New Cobar Complex Project State Significant Development (SSD-10419)

Groundwater Assessment

Prepared for Peak Gold Mines Pty Ltd
December 2020

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Report Number

J190278 RP21

Client

Peak Gold Mines Pty Ltd

Date

18 December 2020

Version

v5 Draft

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Executive Summary

ES1 Project overview

Peak Gold Mines Pty Ltd (PGM), a wholly owned and operated subsidiary of Aurelia Metals Limited (Aurelia), owns and operates the New Cobar Complex located 3 kilometres (km) south-east of Cobar, far western New South Wales (NSW).

The New Cobar Complex Project State Significant Development (SSD) (the Project) is an amalgamation of underground mining at New Cobar, Chesney, and Jubilee deposits and development of new underground workings of the Great Cobar and Gladstone deposits to create the New Cobar Complex Project.

PGM is also seeking to consolidate all existing development approvals applicable to the New Cobar Complex into a single modern consent issued by the Department of Planning, Industry and Environment (DPIE). Approval will be sought for project elements accessed from, and undertaken within, the existing New Cobar Complex located within consolidated mining lease (CML) 6, mining purposes lease (MPL) 0854, and mining leases (ML) ML 1483 and ML 1805.

ES2 Water resources

The Project is located within the Lachlan Fold Belt Murray-Darling Basin (MDB) Groundwater source which is managed by the *Water Sharing Plan for the New South Wales Murray-Darling Basin Fractured Rock Groundwater Sources 2020* (Groundwater WSP) (NSW Government 2020).

The Cobar deposits mined from the New Cobar Complex are located along the eastern margin of the Early Devonian Cobar Basin. The Cobar deposits are located within the Great Cobar Slate (GCS), on a major north to north-west striking, steeply dipping shear zone. The GCS is the upper stratigraphic member of the Devonian Nurri Group meta-sediments, and is associated with a major, north-northwest striking, steeply dipping shear zone (the Great Chesney Fault).

The north-northwest trending fault and fracture complexes control groundwater movement, with groundwater flow parallel to the faults (in a general north-south direction), with little east-west transfer. Major faults exist on the eastern side of the mineral deposits, including the Great Chesney Fault, which are inferred to act as impermeable barriers to groundwater flow. Groundwater levels vary throughout the New Cobar Complex and surrounds, varying by up to 15 metres (m) in an east-west direction across the Great Chesney Fault.

Groundwater flow in the GCS is generally associated with secondary porosity associated with the shear zone as well as within developed secondary porosity in the oxidised GCS (weathered regolith). Oxidised rock typically exists to 100 - 150 m below ground level (mbgl).

Groundwater quality in the vicinity of the New Cobar Complex is brackish to saline with electrical conductivity (EC) ranging from 6,437 micro siemens per centimetre (µS/cm) to 12,800 µS/cm. EC increases with depth as shallow groundwater receives recharge from rainfall. Increasing EC with depth is attributed to water-rock interactions and the increase in dissolved mineral concentrations as water moves along the flow path. Groundwater field pH is slightly acidic to neutral ranging from 6.1 to 7.2. Oxidation potential is generally positive (gaining electrons) ranging from 73.7 mV to 125.9 mV.

Surface water drainage within the New Cobar Complex is largely dominated by sheet wash. Ephemeral drainage lines are only observed to flow during periods of heavy rainfall. There is a man-made reservoir (the Newey Reserve) to the immediate west of the New Cobar Complex.

ES3 Sensitive receivers

There is one water supply work (GW803422) within a 5 km of the New Cobar Complex. It is located at the Cobar District Rugby Club, has been drilled to a depth of 22 metres and is the backup supply for the irrigation of the playing field (only required during times of drought or interruption).

There are no identified high-priority groundwater dependent ecosystems (GDEs) within 5 km of the New Cobar Complex based on the mapping provided in the Groundwater WSP (NSW Government 2020).

Three small GDEs located over 2 km to the east of the New Cobar Complex are categorised as having medium ecological value under the GDE High Ecological Value Aquatic Ecosystems (HEVAE) method (DPIE 2018). The Bureau of Meteorology's (BoM) GDE Atlas also identified high and low potential aquatic GDEs, as well as low to moderate terrestrial GDEs in the vicinity of the New Cobar Complex.

ES4 Monitoring network

Routine groundwater level and water quality monitoring commenced at the New Cobar Complex in April 2020 across a network of six monitoring bores. The network comprises standpipe piezometers with nested monitoring sites which are designed to aid in aquifer characterisation around the Project area operations. The water supply work (GW803422) has also been incorporated into the Project area monitoring network.

The New Cobar Complex monitoring network has been incorporated into the current Peak Gold Water Management Plan (WMP) (EMM 2020b).

ES5 Impact assessment

Numerical modelling and analytical techniques have been used in this assessment to predict quantity and quality changes in groundwater resources. These techniques are in accordance with the Australian Groundwater Modelling Guidelines (Barnett, et al. 2012). The model, referred to as the GC1.0 groundwater model, has been built using all available data.

The Project has the potential to impact on local and regional groundwater sources and sensitive receptors. Potential impacts have been assessed in accordance with the *NSW Aquifer Interference Policy* (AIP) (DPI 2012a) and Project related Secretary's Environmental Assessment Requirements (SEARs) and include:

- Drawdown of greater than two metres is expected at bore GW803422, the only water supply works identified within 5 km of the New Cobar Complex. AIP make good arrangements will be put in place in consultation with the water supply work owner.
- There are no designated high priority GDEs located within five kilometres of the New Cobar Complex. Therefore, the AIP minimal impact consideration is not applicable.
- The high potential GDE mapped by the BoM GDE Atlas at Newey reservoir is a surface water dependent system. It receives overland stormwater runoff from the southern parts of Cobar Town and is not connected to the regional groundwater system. Other potential GDEs are anthropogenic features including farm dams, sewage treatment ponds and the historical Great Cobar slag dump. Modelled depth to groundwater levels indicate that these GDEs are unlikely to be groundwater dependant.
- Identified medium potential terrestrial GDEs are outside the area of expected drawdown of the Project and therefore will not to be impacted by the Project.

- The existing New Cobar Complex open cut will act as a regional groundwater terminal sink post mining cessation, maintaining groundwater flow towards it. Any change in groundwater quality will be localised, therefore the beneficial use category of the aquifer will not change as a result of the Project. The groundwater quality impacts of the Project are consequently anticipated to be negligible.

- The residual impacts, following management measure implementation are generally low and will be managed by updates to the existing WMP to ensure any impacts are identified and managed accordingly.

ES6 Mitigation, monitoring and management

The overarching water management strategy for the Project is to minimise discharges offsite and to maximise the capture and reuse of Project area rainfall runoff. This strategy assists in maintaining a consistent supply of water to the operation and reduces reliance on other external water sources.

A WMP has already been developed and is in use at the New Cobar Complex Project area. It details:

- baseline data;

- objectives and performance criteria including trigger levels for investigating any potentially adverse impacts associated with water management;

- plans to respond to any exceedances of the performance criteria;

- details of the monitoring (including locations, frequency, and parameters), inspection and maintenance programs;

- details of meter type and locations to record groundwater extraction;

- water balance to confirm water take; and

- reporting procedures for the results of the monitoring program.

The WMP was sent to National Resources Access Register (NRAR) seeking comment on the 18th May 2020. No response was received. The WMP will be updated in consultation with DPIE Water, NRAR and NSW EPA to incorporate the Project.

ES7 Water licensing

The numerical groundwater model has also been used to assess water license requirements in accordance with the *Water Management Act 2000* (WMA 2000), the AIP and the relevant statutory WSPs. The peak predicted inflow rate has been modelled at 854 megalitres per year (ML/year) in 2026, which is below PGM's current allocation of 880 unit shares. Predictive uncertainty analysis has identified that although there may exist short periods where the allocation may be exceeded, the probability remains low.

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1 Introduction

1.1 Overview

Peak Gold Mines Pty Ltd (PGM), a wholly owned and operated subsidiary of Aurelia Metals Limited (Aurelia), owns and operates the Peak Gold Mines operation south-east of Cobar, far western New South Wales (NSW) see Figure 1.1.

The PGM operation comprises the New Cobar Complex located 3 kilometres (km) to the south-east of Cobar town centre and the Peak Complex located 10 km south-east of the town centre. Both complexes are located adjacent to Kidman Way, which connects Cobar to Hillston and Griffith to the south.

PGM has been operational since modern mining commenced at the Peak Complex in 1991 and all current mining operates under development approvals issued by Cobar Shire Council (CSC).

The New Cobar Complex Project State Significant Development (SSD) (the Project) is an amalgamation of underground mining at New Cobar, Chesney and Jubilee deposits and development of new underground workings of the Great Cobar and Gladstone deposits to create the New Cobar Complex Project.

PGM is also seeking to consolidate all existing development approvals applicable to the New Cobar Complex into a single modern consent issued by the Department of Planning, Industry and Environment (DPIE). Approval will be sought for project elements accessed from, and undertaken within, the existing New Cobar Complex located within consolidated mining lease (CML) 6, mining purposes lease (MPL) 0854 and mining leases (ML) ML 1483 and ML 1805 (see Figure 1.2).

1.1.1 Background

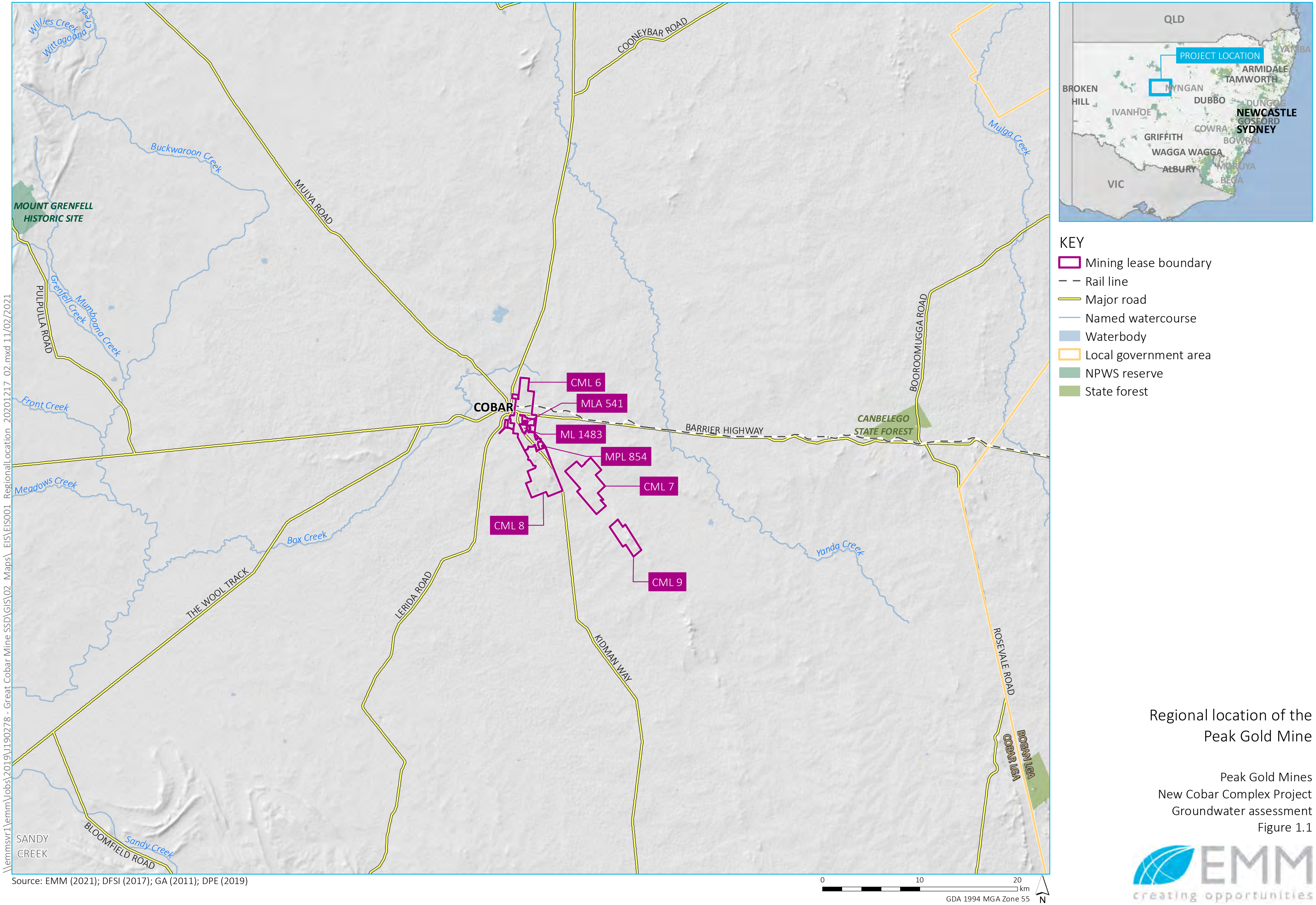
PGM has been operational since mining commenced at the Peak deposit in 1991 producing gold, copper, lead, zinc and silver. Mining at the New Cobar Complex commenced with the open cut in 2000, then transitioned to underground mining in 2004.

The current CSC development approvals at Peak Complex and New Cobar Complex allow for the operations to continue indefinitely and process up to 800,000 tonnes per annum (tpa) of ore. Ore processing, tailings storage and concentrate handling is undertaken at the Peak Complex with ore from the New Cobar Complex trucked by public road to processing facilities at the Peak Complex. Both the processing plant and the tailings storage facility (TSF) are located at the Peak Complex, and activities at those facilities are outside the scope of this Project.

PGM has identified the Gladstone and Great Cobar deposits as targets for further mining to extend the life of operations at the New Cobar Complex. The Great Cobar deposit was historically exploited by surface and shallow underground mining between 1870 and 1919, but no mining of that deposit has been undertaken since that time.

PGM has obtained conditional approval for development of an exploration decline to facilitate exploration activities within the Great Cobar deposit. The objectives of the exploration activities are to:

- further define the mineral resource through underground drilling from an exploration decline; and
- taking of a bulk sample to provide further samples for metallurgical, geotechnical, and associated test work.



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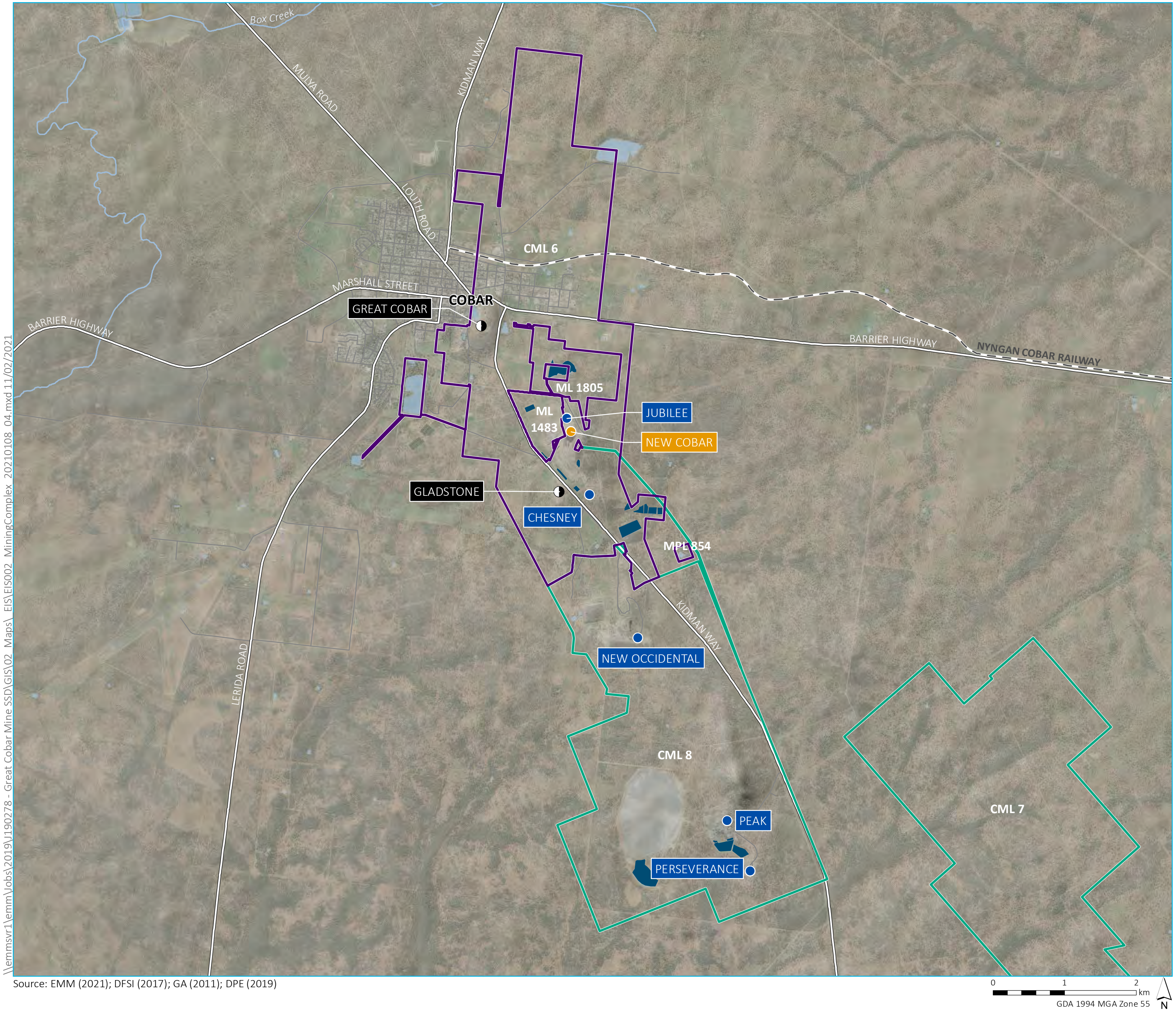
Source: EMM (2021); DFSI (2017); GA (2011); DPE (2019)

KEY
- Mining lease boundary
- Rail line
- Major road
- Named watercourse
- Waterbody
- Local government area
- NPWS reserve
- State forest

Regional location of the Peak Gold Mine

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 1.1

EMM creating opportunities



Source: EMM (2021); DFSI (2017); GA (2011); DPE (2019)

Mining leases and mining complexes

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 1.2

EMM creating opportunities

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1.1.2 Project overview

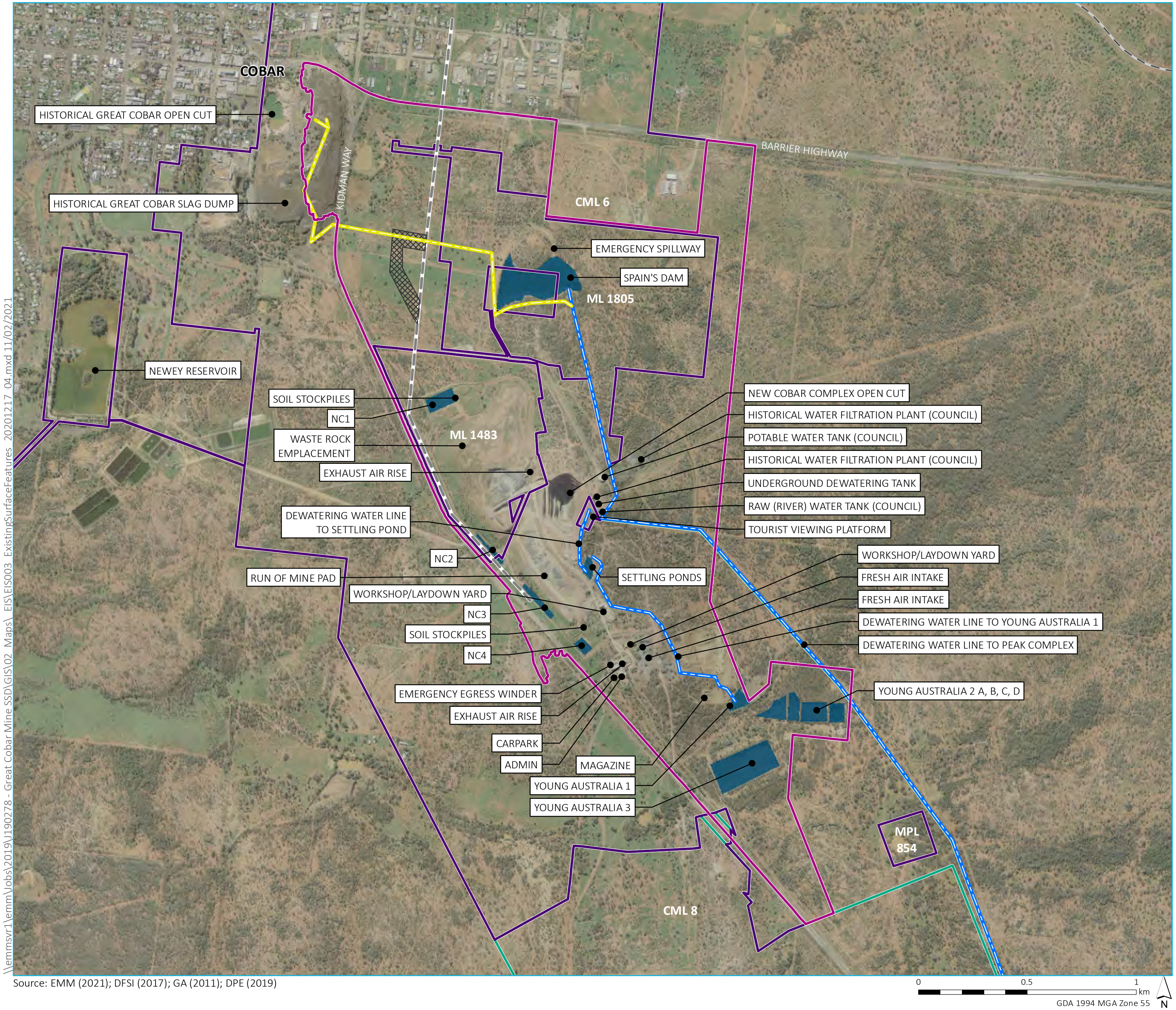
All surface works associated with the Project will be located underground or in the existing, operational mining New Cobar Complex except for a short (no more than 400 m) power line from an existing 22 kilovolt (kV) line servicing PGM to a compact substation within the fresh air intake footprint.

PGM proposes to use the decline, infrastructure, and fresh air intake and exhaust air rise ventilation elements developed for the Great Cobar exploration decline (approved, but not yet constructed) to facilitate Project development. Surface ventilation fans are not required during the development of exploration activities, however as they will be necessary during operation of mining, construction of a new power line and compact substation, to be located adjacent to the fresh air intake is required. The power line will continue to the exhaust air rise where a ventilation fan will be installed at a depth of approximately 100 m or greater below ground level (bgl). An emergency egress winder headframe and winder house will be installed at the fresh air intake for the purpose of mine rescue in the event of an incident below ground preventing evacuation by conventional means. No additional new surface infrastructure is proposed.

The existing surface infrastructure and facilities at the New Cobar Complex currently support underground mining of the New Cobar, Chesney and Jubilee deposits, and will continue to be used for this Project (Figure 1.3 and Figure 1.4). Access to all underground workings in the complex is from a portal and decline at the base of the New Cobar Complex open cut. SSD approval will be sought for the following project elements accessed from, and undertaken within, the existing New Cobar Complex:

- underground mining of the New Cobar Complex including, but not limited to, New Cobar, Jubilee, and Chesney (existing development approval issued by CSC);
- underground mining of the New Cobar Complex including Great Cobar and Gladstone (not yet approved);
- groundwater dewatering of the relevant historic and proposed underground workings via the historic Great Cobar Shaft (existing development approval issued by CSC);
- increase of the number of ore haulage trucks between the New Cobar Complex and Peak Complex from 25 loaded trips per day (50 movements in and out) to 50 loaded trips (100 movements in and out) per day (daylight hours only) averaged over a calendar year. The increase of daily truck movements will provide flexibility to PGM if there are unforeseen production disruptions (e.g. bad weather);
- crushing and screening of ore within the existing New Cobar Complex Run-of-Mine (RoM) pad (existing approval by CSC);
- transportation of ore to the Peak Complex via Kidman Way for processing, using road registered heavy vehicles (existing approval by CSC);
- harvesting of waste rock and:
  - immediately deploying the material underground for use in stope backfilling operations (waste rock will remain underground and will not be transported to the surface as a preference); and
  - transportation of non-acid forming material to the surface and storage within the existing waste rock emplacement (WRE) prior to use across the complexes for construction/rehabilitation tasks (e.g. tailings dam lifts);
- deposition of potential acid forming (PAF) waste rock brought to the surface and stored within the WRE where at end of mine life it would be capped, or progressively returned underground for disposal; and

- continuation of all other approved activities within the New Cobar Complex.



KEY

- Project area
- Pipeline route
- Great Cobar dewatering pipeline
- Existing 22 kV powerline
- Rail line
- Proposed power line corridor
- Mine water management storage

Mining lease boundaries

- New Cobar Complex
- Peak Complex

Source: EMM (2021); DFSI (2017); GA (2011); DPE (2019)

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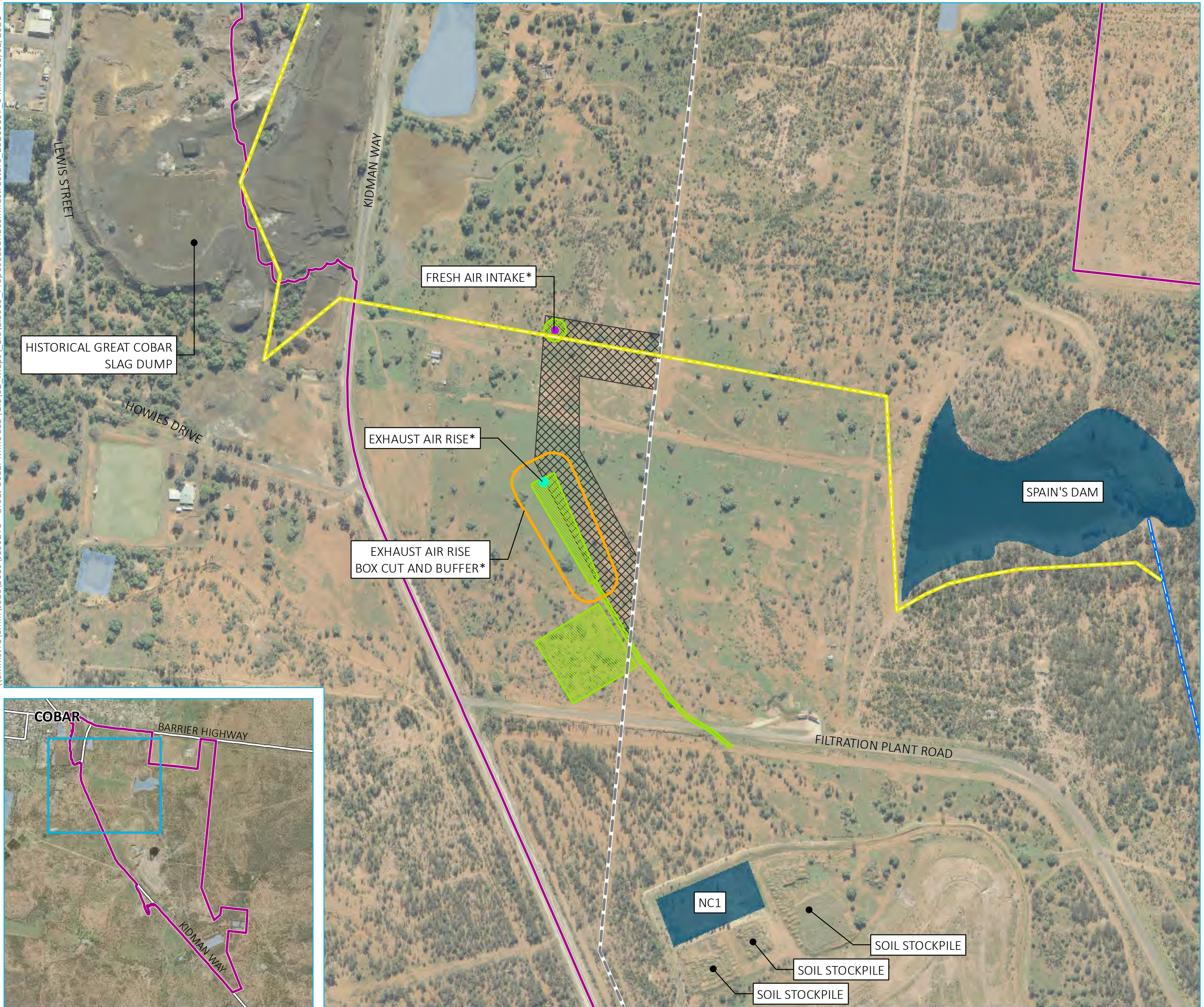
Existing surface features

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 1.3

EMM
creating opportunities



Source: EMM (2021); DFSI (2017); DPE (2019); ELA (2018)

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Proposed surface infrastructure

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 1.4

EMM creating opportunities

Processing will remain at the Peak Complex at the existing approved rate of up to 800,000 tpa, with production of ore from the Great Cobar and Gladstone deposits making up for the future decrease in production from other workings across PGM.

Additionally, there are remaining resources in the New Cobar, Jubilee and Chesney deposits that are mineral rich, but which are currently not economical to mine in isolation. Keeping the New Cobar Complex operational and gaining access to Great Cobar and Gladstone deposits will lead to increases in economies of scale and maximise opportunities to mine these resources and keep PGM operational until 2035.

1.2 Purpose of this report

EMM Consulting Pty Limited (EMM) has been engaged by PGM to prepare and submit an environmental impact statement (EIS) to support an SSD application for the Project under the provisions of clause 8(1) and Clause 5 of Schedule 1 of *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP). The Peak Complex, which is not part of this SSD application will continue to operate under local government (CSC) approvals, as there is no proposed change to this arrangement.

PGM requested Secretary's Environmental Assessment Requirements (SEARs) from DPIE for the SSD EIS in December 2019; these were received in February 2020. The SEARs included a requirement to assess potential groundwater risks associated with the construction and operation of the Project. This groundwater impact assessment (GIA) has been prepared to address the relevant SEARs, provide information to be used in the EIS, and support the SSD application for the Project. The groundwater related matters and EMM responses are tabulated below (Table 1.1).

Table 1.1 Groundwater related SEARs and EMM responses

Item no.	Authority comments	EMM responses
1	Assessment of the likely impacts of the development on the quantity and quality of surface and groundwater resources having regard to the AIP.	Section 9.1.
2	Assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users.	Section 9.
3	Detailed site water balance, including a description of site water demands, water disposal methods (including the location, volume and frequency of any water discharges and management of discharge water quality), water supply arrangements, water supply and transfer infrastructure and water storage structures, including; • an assessment of the reliability of water supply, including consideration of climate change; and • demonstration that water can be obtained from an appropriately authorised supply in accordance with the operating rules of any relevant Water Sharing Plans (WSP);	The site water balance is described in detail in the Project surface water assessment (SWA) (EMM 2020a). Project water supply sourced from groundwater (mine inflows) is discussed in Section 11.
4	Identification of any licensing requirements or other approvals under the *Water Act 1912* and/or *Water Management Act 2000* (WMA 2000), including a description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo;	Section 11.

Table 1.1 Groundwater related SEARs and EMM responses

Item no.	Authority comments	EMM responses
5	Detailed description of the proposed water management system (including sewerage), water monitoring program and other measures to mitigate surface water and groundwater impacts.	The water management system is described in detail in the Project SWA (EMM 2020a). Existing groundwater monitoring is described in Sections 5.1 and 10.3. Groundwater-related mitigation, monitoring and management is discussed in Section 10.

In addition to above SEARs, the following agencies have raised comments regarding GIA:

- DPIE Biodiversity and Conservation Division – letter dated 29 January 2020;
- DPIE Water and the Natural Resources Access Regulator (NRAR) – letter dated 22 January 2020; and
- NSW Environment Protection Authority (EPA) – letter dated 23 January 2020.

Agency comments and EMM responses are provided below (Table 1.2).

Table 1.2 Additional agency requirements and EMM responses

Item no.	Authority comments	EMM responses
DPIE Biodiversity and Conservation Division		
1	The EIS must map the following features relevant to water and soils including: d) groundwater; and e) groundwater dependent ecosystems (GDEs).	The New Cobar Complex and its surrounds are located within the regional fractured rock groundwater system of the Lachlan Fold Belt MDB Groundwater Source. Potential GDEs are mapped within Section 4.8.
2	The EIS must describe background conditions for any water resource likely to be affected by the development, including: a) existing surface and groundwater; b) Water Quality Objectives (WQOs) (as endorsed by the NSW Government http://www.environment.nsw.gov.au/ieo/index.htm) including groundwater as appropriate that represent the community's uses and values for the receiving waters; and d) indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the (ANZG 2018) *Guidelines for Fresh and Marine Water Quality* and/or local objectives, criteria or targets endorsed by the NSW Government.	Background groundwater conditions are described in Section 5. WQOs, in terms of environmental values are described in Section 9.3.

Table 1.2 Additional agency requirements and EMM responses

Item no.	Authority comments	EMM responses
3	The EIS must assess the impacts of the development on water quality, including: a) the nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the WQOs where they are currently being achieved, and contributes towards achievement of the WQOs over time where they are currently not being achieved; and b) identification of proposed monitoring of water quality.	Minimal discharge is proposed to occur from the New Cobar Complex. Potential impacts on receiving waters are described in the Project SWA (EMM 2020a). Groundwater-related monitoring is discussed in Section 10.
DPIE Water and NRAR		
4	The identification of an adequate and secure water supply for the life of the Project. This includes confirmation that water can be sourced from an appropriately authorised and reliable supply. This is also to include an assessment of the current market depth where water entitlement is required to be purchased.	Water supply security is described in the Project SWA (EMM 2020a). Project water supply sourced from groundwater (mine inflows) is discussed in Section 11.
5	A detailed and consolidated Project area water balance.	The Project area water balance is described in detail in the Project SWA (EMM 2020a).
6	Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, and GDEs, and measures proposed to reduce and mitigate these impacts.	Groundwater-related impacts are discussed in Section 9. Groundwater-related mitigation, monitoring and management is discussed in Section 10.
7	Proposed surface and groundwater monitoring activities and methodologies.	Groundwater-related monitoring is discussed in Section 10.
8	Consideration of relevant legislation, policies and guidelines, including the AIP (DPI 2012a), the *Guidelines for Controlled Activities on Waterfront Land* (2018) and the relevant WSPs.	Sections 3, 9.1 and 11.
NSW EPA		
9	If the proposed development intends to discharge waters to the environment, the EIS must demonstrate how the discharge(s) will be managed in terms of water quantity, quality and frequency of discharge and include an impact assessment of the discharge on the receiving environment. This should include: c) description of the proposal including position of any intakes and discharges, volumes, water quality and frequency of all water discharges; d) description of the receiving waters including upstream and downstream groundwater and surface water quality, as well as any other water users; and e) demonstration that all practical options to avoid discharge have been implemented and environmental impacted minimised where discharge is necessary.	Minimal discharge is proposed to occur from the New Cobar Complex. Potential impacts on receiving waters are described in the Project SWA (EMM 2020a).
10	The EIS must describe any water quality monitoring programs to be carried out at the Project area. Water quality monitoring should be undertaken in accordance with the *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales* (EPA 2004).	Groundwater-related monitoring is discussed in Section 10.

2 Project description

Specific details of the Project are presented in Table 2.1 in the context of existing PGM approvals.

Table 2.1 Detailed overview of the Project

Development component	Approved New Cobar Complex operations	New Cobar Complex Project SSD
Tenement	Development approved to occur within the Development Application areas, including CML 6, CML 8, ML 1483, ML 1805 and MPL 854. Mining of the following deposits using underground mining methods, with each deposit accessed via the New Cobar Complex open cut: • New Cobar deposit; • Chesney deposit; and • Jubilee deposit. Minerals processing occurs at the Peak Complex within CML 8 and also includes CML 7 and CML 9.	No change to mine lease area. Mining of the following deposits using underground mining methods, with each deposit accessed via the New Cobar open cut: • New Cobar deposit; • Chesney deposit; • Jubilee deposit; • Gladstone deposit; and • Great Cobar deposit. Processing of materials from the New Cobar Complex will continue at the Peak Complex within CML8 under existing approvals and is therefore outside the scope for this Project.
Approvals	**Cobar Shire Council Development Consent** • New Cobar South Open Cut - LDA 98/99:08 • New Cobar Open Cut - LDA 99/00:22 • New Cobar Underground – 2004/LDA 00003 PGM has received approval from CSC and the Resources Regulator (reference number MAAG0006783, approved in May 2020) to construct an exploration decline, ventilation shafts, and associated infrastructure to facilitate exploration activities within the Great Cobar deposit. This is detailed in the Mining Operations Plan (MOP) for 2019-2022 (PGM 2019). **Other Authorisations and Licences** • EPL -3596 (EPA) • Licence to Manufacture Explosives (New Cobar) - XMNKF200002 (SafeWork NSW) • Dangerous Goods Notification - New Cobar: 35/035154 (SafeWork NSW). • Water Supply Works Approval reference 85WA753861 (Natural Resources Access Regulator)	PGM is seeking to consolidate all existing development consents applicable to the New Cobar Complex including existing mining, proposed underground mining of the Great Cobar and Gladstone deposits and existing surface infrastructure within a single consent issued by DPIE. Once approved, relevant CSC development consents for the New Cobar Complex will be surrendered. The Project will use infrastructure that has been approved but not yet constructed as a result of the exploration decline and associated infrastructure. Other approvals related to the Peak Complex, will be unaffected.
Mining method	Underground stope mining operations commence above a centrally positioned crown pillar and stopes will be extracted from the bottom-up. Bench stopes are backfilled progressively using waste from development and rock from the WRE. Upon completion of each stoping level, voids are backfilled. In some instances, mining against rock fill is required. In these instances, a rock and cement slurry is placed in the stope to provide additional stability.	Expansion of underground stope mining operations will access new deposits at Great Cobar and Gladstone, as well as continued mining of New Cobar, Chesney and Jubilee deposits. The mining method will not change. There is no recorded history of significant subsidence or geotechnical failure associated with the current, modern mining operations at the Peak and New Cobar complexes.

Table 2.1 Detailed overview of the Project

Development component	Approved New Cobar Complex operations	New Cobar Complex Project SSD
	PGM undertake detailed geotechnical assessments of all stopes during the detailed stope design stage prior to mining.	
Blasting	Blasting will be used for the development of the underground workings and is proposed to occur under independent firing conditions (in the preliminary phases). Delays will be used to adjust sequencing and prevent any interaction or vibration enhancement from adjacent blastholes. The approximate number of blasts will be three per 24-hour period, 20 per 7-day period. Explosives are stored in the existing magazine at New Cobar Complex.	No change to blasting method.
Life of mine	Presently, the council approvals have no end date. Current mine plans envisage mining at New Cobar Complex to continue until 2023 under current market assumptions.	The Project will extend the life of mine by 12 years to 2035 under current market assumptions.
Production	Approved for the mining and processing of 800,000 tpa of ore to produce lead, zinc, copper, gold, and silver from both the Peak and New Cobar complexes. Processing occurs at the Peak Complex.	The Project will produce ore within the mining and processing limit of 800,000 tpa for the Peak and New Cobar complexes. Ore will be transported to the existing processing plant at the Peak Complex. The ore will be processed at the Peak Complex processing plant, and tailings will be disposed of at the TSF at the Peak Complex under existing approvals. Processing of ore will only take place at the Peak Complex, therefore is outside the scope of this Project.
Mining extent	The New Cobar Complex comprises a surface disturbance area of approximately 425 hectares. The New Cobar open cut extends to a depth of approximately 100 m below ground level (bgl). Development of underground working at Chesney, Jubilee and New Cobar deposits extends from a portal at the base of the New Cobar open cut.	Development of New Cobar Complex Project will be in stages. The Great Cobar and Gladstone deposits will be accessed via a decline extending from the existing New Cobar Complex underground workings. The proposed underground working depths are approximately 150–800 mbgl for Great Cobar and 350–500 mbgl for Gladstone. The Great Cobar deposit will be accessed by the approved exploration decline off the existing Jubilee workings at approximately 500 mbgl, and the Gladstone deposit will be accessed by a decline off the existing New Cobar underground workings at approximately 350 mbgl.
Tailings storage	All ore is processed at the Peak Complex, with tailings placed within the TSF.	No change.

Table 2.1 Detailed overview of the Project

Development component	Approved New Cobar Complex operations	New Cobar Complex Project SSD
Project area access	Access to the New Cobar and Peak complexes is via Kidman Way.	No change.
Ore transportation	Ore is transported from the New Cobar Complex along 5 km of public road (Kidman Way) in road registered trucks at the rate of 25 trucks (50 truck movements) per day, seven days a week.	Ore will continue to be transported from the New Cobar Complex but at a maximum rate of 100 truck movements per day (in and out of Project area) (daylight hours only), seven days a week averaged over a calendar year. This is an increase in truck movements from a current maximum rate of 50 truck movements per day. The increase of daily truck movements will provide flexibility to PGM if there are unforeseen production disruptions such as poor weather or machinery breakdowns.
Waste rock management	Waste rock generated from underground workings is used preferentially as backfill in previously mined underground stopes. Some waste rock material may be brought to the surface and stored within the existing WRE at the New Cobar Complex until it's required for use in construction or rehabilitation across the Peak and New Cobar complexes.	No change.
Soil management	Application of soil resources management strategies/objectives in accordance with the existing MOP (PGM 2019) and Water Management Plan (WMP) (PGM 2020)).	No change.
Mine ventilation	There are two existing exhaust air rises at the New Cobar Complex – one at the Jubilee workings and one at the Chesney workings. Fresh air is drawn down the portal at the base of the New Cobar Complex open cut and also via two fresh air intakes located near the Chesney ventilation fan. The infrastructure developed as part of the Great Cobar exploration decline will include an exhaust air rise and a fresh air intake.	No new ventilation shafts will be required; the ventilation shafts installed as part of the exploration decline will be required for ongoing mining operations and will remain in place. A new ventilation fan will be required to maintain a safe volume of air flow in the underground workings.
Surface infrastructure	All existing New Cobar Complex surface infrastructure operates under existing CSC approvals.	The Project will require the construction of a short (no more than 400 m long) power line spur between an existing 22 kV line and ventilation shaft (approved, but not yet constructed as part of the Great Cobar exploration decline approvals). This power line will connect to a pad-mounted compact substation to supply power for an emergency egress winder at the fresh air intake and a ventilation fan to be installed at the exhaust air rise. No additional surface infrastructure will be required.

Table 2.1 Detailed overview of the Project

Development component	Approved New Cobar Complex operations	New Cobar Complex Project SSD
Water supply sources and infrastructure	The water requirements for the Peak Complex and the New Cobar Complex (combined) are approximately 580 megalitres per year (ML/yr). The source of this water is typically, comprised of approximately 212 ML/yr from dewatering underground workings at the New Cobar Complex and approximately 368 ML/yr of town water from Burrendong Dam. PGM is licenced to take up to 1,186 ML/yr from Burrendong Dam, however approximately 50% of this water is lost through seepage, evaporation and other methods before arriving at the New Cobar Complex. Following approval for the dewatering of the Great Cobar shaft in 2019, up to 400 ML/yr can be extracted to replace the town water currently being used. This is as part of a move for PGM's operations to be more self-reliant and sustainable in times of drought. The water from the Great Cobar shaft will be used to make up any shortfall in Project area demand that cannot be made up by dewatering of underground workings. It will also reduce PGM's reliance on the town water supply during times of drought.	No change.
Project area water management infrastructure	A water management system is in place at the New Cobar Complex and is operated and managed in accordance with PGM's current WMP. Dewatering water that is used in the New Cobar Complex underground workings is pumped to the New Cobar Complex settling pond for re-use. The water from these settling ponds is preferentially pumped back underground for reuse, or to the Peak Complex for use in the processing circuit. While it is PGM's preference to use water from dewatered mine workings for processing, this may not always be possible due to poor water quality and additional treatment requirements. Dewatering water excess to Project area requirements is pumped to Spain's Dam or Young Australia Dams for evaporation or storage for future reuse.	No change.
Power supply	Electricity to the Project area is via a 22 kV electricity transmission line (ETL) to the Peak Complex substation.	No change to power supply, but an additional power line spur will be required for the ventilation fan to be installed in the exhaust air rise and the emergency egress winder.
Hours of operation	Underground and above ground activities, 24-hour operations, seven days a week.	No change.
Employment	The 2019/2020 workforce at PGM (including both the Peak and New Cobar complexes) totalled 404 full time equivalents (FTE).	Annual labour estimates for New Cobar Complex, being mining and underground maintenance staff range from 57 FTE in 2020/21 to a peak of 272 FTE in 2026/27. These however are not new employees; during the same period, as mining at the Peak Complex ramps down, staff will relocate to New Cobar Complex as their primary location of employment activity. PGM will continue to maintain operational control across the complexes.

Table 2.1 Detailed overview of the Project

Development component	Approved New Cobar Complex operations	New Cobar Complex Project SSD
Mining fleet	The existing/approved indicative mobile equipment fleet used for underground ore extraction, transport and waste rock handling includes: • articulated dump trucks; • cabletec; • compactors; • dozers; • drill rigs. • excavators; • graders; • haul trucks (50 t); • jumbos; • Load haul dump trucks; • loaders; • rollers; • scrapers; • service truck; • underground development drill; • underground diamond drill rigs; • waste rock dump trucks; and • water trucks.	No change.
Rehabilitation and mine closure	Current rehabilitation requirements as per MOP	Mine closure concepts and management measures will continue to be developed via the MOP, which outlines specific soil handling, rehabilitation and post mining landform objectives, in consultation with relevant regulatory authorities. The MOP will be updated and extended as required.

3 Regulatory and policy context and assessment

3.1 Overview

The primary groundwater related statutes that apply to the Project are the WMA 2000 and *Protection of the Environment Operations Act 1997* (POEO Act). The provisions of each Act are applied in accordance with their attendant regulation (including WSPs under the WMA 2000). Projects that intercept groundwater also need to consider the NSW *Aquifer Interference Policy* (AIP) (DPI 2012a), which requires projects to hold licences that account for the volume of water intercepted and consider changes in water quality, as well as water levels and pressures against sensitive receptors in accordance with prescribed minimal impact criteria.

The requirements of the applicable legislation and policies and a summary of assessments of the Project against these key policy requirements are given in the following sections. Most critical is the AIP; discussion of this is included below in the content of the WMA 2000.

