



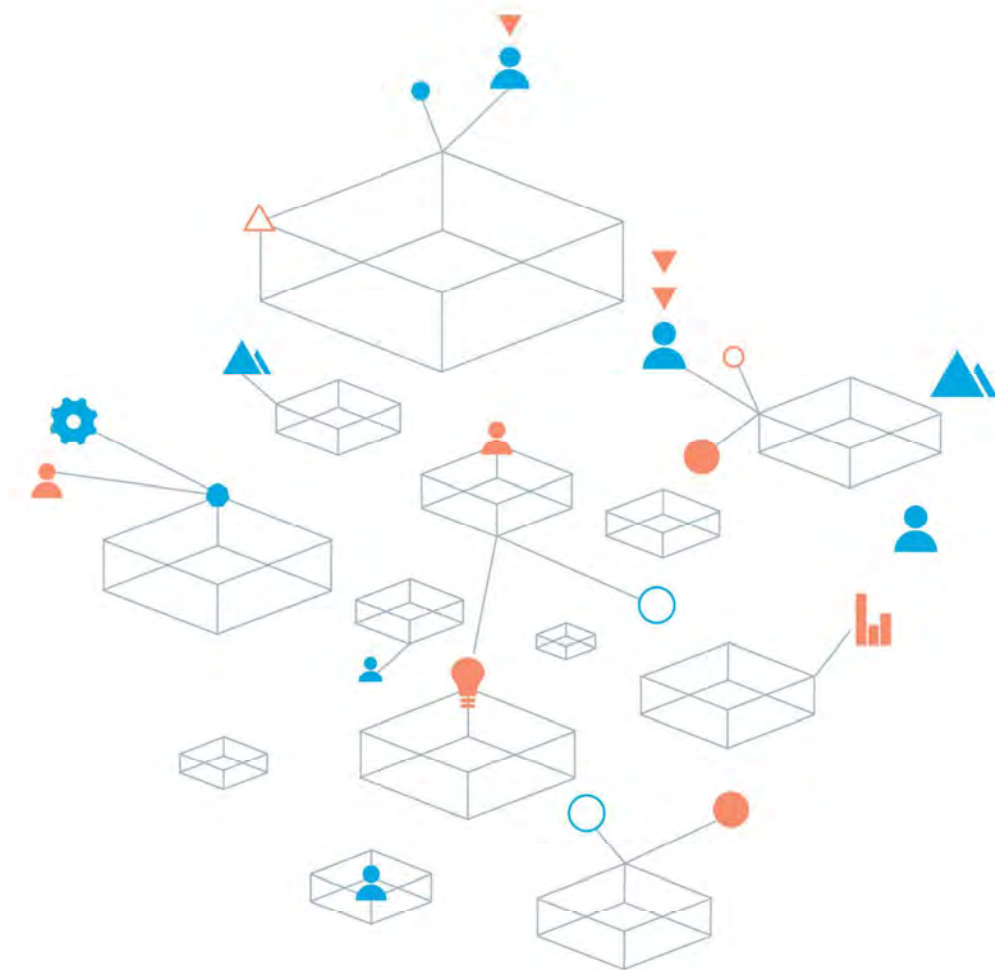
## Appendix H

Groundwater impact assessment (Mine site hydrological assessment)



**EMM Consulting Pty Ltd**  
**Cowal Underground Development EIS**  
**Mine Site Hydrogeological Assessment**

10 September 2020



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projects



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# Cowal Underground Development EIS

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Mine Site Hydrogeological Assessment

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# Executive summary

Cowal Gold Operations (CGO) is an existing open cut mine site, which has been operational since commencement in 2005, located immediately adjacent to the ephemeral lake, Lake Cowal. Evolution Mining seeks to extend mining operations at the CGO by way of an underground development, which would be wholly contained within Mining Lease (ML) 1535. The Underground Development proposal seeks to introduce an underground mine using stope mining practices, in addition to the existing open cut mine, to exploit an identified ore deposit.

A hydrogeological assessment was undertaken by Coffey Services Australia Pty Ltd (Coffey) to assess potential impacts on the groundwater system under the proposed Cowal Gold Operations (CGO) Underground Development. The assessment employed predictive numerical modelling based on an existing numerical groundwater flow model which was completely re-worked, taking into account the proposed underground mining to the north of the existing open pit.

The numerical groundwater flow model was calibrated using an automated process using the open source software PEST. This resulted in adopted aquifer properties that provided a good fit to observed open pit inflows and to groundwater monitoring data from 22 locations over a fourteen year period from 2005 to 2020 and four locations above the proposed underground development where monitoring commenced in February 2020. Calibration results showed vertical hydraulic conductivities for the lake sediments underlying Lake Cowal to be in the very low range and substantially lower than the horizontal hydraulic conductivities. A similar result was found for the weathered rock units underlying the lake sediments.

Modelling results indicate that groundwater table drawdown is expected to lie completely within the CGO mining leases ML1535 and ML1791 over the life of the mine. Combined groundwater inflows into the proposed stopes and access tunnels are predicted to range from approximately 100 m<sup>3</sup>/day in 2022 to 2,300 m<sup>3</sup>/day between 2031 and 2039 and inflow to the open pit is predicted to fall from 1,000 m<sup>3</sup>/day in 2020 to 500 m<sup>3</sup>/day between 2031 and 2039. Following mine closure, groundwater inflow to the open pit is expected to result in a lake forming in the open pit, with the pit lake level rising to a level where groundwater inflow is balanced by evaporation from the pit lake.

An assessment of model parameter and observational uncertainty indicates a possible range of between 1,650 m<sup>3</sup>/day and 3,400 m<sup>3</sup>/day for the combined groundwater inflows into the open pit, stopes and access tunnels between 2031 and 2039.

Groundwater impacts to Lake Cowal are predicted to be negligible.

An assessment of contaminant migration, based on a conservative assessment of contaminant transport parameters, was undertaken. The assessment predicted 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 1.7 km from the Integrated Waste Landform (IWL) walls. Cyanide is introduced to mine tailings during ore processing at a maximum concentration of 20 mg/L and is the only significant chemical in the tailings that is not derived from the host rock. Consideration of cyanide decay times indicates that cyanide concentrations are predicted to fall well below detectable limits prior to seeping outside the CGO mine area.

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Appendix B - Groundwater calibration comparisons

Appendix C - Groundwater level response

Appendix D - Particle tracking

Appendix E - Field investigations report

# 1 Introduction

Evolution Mining (Cowal) Pty Limited (Evolution Mining) is the owner and operator of the Cowal Gold Operations (CGO) located approximately 38 kilometres north-east of West Wyalong, New South Wales (NSW). CGO is an existing open cut mine site, which has been operational since commencement in 2005, and has current approvals in place to continue processing at a rate of 9.8 million tonnes of ore per annum (Mtpa) until 2032. The existing mine site is located immediately adjacent to the ephemeral lake, Lake Cowal.

This report presents the Hydrogeological Assessment conducted by Coffey Services Australia Pty Ltd (Coffey) for Evolution Mining's CGO Underground Development EIS (UG EIS). This report addresses the effects within the area surrounding Mining Lease (ML) 1535.

A companion report has been prepared addressing the effects of the mining operation at a regional scale including the water supply borefields (Coffey report no. SYDGE206418-3-AN dated 27 August 2020).

## 1.1 CGO Underground Development

The area of land to which the CGO Underground Development Consent (DA 14/98) is relevant includes ML1535, ML1791 and the CGO water supply pipeline and Bland Creek Palaeochannel Borefield. Open pit mining operations are currently undertaken within ML1535, which encompasses approximately 2,636 hectares (ha). Evolution Mining seeks to extend mining operations at the CGO by way of an underground development, which would be wholly contained within ML1535. The Underground Development proposal seeks approval for construction and operation of an underground mine at the CGO to extract the GRE46 mineralisation which is located in close proximity to the existing open pit.

Key features of the CGO Underground Development include:

- A box-cut entry to the underground workings;
- A decline from the box-cut to provide access for personnel and maintenance;
- Six access points to the decline for access, ore haulage, ventilation circuit, underground services and emergency egress;
- A network of underground tunnels to provide access to the ore, transportation to the surface and ventilation;
- Use of sub-level open stoping to extract the ore;
- Production of up to 27 Mt of ore at a rate of 1.8 Mtpa;
- Production of approximately 5.74 Mt of waste rock;
- Stopes to be fully backfilled with paste material made from dewatered tailings and cement;
- Delivery of extracted ore and waste rock to the surface by truck;
- Development of a paste fill plant, and the delivery of paste fill via a borehole and the backfilling of underground stopes with the paste; and
- Development of ancillary underground infrastructure to support the underground operation, including dewatering infrastructure, ventilation system, electrical reticulation.

The following two components are part of Modification 16, which is a modification to an existing approval:

- Extension of mine life from 2032 to 2040;
- A height increase from 245 m AHD to 246 m AHD to the final rehabilitated height of the integrated waste landform.

## 1.2 Approvals strategy

To facilitate the Underground Development environmental impact assessment process, Evolution Mining proposes to seek approval under the NSW Environmental Planning and Assessment Act 1979 (EP&A Act) for two separate but inter-related applications:

- Underground workings EIS (UG EIS) – a State Significant Development (SSD) application under section 4.38 of the EP&A Act for the new underground component of the Underground Development. This document represents the Scoping Report that supported the request for SEARs for the SSD application.
- Surface changes modification – a request for modification (Modification 16) to the existing CGO development consent (DA 14/98) under section 4.55 of the EP&A Act for the ancillary surface changes associated with the Underground Development.

## 1.3 Scope of hydrogeological assessment

The objective of this hydrogeological assessment is to provide an assessment of potential impacts associated with the UG EIS, consistent with the requirements outlined in the NSW Department of Planning and Environment (DP&E) Secretary's Environmental Assessment Requirements (SEARs) for the development issued on 27 September 2019, application number SSD-10367.

This report builds upon work carried out for a hydrogeological assessment to assess the impacts of the mining operations in relation to changes proposed in CGO Modification 14 (Coffey, 2018a and Coffey, 2018b).

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

- Characterisation of the hydrogeological environment, including climate, topography, regional geology, mine geology, regional hydrology and hydrogeology.
- Collation and review of existing data, including:
  - Groundwater monitoring data, including groundwater level and groundwater quality results from bores located within the ML (i.e., proximal to the tailings storage facilities, waste rock emplacements, and open pit).
  - Past pit dewatering rates and groundwater drawdown monitoring results.
  - Additional geological data from resource drilling and survey.
- A review of the supplementary investigations undertaken for the UG EIS, which included:
  - Drilling of four vertical boreholes of up to 100 m depth below ground surface near the proposed underground development, with three piezometers installed in each borehole to monitor pore pressures at different depths.
  - Hydraulic testing (packer tests) in the vertical boreholes.



- Drilling and installation of 12 horizontal boreholes at three locations along the GRE46 exploration decline to measure pore pressures at various distances away from the decline.
- 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:
  - Discussion on the proposed modelling approaches to support groundwater impact assessment for the UG EIS, with a description of the mine area groundwater setting covering:
    - Recharge mechanisms.
    - Hydrogeological boundaries.
    - Hydrogeological units.
    - Hydraulic properties.
    - Influence of the flood events and periodic inundation of Lake Cowal.
    - Groundwater quality.
    - Mine groundwater inflows.
- Development and calibration of a 3D numerical groundwater model to model conditions relevant to the proposed underground development and expanded IWL.
- Predictive modelling to assess the following for the CGO Underground Development and Modification 16:
  - Potential changes to the hydrogeological regime as a result of underground mining and expanded IWL.
  - Potential groundwater drawdown associated with the underground mine and open pit dewatering.
  - Expected inflow rates to the underground mine and open pit.
  - Impacts on seepage from Lake Cowal due to the development.
  - Potential seepage rates from the tailings storage facilities (TSF) including the expanded IWL.
  - Groundwater drawdown impacts on Lake Cowal.
  - Transport of contaminants from the IWL after mine closure (adopting a particle tracking method) at 20, 50, 100 and 200 years post-mine closure.
- Sensitivity of modelling results to selected model parameters will be discussed, consistent with contemporary groundwater modelling guidelines.
- A model uncertainty assessment which includes a discussion on the key assumptions influencing model uncertainty and a quantitative assessment of model results for alternate sets of calibrated model parameters.
- Discussion relating to the underground mine and open pit dewatering, including:

- The groundwater regime resulting from the mine operation and discussion of potential contaminant migration from the TSF and IWL.
  - Expected inflow rates to the underground mine and open pit, based on predictive modelling.
  - Discussion on the connectivity between the Lake Cowal surface water and the proposed underground mine and open pit, and potential impacts on Lake Cowal.
  - Potential groundwater drawdown associated with open pit and underground dewatering, based on the predictive modelling.
  - Commentary relating to potential drawdown effects against criteria noted in the Department of Primary Industries NSW Aquifer Interference Policy (September 2012).
  - Qualitative assessment of the expected groundwater quality of water discharging into the underground mine and open pit.
  - Qualitative assessment of impacts on groundwater quality due to open pit and underground mine dewatering.
- Discussion relating to tailings and waste rock emplacement seepage, including:
  - Assessment of predicted seepage rates from the tailings storage facilities including the expanded IWL, based on predictive modelling.
  - Qualitative assessment of the potential groundwater quality impacts down gradient of the tailings storage facilities due to seepage of stored water. Assessed groundwater quality impacts will be reviewed in the context of future 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.
  - Potential contaminant migration from the TSFs and IWL post mine closure.
  - Groundwater level recovery in the vicinity of the underground mine and open pit.
- 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 underground operation on groundwater in ML1535 and neighbouring areas.

## 1.4 Secretary's Environmental Assessment Requirements

The SEARs for the UG EIS (provided on 27 September 2019, application number SSD-10367) included the following requirements related to groundwater:

- An assessment of the likely impacts of the development on the quantity and quality of regional surface water and groundwater resources;
- An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users;

- Water supply arrangements for the development;

The SEARs also nominate a number of policies, plans and guidelines, to be considered during the preparation of this report, as outlined in 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 Summary of background information

### 3.1 Available information

The conceptual and numerical groundwater models described in this report were developed based on the following information provided by Evolution Mining:

- Exploration borehole logs for the proposed underground mine.
- Mine site geological model containing lithology and structure.
- Geophysical gravity survey data.
- Open pit shell design for 2020 to 2024.
- Underground stoping geometry.
- Underground access and haulage tunnel geometry.
- Underground stoping and access tunnel scheduling and extraction volumes.
- GRE46 exploration decline geometry.
- TSF and IWL crest levels.
- Groundwater monitoring records for observation wells in ML1535.
- Mine site dewatering records from 2005 to 2019.

In addition, this report has been prepared taking into consideration previous reports completed by Coffey and others including information provided by the CGO (i.e. Evolution and previous owners of the mine). The principal reports referred to were:

- CGO Underground Development EIS, Groundwater site investigations report, Coffey Report No. SYDGE206418-3-AJ, dated 6 April 2020.
- Groundwater Monitoring Review 2019, Cowal Gold Operation, Coffey Report No. 754-SYDGE270760-AA, dated 30 April 2020.
- Cowal Gold Operations Processing Rate Modification (MOD14), Mine Site Hydrogeological Assessment, Coffey Report No. 754-SYDGE206418-AA, dated 2 March 2018.
- Cowal Gold Operations Processing Rate Modification (MOD14), Bland Creek Palaeochannel Borefield and Eastern Saline Borefield Groundwater Assessment, Coffey Report No. 754-SYDGE206418-BCPB, dated 24 March 2018.
- Cowal Gold Project Geotechnical Investigation Report. SNC-Lavalin Australia Report No. 334371-0000-4GRA-0001 prepared for Barrick Gold of Australia.
- Cowal Gold Mine, Groundwater Level Investigation, Coffey Report No. GEOTLCOV21910AF-AB, dated 26 March 2009.
- Cowal Gold Mine, Pit Dewatering Assessment, Coffey Report No. GEOTLCOV21910AC-AC, dated 5 August 2008.

## 4 Regional setting

The CGO site is located approximately 350 km west of Sydney and 38 km north east of the town of West Wyalong, NSW. The location of the mine is shown in Figure 4-1.

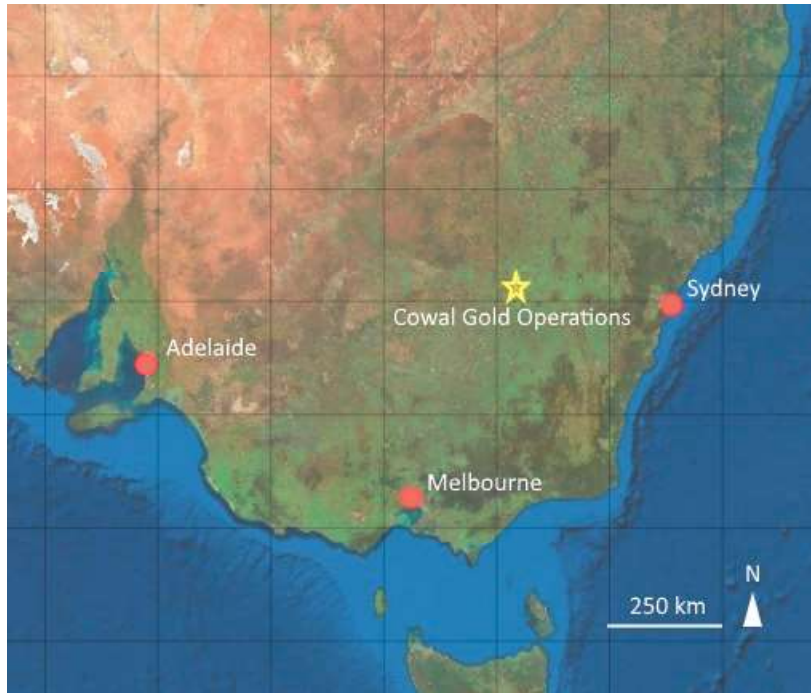


Figure 4-1: Site location

### 4.1 Topography and land use

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 4-2 shows the topography and rivers of the area. The terrain falls gradually from the north-east (Lachlan Floodplain) and south-east (upper Bland Creek Palaeochannel) towards Lake Cowal. Lake Cowal forms a local depression which fills with floodwater every few years.

The floodplains around Lake Cowal, north to Nerang Cowal and south to Marsden have a surface elevation of approximately between 205 m AHD and 210 m AHD. Hills formed by rock outcrops on the fringes of the floodplains reach over 300 m AHD. The Bland Creek Palaeochannel Borefield area has an elevation of just under 210 m AHD.

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).

## 4.2 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 was constructed as part of the initial mine development. 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 (Hydro Engineering & Consulting Pty Ltd, 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, refer to Figure 4-2). 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.



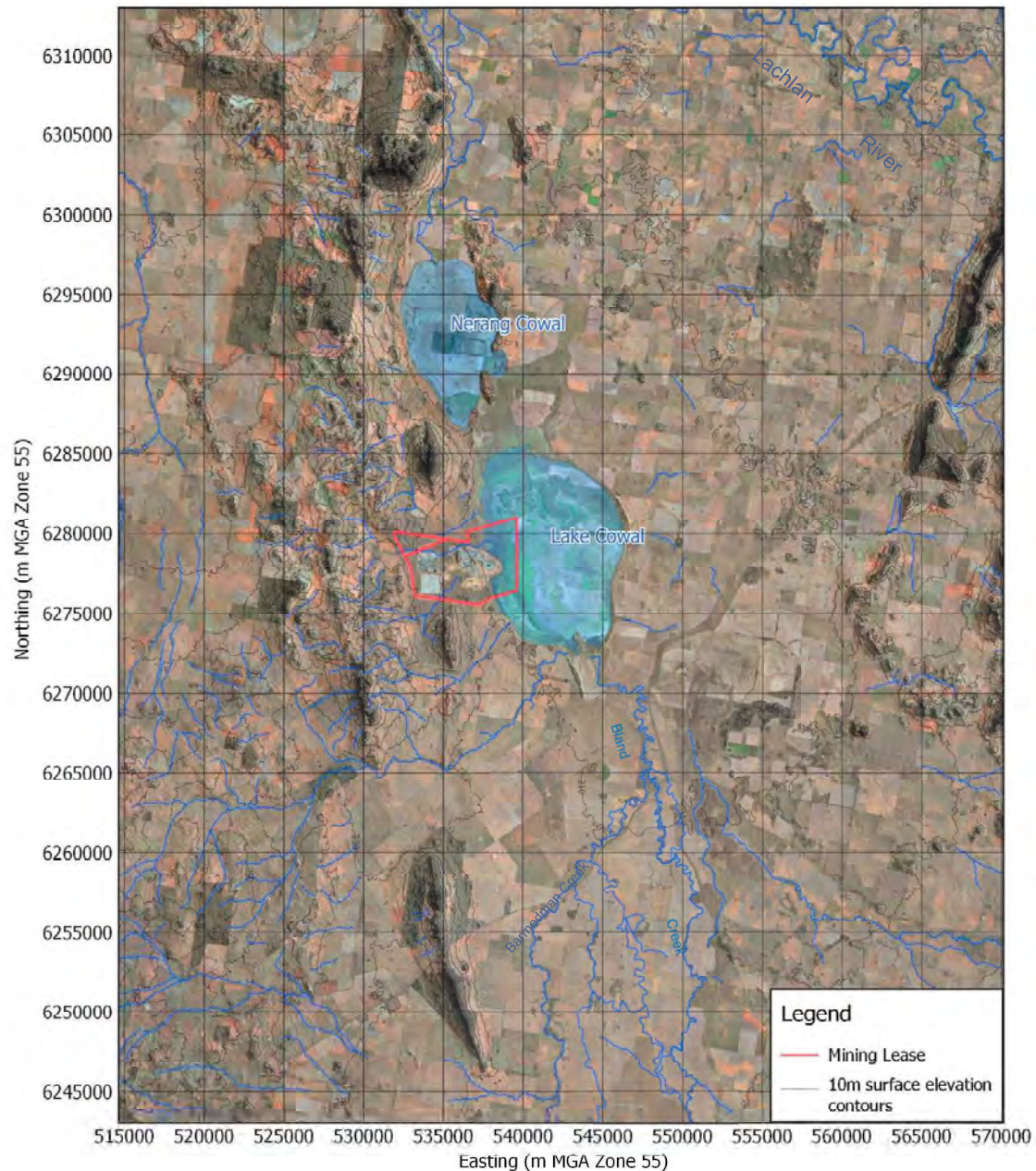


Figure 4-2: Regional setting showing 10 m surface elevation contours (Satellite imagery: ESRI)

### 4.3 Climate

The closest rainfall station to the study area with long-term records is Station 73054 (Wyalong Post Office), operated by the Bureau of Meteorology (BoM) and located approximately 32 km south of ML1535. Table 4-1 lists the average and median monthly rainfall for this station for the years 1895 to 2019. There was no data between 1939 and 1948. The average annual rainfall is 479 mm.

The closest climate station within with reasonable amounts of pan evaporation data is BoM Station 050052 (Condobolin Agricultural Research Station), located about 75 km away. Table 4-1 lists the

average monthly pan evaporation for the station over the period 1973 to 2017. The average annual pan evaporation is 1971 mm.

Table 4-1: Average rainfall and pan evaporation near the mine site

	Rainfall WYALONG POST OFFICE - 073054		Pan evaporation: CONDOBOLIN AG RESEARCH STN - 050052
Month	Mean (mm)	Median (mm)	Mean (mm)
Jan	41	27	310
Feb	38	22	244
Mar	38	23	211
Apr	34	24	129
May	39	30	74
Jun	43	35	48
Jul	42	38	50
Aug	39	38	78
Sep	37	29	117
Oct	45	37	180
Nov	37	35	234
Dec	44	31	298
Annual	479	473	1971

Source: Bureau of Meteorology

Average rainfall data shows no seasonal trend. Pan evaporation is a maximum in summer months and a minimum in winter. A rainfall deficit occurs for all months except June and July. Average annual pan evaporation is over four times the average annual rainfall.

Annual and monthly rainfall from 2005 to 2019 at BoM Station 73054 is shown in Figure 4-3. Note the higher rainfall years of 2010, 2011 and 2016 and the drier periods of 2006 to 2008 and 2015 to 2018, excluding 2016. Cumulative monthly rainfall residual is also shown in Figure 4-3. This is a measure of the accumulated deficit or surplus of rainfall at a particular time, relative to average annual rainfall. Low rainfall periods are characterised by falling cumulative rainfall residual while high rainfall periods are represented by a rising trend. The sustained drought from 2005 to 2010 is clearly evident as is the more recent drought from 2017 to 2020.

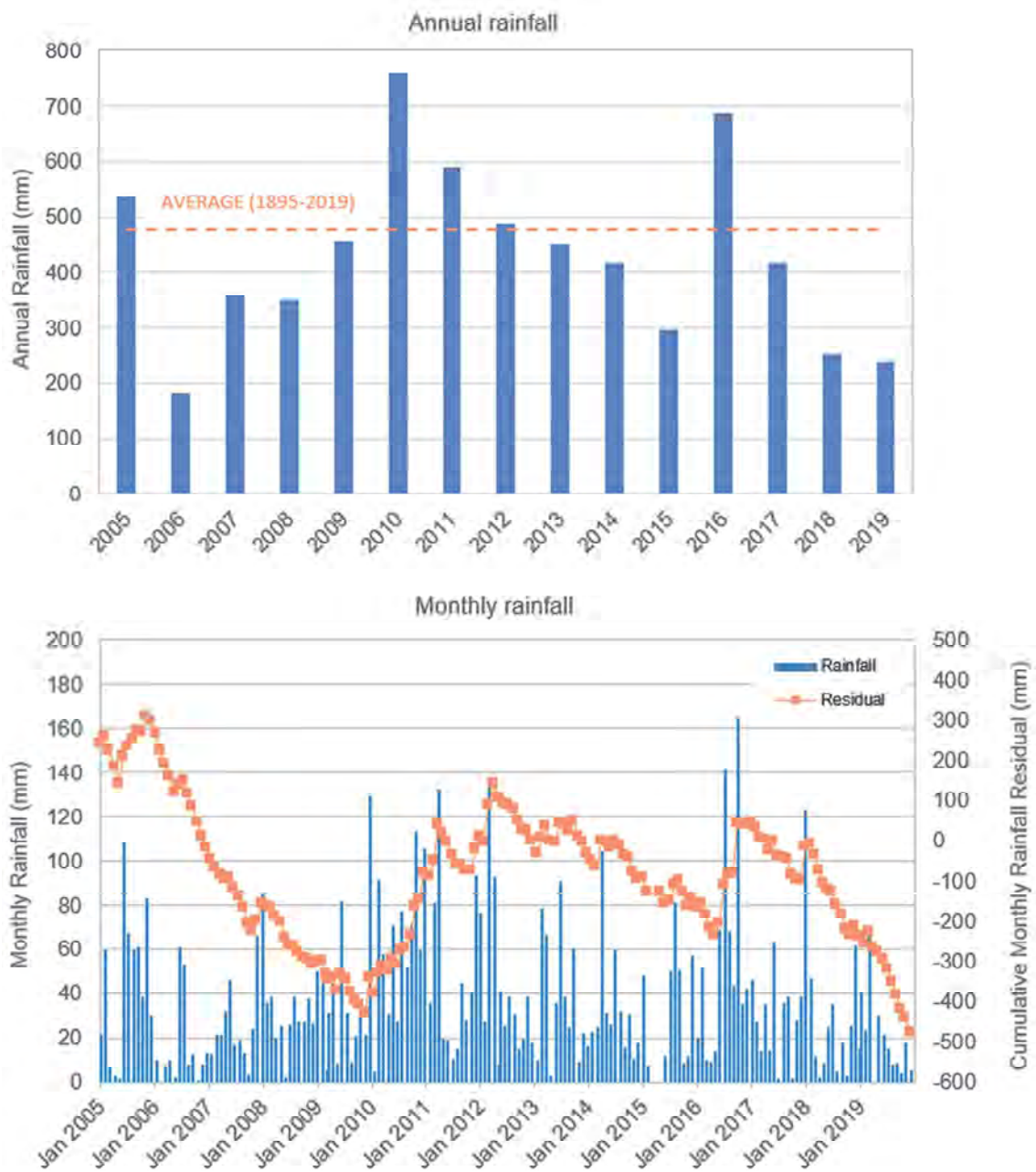


Figure 4-3: Annual and monthly rainfall since 2005 (West Wyalong Post Office, BoM station 73054)

## 4.4 Mine site

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 and 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.
- Bland Creek catchment to the south.

The site includes the following infrastructure, as shown in Figure 4-4:

- An open pit in the east of the site.
- A perimeter waste rock emplacement and lake protection bund running beyond, and around the open pit.
- The waste rock emplacements to the north-west and south-west of the open pit.
- A processing plant located to the west of the open pit.
- A number of contained water storages at various locations across the site. D1, D3 and D9 are shown on the figure.
- Tailings storage facilities comprising two storage dams with approximate dimensions of 1,300 m by 1,300 m in the west of ML1535, which are to be integrated into the IWL.

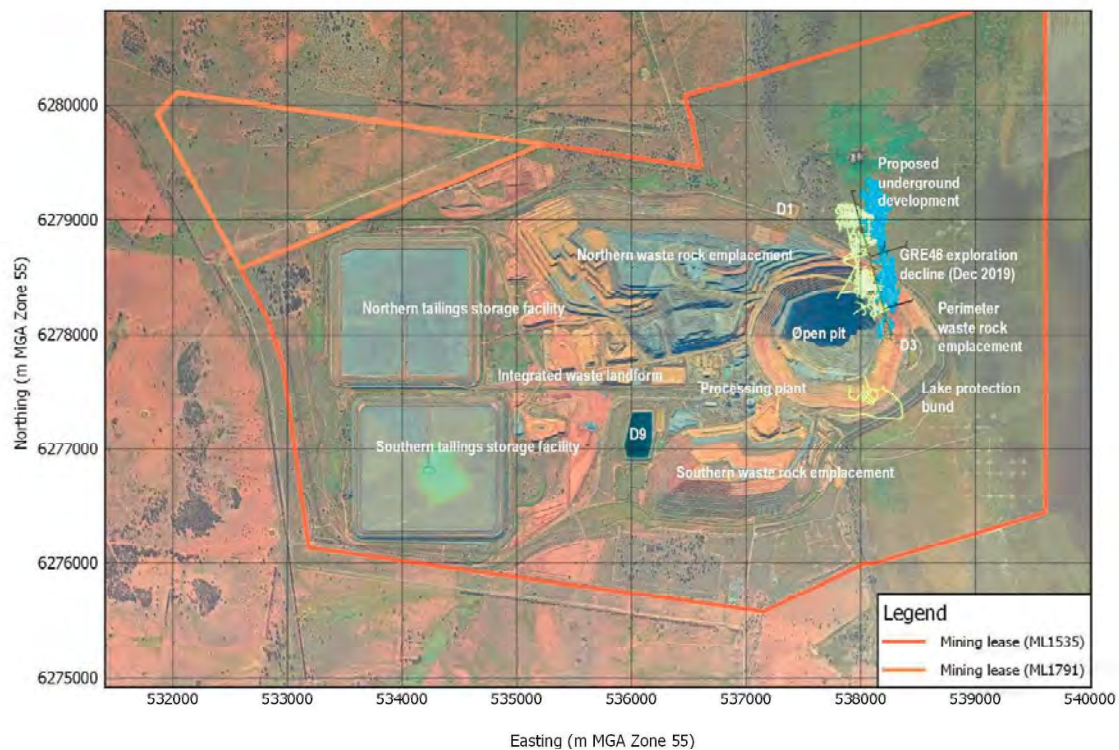


Figure 4-4: Mine site (Aerial imagery provided by Evolution Mining)

## 5 Regional geology

The Forbes 1:250,000 Geological Map shows that the regional geological setting is dominated by the Gilmore Fault Zone also called the Gilmore Suture, a structurally and lithologically complex feature that trends north-south through ML1535, approximately 500 m west of the CGO open pit.

The fault separates a Late Ordovician volcanoclastic 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 ML1535 and thick Quaternary lacustrine sediments underlie Lake Cowal.

The geology of the CGO site and surrounds is illustrated in Figure 5-1 and Figure 5-2.

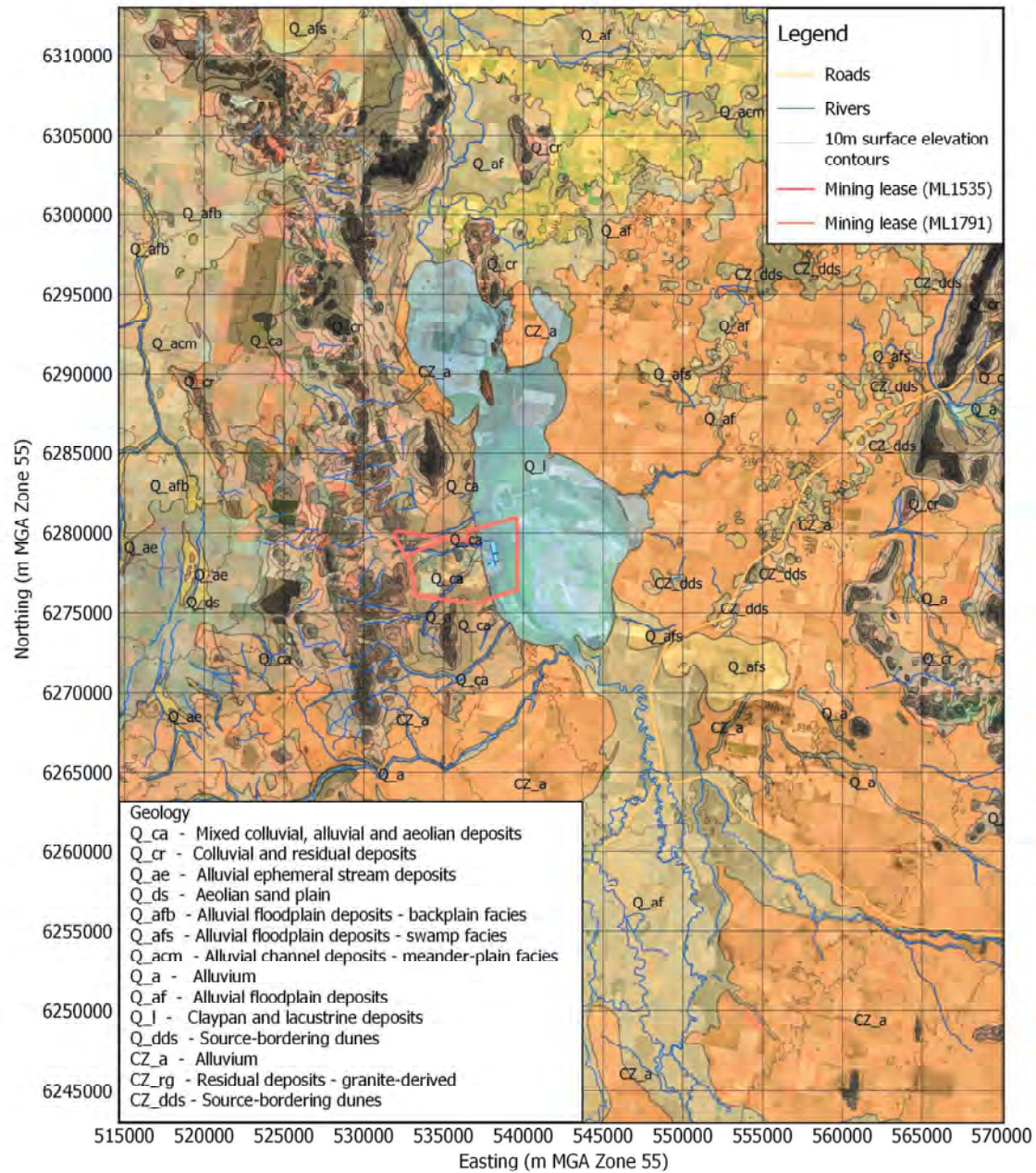


Figure 5-1: Quaternary and Tertiary geology (Source: Seamless Geology of NSW)



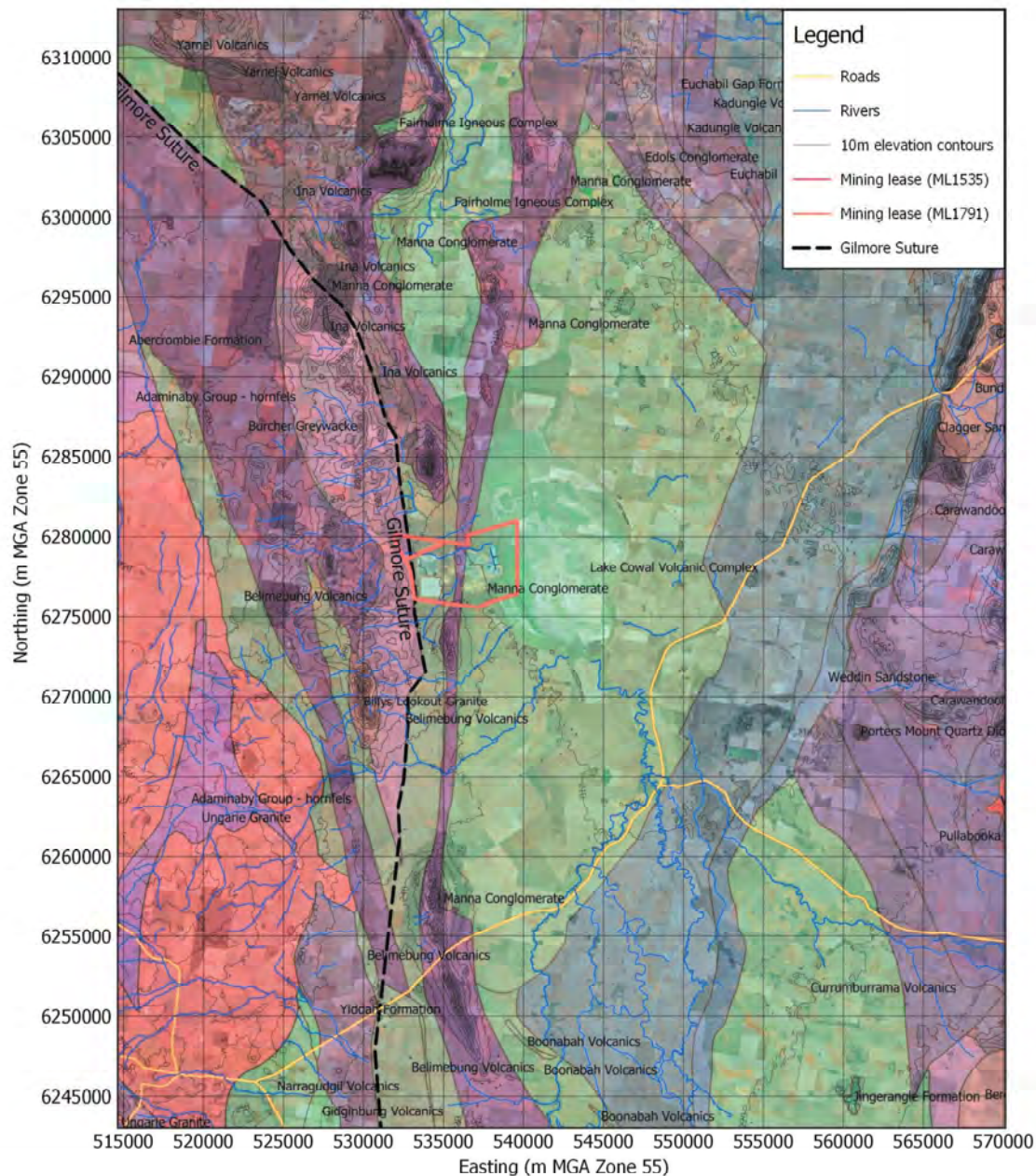


Figure 5-2: Devonian and Ordovician geology (Source: Seamless Geology of NSW)

## 5.1 Mine site 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 stratigraphic units at the site consistently strike at  $215^{\circ}$  and dip  $50^{\circ}$  to the north-west (Miles and Brooker, 1998).

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 is a Tertiary age laterite, 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 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 NOW (NSW Office of Water, now the Department of Primary Industries – Crown Lands and Water [CL&W]), in which values of over 20 m were adopted over the CGO site and surrounds.

A three-dimensional mine geological model was provided by Evolution Mining. Data from this model was used to produce Figure 5-3 and Figure 5-4 which show the rock units and major faults present at the mine site.

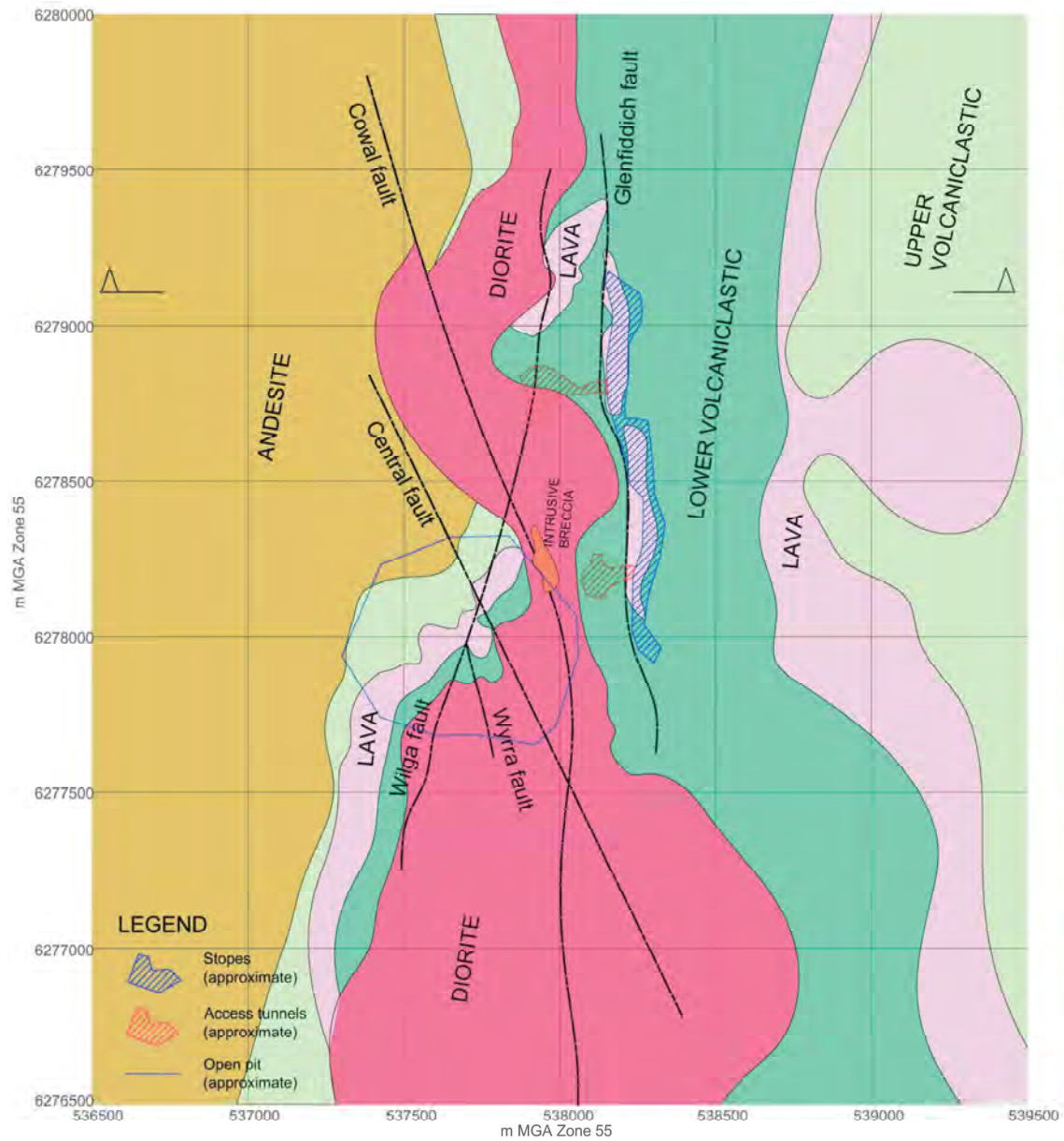


Figure 5-3: Mine site geology at 0 m AHD (based on geological model provided by Evolution Mining)

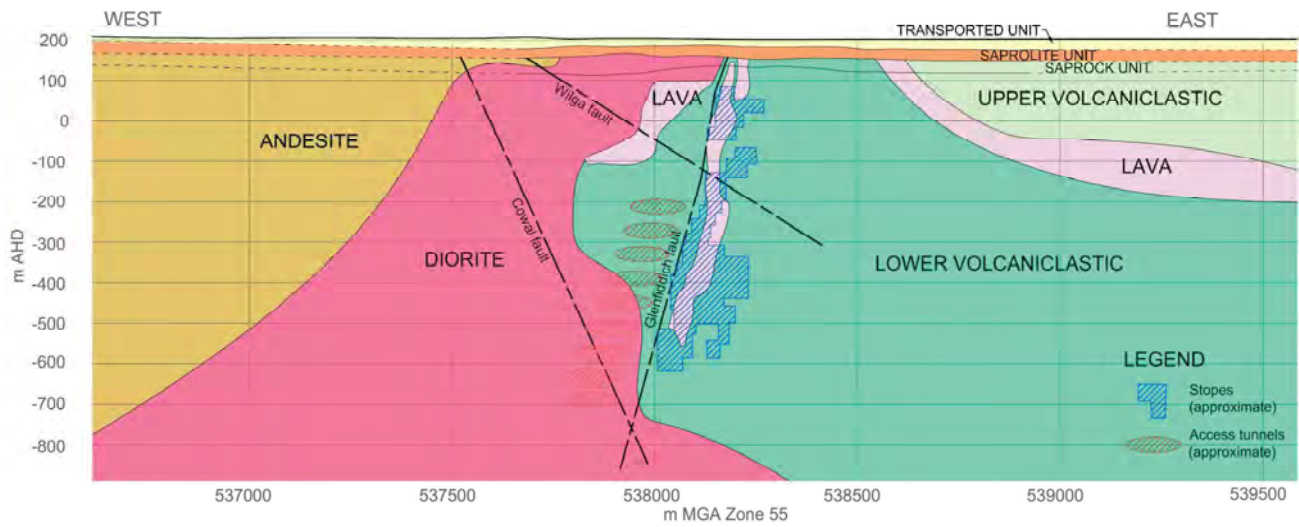


Figure 5-4: Mine site east-west cross section at 6279100N showing proposed stopes and access tunnels (based on geological model provided by Evolution Mining)



## 6 Hydrogeology

### 6.1 Regional hydrogeology

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

- Cowra Formation: Comprising isolated sand and gravel lenses in predominantly silt and clay alluvial deposits, with groundwater of generally higher salinity.
- Lachlan Formation: Comprising 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 as 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.
- 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 ML1535, but that the Lachlan Formation did not extend into ML1535. 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 Bland Creek Palaeochannel Borefield to the north-east of the CGO site and from the Bland Creek system to the south-east of the CGO site have also been used in characterising the regional hydrogeology.

### 6.2 Mine hydrogeology

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

- The Transported unit: Comprising 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 Australia Limited, 2010).
- The Saprolite unit: Underlies the Transported unit and is of relatively low hydraulic conductivity. The unit comprises extremely weathered rock, often weathered to clay.

- The Saprock unit: Underlies the Saprolite unit and occurs in the weathered fractured surface of the Lake Cowal Volcanics. The unit comprises highly to moderately weathered rock with some zones of clay.
- The Primary Rock unit: Consisting of slightly weathered to fresh rock underlying the Saprock unit. This unit is generally considered to be less fractured and less permeable than the Saprock.

Coffey (2009a) developed geological cross-sections through the western area of the CGO site. The locations of the cross-sections are shown on Figure 6-2 and the cross-sections are shown on Figure 6-3 and Figure 6-4. The extent of the Saprolite and Saprock units outside the CGO site are not defined.

Figure 6-1 presents a simplified conceptual cross-section through approximately the centre of the CGO open pit.

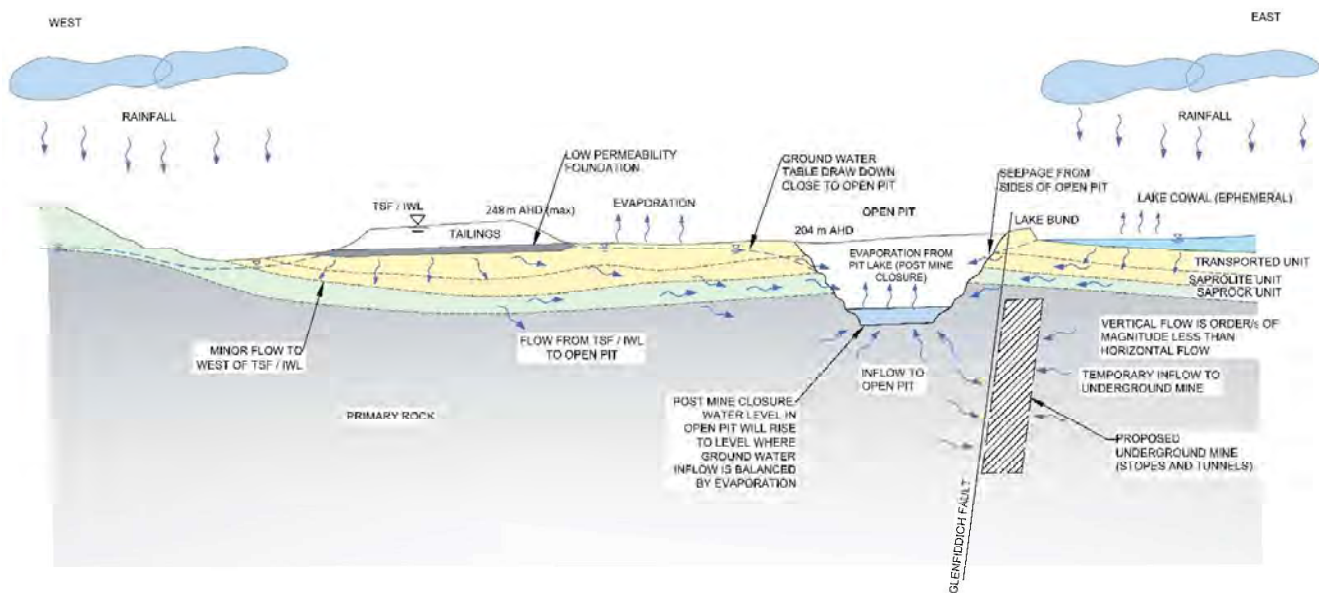


Figure 6-1: Conceptual hydrogeological model



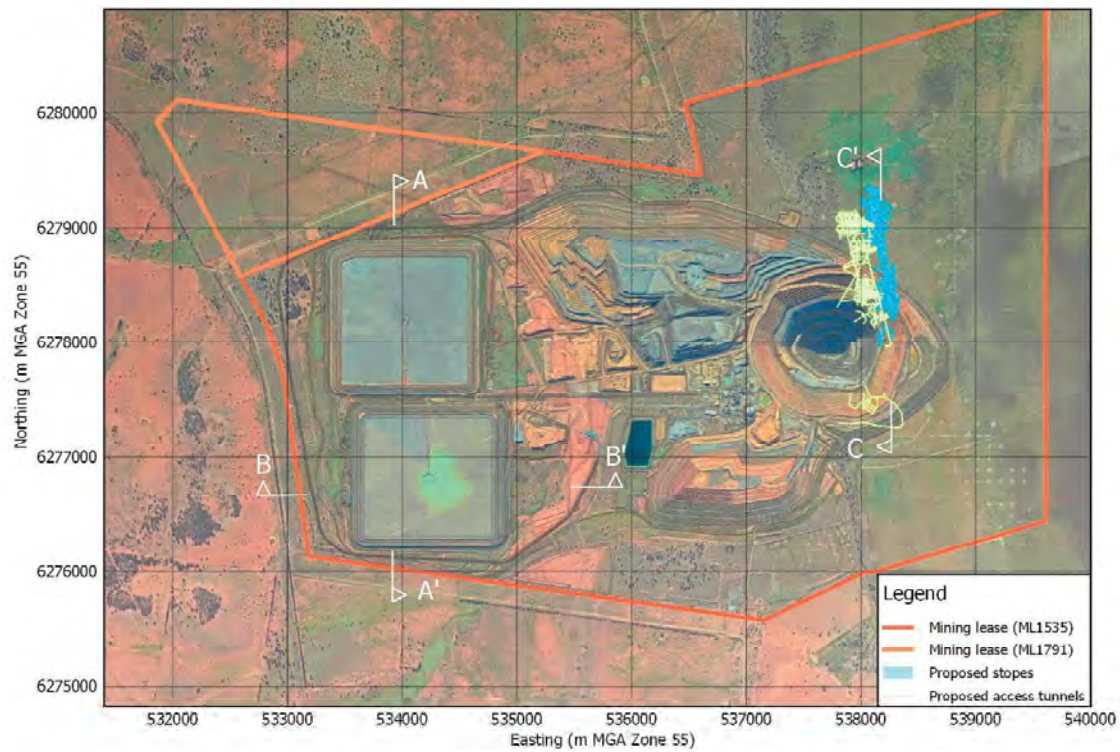


Figure 6-2: Section locations for sections shown in Figure 6-3, Figure 6-4 and Figure 6-6 (Aerial imagery provided by Evolution Mining, December 2019)

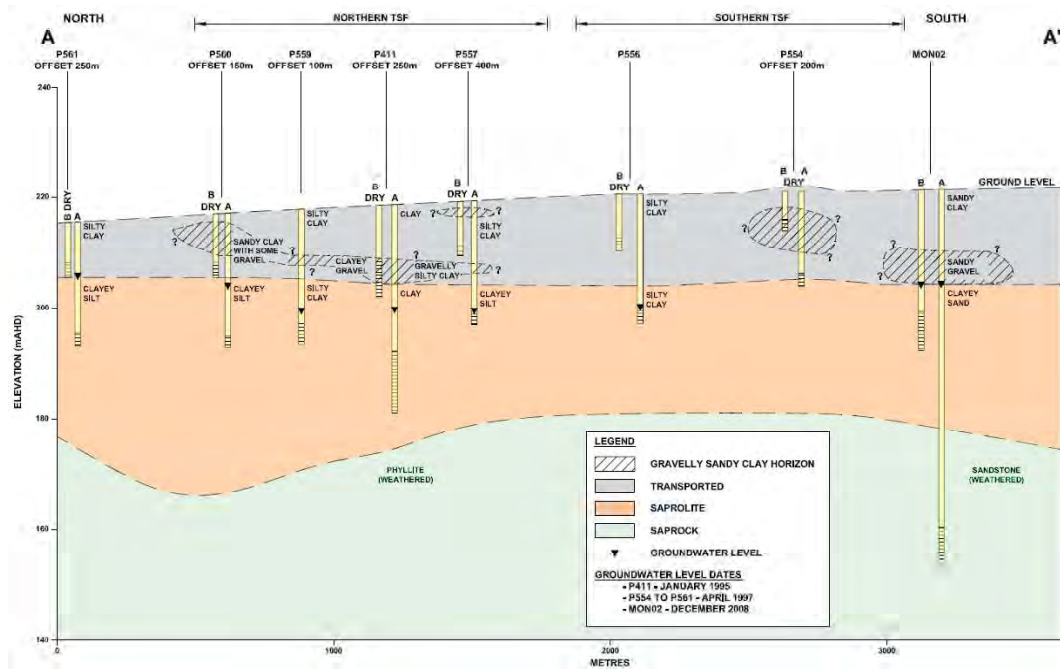


Figure 6-3: Section AA' through the tailings storage facilities showing pre-development groundwater conditions

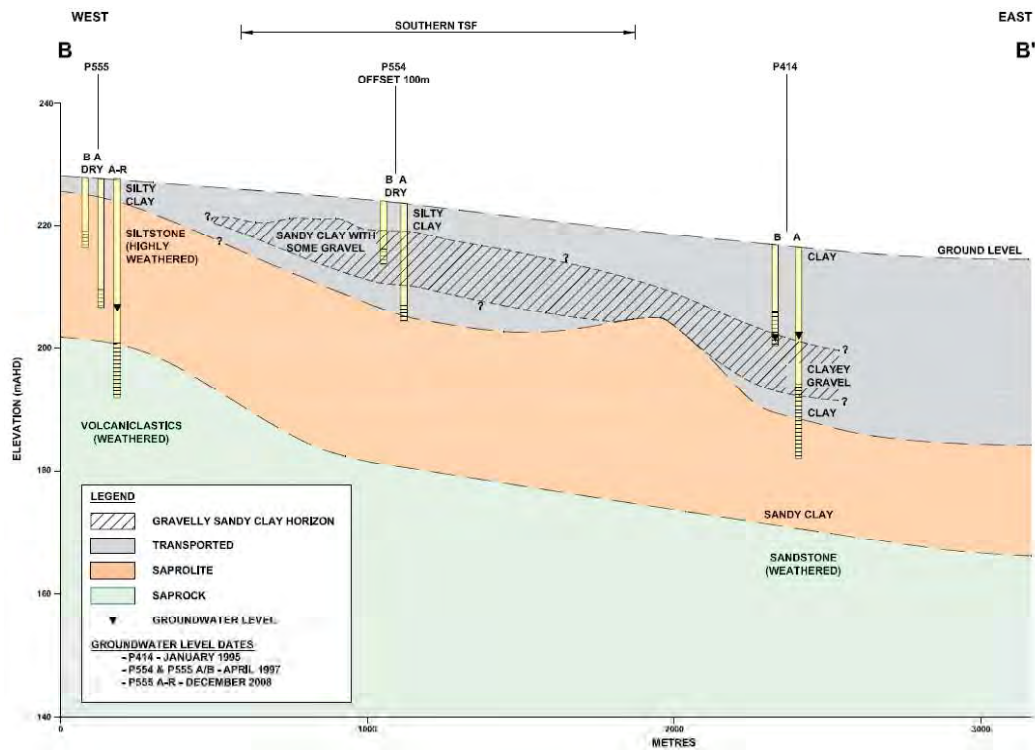


Figure 6-4: Section BB' through the southern tailings storage facility showing pre-development groundwater conditions

## 6.3 Exploration boreholes

Exploration borehole data was provided in digital format by Evolution Mining. The provided exploration boreholes cover an area of approximately 1.3 km (east-west) by 2.5 km (north-south) above the proposed underground mine, as shown in Figure 6-5. This data was used to obtain elevations for the interfaces between the three hydrogeological units described above. A contouring process (kriging) was used to interpolate between boreholes. Figure 6-5 shows the interpreted depth below ground of the Transported and Saprolite units from the exploration boreholes. The depth below ground refers to the ground surface prior to the open pit being excavated.



