Evolution MINING

APPENDIX A

Hydrogeological Assessment

COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION

Environmental Assessment
2018

Resource Strategies

Coffey Services Australia Pty Ltd
Level 19, Tower B, 799 Pacific Highway
Chatswood NSW 2067 Australia

coffey.com

28 March 2018

Our ref: GEOTLCOV21910BG-AH

Evolution Mining (Cowal) Pty Limited
PO Box 210
WEST WYALONG NSW 2671

Attention: Bronwyn Flynn

Dear Bronwyn,

Cowal Gold Operations Processing Rate Modification

The attached reports present hydrogeological assessments of the proposed Cowal Gold Operations Processing Rate Modification (the Modification). The mine is located about 38 kilometres north-east of West Wyalong in New South Wales (NSW).

The reports were prepared for Evolution Mining (Cowal) Pty Limited (Evolution) by Coffey Services Australia Pty Ltd (Coffey). Two companion reports were prepared:

1. One report addressing the operations within Mining Lease 1535 including operation of the mine pit and the tailings storage facilities, including the Integrated Waste Landform proposed for the Modification.
2. A second report addressing the mine water supply borefields within the Bland Creek Palaeochannel Borefield (BCPB) and an Eastern Saline Borefield (ESB). The BCPB and the ESB are located a few kilometres east of the mine.

Evolution proposes to lodge an Environmental Assessment to facilitate approval of the Modification under section 75W of the NSW *Environmental Planning and Assessment Act, 1979*.

Based on the attached assessments, it is concluded that:

- Groundwater drawdown due to open pit mining and dewatering are predicted to generally remain within ML 1535 over the life of the mine.
- There would be negligible impact on Lake Cowal and the associated groundwater system due to the Modification's open pit, pit dewatering and groundwater extraction from ML 1535 saline groundwater supply borefield.
- Analytes associated with potential seepage from the tailings storage facility are expected to remain within groundwaters between the Integrated Waste Landform and the final void over the long-term.

- Evolution would continue to extract groundwater from the Lachlan Formation Water Source in accordance with existing licence entitlements, and in accordance with the contingency strategy.

For and on behalf of Coffey

Ross Best
Senior Principal

Attachments

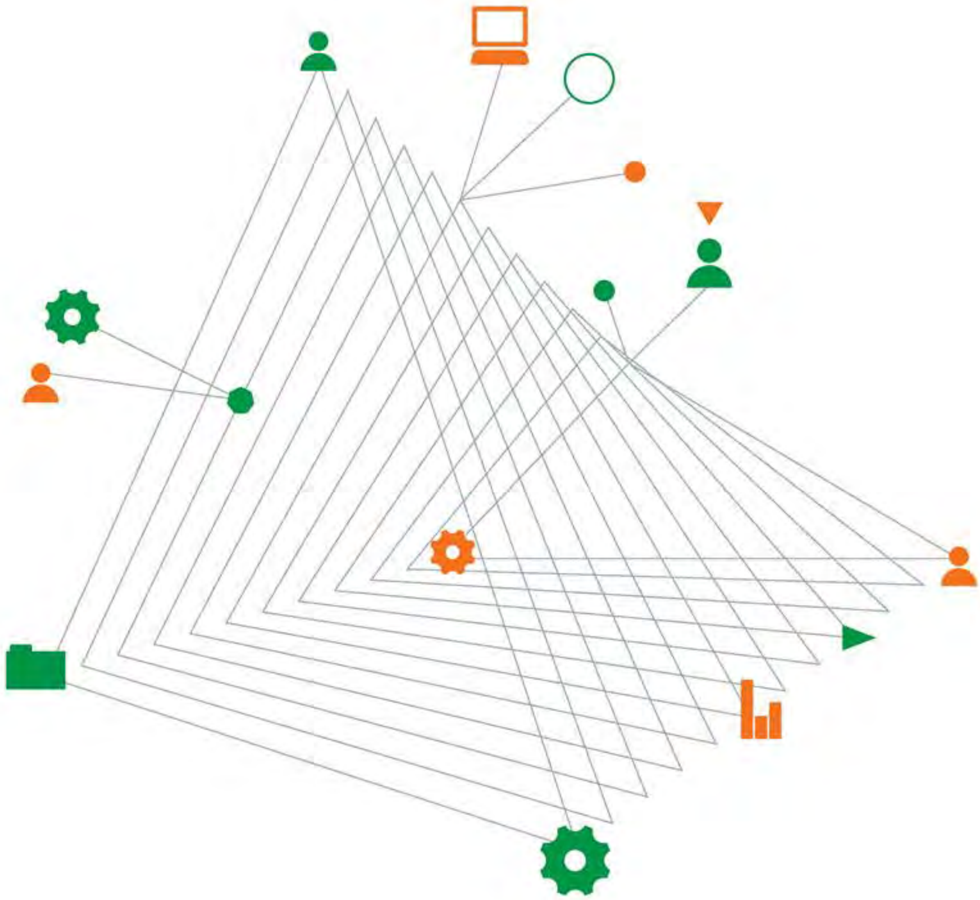
- GEOTLCOV21910BG-AG Cowal Gold Operations Processing Rate Modification Mine Site Hydrogeological Assessment
- GEOTLCOV21910BG-BCPB Cowal Gold Operations Processing Rate Modification Bland Creek Palaeochannel Borefield and Eastern Saline Borefield Groundwater Assessment

Evolution Mining (Cowal) Pty Limited

Cowal Gold Operations Processing Rate Modification (MOD14)

Mine Site Hydrogeological Assessment

2 March 2018



Experience
comes to life
when it is
powered by
expertise

Cowal Gold Operations Processing Rate Modification

Prepared for
Evolution Mining (Cowal) Pty Limited

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2 March 2018

Our ref: SYDGE206418-AA

Document authorisation

Our ref: SYDGE206418-AA

For and on behalf of Coffey

Ross Best
Senior Principal

Quality information

Revision history

Revision	Description	Date	Author	Reviewer	Signatory
Draft	CGO MOD14 Mine site hydrogeological assessment	30 Nov 2017	Sanka Ekanayake, Leon Cho	Ross Best	Ross Best
Final	CGO MOD14 Mine site hydrogeological assessment	2 Mar 2018	Sanka Ekanayake, Leon Cho	Ross Best	Ross Best

Distribution

Report Status	No. of copies	Format	Distributed to	Date
Draft	1	PDF	Bronwyn Flynn (Evolution) Mining [Cowal] Pty Limited	30 Nov 2017
Final	1	PDF	Bronwyn Flynn (Evolution) Mining [Cowal] Pty Limited	6 Mar 2018

Table of Contents

Tables

Figures

Appendices

1 INTRODUCTION

This report presents the Hydrogeological Assessment conducted by Coffey Services Australia Pty Ltd (Coffey) for Evolution (Cowal) Mining Pty Limited's (Evolution) Cowal Gold Operations (CGO) Processing Rate Modification (the Modification). This report addresses the effects within Mining Lease (ML) 1535. A companion report has been prepared addressing the effects of mining operations on the external borefields.

Evolution proposes to lodge an Environmental Assessment (EA) to facilitate approval of the Modification under section 75W of the New South Wales (NSW) *Environmental Planning and Assessment Act, 1979* (EP&A Act). This Hydrogeological Assessment has been prepared to support the EA.

1.1 Modification Background

Evolution is the owner and operator of the CGO located approximately 38 kilometres (km) north-east of West Wyalong in NSW (Figures 1 and 2).

Recent feasibility studies have identified potential opportunities to maximize the ore processing capacity of the CGO's existing processing plant. On this basis, Evolution proposes to modify Development Consent DA 14/98 under section 75W of the NSW EP&A Act to increase the CGO's approved ore processing rate of 7.5 million tonnes per annum (Mtpa) to 9.8 Mtpa (herein referred to as the Modification).

The main activities associated with development of the Modification would include (Figure 3):

- increasing the ore processing rate from 7.5 Mtpa to 9.8 Mtpa;
- modification of the existing Tailings Storage Facilities (TSFs) to form one larger TSF, which would also accommodate mine waste rock (herein referred to as the IWL);
- relocation of water management infrastructure (i.e. the Up-Catchment Diversion System and approved location for contained water storage D10) and other ancillary infrastructure (e.g. internal roads and soil and ore stockpiles) elsewhere within ML 1535 and Mining Lease Application 1;
- installation of a secondary crushing circuit within the existing process plant area;
- duplication of the existing water supply pipeline across Lake Cowal;
- increased annual extraction of water from the CGO's external water supply sources;
- increased consumption of process reagents (including cyanide) and other process consumables;
- an increase in the average and peak workforce employed at the CGO;
- relocation of a travelling stock reserve and Lake Cowal Road; and
- provision of crushed rock material to local councils to assist with road base supplies.

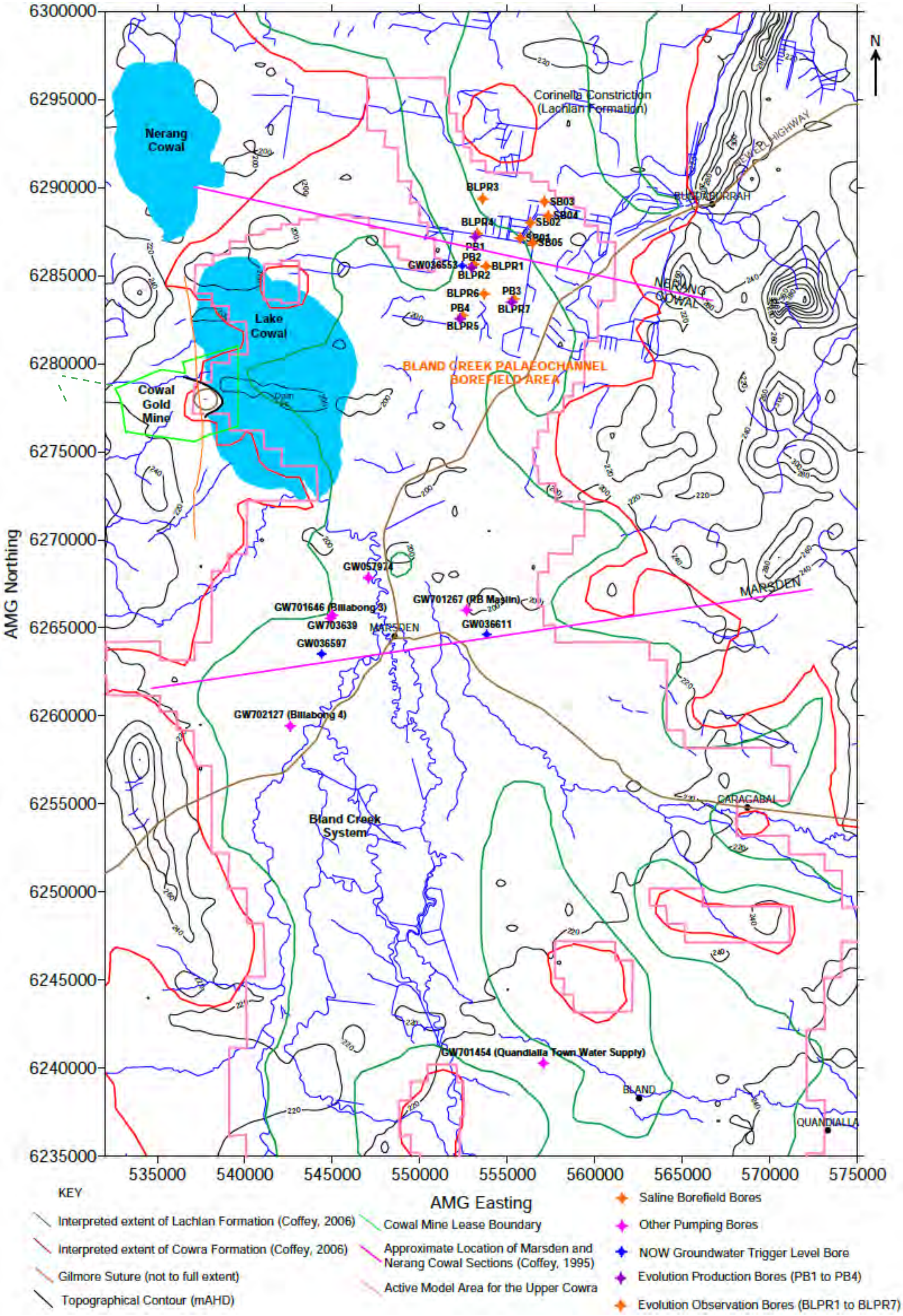
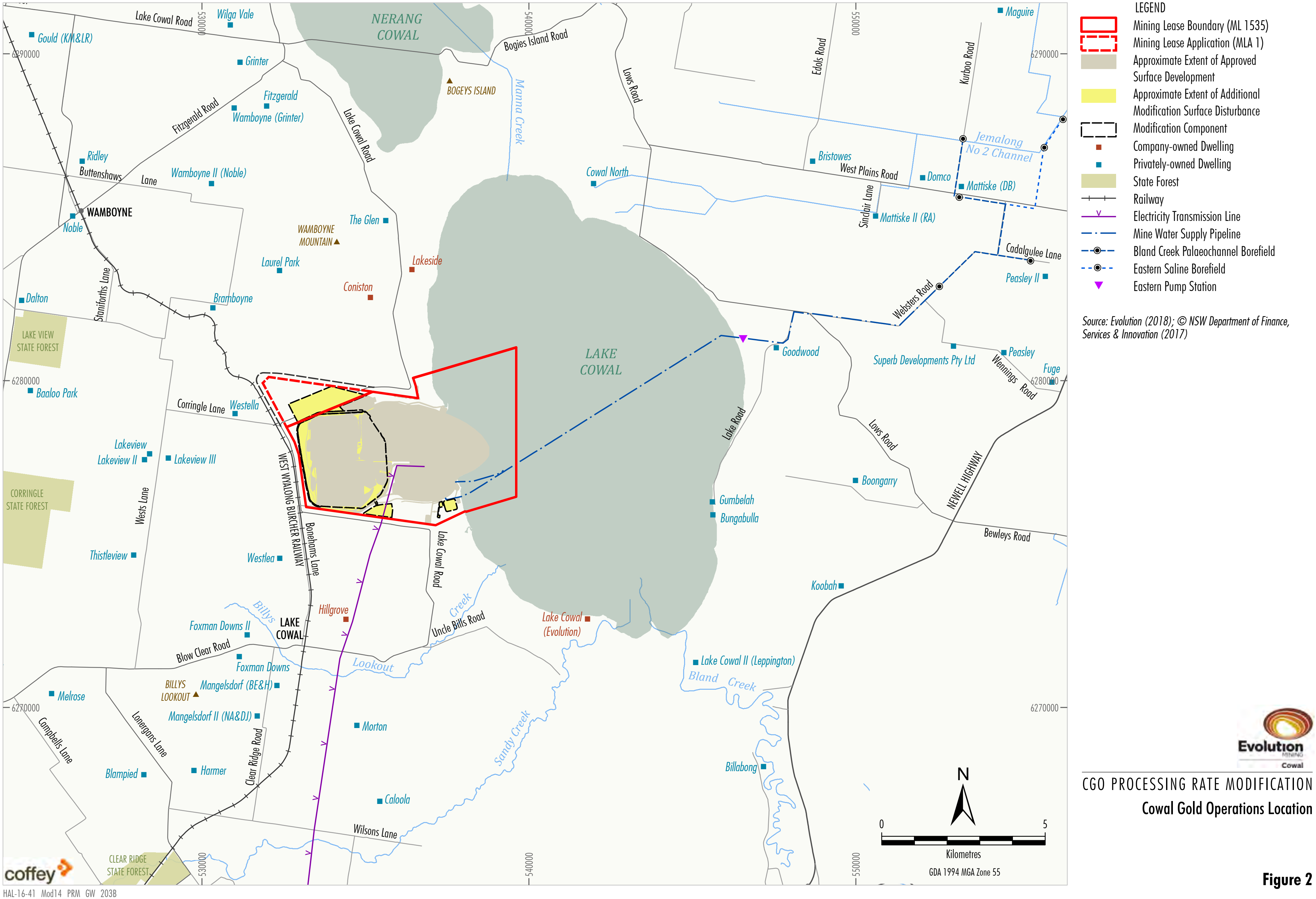


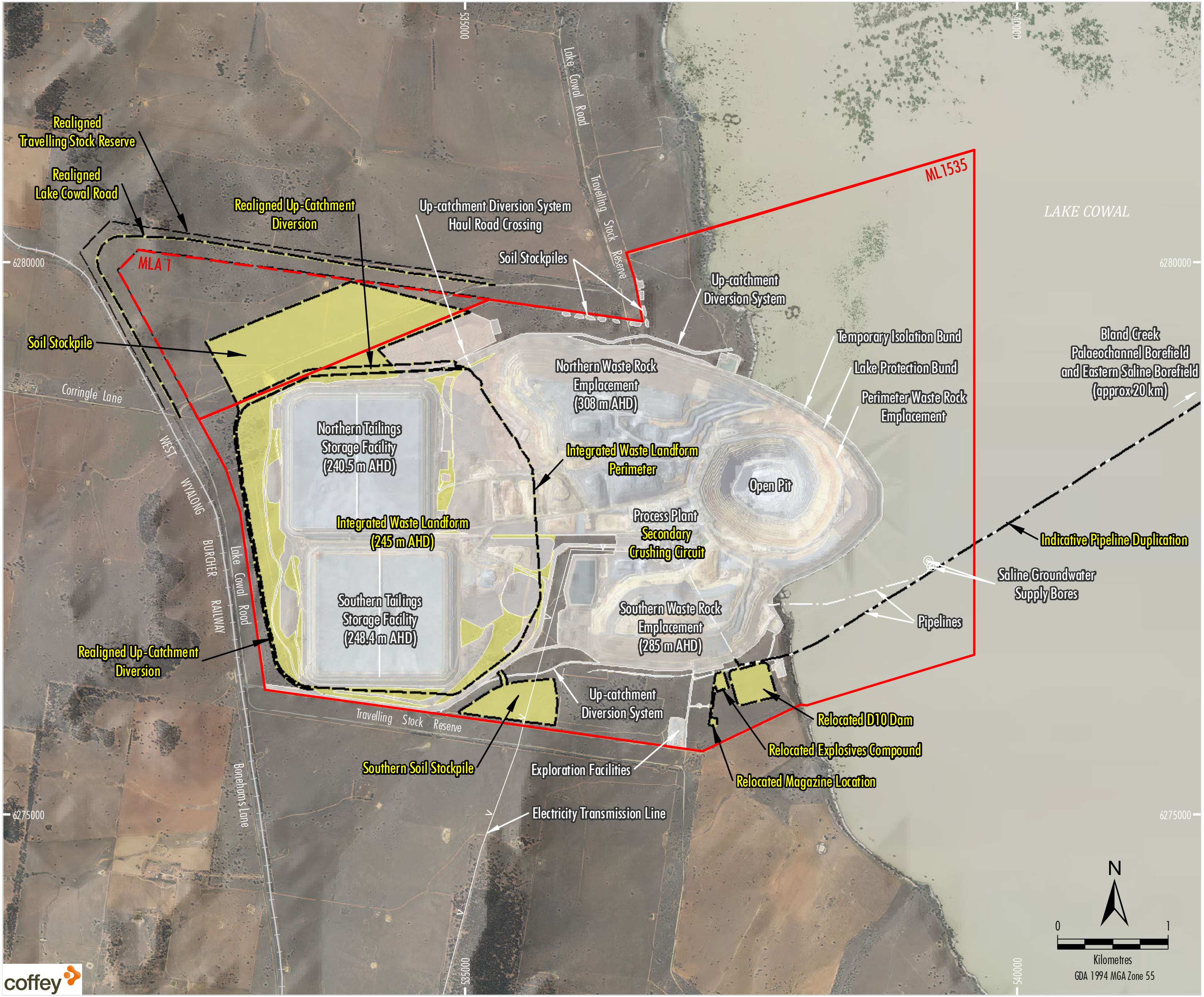
Figure 1 - Regional Location



CGO PROCESSING RATE MODIFICATION

Cowal Gold Operations Location

Figure 2



LEGEND

- Mining Lease Boundary (ML 1535)
- Mining Lease Application Boundary (MLA 1)
- Approximate Extent of Approved Surface Development
- Approximate Extent of Additional Modification Surface Disturbance
- Modification Component

Source: Evolution (2018); © NSW Department of Finance, Services & Innovation (2017)
Orthophoto: Evolution (Oct 2017)

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Cowal

CGO PROCESSING RATE MODIFICATION

Modification General Arrangement

coffey

HAL-16-41_Mod14_PRM_GW_202A

Figure 3

1.2 Scope of Mine Site Hydrogeological Assessment

The objective of this Hydrogeological Assessment is to provide an assessment of potential impacts associated with the Modification consistent with the requirements outlined in the NSW Department of Planning and Environment (DP&E) Secretary's Environmental Assessment Requirements (SEARs) for the Modification provided on 17 November 2017.

This report builds upon work carried out for a hydrogeological assessment to assess the impacts of the mining operations in relation to changes to the CGO Mine Life Modification (Coffey, 2016). That work considered similar issues to those addressed in relation to the Modification.

The key tasks undertaken for this Mine Site Hydrogeological Assessment comprised:

- Characterisation of the hydrogeological environment, including: climate, topography, regional geology, mine geology, regional hydrology and hydrogeology.
- Collation and review of:
  - Groundwater monitoring data, including groundwater level and groundwater quality results from bores located within the ML 1535 (i.e. proximal to the TSFs, waste rock emplacements and open pit).
  - Past pit dewatering rates and groundwater drawdown monitoring results.
- Identification of Groundwater Dependent Ecosystems (GDEs) in the region, based on the Bureau of Meteorology (BoM) GDE Atlas.
- Development of a hydrogeological conceptual model, including:
  - Selection of data for the review.
  - Assessing the need, where relevant, to update the existing mine site numerical model.
  - Proposing modelling approaches to support groundwater impact assessment for the Modification.
  - Updating an existing groundwater numerical model of the mine site to incorporate conditions relevant to the Modification, including the development of the IWL, more recent groundwater monitoring data and dewatering volume records for the pit, and validation of that model against observation data.
  - Predictive modelling to assess the following under the Modification:
    - potential changes to the hydrogeological regime as a result of the development of the IWL under the Modification;
    - potential groundwater drawdown associated with open pit dewatering;
    - expected inflow rates to the open pit;
    - groundwater drawdown and flow impacts on Lake Cowal after mine closure, over both the short term (up to 20 years) and long term (steady state, potentially hundreds of years into the future after mine closure); and
    - sensitivity analysis in relation to the water levels in Lake Cowal.
- Discussion of the groundwater regime resulting from the Modification and discussion of potential contaminant migration from the TSFs and IWL.

- Discussion relating to the open pit and pit dewatering, including:
  - potential changes to the hydrogeological regime as a result of the increased depth of the open pit under the Modification, based on the predictive modelling;
  - expected inflow rates to the open pit, based on the predictive modelling;
  - potential groundwater drawdown due to open pit dewatering, based on the predictive modelling;
  - commentary relating to potential drawdown effects against criteria noted in the NSW Office of Water (NOW) NSW Aquifer Interference Policy (NOW, 2012);
  - qualitative assessment of the expected groundwater quality of water seeping into the open pit;
  - qualitative assessment of impacts on groundwater quality due to pit dewatering.
- Discussion relating to tailings and waste rock emplacement seepage, including:
  - Assessment of predicted seepage rates from the TSFs and IWL, based on the predictive modelling. Seepage rates appraised against current performance by comparing model-predicted groundwater levels against monitored groundwater levels near the TSFs.
  - Qualitative assessment of the potential groundwater quality impacts down-gradient of the IWL due to seepage of stored water. Assessed groundwater quality impacts reviewed in the context of groundwater quality monitoring results.
- Discussion relating to mine closure, based on the predictive modelling and including assessment of:
  - The potential groundwater flow impacts on Lake Cowal after mine closure, over both the short term (up to 20 years) and long term (steady state, potentially hundreds of years into the future after mine closure).
  - Review of groundwater licensing information, including required licences, allocations and the influence of regulatory constraints, and description of water licensing requirements under the Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources, 2012 and the Water Sharing Plan for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources, 2012.
  - Discussion of potential measures to manage, mitigate or avoid the potential impacts of the Modification on groundwater in ML 1535 and neighbouring areas.

1.3 Secretary's Environmental Assessment Requirements

The SEARs for the Modification (provided on 17 November 2017) included the following requirements related to groundwater:

- an assessment of the likely impacts of the proposed Modification on the quantity and quality of surface and groundwater resources;
- an assessment of the likely impacts of the proposed Modification on aquifers, watercourses, riparian land, water supply infrastructure and systems and other water users;
- identification of any water licensing requirements or other approvals under the *Water Act 1912* and/or *Water Management Act 2000*; and
- a detailed description of the proposed water management system, water monitoring program and measures to mitigate surface and groundwater impacts.

The SEARs also include a number of policies, plans and guidelines, which have been considered during the preparation of this report (Section 2).

2 LEGISLATION, POLICY AND GUIDELINES

This assessment has been prepared with consideration of the following policies, guidelines and plans:

- National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (Australian and New Zealand Environment and Conservation Council, 1995).
- NSW *Protection of the Environment Operations Act 1997.*
- The NSW State Groundwater Policy Framework Document (NSW Department of Land and Water Conservation [DLWC], 1997).
- The NSW State Groundwater Quality Protection Policy (DLWC, 1998).
- The NSW Groundwater Dependent Ecosystem Policy (DLWC, 2002).
- NSW Aquifer Interference Policy (NOW, 2012).
- Australian Groundwater Modelling Guidelines (Barnett et al., 2012).
- Guidelines for the Assessment and Management of Groundwater Contamination (Department of Environment and Conservation NSW, 2007).

3 DATA REVIEW

The CGO is located within ML 1535 on the western side of Lake Cowal in Central NSW. A regional location plan illustrating topographical contours and the location of regional groundwater extraction bores (both owned by Evolution and privately owned) is presented in Figure 1.

3.1 Site Layout

The CGO site layout is shown in Figure 3.

The following infrastructure and features are present within ML 1535:

- open pit in the east of the site;
- perimeter waste rock emplacement and lake protection bund running beyond, and around, the open pit;
- northern and southern waste rock emplacements to the north-west and south-west of the open pit;
- processing plant located to the west of the open pit;
- a number of contained water storages at various locations across the site; and
- TSFs comprising two storage dams with approximate dimensions of 1,300 metres (m) by 1,300 m in the west of ML 1535, which are to be integrated into the IWL for the Modification.

3.2 Information Sources

Coffey has a long involvement with the CGO development. This report has been prepared in consideration of the previous reports completed by Coffey and others including information provided by the CGO (i.e. Evolution and previous owners of the mine). Information sources used in the development of the hydrogeological conceptual model are listed in Section 4.

3.3 Topography

The region is characterised by a flat landscape with very low undulating hills and occasional rocky outcrops. The majority of vegetation in the area has been cleared, with most of the cleared areas used for agriculture. Remnant and secondary vegetation is restricted to elevated rocky areas (SNC-Lavalin Australia, 2003).

Figure 4 shows the topography and drainage of the area. Ground slopes fall from the north-east (Lachlan Floodplain) and south-east (upper Bland Creek Palaeochannel) towards Lake Cowal. Lake Cowal forms a local depression and fills with floodwater every few years. Since 1998, Lake Cowal has filled on three occasions: late 2010, 2012 and again in 2016 (Hydro Engineering & Consulting Pty Ltd [HEC], 2018). It drains north-west towards Nerang Cowal, and eventually to the Lachlan River. Flood breakout flows from the Lachlan River at Jemalong Gap and drains towards Lake Cowal.

Ground elevations at the CGO range from approximately 225 m Australian Height Datum (mAHD) on the western ML 1535 boundary to approximately 200 mAHD at the eastern ML 1535 boundary at Lake Cowal. The Bland Creek Palaeochannel Borefield area has an elevation of just under 210 mAHD, with minimal variation. Hills formed by rock outcrops on the fringes of the Bland Creek floodplain reach in excess of 300 mAHD.

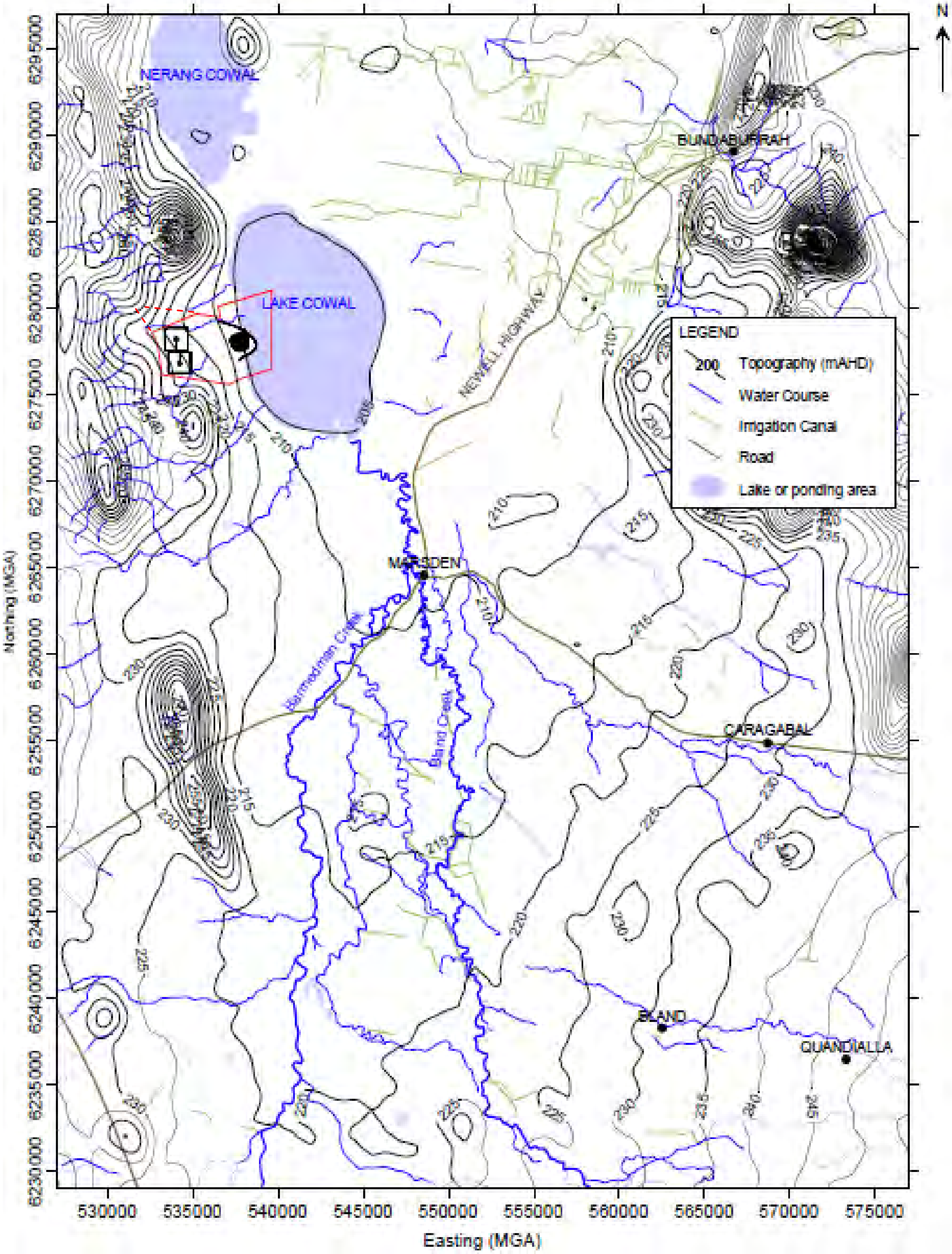


Figure 4 - Drainage and Topography

The CGO is located in the Bland Creek Valley, on the western margin of the Bland Creek Palaeochannel Plain, which is approximately 20 km to 30 km wide, bounded by the following:

- Bland Creek Palaeochannel and Jemalong Range (Tullamore Syncline) to the east;
- Manna Anticline and its associated ridge, together with the regionally extensive Gilmore Suture/Gilmore Fault Zone, located to the west of Lake Cowal;
- Lachlan River to the north; and
- Bland Creek catchment to the south.

3.4 Climate

The closest rainfall station to the study area with long-term records is Station 73054 (Wyalong Post Office), operated by the BoM, and is located approximately 32 km south of ML 1535. This station has no monitoring data between 1939 and 1948. Table 1 lists average and median (Decile 5) monthly rainfall for this station. The average annual rainfall is 479.7 millimetres (mm). Note that the median annual rainfall is not equivalent to the sum of the monthly median rainfalls.

The closest climate station within 100 km of the site with reasonable amounts of pan evaporation data is BoM Station 050052 (Condobolin Agricultural Research Station), located about 75 km away. Table 1 lists the average monthly pan evaporation for the station over the period 1973 to 2017.

Table 1. Average Rainfall and Pan Evaporation in the Regional Area

Month	Wyalong Post Office (73054)		Pan evaporation Condobolin Agricultural Research Station (050052)
	1895 to 2017	1895 to 2017	1973-2017
	Average rainfall (mm)	Decile 5 (median) rainfall (mm)	Mean Total (mm)
January	41.1	26.6	310.0
February	38.6	21.9	243.6
March	38.2	23.0	210.8
April	34.6	24.6	129.0
May	39.2	30.8	74.4
June	43.3	36.3	48.0
July	42.2	38.3	49.6
August	38.9	38.2	77.5
September	37.4	28.6	117.0
October	45.0	37.0	179.8
November	36.7	33.1	234.0
December	44.5	31.8	297.6
Annual	479.7	476.0	1971.3

Source: BoM (2017a).

Average rainfall data shows no obvious seasonal trend. Pan evaporation follows a simple sinusoidal trend that is a maximum in January and December. Using average rainfall, a rainfall deficit occurs for all months of the year except June and July. Average annual pan evaporation is more than three times the average annual rainfall (Table 1).

Annual and monthly rainfall from the beginning of mine life (2005) to 2017 at BoM Station 73054 is shown in Figure 5. Annual rainfall was significantly above the mean annual rainfall for 2010, 2011 and 2016.

The regional annual pan evaporation totals from the nearest BoM pan evaporation stations are as follows:

- 1,971 mm (Condobolin Agricultural Research Station, Station No. 050052, 1973 to 2017).
- 1,569 mm (Condobolin Soil Conservation, Station No. 050102, 1971 to 1985).
- 1,388 mm (Cowra Research Station, Station No. 063023, 1965 to 2010).

3.5 Surface Drainage

Lake Cowal is an ephemeral shallow freshwater lake that is predominantly dry, with water influx during severe rainy seasons (SNC-Lavalin Australia, 2003). The pit envelope encroaches on the lake area, and a lake protection bund and groundwater dewatering programme forms an integral part of the mine plan. The lake is filled by runoff from the Bland Creek catchment to the south and flood breakout from the Lachlan River to the north. Lake Cowal is located within the Bland Creek Valley, a major tributary of the Lachlan River system. The lake overflows into Nerang Cowal, another ephemeral lake to the north, and then into Bogandillon Swamp before flowing to the Lachlan River. Prior to the drought conditions that occurred last decade, the lake was observed to contain some water in seven years out of ten. Since 1998, Lake Cowal has filled on three occasions: late 2010, 2012 and again in 2016 (HEC, 2018).

Watercourses in the area (with the exception of the Lachlan River) are intermittent. Bland and Barmedman Creeks are the largest of the local creeks (Figure 4). They form ephemeral tributaries to Lake Cowal, flowing in from the south. An extensive irrigation canal system is present within the Bland Creek Palaeochannel area and to the north. These canals deliver water from the Lachlan River to irrigators to sustain the agricultural industry in this area.

3.6 Land Use

The Australian Natural Resources Atlas (2009) indicates land use across the region surrounding the CGO site includes livestock grazing, dryland and irrigation agriculture, and unclassified water bodies.

Within the Lachlan River Valley, livestock grazing comprises 69% of land use, followed by dryland agriculture at 22%, nature conservation area at 4% and other uses at 5% (Australian Natural Resources Atlas, 2009).

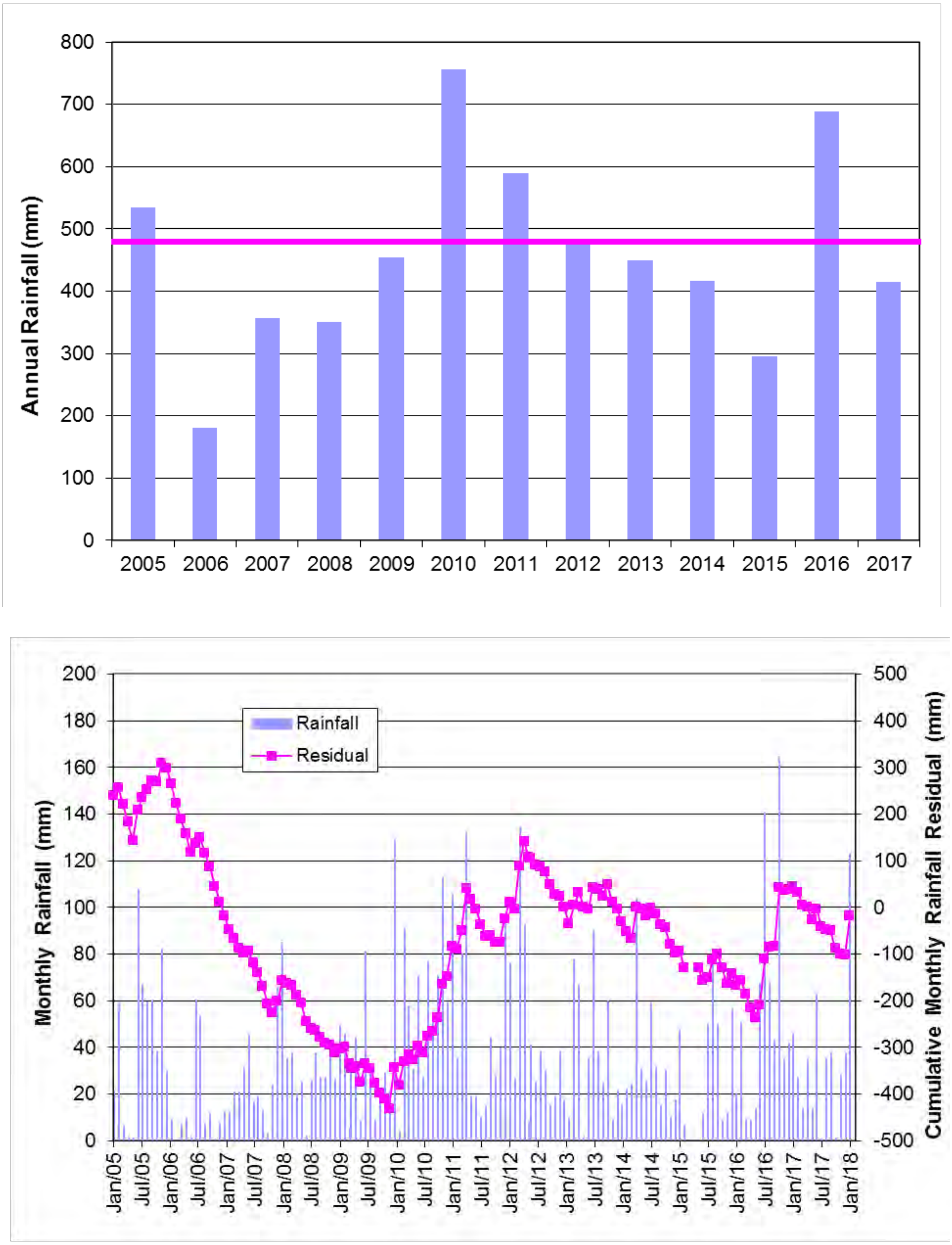


Figure 5 - Annual and Monthly Rainfall during Mine Life (BoM Station 73045)

3.7 Regional Hydrology

The Lachlan River is the major regional surface water system, forming part of the Murray -Darling Basin. The CGO is located on the western side of Lake Cowal, a freshwater lake within the Bland Creek Valley. Lake Cowal receives inflow from:

- Bland Creek, which drains into the lake at its southern end; and
- Lachlan Lake Cowal floodway to the north-east; when flood breakout flows from the Lachlan River are directed (during floods) into the north-east section of Lake Cowal.

The lake covers an area of approximately 10,500 hectares (ha) and holds 150,000 megalitres of water when full. The lake remained dry from the beginning of mine life (early 2005) to mid 2010, when the lake began to fill. Recorded lake water levels are shown in Figure 6.

The lake has a maximum depth of approximately 4 m when full.

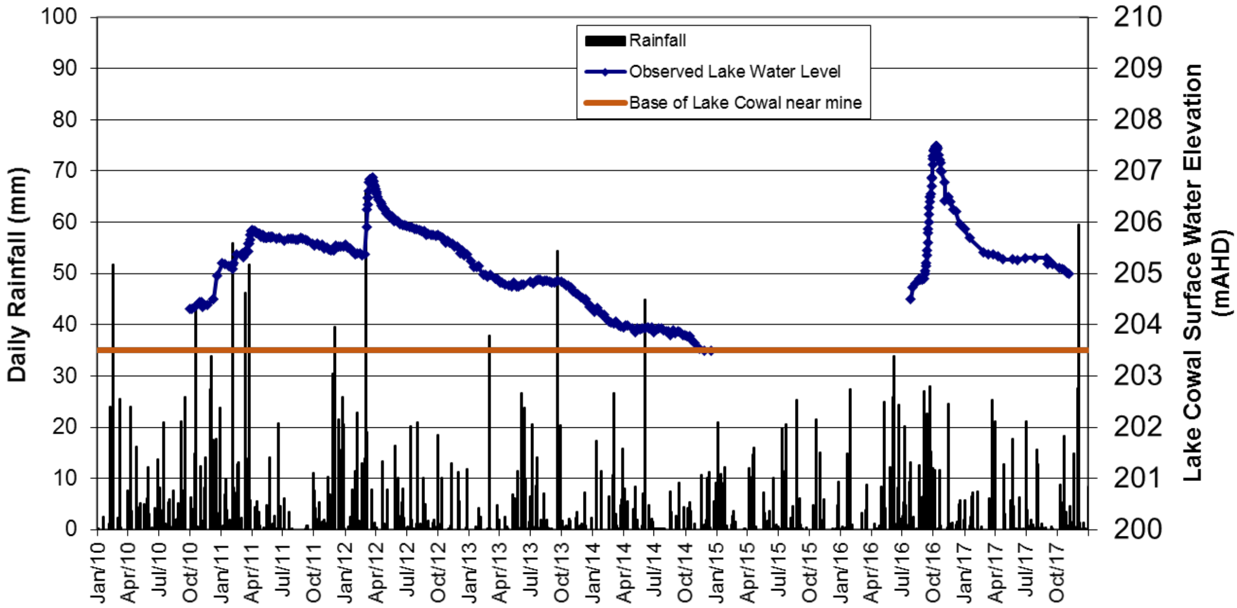


Figure 6 - Lake Cowal Water Levels and Daily Rainfall 2010 to 2017

3.8 Regional Geology

The Forbes Geological Map (SI55-7, 1:250,000) shows that the regional geological setting is dominated by the Gilmore Fault Zone, a structurally and lithologically complex feature that trends north-south through ML 1535, approximately 500 m west of the CGO open pit.

The fault separates a Late Ordovician volcaniclastic sequence (referred to as the Lake Cowal Volcanic Complex) from the Siluro Devonian sedimentary basement to the west. Siluro Devonian sedimentary rocks also occur east of the Lake Cowal Volcanic Complex on the eastern side of Lake Cowal, where the basement has been deeply incised and hosts palaeochannel deposits of the Bland Creek unit.

The region is covered by varying thicknesses of Tertiary and Quaternary regolith deposits. The Bland Creek Palaeochannel Plain was formed by the infilling of the Lachlan and Bland Creek Palaeochannels, located to the north and east of Lake Cowal, respectively, with sediments of the Lachlan and Cowra Formations. The depth of these sediments is over 100 m. Locally, Pleistocene Cowra alluvium overlies ML 1535 and thick Quaternary lacustrine sediments underlie Lake Cowal.

3.9 Mine Geology

The CGO site lies within the Lake Cowal Volcanics, which comprise massive and stratified non-welded pyroclastic debris, overlying a partly brecciated lava sequence, overlying volcanic conglomerate interbedded with siltstone and mudstone. The host rock has a consistent strike of 215 degrees (^{o}) and an approximate dip of 50^{o} to the north-west.

Within the Lake Cowal Volcanic Complex are diorite and gabbro intrusions, one of which is intersected by the CGO open pit. Within the ore body there are several north-south oriented, near vertically dipping faults and fractured dykes.

Overlying the Ordovician host rock (Saprock and Primary) is a Tertiary age laterite (Saprolite), which averages approximately 20 m and varies in thickness across the CGO site, from approximately 15 m to 55 m. Quaternary age sediments of predominantly lacustrine clay (Transported Alluvium) characteristically cover the Tertiary laterite. The depth of sediments across the CGO site and surrounds ranges from approximately 14 m to 55 m. This is consistent with thickness of the Transported Alluvium (Lower Cowra and Upper Cowra Formations) utilised in a calibrated groundwater model developed by the NSW Department of Industry – Water (DI – Water) (formerly NSW Office of Water [NOW]), in which values of over 20 m were adopted over the CGO site and surrounds.

The geology of the CGO site and surrounds is illustrated in Figure 7.

3.10 Regional Hydrogeology

Regionally, groundwater resources are present in the Bland Creek Palaeochannel, and include the following two geological formations:

- **Cowra Formation**: comprises isolated sand and gravel lenses in predominantly silt and clay alluvial deposits, with groundwater of generally higher salinity; and
- **Lachlan Formation**: comprises quartz gravel with groundwater of generally low salinity.

Three distinct alluvial sequences were interpreted to be present, based on the distribution of hydraulic conductivity with depth assessed by Coffey (2006). These are as follows:

- **Upper Cowra Formation**: 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. The average depth to groundwater is approximately 7 m, giving an average saturated thickness of just over 40 m (Coffey, 2006). The data suggest the Upper Cowra sequence generally shows decreasing hydraulic conductivity with depth and greater stratification than that found in deeper layers.
- **Lower Cowra Formation:** this sequence generally occurs over an average depth interval of approximately 50 m to 90 m over most of the CGO site and surrounding area. This layer appears to have lower horizontal hydraulic conductivity values than the Upper Cowra Formation.

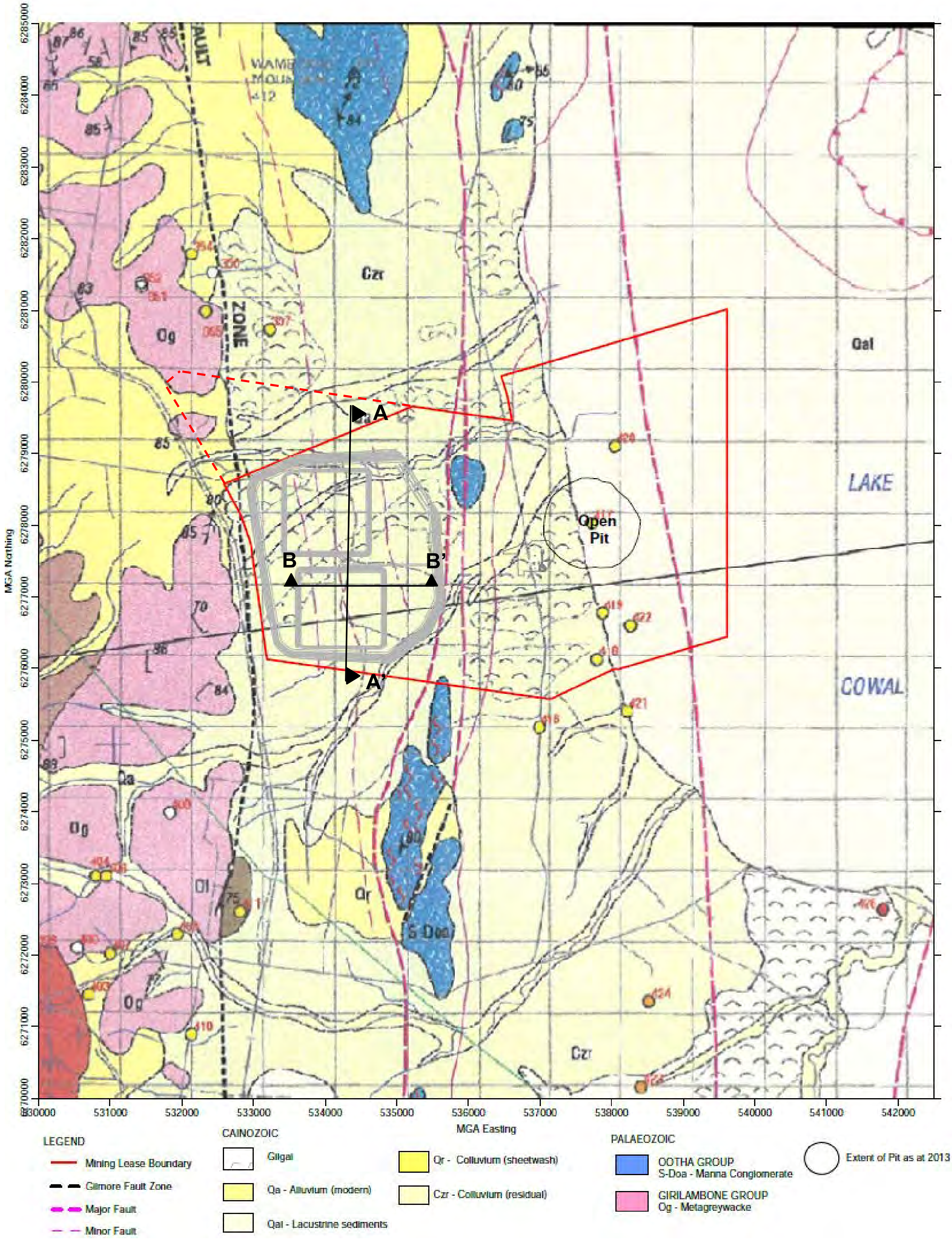


Figure 7 - Mine Site Geology

- **Lachlan Formation**: this sequence generally occurs over an average depth interval of around 90 m to 120 m in the Bland Creek Palaeochannel. Within this formation there were assessed to be two distinct sequences, including:
  - High permeability sands and minor gravels close to, and within, the deeper parts of the palaeochannel.
  - Lower permeability sediments that generally occur further away from the deeper parts of the palaeochannel and surround the high permeability sands and minor gravels. The average hydraulic conductivity of this sequence appears similar to the Lower Cowra Formation.

Coffey (2006) interpreted that the western limit of the Cowra Formation extends within the eastern boundary of ML 1535, but that the Lachlan Formation did not extend into ML 1535. Pre-mining groundwater flow was generally from east to west under a hydraulic gradient of approximately 0.1%, increasing to 0.3% further west.

Geological data available from the off-site borefield used to provide part of the CGO water requirements (the Bland Creek Palaeochannel Borefield) to the north-east and for the Bland Creek system to the south-east of the CGO site, have also been used in characterising the regional hydrogeology.

3.11 Mine Hydrogeology

Coffey (2009a) developed geological cross-sections through the western area of the CGO site. The locations of the cross-sections are shown on Figure 7 and the cross-sections themselves are shown on Figures 8 and 9. The extent of the Saprolite and Saprock units outside the CGO site are not defined. Figure 8 shows a cross-section along the north-south direction while Figure 9 shows a cross-section along the east-west direction.

Figure 10 presents a simplified conceptual cross-section through approximately the centre of the CGO open pit (at Map Grid of Australia [MGA] N6,278,030).

Locally, at the CGO site, four hydrogeological units have been identified:

- The Transported hydrogeological unit comprises alluvium (thick clay sequences and more permeable zones of gravel within a sandy clay matrix) of the Quaternary-aged Cowra Formation. The Cowra Formation is laterally equivalent to the Transported unit (Barrick [mine owner at the time], 2010). (In prior reports and literature, this unit is often termed the Transported Alluvial Aquifer).
- The Saprolite hydrogeological unit underlies the Transported unit, and is of relatively low hydraulic conductivity.
- The Saprock hydrogeological unit underlies the Saprolite unit, and occurs in the weathered fractured surface of the Lake Cowal Volcanics.
- More massive and less permeable Bedrock/Primary Rock underlies the Saprock unit.

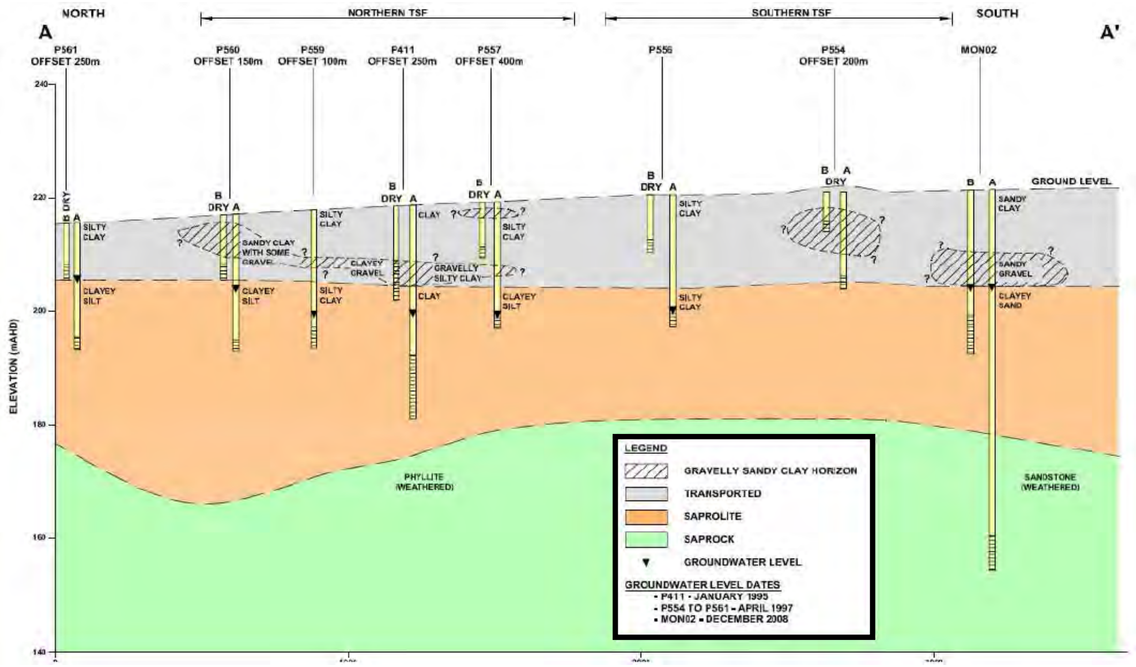


Figure 8 - Section A-A' through Northern Tailings Storage Facility and Southern Tailings Storage Facility

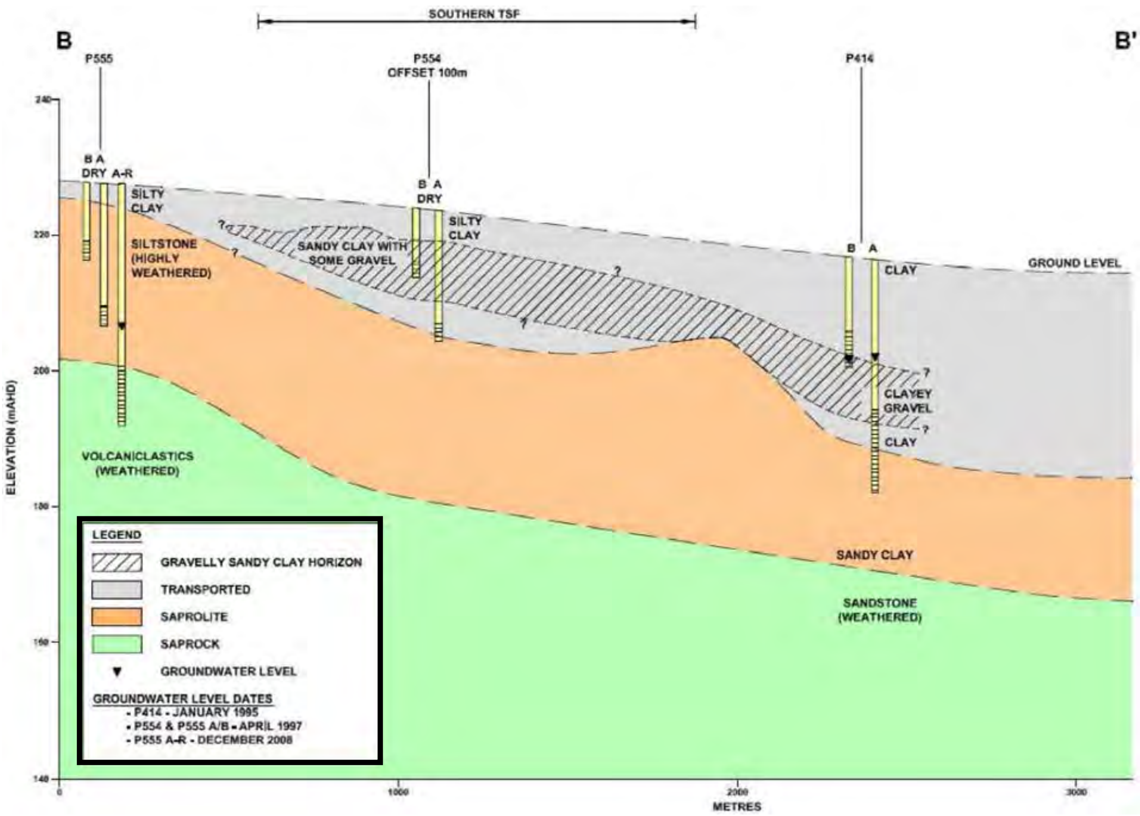


Figure 9 - Section B-B' through Southern Tailings Storage Facility

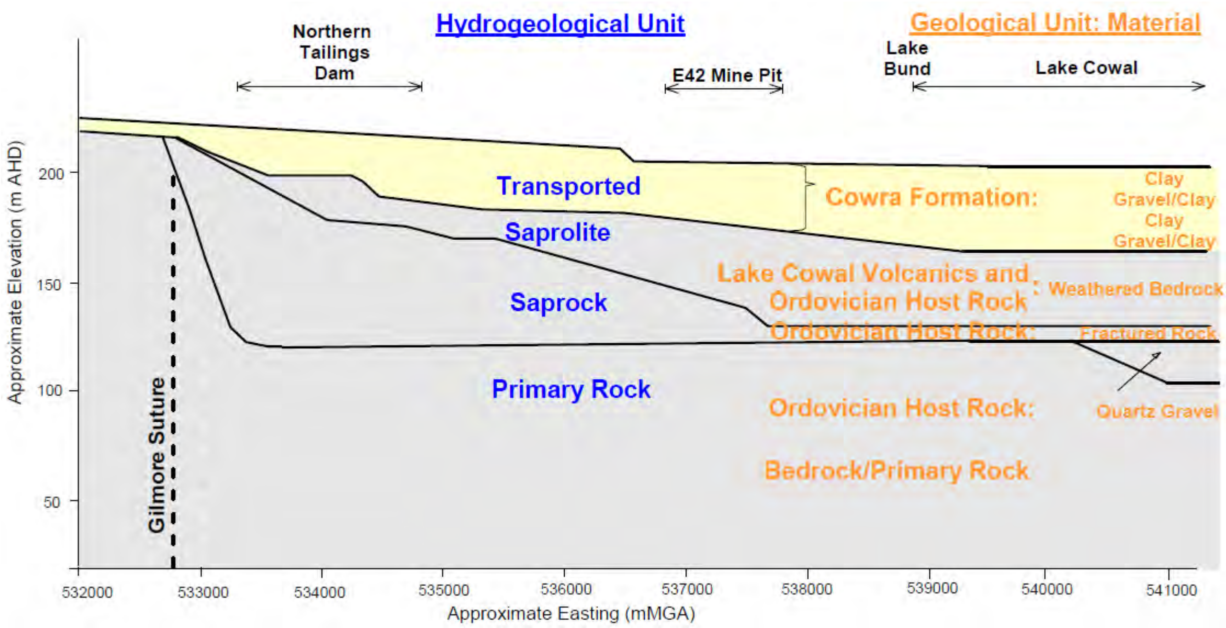


Figure 10 - East-West Section through Mine Lease at MGA N6278030

The Saprolite, Saprock and Bedrock/Primary Rock are considered to be within the fractured rock groundwater system. Surfaces of topographic (ground surface) elevations and the base elevations of the Transported, Saprolite and Saprock hydrogeological units were provided by Evolution for the ML 1535 area, and were updated by Coffey (2012) using additional drilling data provided.

The surfaces of the hydrogeological units were linearly extrapolated from the boundaries of ML 1535 to regions outside ML 1535, with the following considerations:

- Interpolation between the geological cross-sections shown on Figures 8, 9 and 10, based on Coffey (2009a), and data for the CGO open pit and surrounding area (Coffey, 2008) (interpolation between approximately MGA E535500 and MGA E536800).
- The Cowra Formation is laterally equivalent to the Transported unit; the regional interpretation of this unit was adopted from the modelling work carried out for the Bland Creek Palaeochannel.
- Data for the top of bedrock (equivalent to the top of Primary Rock), covering from the eastern side of the CGO site to the eastern boundary of the model domain. The bedrock (Primary Rock) outcrops at the surface along the Gilmore Suture and at Cowal West Hill (Coffey, 1995a).
- The Gilmore Suture marks a geological divide to the west of which the Primary Rock is the only unit underlying the Transported unit.

Figures showing the model adopted surface contours for ground surface level, and the base of the Transported, Saprolite and Saprock units, respectively, over the CGO mine site area are presented in Appendix A, Figures A-1 to A-4.

3.12 Regional Groundwater Levels and Flow Regimes

3.12.1 Groundwater Levels

Regional groundwater levels are discussed in a companion report on the modelling of the Bland Creek Palaeochannel Borefield (Coffey, 2018). The groundwater conditions in the vicinity of the CGO are controlled by more local factors and are not linked to changes in the deep alluvial system forming the Bland Creek Palaeochannel aquifer system.

3.13 Local Groundwater Levels and Flow Regimes

3.13.1 Groundwater Monitoring

The installation details for groundwater monitoring piezometers within ML 1535 are shown in Table 2. Piezometers with the suffix 'A' are the deeper of paired piezometers (typically screened in the Saprolite/Saprock unit), while those with suffix 'B' are shallower (typically screened in the Transported unit). The locations of these piezometers are shown in Figures 11. Figure 12 shows the location of active monitoring.

Groundwater monitoring records for these piezometers are shown in Figure A-5 (Appendix A). Records for piezometers P555A, P555B and P412B show those piezometers have remained dry over the mine life and are, therefore, not shown in the figures. Piezometers PDB4A and PDB4B were decommissioned in September 2009.

Table 2. Mine Area Monitoring Bore Details

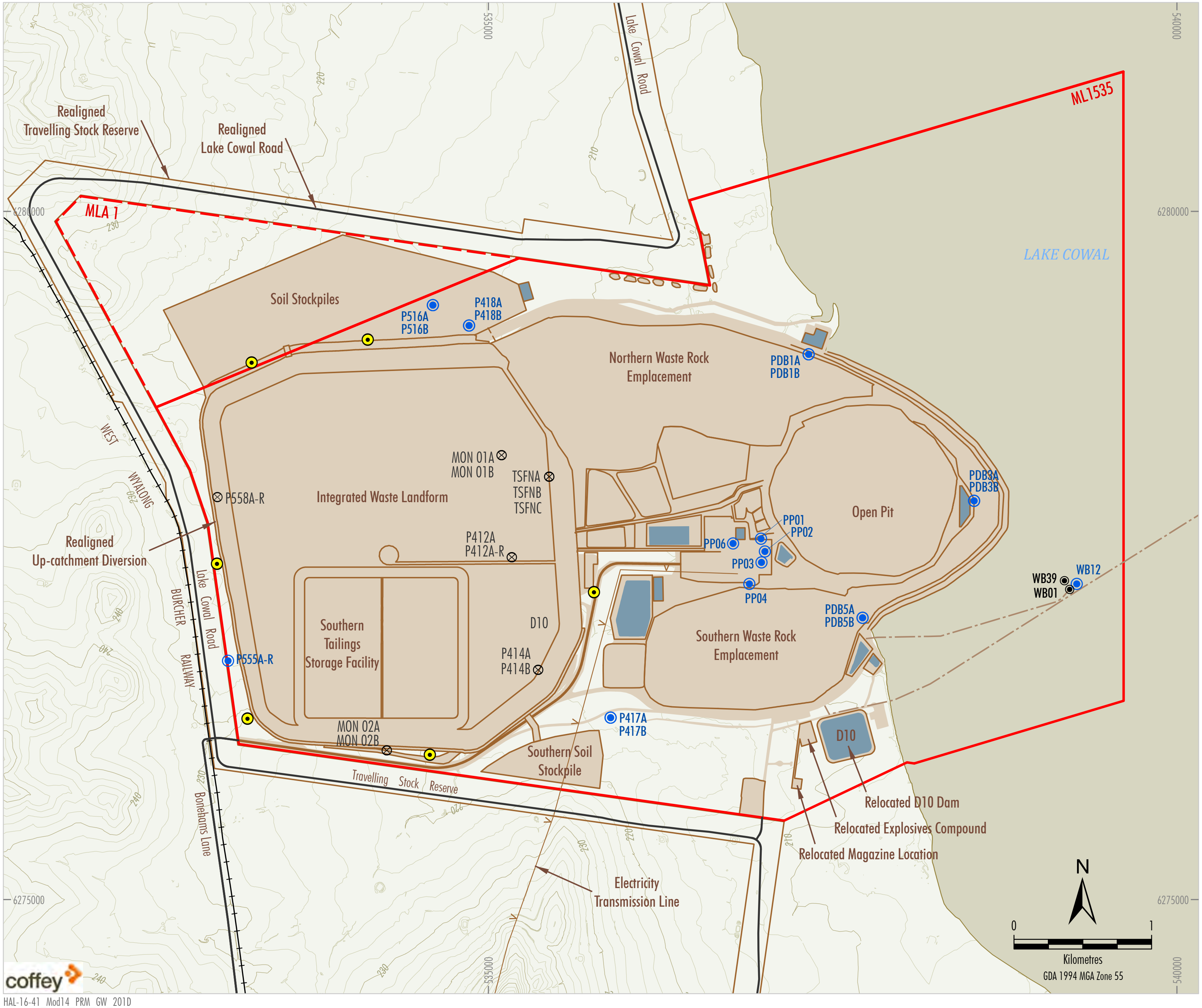
Area	Piezometer Name	Screened Stratum	Top of Casing (mAHD)	Depth (m below ground level)	Screen Intervals (m below ground level)	Status (as of March 2018)
Pit Area	PDB1A	Saprock	208.26	88	82 to 88	Active
	PDB1B	Transported	208.23	20	14 to 20	Active
	PDB3A	Saprock	204.80	100.5	94.5 to 100.5	Active
	PDB3B	Transported	204.82	29.6	23.6 to 29.6	Active
	PDB4A	Saprock	204.84	80	74 to 80	Decommissioned
	PDB4B	Transported	204.84	30.5	24.5 to 30.5	Decommissioned
	PDB5A	Saprock	209.05	82.5	76.5 to 82.5	Active
	PDB5B	Saprolite	208.82	29.8	23.8 to 29.8	Active
Processing Areas	PP01	Transported	215.61	25	13 to 25	Active
	PP02	Transported	213.00	18.5	8.5 to 18.5	Active
	PP03	Saprolite	213.52	51	31 to 51	Active
	PP04	Transported	213.89	19.5	10.5 to 19.5	Active
	PP05	Transported	214.18	20	11 to 20	Decommissioned
	PP06	Transported	214.03	20	11 to 20	Active
Tailings Areas	P555A	Saprolite	227.41	19.8	17.8 to 19.8	Active
	P555A-R	Saprock	227.35	36	27 to 36	Active
	P555B	Saprolite	227.41	10	8 to 10	Active
	P558A-R	Saprolite	224.29	42.6	30.6 to 42.6	Active[1]
	P412A	Saprolite	216.15	30	18 to 30	Active[1]
	P412A-R	Saprolite	216.12	61	55 to 61	Active [1]
	P412B	Transported	216.09	16	10 to 16	Active
	P414A	Saprolite	217.05	34	22 to 34	Active[1]
	P414B	Transported	217.07	16	10 to 16	Active[1]
	P417A	Saprolite	216.49	36	24 to 36	Active
	P417B	Transported	216.47	14	8 to 14	Active
	P418A	Saprolite	214.23	32	20 to 32	Active
	P418B	Transported	214.22	16	10 to 16	Active
	TSFNA	Saprock	215.28	98	92 to 98	Active[1]

[1] Monitoring bore located within extent of the IWL proposed for the Modification (i.e. the bore would be destroyed in approximately 2020 as the IWL is constructed). Active monitoring bores destroyed by the IWL would be replaced with new monitoring bores located outside the extent of the IWL (indicative locations shown on Figure 11). Refer to Section 7.1 for more information.

Table 2 (continued) Mine Area Monitoring Bore Details

Area	Piezometer Name	Screened Stratum	Top of Casing (mAHD)	Depth (m below ground level)	Screen Intervals (m below ground level)	Status (as of March 2018)
Tailings Areas	TSFNB	Transported	215.19	30.1	24.1 to 30.1	Active (destroyed by IWL)[1]
	TSFNC	Transported	215.27	18	12 to 18	Active (destroyed by IWL)[1]
	MON01A	Saprock	215.26	69	63 to 69	Active (destroyed by IWL)[1]
	MON01B	Transported	215.29	15	9 to 15	Active (destroyed by IWL)[1]
	MON02A	Saprock	222.48	69	63 to 69	Active (destroyed by IWL)[1]
	MON02B	Saprolite	222.44	30	24 to 30	Active (destroyed by IWL)[1]
	P561A	Saprolite	215.06	23	21 to 23	Active (destroyed by IWL)
	P561B	Transported	215.05	10	8 to 10	Active (destroyed by IWL)
Lake Protection Bund	PBP1	Transported	209.57	~12 to 13	Assumed 6 to 12	Active
	PBP2	Transported	209.37	11.7		
	PBP3	Transported	209.43±0.2	10.4		
	PBP4	Transported	209.48	~12 to 13		
	PBP5	Transported	209.62	~12 to 13		

[1] Monitoring bore located within extent of the IWL proposed for the Modification (i.e. the bore would be destroyed in approximately 2020 as the IWL is constructed). Active monitoring bores destroyed by the IWL would be replaced with new monitoring bores located outside the extent of the IWL (indicative locations shown on Figure 11). Refer to Section 7.1 for more information.



Evolution Mining Cowal

CGO PROCESSING RATE MODIFICATION

ML 1535
Groundwater Monitoring Locations

Figure 11

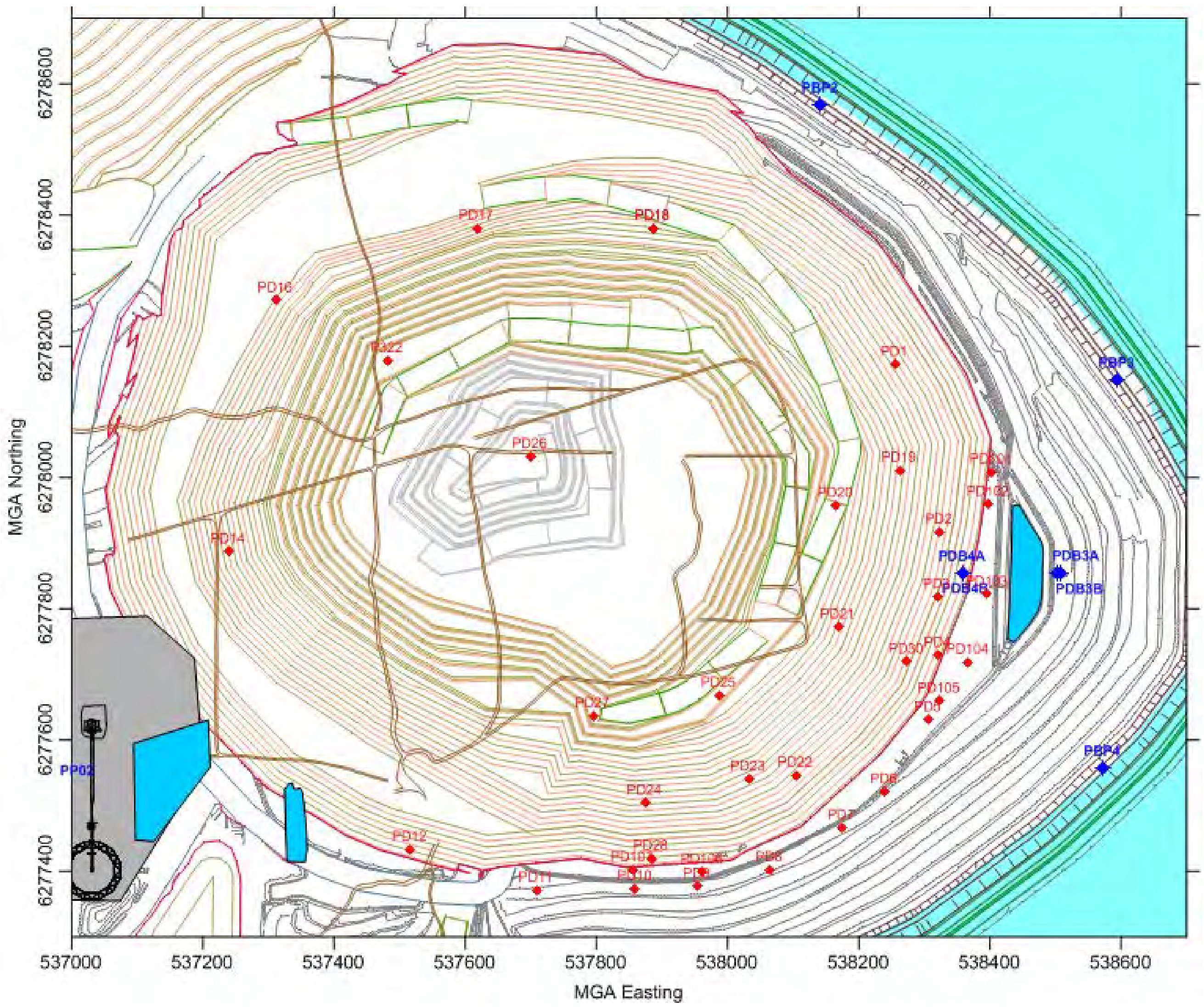


Figure 12 – Pit Groundwater Monitoring (blue) and Dewatering Bores (red)

3.13.2 Groundwater Inflows and Levels within ML 1535

Over the life of the CGO, Lake Cowal remained dry until June 2010, when significant rainfall caused the lake to begin to fill with water. By late 2014 the lake was dry due to evaporation. The lake began to fill with water from the significant rainfall events in June to September 2016; the peak water level recorded being 207.49 mAHD in October 2016. The lake water level dropped rapidly to its “full” level, with the gradual decline in water level continuing at the time of writing.