3.2 Water Management Act 2000

The WMA 2000 is based on the principles of ecologically sustainable development and the need to share and manage water resources for future generations. The WMA 2000 recognises that water management decisions must consider: economic, environmental, social, cultural and heritage factors. In addition, the WMA 2000 recognises that sustainable and efficient use of water delivers economic and social benefits to the state of NSW.

The WMA 2000 provides for water sharing between different water users, including environmental, basic rights or existing water access licence (WAL) holders and provides security for licence holders. The licensing provisions of the WMA 2000 apply to those areas where a WSP has commenced.

One of the key components of the WMA 2000 is the separation of the water licence from the land; this facilitates opportunities for licence holders to trade water. The WMA 2000 outlines the requirements for taking and trading water through WALs, water supply works, and water use approvals.

The WMA 2000 is the primary legislation governing water management and licensing for the Project. The licensing requirements for mining are like other licensing requirements with additional policies and clauses related to mining that need consideration, in particular the AIP, and Section 60 I of the WMA 2000.

3.2.1 Water sharing plans

WSPs are statutory documents that apply to one or more water sources. They contain the rules for sharing and managing water resources within water source areas. The WSPs also set the water management vision and objectives, management rules for WALs, what water is available within the various water sources, and procedures for dealing in licences and water allocations, water supply works approvals, and the extraction of water. WSPs are designed to establish sustainable use and management of water resources. Each WSP is in place for 10 years.

WSPs describe the basis for water sharing and document the water available and how it is shared between environmental, extractive, and other uses. The WSPs also outline the water available for extractive uses within different categories, such as: local water utilities, domestic and stock, basic rights, and access licences.

The groundwater related WSP applicable to the Project is the Groundwater WSP (NSW Government 2020). The Groundwater WSP covers numerous water sources. The New Cobar Complex lies within the Lachlan Fold Belt MDB Groundwater Source, which is the most regionally extensive groundwater source in the WSP.

The Project's effects regarding water sharing and licensing requirements are discussed in Section 11.

i Water availability and licences

The groundwater availability and licences for the Groundwater WSP is shown in Figure 3.1. The information used to create this diagram was sourced from the Groundwater WSP, and from a search of the NSW Water Register (WaterNSW 2020a). This figure demonstrates that the volume of licences within this water source represents almost 60% of the overall availability of water. There is around 107,500 ML/yr of water unassigned within this water source potentially available to be granted.

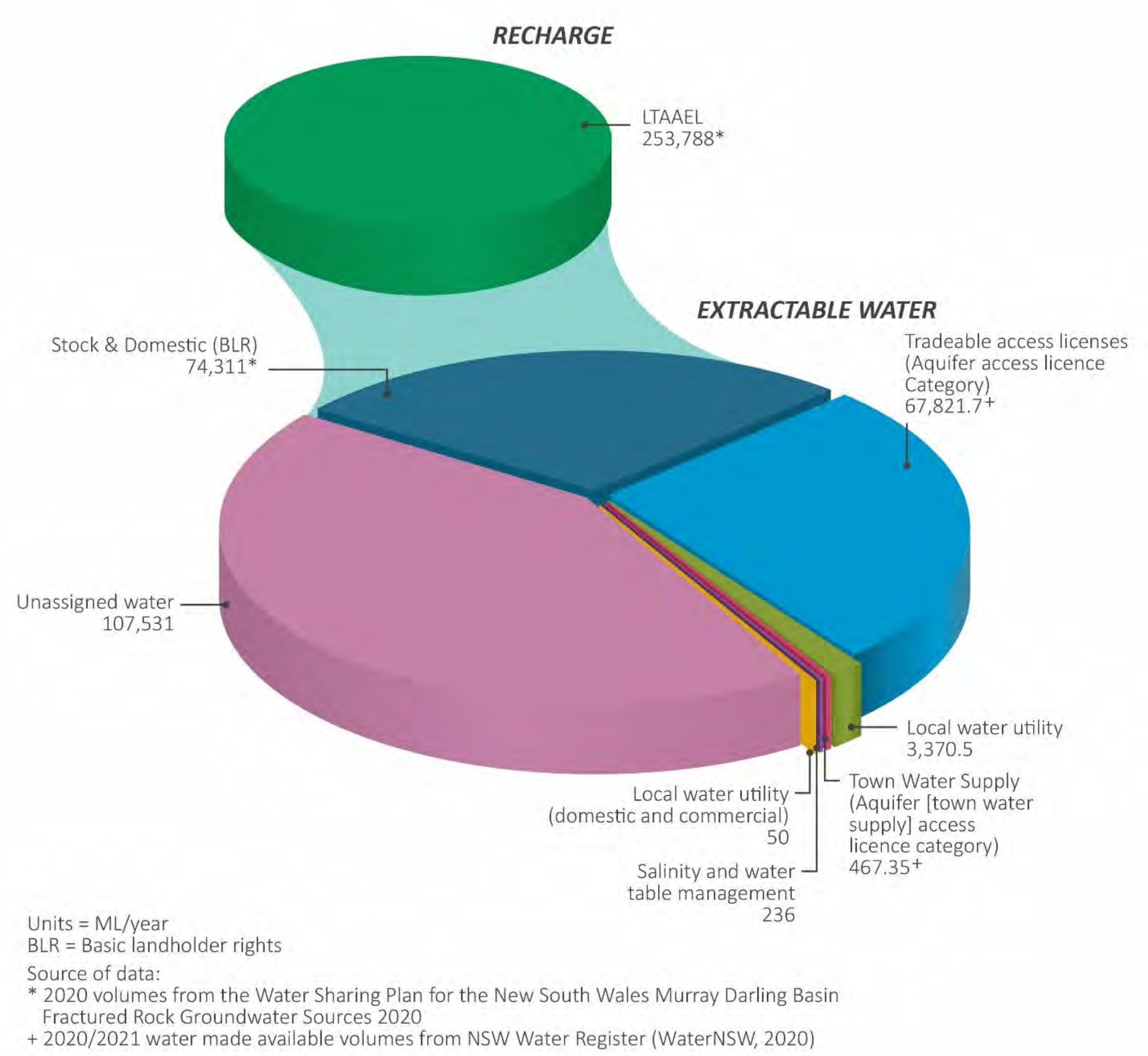


Figure 3.1 Lachlan Fold Belt MDB Fractured Rock Groundwater Source provisions (ML/yr)

PGM currently holds an aquifer[1] water access licence (WAL) (WAL 31045) for 880 shares from the Lachlan Fold Belt MDB Groundwater Source. The WALs and associated work approvals are summarised in Table 3.1.

Table 3.1 Current water supply work approvals

WAL	Share units	Approval number	Water Source	Work Type	Description	Comment
31045	880	85WA752827	Lachlan Fold Belt MDB groundwater source	Extraction works groundwater	Excavation - Groundwater	Dewatering from underground and pits
			Central Groundwater Source	Extraction works groundwater	Excavation - Groundwater	Dewatering from underground and pits
		85WA753861	Lachlan Fold Belt MDB groundwater source	Storages	Excavation	Water take from Great Cobar underground void

ii Other plan rules

The WSPs also establish the rules for granting licences, managing water allocations and accounting for water, trading entitlements and water allocations, and in the case of groundwater, rules for managing the effects of water extraction between users, and between users and dependent environmental assets.

In summary:

- unassigned water entitlement is available in the Lachlan Fold Belt MDB Fractured Rock Groundwater Source, and this can be granted by the NSW Government via controlled allocation releases;
- water trading is restricted to within individual water sources and cannot be traded across water source boundaries i.e. between the Lachlan Fold Belt MDB Groundwater Source and an adjacent groundwater source; and
- carryover[2] is limited to a maximum of 0.1 ML/share for aquifer access licences, and is not allowed for domestic and stock, local water utility, salinity and water table management or special purpose access licences.

The Project will comply with the rules applicable to the water source and further details relating to licensing requirements are discussed in Section 11.

iii Groundwater dependent ecosystems

The NSW WSPs include schedules with lists and/or maps of high priority GDEs, which are required to be assessed using the minimal impact criteria outlined in the AIP. Further details of high priority GDEs in the vicinity of the Project are provided in Section 4.8.2.

1 An aquifer access licence is a category of WAL issued to grant access to use of a specified volume of water from an aquifer.

2 Carryover water is the part of a licensed water allocation which remains unused at the end of the Water Year (July – June period) and which, under certain circumstances and subject to conditions, may be taken in the following Water Year.

3.2.2 NSW Aquifer Interference Policy

The dictionary to the WMA 2000 (under Section 91) defines an 'aquifer interference activity' as an activity involving any of the following:

- penetration of an aquifer;
- interference with water in an aquifer;
- obstruction of the flow of water in an aquifer;
- taking of water from an aquifer in the course of carrying out mining, or any other activity prescribed by the regulations; or
- disposal of water taken from an aquifer in the course of carrying our mining or any other activity prescribed in the regulations.

Section 91 (3) of the WMA 2000 relates to aquifer interference approvals. The requirement to obtain an aquifer interference approval under Section 91 is triggered only when a proclamation has been made under Section 88A that the particular type of approval is required. To date, no proclamation has been made specifying that an aquifer interference approval is required in any part of NSW.

In the meantime, the AIP sets the policy with respect to aquifer interference. The policy explains the role and requirements of the Minister in determining applications for aquifer interference activities. There is a series of seven fact sheets relating to the AIP. Six of these factsheets are relevant to this assessment and have been considered with the policy itself. The AIP:

- clarifies the requirements for licensing water intercepted during aquifer interference activities (such as dewatering for construction, mining, quarrying); and
- defines and establishes 'minimal impacts' for water related assets (such as existing bores and GDEs).

DPIE Water's assessment framework for aquifer interference is included and completed in Appendix A.

The AIP specifically refers to 'take' that is 'required to allow for the effective and safe operation of an activity, for example dewatering to allow mining' (p.3), regardless of whether the take is required to be used. The take, use, and incidental interception of groundwater requires a licence. The AIP states that, unless specifically exempt, a WAL is required under the WMA 2000 where any act by a person carrying out an aquifer interference activity causes any of the following:

- the removal of water from a water source;
- the movement of water from one part of an aquifer to another part of an aquifer; or
- the movement of water from one water source to another water source, such as:
  - from an aquifer to an adjacent aquifer;
  - from an aquifer to a river/lake; or
  - from a river/lake to an aquifer.

The AIP defines water sources as being either ‘highly productive’ or ‘less productive’ based on levels of salinity and average yields from bores. The AIP then further defines water sources by their lithological character, being one of: alluvium, coastal sand, porous rock, or fractured rock.

For each category of water source, the AIP identifies thresholds for minimal impact considerations. These thresholds relate to impacts on the water table, water pressure and water quality, and are ranked as being either ‘level 1 minimal impact’ or ‘level 2 exceeding minimal impact’. The definition of 'minimal impact' is outlined in a series of tables which demonstrate how the criteria are applied for different types of water sources and for different sensitive receptors (i.e. other users and ecosystems).

The Project has been assessed against the minimal harm thresholds defined in the AIP. The AIP divides groundwater sources into ‘highly productive’ or ‘less productive’ based on the yield (>5 litres per second (L/s) for highly productive) and water quality (<1,500 milligrams per litre (mg/L) total dissolved solids for highly productive). Thresholds are set in the AIP for the different groundwater sources for the different minimal impact considerations. Based on the NSW Government’s mapped areas of groundwater productivity in NSW (DPI 2012b), the Project is within the ‘less productive’ fractured rock source. Applicable minimal harm considerations for the Project have been reproduced in Table 3.2.

If an activity is assessed as being ‘minimal impact’ or the impacts are no more than the accuracy thresholds of the model, then it is defined as a ‘minimal impact’. Where impacts are predicted to be ‘greater than minimal impact’ but additional studies show that impacts, although greater than ‘minimal’ do not prevent the long-term viability of the relevant water dependent asset, then the impacts will be defined as ‘acceptable’. Where impacts are predicted to be ‘greater than minimal impact’ and the long-term viability of the water dependent asset is compromised, then the impact is subject to ‘make good’ provisions.

AIP *Fact Sheet 4 – Assessing the Impact* (DPI 2013), outlines how a minimal impact is to be considered. It describes how the minimal impact criteria are applied to both a water supply work and a GDE defined in a WSP (Table 3.2). This fact sheet also defines the term ‘make good provisions' as the requirement to ensure that third parties with water supply works have access to an equivalent supply of water through enhanced infrastructure or other means, for example deepening an existing bore, compensation for extra pumping costs or constructing a new pipeline or bore.

Table 3.2 Minimal impact criteria for 'less productive' porous and fractured rock water sources

Water table	Water pressure	Water quality
1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan. A maximum of a 2 m decline cumulatively at any water supply work. 2. If more than 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan if appropriate studies demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than a 2 m decline cumulatively at any water supply work, then make good provisions should apply.	1. A cumulative pressure head decline of not more than a 2 m decline, at any water supply work. 2. If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. 2. If condition 1 is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

Note: Sourced from AIP (DPI 2012a).

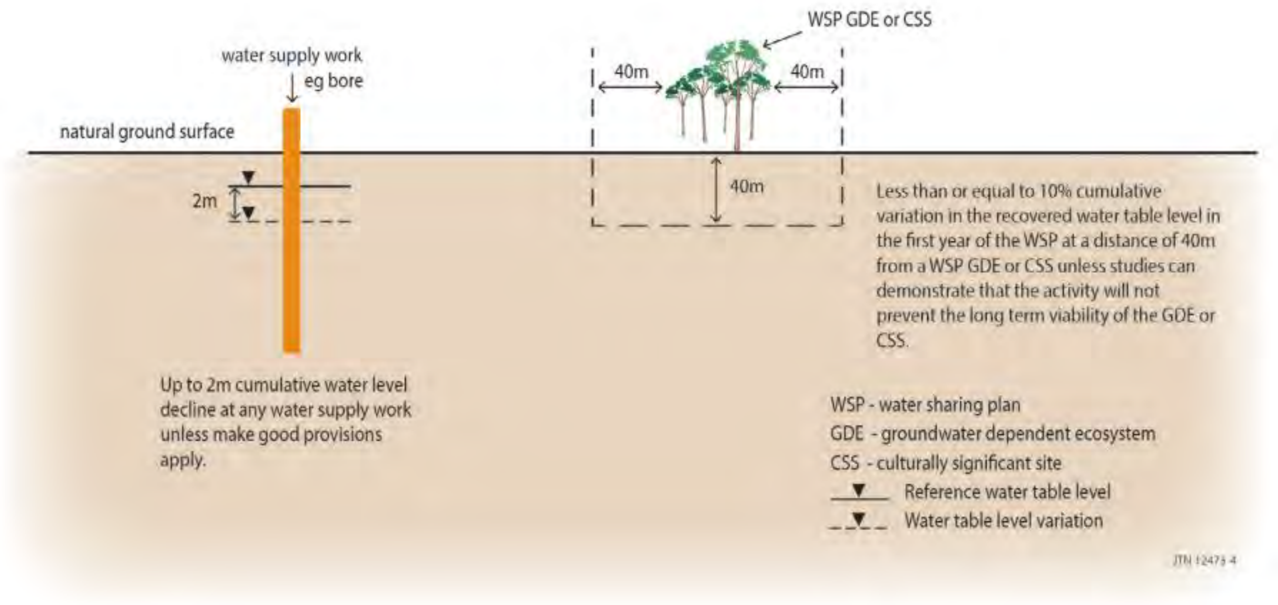


Figure 3.2 Fractured rock groundwater source minimal impact considerations

3.3 NSW Protection of the Environment Operations Act

The POEO Act is the key piece of environment protection legislation administered by the NSW EPA (1997). The POEO Act enables the Government to set protection of the environment policies that provide environmental standards, goals, protocols, and guidelines. The POEO Act also establishes a licensing regime for pollution generating activities in NSW. Under Section 48 of the Act, an environment protection licence (EPL) is required for 'scheduled activities'. PGM currently holds an EPL (licence number 3596) for existing scheduled activities at the New Cobar and Peak Complexes. A licence variation will be sought to accommodate the Project upon approval by DPIE.

The POEO Act also includes a duty to notify relevant authorities of pollution incidents where material harm to the environment is caused or threatened.

3.4 Relevant NSW and Commonwealth plans, policies and guidelines

Other guidelines, and policies relevant to the groundwater assessment are discussed in the following sections.

3.4.1 Risk assessment guidelines for groundwater dependent ecosystems

The risk assessment guidelines for groundwater dependent ecosystems (Serov P 2012) (GDE Risk Assessment Guidelines) are the NSW requirements for assessment and management of GDEs under the WMA 2000. The dictionary to the Groundwater WSP states that:

> groundwater-dependent ecosystem is an ecosystem that has its species composition and natural ecological processes wholly or partially determined by groundwater (NSW Government 2020).

While the GDE Risk Assessment Guidelines states that GDEs:

> explicitly include any ecosystem that uses groundwater at any time or for any duration in order to maintain its composition and condition (Serov P 2012).

An ecosystems dependence on groundwater can be variable, ranging from partial and infrequent dependence, i.e. seasonal or episodic (facultative), to total continual dependence (entire/obligate) as shown graphically in Figure 3.3.

A high-level GDE assessment was undertaken for the Project as part of an overarching groundwater risk assessment and is documented in more detail in Section 7.1.

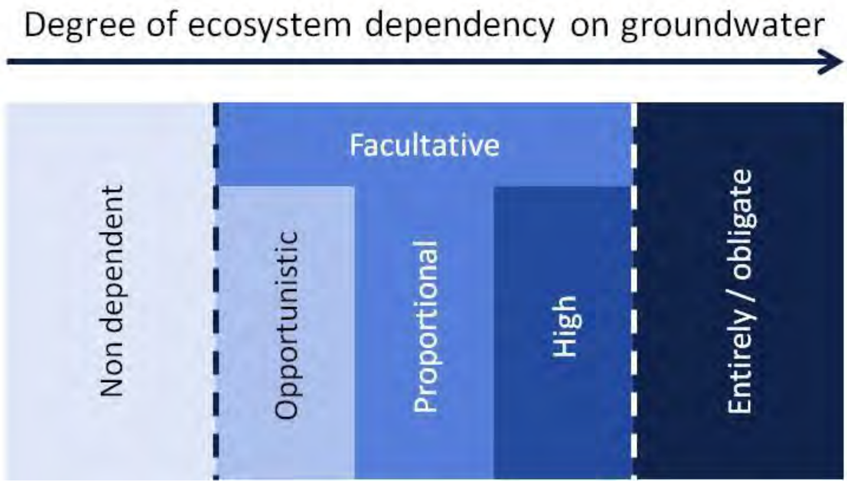


Figure 3.3 Groundwater dependent ecosystem level of dependence on groundwater

3.4.2 State Groundwater Policy Framework Document

The NSW State Groundwater Policy Framework Document (DLWC 1997) aims to manage the groundwater resources of the State so they can sustain environmental, social, and economic outcomes for the people of NSW. The policy is to be considered in resource management decisions made in NSW.

The document is a framework for the following three policies:

- *NSW State Groundwater Quantity Management Policy* (GQMP) (2001 (unpublished));
- *NSW State Groundwater Quality Protection Policy* (GQPP) (DLWC 1998); and
- *NSW State Groundwater Dependent Ecosystem Policy* (GDEP) (DLWC 2002).

This policy establishes the overarching principle for the management of groundwater in NSW, which remains valid 23 years after its inception. The principles of sustainability across the three environmental, social, and economic aspects are still referenced in modern water policies released by the NSW Government.

3.4.3 State Groundwater Quality Protection Policy

The GQPP (DLWC 1998) is a component policy of the *NSW State Groundwater Policy Framework Document*. The GQPP requires that water quality within groundwater systems is managed in accordance with the management principles given in Table 3.3.

Table 3.3 State Groundwater Quality Protection Policy (1998) principles

Groundwater quality management principles	Consideration of the principles
The most sensitive identified beneficial use (or environmental value) is maintained.	The beneficial use of groundwater is industrial (mine use) and recreational (playing field irrigation).
Town water supplies are afforded special protection against contamination.	There are no nearby town water supply bores.
Groundwater pollution should be prevented.	The Project's overarching water strategy is to minimise the impact on the quality of surface water and groundwater receiving environments.
For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource.	The Project is an SSD, and as such a thorough impact assessment has been completed. Baseline environmental monitoring and assessment of the Project's potential impacts has been undertaken.
Groundwater extractors should be responsible for environmental damage or degradation caused by applying groundwater that is incompatible with soil, vegetation or receiving waters.	Groundwater taken to the surface will be managed within the water management system at the surface.
Groundwater dependent ecosystems are afforded protection.	There are no High Priority GDEs within 5 kms of the New Cobar Complex. Given the depth to water table modelled, mapped potential GDEs are not expected to be adversely impacted by the Project (refer to 9.2.1).
Groundwater quality and quantity management is integrated.	Baseline groundwater quantity and quality data has been integrated in the groundwater assessment and the impact assessment.
The cumulative impacts of developments on groundwater quality should be recognised.	Groundwater quality changes as a result of the Project are anticipated to be minimal. As such, cumulative groundwater quality impacts are not anticipated as a result of the Project.
Where possible and practical, environmentally degraded areas should be rehabilitated, and their ecosystem support functions restored.	Post-mining, the mine surface infrastructure will be decommissioned, and areas will be rehabilitated to a state where they can support land uses similar to the current land uses.

3.4.4 Australian Groundwater Modelling Guidelines

The Australian Groundwater Modelling Guidelines (Barnett, et al. 2012) provide a consistent and sound approach for the development of groundwater models in Australia. The guidelines 'propose a point of reference and not a rigid standard' and provide direction on scope and approaches while acknowledging that techniques are continually evolving, and innovation is to be encouraged. The guidelines provide a confidence-based classification system that defines three different classes of model as follows:

- Class 1 – low confidence in model predictions, suitable for use in low value resource or low risk developments;
- Class 2 – high confidence in model predictions, suitable for use in high value resources or projects with medium to high risk developments; and

- Class 3 – high confidence in model predictions, suitable for use in high value resources and projects such as regional sustainable yield assessments.

The guidelines provide information on the data requirements for each model class, such as spatial distribution of bores and temporal groundwater level data. Groundwater resource assessments at major development sites generally require the use of a Class 2 model but Class 1 models are also deemed appropriate for lower risk developments. The onerous data requirements to achieve a Class 3 model (i.e. reliable metered extraction and the duration of the prediction to be not more than three times the calibration data period) mean that for most major projects in NSW, a full Class 3 model is practically unattainable.

The numerical groundwater model for the Project has been prepared in accordance with the Australian groundwater modelling guidelines.

3.4.5 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018) describe the water quality objectives for marine and freshwater environments, aquatic ecosystems, primary industries, and recreational water.

The guidelines should be considered when setting water quality objectives for natural and semi-natural water resources in Australia and New Zealand sustaining current or likely future environmental values (uses). They also set out a framework for the application of water quality trigger levels.

The guidelines are a generic reference and should be used accordingly, i.e. only as a default reference. The Project area has established a groundwater monitoring network to establish baseline conditions and develop trigger levels. Project impacts will be assessed using Project area-specific baseline data and not the generic guidelines, following collection of sufficient (typically >24 months) baseline data.

3.4.6 National Water Quality Management Strategy Guidelines for Groundwater Quality Protection in Australia

The *National Water Quality Management Strategy Guidelines for Groundwater Quality Protection in Australia* (Australian Government 2013) provides a risk-based management framework to protect and enhance groundwater quality for the maintenance of specified environmental values. The framework involves the identification of specific beneficial uses and values for the major groundwater systems, and protection strategies that can emerge to protect each aquifer, including monitoring for all aquifers. Environmental values have been referenced in Section 9.4.

4 Existing environment

4.1 Historical mining

The Cobar field has seen four major stages of mining activity:

- 1870–1921: copper and later gold mining dominated by the Great Cobar mine;
- 1930–1952: gold mining focussed on the New Occidental and Chesney gold mines;
- 1961–1985: major base-metal mining following discoveries at CSA and Elura mines; and
- 1985 to present: renaissance in gold and continued base-metal mining, with new discoveries following systematic exploration (McQueen 2016).

In the early days, the mining method was "hammer and tap" which involved chiselling out the hard sulphide ores to make the holes for explosives. In the early 1900s, the introduction of pneumatic drills for machine mining was introduced and from the 1960s, mining became more highly mechanised with the advent of mobile drilling, loading, and hauling machines.

Problems such as low copper prices, shortage of firewood and high transport costs caused operations to cease in 1889 (McQueen 2016). The railway line finally reached Cobar in 1892, which enabled a group of entrepreneurs to lease the mine and take advantage of the new railway connection to bring coke to Cobar from the coal deposits near Singleton to operate the new water jacket blast furnaces. These furnaces greatly increased copper production.

However, after World War One, demand for copper fell and the mine closed in 1919 on cessation of War Office contracts. Associated mines including Chesney mine were also closed (McQueen 2016).

High-grade gold-silver ore was found at The Peak, a prominent hill 10 km south of Cobar in 1895, which led to the development of a number of mines including the Conqueror-Brown, Blue Lode, Big Lode and Cobar Peak. Ore was also sent to the Great Cobar copper mine for gold recovery by smelting. Small scale activity declined when deeper primary ores were reached in 1906. The demise of local copper mining and smelting in 1919 further reduced activity (McQueen 2016).

The Conqueror and Brown lodes at The Peak were subsequently mined from around 1922 until 1940, and then again (along with the Blue Lode area) intermittently from 1942 to 1953 for a modest output of gold and silver. Over the next three decades there was a general lack of interest in gold exploration due to the fixed gold price and relatively high costs. This changed in 1980 after the price spiked following demonetarisation of gold in 1971.

In 1985 a 570 m deep shaft with cross cuts was commenced at Peak to facilitate underground drilling and to extract a bulk sample for metallurgical testing. Results from a feasibility study were positive and full production commenced in October 1992. From 1998, the operation has also mined the Perseverance orebodies discovered at depth to the south, as well as redevelopments of the historic New Cobar, New Occidental, and Chesney mines.

4.2 Data availability

The sources of available data used to inform this groundwater assessment are summarised in Table 4.1.

Table 4.1 Summary of data availability

Data type	Source	Data period
Climate: • Temperature; • rainfall; and • evaporation	PGM weather station	May 2019 – March 2020
	Bureau of Meteorology (BoM) Station No. 48027, 48237	January 1963 – April 2020
	Scientific Information for Land Owners (SILO) data drill (Queensland Government 2020)	January 1900 – April 2020
Topography	5 m Digital Elevation Model (DEM)[1] (vertical accuracy of 1 m)	Produced July 2014
Existing groundwater bores" • bore yields; and • bore status	WaterNSW Real-time water database (WaterNSW 2020b)	2020
Groundwater levels	WaterNSW Real-time water database (WaterNSW 2020b)	2020
	Dedicated monitoring network	July 1990 – June 2020
Groundwater quality	WaterNSW Real-time water database (previously PINEENA) (WaterNSW 2020b)	2020
	Dedicated monitoring network	Peak Complex: 1990 – present New Cobar Complex: 2020 – present
Hydrogeological properties – local	Falling head tests	Completed at the New Cobar Complex monitoring bores (6)
Hydrogeological properties – regional	(Xingxing Kuanga 2019) (Domenico and Schwartz 1997)	n/a
Surface geology	NSW Seamless Geology[2]	n/a
Structural geology	NSW Seamless Geology[3] – Faults spatial data	n/a
Stratigraphy and lithology	Lithology mapping (Beck Engineering 2020)	2020
GDEs	WSPs	2011 and 2020
	GDE Atlas	2020

Notes: 1. DFSI Spatial Services 2014, NSW Government.
2. Department of Regional New South Wales, NSW Government.

4.3 Climate

The dry climate of the Cobar region is characterised by hot summers and relatively mild winters. The mean maximum temperature ranges from approximately 35.8°C in January to 16.4°C in July, with a mean minimum temperature of 3.1°C. Rainfall is low, and typically highest during the summer months. Rainfall data have been acquired from the Project area weather station (monitored since May 2019) and the surrounding BoM weather stations (Table 4.2).

Records from the SILO Data Drill (Queensland Government 2020) have been obtained to augment the available rainfall data. SILO datasets are constructed from observational records provided by BoM. SILO processes the raw data, which may contain missing values, to derive datasets which are both spatially and temporally complete.

Table 4.2 Summary of Rainfall Records

Station	Name	Period	Elevation	Distance to mine development
Site[1]	PGM weather station	May 2019–present	~265 m AHD[2]	Within the mine development area
48027	Cobar MO	1963–present	260 m AHD[2]	Less than 2 kms
48237	Cobar Airport	1993–present	218 m AHD[2]	Approximately 5.5 kms
SILO	Lat: -31.50. Long: 145.85	1900–present	250 m AHD[2]	Covers the study area

Notes: 1. The PGM weather station is located at 390570, 6513785 GDA94 Zone 55

2. m AHD – metres Australian Height Datum.

The long-term average annual rainfall for the area ranges from 332 millimetres (mm) (Cobar Airport, BoM station 48237) to 389 mm (Cobar MO, BoM station 48027). Rainfall has not been recorded at the Project area for long enough to calculate an annual average. The annual pan evaporation for the area exceeds the rainfall total and averages 2,266 mm (SILO). The area has a large rainfall deficit given to the low rainfall and high evaporation with a net annual rainfall deficit of around -1,449 mm.

The annual average rainfall totals for each of the BoM monitoring stations throughout the available data periods are presented in Table 4.3 and on Figure 4.1. The data is presented against the Southern Oscillation Index (SOI) to display correlation. Sustained positive SOI values above about +8 indicate a La Niña event while sustained negative values below about –8 indicate an El Niño event. In the last 20 years the wettest years have been 2000, 2010, and 2015. The Millennium Drought is apparent from 2002 to 2010, corresponding to low and mostly negative SOI values.

Table 4.3 Average monthly climate

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall	37	37	32	25	29	30	26	27	24	31	32	34	364
Evaporation	335	266	233	148	91	60	68	99	149	215	269	332	2,266
Deficit	-231	-176	-154	-93	-44	-18	-28	-53	-96	-142	-183	-231	-1,449

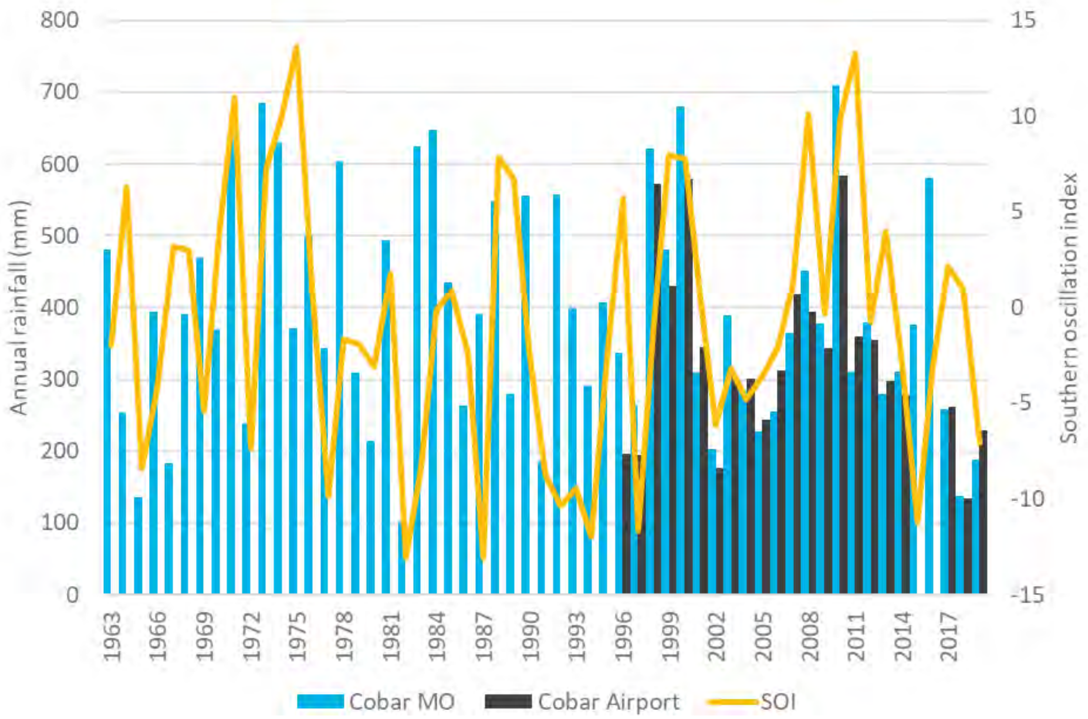


Figure 4.1 Annual rainfall totals 1963 to 2019 (BoM stations 48027 and 48237)

Mean climatic data (rainfall and evaporation) sourced from the climate stations in the area (refer Table 4.2) are presented in Figure 4.2. The figure shows that rainfall does not vary significantly, and evaporation exceeds rainfall throughout the year, with an annual net rainfall deficit of around 1,449 mm.

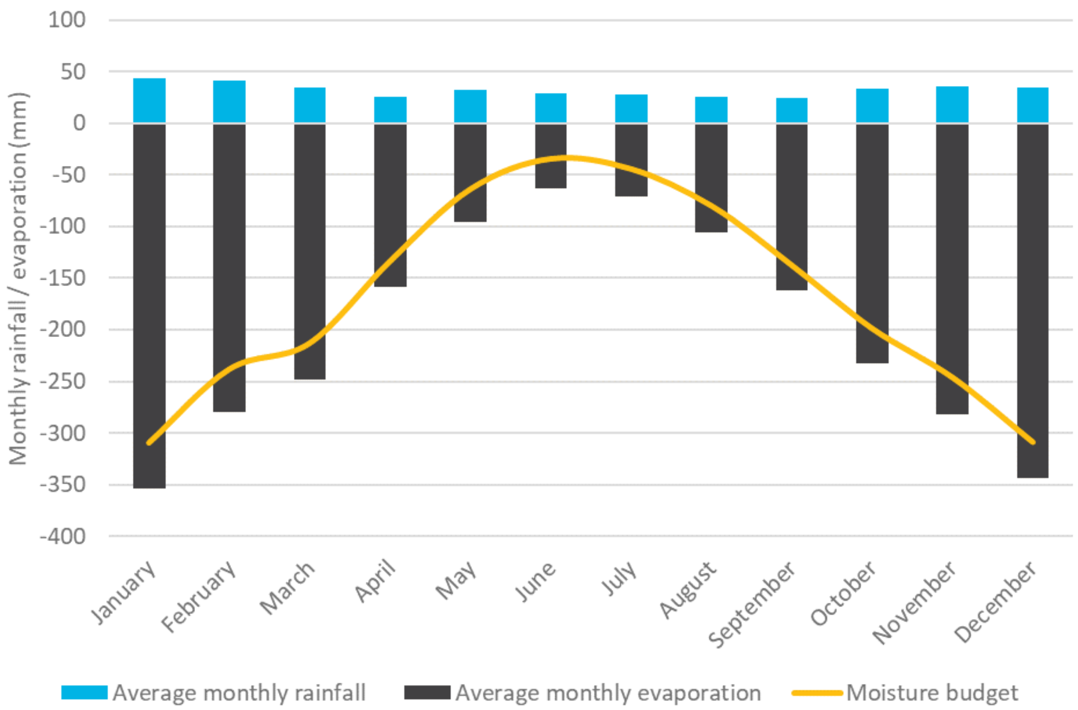


Figure 4.2 Mean climatic conditions

Cumulative deviation from mean (CDFM) rainfall is the accumulated difference between rainfall (in a day, month or year) and the long-term mean, providing an indication of the general climatic trend over time as well as general water availability (soil water, surface water and groundwater). CDFM has been calculated using the full SILO record (1900 to 2019) (Figure 4.3). There is a clear downward trend in the graph, representing below average rainfall for a period of approximately 45 years, from 1900 through to the mid-1940s. From the mid-1940s through to 2000, the trend was largely above average rainfall with some dry years in the late 1960s and early 1980s.

The CDFM (monthly rainfall) is presented for the period January 2000 to end of February 2019 (using climate records from 1900 to February 2019) in Figure 4.4. The plots indicate climate (rainfall) variability is typical of the study area, with periods of:

- above average rainfall occurring in the year 2000, 2008, between 2010 and 2012, and in 2016;
- below average rainfall occurring from 2002 to 2006, and from 2017 to 2020; and
- around average rainfall occurring from 2008 to 2010, and from 2012 to 2016.

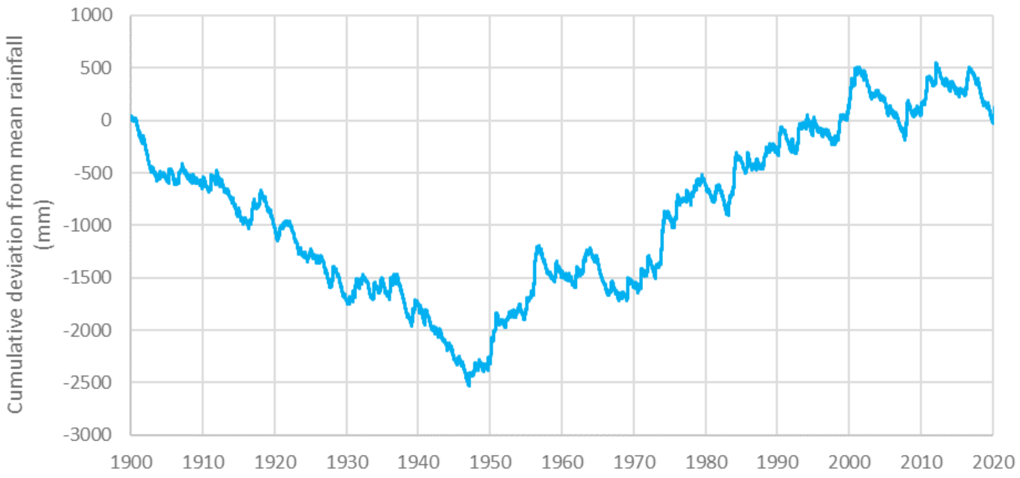


Figure 4.3 CDFM monthly rainfall from SILO (1900 to 2019)

Figure 4.4 CDFM monthly rainfall from SILO (1900 to 2019, presenting only 2000 to 2020)

A comparison of rainfall accumulated from June 2013 to March 2019 for the Project area and SILO record is shown in Figure 4.5. The pattern of this accumulated rainfall and the relatively small difference (17%) between the totals across the five years indicates that the SILO data provides a valid representation of the climate in the study area.

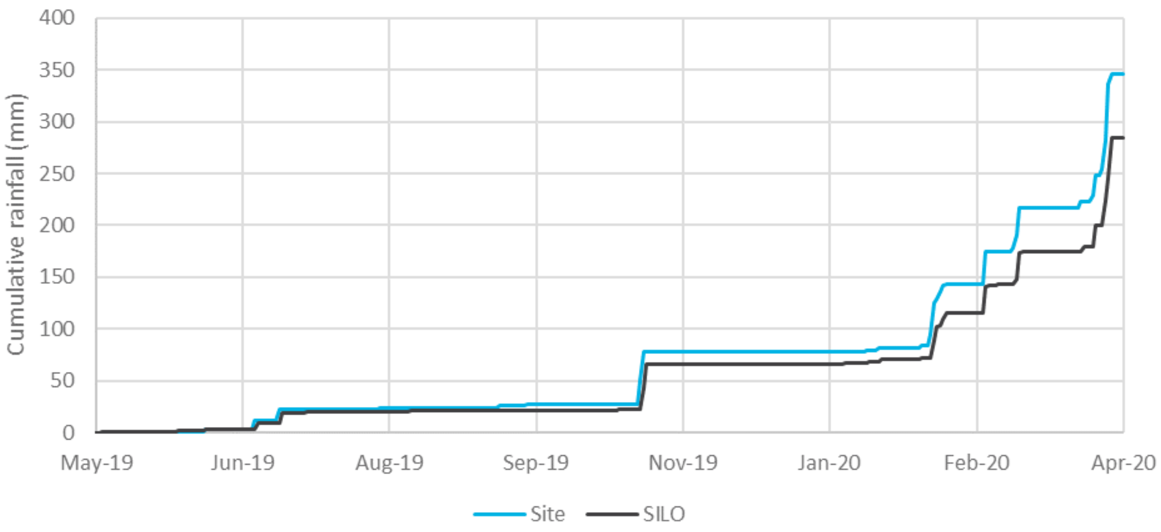


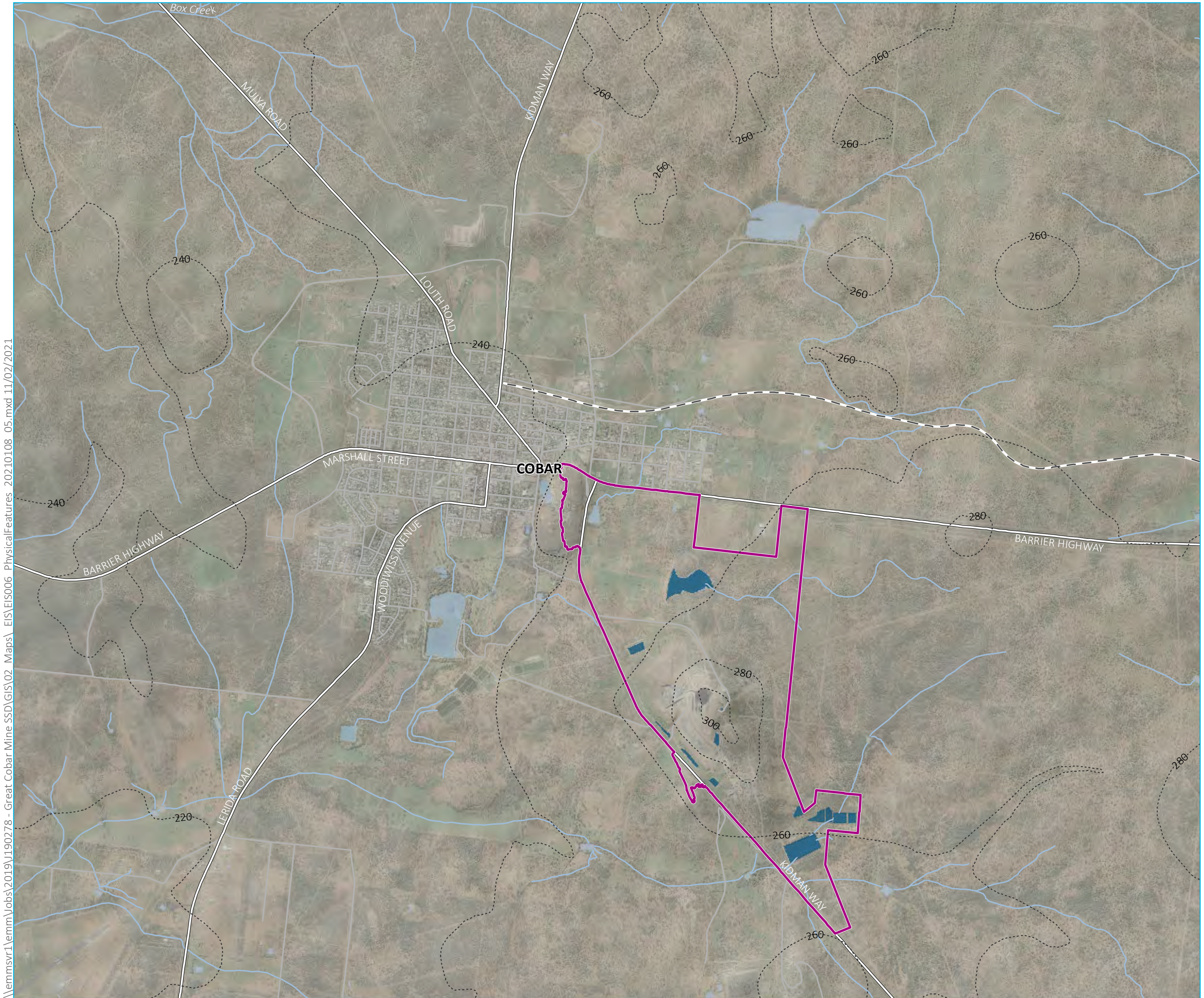
Figure 4.5 Rainfall accumulation comparison between SILO and PGM weather station data records

4.4 Topography

The New Cobar Complex is located within the Cobar Peneplain Bioregion, a subdued bedrock-controlled landscape with a maximum elevation of approximately 300 m AHD (Figure 4.6). The gently undulating landscape is characterised by flat plains interspersed by low, rocky ridges and ranges. The region has low relief, with elevations ranging from approximately 295 m AHD at Fort Bourke Hill (west of the New Cobar open cut) to approximately 240 m AHD at the location of the Great Cobar open cut (historic workings) to the north.

4.5 Surface water

The New Cobar Complex is located within the Yanda Mulga Sandy Creeks Catchment (R.W. Corkery and Co. 2020). Surface water drainage within the complex is largely dominated by sheet wash with mapped drainage features limited to unnamed drainage lines (Figure 4.6). These drainage lines are ephemeral with flows only evident during periods of heavy rainfall. The larger water body to the immediate west of the New Cobar Complex is the man-made reservoir at the Newey Reserve.



KEY

- Project area
- Contour (20 m)
- Rail line
- Major road
- Minor road
- Watercourse/drainage line
- Waterbody
- Mine water management storage

Source: EMM (2021); DFSI (2017); GA (2011); DPE (2019)

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Topography and physical features

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Groundwater assessment
Figure 4.6

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4.6 Regional geology

The Cobar deposits mined from the New Cobar Complex and Peak Complex are located along the eastern margin of the Early Devonian Cobar Basin, which is within the central belt of the Lachlan Orogen. The primary lithologies consist of metamorphosed Ordovician sedimentary basement rock with granite intrusions, overlain by the Late Silurian to Early Devonian Cobar Basin sediments. These in turn are overlain by Late Devonian post-orogenic cover and minor remnants of Mesozoic sediments. Weathering during the Cenozoic has formed deep regolith, which has been locally intruded by minor leucitite lava flows (R.W. Corkery and Co. 2020).

