APPENDIX H
Groundwater impact assessment

Evolution MINING

EMM creating opportunities

Cowal Gold Operations – Open Pit Continuation Project

Groundwater Impact Assessment

Prepared for Evolution Mining

May 2023

Cowal Gold Operations – Open Pit Continuation Project

Groundwater Impact Assessment

Evolution Mining

J190417 RP1

May 2023

Version	Date	Prepared by	Approved by	Comments
1	27 March 2023	Nina Baulch Katharine Bond Henry Noakes James Tuff	Joel Georgiou Janet Krick	Draft
2	14 April 2023	Nina Baulch Katharine Bond	Janet Krick	Updated draft
3	28 April 2023	Nina Baulch Katharine Bond	Joel Georgiou Janet Krick	Updated draft for adequacy review
4	29 May 2023	Nina Baulch Katharine Bond	Joel Georgiou	Final for EIS exhibition

Approved by

Joel Georgiou
Associate Director
29 May 2023

Ground floor 20 Chandos Street
St Leonards NSW 2065
PO Box 21
St Leonards NSW 1590

This report has been prepared in accordance with the brief provided by Evolution Mining and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of Evolution Mining and no responsibility will be taken for its use by other parties. Evolution Mining may, at its discretion, use the report to inform regulators and the public.

© Reproduction of this report for educational or other non-commercial purposes is authorised without prior written permission from EMM provided the source is fully acknowledged. Reproduction of this report for resale or other commercial purposes is prohibited without EMM's prior written permission.

Executive Summary

Evolution Mining (Cowal) Pty Limited (Evolution) is proposing to extend open pit mining operations at its existing Cowal Gold Operations (CGO) open pit and underground gold mine through the Open Pit Continuation Project (the Project). The Project is located approximately 38 kilometres (km) north-east of West Wyalong, in the central west region of New South Wales (NSW).

The Project is classified as State Significant Development (SSD) and approval is required under Part 5, Division 5.2, of the *Environmental Planning and Assessment Act 1979*. The SSD application for the Project is required to be accompanied by an environmental impact statement (EIS) that has been prepared to address Secretary's Environmental Assessment Requirements (SEARs) issued by the Department of Planning and Environment (DPE). This Groundwater Impact Assessment (GIA) has been prepared to support the EIS.

This GIA documents the existing hydrogeological environment, project specific groundwater investigative works, numerical groundwater flow modelling and groundwater impact assessment. The assessment has been prepared in accordance with relevant guidelines and policies including the *Aquifer Interference Policy* (AIP) (DPI Water 2012) and NSW Department of Planning and Environment *Groundwater Assessment Toolbox* (DPE 2022a).

ES1 Environmental setting

The Project is located in an area of generally flat land that is predominantly cleared for agriculture. It is immediately adjacent to the western foreshore of Lake Cowal, which forms a topographic low point. Lake Cowal is an ephemeral, fresh-water lake that is the major hydrological feature in the vicinity of the Project and covers an area of approximately 105 square kilometres. Lake Cowal is predominantly filled by inflow from Bland Creek to the south and when flooding by flood breakout from the Lachlan River to the north-east. When full, Lake Cowal flows to the north-west into Nerang Cowal.

The site overlies Cenozoic alluvium, with floodplain and lacustrine deposits underlying Lake Cowal and Nerang Cowal. The Project area is on the central western edge of a relatively deep (up to 120 metres (m) thick) palaeochannel, which includes the Quaternary Cowra formation and the underlying Neogenic Lachlan Formation. The Project borefield is in the approximate centre of the palaeochannel (targeting the deeper sediments). The basement rock consists of Lachlan Fold Belt (LFB) rock units formed in the Middle Paleozoic period.

The alluvial sequence within the palaeochannel area is split into three groundwater systems, generally based on varying hydrogeological properties. The alluvial groundwater systems include the:

- Upper Cowra groundwater system, an unconfined, phreatic groundwater system supporting the water table (where present). This system is classified as a less productive alluvial groundwater source due to its low yield and high salinity.
- Lower Cowra groundwater system, an unconfined/confined groundwater system underlying the Upper Cowra groundwater system. It is classified as a less productive alluvial groundwater source due to its high salinity.
- Lachlan groundwater system, a confined, highly productive groundwater system underlying the Lower Cowra groundwater system, which does not extend to the proposed mining areas. The Lachlan groundwater system is generally classified as a highly productive alluvial groundwater source due to its good yield.

A fractured rock groundwater system is supported within the laterally continuous LFB rock units. This system is generally confined under the alluvial sequence (where present) and unconfined to semi-confined across the remaining extent. The fractured rock groundwater system is generally classified as a less productive fractured rock groundwater source due to its salinity.

Recharge to the alluvial groundwater systems is primarily from surface water infiltration below the Lachlan River, irrigation channels, and intermittently from the Lachlan River floodway during flooding. Rainfall infiltration forms a relatively minor component of recharge to the alluvial groundwater systems. Discharge from the alluvial groundwater systems generally occurs via flow into the underlying fractured rock groundwater system and extraction by private water users. The fractured rock system is recharged via rainfall within areas of relatively high infiltration, generally located east of the study area, and discharge from overlying alluvial aquifers (where present).

ES2 Assessment approach

The assessment approach considers direct impacts, comprising changes to physical and/or quality aspects of groundwater due to water affecting activities, or the changes to the physical characteristics of aquifers affected by these activities. Indirect effects of water affecting activities are those that arise in response to direct effects (Moran C 2010). The potentially sensitive receptors that have been identified include:

- landholder bores used for irrigation, commercial and industrial, and stock and domestic purposes
- ecosystems that potentially rely on groundwater (terrestrial vegetation and aquatic ecosystems)
- surface water features, including Lake Cowal.

A site specific, numerical groundwater flow model was developed to assess indirect groundwater impacts. The model was built in the Groundwater Vistas 8 Pro graphical user interface and run using the MODFLOW-USGS Transport code. The current model conforms to the *Australian Groundwater Modelling Guidelines* criteria for Class 2 model classification with some elements of Class 3.

ES3 Potential groundwater impacts

The numerical groundwater flow model predicted the following:

- There are two separate drawdown zones associated with the mine and borefield pumping. Drawdown from mining will propagate outside the Mining Lease boundary. However, the difference in drawdown impacts between the approved CGO operations and the additional proposed mining activities are considered minor:
    - The continued operation of the CGO borefields in association with the Project does not result in groundwater level drawdown changes greater than 2 m from its current approved operation.
    - There is no material change in groundwater level drawdown at any landholder bore associated with the Project when it is considered on its own (i.e., incremental drawdown).
- Groundwater levels will remain above the investigation and mitigation trigger levels at the DPE Water bore GW036553 (located near the mine borefield). Water levels at this trigger bore govern the operation of the CGO borefields.
- Under the AIP-specific cumulative impact evaluation (i.e. incorporating the approved operations, the local private bore operations, the CGO borefields plus the Project), the maximum cumulative drawdown is predicted to exceed the AIP minimal impact considerations (2 m drawdown) at four bores.

- Two River Red Gum plant community types, assessed and confirmed as high priority groundwater-dependent ecosystems (GDEs), are predicted to experience greater than 0.5 m drawdown in groundwater level, representing the natural fluctuation in groundwater level.

- Field investigations and chemical analysis suggest that the lake is hydraulically separated from the groundwater system by a small unsaturated zone beneath the lake, and that a pathway does not exist between the mine site activities and the lake. Modelled seepage predictions from Lake Cowal are therefore conservative.

- Contaminant movement via seepage from the WREs and the TSF/IWL are likely to remain localised with potential impacts from acid and metalliferous drainage and/or saline drainage expected to be limited. Furthermore, there are no groundwater users predicted to be impacted. There is ongoing groundwater quality changes around the borefields, resulting from induced leakage from borefield pumping, however this is not predicted to change the groundwater quality beneficial use category (i.e. brackish and suitable for irrigation and industrial uses).

The residual risk assessment concluded that the overall project risk to groundwater quantity and quality is low to moderate.

ES4 Management and mitigation

A project-specific *Water Management Plan* (WMP) has been established and approved by the relevant agencies. This includes the groundwater monitoring program, reporting requirements, spill management and response, corrective actions and contingencies for management measures. The WMP will be reviewed and updated as necessary following Project approval in response to the outcomes of this assessment and any additional related approval requirements.

Ongoing management and mitigation measures include:

- Make good provisions if water supply at private bores is directly affected by the Project, consistent with the current development consent requirements.

- Adaptive management strategies will be implemented to monitor and respond (if required) to Project-related drawdown and uncertain impacts to potentially impacted River Red Gum populations.

- Continued groundwater level and quality monitoring. The monitoring network is established and relates to groundwater monitoring in aquifers beneath the ML area and regionally within the Bland Creek Palaeochannel aquifer.

- Continued review of groundwater levels at the trigger monitoring bores. Pumping from the Bland Creek Palaeochannel borefield will cease if required to meet the trigger levels in accordance with the Groundwater Contingency Strategy and alternate water supplies would be considered, including water internal and external to CGO.

- Continued model validation whereby the groundwater model predictions would be validated by comparison with actual groundwater level data and measured drawdown.

- Periodic model validation whereby the groundwater model predictions would be validated by comparison with actual groundwater level data, mine inflows and measured drawdown.

- Physical controls to manage slurry, constituents of concern and discharges including low permeability basal layers at storages, diversion of flows into water storages/open pits, bunding and sediment traps.

ES5 Licensing

The volume of groundwater required to be licensed for the Project is a total maximum of 2,018.5 ML/yr in the Upper Lachlan Alluvial Groundwater Source Management Zone 7 and 1,664 ML/year in the Lachlan Fold Belt Murray-Darling Basin (MDB) Groundwater Source. Evolution have a total of 4,016 and 3,294 unit shares available in the Upper Lachlan Alluvial Groundwater Source Management Zone 7 and Lachlan Fold MDB Groundwater Source respectively, which is sufficient to cover all groundwater take for the project.

TABLE OF CONTENTS

Executive Summary **ES.1**

1 Introduction **1**

1.1 Background 1

1.2 Project overview 1

1.3 Assessment requirements 2

1.4 Project terminology 7

1.5 Purpose of this report 7

1.6 Groundwater study area 8

2 Regulatory and policy context **10**

2.1 Legislation overview 10

2.2 Relevant NSW Policies 10

2.3 Relevant guidelines 14

3 Description of the environment **15**

3.1 Data availability 15

3.2 Topography and land use 16

3.3 Climate 18

3.4 Hydrological setting 18

3.5 Soils and geology 19

3.6 Hydrogeological setting 26

3.7 Geochemistry 40

3.8 Sensitive receivers 41

4 Site hydrogeological conceptual model **46**

4.1 Overview 46

4.2 Pre-existing conditions prior to mine operation 46

4.3 Conditions during existing mining (prior to the Project) 47

4.4 Hydrogeological conceptual model 51

5 Assessment approach **54**

5.1 Assessment criteria 54

5.2 Potential impacts 58

5.3 Groundwater modelling 61

6 Groundwater impact assessment **72**

6.1 Groundwater levels and drawdown 72

6.2 Groundwater inflow predictions 81
6.3 Groundwater quality predictions 81
6.4 AIP impact assessment 84
6.5 Bland Creek Palaeochannel Borefield trigger monitoring bores 89
6.6 Seepage assessment 91
7 Risk assessment 93
7.1 Risk assessment and management framework 93
7.2 Risk evaluation 94
8 Monitoring, mitigation and management 98
8.1 Groundwater management strategy 98
8.2 Groundwater licensing 100
8.3 Groundwater model verification and review 101
8.4 Residual risk assessment 101
9 Conclusions 104
References 106
Glossary 109

Attachments

Attachment A Regulatory overview
Attachment B Supporting assessment requirements
Attachment C Groundwater Model Report
Attachment D Groundwater model peer review
Attachment E Landholder bore details and monitoring overview
Attachment F AIP landholder bore drawdown plots and hydrographs
Attachment G Multi-variate chemistry assessment

Tables

Table 1.1 Groundwater technical assessment related SEARs 2
Table 1.2 Key Project terms – Project area and areas of disturbance 7
Table 2.1 Relevant legislation and regulations 10
Table 2.2 Summary of existing aquifer water access licences 11
Table 2.3 Summary of Upper Lachlan Alluvial Groundwater Source water requirements and entitlements 13
Table 2.4 Summary of Lachlan Fold Belt MDB Groundwater Source water requirements and entitlements 14
Table 2.5 Relevant guidelines 14
Table 3.1 Data sources for description of environment 15
Table 3.2 Land use categories 16

Table 3.3	Study area stratigraphy	23
Table 3.4	Summary of groundwater systems	27
Table 3.5	Indicative hydraulic properties of hydrogeological units within the study area	30
Table 3.6	DPI Water trigger bores	36
Table 3.7	Aquatic groundwater dependent ecosystems within study area	42
Table 3.8	Terrestrial groundwater dependent ecosystems within the study area	43
Table 5.1	AIP Minimal impact considerations	55
Table 5.2	Groundwater affecting activities, potential effects, impacts on receptors, and assessment methods	58
Table 5.3	Model layer design	64
Table 5.4	Model stress periods	65
Table 5.5	Key Project elements	67
Table 5.6	Combined numeric, narrative, and visual approach for assessing likelihood	70
Table 6.1	Cumulative Project impact – 2 m drawdown	77
Table 6.2	Incremental impact – 2 m drawdown	79
Table 6.3	Details of landholder bores – predicted cumulative drawdown exceeds AIP 2 m drawdown criteria	84
Table 7.1	Evolution risk assessment matrix	93
Table 7.2	Classification of likelihood	93
Table 7.3	Classification of consequence	94
Table 7.4	Assessment of unmitigated potential impacts or events	95
Table 8.1	Potential groundwater risks and management measures	98
Table 8.2	Groundwater licensing requirements summary for approved and proposed CGO operations	100
Table 8.3	Assessment of residual risk of potential impacts or events	102
Table E.1	Registered groundwater bores within the study area	
Table E.2	Groundwater level monitoring data summary	

Figures

Figure 1.1	Regional context	4
Figure 1.2	Local setting	5
Figure 1.3	Project overview	6
Figure 1.4	Groundwater study overview	9
Figure 2.1	Water sharing plans and water source areas	12
Figure 3.1	Topography and land use near the Project	17
Figure 3.2	SILO climate data at Burcher Post Office (station 50010)	18
Figure 3.3	Hydrological setting	20
Figure 3.4	Soil distribution	21

Figure 3.5	Surface geology	22
Figure 3.6	Lachlan Fold Belt geology	25
Figure 3.7	Estimated CGO borefield usage	28
Figure 3.8	Estimated historical use from irrigation bores	28
Figure 3.9	Summary of groundwater monitoring data since 1997	29
Figure 3.10	Groundwater level contours within the Upper Cowra formation	32
Figure 3.11	Groundwater level contours within the Lower Cowra formation	33
Figure 3.12	Groundwater level contours within the Lachlan formation	34
Figure 3.13	Groundwater level contours within the fractured and weathered rock groundwater systems	35
Figure 3.14	DPE Water monitoring bores in proximity to GDEs and trigger bore locations	37
Figure 3.15	Hydrograph, trigger monitoring bore GW036553	38
Figure 3.16	Hydrograph, trigger monitoring bore GW036597	38
Figure 3.17	Hydrograph, trigger monitoring bore GW036611	38
Figure 3.18	Groundwater elevation GW036563	39
Figure 3.19	Groundwater elevation GW036528	39
Figure 3.20	Groundwater elevation GW036551	39
Figure 3.21	Sensitive receivers – registered groundwater bores	44
Figure 3.22	Sensitive receivers – Groundwater dependent ecosystems	45
Figure 4.1	Depth to groundwater – prior to mining	49
Figure 4.2	Depth to groundwater – during mining (prior to the Project)	50
Figure 4.3	Conceptual hydrogeological section – east to west	52
Figure 4.4	Conceptual hydrogeological section – southwest to northeast	53
Figure 5.1	Model domain and grid	63
Figure 6.1a	Cumulative drawdown, Upper Cowra groundwater system (Layer 2), map 1 of 2	73
Figure 6.1b	Cumulative drawdown, Upper Cowra groundwater system (Layer 2), map 2 of 2	74
Figure 6.2a	Cumulative drawdown, top Lachlan Fold Belt (Layer 7), map 1 of 2	75
Figure 6.2b	Cumulative drawdown, top Lachlan Fold Belt (Layer 7), map 2 of 2	76
Figure 6.3	Cumulative drawdown, likelihood of exceedance for 2 m drawdown	78
Figure 6.4	Incremental drawdown, likelihood of exceedance for 2 m drawdown	80
Figure 6.5	Predicted groundwater inflows to pits and the underground mine (1998–2040)	81
Figure 6.6	Results of 200-year particle tracking modelling (Fast Recovery Case)	83
Figure 6.7	Landholder bores – predicted cumulative drawdown exceeds AIP 2 m drawdown criteria	86
Figure 6.8	Drawdown exceedance probability of 0.5 m and high priority listed GDEs	88
Figure 6.9	Modelled drawdown at trigger bore GW036553	89
Figure 6.10	Modelled drawdown at trigger bore GW036597	90
Figure 6.11	Modelled drawdown at trigger bore GW036611	90

Figure 6.12	Modelled induced seepage from Lake Cowal and the irrigation channels	91
Figure 6.13	Modelled seepage from the IWL	92
Figure A.1	AIP minimal impact considerations process (adapted from DPI Water 2012a)	
Figure A.2	Licensing requirements by source (surface water vs groundwater) (DPE Water 2022b)	
Figure A.3	Groundwater dependent ecosystem level of dependence on groundwater	

1 Introduction

1.1 Background

Evolution Mining (Cowal) Pty Limited (Evolution) is the owner and operator of Cowal Gold Operations (CGO), an existing open pit and underground gold mine approximately 38 kilometres (km) north-east of West Wyalong, in the central west region of New South Wales (NSW).

CGO is located on the traditional lands of the Wiradjuri People and is immediately adjacent to the western foreshore of Lake Cowal, which is an ephemeral waterbody. The existing CGO mine is shown at a regional scale and local scale in Figure 1.1 and Figure 1.2, respectively.

CGO was first approved in 1999, and open pit mining operations commenced in 2005. Underground mining operations were approved in 2021 and development works to enable underground mining are underway.

Evolution is seeking approval for further open pit mining operations at CGO through the Open Pit Continuation Project (the Project). The Project primarily seeks to continue the open pit operations by approximately 10 years to 2036 and extend the total mine life by approximately two years to 2042.

The Project is classified as State Significant Development (SSD) and approval is required under Part 5, Division 5.2, of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The SSD application for the Project is required to be accompanied by an environmental impact statement (EIS) that has been prepared to address Secretary's Environmental Assessment Requirements (SEARs) issued by the Department of Planning and Environment (DPE). This Groundwater Impact Assessment (GIA) has been prepared to support the EIS.

1.2 Project overview

The Project will involve further development of the existing E42 Pit and the development of open pit mining in three adjacent orebodies, known as the 'E46', 'GR' and 'E41' pits. It is noted that the three adjacent ore bodies are within the existing mining lease (ML 1535). No change to the approved ore processing rate of 9.8 Mt per annum (million tonnes per year) is proposed.

The Project comprises the following key components:

- The continued operation of activities as approved under DA14/98 and SSD 10367, including operation of the Bland Creek Palaeochannel (BCP) Borefield.
- Development of three new satellite open pits (the 'E46', 'GR' and 'E41' pits) to the north and south of the existing open pit, within the current approved mining lease.
- Extending the existing open pit to the east and south via a 'cutback' within the current approved mine lease.
- Extending open pit mining operations by approximately 10 years to 2036 and total mine life by approximately 2 years to 2042.
- Expansion of the integrated waste landform (IWL) to accommodate life of mine tailings.
- Extension of the lake protection bund (LPB) system to provide continued separation and mutual protection between Lake Cowal and the mine.
- Backfilling of one of the new open satellite pits (E46) with waste rock and establishment of a new waste rock emplacement (WRE) on the backfilled pit to minimise the additional area required for waste rock disposal.

- Expansion of the footprint of the existing WRE areas to accommodate additional waste rock.
- Development of additional topsoil and subsoil stockpiles to accommodate materials from pre-stripping, with materials to be reused during progressive mine rehabilitation.
- Upgrades to existing surface water drainage system, to assist with on-site water management and maximise on-site water conservation.
- Modification of internal site access and haul roads.
- Development of new water storages and relocation of some components of the surface water drainage system.
- Modification and relocation of some existing auxiliary mining infrastructure.

A conceptual Project layout is shown in Figure 1.3, while a detailed description of the Project is contained in Chapter 4 of EIS.

Other than the changes to existing approved activities as set out above, all activities that are currently approved under the existing Ministerial development consents are intended to continue. The existing activities approved under the consents are described in Chapter 3 of the EIS.

The Project will not change existing ore processing rates or methods, tailings disposal methods, main site access, water supply sources or hours of operation. The Project will also retain the existing open pit mining workforce.

1.3 Assessment requirements

1.3.1 Secretary's Environmental Assessment Requirements

This GIA has been prepared in accordance with requirements set out in the SEARs for the Project, the *Guidelines for Groundwater Documentation for SSD/SSI Projects – Technical guideline* (DPE 2022b) as well as other relevant governmental assessment requirements, guidelines and policies, and in consultation with the relevant government agencies.

The SEARs identify matters which must be addressed in the EIS and essentially form its terms of reference. Table 1.1 lists individual requirements relevant to this GIA and the section in this report where the requirements are addressed.

Table 1.1 Groundwater technical assessment related SEARs

Requirement	Section addressed
Water – including:	
• Description of all works/activities that may intercept, extract, use, divert or receive surface water and/or groundwater. This includes the description of any development, activities or structures that will intercept, interfere with or remove groundwater, both temporary and permanent.	Section 1.2 and Chapter 4 of the EIS
• Details of all water take for the life of the development. This is to include water taken directly and indirectly, and the relevant water source where water entitlements are required to account for the water take. If the water is to be taken from an alternative source confirmation should be provided by the supplier that the appropriate volumes can be obtained.	Section 8.2 and Appendix I of the EIS (Water Licensing Strategy).

Table 1.1 Groundwater technical assessment related SEARs

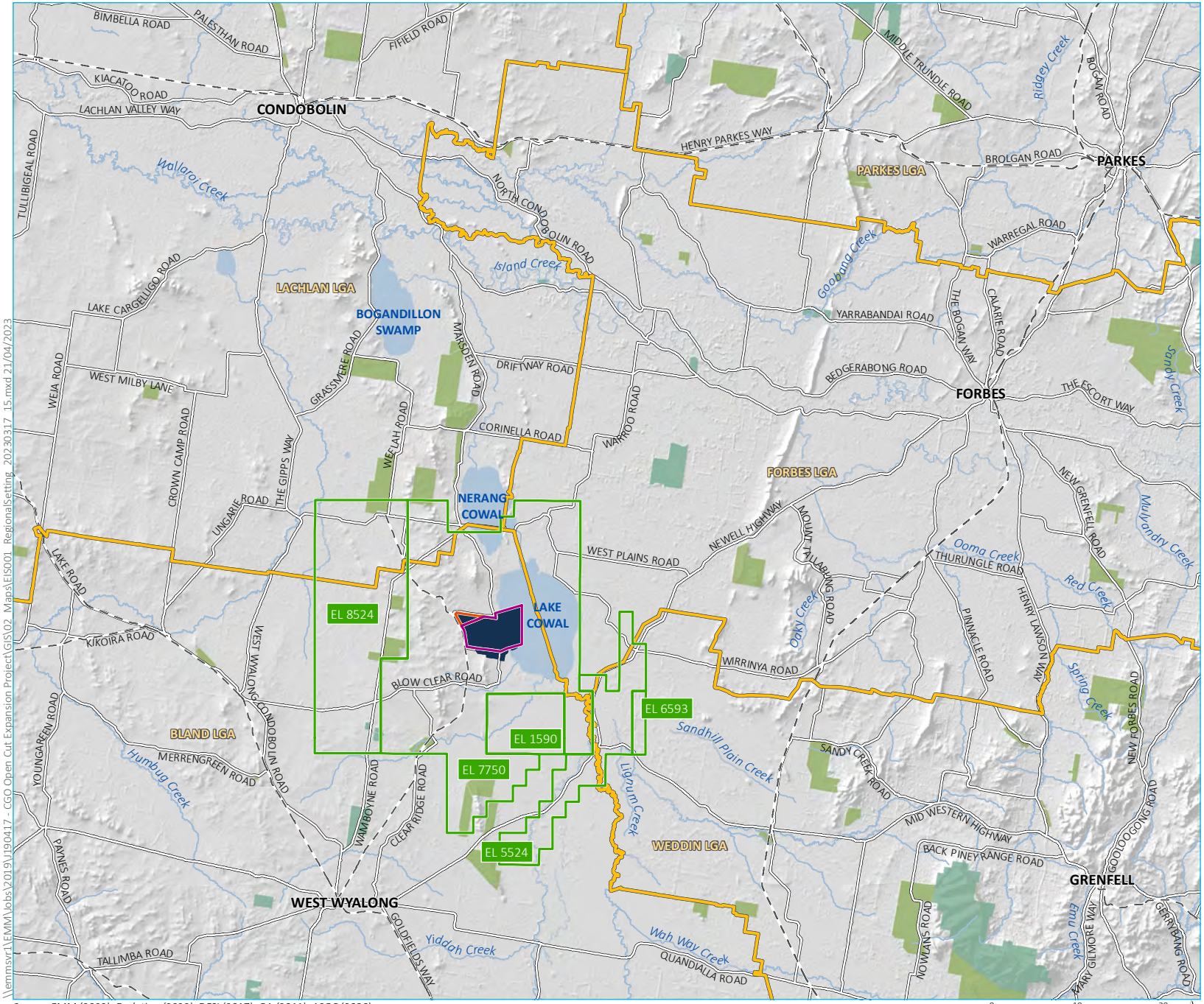
Requirement	Section addressed
• Details of Water Access Licences (WALs) held to account for any take of water where required, or demonstration that WALs can be obtained prior to take of water occurring. This should include an assessment of the current market depth where water entitlement is required to be purchased. Any exemptions or exclusions to requiring approvals or licenses under the *Water Management Act 2000* should be detailed.	Section 8.2 and Appendix I of the EIS (Water Licensing Strategy).
• An assessment of groundwater conditions that provides an understanding of groundwater level across the site under a range of wet and dry conditions.	Chapters 3 and 4
• 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, groundwater dependent ecosystems, and ground water levels; including measures proposed to reduce and mitigate these impacts, having regard to the Aquifer Interference Policy.	Chapter 6
• A detailed and consolidated site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply and transfer infrastructure and water storage structures, and measures to minimise water use.	Appendix G of the EIS (Surface Water Assessment)
• A description of the measures proposed, including monitoring activities and methodologies, to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo.	Chapter 8
• A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.	Chapter 8

1.3.2 Groundwater Assessment Toolbox for Major Projects in NSW

The NSW Department of Planning and Environment–Water *Groundwater Assessment Toolbox* (DPE 2022a) includes the *Guidelines for Groundwater Documentation for SSD/SSI projects* (DPE 2022b). The key requirements for the groundwater assessment for major projects are:

- Part A – Groundwater investigations
- Part B – Groundwater impact assessments
- Part C – Water management plans
- Part D – Water compliance reporting.

The key reporting requirements for Part B, groundwater impact assessments, are detailed in the Guideline Checklist (provided at Attachment B) and have informed this assessment report. Water management plans (Part C) and water compliance reporting (Part D) are post approval requirements and are not dealt with in this groundwater assessment.



KEY

- Project area
- Mining lease (ML1535)
- Mining lease (ML1791)
- Exploration licence (EL)
- Rail line
- Main road
- Named watercourse
- Named waterbody
- Local government area
- NPWS reserve
- State forest

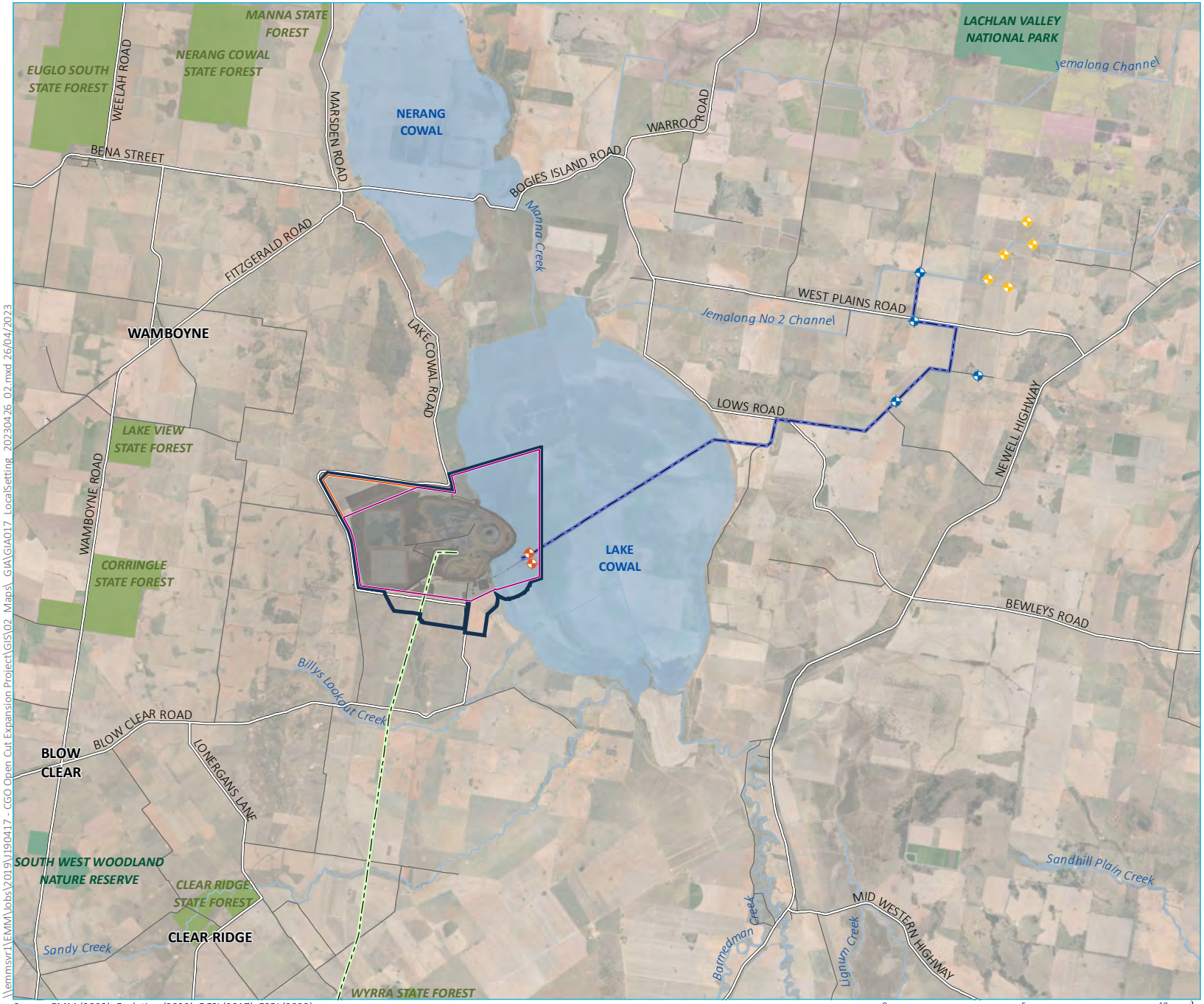
Source: EMM (2023); Evolution (2023); DFSI (2017); GA (2011); ASGC (2006)

\\emmsvr1\EMM\Jobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps\EIS001_RegionalSetting_20230317_15.mxd 21/04/2023

Regional context

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 1.1

EMM
creating opportunities



KEY

- Project area
- DA14/98 approved surface disturbance
- Mining lease (ML1535)
- Mining lease (ML1791)
- Water supply pipeline
- Electricity transmission line
- Major road
- Minor road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest

Pumping bores

- Bland Creek Palaeochannel Borefield (BCPB)
- Eastern Saline Borefield (ESB)
- Saline Borefield

Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023)

0 5 10 km

GDA 1994 MGA Zone 55

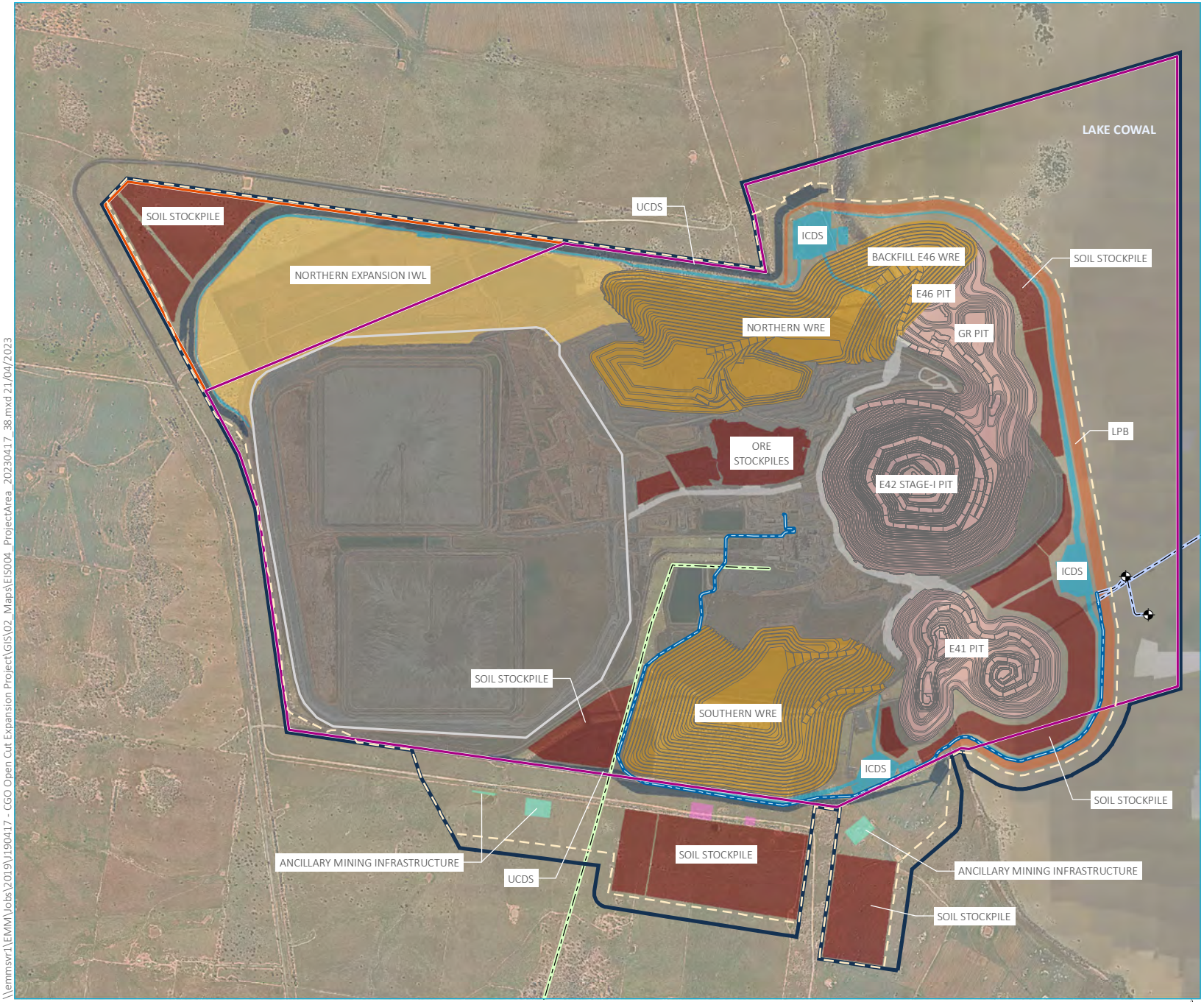
N

\\emmsvr1\EMM\Jobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA017_LocalSetting_20230426_02.mxd 26/04/2023

Local setting

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 1.2

EMM
creating opportunities



KEY

- Project area
- Additional disturbance area
- Approved disturbance area
- Approved IWL footprint
- Mining lease (ML1535) (offset for clarity)
- Mining lease (ML1791) (offset for clarity)
- Saline groundwater supply bore
- Water supply pipeline
- Electricity transmission line

Conceptual project infrastructure

- Open cut pit footprint
- Northern expansion IWL
- Waste rock emplacement (WRE)
- Lake protection bund (LPB)
- Stockpile
- Up catchment diversion system (UCDS)
- Internal Catchment Drainage System (ICDS)
- Ancillary mining infrastructure
- Magazine
- Road
- Water supply pipeline realignment

\\emmsvr1\EMM\Jobs\2019\I190417 - CGO Open Cut Expansion Project\GIS\02_Maps\EIS004_ProjectArea_20230417_38.mxd 21/04/2023

Source: EMM (2023); Evolution (2023); DFSI (2017); Nearmap (2021)

0 1 2 km

GDA 1994 MGA Zone 55

N

Project overview

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 1.3

EMM
creating opportunities

1.4 Project terminology

A summary of key Project terms, particularly relating to the Project area and the disturbance area at CGO (both approved and proposed) are presented in Table 1.2. A full glossary and list of abbreviated terms are provided in the glossary of this report.

Table 1.2 Key Project terms – Project area and areas of disturbance

Term	Definition
Project application area	The area which is subject to the development application in its entirety, encompassing the Project area, water supply pipeline and the BCP Borefield as shown on Figure 1.2.
Project area	The area at the CGO mine site that is the subject of the development application as shown on Figure 1.3.
CGO	Comprises both open pit and underground operations currently approved under DA14/98 and SSD-10367.
The Project	The Project in its entirety, encompassing proposed open pit continuation project components and existing approved activities under DA14/98 and SSD-10367.
Existing and approved surface disturbance areas	Areas that are disturbed, previously disturbed and/or approved under the NSW EP&A Act to be disturbed under the current development consents that apply to CGO.
Additional surface disturbance area	The areas that will be disturbed by the Project that are outside of the existing and approved surface disturbance area for CGO.
Proposed mining footprint	Areas where ore extraction will take place for the Project and includes: • areas outside of the existing and approved disturbance area • areas already disturbed by ore extraction at CGO (i.e. E42 pit) • areas within the existing and approved disturbance footprint but not currently disturbed by ore extraction.
Open pit mining operations	Includes the removal and placement of waste rock in WREs or backfilled into E46 pit, extraction of ore and ancillary activities.
Underground mining operations	Includes the development of stopes and the extraction of ore via long hole stoping, the backfilling of stopes with cemented paste fill and ancillary activities.
Processing operations	Includes the processing of ore from both underground and open pit mining operations and the placement of tailings in the IWL.

1.5 Purpose of this report

This GIA supports the EIS for the construction and operation of the Open Pit Continuation Project. It documents the existing groundwater environment; methods used to assess potential changes to the groundwater environment; the initiatives built into the Project development to avoid and minimise associated impacts; and the mitigation and management measures proposed to address any unavoidable residual impacts.

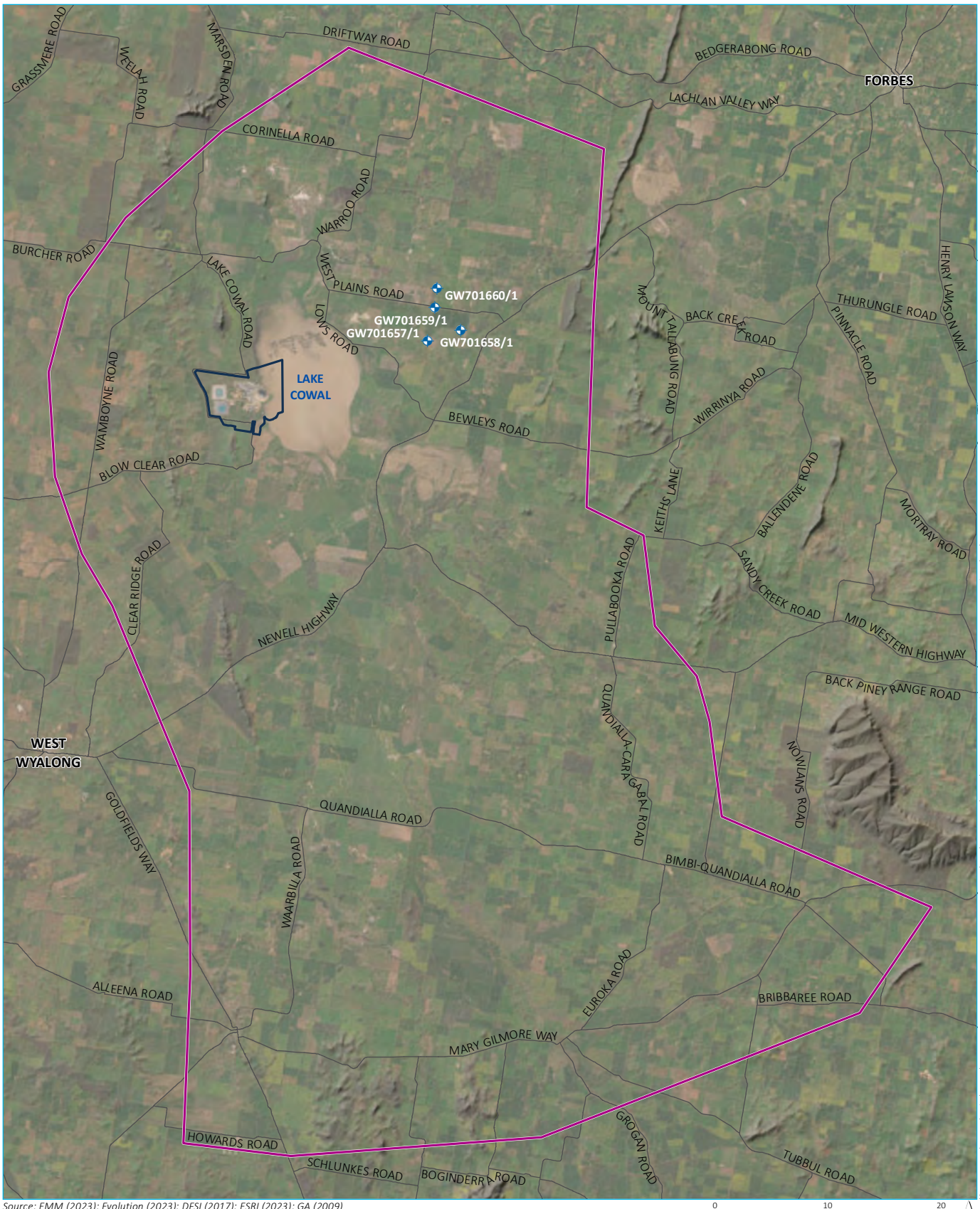
The GIA has been written to satisfy the SEARs relevant to groundwater resources; as well as to inform the wider community about the Project and its potential impacts on the local and regional groundwater environments.

1.6 Groundwater study area

This GIA has considered potential impacts from the Project on groundwater receptors, including social, cultural, environmental and economic that occur within a study area that aligns with the numerical groundwater model boundary (Figure 1.4). At its widest, the study area is approximately 97 km long and 65 km wide. It is shaped to follow or extend beyond the maximum extents of the alluvial Lachlan Formation in the southern, western, and eastern boundaries.

The study area, which is much larger than the Project application area, encompasses:

- all Project-related activities, including the BCP Borefield
- other CGO-related borefields
- three monitoring bores within the BCP with trigger levels set by DPE Water
- nearby registered landholder bores, surface water bodies including Lake Cowal and high-priority groundwater dependant ecosystems (GDEs).



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Major road

Groundwater study area

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 1.4

EMM
creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA015_GwStudyArea_20230426_03.mxd 26/04/2023

2 Regulatory and policy context

An overview of the regulatory framework and guidelines relevant to the GIA is provided in Sections 2.1 to 2.3. Further description and the requirements of the legislations, policies and guidelines are included in Attachment A.

2.1 Legislation overview

The primary groundwater related statutes that apply to the Project are the *Water Act 1912* (Water Act), *Water Management Act 2000* (WM Act), *Protection of the Environment Operations Act 1997* (POEO Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The provisions of each Act are applied in accordance with the attendant regulation.

Table 2.1 lists the legislation relevant to the Project to assess potential impacts on groundwater resources and groundwater-dependent assets.

Table 2.1 Relevant legislation and regulations

Legislation	Authority
Environmental Planning and Assessment Act 1979	DPE – Planning and Assessment
Water Management Act 2000	DPE Water Natural Resources Access Regulator (NRAR)
Water Management (General) Regulation 2018	DPE Water
Protection of Environment Operations Act 1997	NSW Environment Protection Authority (EPA)
Biodiversity Conservation Act 2016	DPE Biodiversity, Conservation and Science Division
Fisheries Management Act 1994	Department of Primary Industries

2.2 Relevant NSW Policies

2.2.1 Overview

The GIA is required to consider the following policies and plans to characterise and assess potential impacts on groundwater resources:

- relevant water sharing plans (WSPs)
- Aquifer Interference Policy (AIP) (2012)
- State Groundwater Dependent Ecosystems Policy (2002)
- Non-Urban Water Metering Policy (2020).

The relevant WSPs are key documents dictating the assessment of the potential impacts of the Project on water resources and are described in Section 2.2.2. Other relevant policies and plans are further detailed in Attachment A.

2.2.2 Water sharing plans

WSPs are statutory documents dictating the management and sharing of water sources. The WSPs set the water management vision and objectives, management rules for water access licences (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 and are periodically reviewed (every 10 years).

Each WSP documents the water available and how it is shared between environmental, extractive, and other uses. The WSPs outline the water availability for extractive uses within different categories, such as: local water utilities, domestic and stock, basic rights and WALs.

Two WSPs apply to the groundwater resources in the study area:

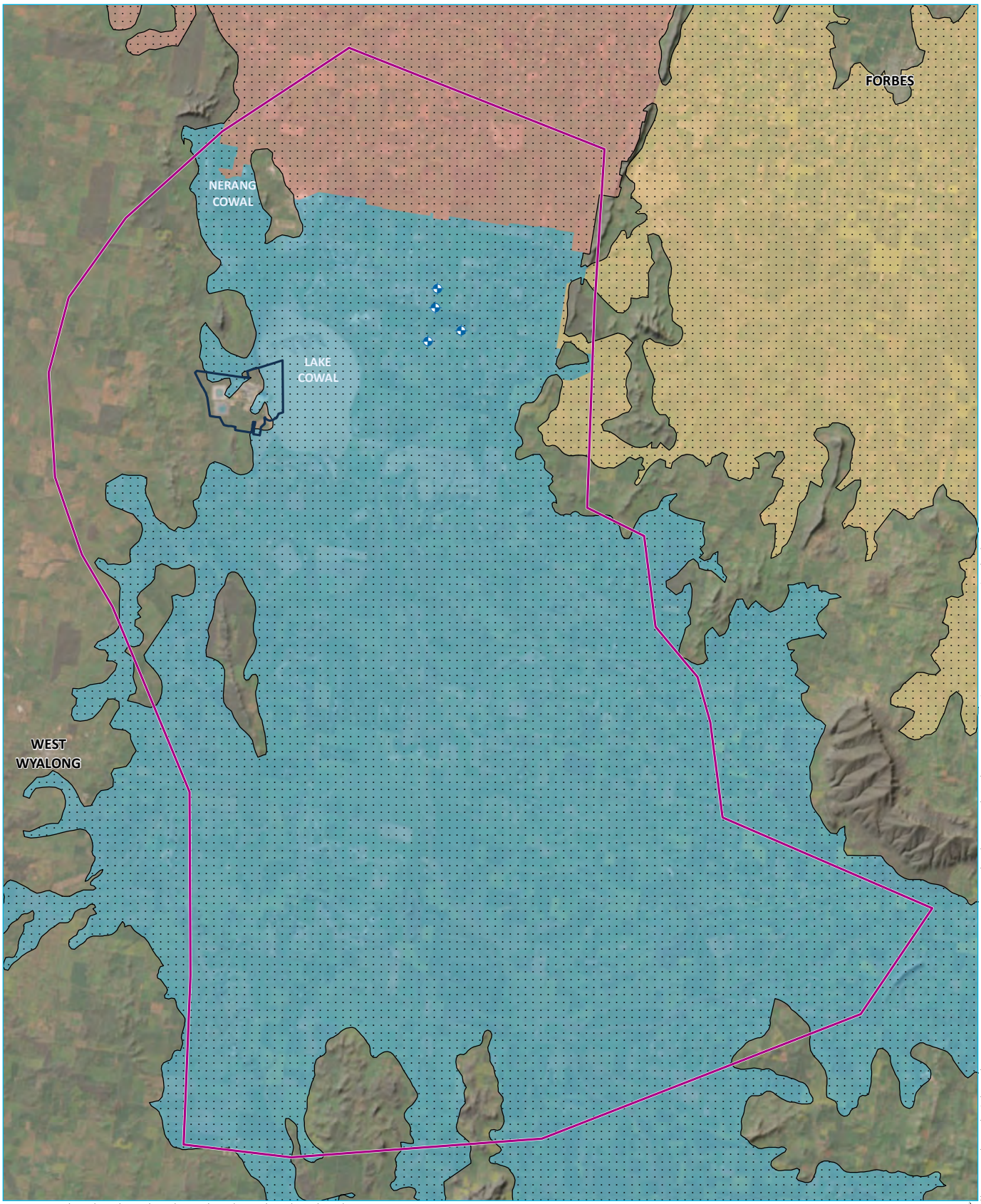
- WSP for the Lachlan Alluvial Groundwater Sources 2020
- WSP for the NSW Murray-Darling Basin (MDB) Fractured Rock Groundwater Sources 2020.

A summary of the existing WALs held by CGO and relevant to groundwater is provided in Table 2.2.

Table 2.2 Summary of existing aquifer water access licences

Licence number	Entitlement[1]	Tenure type	WSP	Water source	Management Zone	Nominated works	Comments
WAL 36569	300 units	Continuing	Lachlan Alluvial	Upper Lachlan Alluvial Groundwater Source	Zone 7	70WA614933	Eastern Saline Borefield
WAL 31864	3,350 units	Continuing	Lachlan Alluvial	Upper Lachlan Alluvial Groundwater Source	Zone 7	70WA614076	BCP borefield
WAL 36615	366 units	Continuing	Lachlan Alluvial	Upper Lachlan Alluvial Groundwater Source	Zone 7	70WA614090	Saline groundwater supply borefield within ML 1535 Pit dewatering
WAL 36617	3,294 units	Continuing	NSW MDB Basin Fractured Rock	Lachlan Fold Belt MDB Groundwater Source	Other	70WA614090	Pit dewatering

Figure 2.1 shows the WSP and water sources in the vicinity of the Project.



Source: EMM (2023); Evolution (2023); DPIE (2021); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Lachlan Alluvial Groundwater Sources 2020 Management zone
  - Upper Lachlan Alluvial Zone 3
  - Upper Lachlan Alluvial Zone 5
  - Upper Lachlan Alluvial Zone 7

The entirety of the map extent is located within WSP for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2020

Water sharing plans and water source areas

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 2.1

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA014_WSPandWSA_20230426_03.mxd 26/04/2023

i Lachlan Alluvial Groundwater Sources 2020

The *WSP for the Lachlan Alluvial Groundwater Sources 2020* (Lachlan Alluvial WSP) covers all water contained within all unconsolidated alluvial sediments below the surface of the ground within the boundaries of the Upper Lachlan, Lower Lachlan and Belubula Valley groundwater sources. The study area is located within the Upper Lachlan Alluvial Groundwater Source, which is divided into management zones. The study area predominantly encompasses the Upper Lachlan Alluvial Zone 7 Management Zone; with a small section of Upper Lachlan Alluvial Zone 3 Management Zone in the north-east corner, and a portion of Upper Lachlan Alluvial Zone 5 Management Zone in the north.

The long-term average annual extraction limit for the Upper Lachlan Alluvial Groundwater Source is 94,168 ML/year.

Table 2.3 presents a summary of the total entitlement shares in the Upper Lachlan Alluvial Groundwater Source. These have not been split into the different management zones, and so represent the total entitlement shares across all eight management zones.

Table 2.3 Summary of Upper Lachlan Alluvial Groundwater Source water requirements and entitlements

Entitlement category	Water Sharing Plan[1]	NSW Water Register[2]
Basic landholder rights (from WSP[1])		
Domestic and stock (ML/year)	6,280	Not applicable
Water access licences		
Domestic and stock (ML/year)	1,238	2,073
Local water utility (ML/year)	7,848	7,848
Aquifer (unit shares)	166,519	166,516.5
Aquifer (High security) (unit shares)	0	0

Notes: 1. Sourced from the Lachlan Alluvial WSP.

2. Total share components were obtained from NSW water register (WaterNSW) for financial year 2022/23.

Evolution currently holds 4,016 unit shares of Aquifer WAL entitlements in the Upper Lachlan Alluvial Zone 7 Management Zone within the Upper Lachlan Alluvial Groundwater Source.

ii Murray-Darling Basin Fractured Rock Groundwater Sources 2020

The study area is located within the Lachlan Fold Belt MDB Groundwater Source, a water source of the *WSP for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2020* (MDB Fractured Rock WSP). The Lachlan Fold Belt MDB Groundwater Source comprises all water contained within:

- all rocks within the outcropped and buried areas
- all alluvial sediments within the outcropped areas, within its mapped boundaries. However, it does not include water sources as defined in the Lachlan Alluvial WSP.

The long-term average annual extraction limit for the Lachlan Fold Belt MDB Groundwater Source is 253,788 ML/year.

Table 2.4 presents a summary of the total entitlement shares in the Lachlan Fold Belt MDB Groundwater Source.

Table 2.4 Summary of Lachlan Fold Belt MDB Groundwater Source water requirements and entitlements

Entitlement category	Water Sharing Plan[1]	NSW Water Register[2]
Basic landholder rights (from WSP[1])		
Domestic and stock (ML/year)	74,311 ML/year	Not applicable
Water access licences		
Domestic and stock (ML/year)	0	0
Local water utility (ML/year)	3,421	3,370.5
Local water utility (Domestic and commercial) (ML/year)	0	65
Aquifer (unit shares)	68,210	74,130.7
Aquifer (General security) (unit shares)	0	0
Aquifer (Town water supply) (ML/year)	0	467.35
Salinity and water table management (ML/year)	236	236

Notes: 1. Sourced from the MDB Fractured Rock WSP.

2. Total share components were obtained from NSW water register (WaterNSW) for financial year 2022/23.

Evolution currently holds 3,294 unit shares of Aquifer WAL entitlements in the Lachlan Fold Belt MDB Groundwater Source.

2.3 Relevant guidelines

The guidelines used in the GIA are presented in Table 2.5, with additional detail included in Attachment A.

Table 2.5 Relevant guidelines

Guidelines	Developed by
Guidelines for the preparation and review of groundwater assessments for major projects in NSW: • Groundwater Assessment Toolbox (DPE 2022a) • Guidelines for Groundwater Documentation for SSD/SSI projects (DPE 2022b) • Minimum Requirements for Groundwater Modelling (DPE 2022c) • Cumulative Groundwater Impact Assessment Approaches (DPE 2022d).	DPE Water 2022
Australian Groundwater Modelling Guidelines	National Water Commission (Barnett 2012)
Uncertainty analysis – Guidance for groundwater modelling within a risk management framework (IESC explanatory note)	Middlemis and Peeters (2018)
Australian and New Zealand Guidelines for Fresh and Marine Water Quality	ANZG 2018
Risk Assessment guidelines for groundwater dependent ecosystems	NSW DPI Office of Water (Serov P 2012)

3 Description of the environment

3.1 Data availability

Table 3.1 Data sources for description of environment

Setting	Public data	Site specific data
Topography	Geoscience Australia - Elevation information system (ELVIS)	-
Land use	DPE – NSW Landuse 2017 v1.2 (accessed via ArcGIS server platform)	-
Climate	DES – SILO climate data	-
Soils and geology	DPIE – Seamless geology datasets (accessed via ArcGIS platform)	Geological logging data from exploration and groundwater monitoring bore installation campaigns
Geological and hydrogeological setting	WaterNSW – Real time water data BoM – National groundwater information system Geoscience Australia – Forbes 1:250,000 hydrogeological map	Groundwater monitoring data provided by Evolution
Borefields and irrigation	(Coffey 2020a) – Technical Assessment	WAL details
Geochemistry	-	*Cowal Gold Project Environmental Geochemical Assessment of Process Tailings, Mine Rock and Surface Zone Materials* (EGi 1995) *Cowal Gold Project Environmental Assessment of Simulated Tailings* (EGi 1996) *Cowal Gold Project Environmental Geochemistry Assessment of Proposed Mining Activities for Cowal Gold Project* (EGi 1997) *Cowal Gold Project Final Void Water Chemistry* (EGi 1998) *Geochemical Assessment of Waste Rock and Process Talings* (EGi 2004) *Cowal Gold Mine E42 Modification, Tailings and Waste Rock Geochemical Assessment* (GEM 2008) *Cowal Gold Mine Augmentation Project, Environmental Geochemistry Assessment of Waste Rock and Tailings* (GEM 2011a) *Cowal Gold Mine Extension Project Pre-Feasibility, Environmental Geochemistry Assessment of Waste Rock, Low Grade Ore and Tailings* (GEM 2011b) *Cowal Gold Mine Extension Modification, Environmental Geochemistry Assessment of Waste Rock and Tailings* (GEM 2013) *Cowal Gold Operations Mine Life Modification, Environmental Geochemistry Assessment of Waste Rock and Tailings* (GEM 2016) *Cowal Gold Operations Underground Development, Environmental Geochemistry Assessment* (GEM 2020a) *Cowal Gold Operations Geochemical Assessment of Proposed Pebble Material Processing* (GEM 2020b)

Table 3.1 Data sources for description of environment

Setting	Public data	Site specific data
Sensitive receivers	DCCEEW – Ramsar wetlands within Australia DCCEEW – Directory of Important Wetlands DPE – High Ecological Value Ecosystem dataset BoM – GDE atlas of Australia WSP – high priority listed GDEs	*Cowal Gold Operations – Biodiversity Development Assessment Report* (EMM 2023)

3.2 Topography and land use

Based on publicly available elevation data (Geoscience Australia 2010), topography within the study area is generally flat, with an average gradient of ~0.04%. Lake Cowal forms a topographic low point and lies at approximately 203 metres Australian height datum (mAHD) when dry. Mountain ranges and peaks within the western, eastern and southern extents of the study area form localised topographic high-points, including the following key topographic features:

- Wamboyne Mountain, approximately 5 km north of the Project and rising to ~290 mAHD
- Jemalong ranges, approximately 33 km north-east of the Project and rising to ~320 mAHD
- Gidgingidginbung Pinnacle, approximately 65 km south of the Project and rising to ~340 mAHD.

Topography and key topographic features are provided on Figure 3.1.

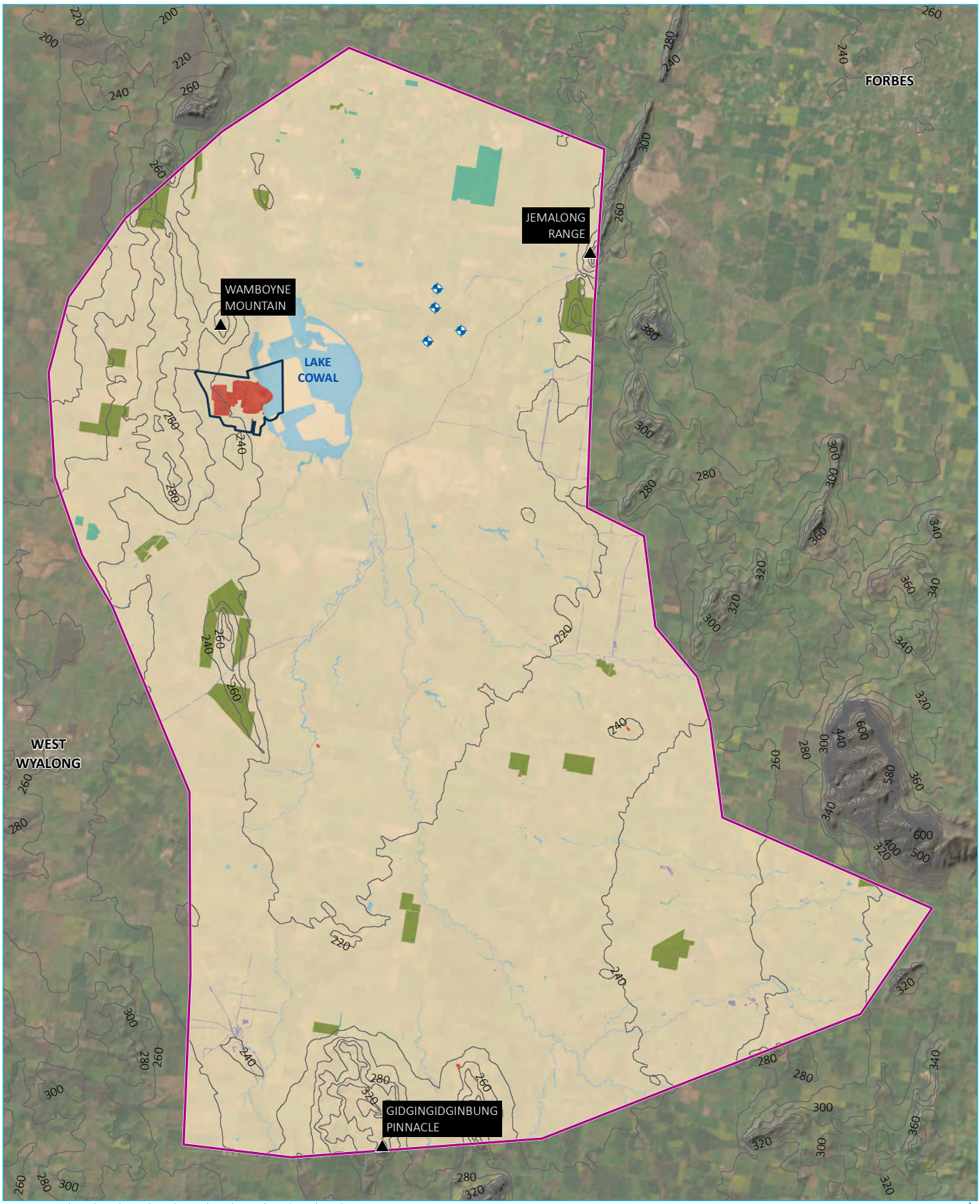
Land within the study area is predominantly used for agriculture (representing 95%) and includes grazing, cropping, animal production and farm related infrastructure. State Forests and water features (such as Nerang Cowal and Lake Cowal) each represent approximately 2% of the study area. Nature reserves, mining (associated with the Project), wetlands and other (road corridors, airstrips etc) collectively account for the remaining 3% (DPE 2020).

A summary of land use within the study area is provided in Table 3.2 and Figure 3.1.

Table 3.2 Land use categories

Land use	Total area (Ha[1])	Percentage of study area
Agriculture	423,390	95
State forests	8,613	2
Water features	8,665	2
Nature reserves	2,011	<1
Mining	1,217	<1
Other	1,101	<1
Wetlands	354	<1

Notes: 1 = Hectares



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA001_TopographyAndLandUse_20230426_03.mxd 26/04/2023

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Key topographic feature
- Topographic contour (20 m)

Land use

- Agriculture
- Forestry
- Mining
- Nature reserve
- Other
- Water features

Topography and land use near the Project

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 3.1

EMM creating opportunities

3.3 Climate

Climate near the Project area is categorised as dry, semi-arid and cold (Geiger 1954). Based on SILO climate date obtained at Burcher Post Office (approximately 20 km north-west of the Project), average annual rainfall is approximately 560 mm and is exceeded by average pan evaporation (~1,800 mm/year) (DES 2022).

As outlined in Figure 3.2, rainfall is relatively constant between months however, evaporations is up to six times higher in January (mid-summer) than June (mid-winter). Based on the previous twelve months of available data, rainfall has been above average for seven months and evaporation has been below average for eleven months (DES 2022), indicating a relatively 'wet' period prior to collation of this GIA.

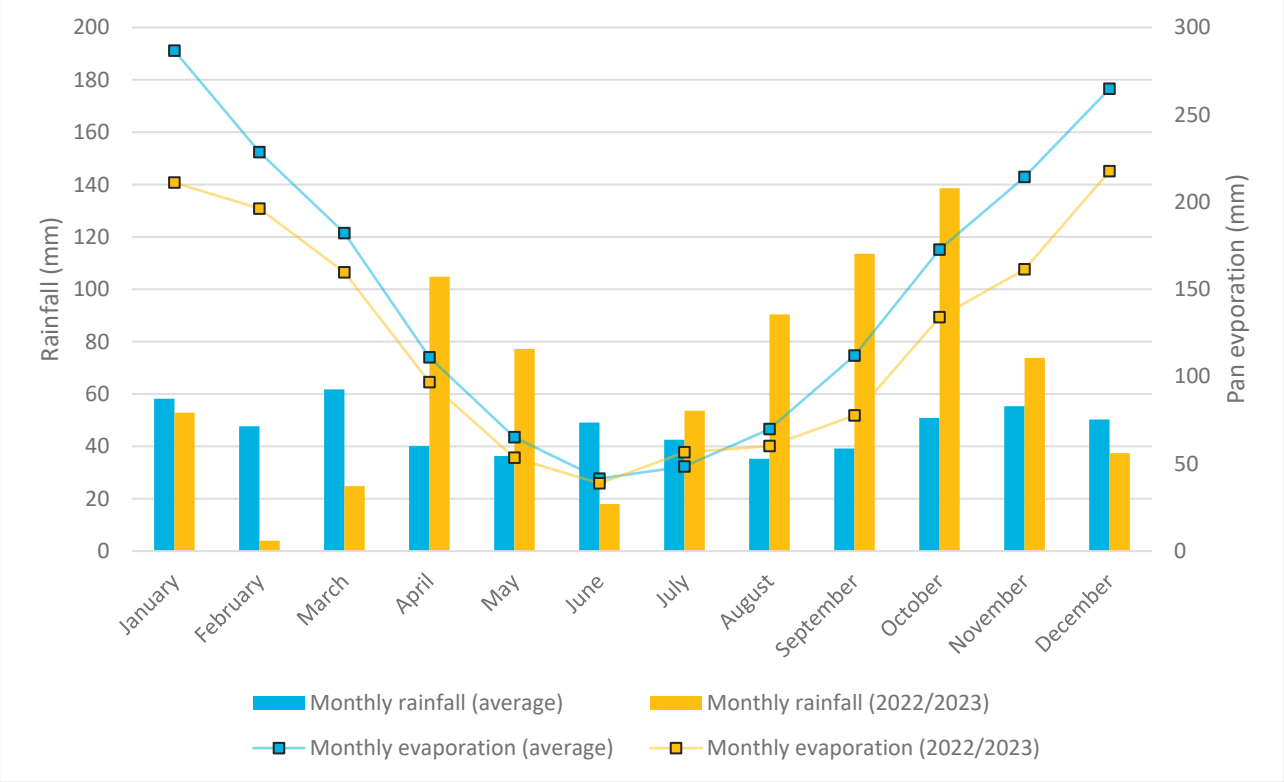


Figure 3.2 SILO climate data at Burcher Post Office (station 50010)

3.4 Hydrological setting

Lake Cowal is an ephemeral, fresh-water lake that is the major hydrological feature within the study area, located adjacent (east) of the Project and covers an area of approximately 105 square kilometres (km^2). Lake Cowal is predominantly filled by inflow from Bland Creek to the south and when flooding by flood breakout from the Lachlan River to the north-east. When full, Lake Cowal flows to the north-west into Nerang Cowal. The Lachlan River, an eight-order, perennial watercourse is located approximately 40 km north of the Project. Bland Creek is a seventh-order watercourse mapped as perennial in the lower reaches (near Lake Cowal) and ephemeral in the upper reaches (within the southern portion of the study area) (DPE 2022e). Bland Creek forms the main drainage feature from the ephemeral watercourses within the southern portion of the study area.

Nerang Cowal is an ephemeral, freshwater lake and wetland, located approximately 10 km north of the Project, is intermittently connected to Lake Cowal. During flooding, Nerang Cowal is recharged by Lake Cowal via Bland Creek.

The Jemalong Irrigation Area (JIA) is located within the northern portion of the study area. The JIA comprises approximately 140 km of interconnected, artificial canals including the Jemalong and Waroo channel systems. The channels systems convey surface water from the Lachlan River for irrigation within the JIA. Based on Strahler stream mapping (DCS 2023), the channel systems are mapped as perennial and likely contain water on a relatively permanent basis.

Key hydrological features and surface water courses are presented on Figure 3.3.

3.5 Soils and geology

3.5.1 Soils

The Australian Soil Classification mapping data (DPE 2012a) classifies the surficial soils of the Cenozoic sediments as predominantly vertosols, chromosols and kandosols. These soils groups are generally characterised by deep to very deep (>100 cm to >150 cm) profiles of poorly drained clays, with slow to very slow infiltration potential (DPE 2012b).

Outcrops of geological units associated with the Lachlan Fold Belt (LFB) (refer Section 3.5.3) are typically overlain with soils characterised as rudosols, tenosols, kurosols and ferrosols. These soil groups are generally formed through the weathering of underlying rock outcrops and colluvial deposition at the base of hill-slopes, generally comprising well drained sands and gravels, with high to very high infiltration potential (DPE 2012b).

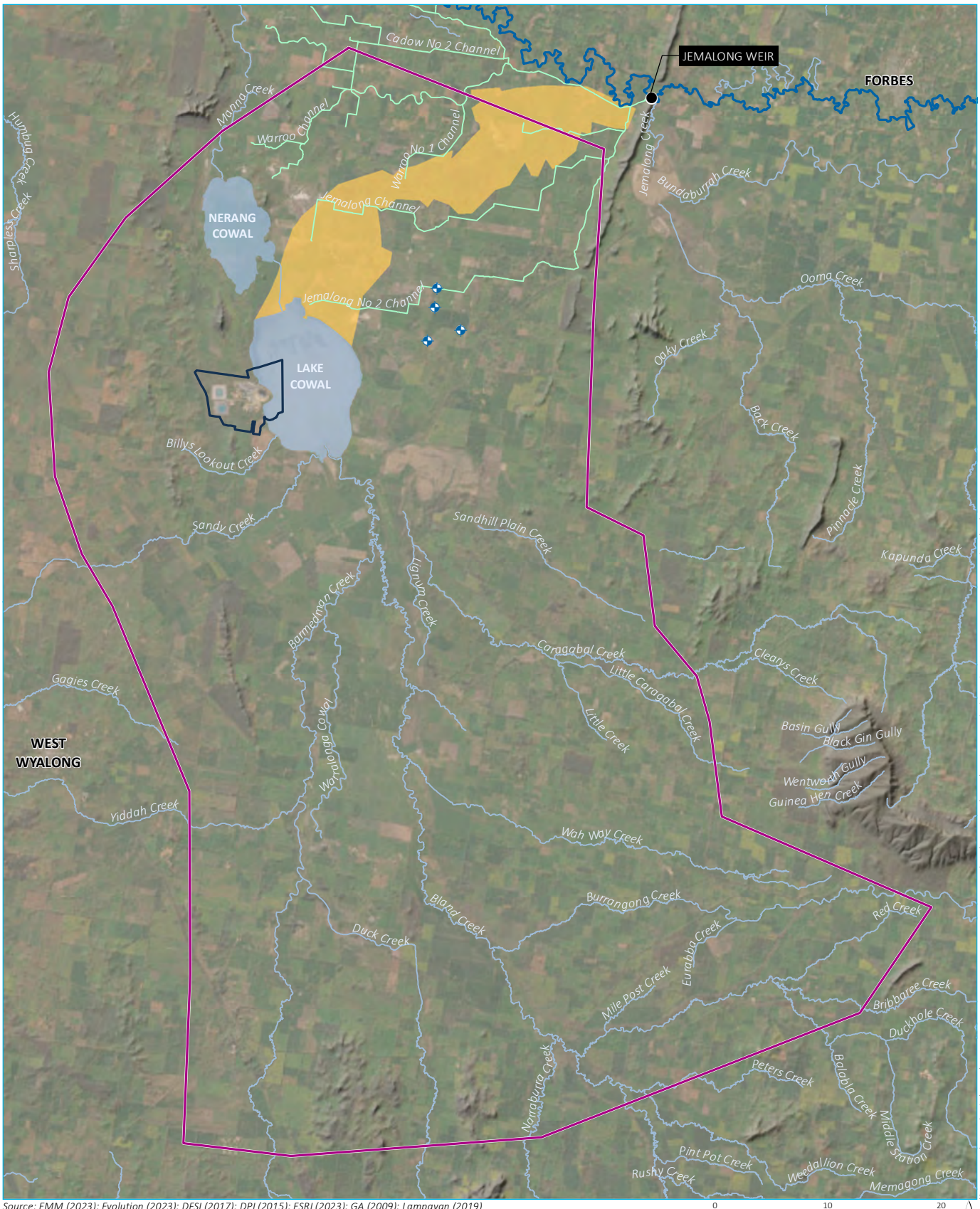
Spatial distribution of soil near the Project is presented on Figure 3.4.

3.5.2 Cenozoic sediment geology

Based on surface geology mapping (Colquhoun 2022), most of the study area is overlain with Cenozoic alluvium, with floodplain and lacustrine deposits underlying Lake Cowal and Nerang Cowal. Mixed colluvial, alluvial, residual and aeolian deposits of sediment extend west of the Project and occupy the lower reaches of the Jemalong Range.

A relatively deep (up to 120 m thick) palaeochannel generally underlies the mapped alluvium. Geological units within the palaeochannel include the Quaternary Cowra formation and the underlying Neogenic Lachlan Formation (Coffey 2020a). The Project area is on the central western edge of the palaeochannel, with the Project borefield in the approximate centre of the palaeochannel (targeting the deeper sediments).

A summary of Cenozoic sediment unit composition and thickness is presented in Table 3.3. Spatial distribution of the units is presented on Figure 3.5.



\\emmsvr1\EMMVJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA002_HydrologicalSetting_20230426_05.mxd 26/04/2023

Source: EMM (2023); Evolution (2023); DFSI (2017); DPI (2015); ESRI (2023); GA (2009); Lampayan (2019)

0 10 20 km

GDA 1994 MGA Zone 55

N

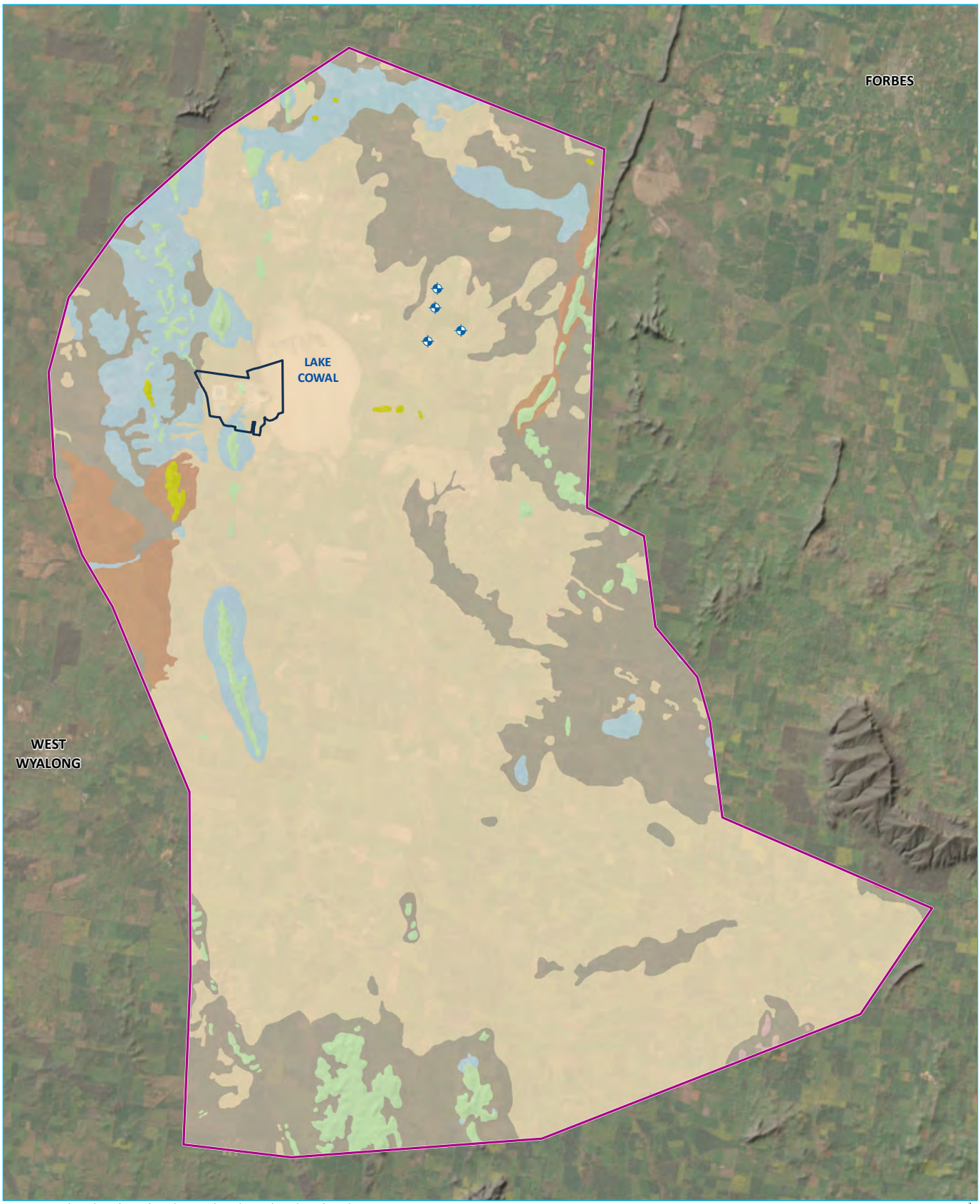
KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Jemalong Weir
- Lachlan River
- Named watercourse
- Named irrigation channel
- Named waterbody
- Floodway (Lampayan 2019)

Hydrological setting

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 3.3

EMM
creating opportunities



Source: EMM (2023); Evolution (2023); ATLAS (2022); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)

Australian soil classification

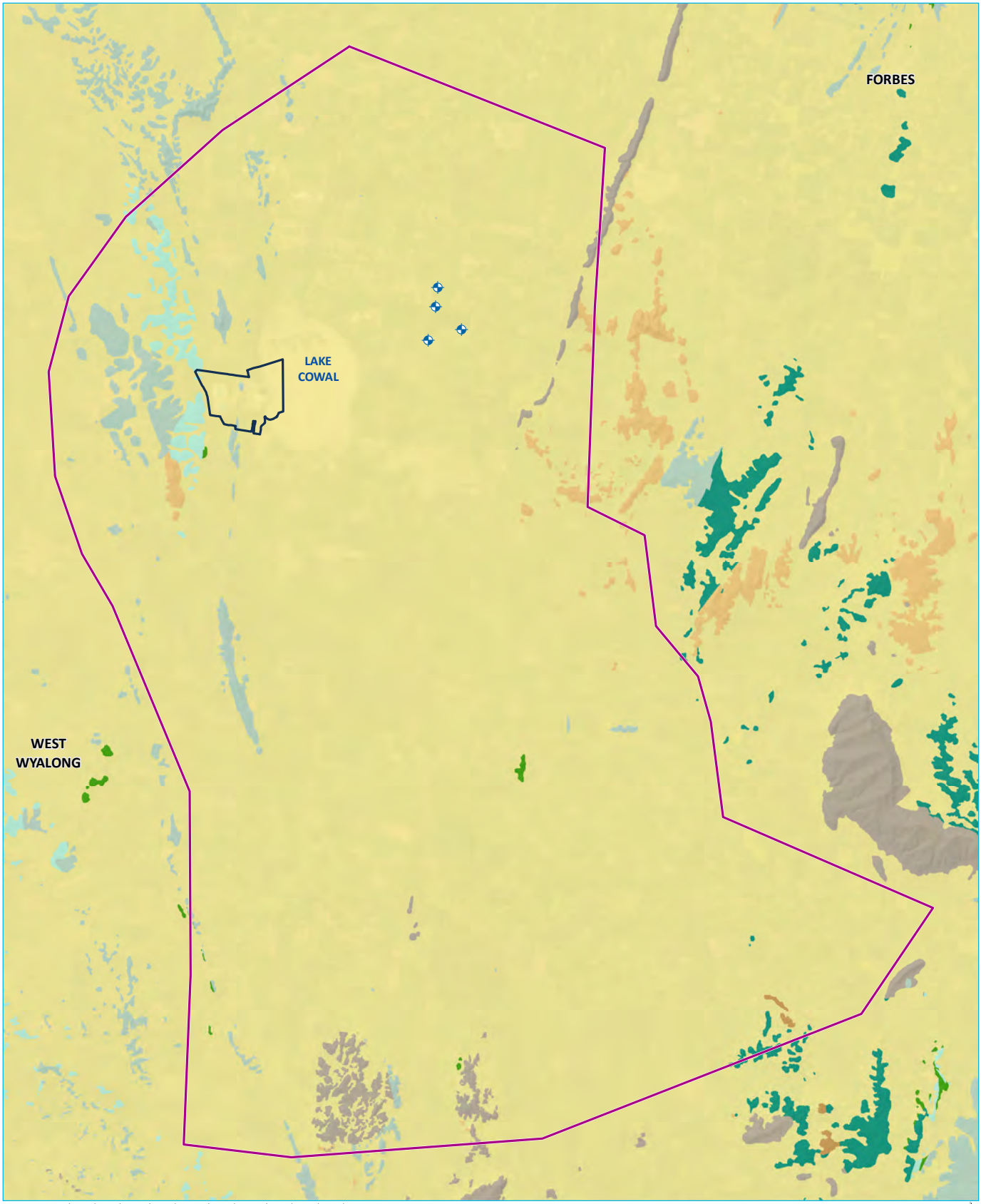
- Chromosols (CH)
- Dermosols (De)
- Ferrosols (FE)
- Kandosols (KA)
- Kurosols (KU)
- Kurosols (natric) (KUn)
- Rudosols (RU)
- Tenosols (TE)
- Vertosols (VE)

Soil distribution

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 3.4

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA003_SoilDistribution_20230426_05.mxd 26/04/2023



Source: EMM (2023); Evolution (2023); DPIE (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)

Surface geology (Colquhoun 2023)

Medial age

- Quaternary
- Early Devonian
- Devonian
- Late Devonian
- Silurian
- Early Ordovician
- Ordovician
- Late Ordovician

Surface geology

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 3.5

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA004_SurfaceGeology_20230426_05.mxd 26/04/2023

Table 3.3 Study area stratigraphy

Era	Period	Formation/group/suite	Thickness (m)	Generalised lithology
Cenozoic	Quaternary	**Cowra formation**	30–50	Clay interbedded with sand and gravel, typically increasing gravel and sand content with depth
	Neogene	Lachlan Formation	<90	Sand and gravel, interbedded with clay
Paleozoic	Devonian	Barmedman Suite	-	Biotite granite
		Bindogandri Suite	-	Granite
		Derriwong Group	-	Volcanic rocks, volcaniclastics, conglomerate and sandstone
		Gilmore Hill Suite	-	Biotite granite
		Hervey Group	-	Sandstone, siltstone, shale and conglomerate
		Narraburra Suite	-	Feldspar granite
		Trundle Group	-	Rhyolite, dacite, quartz sandstone, quartzite, siltstone and shale
		Unassigned Eugowra Granite	-	Quartz diorite, tonalite, diorite and granite
		Unassigned Devonian Intrusions	-	Diorite, quartz diorite and quartz syenite
		Ungrouped Eastern Lachlan Devonian units	-	Dolerite, rhyolite, rhyodacite and dacite
		Unassigned Wagga Batholith units	-	Dolerite and granite
		Ungrouped Devonian sedimentary rocks	-	Greenschist, metapelite, meta-siltstone, phyllite and metasandstone
	Silurian	Ootha Group	-	Siltstone, sandstone, mudstone, conglomerate and rhyolitic tuff
		Ungarie Suite	-	Biotite granodiorite and granite
		Ungrouped Central Lachlan Silurian units	-	Greywacke, conglomerate, rhyolitic tuff, sandstone, andesite and shale
	Ordovician	Adaminaby Group	-	Sandstone, chert, laminated siltstone and mudstone
		Girilambone Group	-	Sandstone, meta-mudstone, chert, conglomerate, siltstone, quartzite, and volcanic rocks
		Lake Cowal Volcanic Complex	-	Andesite, basalt, trachyte, siltstone, sandstone, conglomerate and breccia
		Ungrouped Ordovician igneous units	-	Andesite, basalt, andesitic breccia and sedimentary rocks
		Ungrouped Ordovician units	-	Basalt, breccia, diorite, dolerite, chert, siltstone, mudstone, sandstone, claystone and turbidites

Table 3.3 Study area stratigraphy

Era	Period	Formation/group/suite	Thickness (m)	Generalised lithology
	Cambrian	Unassigned Eastern Lachlan Cambrian Units	-	Tuff, sandstone, conglomerate, andesite, diorite and quartz monzonite

Source: (Colquhoun, et al. 2022) (Lampayan 2001) (Bilge 2012)

Note: Units in bold are excavated during open pit mining for the Project

3.5.3 Lachlan Fold Belt geology

The study area lies within the LFB geological province. The LFB comprises rock units formed in the Middle Paleozoic period, extending across the majority of south-eastern and central NSW (Foster and Gray 2000).

The Project targets epithermal to mesothermal gold mineralisation within the Ordovician Lake Cowal Volcanic Complex (Evolution 2022a), forming part of the LFB and located within the central northern portion of the study area. The remainder of the study area includes Cambrian–Devonian metamorphic, igneous and sedimentary rock formations associated with the LFB. A weathered profile generally overlies the fresh LFB rock units within the study area, comprising saprolite (~30 m thick) and saprock (~50 m thick). Saprolite comprises in situ weathered rock where >20% of the rock mass has been altered, for saprock the alteration or weathering is <20%.

A summary of the assigned LFB geological groups and suites within the study area are provided in Table 3.3. The distribution and extent of the assigned LFB geological groups and suites is presented on Figure 3.6.

3.5.4 Structural geology

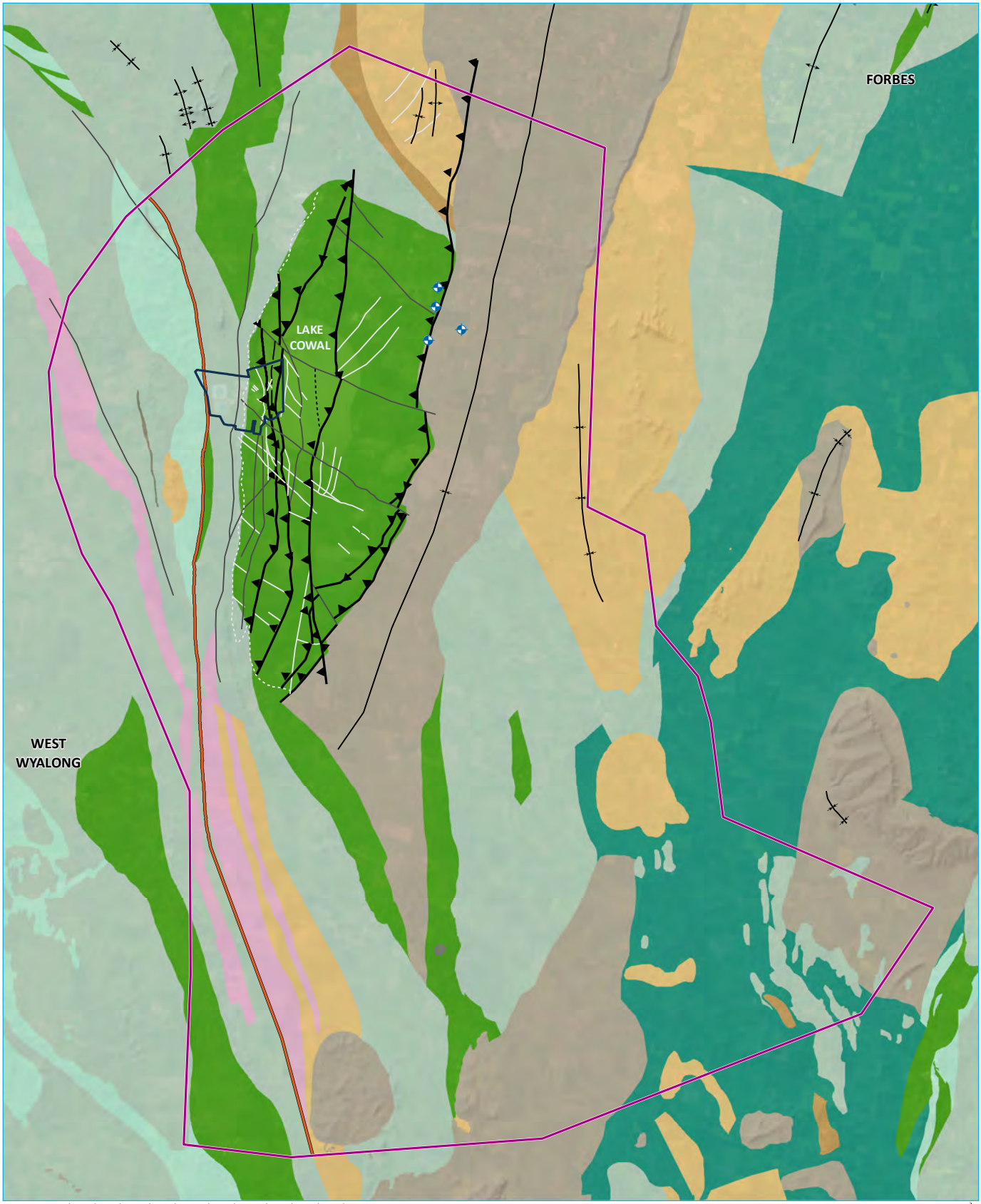
The study area lies within the Bogan Gate Synclinorial zone, a generally north-south trending zone of deformation extending from the NSW / Victorian border (south) to the northern extent of the LFB near Bourke, NSW (Lampayan 2001). The Bogan Gate Synclinorial zone includes the:

- Tullamore Syncline (Lampayan 2001), approximately 20 km east of the Project (to the fold axis) and outcropping as the Jemalong Range in the eastern portion of the study area (refer Figure 3.1).
- Currowong Syncline (Colquhoun, et al. 2022), approximately 30 km east of the Project (to the fold axis) and extending south of the Jemalong Range.

The Gilmore Fault Zone (or Gilmore Suture) is a well-defined north–north-westerly structural feature (Lampayan 2001) immediately west of the Project, forming a distinct boundary between the Wagga Metamorphic Belt and the Macquarie Arc and Silurian rift basins (Venkataramani 2017).

Based on geological data provided by Evolution, multiple structural features (including faults, thrusts, shear zones and unconformity's) are inferred near the Project, generally trending north–northeast within the study area.

Structural features are presented on Figure 3.6.



Source: EMM (2023); Evolution (2023); DPIE (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA005_BasementGeology_20230426_05.mxd 26/04/2023

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)

Regional lineaments (Evolution 2022)

- Fault - major
- Fault - minor
- Shear
- Synform
- Thrust
- Unconformity

Lachlan Orogen geology (Colquhoun 2023)

Medial age

- Early Devonian
- Devonian
- Late Devonian
- Silurian
- Early Ordovician
- Ordovician
- Late Ordovician
- Cambrian

Named structural feature

- Gilmore fault zone
- Anticline
- Syncline

Lachlan Fold Belt geology

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 3.6

EMM
creating opportunities

3.6 Hydrogeological setting

3.6.1 Groundwater systems

Within the saturated zone (i.e. below the water table) the Cenozoic alluvial sediments support alluvial groundwater systems. Groundwater flows through pore spaces within the sediments, with hydraulic conductivity increasing proportionally to sediment grain size (Freeze 1979). The surficial sediments facilitate vertical infiltration from rainfall recharge and surface water however, recharge is limited by the extent and thickness of the Lacustrine Clay.

The alluvial sequence within the palaeochannel area is split into three groundwater systems, generally based on varying hydrogeological properties (i.e. yield, water quality and confinement). The alluvial groundwater systems include the:

- Upper Cowra groundwater system, an unconfined, phreatic groundwater system supporting the water table (where present). This sequence generally occurs from ground surface to an average depth of approximately 45 m to 50 m over most of the CGO site and surrounding area, with an average depth to groundwater of approximately 7 m (Evolution 2022c). The Upper Cowra groundwater system is rarely utilised for water supply, generally providing low yields (<1 L/s, (Lampayan 2001)) of saline (~39,000 micro-siemens per centimetre [µs/cm]) groundwater (Evolution 2022b). In accordance with Section 3.2.1 of the AIP, the Upper Cowra groundwater system is classified as a **less productive** alluvial groundwater source (DPI 2012).

- Lower Cowra groundwater system, an unconfined/confined groundwater system (Bilge 2012) underlying the Upper Cowra groundwater system. Yield from the Lower Cowra groundwater system is highly dependent on intercepting extensive sand and gravel lenses within the formation. Groundwater from the Lower Cowra system can provide up to 40 L/s of saline (~22,500 µs/cm) groundwater (Evolution 2022b). In accordance with Section 3.2.1 of the AIP, the Lower Cowra groundwater system is classified as a **less productive** alluvial groundwater source due to the high salinity (DPI 2012).

- Lachlan groundwater system, a confined, highly productive groundwater system underlying the Lower Cowra groundwater system, which does not extend to the proposed mining areas. This sequence generally occurs over an average depth interval of around 90 m to 120 m in the BCP (Evolution 2022c). The Lachlan groundwater system has been reported to provide up to 200 L/s (Lampayan 2001) of brackish (~2,600 µs/cm, (Evolution 2022b) groundwater. In accordance with Section 3.2.1 of the AIP, the Lachlan groundwater system is generally classified as a **highly productive** alluvial groundwater source (DPI 2012). Vertical head differences between the Lachlan and Lower Cowra formation, especially in areas near pumping centres, indicates the presence of large vertical anisotropy, likely attributed to multiple clay layers observed in the Cowra Formation.

A fractured rock groundwater system is supported within the laterally continuous LFB rock units (refer Section 3.5.3). Groundwater flows within the discontinuities (i.e. fractures, joints, shear-zones etc.), with negligible flow though the undisturbed rock matrix. The fractured rock groundwater system is generally confined under the alluvial sequence (where present) and unconfined to semi-confined across the remaining extent. Bore yields are highly dependent on intercepting connected discontinuities within the rock unit however, are reported as typically low (<1 L/s (Lampayan 2001)). Groundwater within the fractured rock groundwater system is generally saline (~52,000 µs/cm (Evolution 2022b)). In accordance with Section 3.2.1 of the AIP, the fractured rock groundwater system is generally classified as a **less productive** fractured rock groundwater source (DPI 2012).

A summary of hydrogeological units within the study area is presented in Table 3.4.

Table 3.4 Summary of groundwater systems

Groundwater system	Indicative maximum yield (L/s)	Indicative salinity (µS/cm)	Classification[1]
Upper Cowra	<1	39,000	Less productive alluvial groundwater source
Lower Cowra	40	22,500	Less productive alluvial groundwater source
Lachlan	200	2,600[2]	Highly productive alluvial groundwater source
Fractured rock	<1	52,000	Less productive fractured rock groundwater source

Source: (DPI 2012) (Lampayan 2001) (Evolution 2022b)

Notes: 1. In accordance with Section 3.2.1 of the AIP

2. Indicative salinity marginally exceeds the AIP guideline however, extensive utilisation of the Lachlan groundwater system for water supply indicates a highly productive groundwater source

3.6.2 Groundwater borefields

Groundwater supply for CGO is sourced from the following groundwater borefields (shown in Figure 1.2), all regulated under the Lachlan Alluvial WSP:

- The Saline Groundwater Supply Borefield within ML 1535 and Lake Cowal has historically provided <0.6 ML/day of saline water, for the short amount of time it was operational between 2008 and 2010.
- The Eastern Saline Borefield (ESB), 10 km east of Lake Cowal's eastern shoreline, has historically provided approximately 0.5 ML/day of brackish to saline water from the Lower Cowra groundwater system.
- The BCP Borefield, 20 km east-northeast of CGO, provides on average approximately 3.8 ML/day of brackish water within the Lachlan groundwater system, since commencing in 2004. This borefield is near the Jemalong Irrigation Channel No 2 (Figure 1.2).

The annual historical use from the three CGO borefields is shown in Figure 3.7, with data taken from Coffey (2020a) and Evolution. In comparison, the estimated annual historical use from the irrigation bores is shown in Figure 3.8. Irrigation abstraction volumes estimated prior to 2020 were taken from Coffey (2020a). Irrigation take during 2020–2022 was estimated by considering historical pumping patterns during wet and dry rainfall periods. In the wet period between 2010 and 2012 an average one-third of peak drought take was pumped. Therefore, during the 2020–2022 period where rainfall conditions were above average and conditions were wet, one-third of peak drought take was applied.

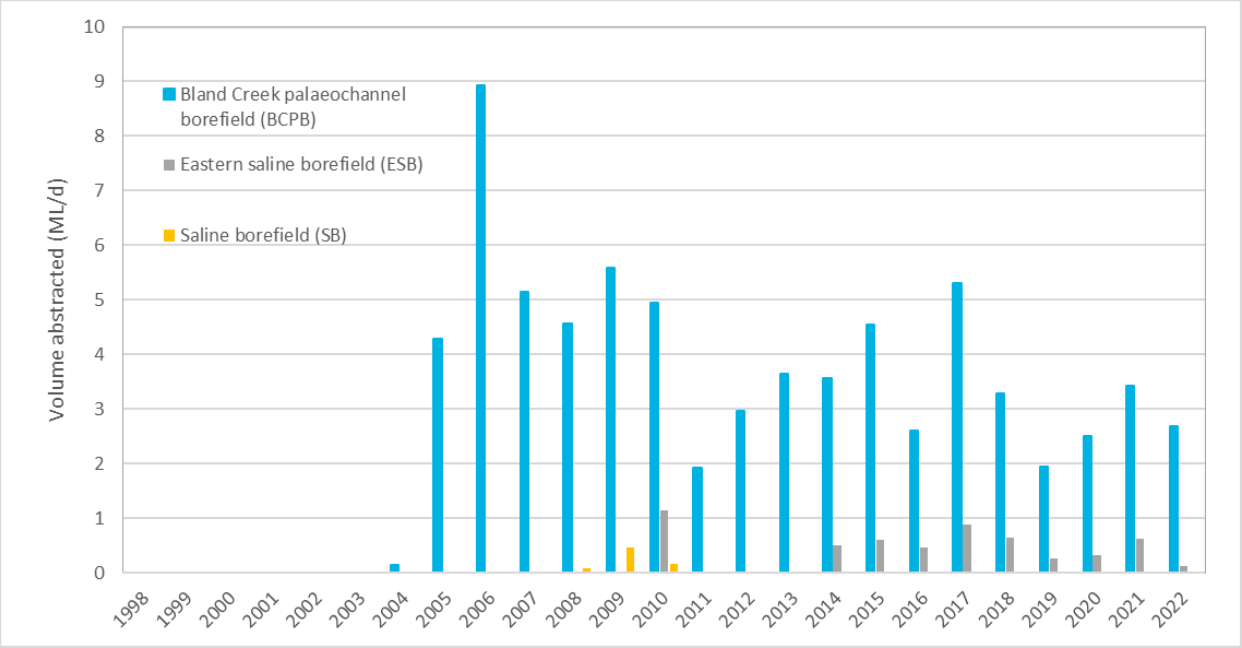


Figure 3.7 **Estimated CGO borefield usage**

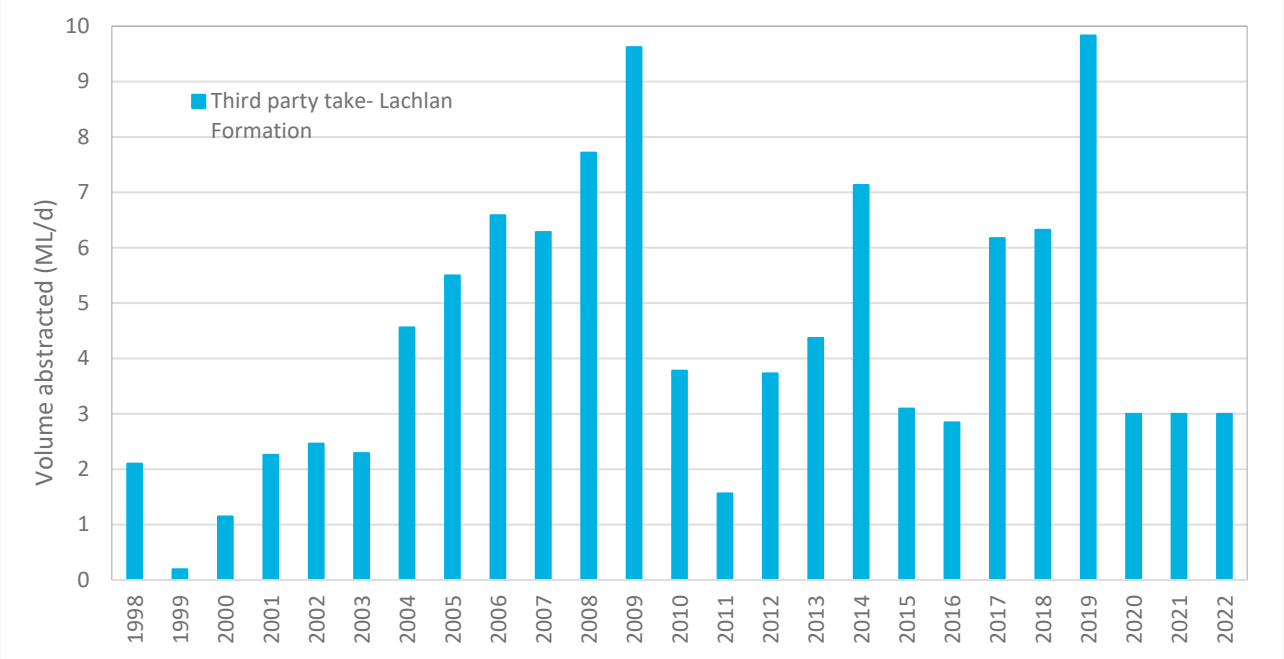


Figure 3.8 **Estimated historical use from irrigation bores**

3.6.3 Groundwater monitoring

There is an extensive groundwater monitoring network near the Project, operated by Evolution as part of its ongoing Water Management Plan for the CGO site (Evolution 2022c). The Project network spans the groundwater systems discussed in Section 3.6.1. Groundwater level and quality monitoring commenced in December 1997 and January 2015 respectively. Groundwater data has been provided by Evolution, except for newly constructed bores installed within Lake Cowal, with the installed designed, supervised and monitored by EMM.

Regionally, there is also groundwater monitoring data available from the National Groundwater Information System (NGIS) database (BoM 2022). Data from the NGIS database has been accessed to supplement groundwater level data obtained from the Project network.

A summary of groundwater level and quality (represented as total observations per year) used to inform this GIA is provided in Figure 3.9. Further information on bore details and associated data periods is attached as Attachment E.

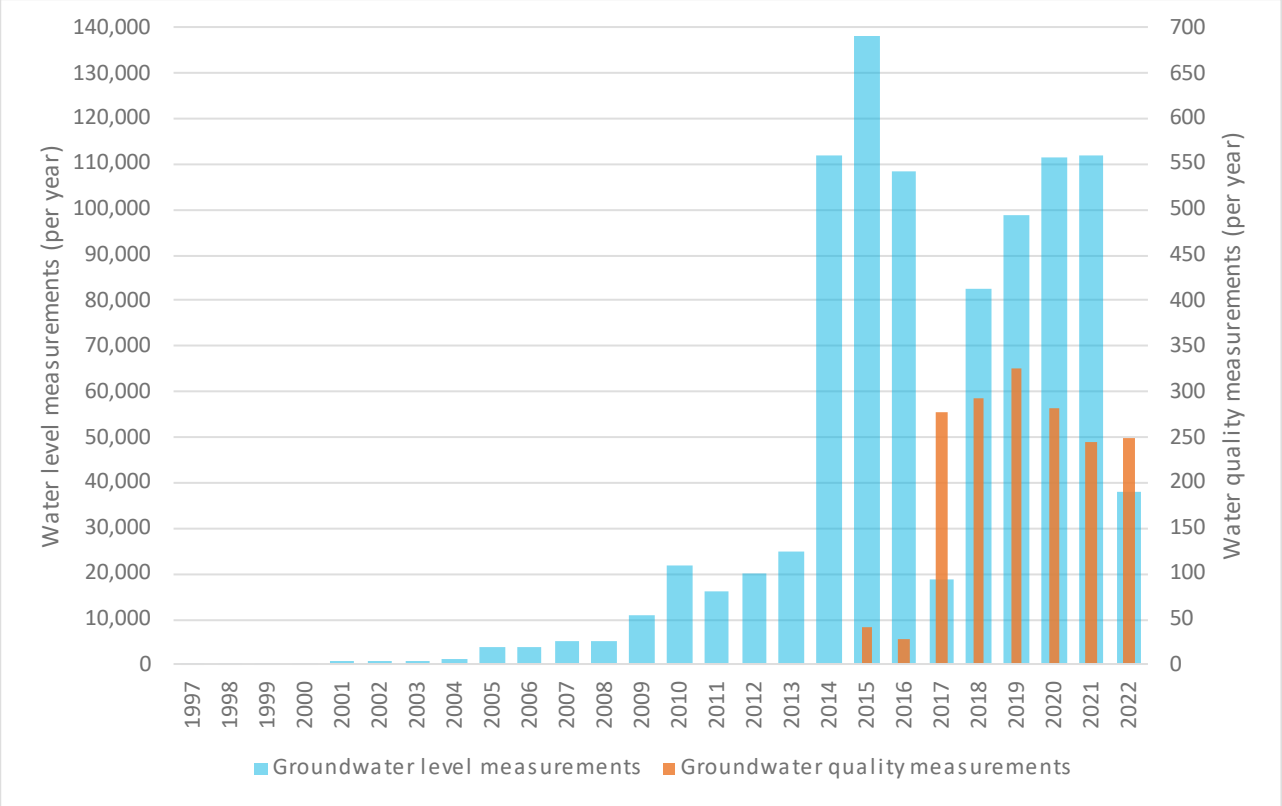


Figure 3.9 Summary of groundwater monitoring data since 1997

3.6.4 Hydraulic properties

Extensive hydraulic conductivity testing has been undertaken at CGO and includes:

- in-situ permeability testing, comprising:
  - rising and falling head tests within monitoring bores
  - packer tests in open boreholes
  - vertical infiltration testing within the IWL

- laboratory based permeability testing of core samples (including the groundwater systems discussed in Section 3.6.1)
- pumping testing at water supply bores.

A summary of indicative hydraulic properties is provided in Table 3.5.

Table 3.5 Indicative hydraulic properties of hydrogeological units within the study area

Unit/groundwater system	Hydraulic conductivity (metres per day)		
	Minimum	Maximum	Arithmetic mean
[1]Lacustrine clay	2×10^{-4}	1×10^{-3}	6×10^{-4}
[1]IWL foundation	9×10^{-7}	2×10^{-4}	7×10^{-5}
[1]Deposited tailings	5×10^{-4}	6×10^{-1}	1×10^{-1}
Upper Cowra	1×10^{-3}	35	2.6
Lower Cowra	1	20	10.5
Lachlan	0.030	100	33
Saprolite	1×10^{-2}	1×10^{-1}	4×10^{-2}
Saprock	2×10^{-3}	1.5	2×10^{-1}
Fresh rock	1×10^{-3}	1×10^{-2}	5×10^{-3}

Source: (Coffey 2020a)

Notes: 1. Unit facilitates vertical infiltration only and value represents vertical hydraulic conductivity

3.6.5 Groundwater levels and flow direction

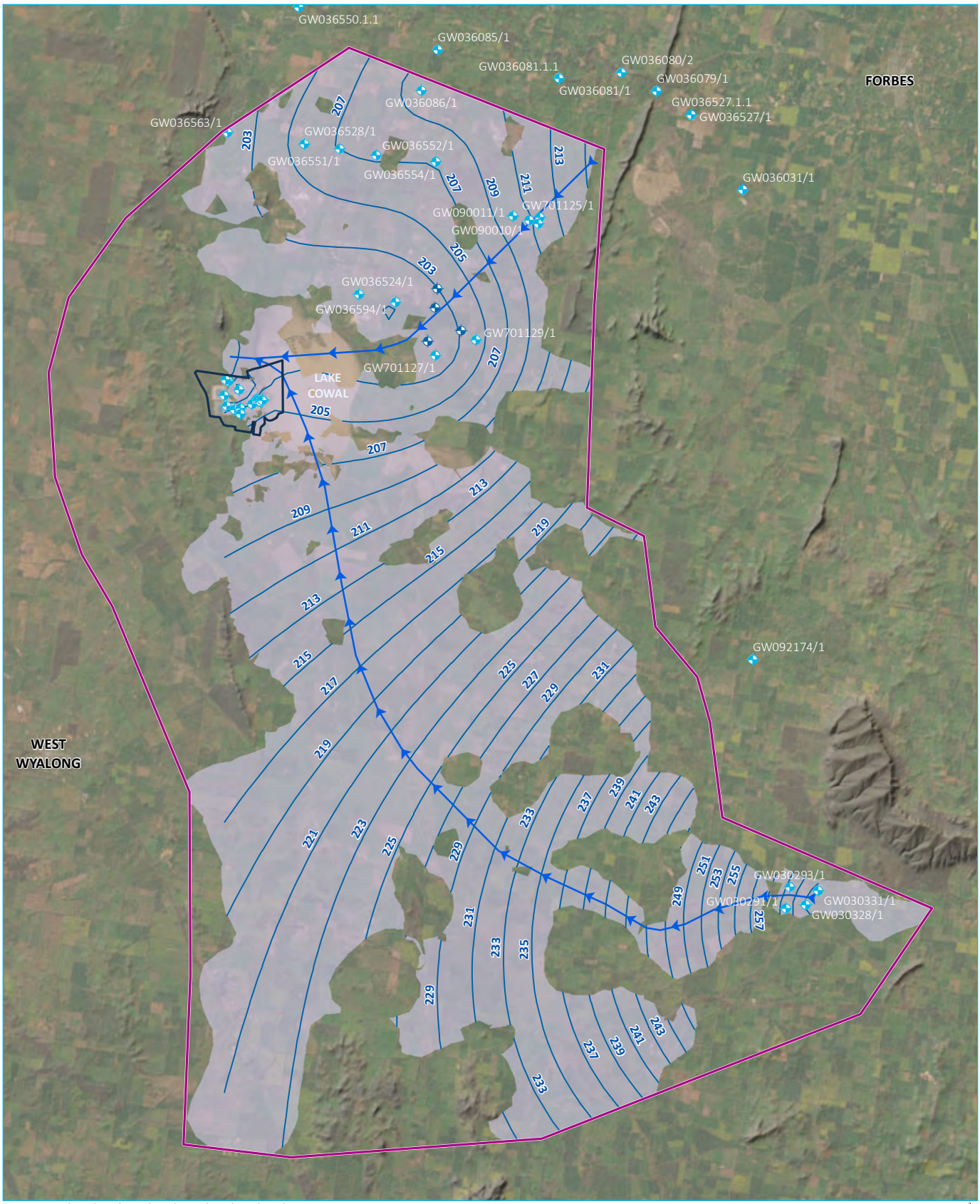
The groundwater table (i.e. phreatic surface) is predominantly within the Upper Cowra groundwater system where present. Beyond the extents of the alluvial groundwater systems, the water table is within the fractured rock groundwater system. Around Lake Cowal the depth to groundwater is between approximately 2–4 m, therefore resulting in a thin unsaturated zone.

Groundwater levels and flow direction in the alluvial groundwater systems are largely influenced by the Lachlan River and local topography. Based on Figure 3.10, Figure 3.11 and Figure 3.12, which show the interpreted groundwater levels for the Upper Cowra Formation, Lower Cowra Formation and Lachlan Formation respectively, flow direction within the alluvial groundwater systems is generally towards the south-west near the Lachlan River within the northern portion of the study area, tending towards an east to west flow direction further south in the study area.

Groundwater levels and flow direction in the fractured rock groundwater system predominantly follow a muted reflection of topography. Based on the measured groundwater contours presented in Figure 3.13, groundwater within the fractured rock groundwater system flows east to west.

Vertical groundwater flow is generally downward within the alluvial groundwater systems (i.e. from the Upper Cowra formation towards the underlying Lower Cowra and Lachlan formations). This is likely exacerbated near large pumping centres extracting groundwater from the Lachlan Formation. Similarly, the Lachlan formation alluvial groundwater system typically flows downward into the fractured rock groundwater system, west of the Project, exacerbated by the geological discontinuities associated with the Gilmore Fault Zone, with the exception of the south-eastern portion of the study area where groundwater level contours indicate an upward flow (i.e. from the fractured rock groundwater system to the overlying Lachlan formation). It is considered the reversal of typical vertical groundwater flow direction in the south-eastern portion of the study area is due to a combination of:

- landholder extraction within the Lachlan alluvial groundwater system
- proximity to recharge zones for the respective groundwater systems (further discussed in Section 4.2).



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

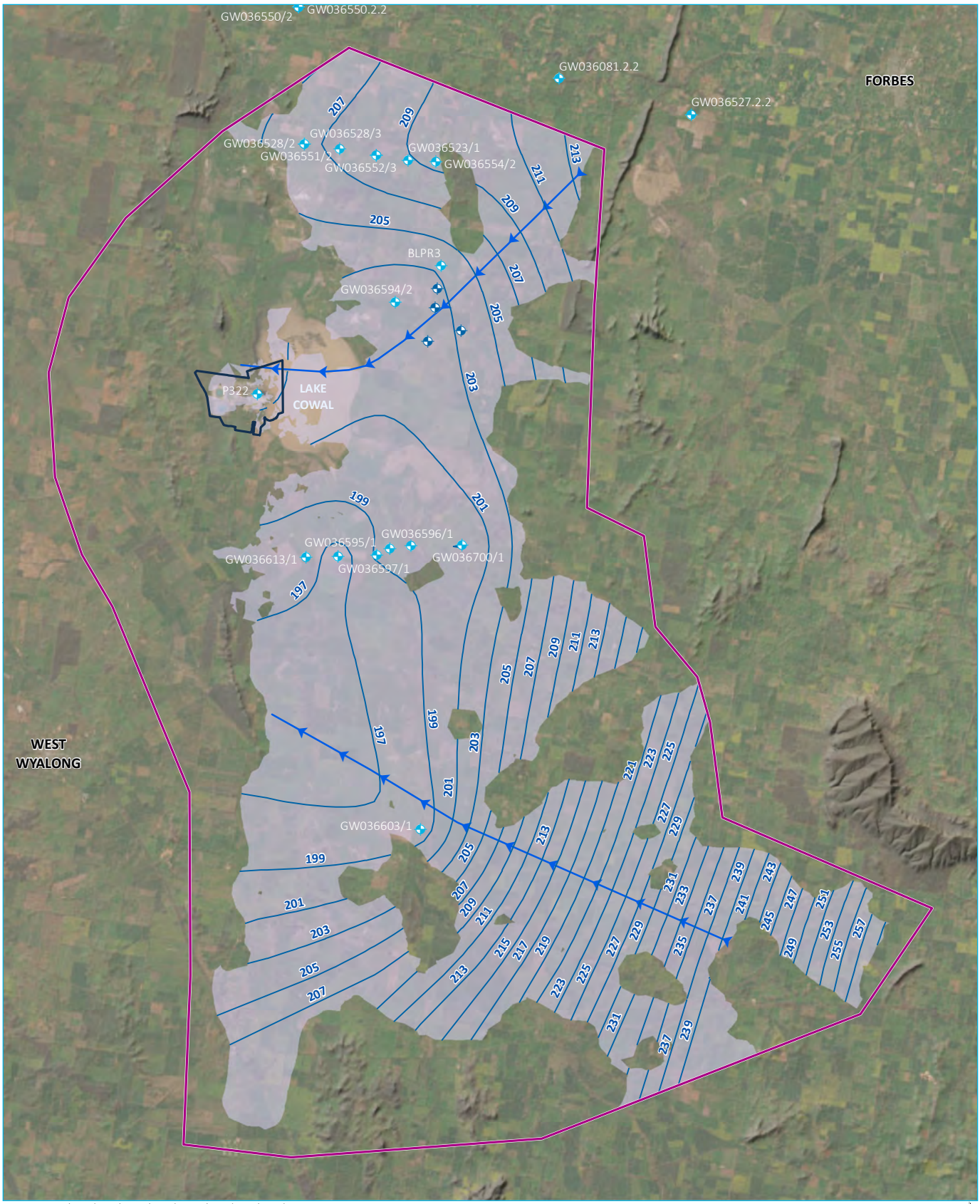
- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Groundwater level point
- Groundwater level contour (mAHD)
- Groundwater flow direction
- Extent of Upper Cowra Formation

Groundwater level contours within the Upper Cowra formation

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 3.10

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA008_UpperCowraGroundwaterSystem_20230426_05.mxd 26/04/2023



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

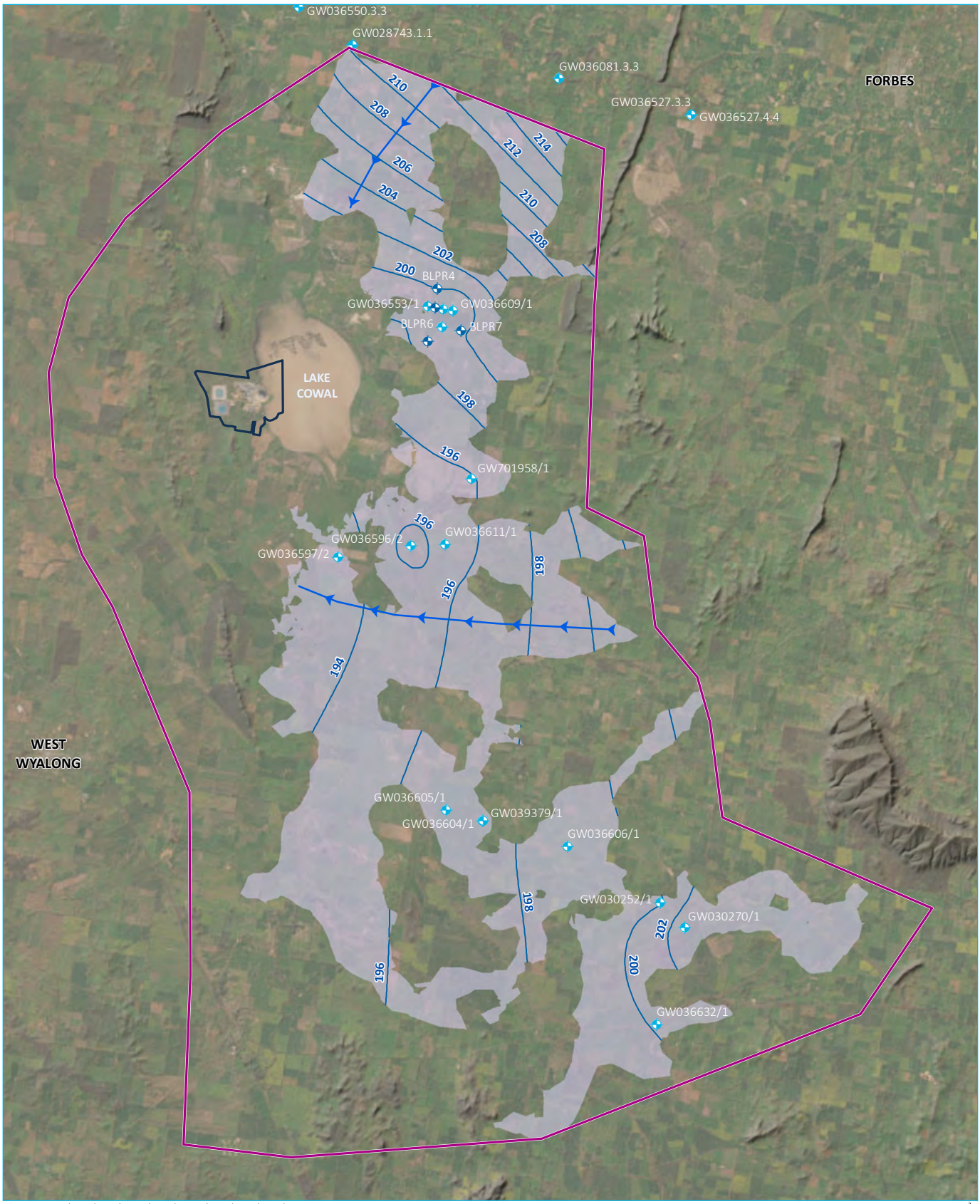
- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Groundwater level point
- Groundwater level contour (mAHD)
- Groundwater flow direction
- Extent of Lower Cowra Formation

Groundwater level contours within the Lower Cowra formation

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 3.11

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA009_LowerCowraGroundwaterSystem_20230426_05.mxd 26/04/2023



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

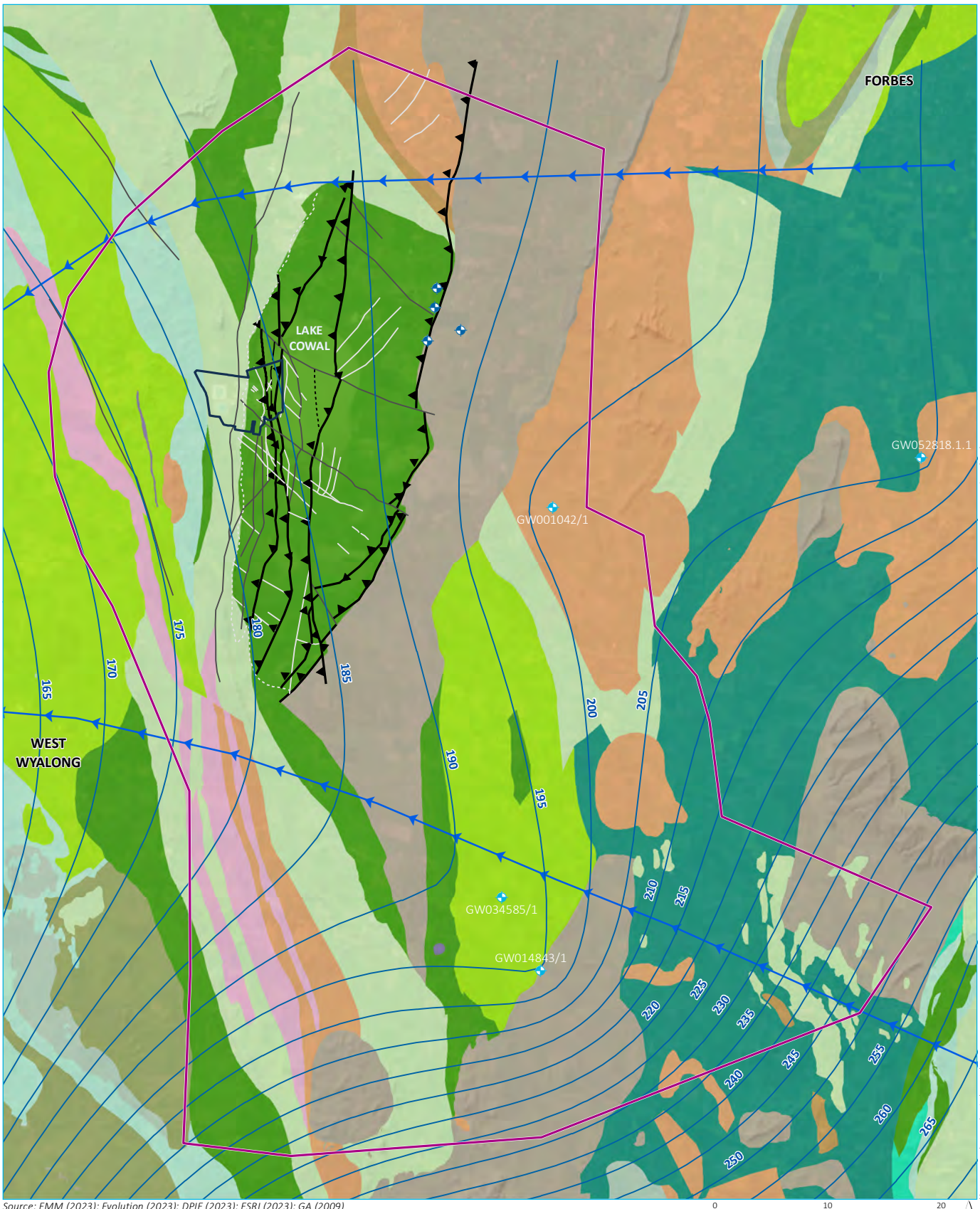
- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Groundwater level point
- Groundwater level contour (mAHD)
- Groundwater flow direction
- Extent of Lachlan Formation

Groundwater level contours within the Lachlan formation

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 3.12

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA010_LachlanFormationGroundwaterSystem_20230426_05.mxd 26/04/2023



Source: EMM (2023); Evolution (2023); DPIE (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMVJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA011_FracturedRockGroundwaterSystem_20230426_05.mxd 26/04/2023

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)

Regional lineaments (Evolution 2022)

- Fault - major
- Fault - minor
- Shear
- Synform
- Thrust
- Unconformity

- Groundwater level point
- Groundwater level contour (mAHD)
- Groundwater flow direction

Lachlan Orogen geology (Colquhoun 2023)

Medial age

- Early Devonian
- Late Devonian
- Devonian
- Ludlow
- Wenlock
- Llandovery
- Silurian
- Early Ordovician
- Middle Ordovician
- Late Ordovician
- Ordovician
- Furongian
- Palaeozoic

Groundwater level contours within the fractured and weathered rock groundwater systems

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 3.13

EMM creating opportunities

i Groundwater levels at trigger bores

Three government monitoring bores serve as groundwater level trigger bores; two provide regional monitoring and one is within the BCP Borefield area. Bore details are provided in Table 3.6, including the prescribed trigger levels, with their location shown in Figure 3.14. These bores are continuously monitored by DPE Water via telemetered in situ level loggers. Bore GW036553 is used for BCP borefield operational compliance, while the other two bores (GW036597 and GW036611) do not govern the operation of this borefield (Coffey 2020b).

Groundwater levels and the associated trigger levels are presented in hydrographs in Figure 3.15, Figure 3.16 and Figure 3.17. There is a slight downwards trend at all monitoring bores, with the greatest overall decrease observed at GW036597, which is in the study areas south. Groundwater levels in the two southern bores, GW036597 and GW036611, both come close to the respective trigger levels in the beginning of 2020 (with the groundwater level at GW036611 being only 0.3 m higher than the trigger level) following sustained drought conditions. It is likely that higher rainfall conditions facilitated less need for groundwater take from 2020 onwards.

Table 3.6 DPI Water trigger bores

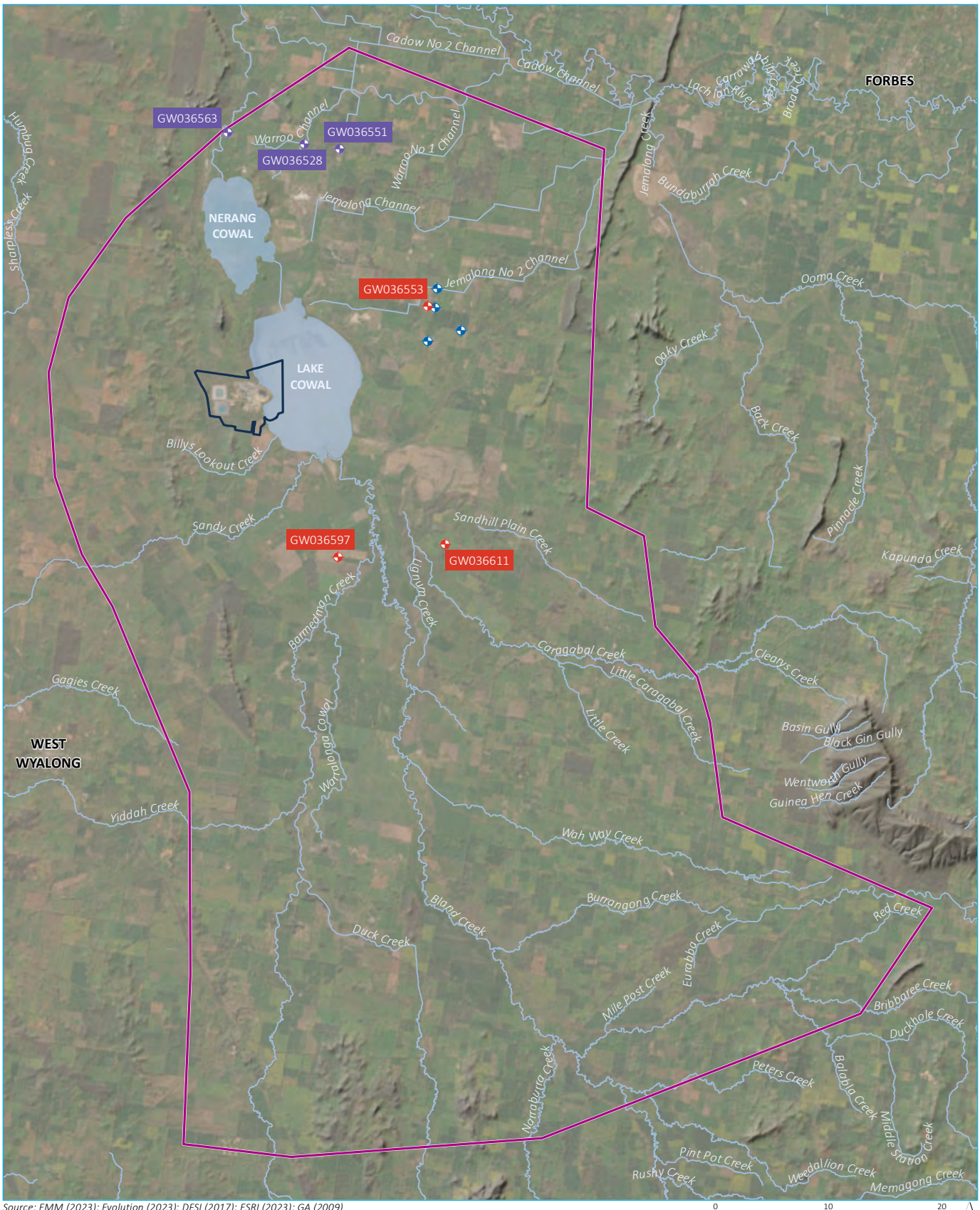
Bore ID	Bore location	Depth (m)	Screen (mbgl[1])	Target lithology	Trigger level (mAHD[2])
GW036553	BCP Borefield area	129	118–126	Sand	137.5 trigger level for investigation 134 trigger level for mitigation
GW036597	Billabong area, west of Bland Creek	106	95.0–98.5	Sand, gravel, clay	143.5 trigger level for investigation
GW036611	Maslin area, east of Bland Creek	124	106.5–112.5	Sand, gravel	145.7 trigger level for investigation

Notes: 1. Metres below ground level
2. Metres Australian height datum

ii Groundwater levels around GDEs

Groundwater levels at three DPE Water groundwater monitoring bores (GW036563, GW036528 and GW036551) in the north-west of the study area were reviewed. These bores were selected for their relative proximity to potential GDEs, while being furthest from the groundwater supply borefields. The locations are also shown in Figure 3.14. All bores targeted sand units and their groundwater hydrographs are presented in Figure 3.18, Figure 3.19 and Figure 3.20. These figures also include the upper and lower percentiles which is equivalent to two standard deviations (this encompasses 95% of all data assuming Gaussian distribution).

Groundwater levels decline in all three monitoring bores around 2003 and increase around 2010. This reflects the approximate inverse of the regional irrigation groundwater abstraction, i.e. when pumping for irrigation is highest between 2004–2010 groundwater levels decline (Figure 3.8). Recent high and sustained rainfall and river levels have contributed to recent increases in groundwater levels.



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA016_GroundwaterLevelTriggerBores_20230426_05.mxd 26/04/2023

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Groundwater level trigger bore
- Groundwater monitoring bore
- Named watercourse
- Named waterbody

DPE Water monitoring bores in proximity to GDEs and trigger bore locations

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 3.14

EMM creating opportunities

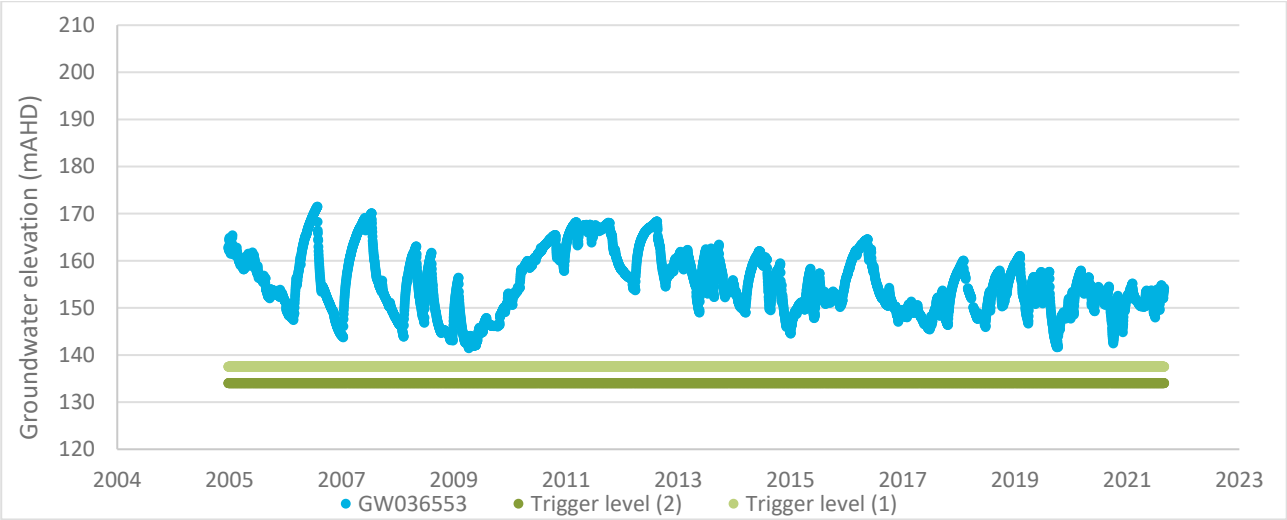


Figure 3.15 Hydrograph, trigger monitoring bore GW036553

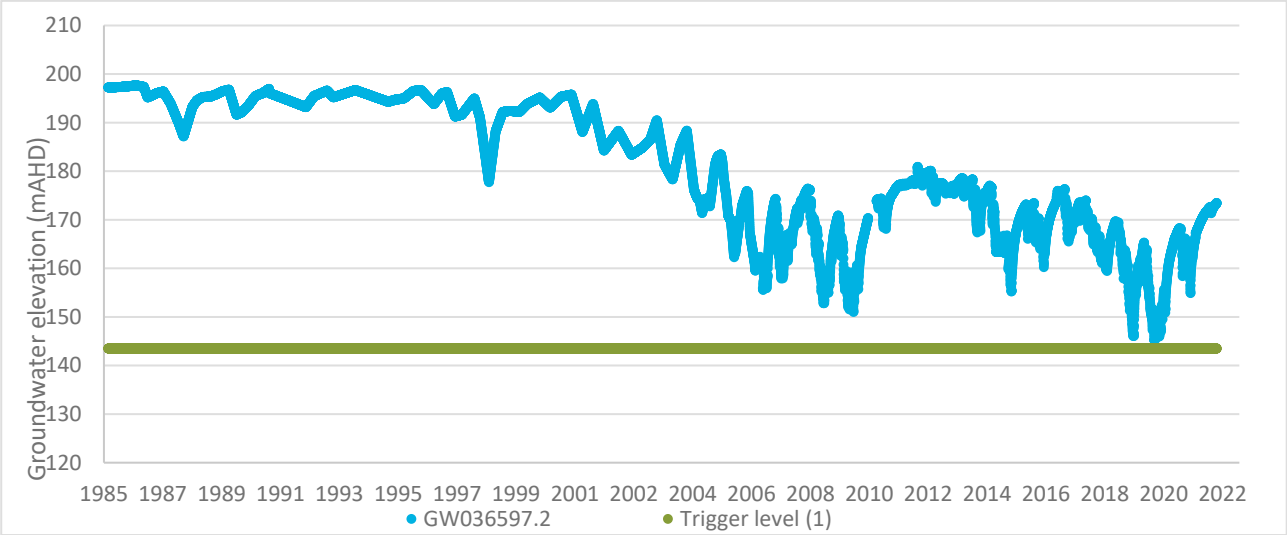


Figure 3.16 Hydrograph, trigger monitoring bore GW036597

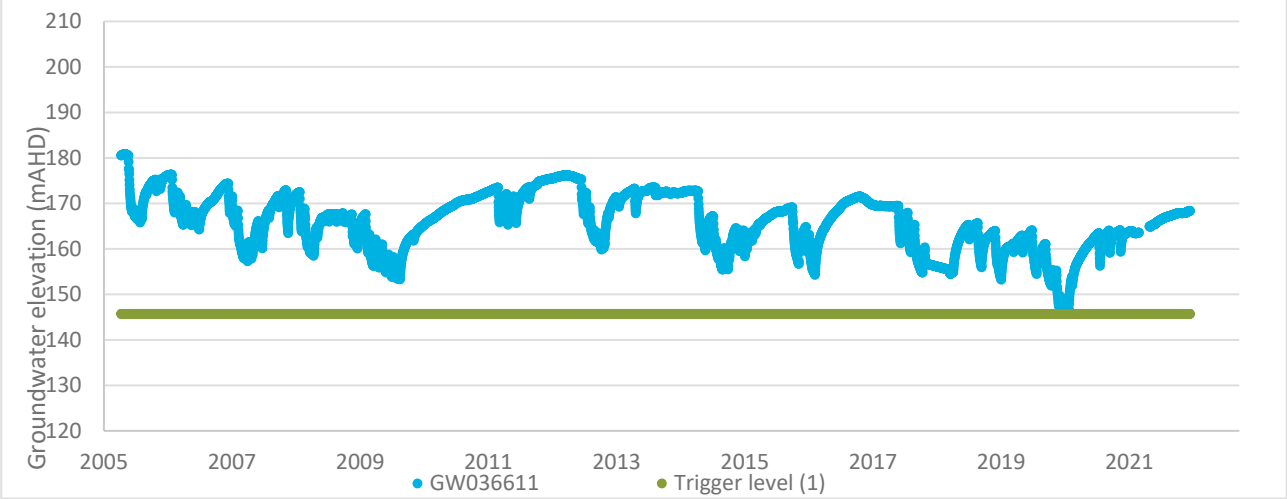


Figure 3.17 Hydrograph, trigger monitoring bore GW036611

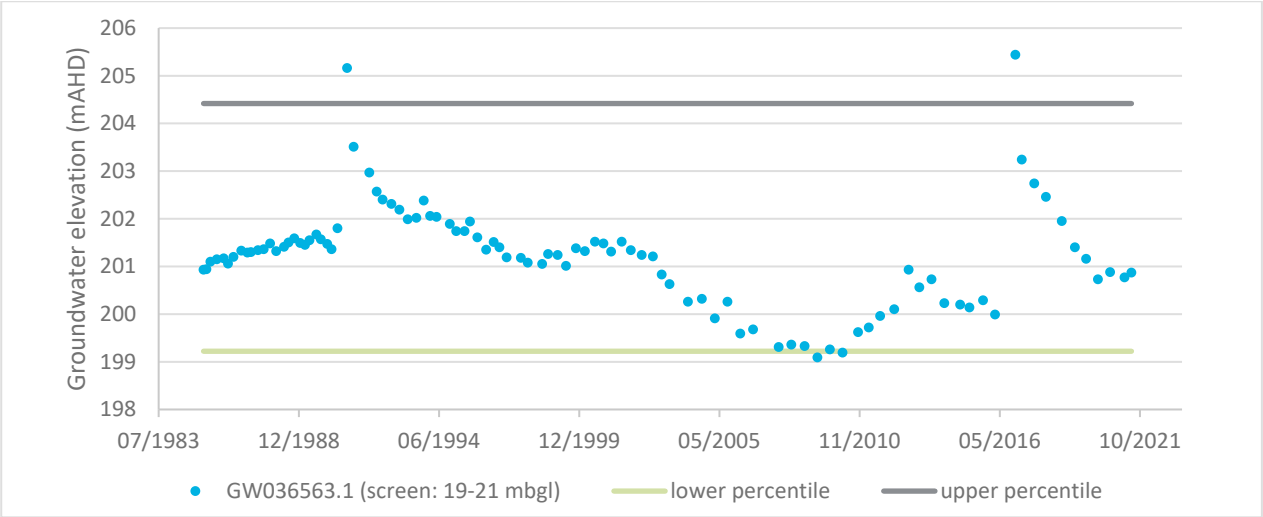


Figure 3.18 **Groundwater elevation GW036563**

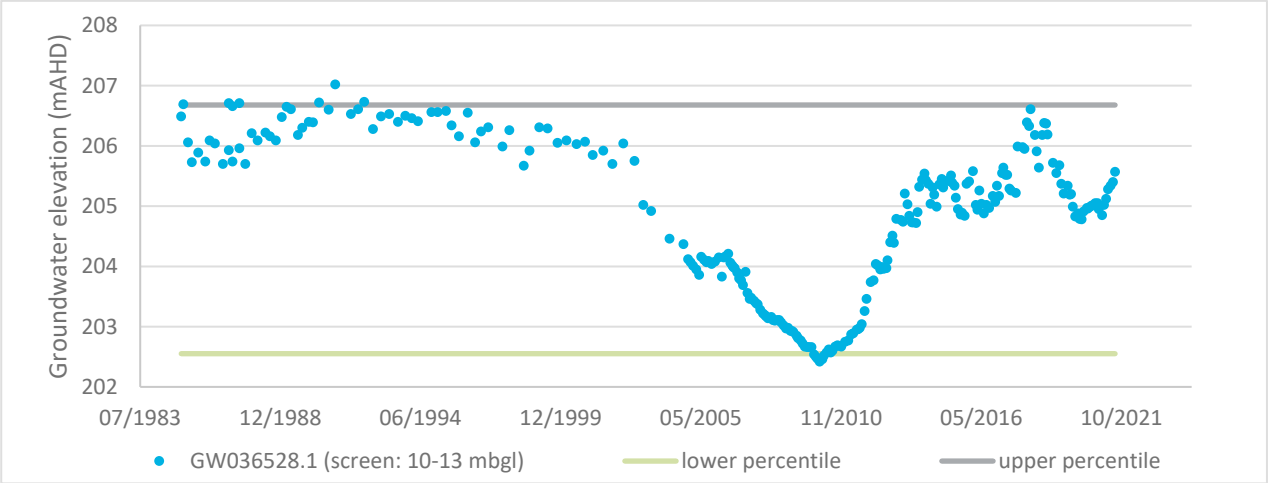


Figure 3.19 **Groundwater elevation GW036528**

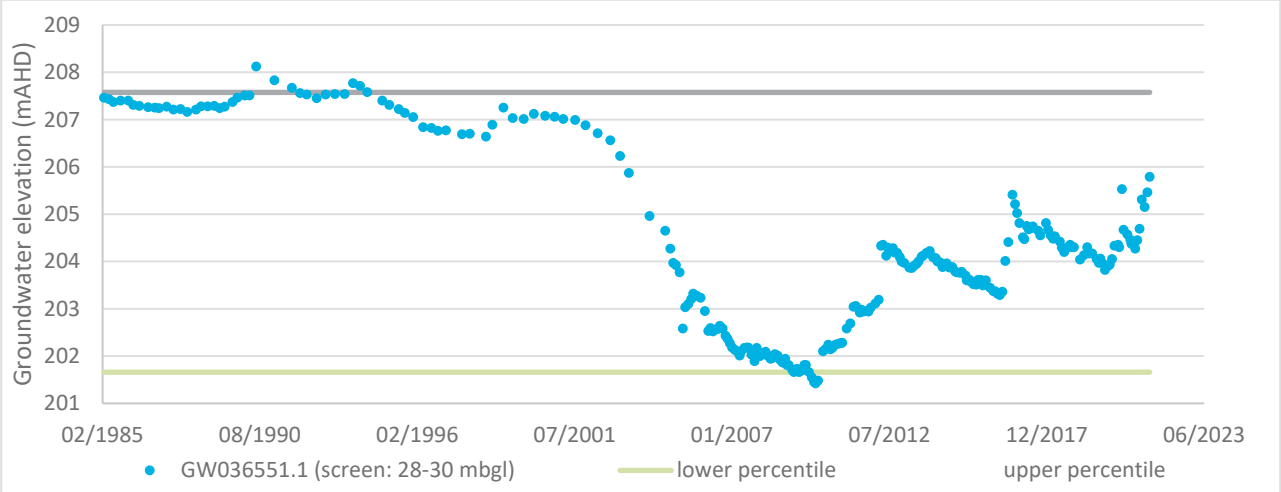


Figure 3.20 **Groundwater elevation GW036551**

3.6.6 Groundwater quality

As discussed in Section 3.6.1, groundwater is typically saline within the study area, with the exception of the Lachlan groundwater system, which is typically brackish. Based on previous studies of the JIA (Lampayan 2001), salinity concentrations are also understood to:

- vary spatially, general decreasing in the alluvial groundwater systems near the Lachlan River (likely due to fresh water recharge)
- be gradually increasing within the region, predominantly due to irrigation induced rising water tables, leading to dryland salinity.

Groundwater monitoring undertaken within the Project area indicates pH is slightly acidic to neutral, with the exception of groundwater near the IWL where the pH is acidic (i.e. between 4.5 and 6 pH units) (Coffey 2020a).

Cyanide is used in the gold extraction process and can potentially leach into groundwater at the existing IWL. However Coffey (2020a) reported that the groundwater quality monitoring indicates cyanide has not been observed at significant concentrations in groundwater. The naturally metalliferous geological host rocks can influence metal concentrations in groundwater, as can CGO operations.

3.7 Geochemistry

A range of geochemical investigations have been conducted for CGO on the mine rock, surface material, waste rock (primary waste rock and oxide), low-grade ore (LGO), ore, and tailings, as detailed in Table 3.1. These have been summarised and expanded on in the recent 2023 geochemical investigation commissioned in support of the CGO Open Cut Expansion Project ((GEM, Cowal Gold Operations Open Cut Expansion Project Environmental Geochemistry Assessment 2023); Appendix E.2 of the EIS). The primary findings of the geochemical assessments for the waste rock, LGO and ore, and tailings are outlined below.

3.7.1 Waste rock

The findings of the 2023 geochemical assessment (Appendix E.2 of the EIS) are generally consistent with the findings from the previous investigations, and are summarised as follows:

- The oxide waste rock is saline and sodic. Investigations also indicated a lack of reactive sulfide within the oxide waste rock samples, which precludes extensive acid generation. Due to a low acid neutralisation capacity (ANC) within the oxide waste rock, these samples have been classified as non-acid forming (NAF) to barren.
- Primary (fresh) waste rock is non- to slightly saline and non- to slightly sodic. In contrast to the oxide waste rock, primary waste rock was found to contain relatively high reactive sulfide; however, the primary waste rock also contains relatively high ANC, is typically NAF and may be acid consuming in some instances. Oxidation of reactive sulfide in the primary waste rock is therefore expected to be neutralised by the available ANC, which will limit acid generation, although there is a risk that drainage from this waste rock will become saline.
- In the 2023 study, one sample of the primary volcaniclastic waste rock from the E41 East deposit was classified as potentially acid forming (PAF), in contrast to the findings of the previous investigations.

- The waste rock is typically enriched with arsenic and antimony, with some samples found to be enriched with silver, cadmium and selenium. Leach testing identified molybdenum and selenium as potentially readily soluble under the prevailing near neutral to slightly alkaline pH conditions of the tests. However, sequential batch water extractions indicated that leaching of environmentally important elements from waste rock at CGO was unlikely to be of concern provided near neutral pH values were maintained.

3.7.2 LGO and ore stockpiles

The LGO and ore characterisation in the 2023 geochemical assessment (Appendix E.2 of the EIS) is generally consistent with the previous investigations, with the exception that a number of PAF samples were identified within the E41 East deposit. The primary findings are:

- The LGO and ore is to be non-saline. Reactive sulfides are, however, present in the samples tested and although most samples are classified as NAF, a number of samples from the E41 East deposit are PAF or PAF low capacity (PAF-LC). In addition, although most LGO and ore is expected to have sufficient acid buffering capacity, the reactive sulfides may result in an increase in salinity following exposure on the surface of the LGO and ore stockpiles.

- The LGO and ore is enriched in arsenic and antimony, with some samples also enriched in silver, cadmium, copper, mercury, selenium and zinc. Leach testing found arsenic, molybdenum and selenium to be readily soluble.

3.7.3 Tailings

Previous and recent investigations into CGO tailings geochemical characteristics are summarised as follows:

- Geochemical investigations on tailings samples indicate that these are generally low in salinity and are non-sodic. The presence of reactive sulfides has been noted in a number of tailings samples; however, the presence of ANC within these samples is expected to limit acid generation and the majority of the tailings are classified as NAF.

- The 2023 geochemical study used ore and LGO samples as proxies for tailings and identified the potential occurrence of small quantities of PAF ore and PAF LGO in the E41 deposit, which may present the risk of acidifying on exposure.

- Elemental analyses conducted on the tailings samples predict high concentrations of arsenic, cadmium, lead, molybdenum, antimony and zinc. Kinetic leach column tests conducted on tailings samples identified the potential for an initial ‘flush’ of soluble copper and zinc from primary tailings. However, it was concluded that this release was most likely to be associated with residual cyanide in the tailings liquor/supernatant from the carbon-in-leach processing procedure and did not represent a long-term concern for water quality.

3.8 Sensitive receivers

3.8.1 Landholder bores

Water users within the study area predominantly access surface water from the Lachlan River (facilitated by the JIA, refer Section 3.4) and groundwater from the Lachlan alluvial groundwater system.

Based on the NGIS database (BoM 2022), there are 312 bores listed within the study area as active, in use or unknown (conservatively assumed to be active for the purpose of this GIA). Groundwater bores that likely provide supply for water users within the study area comprise of:

- commercial and industrial bores (1)
- irrigation bores (21)
- stock and domestic bores (89)
- water supply bores (115)
- dewatering (15)
- unknown and other bores, conservatively assumed to be active for supply (71).

Further detail is provided in the bore summary table in Attachment E. Locations of registered groundwater bores are presented on Figure 3.21. Estimated historical usage has been shown previously in Figure 3.8.

3.8.2 Groundwater dependent ecosystems

Mapping provided in the Lachlan Alluvial WSP indicates that high priority groundwater dependent ecosystems (GDEs) may be found within the study area. Further assessment indicates the high priority GDEs align with the terrestrial GDEs categorised as high–very high priority within the publicly available High Ecological Values Aquatic Ecosystems (HEVAE) GDE dataset (DPE 2022f), and generally align with:

- aquatic GDEs categorised as high potential within the publicly available GDE atlas (BoM 2017)
- important wetlands, as provided in the Directory of Important Wetlands in Australia (DIWA) dataset (DCCEEW 2010), although these are greater in extent.

RAMSAR wetlands are not mapped within the study area (DCCEEW 2022). Further assessment of GDEs, including ground-truthing and dependency is provided in the *Biodiversity Development Assessment Report* (EMM 2023), Appendix J of the EIS.

A summary of relevant aquatic and terrestrial GDEs is provided in Table 3.7 and Table 3.8 respectively. Locations of relevant GDEs are presented in Figure 3.22.

Table 3.7 Aquatic groundwater dependent ecosystems within study area

Name	Groundwater dependence potential (BoM GDE Atlas)	DIWA important wetland	RAMSAR wetland	Mapped area (Ha)
Lake Cowal/Wilbertroy wetlands	High	Yes	No	13,382.8
Nerang Cowal	High	Yes	No	5,617.5
Wetlands (other than Nerang Cowal)	High	No	No	23,667.8

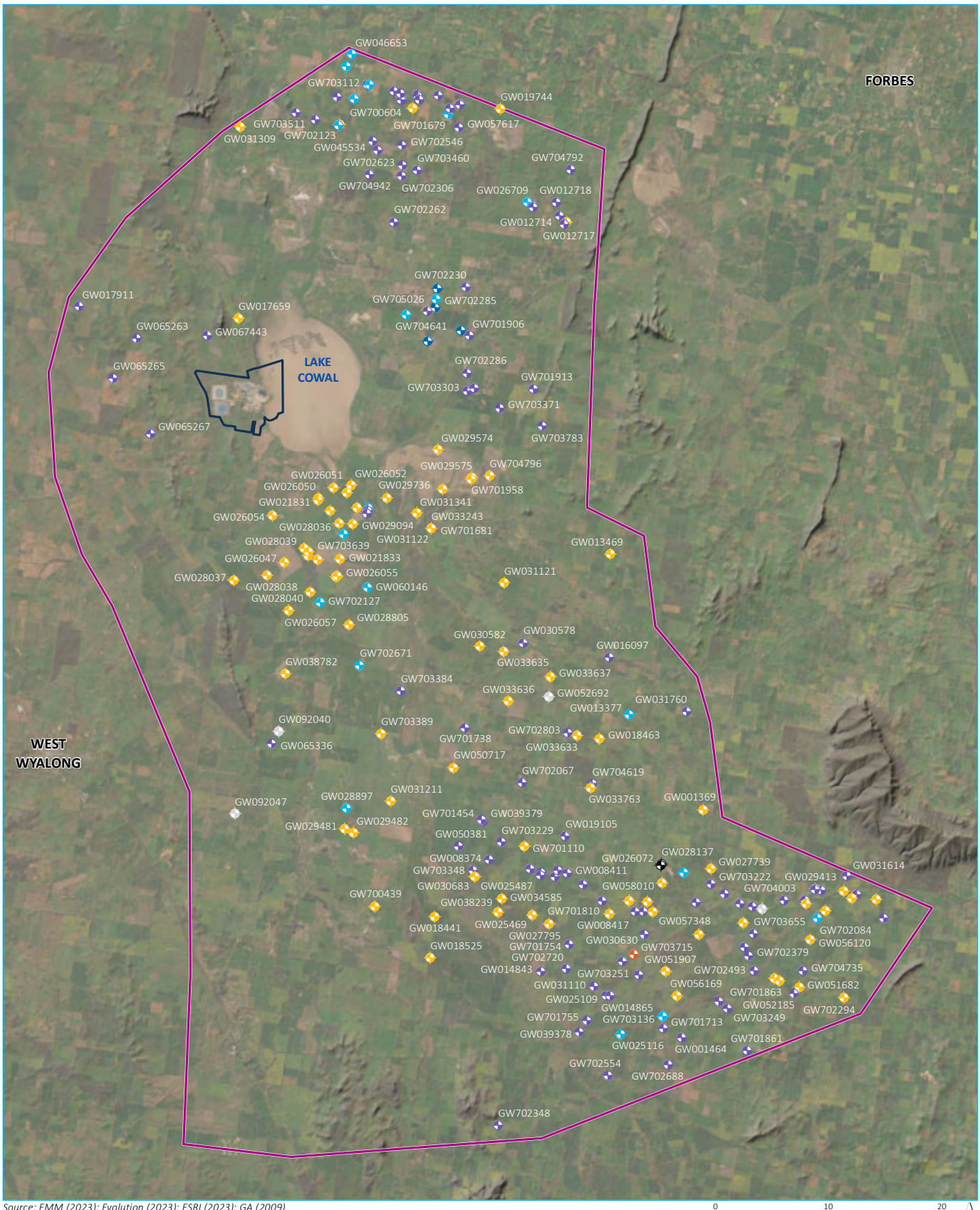
Source: (BoM 2017) (DCCEEW 2010) (DCCEEW 2022)

Table 3.8 Terrestrial groundwater dependent ecosystems within the study area

PCT	Name	HEVAE Category	DPE priority	[1]Mapped area (Ha)
2	River Red Gum-sedge dominated very tall open forest in frequently flooded forest wetland along major rivers and floodplains in south-western NSW	High	High	428.2
5	River Red Gum herbaceous-grassy very tall open forest wetland on inner floodplains in the lower slopes sub-region of the NSW South Western Slopes Bioregion and the eastern Riverina Bioregion.	High	High	267.2
10	River Red Gum – Black Box woodland wetland of the semi-arid (warm) climatic zone (mainly Riverina Bioregion and Murray Darling Depression Bioregion)	High	High	14.4
11	River Red Gum – Lignum very tall open forest or woodland wetland on floodplains of semi-arid (warm) climate zone (mainly Riverina Bioregion and Murray Darling Depression Bioregion)	High	High	164.6
26	Weeping Myall open woodland of the Riverina Bioregion and NSW South Western Slopes Bioregion	High	High	5.2
53	Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains	High	High	13.0
55	Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	High	High	107.2
76	Western Grey Box tall grassy woodland on alluvial loam and clay soils in the NSW South Western Slopes and Riverina Bioregions	High	High	12.8
80	Western Grey Box – White Cypress Pine tall woodland on loam soil on alluvial plains of NSW South Western Slopes Bioregion and Riverina Bioregion	High	High	485.2
185	Dwyers Red Gum – White Cypress Pine – Currawang shrubby woodland mainly in the NSW South Western Slopes Bioregion	High	High	53.4
248	Mixed box eucalypt woodland on low sandy-loam rises on alluvial plains in central western NSW	High	High	0.02
249	River Red Gum swampy woodland wetland on cowals (lakes) and associated flood channels in central NSW	High–very high	High	2,009.1

Source: (DPI 2016), (DPE 2022f)

Notes: 1. Within the study area



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA012_SenitiveReceiverBores_20230426_04.mxd 26/04/2023

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)

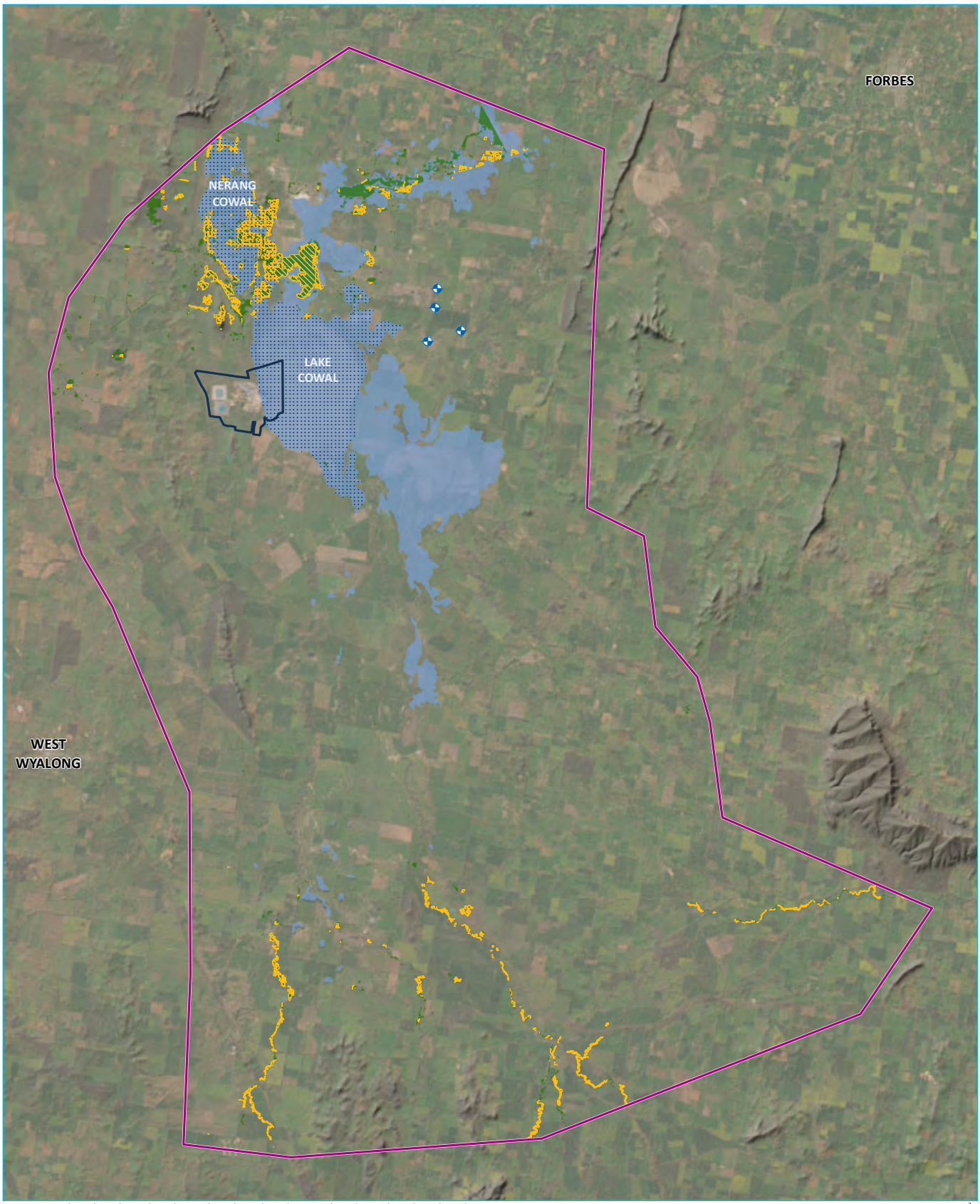
Registered bore

- Water supply
- Stock and domestic
- Irrigation
- Commercial and industrial
- Other
- Unknown

Sensitive receivers
- registered groundwater bores

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 3.21

EMM
creating opportunities



Source: EMM (2023); Evolution (2023); BoM (2023); DPI (2023); HEVAE (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Important wetlands (DIWA)
- Aquatic GDE (BoM)
- Terrestrial GDE (BoM)
- High priority GDE (DPI-Water) (HEVAE)

Sensitive receivers
- Groundwater dependent ecosystems

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 3.22

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA013_SenitiveReceiverGDEs_20230426_05.mxd 26/04/2023

4 Site hydrogeological conceptual model

4.1 Overview

A conceptual model describes the key processes in the hydrological and hydrogeological environment. It is based on hypotheses and assumptions, some of which will be derived from data sourced from the water environment under investigation and others will be based on general hydrogeological or hydrological principles.

The conceptual model further develops the Project hydrogeological setting, forming the basis of assumptions adopted in the numerical models and informing predictions of Project-induced water-related impact(s).

Two hydrogeological conditions are presented, comprising:

- Section 4.2 – Existing conditions prior to mine operation, generally based on site specific and regional groundwater monitoring data around 1997.
- Section 4.3 – Conditions during mining (prior to the Project), generally based on site specific and regional groundwater monitoring data around 2022.

4.2 Pre-existing conditions prior to mine operation

4.2.1 Alluvial groundwater system mechanisms

Recharge to the alluvial groundwater systems is primarily from surface water infiltration below the:

- Lachlan River
- irrigation channels within the JIA
- intermittently from the Lachlan River floodway during flooding (Lampayan 2001).

Rainfall infiltration forms a relatively minor component of recharge to the alluvial groundwater systems, noting the low infiltration potential of the surficial soils discussed Section 3.5.1. Leakage from Lake Cowal can also recharge the underlying alluvial groundwater, where there are cracks and opening in the uppermost clay layer, however this is also expected to be minor in comparison to recharge from the Lachlan River and irrigation channels as discussed in Section 4.3.2.

Discharge mechanisms from the alluvial groundwater systems generally include:

- Flow into the underlying fractured rock groundwater system, noting the predominantly downward groundwater gradient discussed in Section 3.6. Discharge into the fractured rock is likely to be significantly higher west of the Project, exacerbated by the geological discontinuities associated with the Gilmore Fault Zone.
- Extraction by private water users.

4.2.2 Fractured rock groundwater system mechanisms

Recharge to the fractured rock systems occurs via:

- rainfall within areas of relatively high infiltration, generally located east of the study area
- discharge from overlying alluvial aquifers (where present), noting the discharge mechanisms discussed in Section 4.2.1.

The fractured rock groundwater system discussed within this GIA is part of a significantly larger, regional system contained within the LFB. Discharge of that regional groundwater system is not inferred as part of this assessment and is not considered a key conceptual mechanism applicable to the Project. Based on groundwater level contours (refer Figure 3.13), the discharge zone of the fractured rock groundwater system is assumed to be further south-west of the study area.

4.3 Conditions during existing mining (prior to the Project)

4.3.1 Changes to hydrogeological conceptual model during mining

The conceptual model discussed in Section 4.2 is generally consistent with the hydrogeological conditions during mining (prior to the Project), noting the following relevant variations:

- Development of voids within the Project area intercepting groundwater from the Upper Cowra, Lower Cowra and fractured rock groundwater systems, including the pit (Pit E42), with an approved maximum depth of -331 mAHD.
- Creation of the IWL and WREs
- Creation of the following water supply borefields:
  - BCP borefield, extracting groundwater from the Lachlan groundwater system for mine water supply.
  - ES borefield, extracting water from the Lower Cowra groundwater system for mine water supply.
  - Saline borefield, extracting water from the Lower Cowra groundwater system for mine water supply.
- Inflow of groundwater from the Upper Cowra, Lower Cowra and fractured rock groundwater system to Pit E42 inferred from localised drawdown in the eastern portion of the Project area and extending up to 1.5 km from the centre of Pit E42. The Lachlan Formation does not extend to the west, where mining is proposed and is limited to the deeper parts of the palaeochannel.
- A relatively elevated water table (compared to existing conditions prior to mining, refer Section 4.2) across the remainder of the study domain, as inferred from groundwater depth mapping. Likely induced by:
  - Significantly above average rainfall (refer Section 3.3) outside the Project area.
  - Seepage from the IWL and WREs within the western portion of the Project area.

Depth to groundwater contours based on measured data are presented on Figure 4.1 and Figure 4.2 prior to, and during mining respectively.

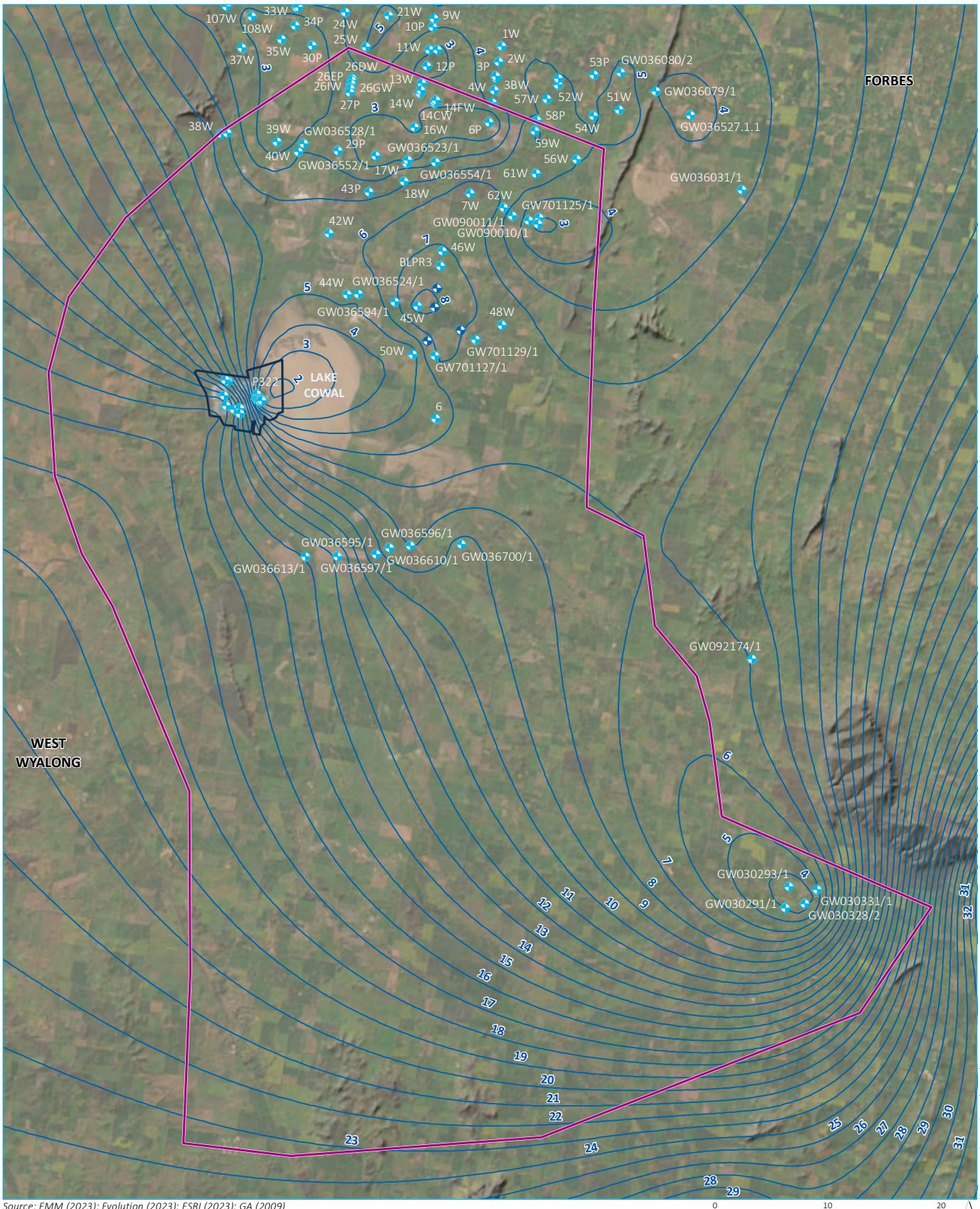
4.3.2 Surface water and groundwater connectivity

Based on a multi-variate analysis of groundwater level trends and water quality data (presented in Attachment G), there is a clear difference in hydro-chemical signatures within the Lake Cowal surface water system and all groundwater systems assessed within the study area. The groundwater level trend analysis showed that all hydrostratigraphic units are strongly influenced by rainfall trends. No bores were primarily influenced by either lake levels or CGO borefield groundwater pumping trends.

There is clear hydrochemical separation between the lake samples and Lachlan Formation samples showing that these populations are hydraulically separated with no overlap (i.e. there is no connection between the lake and the palaeochannel). There is also a clear segregation of water quality signature between the lake and the more saline Cowra Formation and weathered bedrock (which includes the bores around the mining area). The underground mine water samples are compatible with the Cowra Formation and weathered bedrock and show no compatibility with the lake. The separation of surface water systems is hypothesised to be due to the very low hydraulic conductivity properties of the Lacustrine Clay layer overlying the alluvial groundwater systems. Based on this analysis:

- There is no definitive evidence of hydraulic connection between the lake and the bores around Pit E42 and the underground.
- There is no evidence of hydraulic connection between the palaeochannel (i.e. the BCP pumping bores and the ES pumping bores) and the lake, or the palaeochannel and Pit E42 or the underground.

Review of depths to groundwater in Figure 4.1 and Figure 4.2 indicate there is slight groundwater mounding emanating under Lake Cowal. This could suggest that the Lake system is a losing and disconnected system, with groundwater receiving gradual long-term seepage from the Lake when full, which is restricted by the Lacustrine Clay layer.



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

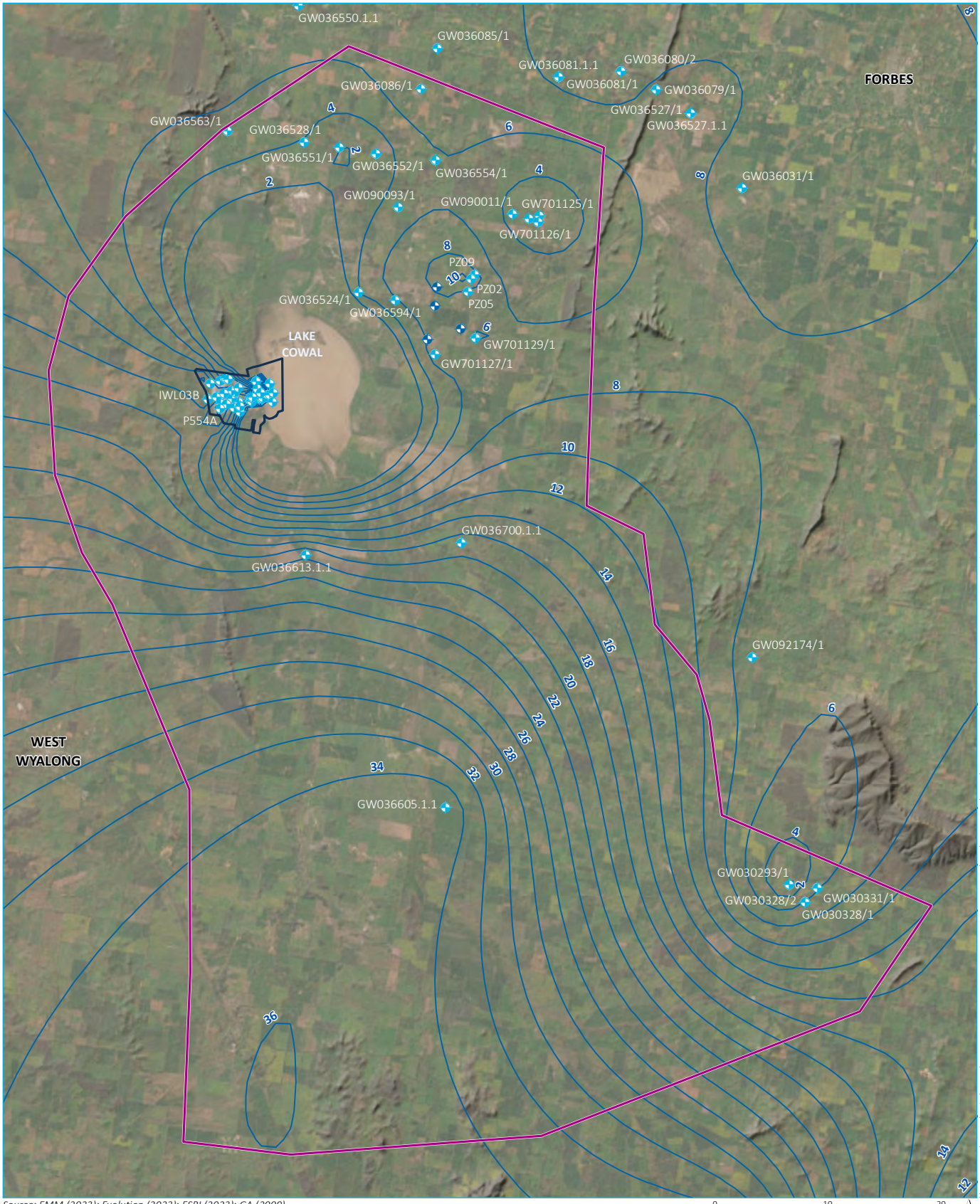
- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Groundwater level point
- Groundwater level contour (m BGL)

Depth to groundwater - Prior to mining

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 4.1

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA006_DepthToGroundwaterPreMining_20230426_04.mxd 26/04/2023



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMM\Jobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA007_DepthToGroundwaterDuringApprovedMining_20230426_06.mxd 26/04/2023

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Groundwater level point
- Groundwater level contour (m BGL)

Depth to groundwater - during mining (prior to the project)

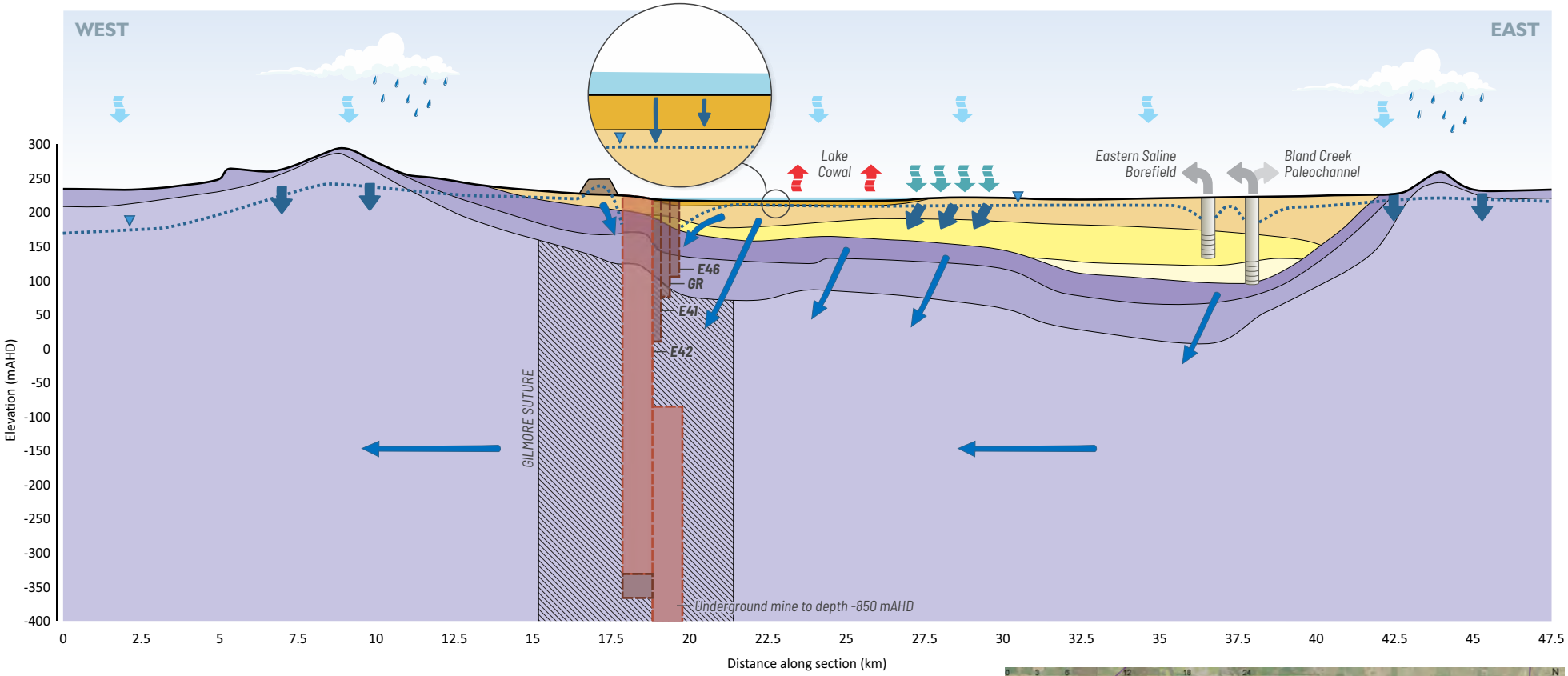
Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 4.2

EMM creating opportunities

4.4 Hydrogeological conceptual model

Graphical representations of the hydrogeological conceptual model are shown in Figure 4.3 and Figure 4.4. These figures include hydrostratigraphic units, groundwater stresses and groundwater flow direction. The conceptual models show the following main attributes:

- The mine is located on the western edge of the palaeochannel, with only the Lacustrine clay and the Upper Cowra Formation existing in the vicinity of the mine.
- Irrigation and rainfall are the main recharge mechanisms. Locally, groundwater systems are recharged by the Lachlan River, irrigation channels, and intermittently from the Lachlan River floodway during flooding.
- The main flow direction is downwards from the palaeochannel sediments to the underlying fractured rock system. Groundwater then continues to flow west and discharges outside of the Project area.
- Evapotranspiration is the main discharge mechanism from the shallow groundwater system, especially during wetter periods when the lakes are full.
- Minor seepage occurs from these lakes; however recharge is limited by the low hydraulic conductivity of the Lacustrine Clay, deposited directly beneath the lakes.
- Inflow of groundwater from the Upper Cowra, Lower Cowra and fractured rock groundwater system flows into Pit E42, causing local drawdown.
- Tailings deposition and WREs induce local groundwater mounds beneath these facilities.



HYDROSTRATIGRAPHY

CENOZOIC

- Lacustrine Clay
- Upper Cowra Formation
- Lower Cowra Formation
- Lachlan Formation

PALEOZOIC

- Saprolite (of the respective underlying rock)
- Saprock (of the respective underlying rock)
- Fresh rock

LEGEND

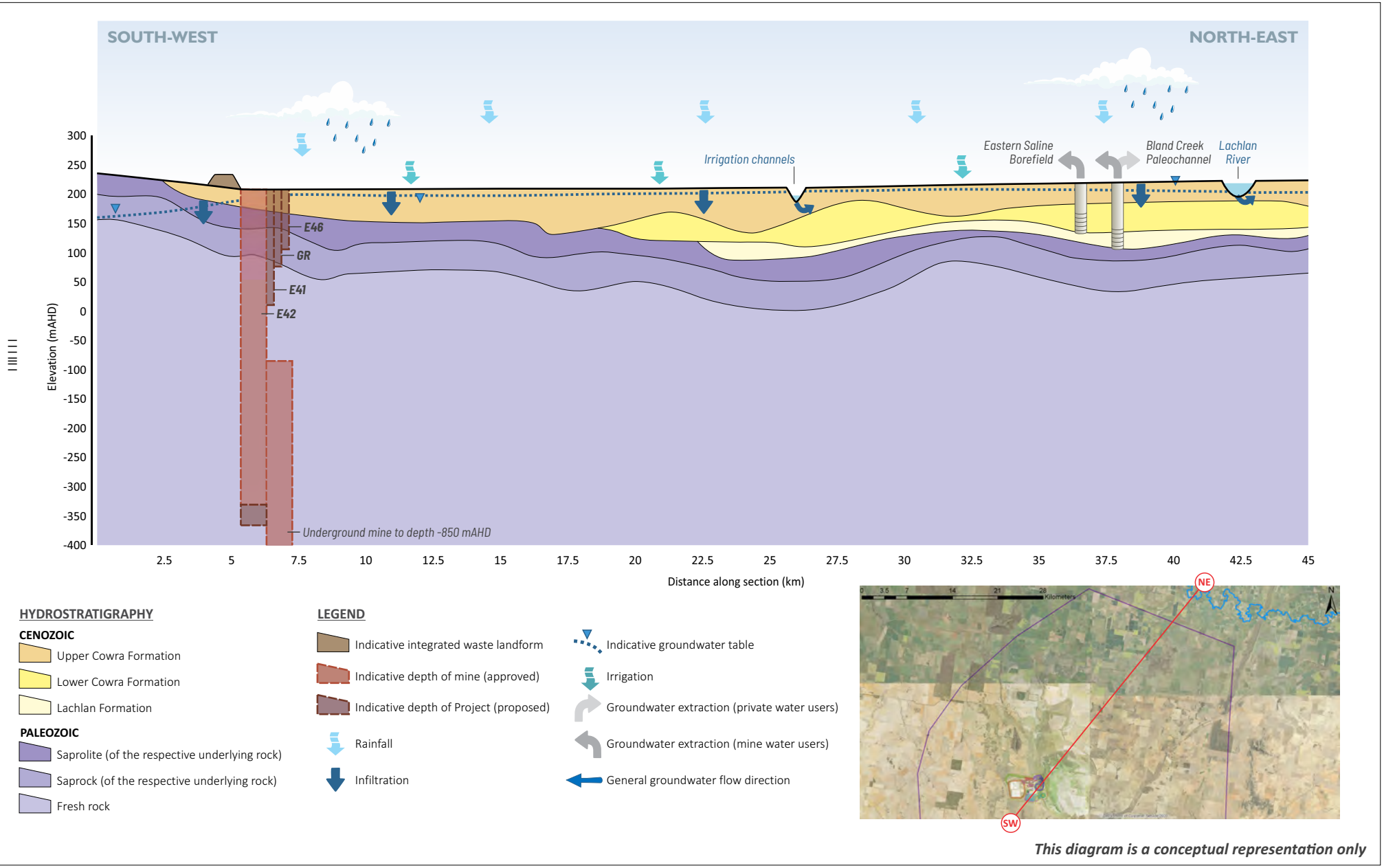
- Indicative integrated waste landform
- Indicative depth of mine (approved)
- Indicative depth of Project (proposed)
- Fracture zone
- Rainfall
- Infiltration
- Indicative groundwater table
- Irrigation
- Evaporation
- Groundwater extraction (private water users)
- Groundwater extraction (mine water users)
- General groundwater flow direction

This diagram is a conceptual representation only

Conceptual hydrogeological section – east to west

Evolution Mining Limited
Groundwater Impact Assessment
Figure 4.3

EMM
creating opportunities



Conceptual hydrogeological section – southwest to northeast

Evolution Mining Limited
Groundwater Impact Assessment
Figure 4.4

EMM
creating opportunities

5 Assessment approach

The Project will intercept groundwater and has the potential to result in changes to the existing groundwater regime. The Project will result in additional depressurisation and intersection of the hydrogeological units directly targeted by mining. However, because the Project area already comprises active and approved mining, the potential for the Project to result in a significant incremental impact on groundwater resources is reduced due to existing and approved impacts and existing depressurisation.

The National Water Commission developed guidelines and a risk framework for assessing local and cumulative effects of mining activities on groundwater systems (Moran C 2010). The framework defines the following four possible direct groundwater effects arising from a project:

- altered groundwater quantity (groundwater levels, pressures and fluxes)
- altered groundwater quality (concentration of salts and other important water quality constituents)
- altered surface water – groundwater interaction
- physical disruption or removal of aquifers (excavation quarry pits).

Direct effects encompass the changes to physical and/or quality aspects of groundwater due to water affecting activities, or the changes to the physical characteristics of aquifers affected by these activities. Indirect effects of water affecting activities are those that arise in response to direct effects (Moran C 2010) and general effects sensitive receptors. The sensitive receptors that have been identified include:

- landholder bores used for irrigation, commercial and industrial, and stock and domestic purposes
- ecosystems that potentially rely on groundwater (terrestrial vegetation and aquatic ecosystems)
- watercourses, drainage lines, creeks and springs.

5.1 Assessment criteria

The assessment of potential Project related impacts on water resources and water users considers the requirements of the WM Act, relevant WSPs and the AIP and other guidelines.

5.1.1 Aquifer Interference Policy

The AIP defines water sources as being either 'highly productive' or 'less productive' based on levels of salinity and average yields from bores. There is only one 'highly productive' groundwater system in the study area, being the Lachlan groundwater system. The remainder of the groundwater systems are 'less productive'. The AIP further defines water sources by their lithological character, comprising either: alluvium, coastal sand, porous rock or fractured rock, and provides minimal impact considerations.

Minimal impact considerations have been developed for impacts on groundwater sources, connected water sources, and their dependent ecosystems, culturally significant sites and water users. For each category, the AIP identifies thresholds for minimal impact considerations. These thresholds relate to impacts on the watertable, 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' and the aspects applicable for the project have been reproduced in Table 5.1 (for alluvial and fractured rock water sources). DPI Water's assessment framework for aquifer interference is included (and completed) in Attachment B.

The AIP requires cumulative groundwater related impacts to be considered. The National Water Commission (Moran C 2010) defines cumulative effects as "the successive, incremental and combined effects of an activity on society, the economy and the environment". For this Project cumulative activities include the three new pits, the deepening of the existing pit, rising of the IWL and continuation of borefield pumping (refer to Table 5.5), as well as continued pumping of existing landholder bores.

Table 5.1 AIP Minimal impact considerations

Watertable	Water pressure	Water quality
Highly productive alluvial aquifers – *Lachlan groundwater system*		
1. Less than or equal to a 10% cumulative variation in the watertable, allowing for typical climatic 'post-WSP' variations, 40 m from any: a) high priority GDE, or b) high priority culturally significant site listed in the schedule of the relevant WSP. A maximum of a 2 m decline cumulatively at any water supply work.	1. A cumulative pressure head decline of not more than 40% of the post-WSP pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.	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. No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. 3. No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the 3D extent of the alluvial water source – whichever is the lesser distance) of a highly connected surface water source that is defined as a reliable water supply. 4. Not more than 10% cumulatively of the 3D extent of the alluvial material in this water source to be excavated by mining activities beyond 200 m laterally from the top of high bank and 100 m vertically beneath a highly connected surface water source that is defined as a reliable water supply.
2. If more than 10% cumulative variation in the watertable, allowing for typical climatic 'post-WSP' variations, 40 m from any: a) high priority GDE, or b) high priority culturally significant site listed in the schedule of the relevant WSP then appropriate studies (including the hydrogeology, ecological condition and cultural function) will need to 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.	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.	3. If conditions 1 to 4 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.

Table 5.1 AIP Minimal impact considerations

Watertable	Water pressure	Water quality
Less productive alluvial water sources – *Upper and Lower Cowra groundwater systems*		
1. Less than or equal to a 10% cumulative variation in the watertable, allowing for typical climatic 'post-WSP' variations, 40 m from any: a) high priority GDE, or b) high priority culturally significant site listed in the schedule of the relevant WSP. A maximum of a 2 m decline cumulatively at any water supply work.	1. A cumulative pressure head decline of not more than 40% of the post-WSP pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.	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. No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. 3. No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the 3D extent of the alluvial water source – whichever is the lesser distance) of a highly connected surface water source that is defined as a reliable water supply. 1. Not more than 10% cumulatively of the 3D extent of the alluvial material in this water source to be excavated by mining activities beyond 200 m laterally from the top of high bank and 100 m vertically beneath a highly connected surface water source that is defined as a reliable water supply.
2. If more than 10% cumulative variation in the watertable, allowing for typical climatic 'post-WSP' variations, 40 m from any: a) high priority GDE; or b) high priority culturally significant site; listed in the schedule of the relevant WSP then appropriate studies (including the hydrogeology, ecological condition and cultural function) will need to 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.	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.	2. If conditions 1 to 4 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.

Table 5.1 AIP Minimal impact considerations

Watertable	Water pressure	Water quality
Less productive porous and fractured rock water sources – *LFB fractured rock groundwater system*		
1. Less than or equal to 10% cumulative variation in the watertable, 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 watertable, 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. 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. 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 NSW Aquifer Interference Policy (DPI Water 2012a)

Cumulative impacts are relevant for groundwater resources and water-dependent assets, including the predicted cumulative change in groundwater levels in the alluvium due to currently approved and proposed mining, which has the potential to affect sensitive receptors identified in Section 3.8.

The AIP requires assessment of cumulative impacts from the commencement of a WSP, which was 2012 for the Lachlan alluvial WSP and 2011 for the MDB Fractured Rock WSP. Cumulative variation in the watertable and/or pressure head decline criteria in the AIP are for 'post-WSP' variations only. EMM understands the reference to 'post-WSP' (in regard to minimal impact considerations) to mean that projects/activities should be assessed against environmental conditions at the time of a WSP first being enacted (or soon after), allowing for climate variation. It is an acknowledgement of activities prior to commencement of the WSP, which in this case include borefield pumping and some mining activity.

Review of long term groundwater level trends at three groundwater monitoring bores near potential GDEs (Section 3.6.5i) indicates the water table varied by approximately 4 to 6 m within the 2.5th to 97.5th percentile (or two standard deviations), range of measurements. Consistent with the minimal impact considerations for high priority GDEs, it has been assumed that a 10% variation to the water table equates to 0.5 m.

5.2 Potential impacts

Table 5.2 presents a brief description of the potential water affecting activities and the potential effects resulting from the project. The study area has existing reliance on groundwater for water supply, as well as the existing landholder bores that are considered in the pre-development or baseline conditions.

Table 5.2 Groundwater affecting activities, potential effects, impacts on receptors, and assessment methods

Direct effect	Water affecting activity	Potential effect	Potential duration	Potential impact at a receptor	Assessment method
During operations					
Quantity	Groundwater inflows to pits and underground workings	Additional aquifer depressurisation or drawdown, changed groundwater flow paths, local induced flows, indirect take from overlying or adjacent water sources. Groundwater take exceeds predictions and licensed volume.	Continuous, may take years to observe	Reduced access to water (landholder bores, GDEs); changes to ecosystem functioning. Unlicensed groundwater take.	Groundwater modelling. Terrestrial and aquatic ecology assessments.
	Pumping from borefield(s)	Additional aquifer depressurisation or drawdown, changed groundwater flow paths, local induced flows, indirect take from overlying or adjacent water sources.	Duration of the Project	Reduced access to water sources, including potentially the Jemalong Irrigation No 2, landholder bores and GDEs; changes to ecosystem functioning.	Groundwater modelling. Terrestrial and aquatic ecology assessments.
	Tailings and spoil storage (IWL and WRE)	Altered recharge, perched/mounded watertable, geotechnical issues.	Continuous (depending on post Project management), may take years to observe	Waterlogging, increase in phreatic surface, changes to ecosystem functioning.	Groundwater modelling. Feasibility study.
Quality	Groundwater inflows to pits and underground workings	Mobilisation of COC (constituents of concern) causing water quality changes, or acid mine drainage from pit walls.	Duration of the Project	Change in beneficial use/environmental or cultural value at water receivers (including Lake Cowal, landholder bores, etc.), changes to ecosystem functioning.	Geochemistry assessment. Groundwater modelling (solute transport/particle-tracking modelling).
	Pumping from borefield(s)	Induced flows from overlying alluvial units causing groundwater mixing and changes to groundwater quality.			Qualitative assessment informed by previous groundwater modelling.

Table 5.2 Groundwater affecting activities, potential effects, impacts on receptors, and assessment methods

Direct effect	Water affecting activity	Potential effect	Potential duration	Potential impact at a receptor	Assessment method
	IWL slurry storages	Leakage of COC, including high salinity water, causing water quality changes to groundwater.			Qualitative assessment.
	WRE spoil storages	Seepage of acid mine drainage and leaching of solutes.			Geochemistry assessment Groundwater modelling (solute transport modelling).
	Use and storage of site plant and machinery with spills and leakage	Hydrocarbon, oil, grease etc groundwater contamination.	Duration of the Project	Localised groundwater quality impact within Project area.	Qualitative assessment.
Surface water-groundwater interactions	Groundwater inflows to pits and underground workings	Increased leakage from watercourses to groundwater causing changes to groundwater quality and reduction in surface water flows.	Duration of the Project, may take years to observe	Possible induced changes to groundwater quality and surface water volume/flows.	Groundwater modelling. Terrestrial and aquatic ecology assessments.
Aquifer disruption	Excavation	Aquifer/aquitard removal causing change in groundwater flow paths.	Permanent, unless backfilled	Reduced/increased water availability at GDEs and connected water source(s).	Groundwater modelling. Terrestrial and aquatic ecology assessments.
	Backfilling	Altered hydraulic properties, change in groundwater flow paths.	Permanent		Groundwater modelling.
Closure					
Quantity	Groundwater inflows to final voids	Evaporative losses of water from final voids, continued groundwater drawdown. Groundwater take exceeds predictions	Often hundreds of years	Reduced access to water, changes to ecosystem functioning. Unlicensed groundwater take.	Groundwater modelling.
	Tailings and spoil storage (IWL and WRE)	Perched watertable, seepage, watertable mounding, geotechnical issues.	Potentially hundreds of years	Waterlogging, detrimental changes to habitat, increase in phreatic surface.	Groundwater modelling. Feasibility study.

Table 5.2 Groundwater affecting activities, potential effects, impacts on receptors, and assessment methods

Direct effect	Water affecting activity	Potential effect	Potential duration	Potential impact at a receptor	Assessment method
Quality	Final pit lakes	Evapoconcentration of COCs within the pit lake, potential acid mine drainage (acidification of pit lake).	Continuous	Change in beneficial use/environmental or cultural value at water receivers (including Lake Cowal, landholder bores, etc.), changes to ecosystem functioning.	Groundwater modelling. Water balance modelling. Geochemistry assessment.
	Tailings and spoil storage (IWL and WRE)	Seepage of acid mine drainage and leaching of solutes.	Potentially many years		Geochemistry assessment.
	Wastewater ponds and water storage	Leakage of COC causing water quality changes to groundwater and surface water systems.	Potentially many years		Water balance modelling. Geochemistry assessment.
Surface water-groundwater interactions	Groundwater inflows to final voids	Increased leakage from watercourses to groundwater causing changes to groundwater quality.	Often hundreds of years	Possible induced changes to water quality comprising freshening of groundwater.	Groundwater modelling. Terrestrial and aquatic ecology assessments.
Aquifer disruption	Backfilling	Altered hydraulic properties, change in groundwater flow paths.	Permanent	Reduced/increased water availability at GDEs and connected water source(s).	Groundwater modelling.

5.3 Groundwater modelling

The main assessment method for groundwater was the development of a numerical groundwater flow model prepared for the project in accordance with the *Australian Groundwater Modelling Guidelines (AGMG)* (Barnett 2012) and adopting a percentile-based approach for assessing impacts consistent with the IESC guidance note on uncertainty analysis (Middlemis and Peeters 2018). The model was built in the Groundwater Vistas V8 Pro graphical user interface and run using the MODFLOW-USGS Transport code. The current model conforms to the *AGMG* criteria for Class 2 model classification with some elements of Class 3. An overview of the groundwater modelling undertaken for the Project is summarised in the following sections, full details are included in Attachment C.

5.3.1 Model objectives

The model objectives are designed to address the SEARs and other agency requirements as outlined in Section 1.3 as well as the Project-related groundwater affecting activities identified in Table 5.2. Specially, the model objectives are to:

- Predict cumulative and incremental changes to groundwater pressure caused by the approved and proposed mining operations.
- Predict the likely impacts on any water courses, riparian environments, and other water users, in particular Lake Cowal, registered landholder bores and the surrounding potential GDEs.
- Estimate the likely mine inflows to inform licensing requirements and support the water balance assessment studies.
- Predict cumulative groundwater level changes caused by the approved and proposed mining operations, as well as landholder bore abstraction at compliance monitoring bores located in the BCP.
- Predict the potential groundwater quality impacts due to seepage from the IWL and WRE.
- Predict mine closure impacts on groundwater and connected surface water.

5.3.2 Model design and development

i Model domain and spatial discretisation

The model domain is approximately 97 km long and 65 km wide at its greatest extents. The domain is generally shaped to follow or extend beyond the maximum extents of the Lachlan Formation in the southern, western, and eastern boundaries.

The domain is large enough to include:

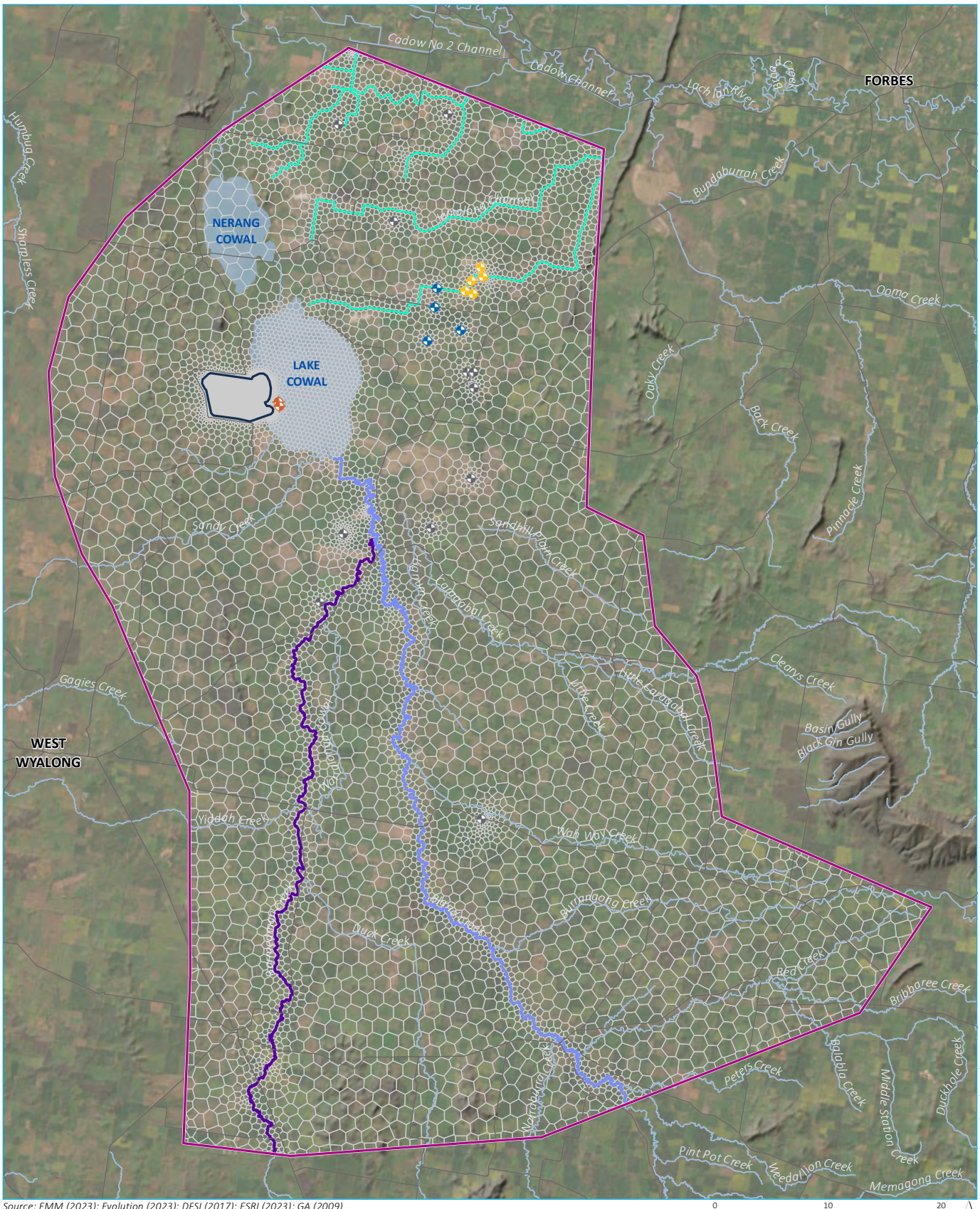
- All mine-related water-affecting features, including excavations at the mine site, and groundwater abstraction for mine process water supply from the ESB and BCP borefield.
- All cumulative effects from other groundwater affecting activities such as landholder abstractions from the Upper Cowra, Lower Cowra and Lachlan Formation.
- All identified receptors with potential to be affected by mining activities (registered landholder bores, GDEs and surface water bodies, including the entire extent of Lake Cowal and Nerang Cowal).
- Jemalong irrigation influences on groundwater flow.

- Model boundary conditions such that regional flow directions can be simulated.

For this project, a Voronoi polygon mesh was created. The adopted maximum cell sizes in key areas of interest are as follows:

- 15 m at the underground development
- 35 to 45 m at the pits
- 80 m at the IWL and WREs
- 100 m at pumping bores
- 390 m at Lake Cowal
- 250–450 m at Bland and Barmedman Creeks
- 400–450 m at the JIL irrigation canals
- 1,500 m maximum over the remainder of the model domain.

The model domain and grid are illustrated in Figure 5.1.



KEY

- Model domain
- Mine site footprint for mesh refinement
- Major road
- Bland Creek
- Barmedman Creek
- Jemalong irrigation channels
- Named watercourses
- Named waterbody
- Voronoi mesh

Pumping bores

- Bland Creek Palaeochannel Borefield (BCPB)
- Eastern Saline Borefield (ESB)
- Saline Borefield
- Third party

Model domain and grid

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 5.1

EMM
creating opportunities

ii Model layers

Seven hydrostratigraphic units (HSUs) were identified within the model domain. These are summarised in Table 5.3. Over the regional model domain, each of the six upper-most HSUs are each represented by a single layer. The basement HSU was discretised into multiple model layers (17 in total) to denote progression of the pits and underground development with time. This resulted in a total of 23 model layers.

Table 5.3 Model layer design

Layer	HSU(s)	Project components	Non-project components	HSU active or pinched out
1	Clay (lacustrine and non-lacustrine origins), basement outcrops and mine site waste material	IWL and WREs	-	Pinched out
2	Upper Cowra Formation	ESB, pits, pit dewatering bores	Landholder bores	Pinched out
3	Lower Cowra Formation	ESB, saline bore, pits, pit dewatering bores	Landholder bores	Pinched out
4	Lachlan Formation	BCP borefield	Landholder bores	Pinched out
5	Saprolite	Pits, underground development, pit dewatering bores	Landholder bores	Active over full domain
6	Saprock	Pits, underground development, pit dewatering bores	Landholder bores	Active over full domain
7-23	Basement (Lachlan Fold Belt, fresh rock)	Pits, underground development, pit dewatering bores	Landholder bores	Layers 7–11 Pinched out Layers 8–12 Active over full domain

iii Boundary conditions

Six types of modelled boundary conditions are employed to represent inflow to and outflow from the groundwater system. These include:

- **Constant head boundary condition**: Along the model edges, constant head boundary conditions have been applied at the model boundaries from the Upper Cowra down to basement to simulate the lateral groundwater flow to and from the broader groundwater system and regional groundwater flow system described in the hydrogeological conceptual model.

- **Recharge**: Three variable recharge zones were applied using the MODFLOW RCH package. Two zones of enhanced recharge, one within the Jemalong Irrigation area, and a second within the footprint of the mine site WREs. The third zone is natural rainfall recharge under non-irrigated land throughout the remainder of the model domain. In addition, recharge is not applied to surface water features. Rainfall recharge was imposed as a percentage of observed rainfall (for transient simulations, except post-mine recovery) or the long-term average rainfall (for steady-state simulations and post-mine recovery). Temporal changes in recharge during transient simulation periods, except post-mining, allowed for seasonal effects to be simulated.

- **Evapotranspiration**: The MODFLOW evapotranspiration segments (ETS) package was used to represent evapotranspiration from the groundwater system. One evapotranspiration zone covering the entire model domain was applied with an extinction depth of 3 m. Evapotranspiration was not applied to surface water features, or over the footprint of IWL (across both the historical and prediction periods). Temporal changes in evapotranspiration during transient simulation periods, except post-mining, again allowed for seasonal effects to be simulated.

- **River**: Major surface water features within the model domain include Lake Cowal, Bland Creek, Barmedman Creek and the irrigation channel network within the Jemalong Irrigation area. These surface water features were all simulated with the MODFLOW River (RIV) package. The RIV package assumes fully saturated conditions and does not account for unsaturated flow. For Lake Cowal, the RIV conductance was set to a very high value (1,000 m^2/d) so the rate of water seepage from or into the lake (disregarding effects of hydraulic head) is controlled by the hydraulic properties of the clay material in model layer 1. The lake bed elevation in the MODFLOW RIV package was set to the top of model layer 1.

  Given the high level of uncertainty in the hydraulic properties of the bed material for the Bland Creek, Barmedman Creek and irrigation channels, the river boundary conductance was allowed to vary during history-matching. These surface water features were simulated using a fixed river stage equal to the topographic elevation and the bed elevation equal to topography minus 1 m.

  Unconfined groundwater flow and solute transport within the IWL was simulated during history matching and predictions, by raising the top of model layer 1 by 100 m within the local area surrounding the IWL. The RIV package was then used to simulate step-changes in head through mining progression. The stage height in the RIV boundary condition was varied to match the IWL elevation based on the mine plan.

- **Wells**: The MODFLOW well (WEL) package was used to simulate major groundwater abstractions from the BCP Borefield, ESB and saline bore, including registered third-party bores within the model domain and bores with historical pumping data. These included groundwater takes for irrigation, stock, domestic, industrial and town water supplies. The WEL package was also used to simulate groundwater abstraction from mine dewatering bores over the history matching period. The prediction scenarios modelled extraction at landholder bores at their full WAL allocation, whereas during the model history-matching measured pumping data was applied where available at these same landholder bores.

