Appendix Q

Groundwater Dependent Ecosystem Assessment

HANSEN BAILEY

JULY 2021

BOGGABRI COAL MINE MOD 8

GROUNDWATER DEPENDENT ECOSYSTEM ASSESSMENT

Question today
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Boggabri Coal Mine MOD 8
Groundwater Dependent Ecosystem Assessment

Hansen Bailey

WSP
Level 3, 51-55 Bolton St
Newcastle NSW 2300
PO Box 1162
Newcastle NSW 2300

Tel: +61 2 4929 8300
Fax: +61 2 4929 8382
wsp.com

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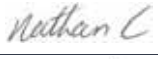
	NAME	DATE	SIGNATURE
Prepared by:	Debbie Landenberger Tanya Bangel	7/07/2021	
Reviewed by:	Nathan Cooper	7/07/2021	
Approved by:	Alex Cockerill	15/07/2021	

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GLOSSARY

Avoid	Measures taken by a proponent such as careful site selection or actions taken through the design, planning, construction, and operational phases of the development to completely avoid impacts on biodiversity values, or certain areas of biodiversity.
Biodiversity offsets	Management actions that are undertaken to achieve a gain in biodiversity values on areas of land to compensate for losses to biodiversity values from the impacts of development.
Biodiversity value	Are the following values: — vegetation integrity--being the degree to which the composition, structure, and function of vegetation at a particular site and the surrounding landscape has been altered from a near natural state. — habitat suitability--being the degree to which the habitat needs of threatened species are present at a particular site. — biodiversity values, or biodiversity-related values, prescribed by the regulations.
Groundwater	Water found in the subsurface in the saturated zone below the water table or piezometric surface i.e. the water table marks the upper surface of groundwater systems.
Hollow bearing tree	A living or dead tree that has at least one hollow. A tree is considered to contain a hollow if: (a) the entrance can be seen; (b) the entrance width is at least 5cm; (c) the hollow appears to have depth (i.e. you cannot see solid wood beyond the entrance); (d) the hollow is at least 1m above the ground. Trees must be examined from all angles.
IBRA region	A bioregion identified under the Interim Biogeographic Regionalisation for Australia (IBRA) system3, which divides Australia into bioregions based on their dominant landscape-scale attributes.
IBRA subregion	A subregion of a bioregion identified under the IBRA system.
Indirect impact	An impact on biodiversity values that occurs when development related activities affect threatened species, threatened species habitat, or ecological communities in a manner other than direct impact. Compared to direct impacts, indirect impacts often: — occur over a wider area than just the site of the development — have a lower intensity of impact in the extent to which they occur compared to direct impacts — occur off site — have a lower predictability of when the impact occurs — have unclear boundaries of responsibility (OEH, 2017).
Minimise	A process applied throughout the development planning and design life cycle which seeks to reduce the residual impacts of the proposal on biodiversity values.
Mitchell landscape	Landscapes with relatively homogeneous geomorphology, soils, and broad vegetation types, mapped at a scale of 1:250,000.

Mitigation	Action to reduce the severity of an impact.
Mitigation measure	Any measure that facilitates the safe movement of wildlife and/or prevents wildlife mortality.
Native vegetation	Means any of the following types of plants native to NSW: — trees (including any sapling or shrub or any scrub) — understorey plants — groundcover (being any type of herbaceous vegetation) — plants occurring in a wetland
PCT classification system	The system of classifying native vegetation approved by the NSW Plant Community Type Control Panel and described in the BioNet Vegetation Classification.
Plant community type	An NSW Plant Community Type (PCT) identified using the BioNet Vegetation Classification system.
Population	A group of organisms, all the same species, occupying a particular area.
Threatened ecological community	Means a critically endangered ecological community, an endangered ecological community or a vulnerable ecological community listed in Schedule 2 of the BC Act.
Threatened species	Critically endangered, endangered, or vulnerable threatened species as defined by Schedule 1 of the BC Act, or any additional threatened species listed under Part 13 of the EPBC Act as critically endangered, endangered, or vulnerable.
Vegetation class	A level of classification of vegetation communities defined in Keith (2004). There are 99 vegetation classes in NSW.
Vegetation formation	A broad level of vegetation classification as defined in Keith (2004). There are 16 vegetation formations and sub-formations in NSW.
Vegetation integrity	The condition of native vegetation assessed for each vegetation zone against the benchmark for the PCT.
Vegetation type	An NSW PCT
Vegetation zone	A relatively homogenous area of native vegetation that is the same PCT and broad condition state.

ABBREVIATIONS

BAM	Biodiversity Assessment Methodology
BC Regulation	Biodiversity Conservation Regulation 2017 (NSW)
BC Act	*Biodiversity Conservation Act 2016* (NSW)
BCM	Boggabri Coal Mine
BCOPL	Boggabri Coal Operations Pty Limited
BGL	Below Ground Level
DAWE	Commonwealth Department of Agriculture, Water and the Environment
DPI	Department of Primary Industries
DPIE	Department of Planning, Industry and Environment
EES	Environment, Energy and Science Group
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EP&A Regulation	Environmental Planning and Assessment Regulation 2000 (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
GDE	Groundwater Dependent Ecosystem
IAR	Idemitsu Australia Resources
IBRA	Interim Biogeographic Regionalisation for Australia
IESC	Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development
LGA	Local Government Area
MCCM	Maules Creek Coal Mine
MNES	Matters of National Significance
MOD	Modification
Mtpa	Million tonnes per annum
OWS	Office of Water and Science
PA	Project Approval granted under the former Part 3A of the EP&A Act
PCT	Plant Community Type
ROM	Run of Mine
TCM	Tarrawonga Coal Mine
TEC	Threatened Ecological Community
WA Act	*Water Act 2007*

1 INTRODUCTION

1.1 PROJECT BACKGROUND

The Boggabri Coal Mine (BCM) is an open cut coal mine located approximately 15 km north east of the Boggabri township in north-western New South Wales (NSW). Boggabri Coal Operations Pty Ltd (BCOPL) operates the BCM on behalf of Idemitsu Australia Resources (IAR) and its joint venture partners.

The Continuation of BCM Project was granted Project Approval (PA) 09_0182 from the Planning Assessment Commission under the former Part 3A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) on 18 July 2012. BCM operates within the Leard State Forest Mining Precinct and is immediately adjacent to the Tarrawonga Coal Mine (TCM) in the south and Maules Creek Coal Mine (MCCM) in the north. PA 09_0182 (which is now known as SSD 09_0182) is supported by the '*Continuation of Boggabri Coal Mine Environmental Assessment*' (Hansen Bailey, 2010) and permits mining operations until December 2033. SSD 09_0182 has been modified on seven occasions to date.

1.2 MODIFICATION 8 DESCRIPTION

BCOPL seeks a modification to SSD 09_0182 under Section 4.55(2) of the EP&A Act to increase the depth of approved mining operations, and to construct a fauna movement crossing over the existing haul road at BCM (MOD 8).

A conceptual layout of MOD 8 is shown on Figure 1.1 and Figure 1.2 and comprises the following changes to approved operations:

- Increasing the approved maximum depth of mining down to the Templemore Coal Seam to recover an additional 61.6 Million tonnes (Mt) of Run of Mine (ROM) coal within the currently approved Mine Disturbance Boundary. It is expected that the additional ROM coal will be suitable for producing a lower ash, higher energy thermal, semi-soft coking, and pulverised coal injection (PCI) quality products for sale to the export market. This will result in the extension of the mine life by six (6) years.
- Construction of a specifically designed fauna movement crossing over the existing haul road between the overburden emplacement area (OEA) and the western side of the regional biodiversity corridor. The establishment of the fauna movement crossing is proposed to improve the movement of fauna from the Leard State Forest through the Southern Rehabilitation Area (SRA).

1.3 SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS

The Commonwealth Department of Agriculture, Water and the Environment (DAWE) has determined that the referred aspects of BCM MOD 8 would be a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (MP 09_0182 Mod 8) (EPBC 2021/8875). The EPBC Act controlling provision for BCM MOD 8 is a water resource, in relation to coal seam gas development and large coal mining development (sections 24D and 24E). As MOD 8 is being assessed by the NSW Government, the assessment will be undertaken in accordance with the bilateral agreement between the Commonwealth Government and NSW Government. On 8 June 2021, Secretary's Environmental Assessment Requirements (SEARs) were issued by the NSW Department of Planning, Industry and Environment (DPIE) to ensure that Commonwealth matters are appropriately addressed within the MOD 8 application.

DPIE has requested that the Modification Report address the SEARs and provide suitable information to be presented to the Independent Expert Scientific Committee (IESC).

Table 1.1 outlines the SEARs for Matters of National Environmental Significance (MNES) listed under the EPBC Act, specifically including the potential impacts to groundwater dependent ecosystems (GDEs).

Table 1.1 MOD 8 GDE Environmental Assessment Requirements (MP 09_0182 Mod 8) (EPBC 2021/8875)

REQUESTED INFORMATION	SECTION WITHIN THIS REPORT
Confirm the distribution of GDEs in the region and the depth to groundwater in areas of potential GDEs (SEAR 23)	Section 3
Include an assessment of GDEs (SEAR 24)	Section 4 and Section 5

The Commonwealth Office of Water Science (OWS) considered the revised groundwater and surface water documentation provided by BCOPL for the EPBC Referral (EPBC 2021/8875) for MOD 8. Regarding GDEs, the OWS provided the following advice to DAWE:

- It is recommended that the proponent conducts ground truthing surveys to support their claim that the three EPBC listed ecological communities are not groundwater dependent. The ground truthing surveys should also consider the interaction between the Maules Creek Formation and alluvium, which the proponent has alluded to being connected to the alluvium.
- The proponent should determine if there are any GDEs (terrestrial or aquatic) present in the areas of predicted groundwater drawdown, including the predicted cumulative groundwater drawdown.
- The outcomes from the survey on GDEs should include maps of modelled groundwater drawdown predictions (including cumulative) overlayed with the GDEs identified through the surveys.
- The proponent should provide the ecological field survey, which determined there is vadophytic GDE species in the project area. This will assist in supporting the claim that the low potential GDEs in the mining area encompassing parts of the Nagero Creek and its tributaries are not groundwater dependent.

This report specifically assesses the areas of incremental groundwater drawdown within the alluvial aquifer resulting from the proposed MOD 8 changes to mine plans, predicted within the Groundwater Impact Assessment (AGE, 2021). The area of interest for understanding the potential for groundwater usage of the remnant vegetation growing on alluvial areas occurs between the existing coal handling infrastructure associated with BCM and Bald Hill to the south west.

1.4 MOD 8 BIODIVERSITY DEVELOPMENT ASSESSMENT REPORT

The potential impacts of MOD 8 on biodiversity values were considered in the Boggabri Coal Mine – Modification 8 Biodiversity Development Assessment Report (WSP, 2021b). The Biodiversity Development Assessment Report was prepared in accordance with the Biodiversity Assessment Methodology (BAM) (DPIE, 2020a) and supplementary BAM Operational Manuals – Stage 1 and Stage 2 (DPIE, 2020b, DPIE 2020c) and included an assessment of GDEs in the MOD 8 study area. This GDE Assessment Report was prepared to provide further information regarding GDEs.

1.5 REGIONAL STUDY AREA

An approximate 10 km radius around the MOD 8 study area, incorporating drainage features such as Back Creek, Goonbri Creek and Bollol Creek and the high potential GDEs that they may support Figure 1.1.

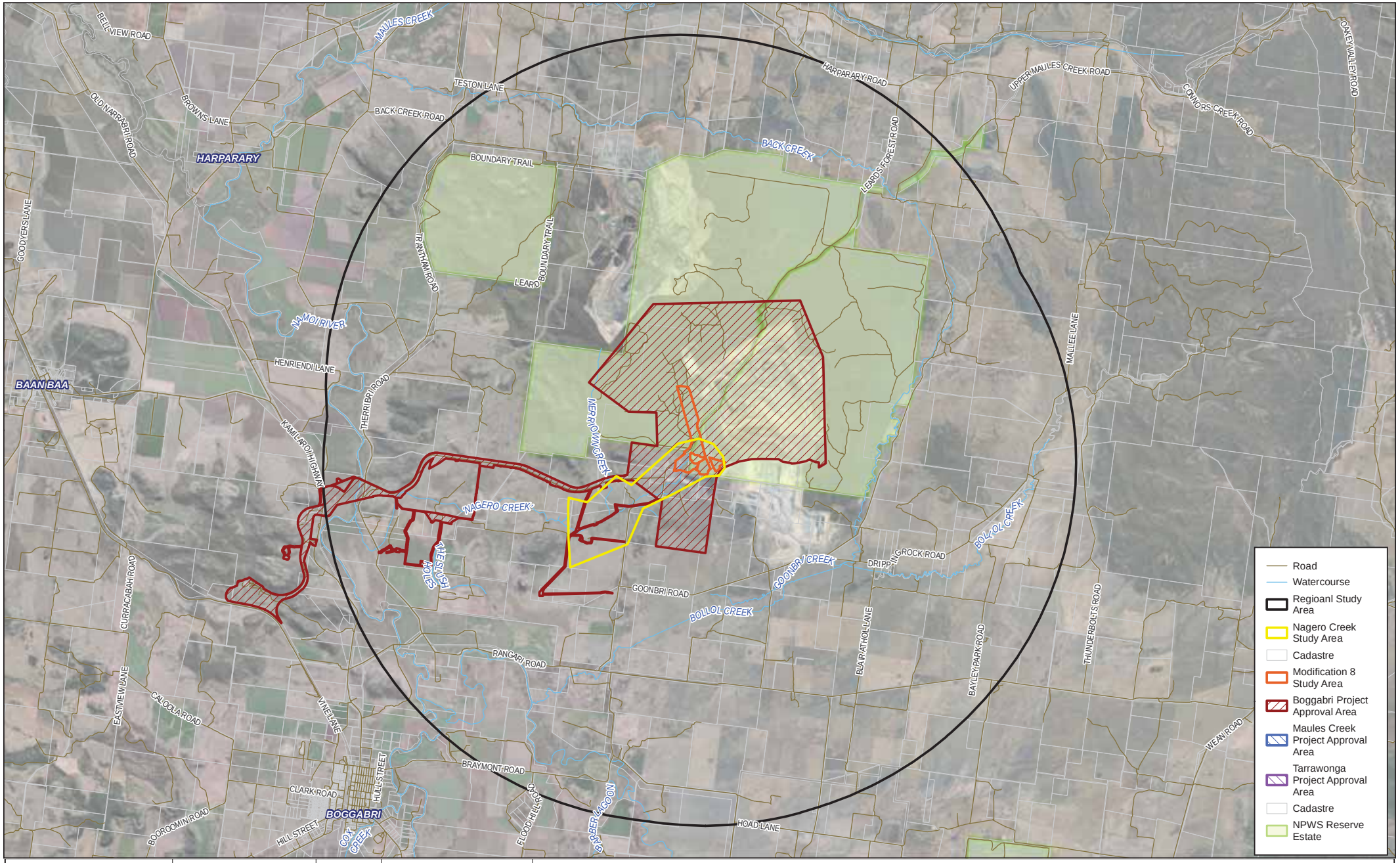
1.6 NAGERO CREEK STUDY AREA

An area of interest for understanding the potential for groundwater usage of the remnant vegetation growing on alluvial areas occurring between the existing coal handling infrastructure associated with BCM and Bald Hill to the south west. The study area for this assessment is shown in Figure 1.2.

1.7 DEFINITIONS

For the purpose of this report the following definitions apply:

- **Regional study area –** an approximate 10 km radius around the MOD 8 study area, incorporating Boggabri, Maules Creek and Tarrawonga Coal Mines, and Back Creek, Goonbri Creek and Bollol Creek (Figure 1.1)
- **Nagero Creek study area –** An area of alluvium to the south-west of BCM potentially subject to cumulative groundwater drawdown (Figure 1.2)
- **MOD 8 study area –** the area which was assessed in the environmental assessment for MOD 8 (Figure 1.1)
- **Project Boundary** – Project Approval (SSD 09_0182) area, which includes the approved activities for the BCM (Figure 1.1).



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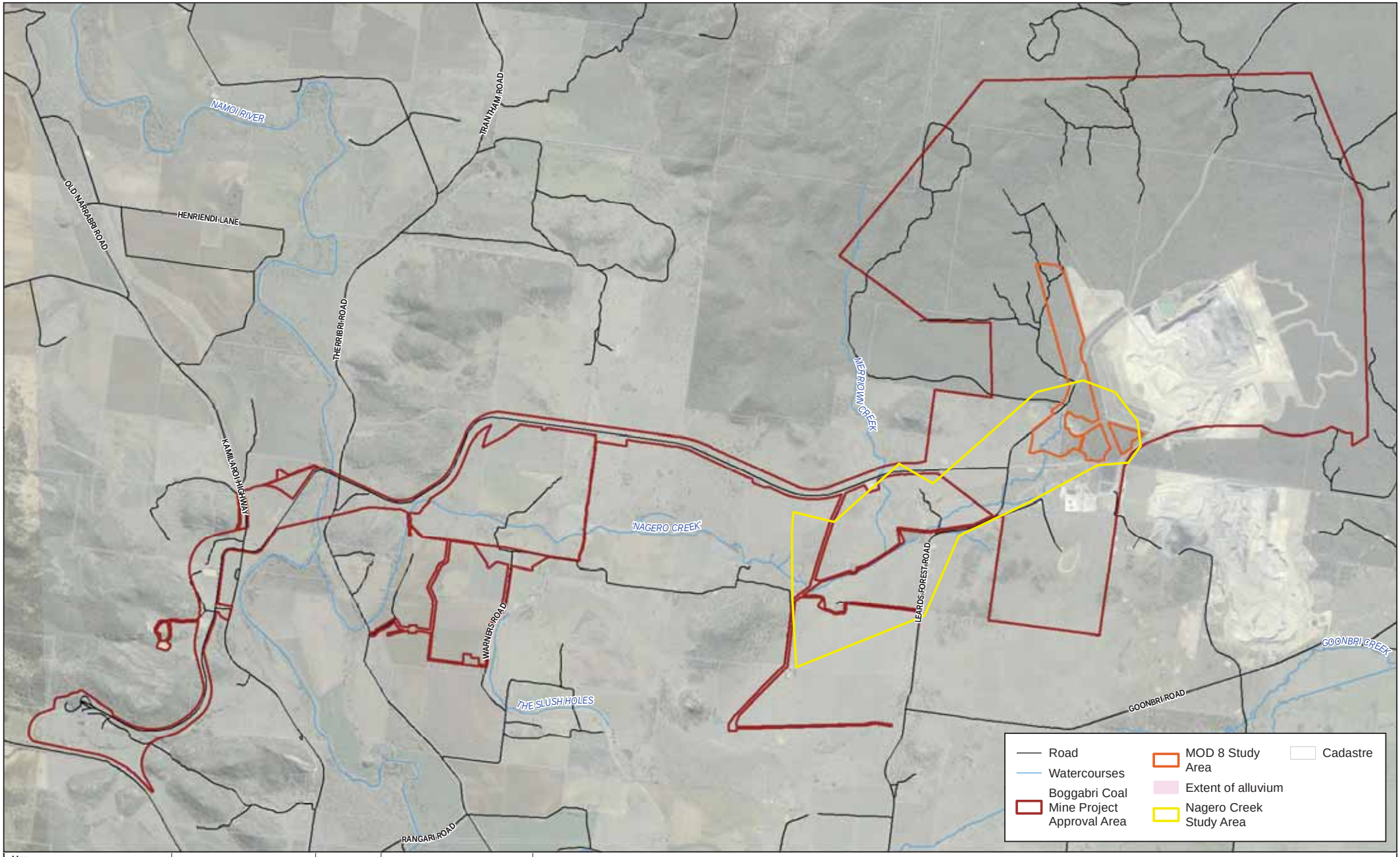
Date: 21/07/2021	Approved by: - D.Landenberger		1:100,000

Data source: Atlass-Aerometrex Pty Ltd via BCOPL (2017).
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand),

Coordinate system: GDA 1994 MGA Zone 56
Scale ratio correct when printed at A3

BOGGABRI GROUNDWATER DEPENDENT ECOSYSTEM REPORT

Figure 1.1
Regional Study Area



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Date: 21/07/2021	Approved by: - D.Landenberger		Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A3

Data source: Atlass-Aerometrex Pty Ltd via BCOPL (2017), Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

BOGGABRI GROUNDWATER DEPENDENT ECOSYSTEM REPORT

Figure 1.2
Nagero Creek Study Area

2 METHODOLOGY

This section provides a detailed description of the methodologies used in the preparation of this report. Methodologies used included a combination of desk-based searches of relevant databases and historical records to identify potential GDEs and the potential cumulative groundwater drawdown impacts to GDEs because of MOD 8.