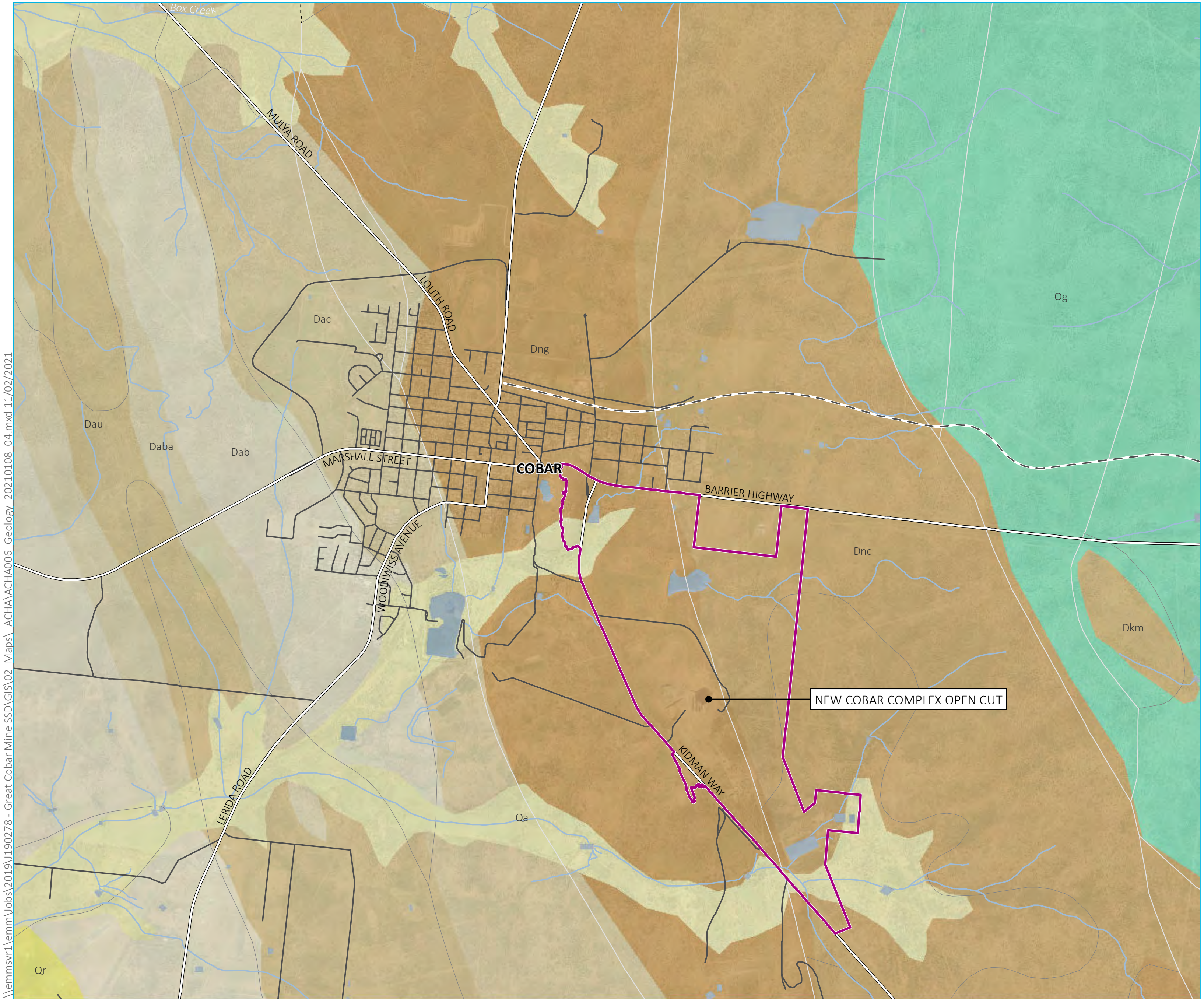
The Cobar deposits are located within the Great Cobar Slate (GCS), on a major north to north-west striking, steeply dipping shear zone. The GCS is the upper stratigraphic member of the Devonian Nurri Group meta-sediments, and is associated with a major, north-north-west striking, steeply dipping shear zone (the Great Chesney Fault; Figure 4.7).

Proposed mining operations will target deposits within the same stratigraphy as all existing PGM operations at both Peak Complex and New Cobar Complex. The simplified stratigraphy is shown in Table 4.4.

Table 4.4 Simplified stratigraphy of the Cobar district

Age	Geological setting	Unit	Composition
Late-Mid Devonian ~395–360 million years (Ma) before present (BP)	Cover	Mulga downs Group	Sandstone, siltstone & shale
Early Devonian ~395–420 Ma BP	Post-rift shelf	Winduck Group	Sandstone & siltstone
	Post-rift basin	Amphitheatre Group	
		• Upper Amphitheatre Group	Sandstone, siltstone & mudstone
		• Biddaburra Formation	Sandstone, siltstone & mudstone
		• Alley Sandstone Member	Sandstone
		• Lower Amphitheatre Group	Sandstone, siltstone, mudstone, minor limestone & volcanics
		• CSA Siltstone	Siltstone & mudstone
	Syn-rift basin	Nurri Group	
		• Great Cobar Slate	Siltstone & mudstone
		• Unnamed Silicic Volcanics	Porphyry & rhyolite
		• Chesney Formation	Sandstone & siltstone
		• Bee Conglomerate Member	Fan conglomerates & sandstones
	Syn-rift shelf	Kopyje Group	Siltstone, sandstone, conglomerate & limestone
		Meryula Formation	
Silurian ~420–445 Ma BP	Basement	Wild Wave Granodiorite	Granodiorite
Cambrian-Ordovician ~445–485 Ma BP	Basement	Girilambone Group	Sandstones, siltstones & meta-sediments

After RPA (2013). Technical Report on the Peak Gold Mines, NSW, Australia



Source: EMM (2021); DFSI (2017); GA (2011); DPE (2019)

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Geological setting

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Groundwater assessment
Figure 4.7

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4.7 Regional hydrogeology

The north-northwest trending fault and fracture complexes control groundwater movement, with groundwater flow parallel to the faults (in a general north-south direction), with little east-west transfer. Major faults exist on the eastern side of the mineral deposits, including the Great Chesney Fault, which are inferred to act as impermeable barriers to groundwater flow. Groundwater levels vary throughout the New Cobar Complex and surrounds, varying by up to 15 m in an east-west direction across the Great Chesney Fault.

Groundwater flow in the GCS is generally associated with secondary porosity associated with the shear zone as well as within developed secondary porosity in the oxidised GCS (weathered regolith). Oxidised rock typically exists to 100 - 150 m bgl.

Previous assessment (EcoLogical 2019) suggests steeply-dipping, north-south elongation to most aquifers, and poor development of east-west fractures. Poor development of east-west fractures limits the extent and flow in this orientation. Hence, whilst situated in close proximity, water bearing fractures strike parallel (north-south) and are generally not hydraulically connected in an east-west direction. Therefore, compartmentalised is developed between regional faults and fracture zones.

Further detailed discussion of the New Cobar Complex hydrogeology is provided in Section 5.

4.8 Sensitive receivers

4.8.1 Private water use

The WaterNSW real-time water data website (WaterNSW 2020b) has been searched to identify records of water supply works surrounding the New Cobar Complex. Water entitlement data from the NSW Water Register (WaterNSW 2020a) has also been considered.

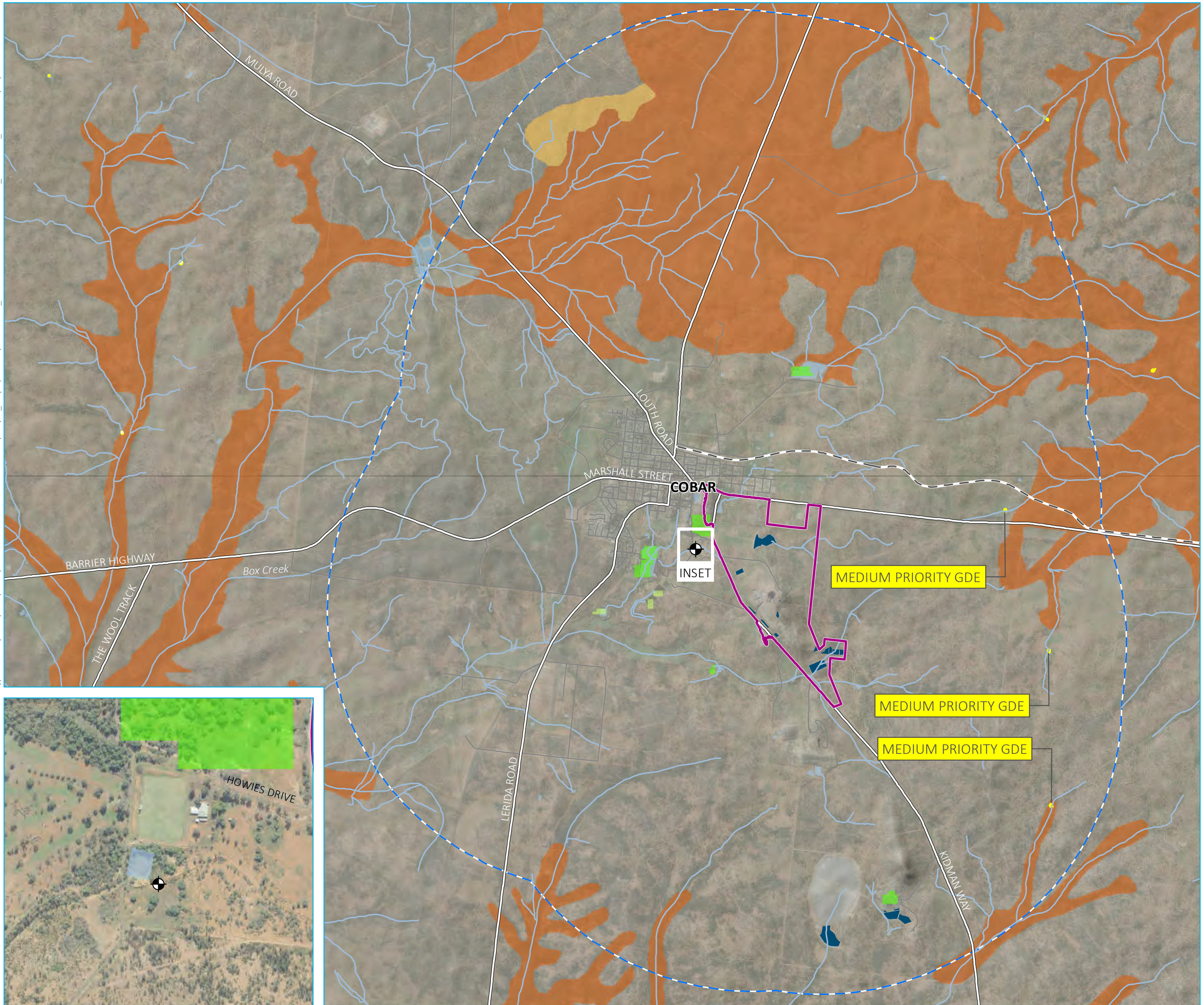
There is one water supply work (GW803422) within a 5 km of the New Cobar Complex. It is located at the Cobar District Rugby Club and used by the club for back-up irrigation of the playing field (during drought or interruption only). Details are provided in Table 4.5. Figure 4.8 shows the location of the water supply work in relation to the New Cobar Complex along with environmental sensitive receivers (see Section 4.8.2).

Table 4.5 Water supply work

Groundwater works ID	Inferred lithology	Licence number	Landholder	Easting	Northing	Bore depth (m bgl)	Yield (L/s)[2]	Standing water level (m bgl)
GW803422	Weathered fractured rock	Not specified	Third-party	389942	6513486	22	0.5	6.0

Notes: 1. L/s=litres per second

PGM have established access to bore GW803422 and commenced a monitoring and sampling program in October 2019. PGM have incorporated this bore into the regular groundwater monitoring schedule as part of its WMP, discussed further in Section 10.2.2.



Source: EMM (2021); PGM (2020); BoM (2017); DFSI (2017); DPIE (2020); DPE (2019); GA (2011)

KEY

- Project area
- Rail line
- Major road
- Minor road
- Watercourse/drainage line
- Waterbody
- Mine water management storage
- Private landholder bore (GW803422.1.1)
- New Cobar Complex buffer (5 km)

Groundwater Dependent Ecosystem Atlas (BoM 2017)

Aquatic GDE potential

- High
- Low

Terrestrial GDE potential

- Moderate
- Low

High Ecological Value Aquatic Ecosystems (DPIE 2020)

Aquatic GDE potential

- Medium
- Low

Sensitive receivers within 5 km of the project area

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 4.8

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4.8.2 Groundwater dependent ecosystems

While regional groundwater systems provide water sources for livestock and other anthropogenic uses, groundwater also supports surface (above ground) and subsurface (below ground) ecosystems that are assessed as beneficial users of groundwater.

A review of the Groundwater WSP, BoM GDE Atlas (BoM 2019), and other relevant legislation and literature has been conducted. The GDE Atlas was developed as a national dataset of Australian GDEs to inform groundwater planning and management.

GDE mapping provided in the Groundwater WSP details no high priority GDEs located within 5 kms of the New Cobar Complex. This mapping is based on the *High Ecological Value Aquatic Ecosystem (HEVAE) Vegetation Groundwater Dependent Ecosystems Value - Western Division* dataset (DPIE 2018). It is understood that the high priority GDEs detailed in the High Priority Groundwater-Dependent Ecosystem Map (GDE024_Version 1) shown in Appendix 2 of the Groundwater WSP are based on the GDEs categorised as high and very high ecological value in this dataset.

Three small GDEs located over two kilometres to the east of the New Cobar Complex (shown in Figure 4.8) are categorised as having medium ecological value under the GDE HEVAE method. A review of the GDE Atlas (Figure 4.8) also identified the following:

- Aquatic GDEs (ecosystems that rely on the surface expression of groundwater–this includes surface water ecosystems which may have a groundwater component, such as rivers, wetlands, and springs):
  - high potential GDEs in the vicinity of the town:
    - associated with the slag dump at the Great Cobar open cut;
    - at the Newey Reservoir to the immediate west of the New Cobar Complex;
    - the old reservoir to the north of the New Cobar Complex;
    - a potential man-made reservoir to the south-west of the New Cobar Complex; and
    - a man-made waterbody to the south associated with the Peak Complex.
  - low potential GDEs to the west of the New Cobar Complex, south of the Newey Reservoir.
- Terrestrial GDES (ecosystems that rely on the subsurface presence of groundwater - includes all vegetation ecosystems):
  - low to moderate potential GDEs are mapped in association with several drainage lines over two kilometres north, east and south of the New Cobar Complex.

The BoM GDE Atlas is considered low reliability and individual locations must generally be field checked to verify the existence and extent of any GDEs.

The Hydrogeological Assessment completed for the Great Cobar Exploration Drive Review of Environmental Factors (EcoLogical 2019) identified potential GDEs occurring as a series of floodplain wetlands to the south of Cobar. The closest was noted to be located 500 m south of the Great Cobar open cut. The report noted that regional groundwater levels in this area are known to be deep (>10 m), meaning it would be unlikely that vegetation would be dependent on groundwater.

5 Hydrogeological assessment

5.1 Groundwater monitoring network

Groundwater monitoring is an essential component in characterising the hydrogeological environment of a project area. Baseline groundwater level and quality information is used to understand the groundwater flow paths, the connection or separation of groundwater bearing zones, and to characterise the existing groundwater system.

PGM has an extensive groundwater monitoring program consisting of six monitoring locations at the New Cobar Complex and 17 monitoring locations at the Peak Complex. The network comprises standpipe piezometers with nested monitoring sites which are designed to aid in aquifer characterisation around the Project area operations. Figure 5.1 shows the monitoring network at both the New Cobar and Peak Complexes.

A local private water bore, GW803422 (Table 4.5) has been incorporated into the Project area monitoring network. Groundwater monitoring locations are shown on Figure 5.1 and were selected based on proximity to potentially sensitive features such as local groundwater works and the proposed developments. The monitoring and sampling program captures groundwater levels and quality of the local groundwater system surrounding the mining operations.

All New Cobar Complex monitoring sites were drilled and constructed in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (NUDLC 2012) and the conditions of the monitoring bore licences. Monitoring bore completion logs for the Project specific monitoring bores are provided in Appendix B.

Routine water monitoring commenced at key Project locations in April 2020, following installation of the Project specific groundwater monitoring network. Monitoring at GW803422 commenced in October 2019. Monitoring at the Peak Complex has been ongoing since July 1990. Monitoring includes measurement of:

- groundwater level;
- physiochemical water quality using a calibrated handheld water quality meter; and
- groundwater samples for laboratory analysis including major ions and dissolved metals.

Monitoring results are discussed further in Section 5.2 (groundwater levels and flow) and Section 5.3 (groundwater quality). Details of monitoring analysis and frequency are outlined in the Peak Gold WMP (EMM 2020b).

5.1.1 New Cobar Complex monitoring bores

A groundwater monitoring network consisting of six monitoring bores was installed at the New Cobar Complex in April 2020. The monitoring network was installed specifically for this Project. Construction details are presented in Table 5.1.

Table 5.1 New Cobar Complex groundwater monitoring network

Station	Location	Easting	Northing	Elevation (m AHD)	Total depth (m bgl)	Screen from - to (m bgl)	Geology
NCMW01_S	Great Cobar slag dump	390148	6513836	234.3	52	46–52	Weathered fractured rock
NCMW01_D		390141	6513835	234.3	100	88–94	Fresh fractured rock
NCMW02_S	Ward Oval	389583	6513868	232.2	60	38–40	Weathered fractured rock
NCMW03_S	'Salty' Dam	390685	6514128	237.0	70	64–70	Weathered fractured rock
NCMW03_D		390683	6514123	237.0	120	95–98	Fresh fractured rock
NCMW06_S	Gladstone	390517	6512735	248.7	60	54–60	Weathered fractured rock

Notes: Map Grid of Australia (MGA) zone 55

5.1.2 Peak Complex monitoring bores

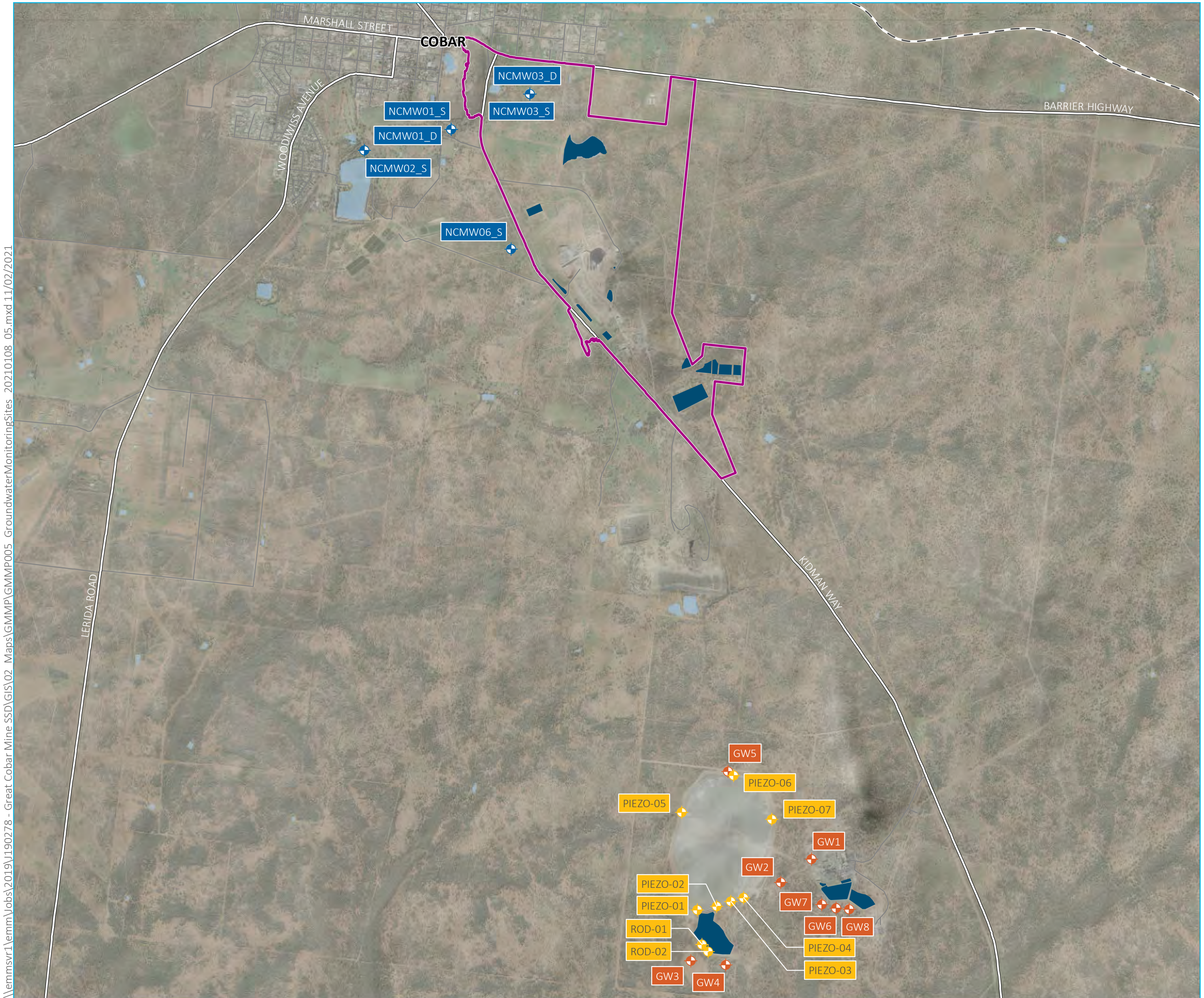
There are eight monitoring bores and eight shallow piezometers at the Peak Complex. The eight piezometers surround the TSF and are specifically used to monitor water levels within the TSF wall to inform wall stability. Details of the monitoring network are presented in Table 5.2.

The Peak Complex monitoring network were used in the model history matching process and to explore the regional groundwater trends given the long time series of observations available. Peak Complex does not form part of this Project approval or assessment. The information is provided as context for the regional hydrogeological conceptualisation and modelling inputs only.

Table 5.2 Peak Complex groundwater monitoring network

Station	Location	Easting	Northing	Elevation (m AHD)	Total depth (m bgl)	Screen from - to (m bgl)	Geology
GW1	RoM pad	393216	6507257	250.6	103	Unknown – casing damaged at 62mbgl	Fresh fractured rock
GW2	TSF	392938	6507051	253.6	96	79 – 91	Fresh fractured rock
GW3	TSF	392131	6506344	238.9	85	67 – 79	Fresh fractured rock
GW4	TSF	392442	6506308	241.7	91	71 – 83	Fresh fractured rock
GW5	TSF	392464	6508046	256.4	77	45 – 49 (open hole) & 61 – 65.5	Fresh fractured rock
GW6*	RWD	393433	6506818	243.9	48	35.5 – 45	Fresh fractured rock
GW7	RWD	393306	6506853	244.4	78	54 – 77	Fresh fractured rock
GW8	RWD	393552	6506808	243.9	78	48.5 – 60	Fresh fractured rock

Notes:
MGA zone 55
* destroyed. No longer operational



KEY

- Project area
- Rail line
- Major road
- Minor road
- Waterbody
- Mine water management storage

Groundwater monitoring location

- New Cobar monitoring bore
- Peak monitoring bore
- Peak piezometer

Source: EMM (2021); PGM (2020); DFSI (2017); GA (2011); DPE (2019)

0 1 2 km

GDA 1994 MGA Zone 55

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Groundwater monitoring network

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 5.1

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5.2 Groundwater levels and flow

5.2.1 Temporal trends

Groundwater levels in the vicinity of the New Cobar Complex are assumed to be influenced by historical mining (both underground and open cut mining), local climatic conditions and topography. Given the limited number of secondary data sources (e.g. WaterNSW groundwater work database), regional and unimpacted mine-related groundwater is assumed to be a subdued reflection of topography and flow way from the elevated plain surrounding Cobar. Depth to groundwater at New Cobar Complex ranges from around 2.8 m bgl at NCMW02, which is south-west of the Great Cobar open cut to 32.4 m bgl at NCMW06. Depth to groundwater at Peak Complex is deeper and ranges from 12.2 m bgl at GW7 to 52.7 m bgl at GW4.

Groundwater level hydrographs for both New Cobar and Peak Complexes are presented in Figure 5.2 and Figure 5.3, respectively. Groundwater levels are generally stable with only minor fluctuations at the New Cobar Complex. Over a longer period as shown at the Peak Complex, groundwater levels can vary by up 40 m in response to various mine related stresses. Seasonal trends are not evident at most of the New Cobar Complex groundwater monitoring sites during the baseline monitoring period. Groundwater level fluctuations observed at GW803422 show evidence of groundwater pumping which is used to abstract water for irrigation of the rugby club playing field. Table 5.3 summarises recent depth to groundwater measurements since 2019.

Table 5.3 Groundwater levels (average 2019-2020)

Station	Minimum groundwater level (m bgl)	Maximum groundwater level (m bgl)	Average groundwater level (m bgl)	Average groundwater elevation (m AHD)
NCMW01_D	13.0	14.9	14.2	220.0
NCMW01_S	12.6	14.3	13.6	220.6
NCMW02	2.8	3.4	3.0	229.6
NCMW03_D	20.6	22.1	21.3	215.8
NCMW03_S	21.9	23.7	22.6	214.4
NCMW06	31.8	32.4	32.0	216.7
GW803422	4.44	9.3	7.75	225.3
GW2	45.1	45.1	45.1	208.6
GW3	46.1	46.1	46.1	192.8
GW4	52.7	52.7	52.7	189.0
GW5	35.4	42.7	39.0	217.4
GW7	12.2	12.2	12.2	232.2
GW8		Dry		

Notes:
GW1 and GW6 not included as bores damaged or destroyed prior to 2019.

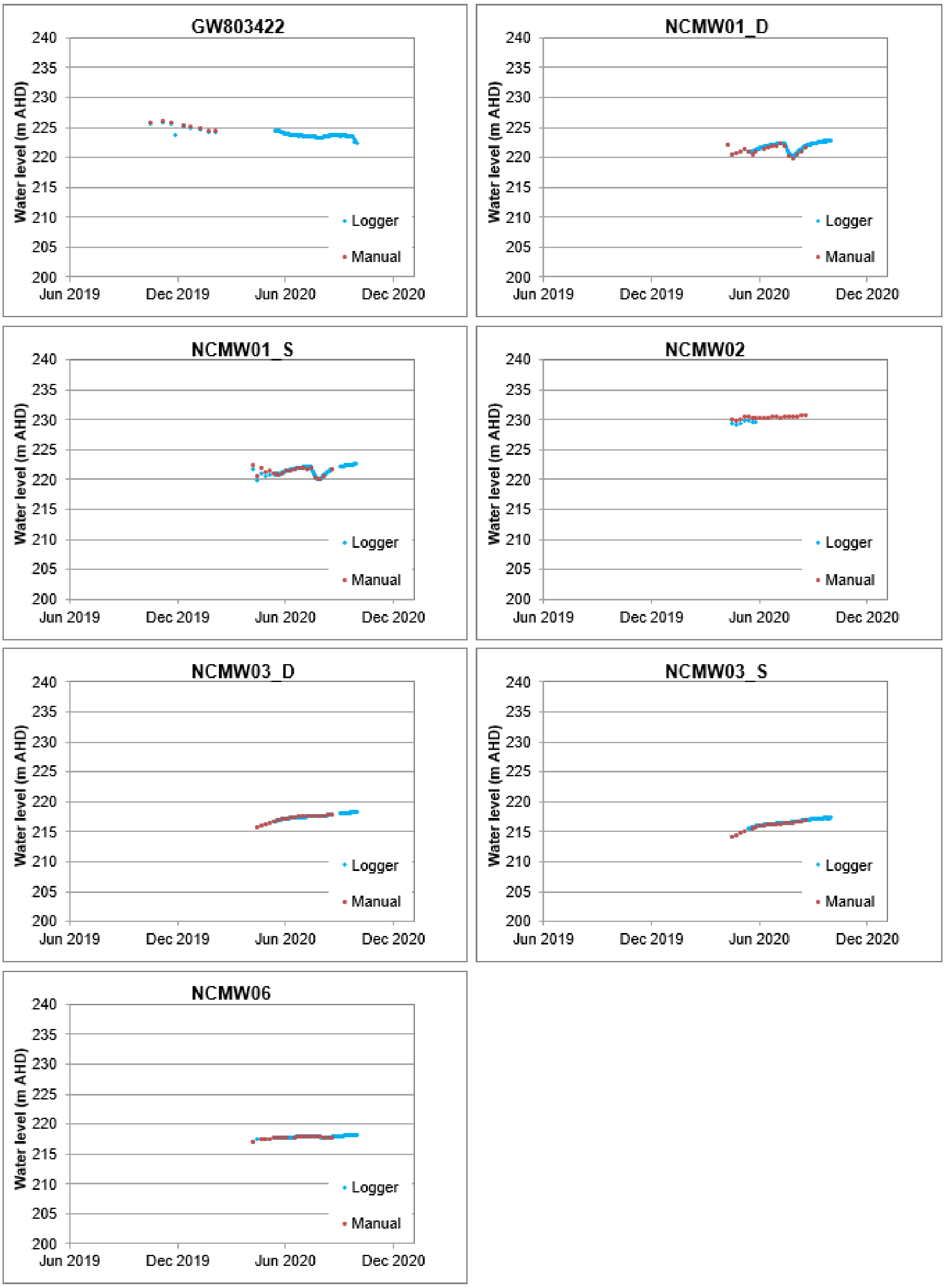


Figure 5.2 New Cobar Complex groundwater hydrographs

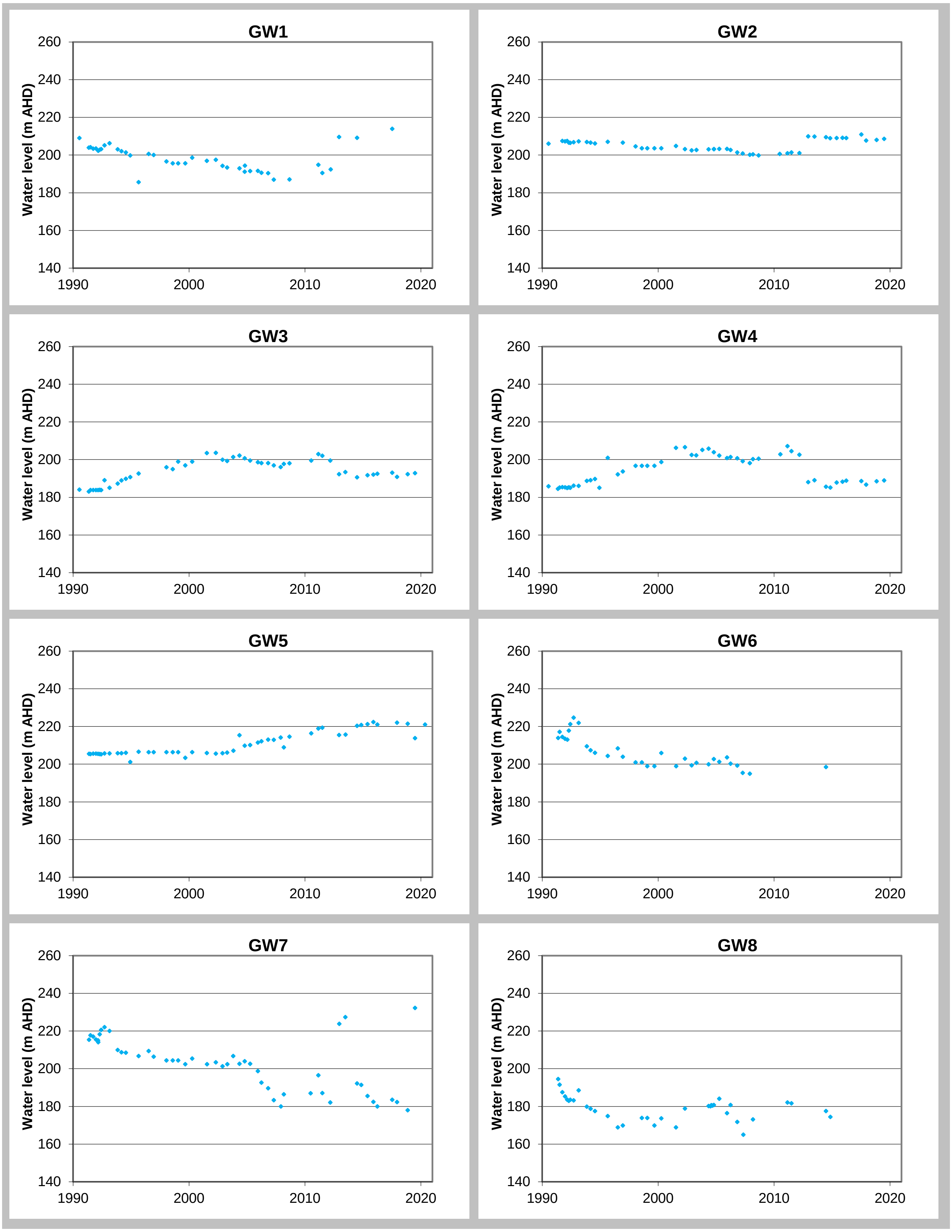


Figure 5.3 Peak Complex groundwater hydrographs

5.2.2 Vertical gradients

Nested monitoring locations allow for the assessment of the vertical movement of groundwater through the fractured rock aquifer. The vertical gradient (i.e. the difference of groundwater pressure elevations) measured at the two nested sites (NCMW01 and NCMW03) is negligible suggesting minimal groundwater leakage occurs under the current conditions at New Cobar Complex and is dominated by horizontal groundwater flow. At the Peak Complex however, groundwater drawdown is observed and is caused by underground mining activities occurring at several hundred meters below the bore screens, suggesting a high component of vertical flow exists here.

5.2.3 Spatial trends

Groundwater elevations are generally higher around the New Cobar Complex and flow southward towards the Peak Complex. Local drawdown is evident around the underground mining areas at Peak Complex, which causes a cone of depression to develop. Observed groundwater levels around the mining operations do not indicate widespread decline. Groundwater levels are relatively shallow to the west of the mining areas as measured in NCMW02 indicating minimal widespread drawdown has occurred since mining began in the Cobar region.

5.3 Groundwater quality

5.3.1 Overview

Groundwater quality from New Cobar Complex monitoring bores is brackish to saline with electrical conductivity (EC) ranging from 6,437 micro siemens per centimetre (µS/cm) in NCMW01_S to 12,800 µS/cm in NCMW02. The monitoring shows that EC increases with depth as shown on Figure 5.4. Shallow groundwater measured in the local groundwater user (GW803422) with a screen depth of 22 m bgl and located directly south of the historical Great Cobar open cut (Figure 4.8) is brackish with an average EC of 2970 µS/cm. Shallow groundwater receives recharge from rainfall hence has a lower EC. Increasing EC with depth is attributed to water-rock interactions and the increase in dissolved mineral concentrations as water moves along the flow path.

Groundwater field pH is slightly acidic to neutral ranging from 6.1 in NCMW01_D to 7.2 (NCMW02). Oxidation potential is generally positive (gaining electrons) ranging from 73.7 mV at NCMW02 to 125.9 mV at NCMW06.

A summary of field groundwater quality results is presented in Table 5.4.

Table 5.4 New Cobar physiochemical groundwater quality (average)

Parameter	Unit	NCMW01_D	NCMW01_S	NCMW02	NCMW03_D	NCMW03_S	NCMW06	GW803422
Electrical conductivity	µS/cm	9,615	6,437	12,690	9,614	12,800	7,291	2,970
pH	pH	6.1	7.0	7.2	7.1	7.1	7.1	7.3
Dissolved oxygen (mg/L)	mg/L	3.9	21.5	20.4	41.3	42.9	17.3	12.8
Redox	mV	-9.5	98.7	73.7	81.7	105.3	125.9	63.4
Temperature	°C	23.9	23.6	23.1	23.7	24.8	21.6	3,349.6

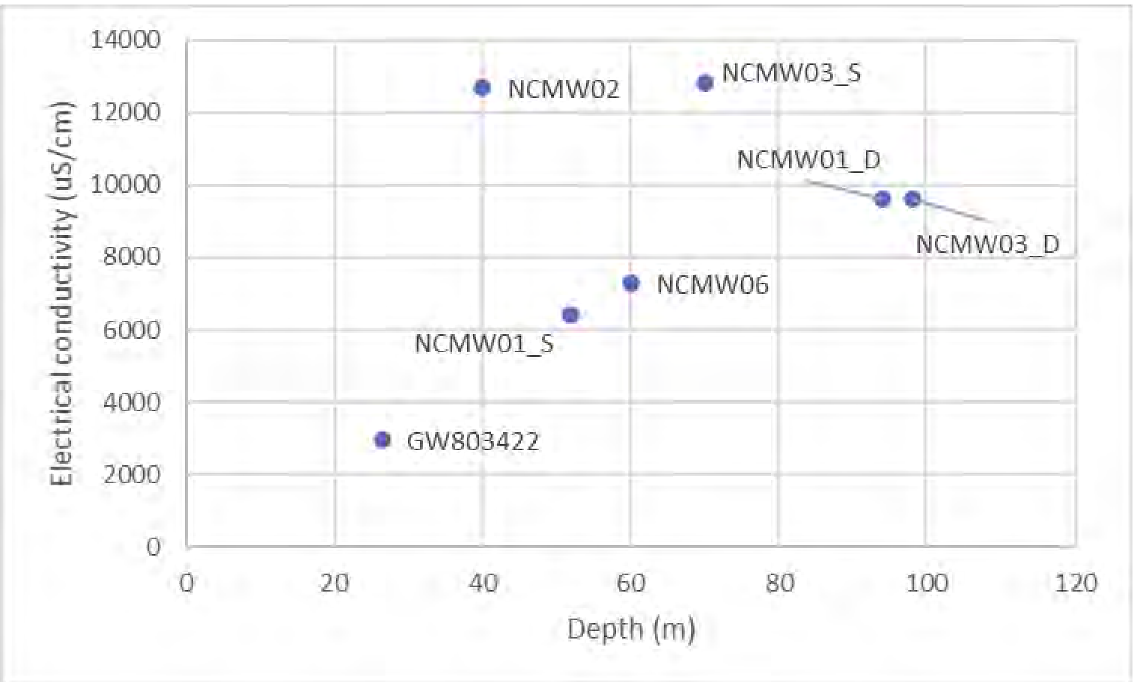


Figure 5.4 Electrical conductivity with depth (m)

5.3.2 Salinity and major ions

Major ions are dominated by chloride (Cl) and sodium (Na). The piper plot shown on Figure 5.5 shows similar major ion ratios for all groundwater in the Cobar area with a Na-Cl-SO_4 water type. Major ions are generally lower in GW803422, likely due to the shallow installation depth and freshening from rainfall infiltration. The groundwater is associated with the fractured rock aquifer and suggests evaporation and water-rock interactions are the main processes influencing groundwater quality within the region. A summary of sampling results is presented in Table 5.5.

Table 5.5 Average major ions concentrations

Parameter	Unit	NCMW01_D	NCMW01_S	NCMW02	NCMW03_D	NCMW03_S	NCMW06	GW803422
Calcium	mg/L	309	132	235	186	293	169	48
Magnesium	mg/L	385	188	398	257	391	263	80
Potassium	mg/L	49	39	64	30	41	44	31
Sodium	mg/L	1,420	1,040	2,060	1,620	2,200	1,090	443
Chloride	mg/L	2,560	1,510	4,090	2,720	4,210	1,520	713
Sulphate	mg/L	1,730	796	1,190	921	1,220	1,210	317
Bicarbonate alkalinity	mg/L	204	334	408	619	468	405	300
Carbonate alkalinity as CaCO3	mg/L	1	1	1	1	1	1	1
Hydroxide alkalinity as CaCO3	mg/L	1	1	1	1	1	1	1
Total alkalinity as CaCO3	mg/L	204	334	408	619	468	405	300

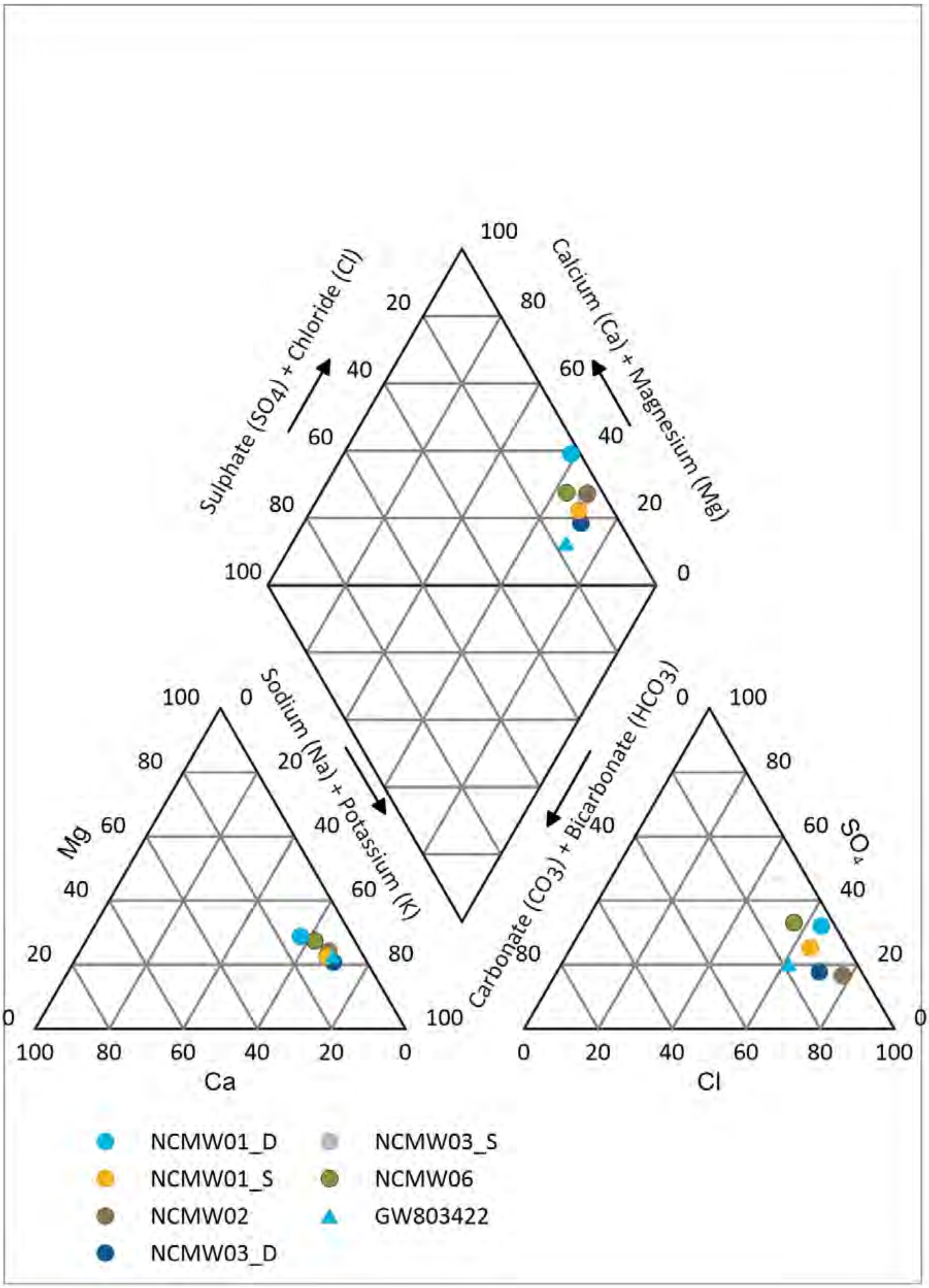


Figure 5.5 Piper plot for the New Cobar Complex

5.3.3 Dissolved metals and metalloids

Dissolved metals have low concentrations and are generally below the laboratory detection limit. Detected dissolved metals include arsenic, boron, cadmium, chromium, copper, lead, manganese, molybdenum, nickel, selenium, and zinc. Concentrations are generally less than 1 mg/L. Concentrations greater than 1 mg/L are:

- boron at NCMW03_D;
- manganese at NCMW01_D; and
- zinc at NCMW01_D.

NCMW01_D and NCMW03_D are located directly south and east of the historical Great Cobar open cut, respectively. A summary of sampling results is presented in Table 5.6.

Table 5.6 Total metals (average)

Parameter	Unit	NCMW01_D	NCMW01_S	NCMW02	NCMW03_D	NCMW03_S	NCMW06	GW803422
Antimony	mg/L	0.0006	<0.0002	<0.0002	0.002	0.01	<0.0002	<0.0002
Arsenic	mg/L	0.0009	0.0004	<0.0002	0.0005	0.0008	0.0002	0.0007
Beryllium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Boron	mg/L	0.76	0.83	0.93	1.37	0.75	0.64	0.47
Cadmium	mg/L	0.03	0.0009	0.0001	<0.00005	0.0001	0.0002	<0.00005
Chromium	mg/L	0.0002	0.001	0.0004	0.0003	0.0003	0.0004	<0.0002
Cobalt	mg/L	0.19	0.0001	<0.0001	0.0003	0.0007	0.001	0.0002
Copper	mg/L	0.0012	0.008	<0.0005	0.0063	0.0022	0.004	0.0028
Gold	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	mg/L	0.0268	0.0016	<0.0001	0.0002	0.0002	0.0005	0.0003
Manganese	mg/L	2.04	0.0006	0.002	0.024	0.042	0.041	0.005
Molybdenum	mg/L	0.0006	0.0006	0.0003	0.002	0.003	0.0007	0.0002
Nickel	mg/L	0.1180	0.0014	0.0006	0.004	0.005	0.002	0.0008
Selenium	mg/L	0.004	0.011	0.015	0.030	0.023	0.013	0.001
Silver	mg/L	<0.0001	0.0003	<0.0001	0.0004	<0.0001	<0.0001	<0.0001
Tin	mg/L	<0.0002	<0.0002	<0.0002	0.016	0.008	0.001	<0.0002
zinc	mg/L	31.300	0.144	0.006	0.027	0.013	0.089	0.009

5.4 Hydraulic testing

Hydraulic slug tests were conducted on monitoring bores at New Cobar Complex (NCMW01 - NCMW06) after construction in May 2020. Tests completed include rising and falling head tests (slug tests) and provides Project area-specific information on the hydraulic properties of the surrounding aquifer. Analysis of this data and calculated hydraulic conductivity (K) results are provided in Table 5.7. Due to the hydraulically tight geology in the study area, it has not been practical to conduct a test pumping program to provide estimates of aquifer storage and additional hydraulic conductivity data.