- **Drain**: Passive 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 Attachment C.

iv Temporal discretisation

A summary of the stress periods used in the history match and prediction simulations is provided in Table 5.4. Model simulations are transient, with the exception of the first two initial stress periods; one transient stress period run to pseudo-steady state to promote numerical stability, and one steady state stress period to establish stable long-term groundwater conditions.

Table 5.4 Model stress periods

Stress period	Duration	Date period	Description
1	274 years 100,000 days	31 December 1997 (ending)	Pseudo-steady state stress period – transient run providing numerical stability for when varying parameter values during the history-matching process.

Table 5.4 Model stress periods

Stress period	Duration	Date period	Description
2	n/a	1 January 1998	Steady-state stress period pre-mining and ESB/BCP Borefield – develops baseline steady state conditions in response to modelled hydraulic properties and boundary conditions.
3–102	Quarterly	2 January 1998 – 1 January 2023	History-matching period – climate stresses and pumping stresses from registered landholder bores prior to the commencement of mining in February 2005. With mine activity stresses from February 2005.
103–174	Quarterly	2 January 2023 – 1 January 2041	Predictive period – climate stress, pumping stresses from registered landholder bores and mine activity stresses.
175	1,000 years	2 January 2041 – 1 January 3041	Predictive period – climate stress, pumping stresses from registered landholder bores and post-mine recovery.

5.3.3 History-matching

The groundwater flow model was history-matched to measured groundwater levels from January 1998 through to January 2023, incorporating annual mine dewatering progression from February 2005 in accordance with a yearly staged mine plan.

A combination of manual and automated (using PESTPP-IES version 4.2.16) approaches were employed during the history-matching process. History-matching was undertaken using temporal hydraulic head data, from the Evolution Mining groundwater monitoring network, Lampayan (2001) hydrogeological study and WaterNSW groundwater monitoring data. Initially, the model was history-matched manually to steady state targets only, using a single value for each hydraulic property per HSU. This approach was aimed at providing an efficient means to arrive at starting parameters that provided a reasonable model-wide fit to long term average hydraulic head data, to use as initial parameter value estimates for subsequent, more computationally demanding, transient history-matching.

The results of the history-marching are provided in the Groundwater Modelling Report provided in Attachment C.

5.3.4 Prediction scenario modelling

i Scenario definition

The groundwater model scenarios developed include the following:

1. **Null scenario:** no mining scenario but includes landholder bore use (irrigation, and stock and domestic) from the palaeochannel.

2. **Approved scenario**: the base case of existing and approved open pit and underground, and borefield groundwater pumping.

3. **Proposed scenario**: the proposed project (pit expansion) plus approved scenario.

For the Proposed scenario, initially two post closure cases were simulated to encapsulate the range of expected conditions following the end of mining. The first case simulates the open voids maintained at their final mining level, i.e. they remain dry (the **'dry' case**). This is highly conservative from a drawdown perspective. The second post closure case deactivates the pits at the end of mining and water levels are allowed to recover within these pits with either backfill or open void properties applied (i.e. the **'fast recovery' case**). However, no recharge or evaporation is applied, and therefore groundwater levels respond more quickly and higher than would be expected in reality. This is likely conservative from a contaminant transport perspective, i.e. any contaminants are likely to be captured within the drawdown cone created by the sink associated with the dry voids. This scenario promotes a system with a weaker sink and thus a smaller capture zone is generated for capturing potential contaminants emanating from the IWL and/or WREs.

A subsequent semi-coupled post closure case was developed following the surface water assessment (ATC Williams 2023) that enabled a more appropriate representation of long-term pit conditions. This additional case, run as base case realisation only, enabled refinement of the GDE and landholder bore impact assessments.

The results of the prediction scenario modelling are provided in the Groundwater Modelling Report provided in Attachment C.

ii Impact definition

To model the change that water affecting activities associated with the mine are having on the groundwater system, impacts have been calculated using the following approach:

- **Cumulative project impact** – Calculated by subtracting the Proposed scenario from the Null scenario. This calculates the total drawdown caused by the Project compared to a 'no mining' scenario. This does not include landholder groundwater pumping.
- **Incremental impact** – Calculated by subtracting the Proposed scenario from the Approved scenario. This calculates the changes associated with the proposed additional CGO operational activities only.
- **AIP cumulative impact** – The AIP requires assessment of cumulative impacts from the commencement of a WSP, which was 2012 for the Lachlan alluvial WSP (the WSP of interest for potentially impacted landholder bores and GDEs). This is calculated by subtracting the Proposed scenario from the conditions experienced during 2012. Conditions prior to these periods are acknowledged as pre-existing to the implementation of a groundwater management regime.

A comparison of the existing approved and Project operations is provided in Table 5.5.

Table 5.5 Key Project elements

Project element	Existing approved operations	Summary of the project
Open pit mining extent and method	Open pit: single open pit developed via conventional open-cut mining encompassing drill, blast, load and haul operations, with an approximate maximum area of 131 ha and final depth of -331 mAHD.	Development of new open pit mining satellite pits to the north of the existing open pit. Proposed expansion of existing open pit to the east and south. The expanded pit E42 will have a maximum depth of -373 mAHD. The maximum depths of the new pits will be 78 mAHD for E46 pit, 105 mAHD for GR pit, and -16 mAHD for E41 pit.
Underground mining	Underground: top down sub-level open stoping to a depth of -850 mAHD with approximately 1,106 stopes developed over the life of the mine. Backfilling of stopes with cemented paste.	No change to open pit mining method or underground mining method or extent.

Table 5.5 Key Project elements

Project element	Existing approved operations	Summary of the project
Ore production	Open pit – approximately 167 Mt of ore over the life of approved open pit mining at CGO. Underground – approximately 27 Mt of ore over the life of approved underground mining at CGO extracted at a rate of up to 2.6 Mtpa of ore.	Open pit – an additional approximately 112 Mt of ore over the life of the Project No change to ore production from the underground.
Ore processing	Gold is extracted from the ore at the processing plant using a conventional carbon-in-leach cyanide leaching circuit. Ore is processed at a rate up to 9.8 Mtpa. Processing of approximately 39.3Mt of mineralised material.	No change
Lake isolation system	Lake isolation system (comprising the temporary isolation bund, lake protection bund and perimeter WRE).	Expansion of the lake protection bund system to provide separation and mutual protection between Lake Cowal and CGO.
Management of waste rock	Open pit operations: Approximately 299 Mt of waste rock over the life of CGO. Underground operations: Approximately 5.74 Mt of waste rock over the life of CGO. Waste rock is emplaced in the northern, southern and perimeter WREs over the life of the CGO, and it is used to form the perimeter of the IWL. The northern waste emplacement has an approved maximum height of 308 m and the southern waste emplacement has an approved maximum height of 283 m.	Approximately an additional 266 Mt of waste rock will be generated. No change to generation of waste rock from underground operations. The existing northern and southern WRE s will be expanded to accommodate the additional waste rock. The expanded northern WRE will have a maximum height of 308 mAHD (no change from existing), while the southern WRE will have a maximum height of 308 mAHD (approximately 30 mAHD higher than existing). Following the extraction of ore the proposed E46 pit will be backfilled and form an additional WRE. The E46 WRE will have a maximum height of 268 mAHD.
Mine tailings	Consistent with the approved IWL, tailings material will continue to be deposited into the expanded IWL as a slurry under sub-aerial conditions. Free water liberated during settling and runoff from incident rainfall will initially be recovered via temporary pump decants prior to commissioning of a central internal decant pond area, from where it would be subsequently recovered for reuse in the processing plant. Consistent with the existing IWL, the tailings deposition will be controlled to promote the segregation of the coarse fraction on the perimeter and the fine fraction towards the centre of the expanded IWL.	No change.
Mineralised material stockpiling	Temporary stockpiling of mineralised material on the northern WRE to a maximum design height of approximately 320 mAHD. This material will be processed and the stockpile will be progressively removed to the height of the approved waste emplacement.	No change.

Table 5.5 Key Project elements

Project element	Existing approved operations	Summary of the project
Tailings management	Tailings are deposited in two tailings storage facilities (TSFs) (Northern and Southern). NTSF and STSF are approved to be constructed to approximately 240 mAHD and 248 mAHD, respectively. These TSFs are also approved to be combined with the northern WRE to form the IWL, which will provide a life of mine tailings strategy. The IWL is approved to be developed to a final height of 246 mAHD.	Expansion of the IWL using a northern expansion to accommodate tailings from processing ore from the new open pits. There will be no change to the maximum height of the IWL.
Soil stockpiles	Development of soil stockpiles within ML 1535 and ML1791	Development of new stockpiles both within and outside of ML1535 and ML1791
Water management	The existing CGO water management infrastructure is comprised of the following key components: • Up-catchment diversion system (UCDS). • In catchment diversion system (ICDS), including the contained water storages. • Lake isolation system (comprising the temporary isolation bund, lake protection bund and perimeter WRE). • Integrated erosion, sediment and salinity control system. • Open pit sump and dewatering borefield. • Pipeline from the tailings deslimer to the paste fill plant to send tailings to the paste fill plant and a return water pipeline from the paste fill plant to the processing facility.	The Project will include the following: • Realignment of the UCDS around new project components. • Adjusting the surface water drainage system to assist with on-site water management and maximise onsite water conservation. The Project will also allow the augmentation of other on-site water storages from time to time depending on water supply and on-site requirements. Temporary erosion and sediment control structures will also be used during the construction of new Project components as required.
Water supply	Water is preferentially sourced from internal sources, and supplemented with water from external sources as follows: Internal sources • Recycled water from the IWL. • Pit sump and pit dewatering borefield. • Rainfall runoff from mine WREs, and other areas within the site which is collected as part of the ICDS and contained in nine on-site water storages. • Approved D10 dam (yet to be constructed). External sources • Saline groundwater from four production bores located south-east of ML 1535. • ESB located approximately 10 km east of Lake Cowal's eastern shoreline. • BCP borefield which comprises four production bores within the BCP located approximately 20 km northeast of the CGO. • Water accessed from the Lachlan River under licence, which is supplied via a pipeline from the Jemalong Irrigation Channel.	The Project will not change the internal or external water supply sources for CGO or the order in which they are preferentially sourced. The operational water balance completed for the Project (refer to Appendix G Surface Water Assessment) predicted a slight decrease on the reliance of external water sources during median rainfall conditions due to an increase in the amount of water reclaimed from the IWL and an increase in the catchment of CGO as a result of the Project (i.e. higher run off volumes captured in the CGO water management system). The water supply pipeline will be rerouted within the additional disturbance footprint where it intersects the new LPB. It will run over the LPB and along the inside toe, around the southern WRE and discharge to dam D9

Table 5.5 Key Project elements

Project element	Existing approved operations	Summary of the project
Pit backfill		Pit E46 is proposed to be backfilled. Pit E41, Pit E42 and Pit GR (noting Pit E42 and Pit GR will form a single void at closure) are proposed to remain as open voids. The E42 final void will be approximately -373 mAHD in depth while the GR final void will be approximately 105 mAHD. The E41 final void will be approximately -16 m AHD.

5.3.5 Assessing likelihood of drawdown

To calculate the likelihood of a given drawdown, a method was employed whereby, at each model cell, for each parameter realisation, the maximum modelled drawdown (irrespective of time) was calculated. Then, the proportion of realisations in which drawdown at a model cell exceeds a given value can be calculated.

The rationale for the percentile-based approach to presenting drawdown from 90 realisations is based on Table 2 of the IESC guidance note on uncertainty analysis (Middlemis and Peeters 2018). That emphasises the importance of calibrated language and having a consistent and precise language to communicate impacts to decision makers.

Table 5.6 provides a summary of the combined numeric, narrative and visual approach to describing likelihood of drawdown exceeding the 2 m threshold at landholder bores and exceeding the 0.5 m threshold at GDEs, as a result of the Project. Please note, modelled results are also assessed to simulate the likelihood of exceedance at the three government trigger levels bores installed within the paleochannel, previously discussed in Section 3.6.5i. This assessment is based on absolute groundwater level and not drawdown, thus the focus of the percentile band analysis is to assess the likelihood of breaching the set trigger levels based on hydrograph analysis.

Table 5.6 provides clarity on how to consider the likelihood bands presented in the impact assessment in Chapter 6.

Table 5.6 Combined numeric, narrative, and visual approach for assessing likelihood

Percentile band (outcomes ranked from small to large)	Colour code	
<P10		It is **very unlikely** that drawdown or hydraulic head **exceeds** the threshold
P10 to P33		It is **unlikely** that drawdown or hydraulic head **exceeds** the threshold
P33 to P67		It is **as likely as not** the drawdown or hydraulic head **exceeds** the threshold
P67 to P90		It is **likely** that drawdown or hydraulic head **exceeds** the threshold
>P90		It is **very likely** that drawdown or hydraulic head **exceeds** the threshold

5.3.6 Groundwater modelling peer review

A peer review of the groundwater model was conducted by Will Minchin, Director of Watershed HydroGeo. The review was undertaken in accordance with the Australian Groundwater Modelling Guidelines (Barnett 2012) and included input and involvement over the following three main stages of groundwater:

- conceptualisation and model updates
- model history-matching
- model predictions/uncertainty.

The peer review concluded the numerical modelling work and associated reporting have been carried out in a professional manner, meeting contemporary industry standards, generally in accordance with the Guiding Principles included in the Australian Groundwater Modelling Guidelines, NSW DPE Guidelines and the IESC Uncertainty Analysis Guidance note. The peer review did not identify 'fatal flaws' with the numerical groundwater model which were considered likely to significantly alter the ability of the model to make useful predictions, particularly considering the uncertainty analysis conducted.

The peer review report is attached in Attachment D.

6 Groundwater impact assessment

6.1 Groundwater levels and drawdown

6.1.1 Groundwater levels

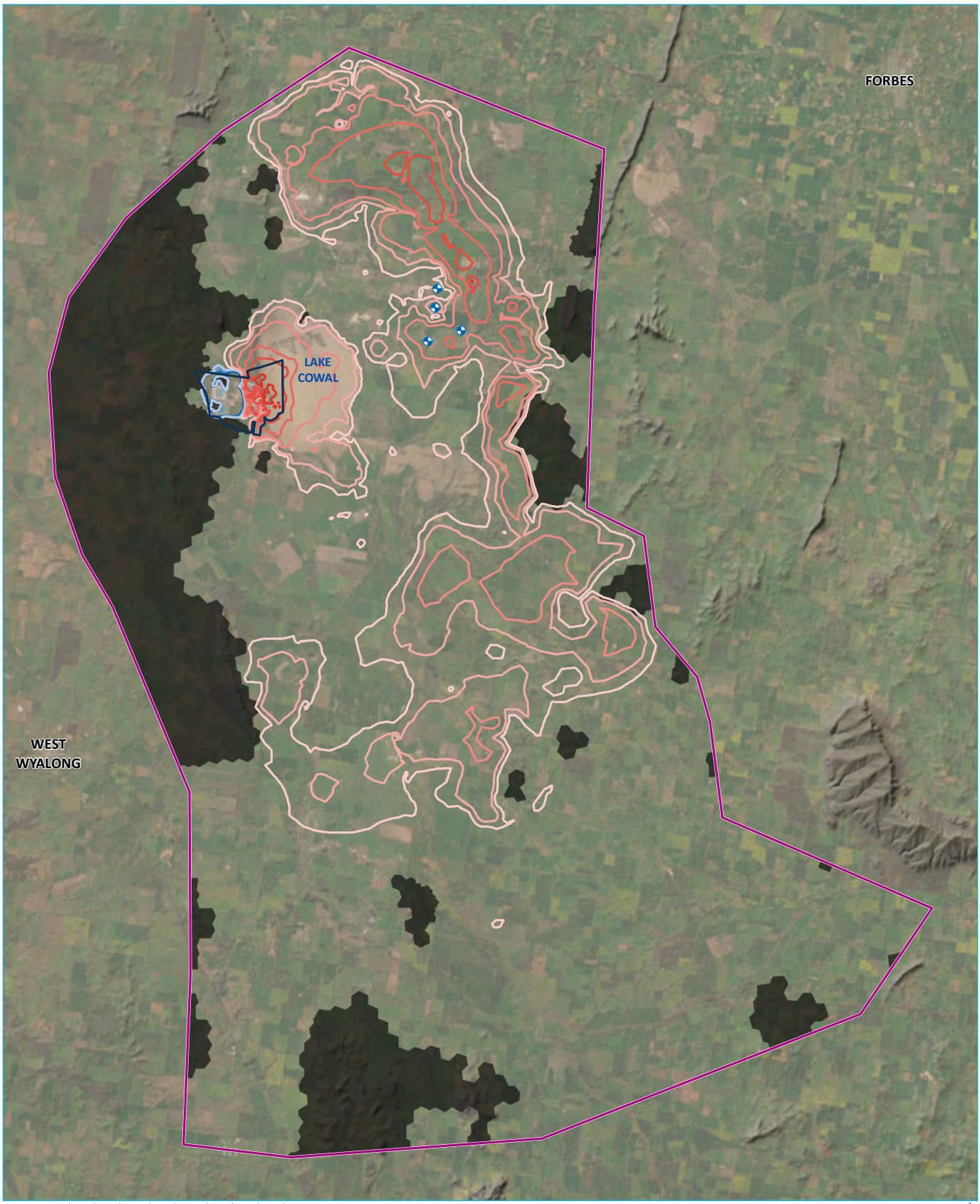
Cumulative predicted groundwater level drawdown for the Project (approved plus proposed CGO operations) is provided for the Upper Cowra groundwater system (model layer 2) and the top of the LFB hard rock unit (model layer 7) in Figure 6.1a and 6.1b, and Figure 6.2a and Figure 6.2b, respectively. Drawdown is shown at the end of mining, and 20 and 100 years post mining. As discussed in Section **Error! Reference source not found.**, two post closure cases are simulated to present the different 'dry' and 'fast recovery' conditions. In the dry case, groundwater flowing into the pits is removed and this is conservative from a drawdown perspective. In the fast recovery case, no evaporation or recharge is applied and this is conservative from a contaminant tracking perspective.

For the Upper Cowra groundwater system, which predominantly hosts the water table, the following is observed:

- There are two separate drawdown zones, one emanating around the mine and the second in the north-east associated with borefield pumping. Drawdown from mining will reach maximums of approximately 25 m, and from borefield pumping approximately 10 m. Drawdown from mining will propagate outside the ML boundary.
- There are small locations of groundwater mounding, where the maximum modelled rise in groundwater level is 5 m, at the end of mining and for the 20 years post mining fast recovery case. Areas of mounding underlie the approved and proposed IWL areas.
- The maximum extent of drawdown is experienced at the end of mining, drawdown does not continue to propagate during the recovery phase (i.e. remaining 100 years).
- There is little difference in groundwater drawdown between the dry and fast recovery cases, with the exception of 100 years post mining where the maximum drawdown around the pit for the dry case is 25 m and for the fast recovery case is 10 m.

For the top of the LFB hard rock unit, the following was observed:

- The maximum drawdown centres under the proposed and approved mining areas. The localised pockets of drawdown in the remainder of the study area are artefacts of where the model layer is present, and vertical propagation of drawdown from other layers.
- By year 100, the maximum drawdown for the open pit recovery case is 10 m, and for the dry case is 100 m. In reality, groundwater levels are more likely to behave like the fast recovery case, with less drawdown and faster groundwater level recovery.
- The dry case shows drawdown expanding laterally during recovery (i.e. expanding between years 20 and 100), while the maximum extent of drawdown for the fast recovery case is seen at year 20.



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Not present

Cumulative drawdown (m)

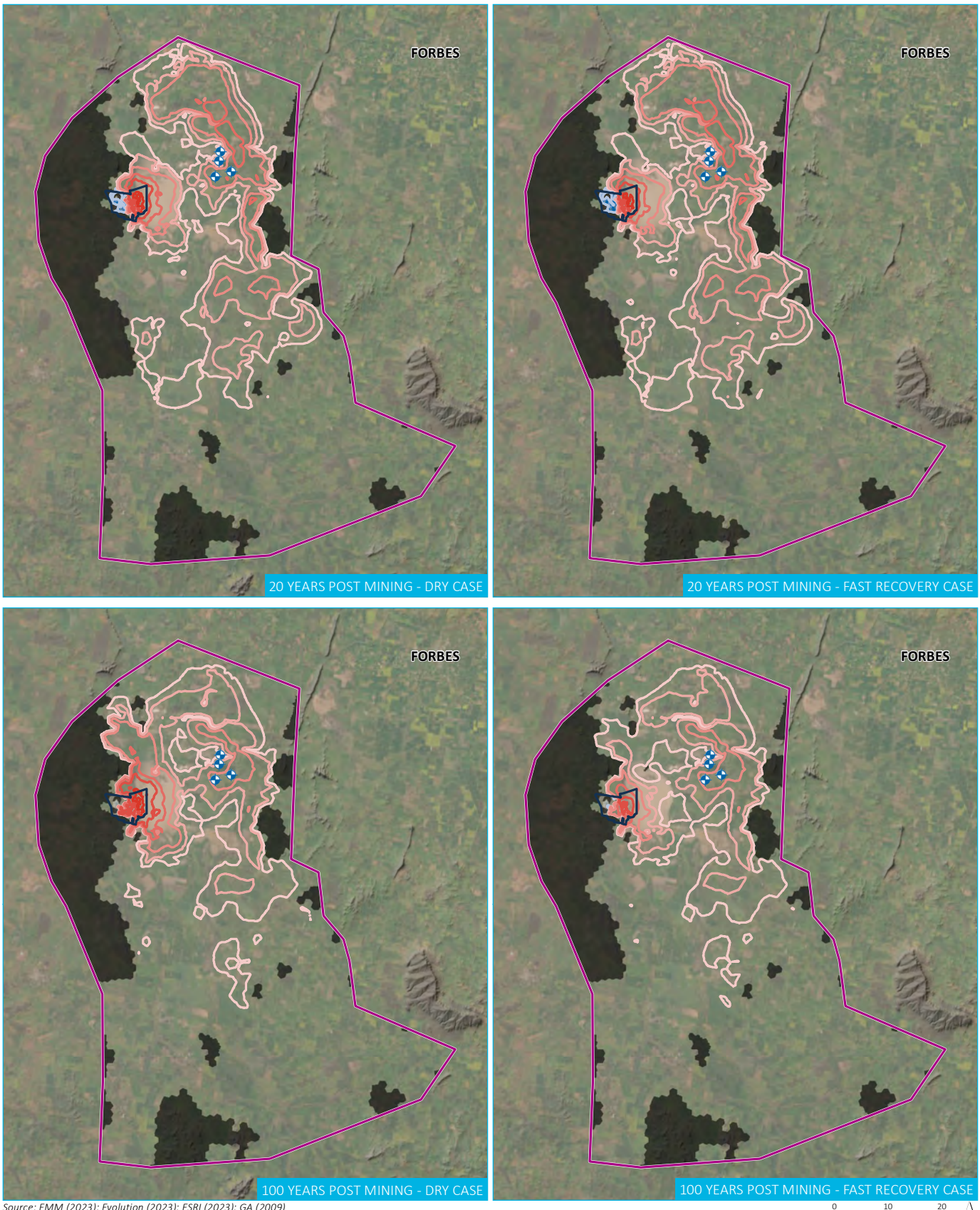
- -5
- -2
- -1
- -0.5
- 0.5
- 1
- 2
- 5
- 10
- 25

Cumulative drawdown, Upper Cowra (Layer 2) map 1 of 2 (end of mining)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 6.1a

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA018a_CumulativeDrawdownUpperCowra1year_20230426_03.mxd 27/04/2023



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA018b_CumulativeDrawdownUpperCowra20and100year_20230426_03.mxd 27/04/2023

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Not present

Cumulative drawdown (m)

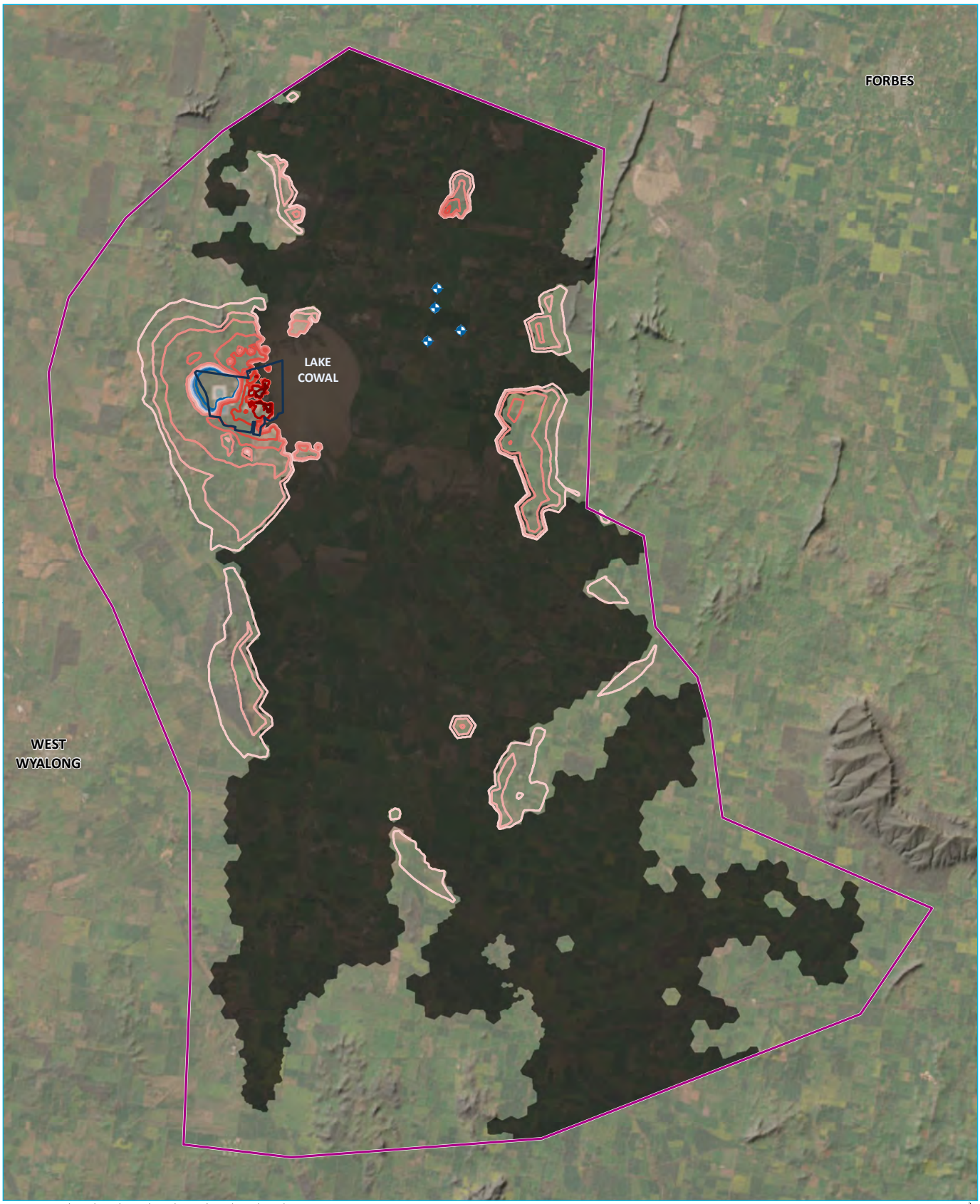
- -5
- -2
- -1
- -0.5
- 0.5
- 1
- 2
- 5
- 10
- 25

Cumulative drawdown, Upper Cowra (Layer 2)

map 2 of 2

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 6.1b

EMM creating opportunities



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Not present

Cumulative drawdown (m)

- -5
- -2
- -1
- -0.5
- 0.5
- 1
- 2
- 5
- 10
- 25
- 50
- 100

Cumulative drawdown, top Lachlan Fold Belt (Layer 7) map 1 of 2 (end of mining)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 6.2a

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA019a_CumulativeDrawdownTopLachlanFoldBelt1year_20230426_03.mxd 27/04/2023

Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Not present

Cumulative drawdown (m)

- -1
- -0.5
- 0.5
- 1
- 2
- 5
- 10
- 25
- 50
- 100

Cumulative drawdown, top Lachlan Fold Belt (Layer 7)
map 2 of 2

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 6.2b

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA019b_CumulativeDrawdownTopLachlanFoldBelt20and100year_20230426_03.mxd 27/04/2023

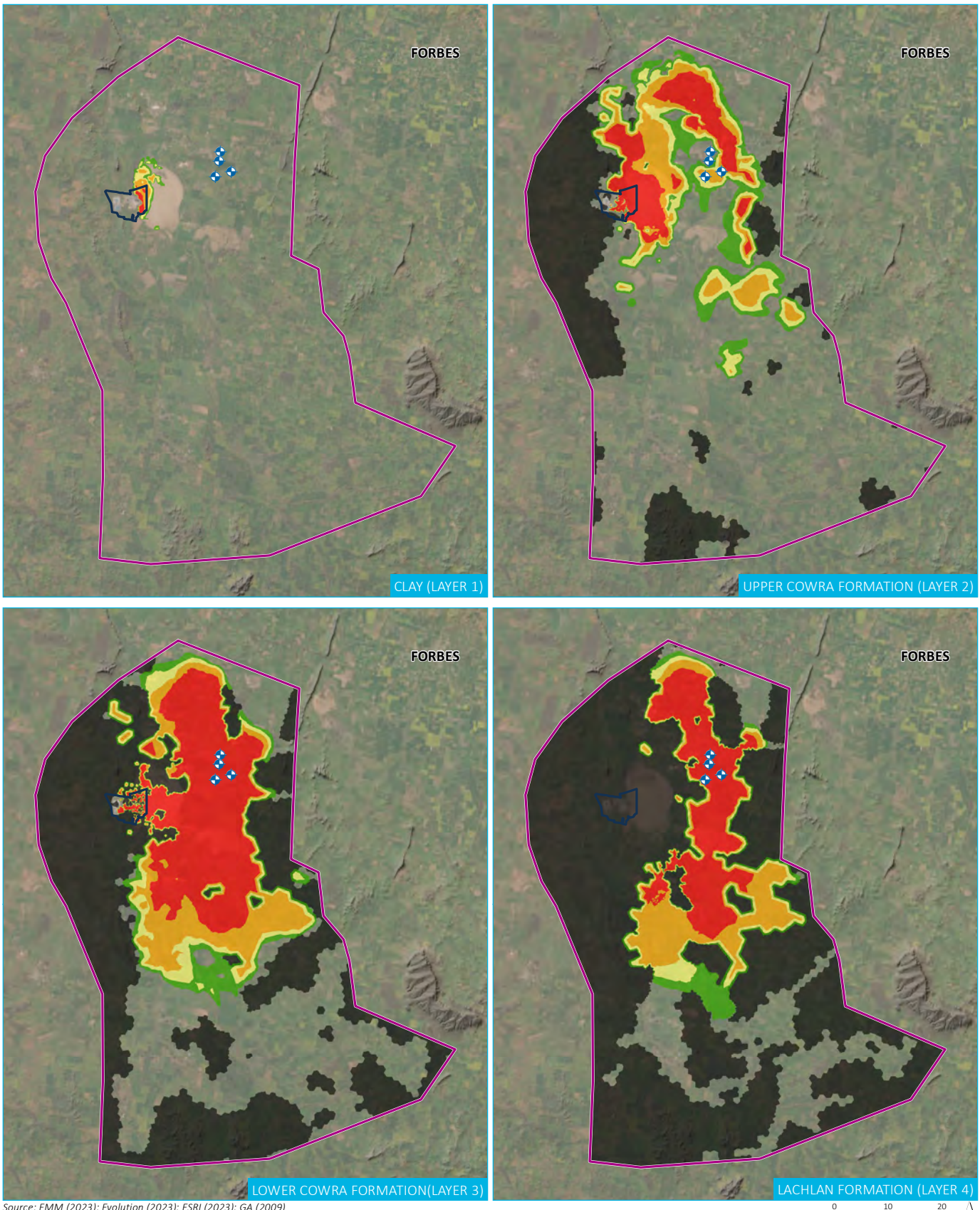
6.1.2 Maximum two metre cumulative Project impact drawdown

The cumulative Project likelihood of exceedance for 2 m drawdown for model layers 1, 2, 3 and 4 are presented in Figure 6.3 with a description of drawdown and likelihood of exceedance included in Table 6.1. These figures present the maximum drawdown likelihood, for the respective contour interval, irrespective of time.

Table 6.1 Cumulative Project impact – 2 m drawdown

Layer	HSU[1]	Description
1	Soil/clay surface	Drawdown associated with mining extends under approximately 1/3 of Lake Cowal. The 'very likely' region is confined to the eastern portion of the Project area.
2	Upper Cowra Formation	Drawdown and associated likelihood of 0.2 m exceedance associated with mining extends to the north and south. Drawdown and associated likelihood of 0.2 m exceedance associated with the palaeochannel abstraction extent more pronounced to the north and represents seepage into the underlying HSUs within areas where third party water supply is concentrated.
3	Lower Cowra Formation	Drawdown around the mine is truncated by the extent of the HSU. Drawdown from the palaeochannel expands to the north and south associated with groundwater take from this unit. The 'very likely' region of drawdown exceeding 2 m is expansive, with the 'likely' and 'very unlikely' exceedances approximately expanding another 7 km and 15 km to the south respectively.
4	Lachlan Formation	Drawdown from the palaeochannel is truncated by the extent of the HSU and associated with direct groundwater take from this unit. There is little difference between the likelihood of exceedance classes, however the 'likely' region expands to the south east and south west. The Lachlan Formation does not extend to the project area.

Notes: 1. Hydrostratigraphic unit.



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km
GDA 1994 MGA Zone 55
N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA020_CumulativeDrawdown2mContours_20230426_03.mxd 27/04/2023

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Not present

2 m cumulative drawdown (likelihood of exceedance)

- 10 %
- 33 %
- 66 %
- 90 %

Cumulative drawdown, likelihood of exceedance for 2 m drawdown

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 6.3

EMM creating opportunities

6.1.3 Maximum two metre incremental impact

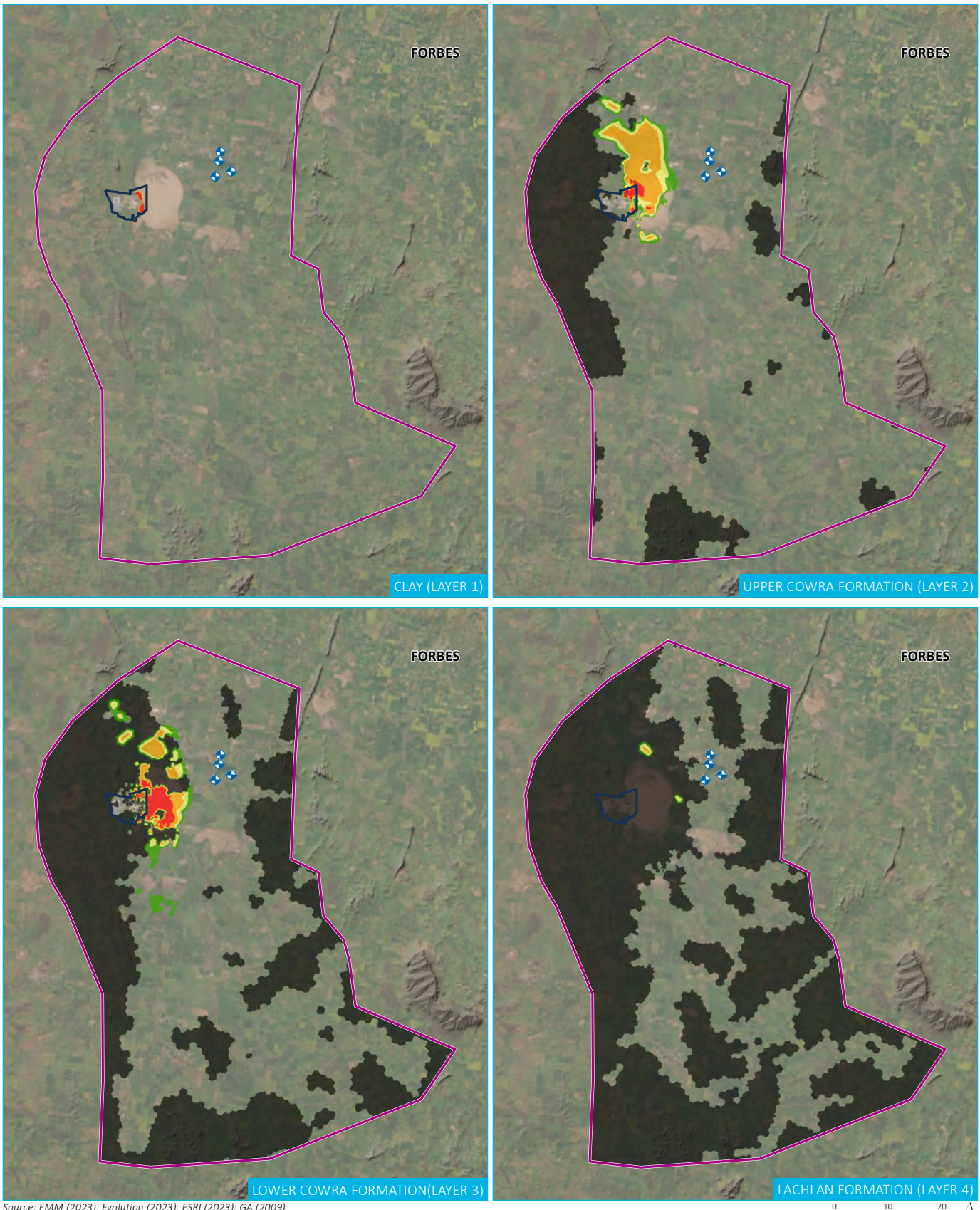
The incremental likelihood of exceedance for 2 m drawdown for model layers 1, 2, 3 and 4 are presented in Figure 6.4 with a description of drawdown and likelihood of exceedance included in Table 6.2. These figures present the maximum drawdown likelihood, for the respective contour interval, irrespective of time.

These predicted incremental drawdowns indicate that the difference in impact between the approved CGO operations and the additional proposed mining activities are minor. There is no change in groundwater level drawdown associated with the continued operation of the CGO borefields greater than 2 m, nor is there any likelihood of additional drawdown greater than 2 m at any landholder bore.

Table 6.2 Incremental impact – 2 m drawdown

Layer	HSU[1]	Description
1	Soil/clay surface	Very localised likelihood of any drawdown, just outside the bund area.
2	Upper Cowra Formation	The 'very likely' region of drawdown likelihood associated with mining extends under the northern half of Lake Cowal. Further north and east, the 'likely' region extends approximately a further 10 km.
3	Lower Cowra Formation	Drawdown to the west of the mine is truncated by the extent of the HSU. The incremental 'very likely' drawdown under Lake Cowal is associated with mine expansion causes some drawdown to occur beneath Lake Cowal. Any seepage form Lake Cowal is considered minor due to a) the model overestimating hydraulic connection between Lake Cowal and the groundwater system, and b) seepage is limited by the low permeability of the superficial clay sediments. The incremental likelihood of any drawdown from borefield pumping is less than 2 m.
4	Lachlan Formation	There is no mine related drawdown, due to the absence of the Lachlan Formation around the mine, nor is there any borefield related drawdown.

Notes: 1. Hydrostratigraphic unit.



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA021_IncrementalDrawdown2mContours_20230426_03.mxd 27/04/2023

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Not present

2 m incremental drawdown (likelihood of exceedance)

- 10 %
- 33 %
- 66 %
- 90 %

Incremental drawdown, likelihood of exceedance for 2 m drawdown

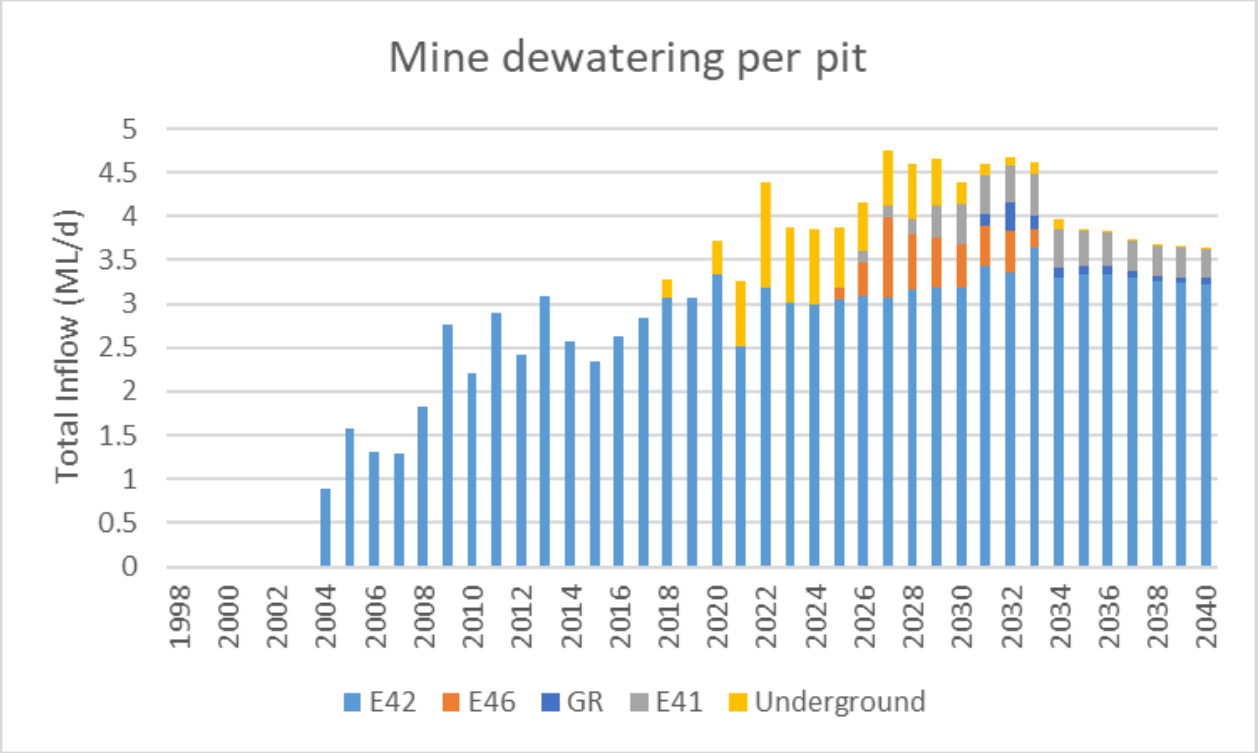
Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 6.4

EMM creating opportunities

6.2 Groundwater inflow predictions

The CGO open pit has been in operation since 2005 and represents a significant groundwater sink. Groundwater is drawn toward the open pit, mainly from the fractured rock aquifer in which most of the open pit is excavated (Coffey 2021).

Combined groundwater inflows into the open pits and underground mine have been predicted to increase from less than 1 ML/day in 2004 to a peak of 4.74 ML/day in 2027 (Figure 6.5). Most of the inflows are predicted to occur in the E42 pit. These modelled inflows represent the total groundwater removed from the groundwater source (i.e. to achieve dry voids in the pits and underground). It includes entrained water in material excavated to surface as well as groundwater removed via evaporation and the ventilation system, and thus represents a greater volumetric flux than that is expected to be managed by the site.



Note: Underground inflows noted during 2018-2000 relates to exploration activities.

Figure 6.5 Predicted groundwater inflows to pits and the underground mine (1998–2040)

Following mine closure, groundwater inflows to the pits are expected to reduce from approximately 3.62 ML/day in 2040 to less than 0.01 ML/day by the start of 2043.

6.3 Groundwater quality predictions

6.3.1 Mining

Contaminant transport from the Project area was simulated using particle tracking modelling over a period of 200 years post-closure. The particles track the movement of 'generic' contaminants that are not constrained by attenuation factors (e.g. sorption, dilution etc) and represent the most conservative cases of contaminant transport (i.e. they behave similarly to conservative parameters such as sulfate).

Three closure scenarios were modelled, as detailed in Section **Error! Reference source not found.**. Figure 6.6 shows the results of the modelled scenario in which dewatering of the pit void ceases at the end of mining (the year 2040) and groundwater is allowed to recover to pre-mining conditions. This 'fast recovery' case represents the most conservative scenario investigated as natural groundwater flow paths are re-established.

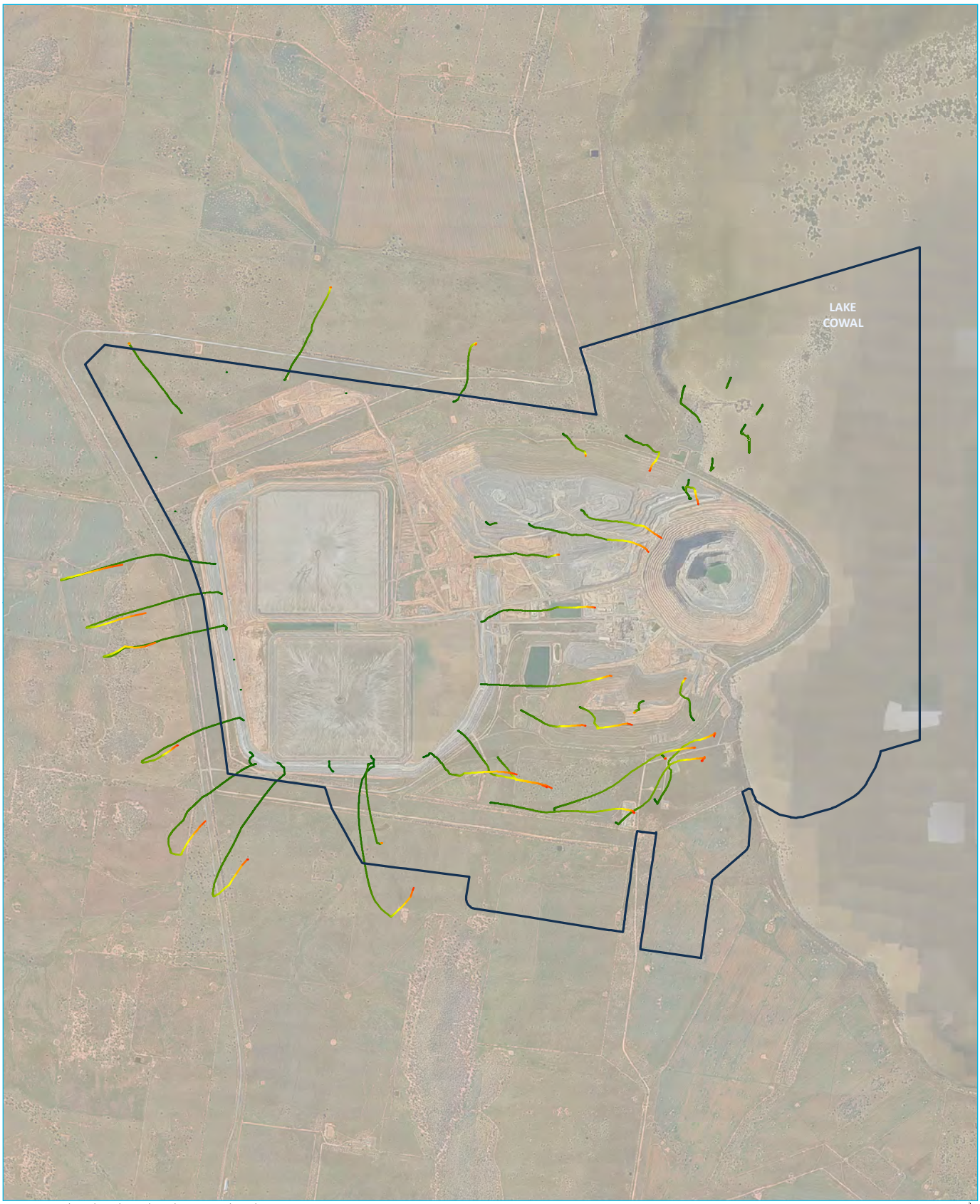
Figure 6.6 shows the following:

- Particles to the east of the TSF and IWL, and those in the vicinity of the void, travel towards the void over the course of the 200 year simulation.
- Particles to the west of the TSF/IWL initially travel away from site, before reversing this trend after approximately 60–80 years and travelling back towards the pit.

The modelled scenario shows that contaminant movement will generally be limited to within the site footprint with minor occurrences of movement away from site. There are no sensitive receivers (landholder bores and high priority GDEs) located in the modelled particle tracking extent.

Since particle movement was based on conservative parameters such as sulfate, the implications of the model results are that contaminant movement from seepage from the waste rock emplacement areas and the TSF/IWL is likely to remain localised. This indicates that potential impacts from acid and metalliferous drainage and/or saline drainage (of which sulfate is an indicator) are likely to be limited.

The quality of the groundwater collected by the dewatering system, comprising groundwater both pumped from vertical dewatering bores and seeping into the open pits, is expected to be similar to existing groundwater quality and would be used as a water supply for the processing plant (Coffey 2020a).



Source: EMM (2023); Evolution (2023); Nearmap (2021)

0 1 2 km

GDA 1994 MGA Zone 55

N

KEY

Project area

Particle tracking (year)

2240

2006

Results of 200-year particle tracking modelling (fast recovery case)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 6.6

EMM
creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA024_200yrParticleTracking_20230426_02.mxd 26/04/2023

6.3.2 Groundwater borefield

Pumping of the Lower Cowra and Lachlan Formations can draw vertical leakage from overlying groundwater sources. In this instance, the Upper Cowra Formation has a higher salinity and this could potentially increase the salinity of the target formations. Coffey (2020b) undertook an assessment of the potential vertical mixing using numerical species transport simulation. Modelling predicted total dissolved solids, a measurement of salinity, in the Lachlan Formation will increase from approximately 1,260 mg/L (milligrams per litre) to 1,490 mg/L by 2032, an increase of around 20% from pre-mining conditions due to groundwater abstraction. This Project does not propose to change the pumping rate, rather the duration of pumping will slightly increase. Extrapolating groundwater quality predictions to 2042, suggests a further possible 20% increase in salinity whereby groundwater TDS could be around 1,700 mg/L, which is still considered brackish.

6.4 AIP impact assessment

Aquifer interference activities, including mining activities, must be assessed against the AIP minimal impact considerations. Approved works that are for the primary purpose of extracting groundwater do not require assessment against the AIP minimal impact consideration. Importantly, this means that the Bland Creek Palaeochannel and Eastern Saline borefields do not need to be assessed against the AIP criteria. However, pumping from the borefields (and existing landholder bores) are included in the assessment of cumulative 'post-WSP' impacts.

6.4.1 Landholder bores

The maximum cumulative groundwater level drawdown was assessed from the year 2012, consistent with the commencement of the relevant WSPs (refer to Section 5.1.1) within a 5 km radius of the incremental drawdown associated with the Project (as detailed in Section 6.1.3). This was considered an adequate buffer to encompass cumulative impacts from activities within the Project area based on the drawdown extends emanating from the mine, borefield and landholder pumping bores while excluding areas of drawdown that are likely to be only impacted by landholder pumping and/or the Project borefields.

While not assessed under the AIP, borefield and landholder groundwater pumping contributes to the cumulative groundwater level drawdown. It must be noted that as the AIP impacts are assessed from 2012, estimated historical landholder pumping data was used for this time period in this model (as it occurred during history matching-), whereas the Proposed scenario modelled extraction at these landholder bores conservatively at their full WAL allocation. This means there was an increase in landholder bore pumping modelled for the Proposed scenario which is likely to lead to an increase in associated modelled drawdown.

Under the AIP minimal impact considerations, there are four potentially impacted landholder bores, whereby the cumulative drawdown incorporating activities within the Project area is predicted to exceed 2 m. The locations of these bores are shown in Figure 6.7, with details of the bores provided in Table 6.3.

Table 6.3 Details of landholder bores – predicted cumulative drawdown exceeds AIP 2 m drawdown criteria

Bore ID	Purpose	Groundwater Source	Bore Depth (m)	Status	Salinity Description	Yield (L/s)
GW028040	Stock and Domestic	Upper Lachlan Alluvial GW Source (Lower Cowra Formation)	43.6	Use	7,001-10,000ppm	
GW702262	Stock and Domestic	Upper Lachlan Alluvial GW Source (Lachlan Formation)	126	Use	1000 mg/L	2.5

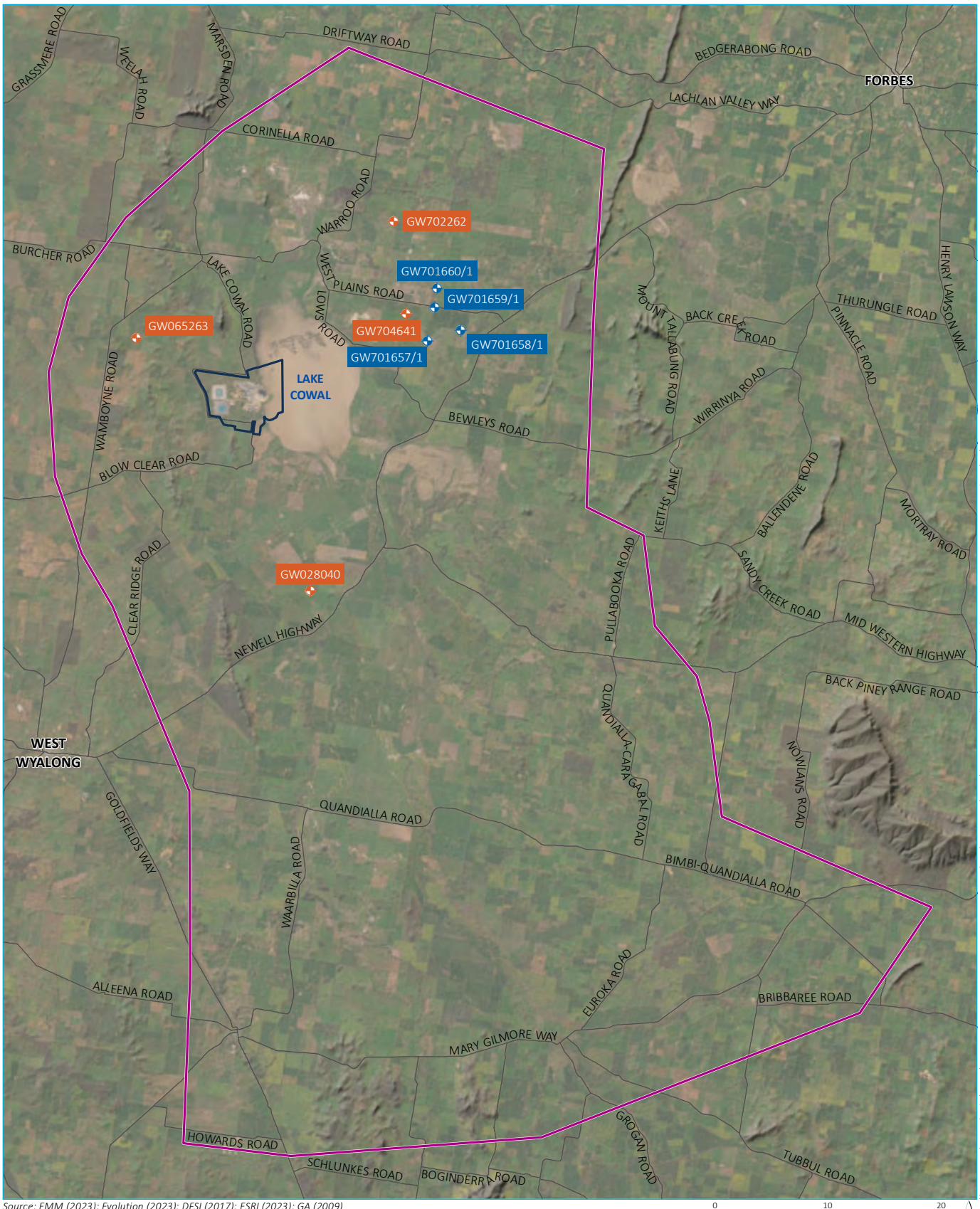
Table 6.3 Details of landholder bores – predicted cumulative drawdown exceeds AIP 2 m drawdown criteria

Bore ID	Purpose	Groundwater Source	Bore Depth (m)	Status	Salinity Description	Yield (L/s)
GW704641	Irrigation	Upper Lachlan Alluvial GW Source (Lachlan Formation)	108	Use	Good	15
GW065263	Stock and Domestic	Lachlan Fold Belt MDB GW Source	83	Unknown		0.13-0.19

The following process was undertaken to determine the number of potentially impacted landholder bores:

- The number of potentially impacted bores within the maximum, cumulative drawdown likelihood exceeding 2 m drawdown extent used for the AIP assessment was determined based on assigned model layers for each bore within the impacted area (as shown in the maximum cumulative likelihood drawdown plots in Attachment F). The maximum cumulative likelihood drawdown incorporates the 'dry' post closure case. The assigned model layer was calculated from bore screen depths (where provided) or bore depth. This indicated that the number of potentially impacted bores was up to 22.

- The modelled hydrographs at these 22 potentially impacted bores (shown in Attachment F) were reviewed to determine timing and extent of potential drawdown. The modelled base case hydrographs incorporate the more representative semi-coupled post closure case. Of the 22 bores, only 4 bores exhibited a drawdown in excess of 2 m at some point between 2012 and 2241 (i.e. 200 years post-mining). Three of the bores exhibited drawdown in excess of 2m during the proposed Project, while the remaining bore (GW065263) exhibited drawdown in excess of 2 m during the post-mining recovery phase only.



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA025_LandholderBoresExceedingCriteria_20230426_02.mxd 26/04/2023

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Landholder bore (exceeding criteria)
- Major road

Landholder bores – predicted cumulative drawdown exceeds AIP 2 m drawdown criteria

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 6.7

EMM
creating opportunities

6.4.2 Water quality

Modelling shows that contaminant movement associated with the Project area will generally be limited to within the Project area footprint with only minor occurrences of movement away from it, where there are no groundwater users (refer to Section 6.3.1). There will be groundwater quality changes around the borefields, resulting from induced leakage from borefield pumping, however impacts associated with the borefield does not require assessment under the AIP. Regardless, the groundwater quality beneficial use category of this water source (i.e. brackish and suitable for irrigation and industrial uses) is not predicted to change i.e. reduce to a lower beneficial use category.

6.4.3 Groundwater dependent ecosystems

Assessment of potential GDEs is addressed in the *Project Biodiversity Assessment Report* (EMM 2023), Appendix J of the EIS. This GIA focuses on high priority listed GDEs listed in the WSPs, which correlate with the HEVAE dataset.

Groundwater levels at three DPE Water groundwater monitoring bores in the north-west of the study area were reviewed from 1983 onwards (Section 3.6.5i). Review of the data range within two standard deviations found the average water level fluctuation was 5 m over the 30 year monitoring period. At high priority GDEs, the AIP requires that less than or equal to 10% cumulative variation in the watertable is assessed. This equates to 0.5 m.

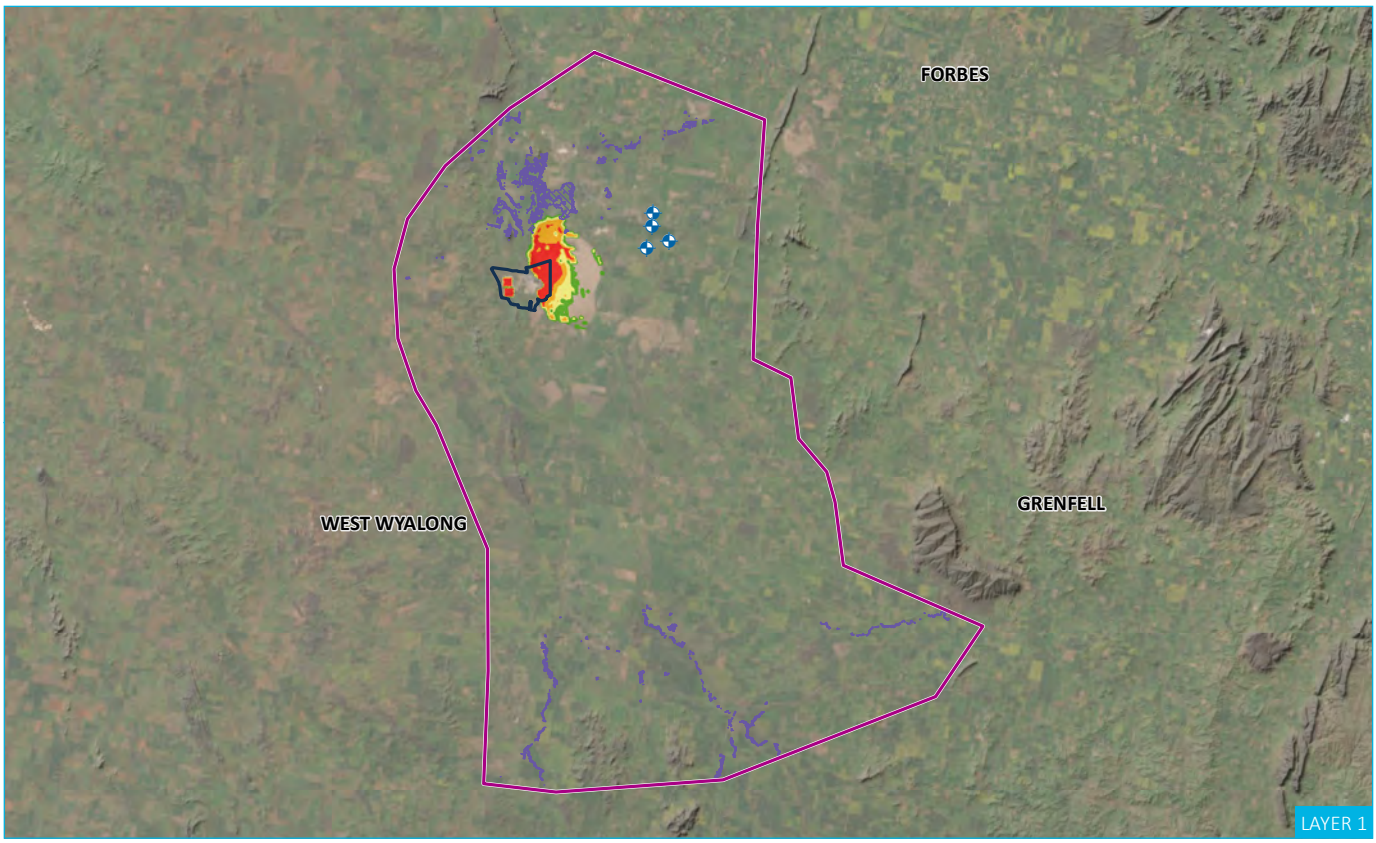
The maximum, cumulative drawdown likelihood exceeding 0.5 m drawdown, since 2012 consistent with the commencement of the relevant WSPs, is presented in Figure 6.8 for model layers 1 and 2, representing the groundwater table. This has been overlain with the HEVAE dataset, comprising high priority listed GDEs as per the AIP.

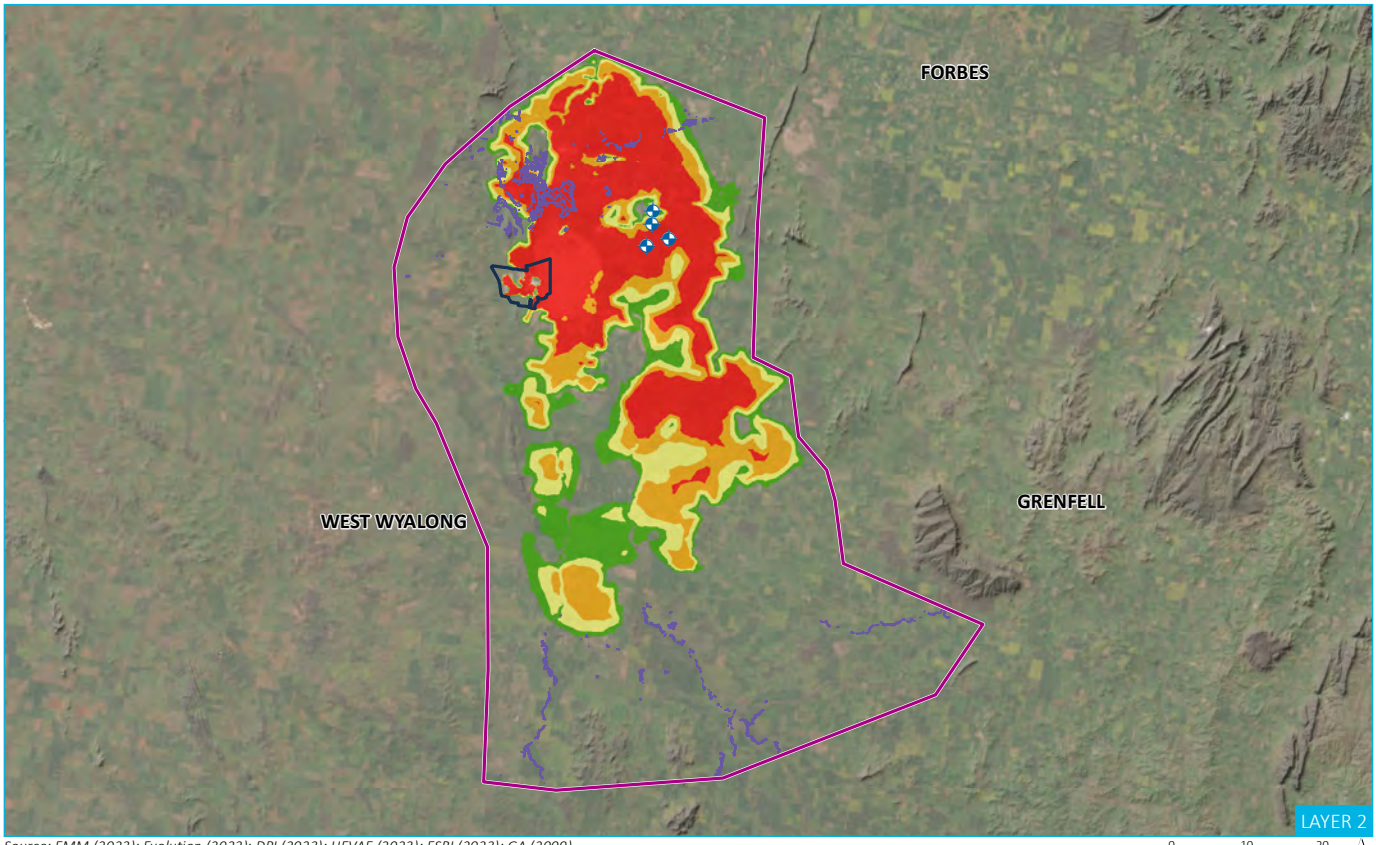
It is very likely there will be drawdown greater than natural water table fluctuations in areas with mapped high priority GDEs to the north of the Project area. This drawdown is caused by both the approved and proposed CGO operations, as well as borefield and landholder groundwater pumping.

Two plant community types (PCTs), assessed and confirmed as high priority GDEs (in the HEVAE dataset and in the *Project Biodiversity Assessment Report*), are predicted to experience greater than 0.5 m drawdown. These are:

- PCT 10: River Red Gum swampy woodland wetland on cowals (lakes) and associated flood channels in central NSW.
- PCT 249: River Red Gum – Black Box woodland wetland of the semi-arid (warm) climatic zone (mainly Riverina Bioregion and Murray Darling Depression Bioregion).

The 10 additional PCTs indicated as HEVAE High Priority GDEs (Table 3.8) were considered to have a negligible dependence on groundwater (EMM 2023).





Source: EMM (2023); Evolution (2023); DPI (2023); HEVAE (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- High priority GDE (DPI-Water) (HEVAE)

0.5 m cumulative drawdown exceedance probability

- 10 %
- 33 %
- 66 %
- 90 %

Drawdown exceedance probability of 0.5 m and high priority listed GDEs

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure 6.8

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA023_CumulativeDrawdown0ptSmContours2012_20230426_03.mxd 26/04/2023

6.5 Bland Creek Palaeochannel Borefield trigger monitoring bores

Modelled groundwater levels at the three regional groundwater monitoring trigger bores were simulated for the base case and the ensemble of predictive realisations and compared to the management thresholds. This drawdown is based on the Proposed scenario and includes landholder pumping, as well as the approved and proposed CGO operations (including borefields). To enable a greater match of drawdown magnitude at the monitoring trigger bores during history-matching, an individual multiplier was used at each bore to improve the modelled drawdown to measured data. This is explained in more detail in the Groundwater Model Report (Attachment C).

The predicted modelled water levels at each of the monitoring trigger bores are shown in Figure 6.9, Figure 6.10 and Figure 6.11. They indicate the following potential impacts:

- Groundwater levels remain above the investigation and mitigation threshold at GW036553 (located in the immediate vicinity of the borefields). The only exception was the P10 percentile around 2010 (during history matching), representing a less than 10% chance of drawdown exceeding the trigger level. The measured data shows that this exceedance did not occur in reality. This bore governs the operation of the BCP borefield (Coffey 2020b).

- Groundwater levels remain above the investigation threshold at GW036597 (located to the south of the borefields) for the P90 percentile and base case. The P10 percentile (considered 'very unlikely', refer to Table 5.6) exceeds the trigger level during the operation of the Project (2023–2041), but then recovers. This bore does not govern the operation of the BCP borefield (Coffey 2020b).

- Base case groundwater levels at GW036611 (located to the south of the borefields) are predicted to just exceed the investigation threshold during the later stages of operation of the Project (from approximately 2035–2040) but will then recover quickly above the trigger level. Post 2040, the P10 percentile is expected to marginally breach the trigger, however this is based on a 'very unlikely' probability of occurrence. This bore does not govern the operation of the BCP borefield (Coffey 2020b).

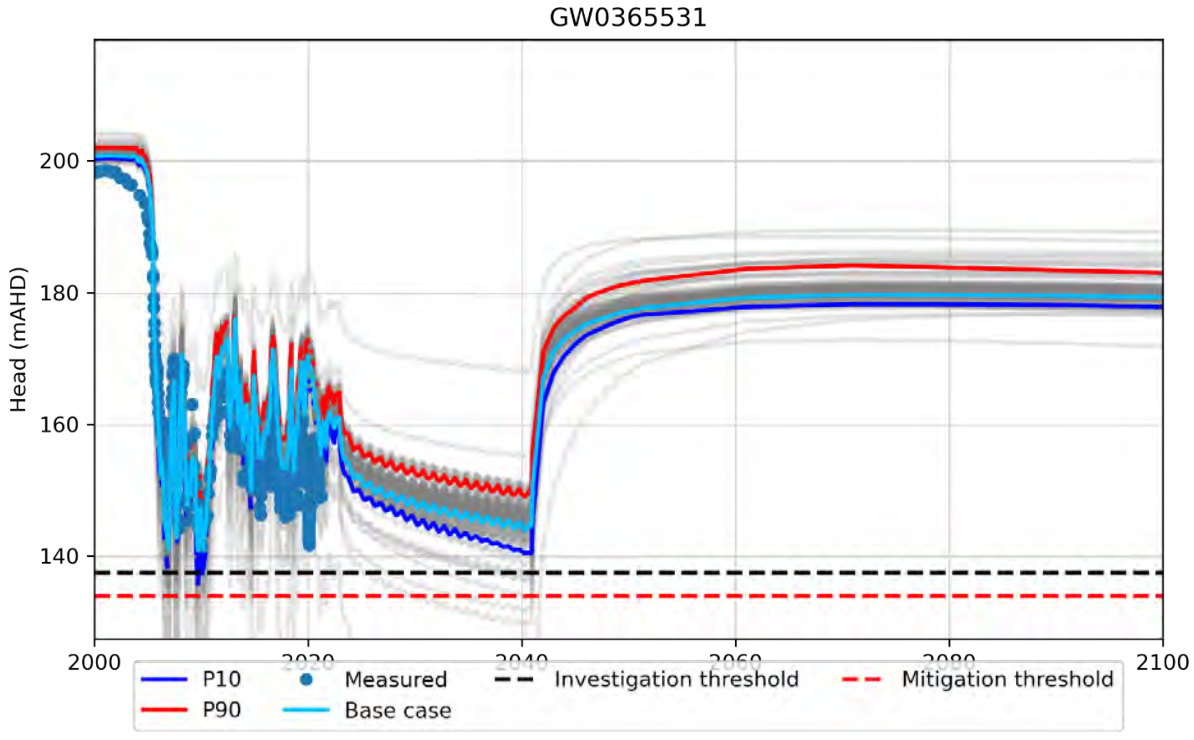


Figure 6.9 Modelled drawdown at trigger bore GW036553

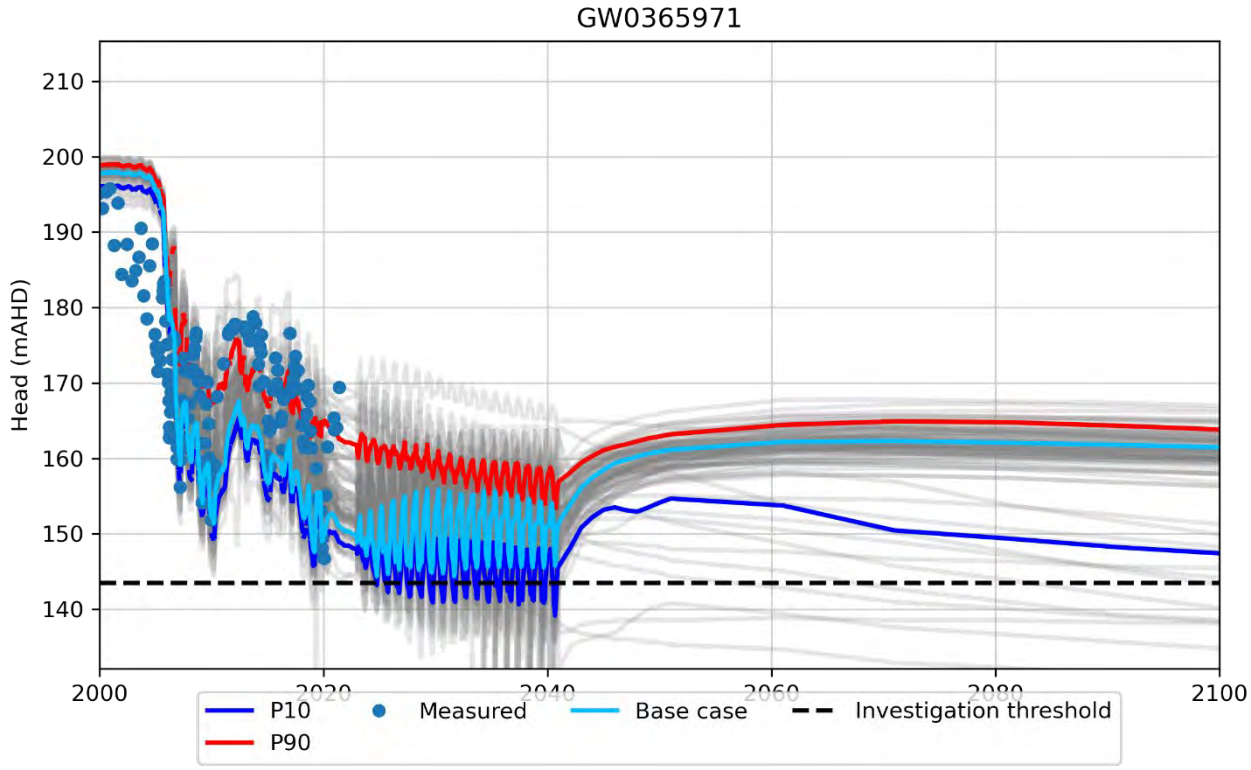


Figure 6.10 Modelled drawdown at trigger bore GW036597

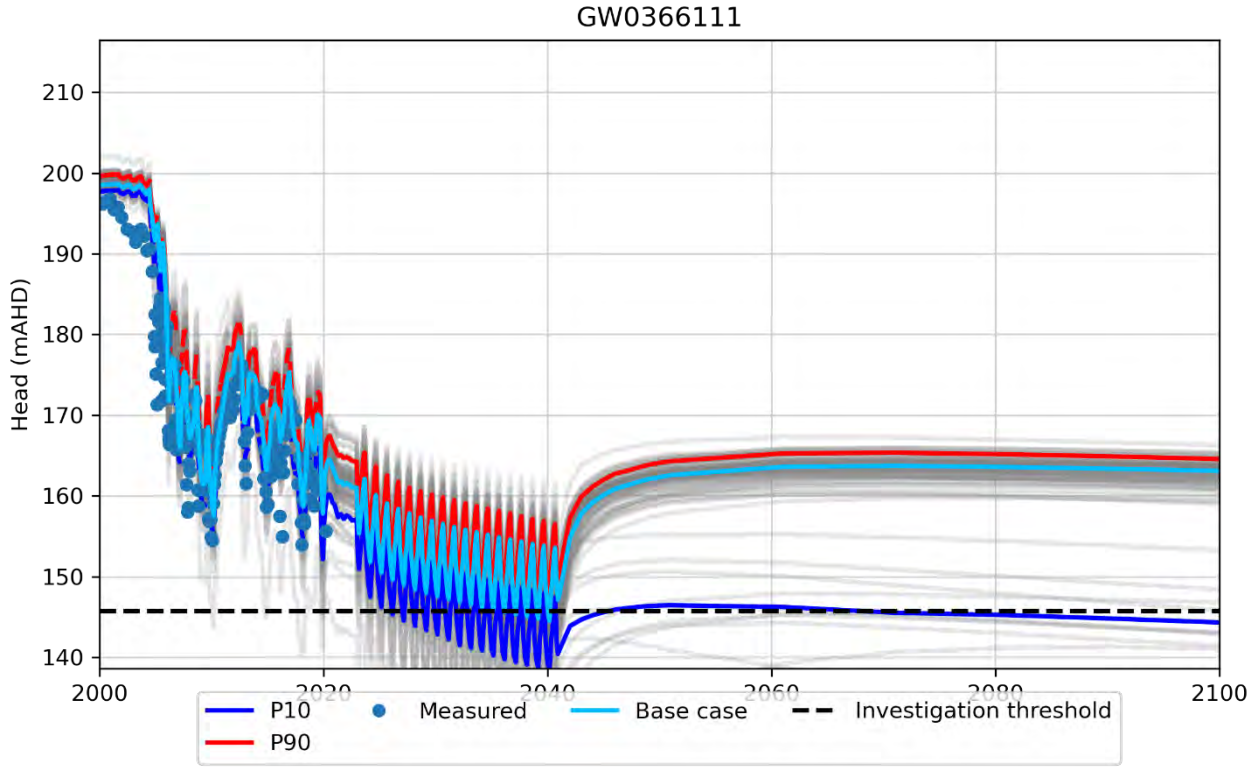


Figure 6.11 Modelled drawdown at trigger bore GW036611

6.6 Seepage assessment

6.6.1 Lake Cowal

The induced modelled seepage during the history-matching and prediction period from Lake Cowal is shown in Figure 6.12. The induced seepage rates are defined as the total additional seepage caused by the Proposed scenario (as defined in Section **Error! Reference source not found.**) compared to the no mining case (i.e. the Null scenario).

The model predicts an induced seepage of around 0.2 ML/d since 2012, with a peak seepage simulated at 0.47 ML/d at 2037. The location of the seepage area aligns with drawdown likelihood plots shown in Section 6.1 for layer 1 and occurs on the eastern portion of the mine site, adjacent to the lake bund. The model has been set up conservatively, whereby Lake Cowal is hydraulically connected to the underlying groundwater system, and thus the surface water/groundwater interaction is largely controlled by the adopted lacustrine clay properties. In reality, field investigations suggest that a small unsaturated zone exists beneath the lake and hence it is hydraulically separated from the groundwater system. Therefore, a pathway does not exist between the CGO operations within the Project area and the lake. The data analytics assessment provided in Attachment G supports this understanding.

6.6.2 Irrigation channels

The induced seepage from the irrigation channels is shown in Figure 6.12. Induced modelled irrigation seepage commences at the start of 2004 and aligns with the ramp up in abstraction from the CGO borefields and landholder bores. From around 2012, modelled seepage remained fairly constant, at less than 0.1 ML/d up until 2022. As modelled drawdown continues to propagate throughout the BCP as shown in Section 6.1, seepage from irrigation channels continues, reaching a peak induced modelled rate of 0.16 ML/d. This aligns with the increase in modelled landholder pumping during the prediction phase, in line with known WAL extraction limits.

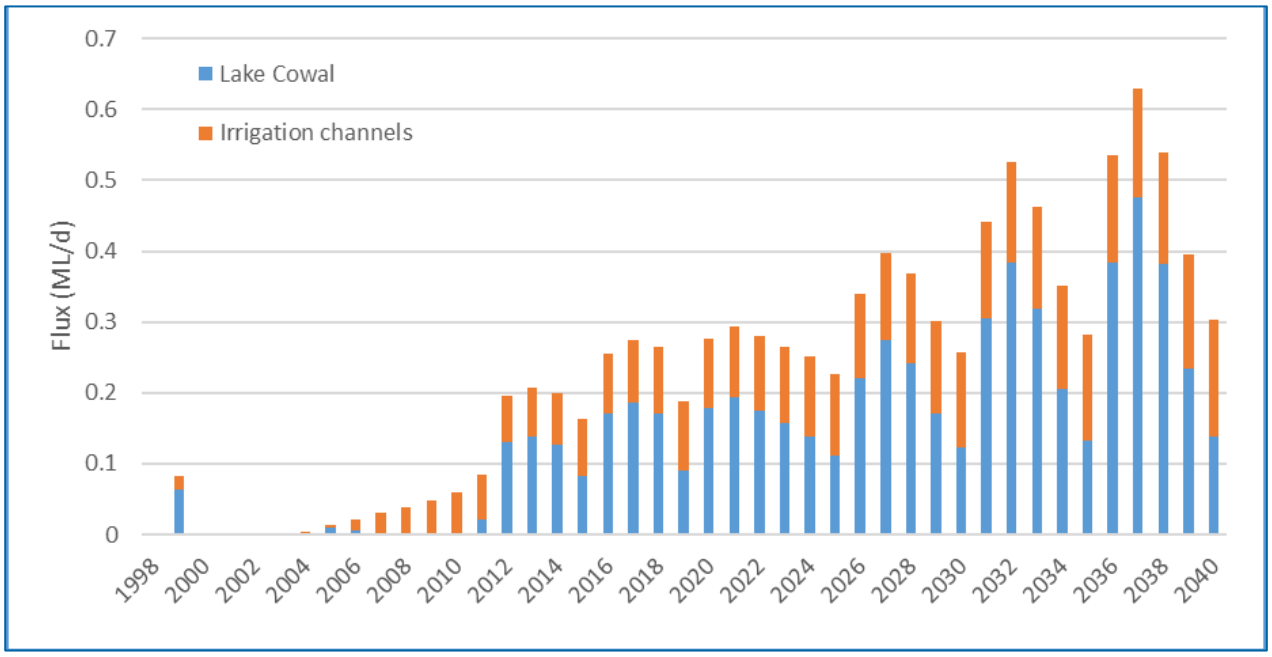


Figure 6.12 Modelled induced seepage from Lake Cowal and the irrigation channels

6.6.3 IWL

The IWL design height for both the existing approved operations and the proposed Project is higher than what is currently operated at site, which is approximately 248 mAHD at 2022 compared to a final maximum height of 251 mAHD. The Project also includes a northern expansion to accommodate tailings from processing ore from the new open pits. Due to this change, modelled seepage rates from IWL increase from around 1 ML/d at 2022 to between 2 and 2.7 ML/d during the prediction period up to 2040 (Figure 6.13).

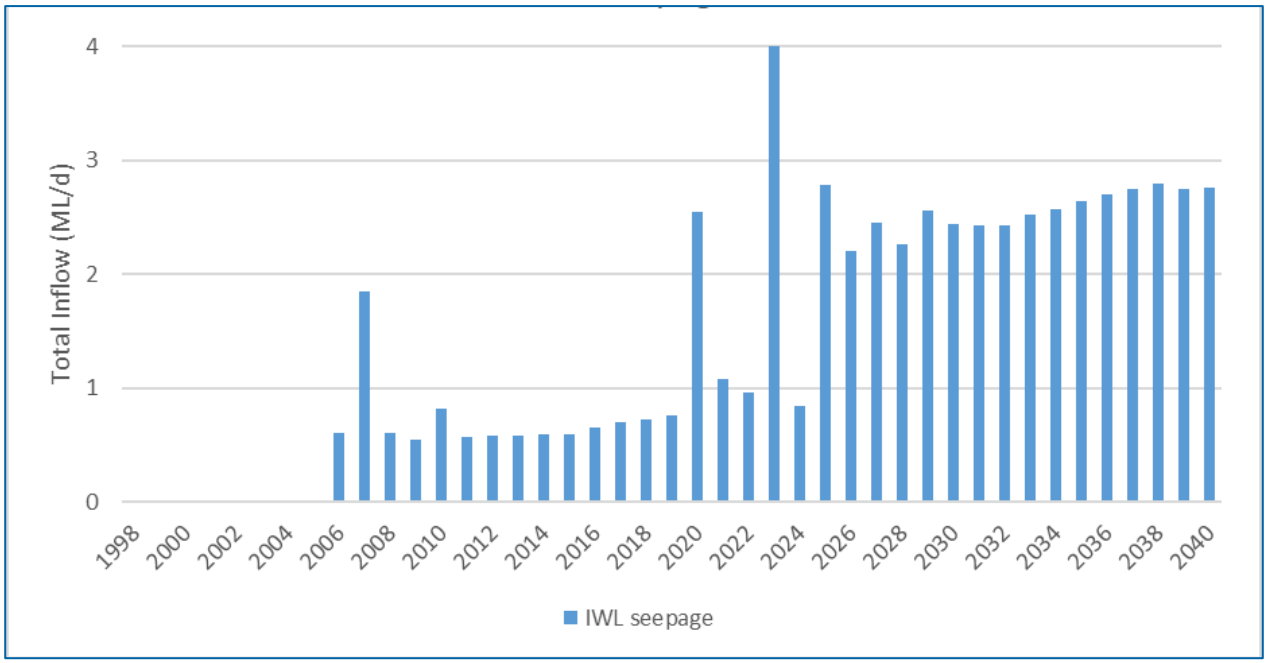


Figure 6.13 Modelled seepage from the IWL

7 Risk assessment

7.1 Risk assessment and management framework

An evaluation of Project activities and potential incremental impacts on groundwater resources and groundwater--dependent assets has been undertaken using a risk assessment framework. The Evolution risk assessment matrix has been used to quantify the potential risks of the Project on groundwater receptors and is presented in Table 7.1.

Table 7.1 Evolution risk assessment matrix

Consequence	Likelihood				
	1 – Highly improbable	2 - Improbable	3 - Possible	4 - Probable	5 – Highly Probable
5 – Extreme	15 Moderate	20 High	22 Material	24 Material	25 Material
4 – Major	10 Moderate	14 Moderate	19 High	21 Material	23 Material
3 – Moderate	6 Low	9 Moderate	13 Moderate	17 High	18 High
2 - Minor	3 Low	5 Low	8 Moderate	12 Moderate	16 Moderate
1 – Very Minor	1 Low	2 Low	4 Low	7 Low	11 Moderate

Evolutions classification of likelihood and risk factors used for the risk assessment are defined in Table 7.2 and Table 7.3.

Table 7.2 Classification of likelihood

1 – Highly improbable	2 – Improbable	3 – Possible	4 – Probable	5 – Highly probable
Once per 100 years or practically impossible or conceivable, but only in extreme circumstances.	Once per 10 years or unlikely to occur or has occurred elsewhere in mining industry within last 10 years.	Once per year or could occur or has occurred elsewhere in the mining industry in the last year.	Once per quarter or likely to occur.	Once per month or less, or will occur, or common or frequent occurrence.

Table 7.3 Classification of consequence

1 – Very minor	2 – Minor	3 – Moderate	4 – Major	5 – Extreme
No lasting environment damage of effect.	Short-term (<1 year) environment damage or effect to a small area of local significance.	Medium-term (<3 year) environment damage or effect to a small area of state or provincial significance.	Widespread and long-term (>3 year) environment damage or effect of national significance.	Significant and permanent environment damage or effect of international significance.
No public concern.	Breach of cultural heritage exclusion zone (no impact).	Unauthorised disturbance of cultural site(s).	Major damage to cultural site(s).	Significant damage to cultural site(s).
0–200 L Hydrocarbon 0–1,000 L mine water, slurry, tailings etc uncontrolled release	200–2,500 L Hydrocarbon. 1,000–50,000 L mine water, slurry, tailings etc uncontrolled release.	2.5 KL – 10 KL Hydrocarbon. 50 KL – 100 KL mine water, slurry, tailings etc uncontrolled release.	10 KL – 100 KL Hydrocarbon. 100 KL – 500 KL mine water, slurry, tailings etc uncontrolled release.	> 100 KL Hydrocarbon. >500 KL Mine water, slurry, tailings etc uncontrolled release.

7.2 Risk evaluation

The risks of potential impacts caused by the Project are summarised in Table 7.4. The risk evaluation assumes no additional controls (beyond those included as part of the Project design) are in place. A revised risk assessment is provided in Section 8.4, and shows the residual risk after mitigation and management measures are implemented.

Table 7.4 Assessment of unmitigated potential impacts or events

Potential impact mechanism	Potential impact/event	Rating reasoning	Risk analysis		
			Likelihood	Consequence	Risk ranking
Operation					
Groundwater quantity: groundwater inflows to pits and underground workings.	Reduced access to water at landholder bores and GDEs causing changes to ecosystem functioning.	Model predicts groundwater drawdown at landholder bores and GDEs, however there are no incremental impacts greater than 2 m at landholder bores.	4	4	21 Mat
Groundwater quantity: pumping from borefield(s).					
Groundwater quantity: spoil, slurry and tailings storage at the IWL and WRE.	Underlying waterlogging, localised increased in depth to the water table causing changes to ecosystem functioning.	Localised impacts, and no potential sensitive receptors in the vicinity of the IWL and WRE.	3	1	4 Low
Groundwater quantity: predicted groundwater take exceeds licensed allocation.	Unlicensed groundwater take.	Model predicts a range of groundwater inflow volumes, with CGO licensing sufficient to cover this take.	1	3	6 Low
Groundwater quality: groundwater inflows to pits and underground workings.	Change in beneficial use/environmental or cultural value at water receivers (including Lake Cowal, landholder bores, etc.), changes to ecosystem functioning.	Groundwater drawn to pit/mining operations will occur.	2	4	14 Mod
Groundwater quantity: pumping from borefield(s).	Induced flows from overlying alluvial units causing groundwater mixing and changes to groundwater quality.	Groundwater salinity in the Lachlan Formation is expected to increase but is predicted to remain brackish.	4	2	12 Mod
Groundwater quality: spoil and tailings storage, and waste rock emplacement.	Seepage of acid mine drainage and leaching of solutes causing changes to groundwater quality.	Potential to occur at unlined storages.	3	2	8 Mod
Groundwater quality: machinery and plant use and storage.	Potential for groundwater contamination.	Potential if spills/leaks occur over non hardstand areas but will be a localised impact and no potential sensitive receptors.	3	1	4 Low

Table 7.4 Assessment of unmitigated potential impacts or events

Potential impact mechanism	Potential impact/event	Rating reasoning	Risk analysis		
			Likelihood	Consequence	Risk ranking
Surface water – groundwater interactions: seepage from water courses/lakes.	Possible induced changes to groundwater quality and surface water volume/flows.	Lake Cowal is hydraulically disconnected to the groundwater (owing to the surficial clay layer). Seepage from irrigation channels is minor.	1	3	6 Low
Aquifer disruption: excavation.	Aquifer/aquitard removal causing change in groundwater flow paths.	Localised impacts within the pit, no sensitive receptors impacted.	5	1	11 Mod
Aquifer disruption: backfilling.	Altered hydraulic properties, change in groundwater flow paths.	Localised impacts within the pit, no sensitive receptors impacted.	5	1	11 Mod
Closure					
Groundwater quantity: groundwater inflows to final voids.	Reduced access to water at landholder bores and GDEs causing changes to ecosystem functioning.	Model predicts groundwater drawdown at landholder bores, with some recovery of groundwater levels. Model predicts drawdown at GDEs.	4	4	21 Mod
Groundwater quantity: spoil and tailings storage, and waste rock emplacement.	Underlying waterlogging, localised increased in depth to the water table causing changes to ecosystem functioning.	Localised impacts, and no potential GDEs in the vicinity of the IWL and WRE.	3	1	4 Low
Groundwater quality: final pit lakes.	Evapoconcentration of COCs within the pit lake, potential acid mine drainage (acidification of pit lake).	Final pit void modelling (Surface Water Assessment, Appendix G of the EIS) indicated that the pit will remain a sink so the concentrated water is unlikely to escape the pit. Localised impacts within the pit, no sensitive receptors impacted.	4	2	12 Mod
Groundwater quality: spoil and tailings storage, and waste rock emplacement.	Seepage of acid mine drainage and leaching of solutes causing changes to groundwater quality.	Potential to occur at unlined storages but driving heads are reducing.	2	2	5 Low

Table 7.4 Assessment of unmitigated potential impacts or events

Potential impact mechanism	Potential impact/event	Rating reasoning	Risk analysis		
			Likelihood	Consequence	Risk ranking
Surface water – groundwater interactions: groundwater inflows to final voids.	Possible induced changes to groundwater quality and surface water volume/flows.	Lake Cowal is hydraulically disconnected to the groundwater (owing to the surficial clay layer). Seepage from irrigation channels is minor.	1	3	6 Low
Aquifer disruption: backfilling.	Altered hydraulic properties, change in groundwater flow paths.	Localised impacts within the pit, no sensitive receptors impacted.	5	1	11 Mod

8 Monitoring, mitigation and management

8.1 Groundwater management strategy

An overview of the Project risks impacting groundwater and the proposed water management and mitigation measures is provided in Table 8.1. Further details are provided in the existing CGO *Water Management Plan* (Evolution 2022c).

Table 8.1 Potential groundwater risks and management measures

Potential impact/risk	Management measure	Timing
Groundwater inflows to pits and underground workings causing reduced access to water at landholder bores and GDEs.	In accordance with the cumulative AIP minimal impact considerations: • An evaluation of make good arrangements may be required at up to 4 bores. • Adaptive management measures may be implemented at high priority GDEs. Groundwater level monitoring at Project monitoring bores and model validation will be undertaken to monitor and confirm model predictions.	Operation and post-closure
Groundwater inflows to pits and underground workings causing possible changes to groundwater quality.	Groundwater quality monitoring will continue to assess groundwater quality trends.	Operation and post-closure
The predicted groundwater take exceeds licensed allocation and groundwater take is unlicensed.	Evolution holds sufficient groundwater entitlement for the predicted groundwater take. In pit monitoring (pump rate and hours of operation) will be undertaken to monitor and confirm actual groundwater take. Data collected from the meter reading will be assessed during the annual review to evaluate groundwater inflows into the mining operations.	Operation and post-closure
Pumping from borefield(s) causing reduced access to water at landholder bores, and GDEs.	Trigger levels and groundwater level monitoring are established to prevent this eventuating.	Operation
Pumping from borefield(s) causing induced flows from overlying alluvial units causing groundwater mixing and changes to groundwater quality.	Groundwater quality at nearby monitoring bores or trigger bores to be monitored for groundwater quality trends. Not predicted to exceed current water quality classification.	Operation
Induced seepages from watercourses and lakes.	Unlikely to eventuate.	Operation and post-closure
Spoil and tailings storage, and WRE causing underlying waterlogging and potential leakage of acid mine drainage and solutes.	Low permeability basal layer, directing flow into water storage dams or the open pit.	Operation and post-closure
Use of IWL with potential leakage of COC including saline groundwater.	Containment of potentially saline and/or contaminated seepage generated from WREs.	Operation and post-closure
Machinery and plant use and storage where there are spills and leakages causing groundwater contamination.	Bunding, diversion drains around the process plant, sediment dams and stockpiles, and sediment traps are used to manage runoff and/or spills.	Operation
Pit excavation and backfilling causing aquifer/aquitard removal and changed hydraulic parameters.	Groundwater level monitoring and model validation will be undertaken to monitor potential changes in groundwater levels outside the pit area.	Operation and post-closure

Table 8.1 Potential groundwater risks and management measures

Potential impact/risk	Management measure	Timing
Final pit lakes where there is evapoconcentration of COCs and potential acid mine drainage (acidification of pit lake).	Groundwater level monitoring and model validation will be undertaken to monitor potential changes in groundwater levels outside the pit area. Groundwater quality monitoring will continue to assess groundwater quality trends.	Operation and post-closure

The key groundwater management measures rely on continued groundwater level and quality monitoring, numerical model validation, review of groundwater levels at the trigger bores, and separation of dirty and clean water streams.

The approved CGO *Water Management Plan* documents the groundwater mitigation and management measures. This includes the groundwater monitoring program, reporting requirements, spill management and response, corrective actions and contingencies for management measures. The WMP will be reviewed and updated following Project approval in response to the outcomes of this assessment and any additional related approval requirements.

8.1.1 Make good – landholder bores

Consistent with the existing development consents, CGO will provide a compensatory water supply to any landowner of privately-owned land whose rightful water supply is adversely and directly impacted (in accordance with the AIP criteria) as a result of the Cowal Gold Operations. Compensatory water supply measures will be developed in consultation with DPE Water and DPE and will provide an alternative long-term supply of water that is equivalent, in quality and volume, to the loss attributable to the CGO. Equivalent water supply will be provided (at least on an interim basis) as soon as practicable after the loss is identified, unless otherwise agreed with the landowner.

8.1.2 Groundwater dependent ecosystem management

The groundwater model predicts that it is very likely there will be drawdown greater than natural water table fluctuations in areas with mapped high priority GDEs to the north of the Project area. This drawdown is caused by both the approved and proposed CGO operations, as well as existing borefield and landholder groundwater pumping. Adaptive management strategies will be implemented to monitor and respond (if required) to Project-related drawdown and uncertain impacts to potentially impacted River Red Gum populations, as detailed in the *Project Biodiversity Assessment Report* (EMM 2023), Appendix J of the EIS. This may involve ground truthing of potentially affected GDEs, monitoring via vegetation plots and groundwater level monitoring.

8.1.3 Groundwater monitoring

In accordance with DA 14/98 condition 4.4(d)(iii), a groundwater monitoring program for the operations phase of the CGO has been developed. The groundwater monitoring program relates to groundwater monitoring in aquifers beneath the ML area and regionally within the BCP aquifer. Groundwater monitoring will continue to be used to validate predictive modelling, particularly in the vicinity of the open pit, IWL and ML 1535 Saline Groundwater Borefield (when in use). Continued monitoring of groundwater salinity will be undertaken in the BCP Borefield to assess potential saline migration. CGO have installed nested monitoring bores within Lake Cowal to monitor for potential hydraulic connection between an inundated Lake Cowal and the underground works. Groundwater quality and level data will continue to be collected from this network throughout the life of the Project.

8.1.4 Groundwater level triggers

Groundwater extraction from the BCP borefield is managed via groundwater trigger levels developed in consultation with DPE Water and other water users within the BCP, including stock and domestic users and irrigators.

Water levels at trigger bore GW036553 (located near the mine borefield) govern the operation of the CGO borefields (Coffey 2020b), as the Development Consent for the existing CGO operations states that Evolution must "*Implement all reasonable and feasible measures to ensure that extraction of groundwater from the borefields does not result in exceedances of established mitigation trigger response levels*". Trigger bore GW036553 is the only monitoring bore with a mitigation trigger level. Numerical model predictions indicate water levels will remain above the investigation and mitigation trigger levels at GW036553.

Pumping from the BCP borefield will cease if required to meet trigger levels in accordance with the Groundwater Contingency Strategy detailed in the *Water Management Plan* (Evolution 2022c). Should the groundwater levels look to be approaching the trigger levels, alternate water supplies would be considered, including water internal and external to CGO, such as the Lachlan River water entitlements.

8.2 Groundwater licensing

Evolution is required to licence groundwater that is intentionally taken or intercepted in accordance with the WM Act and AIP (refer Attachment A), and the SSD Development Consent. This includes water that is taken for use as well as water that is incidentally intercepted and managed as part of construction and operational activities. This will be a licensable volume from the fractured rock aquifer, regulated by the MDB Fractured Rock WSP, and from the overlying sediments, regulated by the Lachlan Alluvial WSP.

The groundwater inflow volumes associated with the project have been informed by the hydrogeological numerical flow modelling. It predicted the following maximum inflows for the two impacted water sources:

- Upper Lachlan Alluvial Groundwater Source Management Zone 7 – 0.33 ML/day in 2026 (total inflow from layers 2, 3 and 4 (Upper Cowra, Lower Cowra and Lachlan Formation, respectively).
- Lachlan Fold Belt MDB Groundwater Source – 4.56 ML/day in 2027 (total inflow from all layers minus layers 2, 3 and 4).

The predicted annual groundwater volumes required to be licensed within each WSP for the Project are summarised in Table 8.2.

Table 8.2 Groundwater licensing requirements summary for approved and proposed CGO operations

Water sharing plan	Management zone/ Groundwater source	Project use (current)	Predicted groundwater inflow/extraction volume requiring licensing (ML/year)	Currently licensed unit share
Lachlan Alluvial Groundwater Sources 2020	Upper Lachlan Alluvial Groundwater Source Management Zone 7	ESB	182.5[1]	300 units (WAL 36569)
		BCP borefield	1,460[2]	3,350 units (WAL 31864)
		Saline groundwater supply borefield within ML 1535 Pit dewatering	**376 (maximum)[3]**	366 units (WAL 36615)

Table 8.2 Groundwater licensing requirements summary for approved and proposed CGO operations

Water sharing plan	Management zone/ Groundwater source	Project use (current)	Predicted groundwater inflow/extraction volume requiring licensing (ML/year)	Currently licensed unit share
NSW Murray Darling Basin Fractured Rock Groundwater Sources 2020	Lachlan Fold Belt MDB Groundwater Source	Pit dewatering	1,664 (maximum)	3,294 units (WAL 36617)

1. Based on 0.5 ML/day extraction (long-term average).
2. Based on 4 ML/day extraction (long-term average).
3. Based on 0.7 ML/day extraction from the saline groundwater supply borefield (long-term average) plus 0.33 ML/day peak inflows from the alluvium.

The predicted volume requiring licensing for the operation of the saline groundwater supply borefield and pit dewatering from the alluvium exceeds the currently licensed unit share for the associated WAL (WAL 36615). However there are additional unit shares available in the Upper Lachlan Alluvial Groundwater Source Management Zone 7 under WAL 36569 or WAL 31864 that would be able to account for these additional volumes. Therefore sufficient entitlement is held by Evolution for the predicted water take from groundwater sources and no additional entitlement is expected to be required for the project. A Water Licensing Strategy has been devised for the Project and is appended separately to the EIS (Appendix I).

Post mining, the long-term inflow rate was assessed to be less than 3.65 ML/year from the fractured rock groundwater source and the Upper Lachlan Alluvial Groundwater Source Management Zone 7 combined. These volumes would continue to require licensing.

8.3 Groundwater model verification and review

The groundwater model predictions would be validated by comparison with actual groundwater level data and measured drawdown. Significant deviations from the predicted impacts will be investigated. Model recalibration will be considered every three years based on analysis of predicted versus actual impacts and undertaken if greater than predicted drawdowns are evident and are considered likely to impact stream baseflows, GDEs and water bores.

Groundwater monitoring data will be used to validate and verify the groundwater model predictions. New data may require a revision and update of the conceptual hydrogeological model prior to updating and recalibrating the numerical model and re-running of predictive scenarios and realisations. Where this is deemed necessary, the WMP may also require updating depending on any changes to the conceptualisation and model predictions.

As mining progresses, a need for further model updates will be assessed every three years based on evaluation of groundwater monitoring data and findings of impact verification.

8.4 Residual risk assessment

Risk evaluation in Section 7.2 is re-assessed considering the recommended controls and management measures outlined above. A revised risk assessment is provided in Table 8.3.

Table 8.3 Assessment of residual risk of potential impacts or events

Potential impact mechanism	Management or mitigation	Residual risk		
		Likelihood	Consequence	Risk ranking
Groundwater inflows to pits and underground workings causing reduced access to water at landholder bores and GDEs.	In accordance with the cumulative AIP minimal impact considerations: • An evaluation of make good arrangements may be required at up to 4 bores. • Adaptive management measures will be implemented at high priority GDEs. Groundwater level monitoring at Project monitoring bores and model validation will be undertaken to monitor and confirm model predictions.	1	4	10 Mod
Groundwater inflows to pits and underground workings causing possible changes to groundwater quality.	Groundwater quality monitoring within and outside the ML.	1	4	10 Mod
The predicted groundwater take exceeds licensed allocation and groundwater take is unlicensed.	Evolution holds sufficient groundwater entitlement for the predicted groundwater take. In pit monitoring (pump rate and hours of operation) will be undertaken to monitor and confirm actual groundwater take. Date collected from the meter reading will be assessed during the annual review to evaluate groundwater inflows into the mining operations.	1	3	6 Low
Pumping from borefield(s) causing reduced access to water at landholder bores, and GDEs.	Trigger levels and groundwater level monitoring are established to prevent this eventuating.	1	4	10 Mod
Pumping from borefield(s) causing induced flows from overlying alluvial units causing groundwater mixing and changes to groundwater quality.	Groundwater quality at nearby monitoring bores or trigger bores to be monitored for groundwater quality trends. Not predicted to exceed current water quality classification.	4	2	12 Mod
Induced seepages from watercourses and lakes, although Lake Cowal is hydraulically disconnected to the groundwater (owing to the surficial clay layer).	Established groundwater level and quality monitoring will continue to assess for potential hydraulic connectivity.	1	3	6 Low
Spoil, slurry and tailings storage at the IWL and WRE causing underlying waterlogging and potential leakage of acid mine drainage and solutes.	Low permeability (compacted) basal layer to prevent vertical leakage. Direction of dirty water flows into water storage dams and/or the open pit.	2	2	5 Low
Machinery and plant use and storage where there are spills and leakages causing groundwater contamination.	Bunding, diversion drains around the process plant, sediment dams and stockpiles, and sediment traps are used to manage runoff and/or spills.	2	1	2 Low
Pit excavation and backfilling causing aquifer/aquitard removal and changed hydraulic parameters.	Groundwater level monitoring and model validation will be undertaken to monitor potential changes in groundwater levels outside the pit area.	5	1	11 Mod

Table 8.3 Assessment of residual risk of potential impacts or events

Potential impact mechanism	Management or mitigation	Residual risk		
		Likelihood	Consequence	Risk ranking
Final pit lakes where there is evapoconcentration of COCs and potential acid mine drainage (acidification of pit lake).	Groundwater level monitoring and model validation will be undertaken to monitor potential changes in groundwater levels outside the pit area. Groundwater quality monitoring will continue to assess groundwater quality trends	4	2	12 Mod

9 Conclusions

Evolution is proposing to extend open pit mining operations at its existing CGO open pit and underground gold mine at Lake Cowal. The potential groundwater impacts were predicted using a numerical groundwater flow model, with impacts to landholder bores, GDEs and surface water features considered. The numerical model predicts the following:

- There are two separate drawdown zones associated with the mine and borefield pumping. Drawdown from mining will propagate outside the ML boundary. However, the difference in drawdown impacts between the approved CGO operations and the additional proposed mining activities are considered minor:
  - The continued operation of the CGO borefields in association with the Project does not result in groundwater level drawdown changes greater than 2 m from its current approved operation.
  - There is no material change in groundwater level drawdown at any landholder bore associated with the Project when it is considered on its own (i.e. incremental drawdown).
- Groundwater levels will remain above the investigation and mitigation trigger levels at the DPE Water bore GW036553 (located near the mine borefield). Water levels at this trigger bore govern the operation of the CGO borefields.
- Under the AIP-specific cumulative impact evaluation (i.e. incorporating the approved operations, the local private bore operations, the CGO borefields plus the Project), the maximum cumulative is predicted to exceed the AIP minimal impact considerations (2 m drawdown) at four bores.
- Two River Red Gum PCTs, assessed and confirmed as high priority GDEs, are predicted to experience greater than 0.5 m drawdown in groundwater level, representing the natural fluctuation in groundwater level.
- Field investigations and chemical analysis suggest that the lake is hydraulically separated from the groundwater system by a small unsaturated zone beneath the lake, and that a pathway does not exist between the mine site activities and the lake. Modelled seepage predictions from Lake Cowal are therefore conservative.
- Contaminant movement via seepage from the WREs and the TSF/IWL are likely to remain localised with potential impacts from acid and metalliferous drainage and/or saline drainage expected to be limited. Furthermore, there are no groundwater users predicted to be impacted. There is ongoing groundwater quality changes around the borefields, resulting from induced leakage from borefield pumping, however this is not predicted to change the groundwater quality beneficial use category (i.e. brackish and suitable for irrigation and industrial uses).

The residual risk assessment concluded that the overall project risk to groundwater quantity and quality is low to moderate, with no high or material risk activities.

Evolution holds sufficient shares in the Upper Lachlan Alluvial Groundwater Source Management Zone 7 and Lachlan Fold Belt MDB Groundwater Source for the predicted water take from these groundwater sources. No additional entitlement is expected to be required for the project.

A project-specific *Water Management Plan* (2022c) has been established and approved by the relevant agencies. This includes the groundwater monitoring program, reporting requirements, spill management and response, corrective actions and contingencies for management measures. The WMP will be reviewed and updated following Project approval in response to the outcomes of this assessment and any additional related approval requirements.

Ongoing management and mitigation measures include:

- Make good provisions if water supply at private bores is directly affected by the Project, consistent with the current development consent requirements.
- Adaptive management strategies will be implemented to monitor and respond (if required) to Project-related drawdown and uncertain impacts to potentially impacted River Red Gum populations.
- Continued groundwater level and quality monitoring. The monitoring network is established and relates to groundwater monitoring in aquifers beneath the ML area and regionally within the BCP aquifer.
- Continued review of groundwater levels at the trigger monitoring bores. Pumping from the BCP borefield will cease if required to meet the trigger levels in accordance with the Groundwater Contingency Strategy and alternate water supplies would be considered, including water internal and external to CGO.
- Periodic model validation whereby the groundwater model predictions would be validated by comparison with actual groundwater level data, mine inflows and measured drawdown.
- Physical controls to manage slurry, COCs and discharges including low permeability basal layers at storages, diversion of flows into water storages/open pits, bunding and sediment traps.

References

ATC Williams. 2023. “Cowal Gold Operations - Surface Water Assessment.”

Barnett, B., Townley, L., Post, V., Evans, R., Hunt, R., Peeters, L., Richardson, S., Werner, A., Knapton, A., & Boronkay, A. 2012. *Australian groundwater modelling guidelines.* National Water Commission.

Bilge, H. 2012. *Upper Lachlan Groundwater Flow Model.* Technical assessment, Sydney: NSW Office of Water.

BoM. 2017. “Groundwater Dependent Ecosystems Atlas.” Accessed 08 15, 2022. http://www.bom.gov.au/water/groundwater/gde/.

—. 2022. “National Groundwater Information System.” Accessed 08 15, 2022. http://www.bom.gov.au/water/groundwater/ngis/.

Coffey. 2020b. *Bland Creek Palaeochannel Borefield and Eastern Saline Borefield Groundwater Assessment.* Coffey Services Australia Pty Ltd .

Coffey. 2021. *CGO Underground Development EIS - Addendum 2 of the hydrogeological assessment.* Coffey Services Australia Pty Ltd.

Coffey. 2020a. *Cowal Underground Development EIS - Mine Site Hydrogeological Assessment.* Sydney: Coffey Services Australia Pty Ltd.

Colquhoun, G P, K S Hughes, L Deyssing, J C Ballard, C B Folkes, G Phillips, A L Troedson, and J A Fitzherbert. 2022. *Seamless Geology dataset, version 2.2 [Digital Dataset].* Digital dataset, Department of Regional NSW, Maitland, NSW: Geological Survey of New South Wales.

DCCEEW. 2010. “Directory of Important Wetlands in Australia (DIWA) Spatial Database.” Energy, the Enninronment and Water Department of Climate Change. Accessed 03 01, 2023. https://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7BED248FC1-7237-4A74-91AC-2DA3FC277E0A%7D.

—. 2022. “Ramsar Wetlands of Australia.” the Environment, Energy and Water Department of Climate Change. Accessed 03 02, 2023. https://www.dcceew.gov.au/sites/default/files/documents/ramsar-sites-australia.pdf.

DCS. 2023. “NSW Hydrography.” Accessed 02 28, 2023. https://datasets.seed.nsw.gov.au/dataset/nsw-hydrography.

DES. 2022. “SILO - Australian climate data from 1889 to yesterday.” Accessed 06 29, 2022. https://www.longpaddock.qld.gov.au/silo/.

DPE. 2012a. “Australian Soil Classification (ASC) soil type map of NSW.” Accessed 02 27, 2023. https://datasets.seed.nsw.gov.au/dataset/australian-soil-classification-asc-soil-type-map-of-nsweaa10.

—. 2022d. *Cumulative groundwater impact assessment approaches, Information paper.* NSW Department of Planning and Environment.

DPE. 2022a. *Groundwater assessment toolbox for major projects in NSW, overview document.* NSW Department of Planning and Environment.

—. 2022b. *Guidelines for Groundwater Documentation for SSD/SSI Projects, Technical guideline.* NSW Department of Planning and Environment.

—. 2022f. “HEVAE Vegetation Groundwater Dependent Ecosystems Value - Lachlan.” Accessed 2 13, 2023. https://datasets.seed.nsw.gov.au/dataset/hevae-vegetation-groundwater-dependent-ecosystems-lachlan.

—. 2012b. “Hydrologic soils groups of NSW.” Accessed 02 22, 2023. https://datasets.seed.nsw.gov.au/dataset/hydrologic-groups-of-soils-in-nsw7f9e8.

—. 2022c. *Minimum groundwater modelling requirements for Major Projects in NSW, Technical guideline.* NSW Department of Planning and Environment.

—. 2020. “NSW Landuse 2017 v1.2.” Edited by State Government of NSW and Department of Planning and Environment. Accessed 01 20, 2023. https://datasets.seed.nsw.gov.au/dataset/nsw-landuse-2017-v1p2-f0ed.

—. 2022e. “Water Management (General) Regulation 2018 hydroline spatial data 1.0.” Accessed 02 15, 2023. https://trade.maps.arcgis.com/apps/webappviewer/index.html?id=07b967fd0bdc4b0099fc5be45b6d1392.

DPI. 2016. “DPI-Water GDE HEVAE High Priority.” Accessed 2 13, 2023. https://spatial-server.industry.nsw.gov.au/arcgis/rest/services/DPIWater/GDE_HEVAE_High_Priority/MapServer/WMTS/1.0.0/WMTSCapabilities.xml.

DPI. 2012. *NSW Aquifer Interference Policy.* Policy document, Department of Primary Industries, Office of Water, Orange: NSW Department of Primary Industries.

EGi. 1996. “Cowal Gold Project Environmental Assessment of Simulated Tailings.”

EGi. 1995. “Cowal Gold Project Environmental Geochemical Assessment of Process Tailings, Mine Rock and Surface Zone Materials.”

EGi. 1997. “Cowal Gold Project Environmental Geochemistry Assessment of Proposed Mining Activities for Cowal Gold Project.”

EGi. 1998. “Cowal Gold Project Final Void Water Chemistry.”

EGi. 2004. “Geochemical Assessment of Waste Rock and Process Talings.”

EMM. 2023. *Cowal Gold Operations - Biodiversity Assessment Report.* Technical assessment, Ecology, Sydney: EMM Consulting Pty Ltd.

Evolution. 2022c. “Cowal Gold Operations Water Management Plan.”

—. 2022a. “Cowal operation - A world class system fact sheet.” Accessed 02 20, 2023. https://evolutionmining.com.au/wp-content/uploads/2022/03/Cowal-fact-sheet-FY22.pdf.

Evolution. 2022b. *Groundwater quality data - Site monitoring.* Evolution Mining Limited.

Foster, David A, and David R Gray. 2000. *Evolution and Structure of the Lachlan Fold Belt (Orogen) of Eastern Australia.* Published paper, Department of Earth Sciences, La Trobe University, Melbourne: Australian Geodynamics Cooperative.

Freeze, R and J. Cherry. 1979. *Groundwater.* University of Michigan: Prentice-Hall.

Geiger, Rudoplf. 1954. “Classification of climates after W. Köppen.” *Landolt-Börnstein – Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik und Technik, alte Serie* 3 (1): 603–607. Accessed 2011.

GEM. 2011a. “Cowal Gold Mine Augmentation Project, Environmental Geochemistry Assessment of Waste Rock and Tailings.”

GEM. 2008. “Cowal Gold Mine E42 Modification, Tailings and Waste Rock Geochemical Assessment.”

GEM. 2013. “Cowal Gold Mine Extension Modification, Environmental Geochemistry Assessment of Waste Rock and Tailings.”

GEM. 2011b. “Cowal Gold Mine Extension Project Pre-Feasibility, Environmental Geochemistry Assessment of Waste Rock, Low Grade Ore and Tailings.”

GEM. 2020a. “Cowal Gold Operations Geochemical Assessment of Proposed Pebble Material Processing.”

GEM. 2016. “Cowal Gold Operations Mine Life Modification, Environmental Geochemistry Assessment of Waste Rock and Tailings.”

GEM. 2023. “Cowal Gold Operations Open Cut Expansion Project Environmental Geochemistry Assessment.”

GEM. 2020b. “Cowal Gold Operations Underground Development, Environmental Geochemistry Assessment.”

Geoscience Australia. 2010. “ELVIS - Elevation and Depth - Foundation Spatial Data.” Accessed 11 20, 2022. https://elevation.fsdf.org.au/.

Lampayan, Rubenito M. 2001. *Groundwater Hydrology and Modelling of the Jemalong and Lake Cowal Aquifer Systems, Lachlan Catchment, NSW.* Thesis, Canberra: Australian National University.

Middlemis, Hugh, and Luk Peeters. 2018. *Uncertainty analysis—Guidance for groundwater modelling within a risk management framework.* Canberra: Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development.

Moran C, Vink S, Straughton G and Howe P. 2010. *Framework for assessing potential local and cumulative effects of mining on groundwater resources - Report 3 Framework for risk-based assessment of cumulative effects to groundwater from mining.* Australian National Water Commission.

Serov P, Kuginis L, Williams J.P. 2012. *Risk assessment guidelines for groundwater dependent ecosystems.* Sydney: NSW Department of Primary Industries, Office of Water.

Venkataramani. 2017. “Subsurface Modelling of The Gilmore Fault Zone - Implications for the Lachlan Tectonic Reconstructions.” Thesis, School of Environment and Life Sciences, University of Newcastle, Newcastle.

Glossary

Term	Description
Additional surface disturbance area	The areas that will be disturbed by the Project that are outside of the existing and approved surface disturbance area for CGO.
AGMG	*Australian Groundwater Modelling Guidelines* (Barnett 2012)
AIP	Aquifer Interference Policy (2012)
ANC	Acid neutralisation capacity
BCPB	Bland Creek Palaeochannel
BoM	Bureau of Meteorology
COC	Constituents of concern
CGO	Cowal Gold Operations Comprises both open pit and underground operations currently approved under DA14/98 and SSD-10367.
DA	Development application
DCCEEW	Commonwealth Department of Climate Change, Energy, the Environment and Water
DES	Queensland Department of Environment and Science
DIWA	Directory of Important Wetlands in Australia
DPE	NSW Department of Planning and Environment
DPE Water	NSW Department of Planning and Environment - Water
EIS	Environmental impact statement
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPA	Environment Protection Authority
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
ESB	Eastern saline borefield
Evolution	Evolution Mining (Cowal) Pty Limited
Existing and approved surface disturbance areas	Areas that are disturbed, previously disturbed and/or approved under the NSW EP&A Act to be disturbed under the current development consents that apply to CGO.
GDE	Groundwater dependent ecosystem
GIA	Groundwater Impact Assessment
ha	hectare
HEVAE	High Ecological Value Aquatic Ecosystem
HSU	Hydrostratigraphic units
ICDS	In catchment diversion system
IESC	Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development
IWL	Integrated waste landform

Term	Description
JIA	Jemalong Irrigation Area
km	Kilometres
L/s	Litres per second
Lachlan Alluvial WSP	*Water Sharing Plan for the Lachlan Alluvial Groundwater Sources 2020*
LFB	Lachlan Fold Belt
LGO	Low-grade ore
LPB	Lake protection bund
m	Metres
m^2/day	Metres squared per day
mAHD	Metres Australian height datum
mbgl	Metres below ground level
MDB	Murray Darling Basin
MDB Fractured Rock WSP	*Water Sharing Plan for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2020*
mg/L	Milligrams per litre
ML	Megalitres
ML	Mine lease
ML/day	Megalitres per day
ML/year	Megalitres per year
Mt per annum	million tonnes per year
µS/cm	Micro siemens per centimetre
NAF	Non-acid forming
NGIS	National Groundwater Information System
NRAR	Natural Resources Access Regulator
NSW	New South Wales
Open pit mining operations	Includes the removal and placement of waste rock in WREs or backfilled into E46 pit, extraction of ore and ancillary activities.
PAF	Potentially acid forming
PCT	Plant community types
POEO Act	NSW *Protection of the Environment Operations Act 1997*
Processing operations	Includes the processing of ore from both underground and open pit mining operations and the placement of tailings in the IWL.
The Project	The Project in its entirety, encompassing proposed open pit continuation project components and existing approved activities under DA14/98 and SSD-10367.

Term	Description
Project application area	The area which is subject to the development application in its entirety, encompassing the Project area, water supply pipeline and the BCP Borefield as shown on Figure 1.2.
Project area	The area at the CGO mine site that is the subject of the development application as shown on Figure 1.3.
Proposed mining footprint	Areas where ore extraction will take place for the Project and includes: • areas outside of the existing and approved disturbance area • areas already disturbed by ore extraction at CGO (i.e. E42 pit) • areas within the existing and approved disturbance footprint but not currently disturbed by ore extraction.
SEARs	Secretary's Environmental Assessment Requirements
SSD	State significant development
SSI	State significant infrastructure
TSF	Tailings storage facility
UCDS	Up-catchment diversion system
Underground mining operations	Includes the development of stopes and the extraction of ore via long hole stoping, the backfilling of stopes with cemented paste fill and ancillary activities.
WRE	Waste rock emplacement
WAL	Water access licences
WSP	Water sharing plan
Water Act	*Water Act 1912*
WM Act	*Water Management Act 2000*
WMP	Water Management Plan

Attachment A
Regulatory overview

EMM
creating opportunities

A.1 Relevant legislation

A.1.1 Water Management Act 2000

The WM Act is the primary legislation governing water management and licensing in NSW.

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

The WM Act provides for water sharing between different water users, including environmental, basic rights or existing WAL holders and provides security for licence holders.

The licensing provisions of the WM Act become effective for any water source once a WSP for that water source commences; it has progressively been enacted across NSW since July 2004.

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

The WM Act is replacing the *Water Act 1912*. This transition occurs for particular water sources when a water sharing plan which applies to those water sources commences. This transition process is largely complete.

i Water Sharing Plans

WSPs are statutory documents that apply to one or more water source areas. They contain the rules for sharing and managing the water resources within water source areas. WSPs are designed to establish sustainable use and management of water resources and are periodically reviewed (every 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 then outline the water available for extractive uses within different categories, such as: local water utilities, domestic and stock, basic rights, and access licences. Long-term average annual extraction limits (LTAAELs) are set by WSPs to define the limit of water that can sustainably be taken for all purposes. Sharing of water is prioritised for the environment, with planned environmental water prescribed under the rules of a WSP to protect the fundamental health of a river or aquifer and the ecosystems that depend on it. Requirements for basic landholder rights and licensed water users are also provided within WSPs. Amongst licensed water users, priority is given to water utilities and licensed stock and domestic use, ahead of commercial purposes such as irrigation and mining.

A.1.2 NSW Protection of the Environment Operations Act

The POEO Act is the key piece of environment protection legislation administered by the NSW EPA. 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, an environment protection licence (EPL) is required for 'scheduled activities'.

Activities that may lead to pollution of waters in NSW are regulated by the EPA under the POEO Act. Where discharge of waters is permitted, it is controlled by licence conditions such that discharges do not result in significant impacts on water resources.

Under Section 120 of the POEO Act, it is an offence to pollute waters or cause harm unless licensed to do so. Pollution in NSW is regulated by the POEO Act with discharges from mine water management systems requiring licensing by an EPL if the discharge would otherwise constitute a pollution of waters.

A.1.3 NSW Biodiversity Conservation Act 2016

Under the BC Act, any activities assessed under Part 5 of the EP&A Act must apply the test of significance to determine whether the proposed activity is likely to significantly impact threatened species or ecological communities. If a significant impact is likely, the proponent may choose to opt into the Biodiversity Offsets Scheme (BOS) or undertake a Species Impact Statement (SIS). These are included elsewhere in the Biodiversity Assessment.

A.1.4 NSW Fisheries Management Act 1994

The FM Act is the principal piece of legislation protecting aquatic habitat in NSW. The FM Act aims to conserve fish stocks, key fish habitat, aquatic vegetation, and threatened species, populations and communities. Threatened aquatic species, populations and communities are listed under Schedules 4, 4A and 5 of the FM Act, while key threatening processes are listed under Schedule 6. Any impact to groundwater level or quality needs to be considered under the FM Act for groundwater dependent rivers if it has the potential to reduce streamflow and block fish passage.

A.2 Relevant policies

A.2.1 Aquifer Interference Policy

i Overview

The AIP was released by the NSW Government in September 2012. The purpose of the AIP is to explain the water licensing and assessment processes for aquifer interference activities under the WM Act and other relevant legislative frameworks.

The dictionary to the WM Act (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.

The AIP clarifies the requirements for obtaining water licences for aquifer interference activities and defines considerations in assessing and providing advice on whether more than minimal impacts might occur to a key water-dependent asset.

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.

The key requirements of the AIP are to:

- Account for, or prevent, the take of water. Where a proposed activity will take water from an aquifer or connected surface water source, adequate arrangements must be in place to account for this water. It is the proponent's responsibility to enable this to be estimated to a suitable level of accuracy, and to ensure necessary WALs are obtained and held.

- Address the 'minimal impact considerations'. Aquifer interference activities can adversely impact groundwater and connected surface water sources by decreasing groundwater pressure and/or lowering the watertable; deteriorating groundwater and surface water quality either due to pollution or increases in salinity; by affecting the health or viability of a groundwater dependent ecosystem; or impacting on a culturally significant site. The AIP provides objective, measurable thresholds for considering the degree of impact an activity may have on the watertable, groundwater pressure and water quality changes. The assessment criteria differ between aquifer types (for example alluvial, porous, fractured) and whether the aquifer is deemed 'highly' or 'less' productive on the basis of natural water quality and extraction yields.

- Propose remedial actions. Where impacts are greater than those that were predicted as part of the relevant approval, proposed remedial actions shall be specified to manage those impacts.

ii AIP assessment process

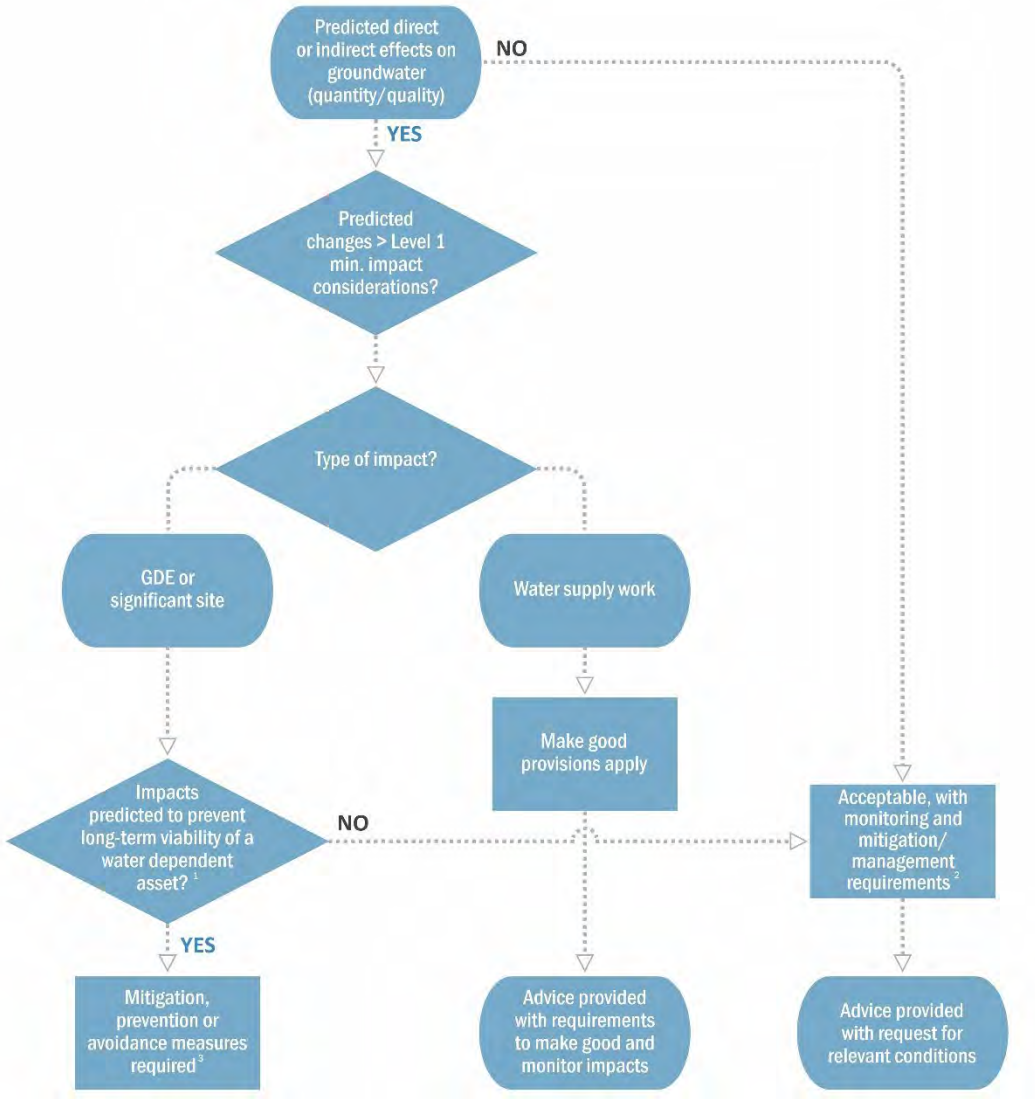
As part of the NSW Government's role in water management, including assessing development proposals and providing advice to the DPE Planning and Assessment Group, DPE Water's approach is based on the principles of "account for, mitigate, avoid/ prevent, and remediate".

The Aquifer Interference Assessment Framework is a step-by-step guide that DPE Water use to assess project proposals against the AIP. The framework has been considered in this assessment and is provided in Attachment B.

a Minimal impact considerations

The WM Act includes the concept of ensuring "no more than minimal harm" for both the granting of WALs and the granting of approvals.

The minimal impact considerations have been developed for impacts on groundwater sources, connected water sources, and their dependent ecosystems, culturally significant site and water users. The AIP minimal impact considerations process is shown in Figure A.1.



1 Assessment as per Serov et al 2012, with consideration of uniqueness, ecological/cultural value and timeframe of the impact.

2 Conditions of approval may include requirements for adaptive management to monitor and mitigate or remediate impacts that exceed level 1 thresholds.

3 Where there are no suitable or practical mitigation or prevention options, the proponent may be asked to avoid impacts by modifying the proposed activity.

Figure A.1 AIP minimal impact considerations process (adapted from DPI Water 2012a)

b Make good provisions

AIP Fact Sheet 4 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 groundwater dependent ecosystem or culturally significant site defined in a WSP.

iii Licensing

The WM Act requires water users or landholders to hold:

- a WAL to take water from a river, lake, dam or groundwater for irrigation, industrial, or commercial purposes
- a water supply work approval to construct and use a water supply work, such as a pump, dam, channel or bore
- a water use approval for a specific purpose at a particular location
- a flood work approval for works on floodplain that diver floodwaters
- a controlled activity approval to carry out work in a watercourse or within 40 metres of the bank of a river, lake of estuary, such as extracting material from a river bed, constructing a creek crossing or residential developments.

However, under Clause 4.41(1)(g) of the EP&A Act, SSD projects are exempt from requiring:

- a water use approval under Section 89 of the WM Act
- a water management work approval under Section 90 of the WM Act, or
- an activity approval (other than an aquifer interference approval) under Section 91 of the WM Act.

As the Project is an SSD, there is no requirement to obtain approvals under the WM Act.

AIP Fact Sheet 3 and the DPE Water (2022b) guidelines provides guidance regarding licensing and accounting for water. Water can be taken directly from a groundwater or surface water source, usually via a pump (in a river or an excavated area) or bore. It can also be taken indirectly when an aquifer interference activity causes water to flow from another connected groundwater or surface water source. Flows induced from other water sources also constitute take of water. In all cases, separate WALs are required to account for the take from all individual water sources.

Take of water is licensed by the source from where the water is taken.

For example, where an aquifer interference activity is taking water from a groundwater source, and this take is causing the movement of water from a connected surface water source into the groundwater source, then an access licence in the regulated or unregulated river water source is required to account for the take of water from that water source and another access licence in the groundwater source is required for the remainder of the take. This is illustrated in Figure A.2 below.

The DPE Water (2022b) guidelines note the total volume of water to be taken from each water source as a result of an aquifer interference activity needs to be estimated before project approval can be granted. A proponent is not required to hold sufficient entitlement prior to project approval; however, the proponent is required to demonstrate the licensing pathway to secure sufficient entitlement for the peak take (including documenting the proposed mechanisms to secure the entitlement, for example trade or controlled allocation orders). A proponent is required to hold sufficient entitlement prior to the take occurring (DPE Water 2022b).

Once the activity commences, the take must be measured and reported (DPE Water 2022b).

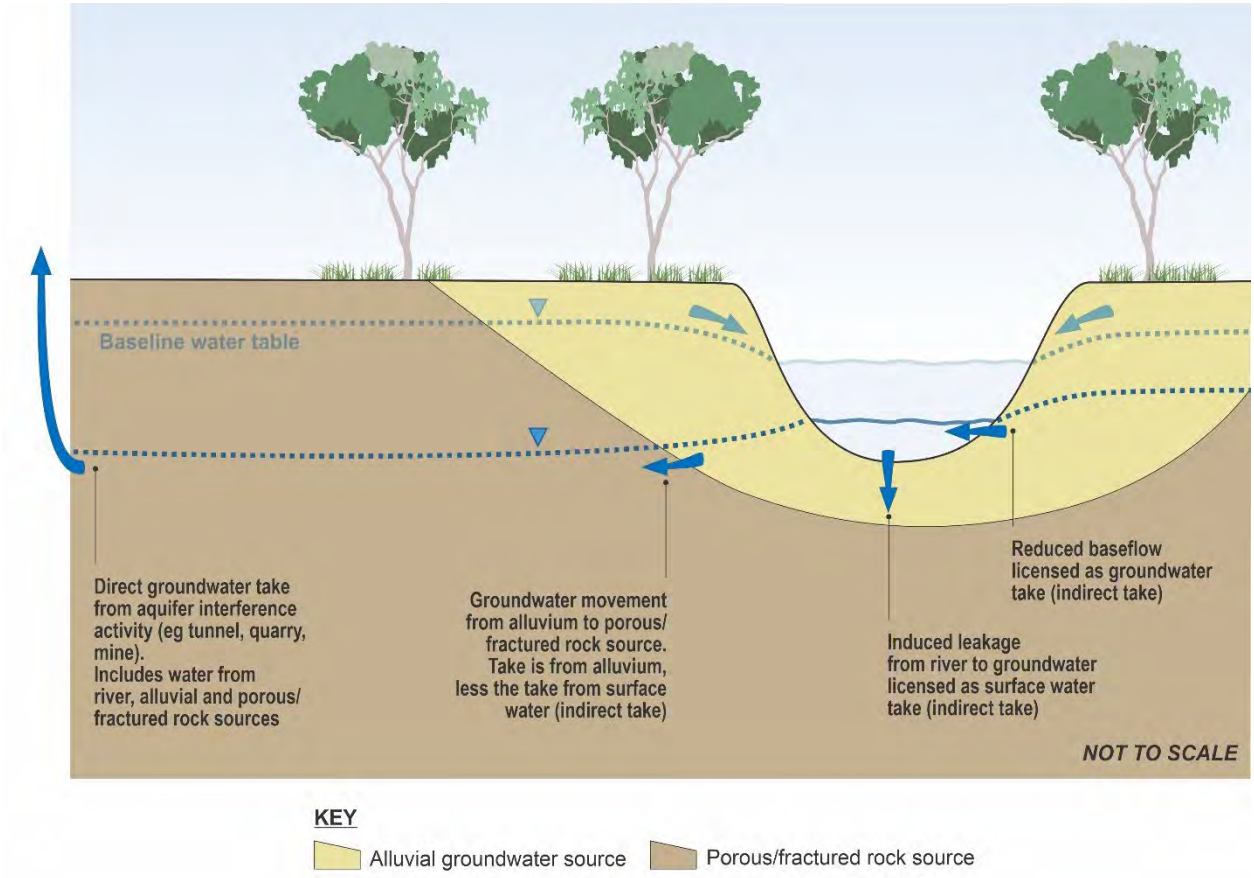


Figure A.2 Licensing requirements by source (surface water vs groundwater) (DPE Water 2022b)

iv NSW State Groundwater Dependent Ecosystems Policy

This policy aims to protect the ecological processes and biodiversity of ecosystems that depend on groundwater. The GDE policy was developed in 2002, and outlines the following principles for managing GDEs:

- The scientific, ecological, aesthetic and economic values of GDEs, and how threats to them may be avoided, should be identified and action taken to ensure the most vulnerable and valuable ecosystems are protected.
- Groundwater extractions should be managed sustainably so that ecological processes and biodiversity are maintained and/or restored.
- Priority should be given to ensuring enough groundwater of a suitable quality is available when needed for:
  - protecting ecosystems which are known to be, or most likely to be, groundwater dependent
  - GDEs which are under immediate or high degree of threat from groundwater-related activities.
- Where scientific knowledge is lacking, the precautionary principle should be applied to protect GDEs.
- Planning, approval and management should aim to minimise adverse impacts on GDEs by:
  - maintaining natural patterns of groundwater flow and not disrupting groundwater levels that are critical for ecosystems

- not polluting or causing adverse changes in groundwater quality
- rehabilitating degraded groundwater systems where practical.

A.3 Relevant guidelines

A.3.1 Groundwater Assessment Toolbox for Major Projects in NSW

DPE Water has developed a Groundwater Assessment Toolbox for Major Projects in NSW (Groundwater Assessment Toolbox) (DPE Water 2022a), which aims to create a collaborative, transparent and enabling environment for the preparation and review of groundwater assessments for major projects in NSW. The documents provide a framework to investigate, assess the impacts on, manage and monitor groundwater resources and their interaction with surface water resources within the footprint of a major project.

The Groundwater Assessment Toolbox is a complementary guidance document that comprises the following documents:

- *Guidelines for Groundwater Documentation for SSD/SSI Projects* (DPE Water 2022b)
- *Minimum Requirements for Groundwater Modelling* (DPE Water 2022c)
- *Cumulative Groundwater Impact Assessment Approaches* (DPE Water 2022d).

These documents denote the role of the NSW Government in project assessment, and the continuation of guidance on and review of post-approvals monitoring and management plans, and compliance reporting.

The GIA has been prepared in accordance with the above guidance documentation.

A.3.2 Australian Groundwater Modelling Guidelines

The Australian Groundwater Modelling Guideline (Barnett 2012) provide a consistent and sound approach for the development of groundwater flow 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 information on the data requirements for models (depending on complexity and level of potential risk and scale), such as spatial distribution of bores and temporal groundwater level data.

The numerical groundwater model for the Project has been prepared in accordance with the Australian Groundwater Modelling Guidelines and peer reviewed using the structure of the 'review checklist' as per the guidelines.

A.3.3 Uncertainty analysis – Guidance for groundwater modelling within a risk management framework

The IESC published guidelines on undertaking uncertainty analysis in March 2018 (Middlemis and Peeters 2018). The guidelines recommend different levels of uncertainty analysis for various project complexities and risks, with the most robust and detailed option being 'stochastic modelling with Bayesian probability quantification'. This detailed uncertainty analysis produces "an ensemble of model predictions ... based on a large number of model evaluations with different parameter values that are all consistent with the observations" (Middlemis and Peeters 2018).

Attachment C details the approach taken for the uncertainty analysis completed as part of the groundwater modelling for the Project.

A.3.4 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) provides guidance on monitoring, assessing and managing ambient water quality in a wide range of water resource types and according to specified environmental values, such as aquatic ecosystems, primary industries, recreation and drinking water. The guidelines provide a framework for:

- establishing water quality objectives
- assessing and managing water quality for environmental values
- establishing protection levels, water quality indicators and trigger values.

A.3.5 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 WM Act.

The GDE Risk Assessment Guidelines provide that GDEs:

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

An ecosystem's dependence on groundwater can be variable, ranging from partial and infrequent dependence, i.e. seasonal or episodic (facultative), to total continual dependence (entire/obligate) (Figure A.3).

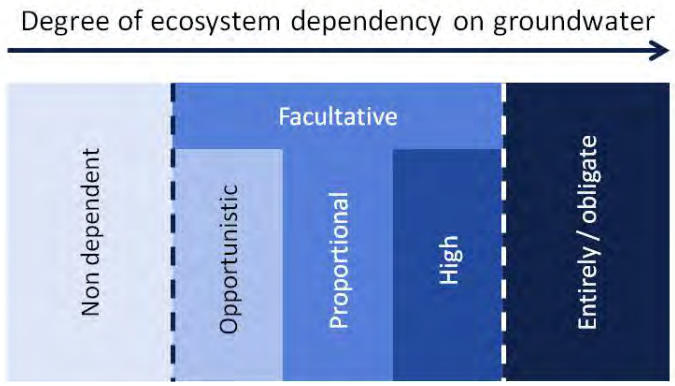


Figure A.3 Groundwater dependent ecosystem level of dependence on groundwater

Serov *et al* (2012) has developed a risk assessment approach, documented in the *Risk Assessment Guidelines for Groundwater Dependent Ecosystems.* The following risk factors are required to be considered in the assessment:

- Impacts to groundwater quantity: reductions in fluctuations in groundwater levels and/or pressure, reductions in seasonal baseflow conditions.
- Impacts to water quality: changes in water quality that may impacts any beneficial uses of the system.
- Impacts to aquifer integrity: changes to geological structure supporting a GDE, including timeframe and severity of impacts.
- Impacts to the biological integrity of the GDE: species diversity or composition, dieback of vegetation, increased exotic species or removal/alteration of habitat.

The risk assessment approach considered the risk of impact (low, medium or high) as well as the ecological value of the GDE (low, medium or high) to determine the overall risk.

Attachment B

Supporting assessment requirements

EMM
creating opportunities

Department of Primary Industries
Office of Water

AQUIFER INTERFERENCE ASSESSMENT FRAMEWORK

Assessing a proposal against the NSW Aquifer Interference Policy – step by step guide

Note for proponents

This is the basic framework which the NSW Office of Water uses to assess project proposals against the **NSW Aquifer Interference Policy (AIP).**

The NSW Aquifer Interference Policy can be downloaded from the NSW Office of Water website (www.water.nsw.gov.au under Water management > Law and policy > Key policies > Aquifer interference).

While you are not required to use this framework, you may find it a useful tool to aid the development of a proposal or an **Environmental Impact Statement (EIS).**

We suggest that you summarise your response to each AIP requirement in the tables following and provide a reference to the section of your EIS that addresses that particular requirement. Using this tool can help to ensure that all necessary factors are considered, and will help you understand the requirements of the AIP.

Table 1. Does the activity require detailed assessment under the AIP?

	Consideration	Response
1	Is the activity defined as an aquifer interference activity?	If **NO,** then no assessment is required under the AIP. If **YES,** continue to Question 2.
2	Is the activity a defined minimal impact aquifer interference activity according to section 3.3 of the AIP?	If **YES**, then no further assessment against this policy is required. Volumetric licensing still required for any water taken, unless exempt. If **NO**, then continue on for a full assessment of the activity.

Note for proponents

Section 3.2 of the AIP defines the framework for assessing impacts. These are addressed here under the following headings:

1. Accounting for or preventing the take of water
2. Addressing the minimal impact considerations
3. Proposed remedial actions where impacts are greater than predicted.

1. Accounting for, or preventing the take of water

Where a proposed activity will take water, adequate arrangements must be in place to account for this water. It is the proponent's responsibility to ensure that the necessary licences are held. These requirements are detailed in Section 2 of the AIP, with the specific considerations in Section 2.1 addressed systematically below.

Where a proponent is unable to demonstrate that they will be able to meet the requirements for the licensing of the take of water, consideration should be given to modification of the proposal to prevent the take of water.

Table 2. Has the proponent:

	AIP requirement	Proponent response	NSW Office of Water comment
1	Described the water source(s) the activity will take water from?	Two WSPs apply to the groundwater resources in the study area: • WSP for the Lachlan Alluvial Groundwater Sources 2020 • WSP for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2020	
2	Predicted the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity?	Yes, refer to Section 8.2 The volume of groundwater required to be licensed for the Project is a total maximum of 2,018.5 ML/yr in the Upper Lachlan Alluvial Groundwater Source Management Zone 7 and 1,664 ML/year in the Lachlan Fold Belt MDB Groundwater Source.	
3	Predicted the total amount of water that will be taken from each connected groundwater or surface water source after the closure of the activity?	Yes, refer to Section 8.2 Post mining the long-term inflow rate was assessed to be less than 3.65 ML/year from the fractured rock groundwater source and the Upper Lachlan Alluvial Groundwater Source Management Zone 7 combined.	
4	Made these predictions in accordance with Section 3.2.3 of the AIP? (refer to Table 3, below)	Yes	
5	Described how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources?	Yes, refer to Section 8.2	
6	Described how any licence exemptions might apply?	Yes, refer to Appendix I of the EIS (Water Licensing Strategy)	
7	Described the characteristics of the water requirements?	Yes, refer to Appendix I of the EIS (Water Licensing Strategy)	

	AIP requirement	Proponent response	NSW Office of Water comment
8	Determined if there are sufficient water entitlements and water allocations that are able to be obtained for the activity?	Yes, refer to Section 8.2 and Appendix I of the EIS (Water Licensing Strategy)	
9	Considered the rules of the relevant water sharing plan and if it can meet these rules?	Yes	
10	Determined how it will obtain the required water?	Project borefield: Section 3.6.2 and Appendix I of the EIS (Water Licensing Strategy)	
11	Considered the effect that activation of existing entitlement may have on future available water determinations?	Yes, there are monitoring trigger bores used to monitor take and inform entitlement. These have also been modelled in the prediction scenarios for the Project.	
12	Considered actions required both during and post-closure to minimize the risk of inflows to a mine void as a result of flooding?	Yes, the expanded Lake Protection Bund has been designed to maintain the required freeboard to withstand an 1% Annual Exceedance Probability (AEP) flood event (including potential wave action), refer to Chapter 4 of the EIS.	
13	Developed a strategy to account for any water taken beyond the life of the operation of the project?	Yes, refer to Appendix I of the EIS (Water Licensing Strategy)	
Will uncertainty in the predicted inflows have a significant impact on the environment or other authorised water users? If **YES,** items 14-16 must be addressed.			
14	Considered any potential for causing or enhancing hydraulic connections, and quantified the risk?		
15	Quantified any other uncertainties in the groundwater or surface water impact modelling conducted for the activity?		

	AIP requirement	Proponent response	NSW Office of Water comment
16	Considered strategies for monitoring actual and reassessing any predicted take of water throughout the life of the project, and how these requirements will be accounted for?		

Table 3. Determining water predictions in accordance with Section 3.2.3
(complete one row only – consider both during and following completion of activity)

	AIP requirement	Proponent response	NSW Office of Water comment
1	**For the Gateway process**, is the estimate based on a simple modelling platform, using suitable baseline data, that is, fit-for-purpose?		
2	**For State Significant Development or mining or coal seam gas production**, is the estimate based on a complex modelling platform that is: • Calibrated against suitable baseline data, and in the case of a **reliable water source,** over at least two years? • Consistent with the Australian Modelling Guidelines? • Independently reviewed, robust and reliable, and deemed fit-for-purpose?	Yes. Considerable data available from the existing operation and surrounding areas has been used to develop and update a regional groundwater model that is based on groundwater monitoring data. The modelling is consistent with the Australian Groundwater Modelling Guidelines and has been independently peer reviewed by Will Minchin. Attachment C describes the groundwater modelling. The peer review report is provided as Attachment D to the Groundwater Impact Assessment report.	
3	In all other processes, estimate based on a desk-top analysis that is: • Developed using the available baseline data that has been collected at an appropriate frequency and scale; and • Fit-for-purpose?		

Other requirements to be reported on under Section 3.2.3

Table 4. Has the proponent provided details on:

	AIP requirement	Proponent response	NSW Office of Water comment
1	Establishment of baseline groundwater conditions?	See Sections 3 & 4	
2	A strategy for complying with any water access rules?	Yes, refer to Appendix I of the EIS (Water Licensing Strategy)	
3	Potential water level, quality or pressure drawdown impacts on nearby basic landholder rights water users?	See Section 6.4.1 Groundwater level drawdown impacts predicted.	
4	Potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources?	See Section 6.4.	
5	Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems?	See Section 6.4.3.	
6	Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems?	See Section 6.3.2 and 6.4.2. Groundwater mixing is expected, but will not change the beneficial use classification.	
7	Potential to cause or enhance hydraulic connection between aquifers?	Not applicable due to mining method.	
8	Potential for river bank instability, or high wall instability or failure to occur?	Not applicable	
9	Details of the method for disposing of extracted activities (for coal seam gas activities)?	Not applicable	

2. Addressing the minimal impact considerations

Note for proponents

Section 3.2.1 of the AIP describes how aquifer impact assessment should be undertaken.

1. Identify all water sources that will be impacted, referring to the water sources defined in the relevant water sharing plan(s). Assessment against the minimal impact considerations of the AIP should be undertaken for each ground water source.
2. Determine if each water source is defined as ‘highly productive’ or ‘less productive’. If the water source is named in then it is defined as highly productive, all other water sources are defined as less productive.
3. With reference to pages 13-14 of the Aquifer Interference Policy, determine the sub-grouping of each water source (eg alluvial, porous rock, fractured rock, coastal sands).
4. Determine whether the predicted impacts fall within Level 1 or Level 2 of the minimal impact considerations defined in Table 1 of the AIP, for each water source, for each of water table, water pressure, and water quality attributes. The tables below may assist with the assessment. There is a separate table for each sub-grouping of water source – only use the tables that apply to the water source(s) you are assessing, and delete the others.
5. If unable to determine any of these impacts, identify what further information will be required to make this assessment.
6. Where the assessment determines that the impacts fall within the Level 1 impacts, the assessment should be ‘Level 1 – Acceptable’
7. Where the assessment falls outside the Level 1 impacts, the assessment should be ‘Level 2’. The assessment should further note the reasons the assessment is Level 2, and any additional requirements that are triggered by falling into Level 2.
8. If water table or water pressure assessment is not applicable due to the nature of the water source, the assessment should be recorded as ‘N/A – reason for N/A’.

Table 5. Minimal impact considerations – *example tables*

Aquifer	**Alluvial aquifer**
Category	**Highly Productive**

Level 1 Minimal Impact Consideration	**Assessment**
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic post-water sharing plan variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work.	Considered in the assessment (see Section 5.1) and results presented in Section 6.4. The conservative cumulative predictions exceed the Level 1 minimal impact consideration.
Water pressure A cumulative pressure head decline of not more than 40% of the post-water sharing plan pressure head above the base of the water source to a maximum of a 2 metre decline, at any water supply work. **OR**, for the Lower Murrumbidgee Deep Groundwater Source: A cumulative pressure head decline of not more than 40% of the post-water sharing plan pressure head above the top of the relevant aquifer to a maximum of a 3 metre decline, at any water supply work.	Considered in the assessment (see Section 5.1) and results presented in Section 6.4. The conservative cumulative predictions exceed the Level 1 minimal impact consideration.
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity. No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. No mining activity to be below the natural ground surface within 200 metres laterally from the top of high bank or 100 metres vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a reliable water supply. Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining activities beyond 200 metres laterally from the top of high bank and 100 metres vertically beneath a highly connected surface water source that is defined as a reliable water supply.	The Project is not predicted to adversely impact groundwater or surface water quality or change the beneficial use category.

Aquifer	**Alluvial aquifer**
Category	**Highly Productive**

Level 1 Minimal Impact Consideration	Assessment
Aquifer	**Coastal sands**
Category	**Highly Productive**

Level 1 Minimal Impact Consideration	Assessment
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work.	Not applicable
Water pressure A cumulative pressure head decline of not more than a 2 metre decline, at any water supply work.	Not applicable
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	Not applicable

Aquifer	Porous Rock – except Great Artesian Basin
Category	Highly Productive

Level 1 Minimal Impact Consideration	Assessment
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work.	Not applicable
Water pressure A cumulative pressure head decline of not more than a 2 metre decline, at any water supply work.	Not applicable
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	Not applicable

Aquifer	Porous Rock – Great Artesian Basin – Eastern Recharge and Southern Recharge
Category	Highly Productive

Level 1 Minimal Impact Consideration	Assessment
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work.	Not applicable
Water pressure Less than 0.2 metre cumulative variation in the groundwater pressure, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. A cumulative pressure level decline of not more than 15 metres, allowing for typical climatic 'post-water sharing plan' variations. The cumulative pressure level decline of no more than 10% of the 2008 pressure level above ground surface at the NSW State border, as agreed between NSW and Queensland.	Not applicable
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	Not applicable

Aquifer	Porous Rock – Great Artesian Basin – Surat, Warrego and Central
Category	Highly Productive

Level 1 Minimal Impact Consideration	Assessment
Water table NOT APPLICABLE	
Water pressure Less than 0.2 metre cumulative variation in the groundwater pressure, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. A cumulative pressure level decline of not more than 30 metres, allowing for typical climatic 'post-water sharing plan' variations. The cumulative pressure level decline of no more than 10% of the 2008 pressure level above ground surface at the NSW State border, as agreed between NSW and Queensland.	Not applicable
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	Not applicable

Aquifer	Fractured Rock
Category	Highly Productive

Level 1 Minimal Impact Consideration	Assessment
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem; or • high priority culturally significant site; listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work.	Not applicable
Water pressure A cumulative pressure head decline of not more than a 2 metre decline, at any water supply work.	Not applicable
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	Not applicable

Aquifer	Alluvial
Category	Less productive

Level 1 Minimal Impact Consideration	Assessment
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work unless make good provisions apply	Considered in the assessment (see Section 5.1) and results presented in Section 6.4. The conservative cumulative predictions exceed the Level 1 minimal impact consideration.
Water pressure A cumulative pressure head decline of not more than 40% of the 'post-water sharing plan' pressure head above the base of the water source to a maximum of a 2 metre decline, at any water supply work.	Considered in the assessment (see Section 5.1) and results presented in Section 6.4. The conservative cumulative predictions exceed the Level 1 minimal impact consideration
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity. No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. No mining activity to be below the natural ground surface within 200 metres laterally from the top of high bank or 100 metres vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a 'reliable water supply'.	The Project is not predicted to adversely impact groundwater or surface water quality or change the beneficial use category.

Aquifer	Porous rock or fractured rock
Category	Less productive

Level 1 Minimal Impact Consideration	Assessment
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work.	Not applicable
Water pressure A cumulative pressure head decline of not more than a 2 metre decline, at any water supply work.	Considered in the assessment (see Section 5.1) and results presented in Section 6.4. The conservative cumulative predictions exceed the Level 1 minimal impact consideration.
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	Not predicted.

3. Proposed remedial actions where impacts are greater than predicted.

Note for proponents

Point 3 of section 3.2 of the AIP provides a basic framework for considerations to consider when assessing a proponent's proposed remedial actions.

Table 6. Has the proponent:

	AIP requirement	Proponent response	NSW Office of Water comment
1	Considered types, scale, and likelihood of unforeseen impacts *during operation*?	Yes, see Section 5.2 and results presented in Attachment C (uncertainty analysis)	
2	Considered types, scale, and likelihood of unforeseen impacts *post closure*?	Yes, see Section 5.2 and results presented in Attachment C (uncertainty analysis)	
3	Proposed mitigation, prevention or avoidance strategies for each of these potential impacts?	See Section 8.1	
4	Proposed remedial actions should the risk minimization strategies fail?	Trigger monitoring bores are a safeguard against groundwater level decline	
5	Considered what further mitigation, prevention, avoidance or remedial actions might be required?	See Section 8.	
6	Considered what conditions might be appropriate?	See Section 8.	

4. Other considerations

Note for proponents

These considerations are not included in the assessment framework outlined within the AIP, however are discussed elsewhere in the document and are useful considerations when assessing a proposal.

Table 7: Has the proponent:

	AIP requirement	Proponent response	NSW Office of Water comment
1	Addressed how it will measure and monitor volumetric take? (page 4 of the AIP)	See Section 8.1 and approved WMP. In pit monitoring (pump rate and hours of operation) will be undertaken to monitor and confirm actual groundwater take.Data collected from the meter reading will be assessed during the annual review to evaluate groundwater inflows into the mining operations.	
2	Outlined a reporting framework for volumetric take? (page 4 of the AIP)	Conducted as part of annual reporting, as per the requirements of the development consents and approved WMP	

More information

www.water.nsw.gov.au

© State of New South Wales through the Department of Trade and Investment, Regional Infrastructure and Services, 2023. You may copy, distribute and otherwise freely deal with this publication for any purpose, provided that you attribute the NSW Department of Primary Industries as the owner.

Disclaimer:

This is a draft document produced as a guide for discussion, and to aid interpretation and application of the NSW Aquifer Interference Policy (2012). All information in this document is drawn from that policy, and where there is any inconsistency, the policy prevails over anything contained in this document.
Any omissions from this framework do not remove the need to meet any other requirements listed under the Policy.

The information contained in this publication is based on knowledge and understanding at the time of writing (April 2023). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up to date and to check currency of the information with the appropriate officer of the Department of Primary Industries or the users independent adviser.

Published by the NSW Department of Primary Industries.

Reference 12279

B.2 NSW Groundwater Guidelines (DPE 2022)

Project setting (If any 'no' answers are recorded, then proponent to provide explanation)	
Scope of the project described (including construction, operation and closure)? Sections 1.2 and **Error! Reference source not found.**; and EIS.	☒ Yes ☐ No
Location of project clearly identified (address and real property description, and/or lot and plan information)? Section 1 and EIS.	☒ Yes ☐ No
Environmental setting described (including topography, climate, the location of surface water features, biodiversity values and land use)? Section 3.	☒ Yes ☐ No
Appreciation of regional and local geological setting clearly stated? Section 3.5.	☒ Yes ☐ No
Geological structural features potentially affecting groundwater behaviour identified? Section 3.5.4.	☒ Yes ☐ No
Will any project related excavation remain above the water table? No.	☐ Yes ☒ No
Have baseline groundwater field investigations been conducted and report provided? Groundwater monitoring network described in Section 3.6.3. Monitoring has been conducted at CGO for a number of years (as per Attachment E) in accordance with the approved WMP.	☒ Yes ☐ No
Have the relevant Water Sharing Plans and relevant water sources been identified? Section 2.2.2.	☒ Yes ☐ No
Has the proponent consulted with the local community, local Aboriginal community, council, DPE-Water, EPA, WaterNSW and Environment, Energy and Science group within DPE (where relevant) to establish cultural and environmental values of the water sources? Consultation for the Project is summarised in the EIS.	☒ Yes ☐ No
Receptors (If any 'no' answers are recorded, then proponent to provide explanation)	
Have mapped high priority groundwater dependent ecosystems, listed in the relevant Water Sharing Plans, been identified? Section 3.8.2.	☒ Yes ☐ No
Has the proponent reviewed the GDE Atlas to identify any other mapped potential groundwater dependent ecosystems in the project area? Section 3.8.2.	☒ Yes ☐ No

Has the proponent identified other potential groundwater dependent ecosystems out of other technical specialist analysis? Have the technical specialists used outputs from the GIA for their ecological assessment? See Appendix J to the EIS and Section 3.8.2.	☒ Yes ☐ No
Have considered and identified potential culturally significant sites listed in the relevant Water Sharing Plans been identified? None are listed in the WSPs.	☒ Yes ☐ No
Has the proponent identified third-party users in the vicinity that might be impacted identified (Registered/unregistered)? See Section 3.8.1.	☒ Yes ☐ No
Groundwater investigations and groundwater impact assessment (If any 'no' answers are recorded, then proponent to provide explanation)	
Groundwater elevation and flow	
Are monitoring bore locations and depths provided and appropriate based on depth and scale of proposed development? Refer to CGO WMP for some details.	☐ Yes ☒ No
Are measurements recorded at a frequency suitable to detect potential changes (EIS or post-approval)? Level loggers installed and record daily measurements (CGO WMP & Attachment E)	☒ Yes ☐ No
Has a bore census of existing third-party bores in the project area been completed?	☐ Yes ☒ No
Is the groundwater baseline provided sufficient (AIP requires 2 years)? Yes numerous locations with more than two years baseline data.	☒ Yes ☐ No
Has the proponent assessed vertical gradients between overlying water sources? Detailed study presented in Attachment G.	☒ Yes ☐ No
Has the proponent provided water table elevation and potentiometric surface contour plans for water sources pre-development (including consideration of wet/winter and summer/dry seasonal variations), supported by points labelled with measured groundwater elevation? Section 4.2.	☒ Yes ☐ No
Has the proponent provided evidence of spatial and temporal assessment of groundwater elevation and flow (that is, vertical and lateral with time and seasons)? Section 4.2 and 4.3.	☒ Yes ☐ No

Hydraulic properties	
Has the proponent conducted hydraulic tests at various locations across the project area? For example, slug tests, pumping tests, packer tests, core tests. Testing has been conducted as part of historical investigations and is summarised in Section 3.6.4.	☒ Yes ☐ No
Has the proponent conducted a literature review of potential hydraulic properties for the water sources in the project area? For example, other projects in the area or textbook values. Have relied on extensive site-specific datasets.	☐ Yes ☒ No
Groundwater quality	
Has the proponent included sufficient spatial & temporal variation in groundwater quality data? Groundwater quality assessments have been conducted as part of historical investigations and are summarised in Section 3.6.6.	☒ Yes ☐ No
Was the potential for cross contamination of aquifers assessed sufficiently? Yes, refer to Section 6.3.	☒ Yes ☐ No
Is the baseline groundwater quality defined and described sufficiently with respect to the cultural and environmental values and the development? Groundwater quality assessments have been conducted as part of historical investigations and are summarised in Section 3.6.6.	☒ Yes ☐ No
Is quality assurance data provided? Available as part of the Annual Reviews, available on CGO's website (https://evolutionmining.com.au/)	☒ Yes ☐ No
Conceptual hydrogeological model	
Has the proponent described the hydrostratigraphic units in the project area? Sections 3.6 and 4.	☒ Yes ☐ No
Has the proponent assessed and described potential surface water-groundwater interaction? Section 4.3.2 and Appendix G	☒ Yes ☐ No
Has the proponent considered existing water use in the area? Section 3.8.1.	☒ Yes ☐ No
Has the proponent provided a graphical representation of the conceptual hydrogeological model (cross section or three dimensional block model) to show hydrostratigraphy and other groundwater processes described above? Section 4.4.	☒ Yes ☐ No
Has the proponent provided a graphical representation of potential groundwater dependence of GDEs within the project area?	☐ Yes ☒ No

Impact assessment (If any 'no' answers are recorded, then proponent to provide explanation)	
Is the assessment methodology commensurate with the risk and as agreed with DPE Water? For example, analytical model versus simple numerical model vs complex numerical model? Numerical groundwater model used that has been informed by historical monitoring and modelling in the area. Refer 5.3.	☒ Yes ☐ No
Has the proponent completed the Aquifer Interference Assessment Framework form? Refer Appendix B.1.	☒ Yes ☐ No
Has the proponent assessed the predicted impacts against the Aquifer Interference Policy "minimal impact considerations"? Section 6.4	☒ Yes ☐ No
Has the proponent assessed the predicted impacts during construction, operations and post-development? Section 6.	☒ Yes ☐ No
Have the potential impacts from changes in water quality, water quantity, aquifer integrity and biological integrity of groundwater dependent ecosystems been identified and quantified? Section 6.4.3 and Appendix J of the EIS.	☒ Yes ☐ No
Has the proponent assessed the potential presence of acid sulfate soils? Considered but not applicable.	☒ Yes ☐ No
Has the proponent assessed the potential for generation of acid metalliferous drainage? Appendix E.2 of the EIS.	☒ Yes ☐ No
Has the proponent documented the predicted annual water take (per water source) on an annual basis? Section 6.2.	☒ Yes ☐ No
Has the proponent documented the licensing pathway proposed to secure the required water entitlement for water access licence(s) for the predicted take? Section 8.2 and Appendix I of the EIS.	☒ Yes ☐ No
Has the proponent assessed impacts on the groundwater dependent ecosystems and culturally significant sites in accordance with the Aquifer Interference Policy considerations? Section 6.4.3 and Appendix J of the EIS.	☒ Yes ☐ No
Management and mitigation measures (If any 'no' answers are recorded, then proponent to provide explanation)	
Are the documented management and mitigation measures practical and measurable? Section 8.	☒ Yes ☐ No

Has the proponent documented the approach to the proposed monitoring program during construction and operations? Section 8.1.3.	☒ Yes ☐ No

Attachment C

Groundwater Model Report

EMM
creating opportunities

Cowal Gold Operations – Open Pit Continuation Project

Numerical Groundwater Modelling

Prepared for Evolution Mining

May 2023

Cowal Gold Operations – Open Pit Continuation Project

Numerical Groundwater Modelling

Evolution Mining

J190417a RP51

May 2023

Version	Date	Prepared by	Approved by	Comments
1	5 May 2023	James Dommisse, Tom Neill	Doug Weatherill	Draft
2	25 May 2023	James Dommisse, Tom Neill	Doug Weatherill	

Approved by

Doug Weatherill
Associate Groundwater Modeller
25 May 2023

Level 4 74 Pirie Street
Adelaide SA 5000

This report has been prepared in accordance with the brief provided by Evolution Mining and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of Evolution Mining and no responsibility will be taken for its use by other parties. Evolution Mining may, at its discretion, use the report to inform regulators and the public.

© Reproduction of this report for educational or other non-commercial purposes is authorised without prior written permission from EMM provided the source is fully acknowledged. Reproduction of this report for resale or other commercial purposes is prohibited without EMM's prior written permission.

Executive Summary

Evolution Mining (Cowal) Pty Limited (Evolution) is proposing to extend open pit mining operations at its existing Cowal Gold Operations (CGO) open pit and underground gold mine through the Open Pit Continuation Project (the Project). The Project is located approximately 38 kilometres (km) north-east of West Wyalong, in the central west region of New South Wales (NSW). The Project primarily seeks to continue the open pit operations by approximately 10 years to 2036 and extend the total mine life by approximately two years to 2042.

To support a groundwater impact assessment (GIA) for the Project EIS, a three-dimensional numerical groundwater flow model has been developed to quantify groundwater level, flow and contaminant migration pathways. The model was built to predict drawdown at nearby water users, environmental receptors and compliance monitoring bores; groundwater inflow to the Project infrastructure; changes to the water balance; and the fate of contaminants sourced from the mine site.

A highly parameterised regional-scale numerical groundwater flow model has been built using the MODFLOW-USG simulation code. The model generally aligns with attributes of a Class 2 model as per the Australian Groundwater Modelling Guidelines (Barnett et al. 2012). The model has been independently reviewed by Will Minchin of Watershed HydroGeo and found to meet the modelling objectives and be fit for the purpose of predicting groundwater level and flow changes associated with the Project.

A Bayesian stochastic modelling approach was deployed to quantify the uncertainty associated with Project groundwater impacts. Both a null scenario and project scenario were simulated using a suite of 200 history-matched parameter realisations to allow for a range of predictions of drawdown, mounding, and water balance.

The groundwater flow model predictions include:

- There are two separate drawdown zones associated with the mine and borefield pumping. Drawdown from mining will propagate outside the boundary of ML1535. However, the difference in drawdown impacts between the approved CGO operations and the proposed mining activities are considered minor:
    - The continued operation of the CGO borefields in association with the Project does not result in groundwater level drawdown 2 m greater than that from current approved operation.
    - There is no material change in groundwater level drawdown at any landholder bore associated with the Project when it is considered on its own (i.e. incremental drawdown).
- Groundwater levels will remain above the investigation and mitigation trigger levels at DPE Water bore GW036553 (located near the mine borefield). Water levels at this trigger bore govern the operation of the CGO borefields.
- Under the Aquifer Interference Policy (AIP)-specific cumulative impact evaluation (i.e. incorporating the approved operations, the local private bore operations, the CGO borefields plus the Project), the maximum cumulative drawdown is predicted to exceed the AIP minimal impact considerations (2 m drawdown) at four landowner bores.
- Two River Red Gum Plant Community Types (PCTs), assessed and confirmed as high priority GDEs, are predicted to experience greater than 0.5 m drawdown in groundwater level, representing the natural fluctuation in groundwater level.
- Field investigations and chemical analysis suggest that the lake is hydraulically separated from the groundwater system by a small unsaturated zone beneath the lake, and that a pathway does not exist between the mine site activities and the lake. Modelled seepage predictions from Lake Cowal are therefore conservative.

- Potential contaminant movement via seepage from the WREs and the TSF/IWL are likely to remain localised with potential impacts from acid and metalliferous drainage and/or saline drainage expected to be limited. Furthermore, there are no groundwater users predicted to be impacted. There are ongoing groundwater quality changes around the borefields, resulting from induced leakage from borefield pumping, however this is not predicted to change the groundwater quality beneficial use category (i.e. brackish and suitable for irrigation and industrial uses).

TABLE OF CONTENTS

Executive Summary ES.1

1 Introduction 1

1.1 Background and context 1

1.2 Project overview 1

1.3 Purpose of this report 6

1.4 Previous modelling 6

1.5 Modelling objectives and plan 10

1.6 Model complexity and confidence classification 11

2 Hydrogeological conceptual model 14

2.1 Overview 14

2.2 Available information 14

2.3 Pre-existing conditions prior to mine development 16

2.4 Conditions during existing mining (prior to the Project) 17

2.5 Hydrogeological conceptual model 18

3 Model design 21

3.1 Overview 21

3.2 Equivalent porous medium approach 21

3.3 Complexity 21

3.4 Software 23

3.5 Domain and spatial discretisation 24

3.6 Temporal discretisation and numerical solution 37

3.7 Boundary conditions 37

4 History-matching 63

4.1 Approach 63

4.2 Performance 69

4.3 Base case hydraulic properties 79

4.4 Ensemble 82

5 Predictive modelling 83

5.1 Overview 83

5.2 Modelled fluxes 83

5.3 Spatial impacts 88

5.4 Temporal impacts 96

5.5 Groundwater quality 99
6 Modelling review checklist 101
6.1 Independent peer review 101
7 Summary 102
8 References 103

Appendices

Appendix A Bore locations
Appendix B Modelled parameter distributions
Appendix C Hydrographs: history-matching
Appendix D Hydrographs: dry pit
Appendix E Groundwater model scenario addendum
Appendix F Independent peer review

Tables

Table 1.1 Modelling objectives 11
Table 1.2 Evaluation of model confidence level classification (after Barnett et al, 2012) 12
Table 2.1 Indicative hydraulic conductivity (m/d) of hydrogeological units within the study area 17
Table 3.1 Summary of model and environmental complexity 22
Table 3.2 Model layers summary 29
Table 3.3 Stress periods 37
Table 3.4 Model edge boundary condition summary 38
Table 3.5 Registered third-party pumping bores used for history-matching and/or predictive simulations 50
Table 3.6 Dewatering bores used in history-matching 56
Table 3.7 Borefield pumping bores used for history-matching and predictive simulations 61
Table 3.8 Predictive scenario definitions 62
Table 4.1 History-matching parameters 67
Table 4.2 Base case realisation history-matching statistics 70
Table 4.3 Modelled water balance at selected times 78
Table 4.4 Base case hydraulic properties for HSUs using pilot points 79
Table 5.1 Model scenario definition 83
Table 5.2 Modelled water balance at selected times in the predictive period 87
Table 5.3 Combined numeric, narrative, and visual approach for assessing the likelihood of drawdown 93
Table A.1 Bore locations

Figures

Figure 1.1	Project and study area	3
Figure 1.2	Mine site	4
Figure 1.3	Referenced bore locations	9
Figure 2.1	Conceptual hydrogeological section – east to west	19
Figure 2.2	Conceptual hydrogeological section – southwest to northeast	20
Figure 3.1	Model domain and Voronoi mesh	26
Figure 3.2	Voronoi mesh in mine area	27
Figure 3.3	Top elevation (pre-mining topographic surface) – model layer 1 (mAHD)	30
Figure 3.4	Top of Upper Cowra – model layer 2 (mAHD)	31
Figure 3.5	Top of Lower Cowra – model layer 3 (mAHD)	32
Figure 3.6	Top of Lachlan – model layer 4 (mAHD)	33
Figure 3.7	Top of Saprolite – model layer 5 (mAHD)	34
Figure 3.8	Top of Saprock – model layer 6 (mAHD)	35
Figure 3.9	Top of basement – model layer 7 only (mAHD)	36
Figure 3.10	Constant head boundary for the Upper Cowra – model layer 2 (mAHD)	39
Figure 3.11	Constant head boundary for the Lower Cowra – model layer 3 (mAHD)	40
Figure 3.12	Constant head boundary for the Lachlan – model layer 4 (mAHD)	41
Figure 3.13	Constant head boundary for the Saprolite, Saprock and basement – in active model layers 5 -23 (mAHD)	42
Figure 3.14	Recharge zones within the model domain simulated using the MODFLOW RCH package	44
Figure 3.15	Measured and extrapolated future rainfall to the end of mining	45
Figure 3.16	Measured and extrapolated future potential evapotranspiration to the end of mining	46
Figure 3.17	Surface water features within the model domain simulated using the MODFLOW RIV package	48
Figure 3.18	Simulated lake levels over history-matching and predictions to end of mining	49
Figure 3.19	Temporal changes in measured lake levels and the synthetic time series developed for predictions	49
Figure 3.20	Location of pumping bores used for history-matching	52
Figure 3.21	Location of pumping bores used for predictions	53
Figure 3.22	Modelled third-party bore abstraction rates	54
Figure 3.23	Measured E42 pit dewatering	55
Figure 3.24	Average daily pumping from all dewatering bores	57
Figure 3.25	Average daily pumping from the UG development	57
Figure 3.26	Mine plan temporal summary	58
Figure 3.27	Modelled open cut pits and underground	59
Figure 3.28	Modelled stage elevation of TSF/IWL RIV boundary condition used during history-matching and predictions (to end of mining)	60

Figure 3.29	Modelled abstraction from mine and third party bores	61
Figure 4.1	History-matching head target locations including the three compliance monitoring bores	64
Figure 4.2	Pilot points used in parameterisation	66
Figure 4.3	Scatter plot of initial hydraulic heads	71
Figure 4.4	Initial hydraulic head residual distribution	72
Figure 4.5	Base case realisation modelled steady-state watertable elevation and residuals	73
Figure 4.6	Scatter plot of transient hydraulic heads	74
Figure 4.7	Transient hydraulic head residual distribution	75
Figure 4.8	Selected modelled and measured hydrographs over the history-matching period	76
Figure 4.9	Selected hydrograph location plan	77
Figure 4.10	Base case realisation modelled transient water balance over the history-matching period	79
Figure 4.11	Saprolite (layer 5) hydraulic property histograms	80
Figure 4.12	Base realisation Saprolite horizontal hydraulic conductivity (layer 5)	81
Figure 4.13	Adopted ensemble history-matching performance	82
Figure 5.1	Prediction 1 modelled water balance	84
Figure 5.2	Prediction 2 modelled water balance	85
Figure 5.3	Prediction 3 modelled water balance	85
Figure 5.4	Modelled inflows to mine workings	86
Figure 5.5	Induced seepage from surface water features	87
Figure 5.6	Cumulative drawdown, Upper Cowra groundwater system (Layer 2), end of mining	89
Figure 5.7	Cumulative drawdown, Upper Cowra groundwater system (Layer 2), post-mining	90
Figure 5.8	Cumulative drawdown, top Lachlan Fold Belt (Layer 7), end of mining	91
Figure 5.9	Cumulative drawdown, top Lachlan Fold Belt (Layer 7), post-mining	92
Figure 5.10	Cumulative impact proportion of exceedance for 2 m drawdown	94
Figure 5.11	Incremental impact proportion of exceedance for 2 m drawdown	95
Figure 5.12	Selected hydrographs over the history-matching and predictive period	96
Figure 5.13	Compliance monitoring bore hydrographs	98
Figure 5.14	GDE hydrographs	99
Figure 5.15	Particle tracking from IWL and WRE	100

1 Introduction

1.1 Background and context

Evolution Mining (Cowal) Pty Limited (Evolution) is the owner and operator of the Cowal Gold Operations (CGO) located immediately adjacent to the ephemeral Lake Cowal, 38 km north-east of West Wyalong, in New South Wales.

CGO was first approved in 1999, and open-pit mining operations commenced in 2005. Underground mining operations were both approved and then commenced in 2021.

CGO is an existing open pit mine site which has been operational since commencement in 2005 and has approvals in place to continue processing at a rate of 9.8 million tonnes of ore per annum (Mtpa) until 2040. The existing mine site is located immediately adjacent to the ephemeral Lake Cowal.

The area of land to which CGO's Development Consent (DA 14/98) is relevant includes Mining Lease (ML) 1535, ML 1791 and CGO's water supply pipeline and Bland Creek Paleochannel Borefield. Open-pit mining operations are currently undertaken within Mining Lease 1535, which encompasses approximately 2,636 hectares.

The existing mine site consists of one open pit (E42 pit), two tailings storage facilities (TSFs) and two waste rock emplacement areas. Mine process water supply from groundwater is taken from three borefields. This includes the Bland Creek Palaeochannel Borefield (BCPB) and Eastern Saline Borefield (ESB) located in the Bland Creek Palaeochannel (BCP) and a third smaller borefield referred to as the Saline Borefield (SB) located in Lake Cowal.

1.2 Project overview

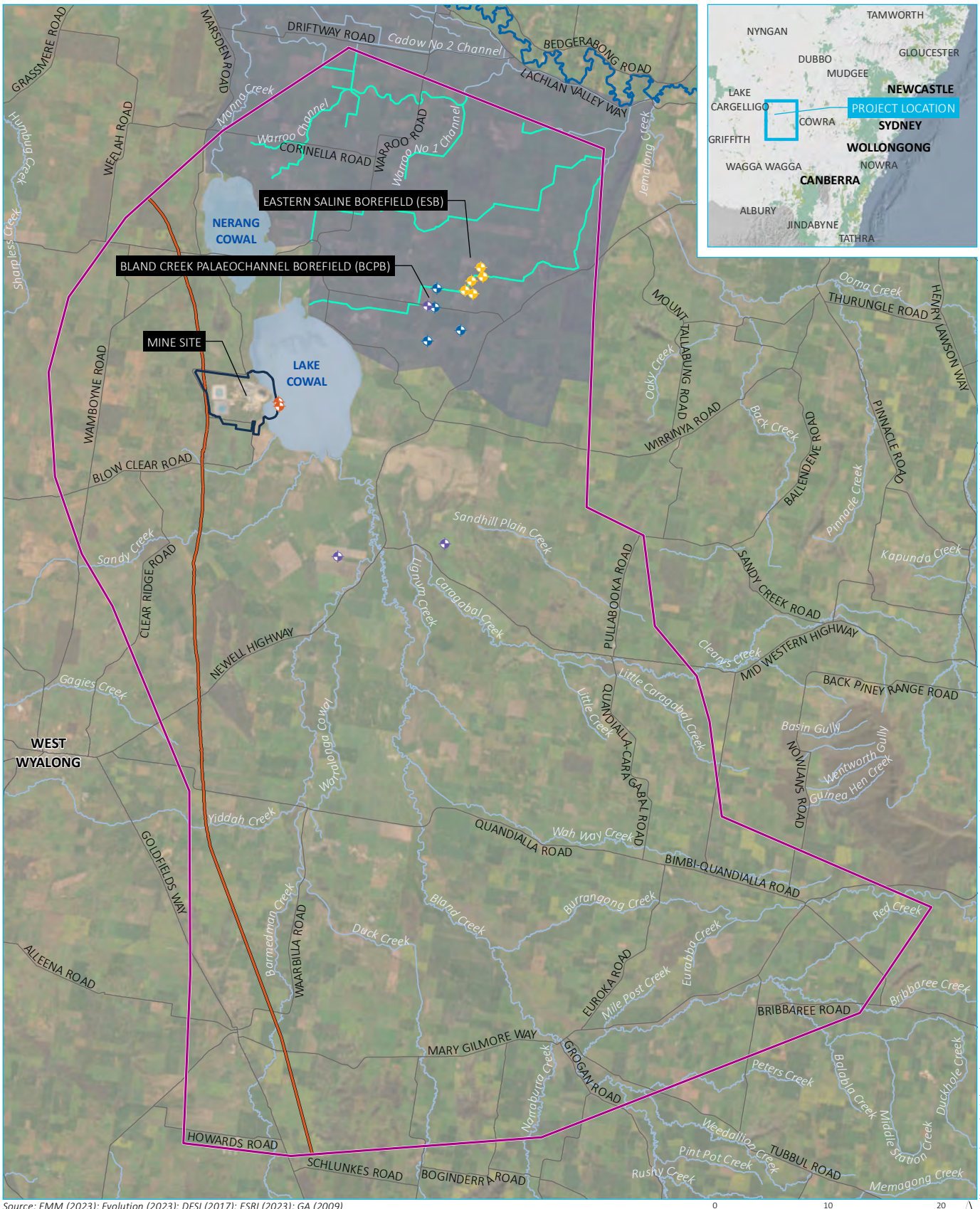
Evolution is seeking approval for further open-pit mining operations at CGO through the Open-pit Continuation (OPC) Project (the Project). The Project primarily seeks to continue the open-pit operations by approximately 10 years to 2036 and extend the total mine life by approximately two years to 2042. The Project study area and mine site area are shown in Figure 1.1 and Figure 1.2 respectively.

The OPC would involve further development of the existing E42 Pit and the development of open-pit mining in three new and adjacent orebodies, known as the 'E46', 'GR' and 'E41' pits. It is noted that the three new and adjacent ore bodies are within the existing mining lease (ML 1535). No change to the approved ore processing rate of 9.8 Mt per annum is proposed.

Other than the changes to existing approved activities as set out above, all activities that are currently approved under the existing Ministerial development consents are intended to continue. The Project comprises the following key components:

- Continued operation of activities as approved under DA14/98 and SSD 10367.
- Continued operation of the BCPB, ESB and SB.
- Development of three new open satellite pits (the 'E46', 'GR' and 'E41' pits) to the north and south of the existing open-pit, within the current approved mining lease.
- Extending the existing open-pit to the east and south via a 'cutback' within the current approved mine lease.
- Extending open-pit mining operations by approximately 10 years to 2036 and total mine life by approximately 2 years to 2042.
- Expansion of the integrated waste landform (IWL) to accommodate life of mine tailings.

- Extension of the lake protection bund (LPB) system to provide continued separation and mutual protection between Lake Cowal and the mine.
- Backfilling of one of the new open satellite pits (E46) with waste rock and establishment of a new waste rock emplacement (WRE) on the backfilled pit to minimise the additional area required for waste rock disposal.
- Expansion of the footprint of the existing WRE areas to accommodate additional waste rock.
- Development of additional topsoil and subsoil stockpiles to accommodate materials from pre-stripping, with materials to be reused during progressive mine rehabilitation.
- Upgrades to existing surface water drainage system, to assist with on-site water management and maximise on-site water conservation.
- Modification of internal site access and haul roads.
- Development of new water storages and relocation of some components of the surface water drainage system.
- Modification and relocation of some existing auxiliary mining infrastructure.



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM001_ProjectAndStudyArea_20230519_05.mxd 19/05/2023

KEY

- Model domain
- Proposed OPC disturbance footprint
- Major road
- Lachlan River
- Named watercourses
- Jemalong irrigation channels
- Jemalong irrigation area
- Named waterbody
- Gilmore fault zone
- Compliance monitoring bore

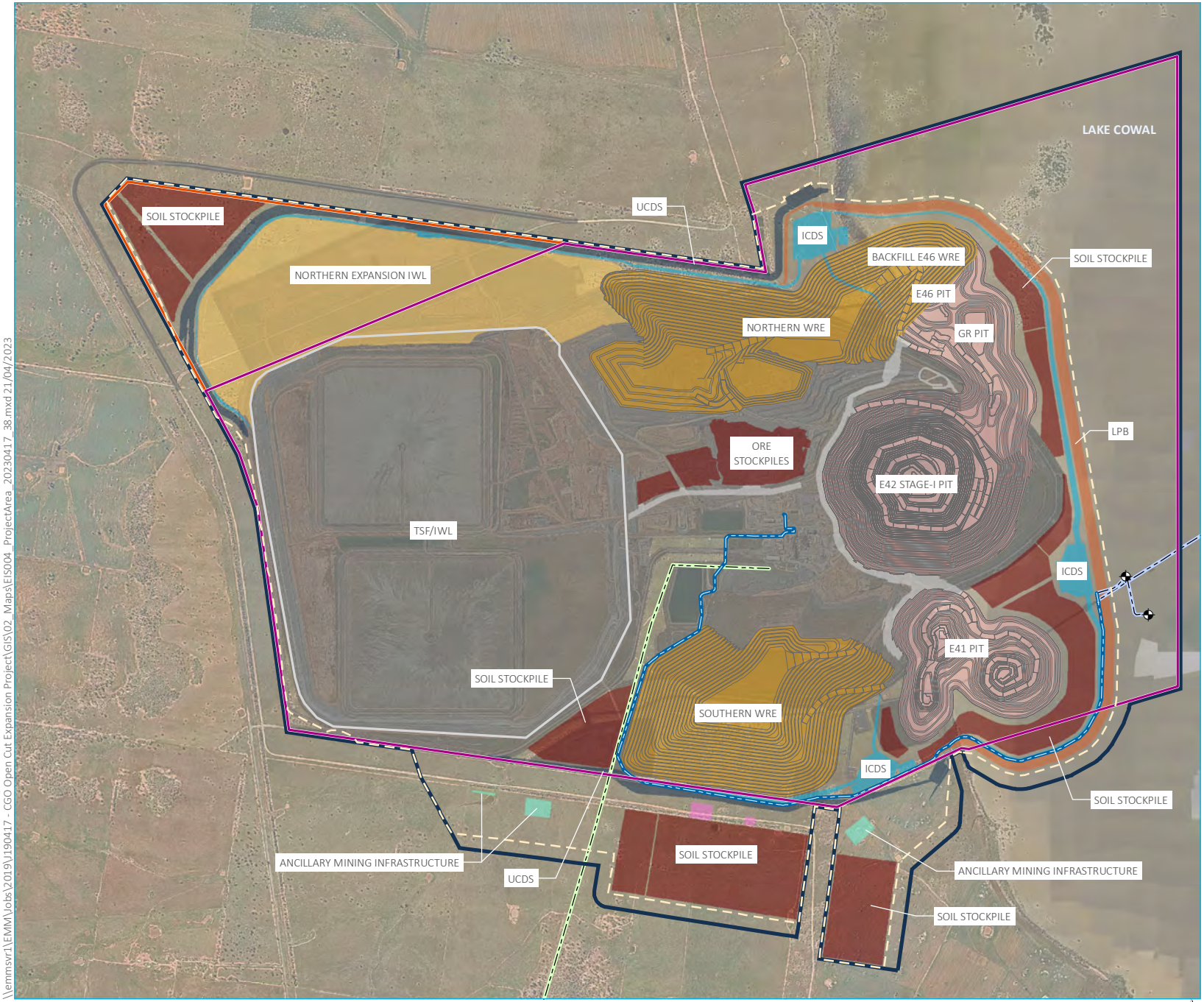
Pumping bores

- Bland Creek Palaeochannel Borefield (BCPB)
- Eastern Saline Borefield (ESB)
- Saline Borefield

Project and study area

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 1.1

EMM
creating opportunities



KEY

- Project area
- Additional disturbance area
- Approved disturbance area
- Approved IWL footprint
- Mining lease (ML1535) (offset for clarity)
- Mining lease (ML1791) (offset for clarity)
- Saline groundwater supply bore
- Water supply pipeline
- Electricity transmission line

Conceptual project infrastructure

- Open cut pit footprint
- Northern expansion IWL
- Waste rock emplacement (WRE)
- Lake protection bund (LPB)
- Stockpile
- Up catchment diversion system (UCDS)
- Internal Catchment Drainage System (ICDS)
- Ancillary mining infrastructure
- Magazine
- Road
- Water supply pipeline realignment

\\emmsvr1\EMM\Jobs\2019\I190417 - CGO Open Cut Expansion Project\GIS\02_Maps\EIS004_ProjectArea_20230417_38.mxd 21/04/2023

Source: EMM (2023); Evolution (2023); DFSI (2017); Nearmap (2021)

0 1 2 km

GDA 1994 MGA Zone 55

N

Mine site

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 1.2

EMM
creating opportunities

1.2.1 Study area

The study area relevant to the GIA aligns with the numerical groundwater model boundary (Figure 1.1). The study area, which is larger than the Project area, encompasses the following:

- CGO sub-surface excavations, tailings and waste rock emplacements.
- Groundwater abstractions from the BCPB, ESB, SB, and third-party bores.
- Three monitoring bores within the BCP with trigger levels set by the NSW government.
- Nearby registered third-party bores.
- Nearby surface water bodies including Lake Cowal.
- Nearby high priority groundwater dependant ecosystems (GDEs) (BoM 2017).
- Identified sites of cultural significance.

i Borefields

The BCPB and ESB are located approximately 15 km and 20 km north-east of the mine site respectively in the BCP. The SB is located approximately 1.1 km east of the mine in Lake Cowal. Of the BCPB and ESB, the BCPB is closest to Lake Cowal, at a distance of 6 km from the eastern edge of the lake. The ESB is located approximately 1.5 km north-east of the BCPB and 19 km south of the Lachlan River (it is the closest of the mine's borefields to the river). Both the BCPB and ESB occur within the Jemalong Irrigation area and adjacent to irrigated land and irrigation canals.

The BCPB consists of four production bores screened into the Lachlan Formation, the ESB consists of five production bores screened into the higher salinity Upper and Lower Cowra Formations, and SB consists of two bores likely screened into the Lower Cowra.

ii Mine site

The mine site is located in the Bland Creek Valley, adjacent to Lake Cowal and on the western margin of the BCP. Broadly, the topographic catchments adjacent to the site include:

- Suture/Gilmore Fault Zone, located to the west of Lake Cowal.
- Lachlan River located 38 km to the north-east.
- Bland Creek catchment to the south.

The site currently includes the following infrastructure, as shown in Figure 1.2:

- Open-pit E42 in the east of the site.
- Perimeter waste rock emplacement and lake protection bund running beyond, and around pit E42.
- Waste rock emplacements to the north-west and south-west of the open-pit.
- Processing plant located to the west of the open-pit E42.
- Contained water storages at various locations across the site.

- Tailings storage facilities.

1.2.2 Groundwater-affecting activities

The Project involves groundwater-affecting (aquifer interference) activities which are described in detail in Section 3.7.6. A summary is provided for initial context while reading this report:

- Existing activities:
  - Groundwater abstraction from the from the BCPB with an annual allocation of 3,350 ML, from the ESB with an annual allocation of 300 ML and from the SB with an annual allocation of 366 ML.
  - Excavation of rock and sediments at E42 pit and UG development. Excavation of these materials has led to groundwater inflows and lowering of the watertable.
  - Tailings and waste rock emplacement resulting in seepage losses to groundwater and potential contaminant migration into and transport within the groundwater system.
- Approved future activities:
  - IWL expansion resulting in increased seepage resulting in greater seepage losses to groundwater and potentially greater contaminant migration into and transport within the groundwater system.
  - Development of the proposed underground mine (UG) using stope mining practises.
- Approvals pending for future activities:
  - OPC for three new open-pit excavations (E46, E41 West, E41 East and GR Pit). Excavation of these materials may lead to increased groundwater inflows and further lowering of the watertable. The E46 pit will be backfilled, whilst all other pits will remain.

1.3 Purpose of this report

This report is a technical appendix that provides detailed documentation of the numerical groundwater flow modelling which, along with the groundwater impact assessment (GIA), is a supporting document for the environmental impact statement (EIS). The groundwater modelling workflow has been developed to meet the "Minimum Groundwater Modelling Requirements for SSD/SSI projects" (DPE 2022) and this report is presented in a sequential manner that is consistent with that guidance. In addition, the modelling predictions will support assessment of future water security for the mine via comparison of predicted drawdown with trigger levels within the BCP.

1.4 Previous modelling

1.4.1 Borefields

i Bland Creek paleochannel borefield – 2006

In 2006, Coffey Geosciences Pty Ltd developed a three-dimensional numerical groundwater flow model to support assessment of potential impacts of pumping from the BCPB on the surrounding environment and other groundwater users (Coffey 2006a; Coffey 2006b). The model was history-matched and used for predictive scenario modelling.

ii Bland Creek paleochannel borefield and eastern saline borefield – 2010 to 2018

In 2010, Coffey Geotechnics Pty Ltd updated the 2006 model due to changes in the mine plan and the introduction of the ESB. The updated model was used to predict potential impacts from the proposed changes in pumping from the BCPB and ESB. The 2010 changes included:

- Division of the Cowra Formation into two model layers (Upper and Lower Cowra Formations), forming a 3-layer model (with the bottom layer representing the Lachlan Formation as before), so pumping from the Cowra Formation could be simulated in more detail.
- Adding ESB production bores SB01 and SB02.
- Revised history-matching of the model to include the addition of new pumping and monitoring records collected since 2006.

Predictive simulations were undertaken in 2013, 2016 and 2017/2018 (Coffey 2013; Coffey 2016; Coffey 2018b) as part of hydrogeological assessments for the Mod 11, Mod 13 and Mod 14 modifications to the mine, respectively. A detailed description of the 2010 model is provided in Coffey (2013).

iii Bland Creek paleochannel borefield and eastern saline borefield – 2020

In 2020, Coffey Services Australia Pty Ltd (Coffey 2020a) used the 2010 version of the numerical model described in Coffey (2013). This work built upon the previous work to assess the impacts of the mining operations in relation Mod 14. The model was updated with additional data collected from the BCPB between 2017 and 2019. This included groundwater level monitoring and pumping data from production bores supplying process water to the mine, as well as private irrigator bores, the largest being those owned by Billabong and Maslin Farms.

The main purpose of the borefields model was to support assessment of future mine water makeup security using pumping rates of 4 ML/d from the BCPB and 1.5 ML/d from the ESB.

The borefields model (Coffey 2020a) extended part way across Lake Cowal, and the mine site, including the area covered by E42 pit, but did not simulate any mine dewatering.

The modelling objective was to predict potential impacts on groundwater levels and quality caused by future groundwater extraction from the BCPB and ESB for the proposed UG development, and what the implication might be for future water security of the mine. Assessment of impacts on Lake Cowal was not addressed by this modelling. A key component of this work was to predict how drawdown might impact groundwater trigger levels set by the NSW government for the BCP.

The numerical modelling, using MODFLOW-2000, was considered to be at a Class 2 level, as defined by the Australian Groundwater Modelling Guidelines (Barnett et al. 2012). The model had three layers, representing the Upper Cowra Formation (layer 1), Lower Cowra Formation (layer 2) and Lachlan Formation (layer 3). The model was parameterised using a zone approach. The Upper Cowra Formation had one parameter zone, the Lower Cowra Formation three parameter zones (northern, central, and southern) and Lachlan Formation two parameter zones.

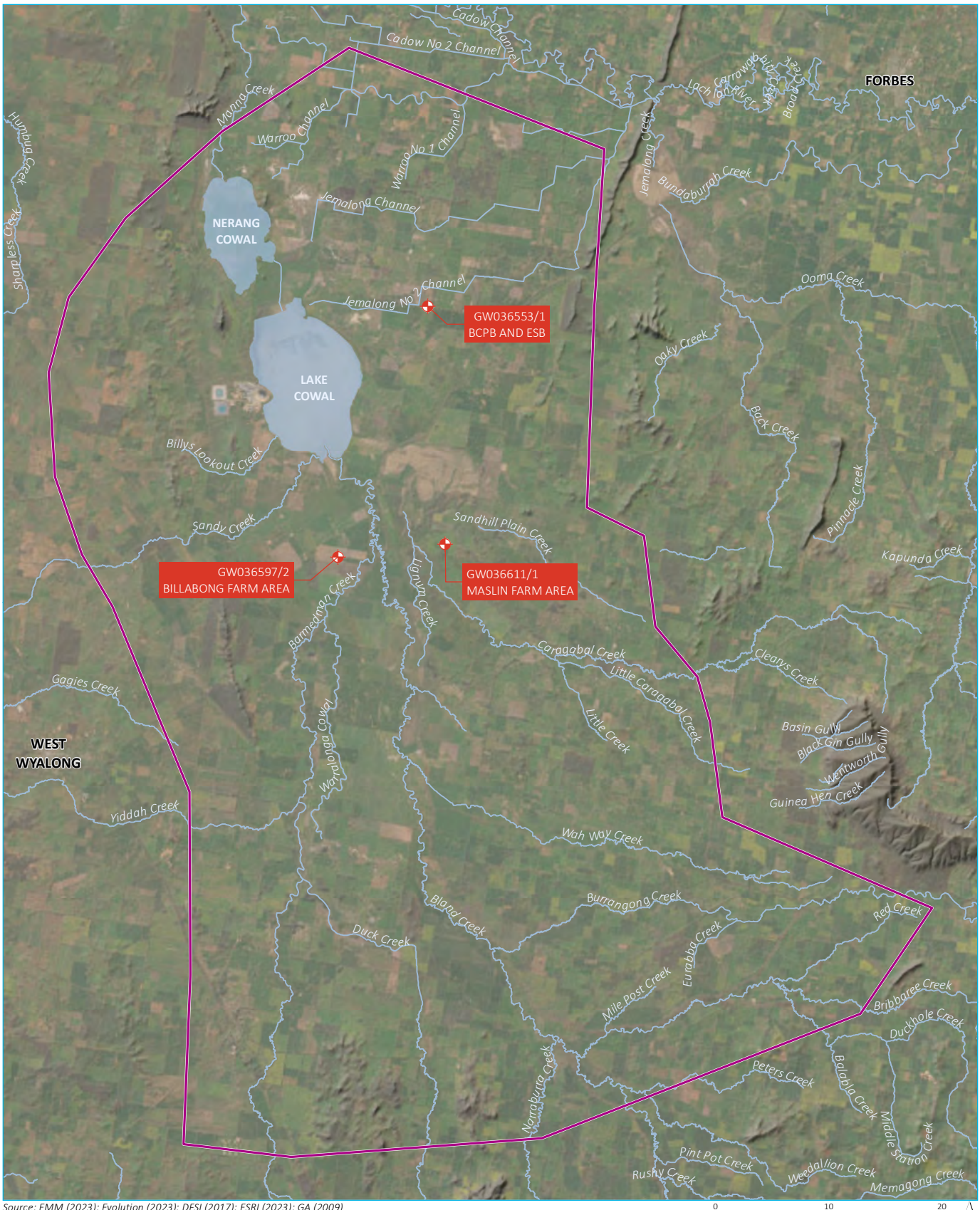
The model results indicated that that concurrent pumping of the BCPB at 4.0 ML/d, ESB at 1.5 ML/d and third-party bores (from 1 January 2020 to 30 June 2040) would not result in groundwater levels in monitoring bore GW036553 (located near the BCPB and used to manage operational pumping from the mine, refer Figure 1.3) to fall below the mitigation trigger level of 134 mAHD. Modelling results also indicated that groundwater levels in monitoring bores GW036597 and GW036611 located 15 kilometres (km) south of the BCPB, and which do not govern operation of the BCPB or ESB, would remain above their trigger levels. Based on the worst-case scenario using model parameters from the predictive sensitivity analysis, the water level at monitoring bore GW036553 was predicted to reach the effective trigger level in late 2033. In contrast, for the best-case scenario, the water level was predicted to be approximately 4 m higher than the trigger level in 2040.

At the cessation of BCPB and ESB pumping, groundwater levels at GW036553 were predicted to recover to around 166 mAHD in 10 years (about 30 m below 1998 water levels), and would continue to gradually recover over time, to a level that is dependent on the volume historically pumped, private bore usage following mine closure, and climatic conditions.

A noted area of uncertainty was predicting the rate of groundwater abstraction by irrigators from Billabong 3/6, Billabong 4 and Maslin Farm bores. A 50 percent increase in future pumping rates would result in the predicted water level at GW036553 reaching the trigger level in 2026. Within the BCPB, maximum drawdown at the end of mine life (2040) was predicted to be 40 m or less in the Lower Cowra Formation and 61 m or less in the Lachlan Formation.

The Coffey (2020a) report also noted potential effects on the reliability of supply from GW029574, a private bore listed on the NSW Government bore register, and only known water bore installed to a depth within the Lower Cowra Formation and within 15 km of the BCPB.

Coffey (2020a) also predicted that total dissolved solids at BLPR1 (one of the four BCPB pumping bores) will increase by about 40 percent or less, by 30 June 2040, in comparison to the pre-mining concentrations.



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM027_ReferencedBores_20230519_01.mxd 19/05/2023

KEY

- Model domain
- Referenced bore
- Named watercourse/channel
- Named waterbody

Referenced bore locations

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 1.3

EMM
creating opportunities

1.4.2 Mine site

i Open-pit – 2008 to 2018

Coffey (2020b) lists the earliest modelling of the mine pit area starting in 2008. Later in 2011, Coffey Geotechnics Pty Ltd developed a three-dimensional numerical groundwater flow model of the pit area and surrounds. This model was used to support assessment of the potential for hydraulic connection between Lake Cowal and the mine site groundwater system, groundwater inflows to the open-pit and the short and long-term effects of mine closure on groundwater conditions. The transient model was history-matched and used for predictive scenario modelling.

Updated history-matching and predictive scenario modelling were carried out in 2013, 2016 and 2018 as part of hydrogeological assessments for the Mod 11, Mod 13 and Mod 14 modifications to the mine, respectively.

ii Open-pit and underground development – 2020

In 2020, Coffey Services Australia Pty Ltd (Coffey 2020b) expanded the previous numerical groundwater model developed in 2011, by adding a re-designed mesh to incorporate the UG development. The model, considered to be Class 2 or 3, was history-matched to monitoring data covering the period 2005 to 2020, and an assessment of model parameter and observational uncertainty was carried out.

The mine site model (Coffey 2020b) does not extend as far as the BCPB and the ESB centres of extraction, nor to the south to the Billabong and Maslin centres of extraction. This means that the mine site model also did not (could not) predict the cumulative impacts of borefield extractions. The model also simulated a final pit (void) lake and paste backfill to the underground voids.

The updated groundwater flow model was built using the FEFLOW (v7.2) simulation code, and history-matched through an automated process using PEST. The history-matching targets included E42 pit inflows, groundwater heads from 24 sites over a fourteen-year period (2005 to 2020) and four locations above the UG development (where monitoring commenced in February 2020).

Resulting modelled vertical hydraulic conductivities for the lake sediments underlying Lake Cowal were very low and any groundwater impacts to Lake Cowal were predicted to be negligible. Combined groundwater inflows into the E42 pit, stopes and access tunnels were predicted to range between 1,650 kL/d and 3,400 kL/d between 2031 and 2039.

Modelling results indicated that watertable drawdown would not extend beyond the mining leases (ML1535 and ML1791) over the life of the mine. Following mine closure, groundwater inflow to the open-pit was predicted to result in a lake forming in the open-pit, rising to a level where groundwater inflow is balanced by evaporation from the pit lake.

An assessment of groundwater quality changes due to seepage from the IWL stored water was undertaken using particle tracking. The assessment predicted that after 100 years, the potential for groundwater quality changes will extend up to 1.7 km from IWL walls. The concentrations from cyanide (the most conservative contaminant) introduced to mine tailings during ore processing were predicted to fall below detectable limits prior to migrating outside the mine area.

1.5 Modelling objectives and plan

A Groundwater Modelling Plan (GMP) was developed early in the project and the modelling was independently peer reviewed at key milestones by Will Minchin, Director of Watershed HydroGeo (Section 6.1).

The modelling objectives were developed in consultation with the GIA team to quantify and support assessment and licensing associated with potential local-scale and/or regional-scale changes to the groundwater system resulting from construction and operation of the Project. The modelling objectives are outlined in Table 1.1.

Table 1.1 Modelling objectives

Objective	Rationale
Predict cumulative groundwater level changes from the mine, ESB, BCPB, SB and third-party abstractions at compliance monitoring bores located in the BCP.	Support assessment of future water security for the mine by predicting drawdown at: • Compliance monitoring bore GW036553 which would potentially reduce the reliability of supply of process water to the mine. • Compliance monitoring bores GW036597 and GW036611 which could reduce the reliability of supply for Billabong Farm and Maslin Farm.
Predict cumulative groundwater drawdown, mounding from the mine, ESB, BCPB, SB and third-party abstractions.	Predict whether the Project is likely to cause minimal or greater than minimal impacts as per the NSW Aquifer Interference Policy (AIP) to designated groundwater users.
Predict cumulative groundwater drawdown, mounding from the mine, ESB, BCPB, SB and third-party abstractions on Lake Cowal.	Quantify the likelihood and potential magnitude of the Project inducing additional seepage losses to groundwater from the lake by comparing the Project case water balance with the null case water balance.
Predict potential impacts on groundwater dependent ecosystems (GDE).	Predict the magnitude and duration of potential groundwater level changes at designated GDEs.
Predict groundwater inflow from the current OGC mine and proposed future Project infrastructure.	Predict inflows to existing open excavation E42 pit, three proposed open-pits, and underground workings, to inform groundwater licensing requirements.
Predict seepage losses to groundwater from the current and proposed future tailings storage facilities including the expanded IWL. Predict the potential groundwater quality impacts down gradient of the TSF due to seepage of stored water.	Predict seepage losses from the existing TSF/IWL and future seepage losses from the Project to support assessment of the potential impacts to: • Lake Cowal (directly, or indirectly through connected water courses). • Water courses connected to groundwater. • Registered third-party bores.
Predict mine closure impacts on groundwater and connected surface water.	Predict long-term changes after mine closure including: • Dissolved solute migration from the TSFs and IWL. • Groundwater level recovery in the vicinity of the underground mine and open pits.

1.6 Model complexity and confidence classification

Groundwater modelling has been conducted in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012). As described in DPE (2022), the level of complexity for an individual model must be commensurate with the modelling objectives (outlined in section above) and the potential impacts on water sources. In this regard, the modelling objectives outlined in Table 1.1 require prediction of impacts at distal features many kilometres from the project, as well as predictions of groundwater level change and groundwater inflows locally as a result of construction activities and operation of the system. To achieve this outcome, the following technical aspects related to model complexity have been considered:

- Regional simplicity of the main hydrostratigraphic units with simplified mesh discretisation. Sufficient spatial coverage of the domain to allow for meaningful predictions to be made at key locations without being overly influenced by boundary conditions or model settings. Simpler model layering in those areas to capture the main hydrostratigraphic units only.