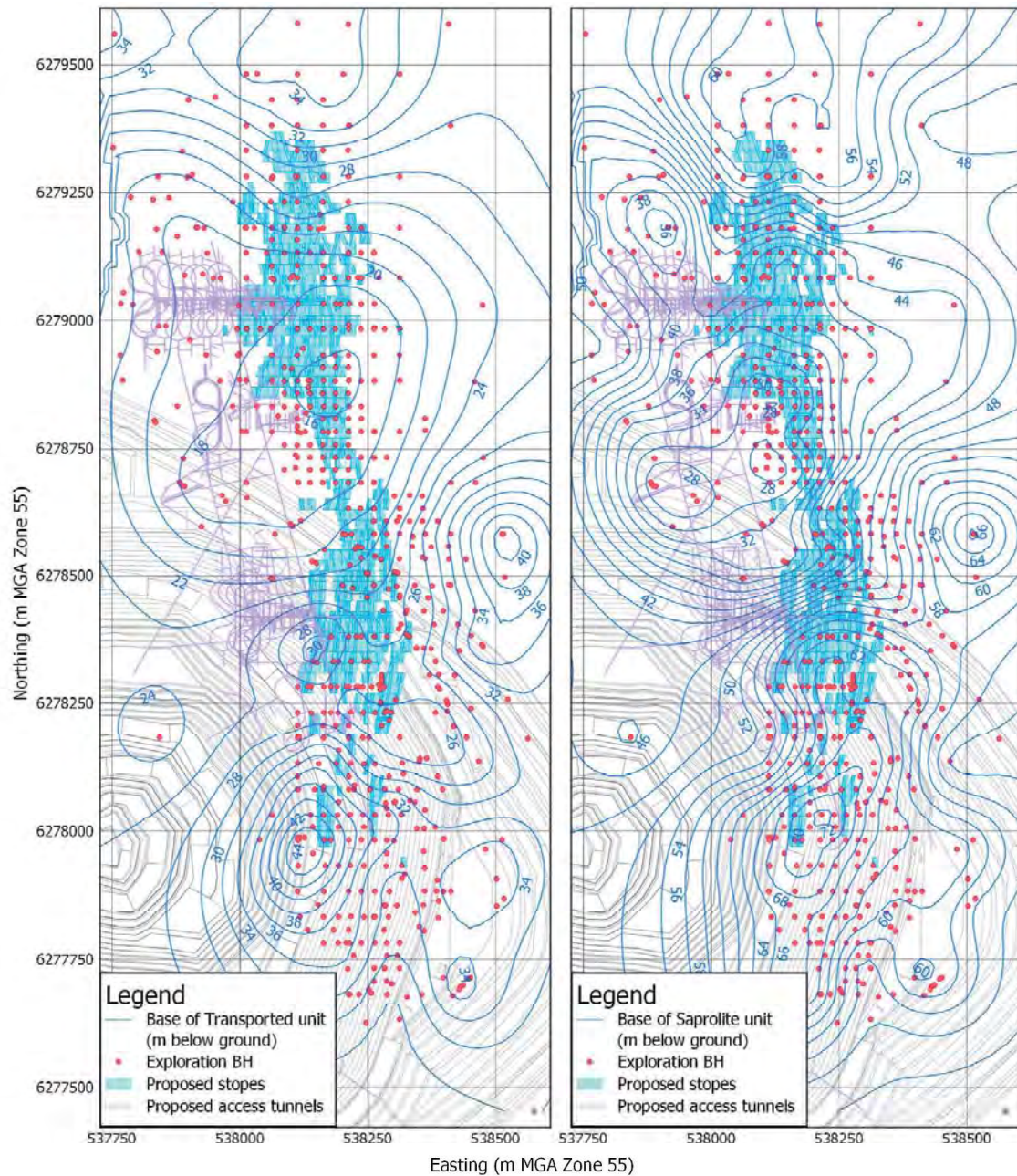


Figure 6-5: Depth to the base of Transported and Saprolite units as interpreted from exploration boreholes

Section CC' shown in Figure 6-6 was produced using the exploration borehole data and the proposed underground mine plan. As shown on the section, the exploration borehole data shows that the four hydrogeological units are continuous in a north south direction over the proposed mine. Note that the stopes are to be constructed entirely in the Primary Rock unit.

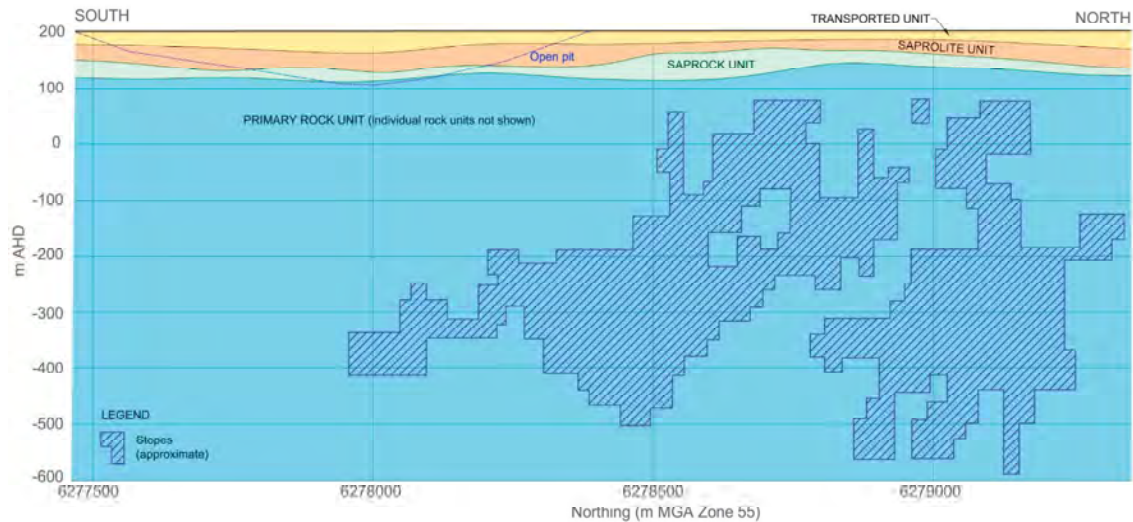


Figure 6-6: Section CC' showing hydrogeological unit elevations interpreted from exploration boreholes

### 6.3.1.1 Faults and structure

The mine geological model provided by Evolution Mining includes several faults, namely the Central, Cowal, Glenfiddich, Wilga and Wyrre faults, and a number of smaller faults. The five major faults all strike approximately north-south, with the Wilga deviating the most from this direction, striking NNE. In addition, the structural contacts between geological units around the mine site strike generally north-south with some localised north west or north east deviations, refer to Figure 5-3 and Figure 5-4.

The faults around the mine site are all non-active and thus unlikely to provide higher conductive pathways for water (Zoback, 2007). The zones surrounding the faults, however, may consist of more fractured rock and may have a higher conductivity. Observation of the exposed Glenfiddich Fault by a Coffey Engineer in the Exploration Decline Tunnel, close the entrance from the open pit in May 2019, showed minor groundwater inflow to the tunnel to be occurring at one side of the fault with little inflow elsewhere along a 150m section of tunnel near its intersection with the fault. The centre of the fault was clay filled.

The Glenfiddich fault was also observed to cross the exploration decline near its southern portal by a Coffey Field Engineer during a field investigation program between January and March 2020. The field investigation report is included as Appendix E. The Glenfiddich fault zone consisted of slightly more fractured rock compared to the surrounding rock over a zone of approximately 8 m width. Some areas of higher inflow were found adjacent to the fault. It is relevant to note, however, that many other areas of higher inflow were found in joints not apparently associated with the Glenfiddich fault or other faults. The widespread and intersecting nature of jointing and faulting observed inside the decline makes it impractical to describe the effect of individual faults on the groundwater flow regime without significant field testing and monitoring at and around the faults.

It does not appear that the Glenfiddich fault is providing a significant preferential conduit for groundwater when it is considered amongst the surrounding fractured rock at the scale of the CGO Underground Development.

## 6.4 Gravity survey

In April 2019, a detailed geophysical gravity survey commissioned by Evolution Mining was carried out by Haines Surveys Pty Ltd (Haines) and presented in a report (Haines Surveys, 2019).



The gravity survey data was provided to Coffey for further analysis and modelling which was carried out in November 2019. The proprietary software program Potent was used. Potent is a Windows-based application in an interactive framework for 3D modelling of potential field data (i.e. gravity and/or magnetics).

The interpretation of the data was calibrated to exploration borehole data, from which the thickness of the Transported unit had been observed directly. The majority of boreholes were clustered over the edge of the central eastern part of the survey area above the proposed underground mine. However, four boreholes were obtained from the NGIS public borehole database. These boreholes provide lithology logs showing the base of the Transported unit. The boreholes are GW703223, GW703225, GW704031 and GW704252. Their locations are shown in Figure 6-7.

The exploration and publicly available boreholes provide a reasonable constraint of the interpretation out to approximately 3 km east of the open pit. The interpreted thickness the Transported unit from the gravity survey data is shown in Figure 6-7. The figure shows that the Transported unit has a thickness ranging between approximately 30 m and 50 m in the area east of the open pit.

The gravity survey interpretation for areas outside those shown on Figure 6-7 did not converge in the analysis and so these areas were excluded from the interpretation.

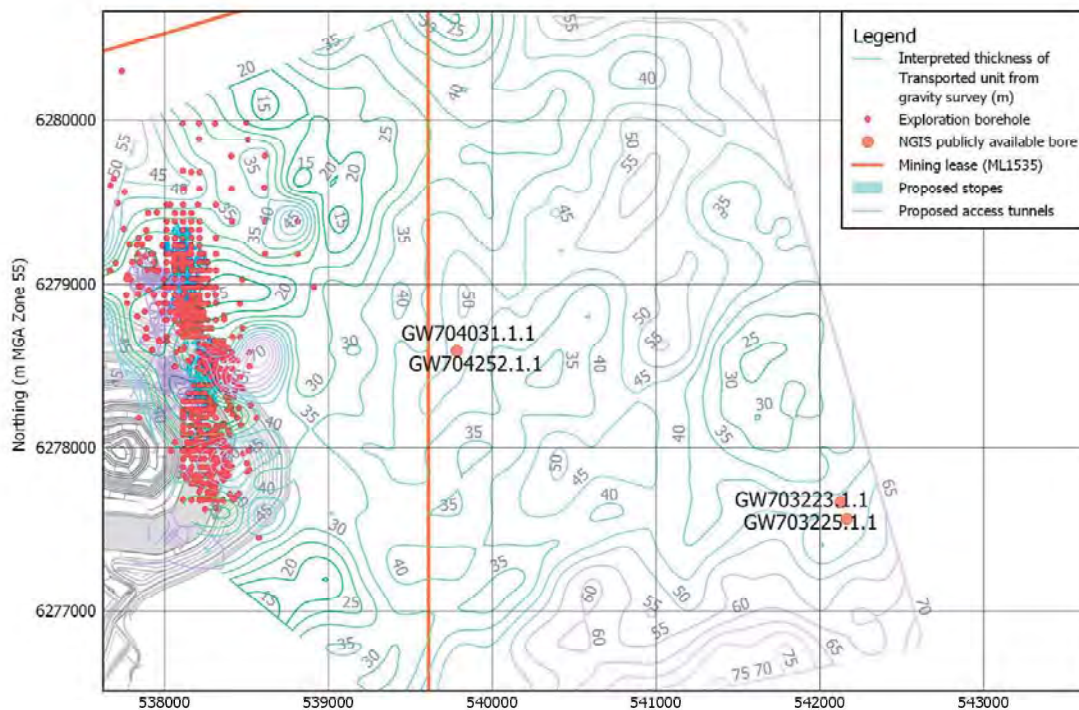


Figure 6-7: Thickness of the Transported unit from gravity survey interpretation

## 6.5 Regional groundwater levels and flow regimes

Regional groundwater levels are discussed in a companion report on the modelling of the Bland Creek Palaeochannel Borefield (Coffey, 2020c).

The groundwater conditions near the CGO open pit are controlled by local factors, such as the tailings storage facilities and open pit, rather than the groundwater conditions in the Bland Creek Palaeochannel aquifer system.

## 6.6 Local groundwater levels and flow regimes

### 6.6.1 Groundwater level monitoring

There are 37 piezometers currently monitoring groundwater levels within ML1535. The coordinates and screen elevations for these piezometers are shown in Table 6-1. The piezometers at PZ13 were re-activated in late August 2019.

12 additional piezometers were installed as part of field investigations in February 2020 at four boreholes to the north of the open pit near the proposed underground mine. These are described in the field investigation report which is included as Appendix E. Their coordinates and elevations are shown in Table 6-2.

The locations of the monitoring wells and piezometers are shown in Figure 6-8.

Table 6-1: Monitoring well details

Area	Well name	Screened unit	Easting (m MGA Zone 55)	Northing (m MGA Zone 55)	Top of casing (m AHD)	Top of screen (m below ground)	Base of screen (m below ground)
Pit Area	PDB1A	Saprock	537281.2	6279032.6	208.3	82.0	88.0
	PDB1B	Transported	537283.3	6279030.7	208.2	14.0	20.0
	PDB3A	Saprock	538502.1	6277855.0	204.8	94.5	100.5
	PDB3B	Transported	538507.2	6277854.6	204.8	23.6	29.6
	PDB5A	Saprock	537769.9	6276932.6	209.1	76.5	82.5
	PDB5B	Saprolite	537774.8	6276931.8	208.8	23.8	29.8
	PZ13VWP1	Primary Rock	538342.3	6278585.0	203.8	120 (VWP depth)	N/A
	PZ13VWP2	Saprock	538342.3	6278585.0	203.8	75 (VWP depth)	N/A
	PZ13VWP3	Saprock	538342.3	6278585.0	203.8	60 (VWP depth)	N/A
	PZ13VWP4	Saprolite	538342.3	6278585.0	203.8	32 (VWP depth)	N/A
Processing Areas	PP01	Transported	536980.7	6277623.0	215.6	13.0	25.0
	PP02	Transported	537009.3	6277527.7	213.0	8.5	18.5
	PP03	Saprolite	536986.5	6277451.1	213.5	31.0	51.0
	PP04	Transported	536894.8	6277292.4	213.9	10.5	19.5
	PP06	Transported	536777.5	6277585.8	214.0	11.0	20.0
	P555A	Saprolite	533112.4	6276760.3	227.4	17.8	19.8



Area	Well name	Screened unit	Easting (m MGA Zone 55)	Northing (m MGA Zone 55)	Top of casing (m AHD)	Top of screen (m below ground)	Base of screen (m below ground)
Tailings Areas	P555A-R	Saprock	533112.4	6276760.3	227.4	27.0	36.0
	P555B	Saprolite	533112.4	6276760.3	227.4	8.0	10.0
	P558A-R	Saprolite	532889.6	6277989.6	224.3	30.6	42.6
	P412A	Saprolite	535170.8	6277494.9	216.2	18.0	30.0
	P412A-R	Saprolite	535171.7	6277491.0	216.1	55.0	61.0
	P412B	Transported	535175.0	6277495.0	216.1	10.0	16.0
	P414A	Saprolite	535363.8	6276681.2	217.1	22.0	34.0
	P414B	Transported	535360.3	6276679.6	217.1	10.0	16.0
	P417A	Saprolite	535889.3	6276337.6	216.5	24.0	36.0
	P417B	Transported	535888.9	6276333.1	216.5	8.0	14.0
	P418A	Saprolite	534862.4	6279181.3	214.2	20.0	32.0
	P418B	Transported	534859.6	6279182.0	214.2	10.0	16.0
	TSFNA	Saprock	535438.0	6278073.9	215.3	92.0	98.0
	TSFNB	Transported	535442.6	6278072.8	215.2	24.1	30.1
	TSFNC	Transported	535447.5	6278071.7	215.3	12.0	18.0
	MON01A	Saprock	535111.7	6278223.5	215.3	63.0	69.0
	MON01B	Transported	535114.5	6278225.1	215.3	9.0	15.0
	MON02A	Saprock	534275.0	6276083.8	222.5	63.0	69.0
	MON02B	Saprolite	534277.1	6276085.9	222.4	24.0	30.0
	P561A	Saprolite	534603.0	6279313.0	215.1	21.0	23.0
	P561B	Transported	534603.0	6279313.0	215.1	8.0	10.0

Table 6-2: Piezometers installed in February 2020

Area	Piezometer name	Screened unit	Easting (m MGA Zone 55)	Northing (m MGA Zone 55)	Sensor elevation (m AHD)
Stopes Area	UG-BH-01 (SG1)	Transported	537751.6	6278843.8	189.1
	UG-BH-01 (SG2)	Transported	537751.6	6278843.8	174.1
	UG-BH-01 (SG3)	Saprock	537751.6	6278843.8	134.1
	UG-BH-02 (SG1)	Transported	538180.0	6279593.8	190.8
	UG-BH-02 (SG2)	Saprolite	538180.0	6279593.8	160.8
	UG-BH-02 (SG3)	Primary Rock	538180.0	6279593.8	103.8
	UG-BH-03 (SG1)	Transported	538019.1	6278883.0	188.9
	UG-BH-03 (SG2)	Saprolite	538019.1	6278883.0	173.9
	UG-BH-03 (SG3)	Primary Rock	538019.1	6278883.0	133.9
	UG-BH-04 (SG1)	Transported	538169.0	6278916.0	188.8
	UG-BH-04 (SG2)	Saprock	538169.0	6278916.0	158.8
	UG-BH-04 (SG3)	Primary Rock	538169.0	6278916.0	102.3

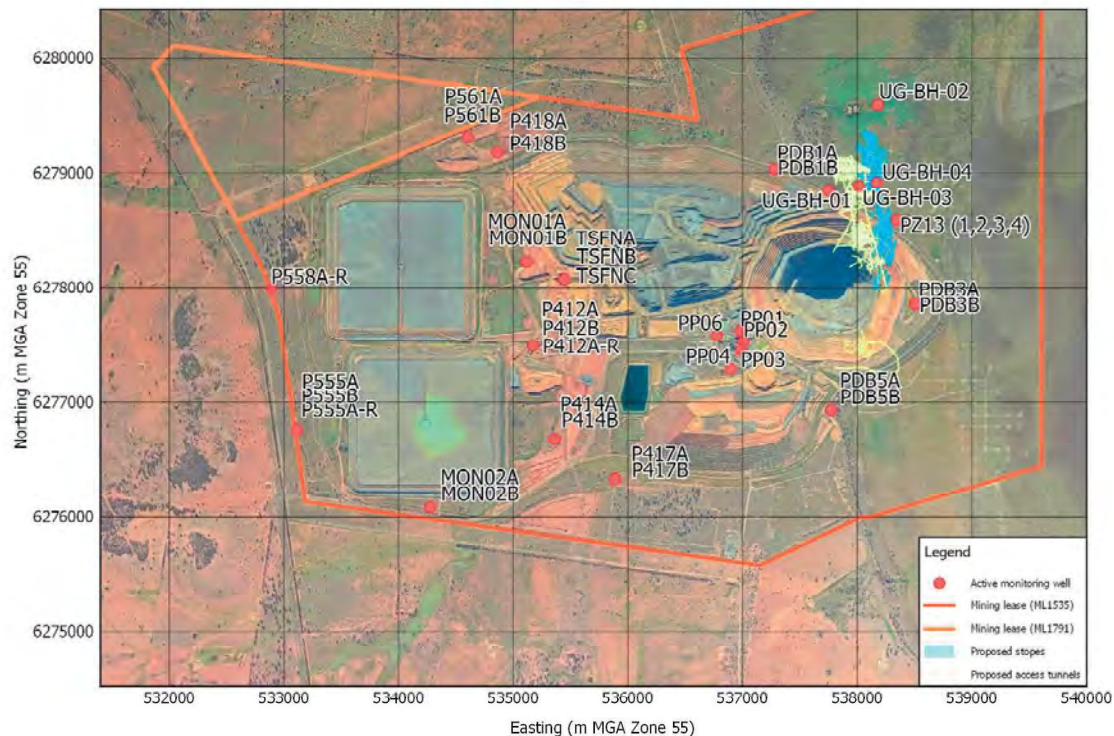


Figure 6-8: Monitoring well locations (Aerial imagery provided by Evolution Mining, December 2019)

## 6.7 Groundwater levels and flow regimes within ML1535

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 again 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 m AHD in October 2016. At the peak, water overflowed to Nerang Cowal. The lake water level dropped rapidly to its full level, controlled by overflow to Nerang Cowal, with the gradual decline in water level continuing to February 2019 when the lake became dry. The lake has remained dry from then until the time of writing in June 2020.

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 7.2). Despite Lake Cowal becoming inundated, groundwater inflows to the open pit are assessed to have remained below or consistent with historical records and are relatively stable. This is likely because the lacustrine sediments that form the lakebed have a very low vertical permeability and act as a low permeability layer between the lake water and underlying aquifers (Coffey, 1997). The results of groundwater model calibration, discussed in Section 8.2, support this understanding.

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 assessable.

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 m<sup>3</sup>/day and 170 m<sup>3</sup>/day, respectively). It is likely that the

groundwater level in piezometer PDB3A has been significantly influenced by pit dewatering since March 2011.

Figure 6-9 shows groundwater head contours in the Transported and Saprolite units taken in December 2019. This figure shows that, in the area between the TSFs and the open pit, groundwater flows eastwards from the TSFs toward the open pit. Groundwater levels over time are presented in Appendix C.

### **6.7.1 Groundwater Response to tailings storage facilities**

Groundwater monitoring records for piezometers in the vicinity of the TSFs are shown in Figure A2 (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 P414B, which is relatively close to the TSFs, is greater than that at TSFNB, located further away. Similarly, in the Saprock unit, MON02A has displayed a significant rise since late 2006, whilst the magnitude of groundwater level rise at MON01A (located further from the TSFs) is lower.

Groundwater levels at 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). 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) predicted 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 should this prove necessary. Possible methods for shallow groundwater control include the use of drainage trenches.

### **6.7.2 Surface Water Bodies**

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

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 1,971 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 1,577 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.

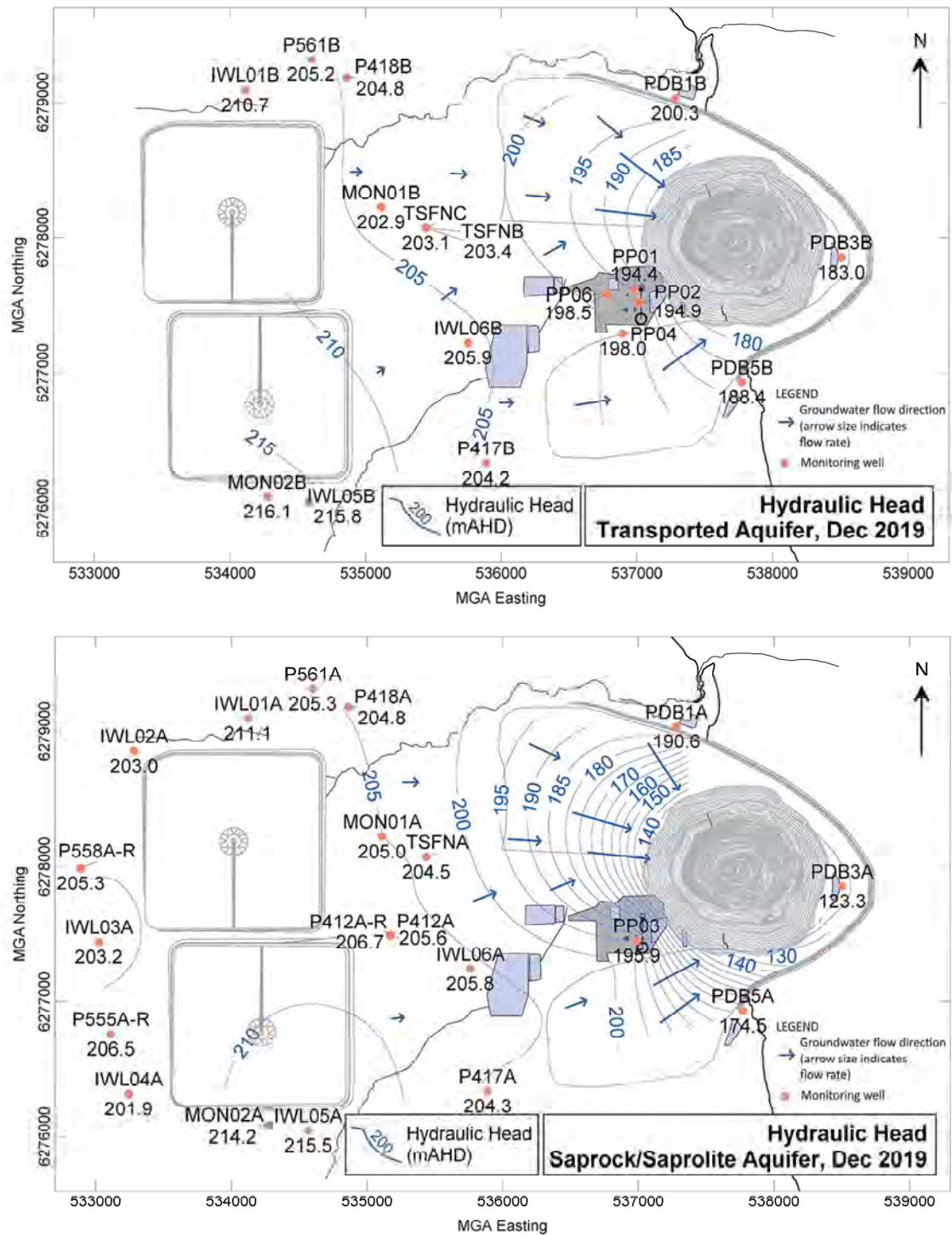


Figure 6-9: Observed hydraulic head in December 2019 for the Transported and Saprolite units (Coffey, 2020b)



## 6.7.3 Groundwater Quality

### 6.7.3.1 Groundwater quality in ML1535

Electrical Conductivity (EC) concentrations and pH levels in groundwater within ML1535 have generally remained stable between 2004 and 2020. 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 7, 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.

### 6.7.3.2 Groundwater contamination in ML1535

6.7.3.3 Cyanide is used in the gold extraction process and is measured by Evolution as both total cyanide and weak acid dissociable (WAD) cyanide. The default guideline value (DGV) of 0.007 mg/L is for non-ionised hydrogen cyanide (HCN) which may be converted to free cyanide (HCN+CN<sup>-</sup>) using the ANZECC Table 8.3.8 and corresponding pH and temperature values (ANZECC, 2000). The total cyanide is free cyanide plus the measurable cyanide from breakdown of metallo-cyanide and organic complexes. The LOR for cyanide is 0.004 mg/L.

Monitoring results for cyanide in groundwater were reviewed for the mine life history (September 2004 to Jan 2020). 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 6-3.

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 January 2020, there is no consistent trend to suggest that significant concentrations of cyanide have leached from the TSFs into the surrounding groundwater.

Table 6-3: 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

Year	Month	Bore	Total Cyanide Concentration (mg/L)	WAD Cyanide Concentration (mg/L)
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	MON02A	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			
2018	No detections above laboratory limit of reporting			
2019	15 October	TSFNB	0.252	<0.004
		TSFNC	0.027	0.02
	25 October	No detections above laboratory limit of reporting		



## 6.8 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 Paleochannel Borefield (formerly known as the Jemalong Borefield Area), located to the north-east of the mine site. Transmissivities averaged 35 square metres per day ( $\text{m}^2/\text{day}$ ) within the Upper Cowra Formation (up to 50 m depth) and  $8 \text{ m}^2/\text{day}$  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 ( $\text{m/day}$ ).

The adopted parameter values for the calibrated model used in a previous pit dewatering assessment (Coffey, 2008) are shown in Table 6-4.

Table 6-4: Adopted model parameters (Coffey, 2008)

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

Source: Coffey (2008)

A calibrated groundwater model developed by Coffey (2009a) to assess groundwater level changes at the mine site adopted the parameter values shown in Table 6-5.

Table 6-5: Adopted Model Parameters (Coffey, 2009a)

Hydrogeological unit	Geological unit	Horizontal Hydraulic Conductivity ( $\text{m/day}$ )	Vertical Hydraulic Conductivity ( $\text{m/day}$ )	Specific Yield
Transported	Cowra Formation	$1.0 \times 10^{-2}$	$3.0 \times 10^{-3}$	0.05
Saprolite	Lake Cowal Volcanics	$1.0 \times 10^{-1}$	$1.0 \times 10^{-2}$	0.002
Saprock	Ordovician Host Rock	$1.0 \times 10^{-2}$	$1.0 \times 10^{-3}$	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  $1.2 \text{ m}^2/\text{day}$  (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  $0.01 \text{ m/day}$ .

Coffey (2009a) collated falling head permeability test data from piezometers located both within and to the east of the TSF 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 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 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 6-6 for a pit dewatering model. It should be noted that the model developed by Hawkes (1998) considered 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 the Department of Primary Industries – Crown Lands and Water [CL&W]) (Bilge, 2012) for the Upper Lachlan catchment adopted horizontal hydraulic conductivities generally ranging from less than 1 to 20 m/day in the Lower Cowra Formation and from less than 1 to 35 m/day in the Upper Cowra Formation over the present model domain.

Table 6-6. 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	$2.0 \times 10^0$ to $3.0 \times 10^0$	$1.0 \times 10^{-4}$	$1.0 \times 10^{-3}$	$1.5 \times 10^{-1}$
Saprolite	Lake Cowal Volcanics	-	$1.0 \times 10^{-4}$	-	-
Saprock	Ordovician Host Rock	$1.5 \times 10^0$	-	$1.0 \times 10^{-2}$	$1.0 \times 10^{-3}$
Primary Rock	Ordovician Host Rock	-	$1.0 \times 10^{-4}$	-	-

Source: Hawkes (1998)

Analysis of pumping tests conducted in 2004 in bores of the Bland Creek Paleochannel Borefields, located to the north-east of the mine site area, provide several values of confined storativity, giving an average storativity of  $1.9 \times 10^{-4}$  for the Lachlan Formation (Groundwater Consulting Services Pty Ltd [GCS], 2006), or an average specific storage of  $9.5 \times 10^{-6} \text{ m}^{-1}$ , 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  $1.7 \times 10^{-4}$  for the Lachlan Formation, or an average specific storage of  $8.5 \times 10^{-6} \text{ m}^{-1}$ , 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 the NSW Department of Industry - 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  $5.5 \times 10^{-6}$  to  $1.7 \times 10^{-5}$  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 Saline Supply Borefield, located within the ML1535. Test results suggest a hydraulic conductivity of the Transported material of approximately 5 m/day and a specific yield of approximately  $1.6 \times 10^{-3}$ .

A calibrated groundwater model used for the MOD14 assessment (Coffey, 2018a) adopted horizontal and vertical hydraulic conductivities of the Transported materials of  $1.0 \times 10^{-2}$  m/d and  $6.5 \times 10^{-4}$  m/d respectively.

A summary of various values of groundwater parameters adopted for previous work is presented in Table 6-7 and Table 6-8.

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.

### 6.8.1.1 Tailings storage facilities

Based on test drilling data, geophysical studies and piezometer installations around the proposed TSF reported by North Limited (1998):

- The foundation of the existing TSF 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 tailings areas prior to mine development was essentially from west to east with a hydraulic gradient of about  $7 \times 10^{-3}$  m.
- Field permeability testing of strata expected to be of higher permeability indicate low horizontal permeability of the order of  $2 \times 10^{-4}$  to  $1 \times 10^{-3}$  m/day for gravelly clay and  $0.6 \times 10^{-4}$  to  $3.5 \times 10^{-4}$  m/day for weathered rock.
- Laboratory infiltration tests indicate vertical permeability of the less permeable soils of the order of  $0.9 \times 10^{-6}$  to  $1.3 \times 10^{-6}$  m/day.

Table 6-7. Summary of horizontal hydraulic conductivity values adopted for previous work

Hydrogeological Unit (Geological Unit)	Value (m/day)	Region	Source	Reference
Transported (Cowra Formation)	$1 \times 10^{-1}$ to $1 \times 10^2$	Jemalong Borefield	Hydraulic testing	Coffey (2006)
	5	Saline Supply Borefield, ML1535	Pumping test	GCS (2008)
	$1 \times 10^{-2}$	TSF	Slug test	Coffey (2009a)
	$1 \times 10^{-2}$	Mine Site	Modelling	Coffey (2009a)

Hydrogeological Unit (Geological Unit)	Value (m/day)	Region	Source	Reference
	$1 \times 10^{-3}$	E42 open Pit	Modelling	Coffey (2008)
	2 to 3	E42 open Pit	Modelling	Hawkes (1998)
	1 to 35	Upper Lachlan catchment	Modelling	Bilge (2012)
	1 to 2	Jemalong	Regional Modelling	Coffey (2011)
	1	Elsewhere		
	$1 \times 10^{-2}$ (horizontal)	Mine Site	Modelling	Coffey (2018a)
	$6.5 \times 10^{-4}$ (vertical)	Mine Site	Modelling	Coffey (2018a)
Transported (Cowra Formation) and Saprolite	$1 \times 10^{-2}$	E42 open Pit	Recovery test	Coffey (2008)
Transported (Cowra Formation), Saprolite and Saprock (Ordovician Host Rock)	$6 \times 10^{-2}$	E42 open Pit	Pumping test	Coffey (1995a)
Saprolite	$2 \times 10^{-2}$	TSF	Slug testing	Coffey (2009a)
	$1 \times 10^{-1}$	Mine Site	Modelling	Coffey (2009a)
	$5 \times 10^{-2}$	E42 open Pit	Modelling	Coffey (2008)
	$2 \times 10^{-2}$	Mine Site	Modelling	Coffey (2018a)
Saprock (Ordovician Host Rock)	$1 \times 10^{-2}$	Mine Site	Modelling	Coffey (2009a)
	$1 \times 10^{-2}$	E42 open Pit	Modelling	Coffey (2008)
	1.5	E42 open Pit	Modelling	Hawkes (1998)
	$2 \times 10^{-3}$	Mine Site	Modelling	Coffey (2018a)
Primary Rock (Ordovician Host Rock)	$1 \times 10^{-2}$	E42 open Pit	Modelling	Coffey (2008)
Lachlan Formation	$3 \times 10^{-2}$ to $1 \times 10^2$	Jemalong Borefield	Hydraulic testing	Coffey (2006)
	3 to 28	Regionally	Regional Modelling	Coffey (2011)

Table 6-8. Summary of specific yield and storage values adopted for previous work

Unit(s)	Specific Yield	Storage Coefficient	Region	Source	Reference
Transported (Cowra Formation)	$1.0 \times 10^{-3}$	$1.5 \times 10^{-1}$	E42 open Pit	See text	Hawkes (1998)
	$1.5 \times 10^{-1}$	-	E42 open Pit	Modelling	Coffey (2008)
	$5.0 \times 10^{-2}$	-	Mine Site	Modelling	Coffey (2009a)
	$6.0 \times 10^{-2}$ to $3.0 \times 10^{-1}$	$5.5 \times 10^{-6}$ to $1.7 \times 10^{-5}$	Upper Lachlan catchment	Modelling	Bilge (2012)

Unit(s)	Specific Yield	Storage Coefficient	Region	Source	Reference
	$1.6 \times 10^{-3}$	-	Saline Supply Borefield, Mine Lease	Pumping test	GCS (2008)
	$4.0 \times 10^{-2}$	$1.5 \times 10^{-5}$	Regionally	Regional Modelling	Coffey (2011)
	$1.5 \times 10^{-1}$	$5 \times 10^{-4}$	Mine Site	Modelling	Coffey (2018a)
Saprolite	$2.0 \times 10^{-2}$	-	E42 open Pit	Modelling	Coffey (2008)
	$2.0 \times 10^{-3}$	-	Mine Site	Modelling	Coffey (2009a)
	$1.0 \times 10^{-4}$	$5 \times 10^{-5}$	Mine Site	Modelling	Coffey (2018a)
Saprock (Ordovician Host Rock)	$1.0 \times 10^{-2}$	$1.0 \times 10^{-3}$	E42 open Pit	See text	Hawkes (1998)
	$2.0 \times 10^{-2}$	-	E42 open Pit	Modelling	Coffey (2008)
	$2.0 \times 10^{-2}$	-	Mine Site	Modelling	Coffey (2009a)
	$1.0 \times 10^{-4}$	$3 \times 10^{-5}$	Mine Site	Modelling	Coffey (2018a)
Primary Rock (Ordovician Host Rock)	$2.0 \times 10^{-2}$	-	E42 open Pit	Modelling	Coffey (2008)
Lachlan Formation	$1.9 \times 10^{-4}$	-	Jemalong Borefield	Pumping test	GCS (2006)
	$1.7 \times 10^{-4}$	-	Jemalong Borefield	Pumping test	Coffey (1995c)
	N/A	$1.5 \times 10^{-5}$	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  $1 \times 10^{-9}$  m/s ( $9 \times 10^{-5}$  m/day).
- 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  $8 \times 10^{-4}$  m/day to  $3 \times 10^{-5}$  m/day, with an arithmetic mean of  $2 \times 10^{-4}$  m/day and a geometric mean of  $1 \times 10^{-4}$  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 6-9 and indicate the reported 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 which is currently being developed as part of the approved Modification 14.



Table 6-9. Tailings Permeability Data (Knight Piesold Pty Ltd, 1994)

Test Type	Sample	Permeability (m/d)	Dry Density (tonnes/m <sup>3</sup> )
Falling Head Permeability Tests	Primary Tailings	0.02	1.29
		0.02	1.29
	Oxide Tailings	0.01	1.18
		0.01	1.2
Consolidation Tests	Primary Tailings	0.62	1.07
		0.09	1.1
		0.02	1.2
	Oxide Tailings	0.27	0.95
		0.03	0.99
		0.01	1.12
		0.01	1.13

Source: Knight Piesold Pty Ltd (1994)

A calibrated groundwater model developed by Coffey (2009a) to assess groundwater level changes associated with the TSFs adopted the parameter values shown in Table 6-10 for tailings materials.

Table 6-10. Adopted Model Parameters (Coffey, 2009a)

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

Source: Coffey (2009a)

A summary of the above information is presented in Table 6-11.

Table 6-11. Summary of TSF parameters adopted for previous work

Hydrogeological Unit	Horizontal Permeability (m/d)	Vertical Permeability (m/d)	Specific Yield	Reference
TSF Foundation	$1 \times 10^{-3}$ to $6 \times 10^{-5}$	$1.3 \times 10^{-6}$ to $9 \times 10^{-7}$	N/A	North Limited (1998)
	N/A	$8.6 \times 10^{-5}$	N/A	URS (2005, 2006)
	N/A	$2 \times 10^{-4}$	N/A	Coffey (1995c)
Deposited Tailings	N/A	$1 \times 10^{-2}$ to $6.2 \times 10^{-1}$	N/A	Knight Piesold (1994)
	$5.0 \times 10^{-2}$	$5.0 \times 10^{-3}$	0.01	Coffey (2009a) (model)
	$5.0 \times 10^{-2}$	$5.0 \times 10^{-4}$	0.015	Coffey (2018a) (model)
TSF Embankment - Clay	$1.0 \times 10^{-4}$	$1.0 \times 10^{-4}$	0.15	Coffey (2009a and 2018a) (models)

### 6.8.1.2 Field investigations in 2020

To support assessment of groundwater level and hydraulic conductivity parameters adopted for the UG EIS, a field investigation program was carried out between 28 January and 29 February 2020, see Appendix E. Coffey field engineers attended the CGO mine site to supervise drilling and testing and to complete the piezometer installations associated with the field investigations.

Four vertical boreholes (UG-BH-01, UG-BH-02, UG-BH-03 and UG-BH-04) were drilled from the surface of Lake Cowal. Lake Cowal was dry during the fieldwork and at the time of writing this report (September 2020). Two boreholes were drilled to 70 m and two boreholes were drilled to 100 m depth. Borehole water pressure (packer) testing was carried out at locations nominated by Coffey on selected boreholes. The borehole locations are shown in Figure 6-8. A summary of the packer test results is shown in Table 6-12. Packer tests were not conducted at UG-BH-01 as a suitable section of non-fractured core to seat the packers was not identified.

Table 6-12: Packer test results on boreholes drilled in 2020

Borehole	Depth (m below ground)	Unit	Hydraulic conductivity (m/day)
UG-BH-02	97.0 – 103.0	Saprock	$2.6 \times 10^{-4}$
UG-BH-03	60.0 – 64.0	Saprock	$< 1 \times 10^{-4}$
UG-BH-03	65.0 – 72.0	Saprock	$< 1 \times 10^{-4}$
UG-BH-04	54.0 – 59.0	Saprock	$9.5 \times 10^{-3}$
UG-BH-04	63.0 – 68.0	Saprock	$3.5 \times 10^{-4}$
UG-BH-04	72.0 – 77.0	Primary Rock	$1.0 \times 10^{-2}$
UG-BH-04	91.0 – 102.0	Primary Rock	$< 1 \times 10^{-4}$

As part of the fieldwork, groundwater seepage into the GRE46 exploration decline was mapped by a Coffey field engineer. The total rate of groundwater inflow into the decline was assessed to be 2.8 L/s on 27 February 2020 based on site records. An assessment of the hydraulic conductivity required to produce this flow rate was carried out. This was done by assuming an equivalent length tunnel in uniform rock with the same approximate groundwater heads and tunnel elevation profile. The resulting hydraulic conductivity was assessed to be  $4.8 \times 10^{-4}$  m/day. This result is similar to the median of the packer testing results ( $2.6 \times 10^{-4}$  m/day) shown in Table 6-12.

## 7 Representation of mining activities

### 7.1 Open pit excavation schedule

Open pit geometries were provided at intervals from December 2005 to June 2010, and for December 2011, June 2012, January 2013, January 2015, January 2018 and January 2020. The planned open pit geometry for 2020 to 2026 (end of open pit mining) was provided by Evolution Mining. Based on this data, Figure 7-1 shows the approximate elevation of the base of the open pit over time.



Figure 7-1: Approximate elevation of base of open pit over time

### 7.2 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 open pit, groundwater flows from in-pit horizontal drains, and rainfall runoff in the pit are directed to pit sumps before being pumped to water storage dams.

CGO records the volumes pumped out of in-pit sumps and the volumes abstracted by the vertical dewatering bores on a monthly basis. 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 drains. Rainfall runoff may come from areas outside the pit footprint. Pit dewatering is discussed further in Section 8.2.9.

Based on modelling and interpretation of pit dewatering volumes, as discussed below in Section 8.2.9, groundwater inflow to the open pit is estimated to have gradually increased since 2008 and at January 2020 there is an estimated 1,000 m<sup>3</sup> of groundwater inflow to the open pit per day. It is relevant to note that no increase in groundwater inflow to the open pit was observed during or following the 2010, 2012 and 2016 lake-fill events based on pit dewatering records.

### 7.3 Storage dams

Storage dams located within the CGO are shown in Figure 7-2. Note that D10 has not been constructed at the time of writing in September 2020. Historical water levels within the storage dams D1, D2, D3, D4, D5A, D6, D8B and D9 were reviewed. Dams D1, D2, D3, D4, D5A, 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, as shown in Appendix A - Figure A3) suggest that water seepage from D9 does not impact groundwater levels. Earlier model calibrations supported this assessment and D9 was not included within the model thereafter.

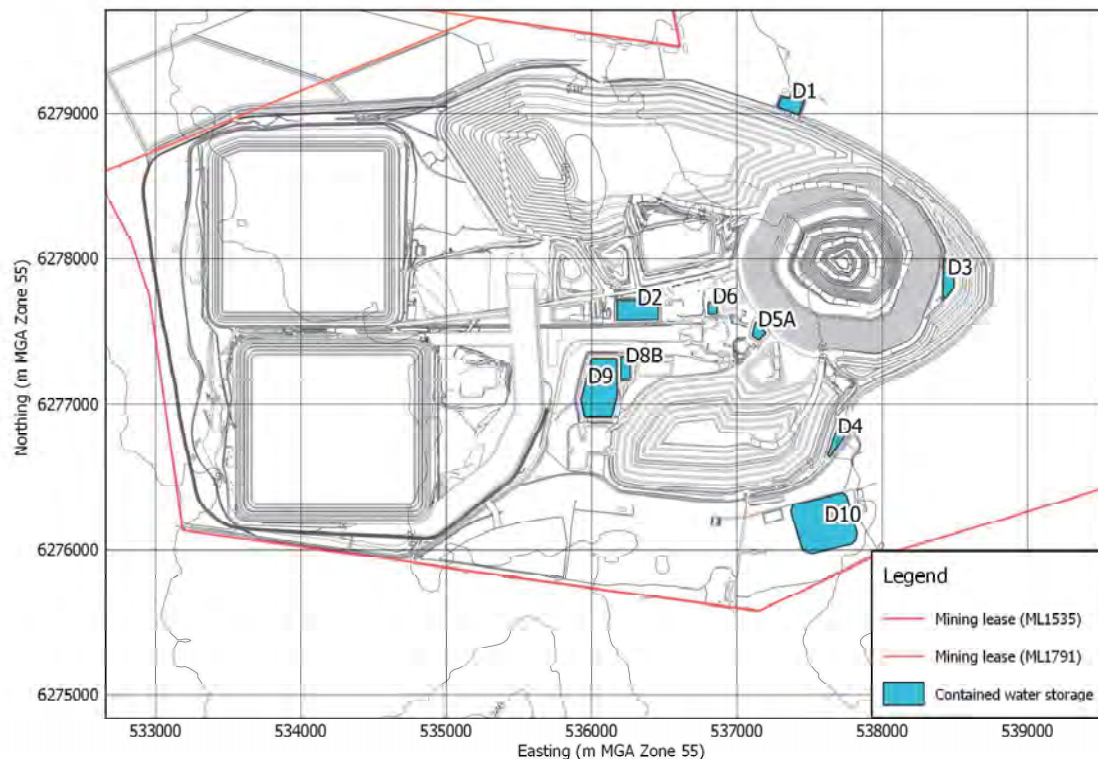


Figure 7-2: Storage dams

### 7.4 Tailings storage facilities and Integrated Waste Landform

Crest levels provided by Evolution Mining are shown in Table 7-1. The IWL (Integrated Waste Landform encompassing the existing tailings storage facilities (TSFs)) is planned to be operational from 1 January 2021.

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 7-1 presents the estimated lowest deposited tailings surface elevation within each dam associated with each raise of the tailings embankment.

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 TSFs, 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 7-3.

Table 7-1: TSF and IWL crest levels and low points

Status Start Date	Northern tailings storage facility				Southern tailings storage facility				Integrated Waste Landform			
	Stage	Operational Status	Crest Level (m AHD)	Low Point (m AHD)	Stage	Operational Status	Crest Level (m AHD)	Low Point (m AHD)	Stage	Operational Status	Crest Level (m AHD)	Low Point (m AHD)
1-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
8-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
9-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
1-Sep-14	4	Active	231.7	228.7	4	Inactive	235.4	232.4				213
2-Nov-15	4	Inactive	231.7	228.7	5	Active	239.0	236.1				213
1-Dec-16	5	Active	236.0	233.1	5	Inactive	239.0	236.1				213
1-Mar-18	5	Inactive	236.0	233.1	6	Active	243.7	240.9				213
1-May-19	6	Active	240.5	237.7	6	Inactive	243.7	240.9				213
1-Jul-20	6	Inactive	240.5	237.7	7	Active	248.4	245.7	1	Active	221.5	220.1
1-Nov-21	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	1	Inactive	221.5	220.1
1-Nov-21	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	2	Active	228.0	225.2
1-Dec-22	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	2	Inactive	228.0	225.2
1-Dec-22	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	3	Active	228.0	225.2
1-Feb-24	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	4	Active	231.5	225.2
1-Apr-25	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	5	Active	236.5	228.7
1-Apr-27	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	6	Active	240.5	233.7
1-May-29	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	7	Active	245.0	237.7
1-Jul-32	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	8	Active	245.0	242.2
31-Dec-32	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	9	Active	246.0	243.2
31-Dec-33	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	10	Active	247.0	244.2
31-Dec-34	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	11	Active	248.0	245.2
31-Dec-35	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	12	Active	249.0	246.2
31-Dec-36	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	13	Active	250.0	247.2
31-Dec-37	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	14	Active	251.0	248.2

31-Dec-39	6	Inactive	240.5	237.7	7	Inactive	248.4	245.7	14	Inactive	251.0	248.2
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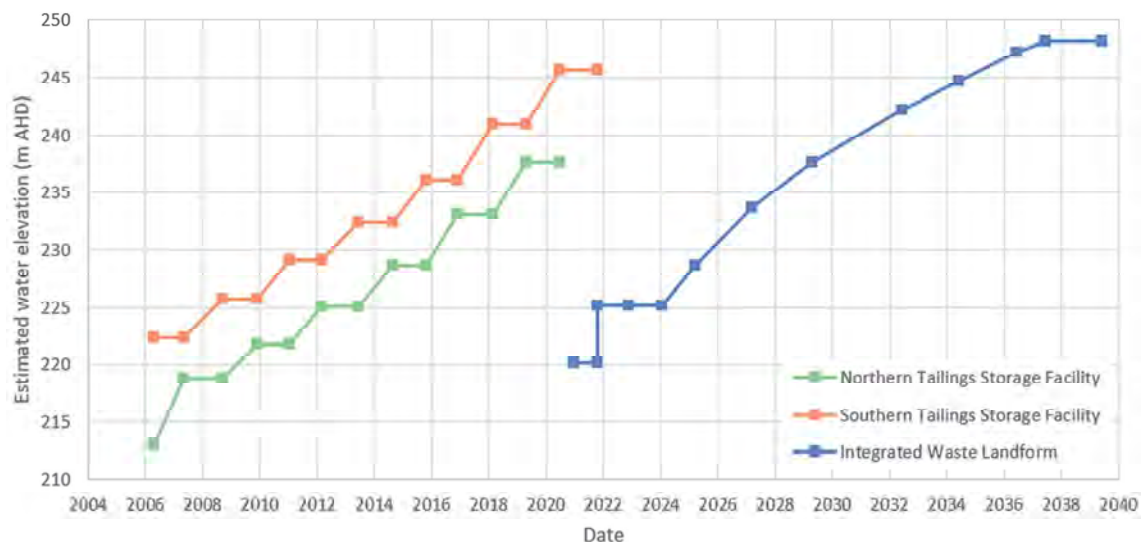


Figure 7-3: TSF and IWL water levels

The hydraulic conductivity of the TSF foundation material is lower than that of the deposited tailings and 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.

## 7.5 Paste fill

As part of the proposed underground mine operation, tailings paste will be used to produce a backfill to support the excavated stopes. This is discussed further in Section 9.1.7.

## 7.6 Proposed underground mine

### 7.6.1 Mine geometry

A sequence of stoping is proposed with development beginning in 2022. The proposed underground mining continues to mid-2039. In the horizontal direction, stoping will cover an area approximately 1500 m long running north from the eastern edge of the open pit and extending to approximately 800 m past the northern edge of the bund, as shown in Figure 7-4. The zone of stoping is approximately 100 m to 200 m in width. To the west of the stoping a network of access and haulage tunnels will extend approximately a further 200 m to the west.

In the vertical direction, the zone of stoping dips toward the east at an angle of approximately 72 degrees from the horizontal. The vertical extents of the stopes are approximately from 80 m AHD to -730 m AHD. Figure 7-5, Figure 7-6 and Figure 7-7 show the proposed stopes and access tunnels in plan and section and Figure 7-8 shows an isometric view.

Figure 7-9 shows the proposed timing of the stopes and access tunnel excavation, with selected times shown.

The proposed total mass of ore to be excavated from the stopes is 26,739,000 tonnes and the total length of access and haulage tunnels is 40 km (information provided by Evolution, reference: GRE-46\_UG\_SSD Design - Final - Capped at 1.8.xlsx).

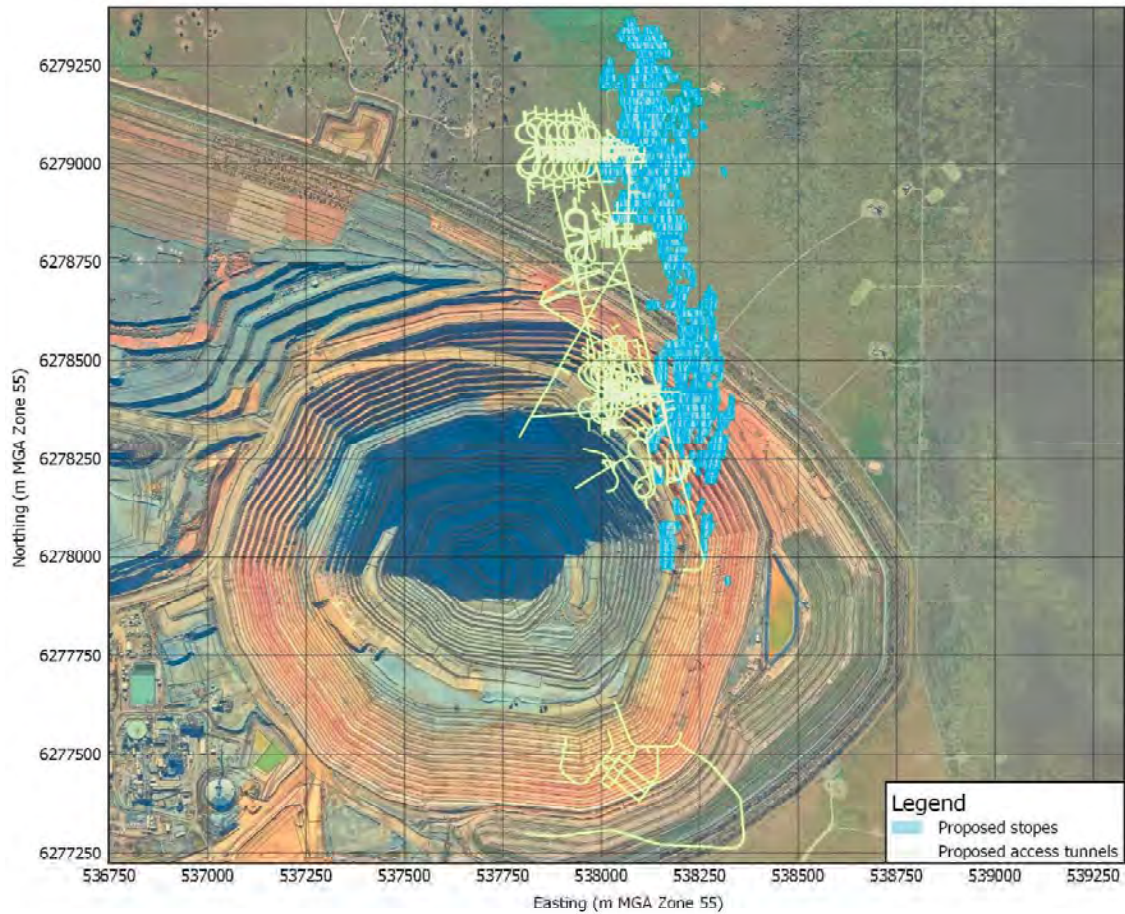


Figure 7-4: Detailed plan view of stopes area (Aerial imagery provided by Evolution Mining, December 2019)



Figure 7-5: Stopes and access tunnels - plan view (m MGA Zone 55)



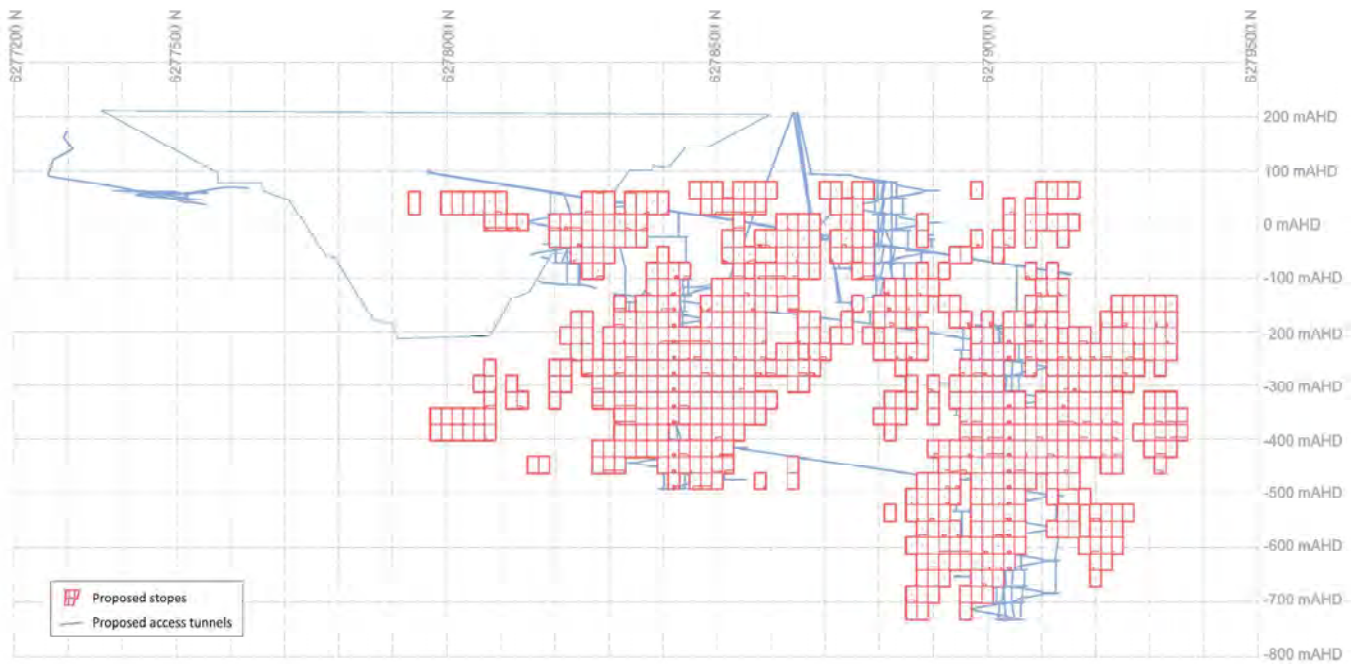


Figure 7-6: Stopes and access tunnels - elevation view looking west (Northings in m MGA Zone 55)

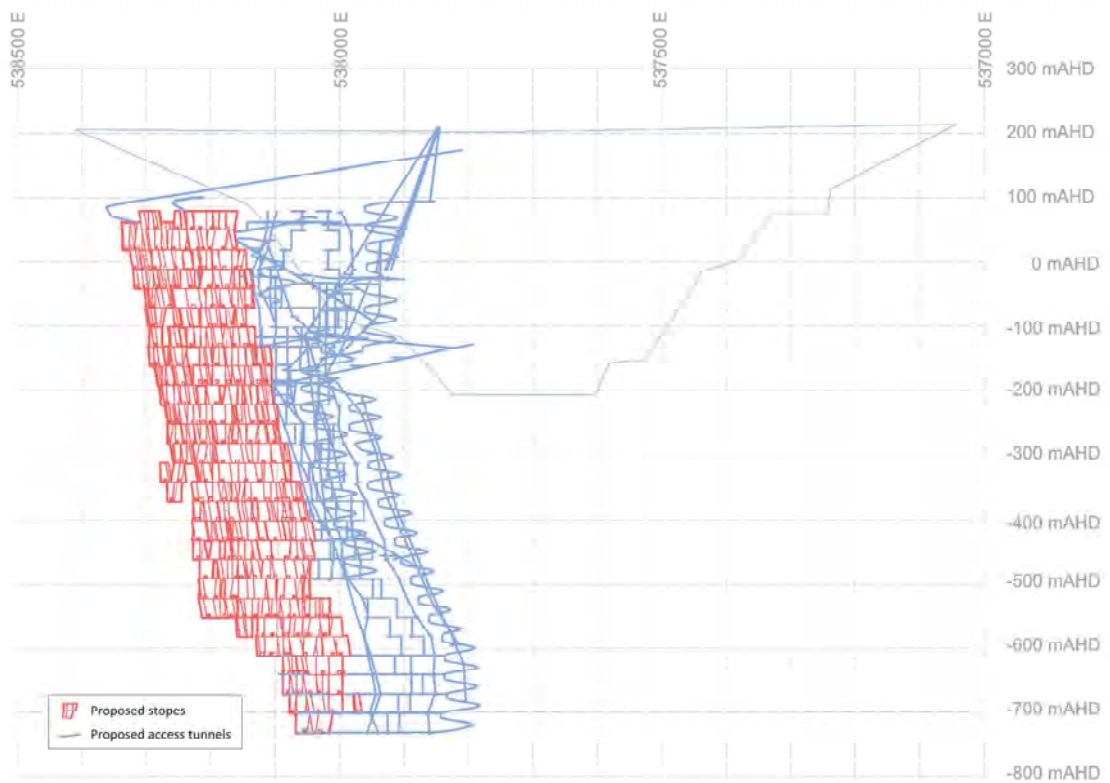


Figure 7-7: Stopes and access tunnels - elevation view looking south (Eastingings in m MGA Zone 55)



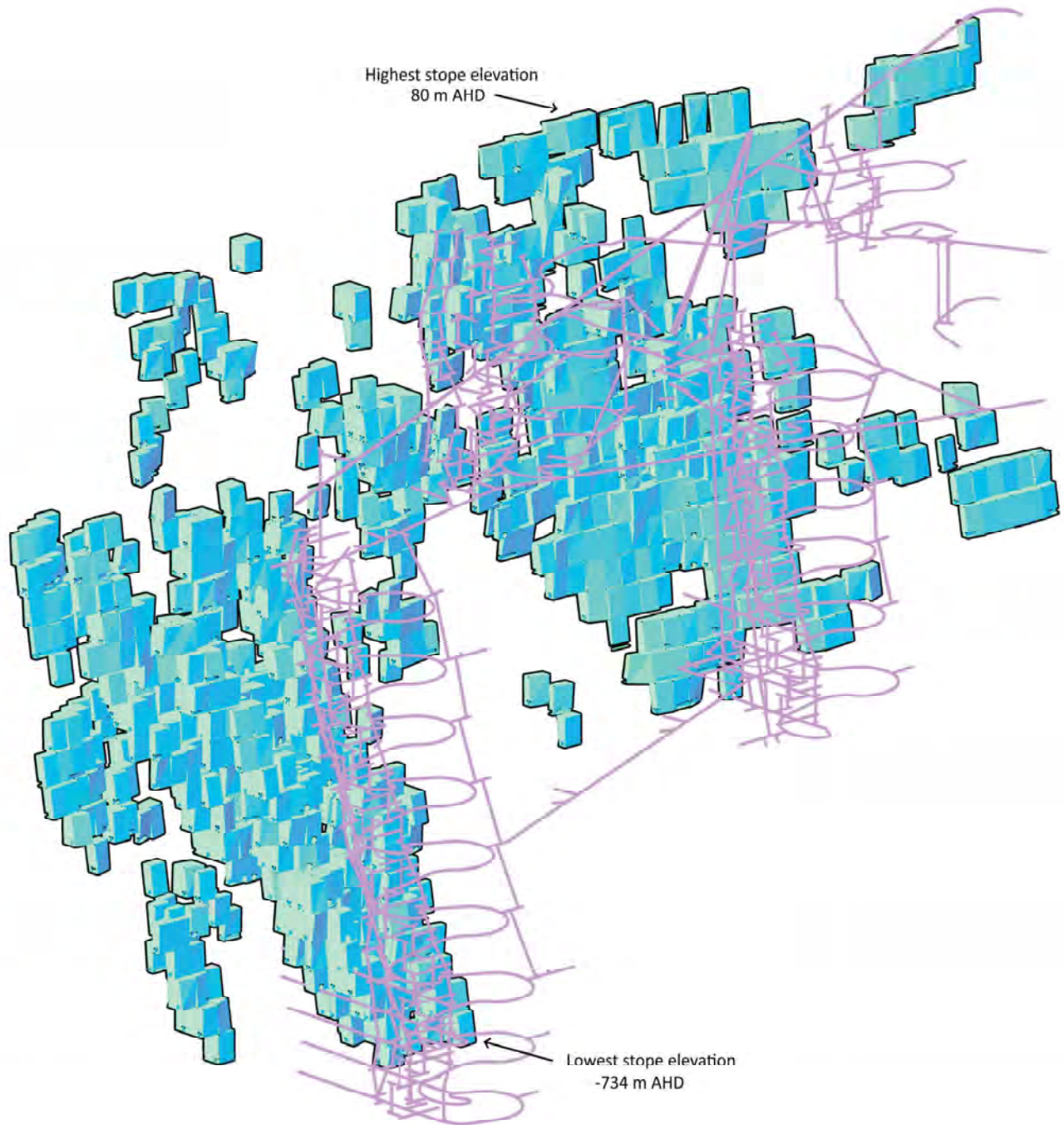


Figure 7-8: Stopes and access tunnels - isometric view from the west

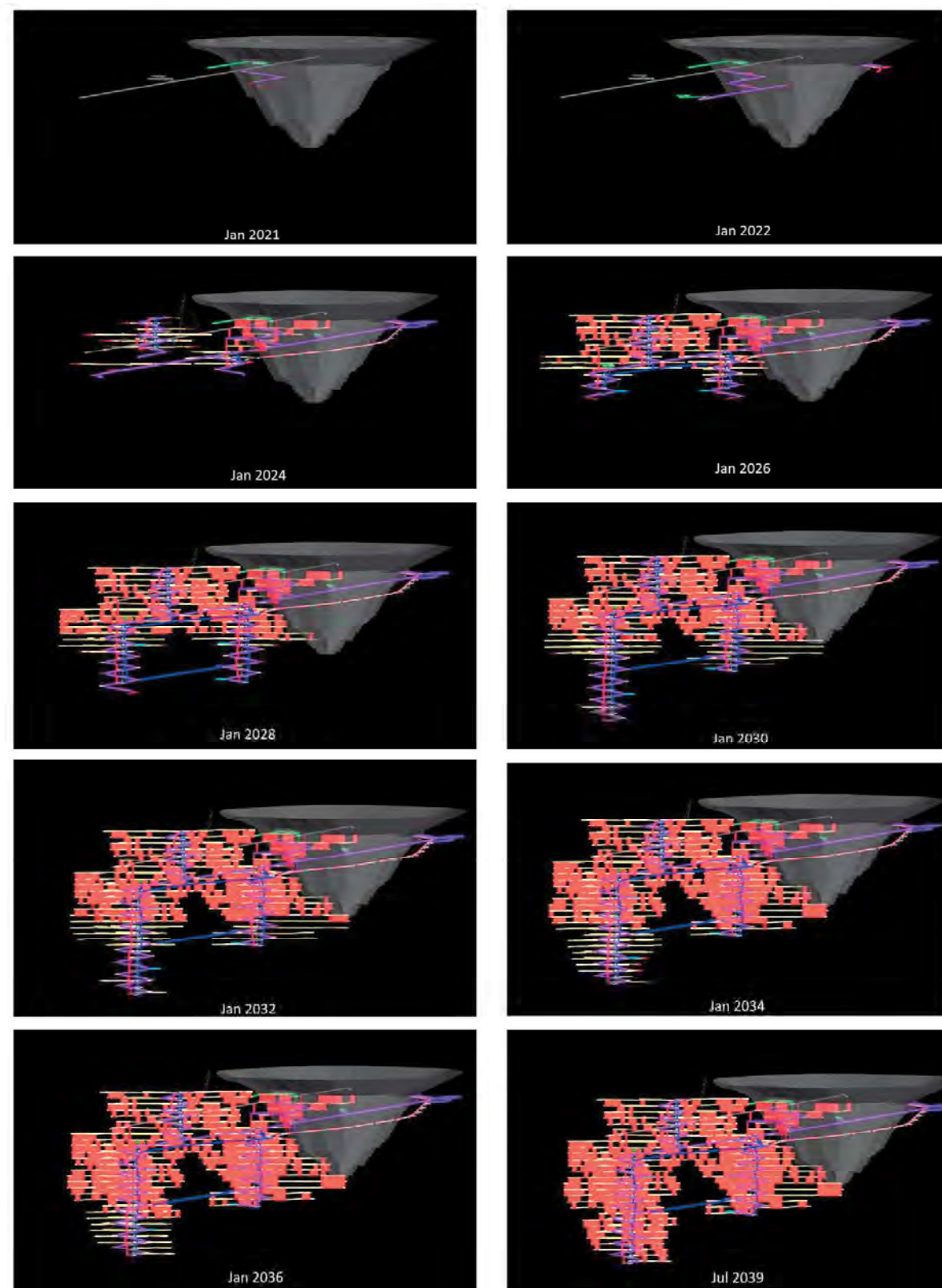


Figure 7-9: Stopes and access tunnel excavation timing

## 8 Numerical model development

A three-dimensional numerical groundwater flow model was developed using the proprietary software Feflow, Version 7.2. The model was used to calibrate hydraulic conductivity, specific storage and rainfall infiltration rates for the conceptual hydrogeological model, based on observed groundwater heads, open pit excavation progress and interpreted pit inflows for the period 1 January 2005 to 1 January 2020.