Since the commencement of the CGO, the underlying aquifers surrounding and intercepting the open pit have been depressurised as a result of inflows to the open pit and active pit dewatering (discussed further in Section 3.17.3). Despite Lake Cowal becoming inundated, groundwater inflows to the open pit are assessed (considering rainfall runoff) to have remained below (or consistent with) historical records and are relatively stable. This is most likely because the lacustrine sediments that form the lake bed have a very low vertical permeability and act as an aquitard (low permeability layer) between lake water and underlying aquifers (Coffey, 1997).

The open pit groundwater inflow observations confirm the finding of Coffey (1997) that the long-term leakage from the lake (when containing water) to underlying aquifers would be very small and not measureable.

It is relevant to note that the groundwater level in piezometer PDB3A fell significantly in March 2011. This corresponds to the date of installation of horizontal drains W911 (passing within 30 m of PDB3A) and W912 (passing within 110 m of PDB3A), both of which reported significant groundwater flows immediately following installation (600 cubic metres per day [m^3/day] and 170 m^3/day, respectively). It is likely that the groundwater level in piezometer PDB3A has been significantly influenced by pit dewatering since March 2011.

3.13.3 Groundwater Response to Tailings Storage Facilities

Groundwater monitoring records for piezometers in the vicinity of the TSFs are shown in Figure A-6 (Appendix A).

Groundwater levels in the Transported, Saprolite and Saprock units in the vicinity of the TSFs show a progressive rise since the CGO began operating. Generally, the magnitude of the groundwater rise correlates with the distance of the monitoring bore from the TSFs. For example, in the Transported unit, the groundwater level rise at bore P414B, which is relatively close to the TSFs, is greater than that at bore TSFNB, located further away. Similarly, in the Saprock unit, bore MON02A has displayed a significant rise since late 2006, whilst the magnitude of groundwater level rise at bore MON01A (located at a greater distance from the TSFs) is lower.

Groundwater levels in piezometers MON02A and MON02B (screened in the Saprock and Saprolite units, respectively) have displayed a significant rise since late 2006. Groundwater level variation around the TSFs was investigated by Coffey (2009a) and Northern Resource Consultants (2016). Rises were assessed to be related to the percolation and the movement of seepage from the TSFs.

Note that modelling carried out for the Cowal Gold Project Environmental Impact Statement (EIS) (North Limited, 1998) showed a groundwater level rise around the tailings impoundments to near the ground surface under some assumptions, in relation to hydraulic properties of the soil profile and tailings dam materials (Appendix N – Attachment N2-A of the EIS). The results at MON02A and MON02B are consistent with this possibility. Well-established measures can be used to control groundwater levels approaching the surface, including use of drainage trenches.

3.14 Surface Water Bodies

Records of Lake Cowal water levels available from August 1990 to November 2001 indicated levels varied between 202.9 mAHD and 206.2 mAHD over this period. Hawkes (1998) reported that the full storage Lake Cowal water level was 205.65 mAHD. North Limited (1998) reported that the full storage Lake Cowal water level was 205.7 mAHD and the bed level was 201.5 mAHD.

Following filling of Lake Cowal, the water level measurement records show that over a 12 month period from May 2012, water level fell at an average rate of between 3 mm and 4 mm per day. Assuming the lake water is lost to evaporation, and considering the annual pan evaporation rate of 1,919 mm, this rate of decline in lake water levels is equivalent to a pan evaporation factor of 0.8 (i.e. an annual open water evaporation rate of 1,535 mm), a factor within the range of expected values for a lake in this regional setting.

When Lake Cowal is full it overflows into Nerang Cowal (North Limited, 1998). Data was not available for historical water levels within Nerang Cowal during wet periods, with the exception that, as of August 2010, it was reported by CGO staff that the water within Lake Cowal had not overflowed into Nerang Cowal. Nerang Cowal is likely to have been dry from 2005 (and possibly earlier) until a flood event in March 2012. Satellite imagery shows that Nerang Cowal also contained water in mid-2016. Nerang Cowal (along with Lake Cowal) flooded in October 2016.

3.15 Groundwater Quality

3.15.1 Groundwater Quality in ML 1535

Electrical Conductivity (EC) concentrations and pH levels in groundwater within ML 1535 have generally remained stable between 2004 and 2017. Monitored pH levels have been slightly acidic to neutral, and have been similar to baseline levels. Monitored pH levels close to the TSFs have generally ranged between 6.5 and 7, with the exception of MON01B (to the east of the northern TSF), with a lower pH generally ranging between 4.5 and 6, TSFNC with a pH of around 6, and PP03 and CB01 with a pH of around 8. While open pit dewatering is causing a localised reduction in groundwater levels, pH and EC appear to be unaffected by this drawdown.

3.15.2 Groundwater Contamination in ML 1535

At the CGO, cyanide (CN) is used in the gold extraction process and is measured by the CGO as both total cyanide and weak acid dissociable (WAD) cyanide. The Australian and New Zealand Environmental Conservation Council and Agricultural Resource Management Council of Australia and New Zealand (ANZECC & ARMACANZ) (2000) trigger value of 0.007 milligrams per litre (mg/L) is for un-ionised hydrogen cyanide (HCN) which may be converted to free cyanide ($HCN + CN^-$) using Table 8.3.8 and corresponding pH and temperature values (ANZECC & ARMACANZ, 2000). The total cyanide is free cyanide plus the measurable cyanide from breakdown of metallo-cyanide and organic complexes.

Monitoring results for cyanide in groundwater were reviewed for the mine life history (September 2004 to June 2017). Within the available data, concentrations over this period have remained below the Limit of Reporting concentration of 0.004 mg/L at all monitoring locations, with the exception of those listed in Table 3.

Generally, cyanide has not been observed at significant concentrations in groundwater over the site. Where monitoring has shown total cyanide to be present, its concentration at individual monitoring locations has not been consistent over time, and its observed presence has not always been supported by WAD analysis.

The groundwater monitoring results suggest that, as of June 2017, there is no consistent trend to suggest that significant concentrations of cyanide have leached from the TSFs into the surrounding groundwater.

Table 3. Cyanide Detections

Year	Month	Bore	Total Cyanide Concentration (mg/L)	WAD Cyanide Concentration (mg/L)
2005	February	P417B	0.006	<0.005
	August	P417B	0.009	<0.005
2006	August	MON01A	0.004	<0.004
2007	September	MON01B	0.084	0.041
2008	March	P417B	0.008	<0.004
	August	PDB3A	0.007	0.006
		PDB4A	0.109	0.040
2009	September	PP01	0.030	0.030
		PP05	0.072	0.040
2010	February	MON01B	0.014	<0.004
		P414B	0.006	<0.004
		P417B	0.007	<0.004
2011	September	PP02	0.004	0.004
	November	MON01A	0.045	0.004
2012	February	TSFNC	0.017	<0.004
	March	PP02	0.016	<0.004
	May	P417B	0.010	<0.004
		PP05	0.017	<0.004
		PP06	0.042	0.017
	October	TSFNA	0.009	<0.004
		TSFNB	0.009	<0.004
		TSFNC	0.010	<0.004
		P418A	0.015	<0.004
		P418B	0.027	0.008
		P558A-R	0.006	<0.004
		P417A	0.005	<0.004
2013	April	MONO2A	0.017	<0.004
		P412A-R	0.027	<0.004
		P417A	0.034	<0.004
		P417B	0.005	<0.004
2014	No detections above laboratory limit of reporting			
2015	September	MON01B	0.012	0.007
		P414B	0.017	0.010
		P417B	0.025	0.016
2016	No detections above laboratory limit of reporting			
2017	No detections above laboratory limit of reporting			

3.16 Aquifer Parameters

Coffey (2006) reviewed hydraulic testing data conducted in pumping bores and observation piezometers screened within the Lachlan and Cowra Formations within the Bland Creek Palaeochannel Borefield (formerly known as the Jemalong Borefield Area), located to the north-east of the CGO. Transmissivities averaged 35 square metres per day (m^2/day) within the Upper Cowra Formation (up to 50 m depth), and 8 m^2/day within the Lower Cowra Formation (average depth 50 m to 90 m). Interpreted horizontal hydraulic conductivities, converted from transmissivity values using the total screened interval of the borehole, typically ranged from 0.1 to 10 metres per day (m/day).

The adopted parameter values for the calibrated model used in a previous pit dewatering assessment (Coffey, 2008) are shown in Table 4.

Table 4. Adopted Model Parameters (Coffey, 2008)

Hydrogeological Unit	Geological Unit	Horizontal Hydraulic Conductivity (m/day)	Vertical Hydraulic Conductivity (m/day)	Specific Yield
Transported	Cowra Formation	1.0×10^{-3}	1.0×10^{-4}	0.15
Saprolite	Lake Cowal Volcanics	5.0×10^{-2}	5.0×10^{-2}	0.02
Saprock	Ordovician Host Rock	1.0×10^{-2}	1.0×10^{-2}	0.02
Primary Rock	Ordovician Host Rock	1.0×10^{-2}	1.0×10^{-2}	0.02

Source: Coffey, 2008.

A calibrated groundwater model developed by Coffey (2009a) to assess groundwater level changes at the CGO mine site adopted the parameter values shown in Table 5.

Table 5. Adopted Model Parameters (Coffey, 2009a)

Hydrogeological Unit	Geological Unit	Horizontal Hydraulic Conductivity (m/day)	Vertical Hydraulic Conductivity (m/day)	Specific Yield
Transported	Cowra Formation	1.0×10^{-2}	3.0×10^{-3}	0.05
Saprolite	Lake Cowal Volcanics	1.0×10^{-1}	1.0×10^{-2}	0.002
Saprock	Ordovician Host Rock	1.0×10^{-2}	1.0×10^{-3}	0.02

Source: Coffey, 2009a.

A recovery test conducted in monitoring bore PD3 (a bore located in the north-west quadrant of the pit and subsequently destroyed by mining), screened over the Transported and Saprolite units, suggested those units possessed a collective transmissivity of 1.2 m^2/day (Coffey, 2008). In consideration of the 90.5 m total screen interval of PD3, the estimated horizontal hydraulic conductivities over both the Transported and Saprolite units were estimated at 0.01 m/day.

Coffey (2009a) collated falling head permeability test data from piezometers located both within and to the east of the TSFs area. Results yielded the following hydraulic conductivity values:

- an arithmetic mean of 0.02 m/day and a geometric mean of 0.01 m/day for the Transported unit at 6 to 16 m below ground surface; and
- an arithmetic mean of 0.05 m/day and a geometric mean of 0.02 m/day for the Saprolite unit at 18 to 36 m below ground surface.

These values are relatively consistent with the PD3 recovery test result noted above and the values adopted in the calibrated pit dewatering assessment model (Coffey, 2008), as shown in Table 4.

No hydraulic test data were available from which an assessment of the specific yield of the Cowra Formation could be made. Numerical modelling conducted by Williams (1993) assumed a value of 5% for the pore volume available for increased storage at the water table in the Upper Cowra Formation in the Jemalong Plains Irrigation District. Based on lithology and literature (Johnson, 1967), a specific yield of 4% was adopted for groundwater supply modelling (Coffey, 2006).

Coffey analysed results from pumping tests undertaken in the dewatering bores in 2004. Bores were screened over the full sequence of Transported, Saprolite and Saprock units. This introduces some uncertainty, as flow components attributable to individual aquifer horizons are unknown. The horizons are somewhat gradational and precise boundaries are difficult to identify. The average hydraulic conductivity from the analysed data was 0.06 m/day.

Based on pumping test, recovery test and slug test data (Coffey, 1995a), Hawkes (1998) adopted the model parameters shown in Table 6 for a pit dewatering model. It should be noted that the model developed by Hawkes (1998) included alternating aquifer and aquitard model layers throughout (i.e. contrastingly high and low hydraulic conductivity units alternated with depth), and divided the Transported unit into two aquifers (relatively high hydraulic conductivity units) and two aquitards (relatively low hydraulic conductivity units). Data was sufficient for this approach in modelling the pit area alone.

A calibrated groundwater model developed by NOW (now DI – Water) (Bilge, 2012) for the Upper Lachlan catchment adopted horizontal hydraulic conductivities generally ranging from less than 1 m/day to 20 m/day in the Lower Cowra Formation and from less than 1 m/day to 35 m/day in the Upper Cowra Formation over the present model domain.

Table 6. Adopted Model Parameters (Hawkes, 1998)

Hydrogeological Unit	Geological Unit	Horizontal Hydraulic Conductivity (m/day)	Vertical Hydraulic Conductivity (m/day)	Specific Yield	Confined Storage Coefficient
Transported	Cowra Formation	2.0×10^{0} to 3.0×10^{0}	1.0×10^{-4}	1.0×10^{-3}	1.5×10^{-1}
Saprolite	Lake Cowal Volcanics	-	1.0×10^{-4}	-	-
Saprock	Ordovician Host Rock	1.5×10^{0}	-	1.0×10^{-2}	1.0×10^{-3}
Primary Rock	Ordovician Host Rock	-	1.0×10^{-4}	-	-

Source: Hawkes, 1998.

Analysis of pumping tests conducted in 2004 in bores of the Bland Creek Palaeochannel Borefields, located to the north-east of the CGO, provide several values of confined storativity, giving an average storativity of 1.9×10^{-4} for the Lachlan Formation (Groundwater Consulting Services Pty Ltd [GCS], 2006), or an average specific storage of 9.5×10^{-6} m^{-1}, assuming a 20 m thick aquifer. A pumping test of seven days duration conducted at BLPR2 (located approximately 18 km to the north-north-east of pit E42) gave an average storativity of 1.7×10^{-4} for the Lachlan Formation, or an average specific storage of 8.5×10^{-6} m^{-1}, assuming a 20 m thick aquifer. The lower permeability sediments that occur further away from the deeper parts of the palaeochannel appear to possess similar hydraulic properties to the Lower Cowra Formation (Coffey, 2006). However, in practical terms, a portion of the assessed storativities will be influenced by vertical leakage from the base of the Lower Cowra Formation during pumping tests.

A calibrated groundwater model developed by NOW (now DI – Water) (Bilge, 2012) for the Upper Lachlan catchment adopted specific yield values generally ranging from 0.06 to 0.25 in the Upper Cowra Formation. Storage coefficients in the same model generally ranged from 5.5×10^{-6} to 1.7×10^{-5} in the Lower Cowra Formation.

GCS (2008) co-ordinated a pumping test in the Transported materials (Cowra Formation). The testing was conducted to assess the potential yield of the ML 1535 saline groundwater supply borefield, located within ML 1535. Test results suggest a hydraulic conductivity of the Transported material of approximately 5 m/day and a specific yield of approximately 1.6×10^{-3}.

A summary of the available data is presented in Tables 7 and 8.

The bedrock has relatively low hydraulic conductivity (Table 7). Coffey (1995a) noted that there was little apparent difference in transmissivity between the major structural features (fractured dykes) within the pit area and relatively fresh bedrock. Therefore, aquifer parameters are expected to be similar for bedrock and geological fault features. The bedrock consists mostly of sedimentary sequences, and is considered to have significantly lower permeability than unconsolidated sediments, except in structurally disturbed areas.

3.16.1 Tailings Storage Facilities

Based on test drilling data, geophysical studies and piezometer installations around the proposed TSFs reported by North Limited (1998), it was concluded that:

- The foundation of the existing TSFs comprises silty clay with some gravelly clay, and highly weathered rock occurring at shallow depth in the west. The thickness of unconsolidated sediments decreases from east to west.
- The groundwater movement through the TSF areas prior to mine development was essentially from west to east, with a hydraulic gradient of approximately 7×10^{-3} m.
- Field permeability testing of strata expected to be of higher permeability indicates low horizontal permeability of the order of 2×10^{-4} to 1×10^{-3} m/day for gravelly clay and 0.6×10^{-4} to 3.5×10^{-4} m/day for weathered rock.
- Laboratory infiltration tests indicate vertical permeability of the less permeable soils of the order of 0.9×10^{-6} to 1.3×10^{-6} m/day.

Table 7. Summary of Horizontal Hydraulic Conductivity Data

Hydrogeological Unit (Geological Unit)	Value (m/day)	Region	Source	Reference
Transported (Cowra Formation)	1×10^{-1} to 1×10^{2}	Jemalong Borefield	Hydraulic testing	Coffey (2006)
	5×10^{0}	ML 1535 Saline Groundwater Supply Borefield, ML 1535	Pumping test	GCS (2008)
	1×10^{-2}	TSF	Slug test	Coffey (2009a)
	1×10^{-2}	Mine Site	Modelling	Coffey (2009a)
	1×10^{-3}	E42 Open Pit	Modelling	Coffey (2008)
	2×10^{0} to 3×10^{0}	E42 Open Pit	Modelling	Hawkes (1998)
	1×10^{0} to 3.5×10^{1}	Upper Lachlan catchment	Modelling	Bilge (2012)
	1 to 2	Jemalong	Regional Modelling	Coffey (2011)
	1	Elsewhere		
Transported (Cowra Formation) and Saprolite	1×10^{-2}	E42 Open Pit	Recovery test	Coffey (2008)
Transported (Cowra Formation), Saprolite and Saprock (Ordovician Host Rock)	6×10^{-2}	E42 Open Pit	Pumping test	Coffey (1995a)
Saprolite	2×10^{-2}	TSF	Slug testing	Coffey (2009a)
	1×10^{-1}	Mine Site	Modelling	Coffey (2009a)
	5×10^{-2}	E42 Open Pit	Modelling	Coffey (2008)
Saprock (Ordovician Host Rock)	1×10^{-2}	Mine Site	Modelling	Coffey (2009a)
	1×10^{-2}	E42 Open Pit	Modelling	Coffey (2008)
	1.5×10^{0}	E42 Open Pit	Modelling	Hawkes (1998)
Primary Rock (Ordovician Host Rock)	1×10^{-2}	E42 Open Pit	Modelling	Coffey (2008)
Lachlan Formation	3×10^{-2} to 1×10^{2}	Jemalong Borefield	Hydraulic testing	Coffey (2006)
	3 to 28	Regionally	Regional Modelling	Coffey (2011)

Table 8. Summary of Specific Yield and Storage Data

Unit(s)	Specific Yield	Storage Coefficient	Region	Source	Reference
Transported (Cowra Formation)	1.0×10^{-3}	1.5×10^{-1}	E42 Open Pit	See text	Hawkes (1998)
	1.5×10^{-1}	-	E42 Open Pit	Modelling	Coffey (2008)
	5.0×10^{-2}	-	Mine Site	Modelling	Coffey (2009a)
	6.0×10^{-2} to 3.0×10^{-1}	5.5×10^{-6} to 1.7×10^{-5}	Upper Lachlan catchment	Modelling	Bilge (2102)
	1.6×10^{-3}	-	ML 1535 Saline Groundwater Supply Borefield, Mine Lease	Pumping test	GCS (2008)
	4.0×10^{-2}	1.5×10^{-5}	Regionally	Regional Modelling	Coffey (2011)
Saprolite	2.0×10^{-2}	-	E42 Open Pit	Modelling	Coffey (2008)
	2.0×10^{-3}	-	Mine Site	Modelling	Coffey (2009a)
Saprock (Ordovician Host Rock)	1.0×10^{-2}	1.0×10^{-3}	E42 Open Pit	See text	Hawkes (1998)
	2.0×10^{-2}	-	E42 Open Pit	Modelling	Coffey (2008)
	2.0×10^{-2}	-	Mine Site	Modelling	Coffey (2009a)
Primary Rock (Ordovician Host Rock)	2.0×10^{-2}	-	E42 Open Pit	Modelling	Coffey (2008)
Lachlan Formation	1.9×10^{-4}	-	Jemalong Borefield	Pumping test	GCS (2006)
	1.7×10^{-4}	-	Jemalong Borefield	Pumping test	Coffey (1995c)
	N/A	1.5×10^{-5}	Regionally	Regional Modelling	Coffey (2011)

URS Australia Pty Limited (URS) (2005, 2006) conducted field investigations and laboratory testing for both the northern and southern TSFs, concluding that:

- investigations consistently showed the uppermost 5 m of the TSF footprints to be essentially clay soils of extremely low permeability;
- laboratory testing of typical samples from within 5 m of floor level yielded permeabilities less than the target permeability of 1×10^{-9} metres per second (m/s) (9×10^{-5} m/day); and
- inspections of cut-off trench excavation and storage floor did not reveal any significant extensive or continuous zones or lenses of high permeability soil that might provide a leakage path.

Surface infiltration tests carried out by site personnel in shallow test pits to the east of the TSF area (Coffey, 1995c) indicated a low infiltration permeability range from 8×10^{-4} m/day to 3×10^{-5} m/day, with an arithmetic mean of 2×10^{-4} m/day and a geometric mean of 1×10^{-4} m/day.

Falling head permeability tests and consolidation tests were conducted by Knight Piesold Pty Ltd (1994) on saturated tailings samples with unrestricted drainage from the base. Results are shown in Table 9 and indicate the permeability of saturated tailings (prior to additional consolidation due to tailings loading or air drying).

The conditions encountered for the floor of the existing TSF are anticipated to apply to the floor of the IWL to be developed as part of the Modification.

Table 9. Tailings Permeability Data (Knight Piesold Pty Ltd, 1994)

Test Type	Sample	Permeability (m/day)	Dry Density (t/m^3)
Falling Head Permeability Tests	Primary Tailings	0.02	1.29
		0.02	1.29
	Oxide Tailings	0.01	1.18
		0.01	1.20
Consolidation Tests	Primary Tailings	0.62	1.07
		0.09	1.10
		0.02	1.20
	Oxide Tailings	0.27	0.95
		0.03	0.99
		0.01	1.12
		0.01	1.13

Source: Knight Piesold Pty Ltd, 1994.
t/m^3 – tonnes per cubic metre.

A calibrated groundwater model developed by Coffey (2009a), to assess groundwater level changes associated with the TSFs, adopted the parameter values shown in Table 10 for tailings materials.

Table 10. Adopted Model Parameters (Coffey, 2009a)

Unit	Horizontal Permeability (m/day)	Vertical Permeability (m/day)	Specific Yield
Deposited Tailings	5.0×10^{-2}	5.0×10^{-3}	0.01
TSF Embankment - Clay	1.0×10^{-4}	1.0×10^{-4}	0.15

Source: Coffey, 2009a.

A summary of the above information is presented in Table 11.

Table 11. Summary of TSF Parameters

Hydrogeological Unit	Horizontal Permeability (m/day)	Vertical Permeability (m/day)	Specific Yield	Reference
TSFs Foundation	1×10^{-3} to 6×10^{-5}	1.3×10^{-6} to 9×10^{-7}	N/A	North Limited (1998)
	N/A	8.6×10^{-5}	N/A	URS (2005, 2006)
	N/A	2×10^{-4}	N/A	Coffey (1995c)
Deposited Tailings	N/A	1×10^{-2} to 6.2×10^{-1}	N/A	Knight Piesold (1994)
	5.0×10^{-2}	5.0×10^{-3}	0.01	Coffey (2009a) (model)
TSFs Embankment - Clay	1.0×10^{-4}	1.0×10^{-4}	0.15	Coffey (2009a) (model)

3.17 Representation of Mining Activities

3.17.1 Mine Production

The indicative mine production schedule for the Modification, provided by Evolution, is shown in Table 12.

3.17.2 Excavation Schedule

Open pit geometries were provided at intervals from December 2005 to June 2010, and for December 2011, June 2012, January 2013 and January 2015. The planned geometry from 2018 to 2032 (mine closure) was provided by Evolution.

Based on this data, Figure 13 shows the base elevation of the open pit at mine closure.

3.17.3 Open Pit Dewatering

A ring of vertical dewatering bores have historically operated to control groundwater levels around the pit. The vertical bore dewatering system was commissioned progressively, commencing in January 2005 to full operation by mid-2005. Records of dewatering volumes for the vertical bores for the period February 2005 to December 2009 indicate relatively consistent results after August 2005.

By 2012, all of the initial sets of bores had been decommissioned. Seven new dewatering bores were installed during 2011 as part of the Stage E pit cutback and began pumping groundwater in November 2011. These were gradually decommissioned with mine groundwater inflow being captured by horizontal drains or emerging from the face. In August 2017 only two vertical dewatering bores remained in use, and by the end of 2017 no vertical dewatering bores were in use.

In addition to the vertical dewatering bores (now all decommissioned), horizontal bores (drains) have been progressively installed (and some decommissioned) within the open pit since 2006. These horizontal bores continue to operate and have proven successful in controlling groundwater pressure behind the pit face.

Groundwater seepage into the pit, groundwater flows from in-pit horizontal drains (bores), and rainfall runoff in the pit are directed to pit sumps (before being pumped to water storage dams).

Table 12. Indicative Mine Production Schedule

The Modification (MOD14)	Year	CGO Year	Waste Rock Mined (Mt[1])	Mineralised Material Mined (Mt[1])			Ore Mined (Mt[1])			Ore Processed (Mt[1])		
				Oxide	**Primary**	**Total**	**Oxide**	**Primary**	**Total**	**Oxide**	**Primary**	**Total**
Existing CGO	2005 to 2017	1 to 13	216.8	5.0	14.5	19.5	16.5	94.4	110.9	5.8	76.5	82.3
CGO Incorporating the Modification	2018	14	21.3	0.2	1.6	1.8	0	7.7	7.7	0	7.4	7.4
	2019	15	18.4	0.2	1.7	2.0	0.1	4.4	4.5	0.4	7.4	7.8
	2020	16	20.4	0	2.3	2.3	0	2.7	2.7	0.4	7.5	7.9
	2021	17	12.1	0	3.8	3.8	0	7.8	7.8	0.4	8.2	8.6
	2022	18	7.3	0	3.9	3.9	0	14.3	14.3	0.4	9.0	9.4
	2023	19	2.4	0	2.6	2.6	0	8.4	8.4	0.4	9.1	9.5
	2024	20	0.6	0	3.4	3.4	0	9.4	9.4	0.4	9.4	9.8
	2025	21	0	0	0	0	0	1.4	1.4	0.4	9.4	9.7
	2026	22	0	0	0	0	0	0	0	0.4	9.1	9.5
	2027	23	0	0	0	0	0	0	0	0.4	7.3	7.7
	2028	24	0	0	0	0	0	0	0	0.4	7.3	7.7
	2029	25	0	0	0	0	0	0	0	0.4	7.3	7.7
	2030	26	0	0	0	0	0	0	0	5.0	4.5	9.5
	2031	27	0	0	0	0	0	0	0	6.8	2.0	8.8
	2032	28	0	0	0	0	0	0	0	0	3.3	3.3
	Sub-Total		**82.5**	**0.4**	**19.3**	**19.8**	**0.1**	**56.1**	**56.4**	**16.3**	**108.0**	**124.3**
Total			**299.3**	**5.4**	**33.9**	**39.3**	**16.6**	**150.5**	**167.1**	**22.1**	**184.6**	**206.6**

[1]Mt – Million tonnes

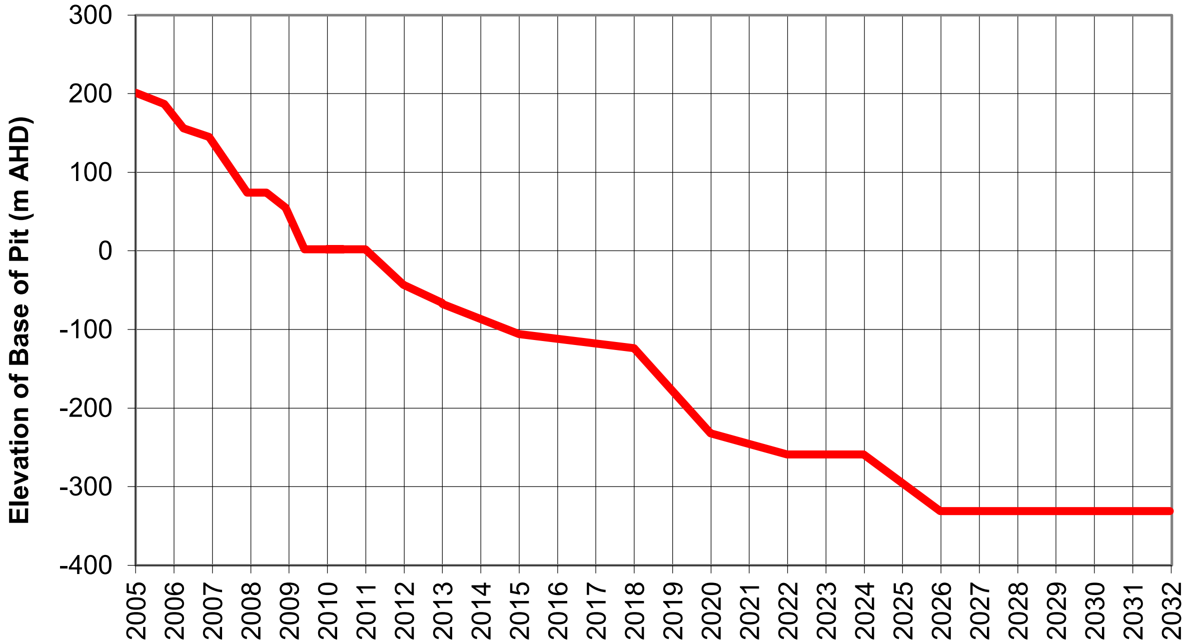


Figure 13 - Elevation of Base of Open Pit

The CGO records the volumes pumped out of in-pit sumps (daily) and the volumes abstracted by the vertical dewatering bores on a monthly basis. The number of vertical dewatering bores has progressively reduced, with no vertical dewatering bores still in use by the end of 2017. The volume pumped out of in-pit sumps in any month is the sum of the volumes from the rainfall runoff, pit face seepage, and horizontal bores (drains). As such, it is not clear what proportion of the volumes reporting to the in-pit sumps is rainfall runoff rather than pit seepage/drainage. CGO staff report that rainfall runoff within the pit is generally significant for daily rainfall over 30 mm.

Figure 14 shows the measured dewatering flow rate (sumps and vertical bores) over the mine life, as well as daily rainfall events over 30 mm. There is a correlation between daily rainfall events over 30 mm and relatively high sump flows between 2010 and 2012, and also between 2015 and 2016. In 2005, 2006 and 2007, this correlation does not appear to be present. However, this may be due to relatively dry pre-existing ground conditions (in 2004, and from 2006 to 2009, the annual rainfall was significantly below the mean annual rainfall, potentially resulting in dry conditions relative to 2010 and 2012, with reduced rainfall runoff for rainfall events over 30 mm).

Groundwater inflows to the pit due to pit seepage and horizontal dewatering bores (drains) between 2010 and 2016 were estimated, considering significant rainfall events and horizontal dewatering bore installation frequency. The interpreted inflows (for pit face seepage and horizontal dewatering bores only, excluding rainfall runoff) are shown in Figure 15. As of mid-2016, it was estimated that groundwater inflows were at approximately 400 m^3/day (i.e. approximately 146 megalitres per year [ML/year]), with approximately 90% of inflows from the Fractured Rock groundwater system and 10% of inflows from the Alluvial groundwater system. A letter from DPI Water to the CGO (then B, titled “Cowal Gold Mine – Request for reallocation of water access licence under the water management act 2000” and dated 7 January 2014, addresses the renewal of water access licences based on these requirements. The interpreted flows were adopted as the measured values against which the model was calibrated.

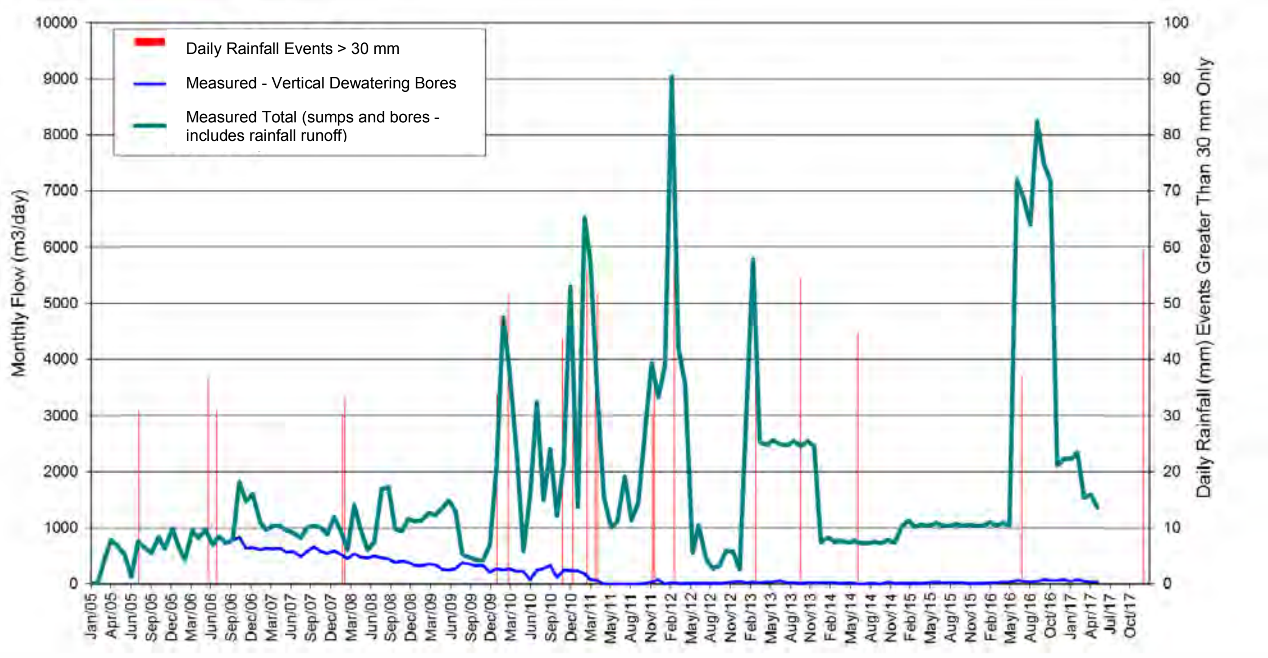


Figure 14 - Pit Dewatering Rates and Rainfall

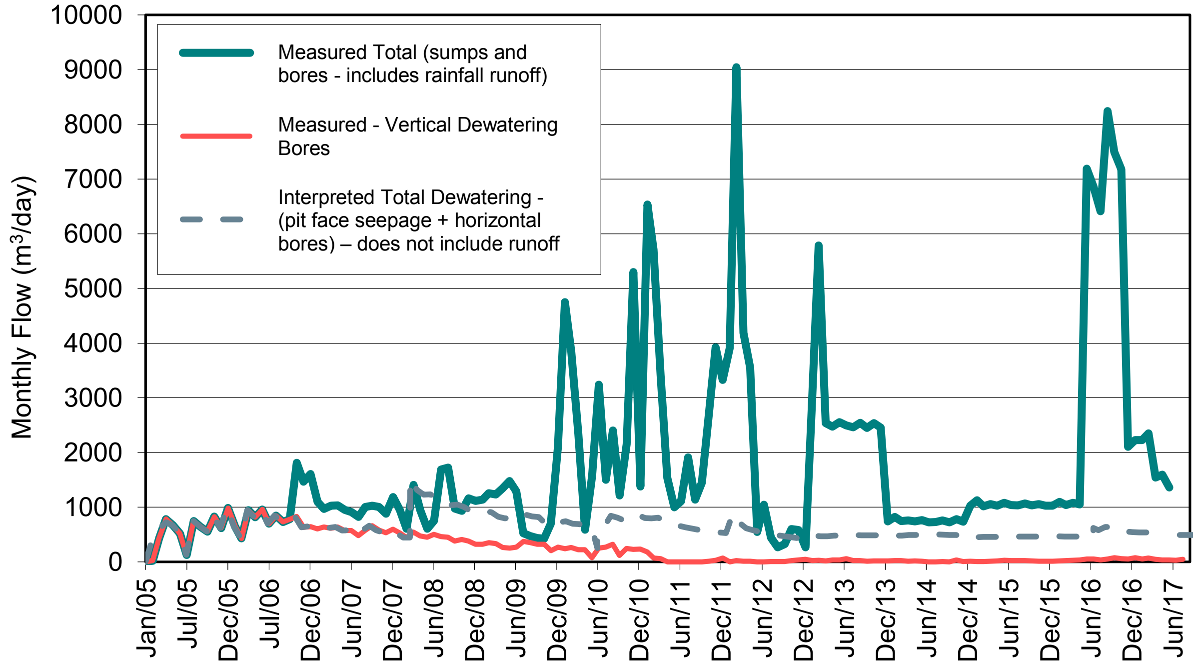


Figure 15 - Interpreted Pit Dewatering Rates

In conclusion, groundwater inflow to the open pit is estimated to have generally decreased since 2008 as the adjacent aquifers surrounding the CGO open pit have become depressurised. No material increase in groundwater inflow to the open pit is estimated to have occurred during or following the 2010, 2012 and 2016 lake-fill events based on monitored pit dewatering records.

3.17.4 Storage Dams

Storage dams located within the CGO are shown in Figure 11. Note that D10 has not been constructed to date. Historical water levels within the storage dams D1, D2, D3, D4, D5, D6, D8B and D9 were reviewed. Dams D1, D2, D4, D5, D6 and D8B were small and located in a way such that their impact on groundwater levels is likely to be insignificant.

Available groundwater monitoring data (for example, PP04 and PP05, screened within the Transported unit, as shown in Figure A-5) suggest that water seepage from dam D9 does not impact groundwater levels. Early transient model calibration simulations supported this assessment, and dam D9 was not included within the model thereafter.

3.17.5 Tailings Storage Facilities

Tailings are understood to have been released to:

- the southern TSF from 20 April 2006 to 15 May 2007;
- the northern TSF from 15 May 2007 to 12 September 2008;
- the southern TSF from 12 September 2008 to 8 December 2009;
- the northern TSF from 8 December 2009 to 16 January 2011;
- the southern TSF from 16 January 2011 to 9 March 2012;
- the northern TSF from 9 March 2012 to 14 June 2013;
- the southern TSF from 14 June 2013 to 1 September 2014;
- the northern TSF from 1 September 2014 to 2 November 2015;
- the southern TSF from 2 November 2015 to 1 December 2016; and
- the northern TSF from 1 December 2016 onwards.

Crest levels provided by Evolution are shown in Table 13. The IWL is planned to be operational from 1 January 2021; and the details of the activities are also shown in Table 13.

Due to tailings solids deposition, the surface of deposited tailings rises over time within each TSF. The lowest elevation of the surface of deposited tailings within each dam was estimated based on the nominated crest levels, known dam geometries, and assuming a tailings beach slope of 0.5%. Table 13 presents the estimated lowest deposited tailings surface elevation within each dam.

Historical tailings dam water levels were not available. However, historical percentage water coverage data for the tailings dams was provided for May 2006 to September 2010, and for March 2012 to November 2012. Based on the geometry of the tailings dams, the maximum water depth within both the northern and southern TSFs, averaged over these periods, is estimated to be 0.2 m.

The average surface water elevation within each TSF is estimated to be the lowest deposited tailings surface point plus 0.2 m (i.e. 0.2 m of standing water lies above the deposited tailings in each dam at any time). The estimated average water elevations are shown in Figure 16.

Table 13. Tailings Dam Crest Levels and Low Points

Status Start Date	Northern Tailings Storage Facility				Southern Tailings Storage Facility				Status Start Date	IWL Deposition			
	Stage	Operational Status	Crest Level (mAHD)	Low Point (mAHD)	Stage	Operational Status	Crest Level (mAHD)	Low Point (mAHD)		Stage	Operational Status	Crest Level (mAHD)	Low Point (mAHD)
01-Jan-06				213.0				213					213
20-Apr-06				213.0	1	Active	225.6	222.4					213
15-May-07	1	Active	222.0	218.8	1	Inactive	225.6	222.4					213
12-Sep-08	1	Inactive	222.0	218.8	2	Active	229.0	225.8					213
08-Dec-09	2	Active	225.0	221.8	2	Inactive	229.0	225.8					213
16-Jan-11	2	Inactive	225.0	221.8	3	Active	232.2	229.1					213
09-Mar-12	3	Active	228.2	225.1	3	Inactive	232.2	229.1					213
14-Jun-13	3	Inactive	228.2	225.1	4	Active	235.4	232.4					213
01-Sep-14	4	Active	231.7	228.7	4	Inactive	235.4	232.4					213
02-Nov-15	4	Inactive	231.7	228.7	5	Active	239.0	236.1					213
01-Dec-16	5	Active	236.0	233.1	5	Inactive	239.0	236.1					213
01-Mar-18	5	Inactive	236.0	233.1	6	Active	243.7	240.9					213
01-May-19	6	Active	240.5	237.7	6	Inactive	243.7	240.9					213
01-Jul-20	6	Inactive	240.5	237.7	7	Active	248.4	245.7	01-Jan-21	1	Active	221.5	220.1
01-Nov-21	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	01-Nov-21	1	Inactive	221.5	220.1
01-Nov-21	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	01-Nov-21	2	Active	228.0	225.2
01-Dec-22	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	01-Dec-22	2	Inactive	228.0	225.2
01-Dec-22	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	01-Dec-22	3	Active	228.0	225.2
01-Feb-24	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	01-Feb-24	4	Active	231.5	225.2
01-Apr-25	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	01-Apr-25	5	Active	236.5	228.7
01-Apr-27	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	01-Apr-27	6	Active	240.5	233.7
01-May-29	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	01-May-29	7	Active	245.0	237.7
01-Jul-32	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	01-Jul-32	7	Inactive	245.0	242.2

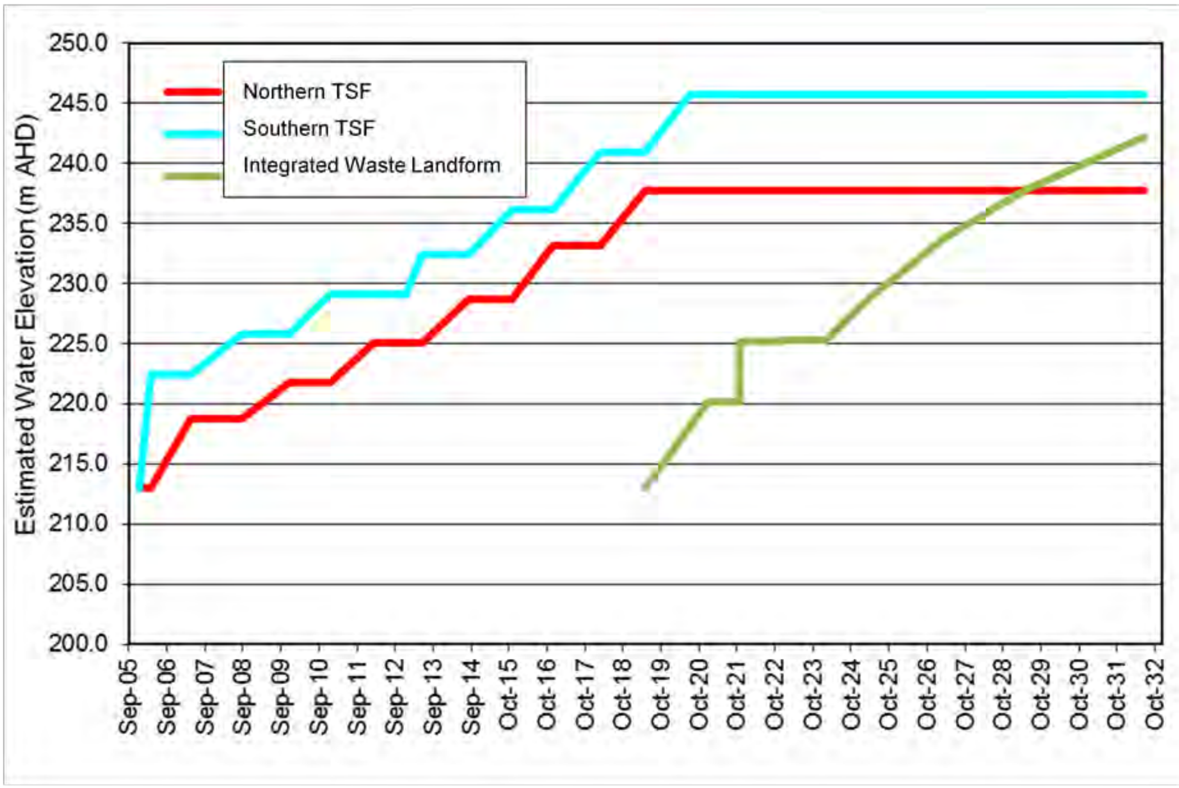


Figure 16 - Tailings Storage Facility Water Levels

Since the hydraulic conductivity of the TSF foundation material is lower than that of the deposited tailings (Table 11), the surface water lying within the storage facility ponds is expected to maintain full hydraulic connection with the top of the TSF foundation material (through the deposited tailings).

4 HYDROGEOLOGICAL MODELLING

A model of the groundwater system in the vicinity of the CGO was established comprising multiple layers over the pit area and the surrounding areas. This model was used to assess potential impacts from the operation of the ML 1535 saline groundwater supply borefield, the potential for hydraulic connection between Lake Cowal and the CGO groundwater system, groundwater inflows to the open pit, the effects of seepage from the TSFs/IWL and the short and long-term effects of mine closure on groundwater conditions.

4.1 Conceptual Model

4.1.1 Model Domain

The domain covered by the Mine Site Model is shown in Figure A-7 (Appendix A), which also shows the model domains considered in previous Coffey models (Coffey, 1995d, 2006, 2009a and 2009b). The model covers the area from MGA E530000 to E545000 and MGA N62650000 to N62880000.

The model domain adopted for groundwater flow modelling is bounded in the west by a high ridge (Cowal West Hill), which is approximately 3 km west of the Gilmore Suture, and in the east by the Bland Creek Palaeochannel. Cowal West Hill in the west separates surface flow (recharge) between an easterly and westerly direction. The Cowal West Hill feature is therefore adopted as the western boundary, over which a constant (with respect to time) groundwater head is likely. The constant (with respect to time) value may vary from north to south.

The Bland Creek Palaeochannel contains a deep alluvial layer that is much more transmissive than the upper regional alluvial aquifer system. Since groundwater heads are likely to be relatively stable in this region, this has been selected as the eastern boundary of the model domain. Groundwater heads within the shallow sediments (Transported unit) beneath Lake Cowal are expected to be similar to the lake surface water head values. Coffey (2006) data for December 1997 suggest the groundwater head along the eastern model boundary outside of Lake Cowal, and within deep strata below the lake, is likely to be approximately 200 mAHD. Similarly, the NOW (now DI – Water) (unknown publication date) model considered a groundwater head within the Upper Cowra Formation of approximately 200 mAHD in this area. Data (Coffey, 2006) suggest groundwater head values at the eastern boundary decline running south to north.

Assessment of groundwater levels at the Nerang Cowal and Marsden sections (Coffey, 1995c) suggested groundwater levels at these locations would not be affected by mine dewatering. Net flow into and out of the domain over the western portion of the northern model domain boundary (western end of Nerang Cowal section) is expected to be negligible. Data were not available for water levels within Nerang Cowal. However, groundwater levels within shallow sediments (Transported unit) beneath Nerang Cowal at the northern model boundary are expected to follow a similar trend to those beneath Lake Cowal, and the levels beneath Nerang Cowal are expected to be slightly lower in value than those beneath Lake Cowal (when the lakes are inundated). This results in groundwater flow in a direction from Lake Cowal towards Nerang Cowal, as confirmed by the historical data shown in Figures A-8 to A-15 (Appendix A), and reported in Coffey (2006).

At the southern model boundary, data (Coffey, 2006) suggests net groundwater flow into or out of the domain is zero.

Groundwater modelling by NOW (now DI – Water) (unknown publication date) adopted initial (pre-mining) groundwater head values in the vicinity of ML 1535 and Lake Cowal ranging from approximately 200 to 230 mAHD (heads falling in an easterly direction) in the Upper Cowra Formation, and values of 230 mAHD in the Lower Cowra Formation. For the Transported hydrogeological unit in the present conceptual model, this is likely to equate to initial (pre-mining) groundwater head values of approximately 200 to 230 mAHD. The eastern values are similar to those reported for April 1996 by Hawkes (1998).

4.1.2 Hydrogeological Units

In terms of the CGO mining activities and CGO geological investigation (Coffey, 1995b; North Limited, 1998), the following seven hydrogeological units have been identified for the purposes of modelling (Mine Site Model):

- ***Transported unit***: Comprises alluvial deposits of relatively low hydraulic conductivity clays and a gravel aquifer within the alluvium which includes Gilgai, Czr, Qa, Qr and Qal sediments (see Figure 7). The waste rock emplacement is represented by this unit, though it generally possesses higher permeability than other alluvial deposits. The recharge from the waste rock emplacements is not considered to significantly impact groundwater movement. Further east this unit becomes the Upper Cowra Formation.
- ***Saprolite unit***: Comprises a soft oxide material (extremely weathered mudstone, sandstone or diorite). This unit lies directly above the base of the Cowra Formation alluvium and forms a more permeable zone throughout the CGO, extending beneath Lake Cowal with unknown thickness.
- ***Saprock unit:*** Comprises a hard oxide material (weathered mudstone, sandstone or diorite) of relatively low hydraulic conductivity, lying above the weathered fractured surface of the Lake Cowal Volcanics. This unit has relatively high clay content and limited water carrying capacity. The Saprolite and Saprock units are considered equivalent to the Lower Cowra Formation.
- ***Lachlan Formation unit:*** Comprises high permeability sands and minor gravels close to, and within, the deeper parts of the Bland Creek Palaeochannel and lower permeability sediments that generally occur further away from the deeper parts of the palaeochannel and surround the high permeability sands and minor gravels. It features over a small area in the far western portion of the modelled domain.
- ***Primary Rock (Bedrock) unit:*** Mainly consists of volcaniclastic rocks of low permeability.

The TSFs and IWL are represented by the following distinct hydrogeological units:

- ***TSFs (and IWL) unit:*** The TSFs comprise about 55% solids, with finely ground rock residue remaining after the flotation and leaching process. The consolidated residue was found to be of low permeability.
- ***TSFs (and IWL) Embankment unit:*** A basal barrier and impermeable liner with an equivalent vertical permeability not greater than 1×10^{-9} m/s (9×10^{-5} m/day) over a thickness of 2 m was present at the base of the TSFs (A letter from URS to the Cowal Gold Project of 20 January 2006 reviewed conditions at the base of the southern TSF taking account of extensive test pitting, trenching and drilling investigations. It concluded that testing had shown the permeability to be typically an order of magnitude lower than the specification of $1\text{x}10^{-9}$ m/s over the uppermost 5 m of the site. Coffey note that removal of borrow material for up to a thickness of 3 m, as nominated in the letter, would leave at least 2 m of low permeability clay at the base of the facility). Coffey anticipate similar conditions would have prevailed in the northern TSF and will prevail beneath the floor of the IWL. Coffey recommend testing of the area to be covered by the IWL to assess vertical permeability.

4.1.3 Groundwater Recharge

Groundwater recharge sources over the Mine Site Model domain include rainfall and surface water bodies (contained water storages and Lake Cowal). These are discussed in Section 4.3.1.

4.1.4 Groundwater Discharge

Groundwater discharges within ML 1535 include open pit dewatering and groundwater supply from the ML 1535 saline borefield. These are discussed in Section 4.3.1.

The Mine Site Model domain lies outside areas of known irrigation such as the Bland Creek Palaeochannel. Irrigation bores identified within the model developed by NOW (now DI – Water) (unknown publication date) for the Upper Lachlan catchment area all lie outside the Mine Site Model domain. Groundwater extraction due to irrigation is, therefore, not considered significant within the Mine Site Model.

It is understood that a number of private stock and domestic bores also extract groundwater from the Upper Cowra Formation; however, the extraction quantities are considered to be small and are, therefore, considered unlikely to be significant within the Mine Site Model domain.

4.2 Numerical Model Development

Based on the Hydrogeological Conceptual Model presented in Section 4, a transient three-dimensional finite element model for simulation of groundwater flow and transport of solutes in groundwater was developed. The existing model was updated with recent conditions. This section discusses the original model development and updates.

Following review of existing modelling software platforms and existing Coffey models for CGO, the finite element software package FEFLOW 6.0, developed by WASY GmbH (now DHI-WASY), was identified as a suitable software platform for this modelling project.

4.2.1 Model Domain, Layers and Discretisation

The model domain covers the same domain as the Mine Site Model Hydrogeological Conceptual Model discussed in Section 5.1. A three-dimensional schematic representation of the Hydrogeological Conceptual Model of the study area is shown in Figure 17.

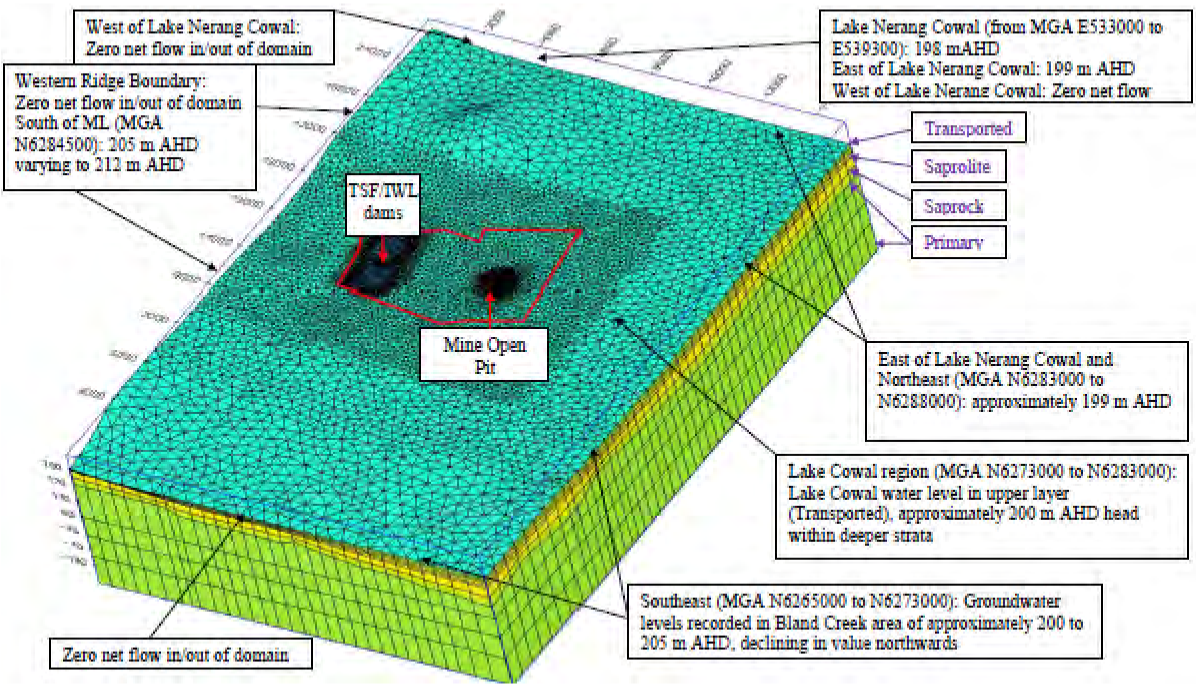


Figure 17 - 3D Representation of Model Domain and Boundary Conditions

The model domain was discretised in a three-dimensional finite element mesh comprising 14 layers. The total number of elements in the mesh is 265,062. Figure 18 displays the model mesh. The boundary of ML 1535 is drawn in red.

The depth of the model extends from ground surface elevation to -500 mAHD, covering the proposed base depth of the open pit at -331 mAHD from 2020. The modelled area covers 370 square kilometres.

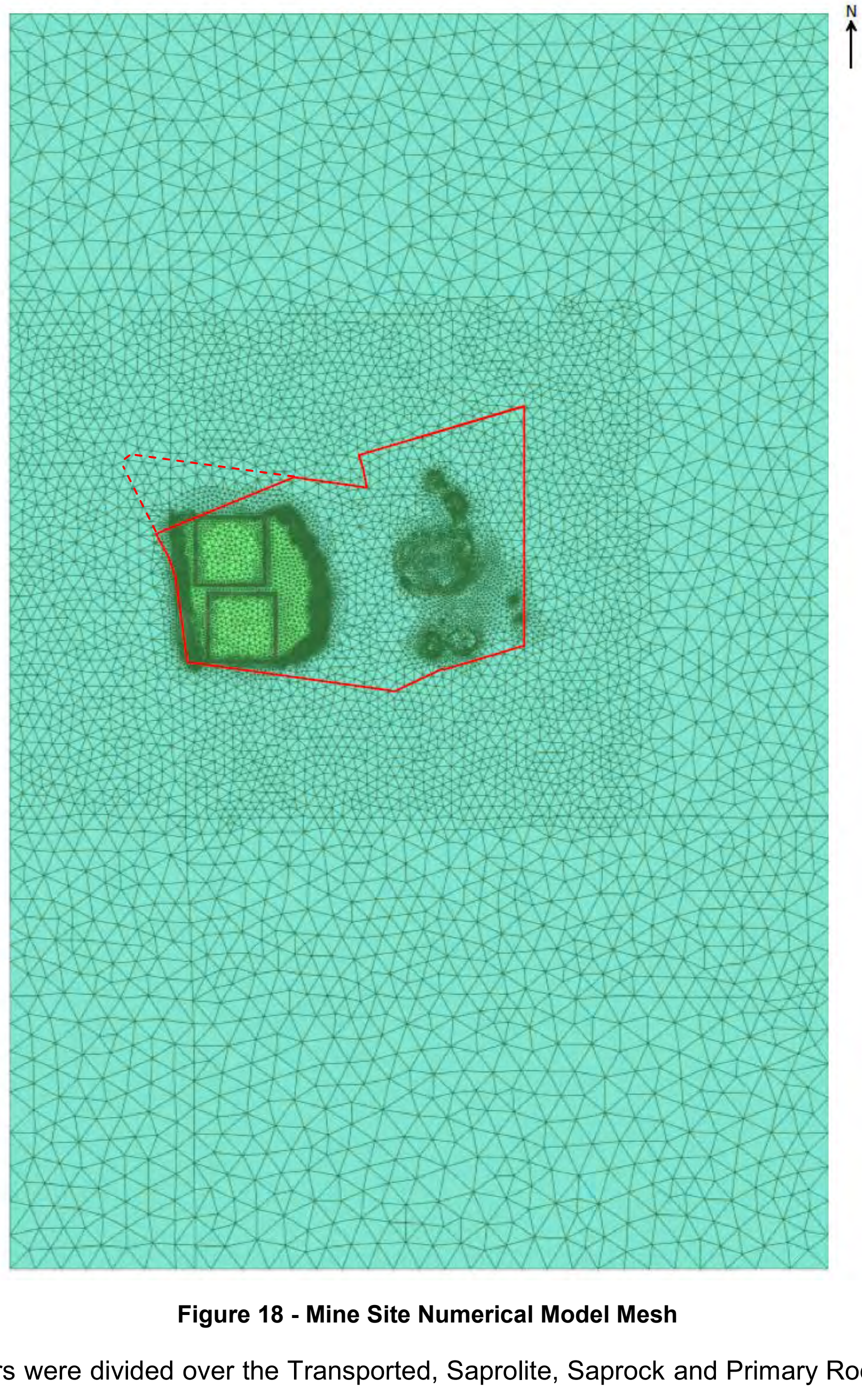


Figure 18 - Mine Site Numerical Model Mesh

The 14 model layers were divided over the Transported, Saprolite, Saprock and Primary Rock hydrogeological units. This division of layers permits future refinement of the model layers (e.g. further subdivision of hydrogeological units) to be made with greater ease. The division is as follows:

- The Transported hydrogeological unit is represented by the top three layers, each with equal thickness, except over the TSF and IWL areas where:
  - the base area of each dam in model Layer 1 is assigned properties in accordance with the deposited tailings material (Table 11);
  - the perimeter wall of each dam in model Layer 1 is assigned properties in accordance with the TSFs embankment clay material (Table 11);
  - the base area of each dam in model Layer 2 is assigned a 1 m thick liner with properties in accordance with the TSFs embankment fill material (Table 11); and
  - the layers were later assigned the properties of IWL embankment clay material and IWL embankment fill material to represent the proposed IWL construction in 2021 (CMW, 2017). The permeability values adopted in designing the IWL are similar to the properties adopted in representing the TSFs in the FEFLOW model.
- The Saprolite hydrogeological unit is defined as model Layers 4 and 5 and the Saprock hydrogeological unit is defined as model Layer 6, except that the model considers the presence of Primary Rock to the west of the Gilmore Suture for these three layers (Primary Rock is interpreted to outcrop near the surface west of the Gilmore Suture).
- The Primary Rock hydrogeological unit is assigned for model Layers 7 to 14.

Topographic (ground surface) elevations and the base elevations of the Transported, Saprolite and Saprock hydrogeological units were provided from mine records for the ML 1535 area. Topographic surface was also provided (at lower resolution) for the wider region. The surfaces of hydrogeological units were linearly extrapolated from the boundaries of ML 1535 to regions outside ML 1535. Figures A-1 to A-4 (Appendix A) show the model adopted surface contours for ground surface level, and the base of the Transported, Saprolite and Saprock units, respectively.

Mesh sizes were designed to meet the following criteria:

- Mesh cell sizes were refined around the open pit to allow effective simulation of dewatering and water level changes in the surrounding area.
- Mesh cell sizes were refined around the TSFs and IWL to allow effective simulation of water level changes in these areas.
- Small mesh sizes were used in the vicinity of the open pit.
- Mesh cell densities were reduced in areas where groundwater conditions were less important for accomplishing modelling objectives, or where data relating to the characteristics of the groundwater system were sparse, or where resolution was unlikely to significantly improve simulation outcomes. Cell density reductions achieved significant decreases in model processing time.

The transient model time step varied throughout numerical simulation, depending on convergence of the model solution, but was restricted to a maximum allowable time step of 10 days.

4.3 Model Calibration

The groundwater model employed for this work was subject to calibration studies during the earlier work. This is described in Coffey (2016).

Transient calibration considered the period 1 January 2005 (pre-mine-development) to 30 June 2017. Simulations were performed in the saturated unconfined aquifer FEFLOW mode. The calibrated model used in the pit dewatering assessment (Coffey, 2008) utilised similar aquifer parameters to those estimated from field data (Coffey, 2008, 2009a). Transient calibration adopted parameter values over the same ranges as those reported in Tables 4 and 5. Given the approximately north-south faulting in the region (Figure 7), the horizontal hydraulic conductivity was considered to be anisotropic within the rock units.

Calibration of open pit boundary conditions and aquifer properties was undertaken taking account of earlier work for assessment of previous modifications. Calibration to groundwater monitoring and recorded dewatering flow rates was conducted with particular focus on the influence of:

- hydraulic conductivities and storativity within the Transported, Saprolite, Saprock and Primary Rock units;
- net accession (recharge and evaporation) rates; and
- varying combinations of seepage boundary conditions (with varying combinations of seepage (drainage) conditions located at the base of the Transported, Saprolite and Saprock units) and varying spatial sizes of "pit sump" time-varying head boundary conditions.

4.3.1 Model Boundary Conditions

4.3.1.1 Recharge and Surface Water Bodies at Mine Site

As adopted for earlier work, a recharge rate of 0.3% mean annual rainfall has been adopted for the domain. Except for the TSFs, surface water bodies on-site are not considered likely to impact groundwater conditions significantly and, therefore, have not been included in the model. This is consistent with treatment in earlier modelling studies. The model adopts the water levels (time-varying constant head boundary conditions) within the northern and southern TSFs shown in Figure 16.

The inundation of Lake Cowal is represented in the model by application of a constant head boundary condition (with values in accordance with Figure 19) at ground surface (model Layer 1) over the area of Lake Cowal for the period over which Lake Cowal was observed to be inundated.

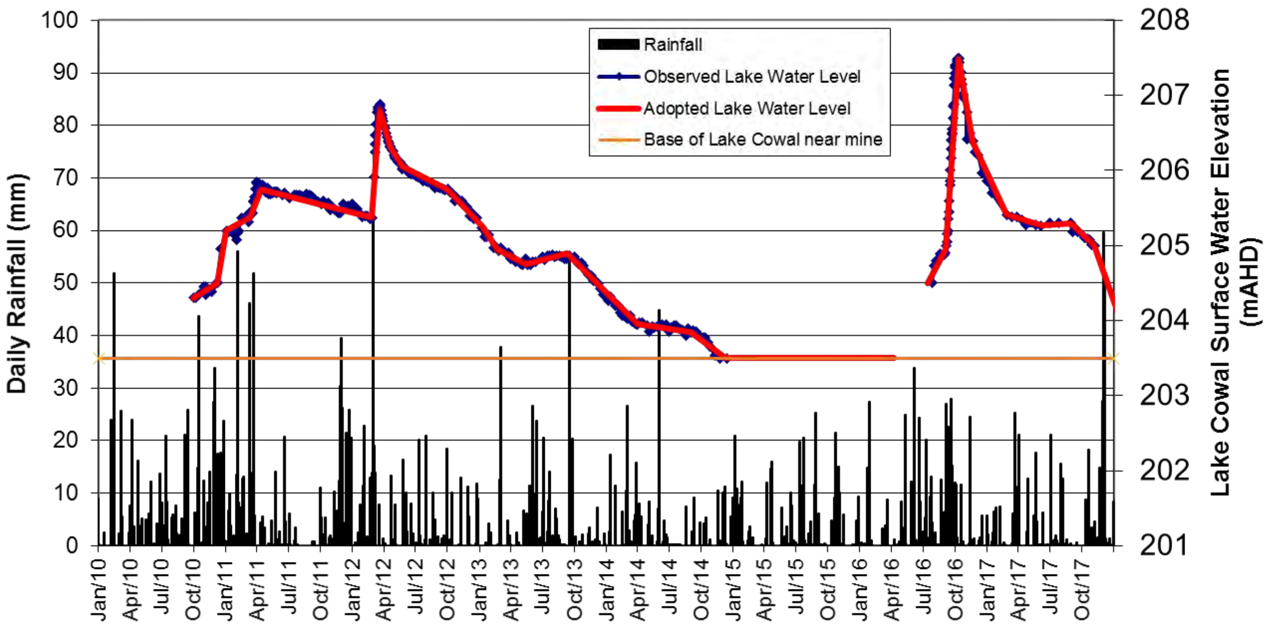


Figure 19 - Adopted Water Levels for Lake Cowal

4.3.1.2 Model Domain Boundaries

Transient model boundary conditions adopted at the boundaries of the model domain were as follows:

- The Cowal West Hill ridge was adopted as the western boundary. At the western model boundary, a constant (with respect to time) head condition from 212 mAHD in the south, falling in value to 205 mAHD approximately 1.8 km north of the CGO, over all layers.
- At the northern model boundary, a constant head at Nerang Cowal of 198 mAHD, and a constant head of 199 mAHD to the east of Nerang Cowal, over all layers.
- The Bland Creek Palaeochannel was adopted as the eastern boundary of the model domain. Lake Cowal is understood to have been dry during 2005. Over the area covered by Lake Cowal, a groundwater level of 200 mAHD (some 1.5 m below lake bed level) was adopted for dry lake conditions; this is consistent with the range of groundwater head elevations modelled by the Bland Creek Palaeochannel Model in this area. Constant (with respect to time) head boundary conditions ranging from 200 mAHD within the Lake Cowal area to (i) 199 mAHD in the north, and (ii) 205 mAHD in the south, were applied to the north and to the south of Lake Cowal, respectively.
- No-flow boundaries at all other model domain extremities over all layers.

4.3.1.3 Open Pit

The open pit was modelled using seepage face and constant head boundary conditions in five stages. The stages correspond with significant lateral expansion of the open pit, the installation of significant numbers of horizontal dewatering bores, and the inundation of Lake Cowal. The periods of the five stages are:

- beginning of mine life to March 2008 (when the open pit expanded significantly and significant numbers of horizontal bores were installed);
- March 2008 to June 2010 (when the lake began to fill);

- June 2010 to June 2016;
- July 2016 to January 2020; and
- February 2020 to June 2032.

The progressive deepening of the open pit was represented by a time-varying constant head boundary condition, which was applied equal to the base elevation of the pit over a base region within the pit (in model Layer 10 for Stages 1 and 2, model Layer 11 for Stage 3, model Layer 12 for Stage 4 and model Layer 13 for Stage 5. Those model layer elevations are consistent with the base elevations of the open pit of the stage periods). The elevation of the pit base during the life of the Modification is shown in Figure 13.

The progressive widening of the open pit was represented by applying a seepage boundary condition ring around the exposed pit face at the base of the Transported, Saprolite and Saprock units, which expanded over the three modelling stages in order to represent the progressive lateral expansion of the open pit. The seepage face boundary conditions applied in the pit area are shown in Figure 20.

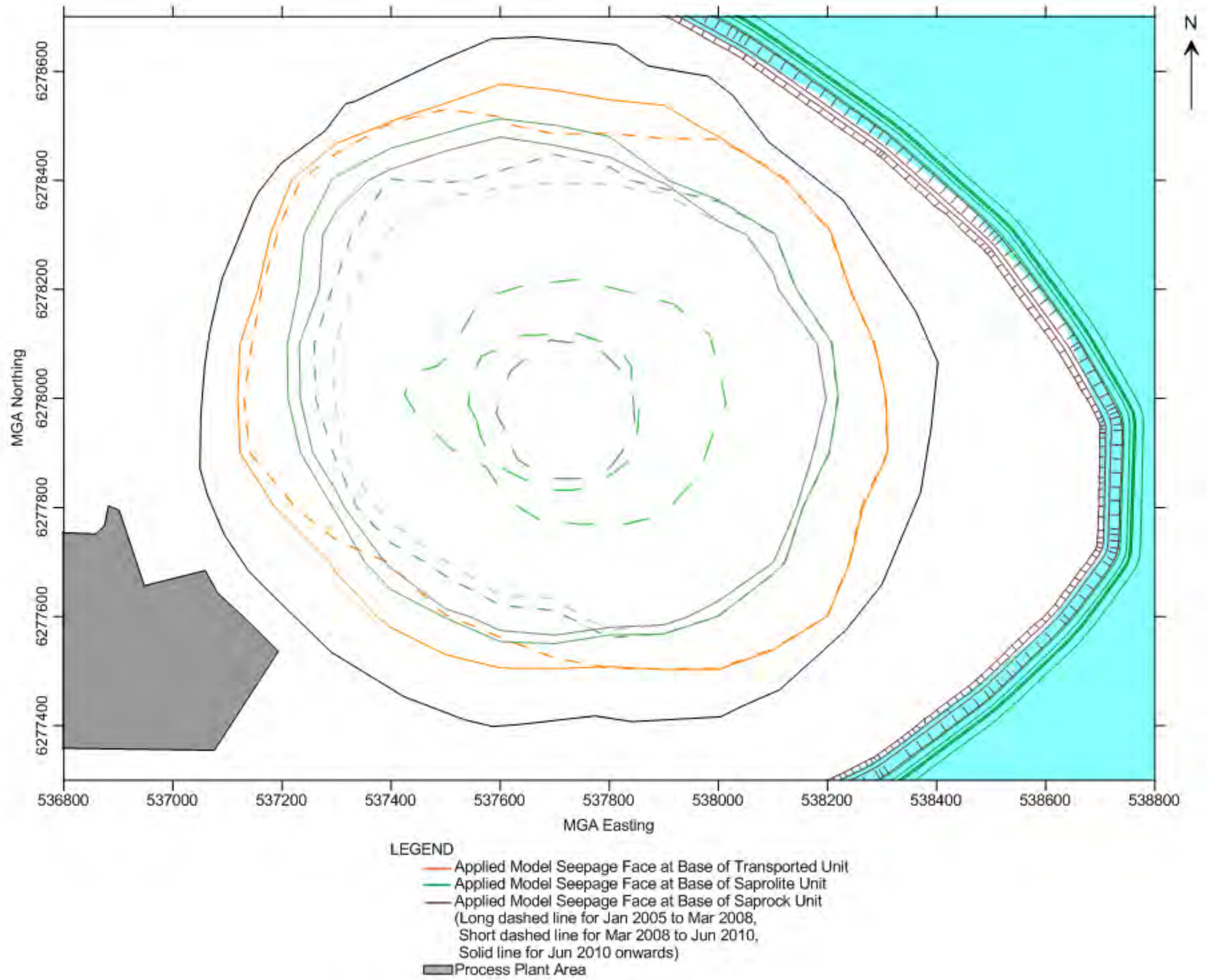


Figure 20 - Open Pit Model Seepage Boundary Conditions

4.3.1.4 Dewatering Bores

The dewatering bores included in the model are listed in Table 14 and their locations shown in Figure 12. The locations of the modelled dewatering bores (PD1 to PD14) provide reasonable representation of the locations of dewatering bores throughout the mine life, including the dewatering bores PD101 to PD107 commissioned in November 2011 (which are located in the vicinity of PD1 to PD10). The dewatering bores have gradually been decommissioned as groundwater seepage has progressively become face seepage and been collected in horizontal bores. Use of horizontal bores has provided sufficient depressurisation of the pit wall. As of December 2017, all remaining vertical dewatering bores had been decommissioned.

The total recorded monthly pumping rates from January 2005 to June 2016 for all dewatering bores were divided equally among the 13 bores included in the model. The adopted pumping rates are shown in Figure 21.

Table 14. Pit Dewatering Bores Used for Transient Calibration

Bore Identification	MGA Northing	MGA Easting	Screen Interval (mAHD)
PD1	538259	6278229	204.3 to 141.3
PD2	538327	6277974	204.2 to 105.2
PD3	538324	6277875	204.3 to 113.8
PD4	538325	6277786	204.4 to 100.4
PD5	538310	6277688	204.3 to 114.3
PD6	538243	6277578	204.3 to 113.3
PD7	538178	6277523	204.4 to 108.0
PD8	538068	6277459	204.4 to 108.9
PD9	537958	6277434	204.5 to 116.5
PD10	537863	6277430	204.6 to 112.1
PD11	537713	6277428	205.1 to 120.1
PD12	537520	6277490	211.0 to 135.5
PD14	537243	6277944	210.9 to 133.9

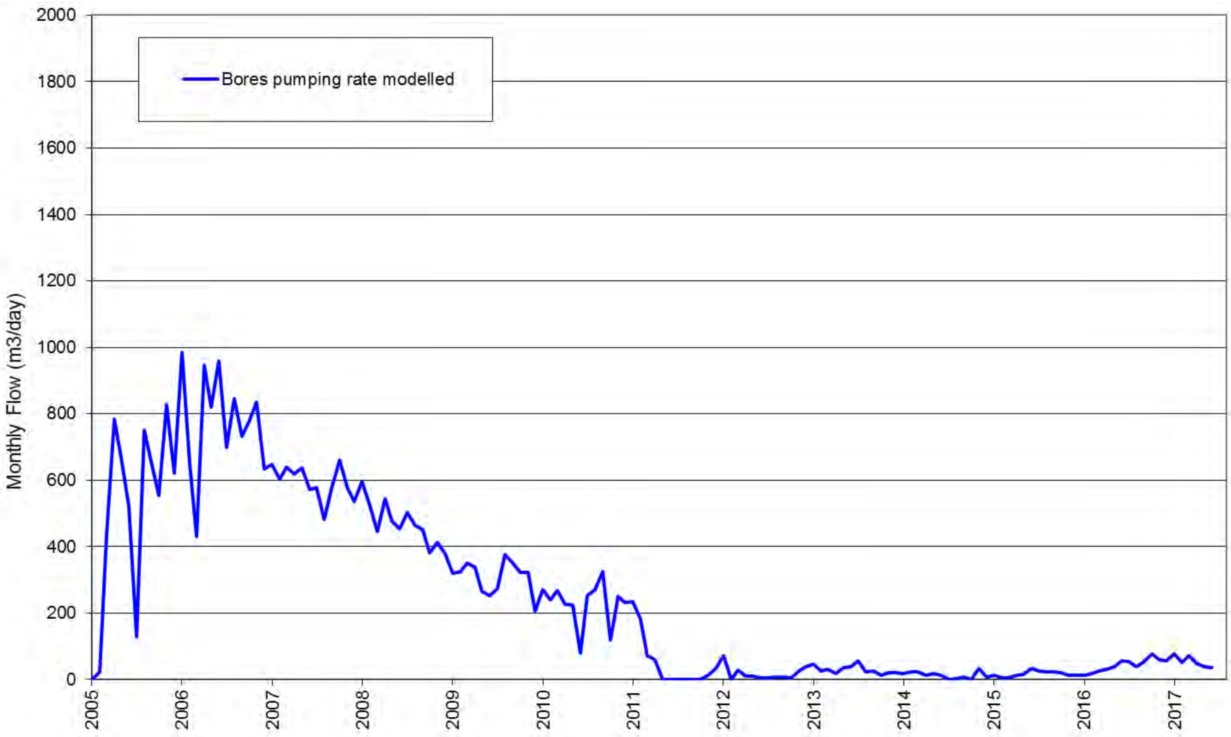


Figure 21 - Pit Vertical Bore Dewatering Rates

4.3.1.5 Groundwater Supply Extraction

ML 1535 saline groundwater supply bores (see Figure 12 for bore locations) may exert influence on the groundwater drawdown behaviour and were, therefore, included within the model. These bores have not been used while Lake Cowal contained water. The following conditions were applied to ML 1535 saline groundwater supply bores located within ML 1535:

- Groundwater extraction from ML 1535 WB01 and ML 1535 WB20 occurred at 0.5 megalitres per day (ML/day) and 0.13 ML/day, respectively, for five days per week, during September 2008 (equivalent continuous pumping rate of 0.35 ML/day and 0.09 ML/day, respectively).
- After September 2008, groundwater was not extracted from ML 1535 WB20.
- After September 2008, groundwater extraction from ML 1535 WB01 occurred at 0.5 ML/day for five days per week from December 2008 to April 2010 (equivalent continuous pumping rate of 0.36 ML/day).
- From April 2010, groundwater was not extracted from the saline supply bore field due to Lake Cowal being inundated (this situation continued for the remainder of the calibration period).