2.1 PERSONNEL

The contributors to the preparation of this paper, their qualifications and roles are listed in Table 2.1.

Table 2.1 Personnel

NAME	QUALIFICATIONS	POSITION AND ROLE
Alex Cockerill	Bachelor of Science (Hons), Accredited BAM Assessor (BAAS17020)	Principal Ecologist –project director
Nathan Cooper	Bachelor of Environmental Science, Graduate Diploma Ornithology and has completed BAM training	Senior Ecologist – project manager, technical review
Tanya Bangel	Bachelor of Environmental Management and Science (Hons) Diploma of Conservation and Land Management Accredited BAM Assessor (BAAS18076)	Senior Ecologist – reporting
Deborah Landenberger	Bachelor of Science (Hons), Accredited BAM Assessor (BAAS18187)	Principal Ecologist – reporting
Isaac Augey	Bachelor of Environmental Science and Management	GIS Consultant – data management and figure preparation

2.2 DESKTOP ASSESSMENT

2.2.1 SPATIAL AND REGIONAL SPECIFIC DATA

The following desktop assessments have been completed:

- Commonwealth Protected Matters Search Tool – DAWE.
- Commonwealth Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology).
- Regional soil and geology maps.
- Boggabri Operations Viewer.
- BCOPL vegetation mapping (project site and biodiversity offsets).
- The following broad-scale mapping projects:
  - State Vegetation Type Map: Border Rivers – Gwydir and Namoi Region Version 2 VIS ID 4467 (OEH, 2016).
  - A vegetation Map for the Namoi Catchment Management Authority, An unpublished report for the Namoi Catchment Management Authority (Eco Logical 2008).

2.3 LITERATURE REVIEW

The following literature has been reviewed to inform the assessment of the potential for GDE's within the Nagero Creek study area and regional study area:

- Australian Groundwater-dependent ecosystem toolbox part 2: Assessment Tools (Sinclair Knight Merz, 2011).
- A Review of Groundwater Dependent Terrestrial Vegetation and Groundwater Depth for the Namoi Catchment Management Authority (Stygoecologia, 2013).
- Maules Creek Coal Mine Biodiversity Impact Assessment (Cumberland Ecology, 2011).
- Report on Maules Creek Coal Project Groundwater Impact Assessment. Draft. Project No. G1508. V2 (AGE, 2011).
- Tarrawonga Coal Project Environmental Assessment – Appendix E (Fauna Assessment) and Appendix F (Flora Assessment) (Cumberland Ecology, 2011).
- Boggabri Coal Mine references
  - Boggabri Coal, Groundwater Management Plan (Idemitsu, 2017).
  - Boggabri Coal Project Groundwater Assessment (Parsons Brinckerhoff, 2005).
  - Continuation of Boggabri Coal Mine - Groundwater Assessment (AGE, 2010).
  - Modification 5 MNES Assessment of the Borefield Development Approved by Modification 5 to project approval No. 09_0182 (WSP | Parsons Brinckerhoff, 2016).
  - Boggabri Coal Mine Modification 8 Biodiversity Development Assessment Report (WSP, 2021b).
  - Groundwater Impact Assessment Boggabri Coal Mine Modification 8 to SSD 09_0182 (AGE, 2021).
  - 2020 Groundwater Dependent Ecosystems and Stream and Riparian Vegetation Health Monitoring (WSP, 2021a).

The following guidelines were referred to assess the impact to GDEs as part of this report:

- Information guidelines Explanatory Note, Assessing Groundwater-dependent Ecosystems. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining (Doody & Hancock *et. al*, 2019).
- Information guidelines for proponents preparing coal seam gas and large coal mining develop proposals (Commonwealth of Australia, 2018).

2.4 VEGETATION MAPPING

Vegetation mapping used in this assessment incorporates the following:

- Field verified vegetation mapping: within the Project Boundary and Biodiversity Offset Areas (BOAs).
- Regional state-based broad-scale vegetation mapping – relied upon within areas that have not been field verified to date.

A detailed description of the different vegetation mapping datasets used for this assessment is provided below.

2.4.1 FIELD VERIFIED VEGETATION MAPPING

Vegetation within and immediately surrounding the Project Boundary have been subject to an array of previous surveys and assessments as part of the establishment and ongoing operation of the BCM. Specifically, these surveys have mapped the vegetation within the Project Boundary, BOAs and areas of Leard State Forest as part of the following investigations.

- Continuation of Boggabri Coal Mine – Biodiversity Impact Assessment (Parsons Brinckerhoff, 2010) which involved mapping of the Project Boundary and Leard State Forest.
- Boggabri Coal Mine Modification 8 Biodiversity Development Assessment Report (WSP, 2021b), which involved vegetation mapping within the 'MOD 8 study area'.
- Boggabri Coal Mine Biodiversity Offset Strategy (WSP, 2019) which included vegetation mapping completed across the biodiversity offset properties of the BCM completed by Parsons Brinckerhoff (now WSP) and Niche Environment and Heritage (2014).
- Other ad hoc vegetation surveys completed as part of the ongoing operation of the BCM for example project modifications, ecological monitoring tree clearing etc.

Where available, the field verified mapping completed as part of the above has been relied upon for this assessment.

2.4.2 REGIONAL STATE-BASED VEGETATION MAPPING

Vegetation within the Nagero Creek and regional study areas have also been mapped at a regional scale by the following broad-scale vegetation mapping projects:

- State Vegetation Type Map: Border Rivers Gwydir / Namoi Region Version 2.0_ID4467 (Office of Environment and Heritage, 2016).
- Refinement of Vegetation Mapping in the Namoi Catchment: Extant and pre-European (Eco Logical Australia, 2013).
- Report on the botany, wildlife and ecology of the Leard State Forest (James B. Croft and Associates, 1983).

For the purposes of this assessment the State Vegetation Type Map: Border Rivers Gwydir/Namoi Region (Office of Environment and Heritage, 2016) was used to determine vegetation within areas where no field verified vegetation mapping occurred. This regional state-based vegetation mapping dataset was selected over other broad-scale vegetation mapping projects as it is the most current regional mapping project which covers the study areas and aligns vegetation types to Plant Community Types (PCTs). As such, it was deemed the most applicable broad-scale vegetation mapping dataset for this assessment.

2.4.3 MNES THREATENED ECOLOGICAL COMMUNITIES MAPPING

Where field verified vegetation mapping occurred, the information collected during surveys were used to determine the PCT for each vegetation type recorded as described in the BioNet Vegetation Classification System (Environment, Energy and Science Group, 2021) and whether the vegetation aligned to any State or Commonwealth listed Threatened Ecological Communities (TECs).

One Commonwealth listed TEC, being Poplar Box Grassy Woodland on Alluvial Plains, was only listed under the EPBC Act on the 4 July 2019. As all field validated vegetation mapping within the BCM Project Boundary and BOAs were conducted prior to 2019, areas of native vegetation in the Nagero Creek and regional study areas with potential to meet the EPBC Act listing have not yet been assessed against the TECs key diagnostic characteristics or condition thresholds. As such, given field verification was unable to be undertaken for inclusion within this assessment, a precautionary approach has been applied and it is assumed for the purposes of this investigation that all remnant patches previously mapped at PCT 101 and areas of PCT 88 on the Namoi alluvial floodplain meet the EPBC Act listing. The only exception to this is areas of derived native grasslands, which do not meet the specific condition thresholds required to form part of the Poplar Box Grassy Woodland on Alluvial Plains EPBC Act listing, unless they form part of a patch. It is recommended that field verification of remnant patches previously mapped as PCT 101 and PCT 88 on the alluvial plain be undertaken to confirm whether they meet the characteristics and thresholds of this TEC.

Where the State Vegetation Type Map: Border Rivers Gwydir / Namoi Region (Office of Environment and Heritage, 2016) was relied upon (i.e. in areas where no field verification has occurred to date) PCT alignment to Commonwealth listed Threatened Ecological Communities was determined using the associated Threatened Ecological Communities

listed for each PCT within the BioNet Vegetation Classification System (Environment, Energy and Science Group, 2021).

3 EXISTING ENVIRONMENT

An overview of landscape features associated with the MOD 8 regional study area and regional assessment of GDEs are presented in Table 3.1.

Table 3.1 Summary of the regional study area landscape features

LANDSCAPE FEATURE	OCCURRENCE IN MOD 8 STUDY AREA
IBRA bioregion	Brigalow Belt South
IBRA subregion	Liverpool Plains
NSW landscape regions (Mitchell landscapes)	Bugaldie Uplands and Liverpool Alluvial Plains
Local Government Area (LGA)	Narrabri Shire Council
Rivers, streams and estuaries	Nagero Creek, Bollol Creek and Back Creek
Important and local wetlands	No important wetlands have been recorded within the MOD 8 study area
Geology	Permian geology (Maules Creek Formation) overlain by Quaternary alluvial deposits
Soils	Predominantly consisting of conglomerate and sandstone with minor siltstone, claystones and intercalated coal seams (AGE, 2010)
Aquifers	Alluvium aquifers

3.1 GROUNDWATER DEPENDENT ECOSYSTEM

3.1.1 TERRESTRIAL AND AQUATIC GDES

A review of the Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology, 2021) identified seven high potential terrestrial GDEs and one high potential aquatic GDE mapped in an approximate 10 km radius of MOD 8 (Table 3.2).

Table 3.2 High potential terrestrial and aquatic GDEs mapped in the regional study area

NAME	GDE POTENTIAL	LEVEL OF ASSESSMENT
Aquatic GDEs		
Namoi River	High potential	National assessment
Terrestrial GDEs		
PCT 112 Black Tea-tree - River Oak - Wilga riparian low forest/shrubland wetland of rich soil depressions	High potential	Regional studies
PCT 599 Blakely's Red Gum - Yellow Box grassy tall woodland on flats and hills in the Brigalow Belt South Bioregion		
PCT 53 Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains		
PCT 55 Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains		

NAME	GDE POTENTIAL	LEVEL OF ASSESSMENT
PCT 78 River Red Gum riparian tall woodland / open forest in the Nandewar Bioregion and Brigalow Belt South Bioregion		
PCT 101 Poplar Box - Yellow Box - Western Grey Box grassy woodland on cracking clay soils mainly in the Liverpool Plains		
PCT 516 Grey Box grassy woodland or open forest of the Nandewar Bioregion and New England Tableland Bioregion		

3.2 REGIONAL GROUNDWATER AQUIFERS

Four types of groundwater aquifers occur within the region consisting of:

- Alluvial aquifer (incorporating the Narrabri formation and Gunnedah formation), which comprises alluvial deposits associated with the Namoi River and its tributaries:
  - mapped as Qx Quaternary Alluvium (Pratt, 1998).
- Maules Creek Formation Aquifer: the major transmissive units are within the coal seams:
  - mapped as Pmx Maules Creek and Goonbri formations (Pratt, 1998).
- Minor colluvium associated with the weathered Boggabri volcanics:
  - mapped as Pbr – Boggabri Volcanics.

The simulated groundwater table depths across the region range from less than 0.5 mbgl and over 300 mbgl as discussed in Section 4.

3.2.1 ALLUVIAL AQUIFER

The Nagero Creek study area is located on the alluvial plain associated with and with tributaries of the Namoi River. Nagero Creek is an ephemeral tributary of the Namoi River and captures runoff from the southern portion of the Leard State Forest (where the BCM is situated) and surrounding areas. Tributaries of Nagero Creek occur within the MOD 8 study area, and to the south-east of Bald Hill, Merrygowen Creek flows into Nagero Creek. These areas are mapped as Quaternary sediments (Qx) (Pratt, 1998) and is likely to be the extent of the alluvial aquifer to the south and west of BCM (BCOPL, 2017a). The alluvial aquifer extends from south and north along the Namoi River and covers wide areas around Boggabri. It forms part of the Upper Namoi groundwater source and is used extensively for irrigation, town water supply and stock and domestic purposes. The groundwater levels are typically within 10 m of the ground surface and there is an established hydraulic connection with the surface water system (BCOPL, 2017a).

Groundwater movement within the alluvium is via intergranular flow, where sandy lenses are interconnected and in hydraulic continuity with the creeks and drainage channels. The regional groundwater flow direction within the alluvium is generally to the north north-west. South of the BCM, groundwater in the alluvium associated with Bollol Creek flows south-west towards the Namoi River. The alluvial aquifer in the vicinity of the BCM is limited within thin valley infill deposits of generally low to variable permeability. The thin alluvium associated with Nagero Creek and Bollol Creek, are downgradient of the mine lease. These creeks are ephemeral and flow only after high rainfall events. Groundwater in these sections of the alluvium is minor compared to the areas in the west and south (BCOPL, 2017a). Detailed studies indicate that groundwater levels are typically 7 mbgl to 10 mbgl on the alluvial plain but can be deeper in places upslope towards the outcropping Boggabri Volcanics (11.2 m at Victoria Park monitoring bore) (Parsons Brinckerhoff, 2010, 2015, AGE 2010). The thickness of the alluvial aquifer ranges from 25 m to 75 m (AGE, 2010). Groundwater levels are shallower in the vicinity of drainage depressions and creeks, particularly during wetter months when they contain surface water.

A pilot survey of stygofauna within and adjacent to BCM was undertaken in 2018 and 2019, including sampling of the alluvial aquifer. Despite eight bores being sampled during this project, only one bore (MW6) yielded stygofauna typical of the aquifers being investigated during the 2018 survey (Austral Research and Consulting, 2020).

In Australia, stygofauna are known from alluvial, limestone karst, fractured rock, and calcrete aquifers (Hancock *et al*. 2005; Humphreys, 2008). To be suitable for stygofauna, aquifers must have sufficient porosity or fractionation (connectivity) for adequate living space and have a sufficient flux of organic matter (DOC) and dissolved oxygen (Humphreys, 2008). The single stygofauna crustacean species identified was Notobathynella (Parabathynellidae). This species is known from the region (Korbel *et. al.* 2013) and has been identified in Tasmania, NSW, Victoria and New Zealand. As stygofauna was only identified from a single bore and limited to a single species, it is difficult to draw conclusions about the connectivity of the alluvial aquifer to support this and other stygofauna species. However, a wider range of stygofaunal species have been identified in the Gunnedah Coal Basin, which encompasses the Namoi River catchment and the BCM site. Korbel *et. al.* (2013) found 21 taxa, which were dominated by copepods, amphipods and syncarids. Findings from these and other reports suggest that there is a diverse range of stygofauna present in contrast to the findings from the pilot survey.

3.3 PLANT COMMUNITY TYPES

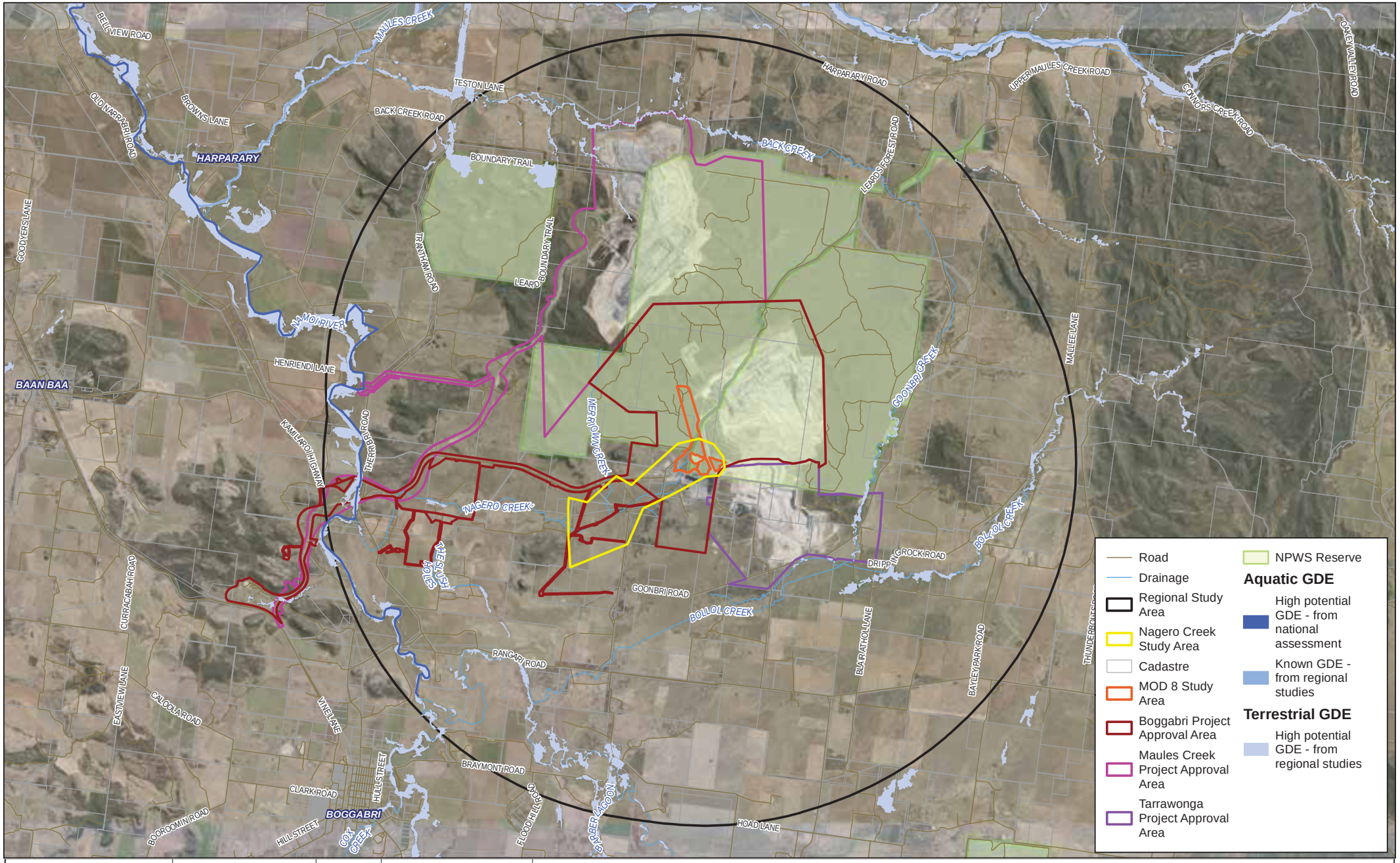
3.3.1 NAGERO CREEK STUDY AREA

Four native PCTs and one non-native vegetation community have been recorded within the Nagero Creek study area as part of previous field surveys completed for the BCM. A summary of these PCTs is provided in Table 3.3 and illustrated in Figure 3.2.

