned by Adani.

#5: Grazing pressures

Stock and feral animal disturbance is listed as a threat in the Recovery plan for the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin (Queensland Government, 2010).

Domestic cattle grazing may lead to impacts on vegetation communities in that stock will browse leaves, trample seedlings and disturb the local hydrology. The grazing regime influences the composition and structure of the herbaceous layer of vegetation. Currently, the area surrounding the Doongmabulla Springs-complex is being predominantly used for cattle grazing. Grazing is managed by the landholder, not by Adani.

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 on land managed by Adani as a management tool to manage threats to vegetation communities. However, Adani commits to engaging where possible with the landholder at the Doongmabulla property regarding grazing practices. 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 may have benefits for neighbouring areas adjacent to the Project area, such as the Doongmabulla Springs-complex, by reducing the dispersal and abundance of weeds in the region.

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, on land under the control of Adani. However, the objective is to also ensure grazing itself does not become a threat. **Table 8-12** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#6: Vegetation clearing / habitat loss

EPBC Approval 2010/5736, condition 6(c)(i) requires details of potential impacts from vegetation clearing be addressed in this plan.

Listed as an impact under the “National Recovery Plan for the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin”.

There is no direct or indirect clearing of vegetation at the Doongmabulla Springs-complex as a result of Project activities.

Management objectives about the threat and impacts include minimising habitat loss and habitat restoration of disturbed areas. **Table 8-12** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#7: Earthworks

EPBC Approval 2010/5736, condition 6(c)(iv) requires details of potential impacts from earthworks be addressed in this plan.

Earthworks/Excavations listed as an impact under the "National Recovery Plan for the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin".

Earthworks carried out as a part of mine construction and operations could lead to increased exposure to light, noise, dust, vehicles and people in areas adjacent to the Project area (Adani, 2012). The Project area is more than 8 km to the east, and there will be no direct incursion from Project vehicles or personnel beyond monitoring required as part of this plan.

Dust, noise, vibration and light spill are described in following sections.

A management objective under this plan is to minimise the risk of light vehicle and machinery strike during earthworks and operations. **Table 8-12** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#8: 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.

The project will use standard construction equipment, general trade equipment and specialised equipment 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 Doongmabulla Springs-complex due to the distance from the activities.

A management objective under this plan is to minimise habitat modification as a result of noise and vibration. **Table 8-12** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#9: 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.

Dust deposition associated with construction and operational is not predicted to impact the Doongmabulla Springs-complex (Appendix L, SEIS; **Table 8-8**).

Table 8-8 Predicted incremental dust impacts (peak) – Table 17, Appendix L, SEIS

ID	Name	Predicted Incremental Deposited Dust (Annual average) (g/m^2/month)
1	Mellaluka	0.003
2	Bygana	0.002
6	Doongmabulla	0.043
17	Carmichael	0.015
18	Moray Downs	0.059
32	Lignum	0.003
V1	MWAV	0.172
A1	Airport Terminal	0.010

Note: Criterion = 2 g/m^2/month (Annual average)

A management objective under this plan is to minimise emissions, particularly dusts. **Table 8-12** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#10: Light spill and other visual impacts

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

Development of the project will necessitate the installation of lighting for safety and security of operations as the proposed 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 an impact of minor significance (Adani 2012).

It is not anticipated light spill will likely impact the Doongmabulla Springs-complex due to the distance from the activities.

A management objective under this plan is to minimise light spill and other visual impacts. **Table 8-12** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers and corrective actions.

8.6 Mitigation and management measures

Required mitigation and management actions under the Recovery Plan for the GAB springs wetland communities ('Community of native species dependent on natural discharge of groundwater from the Great Artesian Basin' – Fensham et al. 2010) include the investigation of stock removal and fencing impacts, review of historic spring flows, monitoring of current spring flows, inventory of all endemic species in spring wetlands, monitoring of endemic species, investigating the ecology and biology of endemic species, study of the interactions between native and exotic spring fauna, better understanding of the habitat requirements of spring-dependent flora and fauna, better understanding of the impacts of fire and grazing regimes on species composition and abundance, and further investigation into the physical and chemical characteristics of springs (Fensham et al. 2010, DoE 2015).

The Moses and Little Moses Springs-groups are included in the Doongmabulla Mound Springs Nature Refuge and are subject to a Conservation Agreement that outlines the management responsibilities for the area. Landowner/s have specific obligations to manage the Nature Refuge, which is not under Adani's direct control. The Conservation Agreement requires the landholder to conserve the area's significant natural resources while permitting limited activities including:

- Low to moderate cattle grazing that does not utilise more than 50% (by weight) of the pasture standing at the end of the growing season.
- The area must be spelled during summer.
- Horses and working dogs are only allowed for the purposes of mustering cattle.
- Feral animal control (including the use of firearms).

Pre-impact groundwater monitoring will inform the updating of the numerical and conceptual groundwater model in order to confirm the source aquifer and predicted impacts. This will be completed before activities associated with predicted impacts occur. The GMMP and GDEMP will be updated once these reviews are complete and hence the mitigation and management measures presented below are based on the current conceptual groundwater model as approved through the EIS which notes that there is not likely to be significant groundwater losses at these springs leading to loss of ecological function.

Activities associated with aquifer drawdown are not expected to commence until approximately 2020, with the reduction in pressure of the Clematis Sandstone aquifer expected after approximately 20 years (GHD 2014).

8.6.1 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 Doongmabulla Springs-complex during the course of the Project and particularly in response to long term monitoring and studies undertaken during each assessment and monitoring stage.

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 and groundwater quality), 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.

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 and research programs. If monitoring and / or greater understanding of the springs and species relationship with groundwater identifies that management measures are ineffective, the GDEMP will be updated with improved management measures.

In the event that groundwater level trigger levels for the Doongmabulla Springs-complex 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 the Doongmabulla Springs-complex (including threatened flora species) 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 Doongmabulla Springs-complex
- Update the GDEMP if required

In accordance with Conditions I4 and I5 of the EA, if the investigation indicates that there is a risk of impacting the Doongmabulla Springs-complex beyond the current project approval, the BOS will be reviewed, and a report prepared within 3 months to identify the actual impact to the Doongmabulla Springs-complex from the mining activities. If the assessment finds that unapproved impacts to the Doongmabulla Springs-complex will occur, the BOS will be amended within 30 days and the amended offset delivered within 12 months. Potential offsets, if required, will include:

- Rehabilitation of GAB springs wetland communities, in re-activated Springs-complexes within the Barcaldine Supergroup, to the same quality as baseline measures for the Doongmabulla Springs-complex wetland communities that become degraded due to groundwater drawdown
- Translocation of threatened and Doongmabulla Springs-complex endemic flora and fauna species to rehabilitated and / or alternative spring habitats within the Barcaldine Supergroup
- Incorporate information from the GAB Springs Research Plan into translocation and rehabilitation measures for offsetting the Doongmabulla Springs-complex wetland communities.

In the event that groundwater drawdown thresholds levels for the Doongmabulla Springs-complex are exceeded, an investigation into the cause will be undertaken and the administering authority notified within 28 days of the detection.

During this time mining activities will be limited to current activities (no expansion or mining of new areas), until the investigation determines the cause of the trigger level exceedance and also to ensure the drawdown impact interim threshold to 0.2m as per EPBC Act condition 3 (d) is not breached.

If the investigation identifies mining activities as the cause, an assessment into the known or likely impacts will be undertaken and mitigation measures identified. Adaptive management measures to be implemented include, but are not limited to:

- Limit mining activities to current activities, until monitoring indicates the trigger level(s) are no longer being exceeded, or at further risk of exceedance.
- Recharge springs using suitable quality groundwater in compliance with the EA.
- Implementation of prepared and approved BOS and Offset Management Plan.

8.7 Monitoring

Table 8-9 summarises the monitoring frequency, duration, type and indicators for the ecological values at the Doongmabulla Springs-complex.

Table 8-9: Doongmabulla Springs-complex monitoring frequency, duration, type and indicators

Monitoring Description	Frequency and duration	Monitoring type#	Indicators
Spring monitoring	Quarterly for the first two years, then annually	Pre-impact Impact	Spring wetland extent Wetland pool depth
Mound springs survey	Quarterly for the first two years, then annually	Pre-impact Impact	Mound spring characteristics
Wetland vegetation monitoring	Quarterly for the first two years, then annually	Pre-impact Impact	Wetland vegetation zone Wetland vegetation species composition and abundance
Threatened and endemic flora populations	Quarterly for the first two years, then annually	Pre-impact Impact	Threatened and endemic species presence
Aquatic invertebrate survey	Quarterly for the first two years, then annually	Pre-impact	Macroinvertebrate taxonomic richness and abundance
Weed and pest surveys	Annually	Pre-impact Impact	Presence of weed species, extent of weed coverage, presence of feral animals, extent of feral animal disturbance
Stygofauna survey	One round of sampling Frequency reviewed thereafter	Pre-impact	Stygofauna presence, stygofauna endemicity
Groundwater monitoring (as per GMMP)	12 hourly (level) At least every two months (quality)	Pre-impact Impact	Groundwater level and rate of drawdown, groundwater quality
Surface water monitoring	Monthly	Pre-impact Impact	Surface water quality, overflow rates

The full suite of tasks comprising the impact phase of monitoring will be confirmed after completion of the Ecological Condition Report (see Section 8.7.3).

8.7.1 Pre-impact monitoring

Consistent with EA Conditions (E13, E14, I3, I4, I5, I8, I10 and I11), EPBC Approval Conditions (6f, 11b, 11g, 11j and 11o) and Project commitment M4.18, ecological and groundwater surveys and monitoring will be carried out at the Doongmabulla Springs-complex.

Pre-impact surveys will be undertaken at all four main wetland areas in the Moses Springs-group, the main wetland area in the Little Moses Springs-group, Joshua Spring and at least 10 mound springs in the Moses Springs-group (**Figure 8-17**). The mound springs in the Moses Springs-group have been selected from previous mounds visited and inventoried during the EIS and by the Queensland Herbarium in 2013 to represent different sizes, the presence of threatened flora (especially Salt Pipewort and Blue Devil) and to cover a geographic spread across the entire Moses Springs-group (**Figures 8-5** to **8-7** and **Figure 8-17**).

Monitoring sites will be selected on the first pre-impact survey, with the objective of selecting sites that are representative of the hydrological and ecological features that occur throughout the Doongmabulla Springs-complex. Of the 10 sites, a number will be identified to act as indicative early warning triggers and control sites.

Pre-impact ecological surveys of the Doongmabulla Springs Complex will be completed by Year 2. A pre-impact monitoring report will be prepared per impact, before the impact occurs.

Spring monitoring

Mapping of the vegetated area perimeter and wetted area, as defined in the 'Wetland Monitoring Methodology for Springs in the Great Artesian Basin' (Fensham & Fairfax, 2009):

- >50% target perennial wetland cover
- Areas where >50% target perennial wetland cover would have been prior to disturbance by pigs or stock
- Areas of free water forming a spring pool contained within target perennial wetland vegetation
- Review and interpretation of remote sensing images if available, following 'A new approach to monitoring spatial distribution and dynamics of wetlands and associated flows of Australian Great Artesian Basin springs using QuickBird satellite imagery' (White & Lewis 2011)
- Produce a digital elevation model for the Doongmabulla Springs-complex
- Spring wetland extent will be monitored at Little Moses, Moses 1, Moses 3, Moses 4 and Geschlichen.

A baseline water level will be established at a reference location for the springs, and water levels will be measured using a reference marker. Surface water level will be measured against the marker during each survey.

This monitoring will complement the wetland area measurements, which provides a surrogate measure of flow via the Fatchen equation.

Spring wetland water level will be monitored at Little Moses, Moses 1, Moses 3, Moses 4 and Geschlichen.

<u>Indicator</u>: spring wetland extent, spring water level.

Mound spring survey

Surveys of 10 mound springs at the Moses Springs-group, to collect the following information:

- Mound diameter, height and perimeter

- Full floristic species composition and abundances
- Population surveys for spring endemic flora species
- Population surveys for EPBC and NC Act listed species
- Photographic references

These surveys will describe both the terrestrial (i.e. non-wetland) and spring wetland vegetation, as well as define the target perennial wetland species.

The mound springs to be monitored are Mouldy Crumpet 4, Mouldy Crumpet 6, Mouldy Crumpet B, Mouldy Crumpet C, Mouldy Crumpet G, Mouldy Crumpet L, Mouldy Crumpet N, Mouldy Crumpet AD, Moses 1A and Moses 1D.

Indicator: Mound spring characteristics

Wetland vegetation monitoring

Monitoring will consist of vegetation surveys along transects and within sub plots. Vegetation transects will be located across the wetland area gradient, from the spring source to the boundary with non-wetland areas. The transects and subplots along the transects will be used to collect the following information:

- Identify wetland zones (pool, saturated, damp, dry) and their boundary locations
- Photographic references (photo point monitoring)
- Wetland vegetation species composition
- Wetland vegetation species abundances (1 m x 1 m subplots spaced 4 m apart, along the transect)

These surveys will describe both the terrestrial (i.e. non-wetland) and spring wetland vegetation.

Baseline vegetation composition surveys will be used to identify target non-endemic and non-threatened perennial wetland species for monitoring at each springs wetland. These species will be monitored using replicate 1 m x 1 m subplots.

Spring wetland vegetation will be monitored at Little Moses, Moses 1, Moses 3, Moses 4, and Geschlichen.

Indicators: wetland vegetation zone, wetland vegetation species composition and abundance

Threatened and endemic flora populations

Targeted searches will be used to identify patches of endemic and threatened wetland flora for monitoring at each springs wetland.

The location, extent, and presence of all threatened and endemic flora will be surveyed and recorded using a differential GPS. The threatened and endemic species to be monitored include:

- Waxy Cabbage Palm *Livistona lanuginosa* (Vulnerable – Moses)
- Blue Devil *Eryngium fontanum* (Endangered - Moses)
- Salt pipewort *Eriocaulon carsonii* (Endangered – Moses)
- *Hydrocotyle dipleura* (Vulnerable - Moses)
- *Isotoma* sp. 'RJ Fensham 3883' (Endemic – Moses)

- *Myriophyllum artesium* (Endangered – Moses and Joshua)
- *Sporobolus pamelae* (Endangered – Moses)
- *Sporobolus partimpatens* (Near Threatened – Moses and Joshua)
- Any other flora identified during baseline surveys as endemic or threatened, and reliant on GAB spring wetlands for survival

Threatened and endemic flora will be surveyed at all spring heads in the Moses Springs-group and monitored at all springs where they occur.

Indicators: Threatened and endemic species presence

Aquatic invertebrate surveys

Aquatic invertebrate sampling (for endemic species) will be based on the methods used for GAB Springs monitoring in the Surat Basin. This includes sweeping an area of up to 5m^2 with a macroinvertebrate net for 5 minutes and transferring samples into a sterile jar (with a preservative) for subsequent laboratory identification to morpho-family level.

Macroinvertebrate assemblage structure will be compared with results obtained during EIS studies, and as well as published results from similar studies of springs in Queensland.

Aquatic invertebrates will be monitored at the Little Moses, Moses 1, Moses 3, Moses 4, Camp spring and Geschlichen wetland areas.

Indicators: Macroinvertebrate taxonomic richness and abundance

Weed and pest surveys

Annual weed and pest surveys will be undertaken at the Doongmabulla Springs-complex to:

- Identify the extent of weeds,
- Identify areas of wetland habitat subject to damage from feral and domestic animals

Indicators: Presence of weed species, extent of weed coverage, presence of feral animals, extent of feral animal disturbance

Stygofauna survey

Stygofauna sampled from two bores within the western Mine Area were identified as belonging to three families that are common to all Australian states.

A round of stygofauna sampling will be undertaken at Doongmabulla (and Mellaluka) Springs-complexes, to determine the presence of stygofauna and to identify if endemicity in the stygofauna community exists within the aquifer.

Indicators: Stygofauna presence, stygofauna endemicity

Groundwater Monitoring

Groundwater monitoring to inform combined baseline and pre-impact dataset for input into model review prior to activities and impacts.

- 12 hourly for water levels and at least every two months for water quality as per GMMP

<u>Indicators</u>: groundwater level, groundwater quality, rate of drawdown

Surface Water Monitoring

Water quality will be assessed (monthly) at Joshua Spring, Little Moses, Mouldy Crumpet 4, Mouldy Crumpet 6, Mouldy Crumpet B, Mouldy Crumpet C, Mouldy Crumpet G, Mouldy Crumpet L, Mouldy Crumpet N, Mouldy Crumpet AD, Moses 1A, Moses 1D, Moses 1, Moses 3, Moses 4 and Geschlichen.

Measure flow rates at Joshua Spring and Dyllingo Creek adjacent to Joshua Spring

<u>Indicators</u>: Surface water quality (analytes in **Appendix A**), overflow rates.

8.7.2 Baseline and pre-impact condition report

At the conclusion of pre-impact surveys an Ecological Condition report will be prepared for the springs. The report will present results from baseline studies (EIS), each of the pre-impact monitoring events, mapping and photo-points and discuss the seasonal and spatial variation in the results. Data from the GMMP monitoring program (or example springs flow/ water level and head pressure) will also be included. Recommendations for refining future ongoing monitoring methodology and frequency will also be made, in conjunction with a review of the relevant management and monitoring plans.

8.7.3 Impact monitoring

Impact surveys and photo monitoring at the Doongmabulla Springs-complex will be undertaken annually for the life of the mine. The full suite of the survey and monitoring program will be confirmed after the completion of the Ecological Condition Report.

Impact survey and monitoring will begin from the predicted groundwater drawdown impacts from the mine (Year 20) and afterwards for the life of the mine, and for at least five years after mining operations are completed. The impact monitoring program will consist of the following:

- Spring monitoring
- Mound springs surveys
- Wetland vegetation monitoring
- Threatened and endemic flora populations
- Aquatic invertebrate surveys
- Stygofauna survey
- Groundwater Monitoring
- Surface Water Monitoring.

Ongoing monitoring will also contribute to the continued understanding of the springs until groundwater drawdown impacts from the mine appear (at approximately 20 years after commencement). Monitoring will focus on the responses of the springs wetlands and mound springs as well as Salt Pipewort and Blue Devil in response to changes in groundwater conditions. The effectiveness of management and mitigation measures with regard to Project related threats will also be monitored.

Events based monitoring will also occur during impact surveys if routine monitoring of groundwater and / or the Doongmabulla Springs-complex wetlands and mound springs identifies that trigger levels have been exceeded. This will consist of investigations, studies and additional monitoring to determine the cause and potential magnitude of impacts as well as identifying adaptive and corrective management measures.

An annual report on the spring condition, including statistical comparison to baseline condition, will be provided to DoEE and DES, including reporting on any change from baseline conditions and planned actions.

The approach to statistical analysis is summarised in **Table 8-10**.

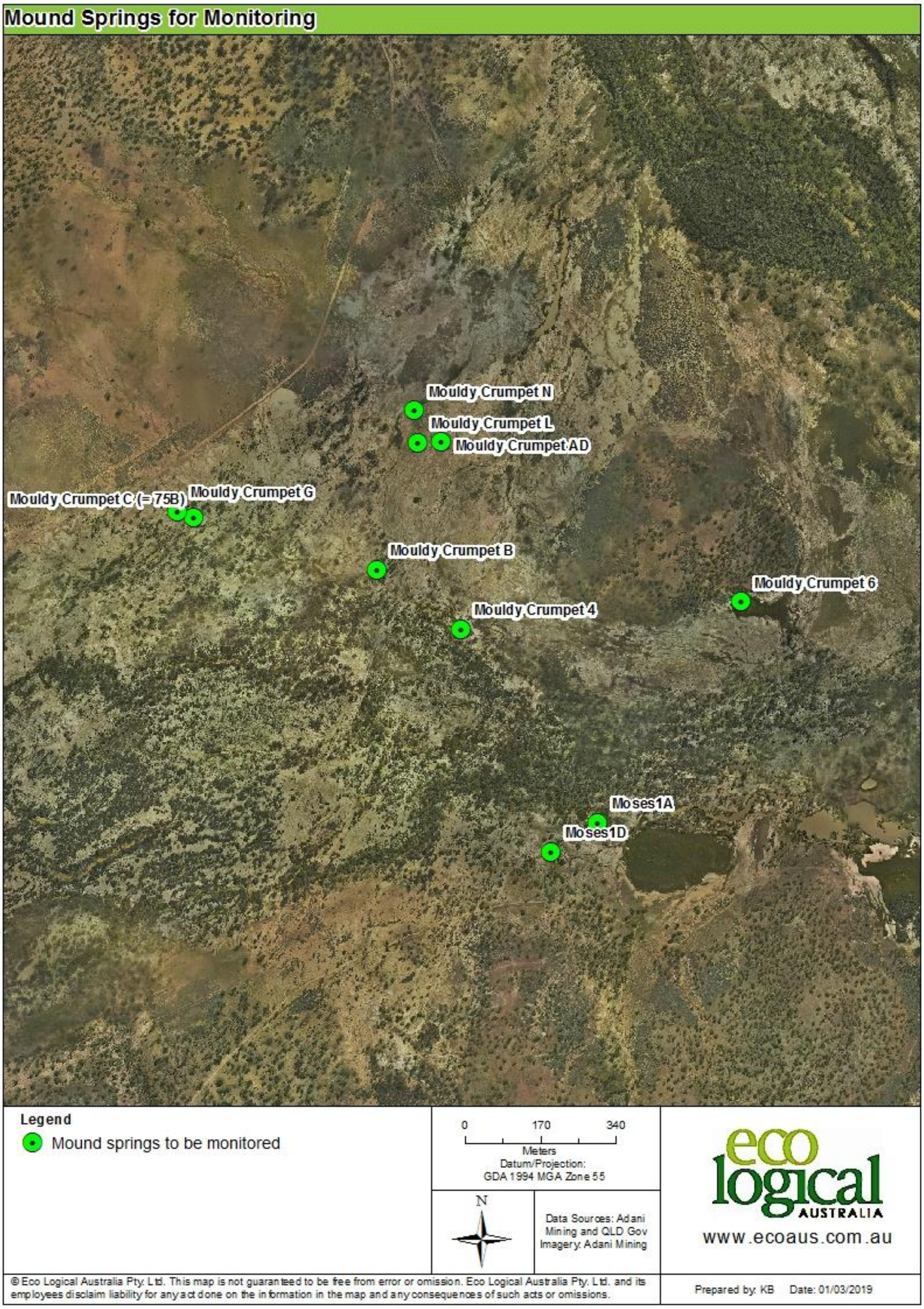


Figure 8-17 Mound springs to be monitored

Table 8-10 Statistical approach for Doongmabulla Springs-complex triggers and monitoring

Indicator	Relevant Triggers	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
Spring wetland extent Wetland pool depth	Statistically significant difference in spring wetland extent and water level from baseline and pre-impact conditions.	Surveys will be undertaken at Moses, Little Moses and Joshua springs. Pre-impact monitored seasonally (wet and dry season) for two years, then seasonally (wet and dry season) until baseline and pre-impact is established.	Perennial wetland extent assessed both on site and via remote sensing. Identify wetland zones (pool, saturated, damp, dry) and their boundary locations Spring water level Photographic reference	Univariate f and t-tests to statistically compare variance and mean extent between time of sample and baseline and pre-impact conditions.
Mound spring characteristics	Statistically significant difference in: Mound diameter, height and perimeter Flora species composition and abundances Presence of spring endemic flora species	The mound springs to be monitored are Mouldy Crumpet 4, Mouldy Crumpet 6, Mouldy Crumpet B, Mouldy Crumpet C, Mouldy Crumpet G, Mouldy Crumpet L, Mouldy Crumpet N, Mouldy Crumpet AD, Moses 1A and Moses 1D. These surveys will describe both the terrestrial (i.e. non-wetland) and spring wetland vegetation, as well as define the target perennial wetland species.	Mound diameter, height and perimeter Full floristic species composition and abundances Population surveys for spring endemic flora species Population surveys for listed species	Univariate f and t-tests to statistically compare variance and mean extent between time of sample and baseline and pre-impact conditions. MDS graphs to show relative spread of plots based on vegetation composition and abundance (cover and species richness). Multivariate PERMANOVA test on parameters to detect significant differences between sampling time and baseline & pre-impact. 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
Wetland vegetation zone Wetland vegetation species composition and abundance	Statistically significant difference in wetland vegetation zone, composition and abundance from baseline and pre-impact conditions.	Surveys will be undertaken at Moses, Little Moses and Joshua springs. Pre-impact monitored seasonally (wet and dry season) for two years, then seasonally (wet and dry season) until baseline and pre-impact is established.	Wetland zone (pool, saturated, damp, dry) and their boundary locations Wetland vegetation species composition Wetland vegetation Species abundances (1 m x 1 m subplots spaced 4 m apart, along the transect).	MDS graphs to show relative spread of plots based on vegetation composition (cover and species richness). Multivariate PERMANOVA test on parameters to detect significant differences between sampling time and baseline & pre-impact. Follow up SIMPER tests to detect the main indicators driving the patterns in the data.
Threatened and endemic species presence	Loss of a threatened species from any spring Statistically significant difference in threatened species presence from baseline and pre-impact conditions.	Surveys will be undertaken at Moses, Little Moses and Joshua springs. Pre-impact monitored seasonally (wet and dry season) for two years, then seasonally (wet and dry season) until baseline and pre-impact is established.	Location, extent and condition of Waxy Cabbage Palm *Livistona lanuginosa* (Vulnerable – Moses) Blue Devil *Eryngium fontanum* (Endangered - Moses) Salt pipewort *Eriocaulon carsonii* subsp. *Orientale* (Endangered – Moses) *Hydrocotyle dipleura* (Vulnerable - Moses) *Isotoma* sp. 'RJ Fensham 3883' (Endemic – Moses) *Myriophyllum artesium* (Endangered – Moses and Joshua) *Sporobolus pamelae* (Endangered – Moses) *Sporobolus partimpatens* (Near Threatened – Moses and Joshua) Any other flora identified during baseline surveys as endemic or threatened, and reliant on GAB spring wetlands for survival.	Univariate f and t-tests to statistically compare threatened species extent, condition and richness between time of sample and baseline & pre-impact conditions. MDS graphs to show relative spread of plots based on vegetation composition (cover and species richness). Multivariate PERMANOVA test on parameters to detect significant differences between sampling time and Baseline & pre-impact. 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
Macroinvertebrate taxonomic richness and abundance Stygofauna presence Stygofauna endemicity	Statistically significant difference in macroinvertebrate and stygofauna taxonomic richness and abundance from baseline and pre-impact conditions	Sweeping an area of up to 5m2 with a macroinvertebrate net for 5 minutes and transferring samples into a sterile jar (with a preservative) for subsequent laboratory identification to morpho-family level. Stygofauna – a round of sampling will be undertaken to determine presence and identifying if endemicity exists.	Macroinvertebrate taxonomic richness and abundance Stygofauna presence Stygofauna endemicity	Macroinvertebrate assemblage structure will be compared with results obtained during EIS studies and other published studies of springs in Queensland. Multivariate PERMANOVA test on parameters to detect significant differences between sampling time and baseline and pre-impact. Follow up SIMPER tests to detect the main indicators driving the patterns in the data.
Presence of weed species Extent of weed coverage Presence of feral animals Extent of feral animal disturbance (within areas controlled by Adani)	Statistically significant increase in weed cover, pests or pest activity above baseline. Identification of new weed or feral animal.	Weed and pest surveys undertaken annually.	Extent of weeds Identify areas of wetland habitat subject to damage from feral and domestic animals	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 feral animal compared to baseline.
Groundwater level and rate of drawdown	Groundwater level drawdown thresholds as outlined in the GMMP, Appendix B and Table E3 in the EA.	Monitoring at the bores listed in Section 8.7.4. Monitored bi-monthly on an ongoing basis.	Groundwater level.	Univariate comparison between groundwater level at time of sampling and groundwater level threshold.

Indicator	Relevant Triggers	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
Groundwater quality	Groundwater Quality Trigger levels as outlined in the GMMP and Table E2 in the EA.	Monitoring at the bores listed in Section 8.7.4. Monitored quarterly as per GMMP.	Water quality parameters as outlined in GMMP.	Descriptive comparison with defined trigger levels.
Surface water quality	Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded.	Surface water quality will be determined using a water quality meter and the collection of samples for laboratory analysis	As per Appendix A	Univariate comparison between surface water at time of sampling and trigger levels.

8.7.4 Groundwater Monitoring Program (GMMP)

Pre-impact monitoring of groundwater quality and levels at Doongmabulla Springs-complex will be undertaken every two months up to commencement of the relevant mining activities. Ongoing monitoring of groundwater quality at Doongmabulla Springs-complex will be undertaken every two months, as described in the GMMP. Monitoring programs will be implemented following approval of the GDEMP.