The calibrated model was then used to predict the impacts from the proposed underground mine on local groundwater levels and flow directions and to predict the rates of groundwater inflow into the proposed underground mine.

Previous modelling has been carried out for the mine site. These models were calibrated based on the available monitoring data and pit inflow records at the time and provide a comparison to calibrated parameters obtained from the current numerical model, which is based on a longer set of monitoring data. Details of previous modelling is described in the following reports:

- Cowal Gold Operations Processing Rate Modification (MOD14), Mine Site Hydrogeological Assessment, Coffey Report No. 754-SYDGE206418-AA, dated 2 March 2018.
- Cowal Gold Mine, Groundwater Level Investigation, Coffey Report No. GEOTLCOV21910AF-AB, dated 26 March 2009.
- Cowal Gold Mine, Pit Dewatering Assessment, Coffey Report No. GEOTLCOV21910AC-AC, dated 5 August 2008.

Due to the significant re-design of the model mesh required to model the proposed stopes and access tunnels, the numerical model described in this report was developed and calibrated as a new model, rather than as an extension of previous models.

### 8.1 Conceptual model

#### 8.1.1 Model domain, layers and discretisation

##### 8.1.1.1 Domain

The model domain is centred approximately on the area between the existing open pit and the tailings storage facilities.

- The model western boundary is located approximately 10 km to the west of the open pit and follows a gentle north south ridge which reaches elevations of between 280 m AHD and 310 m AHD.
- The model eastern boundary is approximately 2 km east of the centre of Lake Cowal, located approximately 7 km east of the open pit.
- The model northern and southern boundaries are located approximately 7 km and 8 km from the open pit respectively. The northern boundary passes through Wamboyne Mountain which reaches an elevation of over 390 m AHD. There were no distinct topographic or geological features for the southern boundary.
- The model extents are 16.6 km east-west and 15.1 km north-south.



These extents were selected to be of such distance from the mine so that conditions at the model boundaries do not influence the model at the mine area over the mine life. Figure 8-1 shows the model boundary.

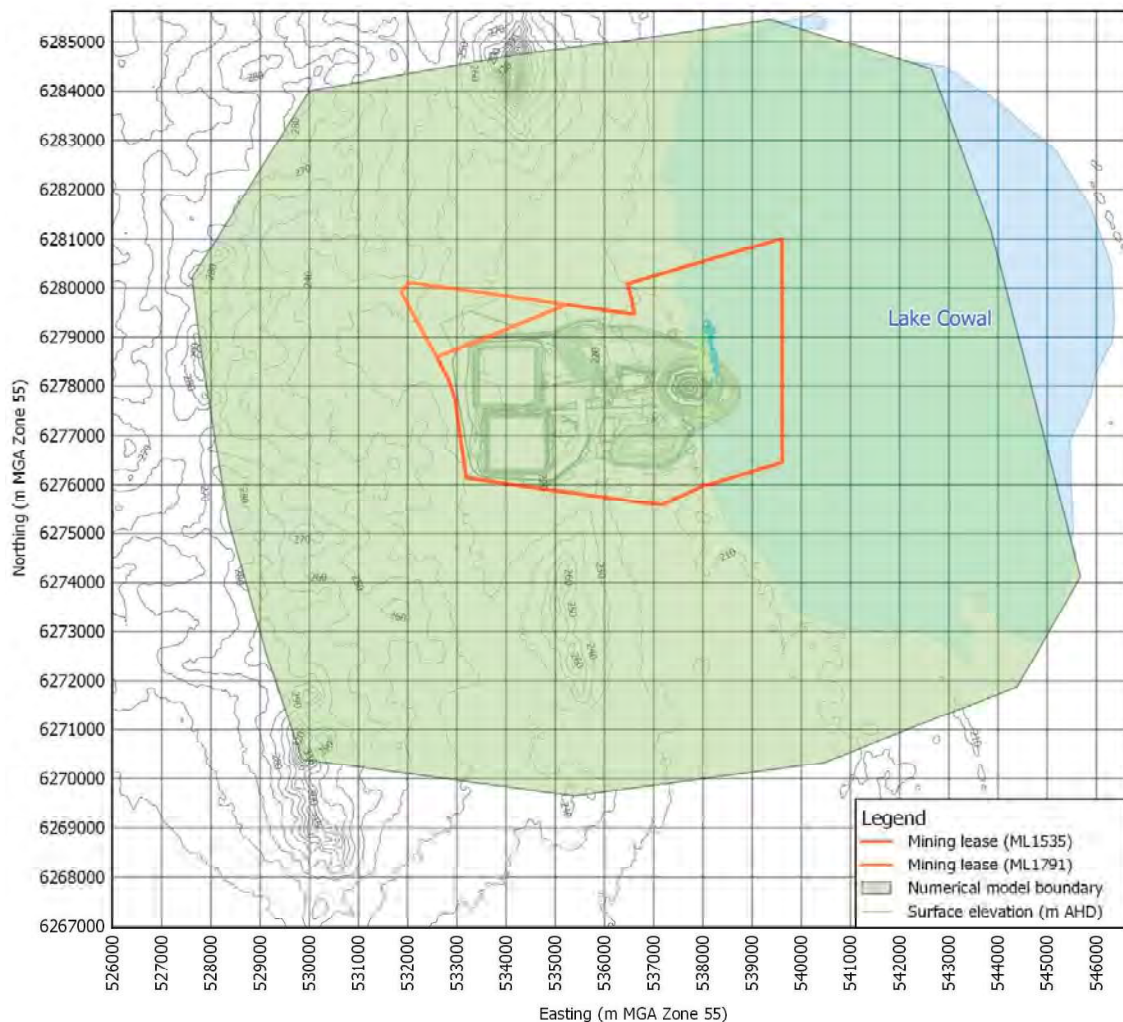


Figure 8-1: Model domain

### 8.1.1.2 Vertical layers

The model was divided into 19 vertical layers. The top of the model was taken as the ground surface from a 1 second resolution digital elevation model sourced from ELVIS (<https://elevation.fsd.org.au/>), a publicly available topographic data set released by the Australian and New Zealand Spatial Information Council (ANZLIC).

The model vertical layers represent the hydrogeological units as follows:

- Transported unit: Model layers 1 and 2, excluding the areas in layer 1 under the TSFs and IWL
- Saprolite unit: Model layers 3 and 4
- Saprock unit: Model layer 5

- Primary Rock unit: Model layers 6 to 19
- TSF and IWL: Model layer 1 under the TSF and IWL footprints only

The base of Transported, Saprolite and Saprock units in the area of the proposed underground mine were interpreted from the excavation borehole logs. The base of the Transported unit east of the mine, in the area shown in Figure 6-7, was interpreted from the gravity survey data, as discussed in section 6.4. Outside of these areas, the base of the units was set to a constant value.

The Primary Rock unit base of model layer elevations were set at 100, 50, 0, -100, -200, -300, -400, -500, -600, -700, -800, -1,000, -1,250 and -1,600 m AHD. The base of the model elevation was selected to be over 800 m below the base of the lowest of the proposed stopes. Figure 8-2 and Figure 8-3 show views of the open pit and stopes elements as represented in the model.

Based upon assessment of the modelled groundwater table near the open pit, the model layers representing the Transported, Saprolite and Saprock units were set as unconfined and the model layers representing the Primary Rock were set as confined.

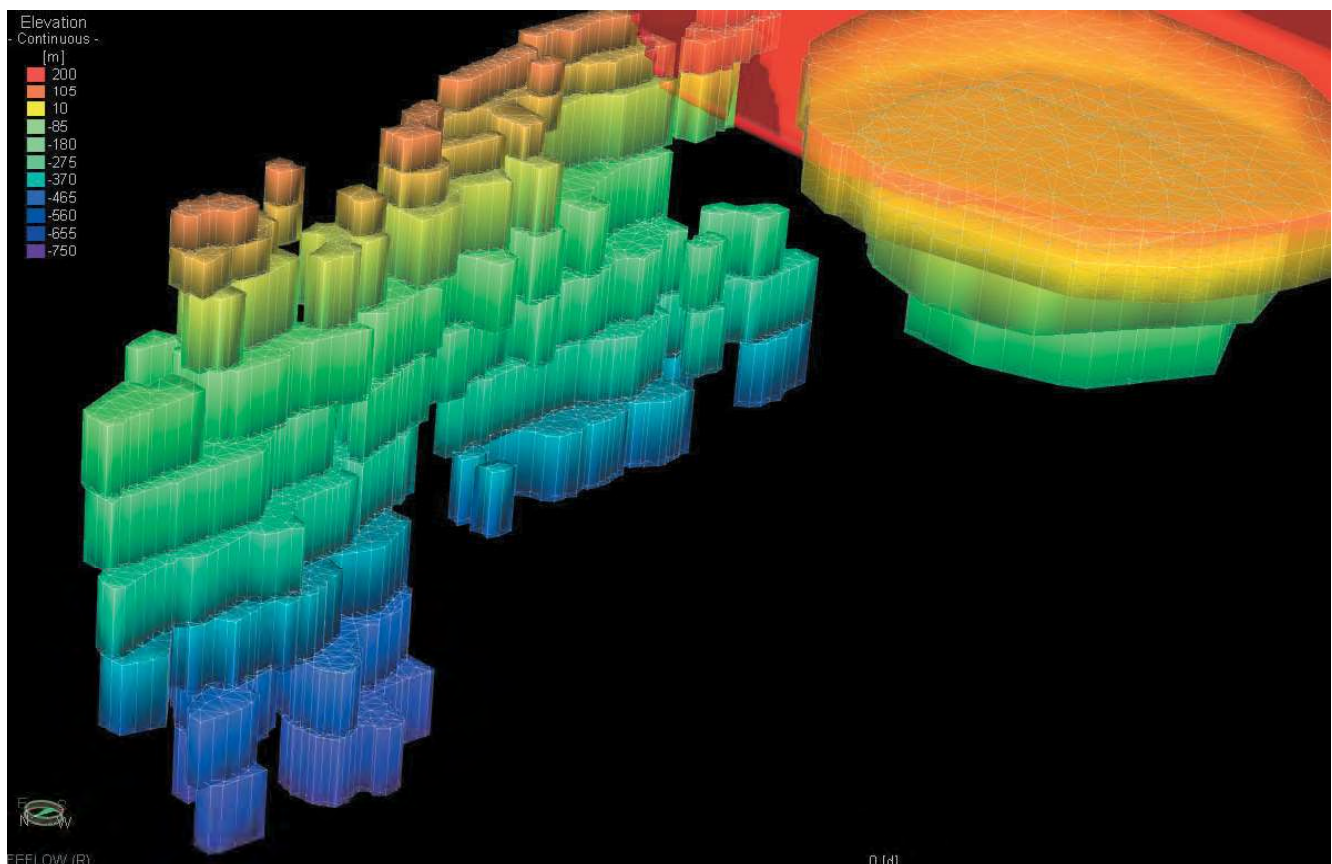


Figure 8-2: View of the open pit and stopes elements as represented in the model, viewed from the north west



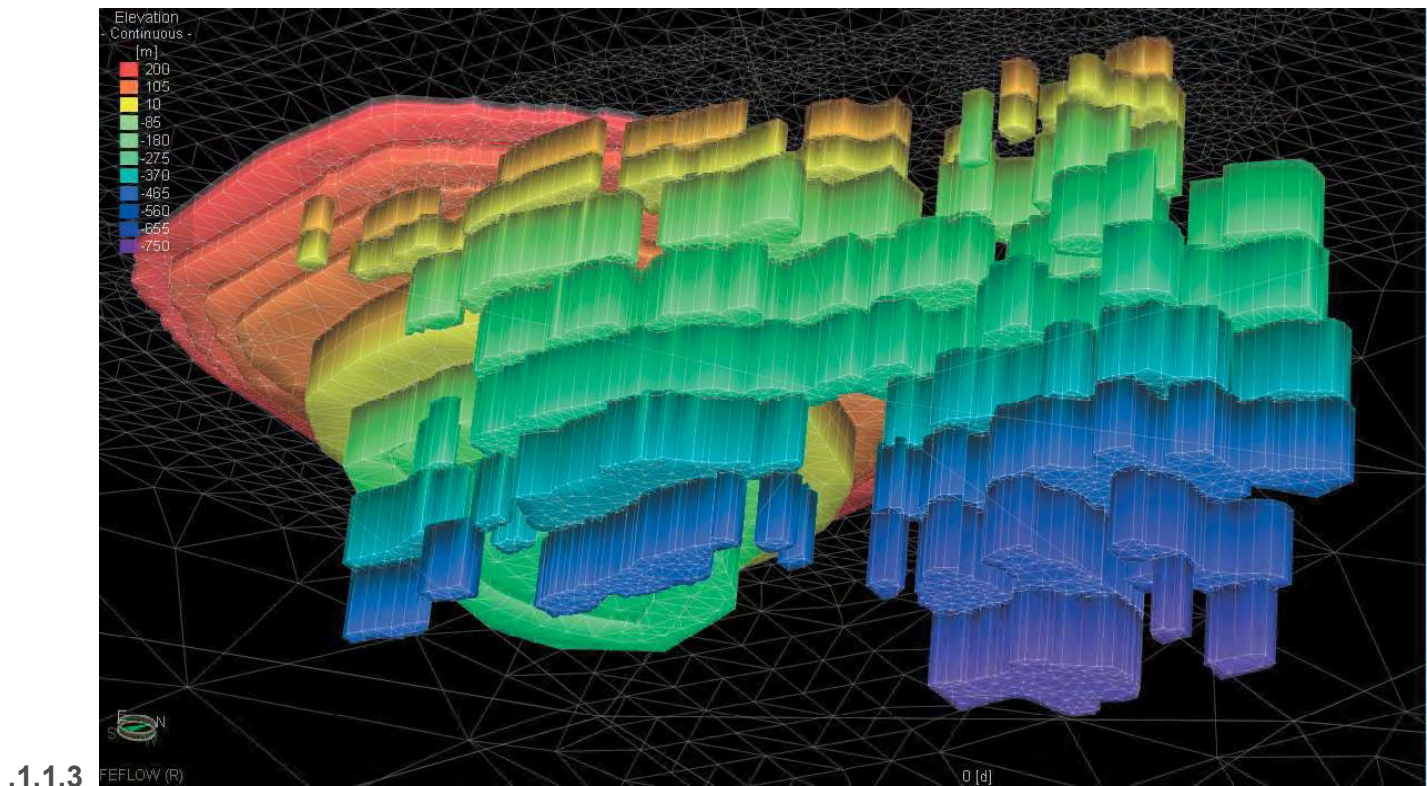


Figure 8-3: View of the stopes and open pit elements as represented in the model, viewed from underneath from the north east

#### 8.1.1.4 Open Pit

The geometry of open pit was provided by Evolution Mining for the years 2020 to 2024. Polygons were created for the intersection of the open pit and the elevations 187.5, 162.5, 137.5, 112.5, 50, -50 and -150 m AHD. These elevations represented the midpoints of the Transported, Saprolite and Saprock units and of layer 6, layer 7, layer 8 and layer 9 in the Primary Rock unit. The open pit was represented in the model as seven blocks in the abovementioned units and/or layers which were turned off sequentially as the pit excavation proceeded with seepage faces applied to allow seepage from the pit sides, as shown in Figure 8-8.

#### 8.1.1.5 Tailings storage facilities and Integrated Waste Landform

The location of the tailings storage facilities including the planned Integrated Waste Landform were taken from CAD files provided by Evolution Mining.

#### 8.1.1.6 Mesh

The model mesh was created using an unstructured triangular meshing (Delaunay Triangulation). A number of input points were specified prior to running the triangulation in order to control the mesh around the open pit, TSFs and IWL and the proposed stopes and access tunnels. This avoided automated refinement on intersecting or curved input lines or very close points, which commonly happens in a constrained Delaunay Triangulation and which can result in many more model elements than are necessary.

The model consists of 187,644 elements and 99,620 nodes. Figure 8-4 shows a plan view of the mesh. Figure 8-5 shows a close up of the mesh in the vicinity of the stopes and open pit.

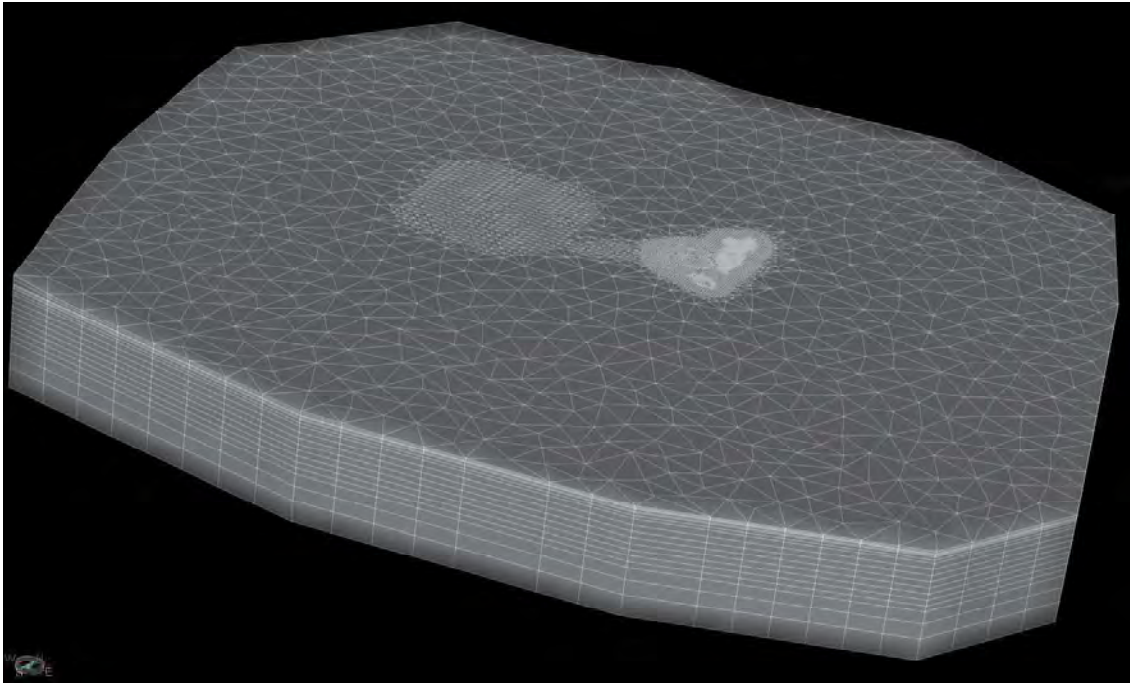


Figure 8-4: Mesh

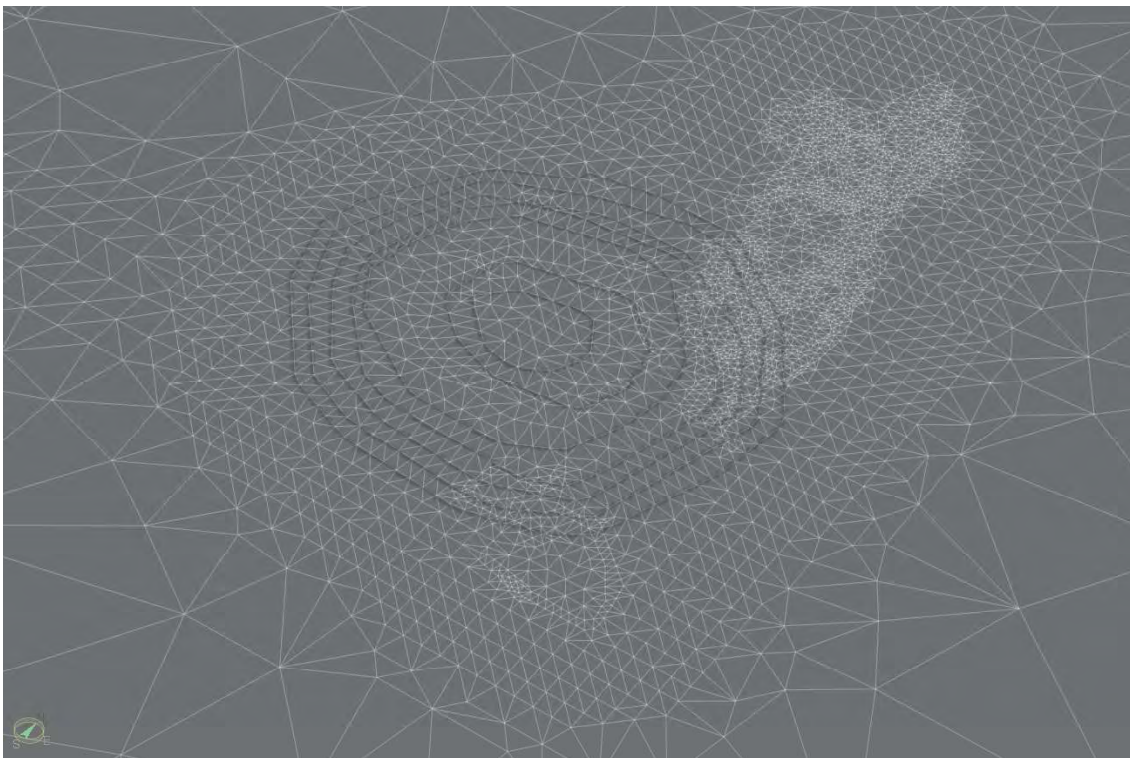


Figure 8-5: Mesh detail near open pit and stopes



## 8.1.2 Boundary conditions

Constant fixed head or no flow boundary conditions were applied to all nodes on the western, eastern, northern and southern model boundaries of the model. These fixed heads were selected based on a steady state calibration against 2004 monitoring well data near the open pit, prior to open pit mining. The steady state calibration was for the purposes of obtaining starting heads over the model domain for 1 January 2004. Rainfall recharge was not applied to the steady state calibration.

The following fixed heads were applied to the model boundaries:

- 198 m AHD on the eastern boundary.
- 205 m AHD along the western boundary.
- Time varying fixed head for Lake Cowal.
- No flow along the southern boundary.
- No flow along the northern boundary.

Figure 8-6 shows the location of the model boundary conditions.

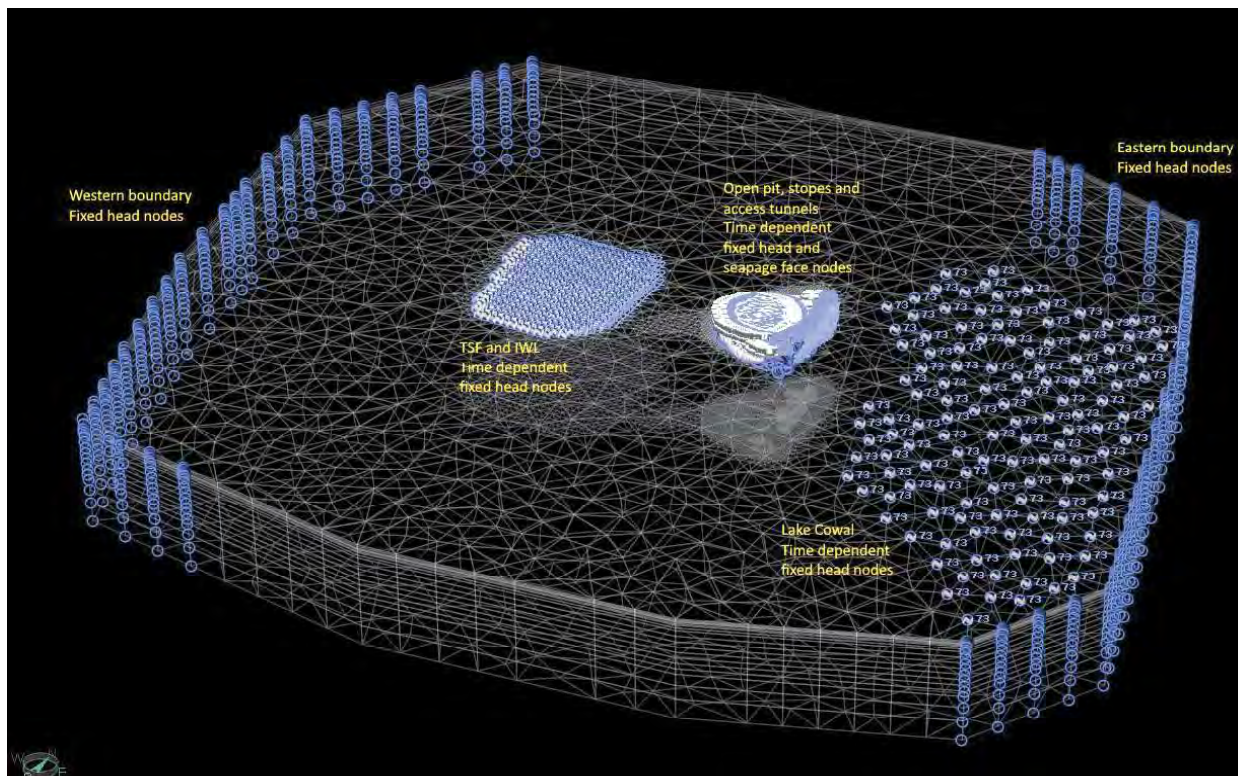


Figure 8-6: Location of model boundary conditions

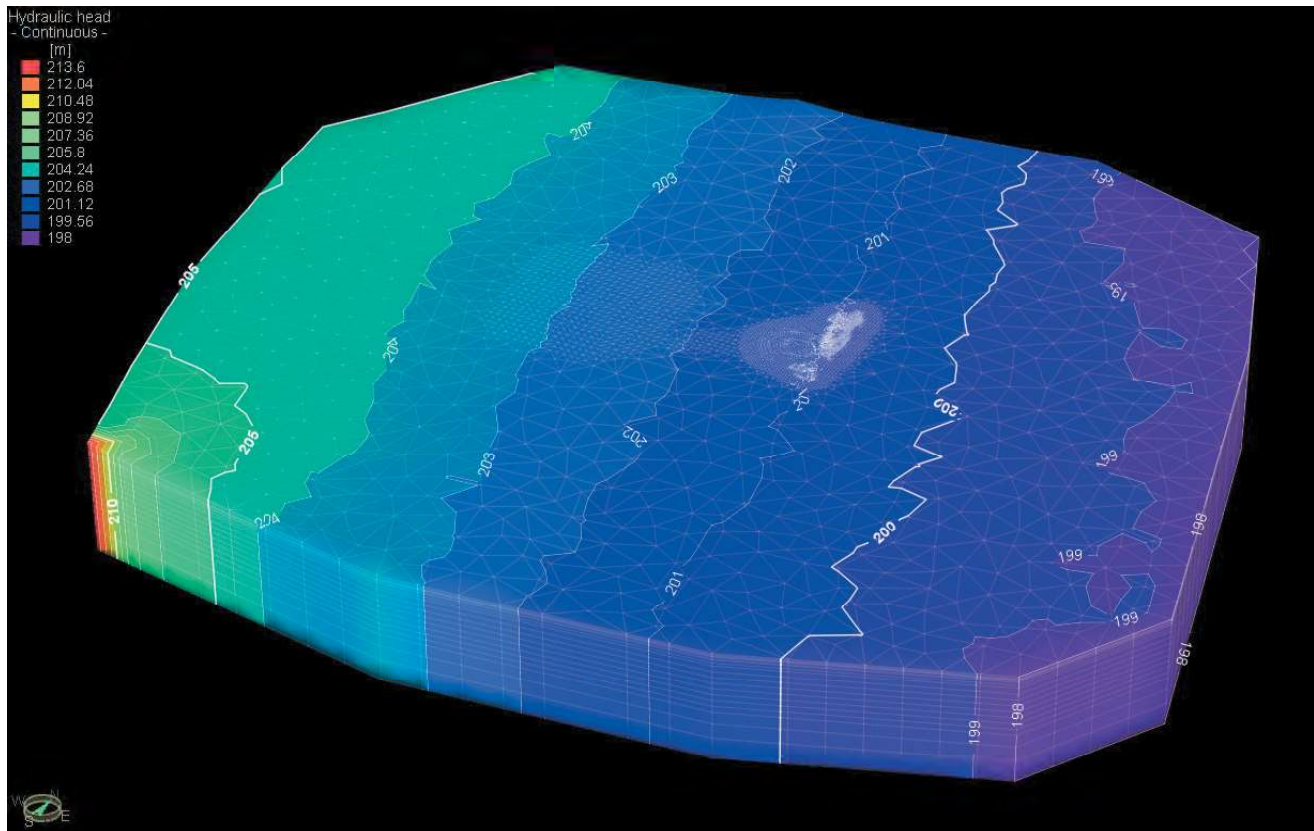


Figure 8-7: Model groundwater heads for 1 January 2004

#### 8.1.2.1 Open Pit

The excavation of the open pit was represented by applying time varying fixed head boundary conditions, not always active, to the base of the pit. Seepage face boundary conditions were applied to the open pit sides. As the pit excavation progressed, blocks of the model were deactivated to represent the pit void.

The process is illustrated in Figure 8-8. The modelled base of pit level is shown in Figure 8-9.

#### 8.1.2.2 Dewatering bores

Mine site pit dewatering was undertaken on site by pumping from pit sumps and from a number of vertical boreholes between 2005 and 2011. In October 2011, the inner group of vertical dewatering bores were decommissioned and a new group of dewatering bores, at further distance from the open pit, were commissioned. During 2011 and 2012, horizontal drains were installed at the eastern side of the open pit at approximately 100 m AHD elevation to aid in depressurisation of the eastern face. Subsequently additional horizontal drains were installed. Figure 8-10 shows the location of the dewatering bores in relation to the edges of the modelled open pit blocks, as shown in Figure 8-2.

The inner group of dewatering bores and bores PD106 and PD107 are located on or inside the modelled pit blocks. These bores were accounted for in the model by seepage faces and fixed head conditions applied to the open pit blocks. The remainder of the bores lie outside the eastern edge of the outermost modelled open pit block. These bores and the horizontal drains were installed between 2011 and 2012. They were represented in the model by seepage faces being applied to a zone of nodes from February 2011 to January 2020, at two node levels at the interface between the Saprock unit and the Primary rock unit (approximate elevation 110 m to 100 m AHD). Figure 8-11 shows the



location of the model seepage face nodes used to model the effects of the dewatering bores and horizontal drains.

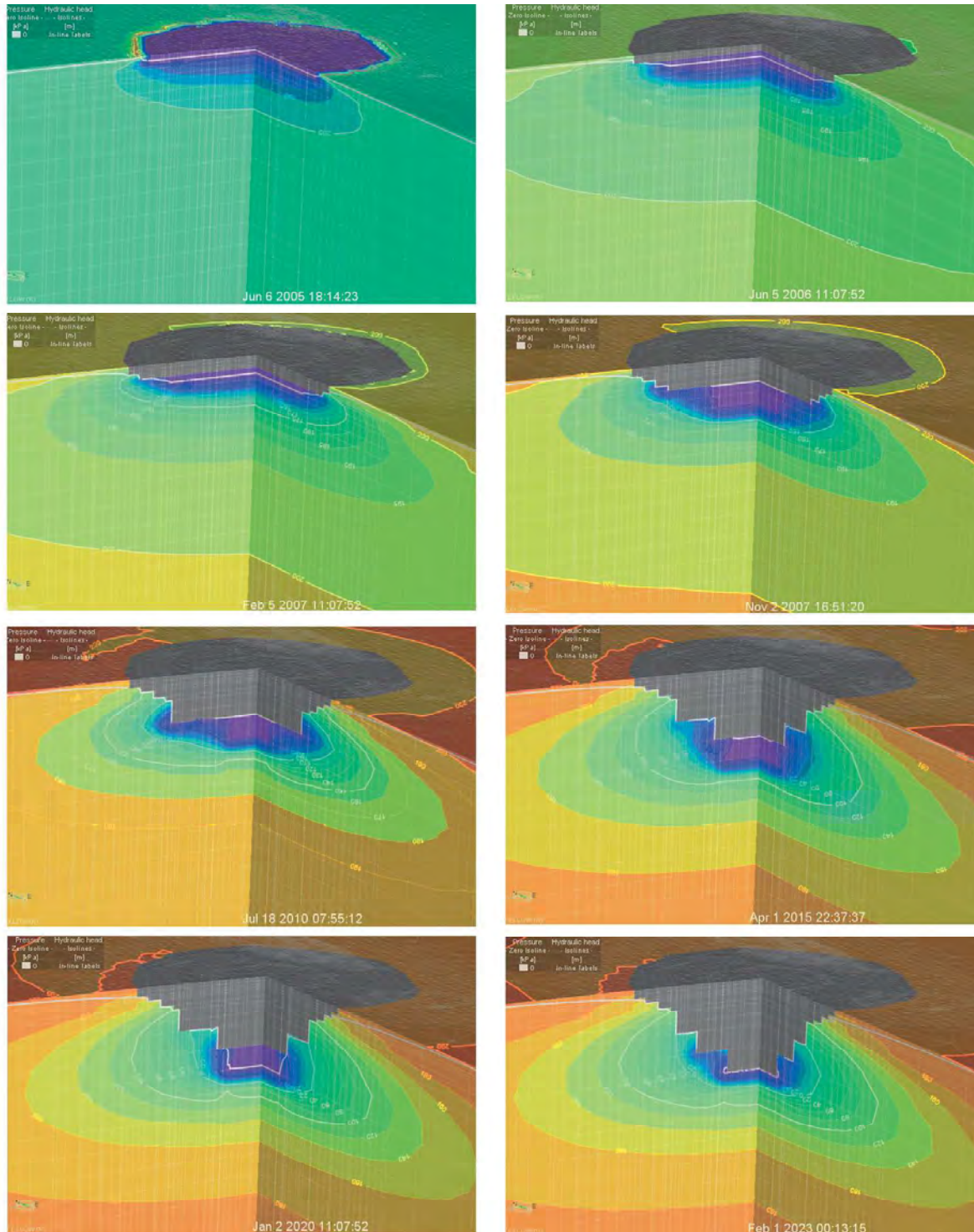


Figure 8-8: Modelling of open pit excavation sequence (contours show hydraulic head, grey signifies inactive elements representing the open pit and the white line shows the water table)



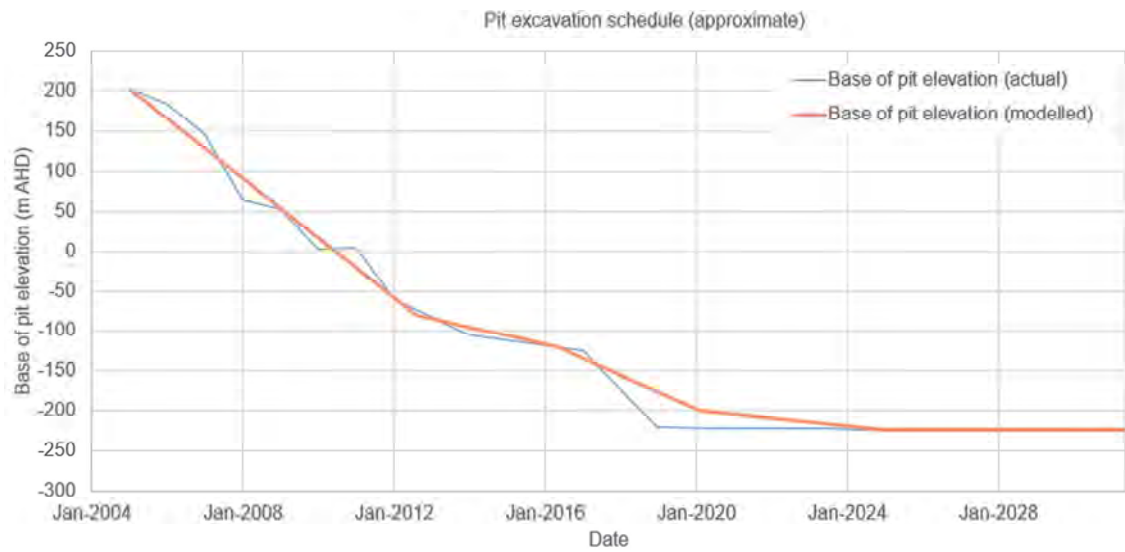


Figure 8-9: Modelled base of pit elevation

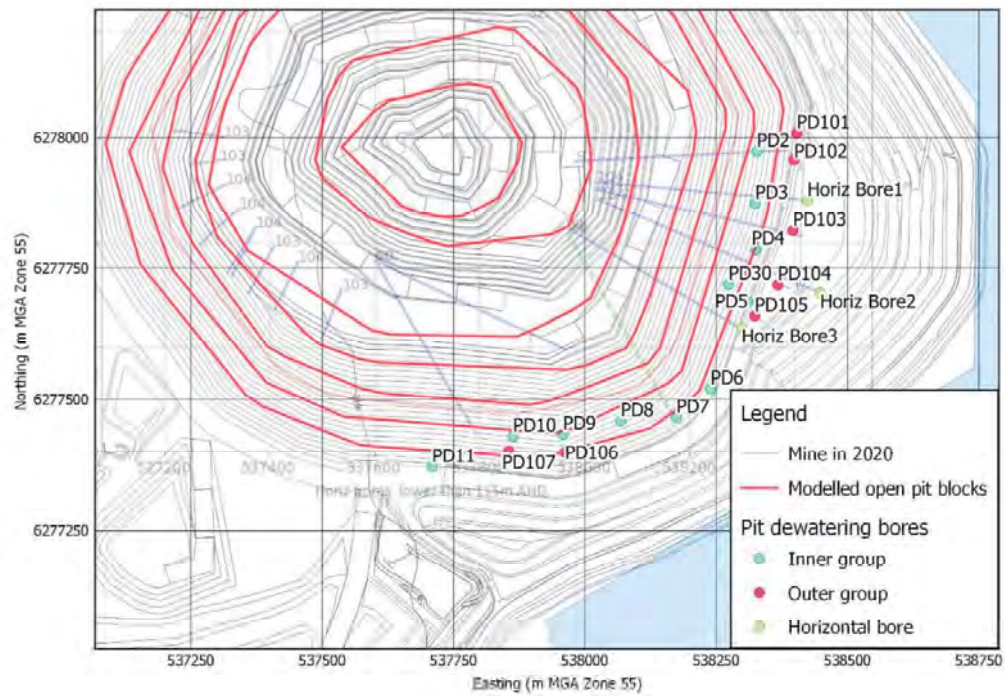


Figure 8-10: Pit dewatering bores

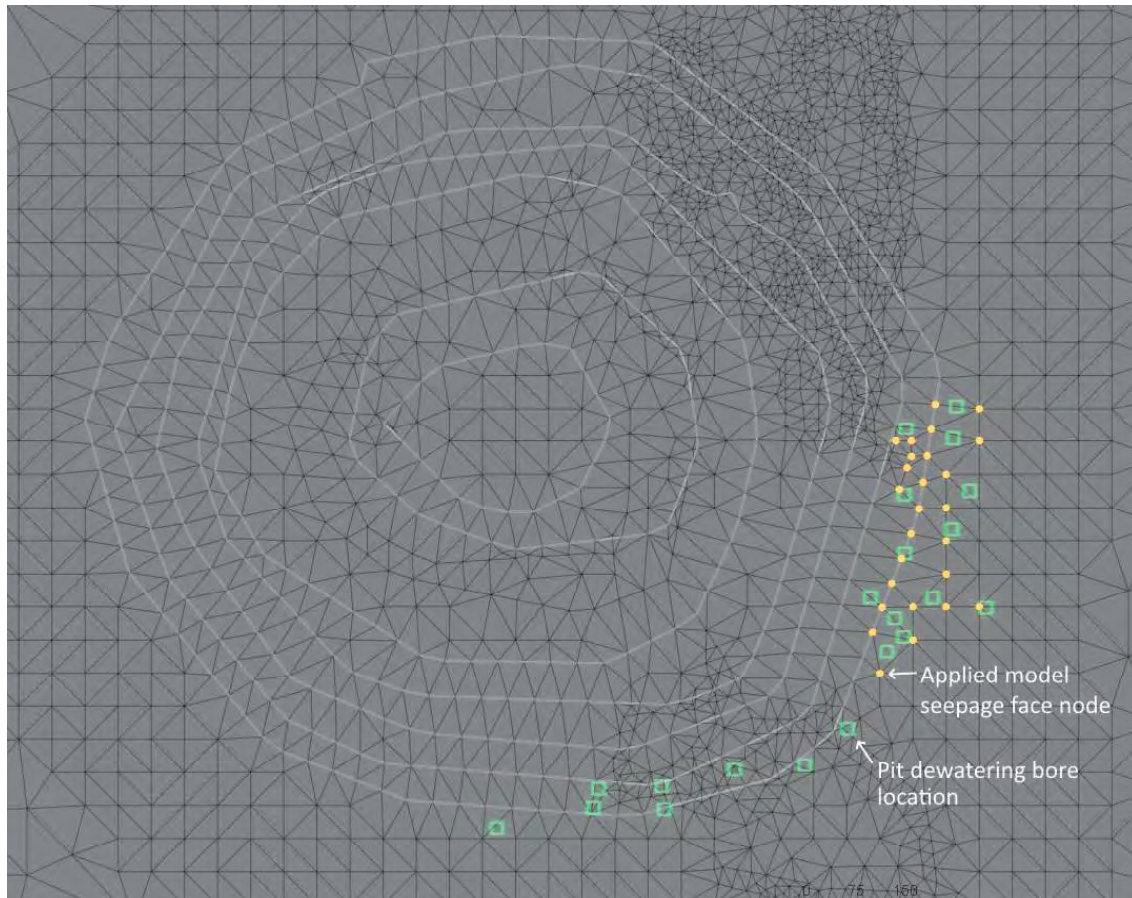


Figure 8-11: Representation of eastern pit dewatering bores in model

### 8.1.2.3 Tailings storage facilities

Time varying head boundary conditions were applied to the nodes representing the north and south tailings storage facilities. The time series were adopted from Table 7-1 and are shown in Figure 8-12.

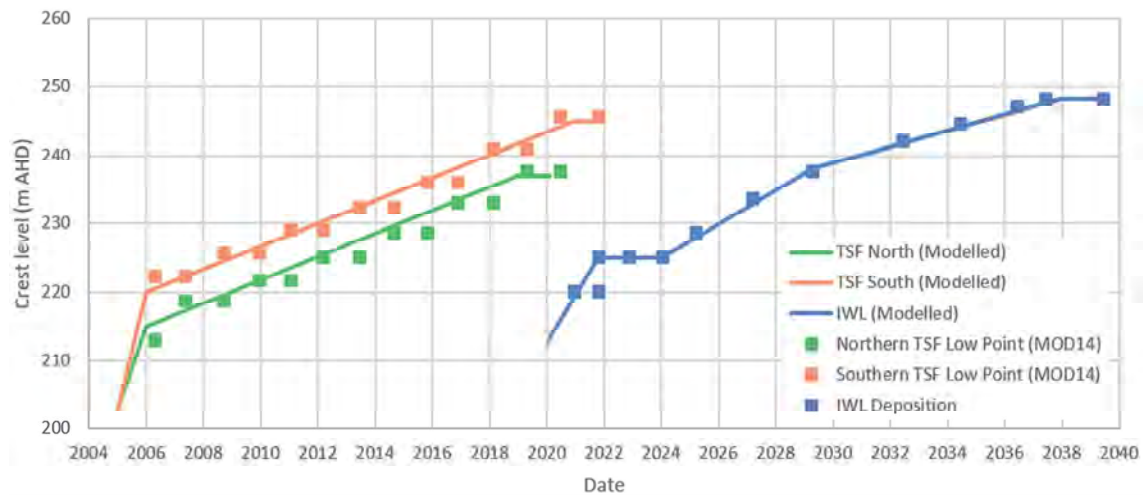


Figure 8-12: Modelled crest levels (time varying fixed head boundary conditions) for the TSFs and IWL

#### 8.1.2.4 Lake Cowal

A time varying fixed head was applied to the surface nodes in the area of Lake Cowal. The observed and modelled water levels for Lake Cowal are shown in Figure 8-13.

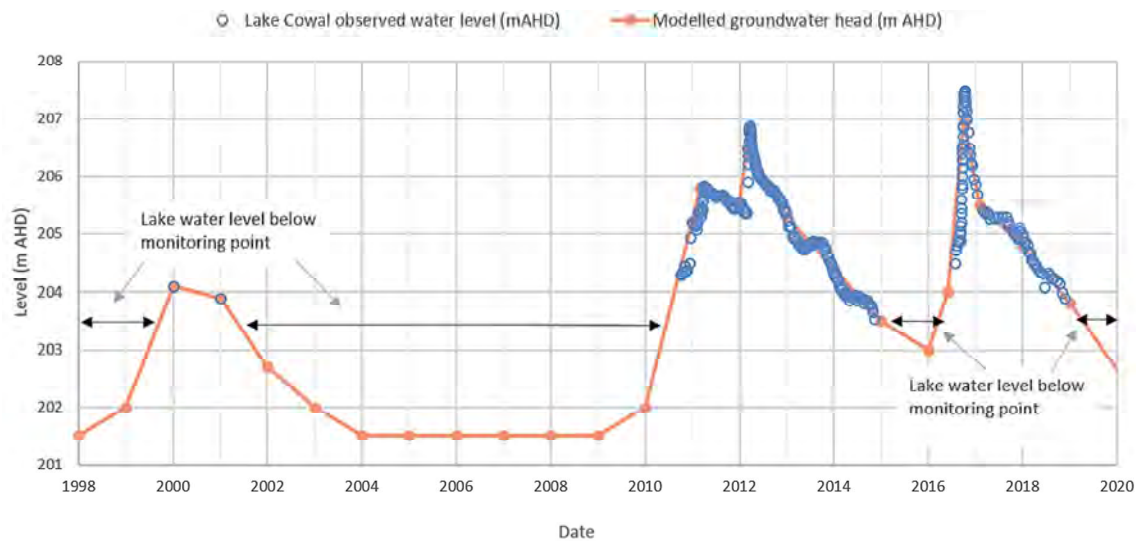


Figure 8-13: Lake Cowal observed and modelled water levels from 1998 to 2020

#### 8.1.2.5 Rainfall infiltration

Rainfall infiltration was applied uniformly to the top layer of the model, with a calibrated value of  $6.9 \times 10^{-6}$  m/d. This represents 0.6% of the average annual rainfall.

## 8.2 Model calibration

### 8.2.1 PEST

Model calibration is the selection of the optimum input parameter values so that the model attains the closest fit to real world observation data.

Model calibration for this assessment was done using the open source software PEST (developed by John Doherty at Watermark Numerical Computing). Using PEST, the conceptual model units are defined and assumed to have constant parameter values over their extents. PEST runs the model multiple times with the object of minimising the differences between modelled groundwater heads and the measured groundwater heads at a set of provided observation wells. This is done by means of a mathematical 'objective function' which is the sum of the squares of the differences between modelled and observed groundwater heads. Further details can be found in the PEST user manual (Watermark Numerical Computing, 2004).

The more zones and/or parameters there are to vary, the more runs of the model PEST will have to make. There is a significant computation time increase as the number of model elements increases, until the time required for PEST becomes prohibitive.

The model was calibrated using FePest Version 7.2 which is a graphical user interface between Feflow and PEST.

The automated calibration method in this assessment using PEST differs from previous calibrations (e.g. Coffey, 2018a) which were done using non-automated processes.

### 8.2.2 Model parameter zones

Model parameter zones were selected based on the model domain discussed in Section 8.1.1, these are:

- Transported unit: Model layers 1 and 2, excluding the area in layer 1 under the TSFs.
- Saprolite unit: Model layers 3 and 4.
- Saprock unit: Model layer 5.
- Primary Rock unit: Model layers 6 to 19.

### 8.2.3 Parameters

For each of the four model zones, the following parameters were allowed to vary until values were found by PEST which minimised the objective function:

- Hydraulic conductivity in two horizontal directions, north-south and east-west.
- Hydraulic conductivity in the vertical direction.
- Specific storage.

The hydraulic conductivity in the north-south direction was set to equal twice the hydraulic conductivity in the east-west direction in order to account for the regional geological structure.

For the TSF foundations, the hydraulic conductivity in the vertical direction was calibrated manually (without PEST). The north-south and east-west hydraulic conductivity for the TSF foundations were set at  $1 \times 10^{-4}$  m/day, adopting the values from the MOD14 assessment (Coffey, 2018a).



Specific yield was not calibrated.

## 8.2.4 Field observations

A total of 22 piezometers with data for the period 1 Jan 2004 to 1 Jan 2020 were used to calibrate the model. Monitoring data from these piezometers is reported by Coffey (2020b) and included as Appendix A. Piezometer details are shown in Table 6-1.

The piezometers at the processing plant were not used in model calibration as the local effects from water storage at the processing plant were not modelled. As described below, PDB3A is influenced by localised dewatering of the eastern open pit face. These local effects are not captured in sufficient detail by the model and so PDB3A was excluded from the calibration to avoid it unduly influencing the calibration results.

Additional monitoring data from piezometers UG-BH-01, UG-BH-02, UG-BH-03 and UG-BH-04, installed in February 2020, and PZ13 which was activated in August 2019, were considered in the calibration. Results from these piezometers led to improvements to earlier calibrations for the Saprock and Primary Rock units. This was evident in improvement in the match between the observed drawdown and the modelled drawdown at the deepest piezometers at UG-BH-01 and UG-BH-02 compared with earlier calibrations which were developed prior to availability of these monitoring records. In particular, the ratio of horizontal to vertical hydraulic conductivity in the Saprock and Primary Rock in the earlier models appeared too low. This was a result of influence of the measurements at borehole PDB3A on a previous calibration. It being one of the only existing piezometers in the Primary Rock. PDB3A is influenced by localised dewatering of the eastern open pit face. This localised dewatering depends on short term pumping rates and individual dewatering bore locations and is not captured in sufficient detail by the regional scale numerical groundwater model.

Following an initial calibration in PEST, the ratio of horizontal to vertical hydraulic conductivity in the Saprock and Primary Rock units was adjusted manually until a reasonable balance was found which provided a closer match to monitoring results at UG-BH-01 and UG-BH-02. This ratio was found to be 0.1 for both units. Further calibration was then done using PEST, with the ratio of horizontal to vertical hydraulic conductivity in the Saprock and Primary Rock units set to 0.1. These PEST runs excluded PDB3A for the reasons described above.

Monitoring results at UG-BH-03, UG-BH-04 and PZ13 were assessed to be significantly influenced by the GRE46 exploration decline and associated exploration drilling and so were not incorporated into the final calibration.

The locations of the piezometers used for the calibration are shown in Figure 8-14.



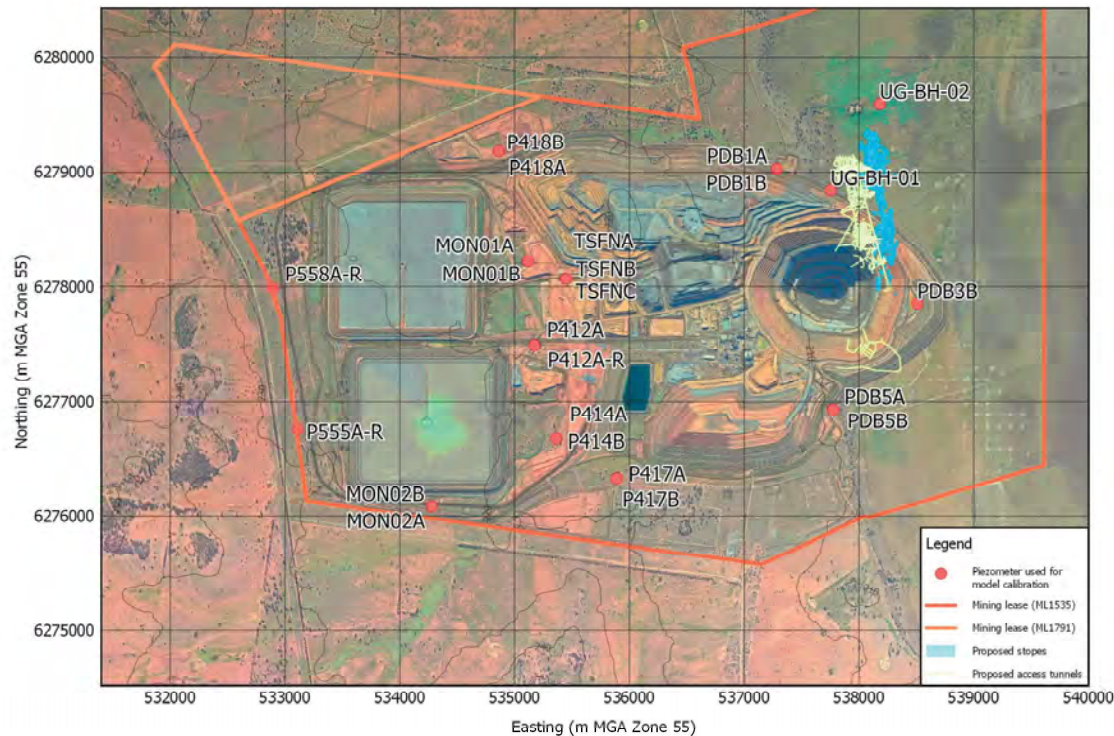


Figure 8-14: Locations of piezometers used for model calibration

## 8.2.5 Inflow to open pit

The observed inflow to the open pit, as shown in Figure 8-18, is heavily affected by rainfall and other external factors. Over some time periods, for example July 2012 to December 2012 and July 2014 to December 2014, there is almost no inflow recorded to the open pit. For this reason, the observed inflow to the open pit was incorporated to the model calibration after the PEST calibration to observed groundwater heads.