There are portions of the Nagero Creek study area which have not been field verified as part of previous field surveys completed for the BCM. The regional State Vegetation Type Map: Border Rivers Gwydir/Namoi Region (Office of Environment and Heritage, 2016) was used to determine vegetation likely to occur within these areas. The regional broad-scale vegetation mapping identified one additional PCT as occurring within Nagero Creek study area (i.e. PCT 101). All remaining vegetation types identified are equivalent to other vegetation types previously identified within the Nagero Creek study area.

Based on general field observations and recent vegetation assessments completed within and surrounding the Nagero Creek study area, the following changes PCT equivalences and changes to the existing vegetation mapping are noted:

- areas of PCT 88 previously mapped south of the coal loader within the Project Boundary and BOAs are considered to align and have been reassigned to PCT 101 in Figure 3.2
- areas of PCT 599 previously mapped as PCT 1329 within the Project Boundary and BOAs are considered to align to and have been reassigned to PCT 599 in Figure 3.2
- areas of PCT 1313 are considered equivalent to vegetation mapped as PCT 592



Map: BC2021_F003_1_PotentialGDE_r1v6	Author: Isaac.Augey	O	0 1.5 3 Kilometers 1:100,000 Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A3
Date: 21/07/2021	Approved by: - D.Landenberger		

Data source: Atlass-Aerometrex Pty Ltd via BCOPL (2017).
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand),

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BOGGABRI GROUNDWATER DEPENDENT ECOSYSTEM REPORT

Figure 3.1
Known and High Potential Terrestrial and Aquatic GDEs

Table 3.3 PCTs identified in the Nagero Creek study area

VEGETATION TYPE	CONDITION	BC ACT STATUS	EPBC ACT STATUS
Field verified (WSP, 2021)			
PCT 88 Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	Intact	Not listed	Not listed
	Modified		
	Shrubby regrowth		
	Derived Native Grasslands (DNG)		
PCT 101 Poplar Box - Yellow Box - Western Grey Box grassy woodland on cracking clay soils mainly in the Liverpool Plains, Brigalow Belt South Bioregion (includes areas south of the coal loader / BCM access road previously mapped as PCT 88 which occur on the Namoi floodplain)	Intact	Not listed	Endangered[3]
	Derived Native Grassland		
PCT 599 Blakely's Red Gum - Yellow Box grassy tall woodland on flats and hills in the Brigalow Belt South Bioregion and Nandewar Bioregion (includes areas mapped as PCT 1329)	Intact	Critically Endangered[1]	Critically Endangered[2]
PCT 1313 White Cypress Pine – Narrow – leaved Ironbark shrub/grass open forest of the western Nandewar Bioregion (equivalent to PCT 592)	Intact	Not listed	Not listed
PCT 1383 White Box Grassy Woodland of the Nandewar and Brigalow Belt South Bioregions	Intact	Critically Endangered[1]	Critically Endangered[2]
Miscellaneous Ecosystem: Highly disturbed areas with no or limited native vegetation	n/a	Not listed	Not listed
Regional state-based vegetation mapping			
PCT 1 Candidate Native Grasslands	n/a	Not listed	Not listed
PCT 101 Poplar Box - Yellow Box - Western Grey Box grassy woodland on cracking clay soils mainly in the Liverpool Plains, Brigalow Belt South Bioregion	Intact	Not listed	Endangered[3]
PCT 592 - Narrow-leaved Ironbark - Cypress pine - White Box shrubby open forest in the Brigalow Belt South Bioregion and Nandewar Bioregion (equivalent to PCT 1313)	n/a	Not listed	Not listed
PCT 588 - White Box - White Cypress Pine shrubby hills open forest mainly in the Nandewar Bioregion	n/a	Not listed	Not listed
Not Native (equivalent to Miscellaneous Ecosystem)	n/a	Not listed	Not listed

(1) Listed as Critically Endangered under BC Act listing for White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland in the NSW North Coast, New England Tableland, Nandewar, Brigalow Belt South, Sydney Basin, South Eastern Highlands, NSW South Western Slopes, South East Corner and Riverina Bioregions

(2) Listed as Critically Endangered under EPBC Act listing for White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland

(3) Listed as Endangered under the EPBC Act listing for Poplar Box Grassy Woodland on Alluvial Plains.

3.3.2 REGIONAL STUDY AREA

A review of the Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology, 2021) identified seven PCTs as having high potential to be GDEs within the regional study area. A summary of these PCTs is provided in Table 3.4 and illustrated in Figure 3.3.

Table 3.4 PCTs identified in association with regional high potential GDEs

VEGETATION TYPE	BC ACT STATUS	EPBC ACT STATUS
PCT 112 Black Tea-tree – River Oak – Wilga riparian low forest/ shrubland wetland of rich soil depressions in the Brigalow Belt South Bioregion	Not listed	Not listed
PCT 599 Blakely's Red Gum - Yellow Box grassy tall woodland on flats and hills in the Brigalow Belt South Bioregion (includes areas mapped as PCT 1329)	Critically Endangered[1]	Critically Endangered[2]
PCT 53 Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains	Not listed[4]	Not listed
PCT 55 Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains	Not listed[5]	Not listed
PCT 101 Poplar Box - Yellow Box - Western Grey Box grassy woodland on cracking clay soils mainly in the Liverpool Plains	Not listed	Endangered[3]
PCT 516 Grey Box grassy woodland or open forest of the Nandewar Bioregion and New England Tableland Bioregion	Not listed	Not listed

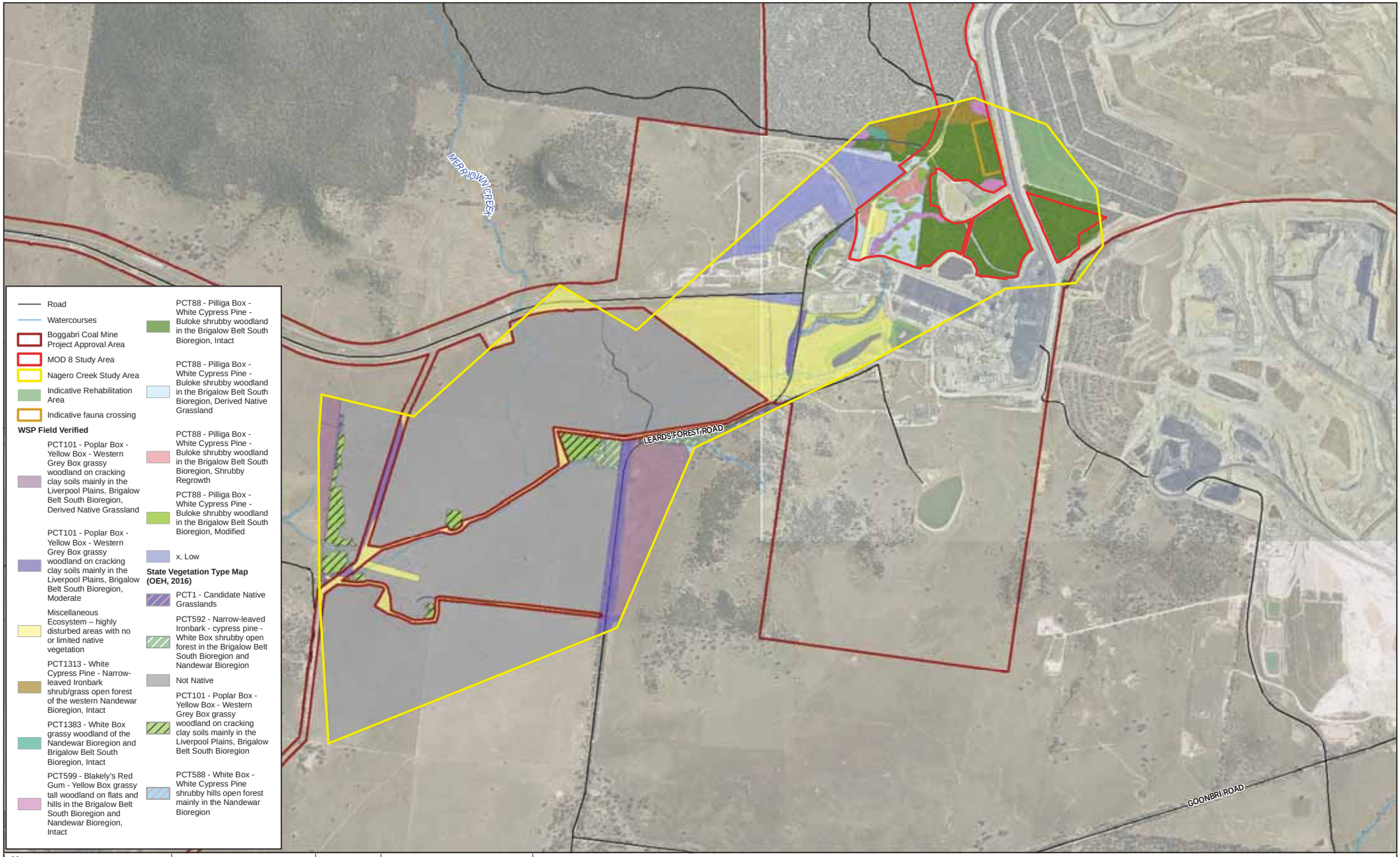
(1) Listed as Critically Endangered under BC Act listing for White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland in the NSW North Coast, New England Tableland, Nandewar, Brigalow Belt South, Sydney Basin, South Eastern Highlands, NSW South Western Slopes, South East Corner and Riverina Bioregions

(2) Listed as Critically Endangered under EPBC Act listing for White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland

(3) Listed as Endangered under the EPBC Act listing for Poplar Box Grassy Woodland on Alluvial Plains

(4) Artesian Springs Ecological Community in the great Artesian Basin is an associated threatened ecological community of PCT 53 in BioNet (Environment, Energy and Science Group, 2021). Despite this, PCT 53 is not considered likely to align to the threatened ecological community for the purpose of this assessment as the regional study area does not occur within the Great Artesian Basin.

(5) There are multiple BC Act listed threatened ecological communities in BioNet (Environment, Energy and Science Group, 2021) which are associated with PCT 55. PCT 55 within the regional study area is not considered likely to align to any of the TECs based on surveys completed on PCT 55 within the locality.



Map: BC2021_F003_2_PCTNageroCreek_r1v8	Author: Isaac.Augey	O	0 250 500 Meters 1:20,000 Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A3
Date: 21/07/2021	Approved by: - D.Landenberger		

Data source: Atlass-Aerometrex Pty Ltd via BCOPL (2017).
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

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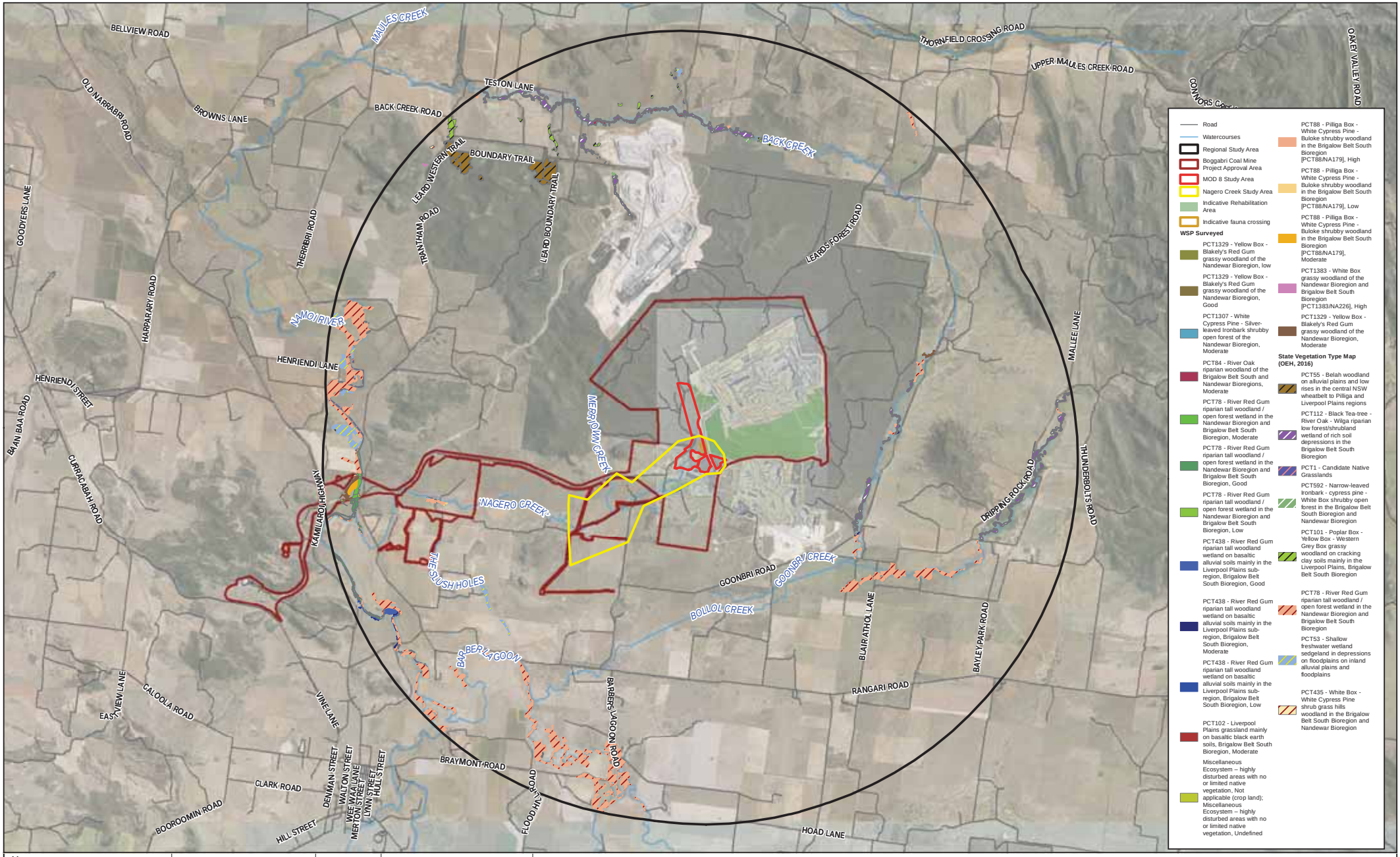
BOGGABRI GROUNDWATER DEPENDENT ECOSYSTEM REPORT

Figure 3.2
Plant Community Types identified in the Nagero Creek study area



Map: BC2021_F003_3_PCTRegStudyArea_r1v3	Author: Isaac.Augey	O	0 1 2 Kilometers
Date: 21/07/2021	Approved by: - D.Landenberger		1:100,000
Data source: Atlass-Aerometrex Pty Ltd via BCOPL (2017). Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community			Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A3

BOGGABRI GROUNDWATER DEPENDENT ECOSYSTEM REPORT

Figure 3.3
Plant Community Types identified in the Regional Study Area

3.4 MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE

3.4.1 THREATENED ECOLOGICAL COMMUNITIES

Six TECs listed under the EPBC Act were predicted to occur in the regional study area (~10 km radius of MOD 8) based on database searches undertaken as part of the Boggabri Coal Mine – Modification 8 Biodiversity Development Assessment Report (WSP, 2021). Of these TECs, four are known to occur in the regional study area based on the following vegetation mapping:

- Field verification mapping surveys undertaken for the Boggabri Coal Mine – Modification 8 Biodiversity Development Assessment Report (WSP, 2021b).
- Field verification mapping surveys completed for the Continuation of Boggabri Coal Mine – Biodiversity Impact Assessment (Parsons Brinckerhoff, 2010), which involved mapping of the Project Boundary and Leard State Forest.
- Boggabri Coal Mine Biodiversity Offset Strategy (WSP, 2019) which included vegetation mapping completed across the biodiversity offset properties of the BCM completed by Parsons Brinckerhoff (now WSP) and Niche Environment and Heritage (2014).
- Other ad hoc vegetation completed as part of the ongoing operation of the BCM for example project modifications, ecological monitoring tree clearing etc.
- Regional broad-scale vegetation mapping i.e. State Vegetation Type Map: Border Rivers Gwydir/Namoi Region Version 2.0_ID4467 (Office of Environment and Heritage, 2016).

A description of each of these four threatened ecological communities listed under the EPBC Act in regard to the regional study area (and therefore the Nagero Creek study area) are provided below in Section 3.4.1.1 to Section 3.4.1.4.

Table 3.5 Threatened ecological communities predicted to occur in the regional study area

THREATENED ECOLOGICAL COMMUNITY	EPBC ACT STATUS	RECORDED IN THE STUDY AREA?[1]
Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	Endangered	Not known to occur in the regional study area
Grey Box (*Eucalyptus microcarpa*) Grassy Woodlands and Derived Native Grasslands of South-eastern Australia	Endangered	Not known to occur in the regional study area
Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland	Critically Endangered	Yes – recorded in the regional study area
Poplar Box Grassy Woodland on Alluvial Plains	Endangered	Yes – recorded in Nagero Creek study area and regional study area
Weeping Myall Woodlands	Endangered	Yes – recorded in the regional study area
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	Critically Endangered	Yes – recorded in Nagero Creek study area and regional study area

3.4.1.1 NATURAL GRASSLANDS ON BASALT AND FINE-TEXTURED ALLUVIAL PLAINS OF NORTHERN NSW AND SOUTHERN QUEENSLAND

Natural grasslands on basalt and fine textured alluvial plains of northern NSW and southern Queensland (Plains Grassland) is listed as a Critically Endangered Ecological Community under the EPBC Act. Plains Grassland is a grassland dominated by native tussock grasses which is highly variable across its range. The community is influenced by soil, rainfall, geology and land use which vary the community's composition and structure (Threatened Species Scientific Committee, 2009).