4.3.1.6 Summary of Applied Boundary Conditions

A summary of the applied boundary conditions for the transient model is provided in Table 15.

Table 15. Summary of Boundary Conditions Employed in Transient Numerical Model

Boundary Location	Boundary Condition Type and Values Adopted	
Surface	Recharge rate:	0.3% of mean annual rainfall (1.44 mm/day)
Eastern Boundary	Bland Creek Palaeochannel: constant head from 199 mAHD to 205 mAHD, except at the boundary locations at which Lake Cowal is present	
Southern Boundary	No-flow	
Western Boundary	Cowal Hill Ridge: constant head from 205 mAHD in the north to 212 mAHD in the south (calibrated from steady state model)	
Northern Boundary	Over Nerang Cowal, a fixed head of 198 mAHD, a no-flow boundary west of Nerang Cowal, and a constant head of 199 mAHD east of Nerang Cowal	
Lake Cowal	Time-varying constant head in Layer 1 (see Figure 19)	
Open Pit	Base elevation of the pit:	Time-varying constant head in Layers 10 to 13 (see Figure 13)
	Pit walls:	Seepage face boundary (drain) in Layers 4, 6 and 7 (see Figure 20)
TSF/IWL	Southern and northern TSFs:	Time-varying constant head (see Figure 16)

mm/day = millimetres per day.

4.3.1.7 Model Assumptions

The following assumptions were employed in the model:

- the Mine Site Model does not include regional areas over which significant groundwater pumping by private owners occurs (e.g. irrigation over farmland);
- the open pit is assumed to be dry (not flooded) during mining (observed on-site conditions support this assumption);
- changes in deposited tailings materials (e.g. due to consolidation or operation processes) were not considered;
- the Jemalong and eastern saline supply borefields are at sufficient distance for drawdown impacts not to affect groundwater levels at the CGO mine site;
- deposited tailings are not removed from the TSFs and IWL; and
- the TSFs, IWL and Lake Cowal are the only surface water bodies within ML 1535 exerting significant impact on groundwater levels.

4.3.1.8 Calibration

The calibration process involved changes to model parameters to better match model outputs with measured response. The results for the adopted model after the calibration process are discussed below.

Figures A-16 to A-18 (Appendix A) show modelled and observed groundwater levels at the locations of the groundwater monitoring piezometers for the calibrated model.

The modelled groundwater levels and trends are generally consistent with those observed. Modelled levels are slightly elevated in some piezometers near the TSFs (Figure A-18 of Appendix A).

Modelled groundwater levels at piezometers PDB3A are somewhat elevated relative to observed groundwater levels. This is likely due to the influence of horizontal bores (W911 and W912) in the pit, which are located relatively close to the PDB3 piezometers and likely to cause significant localised drawdown that may not be representative of other areas in the vicinity of the pit. As the horizontal bores (drains) are not modelled explicitly, these localised effects are not shown in the calibration results. As that impact is expected to be localised, the calibration results are considered reasonable.

At greater distance from the open pit, modelled groundwater levels in piezometers PDB1A and PDB1B (Figure A-16 of Appendix A) compare favourably with observed groundwater levels. Modelled groundwater levels in piezometers PDB5A and PDB5B (Figure A-16 of Appendix A) compare reasonably well with observed groundwater levels, although the rise in PDB5B (screened in the Transported unit) is slightly underestimated.

Modelled groundwater levels in piezometers located in the processing plant area (Figure A-17 of Appendix A) overestimate the drawdown in ground water levels in the vicinity. Hence, the predictions are considered somewhat conservative.

Predictions of groundwater levels in the vicinity of TSFs shows a similar pattern to those observed, with some having fairly good agreement with the measured data. Near the northern TSF, the predictions are overestimating the groundwater levels at piezometers TSFNA, TSFNB, TFSNC and MON01A, while the predictions for P561B underestimates the groundwater level. For the southern TSF, a slight over-prediction of groundwater levels could be observed.

In general, the modelled groundwater levels and rates of drawdown compare favourably with those observed. The aquifer parameters adopted in the model are shown in Table 16 and were employed for the predictive modelling. For available data, aquifer parameter values lie within two orders of magnitude of those adopted in previous studies (Tables 4 and 5).

Modelled groundwater head contours for the Transported (Layer 3), Saprolite (Layer 5), Saprock (Layer 6) units, and the Primary Rock (Layer 11) unit at the end of the calibration period (June 2017) are presented in Figures A-19 to A-22 (Appendix A) respectively. Groundwater levels fall in the vicinity of the pit but the extent of drawdown is generally limited to the ML 1535 area. When compared against groundwater heads observed prior to mine development, the influence of drawdown in June 2017 is confined to within the modelled domain.

Table 16. Adopted Model Parameters

Model Layer(s)	Hydrogeological Unit	Hydraulic Conductivity (m/day)			Specific Storage (m^{-1})	Specific Yield (-)
		K_{xx} (east-west)	K_{yy} (north-south)	K_z (vertical)		
1 to 3	Transported Material	1.0×10^{-2}	1.0×10^{-2}	6.5×10^{-4}	5×10^{-4}	1.5×10^{-1}
4 and 5	Saprolite*	3.4×10^{-2}	1.7×10^{-2}	1.7×10^{-2}	5×10^{-5}	1.0×10^{-4}
6	Saprock*	4.0×10^{-3}	2.0×10^{-3}	2.0×10^{-3}	3×10^{-5}	1.0×10^{-4}
7 to 14	Primary Rock	Varies^	Varies^	5.0×10^{-4}	2×10^{-5}	1.0×10^{-4}
1	TSF Embankment Clay	4.3×10^{-1}	4.3×10^{-1}	4.3×10^{-2}	5×10^{-4}	1.5×10^{-1}
1	Deposited Tailings	5.0×10^{-2}	5.0×10^{-2}	5.0×10^{-4}	5×10^{-4}	1.5×10^{-1}
2	TSF Foundation	1.0×10^{-4}	1.0×10^{-4}	1.0×10^{-4}	5×10^{-4}	1.5×10^{-1}

* Parameter values applied over domain to the east of Gilmore Suture. West of the Gilmore Suture, Primary Rock values apply for the layer.

^ Primary rock horizontal hydraulic conductivity reduces with depth. K_{xx} varies from 2.3×10^{-3} m/day in Layers 7 to 10, reducing approximately linearly to 5×10^{-4} m/day in Layers 14 to 15. K_{yy} is consistently double the value of K_{yy} in Layers 7 to 13.

The modelled and interpreted average monthly total dewatering rates (vertical dewatering bores plus pit face seepage inflows) are shown in Figure 22. Measured dewatering rates compare favourably with modelled rates, providing confidence in the model's ability to accurately represent groundwater flow conditions.

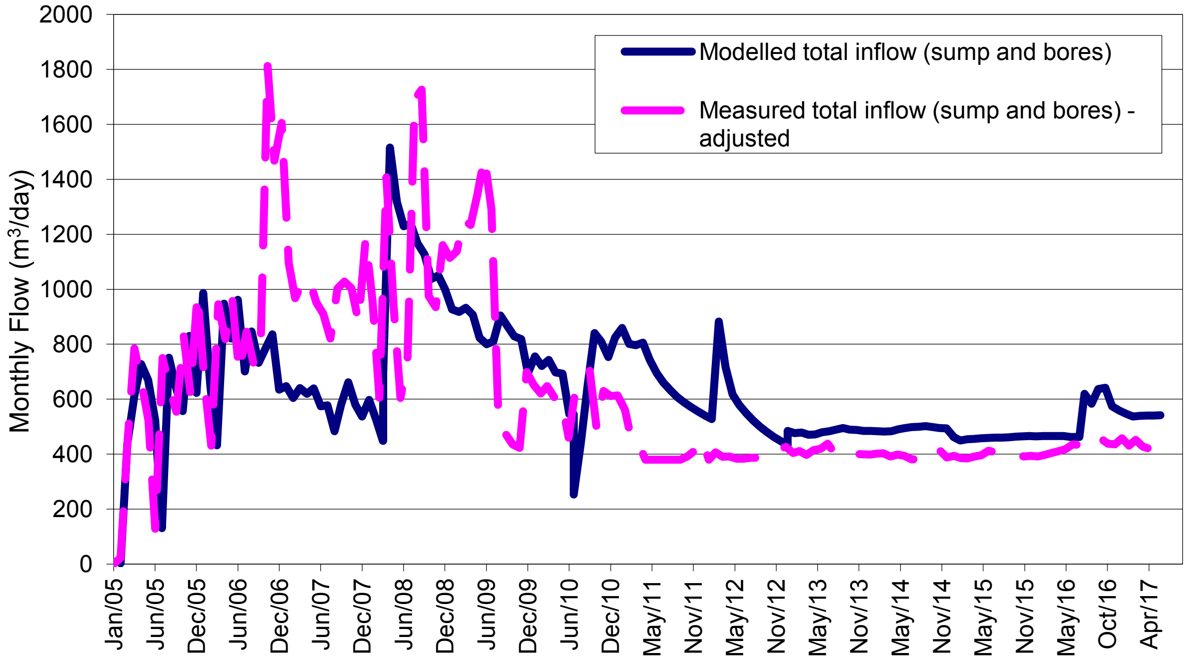


Figure 22 - Modelled Pit Groundwater Inflows

4.4 Predictive Groundwater Flow Modelling

The calibrated model was utilised to predict groundwater flow and drawdown for the Modification. Two scenarios were considered: Lake Cowal being either dry or inundated.

4.4.1 Modelled Conditions

4.4.1.1 Lake Cowal

For the inundated Lake Cowal scenario, a lake water level of 206.5 mAHD, which is 1 m below the recorded peak during the mine operations, was assumed to exist in perpetuity over the lake area.

For the dry Lake Cowal scenario, the lake level was considered to fall consistent with Figure 19, after which time it remained dry.

4.4.1.2 Open Pit

The base elevation of the pit was modelled consistent with that shown in Figure 13, using a constant head boundary condition in model Layer 13. Adopted pit seepage boundary conditions were identical to those used in the calibrated model.

4.4.1.3 Tailings Storage Facilities

The TSFs were assumed to continue rising as shown in Figure 16.

4.4.1.4 Integrated Waste Landform

The IWL was assumed to continue rising as shown in Figure 16.

4.4.1.5 ML 1535 Saline Groundwater Supply Bores

Groundwater is extracted from the ML 1535 saline groundwater supply borefield only when Lake Cowal is dry. Therefore, only the dry scenario considered abstraction.

4.4.1.6 Open Pit Dewatering Bores

Since initial pit development, the flow extracted by the vertical dewatering bores has gradually reduced as the pit wall depressurisation using horizontal drains has been established as the method of groundwater control (see Figure 21). From November 2011, flows extracted from these bores did not make up a significant proportion of groundwater seepage flow to the pit. The last of the vertical dewatering bores were decommissioned in late 2017 as it was demonstrated that horizontal drains successfully depressurise the pit wall without the need for vertical dewatering bores.

4.4.2 Predictive Modelling Results

4.4.2.1 During Mining

Over the future life of the CGO, predicted groundwater levels in the immediate vicinity of the open pit continue to fall in all units due to increasing excavation of the pit. In the vicinity of the TSFs, and eventually around the IWL, groundwater levels would tend to rise in response to the increased water levels within the storage facilities.

For the dry lake scenario at the end of mine life (June 2032), Figures A-23 to A-26 (Appendix A) display model predicted groundwater head contours for the Transported (Layer 3), Saprolite (Layer 5), Saprock unit (Layer 6) and Primary Rock (Layer 11) units respectively. The same modelling results for the inundated lake scenario are shown in Figures A-27 to A-30 (Appendix A).

Figures A-31 to A-38 (Appendix A) reveal that:

- the predicted groundwater drawdown under a dry lake scenario extends approximately 400 m further to the east relative to the inundated lake scenario, due to the absence of the lake;
- the predicted groundwater drawdown due to groundwater extraction from ML 1535 saline groundwater supply borefield is insignificant relative to the groundwater drawdown induced by the open pit;
- significant groundwater drawdown predicted by the model is generally limited to within ML 1535 (to the proposed mine closure) for both dry and inundated lake conditions; and
- when compared against groundwater heads observed prior to mine development (shown in Figures A-8 to A-15 of Appendix A), the influence of drawdown at the end of mine life is limited to within the confines of the modelled domain.

The modelled average monthly total dewatering rate (vertical dewatering bores plus groundwater seepage [i.e. not including rainfall]) to mine closure is shown in Figure 23 for both the dry and inundated lake scenarios. Because the modelling was conducted in numerous stages, modelling outputs have been interpreted considering the transitions in rates between each model stage.

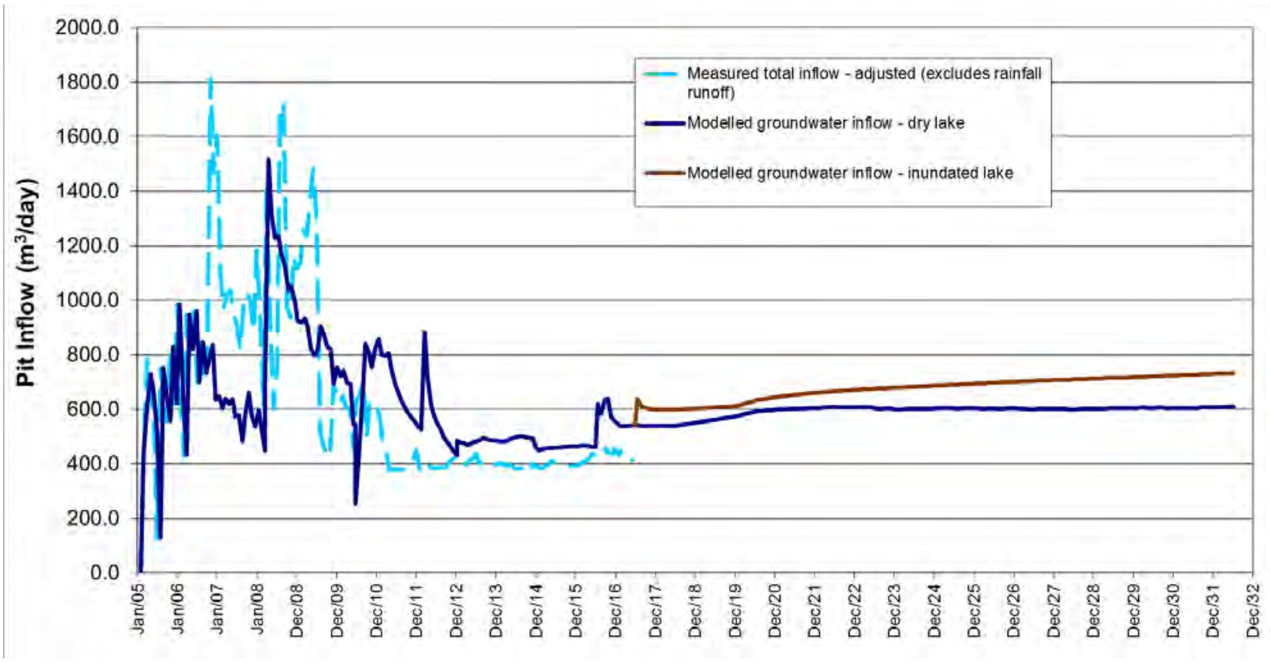


Figure 23 - Model Predicted Groundwater Inflow to Open Pit

Groundwater inflows to the open pit would range between approximately 540 m^3/day and 730 m^3/day between 2017 and mine closure. A difference of approximately 125 m^3/day is observed between dry and inundated lake scenarios at the end of the simulation period (in 2032). This difference results from the very low rates of seepage over the extensive lake area for the lake full scenario.

4.4.2.2 Post-Mine Closure

Post-mine closure, the open pit is expected to gradually fill with water (from groundwater seepage and rainfall), attaining a long-term equilibrium level that will depend on the competing effects of groundwater seepage and rainfall inflowing to the pit and evaporative losses.

Figures A-39 to A-42 (Appendix A) present the model-predicted groundwater drawdown (relative to pre-mining conditions) 20 years after mine closure (2052), for the Transported unit (Layer 3), Saprolite unit (Layer 5), Saprock unit (Layer 6) and Primary Rock unit (Layer 11) , respectively, for the dry lake scenario (groundwater drawdown is presented for the dry lake scenario because it is greater than for the inundated lake scenario).

These predictions represent a conservative estimate of groundwater drawdown, since the modelling assumes the open pit remains empty and modelled groundwater inflows to the pit are, therefore, higher than expected.

The predicted groundwater drawdown for all units at 20 years after mine closure (2052) is not significantly different from the drawdown at the end of mine life (2032).

Following mine closure, water levels within the mine pit will gradually rise, resulting in lower inflow rates until equilibrium is reached between evaporative losses and inflows to the pit from surface runoff and groundwater seepage. As water levels rise within the pit the rate of groundwater seepage will gradually reduce due to the gradual reducing in driving head.

4.4.2.3 Potential Impact on Lake Cowal

The presence of the open pit void is expected to induce additional vertical seepage from Lake Cowal (towards the void) over the long-term.

The model was used to predict the long-term (steady state, post-mine closure) vertical leakage from Lake Cowal considering the lake was inundated in the presence of the open pit void. The model-predicted vertical leakage over the lake area was 3.0×10^{-6} cubic metres per day per squared metre ($m^3/day/m^2$) (of the order of 0.1% of the losses apparent from the monitoring of water level decline in the lake after filling averaging between 3 and 4 mm/day). This equates to a seepage rate of some 4 litres per second over the entire lake and is relatively consistent with the findings of Coffey (1997). The leakage under these conditions is insignificant, particularly when compared to the total lake storage and evaporation losses under natural conditions. For all practical purposes the lake bed sediments (and the Lake Protection Bund) act as an impeding layer to vertical leakage from the lake.

The impact of the open pit, pit dewatering and groundwater extraction from the ML 1535 saline groundwater supply borefield on the waters of Lake Cowal is therefore considered negligible.

4.4.2.4 Model Sensitivity

Coffey expect the sensitivity of the model to be in line with the observed sensitivity of previous groundwater models simulating ML 1535. During the sensitivity analyses conducted on both horizontal and vertical hydraulic conductivity by increasing them by a factor of two, it was observed that the extent of groundwater drawdown in the hydrogeological units increases with increased hydraulic conductivity, and drawdown associated with ML 1535 saline groundwater supply borefield increases. However, significant drawdown (>2 m) remains within ML 1535.

4.5 Groundwater Quality Related to Open Pit Dewatering

The quality of groundwater collected by the dewatering system (including groundwater both pumped from vertical dewatering bores and seeping into the open pit) is expected to be similar to existing groundwater quality and would be used as a water supply for the processing plant. The expected concentration/value range for a number of analytes is provided in Table 17. Pit dewatering will only have a small and localised (i.e. within ML 1535) impact on groundwater quality.

Table 17. Expected Dewatering Groundwater Quality

Analyte	Concentration (mg/L) or Value
pH	5.8 to 7.1
Dissolved sodium	8,000 to 13,000
Sulphate	2,500 to 7,000
Alkalinity (bicarbonate)	80 to 500

5 CONTAMINANT MIGRATION

This section discusses the potential impact to water quality in the vicinity of the TSFs through seepage of stored water.

5.1 Seepage from Tailings Storage Facilities

In 2012 the mean vertical leakage from the northern and southern TSFs, respectively, is estimated using the model to be 180 m^3/day and 220 m^3/day.

The mean vertical leakage from the northern and southern TSFs, respectively, predicted by the model is approximately 250 m^3/day and 280 m^3/day over the future mine life (2017 to 2032). This is equivalent to approximately 0.21 cubic metres per day per metre (m^3/day/m) and 0.23 m^3/day/m for the northern and southern TSFs, respectively, which is consistent with the values of 0.12 m^3/day/m and 0.45 m^3/day/m reported in the EIS at two different sections across the northern and southern TSFs (North Limited, 1998).

5.2 Potential Impact on Groundwater Quality

Assessment of potential impacts to groundwater quality due to seepage from the TSFs and IWL was undertaken using an analytical particle tracking approach. The assessment did not include geochemical processes such as sorption, chemical oxidation and degradation reactions that may hinder contaminant migration. This approach provides a conservative estimate of the likely contaminant travel times through the subsurface because processes of sorption, chemical oxidation and degradation delay or otherwise reduce the mobility of groundwater chemical changes.

Groundwater flow conditions at mine closure for the inundated lake case were considered. Such conditions lead to a conservative assessment, since water levels in Lake Cowal are high under this scenario and, therefore, potentially induce greater flows than when Lake Cowal is dry.

Groundwater seepage velocities within the most permeable unit (Saprolite) in the vicinity of the TSFs were calculated based on long-term model-predicted groundwater heads, assuming a (conservative) Saprolite effective porosity of 1%.

Figure A-43 (Appendix A) displays the possible extent of groundwater quality changes after 50 and 100 years, assuming groundwater begins moving from immediately outside the TSFs' walls. After 100 years, the potential for groundwater quality changes due to seepage from the TSFs stored water extends a distance of approximately 2 km from the IWL wall in all directions.

Cyanide is used in the gold extraction process, and is present in tailings released to the TSFs. The groundwater monitoring results suggest that, as of June 2017, there is no consistent trend to suggest that significant concentrations of cyanide have leached from the TSFs into the surrounding groundwater. Cyanide is, therefore, considered unlikely to be present within groundwater over the site (outside the TSFs).

Current work indicates that cyanide would not reach beyond 2 km from the TSFs wall before 100 years. This assessment represents a conservative case, since cyanide associated with potential seepage from the TSFs degrades due to hydrolysis, volatilisation (to HCN gas), oxidation and biological activity. For this reason, and the fact that the assessment ignores the hindrance to solute migration imposed by the TSFs liner, the likely groundwater transport of cyanide from the TSFs is expected to be much more limited.

Schmidt *et al* (1981) measured an (equivalent) cyanide half life of 3.6 to 30 days in tailings liquors. Burden and Kidd (1987) found half-life constants ranging from 36 to 300 days in laboratory-tested tailings mass. The EIS adopted a cyanide decay half-life of 300 days (North Limited, 1998). Thus, cyanide concentrations at the extent of the 100 year potential groundwater quality change contour shown in Figure A-43 (Appendix A) are likely to be negligible (below current detection concentrations).

The transport of cyanide through groundwater is further retarded due to sorption processes. The EIS adopted a (conservative) cyanide retardation factor of four (North Limited, 1998). Data collected by Allison and Allison (2005) suggest cyanide partition coefficients for soil-soil water range from approximately 4×10^{-3} litres per kilogram (L/kg) to 20 L/kg (mean 5 L/kg). Assuming clay-like (Transported or Saprolite unit) material with bulk density of up to 1.3 t/m^3 and effective porosity ranging from 1% to 30%, retardation factors may range from 1 to well above 2,000, with a mean value of around 600. These retardation factors indicate transport of cyanide would be significantly impeded over the site.

The EIS reported a potential migration of cyanide (at 0.1% of tailings source concentration) to 200 m eastwards from the TSFs after eight years, for high permeability aquifer materials and a cyanide retardation factor of four and decay half life of 300 days (North Limited, 1998). In the long-term, cyanide would degrade in the tailings storage and surface of the underlying aquitard and would be effectively removed from the subsurface. This assessment is less conservative than the above assessment (which does not explicitly consider retardation or decay).

In addition to cyanide, other contaminants such as arsenic, zinc and other heavy metals have the potential to be released from the TSFs. Based on the analytical migration assessment, such contaminants would similarly not reach beyond 2 km from the TSFs wall before 100 years. Again, to provide a conservative assessment of contaminant migration, biological processes and sorption of contaminants to the soil/rock matrix are not considered as these processes would further retard contaminant migration.

Figure A-44 (Appendix A) shows long-term groundwater head contours and groundwater flow direction for the dry lake scenario. The flow directions for the inundated lake scenario are consistent with those for the dry lake scenario. Contaminants associated with potential seepage from the IWL would flow in the direction of the final pit void and ultimately terminate in that void. The final pit void therefore becomes a long-term sink for all groundwater within ML 1535. As a result, analytes are expected to concentrate within the pit voids over hundreds of years (e.g. water salinity in the pit will rise). Analytes associated with potential seepage from the IWL are expected to remain within groundwaters between the IWL and the final void over the long-term.

6 GROUNDWATER LICENSING AND AQUIFER INTERFERENCE POLICY CONSIDERATIONS

6.1 Licensing

The NSW *Water Act 1912* governs water licensing, and the trading and allocation of licences, for both groundwater and surface water resources in NSW where a water sharing plan has not been implemented. The *Water Act 1912* applies to extraction of groundwater, extraction of water from a river, aquifer interference and capture of surface runoff to dams. The *Water Act 1912* is in the process of being progressively phased out and replaced by the NSW *Water Management Act 2000* (WMA). Water licensing and the Aquifer Interference Policy Considerations are also discussed in Attachment 4 of the EA.

Water Sharing Plans are statutory plans for specific water resource areas under the WMA that provide the rules for sharing and managing water resources in NSW. The *Water Act 1912* is repealed for a water resource area once a Water Sharing Plan has commenced for that area, and existing licences are converted to new consents under the WMA.

- The Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources, 2012 commenced on 14 September 2012 and provides the framework for managing groundwater in the Lachlan aquifer until July 2023. The Bland Creek Palaeochannel Borefield and Eastern Saline Borefield operated by CGO draw groundwater from the Lachlan Formation for mine use. These borefields lie within the Upper Lachlan Alluvial Zone 7 Management Zone. ML 1535 lies within the Upper Lachlan Alluvial Zone 7 Management Zone.
- The Water Sharing Plan for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources, 2011 commenced on 16 January 2012 and provides the framework for managing groundwater in the fractured rock aquifers until July 2022. ML 1535 lies within the Lachlan Fold Belt groundwater source of the Murray-Darling Basin, and groundwater dewatering of, and seepage to, the open pit result in extraction of groundwater from the Lachlan Fold Belt (alluvial areas are excluded in this source area). Table 18 lists the statistics for the Murray-Darling Basin groundwater source as provided in the Water Sharing Plan.

Groundwater removal from the fractured rock at the CGO is managed under a Water Sharing Plan: i.e. the *Water Sharing Plan for the Murray-Darling Basin Fractured Rock Groundwater Sources,* which commenced on 16 January 2012. The current version is dated 5 July 2013 with the following amendments (1 July 2016) relevant to the CGO:

- Vary the amount of recharge reserved as planned environmental water as a result of recharge studies undertaken or assessed as adequate by the Minister.
- Modify the long-term average annual extraction limits as a result of recharge studies undertaken or assessed as adequate by the Minister.
- Establish available water determination rules and individual access licence account management rules for major utility access licenses.
- Restrictions on the granting and amendment of water supply works to protect water-dependent Aboriginal cultural assets.
- Allow for the granting of aquifer interference approvals and the management of aquifer interference activities.

These changes to the Water Sharing Plan do not affect the pre-existing licensing arrangements at the CGO.

Table 18. Requirements for Water Sharing (Murray-Darling Basin Fractured Rock – Lachlan Fold Belt Groundwater Source)

Use	Share Component (ML/year)
Stock and domestic	74,311
Town water supply	5,101
Long-term average annual rainfall recharge	224,627 (high environmental value areas) 3,502,609 (non-high environmental value areas)
Environmental water	224,627 (high environmental value areas) 2,626,957 (non-high environmental value areas)
Long-term annual average extraction limit	875,652

ML/year = megalitres per year.

6.1.1 Mine Site Groundwater Extraction

The numerical modelling predicts monthly dewatering rates (due to open pit dewatering and seepage) as shown in Figure 23. The equivalent average annual groundwater take modelled from 2017 to the end of mine life is approximately 235 ML/year (average between lake full and lake empty conditions). Peak dewatering flows (groundwater take) may exceed that value (by up to 40 ML/year) during major campaigns of horizontal drain (bore) installation in the open pit or vertical dewatering bore commissioning.

Peak predicted flow in 2032 is 268 ML/year for the lake full case and 222 ML/year for the lake empty case.

The groundwater taken is predominantly sourced from the rock hydrogeological units. It is assessed that 90% of groundwater inflow originates from the fracture rock aquifer with the remaining 10% from the overlying sediments.

Existing mine groundwater inflows are assessed as 159 ML/year (interpretation of 2017 records).

As per the letter from DPI Water to CGO (then owners Barrick) titled “Cowal Gold Mine – Request for reallocation of water access licence under the water management act 2000” and dated 7 January 2014, the CGO holds licences to access 366 units share components in Lachlan Unregulated and Alluvial water sources and Upper Lachlan Alluvial Zone 7 Management Zone and another 3,294 unit share components in the NSW Murray-Darling Basin Fractured Rock Groundwater Sources.

These include allowance for pumping of 0.7 ML/d (256 ML/year) from the saline borefield (Upper Lachlan Alluvial Zone 7) and allowing 10% (24 ML/year) of the pit groundwater inflow rate from the Upper Lachlan Alluvial Zone 7 deposits with the remaining 90% (216 ML/year) from the fractured rock aquifer.

The saline borefield is submerged and inaccessible when Lake Cowal contains water. Consequently, it is only in use during periods when the lake is empty.

The predicted annual groundwater volumes required to be licensed within each Water Sharing Plan for the Modification are summarised in Table 19.

Table 19. Groundwater Licensing Requirement Summary

Water Sharing Plan	Management Zone/ Groundwater Source	Predicted Groundwater Inflow/Extraction Volume requiring Licensing (ML/year)		Currently Licensed Unit Shares (February 2018)
		Existing	During Modification	
Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources	Upper Lachlan Alluvial Zone 7 Management Zone	Maximum 276[a]	Maximum 282[b]	366
NSW Murray-Darling Basin Fractured Rock Groundwater Sources	Lachlan Fold Belt Groundwater Source	Maximum 179[c]	Average 212[d] Maximum 277[d]	3294

[a] Includes 256 ML/year extraction associated with the saline supply bores within ML 1535 based on peak usage of 0.7 ML/d, plus 10% of assessed existing inflow (159 ML/year), plus 10% of 40 ML/year allowance for additional dewatering flows associated with pit expansion stages or introduction of horizontal drains.

[b] Includes 256 ML/year extraction associated with the saline supply bores within ML 1535 based on peak usage of 0.7 ML/d, plus 10% of assessed maximum modelled inflow (222 ML/year), plus 10% of 40 ML/year allowance for additional dewatering flows associated with pit expansion stages or introduction of horizontal drains. The pit empty case is relevant as the saline water supply bores are not accessible when the lake is full.

[c] Includes 90% of assessed existing inflow (159 ML/year), plus 90% of 40 ML/year allowance for additional dewatering flows associated with pit expansion stages or introduction of horizontal drains.

[d] Average value is 90% of average modelled inflow from 2017 to 2032 (235 ML/year). Maximum value is 90% of the peak modelled lake full inflow of 268 ML/year, plus 90% of an allowance of 40 ML/year for additional dewatering flows associated with pit expansion stages or introduction of horizontal drains.

Post mining groundwater inflows will gradually reduce as water levels rise within the mine void over time. The long-term inflow rate is assessed to be similar to that assessed in an earlier study (Coffey 2016) at 44 ML/year from the fractured rock groundwater source.

6.2 Aquifer Interference Policy Requirements

6.2.1 Mine Site

NOW's *Aquifer Interference Policy* (2012) provides a framework for assessing the impacts of aquifer interference activities on water resources.

Aquifer Interference Policy (NOW, 2012) is relevant to CGO as it applies to mining activities such as open cut voids and the disposal of water taken from aquifers.

Groundwater quality within ML 1535 has EC generally in the range of 30,000 microsiemens per centimetre (µS/cm) to 55,000 µS/cm for the Transported, Saprolite and Saprock units. Data are not available for the Primary Rock, but the EC in the Primary Rock is expected to be similar (or higher due to the presence of salts in the rock). This equates to a total dissolved solids concentration of between 19,200 mg/L and 35,200 mg/L. The groundwater source at CGO is, therefore, defined by the *Aquifer Interference Policy* (NOW, 2012) as a:

… less productive groundwater source …

The minimal impact considerations specified in the *Aquifer Interference Policy* (NOW, 2012) for a less productive groundwater source include:

(i) No more than a specified cumulative variation in the water table within 40 m from a high priority groundwater dependent ecosystem or a high priority culturally significant site.

(ii) No more than a specified limit in the water table decline at any water supply work.

(iii) No more than a specified cumulative pressure head decline at any supply work.

(iv) Any change in groundwater quality that lowers the beneficial use category of the groundwater source beyond 40 m from the activity.

(v) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point of activity.

(vi) No mining activity below the natural ground surface within 200 m laterally from the top of the high bank and 100 m vertically beneath of a highly connected surface water source that is defined as a "reliable water supply".

The model-predicted groundwater drawdown up to 20 years post-mine closure remains largely within ML 1535. As there are no GDEs, priority culturally significant sites or supply works within ML 1535 (or within 40 m of the boundary of ML 1535), minimal impact considerations (i) to (iii) have been met.

Schedule 4 of the Upper Lachlan Alluvial Groundwater Source Water Sharing Plans nominates two high priority GDEs (Bogolong Springs and Old Man Springs). These GDEs are located more than 60 km to the east of the CGO, on the other side of the Bland Creek Palaeochannel. These GDEs are distant from the CGO and would not be affected by mining operations.

Schedule 3 of the NSW Murray-Darling Basin Fractured Rock Groundwater Sources Water Sharing Plan indicated that the closest high priority GDE to the CGO site is Cartwrights Spring, located more than 5 km east-south-east of the site. Coffey do not expect this GDE will be affected by the CGO.

A check was carried out on 29 November 2017 on the BoM's Atlas of Groundwater Dependent Ecosystems. The key findings are as follows:

- High potential aquatic GDE at Lake Cowal immediately east of the CGO, (as shown on Figure 24). This will not be affected as groundwater modelling and observations to date indicate that seepage from Lake Cowal arising from mining operations during periods of inundation is negligible.
- High potential terrestrial GDE approximately 4.5 km north of the CGO comprising Grey Box-White Cypress-pine woodland (as shown on Figure 25). From review of Figure 25, Coffey considers that this vegetation is unlikely to be groundwater dependant, based on knowledge of local groundwater conditions. This area is unlikely to be affected by the mining operation.
- Moderate potential terrestrial GDE surrounding the CGO comprises wetland sedgeland, Mixed Box Eucalypt woodland, and River Red Gum within or at the fringe of Lake Cowal during periods of inundation and is also subject to periods where lake waters are absent between flood events (as shown on Figure 25). The movement water in the lake shore will not be affected by mining operations as the seepage from the lake to the open pit is assessed as being negligible. Further, these communities are considered more likely to be influenced by soil moisture increases during lake full conditions than by the regional or local groundwater resource. As a result, they are considered unlikely to be affected by the mining operations.
- Low potential terrestrial GDE surrounding the CGO comprising Tussock grasslands (as shown on Figure 25). These areas may be affected by changes in soil moisture depending on the root depths. However, the CGO's impacts on the underlying hard rock aquifers are considered to be unlikely to affect any Tussock grasslands.

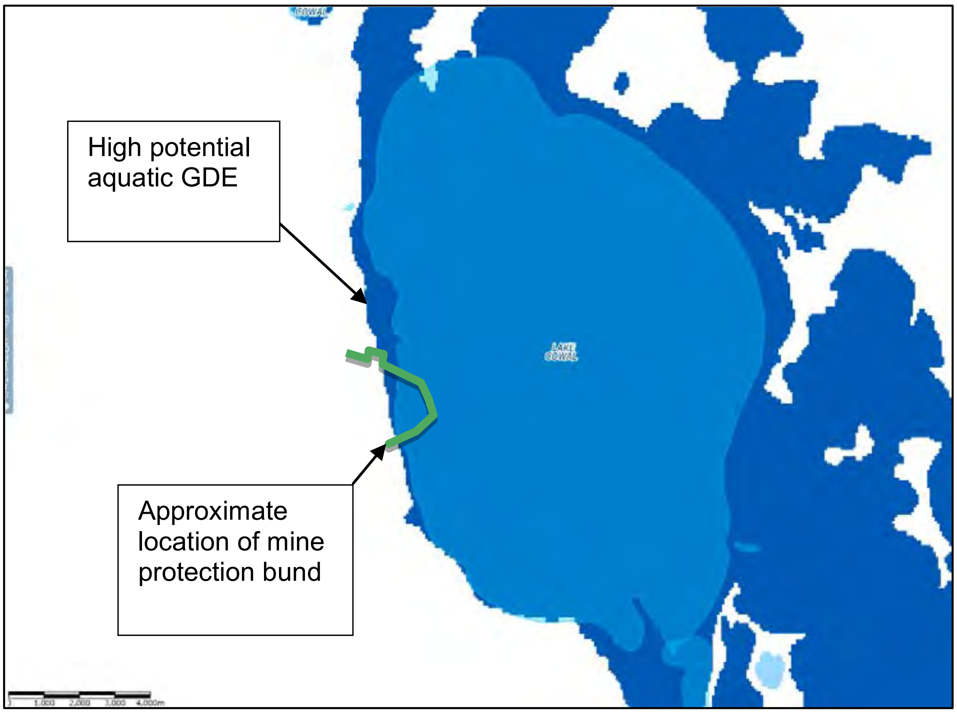


Figure 24 - BoM's Atlas of Groundwater Dependent Ecosystems (Aquatic)

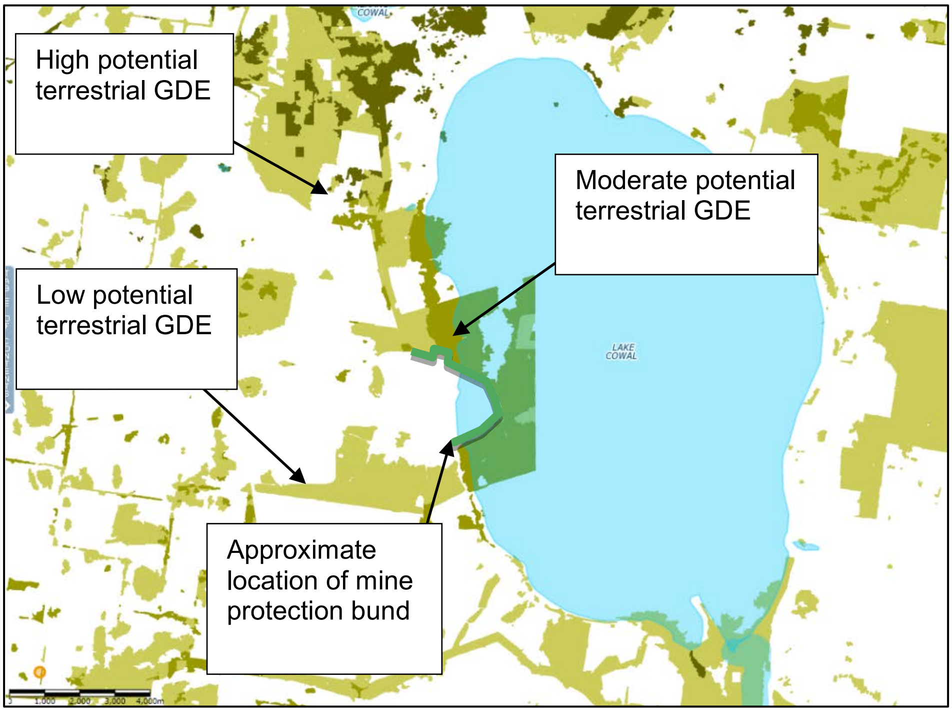


Figure 25 - BoM's Atlas of Groundwater Dependent Ecosystems (Terrestrial)

During the life of the CGO, pit dewatering will only have a small and localised (i.e within ML 1535) impact on groundwater quality. Over the longer term, groundwater will flow towards the open pit void, ultimately terminating there. The groundwater quality in the region surrounding the open pit void is not expected to change significantly due to this process, though the quality of the water within the open pit is expected to change (e.g. salinity will increase). The beneficial use of groundwater is not expected to change due to dewatering or the presence of the open pit void. Thus, minimal impact consideration (iv) is met.

Assuming that the equilibrium surface water level in the final pit void is not as high as ground surface, water from the pit void is not expected to be released (or used). Thus, it is not classified as a highly connected surface water source, meeting minimal impact consideration (v).

Coffey is not aware of any “reliable water supplies” within 200 m laterally from the top of the high bank. Lake Cowal is an ephemeral lake; therefore it is not considered by Coffey to be a “reliable water supply”. Thus, minimal impact consideration (vi) is met.

7 MANAGEMENT AND MITIGATION MEASURES

7.1 Groundwater Levels around the Tailings Storage Facilities

Groundwater levels in piezometers in the vicinity of the TSFs have shown increases in levels in recent years. Of these, the largest rises were recorded at MON02A and MON02B (screened in the Saprock and Saprolite units, respectively) which have displayed a gradual rise since late 2006. Groundwater level variation around the TSFs was investigated by Coffey (2009a) and further investigations were carried out in 2016 by Northern Resource Consultants, where the rises were assessed to be related to the percolation and the movement of seepage from the TSFs.

Ground surface elevation at the MON02 piezometer nest is at about 222 mAHD. In late 2015 groundwater level was approximately 11 m below the ground surface (Northern Resource Consultants, 2016). The screen midpoints are at about 66 m and 27 m below ground at MON02A and MON02B respectively. The equality of water levels at these piezometers suggest minimal vertical hydraulic head gradients, with the potential for shallow hydraulic heads to be the same as deeper in the profile, at that location.

If the current trends were extrapolated linearly the water level at MON02A/ MON02B would reach the ground surface at 222.4 mAHD at the end of 2026. This provides sufficient time to develop and design mitigation measures should they prove necessary. Following mine closure the elevated groundwater levels are expected to dissipate over time as the water levels within the TSFs gradually reduce.

As the water level rises at MONO2A and MONO2B are interpreted to be associated with seepage from the TSFs Coffey recommends:

- continuation of monitoring of piezometers in the vicinity of the TSFs;
- installation of new monitoring piezometers to replace those which will be destroyed (including (MONO2A and MONO2B) by the construction of the IWL, allowing at least six months of overlap so that correlations between the new monitoring piezometers and the ones they will replace can be developed;
- review of groundwater levels on an annual basis; and
- should existing trends continue, develop a groundwater control plan and design control measures to address water level rise which could include:
  - augmentation of the existing monitoring network;
  - pumping groundwater from bores introduced in the vicinity of MON02 back to the TSFs; and/or
  - installation of trench drains and sumps to collect groundwater and suppress further rise in groundwater levels.

Monitoring bores in the vicinity of the existing TSFs would be displaced by the development of the IWL. Figure 11 shows the locations of additional monitoring bores planned by Evolution, to allow monitoring of groundwater levels and chemistry, following establishment of the IWL. Coffey consider the planned monitoring locations to be appropriate and recommend the new monitoring facilities are put in place at least six months in advance of IWL construction, to provide a period of overlap where results from the existing monitoring network are available together with the results from the new monitoring bores.

8 LIMITATIONS

8.1 Numerical Simulation

The results reported are specific to the modelled conditions. In the absence of data, the models adopt conditions and parameter values assumed relevant. Should conditions differ from those adopted in the assessments made, results may vary significantly.

The results reported are subject to the uncertainty inherent in numerical modelling. The numerical models are necessarily simplifications of the real system, and rely on calibration to data of unknown precision to produce predictive results. The results are estimates only and may differ from future observations.

9 CONCLUSIONS

9.1 Groundwater Impacts due to Open Pit Mining

The Mine Site Model predicted groundwater drawdown due to open pit mining and dewatering to generally remain within ML 1535 during the mine life. Groundwater inflows to the open pit range between approximately 540 m^3/day and 730 m^3/day between 2017 and mine closure. Peak dewatering flows (groundwater take) may exceed that value (by up to 40 ML/year) during major campaigns of horizontal drain (bore) installation in the open pit or vertical dewatering bore commissioning. This would result in maximum groundwater inflows of 277 ML/year within the fractured rock groundwater system and 26 ML/year within the alluvial groundwater system. There is a minor difference between the dry and inundated lake scenarios resulting from very low rates of seepage over the extensive lake area for the lake full scenario.

Pit dewatering water quality is expected to be similar to historical conditions. Groundwater quality within ML 1535 is expected to be similar to historical conditions.

9.2 Impacts on Lake Cowal due to Open Pit Mining

Modelling results suggest negligible impact on Lake Cowal and the associated groundwater system due to the open pit, pit dewatering and groundwater extraction from ML 1535 saline groundwater supply borefield.

9.3 Groundwater Quality Impacts due to Potential Seepage from the Tailings Storage Facilities

The mean vertical leakage from the IWL is predicted to be approximately 400 m^3/day during the mine life. Conservative assessment of potential impacts to groundwater quality due to seepage from the IWL suggest that after 100 years the potential for groundwater quality changes due to seepage from the IWL stored water will extend a distance of up to approximately 2 km from the IWL walls. However, the movement of some solutes (such as cyanide) will be impeded by sorption and geochemical processes, and their extent of transport within groundwater is likely to be significantly less.

Long-term (post-mine closure) groundwater conditions indicate that solutes associated with potential seepage from the IWL would flow towards, and ultimately terminate within the final pit void. As a result, analytes associated with potential seepage from the IWL is expected to remain within groundwaters between the IWL and the final void over the long-term.

10 RECOMMENDATIONS

10.1 Data and Monitoring

Coffey recommends:

- continued groundwater monitoring to validate the predictive modelling, particularly in the vicinity of the open pit, TSFs and ML 1535 saline groundwater supply borefield (when in use);
- a final pit void water balance post-mine closure be conducted to assess long-term water levels in the pit void and the potential impact on groundwater quality in the immediate vicinity of the pit void; and
- establishment of new monitoring bores to replace those that would be displaced by the IWL (Figure 11) including MON01A, MON01B, MON02A, MON02B, P414A, P412A, P412A-R, P414B, TSFNA, TSFNB and TSFNC.

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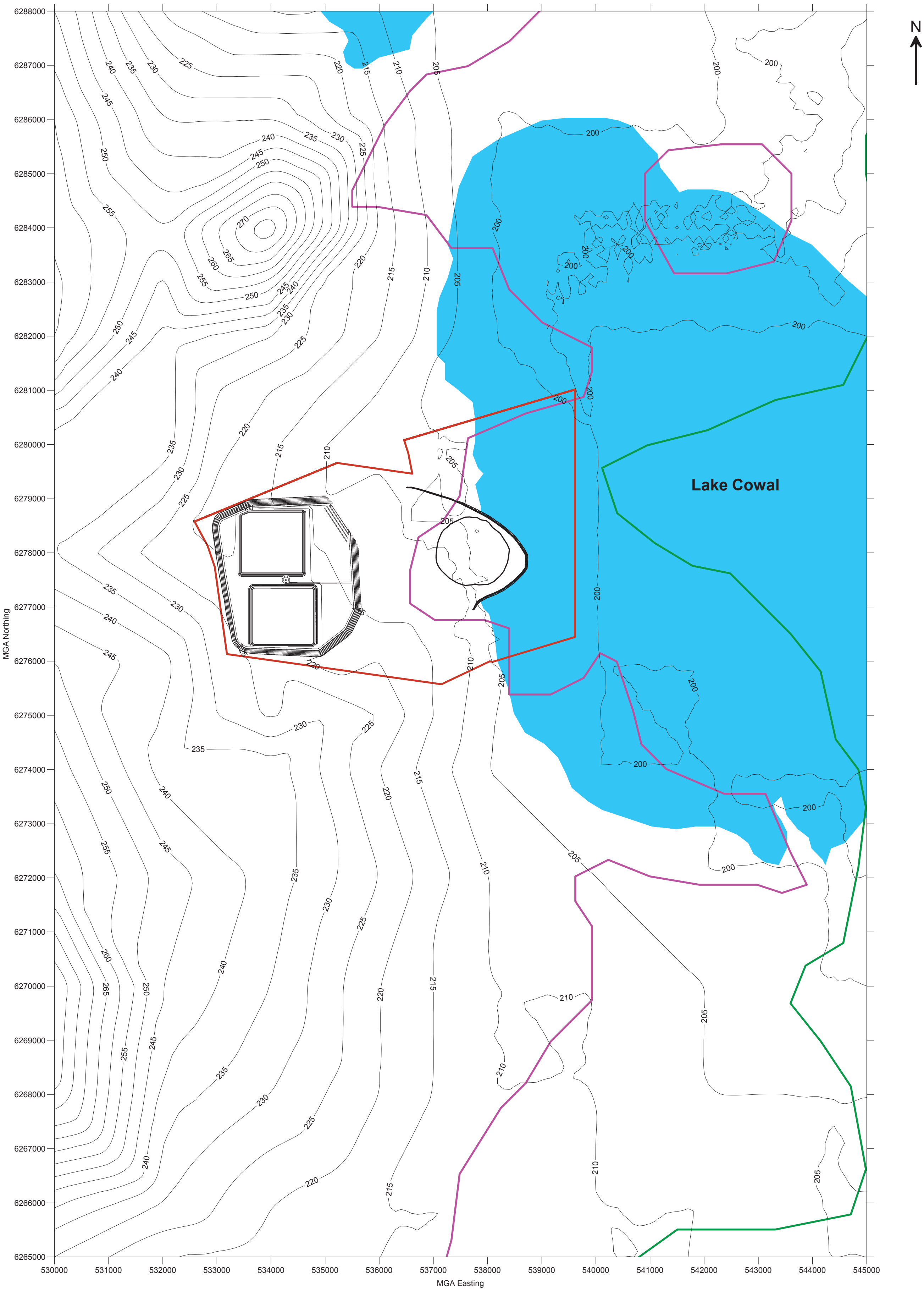
Appendix A - Figures



KEY

Contour of Ground Surface (mAHD)

Interpreted extent of Lachlan Formation

Interpreted extent of Cowra Formation

Mine Lease Boundary

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date	28 NOV 2017	title:	**SURFACE CONTOURS FOR MODEL-ADOPTED GROUND LEVEL**
scale	1:70,000		
original size	A3	project no:	754-SYDGE206418
		figure no:	**FIGURE A-1**

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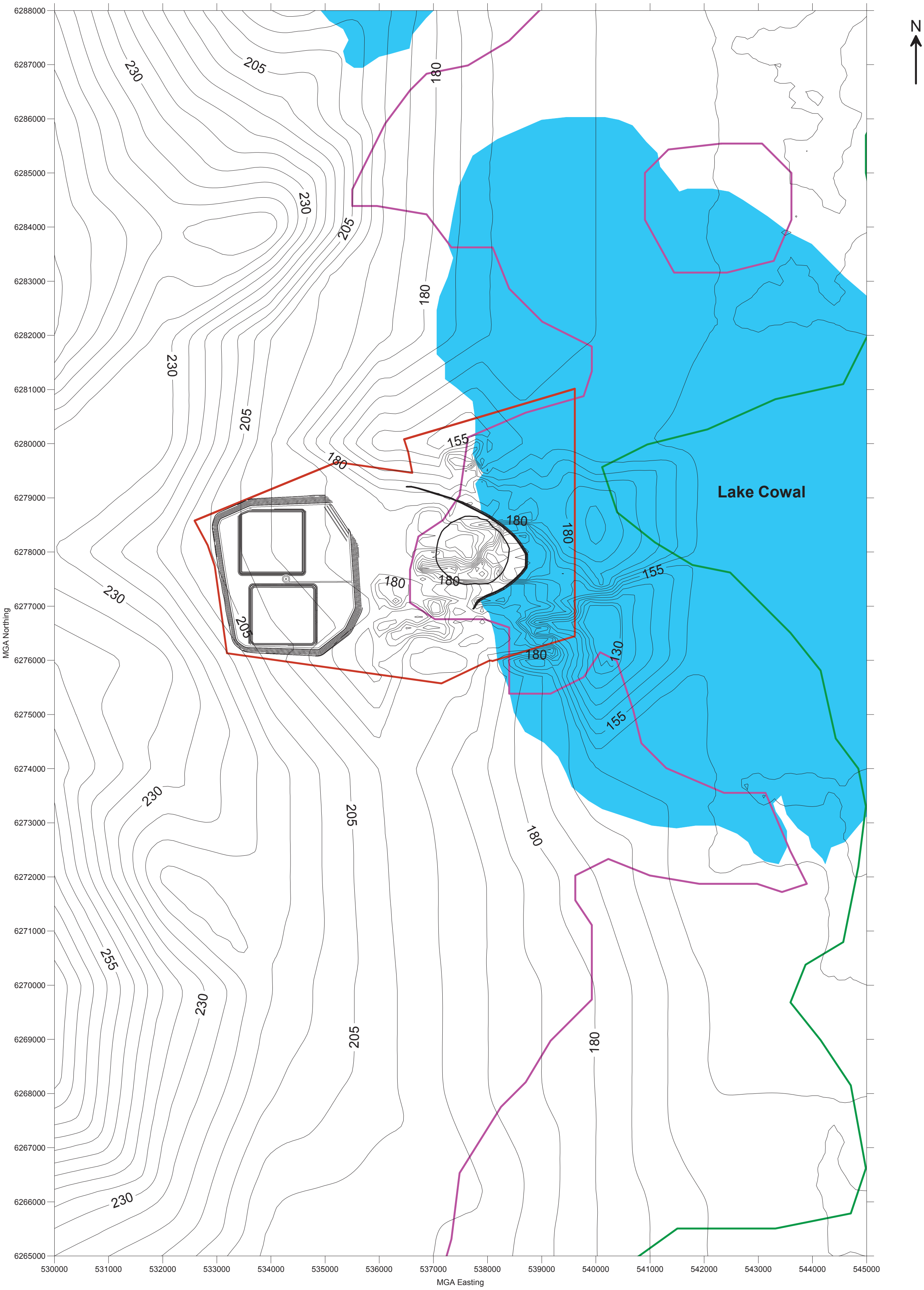
A TETRA TECH COMPANY



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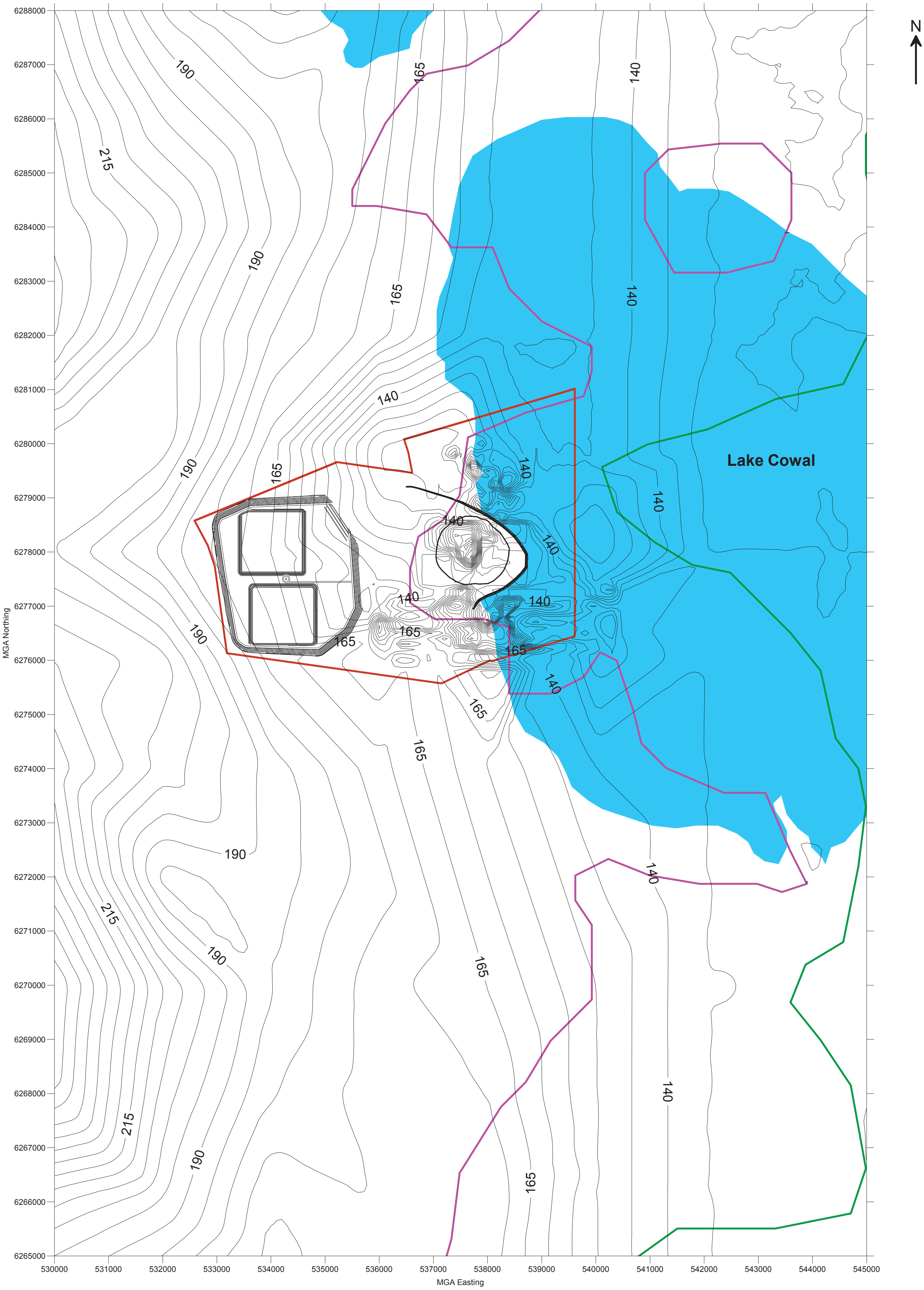

KEY

- Contour of Ground Surface (mAHD)
- Interpreted extent of Lachlan Formation
- Interpreted extent of Cowra Formation
- Mine Lease Boundary

drawn	SE
approved	RJB
date	28 NOV 2017
scale	1:70,000
original size	A3

coffey
A TETRA TECH COMPANY

client:	EVOLUTION MINING (COWAL) PTY LTD
project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
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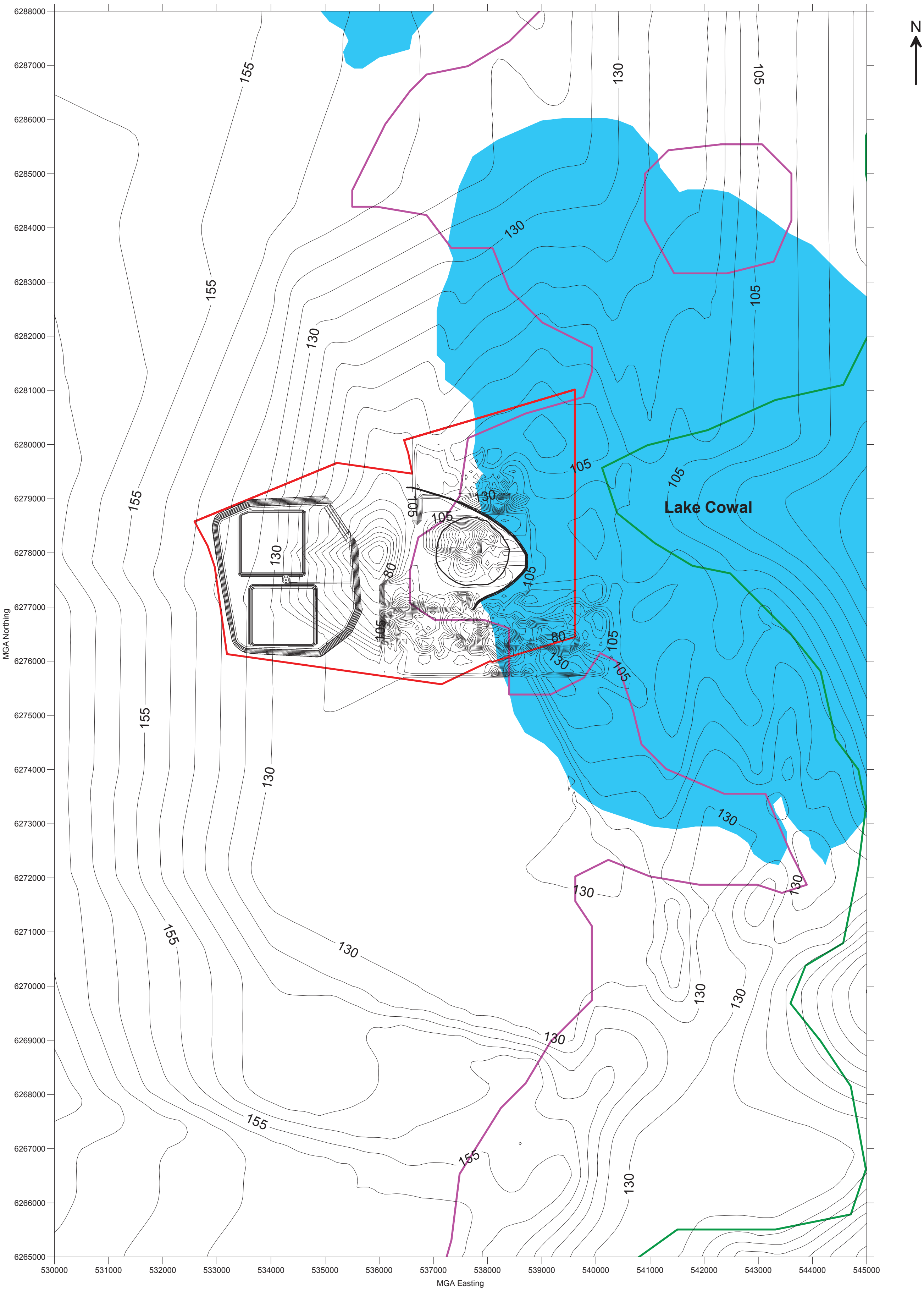

KEY

- Contour of Ground Surface (mAHD)
- Interpreted extent of Lachlan Formation
- Interpreted extent of Cowra Formation
- Mine Lease Boundary

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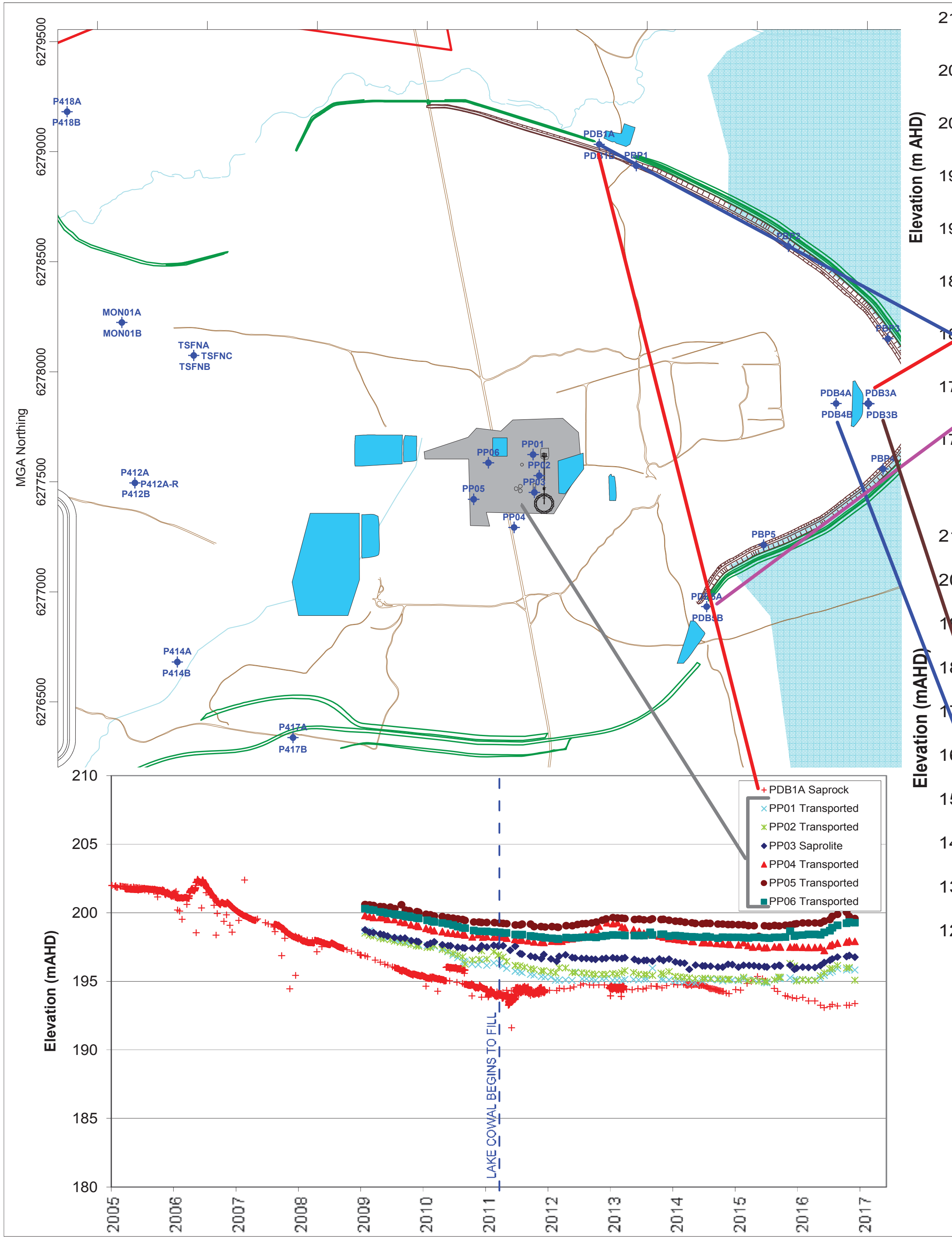
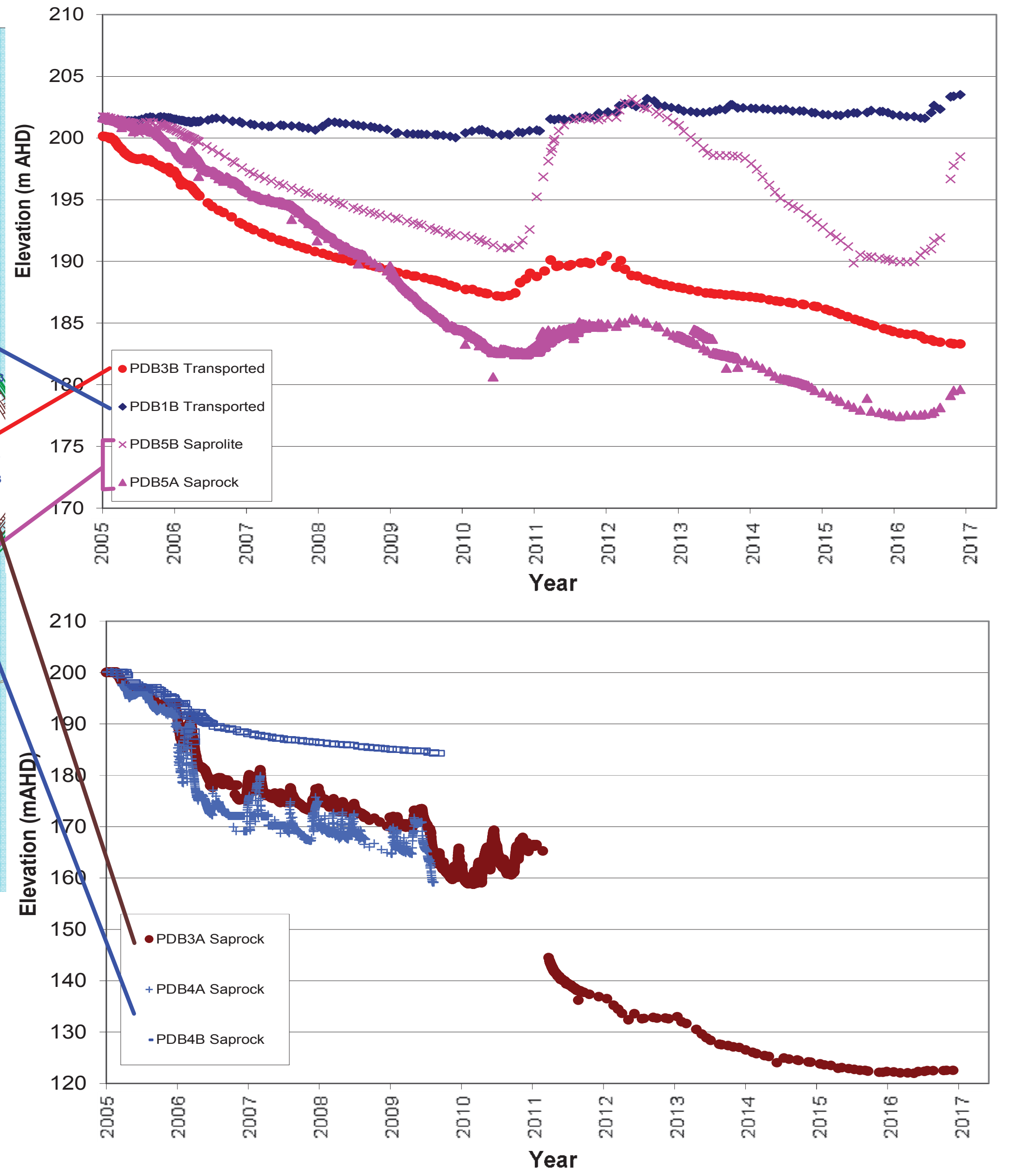
coffey
A TETRA TECH COMPANY





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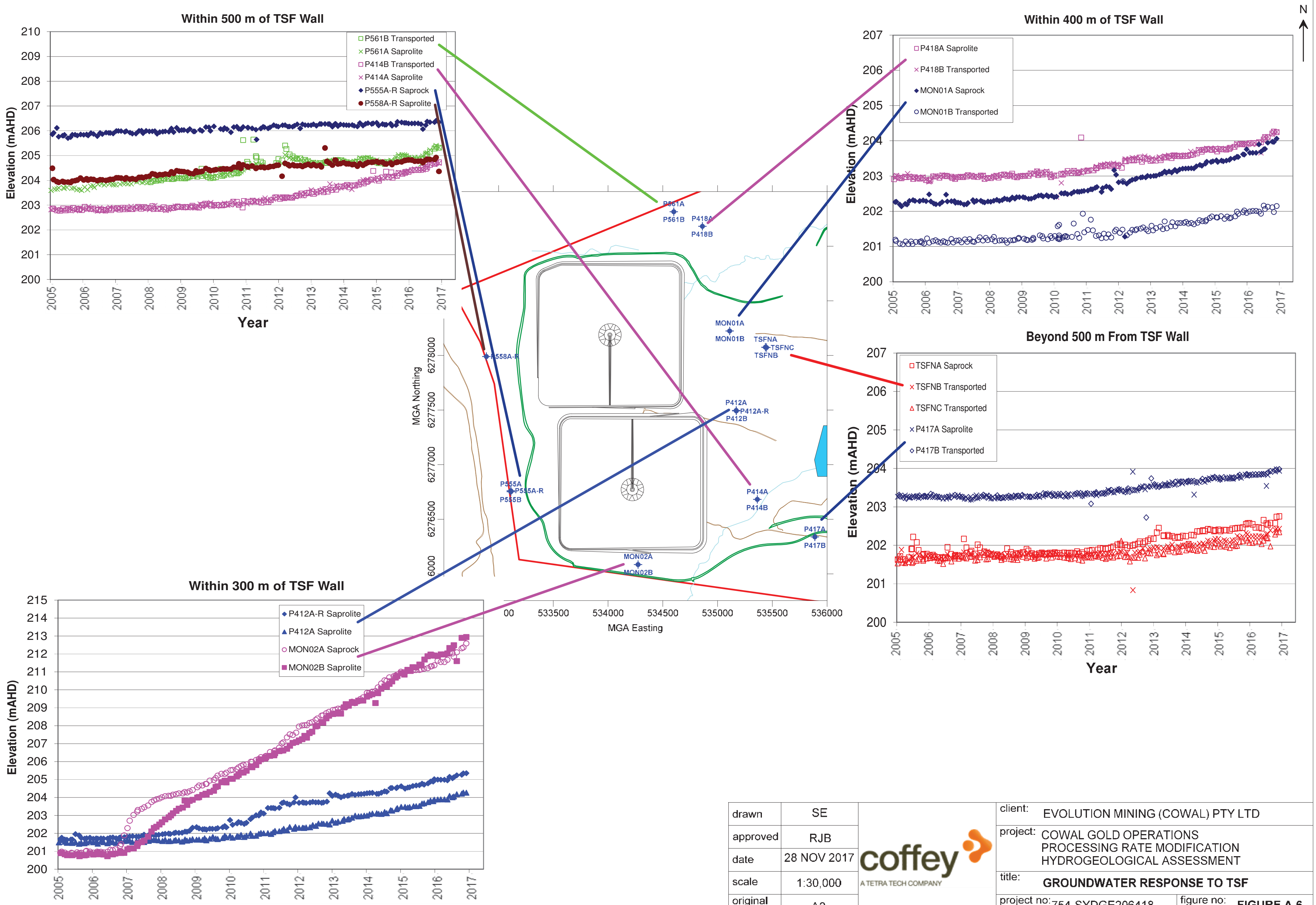