There are five spear wells installed into spring mounds to monitor groundwater levels near spring mounds:

- C18010SP
- C18011SP
- C18012SP
- C18013SP
- C18014SP

Specific groundwater monitoring bores (also shown on **Figure 8-15a-e**) for the Doongmabulla Springs-complex are:

- Moolayember Formation
  - C14020SP
  - C18003SP
- Clematis Sandstone
  - HD02
  - HD03A
  - C14011SP
  - C14012SP
  - C14013SP
  - C14021SP
  - C14033SP
  - C18001SP
  - C18002SP
  - C180118SP

Corresponding groundwater level and quality trigger levels for some of these bores, as well as additional bore monitoring being conducted in the first two-year program prior to the groundwater model rerun, are provided in **Appendix B**.

Monitoring will be a fundamental component of the management approach, with the objective of informing an adaptive management approach with respect to ecological values of the Doongmabulla Springs-complex and springs in the Galilee Basin (GHD 2014).

A refined conceptual model for the Doongmabulla Springs-complex will be developed following the completion of the pre-impact surveys. This will detail the predicted interactions and EWRs as well as responses to groundwater changes. This model will be revised whenever new information is available from monitoring.

Groundwater modelling will be re-run as new information becomes available as per EA and EPBC Act approval conditions (within 2 years after excavation of the first box cut and every 5 years thereafter). The groundwater model re-run will include:

- Analysis of rock properties from the cores of new nested bores to inform hydraulic connectivity within and between hydrogeological units
- The next iteration of the GMMP (after 2 years) will provide piper plots of the major ions for all hydrostratigraphic units included in Environmental Authority condition E3a), representative Doongmabulla Springs-complex springs, and the Carmichael River surface water
- Assessment of groundwater, surface water, and springs using isotope tracers to aid in the assessment of water quality results
- For all new bores, to be drilled after the compilation of the initial GMMP, a minimum of 12 datasets over 24 months, will be collected prior to developing groundwater level thresholds and water quality triggers for discussion with the Queensland Government Department of Environment and Science for inclusion in future iterations of the GMMP
- All new bores will be assessed against the water quality triggers developed for each hydrostratigraphic unit until (and if required) bore specific triggers are developed
- All new bores will be installed as soon as possible so as to compile additional groundwater data to inform the conceptual model and the refinement of the model as required in Environmental Authority conditions E4a and E5
- Any consideration of revising the groundwater level thresholds, based on new data acquired, must assess the potential impacts of the revised groundwater level thresholds on GDEs.

Where groundwater bores are removed or impacted due to underground mining, these will be replaced.

All groundwater models will be independently peer-reviewed prior to submission. Post closure groundwater modelling will be undertaken at least two years prior to closure to confirm and / or validate predicted impacts on the Doongmabulla Springs-complex and inform ongoing mitigation and monitoring measures.

8.8 Triggers for adaptive management and corrective action

Trigger levels for impacts to the Doongmabulla Springs-complex have been developed based on current understanding (in particular the Clematis Sandstone is the source aquifer), available literature and similar studies for GAB spring wetland communities (e.g. OGIA 2015, DNRM 2016a, DNRM 2016b, Fensham et al. 2016). Low-risk trigger levels for biological and ecological indicators are based on statistically significant deviations from conditions determined during baseline surveys.

Triggers include thresholds related to groundwater, wetland area, vegetation composition, weed cover and water quality. Ecological trigger levels (described in **Section 5.3**) will be reviewed at the completion of pre-impact surveys, based on an improved understanding of natural variation in the wetland attributes and the aquifer water levels.

The Doongmabulla Springs-complex wetlands and mound springs will be monitored quarterly during baseline studies, with the results feeding into an adaptive management protocol. If trigger levels are exceeded, the response will be immediate corrective actions if appropriate, and a review of management and offset options.

As per the GMMP, a network of groundwater monitoring bores has been established including bores with the particular aim of monitoring groundwater level and quality in the vicinity of the springs, including the following designated early warning bores:

- HD03A (Clematis Formation)
- C14012SP (Clematis Sandstone)
- HD02 (Clematis Sandstone)
- C 18002 SP (Clematis Sandstone)
- C022P1 (Dunda Beds)
- C 18003 SP (Moolayember formation)
- C180116SP (Rewan Formation)
- C14023SP (Rewan Formation)
- C14024SP (Rewan Formation)
- C9553P1R (Rewan Formation)
- C555P1 (Rewan Formation)
- C556P1 (Rewan Formation)

The GMMP includes a commitment for installation of additional bores, in order to evaluate the vertical gradients between hydrogeological units. These proposed additional monitoring bores will be completed in Upper and Lower Rewan Formation and Dunda Beds and will also be designated as early warning bores for vertical migration of potential drawdown from the deeper coal measures.

The three nests of additional groundwater bores are describe in **Table 8-11.** The bores will be completed within one year of commencement of mining operations.

Table 8-11 Additional groundwater bores as per GMMP

Nest number	Bore ID	Target Formation
1	C19007SP	Dunda Beds
	C19008SP	Top of Rewan
	C19009SP	Bottom of Rewan
2	C19011SP	Dunda Beds
	C19012SP	Top of Rewan
	C19013SP	Bottom of Rewan
3	C19015SP	Dunda Beds
	C19016SP	Top of Rewan
	C19017SP	Bottom of Rewan
	C19018SP	Permian- Bandanna Formation

The location of all monitoring bores listed in this section are included in **Figure 8-18.**

Groundwater drawdown and quality trigger levels will be defined for these bores based on background groundwater monitoring data collected during the baseline monitoring and will be incorporated in the GMMP. The relevant early warning and threshold triggers for aquifers associated with this GDE are described in the GMMP, in **Section 4.3.1** and are also presented in **Appendix B**. The Doongmabulla Springs-complex and groundwater levels will be monitored with the results feeding into an adaptive management protocol.

Low-risk trigger levels for biological and ecological indicators are based on a statistically significant deviation from baseline for the following indicators:

- Wetland area (baseline conditions will be partly informed by desktop studies using historic satellite imagery and associated calculations of wetland area)
- Mound springs characteristics (maximum diameter, height, perimeter length, full floristics species composition and abundance, abundance of spring endemic flora species, abundance of threatened species) Cover and diversity of threatened and endemic flora species and native vegetation
- Wetland pool depth (measured from a specific site in each pool for consistency)
- 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)
- Loss of a threatened and / or endemic flora population from a wetland area
- Reduction in the abundance of threatened and / or endemic fauna
- Change in aquatic invertebrate communities (utilising GAB Monitoring protocols)

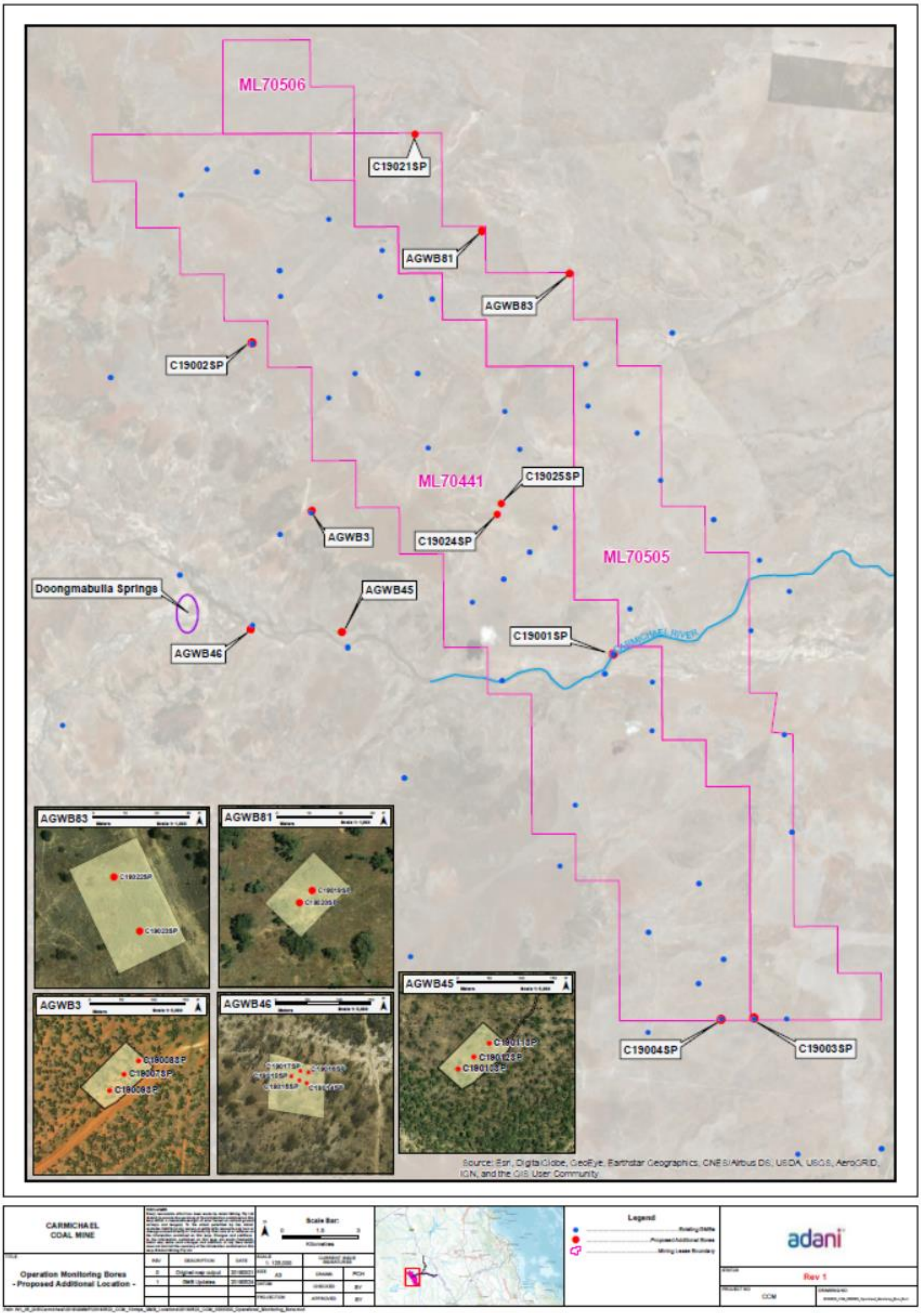


Figure 8-18 Groundwater monitoring bores

If a trigger is exceeded, an investigation will be conducted to determine whether the detected result is caused by mining activities. The investigation should 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)
- Developing a detailed model of relevant environmental variables
- Expert opinion on the potential for environmental harm

In the event that threatened flora or fauna species are discovered during monitoring activities, additional surveys will be required to determine the species dependency on the springs. The GDEMP and Mine Species Management Plan will be updated, and additional offsets may be required. The assessment of potential impacts to the Doongmabulla Springs-complex indicates that no offset is required (GHD 2014). In the event that future monitoring and modelling suggest that impacts will be significant and mitigation and management measures are not feasible, offsets will be considered as part of the Biodiversity Offset Plan.

8.9 Management, Mitigation, Monitoring and Corrective Actions

The threats to the Doongmabulla Springs-complex (including the listed flora species present at the spring) relevant to the Project and potential project impacts and actions minimising impacts to the Doongmabulla Springs-complex are summarised in **Table 8-12**. The table addresses 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 Doongmabulla Springs-complex. **Table 8-12** and **Table 8-10** (Statistical approach for Doongmabulla Springs-complex 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 8-12 Management objectives, performance criteria, adaptive management triggers and corrective actions for the Doongmabulla Springs-complex

#	Potential indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Ecological trigger for adaptive management and corrective actions	Corrective actions
1	Groundwater drawdown from mine activities including dewatering	Minimise the impact of aquifer drawdown caused by mining activities on the Doongmabulla Springs-complex	No impact to Doongmabulla Springs-complex due to aquifer drawdown caused by mining activities other than that approved.	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 GABSRP and RFCRP in relation to GDEMP and GMMP implementation,	**Pre-impact and impact monitoring:** Groundwater Management and Monitoring Program Spring monitoring Wetland vegetation monitoring Aquatic Invertebrate Survey Stygofauna Survey	Groundwater quality Groundwater level Spring wetland extent Spring water level Wetland vegetation species composition and abundance Threatened and endemic flora presence Macroinvertebrate taxonomic richness and abundance Stygofauna presence Stygofauna endemicity	• Groundwater level thresholds as outlined in the GMMP, Appendix B and Table E3 in the EA are exceeded. • Groundwater drawdown rates are exceeded • Groundwater quality trigger levels as outlined in the GMMP and Table E2 in the EA are exceeded. • Statistically significant change in the following indicators compared to baseline / pre-impact conditions: ○ Spring wetland extent ○ Spring water level ○ Wetland vegetation species composition and abundance ○ Threatened and endemic flora presence ○ Macroinvertebrate taxonomic richness and abundance ○ Stygofauna presence ○ Stygofauna endemicity	The appropriate corrective actions will be implemented and may include: • In the event that groundwater level or rate triggers are exceeded, the investigation, response and corrective actions process under the GMMP, section 4.7.2 will be implemented. These actions include: ○ Assess the water balance / budgets and evaluate losses ○ Groundwater level (depth-to-water) evaluation to determine mounding and possible leaks / sources of artificial recharge ○ Implement mitigation if losses are identified , which could include: ▪ Seepage capture schemes, suitable to prevent possible plume migration offsite ▪ Pump and treat schemes to manage possible contaminant plumes ▪ Augmentation of the groundwater monitoring network to identify and monitor plume(s) • Limiting mining to current activities until trigger not exceeded and revision of mine planning or associated activities • 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. • Implementing relevant operational constraints in relation to groundwater drawdown impacts, including revised mine planning or associated activities

#	Potential indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Ecological trigger for adaptive management and corrective actions	Corrective actions
		Minimise the impact of aquifer drawdown caused by mining activities on the Doongmabulla Springs-complex	No impact to Doongmabulla Springs-complex due to degradation of groundwater quality caused by mining activities other than that approved.	No predicted groundwater quality impacts as a result of mining activities. Monitoring bores have been established in suitable locations associated with the Doongmabulla Springs-complex. Adani will undertake additional studies that inform the conceptual model relating to the source aquifer of the Doongmabulla Springs-complex. .	**Pre-impact and impact monitoring:** Groundwater Management and Monitoring Program Spring monitoring Wetland vegetation monitoring Threatened and Endemic Flora populations Aquatic Invertebrate Survey Stygofauna Survey	Groundwater quality Spring wetland extent Spring water level Wetland vegetation zone wetland vegetation species composition and abundance Threatened and Endemic Flora presence Macroinvertebrate taxonomic richness and abundance Stygofauna presence Stygofauna endemicity	• Groundwater quality trigger levels as outlined in the GMMP and Table E2 in the EA are exceeded. • Statistically significant change in the following indicators compared to baseline / pre-impact conditions: • Wetland pool depth • Spring water level • Wetland vegetation zone • wetland vegetation species composition and abundance • Macroinvertebrate taxonomic richness and abundance • Spring wetland extent • Threatened and endemic flora presence • Stygofauna presence • Stygofauna endemicity	
2	Subsidence from underground mining	No habitat impacts related to subsidence	No subsidence impacts, such as ponding and cracking (not predicted for any GDE)	Implement the project Subsidence Management Plan as per the EA. Engagement with landholder at the Doongmabulla property regarding operational practices.	**Pre-impact and impact monitoring:** Subsidence Management Plan	Early warning signs of subsidence, such as ponding, cracking, tilt, strain and displacement.	Measurable evidence of tilt in the vicinity of the Doongmabulla springs-complex attributable to Subsidence.	The appropriate corrective actions will be implemented and may include: • Repeating the relevant survey within 2 months to validate / test findings • Groundwater impact report to be developed within 2 months to inform on background/seasonal/mining related impacts • Reviewing subsidence related infrastructure and drainage within 2 months to identify causal factors and recommend changes to prevent ongoing impacts.

#	Potential indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Ecological trigger for adaptive management and corrective actions	Corrective actions
3	Changes to hydrology	Protection of surface water quality values within waterways of the receiving environment.	No Project related degradation (i.e. dust, coal and heavy metals) of surface water quality in Doongmabulla Springs-complex.	There are no predicted surface water degradation impacts likely to occur at the Doongmabulla Springs-complex. Activities carried out associated with monitoring under this plan must be undertaken to prevent surface water quality degradation. Standard mine operating procedures will include dust control of project areas in accordance with procedures under the Environmental Management Plan.	Surface water quality Groundwater quality Rate of drawdown	• 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. • Physical evidence of degradation to surface water quality.	Surface water quality Groundwater quality Rate of drawdown	The appropriate corrective actions will be implemented and may include: • Scheduling duplicate chemistry testing to confirm water quality against relevant standards, in the event that visual inspection of dust impacts fails within 2 weeks • Reviewing operational activities with respect to dust monitoring protocols and reporting • Engaging with landholder to understand potential impacts from agricultural activities • Reviewing relevant meteorological data • Reviewing adherence to control procedures to ensure compliance • Taking remedial action where compliance has not been adhered to in accordance with Project Dust Management Plan • Communicating with personnel involved and across all site team members (for example, via toolbox meetings) • Reporting to DES as per statutory and project requirements where incidents trigger reporting thresholds.
		Protection of surface water quality values within waterways of the receiving environment.	No degradation of surface water quality by effluent / contaminants / siltation associated with project related activities.	There are unlikely to be sediment or erosion impacts at the Doongmabulla Springs-complex as a result of monitoring and survey activities. Standard mine operating procedures will include ensuring vehicle access to not create a risk of erosion. Any sites used for chemical and fuel storage will be located a safe distance away from Doongmabulla Springs-complex, 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.	**Pre-impact and impact monitoring:** Groundwater Monitoring and Management Plan Surface water monitoring	Surface water quality Groundwater quality	• 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. • • Physical evidence of contamination to Doongmabulla Springs-complex.	The appropriate corrective actions will be implemented and may include: • Immediately reviewing vehicle access arrangements to avoid reoccurrence and address actual cause prior to any subsequent site visits • Reviewing adherence to control procedures to ensure compliance • Engaging with landholder to understand potential impacts from agricultural activities • Reviewing relevant meteorological data • Taking remedial action where compliance has not been adhered to, such as installing erosion and sediment control, within 4 weeks. • Communicating with personnel involved and across all site team members (for example, via toolbox meetings). • Reporting to DES as per statutory and project requirements where incidents trigger reporting thresholds.

#	Potential indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Ecological trigger for adaptive management and corrective actions	Corrective actions
4	Weeds and pests through direct competition or habitat degradation	Reduce weed extent and competition	No introduction of pest plants, invasive understorey species in Doongmabulla Springs-complex associated with project related activities.	Weed hygiene controls, including the use of weed wash down stations, will be implemented in accordance with the PMP to prevent the introduction and spread of declared pest plants and other invasive weeds. Weed free areas within the Doongmabulla Springs-complex will be identified and mapped with strict weed control requirements for entering weed free areas. Adaptive management of weed controls to minimise threats to Doongmabulla Springs-complex. Engagement with landholder at the Doongmabulla property regarding operational practices, particularly about the Olive Hymenachne.	**Pre-impact and impact monitoring:** Threatened and endemic flora populations Weed and Pest Surveys	Threatened and endemic species presence Presence of weed species Extent of weed coverage	• Statistically significant change in threatened and endemic species presence indicator compared to baseline / pre-impact conditions • Results of weed surveys indicate a degradation of Doongmabulla Springs-complex, due to a proliferation of weeds • A significant increase in the abundance of weeds, or pests or identification of new infestations • Introduction or establishment of declared pest plants, and invasive species into previously unaffected areas	The appropriate corrective actions will be implemented and may include: • Engaging with landholder to raise issues within 5 days of investigation • Engaging with landholder to understand potential impacts from agricultural activities • Eliminating potential sources or reasons that are have attributed to an increase in species richness and/or relative abundance of weeds • Amending weed hygiene restrictions for all subsequent access requirements • 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* • Engage with the landholder to protect and restore in Doongmabulla Springs-complex values through implementation of site-specific measures such as weed control, fire management or grazing
	Feral animal impacts	Achieve reduced impacts to the Doongmabulla Springs-complex from feral animal impacts	No increase in spring disturbance due to feral animals associated with project related activities.	The landholder at Doongmabulla springs has an existing management requirement under the Nature Refuge agreement. Adani will support the landholder through information sharing practices and aligning related activities with the landholder land management practices. Engagement with landholder at the Doongmabulla property regarding operational practices.	**Pre-impact and impact monitoring:** Threatened and endemic flora polutations Weed and Pest Surveys	Threatened and endemic species presence Presence of feral animals Extent of feral animal disturbance	• Statistically significant change in threatened and endemic species presence indicator compared to baseline / pre-impact conditions • Results of pest surveys indicate a degradation of Doongmabulla Springs-complex, due to degradation attributed to feral animals • New feral animal observed	The appropriate corrective actions will be implemented and may include: • Engaging with landholder to raise issues within 5 days of investigation. • Engaging with landholder to understand potential impacts from agricultural activities • Increasing the frequency and intensity of pest animal control, working in partnership with the landholder and relevant agencies • Reviewing actions and methods included in the project pest management plan

#	Potential indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Ecological trigger for adaptive management and corrective actions	Corrective actions
5	Grazing pressures	Achieve reduced impacts to the Doongmabulla Springs from grazing impacts	No increase in spring disturbance due to grazing pressure associated with project related activities.	The landholder at Doongmabulla springs has an existing agistment requirement under the Nature Refuge agreement. Details are provide in Section 8.6. Adani will support the landholder through information sharing practices and aligning related activities with the landholder land management practices.	**Pre-impact and impact monitoring:** Threatened and endemic flora polutations	Threatened and endemic species presence	• Statistically significant change in threatened and endemic species presence indicator compared to baseline / pre-impact conditions • Observed degradation of Doongmabulla Springs-complex attributed to grazing pressures as per requirements under the Nature Refuge Agreement (Section 8.6).	The appropriate corrective actions will be implemented and may include: • Engaging with landholder to raise issues within 5 days of investigation. • Engaging with landholder to understand potential impacts from agricultural activities and requirements under the Nature Refuge Agreement • Modifying monitoring and survey access and activities where required to support landholder actions (such as fencing, spelling) • Ensuring staff are following practices related to cattle exclusion such as protocols around gates.
6	Vegetation clearing / habitat loss	Prevent Doongmabulla Springs-complex habitat loss arising from Project activities (other than indirect drawdown as described above)	No direct clearing of vegetation at Doongmabulla Springs-complex unless otherwise approved.	Prior to the commencement of any related site works / monitoring / bore hole drilling 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 clearing. No clearing to be undertaken associated with survey and monitoring activities in and around the Doongmabulla Springs-complex unless otherwise approved and managed in accordance with such approval. Vehicle access will be by existing tracks wherever possible and no new tracks created without the necessary approvals in place.	**Pre-impact and impact monitoring:** Spring monitoring Mound springs survey Wetland vegetation monitoring Threatened and endemic flora populations Aquatic invertebrate survey Stygofauna survey	Spring wetland extent Mound spring characteristics Wetland vegetation zone Wetland vegetation species composition and abundance Threatened and Endemic Flora presence Macroinvertebrate taxonomic richness and abundance Stygofauna presence Stygofauna endemicity	• Statistically significant change in indicators compared to baseline / pre-impact conditions	The appropriate corrective actions will be implemented and may include:engaging with landholder to understand potential impacts from agricultural activities.
7	Earthworks	Minimise impacts on geomorphology	No project earthworks at Doongmabulla Springs-complex associated with project related activities.	There are no predicted or required earthworks impacts likely to occur at the Doongmabulla Springs-complex, as Project activities are limited to ongoing monitoring activities.	**Pre-impact and impact monitoring:** Surface water monitoring Wetland vegetation monitoring	Surface water quality Wetland vegetation zone wetland vegetation species composition and abundance	• Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded. • Degradation or disturbance of Doongmabulla Springs-complex likely to have been caused by earthworks activities	The appropriate corrective actions will be implemented and may include: • Engaging with landholder to understand potential impacts from agricultural activities • Ceasing any earthworks related to project activities in the vicinity of the springs and remediate within 4 weeks of conclusion of investigation. • Reviewing and re design to avoid reoccurrence and address actual cause • Communicating with personnel involved where appropriate and across all site team members (for example, via toolbox meetings).

#	Potential indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Ecological trigger for adaptive management and corrective actions	Corrective actions
8	Noise and vibration	Minimise habitat modification	No disturbance of Doongmabulla Springs-complex from noise and vibration associated with project related activities.	There are no predicted mining related noise and vibration impacts likely to occur at the Doongmabulla Springs-complex Standard mine operating procedures will include noise and vibration management in accordance with procedures under the Environmental Management Plan.	Ongoing engagement with the landholder in accordance with the Environmental Management Plan and System.	Event monitoring for: dB(A) peak particle velocity (PPV)	Degradation of Doongmabulla Springs-complex likely to have been caused by noise or vibration.	The appropriate corrective actions will be implemented and may include: • Engaging with landholder to understand potential impacts from agricultural activities • Reviewing project noise and vibration monitoring program to determine if any exceedance's recorded or noted at the Doongmabulla homestead • Reviewing and re designing project activities to avoid reoccurrence and address actual cause, completion within 3 months of investigation. • Communicating with personnel involved where appropriate and across all site team members (for example, via toolbox meetings).
9	Emissions (including dust)	Minimise emissions (dusts)	No emissions (dust) on photosynthetic ability of flora in the Doongmabulla Springs-complex habitat associated with project related activities.	There are no predicted emissions / dust impacts likely to occur at the Doongmabulla Springs-complex Standard mine operating procedures will include dust control of project areas in accordance with procedures under the Environmental Management Plan.	**Pre-impact and impact monitoring:** Surface water monitoring	Surface water quality	Evidence of degradation of Doongmabulla Springs-complex thought to have been caused by dust or other emissions.	The appropriate corrective actions will be implemented and may include: • Engaging with landholder to understand potential impacts from agricultural activities • Reviewing relevant meteorological data • Reviewing project air quality monitoring program to determine if any exceedance's recorded or noted at the Doongmabulla homestead • mitigating source of dust as per Project Environmental Plan, re inspect within 2 months. • Reducing speed limits to access monitoring locations • Communicating with personnel involved and across all site team members (for example, via toolbox meetings). • Engaging with landowner with regards to related dust matters
10	Light spill and other visual impacts	Minimise light spill	No light disturbance at Doongmabulla Springs-complex associated with project related activities.	There are no activities likely to cause light spill at the Doongmabulla Springs-complex.	**Pre-impact and impact monitoring:** Spring monitoring Mound springs Wetland vegetation monitoring Threatened and endemic flora population Stygofauna survey Aquatic invertebrate survey	Spring wetland extent Mound spring characteristics Wetland vegetation zone Wetland vegetation species composition and abundance Threatened and Endemic Flora presence Stygofauna presence Stygofauna endemicity Macroinvertebrate taxonomic richness and abundance	Direct light spill onto the Doongmabulla Springs-complex.	The appropriate corrective actions will be implemented and may include: • Engaging with landholder to understand potential impacts from agricultural activities • Reviewing relevant meteorological data • Reviewing monitoring and survey activities to determine any association • Reviewing and re designing light controlling devices, or adjust location of light, to reduce light spill and lighting levels below trigger levels and implementation within 3 months. • Communicating with personnel involved and across all site team members (for example, via toolbox meetings).

9 Mellaluka Springs-complex

9.1 Status and description

The Mellaluka wetland is a relatively unknown Springs-complex, and although identified by the DES wetland mapping tool, it is not listed in the Directory of Important Wetlands. The Mellaluka Springs-complex aquifer is believed to be located in the Joe Joe group, although additional studies are required to confirm this because there is very little information available regarding this Springs-complex (GHD 2014).

The Mellaluka Springs-complex consists of three springs:

- Mellaluka Springs-group – a large mounding spring ('Mellaluka Spring') with several vents, and two non-mounding springs. Mellaluka Spring is the largest spring in the group, and it supports a wetland area and dam
- Stories Spring – a discrete non-mounding artesian spring
- Lignum Spring – a discrete non-mounding artesian spring

The Mellaluka Springs-complex contains both mound springs and non-mounding artesian springs (GHD 2014). Although this Springs-complex is not associated with the GAB, the environmental characteristics and formation process are similar to that described above for the Doongmabulla Springs-complex (**Section 8**).

9.2 Distribution

The Mellaluka Springs-complex occurs in an approximately north-south line, between 3 km and 11 km south of the southern boundary of the Project, on Mellaluka Station (GHD 2014) (**Figure 9-1**). The northernmost spring is Lignum Spring, which is 3.6 km north of Stories Spring, with Mellaluka Spring a further 2.3 km to the south (GHD 2014). Each spring is a discrete environment that is not located near any significant waterways (GHD 2014).