For the calibration runs the driving influence is the change in head imposed at the surface of the pit as the pit development takes place. Under these conditions if all hydraulic conductivity values are scaled by the same amount and the ratio of storage parameters to hydraulic conductivity are maintained the drawdown results will be essentially unchanged and only the rate of seepage to the pit will vary. Rainfall infiltration is a secondary factor during the calibration period. In order to maintain a consistent response rainfall infiltration needs to be scaled with the same factor as applied to hydraulic conductivity. Applying this process allows adjustment of the results of calibration runs (carried out to match the drawdown response with time) to match a selected seepage rate to the mine pit.

Following calibration against observed groundwater heads using PEST, modelled and observed inflow rates to the open pit were compared for the period January 2018 to January 2020. The calibrated hydraulic conductivity, specific storage and rainfall recharge parameters were then scaled by the same amount required to provide a reasonable match to observed inflow rates to the open pit for this period. As discussed above, this does not affect the calibration of the model to observed groundwater heads.

Modelled versus observed inflow to the open pit can be seen in Figure 8-18. Uncertainty in the observed inflow to the open pit is considered in Section 8.3.

## 8.2.6 Results

The calibrated model parameters are shown in Table 8-1.

Table 8-1: Calibrated parameters adopted for the current model

Hydrogeological Unit	Model Layers	Hydraulic Conductivity (m/d)			Specific storage (m <sup>-1</sup> )	Specific Yield	Inflow to top of layer (m/d)
		K <sub>xx</sub> (east-west)	K <sub>yy</sub> (north-south)	K <sub>zz</sub> (vertical)			
Transported unit	1 and 2	2.2 x 10 <sup>-2</sup>	2.2 x 10 <sup>-2</sup>	9.9 x 10 <sup>-4</sup>	4.8 x 10 <sup>-4</sup>	0.2 <sup>(3)</sup>	6.9 x 10 <sup>-6</sup>
Saprolite unit	3 and 4	1.1 x 10 <sup>-2</sup>	2.2 x 10 <sup>-2</sup>	3.4 x 10 <sup>-4</sup>	8.1 x 10 <sup>-7</sup>	0.2 <sup>(3)</sup>	n/a
Saprock unit	5	9.2 x 10 <sup>-3</sup>	1.8 x 10 <sup>-2</sup>	9.2 x 10 <sup>-4</sup> (2)	2.2 x 10 <sup>-5</sup>	0.2 <sup>(3)</sup>	n/a
Primary rock unit	6 to 17	1.0 x 10 <sup>-3</sup>	2.1 x 10 <sup>-3</sup>	1.0 x 10 <sup>-4</sup> (2)	1.2 x 10 <sup>-7</sup>	0.1 <sup>(3)</sup>	n/a
TSF foundation	1	1.0 x 10 <sup>-4</sup> (3)	1.0 x 10 <sup>-4</sup> (3)	5.0 x 10 <sup>-5</sup> (3)	2.0 x 10 <sup>-4</sup> (3)	0.2 <sup>(3)</sup>	n/a

(1) Parameter K<sub>yy</sub> set to equal K<sub>xx</sub> in the Transported unit and double K<sub>xx</sub> in the other hydrogeological units

(2) Parameter K<sub>zz</sub> set to 0.1 K<sub>xx</sub> based on manual calibration against piezometers installed in February 2020

(3) Parameter not calibrated by PEST

For comparison, Table 8-2 shows calibrated parameters as reported in the MOD14 assessment (Coffey, 2018a).

Table 8-2: Parameters adopted in the MOD14 assessment (provided for comparison)

Hydrogeological Unit	Hydraulic Conductivity (m/d)			Specific Storage (m <sup>-1</sup> )	Specific Yield
	K <sub>xx</sub> (east-west)	K <sub>yy</sub> (north-south)	K <sub>zz</sub> (vertical)		
Transported unit	1.0 × 10 <sup>-2</sup>	1.0 × 10 <sup>-2</sup>	6.5 × 10 <sup>-4</sup>	5 × 10 <sup>-4</sup>	1.5 × 10 <sup>-1</sup>
Saprolite unit	1.7 × 10 <sup>-2</sup>	3.4 × 10 <sup>-2</sup>	1.7 × 10 <sup>-2</sup>	5 × 10 <sup>-5</sup>	1.0 × 10 <sup>-4</sup>
Saprock unit	2.0 × 10 <sup>-3</sup>	4.0 × 10 <sup>-3</sup>	2.0 × 10 <sup>-3</sup>	3 × 10 <sup>-5</sup>	1.0 × 10 <sup>-4</sup>
Primary rock unit	Varies <sup>(1)</sup>	Varies <sup>(1)</sup>	5.0 × 10 <sup>-4</sup>	2 × 10 <sup>-5</sup>	1.0 × 10 <sup>-4</sup>
TSF foundation	1.0 × 10 <sup>-4</sup>	1.0 × 10 <sup>-4</sup>	1.0 × 10 <sup>-4</sup>	5 × 10 <sup>-4</sup>	1.5 × 10 <sup>-1</sup>

(1) Primary rock horizontal hydraulic conductivity reduces with depth. K<sub>xx</sub> varies from 2.3×10<sup>-3</sup> m/day in Layers 7 to 10, reducing approximately linearly to 5×10<sup>-4</sup> m/day in Layers 14 to 15. K<sub>yy</sub> is consistently double the value of K<sub>xx</sub> in Layers 7 to 13.

Comparing the calibrated parameters for this report against the MOD14 assessment, some observations are:

- The horizontal hydraulic conductivities for the Transported and Saprock units adopted for this assessment are between 2 and 5 times the values adopted for the MOD14 assessment.
- The horizontal hydraulic conductivities for the Saprolite and Primary Rock adopted for this assessment are approximately 0.4 to 1 times the values adopted for the MOD14 assessment.
- The vertical hydraulic conductivity of the Transported unit adopted for this assessment is approximately 1.5 times the value adopted for the MOD14 assessment.

- The vertical hydraulic conductivity of the Saprolite adopted for this assessment is approximately 0.02 times the value adopted for the MOD14 assessment.
- The vertical hydraulic conductivity of the Primary rock unit in this assessment is approximately 0.2 times the value for the MOD14 assessment.
- The specific storages in the Transported and Saprock units adopted for this assessment are approximately equal to the values adopted for the MOD14 assessment.
- The specific storages in the Saprolite and Primary rock units adopted for this assessment are approximately 0.01 to 0.02 times the values adopted for the MOD14 assessment.

The differences result from the automated calibration methods adopted in this assessment, the increased data available for model development and calibration, including the gravity survey results and the pit inflow and observation well data. A key difference is the two orders of magnitude lower vertical hydraulic conductivity for the Saprolite unit resulting from the calibration for this report.

## 8.2.7 Assessment of calibration quality

Figures B1 to B5 in Appendix B show observed vs modelled heads at each of the 22 observation wells used for calibration and at UG-BH-01 and UG-BH-02. PDB3A, which was not used for the calibration, is included for reference. The charts show that a good fit was obtained for all of the observation wells except the following:

- PDB1A and PDB1B which may be influenced by surface water diversion pond D1, which is located in the same area, see Figure 7-2. The difference between observed and modelled heads is less than 5 m and the trend in groundwater levels is reasonably close.
- PDB5A which lies just south of the pit, shows a reasonable fit although the downward trend in the observed results is slightly higher than for the modelled results. This may be a result of localised dewatering in this area which was not captured by the model.
- MON02A and MON02B which lie at the southern edge of TSF South, show a reasonable fit although the observed upward trend in groundwater levels at these wells is slightly greater than the modelled results (reaching approximately 3.5 m difference between observed and modelled heads at MON02B at the end of the calibration period).
- The observed and modelled groundwater levels at PDB3A, from about 2013 onwards, show a difference of up to approximately 24 m. As discussed in Section 8.2.4, this is likely to be the result of localised open pit face dewatering near PDB3A which is not captured in sufficient detail by the regional scale numerical groundwater model.
- Groundwater monitoring at UG-BH-01 and UG-BH-02 commenced in February 2020. As such, it is not possible to draw conclusions about the transient calibration quality at these locations. UG-BH-01 is located very close to the model elements used to represent the excavation of the open pit, and this may influence the results. It is relevant to note, however, that the difference between modelled and observed groundwater levels in March 2020 is less than 4 m for the shallower piezometers and less than 8.5 m for the deeper piezometers.

The statistics for the calibration (as output from PEST) are:

- Correlation coefficient = 0.999
- Root mean square error (RMS) = 1.85 m
- Normalized root mean square error (NRMS) = 4.51 %
- Mean absolute error (MAE) = 1.36 m

The above NRMS value of 4.51 % indicates the quality of the calibration is very good, considering the conceptual model is based on site geological conditions and is not chosen solely in order to improve the calibration fit near observation wells.

Figure 8-15 shows the observed versus modelled groundwater head at each of the observation wells used in the calibration for the period 2005 to 2020, excluding UG-BH-01 and UG-BH-02.

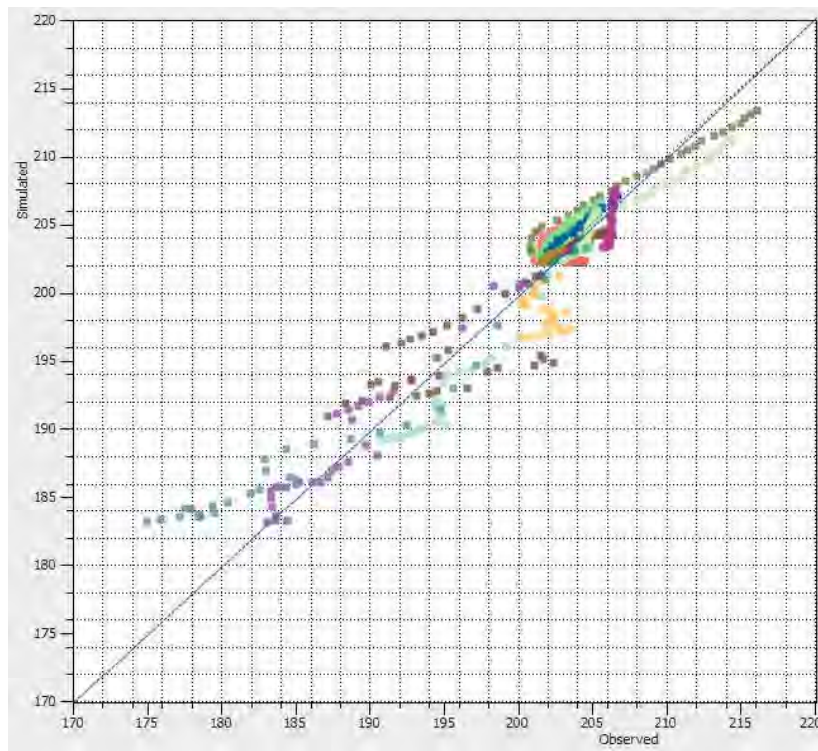


Figure 8-15: Observed versus modelled groundwater head

The Australian Groundwater Modelling Guidelines (Barnett et al, 2012) provide discussion on quantitative measures for assessing calibration quality. These are based on the RMS or the NRMS (called the Scaled RMS in the guidelines). The guidelines do not set quantitative targets that must be achieved, as a target of 5 % NRMSE for example, may not be achievable with all models.

The model mass balance error is generally below, or very close to 1 % from 2005 to 2050. This is the period where groundwater stresses related to open pit excavation and underground mining occur. The mass balance error increases slightly beyond 2050. This is thought to be a result of the adaptive time stepping procedure adopted in the model, which increases when model stresses are small. It can be seen from Figure 10-5 that there is some minor oscillation in the predicted inflow beyond about 2050 however the oscillations are about an average rate and do not increase beyond reasonable bounds. Figure 8-16 shows the model mass balance error percentage at select times.

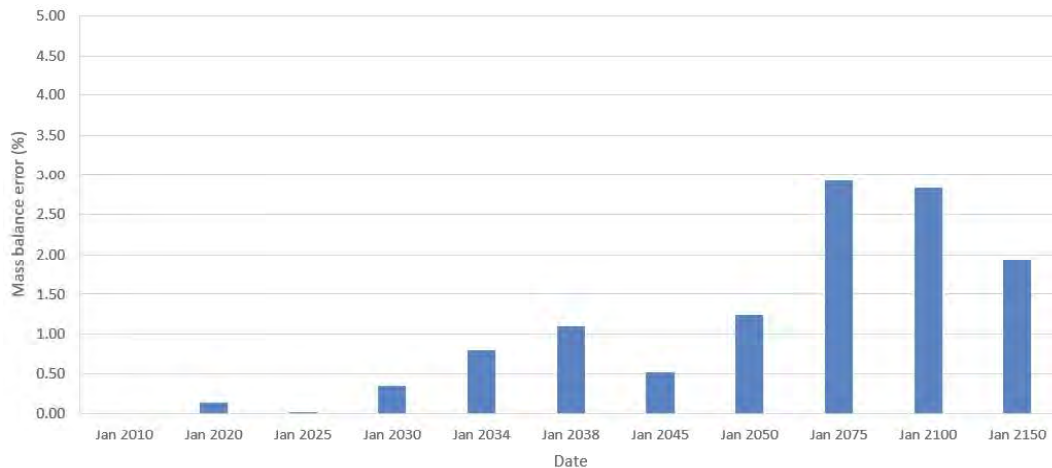


Figure 8-16: Model mass balance error (%) at selected times

## 8.2.8 Parameter sensitivities

Parameter sensitivities were provided by PEST as part of the model calibration. The relative sensitivity of the calibration to the main parameters in each of the hydrogeological units is shown in Figure 8-17.

The figure shows that the model calibration is approximately equally sensitive to the parameters used in the calibration, with the highest sensitivity being 0.225 to the vertical hydraulic conductivity of the Transported unit and the lowest sensitivity being 0.175 to the horizontal hydraulic conductivity of the Saprock unit.

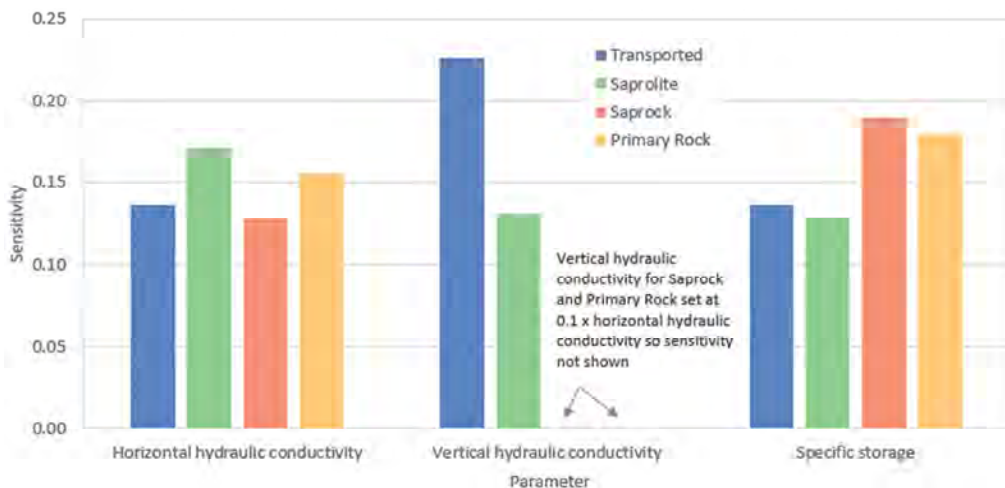


Figure 8-17: Relative sensitivity of the model calibration to parameters

## 8.2.9 Comparison of model with measured pit dewatering rates

Open pit dewatering rates have been provided by Evolution Mining. The provided dewatering rates are highly variable and not well correlated with rainfall, as shown in Figure 8-18. There is some uncertainty in the estimate of groundwater inflow to the open pit based on the provided pit dewatering volumes. During drier periods, such as those shown circled in Figure 8-18, the effects of surface runoff and/or rainfall are likely to be less pronounced and a better estimate can be obtained.



Rainfall inflow has been assessed based on the pit footprint and the effective rainfall and allowing for pan evaporation occurring over 10% of the pit footprint. Effective rainfall has been taken as 75% of daily rainfall above 5 mm. Rainfall is for West Wyalong Post Office (Bureau of Meteorology Station 73054) which shows a good correlation with rainfall at the mine site (Coffey, 2018b).

Modelled groundwater inflow to the open pit output from the numerical model is plotted in Figure 8-18. The modelled groundwater inflow, compared to the measured pit dewatering during dry periods (circled) shows a reasonable fit, particularly in 2007 to 2009, 2011, late 2015 and 2017 to mid-2019. It can be observed that the corrected pit dewatering rates are close to the modelled groundwater inflow during approximately the same periods, except for late 2012 and late 2014.

Evolution Mining staff estimate that during 2019, the rate of groundwater inflow to the open pit was approximately 1,000m<sup>3</sup>/day. The calibrated model agrees well with this inflow rate, with modelled groundwater inflow rates to the open pit of approximately 950 m<sup>3</sup>/day during 2019.

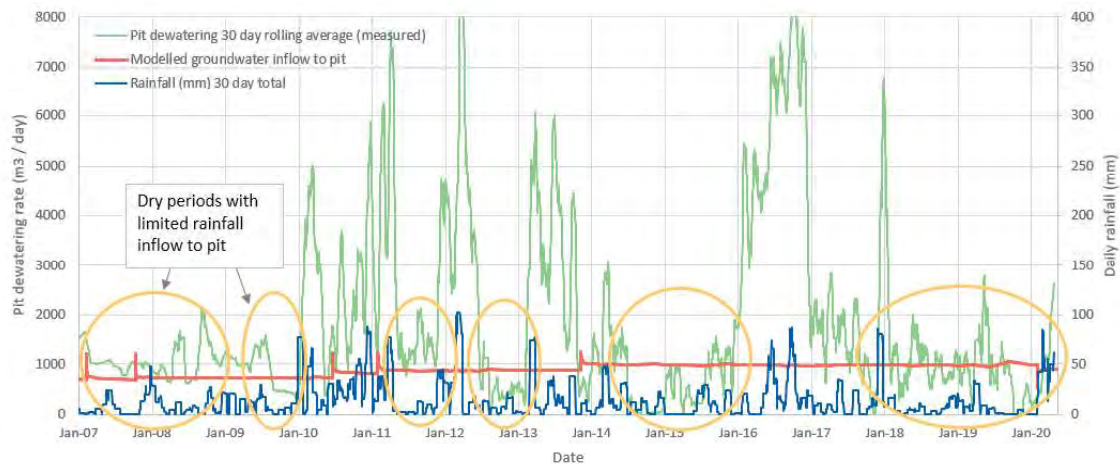


Figure 8-18: Pit dewatering and rainfall

## 8.3 Uncertainty assessment

The calibration process described above used PEST to find a set of parameters which provided a good match between field observations and model results. This was done by the minimisation of the 'objective function' which is the sum of squared differences between field observations and model results. With 16 parameters being calibrated (hydraulic conductivities and specific storages) not including the rainfall infiltration, it is probable there are a number of parameter combinations which result in an objective function small enough for the resulting model to be considered as calibrated. This is known as model parameter uncertainty.

The model parameters were also calibrated to observed open pit inflows as discussed in Section 8.2.5. It is clear from Figure 8-18 that there is uncertainty in the observed rate of groundwater inflow into the open pit. This rate could conceivably be adopted as anywhere between 750 m<sup>3</sup>/d and 1,100 m<sup>3</sup>/d from January 2018 to July 2019. This is an example of observation uncertainty.

A quantitative assessment of model parameter uncertainty was carried out using PEST. In this process, PEST completed a large number of model runs (690 runs) to find alternative calibrated

model parameter sets, the results of which provide an envelope of the range of probable values to particular model results as defined by the user.

PEST was directed to select the four resulting model parameter sets which provided the following maximum and minimum values for groundwater head and inflow to the open pit:

- Parameter set 1: Maximum inflow to the open pit on 1 Jan 2020.
- Parameter set 2: Minimum inflow to the open pit on 1 Jan 2020.
- Parameter set 3: Maximum groundwater head at the location of UG-BH-02 (SG3) at 1 Jan 2020.
- Parameter set 4: Minimum groundwater head at the location of UG-BH-02 (SG3) at 1 Jan 2020.

For each of the cases run by PEST, a condition was imposed that the objective function was allowed to be at most 5% greater than the minimum objective function found in the calibration process described above. This ensured that the resulting model parameter sets were calibrated to the observation data. A total of 690 model runs were completed by PEST during the search for the four model parameter sets which provided the four limiting model results described above. The parameter set with the required maximum or minimum value was selected by PEST for each of the four specified cases.

As discussed in Section 8.2.5, observed inflow rates to the open pit between January 2018 and January 2020 are less influenced by rainfall or other external factors compared to other periods. To incorporate the observed open pit inflows into each of the four model parameter sets, the hydraulic conductivity, specific storage and rainfall recharge parameters for each parameter set was scaled by the same amount required to provide a reasonable match to observed inflow rates to the open pit for the period January 2018 to January 2020. As discussed in Section 8.2.5, this does not affect the calibration of the parameter set to observed groundwater heads.

Table 8-3 shows the objective function and the resulting modelled inflow and groundwater head values at 1 Jan 2020, prior to scaling the results to match actual open pit inflows at 1 Jan 2020. Note that parameter Set 2 turned out to be the same as the calibrated parameter set shown in Table 8-1, which are our adopted model parameters.

Table 8-3: Details of model uncertainty targets, resulting objective functions and model results

Parameter set	Target	Objective function	Model results <sup>(1)</sup> (prior to scaling to observed pit inflows)	
			Pit inflow (m <sup>3</sup> /d)	Groundwater head (m AHD) at UG-BH-02 (SG3)
Set 1	Maximum inflow	2083	1750	191.8
Set 2 (adopted)	Minimum inflow	2033	966	192.8
Set 3 <sup>(2)</sup>	Maximum head	2060	815	197.6
Set 4	Minimum head	2052	1112	192.6

(1) These results are part of the uncertainty assessment and are not model predictions. Model predictions are discussed in Section 10

(2) Parameter K<sub>zz</sub> not tied to K<sub>xx</sub> for Saprock and Primary Rock for this set

Note that Set 3, resulting from the assessment targeting maximum head, actually resulted in a lower open pit inflow than Set 1, which targeted minimum inflow. This is likely a result of the vertical

hydraulic conductivities for the Saprock and Primary Rock not being tied to the horizontal hydraulic conductivities in the assessment for maximum head. In addition, the PEST process is not guaranteed to find the absolute maximums and minimums of the target criteria in each of the assessments.

The resulting parameters are shown graphically in Figure 8-19. The vertical and horizontal hydraulic conductivities are all relatively close, being within approximately a factor of two from one another for each of the hydrogeological units. One exception is the vertical hydraulic conductivity in the Primary Rock unit for Set 3, which is approximately five times greater than the value for the other units. This is to some extent balanced by the lower horizontal hydraulic conductivity for the Primary Rock unit in Set 3. This is likely a result of the vertical hydraulic conductivities for the Saprock and Primary Rock not being tied to the horizontal hydraulic conductivities in the assessment for maximum head. The targeting of maximum head at UG-BH-02 (SG3) for Set 3 results in an improved calibration at that location and hence the tying of those parameters is not required.

The four sets of model parameters were used to assess predicted inflows to the open pit, stopes and access tunnels from 2021 to 2039 and to assess groundwater table drawdowns at 2038. Open pit inflow observational uncertainty was incorporated into the inflow uncertainty assessments as discussed in Section 10.3. Whilst the parameters for the different sets are all relatively close to one another, the resulting predicted inflows differ significantly. Predictive model results are discussed further in Section 10.

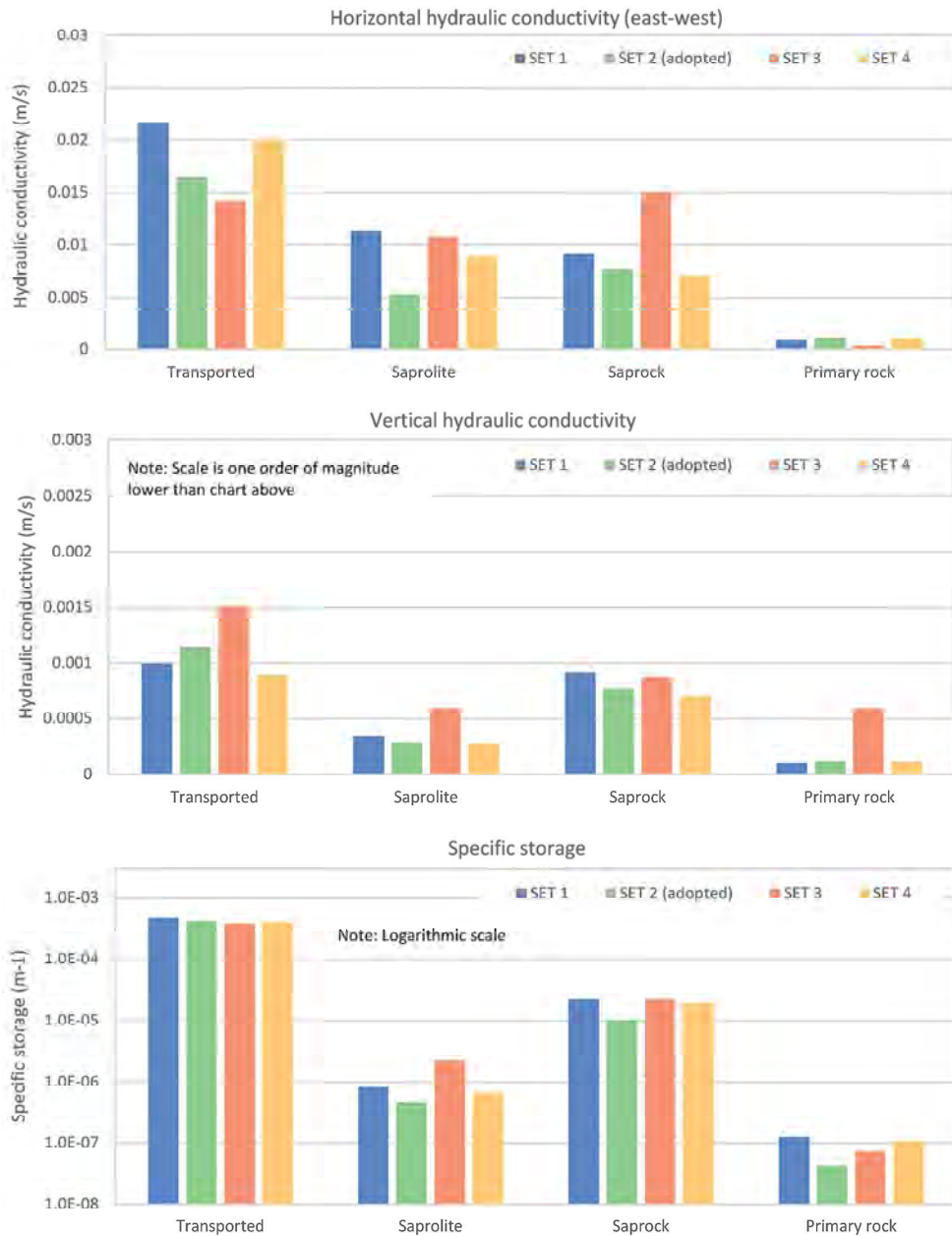


Figure 8-19: Alternative sets of calibrated model parameters

## 8.4 Model classification

The Australian Groundwater Modelling Guidelines (Barnett et al, 2012) provide discussion on confidence level classifications for numerical groundwater models. The model described in this report is considered to meet the criteria for Class 2, and a number of aspects of Class 3. A summary of the key indicators is provided below:

- A conceptual model has been developed which incorporates the principal hydrogeological units and the main sources of groundwater recharge and discharge in the area covered by the model.

- The model is based on geological exploration borehole records and groundwater monitoring and testing in and around the model domain, in particular on mining lease ML1513. These include investigations carried out in the area above the proposed underground mine in 2020 which are included in this report as Appendix E.
- The model was calibrated against 22 piezometers with monitoring data for the period 1 Jan 2004 to 1 Jan 2020, and open pit dewatering records for the period 1 Jan 2005 to 1 Jan 2020.
- The calibration statistics provide a NRMSE of 4.51% which indicates a good match between observations and model results.
- A quantitative model parameter uncertainty analysis has been carried out using the open source software PEST. Consideration of observational uncertainty related to open pit dewatering records has been incorporated in predictive results.
- The model is used to predict impacts to groundwater levels and the groundwater flow regime during the life of the proposed underground mine (2020 to 2040) and the post mining recovery period. The predictive period of underground mining and first 20 years of post-mining recovery (2020 to 2060) is less than three times the timeframe used for calibration.
- The groundwater stresses for the predictive modelling period are similar to those for the calibration period.
- The time discretisation for the predictive modelling period as that for the calibration period. This uses an adaptive time step procedure, as implemented in Feflow Version 7.2.
- The model mass balance error is generally below, or very close to 1 % from 2005 to 2050, as shown in Figure 8-16. This is the period where open pit excavation, underground mining and groundwater recovery in paste backfilled stopes is modelled.



## 9 Predictive modelling

Predictive modelling was undertaken to assess groundwater impacts to Lake Cowal and the area surrounding the mine and to assess inflow rates into the open pit, stopes and access tunnels. In addition, the predictive model was used to assess contaminant transport in groundwater originating from beneath the IWL post mining.

In order to include the stopes in the model mesh, the stopes were represented by simplified polygons at each model vertical layer, as shown in Figure 8-2 and Figure 8-3. This is considered reasonable since groundwater heads at a small distance from the stopes will be smoothed out so as to no longer show the finer details of the stopes and will match groundwater heads from a model where the stopes are represented as a much simpler polygon. To test this expectation, Figure 9-1 was set up in Seep/W. The figure shows steady-state groundwater head contours are smoothed out even at very close distances to a complicated fixed head boundary. This is a result of the governing physics of groundwater flow, where groundwater naturally flows to smooth out differences in hydraulic head.

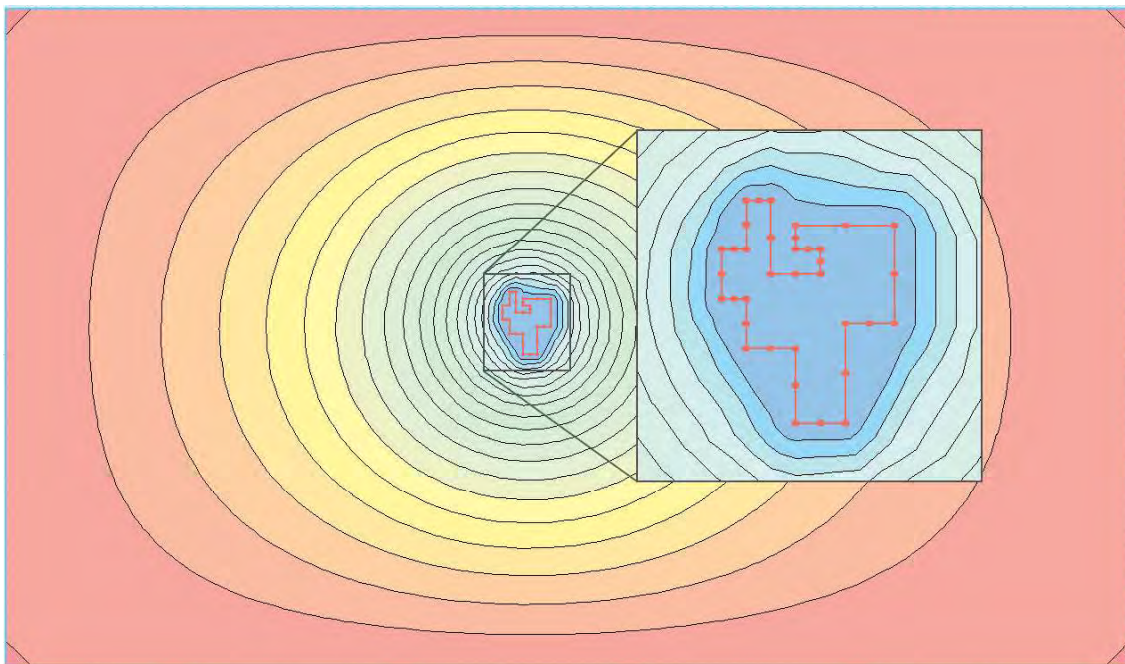


Figure 9-1: Example showing contours of groundwater head are smoothed out only a short distance away from a complicated structure where a fixed head is applied (Image created using Seep/W)

### 9.1 Representation of future mining activities

#### 9.1.1 Open Pit

The excavation of the open pit was represented by applying time varying fixed head boundary conditions to the base of the pit and seepage face boundary conditions to the walls. As the pit excavation progressed, blocks of the model were deactivated to represent the pit void and seepage face boundary conditions applied, as discussed in Section 8.1.2.

Following the end of mining and dewatering of the open pit, groundwater inflow and surface water run-off will gradually fill the base of the open pit, forming a lake. The pit lake water level will rise to a level where net evaporation from the pit lake is balanced by groundwater inflow and surface water run-off into the pit.

The pit lake water level post mining is highly dependent on the surface water regime surrounding the open pit. A preliminary assessment of water level recovery and groundwater inflow to the open pit after the end of mining was carried out by:

- Assuming the pit void to be a conical volume with an upper diameter 1070 m at an elevation of 204 m AHD and a lower diameter of 340 m at an elevation of -225 m, based on pit shell designs provided by Evolution.
- Assuming rainfall inflow of 450 mm to the open pit from a 1,250 m diameter circular catchment.
- Assuming pan evaporation from the surface of the pit lake, the surface area of which was assumed to be circular with diameter dependent on the elevation of the pit lake and the assumed conical volume of the open pit void described above. An average annual evaporation rate of 70 % x 1,800 mm (1,260 mm) was assumed.
- The modelled rate of groundwater inflow to the open pit, which is dependent on the elevation of the pit lake level, was added to the net inflow to the pit lake from evaporation and rainfall.

This was carried out through an iterative process whereby a pit lake elevation timeseries was incorporated into the numerical model as fixed head boundary conditions at the edges of the open pit void. This resulted in a timeseries of groundwater inflow to the open pit, which was then used to update the pit lake elevation timeseries externally. The process was repeated until a reasonable agreement was found between the modelled groundwater inflow to the open pit at successive iterations.

The resulting groundwater inflows to the open pit post mining were provided to the surface water engineers who incorporated them in their assessment of the predicted pit lake level post mining. Following a small number of iterations with the surface water engineers, a reasonable agreement was achieved between the groundwater and surface water models.

The resulting groundwater head at the base of the open pit during mining and recovery is shown in Figure 9-2.

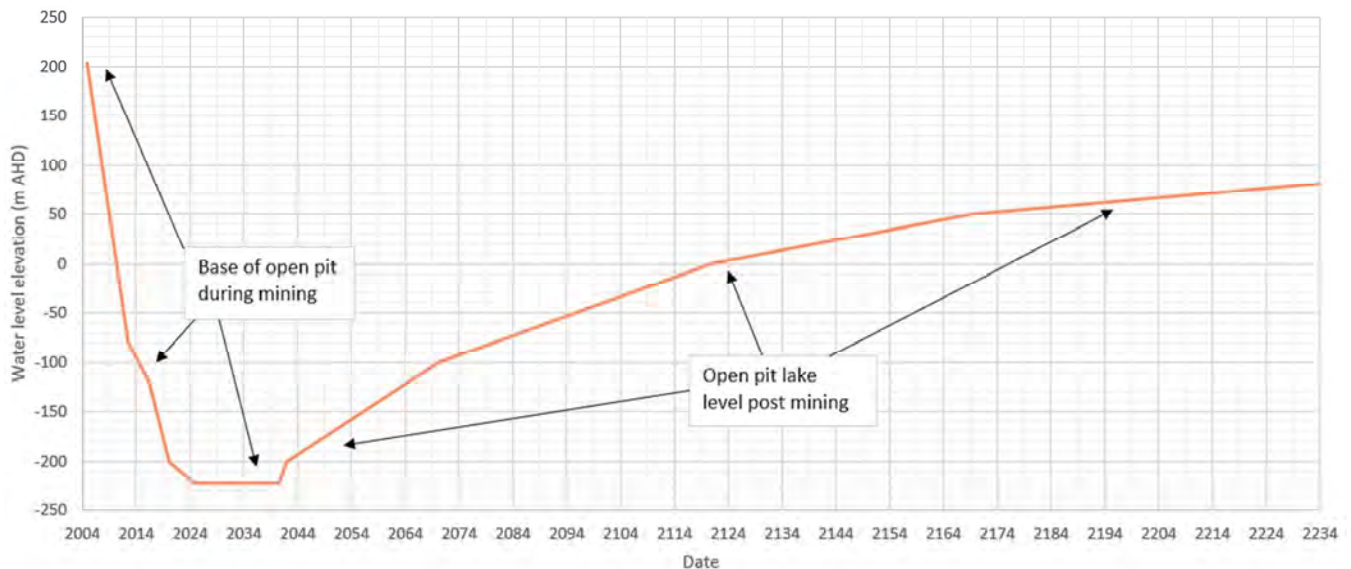


Figure 9-2: Modelled groundwater head at base of open pit

### 9.1.2 Open pit dewatering bores and horizontal drains

Open pit dewatering bores and horizontal drains were modelled for the period February 2011 to January 2020, as discussed in Section 8.1.2.

Dewatering bores and horizontal drains were not modelled beyond 2020.

The effects of dewatering bores and horizontal drains are local in nature and have a similar effect to the model as the outline of the open pit extending slightly outwards. The predictive modelling, with no observations to calibrate against, does not aim to achieve this level of detail or accuracy.

### 9.1.3 ML1535 saline groundwater supply bores

The ML1535 saline groundwater supply bores were not modelled. As indicated in the MOD14 assessment (Coffey, 2018a), the predicted groundwater drawdown due to groundwater extraction from the ML1535 saline groundwater supply bores is insignificant relative to the groundwater drawdown induced by the open pit.

### 9.1.4 Tailings Storage Facilities and Integrated Waste Landform

Section 7.4 provides the historical and proposed water levels for the TSF and IWL. The modelled groundwater levels were taken as equal to the crest levels shown in Figure 9-3. Groundwater fixed head conditions are applied only during the active stages of the TSF / IWL, as indicated by solid lines in the figure.

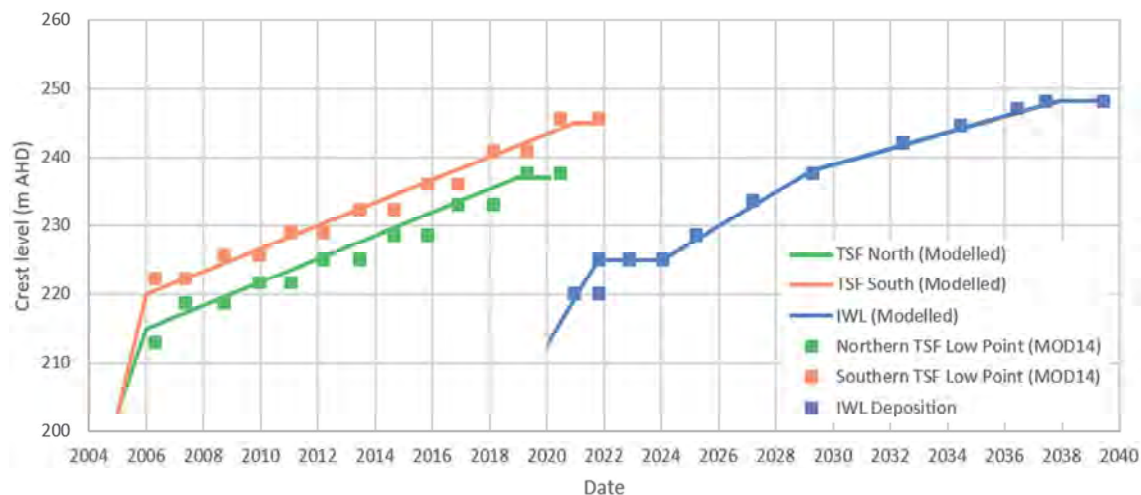


Figure 9-3: Modelled TSF and IWL crest levels

### 9.1.5 Lake Cowal

Time varying fixed heads were applied to the nodes on the surface at the area of Lake Cowal as discussed in Section 8.1.2 and shown in Figure 8-13 for the period 1998 to 2020.

For the period beyond 2020, two scenarios were modelled:

- A dry lake scenario where the groundwater head for the nodes representing Lake Cowal was set at 201.5 m AHD.

- A flooded lake scenario where the groundwater head for the nodes representing Lake Cowal was set at 206 m AHD.

Model results showed that the two scenarios were practically indistinguishable in terms of the predictive model results for groundwater levels, drawdowns and inflows. As such, figures and charts for the flooded lake scenario are not included in this report.

## 9.1.6 Stopes and tunnels

The geometry of the proposed stopes and access and haulage tunnels were provided by Evolution. This data was extracted and converted to suitable file formats for input into the numerical model using Coffey's in-house software. A reasonable balance between an accurate representation of geometry and the complexity of the numerical model is a key consideration when representing geometry in a numerical model.

### 9.1.6.1 Excavation sequence

For the numerical model, the access tunnels have been split into the five areas shown in Figure 9-4.

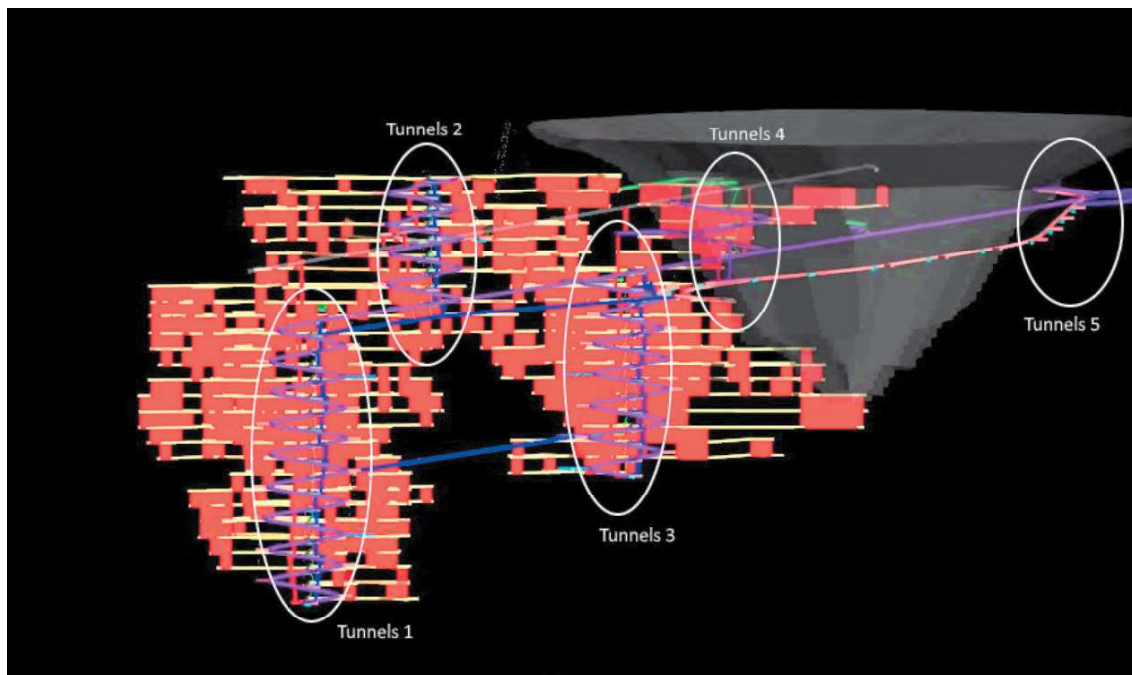


Figure 9-4: Access tunnel areas

Based on the excavation sequence provided by Evolution, which is shown in Figure 7-9, the times shown in Table 9-1 were used to model the stopes and access tunnel excavation sequence.

When the stoping reaches a particular layer, the stopes elements for that layer are deactivated, forming a void, and seepage face boundary conditions are applied so that groundwater flows out of the model and into the void. Due to the relatively high hydraulic conductivity of the paste backfill, as discussed below, the backfilled stopes can be considered as equivalent to a void during mining from a groundwater inflow perspective. For this reason, in the model the stopes voids and seepage face boundary conditions are active from their date of excavation until the end of mining. After the end of mining the recovery of groundwater is modelled by considering the storage within the access tunnels and the residual storage remaining within the stopes filled with paste backfill.

Individual stopes were not modelled. From consideration of scheduling animations provided by Evolution, a representative time of commencement of stoping at each horizontal layer was selected. All stopes elements and boundary conditions for that layer were activated in the model at that time.

When the access tunnels reach a particular layer, seepage face nodes are applied to the nodes representing those tunnels in that layer, allowing groundwater to flow out of the model. Tunnel seepage face nodes are active from the time tunnel development reaches a particular layer elevation until the end of underground mining.

The access tunnel voids were not represented explicitly in the model. Their influence is considered to be captured by modelling of the stopes. The computational time associated with a model mesh fine enough to capture each individual tunnel was deemed to be prohibitive for the purposes of the model, which are to provide a regional scale assessment of impacts groundwater levels and flow regimes.

Table 9-1: Stopes and tunnels excavation sequence (tunnel areas refer to Figure 9-4)

Model layer	Base of layer elevation (m AHD)	Date stoping reaches model layer elevation	Date Tunnels 1 reaches model layer elevation	Date Tunnels 2 reaches model layer elevation	Date Tunnels 3 reaches model layer elevation	Date Tunnels 4 reaches model layer elevation	Date Tunnels 5 reaches model layer elevation
L7	50			01-Jan-24		01-Jan-22	01-Jan-23
L8	0	01-Jan-24		01-Jan-24		01-Jan-22	
L9	-100	01-Jan-25		01-Jan-24		01-Jan-22	
L10	-200	01-Jan-26	01-Jan-25		01-Jan-23		
L11	-300	01-Jan-27	01-Jan-26		01-Jan-26		
L12	-400	01-Jan-29	01-Jan-27		01-Jan-27		
L13	-500	01-Jan-31	01-Jan-29		01-Jan-29		
L14	-600	01-Jan-32	01-Jan-30				
L15	-700	01-Jan-33	01-Jan-31				

### 9.1.7 Paste backfill

The stopes will be filled progressively with paste backfill to provide support. This will influence the timing of recovery of groundwater levels following mine closure.

The paste backfill pre-feasibility study report (Outotec, 2020) was reviewed. A representative hydraulic conductivity of 39 mm/hr ( $1.1 \times 10^{-5}$  m/s) for the paste backfill was quoted in that report. This hydraulic conductivity is at least two orders of magnitude greater than that of the surrounding rock based on calibration of the numerical model to piezometers in ML1535.

Due to the relatively high hydraulic conductivity of the paste backfill compared to the surrounding rock, the backfilled stopes can be considered as equivalent to a void during mining from a groundwater inflow perspective.

### 9.1.8 Groundwater recovery in stopes and access tunnels

Following the end of ore processing, the groundwater levels in the stopes and access tunnels will recover. Air voids or fillable porosity in the paste backfill will fill with groundwater. In addition, the whole volume of the access tunnels with elevations below the outlet to the open pit will fill with



groundwater. This process was represented in the numerical model by a modification to the specific storage parameter for the paste backfill.

Based on the provided total mass of extracted ore and length of access tunnels, as provided by Evolution, the following volumes were assessed, assuming an ore unit weight of 24 kN/m<sup>2</sup> and an average tunnel diameter of 6.5 m:

- Total stopes volume: 64,739,000 m<sup>3</sup>
- Total access tunnels volume: 1,326,000 m<sup>3</sup>

Assuming a fillable porosity of 0.1 in the paste backfill at the end of ore processing / start of groundwater recovery, and including the entire access tunnels volume, the total volume to be filled by groundwater during recovery is 7,800,000 m<sup>3</sup>. Based on observation of model results, this volume will be filled as the groundwater head rises from approximately -300 m AHD to 120 m AHD. This results in a specific storage of:

$$\frac{(\text{Volume of groundwater absorbed})}{(\text{Total volume of stopes and tunnels}) \times (\text{change in head})} = 2.8 * 10^{-4} / \text{m}$$

This specific storage parameter was adopted for the paste backfill from the end of ore processing to the end of model time.

## 10 Predictive modelling results

Figures C1 to C8 in Appendix C provide modelled groundwater head contours at January 2020, January 2038, January 2058 and January 2158. These dates represent approximately the time prior to underground development, just prior to the end of underground mining, and approximately 20 years and 100 years post mining, respectively.

Figures C9 and C10 in Appendix C provide modelled groundwater table drawdown contours at January 2020, January 2038, January 2058 and January 2158. These drawdowns are the predicted change in groundwater table elevation since January 2004.

Figure C11 provides modelled 5 m drawdown and mounding contours for each of the four parameter sets in the uncertainty assessment described in Section 8.3.

### 10.1 Groundwater levels during mining

The figures below show model results at January 2020, January 2038, January 2058 and January 2158. These dates represent approximately the time prior to underground development, just prior to the end of underground mining, and approximately 20 years and 100 years post mining, respectively.

The groundwater heads in the Transported, Saprolite, Saprock and Primary Rock units can all be seen to decrease between 2020 and 2038.

Groundwater head contours in the Transported, Saprolite and Saprock units near the open pit, stopes and access tunnels show a decrease of approximately 5 m between 2020 and 2038. The influence of the underground development on groundwater levels in these units appears to be very small to negligible with only a slight shift apparent in the centre of the groundwater contours towards the location of the underground development at 2038.

Groundwater head contours in the Primary Rock unit at 0 m AHD show a decrease of 80 m in the area above the stopes and access tunnels between 2020 and 2038. This elevation is close to the top of the stopes and access tunnels and the effects of the underground mine can be seen more clearly here.

The drawdown of the groundwater table caused by the open pit, stopes and access tunnels can be seen to lie entirely within ML1535 during and until the end of mining in 2038 except for small areas to the north and south where the 1 m drawdown contour is just outside the mining lease.

Mounding of the groundwater table caused by the IWL is predicted to extend outside the ML 1535, predominantly to the south west.

Figure 10-1, Figure 10-2 and Figure 10-3 show the modelled groundwater table drawdown at January 2020, January 2038 and January 2058, respectively. These drawdowns are the predicted change in groundwater table elevation since January 2004.

Figure 10-4 shows the predicted 5 m groundwater table drawdown and mounding contours in 2038, for the four parameter sets considered in the uncertainty assessment in Section 8.3. The 5 m drawdown contours for Set 1, Set 2 and Set 4 are relatively close, each being within about 200 m from one another. The 5 m drawdown contour for parameter Set 4 extends a further 700 m out to the north east compared to the other sets. This is the result of a higher vertical hydraulic conductivity assigned to the Primary Rock for Set 3, as shown in Figure 8-19. For all parameter sets, the 5 m drawdown contour is predicted to lie within ML1535 in 2038.

The effect on the predicted groundwater table from the underground development only, compared to the currently approved mine plan with no underground development, can be assessed by observing in Figure 10-2 that the groundwater table drawdown contours in 2038 show a very small, barely perceptible elongation over the area of the proposed underground development. In Figure 10-3, the 5 m groundwater table contour in 2058 extends approximately 300 m further out to the north than

where it would be considering the concentric ellipses around the open pit, which are indicative of the effects of the currently approved (open pit) mine plan only.

A similar consideration of the groundwater head contours shown in Figures C1 to C8 in Appendix C, indicate that the effects of the underground development only on the predicted groundwater heads in the Transported, Saprolite and Saprock units appears to be negligible. The effects on the groundwater heads in the Primary Rock unit are more apparent. This can be observed in Figure C7 in Appendix C, which shows the centre of the groundwater head contours shifting away from the open pit towards the area of the underground development during the operation of the underground mine.

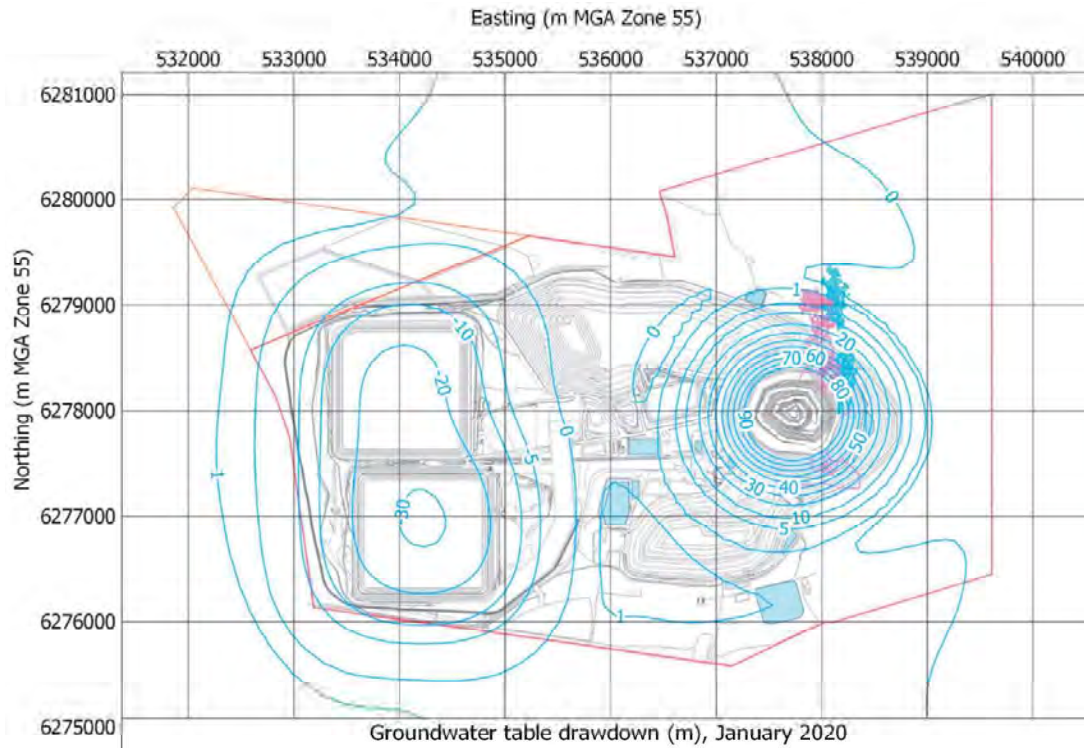


Figure 10-1: Modelled groundwater table drawdown from 2004 to 2020

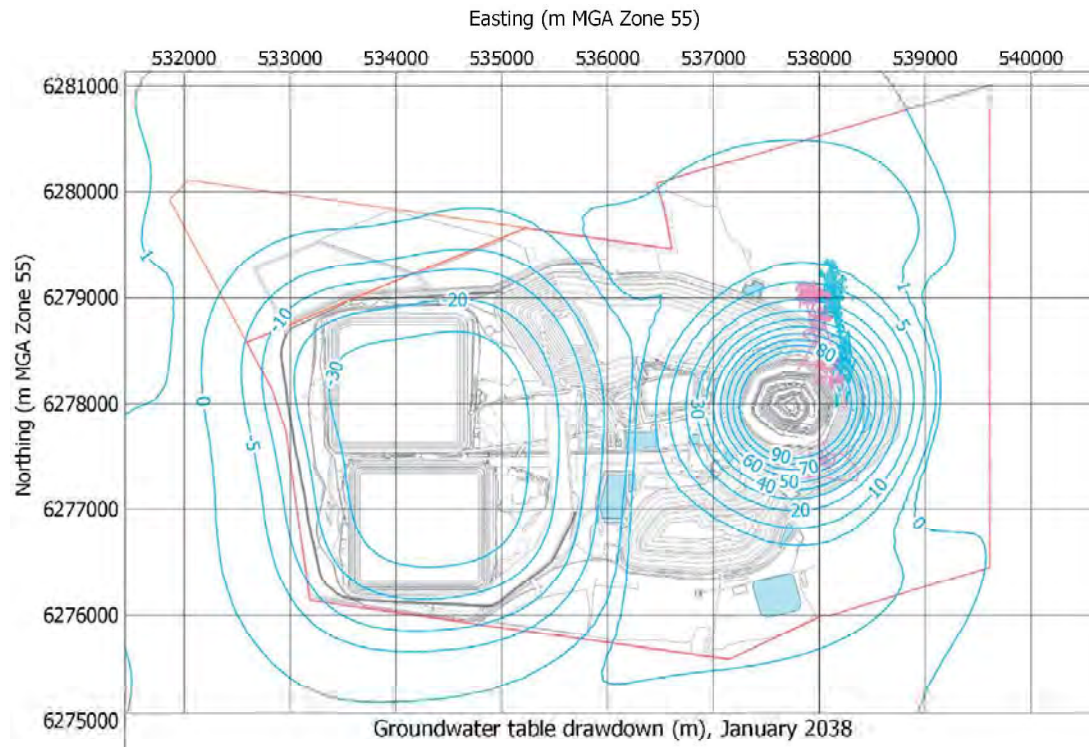


Figure 10-2: Modelled groundwater table drawdown from 2004 to 2038

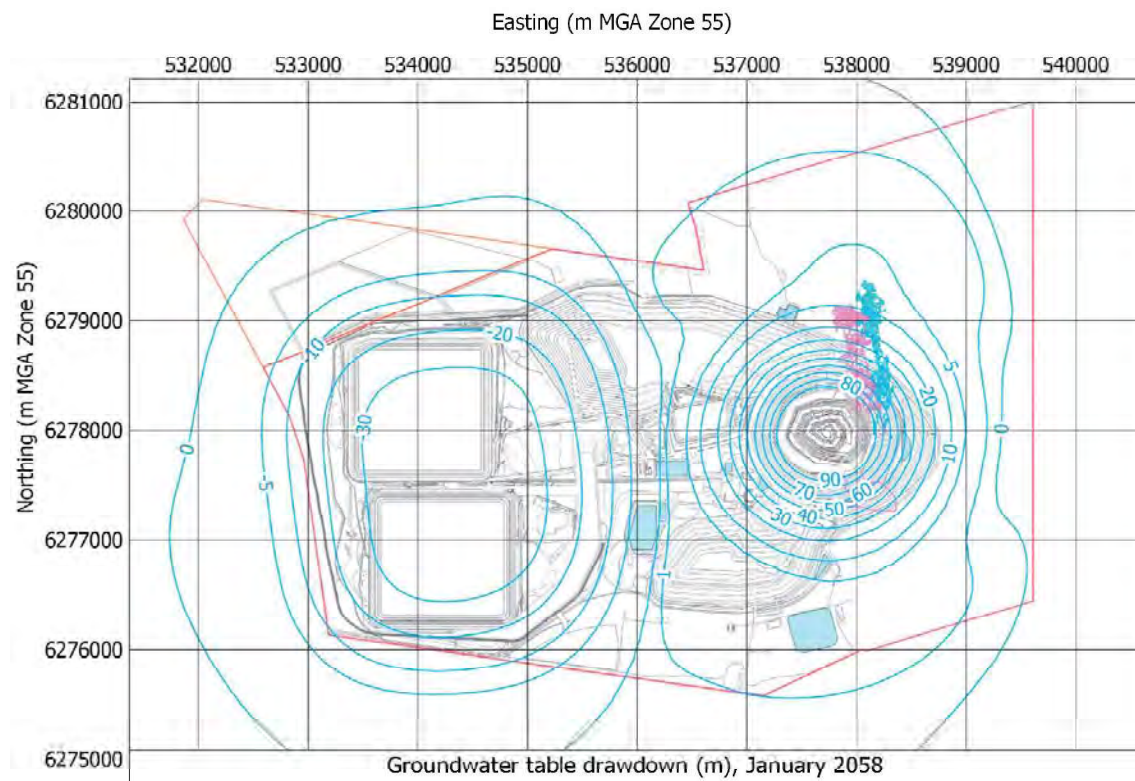


Figure 10-3: Modelled groundwater table drawdown from 2004 to 2058



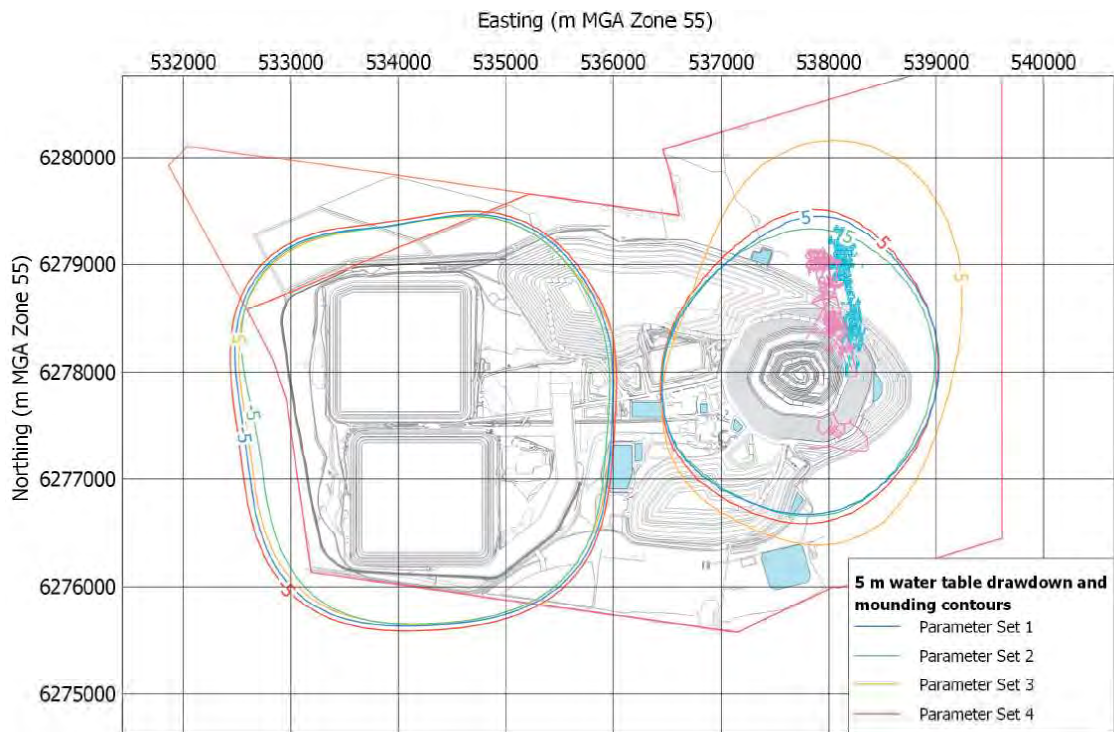


Figure 10-4: Uncertainty in modelled groundwater table drawdown at January 2038

## 10.2 Groundwater levels post mine closure

Following the end of mining in mid-2039, groundwater will continue to flow into the open pit and gradually increase the water level in the open pit. Figure 9-2 shows the modelled water level in the open pit following the end of mining. This was derived based on predicted inflows to the open pit and on provided open pit shell geometry, as discussed in Section 9.1.1.