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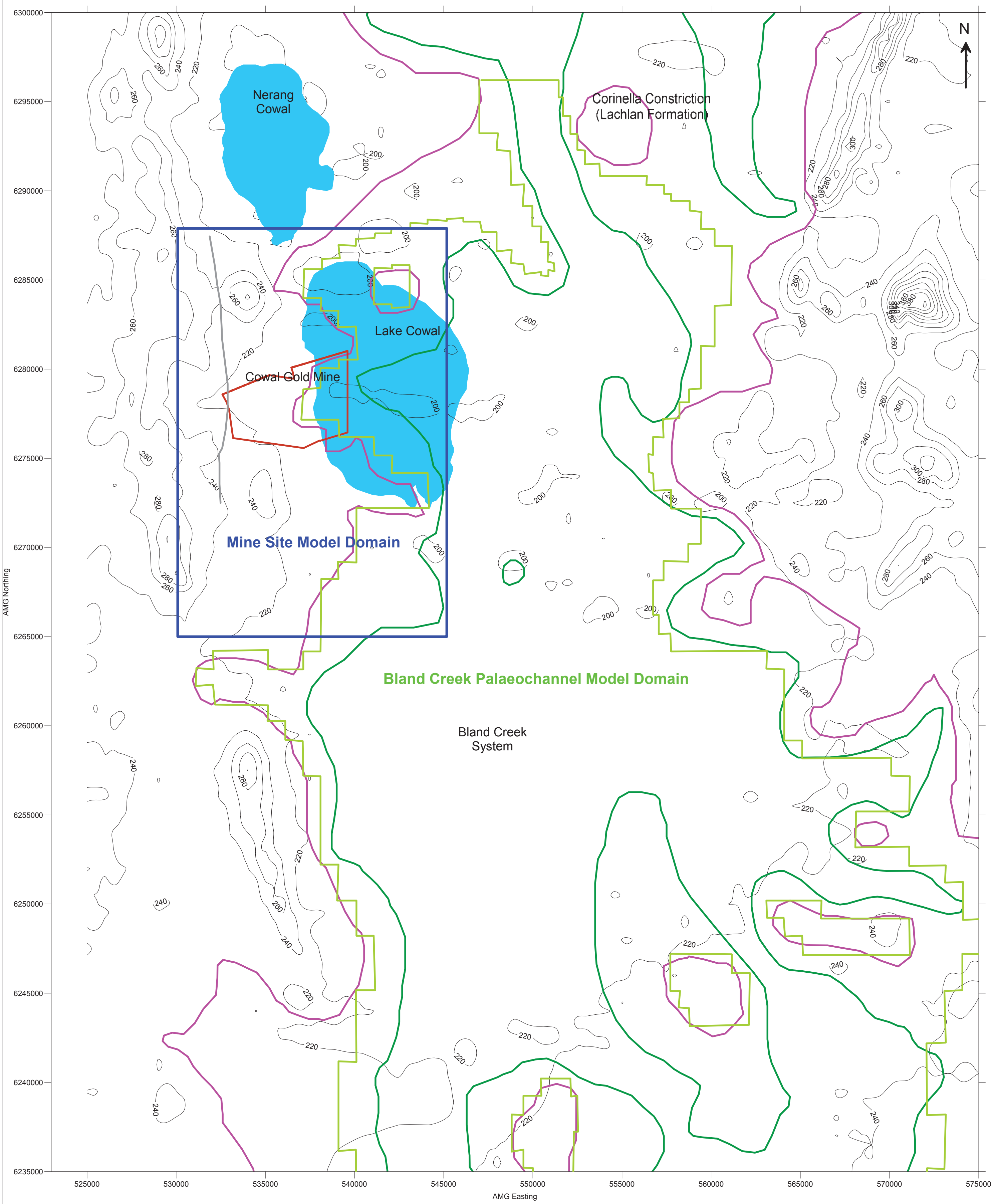

KEY

- Interpreted extent of Lachlan Formation
- Interpreted extent of Cowra Formation
- Gilmore Suture (not to full extent)
- Topographical Contour (mAHD)
- Mine Lease Boundary

drawn	SE	coffey A TETRA TECH COMPANY	client:	EVOLUTION MINING (COWAL) PTY LTD
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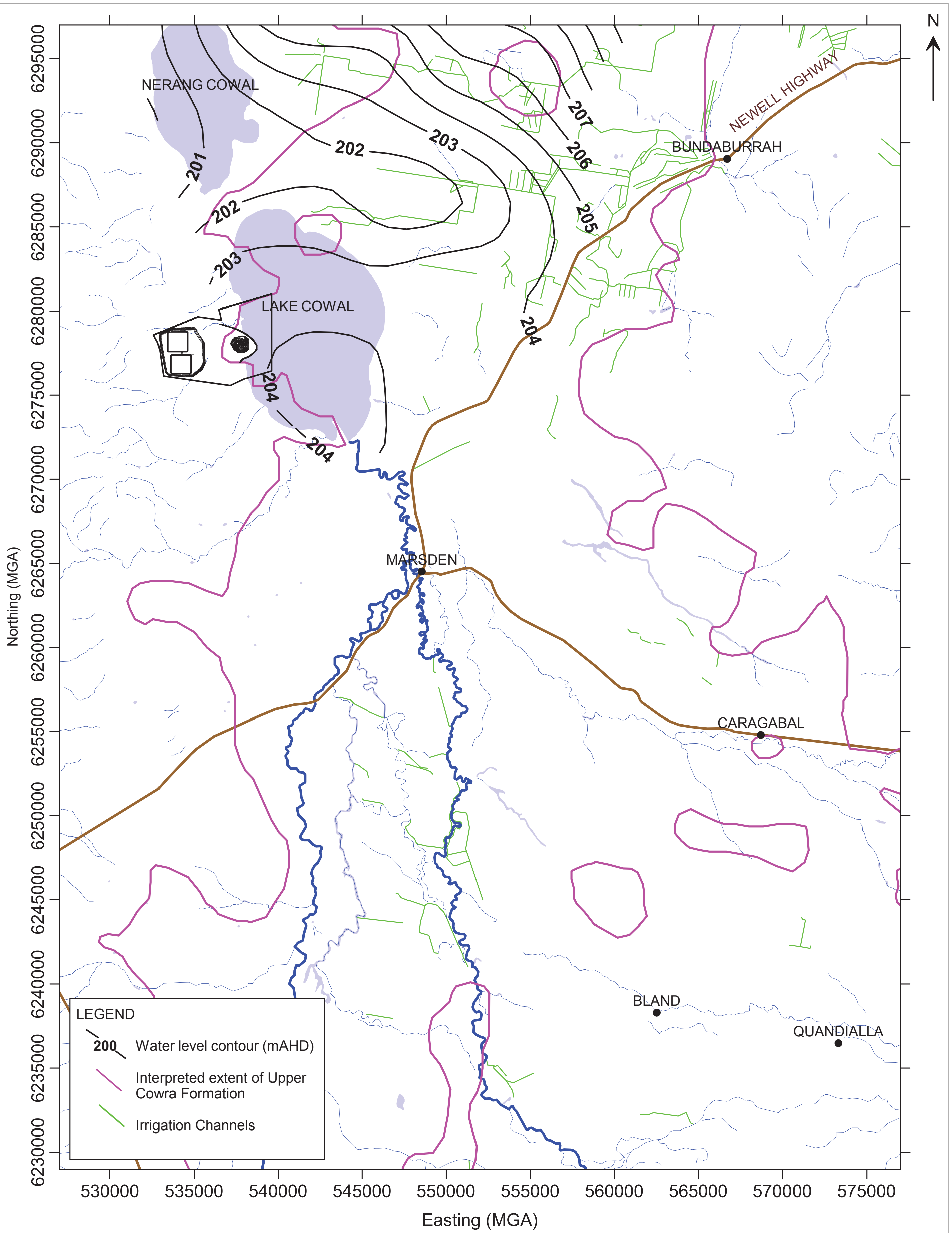

drawn	PT/SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017	title:	**WATER LEVELS IN THE UPPER COWRA FORMATION FOR DECEMBER 1997**
scale	1:300,000		
original size	A4	project no: 754-SYDGE206418	figure no: **FIGURE A-8**

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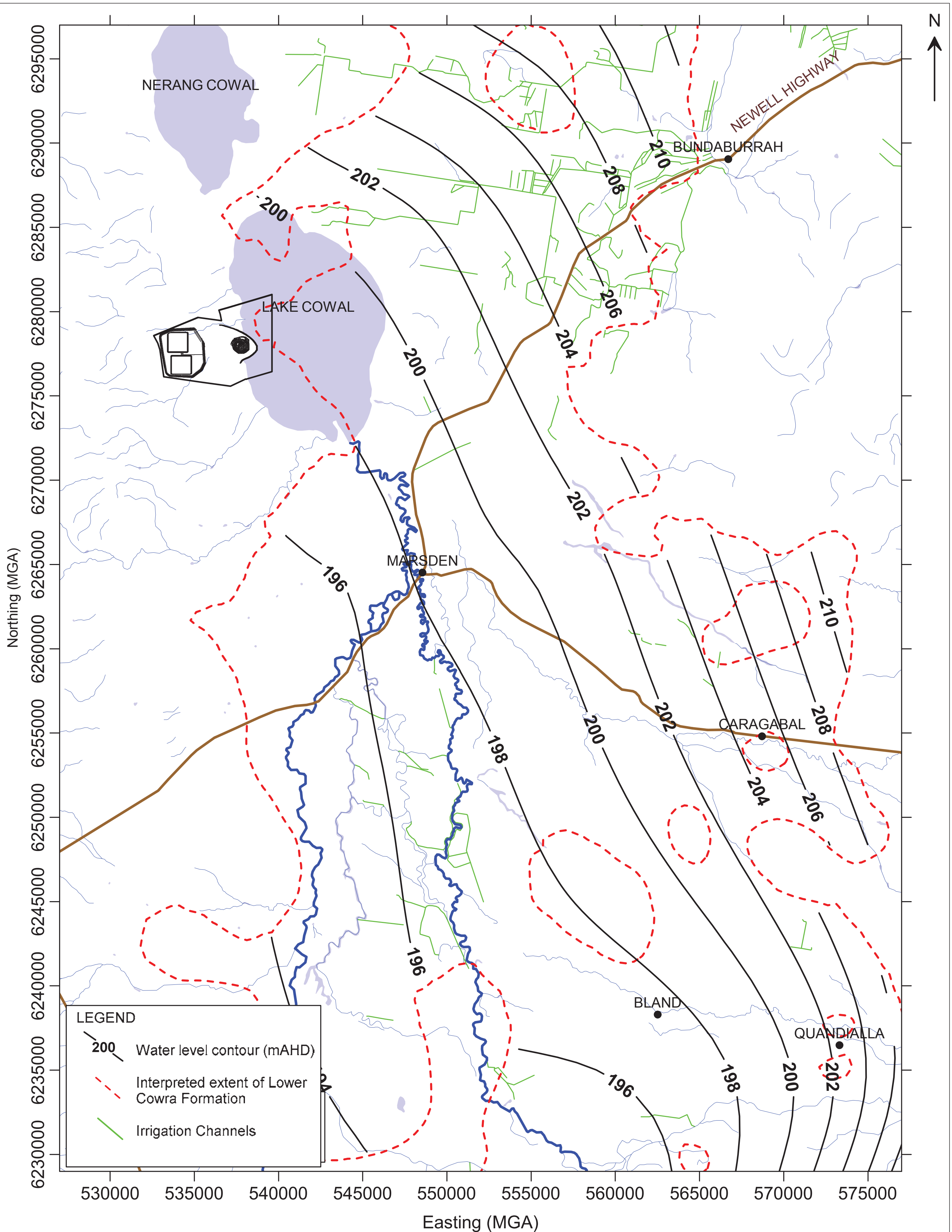
A TETRA TECH COMPANY



drawn	PT/SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017	title:	**WATER LEVELS IN THE LOWER COWRA FORMATION FOR DECEMBER 1997**
scale	1:300,000	project no:	754-SYDGE206418
original size	A4	figure no:	**FIGURE A-9**

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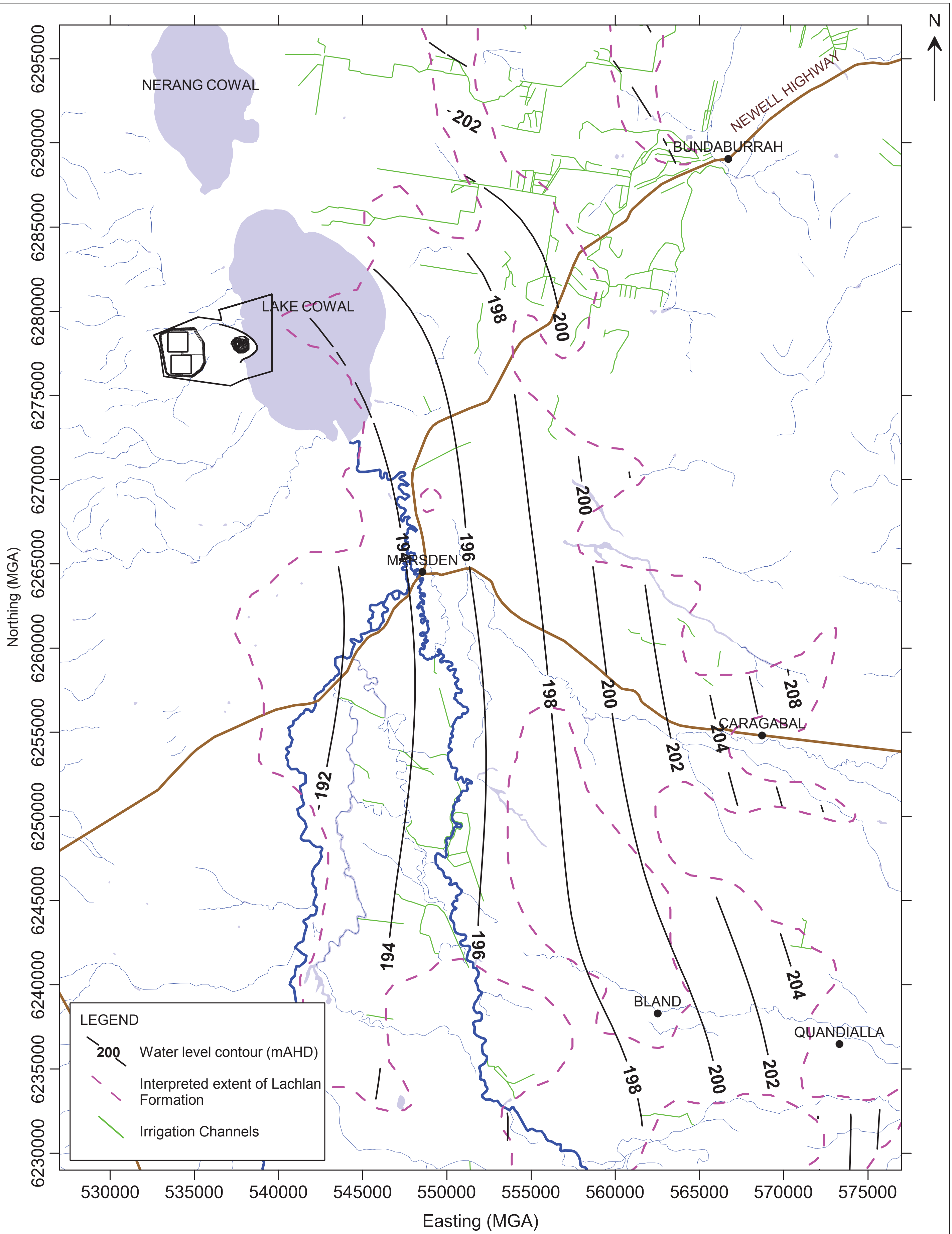

drawn	PT/SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017	title:	**WATER LEVELS IN THE LACHLAN FORMATION FOR DECEMBER 1997**
scale	1:300,000	project no:	754-SYDGE206418
original size	A4	figure no:	**FIGURE A-10**

coffey
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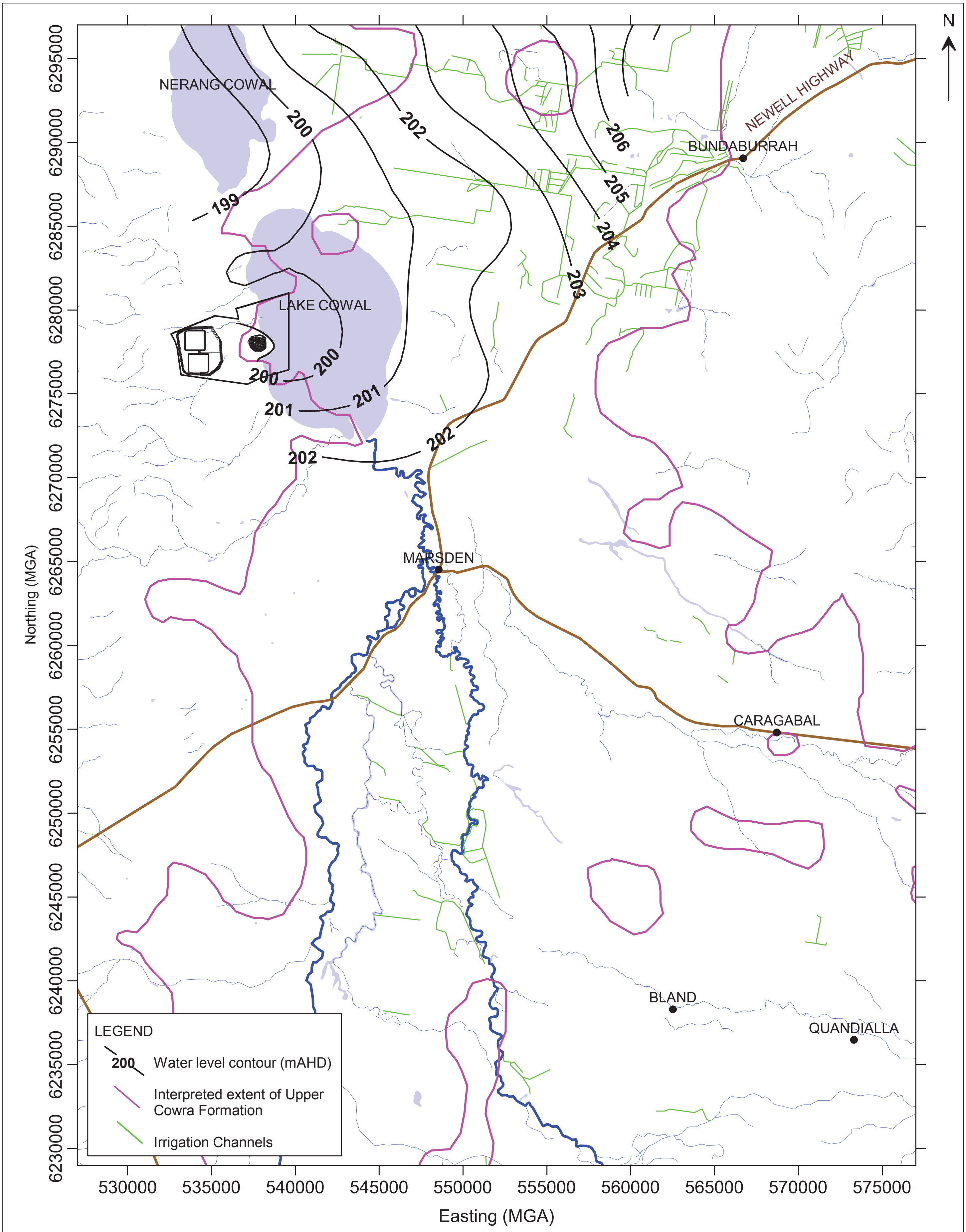
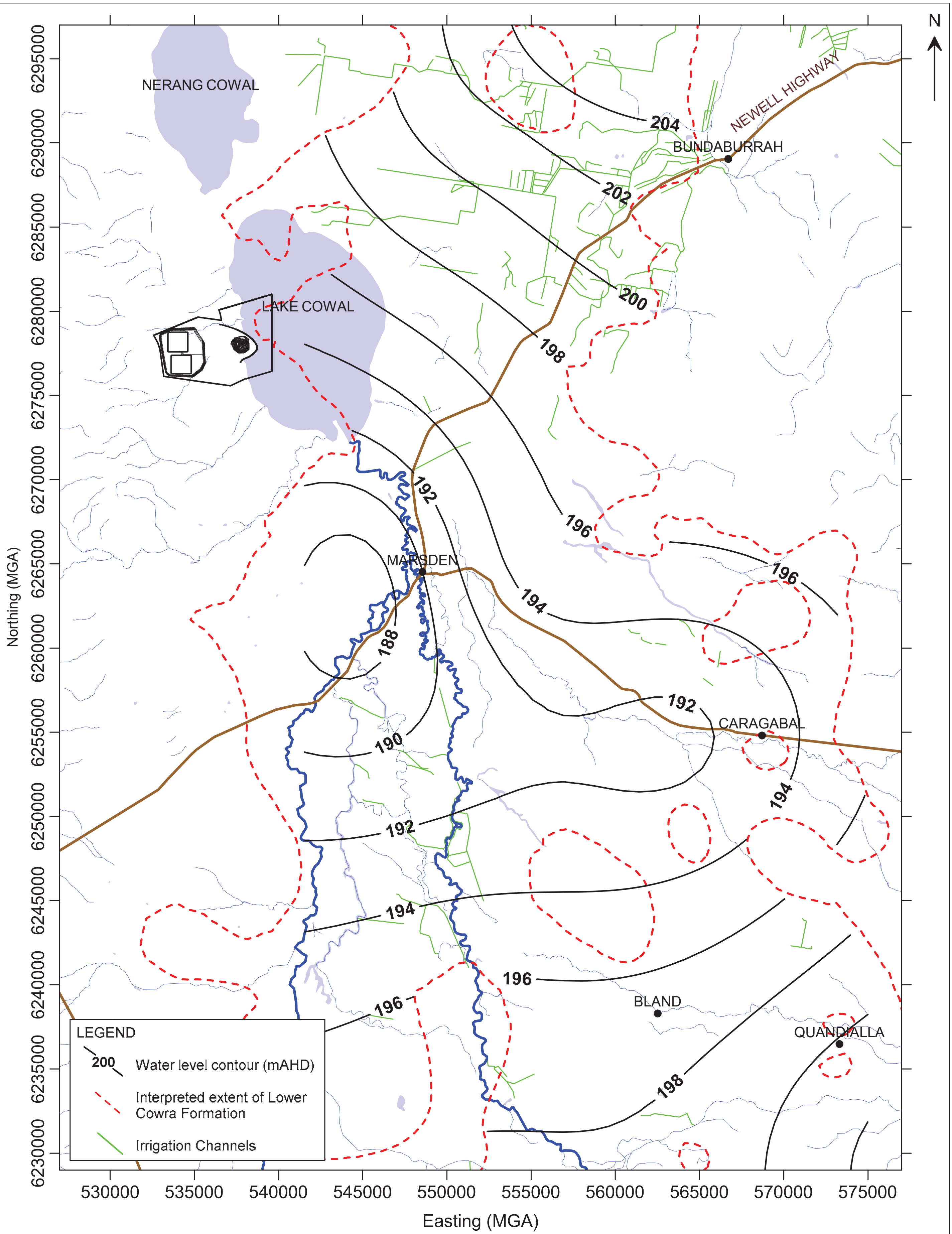
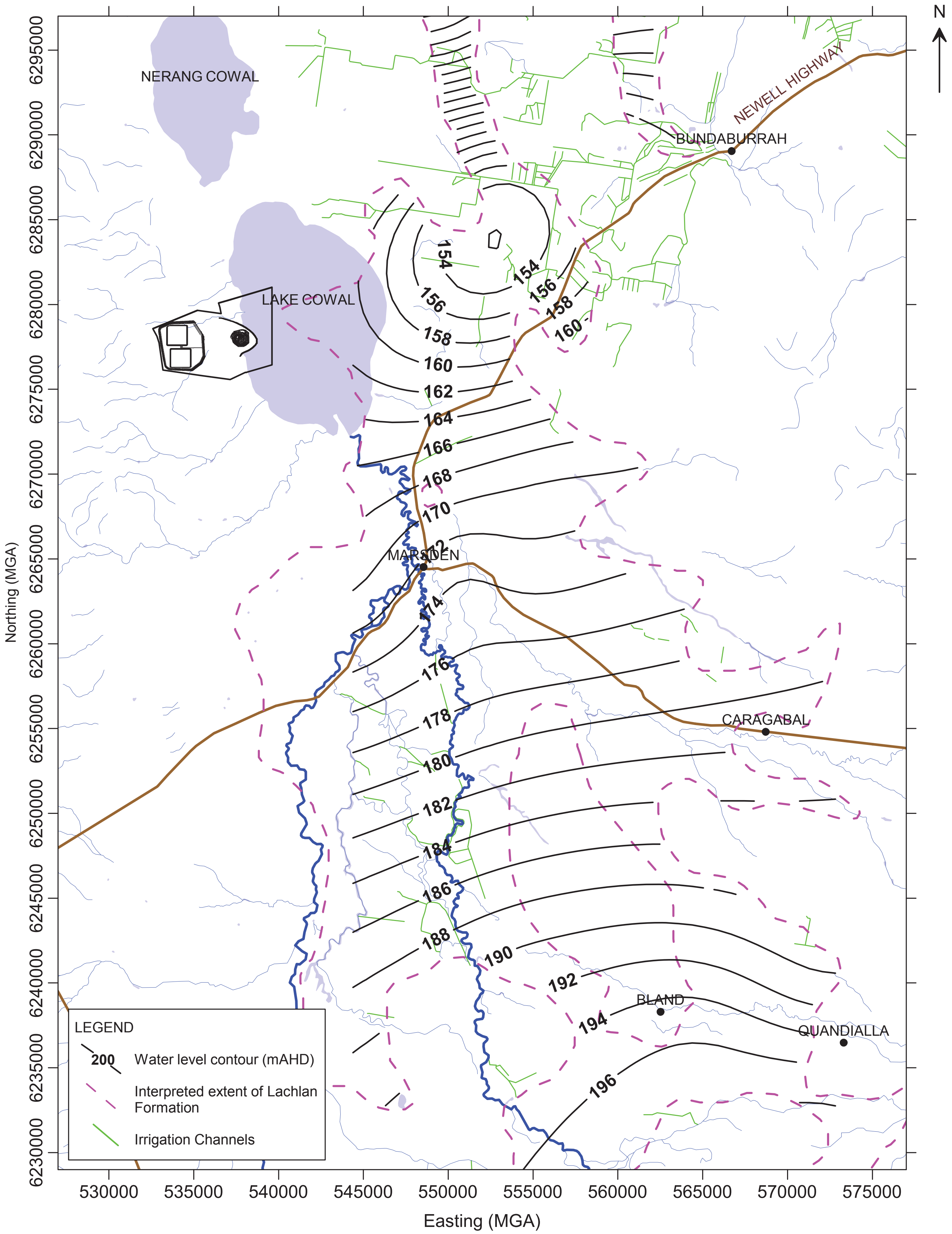


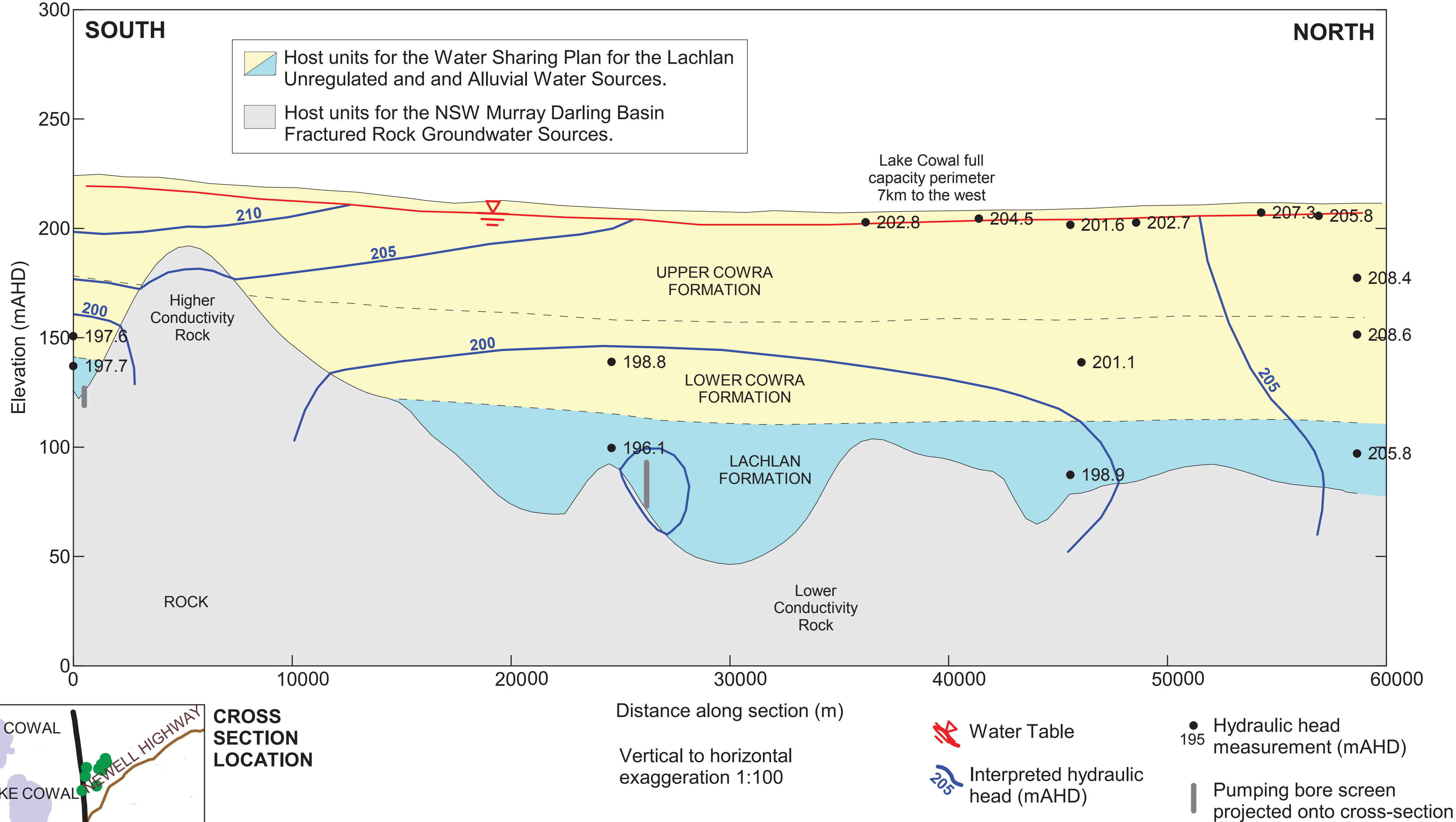
drawn	PT/SE	coffey A TETRA TECH COMPANY	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB		project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017		title:	**WATER LEVELS IN THE UPPER COWRA FORMATION FOR SEPTEMBER 2006**
scale	1:300,000			
original size	A4		project no: 754-SYDGE206418	figure no: **FIGURE A-11**

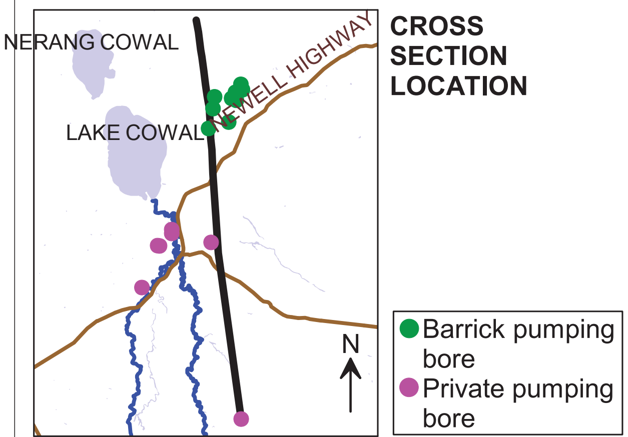


drawn	PT/SE	coffey A TETRA TECH COMPANY	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB		project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017		title:	**WATER LEVELS IN THE LOWER COWRA FORMATION FOR SEPTEMBER 2006**
scale	1:300,000		project no:	754-SYDGE206418
original size	A4		figure no:	**FIGURE A-12**



drawn	PT/SE	coffey A TETRA TECH COMPANY	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB		project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017		title:	**WATER LEVELS IN THE LACHLAN FORMATION FOR SEPTEMBER 2006**
scale	1:300,000		project no:	754-SYDGE206418
original size	A4		figure no:	**FIGURE A-13**





drawn	PT/SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017	title:	**HYDRAULIC HEAD CROSS-SECTION FOR DECEMBER 1997**
scale	H: 1:250,000 V: 1:2,500	project no:	754-SYDGE206418
original size	A4	figure no:	**FIGURE A-14**

coffey
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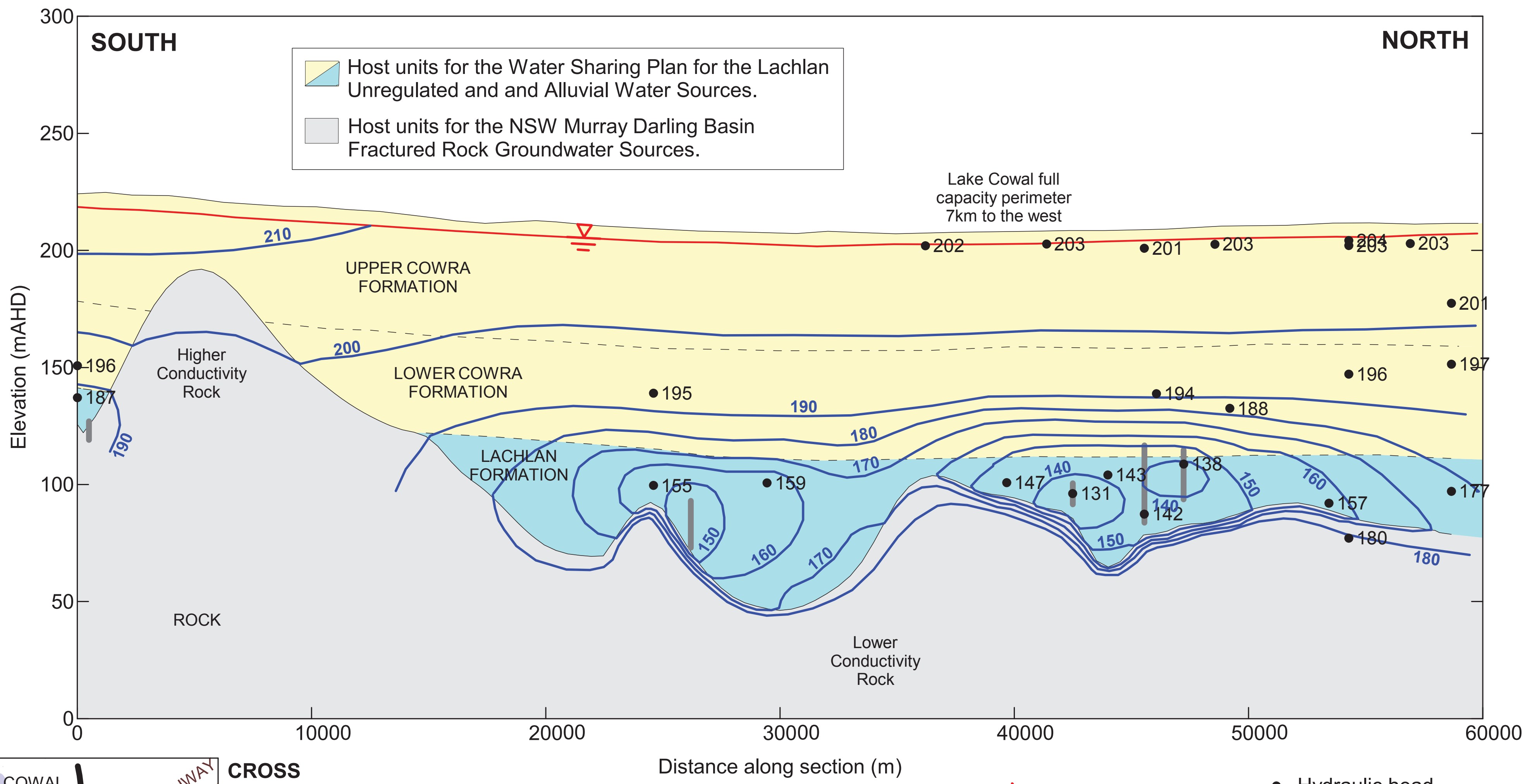


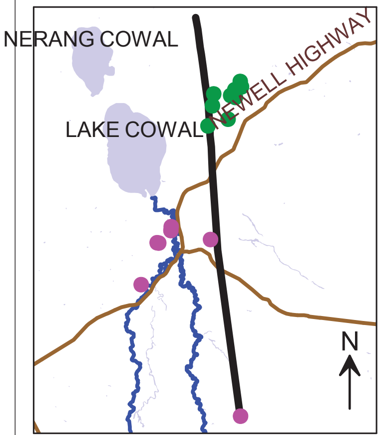
Vertical to horizontal exaggeration 1:100

Water Table

Interpreted hydraulic head (mAHD)

Hydraulic head measurement (mAHD)

Pumping bore screen projected onto cross-section



CROSS SECTION LOCATION

- Barrick pumping bore
- Private pumping bore

drawn	PT/SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017	title:	**HYDRAULIC HEAD CROSS-SECTION FOR JANUARY 2010**
scale	H: 1:250,000 V: 1:2,500	project no:	754-SYDGE206418
original size	A4	figure no:	**FIGURE A-15**

coffey
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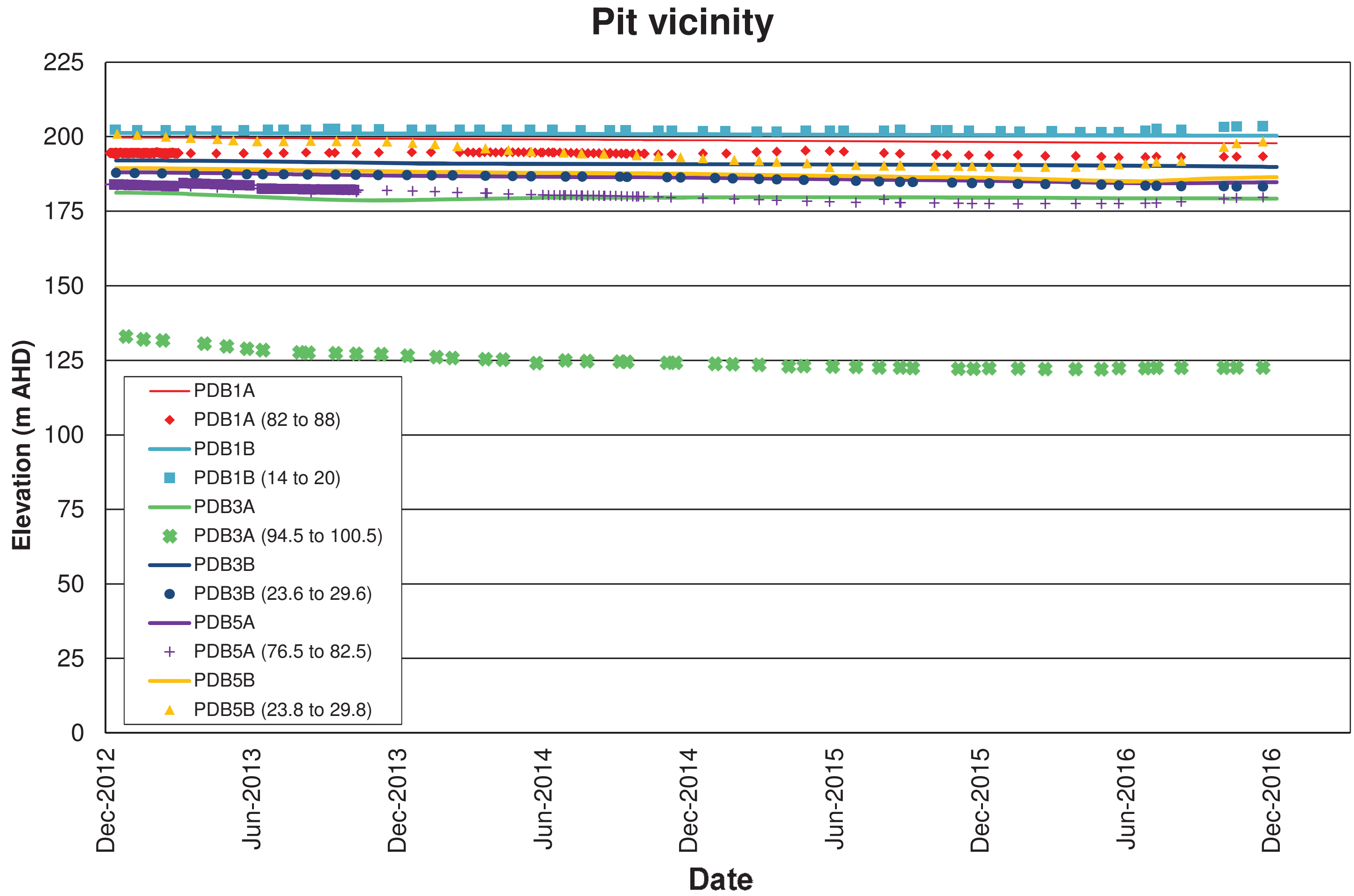


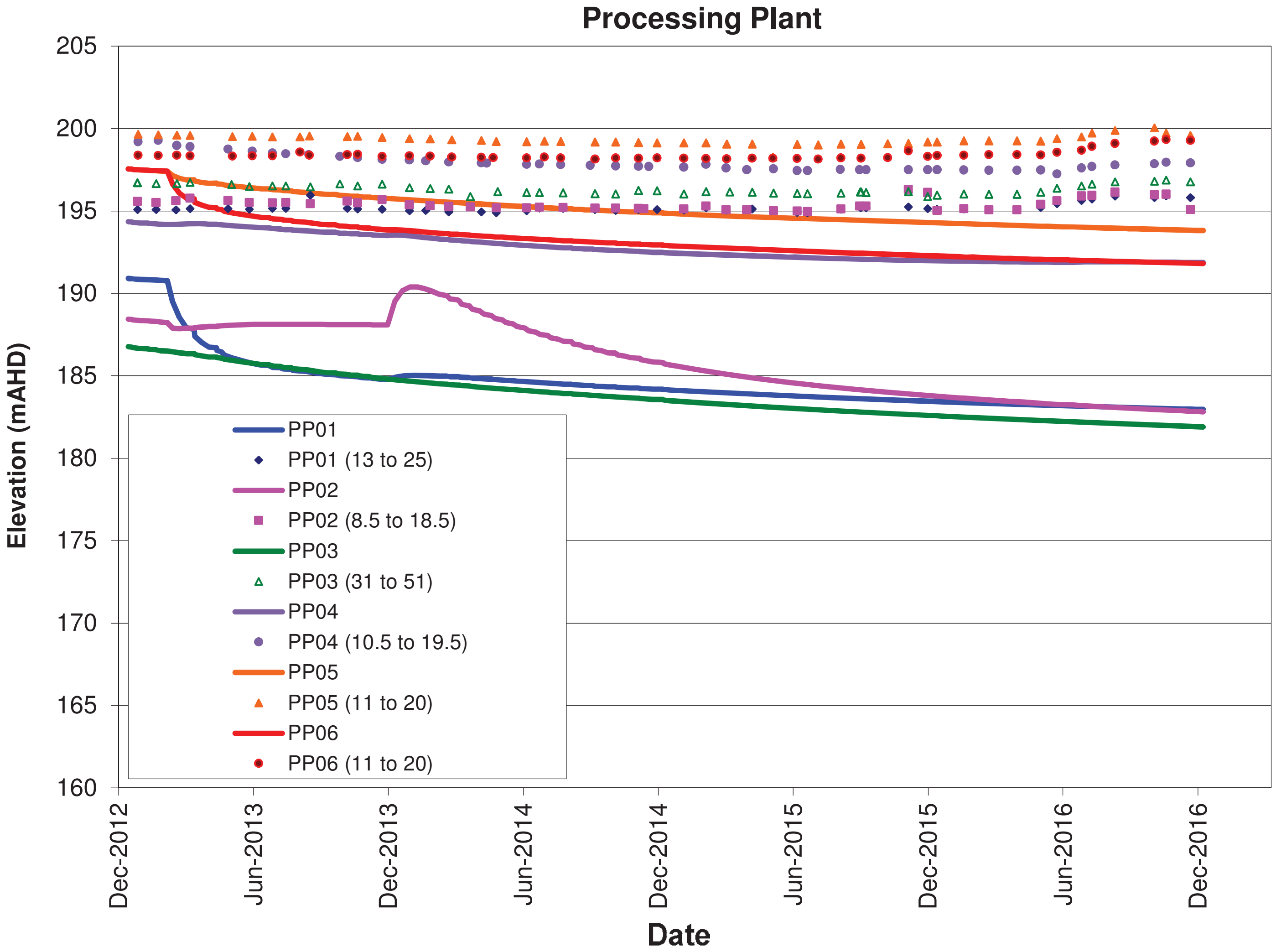
KEY

Solid line - modelled result

Points - monitoring data

PDB1A (82-88) - Bore ID
(screen interval, mbgl)

drawn	SE	coffey A TETRA TECH COMPANY	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB		project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017		title:	CALIBRATION HYDROGRAPHS - PIT AREA
scale	As Shown		project no:	754-SYDGE206418
original size	A4		figure no:	FIGURE A-16



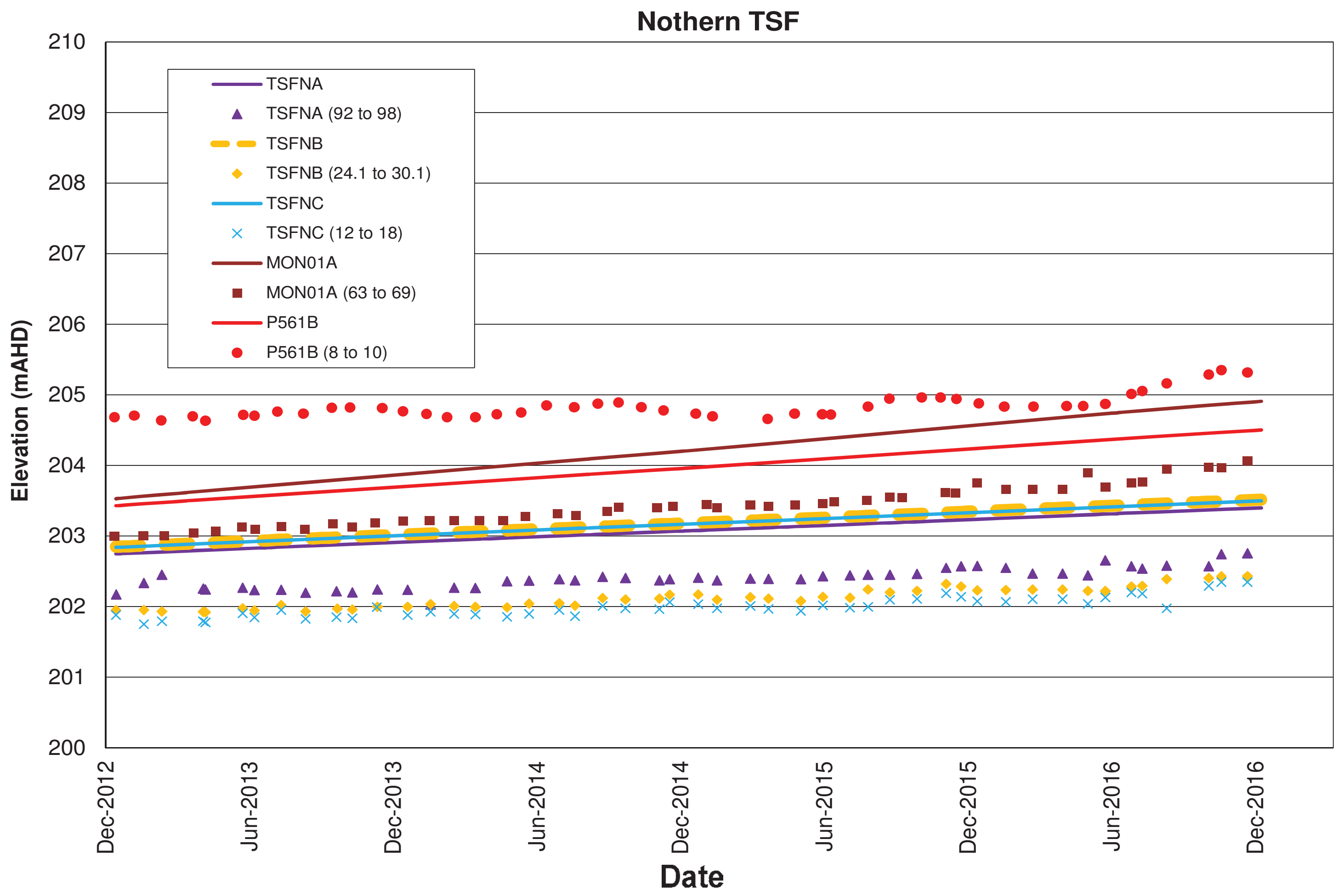
KEY

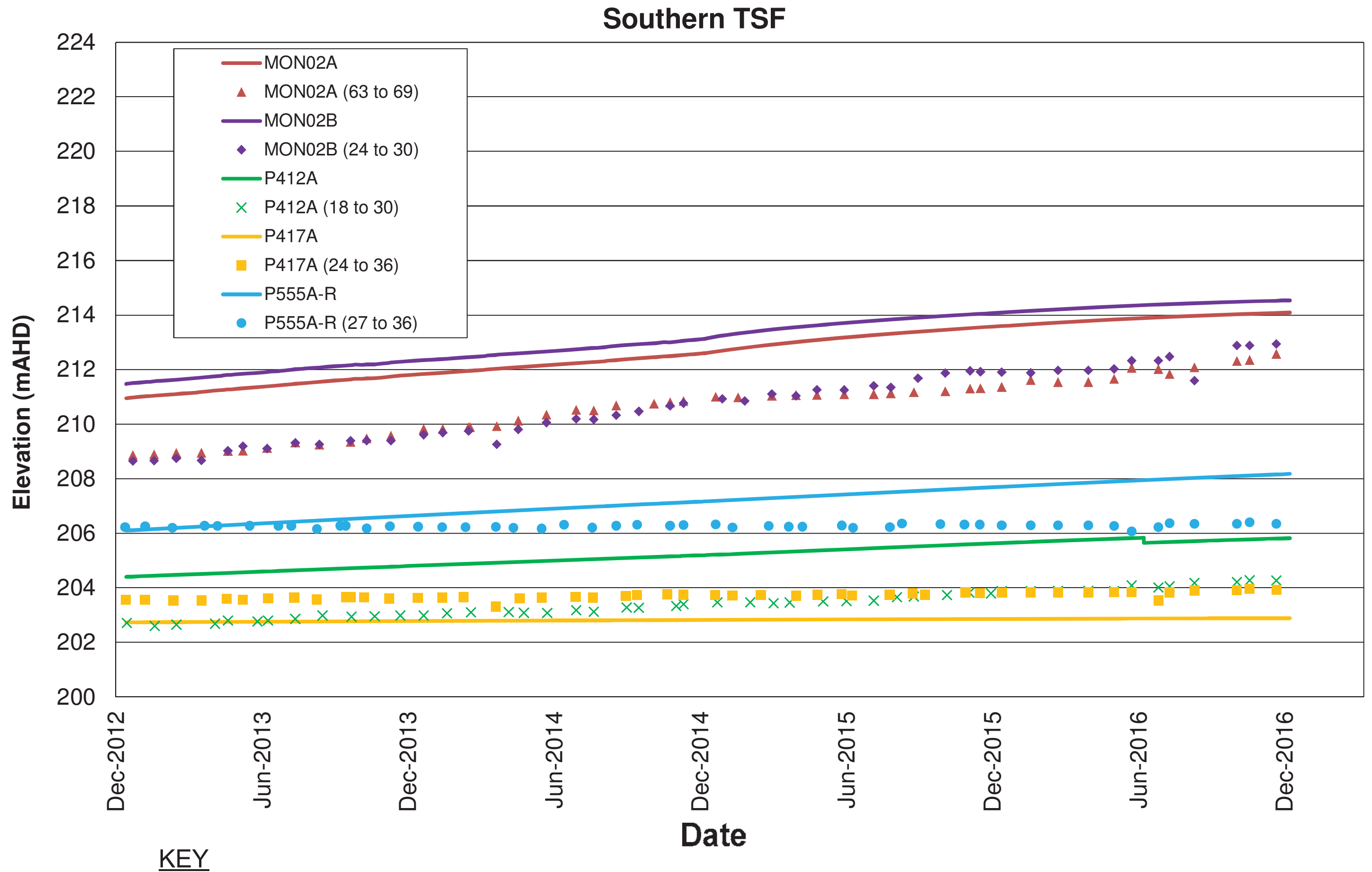
Solid line - modelled result

Points - monitoring data

PDB1A (82-88) - Bore ID (screen interval)

drawn	SE	coffey A TETRA TECH COMPANY	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB		project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017		title:	CALIBRATION HYDROGRAPHS -PROCESSING PLANT AREA
scale	As Shown			
original size	A4		project no: 754-SYDGE206418	figure no: FIGURE A-17





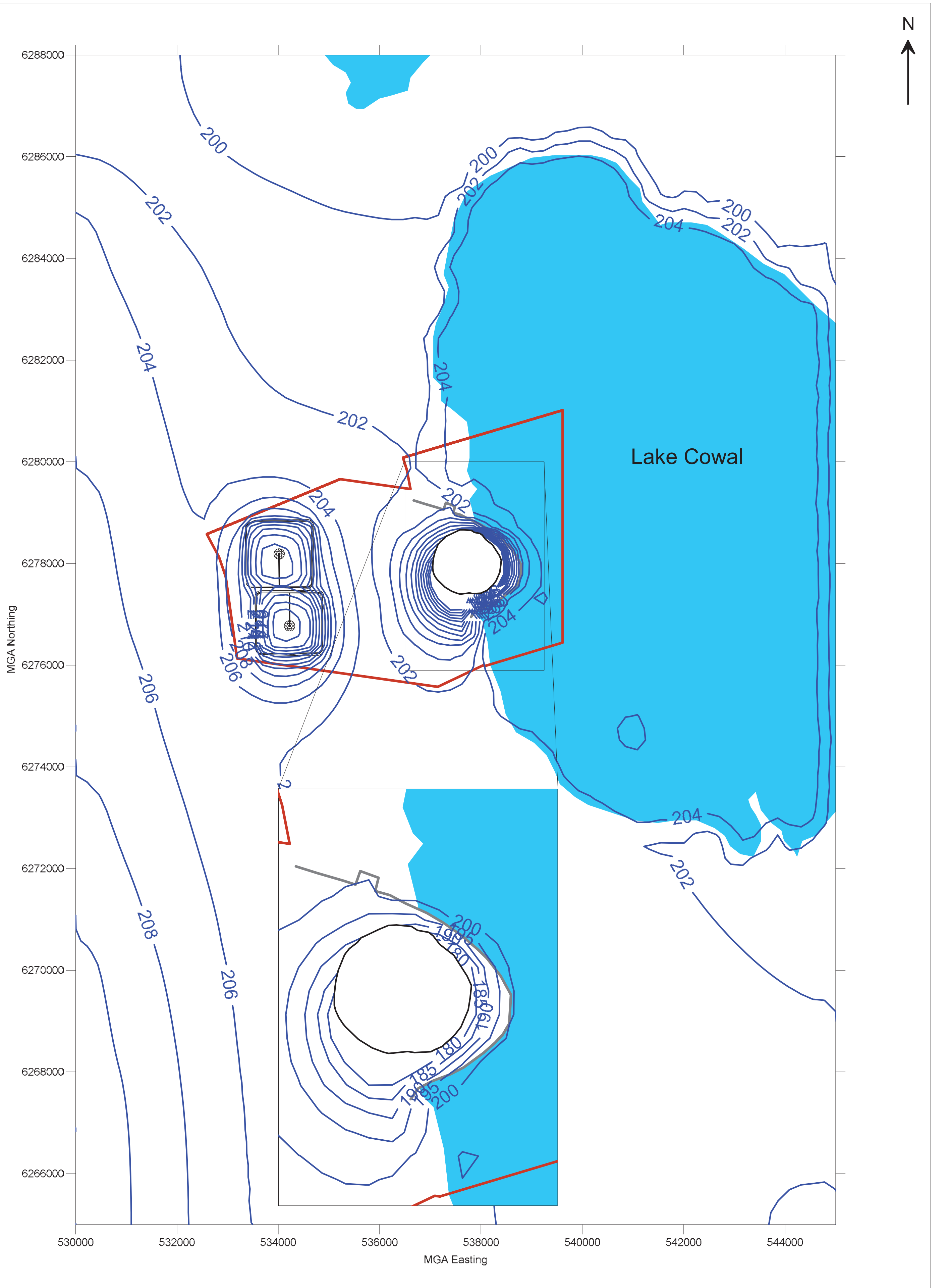
KEY

Solid line - modelled result

Points - monitoring data

PDB1A (82-88) - Bore ID (screen interval, mbgl)

drawn	SE	coffey A TETRA TECH COMPANY	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB		project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017			
scale	As Shown		title:	CALIBRATION HYDROGRAPHS - TSF AREA
original size	A4		project no: 754-SYDGE206418	figure no: FIGURE A-18



LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- Model Predicted Groundwater Head (m AHD)

drawn	SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017	title:	MODELLED GROUNDWATER HEAD IN TRANSPORTED UNIT AT JUNE 2017
scale	1:100,000 (inset 1:50,000)		
original size	A4	project no:	754-SYDGE206418
		figure no:	FIGURE A-19

coffey
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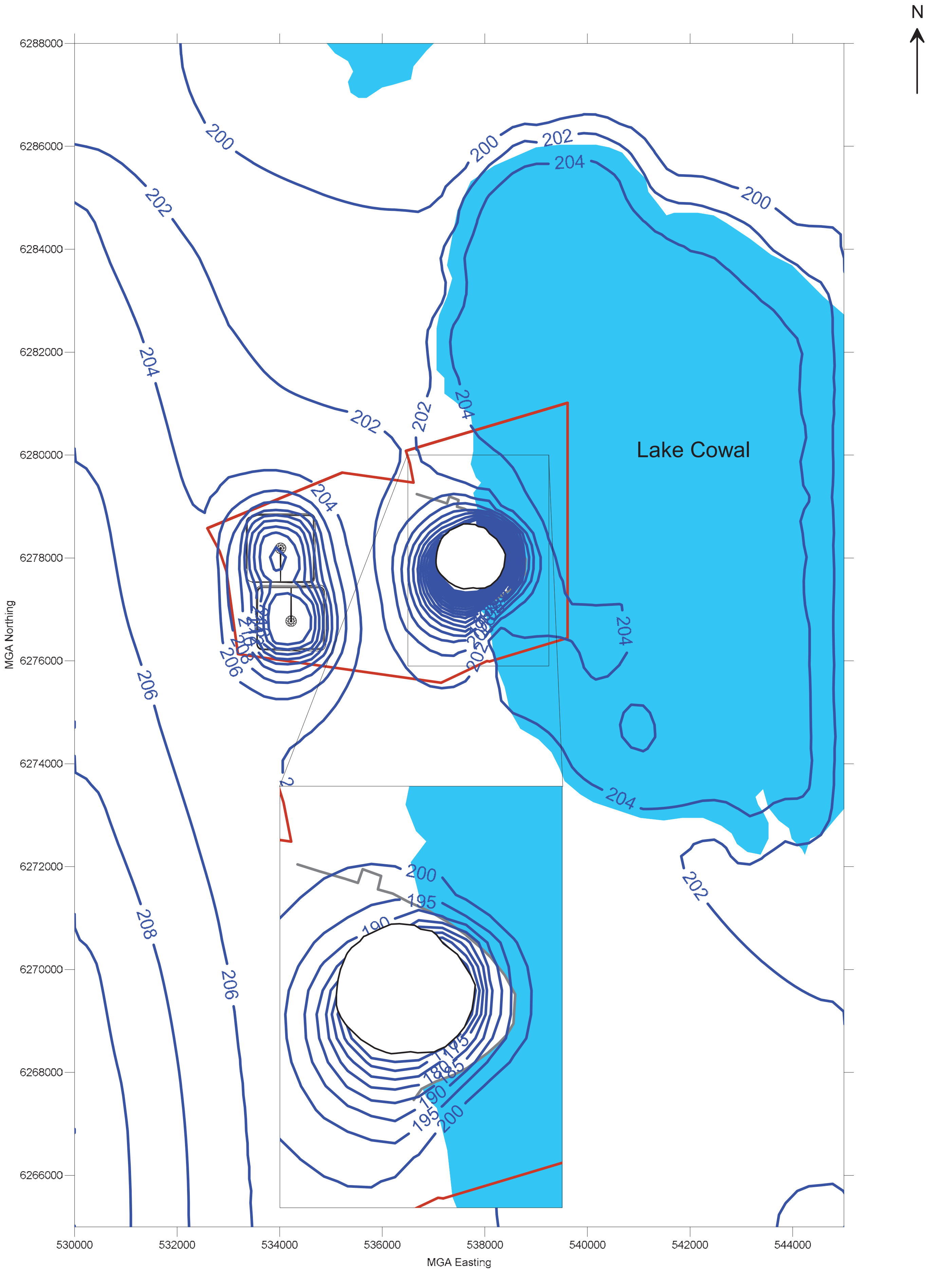


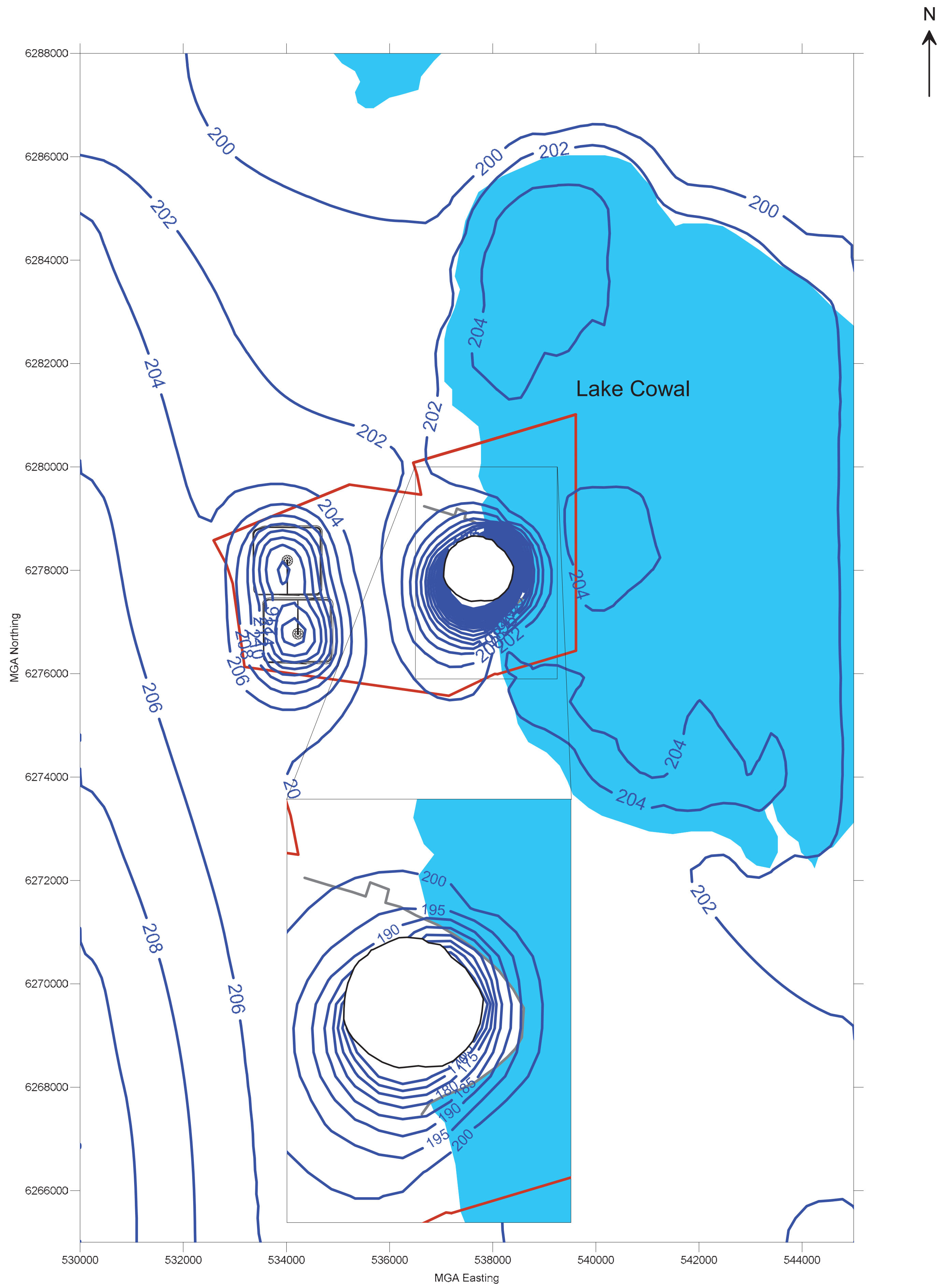
LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- Model Predicted Groundwater Head (m AHD)

drawn	SE
approved	RJB
date	28 NOV 2017
scale	1:100,000 (inset 1:50,000)
original size	A4

coffey A TETRA TECH COMPANY

client:	EVOLUTION MINING (COWAL) PTY LTD
project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
title:	MODELLED GROUNDWATER HEAD IN SAPROLITE UNIT AT JUNE 2017
project no:	754-SYDGE206418
figure no:	FIGURE A-20

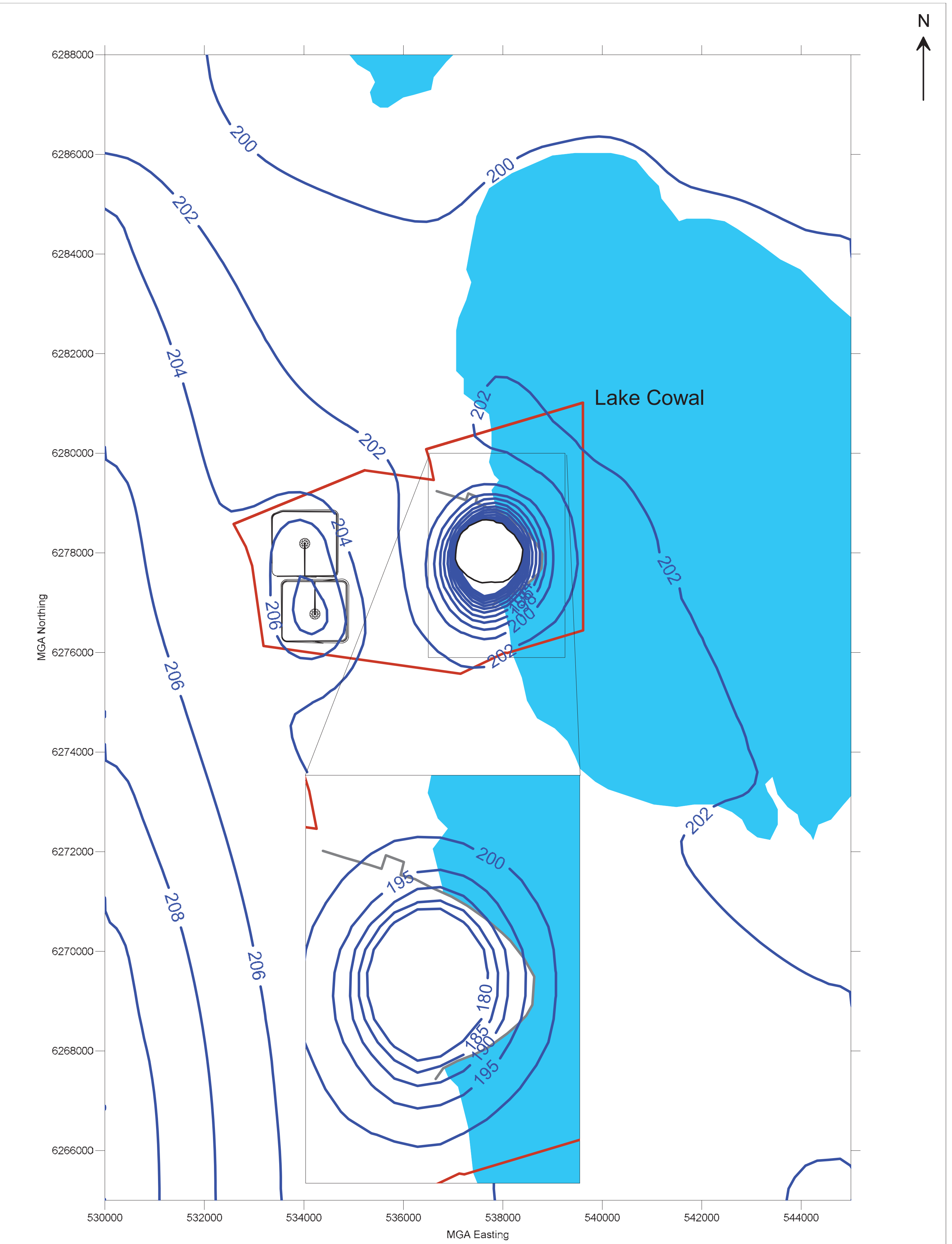


LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- Model Predicted Groundwater Head (m AHD)

drawn	SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017		
scale	1:100,000 (inset 1:50,000)	title:	MODELLED GROUNDWATER HEAD IN SAPROCK UNIT AT JUNE 2017
original size	A4	project no:	754-SYDGE206418
		figure no:	FIGURE A-21

coffey
A TETRA TECH COMPANY



LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- Model Predicted Groundwater Head (m AHD)

drawn	SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	28 NOV 2017	title:	MODELLED GROUNDWATER HEAD IN PRIMARY ROCK UNIT AT JUNE 2017
scale	1:100,000 (inset 1:50,000)	project no:	754-SYDGE206418
original size	A4	figure no:	FIGURE A-22

coffey
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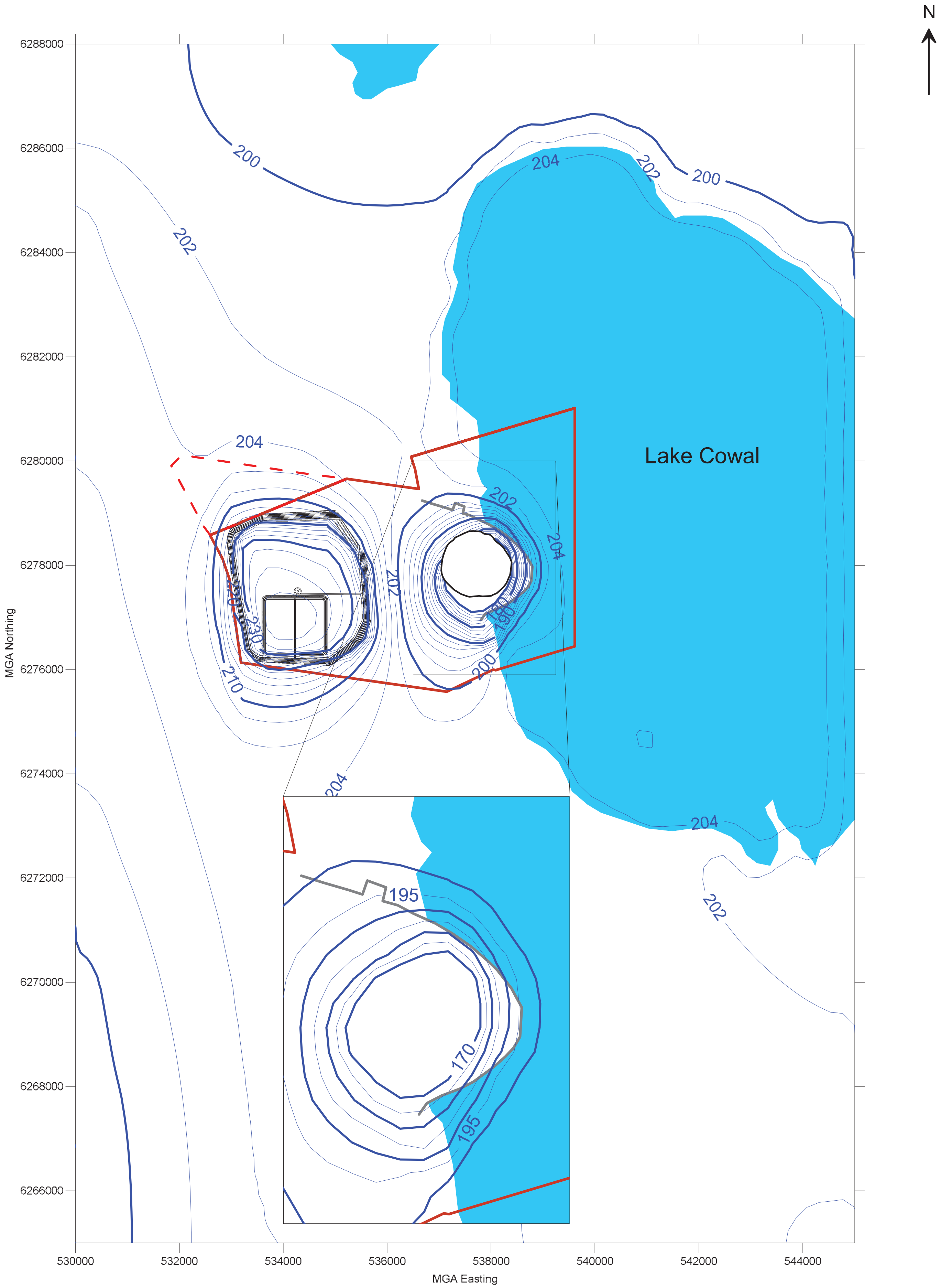

LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Head (m AHD)

drawn	SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	09 Feb 2018	title:	**MODELLED GROUNDWATER HEAD IN TRANSPORTED UNIT AT JUNE 2032, DRY LAKE**
scale	1:100,000 (inset 1:50,000)	project no:	754-SYDGE206418
original size	A4	figure no:	**FIGURE A-23**

coffey
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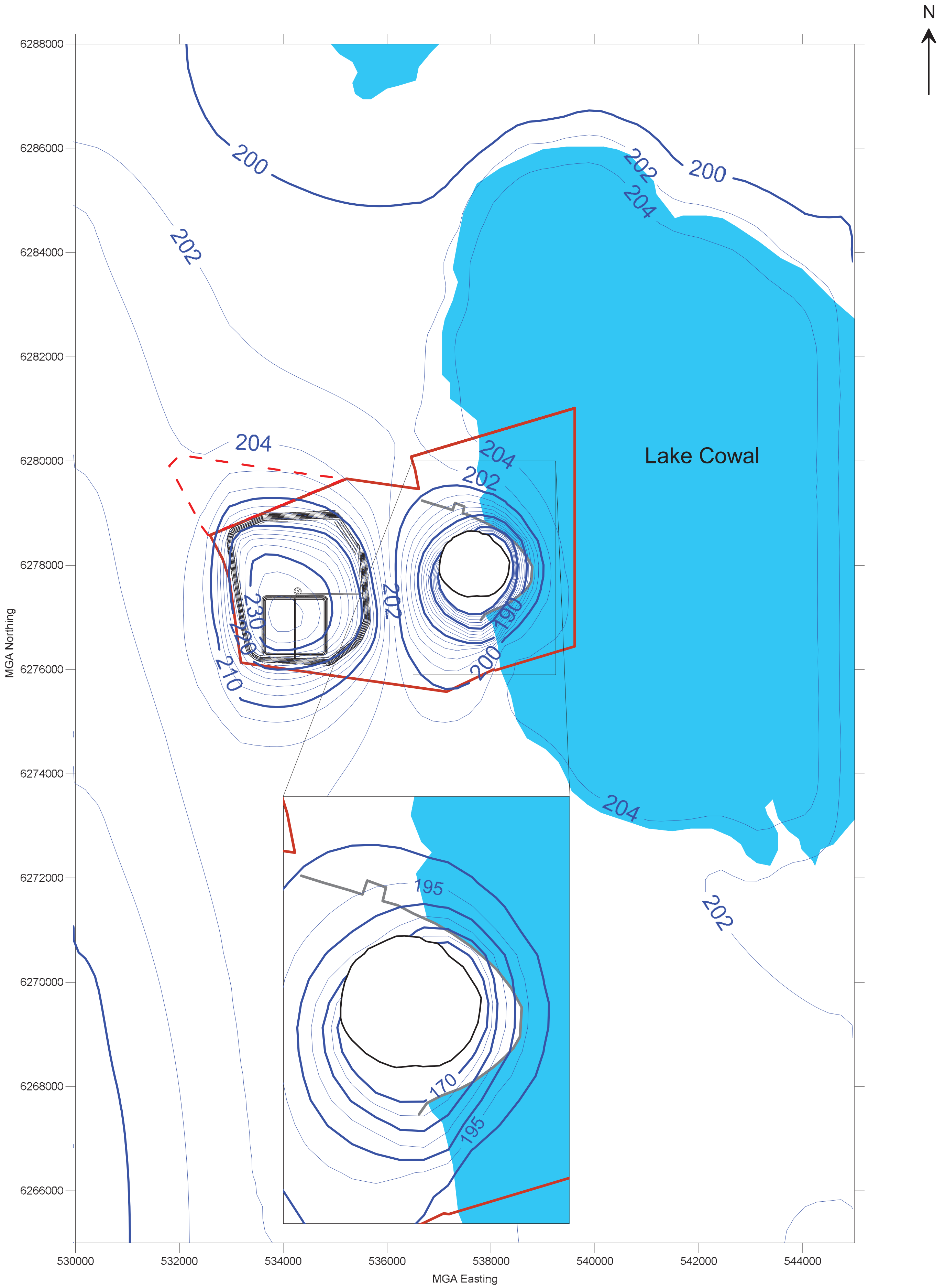


LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Head (m AHD)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:100,000 (inset 1:50,000)
original size	A4

coffey A TETRA TECH COMPANY

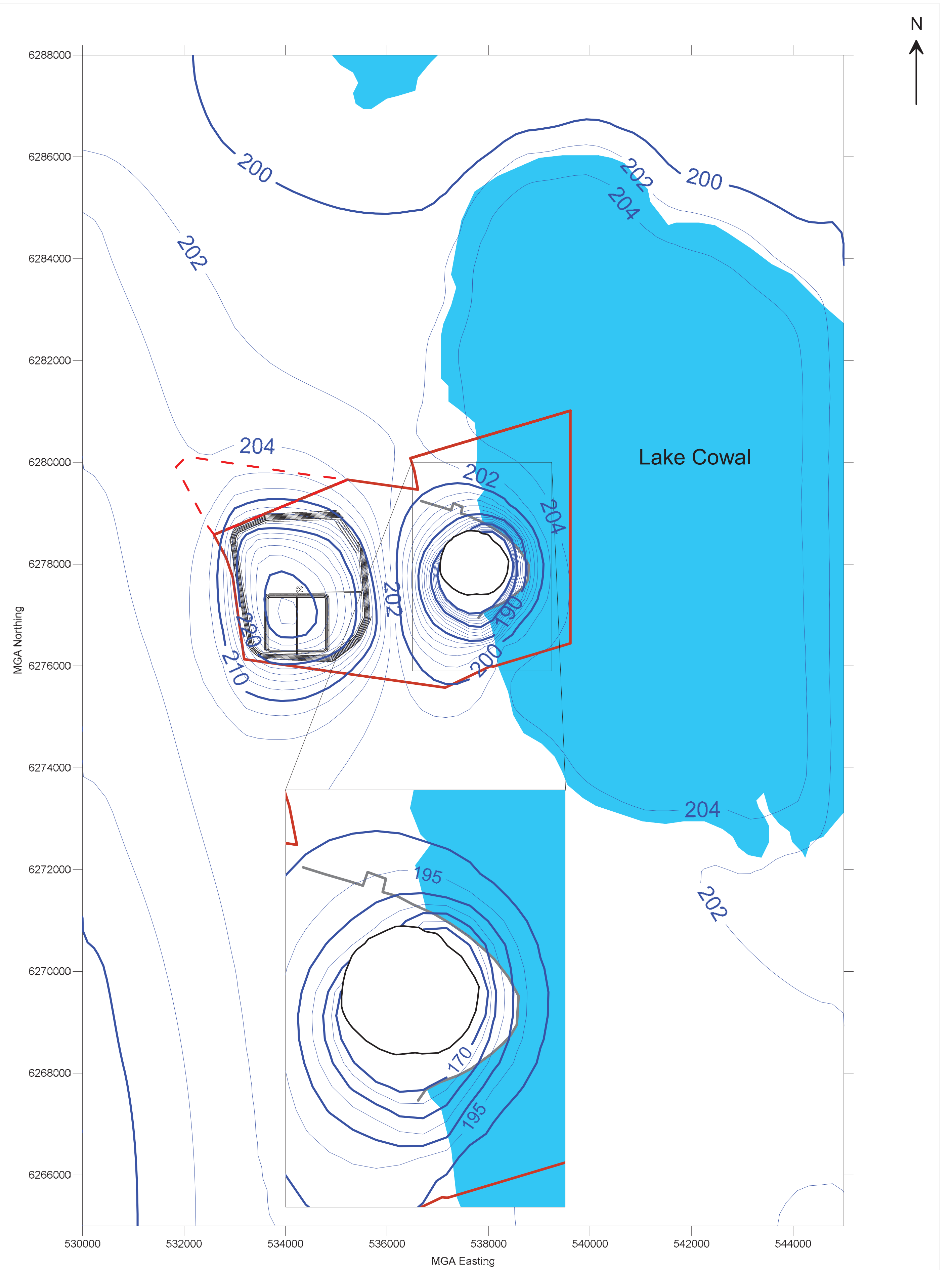
client: EVOLUTION MINING (COWAL) PTY LTD

project: COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT

title: **MODELLED GROUNDWATER HEAD IN SAPROLITE UNIT AT JUNE 2032, DRY LAKE**

project no: 754-SYDGE206418

figure no: **FIGURE A-24**



LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Head (m AHD)

drawn	SE	
approved	RJB	
date	09 Feb 2018	coffey A TETRA TECH COMPANY
scale	1:100,000 (inset 1:50,000)	
original size	A4	

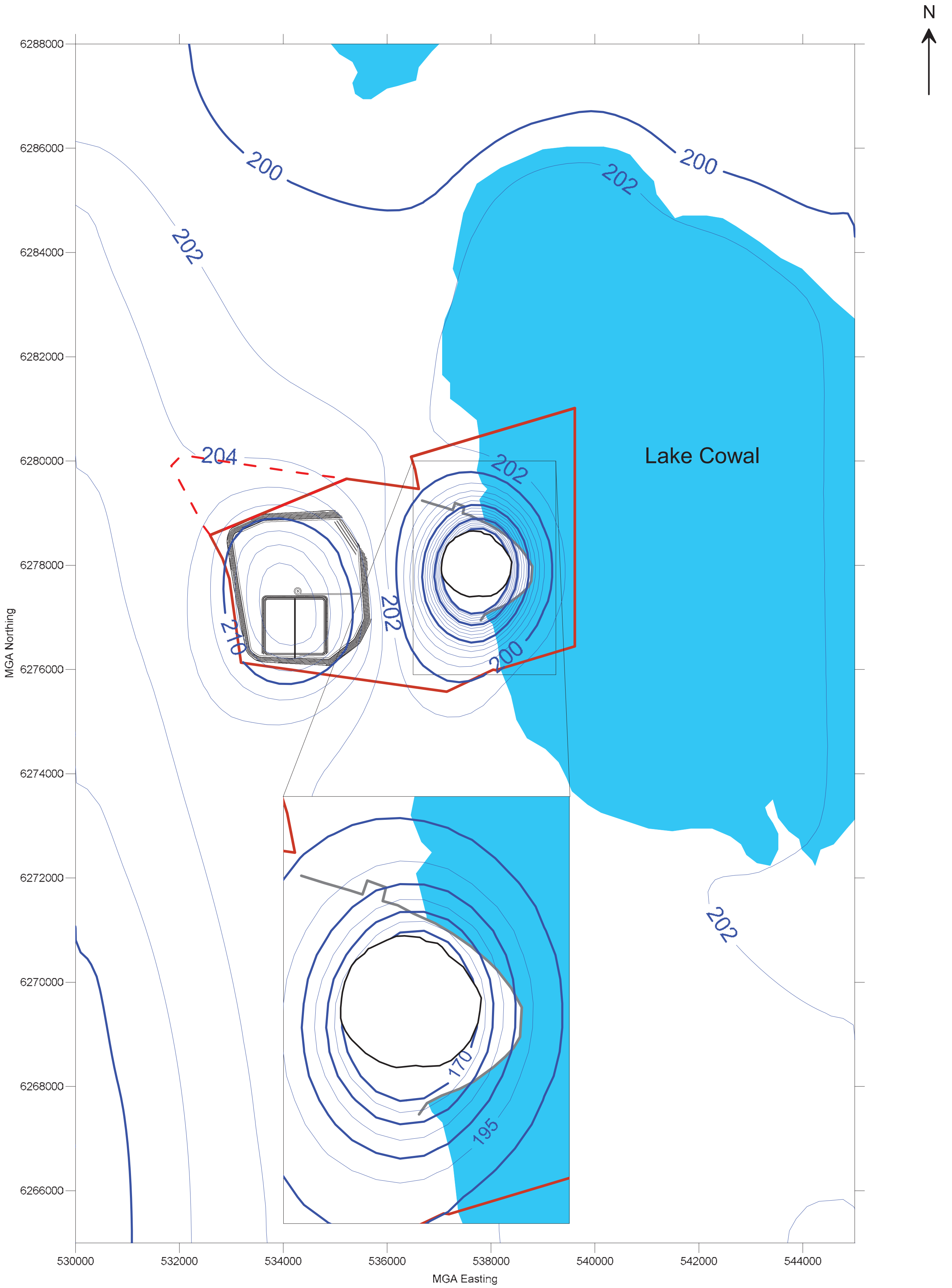
client: EVOLUTION MINING (COWAL) PTY LTD

project: COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT

title: **MODELLED GROUNDWATER HEAD IN SAPROCK UNIT AT JUNE 2032, DRY LAKE**

project no: 754-SYDGE206418

figure no: **FIGURE A-25**

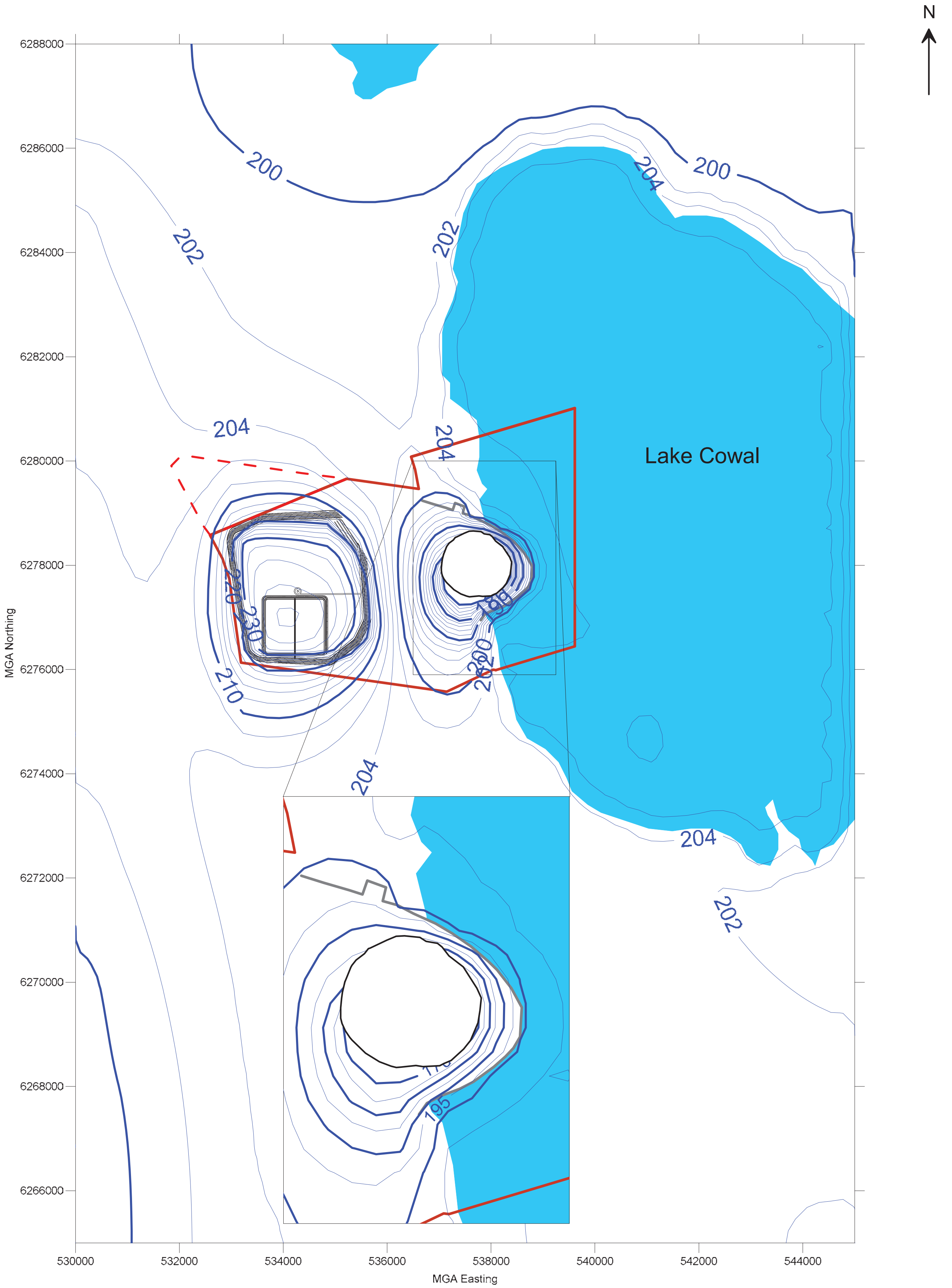


LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Head (m AHD)

drawn	SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	09 Feb 2018		
scale	1:100,000 (inset 1:50,000)	title:	**MODELLED GROUNDWATER HEAD IN PRIMARY ROCK UNIT AT JUNE 2032, DRY LAKE**
original size	A4	project no:	754-SYDGE206418
		figure no:	**FIGURE A-26**

coffey
A TETRA TECH COMPANY

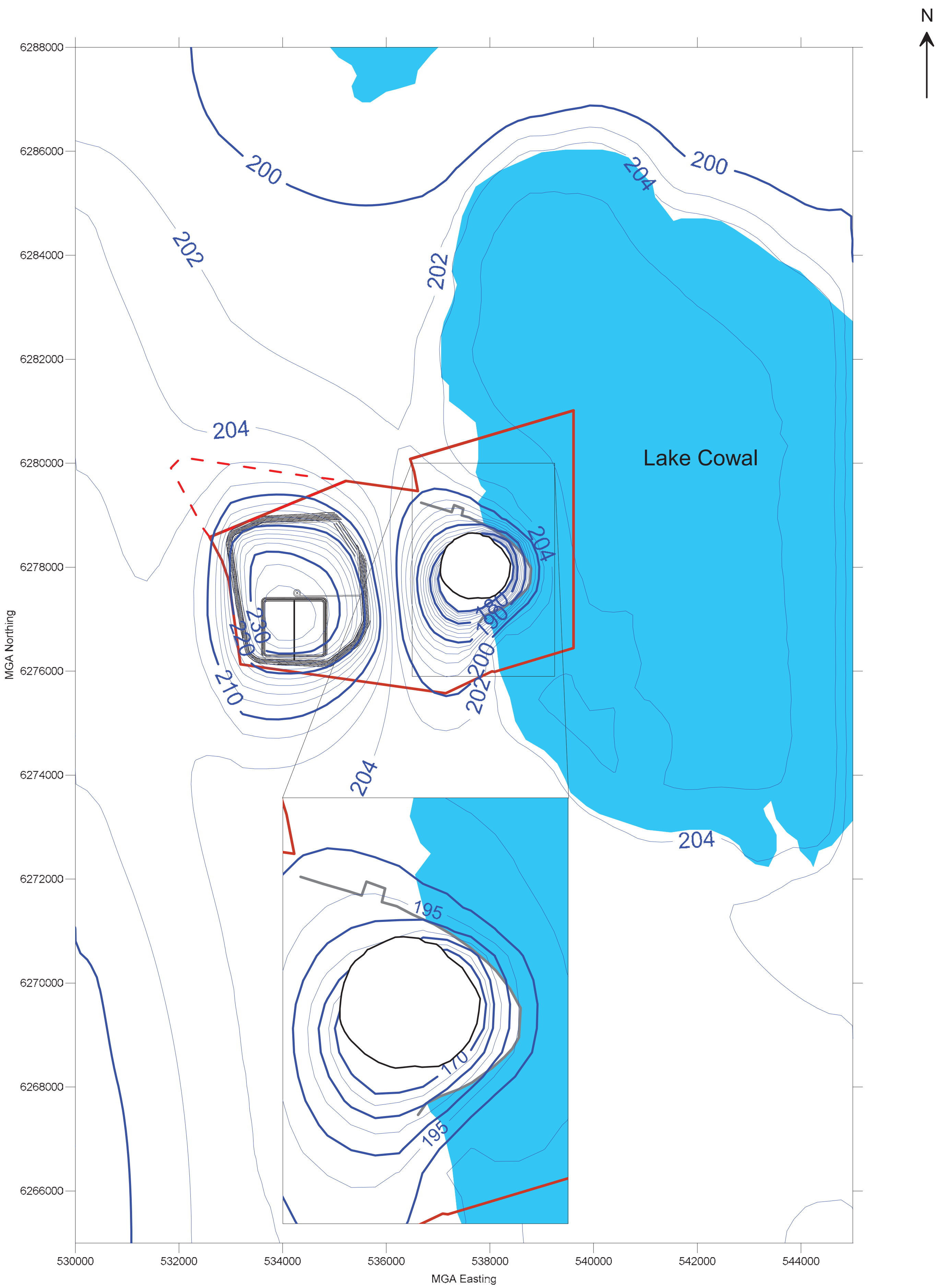


LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Head (m AHD)

drawn	SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	09 Feb 2018	title:	**MODELLED GROUNDWATER HEAD IN TRANSPORTED UNIT AT JUNE 2032, INUNDATED LAKE**
scale	1:100,000 (inset 1:50,000)	project no:	754-SYDGE206418
original size	A4	figure no:	**FIGURE A-27**

coffey
A TETRA TECH COMPANY



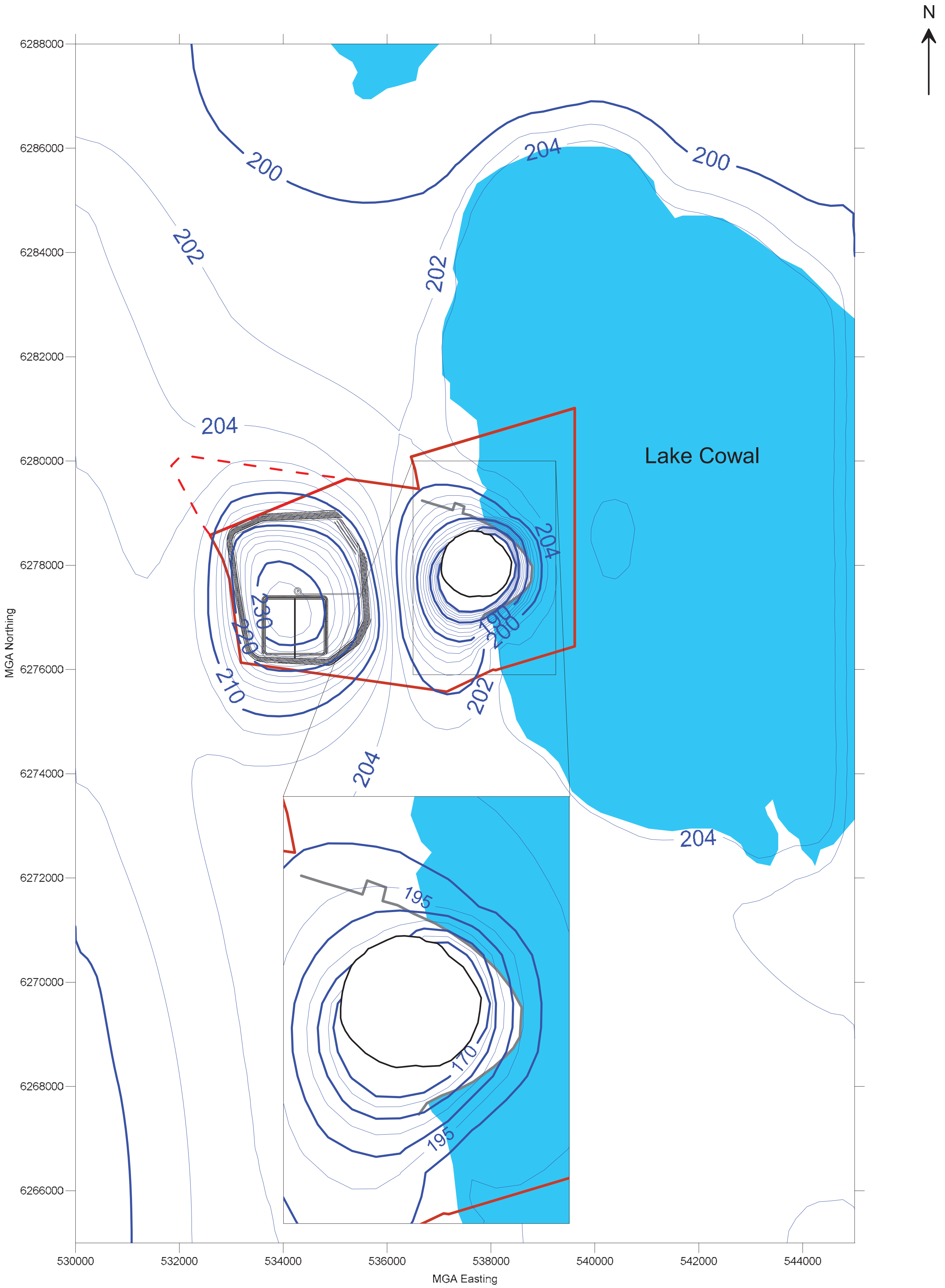
LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Head (m AHD)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:100,000 (inset 1:50,000)
original size	A4

coffey
A TETRA TECH COMPANY

client:	EVOLUTION MINING (COWAL) PTY LTD
project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
title:	**MODELLED GROUNDWATER HEAD IN SAPROLITE UNIT AT JUNE 2032, INUNDATED LAKE**
project no:	754-SYDGE206418
figure no:	**FIGURE A-28**



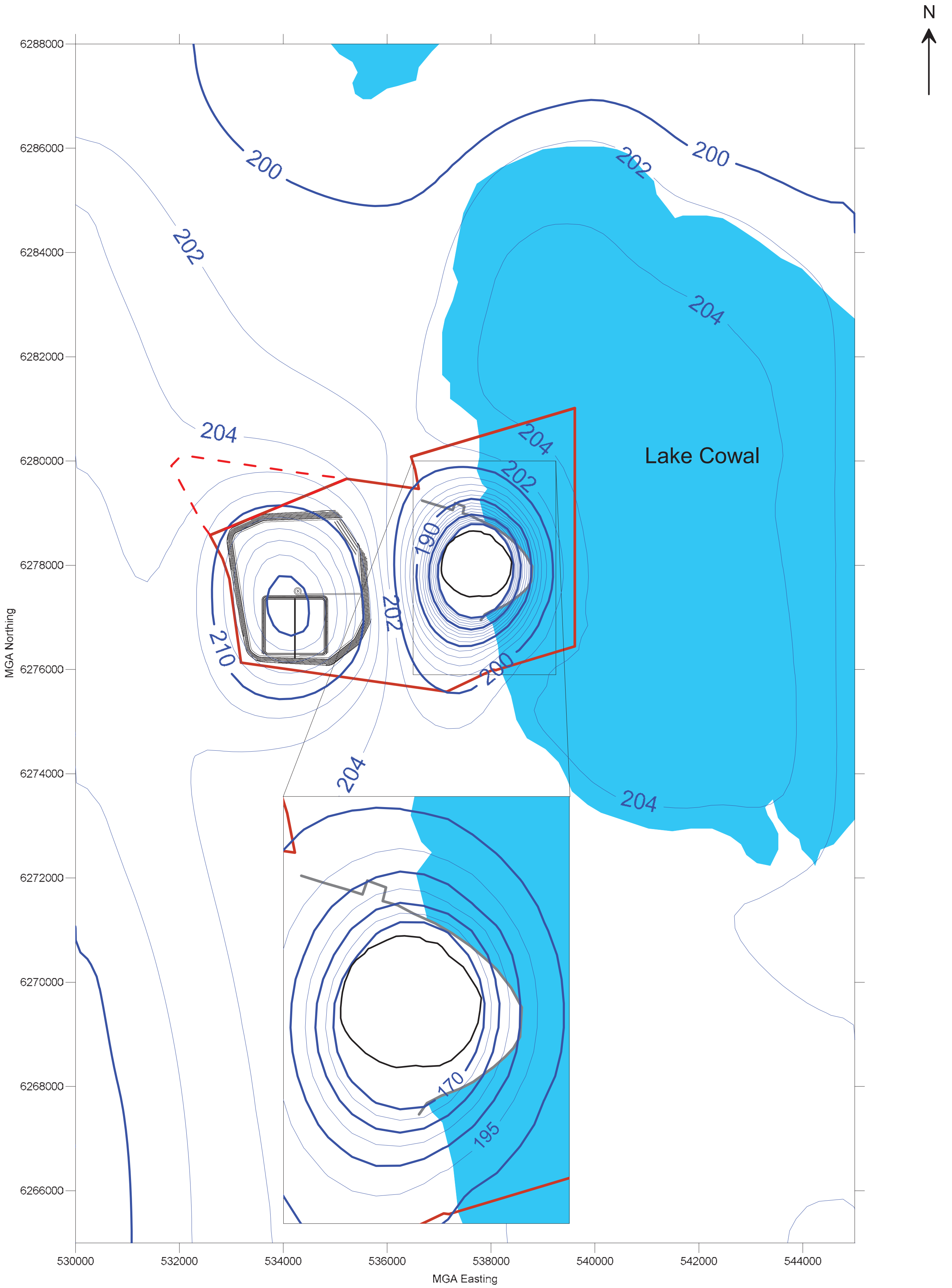
LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Head (m AHD)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:100,000 (inset 1:50,000)
original size	A4

coffey A TETRA TECH COMPANY

client:	EVOLUTION MINING (COWAL) PTY LTD
project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
title:	**MODELLED GROUNDWATER HEAD IN SAPROCK UNIT AT JUNE 2032, INUNDATED LAKE**
project no:	754-SYDGE206418
figure no:	**FIGURE A-29**



LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Head (m AHD)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:100,000 (inset 1:50,000)
original size	A4

coffey
A TETRA TECH COMPANY

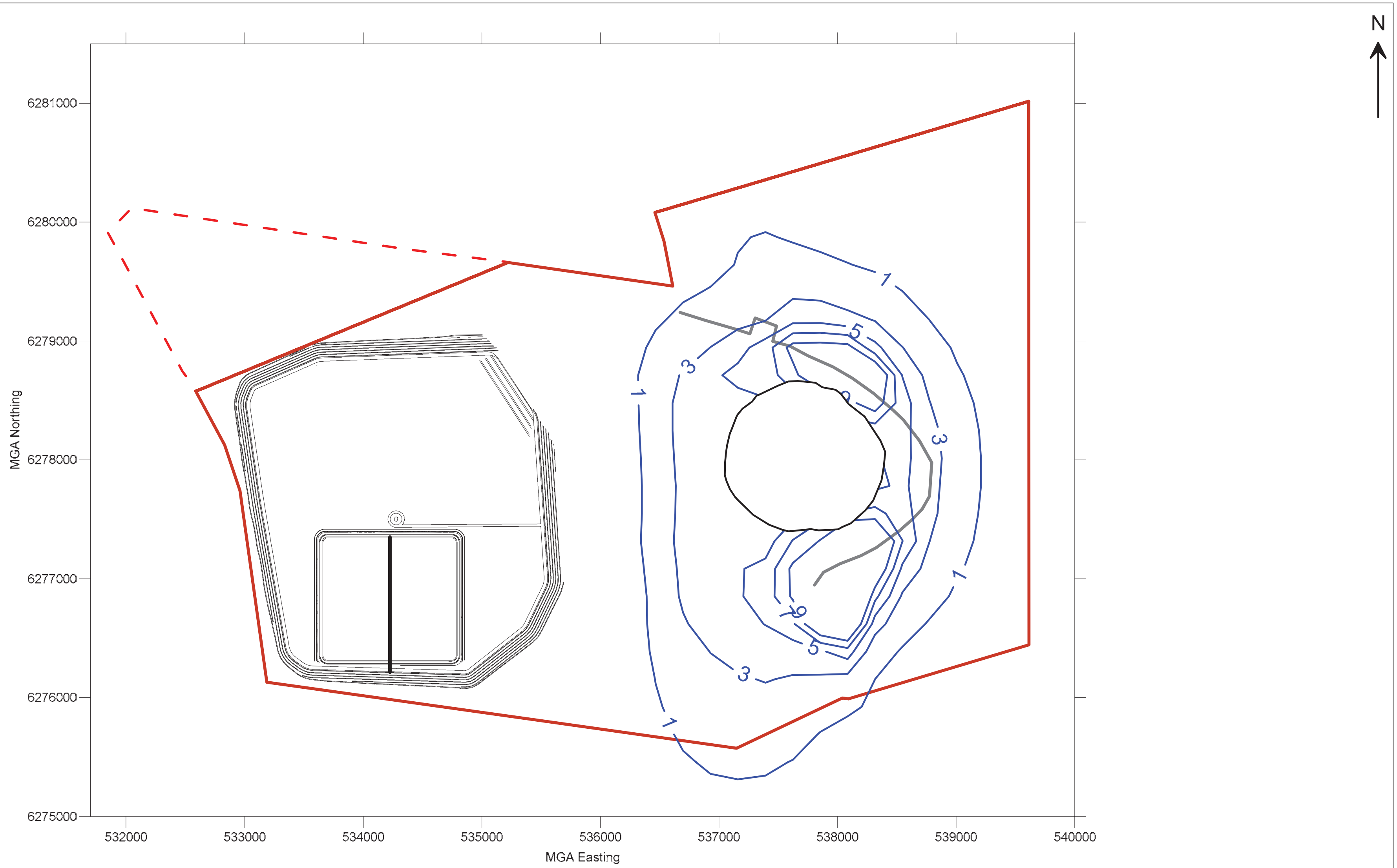
client: EVOLUTION MINING (COWAL) PTY LTD

project: COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT

title: **MODELLED GROUNDWATER HEAD IN PRIMARY ROCK UNIT AT JUNE 2032, INUNDATED LAKE**

project no: 754-SYDGE206418

figure no: **FIGURE A-30**



LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Drawdown (m)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:50,000
original size	A4

coffey
A TETRA TECH COMPANY

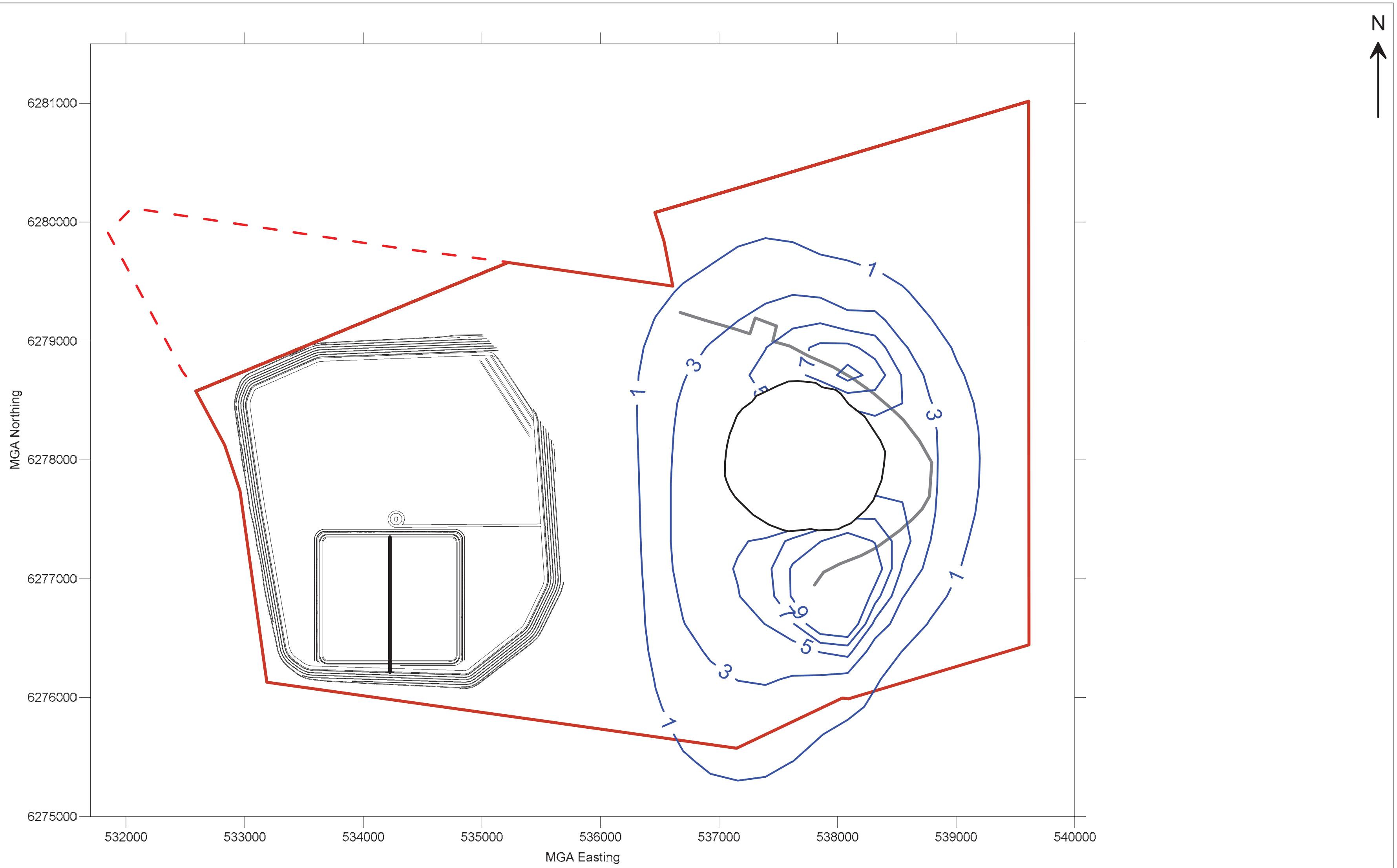
client: EVOLUTION MINING (COWAL) PTY LTD

project: COWAL GOLD OPERATIONS
PROCESSING RATE MODIFICATION
HYDROGEOLOGICAL ASSESSMENT

title: **MODELLED GROUNDWATER DRAWDOWN IN TRANS-PORTED UNIT AT END OF MINE LIFE, DRY LAKE**

project no: 754-SYDGE206418

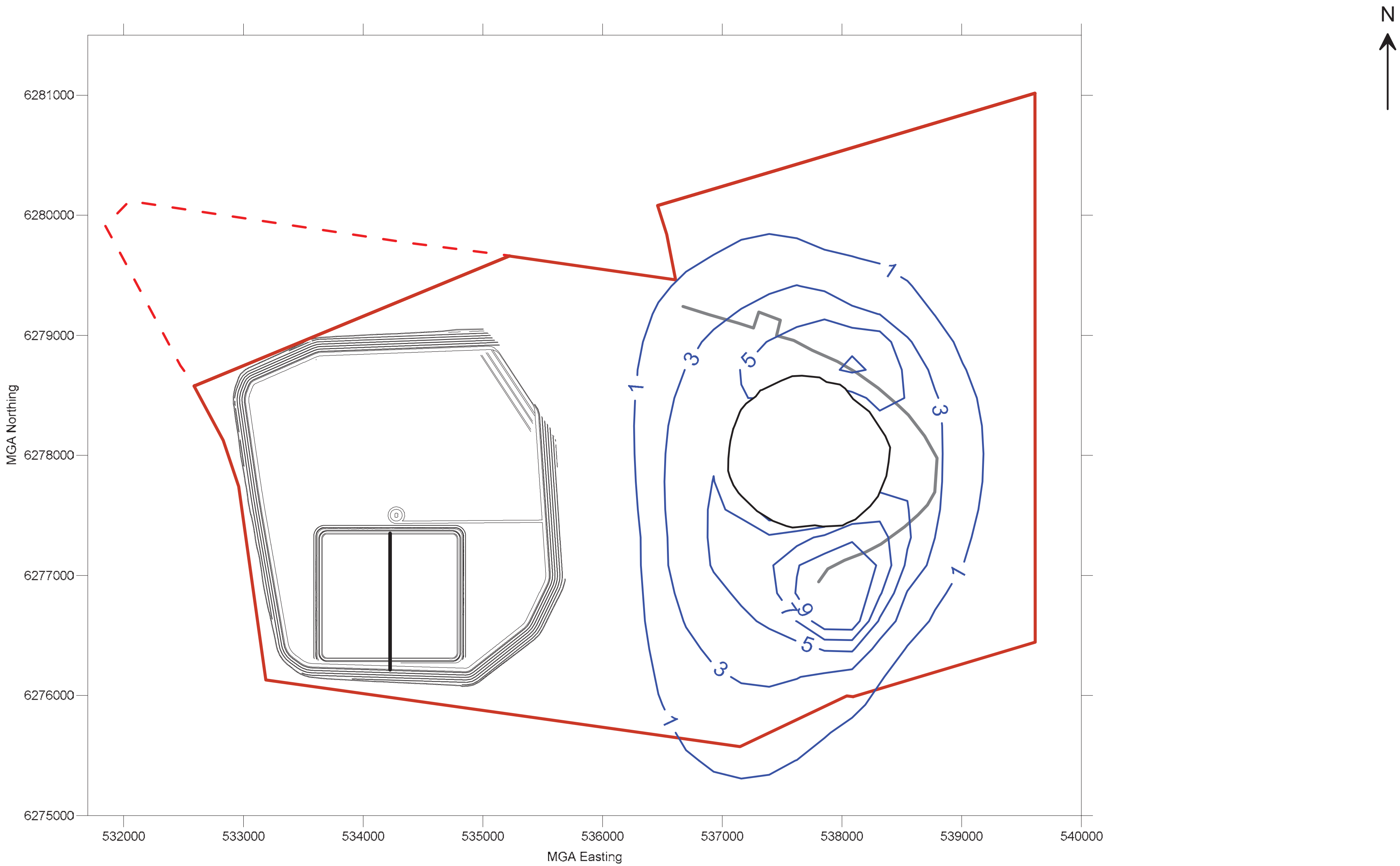
figure no: **FIGURE A-31**



LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Drawdown (m)

drawn	SE	coffey A TETRA TECH COMPANY	client: EVOLUTION MINING (COWAL) PTY LTD
approved	RJB		project: COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	09 Feb 2018		title: **MODELLED GROUNDWATER DRAWDOWN IN SAPROLITE UNIT AT END OF MINE LIFE, DRY LAKE**
scale	1:50,000		project no: 754-SYDGE206418
original size	A4		figure no: **FIGURE A-32**



LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Drawdown (m)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:50,000
original size	A4

coffey
A TETRA TECH COMPANY

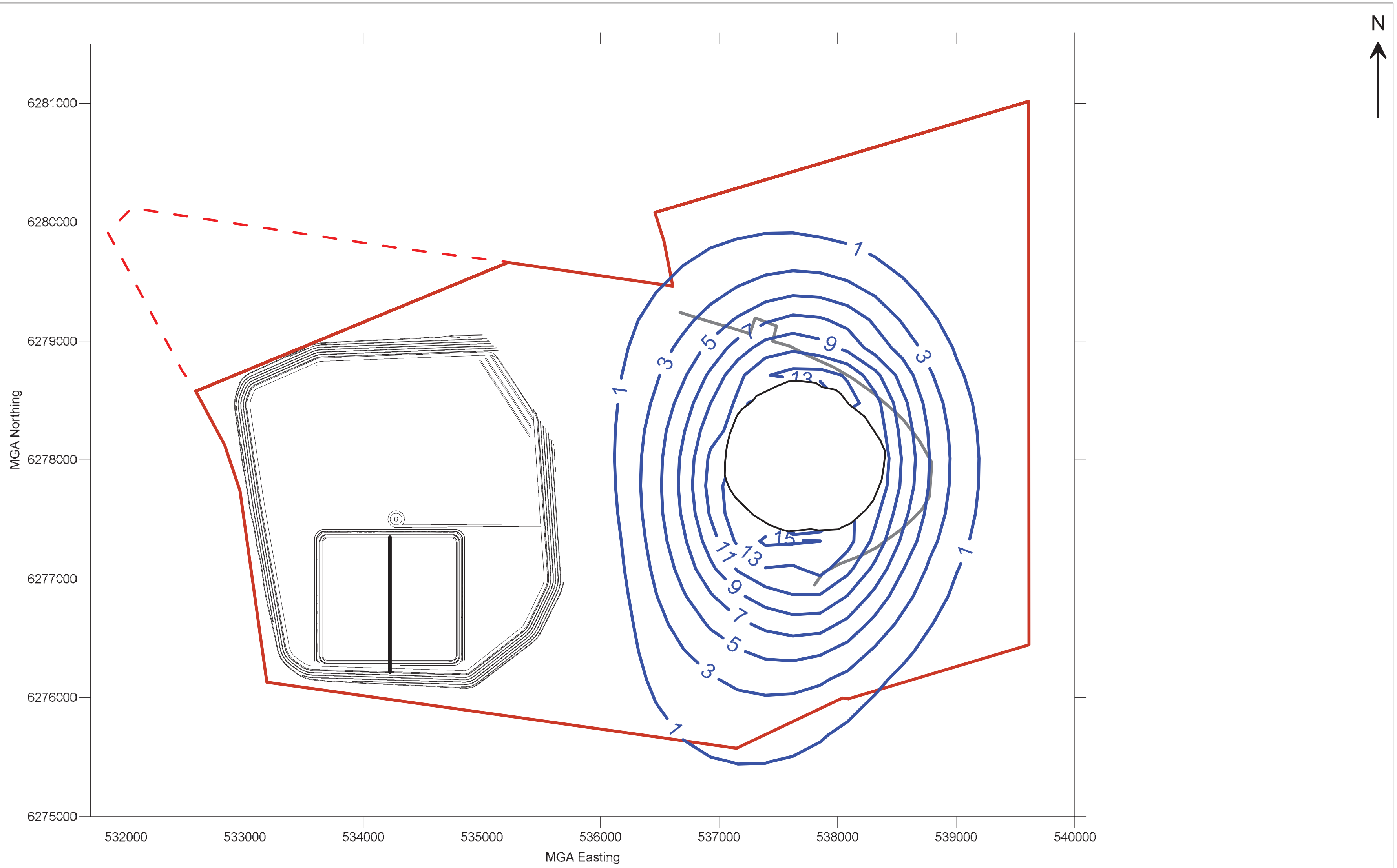
client: EVOLUTION MINING (COWAL) PTY LTD

project: COWAL GOLD OPERATIONS
PROCESSING RATE MODIFICATION
HYDROGEOLOGICAL ASSESSMENT

title: **MODELLED GROUNDWATER DRAWDOWN IN SAPROCK UNIT AT END OF MINE LIFE, DRY LAKE**

project no: 754-SYDGE206418

figure no: **FIGURE A-33**



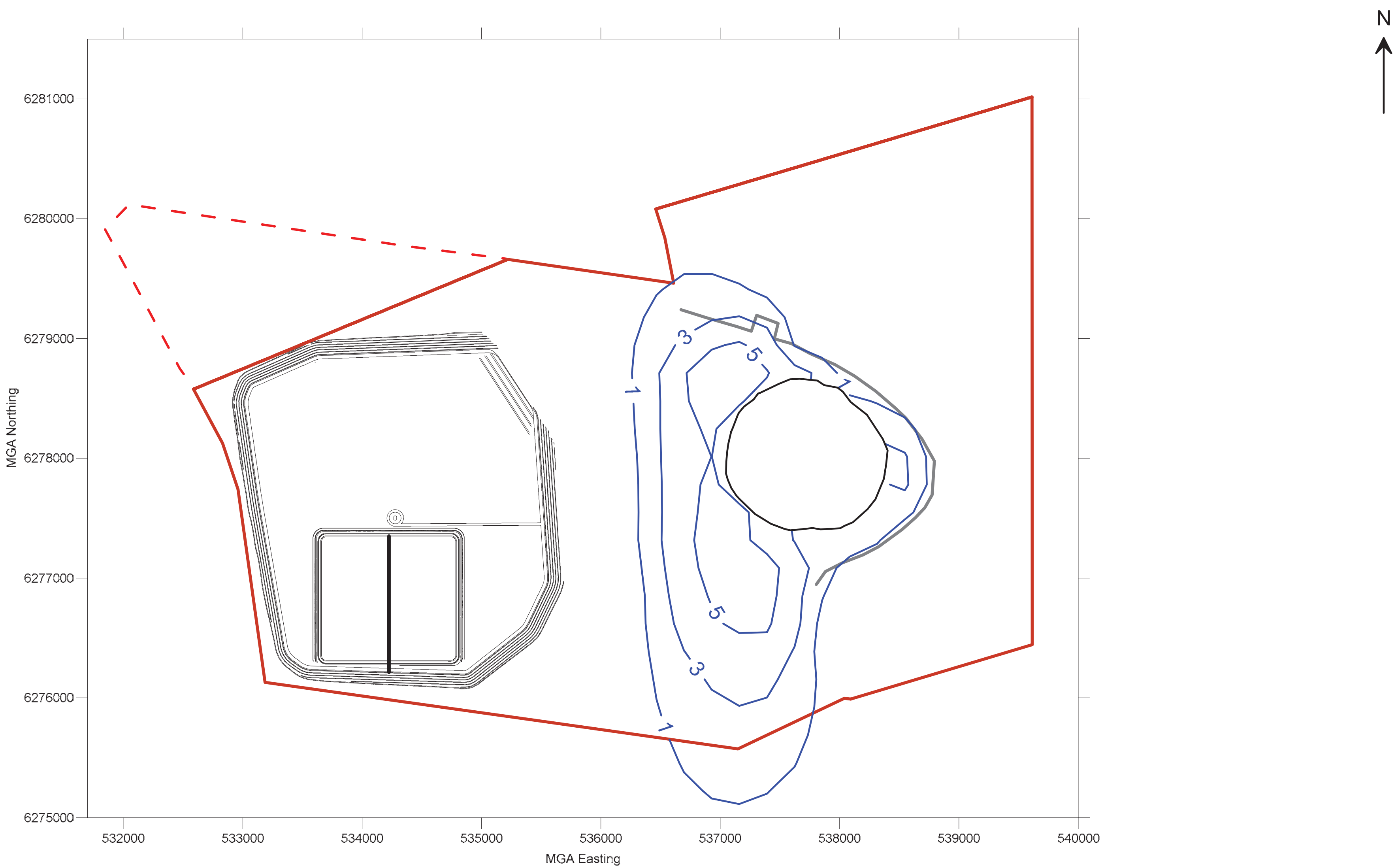
LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Drawdown (m)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:50,000
original size	A4

coffey
A TETRA TECH COMPANY

client:	EVOLUTION MINING (COWAL) PTY LTD
project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
title:	**MODELLED GROUNDWATER DRAWDOWN IN PRIMARY ROCK UNIT AT END OF MINE LIFE, DRY LAKE**
project no:	754-SYDGE206418
figure no:	**FIGURE A-34**



LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Drawdown (m)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:50,000
original size	A4

coffey
A TETRA TECH COMPANY

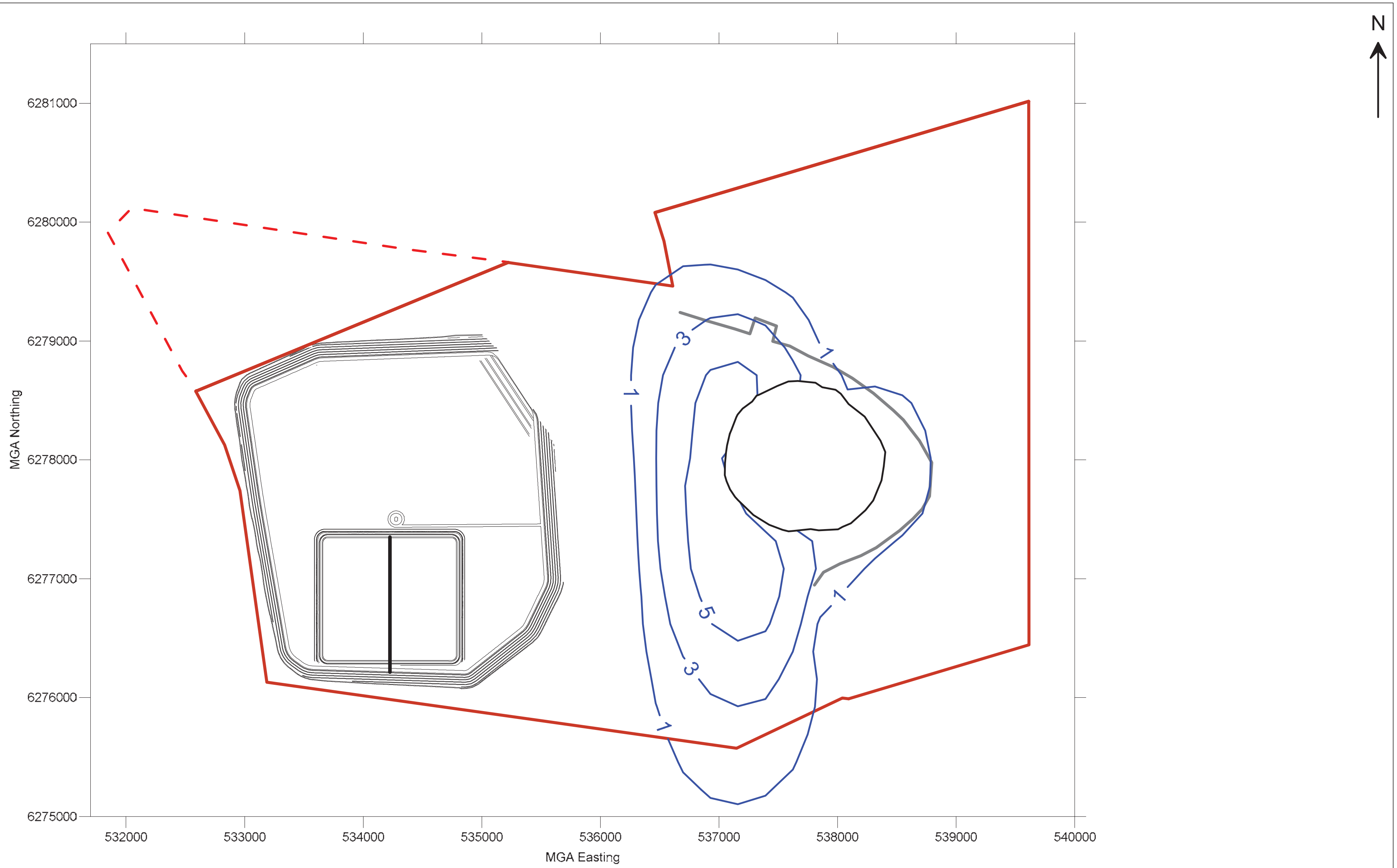
client: EVOLUTION MINING (COWAL) PTY LTD

project: COWAL GOLD OPERATIONS
PROCESSING RATE MODIFICATION
HYDROGEOLOGICAL ASSESSMENT

title: **MODELLED GROUNDWATER DRAWDOWN IN TRANSPORTED UNIT AT END OF MINE LIFE, INUNDATED LAKE**

project no: 754-SYDGE206418

figure no: **FIGURE A-35**



LEGEND

Approximate Extent of Open Pit

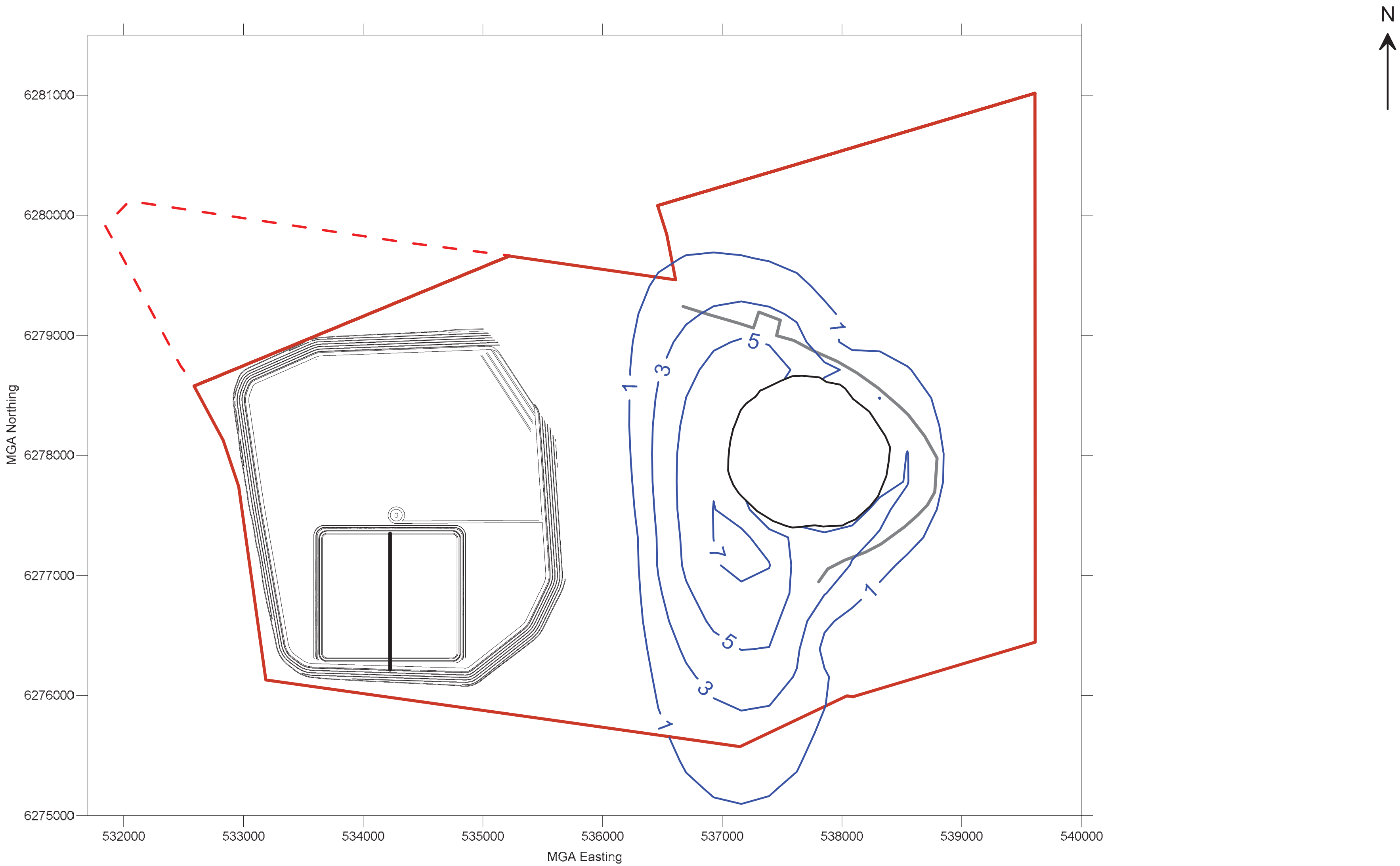
Lake Protection Bund

Mine Lease Boundary

MLA 1 Boundary

Model Predicted Groundwater Drawdown (m)

drawn	SE	coffey A TETRA TECH COMPANY	client: EVOLUTION MINING (COWAL) PTY LTD
approved	RJB		project: COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	09 Feb 2018		title: **MODELLED GROUNDWATER DRAWDOWN IN SAPROLITE UNIT AT END OF MINE LIFE, INUNDATED LAKE**
scale	1:50,000		project no: 754-SYDGE206418
original size	A4		figure no: **FIGURE A-36**



LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Drawdown (m)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:50,000
original size	A4

coffey
A TETRA TECH COMPANY

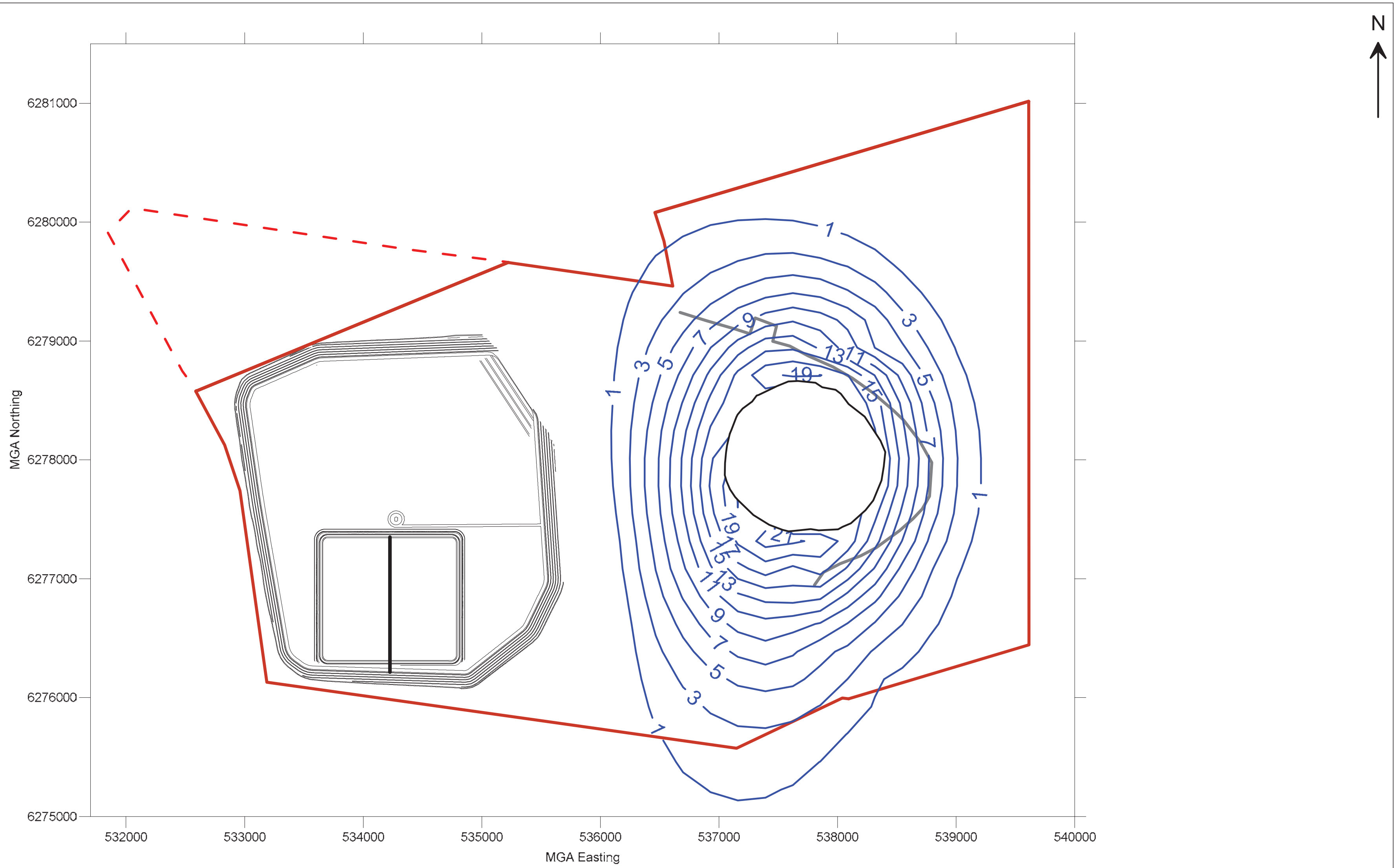
client: EVOLUTION MINING (COWAL) PTY LTD

project: COWAL GOLD OPERATIONS
PROCESSING RATE MODIFICATION
HYDROGEOLOGICAL ASSESSMENT

title: **MODELLED GROUNDWATER DRAWDOWN IN SAPROCK UNIT AT END OF MINE LIFE, INUNDATED LAKE**

project no: 754-SYDGE206418

figure no: **FIGURE A-37**



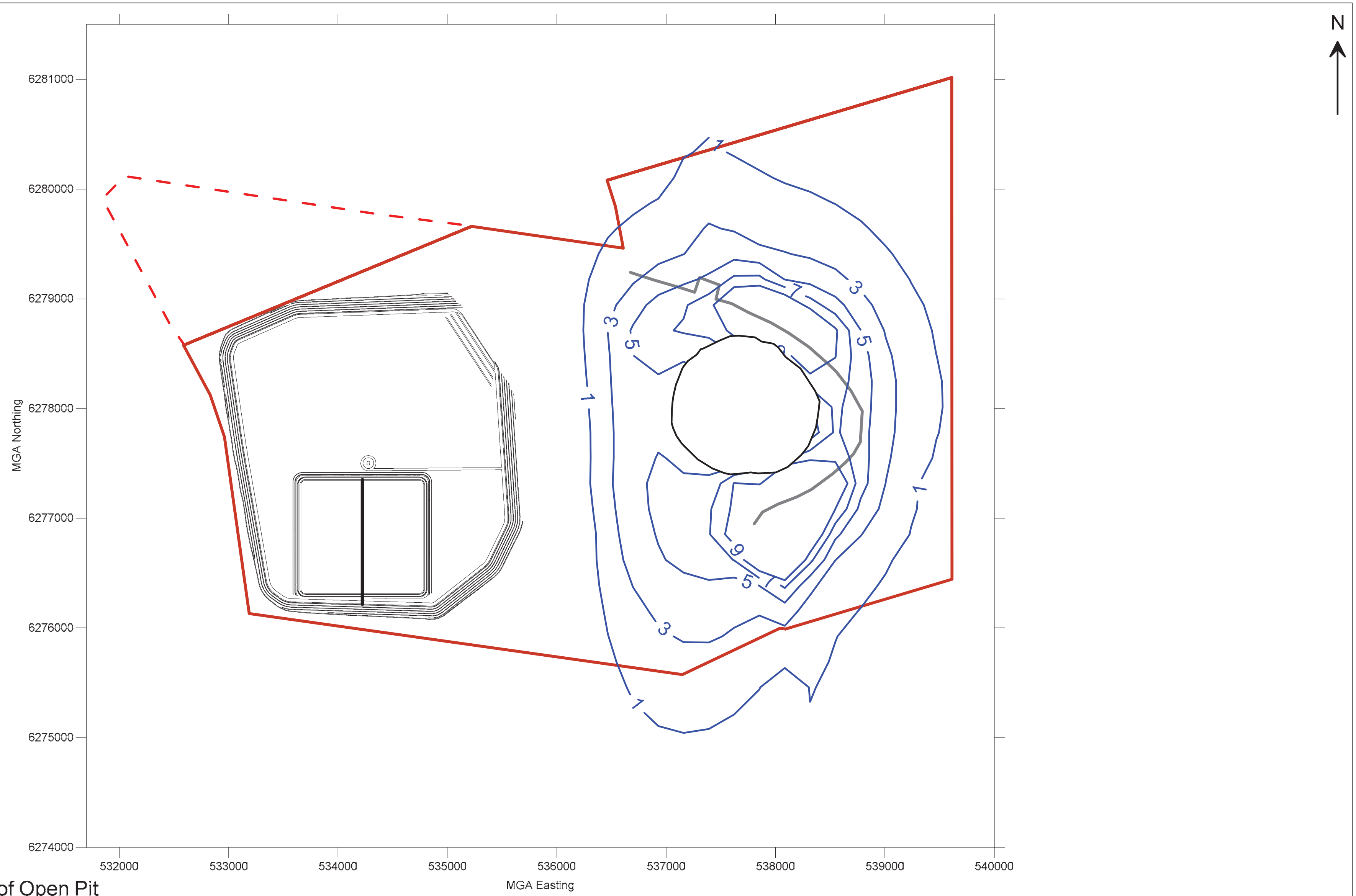
LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Drawdown (m)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:50,000
original size	A4

coffey
A TETRA TECH COMPANY

client:	EVOLUTION MINING (COWAL) PTY LTD
project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
title:	**MODELLED GROUNDWATER DRAWDOWN IN PRIMARY ROCK UNIT AT END OF MINE LIFE, INUNDATED LAKE**
project no:	754-SYDGE206418
figure no:	**FIGURE A-38**



LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Drawdown (m)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:50,000
original size	A4

coffey
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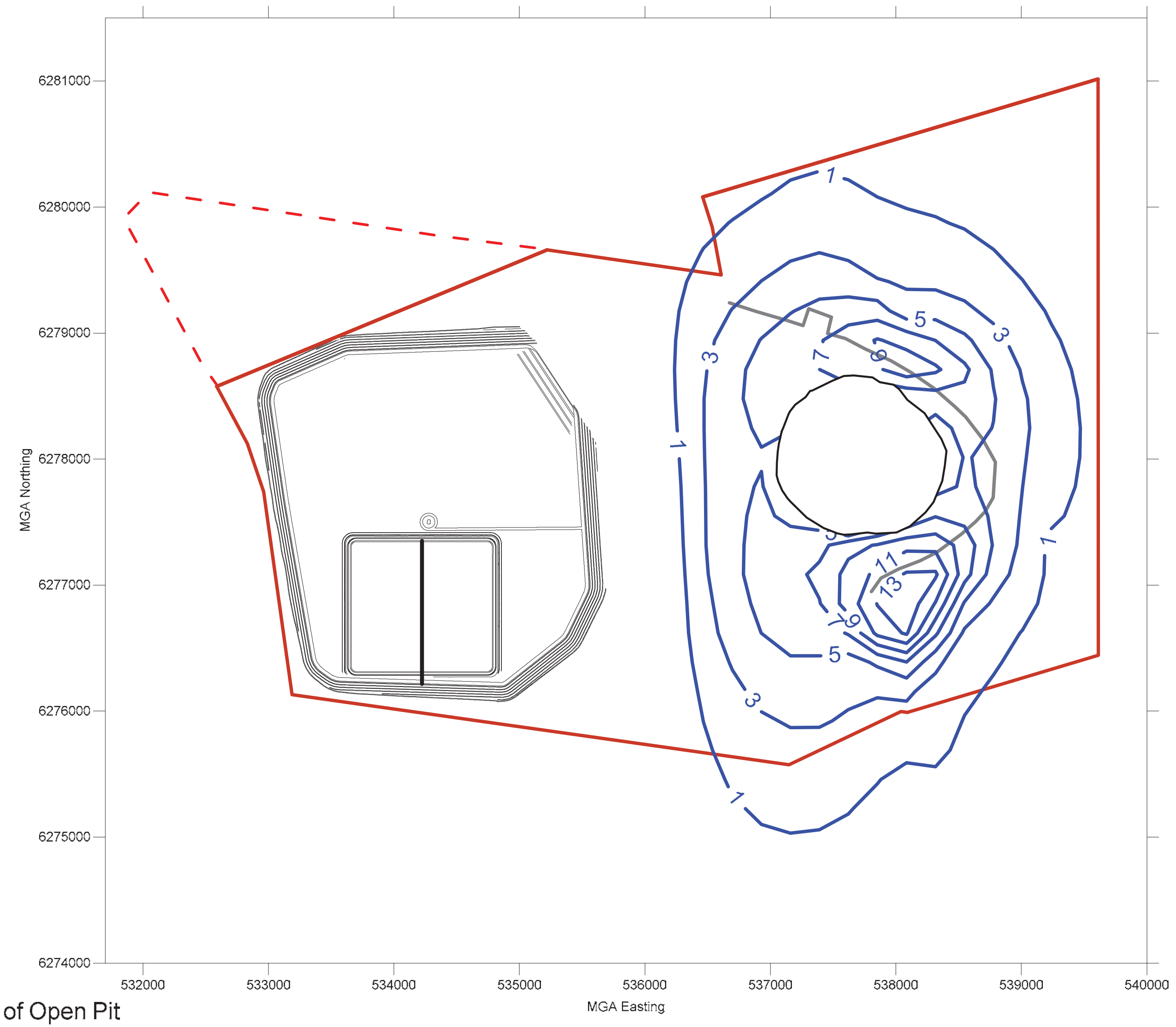
client: EVOLUTION MINING (COWAL) PTY LTD

project: COWAL GOLD OPERATIONS
PROCESSING RATE MODIFICATION
HYDROGEOLOGICAL ASSESSMENT

title: **MODELLED GROUNDWATER DRAWDOWN IN TRANSPORTED UNIT 20 YEARS POST CLOSURE, DRY LAKE**

project no: 754-SYDGE206418

figure no: **FIGURE A-39**



LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Drawdown (m)

drawn	SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	09 Feb 2018	title:	**MODELLED GROUNDWATER DRAWDOWN IN SAPROLITE UNIT 20 YEARS POST CLOSURE,DRY LAKE**
scale	1:50,000	project no:	754-SYDGE206418
original size	A4	figure no:	**FIGURE A-40**

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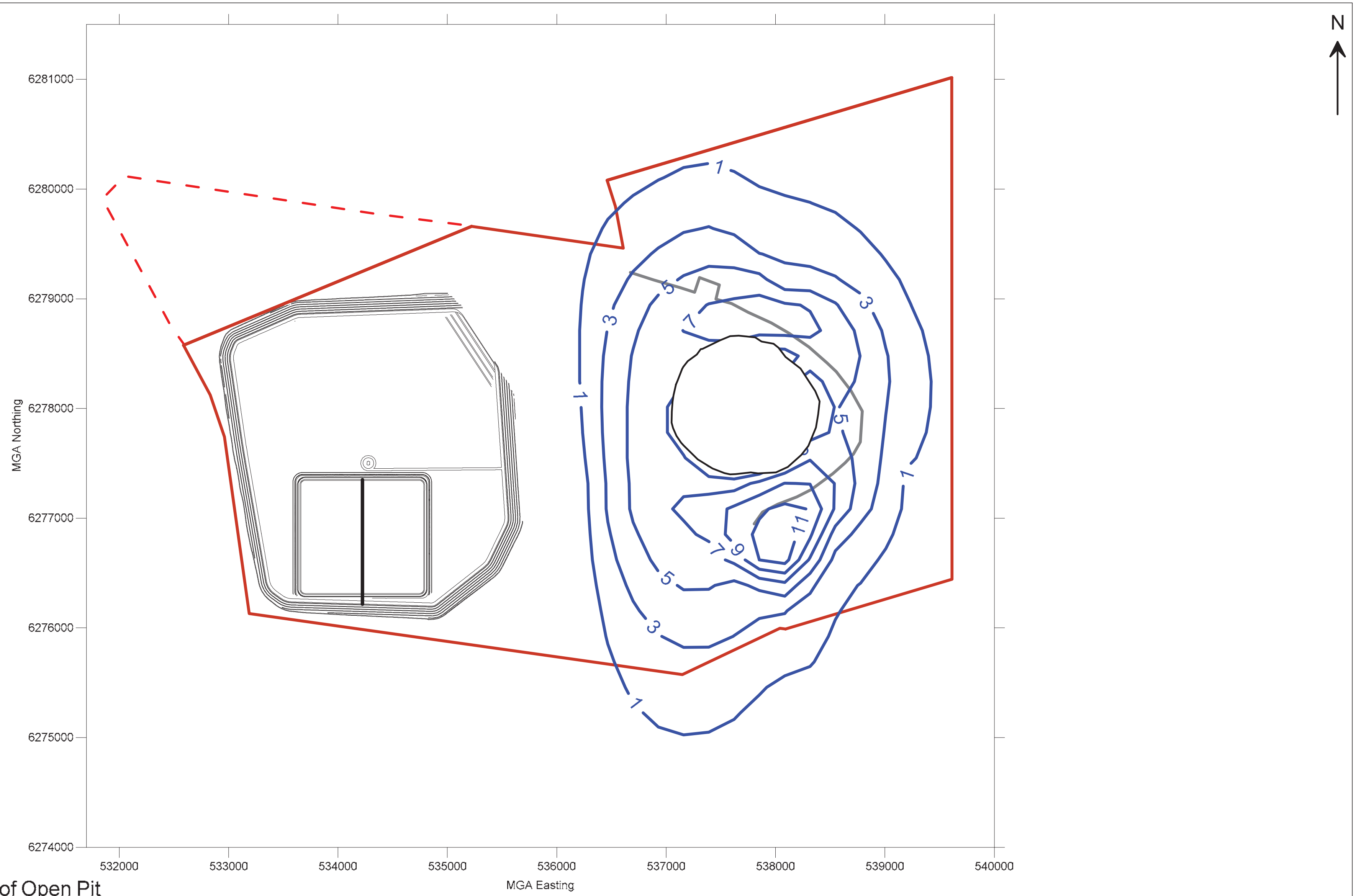

LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Drawdown (m)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:50,000
original size	A4