- Local detail in and around Project features such as pits and underground mine workings, production bores, and watercourses (including Lake Cowal). This is accommodated with both finer mesh discretisation and more detailed model layering.

- The groundwater flow model was not designed to explicitly simulate the unsaturated zone or perched groundwater.

The Australian Groundwater Modelling Guidelines (Barnett et al. 2012) developed a system to classify the confidence level of predictions made with groundwater models. Models are classified as Class 1, Class 2 or Class 3 in order of increasing confidence based on key indicators such as available data, calibration procedures, consistency between calibration and predictive analysis and level of stresses. The three classes of model are defined as:

- Class 1 – low confidence in model predictions, suitable for use in low value resource or low risk developments.
- Class 2 – medium confidence in model predictions, suitable for use in projects with medium to high-risk developments.
- Class 3 – high confidence in model predictions, suitable for use in high value resources and projects such as regional sustainable yield assessments.

Based on previous modelling (Section 1.4), data availability, and modelling objectives, there was an expectation for a Class 2 to Class 3 model to be developed. The modelling conducted for the Project aligns best with the criteria for a medium confidence level (Class 2), with some attributes of Class 3. The following key indicators (based on Table 2-1 of Barnett et al. 2012) are summarised in Table 1.2. The suggested specific use of "prediction of impacts of proposed developments in medium to high value aquifers" is also aligned with a Class 2 to 3 model.

Table 1.2 Evaluation of model confidence level classification (after Barnett et al, 2012)

Data	Class	Calibration	Class	Prediction	Class	Key Indicator	Class
Bore logs and temporal head measurements available.	2	Validation not undertaken.	2	Transient discretisation is different to that of calibration.	2	Key calibration statistics are reasonable although can be poor in some parts of the domain.	2
Bore logs and stratigraphy data available.	3	Calibration to steady-state and transient conditions. Overall reasonable statistics with areas for improvement.	3	Transient calibration over a medium to long time frame compared to that of prediction.	2	Model predictive time frame is less than 10 times longer than calibration period.	2
Some available records of groundwater extraction or injection.	2	Transient history-matching datasets are current and reflect contemporary aquifer conditions.	3	Level and type of stresses included in the predictive model are on the same order of those used in transient calibration.	3	Stresses are not more than 2 times greater than those included in calibration.	3
Rainfall and evaporation data based on mine site information and SILO and BOM synthetic datasets.	3	Model is calibrated to heads (and changes in head) only.	2	Temporal discretisation in predictive model is not the same as that used in calibration.	2	Stress period or calculation interval is broadly different to that used in calibration.	2

Table 1.2 Evaluation of model confidence level classification (after Barnett et al, 2012)

Data	Class	Calibration	Class	Prediction	Class	Key Indicator	Class
Some aquifer testing to define aquifer properties.	2	Some of the key modelling outcomes (flow fields and hydraulic interactions) are reflected in calibration.	2			Some aquifer testing to define aquifer properties.	2
Limited data on streamflow. Only site observations.	1					Cumulative mass balance error is less than 0.5%.	3
Very good quality and spatial coverage of DEM to define ground surface.	3					Model parameter values consistent with conceptual model.	3
						Appropriate computational methods used with appropriate spatial discretisation to model the problem.	2
						The model has been reviewed by an independent hydrogeologist/ groundwater modeller.	3

2 Hydrogeological conceptual model

2.1 Overview

This section provides a summary of the main features of the hydrogeological conceptual model (HCM) that relate to the design, construction and history-matching of the numerical groundwater flow model. A more detailed account of the HCM is provided in the main body of the GIA report.

2.2 Available information

Information, provided by Evolution Mining and sourced elsewhere, used to support the hydrogeological conceptualisation and subsequent numerical model development includes:

- Borefields:
  - BCPB, ESB and SB bore pumping data.
  - BCPB and ESB bore groundwater level monitoring data.
- Hydraulic property data.
- Water quality data.
- Previous modelling reports.

Mine site:

- Exploration borehole logs for the proposed underground mine.
- Mine site geological model containing lithology and structure.
- Geophysical gravity survey data.
- Historical E42 open-pit shell design from 2005 to 2021.
- Future open-pit shell design from 2022 to 2036 Stage H and Stage I.
- Historical underground development from 2019 to 2021.
- Underground access and haulage tunnel geometry from 2021 to 2031 (based on the December 2021 MOS design).
- Underground stoping and access tunnel scheduling and extraction volumes from 2023 to 2035 (based on the December 2021 MOS design).
- E46, E41 West, E41 East and GR Pits exploration pit shell geometry (based on E46BF v8 revision 5).
- TSF (North, South) and IWL crest levels and geometry (2005 to a date TBA).
- Planned IWL North crest levels and geometry (based on design 3000 MC1A01).
- Geological structure modelling.
- Groundwater monitoring records for monitoring bores and vibrating wire piezometers (VWPs).

- Water level record for Lake Cowal.
- Mine site dewatering records from 2005 to 2019.
- Mite site water balance.
- Hydraulic property data.
- Water quality data.
- Mine site climate station data (rainfall from April 2005 and evapotranspiration from December 2006).
- Previous modelling reports.

The following information was obtained from government sources:

- Bureau of Meteorology (BoM):
  - Rainfall and evapotranspiration data.
  - Geological logs.
  - GDE Atlas.
- Geoscience Australia:
  - Elvis Digital Elevation Model (DEM).
- Queensland Department of Environment and Science (DES):
  - Silo grided climate data.
- WaterNSW:
  - Telemetered groundwater level data.
  - Geological logs.
  - NSW Water Register (information on permitted groundwater allocations from third-party users).
- MinView:
  - Geological logs.
  - Geophysical data.
- GIS Data.

The following information was obtained from other consultants:

- Laboratory test results (hydraulic property data, particle size distribution).
- Previous groundwater modelling files.

2.3 Pre-existing conditions prior to mine development

2.3.1 Alluvial groundwater system mechanisms

The alluvial sequence within the palaeochannel area is split into three groundwater systems. These systems include the following:

- Upper Cowra Formation groundwater system, an unconfined, phreatic groundwater system supporting the water table (where present).
- Lower Cowra Formation groundwater system, an unconfined/confined groundwater system underlying the Upper Cowra groundwater system.
- Lachlan Formation groundwater system, a confined, highly productive groundwater system underlying the Lower Cowra groundwater system, which does not extend to the mining area.

Recharge to the alluvial groundwater systems (porous unconsolidated sediments) is primarily from surface water infiltration below the:

- Lachlan River.
- Irrigation channels within the Jemalong Irrigation Area (JIA).
- Intermittently from the Lachlan River floodway during flooding.

Rainfall infiltration forms a relatively minor component of recharge to the alluvial groundwater systems. Leakage from Lake Cowal can also recharge the underlying alluvial groundwater, however this is expected to be minor in comparison to recharge from the Lachlan River and irrigation channels.

Discharge mechanisms from the alluvial groundwater systems generally include:

- Flow into the underlying fractured rock groundwater system, expected to be significantly higher west of the Project associated with geological discontinuities within the Gilmore Fault Zone.
- Abstraction by private water users.

2.3.2 Fractured rock groundwater system mechanisms

A fractured rock groundwater system is supported within the laterally continuous Lachlan Fold Belt (LFB) rock units. This system is generally confined under the alluvial sequence (where present) and unconfined to semi-confined across the remaining extent.

Recharge to the fractured rock system occurs via:

- Diffuse rainfall recharge at areas of outcrop, generally located east of the study area.
- Discharge from overlying alluvial aquifers (where present).

2.3.3 Hydraulic properties

Extensive hydraulic conductivity testing has been undertaken at CGO and includes:

- In-situ permeability testing.
- Laboratory-based permeability testing of core samples.

- Pumping testing at water supply bores.

A summary of indicative hydraulic properties is provided in Table 2.1, with the stated range indicating variability or heterogeneity across the study area (both in terms of depth and spatially), and potentially accounting for some error or uncertainty in measurement.

Table 2.1 Indicative hydraulic conductivity (m/d) of hydrogeological units within the study area

Unit/groundwater system	Minimum	Maximum	Arithmetic mean
[1]Lacustrine clay	2×10^{-4}	1×10^{-3}	6×10^{-4}
[1]IWL foundation	9×10^{-7}	2×10^{-4}	7×10^{-5}
[1]Deposited tailings	5×10^{-4}	6×10^{-1}	1×10^{-1}
Upper Cowra Formation	1×10^{-3}	35	2.6
Lower Cowra Formation	1	20	10.5
Lachlan Formation	0.030	100	33
Saprolite	1×10^{-2}	1×10^{-1}	4×10^{-2}
Saprock	2×10^{-3}	1.5	2×10^{-1}
Fresh rock	1×10^{-3}	1×10^{-2}	5×10^{-3}

Notes: 1. Unit facilitates vertical infiltration only and value represents vertical hydraulic conductivity

2.4 Conditions during existing mining (prior to the Project)

2.4.1 Changes to hydrogeological system during mining

The following variations to the baseline hydrogeological conceptualisation are associated within existing mining activities:

- Development of voids within the Project area intercepting groundwater from the Upper Cowra, Lower Cowra and fractured rock groundwater systems.
- Creation of the IWL and WREs.
- Creation of the following water supply borefields:
  - BCP borefield, extracting groundwater from the Lachlan groundwater system for mine water supply.
  - ES borefield, extracting water from the Lower Cowra groundwater system for mine water supply.
  - Saline borefield, extracting water from the Lower Cowra groundwater system for mine water supply.
- Inflow of groundwater from the Upper Cowra, Lower Cowra and fractured rock groundwater system to E42 with drawdown extending up to 1.5 km from the centre of the pit.
- A relatively elevated watertable across the remainder of the study domain, likely influenced by:
  - Significantly above average rainfall outside the Project area in recent years.

- Seepage from the IWL and WREs within the western portion of the Project area.

2.4.2 Surface water-groundwater connectivity

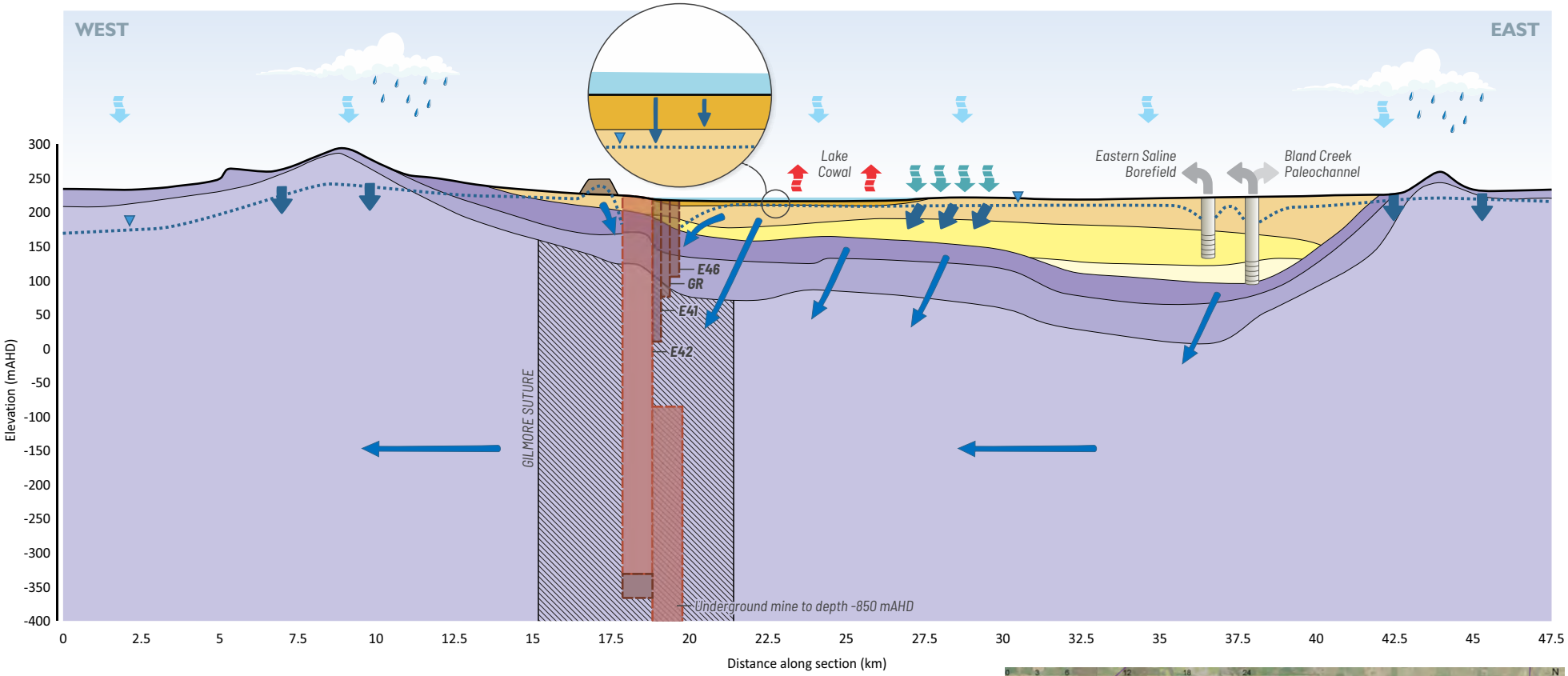
As discussed in the GIA, there is a clear hydrochemical separation between lake samples and Lachlan Formation samples, suggesting hydraulic separation between the lake and the palaeochannel. There is also a clear segregation of water quality signature between the lake and the more saline Cowra Formation and weathered bedrock. The underground mine water samples are compatible with the Cowra Formation and weathered bedrock and show no compatibility with water samples from the lake. The separation of surface water systems is hypothesised to be due to the very low hydraulic conductivity of the Lacustrine Clay layer overlying the alluvial groundwater systems in the bed of the lake. Based on the GIA analysis:

- There is no definitive evidence of hydraulic connection between the lake and the bores around E42 and the underground.
- There is no evidence of hydraulic connection between the palaeochannel and the lake, or between the palaeochannel and historical mine workings (i.e. the E42 pit or the underground mine).

2.5 Hydrogeological conceptual model

Graphical representations of the hydrogeological conceptual model are shown in Figure 2.1 and Figure 2.2. These figures include hydrostratigraphic units, groundwater stresses and groundwater flow direction. The conceptual models show the following main attributes:

- The mine is located on the western edge of the palaeochannel, with only the Lacustrine Clay and the Upper Cowra Formation existing in the vicinity of the mine.
- Irrigation and rainfall are the main recharge mechanisms. Locally, groundwater systems are recharged by the Lachlan River, irrigation channels, and intermittently from the Lachlan River floodway during flooding.
- The main groundwater flow direction is downwards from the palaeochannel sediments to the underlying fractured rock system. Groundwater then continues to flow west and discharges outside of the Project area.
- Evapotranspiration is the main discharge mechanism from the shallow groundwater system.
- Minor seepage occurs from these lakes; however recharge to the underlying groundwater system is limited by the low hydraulic conductivity of the Lacustrine Clay, deposited directly beneath the lakes.
- Inflow of groundwater from the Upper Cowra, Lower Cowra and fractured rock groundwater system flows into E42 and the underground and is removed via dewatering, causing drawdown.
- Tailings deposition and WREs induce local groundwater mounds beneath these facilities.



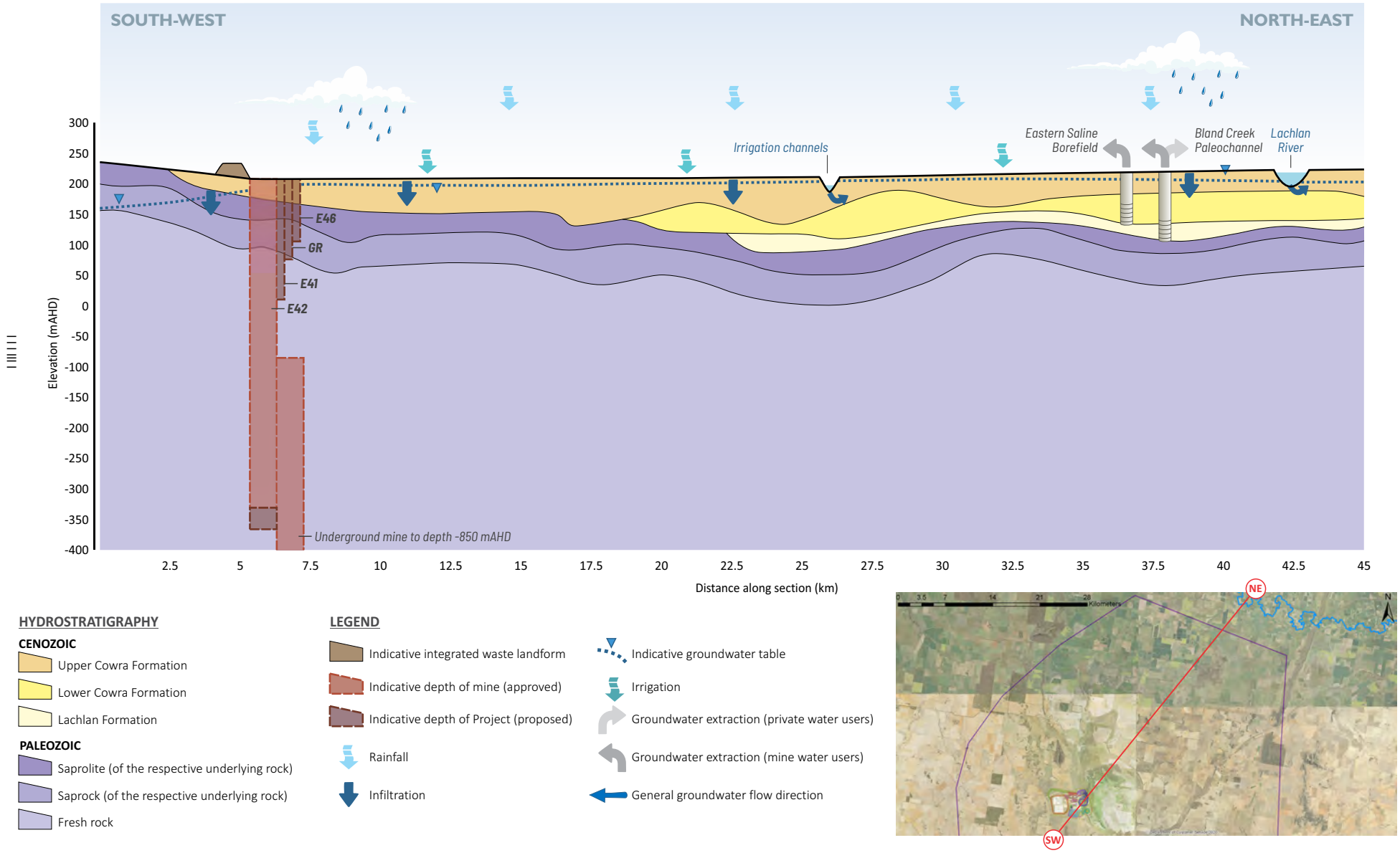
This diagram is a conceptual representation only

Conceptual hydrogeological section – east to west

Evolution Mining Limited
Groundwater Model Report

Figure 2.1

EMM
creating opportunities



Conceptual hydrogeological section – southwest to northeast

Evolution Mining Limited
Groundwater Model Report

Figure 2.2

EMM
creating opportunities

3 Model design

3.1 Overview

In response to the updated hydrogeological conceptual model, advances in modelling software, and to help address previous comments from reviewers and regulators on limitations of previous modelling of the site, a new model has been developed rather than updating the two separate existing models of the mine site and associated water supply.

3.2 Equivalent porous medium approach

Given the scale and complexity of the model and the modelling objectives, the numerical groundwater flow model was designed using an equivalent porous medium (EPM) approach for the fractured and weathered bedrock HSUs. This approach is commonly used in larger-scale groundwater models of fractured rock environments. The EPM method assigns bulk hydraulic properties for an HSU and treats the rock matrix and any associated fracture networks as if they were a single porosity medium such as a granular aquifer (Anderson & Woessner 1991). This approach was adopted for the following reasons:

- It is environmentally conservative to assume that the intermediate fractured rock groundwater system is interconnected at the site-wide scale and is also permeable. This assumption allows for drawdown/mounding to propagate radially outwards from the project components and, therefore, prediction of impacts to receptors is likely skewed towards being conservative.
- From a project water balance perspective, assuming interconnected and permeable fractured rock conditions is also conservative in that it may tend to over-predict groundwater inflow to mine voids, which will reduce the risk of under-estimating groundwater and surface water licensing requirements.
- Dual porosity and discrete fracture network models require significant detail on fracture/joint orientations, spacings, lengths and apertures, which were not available for the geology in the model domain.

It is noted that the EPM approach is appropriate for a larger scale groundwater model, though one of the limitations is small-scale accuracy induced by not capturing the detail in local fracture network properties. The adopted approach to overcome that limitation was to explore predictive uncertainty through probabilistic uncertainty analysis.

3.3 Complexity

The Minimum Groundwater Modelling Requirements for SSD/SSI Projects (DPE 2022) states that:

> An effective model achieves an acceptable level of parsimony, in which the model is simple enough to be manageable, yet complex enough to represent the system at the desired level of detail.

Table 3.1 provides a summary of the model complexity with respect to the environmental complexity and sensitivity (as per Figure 3 on page 19 of the DPE 2022 guidelines). Based on this assessment using DPE's criteria, the model is pitched at medium to high complexity with an environmental complexity and sensitivity that is mainly medium to high complexity. The scale of the development and the importance of receptors necessitates a model complexity of medium to high ranking. This provides confidence that the overall model complexity is appropriate for the risk to the environment.

Table 3.1 Summary of model and environmental complexity

Factor	Comment	Model complexity	Environmental complexity and sensitivity
Model scale	Local-scale, site wide and regional scale	High	-
Layering	Numerical model layers > 5 layers	High	-
Model type	Numerical model with multiple aquifer units	High	-
Model requirements	No density issues, coupled SW-GW requirements, solute transport (particle tracking)	Medium to high	-
Temporal scale	Transient model capable of simulating flow and solute transport	Medium	-
Productive aquifers	Medium to low productivity aquifers	-	Medium to high
Issues	Cumulative effects, irrigation use, third-party groundwater abstractions in the same HSUs and the Project	-	High
Receptors	Receptors partially connected with exploited aquifer and GDEs present	-	Medium to high
Scale of development	Large scale development	-	Medium to high
Water supply risks	Quandialla town water supply bore, 45 km south of mine borefield	-	Medium
Cumulative impacts	Nearby developments in same or other aquifers	-	Medium to high

3.3.1 Model limitations and exclusions

Numerical simulation of the hydrogeological regime in the Study Area has a number of limitations that reflect the complexity of the groundwater system, the scope of the project, data availability, and the restrictions imposed by the software. The main limitations are listed below:

- The equivalent porous medium (EPM) approach is used for representation of the bulk fracture network and rock matrix.
- Faults, bedding planes and fracture/joint planes are not represented as discrete features due to limitations of available detailed structural and hydraulic information related to these features. Pilot points have been used for generation of hydraulic property fields, with sufficiently high spatial resolution to capture any measurable hydraulic influence of faulting.
- The model history-matching includes publicly available regional hydraulic head data. A number of sites only had single measurements of groundwater level; these were used as steady-state targets despite potentially representing higher or lower than typical conditions at the time of measurement.
- No estimations or corrections were made concerning measurement noise/error.
- No simulation of or corrections for water density due to salinity were made.

- Measurements of in-pit dewatering were not used for history-matching, as these data do not account for incident rainfall, evaporation, or entrained water. Predicted mine dewatering was reviewed against measured data for consistency, but not included as targets.
- Near-pit piezometers show variable drawdown trends based on depth. History-matching performance was qualitatively assessed at these locations to ensure appropriate vertical gradient development, but explicit head difference targets were not used.
- No property changes representing fracturing or backfill materials have been included.
- Contaminant fate and transport modelling has not been simulated beyond advective particle tracking, which only provides an indication of groundwater flow patterns.
- Impacts of climatic or weather variations, other than average seasonal fluctuations, are not modelled.

3.4 Software

The model was run using the MODFLOW-USG version 1.10 simulation code (Panday et al. 2013, Panday 2022), through the Groundwater Vistas V8 Pro graphical user interface (Rumbaugh 2020). MODFLOW-USG represents a major revision of the standard MODFLOW code, in that it uses a different underlying numerical scheme; control volume finite difference (CVFD), rather than the previous MODFLOW finite difference (FD) scheme. 'USG' is an acronym for Un-Structured Grid, meaning that MODFLOW-USG Transport supports a variety of structured and unstructured model grids, including those based on cell shapes (Panday et al. 2013). The CVFD method also allows a model cell to be connected to an arbitrary number of adjacent cells, which is not the case with a standard FD scheme. It also includes the Time-Variant Materials (TVM) package to simulate changes in hydraulic properties over time as well as and adaptive time-stepping approach to help with numerical stability and efficiency.

In contrast with structured rectangular finite-difference grids, flexible meshes have several advantages. Firstly, they allow finer mesh resolution to be focused solely in areas of a model that require it (e.g. around the open cut and underground excavations), as opposed to refinement over the entire mesh, significantly decreasing cell count and consequently model run times and file sizes. Secondly, spatial areas not required in the model may be omitted rather than deactivating cells or retaining "dummy" layers (i.e. pinching out of layers). Thirdly, flexible meshes allow cell boundaries to follow important geographical or geological features, such as watercourses or outcrop traces, more accurately modelling the geometry of the physical system. Finally, the orientation of the flow interfaces between cells may vary, allowing preferential flow directions to be modelled with higher accuracy.

Additionally, MODFLOW-USG can simulate variably-saturated flow and can handle desaturation and re-saturation of multiple hydrogeological layers without the "dry cell" problems of traditional MODFLOW. This is pertinent to simulating the depressurisation and desaturation that occurs due to excavation of mine voids. Traditional versions of MODFLOW can handle depressurisation and desaturation to some extent, but model cells that are dewatered are replaced by "dry" cells, which can interfere with the simulation of various flow processes and cause model instability.

3.5 Domain and spatial discretisation

3.5.1 Model extent

The full extent of the groundwater model domain is shown in Figure 1.1. The model domain is approximately 97 km long and 65 km wide at its longest points. The domain is shaped to follow or extend beyond the maximum extents of the Lachlan Formation in the southern, western, and eastern boundaries. The exceptions are two (<800 m long, and <900 m wide) areas to the east where the model cuts through the Lachlan, just before it finishes. These were left out for numerical efficiency and equate to 0.1% of the total Lachlan Formation included in the model.

The northern boundary extends to the north-western edge of the Lachlan Formation and far enough north to include Nerang Cowal. The northern-western edge of the model boundary cuts across the Lachlan, with the model domain finishing approximately 4.5 km south of the Lachlan River.

The southern boundary finishes at a narrowing of the Lower Cowra, and extends beyond the outside edge of the Upper and Lower Cowra where these formations terminate.

The eastern and western boundaries extend beyond the lateral extents of both the Upper and Lower Cowra. The western boundary extends into basement outcrop to avoid drawdown from the mine site reaching the model boundary.

This model extent is adequately large enough to include:

- All mine-related groundwater-affecting features, including excavations at the mine site, and groundwater abstraction for mine process water supply from the Eastern Saline and Bland Creek Palaeochannel borefields.
- All cumulative effects from other groundwater affecting activities such as third-party abstractions from the Upper Cowra, Lower Cowra and Lachlan Formation.
- All identified receptors with potential to be affected by mining activities (registered third-party bores, GDEs and surface water bodies, including the entire extent of Lake Cowal and Nerang Cowal).
- Jemalong Irrigation (JIL) influences on groundwater flow.
- Model boundary conditions such that regional flow directions can be simulated.

3.5.2 Mesh

A Voronoi polygon mesh (Amenta & Bern 1998) was created to spatially discretise the model domain. The mesh contains 16,138 cells in each layer. The model uses a feature of MODFLOW-USG which allows cells to be “pinched out” where a layer is not present, or is less than 0.5 m thick. The pinched-out cells are treated as inactive and are removed from all calculations. Of the 371,174 total cells in the model, approximately 11% are pinched out, resulting in a total of 332,141 active cells.

The Voronoi mesh was generated using AlgoMesh 2.0 (HydroAlgorithmics 2020), which provides significant control over the mesh generation process. The mesh was imported into Groundwater Vistas to build and operate the remainder of the groundwater model.

The following general approach was taken when creating the mesh:

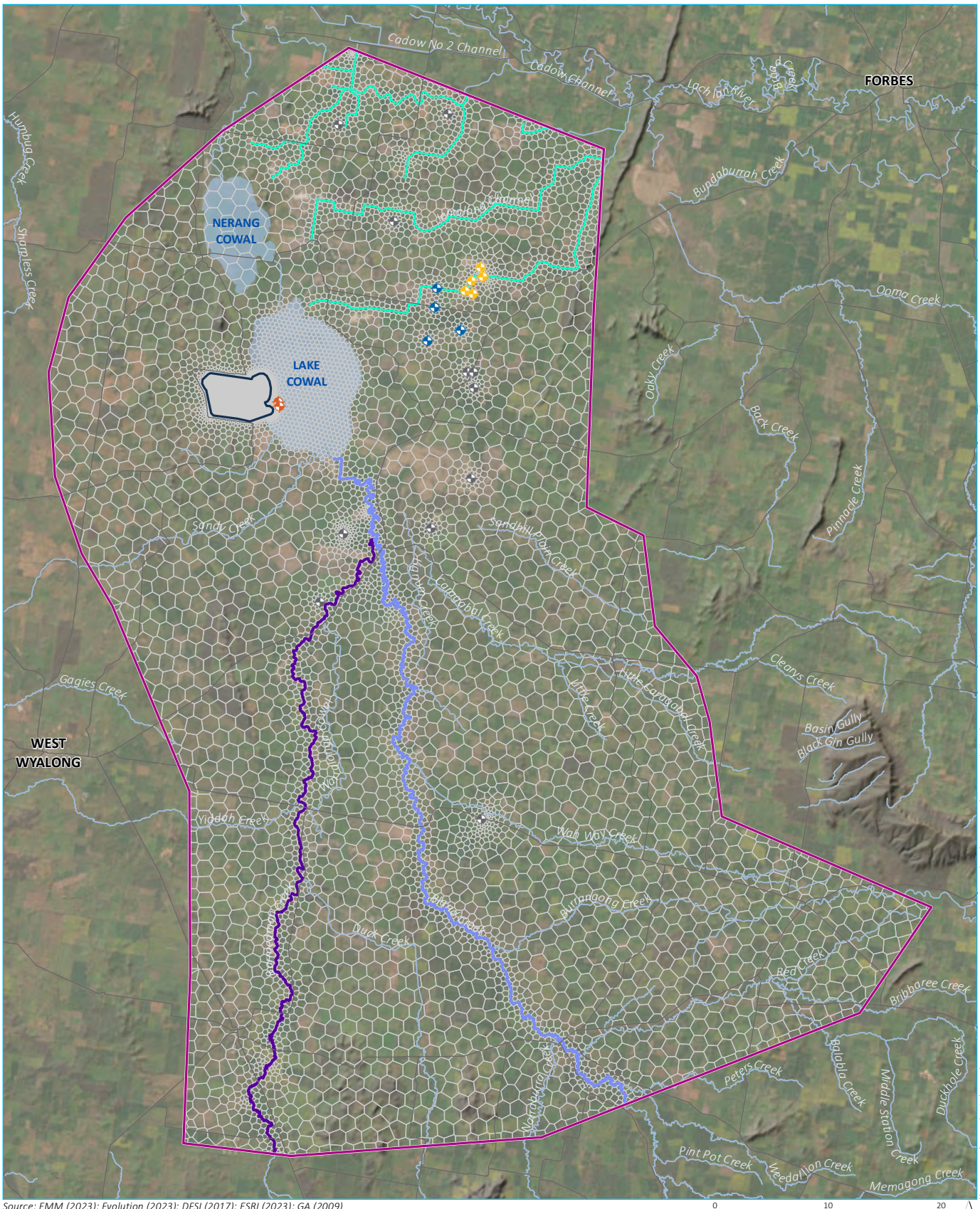
- A buffer around the open-cut pits, UG development, TSF/IWL, WREs, pumping bores, Lake Cowal, JIL irrigation canals, Bland Creek and Barmedman Creek.

- Polylines along the JIL irrigation canals, Bland Creek and Barmedman Creek were sampled at regular intervals to make sure the mesh conformed to mapped drainage networks, and to enforce variable degrees of spatial detail along these surface water features.
- Head target locations were included in the mesh generation process to enforce sufficient spatial detail in areas with observations located close to one another and centralisation within the model cell to minimise interpolation.

In a Voronoi mesh, the maximum 'cell size' in an area is used as a constraint in the creation process, and it is defined as the distance between the centroids of two adjacent cells. The adopted maximum cell sizes in key areas of interest are as follows:

- 15 m at the UG development.
- 35–45 m at the pits.
- 80 m at the TSF/IWL and WREs.
- 100 m at production bores.
- 390 m at Lake Cowal.
- 250–450 m at Bland and Barmedman Creeks.
- 400–450 m at the JIL irrigation canals.
- 1,500 m maximum over the remainder of the model domain.

Cells progressively expand in size moving away from areas of defined refinement. Figure 3.1 shows the Voronoi mesh and a zoomed in view of the mesh at the mine site area is presented in Figure 3.2. Note that some features in Figure 3.2, such as the WREs, overlap with the pits as a function of timing.



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM002_ModelDomainAndVoronoiMesh_20230517_04.mxd 17/05/2023

KEY

- Model domain
- Mine site footprint for mesh refinement
- Major road
- Bland Creek
- Barmedman Creek
- Jemalong irrigation channels
- Named watercourses
- Named waterbody
- Voronoi mesh

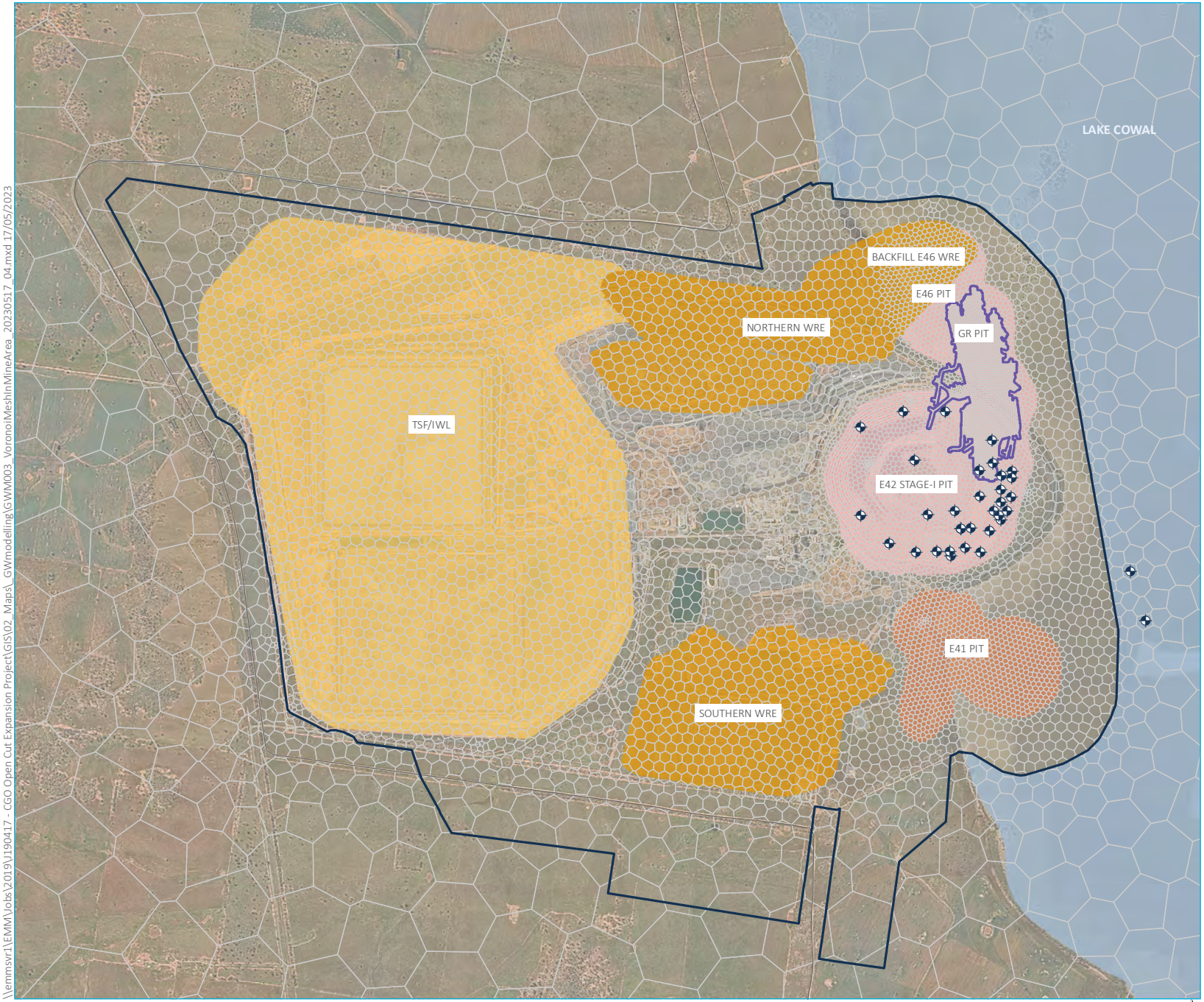
Pumping bores

- Bland Creek Palaeochannel Borefield (BCPB)
- Eastern Saline Borefield (ESB)
- Saline Borefield
- Third party

Model domain and Voronoi mesh

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.1

EMM creating opportunities



KEY

- Proposed OPC disturbance footprint
- Underground development footprint
- Voronoi mesh
- Pumping bores in model
- Major road
- Lake Cowal

Conceptual project infrastructure

- Pit E42, E46 & GRE
- Pit E41
- TSF/IWL
- Waste rock emplacement (WRE)

\\emmsvr1\EMM\Jobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM003_VoronoiMeshInMineArea_20230517_04.mxd 17/05/2023

Source: EMM (2023); Evolution (2023); DFSI (2017); Nearmap (2021)

0 1 2 km

GDA 1994 MGA Zone 55

N

Voronoi mesh in mine area

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.2

EMM
creating opportunities

3.5.3 Layers

A total of 23 model layers were used for the combined needs of representing HSUs and mine excavations. HSU surfaces were created using Leapfrog software to interpolate and extrapolate information from available bore logs. The groundwater flow model layers were defined as follows:

- Model layer 1 represents a surficial clay, basement outcrops, and material for the TSF/IWL and WREs. The top of model layer 1 is taken as the ground surface from a 1 second resolution digital elevation model (DEM) sourced from ELVIS. The layer was given a uniform thickness of 3 m across the model domain.

  To represent unconfined groundwater conditions within the TSF/IWL and model transport of potential contaminants (via particle tracking), the top of model layer 1 was raised to 100 mAHD over the TSF/IWL footprint.

- Model layer 2 represents the Upper Cowra. The base of this layer was taken from the geological model.

- Model layers 3 and 4 represent the Lower Cowra and Lachlan respectively. The top and bottom surfaces for both were taken from the geological model.

- Model layers 5 and 6 represent the Saprolite and Saprock. The top and bottom surfaces of each formation were taken from the geological model within the mine site area. Outside the mine site, sparse amounts of data exist on these formations. As such, they were each assigned uniform regional thickness of 40 m, based on the average thickness observed at the mine site.

- Model layers 7 to 23 represent basement. Basement was discretised into multiple model layers in order to enable representation of progression of the pits and UG development with time as well as to appropriately capture the horizontal and vertical hydraulic gradients, and associated groundwater inflows, resulting from dewatering the excavated components during and post-mining.

- Model layers 8 to 23 have a uniform (flat) elevation. Model layers 8 to 11 are 25 m thick and pinch out where they intersect the base of overlying formations. Model layers 12 to 17 are 50 m thick. Model layer 18 is 75 m thick, layers 19 to 22 are 100 m thick and layer 23 is 125 m thick. The model layers from 12 to 23 do not pinch out because the top surface is deeper than the base of overlying formations. Varying layer thicknesses were used to capture the varying rates of excavation with time across the different pits.

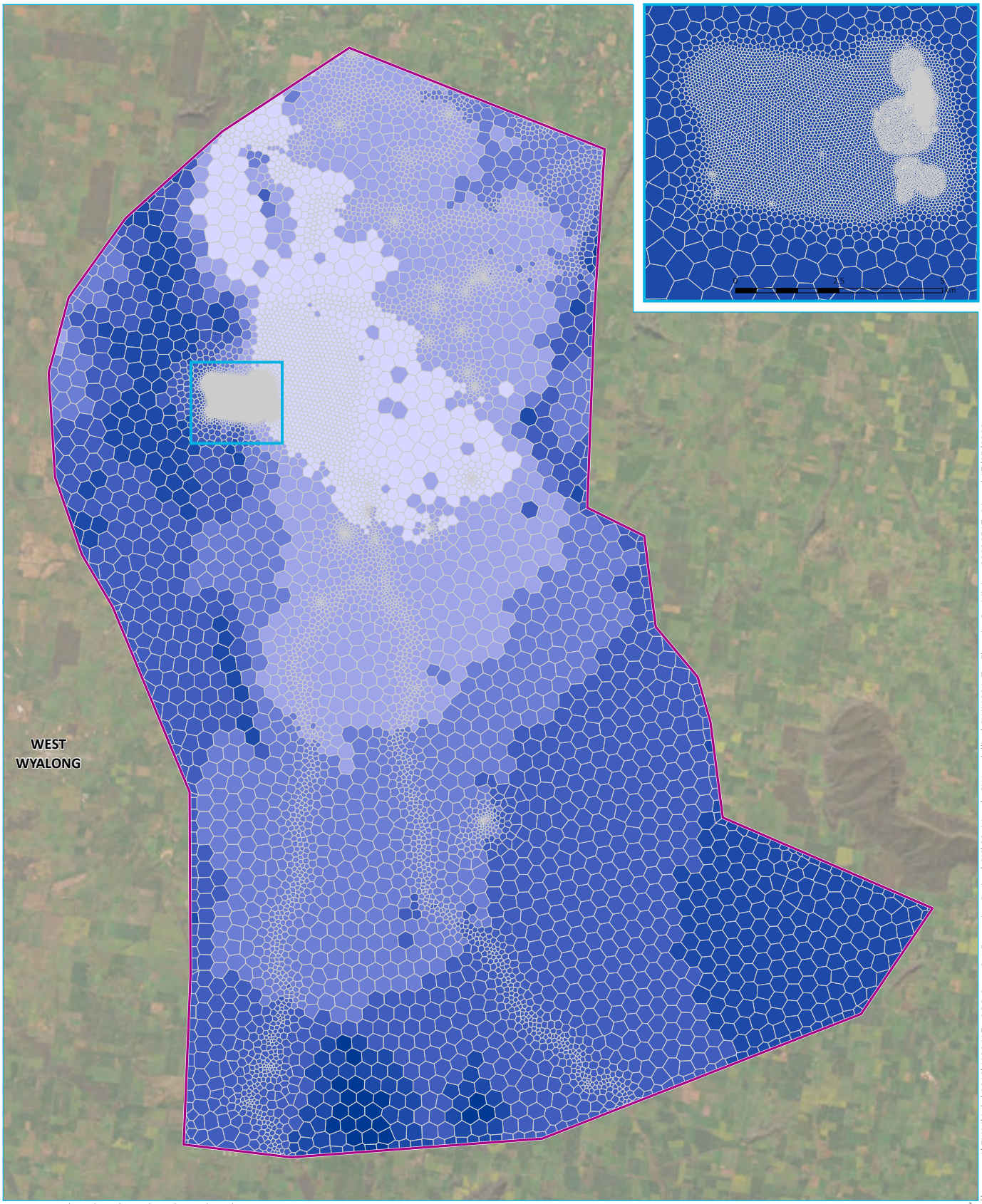
- The base of the model is set at a uniform elevation of -900 mAHD. This is 51 m below the deepest UG development at -849 mAHD.

All MODFLOW-USG layers were set to LAYCON 4 (variably confined/unconfined upstream watertable). This allows each layer to simulate confined or unconfined conditions, depending on the simulated elevation of the watertable at each point in time.

The modelled HSU surfaces are shown in Figure 3.3 to Figure 3.9.

Table 3.2 Model layers summary

Model layer	HSU(s)	Project components	Non-project components
1	Clay (lacustrine and non-lacustrine origins), basement outcrops and mine site waste material	TSF/IWL and WREs	-
2	Upper Cowra Formation	ESB, open pits, pit dewatering bores	Third-party bores
3	Lower Cowra Formation	ESB, SB, open pits, pit dewatering bores	Third-party bores
4	Lachlan Formation	BCPB	Third-party bores
5	Saprolite	Open pits, underground development, pit dewatering bores	-
6	Saprock	Open pits, underground development, pit dewatering bores	-
7-23	Basement	Open pits, underground development, pit dewatering bores	-



Source: EMM (2023); Evolution (2023); ESRI (2023)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

Model domain

Voronoi mesh

Top elevation (pre-mining topographic surface) – model layer 1 (m AHD)

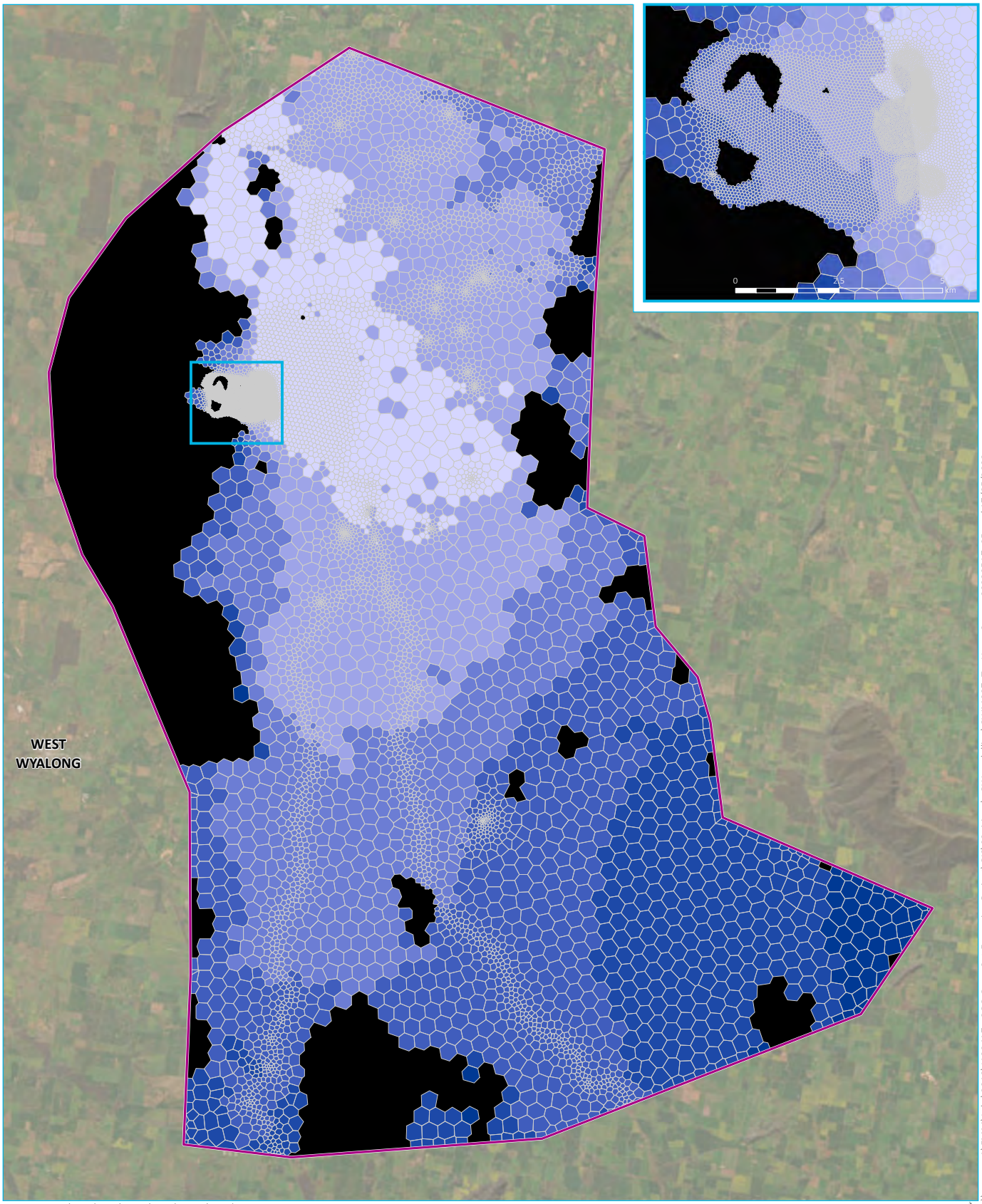
- < 208
- 208 - 215
- 215 - 225
- 225 - 250
- 250 - 300
- > 300

Top elevation (pre-mining topographic surface) – model layer 1 (m AHD)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.3

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM004_TopElevationPreMining_20230517_04.mxd 17/05/2023



Source: EMM (2023); Evolution (2023); ESRI (2023)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Model domain
- Voronoi mesh

Top of Upper Cowra – model layer 2 (m AHD)

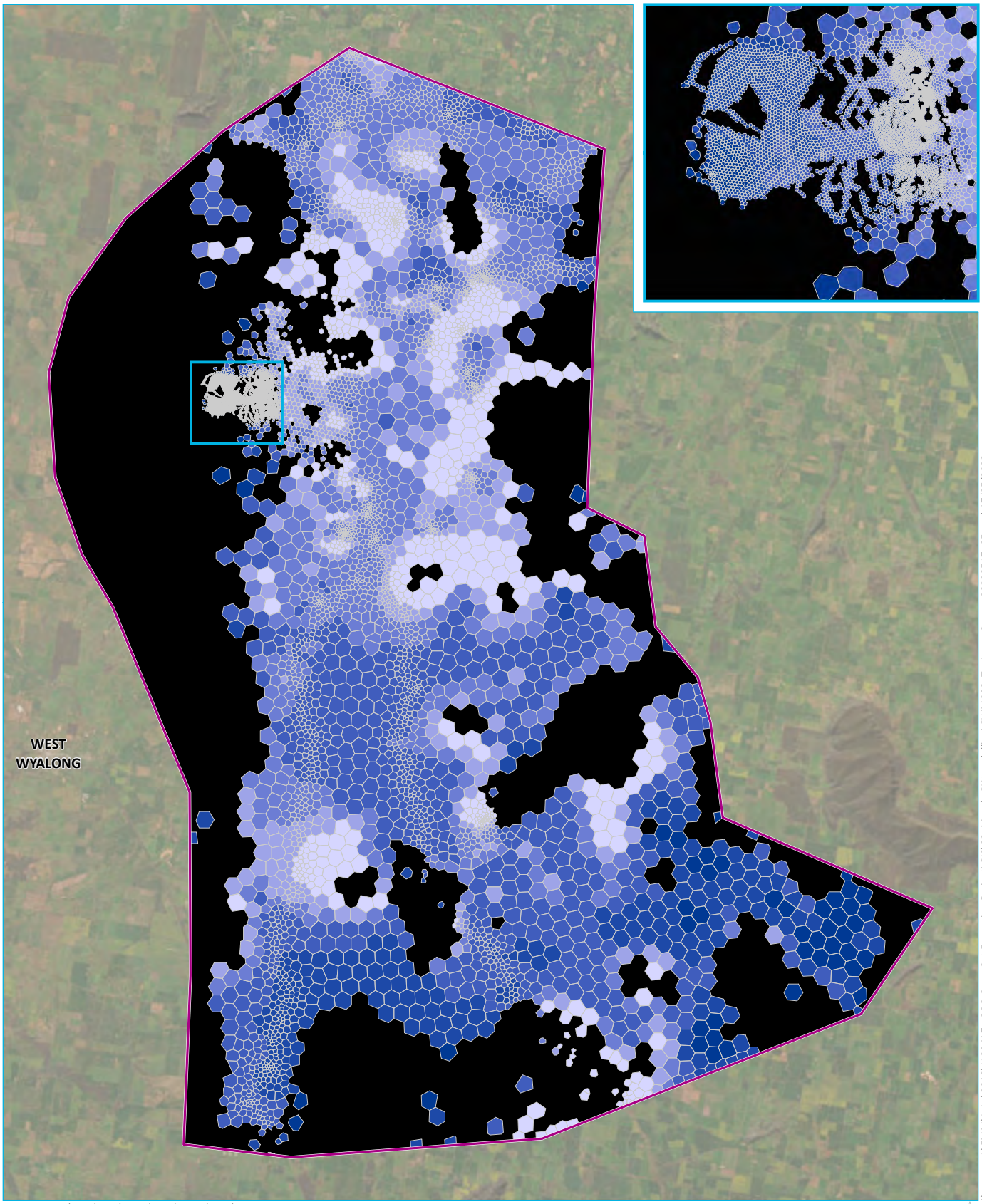
- < 205
- 205 - 212
- 212 - 220
- 220 - 235
- 235 - 270
- > 270
- Not present

Top of Upper Cowra – model layer 2 (m AHD)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.4

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM007_TopUpperCowra_20230517_05.mxd 17/05/2023



Source: EMM (2023); Evolution (2023); ESRI (2023)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Model domain
- Voronoi mesh

Top of Lower Cowra – model layer 3 (m AHD)

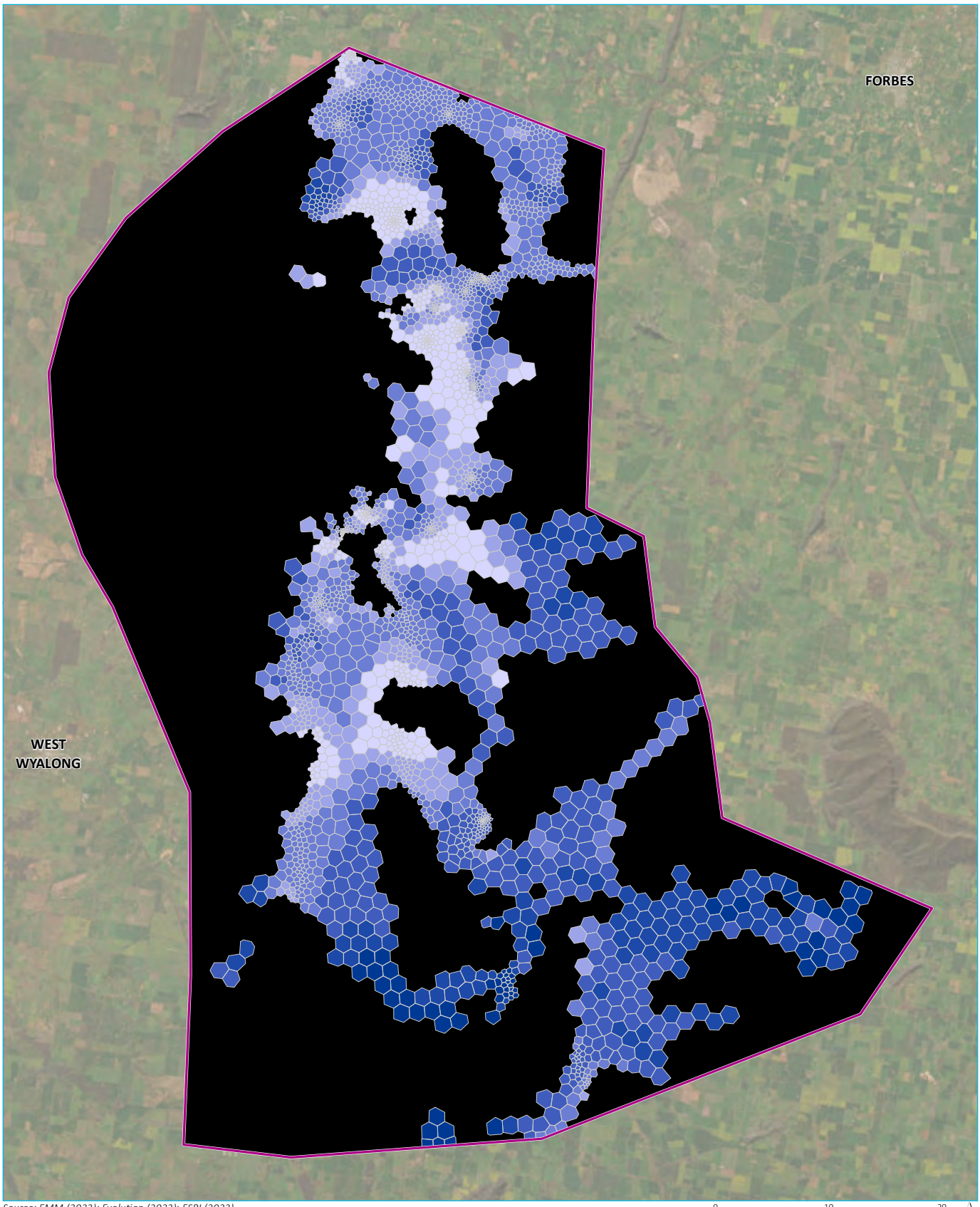
- < 160
- 160 - 170
- 170 - 180
- 180 - 200
- 200 - 220
- > 220
- Not present

Top of Lower Cowra – model layer 3 (m AHD)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.5

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM008_TopLowerCowra_20230517_05.mxd 17/05/2023



Source: EMM (2023); Evolution (2023); ESRI (2023)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Model domain
- Voronoi mesh

Top of Lachlan – model layer 4 (m AHD)

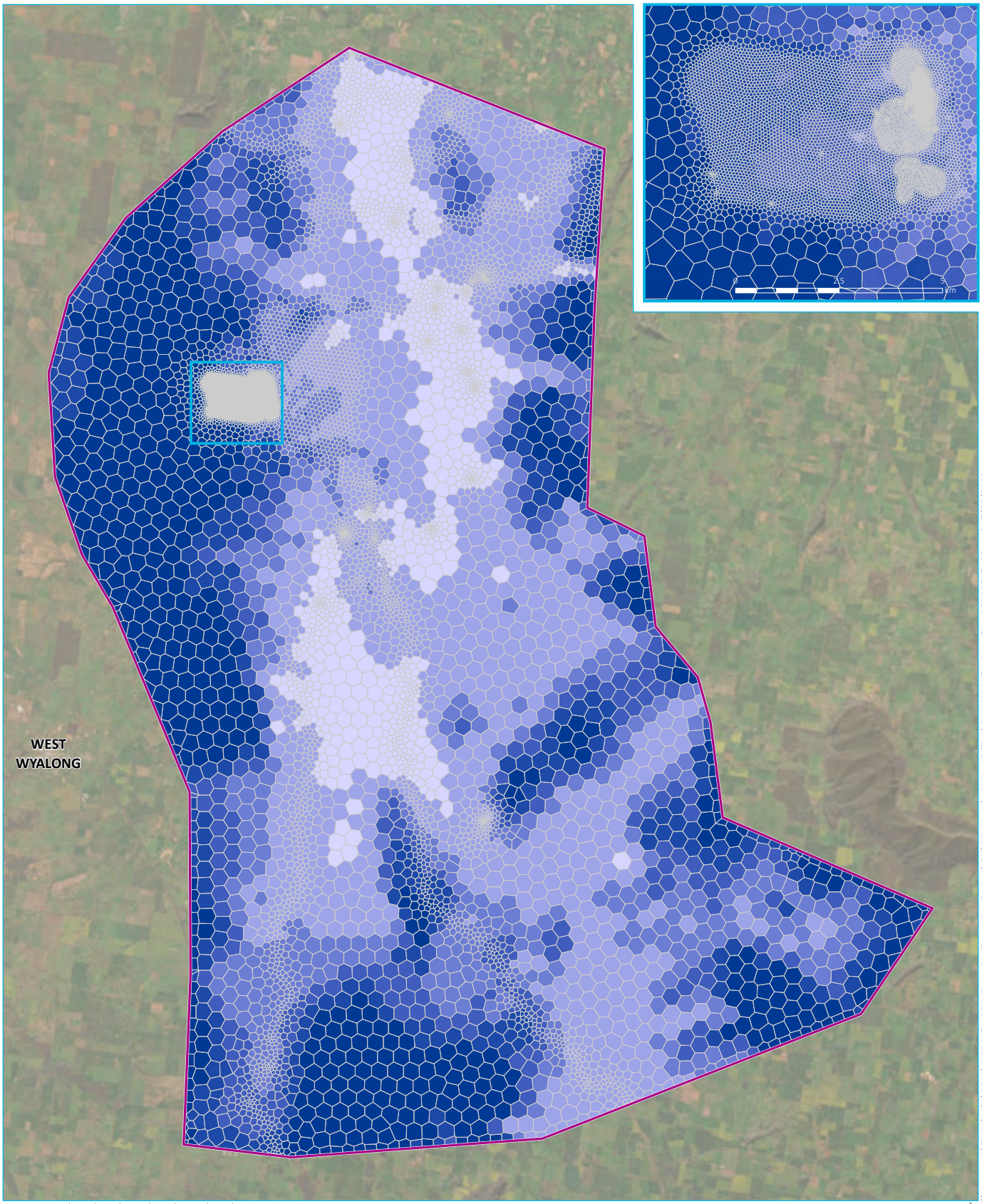
- < 120
- 120 - 130
- 130 - 140
- 140 - 160
- 160 - 180
- > 180
- Not present

Top of Lachlan – model layer 4 (m AHD)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.6

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM009_TopLachlan_20230517_05.mxd 17/05/2023



Source: EMM (2023); Evolution (2023); ESRI (2023)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Model domain
- Voronoi mesh

Top of Saprolite – model layer 5 (m AHD)

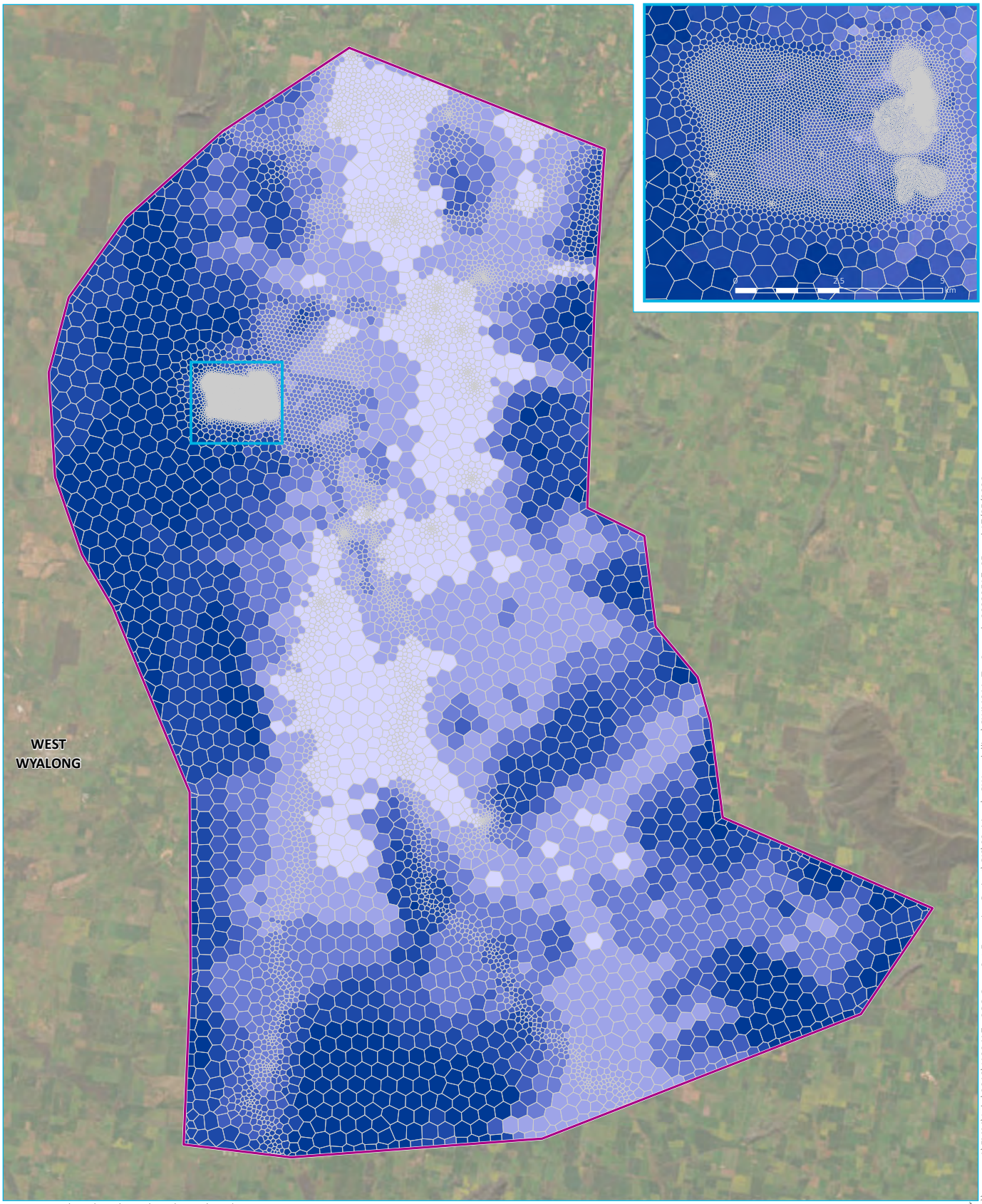
- < 110
- 110 - 150
- 150 - 175
- 175 - 195
- 195 - 220
- > 220

Top of Saprolite – model layer 5 (m AHD)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.7

EMM
creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM010_TopSaprolite_20230517_05.mxd 17/05/2023



Source: EMM (2023); Evolution (2023); ESRI (2023)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Model domain
- Voronoi mesh

Top of Saprock – model layer 6 (m AHD)

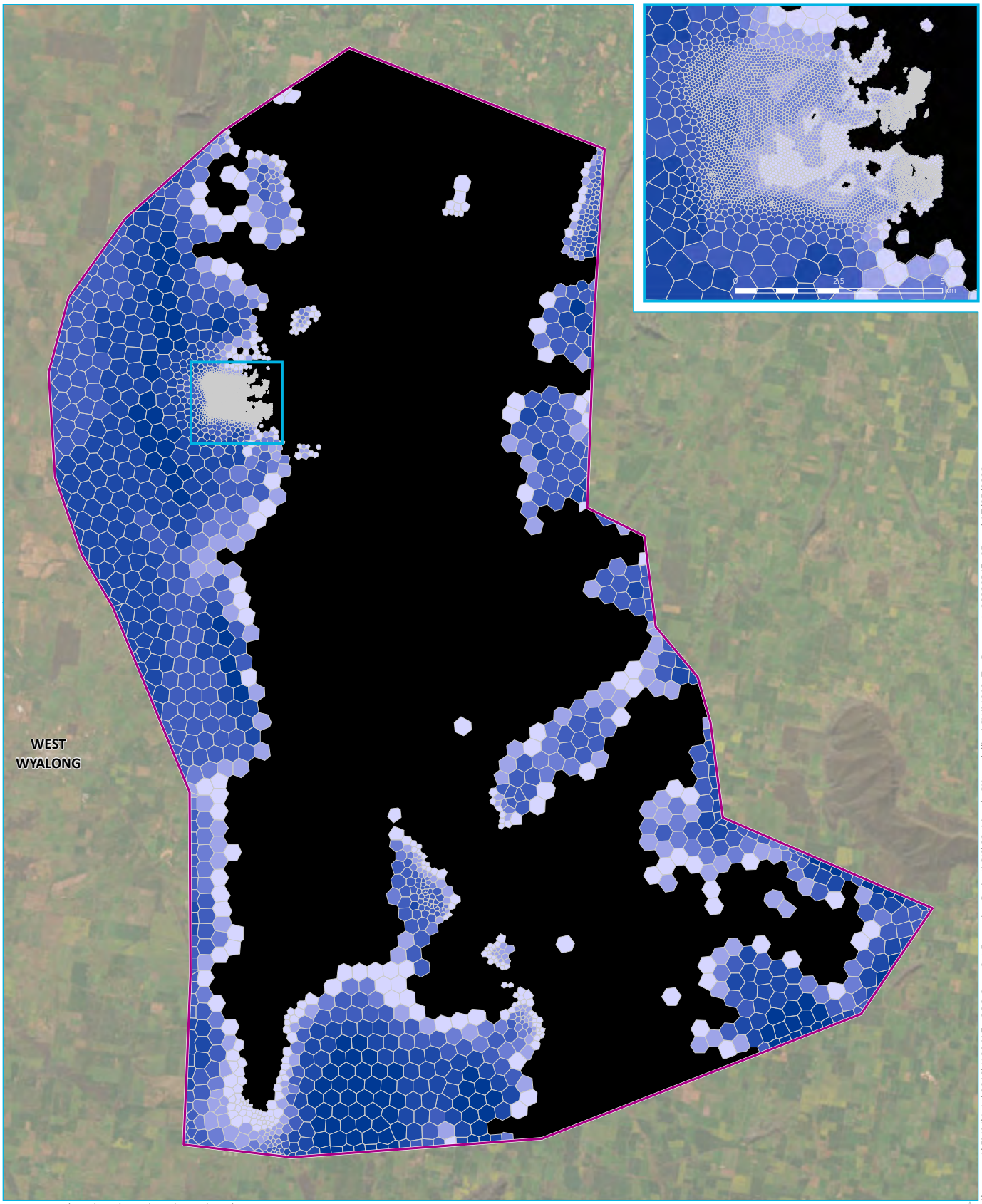
- < 85
- 85 - 115
- 115 - 145
- 145 - 165
- 165 - 200
- > 200

Top of Saprock – model layer 6 (m AHD)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.8

EMM
creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM011_TopSaprock_20230517_05.mxd 17/05/2023



Source: EMM (2023); Evolution (2023); ESRI (2023)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

Model domain

Voronoi mesh

Top of basement – at model layer 7 only (m AHD)

< 110

110 - 120

120 - 130

130 - 150

150 - 180

> 180

Not present

Top of basement – model layer 7 only (m AHD)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.9

EMM
creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM012_TopBasement_20230517_05.mxd 17/05/2023

3.6 Temporal discretisation and numerical solution

The stress periods implemented in the model are summarised in Table 3.3. The history-matching period employs two initial stress periods; one transient stress period run to pseudo-steady state for numerical stability, and one steady state stress period to establish stable long-term groundwater conditions. Following the steady state stress period, 100 quarterly stress periods are employed for the history-matching period from January 1998 to January 2023. This is followed by 72 quarterly stress periods for the predictions until January 2041. Quarterly stress periods were chosen to capture seasonal climatic variability while maintaining manageable computational demands. This was an important consideration given the number of realisations used in the ensemble for history-matching and predictive uncertainty analysis. Post-mining predictions are represented by a single stress period of 1,000 years.

Table 3.3 Stress periods

Stress period	Duration	Date period	Description
1	100,000 d (274 yr)	31 December 1997 (ending)	Pseudo-steady state stress period – transient run providing numerical stability when varying parameter values during the history-matching process.
2	N/A	1 January 1998	Steady-state stress period pre-mining and ESB/BCPB – develops baseline steady state conditions in response to modelled hydraulic properties and boundary conditions.
3–102	Quarterly	2 January 1998 – 1 January 2023	History-matching period – climate stresses and pumping stresses from registered third-party bores prior to the commencement of mining in February 2005. With mine activity stresses from February 2005.
103–174	Quarterly	2 January 2023 – 1 January 2041	Predictive period – climate stress, pumping stresses from registered third-party bores and mine activity stresses.
175	1,000 yr	2 January 2041 – 1 January 3041	Predictive period – climate stress, pumping stresses from registered third-party bores and post-mine recovery.

The adaptive time stepping feature of MODFLOW-USG was used to efficiently discretise stress periods into timesteps such that a numerically stable solution was obtained. The SMS solver was employed to solve the differential equations with a head closure criterion (HCLOSE) of 0.01 m.

3.7 Boundary conditions

3.7.1 Regional groundwater flow

Within the study area groundwater generally flows in a westward direction, with some flow south from the Lachlan River and north from the southern end of the BCP (refer Chapter 2). Groundwater discharges in the form of abstractions from the mine site dewatering, BCPB, ESB and third-party bores will result in local to regional scale drawdown and changes to the direction of groundwater flow. Beneath the Jemalong Irrigation area, additional land surface recharge occurs from irrigation to land and seepage losses from the canal system which may result in some groundwater mounding. Around the TSF/IWL and WREs, localised groundwater mounding occurs due to seepage losses.

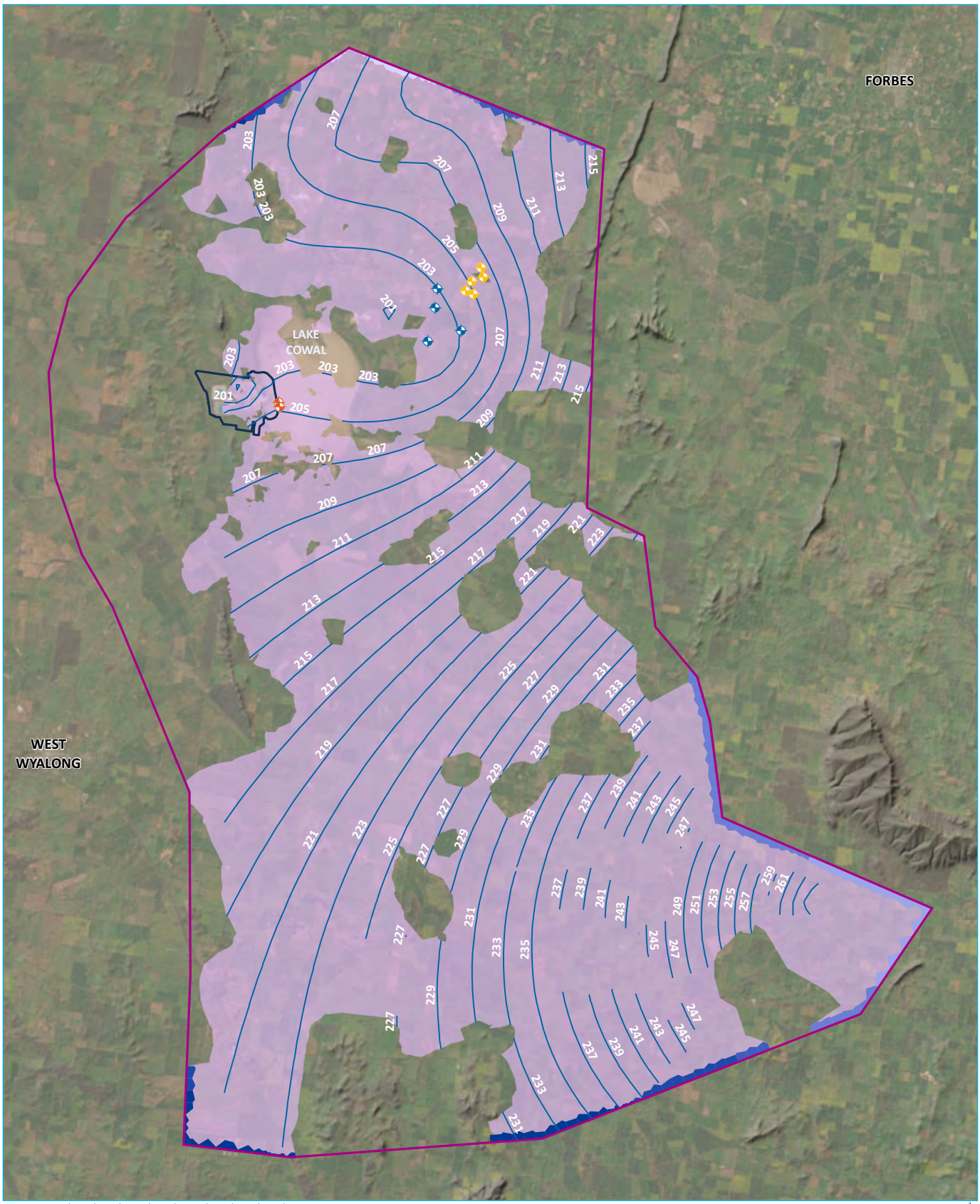
Table 3.4 provides a summary of the head boundary conditions used to simulate local and regional groundwater flow. Constant head boundary conditions (CHD package) are applied at the model boundaries from the Upper Cowra down to basement to simulate lateral groundwater flow to and from the broader regional groundwater flow system described in the HCM. These boundary cells are time-invariant.

Table 3.4 Model edge boundary condition summary

Model layer	HSUs	Boundary type	Flow system	Comments
Layer 1	Clay	None	N/A	Aquitard, dominantly vertical flow assumed, no boundary conditions assigned.
	Basement outcrops	None	Regional	CHD applied in model layers 7–23.
Layer 2	Upper Cowra	CHD	Regional	HSU edges intersecting the model domain.
Layer 3	Upper Cowra	CHD	Regional	HSU edges intersecting the model domain.
Layer 4	Lachlan	CHD	Regional	HSU edges intersecting the model domain. In this case. The northern edge near the Lachlan River.
Layer 5	Saprolite	CHD	Regional	All edges of the model domain.
Layer 6	Saprock	CHD	Regional	All edges of the model domain.
Layer 7–23	Basement	CHD	Regional	HSU edges intersecting the model domain.

The hydraulic head values assigned to the constant head boundary conditions were based on the interpreted potentiometric surfaces developed as part of the hydrogeological conceptual model documented in the GIA. By assigning constant head (CHD) boundary conditions around the model edge, not only at inferred locations of inflow or outflow prior to mining, the model is able to simulate changes to flows across the model boundary that may arise due to simulated groundwater-affecting activities, regardless of whether those locations are conceptualised as being inflow or outflow areas currently. Boundary conditions are inactive at locations where an HSU is pinched out.

The modelled constant head boundaries and HCM head contours are shown in Figure 3.10 to Figure 3.13.



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Proposed OPC disturbance footprint
- Extent of Upper Cowra Formation
- Interpreted groundwater level contour (mAHD)

Pumping bores

- Bland Creek Palaeochannel Borefield (BCPB)
- Eastern Saline Borefield (ESB)
- Saline Borefield

Constant head boundary for the Upper Cowra – model layer 2 (m AHD)

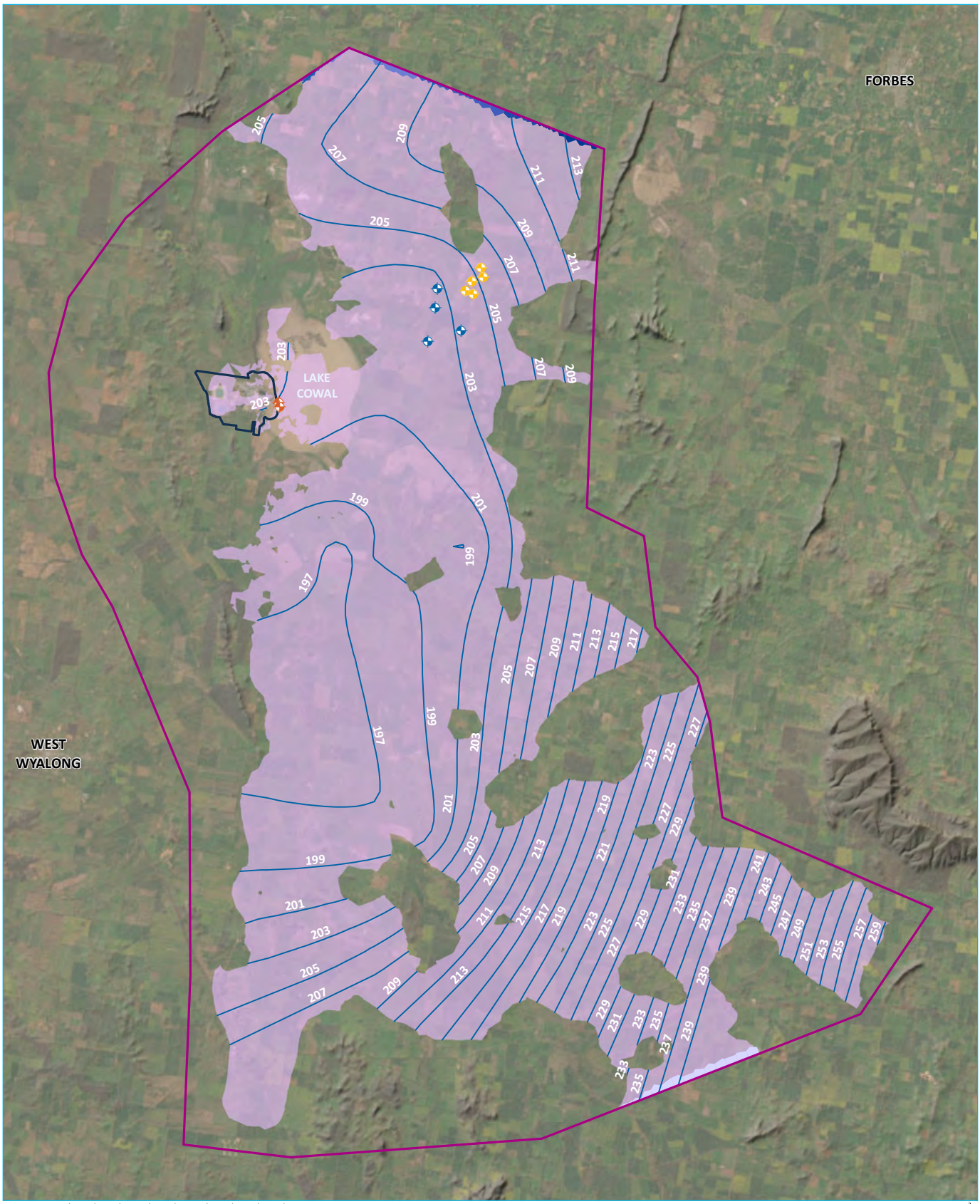
- < 203
- 203 - 208
- 208 - 215
- 215 - 230
- 230 - 250
- > 250

Constant head boundary for the Upper Cowra – model layer 2 (m AHD)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.10

EMM creating opportunities

\\emmsvr1\EMMVJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM013_ConstantHeadUpperCowra_20230517_03.mxd 17/05/2023



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMVJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM014_ConstantHeadLowerCowra_20230517_03.mxd 17/05/2023

KEY

- Study area
- Proposed OPC disturbance footprint
- Extent of Lower Cowra Formation
- Interpreted groundwater level contour (mAHD)

Pumping bores

- Bland Creek Palaeochannel Borefield (BCPB)
- Eastern Saline Borefield (ESB)
- Saline Borefield

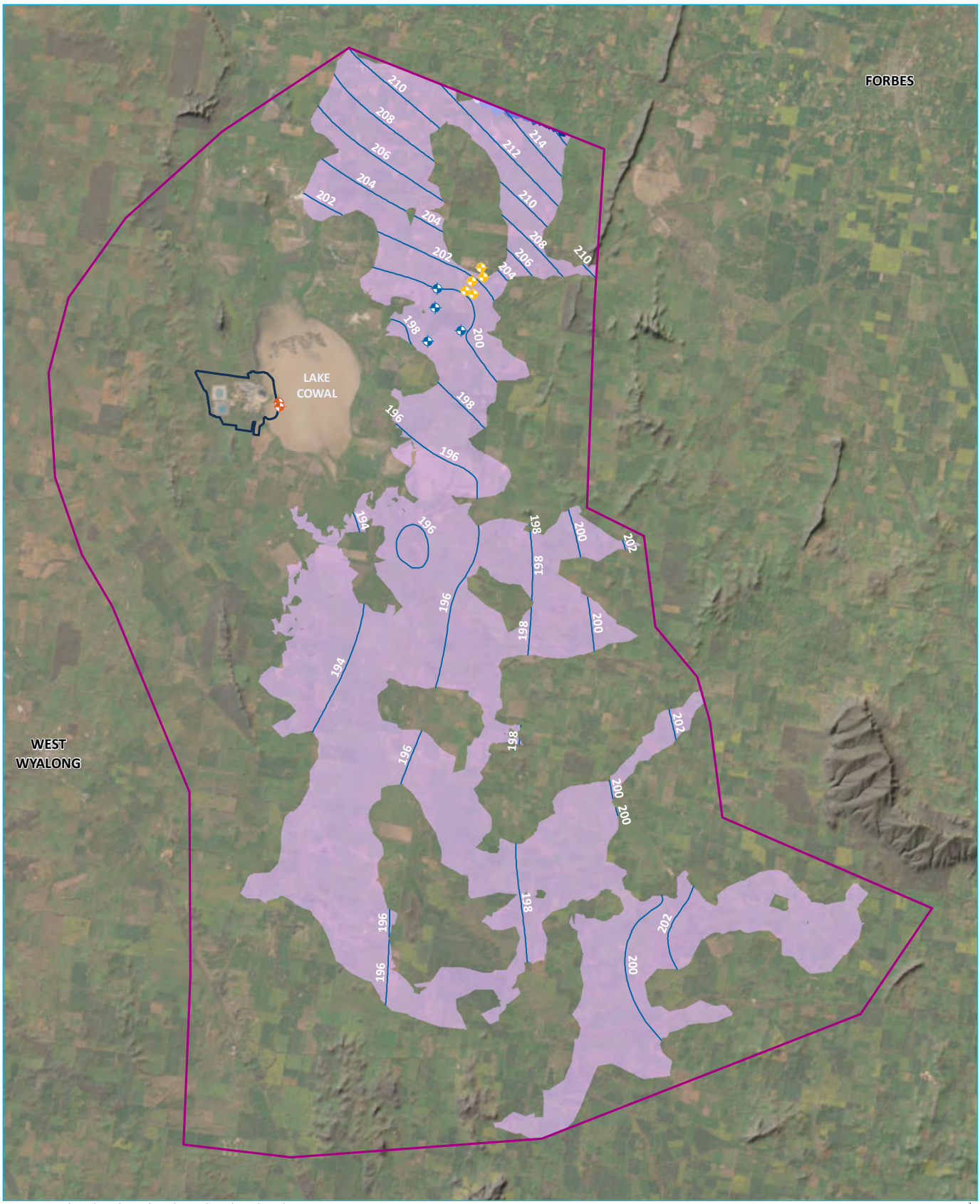
Constant head boundary for the Lower Cowra – model layer 3 (m AHD)

- < 230
- 230 - 233
- 233 - 236
- 236 - 240
- 240 - 245
- > 245

Constant head boundary for the Lower Cowra – model layer 3 (m AHD)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.11

EMM creating opportunities



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

KEY

- Study area
- Proposed OPC disturbance footprint
- Extent of Lachlan Formation
- Interpreted groundwater level contour (mAHD)

Pumping bores

- Bland Creek Palaeochannel Borefield (BCPB)
- Eastern Saline Borefield (ESB)
- Saline Borefield

Constant head boundary for the Lachlan – model layer 4 (m AHD)

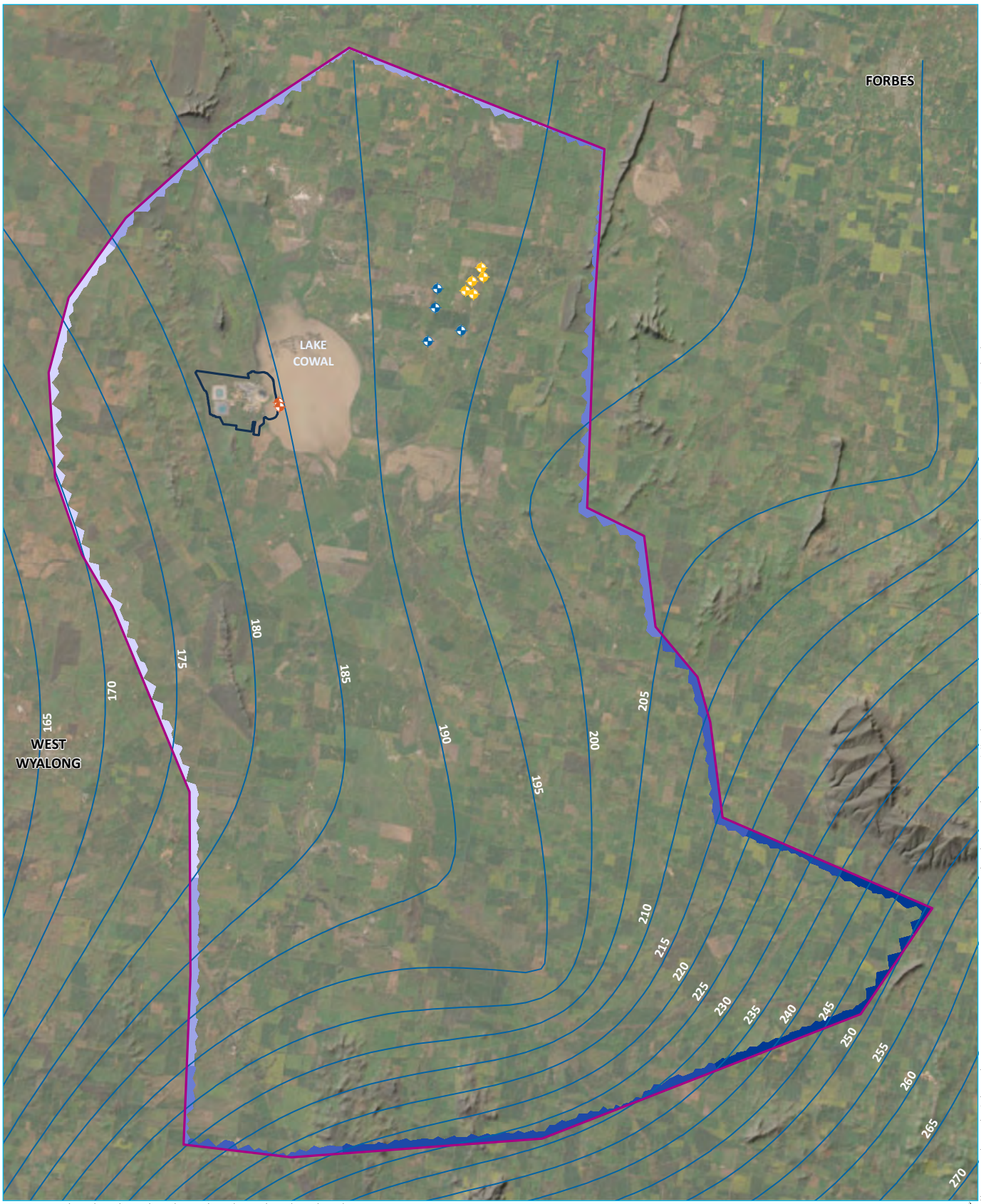
- < 213
- 213 - 214
- 214 - 215
- 215 - 215.5
- 215.5 - 216
- > 216

Constant head boundary for the Lachlan – model layer 4 (m AHD)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.12

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM015_ConstantHeadLachlan_20230517_03.mxd 17/05/2023



Source: EMM (2023); Evolution (2023); DPIE (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM016_ConstantHeadSaproliteSaprockandBasement_20230517_03.mxd 17/05/2023

KEY

- Study area
- Proposed OPC disturbance footprint
- Interpreted groundwater level contour (mAHD)

Pumping bores

- Bland Creek Palaeochannel Borefield (BCPB)
- Eastern Saline Borefield (ESB)
- Saline Borefield

Constant head boundary for the Saprolite, Saprock and basement – in active model layers 5 -23 (m AHD)

- < 180
- 180 - 195
- 195 - 205
- 205 - 220
- 220 - 235
- > 235

Constant head boundary for the Saprolite, Saprock and basement – in active model layers 5 -23 (m AHD)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.13

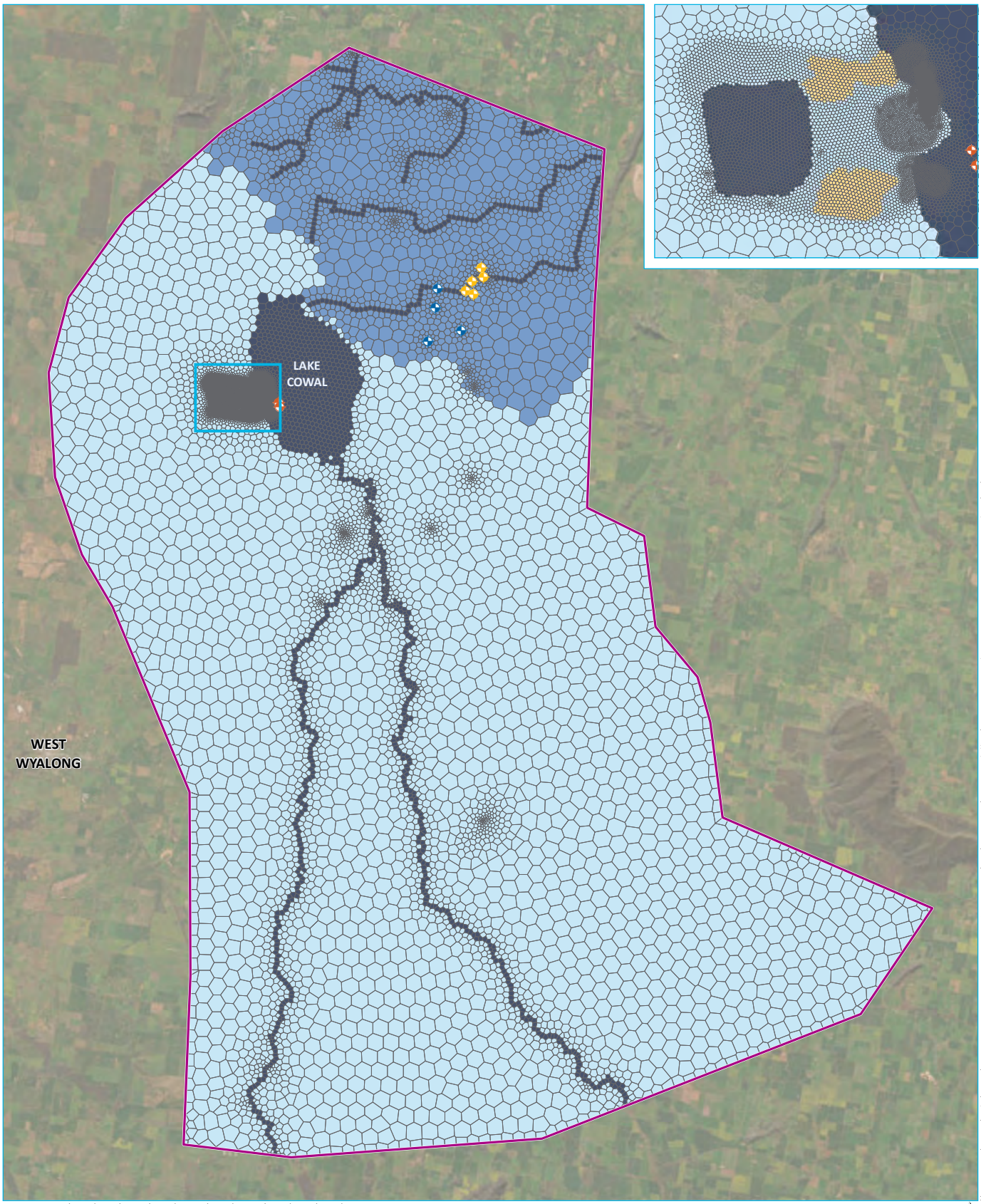
EMM creating opportunities

3.7.2 Recharge

Land surface recharge occurs from rainfall, and a combination of rainfall and irrigation within the Jemalong Irrigation area. An analysis of groundwater hydrographs from 1998 to 2022 (EMM 2023a) showed no clear evidence of flood events. Therefore, recharge from flood events was not simulated explicitly in the model.

The MODFLOW Recharge (RCH) package is used to simulate diffuse rainfall recharge. Three variable recharge zones were applied (Figure 3.14). Two zones of enhanced recharge, one within the Jemalong Irrigation area (Zone 3, and a second within the footprint of the mine site WREs (Zone 4). The dominant zone across the model domain is natural rainfall recharge under non-irrigated land (Zone 1). In addition, recharge is not applied to surface water features (Zone 2).

Rainfall recharge was imposed as a percentage of measured rainfall (for transient stress periods, excluding post-mine recovery) as shown in Figure 3.15 or the long-term average rainfall (for steady-state periods and post-mine recovery). Temporal changes in recharge during transient simulation periods, except post-mining, were calculated per quarterly stress period using the ratio between the measured quarterly rainfall data (converted to a daily average over the duration of each stress period) and the long-term quarterly average from a SILO virtual climate station at the mine site (-33.65, 147.40 – latitude, longitude). From 2023 to the end of mining, recharge was based on the long term quarterly average rate. This allowed seasonal effects to be simulated. The temporally-discretised transient data for rainfall is presented in Figure 3.15.



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Model domain
- Voronoi mesh

Pumping bores

- Bland Creek Palaeochannel Borefield (BCPB)
- Eastern Saline Borefield (ESB)
- Saline Borefield

MODFLOW recharge (RCH) zones

- Zone 1 - Rainfall (dryland)
- Zone 2 - Surface water and TSF/IWL - no recharge
- Zone 3 - Rainfall and irrigation
- Zone 4 - Waste rock dumps

Recharge zones within the model domain simulated using the MODFLOW RCH package

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.14

creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM017_RechargeZones_20230517_03.mxd 17/05/2023

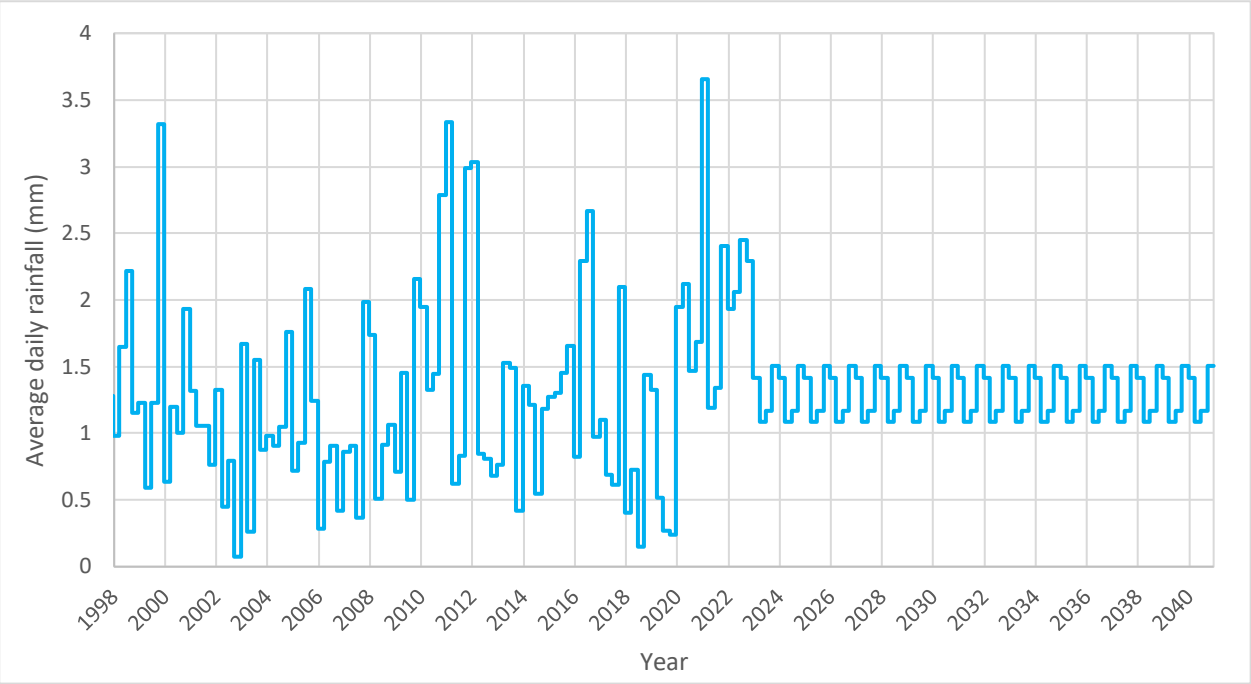


Figure 3.15 Measured and extrapolated future rainfall to the end of mining

Recharge for all zones were calculated as a percentage of the average rainfall per stress period (as per Figure 3.15). The proportion of measured rainfall assigned as recharge was allowed to vary during the history-matching period (see Table 4.1), and returned long-term average rates for the base realisation of:

- Zone 1 – dryland alluvium and rock outcrop areas: 1.2 mm/yr (i.e. equivalent to 0.25% of long-term average rainfall).
- Zone 2 – waterbodies: 0 (no infiltration).
- Zone 3 – Irrigation area: 0.8 mm/yr.
- Zone 4 – WRE: 0.3 mm/yr.

3.7.3 Evapotranspiration

The MODFLOW evapotranspiration segments (ETS) package was used to represent evapotranspiration from the groundwater system. One evapotranspiration zone covering the entire model domain was applied with an extinction depth of 3 m. This value lies within the range of 2 m to 2.5 m used by Lampayan (2001) for a study which included much of the central and northern area of the model domain, and 3 m to 9 m used by Bilge (2012) in a study which included north and south-eastern parts of the model domain. The ETS package is used with one segment across the model domain, with the exception of the TSF/IWL. Due to modelled topography being raised 100 m above the existing landform (Section 3.5.3), a second segment in the ETS package was used such that evapotranspiration behaves as though topography was not changed This configuration simulates evapotranspiration as 'natural' prior to installation of the IWL.

Evapotranspiration is not applied to cells hosting surface water features, or over the footprint of TSF/IWL from the date it was commissioned until the end of the modelled predictive period.

Temporal changes in evapotranspiration during transient simulation periods, except post-mining, were calculated using a similar method as recharge (refer Section 3.7.2). However, unlike recharge which was calculated as a proportion of observed rainfall, maximum potential evapotranspiration was given as equal to the actual data. Temporal changes allowed seasonal effects to be simulated. The discretised transient potential evapotranspiration data are presented in Figure 3.16.

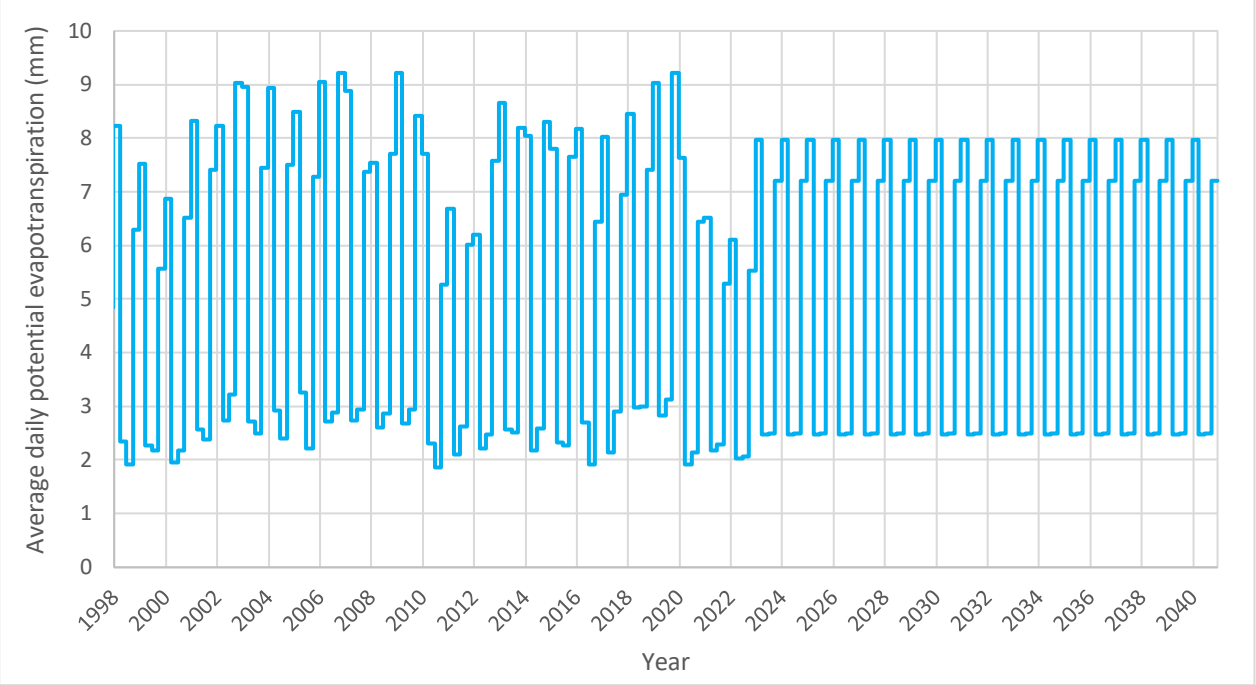


Figure 3.16 Measured and extrapolated future potential evapotranspiration to the end of mining

For steady state simulations and post-mining recovery, evapotranspiration was calculated as a percentage of the long-term mean annual evapotranspiration of 1,762 mm (4.83 mm/d).

3.7.4 Surface water

Major surface water features within the model domain are Lake Cowal, Bland Creek, Barmedman Creek and the irrigation channel network within the Jemalong Irrigation area. These surface water features were all simulated with the MODFLOW River (RIV) package, with further details provided in the following sub-sections. The spatial extent of the surface water features modelled using the RIV package is shown in Figure 3.17.

i Lake Cowal

The RIV package assumes fully saturated conditions and does not account for unsaturated flow. Field observations from the 2022 drilling program on Lake Cowal near the mine site show a perched lake, with unsaturated conditions present between the lake bed and underlying watertable. Therefore, simulating Lake Cowal using the RIV package is considered conservative with respect to the hydraulic connection between the lake and underlying regional groundwater system.

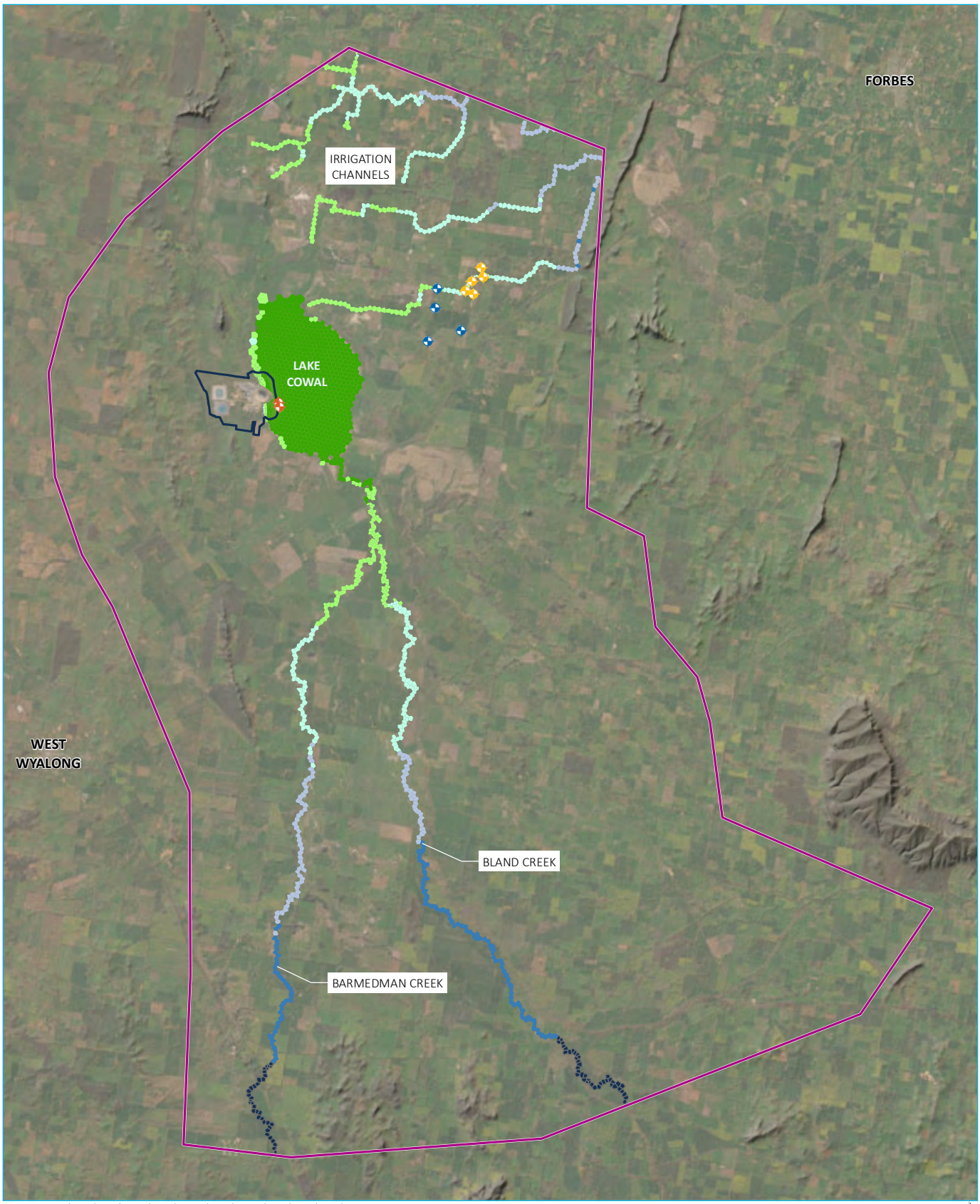
River boundary conditions were activated across the footprint of Lake Cowal, and stage elevation set according to measured data. When the head in a RIV boundary condition is lower than the lake bed elevation at that location, the RIV package will revert to baseflow-only conditions, and seepage losses from the lake will not increase or decrease with changes in head.

Lake water level data were sourced from Coffey (1997) and Evolution's monitoring record. The lake extents were determined by comparing lake water level elevations to the 1 second resolution DEM sourced from ELVIS. During history-matching, the surface area of the lake was allowed to vary with changes in lake water levels. This allowed the distance from the lake edge to the mine to vary with time, and also to account for periods when the lake was dry. The maximum pre-mining lake area was also simulated across the existing mine site. The lake bed elevation was set to the top of model layer 1.

Figure 3.18 shows the simulated lake water levels (RIV stage elevations) used for transient history-matching and predictions to end of mining. The simulated water levels during history-matching were based on measured lake levels. Figure 3.19 shows how lake level variations were derived for the transient predictive period. The variations follow a 5-year cycle of increasing then dropping water levels based on lake level measurements from 2011 to 2022.

A lake water level of 204.3 mAHD was used for the initial pseudo steady state, steady state stress period, and post-mining predictions. This was based on measured lake levels in December 1997 and would be classed as a low lake water level.

Nerang Cowal was not simulated due to the low frequency of water present at surface (EMM 2023a).



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

Model domain

Proposed OPC disturbance footprint

Pumping bores

Bland Creek Palaeochannel Borefield (BCPB)

Eastern Saline Borefield (ESB)

Saline Borefield

Stage elevation (m AHD)

< 206

206 - 210

210 - 215

215 - 220

220 - 230

> 230

Surface water features within the model domain simulated using the MODFLOW RIV package

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.17

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM018_SurfaceWaterFeatures_20230517_04.mxd 17/05/2023

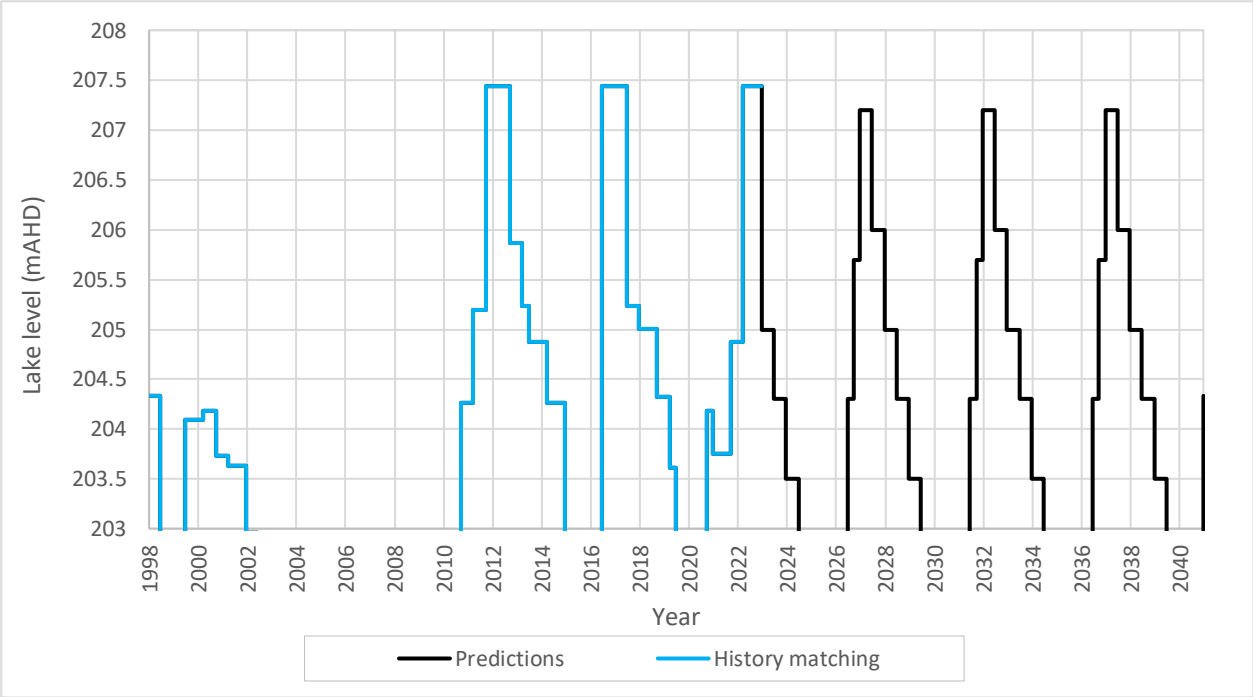


Figure 3.18 **Simulated lake levels over history-matching and predictions to end of mining**

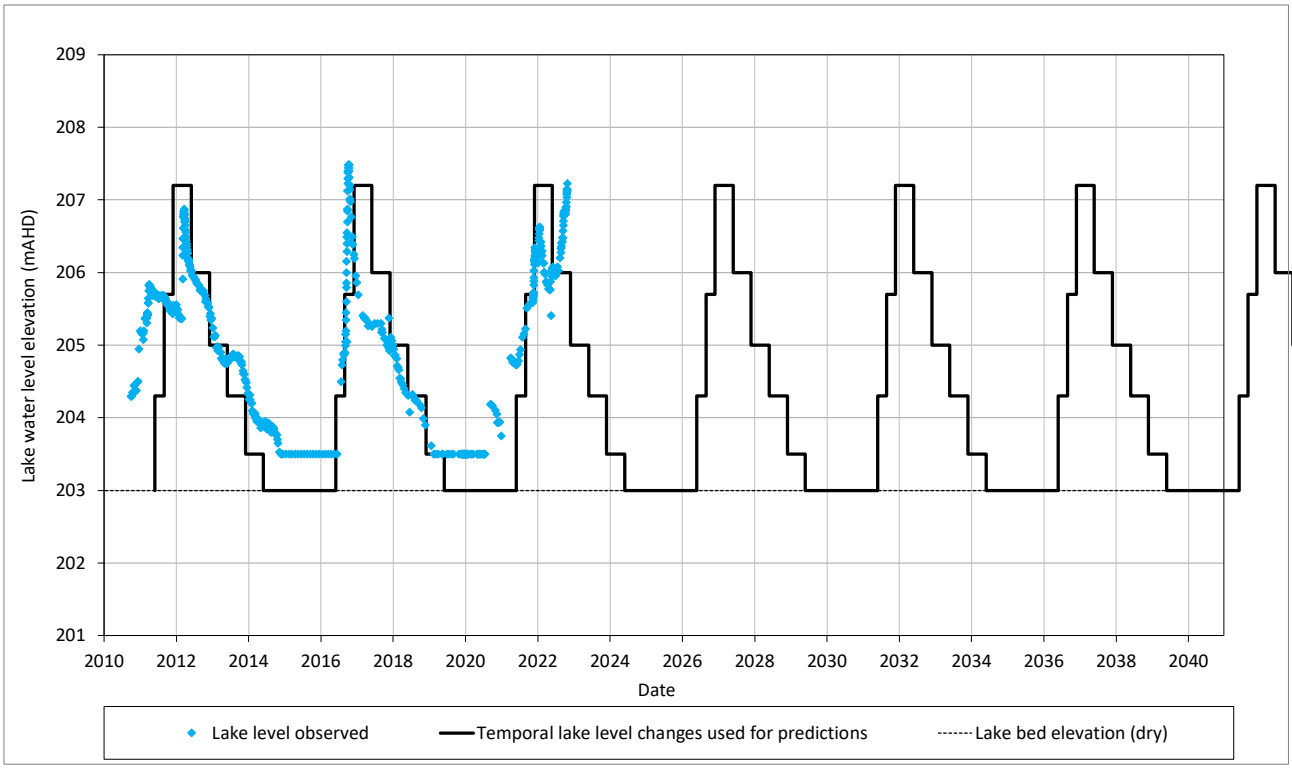


Figure 3.19 **Temporal changes in measured lake levels and the synthetic time series developed for predictions**

ii Bland Creek, Barmedman Creek and irrigation channels

Bed conductance for the Bland Creek, Barmedman Creek and Irrigation Channels was calculated with the following equation:

$$Conductance = \frac{Vertical\ hydraulic\ conductivity\ of\ river\ bed \times Cell\ area}{River\ bed\ thickness}$$

Given the high level of uncertainty in the hydraulic properties of the bed material (vertical hydraulic conductivity, thickness and width), the river boundary conductance was allowed to vary during history-matching.

Bland Creek, Barmedman Creek and the Jemalong irrigation channels were simulated with a fixed river stage equal to the topographic elevation and the bed elevation equal to topography minus 1 m. In reality, the stage height relative to ground will vary depending on the volume of surface water being conveyed. The topography data was extracted from the surface DEM.

3.7.5 Non-project groundwater-affecting activities

i Registered third-party bores

The MODFLOW well (WEL) package was used to simulate major groundwater abstractions from registered third-party bores within the model domain and bores with historical pumping data. These included groundwater takes for irrigation, stock, domestic, industrial and town water supplies. Table 3.5 provides details of the registered third-party pumping bores used for history-matching and/or predictive simulations. The bore locations used in history-matching and predictions are shown in Figure 3.20 and Figure 3.21 respectively.

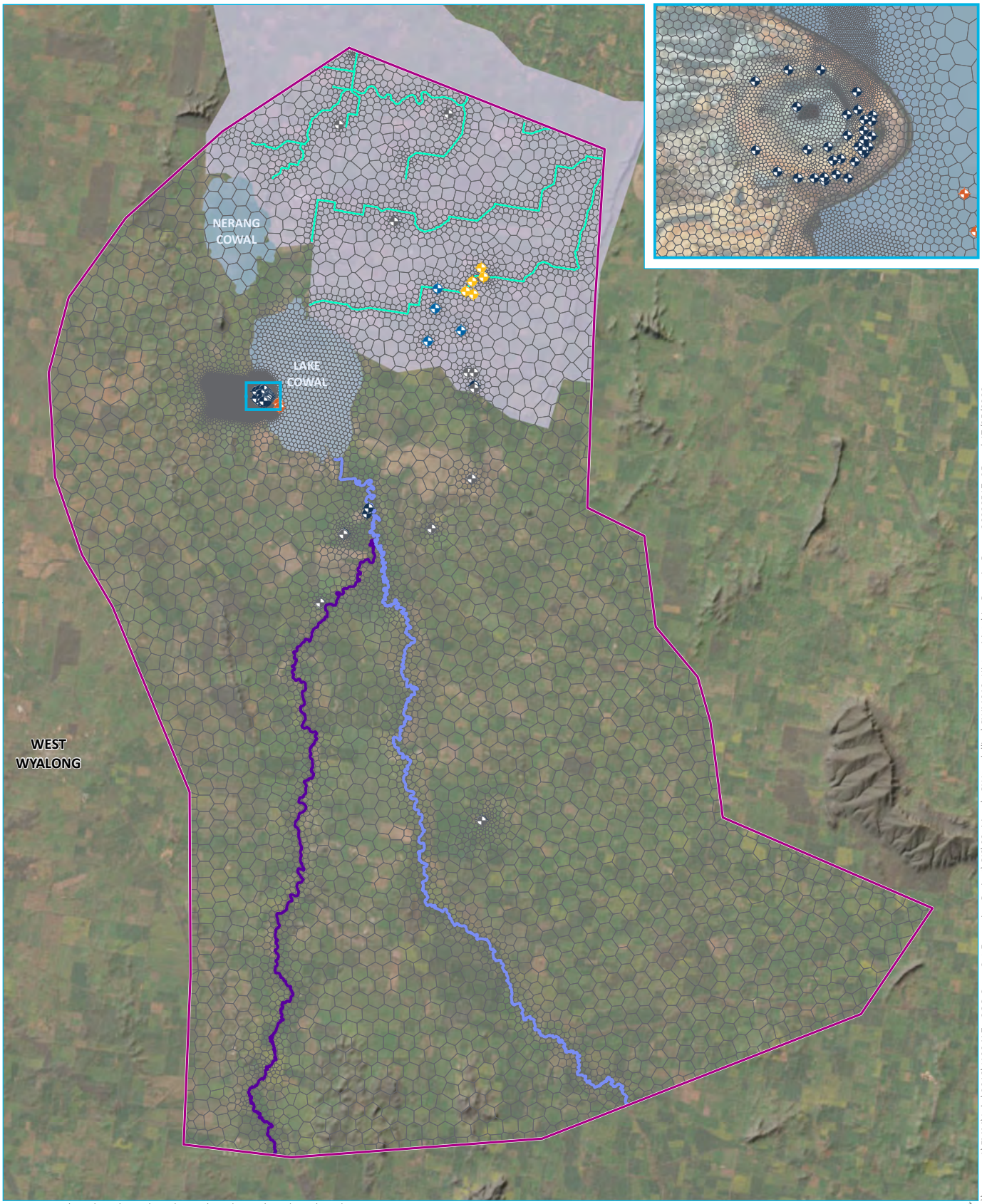
Table 3.5 Registered third-party pumping bores used for history-matching and/or predictive simulations

Bore ID	Easting (MGA94 z55)	Northing (MGA94 z55)	Screen interval (m BGL)	Use	Annual allocation (ML)	Screened HSU
GW029094/1 Billabong 1[1]	547041	6267503	100 - 107.3	Irrigation	2,000 (combined take)	Lachlan
GW057974/1 Billabong 2[1]	547180	6268021	95.5 - 106	Irrigation		Lachlan
GW701646/1 Billabong 3	545012	6265729	98 - 109	Irrigation		Lachlan
GW702127/1 Billabong 4	542922	6259675	108 - 123	Irrigation		Lachlan
GW701267/1 Maslin	552731	6266198	Unknown	Irrigation	2,000	Lachlan
GW701454/1 Quandialla TWS	557158	6240472	98 - 106	Town water supply	266	Lachlan
GW701679	554228	6302728	64-69 & 76-80	Irrigation	570	Lower Cowra and Lachlan
GW701958/1 Muffet	556272	6270630	88 - 93	Stock	100	Lachlan

Table 3.5 Registered third-party pumping bores used for history-matching and/or predictive simulations

Bore ID	Easting (MGA94 z55)	Northing (MGA94 z55)	Screen interval (m BGL)	Use	Annual allocation (ML)	Screened HSU
GW702013/1 Hart	556515	6278585	102 - 109	Stock/domestic	Basic rights	Lachlan
GW702123	544575	6301818	18.3-21.3 & 31.3-37.3	Irrigation	260	Upper and Lower Cowra
GW702262/1 Koreela	549449	6293272	116.5 - 125	Stock/domestic	Basic rights	Lachlan
GW702286/1 Trigalana	555900	6279959	102 - 113	Stock/domestic	Basic rights	Lachlan
Trigalana East	556501	6279959	Unknown	Stock/domestic	Basic rights	Lachlan

Notes: 1. Only used in history-matching. Decommissioned in March 2006



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Model domain
- Voronoi mesh
- Bland Creek
- Barmedman Creek
- Jemalong irrigation channels
- Jemalong irrigation area
- Named waterbody

Pumping bores

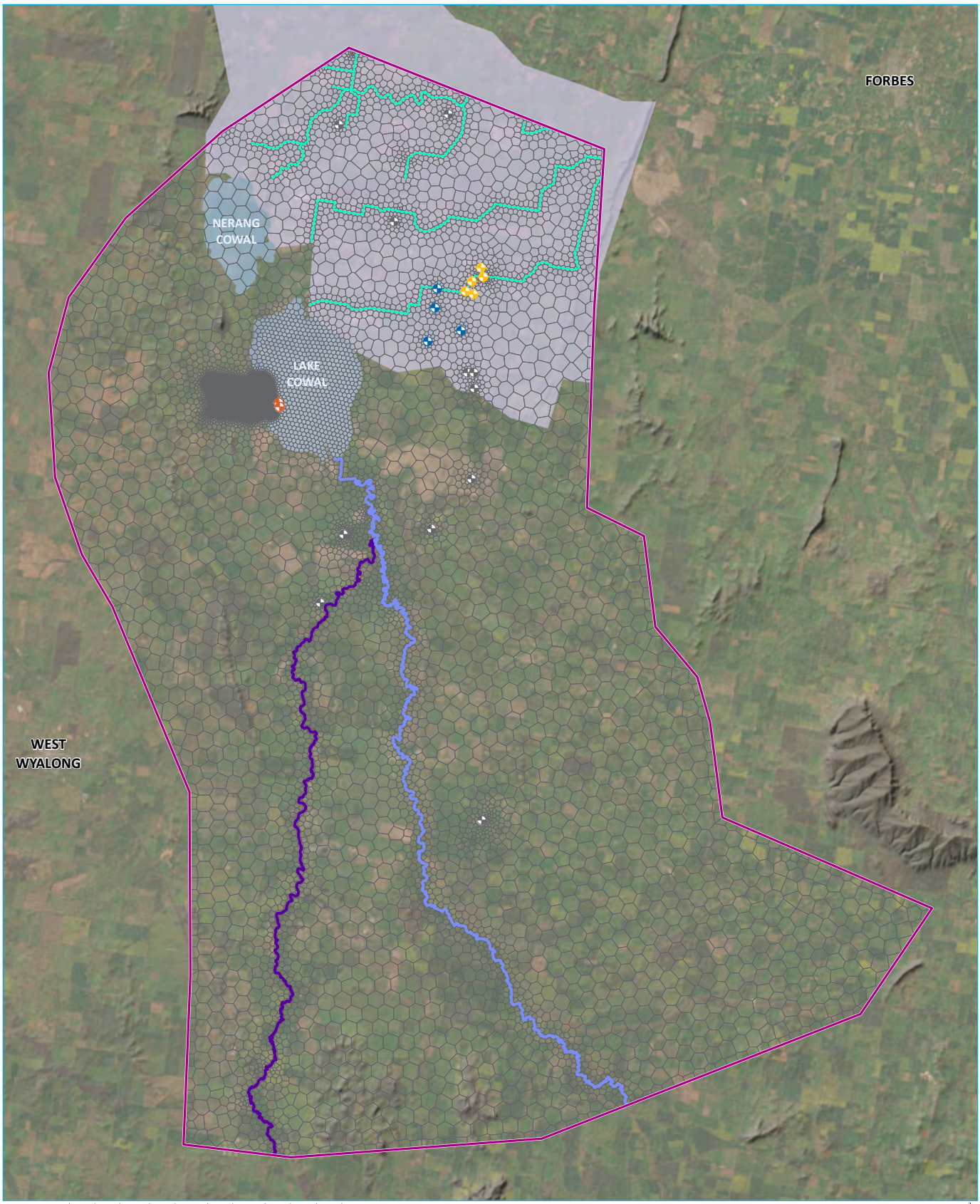
- Bland Creek Palaeochannel Borefield (BCPB)
- Eastern Saline Borefield (ESB)
- Saline Borefield
- Dewatering bore
- Third party

Location of pumping bores used for history matching

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.20

EMM
creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM019_HistoryMatchingPumpingBores_20230517_05.mxd 17/05/2023



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Model domain
- Voronoi mesh
- Bland Creek
- Barmedman Creek
- Jemalong irrigation channels
- Jemalong irrigation area
- Named waterbody

Pumping bores

- Bland Creek Palaeochannel Borefield (BCPB)
- Eastern Saline Borefield (ESB)
- Saline Borefield
- Third party

Location of pumping bores used for predictions

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.21

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM020_PredictionsPumpingBores_20230517_05.mxd 17/05/2023

For history-matching, third-party pumping data were sourced from the Coffey (2020a) borefields model with the exception of years 2021 to 2023. The only other exceptions were irrigation bores GW701679 and GW702123 located in the northern part of the model domain which were added. In the absence of historical pumping data, it was assumed that these two bores were taking 70% of their annual allocation, over an irrigation period of 9 months. Both the Coffey pumping data and estimated pumping rates for GW701679 and GW702123 were down-sampled to a daily time series, then converted to a daily average rate with continuous pumping over each quarterly stress period. For 2021 to 2023 temporal variations during this period were based on the Coffey predictions. Given the lack of historical data, pumping from third-party bores has a high degree of uncertainty.

For predictions, a quarterly average pumping rate was calculated over the time periods January, February, March (Q1), April, May, June (Q2), July, August, September (Q3) and October, November, December (Q4). This was done to provide some seasonality in the pumping data, reflective of past estimated usage. The rates were then up-scaled so that the total volume pumped in a single year was equal to the maximum annual allocation. Where two or more bores shared an allocation, the combined volume from each bore was equal to the annual allocation. Given it is unlikely the bores will use their full allocation each year, the pumping rates are considered to be conservative with respect to cumulative drawdown impacts. Pumping from third-party bores was excluded from stress periods 1 and 2.

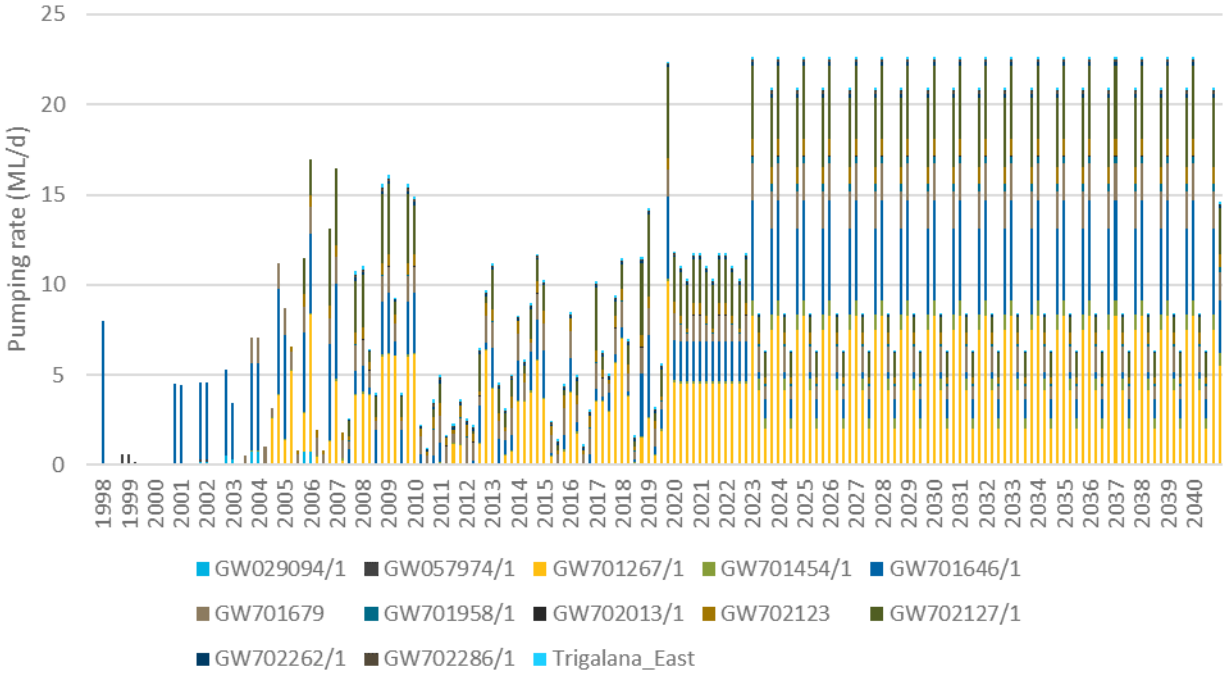


Figure 3.22 Modelled third-party bore abstraction rates

3.7.6 Project groundwater-affecting activities

A summary of the Project activities affecting groundwater is listed below:

- Mine site dewatering activities:
  - Ongoing operation of existing E42 open pit.
  - Approved development of the underground mine using stope mining practises.
  - Approvals pending for pit expansion (OPC) project (Figure 1.2) to include three new open pits (E41, E46, and GR Pits).

- Approvals pending for modifications to the mine plan (MOD1).

- Mine site seepage losses and contaminant sources:
  - TSFs and approved expansion of the Integrated Waste Landform (IWL).
  - WREs.
- Groundwater abstractions for ongoing mine process water supply from the BCPB, ESB and SB.
- Mining-induced changes in HSU hydraulic properties (void space and backfill material).

i Mine site dewatering

Dewatering of the E42 pit commenced in February 2005 and for the UG development in 2021. Pit and underground dewatering has been undertaken using dewatering bores (from February 2005), sump pumping, and horizontal drains which discharge into the pit.

Figure 3.23 shows the available pumping data from the E42 pit. This includes pumping from a combination of sumps and storage dams (D4, D3 and D8A). The water pumped out includes groundwater seepage into the pit, as well as direct rainfall, rainfall runoff, and groundwater flows from in-pit horizontal drains. It does not account for water evaporated from the pit walls, floor and water collections/storages. These measurements are not suitable for use as flux targets, as the groundwater model only accounts for pit inflows and entrained water.

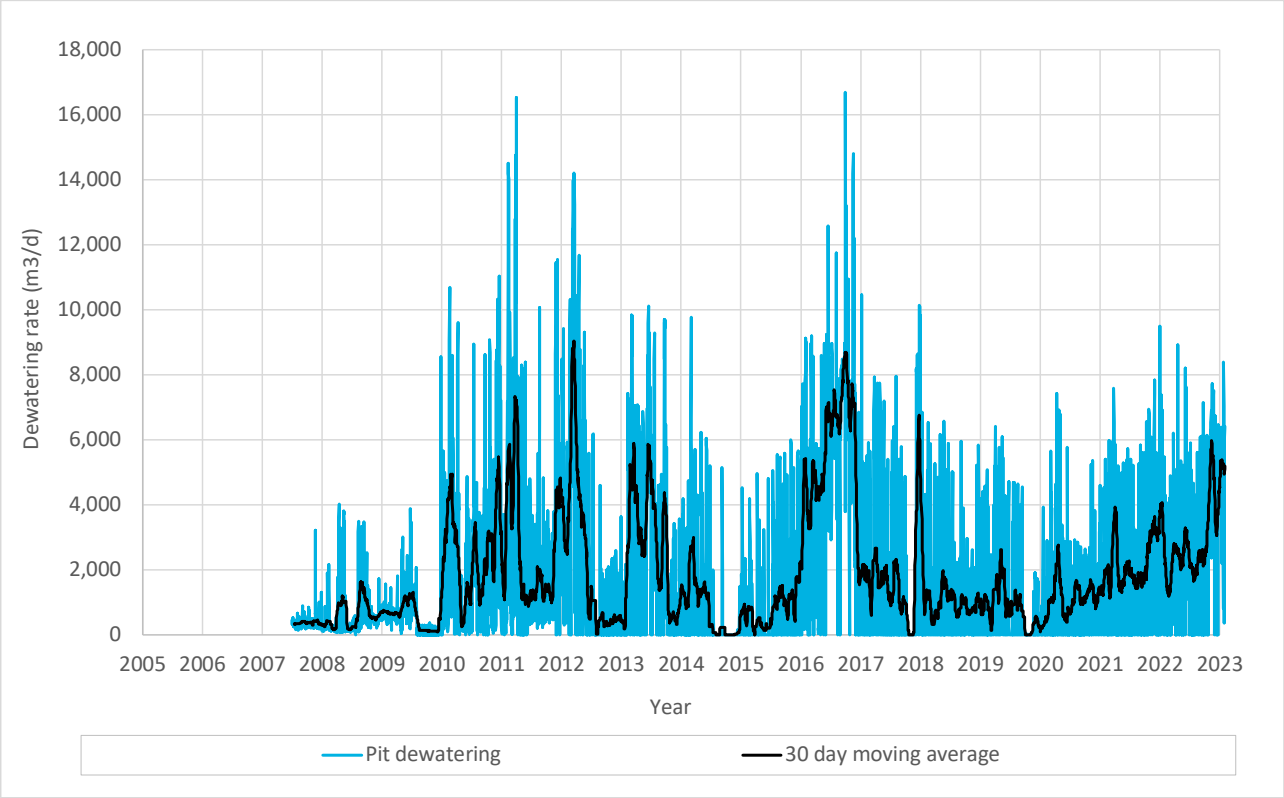


Figure 3.23 Measured E42 pit dewatering

Table 3.6 provides a summary of the pit dewatering bores. Pumping from these bores was included in history-matching. Upper and lower screened HSUs are based on the geological model created for this project, most of these dewatering bores are screened between the Saprock and Upper Cowra, noting that the Lachlan is absent at the mine site. The dewatering bore locations are shown in Figure 3.20.

Table 3.6 Dewatering bores used in history-matching

ID	Easting (MGA94 z55)	Northing (MGA94 z55)	Screen interval (mBGL) or bore depth (mBGL) if unknown	Lowest HSU screened in model	Highest HSU screened in model
P322	537370	6278055	88	Saprock	Lower Cowra
PD1	538258	6278228	51– 63	Saprock	Saprolite
PD10	537863	6277429	80.8–92.8	Saprock	Saprock
PD101	538405	6278009	30–93	Saprock	Upper Cowra
PD102	538400	6277958	30–76	Saprock	Upper Cowra
PD103	538397	6277821	30–90	Saprock	Upper Cowra
PD104	538368	6277720	30–96	Saprock	Upper Cowra
PD105	538323	6277660	30–97.5	Saprock	Upper Cowra
PD106	537962	6277400	30–88	Saprock	Lower Cowra
PD107	537855	6277403	30–88	Saprock	Lower Cowra
PD11	537713	6277427	73–85	Saprock	Saprock
PD12	537520	6277489	90	Saprock	Saprock
PD14	537317	6277690	65–77	Saprolite	Saprolite
PD16	537315	6278326	89–101	Basement	Saprock
PD17	537622	6278436	5–83	Saprock	Upper Cowra
PD18	537925	6278436	4.6–40.6	Saprolite	Upper Cowra
PD19	538266	6278067	Unknown	Saprock	Upper Cowra
PD2	538327	6277973	87–99	Saprock	Saprock
PD20	538168	6278013	83–95	Saprock	Saprolite
PD21	538172	6277828	7.5–98.1	Saprock	Upper Cowra
PD22	538108	6277602	Unknown	Basement	Upper Cowra
PD23	538036	6277596	77–95	Saprock	Saprock
PD24	538036	6277596	3–99.3	Saprock	Upper Cowra
PD26	537703	6278088	0–56	Saprock	Upper Cowra
PD3	538323	6277875	78.5–90.5	Saprock	Saprock
PD30 (PZ23)	538273	6277720	Unknown	Saprock	Upper Cowra
PD4	538324	6277785	2–104	Saprock	Clay
PD5	538309	6277688	100	Saprock	Upper Cowra
PD6	538242	6277577	79–91	Saprock	Saprock
PD7	538177	6277427	107	Saprock	Saprock
PD8	538067	6277459	5.2–95.2	Saprock	Upper Cowra

Figure 3.24 shows the average daily pumping rates from all the dewatering bores based on the measured monthly abstraction volumes. Overall, the volume extracted from the dewatering bores is much less than the volumes of water (groundwater plus surface water) extracted from E42 pit (see Figure 3.23).

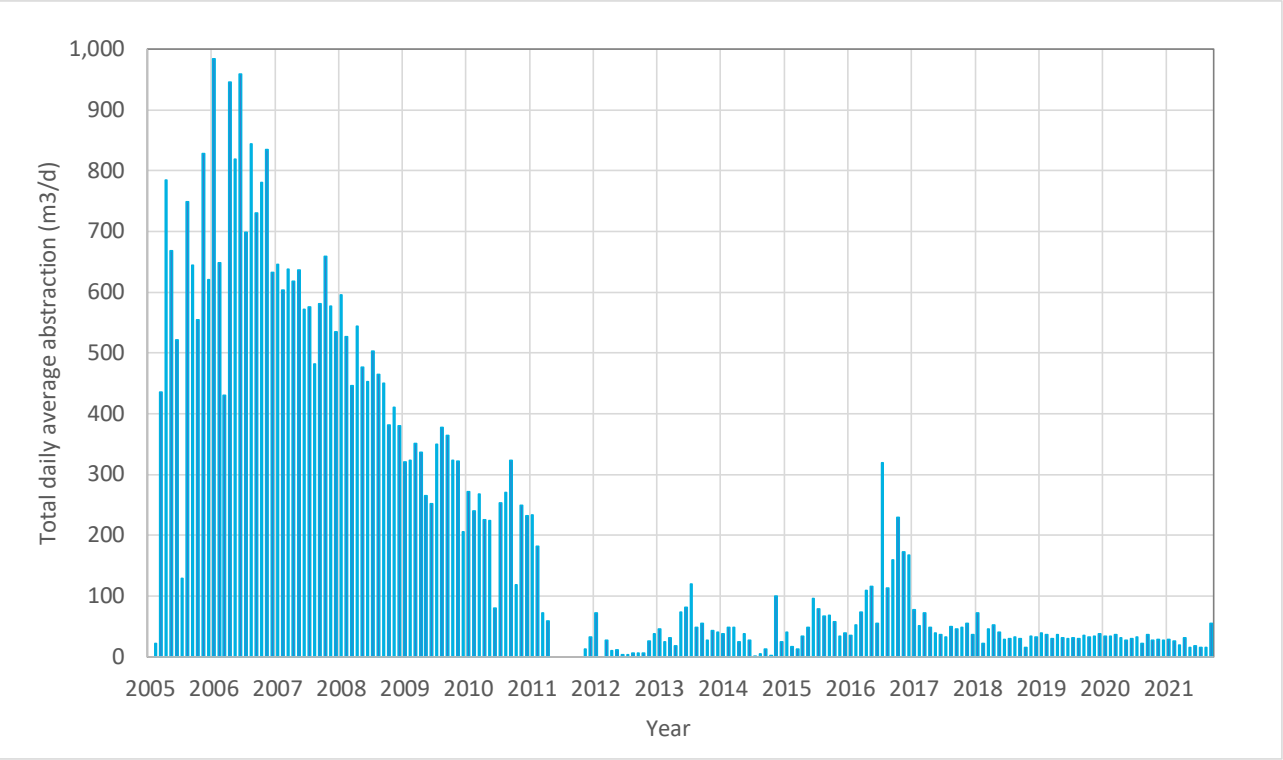


Figure 3.24 Average daily pumping from all dewatering bores

Figure 3.25 shows the average daily rate at which groundwater is abstracted from the UG development. As with Figure 3.23, the measured abstraction is not equivalent to simulated dewatering rates, and is therefore not appropriate to be used for flux targets.

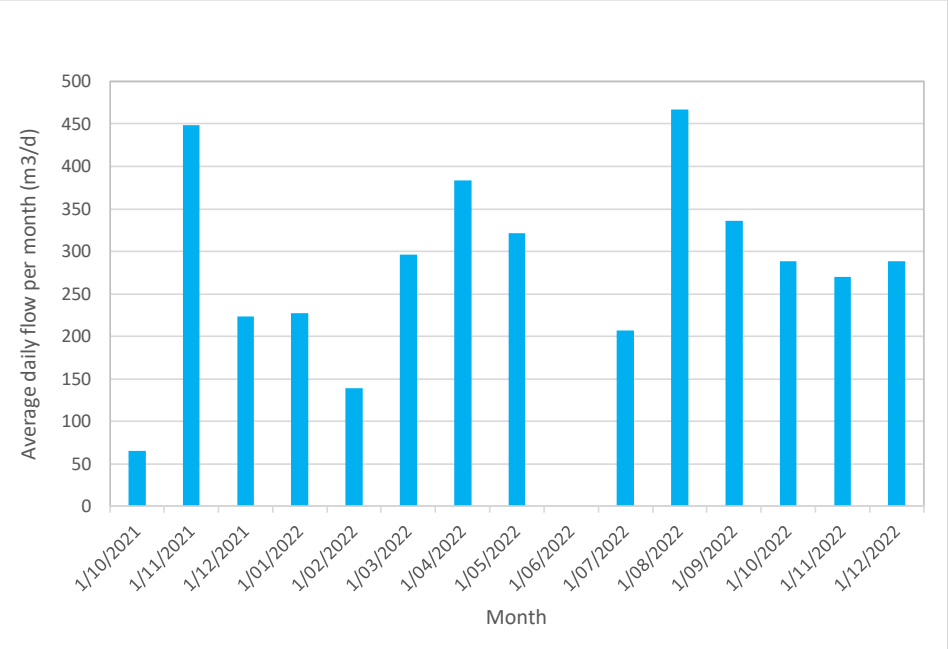


Figure 3.25 Average daily pumping from the UG development

The MODFLOW well (WEL) package was used to simulate groundwater abstraction from the dewatering bores. The pumping rates for each bore were based on the total monthly groundwater abstraction volumes, converted to average continuous pumping rates for each quarterly stress period. Predicted mine dewatering is simulated using drain boundary conditions and, therefore, dewatering bores are only active in the history-matching period.

The MODFLOW drain (DRN) package was used to simulate groundwater abstraction the from open pits and UG development mine voids during history-matching and predictions. This represents removal of any groundwater entrained in excavated material and groundwater inflows to the excavated voids. The E42 in-pit horizontal drains were not included as a separate boundary condition. It has been assumed that the discharge from these drains will be captured by the DRN package used to model groundwater intercepted by the E42 pit.

The mine progression for the pits and UG development is simulated in accordance with a yearly staged mine plan for the history-matching and the predictive period. Drain boundary conditions for the E42 pit are activated at the first stress period of mining in 2004 and for the UG development in 2018. Conductance is set at a suitably high value (1,000 m^2/d) to ensure full dewatering of model cells to the assigned drain stage for the pits and UG development. The modelled pits and underground are presented in Figure 3.27. The DRN package is deactivated in 2041, consistent with proposed mine closure.

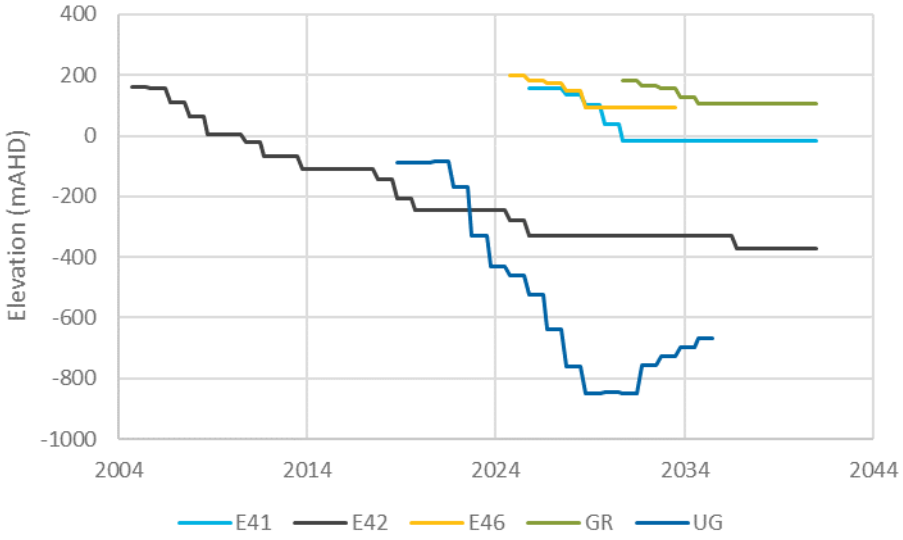
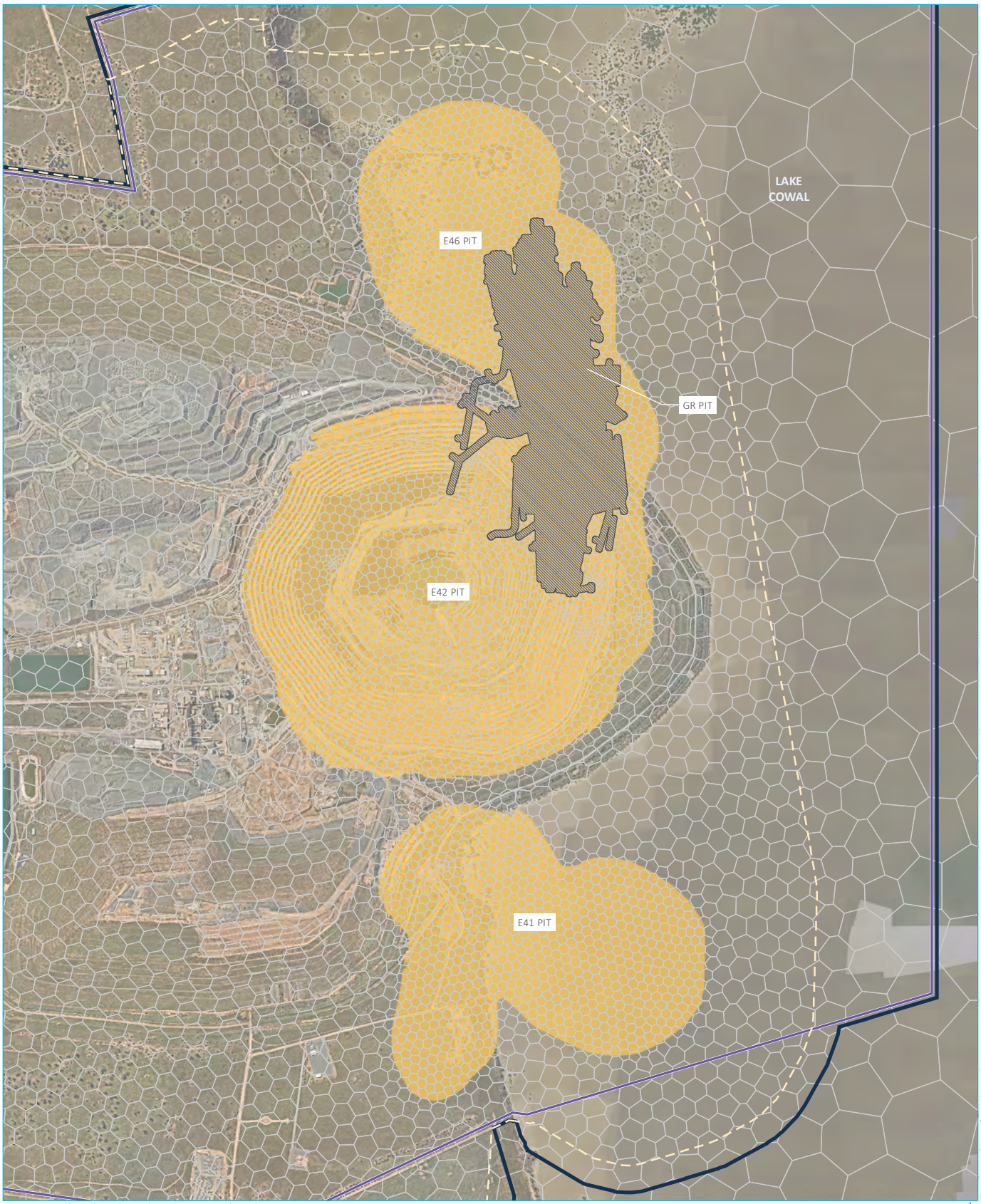


Figure 3.26 Mine plan temporal summary



Source: EMM (2023); Evolution (2023); Nearmap (2021)

0 0.5 1 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM022_ModelledPitsAndUG_20230517_03.mxd 17/05/2023

KEY

- Project area
- Additional disturbance area
- Mining lease (ML1535) (offset for clarity)
- Modelled open pit area
- Modelled underground area
- Voronoi mesh

Modelled open cut pits and underground

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 3.27

EMM
creating opportunities

ii Mine site seepage losses and solute transport

a TSF/IWL and WREs

Hydrographs from bores near the TSF/IWL show groundwater mounding beginning after the commencement of mining. This mounding is considered to be the result of seepage losses to groundwater from the TSF/IWL. Unconfined groundwater flow and solute transport within the TSF/IWL was simulated during history-matching and predictions, by raising the top of model layer 1 by 100 m. The MODFLOW River (RIV) package was then used to simulate step-changes in head through mining progression. The stage height in the RIV boundary condition was varied to that of the TSF/IWL elevation based on the mine plan. The raw annual mine plan data was discretised to model stress periods, with modelled stage elevation shown in Figure 3.28.

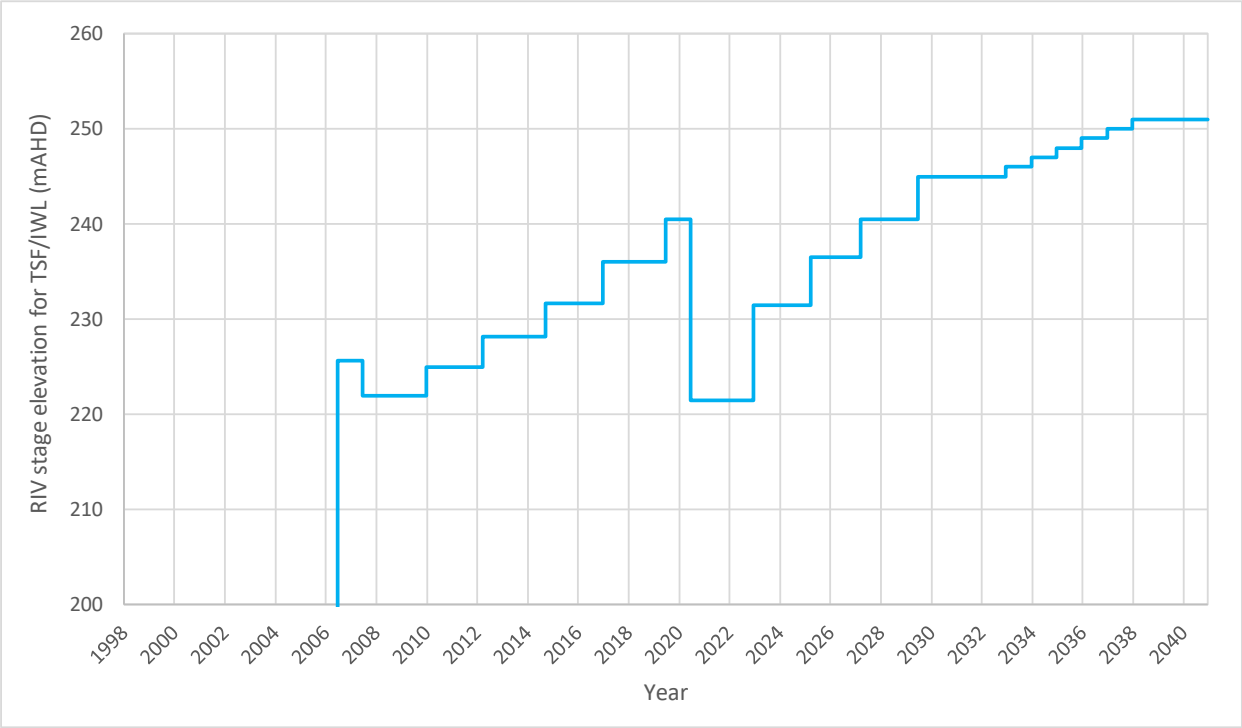


Figure 3.28 Modelled stage elevation of TSF/IWL RIV boundary condition used during history-matching and predictions (to end of mining)

Elevation of the RIV bed was set at the topographic surface prior to commissioning of the TSF/IWL. The RIV conductance was set to a very high value (1,000 m^2/d) so that seepage is a function of the head gradient and hydraulic properties of the TSF/IWL material in model layer 1. For post-mining predictions, the RIV boundary condition was deactivated to allow seepage of the residual water content and dissipation of the groundwater mound. In contrast, the WREs were simulated in the prior parameterisation (refer Section 4.1.3ii) as an area of enhanced groundwater recharge equal to two times natural rainfall recharge within the non-irrigated recharge zone (refer Section 3.7.2). The seepage rate from the WREs was allowed to vary as part of the history-matching period.

b Small water storages

Small water storage facilities around the mine site were excluded from the model because the facilities are either lined or contained in such a way that seepage is designed to be minimal. The small water storages are also minor in comparison with the TSF/IWL.

iii Borefields

The MODFLOW well (WEL) package was used to simulate groundwater abstraction from the BCPB, ESB and SB. Table 3.7 lists the borefield bores and a summary of the bore details. The same bores were pumped for both history-matching and predictive periods. The ESB has a licence to take from five bores (SB01 to SB05). However, historical pumping has only occurred from SB01 and SB02, with only minor pumping from SB04.

Table 3.7 Borefield pumping bores used for history-matching and predictive simulations

Bore ID	Borefield	Easting (MGA94 z55)	Northing (MGA94 z55)	Screen interval or depth if unknown (mBGL)	Screened formation in model	Annual allocation (ML)
GW701657/1	BCPB	552408	6282736	108–117	Lachlan	3,350 (combined)
GW701658/1		555360	6283678	107–128	Lachlan	
GW701659/1		553071	6285635	92–125	Lachlan	
GW701660/1		553276	6287386	95–116	Lachlan	
GW703944 (SB01)	ESB	555740	6287128	54–66	Lower Cowra	300 (combined)
GW703943 (SB02)		556315	6288003	45–66	Lower and Upper Cowra	
SB04		557324	6288376	59–65	Lower Cowra	
WB01	SB	539256	6277288	51.5 depth	Lower and Upper Cowra	366 (combined, alluvial source)
WB20		539362	6276932	45.5 depth	Lower and Upper Cowra	

For history-matching, daily pumping data were sourced from the borefield pumping records. The data were then converted to a daily average rate with continuous pumping over each quarterly stress period. For predictions, uniform abstraction rates of 0.5 and 4.0 ML/d were applied to the Eastern Saline Borefield and Bland Creek Paleochannel bores respectively. Model pumping rates, per model stress period, are presented in Figure 3.29.

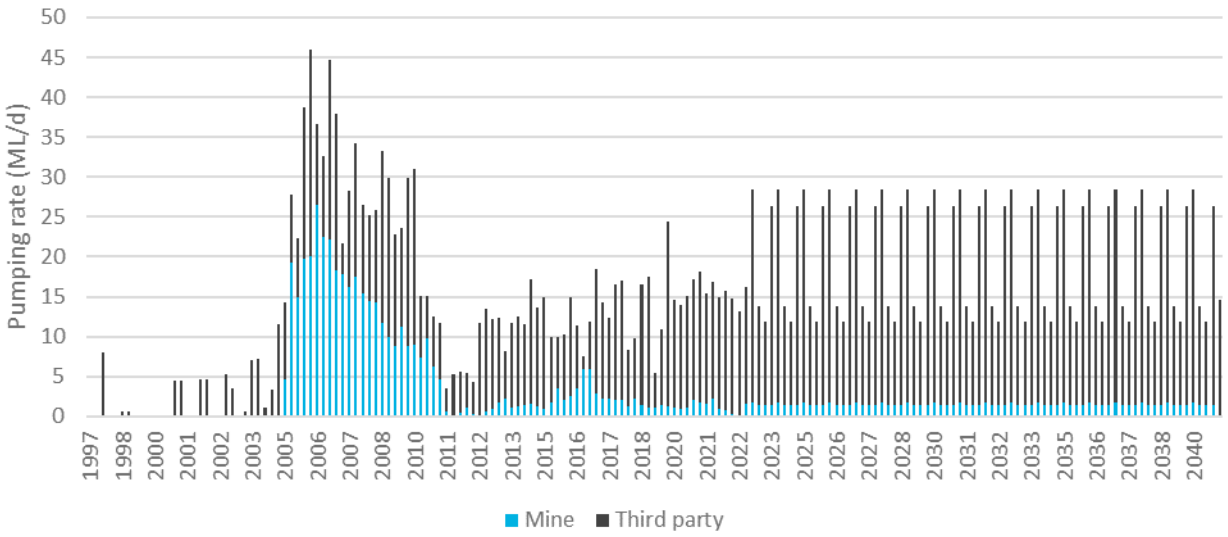


Figure 3.29 Modelled abstraction from mine and third party bores

iv Scenario definition and post-mine recovery period

Four predictive scenarios were developed, with varying prediction and recovery stresses, to allow calculation of predicted impacts. The scenarios are summarised in Table 3.8. Prediction 1 and prediction 2 are used as 'null' scenarios to calculate total impacts of mining (**cumulative** impact) and the impact associated with the proposed additional mining (**incremental** impact) respectively.

Table 3.8 Predictive scenario definitions

ID	Third party bores	Mining activities	Post-mine recovery
Prediction 1	Active	None	N/A
Prediction 2	Active	Approved mine only	Pit remains dry in perpetuity
Prediction 3	Active	Approved and proposed	Pits remain dry in perpetuity
Prediction 4	Active	Approved and proposed	Pit water level allowed to recover with void properties and no surficial fluxes

Two post-closure cases were simulated to encapsulate the range of expected conditions following the end of mining. The first case simulates the open voids maintained at their final mining level. i.e. they remain dry (the **'dry' case**). This is highly conservative from a drawdown perspective. The second post-closure case deactivates the open pits at the end of mining and water levels are allowed to recover within these pits with open void properties applied (i.e. the **'fast recovery' case**). However, no recharge or evaporation is applied, and therefore groundwater levels recover more quickly and higher than would be expected in reality. This is likely conservative from a contaminant transport perspective, as the fast recovery case likely underestimates the ability of the voids to capture potential contaminants emanating from the IWL and WREs.

a Pits

The E46 pit will be backfilled to surface, while the other pits will be left as voids. For E41, E42 and GR pits, there is therefore potential for pit lakes to form, rising to a level determined by the relationship between groundwater inflows to the pits, rainfall and evaporation. Recovery from these three open pits following mining has been simulated using the following methods:

- The dry case maintains the DRN cells as active following mining, keeping the water level at the base of the pits (see Prediction 3 in Table 3.8).
- The fast recovery case (see Prediction 4 in Table 3.8) uses the time-varying materials (TVM) package, applied at model nodes within the residual open pit void, converting the material properties to that of a 'void' at the cessation of mining. Hydraulic conductivity (vertical and horizontal) was set to 1,000 m/d, specific yield to 100% and specific storage was changed to 5×10^{-6} m^{-1}.

b Underground development

The stopes and tunnels will be filled progressively with paste backfill to provide support which will influence the timing of recovery of groundwater levels following mine closure. Following the end of ore processing, the groundwater levels in the stopes and access tunnels will recover and the air voids (fillable porosity) in the paste backfill will fill with groundwater. In addition, the whole volume of the access tunnels with elevations below the outlet to the open pit will also fill with groundwater. In the model, stopes and tunnels were given the same in-situ hydraulic properties as pre-mining, and drains deactivated 3 months after activation.

4 History-matching

4.1 Approach

A combination of manual and automated (using PESTPP-IES version 4.2.16) approaches were employed during the history-matching process. History-matching was undertaken using temporal hydraulic head data, from the Evolution Mining groundwater monitoring network, Lampayan (2001) hydrogeological study and WaterNSW groundwater monitoring data. Initially, the model was history-matched manually to steady state targets only, using a single value for each hydraulic property per HSU. This approach was aimed at providing an efficient means to arrive at starting parameters that provided a reasonable model-wide fit to long term average hydraulic head data, to use as initial parameter value estimates for subsequent, more computationally demanding, transient history-matching.

4.1.1 Temporal modes

The model was history-matched in both steady state and transient modes, combined into a single model run, to obtain model parameterisation consistent with both pre-mining and impacted conditions. This makes the assumption, consistent with the conceptualisation, that the groundwater system was in steady state prior to mining. The steady state solution was used to provide initial heads for the transient history-matching period.

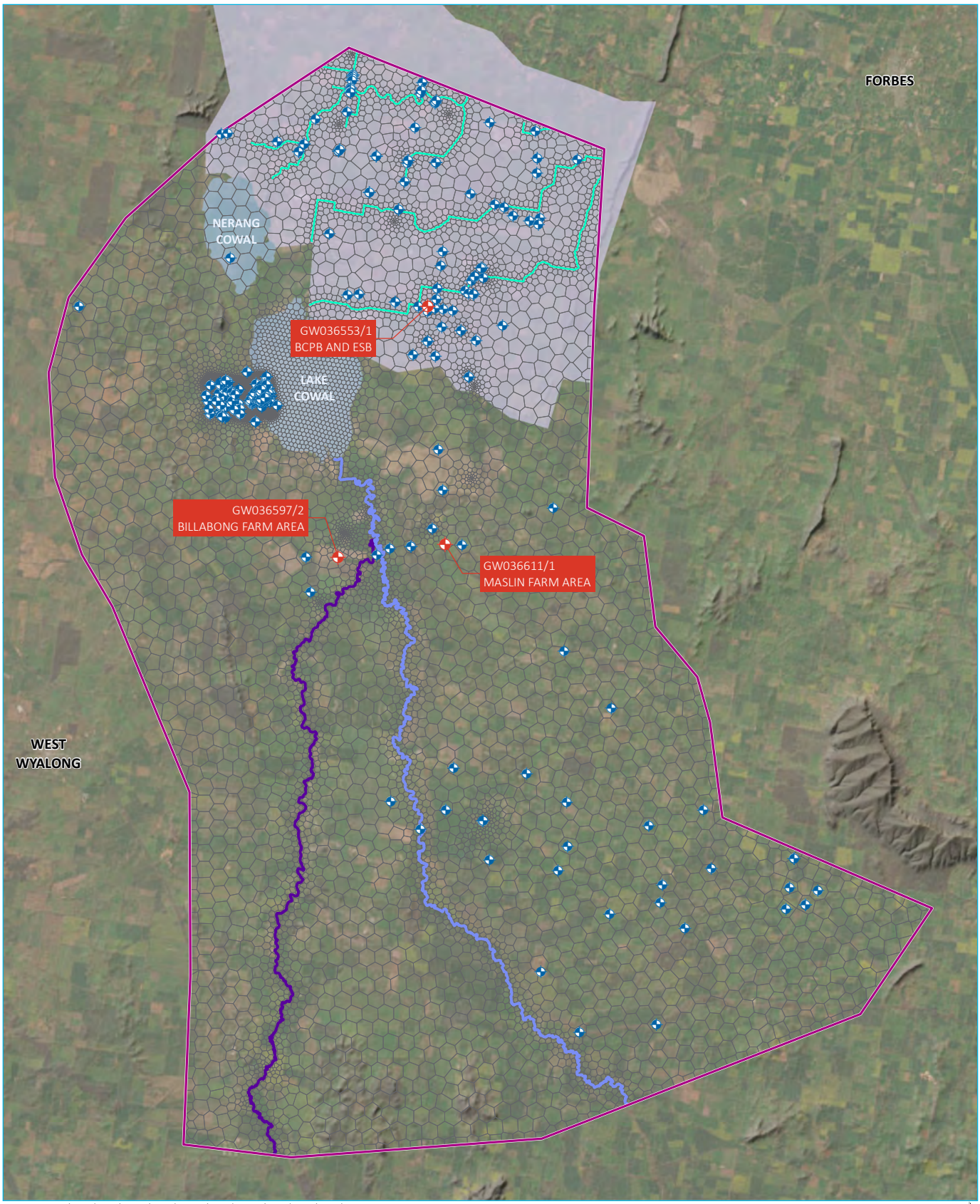
4.1.2 Targets

i Head

A total of 415 monitoring sites were used to compile history-matching head targets. This included monitoring bores and vibrating wire piezometers (VWPs). The nested monitoring bore and VWP sites provided useful information on vertical head gradients. 154 of the bores (primarily VWPs near E42) had a high volume of data, and so were resampled to monthly average values. The total number of head measurements used for history-matching was 30,375, with data from 1998 to 2022. These were converted to history-matching targets as:

- 415 head targets, taken as the first measured groundwater level at each site.
- 29,960 subsequent transient head-change targets, defined as the difference between the current and the first measured hydraulic head value at each site. These behave similarly to drawdown targets but enable the use of head-change targets where the steady-state head is not known (for example where monitoring bores were installed in already impacted areas).
- 30,375 transient head targets, representing the full monitoring dataset.

The head target site locations are shown in Figure 4.1.



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Model domain
- Voronoi mesh
- Bland Creek
- Barmedman Creek
- Jemalong irrigation channels
- Jemalong irrigation area
- Named waterbody
- Compliance monitoring bore
- Head target

History matching head target locations including the three compliance monitoring bores

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 4.1

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM021_HistoryMatchingHeadTarget_20230517_04.mxd 17/05/2023

ii PEST setup

PEST operates with the goal of minimising a least-squares objective function, defined as the sum of squared weighted differences between measurements and corresponding model outputs (known as residuals). Doherty (2016) defines the objective function as:

$$\varphi = \sum (w_i r_i)^2$$

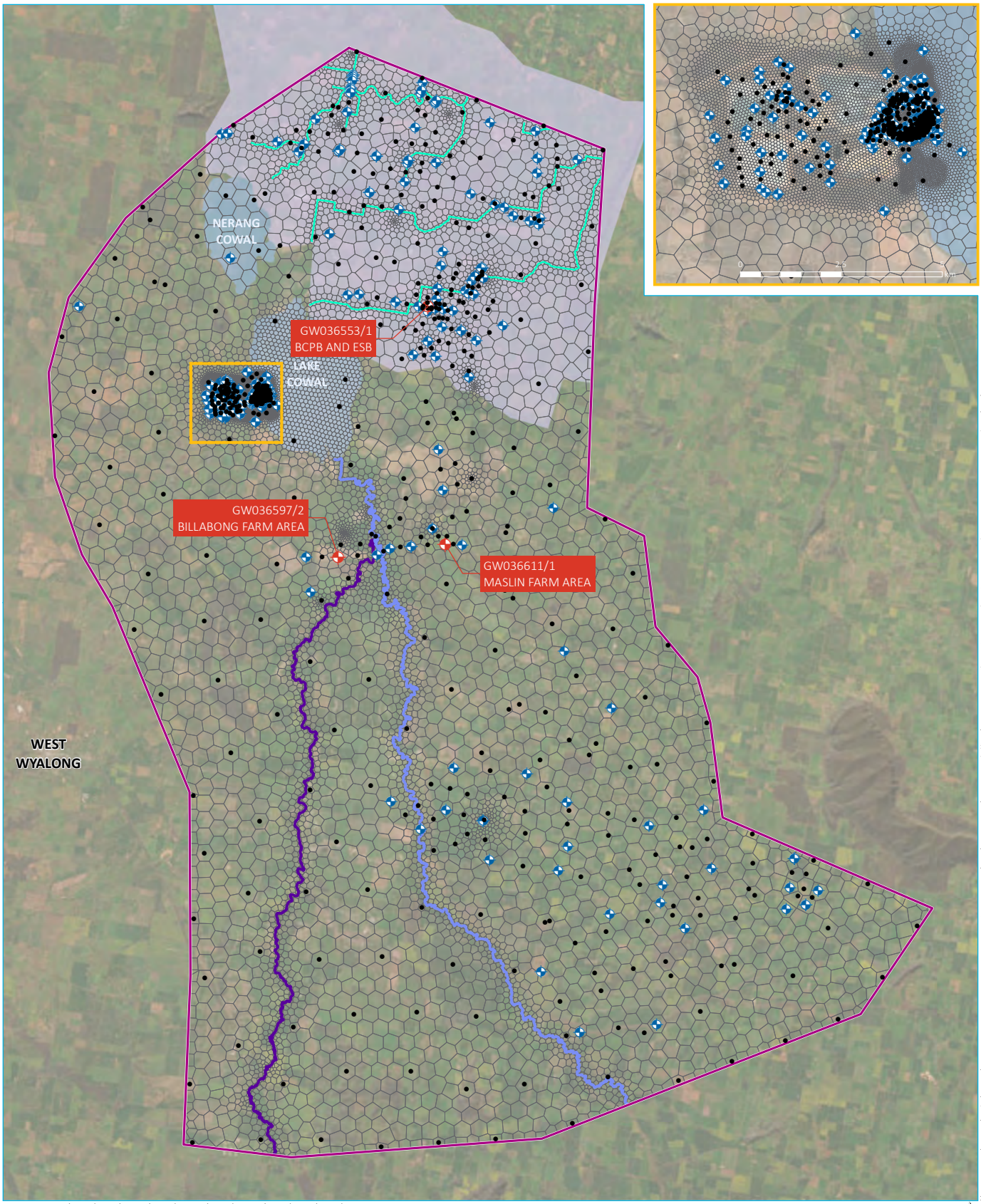
where *r* is the calculated residual, and *w* is a unitless statistical weighting. A weighting scheme was adopted to ensure that absolute groundwater level and trends were represented across all modelled HSUs. The three target types identified in Section 4.1.2.i were subdivided by HSU, creating 21 target groups. The starting objective function was calculated using model outputs produced with initial parameter estimates, and target weights modified such that each group contributed an equal amount to the objective function. This weighting was maintained for PEST-based optimisation. Measurement noise was not included in the PESTPP-IES control file.

4.1.3 Parameterisation

i Pilot points

A highly parameterised approach to model history-matching was undertaken using pilot points for hydraulic properties and zones for recharge and evapotranspiration. This was undertaken to overcome simplifications of the EPM approach, conceptual uncertainty, parameter uncertainty, to improve model performance against measured data, and allow for spatial variability in hydraulic properties. This approach is consistent with best practice guidelines and provides a numerically sound basis for representing site-wide scale heterogeneities (Barnett et al. 2012).

The algorithm employed by PESTPP-IES to calculate the Jacobian matrix is extremely efficient when compared to other versions of PEST and, as a result, there is no effective limit on the number of pilot points that can be incorporated in the history-matching process. A triangulation algorithm was employed to place pilot points between targets (including production bores), and additional pilot points were placed to ensure no greater than 5 km between pilot points. The locations of pilot points are shown in Figure 4.2.



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Model domain
- Voronoi mesh
- Bland Creek
- Barmedman Creek
- Jemalong irrigation channels
- Jemalong irrigation area
- Named waterbody
- Pilot point
- Compliance monitoring bore
- Head target

Pilot points used in history-matching assessment

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 4.2

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM023_PilotPointsUsedInHistoryMatching_20230517_03.mxd 17/05/2023

ii Initial (prior) parameter values

PESTPP-IES requires the user to supply statistical properties of the prior (i.e. pre-history-matching) probability distribution of parameters. Parameters were not assumed to be spatially dependent (correlated), and parameter standard deviations were calculated from the log-transformed range defined in the PESTPP-IES control file, where the upper and lower bounds are taken to represent the 95% confidence interval. Parameters varied as part of the history-matching process were:

- All HSU hydraulic properties (horizontal and vertical hydraulic conductivity, specific storage, specific yield).
- Regional (dryland) and local (WRE) recharge.
- Evapotranspiration extinction depth.
- Conductance of all surface water features.

A 200-realisation ensemble of parameter values was developed as the 'prior' parameter ensemble, and two optimisation iterations (via PESTPP-IES) were employed to develop a parameter field minimising the residuals between modelled and measured values. The adopted iteration included an ensemble of parameter realisations with satisfactory statistical performance. The parameters used for ensemble development are detailed in Table 4.1. Note that basement hydraulic properties were allowed to vary with depth to layer 16, and properties from layer 16 applied to subsequent underlying layers.

Table 4.1 History-matching parameters

Parameter	Location	Parameter type	Starting value	Lower bound	Upper bound
Horizontal hydraulic conductivity (m/d)	Surficial clay	Pilot point	6.08×10^{-4}	1.00×10^{-5}	0.001
Horizontal hydraulic conductivity (m/d)	Upper Cowra	Pilot point	0.025	0.001	10
Horizontal hydraulic conductivity (m/d)	Lower Cowra	Pilot point	0.065	0.001	10
Horizontal hydraulic conductivity (m/d)	Lachlan	Pilot point	2.061	0.05	50
Horizontal hydraulic conductivity (m/d)	Saprolite	Pilot point	0.025	0.01	1
Horizontal hydraulic conductivity (m/d)	Saprock	Pilot point	0.025	0.001	0.1
Horizontal hydraulic conductivity (m/d)	Basement	Pilot point	0.003	0.0001	0.05
Anisotropy ratio (Kh/Kv) (-)	Surficial clay	Pilot point	36.670	1	1000

Table 4.1 History-matching parameters

Parameter	Location	Parameter type	Starting value	Lower bound	Upper bound
Anisotropy ratio (Kh/Kv) (-)	Upper Cowra	Pilot point	17.003	1	1,000
Anisotropy ratio (Kh/Kv) (-)	Lower Cowra	Pilot point	11.948	1	1,000
Anisotropy ratio (Kh/Kv) (-)	Lachlan	Pilot point	5.209	1	1,000
Anisotropy ratio (Kh/Kv) (-)	Saprolite	Pilot point	6.825	1	1,000
Anisotropy ratio (Kh/Kv) (-)	Saprock	Pilot point	5.759	1	1,000
Anisotropy ratio (Kh/Kv) (-)	Basement	Pilot point	4.895	1	1,000
Specific storage (1/m)	Surficial clay	Pilot point	1.00×10^{-6}	1.00×10^{-7}	1.30×10^{-5}
Specific storage (1/m)	Upper Cowra	Pilot point	9.82×10^{-7}	1.00×10^{-7}	1.30×10^{-5}
Specific storage (1/m)	Lower Cowra	Pilot point	1.01×10^{-6}	1.00×10^{-7}	1.30×10^{-5}
Specific storage (1/m)	Lachlan	Pilot point	9.88×10^{-7}	1.00×10^{-7}	1.30×10^{-5}
Specific storage (1/m)	Saprolite	Pilot point	9.60×10^{-7}	1.00×10^{-7}	1.30×10^{-5}
Specific storage (1/m)	Saprock	Pilot point	9.86×10^{-7}	1.00×10^{-7}	1.30×10^{-5}
Specific storage (1/m)	Basement	Pilot point	1.62×10^{-6}	1.00×10^{-7}	1.30×10^{-5}
Specific yield (-)	Surficial clay	Pilot point	5.00%	0.1%	10%
Specific yield (-)	Upper Cowra	Pilot point	4.99%	0.1%	30%
Specific yield (-)	Lower Cowra	Pilot point	2.37%	0.1%	30%
Specific yield (-)	Lachlan	Pilot point	1.00%	0.1%	35%
Specific yield (-)	Saprolite	Pilot point	3.47%	0.1%	10%
Specific yield (-)	Saprock	Pilot point	5.00%	0.1%	5%
Specific yield (-)	Basement	Pilot point	4.23%	0.01%	5%
Recharge (m/d)	Dryland	Zone	1.13×10^{-6}	1.20×10^{-7}	1.20×10^{-5}
Recharge (m/d)	Irrigated area	Zone	2.85×10^{-6}	6.00×10^{-7}	6.00×10^{-5}
Recharge (m/d)	WRD	Zone	2.40×10^{-6}	1.20×10^{-7}	1.20×10^{-5}

Table 4.1 History-matching parameters

Parameter	Location	Parameter type	Starting value	Lower bound	Upper bound
Evapotranspiration extinction depth (m)	Full domain	Zone	3	1	3
River cell conductance (m2/d)	Barmedman Creek	Boundary reach	9629.6	0.01	10,000
River cell conductance (m2/d)	Bland Creek	Boundary reach	9635.4	0.01	10,000
River cell conductance (m2/d)	Irrigation channels	Boundary reach	3794.0	0.01	10,000
River cell conductance (m2/d)	Lake Cowal	Boundary reach	10.4	0.01	10,000
River cell conductance (m2/d)	IWL	Boundary reach	1000	500	5,000

4.2 Performance

4.2.1 Statistical performance

History-match performance was statistically quantified using the scaled root mean square (SRMS) error for hydraulic head, 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.
- h_i is the measured hydraulic head at location/time i.

SRMS errors were calculated for each of the target types. The resultant values are presented in Table 4.2, incorporating calculations without statistical weightings.

Table 4.2 Base case realisation history-matching statistics

Metric	Initial hydraulic head	Transient head-change	Transient head
SRMS	4.8%	4.3%	3.2%
RMS (m)	11.72	10.43	13.14
Minimum residual (m)	-64.36	-95.38	-155.54
Maximum residual (m)	61.14	105.10	95.01
Average residual (m)	0.51	1.93	-1.48
Residual standard deviation (m)	11.71	10.24	13.06
Average absolute residual (m)	7.19	6.40	8.25
Measurement range (m)	246.54	243.44	410.13

The overall statistical performance of the model is considered acceptable for the base case realisation. The measurement ranges are wide, leading to SRMS values under 5% for all target types. Residuals are centred within 2 m of measurements, with a standard deviation of 10 to 13 m and average absolute residual of 6 to 8 m. Probabilistic uncertainty analysis was subsequently used to explore the degree to which uncertainty in the model parameter values relates to predictions of Project impacts.

4.2.2 Hydraulic head

i Initial head

Data from 415 monitoring bores and VWPs were used to evaluate initial groundwater levels. A scatter plot of modelled against measured initial hydraulic head is presented in Figure 4.3, grouped by HSU for the base realisation and showing the ensemble of realisations in semi-transparent grey. The data show:

- Minimal bias for either over-predicted or under-predicted heads.
- Reasonable correlation across the dataset.
- Generally clustered close to a 1:1 line of ideal fit.
- There are few data points where the residual is large, particularly below 150 mAHD (typically representing sites impacted prior to the first measurement.
- The overall fit to measured data indicates a generally good match to sitewide groundwater levels and across the various HSUs that are currently monitored.
- The ensemble results in a wider range of residuals where the model has the poorest match to data.
- Locations with smaller residuals generally have a smaller range across the ensemble.

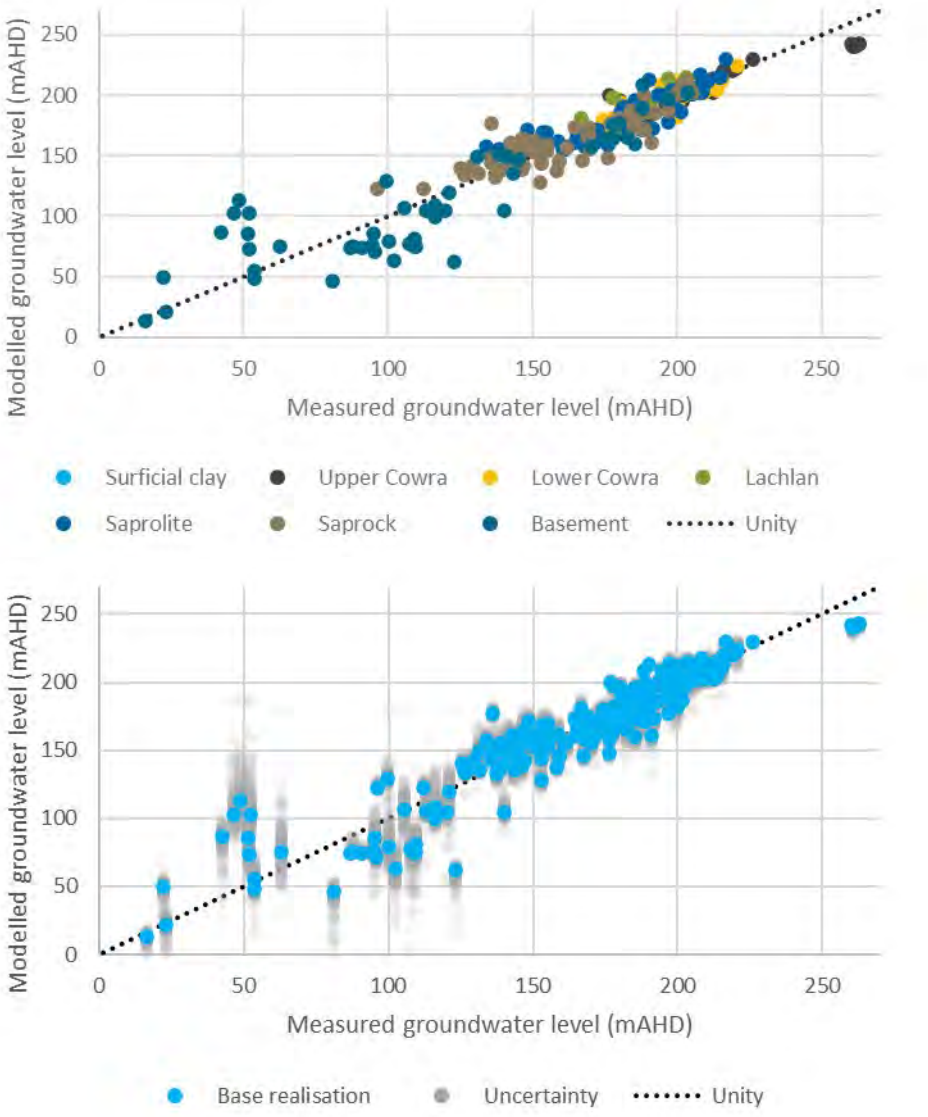


Figure 4.3 Scatter plot of initial hydraulic heads

A histogram of initial measured minus modelled residuals is presented in Figure 4.4. This presents the same data as Figure 4.3, but with a representation of residual frequency in bands around the line of perfect fit. The distribution appears Gaussian, with base realisation mean of 0.51 m and standard deviation of 11.71 m (as detailed in Table 4.2). The distribution for the full ensemble is broadly similar to the base realisation.

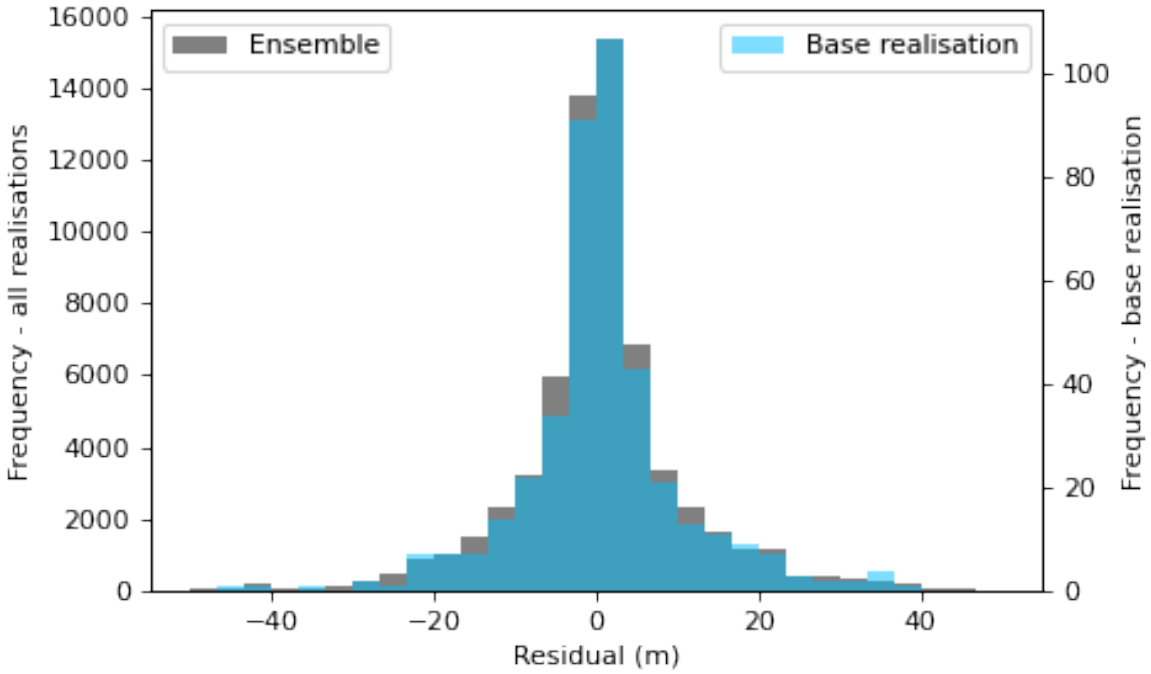
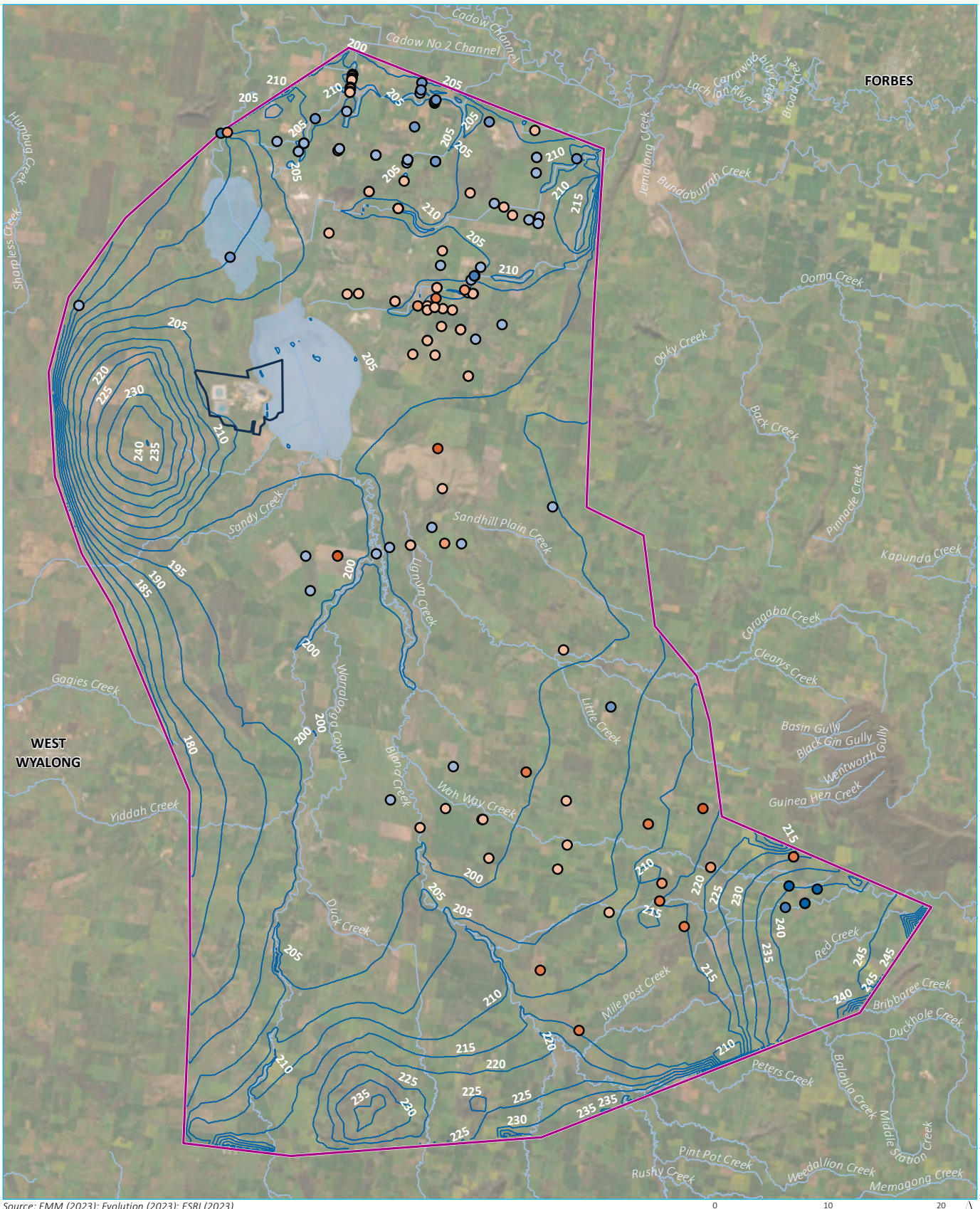


Figure 4.4 Initial hydraulic head residual distribution

The base case realisation modelled steady state watertable elevation is shown in Figure 4.5, along with initial hydraulic head residuals. Residuals within the Project area are not included, as many of these measurements represent impacted conditions for which it is not appropriate to compare to steady state contours. Hydraulic head is largely controlled by topography, and the model replicates the conceptual groundwater flow behaviour. Residuals are spatially variable, though some areas in the north of the domain show consistently higher/lower modelled values than measured.

Overall, these figures represent a reasonable starting condition for groundwater level distribution under baseline steady state conditions.


Cadow Channel
Cadow No 2 Channel
FORBES
Jemalong Creek
Bundaburrah Creek
Broad Creek
Sharpless Creek
Ooma Creek
Oaky Creek
Back Creek
Pinnacle Creek
Kapunda Creek
Sandy Creek
Sandhill Plain Creek
Tarnum Creek
Caragabal Creek
Cleanys Creek
Gagies Creek
WEST WYALONG
Warraloogia Cowal
Blanch Creek
Little Creek
Basin Gully
Black Gin Gully
Wentworth Gully
Guinea Hen Creek
Yiddah Creek
Woh Way Creek
Duck Creek
Red Creek
Mile Post Creek
Bribbaree Creek
Duckhole Creek
Peters Creek
Balabla Creek
Middle Station Creek
Pint Pot Creek
Rushy Creek
Weedallion Creek
Memagong Creek
Source: EMM (2023); Evolution (2023); ESRI (2023)
0
10
20
km
GDA 1994 MGA Zone 55
N
KEY
Model domain
Project area
Modelled watertable elevation (mAHD)
Named watercourses
Named waterbody
Measured minus modelled hydraulic head (m)
< -20
-20 - -10
-10 - -5
-5 - 0
0 - 5
5 - 10
10 - 20
> 20
Modelled steady-state watertable elevation and residuals
Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 4.5
creating opportunities
\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM026_WatertableElevationsAndResiduals_20230517_03.mxd 17/05/2023

ii Transient

A scatter plot of modelled against measured hydraulic head data for the complete history-matching dataset is presented in Figure 4.6. As with Figure 4.4, data are presented for the base case realisation by HSU and for the full uncertainty ensemble. From this figure, key observations on the transient model performance include:

- Above 50 mAHD, minimal bias for either over-predicted or under-predicted heads.
- Below 50 mAHD, modelled groundwater level typically above measured by up to 100 m. These data represent VWP measurements within the basement, showing rapid, large scale drawdown following mine dewatering.
- The overall fit to measured data indicates a generally good match to sitewide groundwater levels and across the monitored HSUs.
- Improved performance was not targeted in the basement VWPs, in order to prioritise a wide ensemble for conservative predictions.

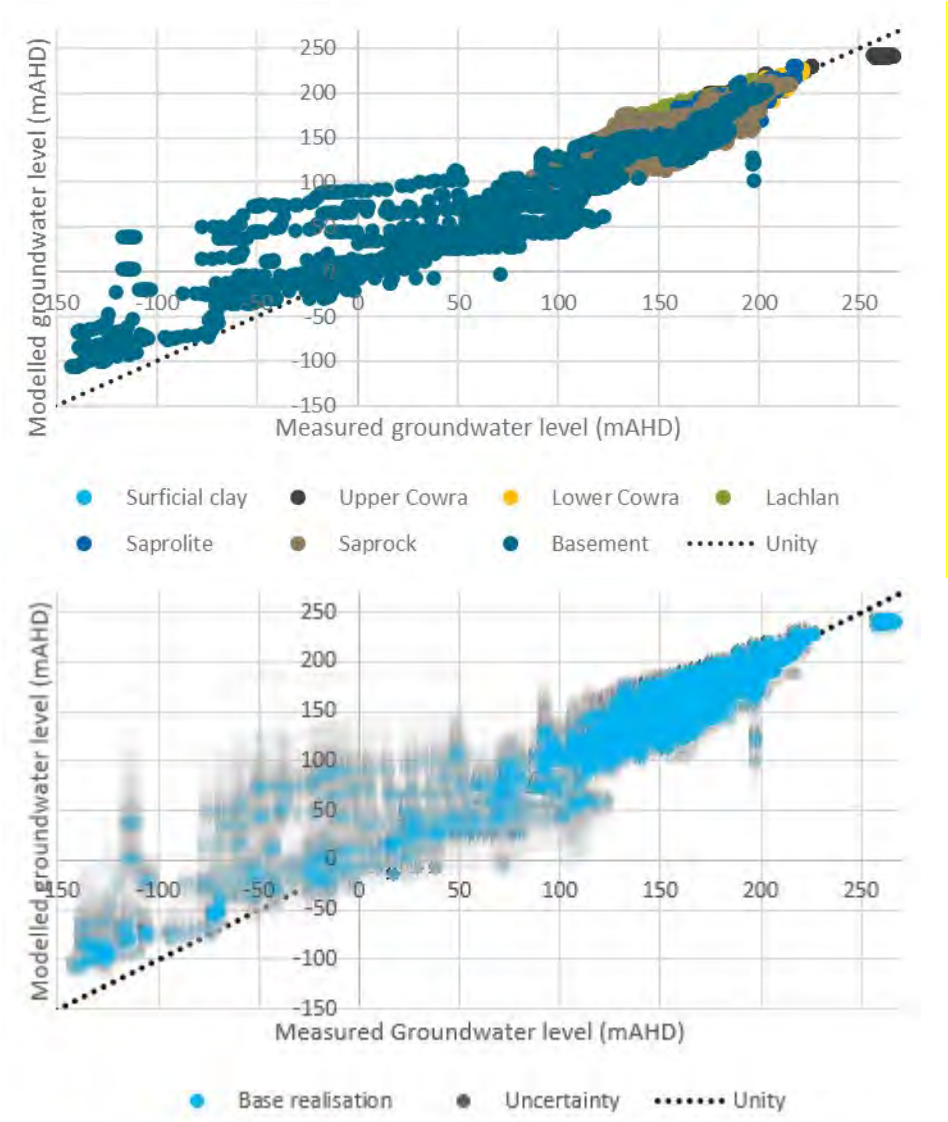


Figure 4.6 Scatter plot of transient hydraulic heads

A histogram of residuals for the full monitoring dataset is presented in Figure 4.7. This presents the same data as Figure 4.6, but with a representation of residual frequency in bands around the line of perfect fit. As with the residuals for initial hydraulic head, the transient residual distribution appears Gaussian, with a base realisation mean of -1.48 m and standard deviation of 13.06 m. The distribution for the full ensemble is broadly similar to the base realisation.

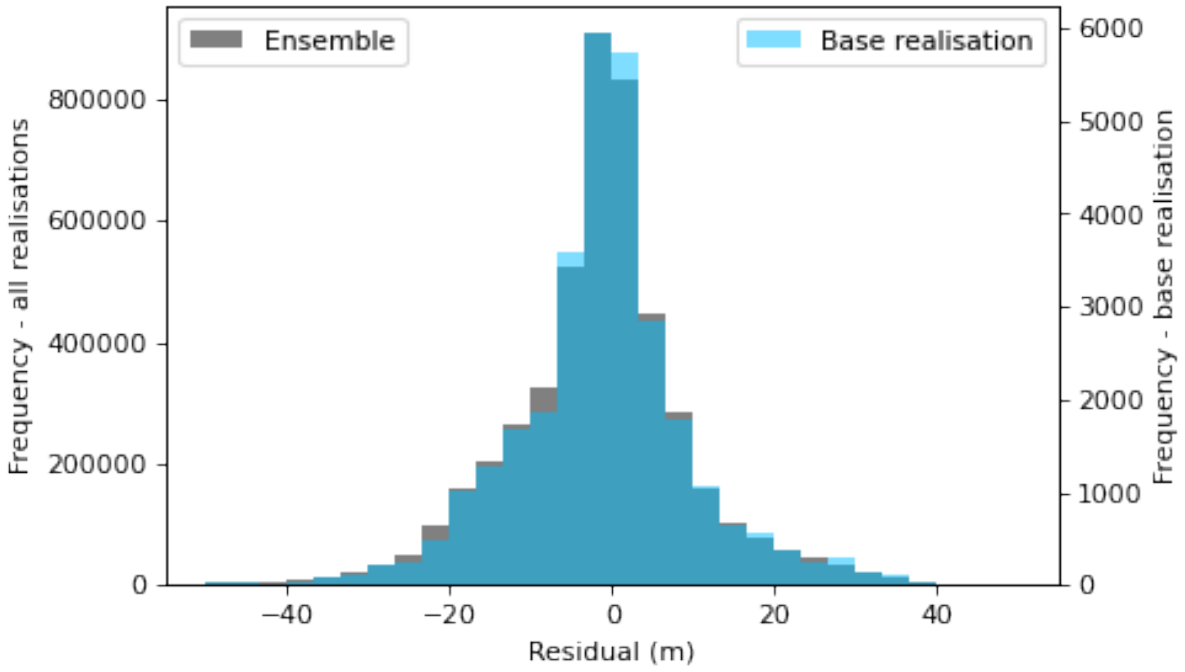


Figure 4.7 Transient hydraulic head residual distribution

Selected hydrographs showing modelled and measured hydraulic head are presented in Figure 4.8. The full set of history-matching hydrographs is presented in Appendix C. The selected hydrographs represent bores inside and outside the Project area, including a trigger level bore. Hydrographs show measured data, the base realisation, the full ensemble, and, where possible, hydrographs produced using the previous mine site model. The locations of the hydrographs are presented in Figure 4.9.

Modelled hydrographs show generally good match to measurements, supplemented by the range of simulated data from the ensemble. Near-pit bores show an improved match to measured data over the previous model, although the magnitude and timing of drawdown are challenging to represent with an annual mine plan representation. VWPs showing differing responses with depth are matched closer than previous models, due to sub-layering of the basement allowing for vertical gradient development. Other locations in the Project area show good modelled delineation between mine-related drawdown and IWL-related mounding. Note that only two realisations in the ensemble (200 realisations) show net drawdown at IWL monitoring bores.

GW036553/1 (Figure 4.8) is a compliance monitoring bore. The initial hydraulic head is reasonably well-matched and shows good transient response to pumping, but long-term drawdown is underestimated by approximately 10 m. This is partly caused by incomplete records of third-party bore pumping in that area.

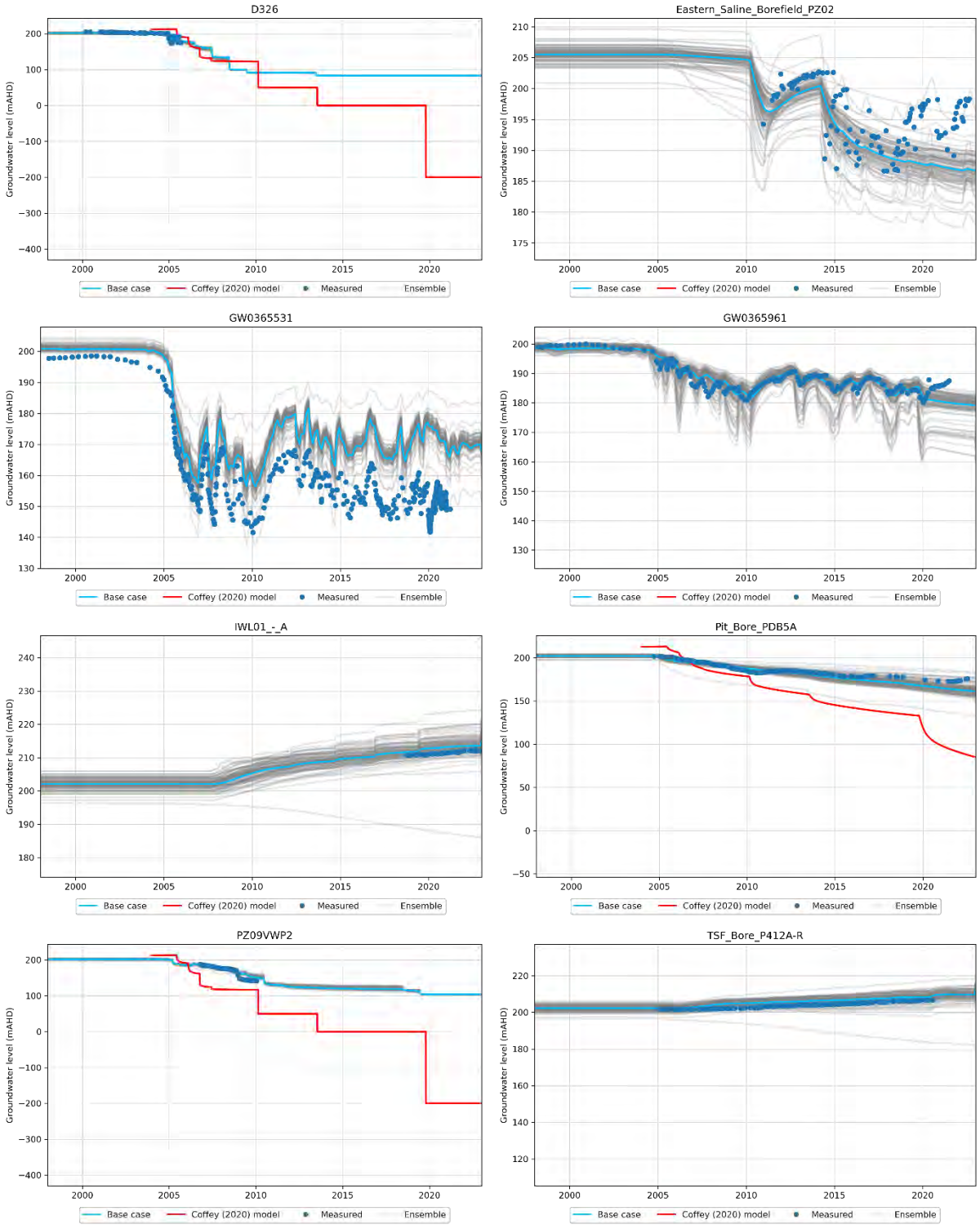
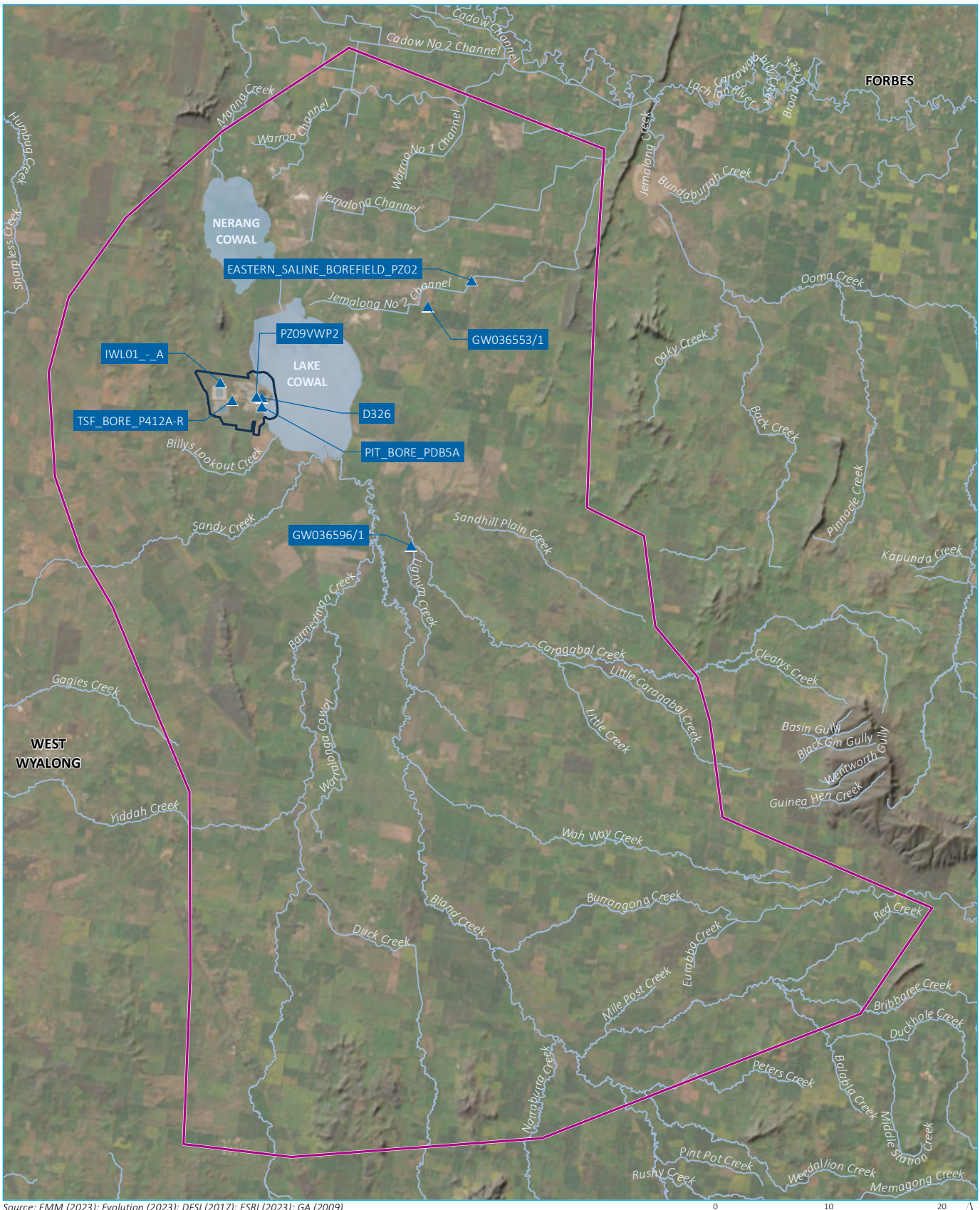


Figure 4.8 **Selected modelled and measured hydrographs over the history-matching period**



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM024_SelectedHydrographLocationPlan_20230517_03.mxd 17/05/2023

KEY

- Hydrograph location
- Model domain
- Proposed OPC disturbance footprint
- Named watercourses
- Named waterbody

Selected hydrograph location plan

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 4.9

EMM
creating opportunities

4.2.3 Water balance

Table 4.3 presents the base case realisation modelled water balance for pre-mining steady state and at selected times through the history-matching period during mining. Corresponding transient time series are shown in Figure 4.10. The steady-state model water balance is dominated by recharge and evapotranspiration, followed by regional throughflow. Well abstraction and mining activities contribute approximately half of the total model water balance, increasing total in/outflows from 20 ML/d to over 50 ML/d. Simulated pit dewatering is approximately in line with estimates (refer Figure 3.23), despite not using flux targets in the history-matching.