As the water level in the open pit will remain below the surrounding groundwater level (assuming the open pit is not flooded with surface water), groundwater surrounding the open pit will continue to flow towards the open pit indefinitely in the absence of any other external factors.

Figures C3 to C8 in Appendix C show that there is predicted to be a slight recovery in groundwater heads around the open pit in the Transported, Saprolite and Saprock units of around 5 m between 2038 and 2058 and then a negligible change between 2058 and 2138. The figures show the recovery of groundwater heads in the Primary Rock unit between 2036 and 2138 is more pronounced. This is related to recovery of drawdown associated with the stopes and also the infilling of the base of the pit with groundwater inflow.

## 10.3 Groundwater inflows during mining

Based on our adopted model parameters, combined groundwater inflow to the open pit and the stopes is predicted to increase from approximately 1,000 m<sup>3</sup>/day in 2020 to a peak of approximately 2,800 m<sup>3</sup>/day in 2031 and continue at this rate until the end of mining and ore processing.

Based on the currently approved mine plan with no underground development, groundwater inflow to the open pit is predicted to remain approximately constant at 1,000 m<sup>3</sup>/day from 2020 to the end of ore processing, and then gradually reduce as the pit lake fills. The additional groundwater inflow resulting from the proposed underground development is predicted to increase from zero at the



commencement of the underground development in 2022 to a peak of approximately 1,800 m<sup>3</sup>/day in 2031 and then continue at this rate until the end of mining in mid-2039.

A model parameter uncertainty assessment was carried out to assess different parameter sets which are calibrated to field observations, as described in Section 8.3. This resulted in four sets of calibrated model parameters which were used to provide four equally probable estimates of groundwater inflow to the open pit, stopes and access tunnels from 2022 to 2039.

Uncertainty in the observed rate of groundwater inflow to the open pit was incorporated by allowing for a possible range in the observed rate of groundwater inflow to the open pit of between 750 m<sup>3</sup>/day and 1,100 m<sup>3</sup>/day for the period January 2018 to January 2020, refer to Figure 8-18. Recall from Section 8.2.5, the observed inflow to the open pit was incorporated into the model calibration by scaling the hydraulic conductivity, specific storage and rainfall recharge parameters by the same amount required to provide a reasonable match to observed inflow rates to the open pit for the period January 2018 to January 2020. This scaling has the effect of changing the modelled inflow rate to the open pit, or other model boundary nodes, without changing the modelled groundwater levels.

To account for the uncertainty in the observed rate of groundwater inflow to the open pit, the maximum and minimum of the four predicted inflows were factored up or down. The scale factor was assessed based on the adopted rate of groundwater inflow to the open pit of 950 m<sup>3</sup>/d on 1 January 2020 which was used for model calibration. At each time point in Figure 10-6, the minimum of the four predicted inflows was scaled by 0.79 (750 divided by 950) and the maximum by 1.16 (1,100 divided by 950) to obtain the minimum and maximum inflows shown in the figure. For the reasons described above and in Section 8.2.5, this is considered appropriate as running the model for these two cases is unlikely to provide any significant additional information.

Figure 10-5 shows the predicted inflow into the open pit, stopes and access tunnels using the adopted model parameters. Figure 10-6 shows the range of predicted inflow during 2022 to 2039 allowing for model parameter and observational uncertainty. Figure 10-7 shows the predicted inflow into each of the mine areas during 2022 to 2039 using the adopted model parameters.

The adopted groundwater inflow estimate for mine planning should be assessed based on consideration of the results shown in Figure 10-6, noting that each of the parameter sets are equally probable based on calibration of the numerical model to field observations as described in Section 8.2 and Section 8.3.

### 10.3.1 Effects of increased fracturing of rock above stopes

An assessment of the potential effects on inflows if stoping development were to result in increased fracturing in the rock overlying the stopes was carried out. The model was run with the horizontal and vertical hydraulic conductivity of the Primary Rock in the area of the stopes, from the level of the base of highest level of stoping up to the interface with the Saprock unit, increased by a factor of 10. The maximum predicted increase in inflow during the period 2020 to 2056 was less than 2 %. This can be understood by considering the low vertical hydraulic conductivities in the Transported, Saprolite and Saprock units overlying the stopes. These units have a combined thickness of between 50 m and 100 m in the area above the stopes. Additionally, as the stoping progresses to depths reaching up to 900 m below the ground surface (see Figure 7-6), a large proportion of the total inflow is predicted to be from flows into the deepest stopes from the nearby rock, rather than from sources close to the ground surface.

### 10.3.2 Effects of increased hydraulic conductivity of lake bed sediments

An assessment of the effects on inflows resulting from a higher hydraulic conductivity in the Transported Unit was carried out by factoring the horizontal and vertical hydraulic conductivity of the Transported Unit up by a factor of 10. The predicted increase in inflow to the stopes and tunnels during the period 2020 to 2056 was less than 2 %. This can be understood by considering that

between the base of the Transported Unit and the top of the highest stopes at approximately 80 m AHD, there is an approximate combined thickness of 60 m to 100 m of Saprolite, Saprock and Primary Rock. The vertical hydraulic conductivities of these units is low based on the calibration of the numerical model to observed groundwater levels and open pit inflows between 2005 and 2020. An assessment of the uncertainty of the hydraulic conductivity of these units, based on observation data, is provided in Section 8.3.

## 10.4 Groundwater inflows post mine closure

Post mining, groundwater inflow to the open pit is expected to rise from approximately 500 m<sup>3</sup>/day in 2040 to 900 m<sup>3</sup>/day in 2066. During this time the access tunnel voids and the paste backfill in the stopes gradually fill with groundwater. From 2066 to 2240 the inflow rate to the open pit is predicted to gradually fall to approximately 600 m<sup>3</sup>/day.

Based on the currently approved mine plan with no underground development, assessed groundwater inflow to the open pit is similar to the assessment with the underground development, decreasing gradually from approximately 1000 m<sup>3</sup>/day in 2040 to approximately 600 m<sup>3</sup>/day in 2240. The difference in predicted inflow to the open pit between 2040 and 2066 is a result of groundwater inflow to the access tunnel voids and paste backfill between 2040 and 2066 for the underground development assessment. This reduces the rate of groundwater inflow to the open pit during this time.

The difference in predicted inflow rates between the dry lake case and the flooded lake case is negligible. This is a result of the low vertical permeabilities of the hydrogeological units.

Following mine closure, during the period from 2040 to 2066, groundwater inflow into the access tunnel voids and paste backfill in the stopes is predicted to fall from 1,650 m<sup>3</sup>/day to less than 100 m<sup>3</sup>/day, as shown in Figure 10-5.

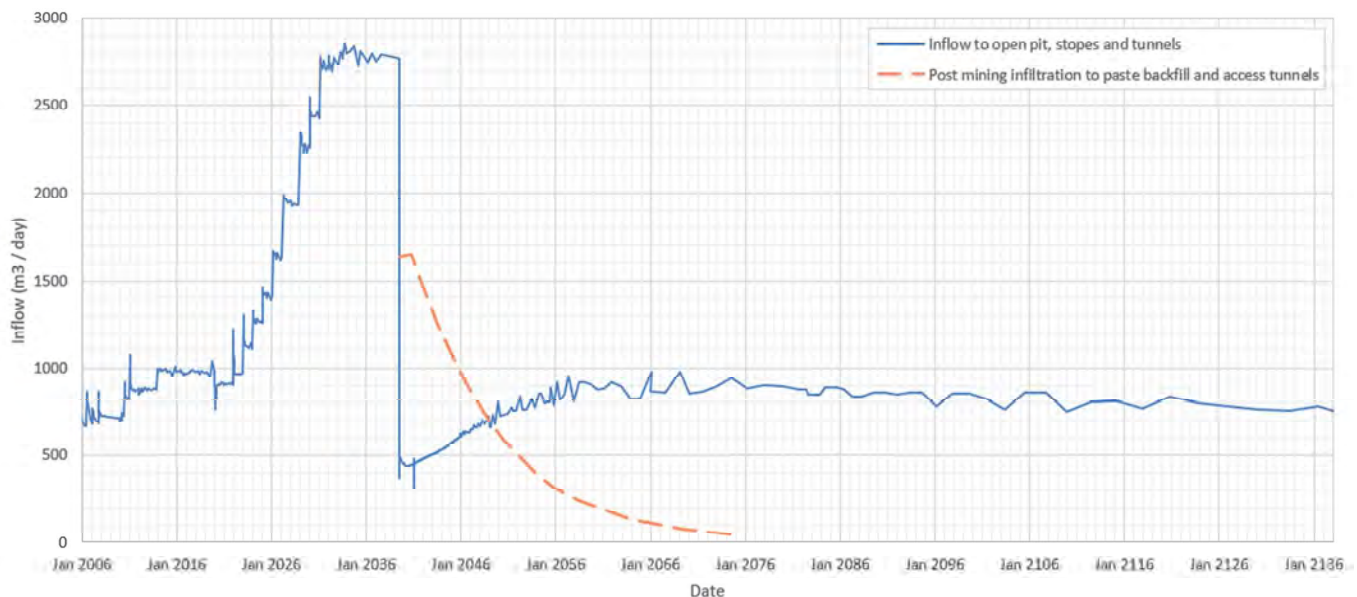


Figure 10-5: Predicted groundwater inflow to the open pit, stopes and access tunnels (2006 to 2138)

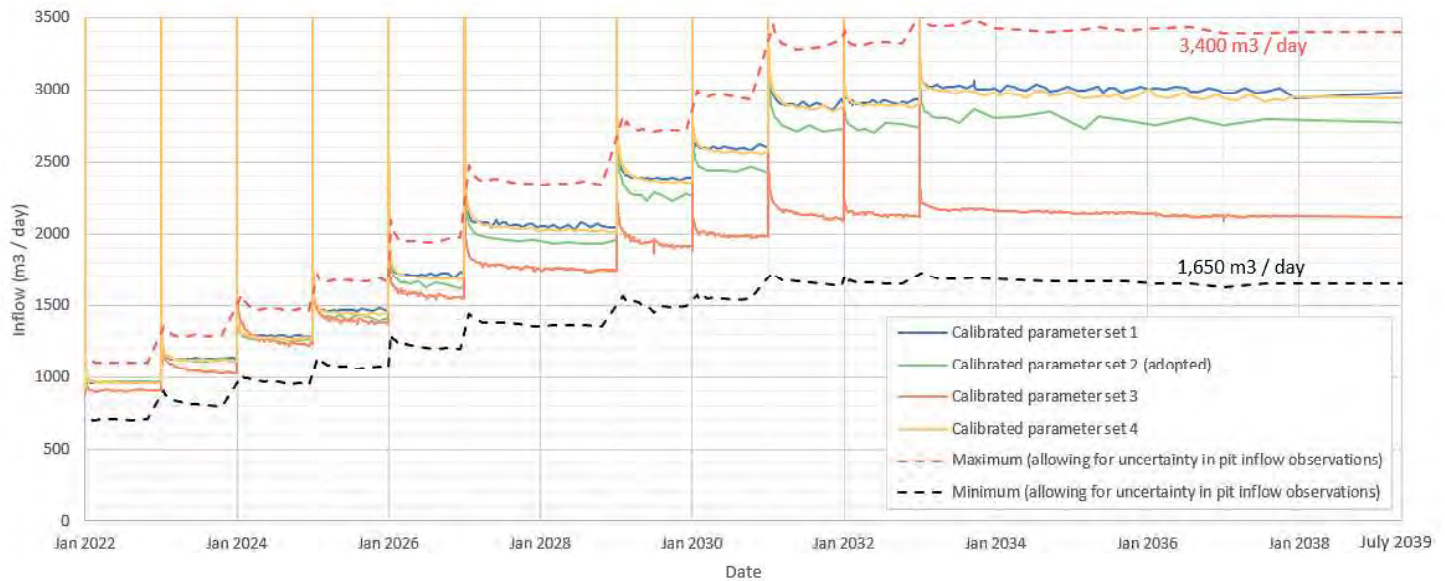


Figure 10-6: Predicted groundwater inflow allowing for model parameter and observational uncertainty (2022 to 2039)

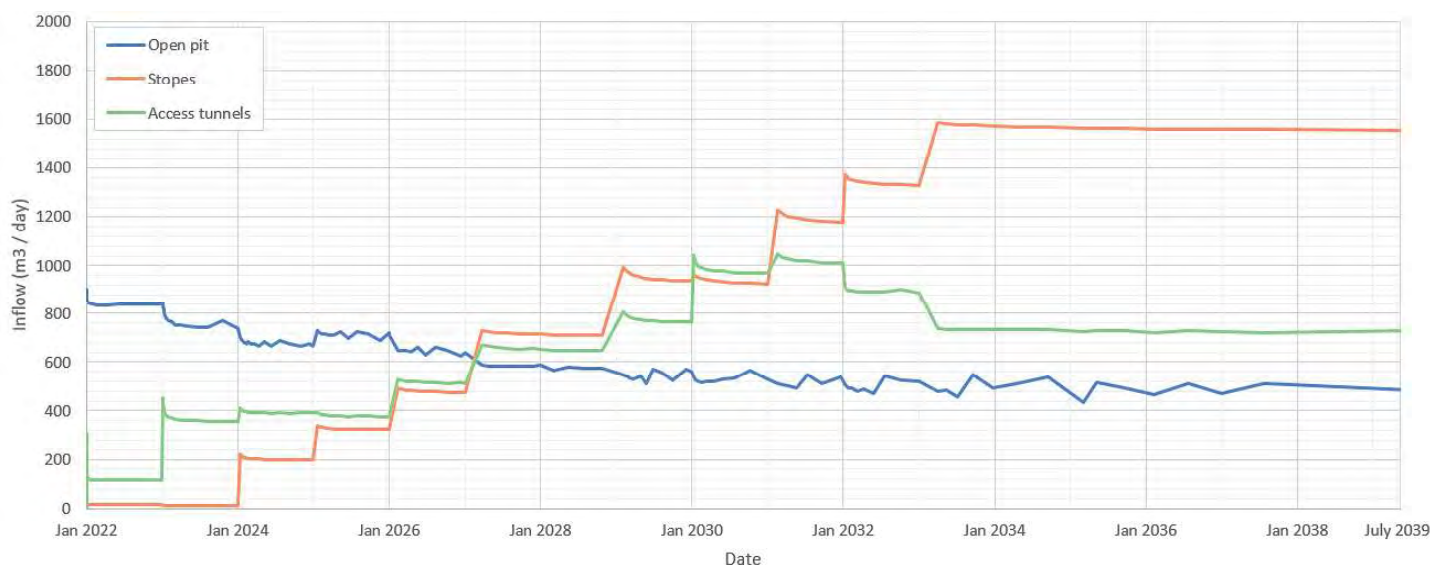


Figure 10-7: Predicted groundwater inflow into each of the mine areas (2022 to 2039)

## 10.5 Potential impact on Lake Cowal

Lake Cowal is a surface water fed water body, originating from Bland Creek and occasional flooding of the Lachlan River. It is separated from the proposed underground development by a 120 m combined thickness of lake sediments and extremely weathered to fresh rock, with vertical permeabilities of less than  $1 \times 10^{-3}$  m/day. As a result of the low vertical permeabilities, the majority of groundwater inflow (1,800 m³/day) will be from deep groundwater originating in the rock surrounding the underground development and not from Lake Cowal.

When Lake Cowal is full it occupies an area of 13,000 hectares, and would thus lose on average 200,000,000 m³/day to evaporation (assuming 1.5 m net pan evaporation, refer to Table 4-1). This means that the average rate of evaporation from the surface of Lake Cowal is approximately 100,000 times the predicted maximum rate of groundwater inflow to the whole underground development. As such, the impact of mine groundwater inflow on the water levels of Lake Cowal is considered to be negligible.

## 10.6 Groundwater quality related to open pit and stopes dewatering

The quality of groundwater collected by the dewatering system (including groundwater both pumped from vertical dewatering bores and seeping into the open pit and stopes) 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 Figure 10-5. Pit dewatering will only have a small and localised (i.e. within ML1535) impact on groundwater quality.

Table 10-1: 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

## 10.7 Contaminant migration

Modification 16 involves a height increase from 245 m AHD to 246 m AHD to the final rehabilitated height of the IWL which is currently being developed as part of the approved Modification 14. This increase in height is approximately 3% of the height of the IWL, which has a base elevation of 213 m AHD, as shown in Table 7-1. A height increase of this percentage is assessed to have a negligible impact on the concentration of contaminants migrating from the IWL.

This section provides an assessment of the movement of contaminants originating from the IWL over a period of up to 200 years after mine closure. Contaminants identified as having the potential to be released from the IWL include cyanide, arsenic, zinc and other heavy metals (Coffey, 2018a). It should be noted that of these, cyanide is the only substance introduced by the mining operation the metals and arsenic derive from the mine ore.

### 10.7.1 Adopted porosity and retardation coefficient due to sorption

A key parameter for the modelling of particle tracking is the effective porosity of the soil/rock medium. Based on our experience with bedrock of similar nature, we consider an effective porosity of 0.01% in the rock to be reasonable for the modelling of the velocity at which water travels through the rock medium.

The movement or transport of contaminants is slower relative to water in an aquifer due to the sorption phenomenon, which is a physical or chemical process by which the solute partitions between groundwater and the soil or rock. This induces a retardation effect to the movement of contaminants in groundwater aquifer. Sorption processes include adsorption, absorption, chemisorption and ion exchange.

The retardation factor due to sorption is defined as:

$$R = 1 + \frac{\rho K_d}{n}$$

Where:

R = Retardation factor

$\rho$  = dry density of soil/rock ( $\text{ML}^{-3}$ )

$K_d$  = Partitioning coefficient in matrix material of fractured media ( $\text{L}^3\text{M}^{-1}$ )

$n$  = Total porosity

Review of soil water partition coefficients for cyanide, arsenic, zinc and other heavy metals tested at Lake Cowal are presented in Table 10-2 (sourced from the Risk Assessment Information System by the US Department of Energy, Office of Environmental Management (rais.ornl.gov)). The results indicate that cyanide has the lowest  $K_d$  of the contaminants considered and therefore the other substances would migrate more slowly than cyanide.

Table 10-2: Soil-water partition coefficient

Contaminants	Soil-Water Partition Coefficient, $K_d$ ( $\text{cm}^3/\text{g}$ )
Arsenic	29
Cadmium	75
Copper	35
Iron	25
Cyanide	9.9
Lead	900
Manganese	65
Mercury	52
Nickel	65
Zinc	62

Assuming the dry density of the rock to be  $2.4 \text{ t/m}^3$  and the total porosity to be 10%, the retardation factor (based on  $K_d$  of 9.9) is predicted to be 240.

Based on our findings above, we have conservatively adopted a retardation factor of 20 in our particle tracking simulation (this is conservative for all other contaminants, such as heavy metals, which have much higher  $K_d$  coefficients). This retardation of the movement of contaminants was modelled by increasing the effective porosity by a factor of 20 (e.g. adopting effective porosity of 0.2% for the rock).

### 10.7.2 Decay in cyanide concentration

Cyanide is subject to gradual decay typically characterised by a half-life (the time for concentration to fall to half its initial value). The rate of decay is uncertain in the conditions beneath the IWL, with half-lives of the order of 300 days quoted for anerobic conditions and much shorter half-lives quoted for aerobic conditions which would apply at the surface of the water in the mine void. For a half-life of 300 days, an initial concentration of 20 mg/L (the concentration of cyanide in tailings delivered to the IWL) would reduce to below 0.001 mg/L after 12 years.

### 10.7.3 Modelling results

Release points were modelled beneath the footprint of the IWL at the base of the Saprolite unit at approximately 150 m AHD. These release points assume that there is presence of contamination within the Saprolite at time of mine closure and conservatively disregard remaining delays in migration through the lining beneath the tailings storage.



The results show groundwater head conditions in the area surrounding the CGO and the paths taken by the modelled tracer particles. Along each of the tracer lines are isochrone markers which show the timing of movement of the particles along their respective tracer lines over equally spaced time intervals.

### 10.7.3.1 Lake dry scenario

For the dry lake scenario, hydraulic head contours at the base of the Saprolite unit and the transport of contaminants are presented in Figures D1 to D4 in Appendix D.

Groundwater levels gradually change with a slow expansion of the cone of depression around the mine pit and gradual rise in water level within the mine void. As water levels rise in the pit the head gradients towards the pit gradually reduce.

From the simulation results, it can be seen that the contaminants travel beyond the IWL up to 900 m, 1,300 m, 1,700 m and 2,300 m in 20, 50, 100, and 200 years post mine closure respectively (not including particles that travel directly into the mine void). Figure 10-8 and Figure 10-9 show a plan and a section view of the predicted movement of contaminants from 2038 to 2058.

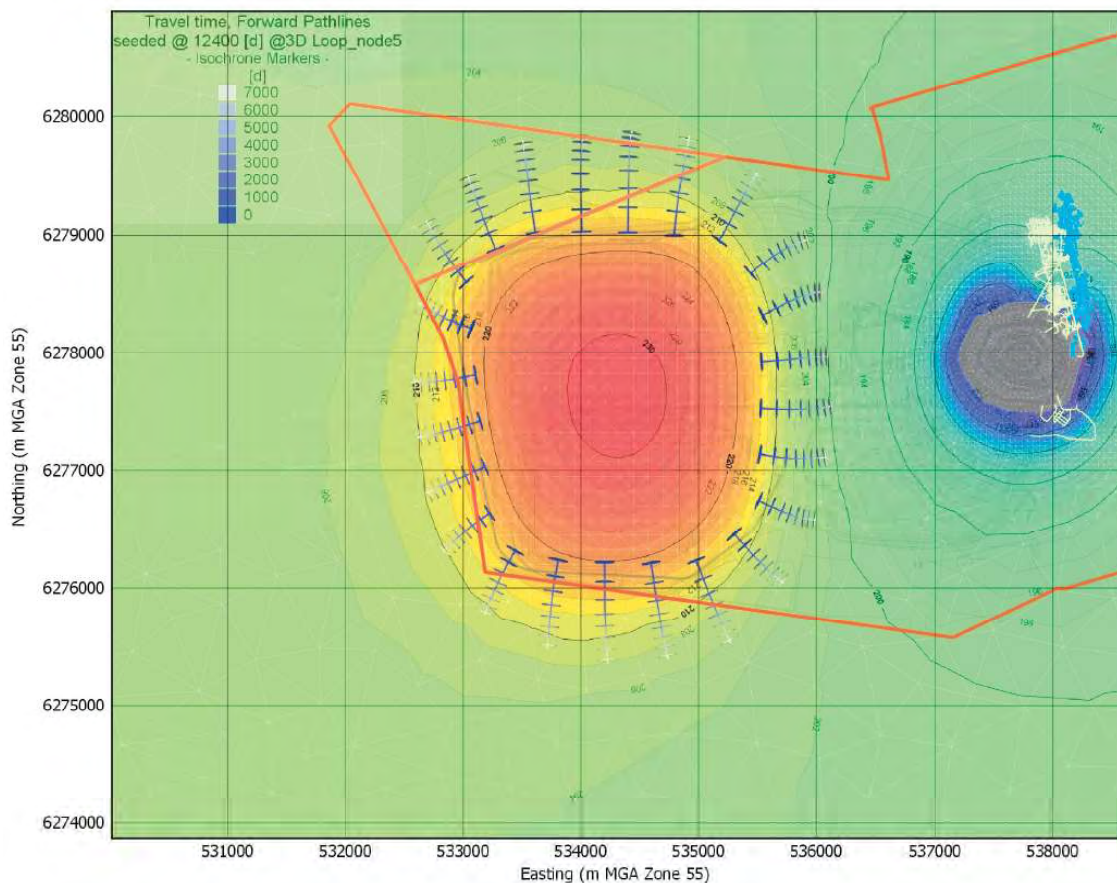


Figure 10-8: Plan view showing predicted movement of contaminants from 2038 to 2058

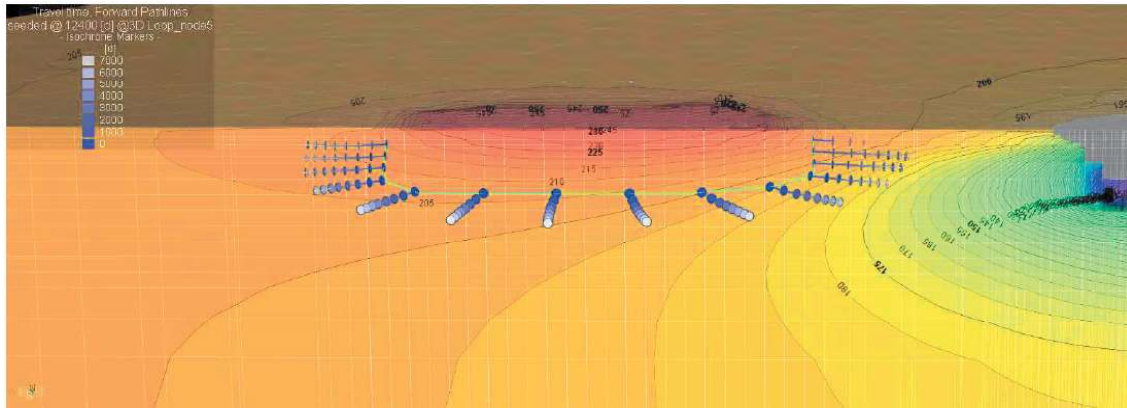


Figure 10-9: Section view looking north showing predicted movement of contaminants from 2038 to 2058

Contaminant particles tend to move initially downward due to the higher groundwater head directly beneath the IWL. They then move horizontally outwards and slightly upwards as the groundwater head equilibrates, similar to flow under a dam wall, for example. Some of the particles are modelled as reaching the ground surface, particularly to the north of the IWL. The movement of particles is entirely contained within the Transported, Saprolite and Saprock units, except for at the edge of the open pit where some particle paths pass through the Primary Rock unit. This is a result of the calibrated vertical hydraulic conductivities being an order of magnitude lower than the horizontal hydraulic conductivities.

Figures D1 to D4 in Appendix D show that the influence of the open pit void on groundwater flow patterns is felt mainly in the Primary Rock unit, except to the east of the IWL where some influence of the open pit void can be seen in the groundwater head contours in the Transported, Saprolite and Saprock units. As such, particles that leave towards the west from the IWL are not redirected toward the open pit within 200 years. The figures show that particles which leave towards the north from the IWL tend to daylight at the ground surface in or within 1 km from the mining lease.

The modelling results for 20 years post mine closure show movement to approximately 900 m away from the IWL. Monitoring to date after more than ten years of mine operation and storage of mine tailings has not resulted in sustained measurement of cyanide in the monitoring network, which includes monitoring points within 300 m of the tailings storage facility. These results are interpreted to indicate that the modelled movement of cyanide from the IWL is conservative, and that the modelled extent is over estimated. Of the substances considered (cyanide and heavy metals) cyanide is expected to be the more mobile because of the published information shows that the partitioning between cyanide and soil and rock is lower than for heavy metals. As a result, movement of other substances is expected to be slower than for cyanide.

The modelling does not take account of decay in cyanide concentration with time, which was discussed in Section 10.7.2. Taking account of decay leads to the conclusion that cyanide concentrations are anticipated to fall well below detection levels after 12 years and so measurable concentrations of cyanide are not anticipated to migrate beyond 1 km from the perimeter of the IWL.

### 10.7.3.2 Lake full scenario

The results for the lake full scenario were found to be approximately equal to the lake dry scenario. This is understandable considering the lake lies to the far side of the open pit from the IWL.

# 11 Groundwater licensing and aquifer interference policy considerations

## 11.1 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 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. ML1535 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. ML1535 lies within the Lachlan Fold Belt groundwater source of the Murray-Darling Basin. Groundwater seepage to the open pit results in extraction of groundwater from the Lachlan Fold Belt (alluvial areas are excluded in this source area). Table 11-1 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 mine site.

Table 11-1: 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

### 11.1.1 Mine Site Groundwater Extraction

The numerical modelling predicts dewatering rates due to inflow to the open pit, stopes and tunnels, as shown in Figure 10-5. The equivalent average annual groundwater take modelled from 2020 to the end of mine life is approximately 796 ML/year (2,180 m<sup>3</sup>/day).

Peak predicted flow from 2031 to 2039 is 1,022 ML/year (2,800 m<sup>3</sup>/day).

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

Existing mine groundwater inflows are assessed as 365 ML/year (1,000 m<sup>3</sup>/day) (interpretation of site dewatering records, refer to Figure 8-18).

A letter from DPI Water to Barrick (then the owners of CGO) titled “Cowal Gold Mine – Request for reallocation of water access licence under the water management act 2000” and dated 7 January 2014, states that 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 256 ML/year (700 m<sup>3</sup>/day) from the saline borefield (Upper Lachlan Alluvial Zone 7) and allowing 10% (37 ML/year, (100 m<sup>3</sup>/day)) of the pit groundwater inflow rate from the Upper Lachlan Alluvial Zone 7 deposits with the remaining 90% (329 ML/year (900 m<sup>3</sup>/day)) from the fractured rock aquifer.

The saline borefield is submerged and inaccessible when Lake Cowal contains water. Consequently, it is only available 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 11-2.

Table 11-2: 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 282	Maximum 293 <sup>a</sup>	366
NSW Murray Darling Basin Fractured Rock Groundwater Sources	Lachlan Fold Belt Groundwater Source	Average 212 Maximum 277	Average 759 <sup>b</sup> Maximum 1004 <sup>c</sup>	3294

a Includes 256 ML/year extraction associated with the saline supply bores within ML1535 based on peak usage of 0.7 ML/d, plus 10% of modelled maximum inflow from the Upper Lachlan Alluvial Zone.

b Modelled average total inflow (796 ML/year) minus average open pit inflow from Upper Lachlan Alluvial Zone (37 ML/year)

c Modelled maximum total inflow (1022 ML/year in 2031-2039) minus open pit inflow from Upper Lachlan Alluvial Zone (18 ML/year in 2021-2039)

Post mining groundwater inflows will gradually reduce as water levels rise within the mine void over time, until they are balanced by evaporation from the pit lake, as discussed in Section 9.1.1. The long-term inflow rate is assessed to be 230 ML/year (630 m<sup>3</sup>/day) from the fractured rock groundwater source and less than 7.3 ML/year (20 m<sup>3</sup>/day) from the Upper Lachlan Alluvial Zone, refer to Figure 10-5.

## 11.2 Aquifer Interference Policy Requirements

### 11.2.1 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 ML1535 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 ML1535. As there are no Groundwater Dependent Ecosystems (GDEs), priority culturally significant sites or supply works within ML1535 (or within 40 m of the boundary of ML1535), 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 15 January 2020 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 11-1). 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 11-2). From review of Figure 11-2, 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 11-2). The movement water in the lake shore will not be affected by mining operations as the seepage from the lake to the open pit, stopes and access tunnels 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 11-2). 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.

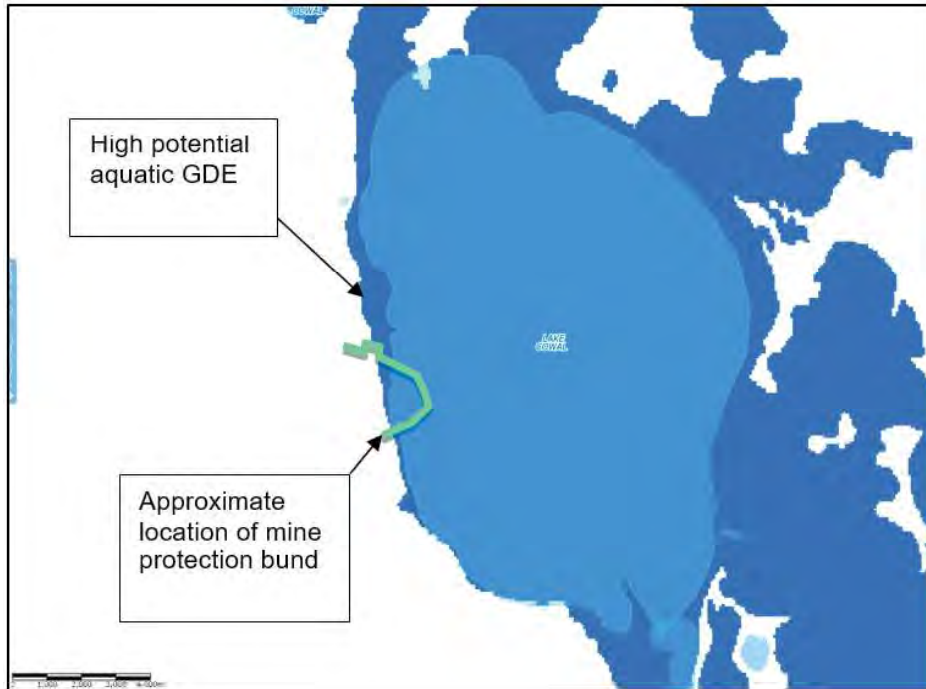


Figure 11-1: BoM Atlas of Groundwater Dependent Ecosystems (Aquatic)

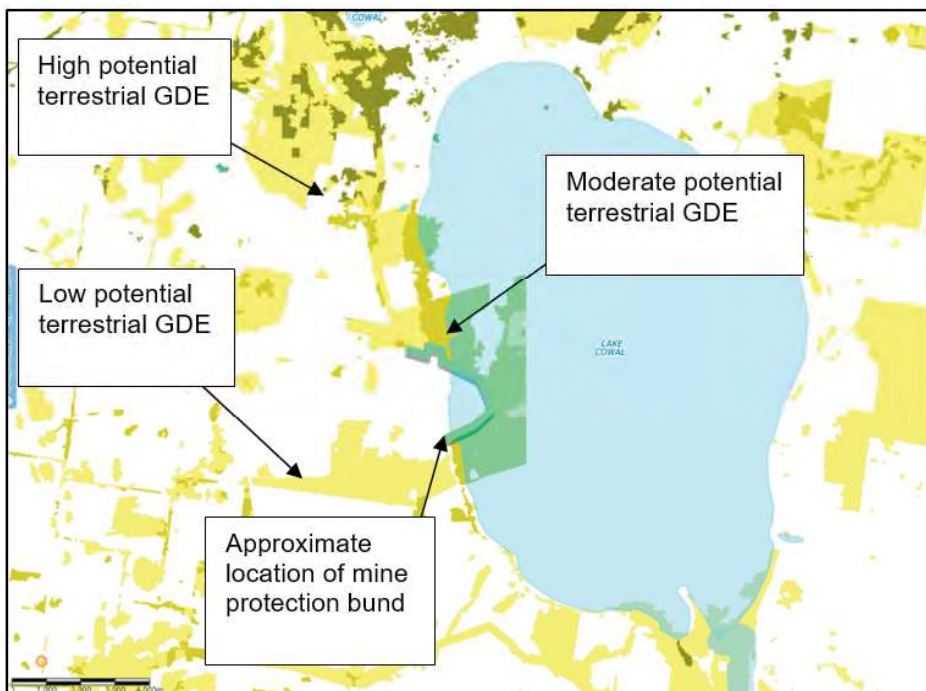


Figure 11-2: BoM Atlas of Groundwater Dependent Ecosystems (Terrestrial)

During the life of the CGO, dewatering from the open pit, stopes and access tunnels will only have a small and localised (i.e. within ML1535) impact on groundwater quality. Over the longer term, groundwater will flow towards the open pit, 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. Thus, minimal impact consideration (iv) is met.

As the equilibrium surface water level in the open pit (the pit lake) following the end of mining will be well below the ground surface (refer to Section 9.1.1), water from the pit lake will not be released. 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, and so is not considered by Coffey to be a “reliable water supply”. Thus, minimal impact consideration (vi) is met.

## 12 Management and mitigation measures

### 12.1 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 m AHD. 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 m AHD 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 MON02A and MON02B 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 MON02A and MON02B) 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.

## 13 Conclusions

### 13.1 Groundwater impacts due to open pit and underground mining

The following points summarise the main findings relating to groundwater impacts due open pit and underground mining:

- Groundwater table drawdown due to open pit and underground mining is predicted to generally remain within ML1535 / ML1791 during the mine life and post mining.
- Groundwater head drawdown due to open pit and underground mining is predicted to generally remain within ML1535 / ML1791 during the mine life, except in the primary rock unit.
- Groundwater inflows to the open pit and underground mine are predicted to range between approximately 1,000 m<sup>3</sup>/day and 2,800 m<sup>3</sup>/day between 2020 and mine closure. This would result in maximum groundwater inflows of 1002 ML/year within the fractured rock groundwater system and 37 ML/year within the alluvial groundwater system.
- There is a negligible difference between dry and inundated lake scenarios. This is a result of the low vertical hydraulic conductivities of the hydrogeological units. These were calibrated based on 22 monitoring wells with groundwater level observations between 2005 and 2020 and on observed inflows to the open pit.
- Pit dewatering water quality is expected to be similar to historical conditions.
- Groundwater quality within ML1535 is expected to be similar to historical conditions.

The impact of the underground development only (excluding the effects related to the currently approved mine) is summarised below:

- The effect on predicted groundwater table drawdown at the end of underground mining caused by the underground development is assessed to be very small to negligible.
- The effect on predicted groundwater heads caused by underground development is assessed to be confined primarily to the Primary Rock unit, with very small to negligible effects in the overlying Transported, Saprolite and Saprock units.
- The additional groundwater inflow caused by the proposed underground development is assessed to increase from zero in 2022 to a peak of approximately 1,800 m<sup>3</sup>/day in 2031 and then continue at approximately this rate until the end of mining in mid-2039.
- Between mid-2039 and approximately 2066 the access tunnel voids and the fillable porosity in the stopes paste backfill gradually fill with groundwater. After this time the impact of the underground mine is assessed to be negligible.

### 13.2 Impacts on Lake Cowal due to open pit and underground mining

Modelling results indicate negligible impact on Lake Cowal due to open pit and underground mining.



### **13.3 Groundwater quality impacts due to potential seepage from the TSFs and IWL**

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. Consideration of Cyanide decay times indicates that Cyanide concentrations are predicted to fall well below detectable limits beyond 1 km from the boundary of the IWL.

## 14 Recommendations

### 14.1 Data and Monitoring

Coffey recommends:

- Continued groundwater monitoring to validate the predictive modelling, particularly in the vicinity of the open pit, TSFs, stopes and access tunnels and ML1535 saline groundwater supply borefield.
- Establishment of new monitoring bores to replace those that would be displaced by the IWL, including MON02A, MON02B, P414A, P414B, P412A, P412A-R, TSFNA, TSFNB, TSFNC, MON01A, MON01B, P558A-R and P555A-R.

## 15 Limitations

### 15.1 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.

## 16 References

- Allison, J.D., and Allison, T.L. (2005). Partition Coefficients for Metals in Surface Water, Soil and Waste. EPA/600/R-05/074, July 2005. U.S. Environmental Protection Agency Office of Research and Development Washington, DC 20460.
- Australian and New Zealand Environmental Conservation Council (1995). National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia.
- Australian and New Zealand Environmental Conservation Council and Agricultural Resources Management Council of Australia and New Zealand (2000). Australian and New Zealand Guidelines for Fresh and Marina Water Quality.
- Australian Natural Resources Atlas (2009). Land Use - Lachlan River Basin 1995/1997. Department of Sustainability, Environment, Water, Population and Communities, Data updated 25 May 2009.
- Barnett, B., Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A. (2012), Australian Groundwater Modelling Guidelines, National Water Commission, Canberra.
- Barrick Australia Limited (2010). Saline Groundwater Assessment – Cowra Aquifer, Cowal Gold Mine, West Wyalong, NSW, Final Report, Project No. BARR010, October 2010.
- Bilge H. (2012). Upper Lachlan Groundwater Flow Model, NSW Office of Water, Sydney.
- Burden, R.J. and Kidd, C.H. (1987). The Environmental Fate of Cyanide in Gold Mine Process Tailings, Proceedings of Annual Conference. Australasian Institute of Mining and Metallurgy, Nelson, New Zealand.
- Bureau of Meteorology (2017a). Climate data online (<http://www.bom.gov.au/climate/data/>).
- Bureau of Meteorology (2017b) Groundwater Dependent Ecosystem Atlas (<http://www.bom.gov.au/water/groundwater/gde/map.shtml>).
- CMW Geosciences (2017). Integrated Waste Landform, Tailing Storage Facility – Cowal Gold Operations, NSW. Report No. PER2016-0917AI Design Report Rev1, 13 October 2017.
- Coffey Services Australia Pty Ltd (1995a). Lake Cowal Project Hydrogeological Modelling and Dewatering Study. Report No. G255/28-AF, 3 April 1995.
- Coffey Services Australia Pty Ltd (1995b). Lake Cowal Project Hydrogeological Study of Tailings Dams Area. Report No. G255/21-AD, February 1995.
- Coffey Services Australia Pty Ltd (1995c). Outside Borefield Feasibility Study for Lake Cowal Project, Report No. G255/24-AJ, February 1995.
- Coffey Services Australia Pty Ltd (1995d). Lake Cowal Project – Hydrogeological Modelling and Dewatering Study. Report No. G255/28-AF, April 1995.
- Coffey Services Australia Pty Ltd (1997). Groundwater Studies – Hydrogeological Assessment.
- Coffey Services Australia Pty Ltd (2006). Cowal Gold Mine, Groundwater Supply Modelling Study, Model Calibration. Report No. S21910/2AK, 15 September 2006.
- Coffey Services Australia Pty Ltd (2008). Cowal Gold Mine, Pit Dewatering Assessment. Report No. GEOTLCOV21910AC-AC, 5 August 2008.
- Coffey Services Australia Pty Ltd (2009a). Cowal Gold Mine, Groundwater Level Investigation. Report No. GEOTLCOV21910AF-AB, 26 March 2009.
- Coffey Services Australia Pty Ltd (2009b). Cowal Gold Mine, Groundwater Monitoring Review 2008. Report No. GEOTLCOV21910AE-AB, 24 February 2009.

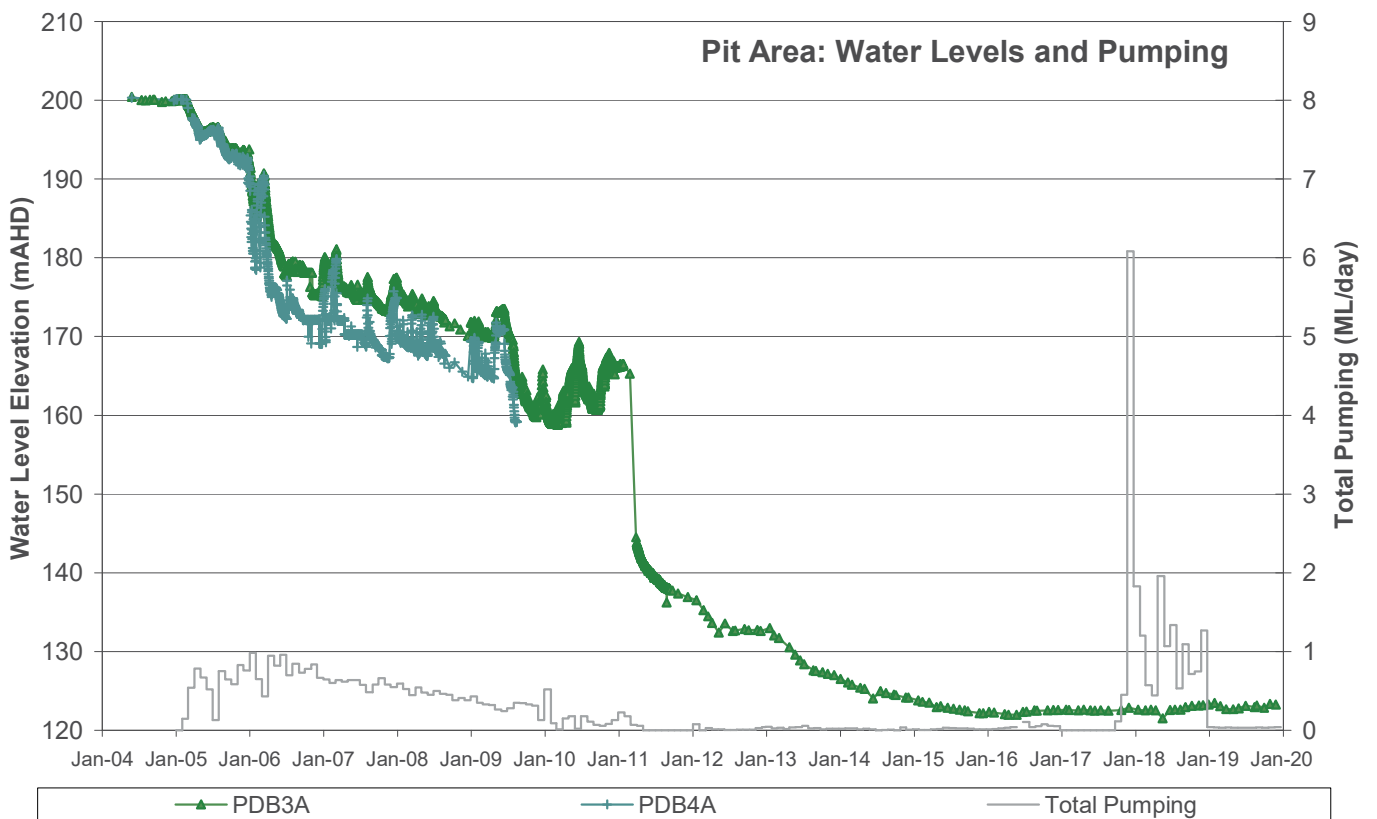
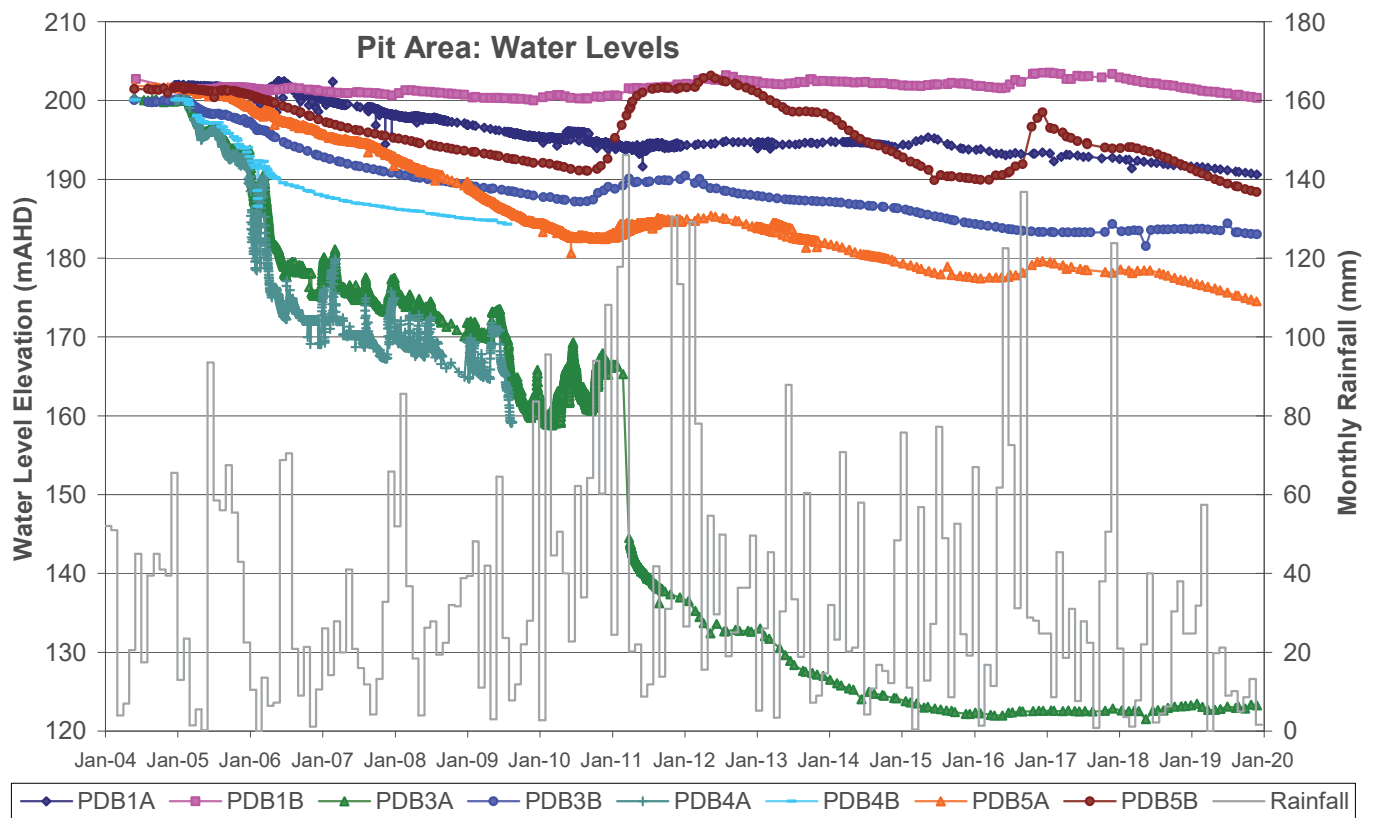
- Coffey Services Australia Pty Ltd (2011). Cowal Gold Mine Augmentation Project, Hydrogeological Assessment. Report No. GEOTLCOV21910AJ-AL, 16 March 2011.
- Coffey Services Australia Pty Ltd (2012). Cowal Gold Mine, Groundwater Monitoring Review 2011. Report No. GEOTLCOV21910AV-AC, 5 September 2012.
- Coffey Services Australia Pty Ltd (2016). Cowal Gold Operations Mine Life Modification, Mine Site Hydrogeological Assessment. Report No. GEOTLCOV21910BG-AG, 10 November 2016.
- Coffey Services Australia Pty Ltd (2018a). Cowal Gold Operations Processing Rate Modification (MOD14), Mine Site Hydrogeological Assessment, Report No. 754-SYDGE206418-AA, dated 2 March 2018.
- Coffey Services Australia Pty Ltd (2018b). Cowal Gold Operations Processing Rate Modification (MOD14), Bland Creek Palaeochannel Borefield and Eastern Saline Borefield Groundwater Assessment, Report No. 754-SYDGE206418-BCPB, dated 24 March 2018.
- Coffey Services Australia Pty Ltd (2020a). CGO Underground Development EIS, Groundwater site investigations report, Report No. SYDGE206418-3-AJ, dated 6 April 2020.
- Coffey Services Australia Pty Ltd (2020b). Groundwater Monitoring Review 2019, Cowal Gold Operation, Report No. 754-SYDGE270760-AA, dated 30 April 2020.
- Coffey Services Australia Pty Ltd (2020b). Cowal Gold Operations Underground EIS, Bland Creek Palaeochannel Borefield and Eastern Saline Borefield Groundwater Assessment, Report No. 754-SYDGE206418-3-AG, dated T.B.A.
- Department of Land and Water Conservation (1997). The NSW State Groundwater Policy Framework Document.
- Department of Land and Water Conservation (1998). The NSW State Groundwater Quality Protection Policy.
- Department of Land and Water Conservation (2002). The NSW Groundwater Dependent Ecosystem Policy.
- Groundwater Consulting Services Pty Ltd (2006). Jemalong Water Supply Borefield Installation and Testing, Cowal Gold Project, West Wyalong, New South Wales. Report BARR003. August.
- Groundwater Consulting Services Pty Ltd (2008). Saline Groundwater Assessment – Alluvial Aquifer E42 Modification, Cowal Gold Mine, West Wyalong, New South Wales. Report BARR010, July 2008.
- Haines Surveys (2019), Lake Cowal 3 Gravity Survey, Evolution Mining Ltd, April - May 2019, Job No. 1906.
- Hawkes, G.E. (1998). Hydrogeology of the Proposed Lake Cowal Gold Mine, NSW. Unpublished MSc Thesis, University of Technology, Sydney.
- Hydro Engineering & Consulting Pty Ltd (2018). Cowal Gold Operations Processing Rate Modification – Hydrological Assessment. Prepared for Evolution Mining Pty Limited.
- Johnson, A.I. (1967). Specific Yield – Compilation of specific yield for various materials. USGS Water-Supply Paper 1662-D, 74p.
- Knight Piesold Pty Ltd (1994). Lake Cowal Project Laboratory Testing of Tailings, Reference 216/2, June 1994.
- Miles, I.N. and Brooker, M.R. (1998). Endeavour 42 deposit, Lake Cowal, New South Wales: a structurally controlled gold deposit, Australian Journal of Earth Sciences 45. 837-847.
- North Limited (1998). Cowal Gold Project Environmental Impact Statement. North Gold WA Limited, 13 March 1998.