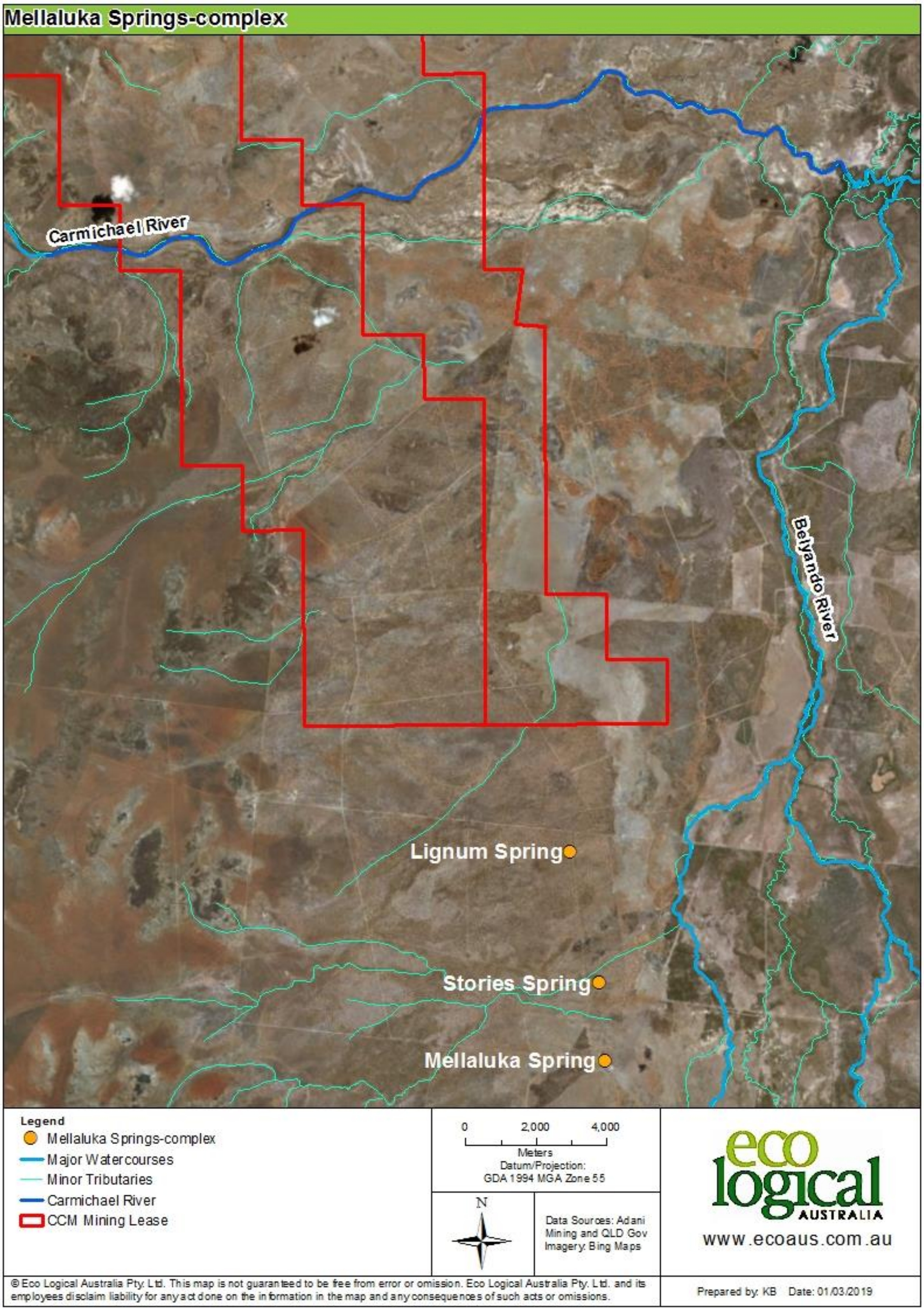


Figure 9-1: Location of Mellaluka Springs-complex

9.3 Ecology

The abundance of perennial water makes the Mellaluka Springs-complex and associated wetlands an important fauna habitat in an otherwise arid environment (GHD 2014). The aquatic fauna community at the Mellaluka Springs-complex is likely to consist of turtles, fish, freshwater shrimps, prawns, crabs and crayfish, microcrustaceans, and a range of aquatic insects and other invertebrates (GHD 2014). No threatened or endemic species are known from Mellaluka Springs; however, an Asteraceae (daisy) *Streptoglossa sp*., collected from the main Mellaluka Springs-group mound could not be matched to a known species by the Queensland Herbarium (GHD 2014). This species was also collected at the Doongmabulla Springs-complex (GHD 2014).

The Mellaluka Springs-complex is an important water source for livestock and domestic use (GHD 2014). There is a bore installed at each of the three springs-groups (GHD 2014). The spring wetlands are accessed by horses and cattle, and domestic pigs and Feral Pigs, which have degraded the water quality by stirring up sediment, and urinating and defecating in the water (GHD 2014). Cattle and pigs have caused the greatest damage to Lignum and Stories springs (GHD 2014), whereas Mellaluka Spring and its associated wetland is fenced off from cattle, although domestic pigs have access (GHD 2014). The Mellaluka Station homestead is adjacent to the Mellaluka Spring (GHD 2014).

9.3.1 Mellaluka Springs-group

The Mellaluka Springs-group (**Figure 9-2**) has formed a peat mound approximately 3 – 4 m taller than the surrounding plain, and about 100 m in diameter. Immediately adjacent to the south of this large mound, two further springs are located, both approximately 20 – 30 m diameter, but neither having formed a mound (GHD 2014). There are several vents on the mound, which feed a large pool about 1 m deep (GHD 2014). There are also several shallow overflow pools and associated wetlands at the foot of the mound (GHD 2014). Large, scalded areas surrounded parts of the base of the Mellaluka Spring mound, and the spring itself is characterised by a dense substrate of peat, topped by a sedgeland to 2 m tall (GHD 2014).

Mellaluka Spring is predominately covered in a tall sedgeland dominated by *Baumea rubiginosa* and *Schoenus falcatu*s, which contained small groves of low Weeping Paperbark trees (GHD 2014). *Phragmites australis*, *Typha domigensis* (cumbungi) and the fern *Cyclosorus interruptus* were also common in places (GHD 2014). Approximately ten tall River Red Gums occur on the apex of the mound, forming a small open-forest of approximately 0.5 ha (GHD 2014).

The groundcover at Mellaluka Spring is thick, and includes leaf litter, woody debris and grasses (GHD 2014). Tree hollows are common in the tall River Red Gums on the apex of the mound, but are sparse in the surrounding paddocks (GHD 2014). This spring provides abundant habitat for frogs, with a perennial water source and dense vegetative cover (GHD 2014).

The non-mounding springs in the Mellaluka Springs-group are located adjacent to the south of the main Mellaluka Spring, and are both approximately 20 – 30 m in diameter (GHD 2014). The saturated areas of these springs are characterised by *P. australis* grasslands with *Leersia hexandra* and *Fimbristylis ferruginosa*, or sedgeland dominated by an unknown tall *Cyperus sp*. (GHD 2014).

The Mellaluka Springs-group appears to have created its own small alluvial plain, exhibiting the same pale, very fine powdery sandy soil around the edges of the springs, as seen at Moses Spring (GHD 2014). These dry areas are characterised by *Sporobolus mitchellii* and *S. virginicus* (Saltwater couch) grasslands with shrubs such as *Chenopodium auricomum* and *Atriplex sp*. (GHD 2014). The woodlands surrounding the Mellaluka Springs-group are dominated by Gidgee (RE 11.4.6) (GHD 2014). Mellaluka Springs-group does not contribute surface water to any nearby waterways (GHD 2014).

Figure 9-2 Mellaluka mound spring (top left), runoff pool (top right), pool in peat (bottom left) and wetland (bottom right; GHD 2014)

9.3.2 Lignum and Stories springs

The northern two springs (**Figure 9-3**) are not permanent and have only one spring or outlet each, which seeps water into of a shallow pond approximately 0.5 – 1 m deep (GHD 2014). Both of these springs (inclusive of their wetlands) are small in size (Stories Spring is approximately 20 x 12 m and Lignum Spring is approximately 20 x 6 m), and both are situated within broad, level to gently undulating sand plains (GHD 2014). The Lignum and Stories springs are discrete outlets that do not flow or contribute surface water to nearby waterways (GHD 2014). They are both slightly modified from their natural state to facilitate access by cattle, with water at just below ground level (GHD 2014).

Stories and Lignum springs contain *Typha domigensis* (cumbungi) almost exclusively (GHD 2014). These springs are located in a large area of intact grassy woodlands dominated by Silver-leaved Ironbark and Reid River Box woodlands (GHD 2014). These woodlands have a high level of structural habitat complexity, although log piles and fallen timber are not common at the springs, and are very sparse at Lignum Spring (GHD 2014). Here, a sparse, light ground cover is provided by leaf litter (GHD 2014). Stories and Lignum springs are likely to provide ephemeral water sources for some threatened species that are likely to inhabitat the surrounding woodland, especially the Black-throated Finch and Squatter Pigeon. The Squatter Pigeon has been recorded adjacent to Lignum Spring (GHD 2013c).

Figure 9-3 Lignum Spring (top) and Stories Spring (bottom; GHD 2014)

9.4 Supporting Groundwater resources

The Colinlea Sandstone was initially considered to be the primary source aquifer for the Mellaluka Springs-complex. However, additional drilling (detailed in the GMMP) indicates complex artesian conditions associated with the Tertiary and Joe Joe Group sediments that provide discharge to the surface in the area of Mellaluka Springs-complex.

Further monitoring of these aquifers including the installation of additional groundwater monitoring bores has been recently undertaken and detailed in the GMMP. The location of these bores is provided in **Figure 9-4**, **Figure 9-5** and **Figure 9-6**.

Groundwater quality indicates mixing / blending of groundwater measured at Mellaluka Springs, when considering the salinity of Tertiary 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.

Based on the site-specific geology, mapping of coal seam subcrop, and the available groundwater quality, it is considered that the groundwater associated with the Mellaluka Springs-complex is sourced from artesian Tertiary and Joe Joe sediments.

This conceptualisation, based on conditions within the area, will be refined overtime as additional groundwater data is compiled and the groundwater model is revised at regular intervals (within 2 years of commencement of mining activities and every 5 years thereafter). The GMMP, and by association the GDEMP, will be revised, as required, in response to modelling refinement.

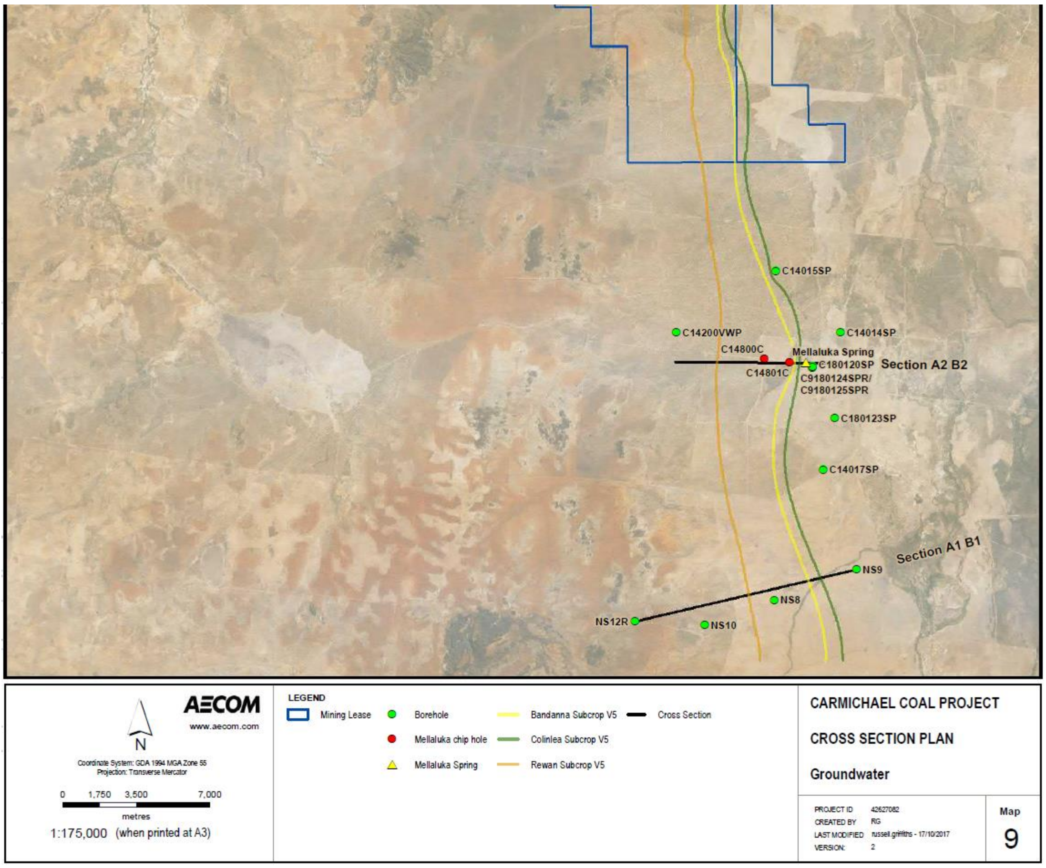


Figure 9-4 Groundwater bores associated with the Mellaluka Springs – bores shown are government exploration bores (Source: GMMP)

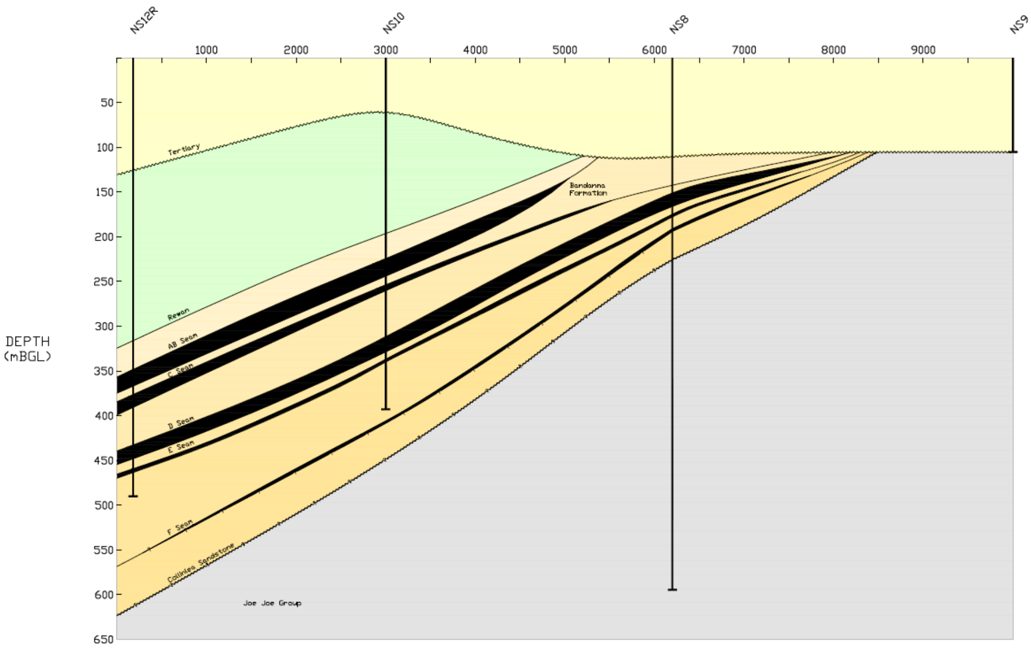


Figure 9-5 Cross section extract of bores associated with the Mellaluka Springs-complex. Water levels (Artesian) are: C9180125SPR 243.10 mAHD, C180120SP 243.48 mAHD, C14015SP 239.15 mAHD and C14014SP 239.32 mAHD. Remaining bores are government exploration bores (Source: GMMP)

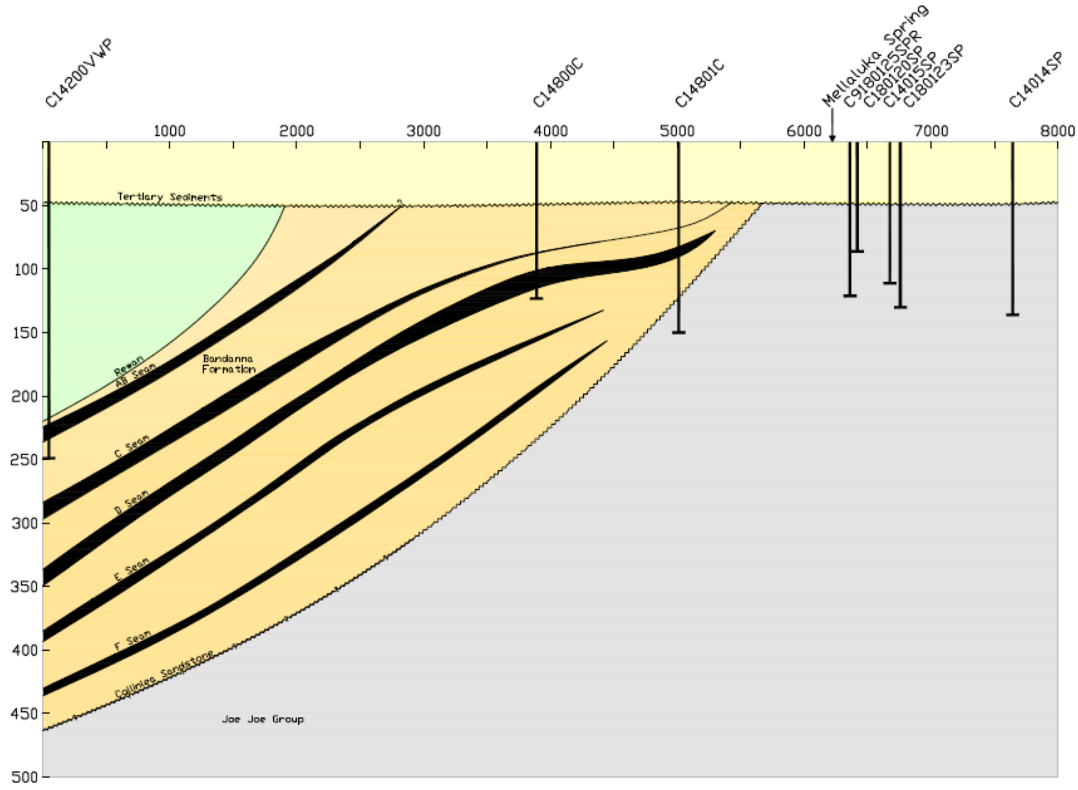


Figure 9-6 Cross section extract of bores associated with the Mellaluka Springs-complex (Source: GMMP)

9.5 Summary of baseline monitoring findings

9.5.1 Mellaluka Springs

Whilst mapped as non-remnant vegetation, there is approximately 3 – 4 ha of remnant vegetation associated with this spring that meets the description of the of concern RE 11.3.22, which is 'Springs, associated with recent alluvia', but also including those on ancient alluvia' (Queensland Herbarium, 2013).

There were three main vegetation communities recorded at this spring.

1. Tall sedgeland to 2 m tall dominated by *Baumea rubiginosa* (soft twig rush) and *Schoenus falcatus* with *Phragmites australis* (common reed), cumbungi and the fern *Cyclosorus interruptus* also common in places. Small groves of Weeping Paperbark were present in the sedgeland, all less than 5 m tall.
   On the apex of the mound, but in sandy soil, were approximately ten tall (to 20 m) river red gums, forming a small open forest of half a hectare.
   Saturated grasslands characterised by *P. australis, L. hexandra* and *Fimbristylis ferruginosa*, or sedgeland dominated by an unknown tall *Cyperus sp*.
2. Dry areas adjacent to pools were comprised of the fine, powdery sand that appears to be characteristic of developed springs. These areas were characterised by grassland of *Sporobolus mitchellii* and freshwater couch with shrubs such as *Chenopodium auricomum* and *Atriplex sp*.
3. The area surrounding Mellaluka Springs is dominated by Gidgee woodland on a clay plain, comprising the RE 11.4.6 (Queensland Herbarium, 2013).

An unidentified daisy, *Streptoglossa sp.*, was collected on the main Mellaluka Spring mound. Further specimens are required to confirm whether it is in fact a new species.

With regards to providing habitat for flora and fauna species, the following findings are noted:

- While the Mellaluka Spring is relatively large, it is isolated from nearby grass and woodland, and habitat connectivity may be compromised for many species.
- The Mellaluka Spring contained the largest community of flora species which in turn created a broad range of habitats.
- The dam at the Mellaluka Spring provides a valuable habitat for turtles as the surface waters are perennial, and prey (frogs, fish, insects and crustaceans) are predicted to be abundant
- The aquatic invertebrate community is likely to consist of decapods (freshwater shrimps, prawns, crabs and crayfish). The Mellaluka Spring provided particularly abundant habitat for amphibians as it had a perennial water source and dense vegetative cover, microcrustaceans and a range of aquatic insects
- While there is little cover provided by submerged timber or floating macrophytes, the peat and clay substrate does provide an environment suitable for aquatic invertebrates.

With regards to threatening processes and disturbance, the following findings are noted:

- The wetlands are accessed by a number of domestic and feral animals which have resulted in moderate disturbances from horses, cattle and pigs.
- The proximity of Mellaluka Station to the Mellaluka Spring may also create some anthropogenic disturbances, for example, from noise and light, increased human activity, chemical spraying and the presence of domestic pigs (which were observed to utilise the wetland).
- A deterrent to mammals at the Mellaluka Spring (excluding the Stories and Lignum springs) are the presence of domestic dogs at the Mellaluka homestead.

Adani undertook further ecological survey of the Mellaluka Springs in 2015 and 2016, particularly in regards to the Coordinator General's Imposed Condition 1 (d)(i). As a result of those surveys, it was confirmed that the Mellaluka Springs-complex does not provide high value habitat for the Black-throated finch and therefore does not require further baseline research as per EPBC Act Condition 6 (k).

9.5.2 Stories and Lignum Springs

Stories and Lignum springs are much simpler springs than those at Mellaluka Springs and the main vegetation features recorded are:

- Both springs are dominated exclusively by cumbungi
- These springs are located in grassy woodland dominated either by Silver-leaved Ironbark (RE11.3.28) or Reid River Box (RE 10.3.6)

With regards to providing habitat for flora and fauna species, the following findings are noted:

- Both springs are unlikely to provide direct habitat for most mammal species, although some small mammals may seek refuge in the denser vegetation within the springs.
- Conversely, Stories and Lignum springs have value for mammals as a perennial source of water, particularly during dry periods.
- While both Stories and Lignum springs contained frogs, the smaller size of the springs and the associated disturbances to the springs make these vents less suitable for supporting large amphibian populations

- Stories and Lignum springs are both situated in woodland where terrestrial habitat connectivity is maintained

With regards to threatening processes and disturbance, the following findings are noted:

- Cattle and pigs have caused extensive damage to these two spring wetlands
- Water quality is degraded through the stirring up of sediment, and urinating and defecating by cattle

9.6 Threats and impacts

Threats and potential direct / indirect project impacts that are required to be addressed as they apply to the Mellaluka Springs-complex are:

- direct and indirect project impacts outlined in the EIS (GHD 2012a; Adani 2012) *Carmichael Coal Mine and Rail Project – Groundwater Dependent Ecosystems Management Plan (11 February 2014*)
- matters outlined in Condition 6(c) require details for impacts and threats to MNES to be included in this plan.

The key threats and potential direct / indirect project impacts identified for Mellaluka Springs-complex that are relevant to the Project are identified in the following sections and **Table 9-1**. It should be noted that the Mellaluka Springs-complex is located a minimum of approximately 3 km (Lignum Spring) from the Project's southern boundary, and will therefore not be subject to direct impacts.

Table 9-1 Mellaluka Springs-complex threats, potential direct / indirect project impacts and matters required to be addressed by conditions

#	Potential Threat or Impact	Potential indirect threat or impact identified in EIS (GHD, 2014)	EPBC Approval, 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 20	**Table 9-4**Table 9-4
2	Subsidence from underground mining	-	(c)(ii)	(5)	Operations Rehabilitation	*Not applicable*	
3	Changes to hydrology and degradation of surface water quality	-	(c)(vii)	(5)	Construction Operations Rehabilitation	*Not applicable*	
4	Weeds and pests through direct competition or habitat degradation	Yes	(c)(ix)	(5)	Construction Operations Rehabilitation	Year 20	
5	Vegetation clearing / habitat loss	Yes	(c)(i)	-	Operations	*Not applicable*	
6	Earthworks	-	(c)(iv)	-	Construction	*Not applicable*	
7	Noise and vibration	-	(c)(v)	-	Construction Operations	*Not applicable*	
8	Emissions (including dust)	-	(c)(vi)	-	Construction Operations	*Not applicable*	
9	Light spill and other visual impacts	-	(c)(vii)	-	Construction Operations	*Not applicable*	

#1: Groundwater drawdown from mine dewatering

EPBC Act Approval 2010/5736, condition 6(c)(iii) requires details of potential impacts from groundwater drawdown of aquifers be addressed in this plan.

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.

A change in groundwater hydrology as a result of the operational phase of the Project (mine), specifically, a reduction in groundwater pressure is the primary potential impact on the Mellaluka Springs-complex (GHD 2014).

During operations, the maximum predicted reduction in groundwater pressure for the Mellaluka Springs-complex (in the Permian-age strata aquifer) is up to 1.16 m at the Mellaluka Spring, 2.35 m at Stories Spring, and 8.26 m at Lignum Spring (GHD 2015). Predictions suggest that these significant impacts will not occur until around 60 years into the proposed life of the mine (GHD 2014). Post-closure reductions in pressure are predicted to be up to 9.46 m at Mellaluka Spring, 13.81 m at Stories Spring, and 25.8 m at Lignum Spring.

The predicted post-closure reductions in pressure in the aquifers of the Mellaluka Springs-complex will have significant impacts on the ecological function for all the springs in the Mellaluka Springs-group, and their capacity to supply domestic and agricultural water, with the springs drying up at the surface (GHD 2014). The predicted draw-down pressure reductions are well below ground level and only the most deep-rooted trees associated with the springs will be able to access groundwater at this depth (GHD 2014). It is concluded that impacts to this spring group will be serious during operations for at least the Lignum and Stories Springs, and of significant magnitude post-closure for the entire Mellaluka Springs-group (GHD 2014).

Conceptually this is represented for the Mellaluka Spring in **Figure 9-7**.

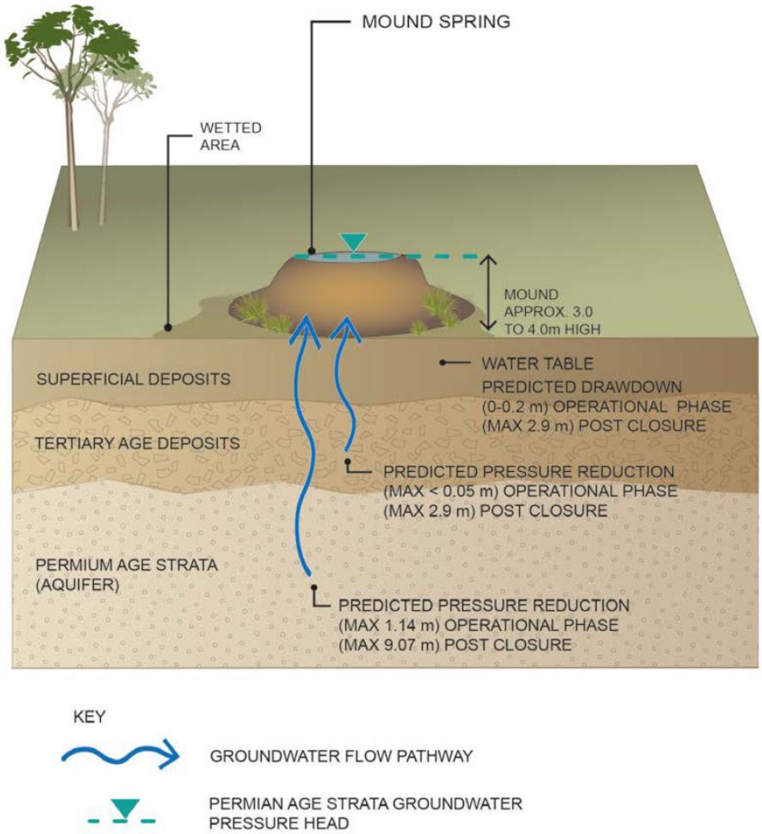
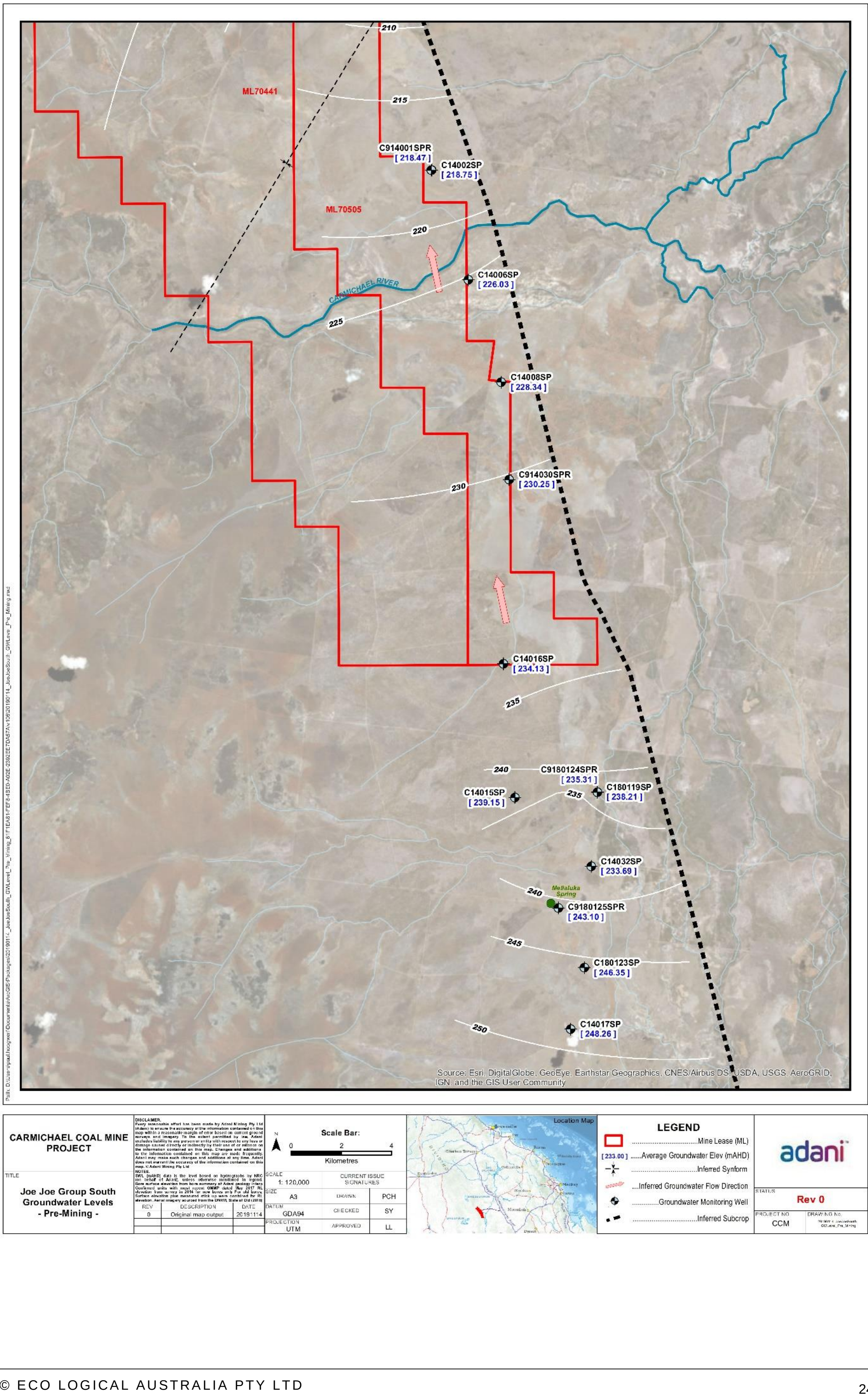


Figure 9-7 Conceptual model of groundwater impacts at the Mellaluka Springs-complex (GHD, 2013b)

However, noting more recent hydrogeological information obtained from recent drilling, it is considered that the groundwater associated with the Mellaluka Springs Complex is sourced from artesian Tertiary and Joe Joe sediments. This conceptualisation, based on conditions within the area, will be refined overtime as additional groundwater data is compiled and the groundwater model is revised at regular intervals (within 2 years of commencement of mining activities and every 5 years thereafter). The GMMP, and also the GDEMP will be revised, as required, in response to modelling refinement.