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A TETRA TECH COMPANY

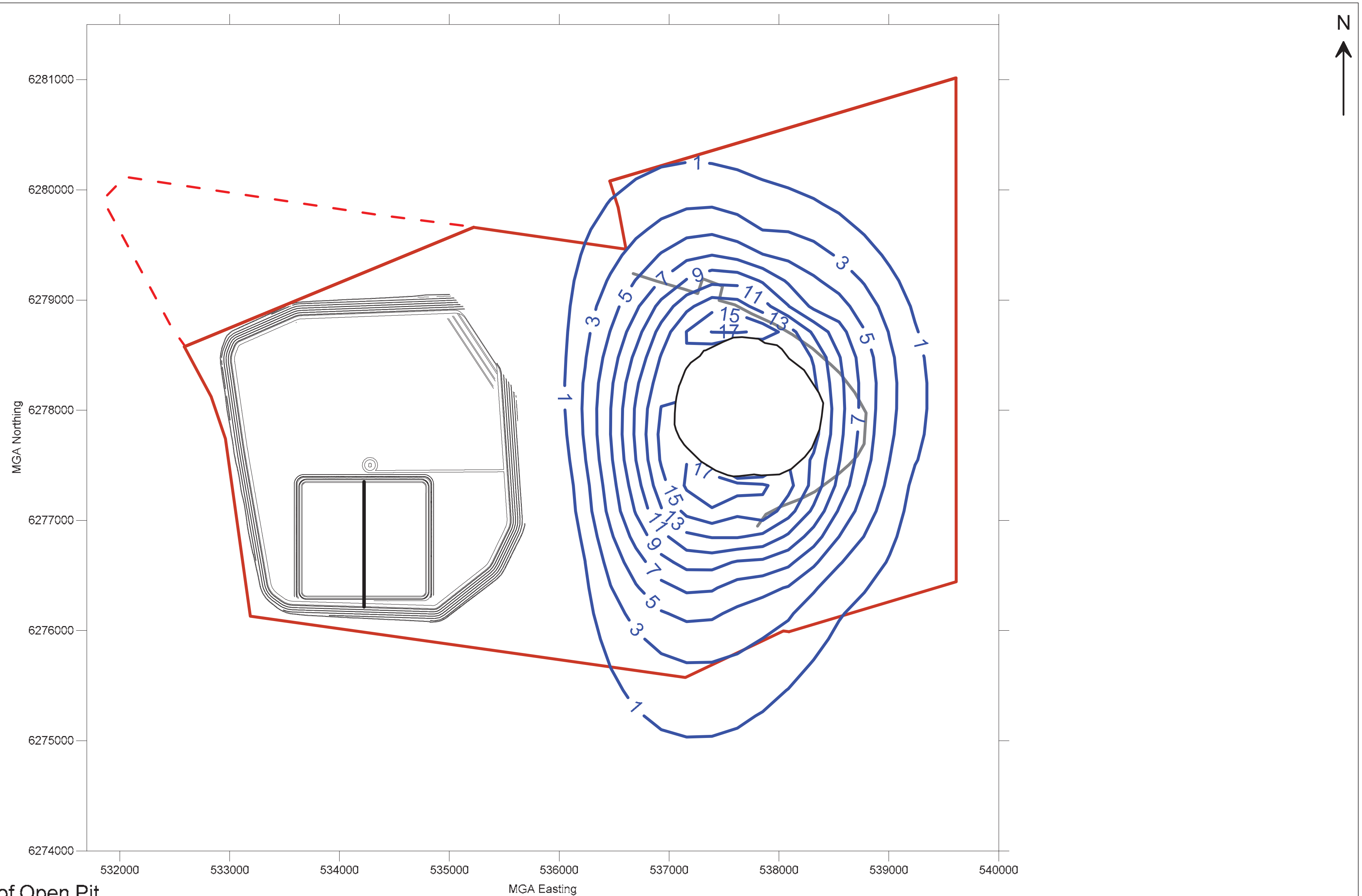
client: EVOLUTION MINING (COWAL) PTY LTD

project: COWAL GOLD OPERATIONS
PROCESSING RATE MODIFICATION
HYDROGEOLOGICAL ASSESSMENT

title: **MODELLED GROUNDWATER DRAWDOWN IN SAPROCK UNIT 20 YEARS POST CLOSURE,DRY LAKE**

project no: 754-SYDGE206418

figure no: **FIGURE A-41**



LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- MLA 1 Boundary
- Model Predicted Groundwater Drawdown (m)

drawn	SE
approved	RJB
date	09 Feb 2018
scale	1:50,000
original size	A4

coffey
A TETRA TECH COMPANY

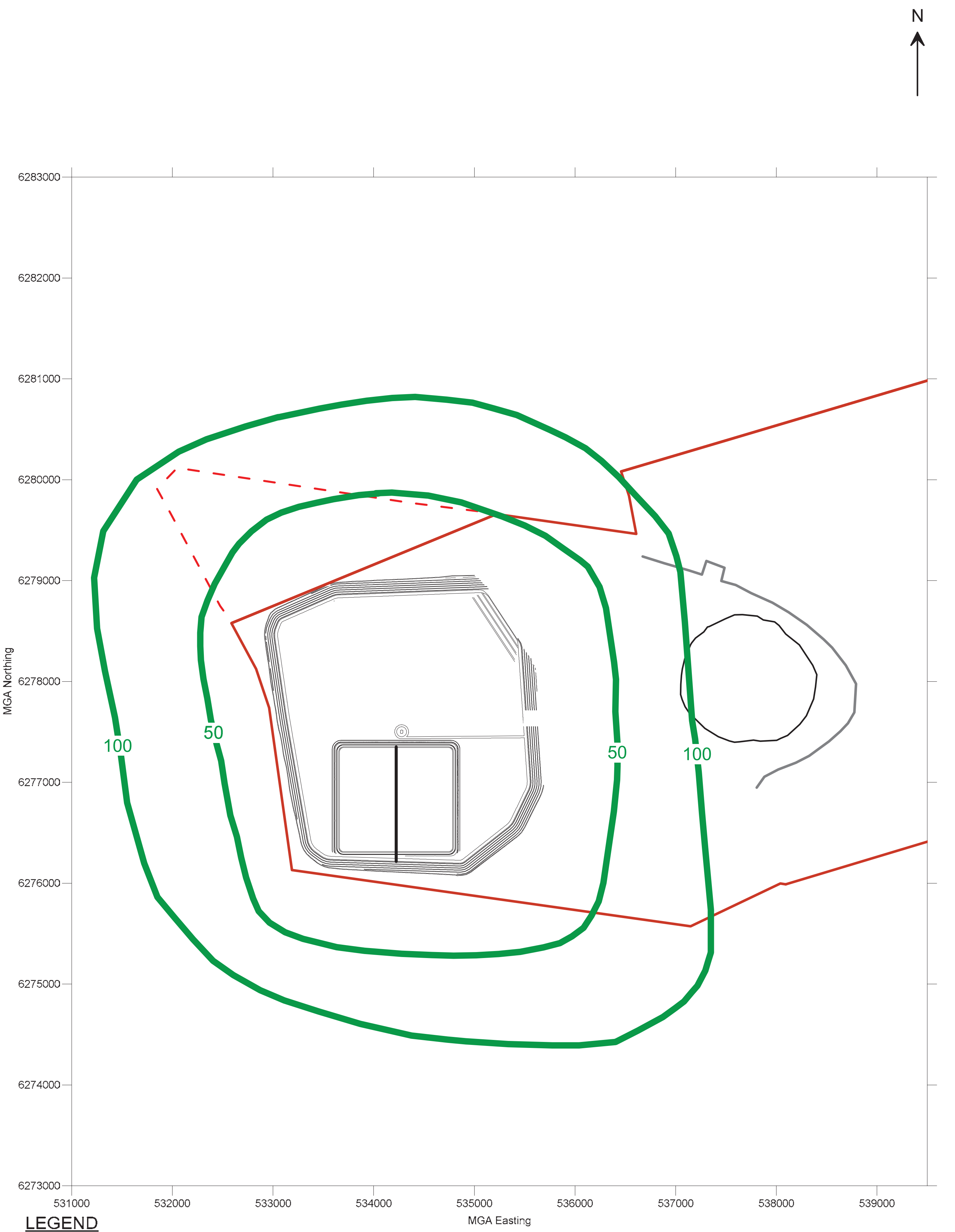
client: EVOLUTION MINING (COWAL) PTY LTD

project: COWAL GOLD OPERATIONS
PROCESSING RATE MODIFICATION
HYDROGEOLOGICAL ASSESSMENT

title: **MODELLED GROUNDWATER DRAWDOWN IN PRIMARY ROCK UNIT 20 YEARS POST CLOSURE,DRY LAKE**

project no: 754-SYDGE206418

figure no: **FIGURE A-42**



LEGEND

Approximate Extent of Open Pit

MLA 1 Boundary

Lake Protection Bund

Mine Lease Boundary

50 Possible Groundwater Quality Change for Groundwater Released From TSF Wall After Time (Years) Assuming Hydraulic Conditions at Mine Closure

drawn	SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	09 Feb 2018	title:	PREDICTED EXTENT OF GROUNDWATER QUALITY CHANGE WITH TIME IN SAPROLITE UNIT
scale	1:50,000	project no:	GEOTLCOV21910BG
original size	A4	figure no:	FIGURE A-43

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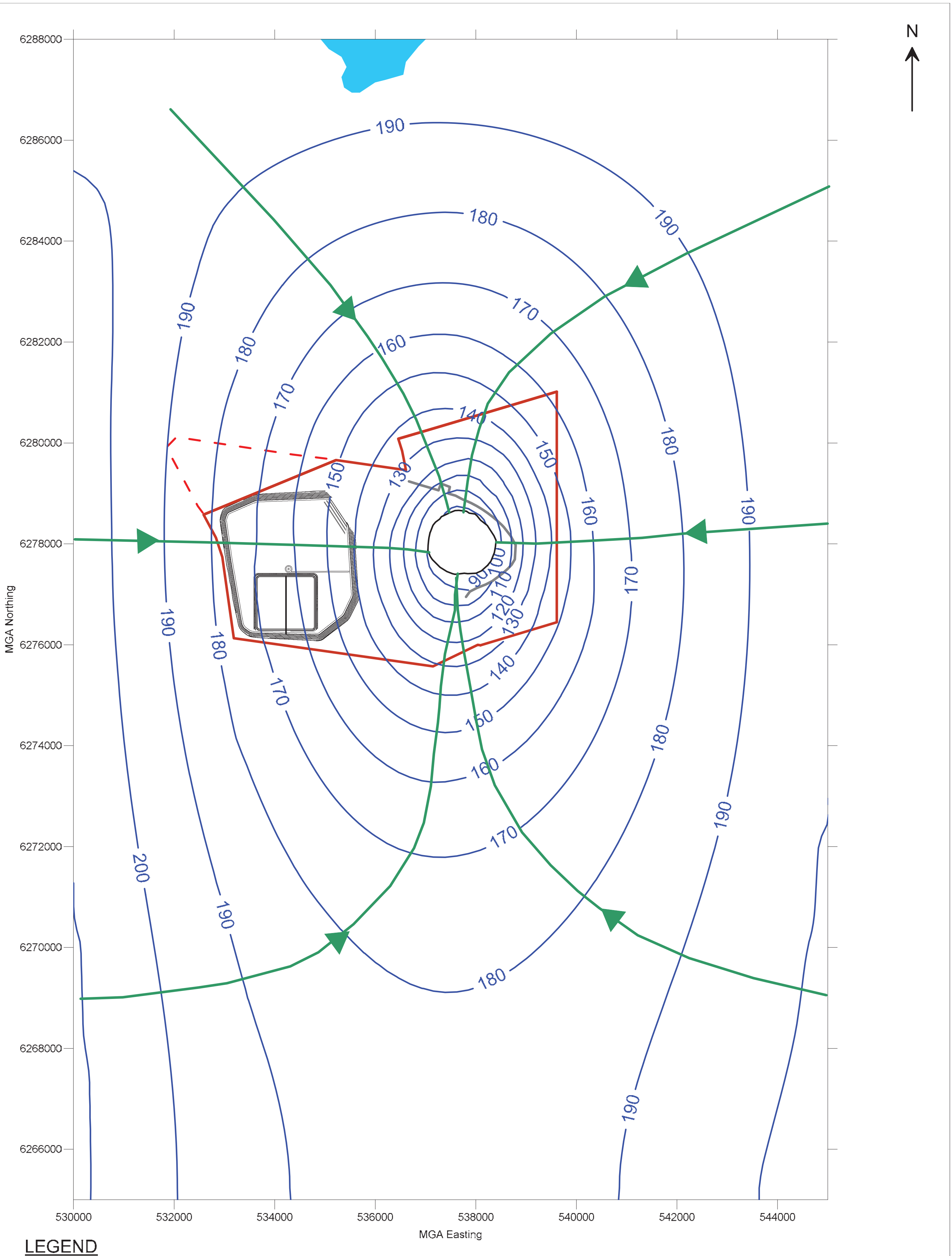

LEGEND

Approximate Extent of Open Pit

Lake Protection Bund

Mine Lease Boundary

MLA 1 Boundary

Direction of Groundwater Flow

drawn	SE	client:	EVOLUTION MINING (COWAL) PTY LTD
approved	RJB	project:	COWAL GOLD OPERATIONS PROCESSING RATE MODIFICATION HYDROGEOLOGICAL ASSESSMENT
date	09 Feb 2018		
scale	1:100,000	title:	GROUNDWATER CONTOURS AND FLOW DIRECTION IN SAPROLITE UNIT, LONG-TERM, DRY LAKE SCENARIO
original size	A4	project no:	GEOTLCOV21910BG
		figure no:	FIGURE A-44

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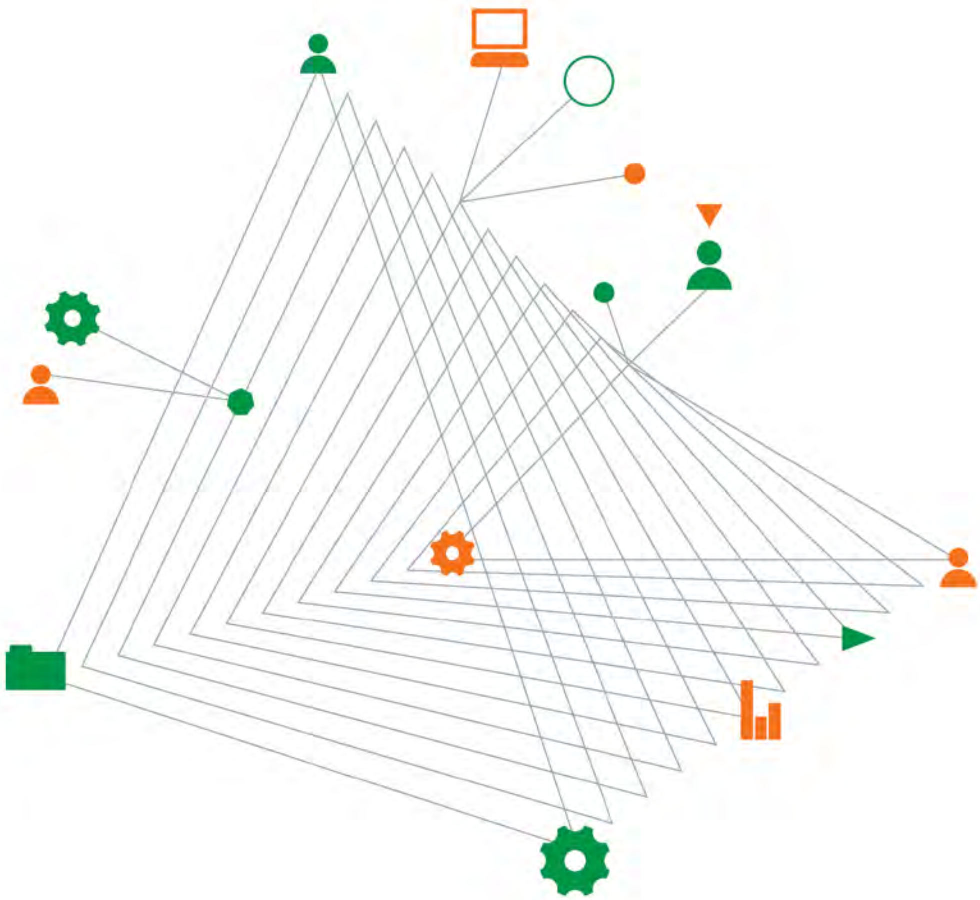
Evolution Mining (Cowal) Pty Limited

Cowal Gold Operations Processing Rate Modification (MOD 14)

Bland Creek Palaeochannel Borefield and Eastern Saline Borefield Groundwater Assessment

24 March 2018



Experience comes to life when it is powered by expertise

Cowal Gold Operations Processing Rate Modification (MOD 14)

Prepared for
Evolution Mining (Cowal) Pty Limited
PO Box 210
WEST WYALONG
NSW 2671

Prepared by
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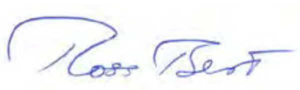
ABN: 55 139 460 521

24 March 2018

Document authorisation

Our ref: 754-SYDGE206418-BCPB

For and on behalf of Coffey



Ross Best
Senior Principal

Quality information

Revision history

Revision	Description	Date	Author	Reviewer	Signatory
Draft	CGO MOD 14 BCPB and ESB Hydrogeological Assessment	22 Jan 2018	Paul Tammetta	Ross Best	Ross Best
Final	CGO MOD 14 BCPB and ESB Hydrogeological Assessment	24 March 2018	Paul Tammetta	Ross Best	Ross Best

Table of Contents

Tables

Figures

Appendices

Executive Summary

A groundwater assessment was undertaken to assess potential impacts due to groundwater extraction from the Bland Creek Palaeochannel Borefield (BCPB) and Eastern Saline Borefield (ESB) under the proposed Processing Rate Modification to the existing Cowal Gold Operations (CGO). The assessment employed predictive numerical simulation using an existing numerical groundwater flow model. An assessment of potential impacts on the groundwater system at the mine site has been undertaken using a separate numerical groundwater flow model and is reported separately.

The NSW government monitors groundwater levels in the Lachlan Formation in each of these areas (at the request of the Bland Palaeochannel Groundwater Users Group) using the following observation bores (with respective trigger levels):

- BCPB Area: Bore GW036553 (Investigation Trigger Level 137.5 metres Australian Height Datum [m AHD] and Mitigation Trigger Level 134 m AHD);
- Billabong Area: Bore GW036597 (Trigger Level 145.8 m AHD); and
- Maslin Area: Bore GW036611 (Trigger Level 143.7 m AHD).

The regulatory constraints for BCPB pumping by CGO, under the current licences held by CGO, are understood to be as follows:

- Daily maximum of 15 megalitres (ML);
- Yearly maximum of 3,650 ML.

If the trigger levels are breached, this would trigger actions to protect the groundwater resource from overuse. Groundwater from this palaeochannel is used for mine process water by CGO. In addition to extraction for process water (from the BCPB), irrigators at the Billabong and Maslin farms also extract significant groundwater volumes from the palaeochannel. Over the period 1 July 2004 to 30 June 2017, the average total pumping rates at the largest groundwater extraction bores (4.28 Megalitres per day [ML/day] at the borefield supplying CGO, 2.56 ML/day at the Billabong bores, and 2.33 ML/day at the Maslin bore) did not result in groundwater levels falling to within 5 metres (m) of the nominated trigger levels for these monitoring bores. Pumping rates for the Billabong and Maslin bores, as used in verification analysis, involve significant assumptions.

Modelling results indicate that the BCPB can pump at a maximum rate of 4.4 ML/day, from 1 July 2017 to 31 December 2032 (in conjunction with the ESB pumping at 1.5 ML/day), without causing the water level in trigger piezometer GW036553 to fall to below the mitigation (lower) trigger level of 134 metres Australian Height Datum (mAHD). The effects of pumping at this rate were also assessed at the locations of monitoring bores GW036597 and GW036611, located 15 kilometres (km) to the south of the mine borefield. At these locations the incremental effects of pumping from the mine bores at 4.4 ML/d from 1 July 2017 to 31 December 2032 were added to a measure of low recorded groundwater levels at these locations (based on the average of the lowest four events on record). The predicted groundwater levels under these conditions remained above the trigger levels for these monitoring bores.

Maximum drawdowns at the end of mine life (2032) are approximately 38 m or less in the Lower Cowra Formation and approximately 66 m or less in the Lachlan Formation. A maximum drawdown of about 31 m (in the Lower Cowra Formation) is modelled for GW029574 (a private bore listed on the NSW Government bore register), the only known water bore installed to a depth within the Lower Cowra Formation and within 15 km of the BCPB. However, the bore is 88 m deep and may be able to continue operation if the screen is sufficiently deep. Overall, maximum modelled drawdown in the Lower Cowra Formation (including drawdown at GW029574) due to the Modification is less than the drawdown in the Lower Cowra Formation predicted for the Mine Life Modification (Coffey, 2016).

Previous simple numerical transport simulation indicates Electrical Conductivity (EC) at BLPR1 will increase by about 20 percent (%) or less, by 31 December 2032, from pre-mining concentrations.

At cessation of BCPB and ESB pumping, groundwater levels at GW036553 are predicted to recover to around 167 mAHD in 10 years (about 29 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.

1. Introduction

This report presents the results of a groundwater assessment of the Bland Creek Palaeochannel Borefield (BCPB) and Eastern Saline Borefield (ESB), both operated by Evolution Mining (Cowal) Pty Limited (Evolution) as water supplies for its Cowal Gold Operations (CGO). The CGO is located approximately 38 kilometres (km) north-east of West Wyalong in New South Wales (NSW). The BCPB and the ESB are located approximately 20 km and 30 km east of the CGO, respectively, within the Bland Creek Palaeochannel. Drawing 1 shows the locations of the BCPB and ESB in relation to the CGO.

The assessment comprised a study of potential impacts on groundwater levels and quality caused by future groundwater extraction from the BCPB and ESB, under the CGO Processing Rate Modification (the Modification).

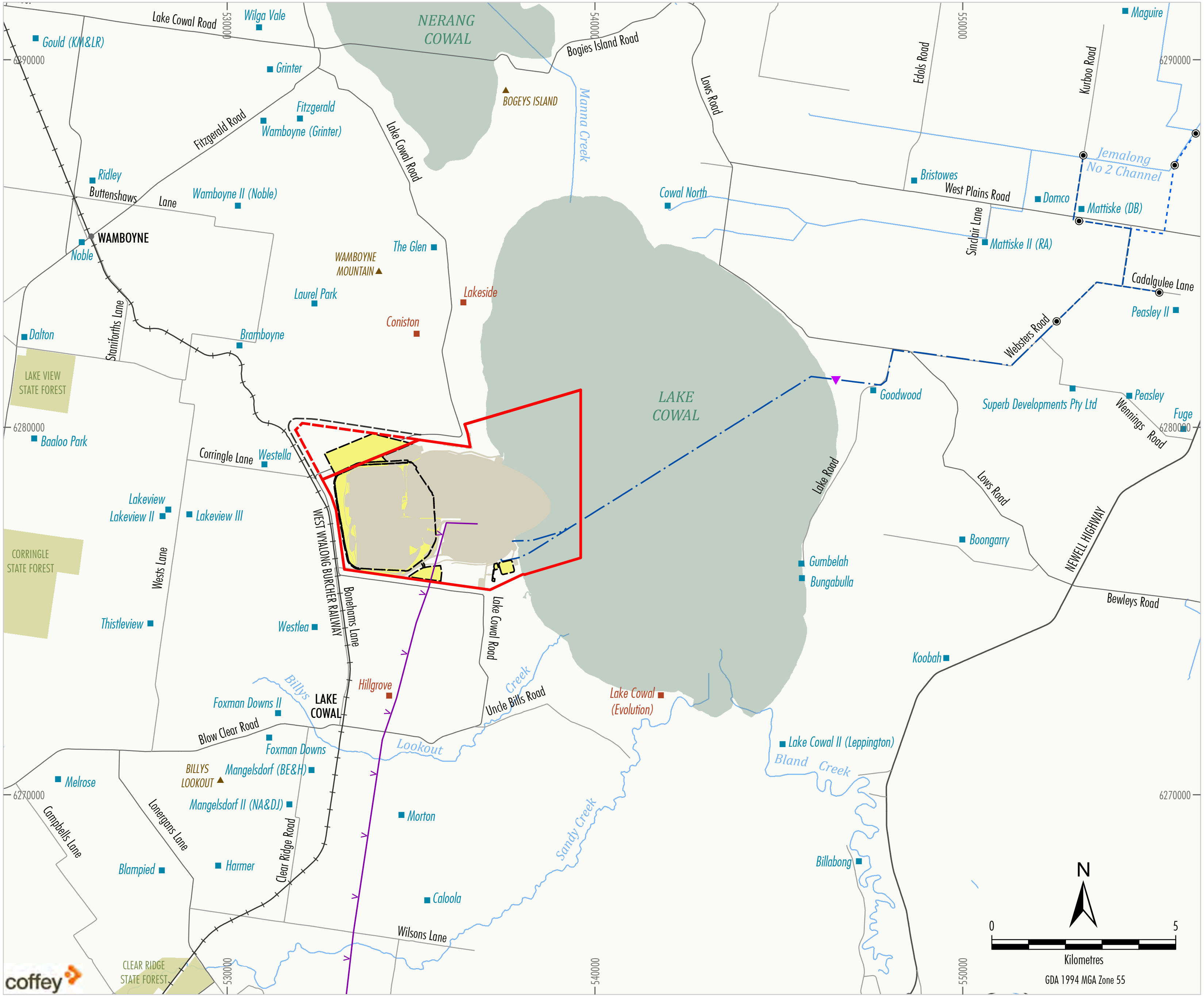
An assessment of potential impacts on the groundwater system at the CGO caused by the Modification was undertaken using a separate numerical groundwater flow model and is reported separately.

1.1. Background

Recent feasibility studies have identified potential opportunities to maximize the ore processing capacity of the CGO’s existing processing plant. On this basis, Evolution proposes to modify Development Consent DA 14/98 under section 75W of the NSW *Environmental Planning and Assessment Act*, 1979 (EP&A Act) to increase the CGO’s approved ore processing rate of 7.5 million tonnes per annum (Mtpa) to 9.8 Mtpa (herein referred to as the Modification).

The main activities associated with development of the Modification would include (refer to Figures 1.1 and 1.2):

- increasing the ore processing rate from 7.5 Mtpa to 9.8 Mtpa;
- modification of the existing Tailings Storage Facilities (TSFs) to form one larger TSF, which would also accommodate mine waste rock (herein referred to as the Integrated Waste Landform [IWL]);
- relocation of water management infrastructure (i.e. the Up-Catchment Diversion System and approved location for contained water storage D10) and other ancillary infrastructure (e.g. internal roads and soil and ore stockpiles) elsewhere within Mining Lease (ML) 1535 and Mining Lease Application (MLA) 1;
- installation of a secondary crushing circuit within the existing process plant area;
- duplication of the existing water supply pipeline across Lake Cowal;
- increased annual extraction of water from the CGO's external water supply sources;
- increased consumption of process reagents (including cyanide) and other process consumables;
- an increase in the average and peak workforce employed at the CGO;
- relocation of a travelling stock reserve (TSR) and Lake Cowal Road; and
- provision of crushed rock material to local councils to assist with road base supplies.



LEGEND

- Mining Lease Boundary (ML 1535)
- Mining Lease Application (MLA 1)
- Approximate Extent of Approved Surface Development
- Approximate Extent of Additional Modification Surface Disturbance
- Modification Component
- Company-owned Dwelling
- Privately-owned Dwelling
- State Forest
- Railway
- Electricity Transmission Line
- Mine Water Supply Pipeline
- Bland Creek Palaeochannel Borefield
- Eastern Saline Borefield
- Eastern Pump Station

Source: Evolution (2018); © NSW Department of Finance, Services & Innovation (2017)

N

0 5

Kilometres

GDA 1994 MGA Zone 55

Evolution MINING Cowal

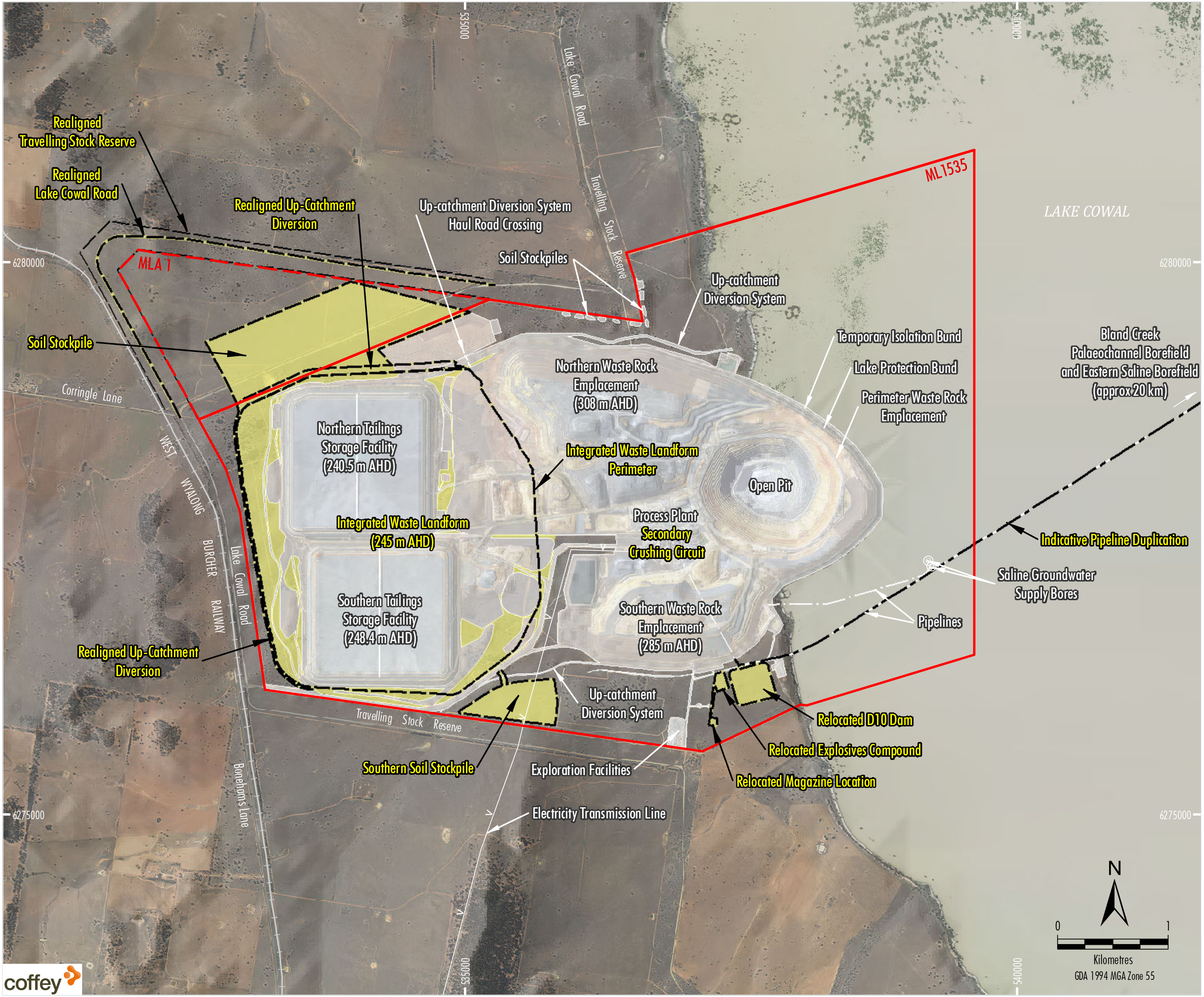
CGO PROCESSING RATE MODIFICATION

Cowal Gold Operations Location

coffey

HAL-16-41_Mod14_PRM_GW_Att_203A

Figure 1.1



LEGEND

- Mining Lease Boundary (ML 1535)
- Mining Lease Application Boundary (MLA 1)
- Approximate Extent of Approved Surface Development
- Approximate Extent of Additional Modification Surface Disturbance
- Modification Component

Source: Evolution (2018); © NSW Department of Finance, Services & Innovation (2017)
Orthophoto: Evolution (Oct 2017)

Evolution MINING
Cowal

CGO PROCESSING RATE MODIFICATION

Modification General Arrangement

HAL-16-41_Mod14_PRM_GW_Att_202A

Figure 1.2

1.2. Previous Studies

In 2006, Coffey Geotechnics Pty Ltd (Coffey) developed a 3-dimensional numerical groundwater flow model for assessing the impacts of pumping from the BCPB on the surrounding environment and other groundwater users (Coffey, 2006). This was calibrated and used for predictive analysis. In 2010, due to changes in the mine plan and the introduction of the ESB, the model was upgraded and used to assess the impacts from proposed future changes in pumping from the BCPB and ESB. The 2010 upgrade comprised the following:

- Division of the Cowra formation into two model layers (the 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.
- Inclusion of the ESB (production bores SB01 and SB02).

Due to the inclusion of an additional layer in the model, and also to ensure that the model is continually updated, the model was recalibrated at the time of the upgrade. This task included the addition of new pumping and monitoring records collected since 2006.

Predictive simulations were undertaken in 2013 and in 2016 (Coffey 2013, 2016). The latter work considered similar issues to those addressed in relation to the proposed Modification. The current assessment builds upon the 2016 work which assessed the impacts of the mining operations in relation to changes to the CGO associated with the approved Mine Life Modification.

The work undertaken in the current study uses the existing recalibrated model to simulate potential impacts on the groundwater system from operation of the BCPB and ESB under the Modification. It incorporates additional BCPB pumping measurements, and additional monitoring piezometer measurements, collected between 2016 and 2017. Refer to Coffey (2013) for a detailed description of the numerical model and the recalibration undertaken in 2010.

2. Site Characteristics

2.1. Topography

The region is characterised by a flat landscape with low undulating hills and occasional rocky outcrops. The majority of vegetation in the area has been cleared, with most of the cleared areas used for agriculture. Remnant and secondary vegetation is restricted to elevated rocky areas (SNC Lavalin Australia, 2003).

Drawing 1 shows the topography and drainage of the area. Ground slopes fall from the north-east (Lachlan Floodplain) and south-east (upper Bland Creek Palaeochannel) towards Lake Cowal. Lake Cowal forms a local depression and fills with flood water every few years. It drains north-west towards Nerang Cowal, and eventually to the Lachlan River. Breakout flows from the Lachlan River at Jemalong Gap drain towards Lake Cowal.

Ground elevations at the CGO range from around 225 metres Australian Height Datum (mAHD) on the western lease boundary to about 200 mAHD at the eastern lease boundary within Lake Cowal. The BCPB area has an elevation of just under 210 mAHD, with minimal variation. Hills formed by rock outcrops on the fringes of the Bland Creek floodplain reach to in excess of 300 mAHD.

2.2. Climate

2.2.1. Regional Averages

The closest rainfall station to the study area with long-term records is Bureau of Meteorology (BoM) Station 73054 (Wyalong Post Office), located south of ML 1535 , in the western part of the Bland Creek Palaeochannel. The closest climate station within 100 km of the site with reasonable amounts of pan evaporation data (from 1973 to 2017) is BoM Station 050052 (Condobolin Agricultural Research Station), located about 65 km to the north-west of the BCPB. **Table 1** lists average rainfall at station 73054 (1895 to 2017) and average monthly pan evaporation at station 050052. For average conditions, a rainfall deficit occurs for all months of the year.

Table 1. Average rainfall and pan evaporation in the regional area.

Month	Mean rainfall (millimetres [mm]) at Wyalong Post Office (73054)	Mean pan evaporation (mm) at Condobolin Agricultural Research Station (050052)
January	41.1	310.0
February	38.6	243.6
March	38.2	210.8
April	34.6	129.0
May	39.2	74.4
June	43.3	48.0
July	42.2	49.6
August	38.9	77.5
September	37.4	117.0
October	45.0	179.8
November	36.7	234.0
December	44.5	297.6
Annual	479.7	1971.3

2.2.2. Mine Site Rainfall

Daily rainfall data is available for the period 2004 to 2017 inclusive from the CGO site weather station. The monthly site rainfall has been correlated with annual rainfall from BoM stations 73054 (Wyalong Post Office) and 50017 (West Wyalong Airport). A study was carried out for the period 2004 to 2015 to check the correlation between rainfall at these locations. More recent data is generally consistent with the correlation indicated. Figure 2.1 illustrates the correlations.

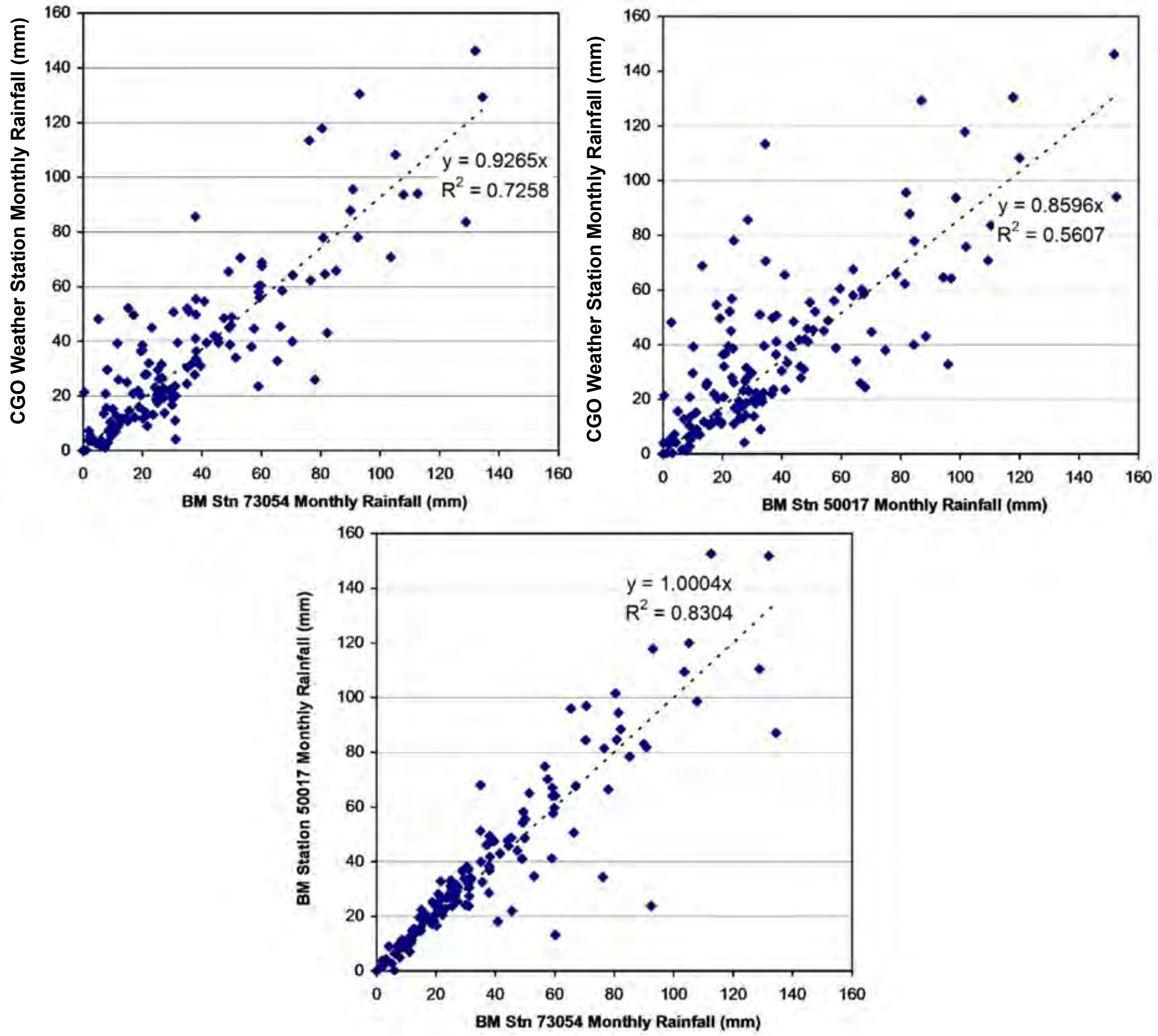


Figure 2.1. Correlation of monthly rainfall from the CGO site weather station with two BoM stations for 2004 to 2015 inclusive.

CGO site rainfall correlates reasonably with station 73054 but less so with station 50017. The residuals normality for station 50017 with the CGO site and station 73054 is poor. CGO site monthly rainfall is an average of 93% of station 73054 rainfall. By corollary, the long-term average annual rainfall at the CGO site is estimated to be 444 mm.

2.3. Surface Drainage

The main water courses in the BCPB area are Bland and Barmedman Creeks (Drawing 1). These are ephemeral and drain into Lake Cowal (also ephemeral), from the south. An extensive irrigation canal system is also present at the BCPB area and to the north. These canals deliver water to irrigators to sustain the local agricultural industry.

Flow gauging data from government flow gauge 412103 (Bland Creek at Morangarell) was available for the period 1976 to 2003. This gauge has a catchment area of 3,110 km^2 and is located in the Burragorang Palaeochannel, about 10 km south of the southern boundary of the modelled area. A review of the flow data for this period indicate the following:

- No flow for 61% of the period (the minimum measurable flow is 0.1 Megalitres per day [ML/day]).
- An average flow over all days of 117 ML/day.
- An average flow over all days of measurable flow (39% of the period) of 298 ML/day.
- A maximum recorded flow of 17,854 ML/day (on 27 July 1993).

A baseflow analysis was undertaken for flow data from gauge 412103 using the local minimum method, implemented using the program BFI and the procedure of Wahl and Wahl (1995). This implementation is based on the deterministic procedure proposed by the British Institute of Hydrology (1980a, 1980b). Using this method, baseflow is estimated by analysing the minima in streamflow time series when partitioned into N-day periods. Unlike filtering methods, the local minimum method cannot calculate baseflows that are greater than streamflow, and makes no assumptions about recession character. Based on experience, and the preferred use of the method by overseas agencies, this method is considered superior to filtering for extraction of baseflow magnitudes. Results of the analysis indicate that baseflow was an average of 0.3% of rainfall between 1977 and 2000.

Lake Cowal is an ephemeral shallow freshwater lake that is filled by runoff from the Bland Creek catchment to the south and flood breakout from the Lachlan River to the north-east. The pit envelope impedes on the lake area, and a lake protection bund and dewatering programme form an integral part of the mine plan. At the overflow (full storage) level of about 205.7 mAHD the lake overflows into Nerang Cowal, another ephemeral lake to the north, and then into Bogandillon Swamp before returning to the Lachlan River. The base of the lake is at about 201.5 mAHD. Figure 2.2 shows available lake water level observations compared to flow at gauge 412103. When the lake is draining, water levels show a quasi-logarithmic fall. Below the full storage level, the rate of water level fall is approximately linear with time. An analysis of eight recession events was undertaken. For each event, the time period was selected such that other data suggest negligible inflows to the lake from creeks and surface runoff were occurring. For each event, pan evaporation and direct rainfall to the lake water body were taken into account. The average fall in lake water level (accounting for rainfall) from the events was equal to 80% of pan evaporation. This is similar to recorded rates of water level fall for large shallow lakes that contain suspended and dissolved solids in a semi-arid climate. Results indicate that transfer of groundwater to or from Lake Cowal is low, with the precision of the results being less than that required to quantify the transfer.

Irrigation canals are extensive and most of their combined reach appears to be unlined. These channels serve as artificial water courses to deliver water for local agriculture but are ephemeral (they are mainly use during the growing season). One of the main channels in the area (the Warroo channel) has been reported as suffering losses through seepage from the channel base (van der Lely, 1993), estimated at around 2,000 ML/year but potentially ranging between 500 and 6000 ML/year.

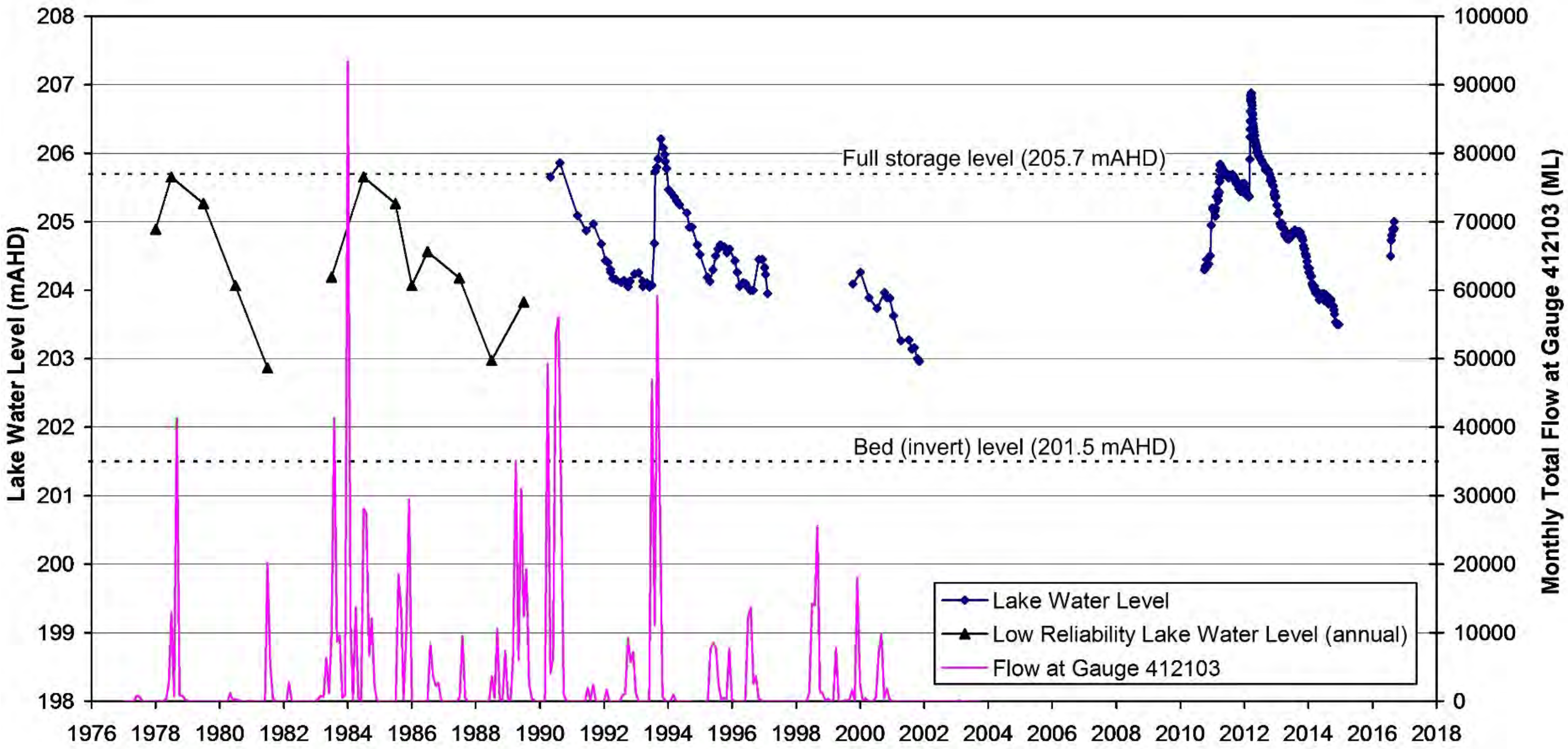


Figure 2.2. Observed water levels in Lake Cowal and flow at gauge 412103.

2.3.1. Recharge to the Water Table

Studies of groundwater chemistry in the Bland Creek Palaeochannel (Carrara et al., 2004) indicate that the Thuddungra region is a recharge area for the Lachlan and Cowra Formations. Results also suggest that the Lachlan Formation shows a generalised preferential lateral groundwater flow system, without significant vertical recharge except in the Thuddungra region. In contrast, results suggest that the shallow part of the Cowra Formation comprises a system where recharge to the groundwater system is dominated by vertical infiltration at the surface, and lateral groundwater flow is limited and local.

Anderson et al. (1993) estimated that recharge through the base of stream channels and over-bank flooding are the dominant recharge processes in the Lachlan Valley. The amount of recharge provided by this process in the Bland Creek Palaeochannel is difficult to assess due to the impact of pumping on groundwater monitoring hydrographs. Minor flooding occurs intermittently in the palaeochannel area, however surface sediments in this area are less permeable than further north in the Jemalong / Wyldes Plains Irrigation District and the main Lachlan Valley, likely resulting in lower recharge from this source compared to the Lachlan Valley.

Coffey (1994) estimated a total accession rate (irrigation deep drainage and rainfall infiltration) to the groundwater system, from numerical model calibration, of between nil and 18 millimetres per year (mm/year) for the Upper Cowra Formation in the Jemalong / Wyldes Plains Irrigation District. The higher infiltration rates were restricted to a 10 km-wide zone south of the Lachlan River. The overall average calibrated recharge to the Upper Cowra Formation between Lake Cowal and the Lachlan River was around 10 mm/year or around 2% of average rainfall.

Ross (1982) estimated that 1.25% of rainfall accedes to the groundwater system in the low salinity groundwater areas of the Upper Lachlan Valley.

Williams (1993) estimated that long-term increases in groundwater storage in the Upper Cowra Formation in the Jemalong / Wyldes Plain Irrigation District were a minimum of about 5.2 mm/year (about 1% of incident rainfall, assuming a refillable void space of 5% at the water table). Results did not allow separate identification of contributions made by flooding, rainfall, and irrigation.

Cook et al (2001) estimated rainfall recharge over agricultural land of the Mallee region near the Murray River (average rainfall 300 to 400 mm/year). Results indicated deep drainage rates varying between 3 mm/year (0.9% of annual rainfall) and 30 mm/year (9% of annual rainfall) at crop rotation sites with average clay contents in the upper 2 m of the surface soil profile varying between 30% and 2% respectively.

Numerical modelling by Williams (1993) for the upper 20 m of the Cowra Formation indicated that evaporation from surface ponding caused by groundwater seeps was occurring in several locations in the more topographically depressed area in the vicinity of the Corinella Constriction.

Hydrograph Analysis for the BCPB Area

With the area characterised by high rates of irrigation, an assessment was undertaken for the area east of Lake Cowal to estimate zones where recharge to the water table is likely to be controlled mainly by rainfall or irrigation. This was the only area in the model domain where significant amounts of water table hydrographs were available (from monitoring piezometers maintained by Jemalong Irrigation Limited [JIL], for the period 1994 to 2006).

The assessment compared piezometer hydrographs to the cumulative monthly rainfall residual. Hydrographs showing a significant correlation with the rainfall residual were classified as being influenced mainly by rainfall. Irrigation may still have been active in these areas, however its influence was interpreted as secondary. Hydrographs showing a characteristic trend of rise during dry conditions were classified as irrigation-dominated.

Figure 2.3 shows the results of the assessment. Piezometer names are a single number. The pattern identifies the area where irrigation is affecting the water table. Recharge will thus vary across the area. Areas with irrigation-dominant recharge may have larger groundwater recharge. The numerical model adopts a single average rate which takes into account the irrigation process, however further south there are fewer tracts of land that are irrigated. Irrigation practices add a degree of approximation to the recharge rate used in the model.

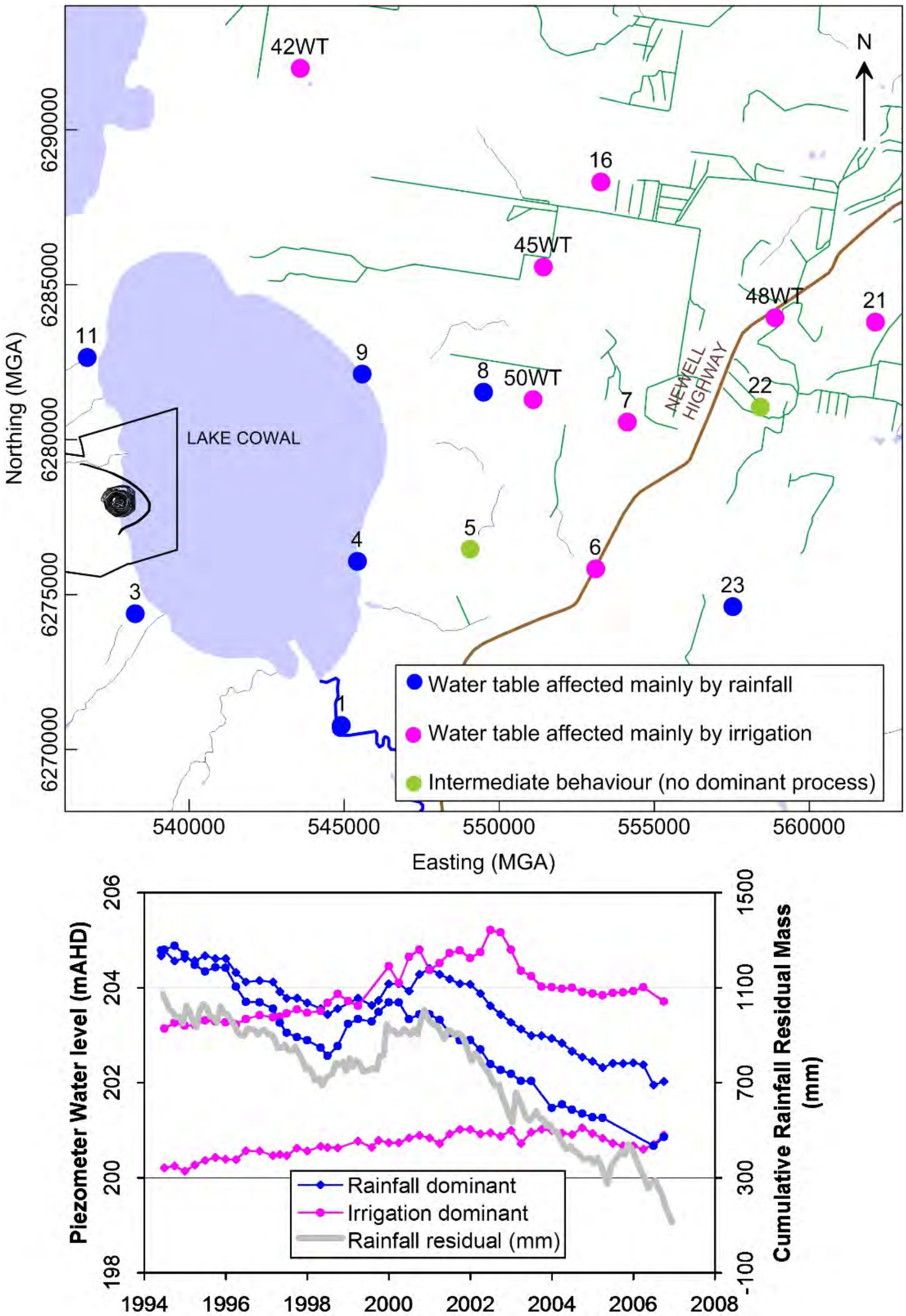


Figure 2.3. Spatial relationship of water table piezometers (maintained by Jemalong Irrigation Limited) classified according to the dominant influence on their hydrographs. Integers at piezometer locations are their names.

2.4. Geology

A detailed discussion of the geology of the area is made in Coffey (2013). A summary is provided below.

The alluvial sequence in the study area consists of the Cowra Formation and the underlying Lachlan Formation. The Lachlan Formation is the main aquifer in the study area. The Cowra Formation has lower hydraulic conductivity (K) and higher groundwater salinity.

The Cowra Formation comprises predominantly stiff red/yellow/brown high plasticity clay (grading to grey at depth) with intermittent sand and silt horizons. The base of the Cowra formation is generally marked by a conspicuous multi-coloured clay layer. Geophysical (gamma) logs and hydraulic test data for bores in the vicinity of the BCPB suggest that the Cowra Formation can be divided into upper and lower sequences. The base of the Upper Cowra sequence is assessed to be at about 47 m below ground level at the BCPB.

The Lachlan Formation consists of light grey fine to coarse-grained sand and fine to medium gravel, mostly composed of smoky quartz, chert, and wood fragments. The Lachlan Formation is underlain by bedrock. Between 2 m and 5 m of clay lies between the base of high K sediments in the Lachlan Formation and the top of bedrock, however in some places the clay is absent. The clay is interpreted to mostly consist of residual weathered product of underlying rocks. The modelled extent of the Lachlan Formation includes lower K sediments surrounding the high permeability sands and minor gravels in the deeper parts of the palaeochannel. The high K sands and minor gravels appear to be located adjacent to steep bedrock surface gradients within the deeper parts of the palaeochannel. The spatial variation in high and low conductivity sediments in the Lachlan Formation indicates that the high conductivity part of the Lachlan Formation bifurcates just north of Marsden.

A constriction in the bedrock surface occurs to the north of the BCPB at Corinella, and is referred to as the Corinella Constriction.

2.5. Subsurface Hydraulic Properties

2.5.1. Hydraulic Conductivity

For previous studies, a large database was compiled of K measurements from *insitu* hydraulic testing. The database consists of the following:

- 26 single rate pump tests conducted at the CGO.
- 3 packer tests in volcanic rocks conducted at the CGO.
- 2 long-term single rate pump tests conducted at two saline borefields (at other sites, not the CGO).
- 6 long-term single rate tests conducted at the BCPB.
- 102 estimates of K from specific capacity data in government records for private water bores. 45 estimates are for the Lachlan Floodplain (north of the Corinella Constriction). Appendix A shows the method used to obtain K from specific capacity.

Figure 2.4 shows the K database developed from these measurements.

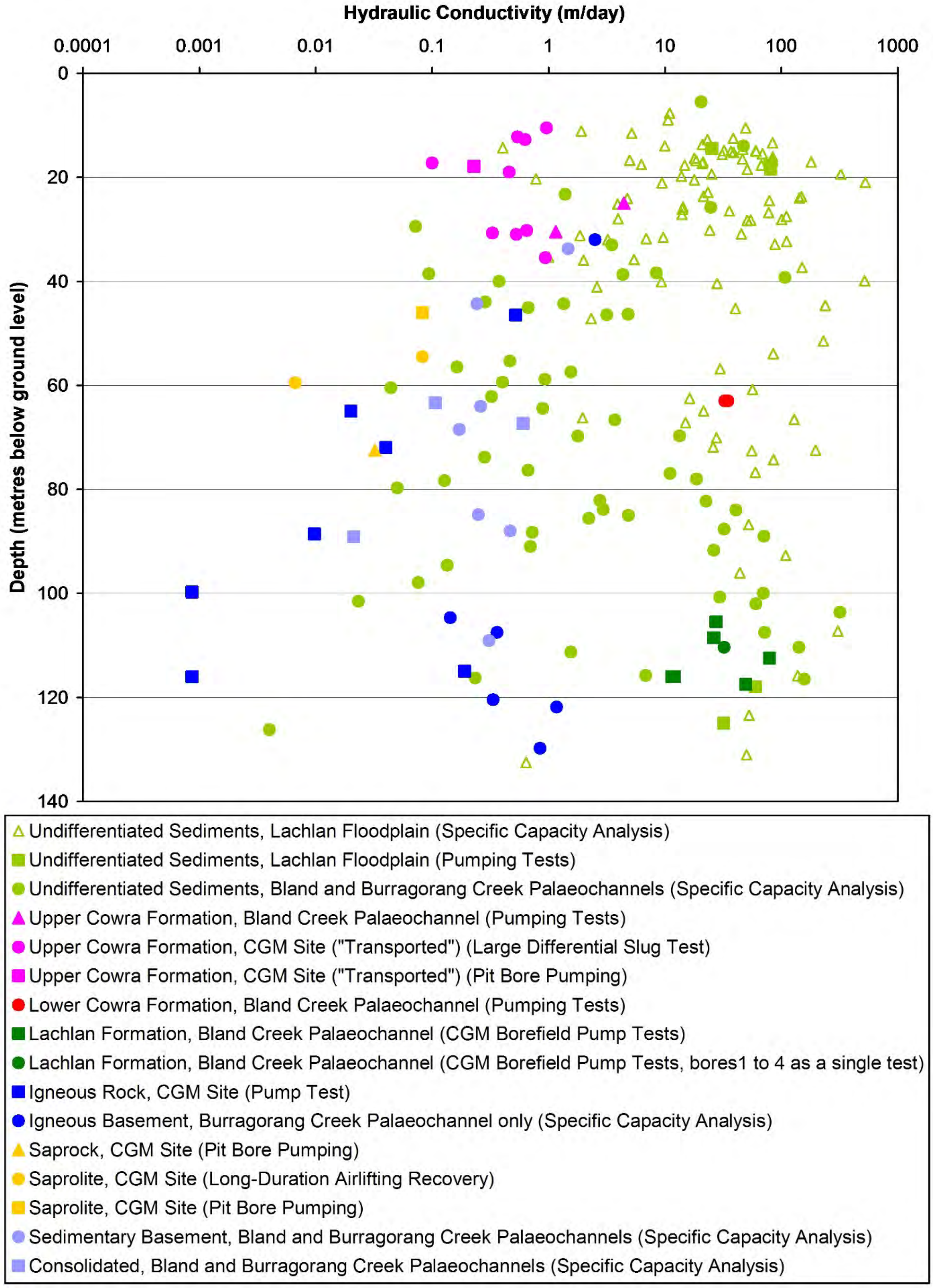


Figure 2.4. K database for the Bland Creek Palaeochannel area.

Three distinct alluvial sequences are interpreted to be present. These are as follows:

- Upper Cowra Formation. This sequence generally occurs from ground surface to an average depth of around 45 m to 50 m. The average depth to groundwater is around 7 m, giving an average saturated thickness of just over 40 m. This sequence generally shows decreasing K with depth.
- Lower Cowra Formation. This sequence generally occurs over an average depth interval of around 50 m to 90 m over most of the study area. This layer appears to have different hydraulic properties to the Upper Cowra formation.
- Lachlan Formation. This sequence generally occurs over an average depth interval of around 90 m to 120 m in the Bland Creek Palaeochannel and between 75 m and 110 m in the Burragorang Palaeochannel. Within this formation, two distinct sequences are interpreted as follows:
  - High K sands and minor gravels close to and within the deeper parts of the palaeochannel. This sequence has a geometric mean K of about 30 metres per day (m/day).
  - Lower K sediments generally occurring further away from the deeper parts of the paleaochannel and surrounding the high K sands and minor gravels. The hydraulic properties of this sequence appear similar to the Lower Cowra Formation.

The Bland Creek Palaeochannel basement consists mostly of sedimentary sequences (at burial depths exceeding 100 m). Igneous basement is present in the upper reaches of the Burragorang Palaeochannel. At the CGO, hydraulic conductivity of weathered and fresh rock follows a pattern of decreasing K with depth. Saprolite retains some of the original rock structure and can host open defects. The high K parts of the Lachlan Formation have a K approximately 100 to 1000 times larger than underlying bedrock. Bedrock at depth in the study area is considered to have significantly lower K than unconsolidated sediments except in structurally disturbed areas.

The bed of Lake Cowal is composed of a lacustrine clay layer of between 3 m and 8 m thickness. Hawkes (1998) reports an average vertical K of 5×10^{-7} m/day for the clay, from laboratory measurements on 7 samples, and an average horizontal K of 6×10^{-5} m/day from three *insitu* hydraulic tests.

2.5.2. Storativity

No hydraulic test data were available from which an assessment of the specific yield of the Cowra Formation could be made. Williams (1993) estimated a value of 5% for the refillable void space at the water table in the Upper Cowra Formation in the Jemalong Plains Irrigation District. Surface sediments in that district are known to have a higher K than surface sediments in the Bland Creek Palaeochannel.

Results from hydraulic tests undertaken in 2004 in BCPB bores indicate an average storativity of 1.9×10^{-4} for the Lachlan Formation (Groundwater Consulting Services Pty Ltd (GCS), 2006). A pump test of seven days duration conducted at BLPR2 in 1995 (Coffey, 1995) indicated an average storativity of 1.7×10^{-4} for the Lachlan Formation. Assuming that confined processes provided the dominant influence on drawdowns during these tests (minimal drainage at the water table during the tests), the storativities are approximately equivalent to average specific storages of 9.5×10^{-6} m^{-1} and 8.5×10^{-6} m^{-1} respectively.

2.6. Groundwater Levels and Flow

2.6.1. Monitoring Network

Groundwater levels in the BCPB and ESB areas are monitored by Evolution using a network of standpipe piezometers as follows:

- BCPB: Piezometers BLPR1 to BLPR7.
- ESB: Piezometers PZ01 (decommissioned in 2012), PZ02, PZ05 to PZ11, and future pumping bores SB03 to SB05.

The NSW Department of Industry – Water (DI-Water) (formerly Office of Water [NOW]) and JIL also maintain extensive networks of standpipe monitoring piezometers in the area for various purposes.

Water level observations from the Evolution piezometers, and a selection of DI-Water and JIL piezometers, have been used in previous studies for assessment of the hydraulic head field, and numerical model calibration and verification. In selecting DI-Water piezometers, the following criteria were generally applied, to reduce the potential for unrepresentative measurements:

- Backfilling of 20 m or less from the base of the borehole to the bottom of the screen.
- Screens placed in separate boreholes.

Where multiple screens were installed in a single borehole, only the lowermost standpipe was selected, subject to the backfilling criterion and other factors.

The resulting network comprises 45 measurement points at 38 locations. Appendix B lists these piezometers and contains a map showing their locations. DI-Water monitors high-rate groundwater extraction in the area at piezometers GW036553, GW036597, and GW036611. These are fitted with automatic water level recorders.

Coffey sourced recorded water levels at DI-Water piezometers GW036553, GW036597, and GW036611, from the NSOW/DI-Water internet-based data delivery system. Monitoring data from other DI-Water and JIL piezometers, and private water bores, was unavailable. The following sections summarise salient features of the hydraulic head field from before CGO operations commenced, using available information.

2.6.2. Hydrographs

Figure 2.5 shows hydrographs for the Upper Cowra, Lower Cowra, and Lachlan Formations in the BCPB area, using an approximately coincident set of monitoring piezometers throughout the vertical profile. They illustrate propagation of depressurisation at depth up through the profile. Increased groundwater extraction from the Lachlan Formation can be seen from the beginning of the drought in the 2000s. The vertical anisotropy of the sediments limits the upward propagation of depressurisation in the Lachlan Formation. The water table appears to remain unaffected over most of the record, however in this area, high volumes of irrigation are applied to the ground surface. The higher conductivity of the Lachlan Formation allows depressurisation from pumping to travel extensively in the lateral direction.

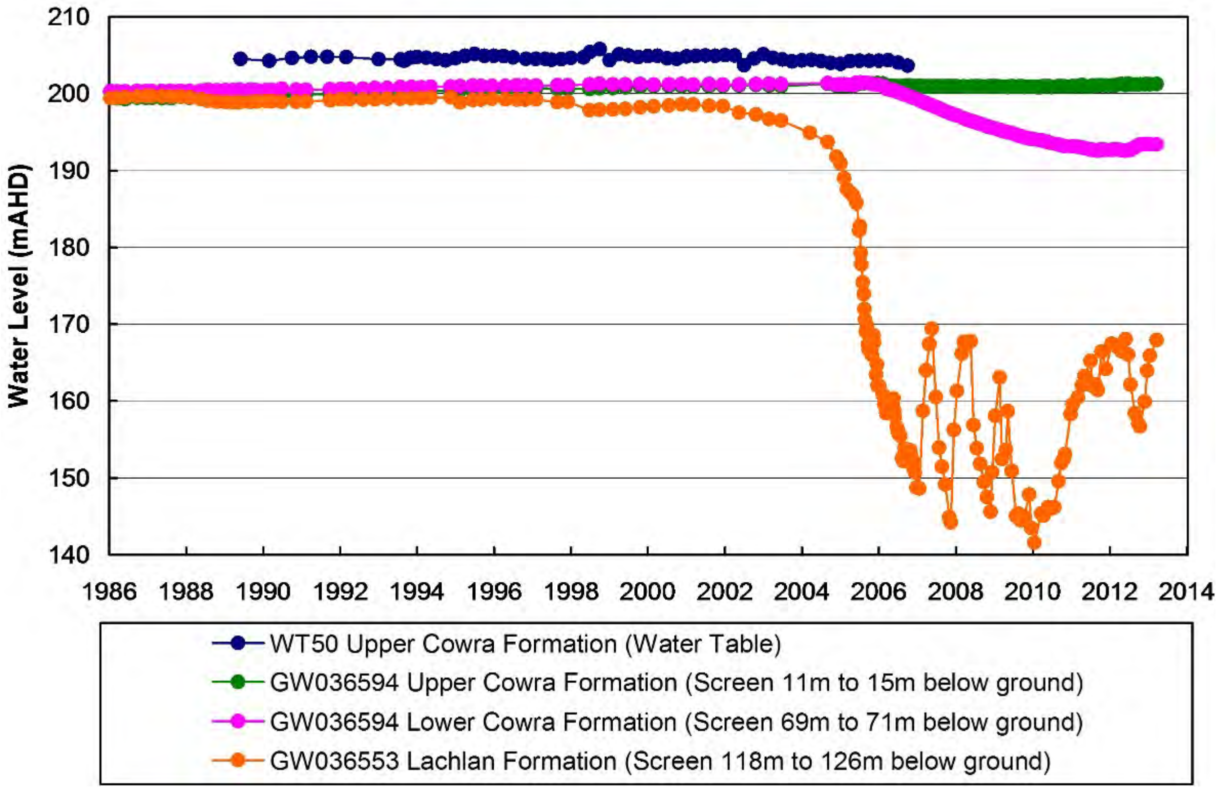


Figure 2.5. Hydrographs for approximately coincident piezometers in the BCPB area.

Figures 2.6 and 2.7 show water level observations for Evolution piezometers and GW036553 at the BCPB and ESB respectively, compared to total pumping, up to June 2017. The strong inverse correlation between piezometer water level and borefield pumping can be seen.

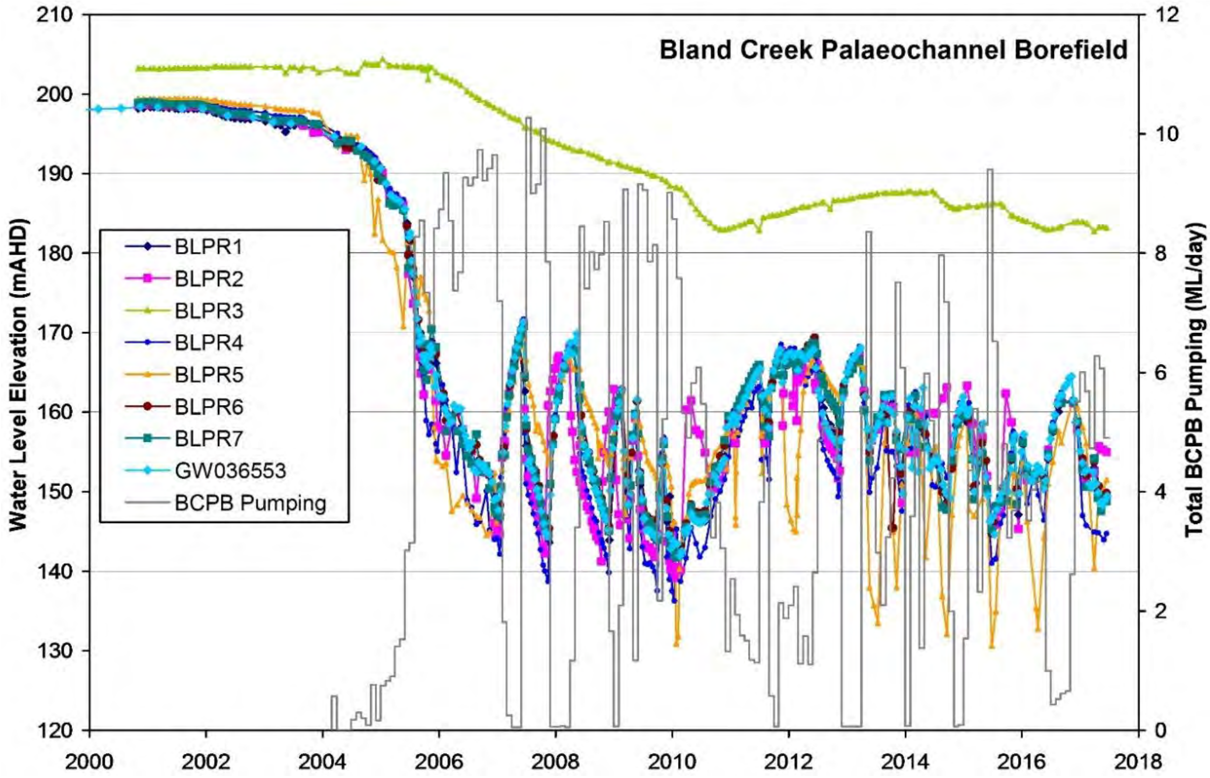


Figure 2.6. Monitoring piezometer hydrographs for the BCPB.

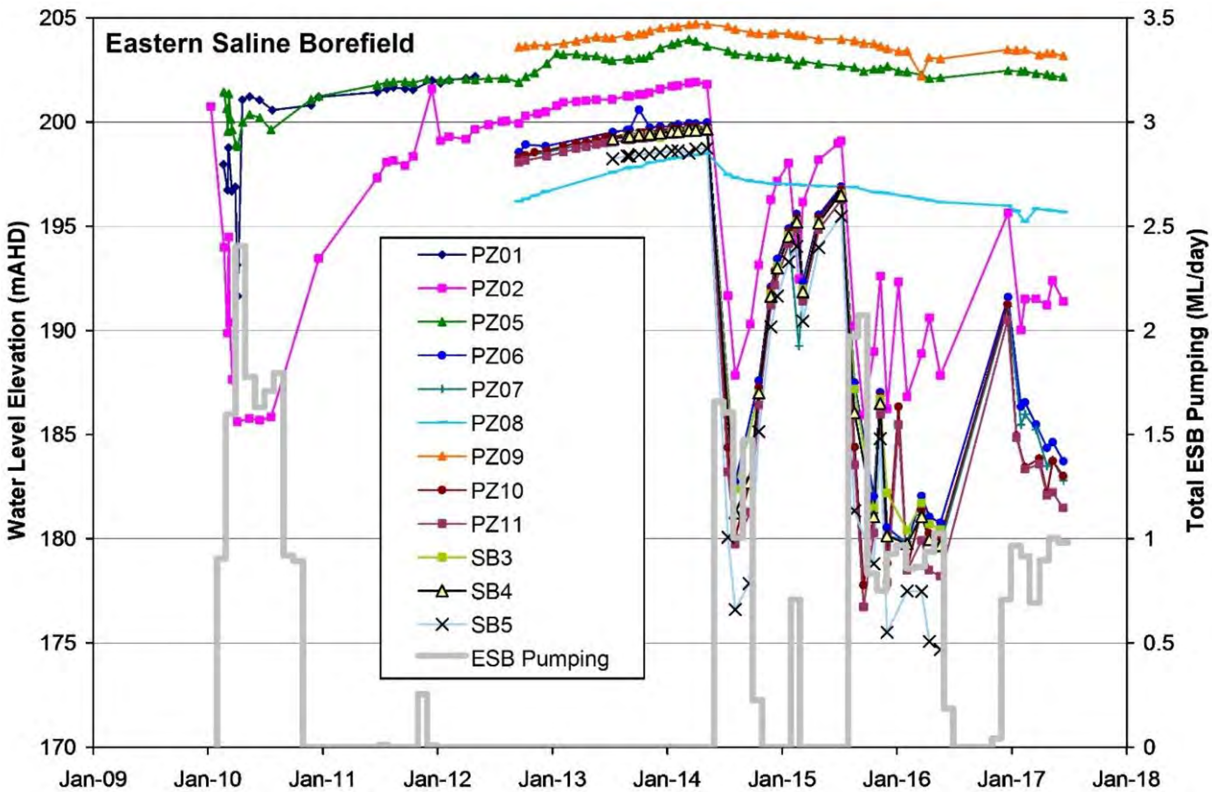


Figure 2.7. Monitoring piezometer hydrographs for the ESB.

2.6.3. Hydraulic Head Surfaces

Available monitoring data has been used to interpolate hydraulic head surfaces for the Upper Cowra, Lower Cowra, and Lachlan Formations for December 1997 (prior to the commencement of significant pumping from the Lachlan Formation) and September 2006 (two years after commencement of the CGO). These surfaces are shown in Appendix C. The main changes in hydraulic head surfaces between these times are:

- The disappearance of the groundwater mound in the Upper Cowra Formation underneath Lake Cowal. The water level in Lake Cowal was probably at around 205 mAHD in mid 1998 (see Figure 2.2).
- The appearance of the drawdown cone around the BCPB.