Plains Grassland has been mapped within the regional study area by Niche Environment and Heritage (2014) (refer to areas mapped as PCT 102 in Figure 3.5). Plains Grassland has not been identified as occurring within the MOD 8 study area nor the Nagero Creek study area.

As no field verification has been undertaken as part of this assessment, it is conservatively assumed that all patches of Plains Grassland mapped in Figure 3.5 are consistent within the Plains Grassland condition criteria outlined in the community's Commonwealth Listing Advice (Threatened Species Conservation Advice, 2009) as the vegetation is located within the Liverpool Plains, occurs on flats (<5%) and likely to contain a projected crown cover of <10% and contain characteristic species.

3.4.1.2 POPLAR BOX GRASSY WOODLAND ON ALLUVIAL PLAINS

Poplar Box Grassy Woodland on Alluvial Plains was listed as an Endangered Ecological Community under the EPBC Act on 4 July 2019. There was a single PCT recorded within the MOD 8 study area which was considered a candidate to form part of the Poplar Box Grassy Woodland on Alluvial Plains threatened ecological community; being PCT 88 Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion.

PCT 88 within the MOD 8 study area was assessed as not meeting the key diagnostic characteristics (Department of Environment and Energy, 2019) of the Poplar Box Grassy Woodland on Alluvial Plains threatened ecological community as it typically occurred as a dry sclerophyll forest with a canopy dominated largely by *Eucalyptus pilligaensis* (Narrow-leaved Grey Box) and a midstorey usually greater than 30% in cover dominated by *Allocasuarina luehmannii* (Bulloak). Given this, PCT 88 within the MOD 8 study area does not form part of the Poplar Box Grassy Woodland on Alluvial Plains threatened ecological community.

As all vegetation mapping completed outside the MOD 8 study area (including areas within the BCM Project Boundary and BOAs) were conducted prior to 2019, areas of native vegetation in the Nagero Creek and regional study areas with potential to meet the EPBC Act listing have not yet been assessed against the threatened ecological community's key diagnostic characteristics or condition thresholds. As such, a precautionary approach has been applied and it is assumed for the purposes of this investigation that all remnant patches previously mapped at PCT 101 and areas of PCT 88 on the Namoi alluvial floodplain meet the EPBC Act listing. The only exception to this is areas of derived native grasslands, which do not form part of the Poplar Box Grassy Woodland on Alluvial Plains EPBC Act listing, unless they form part of a patch.

3.4.1.3 WEEPING MYALL WOODLANDS

Weeping Myall Woodlands is listed as an Endangered Ecological Community under the EPBC Act. This community occurs on inland alluvial plains as a low open to sparse woodland which reaches up to 12 m in height with a canopy dominated by *Acacia pendula* (Weeping Myall).

Weeping Myall Woodland occurs as scattered patches within the regional study area along the Namoi floodplain (Figure 3.5). Within the Project Boundary and BOAs, where this community where this TEC has been field verified, the community occurs as scattered remnants within a fragmented agricultural landscape and as roadside vegetation along Therribri Road, Boggabri NSW (Parsons Brinckerhoff, 2015). Weeping Myall Woodlands has not been identified as occurring within the MOD 8 study area nor the Nagero Creek study area.

To be considered part of the EPBC Act listing of Weeping Myall Woodlands, remnant areas must meet the Commonwealth condition criteria as outlined in the listing advice (Department of the Environment, Water, Heritage and the Arts, 2008). A comparison of the Weeping Myall Woodlands within the Project boundary and BOAs against the Commonwealth condition criteria is provided in Table 3.6.

Table 3.6 Weeping Myall Woodland Commonwealth condition criteria comparison (Parsons Brinckerhoff, 2015)

CRITERIA NUMBER	CONDITION CRITERIA	WEEPING MYALL WOODLAND WITHIN THE REGIONAL STUDY AREA
1	Tree canopy is dominated (at least 50% of trees present) by living, dead or defoliated Weeping Myall trees.	Yes. The Weeping Myall Woodland contained a canopy cover dominated by Weeping Myall.
2	Overstorey must have at least 5% tree canopy cover or at least 25 dead or defoliated mature Weeping Myall trees/ha.	Yes. The Weeping Myall Woodland contained a tree canopy cover with over 5% mature and semi-mature Weeping Myall trees.
3	Area is at least 0.5 ha in size.	Yes. The patch of Weeping Myall Woodland is greater than 0.5 ha in size.
4	The patch has either: — more than two layers of regeneration of Weeping Myall present; or — tallest layer of living, dead or defoliated Weeping Myall trees is at least 4 m tall and of the vegetation cover present, 50% is comprised of native species.	Yes. The Weeping Myall Woodland contained two layers of regeneration. In addition, the canopy is greater than 4 m high and contains greater than 50% native species.
End	**Does the patch meet the Commonwealth condition criteria?**	**Yes. The patch meets all condition criteria for the Commonwealth listing of Weeping Myall Woodland.**

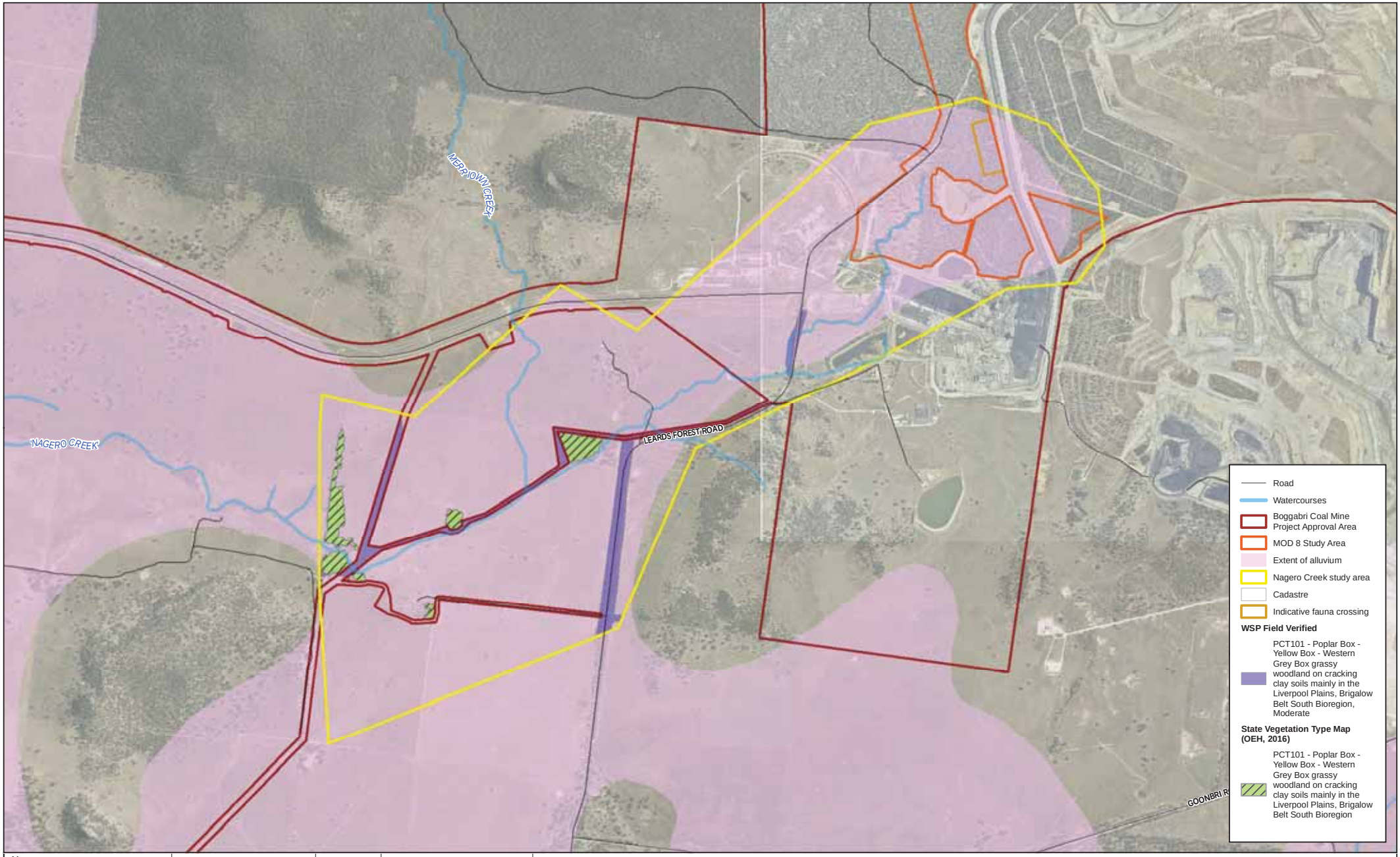
3.4.1.4 WHITE BOX – YELLOW BOX – BLAKELY'S RED GUM GRASSY WOODLAND AND DERIVED NATIVE GRASSLANDS

White Box – Yellow Box – Blakely's Red Gum Woodland and Derived Native Grasslands (Box Gum Woodland) is listed as a Critically Endangered Ecological Community under the EPBC Act. The community occurs as an open grassy woodland with an understorey dominated by native tussock grasses, herbs and scattered shrubs (Threatened Species Scientific Committee, 2006).

Two PCTs recorded within the regional study area have been identified as having potential to align to the Critically Endangered Box Gum Woodland threatened ecological community being:

- PCT 599 Blakely's Red Gum - Yellow Box grassy tall woodland on flats and hills in the Brigalow Belt South Bioregion and Nandewar Bioregion (previously mapped and including areas of PCT 1329).
- PCT 1383 White Box grassy woodland of the Nandewar Bioregion and Brigalow Belt South Bioregion.

PCT 599 and PCT 1383 recorded within the MOD 8 study area were both assessed as meeting the Box Gum Woodland EPBC Act threatened ecological community key diagnostic features and condition thresholds (WSP, 2021b). As no field verification has been undertaken for the remaining areas within the Nagero Creek and regional study areas where these PCT's occur, it is assumed that all patches of Box Gum Woodland mapped in Figure 3.4 and Figure 3.5 are assumed to be consistent within the Box Gum Woodland condition criteria outlined in the community's Commonwealth Listing Advice (Threatened Species Scientific Committee, 2006) as a precautionary approach.

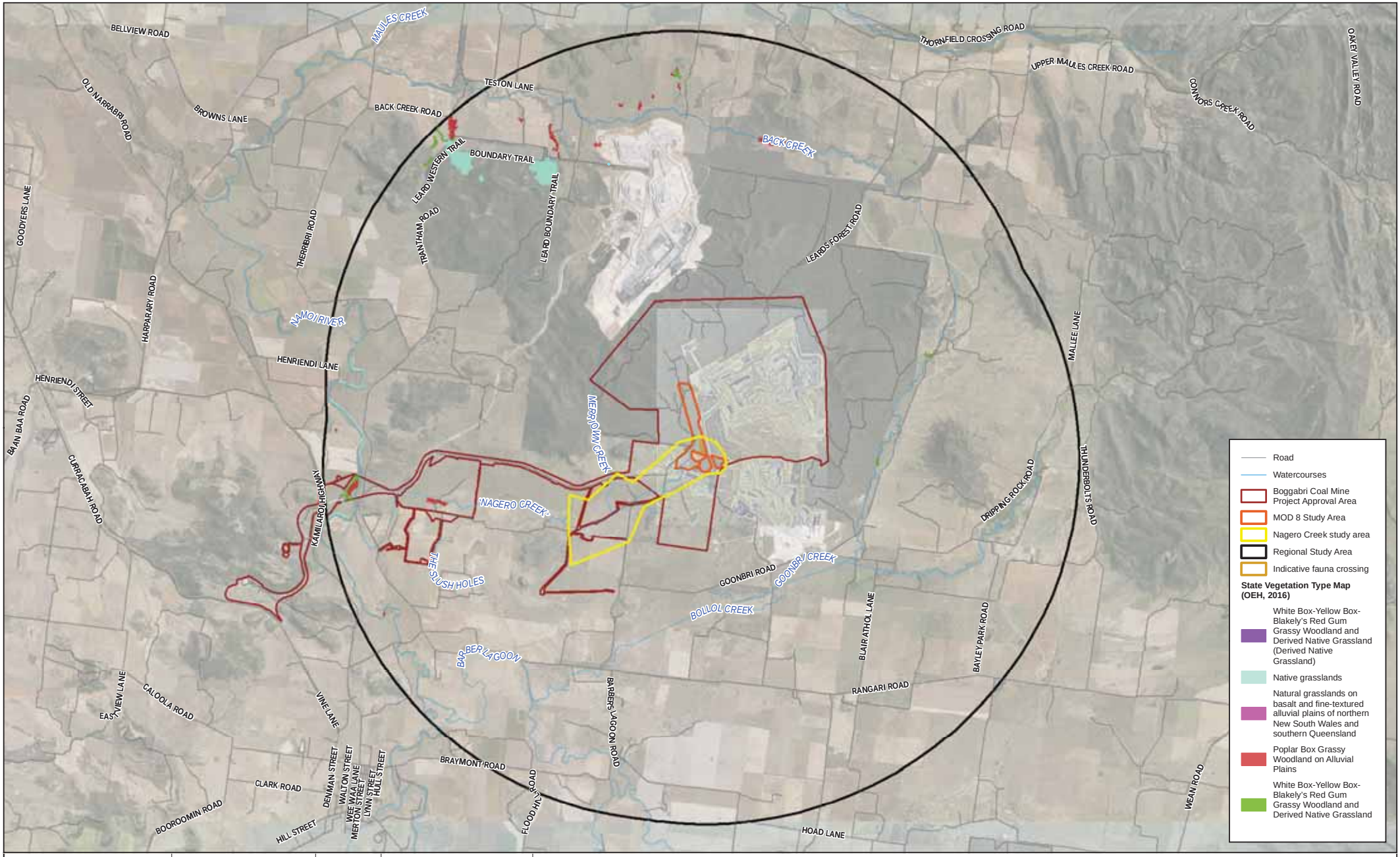


Map: BC2021_F003_4_EPBCGDE_TEC_r1v5	Author: Isaac.Augey	N	0 250 500 Meters 1:20,000 Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A3
Date: 21/07/2021	Approved by: - D.Landenberger		

Data source: Atlass-Aerometrex Pty Ltd via BCOPL (2017), Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

BOGGABRI GROUNDWATER DEPENDENT ECOSYSTEM REPORT

Figure 3.4
EPBC Act Threatened Ecological Communities in the Nagero Creek study area



Map: BC2021_F003_5_EPBC_RegStudyAreaGDE_r1v3	Author: Isaac.Augey		0 1.5 3 Kilometers 1:100,000
Date: 21/07/2021	Approved by: - D.Landenberger		Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A3

Data source: Atlass-Aerometrex Pty Ltd via BCOPL (2017).
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

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BOGGABRI GROUNDWATER DEPENDENT ECOSYSTEM REPORT

Figure 3.5
EPBC Act Threatened Ecological Communities in the Regional Study Area

4 CHARACTERISING GROUNDWATER DEPENDENCE

GDEs include a diverse range of ecosystems from those entirely dependent on groundwater to those that may use groundwater while not having a dependency on it for survival (i.e. ecosystems or organisms that use groundwater opportunistically or as a supplementary source of water) (Hatton & Evans, 1998). Eamus *et al.* (2006) considers the following broad classes of these ecosystems:

- Aquifer and cave ecosystems, where stygofauna (groundwater-inhabiting organisms) may reside within the groundwater resource. The hyporheic zones (see ecosystem 5 in Figure 4.1) of rivers and floodplains are also included in this category because these ecotones often support stygobites (obligate groundwater inhabitants).
- All ecosystems dependent on the surface expression of groundwater. This category includes base-flow rivers and streams, wetlands (see ecosystems 2 and 3 in Figure 4.1), some floodplains and mound springs and estuarine seagrass beds.
- All ecosystems dependent on the subsurface presence of groundwater, often accessed via the capillary fringe (non-saturated zone above the saturated zone of the water table) when roots penetrate this zone. This class includes terrestrial ecosystems such as River Red Gum (*Eucalyptus camaldulensis*) forests on the Murray–Darling Basin (see ecosystems 1 and 4 in Figure 4.1). No surface expression of groundwater is required in this class of GDE.

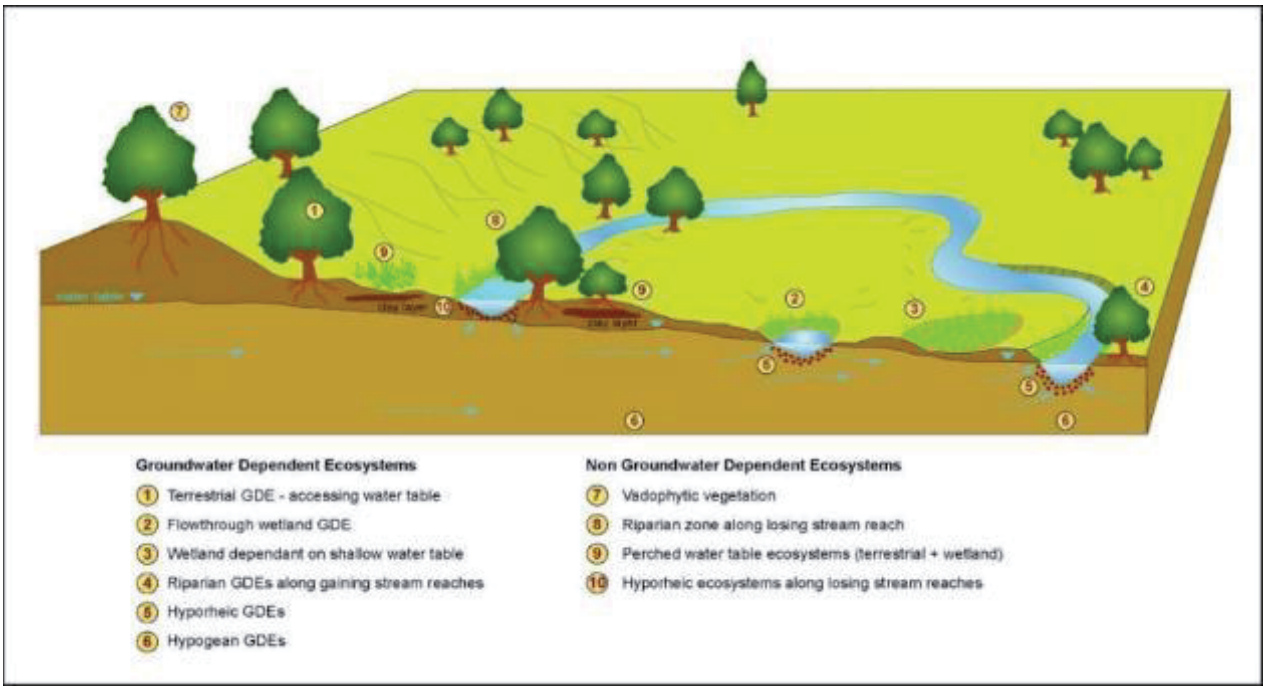


Figure 4.1 Conceptual biophysical model of groundwater dependent ecosystems (source: Eamus *et al.* 2006)

4.1 TREE ROOT DEPTH ANALYSIS

The development of tree root architecture is influenced by both the tree species and range of soil conditions. Mechanical resistance, aeration, fertility and moisture of the soil also influence rooting depth.