Further, as predicted impacts to the Melluka Springs-complex are associated with mining activities south of the Carmichael River and these activities will not commence until Year 10, pre-impact groundwater and ecological monitoring will allow the refinement of this model prior to the commencement of mining activities and hence an updated prediction of impact, triggers and if required, offsets. Actual impacts to the Mellaluka Springs-complex are not predicted to occur for 20 to 25 years after Project commencement.

Figure 9-8a-g on the following pages provides progressive drawdown predictions for the Mellaluka Springs-complex for both the Joe Joe and the Tertiary. The locations of monitoring bores are included on these figures.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Melaluka Spring
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C180123SP
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C14017SP
[248.26]
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
CARMICHAEL COAL MINE PROJECT
TITLE
Joe Joe Group South Groundwater Levels - Pre-Mining -
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NOTES.
SWL (mAHD) data is the level based on hydrographs by NRC (on behalf of Adani), unless otherwise mentioned in legend. Bore surface elevation from bore summary of Adani geology interp Confined 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 (2018)
REV
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Original map output
20191114
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Location Map
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Mine Lease (ML)
[233.00] Average Groundwater Elev (mAHD)
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Inferred Groundwater Flow Direction
Groundwater Monitoring Well
Inferred Subcrop
STATUS
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PROJECT NO
CCM
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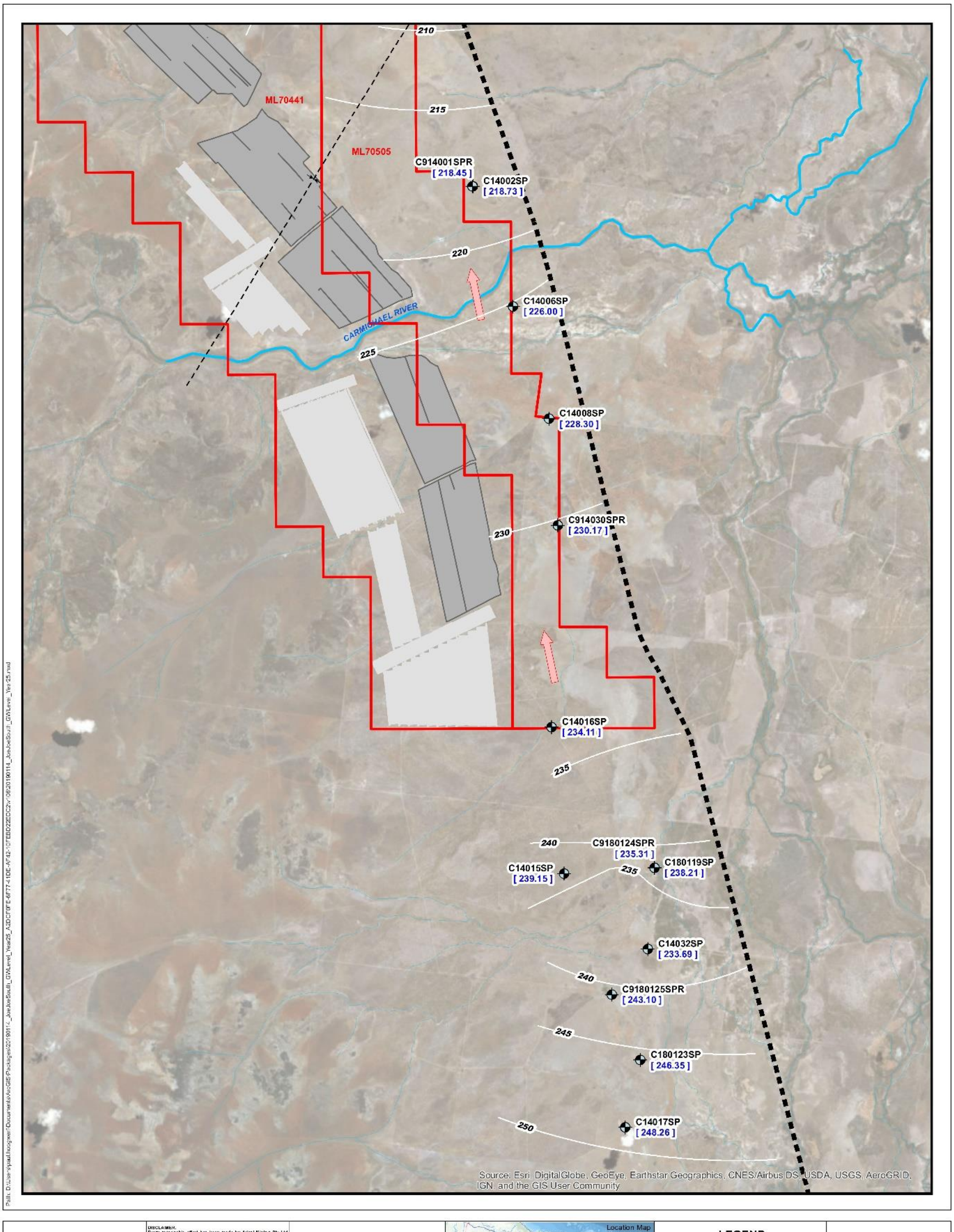

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Scale Bar: 0 2 4 Kilometres

TITLE

Joe Joe Group South Predicted Groundwater Levels - Year 25 -

REV	DESCRIPTION	DATE
0	Original map output	20190114

SCALE 1: 120,000	CURRENT ISSUE SIGNATURES	
SIZE A3	DRAWN	PCH
DATUM GDA94	CHECKED	SY
PROJECTION UTM	APPROVED	LL

LEGEND

- Mine Lease (ML)
- [233.00] Predicted Groundwater Elevation (mAHD)
- Inferred Synform
- Open Cut Mine Working
- Underground Mine Working
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well
- Inferred Subcrop

STATUS: **Rev 0**

PROJECT NO: CCM

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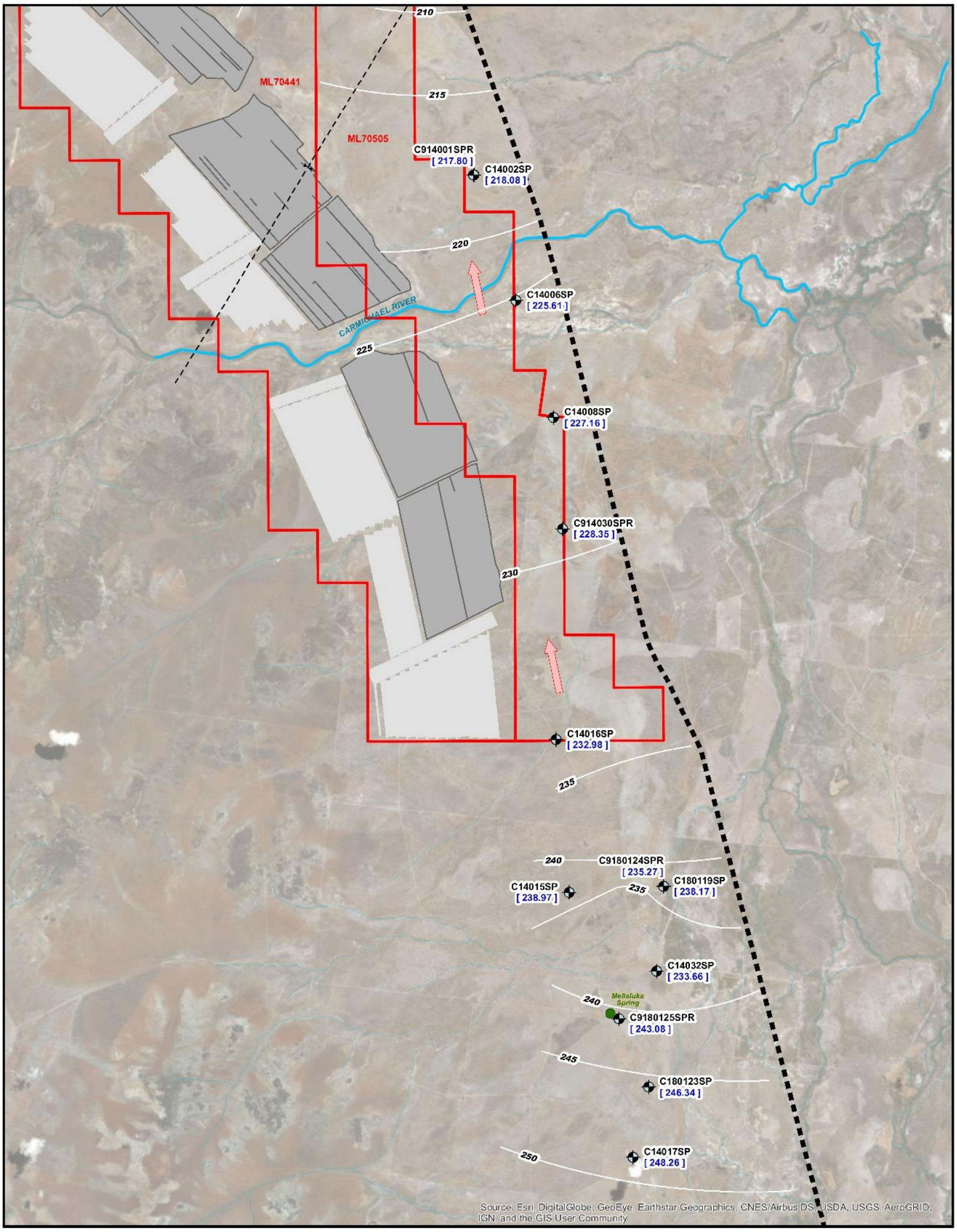

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Scale Bar: 0 2 4 Kilometres

TITLE
Joe Joe South Predicted Groundwater Levels - PC: Post Closure -

REV	DESCRIPTION	DATE
0	Original map output	20190114

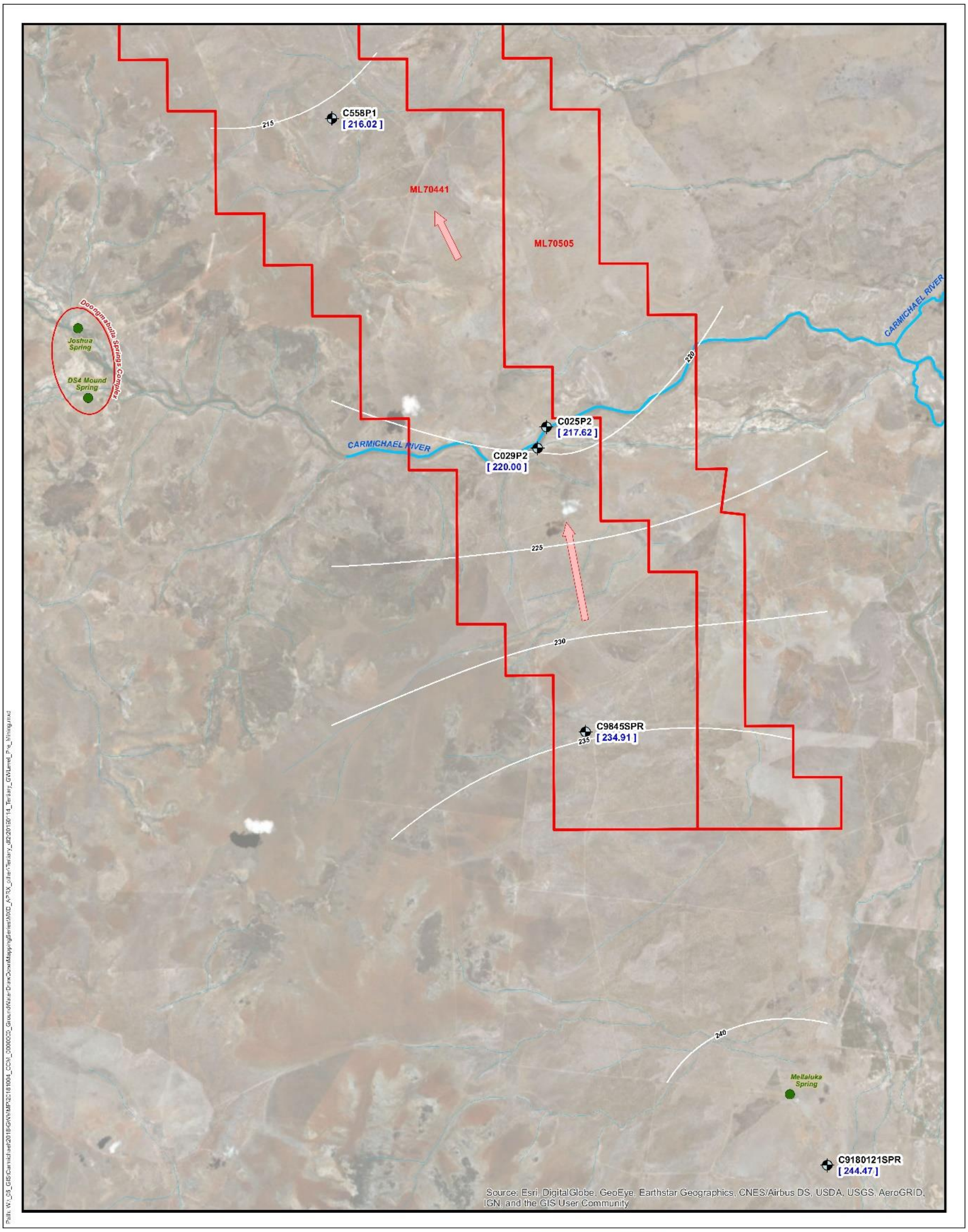
SCALE 1: 120,000	CURRENT ISSUE SIGNATURES	
SIZE A3	DRAWN	PCH
DATUM GDA94	CHECKED	SY
PROJECTION UTM	APPROVED	LL

LEGEND
Mine Lease (ML)
[233.00] Predicted Groundwater Elevation (mAHD)
Inferred Synform
Open Cut Mine Working
Underground Mine Working
Inferred Groundwater Flow Direction
Groundwater Monitoring Well
Inferred Subcrop

STATUS **Rev 0**

PROJECT NO CCM

DRAWING No.



CARMICHAEL COAL MINE PROJECT

TITLE

Tertiary Sediments Groundwater Levels - Pre-Mining -

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NOTES:
SWL (mAHD) data is the average water level based on hydrographs by NRC (on behalf of Adani), unless otherwise mentioned in legend. 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
0	Original map output	20190114

Scale Bar: 0 2 4 Kilometres

SCALE 1: 120,000	CURRENT ISSUE SIGNATURES	
SIZE A3	DRAWN	PCH
DATUM GDA94	CHECKED	SY
PROJECTION UTM	APPROVED	LL

LEGEND

- Mine Lease (ML)
- [233.00] Average Groundwater Elevation (mAHD)
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well

STATUS: **Rev 0**

PROJECT NO: CCM

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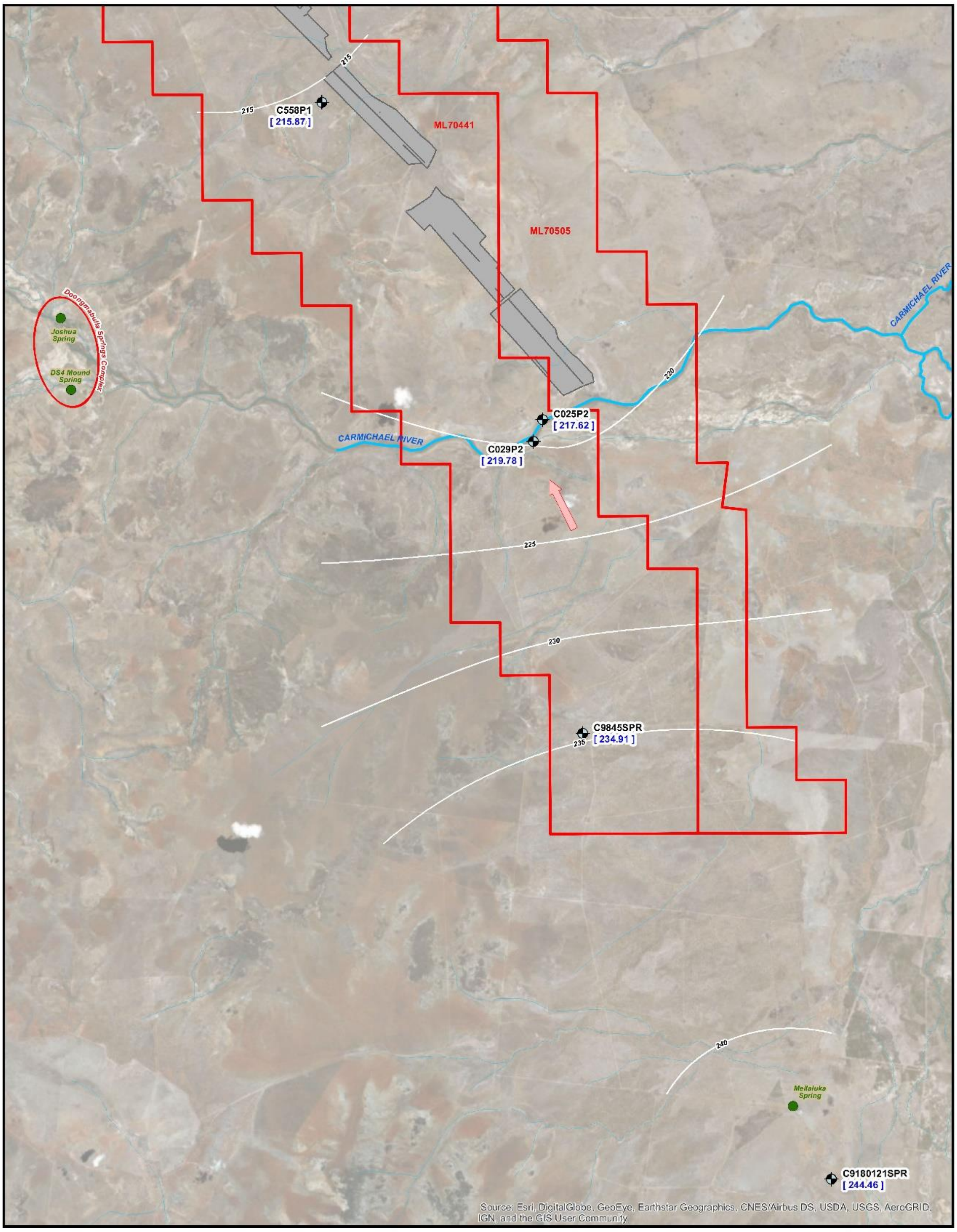

CARMICHAEL COAL MINE PROJECT

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Scale Bar: 0 2 4 Kilometres

TITLE
Tertiary Sediments Predicted Groundwater Levels - Year 5 -

REV	DESCRIPTION	DATE
0	Original map output	20190114

SCALE 1: 120,000	CURRENT ISSUE SIGNATURES	
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DATUM GDA94	CHECKED	SY
PROJECTION UTM	APPROVED	LL

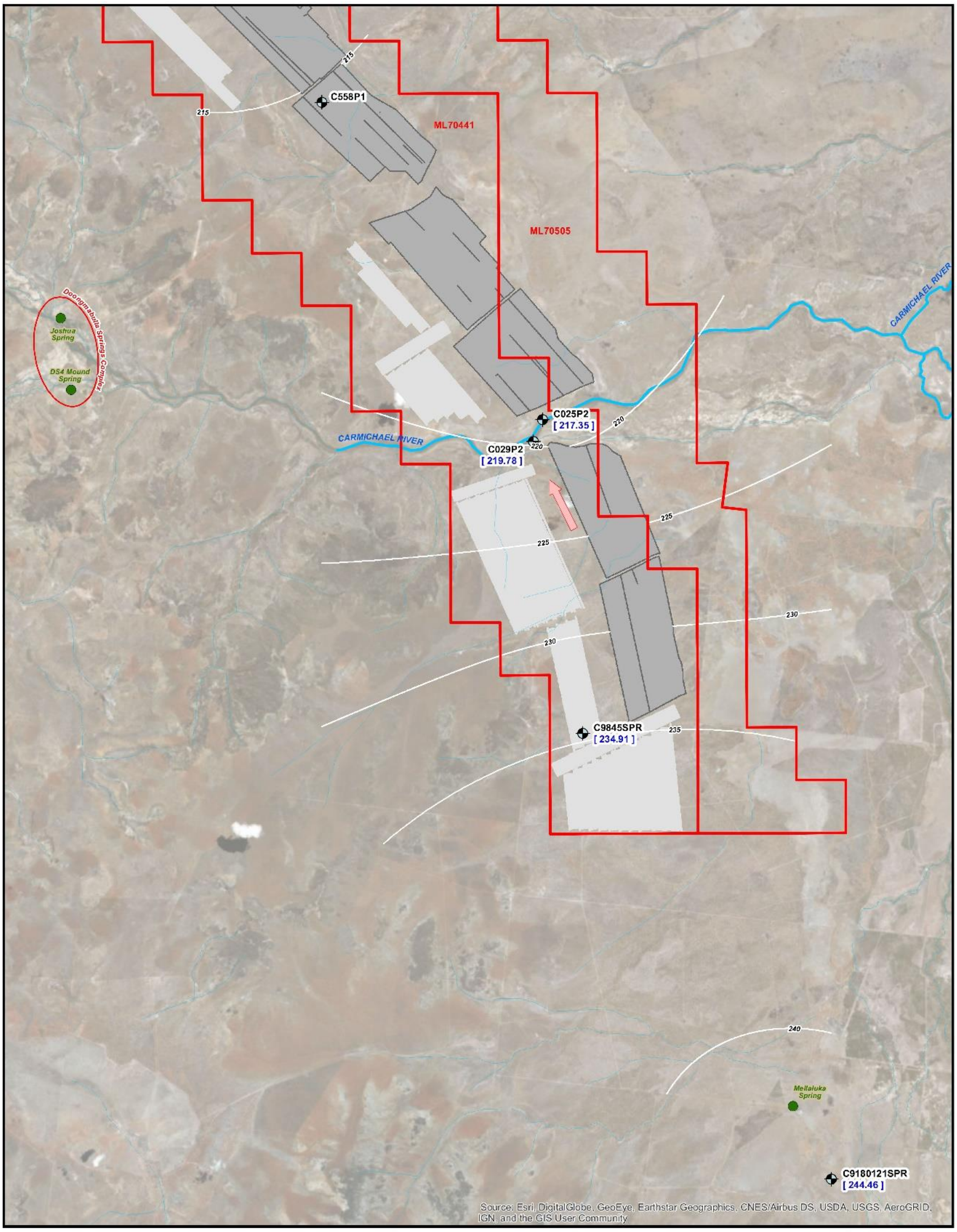
LEGEND

- Mine Lease (ML)
- [233.00] Predicted Groundwater Elevation (mAHD)
- Open Cut Mine Working
- Inferred Groundwater Flow Direction
- Groundwater Monitoring Well

STATUS: **Rev 0**

PROJECT NO: CCM

DRAWING No.



CARMICHAEL COAL MINE PROJECT

TITLE

Tertiary Sediments Predicted Groundwater Levels - Year 25 -

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REV	DESCRIPTION	DATE
0	Original map output	20190114

Scale Bar: 0 2 4 Kilometres

SCALE 1: 120,000	CURRENT ISSUE SIGNATURES	
SIZE A3	DRAWN	PCH
DATUM GDA94	CHECKED	SY
PROJECTION UTM	APPROVED	LL

LEGEND

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

STATUS: **Rev 0**

PROJECT NO: CCM

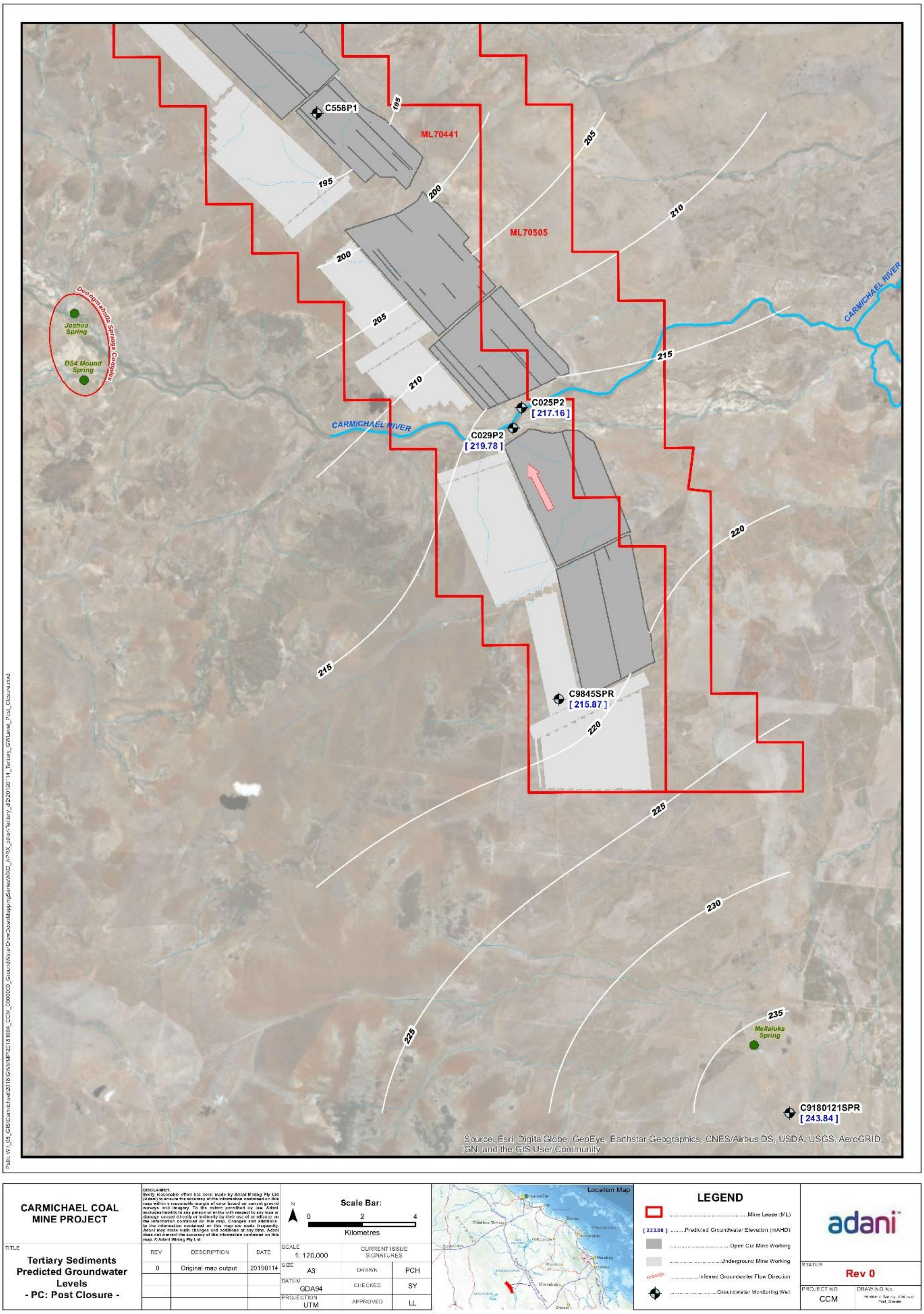

Figure 9-8a-g Predicted groundwater draw down associated with the Mellaluka springs-complex

A management objective under this plan is to manage the impacts of mine dewatering and limit impact of hydrological changes on the Mellaluka Springs-complex from mine dewatering. **Table 9-4** 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

EPBC Approval 2010/5736, condition 6(c)(ii) requires details of potential impacts from subsidence 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 subsidence is predicted to occur within the vicinity of the Mellaluka Springs-complex, the nearest spring (Lignum Spring) being located a minimum of 3 km from the boundary of the Project Area.