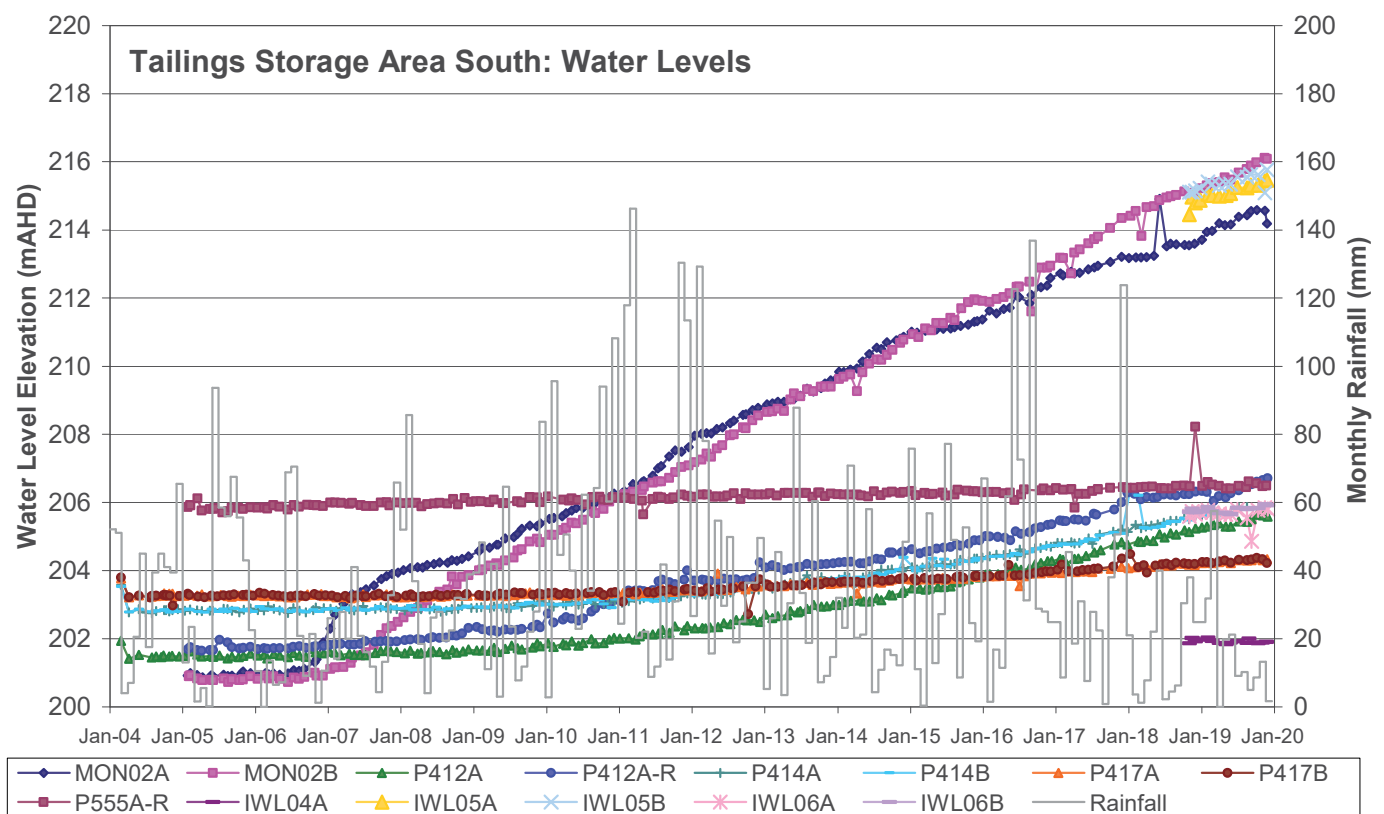
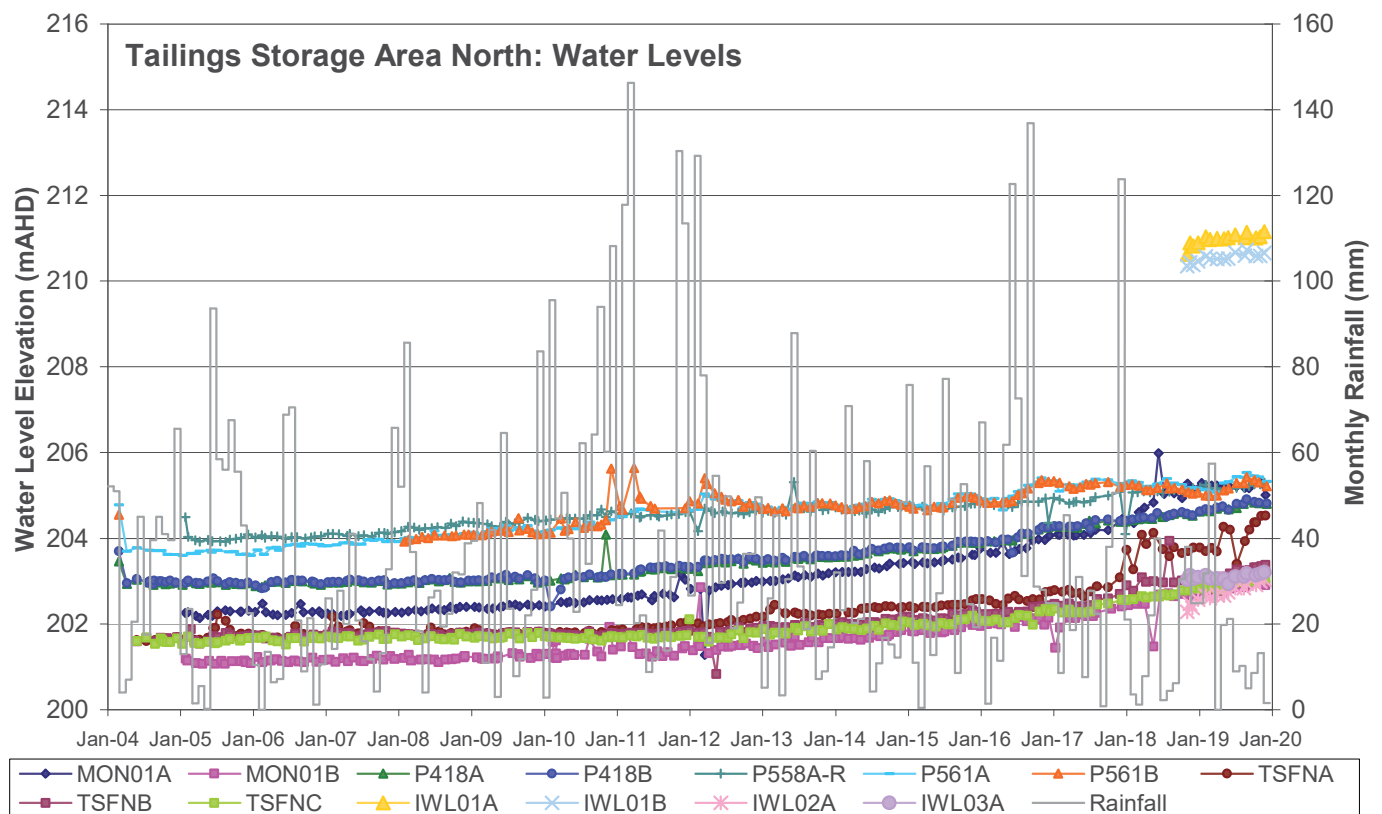
- Northern Resource Consultants (2016). Groundwater Investigation - Progressive Groundwater Level Rise in MON02A and MON02B. March 2016.
- New South Wales Department of Environment and Conservation (2007) Guidelines for the Assessment and Management of Groundwater Contamination.
- New South Wales Office of Water (2012). NSW Aquifer Interference Policy.
- Outotec Pty Ltd (2020). Evolution Mining - Cowal Gold Mine, GRE46 Underground Project, backfill pre-feasibility study, Report No. P6058-R02 Rev0, dated 19 April 2020.
- Schmidt, J.W., L. Simovic and E. Shannon (1981). Development Studies for Suitable Technologies for the Removal of Cyanide and Heavy Metals from Gold Milling Effluents. Proceedings of the 36th Industrial Waste Conference, Purdue University, pp. 831-846.
- SNC-Lavalin Australia (2003). Cowal Gold Project Geotechnical Investigation Report. Report 334371-0000-4GRA-0001 prepared for Barrick Gold of Australia. URS Australia Pty Limited (2005). Cowal Northern Tailings Storage Facility – Floor Permeability, Reference 51755-005.
- URS Australia Pty Limited (2006). Cowal Southern Tailings Storage Facility – Floor Permeability, Reference 43167213.
- Watermark Numerical Computing (2004), PEST – Model independent parameter estimation, User Manual, 5th Edition, Watermark Numerical Computing.
- Williams, B.G. (1993). The Shallow Groundwater Hydrology of the Jemalong – Wyldes Plains Irrigation Districts, NSW Department of Agriculture, March.
- Zoback, M.D. (2007), Reservoir Geomechanics, Cambridge University Press

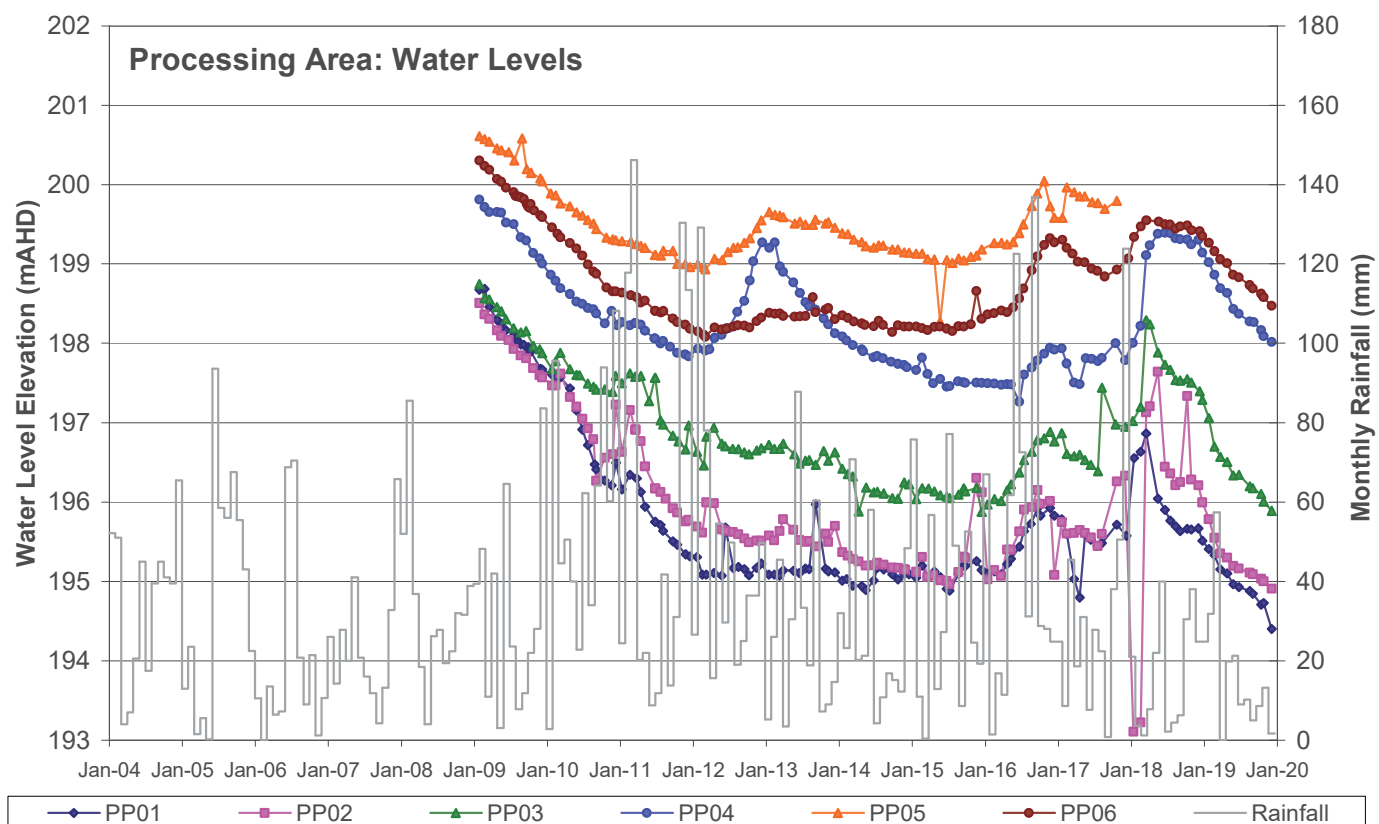


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## **Appendix A - Groundwater monitoring**



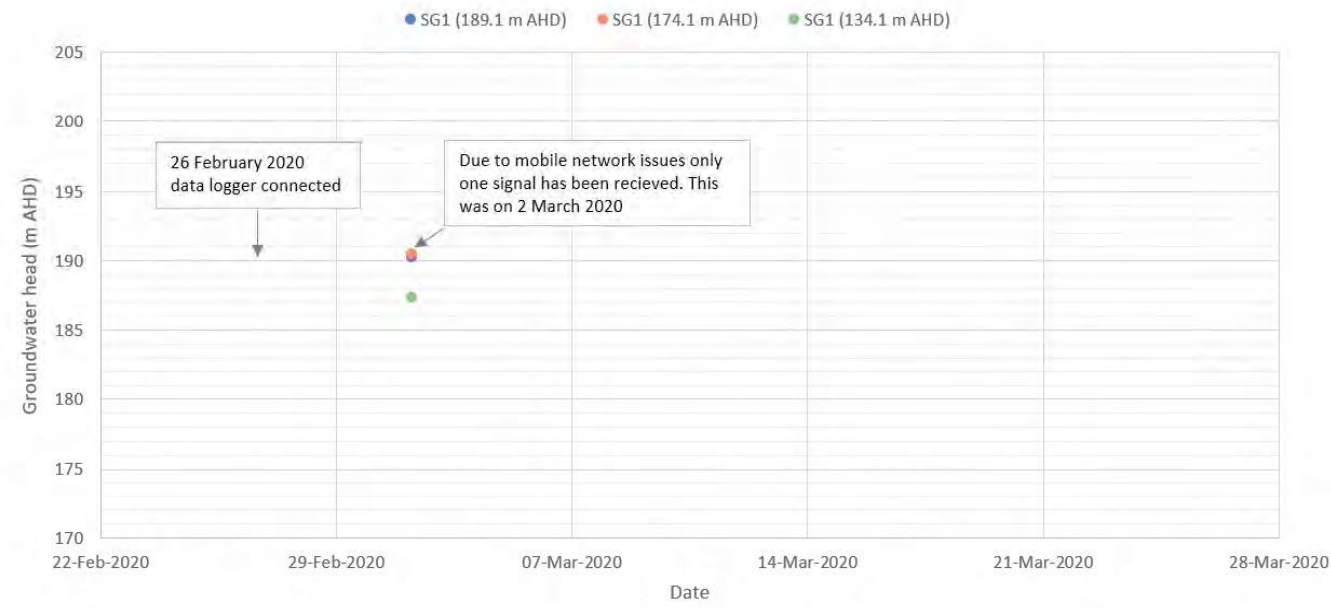




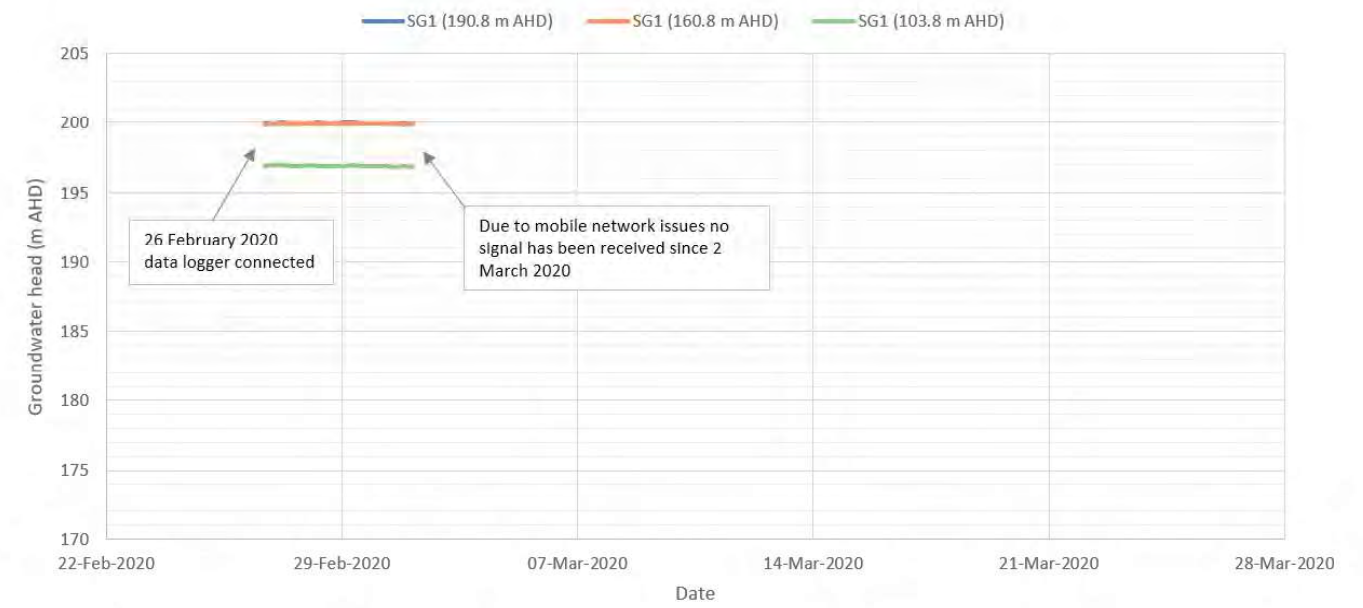


# Groundwater hydrographs - CGO Underground Development EIS

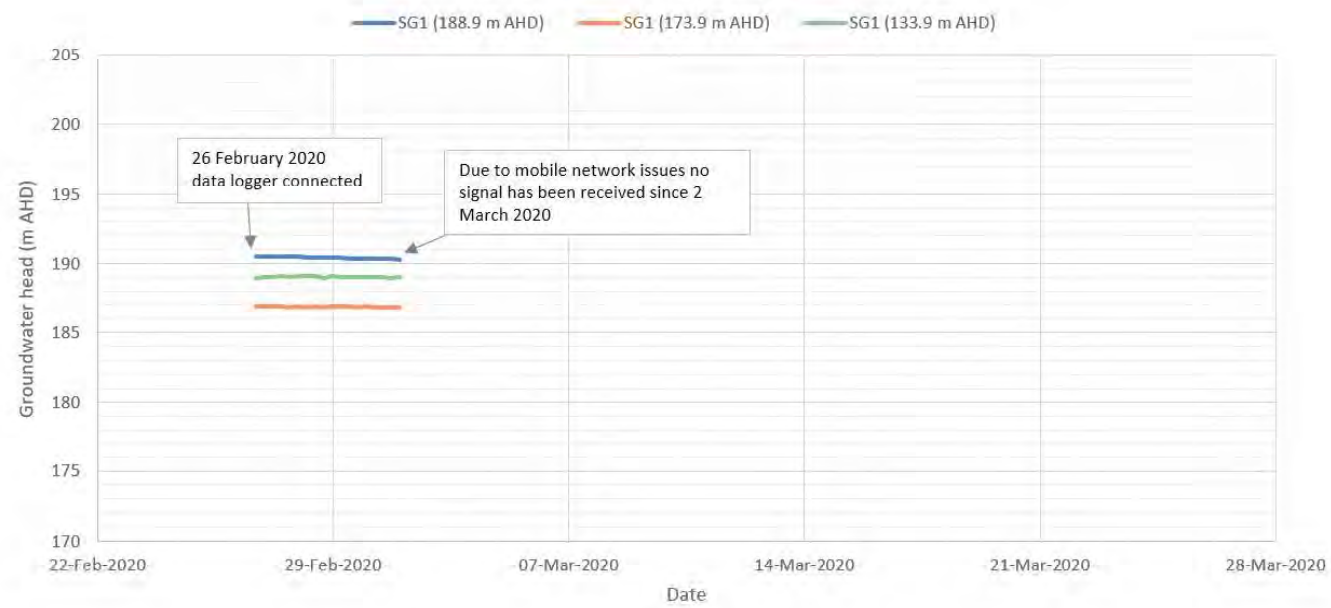
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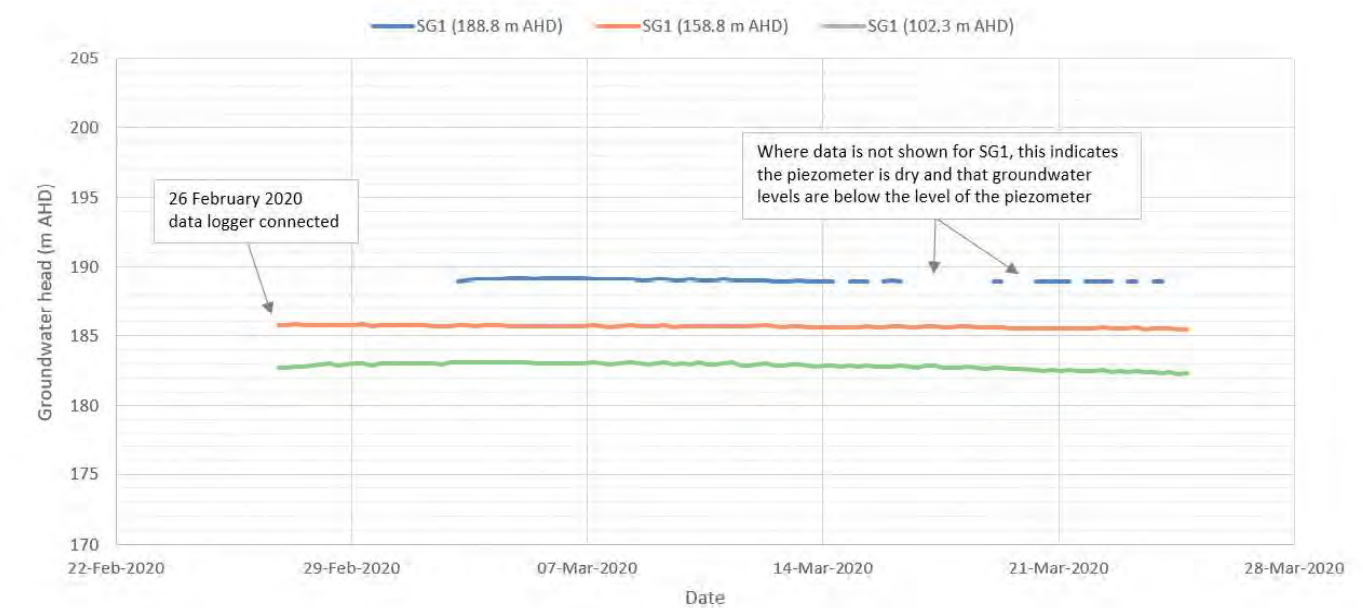
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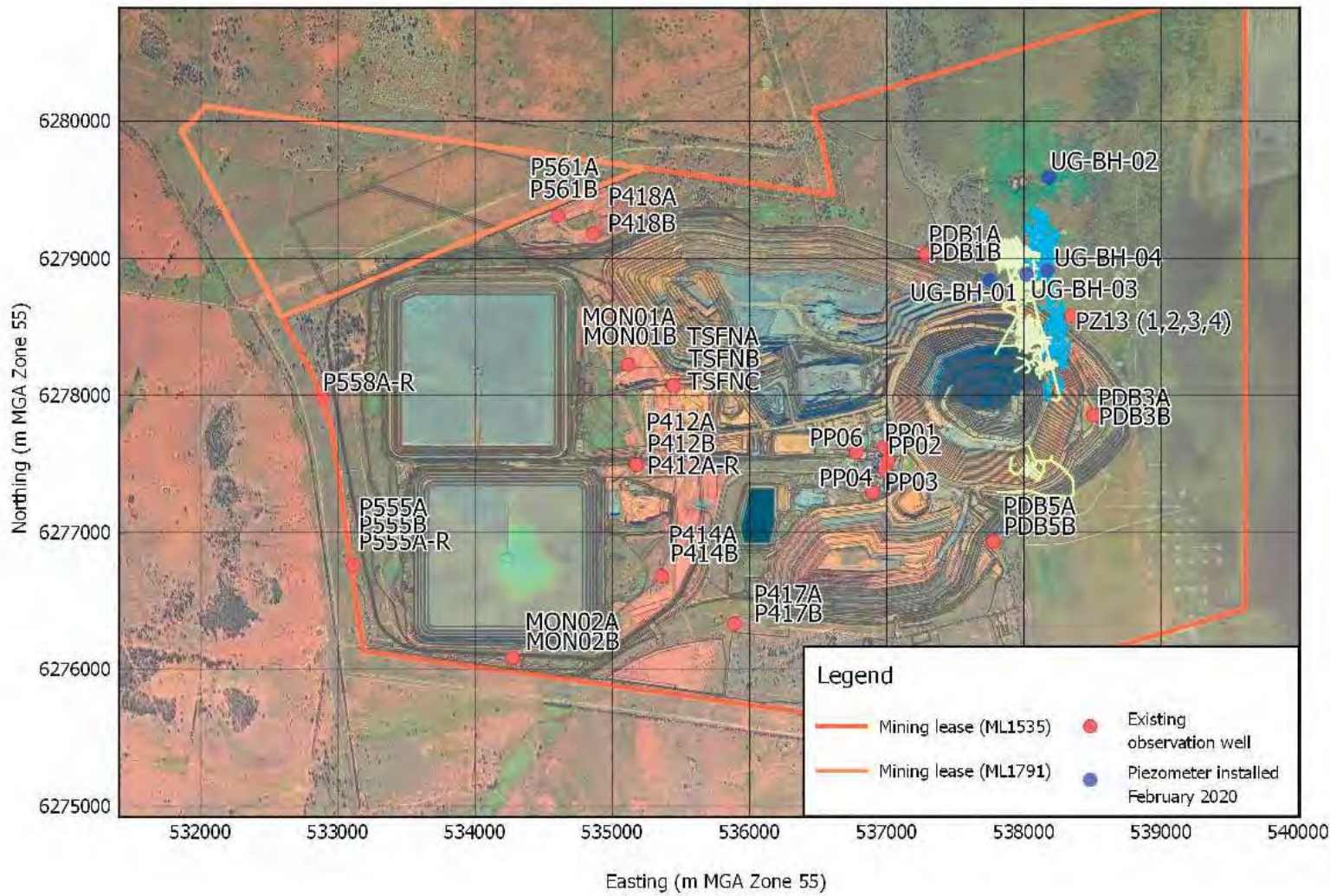


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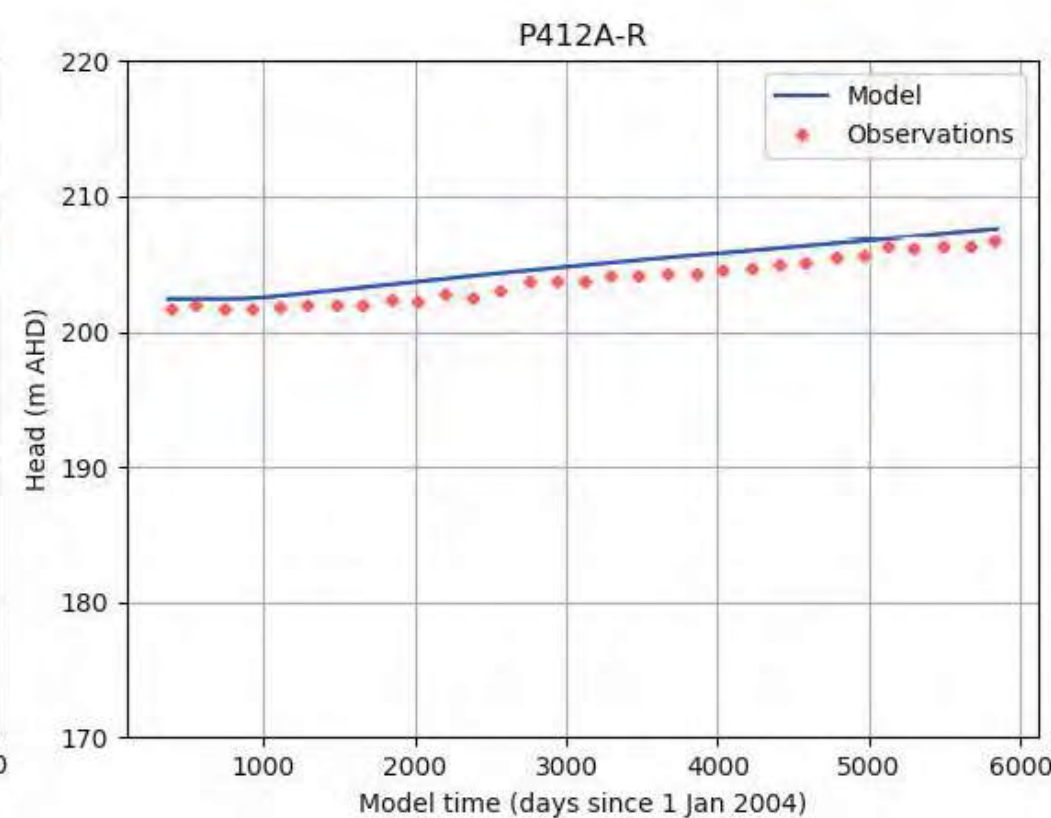
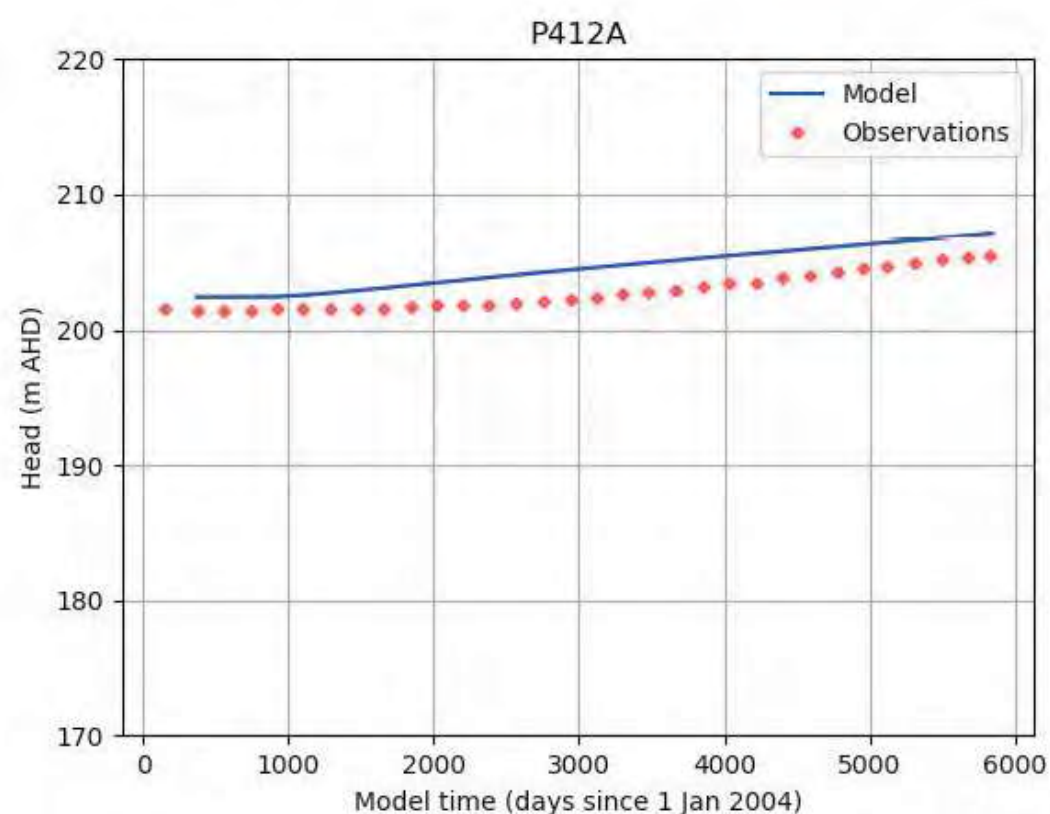
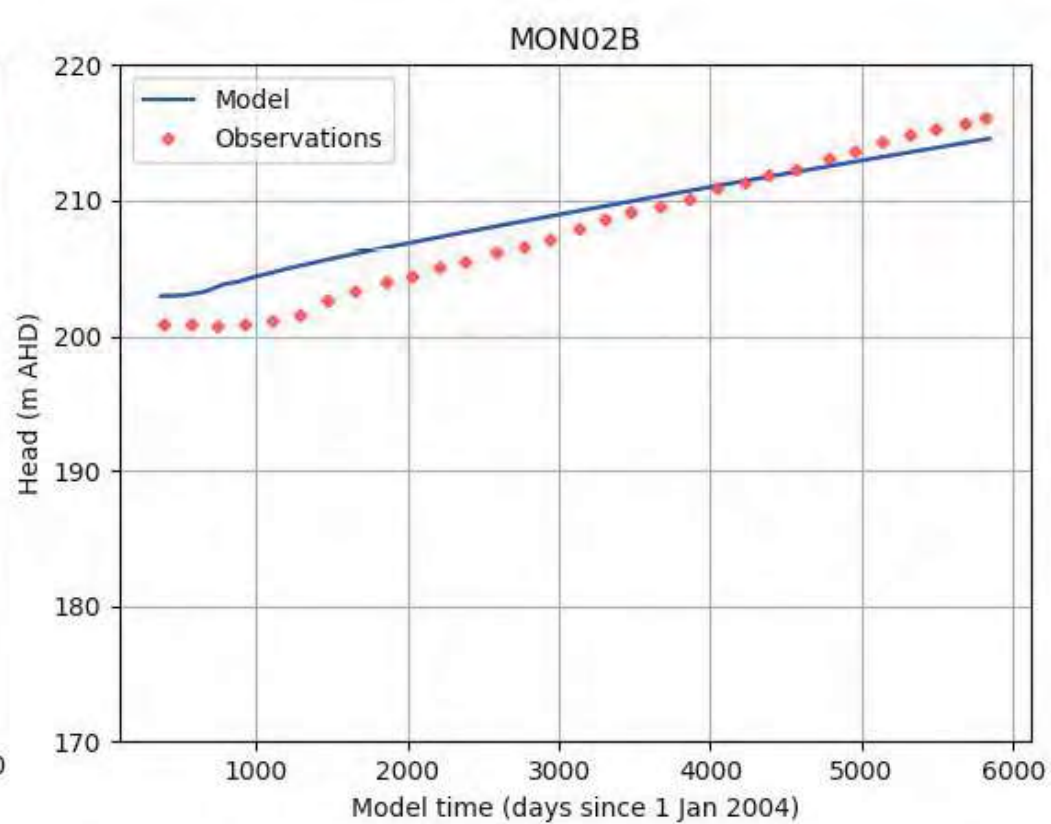
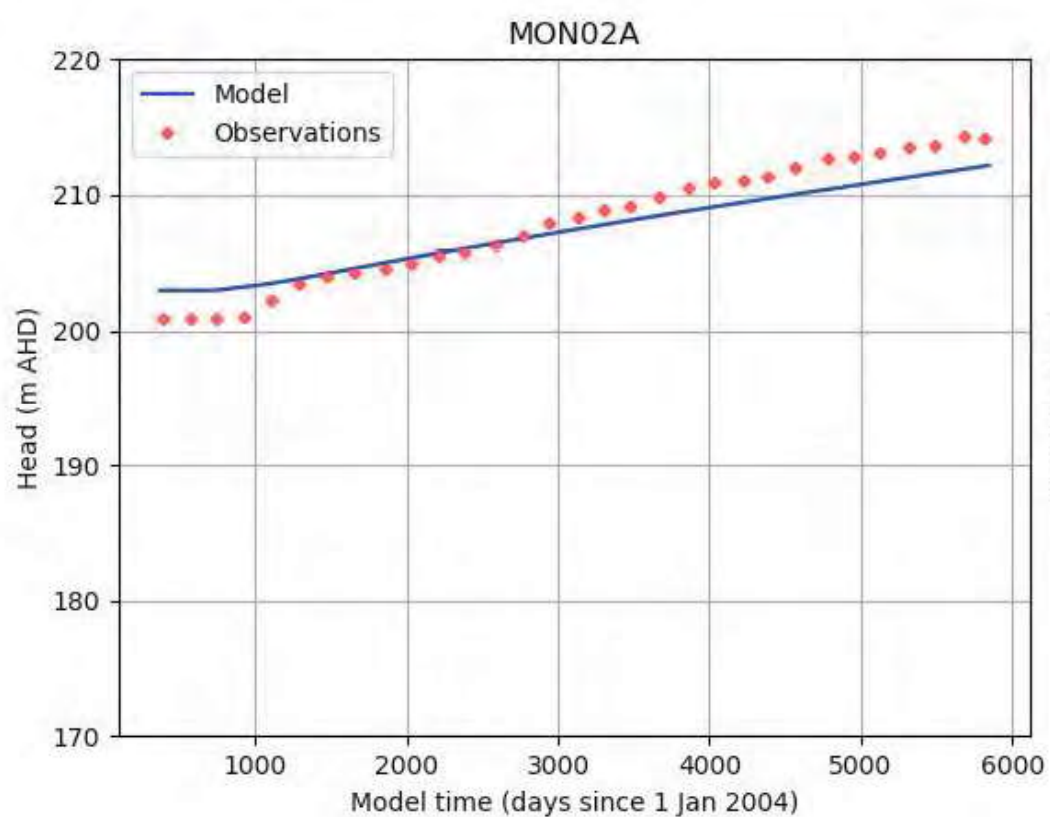
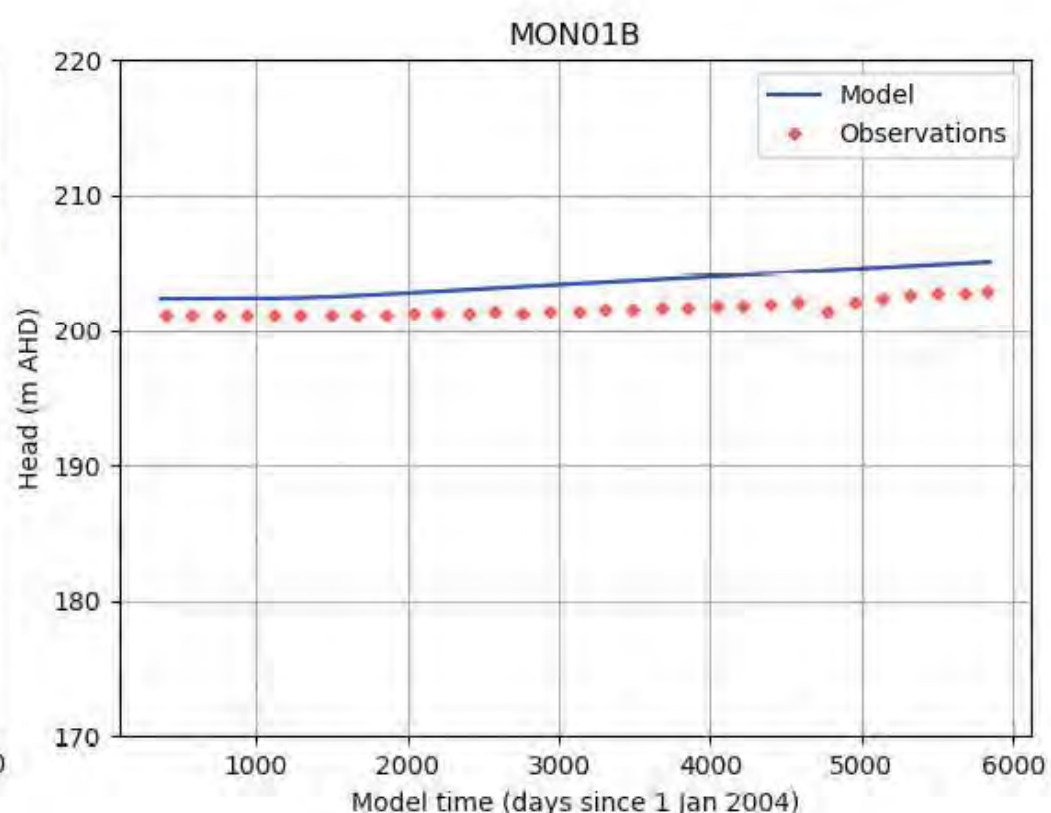
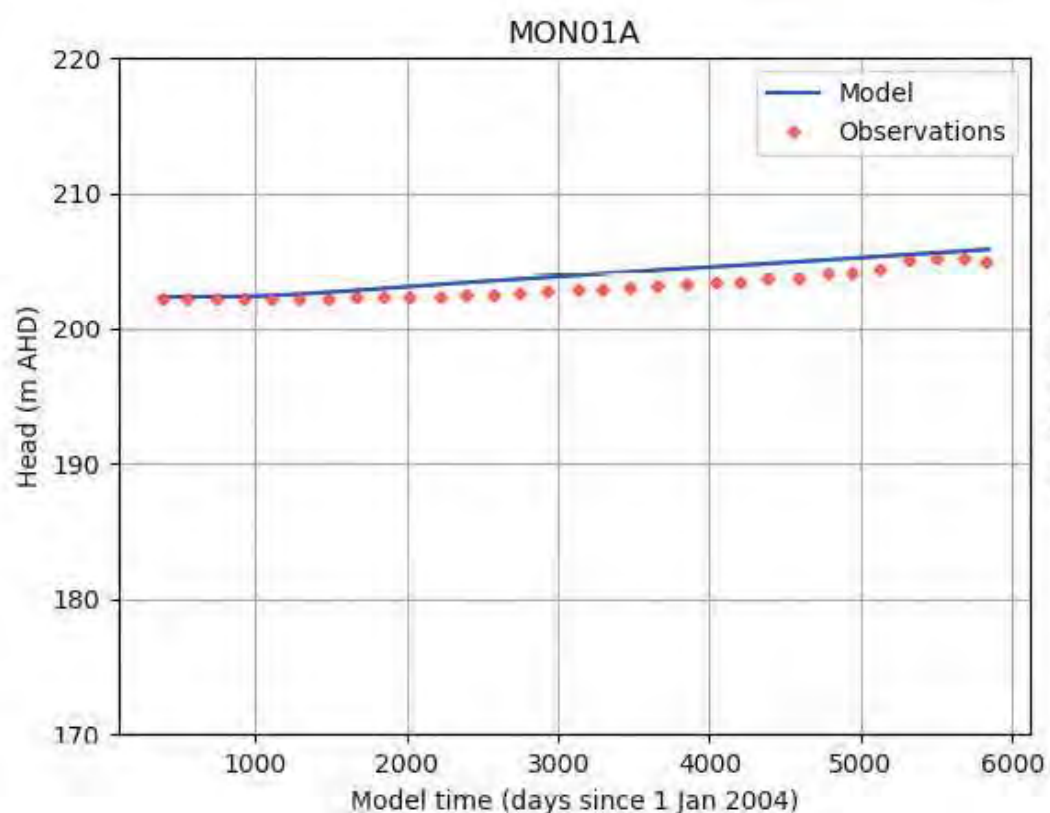
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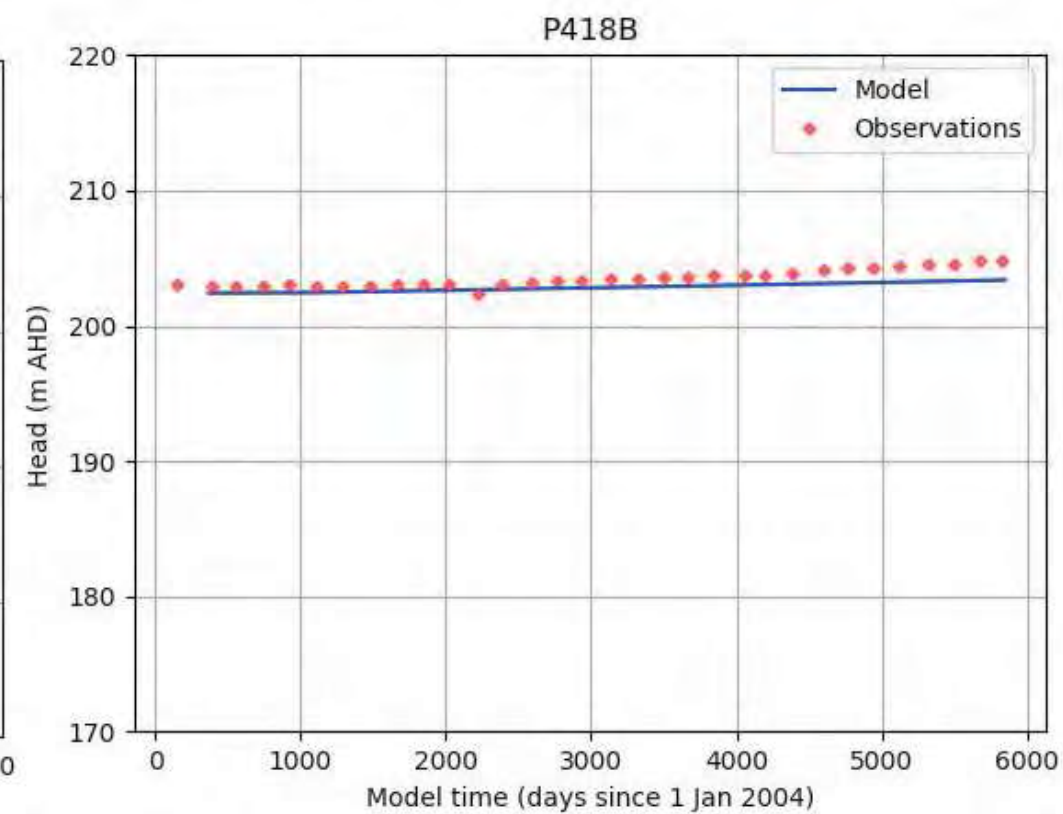
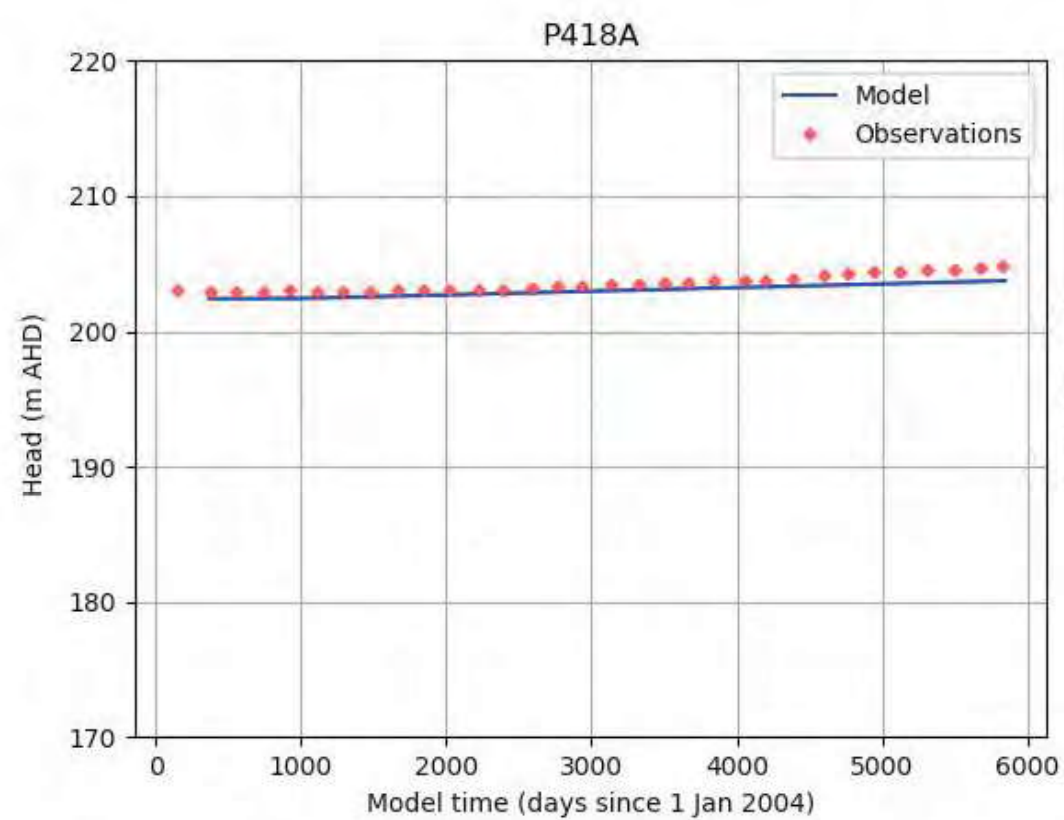
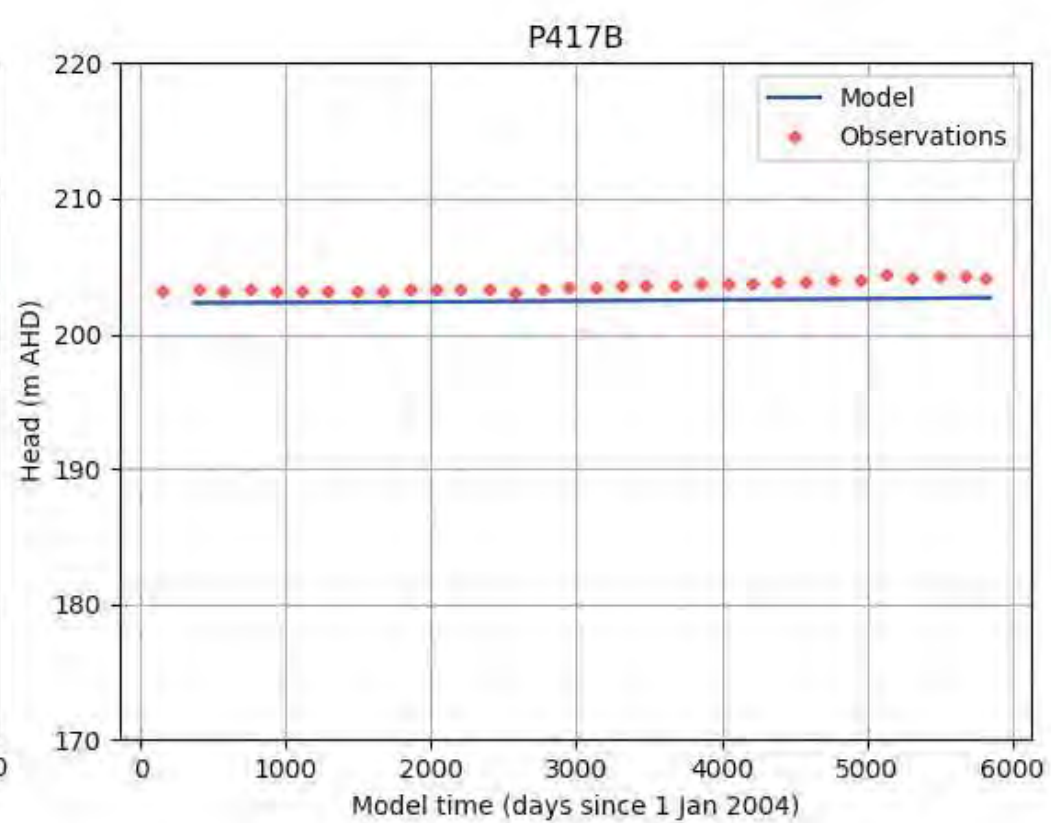
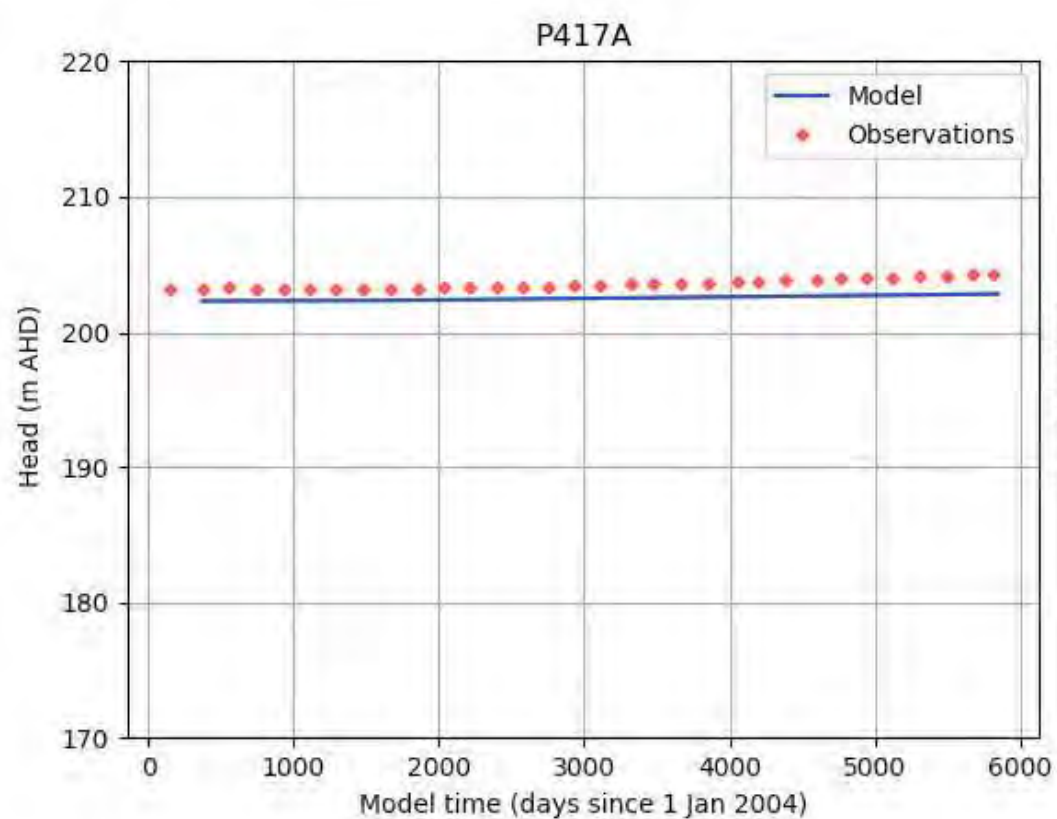
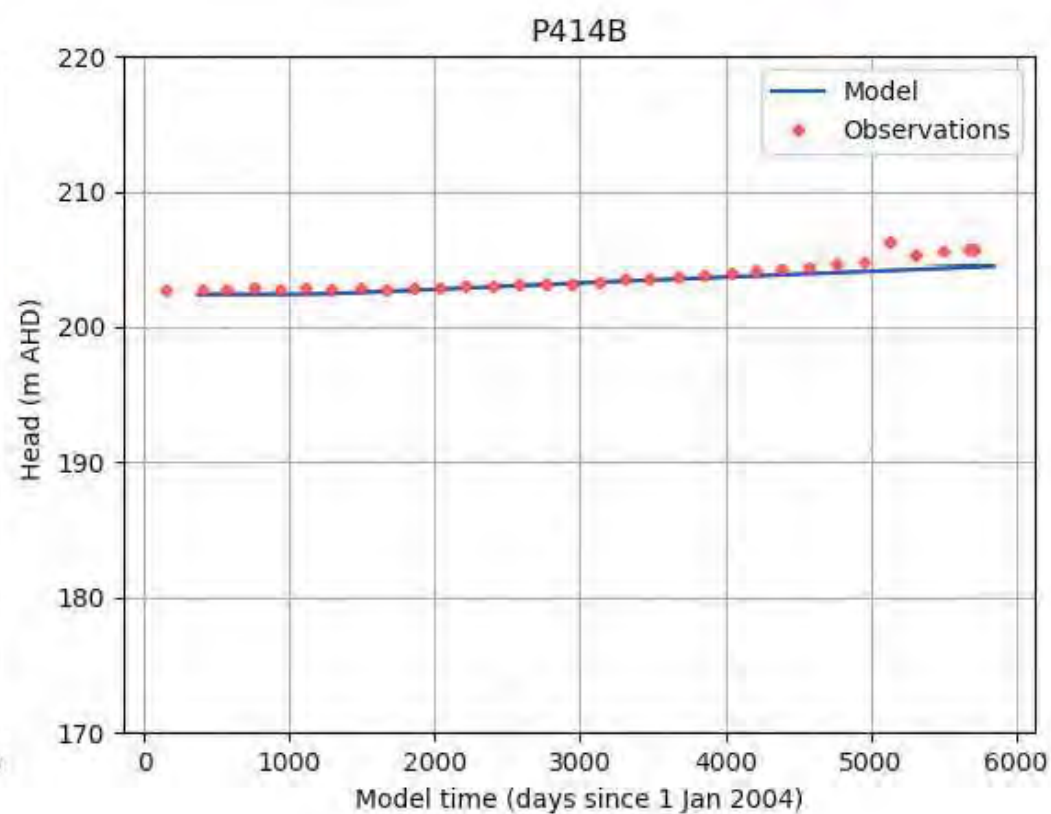
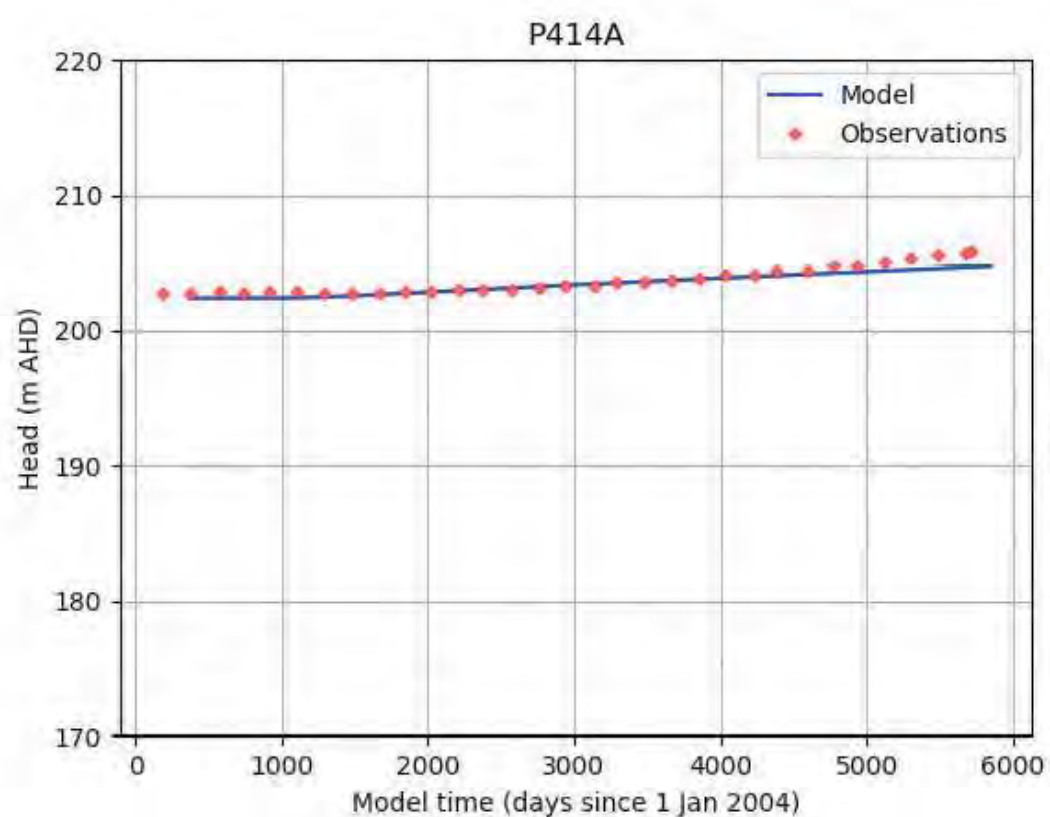