The 1997 surfaces indicate overall westward groundwater flow. Trends in the Lower Cowra and Lachlan Formations suggest north-south structural features on the western side of the palaeochannel may play a part in groundwater drainage. The 2006 surfaces show the effects of significant pumping from the Lachlan Formation at the BCPB and in the Billabong Area. The time at which pumping started in the Billabong area is not known.

Water levels in the Upper Cowra Formation, where data are available, are an average of 5 m below ground level. Vegetation in the area is characterised by food crops and scrub plants, with root depths probably not deeper than 2 m below ground. Consumption of groundwater by evapotranspiration is therefore likely to be negligible, except at Lake Cowal, where water levels can rise to within the vicinity of the lake bottom during wet times.

Near the current mine pit, the Upper Cowra Formation shows some drawdown from drainage into the mine excavation, in conjunction with regional drawdown from drought conditions. This drawdown appears localised and is considered unlikely to significantly affect drawdown in the Upper Cowra, Lower Cowra, and Lachlan Formations further east (in the Bland Creek Palaeochannel).

2.6.4. Hydraulic Head Cross-Sections

Figures 2.8 and 2.9 show interpreted hydraulic heads along a north-south cross-section running approximately through the middle of the model domain, for December 1997 and January 2010 respectively. Salinity corrections have not been applied to the water level measurements however the corrections are not considered necessary given the moderate salinity magnitude of the Upper Cowra, and the inverted salinity profile for the sediments (that is, salinity decreases with depth, which acts to slightly amplify the downward hydraulic head gradient in the Upper Cowra).

In December 1997 pumping from the Lachlan Formation was significantly lower than in subsequent years, since drought conditions had not as yet developed. Hydraulic heads in the Lachlan Formation were similar to those in overlying strata, with gentle vertical gradients. The effect of drainage to the west is subtle but noticeable. Minor inflow from the Corinella Constriction appeared to be occurring. The BCPB and ESB were not active at this time.

The lowest hydraulic heads observed in the Lachlan Formation since monitoring began were observed in January 2010, when the BCPB and private bores were pumping at high levels from the Lachlan Formation. Several bore screens are more than 500 m from the cross-section, but their positions have been projected onto the cross-section. However, hydraulic head contours are for the cross-section itself, therefore the shape of the contours do not closely align with the bore screens. Significant vertical gradients are apparent in the Lower Cowra, in response to significant depressurisation in the Lachlan Formation. Hydraulic head gradients in the underlying rock are interpreted to be large, with minor upward leakage.

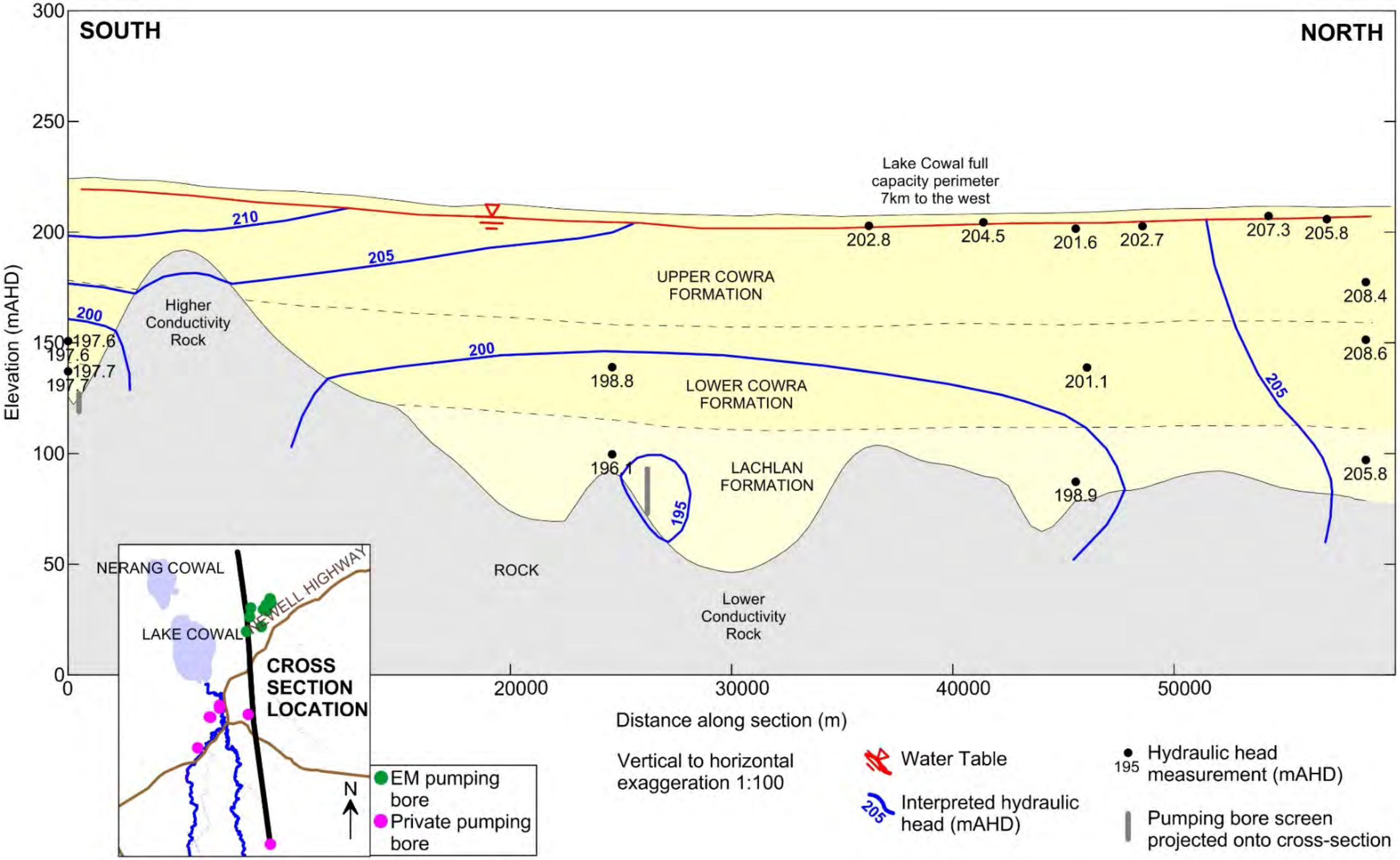


Figure 2.8. Interpreted hydraulic head cross-section for December 1997.

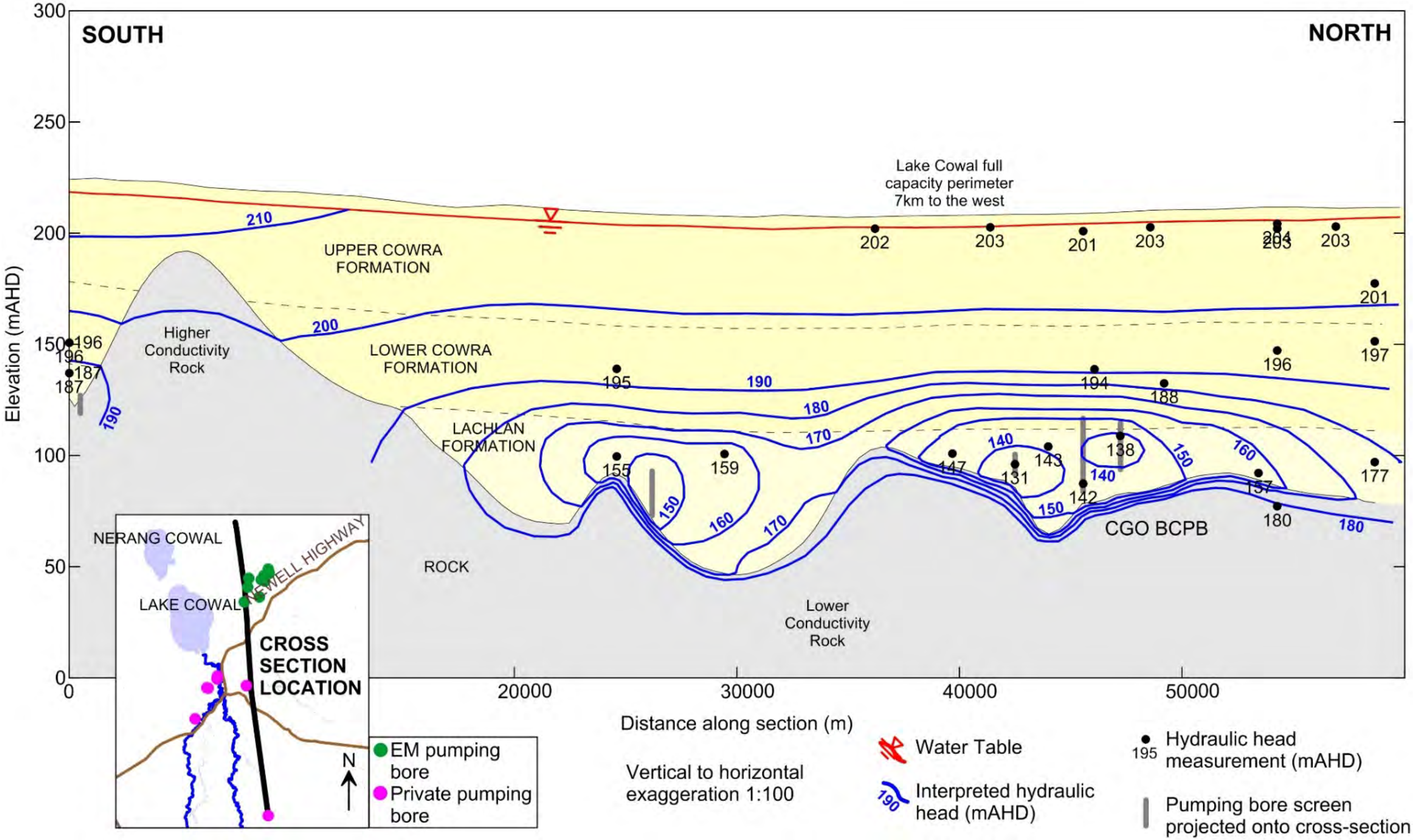


Figure 2.9. Interpreted hydraulic head cross-section for January 2010.

2.7. Groundwater Salinity

Additional monitoring of groundwater electrical conductivity (EC) at the BCPB and ESB, obtained since 2013, has been combined with previously existing data. Figure 2.10 shows EC averages for piezometers in the database, versus depth. The database used in Figure 2.10 is listed in Appendix D.

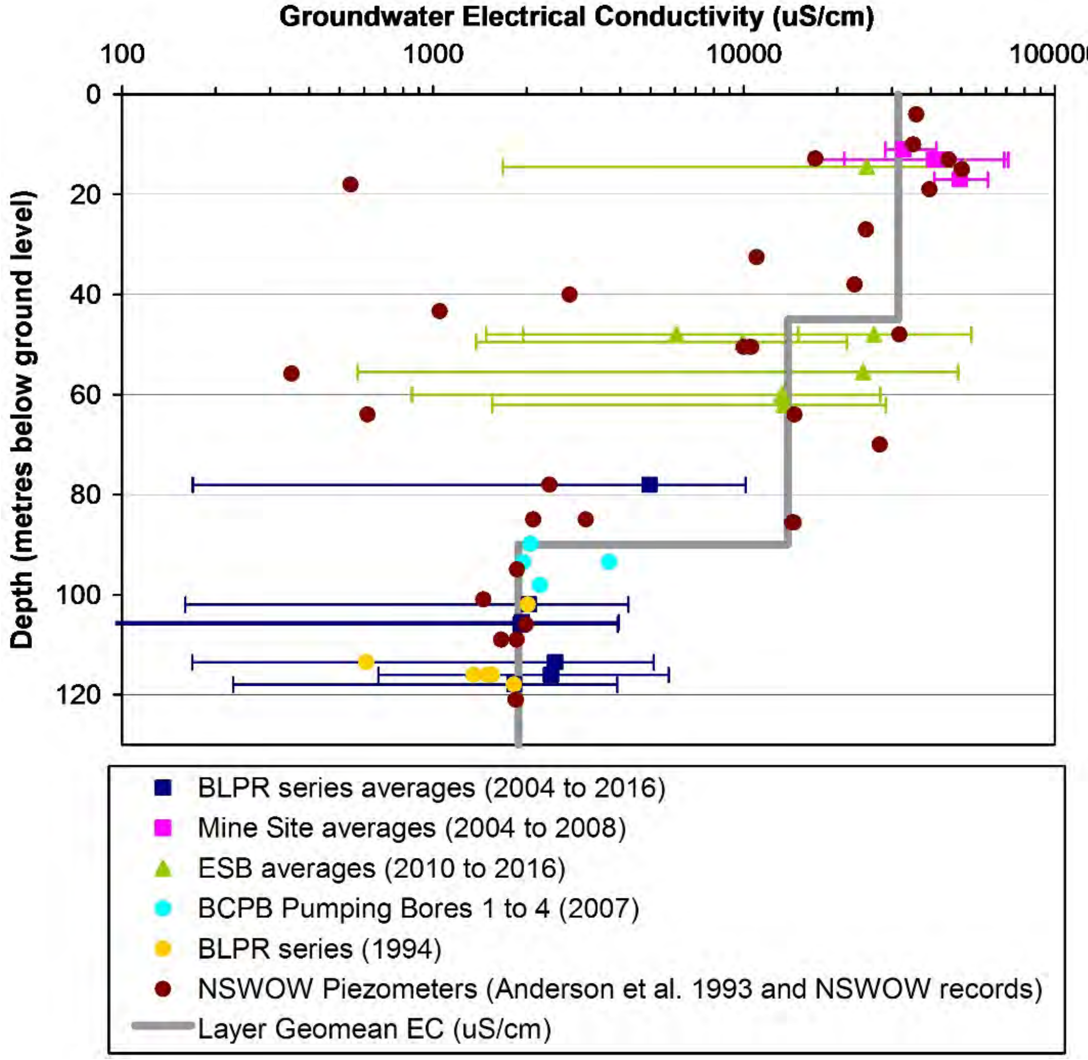


Figure 2.10. EC of groundwater in the regional area versus depth. Error bars indicate one standard deviation either side of the mean.

Figure 2.10 indicates a strong trend of decreasing salinity with depth. The Cowra Formation is conspicuous above 80 m depth with greater salinities than the deeper Lachlan Formation. Near Lake Cowal, salinities in the Upper Cowra Formation are generally high (as are those in the Corinella and Lake Cowal cross-sections in Anderson et al. [1993]).

Figure 2.11 shows field EC measurements from Evolution piezometers at the BCPB and ESB, up to July 2017, with instrumental measurement errors removed.

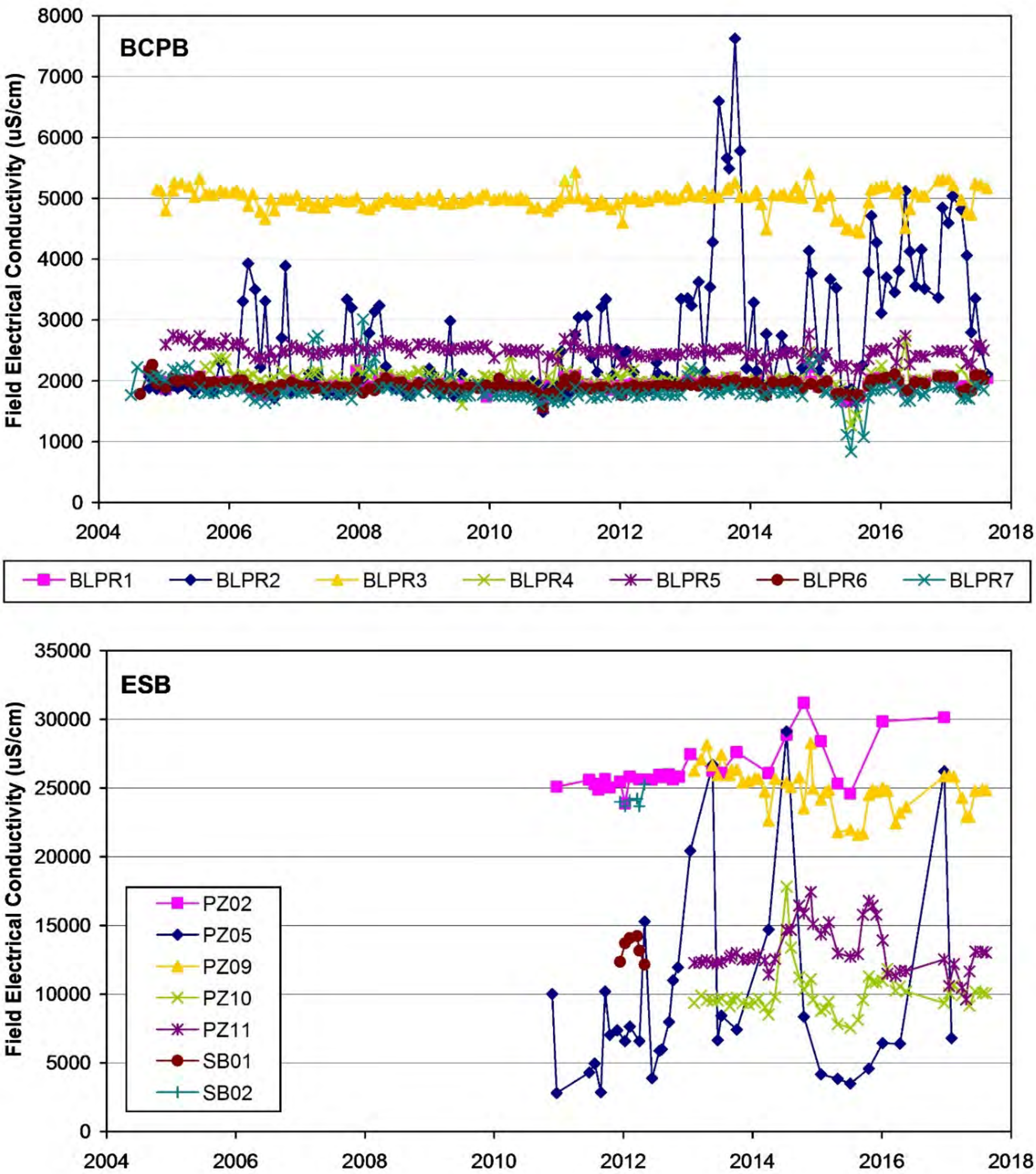


Figure 2.11. Groundwater EC versus time at Evolution monitoring piezometers.

The data show an average salinity of around 2000 µS/cm for the Lachlan Formation, except for BLPR3 (about 5000 µS/cm, screened in the Lower Cowra Formation). BLPR2 shows fluctuating measurements for which the cause is uncertain. Groundwater EC at the ESB is variable within the profile, adhering to the trend of decreasing EC with depth (see Figure 2.10).

2.7.1. Trend Analysis

Trends in Lachlan Formation EC at the BCPB were investigated by comparing an average EC dataset to BCPB pumping and the cumulative annual rainfall residual. The average EC dataset was compiled using observations from BLPR1, 4, 5, 6, and 7. First, observations at these piezometers were average over the length of record. Second, observations at BLPR4 to 7 were offset by an amount equal to the difference between a piezometers average and the average at BLPR1. This produced a dataset with observations referenced to the BLPR1 mean. The process is reasonable given the similarity in absolute value and first derivative between the piezometers.

Figure 2.12a shows the average EC time series compared to BCPB pumping and the cumulative annual rainfall residual. A weak relationship with the rainfall residual may be present, however given the characteristics of the groundwater system and the extraction horizon, a relationship recognisable over a 10-year period would be considered unlikely.

A more perceptible, but inverse, relationship with pumping appears to be present. Figure 2.12b shows the correlation between the derivative in EC and the derivative in BCPB pumping, and identifies a non-negligible inverse relationship. Since vertical flow velocities (from the Lower Cowra Formation into the Lachlan Formation) are likely to be significantly smaller than lateral flow velocities within the Lachlan Formation, the variation in pumping rate is thought to act by laterally attracting transient pulses of more distant lower EC Lachlan Formation groundwater (where downward vertical head gradients are smaller) into the immediate BCPB area, during pumping rate build-up, and thereby removing (or washing away) the slower build-up of higher EC groundwater seeping down from the Lower Cowra Formation. This process would imprint as a higher frequency variation in EC on a broader long-term build-up of EC through vertical drainage, but would not halt the longer-term vertical drainage of overlying groundwater of higher EC. The latter process will act over a broader time scale and will operate while downward vertical head gradients are present. Even should pumping stop completely, vertical drainage will continue afterwards, while these (dissipating) vertical gradients exist.

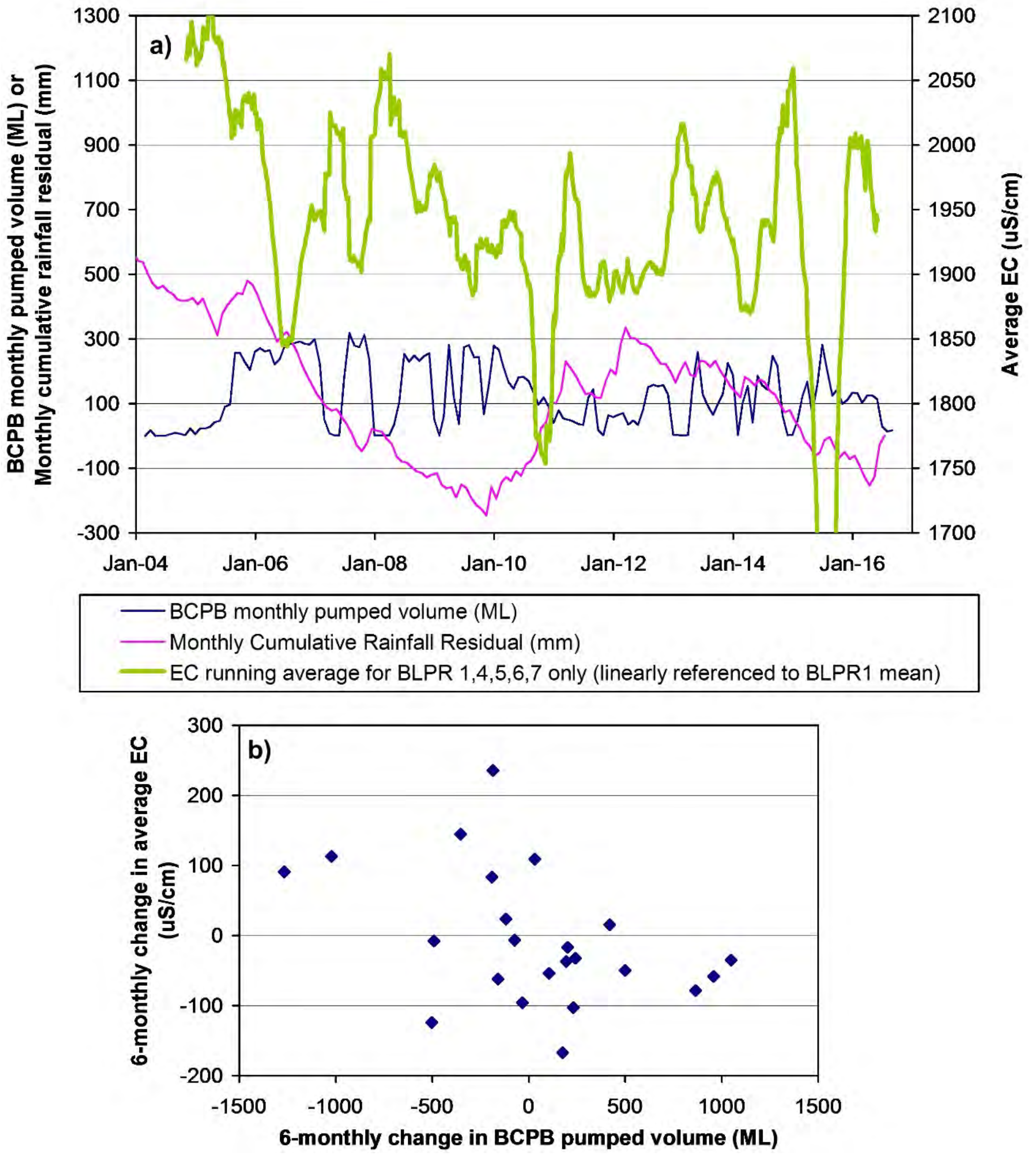


Figure 2.12. a) Comparison of average EC in the Lachlan Formation at the BCPB, and other trends; b) Correlation of EC and BCPB monthly derivatives.

2.8. Groundwater Extraction

Groundwater extraction in the area covered by the model domain occurs from Evolution and private bores. Appendix E lists the pumping bores in the area, and contains a map showing their locations. The list excludes basic rights bores (registered for stock and domestic use) which have no associated entitlement. Basic rights bores are not active in the model. The following discussion excludes basic rights bores.

Table 1 in Appendix E lists the 18 active pumping bores in the model. The model simulates the groundwater system from 1998. Three bores (Billabong 1, 2, and 3) were decommissioned after 1998 and before 2016, and are not active during predictive simulations.

Large groundwater extraction rates are concentrated in three main areas. One of the areas encompasses the CGO BCPB and ESB. The other two areas encompass private bores. These areas are identified on the map in Appendix E. Each area also has a monitoring piezometer used by the NSW government to monitor groundwater levels in the Lachlan Formation (at the request of the Bland Palaeochannel Groundwater Users Group) for groundwater management purposes. These piezometers have associated triggers defined by bore water levels where, should the bore water level fall to the trigger, various management actions are initiated.

If the investigation trigger level is breached the effects on nearby users will be investigated and measures to mitigate impacts on water supply for existing stock and domestic use will be put in place for affected bores. If the mitigation trigger level is breached one or both of the following measures would be put in place in consultation with DI-Water:

- alter the pumping regime to maintain the water level in the impacted stock and domestic bores
- maintain a water supply to the owner/s of impacted stock and domestic bores.

Table 2 lists the main pumping areas and associated pumping bores (see Appendix E for bore details) and trigger piezometers. The pumping bores listed in **Table 2** account for about 96% of the known groundwater extraction from the Lachlan and Cowra Formations in the model area. All bores in **Table 2** pump from the Lachlan Formation except the ESB which pumps from the Cowra Formation.

Table 2. High-extraction pumping areas in the regional area.

Area	Pumping Bores	DI-Water Trigger Piezometer	
		Registration No.	Trigger Level (mAHD)*
BCPB and ESB	BCPB: Evolution Bores 1 to 4. ESB: Evolution bores SB01 and SB02*	GW036553	137.5 (Investigation) 134.0 (Mitigation)
Billabong	Billabong 4 and Billabong 6	GW036597	145.8
Maslin	Maslin Bore	GW036611	143.7

* ESB pumping bores SB03 to SB05 (see Appendix E) are currently not used for pumping.

2.9. BCPB and ESB usage

Total usage for each of the BCPB and ESB, from commencement of the CGO (1 July 2004) to 30 June 2017, is shown graphically in Figures 2.6 and 2.7. The regulatory constraints for BCPB pumping (from the four bores in total), under the licence conditions, are understood to be as follows:

- Daily maximum of 15 ML.
- Yearly maximum of 3,650 ML.

The water supply for the CGO includes a number of surface water and groundwater supplies. Surface water supplies, which are dependent on rainfall, comprise runoff from a series of dams and associated catchments within the Mining Lease, and use of water supplied via the Jemalong irrigation channel when available.

2.10. Groundwater Extraction to Date

Groundwater extraction at the bores in Table 2, over the period 1 July 2004 to 30 June 2017, has maintained a freeboard of 5 m or more for water levels at the three DI-Water trigger piezometers. These extraction rates (including extraction undertaken at Billabong 1, 2, and 3, and excluding pumping at the ESB) are listed in **Table 3**. The pumping rate for the BCPB was obtained from records and estimates based on historical information and advice were made for the extraction for irrigation at the Billabong and Maslin properties.

Table 3. Actual pumping rates at the high extraction bores, averaged over the period 1 July 2004 to 30 June 2017.

Area	Pumping Bores	Average Combined Pumping Rate over the period 1 July 2004 to 30 June 2017 (ML/day)
BCPB	Evolution Bores 1 to 4.	4.28
Billabong *	Billabong 3/6 and 4 ^	2.56
Maslin *	Maslin Bore	2.33

* Significant assumptions have been made in estimating pumping for these bores.

^ Including historical pumping from Billabong bores 1, 2 and 3.

3. Hydrogeological Conceptual Model

Monitoring data collected at the CGO since 2013, supplied to Coffey, supports the conceptual model used in Coffey (2013). There are no observations that suggest any alteration to the conceptual model. The conceptual model from 2013 is adopted in the current study and summarised below.

The climate in the model area is characterised by low rainfall and high evaporation. For average conditions, a rainfall deficit occurs over most months of the year. Surface drainage is intermittent.

Recharge to the groundwater system occurs by the following processes:

- Rainfall infiltration.
- Leakage from Bland Creek when flowing.
- Intermittent flooding.
- Deep drainage from irrigation practices (mostly in the northern areas).
- Groundwater inflow through the Corinella Constriction.

There will also be a minor component of recharge to the fringes of the alluvial sequence from shallow bedrock which will have higher conductivity due to lower overburden pressures.

The subsurface medium comprises unconsolidated sediments. Finer-grained, lower K sediments overlie a thin but significant sequence of coarser-grained, higher K sediments. Media properties, combined with the prevailing climate, creates a system of high groundwater salinity near the surface and lower salinity at depth. Observations collected at the ESB since 2012 have allowed a more detailed definition of the variation of EC with depth.

Discharge from the groundwater system occurs by the following processes:

- Extraction from water supply bores for stock/domestic, irrigation, and industrial uses.
- Intermittent evaporation from surface ponds (local groundwater flow systems only).
- Groundwater outflow through the Corinella Constriction.

4. Numerical Model Verification

Appendix F provides a summary of the numerical model structure, boundary conditions, and calibrated media properties. Refer to Coffey 2013 for a detailed description of the numerical model and the recalibration undertaken in 2010.

In the current work, model verification of measured water levels was undertaken for the following piezometers:

- Evolution BLPR piezometer series (monitoring of the BCPB).
- Evolution PZ02. The screen for this piezometer straddles the model boundary between Layers 1 and 2 (the Upper and Lower Cowra Formations respectively). Verification is undertaken by extracting modelled water levels in both Layers 1 and 2 and comparing to observations.
- DI-Water trigger piezometers (GW036553, GW036597, and GW036611).

Apart from the bores in the BCPB, the bores with the three largest groundwater extraction rates in the model area are Billabong 4, Billabong 6, and Maslin. This extraction significantly affects water levels in DI-Water trigger piezometers GW036597 and GW036611. Prior to the current work, available usage data for these private pumping bores covered a period up to 1 July 2010 only. As part of the current work, usage for the Billabong bores was supplied by the proponent for the period January 2014 to August 2017 inclusive. Usages for the Billabong bores between 2010 and 2014 have been estimated. Usage for the Maslin bore between 2010 and 2017 has been estimated assuming a pump capacity of 7 ML/day.

4.1. Results

Verification hydrographs for the DI-Water mitigation trigger piezometers are shown in **Figure 4.1**. Verification hydrographs for the BLPR series, and PZ02, are shown in Appendix G.

The modelled hydrograph for GW036553 indicates overprediction of water levels from about 2012. Modelled hydrographs for GW036597 and GW036611 are reasonable, however modelled recovery is slower than observed. To incorporate the overprediction present in modelled hydrographs in predictive simulations, the disparity between modelled and observed water levels is taken for the two lowest water level troughs in the series between 2014 and the present, and the averages of these taken. This results in the following overprediction of observed hydrographs, as listed in **Table 4**. Modelled and observed patterns show reasonable agreement.

Table 4. Model overprediction of DI-Water trigger piezometer hydrographs.

Piezometer	Date	Water Level (mAHD)		Difference (m)	Average Difference (m)
		Observed	Calculated		
GW036553	15-Jul-15	144.62	150.55	+ 5.93	+ 5.91
	22-May-17	148.27	154.16	+ 5.89	
GW036597	30-Mar-15	155.45	157.77	+ 2.32	+ 1.97
	11-Apr-16	162.17	163.78	+ 1.62	
GW036611	5-Jan-15	156.26	159.73	+ 3.47	+ 4.78
	11-Apr-16	155.38	161.47	+ 6.09	

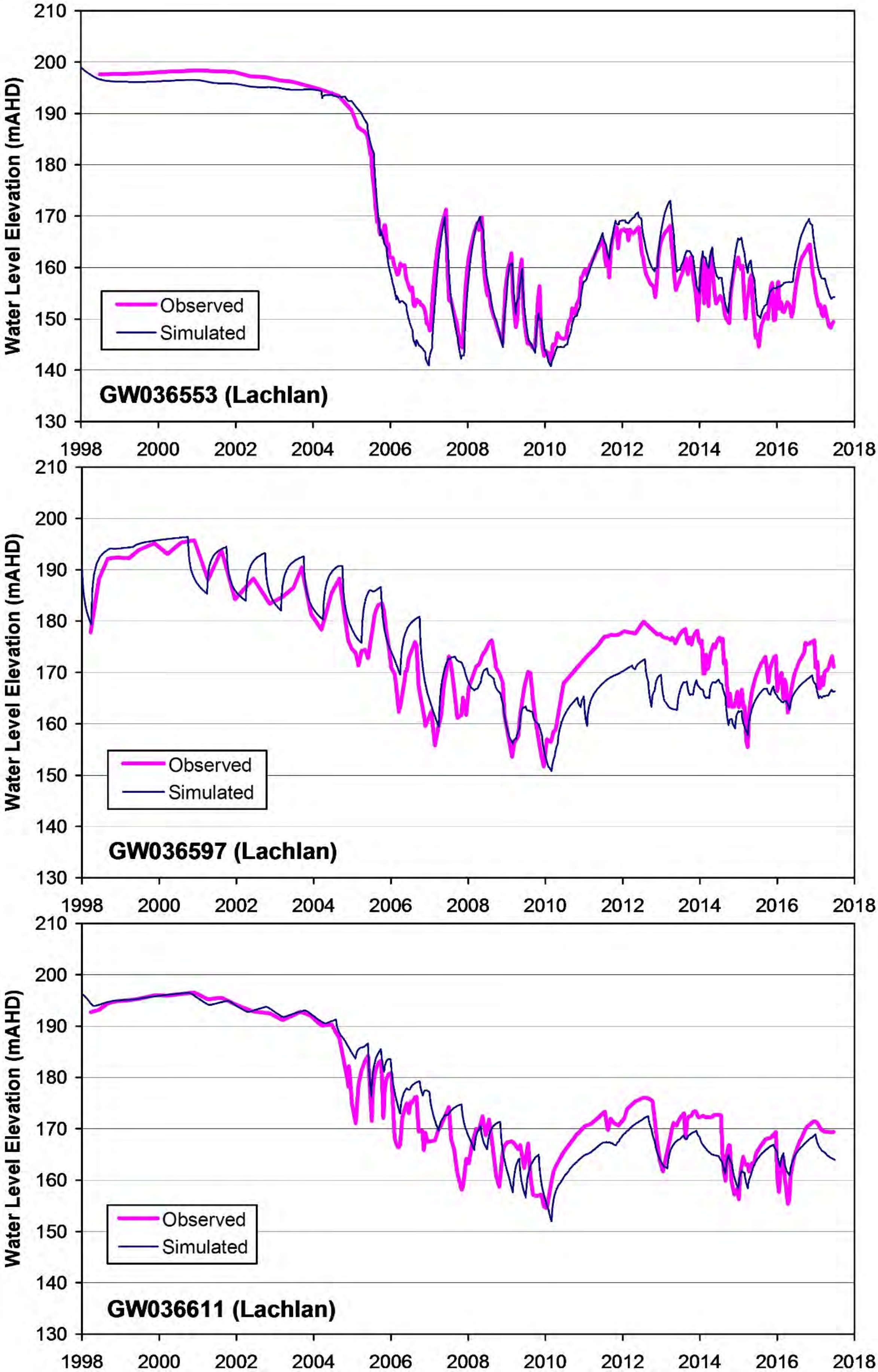


Figure 4.1. Verification hydrographs for DI-Water trigger piezometers.

5. Predictive Simulation

5.1. Simulations

Predictive simulations were modelled as follows:

- The BCPB pumps at the maximum possible rate, beginning 1 July 2017, such that the water level in DI-Water trigger piezometer does not fall below the mitigation trigger level of 134 mAHD. ESB pumping is fixed at 1.5 ML/day (requested by Evolution in the same scenario undertaken in 2013, and adopted here). This scenario required iterative runs to find the maximum rate. BCPB and ESB pumping terminates on 31 December 2032.
- A null case, where CGO pumping never occurs.

For the pumping case, the total pumping is distributed amongst the four bores of the BCPB and the two bores of the ESB according to the proportions pumped by each bore up to 30 June 2017. Pumping at the ESB is subject to the drawdown constraint where the groundwater level in PZ02 (the ESB monitoring piezometer historically showing the largest drawdown) is not to fall below the base of the bore screens. Based on supplied information, the elevation of the base of the PZ02 bore screen is 144.6 mAHD.

The simulations cover a future period of about 25 years commencing on 1 July 2017 and ending on 31 December 2042. This allows for 10 years of recovery following termination of pumping at the BCPB and ESB. The following future conditions are applied:

- Average rainfall occurs from 1 September 2016 as an invariant annual rate equivalent to 1% of 479 mm/year (the average rainfall at Wyalong Post Office between 1896 and 2016).
- Water levels for Lake Cowal, and Bland and Barmedman Creeks, have been assigned by calculating their average water levels over the period of record and applying these averages over the entire simulation period. These averages are 0.35 m for Bland and Barmedman Creeks and 0.5 m for Lake Cowal.
- Private pumping as defined in the following section.

5.2. Private Bore Pumping

Nine private bores are active during the predictive simulations, as listed in **Table 5**. These bores all pump from the Lachlan Formation. Actual past usage is available for four of the bores up to June 2010. Usage is also available for the Billabong bores between 2014 and 2017. For the purpose of verification of the hydrograph for GW036611, usage for Maslin was estimated using a pump capacity of 7 ML/day, and on/off times interpreted from the GW036611 hydrograph. No usage information has ever been received for five of the bores. In 2007 the Lachlan Valley Water Group (LVWG) supplied future usage estimates for all 9 bores, listed in **Table 5**, for use in predictive simulations.

The combined LVWG estimate for the Billabong bores is 4.62 ML/day, which compares with an estimated actual pumping (from significant assumptions) of 2.56 ML/day used in the verification modelling (see Table 3).

The LVWG estimate for the Maslin bore is 4.52 ML/day, which compares with an estimated actual pumping (from significant assumptions) of 2.33 ML/day used in the verification modelling (see **Table 3**).

The LVWG estimates were used in the current work for predictive simulations (applied from 1 July 2017)

Table 5. Private Bore future average annual pumping rates for modelling

Bore	Estimated future average annual usage as at 2007 (Lachlan Valley Water Group)^ (ML/day)
Billabong 3/6*	2.22
Billabong 4	2.40
Maslin	4.52
Quandialla TWS	0.10
Hart	0.02
Moora Moora	0.13
Muffet	0.02
Trigalana	0.08
Trigalana East	0.13
Total:	9.62

* Billabong 3 was replaced by Billabong 6 in 2008 (see Appendix E).
^ Used for predictive simulations (applied from 1 July 2017).

5.2.1. Inactive Pumping Bores

Table 2 in Appendix E lists an additional 10 licensed private pumping bores in the model area that have the potential to pump large amounts, but for which no usage data have ever been received, and no usage estimates have ever been supplied. Their status is unknown, and as a result, they are designated inactive in the model. It is not known if any of these may be pumping groundwater, however their inactivity has allowed reasonable replication of water level observations up to the present. Their future usage was unable to be estimated and they are inactive in predictive simulations.

The Warrakimbo bore, located very close by the Maslin Bore, is licensed for irrigation and has a large allocation. As at 2010, it was understood that the bore installed by Mr Mattiske in 2007 (not active in the model) approximately midway between Bores 1 and 2 of the BCPB, did not operate. Its operation after 2010 is unknown.

Billabong 5 was completed on 23 December 2008 as a replacement for Billabong 1 and 2. The potential for this bore to have been used since 2008, or to be used in the future, is high.

5.3. Results

5.3.1. Water Level Hydrographs

Table 4 shows that the numerical model under predicted drawdown at monitoring bore GW036553 by approximately 5.9 m during periods of high groundwater extraction in 2015 and 2017. While the form of modelled response follows observations a discrepancy between measurement and modelled groundwater level has gradually developed.

Recognising this gradual departure two cases were considered for forward predictions. One involved continuing from the starting point reached in the model on 1 July 2017 and a second approach taking account of the accumulated separation between measurement and model results. For the second approach, the separation between model result and measurement was taken into account by incorporation of an offset on the trigger level to compensate for the departure in the modelling result from observation.

The modelled BCPB pumping rate was calculated for two cases, comprising whether the model over prediction for GW036553 is incorporated (using the offset of +5.91 m) or not. Modelled pumping rates are as follows:

- Case 1 - Model over prediction incorporated (5.91 m added to the mitigation trigger value (134 mAHD) to account for model over prediction): 4.4 ML/day.
- Case 2 - Model over prediction not incorporated (mitigation trigger value (134 mAHD) used as is): 5.3 ML/day.

Figure 5.1 shows the predicted hydrographs for DI-Water trigger piezometers for Case 1. The hydrograph for GW036553 also includes the null case where no CGO pumping occurs. For the predictions in the irrigation area approximately 15 km to the south of the mine bores, the effects of groundwater extraction for CGO were assessed by adding the predicted drawdown associated with mining to the measure of historic low groundwater levels at each of two monitoring bores for which trigger levels are established. The representation of historic low groundwater levels was taken as the average of the four lowest level events on record. The low levels and the timing of these events are shown in Figure 5. In each case they are interpreted to correspond to the end of a period of pumping for irrigation. Results are discussed below.

Modelled future pumping rates are reported to the nearest 0.1 ML/day, rounded down. At a continual pumping rate of 4.4 ML/day, the model indicates that the water level at GW036553 does not fall below the effective mitigation trigger value of trigger value of 139.91 mAHD (134 mAHD actual, plus 5.91 m to account for model over prediction of groundwater level).

Water levels at GW036597 and GW036611 would not fall below the respective trigger values based on predicted mining impacts upon the low historic levels at these locations.

At GW036611, there is no freeboard available at the end of 2032 (about 4 m, decreased by the model over prediction of 4.78 m), to accommodate BCPB pumping.

Modelled water levels in the Cowra Formation at PZ02 at the ESB indicate that they remain above the base of the pumping screens during ESB operation.

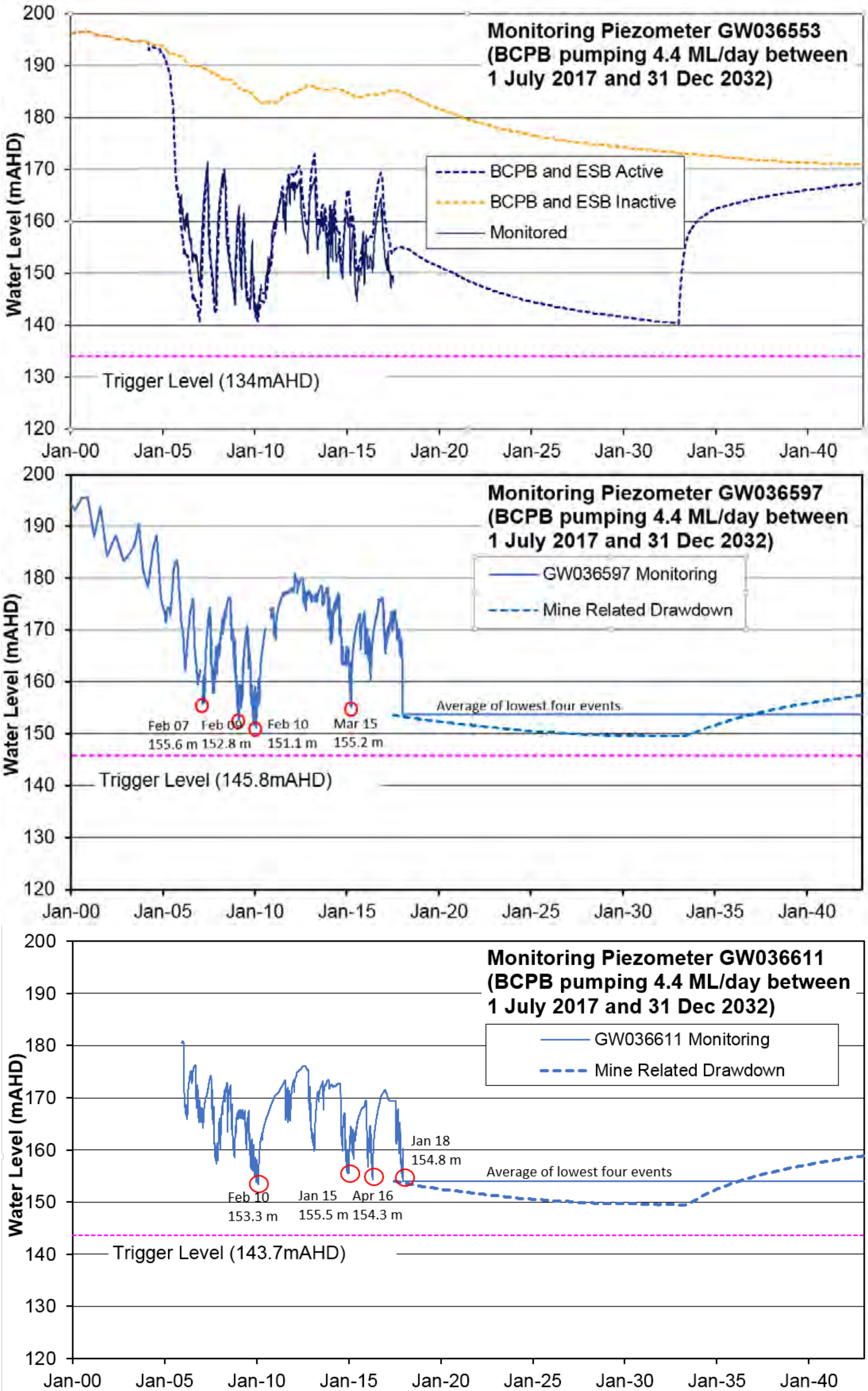


Figure 5.1. Predictive hydrographs for DI-Water trigger piezometers for Case 1.

5.3.2. Water Level Drawdown

Results are presented for Case 1.

Groundwater drawdown achieves a maximum just before the end of BCPB and ESB operation, on 31 December 2032. At this time, the maximum modelled drawdown in the Upper Cowra Formation is 1.1 m, occurring in the central part of the ESB. This drawdown is not expected to create difficulty for the majority of private bores in the area.

Drawdown in the Lower Cowra and Lachlan Formations for 31 December 2032 are shown in Appendix H. **Table 6** provides a summary of results.

Table 6. Drawdown in the Lower Cowra and Lachlan Formations for 31 December 2032 (cessation of BCPB and ESB pumping).

Formation and Location	Case 1
Maximum drawdown in Lower Cowra Formation	
Drawdown (m)	37.7
Location	ESB
Maximum drawdown in Lachlan Formation	
Drawdown (m)	66.3
Location	Maslin Area
Maximum drawdown in Lachlan Formation over the BCPB (m)	61.9

There are private registered bores screened in the Lachlan Formation in the area of the BCPB, however impacts on these bores are being monitored and mitigation measures have been developed to mitigate potential impacts (see below).

Based on a search of registered private water bore records in 2011, there are 34 private bores (excluding government piezometers and Evolution piezometers or pumping bores) within 15 km of the BCPB and ESB which appear to be screened in the Upper and/or Lower Cowra Formations (depths less than 90 m). 32 of these bores are located outside the model domain (29 are located to the east and north-east, on the other side of rock ridges or interpreted shallow bedrock, and three are located to the north-northeast, past the northern model boundary and within the northernmost parts of the Corinella Constriction). The remaining two bores are GW029574 and GW702230. Their locations are shown on the map in Appendix E. **Table 7** lists known completion details for these bores.

Table 7. Registered private bores screened in the Cowra formation within 15 km of the BCPB and ESB (excluding government and Evolution bores).

Bore	Easting (mMGA)	Northing (mMGA)	Depth (mbgl)	Water Level (mbgl)	Licensed use
GW029574	553360	6273194	88	30	Stock
GW702230	555812	6287547	66		Irrigation

GW702230 is located within the ESB and is known as the Duff bore. There is understood to be an agreement between Evolution and the bore owner that permits temporary transfer of water from this bore for use in the CGO water supply.

Government bore records indicate that GW029574 is privately owned, and was installed in 1969. A maximum modelled drawdown of between about 31 m (in the Lower Cowra Formation) is calculated for GW029574, however the bore is 88 m deep and may be able to continue operation if the screen length is sufficiently long and optimally located.

5.3.3. Flow Budgets

Table 8 lists the modelled groundwater flow budget for 31 December 2032, immediately prior to cessation of pumping at the BCPB and ESB, for Case 1, and the null case (BCPB and ESB inactive for the entire simulation period). This time is the time of greatest groundwater drawdown.

Table 8. Flow budgets at the end of BCPB and ESB pumping (31 December 2032).

Component	Case 1		Null (BCPB and ESB Inactive)	
	In (ML/day)	Out (ML/day)	In (ML/day)	Out (ML/day)
Recharge	17.74		17.74	
Media storage		6.38		8.81
River Leakage		1.06		1.27
Flow across Corinella Constriction	4.62		1.64	
Pumping		15.52		9.62
Total	22.36	22.95	19.38	19.70
Discrepancy	-0.59		-0.32	

Note: Component values are rounded to two decimal places. Totals are calculated from unrounded component values, then rounded to 2 decimal places, therefore each total may differ slightly from the sum of corresponding rounded components.

Flow budgets indicate that groundwater pumping is being sourced almost entirely from media storage on 31 December 2032. Flow budget discrepancies are reasonable.

5.3.4. Salinity

Consistent with the numerical simulation of salinity concentrations undertaken in Coffey (2016) for the Mine Life Modification, it is estimated the CGO (incorporating the Modification) would result in total dissolved solids concentrations at BLPR1 to increase by 20% or less from pre-mining concentrations.

5.3.5. Post-mining Water Levels

When ESB and BCPB pumping stops, groundwater levels at GW036553 are predicted to recover to around 167 mAHD in 10 years (about 29 m below 1998 water levels), and would continue to gradually recover over time, to a level that is dependent on the amount historically pumped, private bore usage following CGO closure, and climate. It may take significant periods of time for water levels to recover to levels seen in the late 1990s (prior to the drought and onset of extensive pumping) because of the low rate of media recharge and continuing pumping for agricultural purposes.

6. Summary and Conclusions

An existing model has been used to predict groundwater impacts associated with operation of the ESB and BCPB for the CGO under the Processing Rate Modification. Predictive simulation results are based on significant assumptions regarding high-extraction private water bores in the area.

6.1. Predictive Simulation Results

Over the period 1 July 2004 to 30 June 2017, the average total pumping rates at the largest groundwater extraction bores (4.28 ML/day at the BCPB, 2.56 ML/day at the Billabong bores, and 2.33 ML/day at the Maslin bore) have maintained a freeboard of 5 m or more for water levels at the three DI-Water trigger piezometers. Pumping rates for the Billabong and Maslin bores, as used in verification analysis, involve significant assumptions.

Modelling results indicate that the BCPB can pump at a maximum rate of 4.4 ML/day, from 1 July 2017 to 31 December 2032 (with the ESB pumping at 1.5 ML/day), without causing the water level in trigger piezometer GW036553 to fall to below the mitigation trigger level of 134 mAHD. The effects of pumping at this rate were also assessed at the locations of monitoring bores GW036597 and GW036611 located 15 km to the south of the mine borefield. At these locations the incremental effects of pumping from the mine bores at 4.4 ML/d from 1 July 2017 to 31 December 2032 were added to a measure of low recorded groundwater levels at these locations (based on the average of the lowest four events on record). The predicted groundwater levels under these conditions remained above the trigger levels for these monitoring bores.

Maximum drawdowns at the end of the CGO mine life are approximately 38 m or less in the Lower Cowra Formation and approximately 66 m or less in the Lachlan Formation within the BCPB. A maximum drawdown of approximately 31 m (in the Lower Cowra Formation) is modelled for GW029574, the only known water bore installed to a depth within the Lower Cowra Formation and 10 km to the south of the BCPB. However, the bore is 88 m deep and may be able to continue operation if the screen length is sufficiently long and optimally located.

Previous simple numerical transport simulation for Case 1 (where allowance is made for the departure of model drawdown from observation at the trigger bore near the BCPC – GW036553) indicates EC at BLPR1 will increase by about 20% or less, by 31 December 2032, from pre-mining concentrations.

At cessation of BCPB and ESB pumping, groundwater levels at GW036553 are predicted to recover to around 167 mAHD in 10 years (about 29 m below 1998 water levels).

6.2. Regulatory Considerations

6.2.1. Licence allocation for the BCPB

The following points summarise the licensing situation for the CGO:

- Evolution currently holds 3650 units (ML) / annum in the Lachlan River Water Source.
- For the CGO under the Processing Rate Modification, the estimated (most probable) maximum volumetric extraction from the Lachlan River Water Source is 2866 ML/annum (in calendar year 2031 or Mining Year 27).
- Evolution would continue to extract groundwater from the Lachlan River Water Source in accordance with existing licence entitlements, and in accordance with the contingency strategy as described in Section 6.2.3.

6.2.2. Aquifer Interference Policy

Merrick (2013) states that, according to Principle 14 of the NSW State Groundwater Policy Framework Document, "All activities or works that intersect an aquifer, and are not for the primary purpose of extracting groundwater, need an aquifer interference approval.". Since the BCPB and ESB are for the primary purpose of extracting, and using, groundwater, no aquifer interference approval is needed. However, use of the BCPB and ESB are subject to regulatory requirements according to other legal instruments that may be in force. Specifically for the BCPB, a contingency strategy and mitigation measures are in place as discussed below.

6.2.3. Lachlan Formation Water Source

Contingency Strategy

The groundwater level in the Lachlan Formation in the BCPB area is monitored on a continuous basis by the DI-Water using its groundwater monitoring bore on Burcher Road (GW036553). Contingency measures have been developed for implementation when water levels reach an elevation of either 137.5 mAHD (Investigation Trigger Level) or 134 mAHD (Mitigation Trigger Level). These trigger levels were developed in consultation with NOW (now DI-Water) and other water users within the Bland Creek Palaeochannel, including stock and domestic users and irrigators. The following contingency measures are understood to be associated with each Trigger Level:

- In the event that the groundwater level in GW036553 is below 137.5 mAHD, one or more of the following contingency measures will be implemented in consultation with the DI-Water:
  - Investigate the groundwater level in the Trigalana bore (GW702286) or any other impacted stock and domestic bores.
  - Determine the pump setting in relevant stock and domestic bores.
  - Determine the drawdown rate in GW702286 and other impacted stock and domestic bores.
  - Develop an impact mitigation plan for impacted stock and domestic bores, and/or set up an alternative water supply for the owner of GW702286 and other owners of stock and domestic bores, if necessary.
- In the event that the groundwater level in GW036553 is below 134 mAHD, one or both of the following contingency measures will be implemented in consultation with the DI-Water:
  - Alter the pumping regime to maintain the water level in the impacted stock and domestic bores.
  - Maintain a water supply to the owner/s of impacted stock and domestic bores.

Mitigation Measures

Prior to the drought last decade, stock and domestic water supplies were generally drawn from surface water delivered through the JIL irrigation channel network. The reduced availability and increased cost of this water, driven by reduced rainfall from around 2002 onwards, led to establishment of stock/domestic bores which utilised the Lachlan Formation aquifer. Several consortia were established to share the costs of bore installation and to deliver the water across multiple properties.

The CGO was independently approached by various parties for assistance in upgrading the pumping systems such that their design capacity could be met independently of the abstraction from the Lachlan Formation. The known schemes are listed below (see Appendix E for locations):

- Moora Moora (GW702262).
- West Plains (GW702100).

- Trigalana (GW702286, also known as Trigalana West).
- Trigalana East.

Each of the schemes is understood to comprise the following key elements:

- A single bore equipped with a submersible pump.
- Above-ground storage tanks located near the bore.
- A surface-mounted pump to pressurize the pipeline system.
- A pipeline system with control valves at the user offtake.

The Muffet bore (GW701958) is understood to have provided stock water on a single property, through a solar-powered pumping system. Other private, single-farm systems are reported to be powered by solar, diesel, and mains powered pumps.

It is understood that the following measures were implemented by the CGO for ameliorating the impacts of pumping at the BCPB on stock/domestic bores:

- From 2006 to 2007:
  - Moora Moora: Replacement of the pump, installation of a new pump to a greater depth and upgrade of the electrical power supply to enable the system to maintain design flow.
  - West Plains and Trigalana: Provision of water through a metered polyethylene pipeline direct to the stock water tanks.
  - Muffet: Replacement of an existing solar powered submersible pump with a new pump of larger capacity, setting of the new pump to a greater depth, and upgrade of the solar panel array to increase its electrical output.
- During 2011:
  - West Plains: The bore failed and the CGO paid for replacement of the bore in mid-2011. The bore was operating by the fourth quarter of 2011.
  - Isolation of the West Plains and West Trigalana schemes from the direct supply of water from the BCPB pipeline (although water could still be supplied in an emergency since the pipelines remain in place).

6.2.4. Cowra Formation Water Source

Modelling results indicate a maximum predicted drawdown of about 31 m at bore GW029574, the only known water bore installed to a depth within the Lower Cowra Formation and within 15 km of the BCPB. It is located 10 km south of BCPB. The bore is 88m deep and may be able to continue operation if the screen length is sufficiently long and optimally located. If not, contingency measures may be required for this bore.

7. Limitations

Predictive results are subject to the uncertainty inherent in any numerical modelling. The numerical model is necessarily a simplification of the real system and relies on calibration to observation data to produce predictive results. The results are estimates only and may differ significantly from future observations. Also, actual future extraction from the BCPB and ESB may differ from that adopted for predictive simulations.

8. Recommendations

It is recommended that a statistical analysis be undertaken of the difference between modelled and observed hydrographs (residuals) at DI-Water trigger piezometers, so that an estimate for an offset to be applied to modelled hydrographs (to accommodate model over prediction) can be obtained for a reasonable probability (say 95% confidence). The probability may need to be negotiated with regulatory agencies. This analysis would require synchronisation of observed water level measurements to modelled output, using interpolation algorithms.

There is uncertainty about historical and future groundwater use by irrigators. As a result predictions of groundwater level in areas of significant groundwater use for irrigation are uncertain. Mining impacts in these areas associated with proposed future mine operation were assessed. These assessment may need to be reviewed as information about water usage becomes available.

The numerical model requires updating and verification on a regular basis for it to be able to be used as an effective predictive tool. Model recalibration may be necessary from time to time, using additional observations as they are collected.

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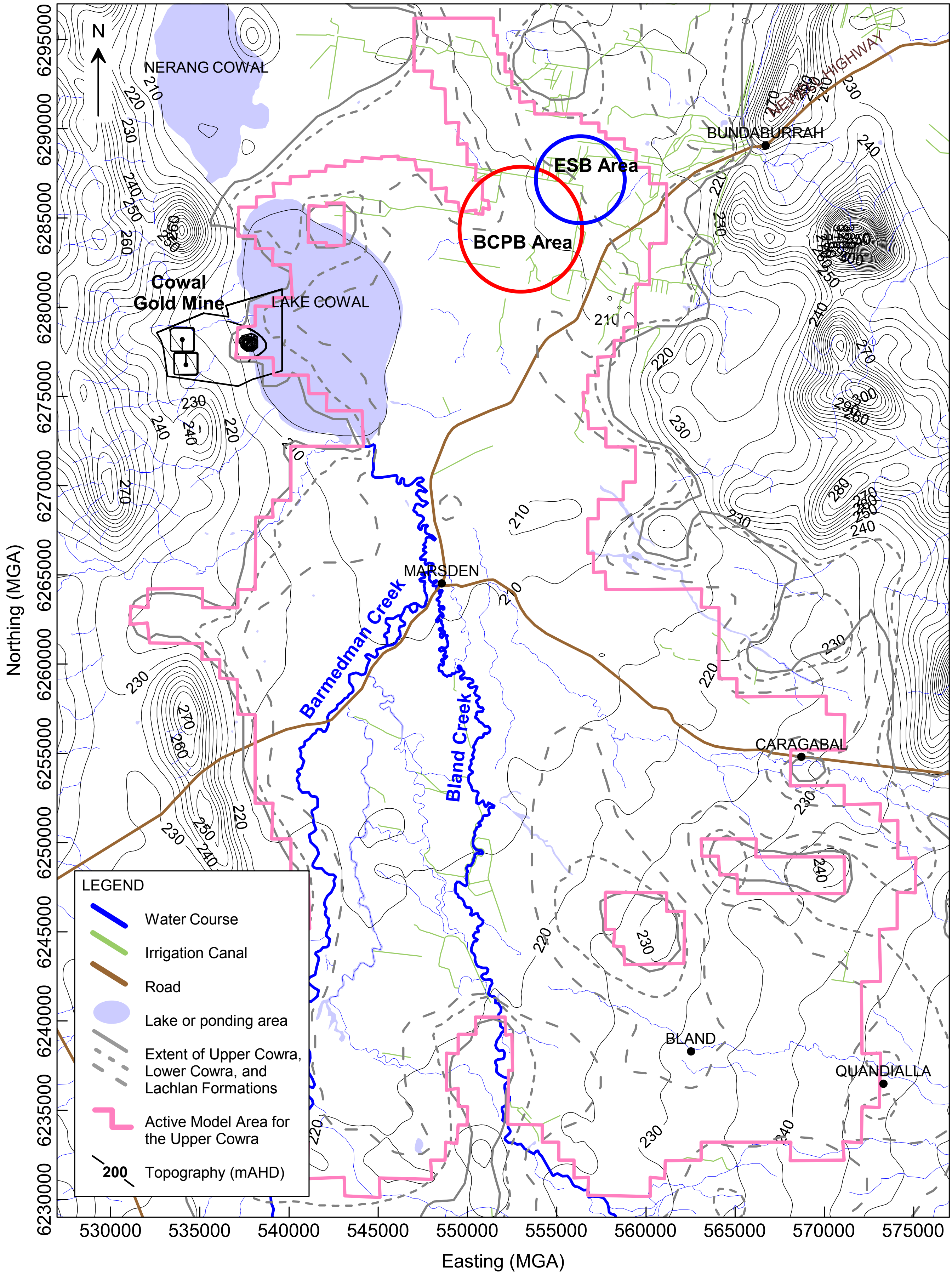
Drawings



drawn	PT		client: Evolution Mining (Cowal) Pty Limited
approved			project: Cowal Gold Operations Mine Life Modification Groundwater Assessment
date	9 Nov 2016	coffey A TETRA TECH COMPANY	title: **Regional Locality Map**
scale	1:300,000		
original size	A4		project no: GEOTLCOV21910BG — figure no: **Drawing 1**

Appendix A - Specific Capacity Analysis

Specific capacity (Sc) is the pumping rate divided by the drawdown in the pumped bore at a specified time. The time is usually taken as 1 day, since most tests are of this duration.

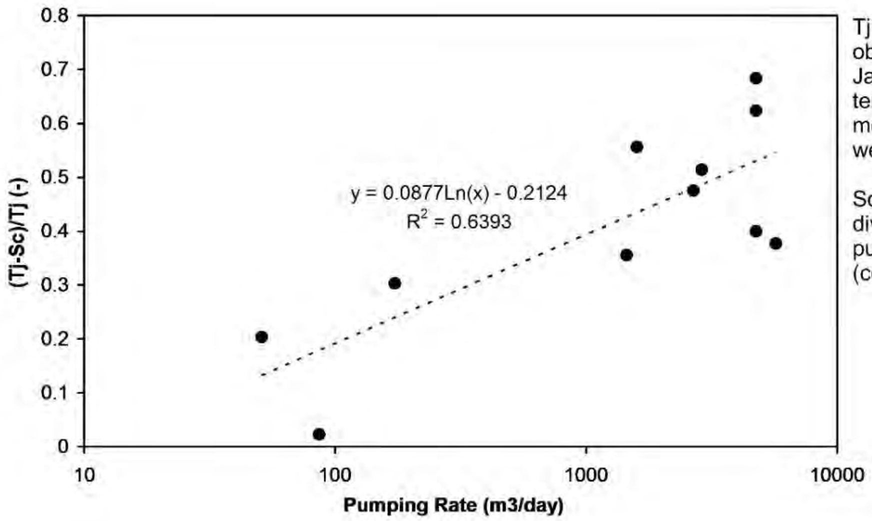
An analysis is undertaken using tests where temporal drawdown data are available. For each test, Sc is calculated at 1 day. Transmissivity (Tj) is interpreted from temporal drawdown at the pumped bore using the Cooper and Jacob (1946) method for confined conditions. The quantity (Tj – Sc)/Tj is then plotted against pumping rate and the relationship approximated with a trendline. This relationship is then used to convert Sc for tests where temporal drawdown is unavailable (the majority of government records). The method assumes the bores in the database are approximately similar in hydraulic behaviour (well loss component), and that dissimilarities in screened lithology are minor.

Table 1 lists the pumping tests (from 9 bores) used to find a relationship, and Figure 1 shows the resulting relationship. For some tests, the drawdown at 1 day was either unavailable or could not be estimated. This adds additional approximation to the fitted line.

Table 1. Bore tests used for specific capacity analysis.

Bore	Screened Formation	Registration Number	Pumping Rate (m3/day)	Test Duration (hours)	Tj* (m2/day)	Interpretation	Specific Capacity Drawdown (m)	Time	Sc (m2/day)	(Tj-Sc)/Tj
CGO BCPB Bore 1	Lachlan	GW701660	2894	0.4	662	Coffey 2008	9.0	1 day	322	0.514
CGO BCPB Bore 2	Lachlan	GW701659	4752	24	870	Coffey 2008	9.1	1 day	522	0.400
CGO BCPB Bore 3	Lachlan	GW701658	4752	24	1242	Coffey 2008	12.1	1 day	393	0.684
CGO BCPB Bore 4	Lachlan	GW701657	4752	24	870	Coffey 2008	14.5	1 day	328	0.623
BLRP2 Test 1	Lachlan		2678	48	460	Coffey 1994 (G255/18-AD)	11.1	1 day	241	0.476
BLRP2 Test 2	Lachlan		5702	168	482	Coffey 1995 (G255/24-AJ)	19.0	1 day	300	0.377
Duff 2009	Lower Cowra	GW702230	1452	91	98	GCS 2010 (BARR010)	23.0	End	63	0.356
Duff 2004	Lower Cowra	GW702230	1597	24	104	Coffey 2008	34.6	1 day	46	0.556
PBA	Upper Cowra		173	53	248	Coffey 1994 (G375/1-AF)	1.0	End	173	0.303
PBB	Upper Cowra		86	5	243	Coffey 1994 (G375/1-AF)	0.4	End	237	0.023
PBC	Upper Cowra		51	44	76	Coffey 1994 (G375/1-AF)	0.8	End	61	0.203

*Tj = Transmissivity using Cooper Jacob (1946) method.



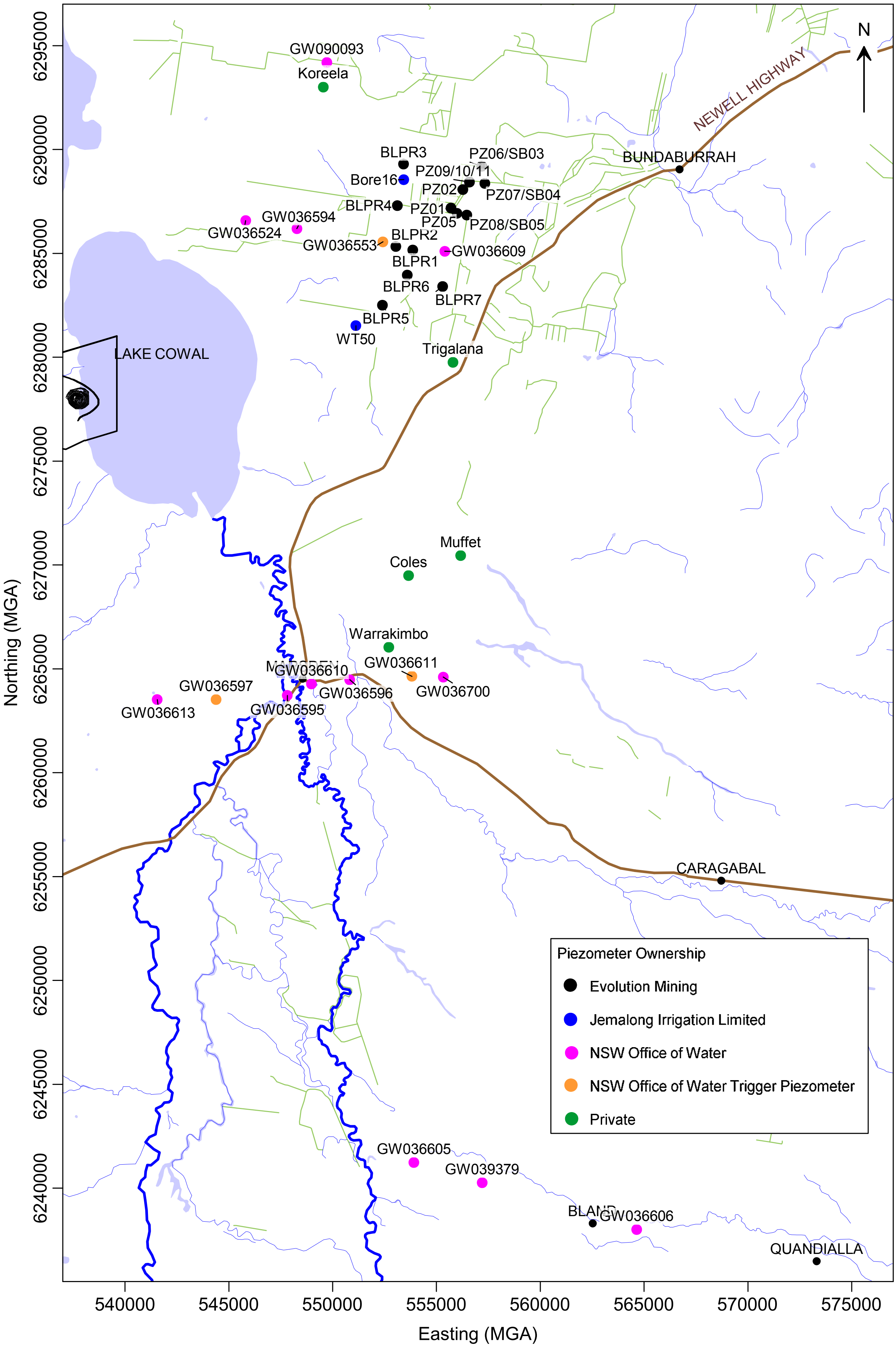
Tj denotes the transmissivity obtained using the Cooper and Jacob (1946) method using temporal drawdown measurements from the pumped well.

Sc denotes the pumping rate divided by the drawdown in the pumped well at a specified time (commonly 1 day).

Figure 1. Results of specific capacity analysis for tests in Table 1.

Appendix B - Groundwater Monitoring Network

Bland Creek Palaeochannel Monitoring Piezometer Network



Bland Creek Palaeochannel Monitoring Bore Network

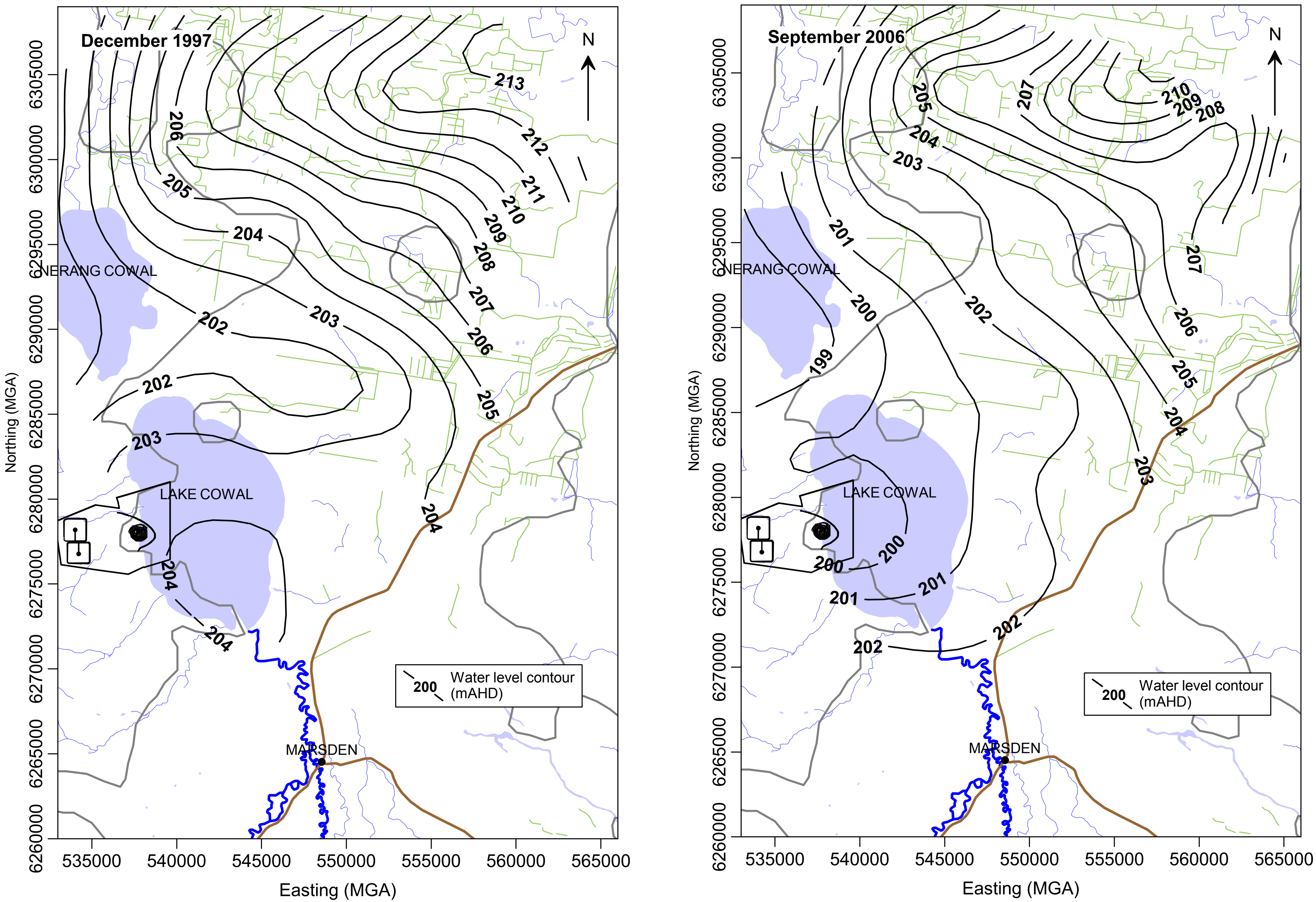
Piezometer / Bore	Owner	Collar Elevation (mAHD)	Easting (mMGA)	Northing (mMGA)	Stratum	Screen (mbgl)		Comment
						From	To	
BLPR1-Ln	Evolution	211.14	553858	6285166	Ln	102	110	BCPB monitoring
BLPR2-Ln	Evolution	209.16	553044	6285330	Ln	106	126	BCPB monitoring
BLPR3-LC	Evolution	210.50	553417	6289305	LC	72	84	BCPB monitoring
BLPR4-Ln	Evolution	210.77	553117	6287305	Ln	94	110	BCPB monitoring
BLPR5-Ln	Evolution	209.61	552392	6282505	Ln	107	120	BCPB monitoring
BLPR6-Ln	Evolution	210.09	553592	6283955	Ln	97	115	BCPB monitoring
BLPR7-Ln	Evolution	210.47	555292	6283405	Ln	103	133	BCPB monitoring
PZ01-UC/LC	Evolution	210.71	555703	6287188	UC/LC	20	80	ESB Monitoring. Decommissioned May 2012.
PZ02-UC/LC	Evolution	210.69	556267	6288075	UC/LC	18	78	ESB Monitoring.
PZ05-UC/LC	Evolution	211.05	555984	6286935	UC/LC	18	78	ESB Monitoring.
PZ06	Evolution	212.09	557239	6289189				ESB Monitoring. Screen interval unknown. Probably UC/LC or LC.
PZ07	Evolution	211.80	557343	6288365				ESB Monitoring. Screen interval unknown. Probably UC/LC or LC.
PZ08	Evolution	210.97	556465	6286840				ESB Monitoring. Screen interval unknown. Probably UC.
PZ09-UC	Evolution	211.19	556580	6288433	UC	13	16	ESB Monitoring
PZ10-LC	Evolution	211.19	556584	6288435	UC/LC	48	51	ESB Monitoring
PZ11-LC	Evolution	211.33	556588	6288437	LC	60	64	ESB Monitoring
SB03	Evolution	211.57	557116	6289198	UC/LC	46	64	ESB Monitoring (outfitted as pumping bore but not pumped)
SB04	Evolution	211.68	557324	6288376	LC	59	65	ESB Monitoring (outfitted as pumping bore but not pumped)
SB05	Evolution	211.06	556447	6286849	LC	58	64	ESB Monitoring (outfitted as pumping bore but not pumped)
Bore16-UC	JIL	211.06	553425	6288550	UC	Water table		Screen interval unknown. Straddles water table.
WT50-UC	JIL	208.56	551121	6281522	UC	Water table		Screen interval unknown. Straddles water table.
GW036524-UC	NSWOW	207.37	546337	6286862	UC	15	17	Backfilled 89 m. Water levels appear to be representative.
GW036553-Ln	NSWOW	209.33	552434	6285773	Ln	118	126	
GW036594-LC	NSWOW	208.79	549558	6286186	LC	69	71	Pipes in same drillhole, but SWLs not the same.
GW036594-UC	NSWOW	208.79	549558	6286186	UC	11	15	Pipes in same drillhole, but SWLs not the same.
GW036595-LC	NSWOW	209.32	547929	6263905	LC	85	87	Backfilled 45 m. SWLs appear to be representative.
GW036596-LC	NSWOW	209.27	550938	6264661	LC	64	66	Pipes in separate drillholes.