As no subsidence is predicted to occur, the management objective is to monitor to ensure there is no habitat alteration through subsidence. **Table 9-4** 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

EPBC Approval 2010/5736, condition 6(c)(viii) requires details of potential impacts from stream diversions and flood levees, be addressed in this plan.

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.

Mellaluka Springs-complex does not contribute surface water to any nearby waterways, being located near the margin of extensive clay plains to the south west, sand plains to the north west, and a large alluvial plain to the east associated with the Belyando River, which is approximately 9 km away (GHD 2014). The focus for this threat is therefore to maintain existing surface water quantity (level) and quality of the Mellaluka Springs-complex, noting that there are existing impacts associated with weeds, feral animals and the impact of domestic animals.

A management objective under this plan is to maintain baseline surface water quantity (level) and quality. **Table 9-4** describes how the management objective will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#4 Weeds and pests through direct competition or habitat degradation

EPBC Approval 2010/5736, condition 6(c)(ix) requires details of potential impacts from weeds and pests, be addressed in 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 ecology of the Mellaluka Springs-complex is currently threatened by pugging from cattle and pigs. This is unlikely to be exacerbated by mining activities and is under the management control of the landowner. All springs in this group are also characterised by the presence of weeds which overtime will further degrade wetland habitat quality, outcompete native vegetation, and potentially reduce the extent of open water available within the spring wetland areas.

Project-related impacts on the Mellaluka Springs-complex through drawdown may exacerbate existing impacts from weeds and pests, by reducing the resilience of the wetland communities and impacting sensitive native flora species. Visits to the Springs-complex to conduct monitoring also have the potential to introduce weeds and pests, if appropriate hygiene measures are not implemented. Impacts from cattle grazing are not under the direct control of Adani, as the Mellaluka Springs-group is located on land not owned by Adani, and grazing is managed by the landholder.

A management objective under this plan is to promote reduced weed competition and habitat degradation from Project-related activities within the Mellaluka Springs-complex, noting that responsibility for weed management at the site rests with the landholder. **Table 9-4** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions. It should be noted that the Mellaluka Springs-complex is located on land that is not owned by Adani.

#5 Vegetation clearing / habitat loss

EPBC Approval 2010/5736, condition 6(c)(i) requires details of potential impacts from vegetation clearing be addressed in this plan.

There is no direct clearing of vegetation at the Mellaluka Springs-complex as a result of Project activities. However, habitat may be impacted by groundwater drawdown (addressed above).

Management objectives about the threat and impacts include minimising habitat loss and habitat restoration of disturbed areas, and if required environmental offsets. **Table 9-4** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#6: 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 and operations could lead to increased exposure to light, noise, dust, vehicles and people in areas adjacent to the Project area (Adani, 2012). The Project area is more than 3 km to the north, and there will be no direct incursion from Project vehicles or personnel beyond monitoring required as part of this plan.

Earthworks carried out as a part of mine construction and operations are unlikely to lead to increased risk and exposure of the Mellaluka Springs-complex to light, noise, dust, vehicles and people. Dust, noise, vibration and light spill are described in the following sections.

A management objective under this plan is to minimise risks during construction and operations. **Table 9-4** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#7: 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.

The project will use standard construction equipment, general trade equipment and specialised equipment 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 Mellaluka Springs-complex, due to its distance from project activities (a minimum of 3 km from the edge of the Project area to the closest spring - Lignum).

A management objective under this plan is to minimise habitat modification as a result of noise and vibration. **Table 9-4** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#8: 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. Dust deposition associated with construction and operational is not predicted to impact the Mellaluka Springs-complex.

A management objective under this plan is to minimise emissions, particularly dusts. **Table 9-4** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

#9: Light spill and other visual impacts

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

Development of the project will necessitate the installation of lighting for safety and security of operations as the proposed 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. This is not expected to be an impact to the Mellaluka Springs-complex.

A management objective under this plan is to minimise light spill and other visual impacts. **Table 9-4** describes how the management objectives will be met, including performance criteria, management actions, monitoring, triggers for adaptive management and corrective actions.

9.7 Mitigation and management measures

Mitigation and management measures will focus on the impacts of groundwater drawdown.

Pre-impact groundwater monitoring will inform the updating of the numerical and conceptual groundwater model in order to confirm the source aquifer and predicted impacts. This will be completed before activities associated with predicted impacts occur. The GMMP and GDEMP will be updated once these reviews are complete and hence the mitigation and management measures presented below are based on the current conceptual groundwater model as approved through the EIS, which notes that there is likely to be significant groundwater lossses at these springs leading to a loss of ecological function.

Therefore, the key mitigation measure at Mellaluka Spring will be to supplement water supplies once operational drawdown impacts on the wetland begin to occur. These impacts will be mitigated through the installation of pumps to supplement surface water availability from alternative water sources (GHD 2014). In the event that this mitigation measure is not successful, then offsets will be implemented (**Section 9.7.2**).

9.7.1 Adaptive Management

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 for example groundwater levels and groundwater quality, surface water quality), 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.

If ongoing declines in ecological values 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 the Mellaluka Springs-complex, then additional mitigation measures will be considered.

9.7.2 Environmental Offsets

The assessment of potential impacts to the Mellaluka Springs-complex indicated that no offset is required (GHD 2014; EPBC Act Approval Condition 10). Predicted impacts to the Mellaluka Springs-complex will be refined through the re-modelling to be undertaken within two years of commencement. This modelling will utilise additional geological and groundwater information to confirm the source aquifer for the Mellaluka Springs-complex and the predicted impacts.

Mitigation measures will be refined in response and offsets proposed, should there be significant residual impacts that cannot be mitigated, or as a corrective action should mitigation measures not be effective. EPBC Act conditions make reference to the potential to offset the ecological function of the Mellaluka spring–group, should the review of the conceptual and numerical impact model at the end of pre-impact monitoring demonstrate groundwater drawdowns consistent with the worst case predictions of the EIS conceptual groundwater model, as described above in **Section 9.6**. Adani will secure ecological offsets if pre-impact monitoring and groundwater model confirm likely complete loss of ecological function at each spring location.

9.8 Monitoring

Table 9-2 summarises the monitoring frequency, duration, type and indicators for the ecological values at the Mellaluka Springs-complex.

Table 9-2: Mellaluka Springs-complex monitoring frequency, duration, type and indicators

Monitoring Description	Frequency and duration	Monitoring type#	Indicators
Spring monitoring	Quarterly for the first two years, then annually	Pre-impact Impact	Spring wetland extent Spring wetland water level Spring characteristics
Wetland vegetation monitoring	Quarterly for the first two years, then annually	Pre-impact Impact	Wetland vegetation zone Wetland vegetation species composition and abundance
Threatened and endemic flora populations	Quarterly for the first two years, then annually	Pre-impact	Threatened and endemic species presence

Monitoring Description	Frequency and duration	Monitoring type#	Indicators
		Impact	
Aquatic invertebrate survey	Twice per year (wet and dry season) for two years, then annually	Pre-impact Impact	Macroinvertebrate taxonomic richness and abundance
Weed and pest surveys	Annually	Pre-impact Impact	Presence of weed species, Extent of weed coverage, Presence of feral animals, Extent of feral animal and cattle disturbance
Stygofauna survey	One round of sampling	Pre-impact	Stygofauna presence, stygofauna endemicity
Groundwater monitoring (as per GMMP)	12 hourly (level) Quarterly (quality)	Pre-impact Impact	Groundwater level, groundwater quality
Surface water quality	Monthly	Pre-impact Impact	Surface water quality

The full suite of tasks comprising the impact phase of monitoring will be confirmed after completion of the Ecological Condition Report (see Section 9.8.2).

9.8.1 Pre-impact monitoring

Pre-impact monitoring will be carried out prior to each project phase, as described in **Table 9-2**. A pre-impact monitoring report will be prepared per impact, before the impact occurs. Spring monitoringBi-annual (wet and dry season) surveys will be completed for two years from commencement of this plan, then the frequency will be reviewed, and nominally revert to annually at each springs-complex: Lignum, Stories and Mellaluka. Surveys will be undertaken to establish the existing condition of the springs and seasonal fluctuations in size, surface water level and vegetation characteristics.

Pre-impact monitoring surveys will also include analysis of spring-head pressure via bores targeting the spring source aquifer, spring wetland characteristics including wetland area and physical condition, water quality, wetland vegetation and any threatened and endemic flora and fauna identified (including the *Streptoglossa* sp. collected from the main Mellaluka Springs-ground mound at Mellaluka Springs-complex and at the Doongmabulla Springs-complex).

Mapping of the vegetated area perimeter and wetted area, as defined in the *'Wetland Monitoring Methodology for Springs in the Great Artesian Basin'* (Fensham & Fairfax, 2009) (even though the Mellaluka Springs-complex is not fed by the Great Artesian Basin):

- >50% target perennial wetland cover
- Areas where >50% target perennial wetland cover would have been prior to disturbance by pigs or stock
- Areas of free water forming a spring pool contained within target perennial wetland vegetation

- Review and interpretation of remote sensing images if available, following 'A new approach to monitoring spatial distribution and dynamics of wetlands and associated flows of Australian Great Artesian Basin springs using QuickBird satellite imagery' (White & Lewis 2011)
- Produce a digital elevation model for the Mellaluka Springs-complex
- Spring wetland extent will be monitored.

A baseline water level will be established at a reference location for the springs, and water levels will be measured using a reference marker. Surface water level will be measured against the marker during each survey.

This monitoring will complement the wetland area measurements, which provides a surrogate measure of flow via the Fatchen equation.

Spring wetland water level will be monitored.

Spring characteristics survey

Surveys of 3 springs at the Mellaluka Springs-complex, to collect the following information:

- Spring diameter, height and perimeter
- Full floristic species composition and abundances
- Population surveys for spring endemic flora species
- Population surveys for EPBC and NC Act listed species
- Photographic references.

These surveys will describe both the terrestrial (i.e. non-wetland) and spring wetland vegetation, as well as define the target perennial wetland species.

Indicator: spring wetland extent, wetland water level, spring characteristics

Wetland vegetation monitoring

Monitoring will consist of vegetation surveys along transects and within sub plots. Vegetation transects will be located across the wetland area gradient, from the spring source to the boundary with non-wetland areas. The transects and subplots along the transects will be used to collect the following information:

- Identify wetland zones (pool, saturated, damp, dry) and their boundary locations
- Photographic references (photo point monitoring)
- Wetland vegetation species composition
- Wetland vegetation species abundances (1 m x 1 m subplots spaced 4 m apart, along the transect)

These surveys will describe both the terrestrial (i.e. non-wetland) and spring wetland vegetation.

Baseline vegetation composition surveys will be used to identify target non-endemic and non-threatened perennial wetland species for monitoring at each springs wetland. These species will be monitored using replicate 1 m x 1 m subplots.

Indicators: wetland vegetation zone, wetland vegetation species composition and abundance

Threatened and endemic flora surveys

Targeted searches will be used to identify patches of endemic and threatened wetland flora for monitoring at each springs wetland.

The location, extent, and presence of all threatened and endemic flora will be surveyed and recorded using a differential GPS.

Threatened and endemic flora will be surveyed at springs.

Indicators: Threatened and endemic species presence.

Aquatic invertebrate surveys

Aquatic invertebrate sampling (for endemic species) will be based on the methods used for GAB Springs monitoring in the Surat Basin and will be undertaken at the Mellaluka Spring. This includes sweeping an area of up to $5m^2$ with a macroinvertebrate net for 5 minutes, and transferring samples into a sterile jar (with a preservative) for subsequent laboratory identification to morpho-family level.

Indicator: Macroinvertebrate genera and species richness

Weed and pest surveys

Weed and pest surveys will be completed annually at each springs-complex: Lignum, Stories and Mellaluka in accordance with the Project pest management plan to:

- Identify the extent of weeds,
- Identify areas of wetland habitat subject to damage from feral and domestic animals

Indicators: Presence of weed species, Extent of weed coverage, Presence of feral animals, Extent of feral animal disturbance

Stygofauna survey

A round of stygofauna sampling will be undertaken for the Mellaluka Springs-complex (at Bore C180120SP) to determine the presence of stygofauna and to identify if endemicity in the stygofauna community exists within the aquifer.

Indicators: Stygofauna presence, stygofauna endemicity

Groundwater monitoring

Groundwater level monitoring will be completed 12 hourly for water levels and at least quarterly for groundwater quality as per the GMMP. Groundwater monitoring will inform a combined baseline and pre-impact dataset for input into model review prior to activities and impacts.

Indicators: groundwater level, groundwater quality

Surface water monitoring

Surface water quality monitoring will be undertaken monthly at the Mellaluka Springs-complex.

Indicator: surface water quality (**Appendix A**)

Pre-impact condition report

At the conclusion of pre-impact surveys an Ecological Condition report will be prepared for the springs. The report will present results from baseline studies and the pre-impact monitoring events, mapping and photo-points and discuss the seasonal and spatial variation in the results. Recommendations for refining future ongoing monitoring methodology and frequency will also be made, in conjunction with a review of the relevant management and monitoring plans.

9.8.2 Impact survey and monitoring

The full suite of impact monitoring program attributes will be confirmed after the completion of the Ecological Condition Report.

Impact survey and monitoring will begin from the predicted groundwater drawdown impacts from the mine (Year 20) and afterwards for the life of the mine, and for at least five years after mining operations are completed. The impact monitoring program will consist of the following:

- Spring monitoring
- Wetland vegetation monitoring
- Threatened and endemic flora populations
- Aquatic invertebrate survey
- Weed and pest surveys
- Stygofauna survey
- Groundwater monitoring
- Surface water monitoring

Ongoing monitoring will also contribute to a pre-impact baseline of the springs until groundwater drawdown impacts from the mine commence (at approximately 20 years after commencement). The approach to statistical analysis is summarised in **Table 9-3**.

Table 9-3 Statistical approach for Mellaluka springs triggers and monitoring

Indicator	Relevant Trigger	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
Spring wetland extent Spring water level	Statistically significant difference in spring wetland extent and water level from baseline and pre-impact conditions.	Surveys will be undertaken at Mellaluka, Stories and Lignum Springs seasonally (wet and dry season) for two years.	Perennial wetland extent assessed both on site and via remote sensing. Identify wetland zones (pool, saturated, damp, dry) and their boundary locations. Photographic reference	Univariate f and t-tests to statistically compare variance and mean extent between time of sample and baseline & pre-impact conditions.
Spring characteristics	Statistically significant difference in: • Spring diameter, height and perimeter • Flora species composition and abundances • Presence of spring endemic flora species	Surveys will describe both the terrestrial (i.e. non-wetland) and spring wetland vegetation, as well as define the target perennial wetland species.	Diameter, height and perimeter Full floristic species composition and abundances Population surveys for spring endemic flora species	Univariate f and t-tests to statistically compare variance and mean extent between time of sample and baseline & pre-impact conditions. MDS graphs to show relative spread of plots based on vegetation composition (cover and species richness). Multivariate PERMANOVA test on parameters to detect significant differences between sampling time and baseline & pre-impact. Follow up SIMPER tests to detect the main indicators driving the patterns in the data.
Wetland vegetation zone Wetland vegetation species composition and abundance	Statistically significant difference in wetland vegetation, zones composition and abundance from baseline & pre-impact conditions.	Surveys will be undertaken at Mellaluka, Stories and Lignum Springs seasonally (wet and dry season) for two years, then seasonally (wet and dry season) until baseline & pre-impact is established.	Wetland zone (pool, saturated, damp, dry) and their boundary locations. Wetland vegetation species composition Wetland vegetation Species abundances (1 m x 1 m subplots spaced 4 m apart, along the transect).	Descriptive comparison between wetland vegetation composition at time of sampling and baseline & pre-impact condition. Univariate f and t-tests to statistically compare variance and mean of wetland vegetation composition parameters between time of sample and baseline & pre-impact conditions. MDS graphs to show relative spread of plots based on vegetation composition (cover and species

Indicator	Relevant Trigger	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
				richness). Multivariate PERMANOVA test on parameters to detect significant differences between sampling time and baseline & pre-impact. Follow up SIMPER tests to detect the main indicators driving the patterns in the data.
Threatened and endemic species presence	Loss of a threatened species from any spring Statistically significant difference in threatened species condition from baseline & pre-impact conditions.	Surveys will be undertaken at Mellaluka, Stories and Lignum Springs. Pre-impact monitored seasonally (wet and dry season) for two years, then seasonally (wet and dry season) until baseline & pre-impact is established.	Any other flora identified during baseline & pre-impact surveys as endemic or threatened, and reliant on wetlands for survival.	Univariate f and t-tests to statistically compare variance and mean of vegetation extent, condition and richness between time of sample and baseline & pre-impact conditions. MDS graphs to show relative spread of plots based on vegetation composition (cover and species richness). Multivariate PERMANOVA test on parameters to detect significant differences between sampling time and baseline & pre-impact. Follow up SIMPER tests to detect the main indicators driving the patterns in the data.
Macroinvertebrate taxonomic richness and abundance Stygofauna presence Stygofauna endemicity	Statistically significant difference in macroinvertebrate and stygofauna taxonomic richness and abundance from baseline & pre-impact conditions	Sweeping an area of up to $5m^2$ with a macroinvertebrate net for 5 minutes and transferring samples into a sterile jar (with a preservative) for subsequent laboratory identification to morpho-family level. Stygofauna – a round of sampling will be undertaken to determine presence and identifying if endemicity exists.	Macroinvertebrate taxonomic richness and abundance Stygofauna presence Stygofauna endemicity	Macroinvertebrate assemblage structure will be compared with results obtained during EIS studies and other published studies of springs in Queensland. Multivariate PERMANOVA test on parameters to detect significant differences between sampling time and Baseline & pre-impact. Follow up SIMPER tests to detect the main indicators driving the patterns in the data.
Presence of weed species	Statistically significant increase in weed cover, pests	Weed and pest surveys undertaken annually.	Extent of weeds	Descriptive comparison of mean weed cover, pest abundance, and

Indicator	Relevant Trigger	Design (to be confirmed following pre-impact surveys)	Parameters	Statistical analysis
Extent of weed coverage Presence of feral animals Extent of feral animal disturbance (within areas controlled by Adani)	or pest activity above baseline. Identification of new weed or feral animal.		Identify areas of wetland habitat subject to damage from feral and domestic animals	area of pest damage at time of sampling to baseline conditions. Log the occurrence of new weed or feral animal compared to baseline.
Groundwater level Rate of drawdown	Groundwater level drawdown thresholds as outlined in the GMMP, Appendix B and Table E3 in the EA and Appendix B.	Monitoring will be completed at the bores listed in Section 9.8.3. Frequency as described in the 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 Section 9.8.3. Monitored quarterly as per GMMP.	Water quality parameters as outlined in GMMP.	Descriptive comparison with defined trigger levels.
Surface water quality	Surface water quality trigger levels in Table F3 and F5 of the EA are exceeded.	Surface water quality will be determined using a water quality meter and the collection of samples for laboratory analysis	As per Appendix A	Univariate comparison between surface water at time of sampling and trigger levels.

9.8.3 Groundwater Monitoring Program

Pre-impact monitoring of groundwater quality and levels at Mellaluka Spring will be undertaken every two months for the period up until commencement of relevant mining activities.

Ongoing monitoring of wetland condition and groundwater levels at nearby bores will be undertaken during mine operations. Monitoring will be a fundamental component of the management approach, with a dual objective of informing an adaptive management approach to remediating the Mellaluka Spring wetland and to contribute to the understanding and protection of the ecological values of springs in the Galilee Basin (GHD 2014).

The key monitoring bores are:

- Tertiary
  - C180122SP
  - C9180121SPR
  - C14031SP
- Joe Joe
  - C180119SP
  - C180120SP
  - C180123SP
  - C9180124SPR
  - C9180125SPR
  - C14015SP
  - C14017SP

The approach to statistical analysis is summarised in **Table 9-3**.

9.9 Trigger levels

Trigger levels (described in **Section 5.3**) will be reviewed at the completion of pre-impact surveys, based on an improved understanding of natural variation in the wetland attributes and the aquifer water levels. Low-risk trigger levels for biological and ecological indicators are based on a statistically significant deviation from the baseline/pre-impact for the following indicators:

- Wetland area (baseline/pre-impact conditions will be partly informed by desktop studies using historic satellite imagery and associated calculations of wetland area)
- Wetland pool depth (measured from a specific site in each pool for consistency)
- 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)
- Native wetland vegetation cover

If a trigger is exceeded, an investigation will be conducted to determine whether the detected result is caused by mining activities. The investigation should 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)
- Developing a detailed model of relevant environmental variables
- Expert opinion on the potential for environmental harm

The relevant Groundwater drawdown and groundwater quality triggers for aquifers associated with this GDE are described in the GMMP and are also presented in **Appendix B**.

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

The threats to the Mellaluka Springs-complex relevant to the Project and potential project impacts and actions minimising impacts to the Mellaluka Springs-complex are summarised in **Table 9-4**. The table addresses 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 Mellaluka Springs-complex. **Table 9-4** and **Table 9-3** (Statistical approach for Mellaluka Springs-complex 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 9-4 Management objectives, performance criteria, adaptive management triggers and corrective actions for Mellaluka Springs-complex

#	Potential indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Ecological triggers for adaptive management and corrective actions	Corrective actions
1	Groundwater drawdown from mine dewatering	Minimise the impact of aquifer drawdown caused by mining activities on the Mellaluka Springs-complex	No greater impact to Mellaluka Springs-complex due to aquifer drawdown caused by mining activities other than that approved.	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 information from the GAB Springs Research Plan into measures for managing and/or remediating the Mellaluka Springs-complex.	**Pre-impact and impact monitoring:** Groundwater Management and Monitoring Program Spring Monitoring Wetland vegetation monitoring Aquatic Invertebrate Survey Stygofauna Survey	Groundwater quality Groundwater level Spring wetland extent Wetland water level Wetland vegetation zone Wetland vegetation species composition and abundance Threatened and endemic flora presence Macroinvertebrate taxonomic richness and abundance Stygofauna presence Stygofauna endemicity	• 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. • Groundwater drawdown rates are exceeded • Statistically significant change in the following indicators compared to baseline / pre-impact conditions: ○ Wetland water level ○ Wetland vegetation zone ○ wetland vegetation species composition and abundance ○ Spring wetland extent ○ Threatened and endemic flora presence ○ Macroinvertebrate taxonomic richness and abundance Stygofauna presence • Stygofauna endemicity	The appropriate corrective actions will be implemented and may include: • In the event that groundwater quality triggers are exceeded, the investigation, response and corrective actions process under the GMMP, section 4.7.2 will be implemented. These actions include: ○ Assess the water balance / budgets and evaluate losses ○ Groundwater level (depth-to-water) evaluation to determine mounding and possible leaks / sources of artificial recharge ○ Implement mitigation if losses are identified , which could include: ▪ Seepage capture schemes, suitable to prevent possible plume migration offsite ▪ Pump and treat schemes to manage possible contaminant plumes ▪ Augmentation of the groundwater monitoring network to identify and monitor plume(s) • Repeating the surveys within 2 months to validate / test findings • Groundwater impact report to be developed within 2 months to inform on background/seasonal/mining related impacts • Increasing ongoing frequency of surveys and review of indicators over the following 12 months • Identifying and implement adaptive management measures and / or alternative rehabilitation strategies in consultation with the Mellaluka landholder • Reviewing and update the Wetland Remediation and Management Plan if necessary • Securing ecological offsets within specified approval timeframes if increased monitoring and groundwater model confirms likely complete loss of ecological function at each spring location.

#	Potential indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Ecological triggers for adaptive management and corrective actions	Corrective actions
		Minimise the impact of aquifer drawdown caused by mining activities on the Mellaluka Springs-complex	No impact to Mellaluka Springs-complex due to degradation of groundwater quality caused by mining activities other than that approved.	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 information from the GAB Springs Research Plan into measures for managing and/or remediating the Mellaluka Springs-complex. Prepare a Wetland Remediation and Management Plan in consultation with the Mellaluka landholder.	**Pre-impact and impact monitoring:** Groundwater Management and Monitoring Program Spring Monitoring Wetland vegetation monitoring Aquatic Invertebrate Survey Stygofauna Survey	Groundwater quality Spring wetland extent Wetland water level Wetland vegetation zone wetland vegetation species composition and abundance Macroinvertebrate taxonomic richness and abundance Threatened and Endemic Flora presence Stygofauna presence Stygofauna endemicity	• Groundwater quality trigger levels as outlined in the GMMP and Table E2 in the EA are exceeded. • Statistically significant change in the following indicators compared to baseline / pre-impact conditions: • Wetland water level • Wetland vegetation zone • wetland vegetation species composition and abundance • Spring wetland extent • Threatened and endemic flora presence • Macroinvertebrate taxonomic richness and abundance • Stygofauna presence • Stygofauna endemicity	The appropriate corrective actions will be implemented and may include: • In the event that groundwater quality triggers are exceeded, the investigation, response and corrective actions process under the GMMP will be implemented • Repeating the surveys within 2 months to validate / test findings • Groundwater impact report to be developed within 2 months to inform on background/seasonal/mining related impacts • Increasing ongoing frequency of relevant surveys and review of indicators over the following 12 months. • Identifying and implementing adaptive management measures and / or alternative rehabilitation strategies in consultation with the Mellaluka landholder. • Reviewing and updating the Wetland Remediation and Management Plan • Securing ecological offsets within specified approval timeframes if increased monitoring and groundwater model confirms likely complete loss of ecological function at each spring location.
		Minimise alterations to surface water / groundwater connectivity from mining activities	No impact to surface water at Mellaluka Springs-complex due to aquifer drawdown caused by direct or indirect mining activities than that approved.	There are no predicted surface water degradation impacts likely to occur at the Mellaluka Springs-complex. Activities carried out associated with monitoring under this plan must be undertaken to prevent surface water quality degradation. Standard mine operating procedures will include dust control of project areas in accordance with procedures under the Environmental Management Plan	**Pre-impact and impact monitoring:** Groundwater Management and Monitoring Program Surface water quality	Groundwater level and quality Surface water level and quality	• 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.**	The appropriate corrective actions will be implemented and may include: • Installing electric submersible pumps (as per relevant industry standards) for this purpose in response to drawdown. This will ensure the continuation of water to the Mellaluka Spring wetlands (and homestead) from an alternative source, providing a continuation of water for ecological services and domestic and agricultural purposes. • Reviewing groundwater trigger drawdown thresholds in relation to relevant ecological trigger exceedance and appropriate actions in accordance with GMMP. • Securing ecological offsets if pre-impact monitoring and groundwater model confirms likely complete loss of ecological function at each spring location
2	Subsidence from underground mining (not predicted to occur within Mellaluka Springs-complex)	Minimise habitat impacts related to subsidence	No impacts, such as ponding and cracking in subsidence areas (not predicted for any GDE)	Unlikely to occur Implement the project Subsidence Management Plan as per the EA. Engagement with landholder at the Mellaluka property regarding operational practices.	**Pre-impact and impact monitoring:** Subsidence Management Plan	Early warning signs of subsidence, such as ponding, cracking, tilt, strain and displacement	Measurable evidence of tilt in the vicinity of the Mellaluka Springs-complex attributable to Subsidence.	The appropriate corrective actions will be implemented and may include: • Repeating the relevant surveys within 2 months to validate / test findings • Groundwater impact report to be developed within 2 months to inform on background/seasonal/mining related impacts • Reviewing subsidence related infrastructure and drainage within 2 months to identify causal factors and recommend changes to prevent ongoing impacts.