The majority of vegetation communities in Leard State Forest occur on slopes and ridges associated with well drained soils characterised by shallow skeletal conglomerate on steeper upper slopes and drainage lines and deep basaltic derived fertile soils on the lower slopes. Such vegetation is disconnected from localised groundwater systems as the roots are unable to grow far into soil horizons that are excessively stony. Consequently, rooting depth in areas of shallow bedrock is limited. Groundwater is not within the root zone of these vegetation types given their location in the landscape, and as such they are not groundwater dependent. These vegetation types, which includes vegetation that occurs adjacent to ephemeral streams, rely on rainfall to support growth and photosynthesis.

Ironbark and box eucalypts, such as those that dominate the lower slopes of the Leard State Forest are shallow rooted and allocate substantial biomass to above-ground parts at the expense of an expansive root system (Fensham and Fairfax, 2007). They are unlikely, therefore, to be groundwater dependent.

Riparian forests, such as the River Red Gum open forest on the banks of the Namoi River rely on the availability of groundwater below the surface but within the rooting depth of the vegetation. The loose, deep, well-drained alluvial soils with large pore spaces promote greater root depths as they are well aerated and provide less resistance to root penetration.

While loamy soils allow considerable root development, the remnant vegetation communities (such as PCT 101 Poplar Box - Yellow Box - Western Grey Box grassy woodland on cracking clay soils mainly in the Liverpool Plains, Brigalow Belt South Bioregion) restricted to the lower lying alluvial plain areas with these soils are generally associated with shallow, perched water tables over impermeable clay lenses rather than groundwater fed by subsurface aquifers. Such vegetation is likely to send roots to the perched water table but not through the impermeable clay lens.

Broad ecosystem scale studies have shown the sclerophyllous shrubland and forest (such as that in regional study area) have a mean rooting depth of 5.2 ± 0.8 m (Candell *et al.* 1996). Average rooting depth for temperate grassland has been shown to be 2.6 ± 0.2 m (Candell *et al.* 1996).

A review of literature of rooting ranging depths by Stygoecologica (2013), found that most deep-rooted woody species only extend approximately 10 mbgl. Nevertheless, in a study investigating the relationship between tree condition and groundwater depth, Kath *et al.* (2014) found a groundwater depth threshold for *Eucalyptus populnea* (Poplar Box) in the range of 12.6 mbgl to 26.6 mbgl beyond which canopy condition declined abruptly. It is postulated that this threshold response in canopy condition may be linked to rooting depth, with chronic groundwater decline decoupling trees from deep soil moisture resources.

4.2 TERRESTRIAL GDES WITHIN THE NAGERO CREEK STUDY AREA

An updated search of the Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology, 2021) identified some areas of the alluvial plain as having a low potential for vegetation reliance on subsurface groundwater. The vegetation mapped within and immediately surrounding the Nagero Creek study area by the Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology, 2021) is assessed as having a low potential to be a GDE (national assessment) (Bureau of Meteorology, 2021).

Based on field surveys for the Boggabri Coal Mine – Modification 8 Biodiversity Development Assessment Report (WSP, 2021b) and desktop assessment of the regional vegetation mapping (Office of Environment and Heritage, 2016), six PCTs and one exotic community have been recorded in the Nagero Creek study area (Table 4.1).

The dependence (or interaction) of the vegetation communities identified in the study area on groundwater was determined by aligning them with the GDE types identified by Eamus *et al.* (2006). Table 4.1 describes the list of PCTs recorded in the Nagero Creek study area and outlines their potential dependence on groundwater.

Table 4.1 Vegetation community dependency on groundwater within the Nagero Creek study area

ECOSYSTEM TYPE[1]	HYDROLOGICAL ECOSYSTEM[2]	PCTS[3]	BC ACT[4]	EPBC ACT[5]	KNOWN GROUNDWATER DEPENDENCY[6]
WSP Field verified Mapping					
Terrestrial ecosystems	7 – Vadophytic vegetation 9 – Perched water table ecosystems	PCT 88 Pilliga Box – White Cypress Pine – Buloke shrubby woodland	-	-	No apparent dependency on groundwater
	7 – Vadophytic vegetation	PCT 1313 White Cypress Pine – Narrow-leaved Ironbark shrub/grass open forest (equivalent to PCT 592)	-	-	No apparent dependency on groundwater
	7 – Vadophytic vegetation	PCT 1383 White Box grassy woodland (equivalent to PCT 435)	CEEC	CEEC	No apparent dependency on groundwater
	7 – Vadophytic vegetation	Highly disturbed areas with no or limited native vegetation			No apparent dependency on groundwater
River Base Flow	8 – Riparian zone along losing stream reach	PCT 599 Blakely's Red Gum – Yellow Box grassy tall woodland (including areas mapped as PCT 1329)	CEEC	CEEC	No apparent dependency on groundwater
Regional state-based vegetation mapping					
Terrestrial ecosystems	7 – Vadophytic vegetation	PCT 592 Narrow-leaved Ironbark – Cypress Pine – White Box shrubby open forest (equivalent to 1313)	-	-	No apparent dependency on groundwater
	7 – Vadophytic vegetation	PCT 588 White Box – White Cypress Pine shrubby hills open forest	-	-	No apparent dependency on groundwater
	1 – Terrestrial GDE – potentially accessing the water table	**PCT 101 Poplar Box - Yellow Box - Western Grey Box grassy woodland (includes area south of the coal loader)**	-	E	**Proportional dependency on groundwater**

1 Ecosystem Types as per Eamus *et al*, (2006) and Murray *et al*, (2003)
2 Hydrological ecosystem classification (Eamus *et al*, 2006)
3 PCTs mapped as per WSP (2020) and Office of Environment and Heritage (2016)
4 CEEC = Critically Endangered Ecological Community listed under the BC Act
5 CEEC = Critically Endangered Ecological Community, E = Endangered Ecological Community listed under the EPBC Act
6 Known groundwater dependency as per Hatton & Evans (1998).

4.2.1 POTENTIAL TERRESTRIAL GDES

Based on the desktop assessment and vegetation classification of GDE types identified by Murray *et al.* (2003) and Eamus *et al.* (2006), one PCT was considered to have potential to be at least partially reliant on access to groundwater (phreatophytic vegetation) in the Nagero Creek study area, including:

- PCT 101 Poplar Box – Yellow Box – Western Grey Box grassy woodland.

4.2.1.1 PCT 101 POPLAR BOX – YELLOW BOX – WESTERN GREY BOX GRASSY WOODLAND

PCT 101 Poplar Box – Yellow Box – Western Grey Box grassy woodland, which is identified as a low potential terrestrial GDE (Bureau of Meteorology, 2021), occurs on the lower lying floodplain and within the upper reaches of Nagero Creek (Figure 4.2). As PCT 101 is considered a low potential terrestrial GDE, it is not likely to be entirely dependent on groundwater; rather it is likely to be opportunistic (facultative) in its use of groundwater. Therefore, it is likely to depend on the subsurface presence of groundwater (often accessed via the capillary fringe – subsurface water just above the water table) in some locations, but not others. As the plants within PCT 101 may at times rely on capillary water in the soil that rises from the water table, any lowering of the water table may result in a reduction in groundwater availability and declining vegetation health during low rainfall periods.

Within the Nagero Creek study area the depth to the groundwater table is estimated between 7 mbgl and 10 mbgl where this community occurs (AGE, 2021). Kath *et al.* (2014) found a groundwater depth threshold for *Eucalyptus populnea* (Poplar Box) in the range of 12.6 mbgl to 26.6 mbgl beyond which canopy condition declined abruptly. Consequently, it is suggested that this threshold response in canopy condition may be linked to rooting depth. Whilst *Eucalyptus populnea* (Poplar Box) would access soil water and perched aquifers, due to their potential for extensive tap roots, they are likely to proportionally use groundwater to fulfil their requirements. Therefore, the Poplar Box – Yellow Box – Western Grey Box grassy woodland is considered a GDE due to its proportional dependence on groundwater.

4.3 VEGETATION HEALTH MONITORING

BCM currently implements monitoring programs that sample and analyse vegetation health within the alluvial plain in association with Nagero Creek and the Namoi River (Figure 6.1), including:

- stream and riparian vegetation health monitoring
- terrestrial groundwater dependent ecosystem monitoring.

Monitoring to date indicates that the condition of terrestrial vegetation health has remained relatively consistent since the commencement of the monitoring programs in 2018 (WSP, 2021a). Vegetation attributes associated with floristic composition, structure and functionality were consistent with or only showed slight increases/decreases in values since 2018. Fluctuations in some vegetation attribute values, such as per cent overstorey cover, have been observed, however this is likely attributable to severe drought conditions experienced between 2017 and 2019. Furthermore, such fluctuations were within the boundaries of the probable mean as predicted by the standard error (WSP, 2021a).

4.4 ALLUVIAL AQUIFER ECOSYSTEM

A single stygofauna crustacean species (Notobathynella (Parabathynellidae)) has previously been recorded from one groundwater monitoring bore (MW6) within the alluvial tongue situated to the south-west of BCM. The alluvial groundwater monitoring bore is positioned on Nagero Creek, with a depth to groundwater <5 mbgl (as measured in late 2018). As stygofauna was only identified from a single bore and limited to a single species, it is difficult to draw conclusions about the connectivity of the alluvial aquifer to support this and other stygofauna species. However, a wider range of stygofaunal species have been identified in the Gunnedah Coal Basin, which encompasses the Namoi River catchment and the BCM site (Korbel *et. al.* 2013). The occurrence of stygofauna in an aquifer can also be a useful indicator that an aquifer supports a broader ecological community that may include components such as bacteria and the roots of phreatophytic trees (Doody & Hancock *et. al.*, 2019).

As stygofauna are subterranean animals that live in groundwater systems, they can be critical components of the aquifer ecosystem that are themselves entirely dependent on groundwater.

4.5 GDES WITHIN THE REGIONAL STUDY AREA

A review of the Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology, 2021) identified six high potential terrestrial GDEs and one high potential aquatic GDE as occurring within regional study area (Table 4.2).

The dependence (or interaction) of the vegetation communities identified in the regional study area on groundwater was determined by aligning them with the GDEs types identified by Eamus *et al.* (2006). Table 4.3 describes the PCTs recorded in the regional study area and outlines their potential dependence on groundwater.

Table 4.2 High potential terrestrial and aquatic GDEs mapped in the regional study area

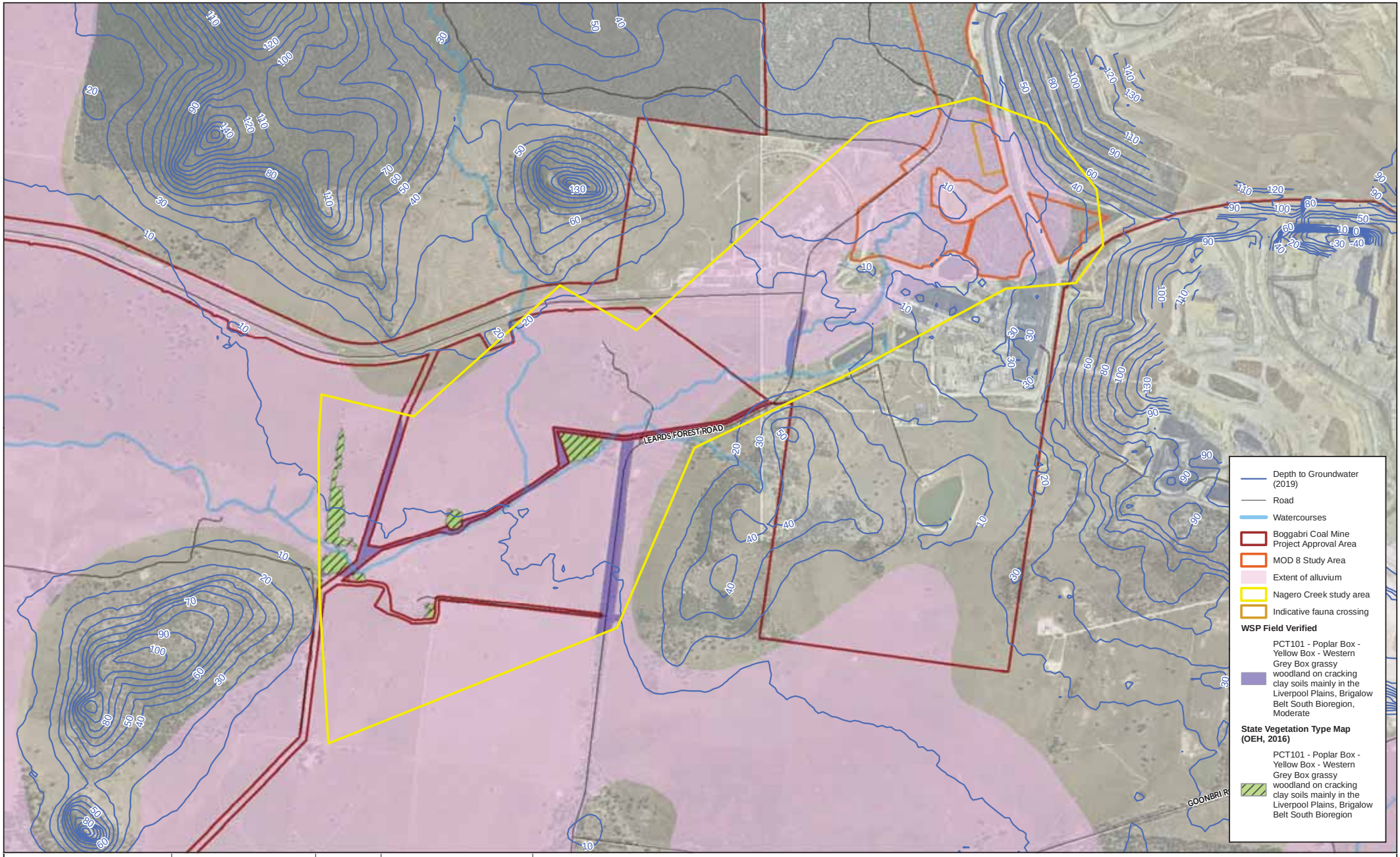
NAME	GDE POTENTIAL	ASSESSMENT
Aquatic GDEs		
Namoi River	High potential	National assessment
Terrestrial GDEs		
PCT 112 Black Tea-tree - River Oak - Wilga riparian low forest/shrubland wetland of rich soil depressions	High potential	Regional studies
PCT 599 Blakely's Red Gum - Yellow Box grassy tall woodland on flats and hills in the Brigalow Belt South Bioregion		
PCT 53 Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains		
PCT 55 Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains		
PCT 78 River Red Gum riparian tall woodland / open forest in the Nandewar Bioregion and Brigalow Belt South Bioregion		
PCT 101 Poplar Box - Yellow Box - Western Grey Box grassy woodland on cracking clay soils mainly in the Liverpool Plains		
PCT 516 Grey Box grassy woodland or open forest of the Nandewar Bioregion and New England Tableland Bioregion		

Based on the desktop assessment and vegetation classification of GDE types identified by Murray *et al.* (2003) and Eamus *et al.* (2006), four PCTs were considered to have potential to be at least partially reliant on access to groundwater and one aquatic system (Table 4.3).

Table 4.3 Potential GDEs within the regional study area

ECOSYSTEM TYPE[1]	HYDROLOGICAL ECOSYSTEM[2]	PCTS[3]	EPBC ACT[4]	KNOWN GROUNDWATER DEPENDENCY[5]	ASSOCIATED DRAINAGE LINE
Aquatic	6 - Hypogean	**Namoi River**	-	**Known dependency on groundwater**	Namoi River
Terrestrial ecosystems	7 – Vadophytic vegetation	PCT 55 Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains	-	No apparent dependency on groundwater	
	7 – Vadophytic vegetation	PCT 516 Grey Box grassy woodland or open forest of the Nandewar Bioregion and New England Tableland Bioregion	-	No apparent dependency on groundwater	-
	7 – Vadophytic Vegetation	PCT 112 Black Tea-tree – River Oak – Wilga riparian low forest/ shrubland wetland	-	No apparent dependency on groundwater	Back Creek, Goonbri Creek, Bollol Creek
River Base Flow	4 – Riparian zone along gaining stream	**PCT 78 River Red Gum riparian tall woodland / open forest**	-	**Proportional dependency on groundwater**	Namoi River,
	1 – Terrestrial GDE – potentially accessing water table	**PCT 101 Poplar Box - Yellow Box - Western Grey Box grassy woodland**	E	**Proportional dependency on groundwater**	Back Creek Alluvial floodplains
	8 – Riparian zone along losing stream	PCT 599 Blakely's Red Gum - Yellow Box grassy tall woodland	CEEC	No apparent dependency on groundwater	Namoi River, Bollol Creek Driggle Draggle Creek
	3 – Wetland dependent on shallow water table	**PCT 53 Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains**	EEC	**Potential dependency on groundwater**	Namoi River, Bollol Creek Driggle Draggle Creek Maules Creek

1 Ecosystem Types as per Eamus *et al*, (2006) and Murray *et al*, (2003)
2 Hydrological ecosystem classification (Eamus *et al*, 2006)
3 PCTs mapped as per WSP (2020) and Office of Environment and Heritage (2016)
4 CEEC = Critically Endangered Ecological Community listed under the BC Act
5 CEEC = Critically Endangered Ecological Community, E = Endangered Ecological Community listed under the EPBC Act
6 Known groundwater dependency as per Hatton & Evans (1998).



Map: BC2021_F004_2_GroundwaterDepth_r1v7	Author: Isaac.Augey	N	0 250 500 Meters 1:20,000 Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A3
Date: 21/07/2021	Approved by: - D.Landenberger		

Data source: Atlass-Aerometrex Pty Ltd via BCOPL (2017), Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

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BOGGABRI GROUNDWATER DEPENDENT ECOSYSTEM REPORT

Figure 4.2
GDEs within the Nagero Creek Study Area and Depth to Groundwater

5 POTENTIAL CUMULATIVE IMPACTS

5.1 NAGERO CREEK STUDY AREA

5.1.1 CUMULATIVE DRAWDOWN IMPACTS

There are three operating mines that have a potential cumulative effect on the alluvial aquifer associated with the Nagero Creek study area, including BCM, TCM and MCCM. At a regional scale, the alluvium is generally thickest within the main Namoi River alluvial plain, thinning towards the edges of the plain and along tributaries (NcNeilage, 2006). There is a small tongue of the alluvial aquifer that is directly adjacent to the south-west corner of BCM, which is associated with the Nagero Creek; a minor watercourse that is fed from the catchment area occupied by BCM (AGE, 2021).