Table 5.7 Hydraulic testing results

Bore ID	Hydraulic conductivity (metres per day (m/day))	Geology
NCMW01_S	25.1	Weathered fractured rock
NCMW01_D	12.5	Fresh fractured rock
NCMW02	2.2	Weathered fractured rock
NCMW03_S	0.12	Weathered fractured rock
NCMW03_D	0.09	Fresh fractured rock
NCMW06	13.8	Weathered fractured rock

5.4.1 Hydraulic conductivity

Slug tests provide an indication of the hydraulic conductivity across the screened lithology within close proximity of a monitoring bore, and account for both matrix and secondary permeability. A total of six slug tests were carried out at six groundwater monitoring bores (Table 5.2). This involved installing an automated pressure transducer in the monitoring bore, displacing water using a slug (a solid cylinder) and measuring the water level displacement over time until it had returned to the static level.

It is noted that the monitoring bores are preferentially screened across the highest yielding sections of the intersected lithology. In addition, the screened intervals at the test locations are screened in across the upper weathered fractured rock and are less than 100 m bgl.

The results provide an estimate of hydraulic conductivity of the discrete water bearing fractures intercepted during drilling (i.e. where the monitoring bore screens were placed). The water bearing fractures represents a small proportion of the total rock mass, which is mostly represented by very low permeability, sub-vertical dipping mudstone/siltstone of the GCS. Due to the nature of the fractured rock aquifer (i.e. dominated by secondary porosity fractures), the slug tests results are biased towards higher hydraulic conductivity sections of the bulk rock mass. Graphical analysis results of individual tests are presented in Appendix C.

The effective hydraulic conductivity was calculated to distribute the hydraulic conductivity over the entire aquifer thickness for the weathered and fresh rock aquifers, rather than apply the hydraulic conductivity from discrete fracture zones as calculated by the slug test analysis. The effective hydraulic conductivity is the result of upscaling or spatial averaging of the heterogeneities of the fractured rock.

This approach is considered reasonable since large sections of the aquifers have a very low hydraulic conductivity (i.e. limited potential to conduct groundwater). The following approach was used to calculate the effective hydraulic conductivity (K_{eff}) for each monitoring bore site at New Cobar:

- K_f is the hydraulic conductivity estimated across the identified fractured zone derived from the slug test analysis (refer to Section 5.4);
- Screen length (b_f) is based on the bore construction detailed in Section 5.1, and is assumed to represent the thickness of the water bearing fractured zone;
- aquifer thickness (b_{nf}) is the water level to the base of the weathered zone for the shallow bores and for the deeper bores, an aquifer thickness of 1000 m has been assumed; and

- the non-fractured areas have a hydraulic conductivity (K_{nf}) and is assumed to have a hydraulic conductivity of 8.64 x 10^{-6} m/d.

Therefore, the effective hydraulic conductivity is:

$$K_{eff} = \frac{(b_{nf} \cdot K_{nf} + b_f \cdot K_f)}{b_f + b_{nf}}$$

The resulting effective hydraulic conductivity values are given in Table 5.8.

Table 5.8 Effective hydraulic conductivity (m/day)

Bore ID	Hydraulic conductivity (m/day) for water bearing zone	Screen length (m)	Aquifer thickness (m)	Non-fractured rock hydraulic conductivity (m/day)*	Effective hydraulic conductivity (m/day)
	(K_f)	(b_f)	(b_{nf})	(K_{nf})	(K_{eff})
NCMW01_S	25.1	6	118.3	8.64 x 10^{-6}	1.2
NCMW01_D	12.5	6	1,000	8.64 x 10^{-6}	7.5 x 10^{-2}
NCMW02_S	2.2	5	118.1	8.64 x 10^{-6}	8.9 x 10^{-2}
NCMW03_S	0.12	6	120.3	8.64 x 10^{-6}	5.1 x 10^{-3}
NCMW03_D	0.09	6	1,000	8.64 x 10^{-6}	5.4 x 10^{-4}
NCMW06_S	13.8	6	121.2	8.64 x 10^{-6}	0.7

Note: * Non fractured hydraulic conductivity unfractured igneous and metamorphic rocks (Domenico and Schwartz 1997)

5.5 Groundwater recharge and discharge

5.5.1 Recharge

Recharge to the groundwater systems is expected to occur primarily via rainfall infiltration. Rainfall distributed recharge is expected to be very low, given the low rainfall and high evapotranspiration in the region. Water enters the aquifer by infiltration through the weathered fractured rock in the upper sections of the GCS and the surficial unconsolidated sediments in the area.

Rainfall recharge in the study area was assessed using the chloride mass balance method (Scanlon 2002). The method assumes chloride concentrations in groundwater arise from aerosols and precipitation with negligible contributions from rock weathering and anthropogenic sources. This assumption allows the estimation of recharge based on the mass of chloride observed in groundwater. Recharge estimates were derived using the median value of chloride concentrations measured during the baseline period from the water table monitoring bores.

Table 5.9 presents recharge estimates based on the following criteria:

- average precipitation rate 364 mm/yr (Table 4.3);
- rainfall chloride concentration 1.07 mg/L (Davies and Russell 2014); and
- groundwater chloride concentrations (adopting the average concentration reported).

Table 5.9 Groundwater recharge estimated from chloride mass balance

Bore ID	Recharge estimate (mm/yr)	Percentage of annual average rainfall
GW803422 (CDRUFC)	0.5	0.15%

Chloride mass balance testing suggests an average rainfall recharge of 0.5 mm/yr; approximately 0.15% of annual average rainfall. The calculated recharge rate using the chloride concentration from GW803422, which has the shallowest installation depth than the surrounding monitoring bores and therefore represents the water table receiving environment.

5.5.2 Discharge

The main discharge in the area is mine dewatering, which is pumped to surface and used within mining and processing operations. There is limited natural groundwater discharge to surface water bodies (e.g. discharge to creeks) and/or loses via evapotranspiration given the depth to groundwater being generally greater than five metres.

5.6 Mine dewatering

Groundwater from the New Cobar Complex underground workings is managed by pumping from development headings to various underground pump stations. The water is then pumped to the New Cobar Complex settlement ponds at the surface, where the sediment is removed. The water from these settlement ponds is preferentially returned underground for use in mining operations or pumped to the Peak Complex for reuse in the processing circuit. The water from the Peak Complex underground workings is pumped to various underground pump stations and then to the surface where it is used in processing operations.

Mine ingress in the area varies with depth and is recorded to range from 14 L/s for shallow (<100 m) workings in the weathered regolith to less than 2 L/s for deep (>200 m) workings (EcoLogical 2016). Average groundwater inflow to the underground operations is <0.5 L/s for Peak Complex and 4-8 L/s for New Cobar Complex. New Cobar Complex groundwater inflow has varied from 15 L/s to less than 1 L/s over the period 2018 to 2019 as shown on Figure 5.6. The temporal changes of inflow volumes reflect the variable aquifer conditions, with the density of fractures intercepted during mining progression determining the relative amount of groundwater ingress.

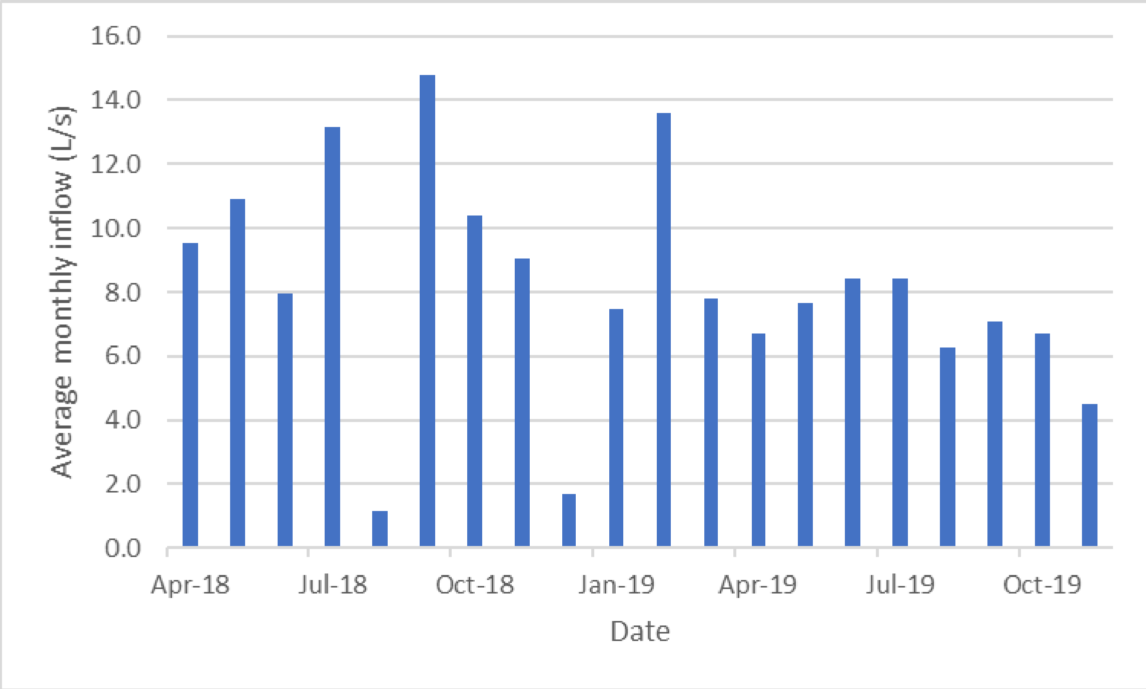


Figure 5.6 Average monthly New Cobar Complex groundwater inflow (L/s)

6 Conceptual hydrogeological model

Current hydrogeochemical understanding of the New Cobar deposits and the surrounding environment is presented in Appendix E of this report, which along with historical data from the neighbouring deposits has been used to develop an understanding of the broader hydrogeological system.

Table 6.1 provides a summary of key knowledge, including the hydrogeological framework, groundwater recharge, groundwater discharge and flow directions; and forms the conceptual hydrogeochemical model for the New Cobar Complex. Groundwater flow, recharge and discharge processes are summarised below for completeness and the conceptual model of the areas is described visually in Figure 6.1 and Figure 6.2 from a local and more regional scale, respectively.

6.1 Groundwater flow

Regionally, groundwater flows away from the elevated paleoplain of the Cobar region to the regional river valleys of the Darling and Macquarie Rivers. Locally, groundwater flow patterns have been altered by historical and contemporary underground mining. Recent groundwater levels collected around the New Cobar Complex do not indicate widespread groundwater level decline due to historical mining operations.

In the study area, groundwater flow in the GCS aquifer flows primarily through discrete water-bearing zones because the rocks that constitute the aquifer have little interconnected primary porosity. These water-bearing zones include fractures that developed parallel and perpendicular (joints) to bedding and widened through chemical dissolution of minerals within the rocks. The water-bearing zones comprise fractures that developed in zones of weakness in the rock in response to various stresses.

The GCS provides little groundwater for use as demonstrated by the few groundwater works throughout the area. The low permeability of the GCS fracture network controls and restricts groundwater movement normal to the fracture planes.

6.2 Groundwater recharge and discharge

Recharge to the groundwater systems is expected to occur primarily via rainfall infiltration, with the chloride mass balance estimating an average rainfall recharge of 0.5 mm/yr; approximately 0.15% of annual average rainfall.

Groundwater withdrawals from the GCS are primarily from underground mine dewatering, with some minor withdrawal occurring historically from the New Cobar open cut. Groundwater inflow into the underground workings is pumped to surface via a series of pipes and pumps and incorporated into the open cut water system.

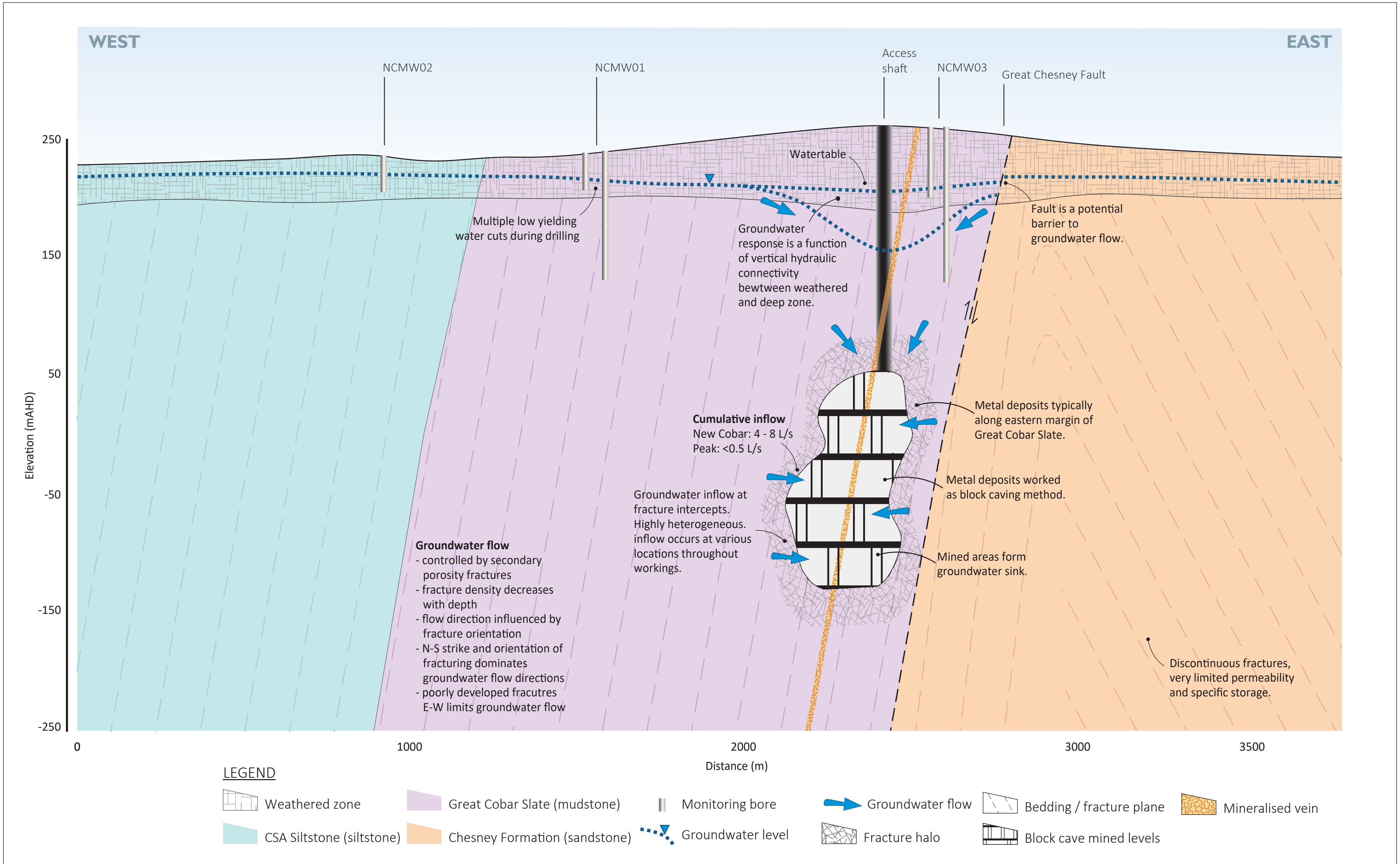
There is limited groundwater discharge to surface in the area, if any, primarily due to the relatively flat relief and the natural depth to groundwater.

Table 6.1 Summary of the New Cobar conceptual hydrogeological model

Feature of conceptual model	Summary of key knowledge
Hydrogeological framework	• the GCS located along the eastern margin of the Early Devonian Cobar Basin, which is within the central belt of the Lachlan Orogen. • faulting and bedding fractures has the potential to disrupt regional groundwater flow. • two hydrostratigraphic units have been identified: the upper weathered fractured rock (0–150 m) and the lower fresh fractured rock (>150 m)
Groundwater levels and flow	• regional groundwater flow occurs generally south and north away from Cobar paleoplain towards the Lachlan and Darling Rivers to the south and north, respectively • the water table elevation in the study area is within the upper weathered fractured rock of the Great Cobar Slate where depth to groundwater is approximately 3 mbgl at NCMW02, increasing to approximately 30 mbgl at NCMW06. (Note that the shallowest first water cut recorded is 22 mbgl at NCMW01S). • there is limited widespread drawdown in the area and groundwater levels have not been affected by historical mining at the New Cobar Complex. However, groundwater responses are observed at the Peak Complex with drawdowns of up to 40 m being measured since 1990. This may demonstrate that vertical connectivity is relatively high. • the Great Chesney Fault, east of the New Cobar Complex is conceptualised as being a barrier to flow, causing potential compartmentalisation of the groundwater system.
Recharge mechanisms	• water enters the aquifer by infiltration through the weathered fractured rock in the upper sections of the GCS and by surficial unconsolidated sediments in the area. • diffuse recharge from rainfall is expected to be low, estimated at 0.15 mm/yr from the chloride mass balance to 3 mm/yr as assumed in the groundwater flow model (Section 8).
Groundwater discharge	• groundwater withdrawals from the GCS are primarily from underground mine dewatering. • there is limited groundwater discharge to surface in the area, primarily due to the relatively flat relief and the natural depth to groundwater.
Aquifer properties	Horizontal hydraulic conductivity: • weathered fractured rock between 0.047 to 4.5 m/d (Domenico and Schwartz 1997). Modelled at 0.015 m/day (Section 8) • fresh fractured rock between 8.64 x 10^{-7} to 0.5 m/d (Domenico and Schwartz 1997). Modelled at 7.39 x 10^{-4} (Section 8) • hydraulic 'slug' testing: 0.12 to 25 m/d, mean 8.9 m/d across the weathered basement fractured zone. Storativity: • weathered fractured rock: 1.3 x 10^{-5} (see Section 8) • fresh fractured rock: 1.3 x 10^{-5} (see Section 8) Specific yield (Sy): • upper weathered fractured rock: 0.05 (see Section 8) • fresh fractured rock: 0.005 (see Section 8)
Hydrogeochemistry	• brackish to saline groundwater quality • groundwater quality increases with depth, at increasing distance form rainfall recharge areas • groundwater system is mainly in an oxidisation environment • groundwater is dominated by a chloride-sodium-sulphate signature • dissolved metals are minor suggesting minor groundwater/mineralogical interaction. • some PAF material has been identified.

Table 6.1 Summary of the New Cobar conceptual hydrogeological model

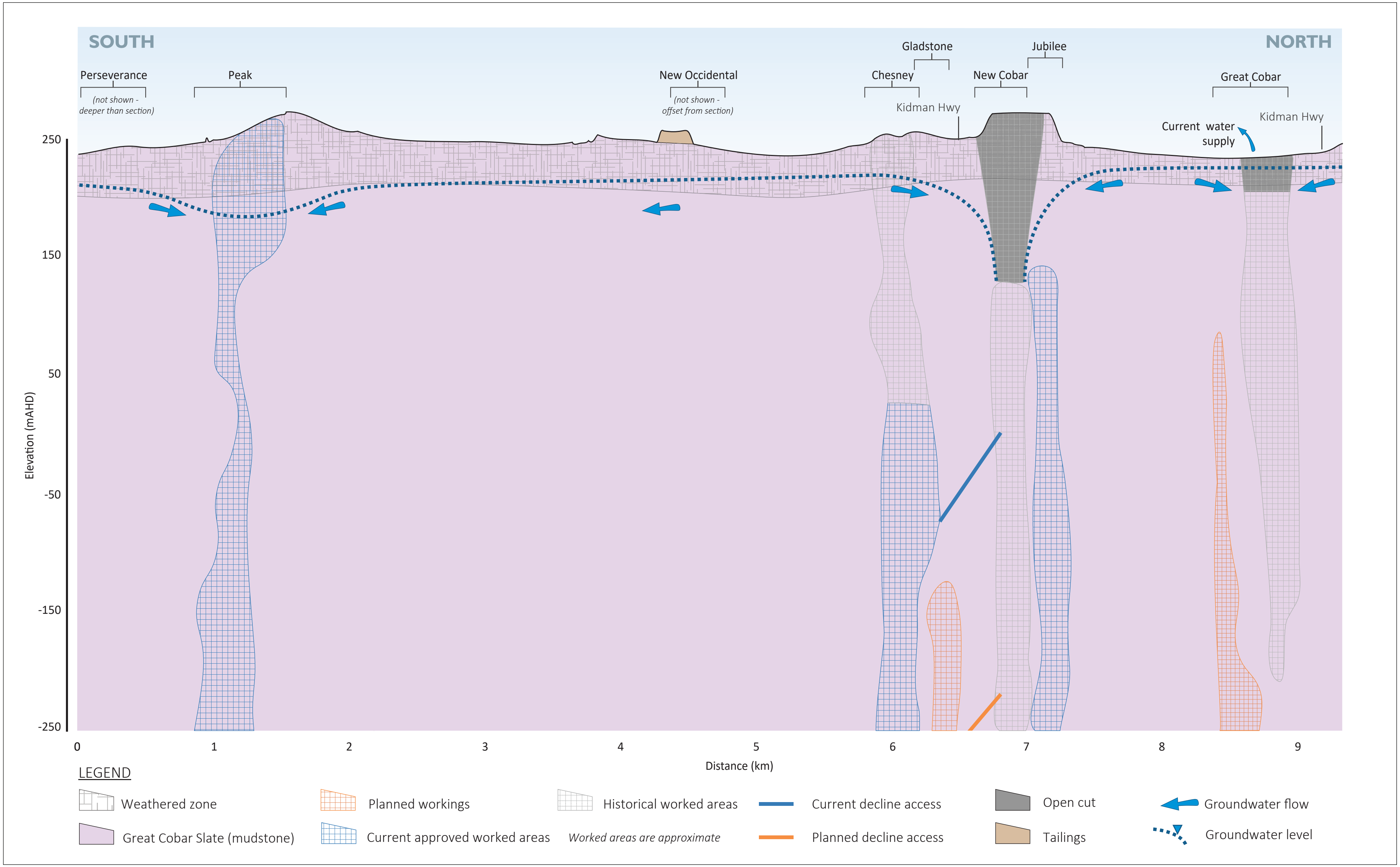
Feature of conceptual model	Summary of key knowledge
Aquifer interception	• groundwater is intercepted by both historic and current mining areas. • groundwater is withdrawn from the aquifer in mine operation areas only • underground void areas formed by historic mining accumulate water in the void space and/or are managed as underground water storages



Conceptual cross section through the planned Great Cobar underground complex (east to west)

Peak Gold Mines
Groundwater Assessment
Figure 6.1

EMM creating opportunities



Conceptual regional long-section (north to south)

Peak Gold Mines
Groundwater Assessment
Figure 6.2

7 Assessment approach

7.1 Risk assessment

The National Water Commission (NWC) mining risk framework (Moran 2010) has been adopted for the groundwater risk assessment. The framework uses a source-pathway- analysis that describes how water-affecting activities might impact on sensitive groundwater receptors. For an effect to occur to a sensitive water receptor, an exposure pathway must exist between a water-affecting activity and a receptor. Risks are characterised by making an informed decision as to the potential for adverse effects to impact sensitive groundwater receptors as a result of mine-related activities.

- The impact assessment quantifies the risk from water-affecting activities and involves assessing the potential consequences arising from the water-affecting activities in terms of direct effects (altered water resource condition) and in terms of possible receptor response (such as reduced water access for other users).

- The risk assessment provides a basis for communicating risks and identifying the management approach strategies that may be necessary. The groundwater monitoring program will continue to collect data and be evaluated. Results of monitoring may be used to review the management measures and approach.

7.1.1 Direct effects

Direct effects encompass changes to physical and/or quality aspects of groundwater, or the changes to the physical characteristics of aquifers as a result of an activity or change to the existing environment. Examples include changes in groundwater levels, changes in groundwater chemistry, or changes in hydraulic properties of aquifers (Moran 2010) as documented in Table 7.1.

7.1.2 Indirect effects

Indirect effects of water affecting activities are those that arise in response to direct effects and typically relate to the potential for impact on sensitive receptors. The indirect effects of the groundwater affecting activities identified are summarised in Table 7.2. The assessment of potential receptor exposure to adverse changes in the groundwater regime (quantity, quality, groundwater and surface water interactions, and physical disruption of aquifers) requires the following:

- knowledge of the location of sensitive receptors within the landscape, particularly in relation to the location and area of influence of water affecting activities;

- an understanding of the receptor's reliance on groundwater (e.g. depth to water table, groundwater flux to baseflow-fed streams, groundwater quality to meet beneficial purposes); and

- an understanding of the spatial and temporal scale of direct groundwater effects at the location of sensitive receptors.

Table 7.1 Direct groundwater-affecting activities

Direct effect	Water affecting activity	Potential risk/effect
Quantity	• mine dewatering	• water table drawdown, aquifer depressurisation.
	• groundwater supply development (mine inflows used as major water supply for the Project)	• insufficient water supply source for Project. • drawdown in landholder bores is significantly larger than predicted.
	• stockpiling	• altered recharge.
	• backfilling	• altered hydraulic properties.
	• wastewater ponds and water storage	• perched water table, seepage, water table mounding, overtopping of dams.
Quality	• mine dewatering	• mobilisation of salts and heavy metals.
	• stockpiling	• acid mine drainage (AMD), leaching of solutes.
	• backfilling	• introducing solutes.
	• wastewater ponds and water storage	• leaching of solutes.
	• dust suppression	• salt retention in landscape.
	• built infrastructure (roads, buildings, plant)	• solutes in runoff.
	• hazardous goods storage (containment failure)	• solutes in runoff, short-term release of contaminants.
Aquifer interception	• excavation / mining	• removal of part or whole of aquifer.
	• backfilling	• altered hydraulic properties.
	• stockpiling	• hydraulic loading of aquifers.
	• Great Cobar development intercepting old underground workings	• in-rush of water from Great Cobar pit, safety concerns for employees working underground.
	• Great Cobar development causing increased leakage from Great Cobar historical underground workings and shaft	• reduction in water security.

Table 7.2 Indirect groundwater effects

Indirect effect	Impacted environmental value	Potential effect (source-pathway-receptor)
Quantity	• aquatic ecosystems	• GDE mapping provided in the Groundwater WSP details no high priority GDEs located within 5 kms of the New Cobar Complex. High potential aquatic GDEs were mapped in the vicinity of the town in the BoM GDE Atlas, including associated with the slag dump at the Great Cobar open cut and at the Newey Reservoir to the immediate west of the New Cobar Complex. Possible effect (although unlikely due to disconnect from deeper aquifer systems being targeted for dewatering) where baseflow is altered within the potential zone of drawdown impact.
	• terrestrial ecosystems (with potential groundwater dependency)	• possible riparian vegetation associated with drainage lines to the north, east and south of the New Cobar Complex. Over 2 km away and will only be impacted if large and widespread impacts occur within the shallower groundwater system, which is not expected.
	• recreational water supply (GW803422)	• potential failure of irrigation bore if drawdown exceed aquifer thickness or screen sections.
	• Historical Great Cobar Pit / old workings	• currently, there is water in the historic Great Cobar open cut void (located on PGM owned land). The water level is higher than surrounding groundwater levels and thus may receive inflow from surface water. The water within the adjacent historical workings is also currently licensed to PGM for operations via an existing shaft. Underground mining could reduce water availability from the void if connected to groundwater.
Quality	• aquatic ecosystems	• GDE mapping provided in the Groundwater WSP details no high priority GDEs located within 5 kms of the New Cobar Complex. High potential aquatic GDEs were mapped in the vicinity of the town in the BoM GDE Atlas, including associated with the slag dump at the Great Cobar open cut and at the Newey Reservoir to the immediate west of the New Cobar Complex. Possible effect (although unlikely due to disconnect from deeper aquifer systems being targeted for dewatering) where baseflow is altered within the potential zone of drawdown impact.
	• terrestrial ecosystems (with potential groundwater dependency)	• possible riparian vegetation associated with drainage lines to the north, east and south of the New Cobar Complex. Effect unlikely due to distance from Project and disconnection from deeper aquifer systems being targeted for dewatering.
	• recreational water supply (rugby club irrigation bore)	• effect unlikely due to possible disconnect between deeper system and shallow weathered regolith.

	• Historical Great Cobar Pit / old workings	• dewatering of new underground declines and stopes may induce local depressurisation/ drawdown cones that could promote the movement of poor-quality groundwater into the Great Cobar open cut and historical workings. However, the risk of water quality reducing below the limit of PGM's currently requirements for processing/mining is small.
Groundwater-surface water interaction	• aquatic ecosystems	• GDE mapping provided in the Groundwater WSP details no high priority GDEs located within 5 km of the New Cobar Complex. High potential aquatic GDEs were mapped in the vicinity of the town in the BoM GDE Atlas, including associated with the slag dump at the Great Cobar open cut and at the Newey Reservoir to the immediate west of the New Cobar Complex. Possible effect (although unlikely due to disconnect from deeper aquifer systems being targeted for dewatering) where baseflow is altered within the potential zone of drawdown impact.
	• terrestrial ecosystems (with potential groundwater dependency)	• possible riparian vegetation associated with drainage lines to the north, east and south of the New Cobar Complex. Effect unlikely due to distance from Project and disconnection from deeper aquifer systems being targeted for dewatering.
Aquifer disruption	• Historical Great Cobar Pit / old workings	• lowering of water level in Great Cobar open cut (located on PGM owned land). The site is a main tourist attraction in town.

7.2 Impact assessment approach

The GIA approach has been to use existing Project area-specific groundwater observations and historical mining information from the Cobar region to develop a conceptual hydrogeological model (Section 6). This conceptual model is a descriptive representation of the groundwater system that incorporates an interpretation of the geological and hydrological conditions. The conceptual model is a way of consolidating the current understanding of the key processes of the groundwater system to assist in the understanding of possible future changes.

A complex 3D numerical flow model has been developed using the information available and consolidated with the conceptual model to make predictions about future changes due to the Project development. The numerical flow model objectives, design and development are outlined in Section 8. The predictive model is used to estimate potential changes to the groundwater system due to the Project development and is also detailed in Section 8. The outputs of the modelling will specifically address assessment requirements as outlined in Table 1.1 and Table 1.2. The modelling is also designed to address the water effecting activities outlined in Table 7.1 and Table 7.2 and guide the development of management approaches as needed to mitigate and manage any potential groundwater impacts.

8 Groundwater numerical model

8.1 Model objectives

The model objectives are designed to address the SEARs and other agency requirements as outlined in Section 0 as well as the Project risks identified in Table 7.1 and Table 7.2. Specially, the model objectives are to:

- assess the historical and predicted changes to groundwater pressure caused by the historical open cut and current and historic underground stope mining operations;
- assess the likely impacts on any water courses, riparian environments, and other water users, namely the GW803422 (water supply work), the historical Great Cobar open cut and the surrounding potential GDEs;
- estimate the likely mine inflows to inform licensing requirements and support the water balance assessment studies;
- estimate the extent of drawdown to inform supporting geochemical studies; and
- simulate any mitigation systems to offset undesirable groundwater impacts, if applicable.

8.2 Model design and development

8.2.1 Model overview and classification

The *Australian groundwater modelling guidelines* (Barnett, et al. 2012) describes three model prediction confidence classifications based on available data and conceptualisation, calibration, and the similarity/difference between the stresses and timeframes used to calibrate the model, and those for which predictions are being made. The modelling documented in this report aligns best with the attributes of a Class 1 model, particularly due to the low number of observation bores in the vicinity of the Project and regionally, and sparse records of historical mine related schedules and dewatering fluxes during the history match period. The model includes some elements that are commensurate with a Class 2 or Class 3 model classification, as aquifer stresses during the history match period are of a similar magnitude and temporal duration to the predictive model.

To address the data uncertainties, history match sensitivity and predictive uncertainty analysis, commensurate to the Project risk and consistent with best practice guidance, has been conducted to quantify the range of potential impacts resulting from the Project.

8.2.2 Software

The model was developed using MODFLOW-USG (Panday, et al. 2017). This modelling code utilises a control volume finite difference formulation, which supersedes finite difference versions of MODFLOW by allowing cells to be connected to an arbitrary number of adjacent cells plus non-adjacent cells. The formulation supports both structured and unstructured grids, and grids based on polygons of varying size/shape. Features of previous MODFLOW releases are included in MODFLOW-USG and additional capabilities are included, such as more advanced handling of re-saturation of dry model cells, adaptive time-stepping, and improved solution calculation with the XMD or PCGU solvers.

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

8.2.3 Model domain, orientation, and spatial discretisation

The model domain covers a rectangular area of 20 km E-W by 20 km N-S, with origin at MGA coordinates 384,747 mE, 6,498,210 mN (Zone 55), rotated 15.48° anticlockwise about the origin. The model domain and grid are illustrated in Figure 8.1. The grid comprises square cells with quadtree refinement around areas of interest. Regional cell spacing is set at 200 m, refined to spacing of 25 m over the mine sites and 6.25 m over the Great Cobar open cut and historical workings.

The domain is large enough to:

- encompass all of the sensitive receptors listed within the scoping requirements;
- include the main hydrogeological boundary conditions influencing groundwater flow, i.e. the regional groundwater gradient; and
- encompass changes to the groundwater system in relation to mine dewatering activities at the Peak and New Cobar Complexes.

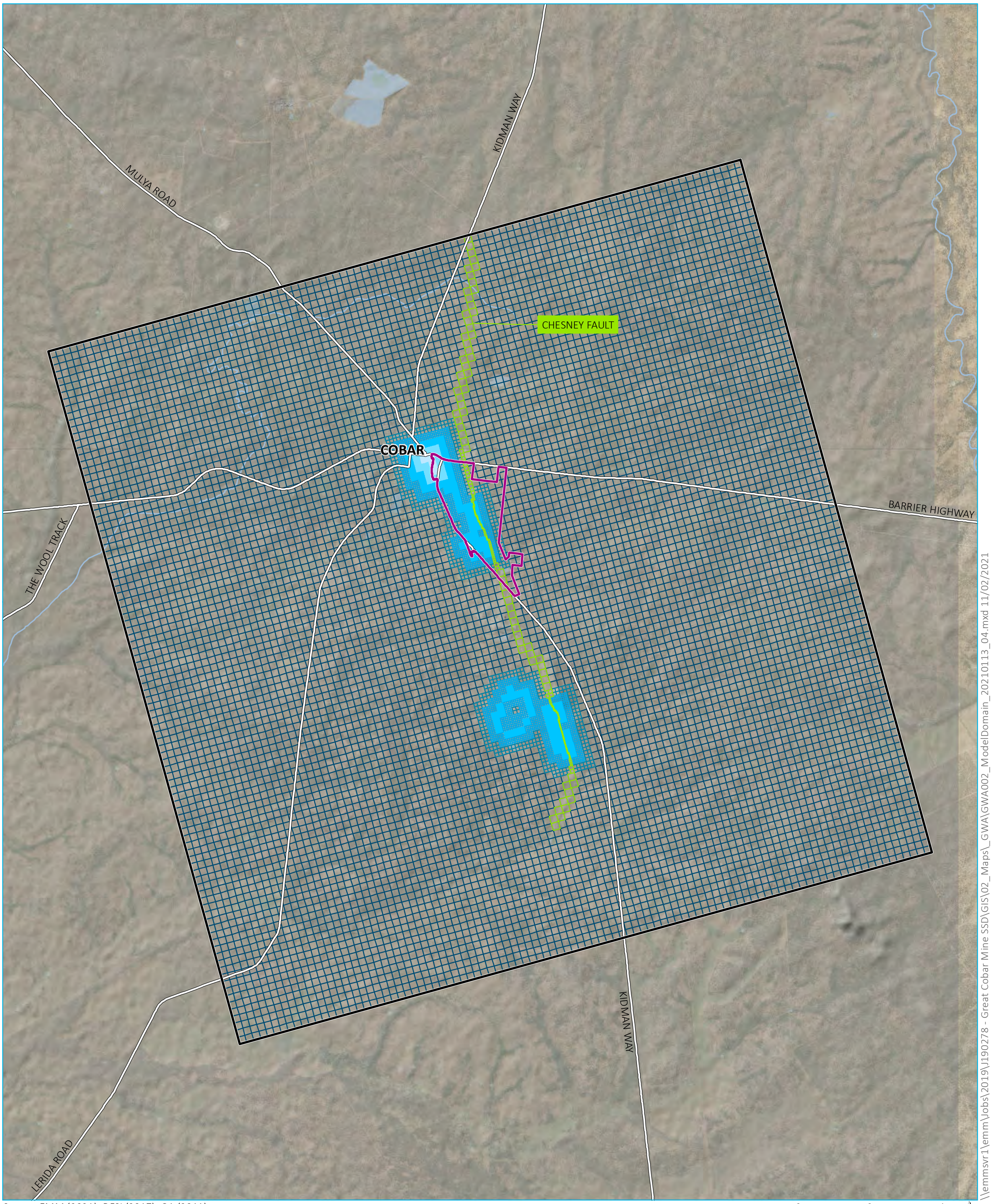
8.2.4 Model layers

Two hydrostratigraphic units (HSUs) were identified within the model domain as follows:

1. weathered fractured rock; and
2. the Primary (fresh) fractured rock.

Over the regional model domain, three layers were developed to represent the weathered fractured rock and three layers represent the Primary rock. Additional vertical refinement around mine workings resulted in 24 model layers. The model layers are summarised in Table 8.1.

The top of fresh rock was sourced from (Beck Engineering 2020); with contact elevations identified from bore logs and interpolated across the monitoring domain. The identified points and contact elevation (m AHD) are presented in Figure 8.2. Elevation of the fractured rock was implemented at a horizontal level across the model domain outside of this area.



Source: EMM (2021); DFSI (2017); GA (2011)

0 2 4 km
GDA 1994 MGA Zone 55
N

KEY

Project area
Model domain
Modelled fault
Model grid - node spacing (m)
6.25
12.5
25
50
100
200
Major road
Named watercourse
Waterbody

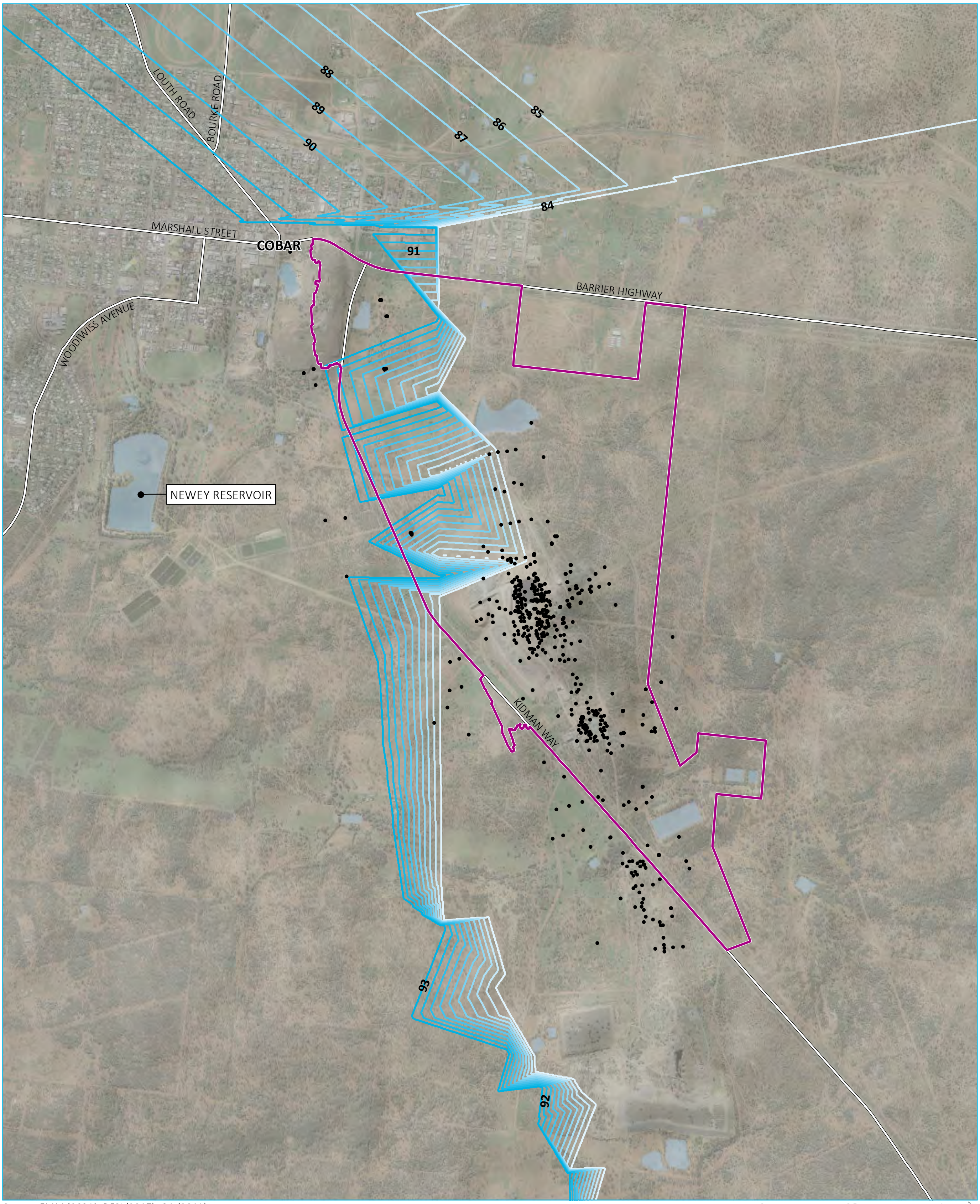
Model domain and grid

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 8.1

EMM
creating opportunities

Table 8.1 Model layer design

Layer	hydrostratigraphic unit	Active footprint	Top	Bottom
1	Weathered fractured rock	Regional domain	Topography	Topography minus 50 m
2	Weathered fractured rock	Regional domain	Topography minus 50 m	Topography minus 100 m
3	Weathered fractured rock	Regional domain	Topography minus 100 m	Top of fresh fractured rock
4	Fresh fractured rock	Regional domain	Top of fresh fractured rock	-500 m AHD regionally 50 m AHD near mine workings
5	Fresh fractured rock	Within 1 km radius of mine workings	50 m AHD	0 m AHD
6	Fresh fractured rock	Within 1 km radius of mine workings	0 m AHD	-50 m AHD
7	Fresh fractured rock	Within 1 km radius of mine workings	-50 m AHD	-100 m AHD
8	Fresh fractured rock	Within 1 km radius of mine workings	-100 m AHD	-150 m AHD
9	Fresh fractured rock	Within 1 km radius of mine workings	-150 m AHD	-200 m AHD
10	Fresh fractured rock	Within 1 km radius of mine workings	-200 m AHD	-250 m AHD
11	Fresh fractured rock	Within 1 km radius of mine workings	-250 m AHD	-300 m AHD
12	Fresh fractured rock	Within 1 km radius of mine workings	-300 m AHD	-350 m AHD
13	Fresh fractured rock	Within 1 km radius of mine workings	-350 m AHD	-400 m AHD
14	Fresh fractured rock	Within 1 km radius of mine workings	-400 m AHD	-450 m AHD
15	Fresh fractured rock	Within 1 km radius of mine workings	-450 m AHD	-500 m AHD
16	Fresh fractured rock	Regional domain	-500 m AHD	-1000 m AHD regionally -550 m AHD near mine workings
17	Fresh fractured rock	Within 1 km radius of mine workings	-550 m AHD	-600 m AHD
18	Fresh fractured rock	Within 1 km radius of mine workings	-600 m AHD	-650 m AHD
19	Fresh fractured rock	Within 1 km radius of mine workings	-650 m AHD	-700 m AHD
20	Fresh fractured rock	Within 1 km radius of mine workings	-700 m AHD	-800 m AHD
21	Fresh fractured rock	Within 1 km radius of mine workings	-800 m AHD	-900 m AHD
22	Fresh fractured rock	Within 1 km radius of mine workings	-900 m AHD	-1,000 m AHD
23	Fresh fractured rock	Regional domain	-1,000 m AHD	-1,500 regionally -1,250 m AHD near mine workings
24	Fresh fractured rock	Within 1 km radius of mine workings	-1,250 m AHD	-1,500 m AHD



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Source: EMM (2021); DFSI (2017); GA (2011)

KEY

- Project area
- • Point used to inform top of fresh rock
- Major road
- Waterbody

Top of fresh fractured rock (mAHD)

- 84
- 85
- 86
- 87
- 88
- 89
- 90
- 91
- 92
- 93

Top of fresh fractured rock geological model

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 8.2

EMM creating opportunities

8.2.5 Boundary conditions

Four types of boundary conditions are employed in the model to represent inflow to and outflow from the groundwater system. These include:

- **Constant head boundary condition**: Along the model edges, constant head boundary conditions (CHBs) allow flow into and out the model domain consistent with the regional groundwater system. Heads were assigned to the boundaries to reflect Project area-based depth to water table measurements; 15 m bgl along the northern boundary and 30 m bgl at the southern boundary, linearly interpolated along the eastern, and western edges;

- **Recharge**: A uniform recharge rate of 0.13 mm/yr (0.05% of rainfall) was applied across the model domain using the MODFLOW RCH package to simulate recharge from rainfall;

- **Evapotranspiration**: A uniform maximum potential evapotranspiration rate of 2,397 mm/yr was assigned across the model domain based on BoM data. An extinction depth of two metres is defined such that evapotranspiration from groundwater only occur when the water table is within two metres of the ground surface. Regionally the water table is below this depth across most of the model domain, however locations with shallow water table depths may exhibit significant losses to the atmosphere. Trees may access groundwater from deeper than two metres, but due to the low vegetation density this value is considered appropriate; and

- **Drain**: Mine dewatering activities were simulated using the MODFLOW drain (DRN) package. At locations and times of dewatering, drain cells were activated with a suitably high conductance (1,000 m^2/d) to fully dewater the model layer. The modelled drain setup is further discussed in Section 8.2.6.

The only permanent surface water feature in the model domain is the Great Cobar open cut which occurs within PGM owned land. In order to simulate the impact of stress at this location it was simulated with void properties (Sy of 100%, Kh and Kv of 1000 m/d) to allow for the water levels to vary dynamically in response to modelled mine dewatering. Water flux at the open cut water surface is assumed to be net negative; as such a negative recharge value equivalent to annual average rainfall minus 95% of potential evaporation was applied i.e. a value of – 1,932 mm/yr has been applied.

8.2.6 Temporal discretisation

A summary of the stress periods used in the history match and prediction simulations is provided in Table 8.2. Model simulations are transient, with the exception of the first pseudo steady-state stress period used to initialise the model in response to simulated recharge, hydraulic conductivity, and regional boundary conditions.