#	Potential indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Ecological triggers for adaptive management and corrective actions	Corrective actions
3	Changes to hydrology	Protection of environmental values within waterways of the receiving environment. Maintain baseline and pre-impact surface water quality Minimise siltation of water resources	No degradation of permanent water sources by effluent / contaminants / siltation as a result of mine operations or activities.	There are no predicted surface water degradation impacts likely to occur at the Mellaluka Springs-complex. Activities carried out associated with monitoring under this plan must be undertaken to prevent surface water quality degradation. Standard mine operating procedures will include dust control of project areas in accordance with procedures under the Environmental Management Plan No unapproved clearing associated with activities at the Mellaluka Springs-complex Any sites used for chemical and fuel storage will be located a safe distance away from Mellaluka Springs-complex, with bunding or other raised barrier, resistant to normal flood events, between chemicals and habitat. Engagement with landholder at the Mellaluka property regarding operational practices.	**Pre-impact and impact monitoring:** Groundwater Monitoring and Management Plan Surface water monitoring Surface water quality monitoring	Surface water quality Rate of drawdown	Physical evidence of contamination to Mellaluka Springs-complex. • 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.	The appropriate corrective actions will be implemented and may include: • More frequent chemistry testing to confirm water quality against relevant standards, in the event that visual inspection of dust impacts fails • Engaging with landholder to understand potential impacts from agricultural activities • Reviewing relevant meteorological data • Reviewing adherence to control procedures to ensure compliance • Taking remedial action where compliance has not been adhered to • Communicating with personnel involved and across all site team members (for example, via toolbox meetings). • Reporting to DES as per statutory and project requirements where incidents trigger reporting thresholds
4	Weeds and pests through habitat degradation	Reduce weed extent and competition	No introduction of pest plants, invasive understorey species in Mellaluka Springs-complex as a result of Project related activities.	Weed hygiene controls, including the use of weed wash down stations, will be implemented in accordance with the PMP to prevent the introduction and spread of declared pest plants and other invasive weeds. Weed free areas within the Mellaluka Springs-complex will be identified and mapped with strict weed control requirements for entering weed free areas. Adaptive management of weed controls to minimise threats to Mellaluka Springs-complex. Engagement with landholder at the Mellaluka property regarding operational practices.	**Pre-impact and impact monitoring:** Threatened and endemic flora populations Weed and Pest Surveys	Threatened and endemic species presence Presence of weed species Extent of weed coverage	• Statistically significant change in threatened and endemic species presence indicator compared to baseline / pre-impact conditions • Results of weed monitoring indicate a degradation of in Mellaluka Springs-complex, due to a proliferation of weeds. • • A significant increase in the abundance of weeds, or pests or identification of new infestations • Introduction or establishment of declared pest plants, and invasive species into previously unaffected areas	The appropriate corrective actions will be implemented and may include: • Eliminating potential sources or reasons that are have attributed to an increase in species richness and/or relative abundance of weeds • Engaging with landholder to raise issues within 5 days of investigation. • Engaging with landholder to understand potential impacts from agricultural activities • Amending weed hygiene restrictions • 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* • Engaging with the landholder to protect and restore in Mellaluka Springs-complex values through implementation of site-specific measures such as weed control, fire management or grazing

#	Potential indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Ecological triggers for adaptive management and corrective actions	Corrective actions
		Achieve reduced impacts to the Mellaluka Springs-complex from Feral animal impacts	No significant increase in spring disturbance due to feral animals as a result of Project related activities.	Adaptive management of pest controls in the Project area to minimise threats to Mellaluka Springs-complex (which lies on adjacent land and requires landholder action). 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. Engagement with landholder at the Mellaluka property regarding operational practices.	**Pre-impact and impact monitoring:** Threatened and endemic flora populations Weed and Pest Surveys	Threatened and endemic species presence Presence of feral animals Extent of feral animal disturbance	• Statistically significant change in threatened and endemic species presence indicator compared to baseline / pre-impact conditions • Results of pest surveys indicate a degradation of Mellaluka Springs-complex, due to degradation attributed to feral animals • New feral animal observed	The appropriate corrective actions will be implemented and may include: • Engaging with landholder to raise issues within 5 days of investigation. • Engaging with landholder to understand potential impacts from agricultural activities • Increasing the frequency and intensity of pest animal control, working in partnership with the landholder • 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 pest animal control methods in targeted pest animal control programs • Increasing feral herbivore management efforts, in conjunction with neighbouring land owners • Increasing invasive predator management efforts, in conjunction with neighbouring land owners.
5	Vegetation clearing / habitat loss	Prevent Mellaluka Springs-complex habitat loss arising from Project activities (other than indirect drawdown as described above)	No direct clearing of vegetation at Mellaluka Springs-complex unless otherwise approved.	Prior to the commencement of any related site works / monitoring / bore hole drilling 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 clearing. Engagement with landholder at the Mellaluka property regarding operational practices.	**Pre-impact and impact monitoring:** Spring Monitoring Wetland vegetation monitoring Threatened and endemic flora population Stygofauna survey Aquatic invertebrate survey	Spring wetland extent Spring characteristics Wetland vegetation zone Wetland vegetation species composition and abundance Threatened and Endemic Flora presence Stygofauna presence Stygofauna endemicity Macroinvertebrate taxonomic richness and abundance	Statistically significant change in indicators compared to baseline / pre-impact conditions	The appropriate corrective actions will be implemented and may include engaging with landholder to understand potential impacts from agricultural activities. •
6	Earthworks	Minimise the risk of light vehicle and machinery strike during earthworks and operations	No fauna strikes at Mellaluka Springs-complex Group due to project related vehicle movements. No project earthworks at Mellaluka Springs-complex associated with project related activities.	Vehicles and plant will drive on pre-determined roads only, and adhere to all speed limits, which will be clearly communicated. There are no predicted or required earthworks impacts likely to occur at Mellaluka Springs-complex, as Project activities are limited to ongoing monitoring activities.	Regular monitoring in accordance with the Environmental Management Plan and System.	Observation of fauna strike	Vehicles observed /reported driving outside designated areas Fauna strike during monitoring or related activities Degradation or disturbance of Mellaluka Springs-complex likely to have been caused by earthworks activities	The appropriate corrective actions will be implemented and may include: • Engaging with landholder to understand potential impacts from agricultural activities • Restricting access / realigning access routes • Reviewing and re designing to avoid reoccurrence and address actual cause • Communicating with personnel involved and across all site team members (for example, via toolbox meetings).

#	Potential indirect project impact	Management objective	Performance Criteria	Management Actions	Monitoring	Monitoring Indicators	Ecological triggers for adaptive management and corrective actions	Corrective actions
7	Noise and vibration	Minimise habitat modification	No disturbance of Mellaluka Springs-complex from noise and vibration, associated with project related activities.	There are no predicted noise and vibration impacts likely to occur at the Mellaluka Springs-complex Standard mine operating procedures will include noise and vibration management in accordance with procedures under the Environmental Management Plan.	Ongoing engagement with the landholder in accordance with the Environmental Management Plan and System.	Event monitoring for: dB(A) peak particle velocity (PPV)	Degradation of Mellaluka Springs-complex likely to have been caused by noise or vibration.	The appropriate corrective actions will be implemented and may include: • Engaging with landholder to understand potential impacts from agricultural activities • Reviewing project noise and vibration monitoring program to determine if any exceedance's recorded or noted at the Mellaluka homestead • 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).
8	Emissions (including dust)	Minimise emissions (dusts)	Emissions attributable to the Project (i.e. dust, coal and heavy metals) do not degrade water source quality in Mellaluka Springs-complex.	There are no predicted emissions / dust impacts likely to occur at the Mellaluka Springs-complex Standard mine operating procedures will include dust control of project areas in accordance with procedures under the Environmental Management Plan.	**Pre-impact and impact monitoring:** Surface water monitoring	Surface water quality	Degradation of Mellaluka Springs-complex likely to have been caused by dust or other emissions.	The appropriate corrective actions will be implemented and may include: • Engaging with landholder to understand potential impacts from agricultural activities • Reviewing of relevant meteorological data • Reviewing of project air quality monitoring program to determine if any exceedance's recorded or noted at the Mellaluka homestead • Where monitoring shows a reduction in habitat condition due to dust, mitigating source of dust • Communicating with personnel involved and across all site team members (for example, via toolbox meetings).
9	Light spill and other visual impacts	Minimise light spill	No light disturbance at Mellaluka Springs-complex.	There are no activities likely to cause light spill at the Mellaluka Springs-complex.	**Pre-impact and impact monitoring:** Spring Monitoring Wetland vegetation monitoring Threatened and endemic flora population Stygofauna survey Aquatic invertebrate survey	Spring wetland extent Spring characteristics Wetland vegetation zone Wetland vegetation species composition and abundance Threatened and Endemic Flora presence Stygofauna presence Stygofauna endemicity Macroinvertebrate taxonomic richness and abundance	Direct light spill onto Mellaluka Springs-complex	The appropriate corrective actions will be implemented and may include: • Engaging with landholder to understand potential impacts from agricultural activities • Reviewing of relevant meteorological data • Reviewing of monitoring and survey activities to determine any association • Reviewing and re designing light controlling devices, or adjust location of light, to reduce light spill and lighting levels below trigger levels • Communicating with personnel involved and across all site team members (for example, via toolbox meetings).

10 Plan updates, reporting and compliance

10.1 Plan updates

This management plan will be reviewed within two years of commencement of mining and from there on every five years. The plan will be amended as required, and in response to new information. This will include updates to the conceptual models of GDEs and trigger levels, changes in the status of listed species or the identification of listed species in the Project area that had not been previously recorded. The groundwater model will be reviewed within two years, as described in the GMMP, with the GDEMP updated accordingly.

In the event that new species or Threatened Ecological Communities are found, then DoEE and/or DES will be notified within five business days and Adani will outline how the conditions of this approval will still be met within 20 business days. Revised management and monitoring arrangements will be identified as part of the adaptive management approach. Updates to the management plan will be made in consultation with DoEE and DES, in accordance with Condition 33 of the EPBC Act approval and Section 143A of the EPBC Act.

If impact monitoring identifies an exceedance of trigger levels, Adani will notify the Department/s in writing within five business days. Within 28 business days, Adani will submit a report detailing the findings of investigations including the known or likely cause and potential magnitude of impacts, corrective actions, recommended mitigation and management measures. An updated GDEMP will then be prepared and submitted to the DoEE and DES for approval.

In all other circumstances, Adani will revise the management plan following the completion of pre-impact monitoring, and resubmit it to DoEE and DES for the Minister’s written approval within 3 months of completion. Once approved, the revised management plan will be implemented. A summary of the timing of key project elements is provided in **Appendix C**.

10.2 Pre-impact studies, reporting and updates

Pre-impact studies will be undertaken for the Doongmabulla Springs-complex, Waxy Cabbage Palm, Carmichael River and Mellaluka Springs-complex GDEs (**Section 5.3**). 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.

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. Trigger levels for groundwater drawdown and ecological impacts (discussed in **Sections 6-9**) will be reviewed, and if appropriate, refined. Adani will verify that pre-impact data are not influenced by mining activities. A pre-impact report containing proposed new recommended trigger levels (to be applied to the operational monitoring of each GDE) will be compiled and submitted for DoEE and DES approval prior to implementation.

This GDEMP will be updated upon approval of the revised trigger levels, which will replace the triggers (where appropriate). 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.

10.3 Annual and compliance reporting

Initially, an annual report on the findings of pre-impact monitoring will be prepared. This will include establishing a database for existing baseline and new pre-impact data. The report will identify any constraints for ongoing monitoring, and identify any changes required to the field sampling plan (on the basis of results from the first year of monitoring). Any changes to the monitoring program will be submitted to DoEE and DES for approval.

In accordance with Condition 31 of the EPBC Act approval, a report will be published on Adani's website within three months of every 12 month anniversary of the commencement of the project. The report will address compliance with each of the conditions of approval, including implementation of management plans (including this GDEMP). Evidence of the date of publication and non-compliance with any of the conditions of approval will be provided to DoEE at this time.

In accordance with Condition I14 of the EA, an annual report of the findings of this GDEMP, including all monitoring results and interpretations as well as a summary of the activities implemented in the previous 12 months, will be prepared and made available on request to the administering authority. The report will include:

- An assessment of background reference groundwater levels
- The condition of each GDE compared with previous monitoring results
- An assessment of long-term trends in the results
- Information on whether any triggers have been exceeded
- The suitability of current groundwater trigger thresholds
- Detail on the effectiveness of avoidance, mitigation and management actions in curtailing adverse impacts on GDE ecosystems
- A description of any adaptive management initiatives implemented
- Details of monitoring undertaken and proposed revisions to existing triggers
- Any offsets required for residual impacts.

The condition assessment of each GDE will include a statistical comparison to baseline conditions to ensure seasonal variations are accounted for and identify any change from the baseline and any planned actions.

Monitoring results and reports will be kept for the life of the project in accordance with Condition 30 of the EPBC Act approval. Adani will conduct periodic audits to monitor compliance with management plan commitments, in accordance with the Adani quality system. Non-compliances with the plan will be reported to the relevant Department (DoEE and DES) within five business days. Adani will integrate the management plan commitments with other aspects of the mine construction and operations, to avoid actions being overlooked.

This GDEMP will be available to all employees, contractors and subcontractors and will be published on Adani's website. Adani will amend the GDEMP in response to regular reviews, monitoring results and changes in legislation, in consultation with regulatory authorities. Amendments to the GDEMP will be updated on Adani's website within 30 business days.

Adani will notify the managing agencies (DoEE and DES) of mining stage closure and commencement.

10.4 Reporting and monitoring of related management plans and programs

Adani is required to develop and implement a number of associated management plans and programs to address the requirements of approval conditions under both Commonwealth and Queensland legislation. Linkages between this GDEMP and these associated management plans and programs are summarised in **Section 1.3**. These plans and programs will be subject to ongoing monitoring, review, and as required update and approval.

Key linkages across research program outcomes, modelling updates and management plan review, update and reporting are summarised in **Table 10-1**.

Table 10-1: Reporting requirements of other management plans with linkages to this GDEMP

Management Plan	Description	Internal Review Frequency	External Review Frequency	Reporting Frequency	Linkage to GDEMP and triggers/corrective actions
Groundwater Management and Monitoring Plan (GMMP) EPBC Approval Condition 3 EA Approval Conditions E4 and E5	The GMMP identifies monitoring, management and mitigation with respect to approved impacts to groundwater resources. The GMMP includes details of groundwater monitoring network for monitoring GAB aquifers, GDEs (Springs, Carmichael River) during all phases of the project including baseline, operations, and post-closure.	The GMMP will be reviewed by an appropriately qualified person by July 2020 and then at regular five-year intervals, as per EA Condition E5 and EPBC Act approval condition 3e 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 years of the initial box cut excavation and then at least every five years afterwards. The review of the groundwater model will include expert review by a person/s of the Minister's / DES choosing.	EA Annual Compliance Report to be prepared by Third Party.	Annual – EPBC Compliance Reporting – Condition 31 Annual - EA Compliance Reporting – Condition A13 Every 5 years – after internal review process	The GMMP provides a framework for the management of groundwater impact, including defining groundwater trigger levels, and MNESMPs for other threatened species and ecological communities. The GMMP will facilitate the detection of any mining related impacts to groundwater (i.e., impacts from establishment and operation of the mine). Relevant triggers from the GMMP (those that are related to groundwater dependent ecosystems) have been included in this GDEMP each sub-plan. Should recommended trigger levels be refined as a result of pre-impact studies (see **Section 5.3**) this will require update of both this GDEMP (see **Section 10.1**) and the GMMP. Where outcomes of the groundwater model review to be conducted within 2 years of commencement of mining activities and every 5 years thereafter (such as triggers, criteria, predicted impacts), this plan will be reviewed and updated accordingly. Additionally, should trigger levels in the GMMP (which are informed by groundwater modelling) require update as part of the GMMP review process every five years, the requirement to update trigger levels in this GDEMP will be reviewed.

Management Plan	Description	Internal Review Frequency	External Review Frequency	Reporting Frequency	Linkage to GDEMP and triggers/corrective actions
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 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.	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 and the impacts of mining activities on water quality and flow.
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	Annually and as directed through the outcomes of discrete research packages. *Note: this plan requires separate approval and hence review frequency will be*		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

Management Plan	Description	Internal Review Frequency	External Review Frequency	Reporting Frequency	Linkage to GDEMP and triggers/corrective actions
	groundwater from the Great Artesian Basin, including the Doongmabulla Springs-complex, in the Galilee Basin.	*determined and approved through that mechanism.*			will inform research programs undertaken under the GAB. This GDEMP 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 GDEMP.
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 detected instigate investigation into the cause of potential environmental harm); 3). The interaction of the Rewan Research Plan (groundwater component) with the GAB Spring

Management Plan	Description	Internal Review Frequency	External Review Frequency	Reporting Frequency	Linkage to GDEMP and triggers/corrective actions
					Research Plan, offset, subsidence, and GDEMP; and 4). Links to the Geoscience Australia regional Galilee Basin numerical groundwater model
Biodiversity Offset Strategy (BOS); GAB Offset Strategy; Offset Area Management Plans (OAMP's) EPBC Approval Conditions 8 to 13 EA Approval Condition I1 to I5	The BOS describes required offsets for unavoidable residual impacts to MNES. The BOS details how the project's offset requirements will be fulfilled and to guide ongoing offset delivery. The BOS was approved in October 2016 In addition to the overarching BOS, OAMPs have been developed that guide the ongoing management and monitoring of MNES and MSES associated with offset delivery, and describes specific management actions for properties to be used as offsets under the BOS. T he GAB Offset Strategy addresses indirect impacts to GAB aquifers	The BOS will be reviewed and updated prior to the commencement of each offset delivery stage. Annual reports over the 5-year period of the GAB Offset program The OAMP will be reviewed after the first year of implementation, and thereafter every 3 years.	The updated and amended BOS will be provided to the Minister for approval prior to the commencement of each offset delivery stage	Annual – EPBC Compliance Reporting – Condition 31 Annual - EA Compliance Reporting – Condition A13 5 yearly BOS Compliance Report Annual OAMP Report, then 3 yearly	The BOS outlines offset requirements for MNES including relevant GDEs. As part of the review of the BOS, offset requirements will be reassessed, and additional offsets delivered, including in the event that groundwater fluctuations exceed the defined GDE groundwater drawdown trigger levels in the project's draft EA and the trigger exceedance is determined to be the result of mining activities and impacts on GDE cannot be feasibly mitigated. Additional offsets may be required under the BOS if impacts are greater than predicted in the EIS. The OAMP includes management of GDE offset areas. The OAMP will be updated to incorporate additional information obtained through research programs or plans (such as this GDEMP), as the results become available.

Management Plan	Description	Internal Review Frequency	External Review Frequency	Reporting Frequency	Linkage to GDEMP and triggers/corrective actions
	The OAMP for Moray Downs West acquits the project's offset liability for GDEs.				
MNES Species Management Plan EPBC Approval Conditions 5, 6 and 7	A Species Management Plan has been prepared and approved by DoEE (20 July 2016). The plan was developed to protect listed species of fauna, flora, ecological communities and the Outstanding Universal Value (OUV) of the Great Barrier Reef World Heritage Area (GBRWHA) from impacts associated with the mine (and offsite infrastructure) project.	The MNES Species Management Plans will be reviewed annually and updated as required. In all other circumstances, Adani will revise the MNES Species Management Plan following pre-clearance surveys and resubmit for DoEE ministerial approval within three months of the survey being completed.	Updates to the MNES Species Management Plan will be made in consultation with DoEE and DES and the Relevant Recovery Team as required. Independent Peer Review to revisions as per EA Condition I7	Annual – EPBC Compliance Reporting – Condition 31 Annual - EA Compliance Reporting – Condition A13 Adani will prepare an annual report on the implementation of the MNES Species Management Plans.	The MNES SMP ensures consistent monitoring, mitigation and management measures for common threats and impacts.

10.5 Qualifications

Persons implementing key tasks described in this GDEMP will have appropriate skills and qualifications. For GDE pre-impact surveys and monitoring, the lead ecologist will have >5 years of experience undertaking assessments of GDEs. Qualifications and experience requirements are summarised in **Table 10-2**. Field surveys will be led by ecologists or botanists with at least 5 years of experience on the Brigalow Belt and/or Desert Uplands Bioregions. A hydrogeologist with at least 5 years of experience will be involved in the analysis of data and reporting, to assist in the interpretation of ecological and hydrological data.

The Doongmabulla Springs-complex will be surveyed and monitored by suitably qualified ecologists / botanists with previous experience in springs and familiarity with their ecology, species and values. In particular the ecologists / botanists will be familiar with the threatened flora species associated with the springs. Macroinvertebrates will be sent to a laboratory for identification to morpho-family level.

Carmichael River surveys and monitoring will be undertaken by experienced terrestrial and aquatic ecologists (leader with >5 years of experience). CORVEG surveys will be led by ecologists / botanists with >5 years of experience in flora surveys in the the Brigalow Belt and/or Desert Uplands Bioregions.

Waxy Cabbage Palm surveys and monitoring will be undertaken by suitably qualified ecologists / botanists who are familiar with the species and experienced in undertaking systematic flora surveys.

Weed monitors will have weed monitoring experience and demonstrable identification skills for all potential terrestrial, wetland and riparian weeds in the Project area.

If the identification of a suspected threatened flora species or previously unrecorded species is not certain, a specimen will be collected and submitted to the Queensland Herbarium for confirmation of identification. If previously unrecorded species or suspected threatened fauna species are observed or collected, the Queensland Museum will be the first contact for identification confirmation (via photographs and / or specimens), followed by persons with demonstrable identifications skills for the suspected threatened species, as outlined in **Table 10-2**.

Persons undertaking ground and surface water monitoring will be trained or be able to demonstrate practical experience in the completion of water monitoring in accordance with relevant sampling manuals or standards.

Table 10-2: Qualification requirements for GDE monitoring and reporting

Component	Qualifications required	Experience required	Demonstrable specialist skills required
Ecological survey of: • Waxy Cabbage Palm • Carmichael River • Doongmabulla Springs-complex • Mellaluka Springs-complex	Ecologist / Botanist with tertiary degree in relevant field	Ecologist / Botanist with degree and >5 years' of experience in the Brigalow Belt and/or Desert Uplands Bioregions	Experience in the identification of: Waxy Cabbage Palm Threatened flora species associated with the Doongmabulla Springs-complex Weed identification Relevant threatened fauna species

Component	Qualifications required	Experience required	Demonstrable specialist skills required
Data analysis and reporting	Ecologist / Botanist with tertiary degree in relevant field Hydrogeologist with tertiary degree in relevant field	Ecologist / Botanist with degree and >5 years' of experience in the Brigalow Belt and/or Desert Uplands Bioregions Hydrologist with >5 years' experience	Interpretation and analysis of complex ecological data Interpretation of groundwater monitoring results in an ecological context

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Appendix A Receiving waters contaminant trigger levels and flow release regime

Refer to Table F3 and Table F5 of the Environmental Authority for further explanation.

Quality characteristic	Trigger level	Monitoring frequency
pH	6.5 - 9	Daily during the release. Table F5 of EA.
Electrical Conductivity (µS/cm)	270	
Turbidity (NTU)	660	
Sulphate (SO_4^{2-}) (mg/L)	250	
Sodium (mg/L)	180	
Aluminium (µg/L)	55	Commencement of release and thereafter weekly during release (first sample to be taken within 2 hours of commencement of release). Table F3 of EA.
Arsenic (µg/L)	13	
Cadmium (µg/L)	0.2	
Chromium (µg/L)	2	
Copper (µg/L)	4	
Iron (µg/L)	300	
Lead (µg/L)	4	
Mercury (µg/L)	0,2	
Nickel (µg/L)	11	
Zinc (µg/L)	30	
Boron (µg/L)	370	
Cobalt (µg/L)	90	
Manganese (µg/L)	1900	
Molybdenum (µg/L)	34	
Selenium (µg/L)	10	
Silver (µg/L)	1	
Uranium (µg/L)	1	
Vanadium (µg/L)	10	
Ammonia as N (µg/L)	900	
Nitrate as NO_3 (µg/L)	1100	
Total Nitrogen (µg/L)	590	
Total Phosphorus (µg/L)	200	
Petroleum hydrocarbons (C6-C9) (µg/L)	20	
Petroleum hydrocarbons (C10-C36) (µg/L)	100	
Fluoride (µg/L)	2000	
Sodium (µg/L)	180000	
Suspended Solids	106	
Sulphate (mg/L)	1000	

Refer to Table F4 of the Environmental Authority for further explanation.

Carmichael River Release Locations	Flow Regime	Receiving Water Flow Rate	Permitted Release Rate	Electrical conductivity release limit (µS/cm)
RP1 and RP2	Low Flow	<0.2 m^3/s for a period of 28 days after natural flow events that exceed 0.2 m^3/s	0.05 m^3/s	168
	Medium Flow	1-5 m^3/s	0.25 m^3/s	840
	Medium Flow	5-10 m^3/s	0.5 m^3/s	1,850
	High Flow	>10 m^3/s	0.5 m^3/s	3,500

Appendix B Groundwater drawdown and quality triggers

Early warning triggers

The aim of the Early Warning triggers is to provide early warning regarding the predicted induced flow from groundwater units associated with the Doongmabulla Springs-complex and the Carmichael River towards the dewatered / depressurised coal seams targeted during mining.

The Early warning triggers have been selected based on the possible change in groundwater levels beyond the recorded natural groundwater level fluctuations (Refer to Table 49 GMMP). The assessment of groundwater level data, compiled during mining operations, will allow for the evaluation of groundwater level trends.

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
Doongmabulla Springs - Clematis Sandstone							
HD02	0.03 m	90	0.46 m (44 months)	0.25 m (½NF + 90% of prediction)	0.26 m (Prediction plus ½NF)	0.26 m	Early warning triggers are suggested as 90% of the predicted drawdown and Impact thresholds are suggested as prediction 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 (½NF + 90% of prediction)	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.

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
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
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.
Doongmabulla Springs - 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 * - note this will also be used as an EWT for the Carmichael River	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.