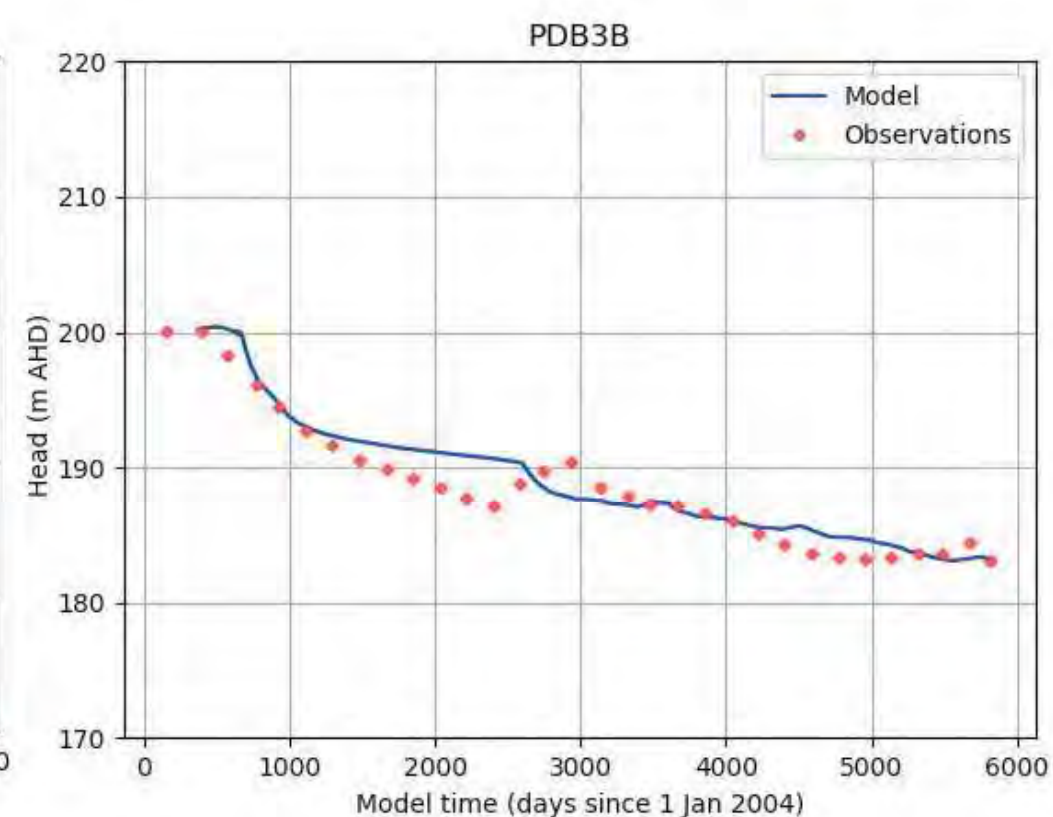
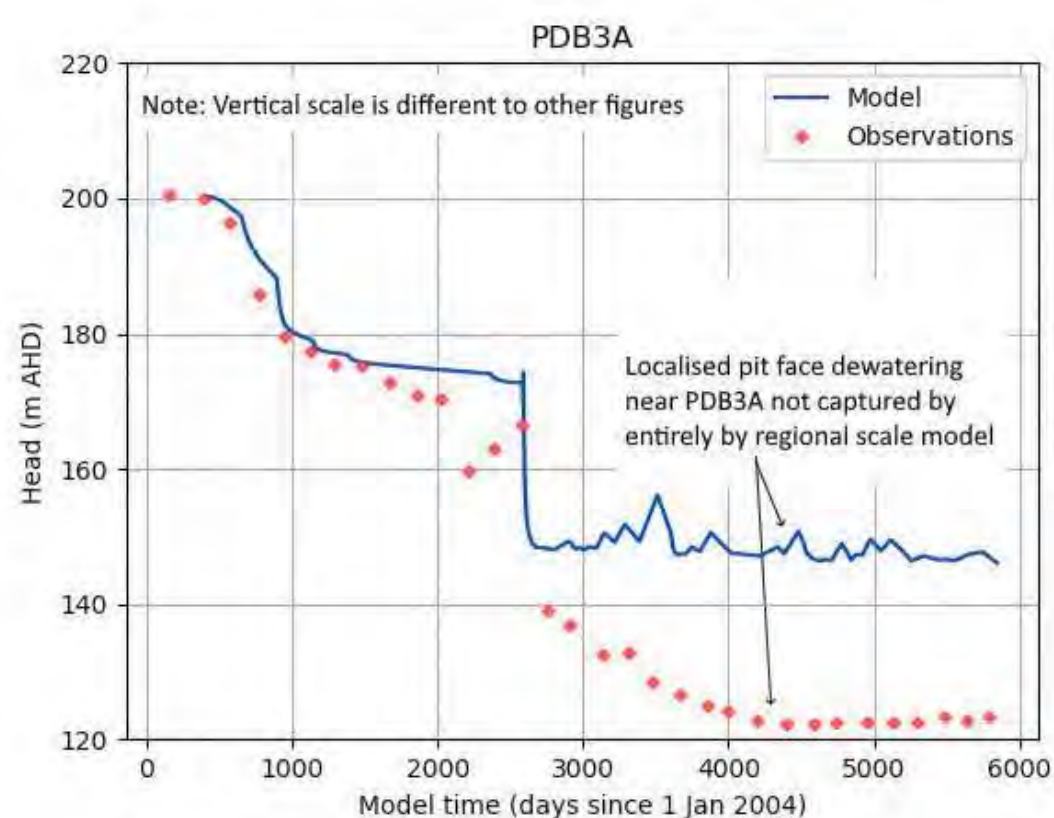
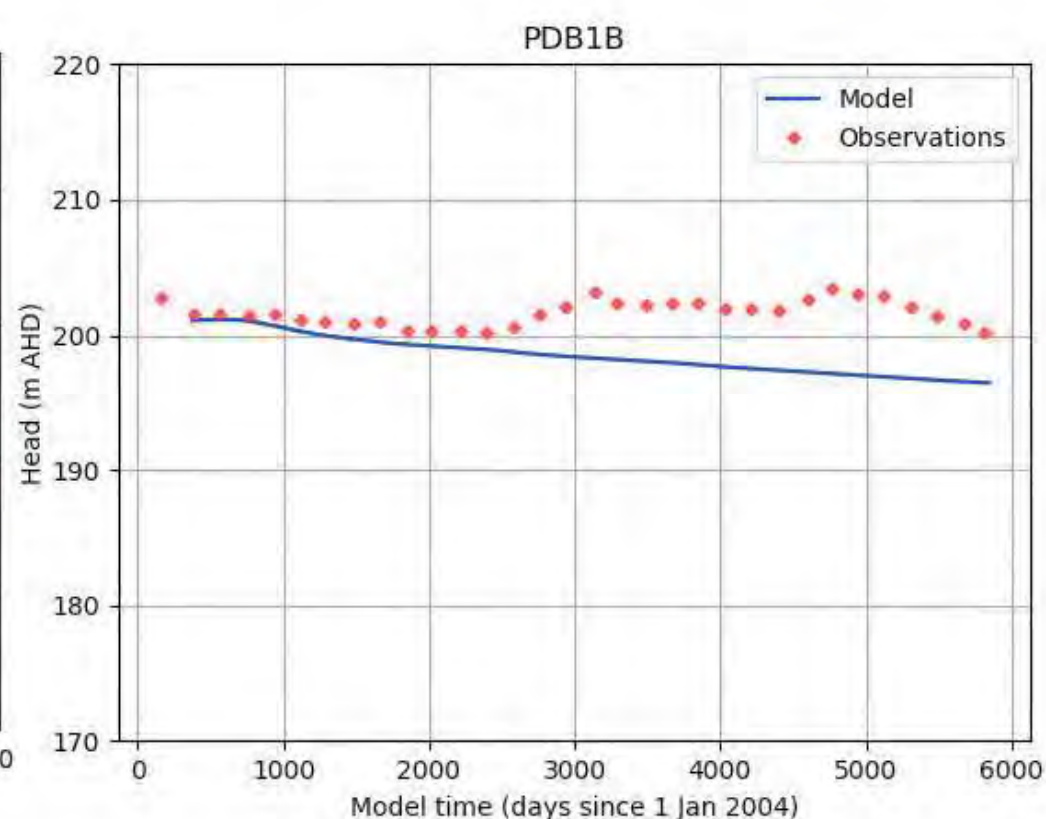
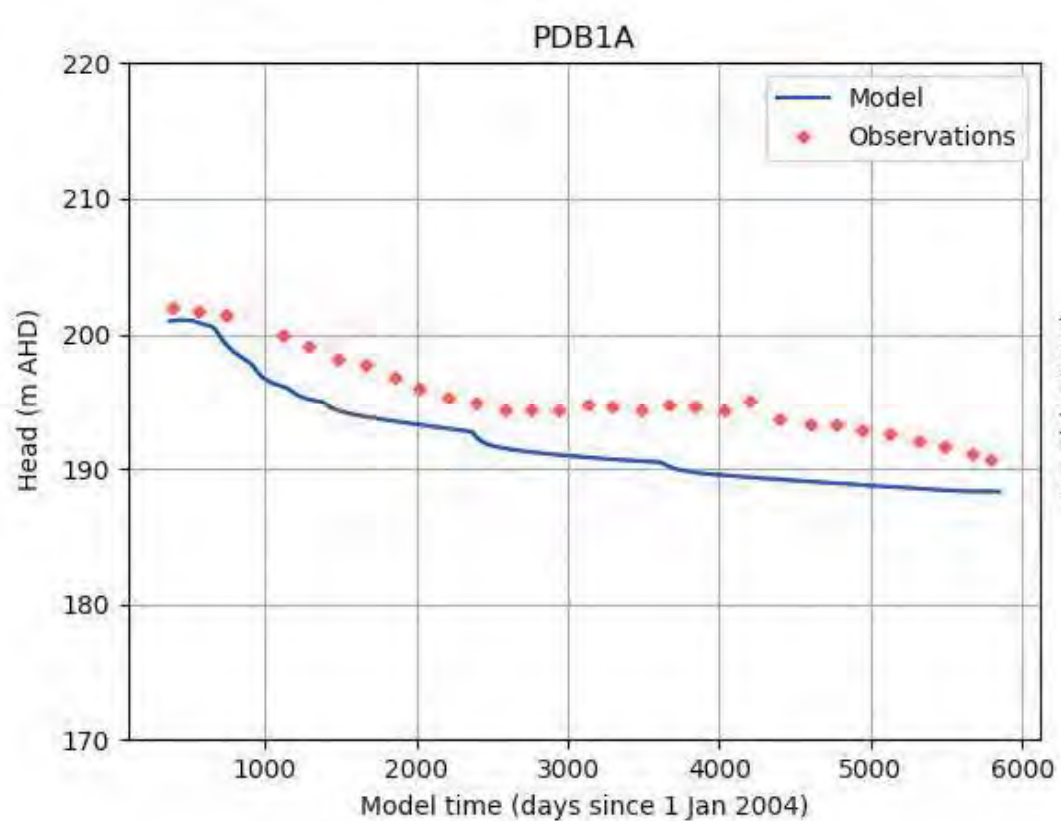
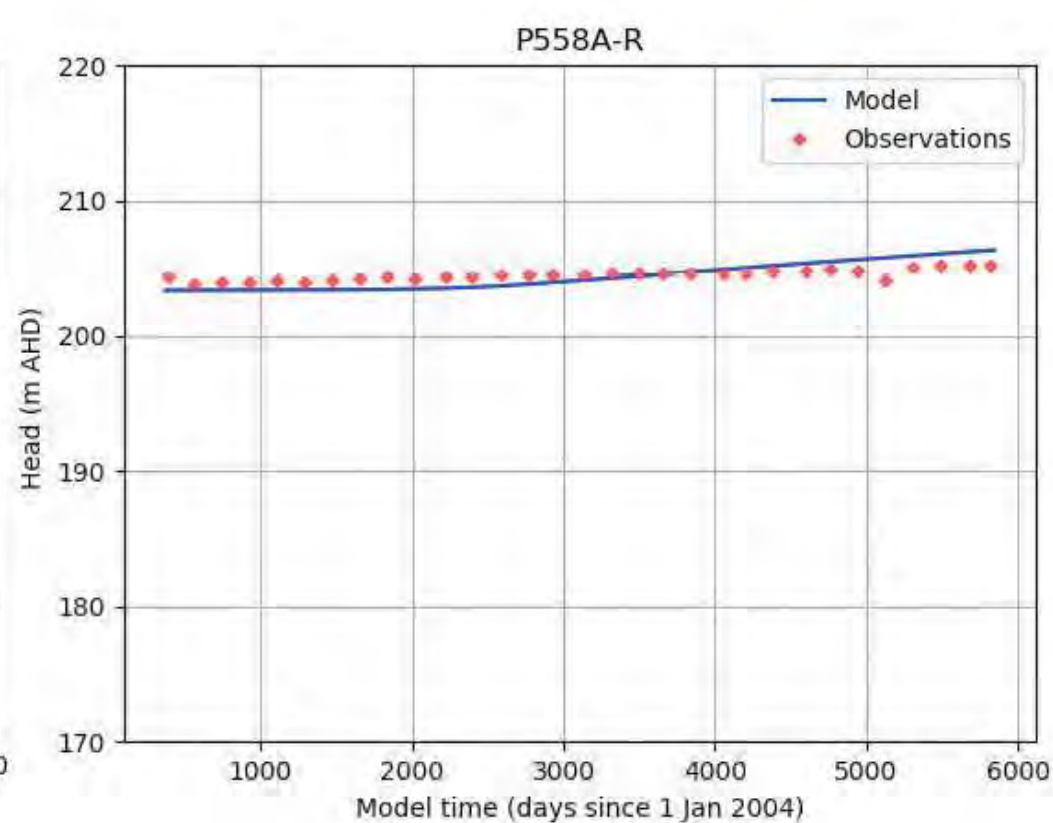
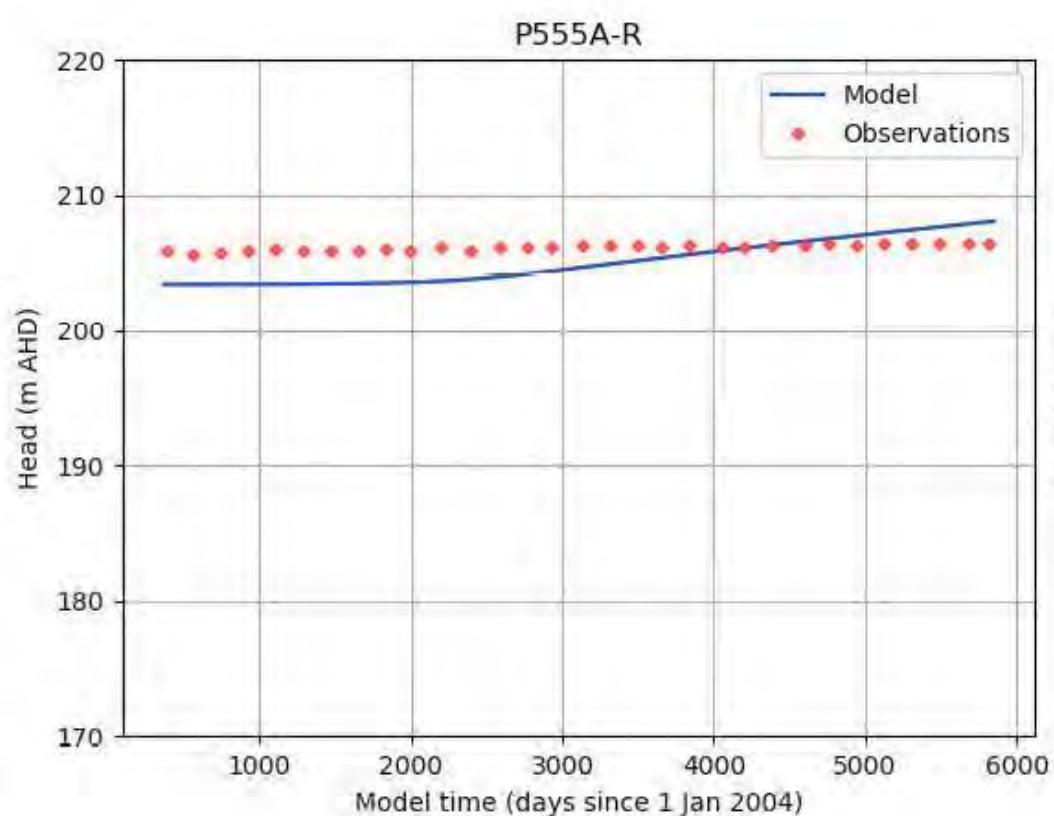
## **Appendix B - Groundwater calibration comparisons**

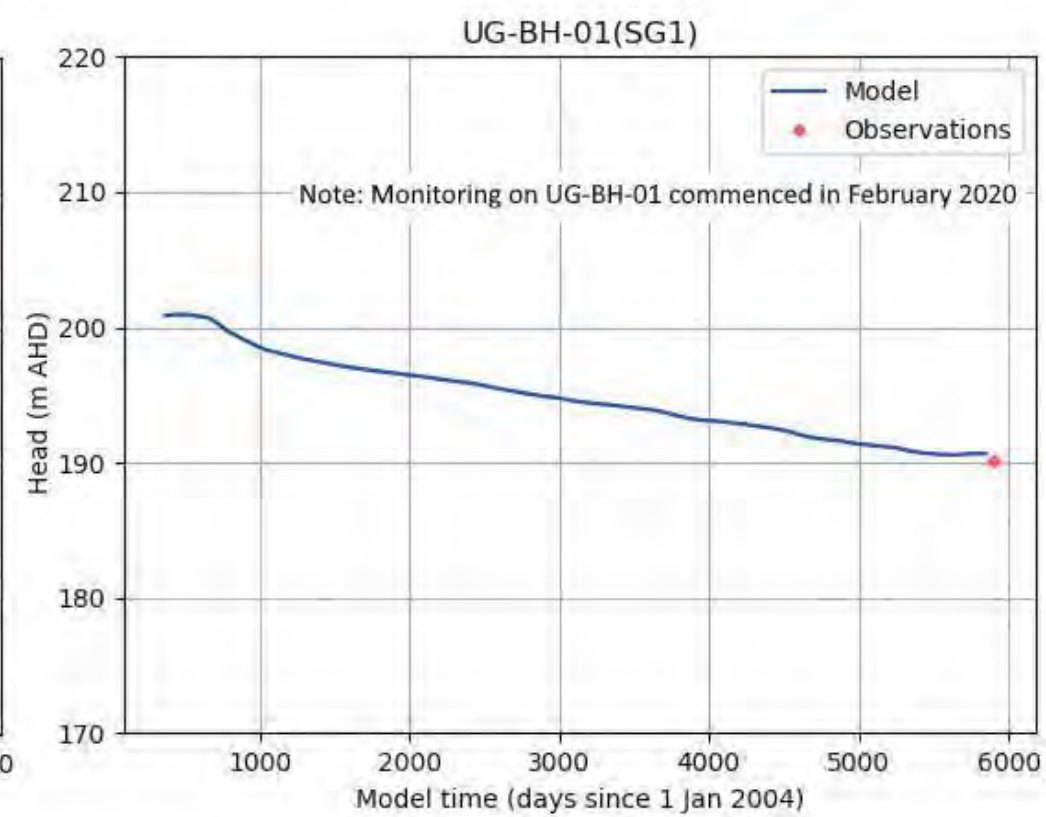
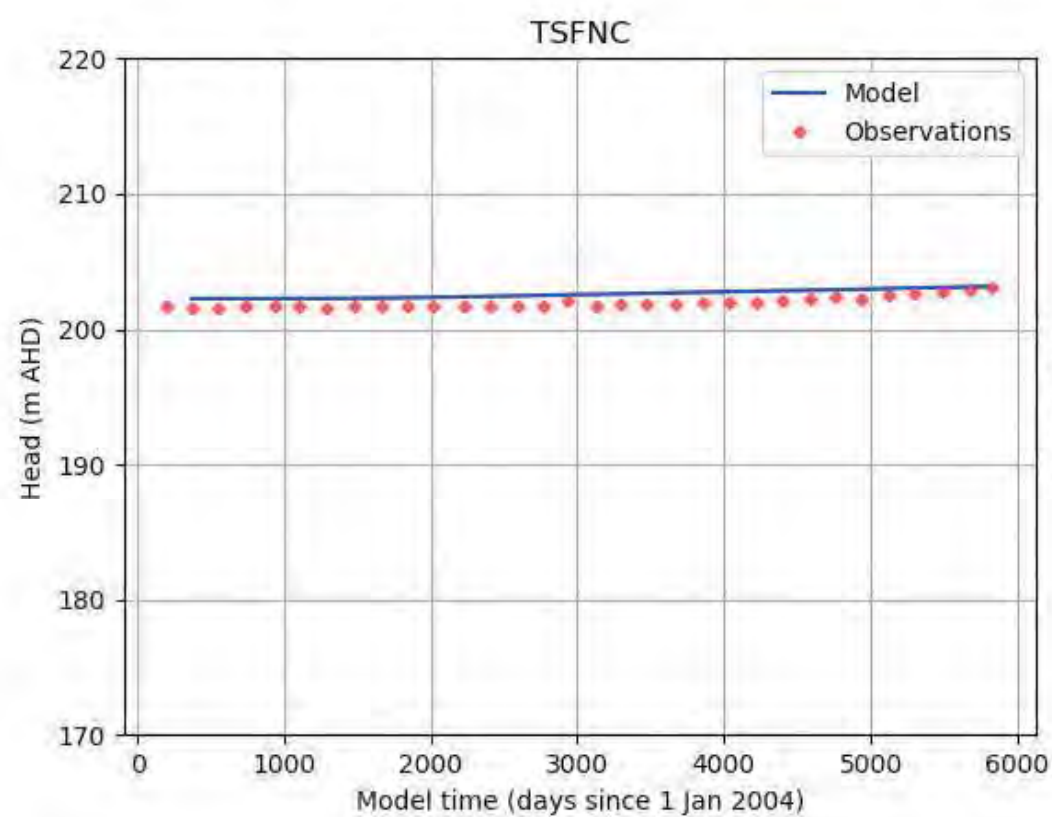
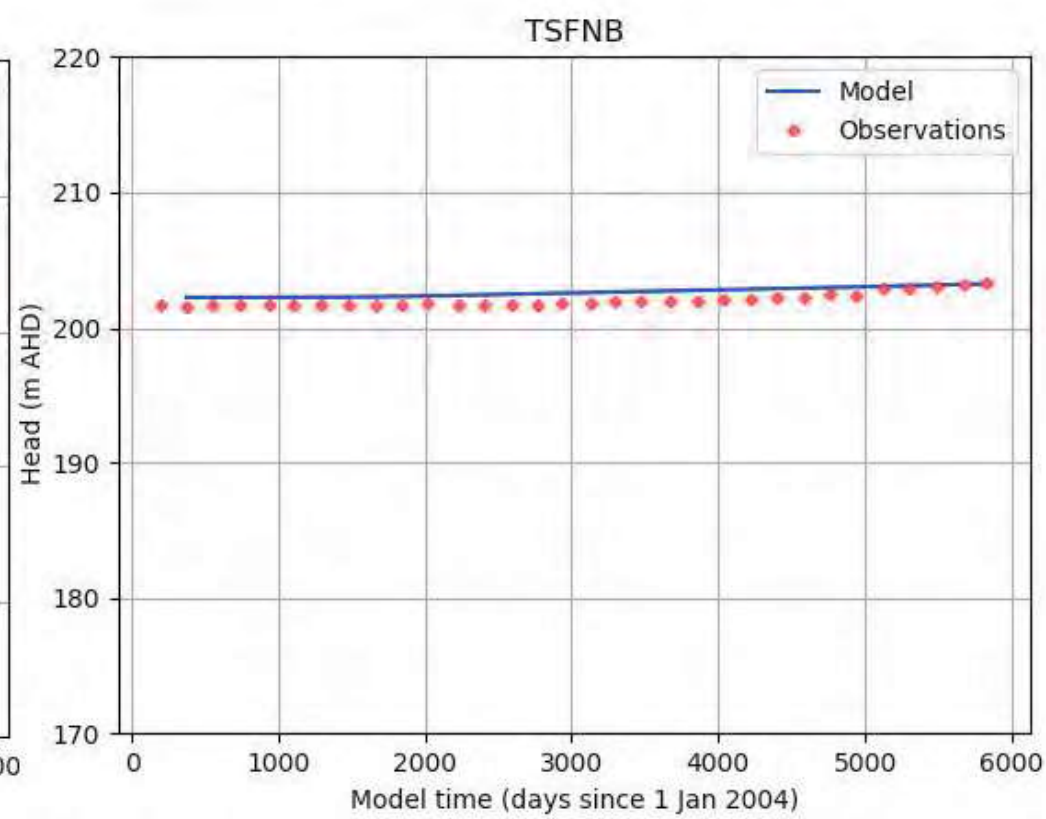
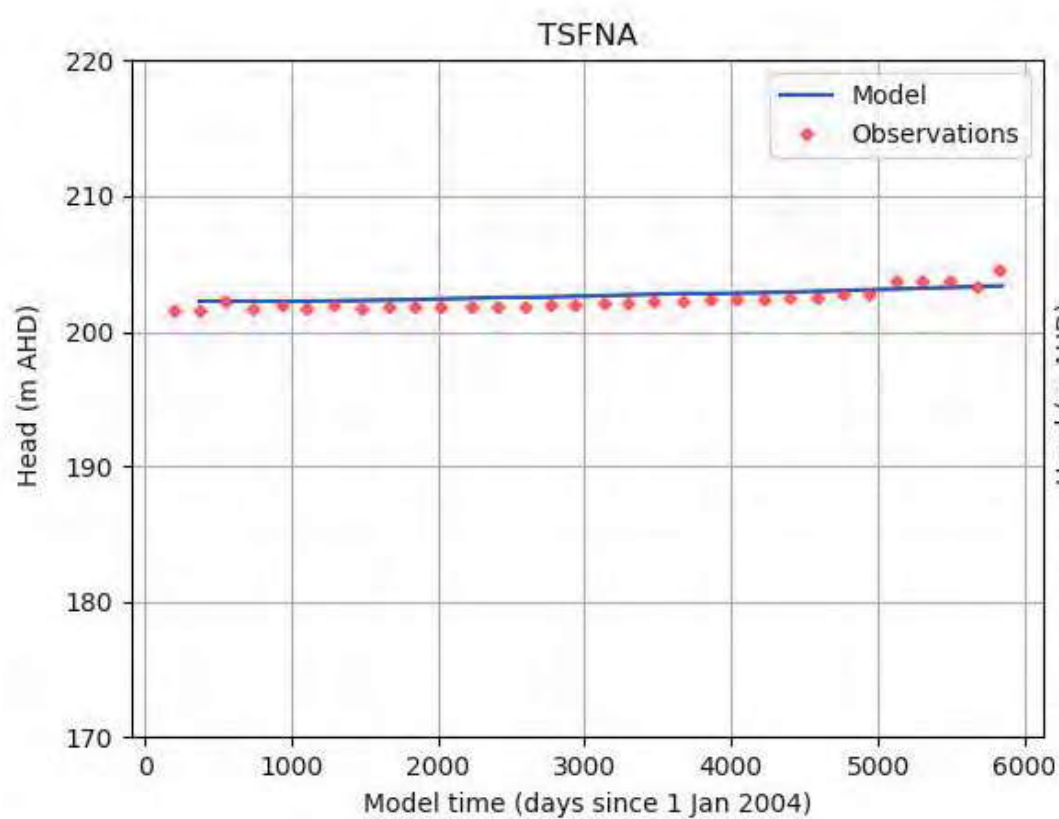
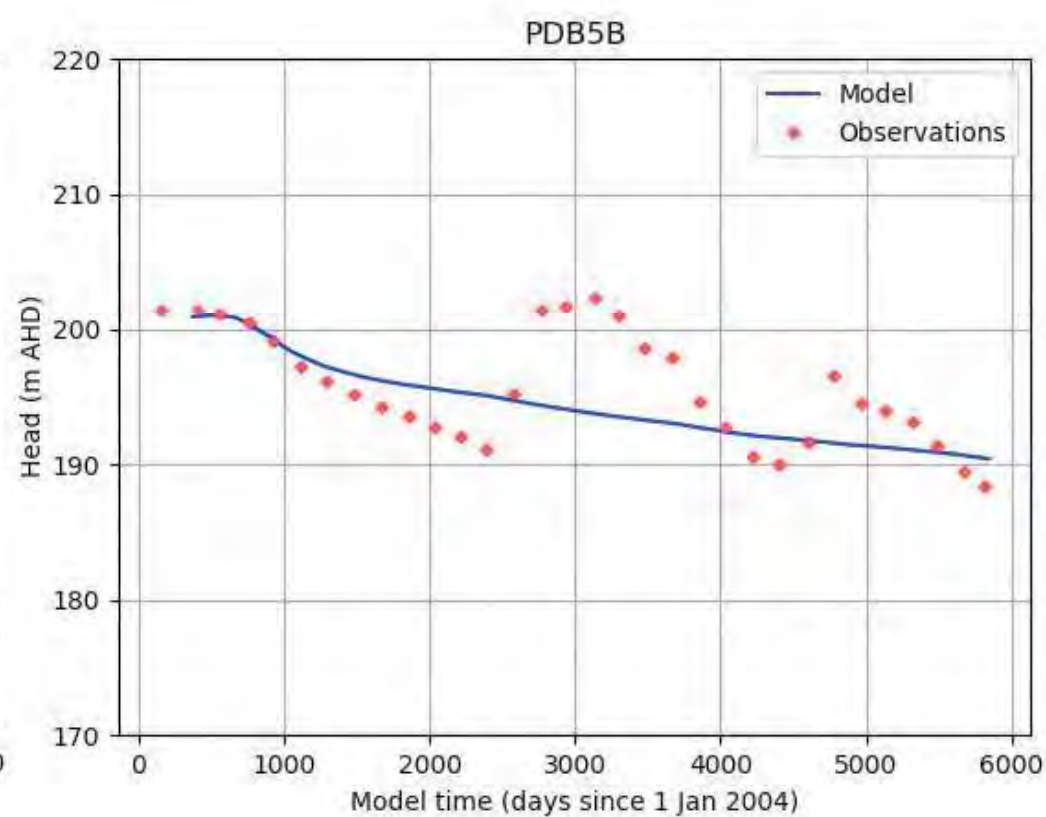
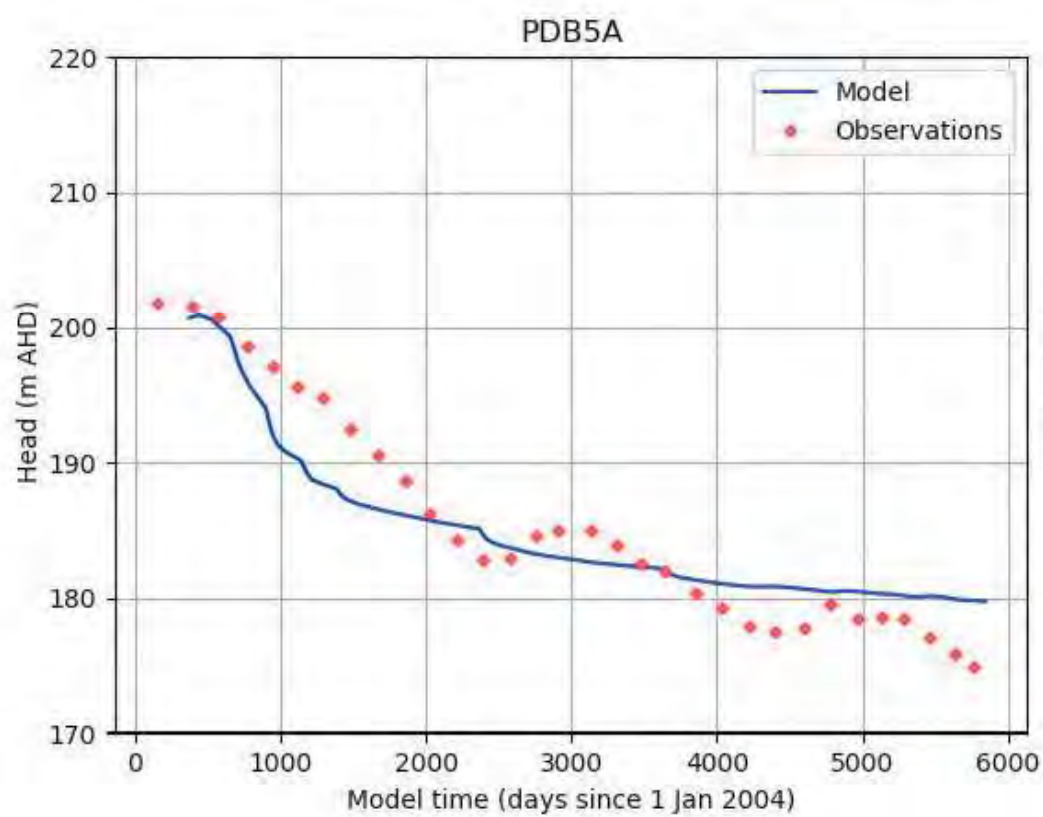






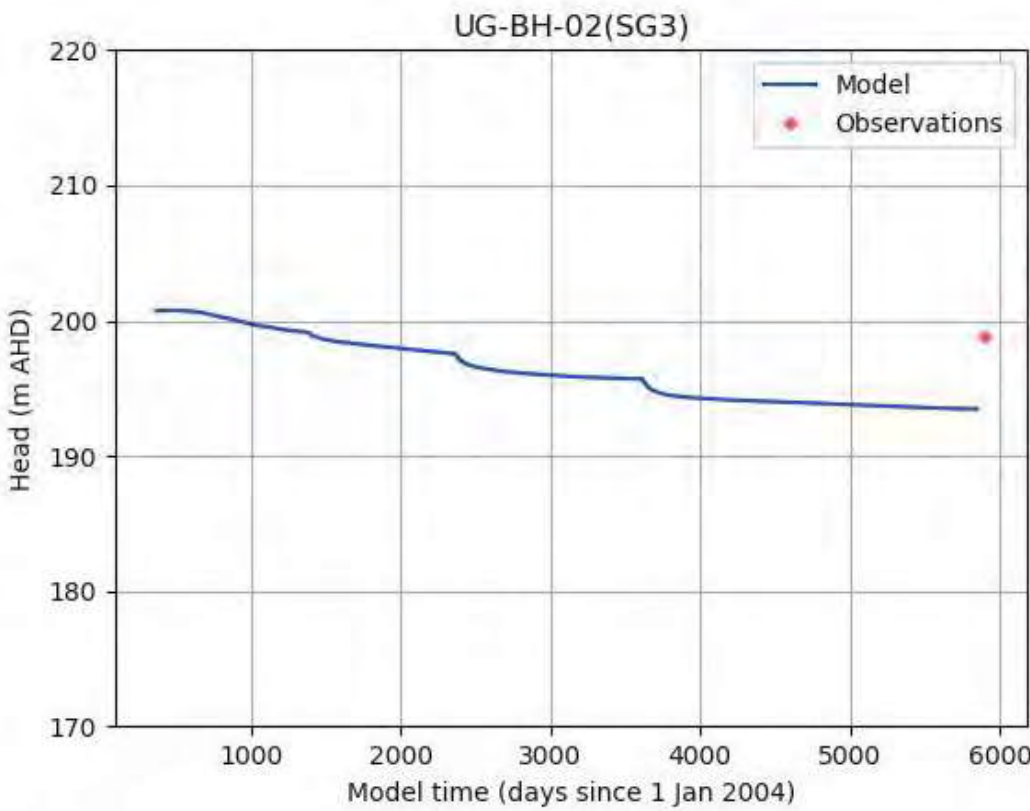
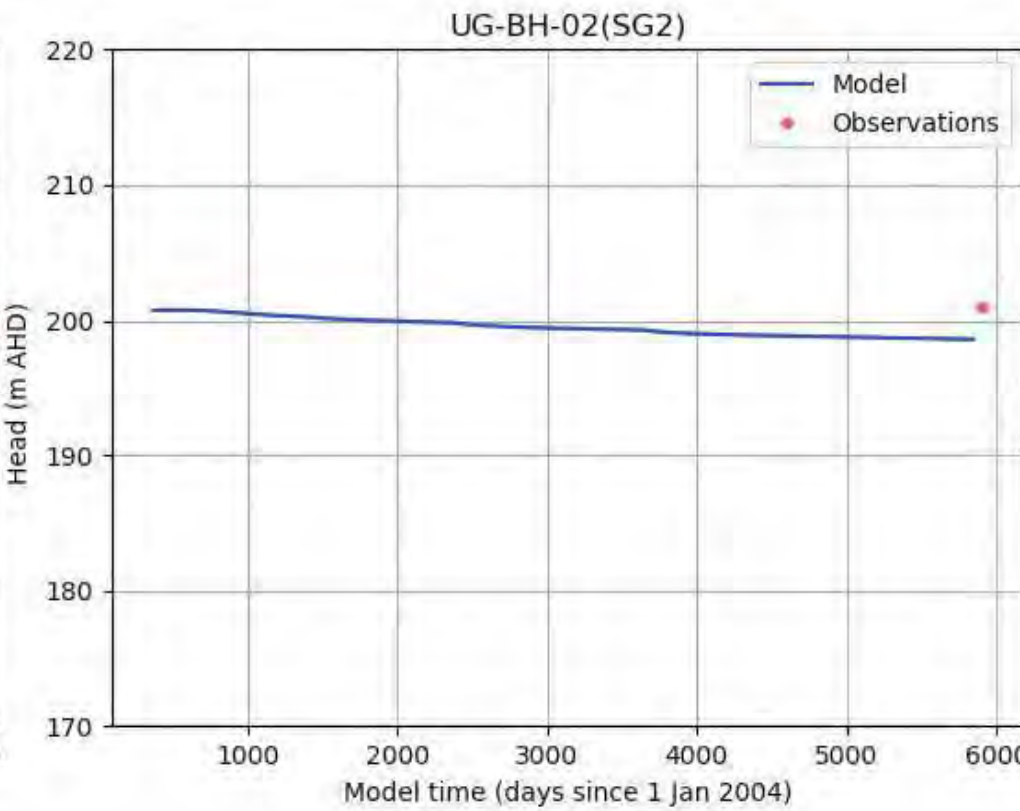
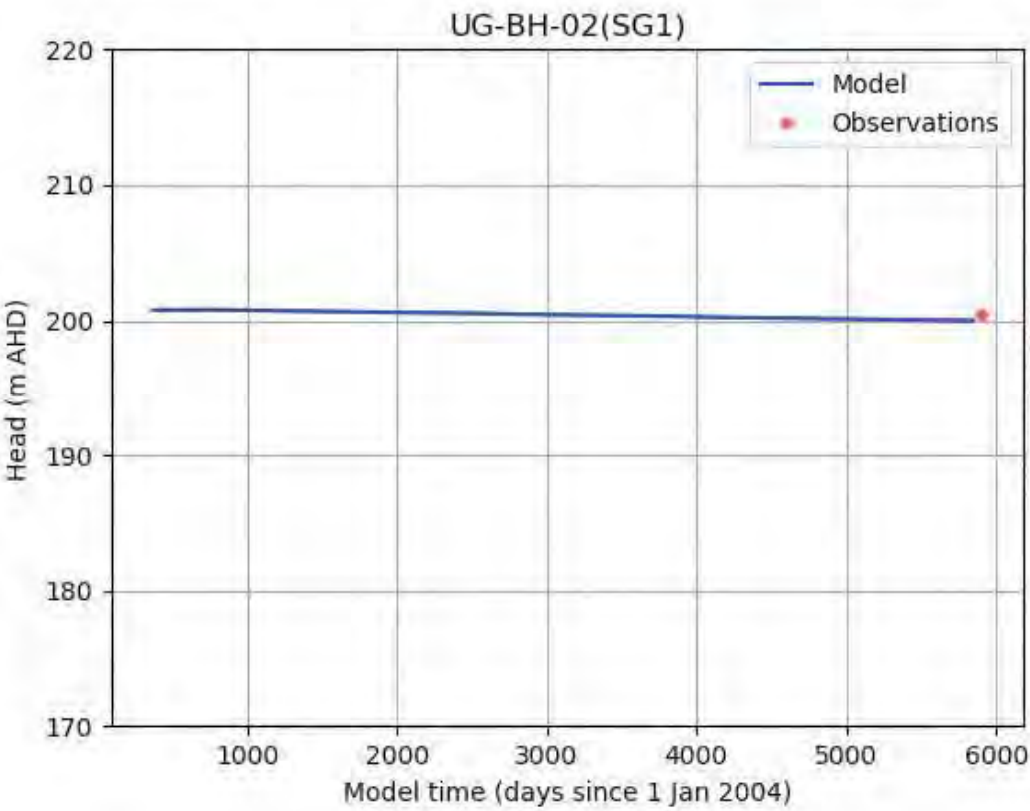
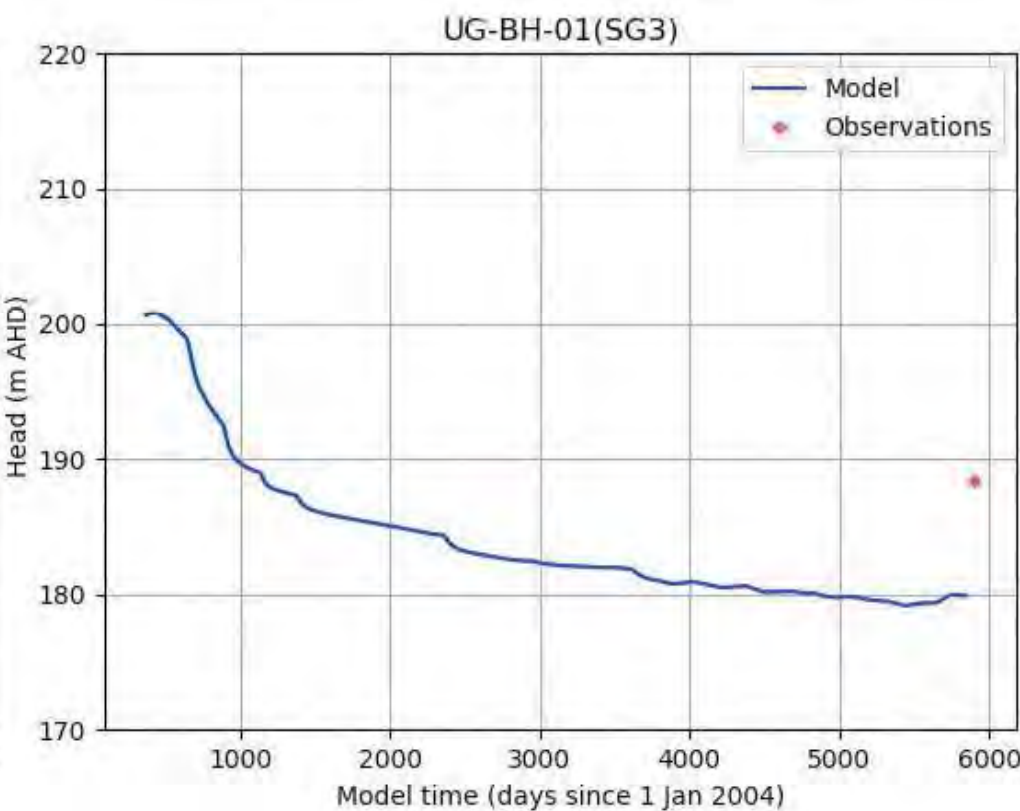
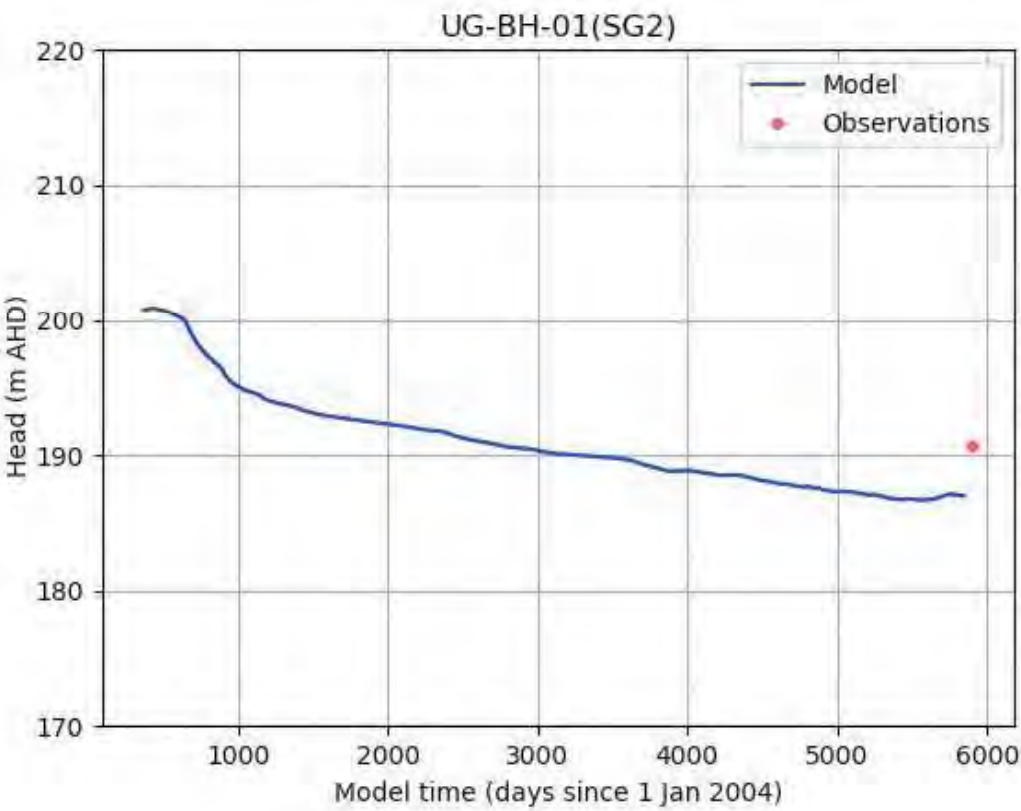




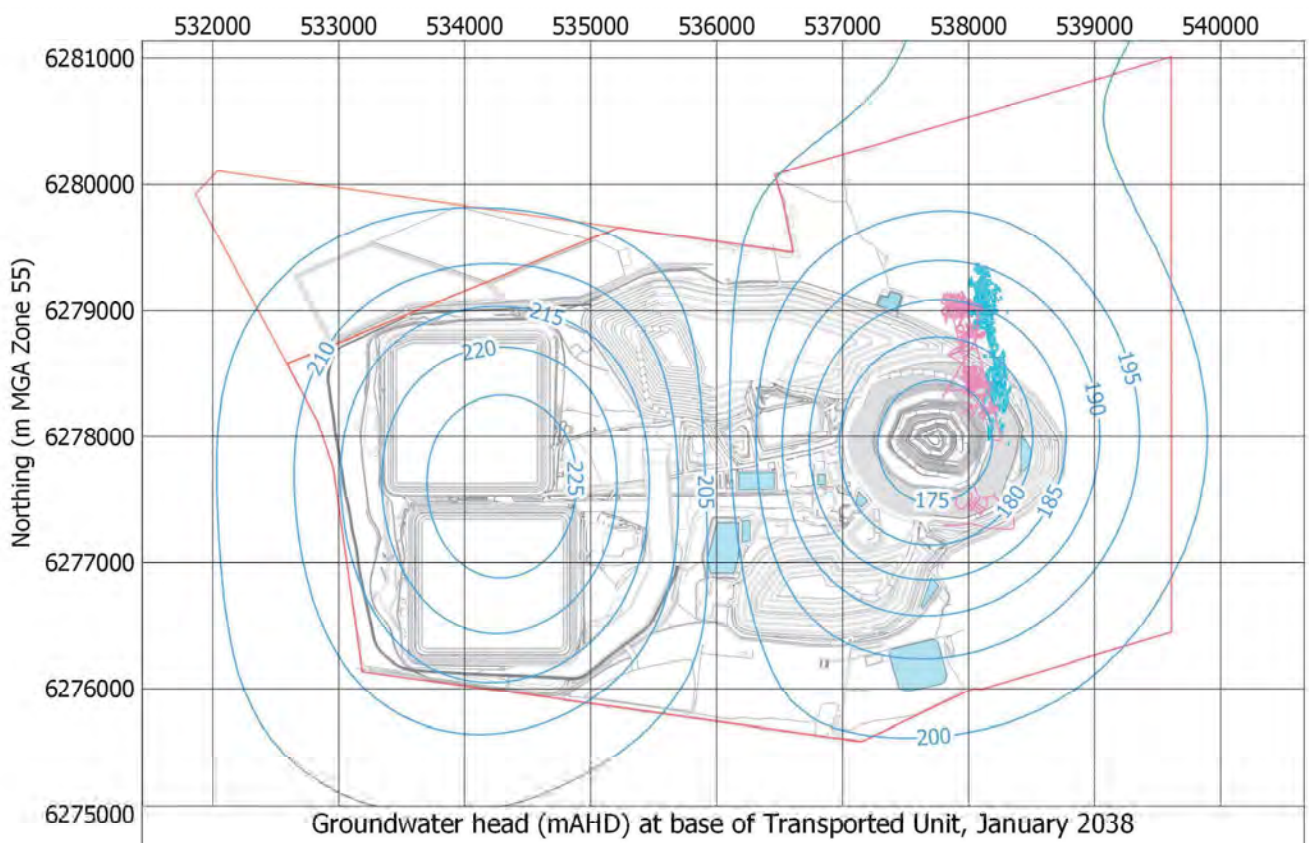
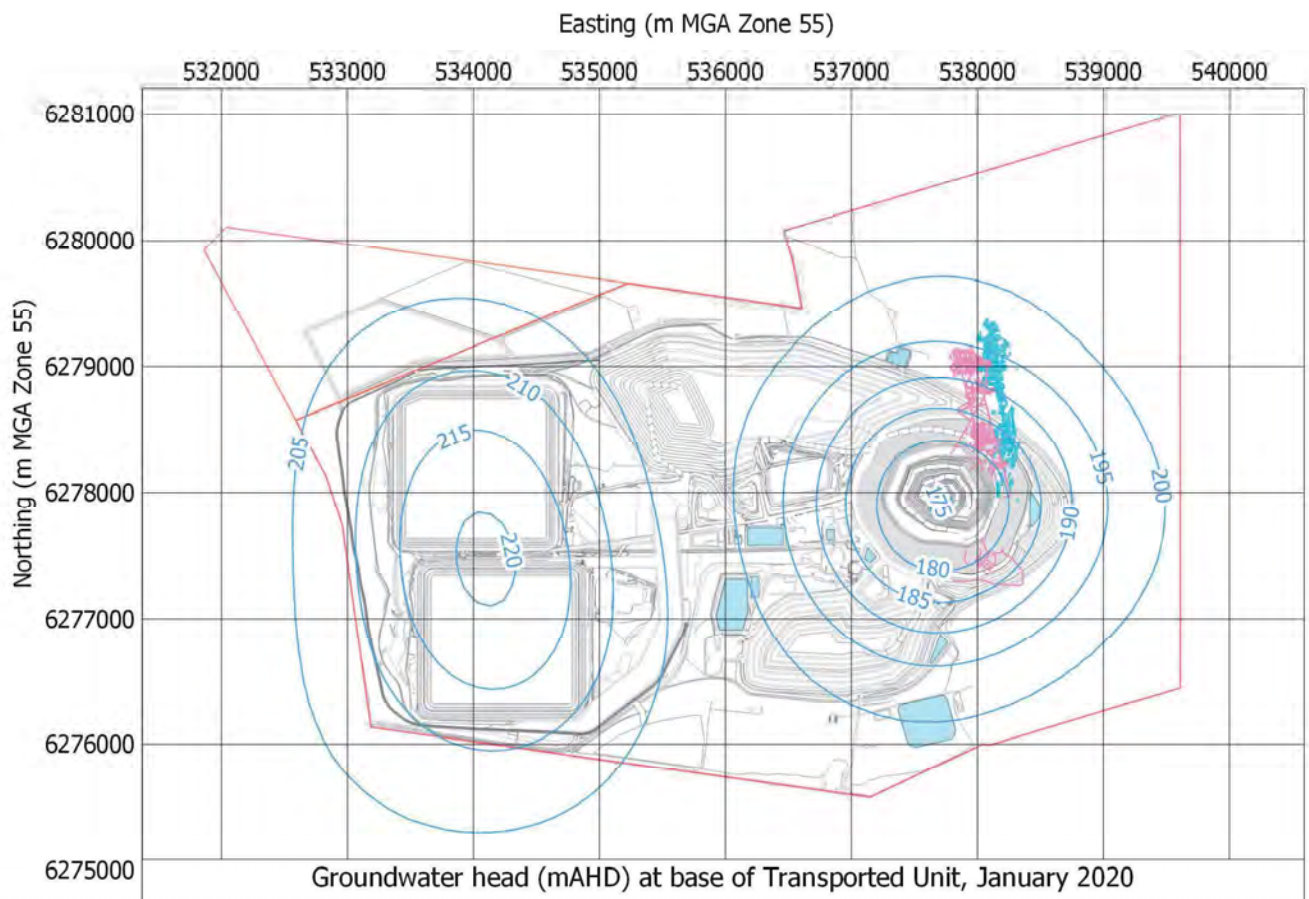




NOTE: Monitoring on UG-BH-01 and UG-BH-02 commenced in February 2020

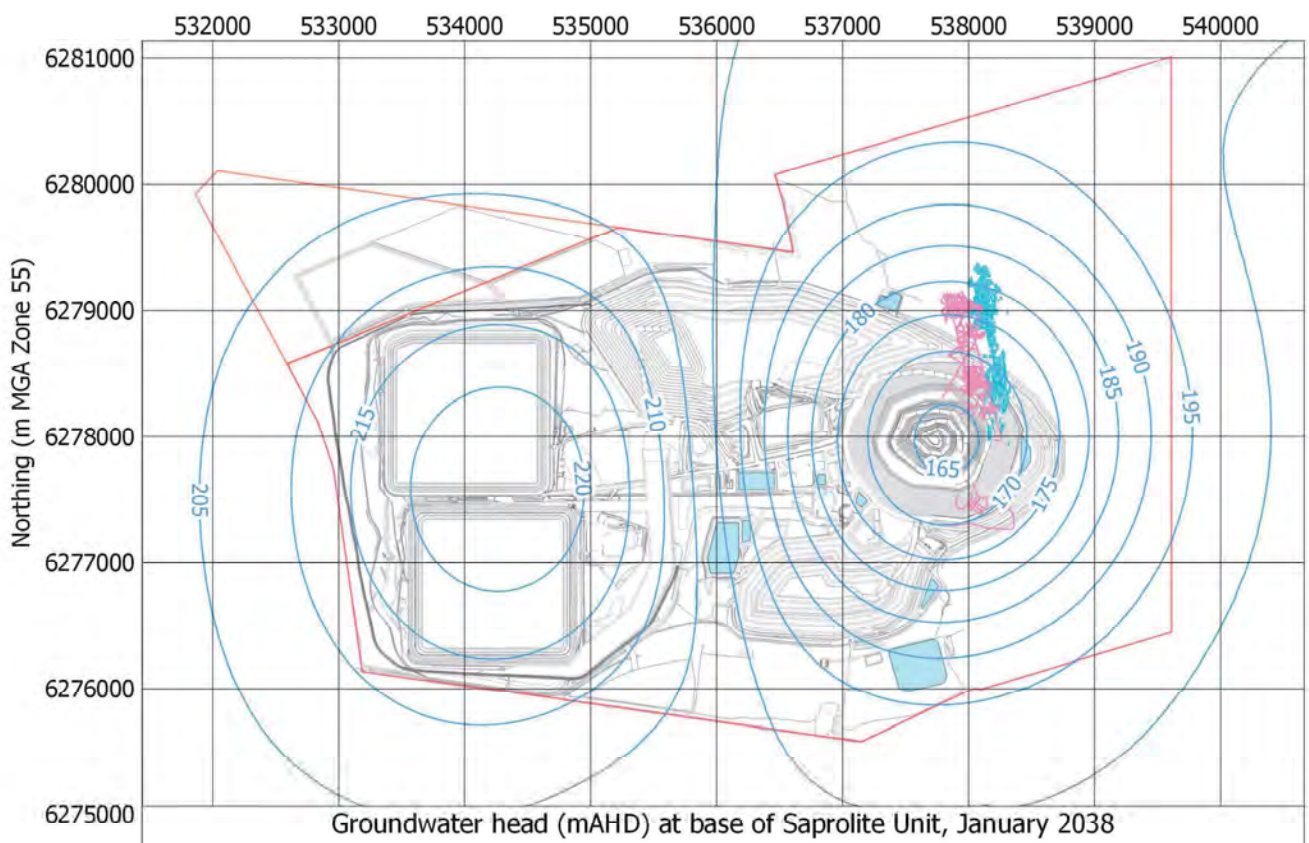
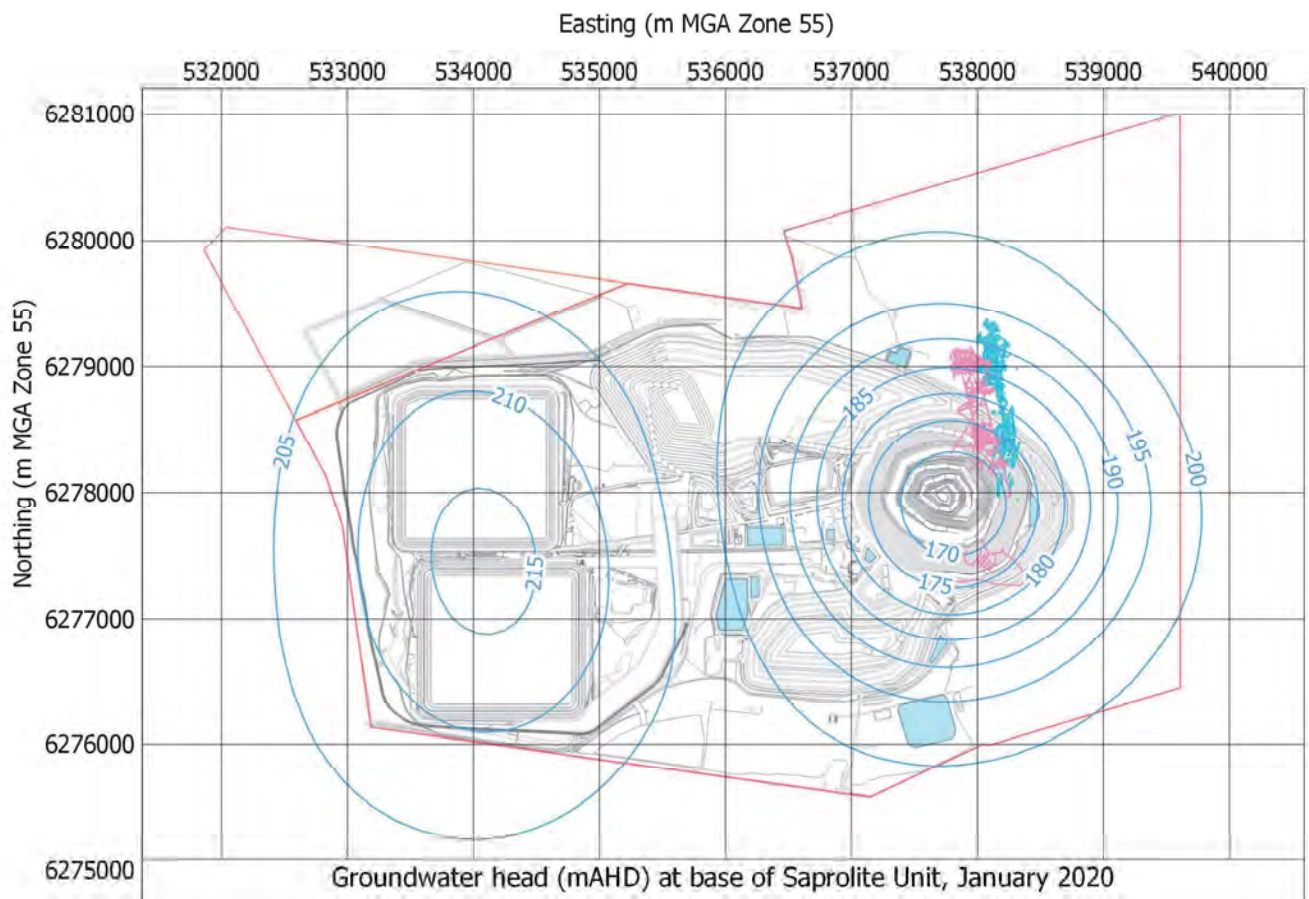