Table 8.2 Model stress periods

Stress period (SP)	Stress period duration	Description
1	10,000 years (pseudo steady state)	Develops initial conditions in response to modelled hydraulic parameters and boundary conditions.
2-31	1 year (transient)	History match period, from 1 January 1990 to 1 January 2020.
32-43	1 year (transient)	Represents the predictive mine plan from 1 January 2020 to 1 January 2032.
44-53	1 year (transient)	Represents 1 to 10 years post-mining.
54	40 years (transient)	Represents 11 to 50 years post-mining.

Table 8.2 Model stress periods

Stress period (SP)	Stress period duration	Description
55	50 years (transient)	Represents 51 to 100 years post-mining.
56	1,000 years (pseudo steady state)	Used to determine long-term impacts of underground mine dewatering as the system reaches a new state of equilibrium.

Mine workings have been implemented in the model from 1992. Workings at the Peak and New Cobar Complexes constitute the history match and predictive periods, with proposed Great Cobar underground workings scheduled to begin in 2023. A summary of the assumed workings (in terms of timing and the depth mined to at the end of each year, shown in m AHD) at the various locations are tabulated in Table 8.3 and shown graphically Figure 8.3 throughout the history match period. Please note, Table 8.3 also includes an estimate of the topographic surface elevation at each mine working, so an appreciation of mining depths below ground surface can be made.

Table 8.3 Summary of modelled mine workings (m AHD)

Stress period	Year from	Peak and Perseverance	Chesney	Gladstone	New Cobar open cut	New Cobar underground	Jubilee	Great Cobar underground
Topographic surface elevation		250	256	257	281	281	265	244
4	1992	-350	--	--	--	--	--	--
5	1993	-382	--	--	--	--	--	--
6	1994	-414	--	--	--	--	--	--
7	1995	-446	--	--	--	--	--	--
8	1996	-479	--	--	--	--	--	--
9	1997	-511	--	--	--	--	--	--
10	1998	-543	--	--	--	--	--	--
11	1999	-575	--	--	--	--	--	--
12	2000	-607	--	--	--	--	--	--
13	2001	-639	--	--	254	--	--	--
14	2002	-671	--	--	222	--	--	--
15	2003	-704	--	--	190	--	--	--
16	2004	-736	-15	--	158	--	--	--
17	2005	-768	-29	--	--	100	--	--
18	2006	-800	-44	--	--	70	--	--
19	2007	-832	-59	--	--	40	--	--
20	2008	-864	-74	--	--	10	--	--
21	2009	-896	-88	--	--	-20	--	--
22	2010	-929	-103	--	--	-50	--	--
23	2011	-961	-118	--	--	-80	--	--
24	2012	-993	-132	--	--	-110	--	--

Table 8.3 Summary of modelled mine workings (m AHD)

Stress period	Year from	Peak and Perseverance	Chesney	Gladstone	New Cobar open cut	New Cobar underground	Jubilee	Great Cobar underground
25	2013	-1,025	-147	--	--	-140	--	--
26	2014	-1,057	-162	--	--	-170	--	--
27	2015	-1,089	-176	--	--	-200	--	--
28	2016	-1,121	-191	--	--	-230	--	--
29	2017	-1,154	-206	--	--	-260	--	--
30	2018	-1,186	-221	--	--	-290	--	--
31	2019	-1,218	-235	--	--	-320	--	--

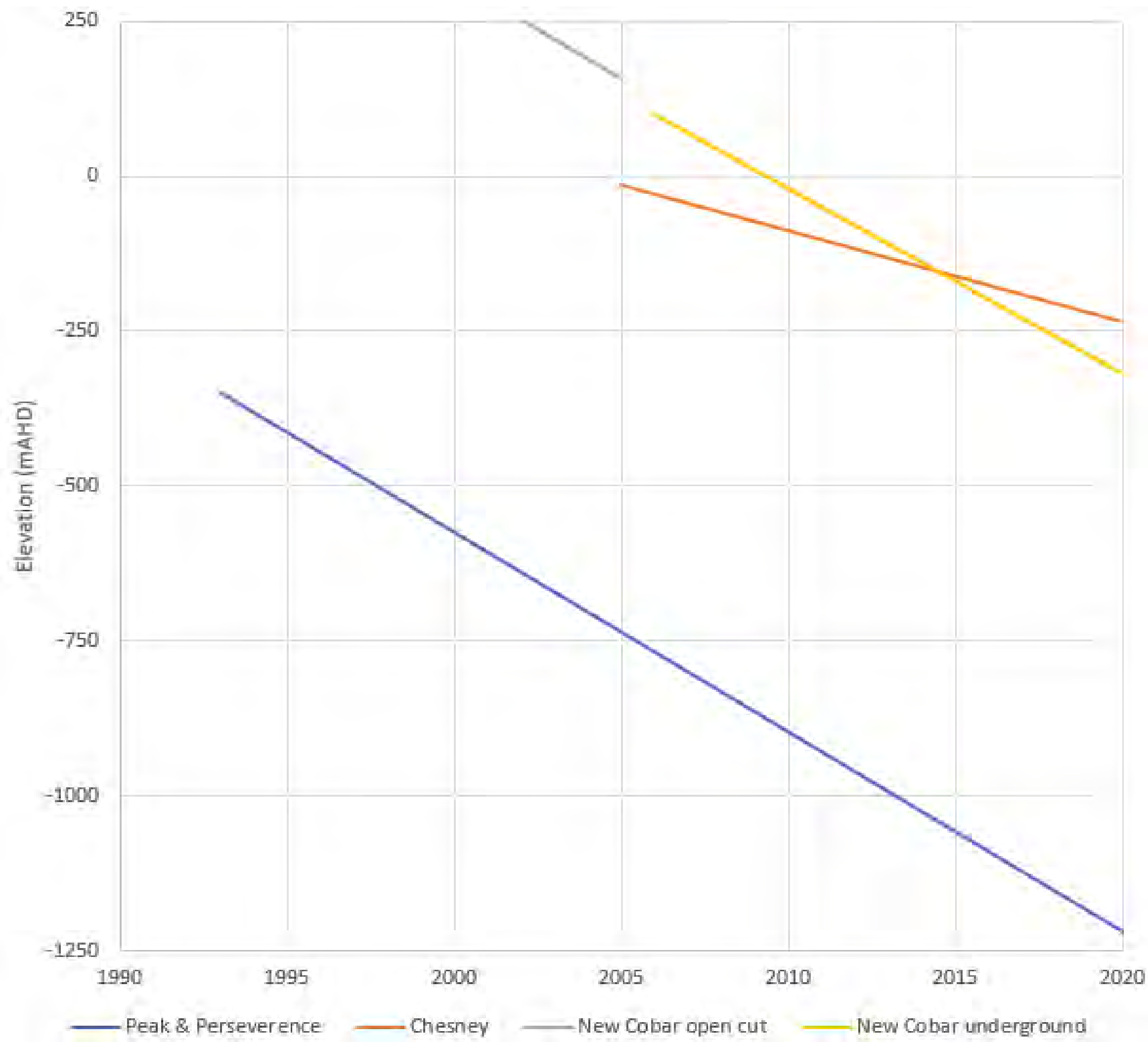


Figure 8.3 Time series of modelled mine working elevations between 1992 and 2020

8.3 Model design assumptions and limitations

All available data has been used to develop the New Cobar Complex numerical model. Data limitations that prohibit the model from reaching a higher-class value (Barnett, et al. 2012) include:

- measured groundwater levels covering a small spatial area, distant from the New Cobar Complex;
- no measured groundwater level data outside the model domain to direct boundary condition development;
- insufficient groundwater level data to fully conceptualise influence of faulting on regional groundwater elevation and flow;
- temporal groundwater level measurements taken at the Peak Complex;
- rising groundwater levels at several bores, though incoming water fluxes (e.g. from TSF seepage) have not been simulated;
- minimal mine progression data necessitating a highly simplified history match stress setup;
- no or minimal measured inflow rates to mine workings; and
- surface water-groundwater interactions at the Great Cobar open cut not fully conceptualised.

The main assumptions adopted in the model include:

- hydrogeological properties for the weathered and fresh fractured rock are applied uniformly across the model domain as equivalent porous media;
- the Great Chesney fault is simulated as a groundwater flow retardation feature, consistent with the conceptualisation;
- other faults, shear zones and specific fractures are not simulated;
- the Great Cobar open cut is a groundwater discharge feature, with net flux at the surface of annual average rainfall minus 95% of annual potential evaporation;
- climatic variability was not simulated due to the conceptualisation supporting a system which receives minimal rainfall recharge and a relatively deep groundwater system which generally will not be affected by evapotranspiration processes;
- groundwater inflows to various mine declines and shafts are not simulated, as the net flux is not considered significant at the scale of the model and mine dewatering impacts; and
- all mine developments from 1990 onwards were simulated with a linear vertical advance rate over the mined footprint.

8.4 History match

8.4.1 Approach

The groundwater flow model was calibrated to measured groundwater levels from July 1990 through to May 2020, incorporating annual mine dewatering progression at multiple sites as detailed in Table 8.3 and Figure 8.3. The history match assessment was performed with the use of parameter zones, assigning hydraulic values to the hydrostratigraphic units, and comparing model statistical performance against measured groundwater levels. Additional validation was performed by assessing modelled groundwater inflows to mine workings at the Peak and New Cobar Complexes at the end of the history match period.

8.4.2 Calibrated hydrogeological properties

Model parameters varied in the history matching process included:

- horizontal hydraulic conductivity (Kh);
- vertical hydraulic conductivity (Kv);
- specific storage; and
- specific yield.

An effective hydraulic conductivity is required to be used in the model to account for the heterogenous nature of the fractured rock, because the groundwater flow zones are limited to discrete (secondary porosity) fractures only. The modelling approach uses bulk equivalent porous media layers to simulate the HSUs and estimate the mine inflows and change in groundwater pressures, hence an effective hydraulic conductivity must be used for the modelled aquifer layers. Discussion and calculation of effective hydraulic conductivity is presented in Section 5.4.1.

Referring to Table 5.8, effective hydraulic conductivity ranges between 5.1 x 10^{-3} to 1.2 m/d for the weathered rock and 7.5 x 10^{-2} to 5.4 x 10^{-4} m/d for the fresh rock. Adopted values for hydraulic conductivity and storage across the model domain are detailed in Table 8.4, which shows that the adopted aquifer parameters that best represent the calibrated model fall within the range of field based estimates.

The deep fractured rock system was simulated with a decreasing hydraulic conductivity with depth; reducing from 7 x 10^{-4} m/d at the top of the unit to 1 x 10^{-6} m/d below -1000 m AHD. A reduction in hydraulic conductivity with depth is a well-documented phenomenon and is caused by the increased compression of the overlying sediment pile, reducing the ability of connected pore space (for unconsolidated sediments) or fractured networks (for hard rock sediments) to transmit groundwater at significant depths. The reduction of observed mine inflows as outlined in Section 5.5.2 also supports this conceptualisation.

The Great Chesney fault was simulated with a hydraulic conductivity of 2.3 x 10^{-5} m/d; lower than the weathered and upper fresh fractured rocks. Open spaces such as mined voids and open cuts had a high hydraulic conductivity of 1,000 m/d applied.

Storage parameters have not been estimated in the field. Specific yield will not have a significant impact on modelled results related to underground mine workings since these mining activities occur within a confined aquifer environment. The specific storage has been set to the theoretical upper limit determined by (Rau, et al. 2018), in an attempt to focus the model calibration on hydraulic and vertical conductivity. The high specific storage values were used to limit the drawdown extent emanating from the New Cobar open cut during the historical match period, with the modelled contours at the end of the history match period (1 January 2020) shown in Figure 8.5. The uncertainty associated with this parameter is acknowledged and is addressed in Section 8.7.4.

Table 8.4 GC1.0 modelled aquifer properties

Hydrostratigraphic unit/location	Horizontal hydraulic conductivity (m/d)	Vertical hydraulic conductivity (m/d)	Specific storage (1/m)	Specific yield (-)
Weathered fractured rock	0.015	0.015	1.3×10^{-5}	5%
Primary fractured rock	7.39×10^{-4}	7.39×10^{-4}	1.3×10^{-5}	0.5%
Primary fractured rock, -500 to -1,000 m AHD	1×10^{-5}	1×10^{-5}	1.3×10^{-5}	0.5%
Primary fractured rock below -1,000 m AHD	1×10^{-6}	1×10^{-6}	1.3×10^{-5}	0.5%
Great Chesney fault	2.3×10^{-5}	2×10^{-5}	1.3×10^{-5}	5%
Underground mined voids	1,000	1,000	1.3×10^{-5}	5%
Open cuts	1,000	1,000	1.3×10^{-5}	100%
New Cobar void backfill	1,000	1,000	1.3×10^{-5}	50%

8.4.3 History match performance

History match performance was quantified using a number of statistical measures. One of the most commonly employed and scalable statistical measurement is the scaled root mean square (SRMS) error, given as a percentage:

$$SRMS = \frac{100}{\Delta H}\sqrt{\frac{1}{n}\sum_{i=1}^{n}[W_i(z_{hi} - h_i)]^2}$$

where:

- ΔH is the range of measured hydraulic heads across the model domain;
- n is the number of measurements used in the history match dataset;
- W_i is the statistical weighting (between 0 and 1) applied to measurement i;
- z_{hi} is the modelled hydraulic head at location/time i; and
- h_i is the measured hydraulic head at location/time i.

The SRMS error for the GC1.0 model is 18.1%, calculated using hydraulic head measurements from 15 monitoring bores with measured hydraulic head ranging from 164 to 245 m AHD. The average residual (calculated as modelled minus measured hydraulic head) is 7.2 m, and the average absolute residual is 11.0 m.

A scatter plot of modelled and measured hydraulic head at the 15 monitoring bores is presented in Figure 8.4. The data display a generally positive bias, with modelled groundwater levels typically higher than measured. Modelled groundwater levels do not reach either extreme of measured levels, likely due to features within the fractured rock that have not been captured in the conceptual model and local details and processes that occur at the Peak Complex. The statistical match is consistent with a Class 1 groundwater model (Barnett, et al. 2012), and a detailed predictive uncertainty analysis was developed commensurate with the model statistical performance and Project risks, which is presented in Section 8.7.4.

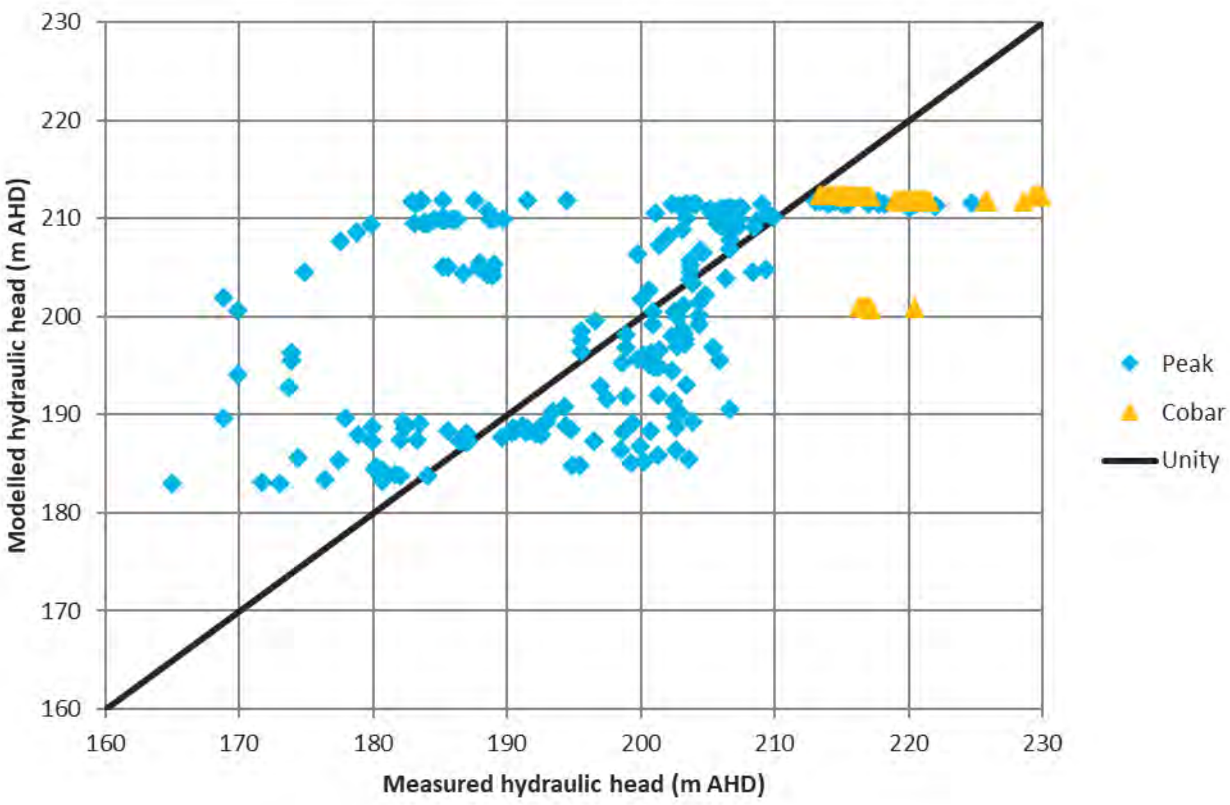


Figure 8.4 Scatter plot of modelled against measured hydraulic head

8.4.4 Hydraulic head

i Groundwater contours

A plot showing the modelled water table elevation at 1990 (steady state) and 2020 is shown in Figure 8.5, with residuals against similar measurement times. Please note, although 1990 does not represent true steady state, it represents a time when modern mining activities recommenced and PGM's data collection processes greatly improved, which is needed to support the build of the numerical model.

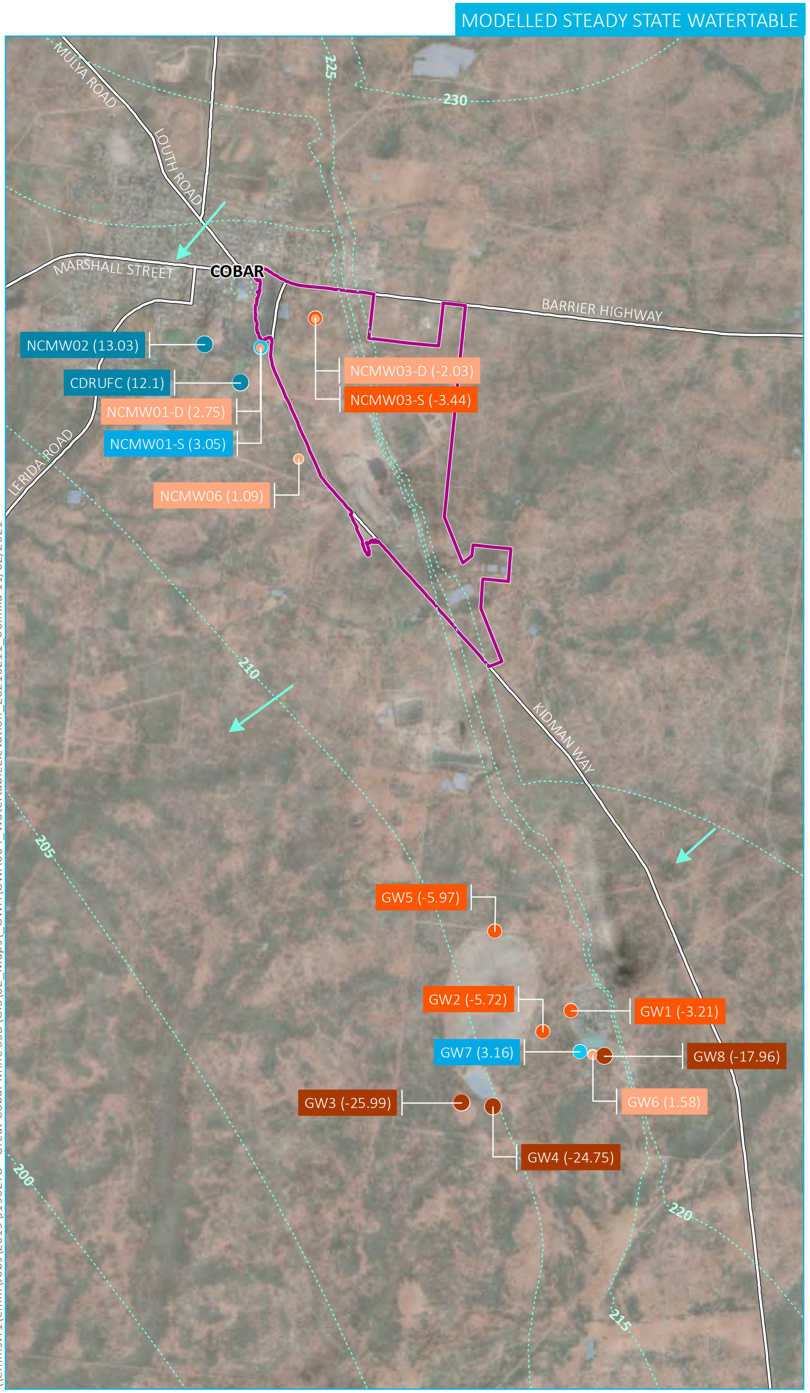
Steady state groundwater flow is broadly from the north-east to south-west, generally following topography. The Great Chesney Fault is modelled with a lower hydraulic conductivity than the weathered and upper fresh fractured rock system, impeding westward groundwater flow. There is a local low point at the Great Cobar open cut; this is simulated as a net groundwater discharge feature due to evaporation loses to the atmosphere. Residuals of the first measured groundwater levels against 1990 modelled heads show an average modelled elevation of 3.5 m above measured, particularly skewed by GW3, GW4, and GW8 at the Peak Complex. NCMW02 shows a modelled head 13.0 m below measured, though the other NCMW bores have an average residual of -0.3 m.

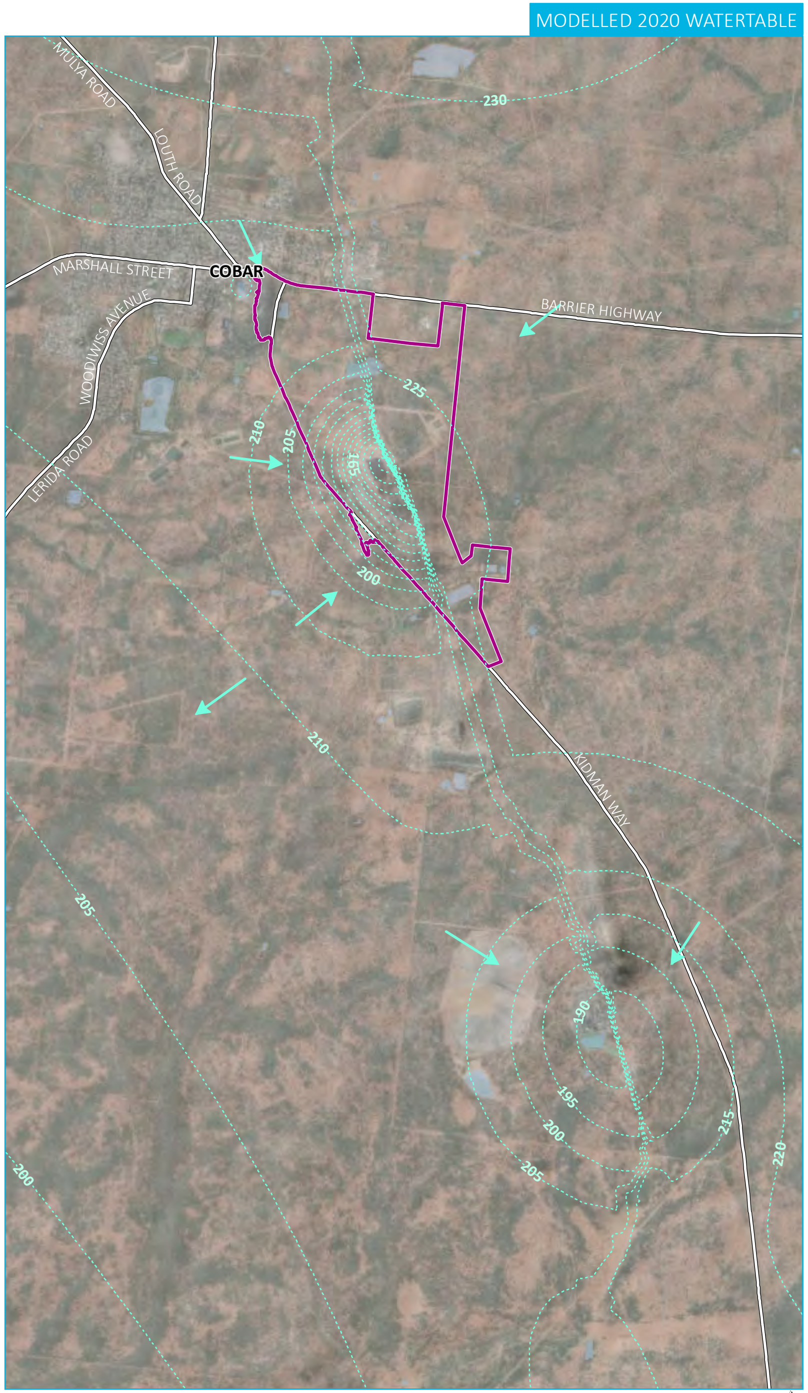
Referring to the January 2020 plot, modelled water table drawdown is observed at both the Peak and New Cobar Complexes. The drawdown at the New Cobar Complex is dominated by the open cut and the more subdued drawdown cone at the Peak Complex is caused by the depressurisation of the underground stopes being mined in this area. The Great Chesney Fault continues to impede the propagation of drawdown, with modelled drawdown to the east more predominant at the Peak Complex, when compared to the New Cobar Complex. The exact hydraulic properties of the Great Chesney Fault are largely unknown and are tested in the predictive uncertainty analysis presented in Section 8.7.4.

ii Hydrographs

Hydrographs at monitoring bores for the transient history match period are presented in Figure 8.6. The bores with the most data are located at the Peak Complex, with monitored groundwater levels being available from 1990 through to 2020. These bores have been assessed against the drawdown responses only, as any additional seepage which may occur from the various dams or tailings storage facility has not been simulated and falls outside of the current scope. Accordingly, monitored groundwater level data showing an increasing trend was not used in the calculation of history match statistics.

Starting conditions and drawdown have been matched reasonably well for bores such as GW1, GW2, GW6, and GW7. Drawdown response at GW8 is slightly delayed, and the starting elevation is higher than measured. Other bores at the Peak Complex do not show as much drawdown response; this is replicated in the modelled trends. Bores located at the New Cobar Complex represent new installation sites and thus do not have as much data to compare against; measurements are from mid-2020. Absolute modelled groundwater levels match observations very well, though it is unclear how much of an influence mining impacts have had historically. For example, NCMW06 shows the worst match to observed data, but this is due to modelled drawdown following mine dewatering. The modelled drawdown at this site is more serve than measured, therefore modelled results are conservative from an impact assessment perspective. Continued monitoring will allow for a more detailed trend to be identified going forward.





KEY
- Project area
- Major road
- Waterbody
- Modelled watertable (mAHD)
- Modelled groundwater flow direction

Steady state residual (m)
- <-10.0
- -9.9 - -3.0
- -2.9 - 3.0
- 3.1 - 10.0
- >10

Modelled steady state watertable elevation and residuals and 2020 watertable elevation

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 8.5

Source: EMM (2021); DFSI (2017); GA (2011)

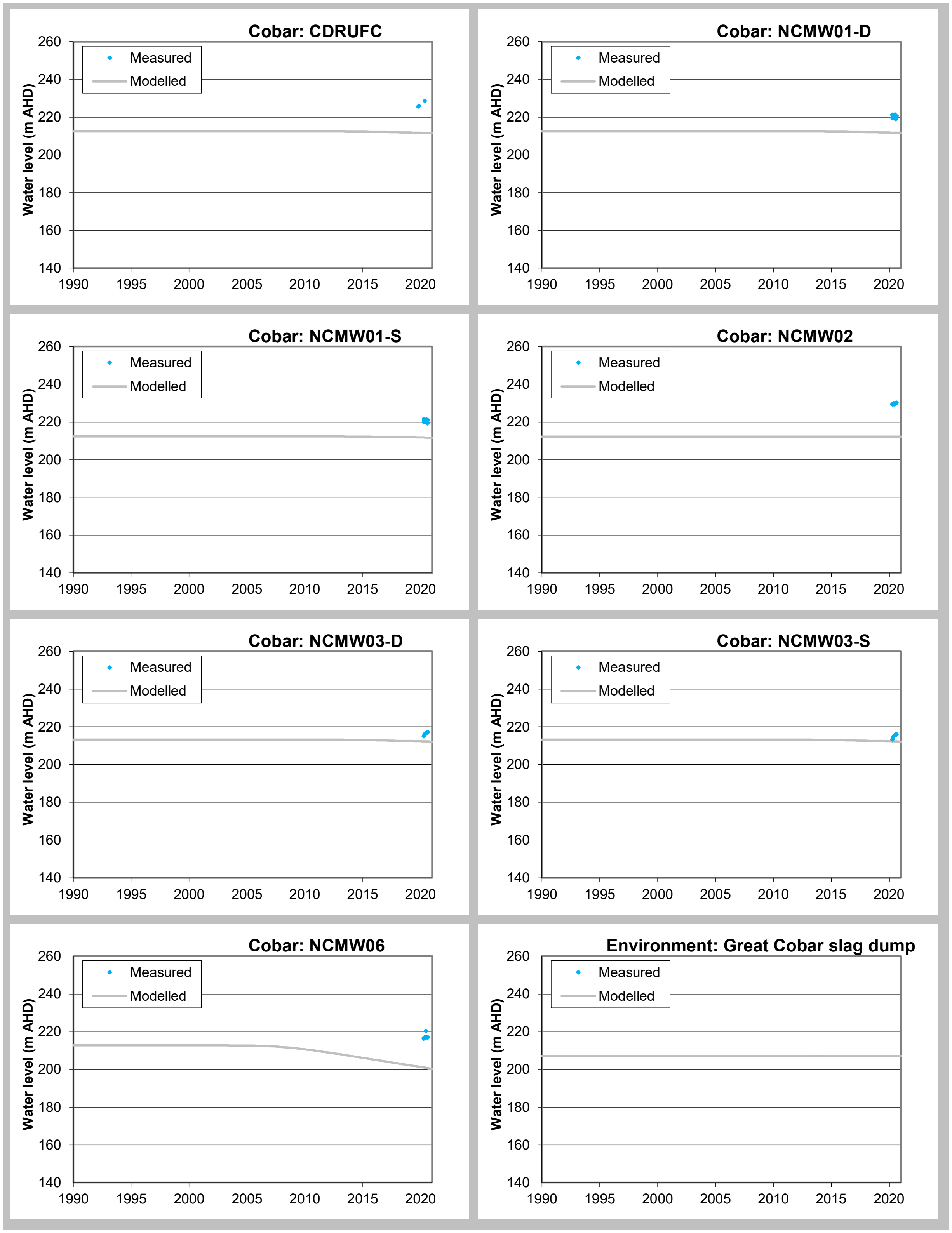


Figure 8.6 - Transient history match hydrographs

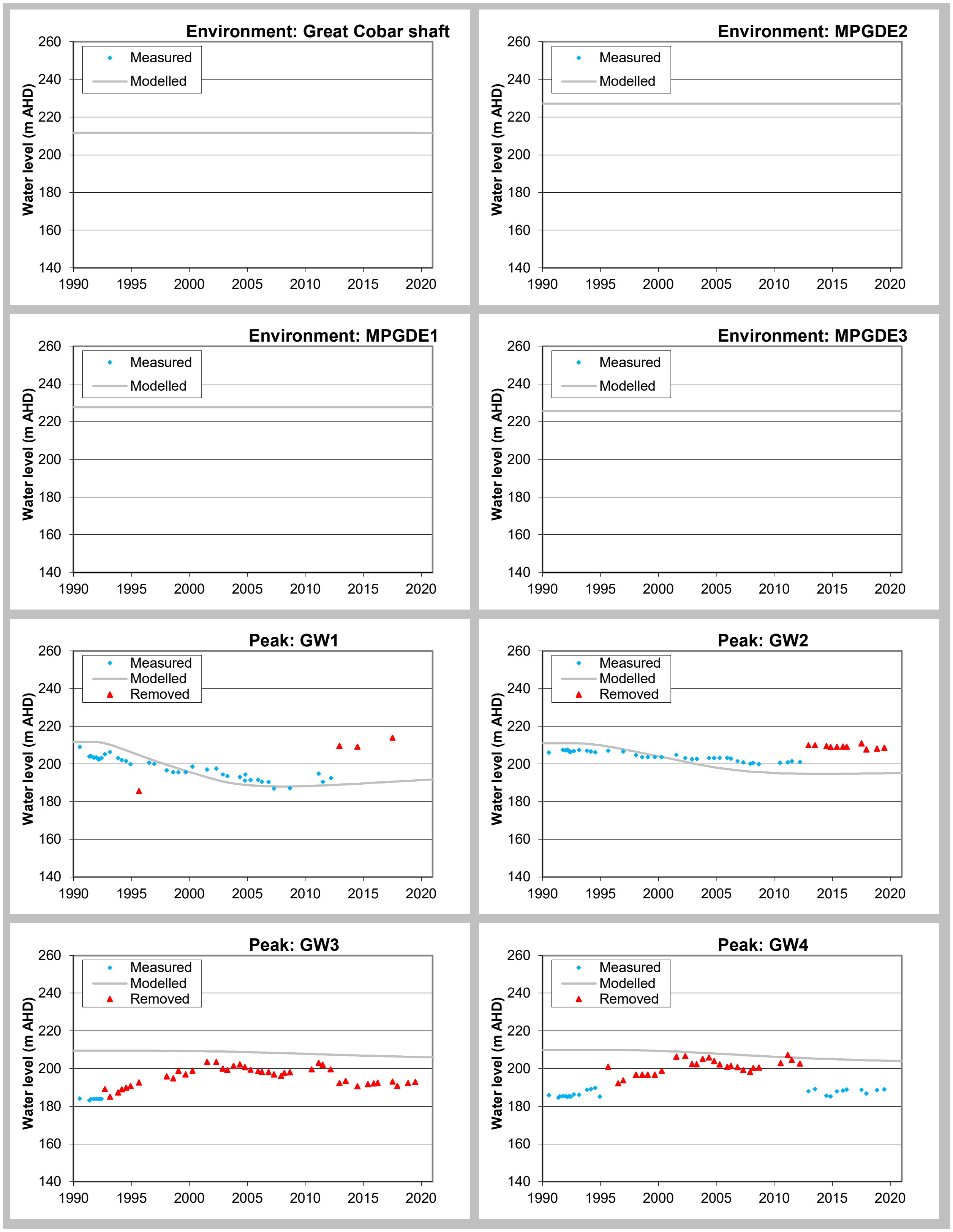


Figure 8.6 - Transient history match hydrographs

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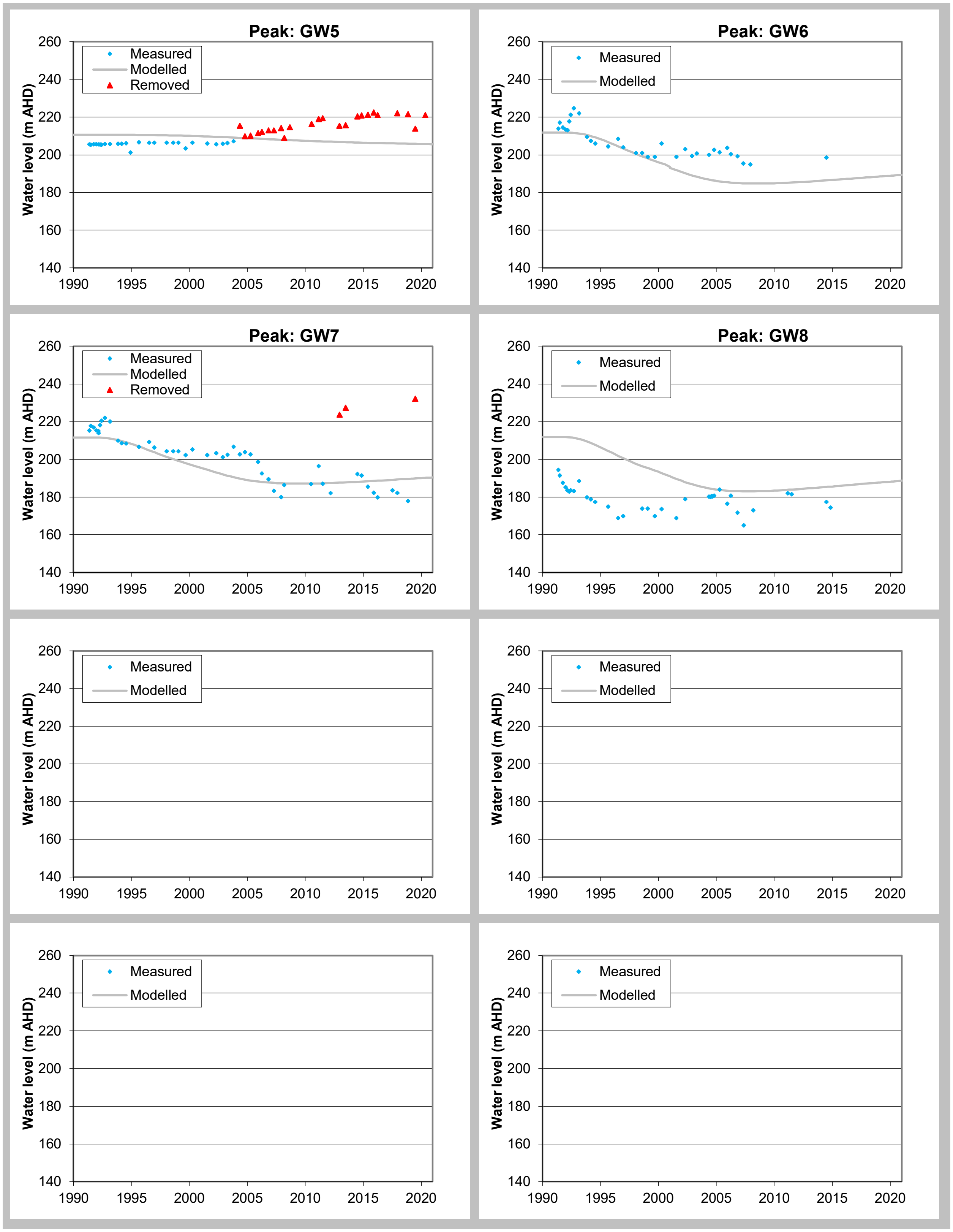


Figure 8.6 - Transient history match hydrographs

\\emmsvr1\EMM\Jobs\2019\J190278 - Great Cobar Mine SSD\Technical studies\Groundwater\4. Modelling\Model output\GC_tpred1c\[GC_tpred1c_hydrographs.xlsm]Fig3

8.4.5 Water balance

The modelled water balance at the end of stress period 1 (January 1990) is presented in Table 8.5. Prior to mine development, the largest fluxes in the model are the regional constant head boundary condition cells, with an inflow to the model of 0.51 ML/d and outflow of 0.62 ML/d. Rainfall-derived recharge is simulated at 0.14 ML/d, and 0.02 ML/d net evaporation removed from the surface of the Great Cobar open cut. Due to the high depth to water table and lack of surface water features, there is no evapotranspiration from other areas of the model. The modelled mass balance error is 0.01%, an acceptable value as outlined by the *Australian Groundwater Modelling Guidelines* (Barnett, et al. 2012).

Table 8.5 Modelled water balance at 1/01/1990

Model flux	Inflow (ML/d)	Outflow (ML/d)
Constant head boundary	0.51	0.62
Rainfall recharge	0.14	-
Great Cobar pit lake surface	-	0.02
Evapotranspiration	-	0.00
Storage	0.01	0.02
Total IN	**0.66**	
Total OUT	**0.66**	
Percentage discrepancy	**0.01%**	

The modelled water balance at the start of 2020 is presented in Table 8.6. Regional fluxes are unchanged from Table 8.5, though the mine dewatering via drain cells represents a significant flux (2.24 ML/d). This is balanced by an increase in both the storage inflow and outflow terms. The mass balance error at this time is 0.00%.

Table 8.6 Modelled water balance at 1/01/2020

Model flux	Inflow (ML/d)	Outflow (ML/d)
Constant head boundary	0.51	0.62
Rainfall recharge	0.14	-
Great Cobar pit lake surface	-	0.02
Evapotranspiration	-	0.00
Mine dewatering drains	-	2.24
Storage	2.60	0.36
Total IN	**3.24**	
Total OUT	**3.24**	
Percentage discrepancy	**0.00%**	

The modelled water balance over the history match period is presented in Figure 8.7. It is apparent that regional fluxes are unchanged over the model duration which is expected due to the low permeability environment, and the biggest applied flux is mine dewatering represented by the drain boundary condition. This flux is balanced by storage fluxes, primarily storage inflow representing a net removal of groundwater from the system. The mass balance error of the model does not exceed 0.01% for the duration of the history match period, which is acceptable and consistent with best practise.

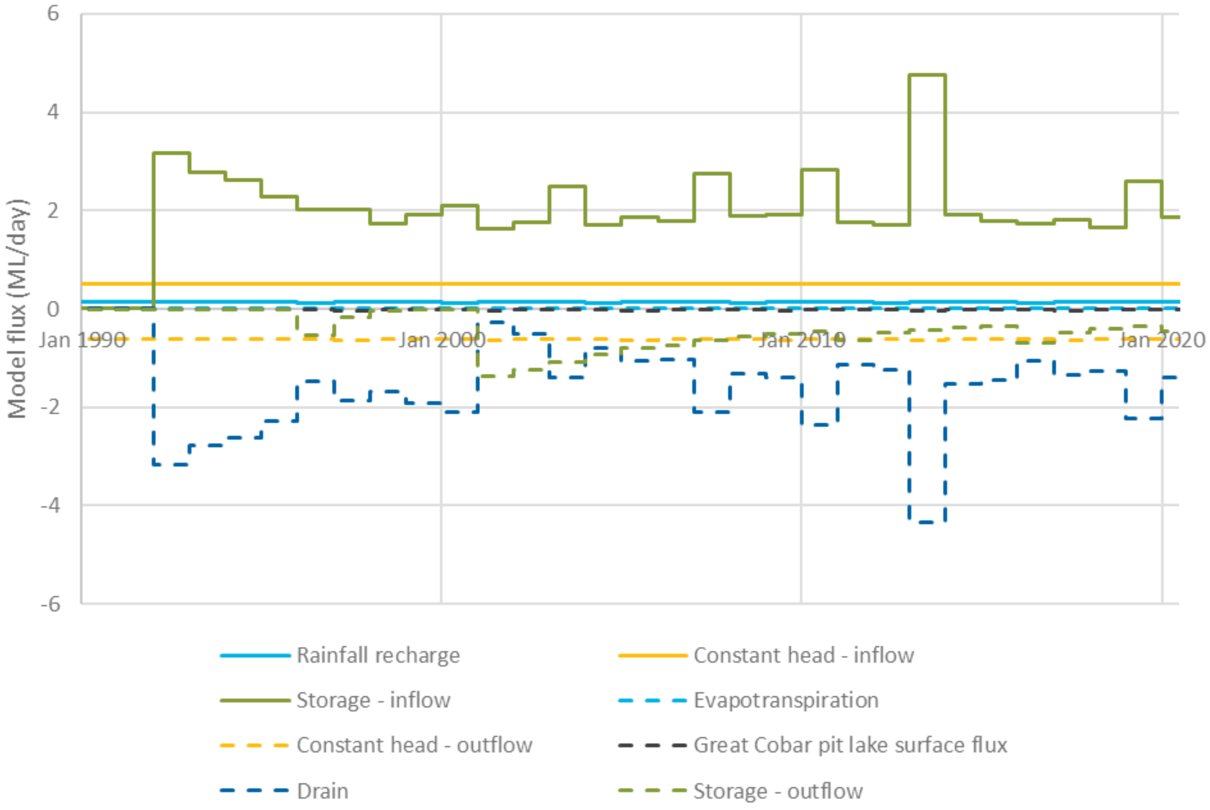


Figure 8.7 Modelled water balance over the history match period

8.4.6 Modelled mine inflows

The modelled mine inflows distributed across the various workings is shown in Figure 8.8. The rates include entrained water (i.e. water that gets removed with the ore) and represent total water take. Modelled inflows are high for the Peak Complex, peaking at over 3,000 kilolitres per day (kL/d) historically with an overall declining trend to a minimum below 200 kL/d by 2020. The variability of modelled dewatering at the Peak Complex from 2002 onwards is an artefact of the vertical model discretisation; the actual dewatering rate is likely closer to a rolling average of the data. The New Cobar Complex is simulated to have experienced a generally increasing inflow with time, exceeding the Peak Complex inflow during most years from 2004 onwards. Measured pumping rates from the New Cobar decline in 2018 and 2019 are shown as point data and is highly variable. The New Cobar Complex modelled inflow is conservatively simulated at approximately 1,000 kL/d near the end of the history match period, and the measured data averages 690 kL/d.