Detailed studies indicate that groundwater levels are typically 7mbgl to 10 mbgl on the alluvial plain but can be deeper in places upslope towards the outcropping Boggabri Volcanics (Parsons Brinckerhoff, 2010 & 2015, AGE 2010). Additionally, groundwater levels are shallower in the vicinity of drainage depressions and creeks, as observed in areas proximate to Nagero Creek with MW6 (near BCM infrastructure) recording groundwater <5 mbgl during stygofauna sampling in late 2018.

Mining induced impacts to the alluvial groundwater system are yet to be observed and no groundwater modelling undertaken to date predicts any significant alluvial drawdown. Cumulative modelling undertaken for MOD 8 presents alluvial drawdown in 2036, which coincides with the end of proposed mining for the BTM Complex (including the proposed extension to mine life for MOD 8). Drawdown at this time and attributable to MOD 8 is limited to the small tongue of alluvium directly south-west of BCM and adjacent to areas where the TCM void extends into the alluvium (AGE 2021). Any increases in alluvial drawdown that can be attributed to MOD 8 are expected to be minimal, if any.

Cumulative drawdown predicted within the alluvium is generally less than 2 m for current approved mining and MOD 8. The predicted drawdown exceeds 2 m in a small portion of the alluvial tongue that is directly south-west of BCM, where a maximum drawdown of approximately 5 m is predicted. Drawdown directly attributable to MOD 8 is only predicted within this area and reaches a maximum of approximately 0.8 m (AGE, 2021). Moving away from the BCM, to the south-west of the Nagero Creek study area, the cumulative drawdown within the alluvium is predicted to be less than 1 m (Figure 5.1).

5.1.2 POTENTIAL IMPACTS TO GDES

The Nagero Creek study area has been historically modified for agricultural and much of its original vegetation (canopy and shrub layers) has been removed. Although some small patches of native vegetation exist on the alluvial plain, most of the remaining vegetation occur in adjacent areas of higher elevation, which are comprised of volcanic outcropping. Nevertheless, one remnant native vegetation community recorded on the alluvial plain was considered to have at least partial dependency on groundwater, being Poplar Box – Yellow Box – Western Grey Box grassy woodland (PCT 101).

PCT 101 has potential to align to the Poplar Box Grassy Woodland on Alluvial Plains TEC which was listed under the EPBC Act on the 4 July 2019. As all field validated vegetation mapping within the BCM Project Boundary and BOAs were conducted prior to 2019, areas of native vegetation in the Nagero Creek and regional study areas with potential to meet the EPBC Act listing have not yet been assessed against the TECs key diagnostic characteristics or condition thresholds. As such, a precautionary approach has been applied and it is assumed for the purposes of this investigation that all remnant patches previously mapped as PCT 101 and areas of PCT 88 on the Namoi alluvial floodplain meet the EPBC Act listing. Field verification of remnant patches previously mapped as PCT 101 and PCT 88 on the alluvial plain are required to be undertaken to confirm whether they meet the characteristics and thresholds of this TEC.

For many terrestrial plants, groundwater forms only part of their overall water balance. Vegetation will extract water from sources where the combination of soil moisture content, root density and hydraulic connectivity requires the least amount of energy (Stygoecologica, 2013). Accordingly, vegetation will use shallow soil water first before seeking

groundwater. Where soil water is insufficient to meet plant water requirements, plants that can access groundwater will become increasingly dependent on that water source as soil water is depleted (Howe *et al.*, 2007).

GDEs that rely solely on groundwater are particularly at risk from water level fluctuations due to roots being distributed just above the water table in the vadose zone (the unsaturated zone above the water table). The viability of these GDEs are likely influenced by groundwater regime parameters, such as alteration of water level and pressure regimes (Stygoecologica, 2013). *Eucalyptus* spp. have a dual (dimorphic) roost system, with lateral roots that are close to the surface, and a taproot that penetrates deep in the soil (Holloway *et al.*, 2013). Therefore, these species can source water from multiple sources (i.e. surface water, soil moisture after rainfall or flooding, and groundwater). Their reliance and use of groundwater are therefore potentially facultative (optional).

A review of literature of rooting ranging depths by Stygoecologica (2013) found that deeper rooting depths down to 30 mbgl or greater for larger tree species are an exception, with most deep-rooted woody species only extending approximately 10 mbgl. In a study by Kath *et al.* (2014), *Eucalyptus populnea* (Poplar Box) was observed to have a tree condition to groundwater depth threshold between 12.6 mbgl and 26.7 mbgl before the canopy showed signs of dieback, suggesting that the species has extensive tap roots capable of accessing alluvial groundwater.

Patches of Poplar Box – Yellow Box – Western Grey Box grassy woodland (PCT 101) occurring in the Nagero Creek study area typically occur where groundwater levels are less than 10 mbgl (Figure 4.2). Therefore, PCT 101's reliance on groundwater in the Nagero Creek study area cannot be discounted and this community has the potential to be impacted. Cumulative drawdown predicted within the alluvium of the Nagero Creek study area that may affect this terrestrial GDE is less than 2 m for current approved mining and MOD 8. Therefore, it is not likely that this potential terrestrial GDE would be substantially impacted by the modelled groundwater drawdown in the alluvium (Figure 5.1).

5.1.3 RISK ASSESSMENT

A risk assessment was conducted that considered the method outlined in Serov *et al.* (2012) to determine if the GDEs within the study area is at high, moderate or low risk from the potential impacts. Based on the risk assessment presented in Serov *et al.* (2012), the alluvial aquifer was considered of high ecological value due to:

- the presence of stygofauna
- the presence of patches of PCT 101 Poplar Box – Yellow Box – Western Grey Box grassy woodland, which without field verification, are assumed to meet the condition thresholds of Poplar Box Grassy Woodland on Alluvial Plains TEC.

Table 5.1 provides an initial assessment for consideration of the magnitude of the risk to the alluvial aquifer and potential terrestrial GDEs. The assessment allows for a high-level examination of the potential impacts and allows the impacts to be ranked based on a high, medium, or low rating. Cumulative impacts associated with current mining operations and MOD 8 is considered to have a low risk of potential impact to terrestrial GDEs (Table 5.1).

Table 5.1 Aquifer and GDE risk assessment

RISK FACTOR	HIGH	MODERATE	LOW	INSUFFICIENT DATA
Water quantity asset				
What will the risk of a change in groundwater levels/ pressure on GDEs?	Predicted reduction in groundwater levels beyond seasonal variation	–	–	–
What will be the risk of a change in the timing or magnitude of groundwater level fluctuations on GDEs?	Predicted fluctuation in groundwater levels potentially beyond seasonal variation	–	–	–
What will be the risk of changing base flow conditions of GDEs?	–	–	Outside of the mined areas, there is no expected change in the direction of flow	–
Water quality asset				
What is the risk changing the chemical conditions of the aquifer?	–	–	Predicted negligible change	–
What is the risk on the aquifer by a change in the freshwater/ saltwater interface?	–	–	Predicted negligible change	–
What is the likelihood of a change in beneficial use on the aquifer?	–	–	Predicted negligible change	–
Aquifer integrity asset				
What is the risk of damage to the geologic structure?	–	–	–	Uncertain
Biological integrity asset				
What is the risk of alterations to the number of native species within the groundwater dependent communities (flora and fauna)?	–	–	Predicted limited reduction to deep-rooted canopy species, however, given partial dependency on groundwater, they are unlikely to be removed completely	–
What is the risk of alterations to the species composition of the groundwater dependent communities (flora and fauna)?	–	–	Predicted negligible change to PCT 101 in the form of potential partial impacts to canopy	–
What is the risk of increasing the presence of exotic flora or fauna?	–	–	Predicted negligible change	–
What is the risk of removing or altering a GDE subtype habitat, e.g. quarrying of limestone around karsts, tramping of cave habitats, sand and gravel extraction?	–	–	–	Uncertain
Risk valuation	**2**	**0**	**7**	**2**
Risk			**Low risk**	

Note: These rankings are indicative only and are means of reaching a descriptive rating for the purpose of the risk assessment. They do not necessarily represent real quantities and should not be used in any other context.

The risk assessment detailed in Serov *et al.* (2012) is a method of outlining the most appropriate management response for a given environmental value under a particular activity. The risk matrix is a component of adaptive management and was designed to recommend the most appropriate management strategies and to test the effectiveness of the management strategies over a time period by combining a monitoring program with an effective framework for adaptive management.

Management strategies for an aquifer and its associated GDEs are based on the comparison of the ecological value of the aquifer and its associated GDEs, against the risk to them by the proposed or current activity (Serov *et al.* 2012). Table 5.2 details management actions proposed by Serov *et al.* (2012) based on the high ecological value of the alluvial aquifer and potential terrestrial GDEs (PCT 101) associated with Nagero Creek, and the predicted low magnitude of risk (Table 5.1).

Table 5.2 Risk matrix management actions (Serov *et al.* 2012)

RISK DESCRIPTOR	MANAGEMENT ACTION FOR SHORT TERM	MANAGEMENT ACTION FOR MID TERM	MANAGEMENT ACTION FOR LONG TERM
High value / low risk	Protection measures for aquifer and GDEs	Continue protection measures for aquifers and GDEs	Adaptive management Continue monitoring
	Baseline risk monitoring	Periodic monitoring and assessment	

BCM currently implements several monitoring programs associated with terrestrial GDEs to satisfy the requirements detailed in the WMP and GWMP, including:

- stream and riparian health monitoring program
- terrestrial vegetation health and composition monitoring program
- stygofauna monitoring.

These programs and the requirement for additional monitoring is described in further detail in Section 6.

5.2 REGIONAL STUDY AREA

There are three coal mines currently operating within the regional study area that are collectively contributing to groundwater impacts. These three mines include the BCM, TCM and the MCCM which are collectively known as the BTM Complex. The cumulative impacts of the BTM Complex on groundwater are routinely assessed using a 3D numerical groundwater flow model which has been refined and updated over the past ten years (AGE, 2021) (Figure 5.2).

The current version of the BTM Complex 3D numerical groundwater flow model was used to simulate potential impacts associated with the BCM current mining impacts and any additional impacts that may arise due to MOD 8. The simulation predicted that any declines in the water table and water pressure would predominantly be due to the existing active mine operations whilst the incremental impact of MOD 8 would be negligible (AGE, 2021).

A summary of the predicted impacts on groundwater within the regional study area is provided below in Section 5.2.1 to Section 5.2.3.

5.2.1 REGIONAL CUMULATIVE IMPACTS

The Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology, 2021) has mapped high potential GDEs as occurring along Back Creek, Namoi River, Barber's Lagoon, Maules Creek, Goonbri Creek and its unnamed tributaries as well as the upper reaches of Bollol Creek within the regional study area.

AGE (2021) have predicted that the cumulative groundwater drawdown impacts beneath potential high priority GDEs mapped by the Bureau of Meteorology (2021), is as follows:

- less than 0.5 m cumulative drawdown in terrestrial GDEs adjacent to small parts of Goonbri Creek and Bollol Creek

- up to 40 m cumulative drawdown in the water table in GDEs adjacent to Back Creek
- up to 5 m of cumulative drawdown in the water table in the upper reaches of Goonbri Creek.

Several of the areas predicted to be impacted have been previously assessed as part of other environmental assessments completed for the BTM Complex and the Vickery Extension Project (AGE, 2021). A brief discussion on each of the above creeks and potential impacts associated with the cumulative impacts from MOD 8 are provided below.

5.2.2 BACK CREEK

The Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology, 2021) has mapped Back Creek in the north of the MCCM as being a high potential terrestrial GDE based on regional studies (2021). The vegetation along Back Creek has been previously mapped by Cumberland Ecology (2011) to consist of riparian vegetation dominated by *Melaleuca bracteata* (Black Tea-tree) which concurs with the broad-scale vegetation mapping which has mapped PCT 112 Black Tea-tree – River Oak – Wilga riparian low forest/ shrubland wetland of rich soil depressions in the Brigalow Belt South Bioregion (PCT 112) (Office of Environment and Heritage, 2016).

Cumberland Ecology (2011) determined that the riparian vegetation along Back Creek was unlikely to be a GDE as *Melaleuca bractaeata* was expected to have a root zone depth of 2-3 mbgl whilst the groundwater monitoring showed that the groundwater was greater than 10 mbgl below the surface thereby suggesting that the *Melaleuca bracteata* riparian vegetation at this location is unlikely to be accessing or dependent upon groundwater.

Simulated depth to groundwater modelling completed by AGE (2021) suggests that there are sections along Back Creek where groundwater is between 0.1 mbgl to 10 mbgl (Figure 5.2). This shallow simulated depth to groundwater (AGE, 2021) and the fact that *Melaleuca bracteata*, like other *Melaleuca* species in the Namoi Catchment Management Authority (Stygoecologia, 2013), are considered to have shallow rooting depths suggests that this community is likely to have access to groundwater at least along some sections of Back Creek. Despite this, there are large portions of Back Creek simulated to have groundwater depths >10 mbgl and up to 40 mbgl (AGE, 2020) suggesting that PCT 112 is unlikely to be totally reliant on groundwater and therefore not considered to be a terrestrial GDE.

5.2.3 GOONBRI CREEK AND BOLLOL CREEK

The Bureau of Meteorology has mapped areas of Goonbri Creek as having high potential to be a terrestrial GDE based on regional studies (2021). Florasearch (2011) also identified a potential terrestrial GDE associated with *Melaleuca bracteata* riparian vegetation along Goonbri Creek and Bollol Creek (i.e. Bracteata Honeymyrtle Riparian Forest). This vegetation is consistent with the broad-scale vegetation mapping which has mapped PCT 112 as also occurring along these creek lines (Office of Environment and Heritage, 2016).

As part of the TCM environment assessment, potential impacts to *Melaleuca bracteata* riparian vegetation along Goonbri Creek and Bollol Creek were considered. The assessment concluded that the project would not have a significant impact on the potential GDE (Resource Strategies, 2011).

Similarly to Back Creek, there are sections along Goonbri Creek where the depth to groundwater has been simulated to be between 0-10 mbgl (AGE, 2021) (Figure 5.2). Despite this, there are also portions of Goonbri Creek containing that contain *Melaleuca bracteata* riparian vegetation where the depth to groundwater is >10 mbgl similar to the riparian vegetation along Back Creek (AGE, 2020). Although riparian vegetation along Goonbri Creek may have access to groundwater at least along some sections of the waterway it is unlikely to be totally reliant upon it and therefore not considered to be a terrestrial GDE.

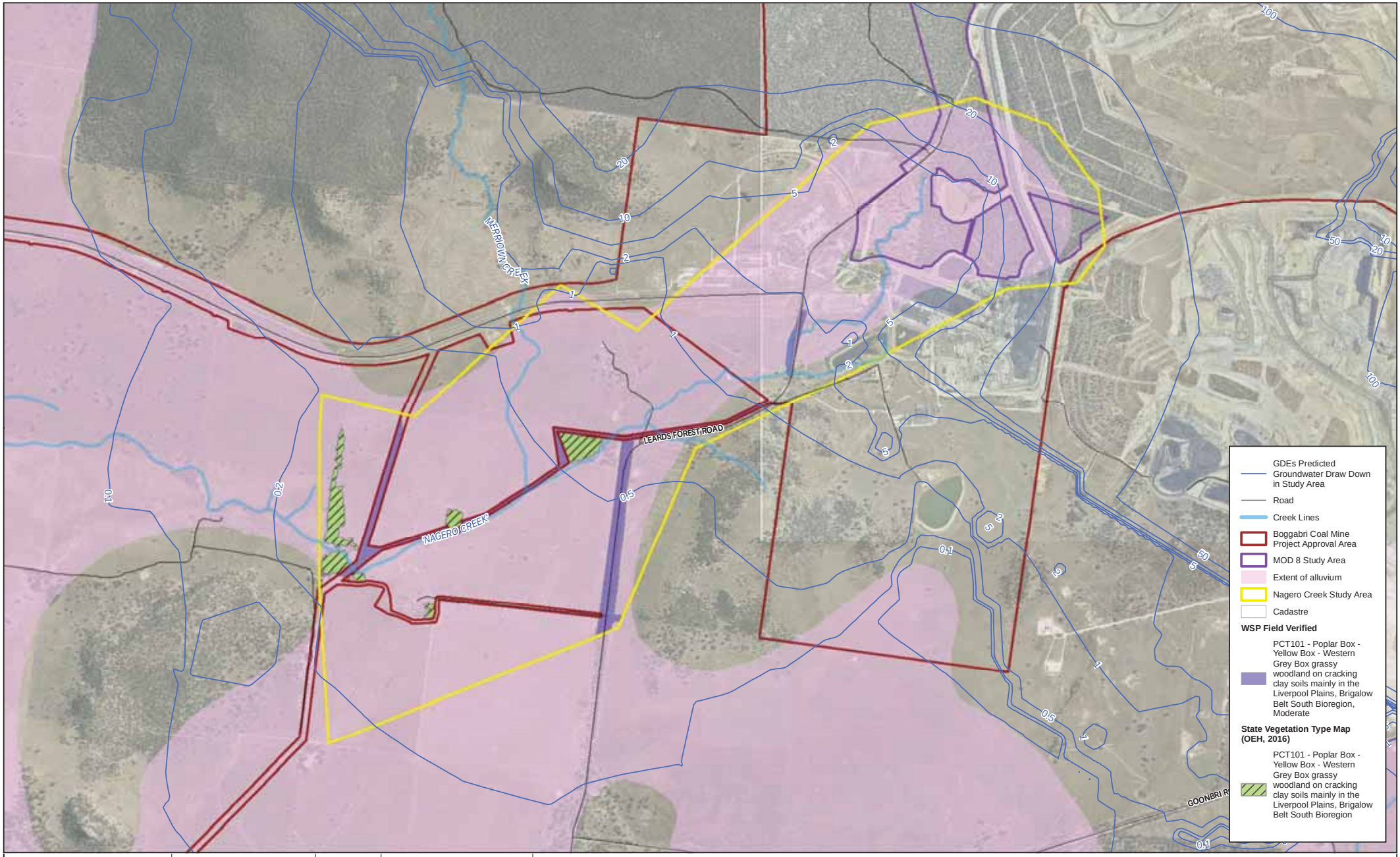
Similarly, depth to groundwater along Bollol Creek has been simulated to be 10-20 mbgl (AGE, 2021) (Figure 5.2). As *Melaleuca bracteata* have shallow root systems likely to extend only 2-3 mbgl (Cumberland Ecology, 2011) the species is not considered likely to access or be reliant upon groundwater along Bollol Creek and therefore is not a terrestrial GDE. Furthermore, as the cumulative impacts along Bollol Creek are likely to be less than 0.5 m, this vegetation community is not considered likely to be impacted upon by the predicted cumulative groundwater drawdown impacts.