Table 4.3 Modelled water balance at selected times

	December 1997 Steady-state Pre-Mining (Lake Cowal Half Full)		January 2009 Transient Mining (Lake Cowal Dry)		January 2015 Transient Mining (Lake Cowal half Full)		January 2023 Transient Mining (Lake Cowal Full)	
	In (ML/d)	**Out (ML/d)**	**In (ML/d)**	**Out (ML/d)**	**In (ML/d)**	**Out (ML/d)**	**In (ML/d)**	**Out (ML/d)**
Regional throughflow	4.94	8.84	5.10	8.65	5.18	8.52	5.31	8.52
Recharge	13.56	0.00	11.25	0.00	12.49	0.00	24.17	0.00
Evapo-transpiration	0.00	12.67	0.00	12.25	0.00	13.16	0.00	26.40
River baseflow and leakage	3.25	0.23	4.21	0.17	4.30	0.14	5.41	0.87
Mine dewatering	0.00	0.00	0.00	1.30	0.00	2.00	0.00	2.62
Well abstraction	0.00	0.00	0.00	17.90	0.00	9.36	0.00	11.38
Storage	0.00	0.00	20.62	0.90	14.71	3.50	17.98	3.10
Total	**21.74**	**21.74**	**41.17**	**41.17**	**36.68**	**36.68**	**52.88**	**52.88**
Water balance error	**0.02%**		**0.01%**		**0.00%**		**0.00%**	

The modelled water balance error is low, with maximum error not exceeding 1% for any of the model stress periods. This indicates good numerical performance of the model and is consistent with best practice guidance (Barnett et al 2012).

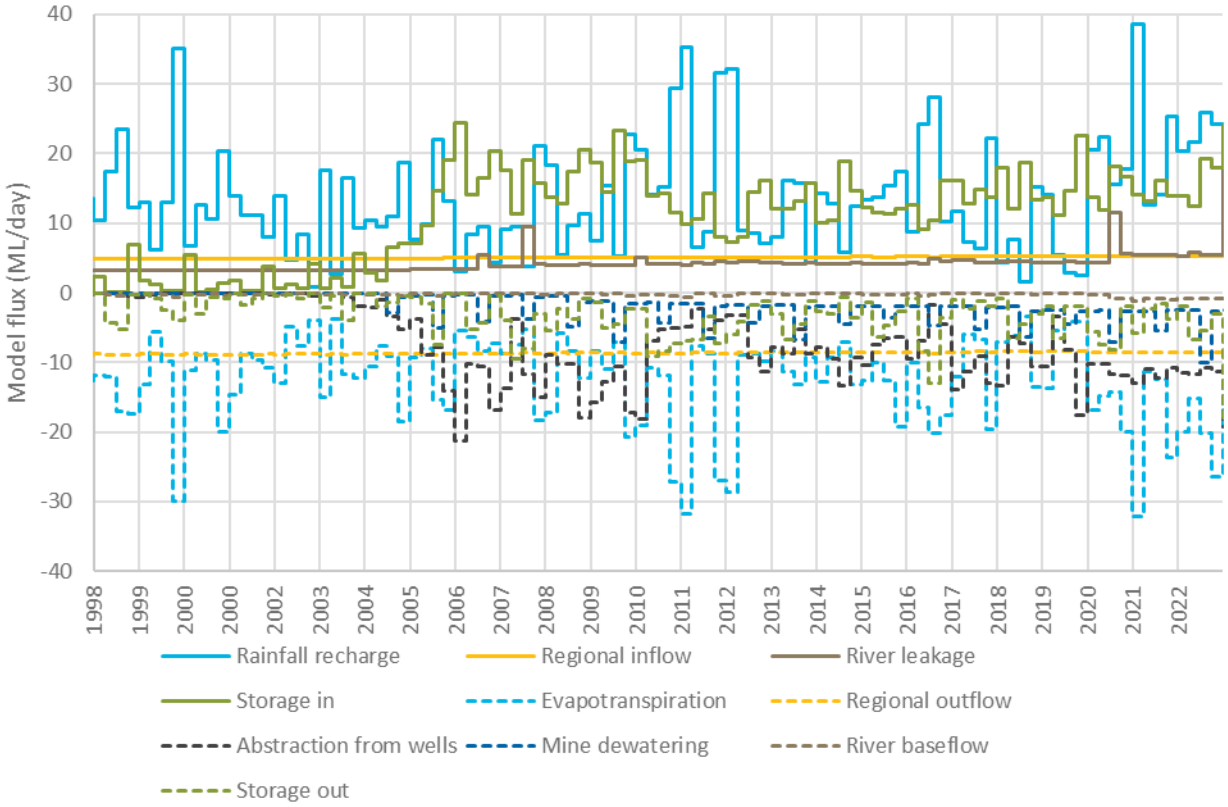


Figure 4.10 **Base case realisation modelled transient water balance over the history-matching period**

4.3 Base case hydraulic properties

Table 4.4 presents a summary of modelled hydraulic properties resulting from the history-matching process, that have been adopted as "base case" hydraulic parameters. Because pilot points were used to develop spatially variable parameters, the minimum, maximum and mean values that were derived from this highly parameterised approach are presented. Note that anisotropy was estimated instead of vertical hydraulic conductivity; these values have been converted to vertical hydraulic conductivity for Table 4.4.

Table 4.4 **Base case hydraulic properties for HSUs using pilot points**

HSU	Kh (m/d)			Kv (m/d)			Ss (m^{-1})			Sy (%)		
	min	mean	max	min	mean	max	min	mean	max	min	mean	max
Clay	1×10^{-5}	0.0058	1	1.14×10^{-8}	0.0012	0.75	1×10^{-7}	8.67×10^{-6}	1.3×10^{-5}	9.98×10^{-4}	0.018	0.1
Upper Cowra	9.97×10^{-4}	0.034	0.93	1×10^{-6}	3.50×10^{-4}	0.51	1×10^{-7}	1.31×10^{-6}	1.3×10^{-5}	0.001	0.051	0.3
Lower Cowra	0.001	0.048	10	1×10^{-6}	0.0048	10	1×10^{-7}	1.02×10^{-6}	1.3×10^{-5}	0.001	0.064	0.3
Lachlan	0.05	18	50	5×10^{-5}	16	50	1×10^{-7}	7.23×10^{-6}	1.3×10^{-5}	9.90×10^{-4}	0.071	0.35
Saprolite	0.01	0.056	1	1×10^{-5}	0.0042	0.75	1×10^{-7}	1.78×10^{-6}	1.3×10^{-5}	0.001	0.037	0.1

Table 4.4 Base case hydraulic properties for HSUs using pilot points

HSU	Kh (m/d)			Kv (m/d)			Ss (m^{-1})			Sy (%)		
	min	mean	max	min	mean	max	min	mean	max	min	mean	max
Saprock	0.001	0.0084	0.1	1×10^{-6}	0.0038	0.1	1×10^{-7}	1.50×10^{-6}	1.3×10^{-5}	0.001	0.0086	0.05
Basement	9.80×10^{-5}	0.0097	0.053	1×10^{-7}	0.0028	0.051	1×10^{-7}	3.13×10^{-6}	1.3×10^{-5}	1×10^{-4}	0.02	0.051

The Saprolite (model layer 5) is spatially extensive and host to a number of users. The pilot point parameter frequency distribution for this unit is presented in Figure 4.11, with frequency for the base realisation on the secondary vertical axis. This shows the variation within the unit for the base realisation and the full ensemble of adopted realisations based on pilot point values, as well as the initial (prior) distribution based on the conceptualisation. A number of pilot points are at the conceptual bounds; when PESTPP-IES calculates values outside of the bounds, this value is replaced with the bound value. Only two iterations of PESTPP-IES were employed, and the centre of the parameter distributions can be seen to have moved from the prior to the posterior.

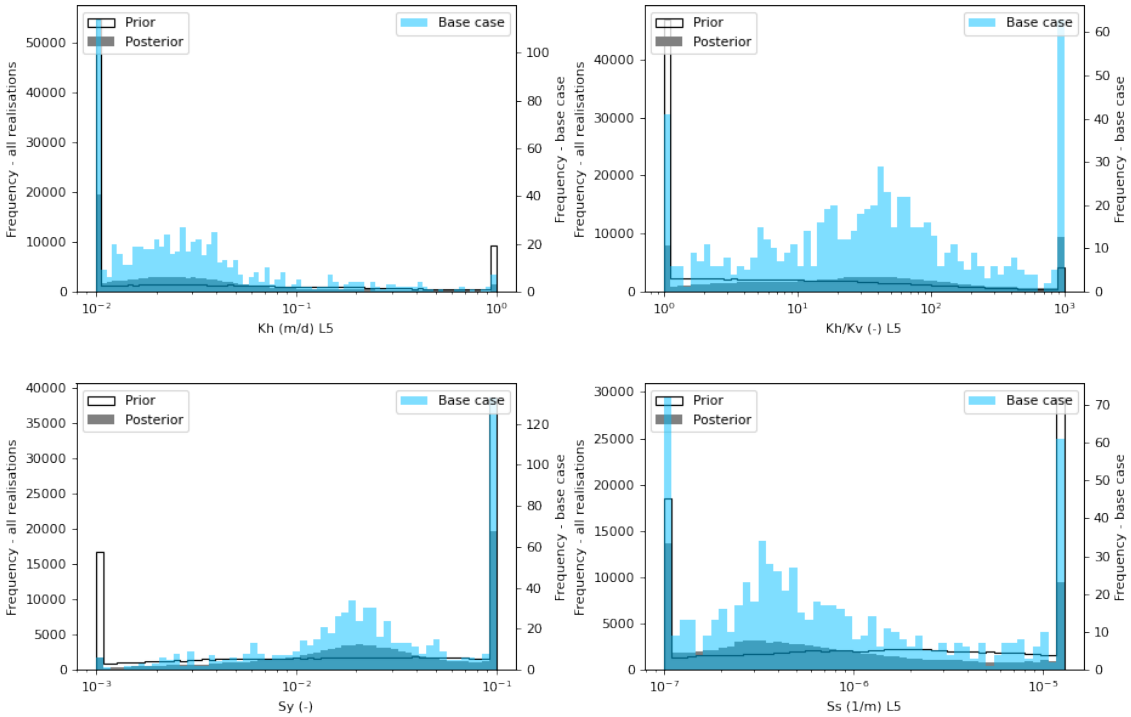
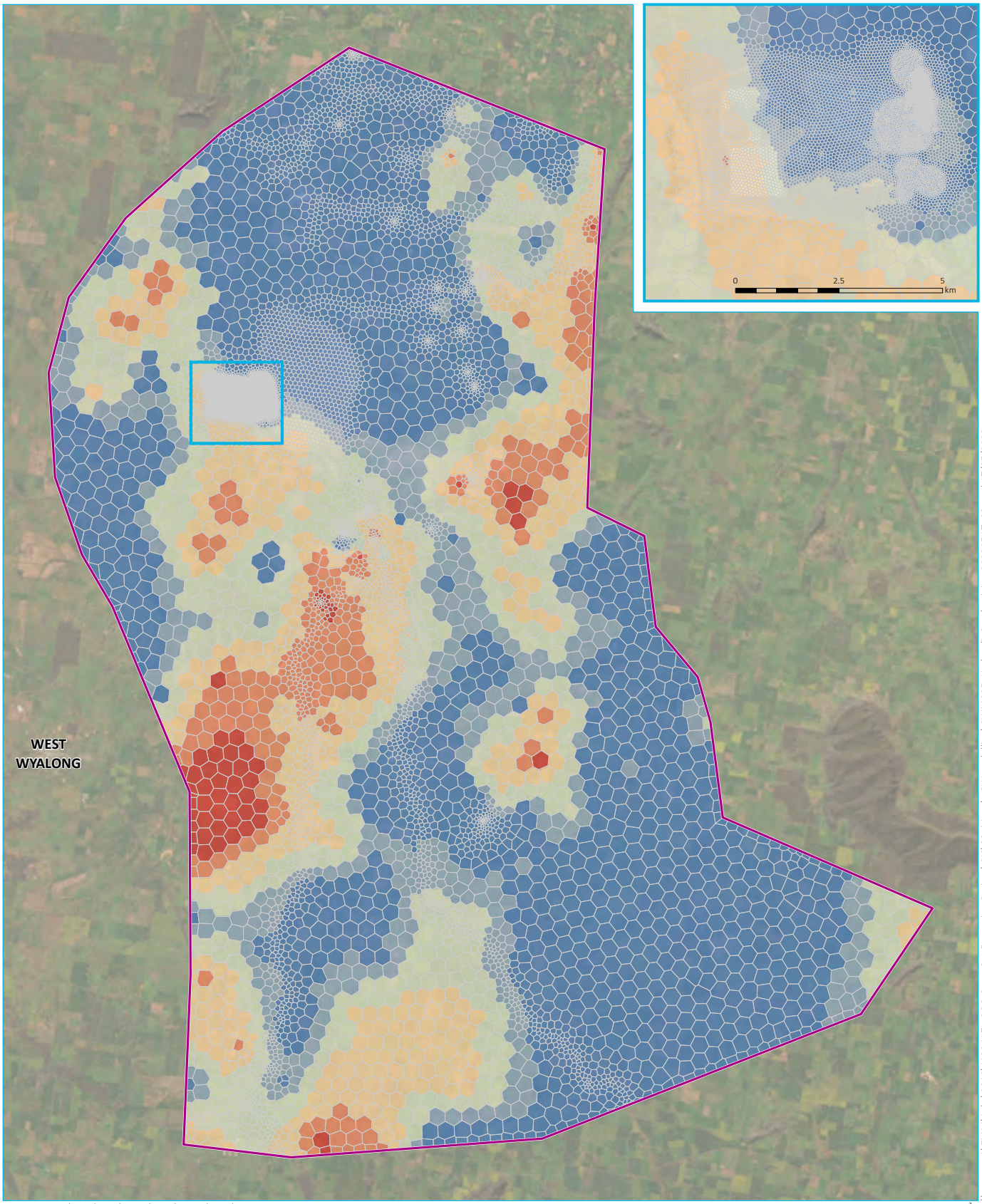


Figure 4.11 Saprolite (layer 5) hydraulic property histograms

The spatial distribution of modelled horizontal hydraulic conductivity in the Saprolite for the base realisation is presented in Figure 4.12. Modelled hydraulic conductivity is generally higher south of the Project area, with a visible band from south west to north east up to 1 m/d. Near the mine and borefields, the simulated hydraulic conductivity is generally from 0.01 to 0.03 m/d.



Source: EMM (2023); Evolution (2023); ESRI (2023)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

Model domain

Voronoi mesh

Horizontal hydraulic conductivity (m/d)

- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1

Base realisation Saprolite horizontal hydraulic conductivity (layer 5)

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 4.12

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWmodelling\GWM025_HydraulicConductivity_20230517_03.mxd 17/05/2023

4.4 Ensemble

As shown in Section 4.2 and 4.3, the Gaussian distribution of parameters developed by PESTPP-IES centred on the base realisation provides an ensemble for Monte Carlo predictive uncertainty analysis. The ensemble has been included on scatter plots, hydrographs, and residual distributions. Additional analysis of history-matching performance across the ensemble was performed, to ensure acceptable performance for predictive uncertainty. Key metrics are presented as histograms in Figure 4.13, with the base realisation as a vertical line and the ensemble distribution in grey. Plots are presented for SRMS and average absolute residual.

The base realisation is not the best performer for individual metrics, but presents the best overall match to measured data. The performance of the ensemble is heavily weighted towards the base realisation, with a tail representing some realisations with worse performance. To ensure conservative prediction of potential impacts, none of the realisations from the ensemble were excluded for the predictive uncertainty analysis.

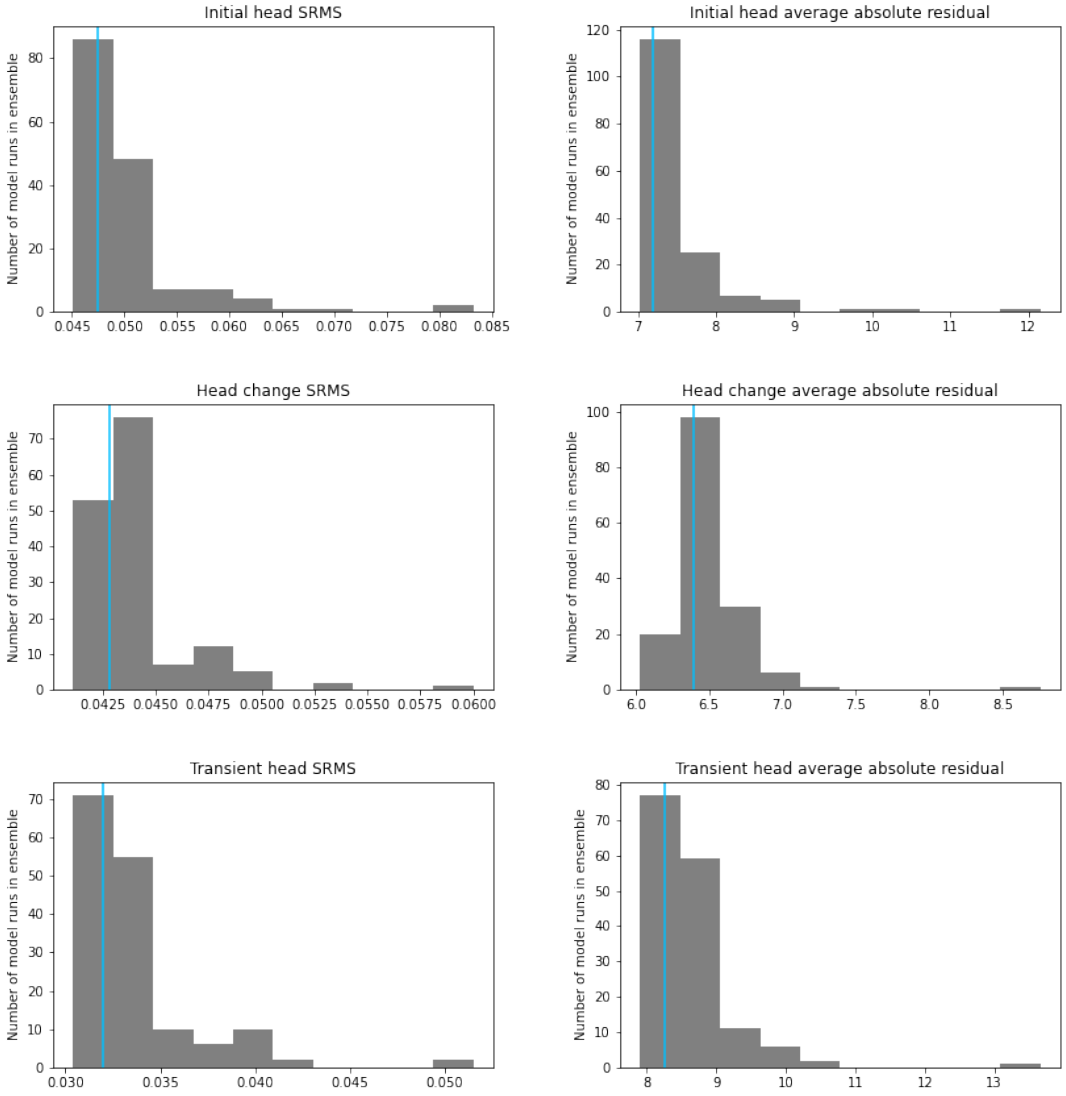


Figure 4.13 Adopted ensemble history-matching performance

5 Predictive modelling

5.1 Overview

As discussed in Section 3.7.6iv, four scenarios were defined for predictive modelling, as follows:

Table 5.1 Model scenario definition

ID	Third party bores	Mining activities	Post-mine recovery
Prediction 1	Active	None	N/A
Prediction 2	Active	Approved mine only	Pit remains dry in perpetuity
Prediction 3	Active	Approved and proposed	Pits remain dry in perpetuity
Prediction 4	Active	Approved and proposed	Pit water level allowed to recover with void properties and no surficial fluxes

Prediction 1 and prediction 2 are used as null scenarios for calculating total impacts of mining (**cumulative** impact) and the impact associated with the proposed additional mining (**incremental** impact) respectively. Two post-closure cases were simulated to encapsulate the range of expected conditions following the end of mining. The first case simulates the open voids maintained at their final mining level. i.e. they remain dry (the **'dry' case**). This is highly conservative from a drawdown perspective, given that the conceptual model suggests the development of a pit lake. The second post-closure case deactivates the open pits at the end of mining and water levels are allowed to recover within these pits with open void properties applied (i.e. the **'fast recovery' case**). However, no recharge or evaporation is applied, and therefore groundwater levels recover more quickly and higher than would be expected in reality. This is likely conservative from a contaminant transport perspective, as the fast recovery case likely underestimates the ability of the voids to capture potential contaminants emanating from the IWL and WREs. That is, the conceptual model is that some recovery will occur, so the reality will lie between the two simulated cases.

The ensemble of realisations was used to run all predictive scenarios, to estimate the range of potential spatial and temporal drawdown impacts to the groundwater system. Only the base realisation was analysed for modelled fluxes.

Late in the modelling process, a further scenario was added to the set of scenarios outlined in Table 5.1. This simulated a more realistic pit lake recovery scenario, utilising inputs from the post-mining pit water balance assessment (ATC Williams 2023). Details of this scenario and associated results are presented in Appendix E.

5.2 Modelled fluxes

The base realisation history-matched model was run deterministically to predict the "base case" impact of the Project on:

- Groundwater inflows to each component of the Project during mining.
- Surface water balances during mining.
- Groundwater inflows to key project components during operation.

The base realisation modelled water balances for the first three scenarios (Table 3.8) are shown in Figure 5.1 to Figure 5.3. Common to all scenarios, the water balance is dominated by rainfall recharge and evapotranspiration, with an increase in pumping from third-party bores simulated in the predictive period. Rainfall-derived recharge is less variable in the predictive period compared to history-matching, due to long-term average values being applied (refer Figure 3.15).

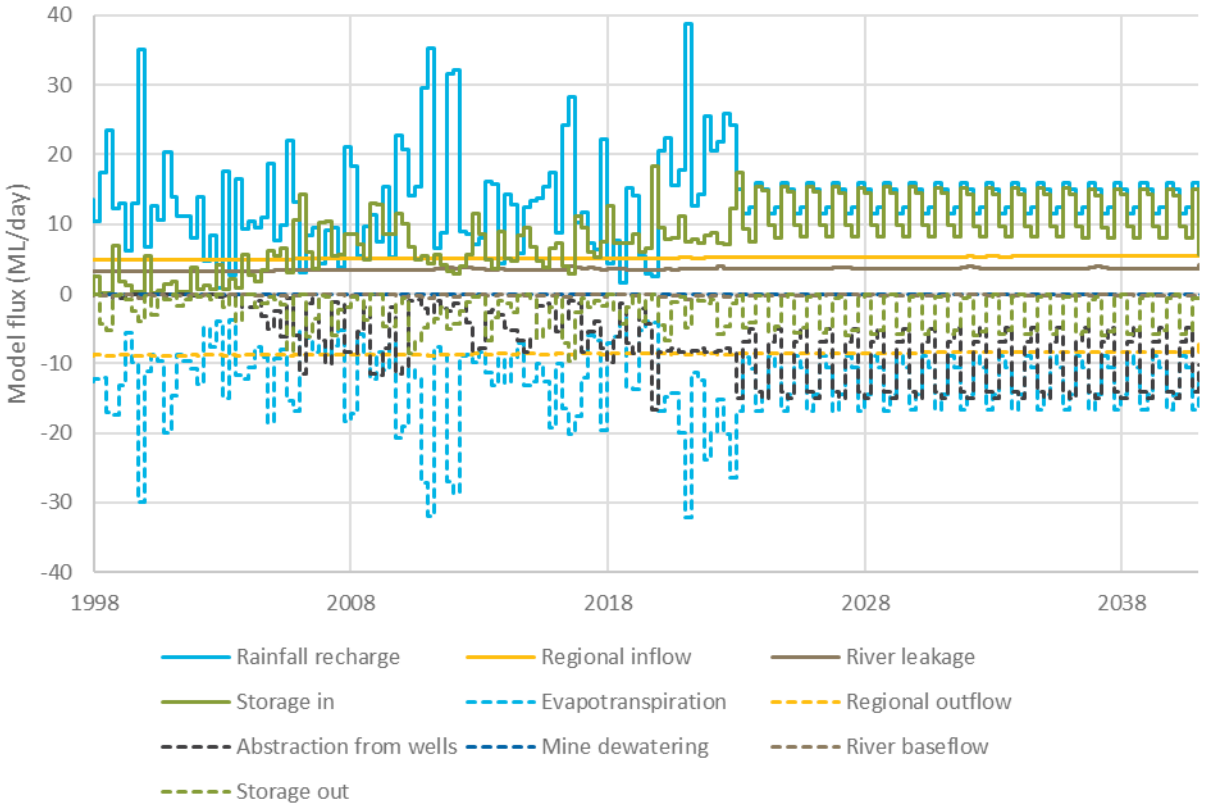


Figure 5.1 Prediction 1 modelled water balance

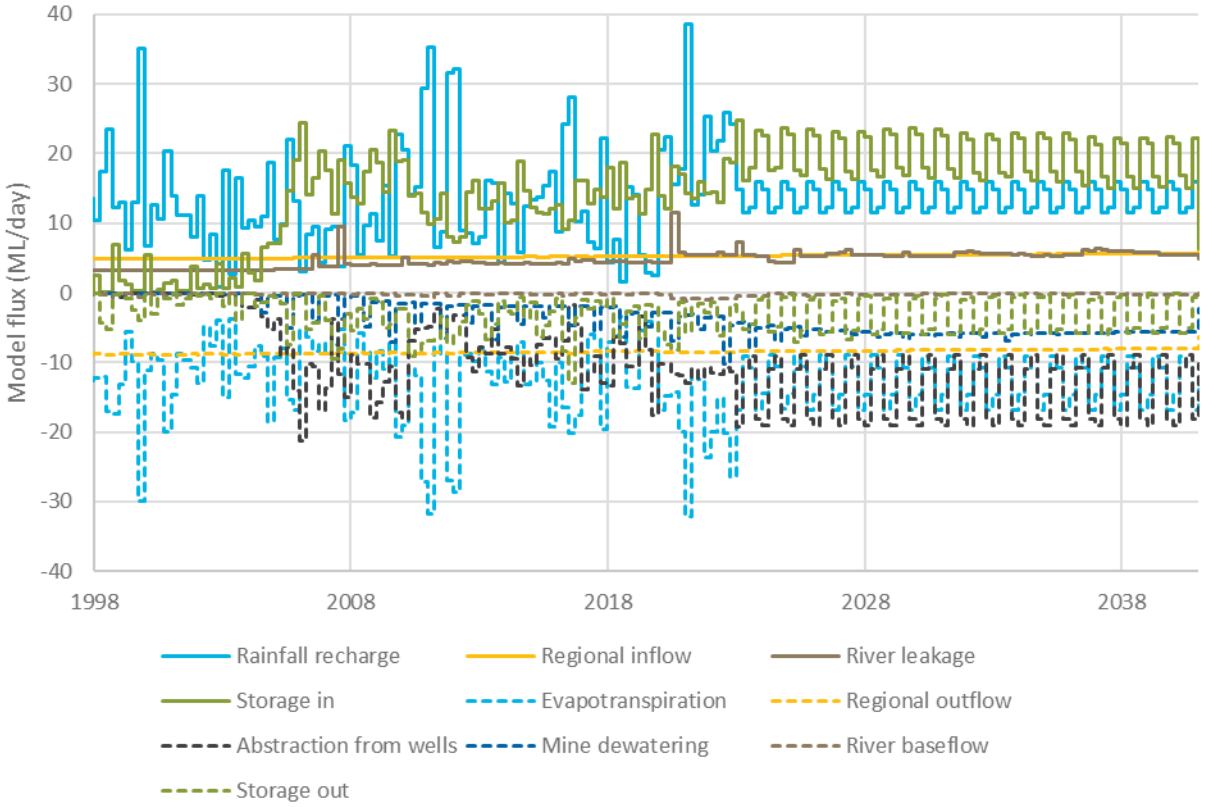


Figure 5.2 **Prediction 2 modelled water balance**

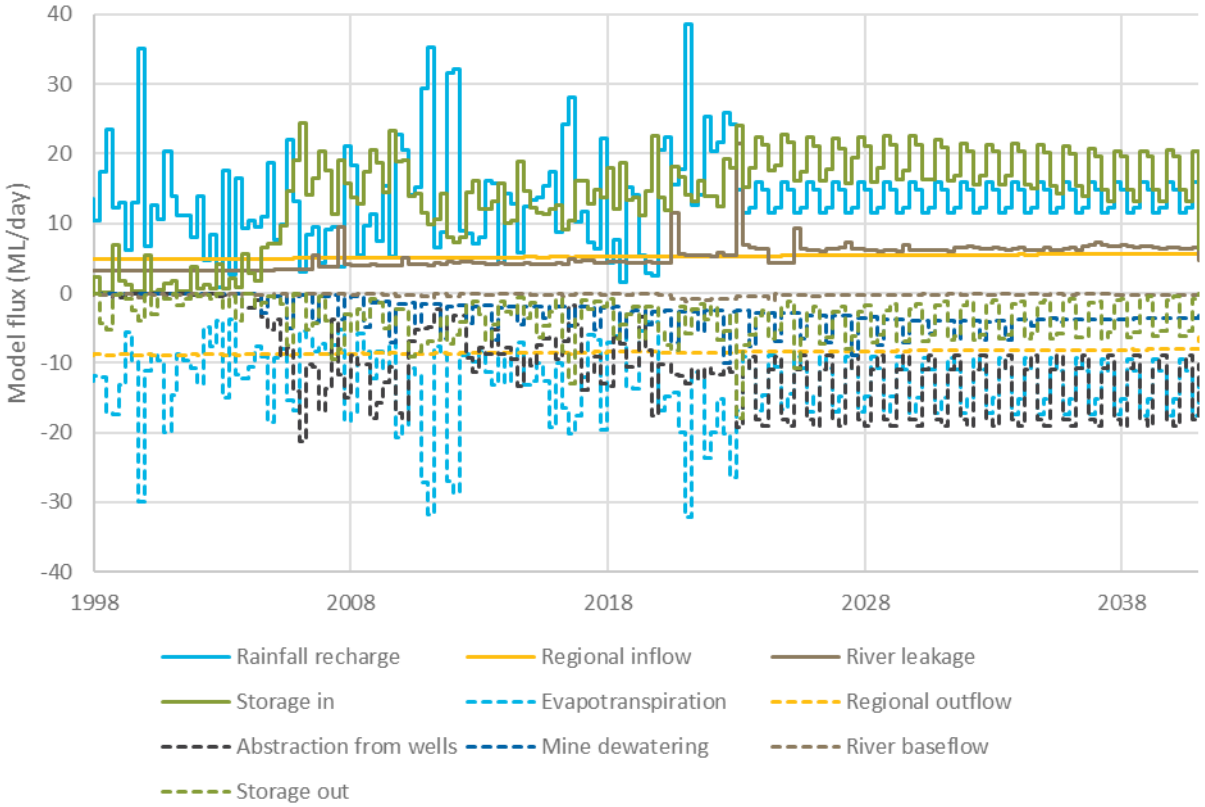


Figure 5.3 **Prediction 3 modelled water balance**

Modelled groundwater removal via mine features for prediction 3 is presented in Figure 5.4, broken into contributions from HSUs and mine areas. The model simulates the majority of water to be sourced from the basement, with minor inflows from shallower HSUs early in the Project life. Predicted inflows are not substantially greater than currently observed, with the model predicting an increase from approximately 4 to 5 ML/d. E42 pit is predicted to be the primary receptor of inflows, as this is the deepest pit (the underground mine is progressively backfilled and is therefore not subjected to inflows for the full footprint).

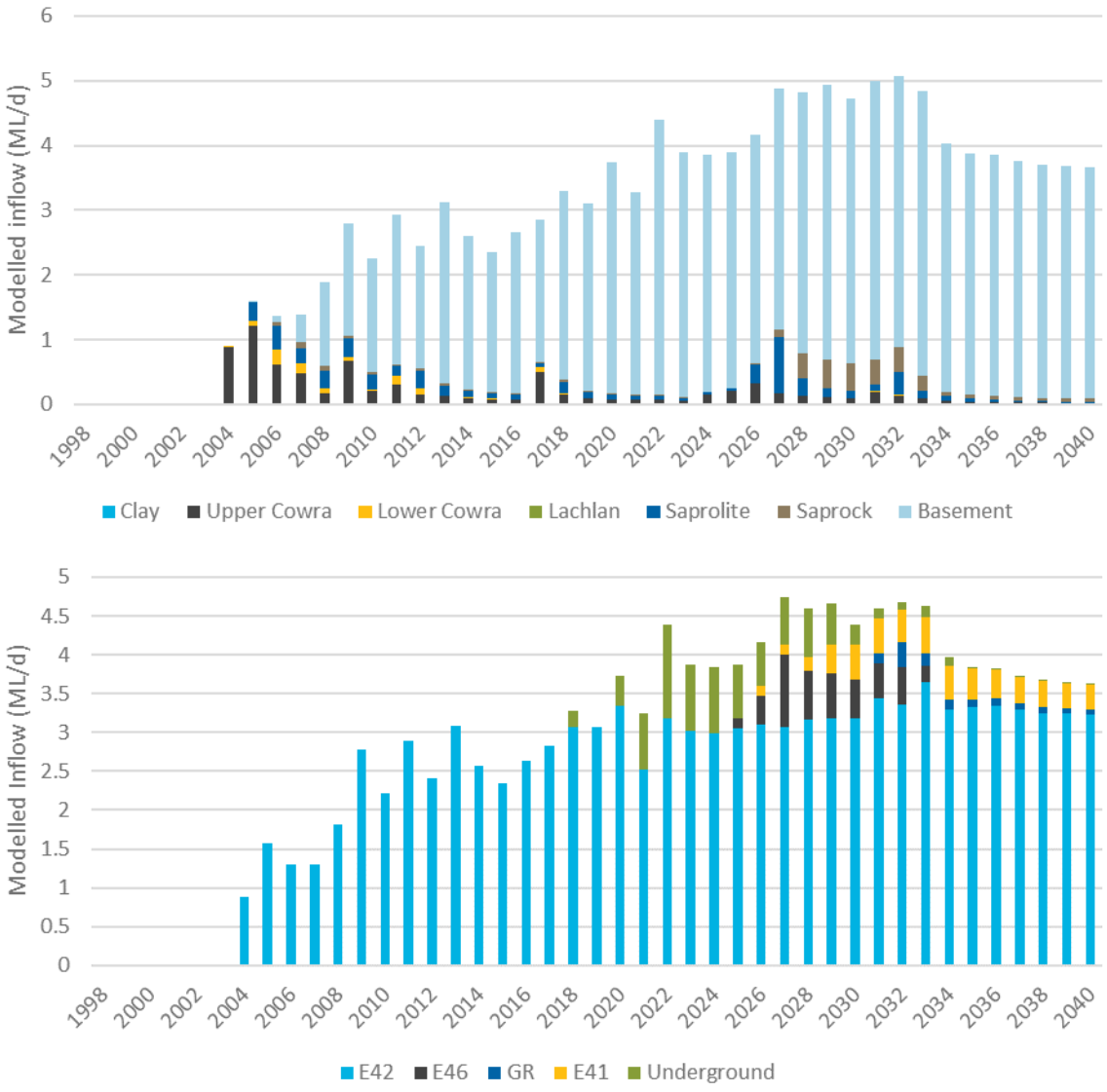


Figure 5.4 Modelled inflows to mine workings

Drawdown is predicted to increase the hydraulic gradient from surface water features, and therefore induce seepage to the groundwater system. IWL deposition is also expected to induce surface water seepage. Modelled induced seepage from surface water features is presented in Figure 5.5, calculated by subtracting net river boundary condition fluxes of prediction 1 from prediction 3 (cumulative impact). The peak combined induced flux from Lake Cowal and creeks/irrigation channels is predicted to be less than 0.6 ML/d, whereas the IWL is predicted to have a consistent seepage rate in excess of 2 ML/d. Spikes are shown at times where new areas of the IWL are activated; the true seepage flux is expected to be smoother. The induced seepage from Lake Cowal is likely conservative, as the model simulates greater hydraulic connectivity between the lake and watertable than is conceptualised (refer Section 2.3).

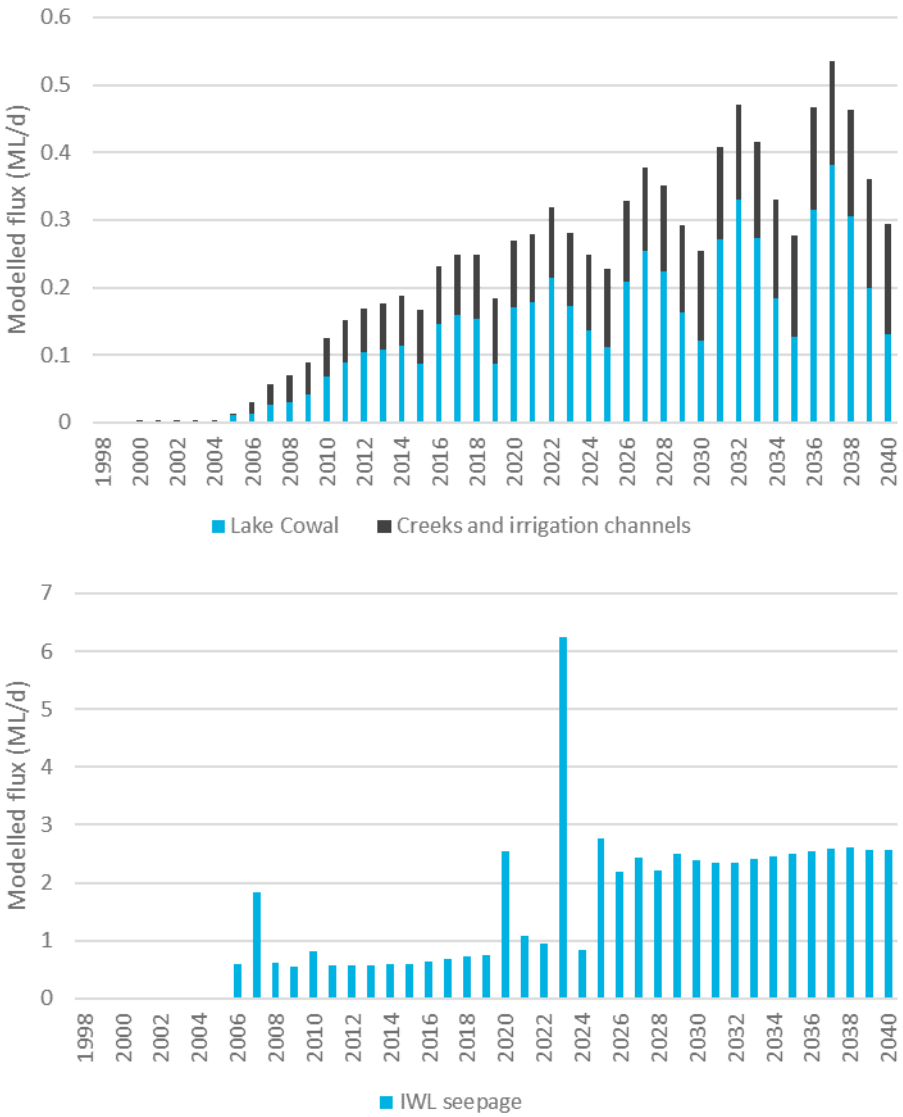


Figure 5.5 **Induced seepage from surface water features**

Continuing from Table 4.3, the modelled water balance for prediction 3 at selected times during the predictive period is presented in Table 5.2. There is a slight decrease in net regional throughflow over the duration of the predictive model, suggesting drawdown impacts are influencing the edges of the model domain. There is an increase in modelled evapotranspiration, which appears to result from IWL seepage.

Table 5.2 **Modelled water balance at selected times in the predictive period**

	January 2025		January 2030		January 2035		January 2040	
	In (ML/d)	Out (ML/d)	In (ML/d)	Out (ML/d)	In (ML/d)	Out (ML/d)	In (ML/d)	Out (ML/d)
Regional throughflow	5.36	8.39	5.47	8.28	5.54	8.17	5.61	8.08
Recharge	15.86	0.00	15.86	0.00	15.86	0.00	15.86	0.00
Evapo-transpiration	0.00	16.71	0.00	17.20	0.00	17.35	0.00	17.52

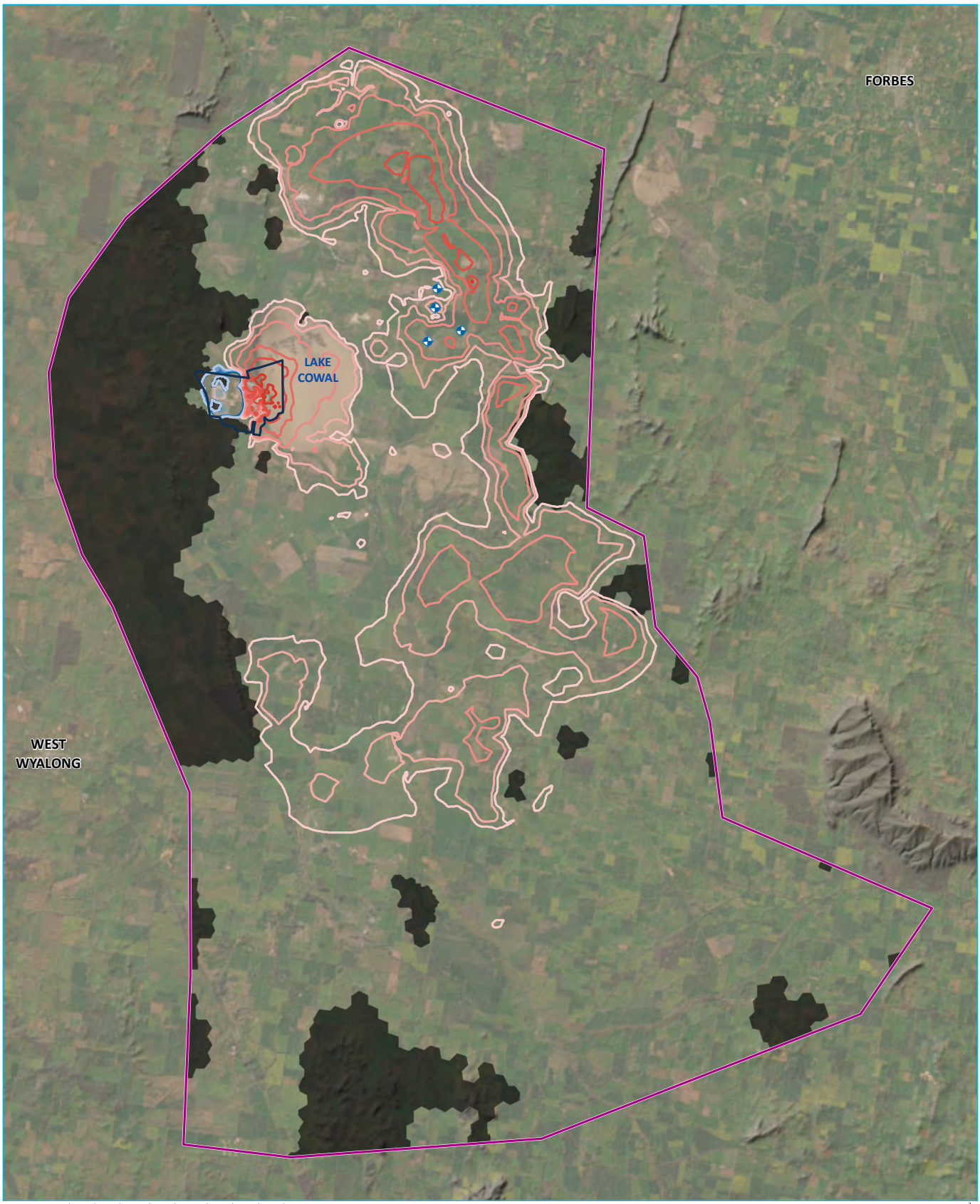
Table 5.2 Modelled water balance at selected times in the predictive period

	January 2025		January 2030		January 2035		January 2040	
	In (ML/d)	Out (ML/d)	In (ML/d)	Out (ML/d)	In (ML/d)	Out (ML/d)	In (ML/d)	Out (ML/d)
River baseflow and leakage	4.33	0.21	6.25	0.24	6.26	0.22	6.52	0.27
Mine dewatering	0.00	2.90	0.00	4.01	0.00	3.72	0.00	3.62
Well abstraction	0.00	18.17	0.00	18.12	0.00	18.10	0.00	18.09
Storage	22.84	2.02	22.59	2.32	21.27	1.36	20.53	0.94
Total	**48.40**	**48.41**	**50.16**	**50.16**	**48.93**	**48.93**	**48.52**	**48.52**
Water balance error	**-0.01%**		**0.00%**		**0.00%**		**0.00%**	

5.3 Spatial impacts

5.3.1 Base realisation drawdown

Cumulative modelled drawdown for the base realisation is presented in Figure 5.6 to Figure 5.9, showing drawdown in the Upper Cowra and basement at the end of mining and at key times post-mining for the dry case and fast recovery case. Modelled drawdown is spatially extensive, arising from mine dewatering and borefield pumping. Mounding from IWL seepage does not extend far beyond the Project area. Following mining, the dry and fast recovery cases show an increasing divergence in modelled drawdown. Partial recovery is simulated for the fast recovery case, whereas the dry case simulates increasing drawdown extent around the open pits. This is apparent in both presented HSUs.



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Not present

Cumulative drawdown (m)

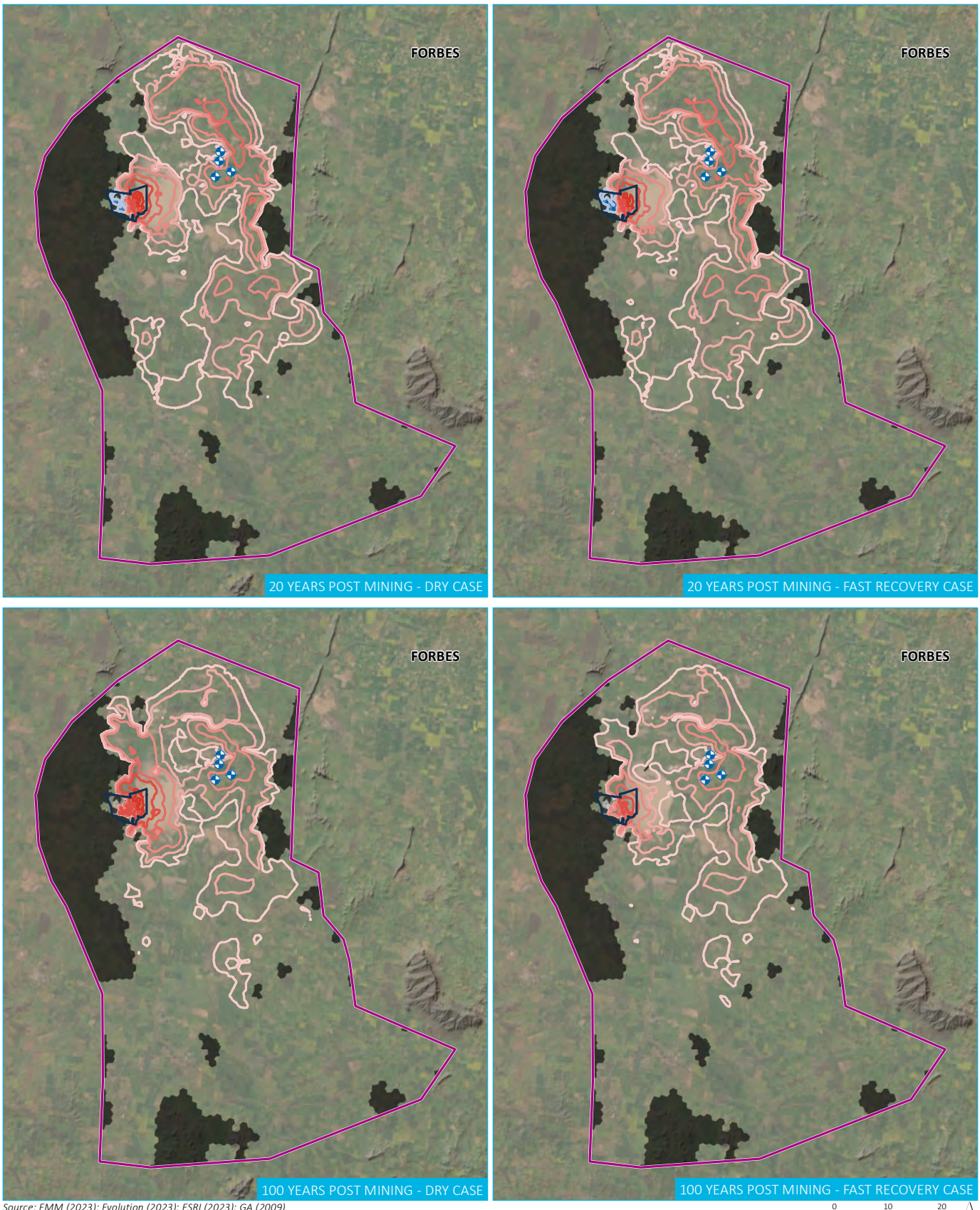
- -5
- -2
- -1
- -0.5
- 0.5
- 1
- 2
- 5
- 10
- 25

Cumulative drawdown, Upper Cowra groundwater system (Layer 2) - end of mining

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 5.6

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA018a_CumulativeDrawdownUpperCowra1year_20230519_04.mxd 19/05/2023



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Not present

Cumulative drawdown (m)

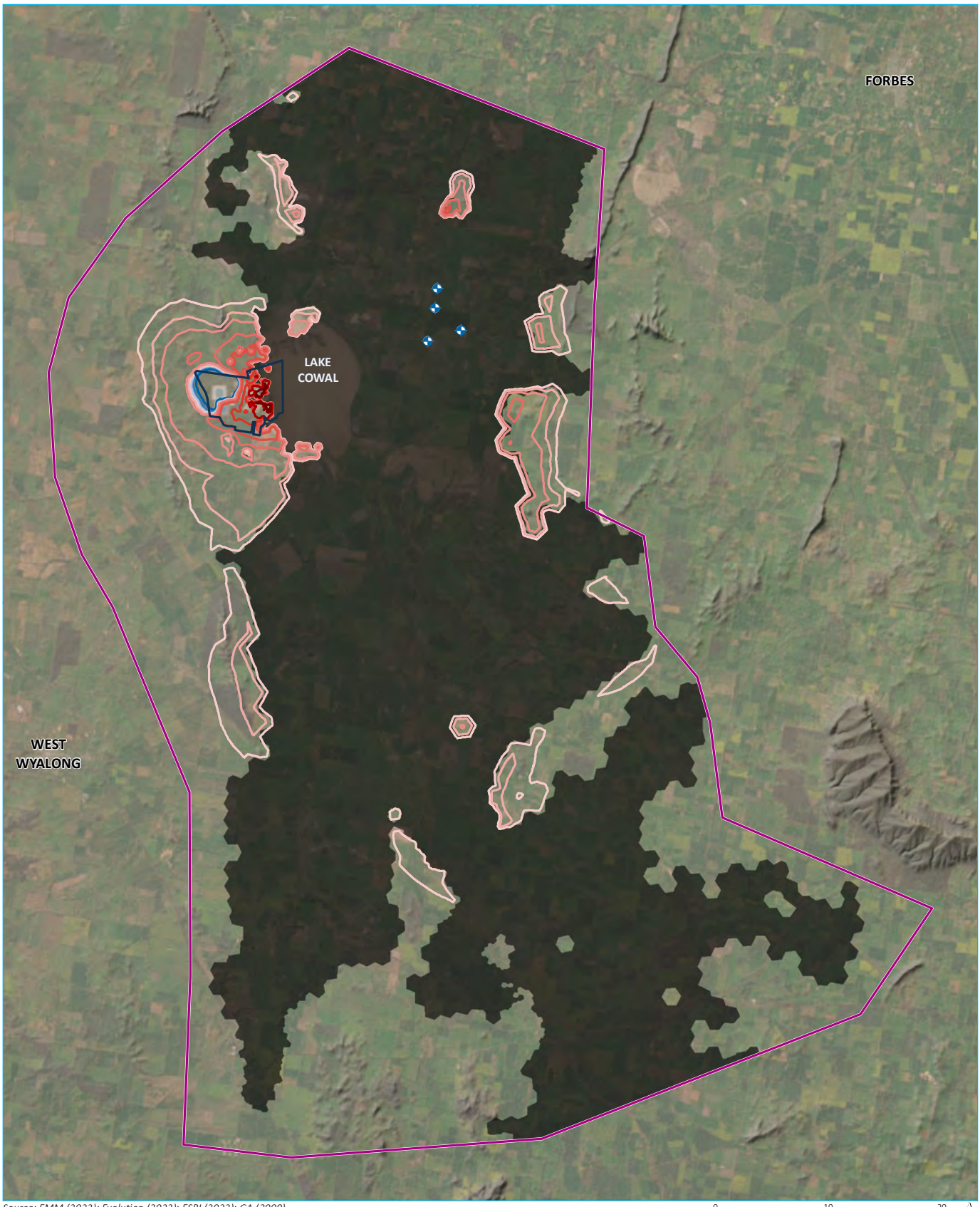
- -5
- -2
- -1
- -0.5
- 0.5
- 1
- 2
- 5
- 10
- 25

Cumulative drawdown, Upper Cowra groundwater system (Layer 2) - post mining

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 5.7

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA018b_CumulativeDrawdownUpperCowra20and100year_20230519_04.mxd 19/05/2023



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Not present

Cumulative drawdown (m)

- -5
- -2
- -1
- -0.5
- 0.5
- 1
- 2
- 5
- 10
- 25
- 50
- 100

Cumulative drawdown, top Lachlan Fold Belt (Layer 7)
end of mining

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 5.8

EMM
creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA019a_CumulativeDrawdownTopLachlanFoldBelt1year_20230519_04.mxd 19/05/2023

Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Not present

Cumulative drawdown (m)

- -1
- -0.5
- 0.5
- 1
- 2
- 5
- 10
- 25
- 50
- 100

Cumulative drawdown, top Lachlan Fold Belt (Layer 7) post mining

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 5.9

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA019b_CumulativeDrawdownTopLachlanFoldBelt20and100year_20230519_04.mxd 19/05/2023

5.3.2 Predictive uncertainty likelihood of exceedance

The ensemble of realisations was used to run predictions 1 to 3, and maximum cumulative and incremental drawdown irrespective of time calculated for each realisation. Then, the proportion of realisations in which drawdown at a model cell exceeds a given value can be calculated. A 2 m threshold was chosen for this analysis.

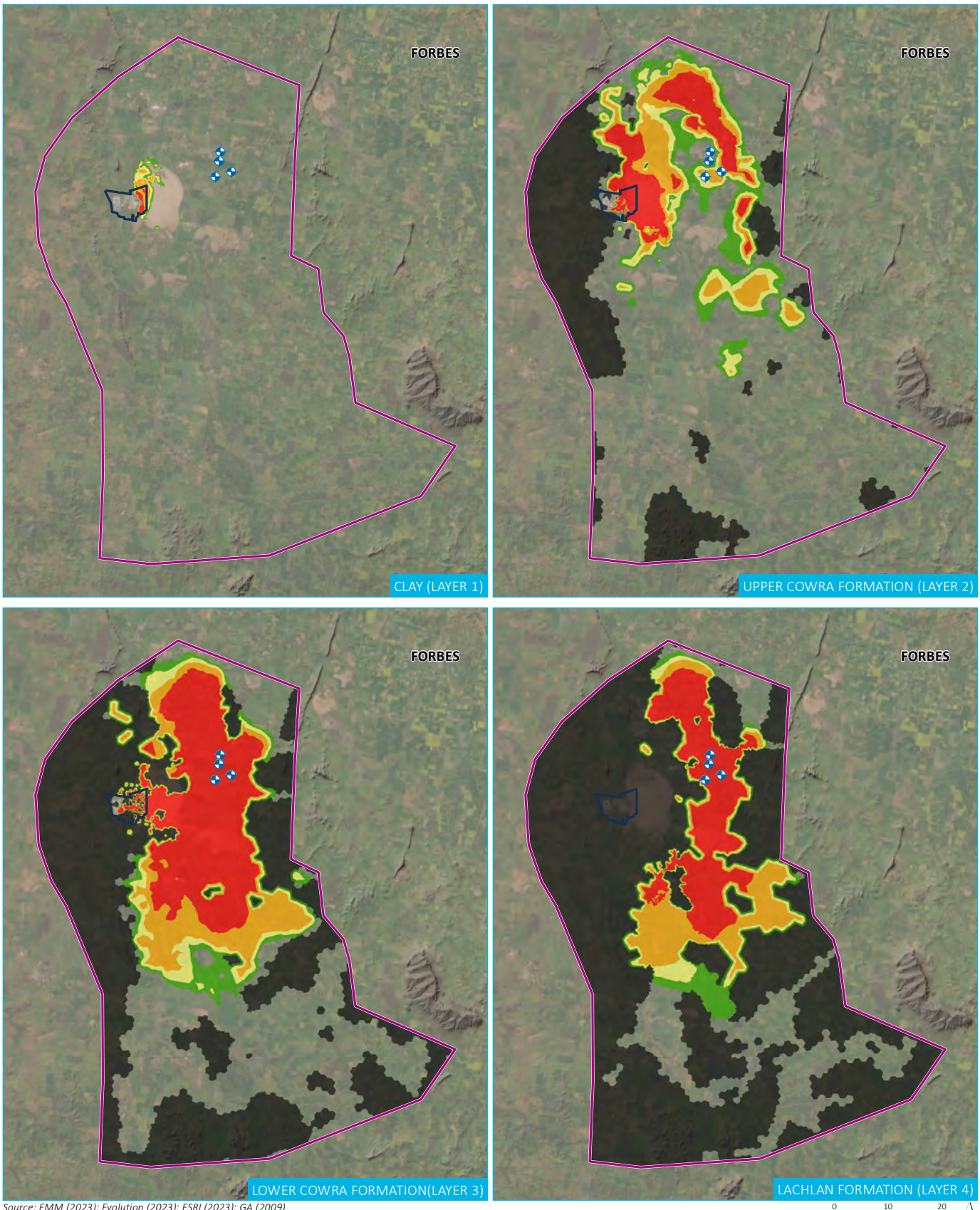
The rationale for the percentile-based approach to presenting drawdown from the uncertainty realisations is based on Table 2 of the IESC guidance note on uncertainty analysis (Middlemis and Peeters 2018). That emphasises the importance of calibrated language and having a consistent and precise language to communicate impacts to decision makers.

Table 5.3 provides a summary of the combined numeric, narrative and visual approach to describing likelihood of drawdown exceeding the 2 m threshold, as a result of the Project. This table will provide the clarity on how to consider the likelihood bands presented in this section.

Table 5.3 Combined numeric, narrative, and visual approach for assessing the likelihood of drawdown

Percentile band (outcomes ranked from small to large)	Colour code	
<P10		It is **very unlikely** that drawdown **exceeds** the threshold
P10 to P33		It is **unlikely** that drawdown **exceeds** the threshold
P33 to P67		It is **as likely as not** the drawdown **exceeds** the threshold
P67 to P90		It is **likely** that drawdown **exceeds** the threshold
>P90		It is **very likely** that drawdown **exceeds** the threshold

Proportion of exceedance plots against a 2 m cumulative and incremental drawdown threshold for the top 4 model layers are presented in Figure 5.10 and Figure 5.11 respectively. The cumulative impact shows the total impact of the Project, whereas the incremental impact shows only the change in groundwater level associated with the proposed additional mining activities. Therefore the cumulative drawdown plots are much more spatially extensive than the incremental drawdown.



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km
GDA 1994 MGA Zone 55
N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Not present

2 m cumulative drawdown (likelihood of exceedance)

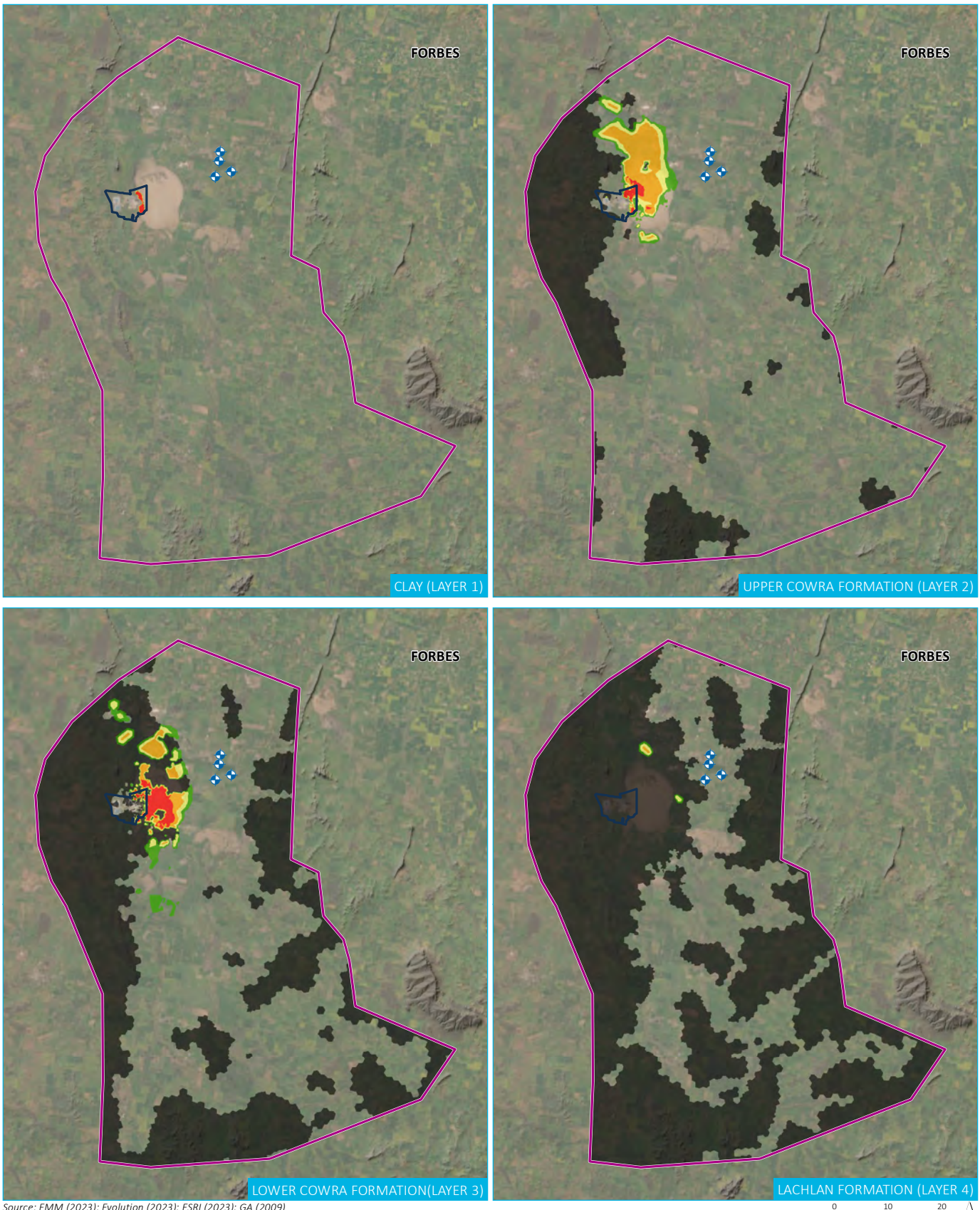
- 10 %
- 33 %
- 66 %
- 90 %

Cumulative impact proportion of exceedance for 2 m drawdown

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 5.10

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA020_CumulativeDrawdown2mContours_20230519_04.mxd 19/05/2023



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km
GDA 1994 MGA Zone 55
N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA021_IncrementalDrawdown2mContours_20230519_04.mxd 19/05/2023

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Not present

2 m incremental drawdown (likelihood of exceedance)

- 10 %
- 33 %
- 66 %
- 90 %

Incremental impact proportion of exceedance for 2 m drawdown

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 5.11

EMM creating opportunities

5.4 Temporal impacts

Hydrographs of absolute groundwater level at the same locations as Figure 4.8 are presented in Figure 5.12 for the dry case, including 100 years post-mining. Near-pit bores show the permanently recessed groundwater level associated with the dry pit representation, whereas monitoring near mine borefields shows some recovery following cessation of pumping. Mounding from IWL seepage is predicted to dissipate and be counteracted by drawdown from the open pits.

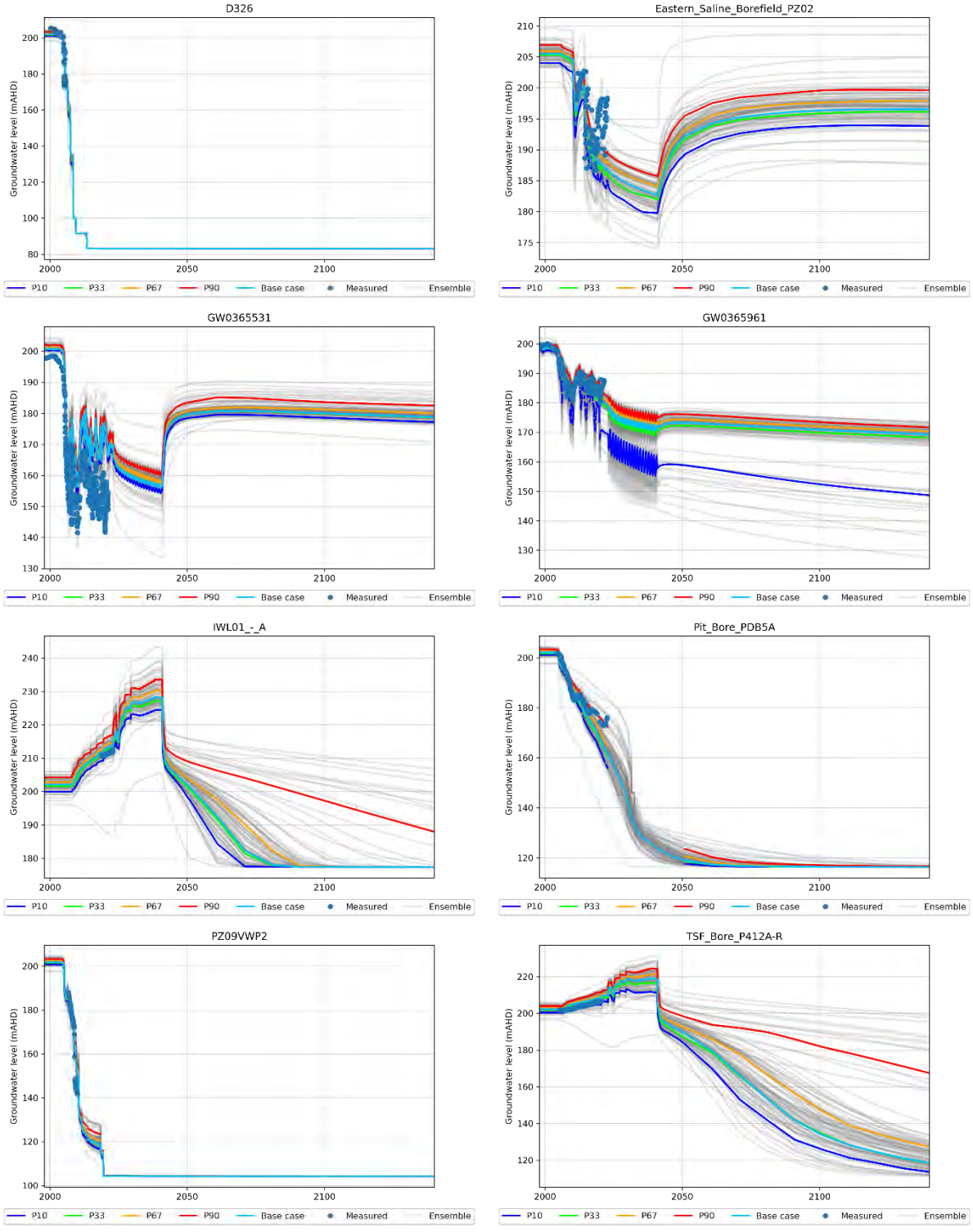


Figure 5.12 Selected hydrographs over the history-matching and predictive period

5.4.1 Drawdown at compliance monitoring bores

Modelled groundwater levels at the three regional groundwater monitoring trigger bores were simulated for the base case and the ensemble of predictive realisations and compared to the management thresholds. This drawdown is based on the Proposed scenario and includes landholder pumping, as well as the approved and proposed CGO operations (including borefields). As discussed previously, there is a mis-match between the observations and the simulated water levels, which is likely influenced by third-party abstraction data (see discussion of history-matching at GW036553 in Section 4.2.2ii). To enable a greater match to the magnitude of measured drawdown at the monitoring trigger bores during history-matching and increase the utility of the model in terms of predicting the likelihood of a breach of trigger levels, an individual multiplier was used at each bore to improve (reduce) the model mismatch. The drawdown multiplier for each bore is as follows:

- GW036553: 1.4
- GW036597: 12
- GW036611: 4.

Modelled hydrographs for the trigger monitoring bores are presented in Figure 5.13. The following impacts are predicted:

- Groundwater levels to remain above the investigation and mitigation threshold at GW036553 for the simulated project scenario. The only exception is the P10 (10th percentile) around 2010 (during history-matching), representing a less than 10% probability of drawdown exceeding the trigger level. The measured data show that this exceedance did not occur in reality.
- Groundwater levels to remain above the investigation threshold at GW036597 for the P90 and base realisation. The P10 percentile (considered ‘very unlikely’) is predicted to exceed the trigger level during the operation of the Project, but then recovers from 2040. The P10 estimate shows the best match for groundwater levels in 2010 to 2012, but the P90 estimate shows a better fit to later data.
- Base realisation groundwater levels at GW036611 are predicted to just exceed the investigation threshold during the later stages of operation of the Project but are then predicted to recover quickly to above the trigger level. Post-2040, the P10 percentile is expected to breach the trigger, however this is based on a ‘very unlikely’ probability of occurrence.

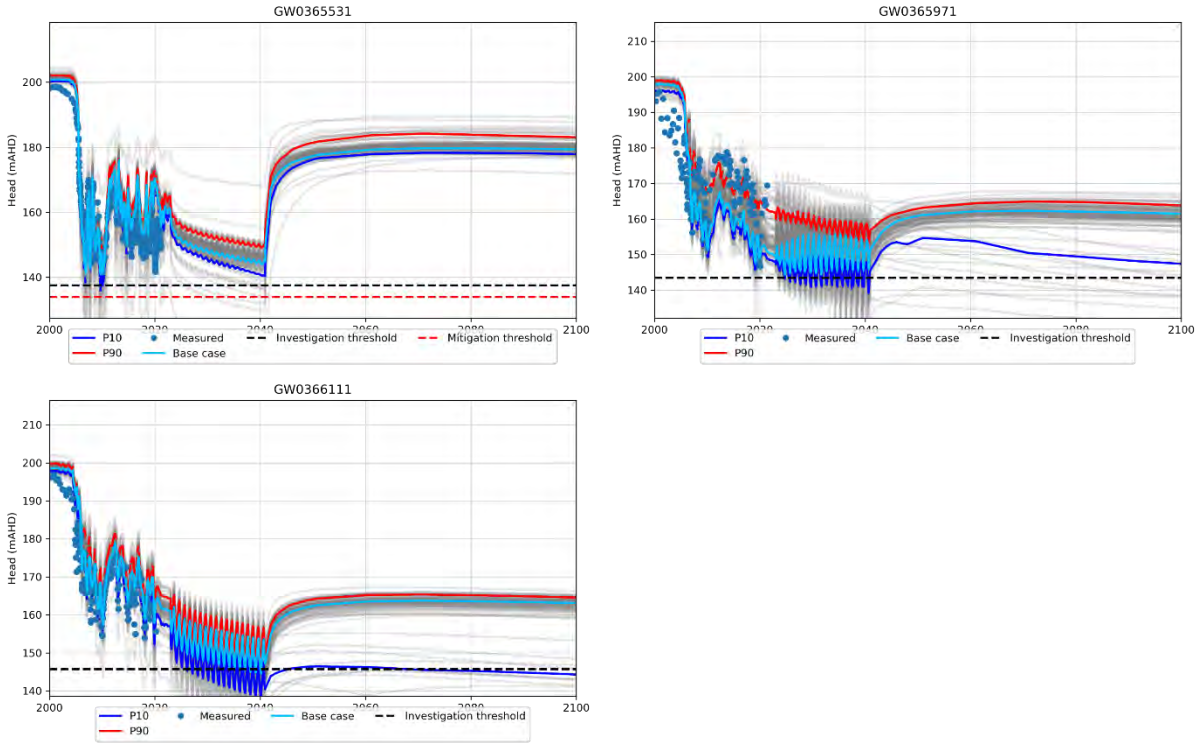


Figure 5.13 Compliance monitoring bore hydrographs

5.4.2 Drawdown at GDEs

As part of the Biodiversity Development Assessment Report (BDAR) (EMM 2023b), GDEs with potential risk of drawdown were identified and hydrographs exported at representative locations. Hydrographs of absolute groundwater level were calculated on base realisation parameters for Prediction 2, 3, and 4 ("Approved", "Proposed – dry case" and "Proposed – wet case" respectively), as well as an additional Prediction 5 ("Proposed – recovery case", discussed in Appendix E). These hydrographs are presented in Figure 5.14. Given the improved representation of long-term pit lake conditions, the new "recovery case" is considered to be the best (most plausible) estimate of the presented scenarios. Drawdown impacts are predicted to be long-term in nature for multiple PCTs, though the incremental impact is not expected to exceed 10 m from the currently approved scenario.

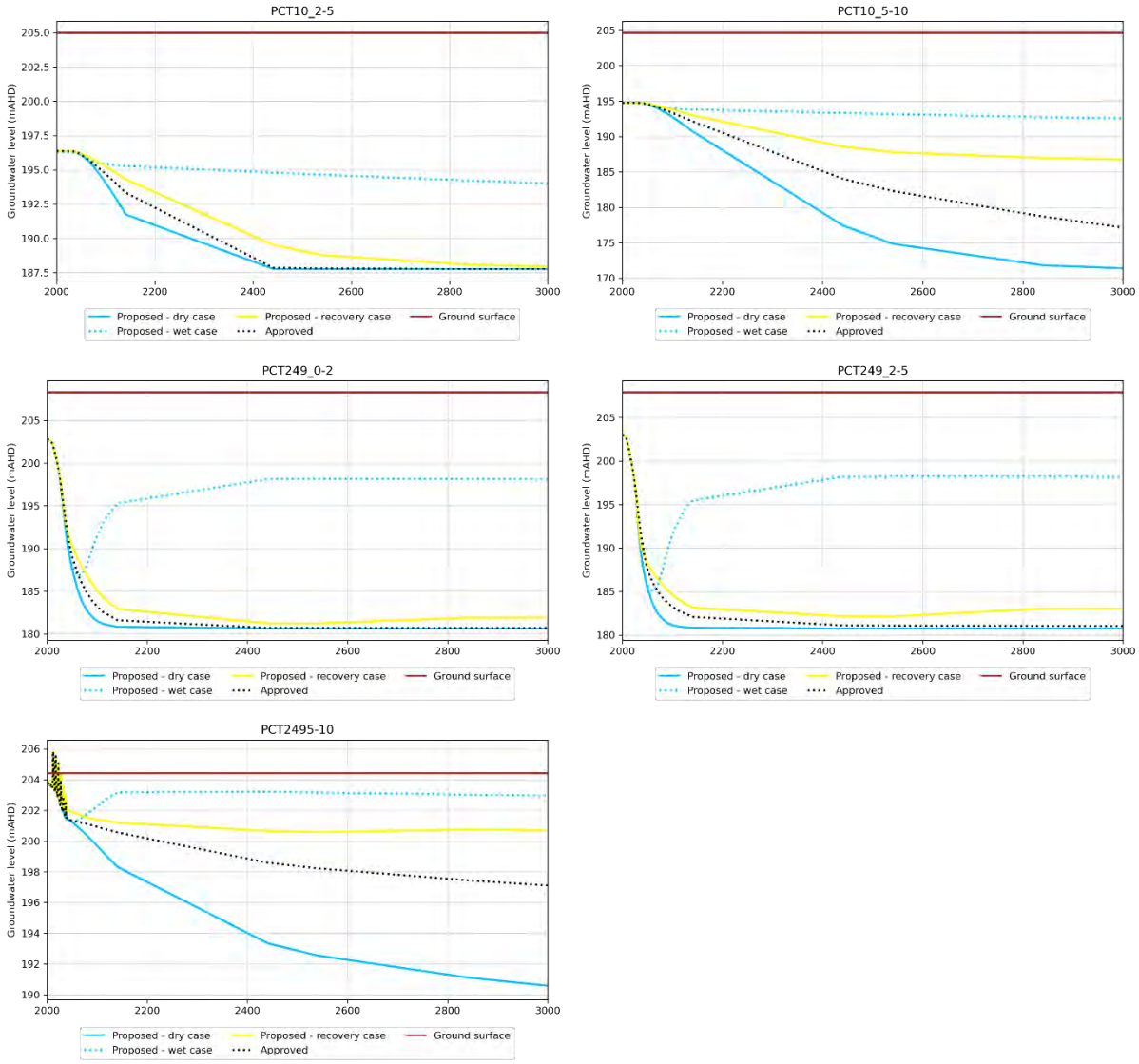
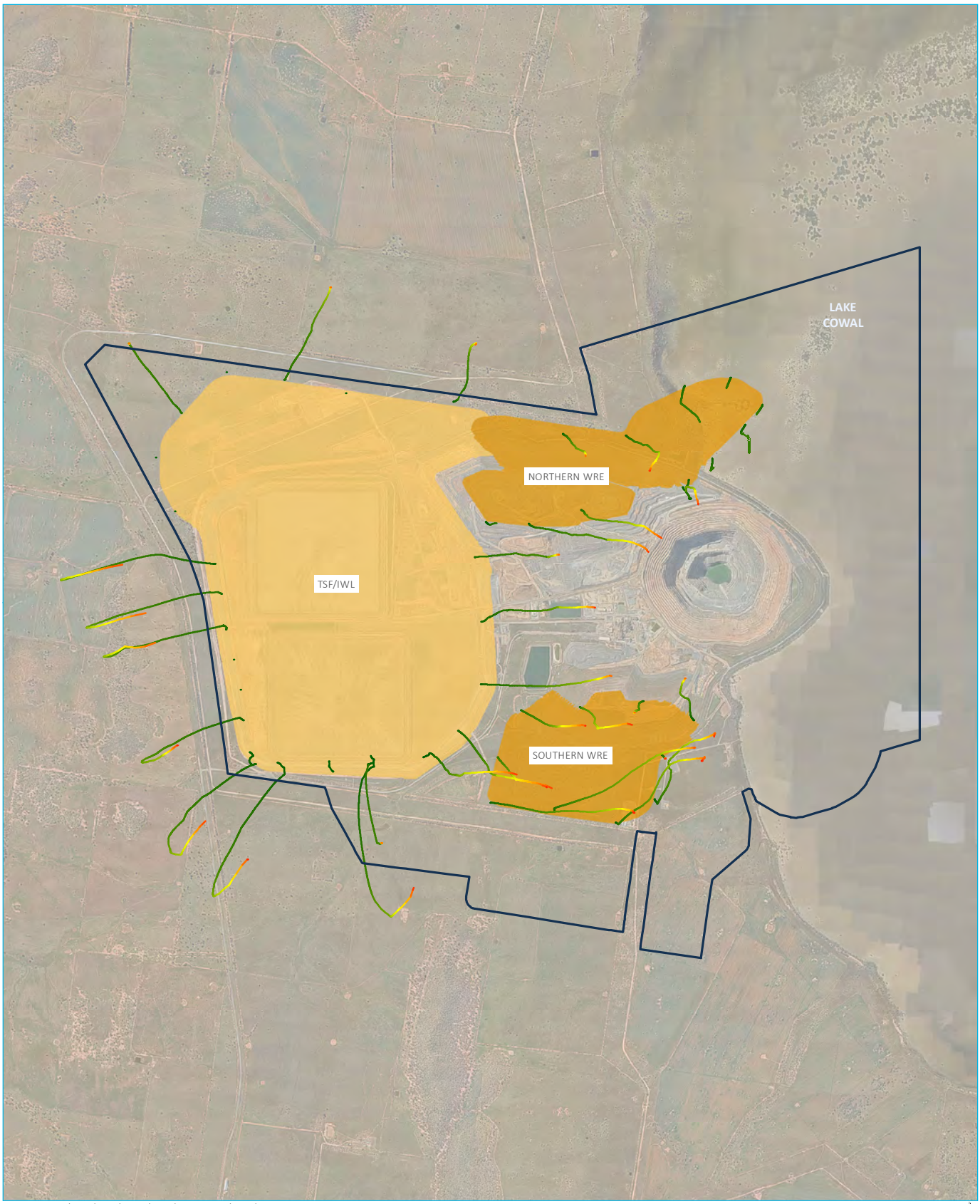


Figure 5.14 GDE hydrographs

5.5 Groundwater quality

Advective particle tracking via MP3DU version 2 (SSPA 2022) was activated at the outer edges of the IWL and WREs and particles tracked for 200 years following the cessation of mining for the fast recovery case. Simulated particle flowpaths are presented in Figure 5.15.

East of the IWL, particles flow directly towards open pits and are removed via evaporation. West of the IWL, particles initially flow westward or southward following the mounding from seepage. Despite the fast recovery model design (which should be conservative with respect to solute transport migration from the site), long-term modelled drawdown from pit voids exceeds the localised mounding at the waste areas (refer Figure 5.7) and the particles reverse direction, move deeper in the aquifer and migrate towards the pits within 100 years of the end of mining. Some particles to the north do not reverse direction, but stagnate within 1 km of the IWL boundary. Potential contaminants from seepage are therefore not expected to enter the regional groundwater system.



Source: EMM (2023); Evolution (2023); Nearmap (2021)

0 1 2 km

GDA 1994 MGA Zone 55

N

KEY

Project area

Conceptual project infrastructure

TSF/IWL

Waste rock emplacement (WRE)

Particle tracking (year)

2240

2006

Particle tracking from IWL and WRE

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Model
Figure 5.15

EMM
creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA024_200yrParticleTracking_20230519_03.mxd 19/05/2023

6 Modelling review checklist

6.1 Independent peer review

The AIP requires that models submitted in support of Major Project developments meet the following criteria:

- Undergo independent review.
- Be consistent with the AGMG.
- Be fit for purpose to the satisfaction of the Minister.

Will Minchin, Director of Watershed HydroGeo was engaged to undertake an independent review of the groundwater modelling. Will is a Hydrogeologist who has been practicing since 2002. He has a strong background in groundwater modelling and ground impact assessment associated with mining and civil projects. Will's review is attached as Appendix F. In summary, Will's review found the model to have been carried out in a professional manner that meets contemporary industry standards, and generally completed in line with relevant industry guidelines. No fatal flaws were identified which would significantly affect the ability of the model to make useful predictions, especially considering the uncertainty analysis conducted.

7 Summary

Evolution is proposing to extend open pit mining operations at its existing CGO open pit and underground gold mine at Lake Cowal. The potential groundwater impacts were predicted using a numerical groundwater flow model, with impacts to landholder bores, GDEs and surface water features considered. The numerical model predicts the following:

- There are two separate drawdown zones associated with the mine and borefield pumping. Drawdown from mining will propagate outside the boundary of ML 1535. However, the difference in drawdown impacts between the approved CGO operations and the proposed mining activities are considered minor:
  - The continued operation of the CGO borefields in association with the Project does not result in groundwater level drawdown 2 m greater than that from current approved operation.
  - There is no material change in groundwater level drawdown at any landholder bore associated with the Project when it is considered on its own (i.e. incremental drawdown).
- Groundwater levels are predicted to remain above the investigation and mitigation trigger levels at DPE Water bore GW036553 (located near the mine borefield). Water levels at this trigger bore govern the operation of the CGO borefields.
- Under the AIP-specific cumulative impact evaluation (i.e. incorporating the approved operations, the local private bore operations, the CGO borefields plus the Project), the maximum cumulative drawdown is predicted to exceed the AIP minimal impact considerations (2 m drawdown) at four bores. Drawdown is calculated for this evaluation as cumulative impact relative to conditions in 2012, and bores which have predicted drawdown exceeding 2 m drawdown in more than 10% of the model realisations were identified as being at risk. This is discussed further in the GIA (EMM 2023a).
- Two River Red Gum PCTs, assessed and confirmed as high priority GDEs, are predicted to experience greater than 0.5 m drawdown in groundwater level, a threshold representing 10% of the natural fluctuation in groundwater level. This is discussed further in the GIA (EMM 2023a).
- Field investigations and chemical analysis suggest that the lake is hydraulically separated from the groundwater system by a small unsaturated zone beneath the lake, and that a pathway does not exist between the mine site activities and the lake. This hydraulic separation is not fully captured in the groundwater model, as some areas of Lake Cowal are simulated as hydraulically connected to the watertable. Modelled seepage predictions from Lake Cowal are therefore conservative.
- Potential contaminant movement via seepage from the WREs and the TSF/IWL are likely to remain localised with potential impacts from acid and metalliferous drainage and/or saline drainage expected to be limited. Furthermore, there are no groundwater users predicted to be impacted. There are ongoing groundwater quality changes around the borefields, resulting from induced leakage from borefield pumping, however this is not predicted to change the groundwater quality beneficial use category (i.e. brackish and suitable for irrigation and industrial uses).

8 References

Anderson MP & Woessner WM 1991, *Applied groundwater modelling*. First edition, Academic Press.

ATC Williams 2023, Cowal Gold Operations Open Pit Continuation Environmental Impact Statement Surface Water Assessment, prepared for EMM Consulting Pty Limited, April 2023.

Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A & Boronkay A 2012, *Australian groundwater modelling guidelines,* Waterlines report series number 12. National Water Commission.

Bilge H 2012, *Upper Lachlan groundwater flow model*, NSW Office of Water, Sydney.

BoM 2017, *Groundwater Dependent Ecosystems Atlas*, accessed 15 August 2022, http://www.bom.gov.au/water/groundwater/gde/

Coffey Services Australia Pty Ltd 2006a, *Cowal Gold Mine, groundwater supply modelling study, model calibration*, report no. S21910/2AK, 15 September 2006.

Coffey Geosciences Pty Ltd 2006b, *Cowal Gold Mine, groundwater supply modelling study, model calibration*, report S21910/02AK, prepared for Barrick Australia Limited, October 2006.

Coffey Geotechnics Pty Ltd 2013, *Final hydrogeological assessment, CGO extension modification*, report GEOTLCOV21910AW-AI, prepared for Barrick, September 2013.

Coffey Services Australia Pty Ltd 2016, *Cowal Gold Operations, mine life modification, Bland Creek palaeochannel borefield and Eastern Saline borefield groundwater assessment*, report GEOTLCOV21910BG-BCPB, prepared for Evolution Mining (Cowal) Pty Ltd, November 2016.

Coffey Services Australia Pty Ltd 2018a, *Cowal Gold Operations, processing rate modification (MOD14), mine site hydrogeological assessment*, report no. 754-SYDGE206418-AA, 2 March 2018.

Coffey Services Australia Pty Ltd 2018b, *Cowal Gold Operations, processing rate modification (MOD14), Bland Creek Palaeochannel borefield and Eastern Saline borefield groundwater assessment*, report no. 754-SYDGE206418-BCPB, 24 March 2018.

Coffey Services Australia Pty Ltd 2020a, *Cowal Gold Operations, underground EIS. Bland Creek Palaeochannel borefield and Eastern Saline borefield groundwater assessment*, prepared for EMM Consulting Pty Ltd, 27 August 2020. SYDGE206418-3-AN.

Coffey Services Australia Pty Ltd 2020b, *Cowal underground development EIS, mine site hydrogeological assessment*, prepared for EMM Consulting Pty Ltd, 10 September, 2020. 754-SYDGE206418-3-AM.

DPE 2022, *Minimum groundwater modelling requirements for Major Projects in NSW. Technical note prepared for the Water Division*, NSW Department of Planning and Environment as part of the Groundwater Modelling Toolbox Project.

Doherty J 2016, *PEST Model-independent parameter estimation user manual part I: PEST, SENSAN and Global Optimisers*, Sixth edition, Watermark Numerical Computing.

EMM 2023a, Cowal Gold Operations – Open Pit Continuation Project, Groundwater Impact Assessment, Prepared for Evolution Mining, May 2023.

EMM 2023b, Cowal Gold Operations – Open Pit Continuation Project, Biodiversity Development Assessment Report, Prepared for Evolution Mining, May 2023.

Environmental Simulations Incorporated 2022, *Groundwater Vistas version 8*. www.groundwatermodels.com

Fandrich R 2016, *Measurements and modelling of evaporation from abandoned mine pit lakes*, AusIMM Life-of-Mine 2016, Brisbane.

HydroAlgorithmics 2020, *AlgoMesh 2*, www.hydroalgorithmics.com/software/algomesh.

Lampayan RM 2001, *Groundwater hydrology and modelling of the Jemalong and Lake Cowal aquifer systems*, Lachlan Catchment, NSW. Unpublished Thesis, The Australian National University, Canberra

Middlemis H & Peeters LJM 2018, *Uncertainty analysis – guidance for groundwater modelling within a risk management framework*. A report prepared for the Independent Expert Scientific Committee on coal seam gas and large coal mining development through the Department of the Environment and Energy, Commonwealth of Australia 2018.

Middlemis H 2021, *Cowal Gold underground development groundwater assessment peer review. Prepared for: NSW Department of Planning Industry and Environment*. 20 May 2021. (Final Review). HydroGeoLogic Pty Ltd.

NSW Department of Planning and Environment 2016, ANUCLIM annual mean rainfall raster, accessed 11 January 2023 from https://www.planningportal.nsw.gov.au/opendata/dataset/anuclim-annual-mean-rainfall-raster-layer

NSW Department of Planning, Industry and Environment 2021a, *Cowal Gold Operations Underground Development (SSD 10367) & Cowal Gold Mine. (DA 14/98) Modification 16. EIS & Modification*, 22 January 2021. OUT20/14674.

NSW Department of Planning, Industry and Environment 2021b, *Cowal Gold Operations Underground Development and Modification 16 (SSD 10367) Response to Submissions*, 29 April 2021. OUT21/2581.

Panday S, Langevin CD, Niswonger RG, Ibaraki, Motomu & Hughes JD 2013, *MODFLOW-USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation*, U.S. Geological Survey Techniques and Methods, book 6, chapter A45.

Panday S 2022, *USG-Transport Version 1.10.0: The Block-Centered Transport Process for MODFLOW-USG*, GSI Environmental, Jun 2022, http://www.gsi-net.com/en/software/free-software/UST-Transport.html

SSPA 2022, mod-PATH3DU version 2, S.S. Papadopulos & Associates, Inc., October 2022, http://mp3du.sspa.com/

Appendix A
Bore locations

EMM
creating opportunities

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
13W	551927	6305468	2	Monitoring
14CW	553067	6303666	2	Monitoring
14DP	553078	6303835	2	Monitoring
14DW	553078	6303835	1	Monitoring
14FW	553185	6303964	2	Monitoring
14W	551783	6304542	2	Monitoring
16W	551307	6301588	2	Monitoring
17W	550608	6298384	2	Monitoring
18W	550353	6296779	2	Monitoring
26BP	545815	6306224	2	Monitoring
26BW	545815	6306224	2	Monitoring
26CW	545790	6306085	2	Monitoring
26DW	545765	6305880	2	Monitoring
26EP	545739	6305705	2	Monitoring
26EW	545739	6305705	1	Monitoring
26HW	545636	6305083	2	Monitoring
26IW	545608	6304940	1	Monitoring
26KW	545583	6304723	1	Monitoring
27P	545590	6304647	2	Monitoring
27W	545590	6304647	1	Monitoring
28W	545322	6302937	2	Monitoring
29P	544522	6299469	2	Monitoring
29W	544523	6299469	2	Monitoring
38W	534198	6301032	5	Monitoring
39W	539161	6300309	2	Monitoring
40P	541051	6299388	2	Monitoring
40W	541051	6299388	2	Monitoring
41W	535011	6290083	2	Monitoring
42W	543750	6292228	2	Monitoring
43P	547283	6295851	2	Monitoring
43W	547283	6295851	2	Monitoring
44W	545329	6286801	2	Monitoring

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
45W	551568	6285778	2	Monitoring
46W	553730	6290631	2	Monitoring
47P	556050	6279565	2	Monitoring
47W	556050	6279565	2	Monitoring
48W	559029	6284144	2	Monitoring
50W	551121	6281522	2	Monitoring
56W	565629	6298756	2	Monitoring
59W	561908	6301271	2	Monitoring
60P	562081	6298889	2	Monitoring
60W	562081	6298889	2	Monitoring
61W	562040	6297507	2	Monitoring
62W	559172	6294512	2	Monitoring
6P	557874	6302033	2	Monitoring
7W	556183	6295736	2	Monitoring
Borefield_Bore_1	553793	6285525	4	Monitoring
Borefield_Bore_2	553082	6285637	4	Monitoring
Borefield_Bore_3	553583	6289370	3	Monitoring
Borefield_Bore_4	553274	6287388	4	Monitoring
Borefield_Bore_5	552439	6282735	4	Monitoring
Borefield_Bore_6	553673	6283963	4	Monitoring
Borefield_Bore_7	555370	6283675	4	Monitoring
CGOMB01A	536500	6280015	3	Monitoring
CGOMB01B	536497	6280015	3	Monitoring
CGOMB02A	537217	6275631	3	Monitoring
CGOMB02B	537217	6275637	3	Monitoring
D323	537965	6278232	6	Monitoring
D325	538004	6277840	6	Monitoring
D326	537763	6277733	6	Monitoring
Eastern_Saline_Borefield_PZ01	555703	6287188	2	Monitoring
Eastern_Saline_Borefield_PZ02	556267	6288075	2	Monitoring
Eastern_Saline_Borefield_PZ05	555984	6286935	2	Monitoring

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
Eastern_Saline_Borefield_PZ08	556465	6286841	3	Monitoring
Eastern_Saline_Borefield_PZ09	556588	6288436	2	Monitoring
Eastern_Saline_Borefield_PZ10	556585	6288435	3	Monitoring
Eastern_Saline_Borefield_PZ11	556582	6288433	3	Monitoring
Eastern_Saline_Borefield_SB3	557116	6289198	3	Monitoring
Eastern_Saline_Borefield_SB5	556447	6286849	2	Monitoring
GW001042/1	563496	6268019	5	Monitoring
GW001369/1	576742	6241432	5	Monitoring
GW002849/1	564684	6242108	3	Monitoring
GW003266/1	561159	6244626	6	Monitoring
GW007803/1	563925	6236076	2	Monitoring
GW008374/1	557852	6237039	3	Monitoring
GW008417/1	568463	6232224	3	Monitoring
GW014843/1	562378	6227153	3	Monitoring
GW017911/1	521666	6285822	6	Monitoring
GW027739/1	577418	6236221	5	Monitoring
GW028040/1	542078	6260622	3	Monitoring
GW029094/1	547041	6267503	4	Pumping
GW029574/1	553360	6273194	2	Monitoring
GW030252/1	572937	6233238	3	Monitoring
GW030270/1	575109	6230994	4	Monitoring
GW030291/1	584034	6232706	2	Monitoring
GW030293/1	584361	6234567	2	Monitoring
GW030328/1	585761	6233041	2	Monitoring
GW030328/2	585761	6233041	2	Monitoring
GW030331/1	586866	6234284	2	Monitoring
GW031028/1	542519	6302322	3	Monitoring
GW031211/1	549157	6242170	2	Monitoring
GW036084/1	558353	6294820	5	Monitoring
GW036086/1	551856	6304832	3	Monitoring
GW036523/1	550698	6298685	2	Monitoring

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
GW036523/2	550698	6298685	5	Monitoring
GW036523/3	550698	6298685	5	Monitoring
GW036524/1	546337	6286862	2	Monitoring
GW036528/1	541506	6300127	2	Monitoring
GW036528/2	541506	6300127	3	Monitoring
GW036528/3	541506	6300127	3	Monitoring
GW036551/1	544672	6299659	2	Monitoring
GW036551/2	544672	6299659	3	Monitoring
GW036552/1	547877	6299086	3	Monitoring
GW036552/2	547877	6299086	3	Monitoring
GW036552/3	547877	6299086	4	Monitoring
GW036553/1	552434	6285773	4	Monitoring
GW036554/1	553151	6298504	2	Monitoring
GW036554/2	553151	6298504	2	Monitoring
GW036554/3	553151	6298504	5	Monitoring
GW036563/1	534784	6301109	2	Monitoring
GW036594/1	549558	6286186	2	Monitoring
GW036594/2	549558	6286186	3	Monitoring
GW036595/1	547929	6263905	3	Monitoring
GW036596/1	550938	6264661	3	Monitoring
GW036596/2	550938	6264661	4	Monitoring
GW036597/1	544505	6263719	3	Monitoring
GW036597/2	544505	6263713	4	Monitoring
GW036603/1	551783	6239735	3	Monitoring
GW036604/1	557258	6240449	4	Monitoring
GW036605/1	554028	6241420	4	Monitoring
GW036606/1	564753	6238189	4	Monitoring
GW036609/1	554624	6285396	4	Monitoring
GW036610/1	549088	6264456	3	Monitoring
GW036611/1	553937	6264823	4	Monitoring
GW036613/1	541663	6263705	3	Monitoring

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
GW036627/1	571942	6240028	7	Monitoring
GW036629/1	573127	6234814	2	Monitoring
GW036700/1	555433	6264788	3	Monitoring
GW036741/1	584776	6237170	2	Monitoring
GW036741/2	584776	6237170	5	Monitoring
GW036825/1	564461	6255397	3	Monitoring
GW039378/1	565829	6221830	4	Monitoring
GW039379/1	557312	6240441	4	Monitoring
GW050717/1	554718	6245127	3	Monitoring
GW057974/1	547180	6268021	4	Pumping
GW090004/1	568613	6250395	2	Monitoring
GW090010/1	561380	6293359	2	Monitoring
GW090011/1	559937	6293796	2	Monitoring
GW090093/1	549832	6294377	2	Monitoring
GW090093/2	549832	6294377	3	Monitoring
GW090093/3	549832	6294377	4	Monitoring
GW700582/1	553274	6287386	4	Monitoring
GW700583/1	552439	6282737	5	Monitoring
GW700585/1	555370	6283681	4	Monitoring
GW701125/1	562296	6293622	2	Monitoring
GW701126/1	562209	6293055	2	Monitoring
GW701127/1	553109	6281447	2	Monitoring
GW701129/1	556703	6282855	2	Monitoring
GW701267/1	552731	6266198	4	Pumping
GW701454/1	557158	6240472	4	Pumping
GW701579/1	553767	6269660	5	Monitoring
GW701646/1	545012	6265729	4	Pumping
GW701657/1	552408	6282736	4	Pumping
GW701658/1	555360	6283678	4	Pumping
GW701659/1	553071	6285635	4	Pumping
GW701660/1	553276	6287386	4	Pumping

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
GW701679	544575	6301818	3	Pumping
GW701681/1	552812	6266221	4	Monitoring
GW701958/1	556272	6270630	4	Pumping
GW702013/1	556515	6278585	4	Pumping
GW702100/1	552407	6285421	4	Monitoring
GW702111/1	553080	6285639	5	Monitoring
GW702123	554228	6302728	2	Pumping
GW702127/1	542922	6259675	4	Pumping
GW702262/1	549449	6293272	4	Pumping
GW702285/1	553174	6286458	4	Monitoring
GW702286/1	555900	6279959	4	Pumping
IWL01_-_A	534124	6279095	5	Monitoring
IWL01_-_B	534112	6279092	3	Monitoring
IWL02_-_A	533284	6278854	5	Monitoring
IWL02_-_B	533277	6278850	3	Monitoring
IWL03_-_A	533024	6277443	6	Monitoring
IWL03_-_B	533024	6277434	2	Monitoring
IWL04_-_A	533243	6276317	6	Monitoring
IWL05_-_A	534568	6276045	5	Monitoring
IWL05_-_B	534584	6276047	5	Monitoring
IWL06_-_A	535762	6277243	5	Monitoring
IWL06_-_B	535757	6277223	3	Monitoring
Monitoring_Bore_P318	537400	6278153	7	Monitoring
Monitoring_Bore_P320	537267	6278003	6	Monitoring
Monitoring_Bore_P321	537380	6277854	5	Monitoring
Monitoring_Bore_P330	537323	6278051	5	Monitoring
Monitoring_Bore_P331	537367	6278052	5	Monitoring
Monitoring_Bore_P410A	535771	6278468	5	Monitoring
Monitoring_Bore_P410B	535771	6278468	2	Monitoring
Monitoring_Bore_P411A	534464	6277938	5	Monitoring
Monitoring_Bore_P411B	534464	6277938	3	Monitoring

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
Monitoring_Bore_P413A	534685	6277000	3	Monitoring
Monitoring_Bore_P413B	534685	6277000	3	Monitoring
Monitoring_Bore_P415A	536934	6277191	5	Monitoring
Monitoring_Bore_P415B	536934	6277191	2	Monitoring
Monitoring_Bore_P416A	535875	6276790	5	Monitoring
Monitoring_Bore_P416B	535875	6276790	2	Monitoring
Monitoring_Bore_P554A	534140	6276603	3	Monitoring
Monitoring_Bore_P554B	534138	6276603	3	Monitoring
Monitoring_Bore_P556A	534163	6277079	5	Monitoring
Monitoring_Bore_P556B	534165	6277079	3	Monitoring
Monitoring_Bore_P557A	533804	6277634	5	Monitoring
Monitoring_Bore_P557B	533801	6277633	3	Monitoring
Monitoring_Bore_P559	534011	6278171	5	Monitoring
Monitoring_Bore_P560A	534386	6278488	5	Monitoring
P322	537370	6278055	3	Pumping
PBP2	538146	6278576	11	Monitoring
PBP3	538598	6278157	2	Monitoring
PBP4	538576	6277565	2	Monitoring
PD1	538258	6278228	5	Pumping
PD10	537863	6277429	6	Pumping
PD101	538405	6278009	2	Pumping
PD102	538400	6277958	2	Pumping
PD103	538397	6277821	2	Pumping
PD104	538368	6277720	2	Pumping
PD105	538323	6277660	2	Pumping
PD106	537962	6277400	3	Pumping
PD107	537855	6277403	3	Pumping
PD11	537713	6277427	6	Pumping
PD12	537520	6277489	6	Pumping
PD14	537317	6277690	5	Pumping
PD16	537315	6278326	6	Pumping

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
PD17	537622	6278436	2	Pumping
PD18	537925	6278436	2	Pumping
PD19	538266	6278067	2	Pumping
PD2	538327	6277973	6	Pumping
PD20	538168	6278013	5	Pumping
PD21	538172	6277828	2	Pumping
PD22	538108	6277602	2	Pumping
PD23	538036	6277596	6	Pumping
PD24	538036	6277596	2	Pumping
PD26	537703	6278088	2	Pumping
PD3	538323	6277875	6	Pumping
PD30_(PZ23)	538273	6277720	2	Pumping
PD4	538324	6277785	1	Pumping
PD5	538309	6277688	2	Pumping
PD6	538242	6277577	6	Pumping
PD7	538177	6277427	6	Pumping
PD8	538067	6277459	2	Pumping
PD9	537958	6277433	6	Pumping
Pit_Bore_PDB1A	537281	6279033	6	Monitoring
Pit_Bore_PDB1B	537283	6279031	2	Monitoring
Pit_Bore_PDB1C	537280	6279030	2	Monitoring
Pit_Bore_PDB2A	537879	6278430	5	Monitoring
Pit_Bore_PDB3A	538502	6277855	6	Monitoring
Pit_Bore_PDB3B	538507	6277854	2	Monitoring
Pit_Bore_PDB4A	538358	6277855	6	Monitoring
Pit_Bore_PDB5A	537770	6276933	6	Monitoring
Pit_Bore_PDB5B	537775	6276932	5	Monitoring
Processing_Plant_Bore_1	536981	6277623	3	Monitoring
Processing_Plant_Bore_2	537009	6277528	2	Monitoring
Processing_Plant_Bore_3	536987	6277451	5	Monitoring
Processing_Plant_Bore_4	536895	6277292	2	Monitoring

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
Processing_Plant_Bore_5	536713	6277423	3	Monitoring
Processing_Plant_Bore_6	536778	6277586	2	Monitoring
PZ01VWP1	537437	6278360	7	Monitoring
PZ01VWP2	537437	6278360	6	Monitoring
PZ01VWP3	537437	6278360	5	Monitoring
PZ02VWP1	537832	6278450	6	Monitoring
PZ02VWP2	537832	6278450	6	Monitoring
PZ02VWP3	537832	6278450	5	Monitoring
PZ03VWP1	538045	6278335	6	Monitoring
PZ03VWP2	538045	6278335	6	Monitoring
PZ03VWP3	538045	6278335	5	Monitoring
PZ04VWP1	538242	6277953	6	Monitoring
PZ04VWP2	538242	6277953	5	Monitoring
PZ04VWP3	538242	6277953	2	Monitoring
PZ05VWP1	538223	6277740	6	Monitoring
PZ05VWP2	538223	6277740	6	Monitoring
PZ06VWP1	538074	6277563	6	Monitoring
PZ06VWP2	538074	6277563	6	Monitoring
PZ06VWP3	538074	6277563	3	Monitoring
PZ07VWP1	537899	6277522	6	Monitoring
PZ07VWP2	537899	6277522	6	Monitoring
PZ08VWP2	537523	6277564	5	Monitoring
PZ08VWP3	537523	6277564	3	Monitoring
PZ09VWP1	537283	6277822	6	Monitoring
PZ09VWP2	537283	6277822	6	Monitoring
PZ09VWP3	537283	6277822	6	Monitoring
PZ11VWP1	537715	6278569	9	Monitoring
PZ11VWP2	537715	6278569	6	Monitoring
PZ11VWP3	537715	6278569	6	Monitoring
PZ12VWP1	538151	6278331	9	Monitoring
PZ12VWP2	538151	6278331	5	Monitoring

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
PZ12VWP3	538151	6278331	5	Monitoring
PZ13VWP1	538338	6278577	8	Monitoring
PZ13VWP2	538338	6278577	6	Monitoring
PZ13VWP3	538338	6278577	6	Monitoring
PZ13VWP4	538338	6278577	5	Monitoring
PZ14VWP1	538502	6277907	9	Monitoring
PZ14VWP2	538502	6277907	6	Monitoring
PZ14VWP3	538502	6277907	5	Monitoring
PZ14VWP4	538502	6277907	5	Monitoring
PZ14VWP5	538502	6277907	3	Monitoring
PZ15VWP1	538398	6277715	9	Monitoring
PZ15VWP2	538398	6277715	6	Monitoring
PZ15VWP3	538398	6277715	6	Monitoring
PZ15VWP4	538398	6277715	5	Monitoring
PZ15VWP5	538398	6277715	5	Monitoring
PZ16VWP1	538299	6277576	9	Monitoring
PZ16VWP2	538299	6277576	6	Monitoring
PZ16VWP3	538299	6277576	6	Monitoring
PZ16VWP4	538299	6277576	5	Monitoring
PZ16VWP5	538299	6277576	5	Monitoring
PZ17VWP1	538517	6277389	8	Monitoring
PZ17VWP2	538517	6277389	6	Monitoring
PZ17VWP3	538517	6277389	6	Monitoring
PZ17VWP4	538517	6277389	5	Monitoring
PZ17VWP5	538517	6277389	2	Monitoring
PZ18VWP1	538114	6277452	9	Monitoring
PZ18VWP2	538114	6277452	6	Monitoring
PZ18VWP3	538114	6277452	5	Monitoring
PZ18VWP4	538114	6277452	5	Monitoring
PZ19VWP1	537936	6277411	9	Monitoring
PZ19VWP2	537936	6277411	6	Monitoring

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
PZ19VWP3	537936	6277411	6	Monitoring
PZ19VWP4	537936	6277411	5	Monitoring
PZ19VWP5	537936	6277411	3	Monitoring
PZ21VWP1	537364	6277581	6	Monitoring
PZ21VWP2	537364	6277581	6	Monitoring
PZ21VWP3	537364	6277581	5	Monitoring
PZ21VWP4	537364	6277581	5	Monitoring
PZ21VWP5	537364	6277581	3	Monitoring
PZ22VWP1	537425	6278461	9	Monitoring
PZ22VWP2	537425	6278461	6	Monitoring
PZ22VWP3	537425	6278461	6	Monitoring
PZ22VWP4	537425	6278461	5	Monitoring
PZ24VWP1	538228	6278087	6	Monitoring
PZ24VWP2	538240	6278095	6	Monitoring
PZ24VWP3	538248	6278099	6	Monitoring
PZ24VWP4	538253	6278102	5	Monitoring
PZ25VWP1	538231	6277867	6	Monitoring
PZ25VWP2	538238	6277874	6	Monitoring
PZ25VWP3	538245	6277880	5	Monitoring
PZ25VWP4	538256	6277888	5	Monitoring
PZ26VWP1	538246	6278258	6	Monitoring
PZ26VWP2	538259	6278258	6	Monitoring
PZ26VWP3	538274	6278258	5	Monitoring
PZ28VWP1	538336	6277986	6	Monitoring
PZ28VWP2	538341	6277986	6	Monitoring
PZ28VWP3	538356	6277986	6	Monitoring
PZ28VWP4	538364	6277986	5	Monitoring
PZ29VWP1	538285	6277808	6	Monitoring
PZ29VWP2	538295	6277808	6	Monitoring
PZ29VWP3	538313	6277808	5	Monitoring
PZ29VWP4	538322	6277808	5	Monitoring

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
PZ29VWP5	538339	6277808	3	Monitoring
PZ30VWP1	538130	6278525	6	Monitoring
PZ30VWP2	538130	6278525	6	Monitoring
PZ31VWP1	537742	6277421	6	Monitoring
PZ31VWP2	537742	6277421	5	Monitoring
PZ31VWP4	537742	6277421	3	Monitoring
PZ32VWP1	538166	6277615	6	Monitoring
PZ32VWP2	538166	6277615	6	Monitoring
PZ32VWP3	538166	6277615	6	Monitoring
PZ33VWP1	538394	6278114	6	Monitoring
PZ33VWP2	538394	6278114	6	Monitoring
PZ33VWP3	538394	6278114	5	Monitoring
PZ33VWP4	538394	6278114	2	Monitoring
PZ35VWP1	537545	6277463	6	Monitoring
PZ35VWP2	537545	6277463	6	Monitoring
PZ35VWP4	537545	6277463	3	Monitoring
PZ36VWP1	537949	6277993	16	Monitoring
PZ36VWP2	537973	6277989	16	Monitoring
PZ36VWP3	537997	6277986	15	Monitoring
PZ36VWP4	538019	6277982	14	Monitoring
PZ36VWP5	538043	6277979	13	Monitoring
PZ36VWP6	538066	6277975	12	Monitoring
PZ37VWP1	537796	6277678	16	Monitoring
PZ37VWP2	537816	6277605	14	Monitoring
PZ37VWP3	537844	6277500	11	Monitoring
PZ37VWP4	537859	6277445	8	Monitoring
PZ37VWP5	537868	6277412	6	Monitoring
PZ37VWP6	537879	6277371	3	Monitoring
PZ38VWP1	537578	6277373	6	Monitoring
PZ38VWP2	537578	6277373	6	Monitoring
PZ38VWP3	537578	6277373	3	Monitoring

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
PZ39VWP1	537479	6277743	15	Monitoring
PZ39VWP2	537430	6277684	13	Monitoring
PZ39VWP3	537397	6277645	12	Monitoring
PZ39VWP4	537365	6277607	9	Monitoring
PZ39VWP5	537333	6277569	6	Monitoring
PZ39VWP6	537296	6277525	2	Monitoring
PZ40VWP1	537124	6277691	6	Monitoring
PZ40VWP2	537124	6277691	5	Monitoring
PZ40VWP3	537124	6277691	3	Monitoring
PZ41VWP1	537035	6277933	6	Monitoring
PZ41VWP2	537035	6277933	5	Monitoring
PZ41VWP3	537035	6277933	3	Monitoring
PZ42VWP1	537389	6278049	15	Monitoring
PZ42VWP2	537298	6278101	12	Monitoring
PZ42VWP3	537235	6278138	9	Monitoring
PZ42VWP4	537175	6278172	6	Monitoring
PZ42VWP5	537149	6278188	5	Monitoring
PZ42VWP6	537135	6278195	5	Monitoring
PZ43VWP1	537688	6278283	15	Monitoring
PZ43VWP2	537677	6278418	12	Monitoring
PZ43VWP3	537669	6278506	7	Monitoring
PZ43VWP4	537667	6278522	6	Monitoring
PZ43VWP6	537663	6278575	2	Monitoring
RA341	537336	6277603	2	Monitoring
RA342	537400	6277512	2	Monitoring
RA344	537599	6277480	3	Monitoring
RA345	537679	6277399	3	Monitoring
RA346	537800	6277500	3	Monitoring
RA347	537850	6277550	3	Monitoring
RA348	537852	6277534	2	Monitoring
RA349	537817	6277500	3	Monitoring

Table A.1 Bore locations

Name	Easting (m)	Northing (m)	Model layer	Purpose
RA350	537817	6277500	3	Monitoring
SB01	555740	6287128	3	Pumping
SB02	556315	6288003	2	Pumping
SB04	557324	6288376	3	Pumping
Trigalana_East	556501	6279959	4	Pumping
TSF_-_INV_-_01	534118	6278893	2	Monitoring
TSF_-_INV_-_01A	534118	6278893	1	Monitoring
TSF_-_INV_-_02	534812	6278684	3	Monitoring
TSF_-_INV_-_03	534731	6278442	3	Monitoring
TSF_-_INV_-_04	534898	6278381	3	Monitoring
TSF_-_INV_-_05	534727	6278282	3	Monitoring
TSF_-_INV_-_06	533778	6277489	3	Monitoring
TSF_-_INV_-_07	534171	6276193	2	Monitoring
TSF_Bore_MON01A	535112	6278224	6	Monitoring
TSF_Bore_MON01B	535115	6278225	3	Monitoring
TSF_Bore_MON02A	534275	6276084	6	Monitoring
TSF_Bore_MON02B	534277	6276086	5	Monitoring
TSF_Bore_P412A	535171	6277495	5	Monitoring
TSF_Bore_P412A-R	535172	6277491	6	Monitoring
TSF_Bore_P414A	535364	6276681	5	Monitoring
TSF_Bore_P414B	535360	6276680	2	Monitoring
TSF_Bore_P417A	535889	6276338	5	Monitoring
TSF_Bore_P417B	535889	6276333	2	Monitoring
TSF_Bore_P418A	534863	6279181	5	Monitoring
TSF_Bore_P418B	534860	6279182	3	Monitoring
TSF_Bore_P555A-R	533112	6276760	5	Monitoring
TSF_Bore_P558A-R	532890	6277990	6	Monitoring
TSF_Bore_P561A	534601	6279315	5	Monitoring
TSF_Bore_P561B	534601	6279317	3	Monitoring
TSF_Bore_TSFNA	535438	6278074	6	Monitoring
TSF_Bore_TSFNB	535443	6278073	3	Monitoring

Table A.1 Bore locations

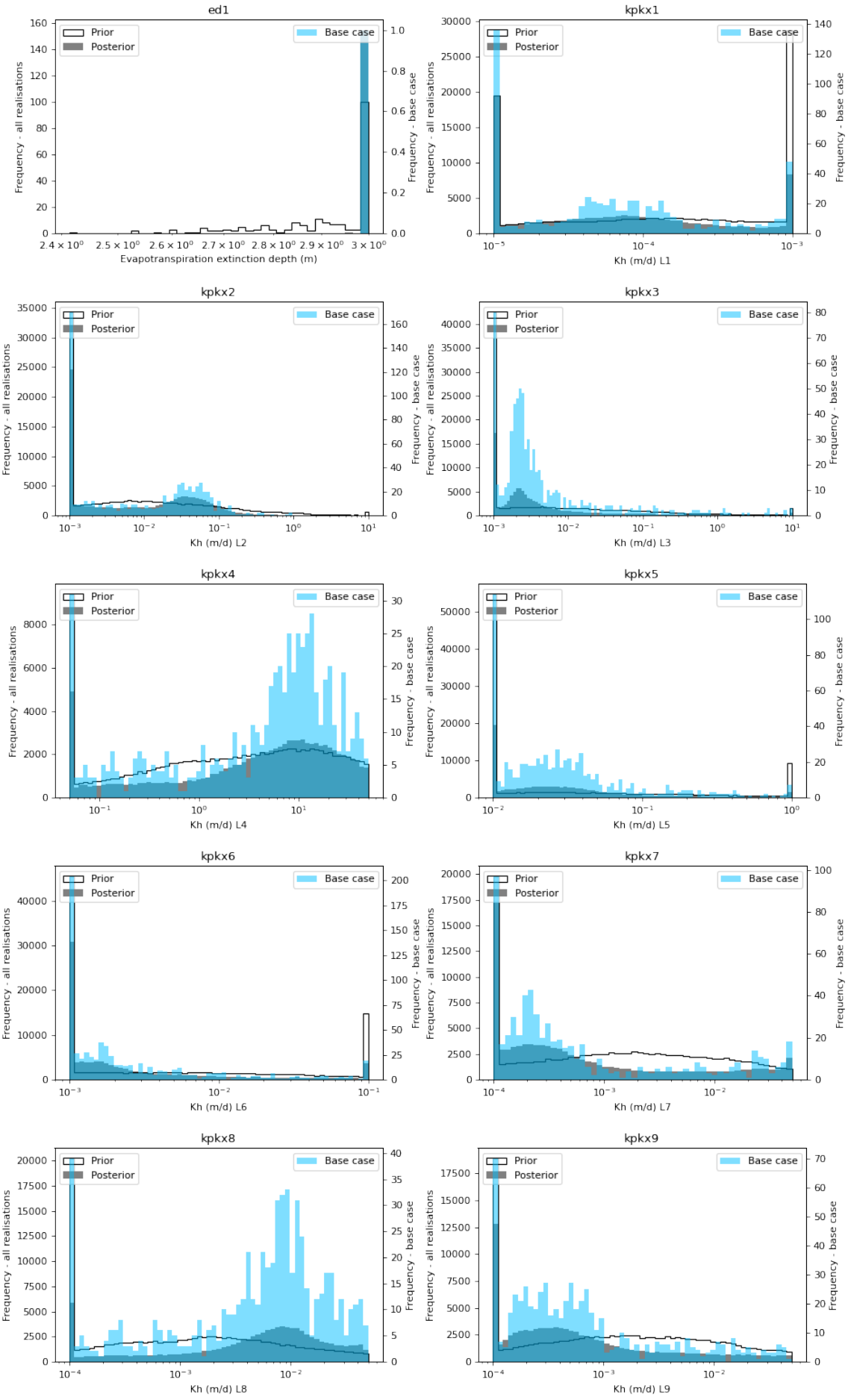
Name	Easting (m)	Northing (m)	Model layer	Purpose
TSF_Bore_TSFNC	535447	6278072	2	Monitoring
UG-BH-01/_SG1	537752	6278844	2	Monitoring
UG-BH-01/_SG2	537752	6278844	2	Monitoring
UG-BH-01/_SG3	537752	6278844	5	Monitoring
UG-BH-02/_SG3	538180	6279594	6	Monitoring
UG-BH-03/_SG1	538019	6278883	2	Monitoring
UG-BH-03/_SG2	538019	6278883	5	Monitoring
UG-BH-03/_SG3	538019	6278883	6	Monitoring
UG-BH-04/_SG1	538169	6278916	2	Monitoring
UG-BH-04/_SG2	538169	6278916	5	Monitoring
UG-BH-04/_SG3	538169	6278916	7	Monitoring
W1825VWP1	538112	6277781	13	Monitoring
W1825VWP2	538112	6277781	12	Monitoring
W1825VWP3	538112	6277781	9	Monitoring
W1829VWP1	537919	6277459	13	Monitoring
W1829VWP2	537924	6277549	12	Monitoring
W1829VWP3	537927	6277609	9	Monitoring
W1831VWP1	537687	6277484	13	Monitoring
W1831VWP2	537696	6277573	12	Monitoring
W1831VWP3	537702	6277633	9	Monitoring
W1832VWP1	537452	6278378	13	Monitoring
W1832VWP2	537484	6278294	12	Monitoring
W1833VWP1	537668	6278254	15	Monitoring
W1833VWP2	537668	6278254	13	Monitoring
W1833VWP3	537668	6278254	12	Monitoring
W271b	538199	6277918	5	Monitoring
W367	537723	6278424	5	Monitoring
W428VWP1	538217	6277943	6	Monitoring
W428VWP2	538123	6277935	6	Monitoring
W429VWP1	538162	6277742	8	Monitoring
W429VWP2	538073	6277775	6	Monitoring

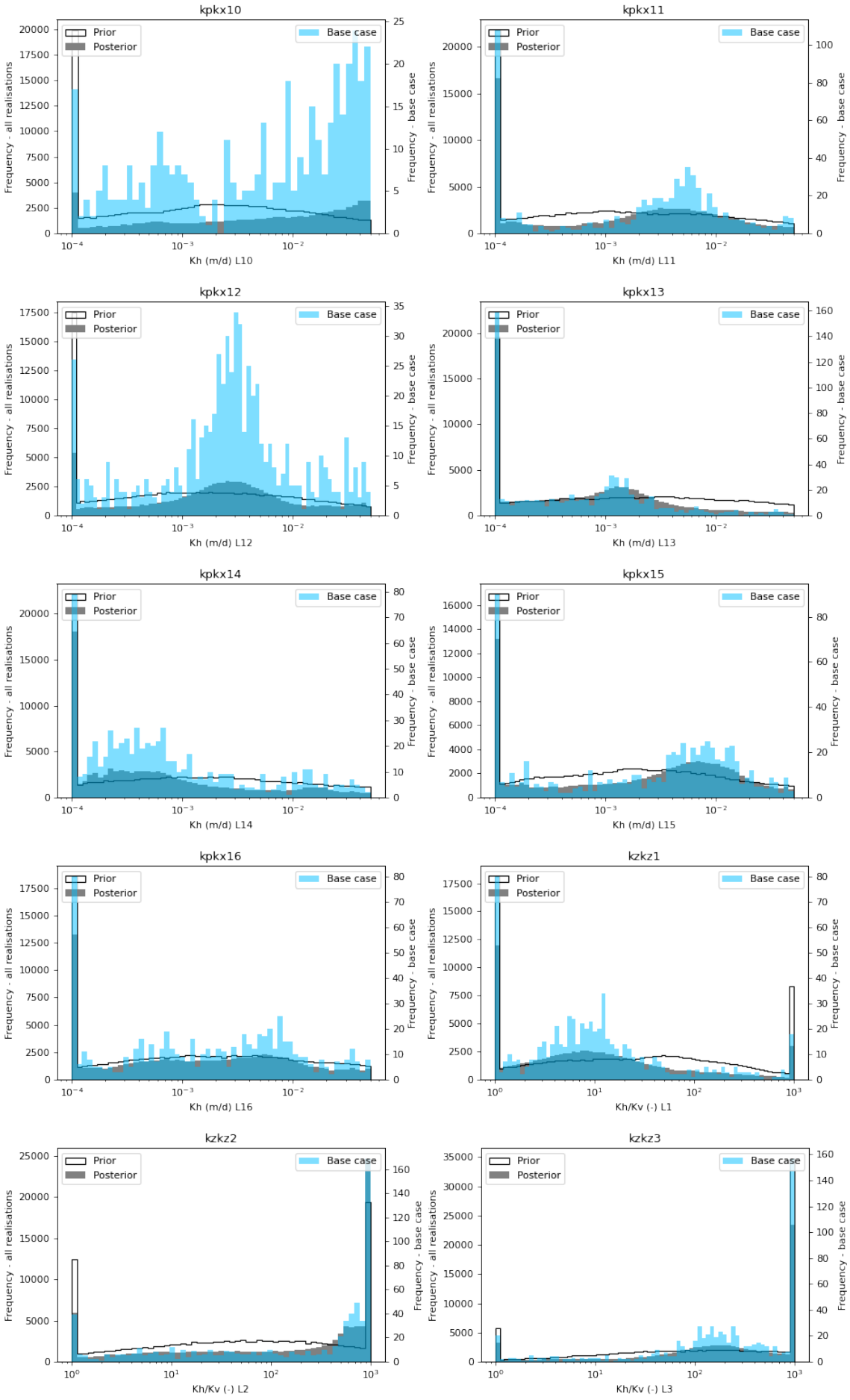
Table A.1 Bore locations

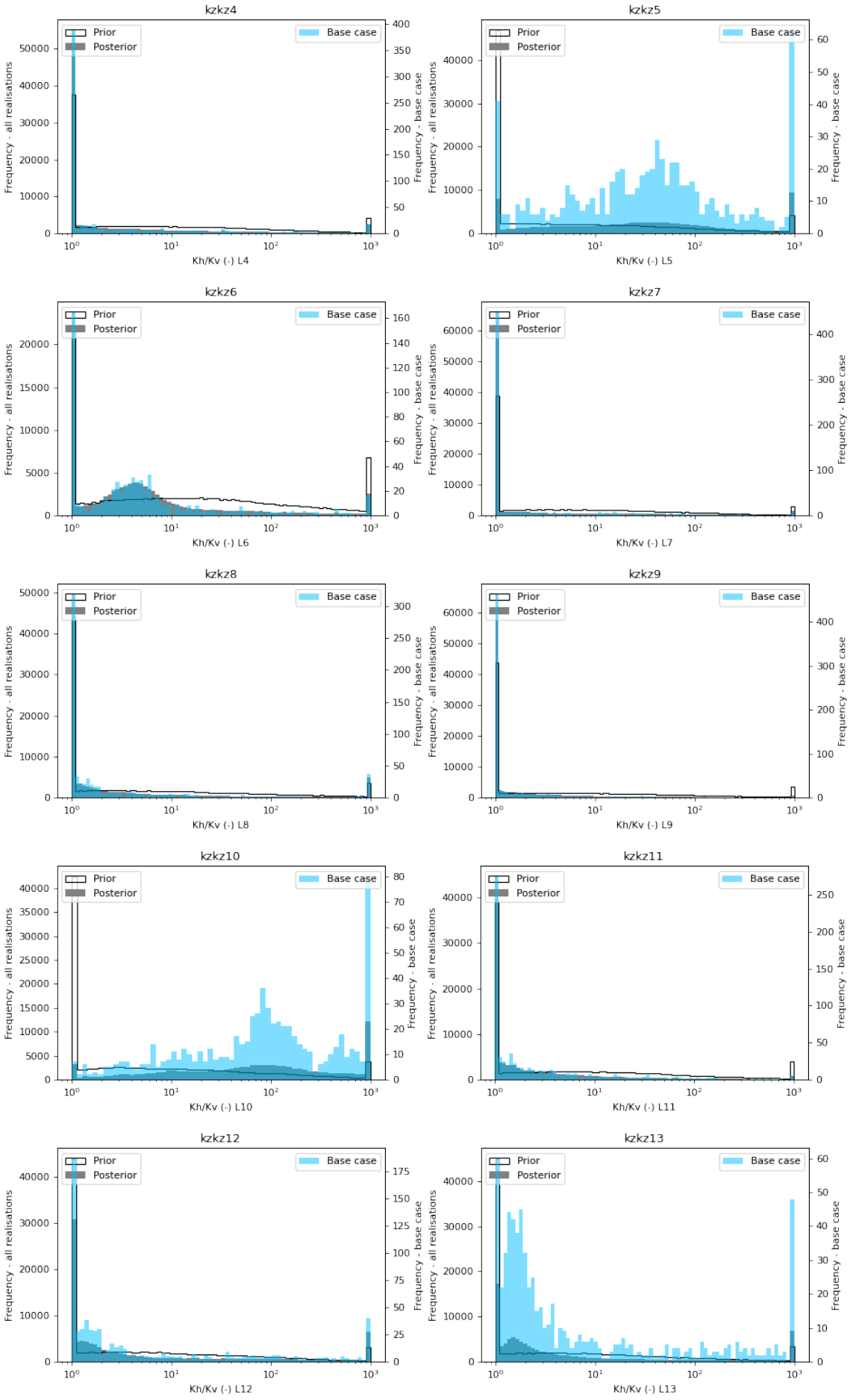
Name	Easting (m)	Northing (m)	Model layer	Purpose
WB01	539256	6277288	2	Pumping
WB12	539144	6277103	3	Monitoring
WB20	539362	6276932	2	Pumping

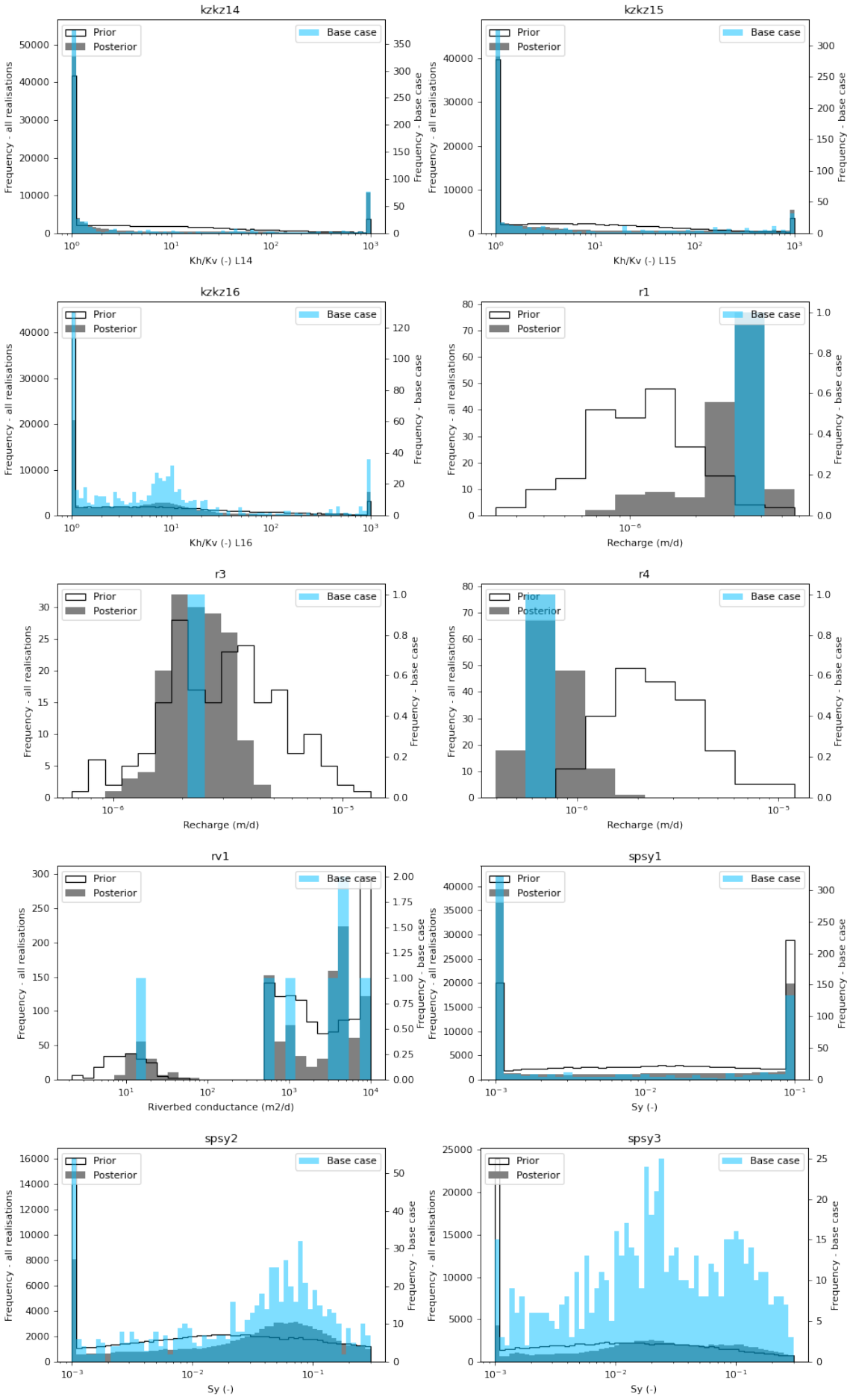
Appendix B
Modelled parameter distributions

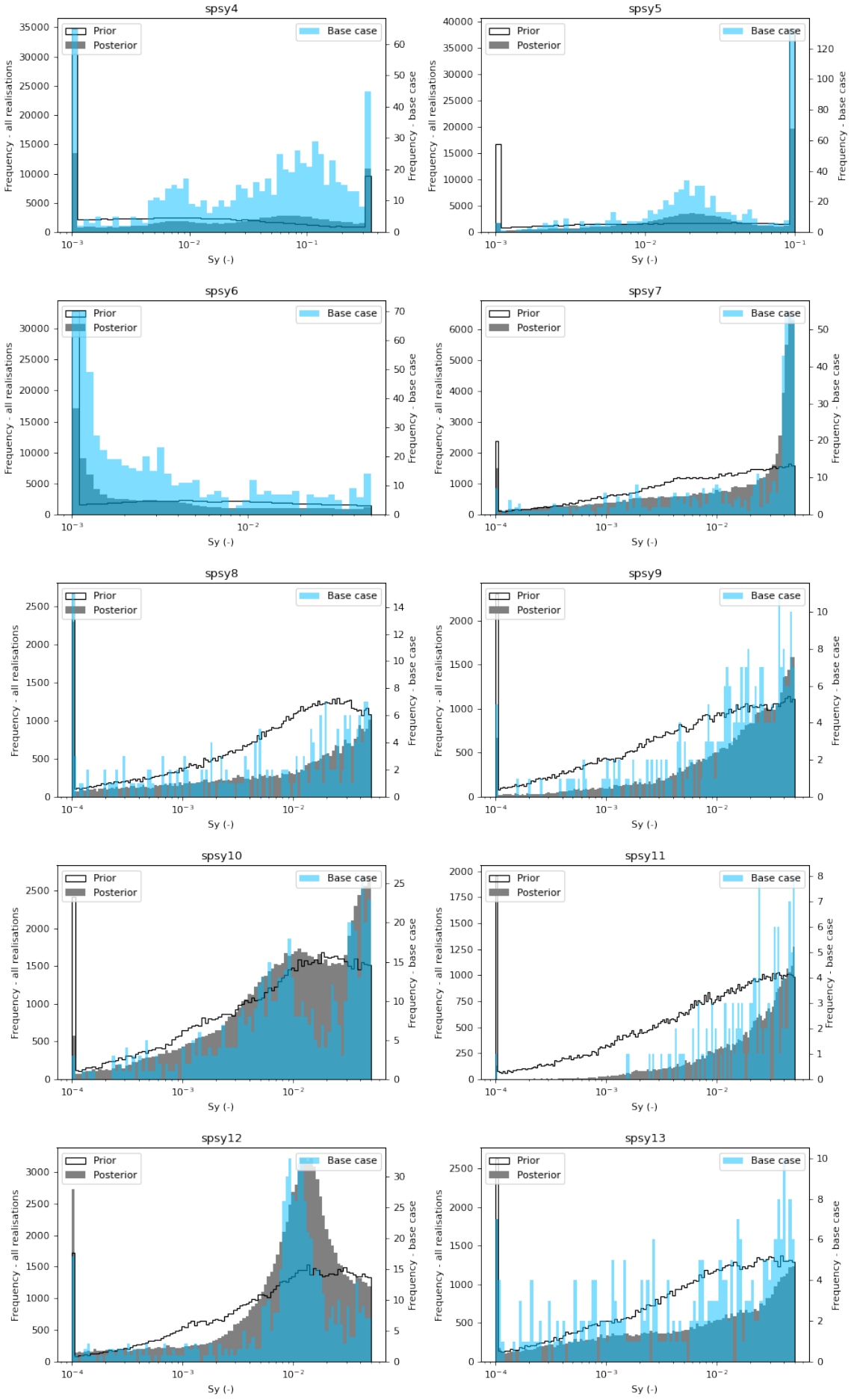
EMM
creating opportunities

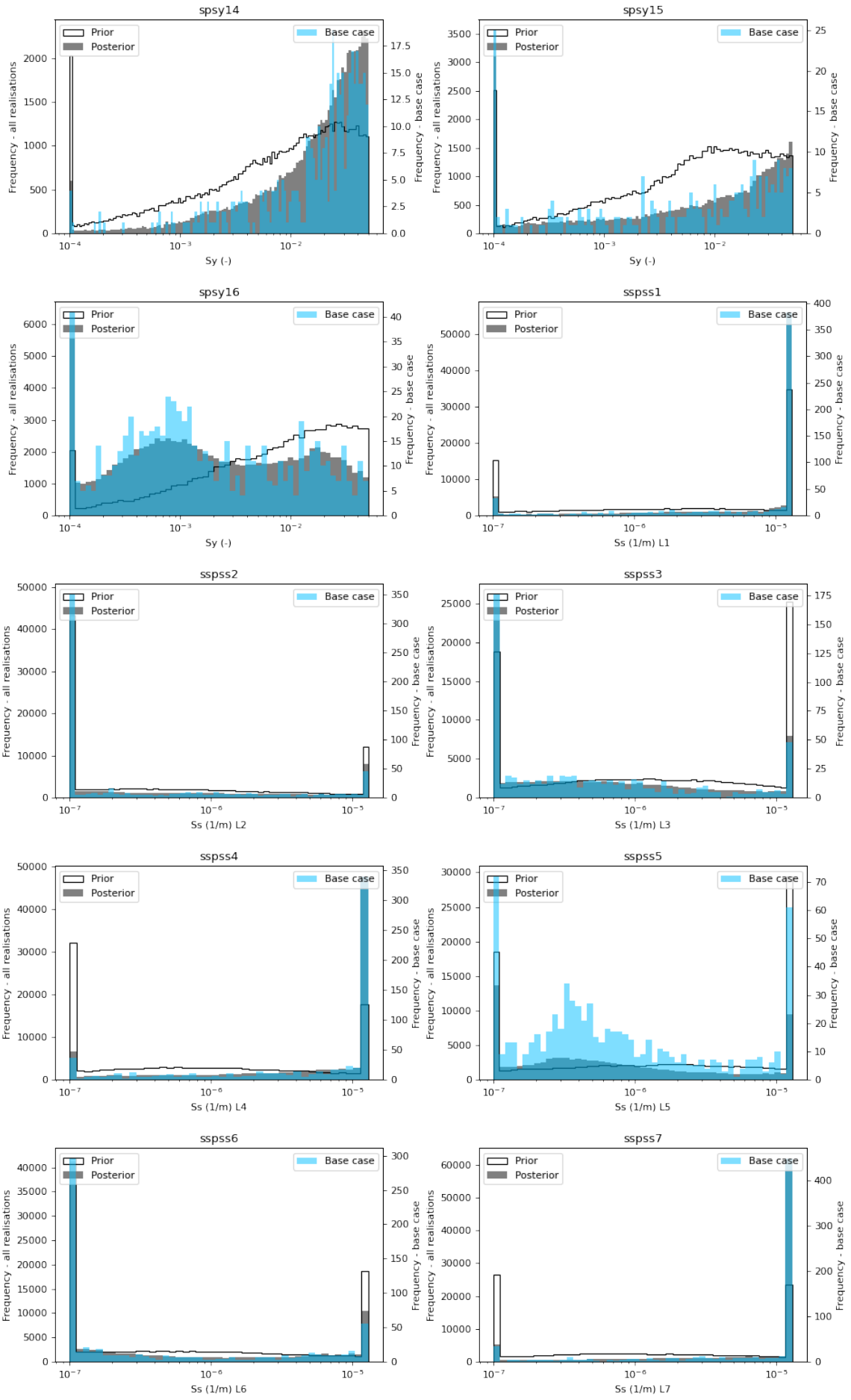

ed1
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Evapotranspiration extinction depth (m)
kpkx1
Kh (m/d) L1
kpkx2
Kh (m/d) L2
kpkx3
Kh (m/d) L3
kpkx4
Kh (m/d) L4
kpkx5
Kh (m/d) L5
kpkx6
Kh (m/d) L6
kpkx7
Kh (m/d) L7
kpkx8
Kh (m/d) L8
kpkx9
Kh (m/d) L9

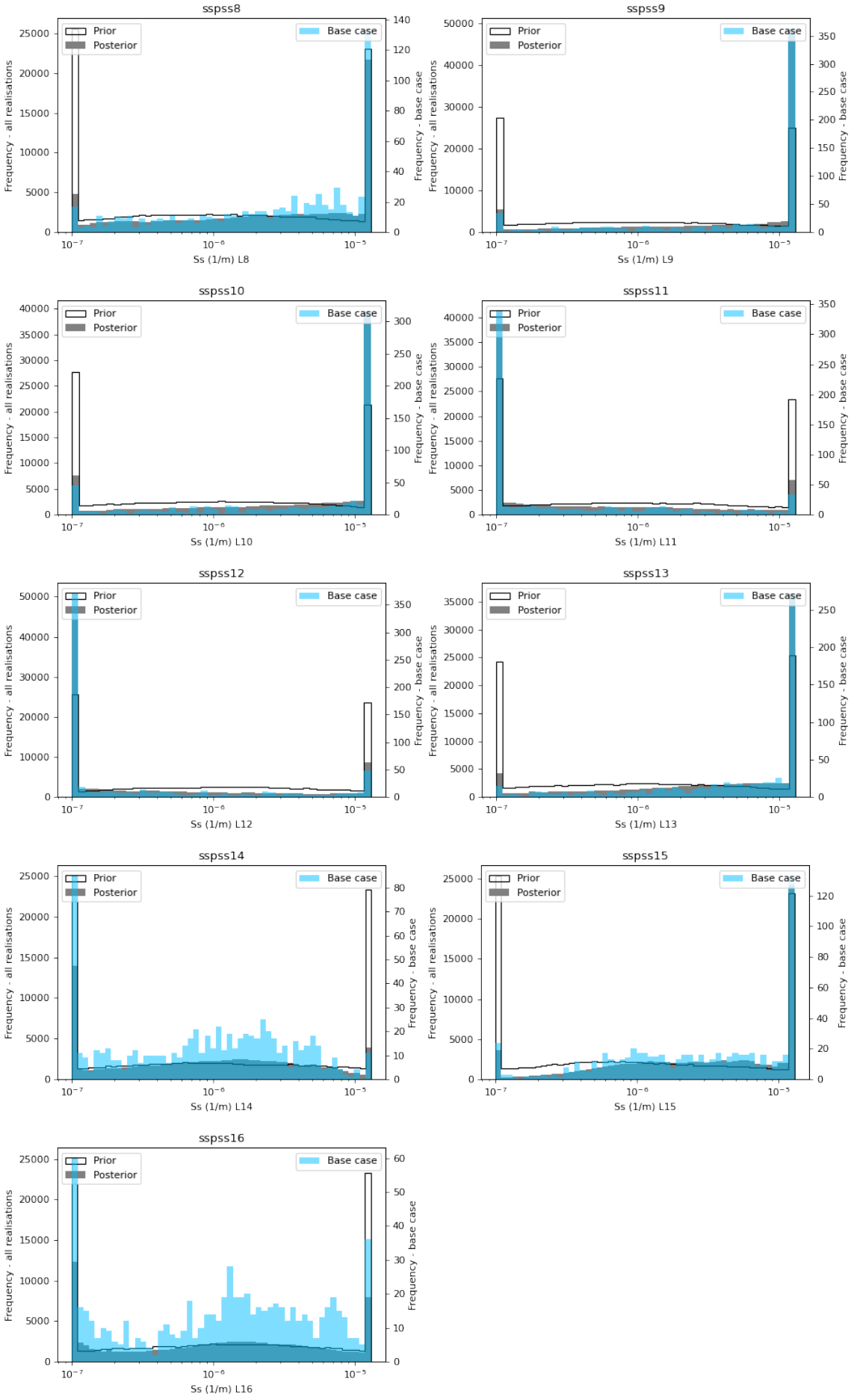

kpkx10
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Kh (m/d) L10
kpkx11
Kh (m/d) L11
kpkx12
Kh (m/d) L12
kpkx13
Kh (m/d) L13
kpkx14
Kh (m/d) L14
kpkx15
Kh (m/d) L15
kpkx16
Kh (m/d) L16
kzkz1
Kh/Kv (-) L1
kzkz2
Kh/Kv (-) L2
kzkz3
Kh/Kv (-) L3


kzkz4
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Kh/Kv (-) L4
kzkz5
Kh/Kv (-) L5
kzkz6
Kh/Kv (-) L6
kzkz7
Kh/Kv (-) L7
kzkz8
Kh/Kv (-) L8
kzkz9
Kh/Kv (-) L9
kzkz10
Kh/Kv (-) L10
kzkz11
Kh/Kv (-) L11
kzkz12
Kh/Kv (-) L12
kzkz13
Kh/Kv (-) L13


kzkz14
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Kh/Kv (-) L14
kzkz15
Kh/Kv (-) L15
kzkz16
Kh/Kv (-) L16
r1
Recharge (m/d)
r3
r4
rv1
Riverbed conductance (m2/d)
spsy1
Sy (-)
spsy2
spsy3


spsy4
spsy5
spsy6
spsy7
spsy8
spsy9
spsy10
spsy11
spsy12
spsy13
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Sy (-)

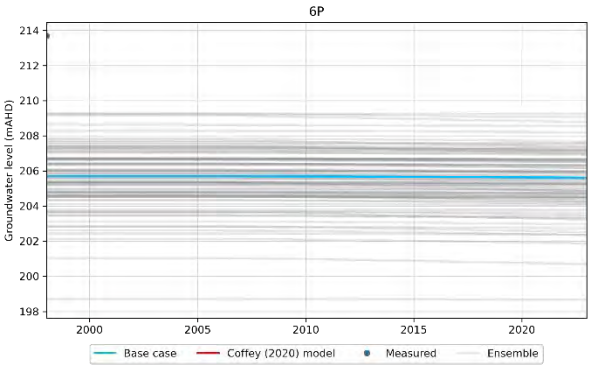

spsy14
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Sy (-)
spsy15
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Sy (-)
spsy16
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Sy (-)
sspss1
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L1
sspss2
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L2
sspss3
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L3
sspss4
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L4
sspss5
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L5
sspss6
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L6
sspss7
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L7

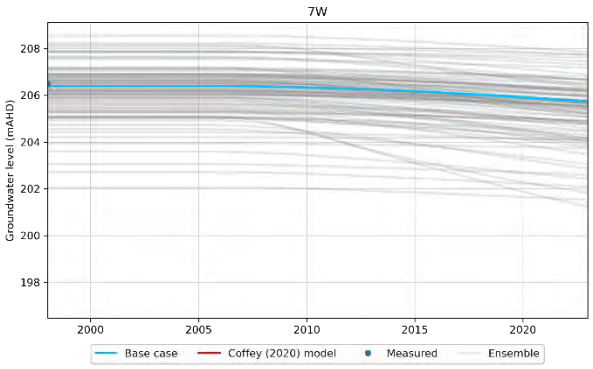

sspss8
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L8
sspss9
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L9
sspss10
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L10
sspss11
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L11
sspss12
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L12
sspss13
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L13
sspss14
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L14
sspss15
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L15
sspss16
Prior
Posterior
Base case
Frequency - all realisations
Frequency - base case
Ss (1/m) L16

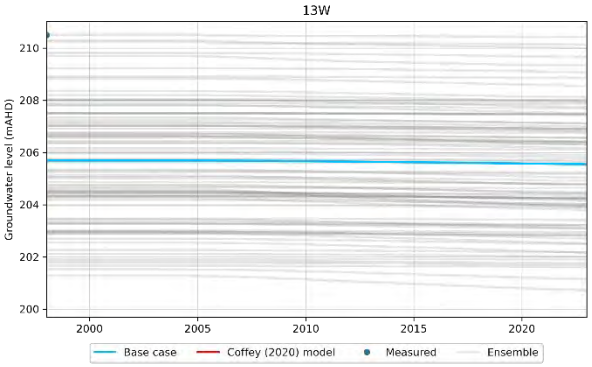
Appendix C

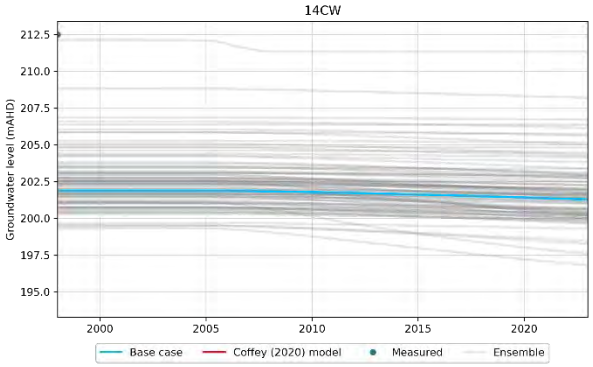
Hydrographs: history-matching

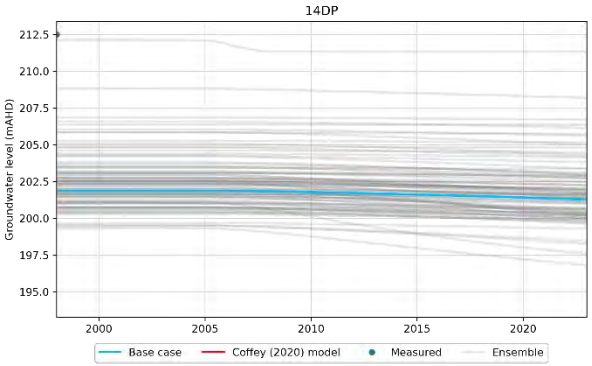
EMM
creating opportunities

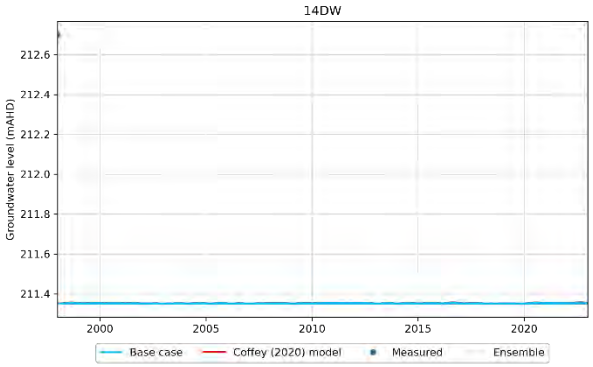

6P
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

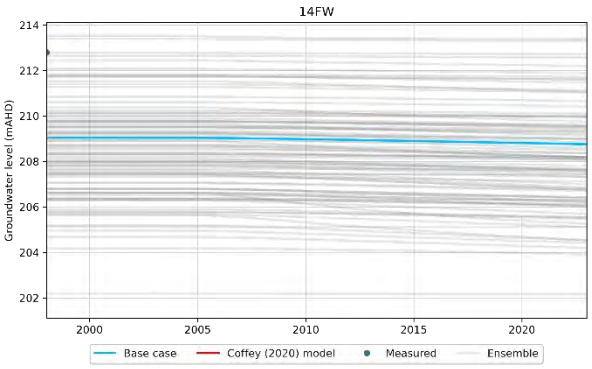

7W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

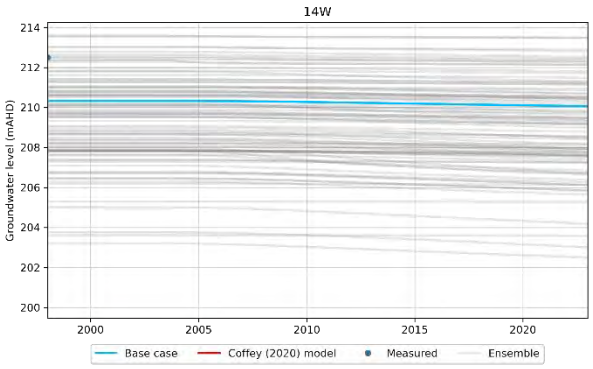

13W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

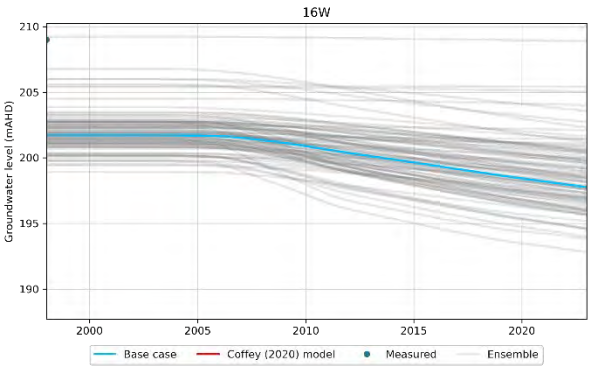

14CW
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

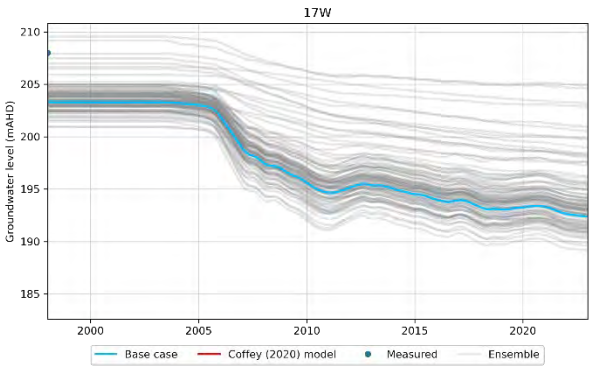

14DP
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

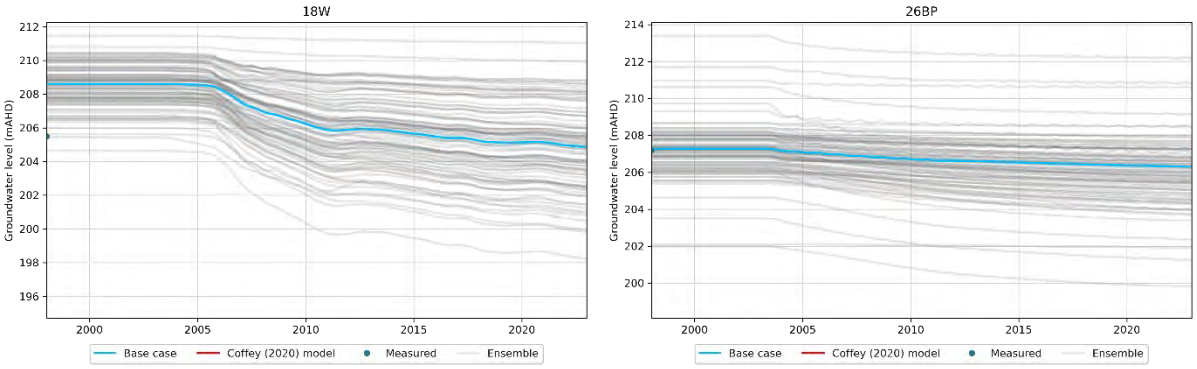

14DW
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


14FW
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

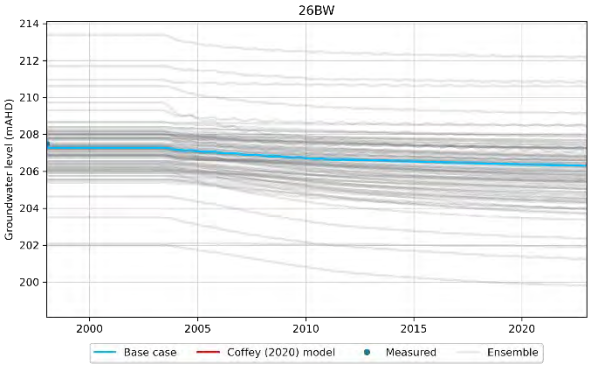

14W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

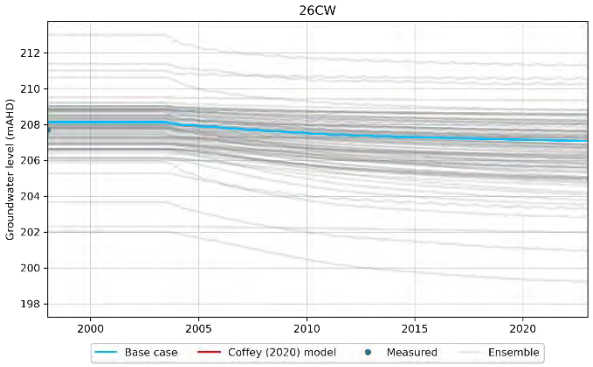

16W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

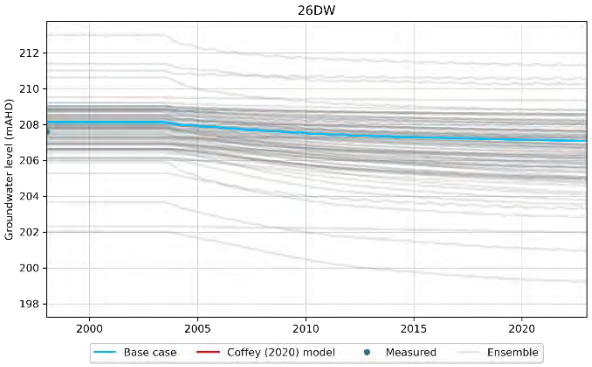

17W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

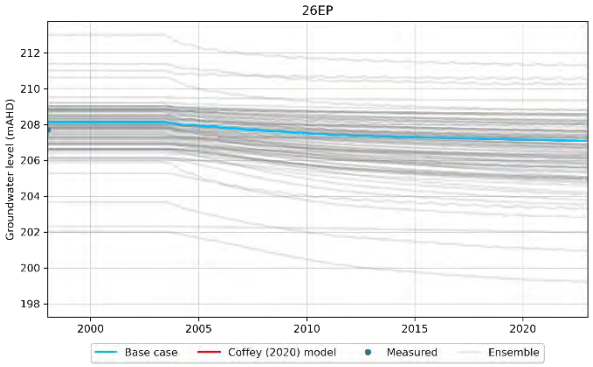

18W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

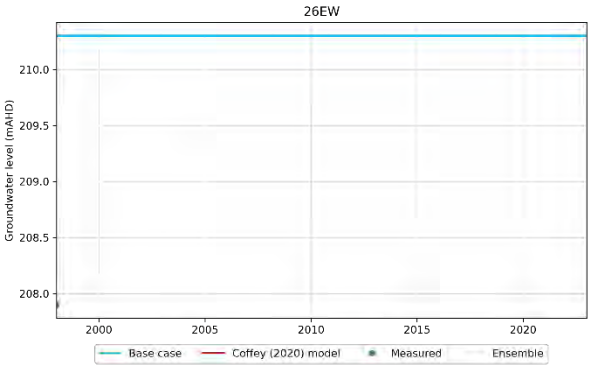
26BP
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

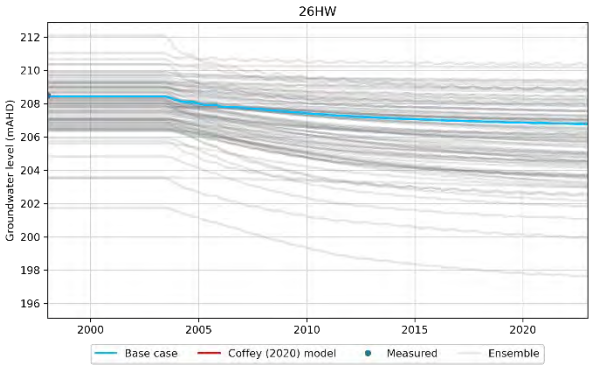

26BW
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

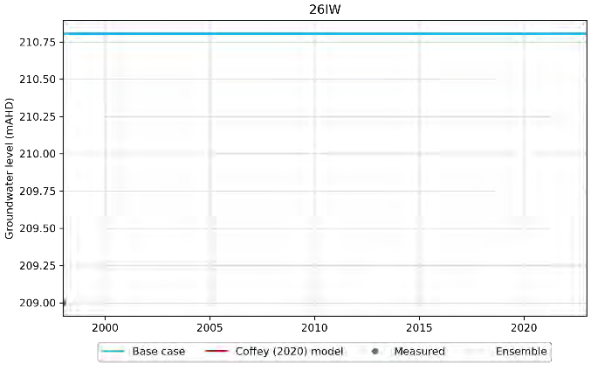

26CW
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

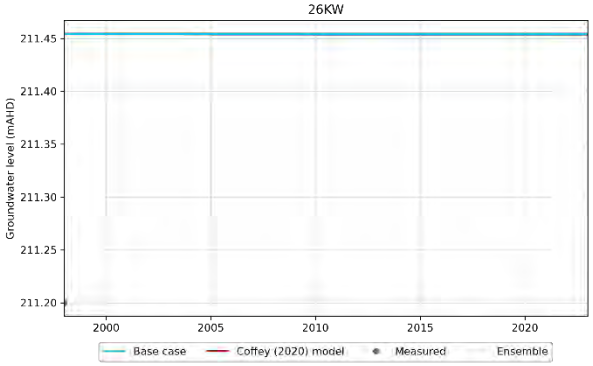

26DW
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

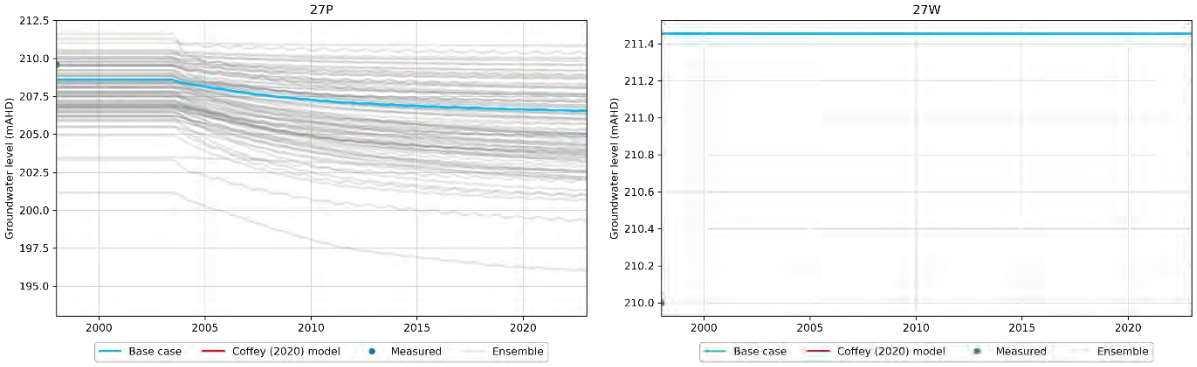

26EP
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


26EW
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

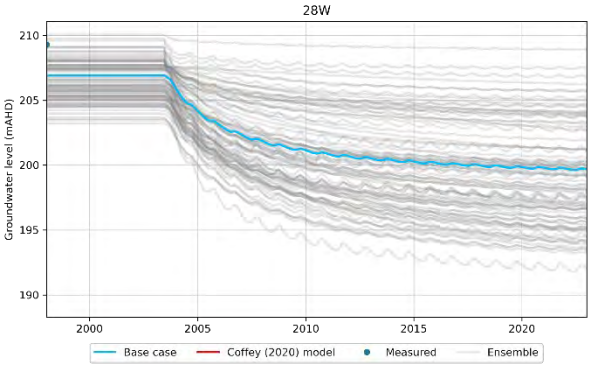

26HW
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

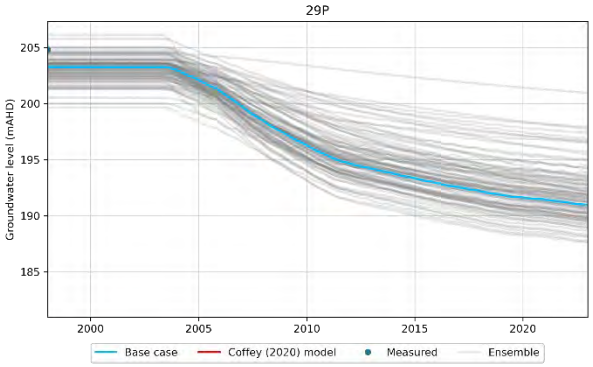

26IW
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

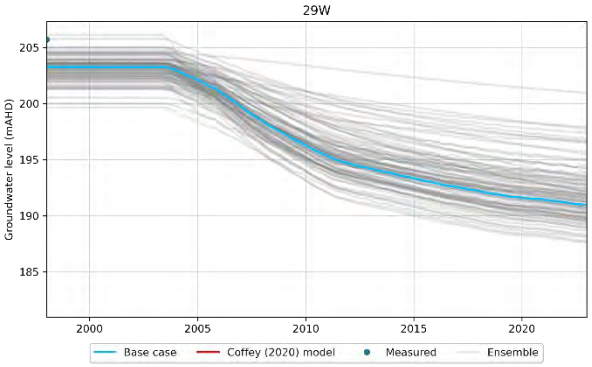

26KW
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

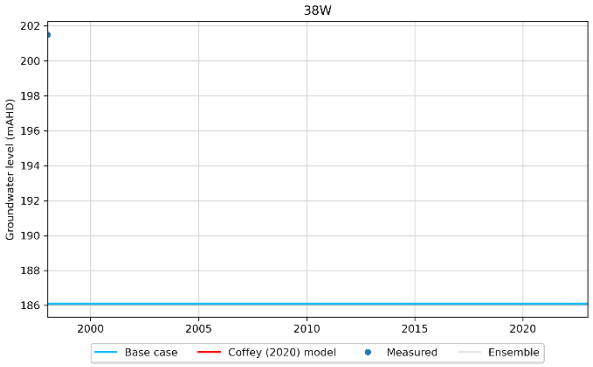

27P
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

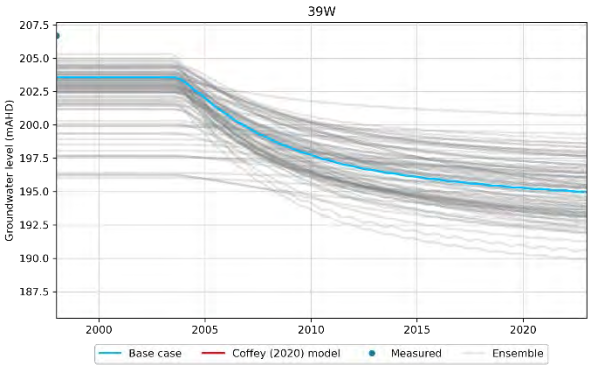
27W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

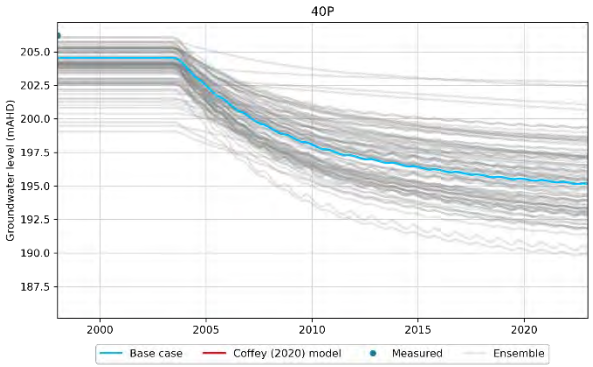

28W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

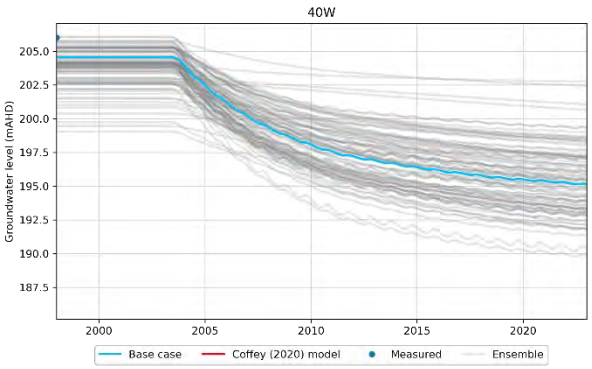

29P
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

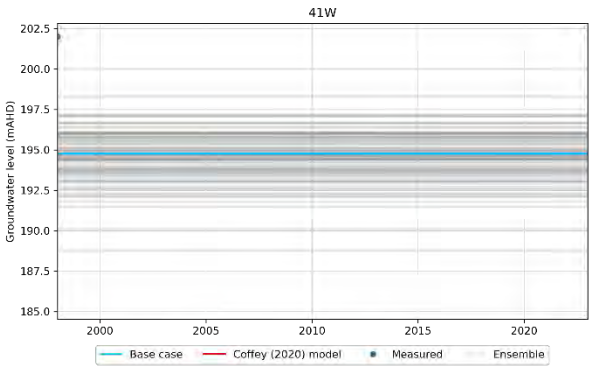

29W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

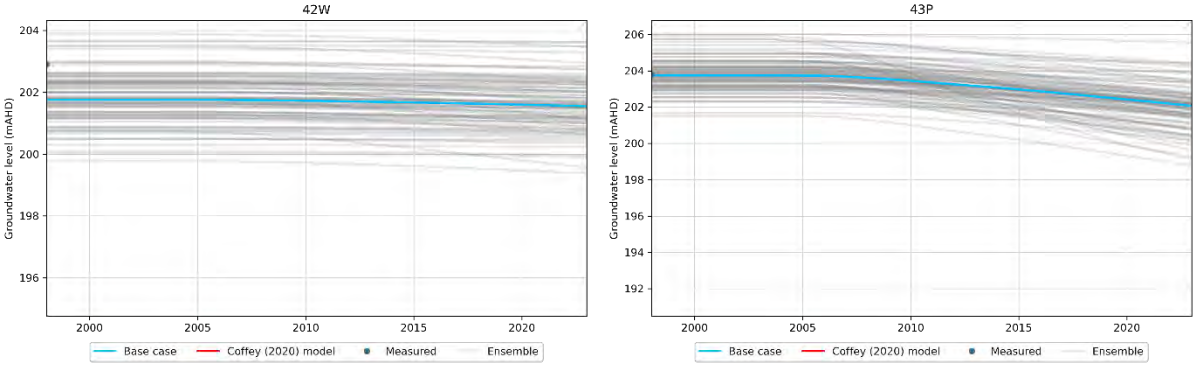

38W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


39W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

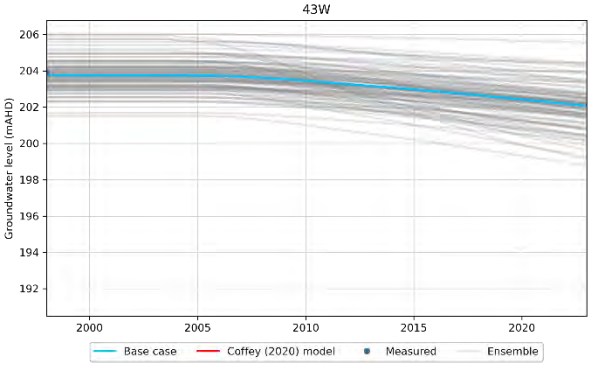

40P
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

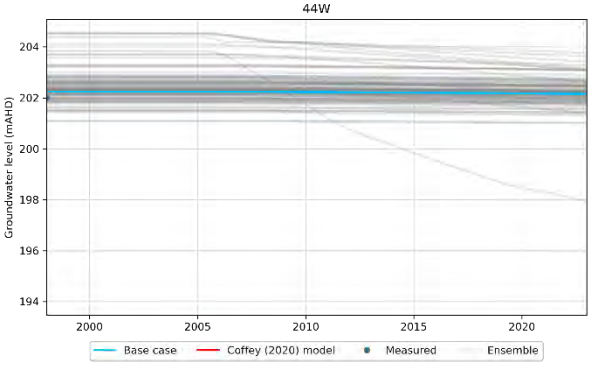

40W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

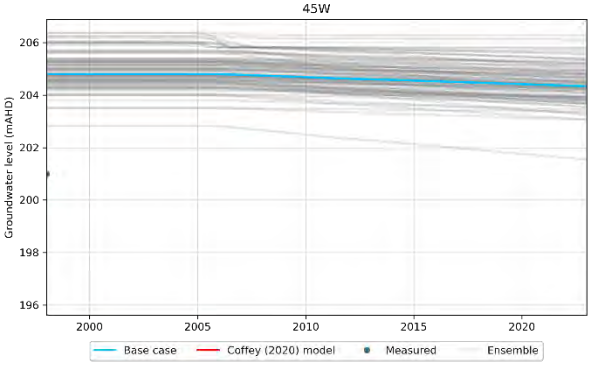

41W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

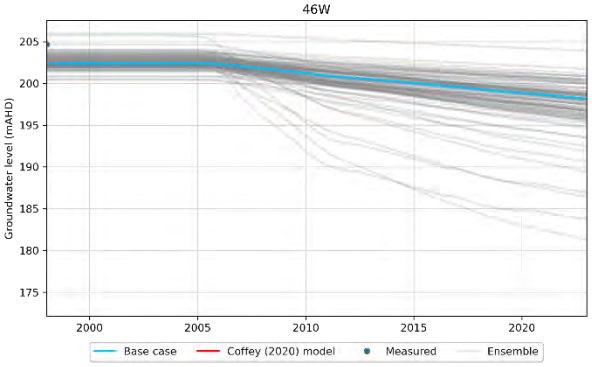

42W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

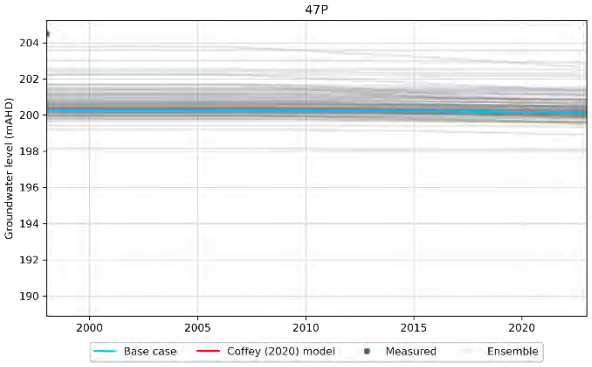
43P
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

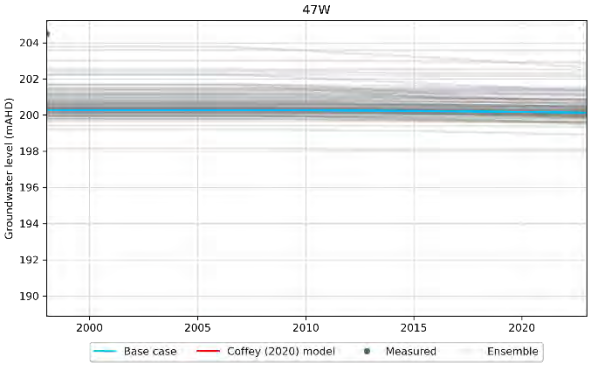

43W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

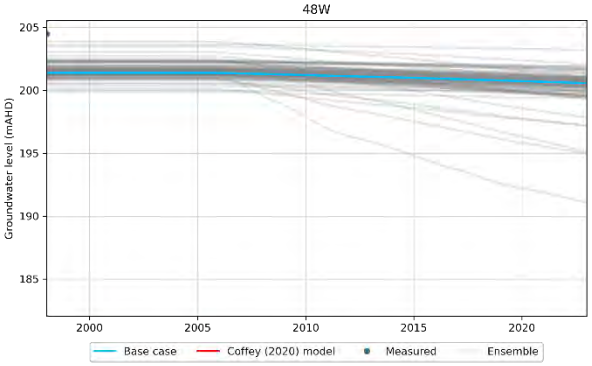

44W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

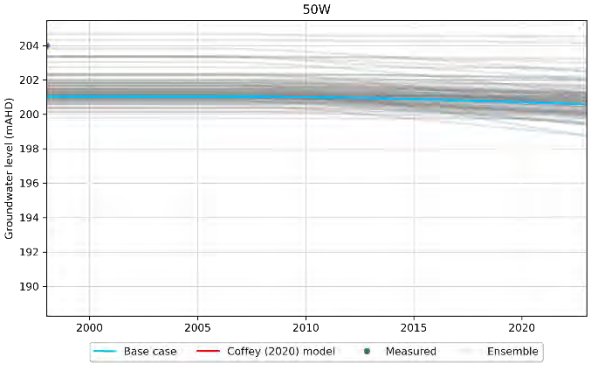

45W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

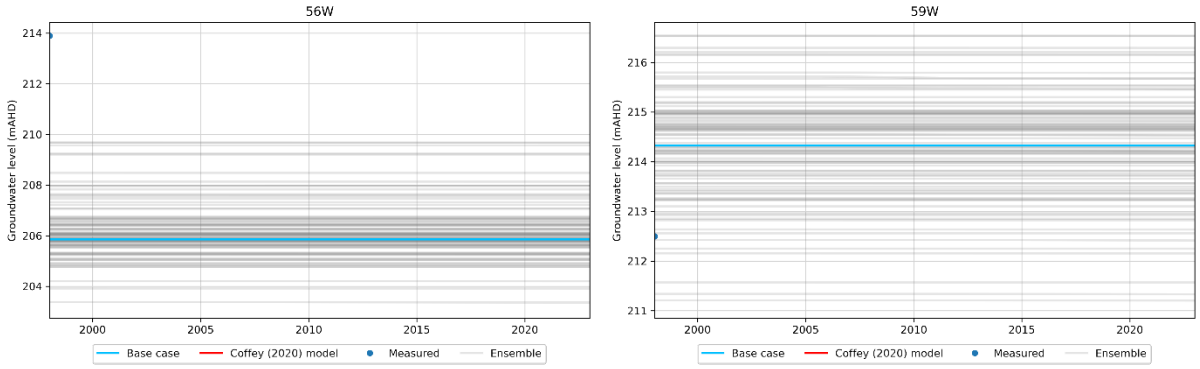

46W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


47P
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

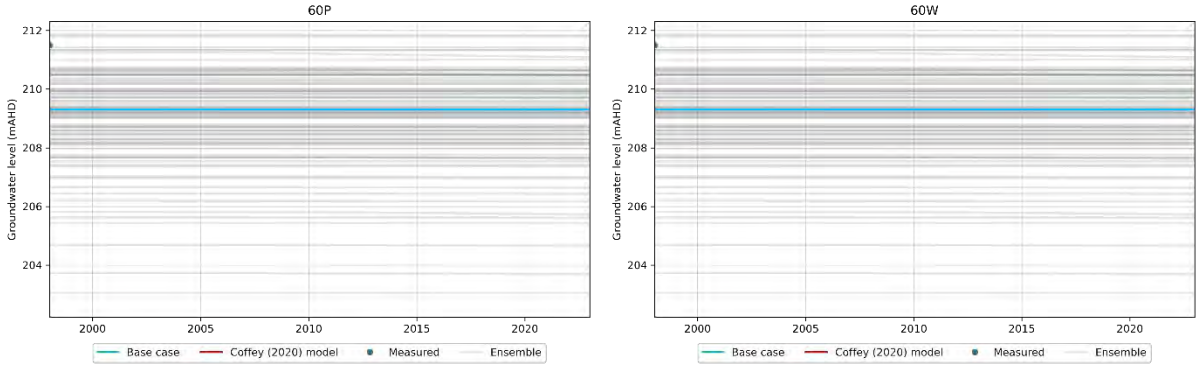

47W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


48W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

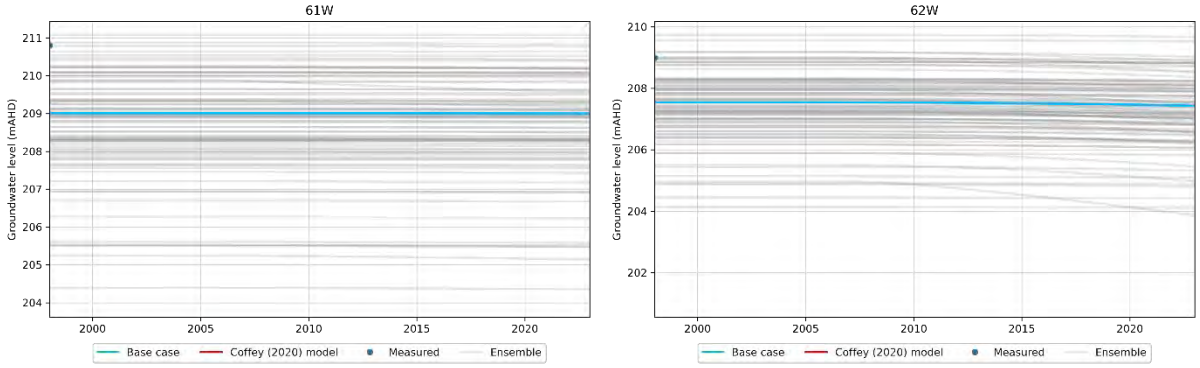

50W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


56W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

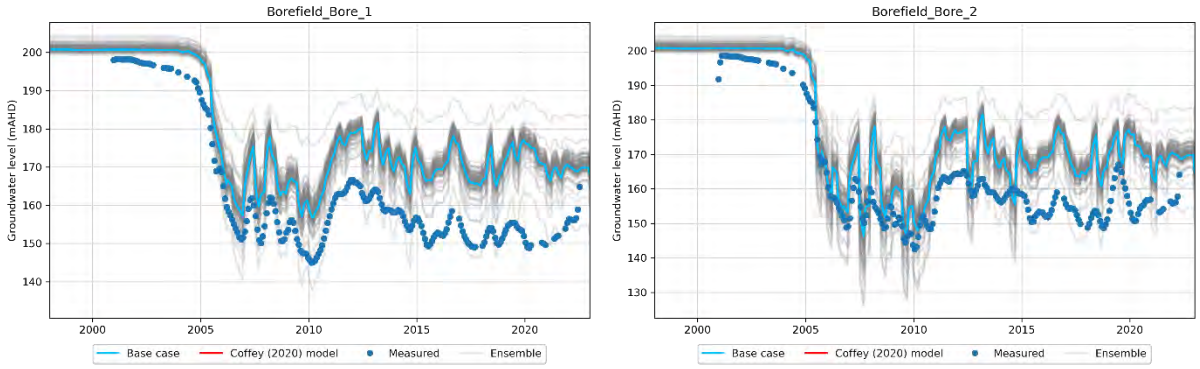
59W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


60P
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

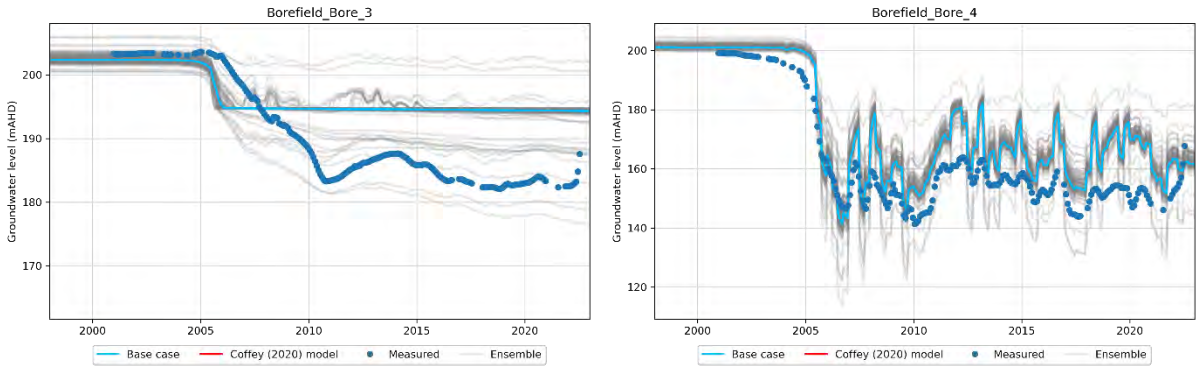
60W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


61W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

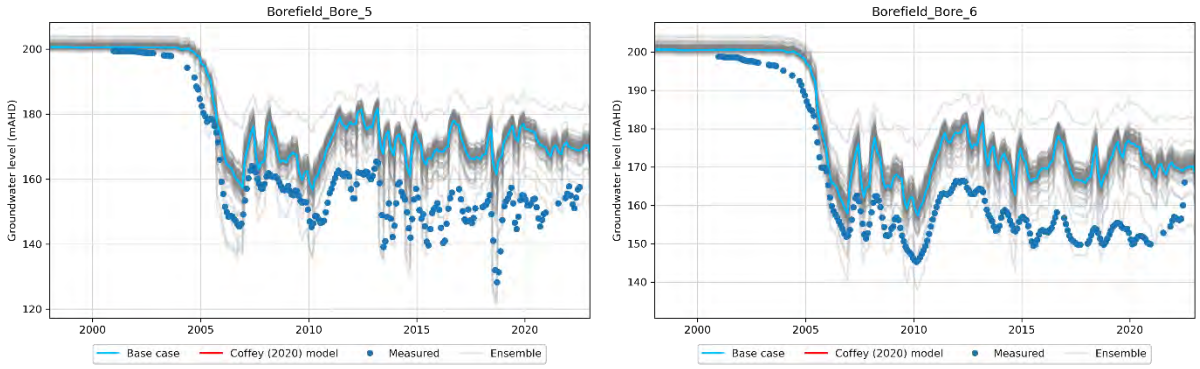
62W
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


Borefield_Bore_1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

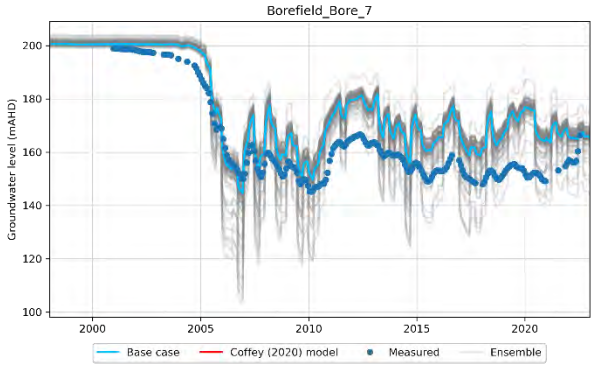
Borefield_Bore_2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

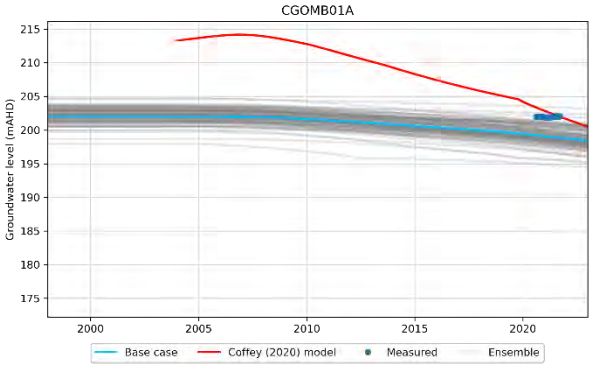

Borefield_Bore_3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

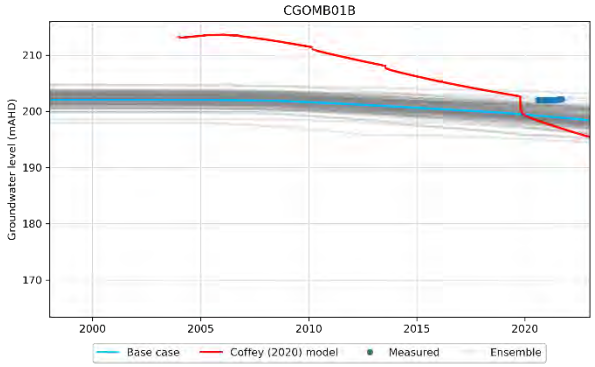
Borefield_Bore_4
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

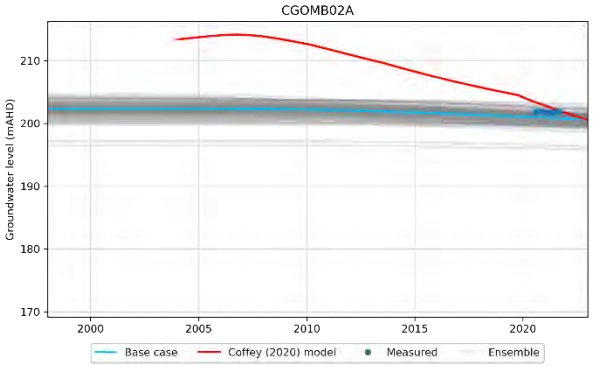

Borefield_Bore_5
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

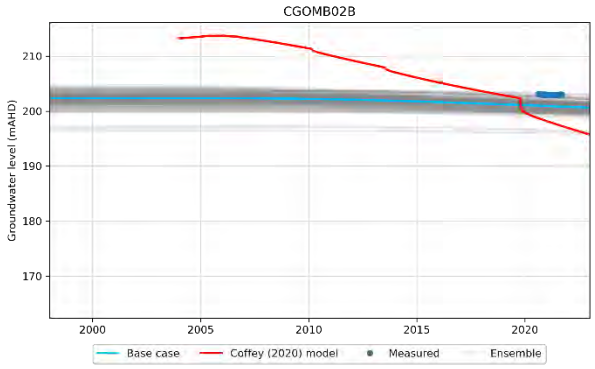
Borefield_Bore_6
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

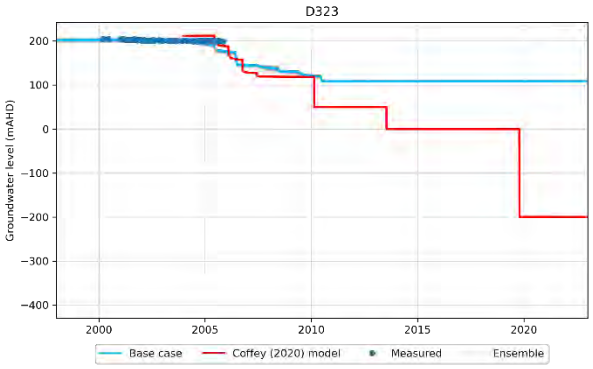

Borefield_Bore_7
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

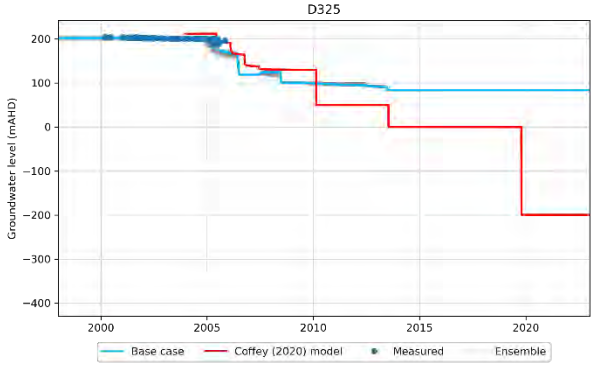

CGOMB01A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

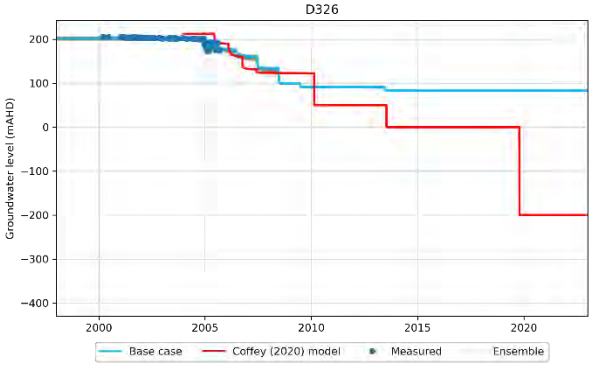

CGOMB01B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

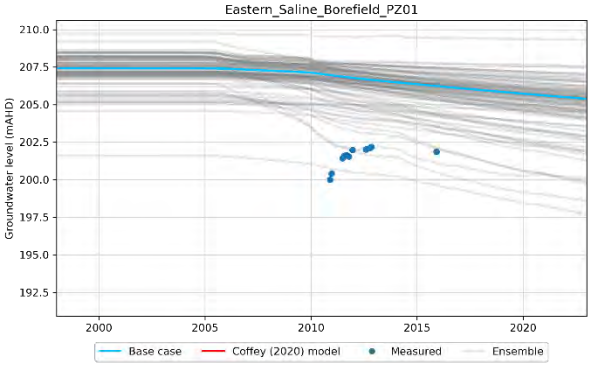

CGOMB02A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

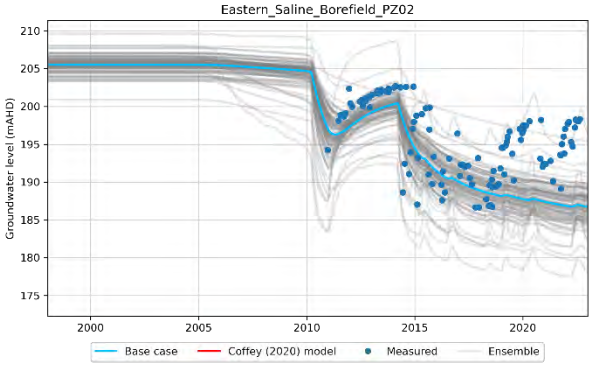

CGOMB02B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

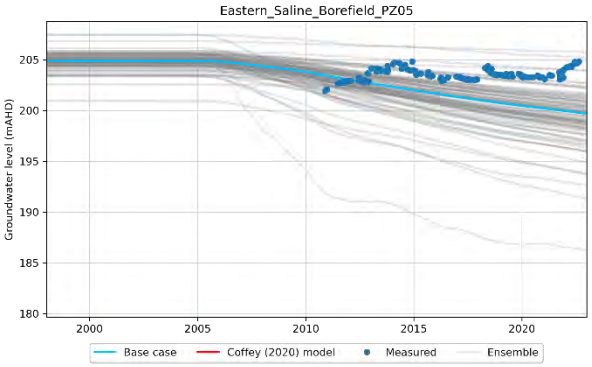

D323
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

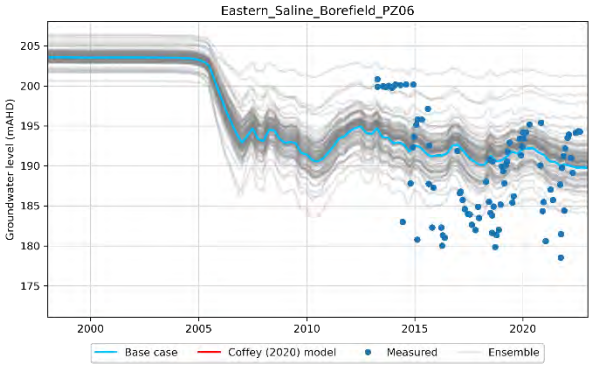

D325
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

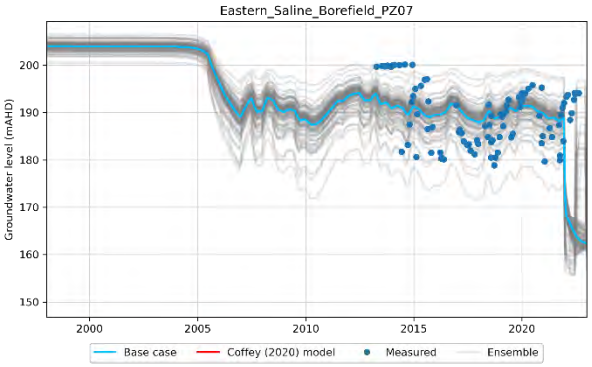

D326
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

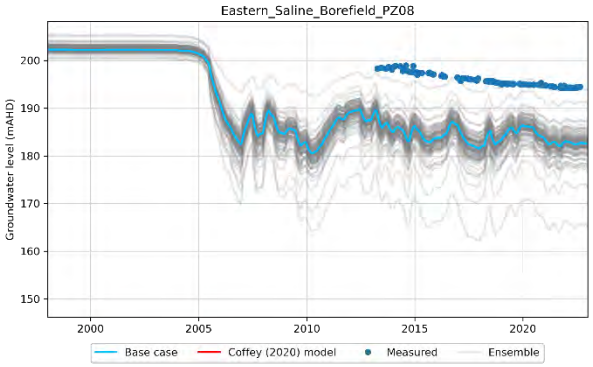

Eastern_Saline_Borefield_PZ01
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

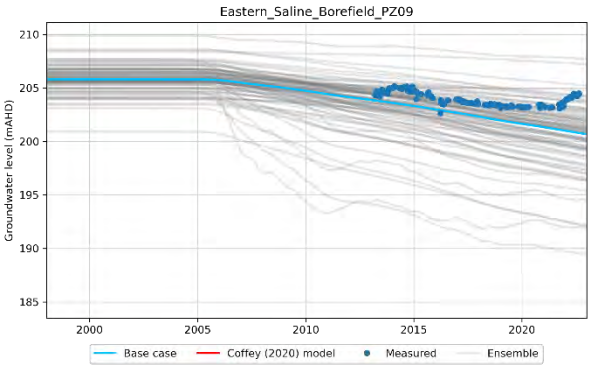

Eastern_Saline_Borefield_PZ02
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

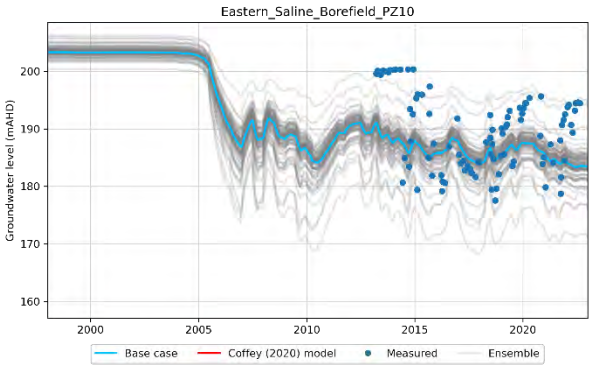

Eastern_Saline_Borefield_PZ05
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

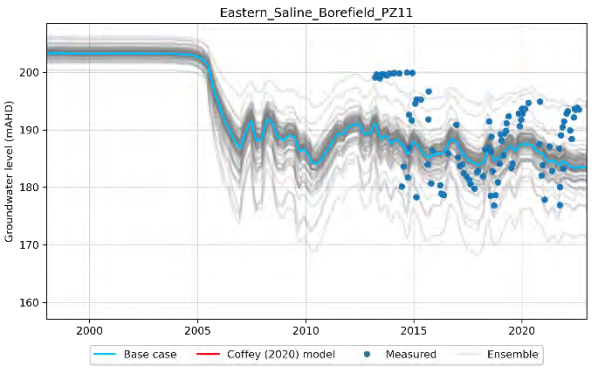

Eastern_Saline_Borefield_PZ06
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

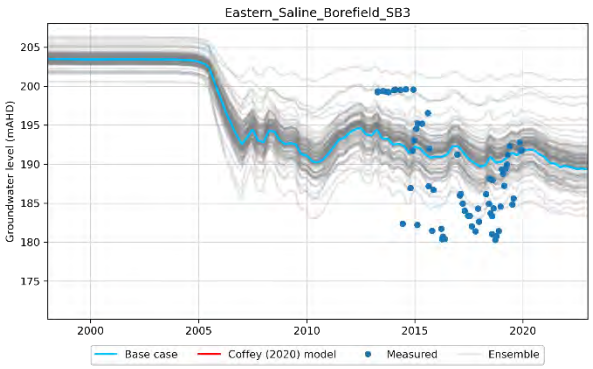

Eastern_Saline_Borefield_PZ07
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

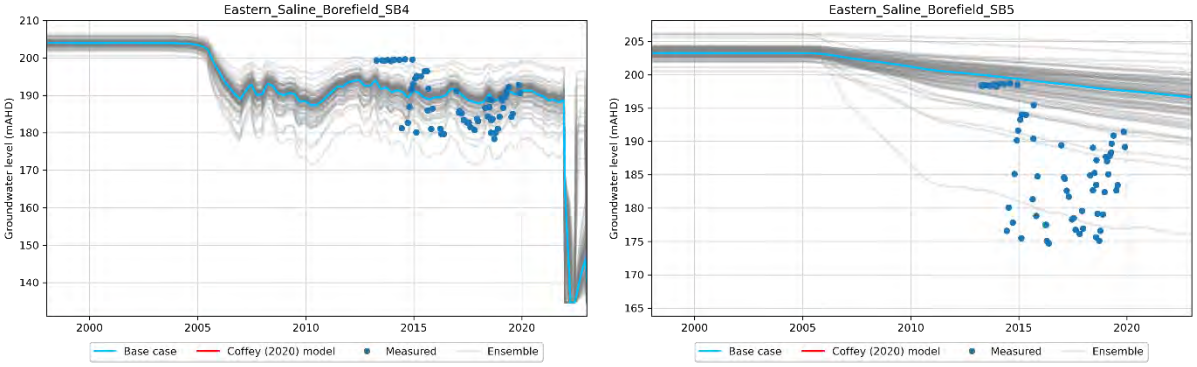

Eastern_Saline_Borefield_PZ08
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


Eastern_Saline_Borefield_PZ09
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

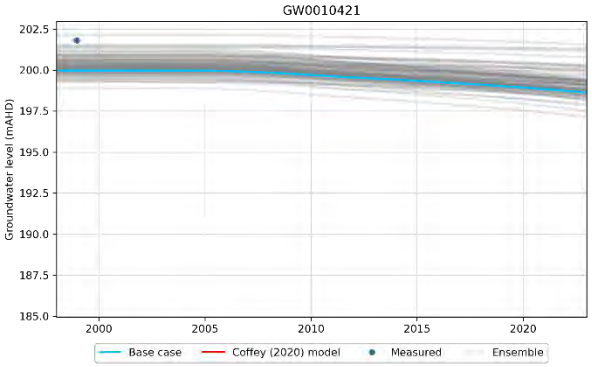

Eastern_Saline_Borefield_PZ10
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

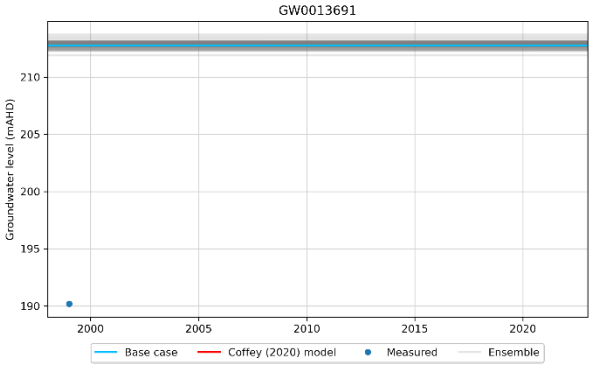

Eastern_Saline_Borefield_PZ11
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

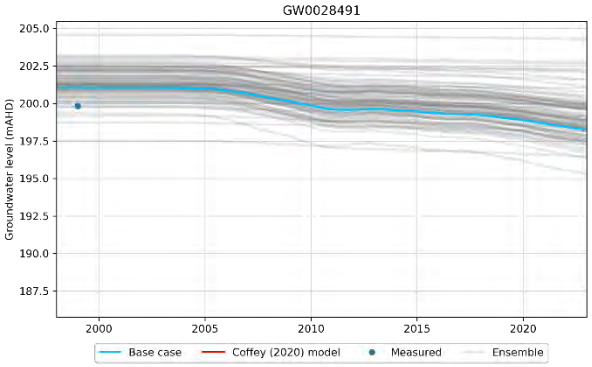

Eastern_Saline_Borefield_SB3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

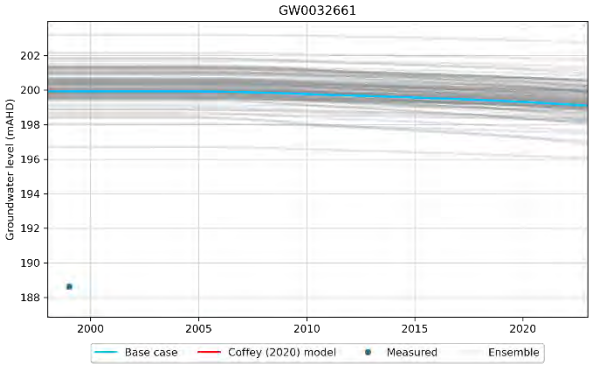

Eastern_Saline_Borefield_SB4
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

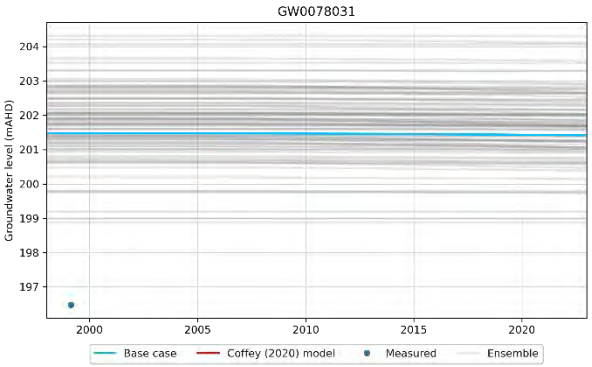
Eastern_Saline_Borefield_SB5
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