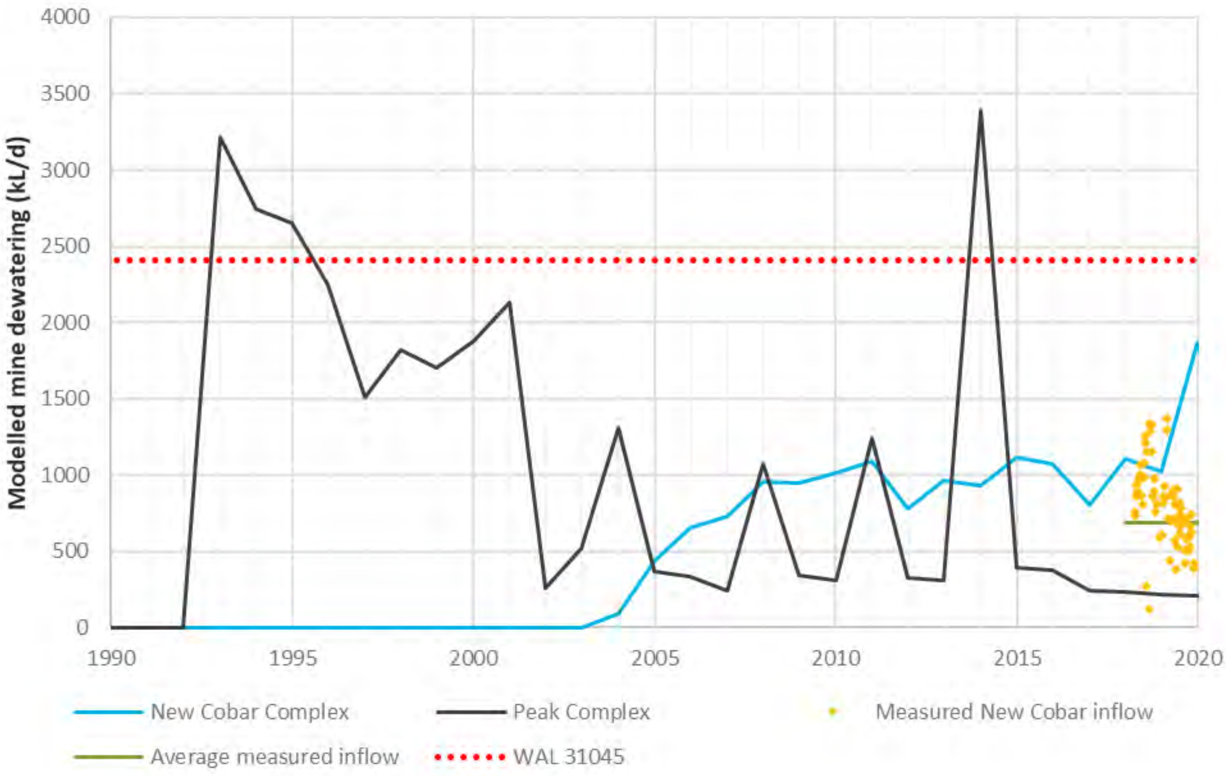


Figure 8.8 Modelled and measured mine inflows

8.5 History match sensitivity analysis

8.5.1 Method

In addition to the adopted base case history match simulation, as detailed above, 15 model runs were completed with parameter values varied from their adopted base case values. The resultant SRMS of each model run was assessed to provide a means to quantify the sensitivity of model performance to variation in selected aquifer parameter values.

8.5.2 Parameter values

Model parameter values varied for the history match sensitivity analysis included:

- horizontal and vertical hydraulic conductivity of weathered and primary fractured rock;
- anisotropy ratio of vertical to horizontal hydraulic conductivity;
- hydraulic conductivity with depth;
- specific storage of weathered and primary fractured rock;
- specific yield of weathered and primary fractured rock; and
- regional recharge.

Multipliers were applied to the base case parameter values ranging from 1/100 to 10. A summary of model runs developed for the sensitivity analysis is given in Table 8.7. Parameter values were chosen to provide reasonable upper and lower bounds for each parameter and to test the influence of assumptions on history match performance. Due to the modelled fit to measured data, only a subset of the sensitivity analysis models was considered appropriate for use in the predictive history match assessment (refer to Section 8.7.4).

Table 8.7 History match sensitivity analysis model parameter values

Model run	Adopted value									
	Weathered fractured rock				Primary fractured rock					
	Horizontal hydraulic conductivity (m/d)	Vertical hydraulic conductivity (m/d)	Specific yield	Specific storage (1/m)	Horizontal hydraulic conductivity (m/d)	Vertical hydraulic conductivity (m/d)	Specific yield	Specific storage (1/m)	Recharge (mm/yr)	Other
Base case	**0.015**	**0.015**	**5%**	**1.3×10^{-5}**	**7.4×10^{-4}**	**7.4×10^{-4}**	**0.5%**	**1.3×10^{-5}**	**0.13**	--
Sensitivity run 1	0.015	**0.003**	5%	1.3×10^{-5}	7.4×10^{-4}	**1.5×10^{-4}**	0.5%	1.3×10^{-5}	0.13	--
Sensitivity run 2	0.015	**0.001**	5%	1.3×10^{-5}	7.4×10^{-4}	**7.4×10^{-5}**	0.5%	1.3×10^{-5}	0.13	--
Sensitivity run 3	0.015	0.015	5%	1.3×10^{-5}	7.4×10^{-4}	7.4×10^{-4}	0.5%	1.3×10^{-5}	**1.3**	--
Sensitivity run 4	0.015	0.015	5%	1.3×10^{-5}	7.4×10^{-4}	7.4×10^{-4}	0.5%	1.3×10^{-5}	**0.5**	--
Sensitivity run 5	0.015	0.015	5%	**5×10^{-6}**	7.4×10^{-4}	7.4×10^{-4}	0.5%	**5×10^{-6}**	0.13	--
Sensitivity run 6	0.015	0.015	5%	**1×10^{-6}**	7.4×10^{-4}	7.4×10^{-4}	0.5%	**1×10^{-6}**	0.13	--
Sensitivity run 7	0.015	0.015	5%	**5×10^{-7}**	7.4×10^{-4}	7.4×10^{-4}	0.5%	**5×10^{-7}**	0.13	--
Sensitivity run 8	**0.073**	**0.073**	5%	1.3×10^{-5}	7.4×10^{-4}	7.4×10^{-4}	0.5%	1.3×10^{-5}	0.13	--
Sensitivity run 9	0.015	0.015	5%	1.3×10^{-5}	**7.4×10^{-5}**	**7.4×10^{-5}**	0.5%	1.3×10^{-5}	0.13	--
Sensitivity run 10	0.015	0.015	5%	1.3×10^{-5}	**7.4×10^{-3}**	**7.4×10^{-3}**	0.5%	1.3×10^{-5}	0.13	--
Sensitivity run 11	0.015	0.015	5%	1.3×10^{-5}	7.4×10^{-4}	7.4×10^{-4}	0.5%	1.3×10^{-5}	0.13	**No decreasing K with depth**
Sensitivity run 12	0.015	0.015	**10%**	1.3×10^{-5}	7.4×10^{-4}	7.4×10^{-4}	**1%**	1.3×10^{-5}	0.13	--
Sensitivity run 13	0.015	0.015	**7.5%**	1.3×10^{-5}	7.4×10^{-4}	7.4×10^{-4}	**0.75%**	1.3×10^{-5}	0.13	--
Sensitivity run 14	0.015	0.015	**1%**	1.3×10^{-5}	7.4×10^{-4}	7.4×10^{-4}	**0.1%**	1.3×10^{-5}	0.13	--
Sensitivity run 15	0.015	0.015	**0.5%**	1.3×10^{-5}	7.4×10^{-4}	7.4×10^{-4}	**0.05%**	1.3×10^{-5}	0.13	--

8.5.3 History match sensitivity analysis

Figure 8.9 presents the results of the history match sensitivity analysis for the range of parameters and values tested. High variation in SRMS error means that the associated parameter is highly constrained, as changes to the value result in significantly worse statistical performance. Small or no change to the SRMS error compared to the base case means the parameter value is less constrained; this value could be changed by a large factor without significantly changing the modelled hydraulic head. The only sensitivity analysis model not presented is run 11, with the alternate conceptualisation of constant hydraulic conductivity with depth. This run resulted in SRMS of 18.7% compared to the base case model's 18.6%, noting that this run has a larger influence on predicted mine inflows to the Peak Complex, more than it does to simulated hydraulic head.

The adopted parameter values of the base case model result in the best match to measured groundwater level data. The SRMS resulting from changed parameter values is highly variable, with many runs exceeding 20%. The most highly constrained parameter is specific storage, with a maximum increase of SRMS to 19.6%. Three of the model runs exceeded 30% SRMS as follows:

1. horizontal and vertical hydraulic conductivity – primary fractured rock: multiplier 10;
2. specific yield: multiplier 0.2; and
3. specific yield: multiplier 0.1.

These parameter values were considered to not fit the measured groundwater level data sufficiently to be used in the predictive uncertainty analysis (Section 8.7.4).

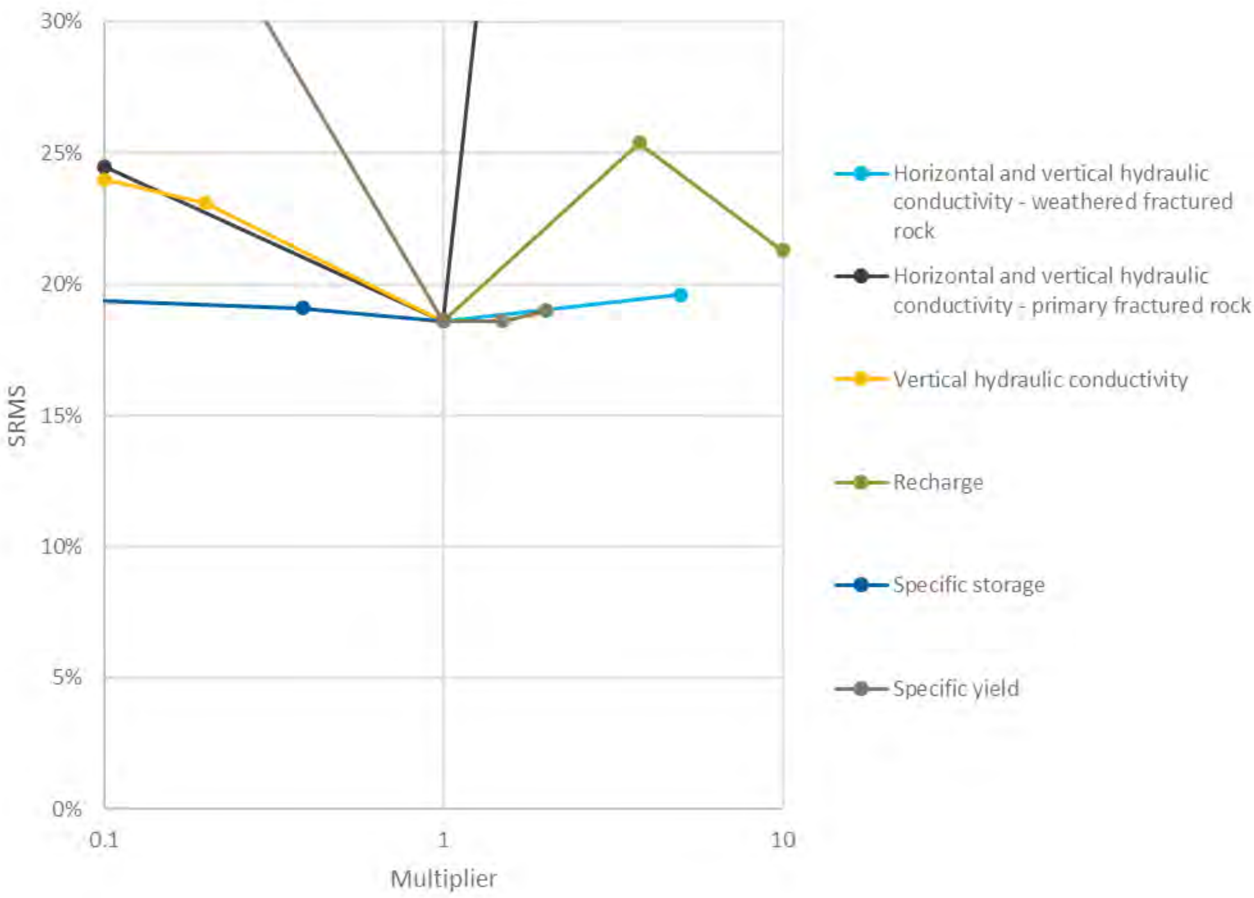


Figure 8.9 History match sensitivity analysis results

8.6 Prediction model setup

8.6.1 Predicted mine schedule

The predictive mine plan extends from 2020 to 2032 and was simulated using yearly stress periods based on three dimensional (3D) spatial datasets sets supplied by PGM. The predictive mine plan for individual deposits is presented in Table 8.8, showing the maximum depths for each stress period. The deposits progress in different directions spatially and vertically; with each deposit in the prediction period generally moving towards shallower mining elevations over time with the exception of Chesney. Void properties are activated in mined-out areas to allow for hydraulic connection and continued dewatering if required.

Table 8.8 Predicted deposit working lowest elevations (m AHD)

Stress period	Year from	Peak and Perseverance	Chesney	Gladstone	New Cobar open cut	New Cobar underground	Jubilee	Great Cobar underground
32	2020	-1,250	--	--	--	--	-244	--
33	2021	-1,282	--	-63	--	--	-183	-433
34	2022	-1,314	-67	-73	--	--	-136	-563

Table 8.8 Predicted deposit working lowest elevations (m AHD)

Stress period	Year from	Peak and Perseverance	Chesney	Gladstone	New Cobar open cut	New Cobar underground	Jubilee	Great Cobar underground
35	2023	-1,346	-294	--	--	--	--	-574
36	2024	-1,379	-342	-217	--	--	--	-570
37	2025	-1,379	-441	-253	--	--	--	-520
38	2026	--	-436	-250	--	--	--	-495
39	2027	--	-385	-174	--	--	--	-445
40	2028	--	-286	-92	--	--	--	-421
41	2029	--	--	-17	--	--	--	-346
42	2030	--	--	--	--	--	--	-368
43	2031	--	--	--	--	--	--	-43

8.6.2 Modelled mining and void assumptions

The mine plan was provided as 3D data summarised to yearly increments. This allows for greater detail to be captured in the model design compared to the history match period, where a uniform elevation was assigned over each mine footprint with a linear vertical advance rate. Despite this, the full detail of mined stopes cannot be captured within the model grid and layer discretisation. Each model cell corresponding to active mining in each stress period was analysed for highest and lowest mined area. Drain boundary condition cells were activated in each model layer that mining was active, with stage elevation set equal to the base of the mine in that area. Following active mining, the model cells were converted to void properties (the same as the Peak Complex and other deposits at the New Cobar Complex) to allow hydraulic connection through the mine. A conservative assumption was applied that any backfill materials do not alter the void properties; this assumption is assessed in the predictive uncertainty analysis in Section 8.7.4.

8.7 Numerical groundwater model results

To meet the model objectives, the base case scenario as documented in Section 8.2 was run in prediction mode by simulating the resulting effect on the groundwater system caused by the mine schedule as summarised in Section 8.6. A summary of the prediction results and how this may cause an impact on the groundwater system and corresponding receptors are included in the following sections.

8.7.1 Mine inflows

Figure 8.10 shows the modelled groundwater take due to mining, which includes keeping the mine workings dry at depth and the extraction of any entrained water along with the ore. Progression of active mine workings were provided to EMM and are detailed in Section 8.6.1. New Cobar Complex dewatering continues to increase to a peak of 2,340 kL/d (854 ML/yr) in 2026 and then reduces towards the end of mining. The variability of dewatering rates between years is largely a result of model discretisation; with annual stress periods and model layers representing mine stopes 50 m thick. A three-year rolling average dewatering rate is presented alongside to show what the actual average dewatering rates may be once mining is commenced. The peak dewatering rate around 2025 corresponds to mining at the greatest depth of the Great Cobar deposit, as shown in Section 8.6.

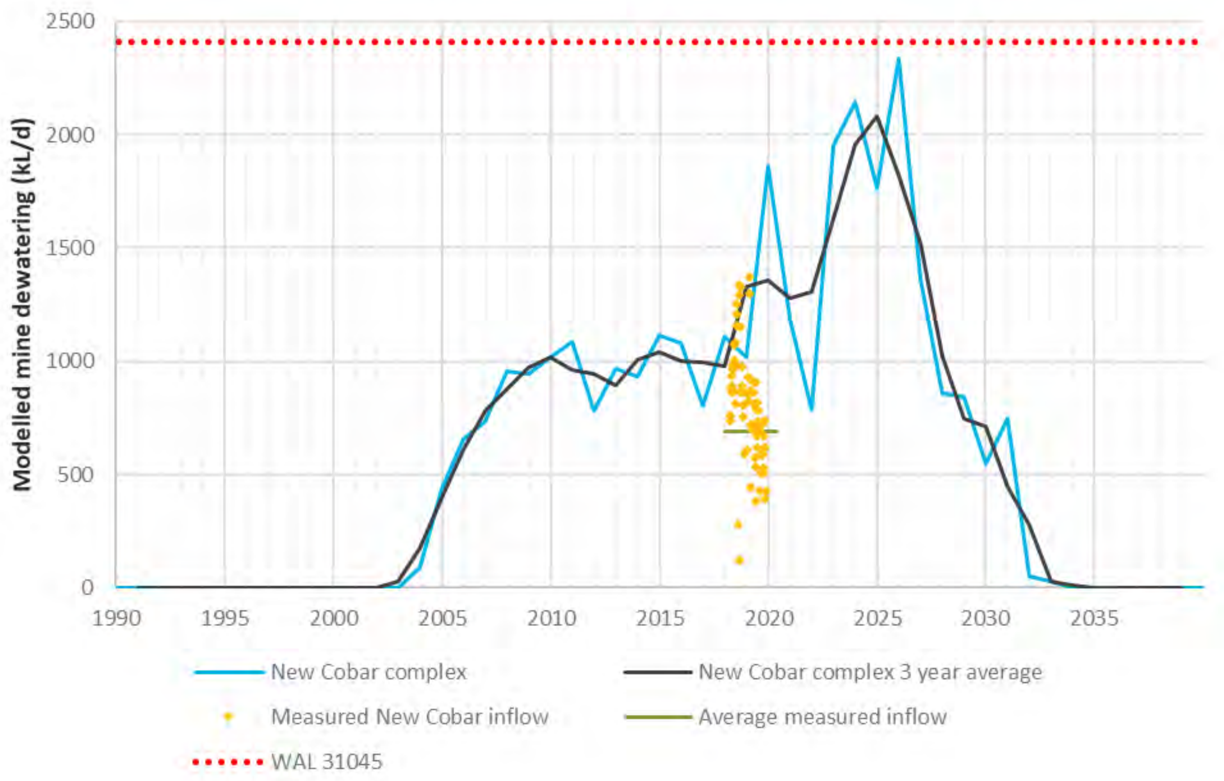


Figure 8.10 History match and prediction period mine dewatering by location

8.7.2 Modelled water balance

The modelled water balance for the duration of the predictive model is shown in Figure 8.11. As with the history match period, mine dewatering is shown in the drain output flux, balanced by storage fluxes. No significant flux is induced in other boundary conditions, which also suggests that mining induced drawdown does not reach the model domain extents throughout the history match and prediction period.

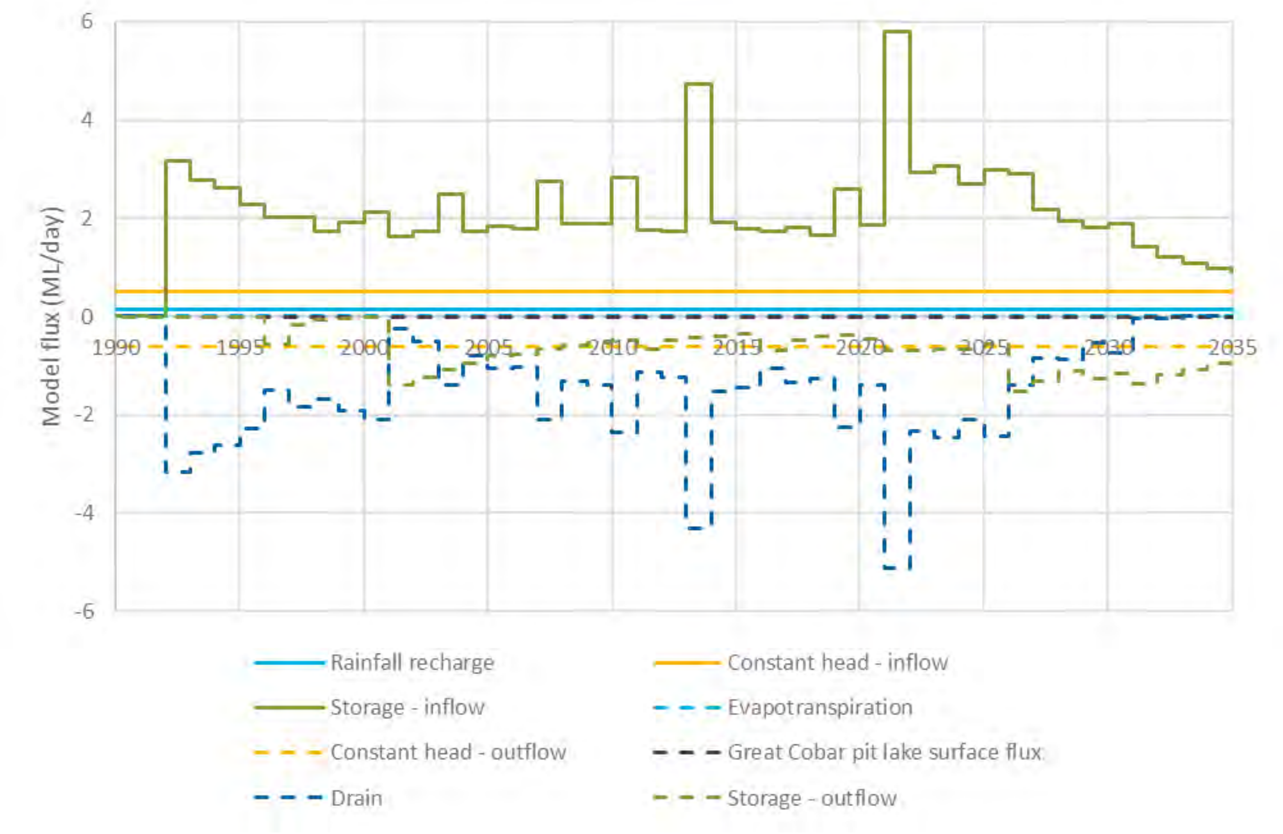


Figure 8.11 History match and prediction period model water balance

The model water balance at the end of mining is presented in Table 8.9. Excluding storage, all of the fluxes from the pre-mining water balance (Table 8.5) are unchanged. Mine dewatering is low at 0.05 ML/d, as expected for the end of mining as the mine footprint has been dewatered and groundwater drawdown continues to propagate. This is shown in the high storage fluxes in and out of model cells (1.42 ML/d and 1.38 ML/d respectively), representing continued change in groundwater levels. The modelled water balance also shows a zero mass balance discrepancy, supporting that the modelling solution is very stable and is consistent with best practise.

Table 8.9 Modelled water balance at 1/01/2032

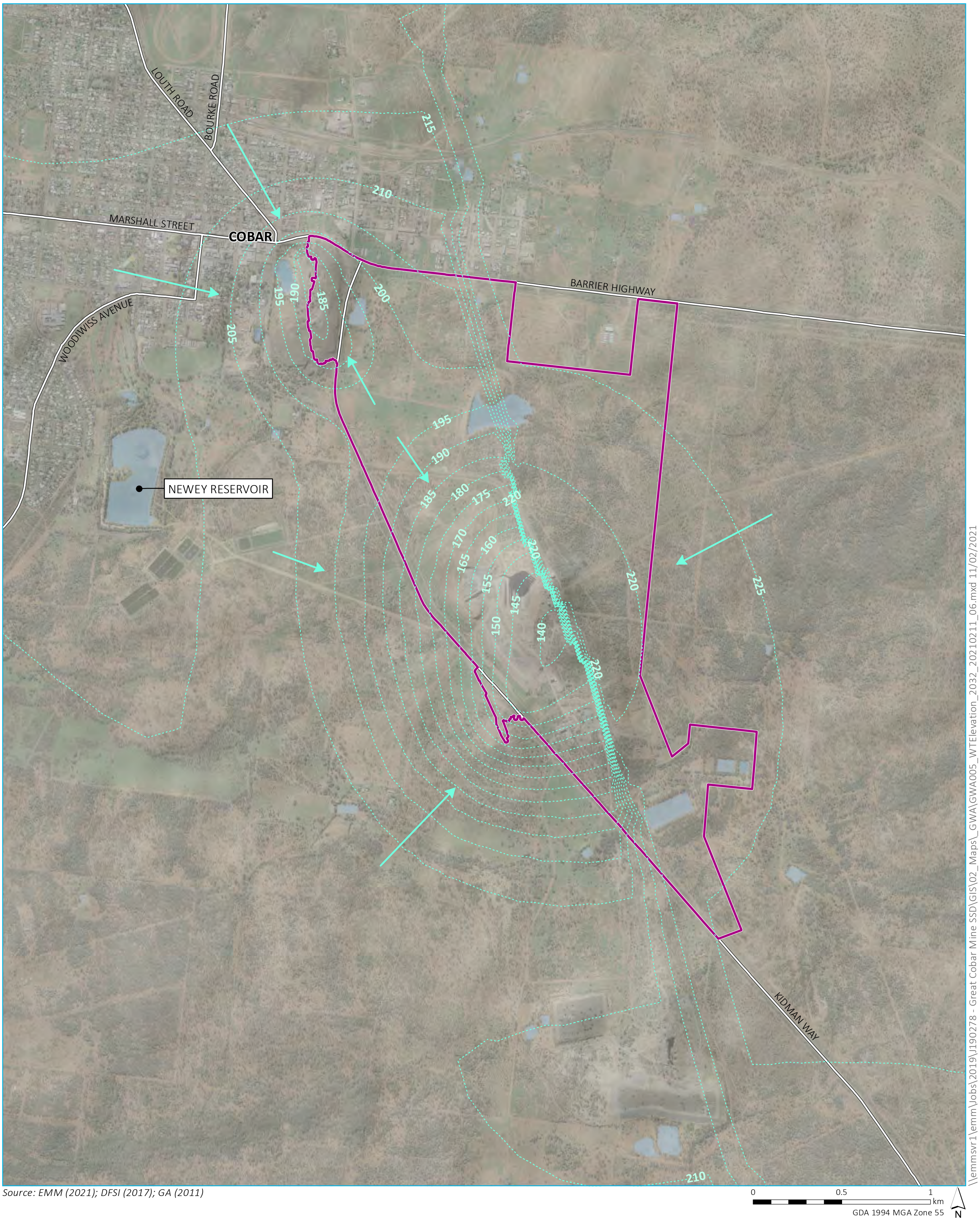
Model flux	Inflow (ML/d)	Outflow (ML/d)
Constant head boundary	0.51	0.62
Rainfall recharge	0.14	--
Great Cobar pit lake surface	--	0.02
Evapotranspiration	--	0.00
Mine dewatering drains	--	0.05
Storage	1.42	1.38
Total IN	**2.07**	
Total OUT	**2.07**	
Percentage discrepancy	**0.0%**	

8.7.3 Groundwater level changes

Modelled water table elevation at the end of mining (1 January 2032) is presented in Figure 8.12. Away from the Project area, the regional water table is unchanged from the pre-mining steady state results (Figure 8.5). Drawdown is simulated to occur during and following mine dewatering activities. At the New Cobar Complex, the drawdown is pronounced, as workings begin from surface level (New Cobar open cut) and progress downwards with comparatively little overburden material. The lowest water table elevation at the New Cobar Complex is around 140 m AHD, while at the planned Great Cobar deposit workings, the water table reduces to approximately 185 m AHD. Groundwater flow is conceptualised to be minimal across the Great Chesney Fault; there is little modelled change to groundwater levels east of the fault compared to the west.

Modelled water table drawdown at the end of mining is presented in Figure 8.13. Drawdown was calculated against a predictive 'null scenario' where none of the deposits at the New Cobar Complex are dewatered from January 2020. This allows for the calculation of modelled impact resulting from planned workings, delineated from the cumulative impacts of historical workings as shown in the water table contours. The modelled impact exceeds 20 m of water table drawdown at two locations; at the Great Cobar deposit and south of the New Cobar open cut. Drawdown is buffered to the east by the Great Chesney Fault, and the two metre contour extends approximately 850 to 1,000 m from the centre of drawdown at the Great Cobar deposit.

Modelled water table contours are presented for 100 and 1,000 years following cessation of mining in Figure 8.14 and Figure 8.15 respectively. Residual drawdown is most apparent at the New Cobar open cut, where groundwater recovery is predicted to occur. Any potential surface expression of water to the New Cobar open cut is expected to be removed by evaporation, given the evaporation rates far exceed the modelled ingress volume of groundwater. Modelled groundwater flow is broadly from north to south, with some surface discharge expected at the historic Great Cobar and New Cobar open cut, redirecting groundwater that was simulated to flow towards the south-west (Figure 8.5).



Source: EMM (2021); DFSI (2017); GA (2011)

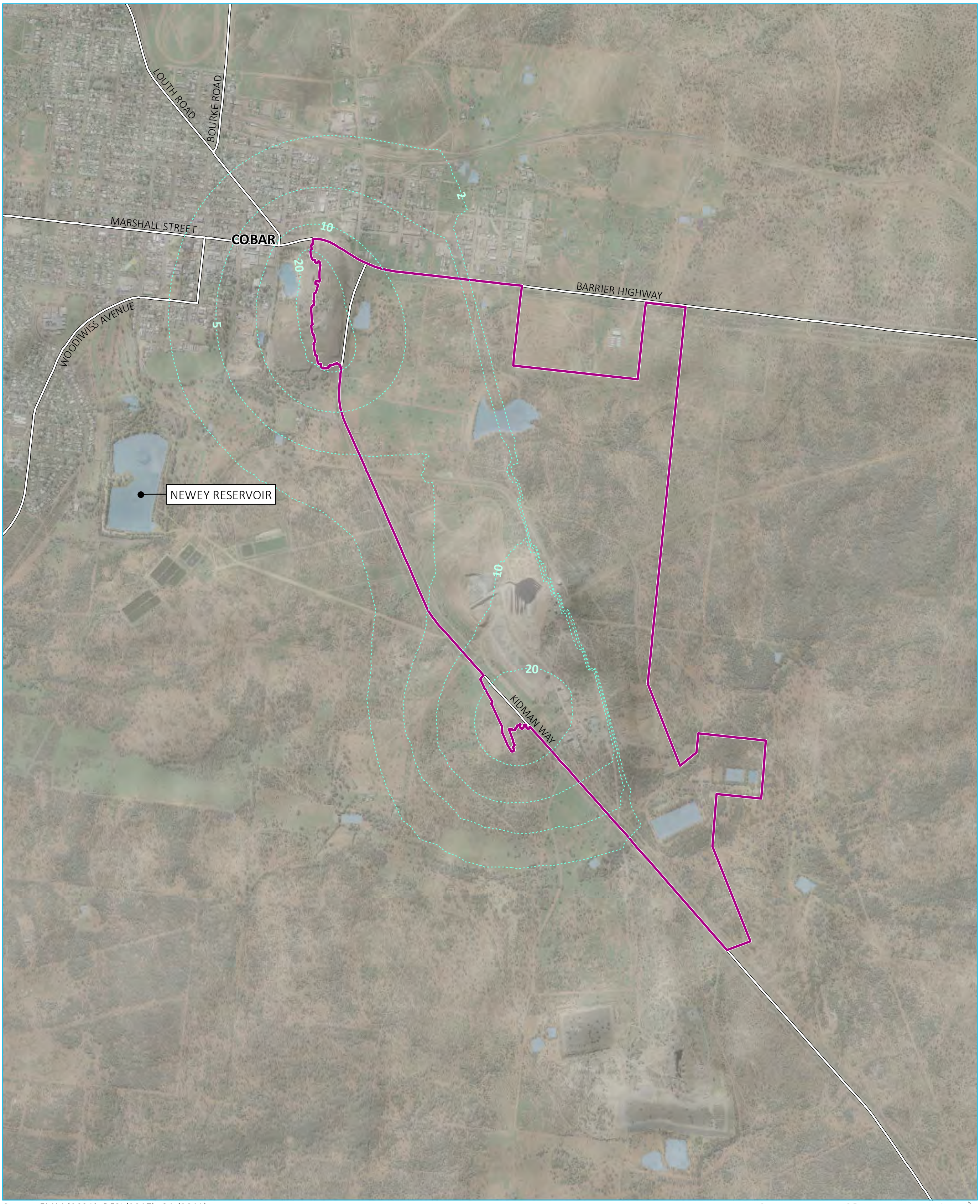
KEY

- Project area
- Modelled watertable elevation (mAHD)
- Modelled groundwater flow direction
- Major road
- Waterbody

Modelled watertable elevation at 1 January 2032

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 8.12

creating opportunities



Source: EMM (2021); DFSI (2017); GA (2011)

KEY

Project area

Modelled drawdown (m)

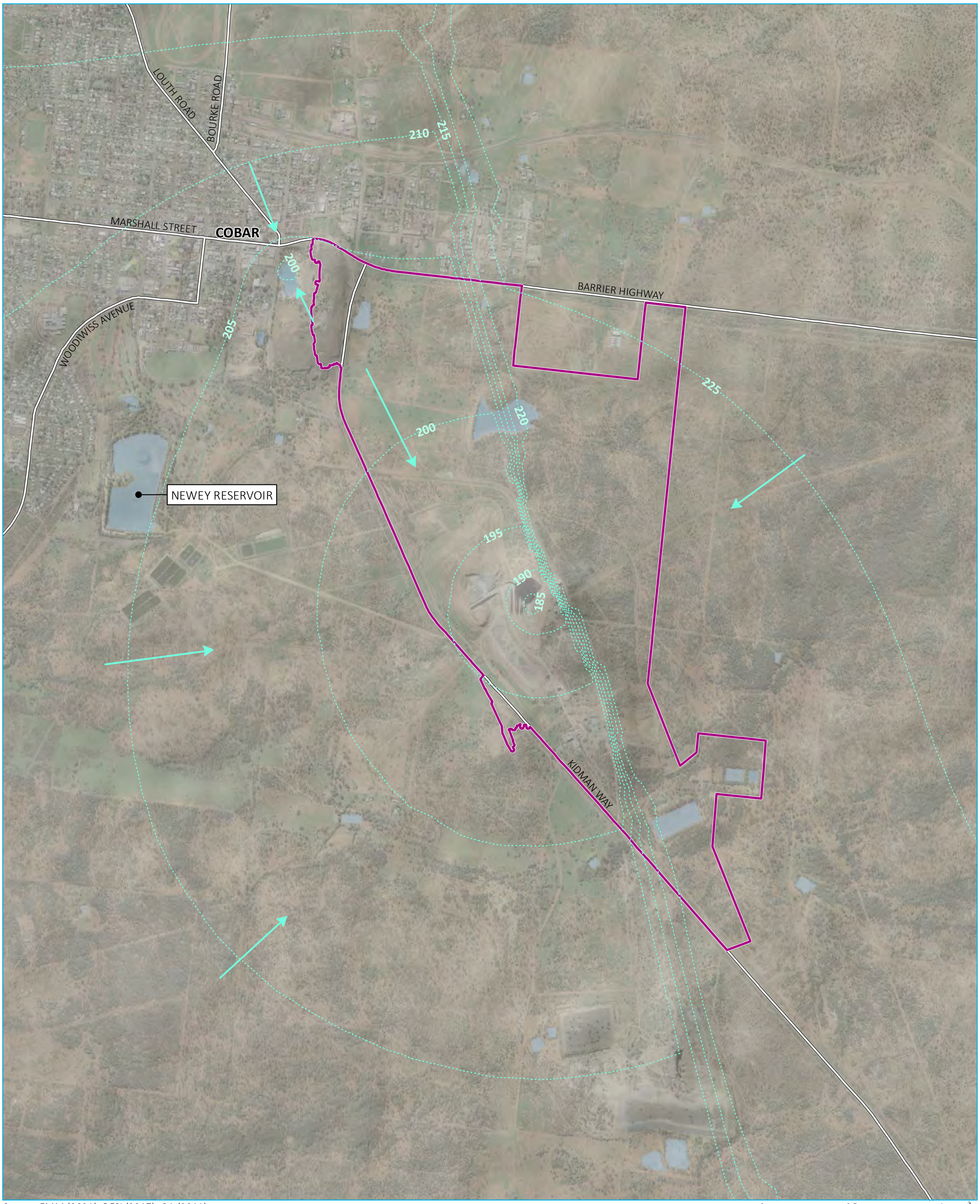
Major road

Waterbody

Modelled watertable drawdown at 1 January 2032

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 8.13

creating opportunities



Source: EMM (2021); DFSI (2017); GA (2011)

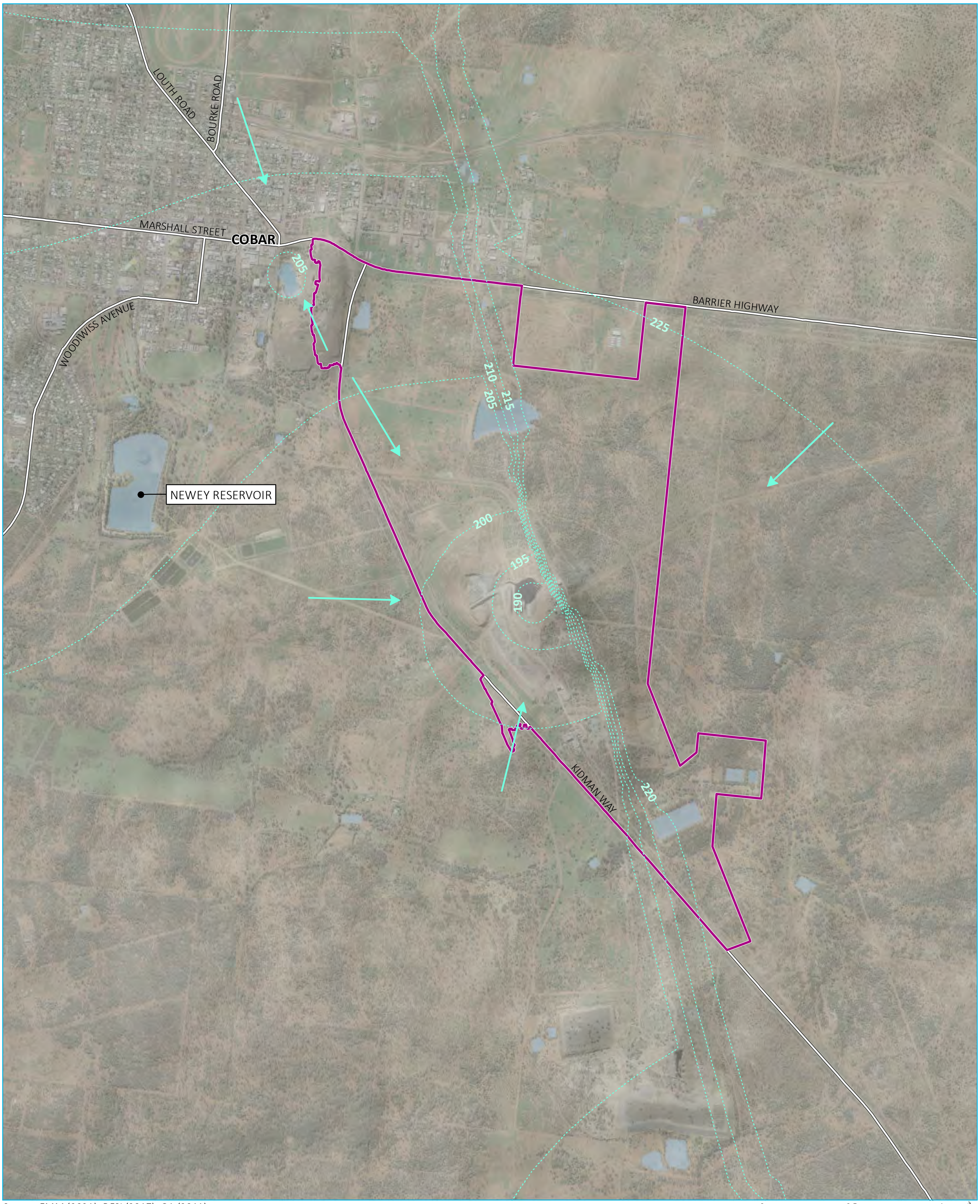
KEY

- Project area
- Modelled watertable elevation (mAHD)
- Modelled groundwater flow direction
- Major road
- Waterbody

Modelled watertable elevation
100 years following mining

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 8.14

EMM
creating opportunities



Source: EMM (2021); DFSI (2017); GA (2011)

0 0.5 1 km

GDA 1994 MGA Zone 55

N

KEY

Project area

Modelled watertable elevation (mAHD)

Modelled groundwater flow direction

Major road

Waterbody

Modelled watertable elevation
1,000 years following mining

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 8.15

EMM creating opportunities

Figure 8.16 shows modelled hydrographs of predicted groundwater levels from pre-mining through to 2100 at some of the New Cobar Complex monitoring bores and at the historical Great Cobar open cut. Hydrographs are presented over approximately 70 years to maintain visibility of the measured groundwater level trends, though the model has been run for 1,000 years following cessation of mining to capture any potential long-term residual effects on the groundwater system.

The predictive model simulates a very slow recovery over several hundred years. The maximum drawdown impact is simulated to occur between 2010 and 2050 depending on screen depth, due to the vertical progression of drawdown from depth towards the water table.

Monitoring bores at the New Cobar Complex have comparatively brief monitoring periods, though the absolute pre-impact modelled groundwater levels are reasonable. Drawdown is predicted to increase beyond the end of mining, peaking as late as 2040 for some locations, between 20 and 30 m below pre-mining levels. Water levels within the Great Cobar open cut are also predicted to reduce due to the proposed underground mining development and is discussed further in Section 9.2, referred to in conjunction with the Great Cobar slag dump.

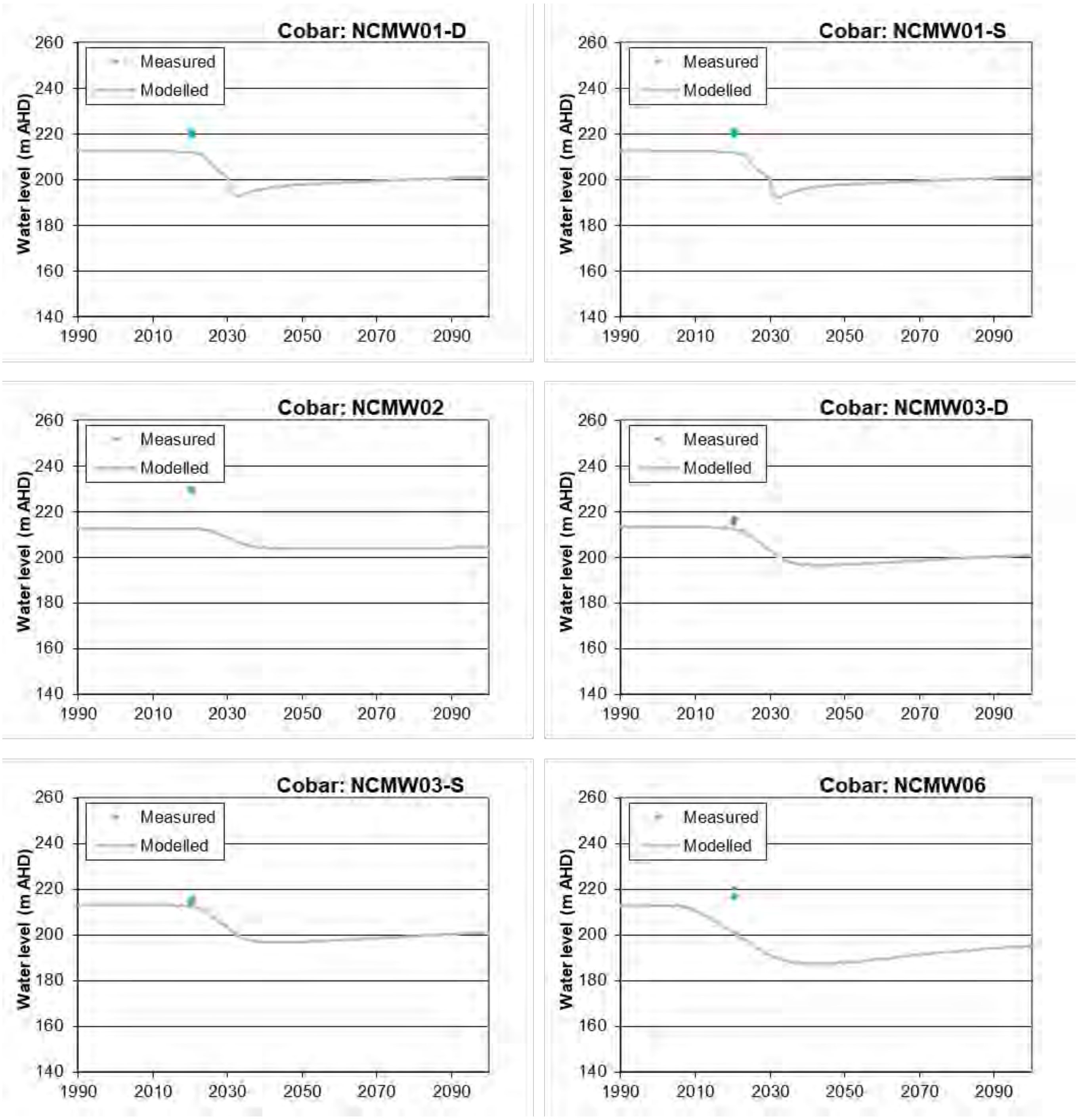


Figure 8.16 Predictive modelled hydrographs at Project area monitoring bores

8.7.4 Predictive uncertainty analysis

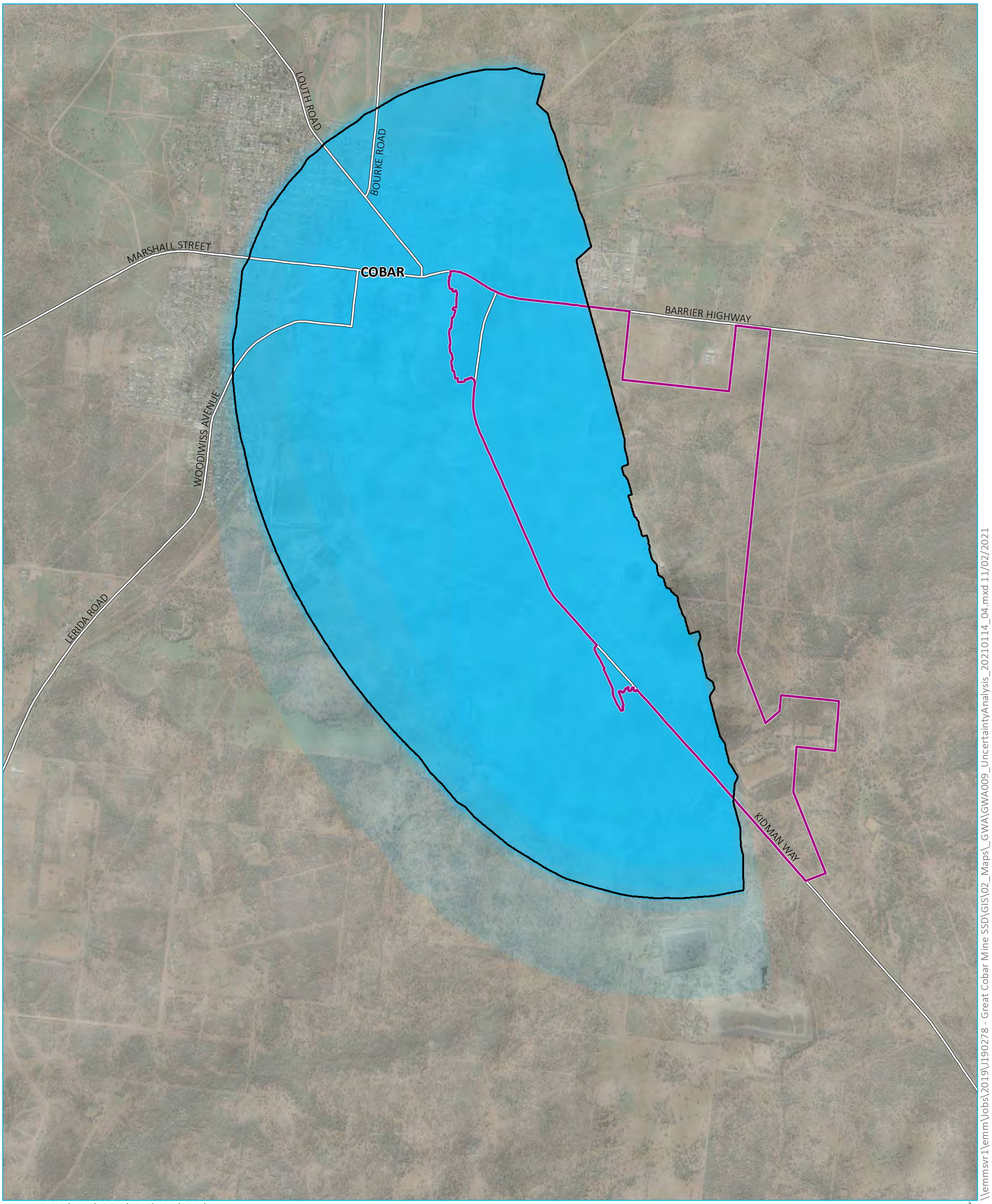
A Type 1 deterministic predictive uncertainty analysis (Middlemis and Peeters 2018) was conducted to determine plausible ranges of potential impacts arising from mine dewatering during mining of the Great Cobar deposit. The models developed for the history match sensitivity analysis (Section 8.5.3) were used to identify parameter values to employ for predictive uncertainty analysis. Of the 15 models run for the sensitivity analysis, 11 scenarios returned a satisfactory statistical performance with SRMS error <30%. These parameter values were used to run predictive scenarios for the New Cobar Complex mine plan. Four additional models were developed for the predictive uncertainty analysis, varying storage and hydraulic conductivity parameters of the backfill applied to mined stopes. A summary of model runs for the predictive uncertainty analysis is given in Table 8.10.