5.3 IMPACTS ON MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE

An assessment of vegetation occurring within the Nagero Creek study area identified the presence of one remnant native vegetation community on the alluvial plain which is considered to have at least partial dependency on groundwater, being PCT 101 Poplar Box – Yellow Box – Western Grey Box grassy woodland. In the absence of field verification, this assessment has conservatively assumed that this vegetation community is consistent with the Poplar Box Grassy Woodland on Alluvial Plains Endangered Ecological Community listed under the EPBC Act (includes remnant patches of PCT 101).

Cumulative drawdown predicted within the alluvium of the Nagero Creek study area which may affect this terrestrial GDE is less than 2 m for current approved mining and MOD 8. The predicted drawdown exceeds 2 m in a small portion of the alluvial tongue that is directly south-west of BCM, where a maximum drawdown of approximately 5 m is predicted. Drawdown directly attributable to MOD 8 is only predicted within this area and reaches a maximum of approximately 0.8 m (AGE, 2021).

An Assessment of Significance has been completed to assess the predicted groundwater drawdown impacts associated with MOD 8 on Poplar Box Grassy Woodland on Alluvial Plains TEC listed under the EPBC Act (Appendix A). This Assessment of Significance concluded that any cumulative impacts on this TEC within the Nagero Creek study area is likely to be negligible and not result in a significant impact.

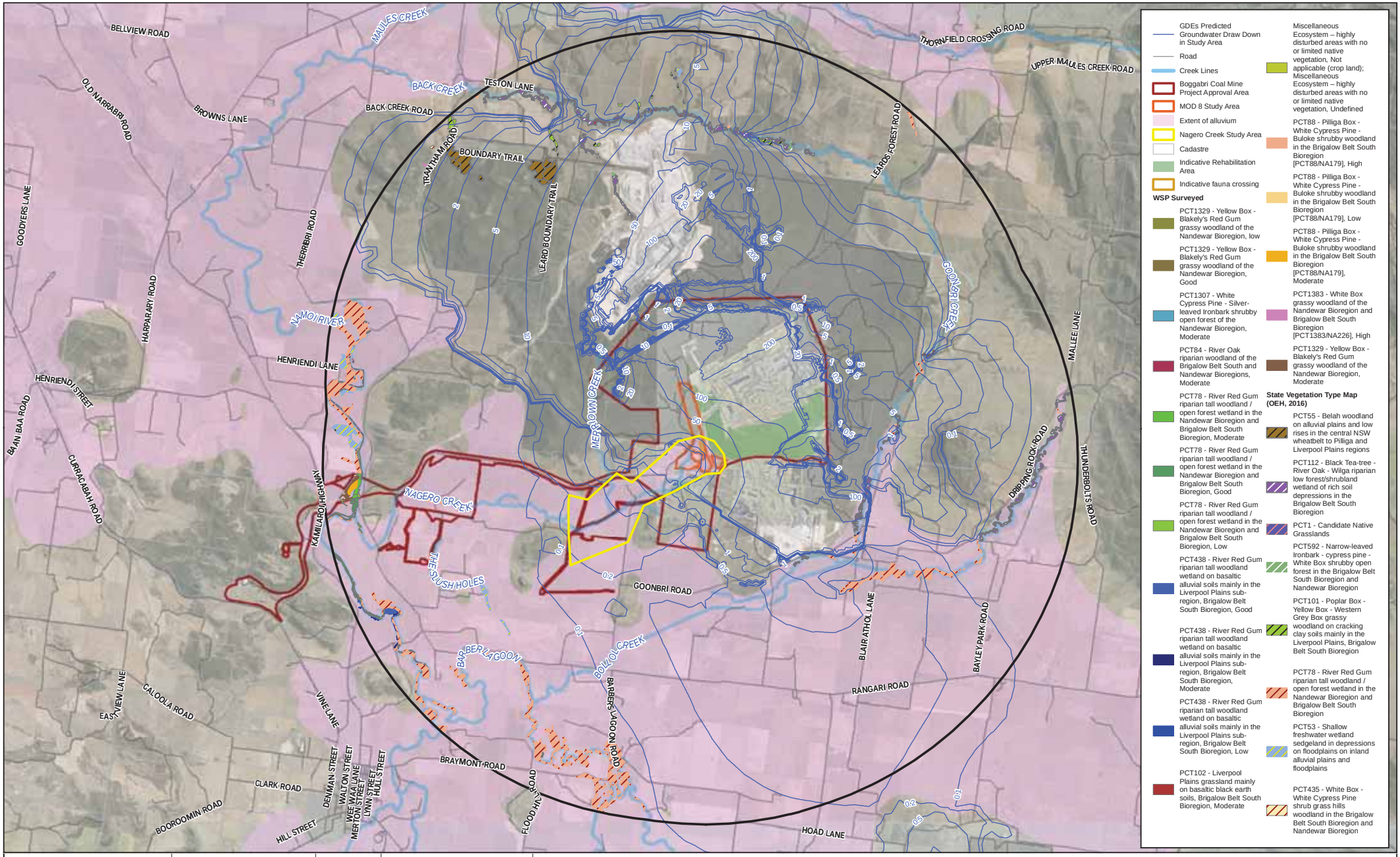


Map: BC2021_F005_1_PotentialGDEsNagero_r1v7	Author: Isaac.Augey	N	0 250 500 Meters 1:20,000
Date: 21/07/2021	Approved by: - D.Landenberger		Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A3

Data source: Atlass-Aerometrex Pty Ltd via BCOPL (2017).
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

BOGGABRI GROUNDWATER DEPENDENT ECOSYSTEM REPORT

Figure 5.1
Potential GDEs and Modelled Predicted Cumulative Groundwater Drawdown (Nagero Creek Study Area)



Map: BC2021_F005_2_PotentialGDEsRegional_r1v3	Author: Isaac.Augey		0 1 2 Kilometers
Date: 21/07/2021	Approved by: - D.Landenberger		1:100,000
Data source: Atlass-Aerometrex Pty Ltd via BCOPL (2017). Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community			Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A3

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BOGGABRI GROUNDWATER DEPENDENT ECOSYSTEM REPORT

Figure 5.2

Potential GDEs and Modelled Predicted Cumulative Groundwater Drawdown (Regional Study Area)

6 MANAGEMENT MEASURES

6.1 CURRENT MANAGEMENT PLANS AND MONITORING

6.1.1 CURRENT MANAGEMENT PLANS

As specified in the *'Groundwater Impact Assessment Boggabri Coal Mine Modification 8 to SSD 09_0182'* (AGE, 2021) report, BCM operates under the project's approved Water Management Plan (WMP) (Boggabri Coal Operations Pty Ltd, 2017b), Groundwater Management Plan (GWMP) (BCOPL, 2017a) as well as the BTM Complex's (BTMs) Groundwater Management Strategy (Resource Strategies, 2019). These management plans were prepared in consultation with relevant NSW government authorities in accordance with each BTM Complex mine's planning approval (SSD 09_0182 for BCM) due to potential impacts on surface and groundwater systems associated with the project.

In accordance with the SSD 09_0182, these management plans incorporate requirements for monitoring and assessing terrestrial GDEs (including stygofauna) and stream and riparian vegetation health. The specific requirements for the monitoring and assessment of water stipulated in SSD 09_0182, and therefore already included in the SWMP and GWMP, are summarised below in Table 6.1.

Table 6.1 BCM Conditions of approval relevant to stygofauna, GDEs and stream and riparian vegetation health

CONDITION OF APPROVAL	REQUIREMENT
Schedule 3 Condition 38	The proponent shall prepare and implement a Water Management Plan for the project to the satisfaction of the Secretary. This plan must be prepared in consultation with OEH, DPI Water, North West LLS and the CCC, by suitably qualified and experienced person/s whose appointment has been approved by the Secretary, and be submitted to the Secretary for approval within 6 months of the date of this approval… (which shall include)
	B) A Surface Water Management Plan, which includes:
	— Performance criteria for the following, including trigger levels for investigating any potentially adverse impacts associated with the project. — Stream and riparian vegetation health, including the Namoi River.
	C) A Groundwater Management Plan, which includes:
	— Detailed baseline data of groundwater levels, yield and quality in the region, and privately-owned groundwater bores including a detailed survey/schedule of groundwater dependent ecosystems (including stygofauna), that could be affected by the project.
	— A program to monitor and assess: — Groundwater dependent ecosystems (including potential impacts on stygofauna and riparian vegetation).

CONDITION OF APPROVAL	REQUIREMENT
	— Modification 5 (MOD5) specific monitoring requirement: — To assess the impacts of the borefield on the native vegetation, monitoring of health and composition of the terrestrial vegetation, which will include biannual vegetation monitoring within the locality of MOD5 and proposed draw down impacts will be conducted to identify potential poor vegetation health associated with the groundwater extraction. If impacts are identified they will be assessed against water levels in groundwater monitoring bores and climatic conditions to identify any potential correlation between vegetation health and groundwater extraction. The result of the monitoring will be reported in the Annual Review.

6.1.2 EXISTING MONITORING PROGRAMS BEING IMPLEMENTED

The current monitoring programs associated with terrestrial GDEs being implemented by BCM to satisfy the requirements details in the WMP and GWMP include:

- Stream and riparian health monitoring program (five permanent monitoring locations situated along Nagero Creek and the Namoi River) which includes the collection of the follow data from each monitoring location on an annual basis:
  - quantitative transect/plot survey as described in Section 2.1.1, Insert 5 and Table 7.2 of the Biodiversity Management Plan (WSP, 2018) which captures the general structure, health, floristic composition, habitat attributes, weed invasion and disturbances at each location
  - photographic monitoring of the vegetation and immediate landscape along the 50 m transect
  - qualitative and observational physical stream characteristics including waterway type, average size of the stream channel (width/depth), stream bed composition, flow category and water clarity, surrounding water abstractions, surrounding land uses and disturbances, riparian corridor and general seasonal weather conditions leading up to each monitoring event.
- Terrestrial vegetation health and composition monitoring program (11 permanent monitoring locations (includes the five stream and riparian heath monitoring sites) situated along the Namoi River floodplain within PCT 101 and PCT 78) which includes collecting the following data from each monitoring location on a biannual basis (autumn and spring):
  - quantitative transect/plot survey as described in Section 2.1.1, Insert 5 and Table 7.2 of the Biodiversity Management Plan (WSP, 2018) which captures the general structure, health, floristic composition, habitat attributes, weed invasion and disturbances at each location
  - photographic monitoring of the vegetation and immediate landscape along the 50 m transect.
- Stygofauna bore monitoring (GDE bore monitoring locations situated along the Namoi River floodplain) which includes the following procedure at each groundwater monitoring bore on an annual basis:
  - photographic monitoring of bore and surroundings (including native vegetation and immediate landscape)
  - depth of bore
  - in-situ water quality testing (if conductivity less than 1500 µS/cm sampling continues)
  - net dipped and raised through the water column six times (three with a 150 µm mesh size net and three times with a 50 πm mesh)
  - samples placed into a tray, stained with rose Bengal and preserved in ethanol

- sample analysed in a laboratory under a microscope to identify any potential stygofauna present.

The above monitoring programmes have been regularly implemented since the baseline monitoring session in 2018 to establish and monitor baseline conditions of stream, riparian and terrestrial vegetation health and stygofauna associated with the Namoi River floodplain aquifer.

6.2 RECOMMENDATIONS

The Poplar Box Grassy Woodland on Alluvial Plains TEC was only listed under the EPBC Act on the 4 July 2019. As all field validated vegetation mapping within the BCM Project Boundary and BOAs were conducted prior to 2019, areas of native vegetation in the Nagero Creek and regional study areas with potential to meet the EPBC Act listing have not yet been assessed against the TECs key diagnostic characteristics or condition thresholds. As such, given field verification was unable to be undertaken for inclusion within this assessment due to time constraints, a precautionary approach has been applied and it is assumed for the purposes of this investigation that all remnant patches previously mapped at PCT 101 and areas of PCT 88 on the Namoi alluvial floodplain meet the EPBC Act listing. The only exception to this is areas of derived native grasslands, which do not form part of the Poplar Box Grassy Woodland on Alluvial Plains EPBC Act listing, unless they form part of a patch. It is recommended that field verification of remnant patches previously mapped as PCT 101 and PCT 88 on the alluvial plain be undertaken to confirm whether they meet the characteristics and thresholds of this TEC.

It is also recommended that the existing monitoring programs required under the BCM WMP/GWMP and the BTM WMP be continued. As only a single terrestrial GDE monitoring location (i.e. Na11) occurs within the Nagero Creek study area which is likely to be impacted upon by potential cumulative drawdown impacts associated with the BCM and MOD 8 (in conjunction with the neighbouring MCCM and BCM), it is recommended that additional terrestrial, stream and stygofauna monitoring locations be added to this area within the extent of the alluvium. The additional monitoring locations should target the potential terrestrial GDEs identified in this report (i.e. PCT 101 and stygofauna habitat). As the remaining existing monitoring locations are situated outside the Nagero Creek study area and not considered likely to be impacted by the cumulative draw-down impacts associated with MOD 8 they will function as reference sites for the additional monitoring locations identified in Table 6.2 and illustrated in Figure 6.1.

The purpose of these additional monitoring locations would be to monitor existing baseline conditions as well as the potential impacts of the increased depth of mining at BCM to evaluate the success or failure of the mitigation measures implemented to reduce possible terrestrial GDE impacts associated with MOD 8 as specified in the MOD 8 BDAR (WSP, 2021b), GIA (AGE, 2021) and other supporting documents.

Indicative locations and the rationale for the proposed additional monitoring locations are provided in Table 6.2 and illustrated in Figure 6.1.

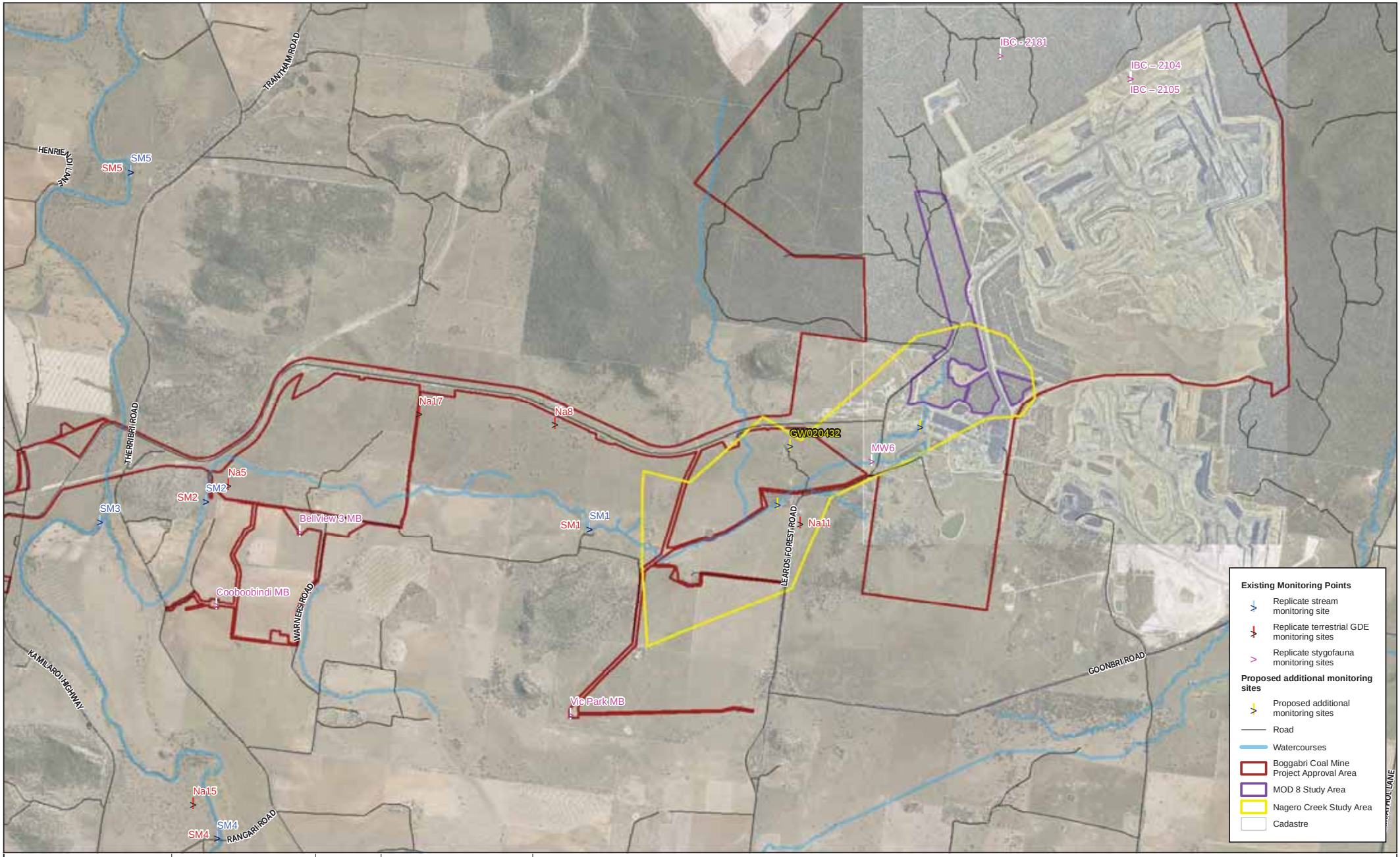
Table 6.2 Additional monitoring locations recommended

LOCATION	TYPE OF MONITORING REQUIRED	RATIONALE
Location 1 – located along Nagero Creek south of BCM entrance access road	Terrestrial vegetation GDE and stream monitoring	Located within the study area and extent of terrestrial GDEs likely to be impacted upon by the project and MOD 8. If impacts on terrestrial GDEs are identified at this location during monitoring it will enable adaptive management to be implemented i.e. rehabilitation of affected areas.
Location 2 – located along Nagero Creek within PCT 101 west of LSF road somewhere within Victoria Park property	Terrestrial vegetation GDE and stream monitoring	Located in PCT 101 within the study area and extent of terrestrial GDEs likely to be impacted upon by the project and MOD 8. If impacts on terrestrial GDEs are identified at this location during monitoring it will enable adaptive management to be implemented i.e. rehabilitation of affected areas.
GW020432	Stygofauna bore hole monitoring	GW020432 is located within the study area and extent of alluvium likely to be impacted upon by the project and MOD 8. If impacts on stygofauna are identified at this bore hole during monitoring it will enable adaptive management to be implemented i.e. rehabilitation of affected areas.

Another recommendation is that canopy condition (i.e. noting observations of any canopy dieback or water stress if evident taking into consideration seasonal conditions e.g. drought stress) be specifically targeted as part of the existing monitoring programs where appropriate to assist in detecting any changes in terrestrial GDE health overtime in response to MOD 8. This is recommended as canopy decline has been shown to be connected to and be an indicator of groundwater disconnection especially for impacts over extended periods of time. Specifically, this relationship has been shown to include instances of severe dieback of *Eucalyptus camaldulensis* (River Red Gum) and *Eucalyptus populnea* (Poplar Box) (Kath *et al*., 2014) both of which occur along the Namoi River floodplain within PCT 101.