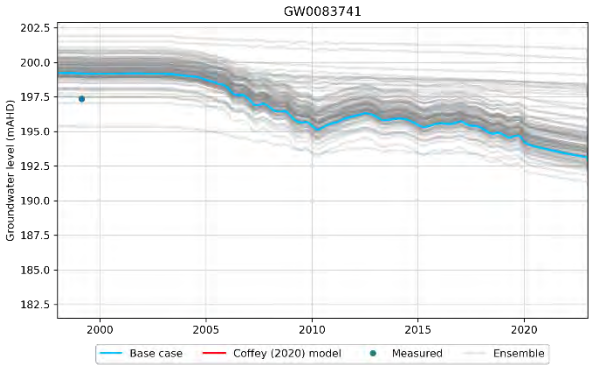

GW0010421
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

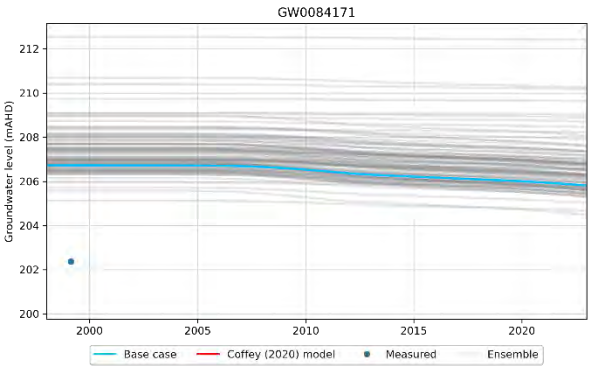

GW0013691
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

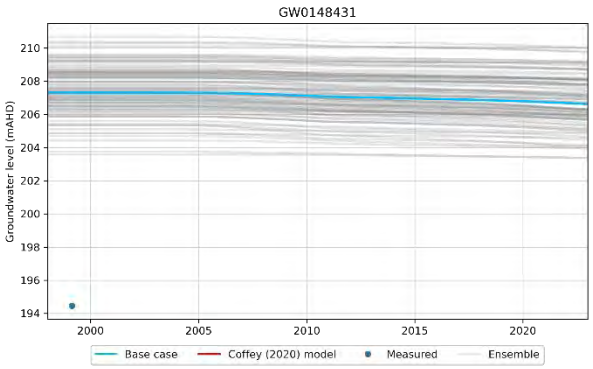

GW0028491
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

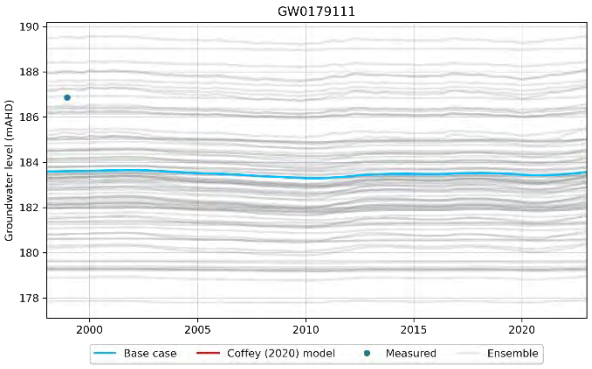

GW0032661
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

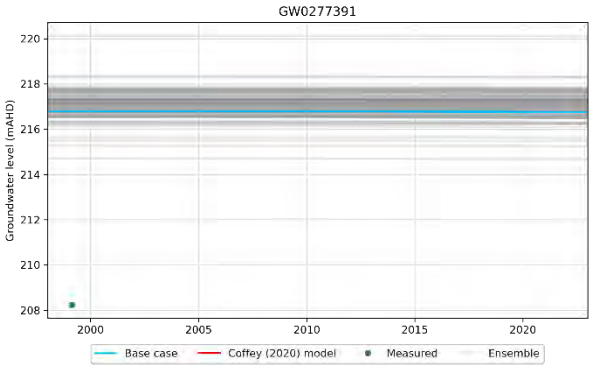

GW0078031
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

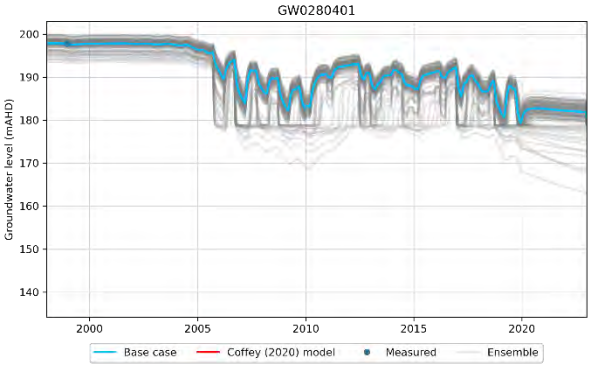

GW0083741
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

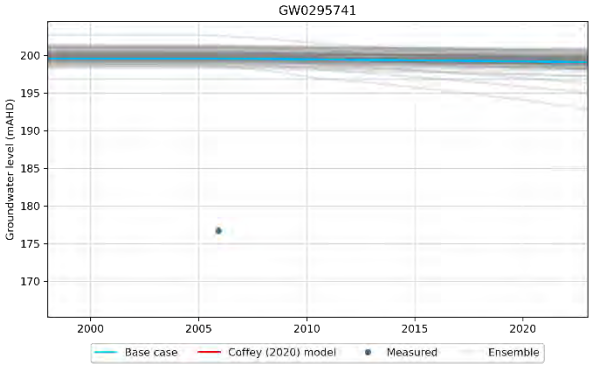

GW0084171
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

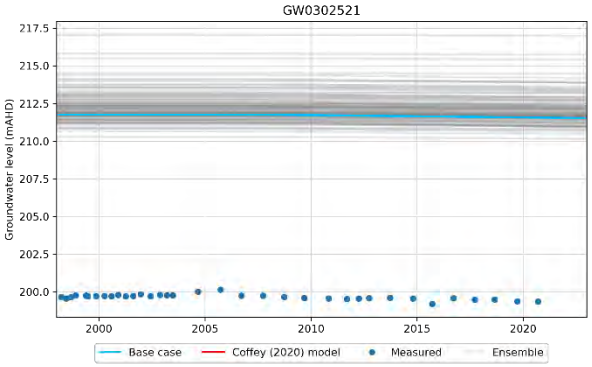

GW0148431
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

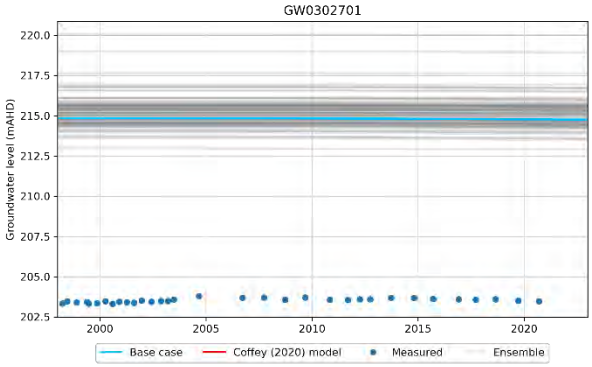

GW0179111
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

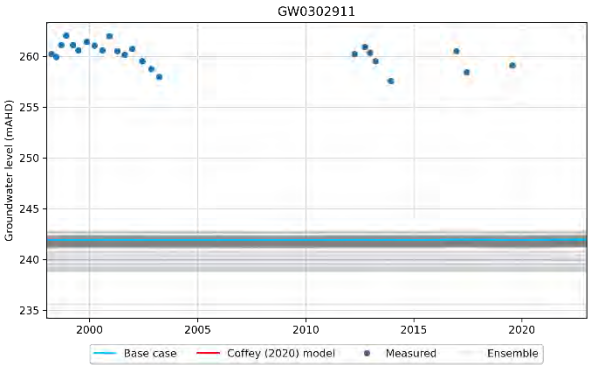

GW0277391
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

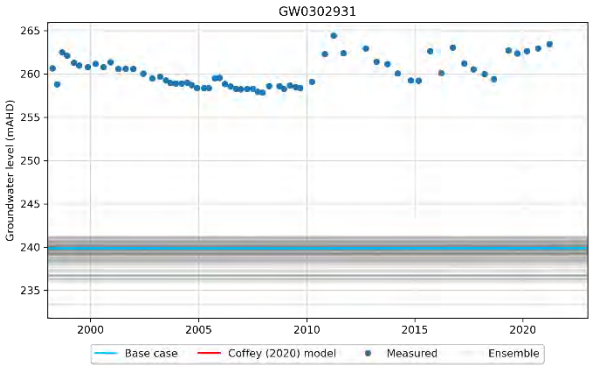

GW0280401
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

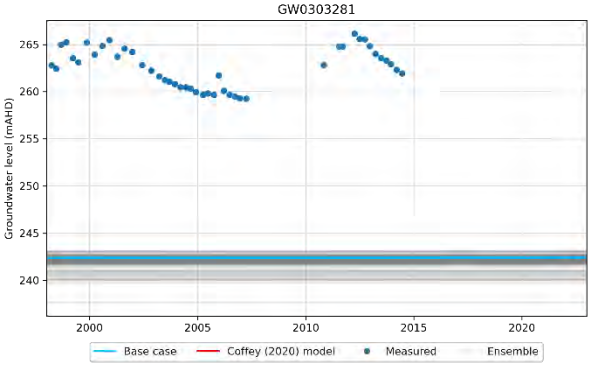

GW0295741
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

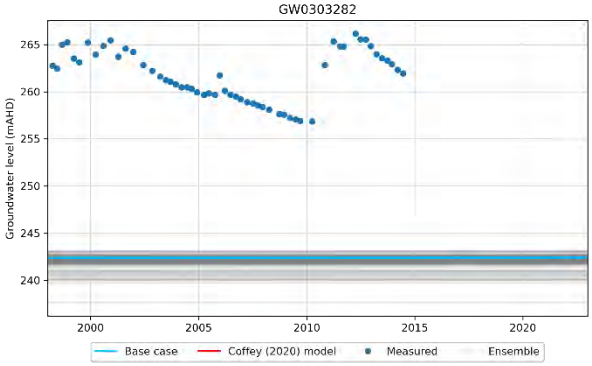

GW0302521
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

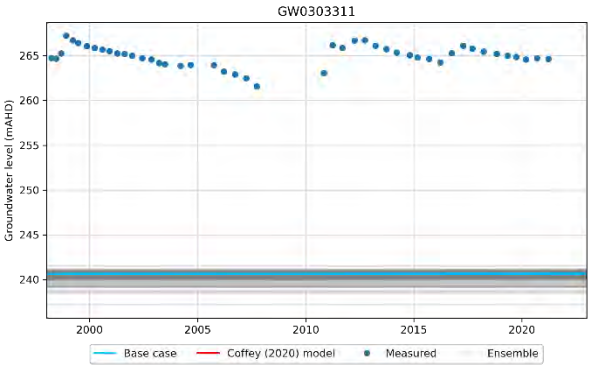

GW0302701
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

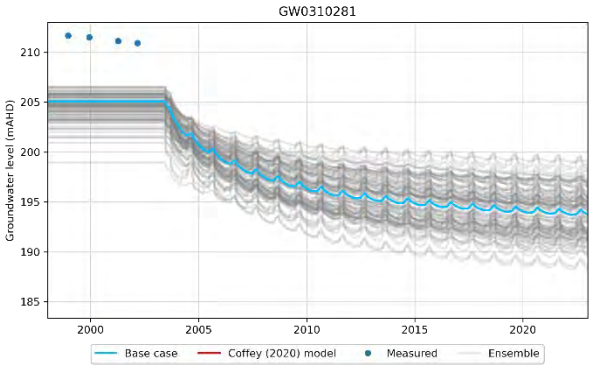

GW0302911
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

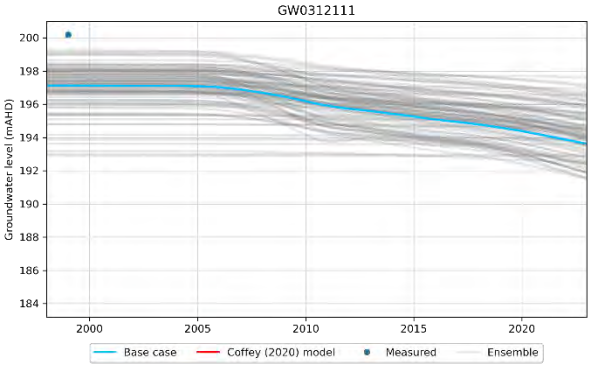

GW0302931
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

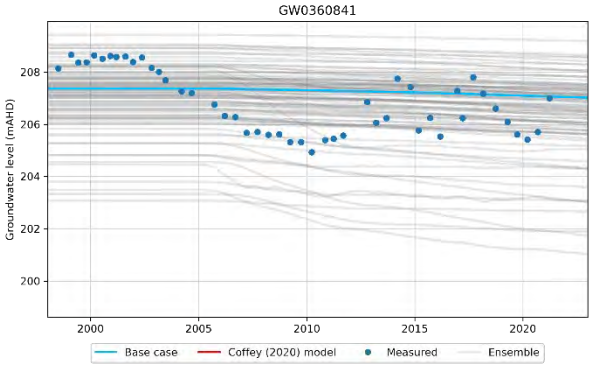

GW0303281
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

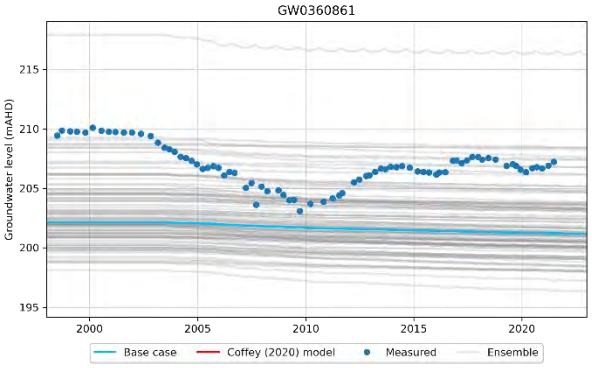

GW0303282
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

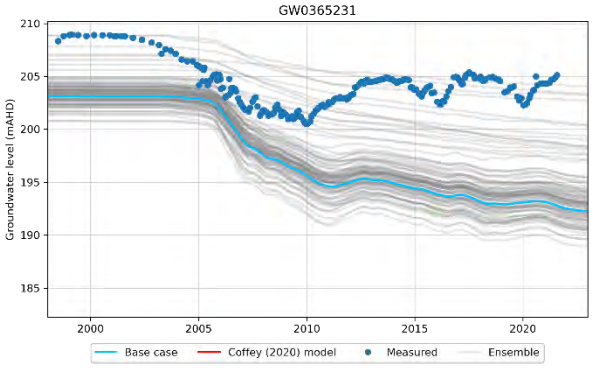

GW0303311
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

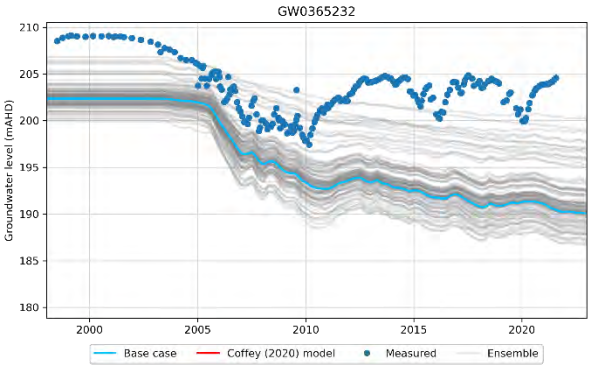

GW0310281
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

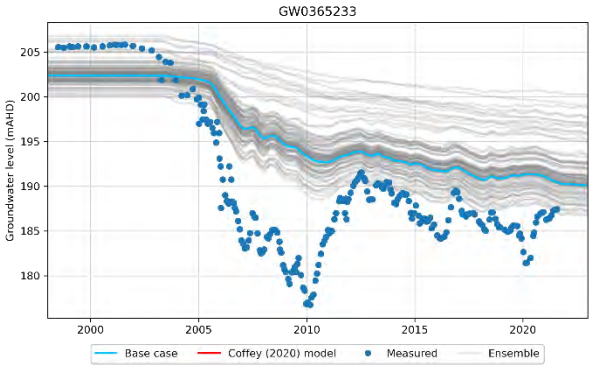

GW0312111
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

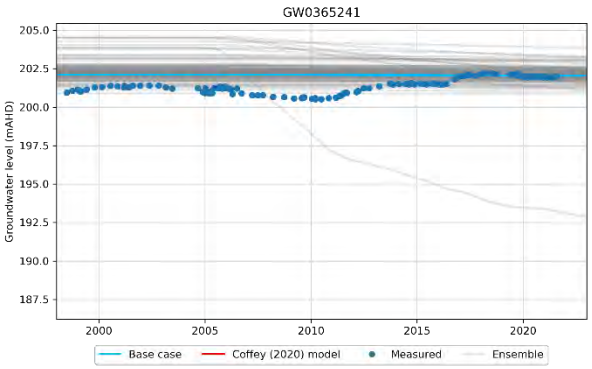

GW0360841
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

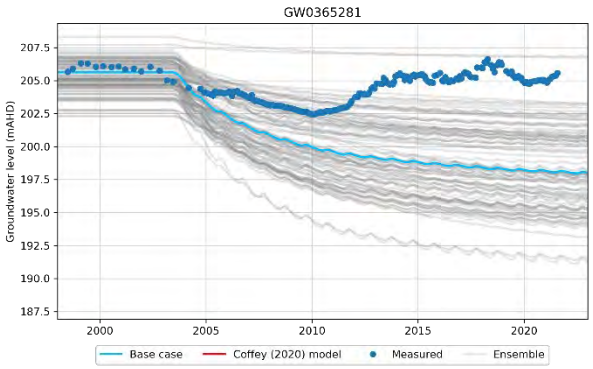

GW0360861
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

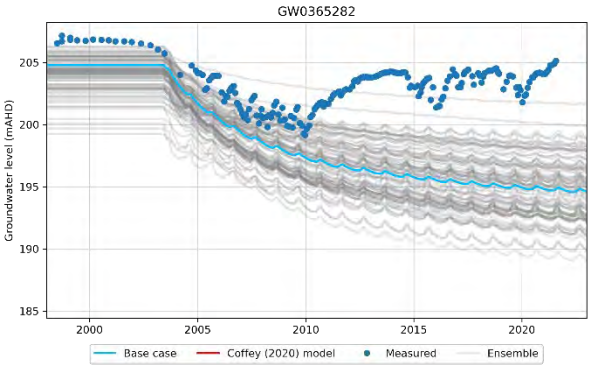

GW0365231
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

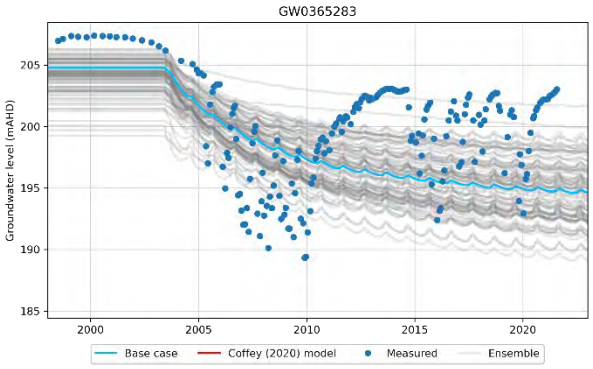

GW0365232
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

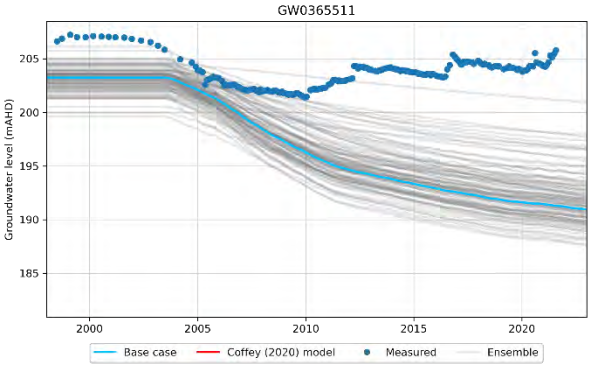

GW0365233
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

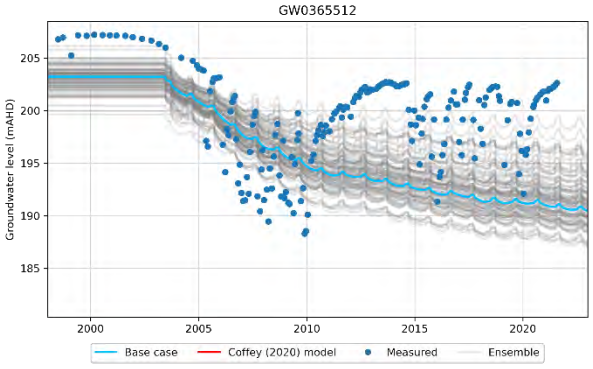

GW0365241
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

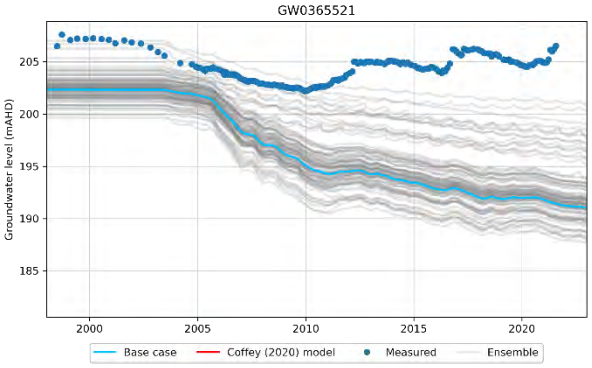

GW0365281
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

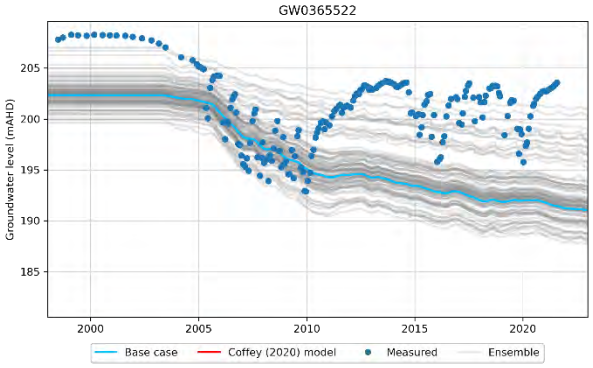

GW0365282
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

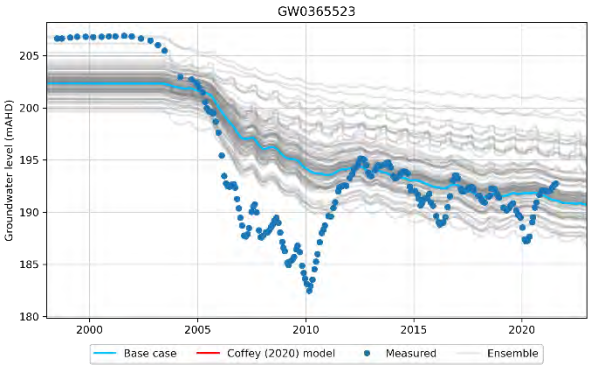

GW0365283
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

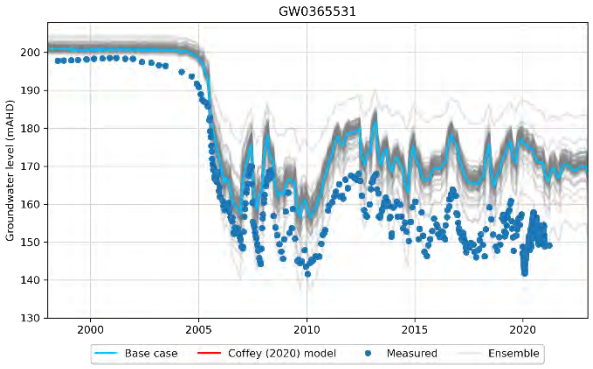

GW0365511
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

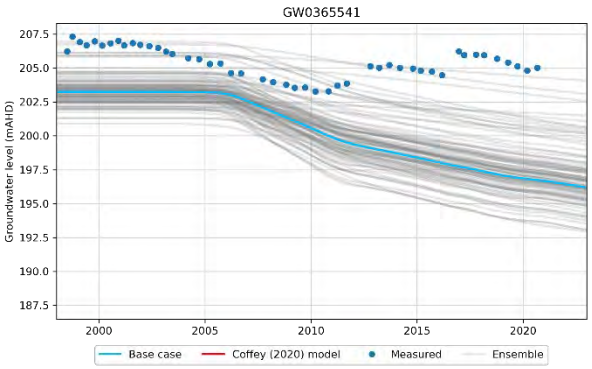

GW0365512
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

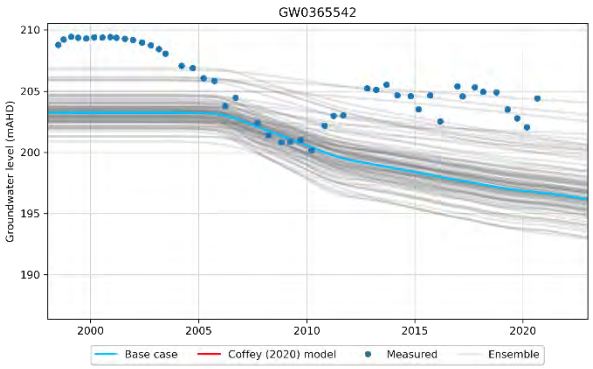

GW0365521
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

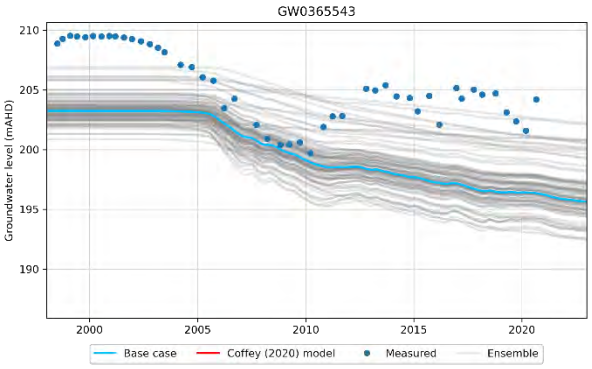

GW0365522
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

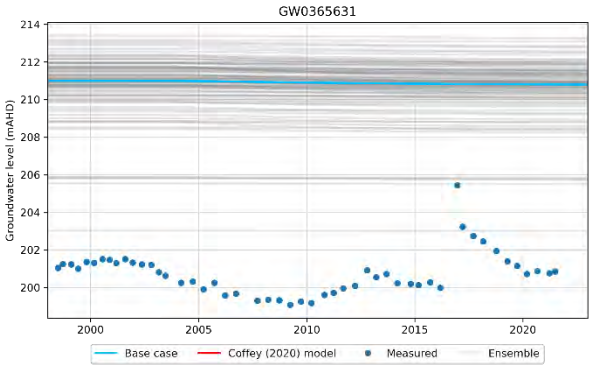

GW0365523
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

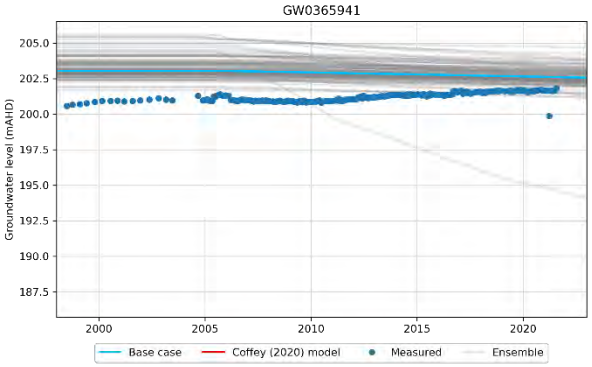

GW0365531
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

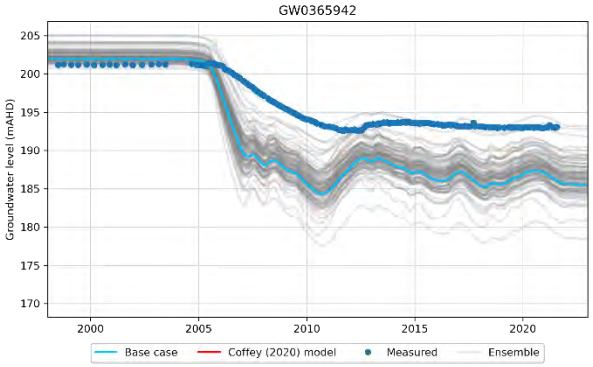

GW0365541
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

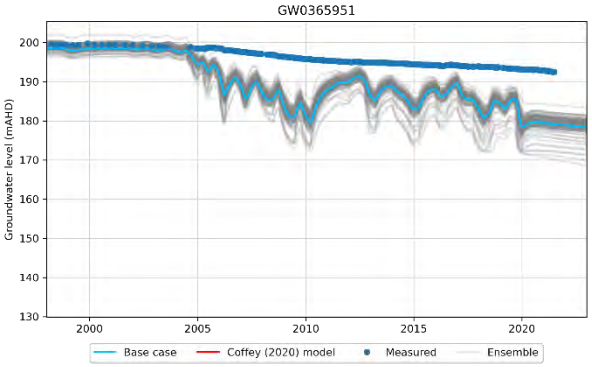

GW0365542
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

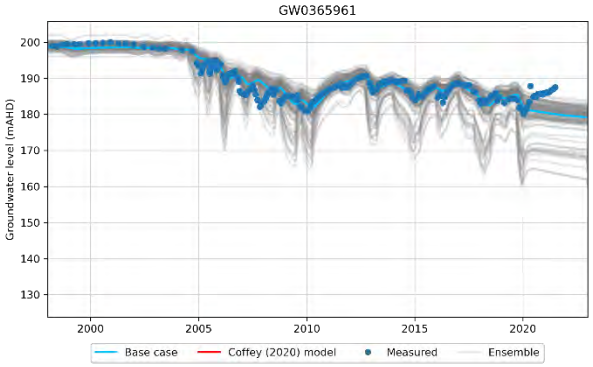

GW0365543
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

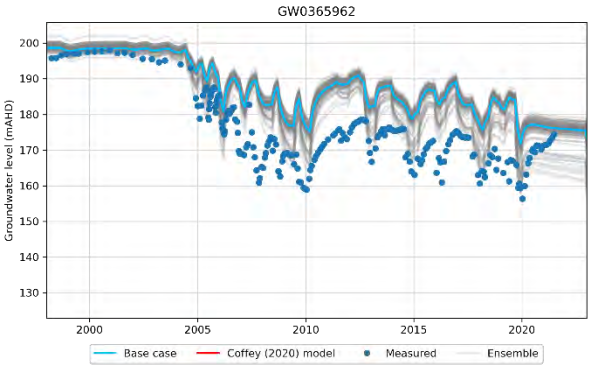

GW0365631
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

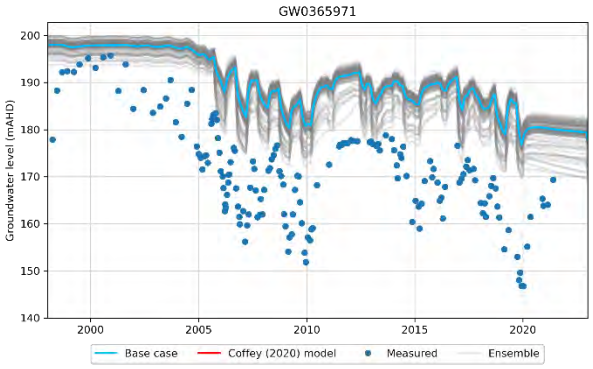

GW0365941
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

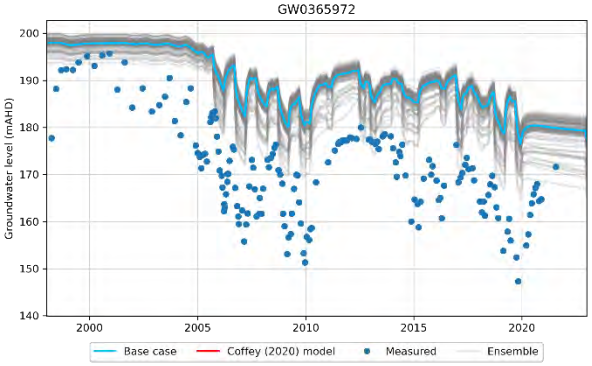

GW0365942
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

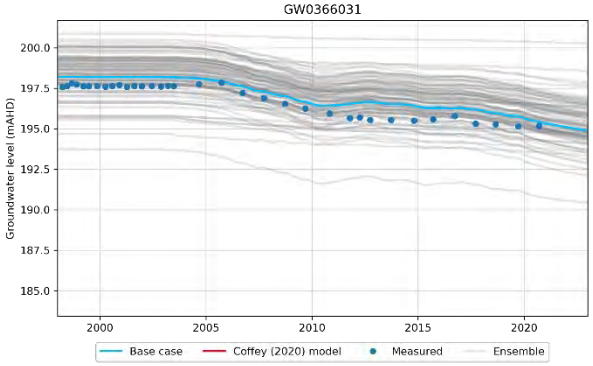

GW0365951
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

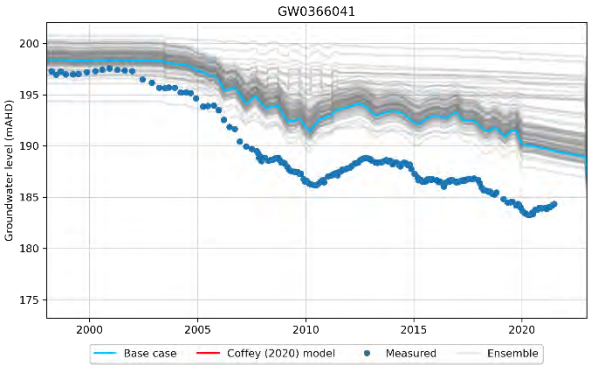

GW0365961
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

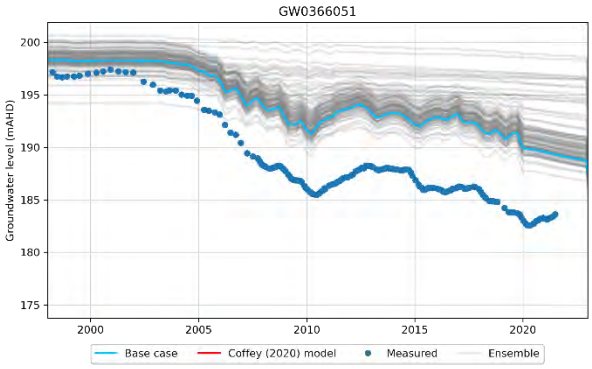

GW0365962
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

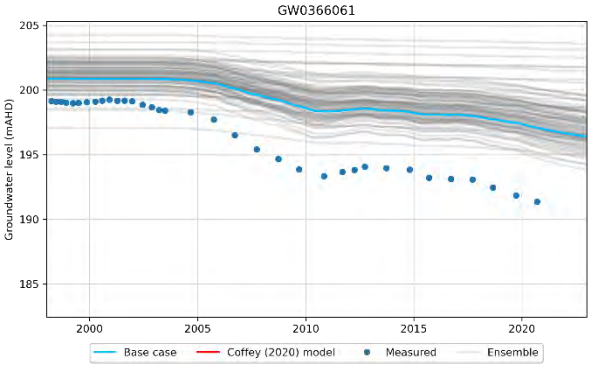

GW0365971
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

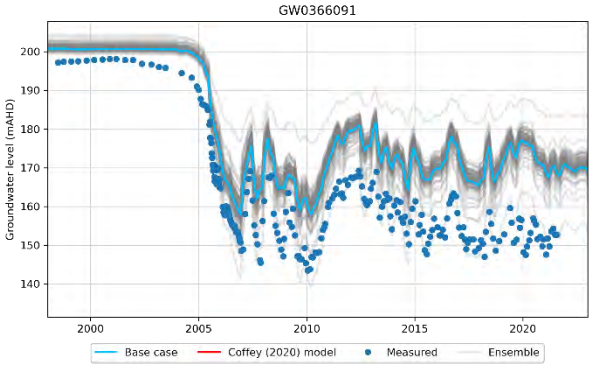

GW0365972
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

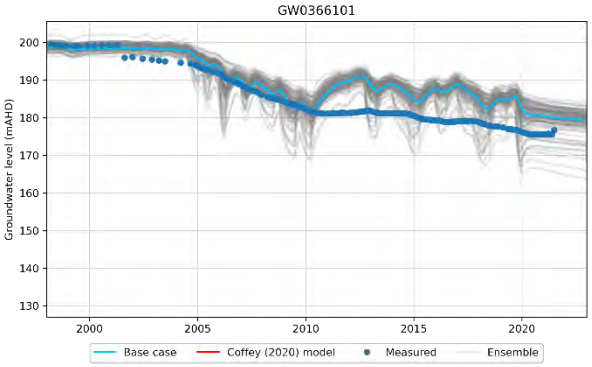

GW0366031
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

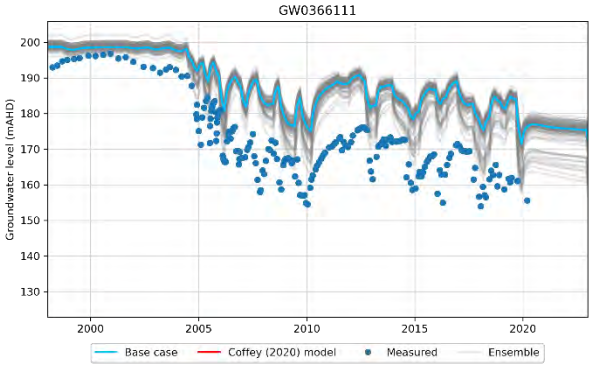

GW0366041
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

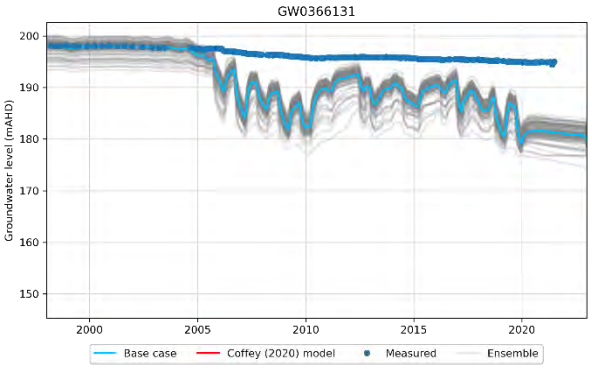

GW0366051
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

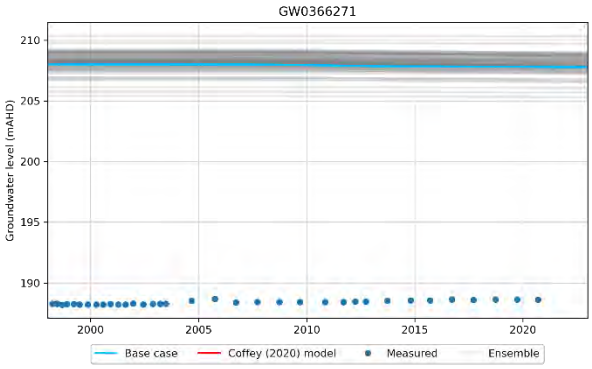

GW0366061
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

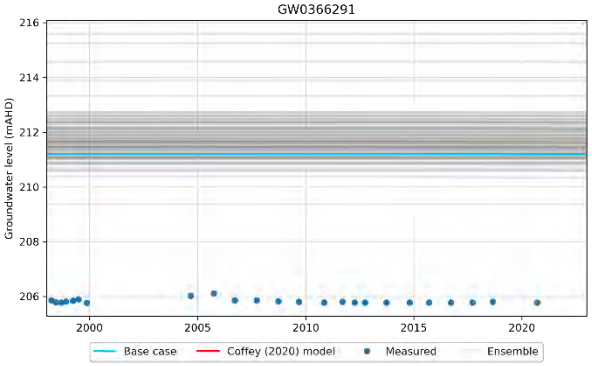

GW0366091
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

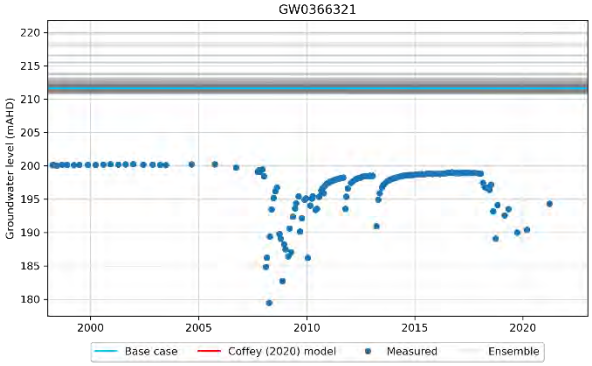

GW0366101
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

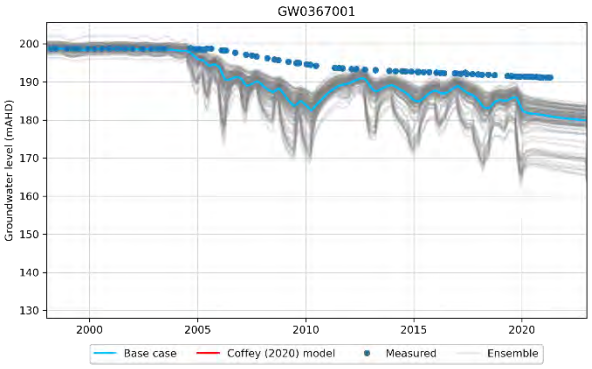

GW0366111
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

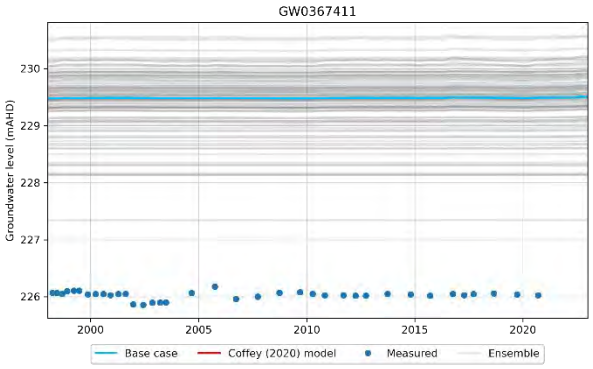

GW0366131
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

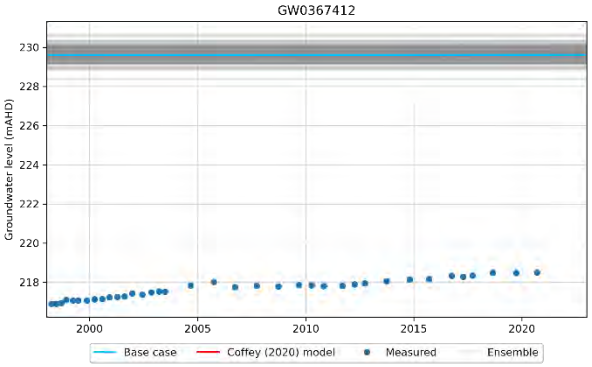

GW0366271
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

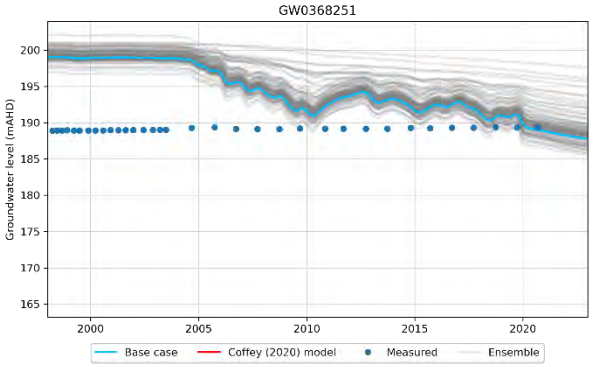

GW0366291
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

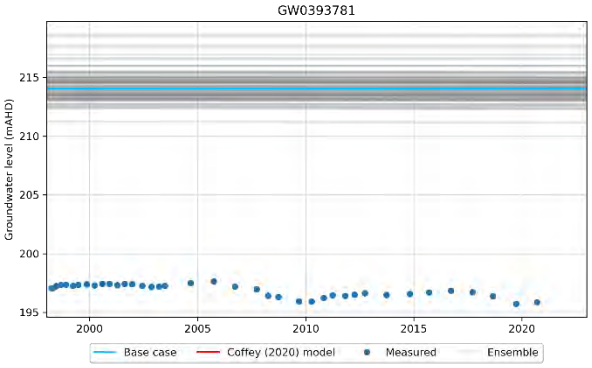

GW0366321
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

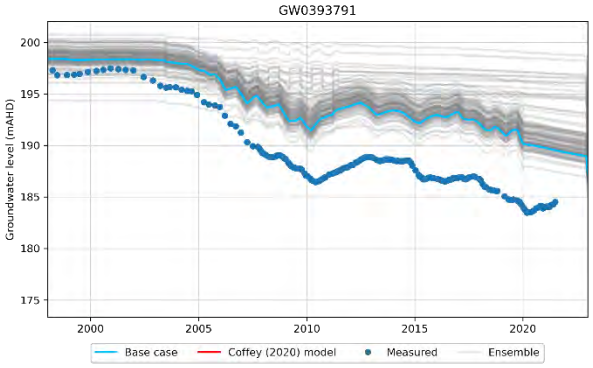

GW0367001
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

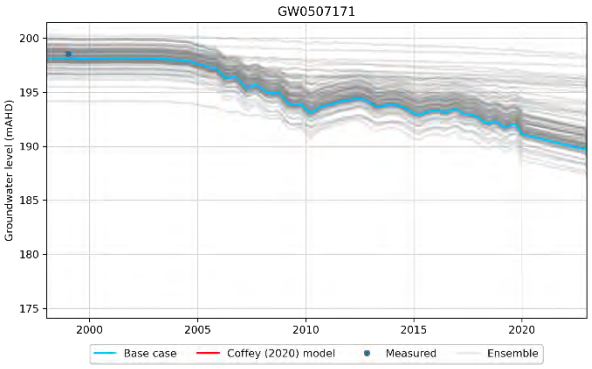

GW0367411
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

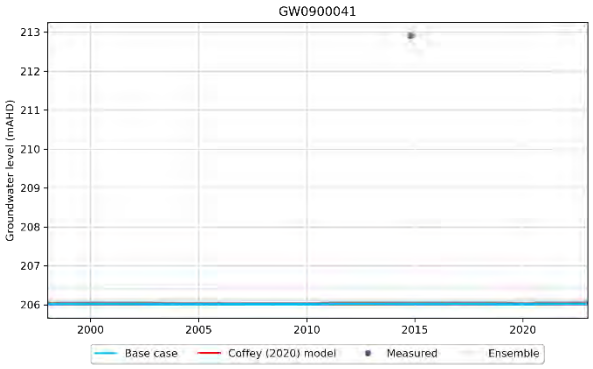

GW0367412
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

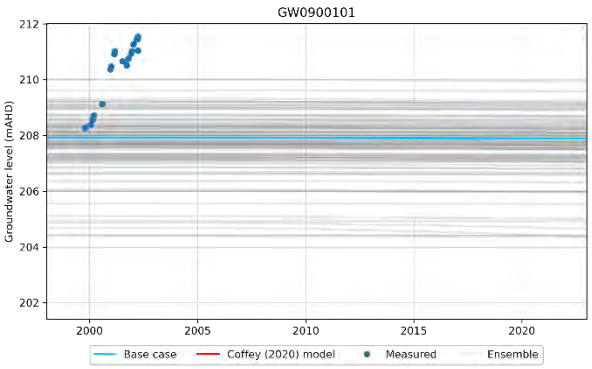

GW0368251
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

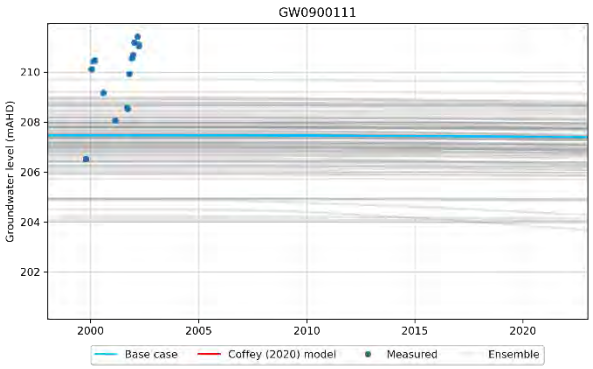

GW0393781
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

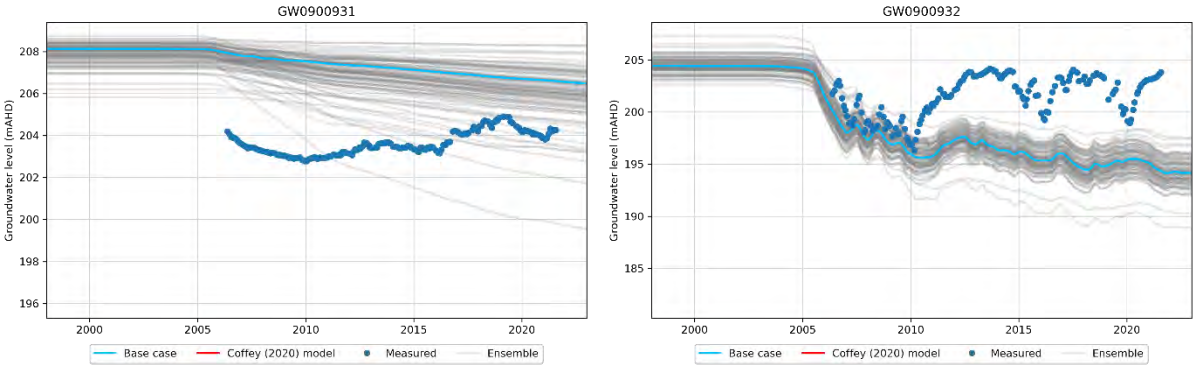

GW0393791
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


GW0507171
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

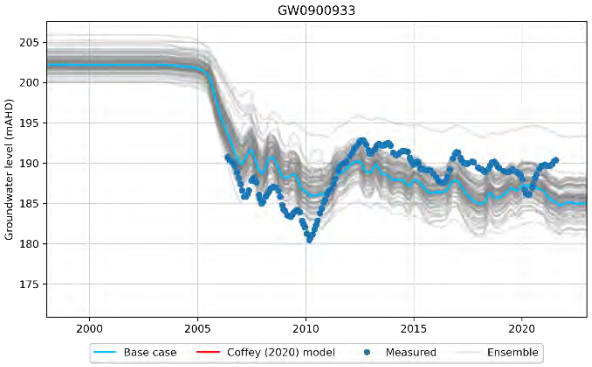

GW0900041
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

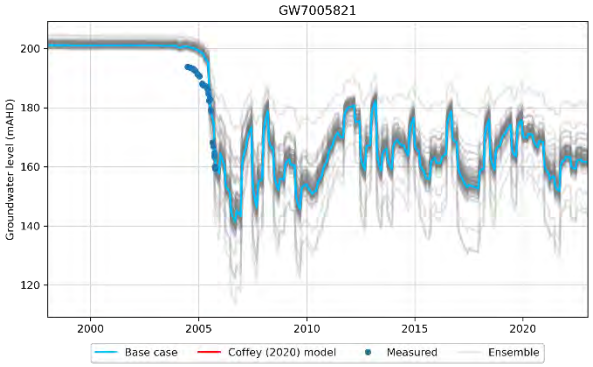

GW0900101
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

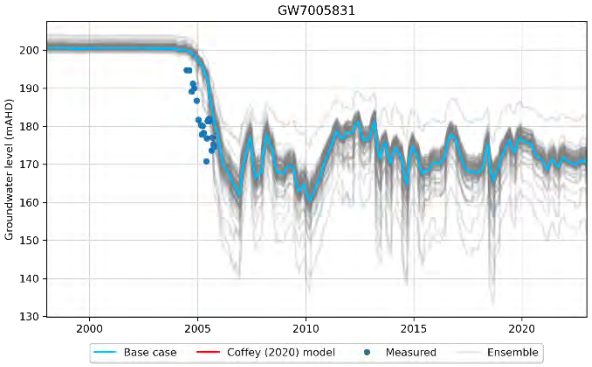

GW0900111
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

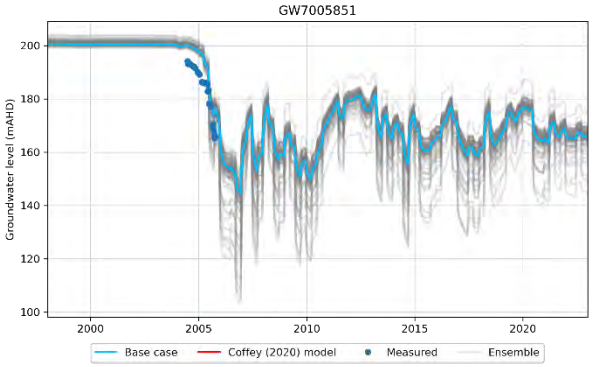

GW0900931
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

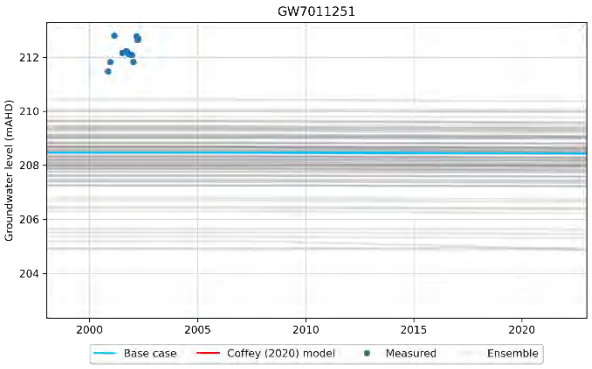
GW0900932
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

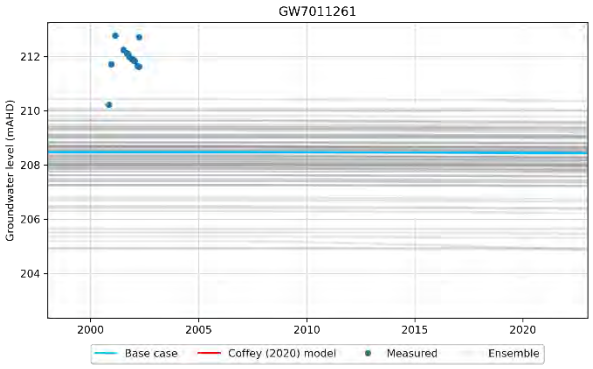

GW0900933
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

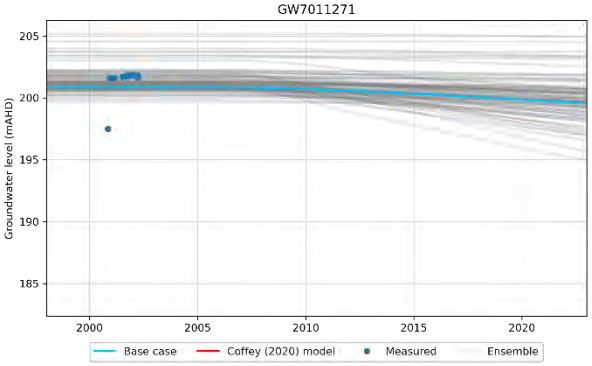

GW7005821
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

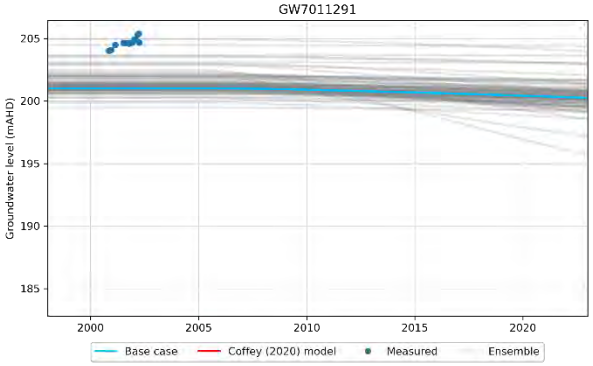

GW7005831
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

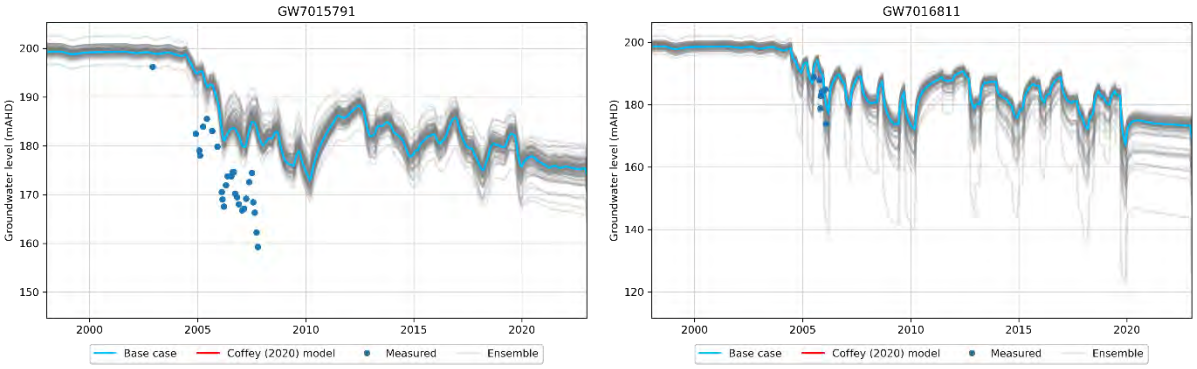

GW7005851
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


GW7011251
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

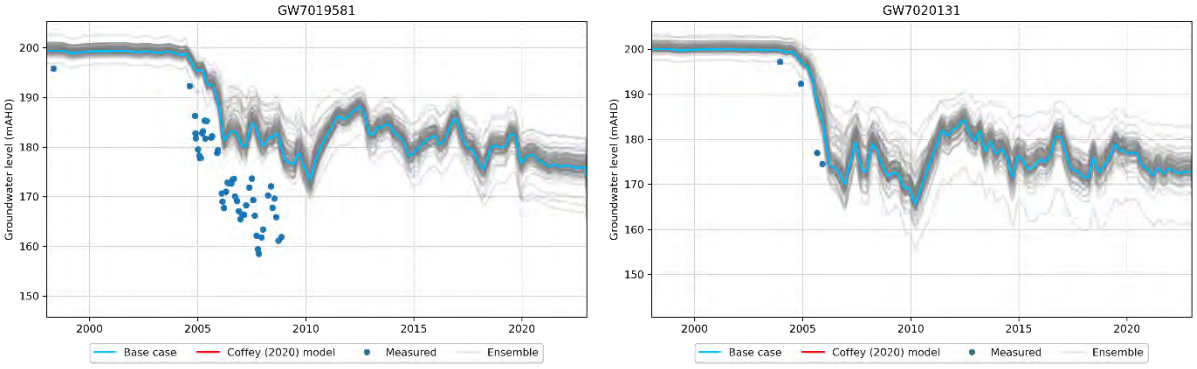

GW7011261
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


GW7011271
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

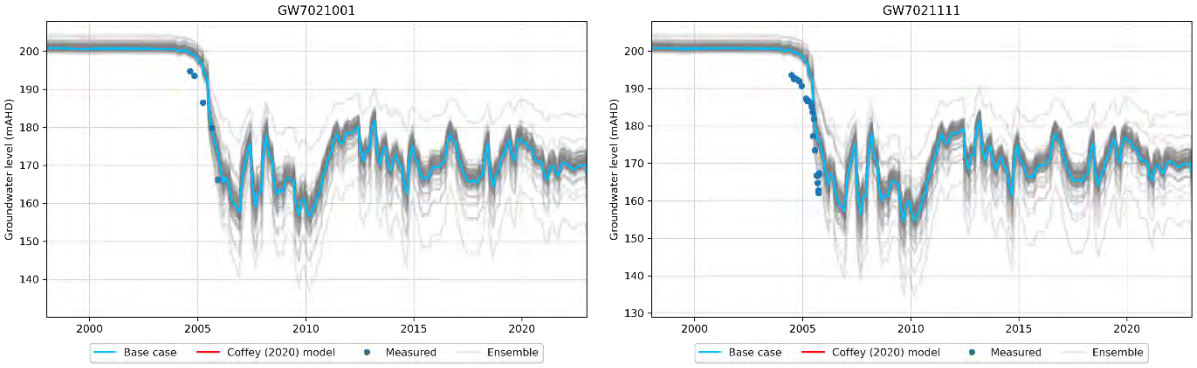

GW7011291
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


GW7015791
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

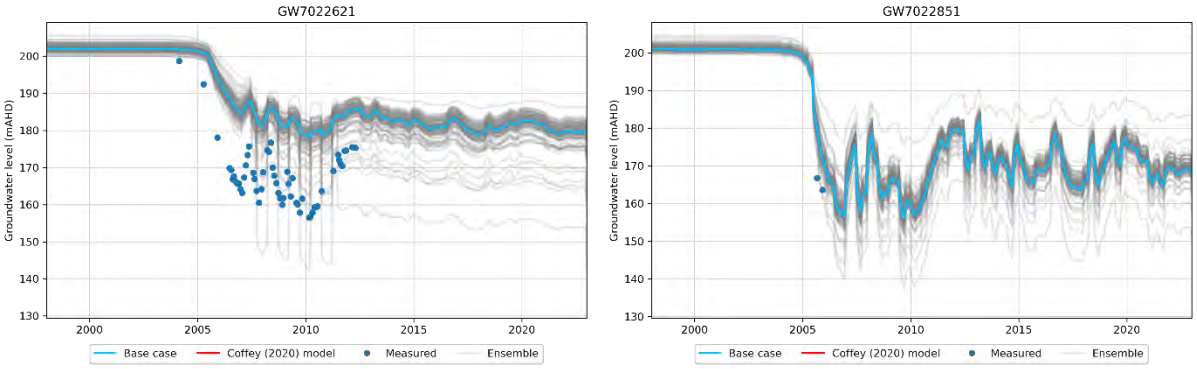
GW7016811
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


GW7019581
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

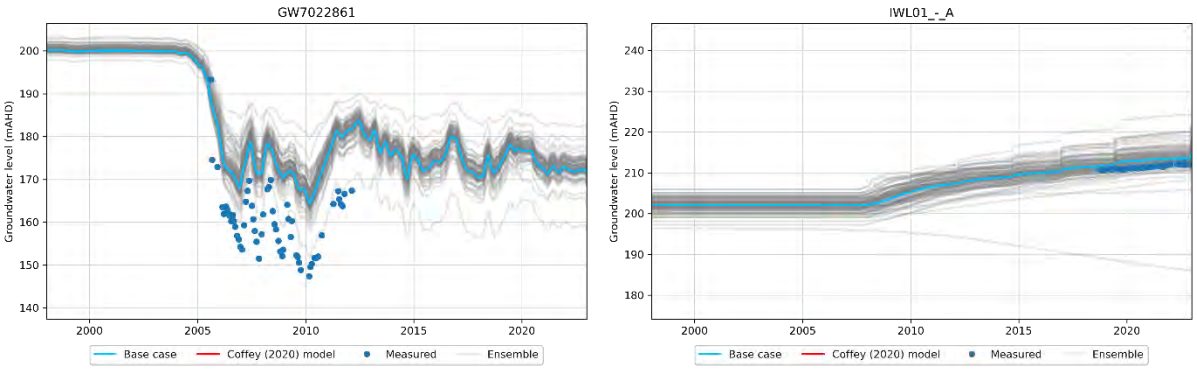
GW7020131
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


GW7021001
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

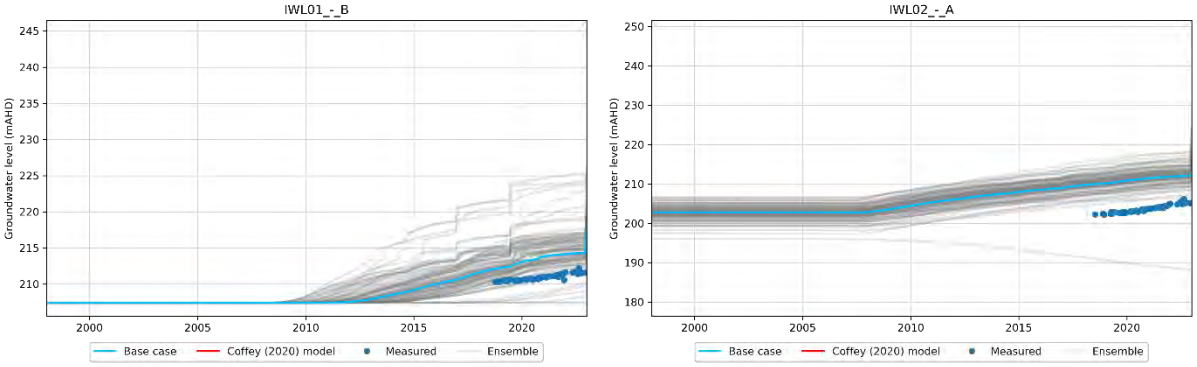
GW7021111
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


GW7022621
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

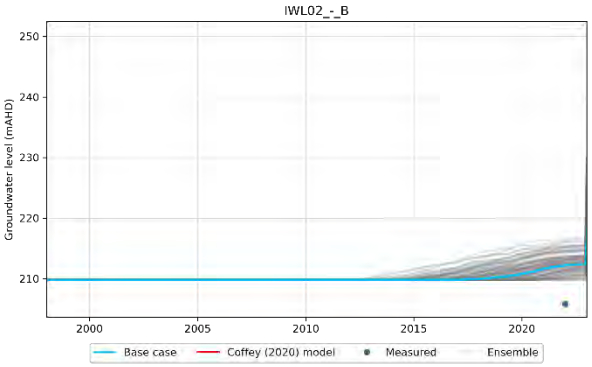
GW7022851
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

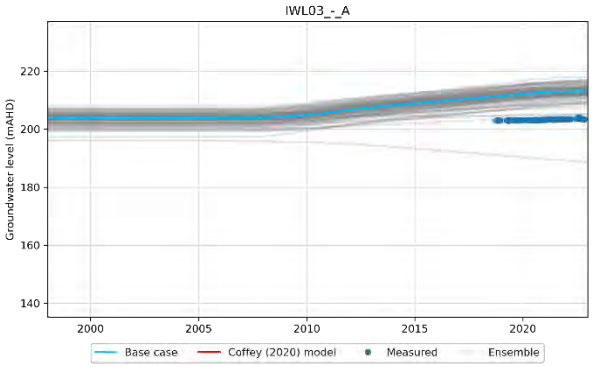

GW7022861
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

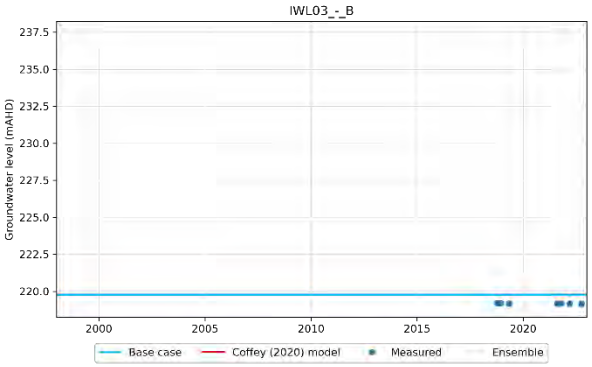
IWL01_-_A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

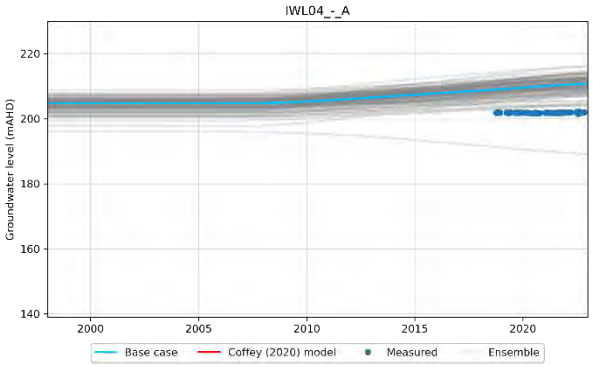

IWL01_-_B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

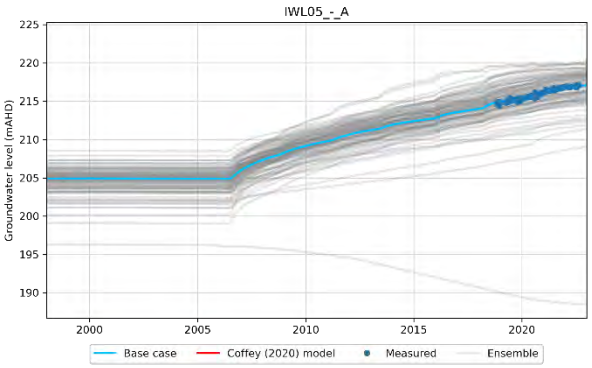
IWL02_-_A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

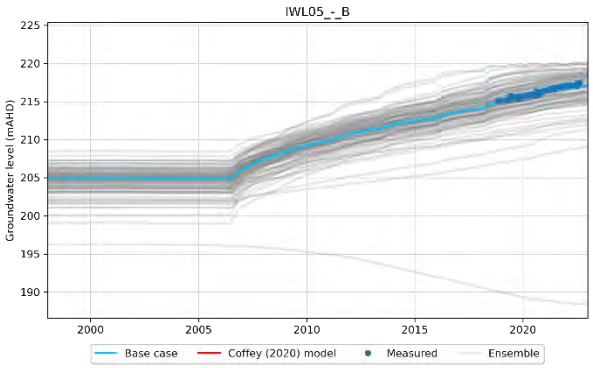

IWL02_-_B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

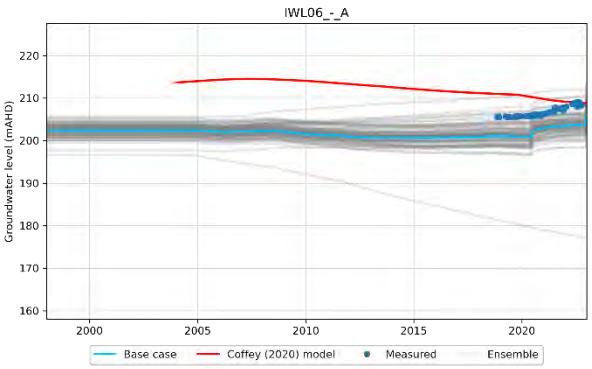

IWL03_-_A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

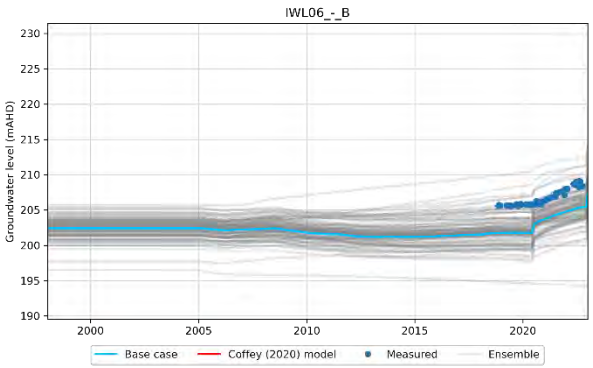

IWL03_-_B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

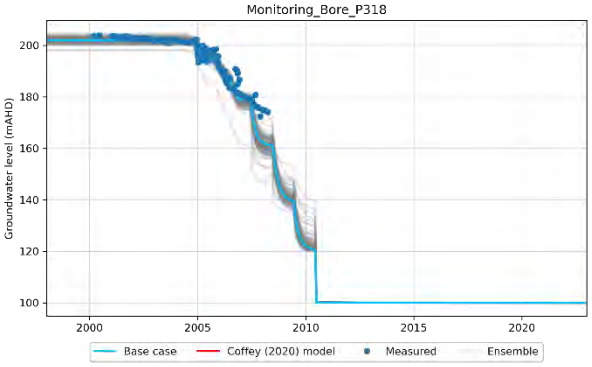

IWL04_-_A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

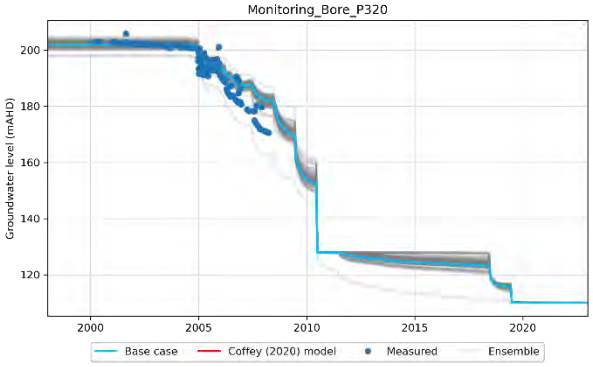

IWL05_-_A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

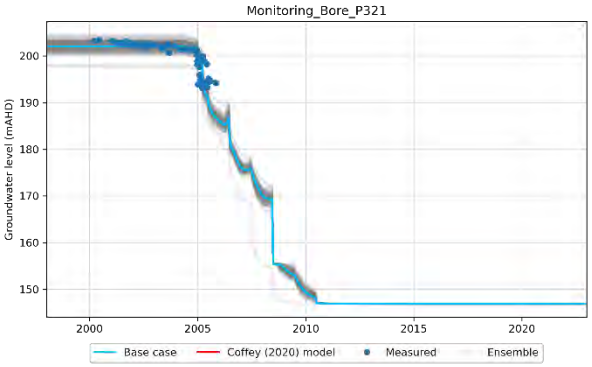

IWL05_-_B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

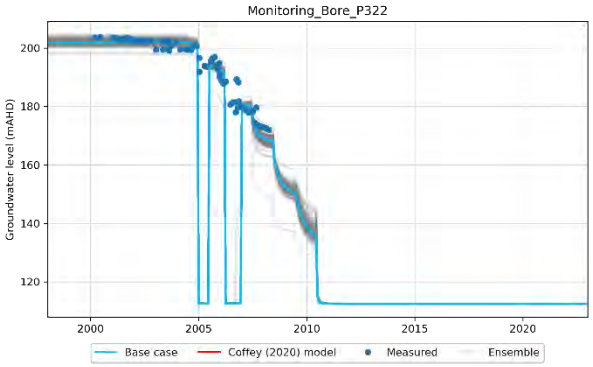

IWL06_-_A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

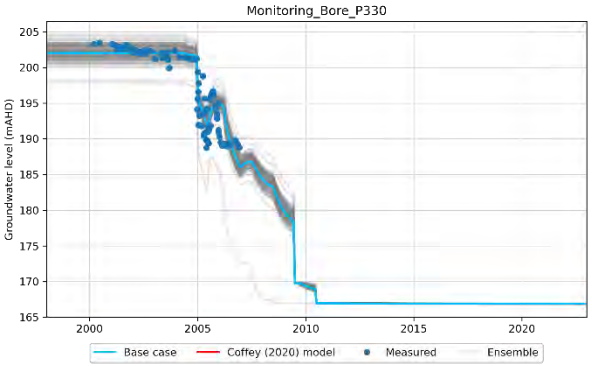

IWL06_-_B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

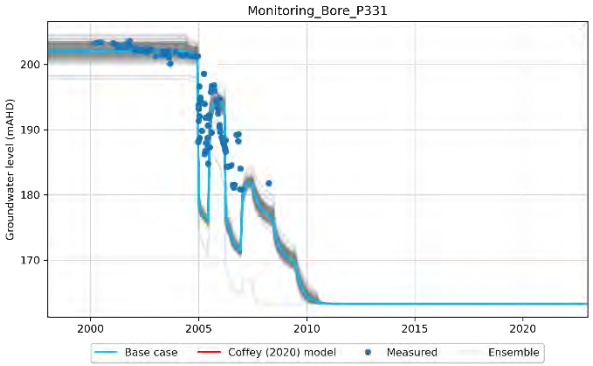

Monitoring_Bore_P318
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

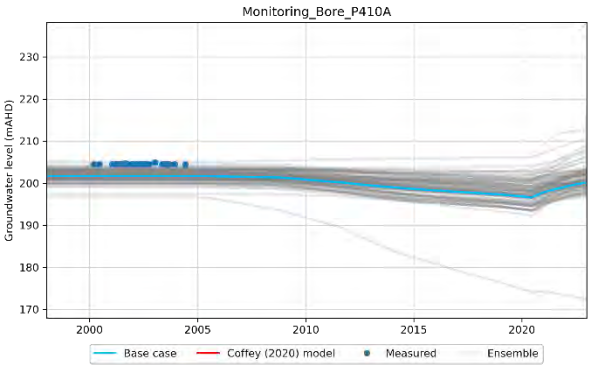

Monitoring_Bore_P320
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

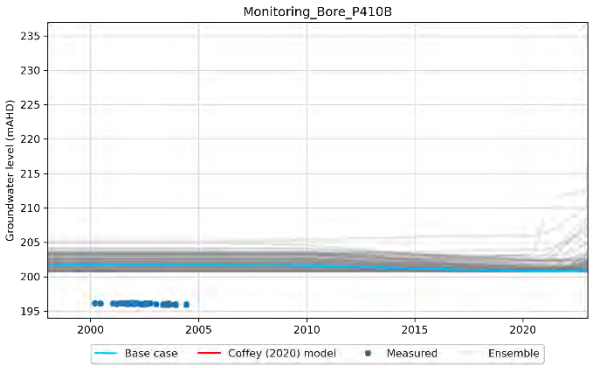

Monitoring_Bore_P321
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

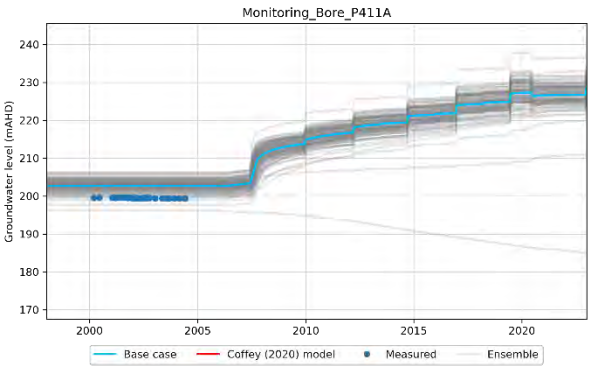

Monitoring_Bore_P322
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

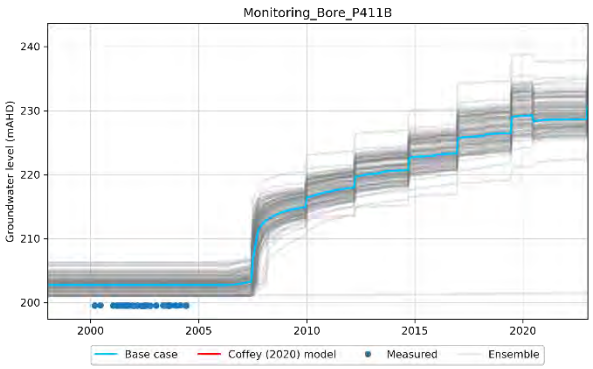

Monitoring_Bore_P330
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

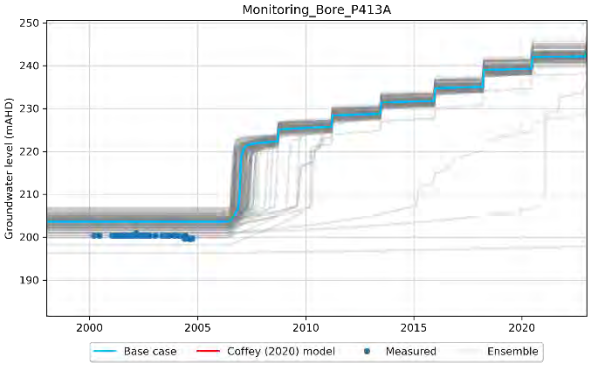

Monitoring_Bore_P331
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

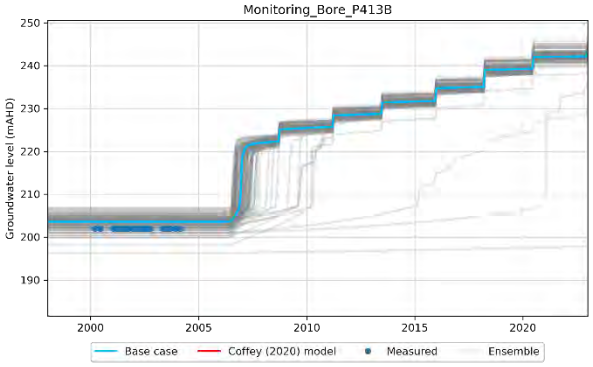

Monitoring_Bore_P410A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

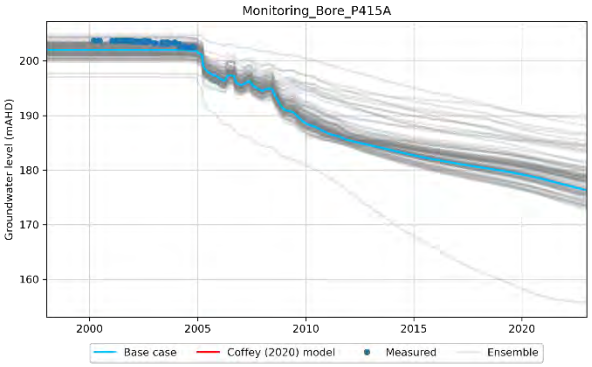

Monitoring_Bore_P410B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

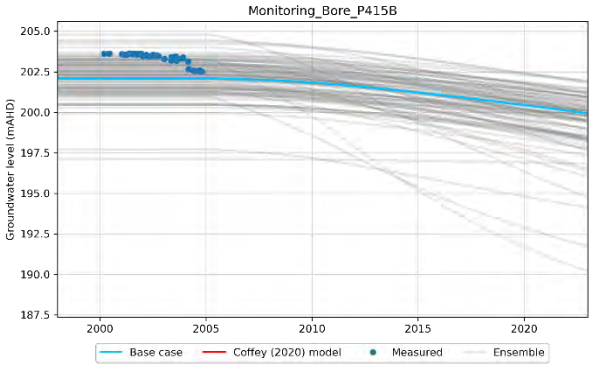

Monitoring_Bore_P411A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

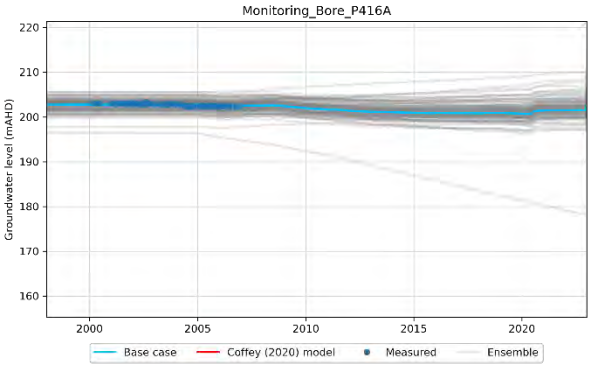

Monitoring_Bore_P411B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

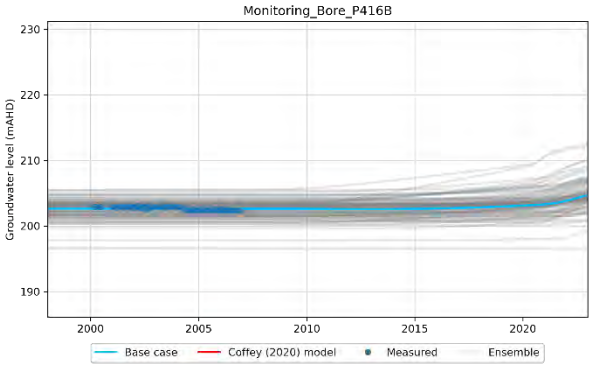

Monitoring_Bore_P413A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

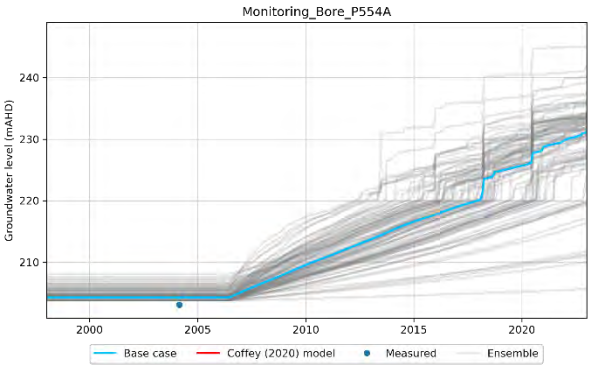

Monitoring_Bore_P413B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

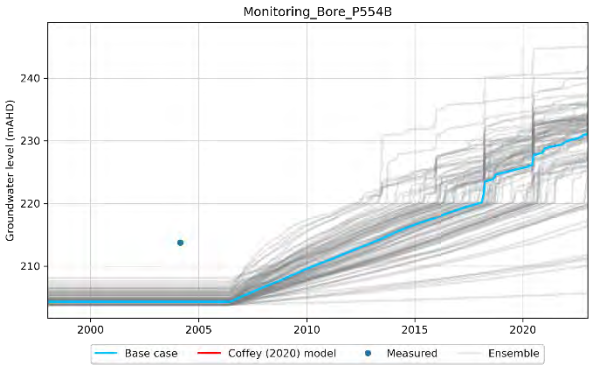

Monitoring_Bore_P415A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

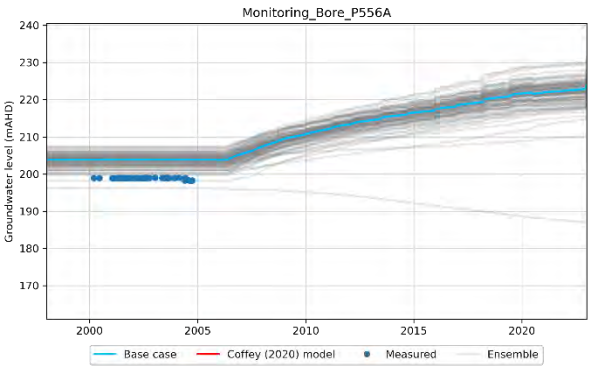

Monitoring_Bore_P415B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

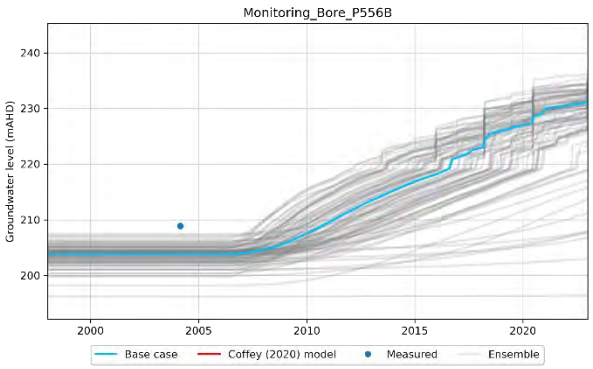

Monitoring_Bore_P416A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

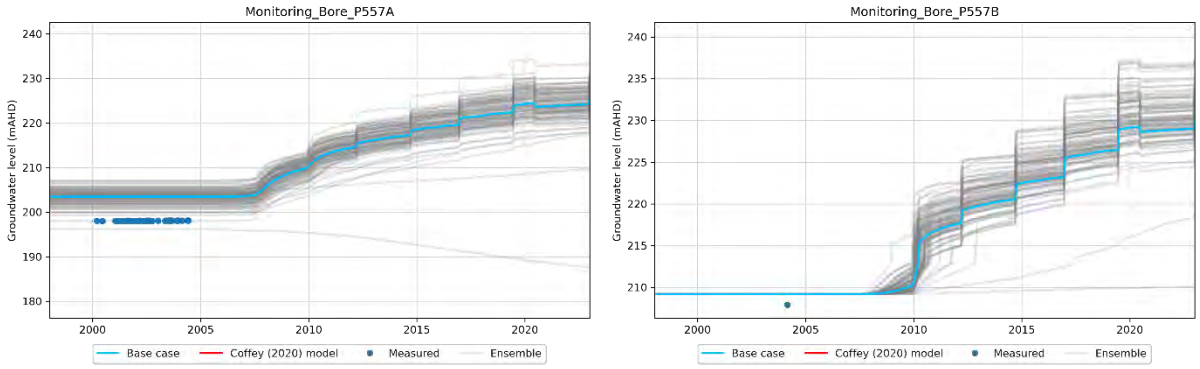

Monitoring_Bore_P416B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


Monitoring_Bore_P554A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

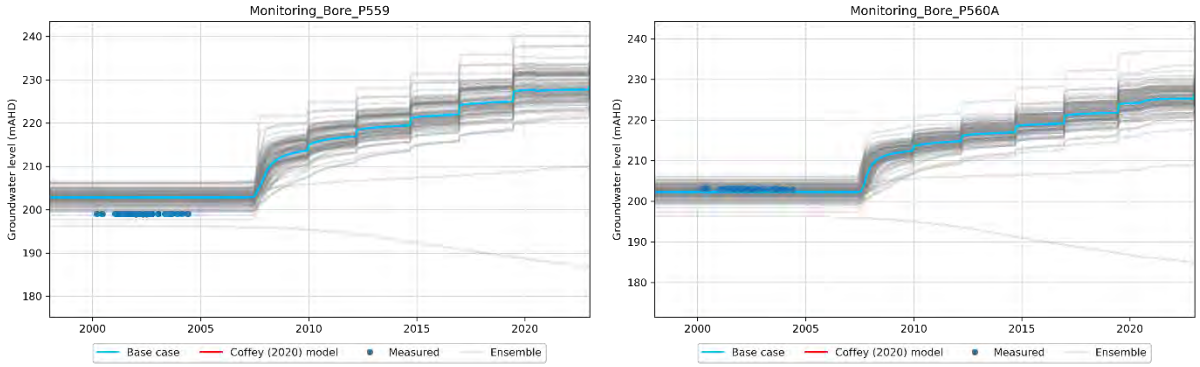

Monitoring_Bore_P554B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


Monitoring_Bore_P556A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

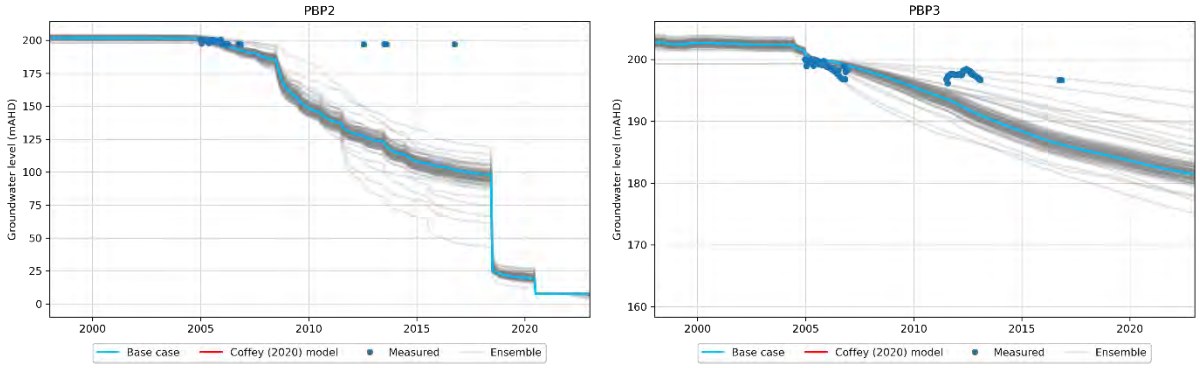

Monitoring_Bore_P556B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


Monitoring_Bore_P557A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

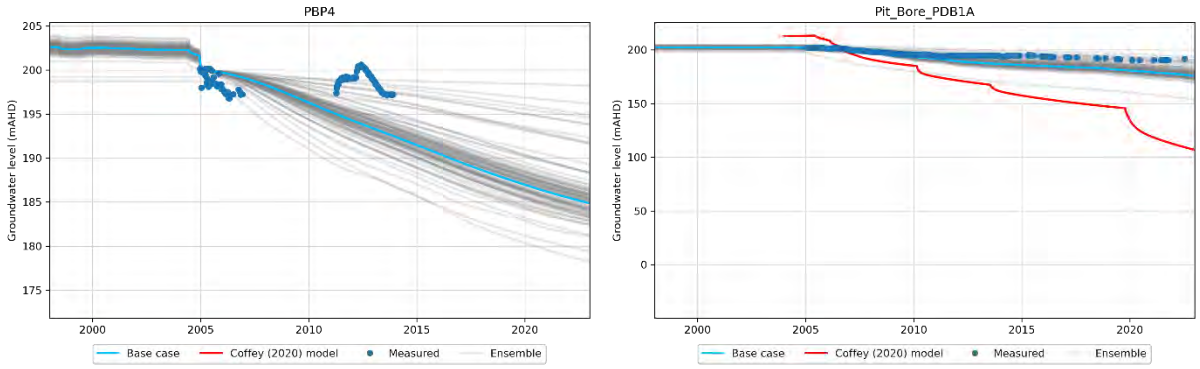
Monitoring_Bore_P557B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


Monitoring_Bore_P559
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

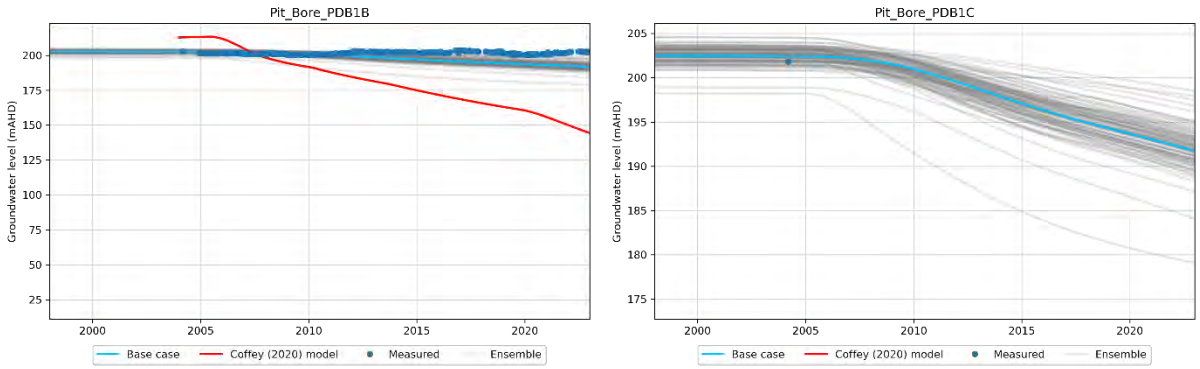
Monitoring_Bore_P560A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PBP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

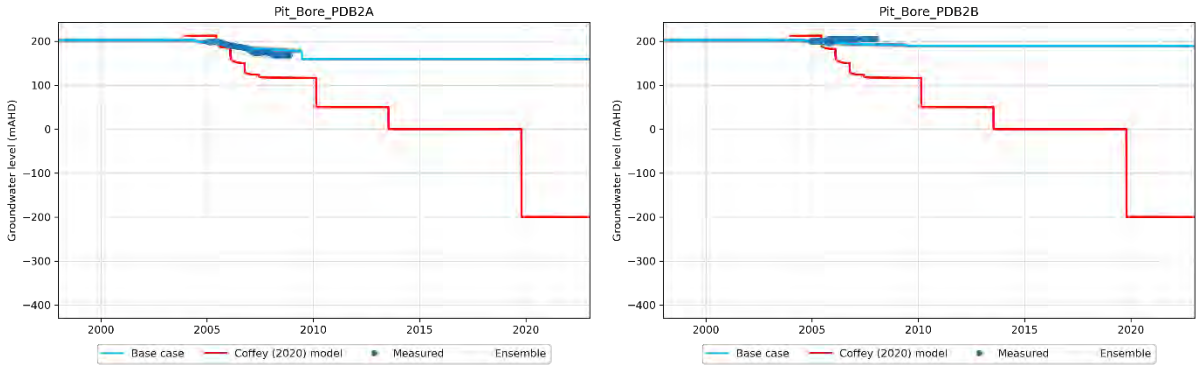
PBP3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PBP4
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

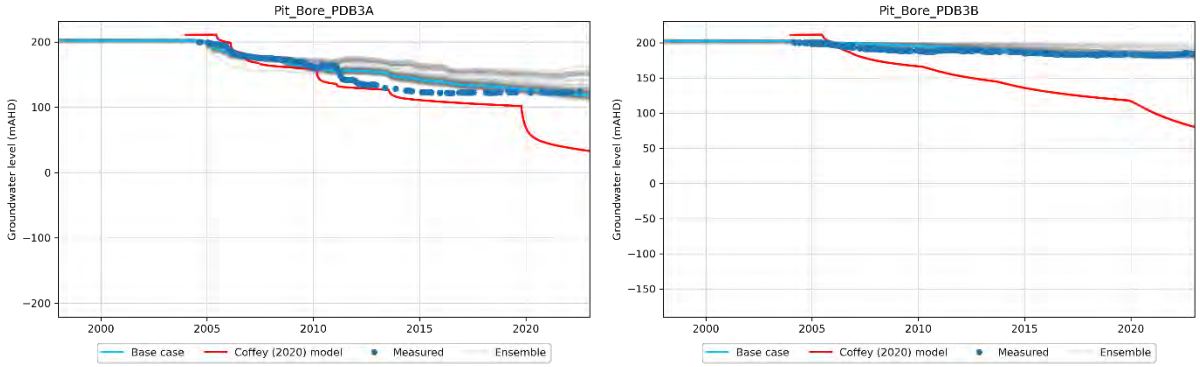
Pit_Bore_PDB1A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


Pit_Bore_PDB1B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

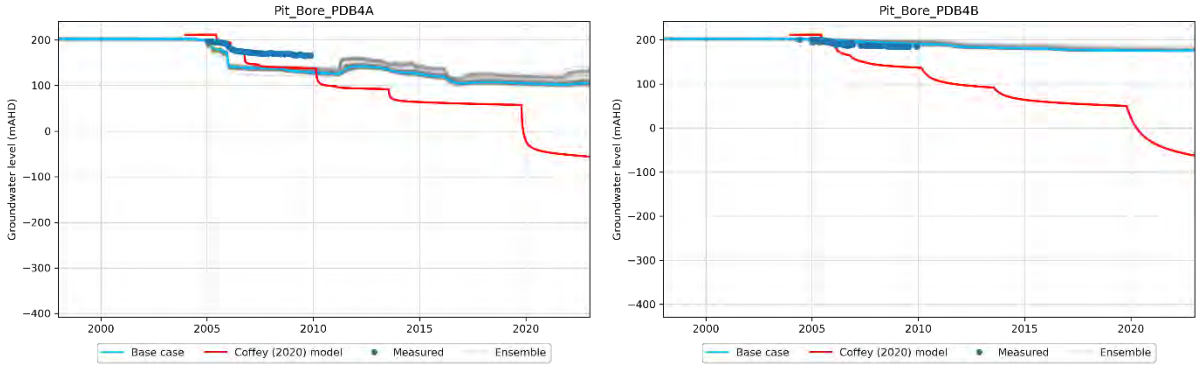
Pit_Bore_PDB1C
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


Pit_Bore_PDB2A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

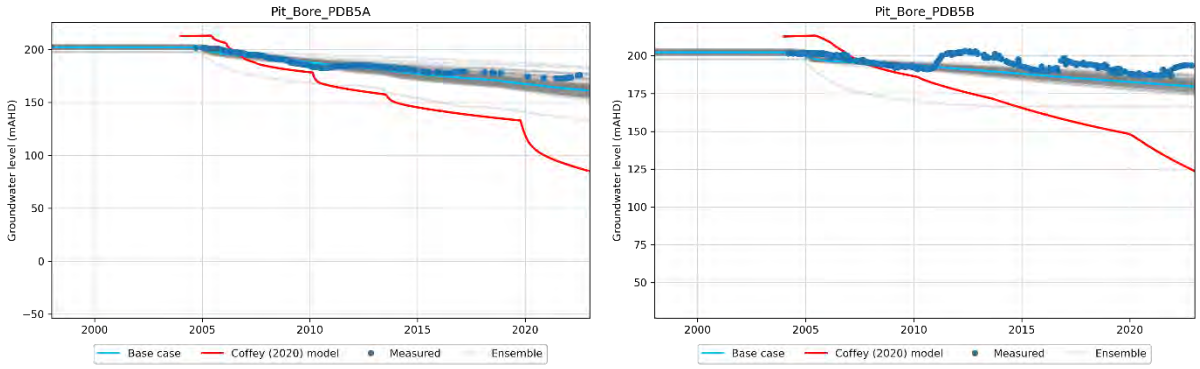
Pit_Bore_PDB2B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


Pit_Bore_PDB3A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

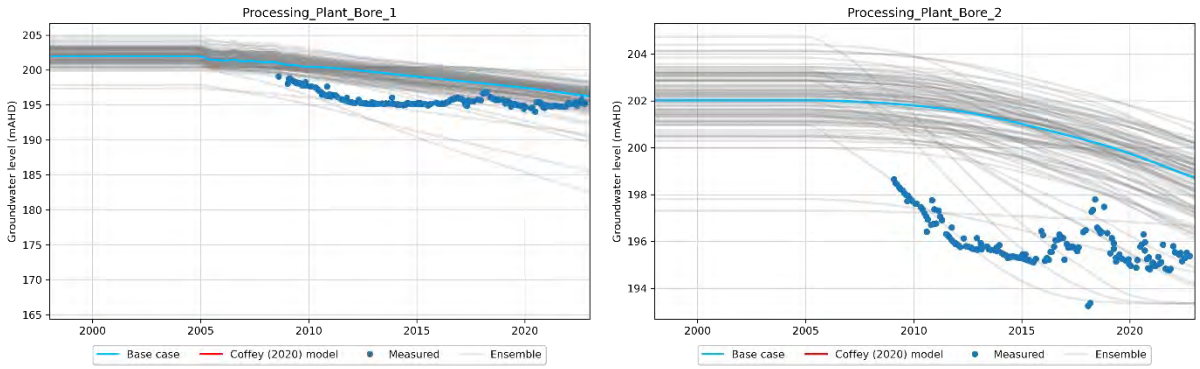
Pit_Bore_PDB3B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


Pit_Bore_PDB4A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

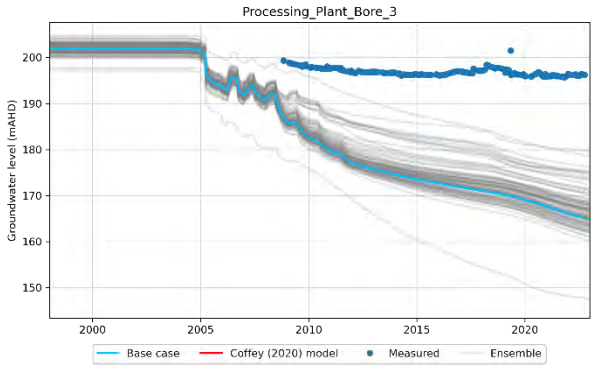
Pit_Bore_PDB4B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

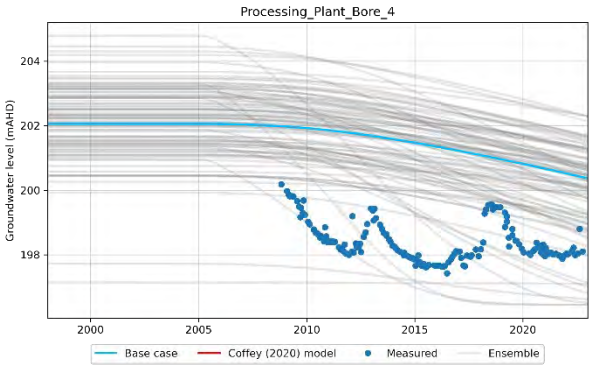

Pit_Bore_PDB5A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

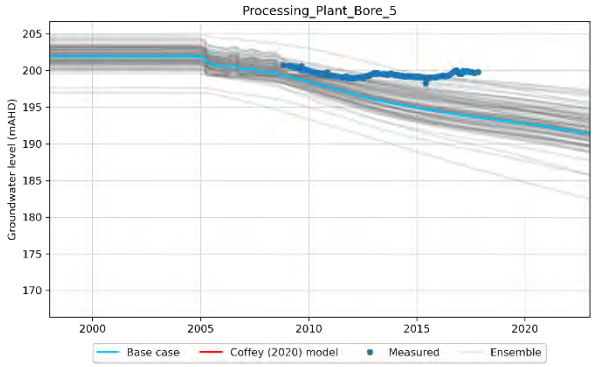
Pit_Bore_PDB5B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

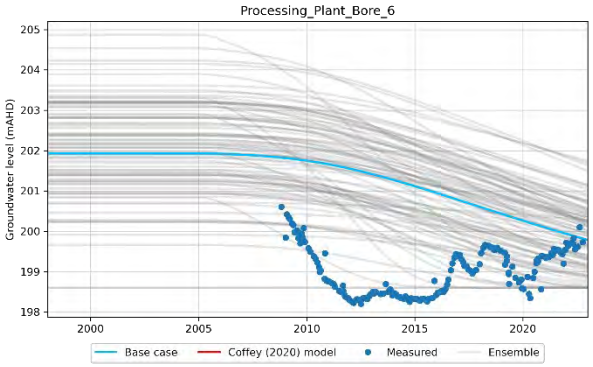

Processing_Plant_Bore_1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

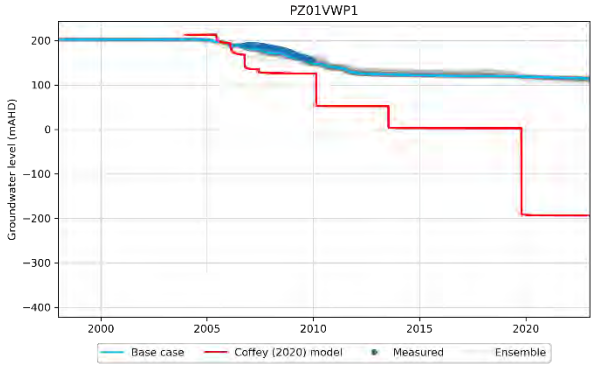
Processing_Plant_Bore_2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

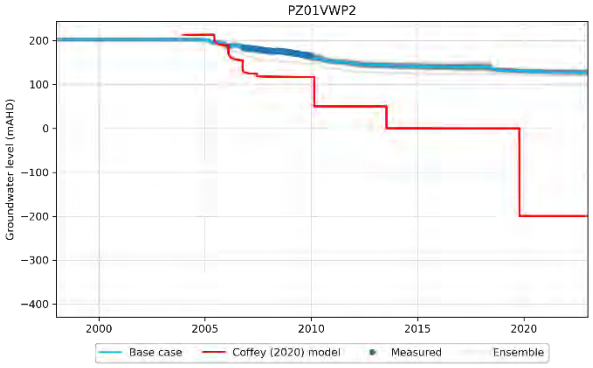

Processing_Plant_Bore_3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

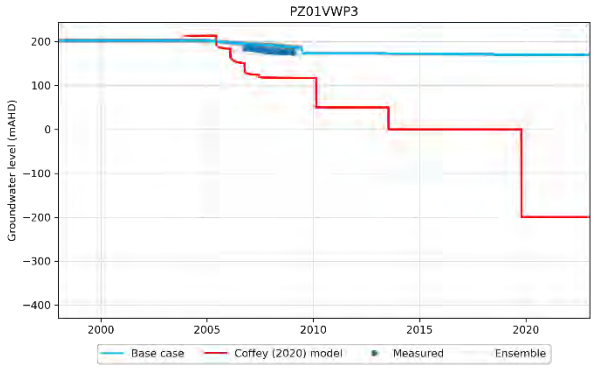

Processing_Plant_Bore_4
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

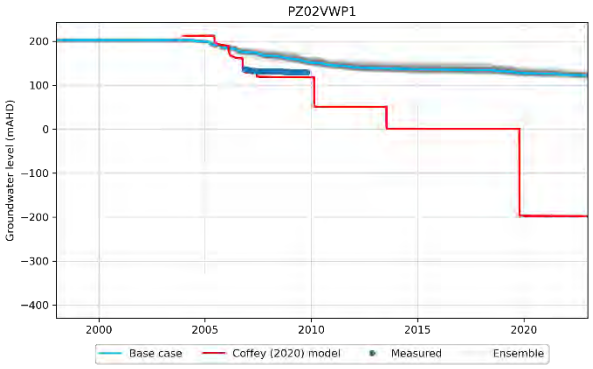

Processing_Plant_Bore_5
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

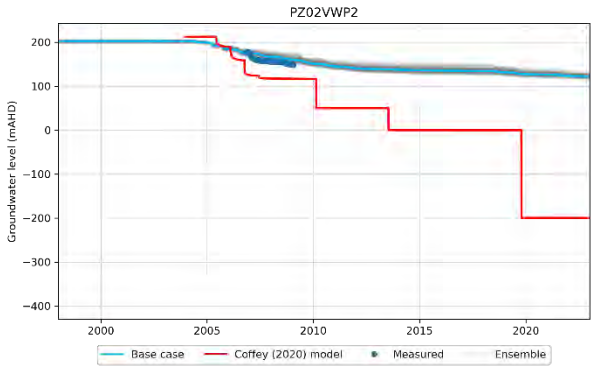

Processing_Plant_Bore_6
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

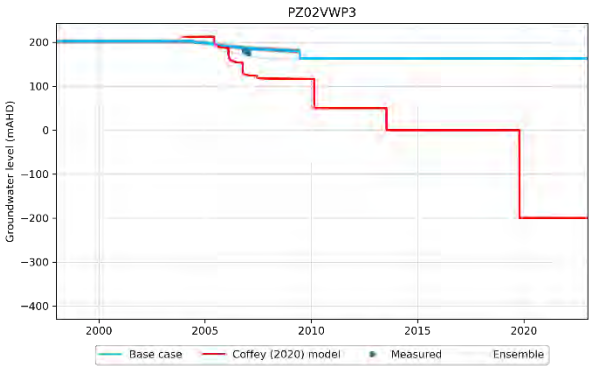

PZ01VWP1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

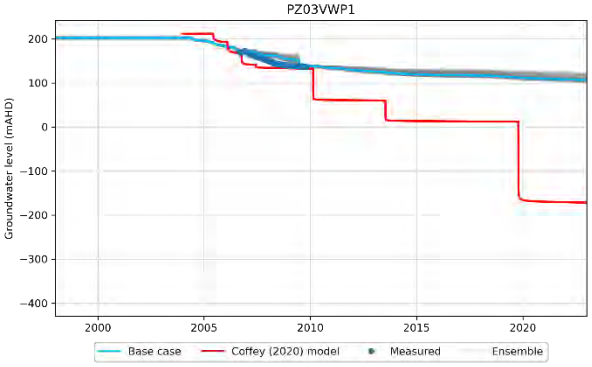

PZ01VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

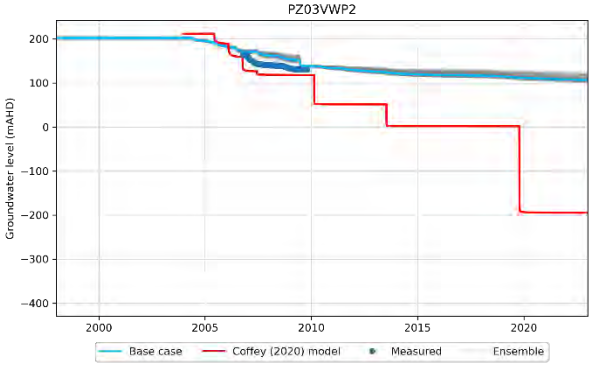

PZ01VWP3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

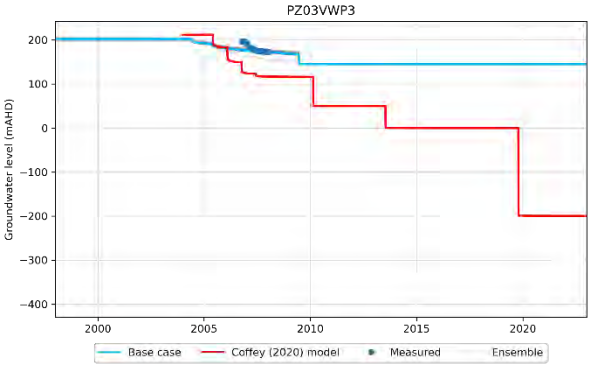

PZ02VWP1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

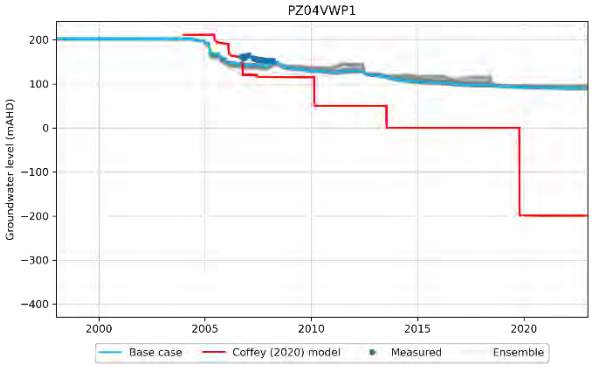

PZ02VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

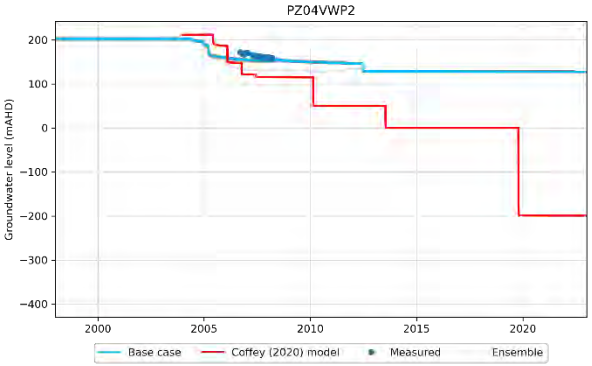

PZ02VWP3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

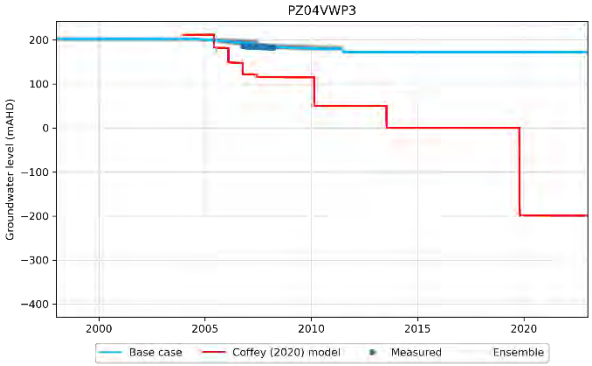

PZ03VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

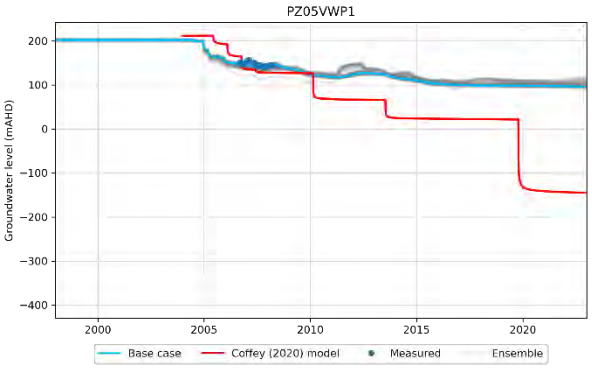

PZ03VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

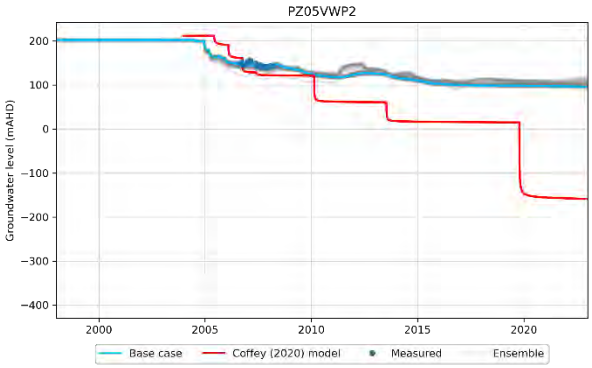

PZ03VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

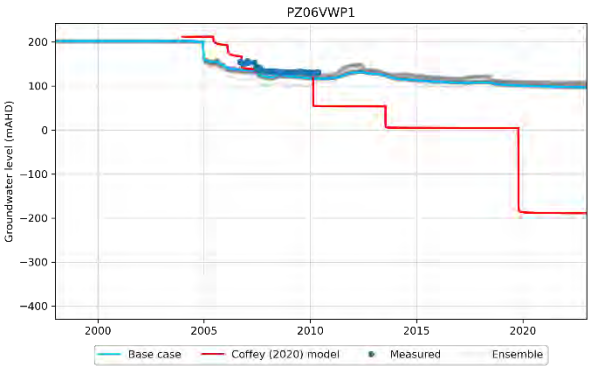

PZ04VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

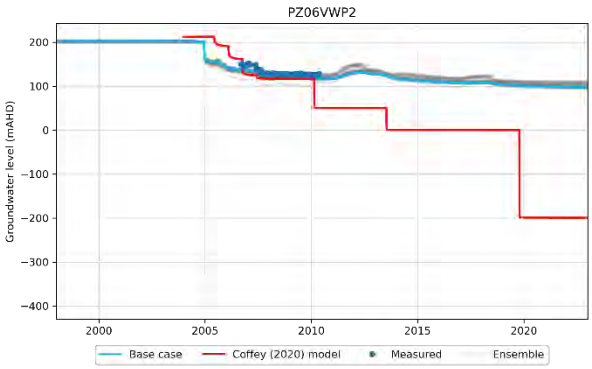

PZ04VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

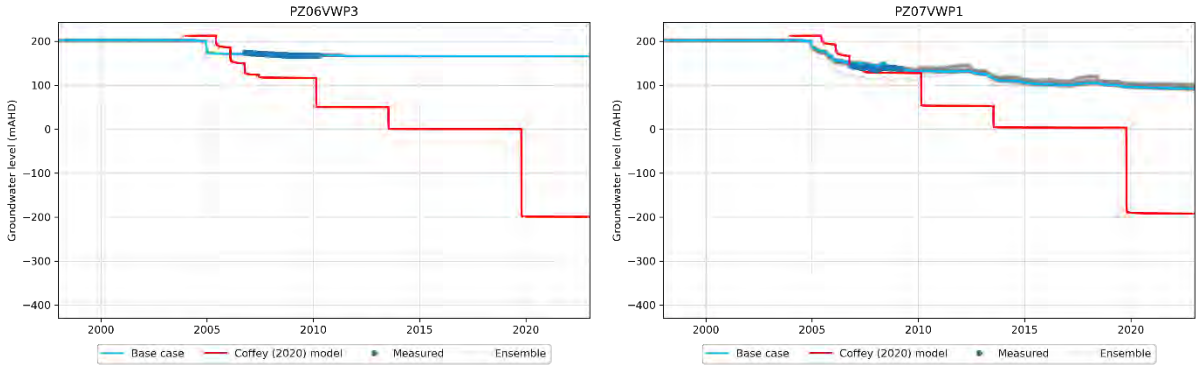

PZ04VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ05VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

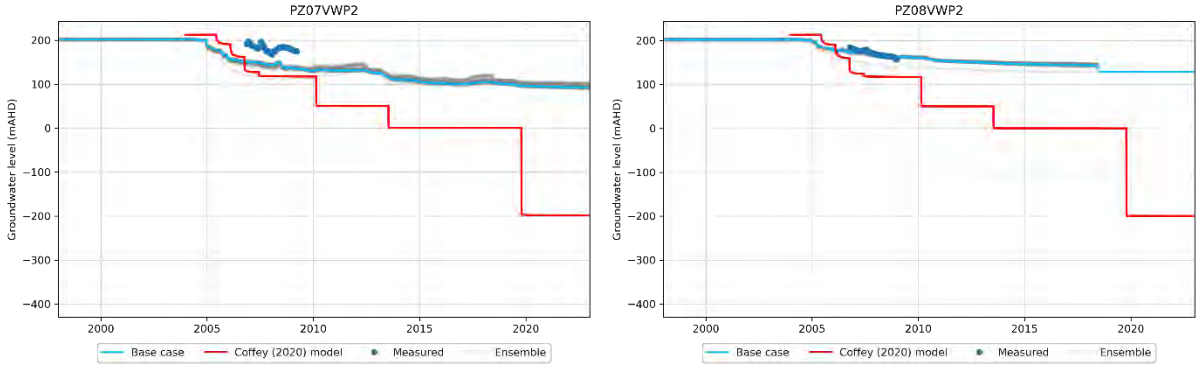

PZ05VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ06VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

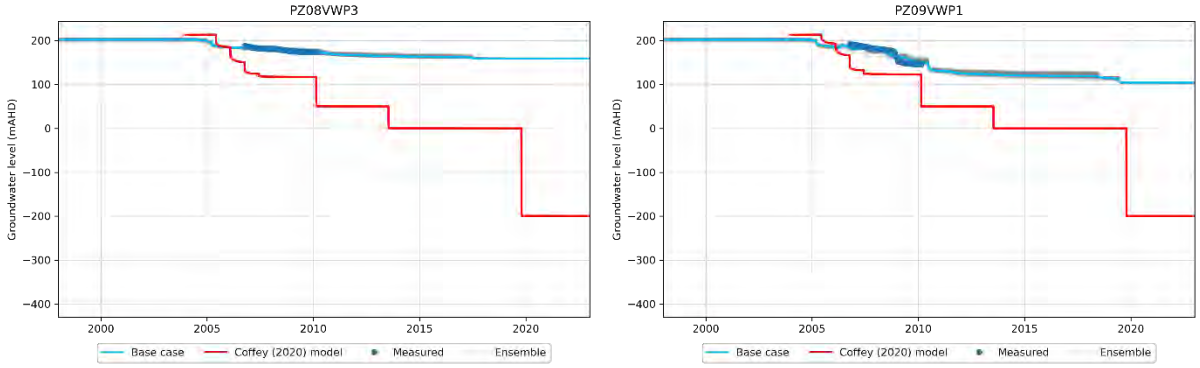

PZ06VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ06VWP3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

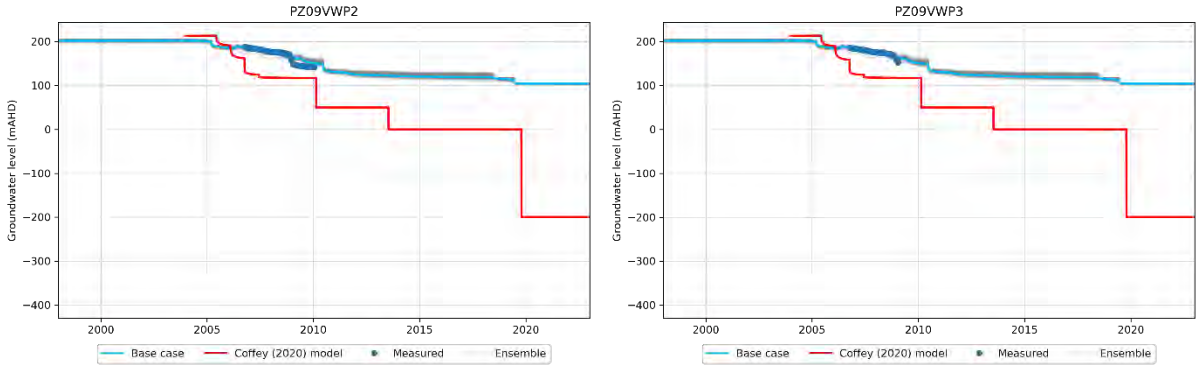
PZ07VWP1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ07VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

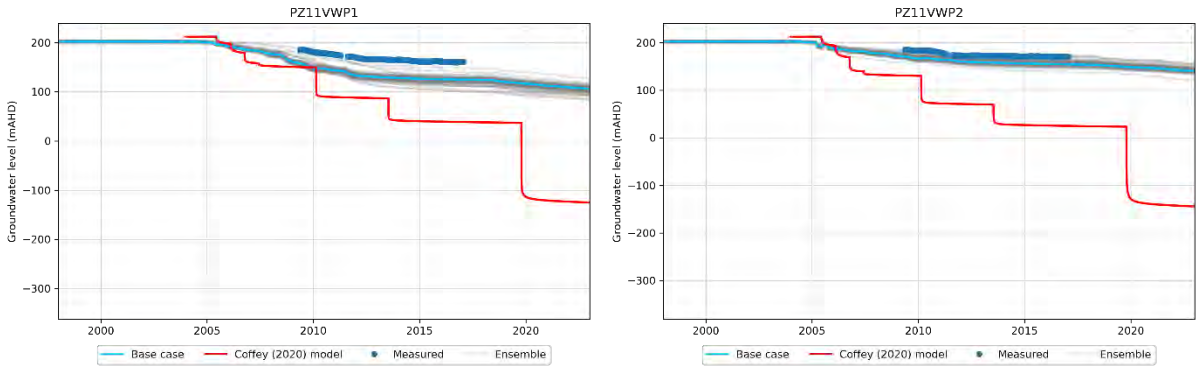
PZ08VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ08VWP3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

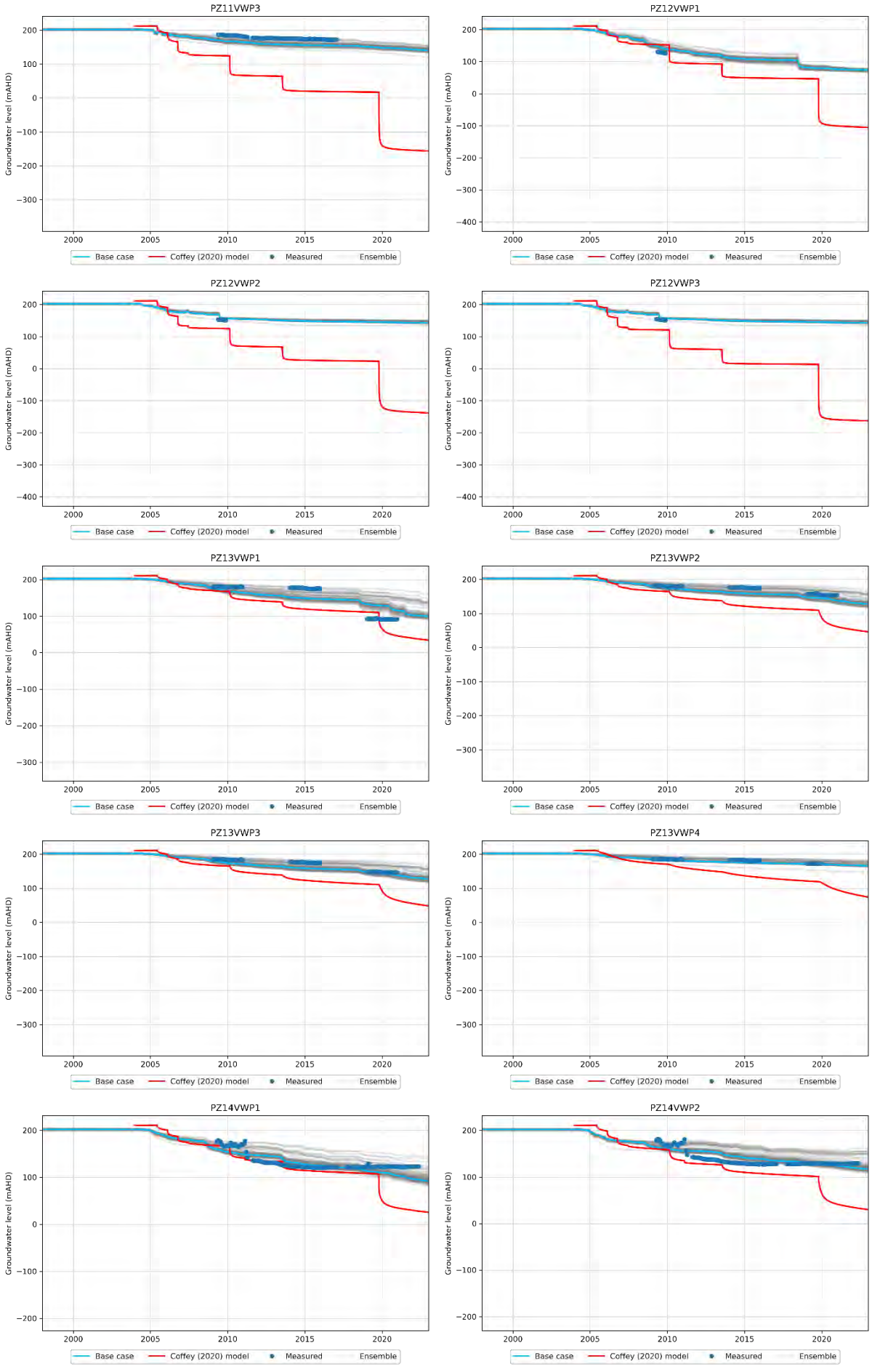
PZ09VWP1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

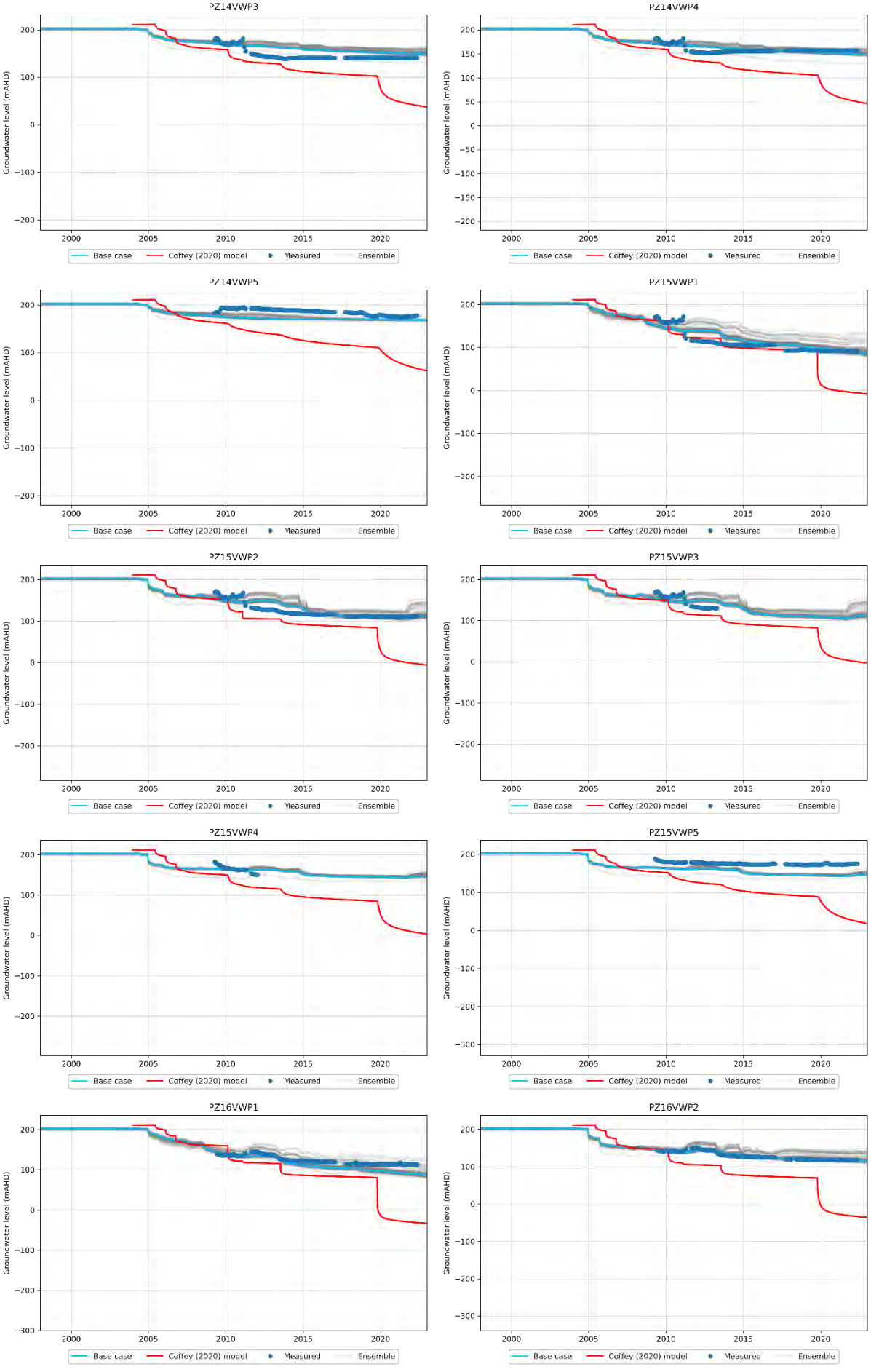

PZ09VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

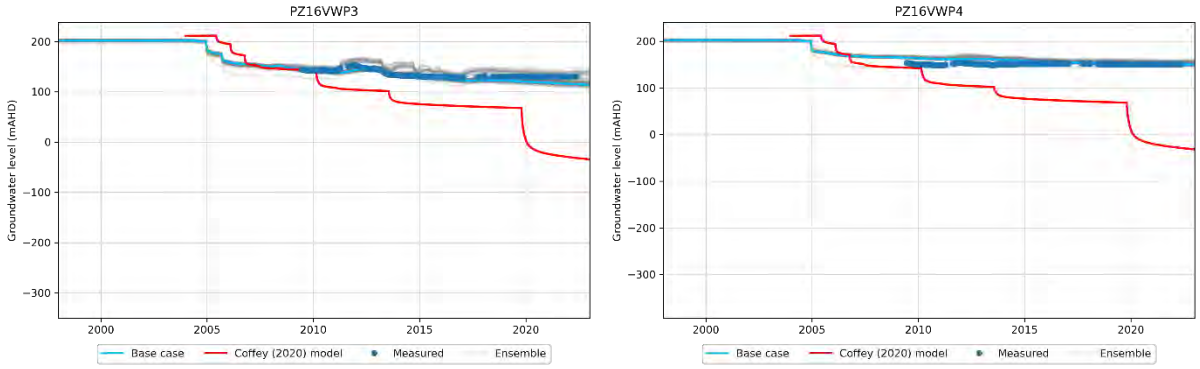
PZ09VWP3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ11VWP1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

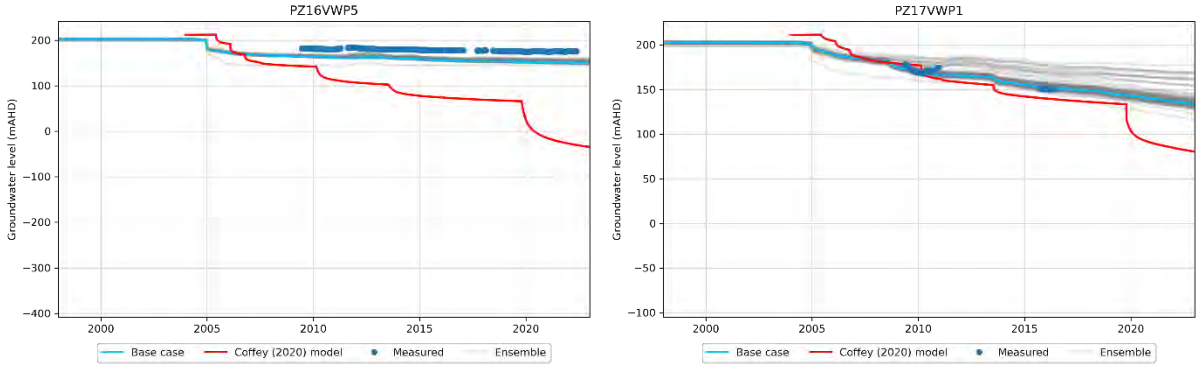
PZ11VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ11VWP3
PZ12VWP1
PZ12VWP2
PZ12VWP3
PZ13VWP1
PZ13VWP2
PZ13VWP3
PZ13VWP4
PZ14VWP1
PZ14VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

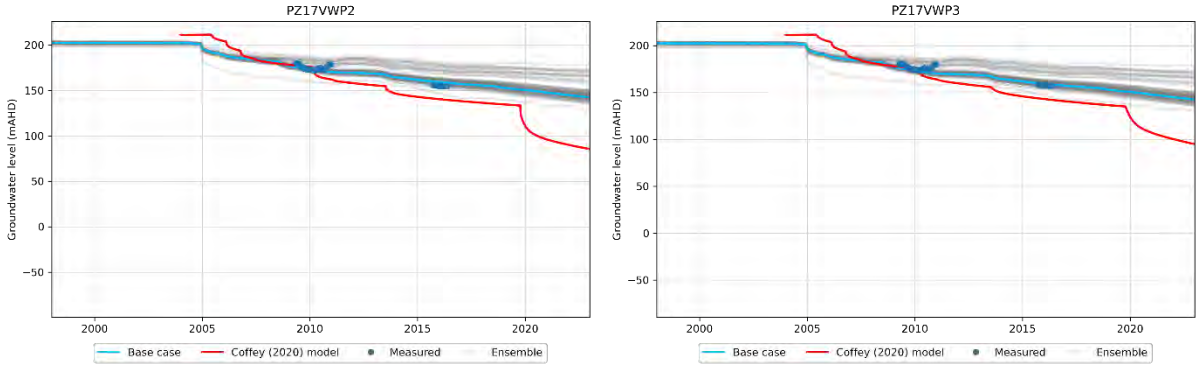

PZ14VWP3
PZ14VWP4
PZ14VWP5
PZ15VWP1
PZ15VWP2
PZ15VWP3
PZ15VWP4
PZ15VWP5
PZ16VWP1
PZ16VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ16VWP3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

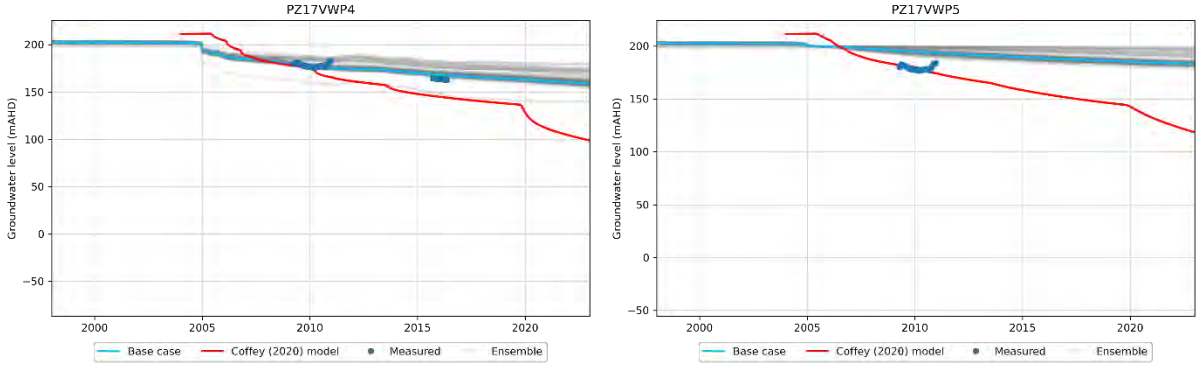
PZ16VWP4
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ16VWP5
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

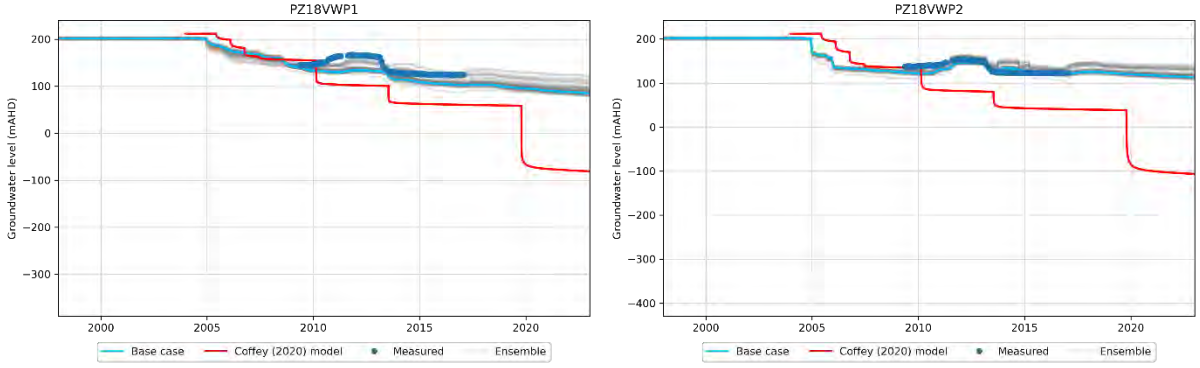
PZ17VWP1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ17VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

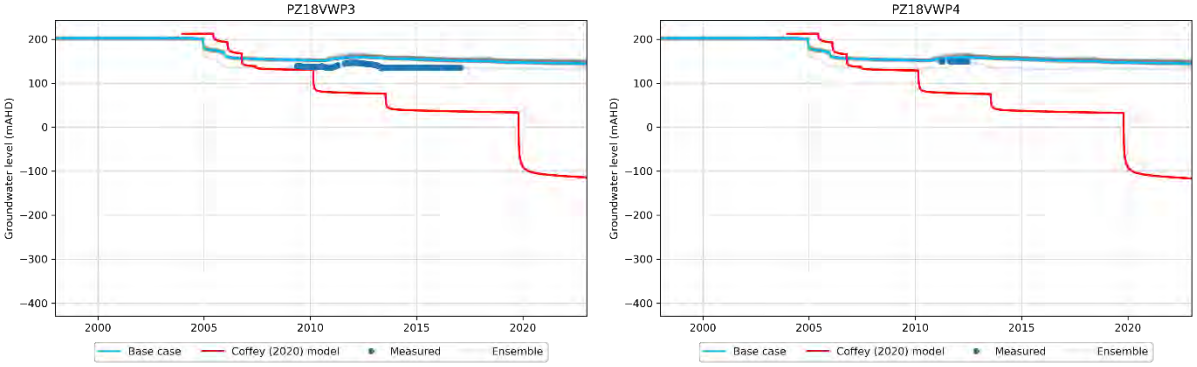
PZ17VWP3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ17VWP4
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

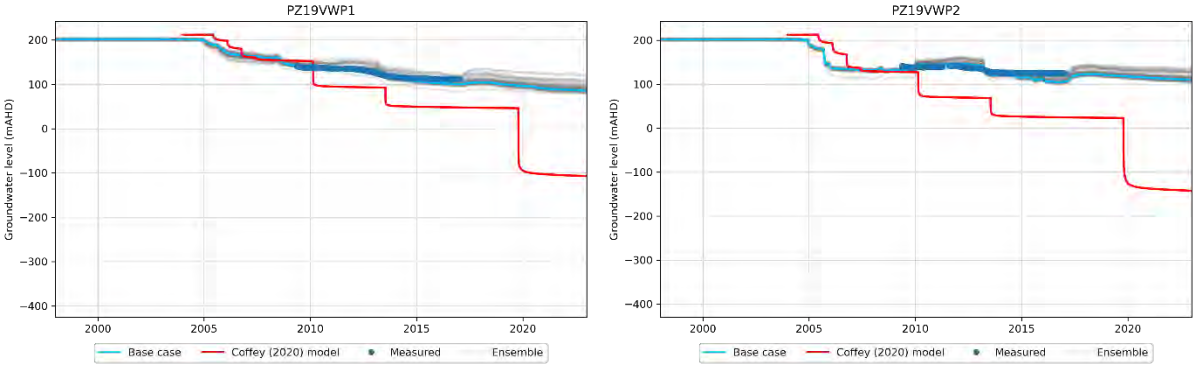
PZ17VWP5
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ18VWP1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

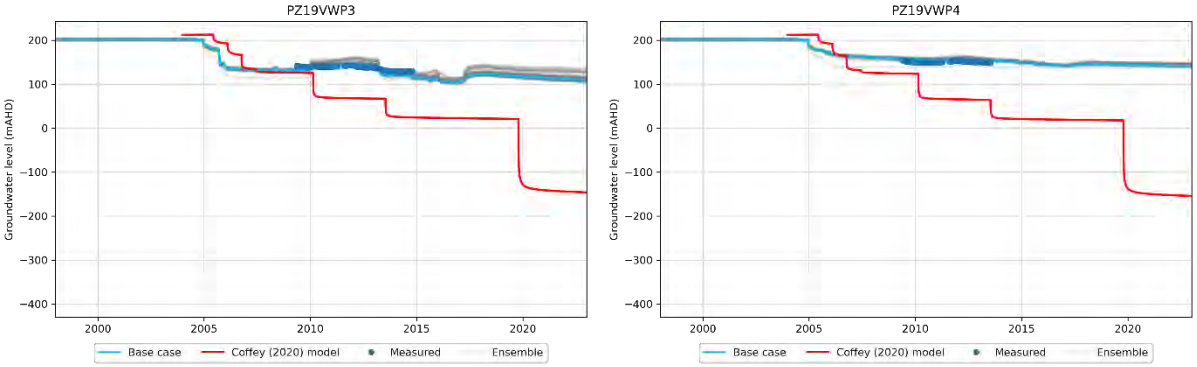
PZ18VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ18VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

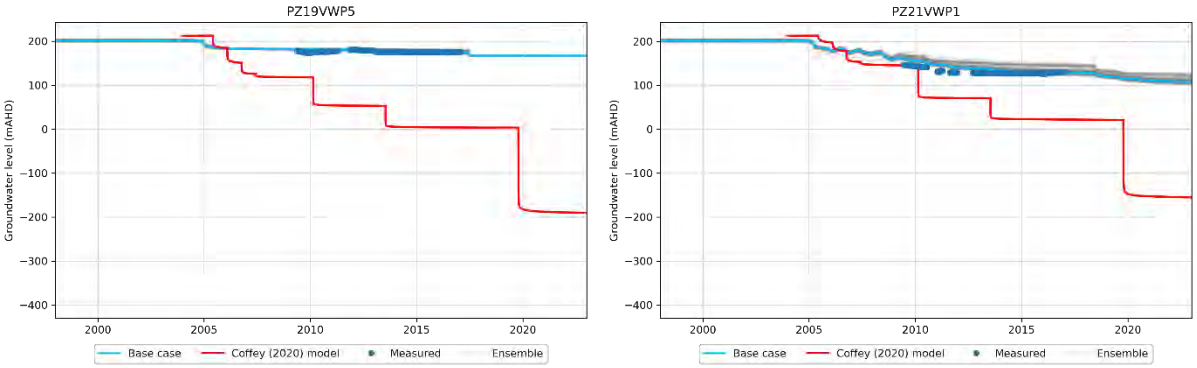
PZ18VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ19VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

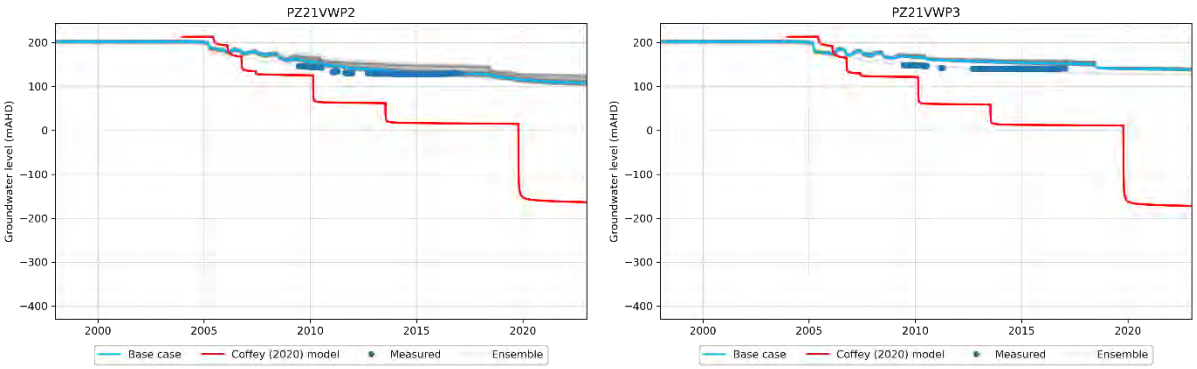
PZ19VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ19VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

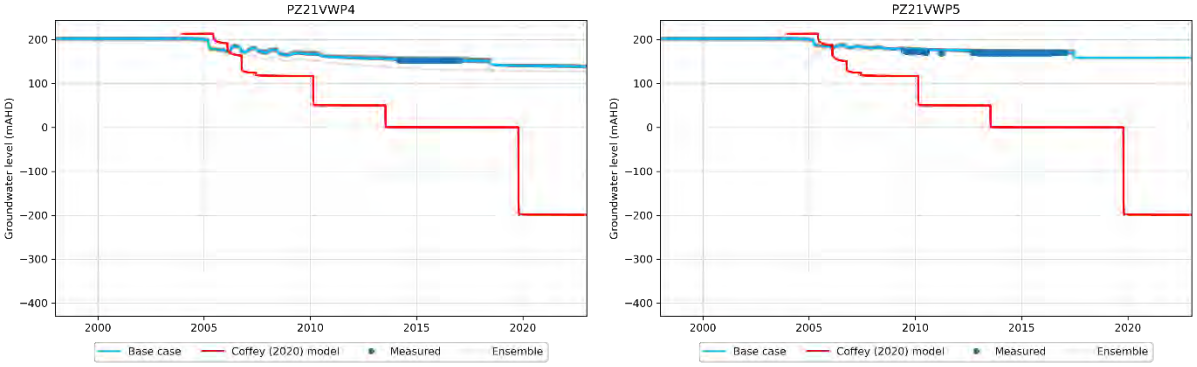
PZ19VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ19VWP5
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

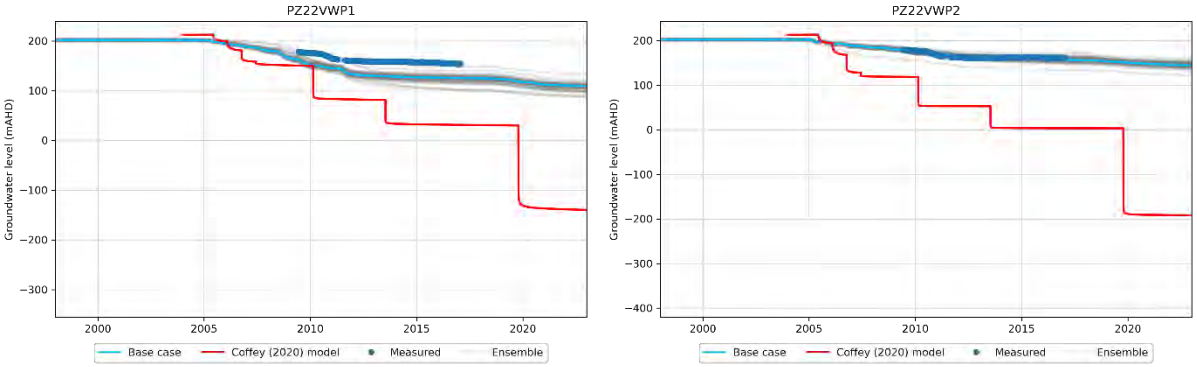
PZ21VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ21VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

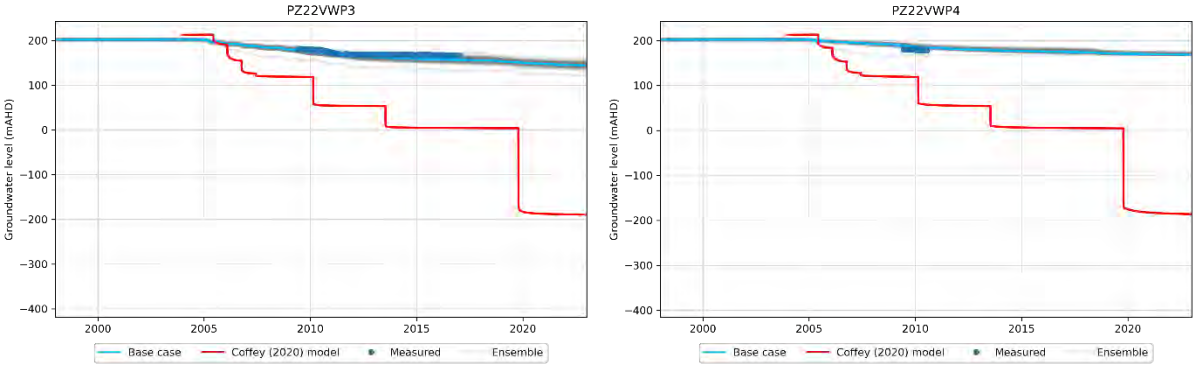
PZ21VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ21VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

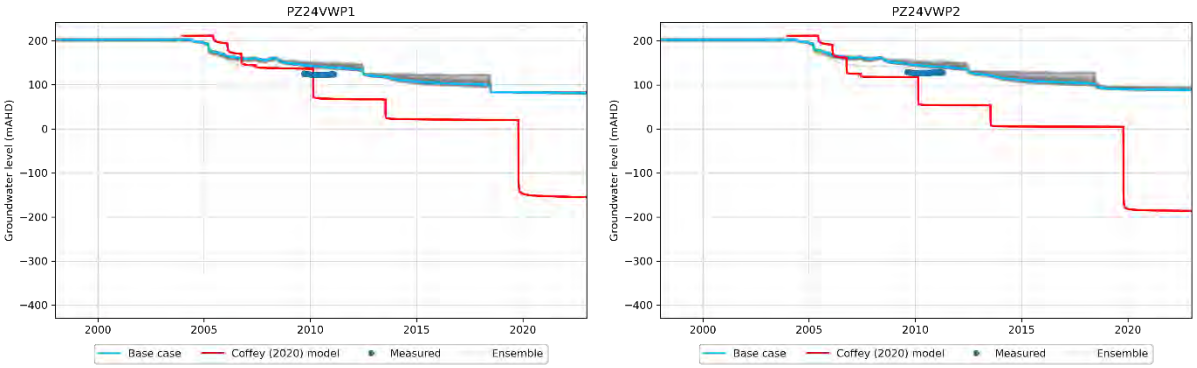
PZ21VWP5
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ22VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

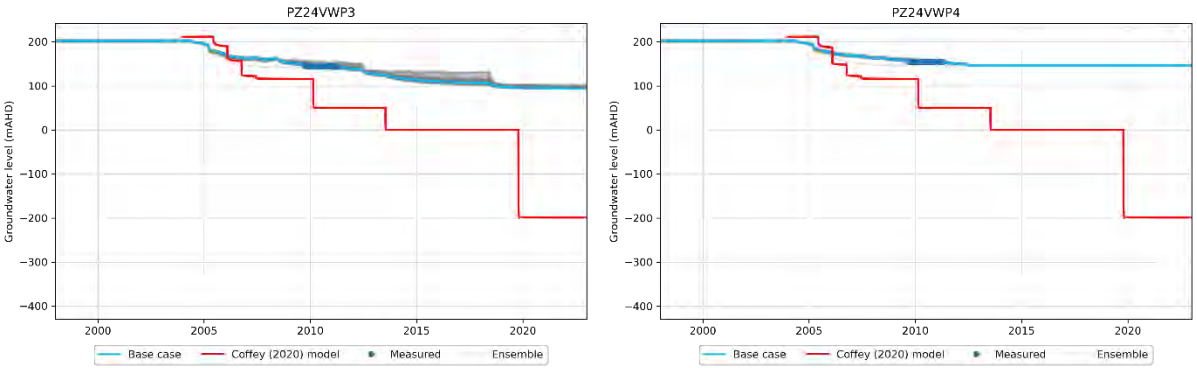
PZ22VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ22VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

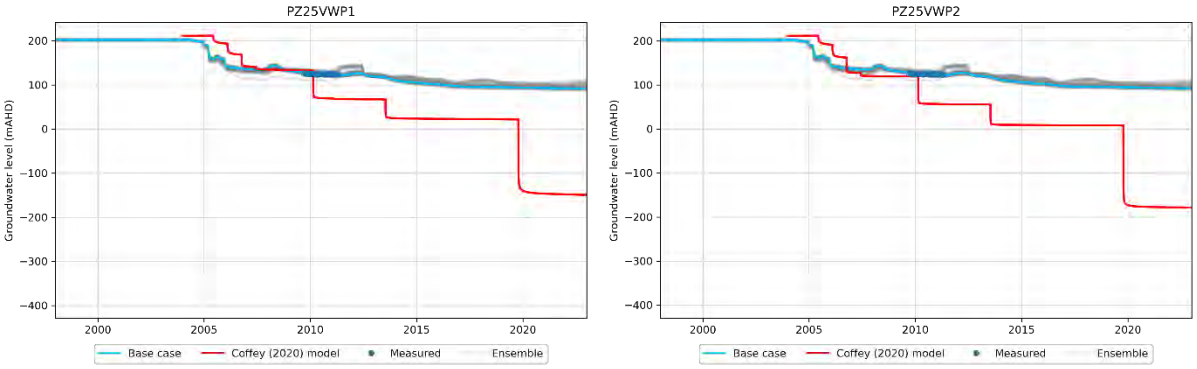
PZ22VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ24VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

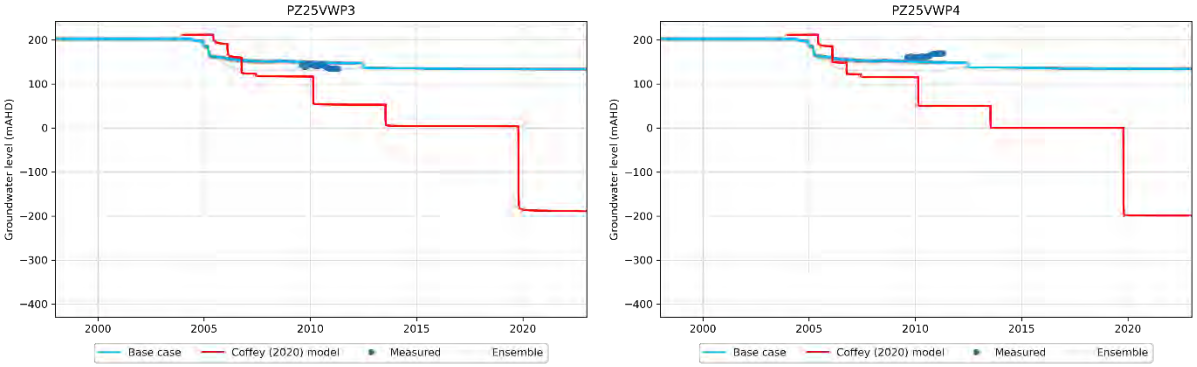
PZ24VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ24VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

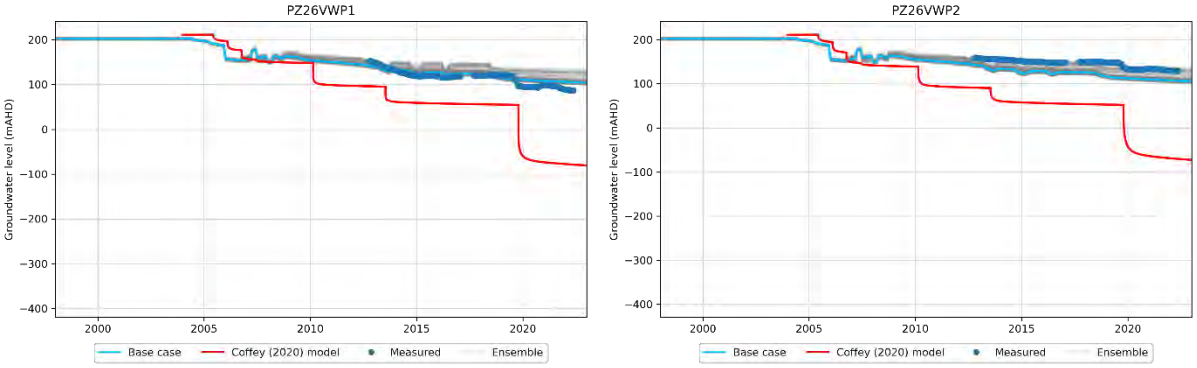
PZ24VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ25VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

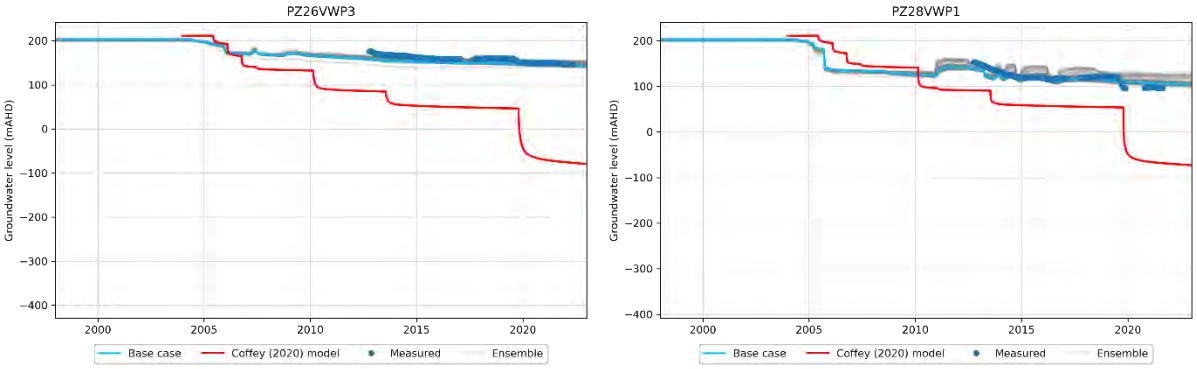
PZ25VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ25VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

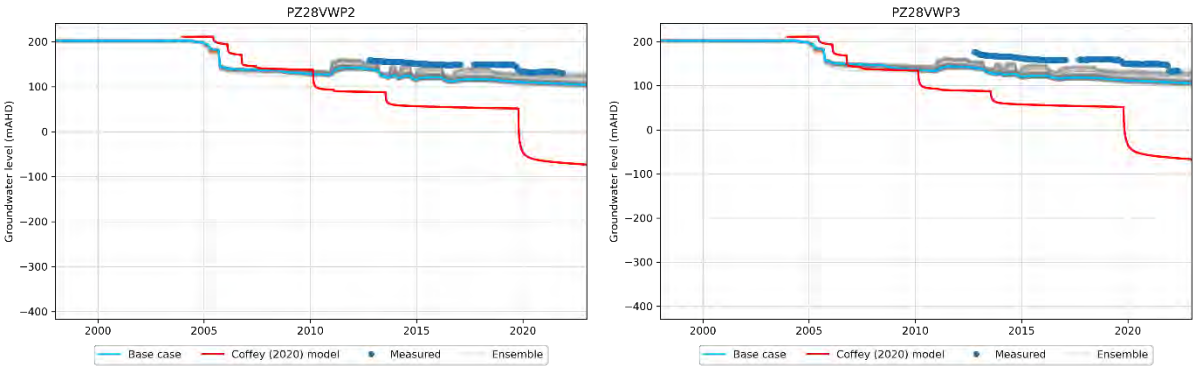
PZ25VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ26VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

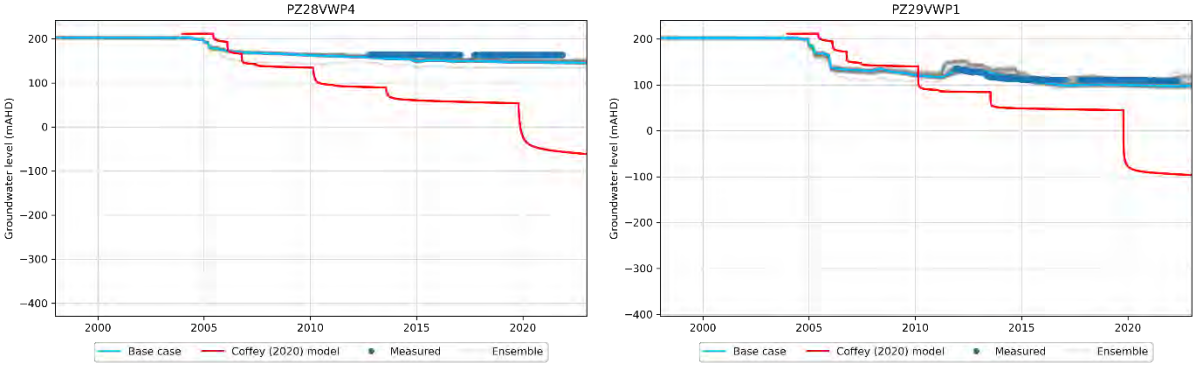
PZ26VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ26VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

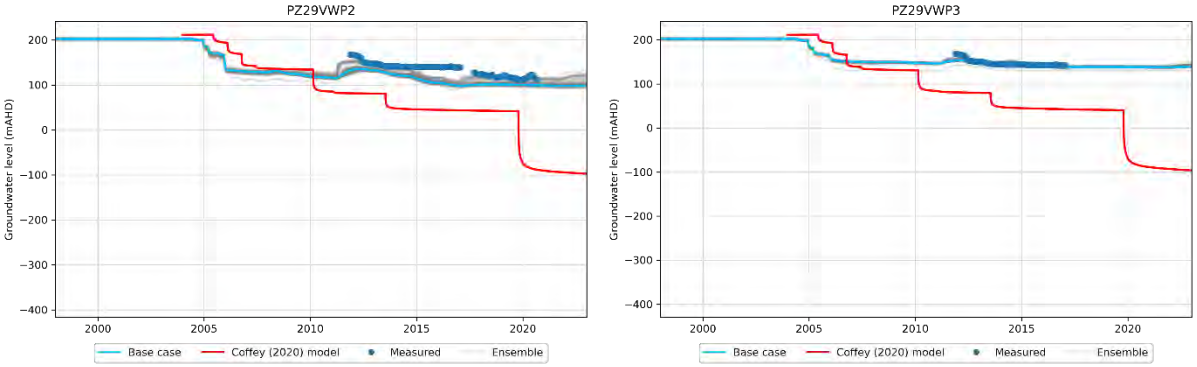
PZ28VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ28VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

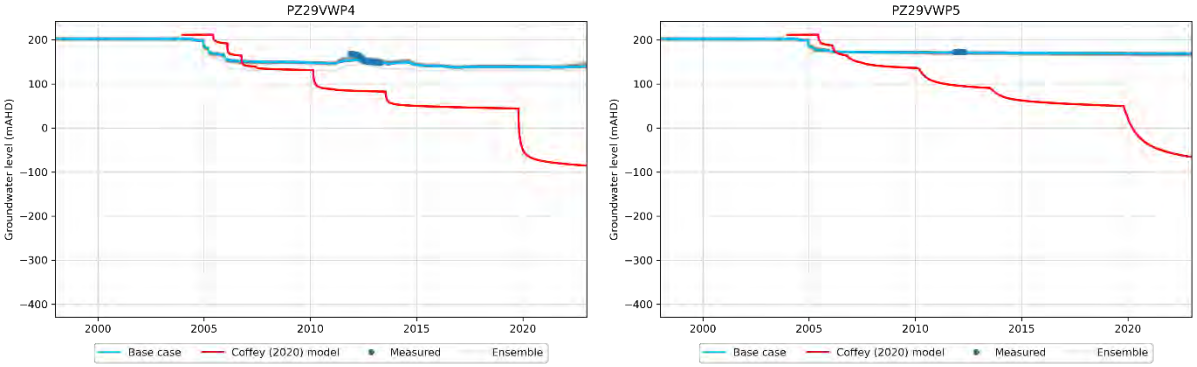
PZ28VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ28VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

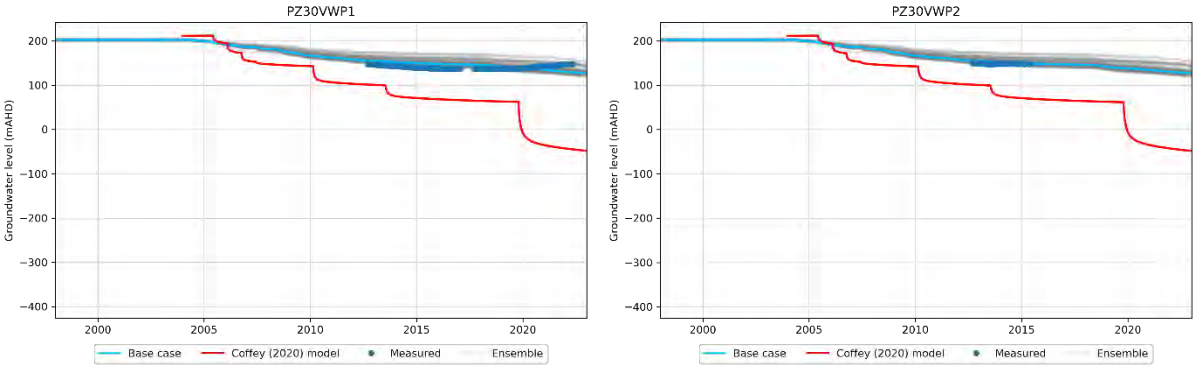
PZ29VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ29VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

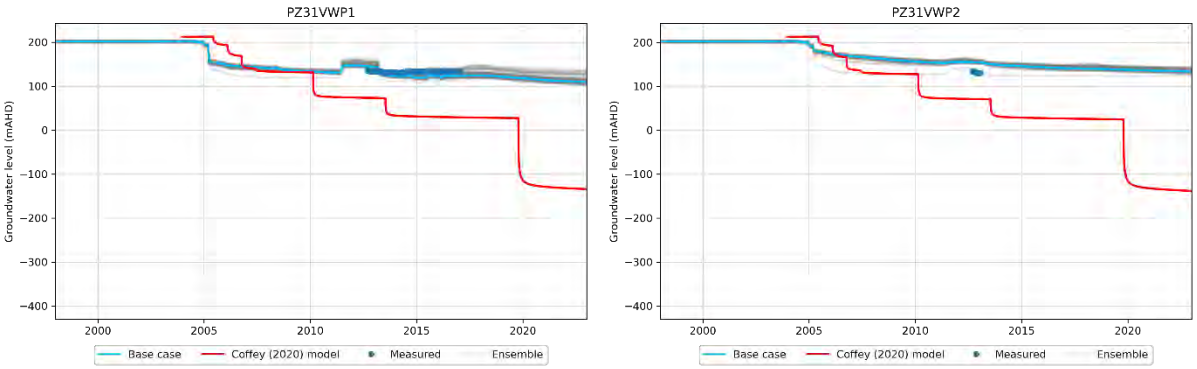
PZ29VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ29VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

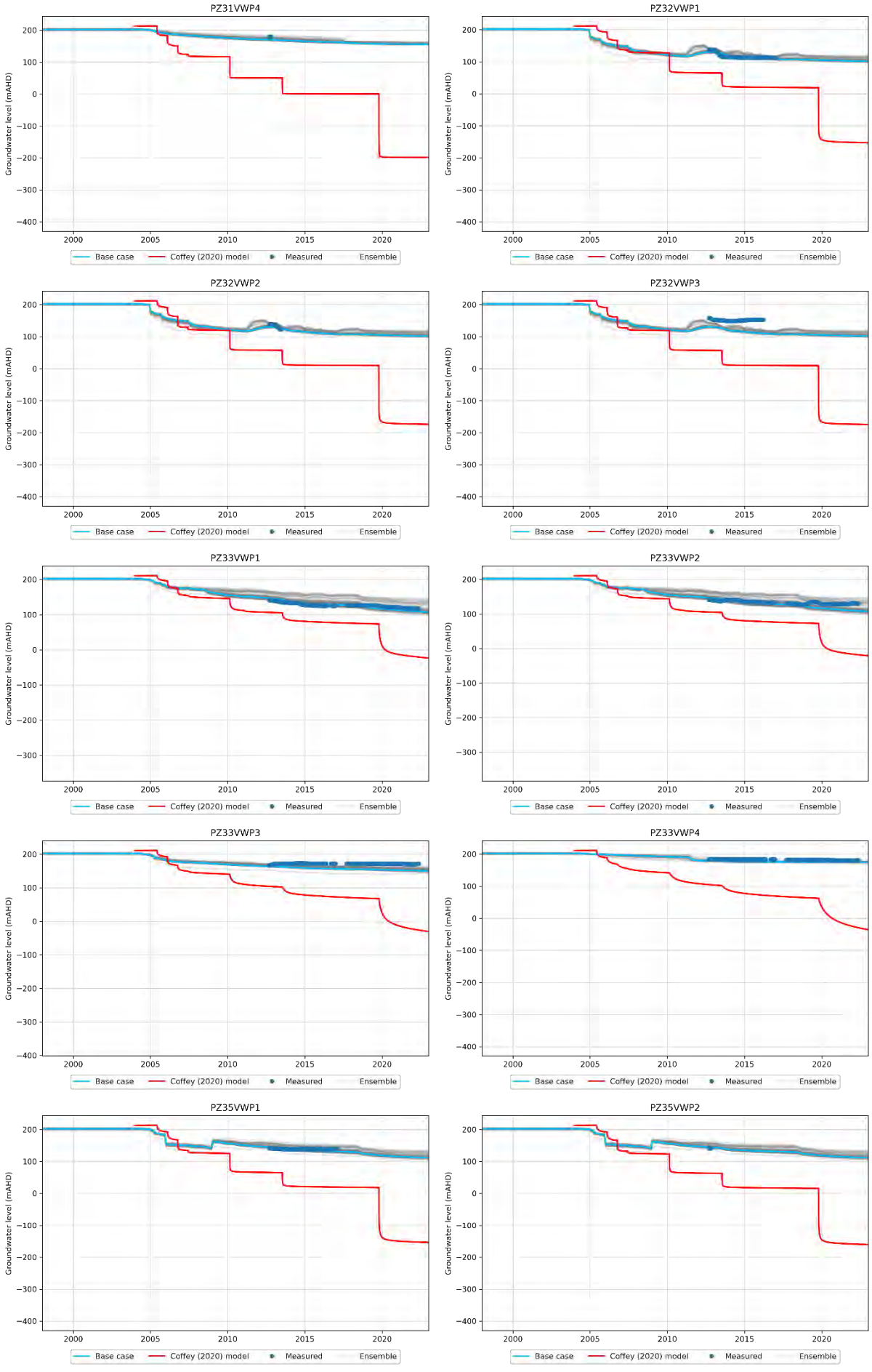
PZ29VWP5
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

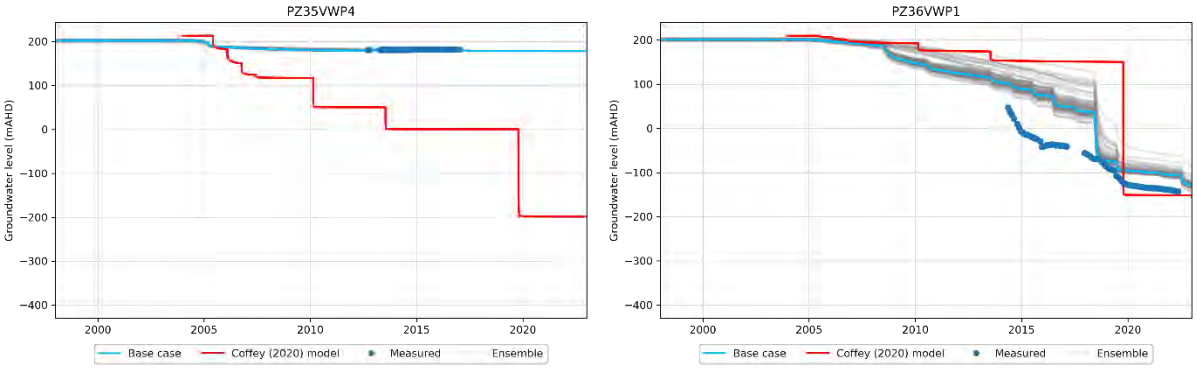

PZ30VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

PZ30VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

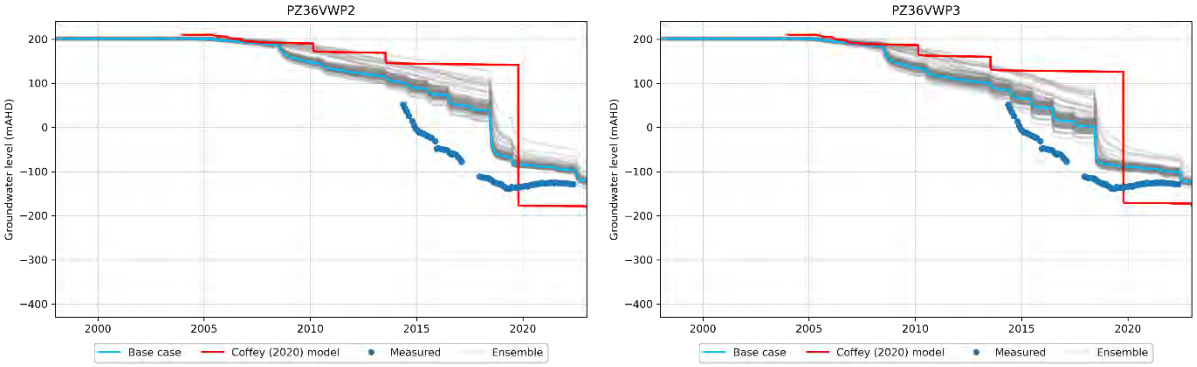

PZ31VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

PZ31VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

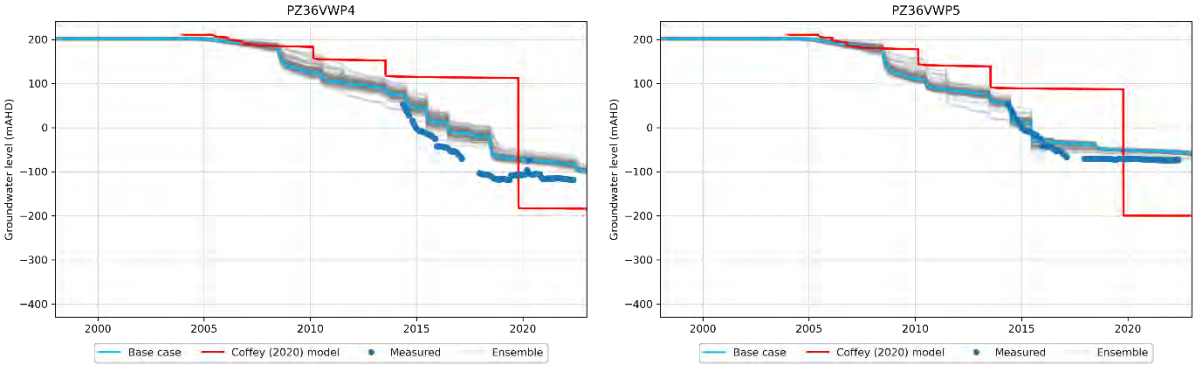

PZ31VWP4
PZ32VWP1
PZ32VWP2
PZ32VWP3
PZ33VWP1
PZ33VWP2
PZ33VWP3
PZ33VWP4
PZ35VWP1
PZ35VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ35VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

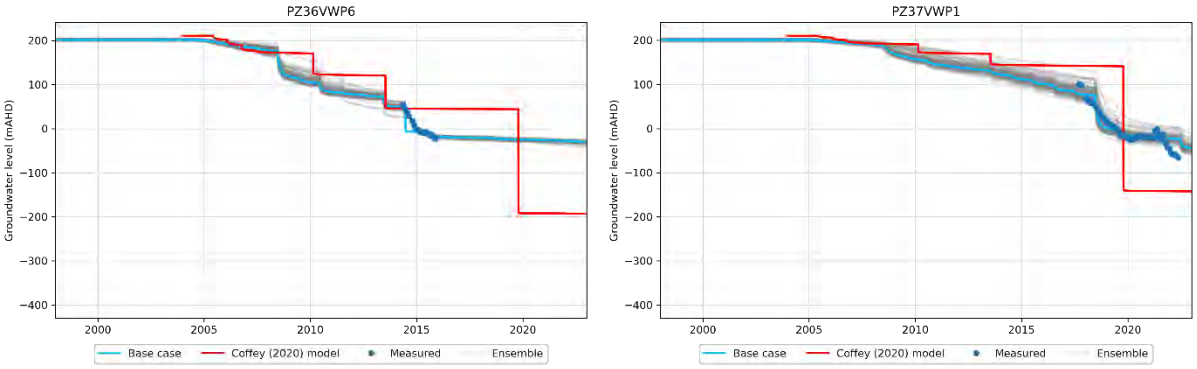
PZ36VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ36VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

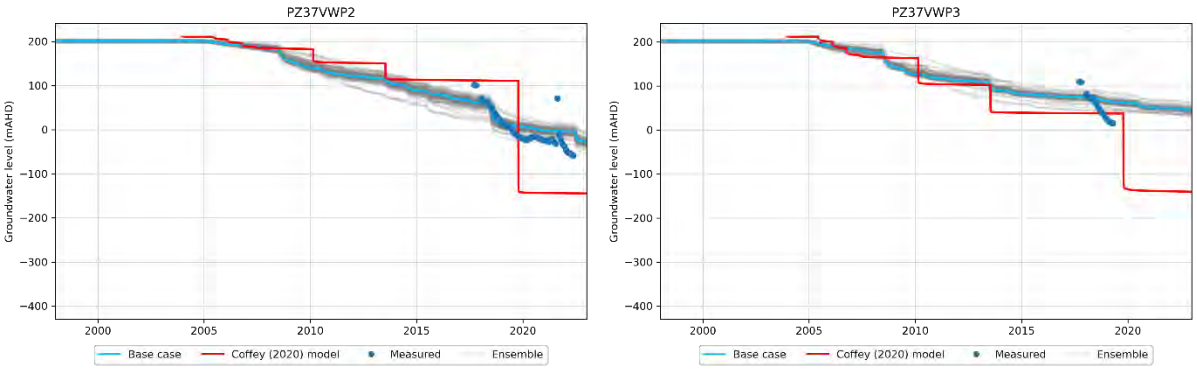
PZ36VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ36VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

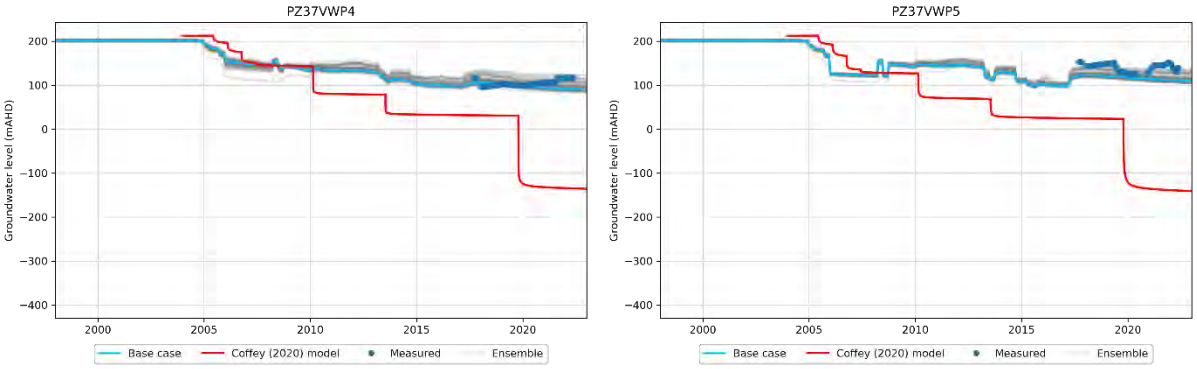
PZ36VWP5
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ36VWP6
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

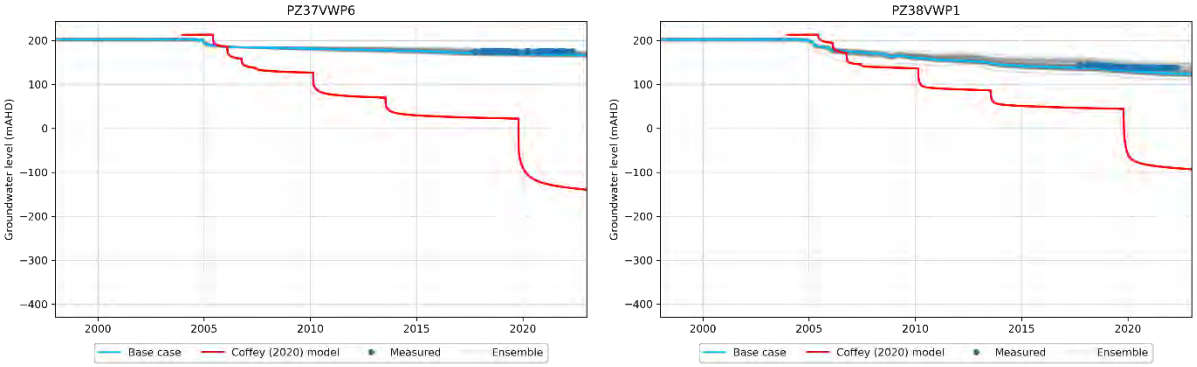
PZ37VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ37VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

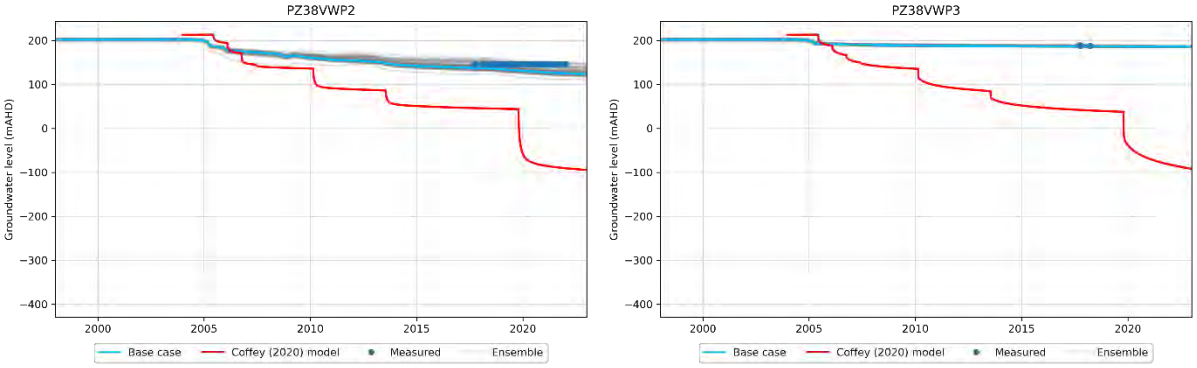
PZ37VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ37VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

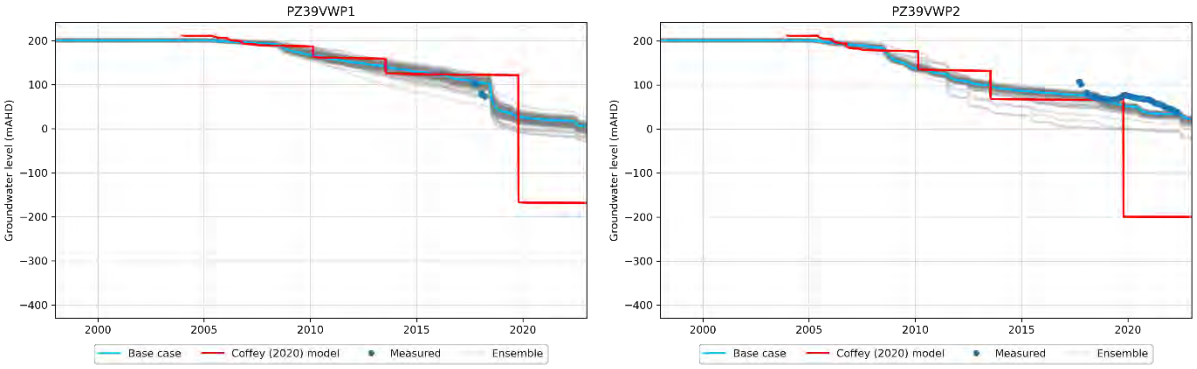
PZ37VWP5
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ37VWP6
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

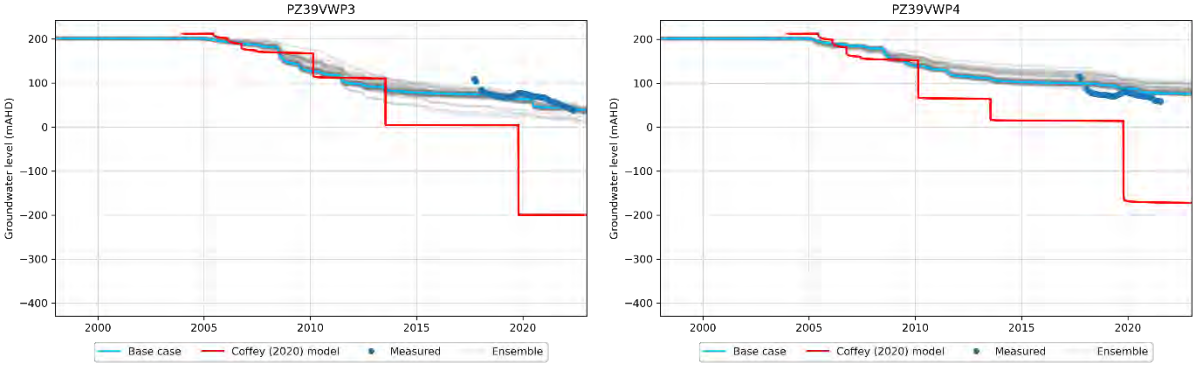
PZ38VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ38VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

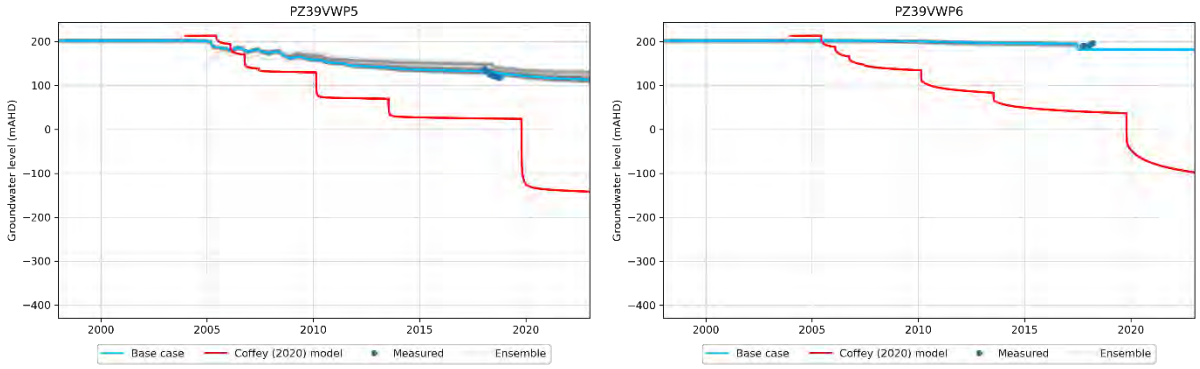
PZ38VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ39VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

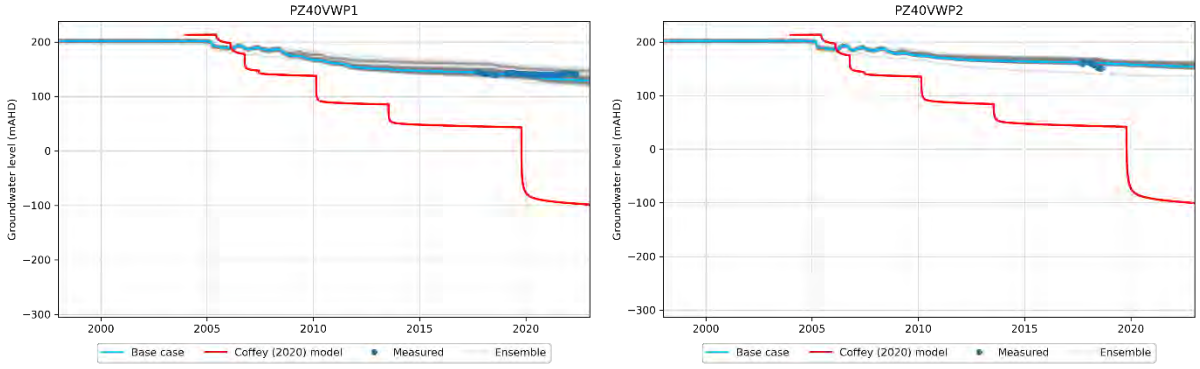
PZ39VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ39VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

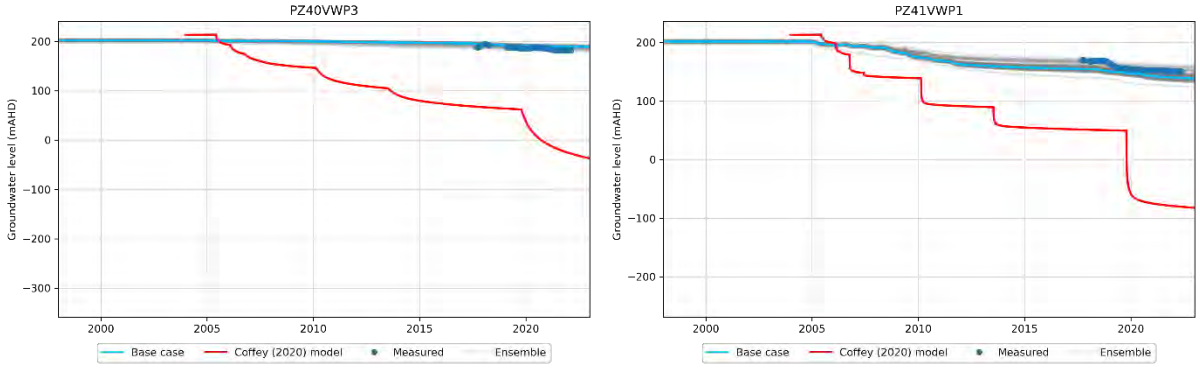
PZ39VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ39VWP5
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

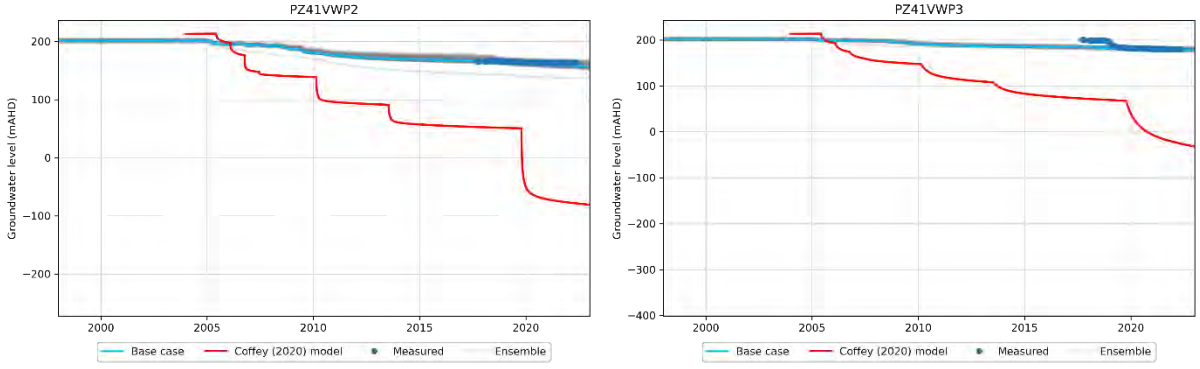
PZ39VWP6
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ40VWP1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

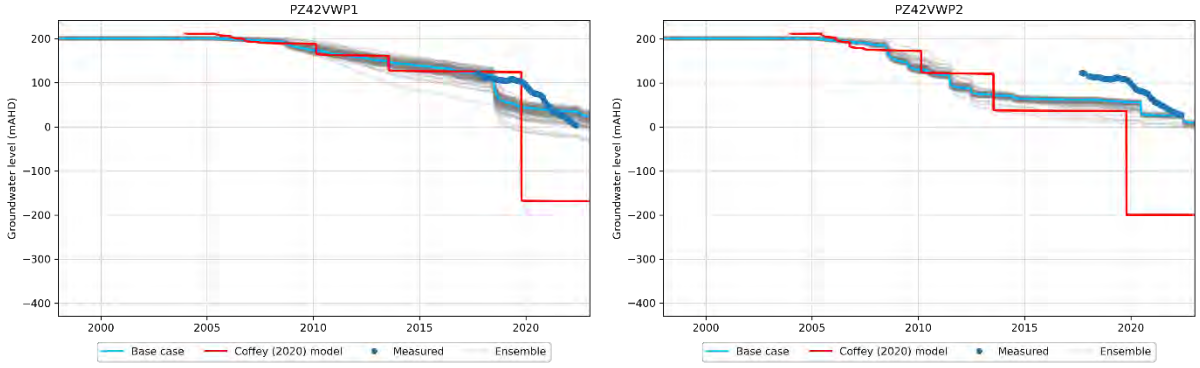
PZ40VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ40VWP3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

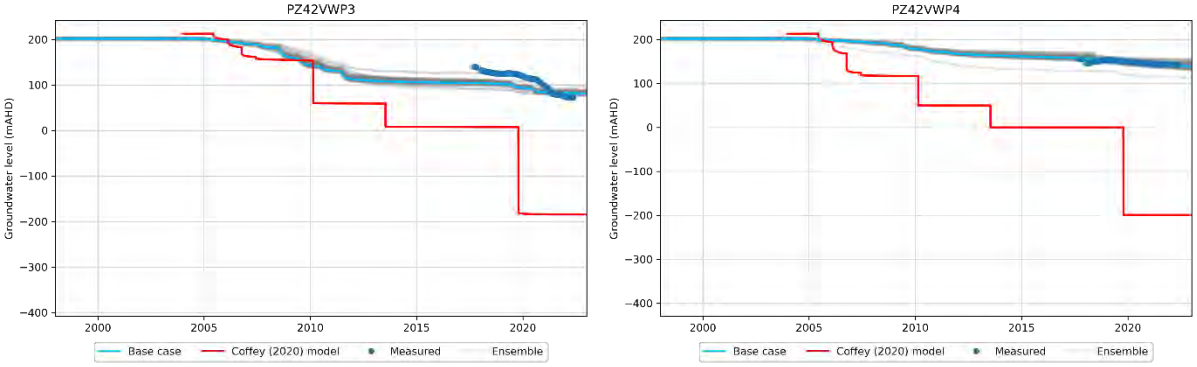
PZ41VWP1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ41VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

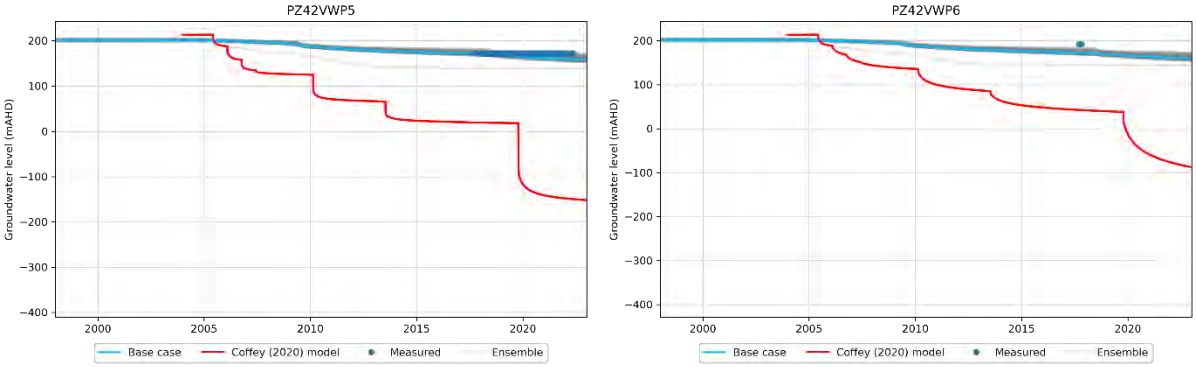
PZ41VWP3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ42VWP1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

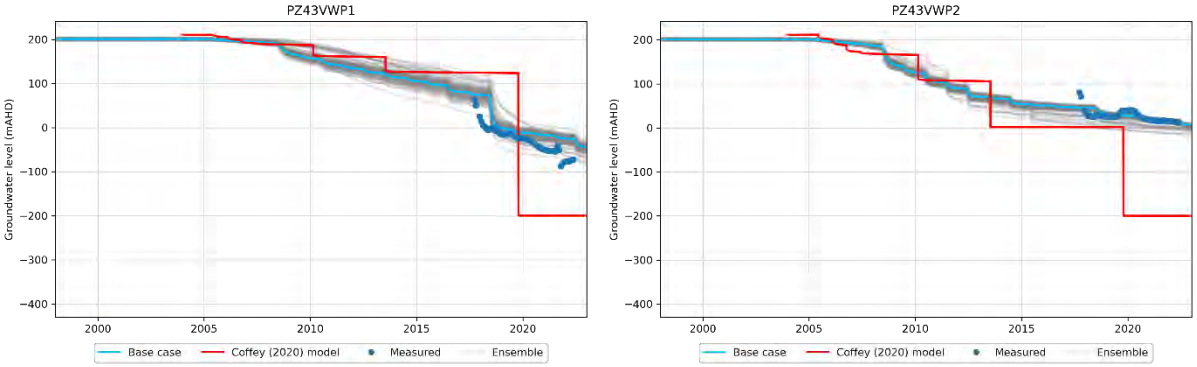
PZ42VWP2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


PZ42VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

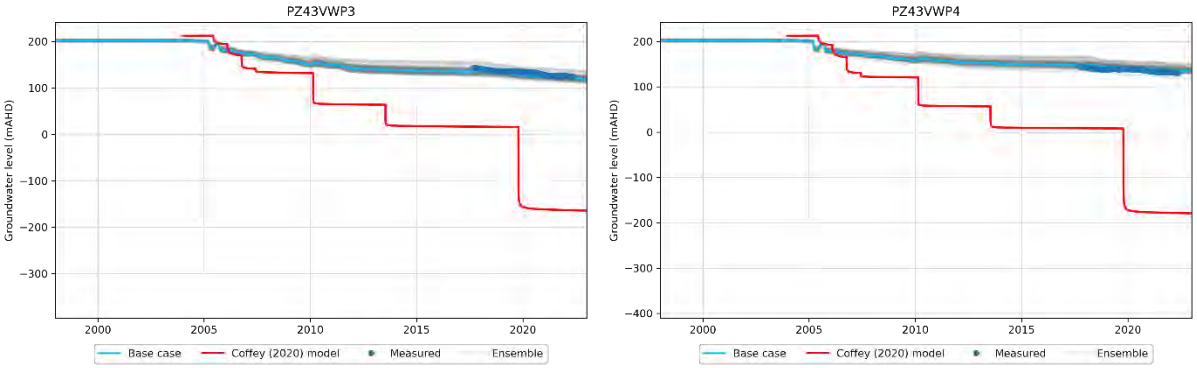
PZ42VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ42VWP5
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

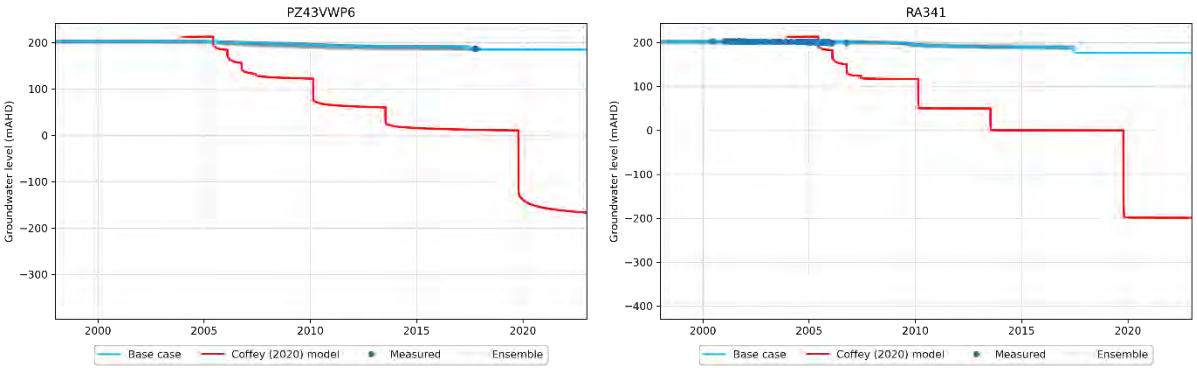
PZ42VWP6
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ43VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

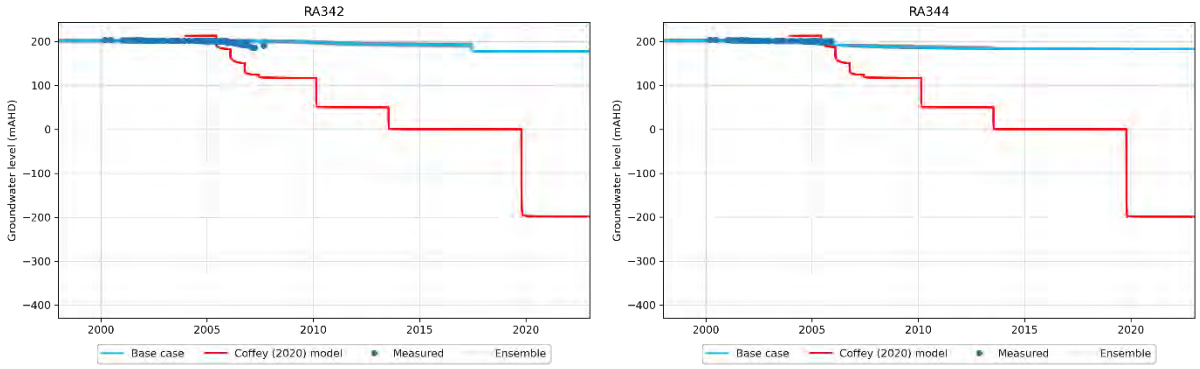
PZ43VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ43VWP3
Groundwater level (mAHD)
200
100
0
−100
−200
−300
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

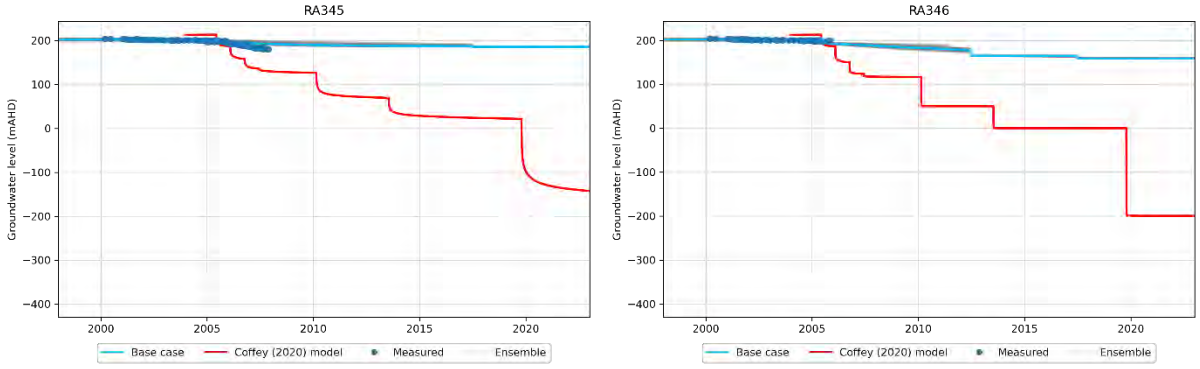
PZ43VWP4
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


PZ43VWP6
Groundwater level (mAHD)
200
100
0
−100
−200
−300
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble

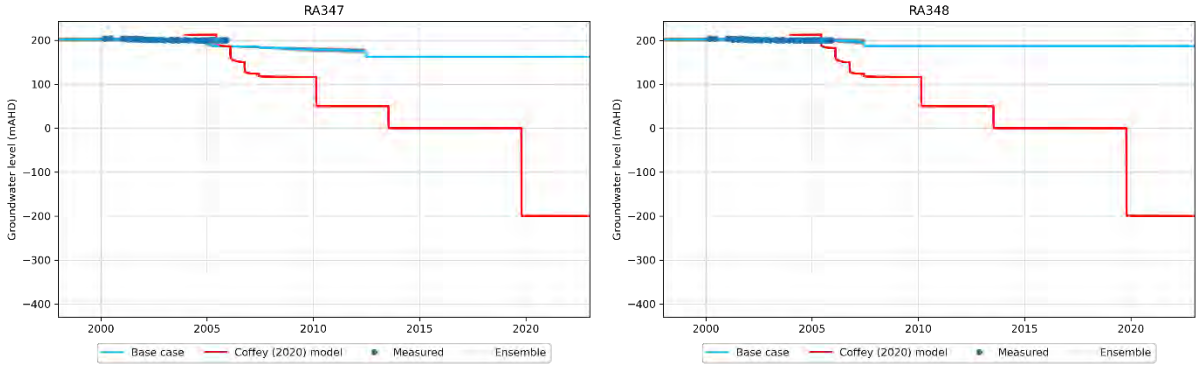
RA341
Groundwater level (mAHD)
200
100
0
−100
−200
−300
−400
2000
2005
2010
2015
2020
Base case
Coffey (2020) model
Measured
Ensemble


RA342
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

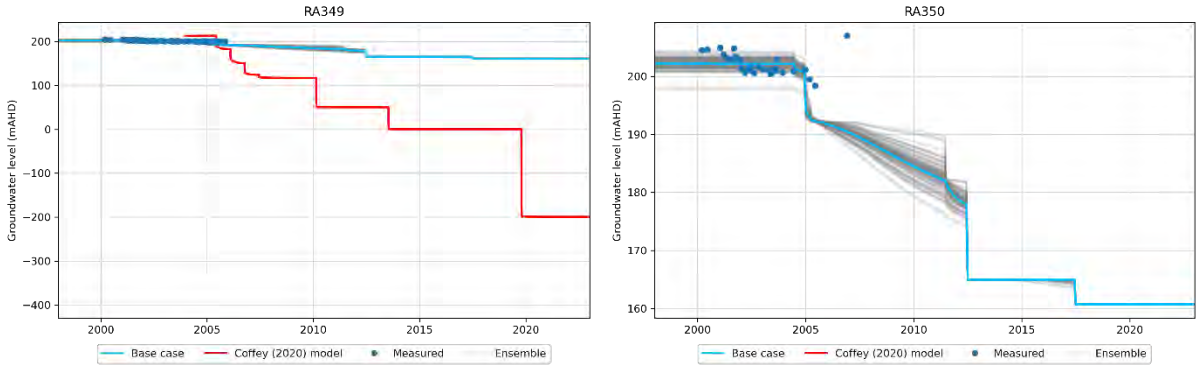
RA344
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


RA345
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

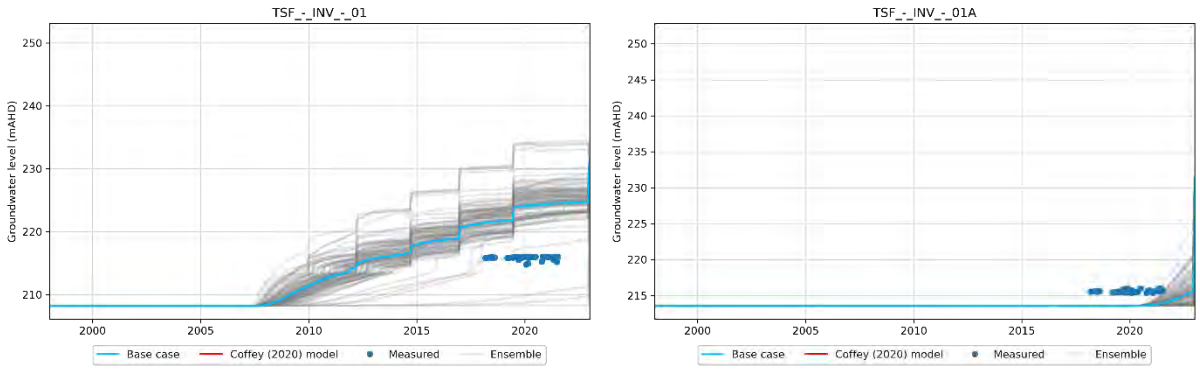
RA346
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


RA347
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

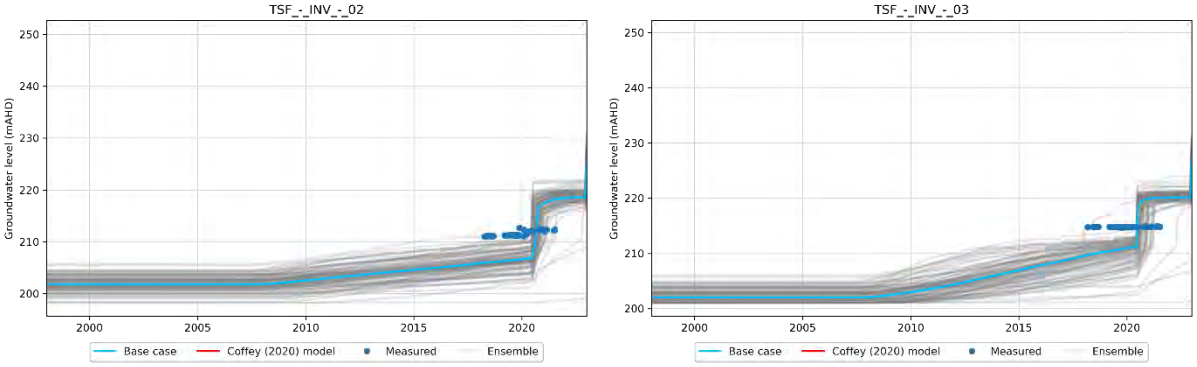
RA348
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


RA349
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

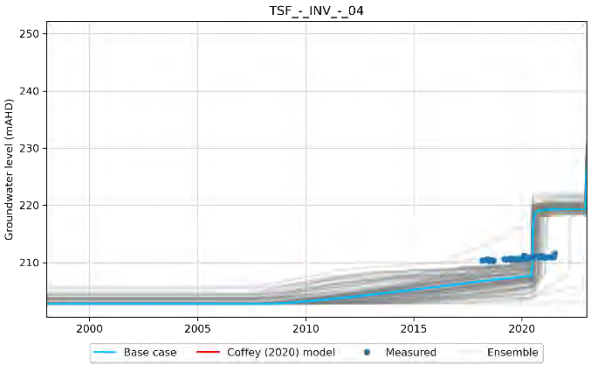
RA350
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

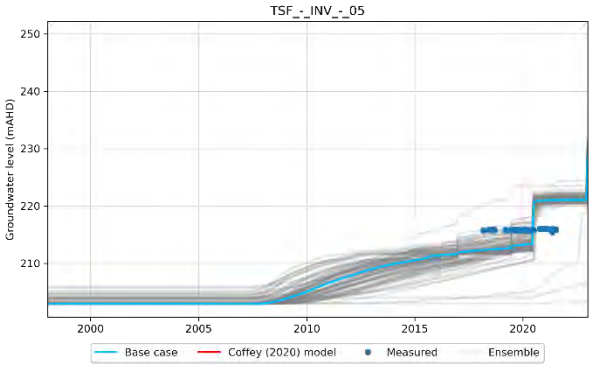

TSF_-_INV_-_01
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

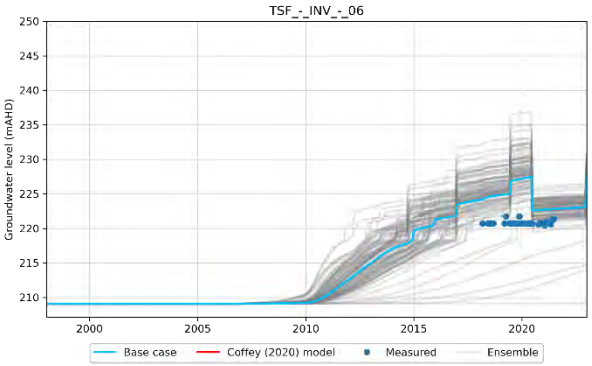
TSF_-_INV_-_01A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

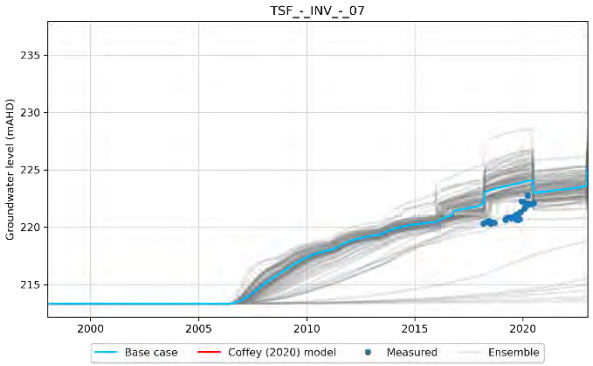

TSF_-_INV_-_02
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

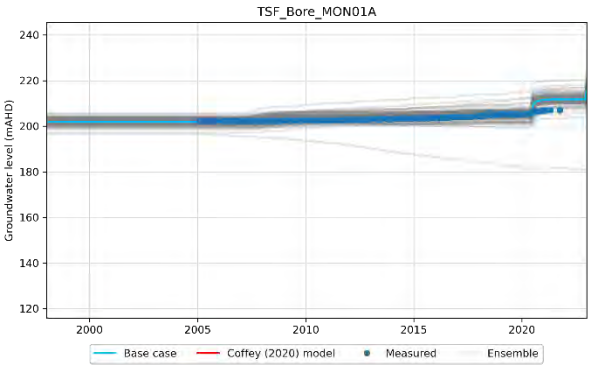
TSF_-_INV_-_03
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

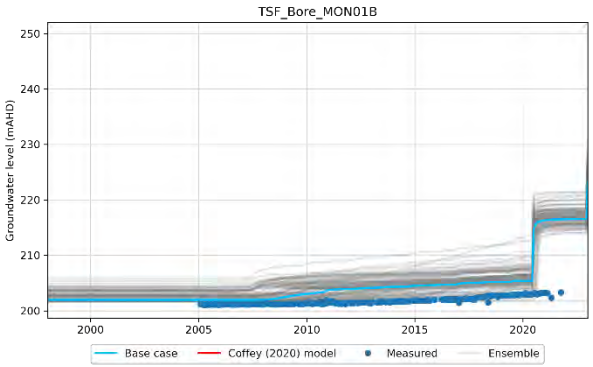

TSF_-_INV_-_04
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

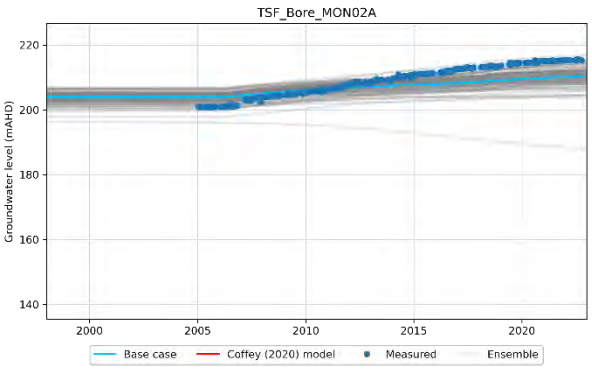

TSF_-_INV_-_05
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

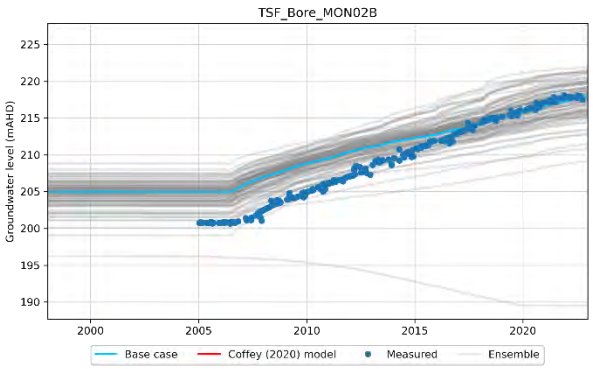

TSF_-_INV_-_06
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

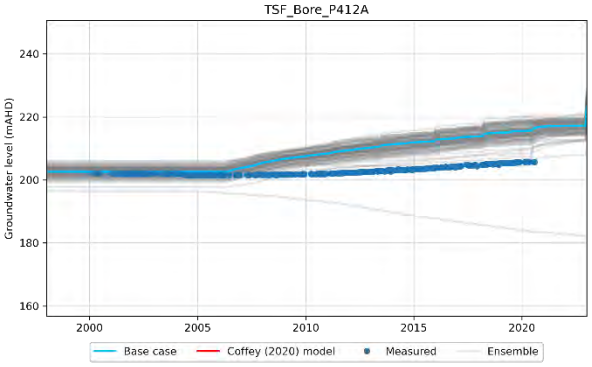

TSF_-_INV_-_07
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

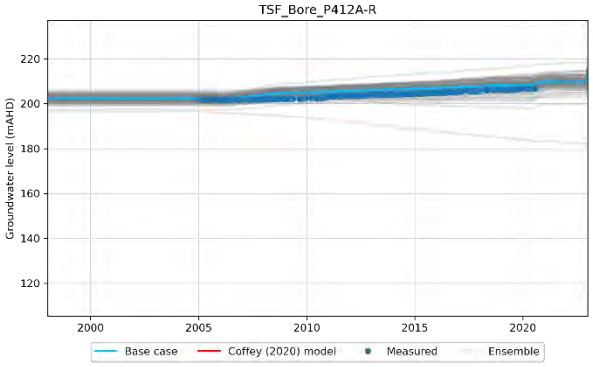

TSF_Bore_MON01A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

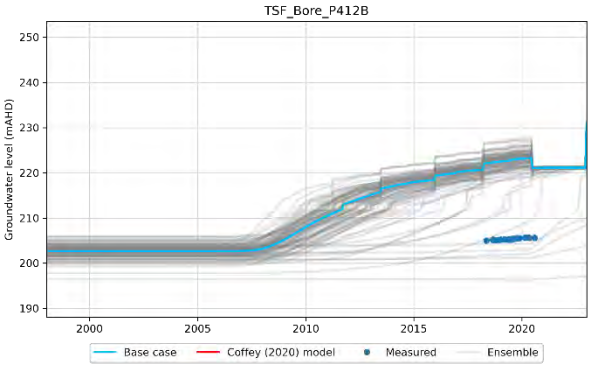

TSF_Bore_MON01B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

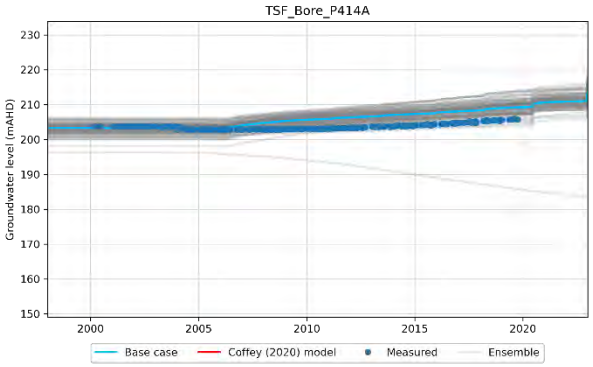

TSF_Bore_MON02A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

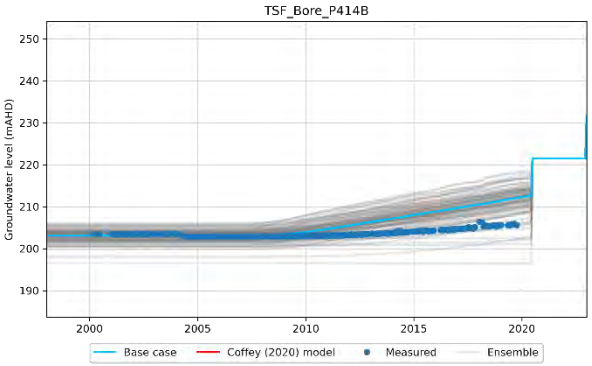

TSF_Bore_MON02B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

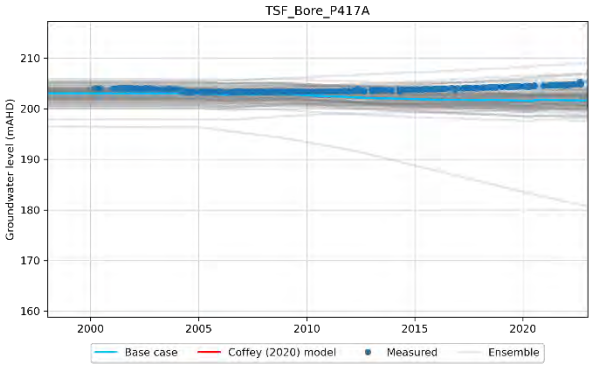

TSF_Bore_P412A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

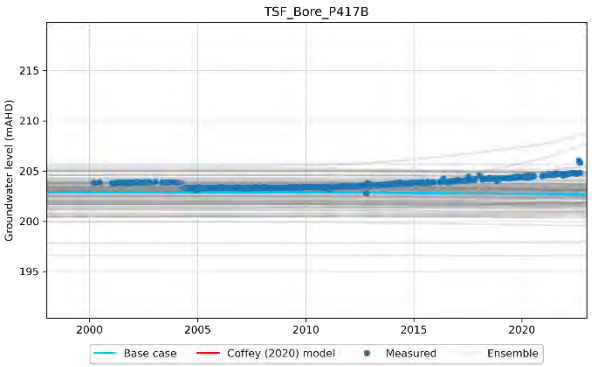

TSF_Bore_P412A-R
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

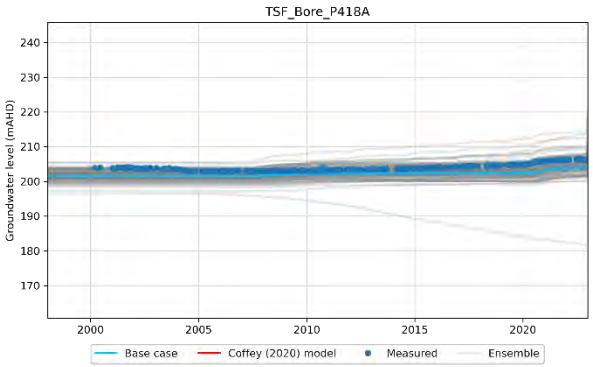

TSF_Bore_P412B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

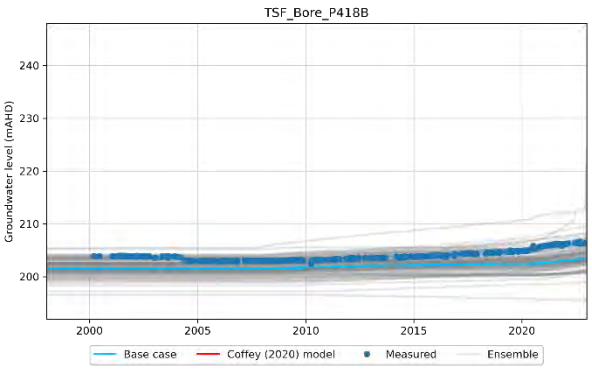

TSF_Bore_P414A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

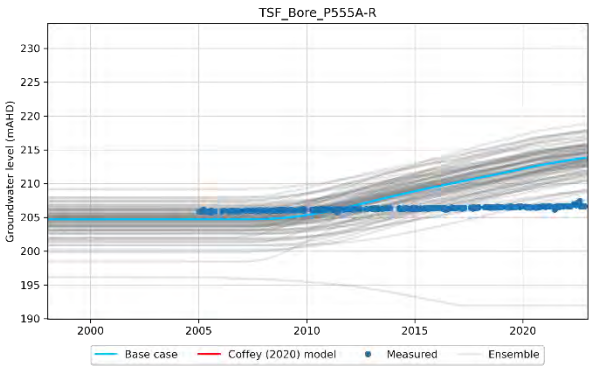

TSF_Bore_P414B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

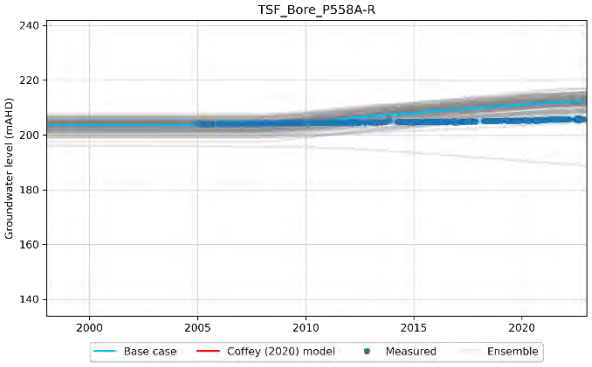

TSF_Bore_P417A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

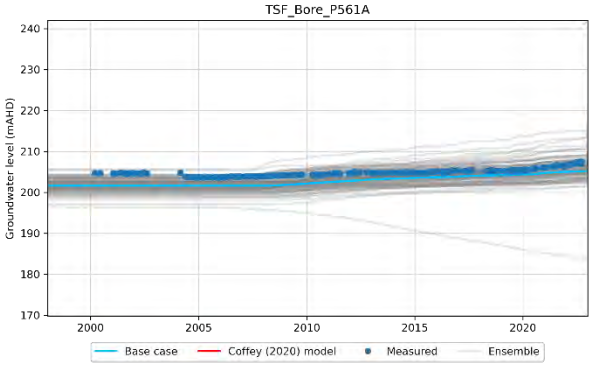

TSF_Bore_P417B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

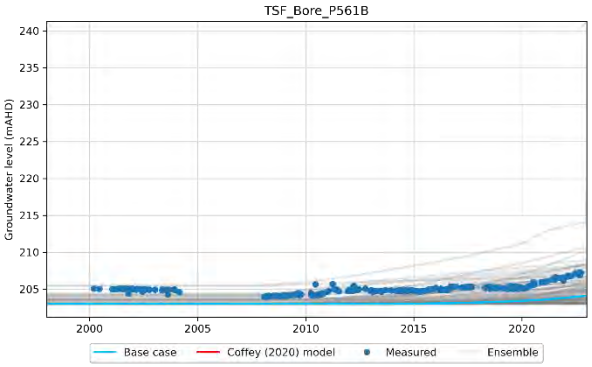

TSF_Bore_P418A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

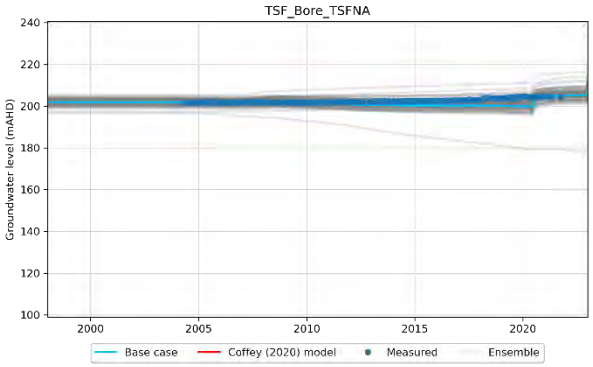

TSF_Bore_P418B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

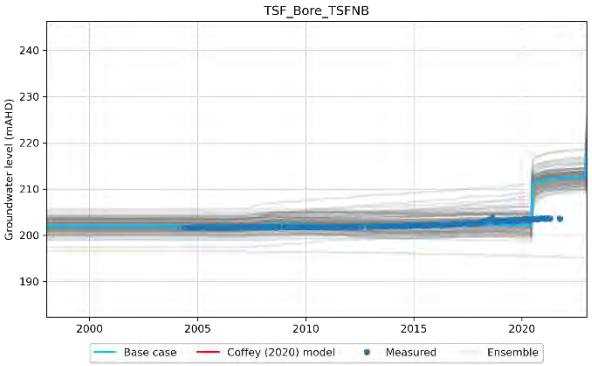

TSF_Bore_P555A-R
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

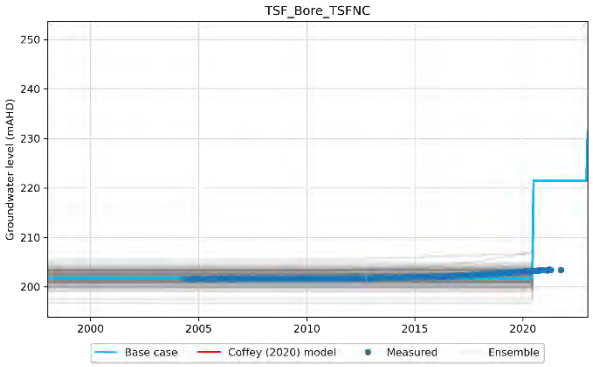

TSF_Bore_P558A-R
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

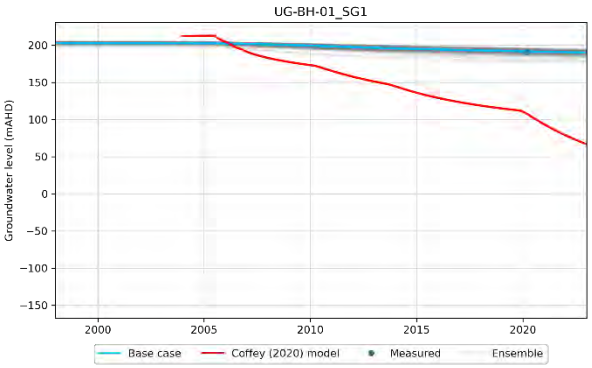

TSF_Bore_P561A
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

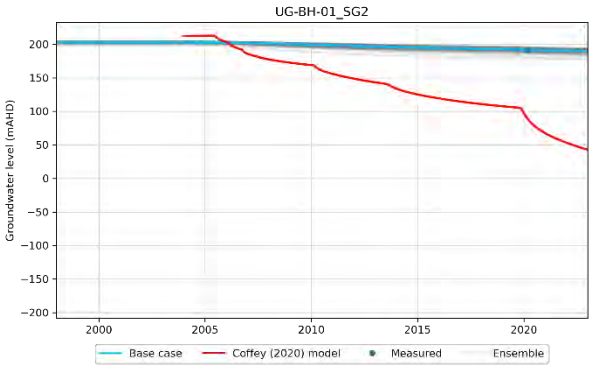

TSF_Bore_P561B
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

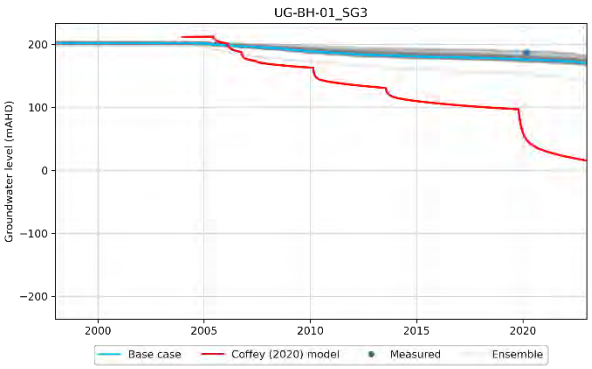

TSF_Bore_TSFNA
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

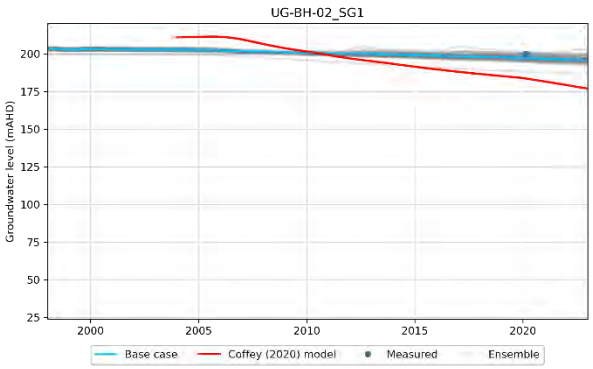

TSF_Bore_TSFNB
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

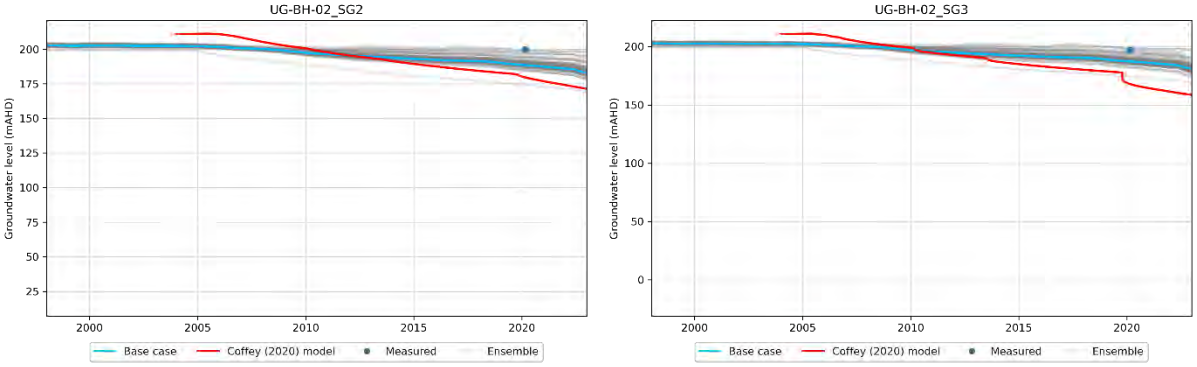

TSF_Bore_TSFNC
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


UG-BH-01_SG1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

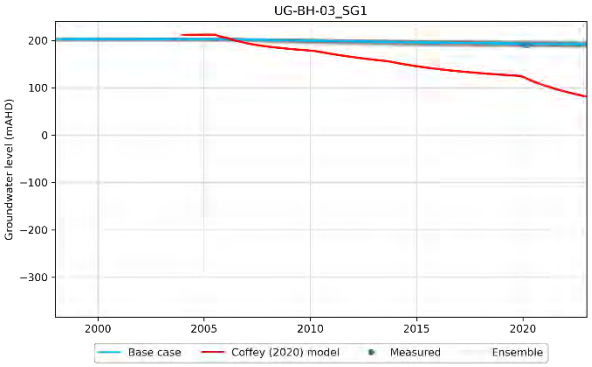

UG-BH-01_SG2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

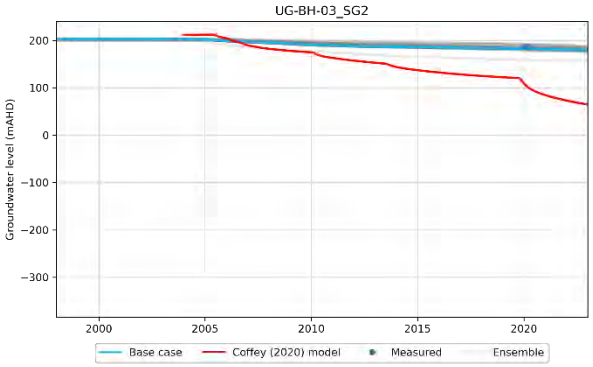

UG-BH-01_SG3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

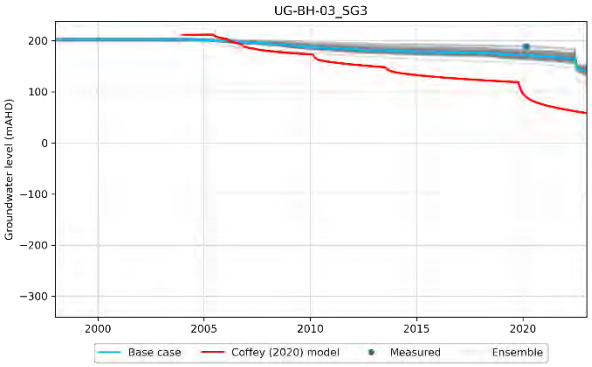

UG-BH-02_SG1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

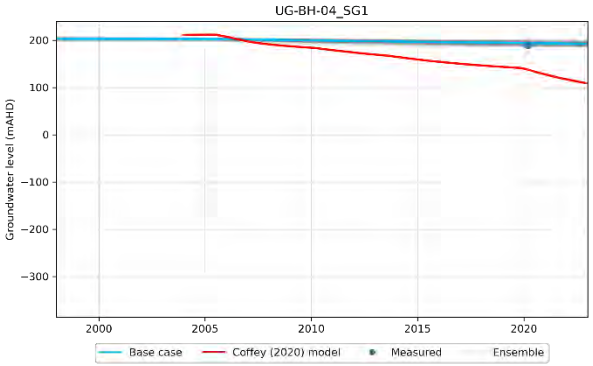

UG-BH-02_SG2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

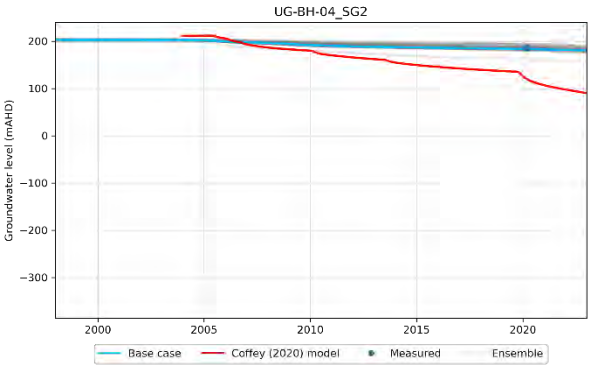
UG-BH-02_SG3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

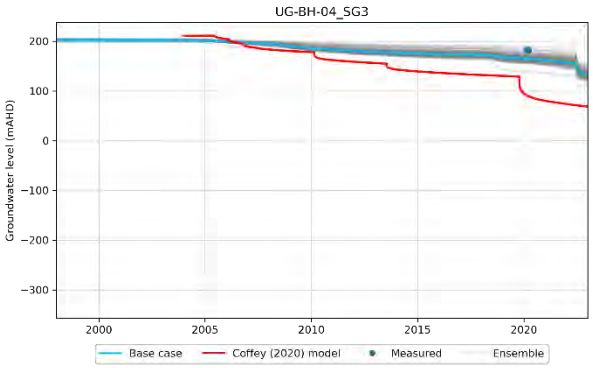

UG-BH-03_SG1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

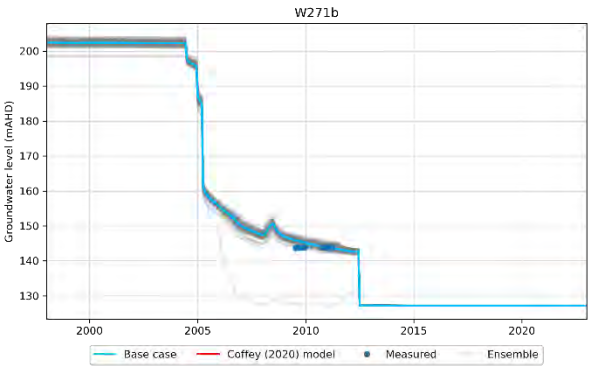

UG-BH-03_SG2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

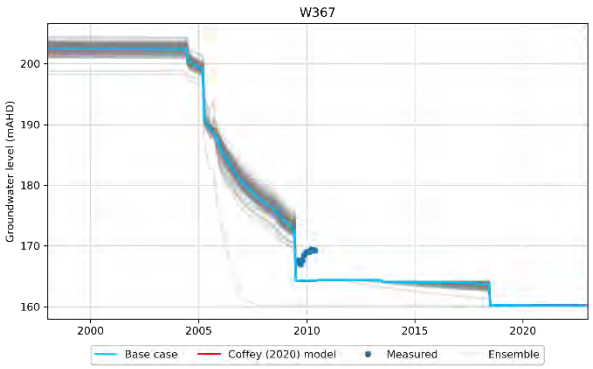

UG-BH-03_SG3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

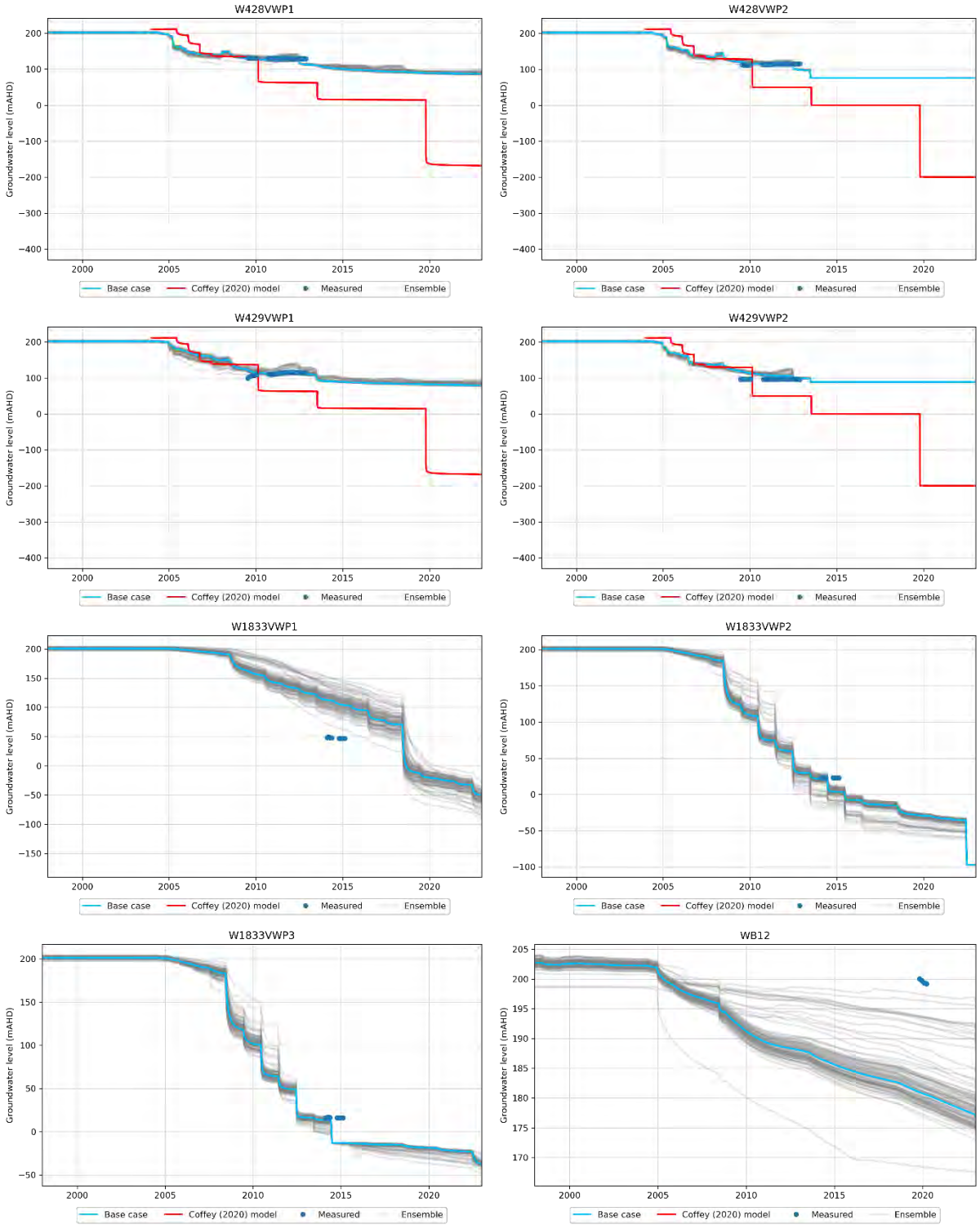

UG-BH-04_SG1
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


UG-BH-04_SG2
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble


UG-BH-04_SG3
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

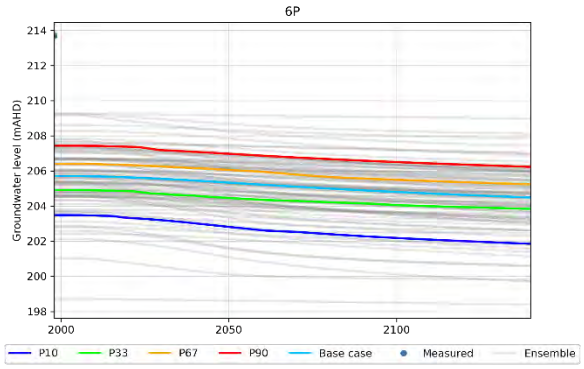

W271b
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

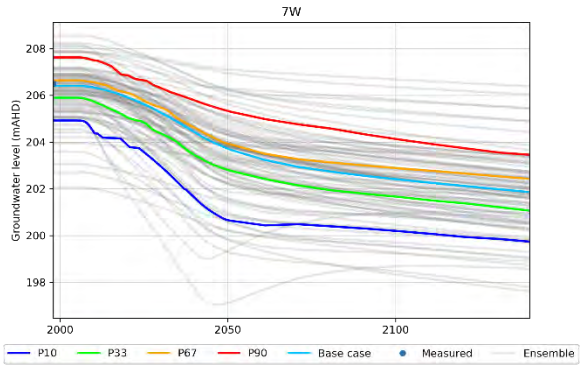

W367
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

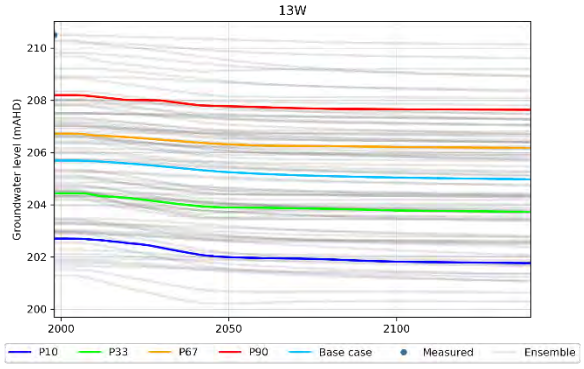

W428VWP1
W428VWP2
W429VWP1
W429VWP2
W1833VWP1
W1833VWP2
W1833VWP3
WB12
Groundwater level (mAHD)
Base case
Coffey (2020) model
Measured
Ensemble

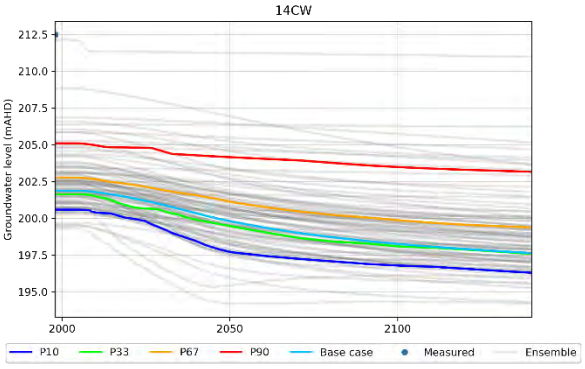
Appendix D
Hydrographs: dry pit

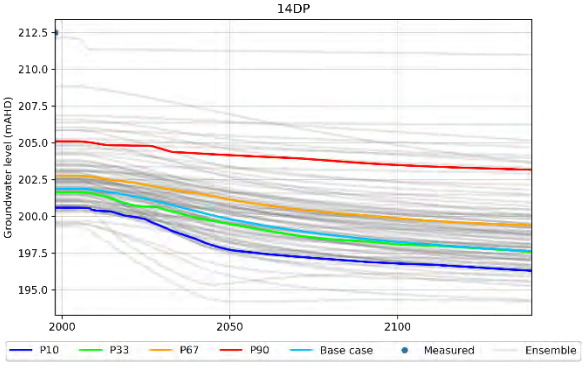
EMM
creating opportunities

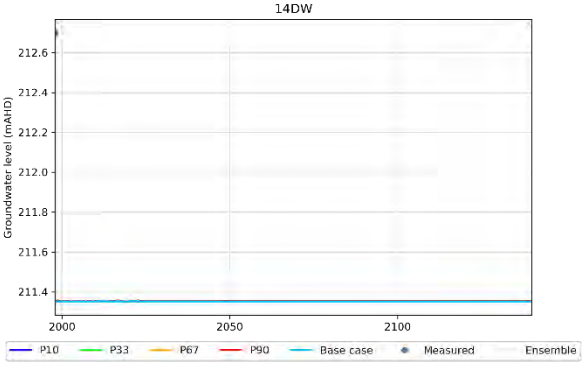

6P
Groundwater level (mAHD)
214
212
210
208
206
204
202
200
198
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

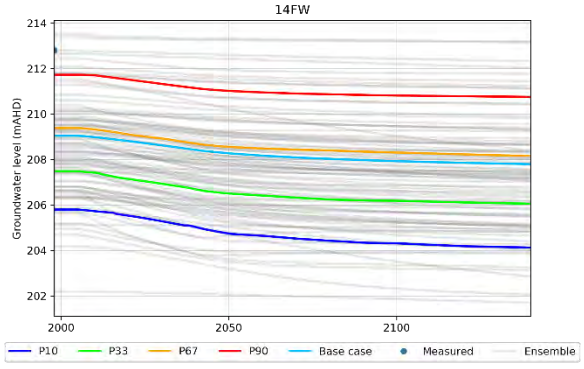

7W
Groundwater level (mAHD)
208
206
204
202
200
198
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

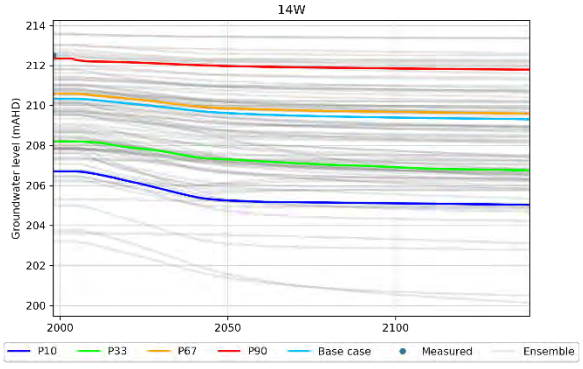

13W
Groundwater level (mAHD)
210
208
206
204
202
200
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

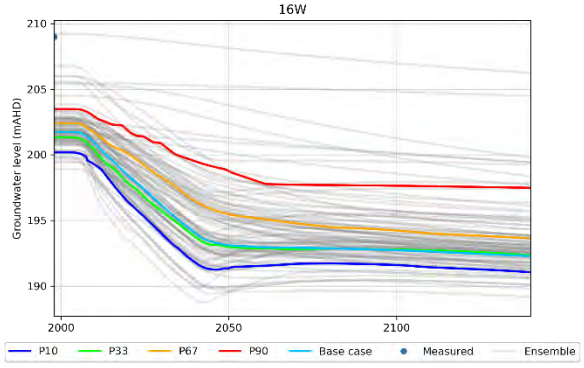

14CW
Groundwater level (mAHD)
212.5
210.0
207.5
205.0
202.5
200.0
197.5
195.0
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

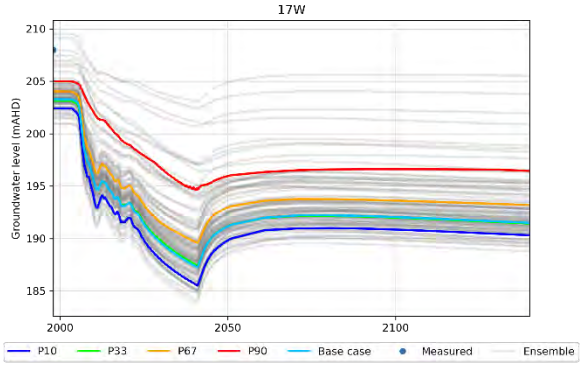

14DP
Groundwater level (mAHD)
212.5
210.0
207.5
205.0
202.5
200.0
197.5
195.0
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

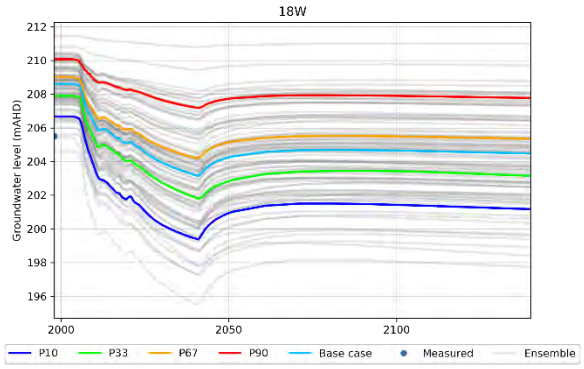

14DW
Groundwater level (mAHD)
212.6
212.4
212.2
212.0
211.8
211.6
211.4
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

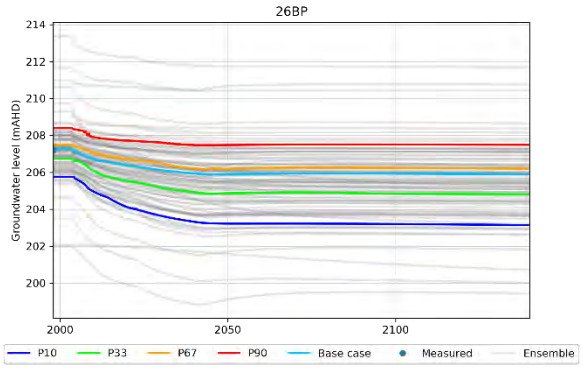

14FW
Groundwater level (mAHD)
214
212
210
208
206
204
202
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

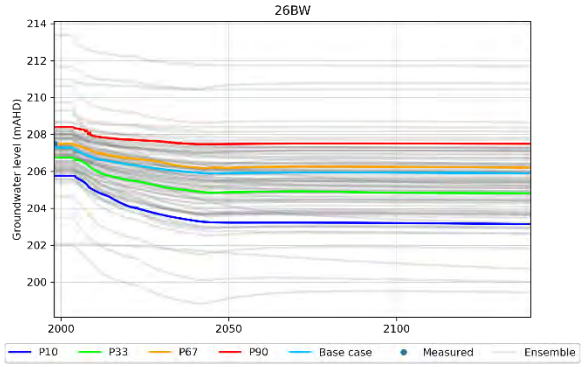

14W
Groundwater level (mAHD)
214
212
210
208
206
204
202
200
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

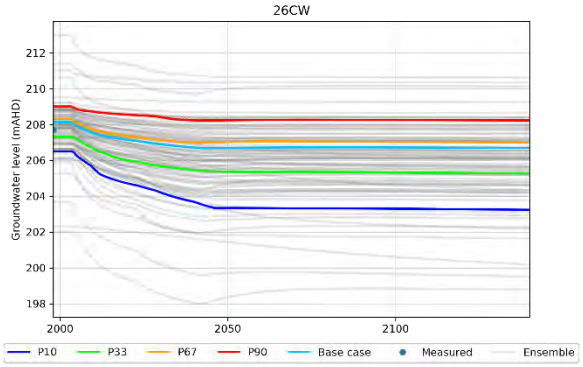

16W
Groundwater level (mAHD)
210
205
200
195
190
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

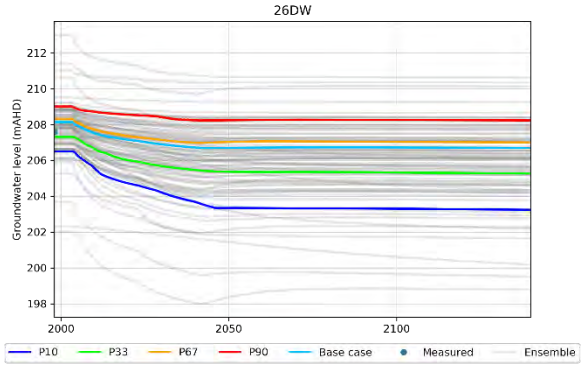

17W
Groundwater level (mAHD)
210
205
200
195
190
185
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

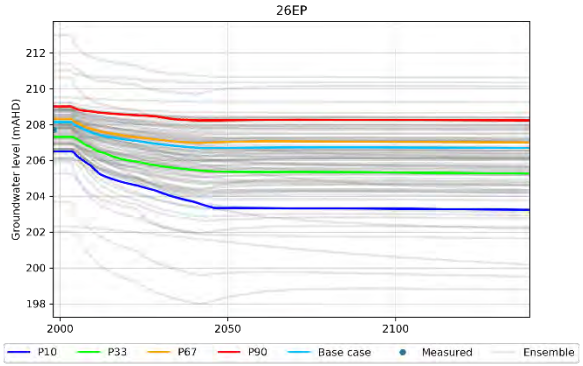

18W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

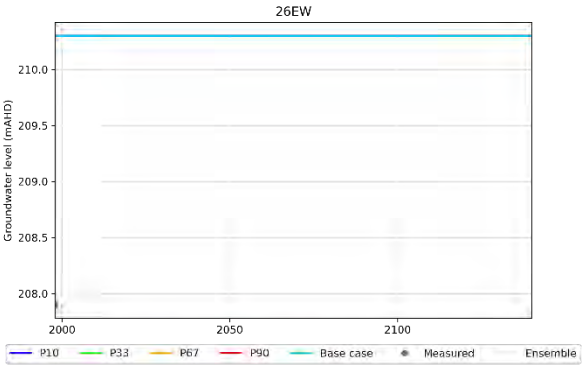

26BP
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

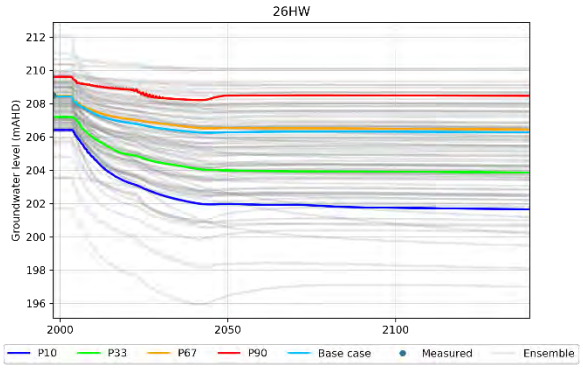

26BW
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

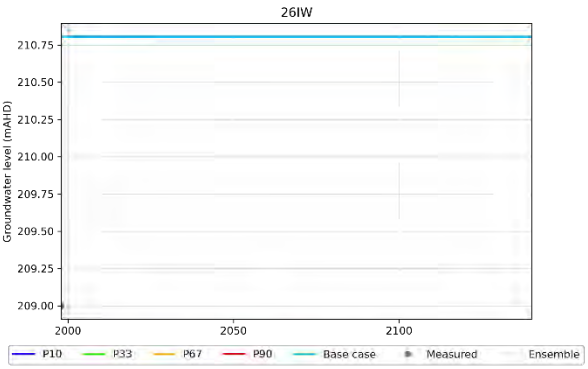

26CW
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

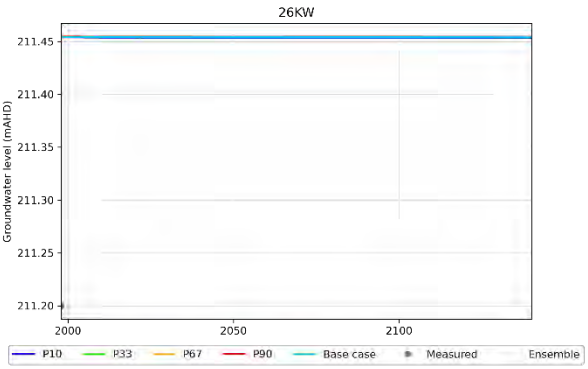

26DW
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

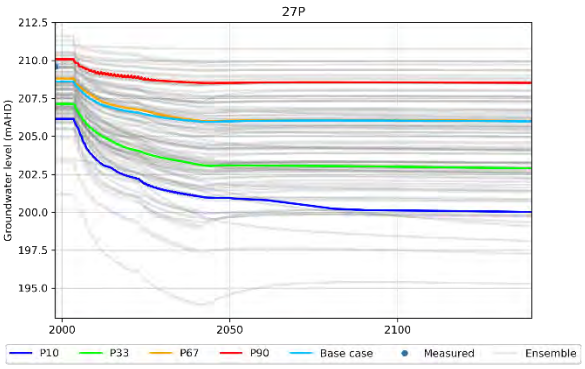

26EP
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

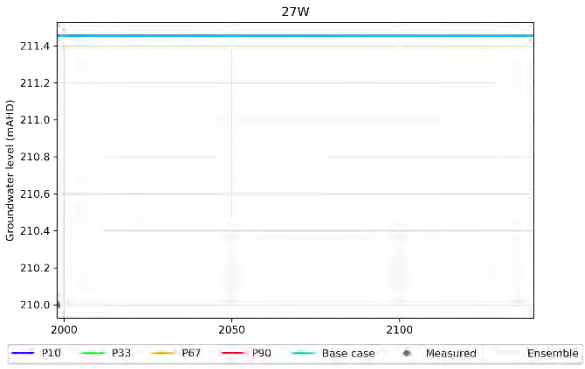

26EW
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

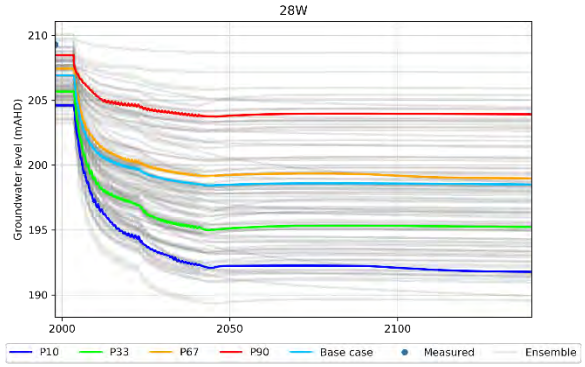

26HW
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

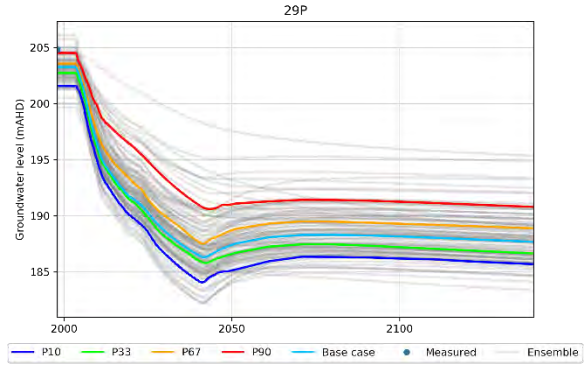

26IW
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

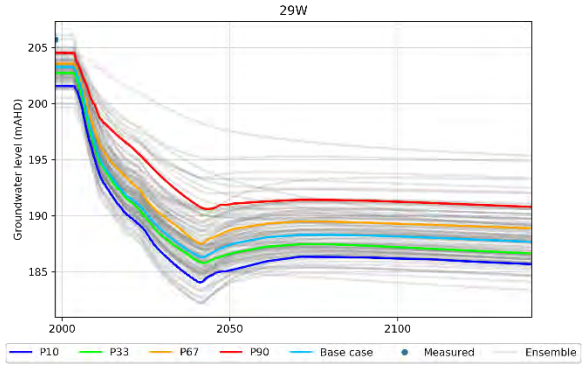

26KW
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

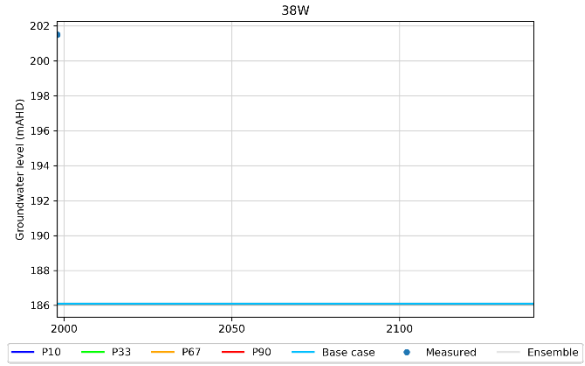

27P
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

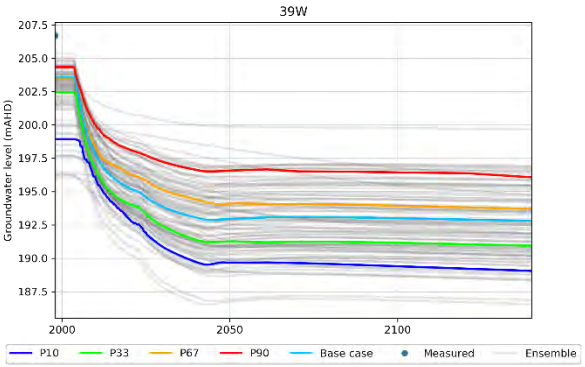

27W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

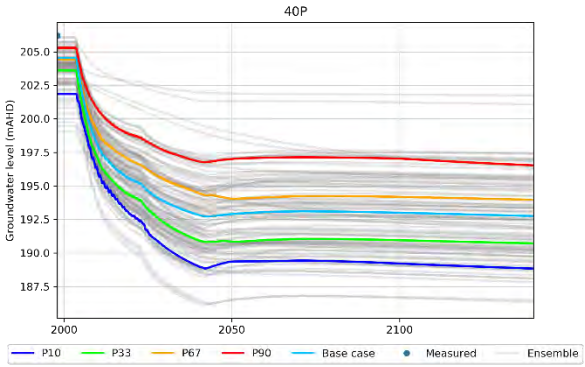

28W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

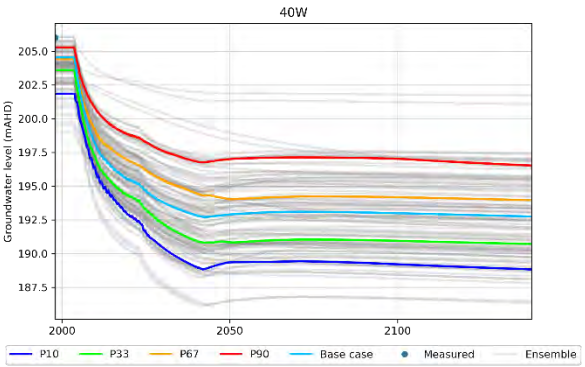

29P
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

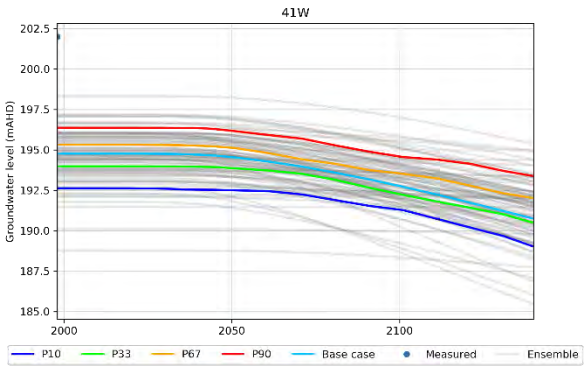

29W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

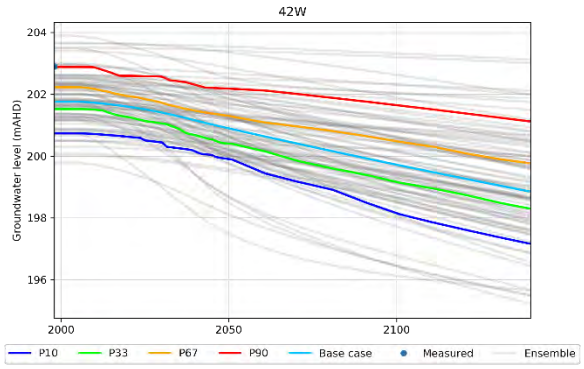

38W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

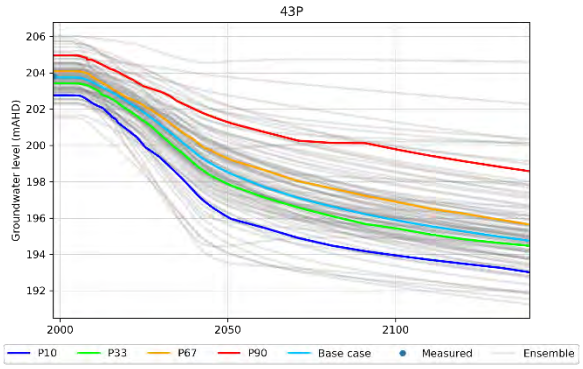

39W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

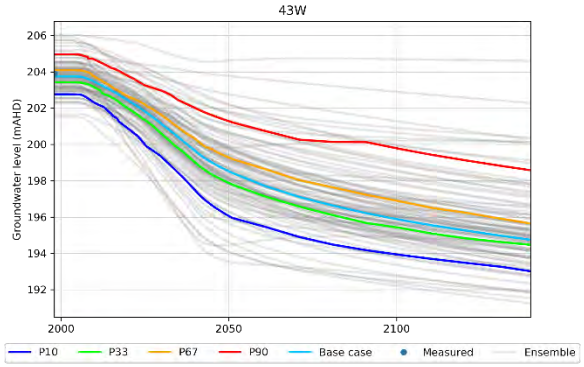

40P
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

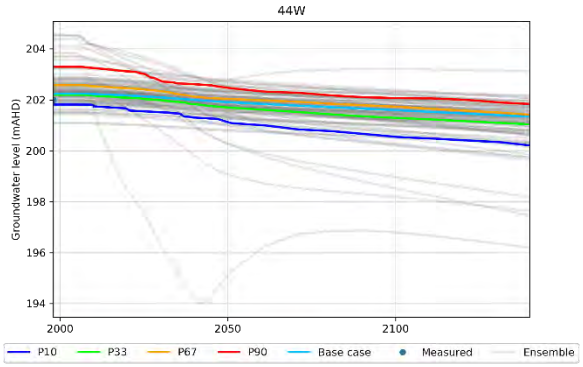

40W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

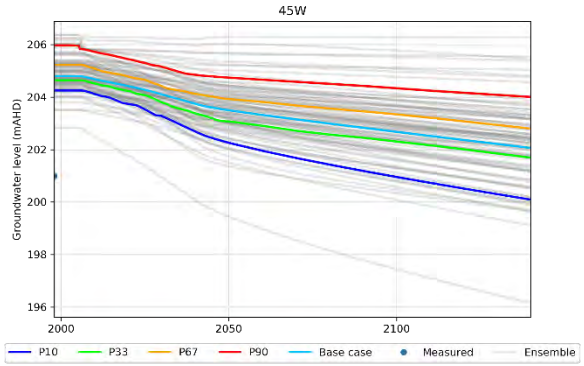

41W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

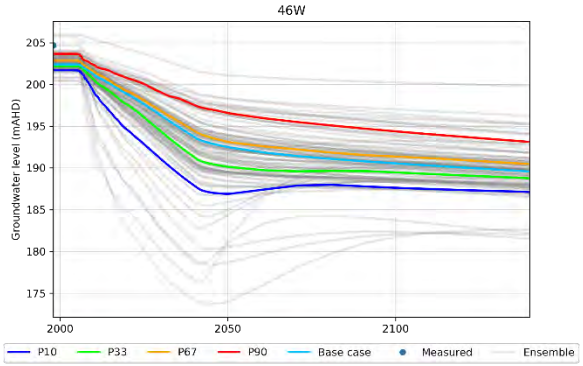

42W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

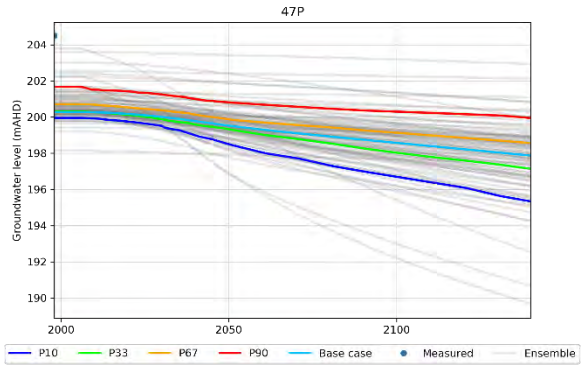

43P
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

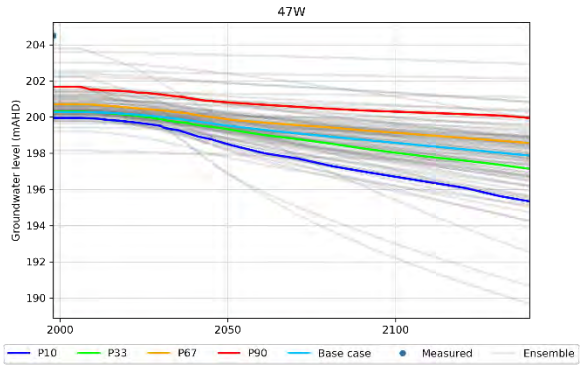

43W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

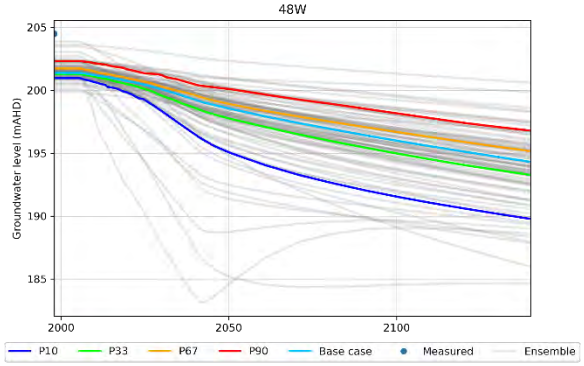

44W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

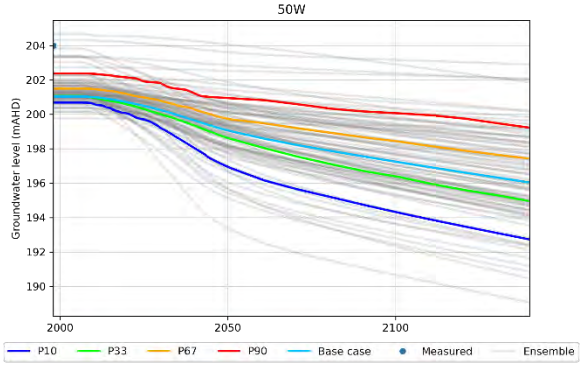

45W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble


46W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

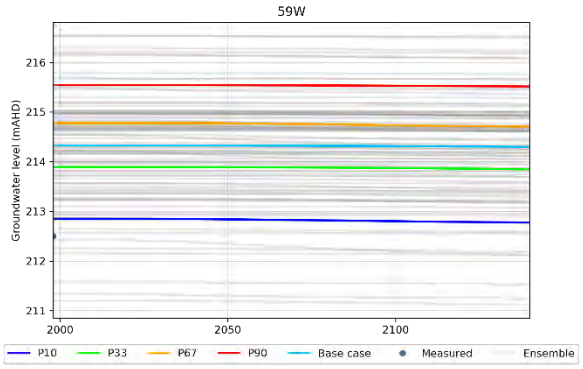

47P
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

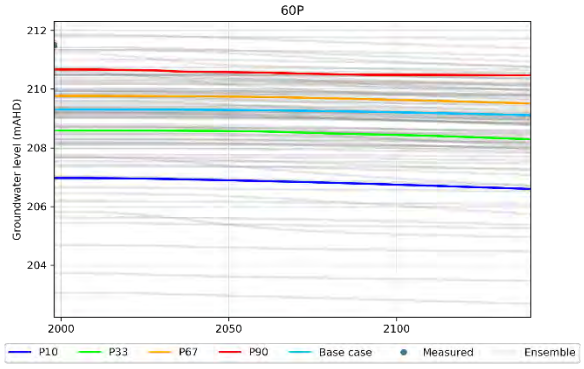

47W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

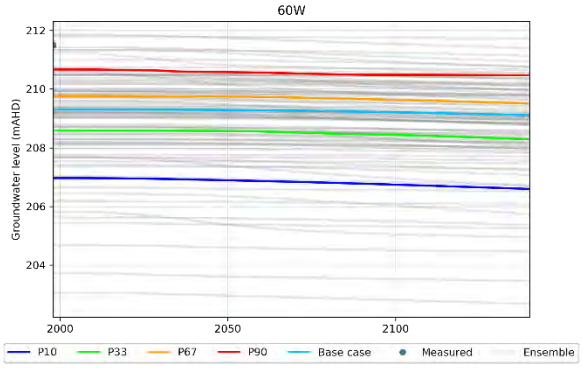

48W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

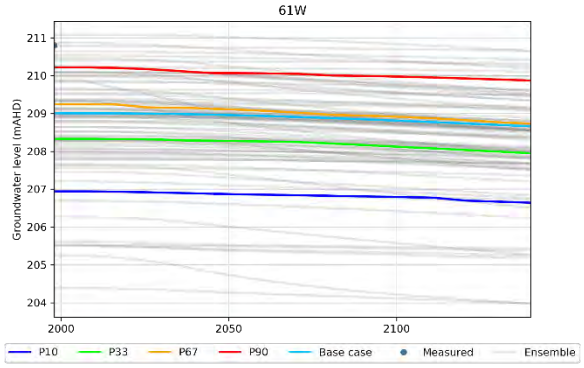

50W
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

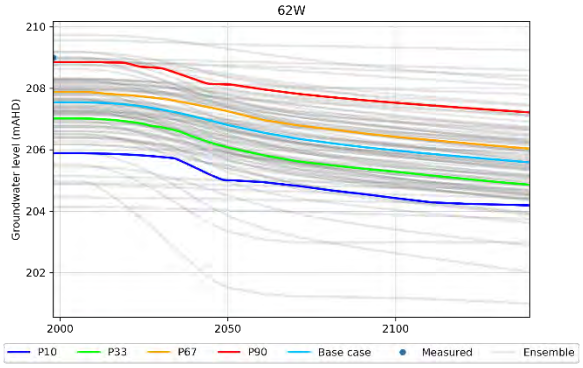
56W
Groundwater level (mAHD)
214
212
210
208
206
204
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

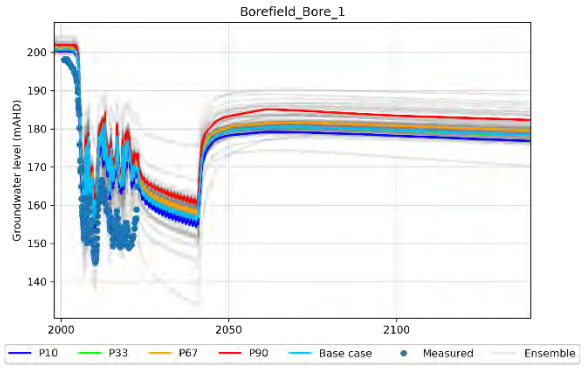

59W
Groundwater level (mAHD)
216
215
214
213
212
211
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

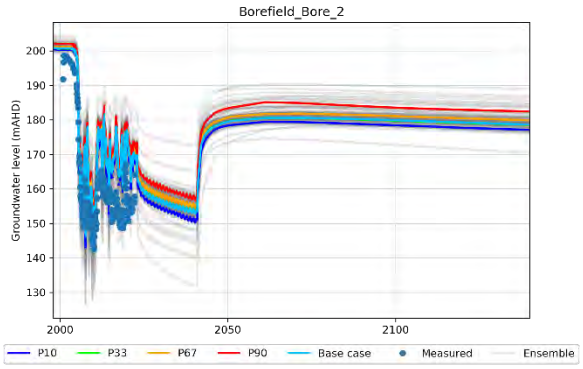

60P
Groundwater level (mAHD)
212
210
208
206
204
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

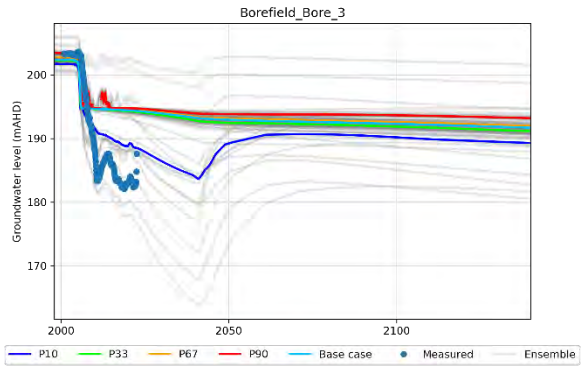

60W
Groundwater level (mAHD)
212
210
208
206
204
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

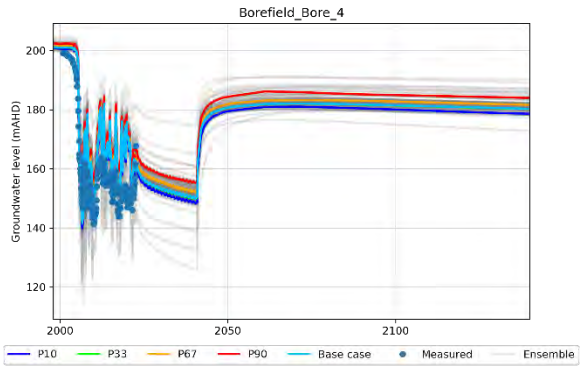

61W
Groundwater level (mAHD)
211
210
209
208
207
206
205
204
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

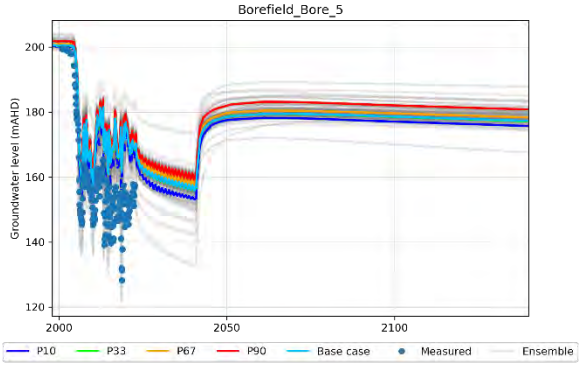

62W
Groundwater level (mAHD)
210
208
206
204
202
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

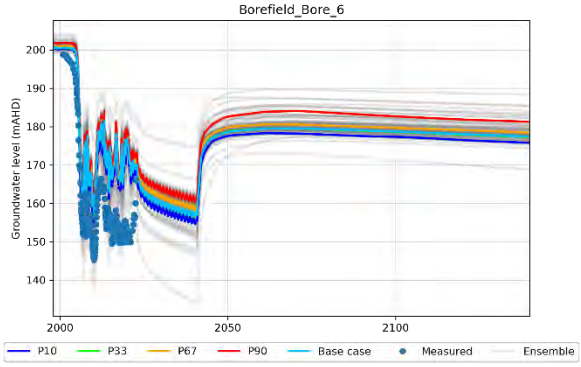

Borefield_Bore_1
Groundwater level (mAHD)
200
190
180
170
160
150
140
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

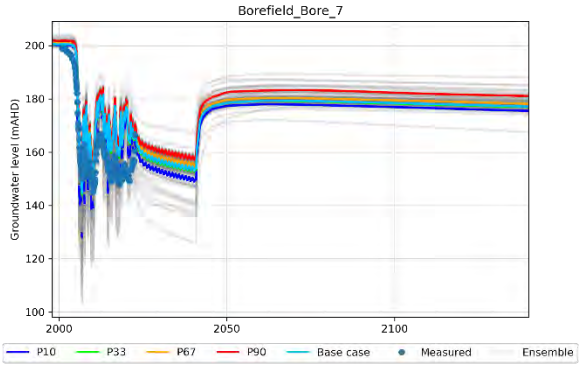

Borefield_Bore_2
Groundwater level (mAHD)
200
190
180
170
160
150
140
130
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

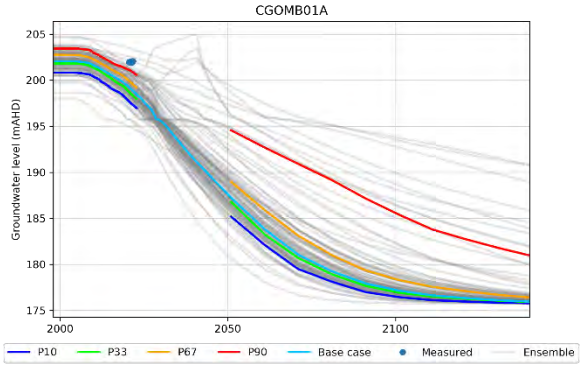

Borefield_Bore_3
Groundwater level (mAHD)
200
190
180
170
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

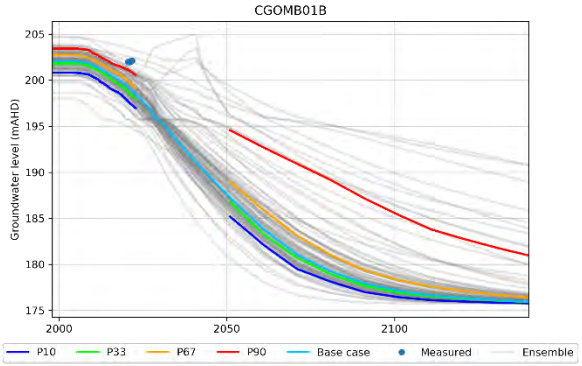

Borefield_Bore_4
Groundwater level (mAHD)
200
180
160
140
120
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

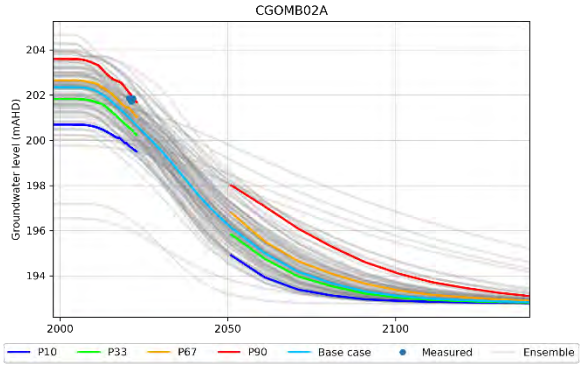

Borefield_Bore_5
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

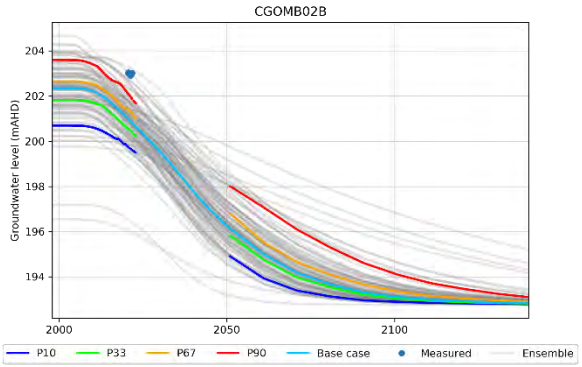

Borefield_Bore_6
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

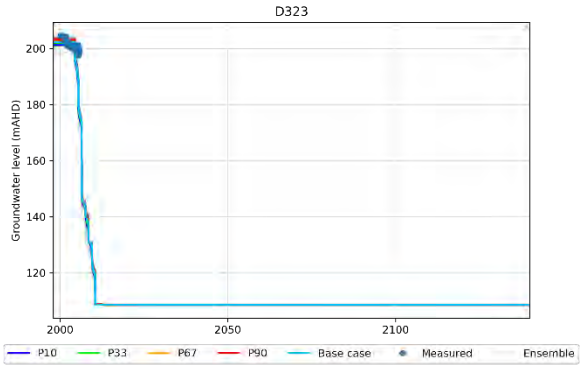

Borefield_Bore_7
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

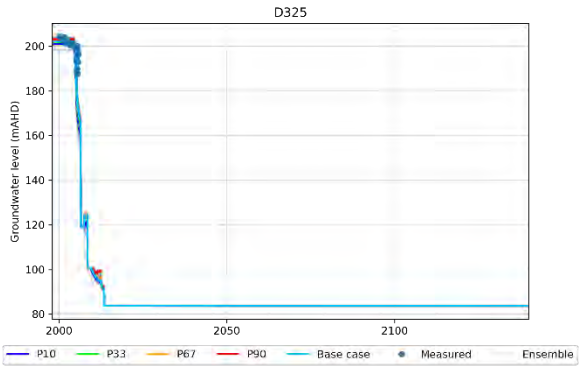

CGOMB01A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

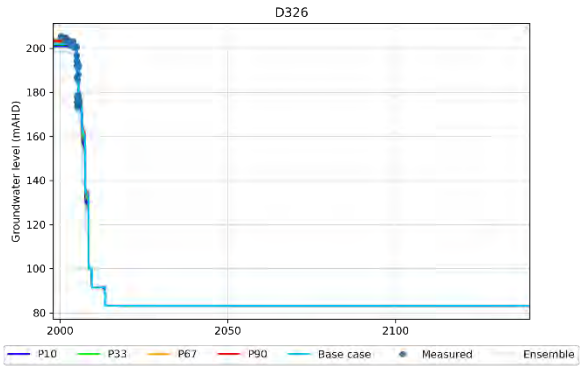

CGOMB01B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

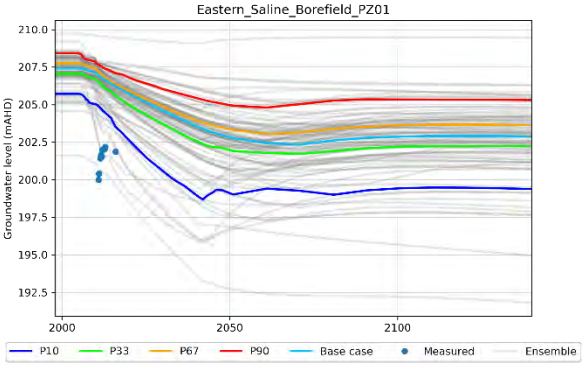

CGOMB02A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

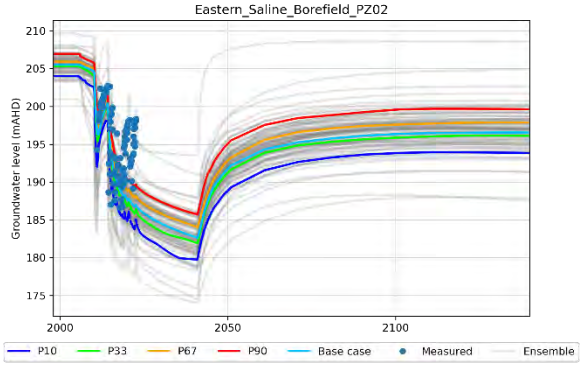

CGOMB02B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

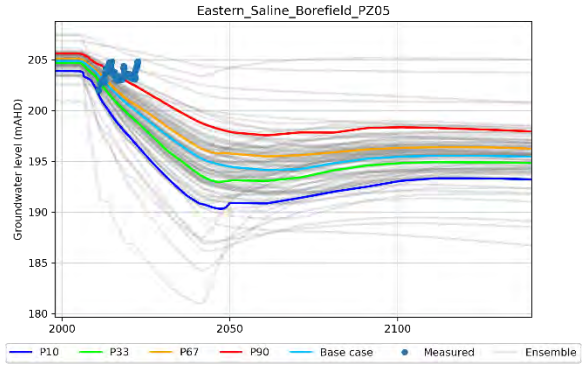

D323
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

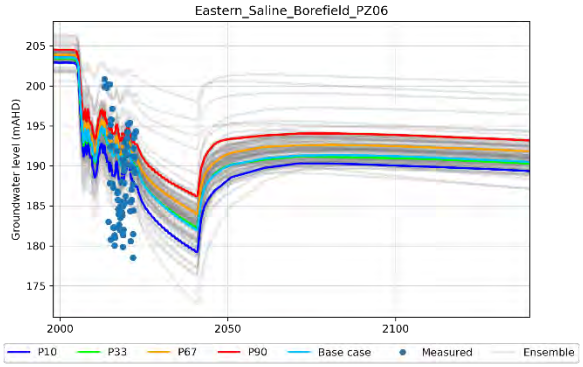

D325
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

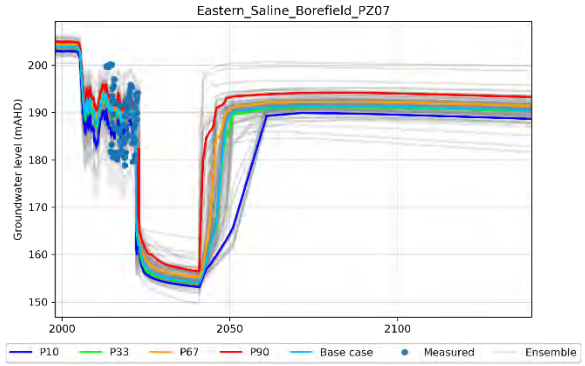

D326
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

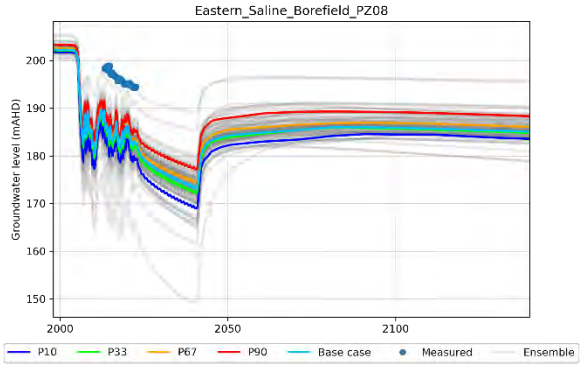

Eastern_Saline_Borefield_PZ01
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

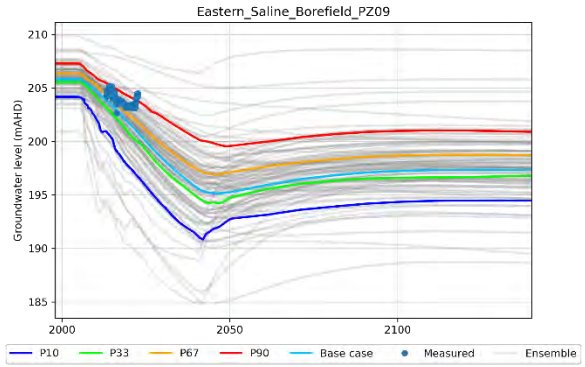

Eastern_Saline_Borefield_PZ02
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

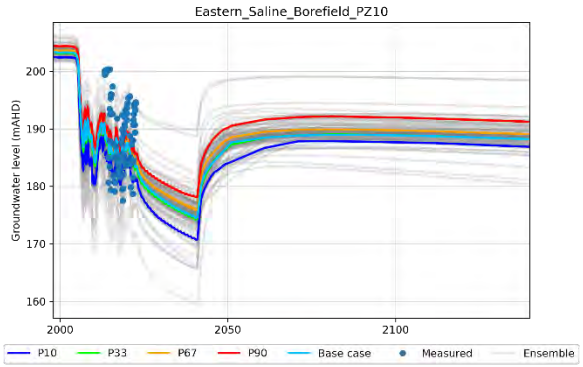

Eastern_Saline_Borefield_PZ05
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

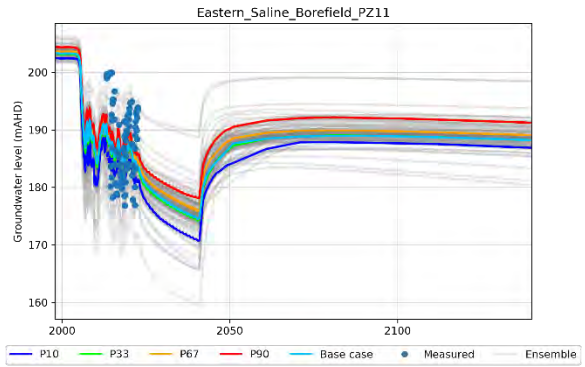

Eastern_Saline_Borefield_PZ06
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

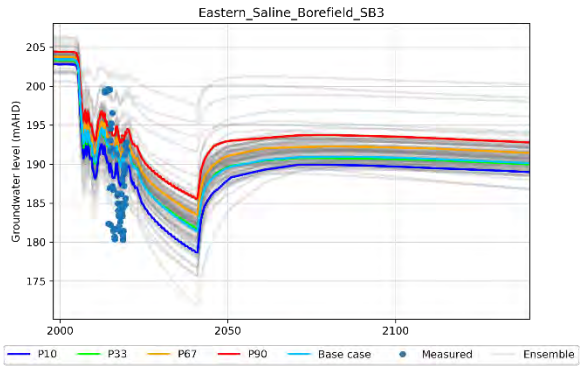

Eastern_Saline_Borefield_PZ07
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

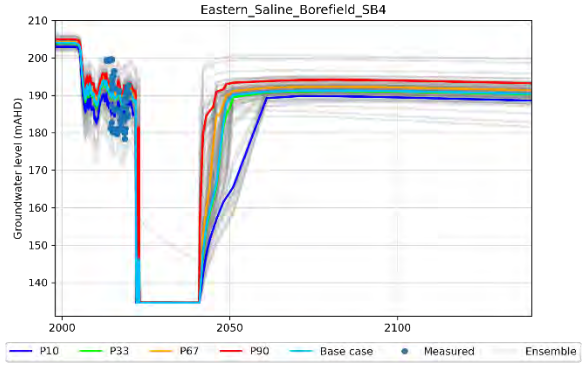

Eastern_Saline_Borefield_PZ08
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

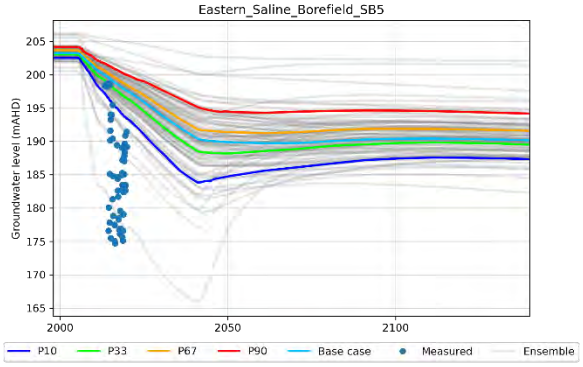

Eastern_Saline_Borefield_PZ09
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

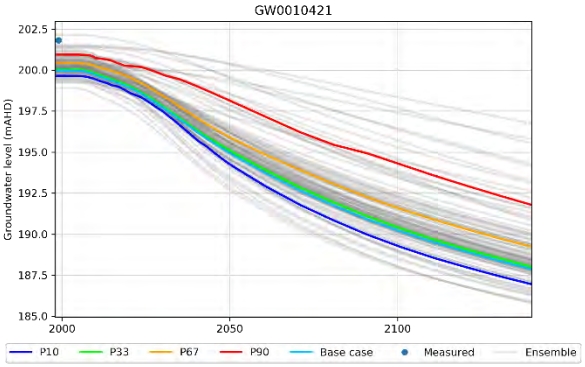

Eastern_Saline_Borefield_PZ10
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

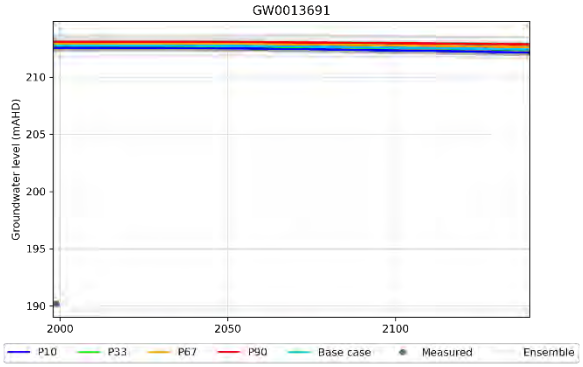

Eastern_Saline_Borefield_PZ11
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

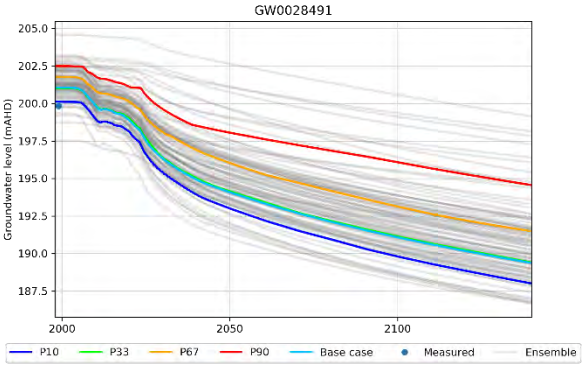

Eastern_Saline_Borefield_SB3
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

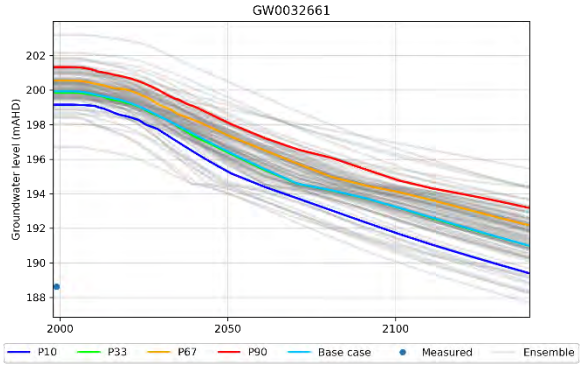

Eastern_Saline_Borefield_SB4
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

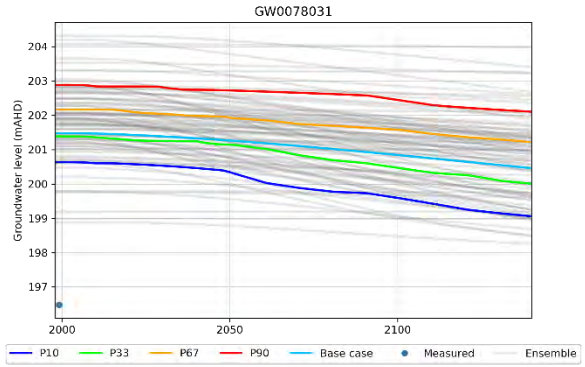

Eastern_Saline_Borefield_SB5
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

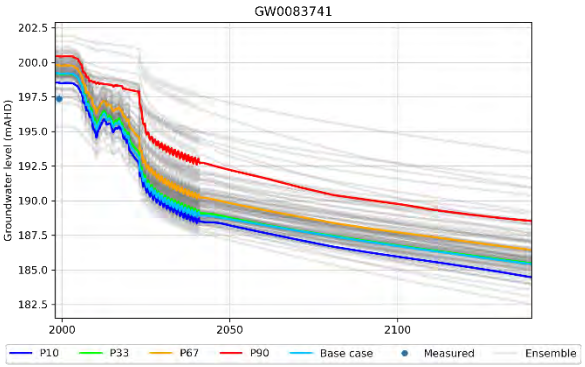

GW0010421
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

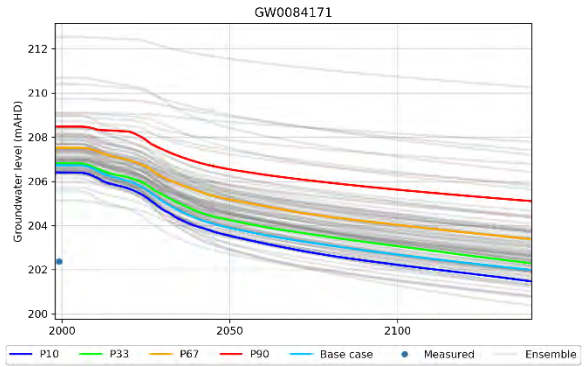

GW0013691
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

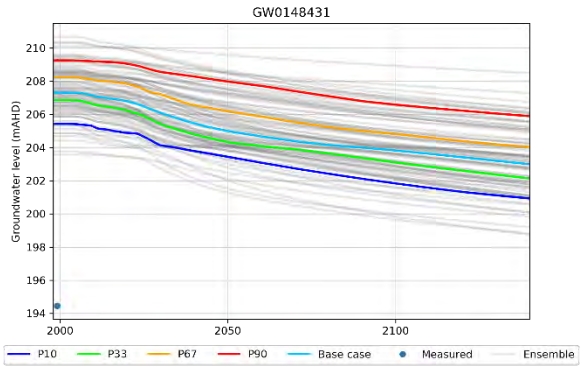

GW0028491
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

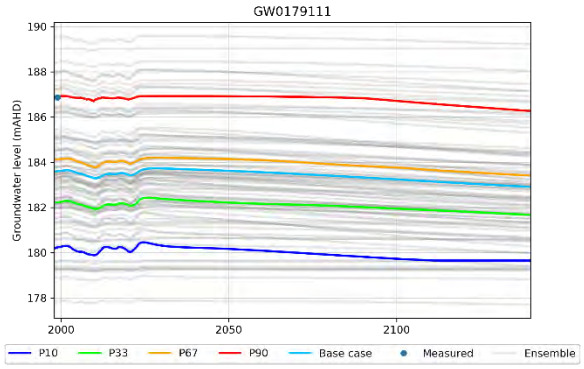

GW0032661
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

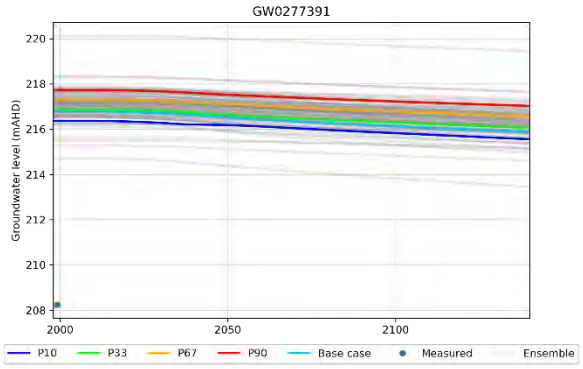

GW0078031
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

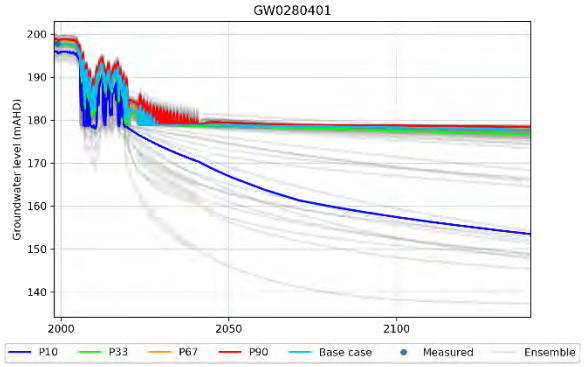

GW0083741
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

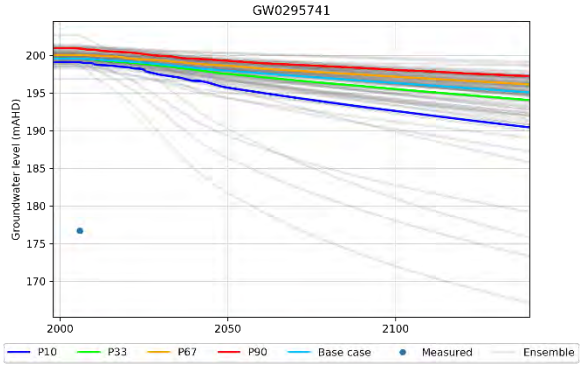

GW0084171
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

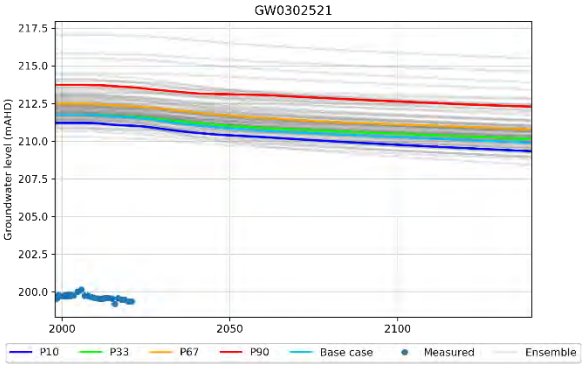

GW0148431
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

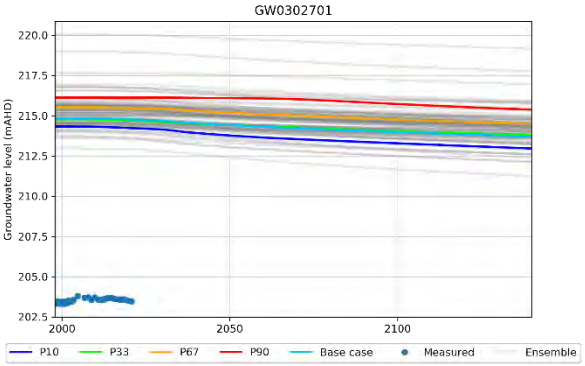

GW0179111
Groundwater level (mAHD)
190
188
186
184
182
180
178
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

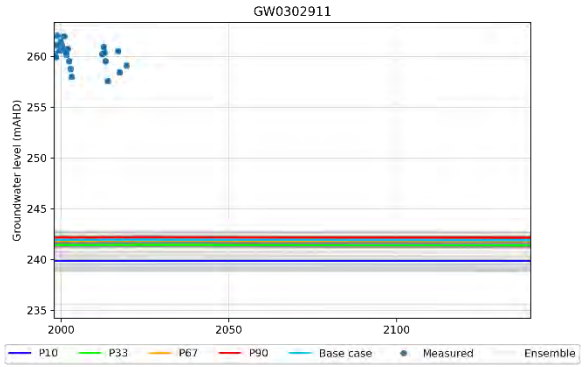

GW0277391
Groundwater level (mAHD)
220
218
216
214
212
210
208
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

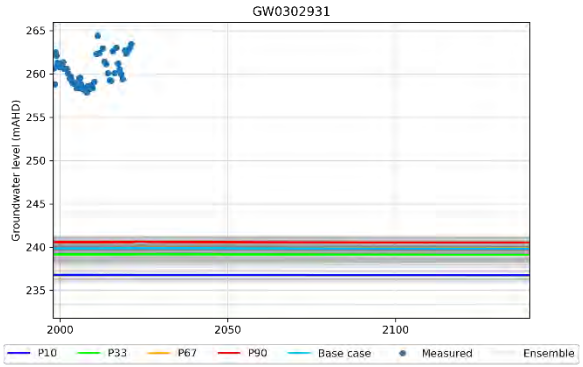

GW0280401
Groundwater level (mAHD)
200
190
180
170
160
150
140
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

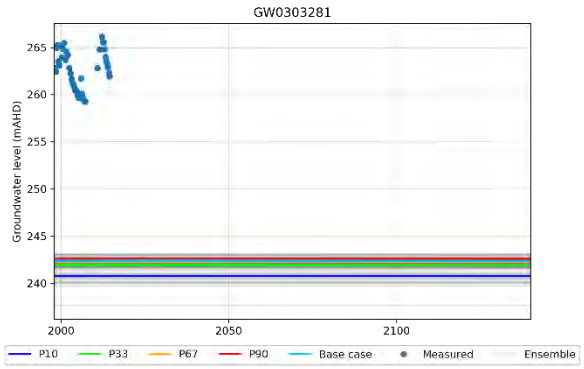

GW0295741
Groundwater level (mAHD)
200
195
190
185
180
175
170
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

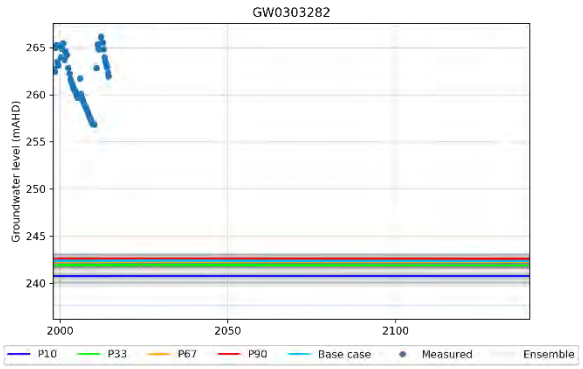

GW0302521
Groundwater level (mAHD)
217.5
215.0
212.5
210.0
207.5
205.0
202.5
200.0
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

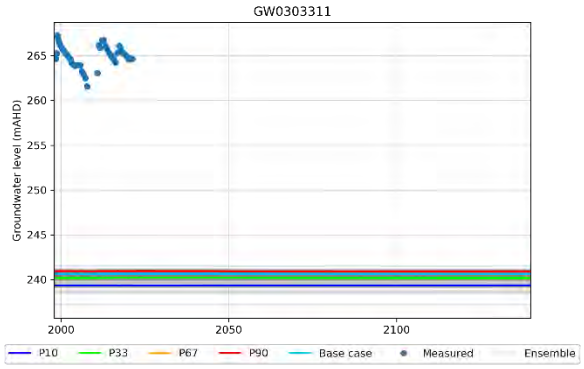

GW0302701
Groundwater level (mAHD)
220.0
217.5
215.0
212.5
210.0
207.5
205.0
202.5
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

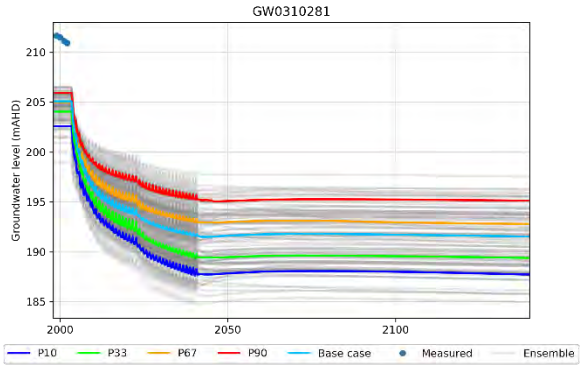

GW0302911
Groundwater level (mAHD)
260
255
250
245
240
235
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

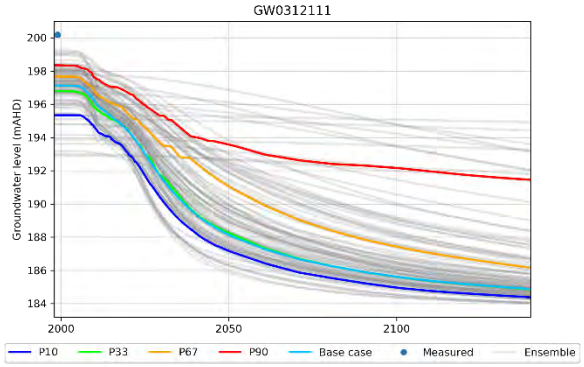

GW0302931
Groundwater level (mAHD)
265
260
255
250
245
240
235
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

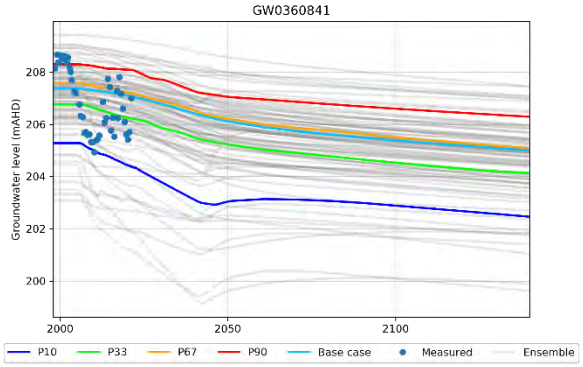

GW0303281
Groundwater level (mAHD)
265
260
255
250
245
240
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

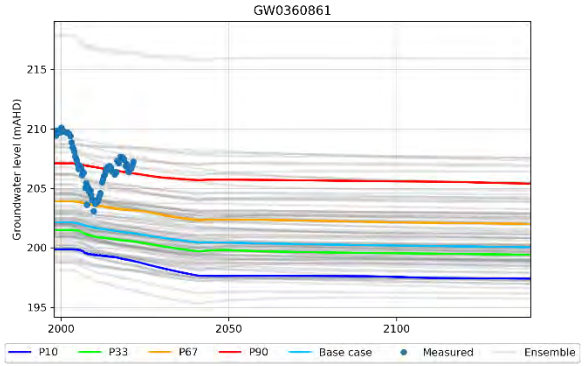

GW0303282
Groundwater level (mAHD)
265
260
255
250
245
240
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

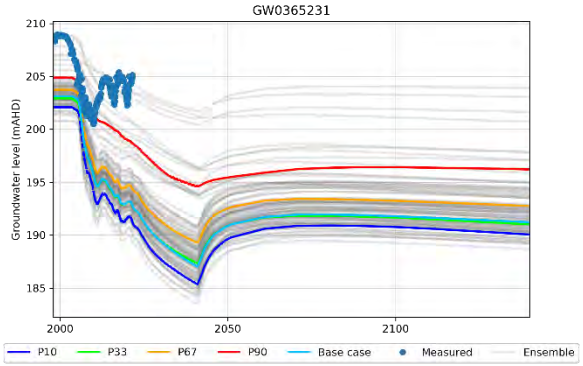

GW0303311
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

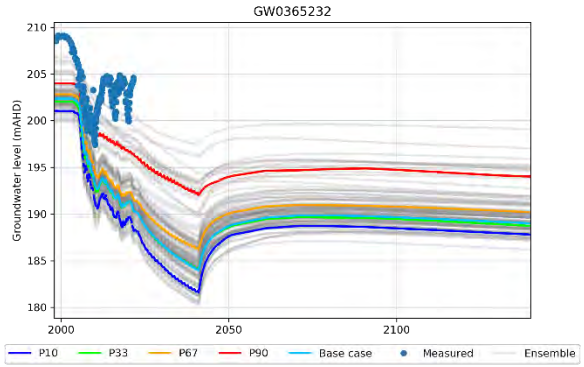

GW0310281
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

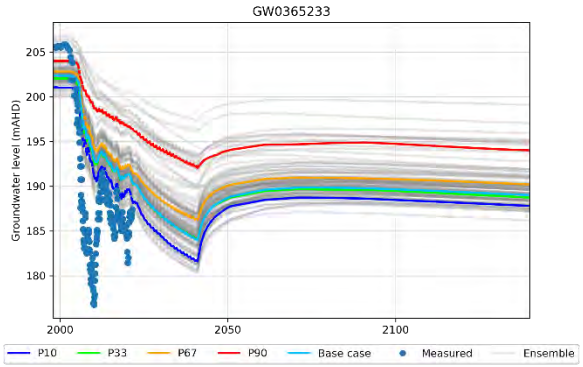

GW0312111
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

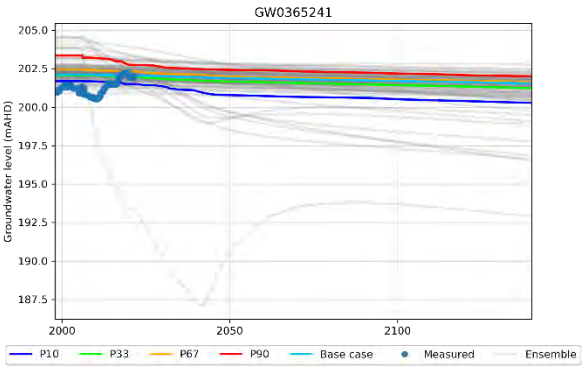

GW0360841
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

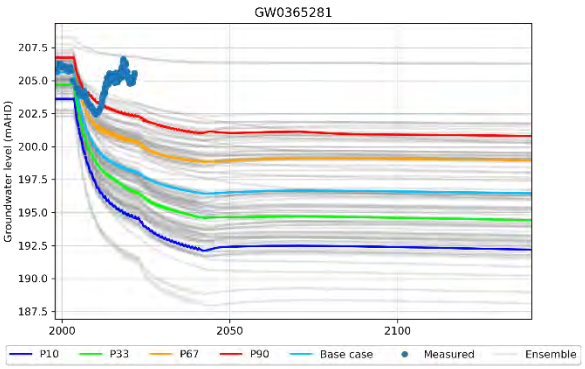

GW0360861
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

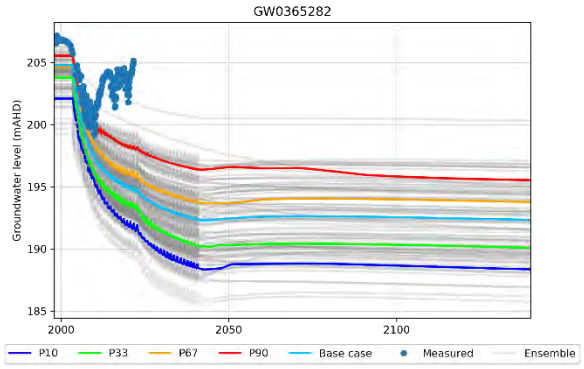

GW0365231
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

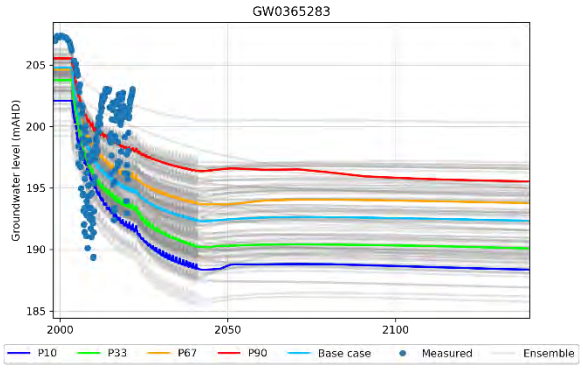

GW0365232
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

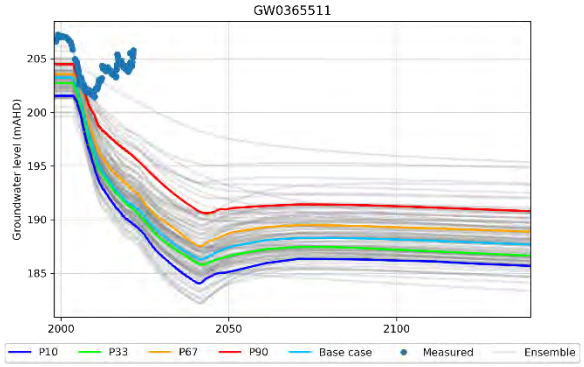

GW0365233
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

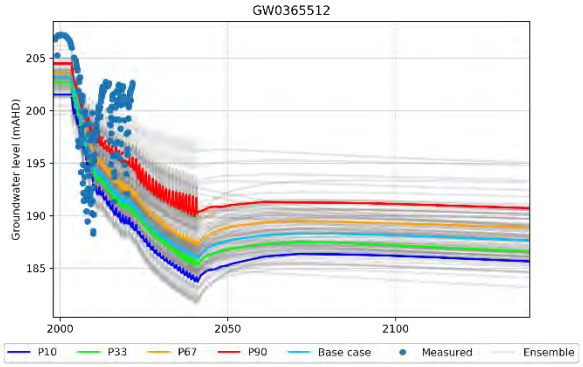

GW0365241
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

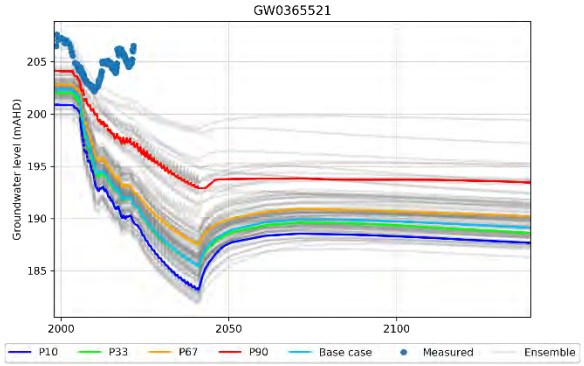

GW0365281
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

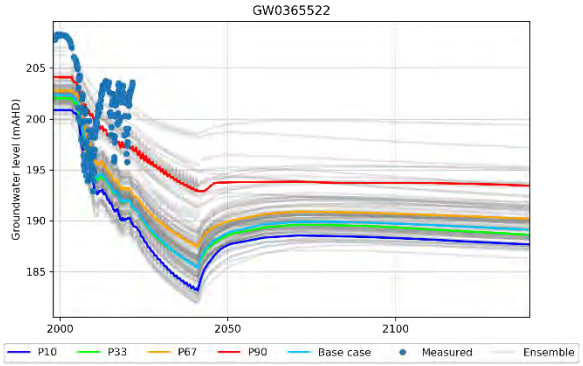

GW0365282
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

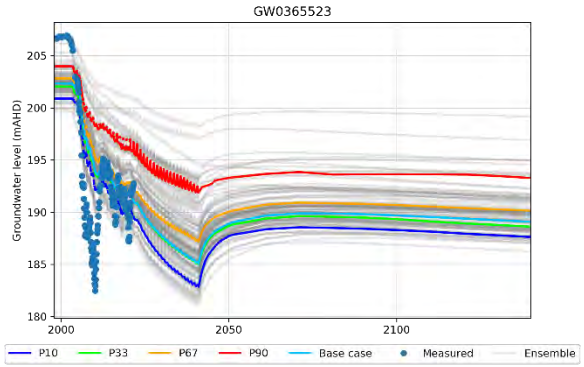

GW0365283
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

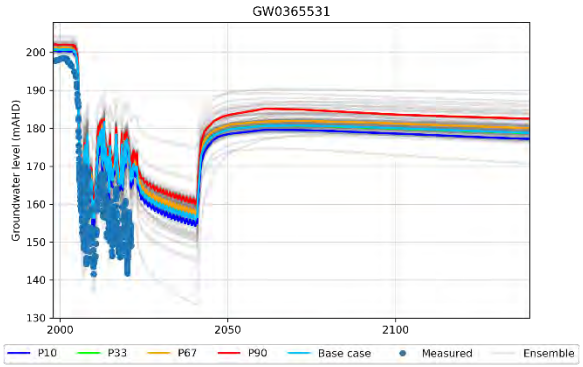

GW0365511
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

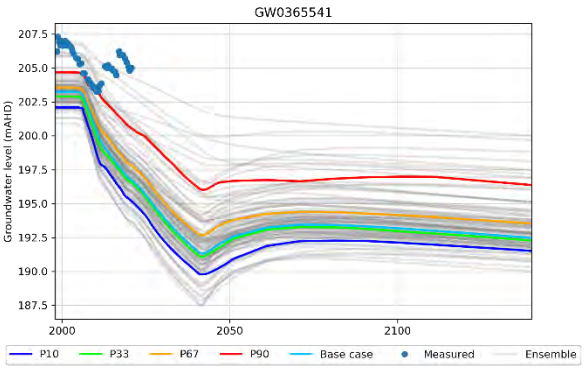

GW0365512
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

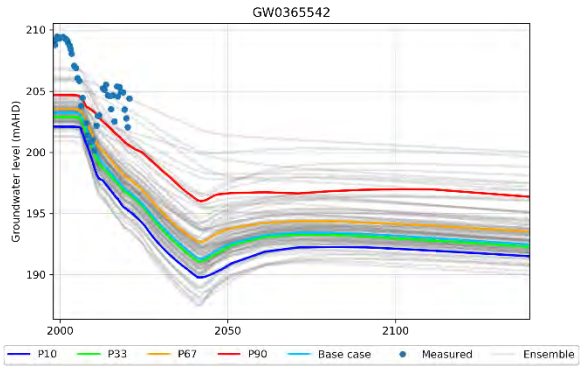

GW0365521
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

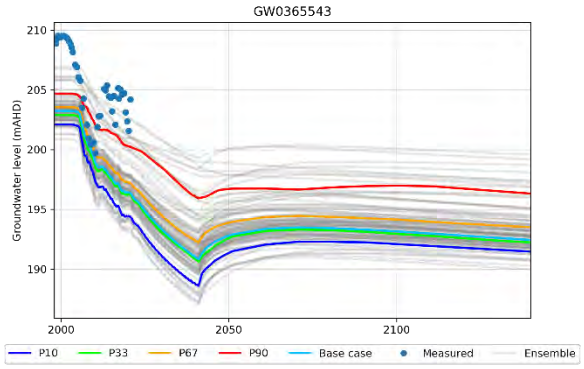

GW0365522
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

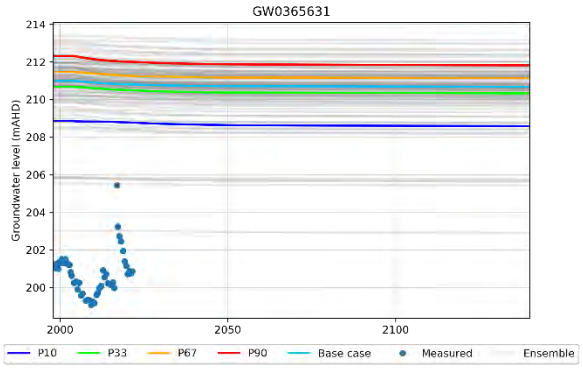

GW0365523
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

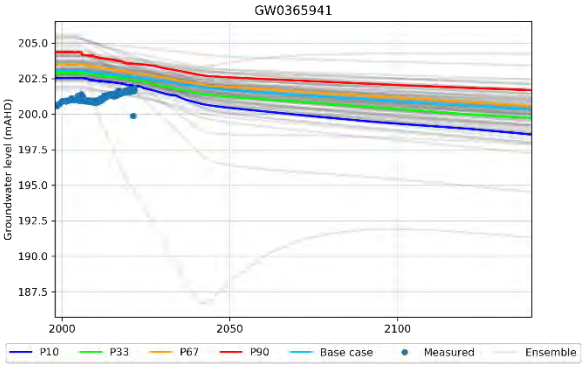

GW0365531
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

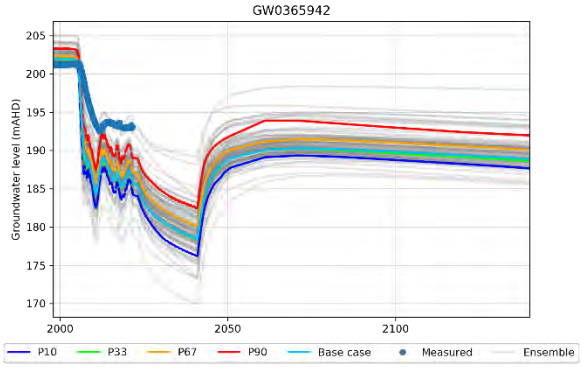

GW0365541
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

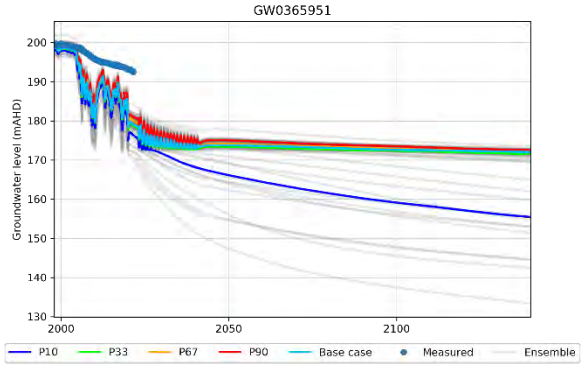

GW0365542
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

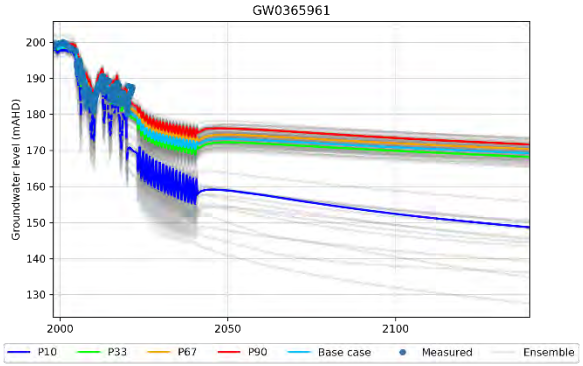

GW0365543
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

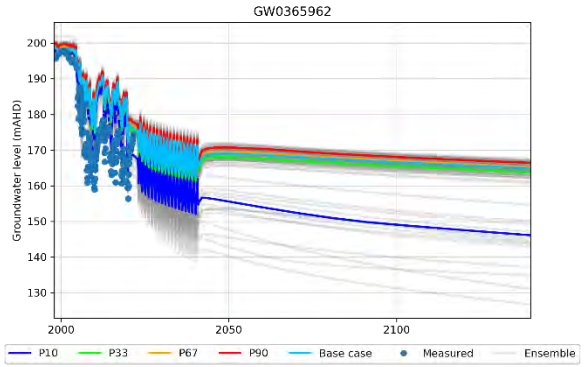

GW0365631
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

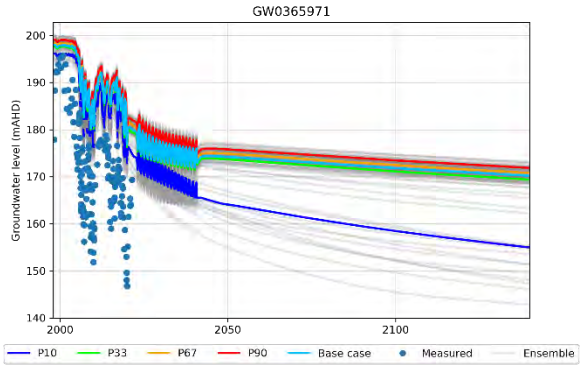

GW0365941
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

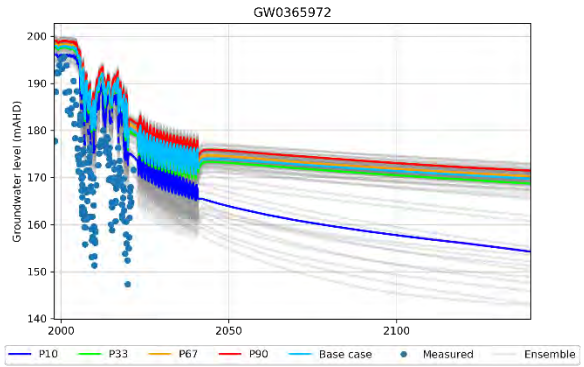

GW0365942
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

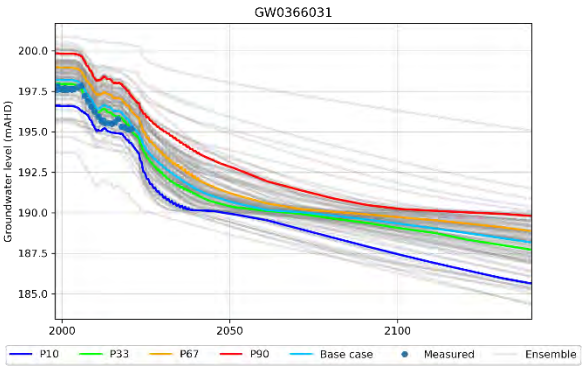

GW0365951
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

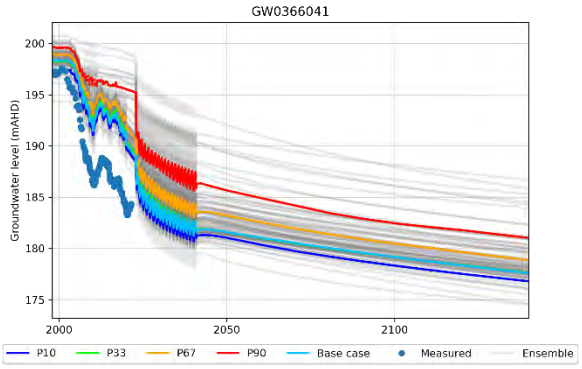

GW0365961
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

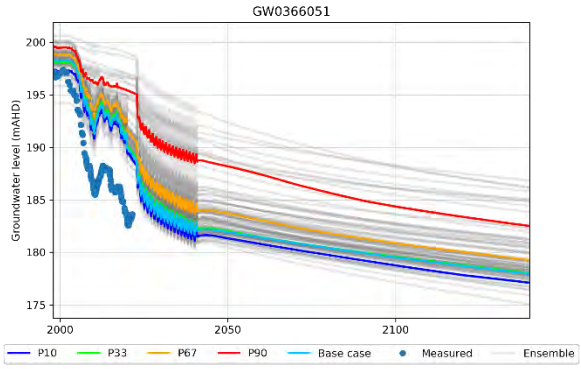

GW0365962
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

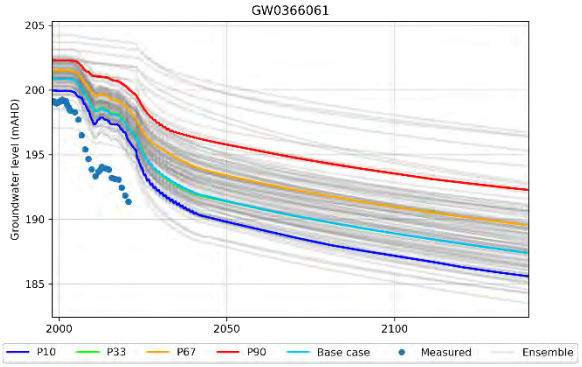

GW0365971
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

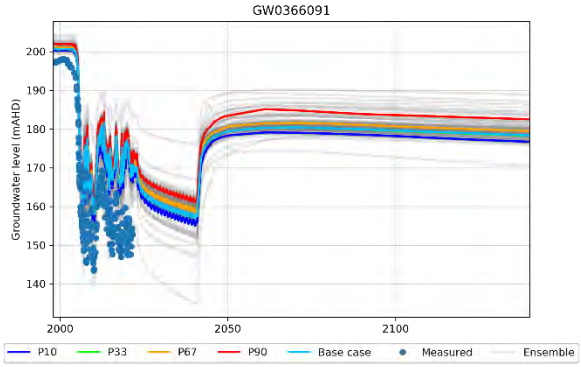

GW0365972
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

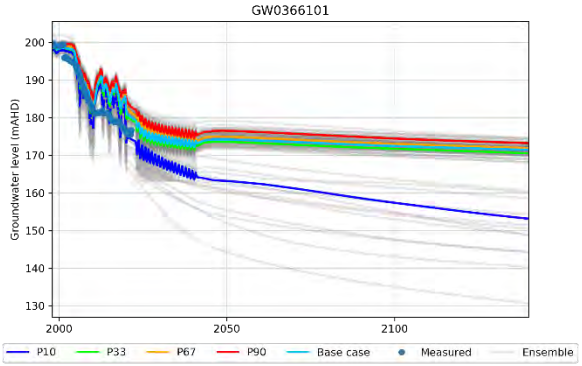

GW0366031
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

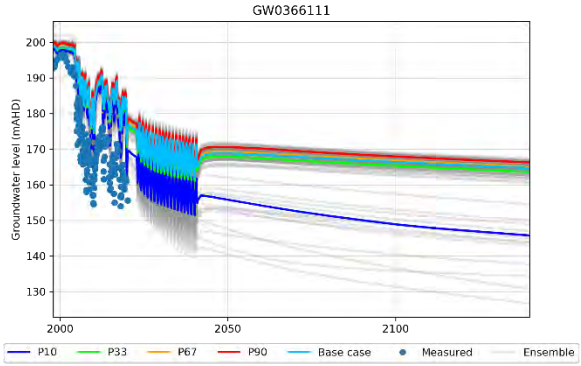

GW0366041
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

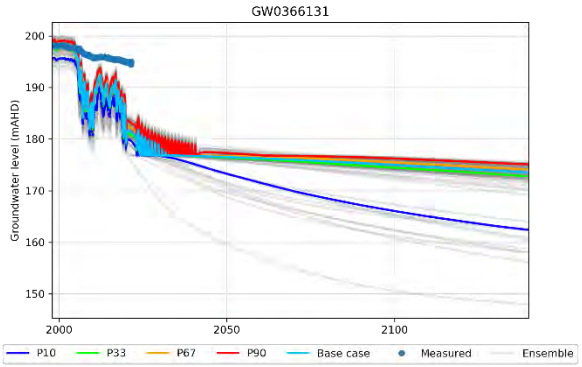

GW0366051
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

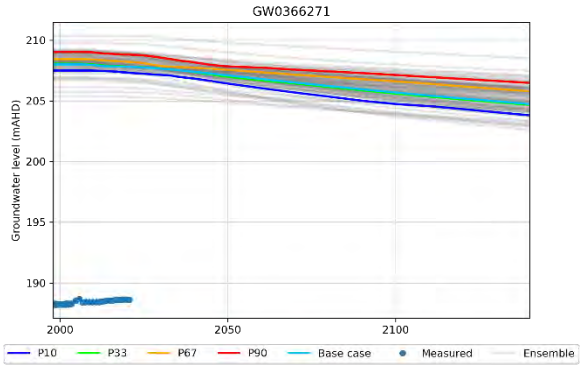

GW0366061
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

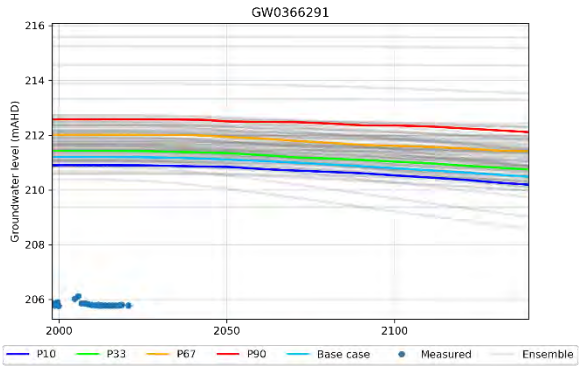

GW0366091
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

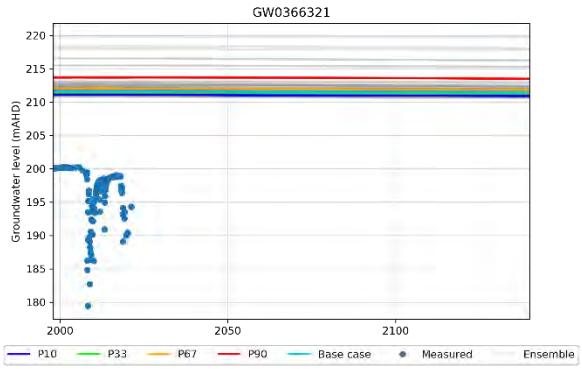

GW0366101
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

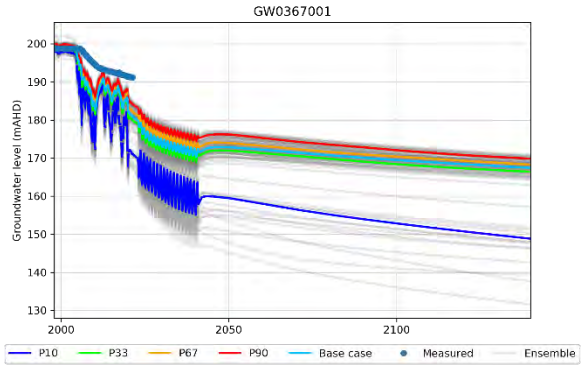

GW0366111
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

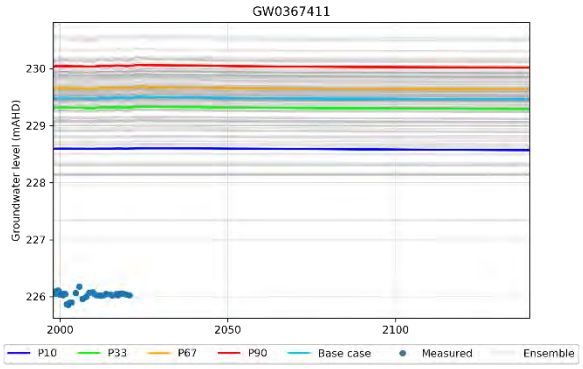

GW0366131
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

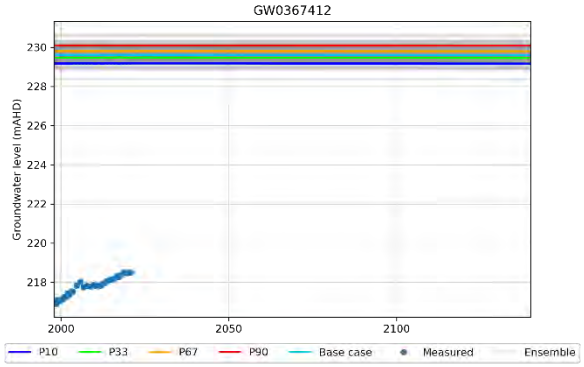

GW0366271
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

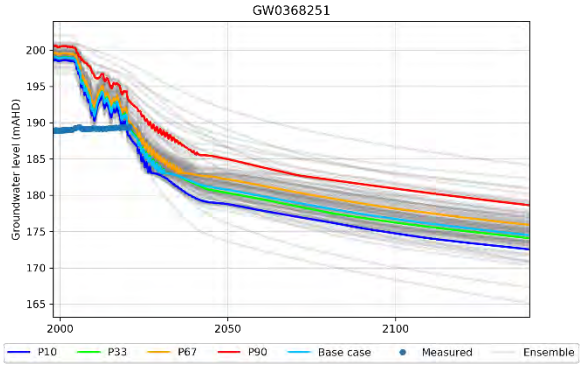

GW0366291
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

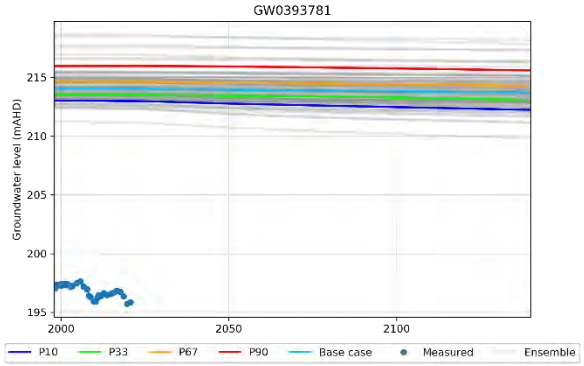

GW0366321
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

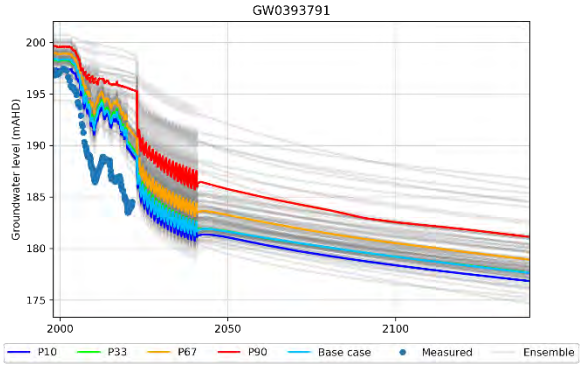

GW0367001
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

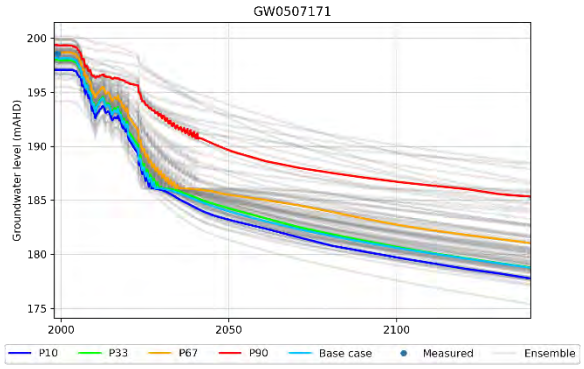

GW0367411
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

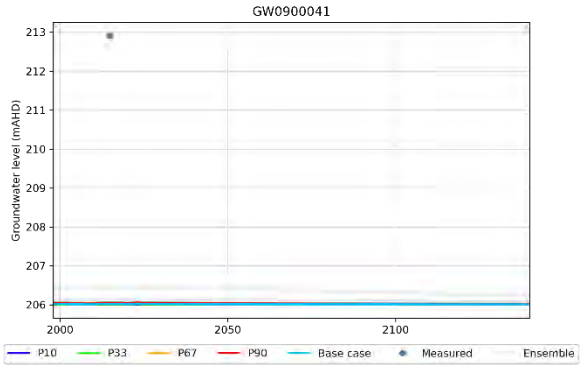

GW0367412
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

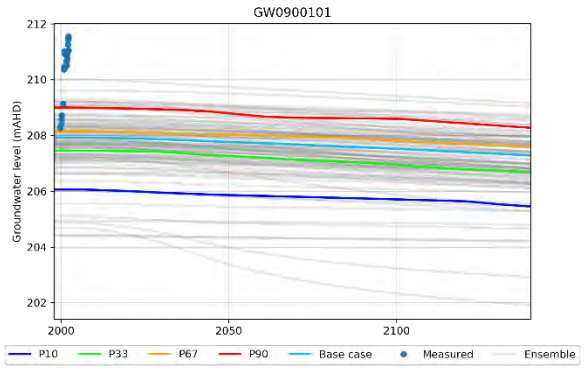

GW0368251
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

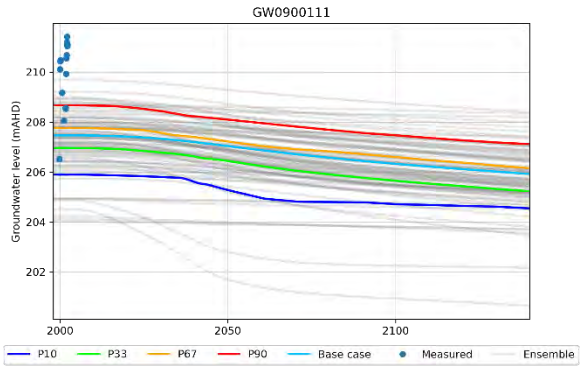

GW0393781
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

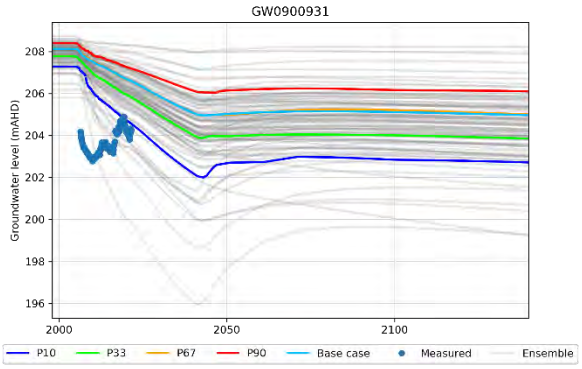

GW0393791
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

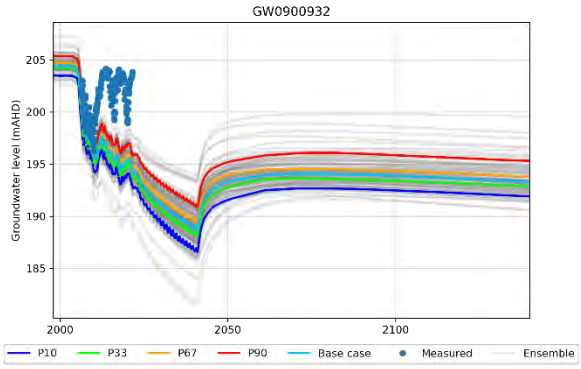

GW0507171
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

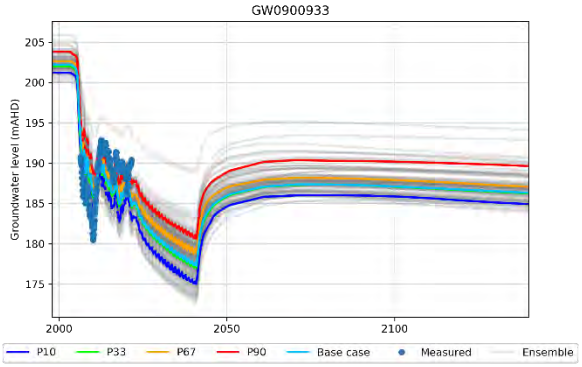

GW0900041
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

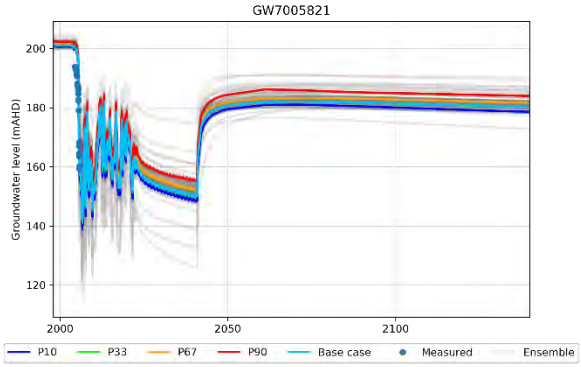

GW0900101
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

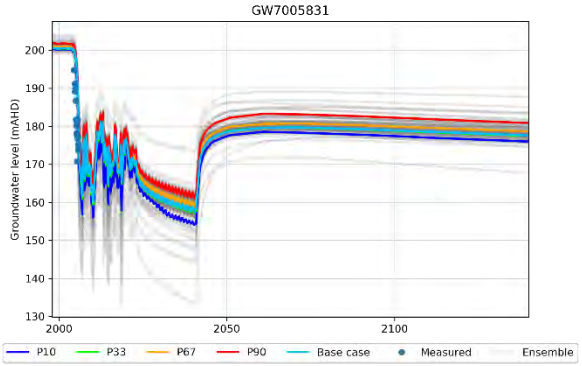

GW0900111
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

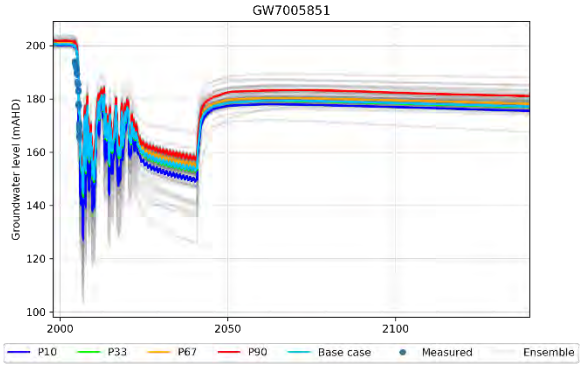

GW0900931
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

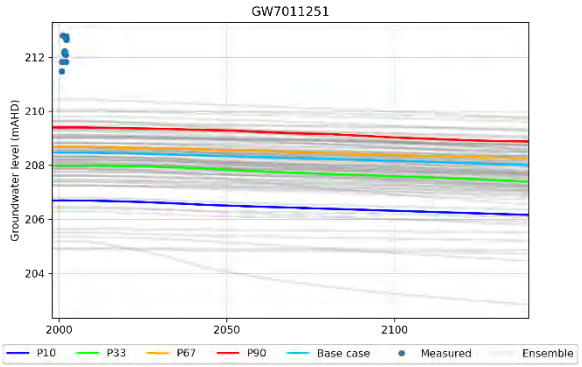

GW0900932
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

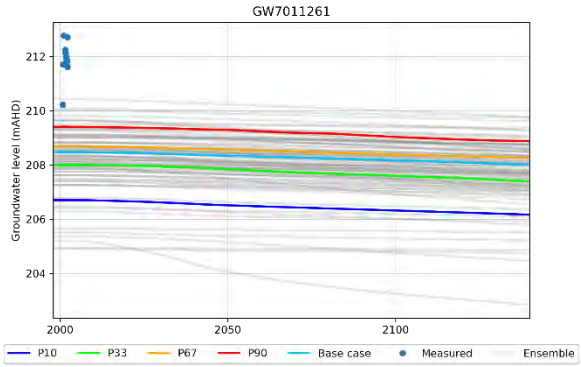

GW0900933
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

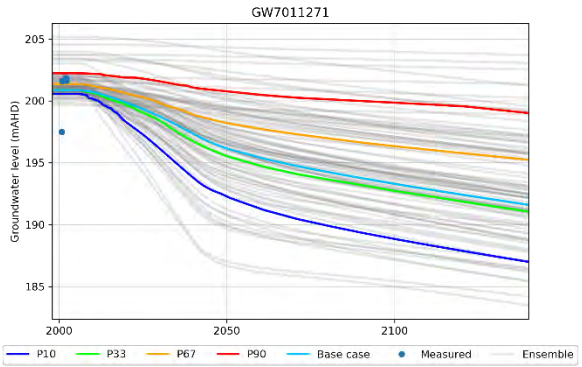

GW7005821
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

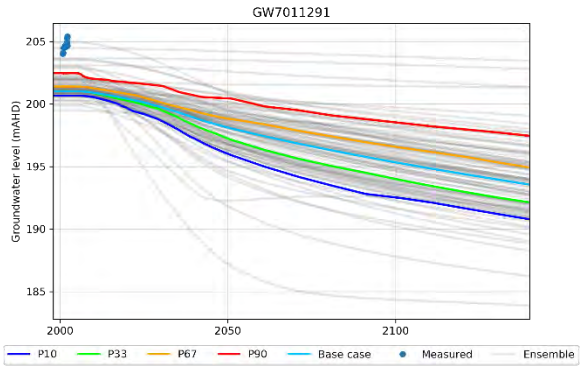

GW7005831
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

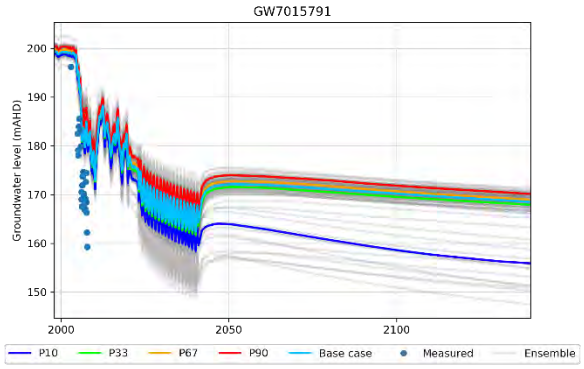

GW7005851
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

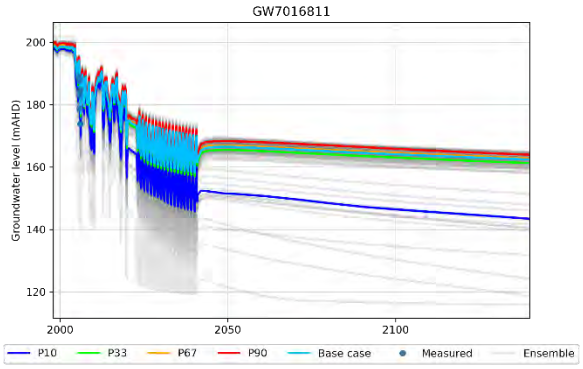

GW7011251
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

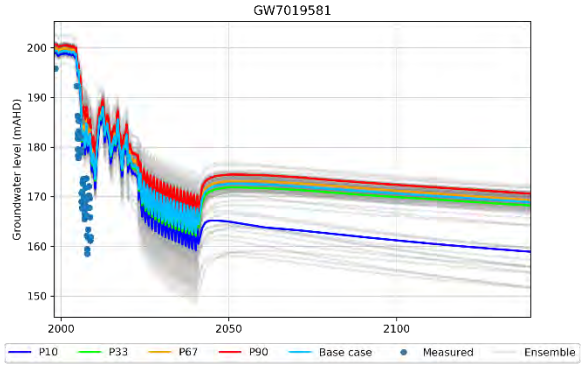

GW7011261
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

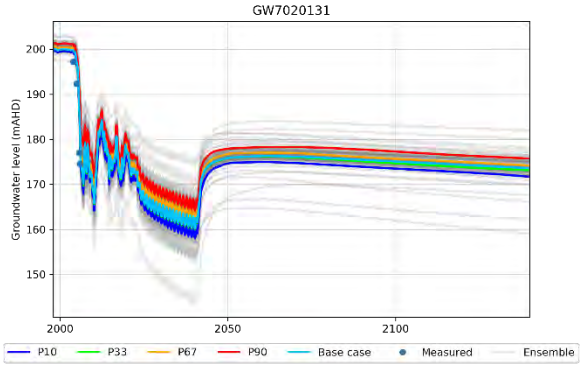

GW7011271
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

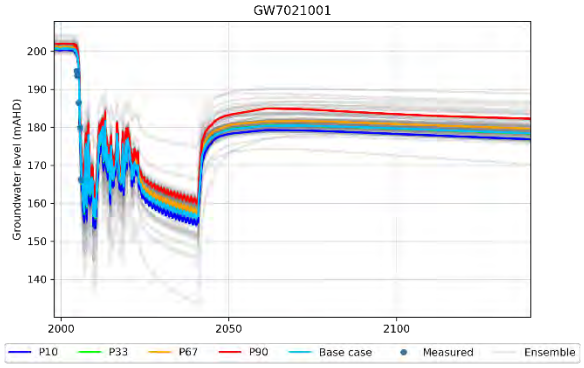

GW7011291
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

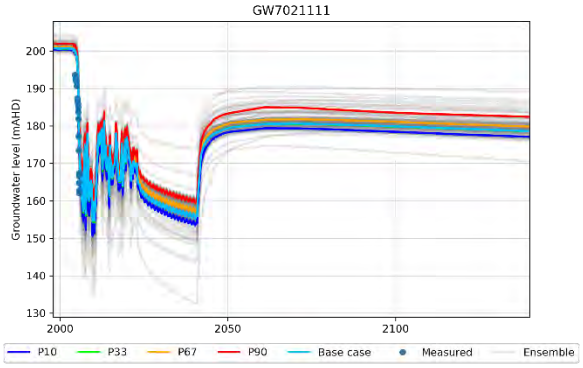

GW7015791
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

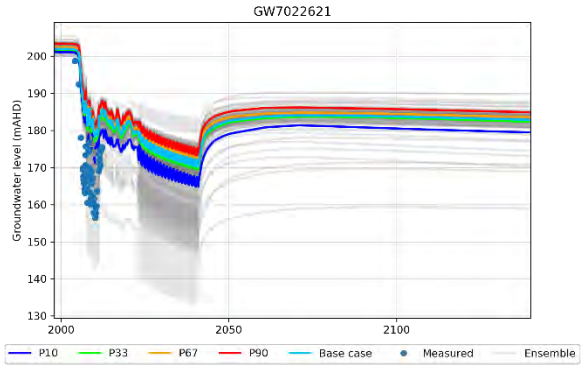

GW7016811
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

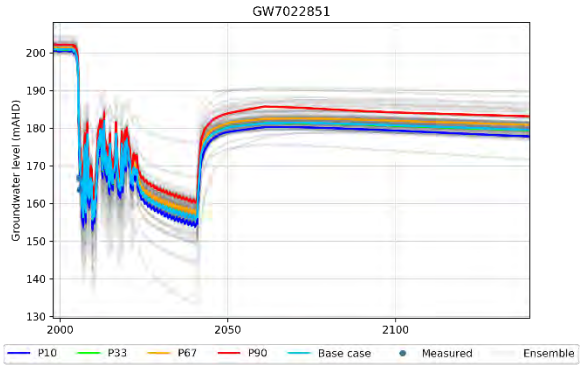

GW7019581
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

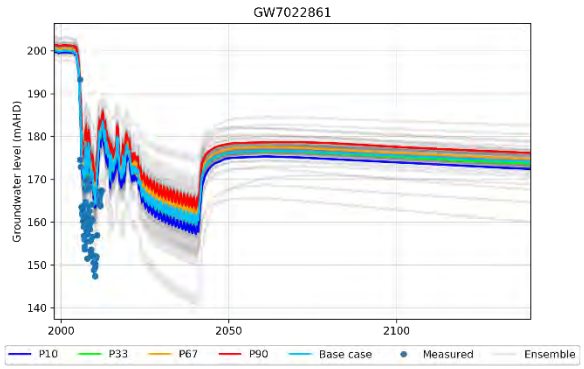

GW7020131
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

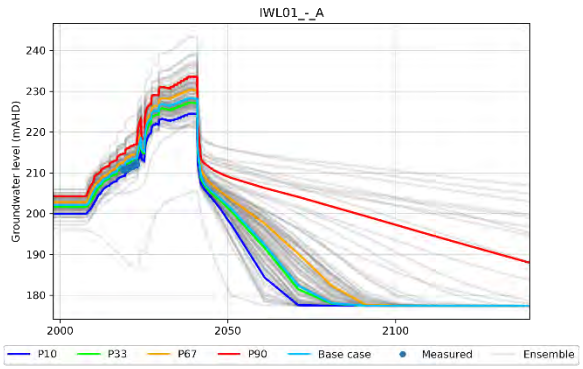

GW7021001
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

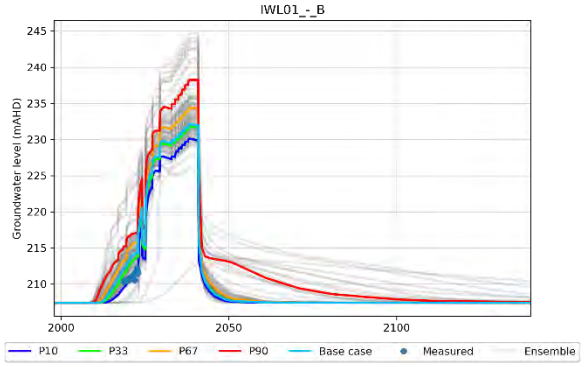

GW7021111
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

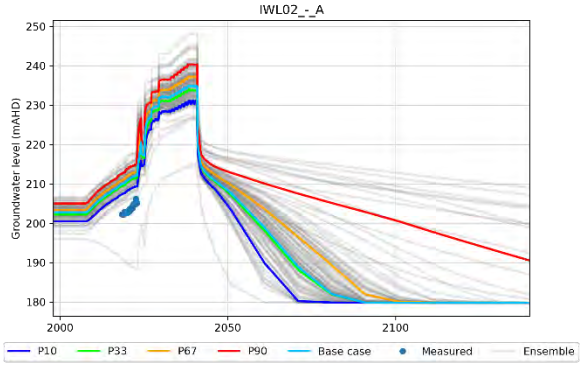

GW7022621
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

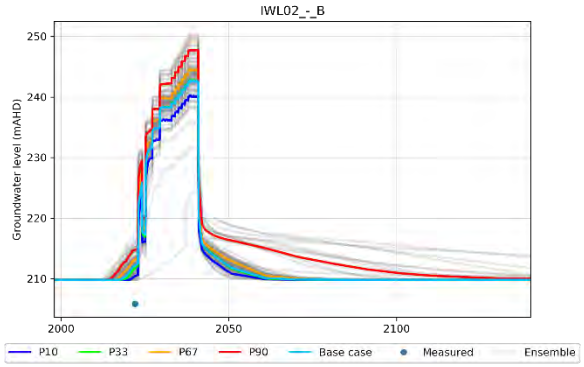

GW7022851
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

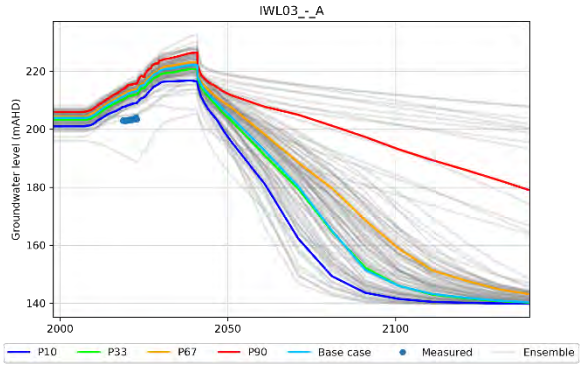

GW7022861
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

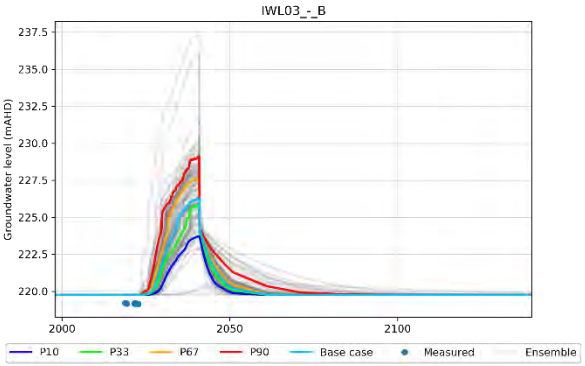

IWL01_-_A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

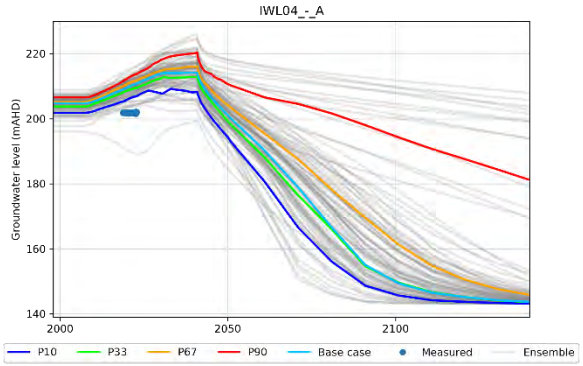

IWL01_-_B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

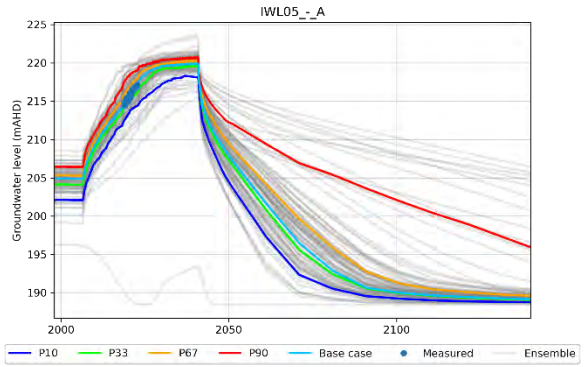

IWL02_-_A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

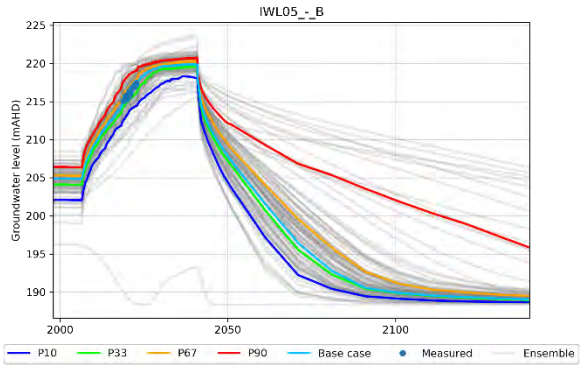

IWL02_-_B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

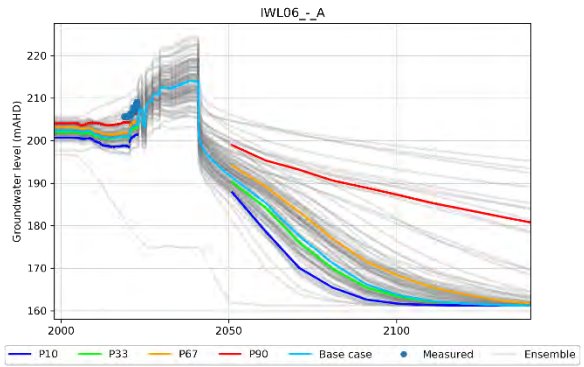

IWL03_-_A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

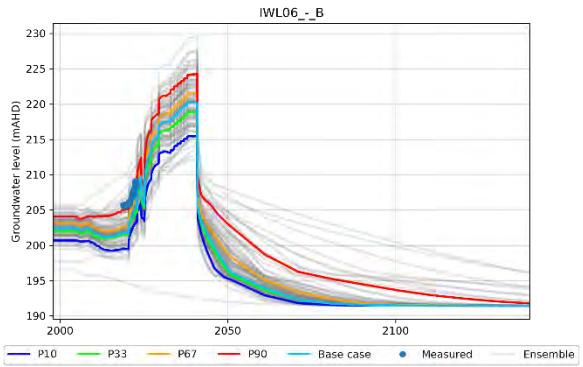

IWL03_-_B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

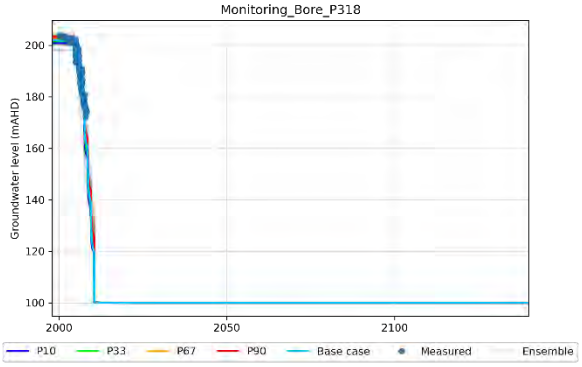

IWL04_-_A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

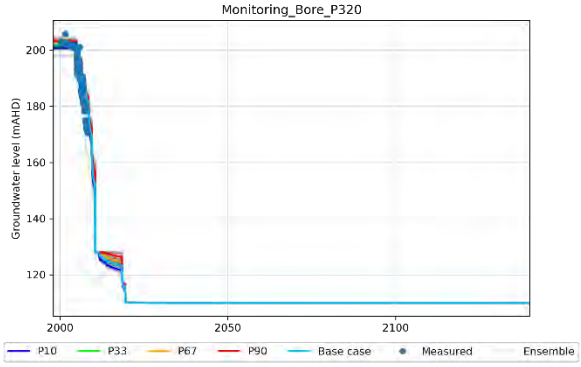

IWL05_-_A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

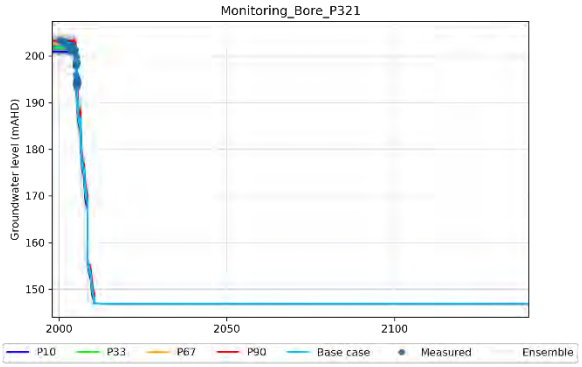

IWL05_-_B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

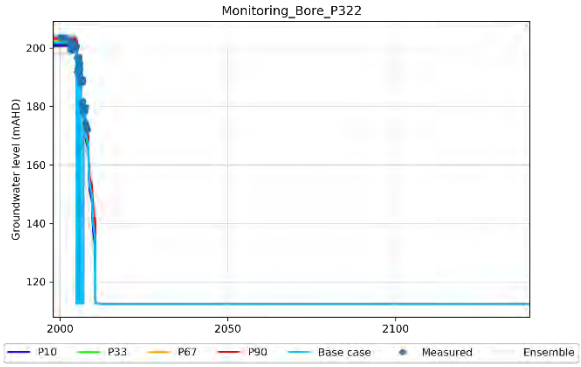

IWL06_-_A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

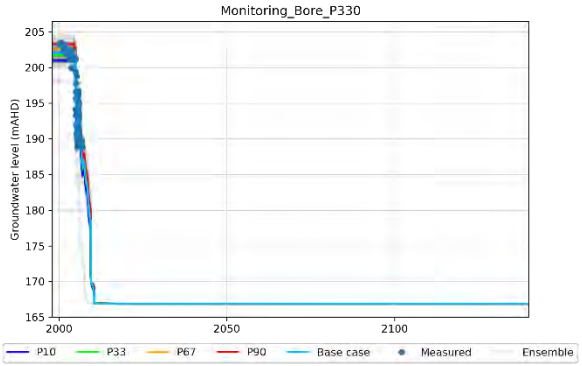

IWL06_-_B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

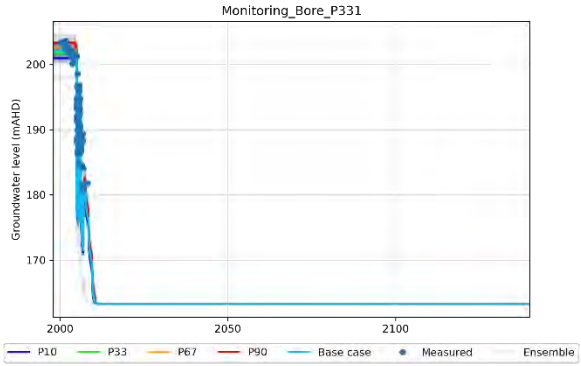

Monitoring_Bore_P318
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

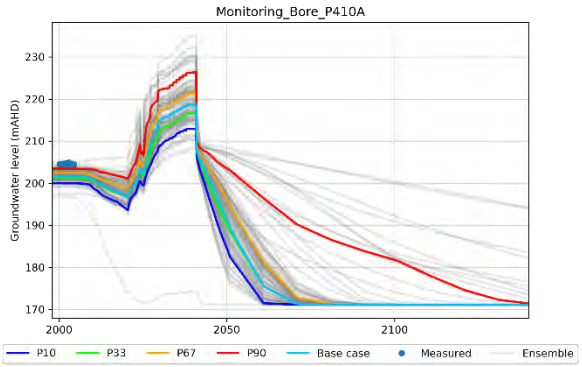

Monitoring_Bore_P320
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

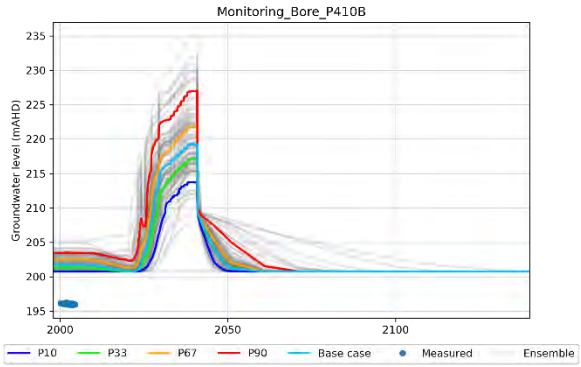

Monitoring_Bore_P321
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

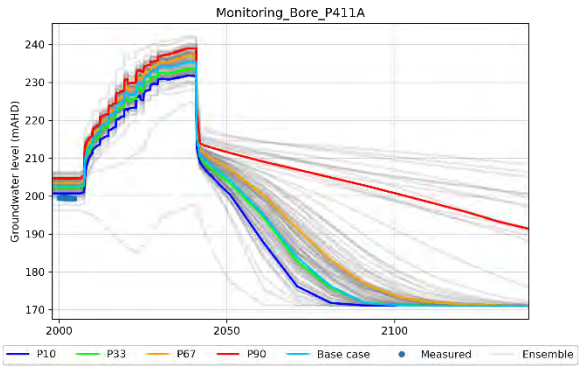

Monitoring_Bore_P322
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

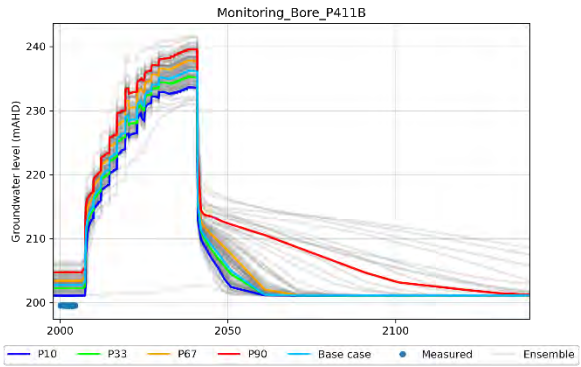

Monitoring_Bore_P330
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

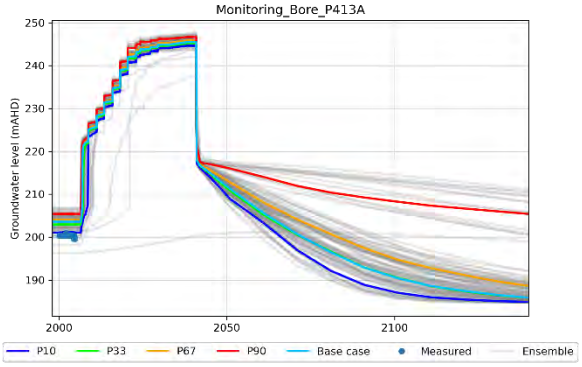

Monitoring_Bore_P331
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

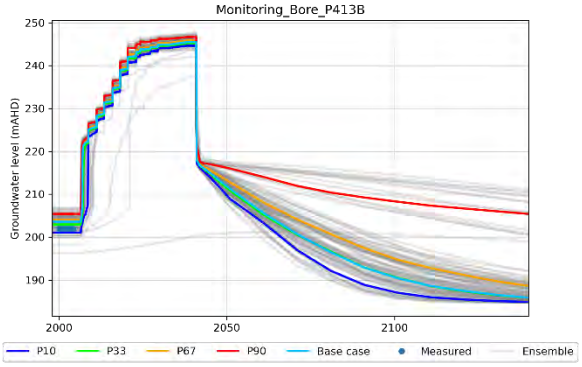

Monitoring_Bore_P410A
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

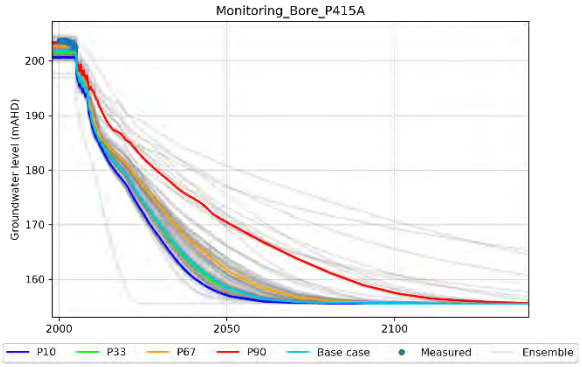

Monitoring_Bore_P410B
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

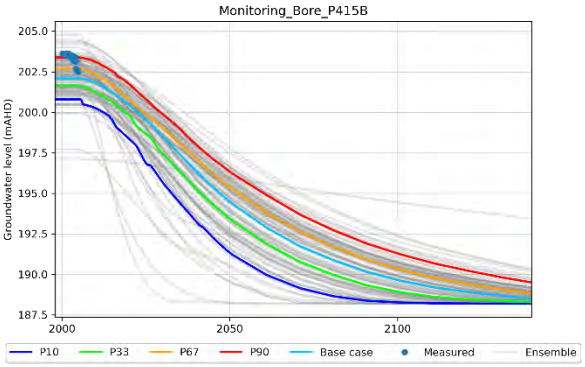

Monitoring_Bore_P411A
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

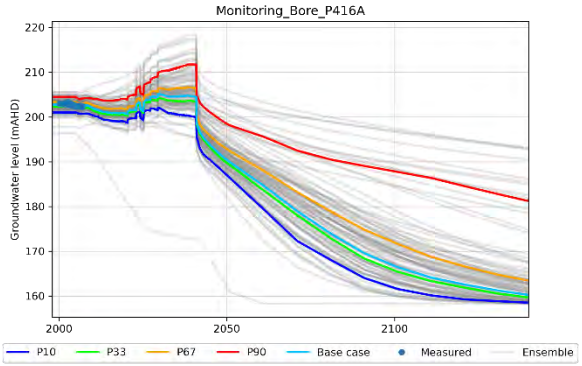

Monitoring_Bore_P411B
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

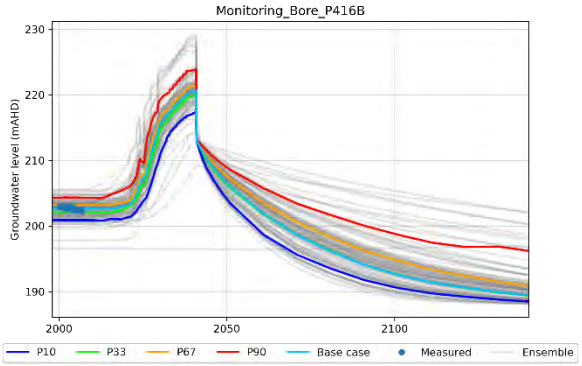

Monitoring_Bore_P413A
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

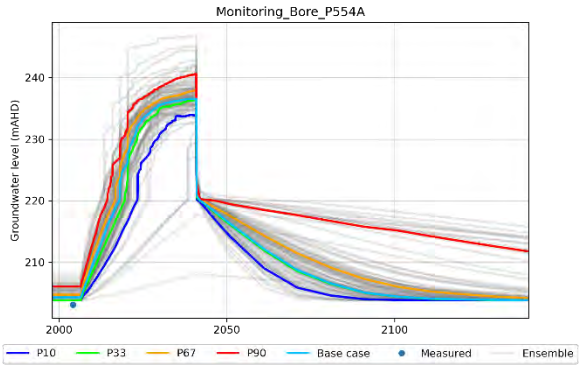

Monitoring_Bore_P413B
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

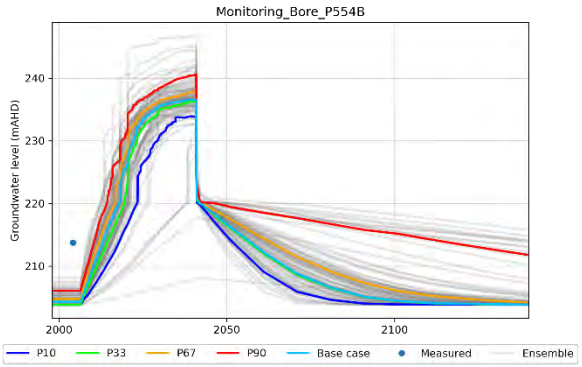

Monitoring_Bore_P415A
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

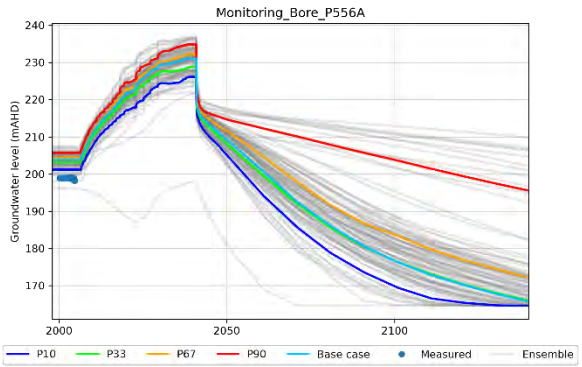

Monitoring_Bore_P415B
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

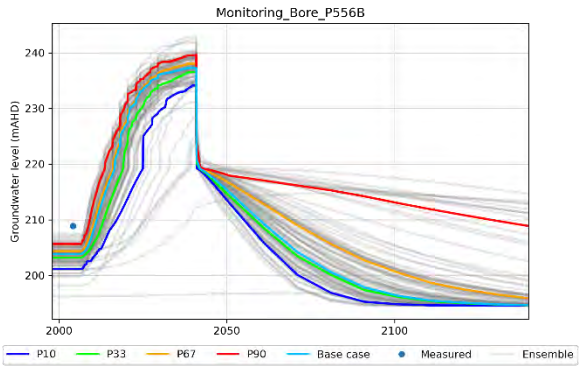

Monitoring_Bore_P416A
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

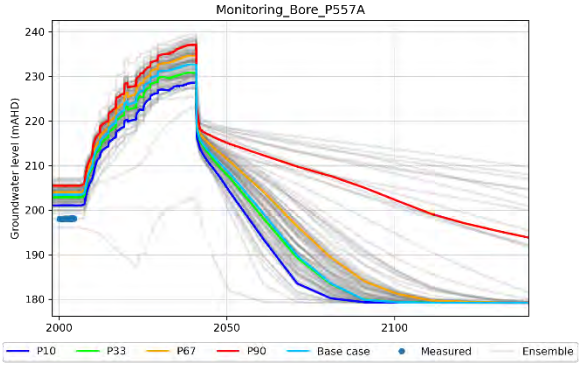

Monitoring_Bore_P416B
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

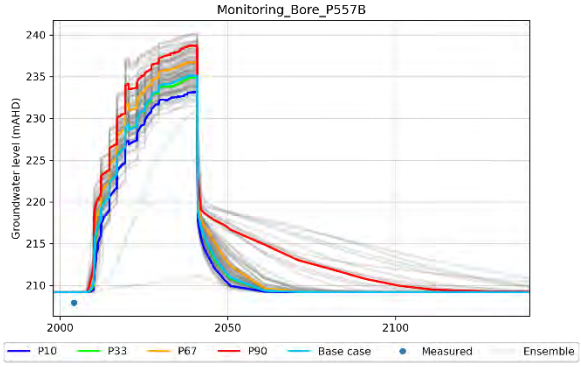

Monitoring_Bore_P554A
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

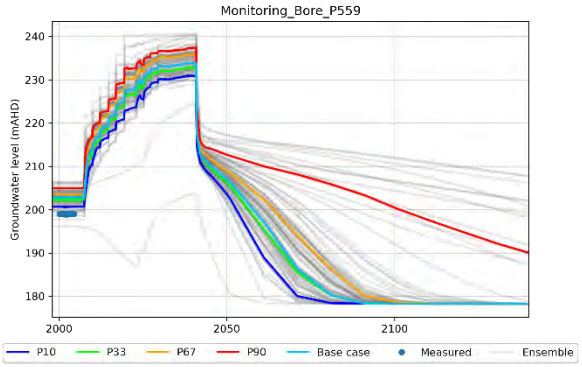

Monitoring_Bore_P554B
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

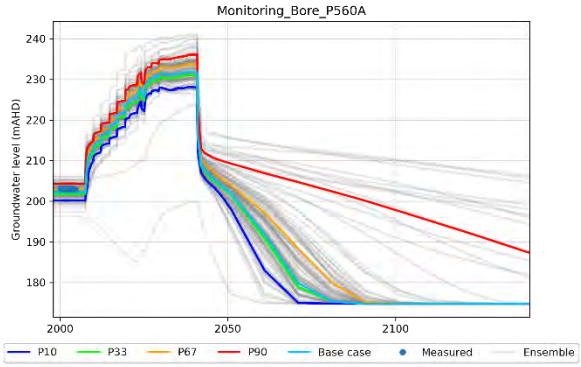

Monitoring_Bore_P556A
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

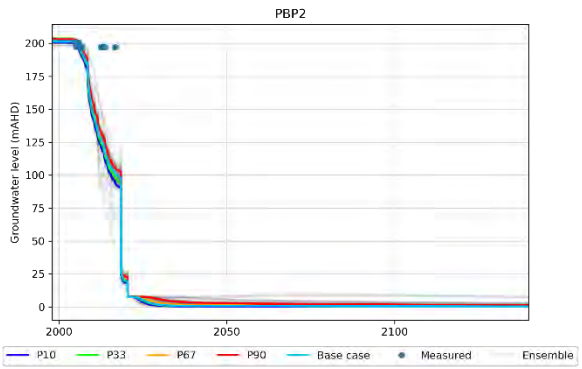

Monitoring_Bore_P556B
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

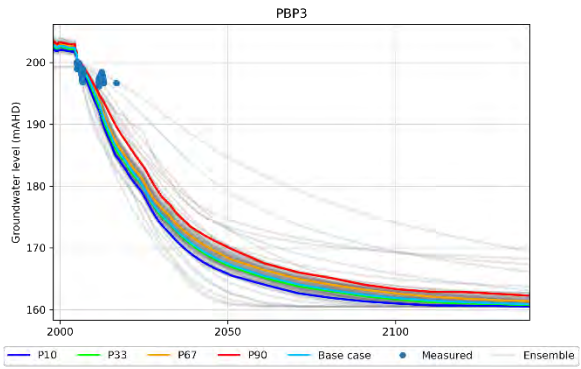

Monitoring_Bore_P557A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

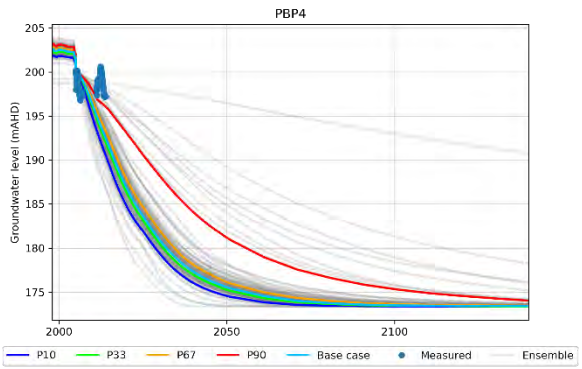

Monitoring_Bore_P557B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

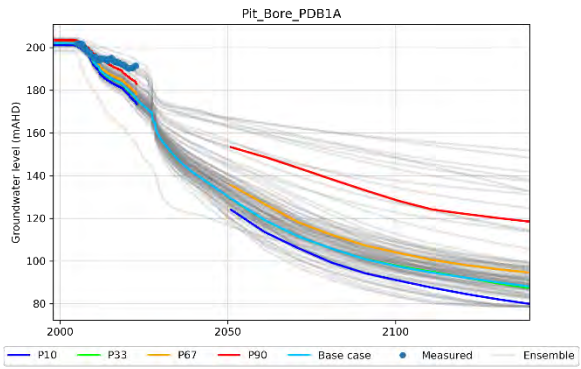

Monitoring_Bore_P559
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

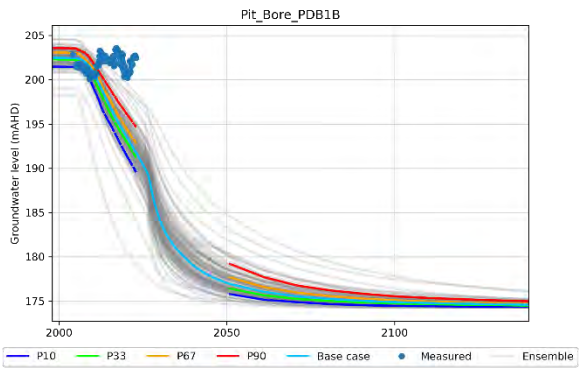

Monitoring_Bore_P560A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

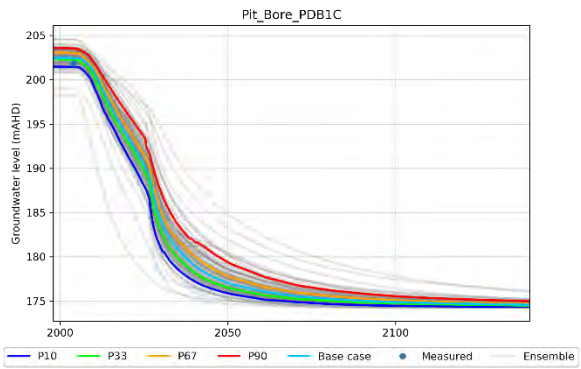

PBP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

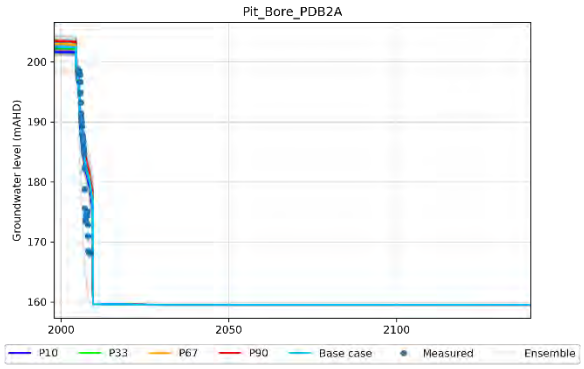

PBP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

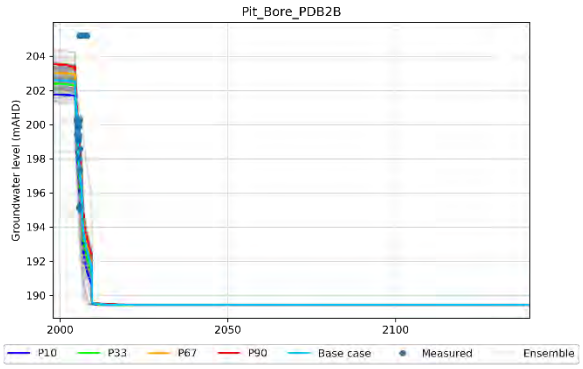

PBP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

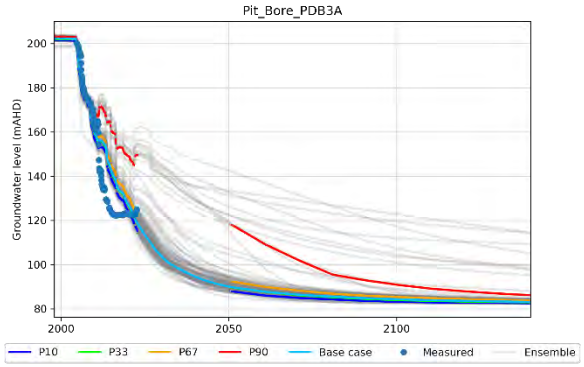

Pit_Bore_PDB1A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

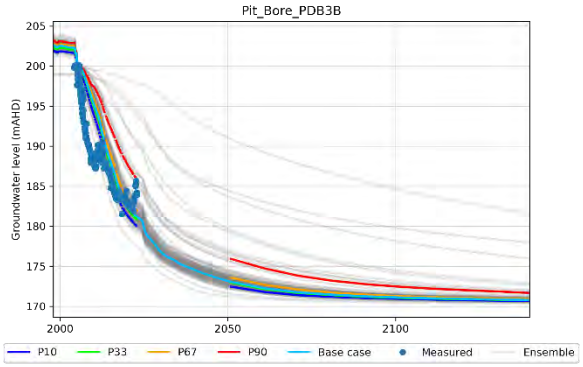

Pit_Bore_PDB1B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

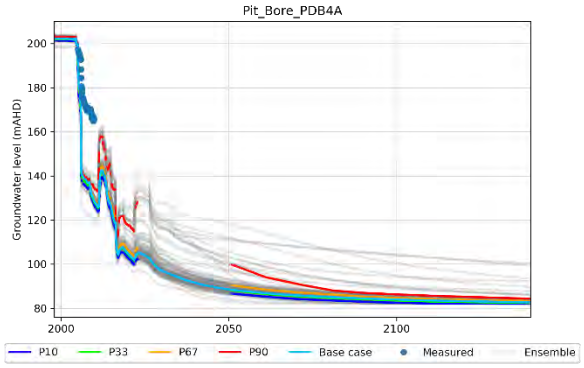

Pit_Bore_PDB1C
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

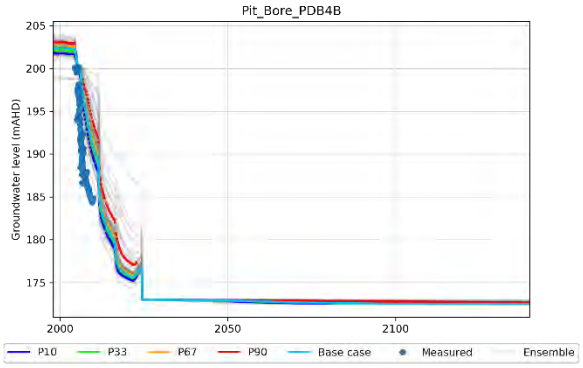

Pit_Bore_PDB2A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

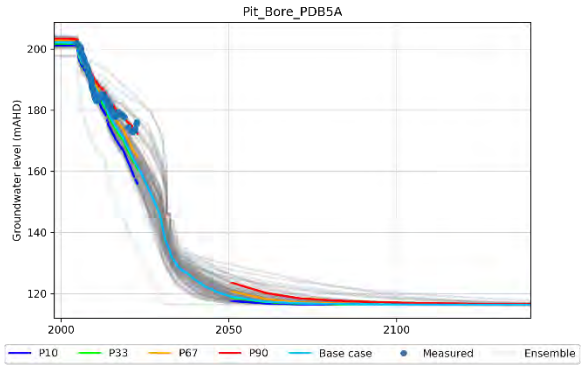

Pit_Bore_PDB2B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

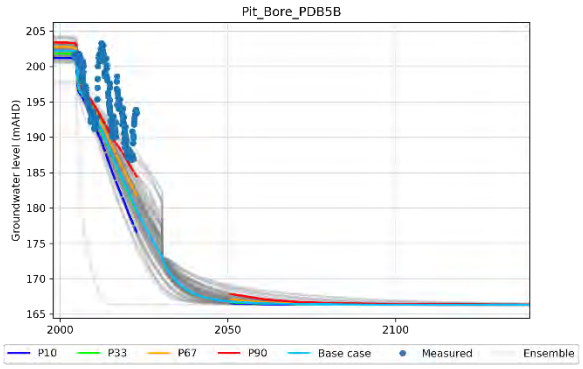

Pit_Bore_PDB3A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

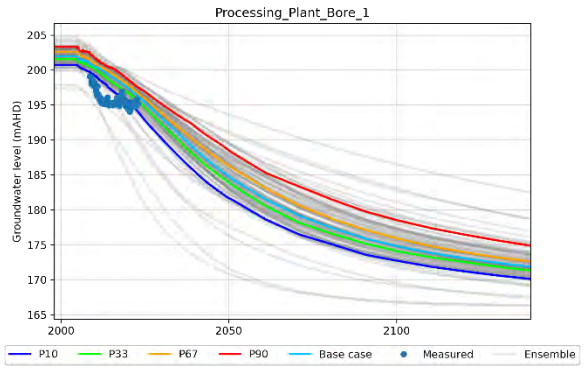

Pit_Bore_PDB3B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

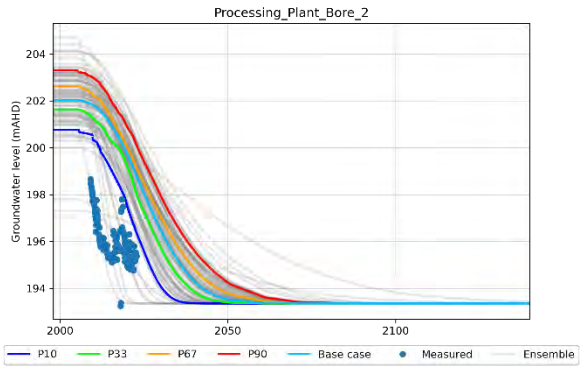

Pit_Bore_PDB4A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

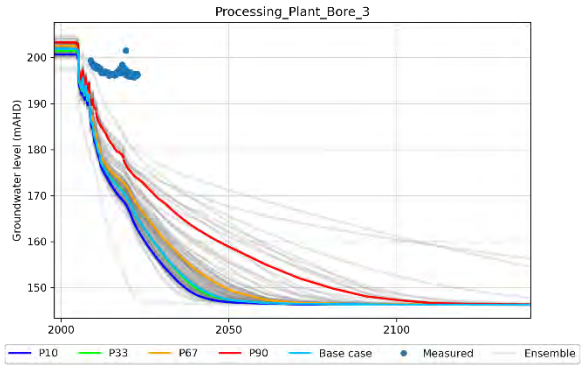

Pit_Bore_PDB4B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

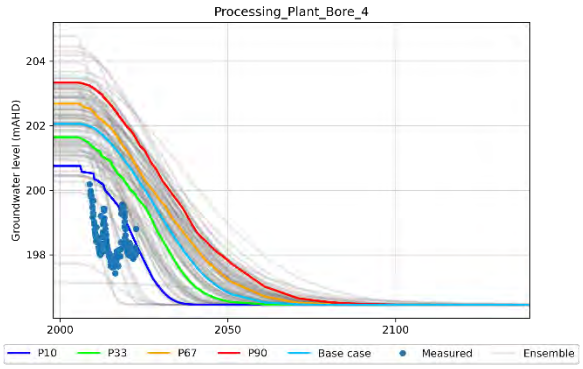

Pit_Bore_PDB5A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

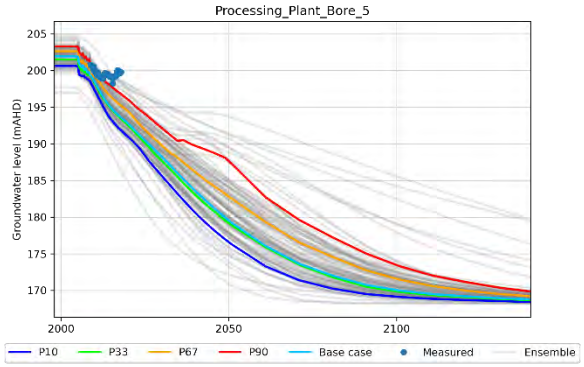

Pit_Bore_PDB5B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

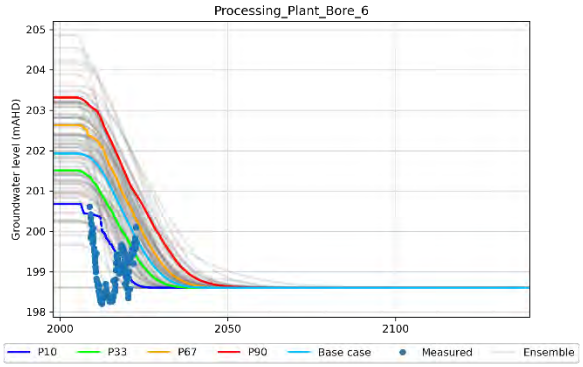

Processing_Plant_Bore_1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

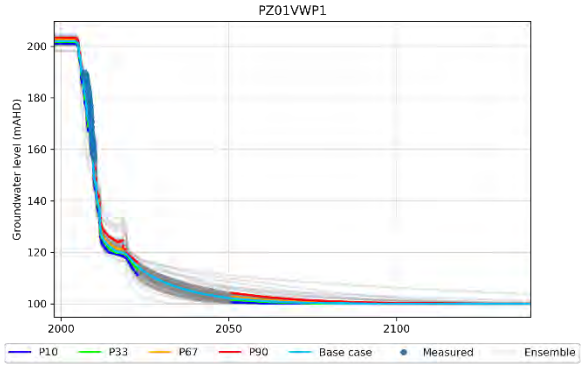

Processing_Plant_Bore_2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

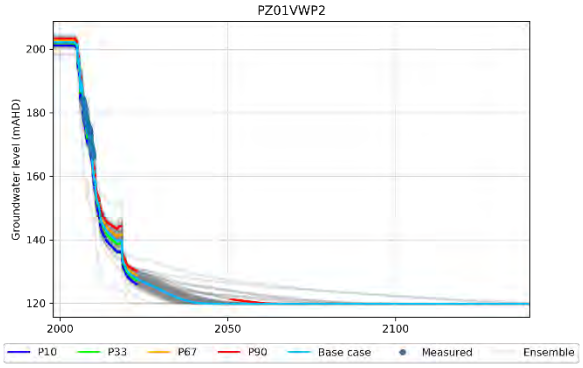

Processing_Plant_Bore_3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

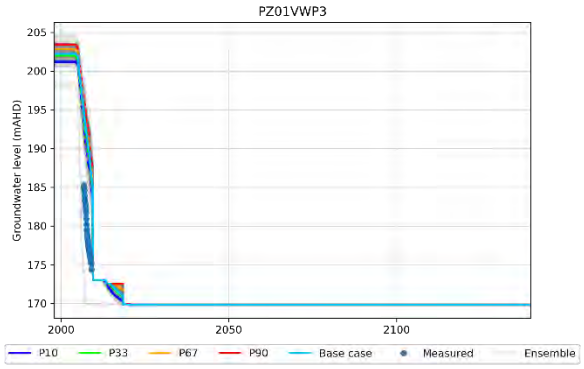

Processing_Plant_Bore_4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

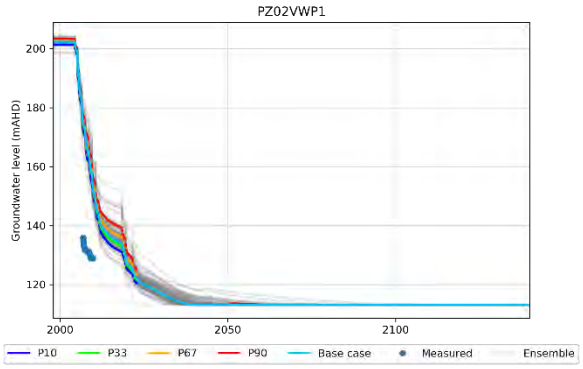

Processing_Plant_Bore_5
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

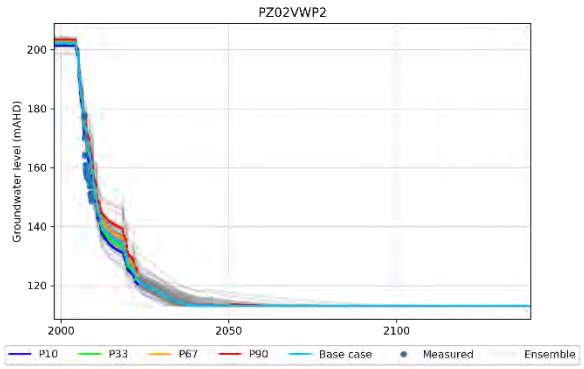

Processing_Plant_Bore_6
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

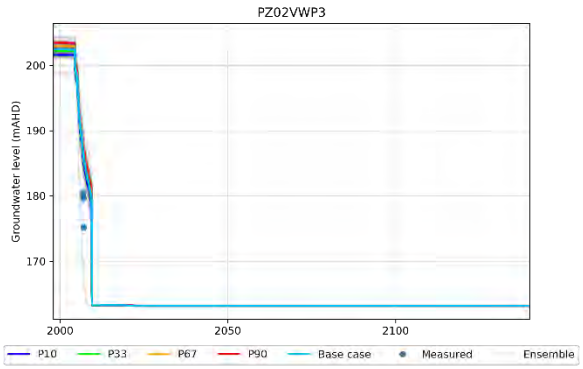

PZ01VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

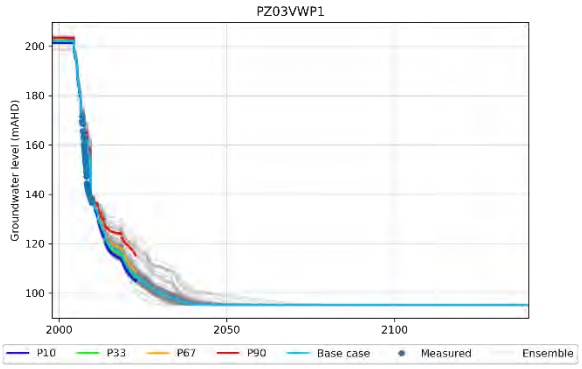

PZ01VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

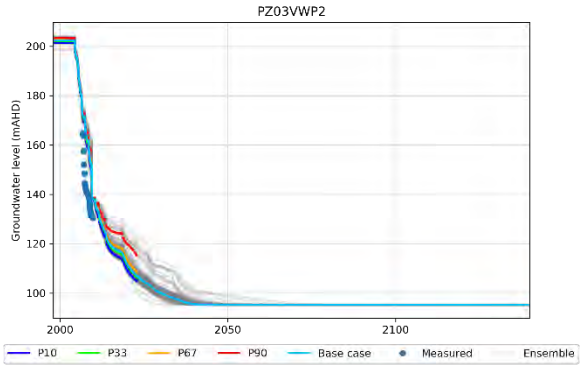

PZ01VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

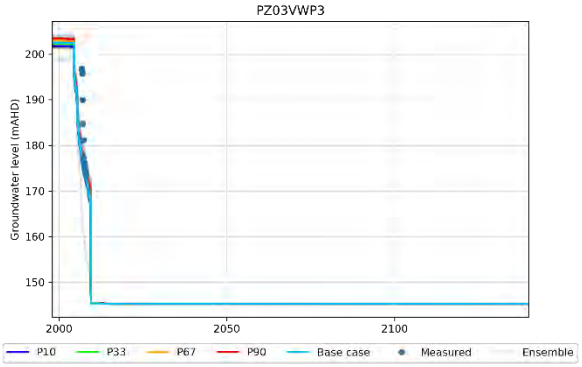

PZ02VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

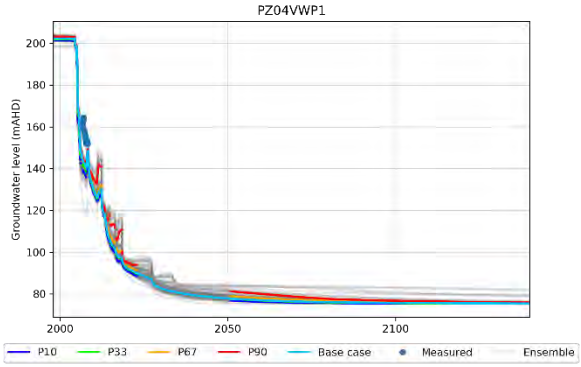

PZ02VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

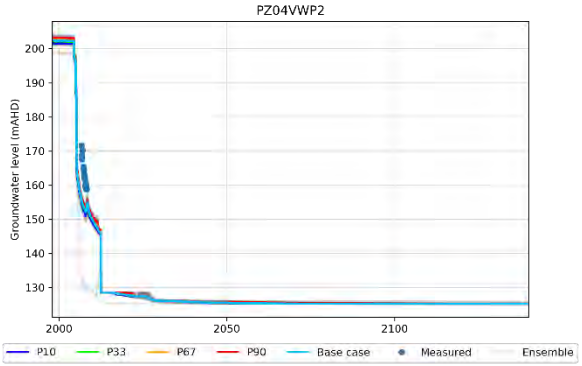

PZ02VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

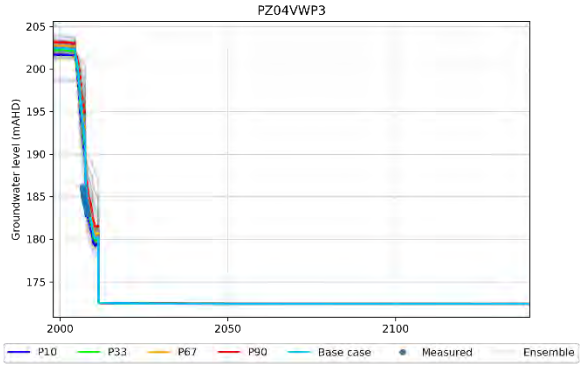

PZ03VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

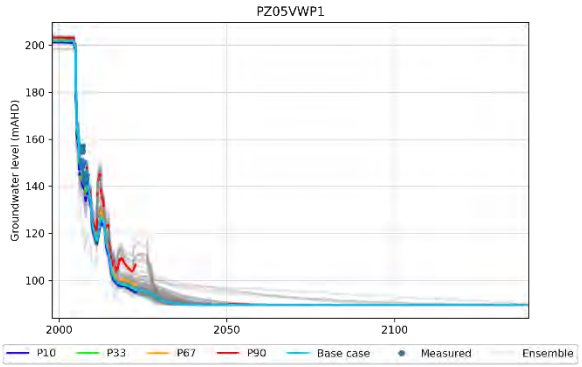

PZ03VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

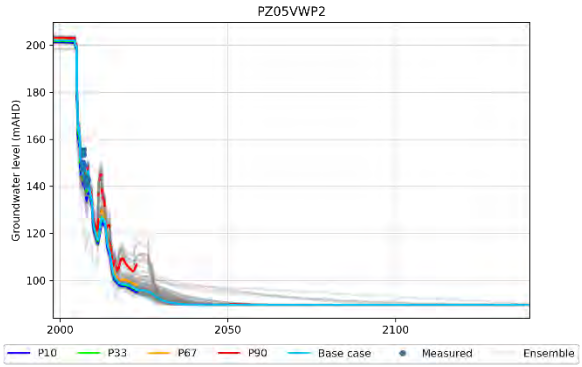

PZ03VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

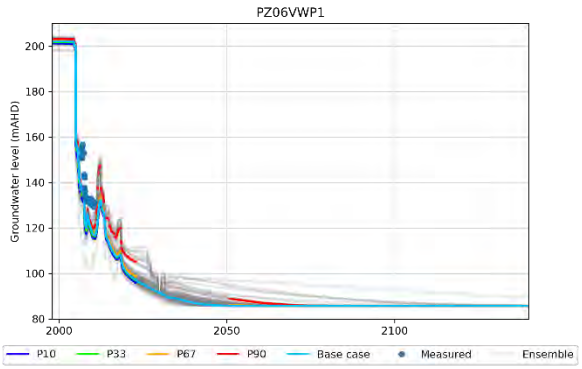

PZ04VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

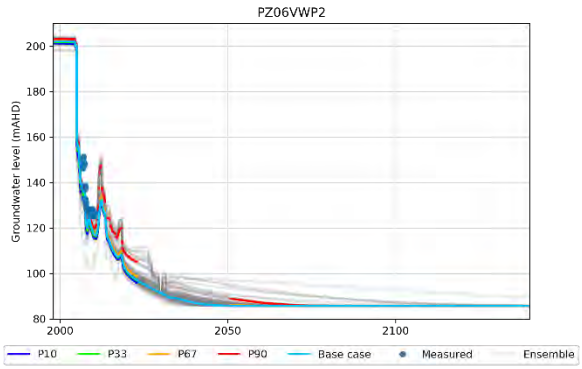

PZ04VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

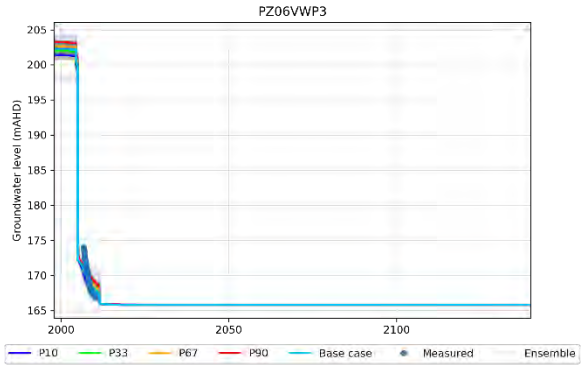

PZ04VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

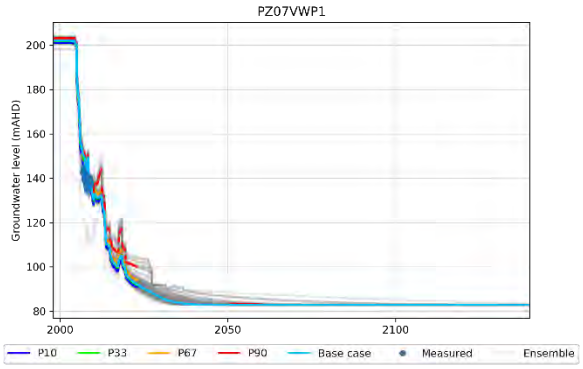

PZ05VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

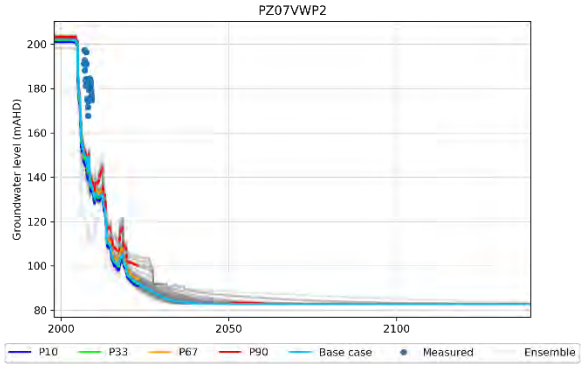

PZ05VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

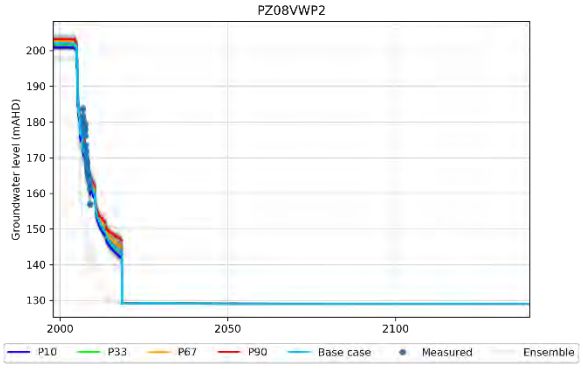

PZ06VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

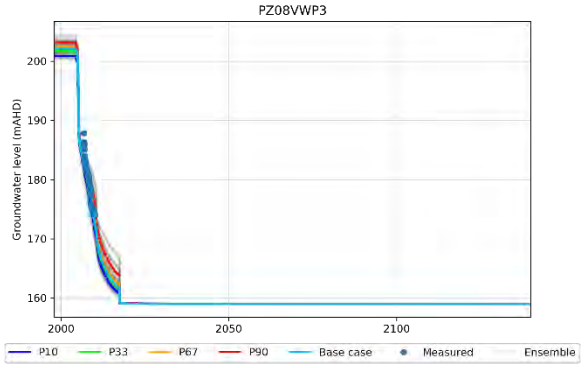

PZ06VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

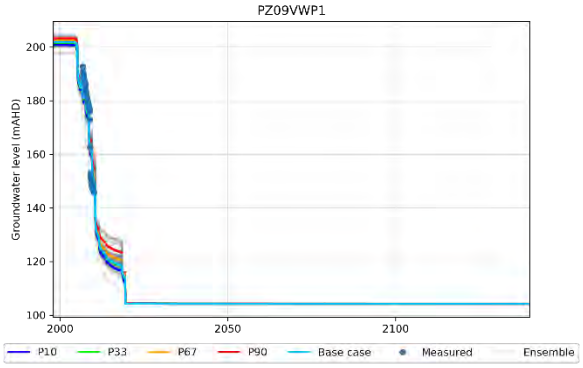

PZ06VWP3
Groundwater level (mAHD)
205
200
195
190
185
180
175
170
165
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