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
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
Carmichael River – all relevant aquifers							
HD03B	0.004 m	64	1.26 m (47 months)	0.63 m (½NF + 75% of Prediction)	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)	0.92 m (½NF + 50% of prediction)	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)	0.59 m (½NF + 25% of prediction)	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)	0.45 m (½NF + 50% of prediction)	0.55 m (½NF + 75% of prediction)	0.655 m	Induced flow from Tertiary sediments adjacent to river. 220.00 mAHD average groundwater level

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
C025P1	1.87 m	59	0.51 m (58 months)	0.72 m (½NF + 25% of prediction)	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 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)	1.20 m (½NF + 50% of prediction)	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)	0.21 m (½NF + 75% of Prediction)	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
C14027SP	0.018 m	500	0.22 m (25 months)	0.12 m (½NF + 75% of Prediction)	0.13 m (Prediction plus ½NF)	0.13 m	

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
C14006SP	0.42 m	500	0.94 m (10 months)	0.68 m (½NF + 50% of prediction)	0.79 m (½NF + 75% of prediction)	0.89 m	comparison to the average groundwater level reference level over time). Induced flow from artesian Joe Joe Group unit adjacent to river 226.03 mAHD average groundwater level

Groundwater drawdown triggers

Table B-1 provides detail of groundwater drawdown triggers for those bores associated with each of the four GDEs (see Tables 45 and 46 of the GMMP)

Table B-1 Groundwater drawdown triggers

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[1])	Comment / Reference Level	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)
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	Alluvium	427559.00	7556120.00
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	Dunda Beds	433648.21	7554818.54

[1] The total change in groundwater level, relative to the average groundwater level (**Appendix E of GMMP**), 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)	Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[1])	Comment / Reference Level	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)
C029P1	0.33 m	50	1.01 m (65 months)	0.67 m (½NF + 50% of prediction)	0.8359 m	Induced flow from GAB unit, Dunda Beds, adjacent to river impacting on alluvium. 214.77 mAHD average groundwater level	Alluvium	437691.19	7555082.39
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	Tertiary	437687.63	7555080.91
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 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)	Alluvium	438015.54	7555845.80

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[1])	Comment / Reference Level	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)
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	Tertiary	438010.34	7555844.69
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).	Alluvium	443775.64	7559581.18
C14027SP	0.018 m	500	0.22 m (25 months)	0.13 m (Prediction plus ½NF)	0.13 m		Alluvium	444964.65	7558330.02
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	Early Permian	443446.61	7556785.07
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	Clematis	423796.76	7568090.93
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	Clematis	418210.8	7566775.83

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[1])	Comment / Reference Level	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)
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	Clematis	426130.96	7561454.81
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	Clematis	424896.07	7560596.18
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	Clematis	424895.49	7560591.10
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	Clematis	423822.04	7557008.25
HD03A	0.18 m	87	1.02 m (44 months)	0.69 m (Prediction plus ½NF)	0.69 m		Clematis	427562.00	7556132.00
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)	Clematis	429796.25	7550966.33

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[1])	Comment / Reference Level	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)
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	Dunda Beds	426812.52	7565961.84
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	Dunda Beds	433648.21	7554818.54
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	Dunda Beds	429801.74	7550968.73
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	Dunda Beds	435915.16	7547522.16
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	Rewan	421010.11	7573974.87
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	Rewan	436524.08	7549881.55
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	Rewan	432461.38	7557892.99
Doongmabulla to West of Mine Lease									

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[1])	Comment / Reference Level	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)
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	Clematis	423822.04	7557008.25
HD03A	0.18 m	87	1.02 m (44 months)	0.69 m (Prediction plus ½NF)	0.69 m		Clematis	427562.00	7556132.00
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	Clematis	424895.49	7560591.10
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	Dunda Beds	426812.52	7565961.84
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	Clematis	424896.07	7560596.18
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)	Clematis	429796.76	7550966.33
C14206V WP_1	36 m	84	-	32.4 m (90% of max drawdown predicted)	-	AB Seam. 224.00 mAHD	AB Seam	429783.15	7550956.80

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[1])	Comment / Reference Level	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)
C558VWP1	143.05 m	586	-	129 m (90% of max drawdown predicted)	-	D seam. 212.00 mAHD	D seam	430311.51	7566903.01
C968VWP_P2	206.2 m	12	-	186 m (90% of max drawdown predicted)	-	D seam. 355.00 mAHD	D seam	424873.59	7570989.17
C968VWP_P5	170.72 m	15	-	154 m (90% of max drawdown predicted)	-	AB seam. 192.80 mAHD	AB seam	424873.59	7570989.17
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	D seam	442363.39	7543815.03
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	AB Seam	441384.00	7542877.33
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.	Tertiary / Early Permian	447056.56	7531729.89

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[1])	Comment / Reference Level	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)
C180122SP	0.045 m	586	0.75 m (29 months)	0.42 m (Prediction plus ½NF)	0.42 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).	Tertiary / Early Permian	448579.21	7536348.70
C180119SP	0.045 m	586	0.49 m (22 months)	0.29 m (Prediction plus ½NF)	0.29 m		Early Permian	448587.45	7536355.38
C180123SP	0.007 m	586	0.67 m (28 months)	0.34 m (Prediction plus ½NF)	0.34 m		Early Permian	448077.54	7529357.50
C9180124SPR	0.045 m	586	0.55 m (24 months)	0.32 m (Prediction plus ½NF)	0.32 m		Early Permian	448600.00	7536357.00
C9180125SPR	0.02 m	586	1.07 m (25 months)	0.56 m (Prediction plus ½NF)	0.56 m		Early Permian	447039.74	7531738.83
Early Warning 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	Early Permian	444852.34	7541471.06
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	Tertiary	439410.87	7544903.28

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[1])	Comment / Reference Level	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)
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	Tertiary / Early Permian	445059.11	7548820.62
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	Early Permian	440350.8	7568518.85
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	Early Permian	445072.27	7548821
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	Early Permian	445301.98	7536138.69
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	AB seam	422017.38	7574974.58
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	Early Permian	440355.93	7568513.34

Bore ID	Deepest Predicted Drawdown	Time when Deepest Drawdown will occur (years)	Natural fluctuation (NF) (monitoring period)	Impact Threshold (criteria)	Total Change in Water Level (½NF + Model predictions[1])	Comment / Reference Level	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)
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	Early Permian	444760.74	7552697.83
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	Rewan	439392.91	7540908.81
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	Clematis / Rewan Group	430036.80	7543917.13
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	Moolayember	418230.28	7566782.35

Groundwater quality triggers

Proposed trigger levels have been assigned to each of the water quality parameters for formations. Proposed triggers 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 the tables below below and were derived for each of the groundwater units based on statistical evaluation of existing datasets, and following additional recommendations by the Queensland Department of Environment and Science.

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 project 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.

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 B-210-3 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

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)
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*
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	0.1[28]	0.1	0.1	0.1
T. Phosphorous	mg/L P	0.1	**0.3**	**0.1**	**0.1**

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)
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).
Bold - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC 2000 and ANZECC 2018 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 level 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 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 2000 guidelines and where <8 results above LORs were available.
** - pH trigger levels recommended by the Queensland Department of Environment and Science.
0.06 µg/L Hg adopted, which is the ANZECC 2000, 2018 guidelines 99% protection trigger levels for freshwater aquatic ecosystems.
Grey text denotes trigger levels refined by Queensland Department of Environment and Science
28 Nitrite adopted guideline values from ANZECC Volume 3 Table 9.4.32

Tertiary Sediments

As a result of the extensive assessment and quality assurance 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.

Table B-310-4 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	1.5	1.5	1.5
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**

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)
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*
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	0.1	0.1	0.1
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

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)
Total Dissolved Solids	mg/L	**5,600**	**8,660**	**2,300**

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 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 level 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 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 2000 guidelines and where <8 results above LORs were available.

** - pH trigger levels recommended by the Queensland Department of Environment and Science

0.06 µg/L Hg adopted, which is the ANZECC 2000, 2018 guidelines 99% protection trigger levels for freshwater aquatic ecosystems.

Grey text denotes trigger levels refined by Queensland Department of Environment and Science

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 B-23 Clematis Sandstone Proposed 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	1.5	1.5
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**

Parameter	Units	Bores HD03A and C14021SP Contaminant Trigger Levels (85th Percentiles)	All other Clematis Bores Contaminant Trigger Levels (85th Percentiles)
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*
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	0.1	0.1
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

Proposed trigger levels have been assigned to each of the water quality parameters for formations. Proposed triggers 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 the tables below below and were derived for each of the groundwater units based on statistical evaluation of existing datasets, and following additional recommendations by the Queensland Department of Environment and Science.

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 project 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.

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 B-210-3 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 SO4	**1,900**	**1,100**	450	**14**

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)
Alkalinity	mg/L CaCO3	**404**	**2,400**	**355**	**150**
Sulphide	mg/L S2	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*
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

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)
Nitrite	mg/L N	0.128	0.1	0.1	0.1
T. Phosphorous	mg/L P	0.1	**0.3**	**0.1**	**0.1**
Total Recoverable Hydrocarbons	ppb (C6 – C9)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C6 – C10)	Detect above LOR	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C10 – C40)	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).

Bold - 95% protection trigger levels for freshwater aquatic ecosystems from Table 3.4.1 in the ANZECC 2000 and ANZECC 2018 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 level 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 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 2000 guidelines and where <8 results above LORs were available.

** - pH trigger levels recommended by the Queensland Department of Environment and Science.

0.06 µg/L Hg adopted, which is the ANZECC 2000, 2018 guidelines 99% protection trigger levels for freshwater aquatic ecosystems.

Grey text denotes trigger levels refined by Queensland Department of Environment and Science

28 Nitrite adopted guideline values from ANZECC Volume 3 Table 9.4.32

Tertiary Sediments

As a result of the extensive assessment and quality assurance 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.

Table B-310-4 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 SO4	240	**430**	**98**
Alkalinity	mg/L CaCO3	**240**	**420**	**60**
Sulphide	mg/L S2	1.5	1.5	1.5
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**

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)
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*
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	0.1	0.1	0.1
T. Phosphorous	mg/L P	**0.03**	**0.19**	**0.09**
Total Recoverable Hydrocarbons	ppb (C6 – C9)	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C6 – C10)	Detect above LOR	Detect above LOR	Detect above LOR
Total Recoverable Hydrocarbons	ppb (C10 – C40)	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

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)
Total Dissolved Solids	mg/L	**5,600**	**8,660**	**2,300**

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 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 level 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 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 2000 guidelines and where <8 results above LORs were available.

** - pH trigger levels recommended by the Queensland Department of Environment and Science

0.06 µg/L Hg adopted, which is the ANZECC 2000, 2018 guidelines 99% protection trigger levels for freshwater aquatic ecosystems.

Grey text denotes trigger levels refined by Queensland Department of Environment and Science

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 B-510-5 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	1.5	1.5
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**

Parameter	Units	Bore C027P2 Contaminant Trigger Levels (85th Percentiles)	All other Dunda Beds Bores Contaminant Trigger Levels (85th Percentiles)
Manganese	µg/L Mn	**1,900** (220)	**1,900** (28.8)
Molybdenum	µg/L Mo	34*	34*
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	0.1	0.1
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**

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 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 level 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 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 2000 guidelines and where <8 results above LORs were available.

** - pH trigger levels recommended by the Queensland Department of Environment and Science.
0.06 µg/L Hg adopted, which is the ANZECC 2000, 2018 guidelines 99% protection trigger levels for freshwater aquatic ecosystems.

Grey text denotes trigger levels refined by Queensland Department of Environment and Science

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 B-510-6B-5** for bore C008P1 are considered to be interim trigger levels for the first two years of the GMMP in lieu of sufficient data.

Table B-510-6 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	480 (average[1])	**18.5**	**6**
Magnesium	mg/L Mg	410 (average)	**17**	**8**
Potassium	mg/L K	110 (average)	**7.6**	**8**
Sodium	mg/L Na	3,700 (average)	**755**	**130**
Chloride	mg/L Cl	7,600 (average)	**1,100**	**170**
Sulphate	mg/L SO_4	280	57	**50**
Alkalinity	mg/L $CaCO_3$	300 (average)	**171**	**140**

[1] Based on the average of five (5) values recorded for this bore

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)
Sulphide	mg/L S_2	1.5	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**
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)

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)
Nitrite	mg/L N	0.1	0.1	0.1
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	14,600 (average)	**2,465**	**490**

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.
- [1] Based on the average of five (5) values recorded for this bore

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 B-6B-6** 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 B-6B-6 below presents the trigger levels for the AB Seam.

Table B-6 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 $CaCO_3$	480 (average)	**480**
Sulphide	mg/L S_2	5 (average)	**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)

Parameter	Units	Bore C007P2 Contaminant Trigger Levels (85th Percentiles)	All other Bandanna Formation Bores Contaminant Trigger Levels (85th Percentiles)
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**
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	0.1	0.1
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**

Parameter	Units	Bore C007P2 Contaminant Trigger Levels (85th Percentiles)	All other Bandanna Formation Bores Contaminant Trigger Levels (85th Percentiles)
Electrical Conductivity	µS/cm	16,500 (average[2])	**3,000**
Total Dissolved Solids	mg/L	10,500 (average)	**1,800**

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 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 level 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 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 2000 guidelines and where <8 results above LORs were available.

** - pH trigger levels recommended by the Queensland Department of Environment and Science.

0.06 µg/L Hg adopted, which is the ANZECC 2000, 2018 guidelines 99% protection trigger levels for freshwater aquatic ecosystems.

[2] Average values, based on less than 8 readings, are to be used initially until additional data is compiled

Grey text denotes trigger levels refined by Queensland Department of Environment and Science

[2] Average values, based on less than 8 readings, are to be used initially until additional data is compiled

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** B-7**B-7** below.

Table B-7 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**	1.5	1.5	1.5	**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**

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)
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**
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	0.1	0.1	0.1	0.1	0.1
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

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)
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

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 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 level 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 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 2000 guidelines and where <8 results above LORs were available.

** - pH trigger levels recommended by the Queensland Department of Environment and Science.

0.06 µg/L Hg adopted, which is the ANZECC 2000, 2018 guidelines 99% protection trigger levels for freshwater aquatic ecosystems.

Grey text denotes trigger levels refined by Queensland Department of Environment and Science.

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 B-810-7** presents the trigger levels for the Joe Joe Group bores.

Table B-810-7 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	0.5 (LOR)	0.5	0.5	**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**

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)
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**
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	0.1	0.1	0.1	0.1
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**

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)
Total Dissolved Solids	mg/L	**32,000**	**13,000**	**5,100**	**1,600**

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 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 level 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.

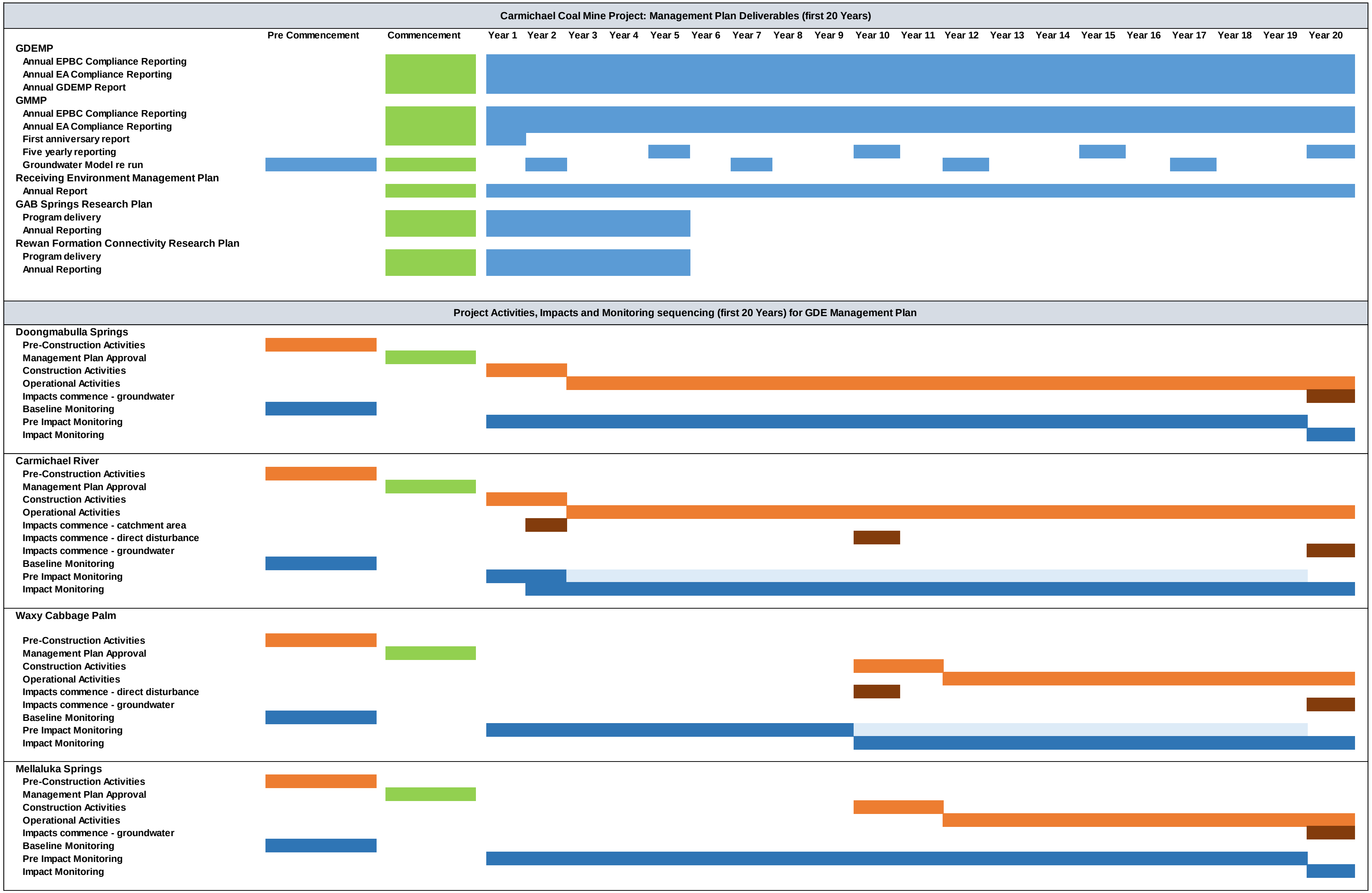
NV - no published guideline value; however, there were results above LOR (less than 8).

*- trigger level adopted from Section 8.3.7 of the ANZECC 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 2000 guidelines and where <8 results above LORs were available.

** - pH trigger levels recommended by the Queensland Department of Environment and Science

0.06 µg/L Hg adopted, which is the ANZECC 2000, 2018 guidelines 99% protection trigger levels for freshwater aquatic ecosystems.

Appendix C Chart showing timing of key project element


Carmichael Coal Mine Project: Management Plan Deliverables (first 20 Years)
Pre Commencement
Commencement
Year 1
Year 2
Year 3
Year 4
Year 5
Year 6
Year 7
Year 8
Year 9
Year 10
Year 11
Year 12
Year 13
Year 14
Year 15
Year 16
Year 17
Year 18
Year 19
Year 20
GDEMP
Annual EPBC Compliance Reporting
Annual EA Compliance Reporting
Annual GDEMP Report
GMMP
Annual EPBC Compliance Reporting
Annual EA Compliance Reporting
First anniversary report
Five yearly reporting
Groundwater Model re run
Receiving Environment Management Plan
Annual Report
GAB Springs Research Plan
Program delivery
Annual Reporting
Rewan Formation Connectivity Research Plan
Program delivery
Annual Reporting
Project Activities, Impacts and Monitoring sequencing (first 20 Years) for GDE Management Plan
Doongmabulla Springs
Pre-Construction Activities
Management Plan Approval
Construction Activities
Operational Activities
Impacts commence - groundwater
Baseline Monitoring
Pre Impact Monitoring
Impact Monitoring
Carmichael River
Pre-Construction Activities
Management Plan Approval
Construction Activities
Operational Activities
Impacts commence - catchment area
Impacts commence - direct disturbance
Impacts commence - groundwater
Baseline Monitoring
Pre Impact Monitoring
Impact Monitoring
Waxy Cabbage Palm
Pre-Construction Activities
Management Plan Approval
Construction Activities
Operational Activities
Impacts commence - direct disturbance
Impacts commence - groundwater
Baseline Monitoring
Pre Impact Monitoring
Impact Monitoring
Mellaluka Springs
Pre-Construction Activities
Management Plan Approval
Construction Activities
Operational Activities
Impacts commence - groundwater
Baseline Monitoring
Pre Impact Monitoring
Impact Monitoring

Appendix D Compliance matrix

Approval & condition number	Description of Condition or Commitment	How Addressed	Section of GDE Management Plan
EPBC Act Approval, condition 5	At least three months prior to commencement of mining operations, the approval holder must submit to the Minister for approval Matters of National Environmental Significance plan/s for the management of direct and indirect impacts of mining operations on MNES.	MNESMP for the Carmichael mine and off-site infrastructure, were lodged and approved on 20 July 2016. Linked to these overarching plans, two further specific plans relating to MNES have been prepared. A Black-throated Finch Management Plan was lodged on 11 May 2017, and this Groundwater Dependent Ecosystems Management Plan (GDEMP) was lodged on 7 November 2016. Commencement of mining operations, in accordance with the approval condition, has not yet occurred. This plan addresses the management of direct and indirect impacts of mining construction and operations on GDEs. Management of impacts from mining construction and operations are contained in Table 6-9 Carmichael River, Table 7-6 Waxy Cabbage Palm, Table 8-10 Doongmabulla Springs-complex and Table 9-4 Mellaluka Springs-complex. Direct impacts have largely been avoided through project design (e.g. buffer along the Carmichael River), however construction of a bridge over the Carmichael River will require clearing of some riparian habitat, including five Waxy Cabbage Palm individuals. Indirect impacts predominantly relate to the potential for groundwater drawdown.	Sections 6.4, 7.4, 8.5 and 9.6 Tables 6-9, 7-6, 8-10 and 9-4
	Note: If the MNESMP does not address any specific future activities (e.g. possible additional seismic surveys or specific mining stages) it should be updated in accordance with Condition 33.	If this management plan does not address any specific future activities (e.g. possible additional seismic surveys or specific mining stages) it will be updated in accordance with condition 33 of the EPBC Act approval.	
EPBC Act Approval, condition 6	The MNESMP must incorporate the results of the groundwater flow model re-run (Condition 23) where relevant, and be consistent with relevant recovery plans, threat abatement plans and approved conservation advices and must include:	Section 4.3.2 and Section 6.6.1 describe how the groundwater model re-run has been included. There are numerous 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. These are summarised in Section 1.4. These include the National Recovery Plan for Great Artesian Basin discharge spring wetlands (Fensham et al. 2010) and Commonwealth Approved Conservation Advice for Waxy Cabbage Palm (*Livistona lanuginosa*) (DEWHA, 2008). Threats identified in the National Recovery Plan for Great Artesian Basin discharge spring wetlands are addressed specifically in Section 8.5 (Doongmabulla Springs-complex). Aquifer drawdown is listed as a key threat in the Recovery plan for the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin. Other threats include stock and feral animal disturbance, changes to hydrology, vegetation clearance, and incursion by weeds. Potential project impacts are discussed in Section 8.5. Monitoring and research activities of the GDEMP closely align with recovery objectives described in Section 4 of the National Recovery Plan for Great Artesian Basin discharge spring wetlands (e.g. ensure flows do not decrease lower than natural variability, engage custodians in responsible management of springs). Further details of these measures are provided in Section 8.10 of the GDEMP. Threats identified in the Conservation Advice for Waxy Cabbage Palm are addressed specifically in Section 7.4. The main threats to the species are fire, trampling and grazing by stock, clearing for agricultural development, changes in water levels and introduction of invasive weeds. Potential project impacts are discussed in Section 7.4. Monitoring and research activities of the GDEMP closely align with recovery and threat abatement actions described in the Conservation Advice for Waxy Cabbage Palm (e.g. monitor known populations, stock management plans, fire management, control of invasive weeds). Further details of these measures are provided in Section 7.6 of the GDEMP. There are no recovery plans, threat abatement plans and approved conservation advices for the Carmichael River. The SPRAT profile for the GAB springs community lists two relevant abatement plans: *Threat abatement plan for the biological effects, including lethal toxic ingestion, caused by cane toads*, and, *Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs*. The GDEMP includes specific monitoring tasks (Section 8.7) to identify damage to springs caused by pigs, and to monitor the presence of pigs and cane toads, at the Doongmabulla Springs-complex. The GDEMP is therefore consistent with the threat abatement plans, which prioritise a science-based approach to the monitoring and control of these pest species.	Section 4.3.2 and Section 6.6.1 Sections 7.4 and 7.6, Sections 8.5 and 8.10 Section 8.7
	a) A description of environmental values for each of the Matters of National Environmental Significance addressed in the plan	A description of environmental values for the listed GDEs is provided in Section 6.1 Carmichael River, Section 7.1 Waxy Cabbage Palm, Section 8.2 Doongmabulla Springs-complex and Section 9.2 Mellaluka Springs-complex. The descriptions include the status under Commonwealth and State legislation, ecology and habitat values and distribution in the vicinity of the project area.	Sections 6.3, 7.3, 8.4 and 9.5
	b) Details of baseline and impact monitoring measures to be implemented for each of the Matters of National Environmental Significance including control and impact sites to be monitored throughout the life of the project. The monitoring must provide sufficient data to quantify likely impacts resulting from mining operations, including subsidence and changes in groundwater levels, to set habitat management goals (Conditions 6e) and 6f)).	A description of pre-impact and impact monitoring measures for GDEs is provided in Sections 6.6 and 6.7 Carmichael River, Section 7.6 Waxy Cabbage Palm, Section 8.7 Doongmabulla Springs-complex and Section 9.8 Mellaluka Springs-complex, of the GDEMP. The location of monitoring sites is provided on Figures 6-13, 7-8 and 8-17. The monitoring will quantify impacts resulting from mining activities and provide feedback on the effectiveness of mitigation measures. The monitoring will include consideration of the impacts from subsidence, and groundwater drawdown on GDE habitat values. Performance criteria and triggers for corrective actions are contained in Section 6.9 Carmichael River, Section 7.9 Waxy Cabbage Palm, Section 8.10 Doongmabulla Springs-complex and Section 9.9 Mellaluka Springs-complex. Initial ecological trigger levels are described in Section 5.3.	Sections 6.6 and 6.7, 7.6, 8.7 and 9.8 Figures 6-13, 7-8 and 8-17 Sections 6.9, 7.9, 8.10 and 9.9

Approval & condition number	Description of Condition or Commitment	How Addressed	Section of GDE Management Plan
	c) Details of potential impacts, including area of impact, on each of the Matters of National Environmental Significance from mining operations, including impacts from:	Details of potential impacts of the project on the GDEs are addressed in Sections 6 to 9 of the GDEMP. An area of impact (vegetation clearing), or estimate of level of groundwater drawdown is provided in relevant subsections of Sections 6 to 9, for potential impacts for which a quantitative estimate can be provided. For example, area of vegetation clearing for the Carmichael River in Section 6.4, area of Waxy Cabbage Palm habitat potentially impacted by groundwater drawdown in Section 7.4, estimate of levels of groundwater drawdown in mine operations at Doongmabulla Springs and Mellaluka Springs in Sections 8.5 and 9.6 respectively. Cross-references for specific impacts are provided below.	Sections 6.4, 7.4, 8.5 and 9.6
	(i) Vegetation clearing	Details of impacts from vegetation clearing are described in Section 6.4 Carmichael River and Section 7.4 (Waxy Cabbage Palm). No vegetation clearing for the Project will take place at either Doongmabulla Springs or Mellaluka Springs.	Section 6.4 and Section 7.4
	(ii) Subsidence from underground mining, including subsidence induced fracturing and any changes to groundwater or surface water flow	No subsidence is predicted to occur within Waxy Cabbage Palm habitat on the Carmichael River, as modelled in the EIS for the Project. No subsidence is predicted to occur in the vicinity of the Doongmabulla Springs or Mellaluka Springs-complexes (Section 8.5 and Section 9.6).	Section 6.4 Section 8.5 and Section 9.6
	(iii) Mine dewatering	Hydrogeology, groundwater resources and their relationship to GDEs are summarised in Section 4.3 (drawn from the Groundwater Management and Monitoring Plan (GMMP). Details of groundwater drawdown as a result of mine dewatering, specific to each GDE are described in Section 6.4 Carmichael River, Section 7.4 Waxy Cabbage Palm, Section 8.5 Doongmabulla Springs-complex and Section 9.6 Mellaluka Springs-complex.	Section 4.3 Sections 6.4, 7.4, 8.5 and 9.6
	(iv) Earthworks	A buffer of 500 m either side of the Carmichael River will be maintained in the Project. The only direct impact in this corridor will be construction of a haul road corridor across the Carmichael River, described in Section 6.4. 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. This is described in Section 7.4. The Project area is over more than 8km to the east of Doongmabulla Springs and 3km to the north of Mellaluka Springs, and there will be no direct incursion from Project vehicles or personnel beyond monitoring required as part of this plan. There will be no direct impact from earthworks on these Springs-complexes and potential impacts from light, dust and noise are described separately (Section 8.5 and Section 9.6).	Section 6.4 and Section 7.4 Section 8.5 and Section 9.6
	(v) Noise and vibration	A description of anticipated noise and vibration impacts on the values of the Carmichael River, is provided in Section 6.4. Noise and vibration is not a perceivable impact on the Waxy Cabbage Palm. No impacts from noise and vibration are predicted in the vicinity of the Doongmabulla Springs or Mellaluka Springs-complexes, due to the distance from the Project area (Section 8.5 and Section 9.6).	Section 6.4 Section 8.5 and Section 9.6
	(vi) Emissions (including dust)	Details of impacts from emissions (including dust), specific to each GDE are described in Section 6.4 Carmichael River, Section 7.4 Waxy Cabbage Palm, Section 8.5 Doongmabulla Springs-complex and Section 9.6 Mellaluka Springs-complex.	Sections 6.4, 7.4, 8.5 and 9.6
	(vii) Light spill and other visual impacts	A description of anticipated light spill impacts on the values of the Carmichael River, is provided in Section 6.4. Light spill and visual impacts are not a perceivable impact on the Waxy Cabbage Palm. No impacts from light spill or other visual impacts are predicted in the vicinity of the Doongmabulla Springs or Mellaluka Springs-complexes, due to the distance from the Project area (Section 8.5 and Section 9.6).	Section 6.4 Section 8.5 and Section 9.6
	(viii) Stream diversion and flood levees	Impacts on the Carmichael River from flood levees, and changes in hydrology, are described in Section 6.4. Changes to the hydrology of the Project Area, during the construction and operational project phases, were identified in the EIS as an indirect impact on Waxy Cabbage Palm habitat and the Carmichael River. Changes to hydrology indirectly impacting Waxy Cabbage Palm and the Carmichael River may include potential stream diversions, flood levees and contamination of surface waters (Section 7.4). These activities are likely to commence from construction, in Year 1. There is no predicted significant impact to Doongmabulla Springs associated with the changes to the flooding conditions associated with the construction of levees on either side of the Carmichael River (Section 8.5). Mellaluka Springs-complex does not contribute surface water to any nearby waterways, being located near the margin of extensive clay plains to the south west, sand plains to the north west, and a large alluvial plain to the east associated with the Belyando River, which is approximately 9 km away (Section 9.6).	Section 6.4 and Section 7.4 Section 8.5 and Section 9.6
	(ix) Weeds and pests	Details of impacts from weeds and pests, specific to each GDE are described in Section 6.4 Carmichael River, Section 7.4 Waxy Cabbage Palm, Section 8.5 Doongmabulla Springs-complex and Section 9.6 Mellaluka Springs-complex. Doongmabulla Springs and Mellaluka Springs are located on land not owned by Adani, and the only Project activities will be visits to conduct monitoring associated with this GDEMP.	Sections 6.4, 7.4, 8.5 and 9.6