Targeting canopy health has been recommended as it is considered the key stratum of PCT 101 considered likely to be affected by potential groundwater drawdown impacts associated with MOD 8 given their estimated root depths (approximately extend between 12-26 mbgl) and the depth of groundwater within the Nagero Creek study area (between 7-10 mbgl). Canopy species such as *Eucalyptus populnea* (Poplar Box) and *Eucalyptus camaldulensis* (River Red Gum) will represent key indicators to assist in the early detection of mitigation measures failure and trigger adaptive management responses.

Given the specific impacts to groundwater assets are predicted to be minimal relative to the approved mining (AGE, 2021) rehabilitation actions are not recommended. The only exception to this would be where impacts associated with the MOD 8 GDE draw-down impacts are observed by the above monitoring programs. Where impacts are observed, it is recommended that rehabilitation actions be conducted in the affected areas to remediate impacts.



Map: BC2021_F006_1_MonitoringLocations_r1v3	Author: Isaac.Augey		0 500 1,000 Meters 1:40,000 Coordinate system: GDA 1994 MGA Zone 56 Scale ratio correct when printed at A3
Date: 21/07/2021	Approved by: - D.Landenberger		

Data source: Atlass-Aerometrex Pty Ltd via BCOPL (2017).
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

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BOGGABRI GROUNDWATER DEPENDENT ECOSYSTEM REPORT

Figure 6.1
Existing and proposed monitoring locations

7 CONCLUSION

BCOPL is seeking a modification to SSD 09_0182 under Section 4.55(2) of the EP&A Act to increase the depth of approved mining operations, and to construct a fauna movement crossing over the existing haul road at BCM (MOD 8). The Commonwealth DAWE has determined that the proposed MOD 8 would be a controlled action under the EPBC Act (MP 09_0182 Mod 8) (EPBC 2021/8875). The MOD 8 SEARs relevant to MNES (i.e. a water resource, in relation to coal seam gas development and large mining development), included an assessment on GDEs, which is the subject of this report.

This assessment considered the potential groundwater dependence of vegetation types present, analysis of hydrological modelling and depth to groundwater simulations completed as part of the MOD 8 Groundwater Impact Assessment (AGE, 2021), and an assessment of potential groundwater drawdown impacts. This analysis was undertaken in two disparate study areas, the first of which incorporated an assessment of the alluvial aquifer that extends to the south-west of BCM in association with an episodic drainage line known locally as Nagero Creek. The second incorporated an extended regional setting to consider the potential for GDEs to occur in association with several drainage features proximate to BCM and the Leard State Forest.

Although heavily cleared for agriculture, the characterisation of potential GDEs within the Nagero Creek study area identified one EPBC Act listed TEC as a potential terrestrial GDE that may access groundwater as part of their overall water requirements. This included:

- areas of PCT 101 consistent with the Poplar Box Grassy Woodland on Alluvial Plains Endangered Ecological Community.

The Poplar Box Grassy Woodland on Alluvial Plains TEC was only listed under the EPBC Act on the 4 July 2019. As all field validated vegetation mapping within the BCM Project Boundary and BOAs were conducted prior to 2019, areas of native vegetation in the Nagero Creek and regional study area with potential to meet the EPBC Act listing have not yet been assessed against the TECs key diagnostic characteristics or condition thresholds. As such, a precautionary approach has been applied and it is assumed for the purposes of this investigation that all remnant patches previously mapped at PCT 101 and areas of PCT 88 on the Namoi alluvial floodplain meet the EPBC Act listing.

Detailed studies indicate that groundwater levels are typically 7 to 10 mbgl on the alluvial plain but can be shallower in the vicinity of drainage depressions and creeks, as observed in some areas proximate to Nagero Creek. Mining induced impacts to the alluvial groundwater system are yet to be observed and no groundwater modelling undertaken to date predicts any significant alluvial drawdown. Cumulative drawdown predicted within the alluvium is generally less than 2 m for current approved mining and MOD 8, with a maximum drawdown of approximately 5 m predicted in small portion of the alluvial tongue that is directly south-west of BCM. Moving away from the BCM to the south-west, the cumulative drawdown within the alluvium is predicted to be less than 1 m.

Eucalyptus spp. have a dual (dimorphic) roost system, with lateral roots that are close to the surface, and a taproot that penetrates deep in the soil. Therefore, these species can source water from multiple sources and their reliance and use of groundwater may therefore be facultative. It is considered that most deep-rooted woody species only extend approximately 10 mbgl. However, *Eucalyptus populnea* (Poplar Box) has been observed to have a tree condition to groundwater depth threshold between 12 mbgl and 26 mbgl before the canopy showed signs of dieback, suggesting that the species has extensive tap roots capable of accessing alluvial groundwater. A maximum potential cumulative groundwater drawdown of 0.8 m as a result of MOD 8 alone in areas where PCT 101 Poplar Box – Yellow Box – Western Grey Box grassy woodland occurs is not likely to significantly impact this community as determined by the Assessment of Significance completed as part of this investigation.

Within the regional study area, the Groundwater Dependent Ecosystem Atlas mapped high potential GDEs as occurring along Back Creek, Namoi River, Barber's Lagoon, Maules Creek, Goonbri Creek and its unnamed tributaries as well as the upper reaches of Bollol Creek. Based on the desktop assessment and vegetation classification of GDE types, five PCTs were considered to have potential to be at least partially reliant on access to groundwater and one aquatic system

(the Namoi River). The predicted cumulative groundwater drawdown impacts beneath potential high priority GDEs mapped by the Bureau of Meteorology (2021), includes:

- less than 0.5 m cumulative drawdown in terrestrial GDEs adjacent to small parts of Goonbri Creek and Bollol Creek
- up to 40 m cumulative drawdown in the water table in GDEs adjacent to Back Creek
- up to 5 m of cumulative drawdown in the water table in the upper reaches of Goonbri Creek.

The alluvial aquifer nearby BCM has also been found to contain stygofauna. However, as stygofauna are currently known from a single bore and limited to a single species (which occurs in other locations in the Namoi Valley and beyond), it is difficult to draw conclusions about the connectivity of the alluvial aquifer to support this and other stygofauna species. The occurrence of stygofauna in an aquifer suggests that the aquifer may support a broader ecological community that could include components such as the roots of phreatophytic trees.

A risk assessment completed on potential GDEs in the study area determined that the alluvial aquifer was of high ecological value, due to the presence of stygofauna and patches of PCT 101 Poplar Box – Yellow Box – Western Grey Box grassy woodland TEC (to be field validated). A high-level examination of the cumulative impact associated with current mining operations and MOD 8 was considered to have a low risk to terrestrial GDEs.

It is recommended that existing monitoring programs required under the BCM Groundwater Management Plan and Surface Water Management Plan be continued. Where necessary, additional terrestrial, stream and stygofauna monitoring locations are recommended within the extent of the alluvium, targeting the potential terrestrial GDEs identified in this report. If these monitoring programs identify impacts associated with the predicted MOD 8 groundwater drawdown, it is recommended that affected areas be rehabilitated.

8 LIMITATIONS

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APPENDIX A

ASSESSMENT OF SIGNIFICANCE

A1 POPLAR BOX GRASSY WOODLAND ON ALLUVIAL PLAINS

A1.1 STATUS

Poplar Box Grassy Woodland on Alluvial Plains is listed as an Endangered Ecological Community under the EPBC Act.

A1.2 SPECIFIC IMPACTS

Poplar Box Grassy Woodland on Alluvial Plains has been identified as a potential terrestrial GDE within the Nagero Creek study area (i.e. the area of investigation based on the predicted area of groundwater drawdown as a result of MOD 8) and therefore has potential to be indirectly impacted upon by predicted groundwater drawdown impacts (up to 0.8 m) associated with MOD 8. Within the Nagero Creek study area, this community is considered to include all remnant patches of PCT 101 Poplar Box - Yellow Box - Western Grey Box grassy woodland on cracking clay soils mainly in the Liverpool Plains, Brigalow Belt South Bioregion (PCT 101) that has been mapped previously by both field validated and broad-scale vegetation mapping.

Poplar Box Grassy Woodland on Alluvial Plains was listed under the EPBC Act on the 4 July 2019. As all field validated vegetation mapping within the BCM Project Boundary and biodiversity offsets was conducted prior to 2019, areas of native vegetation in the Nagero Creek study area with potential to meet the EPBC Act listing have not yet been assessed against the threatened ecological community's key diagnostic characteristics or condition thresholds. Therefore, a precautionary approach has been applied and it is assumed for the purposes of this investigation all remnant patches previously mapped at PCT 101 meet the EPBC Act listing. The only exception to this is areas of derived native grasslands which do not form part of the Poplar Box Grassy Woodland on Alluvial Plains EPBC Act listing unless they form part of a patch. Field verification of remnant patches previously mapped as PCT 101 and PCT 88 on the alluvial plain are required to confirm whether they meet the characteristics and thresholds of this TEC.

PCT 101 within the Nagero Creek study area has a canopy typically dominated by *Eucalyptus populnea* (Poplar Box) which can have a deep extensive taproot system (recorded to extend up to a maximum of 25 mbgl) capable of and previously observed as accessing groundwater (Kath *et al.*, 2014) to obtain its water requirements. The species is considered to access groundwater preferably between 12 mbgl and 25 mbgl (Kath *et al.*, 2014). As the groundwater level within the Nagero Creek study area is predicted to be approximately 7-10 mbgl (AGE, 2021) the roots of *Eucalyptus populnea* are considered likely to penetrate and utilise the groundwater to some degree. Therefore, PCT 101's reliance on groundwater within the study area cannot be discounted and maybe impacted upon by the predicted 0.8 m MOD 8 drawdown and cumulative active mining (with MOD 8) impacts of up to 5 m.

The predicted MOD 8 groundwater drawdown impacts have potential to indirectly impact small patches of the Poplar Box Grassy Woodland on Alluvial Plains ecological community listed under the EPBC Act which occurs within the Nagero Creek study area (subject to field validation). These impacts are discussed in more detail below.

A1.3 EPBC ACT SIGNIFICANT IMPACT ASSESSMENT

The following assessment has been undertaken following the Matters of National Environmental Significance, Significant Impact Guidelines 1.1 (Department of Environment, 2013).

An action is likely to have a significant impact on a critically endangered or endangered ecological community if there is a real chance or possibility that it will:

A1.3.1 REDUCE THE EXTENT OF THE ECOLOGICAL COMMUNITY

The predicted groundwater drawdown impacts associated with MOD 8 have potential to indirectly impact small patches of Poplar Box Grassy Woodland on Alluvial Plains.

Approximately 1,881.9 ha of PCT 101 has been mapped within 15 km of the MOD 8 study area by broad-scale vegetation mapping (Department of Planning, Industry and Environment, 2016). The small patches of Poplar Box Grassy Woodland on Alluvial Plains in the study area with potential to be indirectly impacted upon represents <1% of that mapped as occurring within the region.

Given the specific impacts to groundwater assets predicted are to be minimal relative to the approved mining (AGE, 2021) and impact less than 1% of the Poplar Box Grassy Woodland on Alluvial Plains mapped within the region, MOD 8 is unlikely to significantly reduce the extent of the endangered ecological community to an extent that would place it at risk of extinction.

A1.3.2 FRAGMENT OR INCREASE FRAGMENTATION OF AN ECOLOGICAL COMMUNITY, FOR EXAMPLE BY CLEARING VEGETATION FOR ROADS OR TRANSMISSION EASEMENTS

Poplar Box Grassy Woodland on Alluvial Plains within the study area is already highly fragmented as a result of past and current land uses, primarily agriculture and mine infrastructure. MOD 8 will not result in the direct removal nor fragment the community into two or more patches.

If indirect impacts result in canopy dieback, localised fragmentation of the canopy stratum may occur to the small patches of Poplar Box Grassy Woodland on Alluvial Plains within the Nagero Creek study area. In this circumstance, midstorey and groundcover components of the community are likely to remain as species which comprise these stratum are unlikely to be reliant on groundwater given their shallow root depth (i.e. shrub, forb, fern and grass species likely to have shallow root systems <7 m where the groundwater table is predicted to occur).

A1.3.3 ADVERSELY AFFECT HABITAT CRITICAL TO THE SURVIVAL OF AN ECOLOGICAL COMMUNITY

Areas critical to the survival of the ecological community are identified in the Conservation Advice (including listing advice) for the Poplar Box Grassy Woodland on Alluvial Plains (Department of Environment and Energy, 2019). As specified in the conservation advice for the ecological community, the areas considered most critical to the survival of Poplar Box Grassy Woodland on Alluvial Plains are those in the '*best quality, most intact patches… as outlined in Class A – Highest Condition of Table 3'.*

An assessment of PCT 101 against the endangered ecological community condition thresholds specified in Table 3 of the conservation advice has not yet been completed. Despite this, based on WSP's previous observations whilst completing other surveys, it is considered likely that most if not all remnant patches of PCT 101 within the Nagero Creek study area have potential to meet the Class A condition criteria.

Given the above, a precautionary approach has been taken and it is considered likely that MOD 8 has potential to indirectly impact small patches of habitat critical to the survival of the Poplar Box Grassy Woodland on Alluvial Plains ecological community.

A1.3.4 MODIFY OR DESTROY ABIOTIC (NON-LIVING) FACTORS (SUCH AS WATER, NUTRIENTS OR SOIL) NECESSARY FOR AN ECOLOGICAL COMMUNITY'S SURVIVAL, INCLUDING REDUCTION IN GROUNDWATER LEVELS, OR SUBSTANTIAL ALTERATION OF SURFACE WATER DRAINAGE PATTERNS

The predicted groundwater drawdown impacts (of up to 0.8 m) predicted for MOD 8 have potential to modify existing groundwater levels within the Nagero Creek study area. Impacts associated with the predicted drawdown are likely to be limited largely to the canopy stratum of PCT 101 which is typically dominated by *Eucalyptus populnea* (Poplar Box). This species has been known to have extensive roots systems that utilise groundwater resources preferably between 12 mbgl and 25 mbgl (Kath *et al.*, 2014).

A drawdown of 0.8 m may have impacts on the root systems of *Eucalyptus populnea.* However, these impacts are relatively minor given the current groundwater level is predicted to be approximately 7-10 mbgl (AGE, 2021), whereas the root systems of *Eucalyptus populnea* have been observed to reach up to 25 mbgl (Kath *et al.*, 2014). This suggests that if the drawdown of 0.8 m (and a cumulative impact of up to 5 m) does occur, the species will continue to be able to access the groundwater for its water requirements. An exception to this maybe during times of severe and/or extended drought conditions where the groundwater may drawdown further.

Although drought conditions may exacerbate the predicted drawdown impacts, it is considered unlikely that severe or prolonged drought would impact the canopy stratum of PCT 101 to an extent that it would result in severe canopy dieback. Stream and terrestrial GDE monitoring undertaken between 2018 and 2020 occurred through severe drought conditions which affected most of NSW. This drought was assisted by well below average rainfall received in the region for an extended period between 2017 and 2019, which gradually eased in 2020. Vegetation attributes associated with floristic composition, structure and functionality were consistent with or only showed slight increases/decreases in values since 2018 (WSP, 2021a). Fluctuations in some vegetation attribute values, such as per cent overstorey cover, have been observed, and are likely attributable to severe drought conditions experienced between 2017 and 2019. However, such fluctuations were not considered significant as observations occurred within the boundaries of the probable mean as predicted by the standard error (WSP, 2021a).

Given the above, MOD 8 is considered unlikely to modify or destroy any abiotic factors necessary for the survival of the ecological community within the Nagero Creek study area.

A1.3.5 CAUSE A SUBSTANTIAL CHANGE IN THE SPECIES COMPOSITION OF AN OCCURRENCE OF AN ECOLOGICAL COMMUNITY, INCLUDING CAUSING A DECLINE OR LOSS OF FUNCTIONALLY IMPORTANT SPECIES, FOR EXAMPLE THROUGH REGULAR BURING OR FLORA OR FAUNA HARVESTING

PCT 101 within the Nagero Creek study area is already highly disturbed as a result of past and current land uses, primarily agriculture and mine infrastructure. Due to this the species composition of the community within the Nagero Creek study area is already modified.

The predicted drawdown impacts associated with MOD 8 are anticipated to be relatively minor and potentially only impact the canopy stratum of the ecological community. As mentioned above, even if extended drought conditions prevail it is considered unlikely that the canopy stratum would suffer as a result of these drawdown impacts. As such, it is considered unlikely that the predicted drawdown impacts will cause a substantial change in the species composition of the ecological community.

A1.3.6 CAUSE A SUBSTANTIAL REDUCTION IN THE QUALITY OR INTEGRITY OF AN OCCURRENCE OF AN ECOLOGICAL COMMUNITY, INCLUDING, BUT NOT LIMITED TO:

(I) ASSISTING INVASIVE SPECIES, THAT ARE HARMFUL TO THE LISTED ECOLOGICAL COMMUNITY, TO BECOME ESTABLISHED, OR

Predicted MOD 8 drawdown impacts are unlikely to significantly increase the spread of existing invasive species or contribute to the introduction of new species that are harmful to the Poplar Box Grassy Woodland on Alluvial Plain ecological community.

(II) CAUSING REGULAR MOBILISATION OF FERTILISERS, HERBICIDES OR OTHER CHEMICALS OR POLLUTANTS INTO THE ECOLOGICAL COMMUNITY WHICH KILL OR INHIBIT THE GROWTH OF SPECIES IN THE ECOLOGICAL COMMUNITY, OR

Predicted MOD 8 drawdown impacts are unlikely to cause regular mobilisation of fertilisers, herbicides or other chemicals and pollutants into the Poplar Box Grassy Woodland on Alluvial Plain ecological community.

(III) INTERFERE WITH THE RECOVERY OF THE ECOLOGICAL COMMUNITY

A recovery plan has not been prepared for the ecological community, however, priority protection, conservation management and recovery actions have been identified in the Conservation Advice (including listing advice) for the Poplar Box Grassy Woodland on Alluvial Plains (Department of Environment and Energy, 2019). These include:

- protect the ecological community to prevent further loss of extent and condition
- restore the ecological community within its current and potential range by active abatement of threats, revegetation and other conservation initiatives
- communicate- engage and support people to increase understanding of the value and function of the ecological community and encourage their efforts in its protection and recover
- research and monitoring to improve our understanding of the ecological community and methods for restoration and protection over the long-term.

MOD 8 has potential to interfere with one of the above actions; being ‘protect the ecological community to prevent further loss of extent and condition’.

A1.3.7 CONCLUSION

The predicted groundwater drawdown impacts associated with MOD 8 have potential to indirectly impact small patches of Poplar Box Grassy Woodland on Alluvial Plains. Based on broad-scale vegetation mapping this equates to an impact on <1% of the community within the region (i.e. within 15 km of the MOD 8 study area).

The predicted groundwater drawdown impacts of MOD 8 are considered negligible and unlikely to lead to a significant impact on this ecological community.