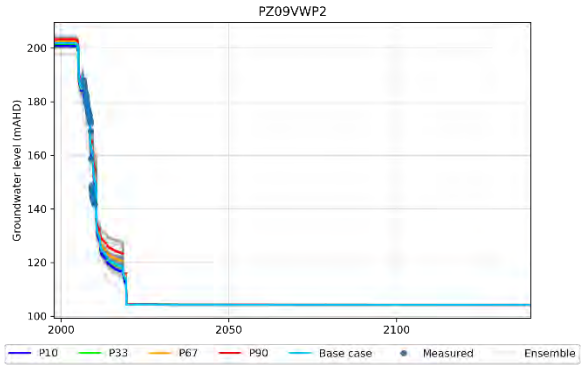

PZ07VWP1
Groundwater level (mAHD)
200
180
160
140
120
100
80
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

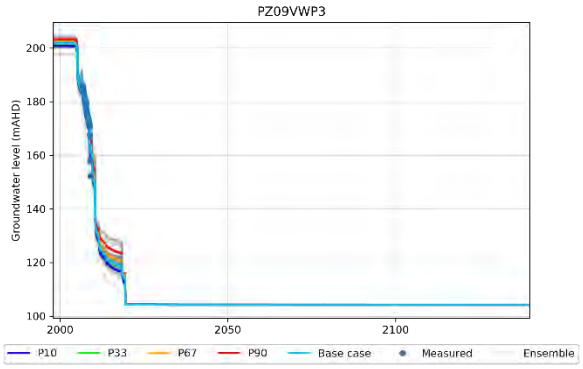

PZ07VWP2
Groundwater level (mAHD)
200
180
160
140
120
100
80
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

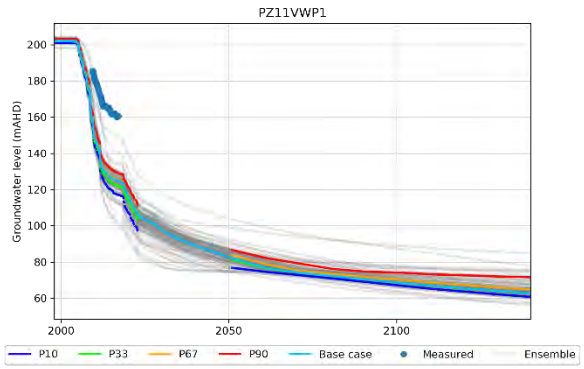

PZ08VWP2
Groundwater level (mAHD)
200
190
180
170
160
150
140
130
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

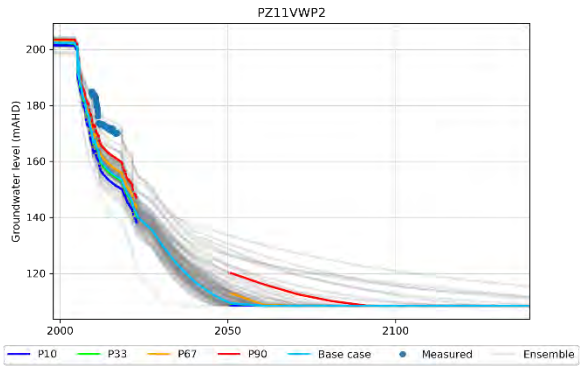

PZ08VWP3
Groundwater level (mAHD)
200
190
180
170
160
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

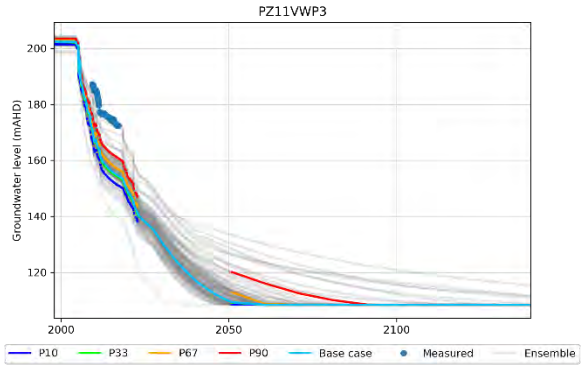

PZ09VWP1
Groundwater level (mAHD)
200
180
160
140
120
100
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

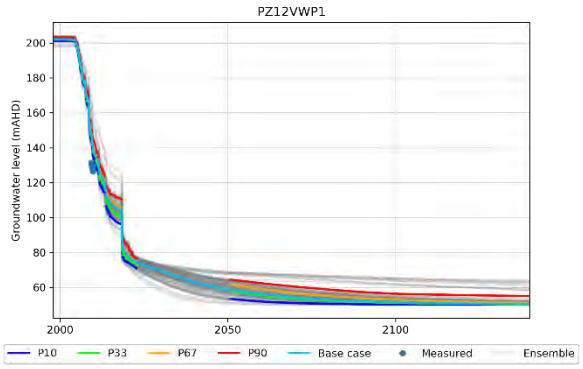

PZ09VWP2
Groundwater level (mAHD)
200
180
160
140
120
100
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

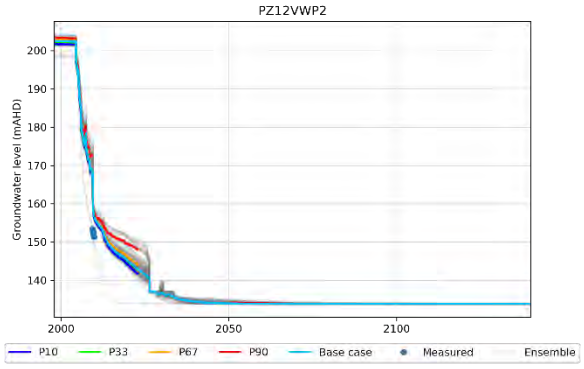

PZ09VWP3
Groundwater level (mAHD)
200
180
160
140
120
100
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

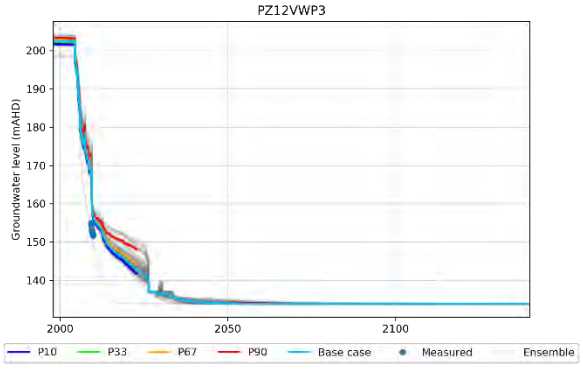

PZ11VWP1
Groundwater level (mAHD)
200
180
160
140
120
100
80
60
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

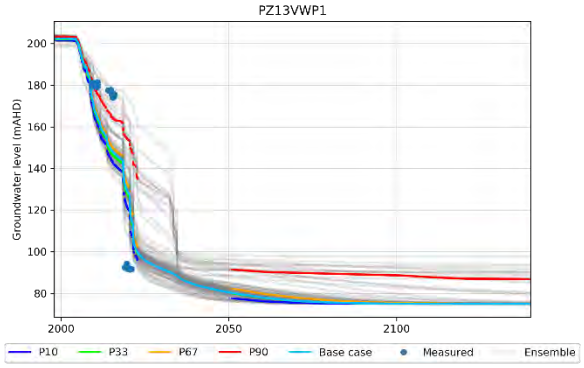

PZ11VWP2
Groundwater level (mAHD)
200
180
160
140
120
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

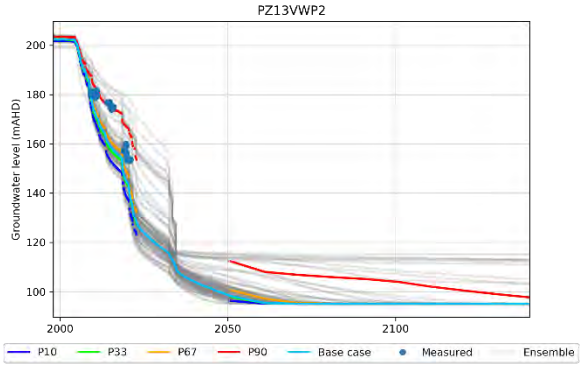

PZ11VWP3
Groundwater level (mAHD)
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

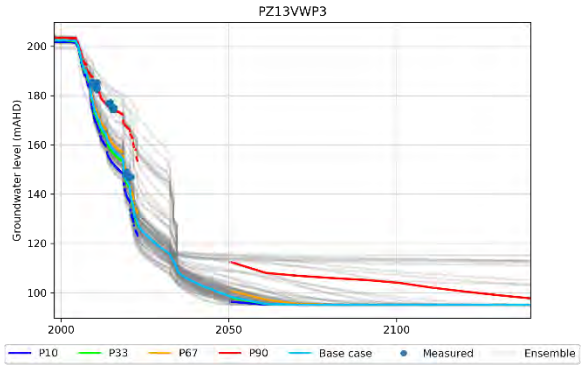

PZ12VWP1
Groundwater level (mAHD)
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

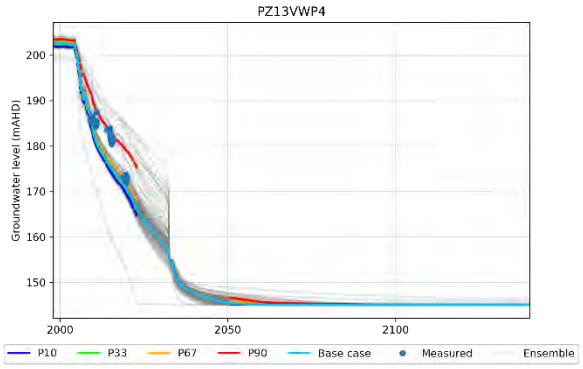

PZ12VWP2
Groundwater level (mAHD)
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

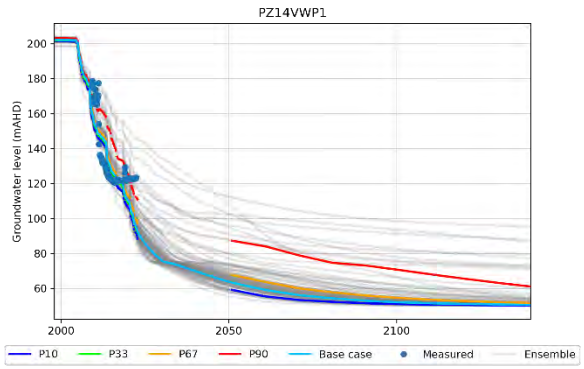

PZ12VWP3
Groundwater level (mAHD)
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

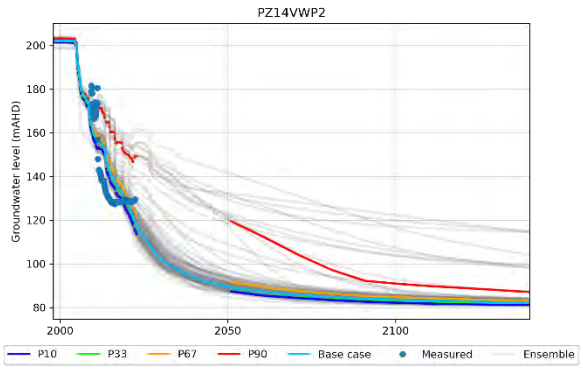

PZ13VWP1
Groundwater level (mAHD)
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

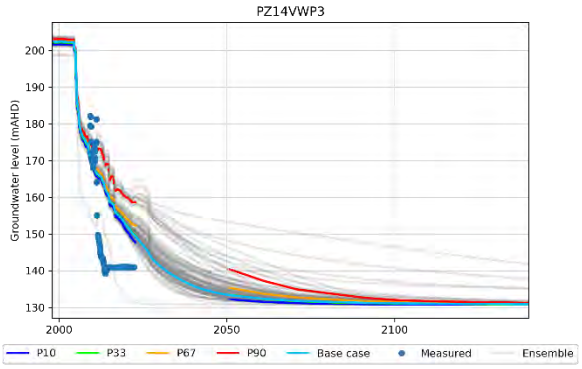

PZ13VWP2
Groundwater level (mAHD)
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

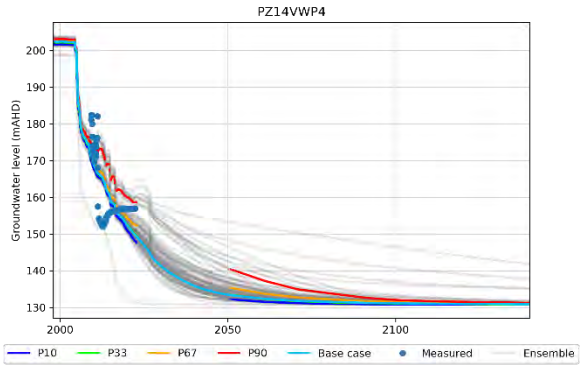

PZ13VWP3
Groundwater level (mAHD)
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

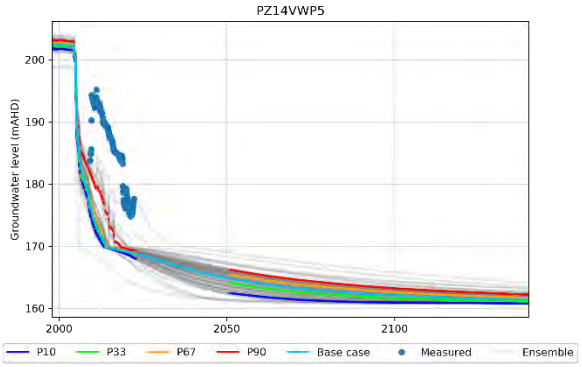

PZ13VWP4
Groundwater level (mAHD)
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

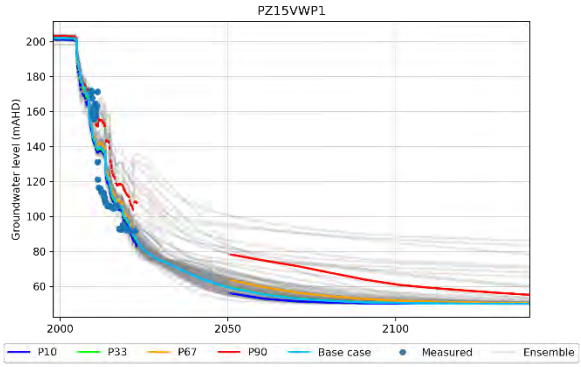

PZ14VWP1
Groundwater level (mAHD)
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

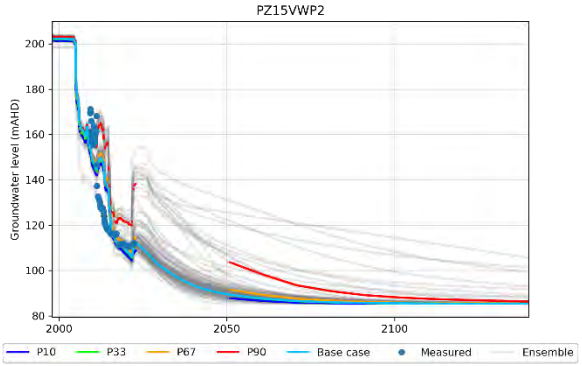

PZ14VWP2
Groundwater level (mAHD)
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

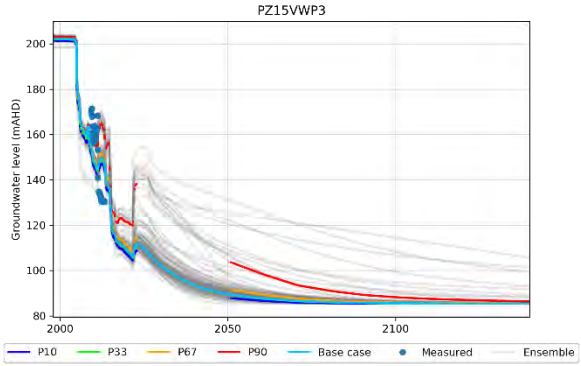

PZ14VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

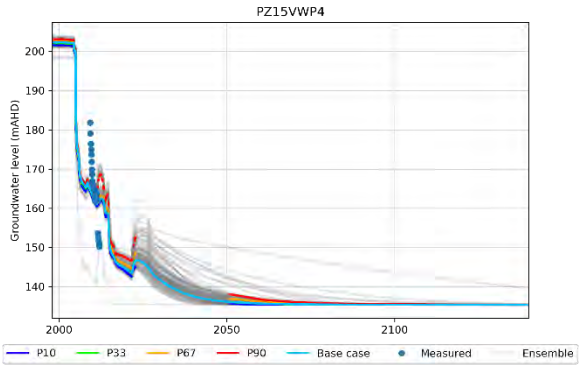

PZ14VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

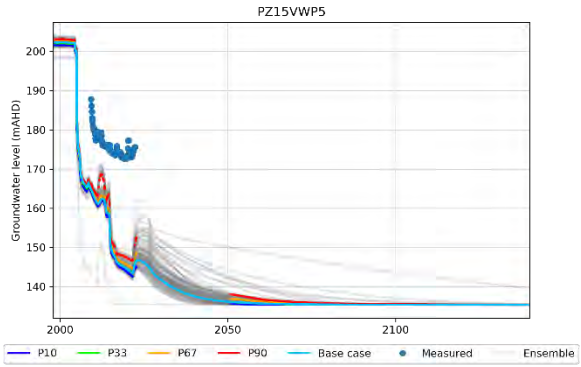

PZ14VWP5
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

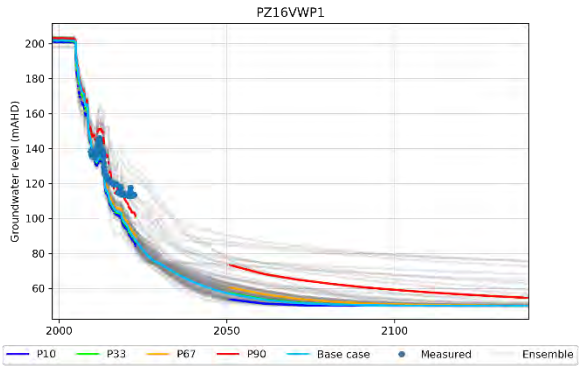

PZ15VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

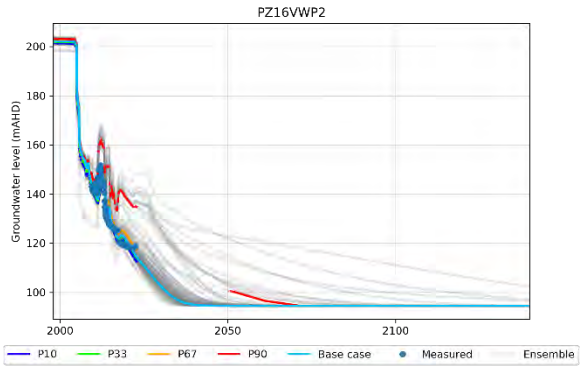

PZ15VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

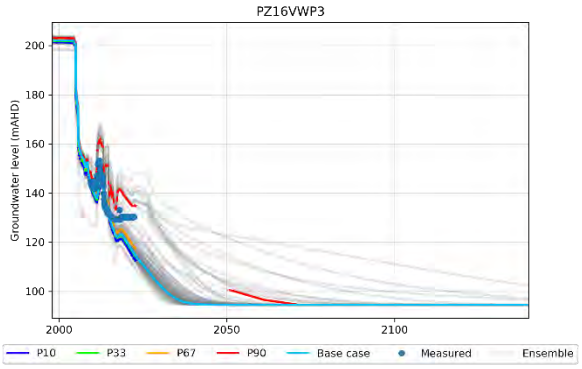

PZ15VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

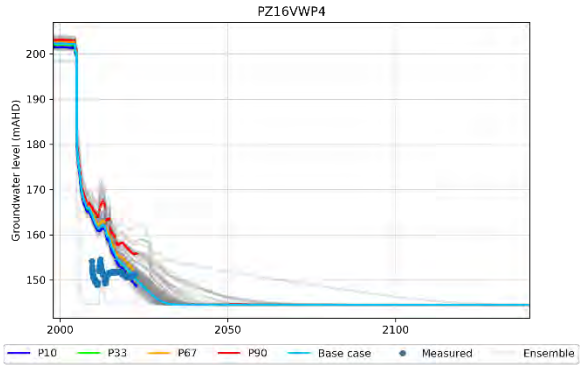

PZ15VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

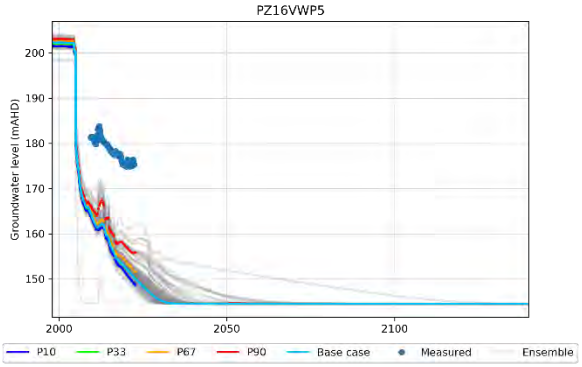

PZ15VWP5
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

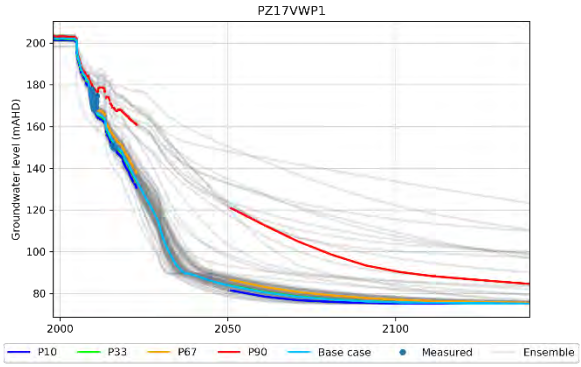

PZ16VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

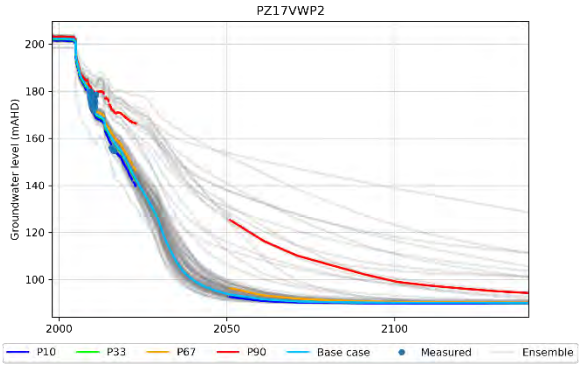

PZ16VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

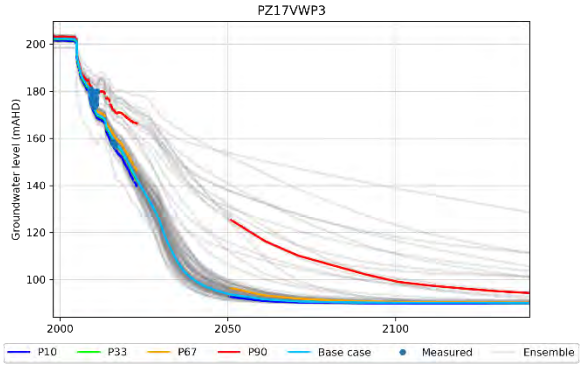

PZ16VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

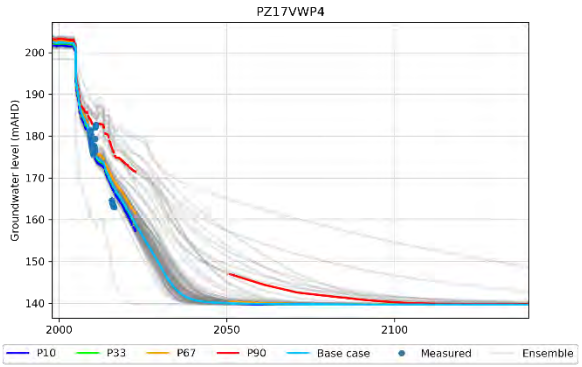

PZ16VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

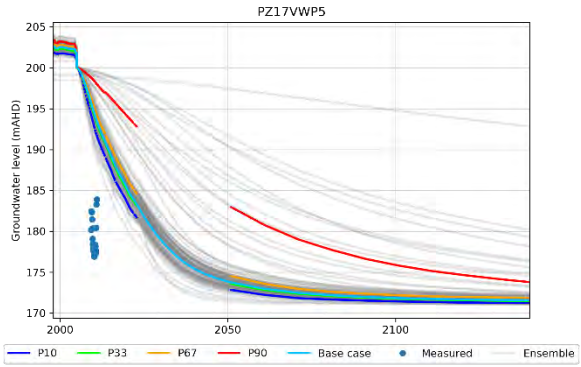

PZ16VWP5
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

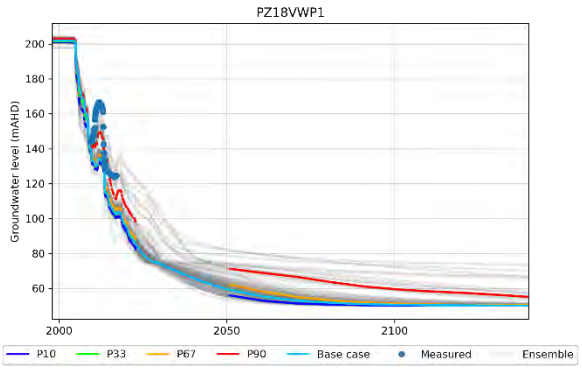

PZ17VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

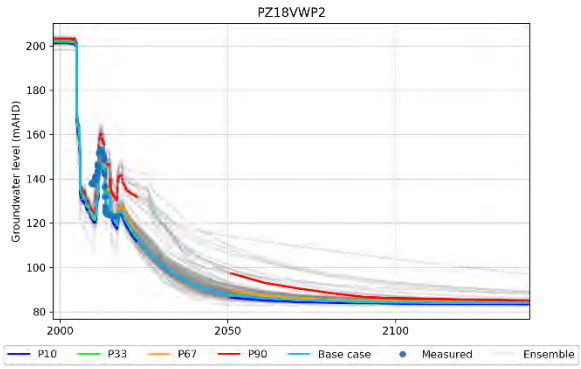

PZ17VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

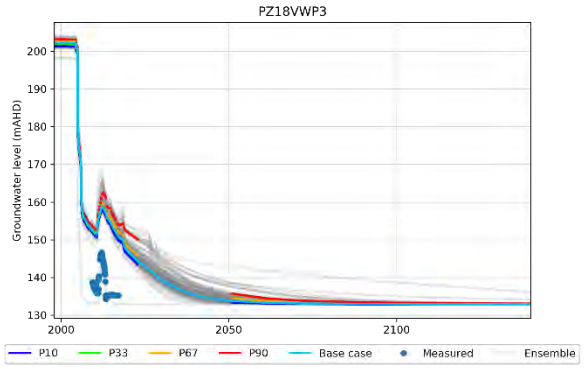

PZ17VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

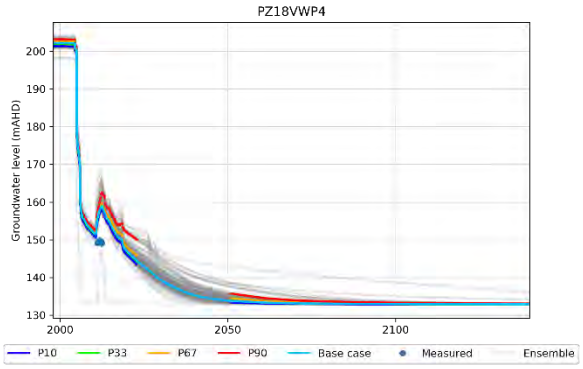

PZ17VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

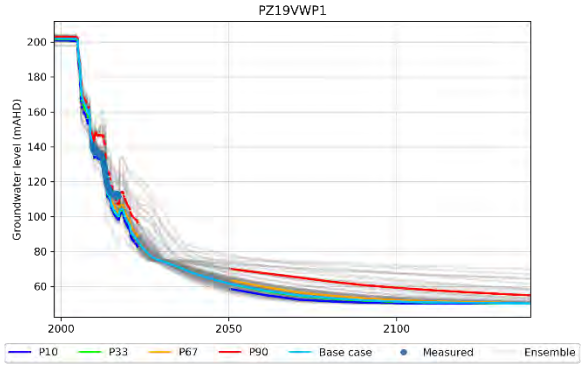

PZ17VWP5
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

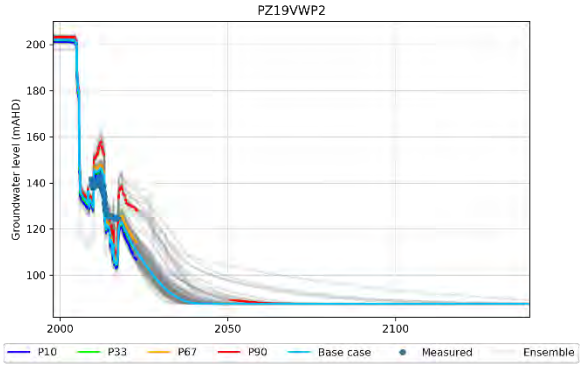

PZ18VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

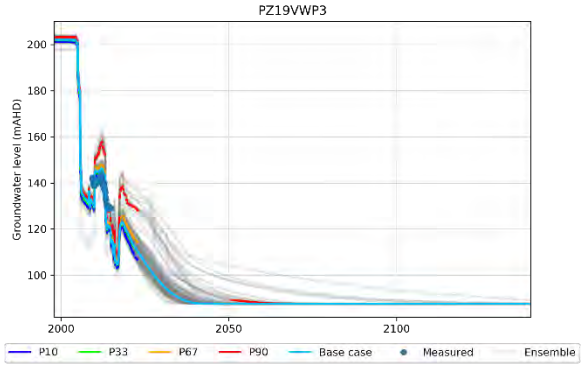

PZ18VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

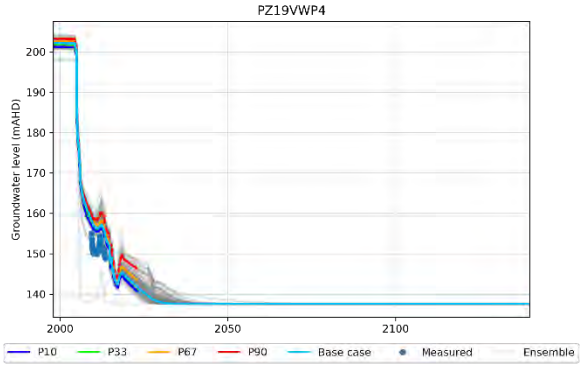

PZ18VWP3
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

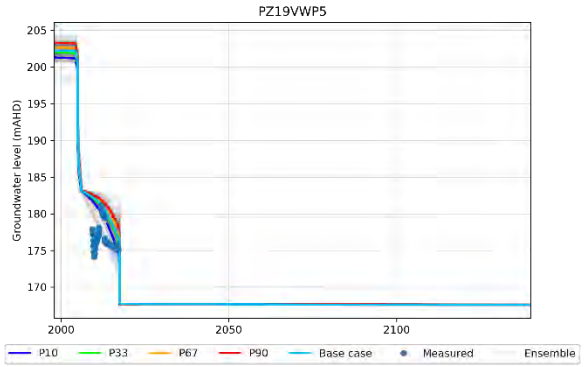

PZ18VWP4
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

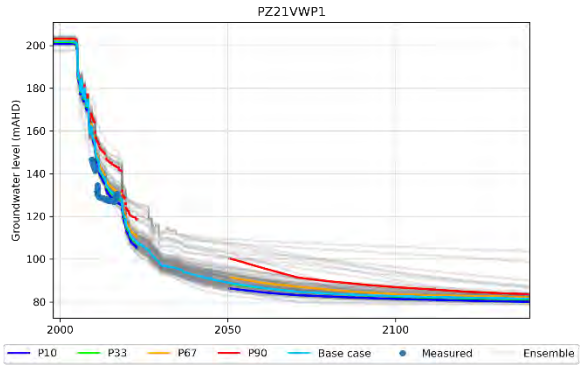

PZ19VWP1
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

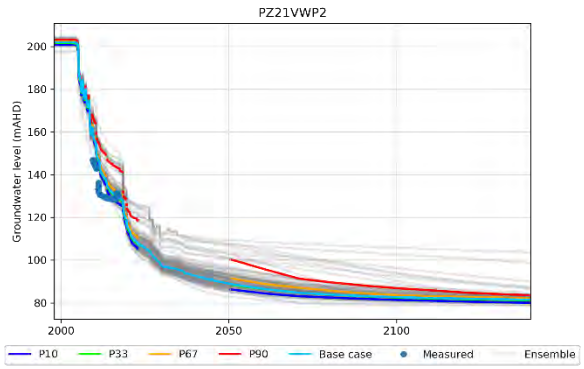

PZ19VWP2
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

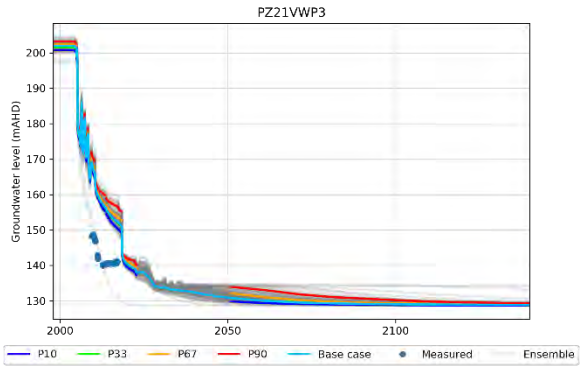

PZ19VWP3
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

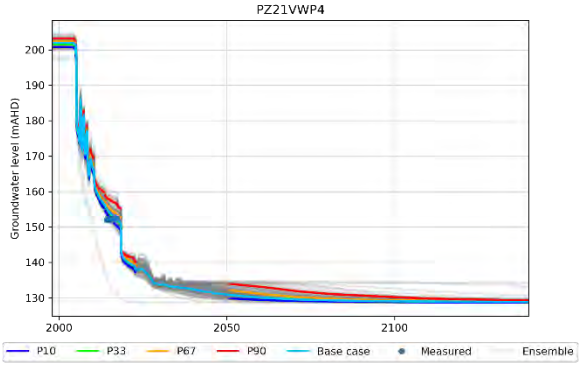

PZ19VWP4
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

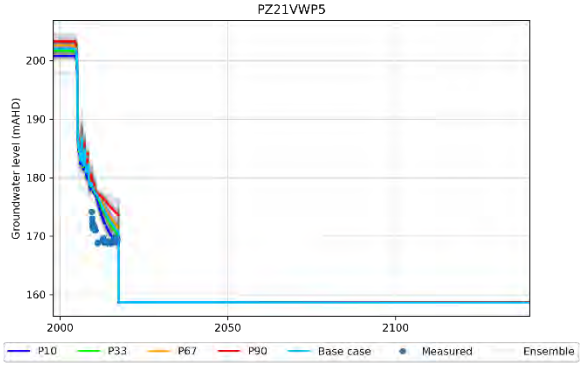

PZ19VWP5
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

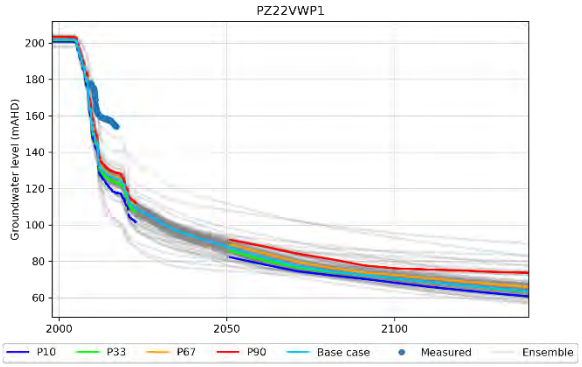

PZ21VWP1
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

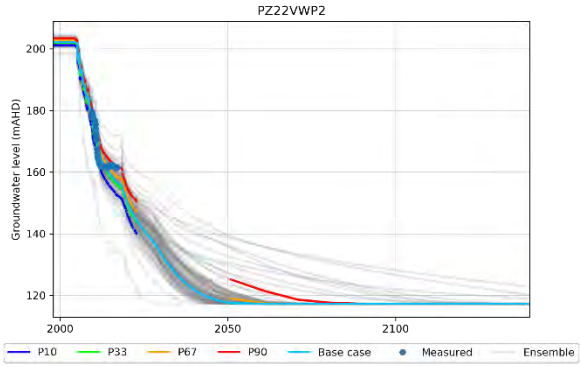

PZ21VWP2
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

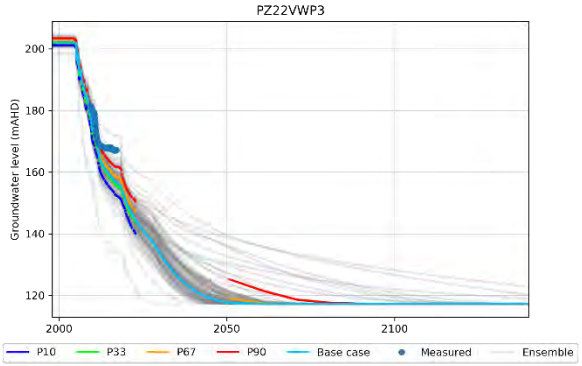

PZ21VWP3
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

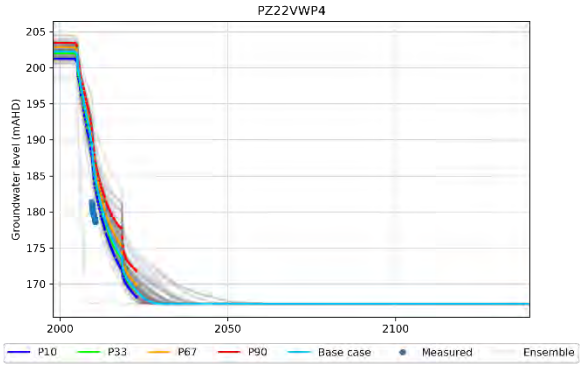

PZ21VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

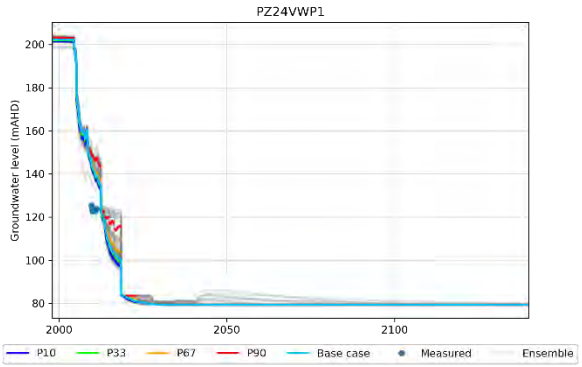

PZ21VWP5
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

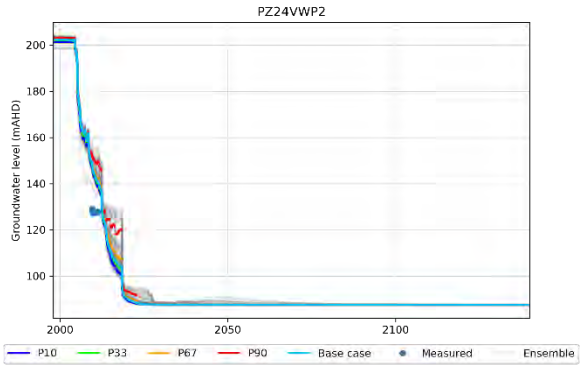

PZ22VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

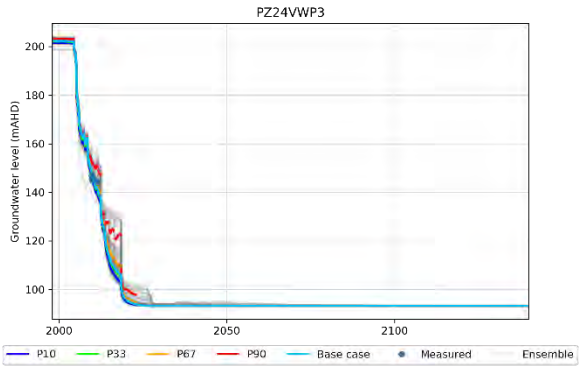

PZ22VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

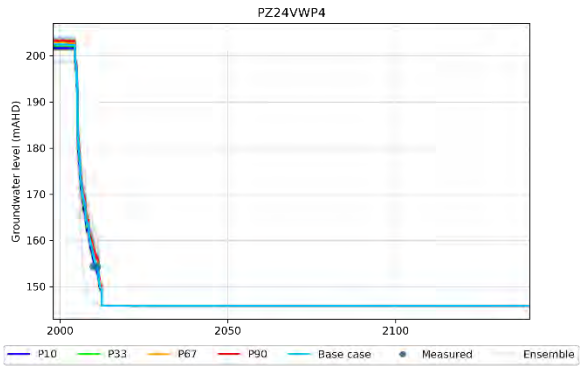

PZ22VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

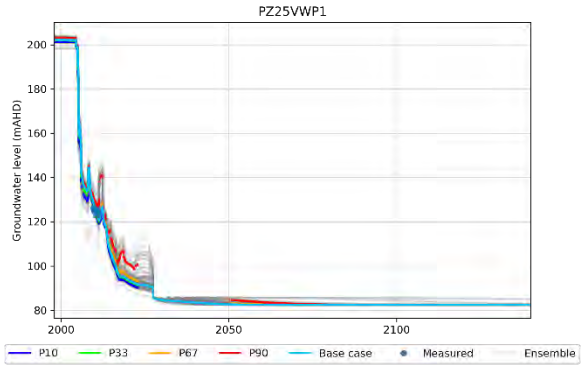

PZ22VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

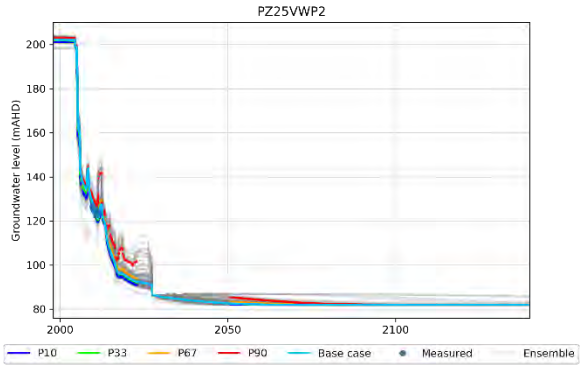

PZ24VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

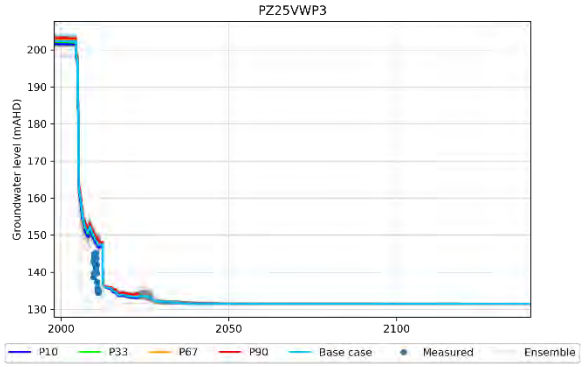

PZ24VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

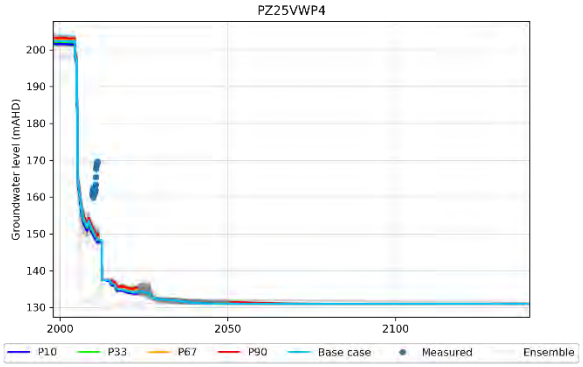

PZ24VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

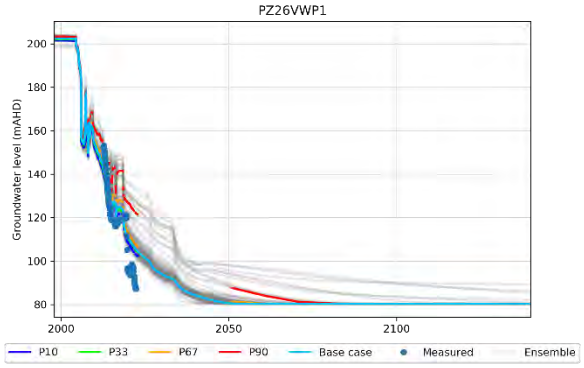

PZ24VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

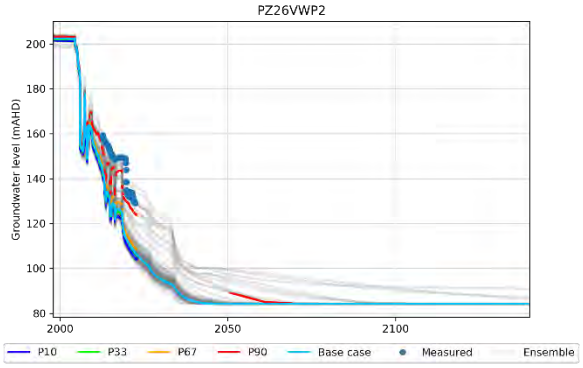

PZ25VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

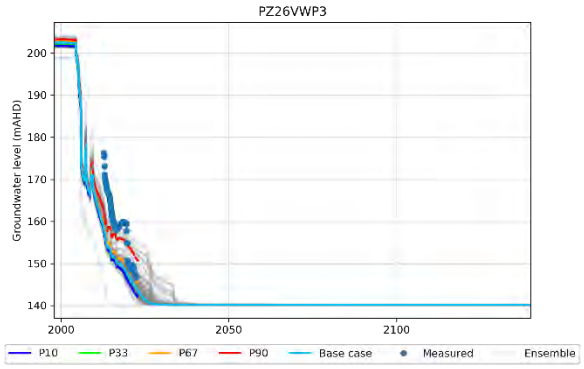

PZ25VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

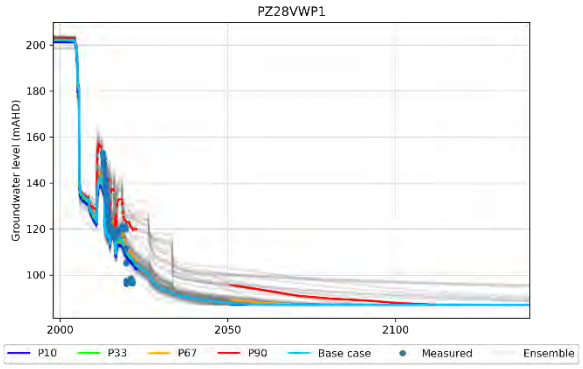

PZ25VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

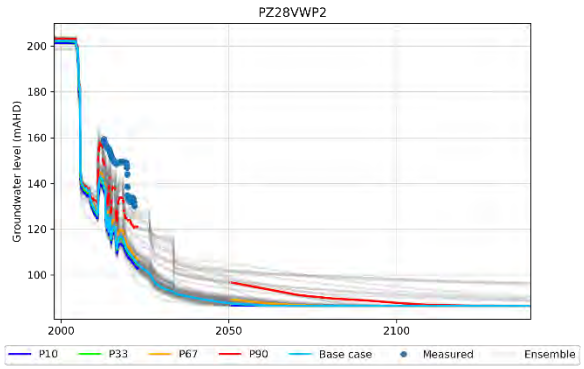

PZ25VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

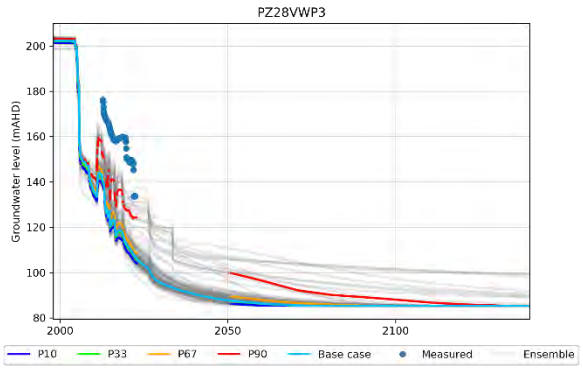

PZ26VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

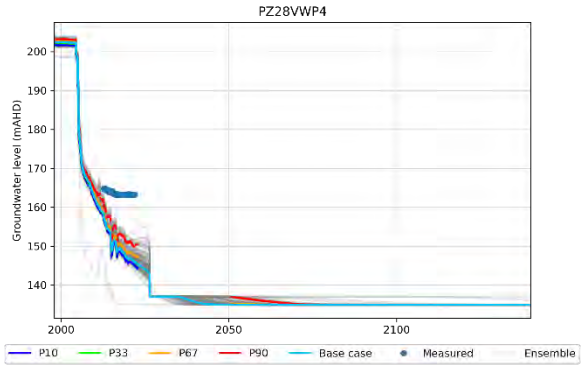

PZ26VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

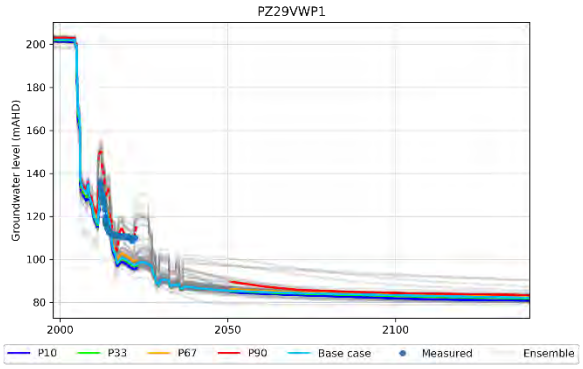

PZ26VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

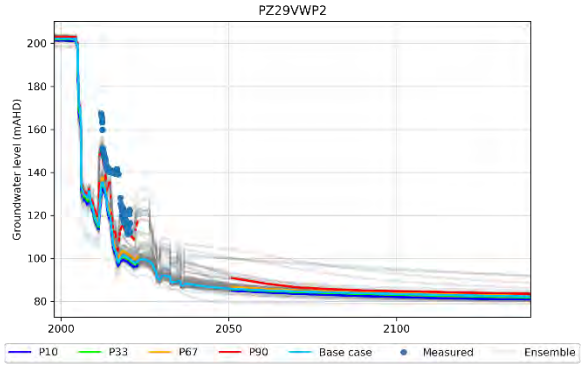

PZ28VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

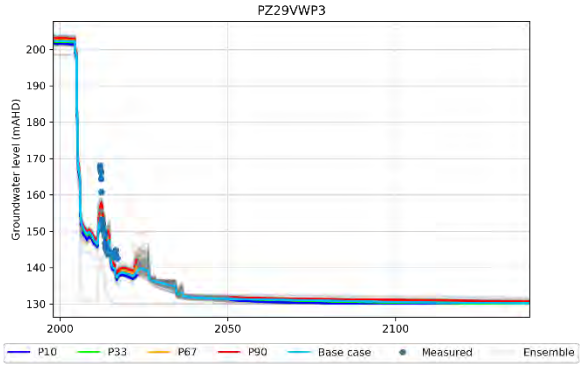

PZ28VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

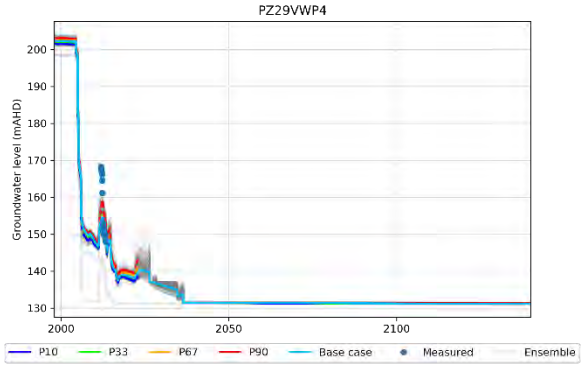

PZ28VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

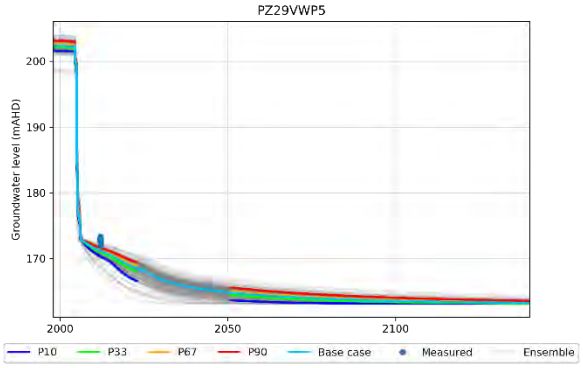

PZ28VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

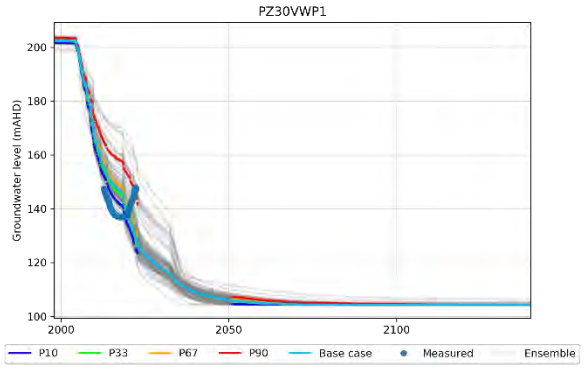

PZ29VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

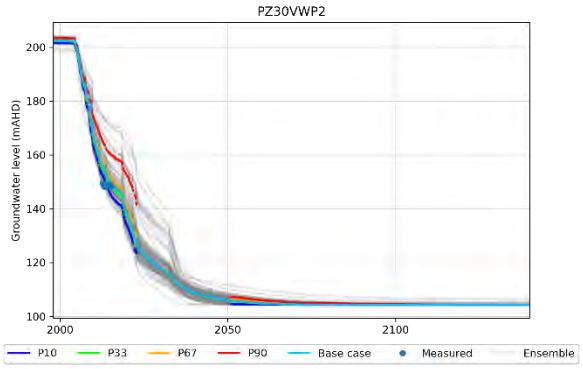

PZ29VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

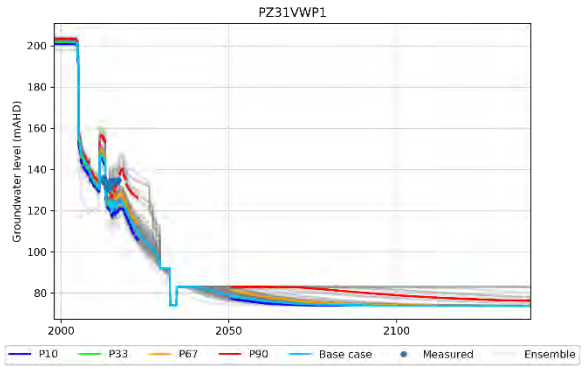

PZ29VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

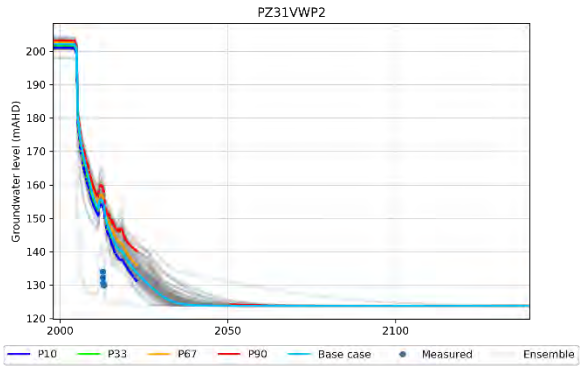

PZ29VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

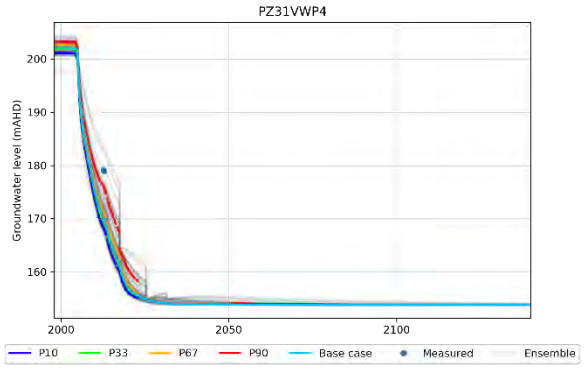

PZ29VWP5
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

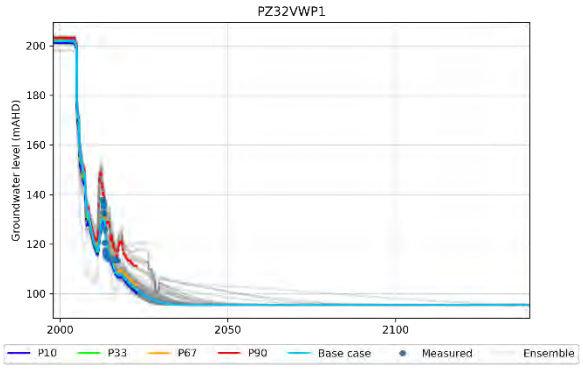

PZ30VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

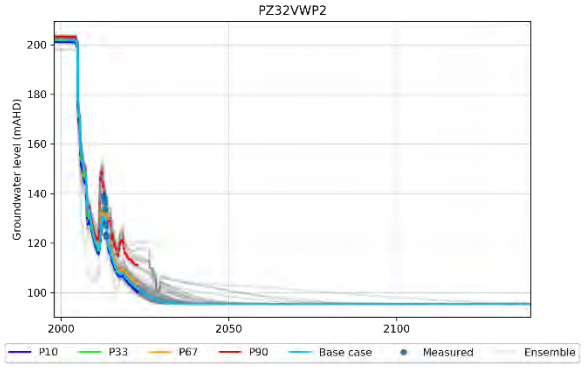

PZ30VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

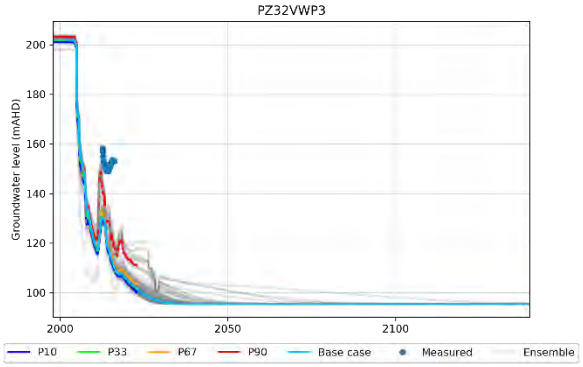

PZ31VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

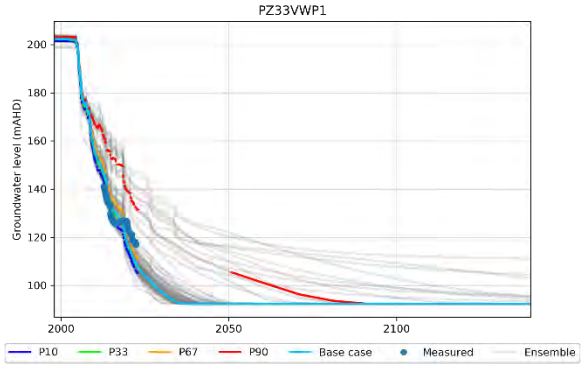

PZ31VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

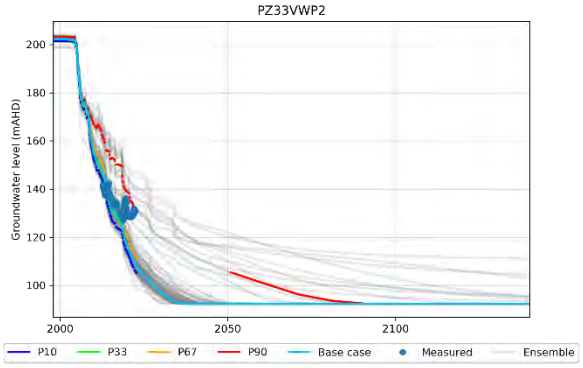

PZ31VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

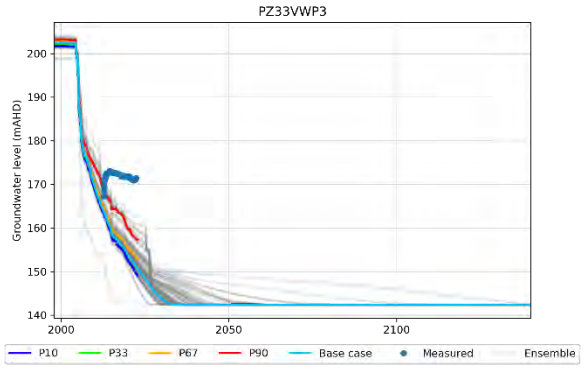

PZ32VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

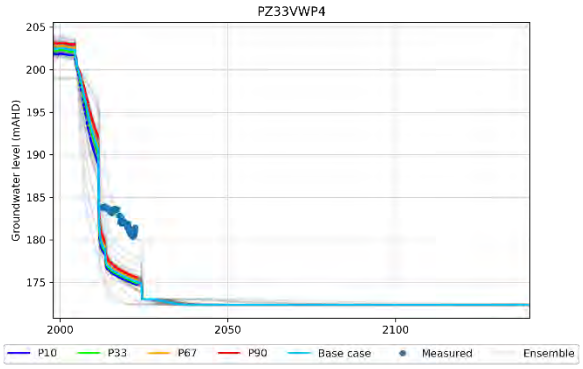

PZ32VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

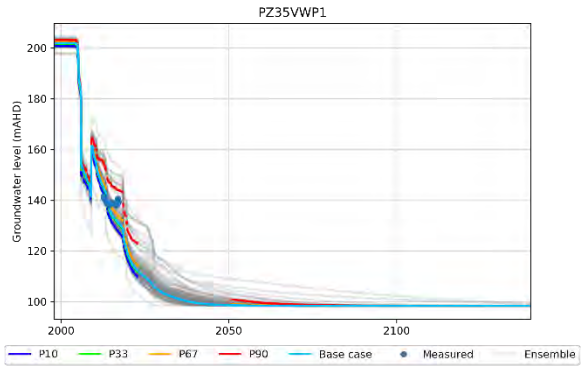

PZ32VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

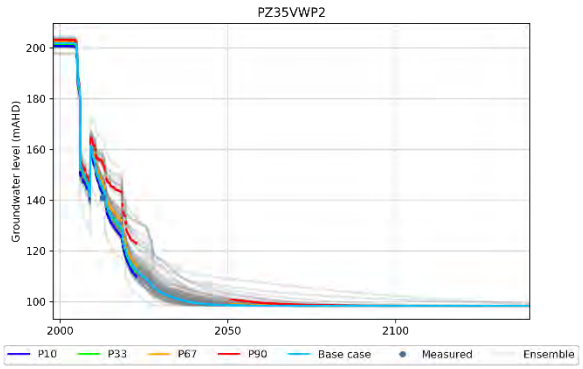

PZ33VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

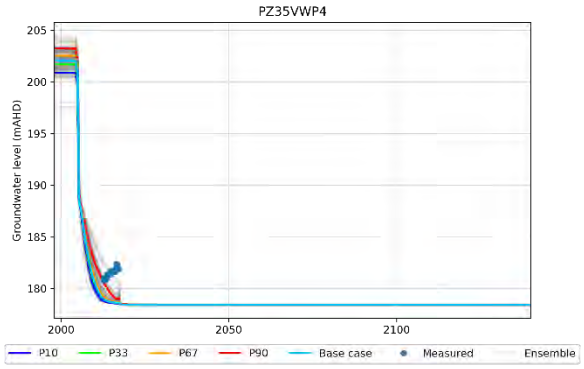

PZ33VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

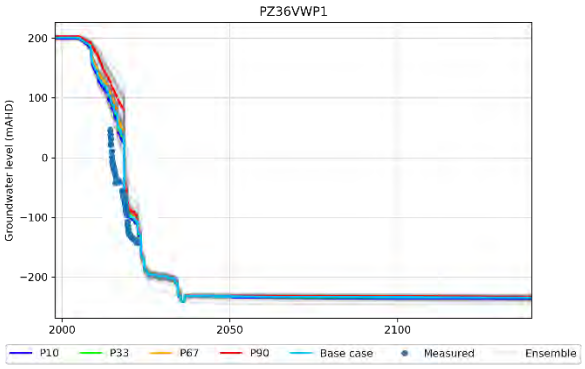

PZ33VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

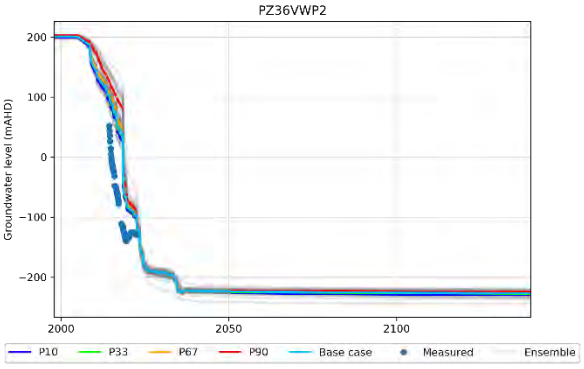

PZ33VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

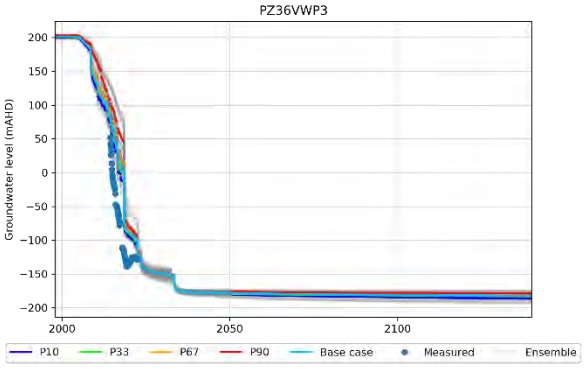

PZ35VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

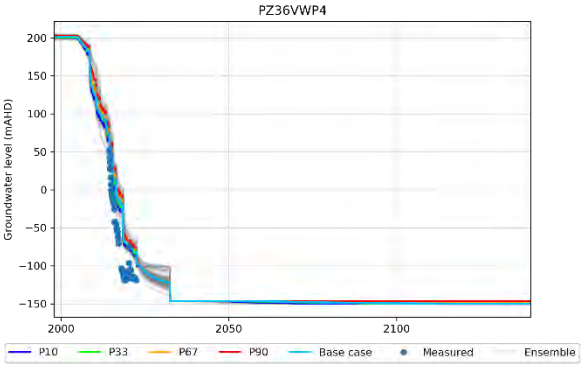

PZ35VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

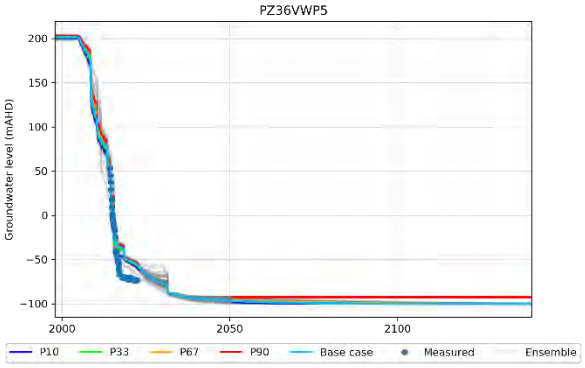

PZ35VWP4
Groundwater level (mAHD)
205
200
195
190
185
180
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

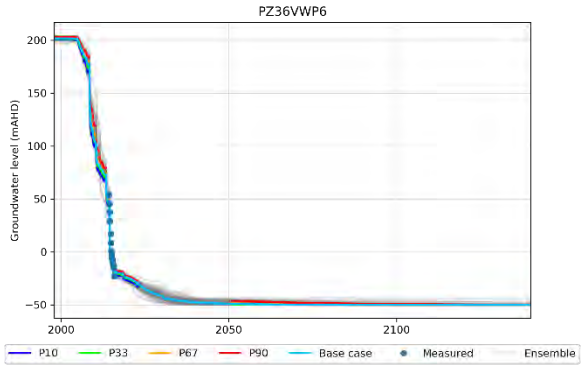

PZ36VWP1
Groundwater level (mAHD)
200
100
0
−100
−200
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

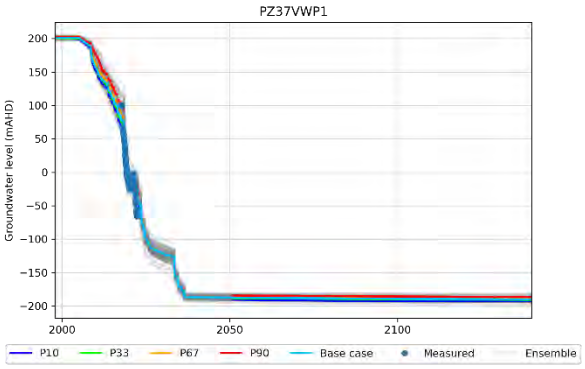

PZ36VWP2
Groundwater level (mAHD)
200
100
0
−100
−200
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

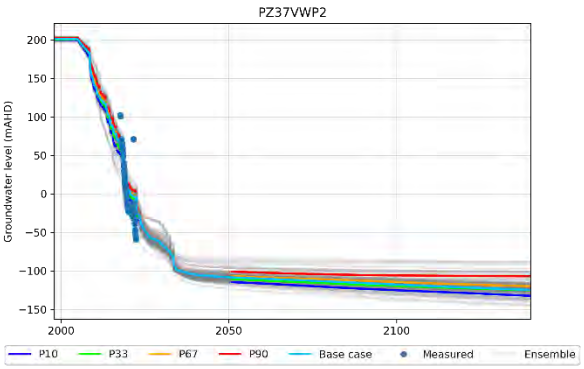

PZ36VWP3
Groundwater level (mAHD)
200
150
100
50
0
−50
−100
−150
−200
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

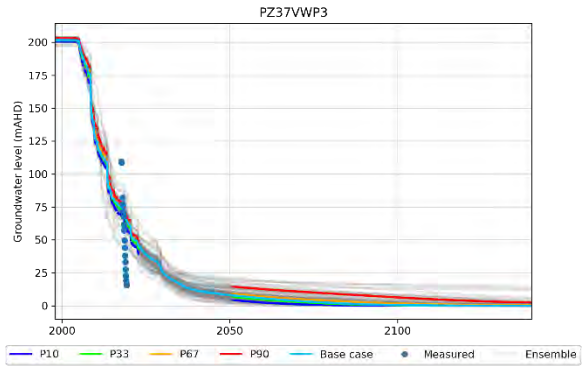

PZ36VWP4
Groundwater level (mAHD)
200
150
100
50
0
−50
−100
−150
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

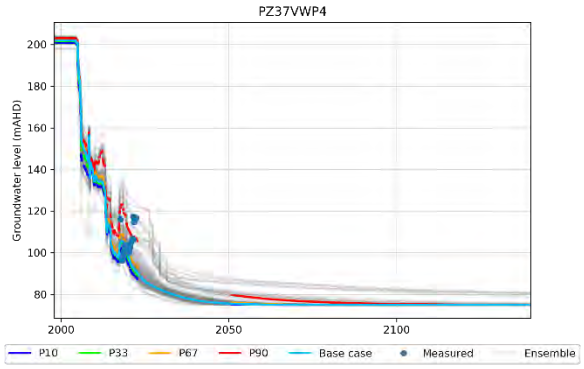

PZ36VWP5
Groundwater level (mAHD)
200
150
100
50
0
−50
−100
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

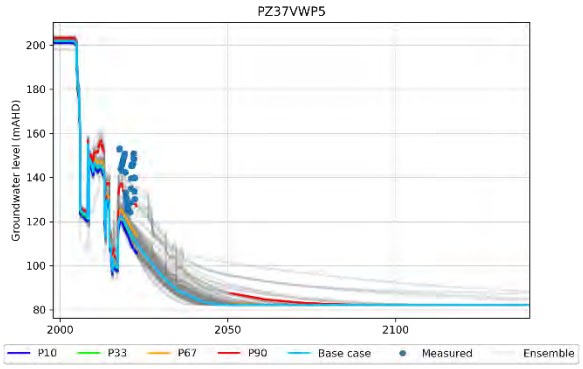

PZ36VWP6
Groundwater level (mAHD)
200
150
100
50
0
−50
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

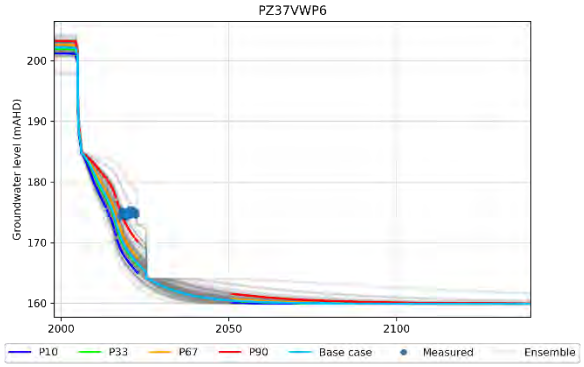

PZ37VWP1
Groundwater level (mAHD)
200
150
100
50
0
−50
−100
−150
−200
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

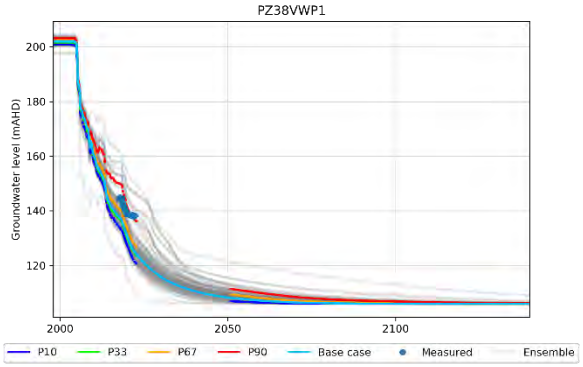

PZ37VWP2
Groundwater level (mAHD)
200
150
100
50
0
−50
−100
−150
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

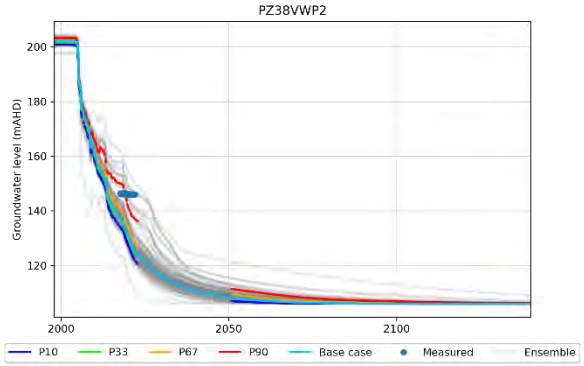

PZ37VWP3
Groundwater level (mAHD)
200
175
150
125
100
75
50
25
0
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

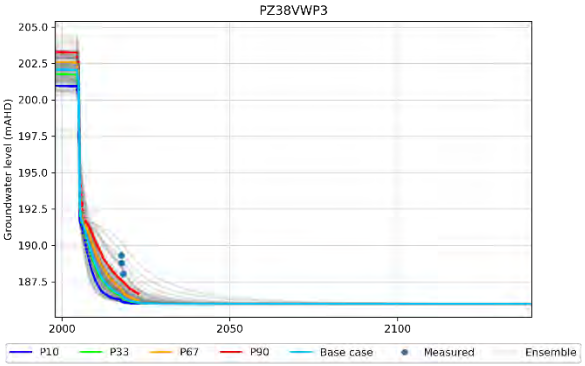

PZ37VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

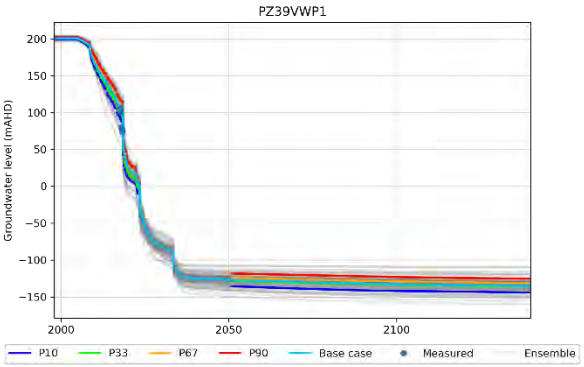

PZ37VWP5
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

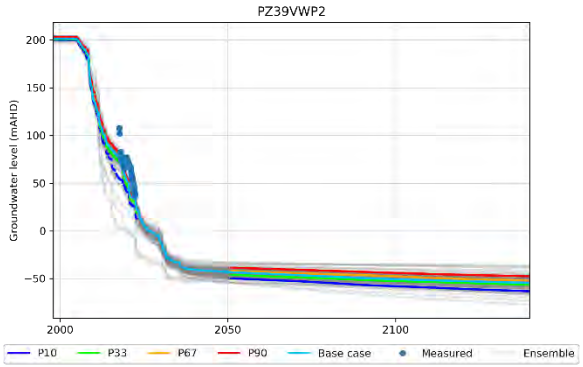

PZ37VWP6
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

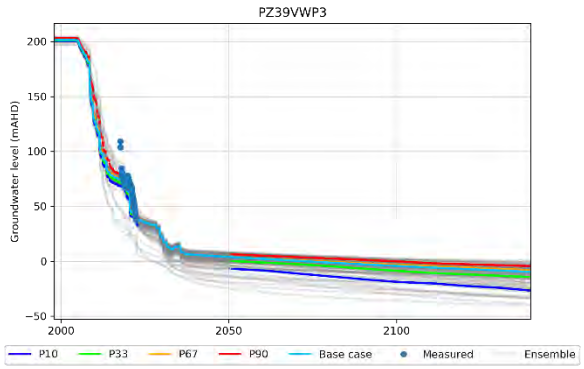

PZ38VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

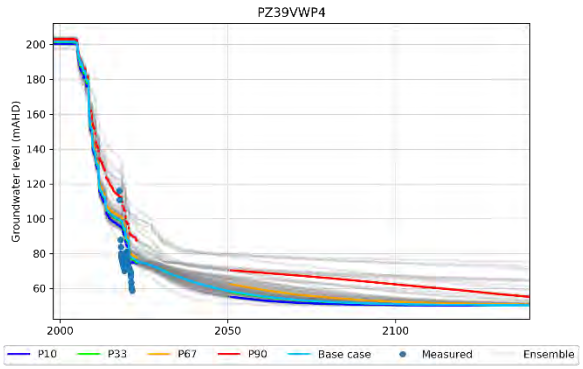

PZ38VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

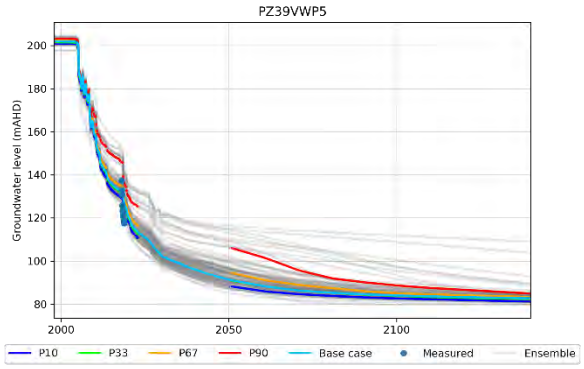

PZ38VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

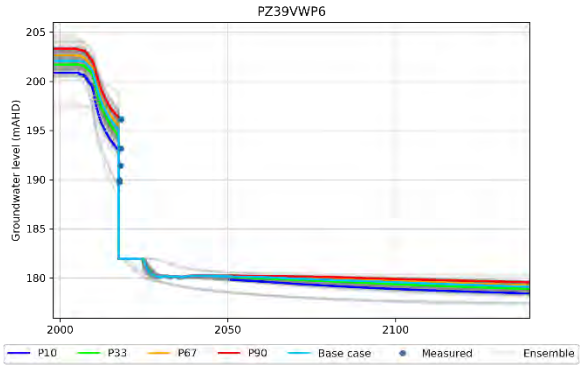

PZ39VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

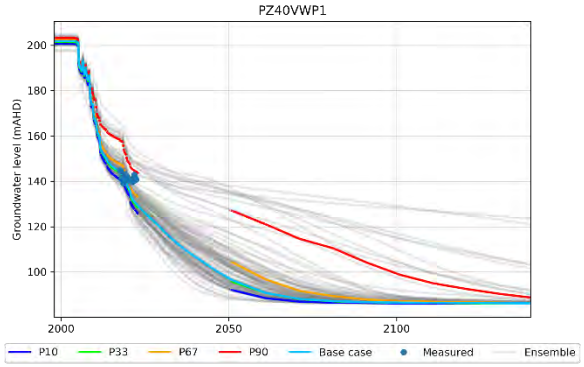

PZ39VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

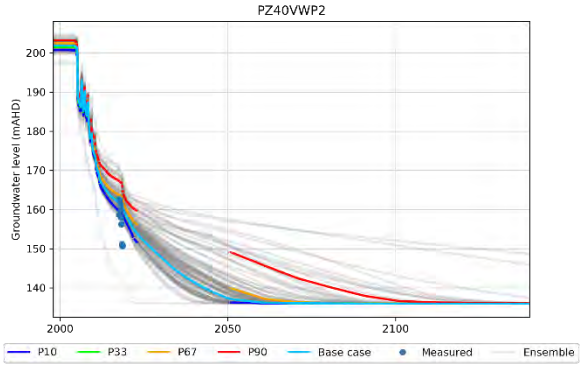

PZ39VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

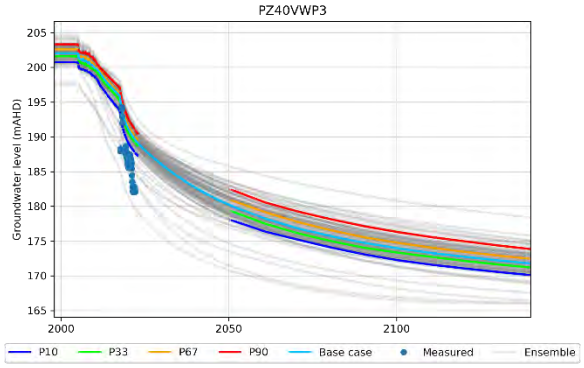

PZ39VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

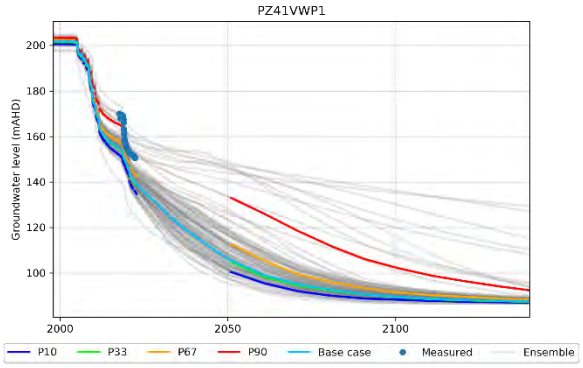

PZ39VWP5
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

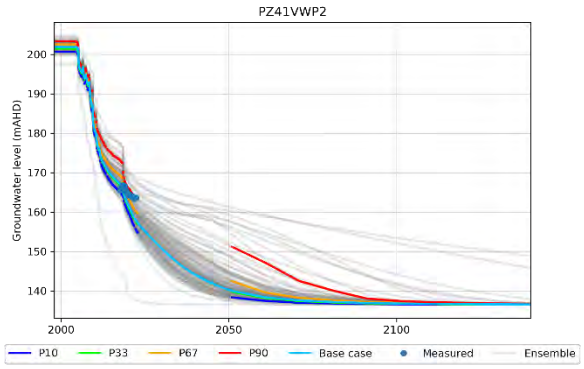

PZ39VWP6
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

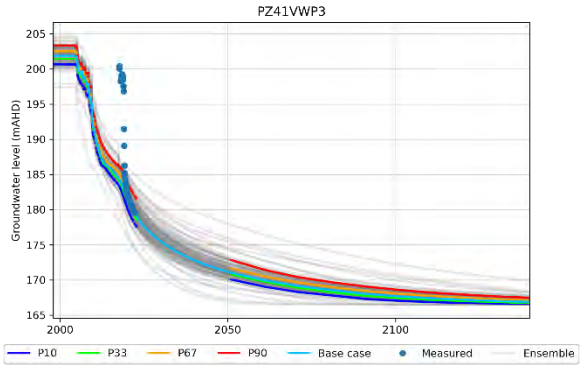

PZ40VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

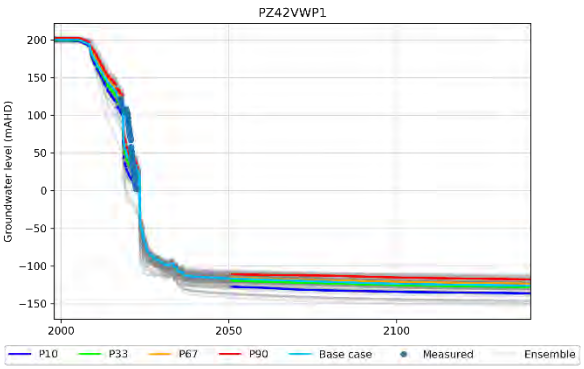

PZ40VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

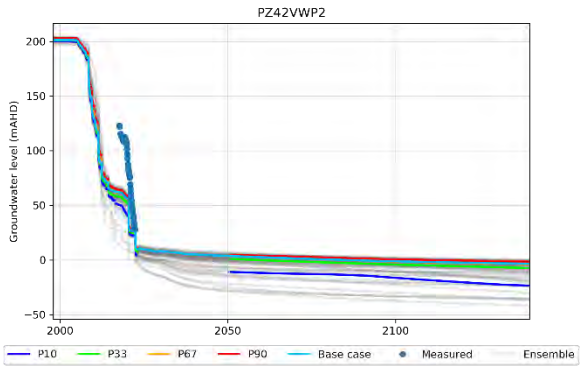

PZ40VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

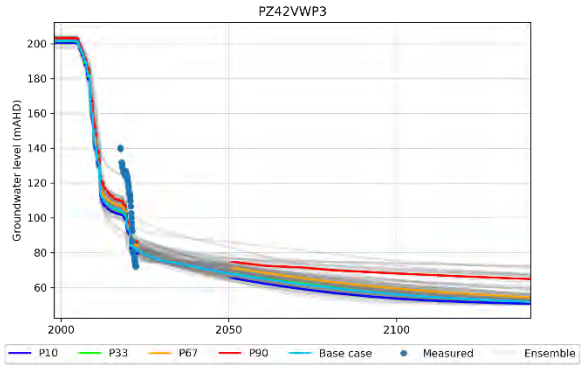

PZ41VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

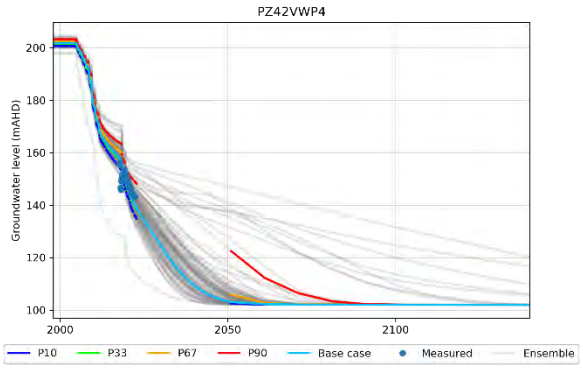

PZ41VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

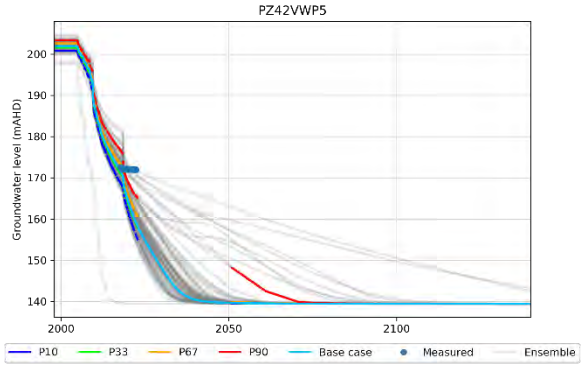

PZ41VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

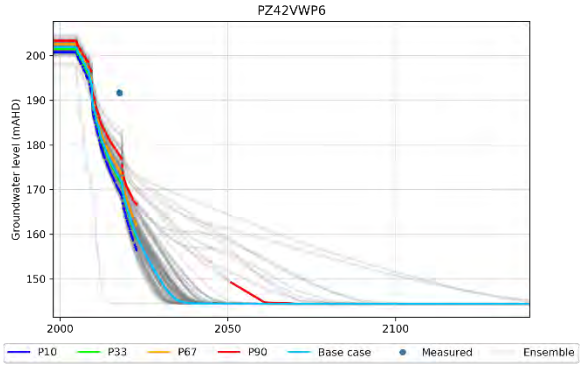

PZ42VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

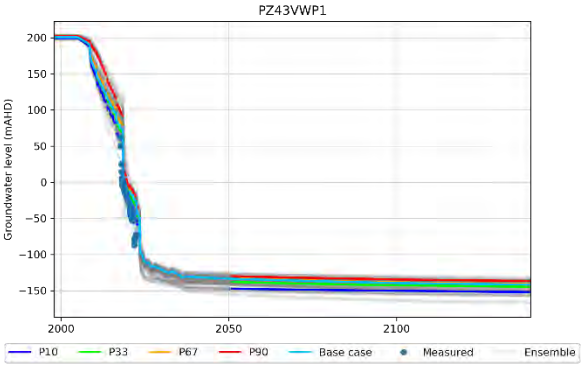

PZ42VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

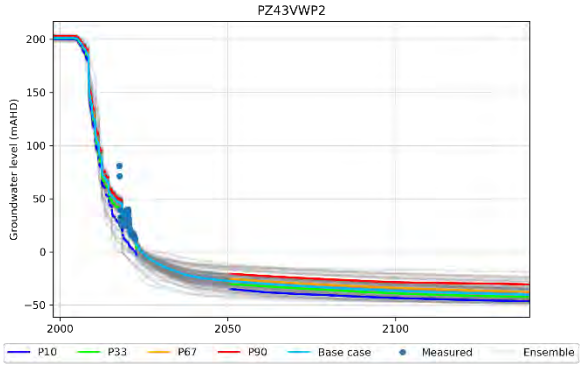

PZ42VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

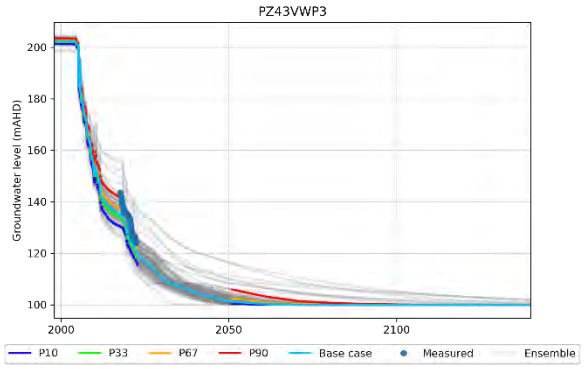

PZ42VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

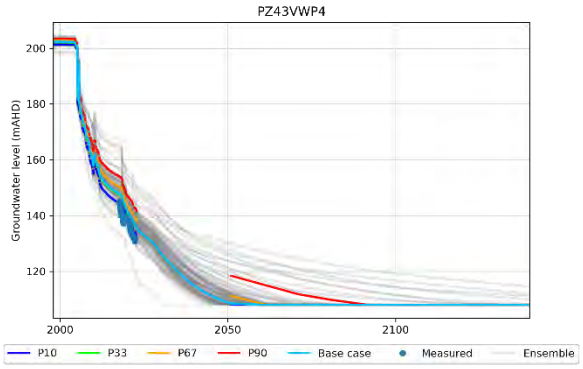

PZ42VWP5
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

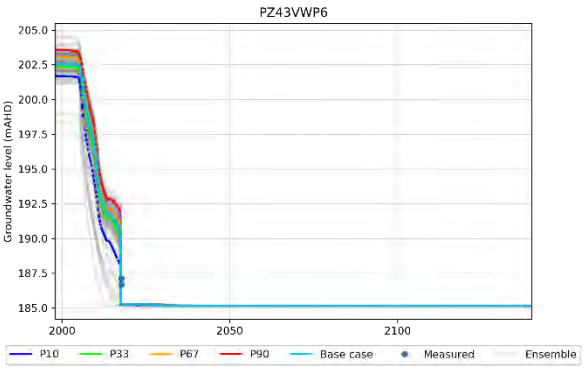

PZ42VWP6
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

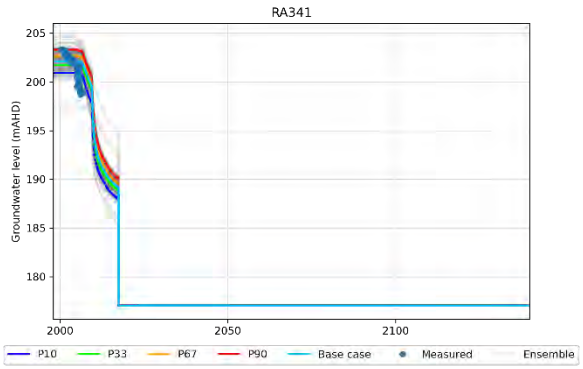

PZ43VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

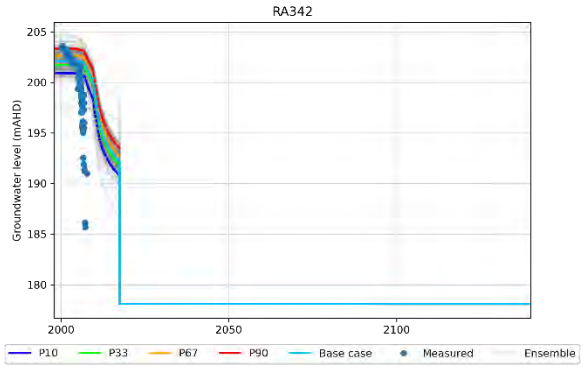

PZ43VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

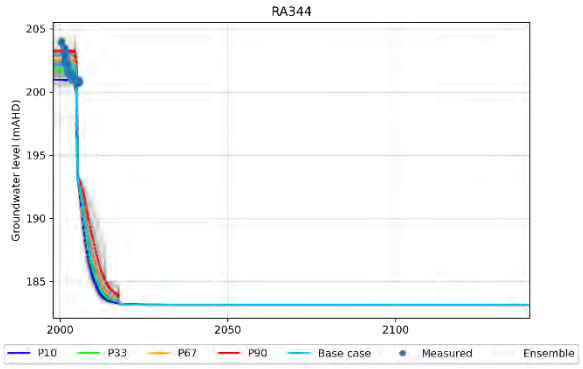

PZ43VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

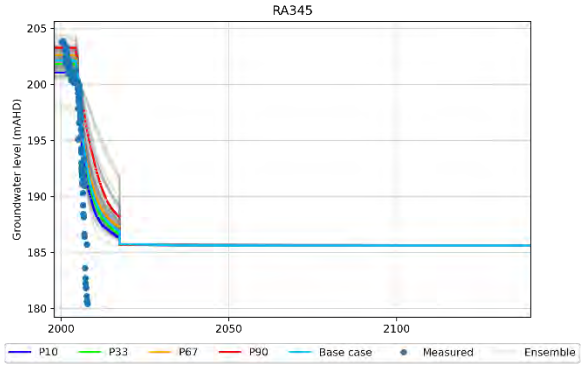

PZ43VWP4
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

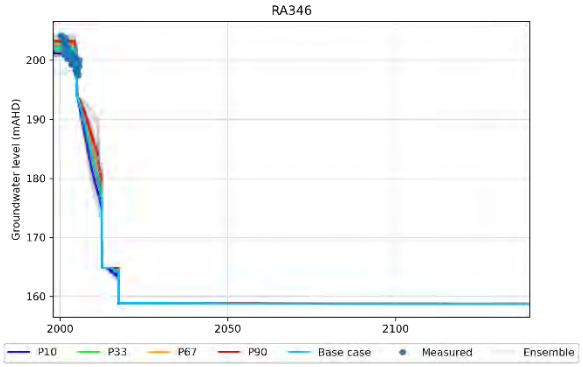

PZ43VWP6
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

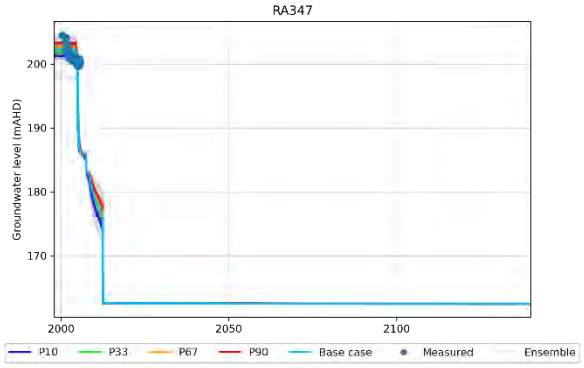

RA341
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

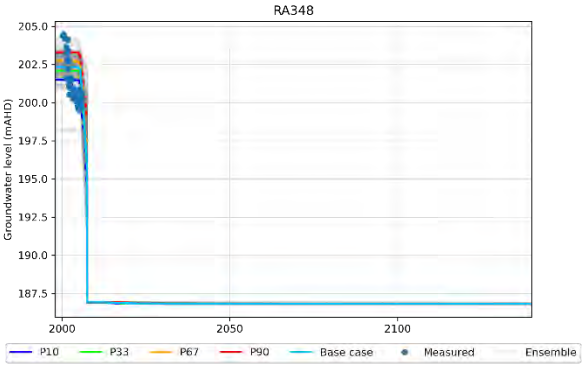

RA342
Groundwater level (mAHD)
205
200
195
190
185
180
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

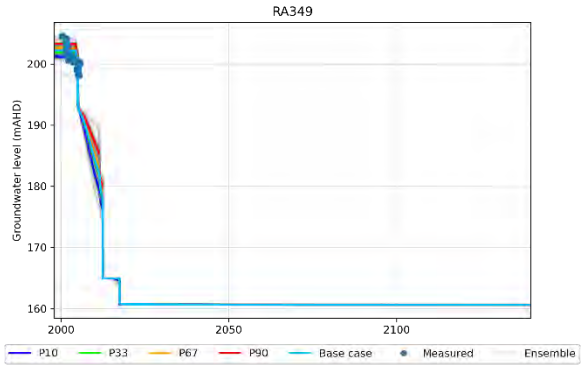

RA344
Groundwater level (mAHD)
205
200
195
190
185
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

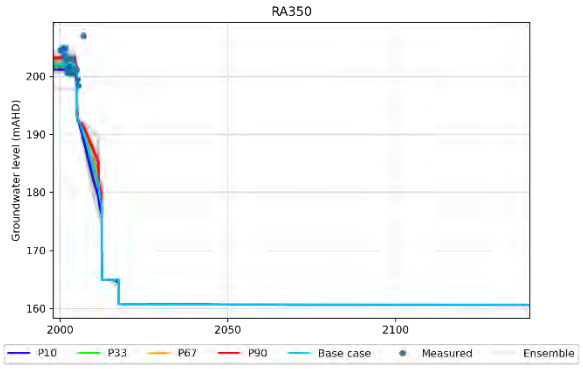

RA345
Groundwater level (mAHD)
205
200
195
190
185
180
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

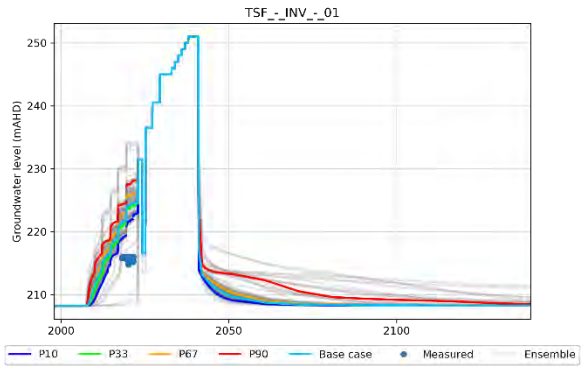

RA346
Groundwater level (mAHD)
200
190
180
170
160
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

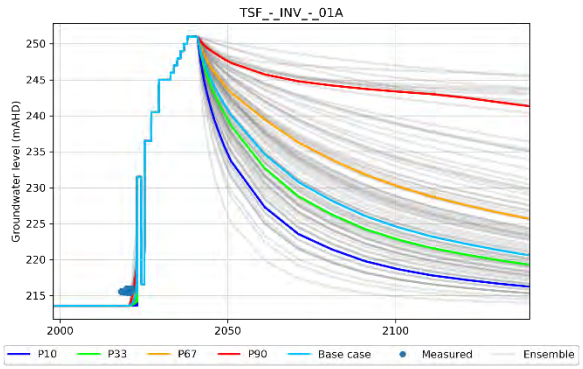

RA347
Groundwater level (mAHD)
200
190
180
170
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

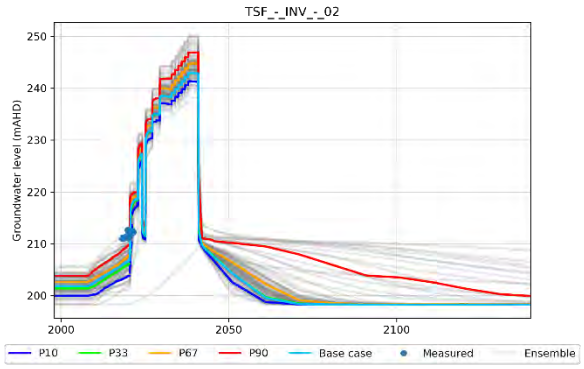

RA348
Groundwater level (mAHD)
205.0
202.5
200.0
197.5
195.0
192.5
190.0
187.5
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

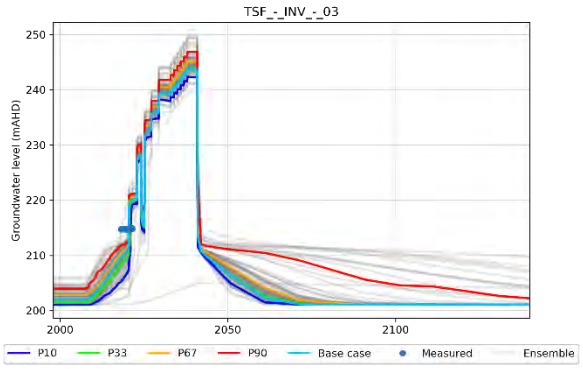

RA349
Groundwater level (mAHD)
200
190
180
170
160
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

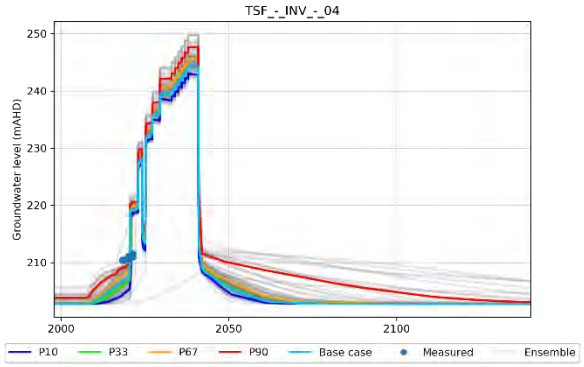

RA350
Groundwater level (mAHD)
200
190
180
170
160
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

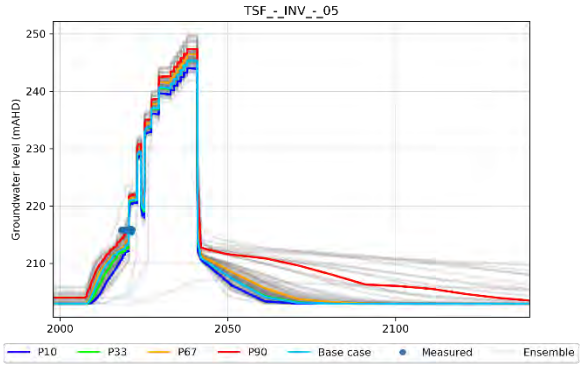

TSF_-_INV_-_01
Groundwater level (mAHD)
250
240
230
220
210
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

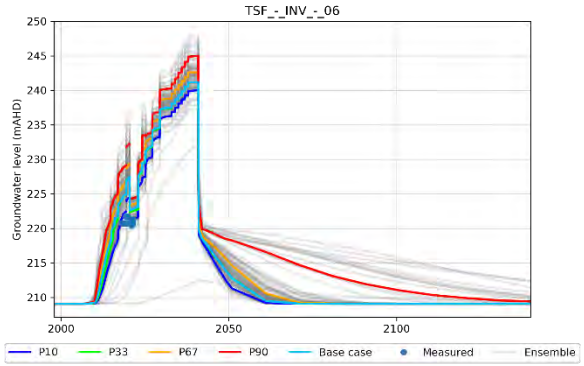

TSF_-_INV_-_01A
Groundwater level (mAHD)
250
245
240
235
230
225
220
215
2000
2050
2100
P10
P33
P67
P90
Base case
Measured
Ensemble

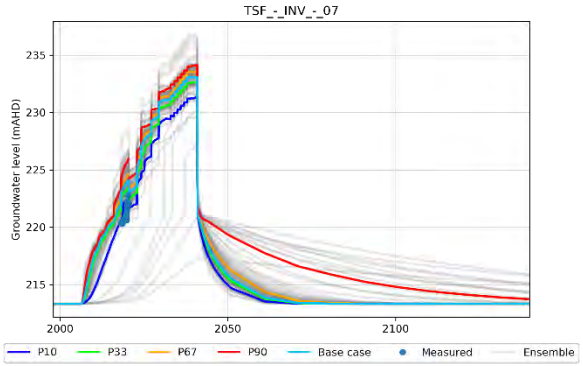

TSF_-_INV_-_02
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

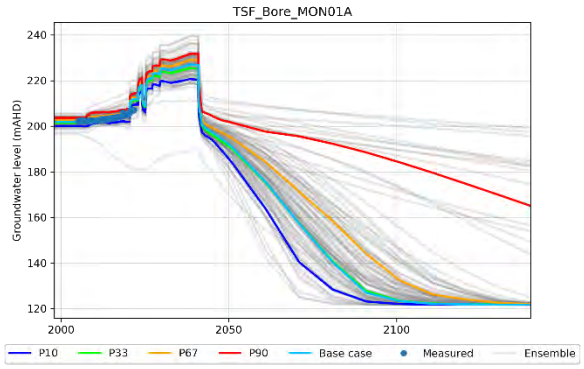

TSF_-_INV_-_03
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

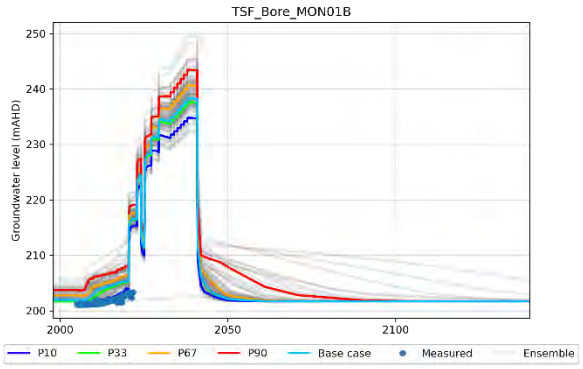

TSF_-_INV_-_04
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

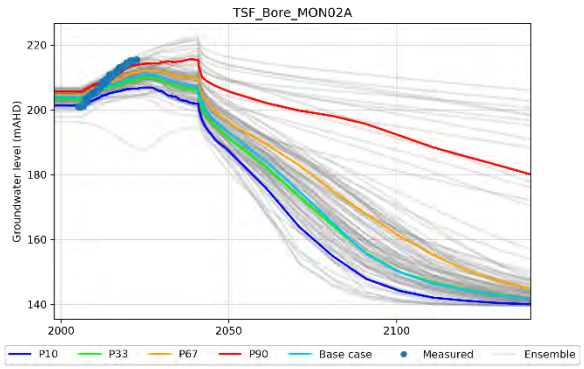

TSF_-_INV_-_05
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

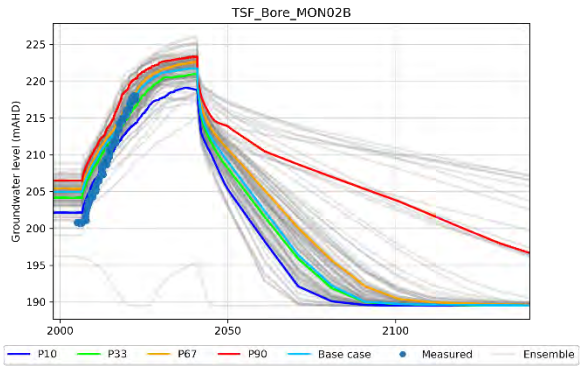

TSF_-_INV_-_06
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

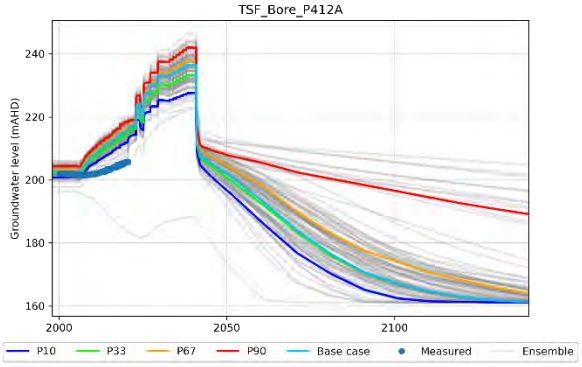

TSF_-_INV_-_07
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

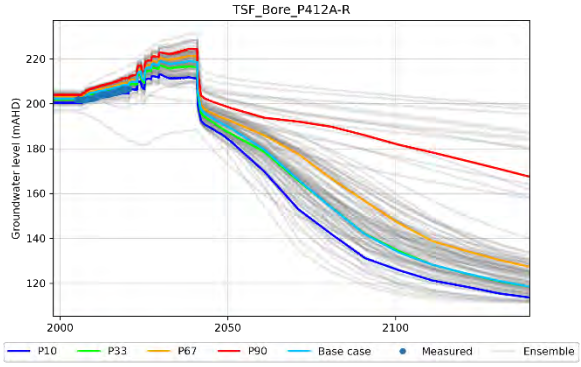

TSF_Bore_MON01A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

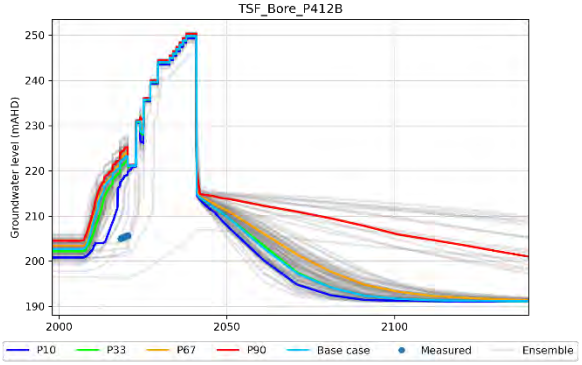

TSF_Bore_MON01B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

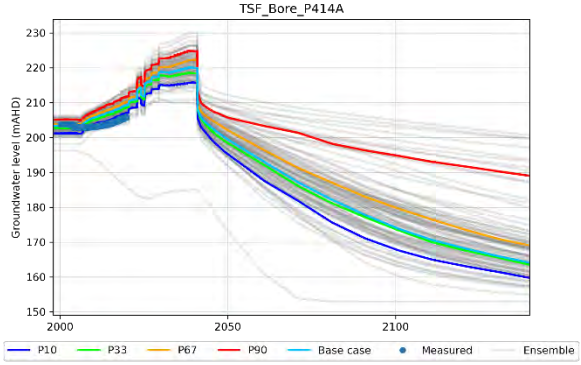

TSF_Bore_MON02A
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

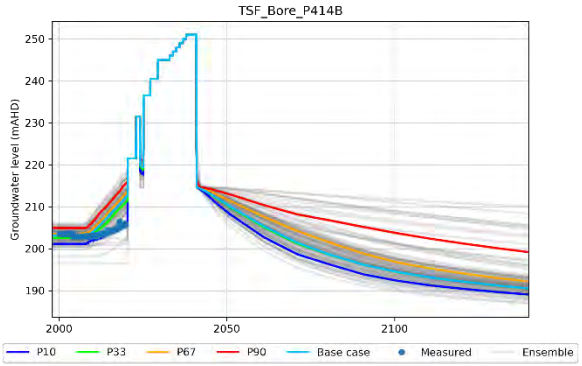

TSF_Bore_MON02B
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

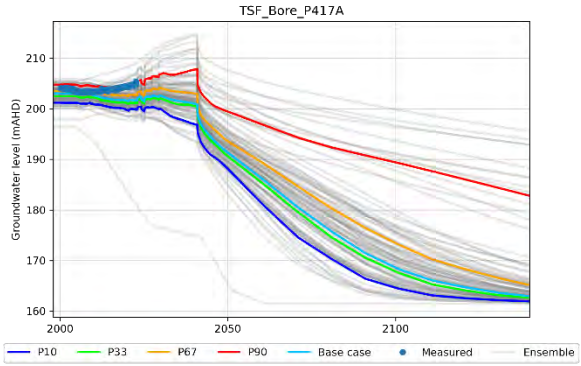

TSF_Bore_P412A
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

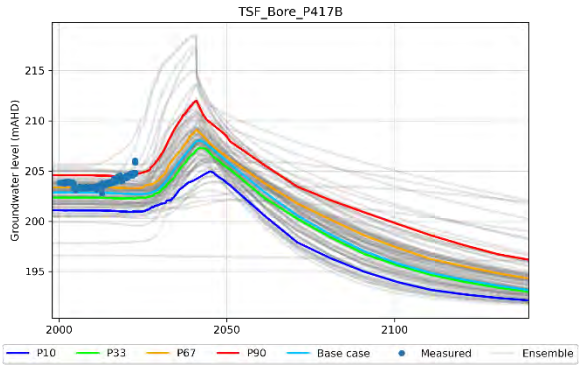

TSF_Bore_P412A-R
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

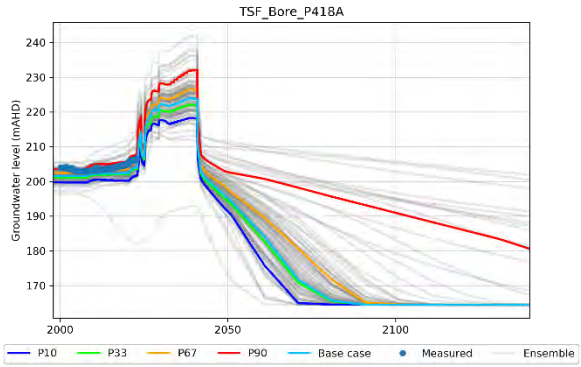

TSF_Bore_P412B
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

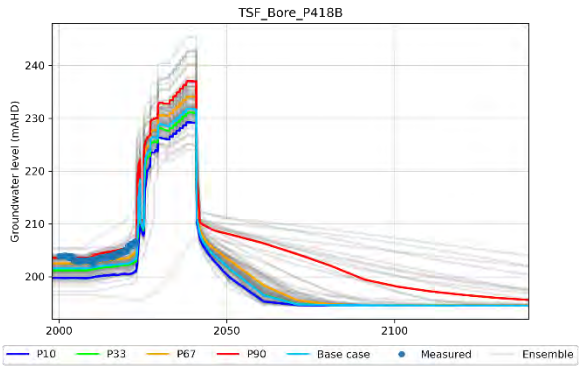

TSF_Bore_P414A
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

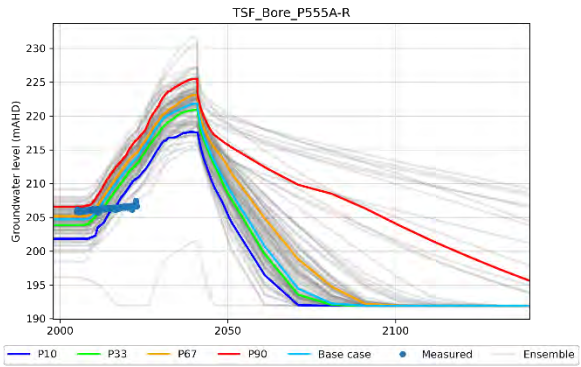

TSF_Bore_P414B
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

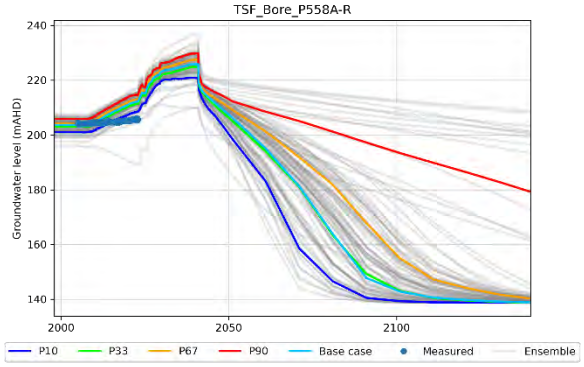

TSF_Bore_P417A
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

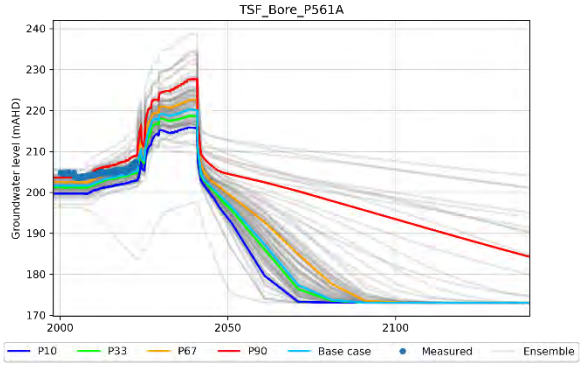

TSF_Bore_P417B
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

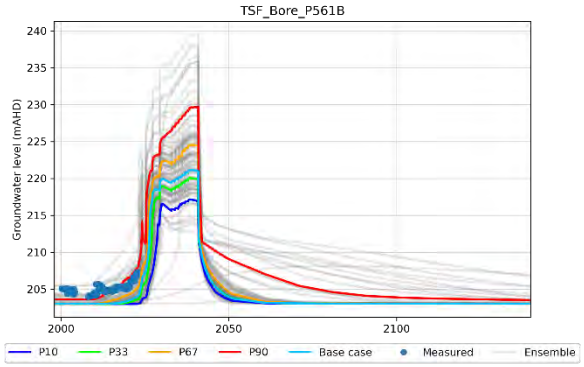

TSF_Bore_P418A
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

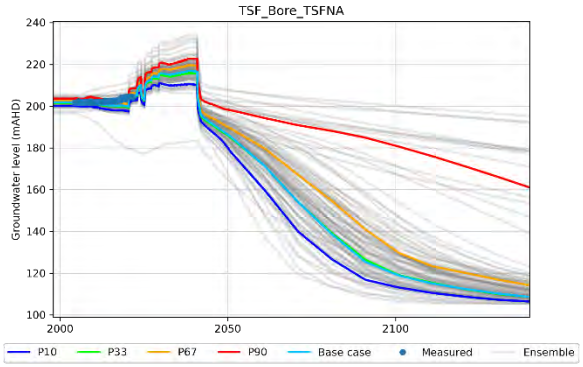

TSF_Bore_P418B
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

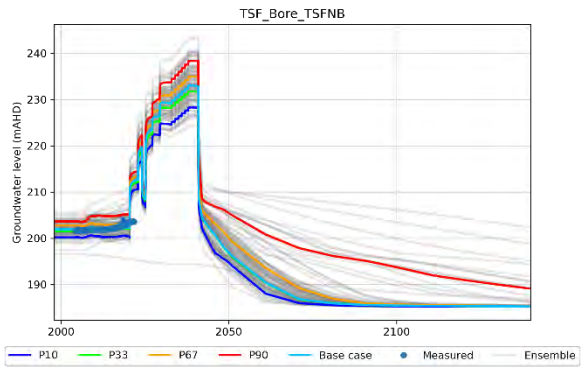

TSF_Bore_P555A-R
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

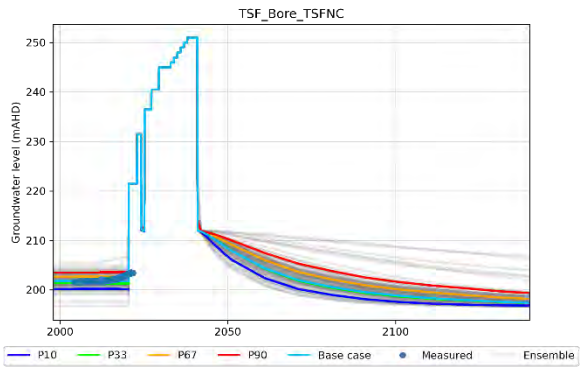

TSF_Bore_P558A-R
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

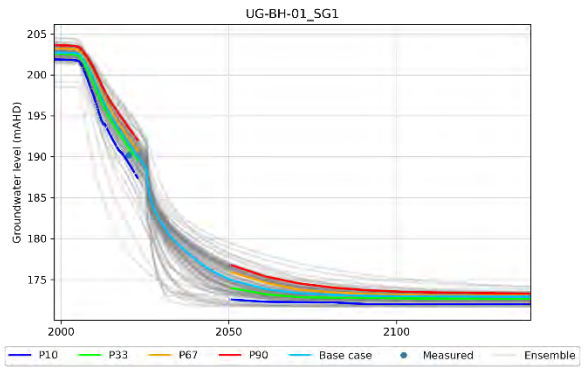

TSF_Bore_P561A
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

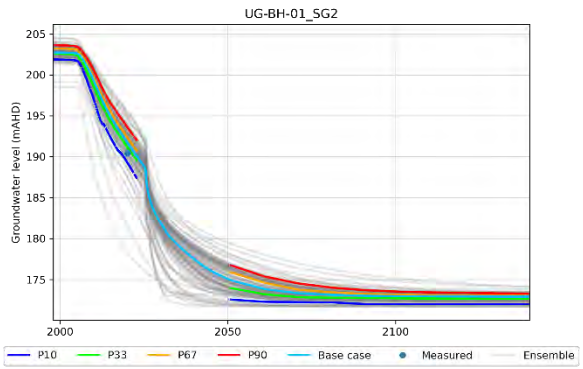

TSF_Bore_P561B
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

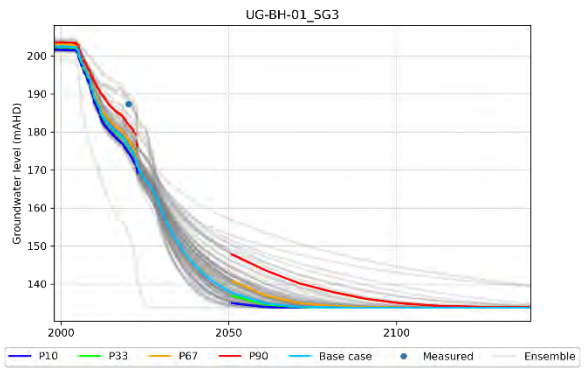

TSF_Bore_TSFNA
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

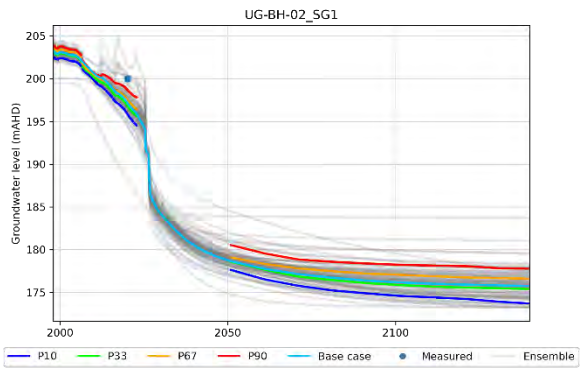

TSF_Bore_TSFNB
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

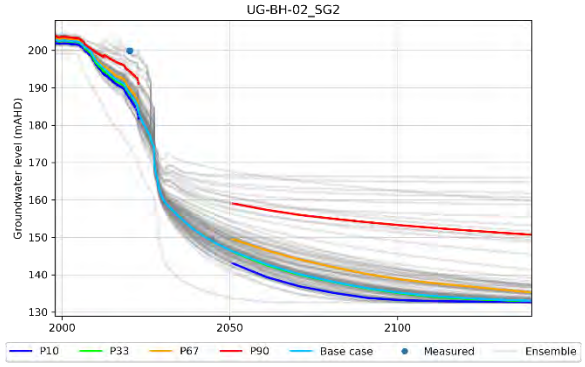

TSF_Bore_TSFNC
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

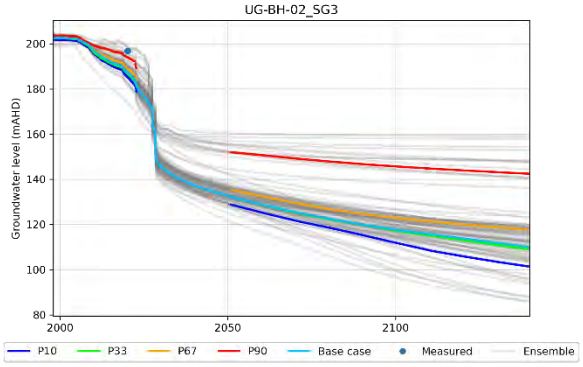

UG-BH-01_SG1
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

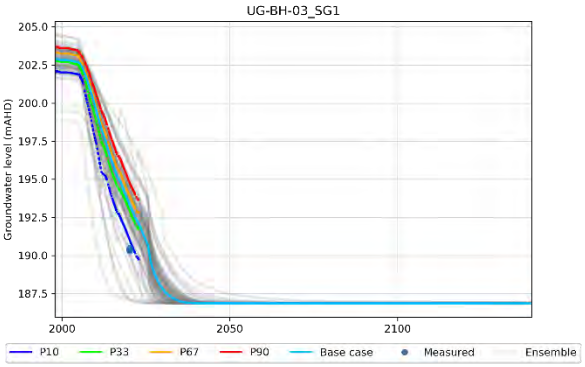

UG-BH-01_SG2
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

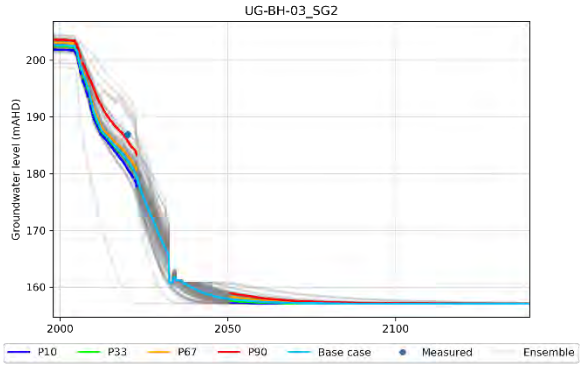

UG-BH-01_SG3
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

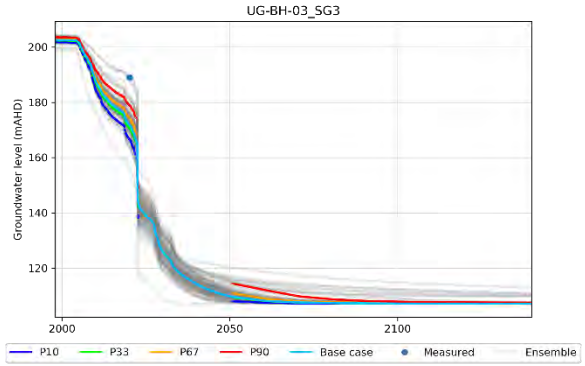

UG-BH-02_SG1
Groundwater level (mAHD)
P10 P33 P67 P90 Base case Measured Ensemble

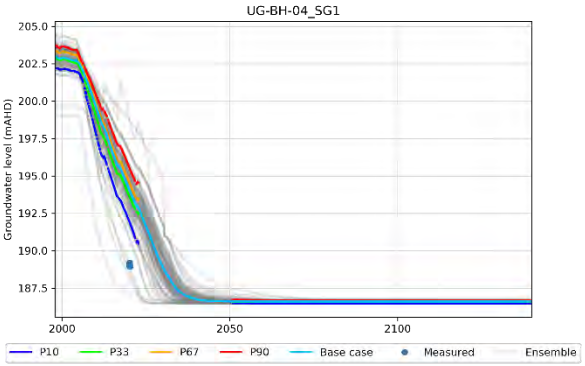

UG-BH-02_SG2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

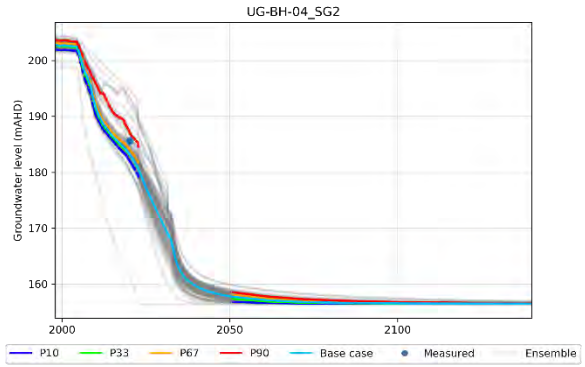

UG-BH-02_SG3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

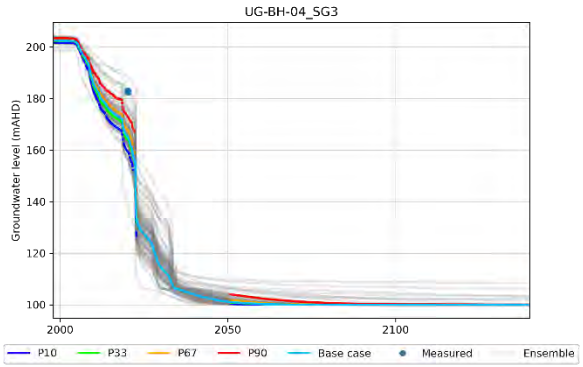

UG-BH-03_SG1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

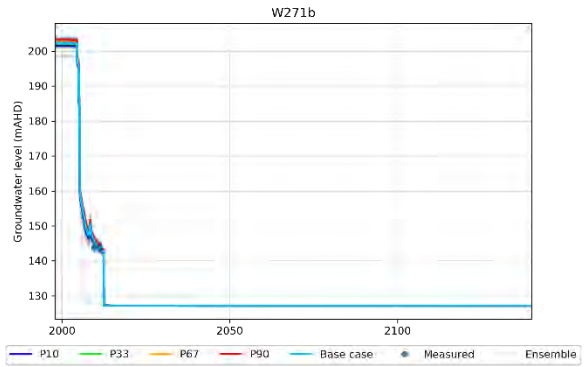

UG-BH-03_SG2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

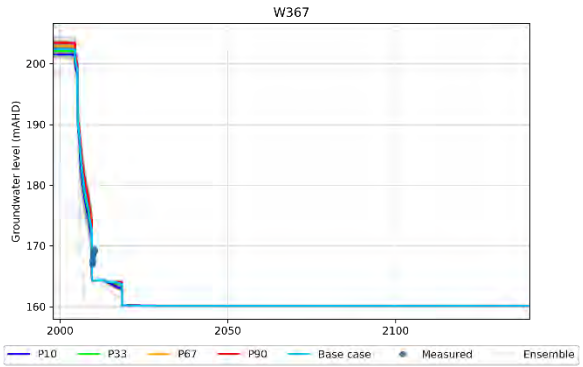

UG-BH-03_SG3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

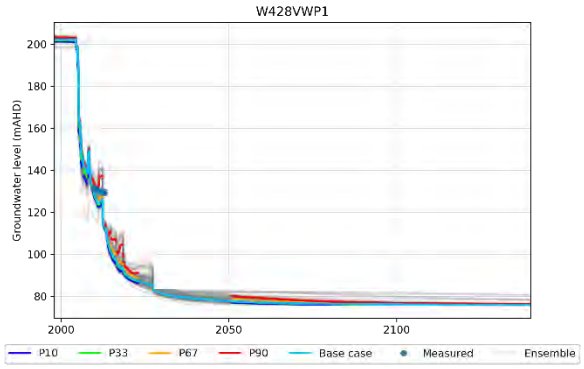

UG-BH-04_SG1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

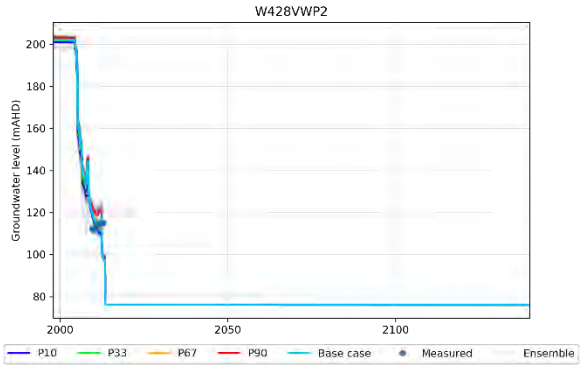

UG-BH-04_SG2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

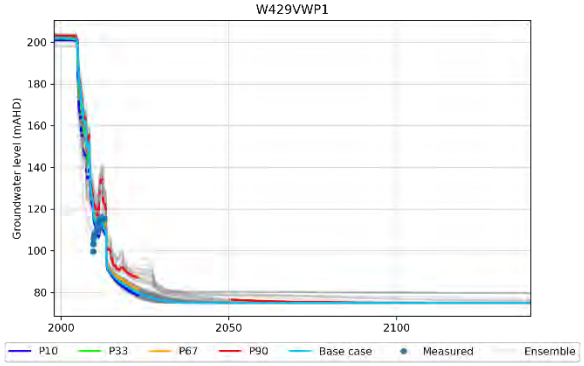

UG-BH-04_SG3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

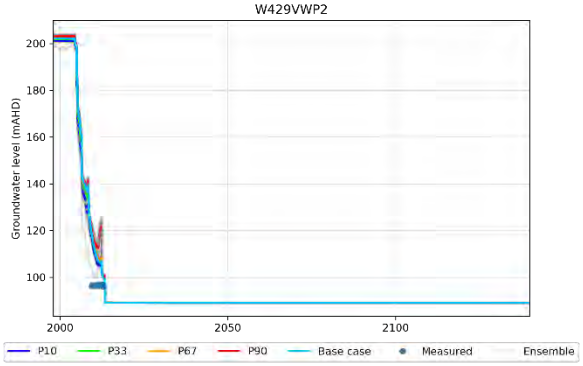

W271b
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

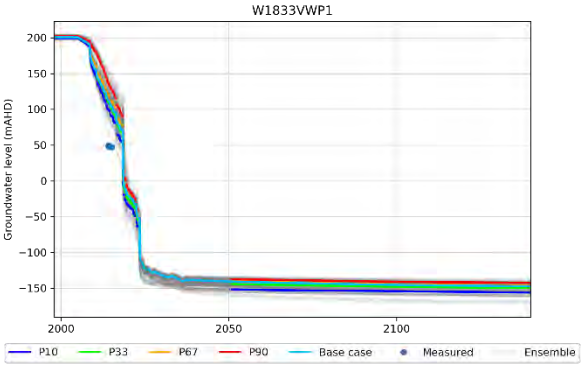

W367
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

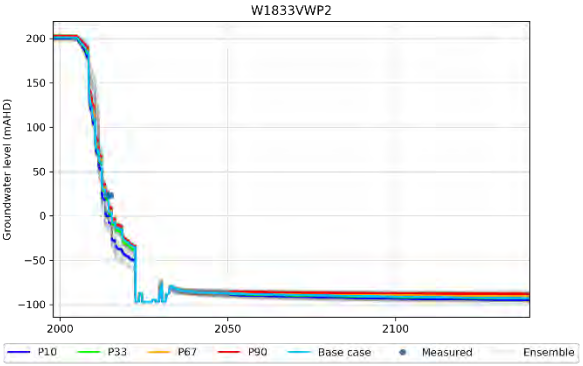

W428VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

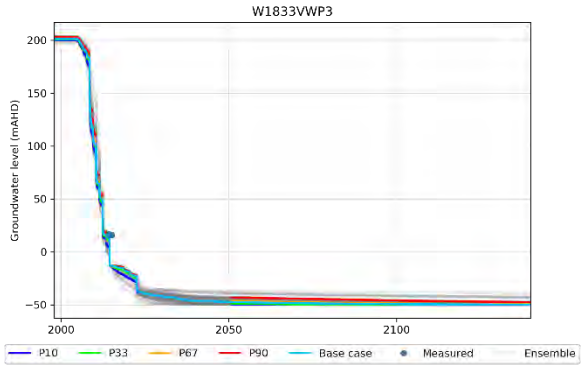

W428VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

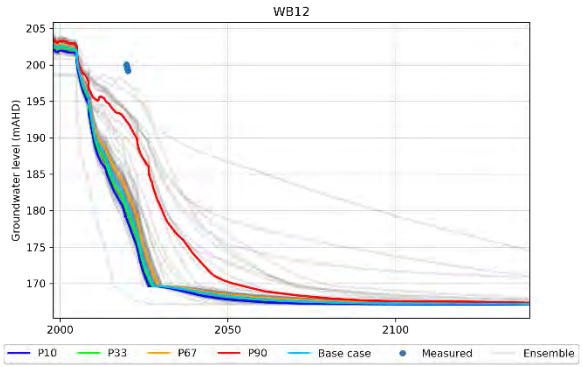

W429VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble


W429VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble


W1833VWP1
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble


W1833VWP2
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble


W1833VWP3
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble


WB12
Groundwater level (mAHD)
P10
P33
P67
P90
Base case
Measured
Ensemble

Appendix E

Groundwater model scenario addendum

EMM
creating opportunities

Level 4 74 Pirie Street
Adelaide SA 5000
08 8232 2253
www.emmconsulting.com.au

Memorandum

11 May 2023

Subject: Cowal Gold Operations - Open Pit Continuation Project
Numerical Groundwater Modelling Scenario Addendum

Introduction

Evolution Mining (Cowal) Pty Limited (Evolution) is proposing to extend open pit mining operations at its existing Cowal Gold Operations (CGO) open pit and underground gold mine through the Open Pit Continuation Project (the Project). The Project is located approximately 38 kilometres (km) north-east of West Wyalong, in the central west region of New South Wales (NSW).

To support a groundwater impact assessment (GIA) for the Project EIS, a three-dimensional numerical groundwater flow model has been developed to quantify groundwater level, flow and contaminant migration pathways. The model was built to predict drawdown at nearby water users, environmental receptors and compliance monitoring bores; groundwater inflow to the Project infrastructure; changes to the water balance; and the fate of contaminants sourced from the mine site.

This memorandum is intended to be read in conjunction with the numerical groundwater modelling report, and details additional scenario modelling for the post-mining recovery period.

The main report describes two predictive scenarios for the proposed mining activities:

- Prediction 3: pits remain dry in perpetuity. Achieved through leaving pit DRN cells active through the post-mining period. Used for conservative assessment of drawdown.
- Prediction 4: pit water level allowed to recover with void properties and no surficial fluxes. Achieved through deactivation of pit DRN cells and activation of TVM properties representing a void. Used for conservative assessment of IWL seepage fate, and for estimating relationship of pit inflow vs water level.

MODFLOW-USG has the capability of directly simulating surficial fluxes from a pit lake, but with low resolution pit geometry and often results in numerical instability. For this reason, the above scenarios were developed for preliminary impact assessment, and a semi-coupled predictive scenario developed following completion of the Surface Water Assessment for more appropriate representation of long-term pit conditions (ATC Williams 2023). This memo describes the new predictive scenario (Prediction 5) and results.

Scenario definition

The surface water assessment included final void water balance modelling, incorporating simulated pit inflows as a function of water level from the groundwater model alongside surficial fluxes (rainfall, runoff and

evaporation). Two pit voids were simulated; E42/GR and E41. Water balance modelling was undertaken for a post-mining period of 1,000 years, estimating long-term fill levels of approximately 104 mAHD for E42/GR and 126 mAHD for E41. The simulated pit lake water levels are presented in Figure 1, with additional series representing the temporal discretisation adopted for the updated groundwater model scenario. Pit lake water levels show an initial rapid rise, logarithmically reducing before reaching a plateau near 100 mAHD.

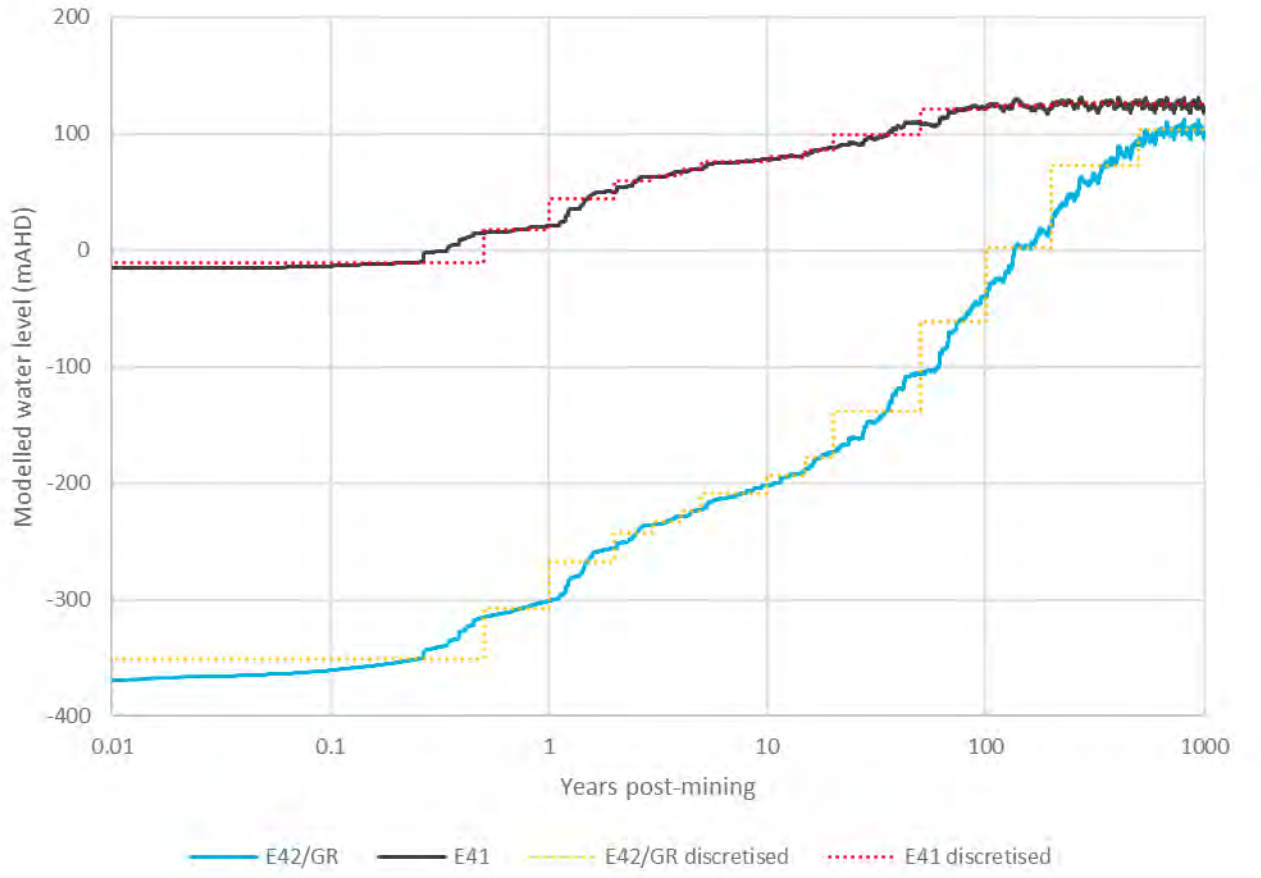


Figure 1 Simulated pit lake water level

In the groundwater model the pit lakes were simulated with the use of general head boundary (GHB) cells, with a high conductance of 10,000 m^2/day. Due to the rate of initial rise and time to reach equilibrium, the pit lake groundwater levels were simulated with stress periods starting from 6 months and gradually increasing up to 500 years. The temporal discretisation adopted in the groundwater model is presented visually in Figure 1 (see dashed yellow and red series) and tabulated in Table 1. The water level in E41 is predicted to stabilise within 50-100 years following mining, whereas E42/GR is predicted to take approximately 500 years to stabilise. The stress period design accounts for the rate of pit lake development, with a maximum stage elevation difference between stress periods of 77 m.

Table 1 Post-mining stress periods and simulated pit water level

Stress period	Start	End	Years post-mining	E42/GR (mAHD)	E41 (mAHD)
175	1/01/2041	1/07/2041	0.5	-351.0	-10.2
176	1/07/2041	1/01/2042	1	-307.5	18.1
177	1/01/2042	1/01/2043	2	-267.3	44.3

Table 1 Post-mining stress periods and simulated pit water level

Stress period	Start	End	Years post-mining	E42/GR (mAHD)	E41 (mAHD)
178	1/01/2043	1/01/2044	3	-243.3	59.3
179	1/01/2044	1/01/2045	4	-233.0	64.6
180	1/01/2045	1/01/2046	5	-224.4	70.0
181	1/01/2046	1/01/2051	10	-209.1	76.1
182	1/01/2051	1/01/2056	15	-193.8	80.8
183	1/01/2056	1/01/2061	20	-178.0	86.5
184	1/01/2061	1/01/2091	50	-138.2	98.9
185	1/01/2091	1/01/2141	100	-61.0	121.3
186	1/01/2141	1/01/2241	200	2.5	124.1
187	1/01/2241	1/01/2541	500	72.4	126.7
188	1/01/2541	1/01/3041	1,000	103.8	125.9

Predictive results

The predictive groundwater model scenario was run with base realisation parameters, and hydrographs exported showing absolute hydraulic head and cumulative drawdown against 2012 levels. Long-term predicted groundwater impacts are between the levels simulated for the dry and wet case, with varying magnitude depending on proximity to the pits. Selected hydrographs are presented in Figure 2, duplicating Figure 5.12 in the groundwater modelling report (showing the dry case including ensemble), with a series added for the base realisation recovery scenario. The difference between the base case and recovery case are most apparent for bores near the IWL; these predict slower net drawdown for the recovery case.

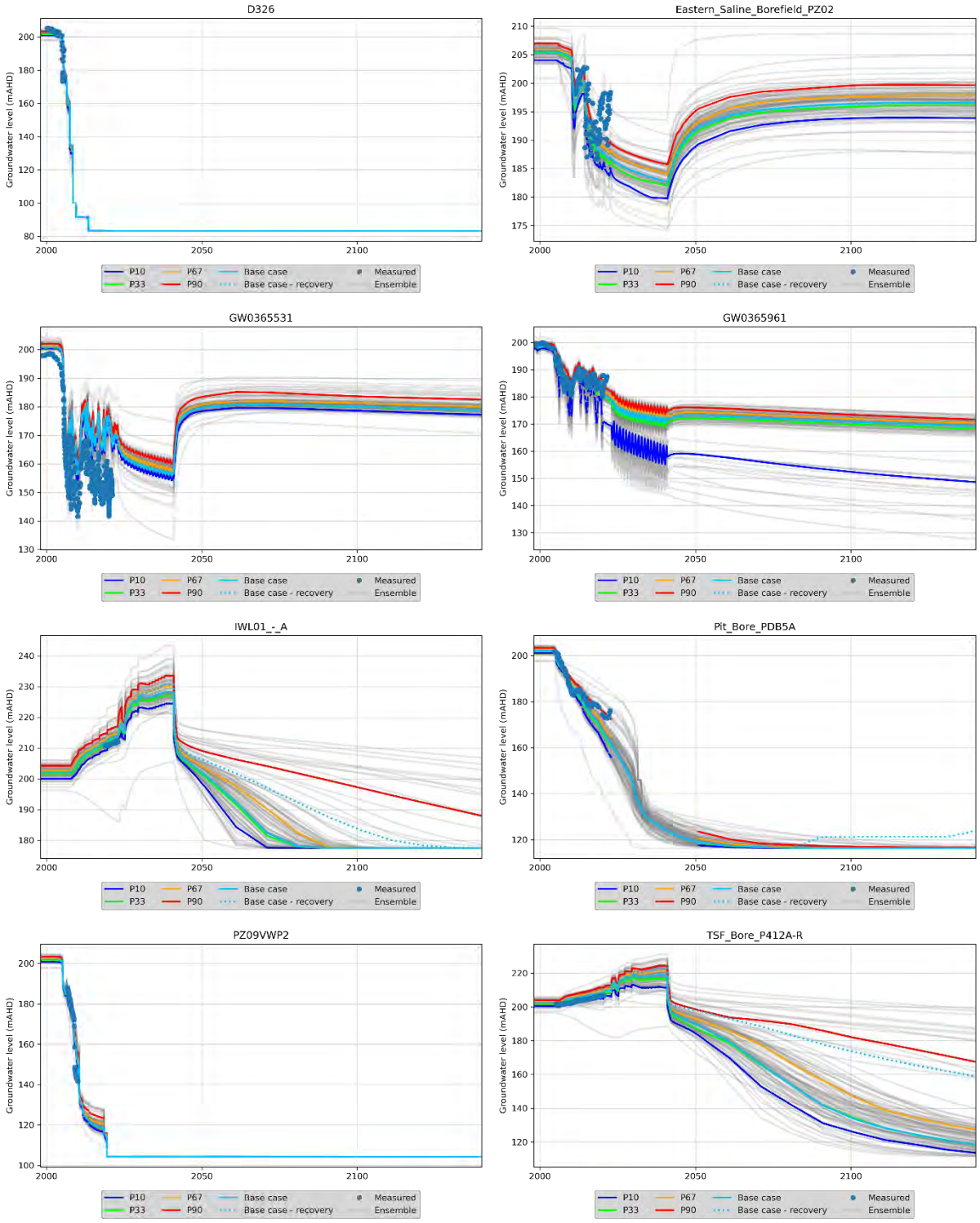


Figure 2 **Selected hydrographs over the history-matching and predictive period with recovery case**

Tom Neill
Senior Hydrogeologist / Modeller
tneill@emmconsulting.com.au

References

ATC Williams 2023, Cowal Gold Operations Open Pit Continuation Environmental Impact Statement Surface Water Assessment, prepared for EMM Consulting Pty Limited, April 2023.

Appendix F
Independent peer review

EMM
creating opportunities

25 May 2023

Watershed HydroGeo
ABN: 95 615 827 499

To:	**Doug Weatherill** EMM Level 4, 74 Pirie Street, Adelaide SA 5000	81 North St, Nowra N.S.W. AUSTRALIA 2541 phone: +61 (0)432 812 773
cc:	Katharine Bond	
From:	Will Minchin	will.minchin@watershedhg.com

Lake Cowal OPC EIS –review of Groundwater Modelling Report (May 2023)

Your Ref: J190417a provided 25/05/2023 **Our Ref:** EMM001-20230525a

1 Introduction

Will Minchin of Watershed HydroGeo was requested by EMM to review their groundwater modelling for the current Lake Cowal Gold Mine EIS (the Open Pit Continuation ["OPC"] EIS), where the modelling feeds into the overarching Groundwater Impact Assessment (GIA).

This letter is part of Task 4 (and building on Tasks 2 and 3) as agreed with EMM, and documents a second review of EMM's Groundwater Modelling Report ("the EMM report"), provided as documents/files on 19/05/2023:

- J190417a_1_Groundwater-LakeCowalOPC-EIS_GWModel_V0-7.docx
- J190417a_1_Groundwater-LakeCowalOPC-EIS_GWModel_V0-7.pdf
- along with some additional responses to Will Minchin's earlier comments and suggestions regarding EMM's V0-5 documents (provided on 05/05/2023 and reviewed by Will on 11/05/2023, and V0-6 documents provided 19/05/2023 and reviewed 24/05/23).

I emphasise that I have not reviewed the Response to Submissions on the previous Underground Development EIS by Coffey and EMM which document proposed corrective actions on the previous (and separate) mine and borefield models.

Additionally, a second document was also provided by EMM for review, being the Numerical Groundwater Modelling Scenario Addendum ("the Modelling Scenario Addendum"):

- J190417a_1_Groundwater-LakeCowalOPC-EIS_GWModel_scenario_addendum_V0_1_TN.docx

2 Review of EMM report

Initial review

Comments from the initial review were made regarding typographical errors, suggestions to improve text and figure clarity, and to include clearer links to the overarching GIA (also by EMM), along with inclusion of some summaries of significant field data from the Groundwater Assessment (e.g. hydraulic conductivity data/estimates).

The vast majority of these have been acted on by EMM prior to this current (final) review.

Current (final) review

The main comments regarding technical issues, modelling and impact assessment are documented in the table below. Some typographical errors and comments on the clarity of

text have been provided in the .DOCX version of the EMM report. Minor typographic comments are not repeated here, although comments regarding figures are tabulated below.

While the links between the Modelling Report and the GIA have improved in the latest version of the report, there remains an assumption that the reader is familiar with the content of the GIA.

Appendix A presents the model review checklist from the Australian Groundwater Modelling Guidelines ("AGMG").

Based on the review of the documentation and the AGMG checklist, some specific items are raised in below.

Reference in EMM	Text or sub-heading in EMM	Watershed comment
Section 2.3.3	Hydraulic properties	As noted in the checklist (Appendix A), confidence in the modelling would be improved through more analysis of likely hydraulic conductivities and specific yield, or even just statement of possible values from a literature review. That said, the range in parameters applied to PESTPP are plausible (other than the modelled Kh for the Lower Cowra Formation, which looks low compared to the ranges in Table 2.1.
Section 3.7.2	Recharge	As noted in the checklist (Appendix A), confidence in the modelling would be improved through more analysis of likely recharge rates, or even just statement of possible rates from literature review. That said, the range in parameters applied to PESTPP are plausible.
Section 4.2.2ii	Discussion of history-match (calibration) at compliance bores.	I note the specific commentary provided regarding simulated groundwater levels at one of the compliance bores (GW036553/1), and the mis-match at the other two compliance bores (GW036553 and GW036597 – hydrographs on p. C12 and C13 respectively in Appendix C). This is required to provide context, given that the model is subsequently used to make predictions of the likelihood of a breach of investigation/mitigation levels (Section 5.4.1).
Section 5.2	Modelled flux impacts	Modelled (predicted) flux impacts are described only by the base realisation, and not the full ensemble of 200 realisations which quantifies the likely uncertainty in a prediction. It would be useful to the regulator to understand the potential range in flux impacts, especially given that EMM have already carried out the significant amount of work required to develop and run the model ensemble.
Section 5.4.1	Discussion of future groundwater levels at compliance bores.	It is important for readers to understand the context provided (see above re: Section 4.2.2ii) as to why drawdown multipliers are used to 'scale' the predicted groundwater levels at the three compliance bores. Then, in the discussion of the likelihood of breaches of the trigger levels, based on comparison of the P90/base/P10 estimates and the observed (historical) data, I think the reader should focus more on the base/P10 estimates from the model when drawing inferences from the simulated scenarios. I think this would improve the utility of the model in regard to the regulator understanding of potential impacts.
Section 5.4.2	Discussion of future groundwater levels at GDEs.	Modelled groundwater levels (from the base realisation) are presented at the PCT locations. The discussion of drawdown here is brief. The modeller has indicated that the implications of the drawdown at PCTs are discussed further in the BDAR. I have not reviewed that.
Section 5?	Drawdown at land-holder bores	The Summary in Section 7 states that drawdown >2 m is predicted at 4 third-party bores, however there is no discussion in Section 5 as to how this was calculated. In the most recent version, the modeller included the relevant detail in Section 7, i.e. that the 4 bores identified were those with >2m drawdown in >=10% of model realisations. This is a reasonable and conservative approach, but would have preferred more detail in Section 5.

Model Scenario Addendum

I have reviewed the Addendum. Apart from suggestions related to clarity of that document and integration with the Modelling Report, there are no issues to address, other than perhaps a statement from the modellers as to whether they considering this final model scenario to be "the likely" scenario behaviour (compared to the 'Dry' and 'Fast recovery' cases.

3 IESC Uncertainty Guideline checklist

Appendix B presents the IESC Uncertainty Guideline 'Fatal Flaws' Checklist (Table 3 from the IESC document).

An assessment of whether a modelling study such as the EMM study reviewed here meets a set of criteria is subjective. For the most part, in my opinion, the modelling study meets or partially meets the requirements as set out by the IESC checklist. One item where this modelling assessment would not meet the IESC guideline:

- #8 Identifiability/sensitivity. This is not reported in the EMM report. However, in the opinion of this reviewer, the use of an ensemble precludes the requirement for a formal analysis of sensitivity and identifiability (given that parameter sensitivities are incorporated into the model predictions via a suitably sized model ensemble). As such, this is not a "fatal flaw", as might be interpreted from the name of the checklist.
- It is also not known by this reviewer whether the Proponent has engaged with regulators (#1).

Overall, the use of an ensemble method (PESTPP-IES) for history-matching and uncertainty analysis is industry-standard (or better).

4 Concluding statements

The numerical modelling work, and the reporting of that in the Modelling Report and accompanying Modelling Scenario Addendum have been carried out in a professional manner that meets contemporary industry standards. The modelling work has generally been completed in line with the Guiding Principles included in the Australian Groundwater Modelling Guidelines, the NSW SSI guidance (DPE Water, 2022), and the IESC Uncertainty Analysis Guidance Note.

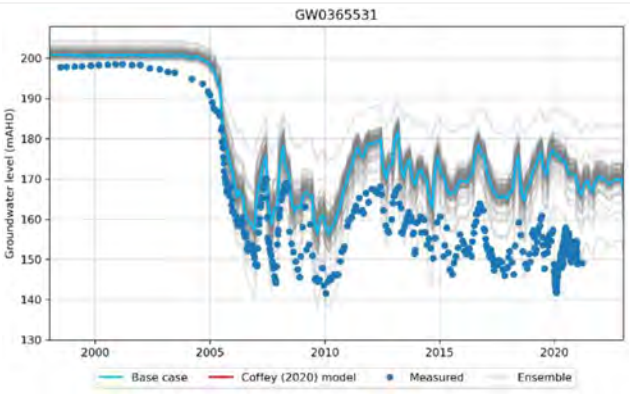
I have not identified any fatal flaws in the work which are likely to significantly affect the ability of the model to make useful predictions, especially considering the uncertainty analysis conducted.

In regard to the reporting of uncertainty, it would be useful to update the reporting to include uncertainty bounds on the flux impacts (e.g. groundwater inflow and take, loss of surface water) using the full model ensemble, as has already been done for most of the groundwater level and drawdown predictions.

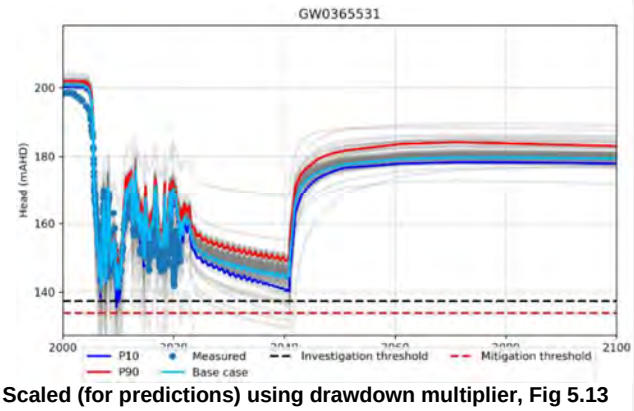
Regarding the compliance monitoring bores, as noted earlier, it is important that the reader understand the model results presented in the history-matching section and then how those model results are used to infer the likelihood of breaching trigger levels at the compliance bores.

It is preferred that more detail be included in the reporting, i.e. how the scaling was used to convert 'raw' hydrograph to scaled 'hydrographs' (in essence to explain the image below).

However, I do agree with the approach by EMM taken to carry out 'scaling' of the raw model results to improve the reliability of inferences made regarding future project-related drawdown at these compliance bores. This is especially important given that the modelling work/analysis is not the sole influence on the ability to replicate historical drawdowns at those sites – input data, by way of abstraction rates, is a significant influence, and although I have not reviewed that data, EMM note that it is likely incomplete.



Compliance bore GWLs: "raw" (from history-matching), Fig 4.8



Scaled (for predictions) using drawdown multiplier, Fig 5.13

Future works

In the future I suggest that the model be reviewed and updated at regular intervals. In the absence of recommendations in the Modelling Report, based on the findings of this review I suggest that the following items be addressed in the first such iteration:

- Improve the analysis of recharge and then the modelling recharge distribution and estimation regarding dryland and irrigation areas, as well as considering outcrop geology.
- Re-running history matching (and ensemble development) to:
  - Include further analysis of hydraulic conductivity with depth and spatially, especially in relation to the structural zone(s)/faults in the area, and that this analysis is passed to the parameterisation.
  - Review whether it is possible to include dewatering/abstraction from the underground mine as a flux target. It may not be possible, similar to the acknowledged problem that pumping rates from open cuts are not reliable re: groundwater inflow.
  - Include vertical head gradients as targets, and ensure some charting/reporting of model performance (e.g. hydrographs at nested sites or X:Y plot).
  - Focus on the simulated groundwater levels at the compliance bores in the palaeochannel (alluvial) system. (i.e. apply higher weights to the relevant observations). I raise the point that third party groundwater abstraction (and the data to support input of that in the model) is likely most important in attempting to match groundwater levels. As such, this should be attempted, but regulator review of the ability of the model to match the groundwater levels needs to acknowledge the potential difficulty in doing so.

Please contact me if further clarification is required.

Yours sincerely,

Will Minchin

0432 812 773

will.minchin@watershedhg.com

e:\wshed\proj_reviews\emm001_lakecowal\report\emm001\20230525_modellingreportrev3\20230525_lakecowal-gwmodelling_review of modelling report(v3)(may2023).docx

Appendix A: Review checklist (2012 National Guidelines)

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
1. Planning				
1.1 Are the project objectives stated?			Y	Sections 1.2-1.3
1.2 Are the model objectives stated?			Y	Section 1.5 and Table 1.1
1.3 Is it clear how the model will contribute to meeting the project objectives?				
1.4 Is a groundwater model the best option to address the project and model objectives?			Y	
1.5 Is the target model confidence-level classification stated and justified?			Y	Target class stated as Class 2-3 (Section 1.6) based on building on previous modelling + data availability.
1.6 Are the planned limitations and exclusions of the model stated?			Y	Section 3.3.1 added following initial peer review. This clearly highlights key limitations in the modelling.
2. Conceptualisation				
	Watershed HydroGeo has not reviewed the GIA report which has the full conceptual model. This review is based on the summary in the modelling report.			
2.1 Has a literature review been completed, including examination of prior investigations?			Y	Literature and model review from earlier modelling investigations is documented here.
2.2 Is the aquifer system adequately described?		Y		
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)			Y	
2.2.2a lateral extent, boundaries and …			Y	Model extent clearly shown on Figure 4.1, with text summary of inflow/outflow mechanisms (Sections 2.5 and 3.7.1).
2.2.2b …significant internal features such as faults and regional folds	N			Gilmore Fault/Suture shown on 2 x X-sections, and mapped on Figure 1.1. Not parameterised explicitly (as noted in limitations). This might be appropriate, but further analysis should be presented to justify this position.
2.2.3 aquifer geometry including layer elevations and thicknesses		Y		Layer elevation maps are clear, and there is some text re: layer thickness, but it would be helpful to map thickness of key units and/or tabulate thickness in key areas (e.g. average thickness to Section 3.5.3 (Table 3.2).
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?		Y		A brief but appropriate description of unconfined/confined/mixed conditions for alluvium/bedrock is provided in Sections 2.3.1-2.3.2.
2.3 Have data on groundwater stresses been collected and analysed?				
2.3.1 recharge from rainfall, irrigation, floods, lakes		Y		Other than statements that the contribution from rainfall is minor in comparison to surface water leakage, there is no quantification of likely recharge. However prior estimates of recharge (Table 4.1) have been reviewed, and the upper limit is equivalent to 0.9% of average rainfall for dryland areas, and 4.7% for irrigated areas. These seem

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
				appropriate. Would prefer to have seen more quantification/literature review, including consideration of geology type.
2.3.2 river or lake stage heights			Y	
2.3.3 groundwater usage (pumping, returns etc)			Y	Section 3.7.5 and 3.7.6
2.3.4 evapotranspiration		Y		Section 3.7.3 contains useful descriptions of the PE rates, noting that the potential rate of evaporation from the water table should be less than the total potential evaporation measured in a pan (given that rainfall reduces this demand).
2.3.5 other?				
2.4 Have groundwater level observations been collected and analysed?				*Assume that this is presented in the GIA*
2.4.1 selection of representative bore hydrographs				*Assume that this is presented in the GIA*
2.4.2 comparison of hydrographs				*Assume that this is presented in the GIA*
2.4.3 effect of stresses on hydrographs				*Assume that this is presented in the GIA*
2.4.4 water table maps/piezometric surfaces?				*Assume that this is presented in the GIA*
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?				*Assume that this is presented in the GIA*
2.5 Have flow observations been collected and analysed?			Y	Dewatering rates from the open cut are presented in Section 3.7.6.
2.5.1 baseflow in rivers				*Assume that this is presented in the GIA*
2.5.2 discharge in springs				*Assume that this is presented in the GIA.*
2.5.3 location of diffuse discharge areas?				*Assume that this is presented in the GIA*
2.6 Is the measurement error or data uncertainty reported?				
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	N			Measurement error not discussed – stated as a limitation.
2.6.2 spatial variability/heterogeneity of parameters		Y		Hydraulic conductivity ranges are stated (Table 2.1). Would like to have seen more re: K with depth, and possibly whether there is a correlation with fault zones.
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	N			Unimportant for this study
2.7 Have consistent data units and geometric datum been used?			Y	
2.8 Is there a clear description of the conceptual model?		Y		
2.8.1 Is there a graphical representation of the conceptual model?			Y	Figure 2.1 and 2.2.
2.8.2 Is the conceptual model based on all available, relevant data?			Y	
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?			Y	Yes. EVT rates might be slightly high, but would have little effect on predictive capability of the model (especially in ensemble)
2.9.1 Are the relevant processes identified?			Y	
2.9.2 Is justification provided for omission or simplification of processes?			Y	

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
2.10 Have alternative conceptual models been investigated?		No		Mature conceptualisation building on previous modelling and investigation.
3. Design and construction				
3.1 Is the design consistent with the conceptual model?			Y	
3.2 Is the choice of numerical method and software appropriate?			Y	
3.2.1 Are the numerical and discretisation methods appropriate?			Y	Voronoi mesh with appropriate refinement. SMS solver with HCLOSE = 0.01m.
3.2.2 Is the software reputable?			Y	Section 3.4 - MF-USG-T is industry-standard, especially for mining applications.
3.2.3 Is the software included in the archive or are references to the software provided?			Y	MF-USG-T is available for free
3.3 Are the spatial domain and discretisation appropriate?				
3.3.1 1D/2D/3D			3D	
3.3.2 lateral extent			Y	
3.3.3 layer geometry?			Y	
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?			Y	Section 3.5.2 - variable sized Voronoi mesh, refined around features of interest
3.3.5 Is the vertical discretisation appropriate? Are aquitards divided into multiple layers to model time lags of propagation of responses in the vertical?			Y	
3.4 Are the temporal domain and discretisation appropriate?			Y	Section 3.6
3.4.1 steady state or transient			Y	Mixed, pseudo SS (SP1), SS (SP2) and then subsequent TR stress periods
3.4.2 stress periods			Y	100 TR SPs for history-matching, 73 for predictive.
3.4.3 time steps?			Y	Adaptive time-stepping was used
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?			Y	There is a very slight increase in regional inflow in predictive modelling, however the drawdowns do not appear constrained or affected by this.
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?		Y		For most processes, it is good. The initial report requires some additional explanation of the use of ETS package. (ETS mainly used as a convenience re: topography including waste landforms) and also would prefer to see more analysis of recharge as noted previously. These would have minimal effect on predictions).
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?			Y	Modellers are aware of potential for boundaries to affect modelled drawdown. Slight change in inflow from regional boundaries discussed in Section 5.2.
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?		Y		The actual analysis of recharge rates is deficient, but the rates applied as ranges to the history-matching process are plausible and seem appropriate.
3.5.4 Are lateral boundaries time-invariant?			Y	Time-invariant GHBs (Section 3.7.1).

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
3.6 Are the initial conditions appropriate?			Y	Simulated via steady state stress periods with variable hydraulic properties.
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?			Y	Based on steady state model
3.6.2 Is the effect of initial conditions on key model outcomes assessed?			Y	Use of ensemble method accounts for uncertainty in initial conditions
3.6.3 How is the initial concentration of solutes obtained (when relevant)?				Not relevant
3.7 Is the numerical solution of the model adequate?				
3.7.1 Solution method/solver			Y	SMS
3.7.2 Convergence criteria			Y	HCLOSE = 0.01m
3.7.3 Numerical precision		Y		Not stated, but unimportant

4. Calibration and sensitivity

4.1 Are all available types of observations used for calibration?		Y	Y	Heads and head change. Dewatering rates not used, which is appropriate for open cut, and probably also for underground mine (see recommendation for future work).
4.1.1 Groundwater head data			Y	
4.1.2 Flux observations		Y		See comment above re: flux targets and dewatering rates.
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.		N/A		
4.2 Does the calibration methodology conform to best practice?		Y		Vertical head gradient targets not used in PEST history-matching. Modellers indicate that qualitative verification of these gradients has occurred, but this is not easily accessible or revised by the reader.
4.2.1 Parameterisation			Y	Pilot points with PESTPP-IES
4.2.2 Objective function			Y	PESTPP-IES objective function (Section 4.1.2)
4.2.3 Identifiability of parameters		N		No, but in my view, unimportant having used ensemble method.
4.2.4 Which methodology is used for model calibration?				Automated history-matching via PESTPP-IES and pilot points.
4.3 Is a sensitivity of key model outcomes assessed against?				
4.3.1 parameters			Y	Inbuilt into -IES ensemble method (for K and S).
4.3.2 boundary conditions			Y	Inbuilt into -IES ensemble method (for recharge and ET and RIV conductance).
4.3.3 initial conditions			Y	Inbuilt into -IES ensemble method (for GWLs that are responsive to the variable params and BCs).
4.3.4 stresses			Y	Inbuilt into -IES ensemble method (for recharge and ET (but not for pit dewatering)

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
4.4 Have the calibration results been adequately reported?		Y		Generally yes, with some items raised below
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?			Y	Size of charts in Fig 4.8 could be increased on A4 page, but ok in a PDF.
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	N			Report states that vertical gradients have been reviewed/verified. However there is no easily accessible way for the reader to check this.
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?			Y	Good reporting of various AGMG statistics and X:Y correlation (although these charts could be made clearer).
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?			Y	
4.5.1 spatially		Y		Most of the hydrographs indicate good degree of calibration, but the reporting of spatial calibration could be improved (Figure 4.5 is ok – even a different colour scheme for the +/-0-5m residuals would assist).
4.5.2 temporally		Y (note only one compliance bore discussed, but discussion relevant to all three)		Most of the hydrographs in Appendix C indicate good degree of calibration and consistent improvement on previous modelling. Drawdown in basement unit tends to be under-estimated in model. However that is of lower importance to key drawdown predictions (drawdown in alluvium). I note the brief discussion of the model performance (mis-match) at one of the compliance monitoring bores in Section 4.2.2ii, which is important context for the later discussion of predicted GWLs (Section 5.4.1).
4.6 Are the calibrated parameters plausible?		Y		Hydraulic conductivities from data are presented in Table 2.1 and can be compared with model ranges in Tables 4.1 and 4.4. The comparison is not easy for the reader; however most parameters are plausible, with the possible exception of Lower Cowra Kh (modelled values seem low). Specific yield estimates from field data or literature are not presented, however the modelled ranges appear plausible based on experience.
4.7 Are the water volumes and fluxes in the water balance realistic?		Y		Yes. Although flux targets are not used, comparison with dewatering rates (Table 4.3 vs Section 3.7.6 suggests plausible flux). Recharge rates are plausible.
4.8 has the model been verified?		Y		Not formally, but data used to maximise the set of calibration targets.
5. Prediction				
5.1 Are the model predictions designed in a manner that meets the model objectives?			Y	

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
5.2 Is predictive uncertainty acknowledged and addressed?	Fluxes		GWL & DDN	Addressed via ensemble method, but only for groundwater levels and drawdown (not flux).
5.3 Are the assumed climatic stresses appropriate?		Y		Seasonal long-term averages used for predictive period, plus the use of two end-members for pit recovery can be considered a proxy for extreme wet/dry conditions. The additional scenario reported in the Addendum is considered a 'more likely' scenario for pit water level recovery.
5.4 Is a null scenario defined?			Y	Yes, two baseline scenarios used to estimate incremental and cumulative impacts via subtraction.
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?			Y	
5.5.1 Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there reference to the associated reduction in model confidence?			Y	Private bore pumping is similar in historical and future periods, and mine dewatering will increase but not markedly.
5.5.2 Are well losses accounted for when estimating maximum pumping rates per well?				Not required.
5.5.3 Is the temporal scale of the predictions commensurate with the calibrated model? If not, is there reference to the associated reduction in model confidence?			Y	This was also assessed by the modellers in Table 1.2
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?			Y	
5.6 Do the prediction results meet the stated objectives?		Y		Brief discussion of drawdown effects at compliance bores, GDEs and third-party bores has been added since initial review, and this was necessary. Some more detailed comments are made in the body of my review.
5.7 Are the components of the predicted mass balance realistic?				
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?				Not checked.
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?				Not checked
5.7.3 Are there any anomalous boundary fluxes due to superposition of head dependent sinks (e.g. evapotranspiration) on head-dependent boundary cells (Type 1 or 3 boundary conditions)?		Y		None are evident from reporting
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?			Y	Defined as a small percentage of rainfall.
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?				Cannot determine from reporting
5.8 Has particle tracking been considered as an alternative to solute transport modelling?			Y	Section 5.5

6. Uncertainty

6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	Fluxes		GWL & DDN	GWLs and drawdown contours presented with probabilities based on ensemble.

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
				Fluxes – only presented as single number from base realisation.
6.2 Is the model with minimum prediction-error variance chosen for each prediction?			Y	Base realisation is selected for fluxes, and Fig 4.13 demonstrates that it is close to minimum error variance across all metrics. Full ensemble used for drawdown predictions.
6.3 Are the sources of uncertainty discussed?		Y		
6.3.1 measurement of uncertainty of observations and parameters		Y		Brief discussion in modelling report (mine dewatering rates, register bore pumping rates), and the potential for error in permeability measurements, but not for groundwater level. *The modeller has indicated that this is discussed in the GIA (but this has not been seen by this reviewer.*
6.3.2 structural or model uncertainty			Y	Uncertainty associated with spatial and temporal discretisation, EPM and parameters discussed.
6.4 Is the approach to estimation of uncertainty described and appropriate?		Y	Y	Ensemble method with 200 realisations is best practice. However only used to quantify possible range in drawdown, not flux effects.
6.5 Are there useful depictions of uncertainty?			Y	Range in predicted GWLs and drawdown contours illustrated clearly.

7. Solute transport

7.1 Has all available data on the solute distributions, sources and transport processes been collected and analysed?				Not relevant – particle tracking employed.
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?			Y	Same model domain
7.3 Is the choice of numerical method and software appropriate?			Y	MP3DU for particle tracking with MF-USG-T
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?			Y	Not relevant
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?				Not relevant
7.6 Are the solver and its parameters appropriate for the problem under consideration?				Not relevant
7.7 Has the relative importance of advection, dispersion and diffusion been assessed?				Not relevant
7.8 Has an assessment been made of the need to consider variable density conditions?				Not relevant here– particle tracking employed, and density effects absent.
7.9 Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?				Not relevant – particle tracking employed.
7.10 Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?				Not relevant
7.11 Is the calibration based on meaningful metrics?				Not relevant

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
7.12 Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?				Not relevant
7.13 Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?				Not relevant
7.14 Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?				Not relevant
7.15 Does the report address the role of geologic heterogeneity on solute concentration distributions?				Not relevant
8. Surface water–groundwater interaction				
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?			Y	
8.2 Is the implementation of surface water–groundwater interaction appropriate?			Y	Yes, interaction with creeks and Lake Cowal represented appropriately. Nerang Cowal not explicitly repeated as a boundary condition based on conceptual model (very infrequent ponding)– this is appropriate.
8.3 Is the groundwater model coupled with a surface water model?				No, but not required
8.3.1 Is the adopted approach appropriate?				Not relevant
8.3.2 Have appropriate time steps and stress periods been adopted?				Not relevant
8.3.3 Are the interface fluxes consistent between the groundwater and surface water models?				Not relevant

Appendix B: Review checklist for uncertainty assessment

(IESC Guideline Table 3—Fatal flaws review checklist for uncertainty assessment

1	Is there evidence of engagement ('without prejudice') between the project proponent and regulatory agencies, from the project outset and at subsequent key stages: • to discuss and agree on the project objectives and the modelling objectives? • to discuss and agree on the uncertainty analysis methodologies, including the nature and scope of the (minimum requirement) qualitative uncertainty analysis, and the quantitative uncertainty analysis for high-risk projects? • to review the reporting on the modelling and uncertainty analyses? • to agree on justifications of assumptions/criteria applied to implement the methodology? • to understand the implications of the results in terms of environmental decision-making? • to identify whether an independent technical review of the modelling and/or the uncertainty analysis is warranted?
2	Is the modelling and uncertainty analysis methodology designed to provide information for decision makers on the effects of uncertainty on the project objectives (echoing the definition of risk in AS/NZS ISO31000:2009) and on the effects of potential bias?
3	Are the adopted conceptual model, complexity–simplicity balance and applied modelling package capabilities commensurate with the overall risk context and the models purpose of investigating the uncertainty/risk issues (i.e. based on the evidence available of engagement identified in item 1)?
4	Has the uncertainty assessment and modelling methodology been designed and implemented using all the available data? Detailed consideration of the hydrological stressors arising from the development and of natural stressors, including climate variability, and unbiased consideration of water-related asset values and causal pathways for potential impacts (direct, indirect and cumulative) should be provided.
5	Where history-match conditional calibration is undertaken, has it minimised non-uniqueness and error variance (using approaches recommended in the AGMG)? If not, is a reasoned justification provided? Is an acceptable level of model-to-measurement mismatch defined for the conditional calibration?
6	Are all simulations consistent with all relevant information/data (using approaches recommended in the AGMG)? If not, is a reasoned justification provided?
7	Has the model been submitted to stress testing in which a number of extreme parameter combinations (representing a computationally intensive automated conditional calibration or stochastic model evaluation) are tested for model convergence?
8	Has a parameter sensitivity analysis and/or a parameter identifiability analysis been completed to identify which parameters can be constrained by the available observations and which parameters affect the simulations the most? Are the implications discussed?
9	Have all reports been prepared in an open, honest and transparent way that is: • open to independent scrutiny and not prone to misinterpretation • based on agreed and transparent model objectives • tailored to decision-makers' needs (focusing on messages relevant to their decisions) • presented in plain and clear language (precise, jargon-free, calibrated), with useful graphics.

Australia

SYDNEY
Ground floor 20 Chandos Street
St Leonards NSW 2065
T 02 9493 9500

NEWCASTLE
Level 3 175 Scott Street
Newcastle NSW 2300
T 02 4907 4800

BRISBANE
Level 1 87 Wickham Terrace
Spring Hill QLD 4000
T 07 3648 1200

CANBERRA
Level 2 Suite 2.04
15 London Circuit
Canberra City ACT 2601

ADELAIDE
Level 4 74 Pirie Street
Adelaide SA 5000
T 08 8232 2253

MELBOURNE
Suite 8.03 Level 8 454 Collins Street
Melbourne VIC 3000
T 03 9993 1900

PERTH
Suite 9.02 Level 9 109 St Georges Terrace
Perth WA 6000

Canada

TORONTO
2345 Yonge Street Suite 300
Toronto ON M4P 2E5

VANCOUVER
60 W 6th Ave Suite 200
Vancouver BC V5Y 1K1

linkedin.com/company/emm-consulting-pty-limited

emmconsulting.com.au

Attachment D

Groundwater model peer review

EMM
creating opportunities

25 May 2023

Watershed HydroGeo
ABN: 95 615 827 499

To:	**Doug Weatherill** EMM Level 4, 74 Pirie Street, Adelaide SA 5000	81 North St, Nowra N.S.W. AUSTRALIA 2541 phone: +61 (0)432 812 773
cc:	Katharine Bond	
From:	Will Minchin	will.minchin@watershedhg.com

Lake Cowal OPC EIS –review of Groundwater Modelling Report (May 2023)

Your Ref: J190417a provided 25/05/2023 **Our Ref:** EMM001-20230525a

1 Introduction

Will Minchin of Watershed HydroGeo was requested by EMM to review their groundwater modelling for the current Lake Cowal Gold Mine EIS (the Open Pit Continuation ["OPC"] EIS), where the modelling feeds into the overarching Groundwater Impact Assessment (GIA).

This letter is part of Task 4 (and building on Tasks 2 and 3) as agreed with EMM, and documents a second review of EMM's Groundwater Modelling Report ("the EMM report"), provided as documents/files on 19/05/2023:

- J190417a_1_Groundwater-LakeCowalOPC-EIS_GWModel_V0-7.docx
- J190417a_1_Groundwater-LakeCowalOPC-EIS_GWModel_V0-7.pdf
- along with some additional responses to Will Minchin's earlier comments and suggestions regarding EMM's V0-5 documents (provided on 05/05/2023 and reviewed by Will on 11/05/2023, and V0-6 documents provided 19/05/2023 and reviewed 24/05/23).

I emphasise that I have not reviewed the Response to Submissions on the previous Underground Development EIS by Coffey and EMM which document proposed corrective actions on the previous (and separate) mine and borefield models.

Additionally, a second document was also provided by EMM for review, being the Numerical Groundwater Modelling Scenario Addendum ("the Modelling Scenario Addendum"):

- J190417a_1_Groundwater-LakeCowalOPC-EIS_GWModel_scenario_addendum_V0_1_TN.docx

2 Review of EMM report

Initial review

Comments from the initial review were made regarding typographical errors, suggestions to improve text and figure clarity, and to include clearer links to the overarching GIA (also by EMM), along with inclusion of some summaries of significant field data from the Groundwater Assessment (e.g. hydraulic conductivity data/estimates).

The vast majority of these have been acted on by EMM prior to this current (final) review.

Current (final) review

The main comments regarding technical issues, modelling and impact assessment are documented in the table below. Some typographical errors and comments on the clarity of

text have been provided in the .DOCX version of the EMM report. Minor typographic comments are not repeated here, although comments regarding figures are tabulated below.

While the links between the Modelling Report and the GIA have improved in the latest version of the report, there remains an assumption that the reader is familiar with the content of the GIA.

Appendix A presents the model review checklist from the Australian Groundwater Modelling Guidelines ("AGMG").

Based on the review of the documentation and the AGMG checklist, some specific items are raised in below.

Reference in EMM	Text or sub-heading in EMM	Watershed comment
Section 2.3.3	Hydraulic properties	As noted in the checklist (Appendix A), confidence in the modelling would be improved through more analysis of likely hydraulic conductivities and specific yield, or even just statement of possible values from a literature review. That said, the range in parameters applied to PESTPP are plausible (other than the modelled Kh for the Lower Cowra Formation, which looks low compared to the ranges in Table 2.1.
Section 3.7.2	Recharge	As noted in the checklist (Appendix A), confidence in the modelling would be improved through more analysis of likely recharge rates, or even just statement of possible rates from literature review. That said, the range in parameters applied to PESTPP are plausible.
Section 4.2.2ii	Discussion of history-match (calibration) at compliance bores.	I note the specific commentary provided regarding simulated groundwater levels at one of the compliance bores (GW036553/1), and the mis-match at the other two compliance bores (GW036553 and GW036597 – hydrographs on p. C12 and C13 respectively in Appendix C). This is required to provide context, given that the model is subsequently used to make predictions of the likelihood of a breach of investigation/mitigation levels (Section 5.4.1).
Section 5.2	Modelled flux impacts	Modelled (predicted) flux impacts are described only by the base realisation, and not the full ensemble of 200 realisations which quantifies the likely uncertainty in a prediction. It would be useful to the regulator to understand the potential range in flux impacts, especially given that EMM have already carried out the significant amount of work required to develop and run the model ensemble.
Section 5.4.1	Discussion of future groundwater levels at compliance bores.	It is important for readers to understand the context provided (see above re: Section 4.2.2ii) as to why drawdown multipliers are used to 'scale' the predicted groundwater levels at the three compliance bores. Then, in the discussion of the likelihood of breaches of the trigger levels, based on comparison of the P90/base/P10 estimates and the observed (historical) data, I think the reader should focus more on the base/P10 estimates from the model when drawing inferences from the simulated scenarios. I think this would improve the utility of the model in regard to the regulator understanding of potential impacts.
Section 5.4.2	Discussion of future groundwater levels at GDEs.	Modelled groundwater levels (from the base realisation) are presented at the PCT locations. The discussion of drawdown here is brief. The modeller has indicated that the implications of the drawdown at PCTs are discussed further in the BDAR. I have not reviewed that.
Section 5?	Drawdown at land-holder bores	The Summary in Section 7 states that drawdown >2 m is predicted at 4 third-party bores, however there is no discussion in Section 5 as to how this was calculated. In the most recent version, the modeller included the relevant detail in Section 7, i.e. that the 4 bores identified were those with >2m drawdown in >=10% of model realisations. This is a reasonable and conservative approach, but would have preferred more detail in Section 5.

Model Scenario Addendum

I have reviewed the Addendum. Apart from suggestions related to clarity of that document and integration with the Modelling Report, there are no issues to address, other than perhaps a statement from the modellers as to whether they considering this final model scenario to be "the likely" scenario behaviour (compared to the 'Dry' and 'Fast recovery' cases.

3 IESC Uncertainty Guideline checklist

Appendix B presents the IESC Uncertainty Guideline 'Fatal Flaws' Checklist (Table 3 from the IESC document).

An assessment of whether a modelling study such as the EMM study reviewed here meets a set of criteria is subjective. For the most part, in my opinion, the modelling study meets or partially meets the requirements as set out by the IESC checklist. One item where this modelling assessment would not meet the IESC guideline:

- #8 Identifiability/sensitivity. This is not reported in the EMM report. However, in the opinion of this reviewer, the use of an ensemble precludes the requirement for a formal analysis of sensitivity and identifiability (given that parameter sensitivities are incorporated into the model predictions via a suitably sized model ensemble). As such, this is not a "fatal flaw", as might be interpreted from the name of the checklist.
- It is also not known by this reviewer whether the Proponent has engaged with regulators (#1).

Overall, the use of an ensemble method (PESTPP-IES) for history-matching and uncertainty analysis is industry-standard (or better).

4 Concluding statements

The numerical modelling work, and the reporting of that in the Modelling Report and accompanying Modelling Scenario Addendum have been carried out in a professional manner that meets contemporary industry standards. The modelling work has generally been completed in line with the Guiding Principles included in the Australian Groundwater Modelling Guidelines, the NSW SSI guidance (DPE Water, 2022), and the IESC Uncertainty Analysis Guidance Note.

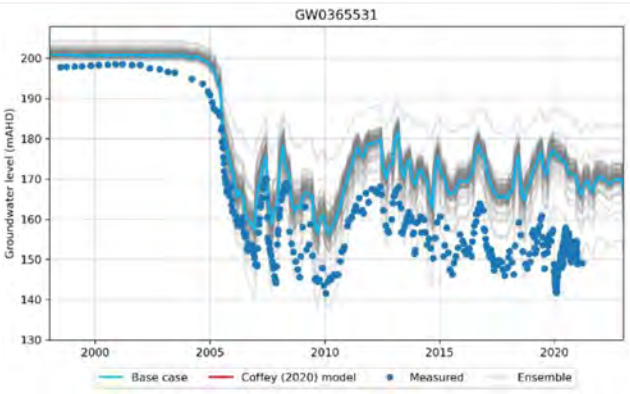
I have not identified any fatal flaws in the work which are likely to significantly affect the ability of the model to make useful predictions, especially considering the uncertainty analysis conducted.

In regard to the reporting of uncertainty, it would be useful to update the reporting to include uncertainty bounds on the flux impacts (e.g. groundwater inflow and take, loss of surface water) using the full model ensemble, as has already been done for most of the groundwater level and drawdown predictions.

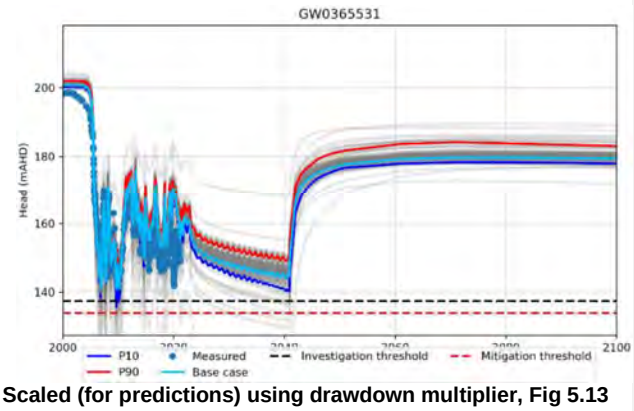
Regarding the compliance monitoring bores, as noted earlier, it is important that the reader understand the model results presented in the history-matching section and then how those model results are used to infer the likelihood of breaching trigger levels at the compliance bores.

It is preferred that more detail be included in the reporting, i.e. how the scaling was used to convert 'raw' hydrograph to scaled 'hydrographs' (in essence to explain the image below).

However, I do agree with the approach by EMM taken to carry out 'scaling' of the raw model results to improve the reliability of inferences made regarding future project-related drawdown at these compliance bores. This is especially important given that the modelling work/analysis is not the sole influence on the ability to replicate historical drawdowns at those sites – input data, by way of abstraction rates, is a significant influence, and although I have not reviewed that data, EMM note that it is likely incomplete.



Compliance bore GWLs: "raw" (from history-matching), Fig 4.8



Scaled (for predictions) using drawdown multiplier, Fig 5.13

Future works

In the future I suggest that the model be reviewed and updated at regular intervals. In the absence of recommendations in the Modelling Report, based on the findings of this review I suggest that the following items be addressed in the first such iteration:

- Improve the analysis of recharge and then the modelling recharge distribution and estimation regarding dryland and irrigation areas, as well as considering outcrop geology.
- Re-running history matching (and ensemble development) to:
  - Include further analysis of hydraulic conductivity with depth and spatially, especially in relation to the structural zone(s)/faults in the area, and that this analysis is passed to the parameterisation.
  - Review whether it is possible to include dewatering/abstraction from the underground mine as a flux target. It may not be possible, similar to the acknowledged problem that pumping rates from open cuts are not reliable re: groundwater inflow.
  - Include vertical head gradients as targets, and ensure some charting/reporting of model performance (e.g. hydrographs at nested sites or X:Y plot).
  - Focus on the simulated groundwater levels at the compliance bores in the palaeochannel (alluvial) system. (i.e. apply higher weights to the relevant observations). I raise the point that third party groundwater abstraction (and the data to support input of that in the model) is likely most important in attempting to match groundwater levels. As such, this should be attempted, but regulator review of the ability of the model to match the groundwater levels needs to acknowledge the potential difficulty in doing so.

Please contact me if further clarification is required.

Yours sincerely,

Will Minchin

0432 812 773

will.minchin@watershedhg.com

e:\wshed\proj_reviews\emm001_lakecowal\report\emm001\20230525_modellingreportrev3\20230525_lakecowal-gwmodelling_review of modelling report(v3)(may2023).docx

Appendix A: Review checklist (2012 National Guidelines)

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
1. Planning				
1.1 Are the project objectives stated?			Y	Sections 1.2-1.3
1.2 Are the model objectives stated?			Y	Section 1.5 and Table 1.1
1.3 Is it clear how the model will contribute to meeting the project objectives?				
1.4 Is a groundwater model the best option to address the project and model objectives?			Y	
1.5 Is the target model confidence-level classification stated and justified?			Y	Target class stated as Class 2-3 (Section 1.6) based on building on previous modelling + data availability.
1.6 Are the planned limitations and exclusions of the model stated?			Y	Section 3.3.1 added following initial peer review. This clearly highlights key limitations in the modelling.
2. Conceptualisation				
	Watershed HydroGeo has not reviewed the GIA report which has the full conceptual model. This review is based on the summary in the modelling report.			
2.1 Has a literature review been completed, including examination of prior investigations?			Y	Literature and model review from earlier modelling investigations is documented here.
2.2 Is the aquifer system adequately described?		Y		
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)			Y	
2.2.2a lateral extent, boundaries and …			Y	Model extent clearly shown on Figure 4.1, with text summary of inflow/outflow mechanisms (Sections 2.5 and 3.7.1).
2.2.2b …significant internal features such as faults and regional folds	N			Gilmore Fault/Suture shown on 2 x X-sections, and mapped on Figure 1.1. Not parameterised explicitly (as noted in limitations). This might be appropriate, but further analysis should be presented to justify this position.
2.2.3 aquifer geometry including layer elevations and thicknesses		Y		Layer elevation maps are clear, and there is some text re: layer thickness, but it would be helpful to map thickness of key units and/or tabulate thickness in key areas (e.g. average thickness to Section 3.5.3 (Table 3.2).
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?		Y		A brief but appropriate description of unconfined/confined/mixed conditions for alluvium/bedrock is provided in Sections 2.3.1-2.3.2.
2.3 Have data on groundwater stresses been collected and analysed?				
2.3.1 recharge from rainfall, irrigation, floods, lakes		Y		Other than statements that the contribution from rainfall is minor in comparison to surface water leakage, there is no quantification of likely recharge. However prior estimates of recharge (Table 4.1) have been reviewed, and the upper limit is equivalent to 0.9% of average rainfall for dryland areas, and 4.7% for irrigated areas. These seem

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
				appropriate. Would prefer to have seen more quantification/literature review, including consideration of geology type.
2.3.2 river or lake stage heights			Y	
2.3.3 groundwater usage (pumping, returns etc)			Y	Section 3.7.5 and 3.7.6
2.3.4 evapotranspiration		Y		Section 3.7.3 contains useful descriptions of the PE rates, noting that the potential rate of evaporation from the water table should be less than the total potential evaporation measured in a pan (given that rainfall reduces this demand).
2.3.5 other?				
2.4 Have groundwater level observations been collected and analysed?				*Assume that this is presented in the GIA*
2.4.1 selection of representative bore hydrographs				*Assume that this is presented in the GIA*
2.4.2 comparison of hydrographs				*Assume that this is presented in the GIA*
2.4.3 effect of stresses on hydrographs				*Assume that this is presented in the GIA*
2.4.4 water table maps/piezometric surfaces?				*Assume that this is presented in the GIA*
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?				*Assume that this is presented in the GIA*
2.5 Have flow observations been collected and analysed?			Y	Dewatering rates from the open cut are presented in Section 3.7.6.
2.5.1 baseflow in rivers				*Assume that this is presented in the GIA*
2.5.2 discharge in springs				*Assume that this is presented in the GIA.*
2.5.3 location of diffuse discharge areas?				*Assume that this is presented in the GIA*
2.6 Is the measurement error or data uncertainty reported?				
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	N			Measurement error not discussed – stated as a limitation.
2.6.2 spatial variability/heterogeneity of parameters		Y		Hydraulic conductivity ranges are stated (Table 2.1). Would like to have seen more re: K with depth, and possibly whether there is a correlation with fault zones.
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	N			Unimportant for this study
2.7 Have consistent data units and geometric datum been used?			Y	
2.8 Is there a clear description of the conceptual model?		Y		
2.8.1 Is there a graphical representation of the conceptual model?			Y	Figure 2.1 and 2.2.
2.8.2 Is the conceptual model based on all available, relevant data?			Y	
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?			Y	Yes. EVT rates might be slightly high, but would have little effect on predictive capability of the model (especially in ensemble)
2.9.1 Are the relevant processes identified?			Y	
2.9.2 Is justification provided for omission or simplification of processes?			Y	

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
2.10 Have alternative conceptual models been investigated?		No		Mature conceptualisation building on previous modelling and investigation.
3. Design and construction				
3.1 Is the design consistent with the conceptual model?			Y	
3.2 Is the choice of numerical method and software appropriate?			Y	
3.2.1 Are the numerical and discretisation methods appropriate?			Y	Voronoi mesh with appropriate refinement. SMS solver with HCLOSE = 0.01m.
3.2.2 Is the software reputable?			Y	Section 3.4 - MF-USG-T is industry-standard, especially for mining applications.
3.2.3 Is the software included in the archive or are references to the software provided?			Y	MF-USG-T is available for free
3.3 Are the spatial domain and discretisation appropriate?				
3.3.1 1D/2D/3D			3D	
3.3.2 lateral extent			Y	
3.3.3 layer geometry?			Y	
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?			Y	Section 3.5.2 - variable sized Voronoi mesh, refined around features of interest
3.3.5 Is the vertical discretisation appropriate? Are aquitards divided into multiple layers to model time lags of propagation of responses in the vertical?			Y	
3.4 Are the temporal domain and discretisation appropriate?			Y	Section 3.6
3.4.1 steady state or transient			Y	Mixed, pseudo SS (SP1), SS (SP2) and then subsequent TR stress periods
3.4.2 stress periods			Y	100 TR SPs for history-matching, 73 for predictive.
3.4.3 time steps?			Y	Adaptive time-stepping was used
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?			Y	There is a very slight increase in regional inflow in predictive modelling, however the drawdowns do not appear constrained or affected by this.
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?		Y		For most processes, it is good. The initial report requires some additional explanation of the use of ETS package. (ETS mainly used as a convenience re: topography including waste landforms) and also would prefer to see more analysis of recharge as noted previously. These would have minimal effect on predictions).
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?			Y	Modellers are aware of potential for boundaries to affect modelled drawdown. Slight change in inflow from regional boundaries discussed in Section 5.2.
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?		Y		The actual analysis of recharge rates is deficient, but the rates applied as ranges to the history-matching process are plausible and seem appropriate.
3.5.4 Are lateral boundaries time-invariant?			Y	Time-invariant GHBs (Section 3.7.1).