Approval & condition number	Description of Condition or Commitment	How Addressed	Section of GDE Management Plan
	d) Measures that will be undertaken to mitigate and manage impacts on Matters of National Environmental Significance resulting from mining operations. These measures must include but not be limited to:	A description of measures that will be undertaken to mitigate and manage impacts on the GDEs resulting from mining operations is provided in relevant subsections in Sections 6-9. Specific cross-references are provided in sub-sections below.	Sections 6 to 9
	(i) The use of fauna spotters prior to and during all vegetation clearing activities to ensure impacts on Matters of National Environmental Significance are minimised	Fauna spotters will be used prior to and during all vegetation clearing activities to ensure impacts on Matters of National Environmental Significance are minimised. Vegetation clearing is proposed for 5.7 ha of Waxy Cabbage Palm habitat in the Carmichael River, required for the haul road corridor across the Carmichael River. No vegetation clearing is proposed for the Doongmabulla Springs-complex or Mellaluka Springs-complex.	Sections 6.9 and 7.9
	(ii) Measures to avoid impacts on Matters of National Environmental Significance and their habitat located in the Project Area, but outside areas to be cleared, constructed upon and / or undermined, including adjacent to cleared areas	Management actions to avoid impacts on MNES outside of the Project footprint, are contained in Section 6.9 Carmichael River, Section 7.9 Waxy Cabbage Palm, Section 8.10 Doongmabulla Springs-complex and Section 9.9 Mellaluka Springs-complex. These include indirect impacts such as weeds and pests, changes in hydrology, impacts from groundwater drawdown and emissions. Doongmabulla Springs and Mellaluka Springs are located on land not owned by Adani, and the only Project activities will be visits to conduct monitoring associated with this GDEMP.	Sections 6.9, 7.9, 8.10 and 9.9
	(iii) Measures to rehabilitate all areas of Matters of National Environmental Significance habitat	Rehabilitation activities associated with the Project at the Carmichael River and for the Waxy Cabbage Palm arediscussed in Table 6-10 and Table 7-6. Doongmabulla Springs and Mellaluka Springs are located on land not owned by Adani, and the only Project activities will be visits to conduct monitoring associated with this GDEMP. No rehabilitation is required in these GDEs.	Table 6-10 and Table 7-6.
	(iv) Habitat management measures including but not limited to management of subsidence and groundwater impacts of the project	Management actions to avoid impacts on MNES outside of the Project footprint, are contained in Section 6.9 Carmichael River, Section 7.9 Waxy Cabbage Palm, Section 8.10 Doongmabulla Springs-complex and Section 9.9 Mellaluka Springs-complex. These include indirect impacts such as weeds and pests, changes in hydrology, impacts from groundwater drawdown and emissions. No subsidence is predicted to occur in the vicinity of the Doongmabulla Springs or Mellaluka Springs-complexes (Section 8.5 and Section 9.6). Details of groundwater drawdown as a result of mine dewatering, specific to each GDE are described in Section 6.4 Carmichael River, Section 7.4 Waxy Cabbage Palm, Section 8.5 Doongmabulla Springs-complex and Section 9.6 Mellaluka Springs-complex.	Sections 6.9, 7.9, 8.10 and 9.9 Sections 6.4, 7.4, 8.5 and 9.6
	e) Goals for habitat management for each relevant Matters of National Environmental Significance	Management objectives, performance criteria and triggers for corrective actions are contained in Section 6.9 Carmichael River, Section 7.9 Waxy Cabbage Palm, Section 8.10 Doongmabulla Springs-complex and Section 9.9 Mellaluka Springs-complex. Initial ecological trigger levels are described in Section 5.3. Management actions to achieve these outcomes are also described in these sections.	Sections 6.9, 7.9, 8.10 and 9.9
	f) A table of specific criteria for assessing the success of management measures against goals, and triggers for implementing corrective measures if criteria are not met within specified timeframes. This table must include but not be limited to measures relating to subsidence and groundwater impacts, including early warning triggers for impacts on groundwater at the Doongmabulla Springs Complex and the Carmichael River. Goals and triggers must be based on the baseline condition of the relevant Matters of National Environmental Significance as determined through baseline monitoring (see Conditions 3b) and 6b)). Corrective measures must include provision of offsets where it is determined that corrective management measures have not achieved goals within specified timeframes (see Conditions 11m) and 11o)).	Initial trigger levels are described in Section 5.3, and a summary of corrective actions provided in Section 5.6. A summary of existing baseline monitoring is provided in Section 6.3 Carmichael River, Section 7.3 Waxy Cabbage Palm, Section 8.4 Doongmabulla Springs-complex and Section 9.5 Mellaluka Springs-complex. This baseline monitoring has informed management objectives, performance criteria and triggers for corrective actions, which are contained in Section 6.9 Carmichael River, Section 7.9 Waxy Cabbage Palm, Section 8.10 Doongmabulla Springs-complex and Section 9.9 Mellaluka Springs-complex. Offset requirements will be reassessed and additional offsets delivered, in the event that groundwater fluctuations exceed the defined GDE groundwater drawdown trigger levels in the project's draft EA and the trigger exceedance is determined to be the result of mining activities and impacts on GDE cannot be feasibly mitigated. This will be subject to approval from government agencies.	Section 5.3 and 5.6 Sections 6.3, 7.3, 8.4 and 9.5 Sections 6.9, 7.9, 8.10 and 9.9

Approval & condition number	Description of Condition or Commitment	How Addressed	Section of GDE Management Plan
	g) An ongoing monitoring program to determine the success of mitigation and management measures against the stated criteria in Condition 6f), including monitoring locations, parameters and timing. Monitoring for water resource Matters of National Environmental Significance must include hydrogeological, hydrological and ecological parameters.	A summary of the monitoring approach is provided in Section 5.5, with Investigations and Corrective Actions described in Section 5.6. Details of the ongoing monitoring program specific to each GDE is provided in Section 6.6 and 6.7 Carmichael River, Section 7.6 Waxy Cabbage Palm, Section 8.7 Doongmabulla Springs-complex and Section 9.8 Mellaluka Springs-complex. Monitoring is described in terms of pre-impact and impact monitoring, and includes hydrogeological, hydrological and ecological parameters. A summary of existing baseline monitoring is provided in Section 6.3 Carmichael River, Section 7.3 Waxy Cabbage Palm, Section 8.4 Doongmabulla Springs-complex and Section 9.5 Mellaluka Springs-complex.	Section 5.5 Sections 6.6 and 6.7, 7.6, 8.7 and 9.8 Sections 6.3, 7.3, 8.4 and 9.5
	h) Details of how compliance will be reported	Annual and compliance monitoring is described in Section 10.3 of the GDEMP, including periodic reporting and audits to monitor compliance with management plan requirements. Reporting and monitoring of related plans is described in Section 10.4.	Section 10.3 and 10.4
	i) Details of how the MNESMP will be updated to incorporate and address outcomes from research undertaken for Matters of National Environmental Significance under this and any state approvals, including updating of goals, criteria and triggers (as required under Conditions 3c), 3d) 6e) and 6f)).	The relationship between the GDEMP and other management plans and programs is described in Section 1.3, and the relationship with research programs and guidelines is set out in Section 1.4. 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. 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. An adaptive management approach will be taken and revisions to the GDEMP. Adaptive management is summarised in each GDE chapter (Section 6.8 Carmichael River, Section 7.8 Waxy Cabbage Palm, Section 8.6.1 Doongmabulla Springs-complex and Section 9.7.1 Mellaluka Springs-complex). Requirements for updating the GDEMP are summarised in Section 10.1, including scheduled updates and triggers for additional unscheduled updates. Annual and compliance reporting is set out in Section 10.3. Triggers will be updated where appropriate at the completion of pre-impact studies and monitoring and where relevant updates are made to the GMMP (Section 5.3). A revision of triggers will also occur where information from related management and research plans (as described in Section 10.4) informs this GDEMP.	Section 1.3 and 1.4, Section 5.3 Sections 6.8, 7.8, 8.6.1 and 9.7.1 Section 10.1 to 10.4
	j) Provisions to ensure that suitably qualified and experienced persons are responsible for undertaking monitoring, review and implementation of the MNESMP	Persons implementing key tasks described in this GDEMP will have appropriate skills and qualifications. Section 10.5 of the GDEMP outlines the qualifications of persons responsible for monitoring, reviewing and implementing the plan.	Section 10.5
	k) In the event that the future baseline research required by the Queensland Coordinator-General (Appendix 1, Section 3, Condition 1 of the Coordinator-General's Assessment Report) identifies that the Mellaluka Springs Complex provides high value habitat for the Black-throated finch, the approval holder must include management measures to address impacts resulting from drawdown at the Mellaluka Springs Complex in the MNESMP	Studies have determined that the Mellaluka Springs-complex does not provide BTF habitat. A letter from the Office of the Coordinator-General, dated 22 July 2016, has been received confirming the Commonwealth and Queensland government's acceptance of this finding.	Not applicable
	l) Details of how, where habitat for an EPBC Act listed threatened species or community not previously identified and reported to the Department is found in the Project Area, the approval holder will notify the Department in writing within five business days of finding this habitat, and within 20 business days of finding this habitat will outline in writing how the conditions of this approval will still be met (refer Condition 11j)).	This condition is addressed in the approved threatened species management plan for the Carmichael Mine. Section 5.1 of that plan says "In the event that new species or Threatened Ecological Communities are found, then DoEE and/or DES will be notified within five business days and Adani will outline how the conditions of this approval will still be met within 20 business days". This statement is also included in Section 10.1 of this GDEMP.	Sections 6 to 9
EPBC Act Approval, condition 7	Mining operations must not commence until the required MNESMP have been approved by the Minister in writing. The approved plan/s must be implemented. Note – Management plans such as the Black-throated Finch Management Plan and the Groundwater Dependent Ecosystems Management Plan may also be required under state approvals. Wherever possible a combined document should be prepared to address both state government and EPBC Act approval conditions. Note – Impacts of the action other than mining operations will be offset as required in accordance with Conditions 8 to 11, but will be otherwise managed in accordance with state approvals – this is of particular relevance when impacts may occur prior to approval of the MNESMP.	Mining operations will not commence until this plan has been approved. This plan addresses the combined requirements of the Commonwealth and Queensland governments in one document, as encouraged by the condition.	Section 3.2

Approval & condition number	Description of Condition or Commitment	How Addressed	Section of GDE Management Plan
EPBC Act Approval, condition 9	To compensate for authorised unavoidable impacts on Matters of National Environmental Significance, the approval holder must submit a Biodiversity Offset Strategy (BOS) and a GAB Offset Strategy to the Minister for approval at least three months prior to the commencement of mining operations.	A Biodiversity Offset Strategy (BOS) has been developed separately, and submitted for the Project. The strategy was approved in October 2016. This GDEMP is consistent with the BOS. The relationship between the GDEMP and the BOS is described in Section 1.3 and Section 10.4, as well as relationships to the Great Artesian Basin (GAB) Offset Strategy and Offset Area Management Plans (OAMPs).	Section 1.3 and Section 10.4.
EPBC Act Approval, condition 10	Offsets for authorised unavoidable impacts (defined in Table 1), and water resource impacts must be managed in accordance with the BOS and the GAB Offset Strategy.	As part of the review of the BOS, offset requirements will be reassessed and additional offsets delivered, including in the event that groundwater fluctuations exceed the defined GDE groundwater drawdown trigger levels in the project's draft EA and the trigger exceedance is determined to be the result of mining activities and impacts on GDE cannot be feasibly mitigated. The OAMP includes management of GDE offset areas. The OAMP will be updated to incorporate additional information obtained through research programs or plans (such as this GDEMP), as the results become available.	Section 1.3 and Section 10.4.
Environmental Authority, condition A5	Except where specified otherwise in another condition of this environmental authority, all monitoring records or reports required by this environmental authority must be kept for a period of not less than 5 years.	Monitoring results and reports will be kept for the life of the project in accordance with Condition 30 of the EPBC Act approval.	Section 10.3
Environmental Authority, condition H5	Self-sustaining vegetation and native ecosystem, as per Table H1 – Rehabilitation Acceptance Criteria (Appendix 2), must be consistent with the reference sites identified in Table H2 – Reference Sites and Figure H5: Reference Sites.	Rehabilitation activities associated with the Project at the Carmichael River and for Waxy Cabbage Palm are discussed in Table 6-10 and Table 7-6. Doongmabulla Springs and Mellaluka Springs are located on land not owned by Adani, and the only Project activities will be visits to conduct monitoring associated with this GDEMP. No rehabilitation is required in these GDEs. Any rehabilitation that takes place will be consistent with the Project Rehabilitation Plan.	Table 6-10 and Table 7-6.
Environmental Authority, condition I11	The proponent must develop and implement a Groundwater Dependent Ecosystems 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.	This GDEMP was lodged on 7 November 2016. Mining operations will not commence until this plan has been approved. This management plan in whole addresses the requirement of this condition. This plan addresses the management of direct and indirect impacts of mining construction and operations on GDEs. Management of impacts from mining construction and operations are contained in Table 6-9 Carmichael River, Table 7-6 Waxy Cabbage Palm, Table 8-10 Doongmabulla Springs-complex and Table 9-4 Mellaluka Springs-complex.	Section 3.2 Tables 6-9, 7-6, 8-10 and 9-4
Environmental Authority, condition I12	This GDEMP must be approved by the administering authority in writing and this GDEMP published on a website before the commencement of Project Stage 2.	This GDEMP was lodged on 7 November 2016. Mining operations will not commence until this plan has been approved. This management plan in whole addresses the requirement of this condition. This GDEMP will be available to all employees, contractors and subcontractor and will be published on Adani's website. Adani will amend the GDEMP as necessary in response to regular reviews, monitoring results and changes in legislation, in consultation with regulatory authorities. Any changes to the GDEMP will be updated on Adani's website within 30 business days.	Section 10.3
Environmental Authority, condition I13	For the purposes of conditions I11 and I12, 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.	This GDEMP as a whole addresses the requirement of this condition.	Sections 6 to 9
Environmental Authority, condition I14	A report of the findings of this GDEMP, including all monitoring results and interpretations, must be prepared annually and made available on request to the administering authority. The report must include:	Annual and compliance reporting is summarised in Section 10.3. An annual report of the findings of this GDEMP, including all monitoring results and interpretations as well as a summary of the activities implemented in the previous 12 months, will be prepared and made available on request to the administering authority.	Section 10.3
	a) An assessment of background reference groundwater levels (see condition E9).	A summary of the content of the report (including this sub-condition) is provided in Section 10.3.	Section 10.3
	b) The condition of each GDE compared with previous monitoring results.	A summary of the content of the report (including this sub-condition) is provided in Section 10.3.	Section 10.3
	c) The suitability of current groundwater trigger thresholds (as defined in condition E13).	A summary of the content of the report (including this sub-condition) is provided in Section 10.3.	Section 10.3
	d) Detail on the effectiveness of avoidance, mitigation and management actions in curtailing adverse impacts on GDE ecosystems.	A summary of the content of the report (including this sub-condition) is provided in Section 10.3.	Section 10.3
	e) A description of any adaptive management initiatives implemented.	A summary of the content of the report (including this sub-condition) is provided in Section 10.3.	Section 10.3
	f) Any offsets required for residual impacts.	A summary of the content of the report (including this sub-condition) is provided in Section 10.3.	Section 10.3

Approval & condition number	Description of Condition or Commitment	How Addressed	Section of GDE Management Plan
Environmental Authority, Appendix 1 Definitions	A GDEMP is a plan developed by a suitably qualified and experienced person that is consistent with any Bioregional Management Plan for the bioregion, the Water Resource (Great Artesian Basin) Plan and relevant threat abatement plans, conservation advice and project species management plans. The plan must include:	The GDEMP has been developed by a team of experienced scientists who are suitably qualified in the fields of terrestrial ecology, aquatic ecology and the management of groundwater dependent ecosystems. The authors have extensive tertiary qualifications relevant to the field, and decades of experience. Further details of the qualifications and experience of the authors, including CVs, can be provided to DoEE and DES upon request. Persons implementing key tasks described in this GDEMP will have appropriate skills and qualifications. Section 10.5 of the GDEMP outlines the qualifications of persons responsible for monitoring, reviewing and implementing the plan. There are numerous 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. These are summarised in Section 1.4.	Plan as a whole
	1) A description and map of each GDE potentially or indirectly impacted by mining activities	A description of environmental values for the listed GDEs is provided in Section 6.1 Carmichael River, Section 7.1 Waxy Cabbage Palm, Section 8.2 Doongmabulla Springs-complex and Section 9.2 Mellaluka Springs-complex. Maps of each GDE are provided in these sections.	Sections 6.1, 7.1, 8.2 and 9.2
	2) Detailed baseline monitoring (using QuickBird imagery or similar) to be undertaken on the specific ecology of each GDE, groundwater level, groundwater and surface water quality, threatened species and ecosystem function	Pre-impact monitoring including photo monitoring and satellite imagery (e.g. QuickBird) will be carried out on each GDE (Section 6.6 Carmichael River, Section 7.6 Waxy Cabbage Palm, Section 8.7.1 Doongmabulla Springs-complex and Section 9.8.1 Mellaluka Springs-complex).	Sections 6.6, 7.1, 8.7.1 and 9.8.1
	3) Detailed baseline research to establish:	-	-
	a) the extent and ecological composition of each GDE, in accordance with the Wetland Monitoring Methodology for springs in the Great Artesian Basin (R Fensham, 2009) where applicable.	A description of environmental values for the listed GDEs, including existing baseline data, is provided in Section 6.1 Carmichael River, Section 7.1 Waxy Cabbage Palm, Section 8.2 Doongmabulla Springs-complex and Section 9.2 Mellaluka Springs-complex. Pre-impact surveys will supplement the existing baseline data and follow this methodology. This methodology is only applicable to the Doongmabulla and Mellaluka Springs-complexes.	Sections 6.1, 7.1, 8.2 and 9.2
	b) the source aquifer(s) for the groundwater supply to the GDE.	Details of the source aquifers are described in Section 8.3 Doongmabulla Springs-complex and Section 9.4 Mellaluka Springs-complex. Adani will further investigate the source aquifer for Mellaluka Springs-complex (Section 9.7), and will undertake additional studies that inform the conceptual model relating to the source aquifer of the Doongmabulla Springs-complex (Section 8.10).	Sections 8.3 and 9.4 Section 8.10 and Section 9.7
	c) the natural variation of the groundwater level/pressure.	The Groundwater Monitoring Program (undertaken separately to the GDEMP but informing the studies) is summarised in Sections 6.6 and 6.7 Carmichael River, Section 7.6 Waxy Cabbage Palm, Sections 8.3 and 8.7 Doongmabulla Springs-complex and Sections 9.4 and 9.6 Mellaluka Springs-complex. Triggers include thresholds related to groundwater, wetland area, vegetation composition, weed cover and water quality. Initial trigger levels (described in Section 5.3) will be reviewed at the completion of pre-impact surveys, based on an improved understanding of natural variation in the GDE attributes and the aquifer water levels.	Sections 6.6 and 6.7, 7.6, 8.3 and 8.7 and 9.4 and 9.6
	d) GDE ecosystem pressure response to groundwater level/pressure fluctuation.	The Groundwater Monitoring Program (undertaken separately to the GDEMP but informing the studies) is summarised in Sections 6.6 and 6.7 Carmichael River, Section 7.6 Waxy Cabbage Palm, Sections 8.3 and 8.7 Doongmabulla Springs-complex and Sections 9.4 and 9.6 Mellaluka Springs-complex. An adaptive management approach will be adopted to ensure impacts are within the approved limits, linking GDE values with the underpinning groundwater model and assessing interactions with groundwater, responses to changes and natural variations for GDEs in the Project area.	Sections 6.6 and 6.7, 7.6, 8.3 and 8.7 and 9.4 and 9.6
	4) A description of how the results of baseline research and annual monitoring are to be used to determine any changes in GDE ecology attributable to mining activities.	A summary of the monitoring approach is provided in Section 5.5, with Investigations and Corrective Actions described in Section 5.6. In each GDE subsection, the monitoring program specific to each GDE is described, including performance criteria and triggers for corrective actions (Section 6.7 Carmichael River, Section 7.6 Waxy Cabbage Palm, Section 8.7 Doongmabulla Springs-complex and Section 9.8 Mellaluka Springs-complex).	Sections 6.7, 7.7, 8.8 and 9.9
	5) 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.	Potential impacts (with summary tables indicating Project stages) are provided in Section 6.4 Carmichael River, Section 7.4 Waxy Cabbage Palm, Section 8.5 Doongmabulla Springs-complex and Section 9.6 Mellaluka Springs-complex. Direct and indirect project impacts outlined in the EIS (GHD 2012a; Adani 2012) Carmichael Coal Mine and Rail Project – Groundwater Dependent Ecosystems Management Plan (11 February 2014), as well as matters outlined in EPBC approval or Environmental Authority conditions have details for impacts and threats included in this plan.	Sections 6.4, 7.4, 8.5 and 9.6
	6) Mitigation measures to be undertaken to avoid, mitigate, offset and manage impacts to GDE environmental values resulting from each stage of the project.	A description of measures that will be undertaken to mitigate and manage impacts on the GDEs resulting from mining operations is provided in relevant subsections in Sections 6-9.	Sections 6-9

Approval & condition number	Description of Condition or Commitment	How Addressed	Section of GDE Management Plan
Adani Commitment, M4.23	Impacts to the waxy cabbage palm will be managed and mitigated through:	-	-
	a) The supplementary introduction of surface water to the channel near the upstream Mine Area boundary through controlled discharges.	Corrective actions (if changes in Waxy Cabbage Palm habitat occur from groundwater drawdown impacts) will be implemented, which will include possible supplementary introduction of surface water near the upstream mine area boundary through controlled discharges.	Section 7.9
	b) Intensive monitoring of riparian condition, base flows and groundwater levels.	Surface Water Monitoring at the Carmichael River will be carried out monthly, in accordance with the Receiving Environment Monitoring Program. Flow data will be monitored daily and reported monthly prior to construction, during operation and post operation (Section 7.6.1). Riparian 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 riparian community health survey will be carried out biannually (wet and dry season), for two years, and then the frequency will be reviewed (Section 7.6.1).	Section 7.6.1
	c) Removal of weeds and pest animals.	Weed and pest surveys will be undertaken yearly along the Carmichael River to identify the extent of weeds, especially Rubber Vine, identify areas of Waxy Cabbage Palm habitat subject to pig damage and identify areas for weed and pest management activities in accordance with the Pest Management Plan (Section 7.6). Doongmabulla Springs and Mellaluka Springs are located on land not owned by Adani, and the only Project activities will be visits to conduct monitoring associated with this GDEMP. Weed hygiene controls, including the use of weed wash down stations, will be implemented in accordance with the PMP to prevent the introduction and spread of declared pest plants and other invasive weeds.	Section 7.6
	d) Possible translocation of individual plants (if deemed viable), seed collection and planting programs.	Corrective actions (if changes in Waxy Cabbage Palm habitat occur from groundwater drawdown impacts) will be implemented, which will include possible translocation of plants and/or seed collection and planting programs.	Section 7.9
	e) Research and monitoring to understand distributional range, water dependency requirements and threatening process triggers.	Waxy Cabbage Palm condition surveys will be carried out in pre-impact monitoring. Additionally an Environmental Water Requirement Assessment will be undertaken which will review the requirements of the species, particularly relating to water use.	Section 7.6
Adani Commitment, M4.24	Flow and groundwater level monitoring, mapping and measurements of the perimeter of the main wetland areas and selected isolated mound springs to monitor changes to the springs.	Hydrological, hydrogeological and ecological monitoring of GDEs is provided in Sections 6-9.	Sections 6-9
Adani Commitment, M4.25	Ecological studies of aquatic invertebrates, blue devil, salt pipewort and stygofauna will be conducted in the springs with associated reporting of results.	Ecological studies of Doongmabulla Springs is provided in Section 8.7, and of Mellaluka Springs in Section 9.8. These sections address relevant environmental values stated in the commitment associated with these GDEs.	Section 8.7 and Section 9.8
Adani Commitment, M4.26	Pumping groundwater to the surface may act to offset the loss of some sections of the Mellaluka Spring wetland, and the proponent will install electric submersible pumps when drawdown commences for this purpose. Additional detail will be presented in the Draft GDE Management Plan.	Adani will prepare a Wetland Remediation and Management Plan in consultation with the Mellaluka landholder. This plan will include pumping groundwater to the surface to compensate for the loss of some sections of the Mellaluka Spring wetland. Adani will install electric submersible pumps for this purpose when drawdown commences. This will ensure the continuation of water to the Mellaluka Spring wetlands (and homestead).	Section 9.9
Adani Commitment, M4.27	Adani will provide a Draft Groundwater Dependant Ecosystem (GDE) Management Plan for approval prior to the commencement of construction. This plan will address impacts to the following GDE"s: • Doongmabulla Springs-complex • Mellaluka Springs-complex • Carmichael River, particularly the Waxy Cabbage Palm The Plan will include the following:	This GDEMP was lodged on 7 November 2016. This plan addresses the management of direct impacts of mining construction and operations on GDEs. Management of direct impacts from mining construction and operations are contained in Table 6-9 Carmichael River, Table 7-6 Waxy Cabbage Palm, Table 8-10 Doongmabulla Springs-complex and Table 9-4 Mellaluka Springs-complex. Direct impacts have largely been avoided through project design (e.g. buffer along the Carmichael River), however construction of a bridge over the Carmichael River will require clearing of some riparian habitat, including five Waxy Cabbage Palm individuals. This plan also addresses the management of indirect impacts of mining construction and operations on GDEs. Specifically management actions of indirect impacts are located in Table 6-9 Carmichael River, Table 7-6 Waxy Cabbage Palm, Table 8-10 Doongmabulla Springs-complex and Table 9-4 Mellaluka Springs-complex. Indirect impacts predominantly relate to the potential for groundwater drawdown.	Sections 6 to 9 (Tables 6-9, 7-6, 8-10 and 9-4)
	a) A management framework that aligns with the other project management plans.	The GDEMP is consistent with other management plans prepared for the Project. Linkages to other management plans, particularly the GMMP which informs this GDEMP, is provided in Section 1.3.	Section 1.3
	b) Clear statements regarding the intent, approval requirements, objectives and actions.	Management objectives, performance criteria, management measures and triggers for corrective actions are contained in Section 6.9 Carmichael River, Section 7.9 Waxy Cabbage Palm, Section 8.10 Doongmabulla Springs-complex and Section 9.9 Mellaluka Springs-complex. Approval requirements are addressed in Appendix D.	Sections 6.9, 7.9, 8.10 and 9.9 Appendix D

Approval & condition number	Description of Condition or Commitment	How Addressed	Section of GDE Management Plan
	c) Details of how the management plan will be applied across the project phases – pre construction / construction / operation / post operations, offset areas.	Potential impacts to GDEs have been described by Project phase (Section 6.4 Carmichael River, Section 7.4 Waxy Cabbage Palm, Section 8.5 Doongmabulla Springs-complex and Section 9.6 Mellaluka Springs-complex). The subsequent sections identifying management actions and monitoring programs specify timing of monitoring and management actions being carried out, by pre-impact and impact phases. Section 2.2 describes the relationship between project phases (including the corresponding GDE toolbox stage) and implementation.	Section 2.2 Sections 6.4, 7.4, 8.5 and 9.6
	d) Details of any proposed adaptive monitoring program to support the plan objectives.	Details of adaptive management are provided in each GDE chapter (Section 6.8 Carmichael River, Section 7.8 Waxy Cabbage Palm, Section 8.6.1 Doongmabulla Springs-complex and Section 9.7.1 Mellaluka Springs-complex).	Sections 6.8, 7.8, 8.6.1 and 9.7.1
	e) Details of how experts will be used in a review capacity to inform ongoing monitoring and management.	This management plan will be reviewed within two years of commencement of mining and from there on every five years. The plan will be amended as required, and in response to new information. Persons implementing key tasks described in this GDEMP will have appropriate skills and qualifications.	Section 10.1, Section 10.5
	f) Incorporates all proposed management and mitigation measures, including reference to relevant State and Federal Guidelines of relevance to these GDE"s.	Management objectives, performance criteria, management measures and triggers for corrective actions are contained in Section 6.9 Carmichael River, Section 7.9 Waxy Cabbage Palm, Section 8.10 Doongmabulla Springs-complex and Section 9.9 Mellaluka Springs-complex. There are numerous 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. These are summarised in Section 1.4.	Sections 6.9, 7.9, 8.10 and 9.9
	g) Specific performance targets and how these will be measured and reported.	Management objectives, performance criteria, management measures and triggers for corrective actions are contained in Section 6.9 Carmichael River, Section 7.9 Waxy Cabbage Palm, Section 8.10 Doongmabulla Springs-complex and Section 9.9 Mellaluka Springs-complex.	Sections 6.9, 7.9, 8.10 and 9.9

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