Piezometer / Bore	Owner	Collar Elevation (mAHD)	Easting (mMGA)	Northing (mMGA)	Stratum	Screen (mbgl)		Comment
						From	To	
GW036596-Ln	NSWOW	209.00	550938	6264661	Ln	85	87	Pipes in separate drillholes.
GW036597-Ln	NSWOW	209.81	544505	6263713	Ln	95	99	Pipes in same drillhole. SWLs same as 36597-LC. Only Ln screen used.
GW036605-Ln	NSWOW	221.11	554028	6241420	Ln	80	86	
GW036606-Ln	NSWOW	234.18	564753	6238189	Ln	99	105	
GW036609-Ln	NSWOW	210.92	554624	6285396	Ln	106	113	
GW036610-LC	NSWOW	209.33	549088	6264456	LC	64	68	Backfilled 45 m. Water levels appear to be representative.
GW036611-Ln	NSWOW	209.09	553937	6264823	Ln	107	113	
GW036613-LC	NSWOW	213.41	541663	6263705	LC	35	45	Backfilled 33 m. Screen in UC but SWLs interpreted as LC.
GW036700-LC	NSWOW	209.03	555433	6264788	LC	65	75	No backfill.
GW039379-Ln	NSWOW	223.99	557312	6240441	Ln	74	100	Directly coincident with 36604-Ln (36604-Ln not used).
GW090093-LC	NSWOW	210.19	549832	6294377	LC	60	66	Pipes in separate drillholes.
GW090093-Ln	NSWOW	210.12	549832	6294377	Ln	130	136	Pipes in separate drillholes.
GW090093-UC	NSWOW	210.05	549832	6294377	UC	5	11	Pipes in separate drillholes.
Coles (GW701579)	Private	209.20	553767	6269660	Ln	107	110	
Koreela (GW702262)	Private	212.80	549449	6293272	Ln	117	125	Also in model as a pumping bore.
Muffet (GW701958)	Private	209.00	556272	6270630	Ln	88	93	Also in model as a pumping bore.
Trigalana (GW702286)	Private	208.30	555900	6279959	Ln	102	113	Also in model as a pumping bore.
Warrakimbo (GW701681)	Private	208.00	552812	6266221	Ln			Very close to Maslin Pumping Bore.

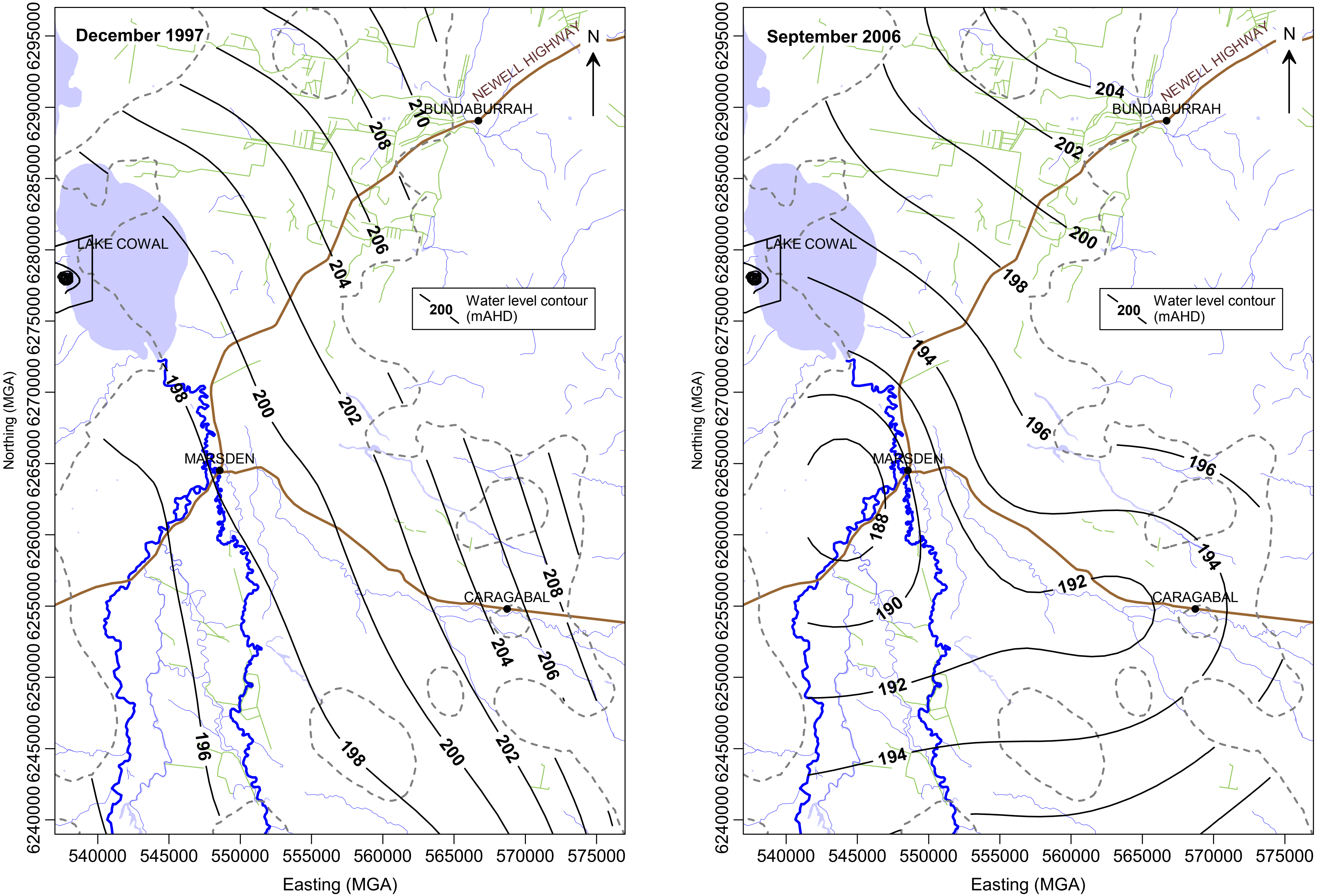
Glossary: JIL denotes Jemalong Irrigation Limited. mbgl denotes metres below ground level. UC denotes Upper Cowra Formation. LC denotes Lower Cowra Formation. Ln denotes Lachlan Formation. SWL denotes standing water level.

Appendix C – Interpolated Hydraulic Head Surfaces

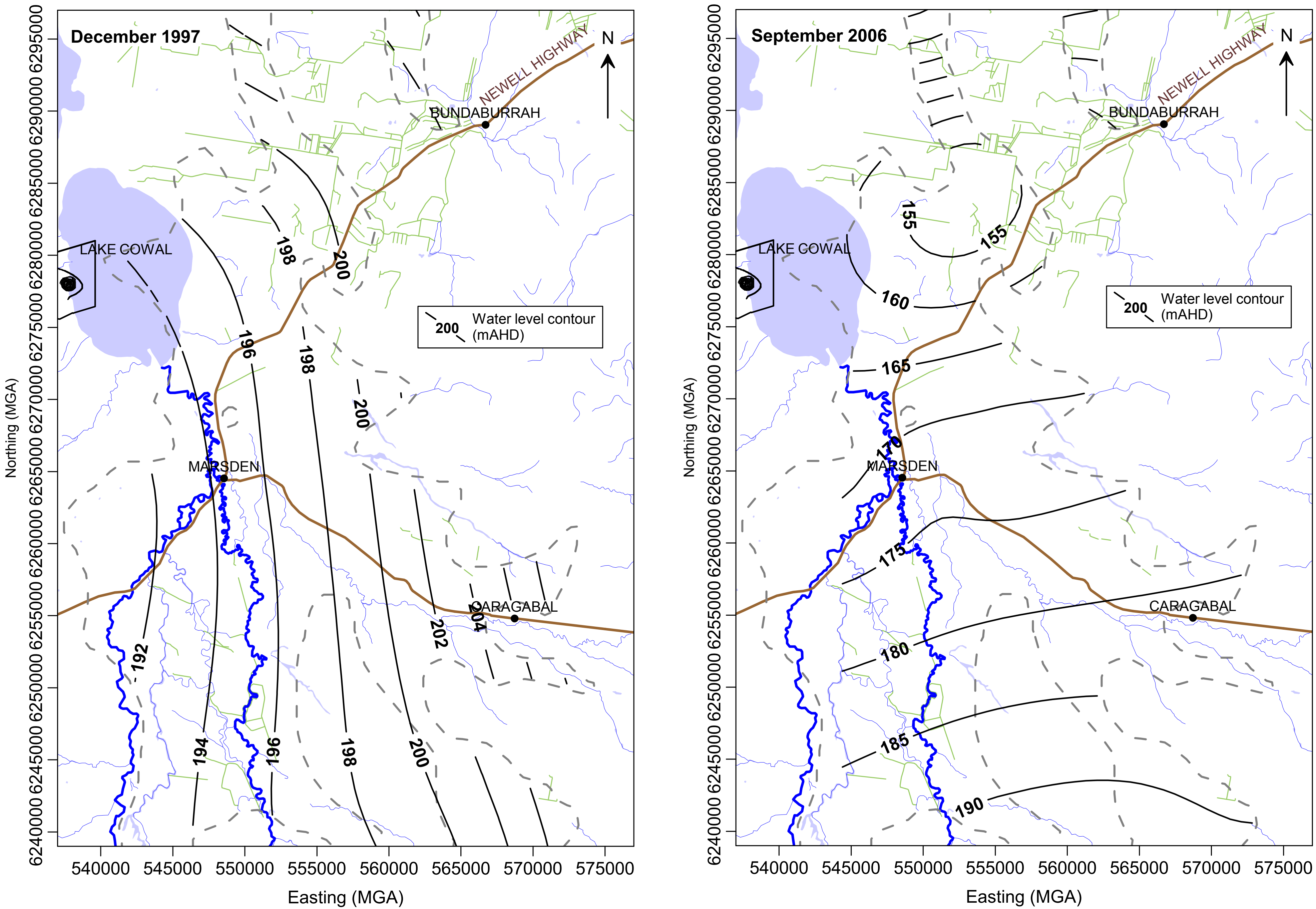
Interpolated Hydraulic Head Surfaces for the Upper Cowra Formation



Interpolated Hydraulic Head Surfaces for the Lower Cowra Formation



Interpolated Hydraulic Head Surfaces for the Lachlan Formation



Appendix D - Groundwater Electrical Conductivity Averages

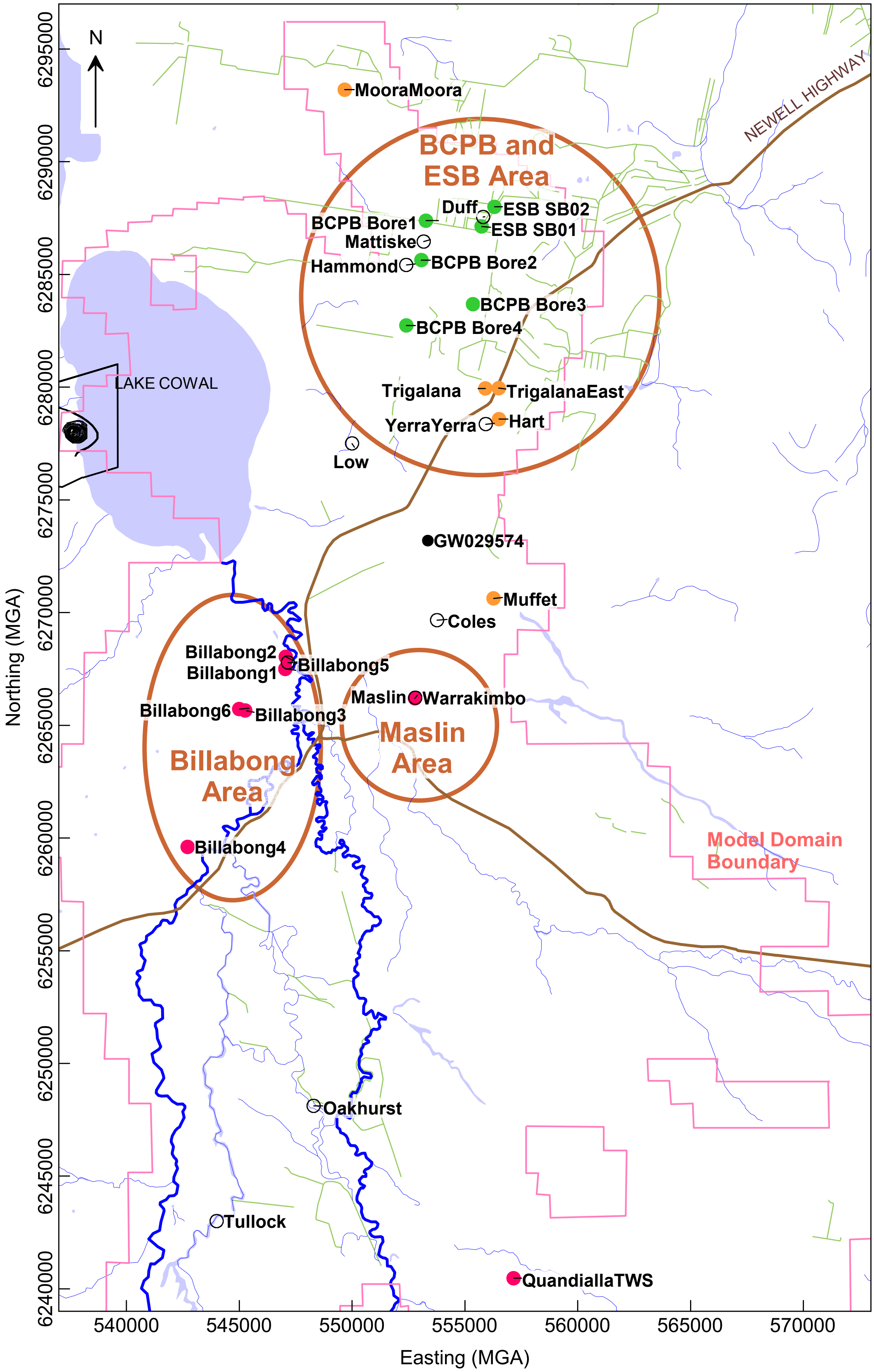
Groundwater Electrical Conductivity Database

Bore	Log-Average EC (uS/cm)	Average EC minus one standard deviation* (uS/cm)	Average EC plus one standard deviation* (uS/cm)	Depth (mbgl)	Data Source
BLPR1 (2004 to 2016)	1933	1848	2023	106	BLPR series averages. Barrick / EM.
BLPR2 (2004 to 2016)	2400	1733	3323	116	
BLPR3 (2004 to 2016)	4979	4810	5153	78	
BLPR4 (2005 to 2016)	2038	1878	2211	102	
BLPR5 (2005 to 2016)	2473	2305	2653	114	
BLPR6 (2004 to 2016)	1917	1831	2007	106	
BLPR7 (2004 to 2016)	1826	1598	2086	118	
P414B (2004 to 2008)	41055	38554	43720	13	Mine Site averages. Barrick / EM.
P417B (2004 to 2008)	32621	29238	36395	11	
P418B (2004 to 2008)	44208	41971	46564	13	
PDB1B (2004 to 2008)	49494	48600	50404	17	
PZ02 (2010 to 2016)	26170	24688	27741	48	ESB averages. Barrick / EM.
PZ05 (2010 to 2016)	6064	4114	8937	48	
PZ09 (2013 to 2016)	24866	23188	26666	15	
PZ10 (2013 to 2016)	9921	8544	11519	50	
PZ11 (2013 to 2016)	13444	11896	15193	62	
SB01 (2011 to 2012)	13258	12404	14171	60	
SB02 (2011 to 2012)	24150	23577	24737	56	
BCPB Bore1	2210			98	BCPB Pumping Bores 1 to 4. Barrick / EM.
BCPB Bore2	2060			90	
BCPB Bore3	1950			94	
BCPB Bore4	3690			93	
BLPR2	1350			116	Coffey report G255/18-AD (1994). Sampled 6 Jan 1994.
BLPR2	1500			116	Coffey report G255/18-AD (1994). Sampled 6 Mar 1994.
BLPR2	1550			116	Coffey report G255/24-AJ (1994). Sampled 12 Apr 1994.
BLPR2	1540			116	Coffey report G255/24-AJ (1994). Sampled 24 Nov 1994.
BLPR4	2020			102	Coffey report G255/24-AJ (1994). Sampled 12 Aug 1994.
BLPR5	610			114	Coffey report G255/24-AJ (1994). Sampled 12 Aug 1994.
BLPR7	1820			118	Coffey report G255/24-AJ (1994). Sampled 12 Aug 1994.
GW036524	50300			15	NSWOW Piezometers (Anderson et al. 1993 and NSWOW records).
GW036528	35100			10	
GW036528	22700			38	
GW036528	10570			51	
GW036528	9990			51	
GW036551	35900			4	
GW036551	24700			27	
GW036551	2750			40	
GW036552	11000			33	
GW036552	615			64	
GW036552	1451			101	
GW036553	2100			85	
GW036553	1850			121	
GW036553	1846			121	
GW036554	17000			13	
GW036554	1050			43	
GW036554	351			56	
GW036563	39600			19	
GW036594	45600			13	
GW036594	27400			70	
GW036595	14490			86	
GW036595	14300			86	
GW036596	3100			85	
GW036597	544			18	
GW036597	2370			78	
GW036597	1864			95	
GW036609	1990			106	
GW036610	14550			64	
GW036611	1857			109	
GW036611	1655			109	
GW036613	31700			48	

Green shading indicates single measurement only.
* in log space.

Appendix E - Pumping Bores

Bland Creek Palaeochannel Pumping Bores



- EM CGO bore (active in model).
- Private bore active in model. Usage data available to June 2010, or decommissioning, whichever earlier (except for Billabong 1, where supplied usage data ends June 2004, but bore was decommissioned in March 2006).
- Private bore active in model. No usage data available but necessarily included in model (from 2007) for calibration and predictive periods. Usage estimates supplied by Lachlan Valley Users Group.
- Private bore inactive in model (no usage data available).

Bland Creek Palaeochannel Pumping Bore Manifest (excludes basic rights bores, and includes only those in the model domain).

Table 1. Active Pumping Bores in the Model Domain.

Bore Number and/or Name	Owner	Easting (mMGA)	Northing (mMGA)	Ground Elevation (mAHD)	Collar Elevation (mAHD)	Screen Interval (mbgl)		Screened Stratum	Allocation (ML/year)	Comment
						From	To			
Bore1 (GW701660)	Evolution	553276	6287386	209.7	210.4	95	116	Ln	3650	BCPB. Commenced 2004.
Bore2 (GW701659)		553071	6285635	208.7	209.4	92	125	Ln		
Bore3 (GW701658)		555360	6283678	209.4	210.1	107	128	Ln		
Bore4 (GW701657)		552408	6282736	208.5	209.2	108	117	Ln		
SB01 (GW703944)		555740	6287128	210.7	211.3	54	66	LC		ESB. Commenced February 2010
SB02 (GW703943)		556315	6288003	210.6	211.5	45	66	UC/LC		
GW029094 (Billabong 1)	Private	547041	6267503			100	107	Ln	2000	Decommissioned in March 2006. To have been replaced by Billabong 5 in 2008.
GW057974 (Billabong 2)		547180	6268021			96	108	Ln		Decommissioned in March 2004. To have been replaced by Billabong 5 in 2008.
GW701646 (Billabong 3)		545012	6265729		208.0	98	109	Ln		Decommissioned in late 2008. Replaced by Billabong 6.
GW702127 (Billabong 4)		542922	6259675		210.0	108	123	Ln		Commenced October 2005. Replacement for Billabong 1 and Billabong 2.
GW703639 (Billabong 6)		545000	6265720			98	110	Ln		Commenced after 30 June 2008. Replacement for Billabong 3.
GW701267 (Maslin)		552731	6266198				125[1]	Ln	2000	
GW701454 (QuandiallaTWS)		557158	6240472			98	106	Ln	266	
GW701958 (Muffet)		556272	6270630			88	93	Ln	100	Sandpack from 87 m to 95 m bgl.
GW702013 (Hart)		556515	6278585			102	109	Ln		
GW702262 (MooraMoora)		549449	6293272		212.8	117	125	Ln		Also known as Koreela / McDonald.
GW702286 (Trigalana)		555900	6279959		208.3	102	113	Ln		Also known as the Fuge bore.
Trigalana East		556501	6279959				110[2]	Ln		

1. Completed depth (screen details unavailable).
2. Screen base is an estimate based on structure contour surfaces developed for modelling.
Glossary: mbgl denotes metres below ground level. UC denotes Upper Cowra Formation. LC denotes Lower Cowra Formation. Ln denotes Lachlan Formation. SWL denotes standing water level.

Table 2. Pumping Bores In the Model Domain For Which No Usage Data Are Available (Designated Inactive In the Model).

Bore Number and/or Name	Owner	Easting (mMGA)	Northing (mMGA)	Ground Elevation (mAHD)	Collar Elevation (mAHD)	Screen Interval (mbgl)		Screened Stratum	Allocation (ML/year)	Comment
						From	To			
GW701579 (Coles)	Private	553767	6269660			107	111	Ln		
GW701681 (Warrakimbo)		552812	6266221			96	111	Ln		Used as an observation bore until 2006.
GW702100 (Hammond)		552407	6285421			107	115	Ln		
GW702230 (Duff)		555812	6287547				66[1]	UC/LC		Pump tested for ESB.
GW702285 (Mattiske)		553174	6286458			105	114	Ln	1960	
GW703303 (YerraYerra)		555926	6278354			109	114	Ln		Sandpack from 60 to 115 mbgl.
GW703389 (Oakhurst)		548300	6248113				40[1]	UC/LC		
GW703638 (Billabong 5)		547160	6267785			90	108	Ln		Replacement for Billabong 1 and 2.
Low		550000	6277500						2000	Licence application lodged
Tullock		544000	6243000						2000	Licence application lodged

1. Completed depth (screen details unavailable).
Glossary: mbgl denotes metres below ground level. UC denotes Upper Cowra Formation. LC denotes Lower Cowra Formation. Ln denotes Lachlan Formation. SWL denotes standing water level.

Appendix F - Bland Creek Palaeochannel Numerical Groundwater Flow Model

Table of contents

Tables

Figures

Bland Creek Palaeochannel Numerical Groundwater Flow Model

1. Structure

The model active area covers about 1,800 km^2. Figure 1 shows the calculated extents of the Upper Cowra, Lower Cowra, and Lachlan Formations, and the boundary of the modelled area (for the uppermost model layer).

Figure 2 shows the modelled areas for each of the three model layers. The total extents of the Cowra and Lachlan Formations (calculated from borehole data and bedrock outcrop) are also shown in Figure 2 as the darker lines. The model areas do not extend to the extremities of the calculated total extents of the sediments since in these areas the sediments in each formation thin out considerably and practical limits were applied to the model boundaries. The model grid consists of a uniform mesh of 50 m by 50 m cells over the Bland Creek Palaeochannel Borefield (BCPB) area (covering an area of about 36 km^2) gradually expanding to a maximum cell size of 1 km by 1 km at the edges of the model area. Cell dimensions increase by a factor of 1.2 between cells to maintain model stability and allow accurate calculation of heads.

The groundwater system is simulated using three layers as follows:

- Layer 1: The Upper Cowra Formation (unconfined). The base of the Upper Cowra is set to 47 m below ground level based on hydraulic conductivity (K) data and downhole gamma logs from bores in the vicinity of the BCPB.
- Layer 2: The Lower Cowra Formation (confined / unconfined).
- Layer 3: The Lachlan Formation (confined / unconfined).

The Upper Cowra Formation has one parameter zone (see Figure 2). The Lower Cowra Formation has three parameter zones (northern, central, and southern) of approximately equal extent, broadly based on geology. The Lachlan Formation has two parameter zones representing:

- High K sands and gravels close to and within the deeper parts of the palaeochannel.
- Lower K, finer-grained sediments that generally occur further away from the deeper parts of the paleaochannel and surround the high K sands and gravels.

K measurements indicate that bedrock K is probably about 1000 times lower, at the same depth, than the high K part of the Lachlan Formation in the deeper parts of the palaeochannel (about 100 m depth). Therefore, bedrock in the Bland Creek Palaeochannel underlying the alluvial sequence has been assumed to be impermeable for the purpose of numerical simulation, and has not been modelled. This is considered reasonable since the rock occurs at burial depths exceeding 100 m (significantly lowering its hydraulic conductivity), and is separated from the alluvial sequence by a low K clay palaeosol of several metres thickness.

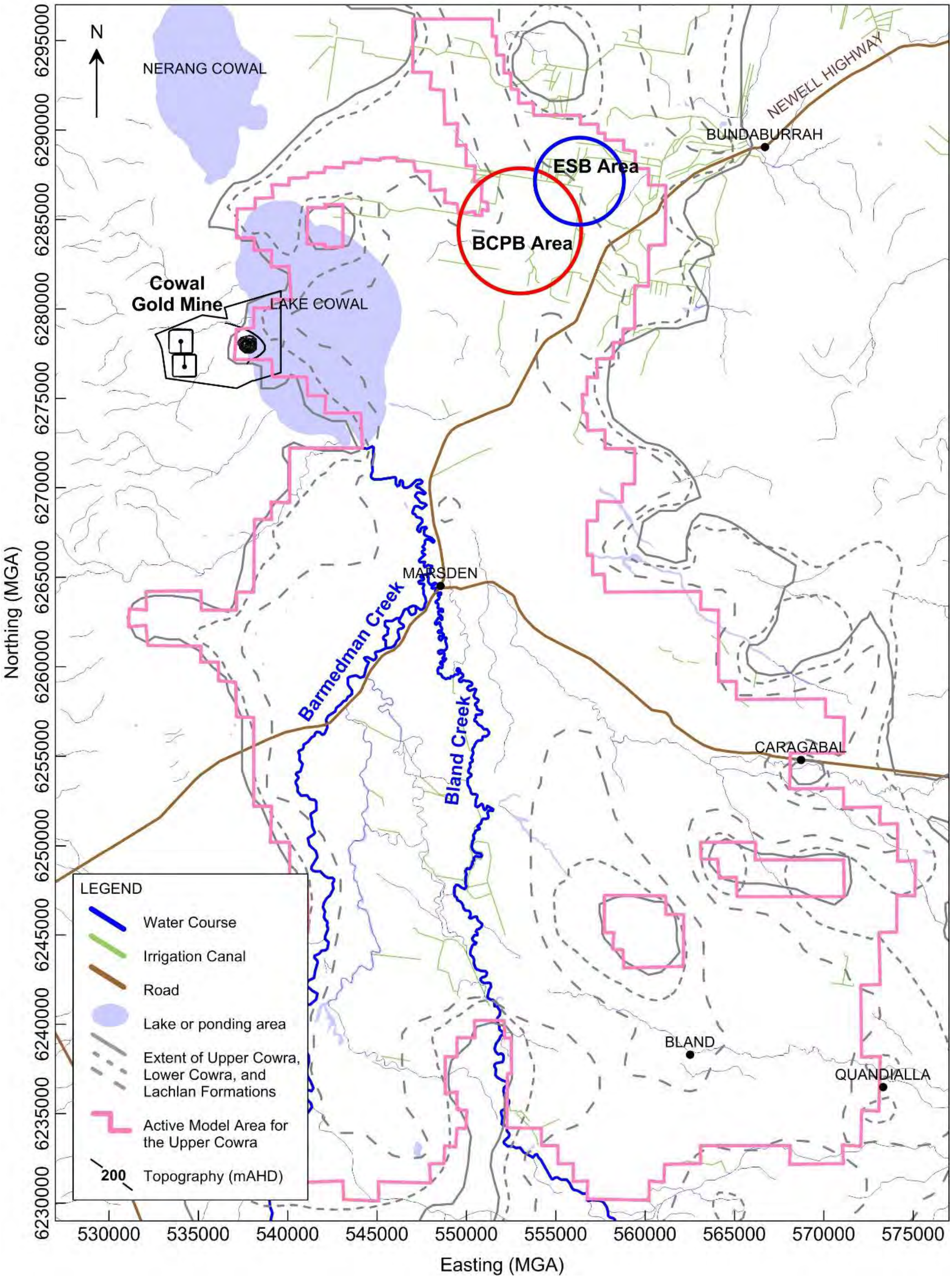
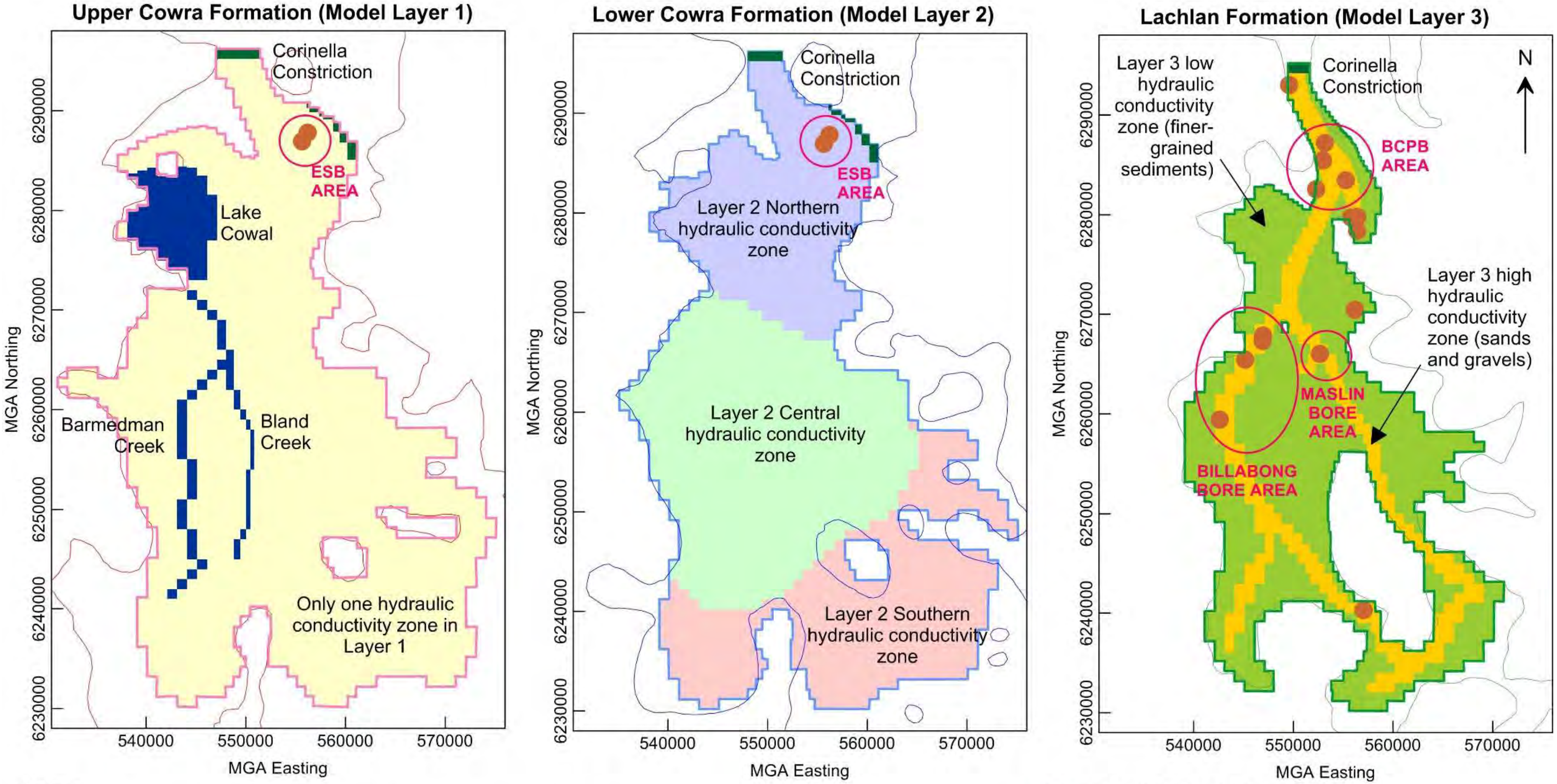


Figure 1. Model domain boundary.



NOTE:
1. Thicker lighter-coloured lines indicate model layer boundaries.
2. Thinner darker-coloured lines indicate interpreted total extents of the formations (to zero thickness).
3. Storativity parameter zones are the same as K parameter zones.

BOUNDARY CONDITIONS:
- General Head
- River or lake
- Pumping well

Figure 2. Layer parameter zones and boundary conditions.

2. Boundary conditions

Model boundary conditions are illustrated in Figure 2 and described below.

Rainfall recharge is applied at a uniform percentage of incident rainfall (on a daily, monthly, or yearly basis, depending on stress period size) over the entire extent of the Cowra Formation in the model domain.

The northern boundary of the model was chosen at a point where narrowing of the Bland Creek Palaeochannel is interpreted to occur in the Lachlan Formation at the Corinella Constriction (see Figure 2). Including the area to the north of this point and beyond would have involved the added complexity of treatment of the Lachlan Valley groundwater system and the associated groundwater interactions. To allow groundwater flow across this boundary, a general head condition was applied in all three layers. The general head boundary conditions assigned at this location allow aquifer flow to enter and leave the model at a rate proportional to the difference in head across the boundary.

Parameters for the general head boundaries were initially calculated by assuming that the Lachlan River and Goobang Creek to the north act as ultimate hydraulic controls, and calculating the conductances based on average cell widths, distances to these boundaries from the Corinella Constriction, and estimated layer hydraulic conductivities over this distance. Conductances were then varied slightly during calibration based on the hydrograph for the Koreela bore and government monitoring piezometer GW090093 (see Appendix B of the main report).

Based on a review of stream flow and river stage data from the Government Pinneena database, and field observations, the following water courses have been included in the model using the River package:

- Barmedman and Bland Creeks near Lake Cowal.
- Lake Cowal.

These water courses were selected based on groundwater hydrographs and duration of water flow. Riverbed elevations were assessed from topographic maps, digital elevation data, and stream gauging station survey information. These data were used to assign smoothly-varying riverbed elevations over the model area for the creeks and Lake Cowal. River water level heights were obtained from the Pinneena database. Water levels for Lake Cowal were estimated from data presented in the Cowal Gold Project Environmental Impact Statement (North Limited 1998).

Leakage from Lake Cowal is expected to flow in a northwesterly direction, out of the model active area. To the northwest of Lake Cowal lies Nerang Cowal and a thin cover of surface soil overlying rock. In the model, flow of lake leakage is not possible from the lake to the northwest (because the Upper Cowra Formation is not present there), therefore the calibrated conductance of the lake bed material allows only that flow which reports to the active area of the Upper Cowra Formation in the model.

The CGO Western Saline Borefield (WSB) is located in the mine lease and is included in a separate local groundwater model for the mine lease area, and is not included in the regional model of the current work. The WSB pumps from the Upper Cowra Formation only, at relatively small rates, and is considered unlikely to significantly affect drawdown in the Upper Cowra, Lower Cowra, or Lachlan Formations further east.

The CGO mine pit is included in the separate local groundwater model and is not included in the regional model. The mine pit is located on the western margin of the regional model and intersects alluvial sediments, saprolite (clay), and fractured media. The alluvial sediments are the equivalent of the Upper Cowra Formation. They have been slightly impacted by drainage into the mine pit. The Lower Cowra and Lachlan Formations are not present at the mine site. The drawdown in the Upper Cowra Formation from pit drainage has been small and localised, and is considered unlikely to significantly affect drawdown in the Upper Cowra, Lower Cowra, or Lachlan Formations further east. Drawdown in the saprolite, saprock, and fresh rock from drainage at the mine pit is not likely to influence groundwater processes in the active model area, apart from the localised effect near the pit of inducing vertical drainage from the Upper Cowra Formation (in addition to lateral drainage towards the pit face).

18 pumping bores are active in calibration, verification, or predictive model simulations. These comprise six Evolution bores (4 at the BCPB and 2 at the ESB) and 12 private bores. Appendix E of the main report lists these bores and their details. Low-extraction basic rights bores (used for stock and domestic purposes) are not included.

2.1. Recharge and discharge processes

Model recharge processes are:

- Rainfall recharge.
- Leakage from rivers (Bland Creek and Lake Cowal).
- Flow into the model from the Corinella Constriction in all layers.

Model discharge processes are:

- Groundwater extraction from the Upper Cowra, Lower Cowra, and Lachlan Formations.
- Leakage to rivers (Bland Creek and Lake Cowal).
- Flow out of the model to the Corinella Constriction in all layers.

Evaporation is not modelled because the average depth of the water table in the Upper Cowra Formation is around 5 m over the majority of the model domain, and below the extinction depth typical for the land use, surface lithology, and climate of the area.

Intermittent recharge from flooding from remnant ponds outside the water course channels is not modelled in calibration simulations since no flooding was known to have occurred in the area during the model calibration period. However, the calibrated riverbed conductances and rainfall recharge would incorporate the effect of this process where it may have occurred but was not explicitly identified in observations.

3. Media properties

Calibrated model media properties are listed in Table 1.

Initial estimates for riverbed conductance were based on consideration of values used for river systems in the Lower Namoi Valley groundwater flow model (Merrick 1989). The Lower Namoi Valley and Bland Creek Palaeochannel display many similar characteristics such as climate, subsurface media types, and river types.

Automated parameter estimation conducted as part of the 2006 modelling process indicated that the calibrated values for various parameters were considered defensible and appropriate based on site-specific observations, published studies, and model formulation. A finding of the estimation study was that in the more southerly parts of the model domain the vertical leakance in the Cowra Formation was likely to be lower than the calibrated value of the 2006 model. It was considered that, based on available data, the vertical leakance between the Cowra and Lachlan Formations was likely to decrease in a southerly direction. This finding was taken into account by dividing the Lower Cowra Formation into three zones (northern, central, and southern) of approximately equal extent, broadly based on geology, so that vertical leakance could be varied between zones.

Table 1. Calibrated model media properties.

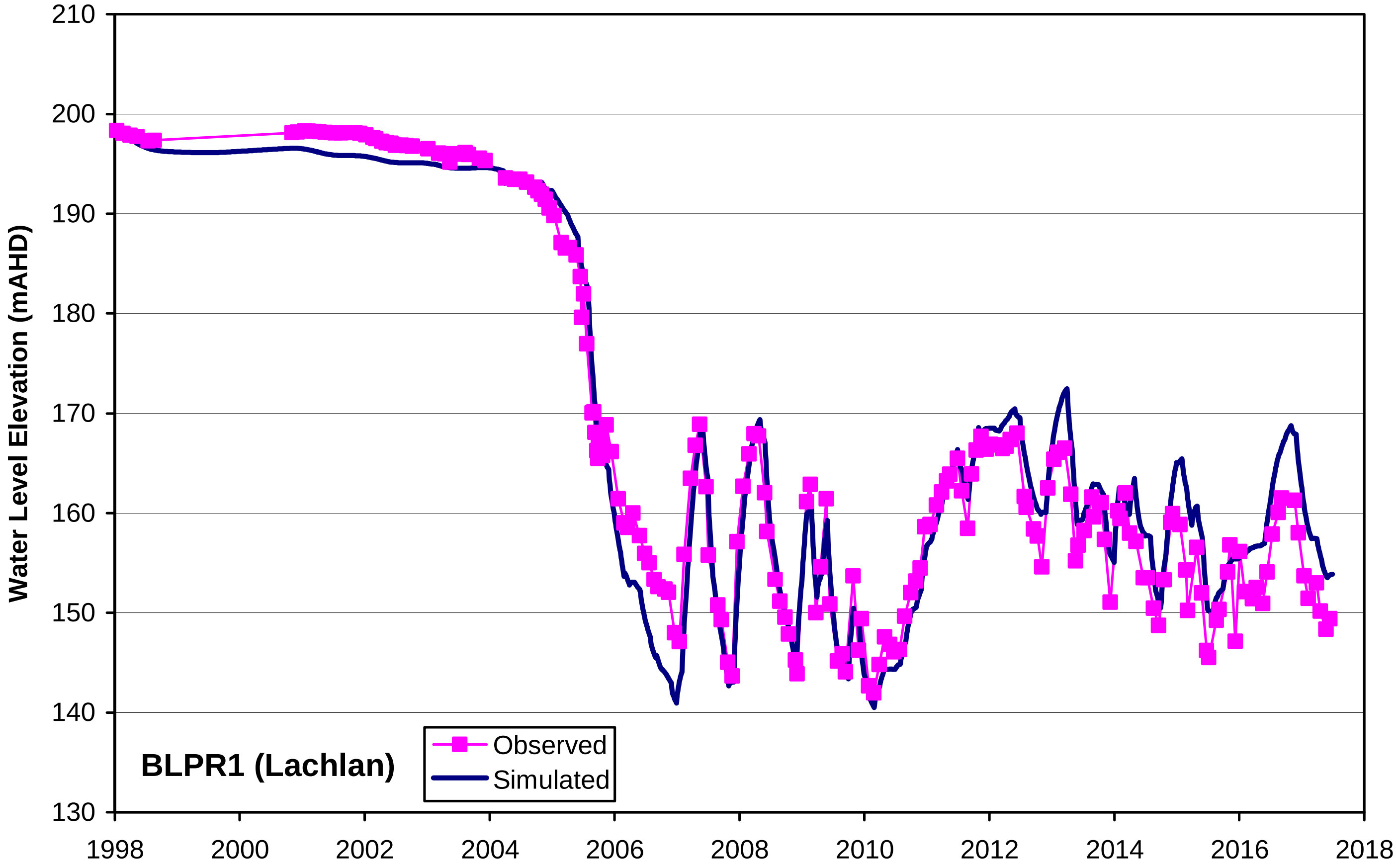
Parameter	Model Zone					
	Upper Cowra	Lower Cowra (North)	Lower Cowra (Central)	Lower Cowra (South)	Lachlan (Low Conductivity)	Lachlan (High Conductivity)
Lateral Hydraulic Conductivity (m/day)	1	2	1	1	3	28
Average Thickness over Model Area (m)	35	34	34	34	30	30
Average Transmissivity over Model Area (m^2/day)	35	68	34	34	90	840
Vertical Hydraulic Conductivity (m/day)	6×10^{-5}	1×10^{-5}	6×10^{-6}	1×10^{-5}	3	28
Specific Storage (m^{-1})	N/A	1.5×10^{-5}	1.5×10^{-5}	1.5×10^{-5}	1.5×10^{-5}	1.5×10^{-5}
Specific Yield	0.04	N/A	N/A	N/A	N/A	N/A
General Head Boundaries						
External Head (mAHD)	198	196	N/A	N/A	N/A	196
Conductance (m^2/day)	1	1	N/A	N/A	N/A	25
River Bed Conductance (m^2/day):						
Bland and Barmedman Creeks	10	N/A	N/A	N/A	N/A	N/A
Lake Cowal	5	N/A	N/A	N/A	N/A	N/A
Rainfall Recharge (% of average annual rainfall)	1.0	N/A	N/A	N/A	N/A	N/A

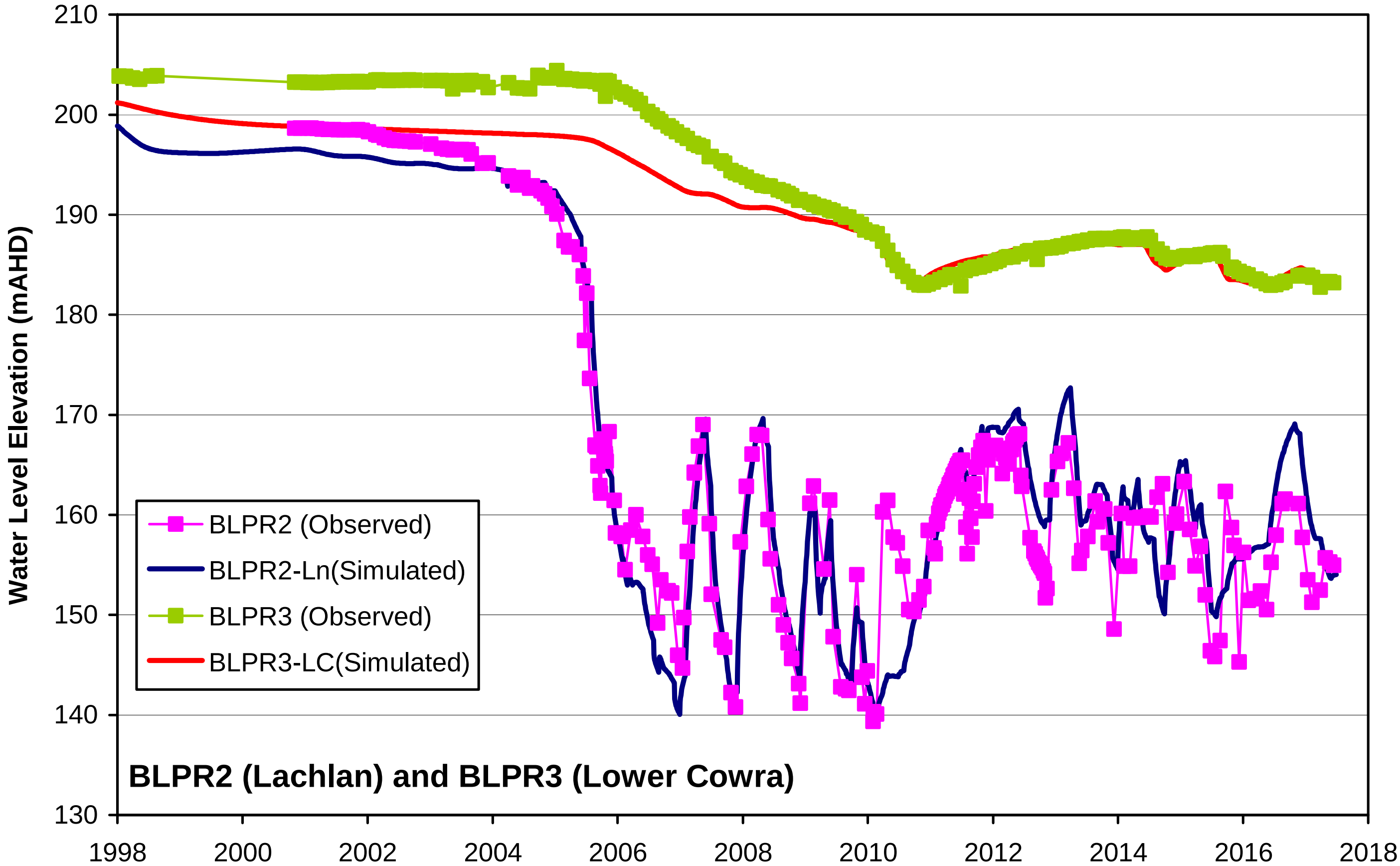
Assuming an average river channel width of 20 m (including overbank ponds), an average river reach of 1200 m in each cell, and 0.2 m of barrier material in the river bottom, the calibrated riverbed conductance for Bland and Barmedman Creeks is equivalent to a vertical hydraulic conductivity for the river bed barrier material of 9×10^{-5} m/day. For Lake Cowal leakage occurs over the entire area of each cell so the riverbed conductance is equivalent to a vertical hydraulic conductivity in the lake bed material of 1×10^{-6} m/day. This compares favourably with results from laboratory analysis of lakebed sediments indicating an average vertical hydraulic conductivity of 5.0×10^{-7} m/day (Hawkes 1998), allowing for upscaling from a laboratory sample scale to a regional scale. Hydraulic test results in Hawkes (1998) also indicate an average lateral hydraulic conductivity for the lake bed material of 5.5×10^{-5} m/day for one location on the lake.

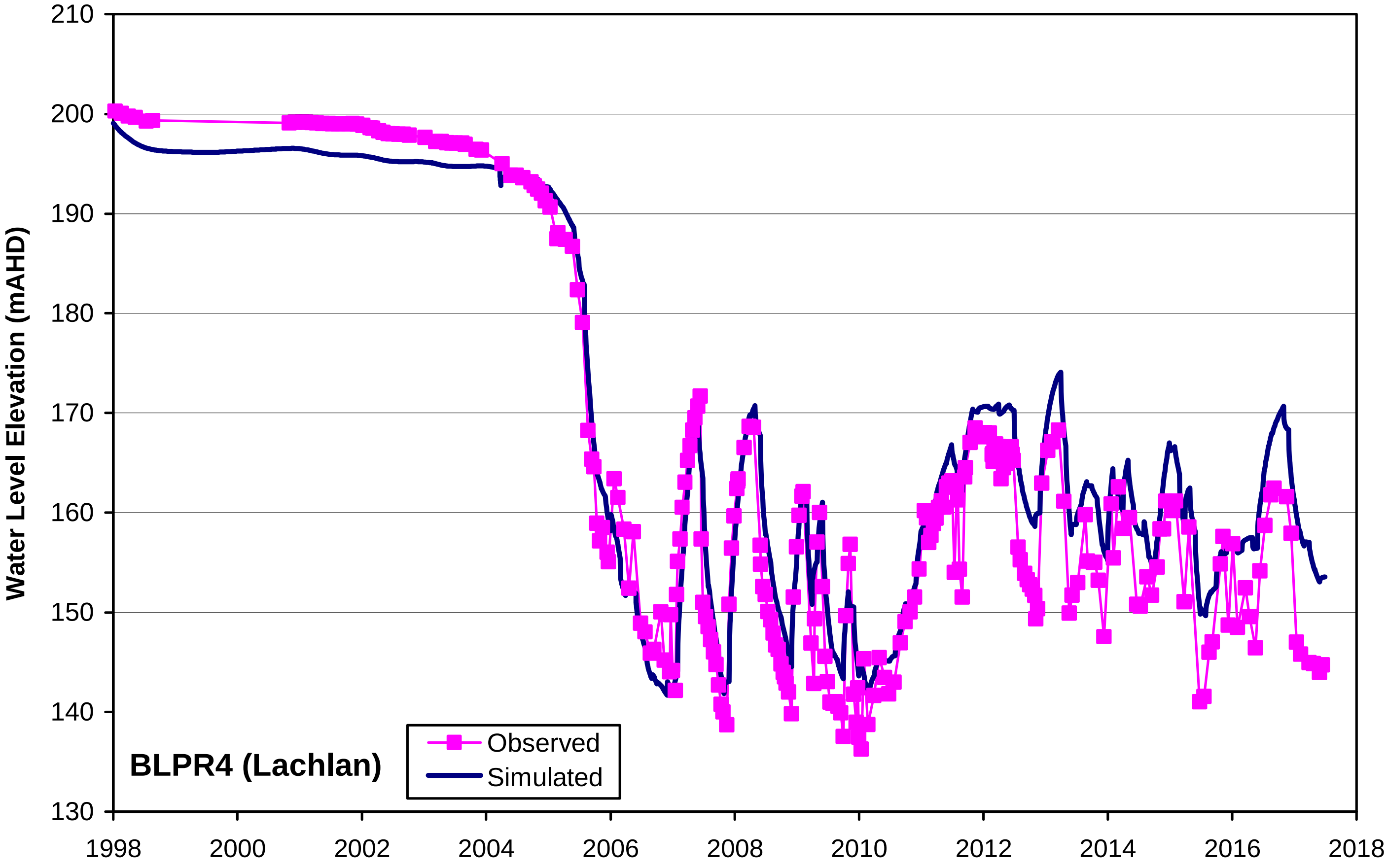
Rainfall recharge is calibrated to 1% of annual rainfall and compares favourably with other estimates for the area (between 0.3% and 2%). It is an overall average for the model area, mostly comprising recharge from rainfall and irrigation, but also likely to contain a small component representing seepage from shallow, higher conductivity rock on the fringes of the alluvial sediments. It is also likely that the calibrated value includes the effects of intermittent ponding associated with water courses.

The calibrated specific storage (1.5×10^{-5} m^{-1}) compares favourably with pump test results (average of around 9×10^{-6} m^{-1}).

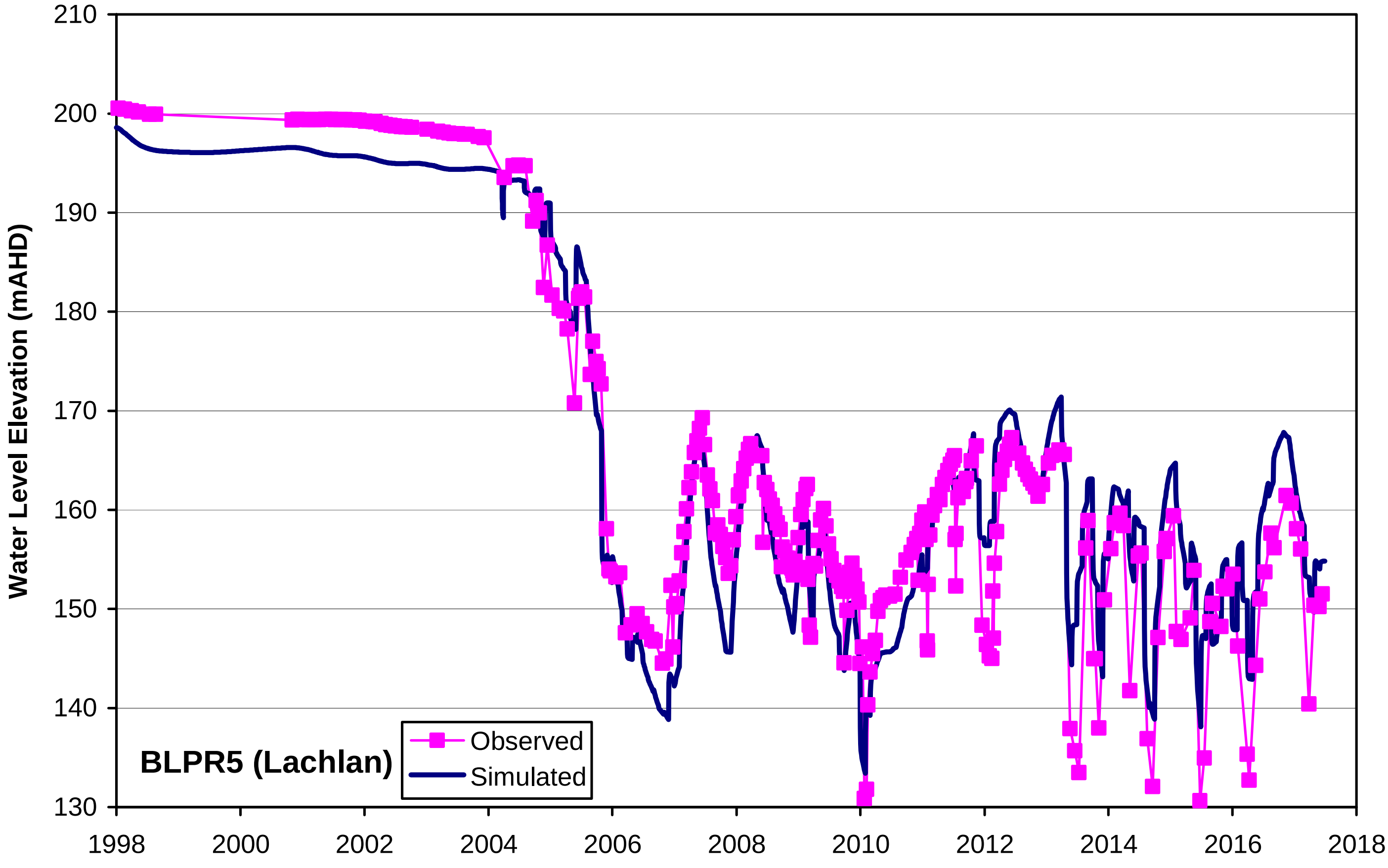
Appendix G - Verification Hydrographs


Water Level Elevation (mAHD)
210
200
190
180
170
160
150
140
130
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
BLPR1 (Lachlan)
Observed
Simulated

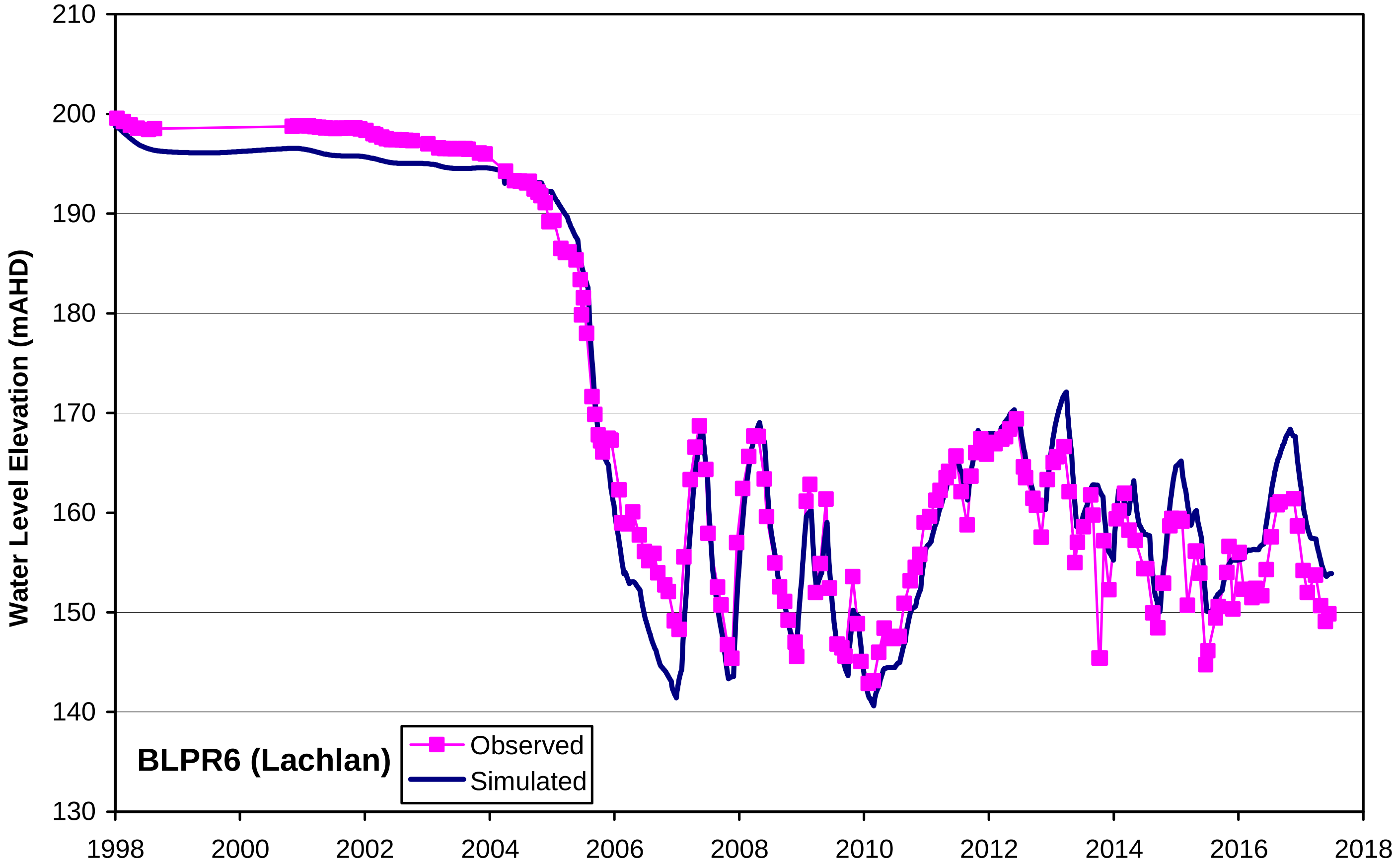

Water Level Elevation (mAHD)
210
200
190
180
170
160
150
140
130
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
BLPR2 (Observed)
BLPR2-Ln(Simulated)
BLPR3 (Observed)
BLPR3-LC(Simulated)
BLPR2 (Lachlan) and BLPR3 (Lower Cowra)



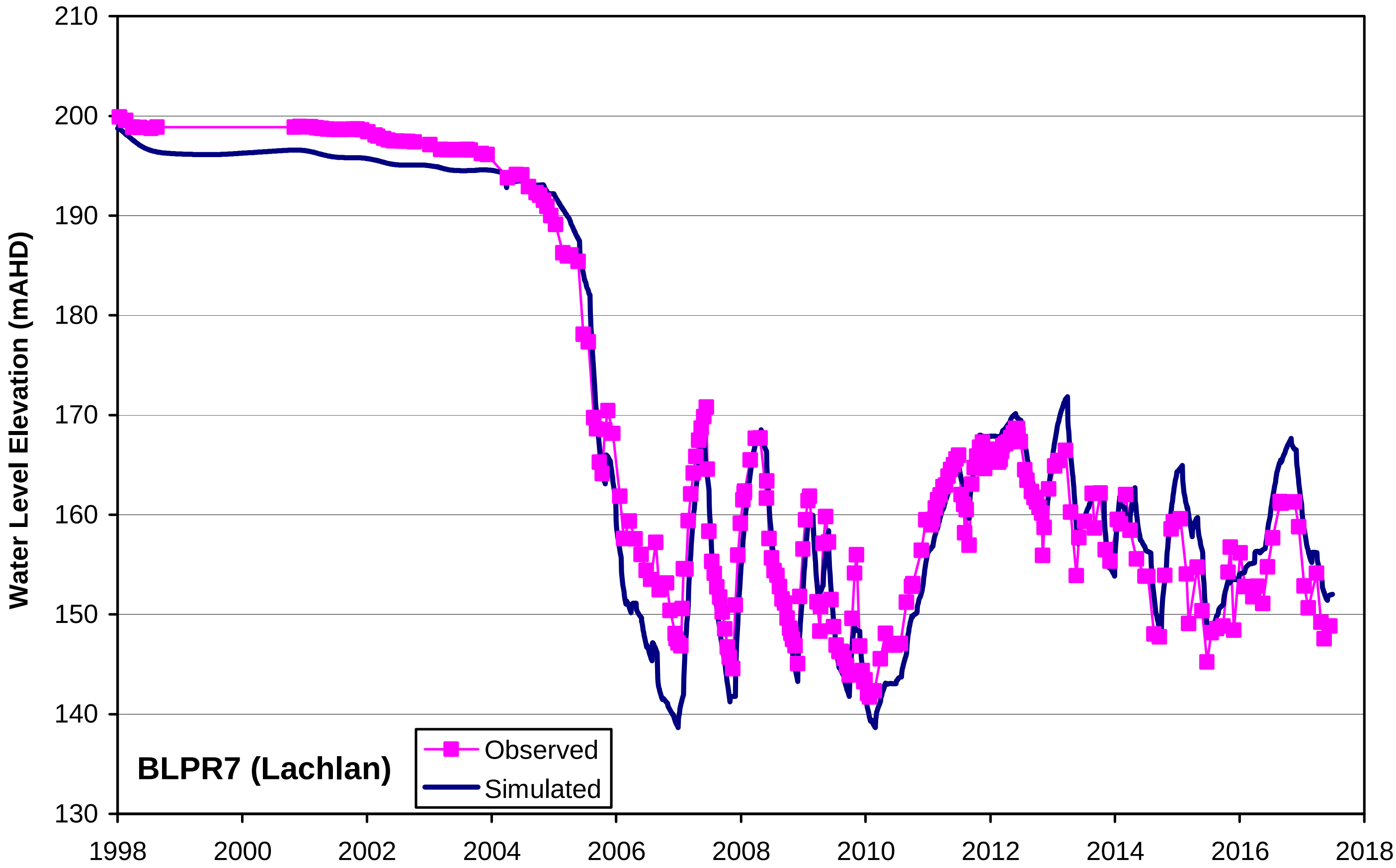
Water Level Elevation (mAHD)
210
200
190
180
170
160
150
140
130
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
BLPR4 (Lachlan)
Observed
Simulated



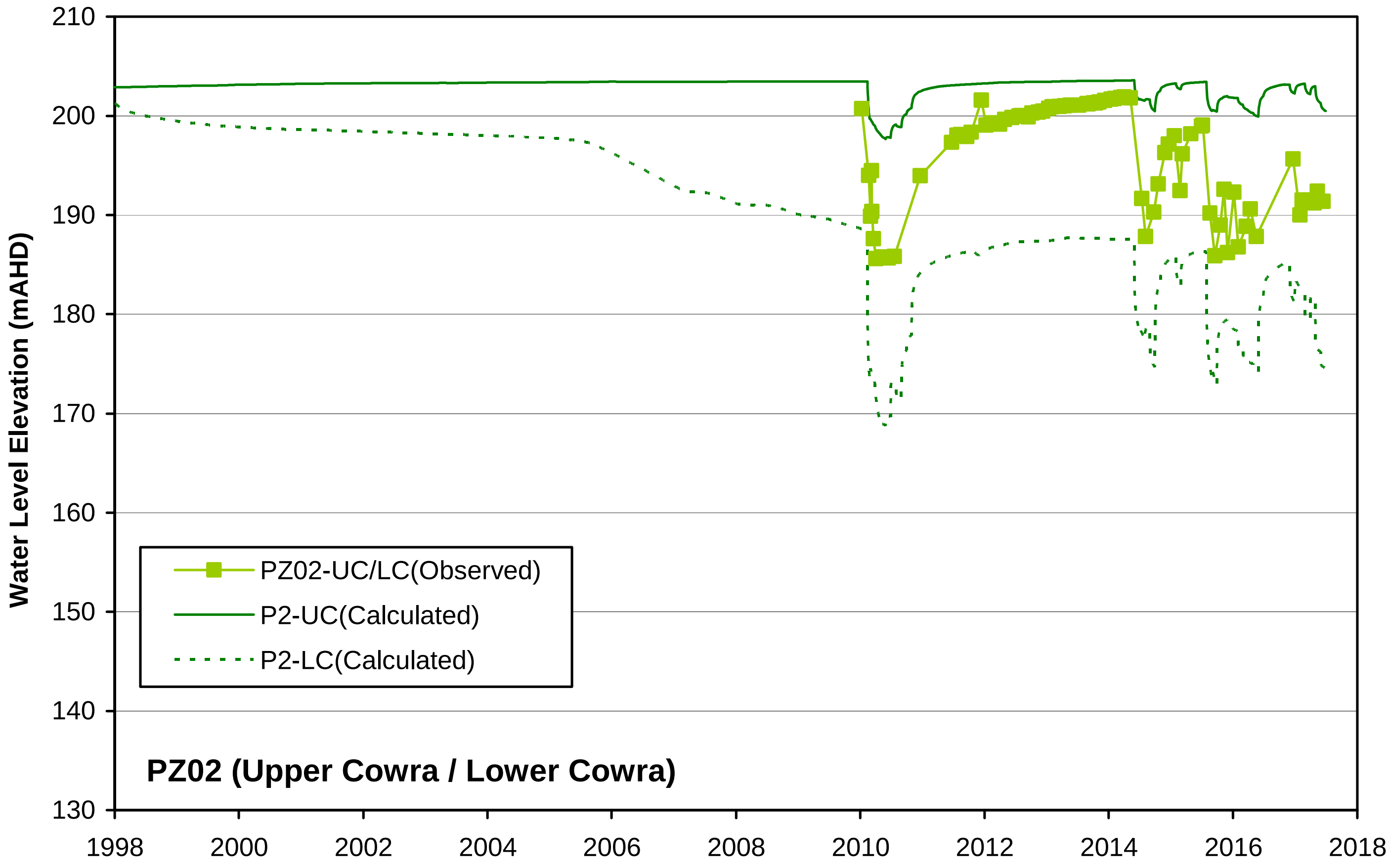
Water Level Elevation (mAHD)
210
200
190
180
170
160
150
140
130
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
BLPR5 (Lachlan)
Observed
Simulated



210
200
190
180
170
160
150
140
130
Water Level Elevation (mAHD)
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
BLPR6 (Lachlan)
Observed
Simulated



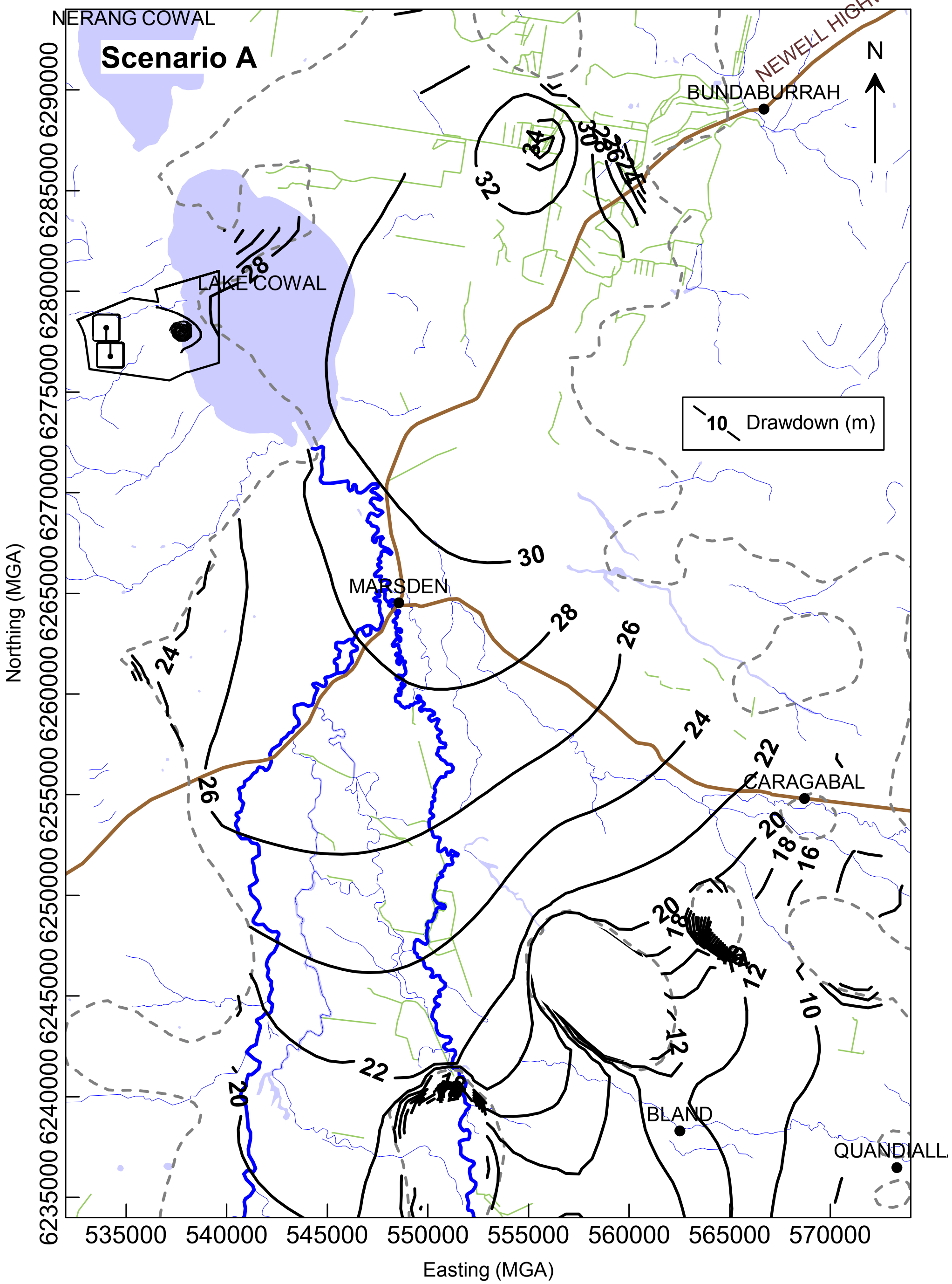
210
200
190
180
170
160
150
140
130
Water Level Elevation (mAHD)
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
BLPR7 (Lachlan)
Observed
Simulated



Water Level Elevation (mAHD)
210
200
190
180
170
160
150
140
130
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
PZ02-UC/LC(Observed)
P2-UC(Calculated)
P2-LC(Calculated)
PZ02 (Upper Cowra / Lower Cowra)

Appendix H - Drawdown in the Lower Cowra and Lachlan Formations at the end of BCPB and ESB Operation (31 Dec 2032)

Drawdown in the Lower Cowra Formation at the end of BCP and ESB Pumping (31 Dec 2032)



Drawdown in the Lachlan Formation at the end of BCP and ESB Pumping (31 Dec 2032)