Given the low recharge and hydraulic conductivity of the system, the maximum spatial extent of the drawdown impact is not predicted to occur at the end of mining. This is observed in the modelled hydrographs (Figure 8.16), where drawdown at monitoring bores continues to increase for 10 to 20 years following the cessation of mining.

Results of the predictive uncertainty analysis are presented as the maximum modelled drawdown at any time, shown as a two-metre drawdown contour. The results are given in Figure 8.17. The base case modelled drawdown is highlighted, and each of the predictive uncertainty runs are presented as a graduated blue shading. The majority of uncertainty runs result in maximum drawdown extent approximately equal to or within the footprint of the base case modelled drawdown, suggesting that the adopted model parameter values are conservative with regards to impact assessment. One model predicts greater drawdown; uncertainty run eight where the hydraulic conductivity of the weathered fractured rock is increased by approximately five times. The result is an increase of 650 m to the south, and minimal additional impact towards the north.

Table 8.10 Predictive uncertainty analysis model parameter values

Model run	Adopted value											
	Weathered fractured rock				Primary fractured rock				Stope backfill			
	Horizontal hydraulic conductivity (m/d)	Vertical hydraulic conductivity (m/d)	Specific yield	Specific storage (1/m)	Horizontal hydraulic conductivity (m/d)	Vertical hydraulic conductivity (m/d)	Specific yield	Specific storage (1/m)	Hydraulic conductivity (m/d)	Specific yield	Recharge (mm/yr)	Other
Base case	**0.015**	**0.015**	**5%**	**1.3 x 10^{-5}**	**7.4 x 10^{-4}**	**7.4 x 10^{-4}**	**0.5%**	**1.3 x 10^{-5}**	**1,000**	**50%**	**0.13**	--
Uncertainty run 1	0.015	**0.003**	5%	1.3 x 10^{-5}	7.4 x 10^{-4}	**1.5 x 10^{-4}**	0.5%	1.3 x 10^{-5}	1,000	**50%**	0.13	--
Uncertainty run 2	0.015	**0.001**	5%	1.3 x 10^{-5}	7.4 x 10^{-4}	**7.4 x 10^{-5}**	0.5%	1.3 x 10^{-5}	1,000	50%	0.13	--
Uncertainty run 4	0.015	0.015	5%	1.3 x 10^{-5}	7.4 x 10^{-4}	7.4 x 10^{-4}	0.5%	1.3 x 10^{-5}	1,000	50%	**0.5**	--
Uncertainty run 5	0.015	0.015	5%	**5 x 10^{-6}**	7.4 x 10^{-4}	7.4 x 10^{-4}	0.5%	**5 x 10^{-6}**	1,000	50%	0.13	--
Uncertainty run 6	0.015	0.015	5%	**1 x 10^{-6}**	7.4 x 10^{-4}	7.4 x 10^{-4}	0.5%	**1 x 10^{-6}**	1,000	50%	0.13	--
Uncertainty run 7	0.015	0.015	5%	**5 x 10^{-7}**	7.4 x 10^{-4}	7.4 x 10^{-4}	0.5%	**5 x 10^{-7}**	1,000	50%	0.13	--
Uncertainty run 8	**0.073**	**0.073**	5%	1.3 x 10^{-5}	7.4 x 10^{-4}	7.4 x 10^{-4}	0.5%	1.3 x 10^{-5}	1,000	50%	0.13	--
Uncertainty run 9	0.015	0.015	5%	1.3 x 10^{-5}	**7.4 x 10^{-5}**	**7.4 x 10^{-5}**	0.5%	1.3 x 10^{-5}	1,000	50%	0.13	--
Uncertainty run 11	0.015	0.015	5%	1.3 x 10^{-5}	7.4 x 10^{-4}	7.4 x 10^{-4}	0.5%	1.3 x 10^{-5}	1,000	50%	0.13	**No decreasing K with depth**
Uncertainty run 12	0.015	0.015	**10%**	1.3 x 10^{-5}	7.4 x 10^{-4}	7.4 x 10^{-4}	**1%**	1.3 x 10^{-5}	1,000	50%	0.13	--
Uncertainty run 13	0.015	0.015	**7.5%**	1.3 x 10^{-5}	7.4 x 10^{-4}	7.4 x 10^{-4}	**0.75%**	1.3 x 10^{-5}	1,000	50%	0.13	--
Uncertainty run 16	0.015	0.015	5%	1.3 x 10^{-5}	7.4 x 10^{-4}	7.4 x 10^{-4}	0.5%	1.3 x 10^{-5}	**100**	50%	0.13	--
Uncertainty run 17	0.015	0.015	5%	1.3 x 10^{-5}	7.4 x 10^{-4}	7.4 x 10^{-4}	0.5%	1.3 x 10^{-5}	**10**	50%	0.13	--
Uncertainty run 18	0.015	0.015	5%	1.3 x 10^{-5}	7.4 x 10^{-4}	7.4 x 10^{-4}	0.5%	1.3 x 10^{-5}	1,000	**75%**	0.13	--
Uncertainty run 19	0.015	0.015	5%	1.3 x 10^{-5}	7.4 x 10^{-4}	7.4 x 10^{-4}	0.5%	1.3 x 10^{-5}	1,000	**25%**	0.13	--



Source: EMM (2021); DFSI (2017); GA (2011)

0 0.5 1 km
GDA 1994 MGA Zone 55
N

KEY

Project area

Base case

Major road

Number of predictive uncertainty simulations

15

1

Predictive uncertainty analysis modelled maximum drawdown extent

Peak Gold Mines
New Cobar Complex Project
Groundwater assessment
Figure 8.17

EMM creating opportunities

9 Impact assessment

9.1 Aquifer interference policy

The AIP outlines the minimal impacts considerations for assessing potential groundwater impacts in NSW, as well as requirements for obtaining water licences for aquifer interference activities. This section compares the expected impacts against the minimal impacts considerations of the AIP and discusses compliance with the policy. Licensing requirements for the Project are detailed in Section 11.

9.1.1 Minimal impact considerations

The minimal impact considerations are a series of thresholds that define minimal impacts from aquifer interference activities. There are two levels of minimal impact considerations specified in the AIP, being Level 1 and Level 2. If the predicted impacts are less than the threshold level specified by the Level 1, then these impacts are acceptable under the AIP. Where the predicted impacts are greater than the Level 1 minimal impact considerations, then additional studies are required to fully assess and manage these predicted impacts. If this assessment shows that the predicted impacts do not prevent the long-term viability of the relevant water-dependent asset, then the impacts will be considered acceptable.

Table 9.1 compares the potential Project impacts with the minimal impact considerations for less productive porous and fractured rock water sources.

Table 9.1 Minimal impact considerations – less productive porous and fractured rock water sources

Groundwater WSP	
Aquifer	**Lachlan Fold Belt MDB Groundwater Source**
Category	**Less productive**
Level 1: Minimal Impact Considerations	**Assessment**
<u>**Water table**</u> Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan **or** A maximum of a 2 m decline cumulatively at any water supply work.	At the time of writing, there were no high priority culturally significant sites listed within the Groundwater WSP located within 5 km of the New Cobar Complex. There are no high priority GDE's mapped or listed in the WSP within 5 km of the New Cobar Complex. As outlined in Section 9.2.1, greater than 2 m drawdown at GW803422 is predicted to occur. Make good arrangements will be put in place in consultation with the water supply work owner. **Conclusion: exceeds Level 1 minimal impact consideration thresholds – Level 2 minimal make good provisions may apply.**
<u>**Water pressure**</u> A cumulative pressure head decline of not more than a 2 m decline, at any water supply work	Not applicable – there are no water supply works with semi-confined or confined aquifer systems in the region. **Conclusion: minimal impact consideration does not apply.**

Table 9.1 Minimal impact considerations – less productive porous and fractured rock water sources

Groundwater WSP	
Aquifer	**Lachlan Fold Belt MDB Groundwater Source**
Category	**Less productive**
Level 1: Minimal Impact Considerations	**Assessment**
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity	The existing New Cobar open cut will act as a regional groundwater terminal sink, maintaining groundwater flow towards it. Any change in groundwater quality will be localised and flowpaths controlled by the terminal sink. Furthermore, the one water supply work has a total depth of 22 m and draws groundwater from the shallow water table. The underground mine workings of the Project are greater than 500 m depth. Therefore, the source and pathways of groundwater do not interact. **Conclusion: does not exceed Level 1 minimal impact consideration thresholds.**

9.2 Groundwater level changes

9.2.1 Private water users

Predictive simulations were used to quantify the potential impact for active registered water supply bores. There is one water supply work (GW803422) within a 5 km of the New Cobar Complex. The water supply work is a groundwater bore located at the Cobar District Rugby Club and used by the club for irrigation of the playing field during times of drought or interruption. Their main supply of water is provided by the Cobar Water Board from Burrendong Dam. Details of the groundwater bore are provided in Table 4.5. Impacts have been assessed using the AIP minimal impact requirements of a maximum two metre decline cumulatively at any water supply work.

The predictive modelling shows drawdown occurring at GW803422. The drawdown hydrograph is shown Figure 9.1. A maximum drawdown of around 12.5 m is predicted to occur around 2050. As this drawdown may reduce the pumping capacity and extractable yield from the water supply bore, PGM have committed to make good arrangements to supply supplementary water to replace any reduction in pumping capacity that may occur.

GW803422 is part of the New Cobar Complex groundwater monitoring network. Monitoring frequency and parameters are outlined in the PGM WMP (EMM 2020b). A Trigger Action Response Plan (TARP) is included in the WMP outlining corrective actions if greater than two metre drawdown occurs.

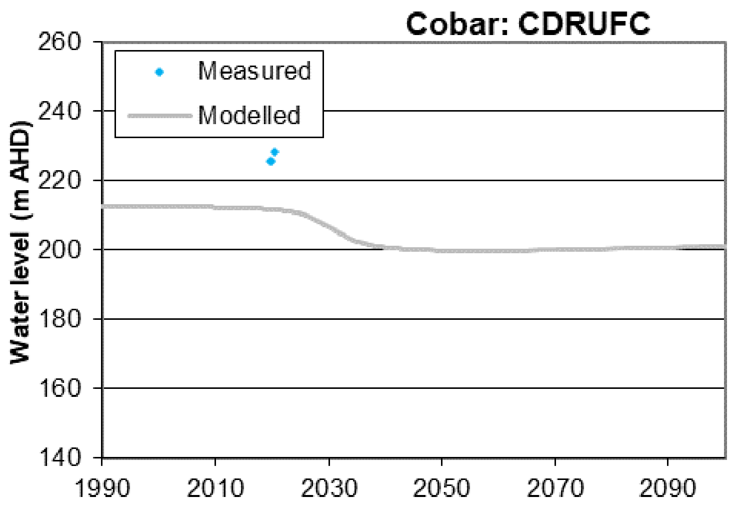


Figure 9.1 Drawdown hydrograph at GW803422

9.2.2 Groundwater dependent ecosystems

Potential impacts have been assessed using the AIP minimal impact requirements. A change of less than or equal to a 10% cumulative variation in the water table at a high priority GDE is considered. As stated in Section 4.8.2, there are no designated high priority GDEs under the Groundwater WSP located within 5 kms of the New Cobar Complex. Therefore, the AIP minimal impact consideration is not applicable.

Despite this, further review and assessment of GDEs listed under the BoM GDE Atlas and other relevant literature has been conducted by EMM as part of the groundwater impact assessment for the Project. In summary, regional groundwater levels in this area are known to be deep (>10 m), as supported by the modelled depth to water map (Figure 9.2) and the maximum groundwater drawdown due to the Project is not expected to have an impact on any potential GDEs. This is discussed further in the sections below.

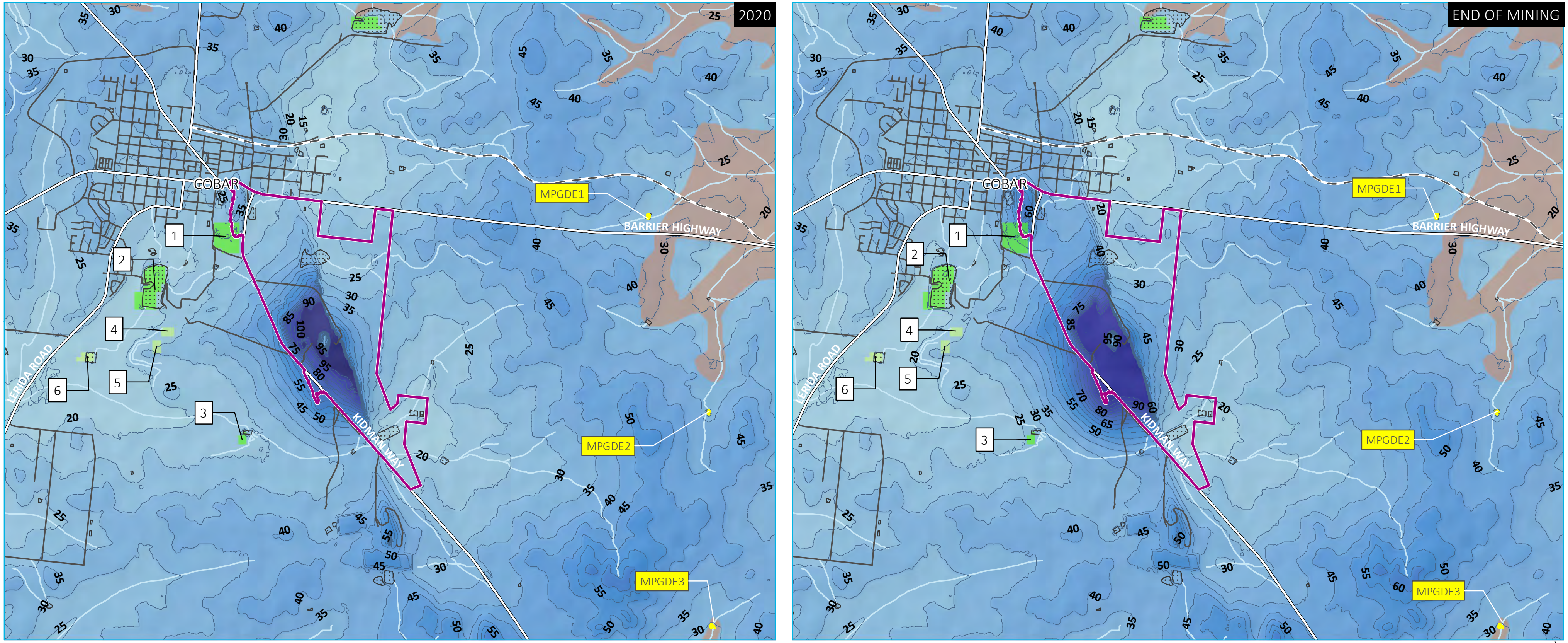
i Aquatic GDE

The closest of the high potential aquatic GDEs mapped in the BoM GDE Atlas is located 500 m south of the historic Great Cobar open cut, and 500 m north-west of the power line corridor. This comprises the area occupied by the historic Great Cobar slag heap. The site is man-made of slag waste from the historical copper smelter that operated at there between the late 1880s and 1920. It is largely bare, disturbed ground supporting some exotic grasses. There is a reduced likelihood of groundwater dependency with increasing groundwater depth, with depth to groundwater of 20 mbgl considered the maximum that can support a GDE. It is possible to further subdivide into zones of 0 - 5 mbgl (GDEs with high groundwater dependency), 5 – 10 mbgl (GDEs with moderate dependency) and 10 – 20 mbgl GDEs with low dependency) (IESC 2019). Groundwater levels in this area are modelled to be between 20 and 25 mbgl (Figure 9.2) therefore there is likely to be no interaction between groundwater and any biodiversity at this location, therefore it is highly unlikely that this location is a GDE.

Another high potential aquatic GDE mapped on the GDE Atlas is located at the Newey Reservoir, located 1.2 km west of the New Cobar Complex. Groundwater levels in this area are modelled to be between 15 and 20 mbgl. Therefore, it is unlikely that the surface water body at the Newey Reservoir is connected to groundwater, and hence highly unlikely that this location is a GDE.

There are an additional four potential aquatic GDEs (one high potential and three medium potential) mapped by the GDE Atlas within 5 km of the New Cobar Complex. These are related to farm dams and the Cobar sewage treatment works. The depth to groundwater at each of these locations is greater than 15 mbgl, therefore they are not expected to be GDEs.

Three small GDEs (MPGDE1 – MPGDE3) located over two kilometres to the east of the New Cobar Complex (shown in Figure 4.8 and again in on Figure 9.2) are categorised as having medium ecological value under the GDE HEVAE method. Due to the distance between the Project and these GDEs, as well as the Great Chesney Fault forming a barrier to groundwater flow east of the Project area, the maximum drawdown does not extend to the GDE locations. Furthermore, groundwater levels in this area are modelled at 2020 to be between 15 and 20 mbgl with no change expected by the end-of-mining in this area, as shown on Figure 9.2. Therefore, there is unlikely to be interaction between groundwater and any biodiversity at this location, and highly unlikely that this location is a GDE.



Source: EMM (2021); PGM (2020); DFSI (2017); BoM (2017); DPIE (2020)

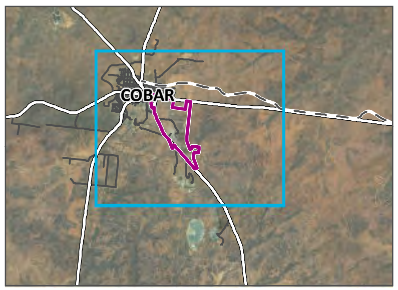
0 2 4 km

GDA 1994 MGA Zone 55

N

GDE REFERENCE

1 - Great Cobar slag dump
2 - Newey Reservoir
3 - Farm dam 1
4 - Sewage treatment plant 1
5 - Sewage treatment plant 2
6 - Farm dam 2



KEY

Project area

Existing environment

- Rail line
- Major road
- Minor road
- Watercourse/drainage line
- Waterbody

Groundwater Dependent Ecosystem Atlas (BoM 2017)

Aquatic GDE potential

- High
- Low

Terrestrial GDE potential

- Moderate

High Ecological Value Aquatic Ecosystems (DPIE 2020)

Aquatic GDE potential

- Medium

Depth to groundwater

- 10 m
- 15 m
- 20 m
- 25 m
- 30 m
- 35 m
- 40 m
- 45 m
- 50 m
- 55 m
- 60 m
- 65 m
- 70 m
- 75 m
- 80 m
- 85 m
- 90 m
- 95 m
- 100 m
- >100 m

Depth to groundwater 2020 and end of mining

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New Cobar Complex Project
Groundwater assessment
Figure 9.2

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ii Terrestrial GDE

Areas with moderate potential to be terrestrial GDEs are mapped in areas to the north, south, east, and west of the New Cobar Complex as shown in Figure 9.3. The figure also shows the maximum modelled drawdown experienced at the water table throughout the mining period. All mapped potential terrestrial GDEs are outside the area of expected drawdown of the Project and therefore will not to be impacted by the Project.

Access to the groundwater is dependent on several factors with the core factor being the depth to the water table. As terrestrial vegetation communities are composed of a range of vegetation types, with a range of rooting depths and strategies there is a relationship between groundwater depth and the types and composition of the vegetation that can access it (Serov et al. 2012, Serov 2013).

Considerations in evaluating terrestrial ecosystems and their potential dependency on groundwater included:

- association with groundwater levels across the region;
- the physiology of plant species that occur in that community and their likely dependence on water availability;
- a Plant Community Type's (PCTs) location in the landscape; and
- if the rooting depth of vegetation would be able to take up groundwater based on likely depth of the aquifer and soil characteristics.

To identify groundwater-dependent terrestrial ecosystems (phreatophytes), an analysis was undertaken documenting the association of the PCTs found within the potential groundwater drawdown area with groundwater levels as modelled by the regional numerical groundwater flow model. All PCTs within the groundwater model domain were assessed, which includes those up to 15 km distant from the Project area.

An intersection was undertaken in ArcGIS between PCTs mapped in the regional vegetation mapping against groundwater levels in the following categories:

- 0 - 0.5 m bgl;
- 0.5 - 2 m bgl;
- 2 - 5 m bgl;
- 5 - 20 m bgl; and
- >20 m bgl.

The percentage of each PCT within these bands was determined, and the criteria listed in Table 9.2 was applied to provide an initial determination of the dependence of PCTs within the Project area on groundwater. Ecological knowledge of the PCTs, along with knowledge of the floristics of each PCT were applied to confirm the results of this initial analysis, with some PCT amended based on this additional layer of assessment.

Table 9.2 Criteria used for determining groundwater dependence of PCTs

Dependence on groundwater	Criteria
Entirely/obligate	More than 50% of the PCT is mapped in areas with groundwater at 0.5 m bgl or less, or more than 75% of the PCT is mapped in areas with groundwater at 2 m bgl or less.

Table 9.2 Criteria used for determining groundwater dependence of PCTs

Dependence on groundwater	Criteria
Facultative - high	More than 50% of the PCT is mapped in areas with groundwater at 2 mbgl or less, and more than 75% of the PCT is mapped in areas with groundwater at 5 mbgl or less.
Facultative - proportional	More than 75% of the PCT is mapped in areas with groundwater at 5 m bgl or less, but less than 50% of the PCT is mapped in areas with groundwater at 2 mbgl or less.
Facultative - opportunistic	More than 50% of the PCT is mapped in areas with groundwater at 5 m bgl or less, but less than 75% of the PCT is mapped in areas with groundwater at 5 mbgl and/or less than 50% of the PCT is mapped in areas with groundwater at 2 m bgl.
Non-dependent	Evenly distributed across groundwater levels, with generally less than 50% of the PCT mapped in areas with groundwater at 5 m bgl or less.

Analysis of the distribution of PCTs in relation to the simulated regional groundwater levels identified that none of the PCTs mapped are associated with shallow groundwater systems (Table 9.3), indicating that none of the vegetation within the groundwater drawdown area is considered groundwater dependent. Although some PCTs show an association with groundwater at depths of 10–20 m bgl, these systems are more likely aligned with landscape factors, such as slope position. Further, the floristic composition of these communities does not indicate any reliance on groundwater systems.

Table 9.3 Potential terrestrial GDEs within the groundwater model domain

PCT ID	PCT Name	Percentage of vegetation area overlapping simulated regional groundwater level depth mbgl (metres below ground level)					
		0 - 0.5 m bgl	0.5 - 2 m bgl	2 - 5 m bgl	5-10 m bgl	10-20 m bgl	>20 m bgl
12	Shallow marsh wetland of regularly flooded depressions on floodplains mainly in the semi-arid (warm) climatic zone (mainly Riverina Bioregion and Murray Darling Depression Bioregion)	0%	0%	0%	0%	100%	0%
23	Yarran tall open shrubland of the sandplains and plains of the semi-arid (warm) and arid climate zones	0%	0%	0%	0%	0%	100%
53	Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains	0%	0%	0%	0%	44%	56%
72	White Cypress Pine - Poplar Box woodland on footslopes and peneplains mainly in the Cobar Peneplain Bioregion	0%	0%	0%	0%	12%	88%
77	Yarran shrubland of the NSW central to northern slopes and plains	0%	0%	0%	0%	34%	66%
103	Poplar Box - Gum Coolabah - White Cypress Pine shrubby woodland mainly in the Cobar Peneplain Bioregion	0%	0%	0%	0%	34%	66%
105	Poplar Box grassy woodland on flats mainly in the Cobar Peneplain Bioregion and Murray Darling Depression Bioregion	0%	0%	0%	0%	55%	45%

Table 9.3 Potential terrestrial GDEs within the groundwater model domain

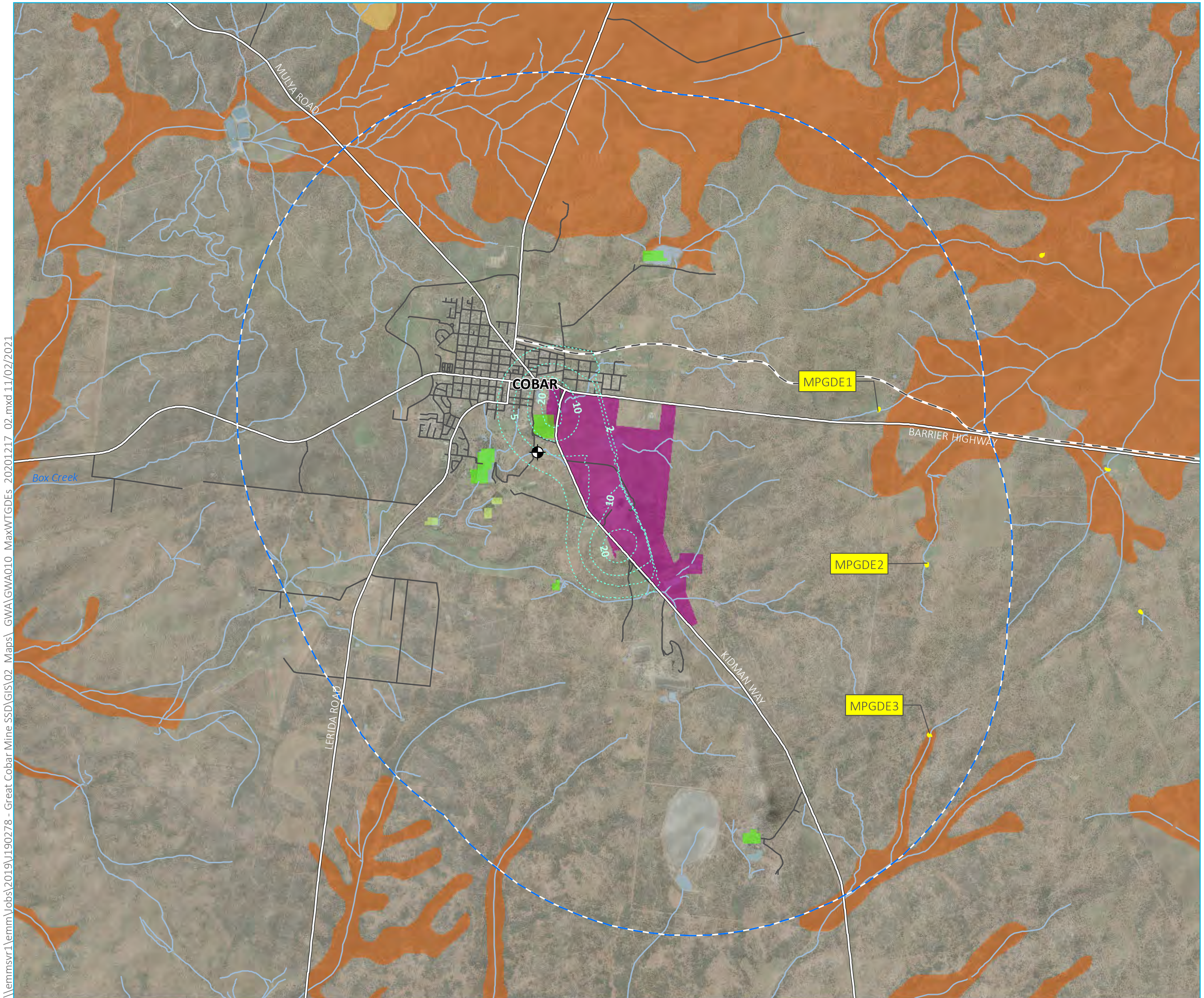
PCT ID	PCT Name	Percentage of vegetation area overlapping simulated regional groundwater level depth mbgl (metres below ground level)					
		0 - 0.5 m bgl	0.5 - 2 m bgl	2 - 5 m bgl	5-10 m bgl	10-20 m bgl	>20 m bgl
108	Gum Coolabah - Mulga open woodland on gravel ridges of the Cobar Peneplain Bioregion	0%	0%	0%	0%	14%	86%
109	Poplar Box - Mulga - Ironwood woodland on red loam soils on plains in the Cobar Peneplain Bioregion and north-eastern Mulga Lands Bioregion	0%	0%	0%	0%	60%	40%
115	Eurah shrubland of inland floodplains	0%	0%	0%	0%	100%	0%
118	Gidgee chenopod woodland on red-brown clays in the semi-arid (hot) climate zone mainly in the Mulga Lands Bioregion.	0%	0%	0%	0%	100%	0%
125	Mulga - Ironwood shrubland on loams and clays mainly of the Cobar Peneplain Bioregion	0%	0%	0%	0%	11%	89%
129	Cabbage-tree Wattle shrubland of the inland plains and drainage lines	0%	0%	0%	0%	0%	100%
134	Ironwood woodland of the semi-arid plains	0%	0%	0%	0%	11%	89%
137	Whitewood - Western Rosewood low woodland of the NSW north western plains	0%	0%	0%	0%	100%	0%
143	Narrow-leaved Hopbush - Scrub Turpentine - Senna shrubland on semi-arid and arid sandplains and dunes.	0%	0%	0%	0%	100%	0%
174	Mallee - Gum Coolabah woodland on red earth flats of the eastern Cobar Peneplain Bioregion	0%	0%	0%	0%	31%	69%
180	Grey Mallee - White Cypress Pine woodland on rocky hills of the eastern Cobar Peneplain Bioregion	0%	0%	0%	0%	0%	100%
193	Red Mallee - White Mallee extremely tall tree mallee on silty-loam-clay soils of central south-western NSW	0%	0%	0%	0%	6%	94%
229	Derived mixed shrubland on loamy-clay soils in the Cobar Peneplain Bioregion	0%	0%	0%	0%	43%	57%
238	Permanent and semi-permanent freshwater lakes wetland of the inland slopes and plains	0%	0%	0%	0%	55%	45%

It is therefore considered that there is a negligible risk to native vegetation and PCTs, including threatened species habitat, from groundwater drawdown arising from the Project.

In summary, as presented in Table 9.4, groundwater drawdown as a result of the Project is not expected to have an impact on any potential GDEs. Numbers 1–6 identified in column 1 relate to labels identified in Figure 9.2 which correspond with descriptions in the table.

Table 9.4 Potential GDEs in the vicinity of the New Cobar Complex

No.	GDE name	Listing	Distance to dewatering location(s)	Potential impact discussion
1	Cobar slag dump	BoM GDE Atlas – high potential aquatic	Located above dewatering point	Highly unlikely to be a GDE due to depth to groundwater and highly disturbed nature.
2	Newey Reservoir	BoM GDE Atlas – high potential aquatic	1.2 km south-west	Highly unlikely to be a GDE due to depth to groundwater. Minimal change to groundwater levels as a result of the Project.
3	Farm dam 1	BoM GDE Atlas – high potential aquatic	1.2 km south-west	Highly unlikely to be a GDE due to depth to groundwater. Minimal change to groundwater levels as a result of the Project.
4	Sewage treatment plant 1	BoM GDE Atlas – low potential aquatic	1.5 km south-west	Highly unlikely to be a GDE due to depth to groundwater and disturbed nature. Minimal change to groundwater levels as a result of the Project.
5	Sewage treatment plant 2	BoM GDE Atlas – low potential aquatic	1.5 km south-west	Highly unlikely to be a GDE due to depth to groundwater and disturbed nature. Minimal change to groundwater levels as a result of the Project.
6	Farm dam 2	BoM GDE Atlas – low potential aquatic	2.6 km south-west	Highly unlikely to be a GDE due to depth to groundwater. No change to groundwater levels as a result of the Project.
7	MPGDE1	HEVAE dataset – medium potential aquatic	5.3 km east	Highly unlikely to be a GDE due to depth to groundwater. No change to groundwater levels as a result of the Project.
8	MPGDE2	HEVAE dataset – medium potential aquatic	5.1 km east	Highly unlikely to be a GDE due to depth to groundwater. No change to groundwater levels as a result of the Project.
9	MPGDE3	HEVAE dataset – medium potential aquatic	6.1 km east	Highly unlikely to be a GDE due to depth to groundwater. No change to groundwater levels as a result of the Project.
10	Terrestrial GDEs	BoM GDE Atlas – moderate potential	Nearest 3 km north	Highly unlikely to be a GDE due to depth to groundwater. No change to groundwater levels as a result of the Project.



KEY

- Maximum modelled watertable drawdown (m)
- Private landholder bore (GW803422.1.1)
- Rail line
- Major road
- Minor road
- Watercourse/drainage line
- Waterbody
- Project area buffer (5 km)
- Project area

Groundwater Dependent Ecosystem Atlas (BoM 2017)

Aquatic GDE potential

- High
- Low

Terrestrial GDE potential

- Moderate
- Low

High Ecological Value Aquatic Ecosystems (DPIE 2020)

Aquatic GDE potential

- Medium

Source: EMM (2021); BoM (2017); DFSI (2017); DPIE (2020); DPE (2019); GA (2011)

0 1 2 km

GDA 1994 MGA Zone 55

N

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Maximum watertable drawdown and GDE locations

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Groundwater assessment
Figure 9.3

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9.3 Change in water storage in Great Cobar underground and water security

The groundwater modelling results are incorporated into the detailed water availability assessment. Water security for the Project is addressed in detail in the Project SWA (EMM 2020a).

Modelled groundwater inflows to mine workings from the predictive uncertainty analysis (Section 8.7.4) were used to estimate makeup water supply requirements, covering the adopted base case model (Section 8.4.2) and upper and lower bounds of modelled mine inflows. The assessment considers groundwater inflows and available water volumes from Burrendong Dam under various climate conditions to estimate water shortfalls that must be supplied from a source outside of the New Cobar complex. Additional groundwater model scenarios were developed based on the makeup water supply requirements, with modelled groundwater extraction from the historic Great Cobar void to fulfill the supply, in excess of mine related inflows. Conservative estimates were applied, neglecting any available storage from Burrendong Dam. Annual extraction rates for the additional model scenarios are detailed in Table 9.5 and Appendix D, and are derived from the water balance model (EMM 2020a).

There is uncertainty regarding potential inflows and the capacity for the historic Great Cobar void to adequately supply makeup water. Groundwater models were run extracting the simulated range of makeup water volumes, and additional scenarios were run simulating a range of potential Great Cobar void volumes from 0.4 to 2.8 gigalitres (GL) (the volume is estimated to be approximately 1.6 GL). Water security is assessed by monitoring the response of modelled water level in the void to pumping at various rates during mining. This is presented as hydrographs for each predictive scenario, shown in Figure 9.4. GC_tpred1 shows modelled drawdown from the base case groundwater model, representing the simulated impact of mine dewatering on water level in the void, without any additional water supply from the shaft. Predictions 2 – 4 show the impact from the shaft makeup water supply scenarios. Without additional water extraction, the water level in the void is predicted to reduce by approximately 30 m in 2031. The addition of water supply pumping results in modelled drawdown in the void of between 60 and 190 m. The void does not dry out at any time in these simulations.

Figure 9.5 shows modelled water levels in the Great Cobar void with various available water extraction volumes, based on uncertainty related to void size and dimensions. Modelled drawdown is more significant with a smaller available volume; the scenario with 0.4 GL of available water returns a maximum drawdown of 230 m. This is insufficient to dry the void to its base, so there is still additional water available in the most conservative scenario, thus suggesting the risk associated with water security for the Project is low.

Regional impacts to groundwater levels following makeup water supply pumping are discussed in Appendix D. Makeup water supply requirements are closely linked to the effective regional hydraulic parameters of the fractured rock system, and resultant drawdown is fairly well constrained across the model scenarios. The 2 m modelled drawdown contour increases in extent by approximately 700 m to the north and west, covering much of the Cobar town. Towards the south of the model domain, there is virtually no change to modelled drawdown.

Table 9.5 Great Cobar makeup water supply requirements

Year	Model stress period	GC_tpred2 water supply rate (kL/d)	GC_tpred3 water supply rate (kL/d)	GC_tpred4 water supply rate (kL/d)
2020	32	442	821	5
2021	33	834	1,074	364
2022	34	7	190	2
2023	35	0	210	0
2024	36	0	490	0
2025	37	0	83	0

Table 9.5 Great Cobar makeup water supply requirements

Year	Model stress period	GC_tpred2 water supply rate (kL/d)	GC_tpred3 water supply rate (kL/d)	GC_tpred4 water supply rate (kL/d)
2026	38	257	436	0
2027	39	760	981	159
2028	40	786	914	197
2029	41	1,074	1,298	1,062
2030	42	877	1,094	855
2031	43	1,563	1,580	1,544

Note: kL/day = kilolitres per day

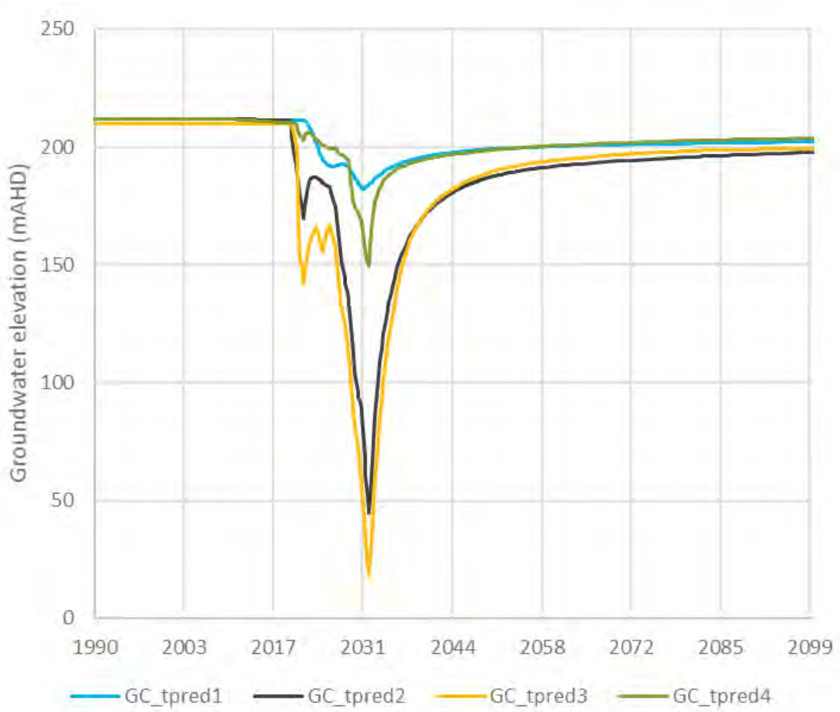


Figure 9.4 Great Cobar shaft modelled groundwater elevation hydrograph

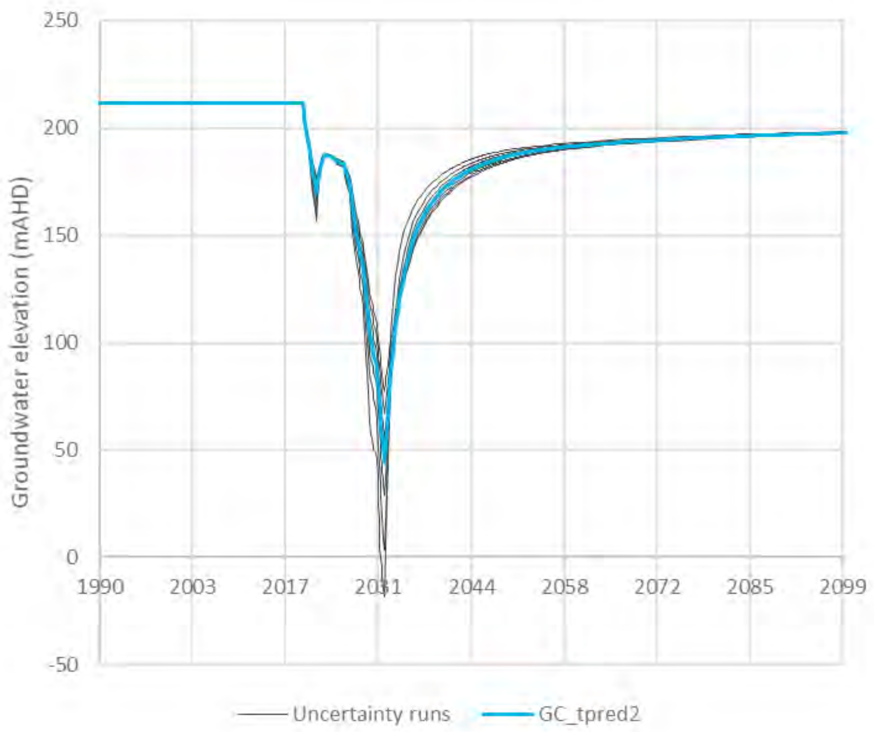


Figure 9.5 Great Cobar shaft modelled mine void uncertainty analysis groundwater elevation hydrograph

9.4 Groundwater quality changes

9.4.1 Water quality protection framework

The *National Water Quality Management Strategy Guidelines for Groundwater Quality Protection in Australia* (Australian Government 2013) relies on a framework which requires the identification of existing and potential environmental value categories for groundwater. 'Environmental value' is the term applied to a particular category of value or use of the groundwater that is important for a healthy ecosystem or for public benefit, welfare, safety or health. The environmental value classification for a groundwater body should be based on the potential inherent values of groundwater in the long term.

Six environmental value categories are described in *Australian and New Zealand fresh and marine water quality guidelines* (ANZG 2018). Of these, two environmental value categories are considered relevant to the groundwater resources in the vicinity of the New Cobar Complex - recreation and aesthetics (sporting field irrigation during times of drought); and industrial water (mine water).

9.4.2 Source of potential pollution

Exposure of PAF lithologies during mining operations has the potential to impact groundwater quality if seepage through PAF material has a pathway to sensitive receptors (e.g. water supply works and GDEs). PGM's management of waste rock and tailings is designed to prevent adverse groundwater quality impacts by:

- maintaining an inward groundwater gradient towards the Great Cobar void and limiting the pathways to the regional aquifer and GDEs;
- appropriately managing seepage from surface waste stockpiles, including the New Cobar Waste Rock Dump (WRD) and the Peak Complex TSF; and
- appropriately managing mine-impacted ('contact') water.

Several studies have been commissioned to assess the potential impacts (changes) to groundwater quality based on investigating the geochemical properties of waste material and seepage water quality anticipated to be generated during mining operations [3] [4] [5] [6]. Following the conclusions of these studies and the provisions laid out in the MOP (PGM 2019), studies demonstrate that the groundwater quality impacts of the Project will be low. The beneficial use category (industrial and recreational) of the regional fractured rock aquifer will not change. The following sections outline the potential sources of impacts and the measures taken to limit pathways.

9.4.3 Seepage from stockpiles and water storages

Most waste rock samples analysed to date are classified as non-acid forming (NAF) or potentially acid forming, albeit with a low capacity to generate acidic drainage (PAF-LC), and seepage derived from these waste rock types is expected to present a low risk to groundwater quality [7].

Some waste rock samples are classified as PAF, with an increased risk of impact on groundwater quality if exposed to ambient conditions (rainfall and oxygen). Leachate studies simulating seepage from the Peak TSF may be considered as 'worst case' examples of the water quality expected to be derived from exposed PAF waste. To prevent adverse impacts on groundwater quality from the New Cobar Complex WRD and other waste stockpile seepage, PGM will implement the following management measures:

- preferential usage of PAF waste rock as backfill in underground voids. If voids are unavailable, transportation of PAF waste rock to the surface and storage in New Cobar WRD will be undertaken. PAF material may also be used in the construction of the TSF dam raises (on internal TSF walls only); and
- lower reactivity NAF material will be used for capping and construction.

9.4.4 Discharge waters to the environment

Water quality across the Project area is influenced by whether a waterbody receives mine contact water or not (EMM 2020a). Water management dams that receive mine contact water are shown to have higher concentrations of electrical conductivity, total dissolved solids, sulphate, and metals. Spain's Dam generally has the highest concentrations of these substances, which may be attributed to it being the primary discharge point for excess mine dewatering water. Water quality improves moving downstream in the Young Australia Complex, which may be attributed to runoff from a broader catchment area diluting mine contact discharge, and/or the settlement of sediment as water passes through the series of water management dams.