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
3.6 Are the initial conditions appropriate?			Y	Simulated via steady state stress periods with variable hydraulic properties.
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?			Y	Based on steady state model
3.6.2 Is the effect of initial conditions on key model outcomes assessed?			Y	Use of ensemble method accounts for uncertainty in initial conditions
3.6.3 How is the initial concentration of solutes obtained (when relevant)?				Not relevant
3.7 Is the numerical solution of the model adequate?				
3.7.1 Solution method/solver			Y	SMS
3.7.2 Convergence criteria			Y	HCLOSE = 0.01m
3.7.3 Numerical precision		Y		Not stated, but unimportant

4. Calibration and sensitivity

4.1 Are all available types of observations used for calibration?		Y	Y	Heads and head change. Dewatering rates not used, which is appropriate for open cut, and probably also for underground mine (see recommendation for future work).
4.1.1 Groundwater head data			Y	
4.1.2 Flux observations		Y		See comment above re: flux targets and dewatering rates.
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.		N/A		
4.2 Does the calibration methodology conform to best practice?		Y		Vertical head gradient targets not used in PEST history-matching. Modellers indicate that qualitative verification of these gradients has occurred, but this is not easily accessible or revised by the reader.
4.2.1 Parameterisation			Y	Pilot points with PESTPP-IES
4.2.2 Objective function			Y	PESTPP-IES objective function (Section 4.1.2)
4.2.3 Identifiability of parameters		N		No, but in my view, unimportant having used ensemble method.
4.2.4 Which methodology is used for model calibration?				Automated history-matching via PESTPP-IES and pilot points.
4.3 Is a sensitivity of key model outcomes assessed against?				
4.3.1 parameters			Y	Inbuilt into -IES ensemble method (for K and S).
4.3.2 boundary conditions			Y	Inbuilt into -IES ensemble method (for recharge and ET and RIV conductance).
4.3.3 initial conditions			Y	Inbuilt into -IES ensemble method (for GWLs that are responsive to the variable params and BCs).
4.3.4 stresses			Y	Inbuilt into -IES ensemble method (for recharge and ET (but not for pit dewatering)

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
4.4 Have the calibration results been adequately reported?		Y		Generally yes, with some items raised below
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?			Y	Size of charts in Fig 4.8 could be increased on A4 page, but ok in a PDF.
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	N			Report states that vertical gradients have been reviewed/verified. However there is no easily accessible way for the reader to check this.
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?			Y	Good reporting of various AGMG statistics and X:Y correlation (although these charts could be made clearer).
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?			Y	
4.5.1 spatially		Y		Most of the hydrographs indicate good degree of calibration, but the reporting of spatial calibration could be improved (Figure 4.5 is ok – even a different colour scheme for the +/-0-5m residuals would assist).
4.5.2 temporally		Y (note only one compliance bore discussed, but discussion relevant to all three)		Most of the hydrographs in Appendix C indicate good degree of calibration and consistent improvement on previous modelling. Drawdown in basement unit tends to be under-estimated in model. However that is of lower importance to key drawdown predictions (drawdown in alluvium). I note the brief discussion of the model performance (mis-match) at one of the compliance monitoring bores in Section 4.2.2ii, which is important context for the later discussion of predicted GWLs (Section 5.4.1).
4.6 Are the calibrated parameters plausible?		Y		Hydraulic conductivities from data are presented in Table 2.1 and can be compared with model ranges in Tables 4.1 and 4.4. The comparison is not easy for the reader; however most parameters are plausible, with the possible exception of Lower Cowra Kh (modelled values seem low). Specific yield estimates from field data or literature are not presented, however the modelled ranges appear plausible based on experience.
4.7 Are the water volumes and fluxes in the water balance realistic?		Y		Yes. Although flux targets are not used, comparison with dewatering rates (Table 4.3 vs Section 3.7.6 suggests plausible flux). Recharge rates are plausible.
4.8 has the model been verified?		Y		Not formally, but data used to maximise the set of calibration targets.
5. Prediction				
5.1 Are the model predictions designed in a manner that meets the model objectives?			Y	

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
5.2 Is predictive uncertainty acknowledged and addressed?	Fluxes		GWL & DDN	Addressed via ensemble method, but only for groundwater levels and drawdown (not flux).
5.3 Are the assumed climatic stresses appropriate?		Y		Seasonal long-term averages used for predictive period, plus the use of two end-members for pit recovery can be considered a proxy for extreme wet/dry conditions. The additional scenario reported in the Addendum is considered a 'more likely' scenario for pit water level recovery.
5.4 Is a null scenario defined?			Y	Yes, two baseline scenarios used to estimate incremental and cumulative impacts via subtraction.
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?			Y	
5.5.1 Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there reference to the associated reduction in model confidence?			Y	Private bore pumping is similar in historical and future periods, and mine dewatering will increase but not markedly.
5.5.2 Are well losses accounted for when estimating maximum pumping rates per well?				Not required.
5.5.3 Is the temporal scale of the predictions commensurate with the calibrated model? If not, is there reference to the associated reduction in model confidence?			Y	This was also assessed by the modellers in Table 1.2
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?			Y	
5.6 Do the prediction results meet the stated objectives?		Y		Brief discussion of drawdown effects at compliance bores, GDEs and third-party bores has been added since initial review, and this was necessary. Some more detailed comments are made in the body of my review.
5.7 Are the components of the predicted mass balance realistic?				
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?				Not checked.
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?				Not checked
5.7.3 Are there any anomalous boundary fluxes due to superposition of head dependent sinks (e.g. evapotranspiration) on head-dependent boundary cells (Type 1 or 3 boundary conditions)?		Y		None are evident from reporting
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?			Y	Defined as a small percentage of rainfall.
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?				Cannot determine from reporting
5.8 Has particle tracking been considered as an alternative to solute transport modelling?			Y	Section 5.5

6. Uncertainty

6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	Fluxes		GWL & DDN	GWLs and drawdown contours presented with probabilities based on ensemble.

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
				Fluxes – only presented as single number from base realisation.
6.2 Is the model with minimum prediction-error variance chosen for each prediction?			Y	Base realisation is selected for fluxes, and Fig 4.13 demonstrates that it is close to minimum error variance across all metrics. Full ensemble used for drawdown predictions.
6.3 Are the sources of uncertainty discussed?		Y		
6.3.1 measurement of uncertainty of observations and parameters		Y		Brief discussion in modelling report (mine dewatering rates, register bore pumping rates), and the potential for error in permeability measurements, but not for groundwater level. *The modeller has indicated that this is discussed in the GIA (but this has not been seen by this reviewer.*
6.3.2 structural or model uncertainty			Y	Uncertainty associated with spatial and temporal discretisation, EPM and parameters discussed.
6.4 Is the approach to estimation of uncertainty described and appropriate?		Y	Y	Ensemble method with 200 realisations is best practice. However only used to quantify possible range in drawdown, not flux effects.
6.5 Are there useful depictions of uncertainty?			Y	Range in predicted GWLs and drawdown contours illustrated clearly.

7. Solute transport

7.1 Has all available data on the solute distributions, sources and transport processes been collected and analysed?				Not relevant – particle tracking employed.
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?			Y	Same model domain
7.3 Is the choice of numerical method and software appropriate?			Y	MP3DU for particle tracking with MF-USG-T
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?			Y	Not relevant
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?				Not relevant
7.6 Are the solver and its parameters appropriate for the problem under consideration?				Not relevant
7.7 Has the relative importance of advection, dispersion and diffusion been assessed?				Not relevant
7.8 Has an assessment been made of the need to consider variable density conditions?				Not relevant here– particle tracking employed, and density effects absent.
7.9 Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?				Not relevant – particle tracking employed.
7.10 Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?				Not relevant
7.11 Is the calibration based on meaningful metrics?				Not relevant

Review questions	*No / Poor*	*Adeq -uate*	*Yes / Good*	*Comment*
7.12 Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?				Not relevant
7.13 Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?				Not relevant
7.14 Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?				Not relevant
7.15 Does the report address the role of geologic heterogeneity on solute concentration distributions?				Not relevant
8. Surface water–groundwater interaction				
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?			Y	
8.2 Is the implementation of surface water–groundwater interaction appropriate?			Y	Yes, interaction with creeks and Lake Cowal represented appropriately. Nerang Cowal not explicitly repeated as a boundary condition based on conceptual model (very infrequent ponding)– this is appropriate.
8.3 Is the groundwater model coupled with a surface water model?				No, but not required
8.3.1 Is the adopted approach appropriate?				Not relevant
8.3.2 Have appropriate time steps and stress periods been adopted?				Not relevant
8.3.3 Are the interface fluxes consistent between the groundwater and surface water models?				Not relevant

Appendix B: Review checklist for uncertainty assessment

(IESC Guideline Table 3—Fatal flaws review checklist for uncertainty assessment

1	Is there evidence of engagement ('without prejudice') between the project proponent and regulatory agencies, from the project outset and at subsequent key stages: • to discuss and agree on the project objectives and the modelling objectives? • to discuss and agree on the uncertainty analysis methodologies, including the nature and scope of the (minimum requirement) qualitative uncertainty analysis, and the quantitative uncertainty analysis for high-risk projects? • to review the reporting on the modelling and uncertainty analyses? • to agree on justifications of assumptions/criteria applied to implement the methodology? • to understand the implications of the results in terms of environmental decision-making? • to identify whether an independent technical review of the modelling and/or the uncertainty analysis is warranted?
2	Is the modelling and uncertainty analysis methodology designed to provide information for decision makers on the effects of uncertainty on the project objectives (echoing the definition of risk in AS/NZS ISO31000:2009) and on the effects of potential bias?
3	Are the adopted conceptual model, complexity–simplicity balance and applied modelling package capabilities commensurate with the overall risk context and the models purpose of investigating the uncertainty/risk issues (i.e. based on the evidence available of engagement identified in item 1)?
4	Has the uncertainty assessment and modelling methodology been designed and implemented using all the available data? Detailed consideration of the hydrological stressors arising from the development and of natural stressors, including climate variability, and unbiased consideration of water-related asset values and causal pathways for potential impacts (direct, indirect and cumulative) should be provided.
5	Where history-match conditional calibration is undertaken, has it minimised non-uniqueness and error variance (using approaches recommended in the AGMG)? If not, is a reasoned justification provided? Is an acceptable level of model-to-measurement mismatch defined for the conditional calibration?
6	Are all simulations consistent with all relevant information/data (using approaches recommended in the AGMG)? If not, is a reasoned justification provided?
7	Has the model been submitted to stress testing in which a number of extreme parameter combinations (representing a computationally intensive automated conditional calibration or stochastic model evaluation) are tested for model convergence?
8	Has a parameter sensitivity analysis and/or a parameter identifiability analysis been completed to identify which parameters can be constrained by the available observations and which parameters affect the simulations the most? Are the implications discussed?
9	Have all reports been prepared in an open, honest and transparent way that is: • open to independent scrutiny and not prone to misinterpretation • based on agreed and transparent model objectives • tailored to decision-makers' needs (focusing on messages relevant to their decisions) • presented in plain and clear language (precise, jargon-free, calibrated), with useful graphics.

Attachment E

Landholder bore details and monitoring overview

EMM
creating opportunities

E.1 Registered groundwater bores within the study area

Table E.1 Registered groundwater bores within the study area

Bore ID	Easting	Northing	Type	Screen top	Screen Bottom	Bore depth
GW001012.1.1	565852	6270005	Unknown	Unknown	Unknown	26.8
GW001042.1.1	563496	6268019	Unknown	Unknown	Unknown	38.4
GW001067.1.1	565039	6267762	Unknown	Unknown	Unknown	96.6
GW001169.1.1	558964	6238480	Unknown	Unknown	Unknown	102.4
GW001188.1.1	561227	6235354	Unknown	Unknown	Unknown	122.8
GW001232.1.1	556223	6239143	Unknown	Unknown	Unknown	56.1
GW001306.1.1	558241	6237806	Unknown	Unknown	Unknown	78.9
GW001349.1.1	576527	6240202	Unknown	Unknown	Unknown	54.6
GW001366.1.1	580728	6236348	Unknown	Unknown	Unknown	69.2
GW001369.1.1	576742	6241432	Stock and Domestic	Unknown	Unknown	69.5
GW001423.1.1	585600	6227680	Unknown	Unknown	Unknown	120.7
GW001464.1.1	574812	6221334	Water Supply	Unknown	Unknown	76.2
GW002686.1.1	563790	6235152	Unknown	0	9.1	81.7
GW002705.1.1	557666	6231711	Unknown	0	9.9	111.6
GW002823.1.1	556522	6237663	Unknown	Unknown	Unknown	67.7
GW002849.1.1	564684	6242108	Unknown	Unknown	Unknown	114.3
GW002916.1.1	560043	6238719	Unknown	Unknown	Unknown	61.6
GW002951.1.1	558123	6235220	Unknown	Unknown	Unknown	79.2
GW002965.1.1	569478	6234373	Unknown	0	2.9	82.6
GW002977.1.1	571591	6235620	Unknown	Unknown	Unknown	62.8
GW002990.1.1	570338	6236184	Unknown	Unknown	Unknown	151.2
GW003074.1.1	563082	6232693	Unknown	0	8.2	59.4
GW003075.1.1	559333	6231793	Unknown	Unknown	Unknown	137.8
GW003107.1.1	557916	6239071	Unknown	0	3	61
GW003118.1.1	567469	6233032	Unknown	0	2.8	57.3
GW003224.1.1	568903	6239829	Unknown	Unknown	Unknown	146.3
GW003266.1.1	561159	6244626	Unknown	Unknown	Unknown	99.1
GW003299.1.1	550162	6277123	Unknown	Unknown	Unknown	110.3
GW007234.1.1	570215	6233351	Stock and Domestic	Unknown	Unknown	50.6
GW007715.1.1	561489	6236215	Water Supply	Unknown	Unknown	63.1

Table E.1 Registered groundwater bores within the study area

Bore ID	Easting	Northing	Type	Screen top	Screen Bottom	Bore depth
GW007803.1.1	563925	6236076	Water Supply	Unknown	Unknown	123.4
GW008374.1.1	557852	6237039	Water Supply	91.101	92.3	92.4
GW008385.1.1	566122	6234828	Water Supply	0.002	0.8	174.3
GW008411.1.1	564718	6235824	Water Supply	77.4	78.6	78.9
GW008417.1.1	568463	6232224	Stock and Domestic	57.6	58.8	59.1
GW012316.1.1	551124	6303296	Stock and Domestic	36.6	38.1	38.1
GW012329.1.1	551595	6304372	Water Supply	Unknown	Unknown	39.6
GW012340.1.1	553352	6304393	Water Supply	27.6	28.7	28.7
GW012352.1.1	544712	6301850	Stock and Domestic	61.4	61.9	61.9
GW012357.1.1	550046	6304596	Water Supply	35.1	36.6	36.6
GW012714.1.1	564028	6293795	Water Supply	Unknown	Unknown	22.6
GW012715.1.1	561686	6294734	Water Supply	Unknown	Unknown	18
GW012717.1.1	564436	6293022	Water Supply	Unknown	Unknown	28
GW012718.1.1	563778	6294967	Water Supply	Unknown	Unknown	25.6
GW013377.1.1	570182	6249800	Irrigation	Unknown	Unknown	0
GW013469.1.1	568537	6263980	Stock and Domestic	0	6.1	72.2
GW014816.1.1	551697	6304063	Water Supply	22.6	23.7	23.6
GW014843.1.1	562378	6227153	Water Supply	Unknown	Unknown	167.6
GW014865.1.1	568513	6224985	Water Supply	Unknown	Unknown	119.5
GW014950.1.1	544413	6304223	Water Supply	60.3	61.3	61.3
GW016097.1.1	568421	6254864	Water Supply	Unknown	Unknown	80.5
GW017659.1.1	535739	6284733	Stock and Domestic	61.9	64.9	64.9
GW017911.1.1	521666	6285822	Water Supply	58.8	75.9	75.9
GW018441.1.1	553078	6231984	Stock and Domestic	0	0	100.9
GW018463.1.1	567599	6247693	Stock and Domestic	Unknown	Unknown	63.4
GW018525.1.1	552673	6228383	Stock and Domestic	71.1	76.6	79.2
GW019105.1.1	564561	6239121	Water Supply	0	1.8	88.7
GW019463.1.1	541505	6300879	Unknown	Unknown	Unknown	0
GW019744.1.1	558873	6303222	Stock and Domestic	0	0	12.8
GW020665.1.1	581927	6232672	Unknown	Unknown	Unknown	6.7
GW021831.1.1	542757	6268720	Stock and Domestic	Unknown	Unknown	61

Table E.1 Registered groundwater bores within the study area

Bore ID	Easting	Northing	Type	Screen top	Screen Bottom	Bore depth
GW021832.1.1	545835	6266611	Stock and Domestic	Unknown	Unknown	115.8
GW021833.1.1	544715	6263536	Stock and Domestic	Unknown	Unknown	115.8
GW021834.1.1	545308	6269355	Stock and Domestic	Unknown	Unknown	39.6
GW022931.1.1	533675	6291731	Unknown	Unknown	Unknown	33.5
GW023152.1.1	569272	6230709	Unknown	Unknown	Unknown	86.9
GW023502.1.1	587813	6234097	Unknown	Unknown	Unknown	5.5
GW024457.1.1	547312	6305410	Irrigation	0	3.4	139.3
GW025109.1.1	568128	6224988	Water Supply	Unknown	Unknown	114
GW025116.1.1	569461	6221621	Irrigation	Unknown	Unknown	105.2
GW025469.1.1	561616	6232087	Stock and Domestic	Unknown	Unknown	132.3
GW025487.1.1	556560	6235506	Stock and Domestic	74.6	80.7	80.8
GW025682.1.1	579957	6233120	Water Supply	Unknown	Unknown	7.2
GW025704.1.1	592013	6233503	Stock and Domestic	Unknown	Unknown	61
GW026045.1.1	535551	6261819	Stock and Domestic	Unknown	Unknown	47.2
GW026046.1.1	541914	6264165	Stock and Domestic	0	0	133.5
GW026047.1.1	539800	6263219	Stock and Domestic	Unknown	Unknown	94.5
GW026048.1.1	542734	6263453	Stock and Domestic	0	2.3	108.2
GW026049.1.1	543834	6267760	Stock and Domestic	Unknown	Unknown	114.3
GW026050.1.1	542758	6268874	Stock and Domestic	0	5.2	118.9
GW026051.1.1	544126	6269822	Stock and Domestic	0	5.6	97.8
GW026052.1.1	545723	6270030	Stock and Domestic	Unknown	Unknown	107.9
GW026053.1.1	546202	6268026	Stock and Domestic	Unknown	Unknown	111.3
GW026054.1.1	538763	6267412	Stock and Domestic	Unknown	Unknown	76.2
GW026055.1.1	544476	6262059	Stock and Domestic	Unknown	Unknown	78.8
GW026056.1.1	541887	6263826	Stock and Domestic	0	10.7	126.8
GW026057.1.1	540168	6258937	Stock and Domestic	Unknown	Unknown	115.8
GW026072.1.1	573009	6236564	Other	Unknown	Unknown	0
GW026709.1.1	561249	6294984	Irrigation	Unknown	Unknown	106.4
GW026876.1.1	578500	6233686	Unknown	Unknown	Unknown	6.1
GW027413.1.1	562357	6235624	Water Supply	0	3	81.4
GW027662.1.1	545962	6304123	Irrigation	129.5	132.5	148.4

Table E.1 Registered groundwater bores within the study area

Bore ID	Easting	Northing	Type	Screen top	Screen Bottom	Bore depth
GW027739.1.1	577418	6236221	Stock and Domestic	Unknown	Unknown	129.5
GW027753.1.1	580276	6231423	Stock and Domestic	Unknown	Unknown	7.3
GW027795.1.1	563124	6231307	Stock and Domestic	Unknown	Unknown	64
GW028022.1.1	546818	6267530	Unknown	Unknown	Unknown	0
GW028036.1.1	544601	6266648	Stock and Domestic	32.9	38.7	38.7
GW028037.1.1	535319	6261635	Stock and Domestic	Unknown	Unknown	72.2
GW028038.1.1	538253	6262086	Stock and Domestic	30.9	37	110
GW028039.1.1	541503	6264444	Stock and Domestic	0	4.9	41.5
GW028040.1.1	542078	6260622	Stock and Domestic	37.5	43.6	43.6
GW028137.1.1	573060	6236626	Other	Unknown	Unknown	86.3
GW028512.1.1	546818	6267592	Stock and Domestic	Unknown	Unknown	127.4
GW028742.1.1	545252	6306960	Irrigation	Unknown	Unknown	142.6
GW028805.1.1	545510	6257742	Stock and Domestic	92.4	94.2	94.2
GW028897.1.1	545279	6241542	Irrigation	0	0	80.8
GW029094.1.1	547041	6267503	Water Supply	100	107.3	111.3
GW029095.1.1	583909	6233517	Unknown	Unknown	Unknown	6.4
GW029413.1.1	586610	6234417	Unknown	Unknown	Unknown	8.2
GW029414.1.1	587173	6234227	Unknown	Unknown	Unknown	6.7
GW029481.1.1	545091	6239726	Stock and Domestic	Unknown	Unknown	150.9
GW029482.1.1	545884	6239353	Stock and Domestic	Unknown	Unknown	82.3
GW029574.1.1	553360	6273194	Stock and Domestic	Unknown	Unknown	87.8
GW029575.1.1	556332	6270682	Stock and Domestic	94.5	96.3	96.6
GW029736.1.1	548858	6268937	Stock and Domestic	Unknown	Unknown	87.8
GW029824.1.1	541174	6253696	Stock and Domestic	Unknown	Unknown	29
GW029825.1.1	540297	6252838	Stock and Domestic	Unknown	Unknown	96
GW030333.1.1	586280	6234758	Exploration	Unknown	Unknown	0
GW030572.1.1	570720	6232423	Water Supply	0	0	84.7
GW030578.1.1	560847	6256147	Water Supply	Unknown	Unknown	95.4
GW030582.1.1	556990	6255802	Stock and Domestic	90.7	96.7	99.4
GW030627.1.1	548006	6299524	Exploration	0	3	0
GW030630.1.1	571577	6230446	Water Supply	71.2	72.7	74.1

Table E.1 Registered groundwater bores within the study area

Bore ID	Easting	Northing	Type	Screen top	Screen Bottom	Bore depth
GW030636.1.1	548006	6299524	Water Supply	26.4	27.2	30.2
GW030683.1.1	556560	6235506	Stock and Domestic	110.5	112.1	113.7
GW030802.1.1	575030	6235902	Irrigation	99.2	119	119
GW031028.1.1	542519	6302322	Water Supply	65.8	67.6	94.8
GW031110.1.1	567084	6225797	Water Supply	Unknown	Unknown	85.3
GW031121.1.1	559158	6261394	Stock and Domestic	Unknown	Unknown	109.7
GW031122.1.1	552729	6266237	Stock and Domestic	Unknown	Unknown	65.8
GW031211.1.1	549157	6242170	Stock and Domestic	0	0	38.1
GW031309.1.1	535905	6301609	Stock and Domestic	Unknown	Unknown	87.5
GW031341.1.1	551475	6267537	Stock and Domestic	Unknown	Unknown	134.1
GW031614.1.1	589417	6235623	Water Supply	Unknown	Unknown	85
GW031760.1.1	575270	6250069	Water Supply	Unknown	Unknown	114
GW032827.1.1	564669	6293206	Stock and Domestic	0	0.6	27.7
GW033243.1.1	552729	6266237	Stock and Domestic	0	0.6	104.5
GW033533.1.1	580463	6235303	Unknown	Unknown	Unknown	1.8
GW033534.1.1	569959	6236988	Unknown	Unknown	Unknown	6.1
GW033620.1.1	581135	6229999	Unknown	Unknown	Unknown	36.6
GW033621.1.1	593759	6233671	Unknown	Unknown	Unknown	27.4
GW033630.1.1	596176	6231767	Unknown	Unknown	Unknown	30.5
GW033633.1.1	565623	6247953	Stock and Domestic	Unknown	Unknown	73.2
GW033635.1.1	559120	6255388	Stock and Domestic	Unknown	Unknown	79.6
GW033636.1.1	559530	6250981	Stock and Domestic	Unknown	Unknown	118.9
GW033637.1.1	563269	6253175	Stock and Domestic	Unknown	Unknown	60
GW033763.1.1	566823	6243356	Stock and Domestic	Unknown	Unknown	101.5
GW033993.1.1	589148	6234270	Stock and Domestic	Unknown	Unknown	5.5
GW034084.1.1	563639	6235554	Water Supply	Unknown	Unknown	62.2
GW034096.1.1	587542	6232529	Stock and Domestic	86.6	88.3	88.4
GW034585.1.1	558985	6233613	Stock and Domestic	Unknown	Unknown	111.2
GW034779.1.1	571804	6233308	Stock and Domestic	Unknown	Unknown	7.6
GW034900.1.1	585804	6233130	Stock and Domestic	Unknown	Unknown	9.1
GW035705.1.1	576345	6230377	Stock and Domestic	Unknown	Unknown	7.6

Table E.1 Registered groundwater bores within the study area

Bore ID	Easting	Northing	Type	Screen top	Screen Bottom	Bore depth
GW036552.1.1	547877	6299086	Unknown	32.5	36.5	0
GW036552.2.2	547877	6299086	Unknown	64	70	0
GW036596.1.1	550938	6264661	Unknown	64	65.5	0
GW037522.1.1	576112	6233275	Water Supply	Unknown	Unknown	0
GW038239.1.1	558618	6232383	Stock and Domestic	58.5	60.3	61.2
GW038782.1.1	539862	6253394	Stock and Domestic	Unknown	Unknown	117.3
GW039378.1.1	565829	6221830	Water Supply	80	81	87
GW039379.1.1	557312	6240441	Water Supply	94.6	99.9	76.2
GW042945.1.1	586818	6231889	Irrigation	Unknown	Unknown	118.3
GW045534.1.1	547597	6300389	Water Supply	Unknown	Unknown	0
GW046653.1.1	545748	6308035	Irrigation	0	0	67.1
GW050381.1.1	555165	6238194	Water Supply	63.7	65.2	75.3
GW050717.1.1	554718	6245127	Stock and Domestic	62	68	68
GW051682.1.1	585198	6225712	Stock and Domestic	Unknown	Unknown	80.2
GW051907.1.1	573423	6227135	Stock and Domestic	Unknown	Unknown	121.9
GW052185.1.1	584758	6225223	Water Supply	Unknown	Unknown	80.2
GW052692.1.1	563103	6251389	Unknown	Unknown	Unknown	59.1
GW054062.1.1	558617	6236295	Unknown	0	0	61
GW055001.1.1	581057	6232833	Water Supply	Unknown	Unknown	6.4
GW056120.1.1	586185	6229985	Stock and Domestic	112	125	125
GW056169.1.1	574405	6225002	Stock and Domestic	Unknown	Unknown	146
GW057348.1.1	572284	6232412	Stock and Domestic	Unknown	Unknown	123
GW057617.1.1	555196	6301580	Water Supply	29.8	32	32
GW057974.1.1	547180	6268021	Irrigation	100	106	107
GW058010.1.1	573099	6234931	Stock and Domestic	Unknown	Unknown	0
GW060146.1.1	547094	6260999	Irrigation	Unknown	Unknown	160
GW064091.1.1	551595	6304372	Water Supply	24	25	27.5
GW064102.1.1	551544	6304495	Water Supply	24	25	27.5
GW065263.1.1	526712	6282976	Water Supply	71	82	83
GW065265.1.1	524667	6279470	Water Supply	40	52	53
GW065267.1.1	527977	6274574	Water Supply	44	58	59

Table E.1 Registered groundwater bores within the study area

Bore ID	Easting	Northing	Type	Screen top	Screen Bottom	Bore depth
GW065336.1.1	538681	6247239	Water Supply	Unknown	Unknown	90
GW067443.1.1	532941	6283252	Water Supply	Unknown	Unknown	80
GW070191.1.1	587141	6234290	Water Supply	Unknown	Unknown	5.9
GW090093.2.2	549832	6294377	Unknown	60	66	0
GW090093.1.1	549832	6294377	Unknown	5	11	0
GW092040.1.1	539283	6248324	Unknown	3.35	4.35	0
GW092047.1.1	535392	6241035	Unknown	3.55	4.55	0
GW700247.1.2	544624	6299664	Unknown	8.2	8.8	9.4
GW700247.1.1	544624	6299664	Unknown	Unknown	Unknown	9.4
GW700301.1.1	545654	6304525	Unknown	Unknown	Unknown	6.1
GW700380.1.1	578116	6224535	Water Supply	96	102	108
GW700439.1.1	547814	6232935	Stock and Domestic	83.75	86.25	95
GW700451.1.1	534164	6274535	Unknown	8	10	0
GW700452.1.1	533214	6274785	Unknown	8	10	0
GW700453.1.1	534214	6276035	Unknown	8	10	0
GW700454.1.1	533964	6276735	Unknown	8	10	0
GW700456.1.1	533813	6277435	Unknown	8	10	0
GW700457.1.1	534564	6279335	Unknown	8	10	0
GW700458.1.1	534464	6278885	Unknown	8	10	0
GW700603.1.1	550088	6304035	Water Supply	11.5	13.5	13.63
GW700604.1.1	550088	6303935	Water Supply	11.5	13.5	13.63
GW700605.1.1	550172	6304041	Water Supply	11.5	13.5	13.63
GW700725.1.1	578613	6233985	Water Supply	Unknown	Unknown	5.5
GW700846.1.1	562438	6235910	Water Supply	Unknown	Unknown	48.7
GW701110.1.1	560938	6238160	Stock and Domestic	0	0	83.5
GW701280.1.1	541117	6220146	Unknown	2.97	8.97	0
GW701281.1.1	537104	6229888	Unknown	14.08	16.08	0
GW701285.1.1	538209	6231899	Unknown	0	46	0
GW701289.1.1	540163	6241710	Unknown	6	12	0
GW701292.2.2	539792	6220243	Unknown	46	51	0
GW701292.1.1	539792	6220243	Unknown	2.95	9.97	0

Table E.1 Registered groundwater bores within the study area

Bore ID	Easting	Northing	Type	Screen top	Screen Bottom	Bore depth
GW701299.3.3	538755	6216884	Unknown	28.001	31	0
GW701299.1.1	538755	6216884	Unknown	9.001	12	0
GW701300.1.1	537708	6220172	Unknown	9.95	15.95	0
GW701454.1.1	557158	6240472	Water Supply	98	106	114
GW701579.1.1	553767	6269660	Stock and Domestic	107	110	114
GW701656.1.1	553263	6285535	Dewatering	122	126	130
GW701679.1.1	554228	6302728	Irrigation	31.3	37.3	96
GW701681.1.1	552812	6266221	Water Supply	109	111	111
GW701713.1.1	573203	6222090	Water Supply	107	108	116
GW701738.1.1	555725	6248706	Water Supply	95	98	100
GW701754.1.1	564898	6229560	Water Supply	107	112	115
GW701755.1.1	566458	6222790	Water Supply	104	110	110
GW701756.1.1	571058	6226845	Water Supply	Unknown	Unknown	180.4
GW701810.1.1	567817	6233427	Water Supply	80	86	90
GW701861.1.1	580613	6220175	Water Supply	90	110	135
GW701863.1.1	583453	6226315	Stock and Domestic	129	135	138
GW701906.1.1	556068	6283245	Water Supply	107	110.5	111.2
GW701913.1.1	561749	6278523	Water Supply	50	55	60
GW701958.1.1	556272	6270630	Stock and Domestic	92	93	95
GW702013.1.1	556515	6278585	Water Supply	106	109	111
GW702067.1.1	560740	6243774	Water Supply	48	66	72
GW702084.1.1	586713	6231765	Water Supply	Unknown	Unknown	182
GW702100.1.1	552407	6285421	Water Supply	112.5	114.5	115
GW702123.1.1	544575	6301818	Irrigation	76	80	80
GW702127.1.1	542922	6259675	Irrigation	113	123	123
GW702230.1.1	555812	6287547	Water Supply	63	64.5	65.5
GW702249.1.1	538371	6278413	Dewatering	65	90	100
GW702250.1.1	538440	6278158	Dewatering	87	99	114.5
GW702251.1.1	538436	6278060	Dewatering	78.5	90.5	91.5
GW702252.1.1	538437	6277970	Dewatering	2	104	113
GW702253.1.1	538422	6277873	Dewatering	1.401	90	100

Table E.1 Registered groundwater bores within the study area

Bore ID	Easting	Northing	Type	Screen top	Screen Bottom	Bore depth
GW702254.1.1	538355	6277762	Dewatering	79.001	91.5	98
GW702255.1.1	538290	6277612	Dewatering	11.2	96.4	107
GW702256.1.1	538180	6277643	Dewatering	5.201	95.2	106
GW702257.1.1	538071	6277618	Dewatering	78	87	101
GW702258.1.1	537976	6277614	Dewatering	80.801	92.8	102
GW702259.1.1	537826	6277612	Dewatering	73.001	85	95
GW702260.1.1	537633	6277674	Dewatering	6.5	75.5	90
GW702261.1.1	537430	6277875	Dewatering	65.001	77	90
GW702262.1.1	549449	6293272	Water Supply	122	125	126
GW702285.1.1	553174	6286458	Irrigation	111	114	114
GW702286.1.1	555900	6279959	Water Supply	109	113	113.2
GW702294.1.1	589131	6224795	Stock and Domestic	119	121.5	135
GW702306.1.1	550115	6297268	Water Supply	32	36	55
GW702331.1.1	561755	6294581	Water Supply	34	37	38
GW702347.1.1	580368	6229250	Water Supply	Unknown	Unknown	205
GW702348.1.1	558673	6213620	Water Supply	88	100	145
GW702379.1.1	580717	6228523	Water Supply	68	80	125
GW702446.1.1	592628	6231845	Water Supply	99	106	106
GW702449.1.1	549463	6304810	Water Supply	11	17	31
GW702468.1.1	585729	6233463	Water Supply	107	112	115
GW702480.1.1	555269	6303586	Water Supply	Unknown	Unknown	15
GW702493.1.1	581199	6227206	Water Supply	90	102	102
GW702546.1.1	550184	6300015	Water Supply	113	117	118
GW702554.1.1	568344	6217961	Water Supply	110	122	130
GW702623.1.1	550224	6298246	Water Supply	121	127	135
GW702671.1.1	546442	6254151	Irrigation	95	98	100
GW702688.1.1	573669	6218959	Water Supply	79	87	87
GW702720.1.1	564659	6227413	Water Supply	98	108	145
GW702726.1.1	589854	6233607	Stock and Domestic	24	28	158
GW702803.1.1	564805	6248184	Water Supply	78	84	84
GW702877.1.1	544590	6301823	Water Supply	72	78	84

Table E.1 Registered groundwater bores within the study area

Bore ID	Easting	Northing	Type	Screen top	Screen Bottom	Bore depth
GW703032.1.1	555307	6303646	Water Supply	22.5	25.5	26.5
GW703112.1.1	547105	6305415	Water Supply	113.5	116.5	117
GW703136.1.1	573150	6223145	Irrigation	84	97	97
GW703170.1.1	572301	6220827	Dewatering	84	87	91
GW703222.1.1	577447	6234906	Water Supply	51.3	53.3	53.3
GW703229.1.1	558927	6238546	Water Supply	66.6	72.6	78
GW703249.1.1	578903	6223907	Water Supply	106	108	111
GW703251.1.1	569575	6228005	Water Supply	Unknown	Unknown	4.5
GW703273.1.1	557183	6240470	Water Supply	98	106	110
GW703303.1.1	555926	6278354	Water Supply	109	114	115
GW703348.1.1	556408	6236046	Water Supply	78	80	86
GW703371.1.1	558784	6276810	Water Supply	66	71	35
GW703384.1.1	550045	6251899	Water Supply	Unknown	Unknown	40
GW703389.1.1	548300	6248113	Stock and Domestic	Unknown	Unknown	40
GW703460.1.1	551480	6297801	Water Supply	34	36	36
GW703511.1.1	540798	6302916	Water Supply	36.5	38.5	65.1
GW703638.1.1	547160	6267785	Water Supply	90.2	108.2	109.7
GW703639.1.1	545000	6265720	Irrigation	98	109	110
GW703655.1.1	581168	6230493	Water Supply	Unknown	Unknown	205
GW703703.1.1	583007	6226515	Stock and Domestic	Unknown	Unknown	120
GW703704.1.1	586622	6234362	Water Supply	69	75	75
GW703715.1.1	570586	6228675	Commercial and Industrial	Unknown	Unknown	0
GW703783.1.1	562527	6275232	Water Supply	109	113	113
GW704003.1.1	583878	6233437	Water Supply	112	115	115
GW704513.1.1	544349	6261947	Stock and Domestic	96	102.4	103.4
GW704547.1.1	573167	6223179	Irrigation	96	99	99
GW704550.1.1	554377	6303265	Water Supply	Unknown	Unknown	30
GW704600.1.1	590274	6233932	Water Supply	108	111	111
GW704619.1.1	566934	6243718	Water Supply	72	80	80
GW704641.1.1	550531	6285081	Irrigation	101	107	108
GW704735.1.1	585523	6227232	Water Supply	78	102	138

Table E.1 Registered groundwater bores within the study area

Bore ID	Easting	Northing	Type	Screen top	Screen Bottom	Bore depth
GW704792.1.1	565031	6297868	Water Supply	Unknown	Unknown	11
GW704796.1.1	557882	6270848	Stock and Domestic	104	108	109
GW704942.1.1	547275	6297435	Water Supply	65	68	69
GW704955.1.1	571447	6232427	Water Supply	77	83	115
GW705026.1.1	552396	6285418	Stock and Domestic	Unknown	Unknown	123

E.2 Groundwater level monitoring data summary

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
13W[1]	551927	6305468	31/12/1997	31/12/1997	1
14CW[1]	553067	6303666	31/12/1997	31/12/1997	1
14DP[1]	553078	6303835	31/12/1997	31/12/1997	1
14DW[1]	553078	6303835	31/12/1997	31/12/1997	1
14FW[1]	553185	6303964	31/12/1997	31/12/1997	1
14W[1]	551783	6304542	31/12/1997	31/12/1997	1
16W[1]	551307	6301588	31/12/1997	31/12/1997	1
17W[1]	550608	6298384	31/12/1997	31/12/1997	1
18W[1]	550353	6296779	31/12/1997	31/12/1997	1
26BP[1]	545815	6306224	31/12/1997	31/12/1997	1
26BW[1]	545815	6306224	31/12/1997	31/12/1997	1
26CW[1]	545790	6306085	31/12/1997	31/12/1997	1
26DW[1]	545765	6305880	31/12/1997	31/12/1997	1
26EP[1]	545739	6305705	31/12/1997	31/12/1997	1
26EW[1]	545739	6305705	31/12/1997	31/12/1997	1
26HW[1]	545636	6305083	31/12/1997	31/12/1997	1
26IW[1]	545608	6304940	31/12/1997	31/12/1997	1
26KW[1]	545583	6304723	31/12/1997	31/12/1997	1
27P[1]	545590	6304647	31/12/1997	31/12/1997	1
27W[1]	545590	6304647	31/12/1997	31/12/1997	1
28W[1]	545322	6302937	31/12/1997	31/12/1997	1

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
29P[1]	544522	6299469	31/12/1997	31/12/1997	1
29W[1]	544523	6299469	31/12/1997	31/12/1997	1
38W[1]	534198	6301032	31/12/1997	31/12/1997	1
39W[1]	539161	6300309	31/12/1997	31/12/1997	1
40P[1]	541051	6299388	31/12/1997	31/12/1997	4
40P[1]	541051	6299388	31/12/1997	31/12/1997	1
40W[1]	541051	6299388	31/12/1997	31/12/1997	1
41W[1]	535011	6290083	31/12/1997	31/12/1997	1
42W[1]	543750	6292228	31/12/1997	31/12/1997	1
43P[1]	547283	6295851	31/12/1997	31/12/1997	1
43W[1]	547283	6295851	31/12/1997	31/12/1997	1
44W[1]	545329	6286801	31/12/1997	31/12/1997	1
45W[1]	551568	6285778	31/12/1997	31/12/1997	1
46W[1]	553730	6290631	31/12/1997	31/12/1997	1
47P[1]	556050	6279565	31/12/1997	31/12/1997	1
47W[1]	556050	6279565	31/12/1997	31/12/1997	1
48W[1]	559029	6284144	31/12/1997	31/12/1997	1
50W[1]	551121	6281522	31/12/1997	31/12/1997	1
56W[1]	565629	6298756	31/12/1997	31/12/1997	1
59W[1]	561908	6301271	31/12/1997	31/12/1997	1
60P[1]	562081	6298889	31/12/1997	31/12/1997	1
60W[1]	562081	6298889	31/12/1997	31/12/1997	1
61W[1]	562040	6297507	31/12/1997	31/12/1997	1
62W[1]	559172	6294512	31/12/1997	31/12/1997	1
6P[1]	557874	6302033	31/12/1997	31/12/1997	1
7W[1]	556183	6295736	31/12/1997	31/12/1997	1
Borefield Bore 1	553792.5	6285525	14/01/1998	6/09/2022	271
Borefield Bore 2	553082.4	6285637	3/11/2000	29/05/2022	321
Borefield Bore 3	553583.3	6289370	14/01/1998	24/08/2022	275
Borefield Bore 4	553274.5	6287388	14/01/1998	24/08/2022	332
Borefield Bore 5	552439.4	6282735	14/01/1998	24/08/2022	346

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
Borefield Bore 6	553673	6283963	14/01/1998	24/08/2022	269
Borefield Bore 7	555370.2	6283675	14/01/1998	24/08/2022	334
CGOMB01A[2]	536504.5	6280015	16/08/2020	15/09/2021	14
CGOMB01B[2]	536497	6280015	16/08/2020	15/09/2021	14
CGOMB02A[2]	537216.8	6275631	16/08/2020	15/09/2021	14
CGOMB02B[2]	537217.4	6275637	16/08/2020	15/09/2021	14
D323	537964.7	6278232	11/03/2000	3/11/2005	68
D325	538004	6277840	11/03/2000	3/11/2005	66
D326	537762.7	6277733	11/03/2000	5/09/2005	60
Eastern Saline Borefield PZ01	537437	6278360	26/11/2010	1/12/2015	13
Eastern Saline Borefield PZ02	556267	6288075	21/12/2010	24/08/2022	121
Eastern Saline Borefield PZ05	555983.8	6286935	26/11/2010	24/08/2022	124
Eastern Saline Borefield PZ06	557238.4	6289189	9/04/2013	24/08/2022	91
Eastern Saline Borefield PZ07	557343.1	6288365	9/04/2013	24/08/2022	95
Eastern Saline Borefield PZ08	556464.9	6286841	9/04/2013	24/08/2022	97
Eastern Saline Borefield PZ09	556588.4	6288436	18/03/2013	24/08/2022	102
Eastern Saline Borefield PZ10	556584.9	6288435	18/03/2013	24/08/2022	102
Eastern Saline Borefield PZ11	556581.9	6288433	18/03/2013	24/08/2022	102
Eastern Saline Borefield SB3	557116	6289198	9/04/2013	18/12/2019	62
Eastern Saline Borefield SB4	557324	6288376	9/04/2013	29/11/2019	64
Eastern Saline Borefield SB5	556447	6286849	9/04/2013	29/11/2019	64
GW001042/1[1]	563496	6268019	15/12/1998	15/12/1998	1
GW001369/1[1]	576742	6241432	1/01/1999	1/01/1999	1
GW002849/1[1]	564684	6242108	1/01/1999	1/01/1999	1
GW003266/1[1]	561159	6244626	1/01/1999	1/01/1999	1
GW007803/1[1]	563925	6236076	19/02/1999	19/02/1999	1
GW008374/1[1]	557852	6237039	19/02/1999	19/02/1999	1
GW008417/1[1]	568463	6232224	19/02/1999	19/02/1999	1
GW014843/1[1]	562378	6227153	19/02/1999	19/02/1999	1
GW017911/1[1]	521666	6285822	16/12/1998	16/12/1998	1
GW027739/1[1]	577418	6236221	19/02/1999	19/02/1999	1

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
GW028040/1[1]	542078	6260622	15/12/1998	15/12/1998	1
GW029574/1	553360	6273194	30/11/2005	30/11/2005	1
GW030252/1[1]	572937	6233238	24/03/1998	15/09/2020	35
GW030270/1[1]	575109	6230994	24/03/1998	15/09/2020	33
GW030291/1[1]	584034	6232706	24/03/1998	23/07/2019	24
GW030293/1[1]	584361	6234567	24/03/1998	23/03/2021	63
GW030328/1[1]	585761	6233041	24/03/1998	19/06/2014	45
GW030328/2[1]	585761	6233041	24/03/1998	19/06/2014	56
GW030331/1[1]	586866	6234284	24/03/1998	23/03/2021	46
GW031028/1[1]	542519	6302322	16/12/1998	27/02/2002	4
GW031211/1[1]	549157	6242170	1/01/1999	1/01/1999	1
GW036084/1[1]	558353	6294820	1/07/1998	24/03/2021	47
GW036086/1[1]	551856	6304832	30/06/1998	23/06/2021	79
GW036523/1[1]	550698	6298685	30/06/1998	30/07/2021	482
GW036523/2[1]	550698	6298685	30/06/1998	30/07/2021	482
GW036523/3[1]	550698	6298685	30/06/1998	30/07/2021	480
GW036524/1[1]	546337	6286862	26/06/1998	30/07/2021	248
GW036528/1[1]	541506	6300127	26/06/1998	30/07/2021	202
GW036528/2[1]	541506	6300127	26/06/1998	30/07/2021	204
GW036528/3[1]	541506	6300127	26/06/1998	30/07/2021	201
GW036551/1[1]	544672	6299659	26/06/1998	30/07/2021	202
GW036551/2[1]	544672	6299659	26/06/1998	30/07/2021	202
GW036552/1[1]	547877	6299086	26/06/1998	30/07/2021	201
GW036552/2[1]	547877	6299086	26/06/1998	30/07/2021	200
GW036552/3[1]	547877	6299086	26/06/1998	30/07/2021	201
GW036553/1[1]	552434	6285773	26/06/1998	23/03/2021	837
GW036554/1[1]	553151	6298504	30/06/1998	1/09/2020	47
GW036554/2[1]	553151	6298504	30/06/1998	1/09/2020	47
GW036554/3[1]	553151	6298504	30/06/1998	1/09/2020	47
GW036563/1[1]	534784	6301109	26/06/1998	1/07/2021	50
GW036594/1[1]	549558	6286186	26/06/1998	30/07/2021	196

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
GW036594/2[1]	549558	6286186	26/06/1998	30/07/2021	196
GW036595/1[1]	547929	6263905	24/03/1998	30/06/2021	198
GW036596/1[1]	550938	6264661	24/03/1998	30/06/2021	229
GW036596/2[1]	550938	6264661	24/03/1998	30/06/2021	229
GW036597/1[1]	544505	6263719	24/03/1998	27/05/2021	165
GW036597/2[1]	544505	6263713	24/03/1998	30/07/2021	342
GW036603/1[1]	551783	6239735	24/03/1998	15/09/2020	35
GW036604/1[1]	557258	6240449	24/03/1998	30/06/2021	186
GW036605/1[1]	554028	6241420	24/03/1998	30/06/2021	187
GW036606/1[1]	564753	6238189	24/03/1998	15/09/2020	35
GW036609/1[1]	554624	6285396	26/06/1998	30/07/2021	236
GW036610/1[1]	549088	6264456	24/03/1998	30/06/2021	202
GW036611/1[1]	553937	6264823	24/03/1998	12/03/2020	422
GW036613/1[1]	541663	6263705	24/03/1998	30/06/2021	184
GW036627/1[1]	571942	6240028	24/03/1998	15/09/2020	35
GW036629/1[1]	573127	6234814	24/03/1998	15/09/2020	24
GW036632/1[1]	572627	6222506	24/03/1998	23/03/2021	160
GW036700/1[1]	555433	6264788	24/03/1998	22/04/2021	89
GW036741/1[1]	584776	6237170	24/03/1998	15/09/2020	37
GW036741/2[1]	584776	6237170	24/03/1998	15/09/2020	37
GW036741/3[1]	584776	6237170	24/03/1998	15/09/2020	37
GW036825/1[1]	564461	6255397	24/03/1998	10/09/2020	34
GW039378/1[1]	565829	6221830	24/03/1998	15/09/2020	39
GW039379/1[1]	557312	6240441	24/03/1998	30/06/2021	186
GW050717/1[1]	554718	6245127	1/01/1999	1/01/1999	1
GW090004/1	568613	6250395	24/10/2014	24/10/2014	1
GW090010/1	561380	6293359	9/10/1999	27/03/2002	21
GW090011/1	559937	6293796	10/10/1999	27/03/2002	16
GW090093/1	549832	6294377	19/05/2006	30/07/2021	172
GW090093/2	549832	6294377	19/05/2006	30/07/2021	173
GW090093/3	549832	6294377	19/05/2006	30/07/2021	173

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
GW700582/1	553274	6287386	28/06/2004	10/10/2005	24
GW700583/1	552439	6282737	28/06/2004	10/10/2005	25
GW700585/1	555370	6283681	28/06/2004	10/10/2005	25
GW701125/1	562296	6293622	6/11/2000	27/03/2002	14
GW701126/1	562209	6293055	6/11/2000	27/03/2002	14
GW701127/1	553109	6281447	6/11/2000	27/03/2002	13
GW701129/1	556703	6282855	6/11/2000	27/03/2002	13
GW701579/1	553767	6269660	1/12/2002	11/10/2007	28
GW701681/1	552812	6266221	1/07/2005	26/01/2006	7
GW701958/1	556272	6270630	29/04/1998	13/11/2008	51
GW702013/1	556515	6278585	12/12/2003	30/11/2005	4
GW702100/1	552407	6285421	25/08/2004	30/11/2005	5
GW702111/1	553080	6285639	28/06/2004	10/10/2005	24
GW702262/1	549449	6293272	19/02/2004	20/04/2012	56
GW702285/1	553174	6286458	29/08/2005	30/11/2005	2
GW702286/1	555900	6279959	15/08/2005	15/02/2012	61
IWL01 - A	534123.9	6279095	12/10/2018	4/12/2022	48
IWL01 - B	534112.5	6279092	12/10/2018	4/12/2022	48
IWL02 - A	533283.5	6278854	12/07/2018	4/12/2022	48
IWL02 - B	533276.7	6278850	3/01/2022	3/01/2022	1
IWL03 - A	533023.7	6277443	12/10/2018	4/11/2022	49
IWL03 - B	533024.5	6277434	12/10/2018	2/10/2022	8
IWL04 - A	533243	6276317	12/10/2018	4/11/2022	48
IWL04 - B	533244	6276302	3/01/2019	3/01/2019	1
IWL05 - A	534567.7	6276045	12/11/2018	18/08/2022	49
IWL05 - B	534583.6	6276047	12/11/2018	18/08/2022	49
IWL06 - A	535761.6	6277243	12/11/2018	3/10/2022	49
IWL06 - B	535756.8	6277223	12/11/2018	3/10/2022	49
Monitoring Bore P318	537400	6278153	11/03/2000	31/03/2008	144
Monitoring Bore P320	537267	6278003	11/03/2000	31/03/2008	150
Monitoring Bore P321	537380	6277854	11/03/2000	3/11/2005	69

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
Monitoring Bore P322	537370	6278055	11/03/2000	31/03/2008	89
Monitoring Bore P330	537323	6278051	11/03/2000	4/12/2006	98
Monitoring Bore P331	537367	6278052	11/03/2000	31/03/2008	110
Monitoring Bore P410A	535771	6278468	11/03/2000	4/06/2004	34
Monitoring Bore P410B	535771	6278468	11/03/2000	4/06/2004	35
Monitoring Bore P411A	534464	6277938	11/03/2000	4/06/2004	37
Monitoring Bore P411B	534464	6277938	11/03/2000	4/06/2004	37
Monitoring Bore P413A	534685	6277000	11/03/2000	27/09/2004	40
Monitoring Bore P413B	534685	6277000	11/03/2000	25/02/2004	31
Monitoring Bore P415A	536934	6277191	11/03/2000	18/10/2004	42
Monitoring Bore P415B	536934	6277191	11/03/2000	18/10/2004	42
Monitoring Bore P416A	535875	6276790	11/03/2000	9/12/2006	66
Monitoring Bore P416B	535875	6276790	11/03/2000	9/12/2006	67
Monitoring Bore P554A	534139.9	6276603	25/02/2004	25/02/2004	1
Monitoring Bore P554B	534137.6	6276603	25/02/2004	25/02/2004	1
Monitoring Bore P556A	534163.1	6277079	11/03/2000	27/09/2004	40
Monitoring Bore P556B	534164.8	6277079	25/02/2004	25/02/2004	1
Monitoring Bore P557A	533804.4	6277634	11/03/2000	4/06/2004	37
Monitoring Bore P557B	533801.5	6277633	25/02/2004	25/02/2004	1
Monitoring Bore P559	534010.8	6278171	11/03/2000	4/06/2004	37
Monitoring Bore P560A	534386.5	6278488	11/03/2000	25/05/2004	36
PBP2	538145.8	6278576	22/12/2004	29/09/2016	60
PBP3	538598	6278157	21/12/2004	2/11/2016	138
PBP4	538575.8	6277565	20/12/2004	27/11/2013	170
PZ01VWP1[2]	537437	6278360	15/09/2006	16/12/2009	39
PZ01VWP2[2]	537437	6278360	16/10/2006	16/12/2009	38
PZ01VWP3[2]	537437	6278360	16/10/2006	16/01/2009	27
PZ02VWP1[2]	537832	6278450	15/11/2006	16/10/2009	35
PZ02VWP2[2]	537832	6278450	15/11/2006	16/01/2009	26
PZ02VWP3[2]	537832	6278450	15/11/2006	16/01/2007	3
PZ03VWP1[2]	538045	6278335	15/09/2006	16/10/2009	36

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
PZ03VWP2[2]	538045	6278335	16/10/2006	16/10/2009	36
PZ03VWP3[2]	538045	6278335	16/10/2006	16/01/2008	15
PZ04VWP1[2]	538242	6277953	15/09/2006	16/03/2008	17
PZ04VWP2[2]	538242	6277953	15/09/2006	16/03/2008	17
PZ04VWP3[2]	538242	6277953	16/10/2006	16/03/2008	17
PZ05VWP1[2]	538223	6277740	15/09/2006	16/03/2008	17
PZ05VWP2[2]	538223	6277740	15/09/2006	16/03/2008	17
PZ06VWP1[2]	538074	6277563	15/09/2006	16/05/2010	43
PZ06VWP2[2]	538074	6277563	15/09/2006	16/05/2010	43
PZ06VWP3[2]	538074	6277563	16/10/2006	15/04/2010	42
PZ07VWP1[2]	537899	6277522	15/11/2006	16/03/2009	28
PZ07VWP2[2]	537899	6277522	15/11/2006	16/03/2009	28
PZ08VWP2[2]	537523	6277564	16/10/2006	16/12/2008	26
PZ08VWP3[2]	537523	6277564	16/10/2006	16/03/2010	41
PZ09VWP1[2]	537283	6277822	16/10/2006	13/02/2010	40
PZ09VWP2[2]	537283	6277822	16/10/2006	16/01/2010	39
PZ09VWP3[2]	537283	6277822	16/10/2006	16/01/2009	27
PZ11VWP1[2]	537715	6278569	16/05/2009	16/01/2017	89
PZ11VWP2[2]	537715	6278569	16/05/2009	16/01/2017	90
PZ11VWP3[2]	537715	6278569	16/05/2009	16/01/2017	90
PZ12VWP1[2]	538151	6278331	16/05/2009	15/11/2009	7
PZ12VWP2[2]	538151	6278331	16/05/2009	15/11/2009	7
PZ12VWP3[2]	538151	6278331	15/04/2009	15/11/2009	8
PZ13VWP1[2]	538338.2	6278577	16/01/2009	16/12/2020	72
PZ13VWP2[2]	538338.2	6278577	16/01/2009	16/12/2020	72
PZ13VWP3[2]	538338.2	6278577	16/01/2009	16/12/2020	72
PZ13VWP4[2]	538338.2	6278577	16/01/2009	16/12/2019	60
PZ14VWP1[2]	538501.9	6277907	15/04/2009	16/05/2022	147
PZ14VWP2[2]	538501.9	6277907	15/04/2009	16/05/2022	147
PZ14VWP3[2]	538501.9	6277907	15/04/2009	16/05/2022	147
PZ14VWP4[2]	538501.9	6277907	15/04/2009	16/05/2022	147

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
PZ14VWP5[2]	538501.9	6277907	15/04/2009	16/05/2022	147
PZ15VWP1[2]	538397.7	6277715	15/04/2009	16/05/2022	147
PZ15VWP2[2]	538397.7	6277715	15/04/2009	16/05/2022	147
PZ15VWP3[2]	538397.7	6277715	15/04/2009	15/04/2013	46
PZ15VWP4[2]	538397.7	6277715	15/04/2009	16/01/2012	31
PZ15VWP5[2]	538397.7	6277715	15/04/2009	16/05/2022	147
PZ16VWP1[2]	538299.4	6277576	15/06/2009	16/05/2022	143
PZ16VWP2[2]	538299.4	6277576	15/06/2009	16/05/2022	142
PZ16VWP3[2]	538299.4	6277576	15/06/2009	16/05/2022	142
PZ16VWP4[2]	538299.4	6277576	15/06/2009	16/05/2022	142
PZ16VWP5[2]	538299.4	6277576	15/06/2009	16/05/2022	141
PZ17VWP1[2]	538516.9	6277389	16/05/2009	16/05/2016	29
PZ17VWP2[2]	538516.9	6277389	16/05/2009	16/05/2016	29
PZ17VWP3[2]	538516.9	6277389	15/04/2009	16/05/2016	30
PZ17VWP4[2]	538516.9	6277389	15/04/2009	16/05/2016	30
PZ17VWP5[2]	538516.9	6277389	15/04/2009	16/12/2010	21
PZ18VWP1[2]	538114	6277452	16/05/2009	16/01/2017	90
PZ18VWP2[2]	538114	6277452	16/05/2009	16/01/2017	90
PZ18VWP3[2]	538114	6277452	16/05/2009	16/01/2017	90
PZ18VWP4[2]	538114	6277452	16/03/2011	15/06/2012	13
PZ19VWP1[2]	537936	6277411	16/05/2009	16/01/2017	90
PZ19VWP2[2]	537936	6277411	16/05/2009	16/01/2017	90
PZ19VWP3[2]	537936	6277411	16/05/2009	16/10/2014	63
PZ19VWP4[2]	537936	6277411	16/05/2009	16/07/2013	48
PZ19VWP5[2]	537936	6277411	16/05/2009	16/01/2017	87
PZ21VWP1[2]	537364	6277581	15/06/2009	16/01/2017	76
PZ21VWP2[2]	537364	6277581	15/06/2009	16/01/2017	76
PZ21VWP3[2]	537364	6277581	15/06/2009	16/01/2017	69
PZ21VWP4[2]	537364	6277581	16/03/2014	16/01/2017	35
PZ21VWP5[2]	537364	6277581	15/06/2009	16/01/2017	69
PZ22VWP1[2]	537425	6278461	15/06/2009	16/01/2017	89

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
PZ22VWP2[2]	537425	6278461	15/06/2009	16/01/2017	89
PZ22VWP3[2]	537425	6278461	15/06/2009	16/01/2017	89
PZ22VWP4[2]	537425	6278461	15/06/2009	16/07/2010	14
PZ24VWP1[2]	538228	6278087	15/09/2009	13/02/2011	18
PZ24VWP2[2]	538240	6278095	16/08/2009	15/04/2011	21
PZ24VWP3[2]	538248	6278099	15/09/2009	15/04/2011	20
PZ24VWP4[2]	538253	6278102	15/09/2009	15/04/2011	18
PZ25VWP1[2]	538231	6277867	15/09/2009	15/04/2011	20
PZ25VWP2[2]	538238	6277874	15/09/2009	15/04/2011	20
PZ25VWP3[2]	538245	6277880	16/08/2009	15/04/2011	21
PZ25VWP4[2]	538256	6277888	16/08/2009	15/04/2011	21
PZ26VWP1[2]	538246.5	6278258	16/10/2012	16/05/2022	108
PZ26VWP2[2]	538259.2	6278258	16/10/2012	16/05/2022	108
PZ26VWP3[2]	538274.4	6278258	16/10/2012	16/05/2022	108
PZ28VWP1[2]	538336.4	6277986	16/10/2012	16/08/2021	89
PZ28VWP2[2]	538340.9	6277986	16/10/2012	15/11/2021	102
PZ28VWP3[2]	538355.9	6277986	16/10/2012	16/05/2022	108
PZ28VWP4[2]	538363.9	6277986	16/10/2012	15/11/2021	102
PZ29VWP1[2]	538284.5	6277808	15/11/2011	16/05/2022	119
PZ29VWP2[2]	538295.4	6277808	15/11/2011	16/08/2020	98
PZ29VWP3[2]	538312.6	6277808	15/11/2011	16/01/2017	63
PZ29VWP4[2]	538321.8	6277808	15/11/2011	15/04/2013	18
PZ29VWP5[2]	538339	6277808	15/11/2011	15/04/2012	6
PZ30VWP1[2]	538129.9	6278525	15/09/2012	16/05/2022	109
PZ30VWP2[2]	538129.9	6278525	15/09/2012	16/05/2015	30
PZ31VWP1[2]	537742	6277421	15/09/2012	16/01/2017	53
PZ31VWP2[2]	537742	6277421	15/09/2012	16/01/2013	5
PZ31VWP4[2]	537742	6277421	15/09/2012	16/10/2012	2
PZ32VWP1[2]	538166	6277615	15/09/2012	16/01/2017	53
PZ32VWP2[2]	538166	6277615	15/09/2012	15/06/2013	10
PZ32VWP3[2]	538166	6277615	15/09/2012	16/03/2016	43

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
PZ33VWP1[2]	538394.2	6278114	15/09/2012	16/05/2022	104
PZ33VWP2[2]	538394.2	6278114	15/09/2012	16/05/2022	104
PZ33VWP3[2]	538394.2	6278114	15/09/2012	16/05/2022	104
PZ33VWP4[2]	538394.2	6278114	15/09/2012	16/05/2022	104
PZ35VWP1[2]	537545	6277463	15/09/2012	16/01/2017	53
PZ35VWP2[2]	537545	6277463	15/09/2012	16/10/2012	2
PZ35VWP4[2]	537545	6277463	15/09/2012	16/01/2017	48
PZ36VWP1[2]	537949.2	6277993	16/05/2014	16/05/2022	86
PZ36VWP2[2]	537972.9	6277989	16/05/2014	16/05/2022	86
PZ36VWP3[2]	537996.6	6277986	16/05/2014	16/05/2022	86
PZ36VWP4[2]	538018.9	6277982	16/05/2014	16/05/2022	86
PZ36VWP5[2]	538042.6	6277979	16/05/2014	16/05/2022	86
PZ36VWP6[2]	538066.3	6277975	16/05/2014	15/11/2015	17
PZ37VWP1[2]	537796.4	6277678	15/09/2017	16/05/2022	55
PZ37VWP2[2]	537816	6277605	15/09/2017	16/05/2022	55
PZ37VWP3[2]	537843.9	6277500	15/09/2017	15/04/2019	18
PZ37VWP4[2]	537858.7	6277445	15/09/2017	16/05/2022	55
PZ37VWP5[2]	537867.7	6277412	15/09/2017	16/05/2022	50
PZ37VWP6[2]	537878.7	6277371	15/09/2017	16/05/2022	49
PZ38VWP1[2]	537578.4	6277373	15/09/2017	15/04/2022	52
PZ38VWP2[2]	537578.4	6277373	15/09/2017	16/01/2022	47
PZ38VWP3[2]	537578.4	6277373	15/09/2017	16/03/2018	3
PZ39VWP1[2]	537479.1	6277743	15/09/2017	16/03/2018	5
PZ39VWP2[2]	537429.6	6277684	15/09/2017	16/05/2022	55
PZ39VWP3[2]	537397.4	6277645	15/09/2017	16/05/2022	55
PZ39VWP4[2]	537365.2	6277607	15/09/2017	16/07/2021	45
PZ39VWP5[2]	537333.4	6277569	16/01/2018	16/10/2018	10
PZ39VWP6[2]	537296.2	6277525	15/09/2017	16/03/2018	5
PZ40VWP1[2]	537124.1	6277691	15/09/2017	16/05/2022	49
PZ40VWP2[2]	537124.1	6277691	15/09/2017	16/08/2018	9
PZ40VWP3[2]	537124	6277691	15/09/2017	13/02/2022	43

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
PZ41VWP1[2]	537034	6277933	15/09/2017	16/05/2022	55
PZ41VWP2[2]	537034	6277933	15/09/2017	16/05/2022	55
PZ41VWP3[2]	537034	6277933	15/09/2017	16/05/2022	55
PZ42VWP1[2]	537388	6278049	15/09/2017	16/05/2022	55
PZ42VWP2[2]	537297	6278101	15/09/2017	16/05/2022	55
PZ42VWP3[2]	537235	6278138	15/09/2017	16/05/2022	55
PZ42VWP4[2]	537174	6278172	15/09/2017	16/05/2022	55
PZ42VWP5[2]	537148	6278188	15/09/2017	16/05/2022	54
PZ42VWP6[2]	537135	6278195	15/09/2017	16/10/2017	2
PZ43VWP1[2]	537688	6278283	15/09/2017	16/05/2022	56
PZ43VWP2[2]	537676	6278418	15/09/2017	16/05/2022	56
PZ43VWP3[2]	537668	6278506	15/09/2017	16/05/2022	56
PZ43VWP4[2]	537667	6278522	15/09/2017	16/05/2022	56
PZ43VWP6[2]	537662	6278575	15/09/2017	16/10/2017	2
Pit Bore PDB1A[2]	537281	6279033	16/01/2005	16/07/2022	150
Pit Bore PDB1B	537283	6279031	6/03/2004	4/12/2022	270
Pit Bore PDB1C	537280	6279030	6/03/2004	6/03/2004	1
Pit Bore PDB2A[2]	537879	6278430	16/01/2005	15/11/2008	47
Pit Bore PDB2B	537884	6278430	20/12/2004	30/12/2007	66
Pit Bore PDB3A[2]	538502	6277855	16/08/2004	16/07/2022	154
Pit Bore PDB3B	538507	6277854	8/03/2004	4/12/2022	272
Pit Bore PDB4A[2]	538358	6277855	16/01/2005	15/11/2009	59
Pit Bore PDB4B	538363	6277855	26/05/2004	5/12/2009	111
Pit Bore PDB5A[2]	537770	6276933	15/09/2004	16/07/2022	156
Pit Bore PDB5B	537775	6276932	8/03/2004	5/11/2022	279
Processing Plant Bore 1	536980	6277623	10/08/2008	6/10/2022	169
Processing Plant Bore 2	537009	6277528	30/01/2009	6/10/2022	163
Processing Plant Bore 3	536986	6277451	30/10/2008	6/10/2022	166
Processing Plant Bore 4	536895	6277292	30/10/2008	6/10/2022	164
Processing Plant Bore 5	536713	6277423	30/10/2008	30/10/2017	105
Processing Plant Bore 6	536777	6277586	30/10/2008	6/10/2022	170

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
RA341	537336	6277603	12/06/2000	1/10/2006	105
RA342	537400	6277512	11/03/2000	1/09/2007	125
RA344	537599	6277480	11/03/2000	1/12/2005	70
RA345	537679	6277399	11/03/2000	23/11/2007	119
RA346	537800	6277500	11/03/2000	3/11/2005	61
RA347	537850	6277550	11/03/2000	1/12/2005	75
RA348	537852	6277534	11/03/2000	1/12/2005	75
RA349	537817	6277500	11/03/2000	3/11/2005	68
RA350	537817	6277500	11/03/2000	29/11/2006	33
TSF - INV - 01	534118	6278893	9/03/2018	15/07/2021	35
TSF - INV - 01A	534118	6278893	9/03/2018	15/07/2021	35
TSF - INV - 02	534812	6278684	9/04/2018	15/07/2021	32
TSF - INV - 03	534730.6	6278442	9/03/2018	15/07/2021	37
TSF - INV - 04	534897	6278381	9/03/2018	15/07/2021	36
TSF - INV - 05	534727	6278282	9/03/2018	15/07/2021	36
TSF - INV - 06	533777	6277489	9/03/2018	24/06/2021	35
TSF - INV - 07	534171	6276193	9/03/2018	30/06/2020	26
TSF Bore MON01A	535111	6278224	26/01/2005	5/10/2021	195
TSF Bore MON01B	535114	6278225	27/01/2005	5/10/2021	195
TSF Bore MON02A	534275	6276084	11/01/2005	2/10/2022	213
TSF Bore MON02B	534277	6276086	11/01/2005	2/10/2022	211
TSF Bore P412A	535170	6277495	11/03/2000	1/08/2020	224
TSF Bore P412A-R	535171	6277491	27/01/2005	1/08/2020	182
TSF Bore P412B	535175	6277495	9/05/2018	1/08/2020	22
TSF Bore P414A	535363	6276681	11/03/2000	4/10/2019	218
TSF Bore P414B	535360	6276680	11/03/2000	4/10/2019	219
TSF Bore P417A	535889	6276338	11/03/2000	13/09/2022	256
TSF Bore P417B	535889	6276333	11/03/2000	13/09/2022	258
TSF Bore P418A	534862	6279181	11/03/2000	4/12/2022	256
TSF Bore P418B	534859	6279182	11/03/2000	4/12/2022	256
TSF Bore P555A-R	533112	6276760	11/01/2005	4/11/2022	212

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
TSF Bore P558A-R	532889	6277990	11/01/2005	4/11/2022	426
TSF Bore P558A-R	532839	6277947	11/01/2005	4/11/2022	426
TSF Bore P561A	534601	6279315	11/03/2000	20/09/2022	232
TSF Bore P561B	534601	6279317	11/03/2000	20/09/2022	202
TSF Bore TSFNA	535438	6278074	25/05/2004	5/10/2021	202
TSF Bore TSFNB	535442	6278073	25/05/2004	5/10/2021	204
TSF Bore TSFNC	535447	6278072	25/05/2004	5/10/2021	204
UG-BH-01/ SG1	537751	6278844	2/03/2020	2/03/2020	1
UG-BH-01/ SG2	537751	6278844	2/03/2020	2/03/2020	1
UG-BH-01/ SG3	537751	6278844	2/03/2020	2/03/2020	1
UG-BH-02/ SG1	538180	6279594	26/02/2020	2/03/2020	18
UG-BH-02/ SG2	538180	6279594	26/02/2020	2/03/2020	18
UG-BH-02/ SG3	538180	6279594	26/02/2020	2/03/2020	6
UG-BH-03/ SG1	538019	6278883	26/02/2020	1/03/2020	5
UG-BH-03/ SG2	538019	6278883	26/02/2020	1/03/2020	5
UG-BH-03/ SG3	538019	6278883	26/02/2020	1/03/2020	5
UG-BH-04/ SG1	538169	6278916	27/02/2020	24/03/2020	23
UG-BH-04/ SG2	538169	6278916	26/02/2020	24/03/2020	28
UG-BH-04/ SG3	538169	6278916	26/02/2020	24/03/2020	28
W1825VWP1[2]	538112	6277781	16/03/2014	15/04/2015	8
W1825VWP2[2]	538112	6277781	16/03/2014	13/02/2015	7
W1825VWP3[2]	538112	6277781	16/03/2014	15/04/2015	8
W1829VWP1[2]	537919	6277459	16/03/2014	13/02/2015	7
W1829VWP2[2]	537924	6277549	16/03/2014	13/02/2015	7
W1829VWP3[2]	537927	6277609	16/03/2014	13/02/2015	7
W1831VWP1[2]	537687	6277484	16/03/2014	16/12/2014	6
W1831VWP2[2]	537696	6277573	16/03/2014	16/12/2014	6
W1831VWP3[2]	537702	6277633	16/03/2014	16/12/2014	5
W1832VWP1[2]	537452	6278378	13/02/2014	13/02/2015	8
W1832VWP2[2]	537484	6278294	13/02/2014	13/02/2015	8
W1833VWP1[2]	537668	6278254	13/02/2014	13/02/2015	8

Table E.2 Groundwater level monitoring data summary

Bore	Easting	Northing	Water level start	Water level finish	Water level count
W1833VWP2[2]	537668	6278254	13/02/2014	13/02/2015	8
W1833VWP3[2]	537668	6278254	13/02/2014	13/02/2015	8
W271BVWP1[2]	538199	6277918	16/07/2009	16/03/2011	13
W367VWP1[2]	537723	6278424	16/08/2009	16/05/2010	10
W428VWP1[2]	538217	6277943	16/07/2009	15/11/2012	34
W428VWP2[2]	538123	6277935	16/07/2009	15/11/2012	34
W429VWP1[2]	538162	6277742	16/07/2009	15/11/2012	33
W429VWP2[2]	538073	6277775	15/06/2009	15/11/2012	34
WB12	539143	6277103	29/10/2019	20/03/2020	5

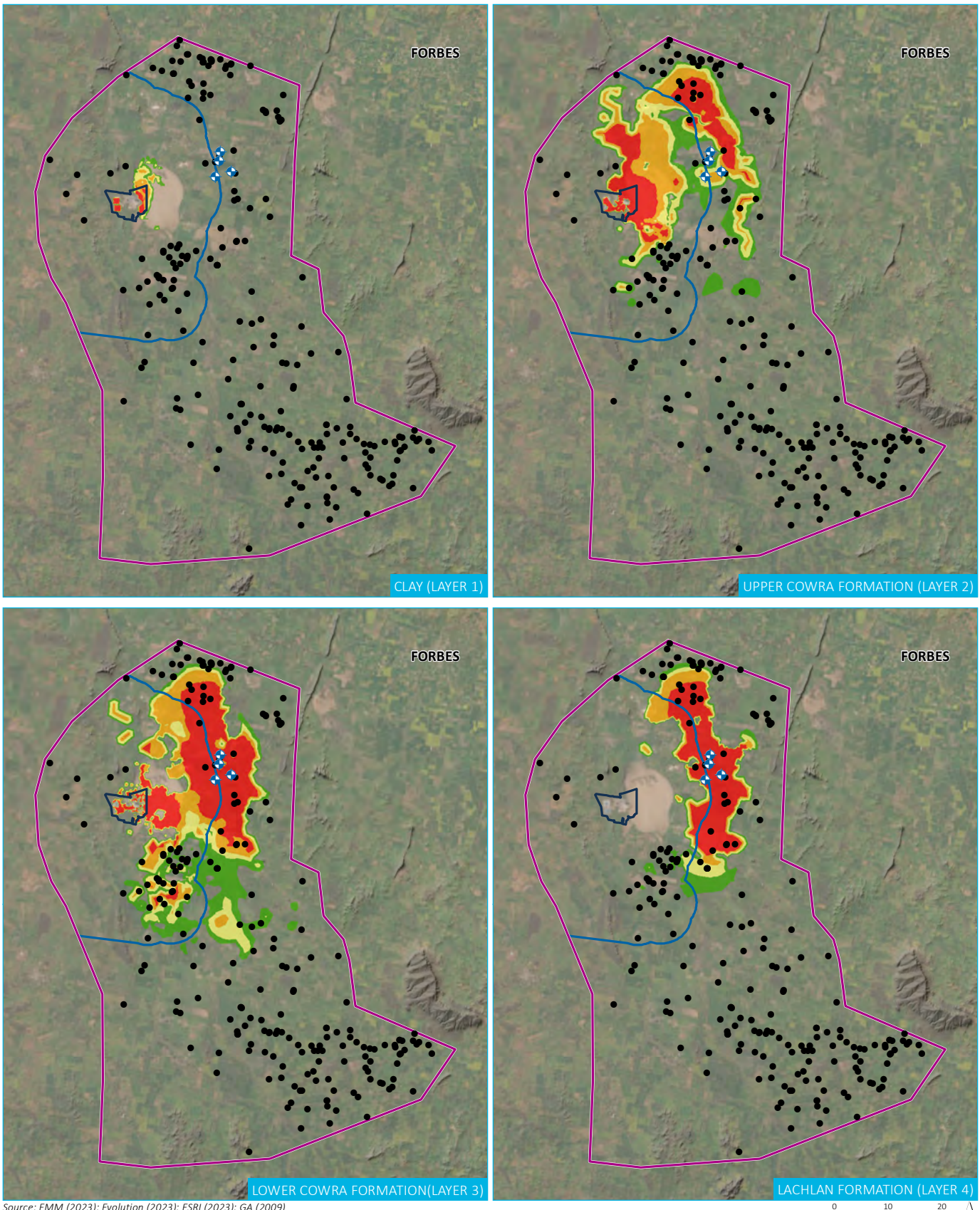
[1] monitoring data exists prior to 31/12/1997 but only data recorded on/after 31/12/1997 were used for head targets

[2] resampled to monthly average values

Attachment F

AIP landholder bore drawdown plots and hydrographs

EMM
creating opportunities



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km
GDA 1994 MGA Zone 55

N

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA022a_CumulativeDrawdown2mContours2012Layers1to4_20230426_03.mxd 26/04/2023

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Registered bore
- 2 m incremental drawdown 5 km buffer

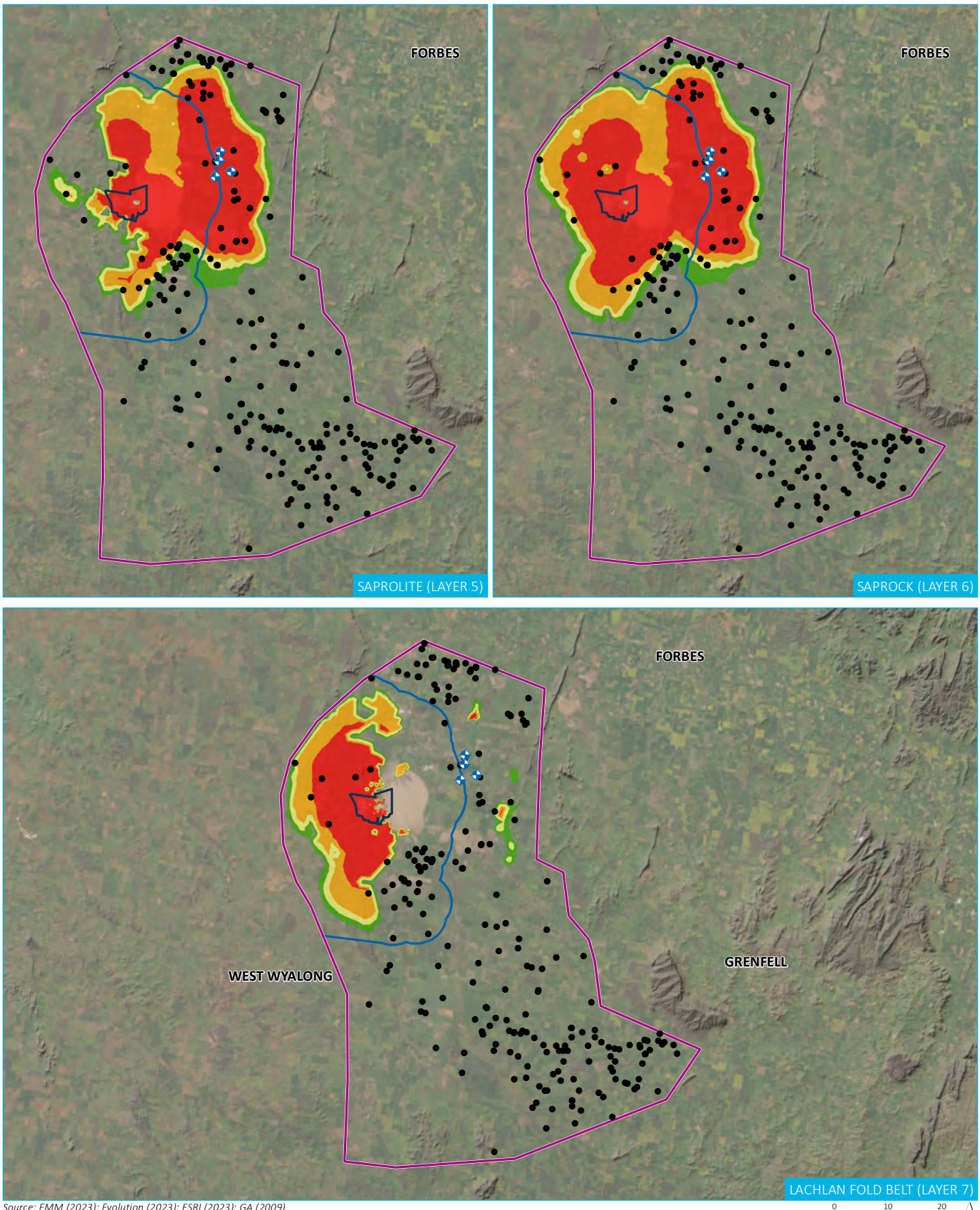
2 m cumulative drawdown exceedance probability

- 10 %
- 33 %
- 66 %
- 90 %

Drawdown exceedance probability of 2 m, from 2012 - map 1 of 2

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure F.1a

EMM creating opportunities



Source: EMM (2023); Evolution (2023); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Study area
- Project area
- Bland Creek Palaeochannel Borefield (BCPB)
- Registered bore
- 2 m incremental drawdown 5 km buffer

2 m cumulative drawdown exceedance probability

- 10 %
- 33 %
- 66 %
- 90 %

Drawdown exceedance probability of 2 m, from 2012 - map 2 of 2

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Impact Assessment
Figure F.1b

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GIA\GIA022b_CumulativeDrawdown2mContours2012Layers5to7_20230426_03.mxd 26/04/2023

Attachment G

Multi-variate chemistry assessment

EMM
creating opportunities

Level 1 87 Wickham Terrace
Spring Hill QLD 4000
07 3648 1200
www.emmconsulting.com.au

Memorandum

16 March 2023

To: File

From: Dr Tim Ezzy

Subject: Summary of Groundwater Data Analytics for Lake Cowal GIA

1 Introduction and Objectives

This technical memorandum summarises the groundwater data analytics workflow that was designed to provide insights into key hydraulic interactions between different hydrostratigraphic units (HSUs) at the Cowal Gold Operations (CGO) at the Lake Cowal site and various natural (lake, paleochannel) and mining (open cut and underground) features. This package of work was completed to support the Lake Cowal groundwater impact assessment (GIA). The objectives of the data analytics include:

- analyse groundwater level and/or groundwater quality trends at key sentinel bores to interrogate the degree of hydraulic connection between the lake and the bores around the open cut pit and underground
- analyse groundwater level and/or groundwater quality trends at that support hydraulic connection between the paleochannels and the lake, or the paleochannels and the open cut pit and/or underground
- analyse groundwater level and/or groundwater quality trends to help understand the hydraulic connection between monitoring bores and climatic effects.

2 Scope of Work

The scope of work for the data analytics included:

- collate and QA/QC input datasets for groundwater levels, site rainfall, lake levels, CGO pumping at the open cut, pumping from the Eastern Saline Borefield (ESB), and pumping from the Bland Creek Paleochannel (BCPC)
- plot group groundwater level hydrographs for each major HSU to select sentinel bores for more detailed analysis
- undertake time series correlation analysis between sentinel bore groundwater levels and various environmental stresses to identify any potential causal mechanisms for groundwater level change

- examine the CGO hydrochemistry database and interrogate to identify indicator parameters for multivariate statistical analysis
- undertake multivariate statistical analysis to establish water quality signature for the lake and each HSU and consider if there is chemical evidence to support any hydraulic interactions
- summarise both groundwater level and groundwater chemistry evidence for hydraulic interactions.

3 Datasets

Table 3.1 summarises the datasets and their sources that were used in the data analytics workflows.

Table 3.1 Datasets used in the data analytics workflows

Dataset	Description	Source
Groundwater level data	Time series groundwater level data dating back to the 1980s	NSW Real-time Data Website, MonitorPro Desktop – Groundwater Monitoring Data, client provided spreadsheets titled "All Data Coffey 2020 Borefields – 4.0M", "2021.08 Compiled Piezo Data.xlsx", "2017 Stage H Piezometers.xlsx", "2012.02.16 VWP Groundwater Head - All Data.xlsx", "2009 Piezometer.xlsx", "Bund Stand Pipe Piezo Water Levels.xlsx", "PitPiezoLevels v7.xlsm", "VWP Master Compiled Data – Master (20220501).xlsx", "EMMCGO_Bores_Data from CGO", "20221021_Borefield.xlsx", and "Bore_Piezo_Data_20211005_toCGO.xls".
Rainfall data	Daily rainfall data covering the period 1975 to 2022	SILO climate database for Lat, Long: -33.65 147.40 (decimal degrees).
Lake Cowal lake levels	Daily lake level datasets covering the period 1973 to 2022	Client provided spreadsheets titled "Lake Cowal Survey Levels_20220627.xls", "Lake Levels.xls", and "fig4.2_LakeCowaldata_only.xlsx".
CGO open cut pumping	Monthly CGO open cut pumping data covering the period 2007 to 2022	Client provided spreadsheets titled "Site Water Tracker V2.xlsx" and "Pit_Dewatering_DATASHEET_(DOC-ENV-DTS-659644).xlsx".
ESB pumping	Monthly ESB pumping data covering the period 2005 to 2022	Client provided spreadsheet titled "Site Water Tracker V2.xlsx".
BCPC pumping	Monthly BCPC pumping data covering the period 2007 to 2022	Client provided spreadsheet titled "Site Water Tracker V2.xlsx".
Sitewide hydrochemistry data	Hydrochemistry data covering the period 2015 to 2023	MonitorPro Desktop – Groundwater Monitoring Data, Lake Water Monitoring, Tailings, Underground.

4 Methods

4.1 Correlation Analysis

Groundwater level data were correlated with environmental stresses to test if a causal mechanism could be established between each individual stress and the groundwater response. The key stresses that were considered included:

- site rainfall trends represented using a cumulative deviation from mean monthly rainfall (CDMMR). The default hypothesis with most groundwater systems is that rainfall recharge processes are a primary driver for groundwater storage (and level) changes in an aquifer
- Lake Cowal lake elevation. An alternative hypothesis is that lake levels drive recharge into the transported sediments and influence groundwater levels
- CGO open cut pumping. An alternative hypothesis is that passive and active open cut dewatering creates a drawdown response in the various HSUs and that this drawdown propagates through these HSUs and leads to change in groundwater storage (and groundwater levels)
- ESB pumping. An alternative hypothesis is that pumping in the ESB creates a drawdown response in the various HSUs and that this drawdown propagates through these HSUs and leads to change in groundwater storage (and groundwater levels)
- BCPC pumping. An alternative hypothesis is that pumping in the BCPC creates a drawdown response in the various HSUs and that this drawdown propagates through these HSUs and leads to change in groundwater storage (and groundwater levels).

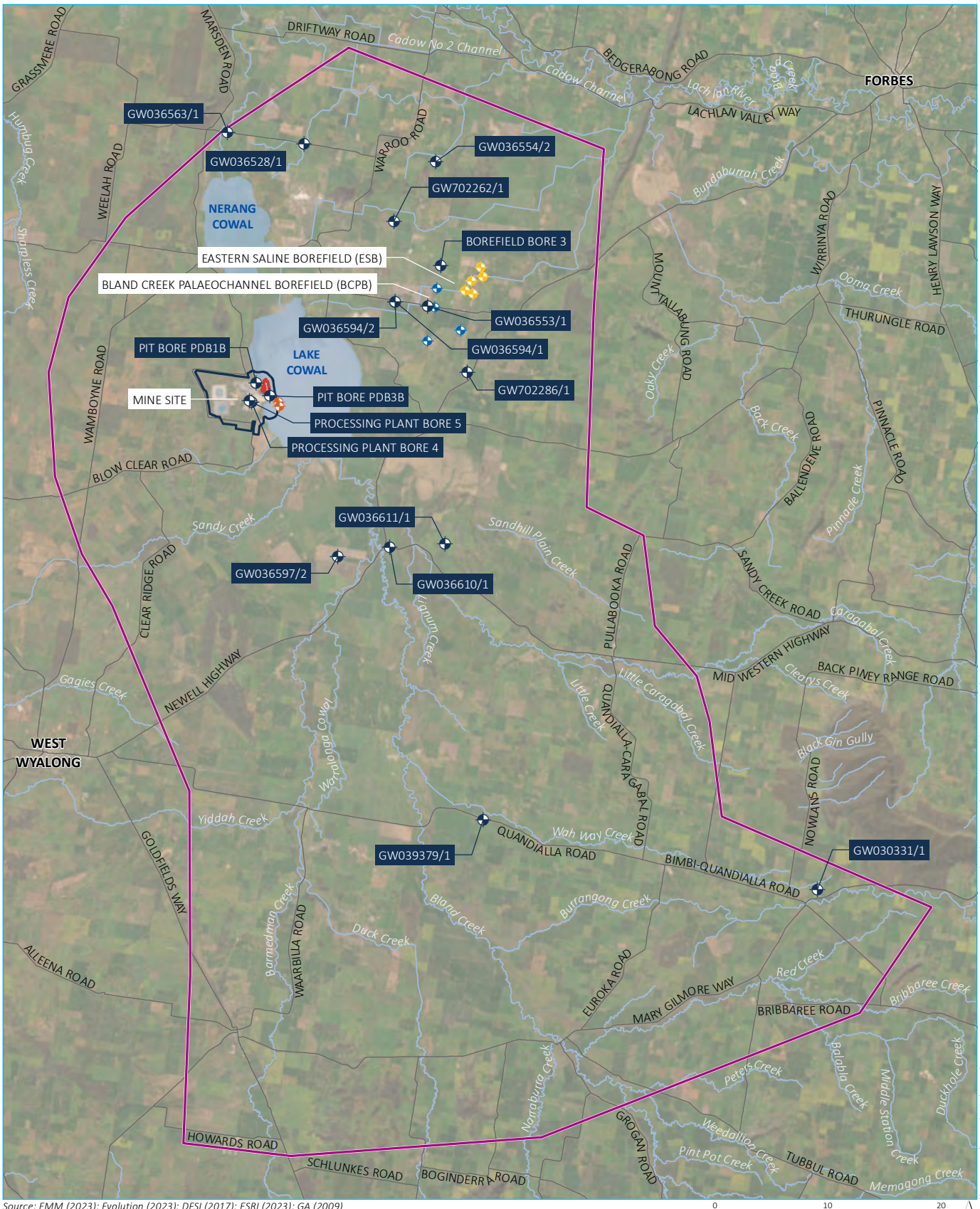
The workflow for the correlation analysis is summarised in Table 4.1

Table 4.1 Correlation analysis workflow

Workflow Stage	Description
1 Select sentinel bores	All monitoring bores with temporal groundwater level data were plotted as group hydrographs per HSU. For each HSU, the length of record, availability of pre-mining groundwater levels, spatial location (mine site, BCPC, regional), and variability in groundwater level trends were all considered as factors in site selection. The locations of the sentinel bores are presented in Figure 4.1.
2 Import datasets into Python	The datasets described in Table 3.1 (excluding hydrochemistry) were imported into a Python Jupyter Labs notebook. Python was selected as it allows for streamlined customised analysis that can be deployed in batch mode across multiple bores. The Python workflow is reproducible and makes use of industry standard libraries including Pandas, NumPy and Matplotlib.
3 Resample and smooth datasets	A linear interpolation was applied simultaneously with a monthly resampling using a mean to produce a continuous monthly time series for each stress and groundwater levels for each sentinel bore. This approach ensures consistency between each dataset. A rolling mean removed the influence of noise and fine-scale variability in each dataset also. This process essentially yields a trend component for the groundwater levels and the stresses. The rainfall data and each pumping dataset were further processed to calculate the cumulative deviation from mean monthly value. This shows trends of above average and below average rainfall and pumping and makes cleaner correlation with otherwise noisy datasets.

Table 4.1 Correlation analysis workflow

Workflow Stage	Description
4 Breakpoint identification and implementation	Time series correlation analysis is most effective when there is a comparison of two monotonic signals. A monotonic signal is a mathematical term that refers to a consistent trend in one prominent direction, such as a persistent increasing or decreasing trend. Monotonic trends can be linear or non-linear. For this workflow, the default hypothesis was that groundwater levels trends are predominantly influenced by rainfall recharge. As such the CDMMR was used to pick breakpoints. Each breakpoint separated the rainfall dataset into discrete periods of monotonic above average or below average trends. The groundwater levels at each sentinel bore within these discrete time intervals are then individually correlated with each stress variable. The default expectation being that above average rainfall will correlate with rising groundwater levels and below average rainfall will correlate with falling groundwater levels. Deviations from this expectation and higher correlations with other stresses such as lake levels or pumping would trigger those alternative hypotheses.
5 Correlation analysis	Cross correlation analysis within designated time periods was performed using Spearman rank correlation. A Spearman correlation is an indicator of strength and direction of association between two variables. This derives a Spearman rank coefficient where a value of +1 implies perfect positive correlation (both variables rise together), a value of 0 implies no association and a value of -1 implies perfect inverse correlation (one variable rises while the other falls). **A cautionary note**: Correlation does not equal causation. This workflow is trying to rule out relationships towards narrowing down the list of what environmental stresses are influencing groundwater level changes in the study area.
6 Visualisation of outputs	The outputs of the correlation analysis are presented graphically in Appendix A. For each sentinel bore five stacked plots are produced. On each plot the groundwater level is presented on the primary y axis as both raw data (dark blue scatter dots) and smoothed and interpolated monthly data (dark blue line). The stress being correlated with groundwater level is presented on the second y axis (from top to bottom: lake level, ESB pumping, CDMMR, CGO pumping, and BCPC pumping). The climate breakpoints are presented as vertical black lines and each time being correlated is presented as iterative grey and white panels. The Spearman correlation score is presented within a text box at the end of each time (the score is the correlation for the time between that breakpoint and the one prior). A green score represents a positive correlation, and an orange score represents an inverse correlation. A grey 'nan' score means insufficient data to correlate for that time.



Source: EMM (2023); Evolution (2023); DFSI (2017); ESRI (2023); GA (2009)

0 10 20 km

GDA 1994 MGA Zone 55

N

KEY

- Model domain
- Proposed OPC disturbance footprint
- Approved underground development
- Major road
- Named watercourse
- Named waterbody
- Sentinel bore

Pumping bores

- Bland Creek Palaeochannel Borefield (BCPB)
- Eastern Saline Borefield (ESB)
- Saline Borefield

Location of sentinel bores used in groundwater level trend analysis

Evolution Mining
Cowal Gold Operations
Open Pit Continuation Project
Groundwater Data Analytics
Figure 4.1

EMM creating opportunities

\\emmsvr1\EMMJobs\2019\J190417 - CGO Open Cut Expansion Project\GIS\02_Maps_GWdataAnalyticsMemo\GWDA001_LocationOfSentinelBores_20230413_02.mxd 13/04/2023

4.2 Hydrochemistry multivariate statistics

The workflow for the hydrochemistry multivariate statistics is presented in Table 4.2. For this investigation, EMM employed a multivariate statistical workflow to derive main water quality groups for a common set of parameters. Python's Scikit-learn machine learning library was used to undertake the K Means Cluster Analysis (KCA) and Principal Components Analysis (PCA) to verify these water quality groups. Clustering and dimensionality reduction techniques are commonly used in large hydrochemical studies (e.g. OGIA, 2019; Raiber and Suckow, 2017).

Table 4.2 Multivariate statistics workflow

Workflow Stage	Description
1 Import datasets into Python	The hydrochemistry dataset described in Table 3.1 was imported into a separate Python Jupyter Labs notebook.
2 Identify missing analytes and resolving rounded zeros	The 'missingno' library was used to map out graphically the presence and absence of individual hydrochemistry analytes at a 'whole of dataset' scale. Missing analytes are problematic in multivariate statistics as blank values are not acceptable inputs. This means either missing values must be filtered out as samples, or analytes, or those missing values need to be imputed with a replacement value (such as the mean concentration). Rounded zeros are those values that are below detection limit. For this workflow we have replaced all values that were below detection limit with an absolute value of half the detection limit. This is a commonly accepted technique in hydrochemistry interpretation.
3 Label each sample with a distinct province (HSU or mine feature)	Each water quality sample was labelled as either Lachlan Formation, Cowra Formation, weathered rock, lake samples, groundwater samples proximal to tailings, or underground mine samples.
4 Establish indicator parameters	For each of the six main provinces established in Stage 3, a histogram for each individual water quality analyte was produced. These histograms were visually inspected to identify which analytes showed maximum variance between each province, as having variance allows the multivariate statistical algorithms to differentiate samples and create unique 'signatures'. Those analytes with maximum variance are called indicator parameters. For this assessment the final eleven indicator parameters were: • Bicarbonate, Calcium, Chloride, Electrical conductivity, Iron, Magnesium, pH, Potassium, Sodium, Sulphate, and Zinc.
5 KCA	a) Standardise the data so that analyte concentrations don't 'overpower' or bias the interpretation. b) Run an inertia analysis for KCA to identify how many water quality groups best describe the variance in the multivariate data. This is evaluated by identifying the elbow in the inertia plot and sometimes adding a group for margin effects. c) Run KCA on the select number of cluster groups. d) Analyse: • the statistics for each water quality group • the bore membership for each group • review spatial trends with maps and scatter plots.
6 PCA	Run PCA on the same standardised dataset used for KCA. Analyse: the bore membership in each group and how this differs to KCA; maps of water quality groups; 2D scatter biplots and 3D scatter plots.
7 Overall interpretation	Summarise learnings from both KCA and PCA.

5 Results

5.1 Groundwater Level Correlation Analysis

The individual correlation analysis plots are presented in Appendix A and the location of the sentinel bores is presented in Figure 4.1. A summary of the interpretation of those detailed plots is presented in Table 5.2. For additional convenience, those stresses that had a strong correlation with groundwater levels are highlighted blue, and a moderate correlation is highlighted light blue. Conversely, if the correlation is poor then a grey cell highlight is applied. The overall interpretation of the correlation analysis per bore is provided in the far-right column called "Summary Comments". The interpretations from Table 5.2 have been further distilled and presented in Table 5.1 as potential causal mechanisms that best explain responses in groundwater levels.

Table 5.1 shows that all HSUs are strongly influenced by rainfall trends. No bores were primarily influenced by either lake levels or CGO pumping trends. The mine commencement in 2005 correlates with sudden drawdown in four bores: one in the transported material at the mine site; two bores in Lower Cowra formation above the BCPC; and one bore in Lachlan formation within the BCPC. It is interpreted that the three bores within and above the BCPC have potential to be affected by mine startup (due to timing of impacts) and may be associated with increased pumping of that paleochannel when mining commenced. It is also possible that this drawdown is associated with landholder pumping, as observed, in five Lachlan formation bores in the BCPC which have long-term drawdown prior to mining that is associated with long-term landholder of that aquifer. Of concern, those landholder pumping effects are not reducing over time and continue to deplete the storage in the aquifer.

Table 5.1 Summary of potential causal mechanisms that explain groundwater level changes

HSU	Area	Number of bores correlating with a particular stress					
		Total sentinel bores analysed	Rainfall	ESB pumping	BCPC pumping	Mine startup	Landholder pumping
Transported	Regional	1	1				
	Mine area	4	2			1	
Upper Cowra	Regional	2	2				
	Bland Creek paleochannel	1					
Lower Cowra	Regional	1	1				
	Near the Bland Creek paleochannel	3	1	1		2	
Lachlan	Bland Creek paleochannel	6	6		1	1	5

Table 5.2 Summary of correlation trend analysis between groundwater levels at sentinel bores and environmental stresses

Sentinel Bore ID	HSU and Location	Environmental stresses					Summary Comments
		Correlation with rainfall trends	Correlation with lake levels	Correlation with ESB pumping	Correlation with CGO pumping	Correlation with BCPC pumping	
Borefield Bore 3	Lower Cowra / BCPC	Direct correlation is poor. There is, however, a moderate lag time response which suggests it could be causal mechanism.	Sporadic and inconsistent correlation between lake level fluctuations and groundwater levels. Not a causal mechanism at this location.	Very strong inverse correlation from 2009 onwards where increased pumping leads to enhanced drawdown and decreased pumping leads to recovery of groundwater levels. A causal mechanism.	Poor correlation between groundwater level and CGO pumping. Not a causal mechanism.	Poor correlation between groundwater level and BCPC pumping using existing break points. Visually there is an argument for inverse correlation between these two variables if different breakpoints are used. Potential to be a causal mechanism.	Groundwater levels in this bore tend to have a lag response to rainfall of 1-2 years, such that below average rainfall leads to declining levels afterwards and above average rainfall corresponds with increasing levels a year or two later. Strong correlation with ESB pumping. A significant drawdown stress in 2005 has led to 20 m of drawdown at this bore. This drawdown may be associated with mine startup and subsequent increases in paleochannel pumping in 2005.

Table 5.2 Summary of correlation trend analysis between groundwater levels at sentinel bores and environmental stresses

Sentinel Bore ID	HSU and Location	Environmental stresses					Summary Comments
		Correlation with rainfall trends	Correlation with lake levels	Correlation with ESB pumping	Correlation with CGO pumping	Correlation with BCPC pumping	
GW030331/1	Upper Cowra / Regional Southeast	Strong long-term correlation between groundwater levels and rainfall trends in both wetter and drier periods.	Occasional strong relationship such as post-2010. Very poor correlation for the 30 years prior (1980 to 2010). Suspect that correlations are not causation and relate to climate signal coincidence in this case.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Some correlation between groundwater level and CGO pumping but would expect negative correlation if this were a causal mechanism, which rules it out.	Some correlation between groundwater level and BCPC pumping but would expect more consistent negative correlation if this were a causal mechanism, which rules it out.	Groundwater levels strongly correlate to climate.
GW036528/1	Transported / Regional North	Strong positive correlation between 2000 and 2012. Outside that period, the correlation with rainfall is poor.	Poor correlation between groundwater level and lake level. Not a causal mechanism.	Some correlation between groundwater level and ESB pumping but would expect consistent negative correlation if this were a causal mechanism, which rules it out.	Some correlation between groundwater level and CGO pumping but would expect consistent negative correlation if this were a causal mechanism, which rules it out.	Some correlation between groundwater level and BCPC pumping but would expect consistent negative correlation if this were a causal mechanism, which rules it out.	Groundwater levels correlate with climate between 2000 and 2012, but outside of that period, there is not a clear causal mechanism across the environmental stresses considered. Some other factor needed to explain groundwater level trends.

Table 5.2 Summary of correlation trend analysis between groundwater levels at sentinel bores and environmental stresses

Sentinel Bore ID	HSU and Location	Environmental stresses					Summary Comments
		Correlation with rainfall trends	Correlation with lake levels	Correlation with ESB pumping	Correlation with CGO pumping	Correlation with BCPC pumping	
GW036553/1	Lachlan / BCPC and ESB	Moderate positive correlation with climate to suggest rainfall is playing a minor part io the groundwater level trend. Not the primary driver though.	Occasional strong relationship such as post-2010. Very poor correlation for the 25 years prior (1985 to 2010). Suspect that correlations are not causation and relate to climate signal coincidence in this case.	Some poor positive correlation between groundwater level and ESB pumping but would expect consistent negative correlation if this were a causal mechanism, which rules it out.	Some correlation between groundwater level and CGO pumping but would expect consistent negative correlation if this were a causal mechanism, which rules it out.	Some poor negative correlation between groundwater level and BCPC pumping but would expect consistent strong negative correlation if this were a causal mechanism, which rules it out.	A significant drawdown stress in 2005 has led to 50 m of drawdown at this bore. This drawdown may be associated with mine startup and subsequent increased paleochannel pumping after 2005. Since that time that drawdown has been sustained with clear pumping impacts in the hydrograph signature, while climate plays a minor role in background trends.
GW036554/2	Lower Cowra / Regional North	Strong long-term correlation between groundwater levels and rainfall trends in both wetter and drier periods.	Occasional strong relationship such as post-2010. Very poor correlation for the 25 years prior (1985 to 2010). Suspect that correlations are not causation and relate to climate signal coincidence in this case.	Some poor positive correlation between groundwater level and ESB pumping but would expect consistent negative correlation if this were a causal mechanism, which rules it out.	Some correlation between groundwater level and CGO pumping but would expect consistent negative correlation if this were a causal mechanism, which rules it out.	Some poor negative correlation between groundwater level and BCPC pumping but would expect consistent strong negative correlation if this were a causal mechanism, which rules it out.	Groundwater levels strongly correlate to climate.

Table 5.2 Summary of correlation trend analysis between groundwater levels at sentinel bores and environmental stresses

Sentinel Bore ID	HSU and Location	Environmental stresses					Summary Comments
		Correlation with rainfall trends	Correlation with lake levels	Correlation with ESB pumping	Correlation with CGO pumping	Correlation with BCPC pumping	
GW036563/1	Upper Cowra / Regional North	Strong long-term correlation between groundwater levels and rainfall trends in both wetter and drier periods. Large groundwater level rises in 1991 and 2016 not well explained by rainfall trends, however.	Inconsistent correlation between lake level and groundwater level rise and falls. Stronger correlation with climate.	Some poor positive correlation between groundwater level and ESB pumping but would expect consistent negative correlation if this were a causal mechanism, which rules it out.	Some correlation between groundwater level and CGO pumping but would expect consistent negative correlation if this were a causal mechanism, which rules it out.	Some poor negative correlation between groundwater level and BCPC pumping but would expect consistent strong negative correlation if this were a causal mechanism, which rules it out.	Groundwater levels strongly correlate with climate. Large groundwater level rises in 2016 may be explained by rising lake levels, although not conclusive.
GW036594/1	Upper Cowra / BCPC	Poor and inconsistent correlation between rainfall and rising groundwater levels.	Poor correlation between groundwater level and lake level. Not a causal mechanism.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Some correlation between groundwater level and CGO pumping but would expect consistent negative correlation if this were a causal mechanism, which rules it out.	Some poor negative correlation between groundwater level and BCPC pumping but would expect consistent strong negative correlation if this were a causal mechanism, which rules it out.	There is not a clear causal mechanism across the environmental stresses considered. Some other factor needed to explain groundwater level trends.

Table 5.2 Summary of correlation trend analysis between groundwater levels at sentinel bores and environmental stresses

Sentinel Bore ID	HSU and Location	Environmental stresses					Summary Comments
		Correlation with rainfall trends	Correlation with lake levels	Correlation with ESB pumping	Correlation with CGO pumping	Correlation with BCPC pumping	
GW036594/2	Lower Cowra / BCPC	Poor and inconsistent correlation between rainfall and rising groundwater levels.	Poor correlation between groundwater level and lake level. Not a causal mechanism.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Poor correlation between groundwater level and CGO pumping. Not a causal mechanism.	Poor correlation between groundwater level and BCPC pumping. Not a causal mechanism.	A significant drawdown stress in 2005 has led to 5m of sustained drawdown at this bore. This drawdown may be associated with mine startup and subsequent increased paleochannel pumping in 2005. Poor correlation with environmental stresses outside of that sustained drawdown stress.
GW036597/2	Lachlan / BCPC	Strong long-term correlation between groundwater levels and rainfall trends in both wetter and drier periods.	Occasional strong relationship such as post-2010. Very poor correlation for the 25 years prior (1985 to 2010). Suspect that correlations are not causation and relate to climate signal coincidence in this case.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Poor correlation between groundwater level and CGO pumping. Not a causal mechanism.	Poor correlation between groundwater level and PCPC pumping. Not a causal mechanism.	Groundwater levels strongly correlate with climate. Unusual 30m decline in heads during Millennium Drought (2000 to 2010), although no change in declining rate before mining (pre-2005) and post mining to suggest mine-related impacts at this bore. **Likely drawdown from landholder pumping.**

Table 5.2 Summary of correlation trend analysis between groundwater levels at sentinel bores and environmental stresses

Sentinel Bore ID	HSU and Location	Environmental stresses					Summary Comments
		Correlation with rainfall trends	Correlation with lake levels	Correlation with ESB pumping	Correlation with CGO pumping	Correlation with BCPC pumping	
GW036610/1	Lower Cowra / BCPC	Poor and inconsistent correlation between rainfall and rising groundwater levels.	Poor correlation between groundwater level and lake level. Not a causal mechanism.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Poor correlation between groundwater level and CGO pumping. Not a causal mechanism.	Poor correlation between groundwater level and PCPC pumping. Not a causal mechanism.	A significant drawdown stress in 2000 has led to 20m of drawdown at this bore. This drawdown prior to mine startup and dewatering in 2005. **Likely drawdown from landholder pumping regionally.** Poor correlation with environmental stresses outside of that sustained drawdown stress.
GW036611/1	Lachlan / BCPC	Strong long-term correlation between groundwater levels and rainfall trends in both wetter and drier periods.	Occasional strong relationship such as post-2010. Very poor correlation for the 25 years prior (1985 to 2010). Suspect that correlations are not causation and relate to climate signal coincidence in this case.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Poor correlation between groundwater level and CGO pumping. Not a causal mechanism.	Poor correlation between groundwater level and PCPC pumping. Not a causal mechanism.	A significant drawdown stress in 2000 has led to 40m of drawdown at this bore. This drawdown prior to mine startup and dewatering in 2005. **Likely drawdown from regional and local landholder pumping.** Strong correlation with rainfall also.

Table 5.2 Summary of correlation trend analysis between groundwater levels at sentinel bores and environmental stresses

Sentinel Bore ID	HSU and Location	Environmental stresses					Summary Comments
		Correlation with rainfall trends	Correlation with lake levels	Correlation with ESB pumping	Correlation with CGO pumping	Correlation with BCPC pumping	
GW039379/1	Lachlan / BCPC	Moderate to Strong long-term correlation between groundwater levels and rainfall trends in both wetter and drier periods.	Occasional strong relationship such as post-2010. Very poor correlation for the 25 years prior (1985 to 2010). Suspect that correlations are not causation and relate to climate signal coincidence in this case.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Poor correlation between groundwater level and CGO pumping. Not a causal mechanism.	Poor correlation between groundwater level and PCPC pumping. Not a causal mechanism.	A significant drawdown stress in 2002 has led to 10m of drawdown at this bore. This drawdown prior to mine startup and dewatering in 2005. **Likely drawdown from regional and local landholder pumping.** Strong correlation with rainfall also.
GW702262/1	Lachlan / BCPC	Moderate to Strong long-term correlation between groundwater levels and rainfall trends in both wetter and drier periods.	Poor correlation between groundwater level and lake level. Not a causal mechanism.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Poor correlation between groundwater level and CGO pumping. Not a causal mechanism.	Moderate correlation with BCPC pumping. May be a causal mechanism.	A significant drawdown stress occurs from the start of monitoring in 2004 has led to 40m of drawdown at this bore. This drawdown prior to mine startup and dewatering in 2005. **Likely drawdown from regional and local landholder pumping.** Strong correlation with rainfall and moderate inverse correlation with BCPC pumping.

Table 5.2 Summary of correlation trend analysis between groundwater levels at sentinel bores and environmental stresses

Sentinel Bore ID	HSU and Location	Environmental stresses					Summary Comments
		Correlation with rainfall trends	Correlation with lake levels	Correlation with ESB pumping	Correlation with CGO pumping	Correlation with BCPC pumping	
GW702286/1	Lachlan / BCPC	Moderate to Strong long-term correlation between groundwater levels and rainfall trends in both wetter and drier periods.	Poor correlation between groundwater level and lake level. Not a causal mechanism.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Some correlation between groundwater level and CGO pumping but would expect consistent negative correlation if this were a causal mechanism, which rules it out.	Poor correlation between groundwater level and PCPC pumping. Not a causal mechanism.	A significant drawdown stress occurs from the start of monitoring in 2006 has led to 40 m of drawdown at this bore. There is no data prior to mining startup and dewatering in 2005 to conclusively associate impact to stress. Strong correlation with rainfall.
Pit Bore PDB1B	Transported / Pit area	Strong long-term correlation between groundwater levels and rainfall trends in both wetter and drier periods	Inconsistent relationship such as positive correlations for some of the time post-2010. Poor correlation prior to 2010 and groundwater levels rise prior to lake levels rising which tends to rule it out.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Some correlation between groundwater level and CGO pumping but would expect consistent negative correlation if this were a causal mechanism, which rules it out.	Poor correlation between groundwater level and PCPC pumping. Not a causal mechanism.	Strong correlation to rainfall. Inconsistent correlation to lake levels. Doesn't seem to be affected by mine.

Table 5.2 Summary of correlation trend analysis between groundwater levels at sentinel bores and environmental stresses

Sentinel Bore ID	HSU and Location	Environmental stresses					Summary Comments
		Correlation with rainfall trends	Correlation with lake levels	Correlation with ESB pumping	Correlation with CGO pumping	Correlation with BCPC pumping	
Pit Bore PDB3B	Transported / Pit area	Moderate to poor correlation with rainfall.	Poor correlation with lake levels.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Poor correlation between groundwater level and CGO pumping. Not a causal mechanism.	Poor correlation between groundwater level and PCPC pumping. Not a causal mechanism.	A significant drawdown stress in 2005 has led to 18 m of drawdown at this bore. This drawdown most likely associated with mine startup. Moderate to poor correlation with rainfall.
Processing Plant Bore 4	Transported / Processing Area	Poor and inconsistent correlation between rainfall and rising groundwater levels.	Poor correlation with lake levels.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Poor correlation between groundwater level and CGO pumping. Not a causal mechanism.	Poor correlation between groundwater level and PCPC pumping. Not a causal mechanism.	There is not a clear causal mechanism across the environmental stresses considered. Some other factor needed to explain groundwater level trends.
Processing Plant Bore 5	Transported / Processing Area	Poor and inconsistent correlation between rainfall and rising groundwater levels.	Poor correlation with lake levels.	Poor correlation between groundwater level and ESB pumping. Not a causal mechanism.	Poor correlation between groundwater level and CGO pumping. Not a causal mechanism.	Poor correlation between groundwater level and PCPC pumping. Not a causal mechanism.	There is not a clear causal mechanism across the environmental stresses considered. Some other factor needed to explain groundwater level trends.

5.2 Hydrochemistry Multivariate Statistics

5.2.1 Cluster Analysis

i Inertia analysis to evaluate number of water quality classes

Inertia is a measure of how well a group of clusters explains a dataset. It measures the distances between each individual data point and the centroid of the cluster it belongs to. This distance is squared and then summed across the entire cluster. By adding more clusters, the inertia is reduced as the individual errors of these distance calculations will also reduce as they have more centroids to be close to. The optimal number of clusters is identified via the elbow point in the inertia plot, where adding further groups fails to make a material improvement in the inertia.

Figure 5.1 presents the inertia plot for the Lake Cowal hydrochemistry dataset. This plot shows that maximum variance in the hydrochemical dataset is explained by three to four clusters (water quality groups). The addition of a fifth or more group doesn't help to improve the segregation of the data into meaningful groups. Based on this inertia plot, four water quality groups were selected for the KCA and PCA.

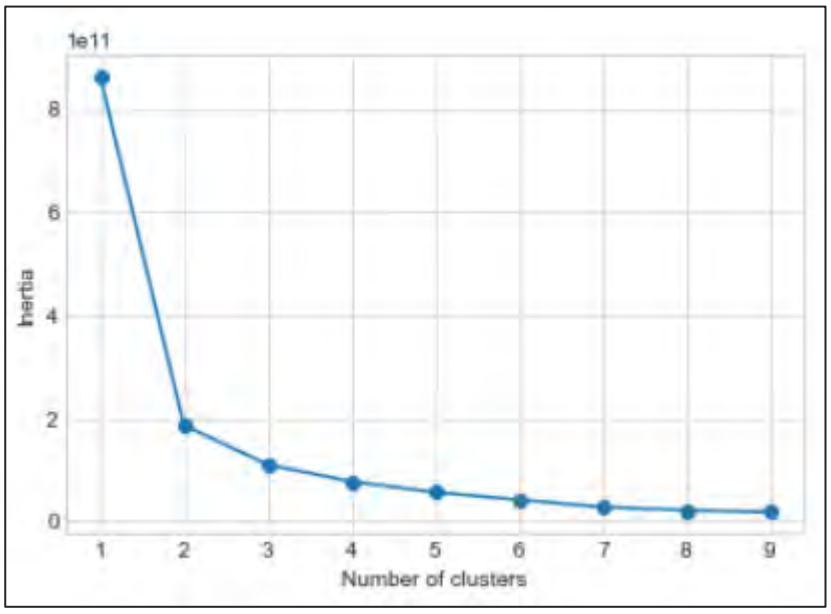


Figure 5.1 KCA inertia plot

ii K means cluster analysis

KCA is one of the simplest and most commonly used clustering algorithms (Muller and Guido, 2016). The algorithm iteratively adjusts the cluster centroids and the membership of the closest data points until the error of those distances is minimised. Once the algorithm has completed its iterations, each data point is then assigned to a particular cluster with each data point within that cluster having multivariate similarity, and each data point between clusters having maximum multivariate differences.

The first step in KCA (and PCA) is to standardise the data. Feature scaling is a mathematical procedure to ensure all parameters have a common scale. That way parameters with higher concentrations (e.g. Na and Cl) don't overwhelm and dominate the algorithm. In doing so, subtle concentrations of minor elements (e.g. metals) have an equal opportunity to differentiate between samples. Standardisation was performed using the Standard Scaler function within Scikit Learn's pre-processing library. Standardisation first subtracts the mean value from each data point (so standardised values always have a mean of zero) and then divides it by the standard deviation so that the resulting distribution has unit variance (Geron, 2019).

Once the data is standardised, the Kmeans function within Scikit Learn is deployed using the number of pre-defined clusters (in this example, four). At the completion of the KCA, each bore is then labelled as being within one of each of the four water quality groups. Bivariate scatter plots of key parameters are then constructed to evaluate how successful the KCA was in separating the data.

Figure 5.2 below present a bivariate scatter plot of Na versus HCO_3, with each water quality sample labelled one of four colours, corresponding to which of the four groups it was attributed to (note: Python is zero indexed, and the first index is therefore prescribed with a zero and the second with a one and so forth). There is clear separation of the water quality groups when viewing a dominant cation (Na) and a dominant anion (HCO_3).

Table 5.3 Mean concentrations of indicator analytes for each of the four water quality groups

Cluster class	Bicarbonate (HCO3) (mg/L)	Calcium (Ca) (mg/L)	Chloride (Cl) (mg/L)	Conductivity (EC) (µS/cm)	Magnesium (Mg) (mg/L)	pH (SU)	Potassium (K) (mg/L)	Sodium (Na) (mg/L)	Sulfate (SO4) (mg/L)	Zinc (Zn) (mg/L)	Iron (Fe) (mg/L)
0	163.1	149.4	1388.8	5369.4	125.9	7.7	15.8	865.3	751.2	0.01	0.4
1	515.2	477.8	12803.0	39702.7	1154.7	7.5	32.7	7839.8	3436.8	0.01	0.3
2	230.1	915.7	17172.9	50008.1	1728.9	7.3	70.0	9517.3	4234.1	0.05	0.6
3	0.9	172.7	10165.1	31878.2	729.2	3.9	13.4	6246.0	2663.2	0.04	0.1

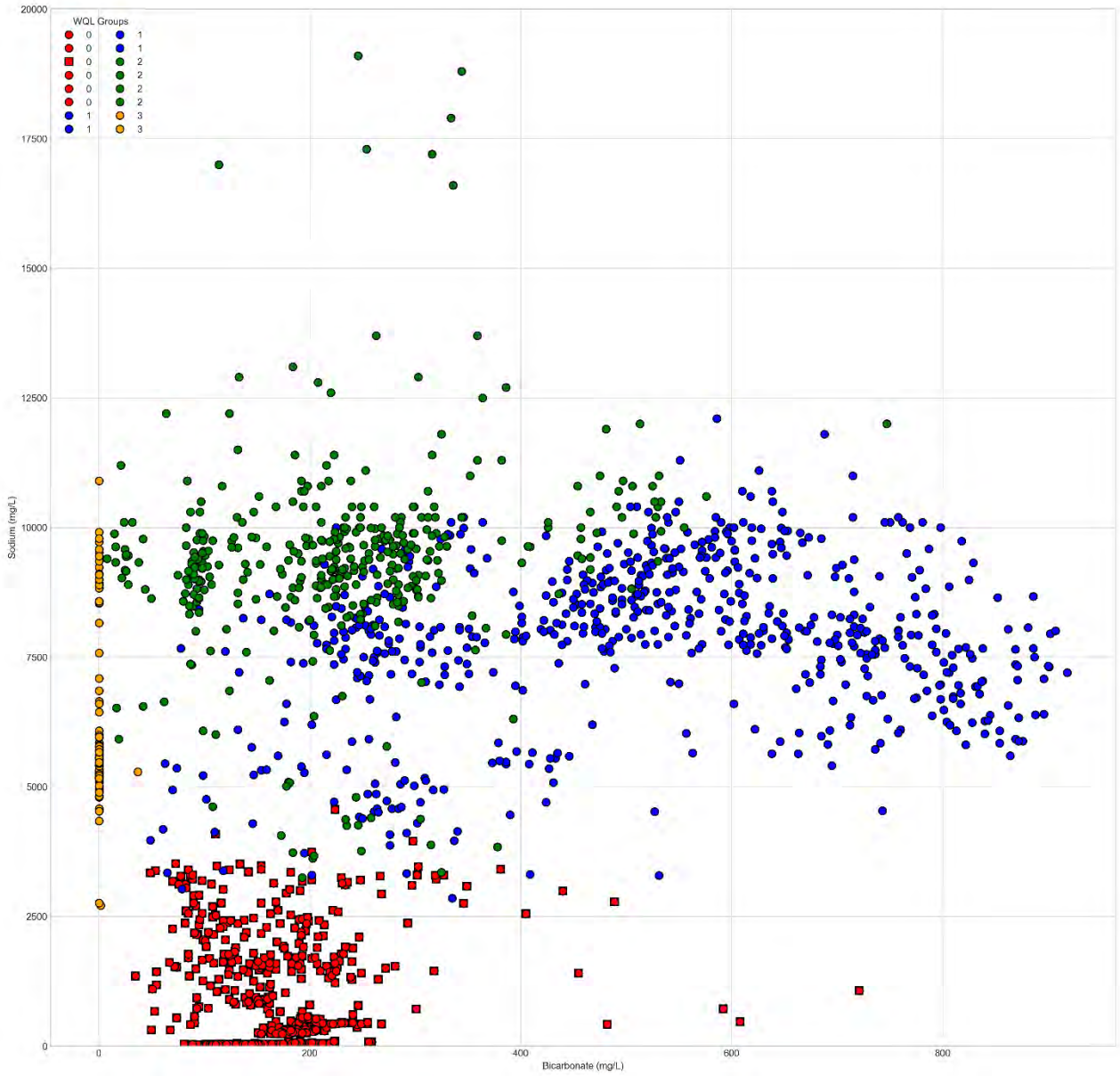


Figure 5.2 **Scatter plot of sodium versus bicarbonate with colour of symbols reflecting water quality group membership**

5.2.2 Principal Component Analysis

PCA is a dimensionality reduction technique that transforms and rotates the standardised dataset so that the rotated features are statistically uncorrelated (Muller and Guido, 2016). The algorithm then finds the direction of maximum variance, which is the direction along which most of the data variance is contained (the first principle component). The algorithm then finds the direction that contains the most residual information while being orthogonal to the first vector (the second principal component). This process is repeated, with each additional component explaining less and less of the multivariate data variance. The process is considered to be dimensionality reduction as it can reduce, in this case thirteen parameters, down to three or four while maintaining a bulk of the system variance.

The standardised dataset was analysed Scikit Learn's PCA algorithm. The PCA has been able to represent nearly 70% of the raw data variance by using just three principal components, with a bulk of that variance retained in the first component (>50%). The ultimate advantage of the PCA, is that visualising three parameters is far more intuitive to understand system variance than looking at dozens or hundreds of scatter plots across countless different combinations of indicator parameters.

Figure 5.3 presents a PCA biplot of principal component one (x axis) versus principal component two (y axis). The symbology colours reflect the previously determined KCA water quality cluster groups. The size of the graduated symbol reflects the salinity (electrical conductivity) of each sample with lowest salinity having smallest symbols and highest salinity the largest symbols. The central coordinate (0,0) represents the mean of each of the eleven standardised parameters. The black vectors represent the direction in which each individual parameter tends to increase in concentration beyond the mean concentration for that parameter. This plot shows that the lake samples are extremely fresh and dilute in all of the main cations, anions and metals (as shown by concentrations significantly below the mean), and the Lachlan Formation is more brackish (fivefold increase) with higher salinity (symbol size) and distinctly higher concentrations of the major cations and anions (those vectors all point to the right of the plot). There is clear separation between the lake samples and Lachlan Formation samples showing that these populations are hydraulically separated with no overlap.

Figure 5.4 is a repeat of Figure 5.3 with the incremental addition of Cowra Formation samples. Those samples are saline and again show clear separation from the lake and Lachlan Formation samples. This clear segregation of water quality signature suggest that the lake and these two HSUs do not hydraulically interact. There are three Cowra samples (ESB PZ05, Borefield Bore 3 and ESB SB4) that look similar to the population of the Lachlan Formation and perhaps indicate that these bores are either in fact Lachlan Formation bores, or that there is effective hydraulic connection between the Cowra and Lachlan formations in these discrete area of the BCPC.

Figure 5.5 is a repeat of Figure 5.3 with the incremental addition of underground mine samples. Those samples are saline and occupy a similar space to the Cowra Formation samples. As mentioned above, this clear segregation of water quality signature suggest that the lake and the underground mine indicates that these two entities do not hydraulically interact. These is one underground sample (GAL 1000 Mono) that is chemically affiliated with the Lachlan Formation.

Figure 5.6 is a repeat of Figure 5.3 with the incremental addition of weathered bedrock samples. Those samples are saline and occupy a similar space to the Cowra Formation and underground samples. As mentioned above, this clear segregation of water quality signature suggest that the lake and the weathered bedrock do not hydraulically interact. There is one bore (Processing Plant Bore 3) that is chemically affiliated with the Lachlan Formation in early 2017 samples, but trends away from the Lachlan and becomes more like weathered bedrock in 2018 to 2022 samples.

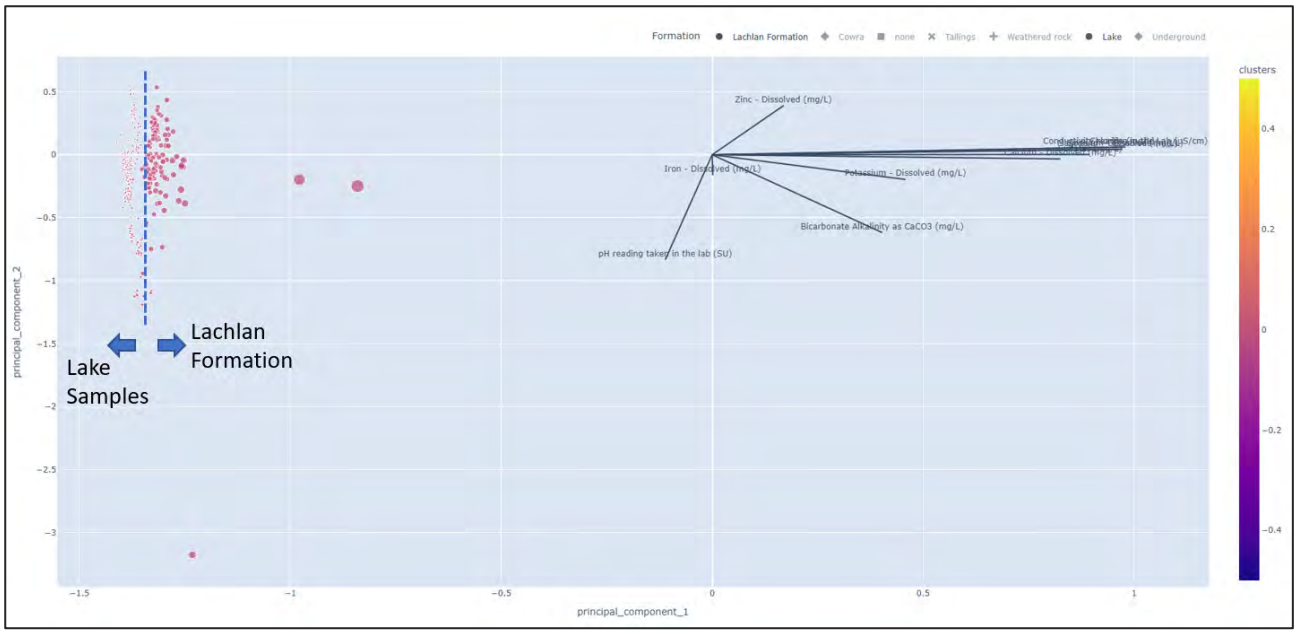


Figure 5.3 PCA biplot of first two principal components showing contrast between fresh lake samples (left of dashed line) and brackish Lachlan Formation samples (right of dashed lines). Colour of symbols reflect KCA cluster groupings and size of symbol reflects salinity concentration.

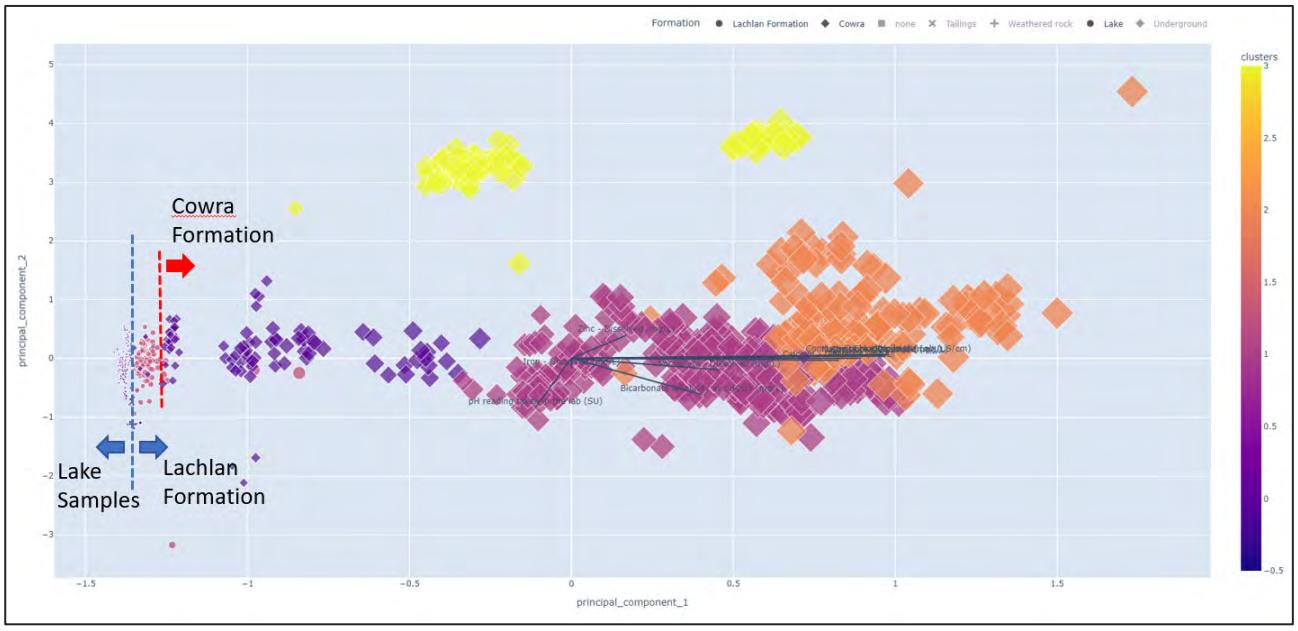


Figure 5.4 PCA biplot of first two principal components showing contrast between fresh lake samples (left of blue dashed line), brackish Lachlan Formation samples (right of blue dashed lines), and saline Cowra Formation (right of red dashed line). Colour of symbols reflect KCA cluster groupings and size of symbol reflects salinity concentration.

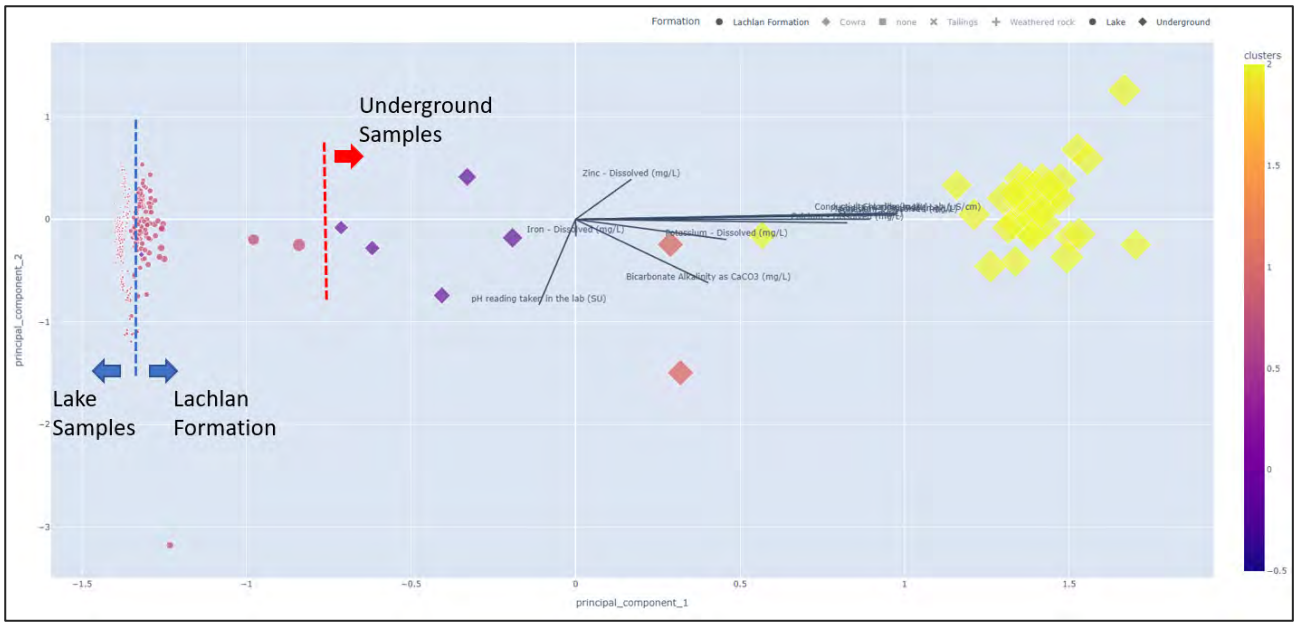


Figure 5.5 PCA biplot of first two principal components showing contrast between fresh lake samples (left of blue dashed line), brackish Lachlan Formation samples (right of blue dashed lines), and saline underground samples (right of red dashed line). Colour of symbols reflect KCA cluster groupings and size of symbol reflects salinity concentration.

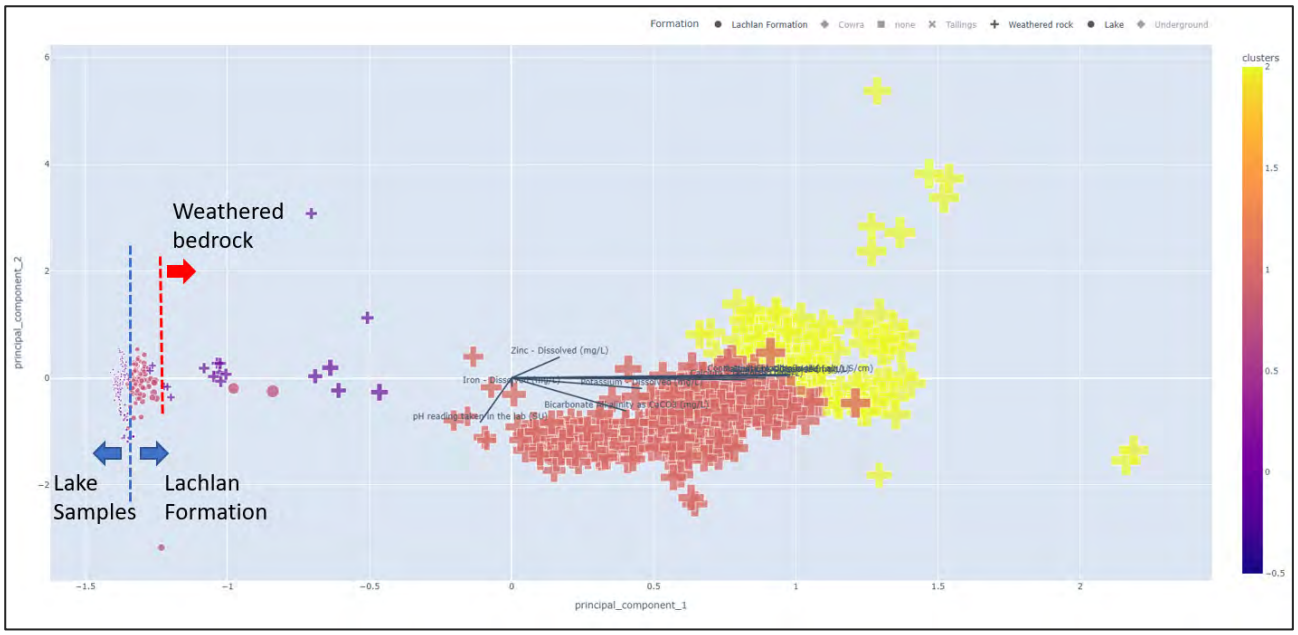


Figure 5.6 PCA biplot of first two principal components showing contrast between fresh lake samples (left of blue dashed line), brackish Lachlan Formation samples (right of blue dashed lines), and saline weathered bedrock samples (right of red dashed line). Colour of symbols reflect KCA cluster groupings and size of symbol reflects salinity concentration.

6 Conclusions

Two independent lines of evidence (groundwater level trends and hydrochemical signatures) were interrogated using data analytics workflows to evaluate whether:

- there is evidence of hydraulic connection between the lake and the bores around the open cut pit and underground
- there is evidence of hydraulic connection between the paleochannels and the lake, or the paleochannels and the open cut pit or underground.

The groundwater level trend analysis showed that all HSUs are strongly influenced by rainfall trends. No bores were primarily influenced by either lake levels or CGO pumping trends. The mine commencement in 2005 correlates with sudden drawdown in four bores: one in the transported material at the mine site; two bores in Lower Cowra near the BCPC; and one bore in Lachlan within the BCPC. It is interpreted that the three bores in the BCPC that are potentially affected by mine startup may be associated with increased pumping of that paleochannel when mining commenced. Conversely, five Lachlan bores in the BCPC have long-term drawdown prior to mining that is associated with long-term landholder use of that aquifer. Of concern, those landholder pumping effects are not reducing over time and continue to deplete the storage in the aquifer.

There is clear hydrochemical separation between the lake samples and Lachlan Formation samples showing that these populations are hydraulically separated with no overlap (i.e. no connection between the lake and the paleochannel). There is also a clear segregation of water quality signature between the lake and the more saline Cowra Formation and weathered bedrock (which includes the bores around the mining area). The underground mine water samples are compatible with the Cowra and weathered bedrock and show no compatibility with the lake.

Based on this analysis:

- there is no definitive evidence of hydraulic connection between the lake and the bores around the open cut pit and underground
- there is no evidence of hydraulic connection between the paleochannel and the lake, or the paleochannel and the open cut pit or underground.

Yours sincerely

Dr Tim Ezzy
Groundwater Team Manager
tezzy@emmconsulting.com.au

References

Geron, A. 2019. Hands-on machine learning with Scikit-Learn, Keras and TensorFlow: Concepts, tools, and techniques to build intelligent systems. O'Reilly, Boston. Second Edition.

Muller, A and Guido, S. 2016. Introduction to machine learning with Python: A guide for data scientists. O'Reilly, Boston.

OGIA, 2019. Underground water impact report for the Surat cumulative management area. Department of Natural Resources, Mines and Energy, Queensland. July 2019.

Raiber, M and Suckow, A. 2017. Hydrochemical assessment of the Hutton and Precipice sandstones in the northern Surat Basin. CSIRO, Australia.

Appendix A
Groundwater level trend analysis

EMM
creating opportunities

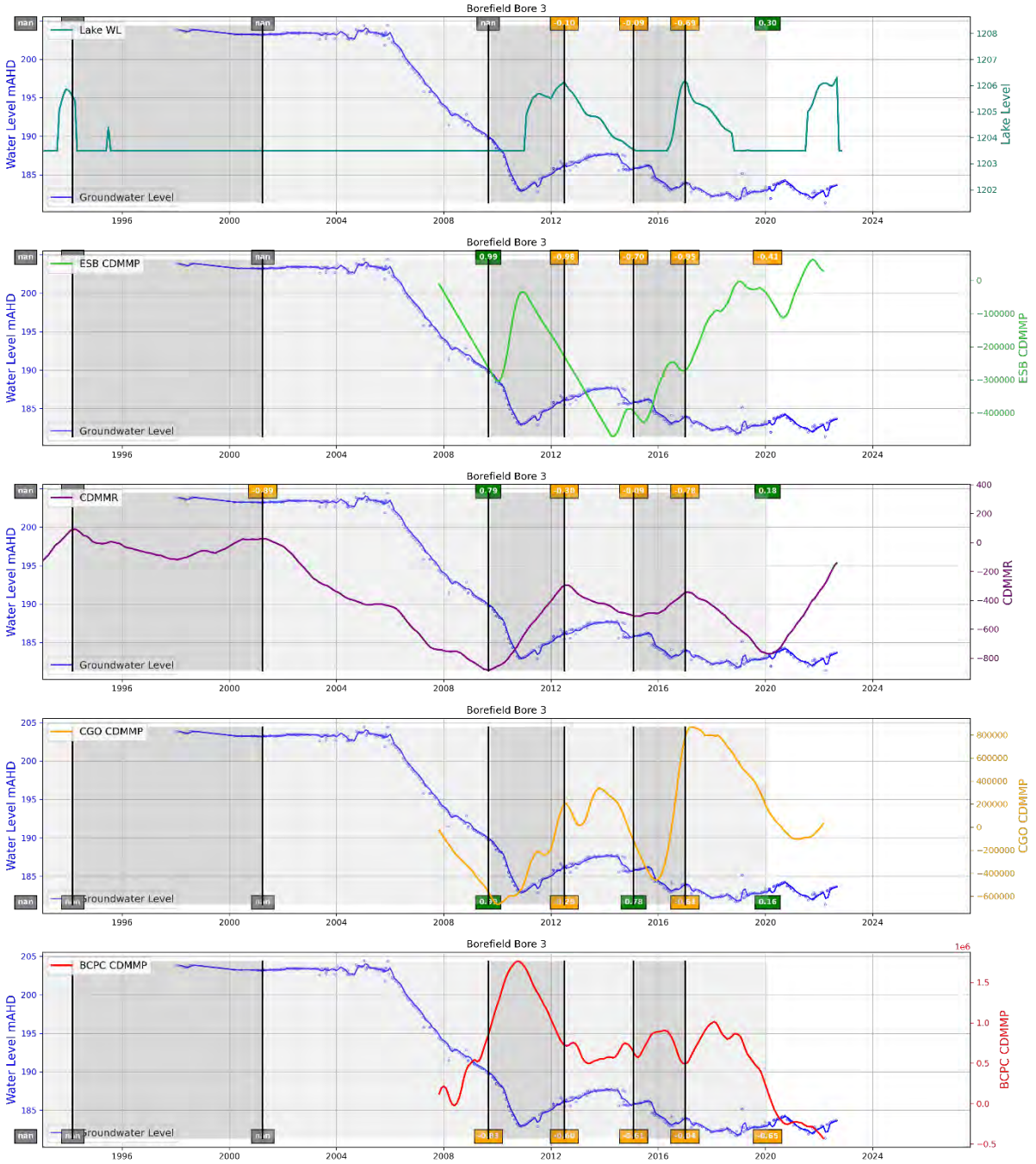


Figure A.1 **Borefield Bore 3 groundwater level correlation analysis**

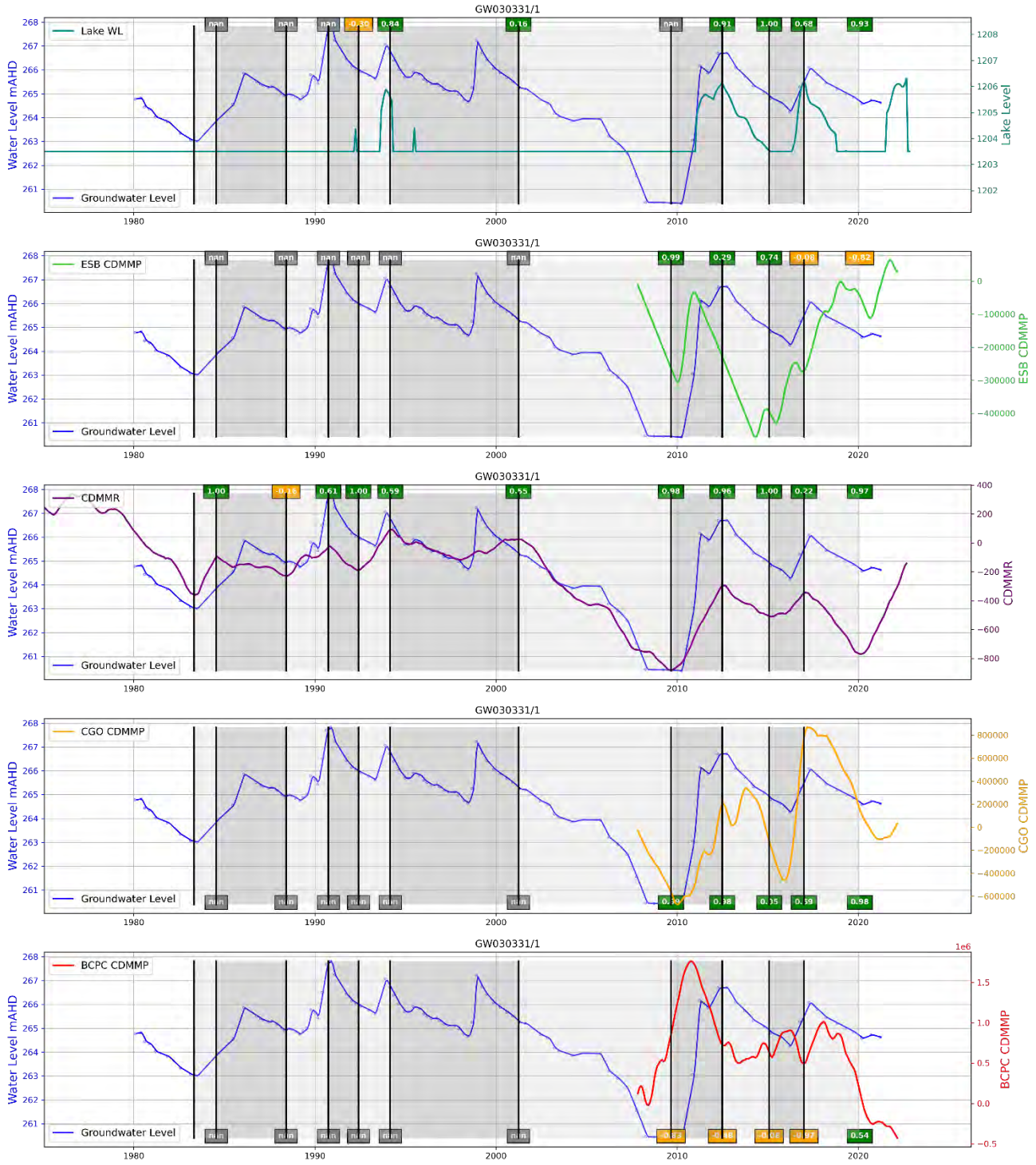


Figure A.2 GW030331/1 groundwater level trend analysis

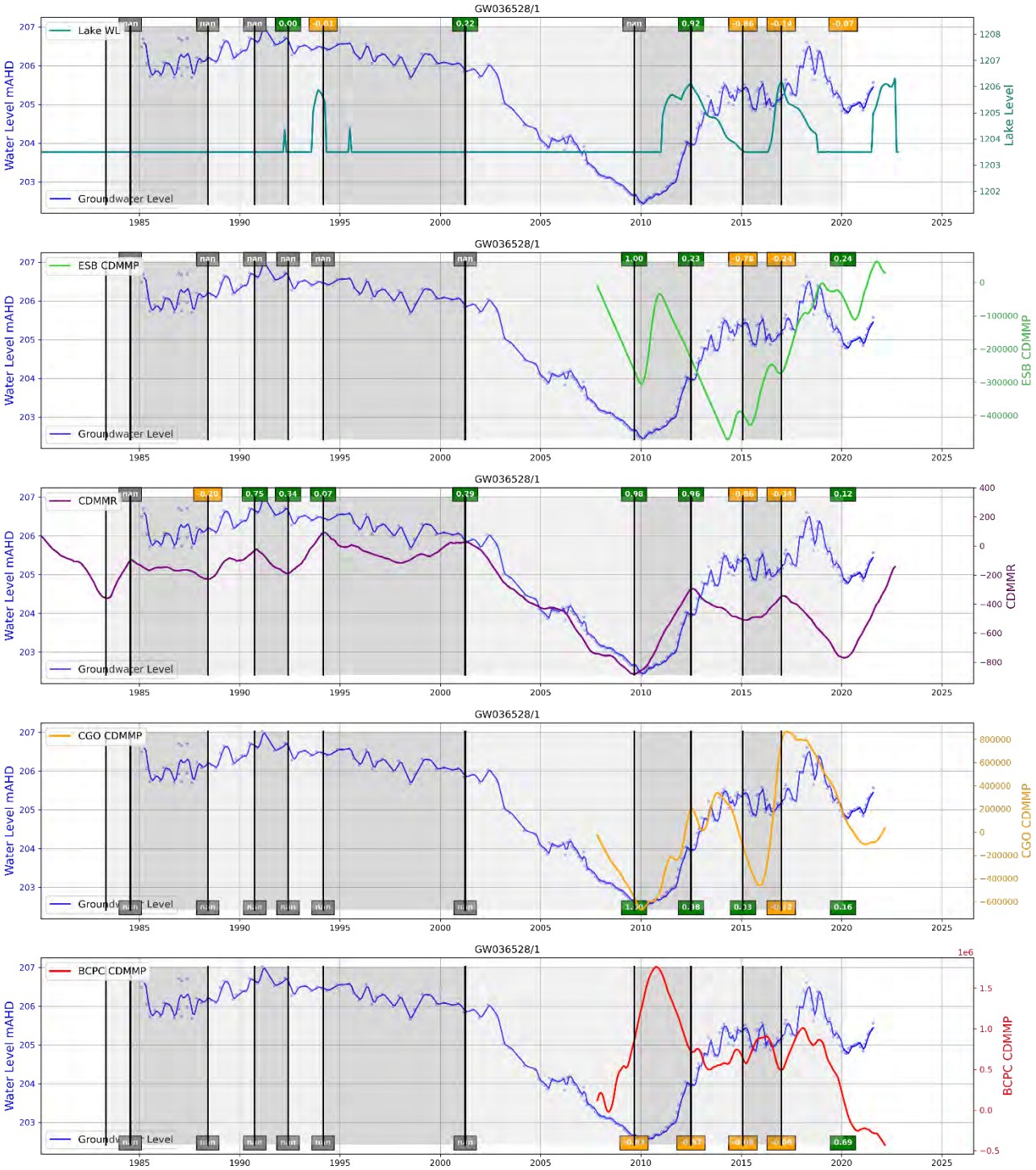


Figure A.3 GW036528/1 groundwater level trend analysis

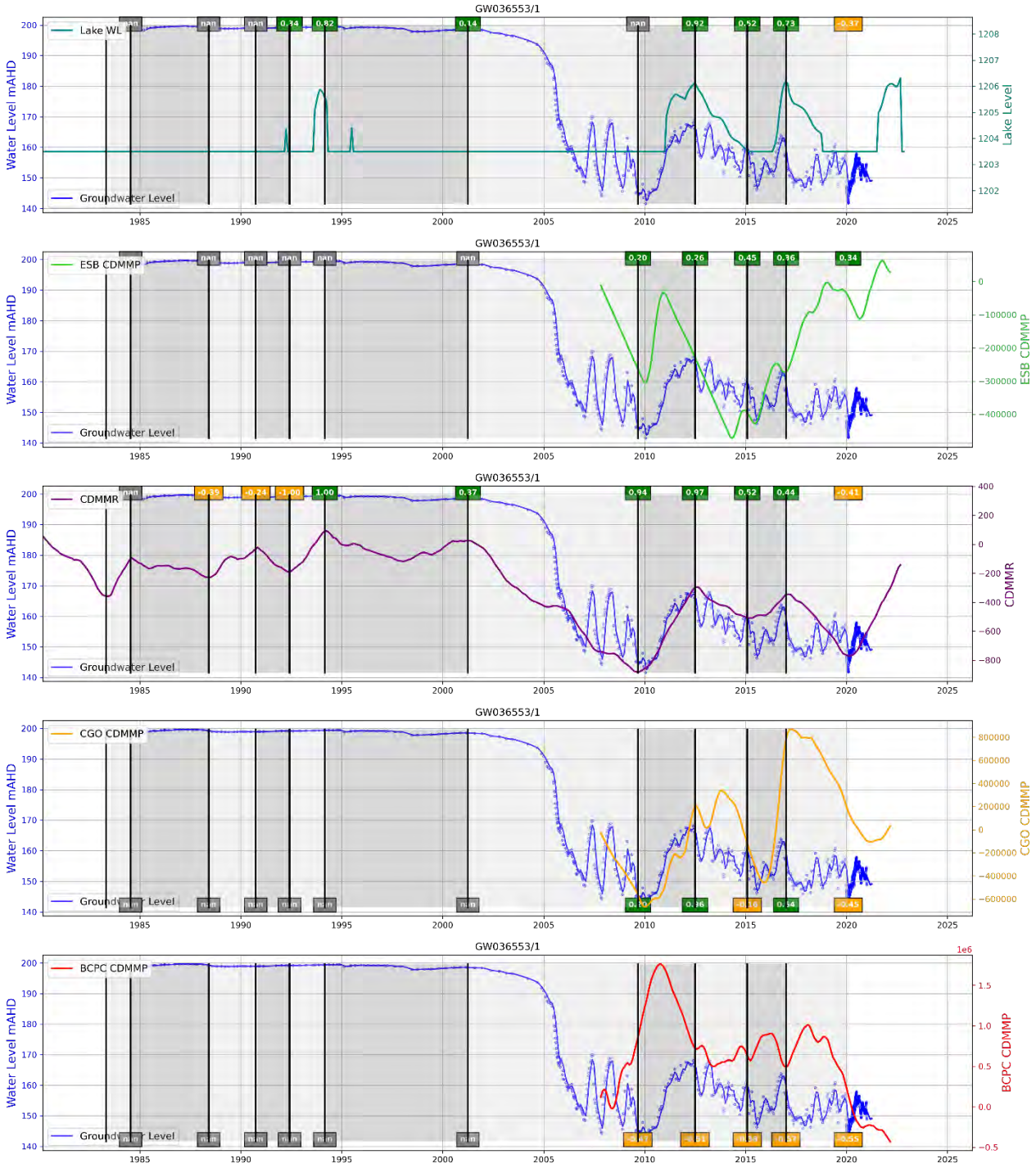


Figure A.4 GW036553/1 groundwater level trend analysis

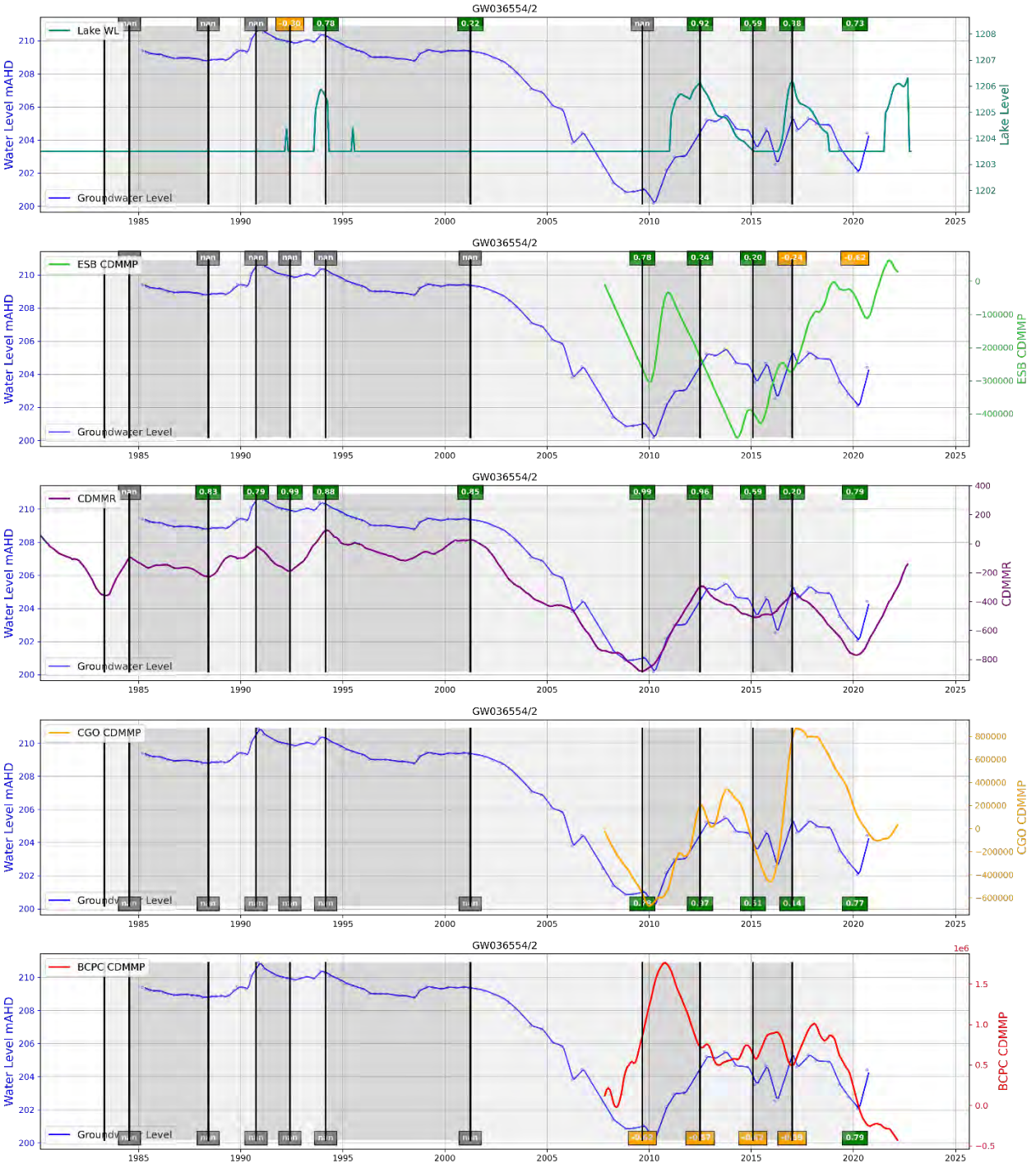


Figure A.5 GW036554/2 groundwater level trend analysis

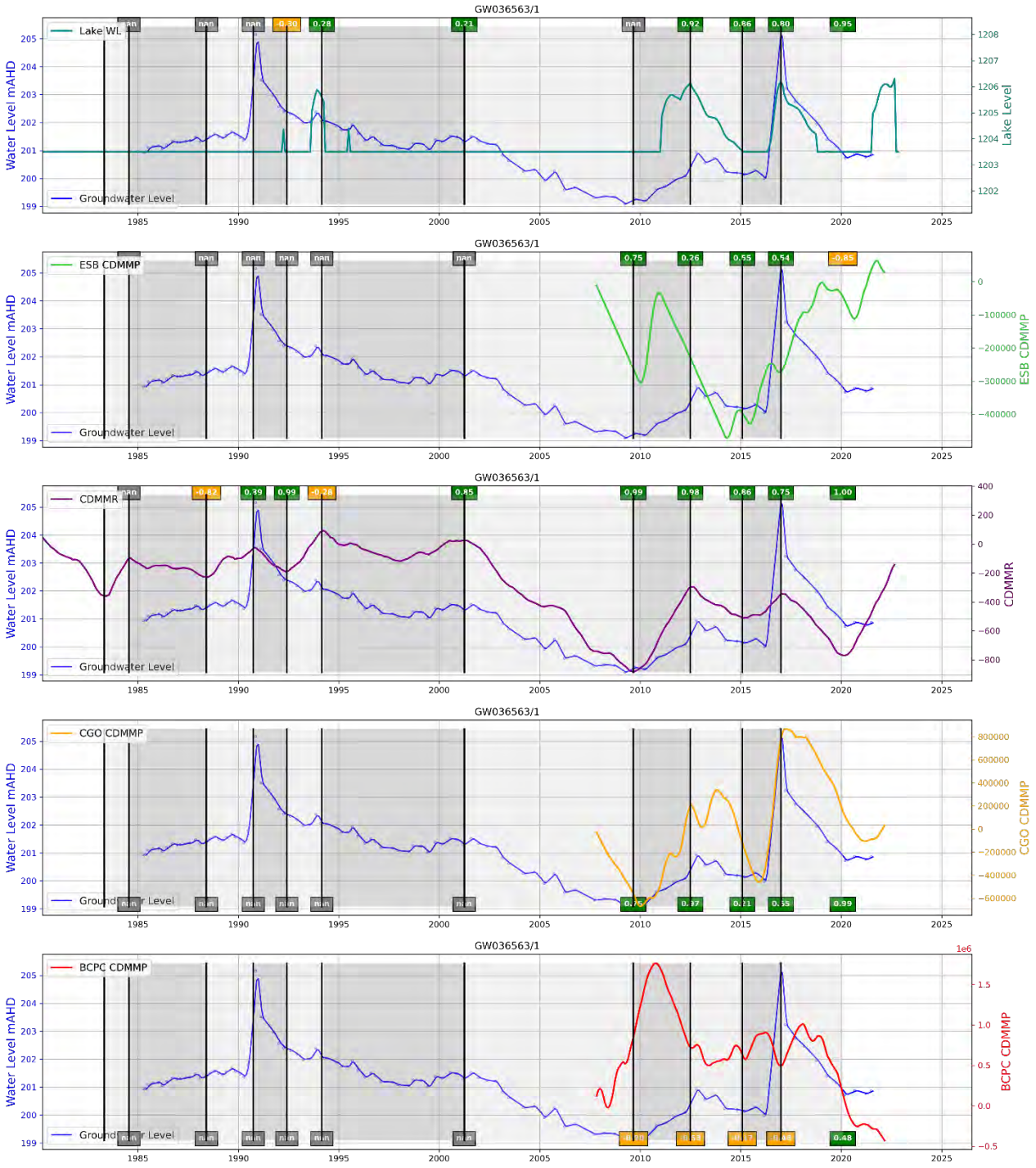


Figure A.6 GW036563/1 groundwater level trend analysis

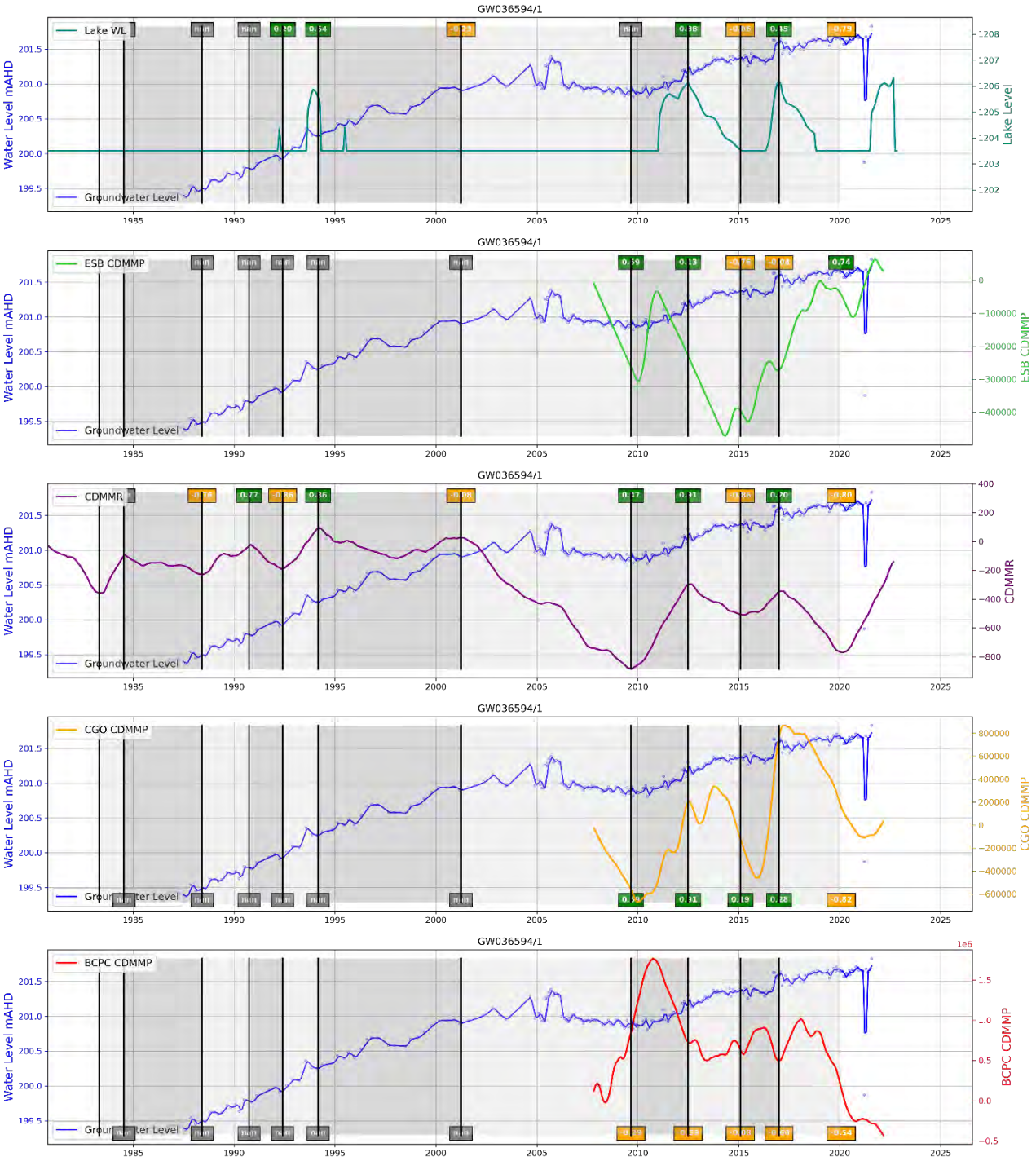


Figure A.7 GW036594/1 groundwater level trend analysis

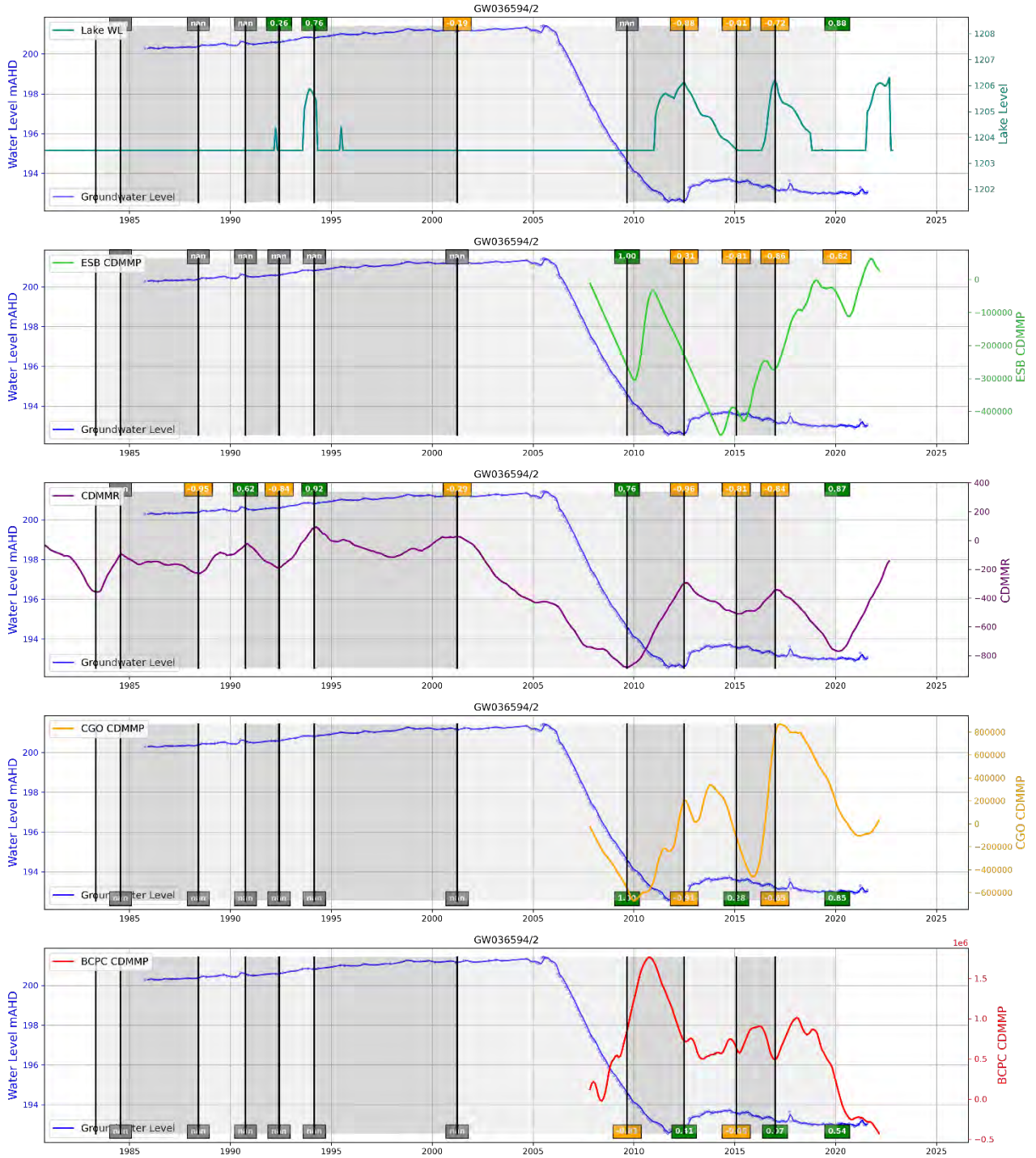


Figure A.8 GW036594/2 groundwater level trend analysis

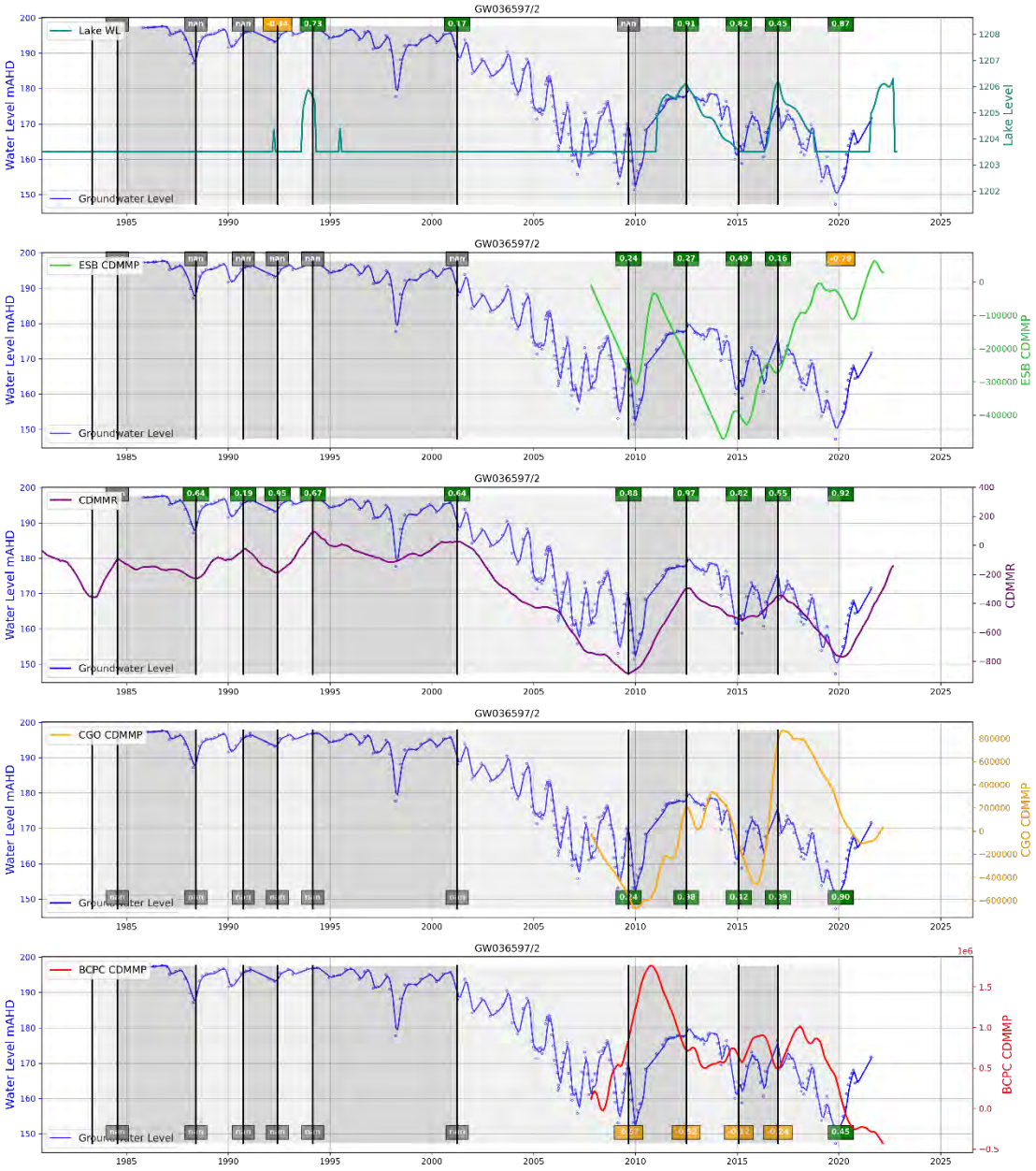


Figure A.9 GW036597/2 groundwater level trend analysis

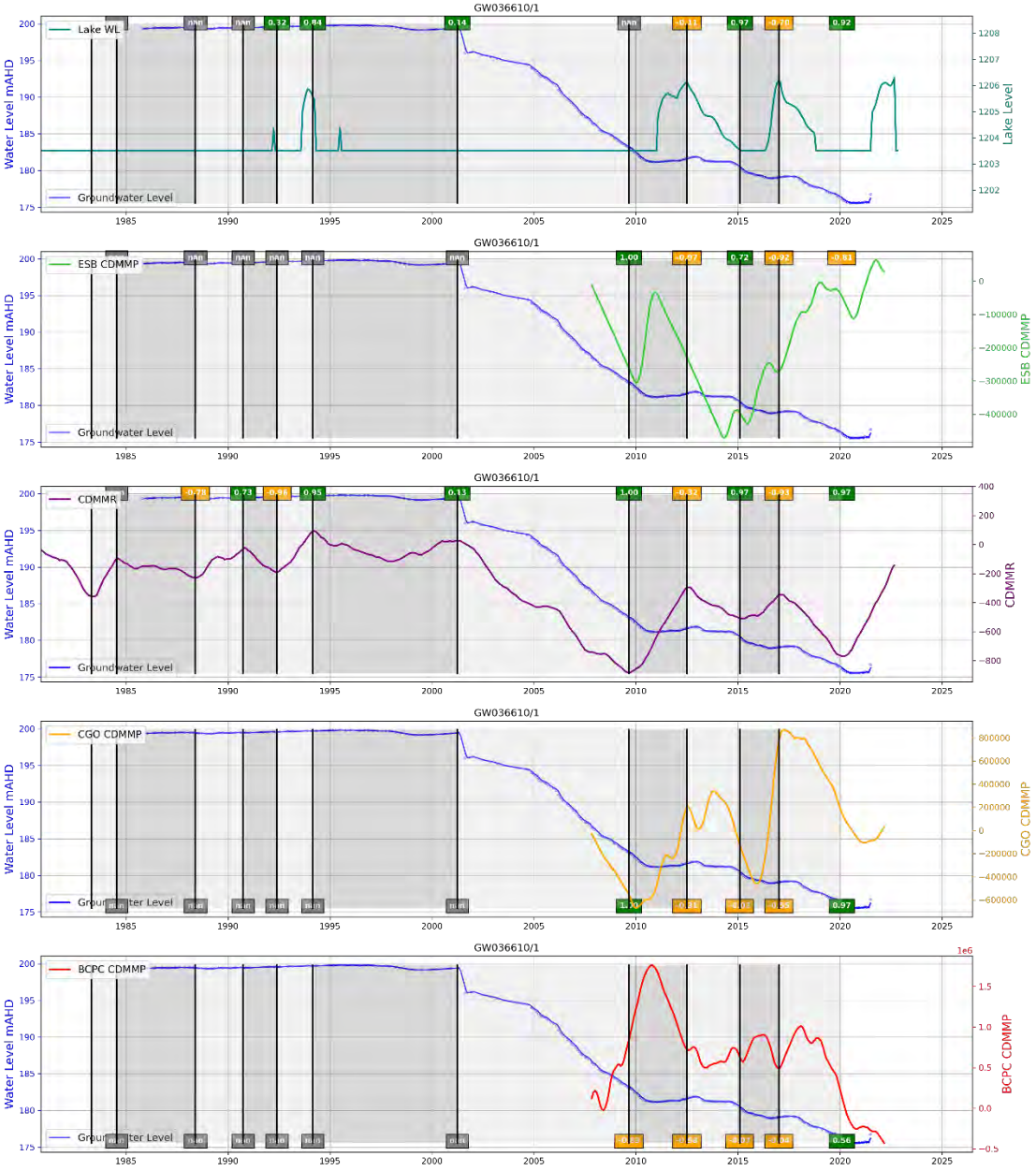


Figure A.10 GW036610/1 groundwater level trend analysis

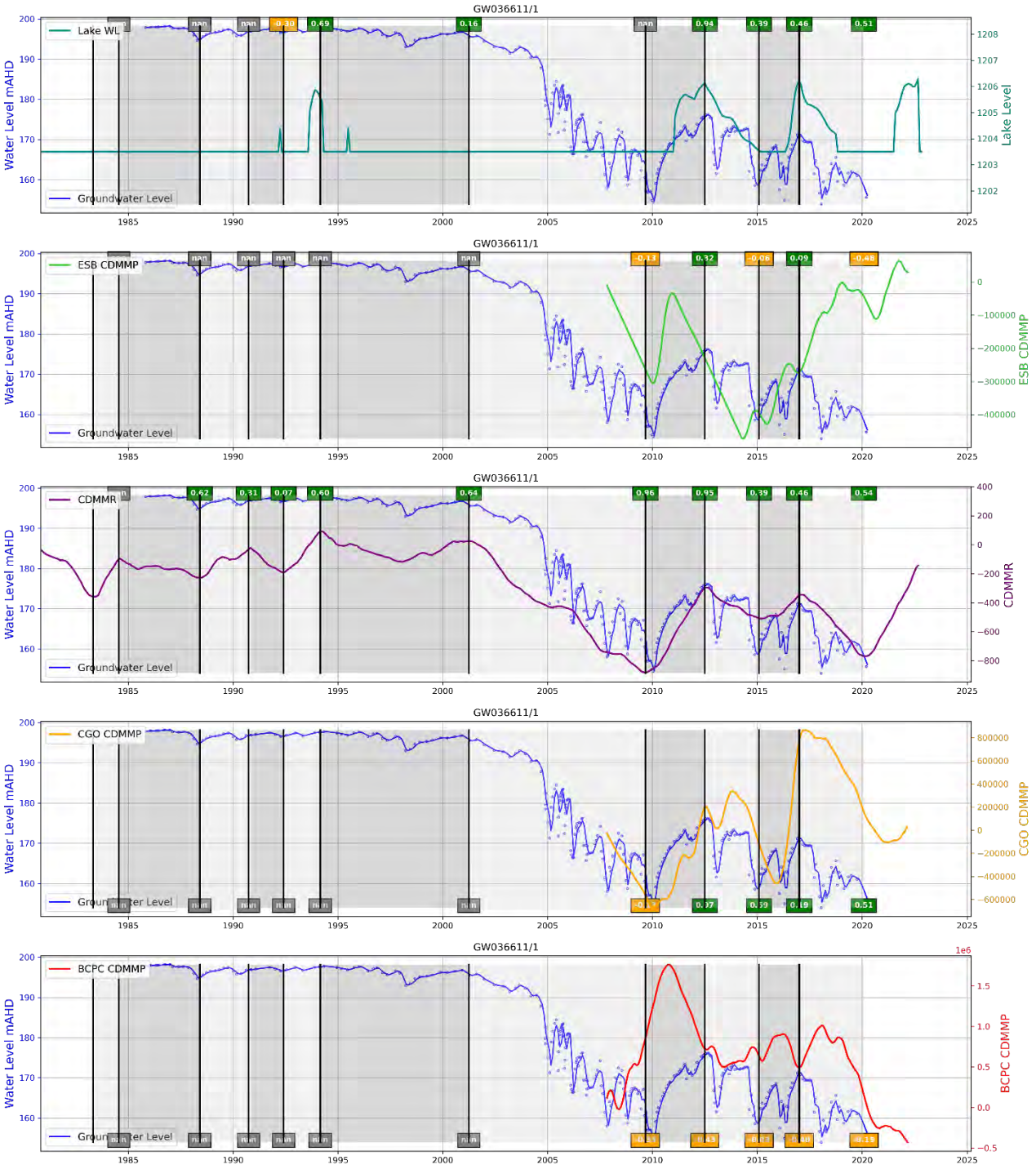


Figure A.11 GW036611/1 groundwater level trend analysis

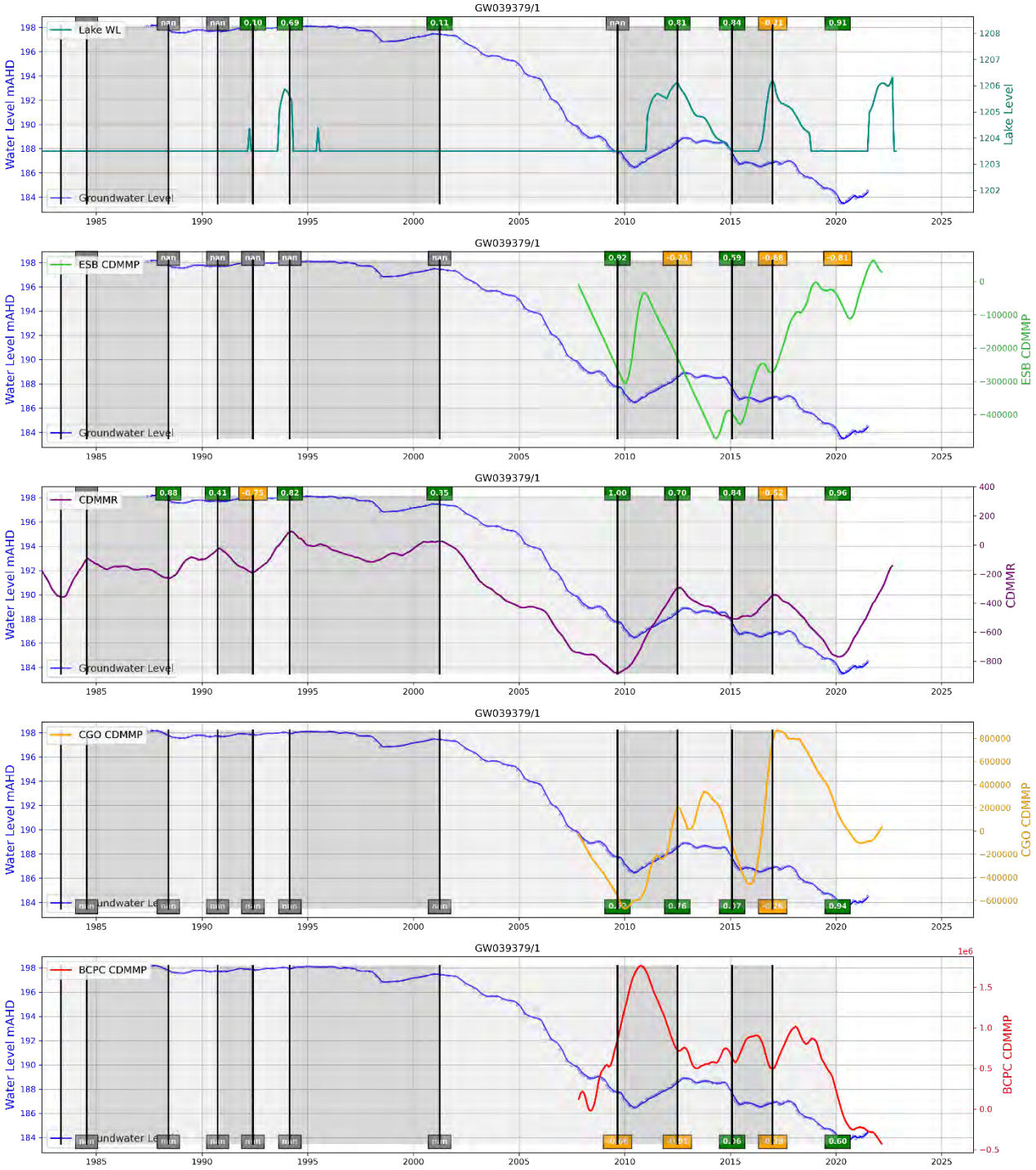


Figure A.12 GW039379/1 groundwater level trend analysis

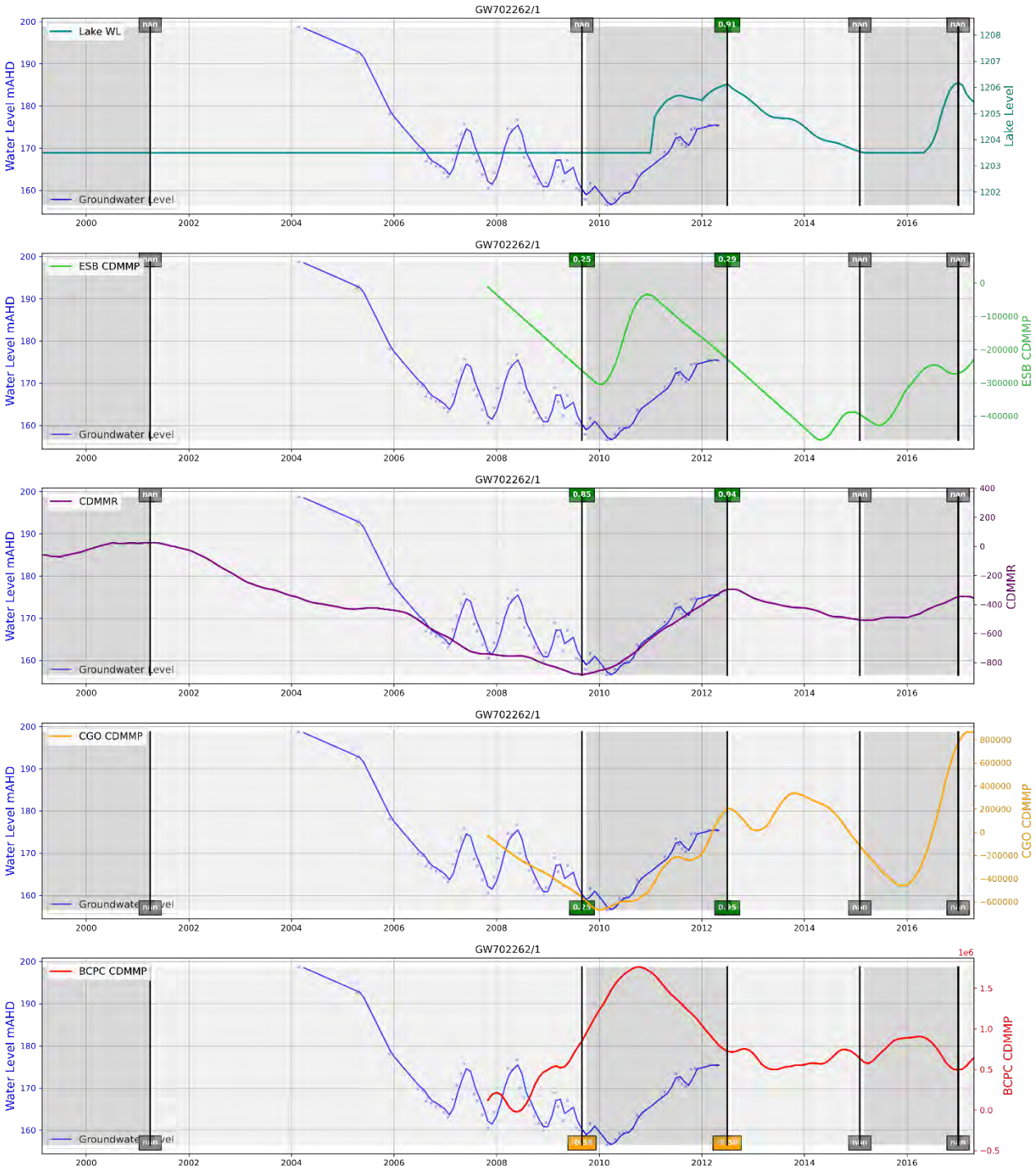


Figure A.13 GW702262/1 groundwater level trend analysis

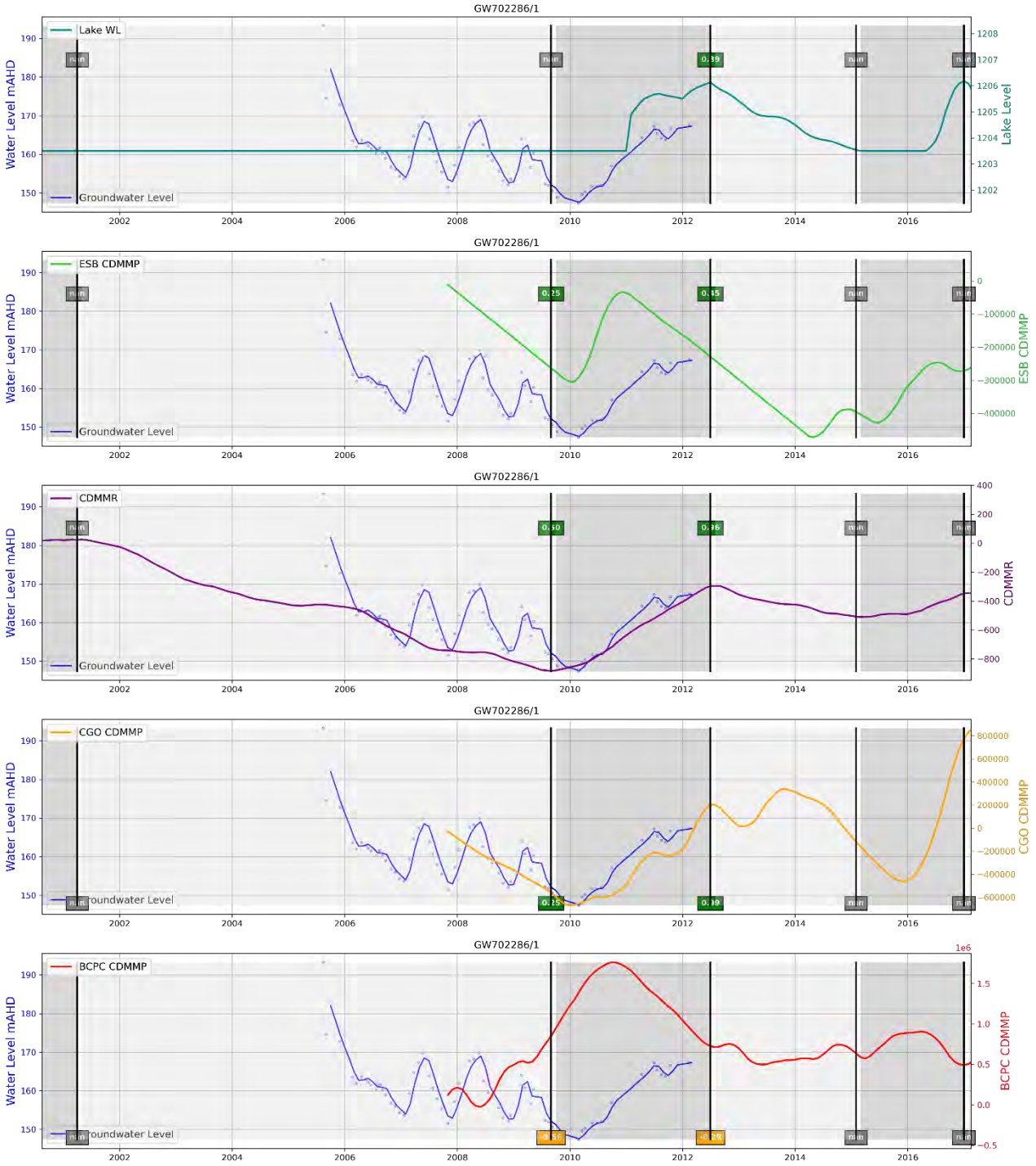


Figure A.14 GW702286/1 groundwater level trend analysis

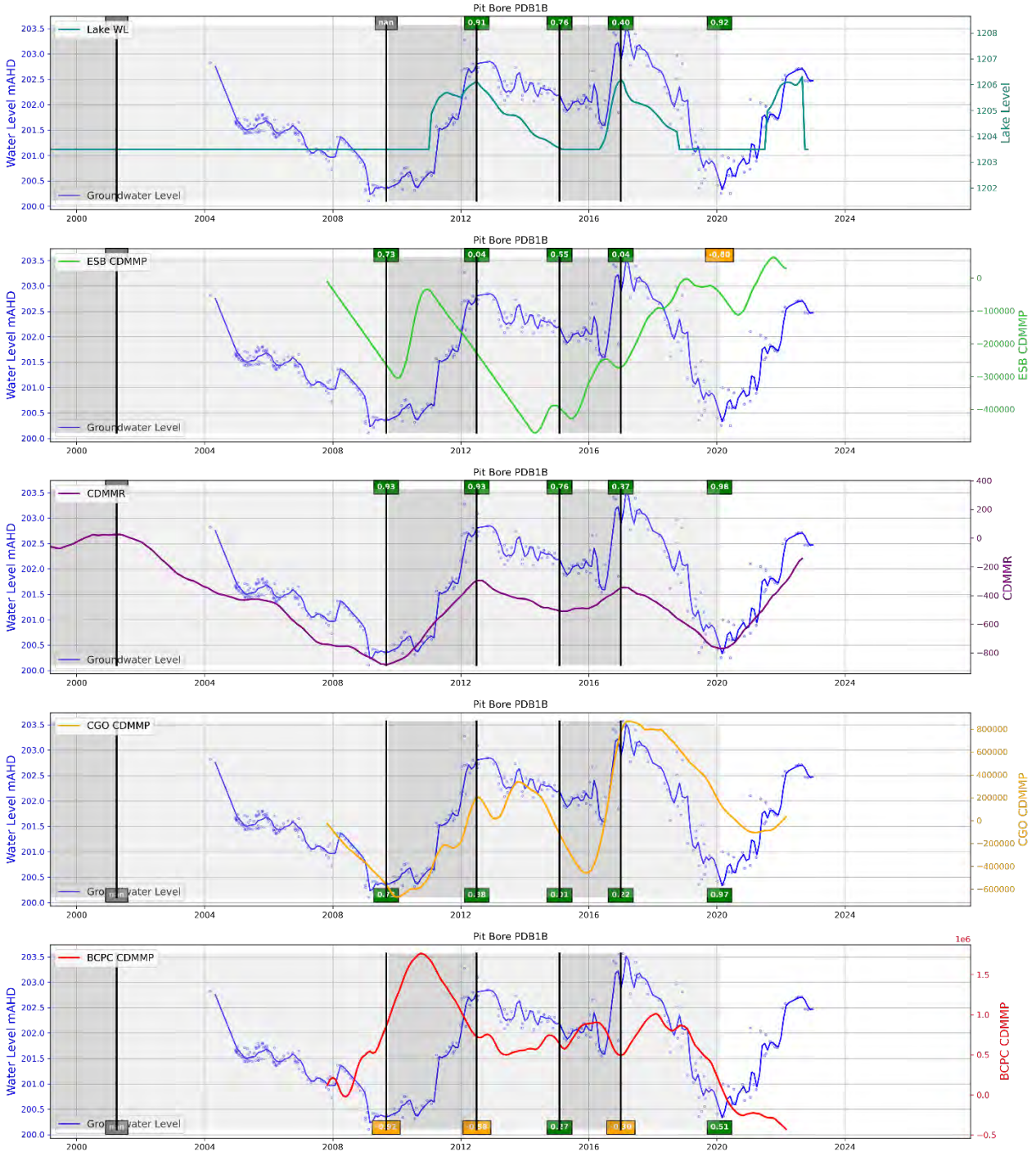


Figure A.15 Pit Bore PDB1B groundwater level trend analysis

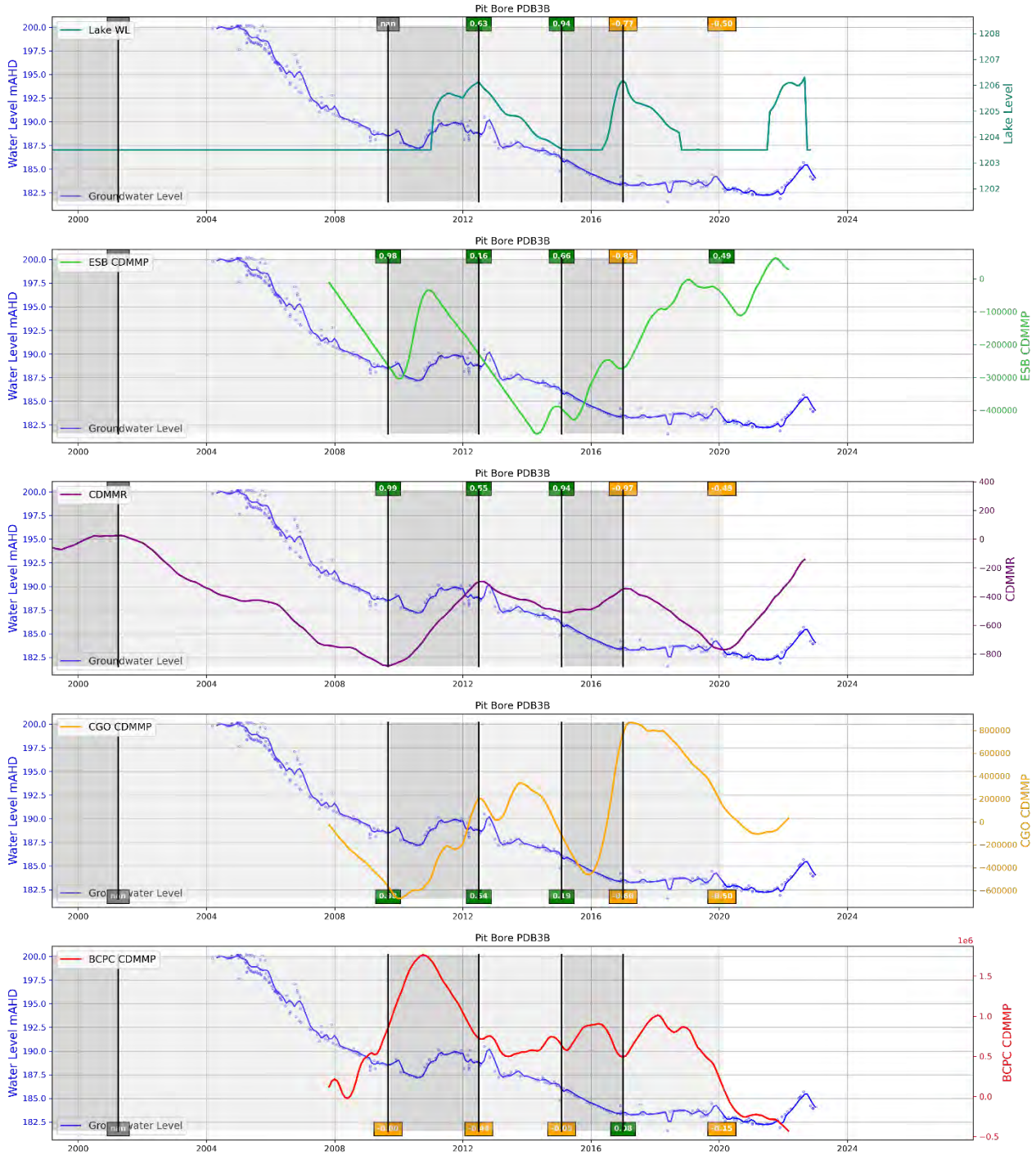


Figure A.16 Pit Bore PDB3B groundwater level trend analysis

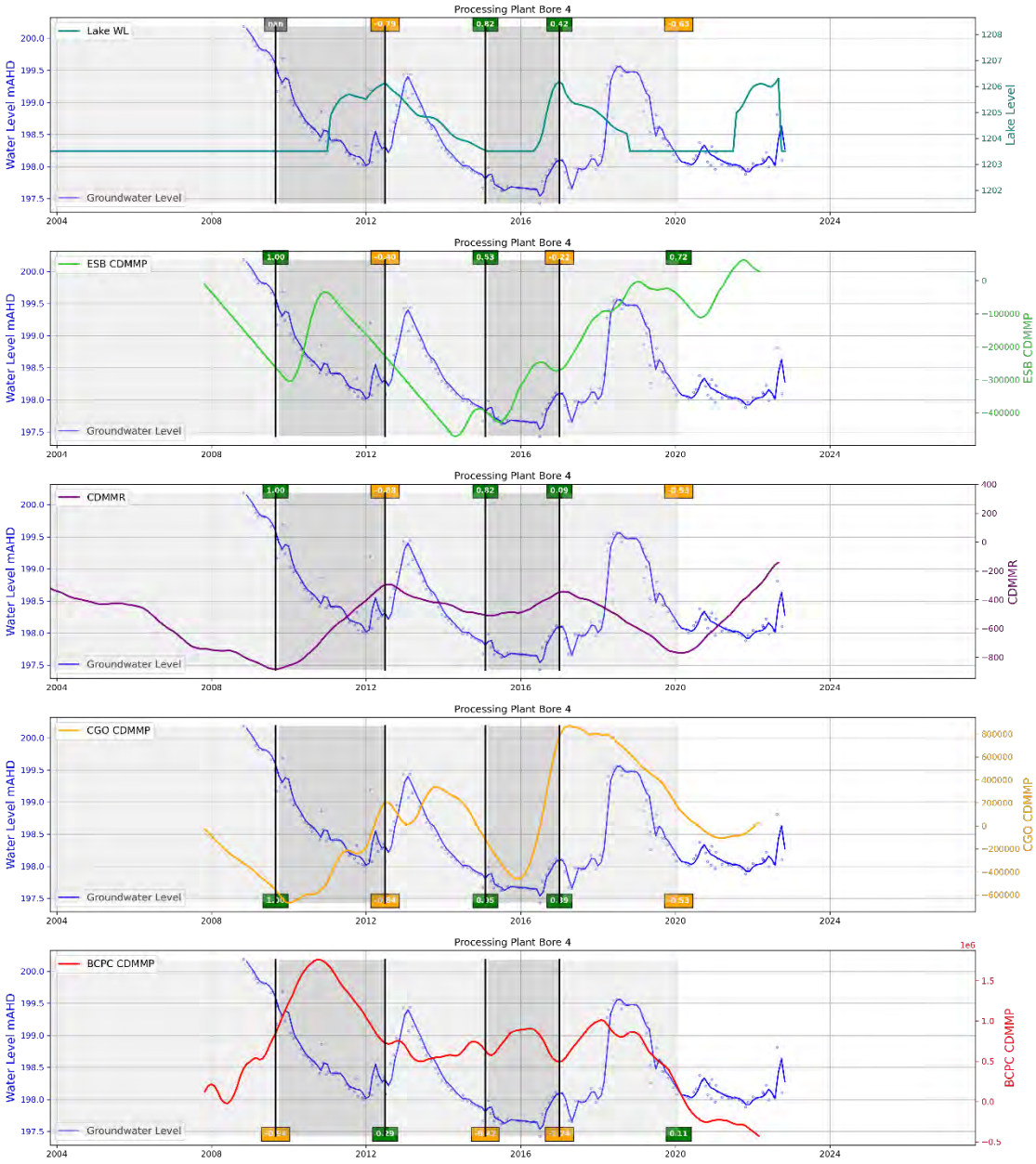


Figure A.17 Processing Plant Bore 4 groundwater level trend analysis

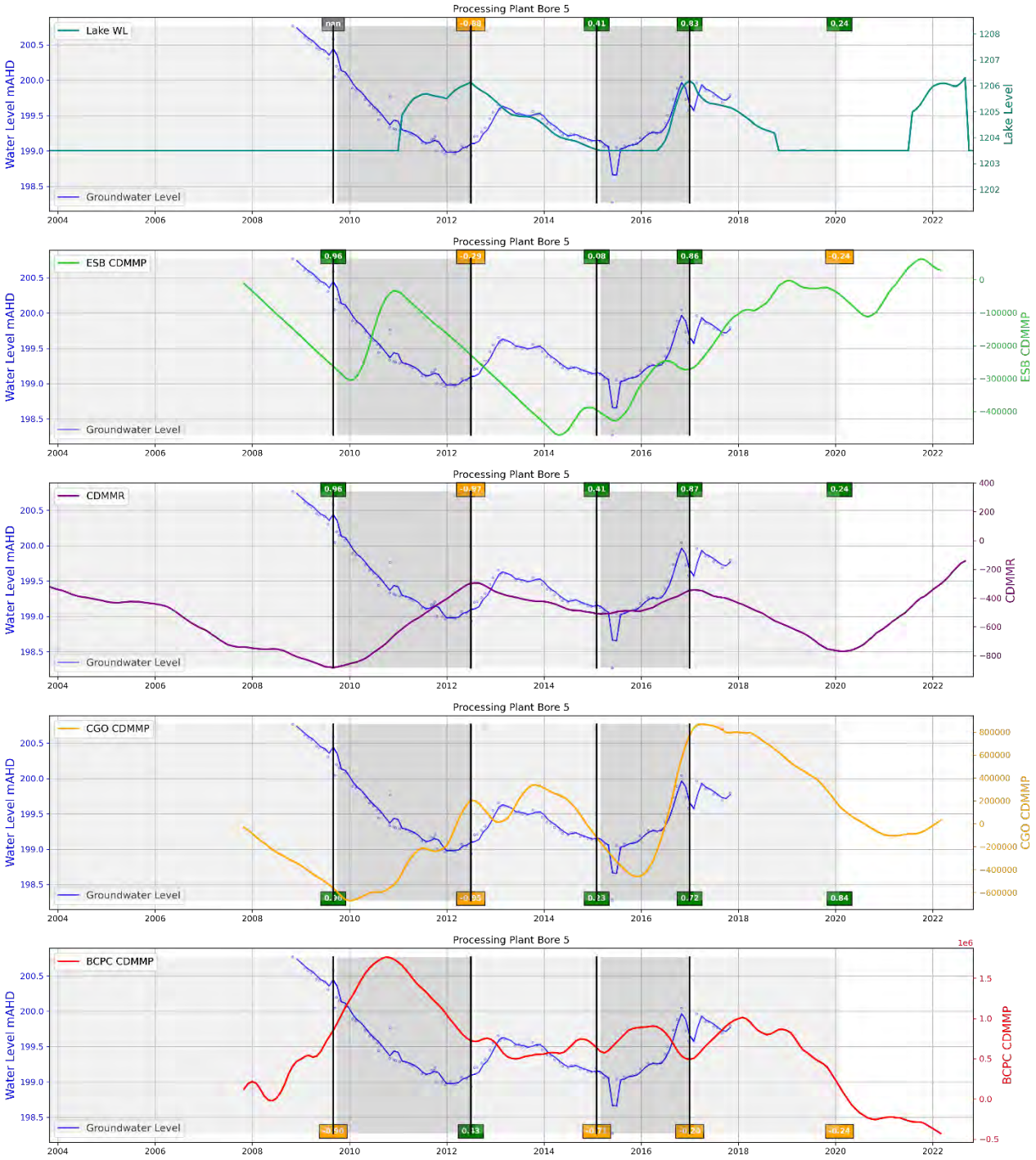


Figure A.18 Processing Plant Bore 5 groundwater level trend analysis

Australia

SYDNEY
Ground floor 20 Chandos Street
St Leonards NSW 2065
T 02 9493 9500

NEWCASTLE
Level 3 175 Scott Street
Newcastle NSW 2300
T 02 4907 4800

BRISBANE
Level 1 87 Wickham Terrace
Spring Hill QLD 4000
T 07 3648 1200

CANBERRA
Suite 2.04 Level 2
15 London Circuit
Canberra City ACT 2601

ADELAIDE
Level 4 74 Pirie Street
Adelaide SA 5000
T 08 8232 2253

MELBOURNE
Suite 8.03 Level 8
454 Collins Street
Melbourne VIC 3000
T 03 9993 1900

PERTH
Suite 9.02 Level 9
109 St Georges Terrace
Perth WA 6000
T 08 6430 4800

Canada

TORONTO
2345 Yonge Street Suite 300
Toronto ON M4P 2E5
T 647 467 1605

VANCOUVER
60 W 6th Ave
Vancouver BC V5Y 1K1
T 604 999 8297

linkedin.com/company/emm-consulting-pty-limited

emmconsulting.com.au