The water quality of waterbodies that receive runoff from dirty water or rehabilitated catchments is generally within water quality objective (WQO) ranges. This is also the case for Salty dam which is located downstream of Spain's Dam and receives runoff from both a natural catchment and the Cobar town industrial area stormwater network.

[3] SGM (2019). Geochemistry Review New Cobar Waste Rock Dump.

[4] SGM (2020). Cover Column Trials.

[5] SRK (2007). Geochemical Characterisation of Tailings.

[6] ELA (2019). Review of Environmental Factors.

[7] EMM (2020). New Cobar Complex Project (SSD 10419) – previous geochemistry investigations summary.

Elevated total suspended solids concentrations, which have been observed in one of two samples collected at Salty dam, are often attributed with stormwater runoff from urban/developed areas. Water quality at Salty dam is expected to be primarily influenced by runoff from the upstream industrial area stormwater network.

9.4.5 Water quality changes due to increased drawdown

Increased drawdown from dewatering during mining operations may impact groundwater by exposing previously saturated lithologies to oxygen. Based on previous geochemical investigations (Appendix E), a large proportion of the lithologies affected by drawdown are anticipated to be NAF and is not expected to adversely affect groundwater quality. Exposed PAF rock may present an increased risk of adverse effects on groundwater. However, mine dewatering followed by a slow recovery of heads as the voids slowly fill with groundwater, will result in inward draining of groundwater into the New Cobar Complex voids and will prevent outward seepage of acidic and metalliferous water. In addition, this water will be utilised for mining operations and will be managed accordingly.

9.4.6 Water quality changes due to exposure/rewetting of backfill material

PAF backfill has been exposed on excavation and rewetting may mobilise acidity and metals. However, since the groundwater gradient will be towards the New Cobar Complex voids following cessation of mining (both underground and open cut), pathways to receptors and/or to the regional aquifer are limited. The modelled groundwater contours and corresponding flow directions 100 and 1000 years following cessation of mining are shown on Figure 8.14 and Figure 8.15 respectively, which demonstrates that the existing New Cobar open cut remain a terminal sink. Within arid environments, open cut commonly become terminal sinks as the rate of evaporation (outflow) far exceeds total inflow reporting to the open cut which includes a combination of groundwater inflow, direct rainfall, and runoff.

Furthermore, the one water supply work GW803422 located at the Cobar District Rugby Club and used by the club for irrigation of the playing field during drought has a total depth of 22 m (Table 4.5), which is well above the proposed Project mining area. Groundwater quality impacts of the Project will be negligible with groundwater flow being maintained towards the existing New Cobar open cut. Therefore, water quality changes in the aquifer are controlled, and the beneficial use category will not change as a result of the Project.

9.5 Cumulative impacts

The GIA has considered the potential cumulative impacts for all stages of the development. The surrounding operating mines nearby are the Peak Complex located around 10 km to the south (incorporated into the Project's numerical model) and CSA mine, located around 20 km to the north. The predicted drawdown from this Project has been assessed and is shown to be localised, extending around two km from the active mining area. The location of the receptors in the vicinity of the mine and the distance to the other mining operations results in no cumulative impacts on sensitive receptors.

9.6 Mine recovery

i Groundwater level changes

In Section 8.7.3, groundwater contours at the end of mining, 100 and 1000 years post mining indicated that residual drawdown would exist at the Great Cobar underground mine voids for a period of time, but longer term, the New Cobar open cut will remain a sink within the groundwater system. Figure 9.6 further explores the long-term recovery of groundwater levels by plotting the modelled groundwater levels at the Project area monitoring bores. Groundwater levels slowly recover over time and become mostly stable within about 270 years post mining cessation.

Figure 9.7 shows the modelled two metre drawdown contour post mining cessation at several times between end of mining and up to 1000 years post mining. Due to the low transmissivity, low storage and low recharge environment, residual drawdown persists > 100 years post mining. By 1000 years post mining, there is no residual two metre drawdown that exists between the Great Cobar mining scenario and the null-case scenario.

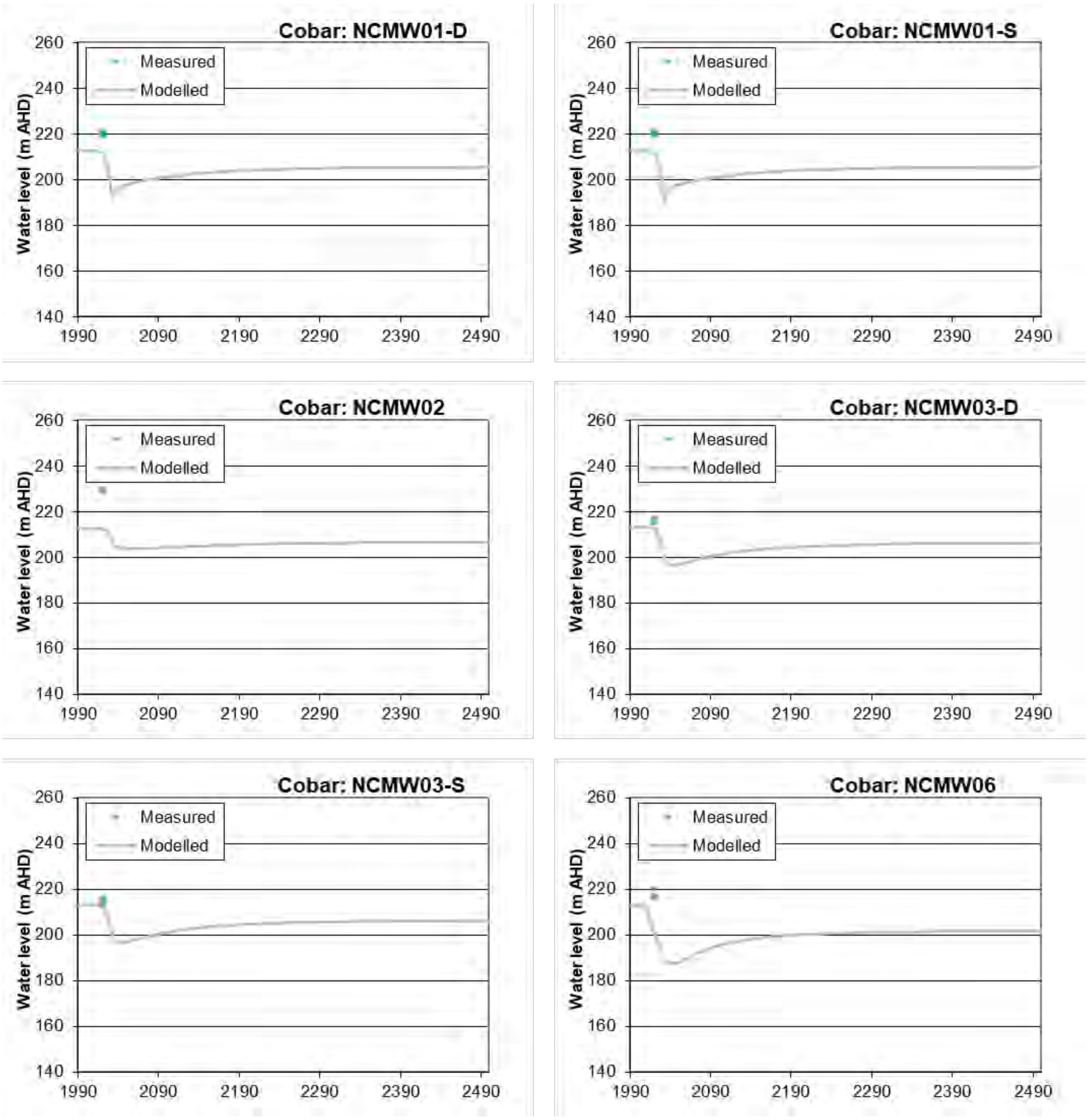
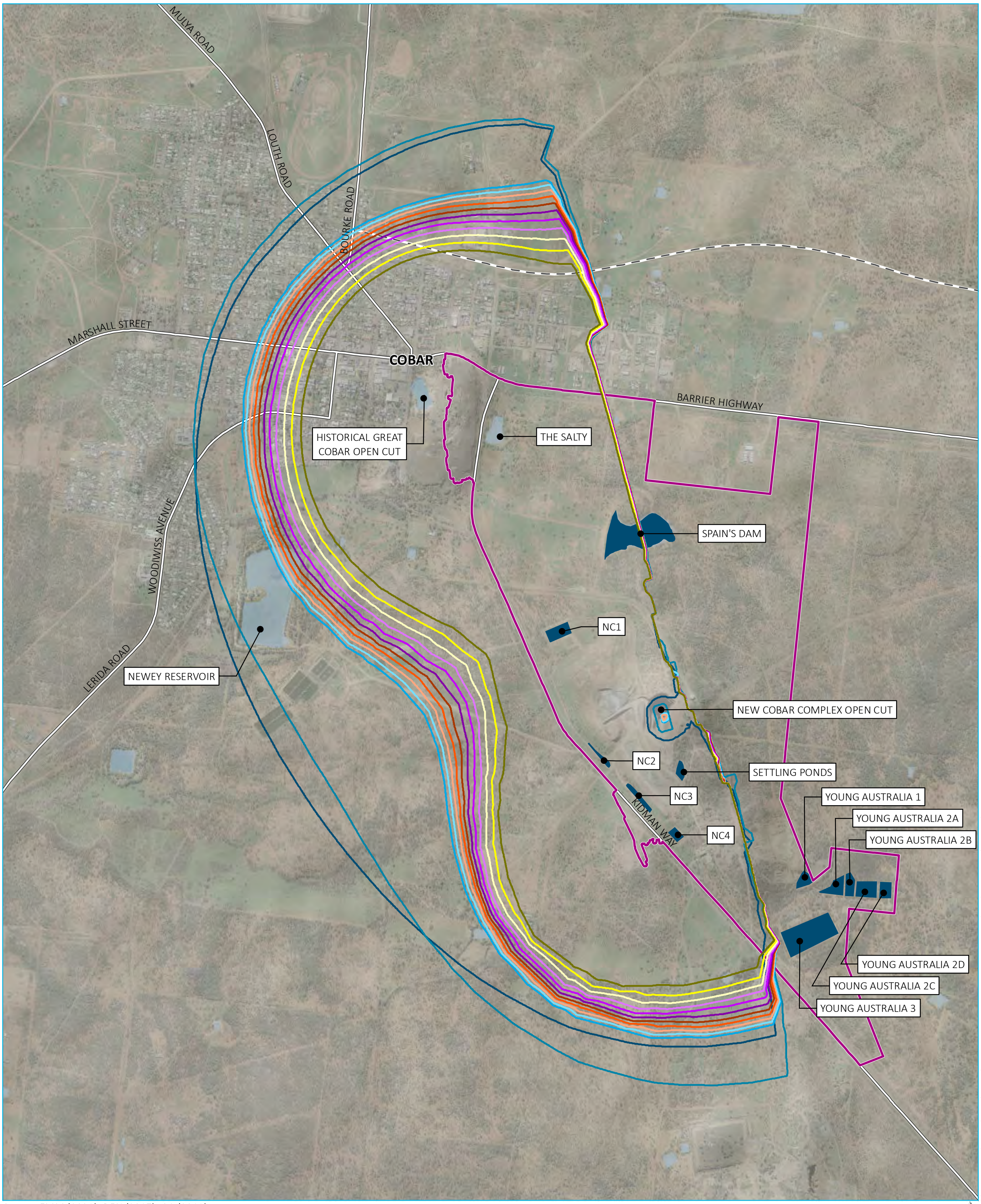


Figure 9.6 Modelled groundwater level recovery at Project area monitoring bores



Source: EMM (2021); DFSI (2017); GA (2011)

KEY

- Project area

Modelled 2 m watertable drawdown contour

- End of mining
- Recovery year 1
- Recovery year 2
- Recovery year 3
- Recovery year 4
- Recovery year 5
- Recovery year 6
- Recovery year 7
- Recovery year 8
- Recovery year 9
- Recovery year 10
- Recovery year 50
- Recovery year 100
- Rail line
- Major road
- Mine water management storage
- Waterbody

Modelled 2 m drawdown extent following cessation of mining

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Groundwater assessment
Figure 9.7

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ii Water balance

The modelled water balance for the duration of the predictive model including 1,000 years post-mining is shown in Figure 9.8. Drain fluxes representing mine dewatering quickly drop to zero, and storage fluxes recover more gradually.

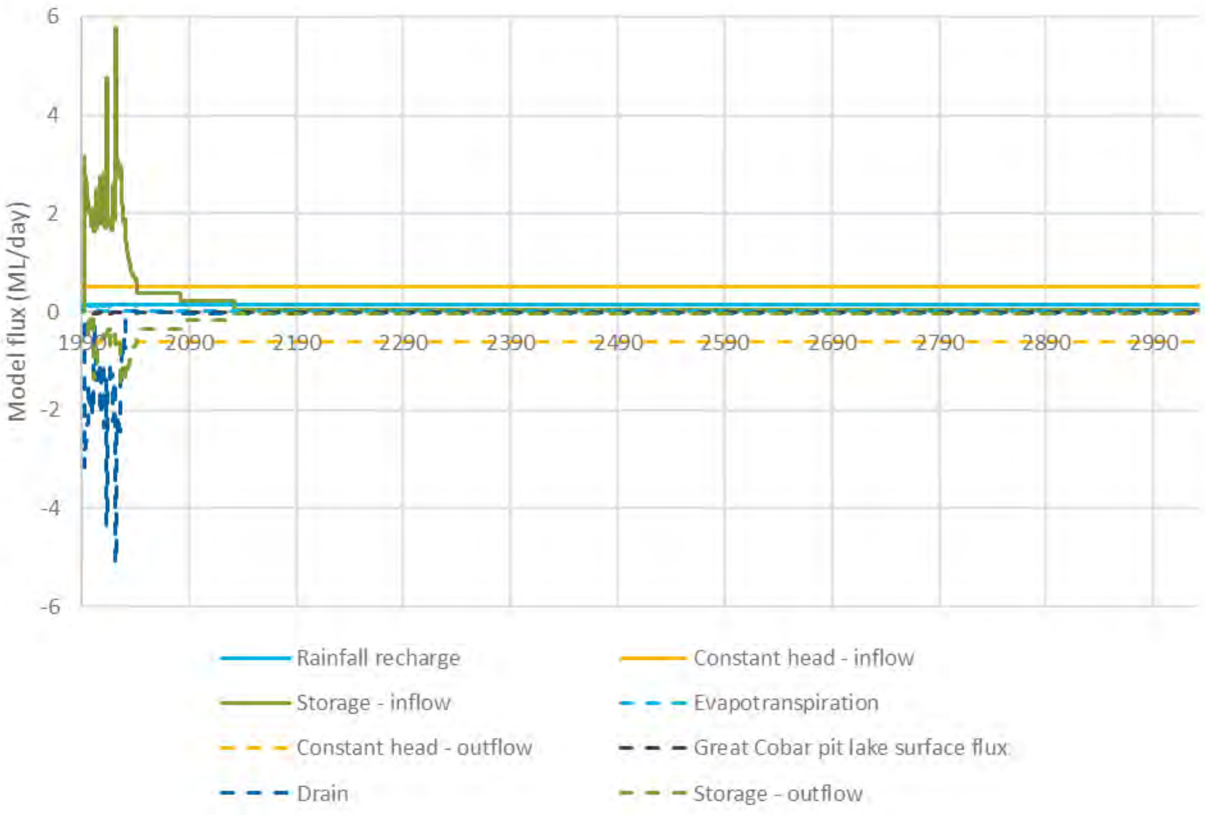

Figure 9.8 Prediction and recovery period model water balance

The modelled water balance 100 years following the end of mining is presented in Table 9.6. Compared to the water balance at the end of mining (Table 8.9), the most significant change is in storage flux. There is a total modelled storage inflow of 0.21 ML/d, and outflow of 0.18 ML/d. By this time constant head boundary flow has become the largest flux in the model, as with the water balance prior to mining (Table 8.4). There is still a small flux out of the model via drain cells; this represents surface expression of groundwater (and subsequent loss to evaporation which is simulated using the drain boundary condition) at the New Cobar Complex open cut. Drain cells were held active over this footprint to simulate long-term evaporation flux following recovery of the water table. The modelled water balance also shows a zero-mass balance discrepancy.

Table 9.6 Modelled water balance at 1/01/2132

Model flux	Inflow (ML/d)	Outflow (ML/d)
Constant head boundary	0.51	0.62
Rainfall recharge	0.14	--
Great Cobar pit lake surface	--	0.02

Table 9.6 Modelled water balance at 1/01/2132

Model flux	Inflow (ML/d)	Outflow (ML/d)
Evapotranspiration	--	0.00
Mine dewatering drains	--	0.03
Storage	0.21	0.18
Total IN	**0.86**	
Total OUT	**0.86**	
Percentage discrepancy	**0.00%**	

The modelled water balance 1,000 years following mining is presented in Table 9.7. A slight change is observed in constant head fluxes, likely caused by numerical drift instead of impacts reaching model boundaries. Storage fluxes continue to reduce, suggesting that the model approaches steady state, and the surface expression at the New Cobar open cut has increased. The relatively low flux would likely be evaporated rather than forming a pit lake. As with Table 9.6, the mass balance discrepancy is 0.00%, supporting that the modelling solution is stable.

Table 9.7 Modelled water balance at 1/01/3032

Model flux	Inflow (ML/d)	Outflow (ML/d)
Constant head boundary	0.52	0.61
Rainfall recharge	0.14	--
Great Cobar pit lake surface	--	0.02
Evapotranspiration	--	0.00
Mine dewatering drains	--	0.05
Storage	0.05	0.03
Total IN	**0.71**	
Total OUT	**0.71**	
Percentage discrepancy	**0.00%**	

9.7 Residual impacts

This section describes the residual impacts and summarises the residual risks to the groundwater environment.

The effect assessment presented in Chapter 7, i.e. prior to implementation of the management measures, identified water affecting activities with the potential for both direct and indirect impacts to the groundwater environment. For each water affecting activity, Table 9.8 (direct) and Table 9.9 (indirect):

- Identifies the water affecting activity and potential risk/effect;
- lists the existing and proposed mitigation controls and actions; and
- provides an assessment of the residual risk.

Table 9.8 Direct groundwater-affecting activities risk assessment

Direct effect	Water affecting activity	Potential risk/effect	Mitigation actions/controls (existing and proposed)	Residual risk
Quantity	• mine dewatering	• water table drawdown, aquifer depressurisation. • drawdown in landholder bores is significantly larger than predicted.	• groundwater level change will continue to be monitored by the Project area monitoring network. • WMP and TARP are implemented. • make good arrangements will be implemented to replace water supply work (GW803422), if required. Make good arrangements may include measures such as: – provision of supplementary water to offset loss in water supply; – provision of a new submersible pump to sustain a lost yield; – lowering pumping infrastructure within the bore to increase available drawdown; or – drilling a new bore for the landowner.	• **Medium** – some drawdown is likely to occur
	• groundwater supply development (mine inflows used as major water supply for the Project)	• insufficient water supply source for Project.	• metering and monitoring will be in place to record the volume of water removed from the underground mine. • use of mine inflow water as a priority over external water supply. • Great Cobar underground has approximately 4 years of supply volume (1,600 ML) available for use as water security. This assumes a constant pumping rate of ~13 L/s, 24 hours a day, and assumes no other water is harvested from surface water sources.	• **Low** – secondary storage in Great Cobar underground and mine inflow is available should Macquarie and Cudgegong Regulated Rivers Source be unavailable
	• stockpiling	• altered recharge.	• soil stockpiles will continue to be placed in bunded areas.	• **Low** – minimal changes to existing recharge pathways
	• backfilling	• altered hydraulic properties.	• backfill of worked stopes will be predominantly undertaken with crushed waste rock. cement aggregate fill (CAF) is proposed in some of the less deep steps in the weathered rock zone.	• **Low** – no change in the regional flow dynamics

Table 9.8 Direct groundwater-affecting activities risk assessment

Direct effect	Water affecting activity	Potential risk/effect	Mitigation actions/controls (existing and proposed)	Residual risk
			• worked areas will have a higher storage and hydraulic conductivity than the surrounding rock matrix.	
	• wastewater ponds and water storage	• perched water table, seepage, water table mounding, overtopping of dams.	• sediment is regularly removed from water ponds. • maximise the reuse of water from onsite storages - stored water is preferentially and regularly used onsite and water storage levels maintained to prevent overtopping.	• **Low** – ongoing maintenance is used to maintain water ponds
Quality	• mine dewatering	• mobilisation of salts and heavy metals.	• mine operations will remove groundwater for safe working conditions. • groundwater quality change will continue to be monitored by Project area monitoring network. • WMP and TARP are implemented. • make good arrangements will be implemented to replace water supply work (GW803422), if required.	• **Low** – existing groundwater is saline and of poor quality
	• stockpiling	• AMD, leaching of solutes.	• PAF material is preferentially used as stope backfill underground and is not brought to the surface. • if it is unavoidable to bring material to the surface, PAF will be stored in the WRD.	• **Low** – no change to existing waste rock management.
	• backfilling	• introducing solutes.	• backfill of worked stopes will be predominantly undertaken with crushed waste rock. Cemented aggregate fill is proposed in some shallower steps in the weathered rock zone. • New Cobar open cut will be retained post mining (unfilled) and therefore will act as a terminal groundwater sink directing groundwater flow (and any potential solutes) towards it until a new equilibrium is reached.	• **Low** – backfilled areas are well below the level of the existing groundwater user extraction level
	• wastewater ponds and water storage	• leaching of solutes	• Sediment is regularly removed from water ponds.	• **Low** – ongoing maintenance is used to maintain water ponds

Table 9.8 Direct groundwater-affecting activities risk assessment

Direct effect	Water affecting activity	Potential risk/effect	Mitigation actions/controls (existing and proposed)	Residual risk
			• stored water is regularly used onsite and water storage levels maintained to prevent overtopping.	
	• built infrastructure (roads, buildings, plant)	• solutes in runoff.	• the mine development will include runoff containment systems and other features to restrict surface water runoff within the Project disturbance area. Drainage will continue to report to water management dams and reused in process water within a contained system. •	• **Low** – runoff and drainage management plan in place
	• hazardous goods storage (containment failure)	• solutes in runoff, short-term release of contaminants.	• existing dedicated and bunded storage areas for fuel and reagents, and runoff containment systems for ore stockpiles will be maintained over the operational period while potential pollutants remain on site.	• **Low** – dedicated bunded and managed area
Aquifer interception	• excavation/mining	• removal of part or whole of aquifer.	• groundwater inflows into underground workings will occur and be managed as part of the mine water management system.	• **Low –** 20 years of current operational experience
	• Great Cobar development intercepting old underground workings	• in-rush of water from Great Cobar pit, safety concerns for employees working underground.	• mine operations plan and safety plans will continue to be implemented to maintain safe working conditions.	• **Low** – historic mining areas are well known
	• Great Cobar development causing increased leakage from Great Cobar historical underground workings and shaft	• reduction in water security.	• licenced raw water may be sourced from the Macquarie and Cudgegong Regulated Rivers Source in the event of mine inflows and shaft pumping not meeting Project area water requirements. • Great Cobar levels will be monitored, and water balance updated as required.	• **Low** – water balance is updated regularly. Bore field developed if required

Table 9.9 Indirect groundwater effects

Indirect effect	Impacted environmental value	Potential risk/effect	Mitigation actions/controls	Residual risk
Quantity	• aquatic ecosystems	• GDE mapping provided in the Groundwater WSP details no high priority GDEs located within 5 kms of the New Cobar Complex. High potential aquatic GDEs were mapped in the vicinity of the town in the BoM GDE Atlas, including associated with the slag dump at the Great Cobar open cut and at the Newey Reservoir to the immediate west of the New Cobar Complex. Possible effect (although unlikely due to disconnect from deeper aquifer systems being targeted for dewatering) where baseflow is altered within the potential zone of drawdown impact.	• none – impact assessment identified areas as being outside of the drawdown area and modelled groundwater depths indicate that mapped ecosystems are unlikely to be groundwater-dependent.	• **Low** – outside area of drawdown and deep modelled groundwater elevations
	• terrestrial ecosystems (with potential groundwater dependency)	• possible riparian vegetation associated with drainage lines to the north, east and south of the New Cobar Complex. Over 2 km away and will only be impacted if large impacts occur within the shallower groundwater system.	• none –, an analysis of the distribution of PCTs in relation to the simulated regional groundwater levels identified that none of the PCTs mapped are associated with shallow groundwater systems, indicating that none of the vegetation within the groundwater drawdown area is considered groundwater dependent.	• **None**.

Table 9.9 Indirect groundwater effects

Indirect effect	Impacted environmental value	Potential risk/effect	Mitigation actions/controls	Residual risk
	• recreational water supply (rugby club irrigation bore)	• potential failure of irrigation bore if drawdown exceed aquifer thickness or screen sections.	• groundwater level change will continue to be monitored by the Project area monitoring network. • WMP and TARP are implemented. • make good arrangements will be implemented to replace water supply work (GW803422), if required. Make good arrangements may include measures such as: – provision of supplementary water to offset loss in water supply; – provision of a new submersible pump to sustain a lost yield; – lowering pumping infrastructure within the bore to increase available drawdown; or – drilling a new bore for the landowner.	• **Medium** – some drawdown at the bore is likely to occur.
	• historical Great Cobar Pit / old workings	• currently, there is water in the historic Great Cobar open cut void (located on PGM owned land). The area may receive inflow from surface water. The water within the adjacent historical workings is also currently licensed to PGM for operations via an existing shaft. Underground mining could reduce water availability from the void if connected to groundwater.	• licenced raw water may be sourced from the Macquarie and Cudgegong Regulated Rivers Source in the event of mine inflows and shaft pumping not meeting Project area water requirements. • Great Cobar levels will be monitored, and water balance updated as required.	• **Low** – water balance is updated regularly. Bore field developed if required.

Table 9.9 Indirect groundwater effects

Indirect effect	Impacted environmental value	Potential risk/effect	Mitigation actions/controls	Residual risk
Quality	• aquatic ecosystems	• GDE mapping provided in the Groundwater WSP details no high priority GDEs located within 5 km of the New Cobar Complex. High potential aquatic GDEs were mapped in the vicinity of the town in the BoM GDE Atlas, including associated with the slag dump at the Great Cobar open cut and at the Newey Reservoir to the immediate west of the New Cobar Complex. Possible effect (although unlikely due to disconnect from deeper aquifer systems being targeted for dewatering) where baseflow is altered within the potential zone of drawdown impact.	• none – impact assessment identified areas as being outside of the drawdown area and modelled groundwater depths indicate that mapped ecosystems are unlikely to be groundwater-dependent.	• **Low** – outside area of drawdown and deep modelled groundwater elevations
	• terrestrial ecosystems (with potential groundwater dependency)	• possible riparian vegetation associated with drainage lines to the north, east and south of the New Cobar Complex. Effect unlikely due to distance from Project and disconnection from deeper aquifer systems being targeted for dewatering.	• none – an analysis of the distribution of PCTs in relation to the simulated regional groundwater levels identified that none of the PCTs mapped are associated with shallow groundwater systems, indicating that none of the vegetation within the groundwater drawdown area is considered groundwater dependent.	• **None**.

Table 9.9 Indirect groundwater effects

Indirect effect	Impacted environmental value	Potential risk/effect	Mitigation actions/controls	Residual risk
	• recreational water supply (rugby club irrigation bore)	• effect unlikely due to possible disconnect between deeper system and shallow weathered regolith.	• groundwater level change will continue to be monitored by the Project area monitoring network. • WMP and TARP are implemented. • make good arrangements will be implemented to replace water supply work (GW803422), if required. Make good arrangements may include measures such as: – provision of supplementary water to offset loss in water supply; – provision of a new submersible pump to sustain a lost yield; – lowering pumping infrastructure within the bore to increase available drawdown; or – drilling a new bore for the landowner.	• **Low** – Project unlikely to change shallow groundwater quality
	• historical Great Cobar Pit/old workings	• dewatering of new underground declines and stopes may induce local depressurisation/ drawdown cones that could promote the movement of poor-quality groundwater into the Great Cobar open cut and historical workings. However, the risk of water quality reducing below the limit of PGM's currently requirements for processing/mining is small.	• water treatment as required.	• **Low** – treat water if needed

Table 9.9 Indirect groundwater effects

Indirect effect	Impacted environmental value	Potential risk/effect	Mitigation actions/controls	Residual risk
Groundwater-surface water interaction	• aquatic ecosystems	• GDE mapping provided in the Groundwater WSP details no high priority GDEs located within 5 km of the New Cobar Complex. High potential aquatic GDEs were mapped in the vicinity of the town in the BoM GDE Atlas, including associated with the slag dump at the Great Cobar open cut and at the Newey Reservoir to the immediate west of the New Cobar Complex.	• none – impact assessment identified areas as being outside of the drawdown area and modelled groundwater depths indicate that mapped ecosystems are unlikely to be groundwater-dependent.	• **Low** – outside area of drawdown and deep modelled groundwater elevations
	• terrestrial ecosystems (with potential groundwater dependency)	• possible riparian vegetation associated with drainage lines to the north, east and south of the New Cobar Complex. Effect unlikely due to distance from Project and disconnection from deeper aquifer systems being targeted for dewatering.	• none – an analysis of the distribution of PCTs in relation to the simulated regional groundwater levels identified that none of the PCTs mapped are associated with shallow groundwater systems, indicating that none of the vegetation within the groundwater drawdown area is considered groundwater dependent.	• **None**.
Aquifer disruption	• historical Great Cobar Pit / old workings	• lowering of water level in Great Cobar open cut (located on PGM owned land).	• Great Cobar levels will be monitored.	• **Low** – Great Cobar pit not used by mine

10 Monitoring, mitigation, and management

10.1 Overview

An overview of the proposed monitoring, mitigation, and management measures to reduce the potential impact of the Project on sensitive receptors is presented. The planned water management strategy for the Project and specific measures to mitigate or manage identified potential impacts to sensitive receptors or potential risks to the Project are discussed.

10.2 Water management

10.2.1 Water management strategy

The overarching PGM water management strategy is to maintain a zero discharge Project area, and to maximise the capture and reuse of Project area rainfall runoff. This strategy assists in maintaining a consistent supply of water to the operation and reduces reliance on other external water sources.

The specific objectives of the Project area water management are as follows:

- minimise and or eliminate the volume of water discharged offsite;
- maximise the reuse of water from onsite storages;
- minimise the impact on the quality of surface water and groundwater receiving environments;
- minimise the impact on surface water and groundwater quantity; and
- maximise the containment of potentially contaminated Project area water while segregating water of differing types and quality.

The water management strategy is described further in the Project SWA (EMM 2020a).

10.2.2 Water Management Plan

A WMP has been developed and is in use for the PGM operations (EMM 2020b). The WMP covers existing operations at both the New Cobar and Peak Complexes. It was recently revised in May 2020 by EMM for PGM (EMM 2020b) and submitted to NRAR for comment. No comment has been received to date. The WMP documents the following:

- baseline data;
- objectives and performance criteria including trigger levels for investigating any potentially adverse impacts associated with water management;
- plans to respond to any exceedances of the performance criteria;
- details of the monitoring (including locations, frequency, and parameters), inspection and maintenance programs;

- details of meter type and locations to record groundwater extraction;
- water balance to confirm water take; and
- reporting procedures for the results of the monitoring program.

The WMP will be updated in consultation with DPIE Water, NRAR, and EPA and will incorporate any conditional approval requirements for this Project. The WMP will provide a program for reviewing and updating the numerical groundwater model as more data and information become available during the operation of the mine. The WMP will outline the reporting requirements against each of the Project approvals.

10.3 Monitoring

The groundwater monitoring network is discussed in Section 5.1. The groundwater monitoring network currently includes 23 monitoring locations across the New Cobar and Peak Complexes and one existing / third-party bore. Details of monitoring analysis and frequency are outlined in the WMP (EMM 2020b). Any potential development and expansion of the monitoring network will occur in consultation with NRAR and DPIE Water.

All water quality monitoring will be undertaken in accordance with the *Approved Methods for the Sampling and Analysis of Water Pollutant in NSW* (EPA 2004). The suite of water quality analytes (i.e. constituents) to be sampled and the frequency of sampling will be reviewed and updated in the existing PGM WMP.

The need for, and methodology of, ongoing water monitoring after mining has ceased will be confirmed during development of the detailed mine closure plan.

10.4 Groundwater model verification and review

Future improvements to the numerical groundwater flow model will be undertaken as and when new data become available, particularly where there is a divergence of observed groundwater system response from the predicted. Groundwater monitoring data (including groundwater abstraction (sump pumping rates) and groundwater level observations), will be used to verify and validate the groundwater model predictions, with updated predictions re-forecasted if required.

New data may prompt a revision and update of the conceptual hydrogeological model prior to updating and recalibrating the numerical model and re-running of predictive scenarios. This will be important in the early stages of mining the new deposits (first 2–3 years) to guide mine water management requirements, review predicted impacts and guide water licensing requirements.

As mining progresses, a need for further model updates will be assessed every two years based on evaluation of groundwater monitoring data and findings of impact verification. It is expected the confidence level of model predictions (Barnett, et al. 2012) will increase over time as the model is updated to reflect the observed effects on groundwater obtained from the monitoring program.

11 Groundwater licensing

11.1 NSW Water legislation and policies for licensing water

Mining projects are required to licence water that is either taken or intercepted in accordance with the WMA 2000, the AIP and the relevant statutory WSPs. PGM are required to hold WALs in each affected water source to account for all water extracted and intercepted. In accordance with the AIP, the Project is required to licence both the direct and indirect groundwater take from adjacent and overlying water sources. For this Project, the volume of water to be licensed has been determined to be the groundwater inflow to the underground mine that is physically handled by the mine water management system.

The results from the groundwater model (Section 8.7) have been used to estimate the required groundwater licence entitlements for the Project, based on the predicted total groundwater inflow rates to the operational mining areas.

11.2 Predicted take from the Lachlan Fold Belt MDB Groundwater Source

The Project will have a direct take of water from the Lachlan Fold Belt MDB Groundwater Source comprising groundwater inflow to the underground mine. The predicted mine inflow rates are detailed in Section 8.7.1 and have been modelled conservatively in relation to the base case scenario. The rates are summarised below:

- the predicted mine inflow rate in 2020 ranged between 365 ML/yr and 679 ML/yr, compared to an average measured inflow of 252 ML/yr;
- the peak predicted inflow rate in 2026 is 854 ML/yr;
- the inflow rate at the end of mining is predicted to be 11 ML/yr; and
- the Great Cobar mined stopes are predicted to become a throughflow system within 10 years following mine closure.

A chart of the total predicted groundwater take over time is shown on Figure 11.1, which shows that the base case model does not exceed the PGM's current water access license limit of 880 unit shares (880 ML/yr or 2,410 kL/d). In addition to the modelled base case scenario, the maximum (High inflow) and minimum (Low inflow) scenarios are also shown based on the predictive uncertainty analysis. The High inflow scenario shows increases above the WAL for short periods of time. However, given the modelled stress periods are based on yearly mine stresses, the modelled inflows by design are conservative (i.e. the modelled flows for the 'High inflow' case are nearly doubled compared to the measured flows during 2019-2020), and only two scenarios tested from the suite of scenarios indicated short periods of mine inflows in excess of the WAL, it is considered unlikely that mine inflows will exceed the water access license limit of 880 unit shares. Ongoing mine inflows will be monitored and compared to the modelled results for validation. If the observed trends start to increase at a greater rate than the modelled results indicate, model recalibration and updated forecasts may be required.

Since the Lachlan Fold Belt MDB Groundwater Source is present at surface and there are no other groundwater sources in the area, no indirect take will occur.

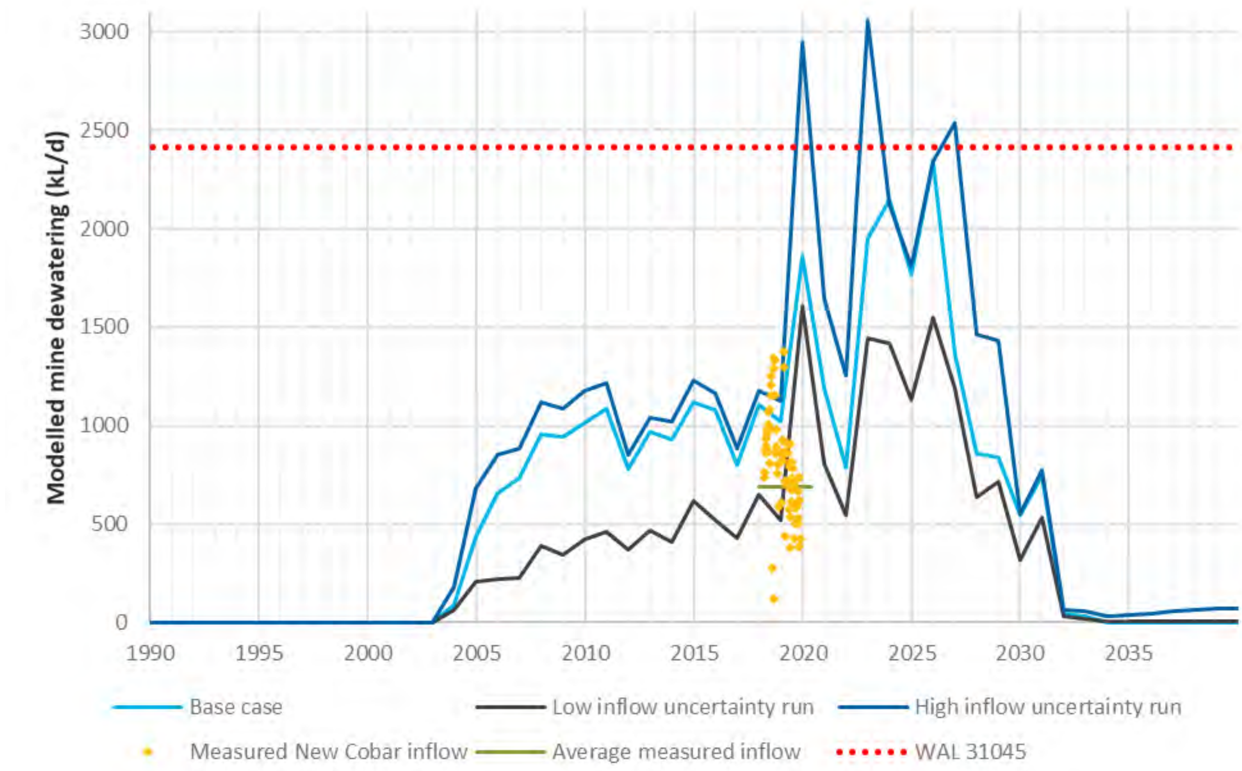

Figure 11.1 Predicted groundwater take (direct) over time

11.2.1 Predictive uncertainty regarding mine inflows and water management

Groundwater model history matching (Section 8.4) was undertaken by comparing model results against three physical measurements:

- regional groundwater elevation;
- changes to groundwater elevation following mining; and
- rate of groundwater extraction during mining.

Hydraulic parameters in the groundwater model were varied within the bounds of the conceptual hydrogeological model (Section 6) to provide the best match to each of the above measurements. As the model has been designed to assess regional environmental impacts, the greatest effort was spent in matching temporal groundwater trends. Pre-impact groundwater levels and mine inflows were considered important to match for groundwater model accuracy, but with a greater allowance for error to avoid worsening the match to temporal groundwater trends. As shown in Figure 11.1, the parameters adopted for the base case groundwater model are conservative with regards to mine inflows; the model tends to over-estimate inflows fairly consistently. The best match to mine inflow is actually simulated with the 'low inflow' run from the predictive uncertainty analysis (Section 8.7.4).

The low inflow groundwater model corresponds to uncertainty run 2 (from Table 8.10), with vertical hydraulic conductivity 6.67% to 10% of the adopted values in the base case model for weathered and primary fractured rock, respectively. As identified in the history match sensitivity analysis (Figure 8.9), these parameter values return a poor match against measured groundwater levels; SRMS of 24.0% against the base case model SRMS of 18.6%. Accordingly, the base case model is considered most appropriate for estimating environmental impacts, but the low inflow model is more appropriate for estimating operational groundwater inflows to mine workings. EMM suggest that the low inflow model results can be used in the interest of Project area water balance modelling.

11.2.2 Required groundwater licence entitlements

PGM currently holds WAL 31045 for 880 unit shares from the Lachlan Fold Belt MDB Groundwater Source. The WALs and associated work approvals are summarised in Table 3.1.

If it is considered necessary for PGM to purchase additional water shares for the Project, there are sufficient licence entitlements available in the Lachlan Fold Belt MDB Groundwater Source for this take. The mechanisms available for PGM to purchase these licence entitlements are:

- purchase of unassigned water during a controlled allocation order, which occur approximately every 18 months; or
- trading of existing water allocations (water allocation assignment or share assignment).

Based on the results of the numerical groundwater model, the maximum volume required for licensing in the Lachlan Fold Belt MDB Groundwater Source is conservatively estimated to be 854 ML/yr in 2026 as suggested by the base case scenario A more likely peak flow is likely to be closer to the “low inflow” scenario with a rate of 548 ML/yr as discussed in 11.2.1 above. The underground void is predicted to act as a groundwater sink following completion of mining until equilibrium conditions are reached. As such groundwater inflows to the void will continue after mining and will eventually become a throughflow system, with the New Cobar open cut becoming the long-term sink feature within the groundwater system.

12 Conclusions

A numerical groundwater model has been built using all available data to simulate historical and predicted groundwater effects associated with the expansion of the New Cobar Complex.

The Project has the potential to impact on local and regional groundwater sources and sensitive receptors. Potential impacts have been assessed in accordance with the AIP and Project related SEARs and include:

- drawdown of greater than 2 m is expected at bore GW803422, the only water supply works identified within 5 km of the New Cobar Complex. Under the AIP, make good arrangements will be put in place in consultation with the water supply work owner.

- there are no designated high priority GDEs located within five kilometres of the New Cobar Complex. Therefore, the AIP minimal impact consideration is not applicable.

- the high potential GDE mapped by the BoM GDE Atlas at Newey reservoir is a surface water dependent system. It receives stormwater runoff in the reservoir and is not connected to the regional groundwater system. Other potential GDEs are anthropogenic features including farm dams and the historical slag dump. Modelled depth to groundwater levels indicate that these GDEs are unlikely to be groundwater dependant.

- identified medium potential terrestrial GDEs are outside the area of expected drawdown of the Project and therefore will not to be impacted by the Project.

- the existing New Cobar Complex open cut will act as a regional groundwater terminal sink post mining, maintaining groundwater flow towards it. Any change in groundwater quality will be localised, therefore the beneficial use category of the aquifer will not change because of the Project. The groundwater quality impacts of the Project are consequently anticipated to be negligible.

- the residual impacts, following management measure implementation are generally low and will be managed by updates to the existing WMP and the TARP to ensure any impacts are identified and managed accordingly.

Monitoring of the PGM groundwater network will continue, and the network has been expanded to target the identification of potential impacts from mining activities. Monitoring each component of the water management system underpins if, how, and when management responses are required. Triggers and thresholds will be reviewed and updated to provide context on if, how, and when management measures are required as part of the revised WMP.

The numerical groundwater model has also been used to assess water license requirements in accordance with the WMA 2000, the AIP and the relevant statutory WSPs. The peak predicted inflow rate has been modelled at 854 ML/yr in 2026, which is below PGM's current allocation of 880 unit shares. Predictive uncertainty analysis has identified that although there may exist short periods where the allocation may be exceeded, the probability remains low.

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Acronyms and abbreviations

Term	Description
3D	Three dimensional
AHD	Australian Height Datum
AIP	Aquifer Interference Policy
Aurelia	Aurelia Metals Limited
bgl	Below ground level
b_{nf}	AQUIFER THICKNESS
BoM	Bureau of Meteorology
CAF	Cemented aggregate fill
CDFM	Cumulative deviation from mean
CHBs	Constant head boundary conditions
Cl	Chlorine
CML	Consolidated mining lease
CSC	Cobar Shire Council
Dem	Digital Elevation Model
DPIE	Department of Planning, Industry and Environment
EC	Electrical conductivity
EIS	Environmental impact statement
EMM	EMM Consulting Pty Limited
EPA	Environment Protection Authority (NSW)
EPL	Environment protection licence
ETL	Electricity transmission line
FTE	Full time equivalent
GCS	Great Cobar Slate
GDEs	Groundwater dependent ecosystems
GDE Atlas	BoM Groundwater Dependent Ecosystems Atlas
GMP	Groundwater Management Plan
Groundwater WSP	*Water Sharing Plan for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2020*
GUI	Graphical user interface
HEVAE	High Ecological Value Aquatic Ecosystems
HSUs	Hydrostratigraphic units
K	Hydraulic conductivity
K_{eff}	Effective hydraulic conductivity
K_f	Hydraulic conductivity estimated across the identified fractured zone derived from the slug test analysis

Term	Description
Kh	Horizontal hydraulic conductivity
kL/d	Kilolitres per day
km	Kilometres
kV	Kilovolt
L/s	Litres per second
m/d	Metres per day
MDB	Murray-Darling Basin
mg/L	Milligrams per litre
MGA	Map Grid of Australia
ML	Mining leases or megalitres
ML/year	Megalitres per year
mm	Millimetres
MOP	Mining Operation Plan
MPL	Mining purposes lease
µS/cm	Micro siemens per centimetre
Na	Sodium
NAF	Non-acid forming
NRAR	Natural Resources Access Regulator
NSW	New South Wales
NWC	National Water Commission
PAF	Potential acid forming
PCT	Plant Community Type
PGM	Peak Gold Mines Pty Ltd
POEO Act	*Protection of the Environment Operations Act 1997*
RoM	Run-of-Mine
SEARs	Secretary's Environmental Assessment Requirements
SILO	Scientific Information for Land Owners
Slug tests	Rising and falling head tests
SOI	Southern Oscillation Index
SRD SEPP	*State Environmental Planning Policy (State and Regional Development) 2011*
SRMS	Scaled root mean square
SSD	State significant development
Sy	Specific yield
TARP	Trigger Action Response Plan
the Project	New Cobar Complex Project
tpa	Tonnes per annum
TSF	Tailings storage facility

Term	Description
WAL	Water access licence
WMA 2000	*Water Management Act 2000*
WMP	Water Management Plan
WQO	Water quality objectives
WRD	Waste Rock Dump
WRE	waste rock emplacements
WSP	Water Sharing Plans