## **Appendix C - Groundwater level response**

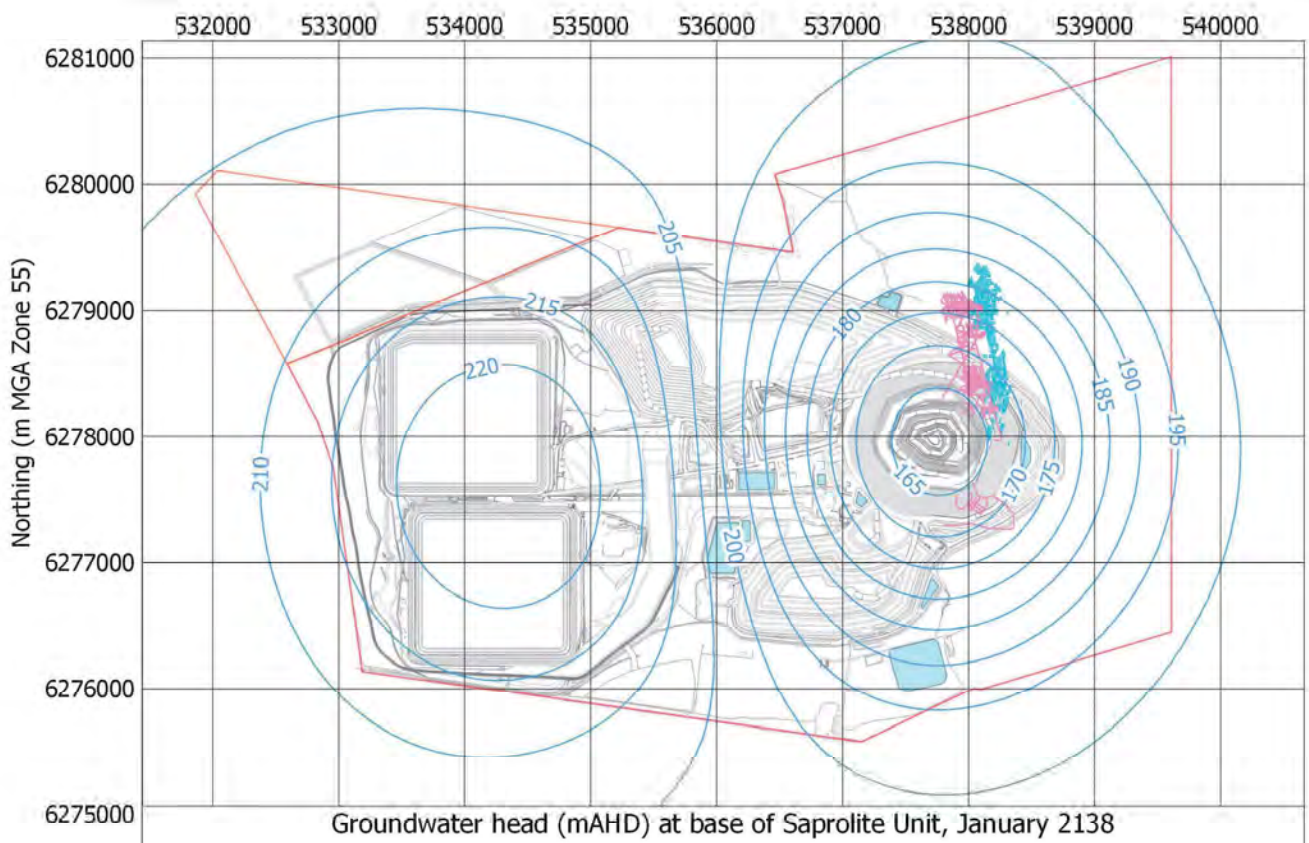
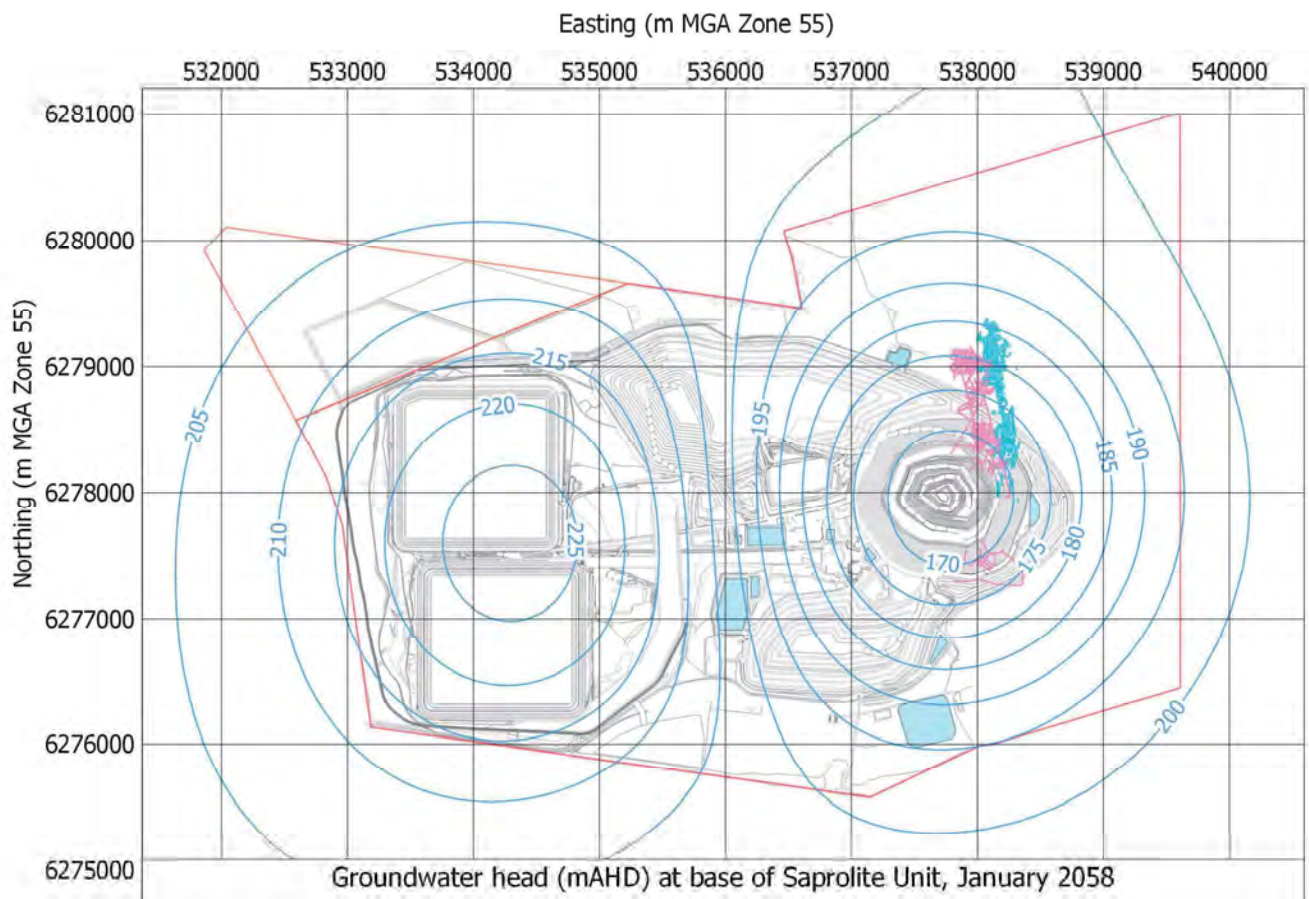


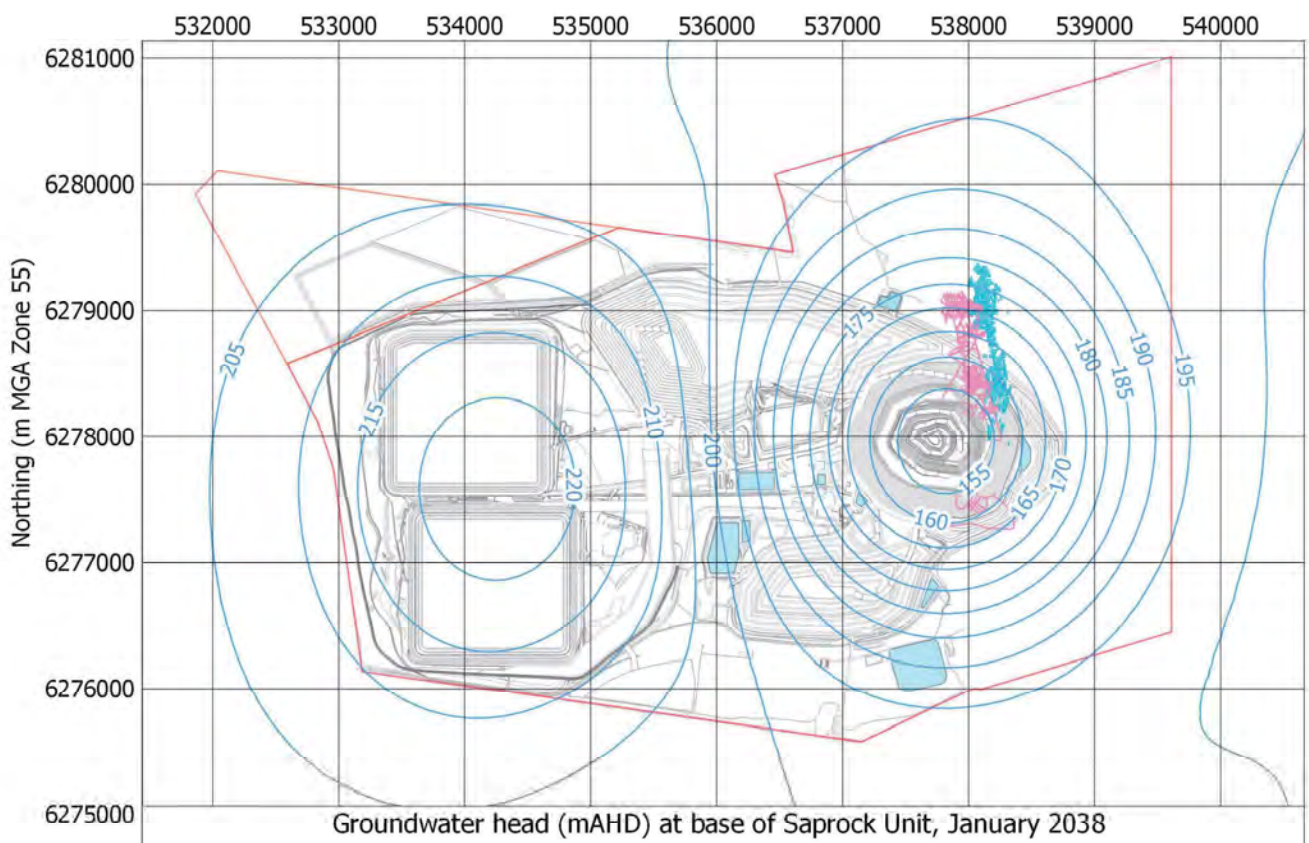
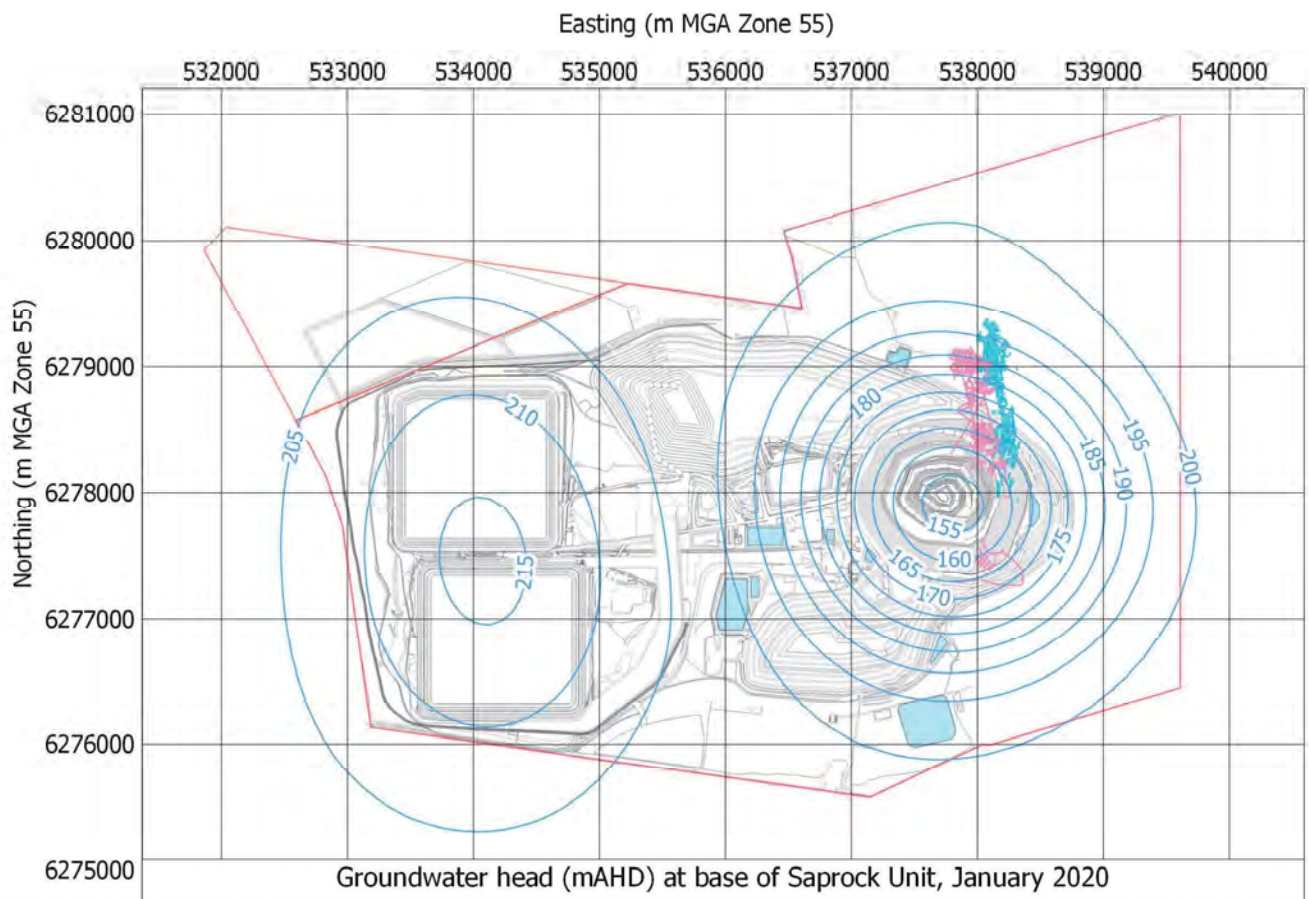




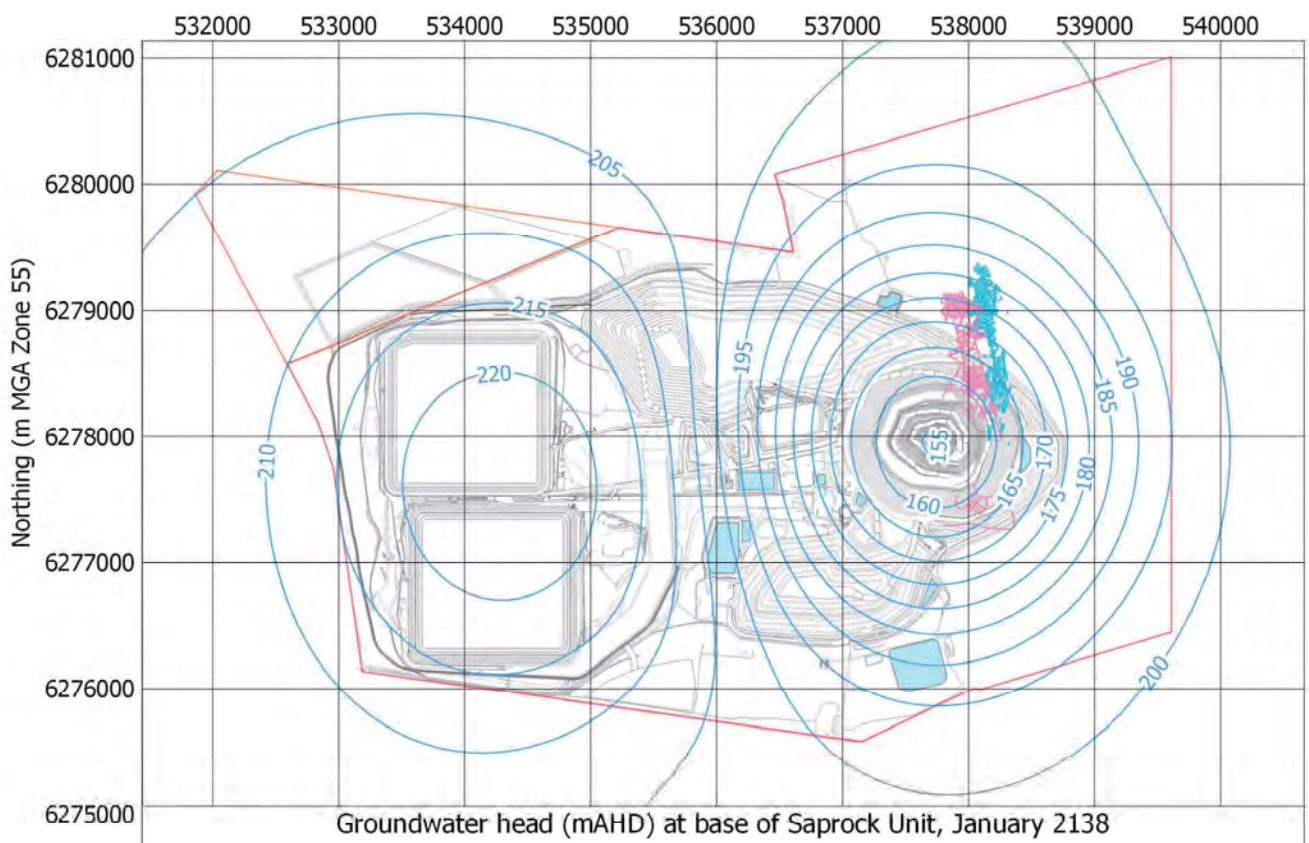
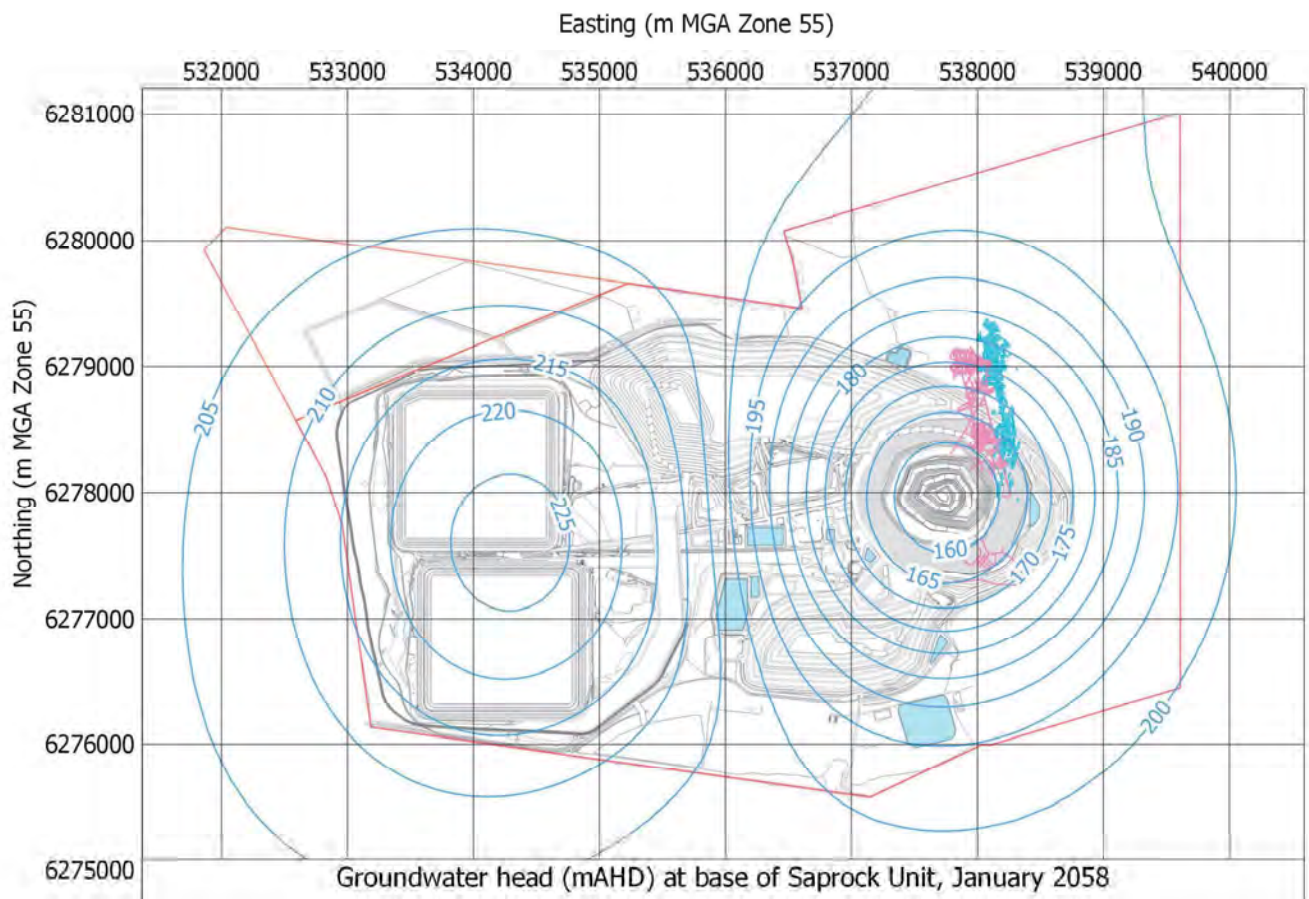




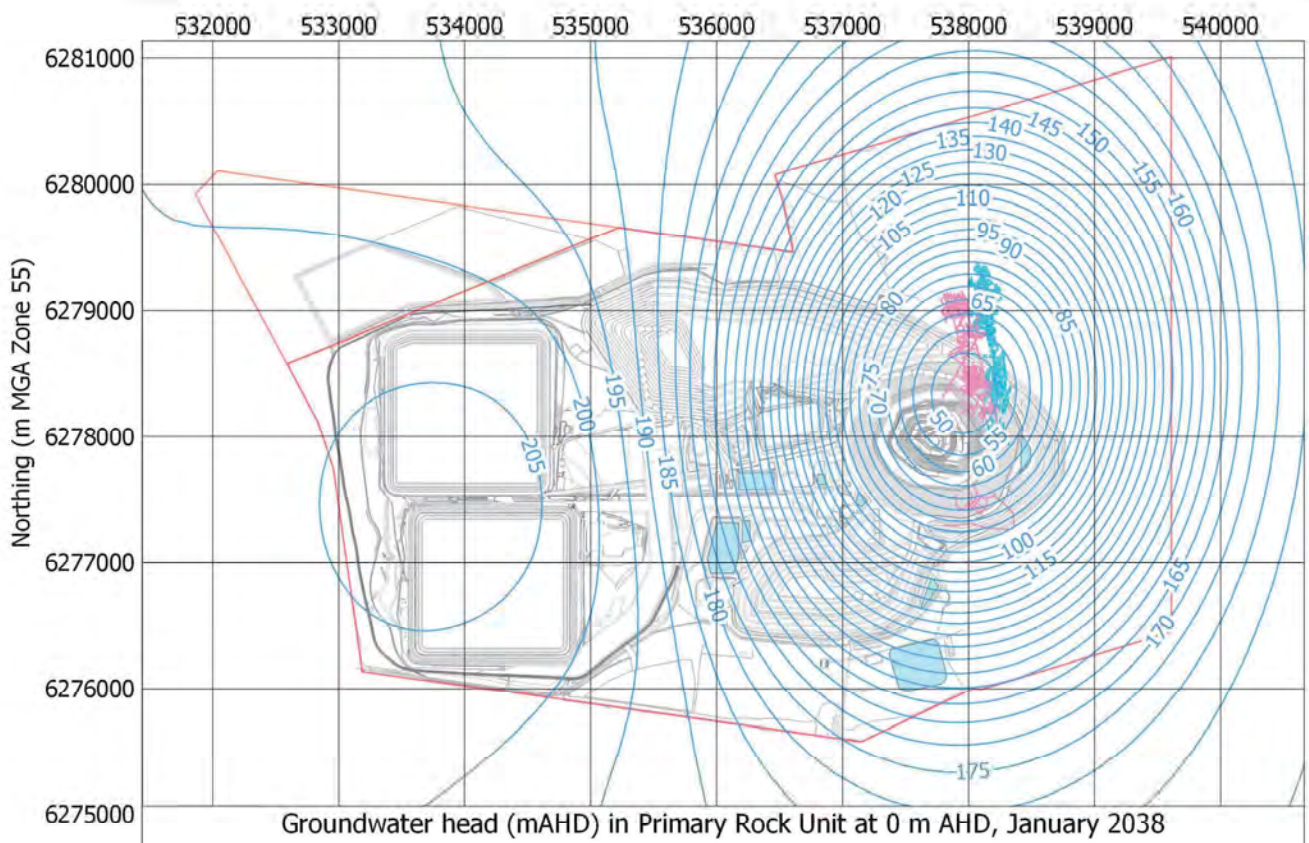
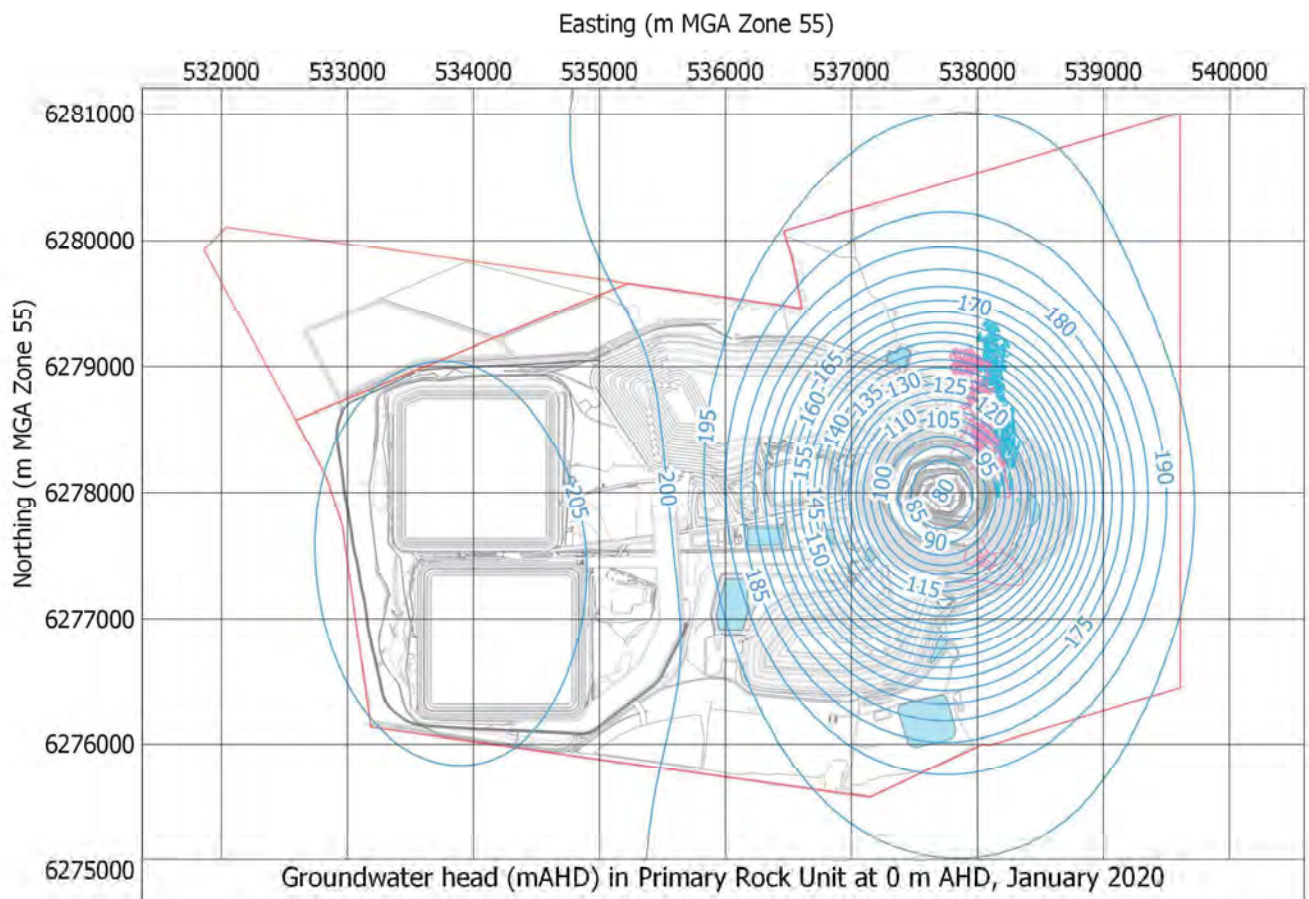




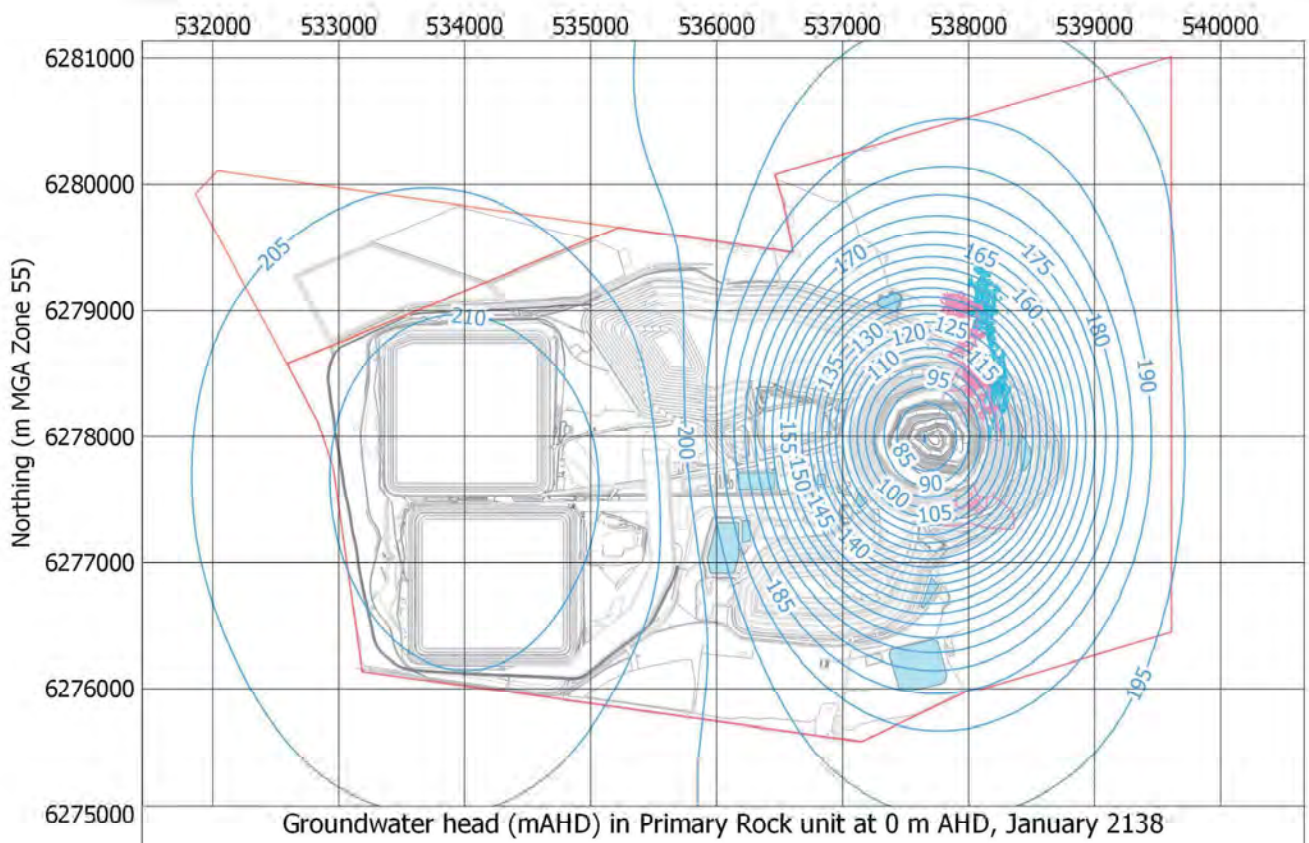
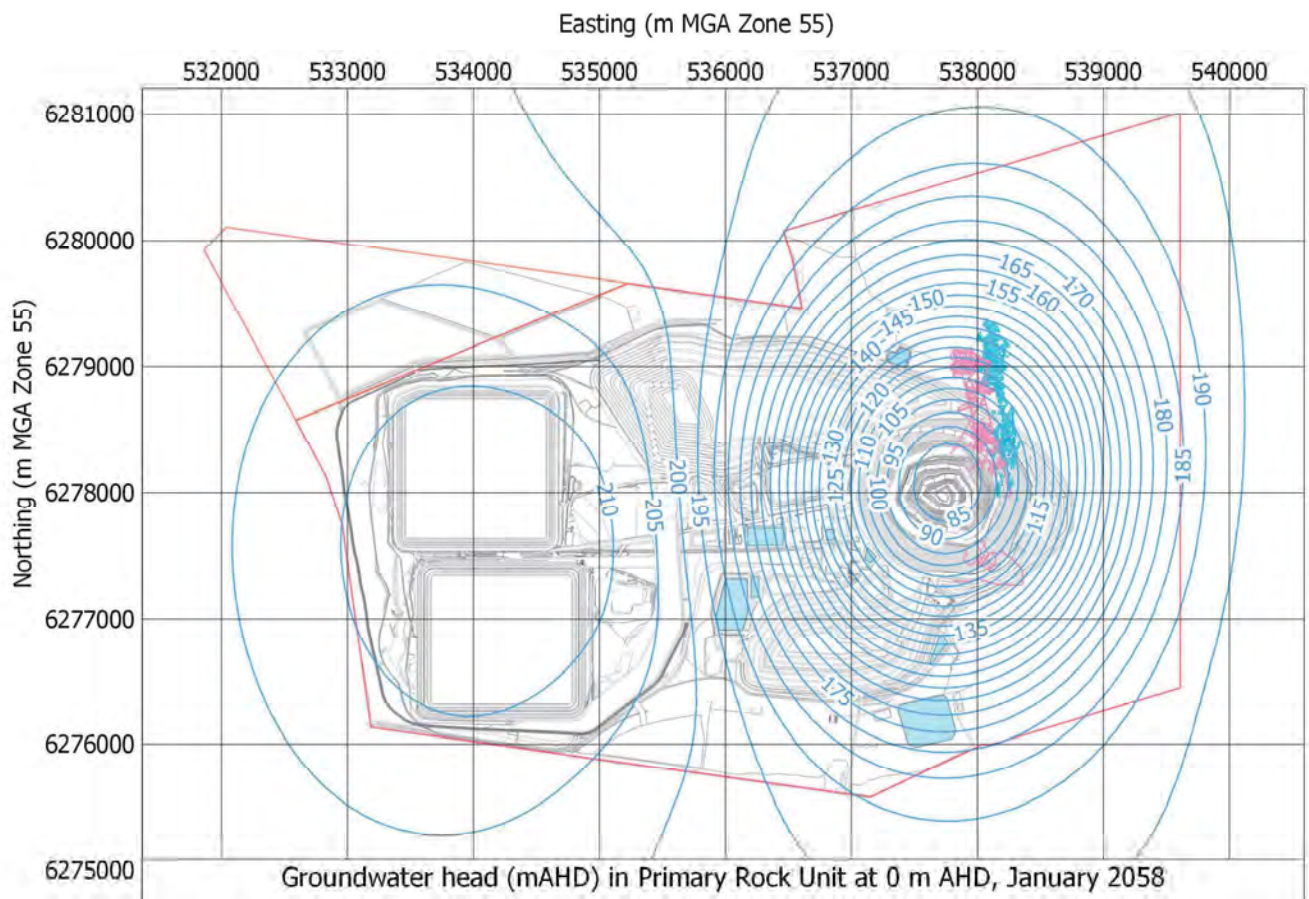


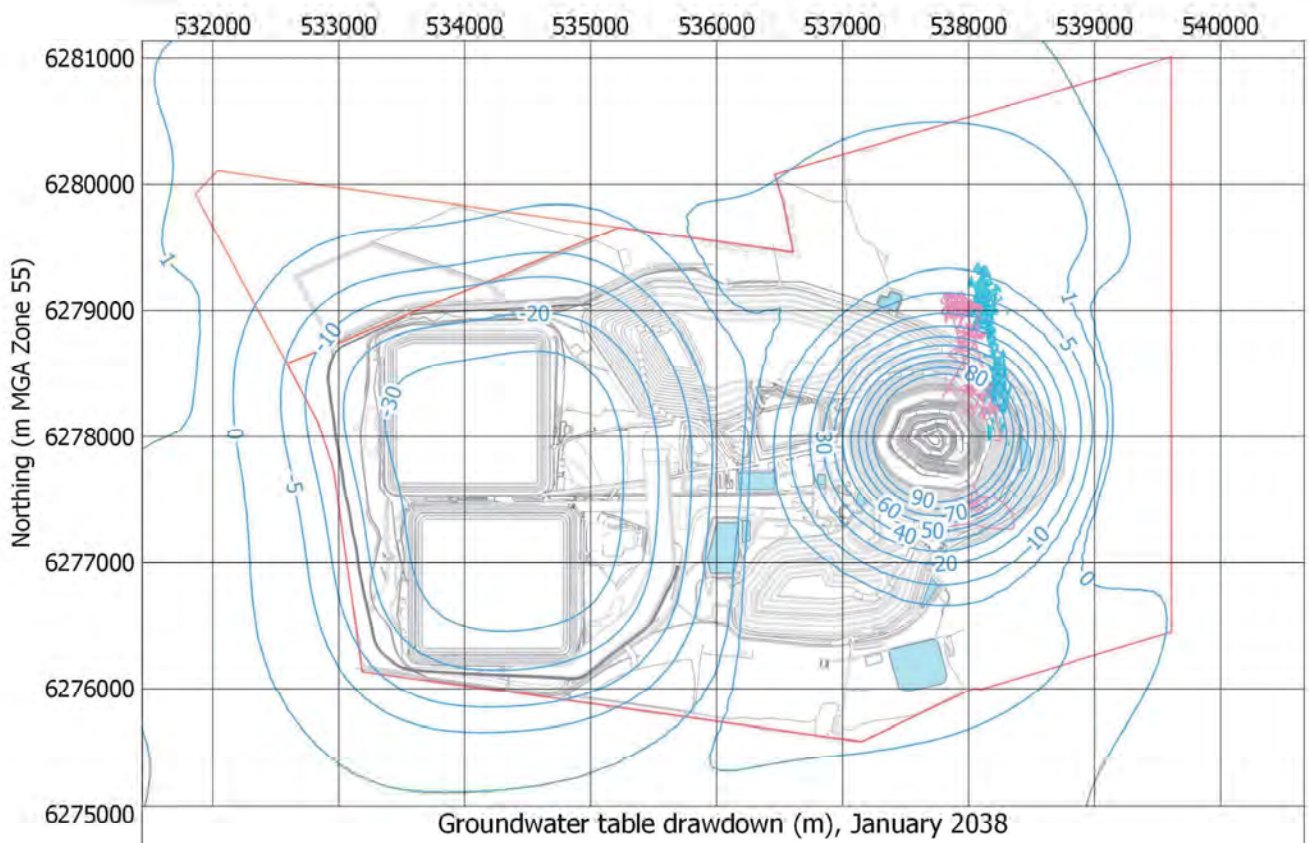
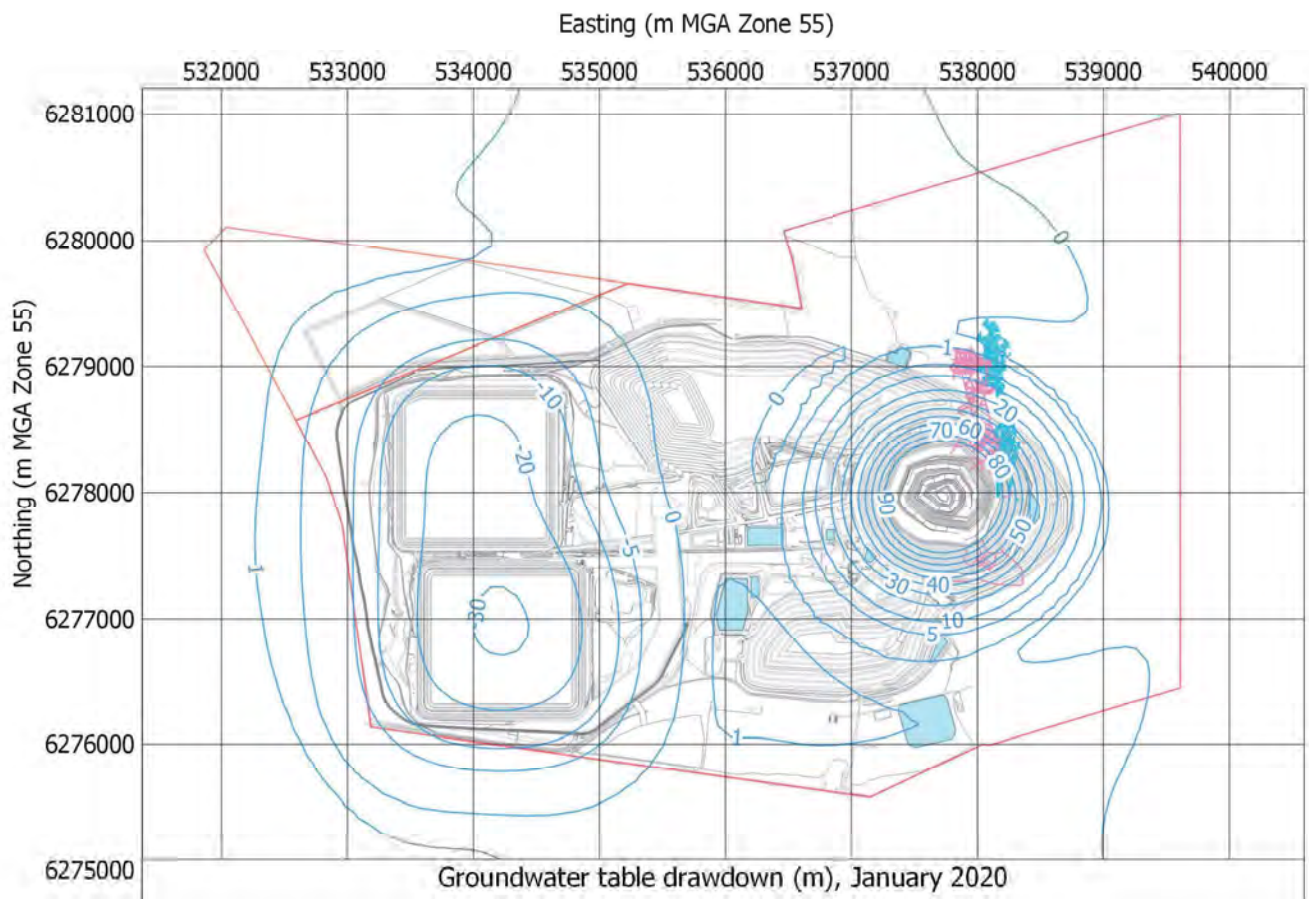




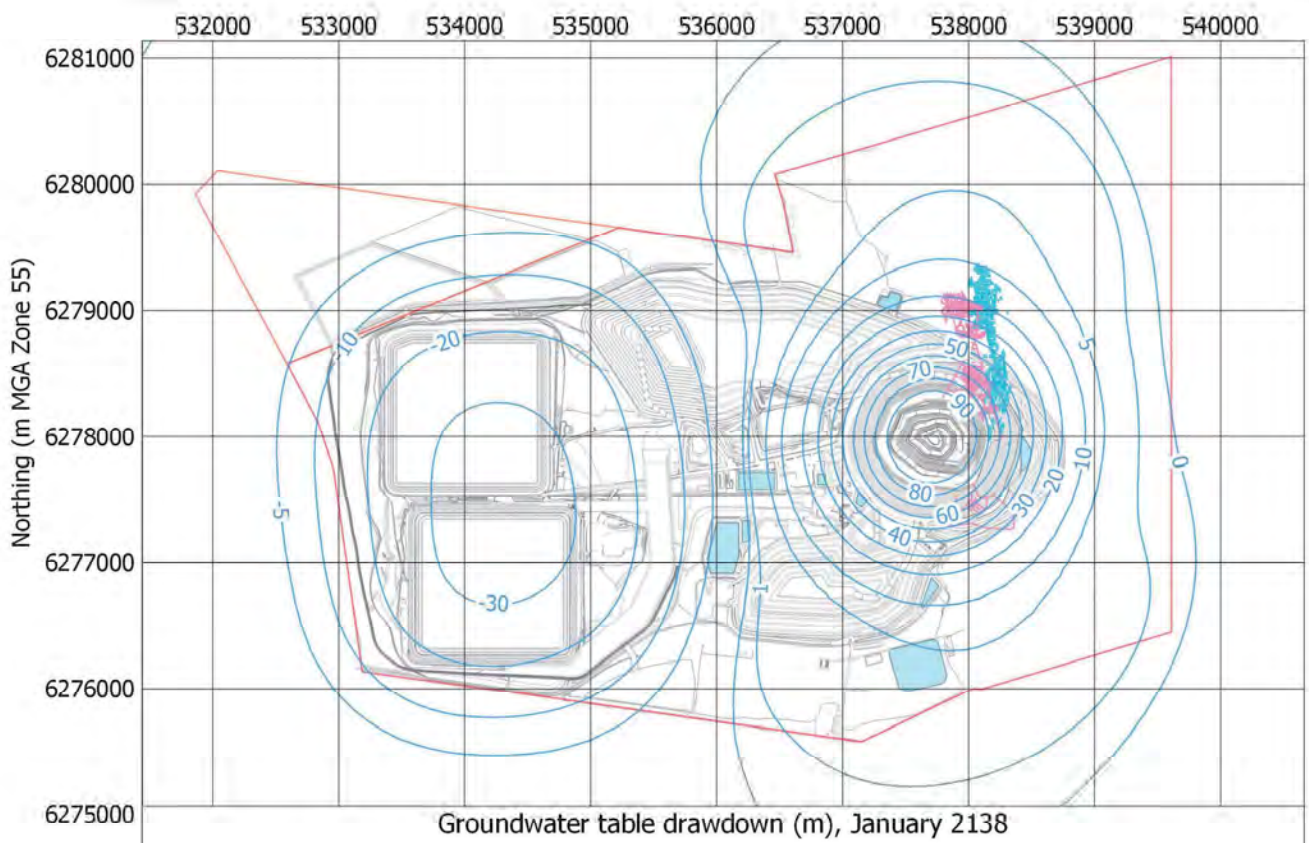
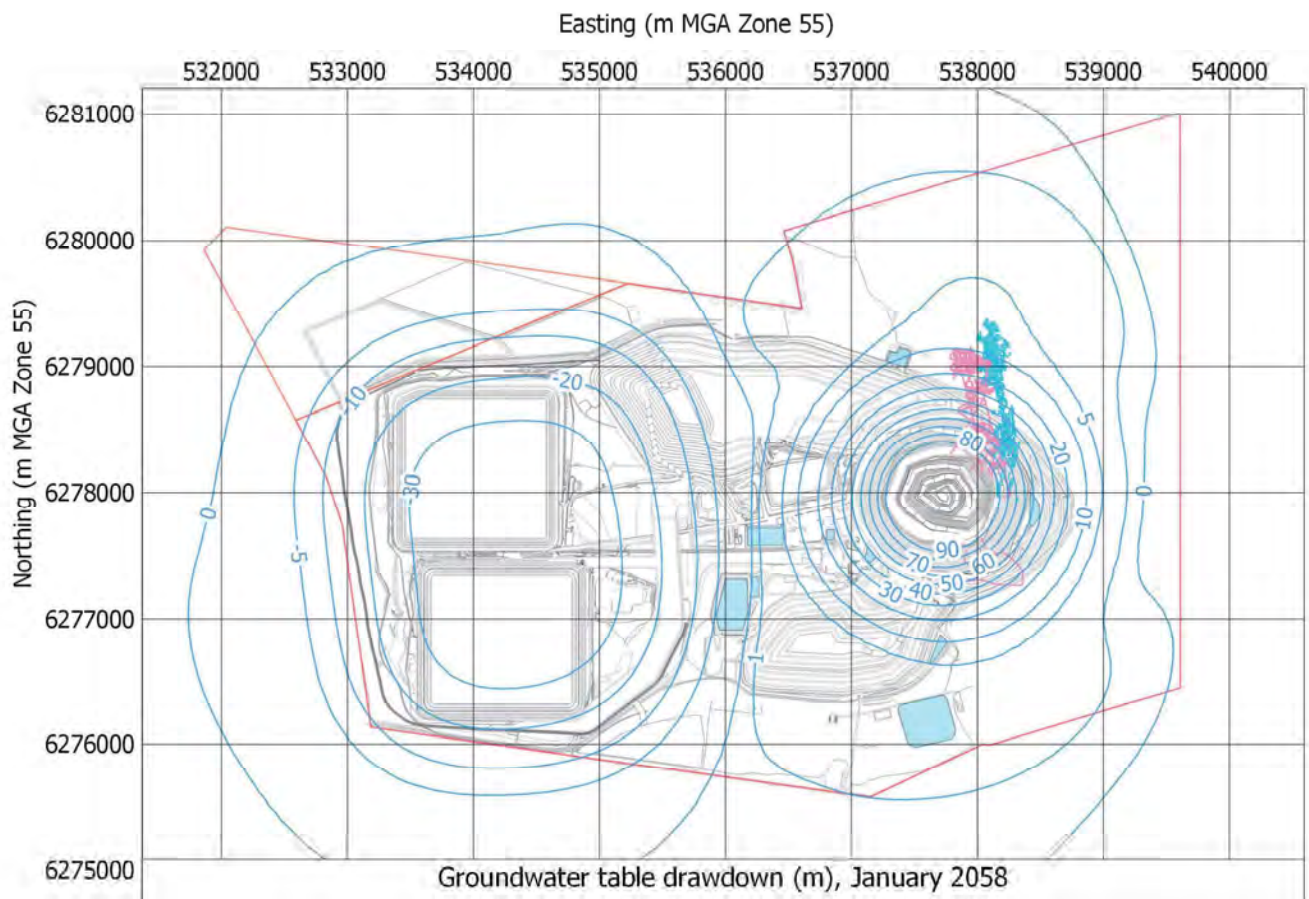




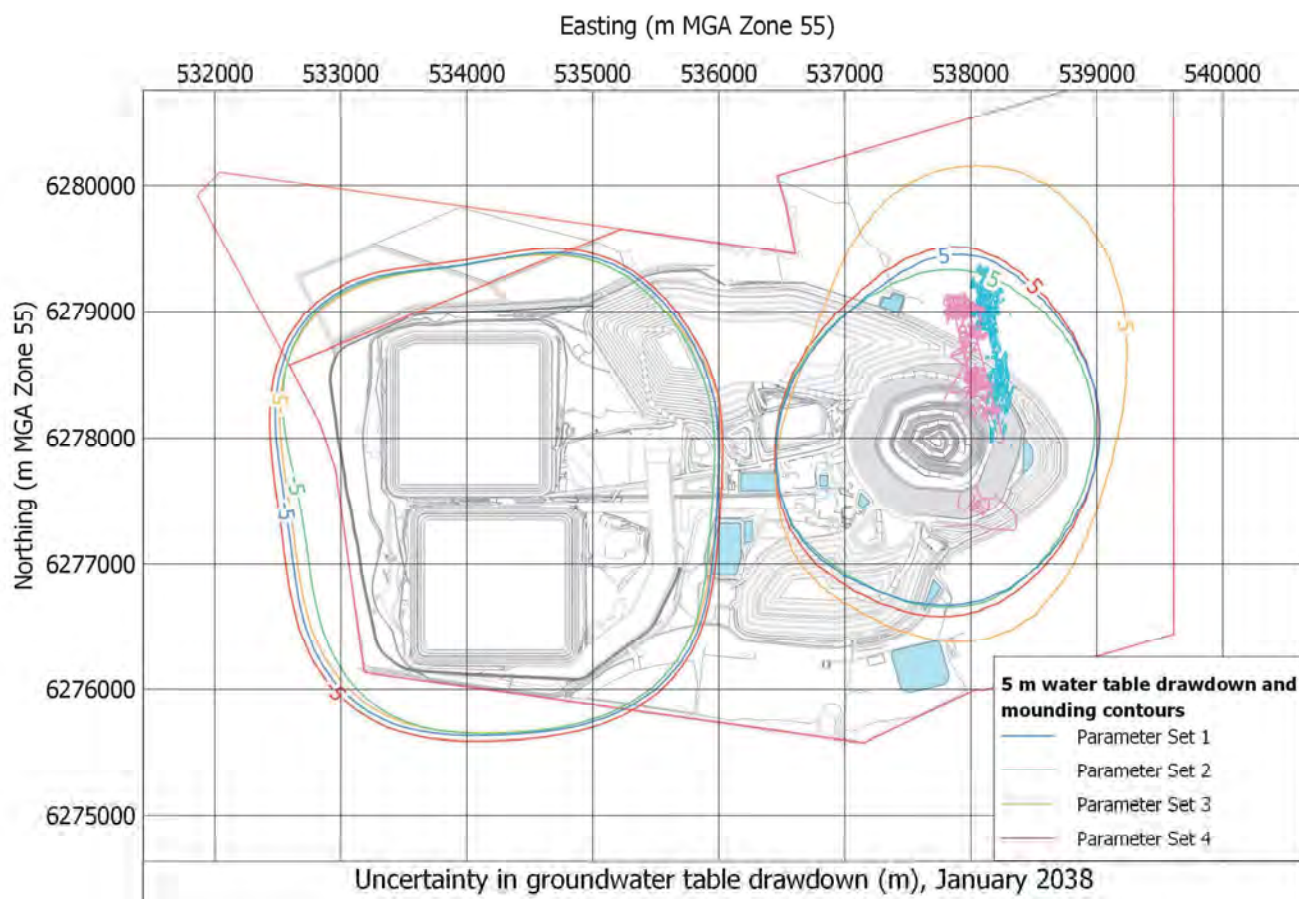




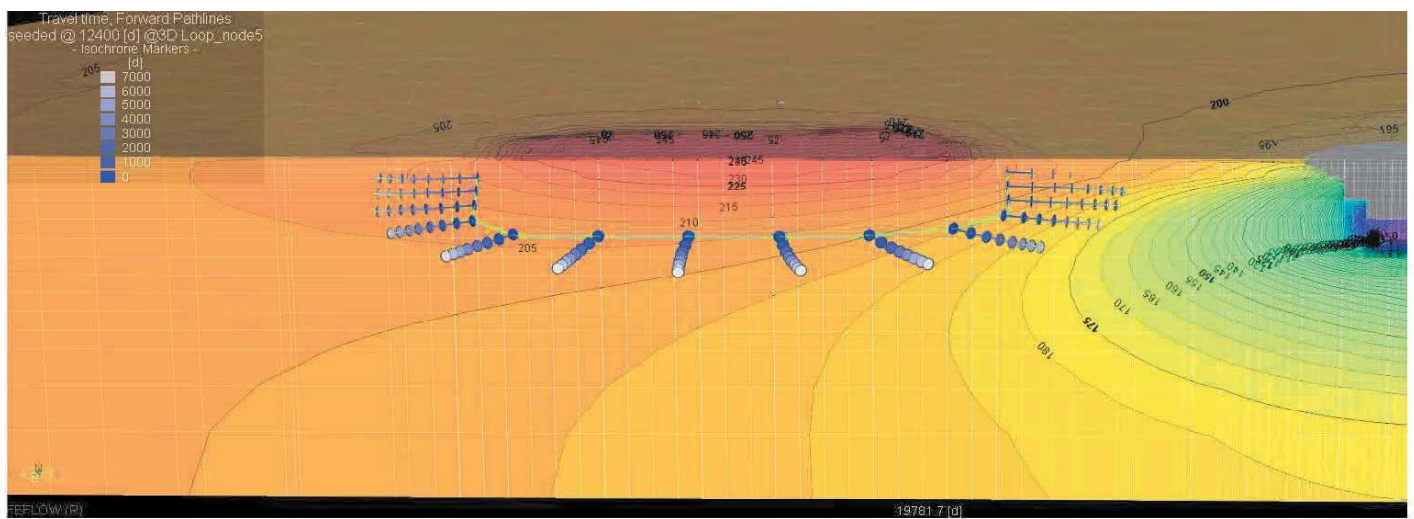
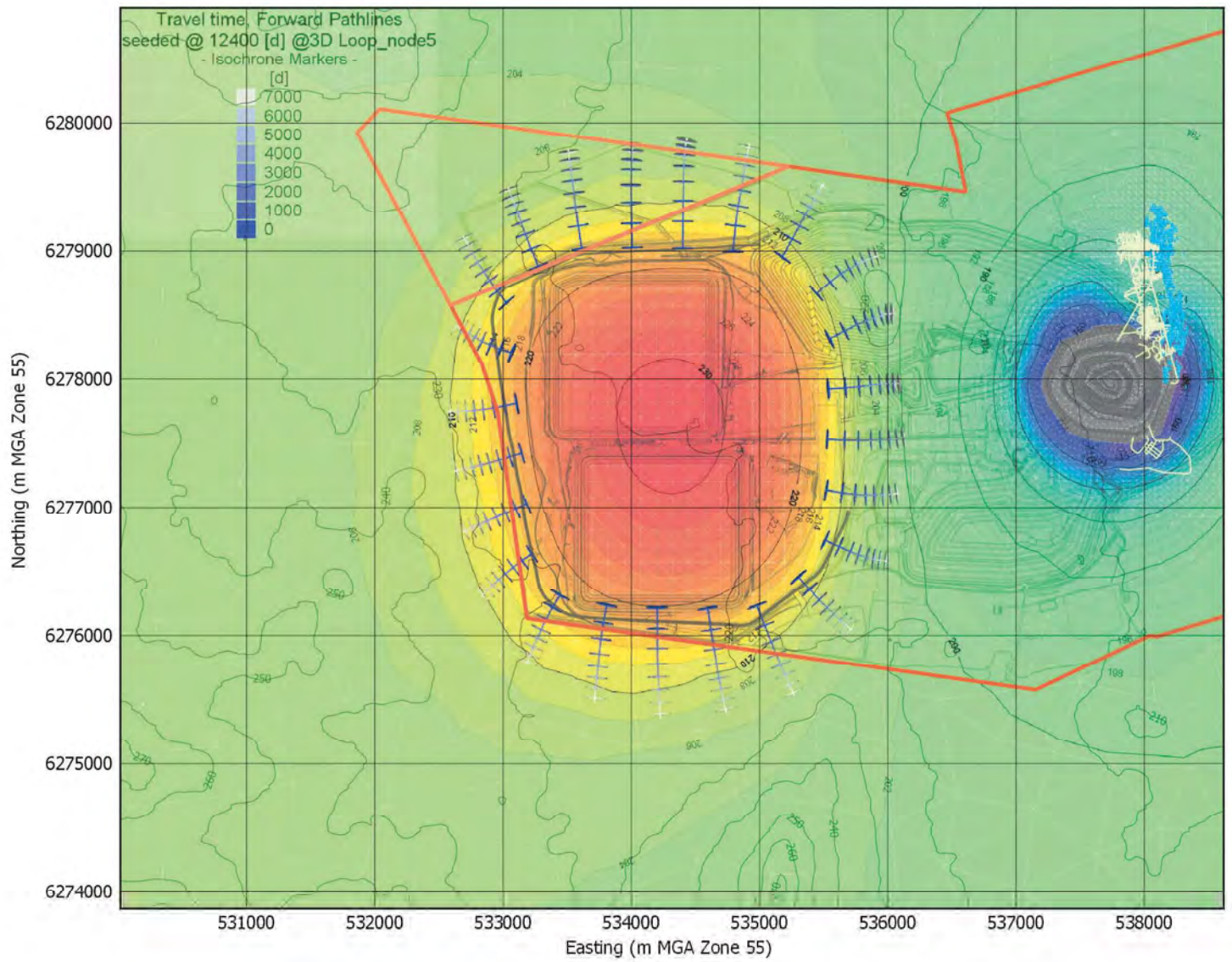




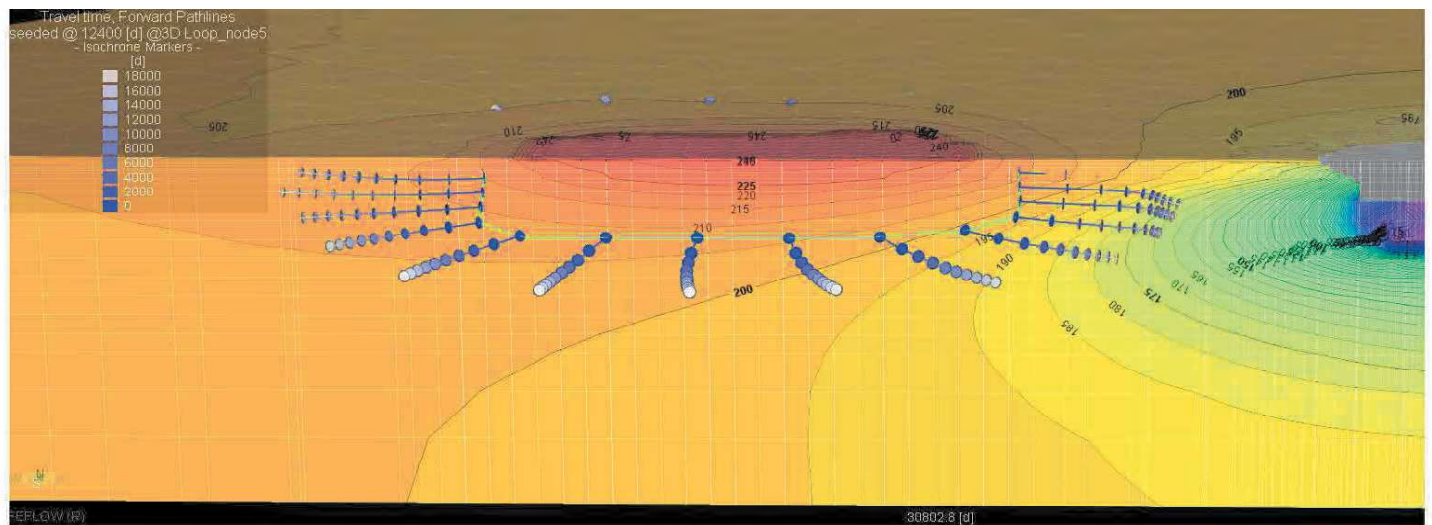
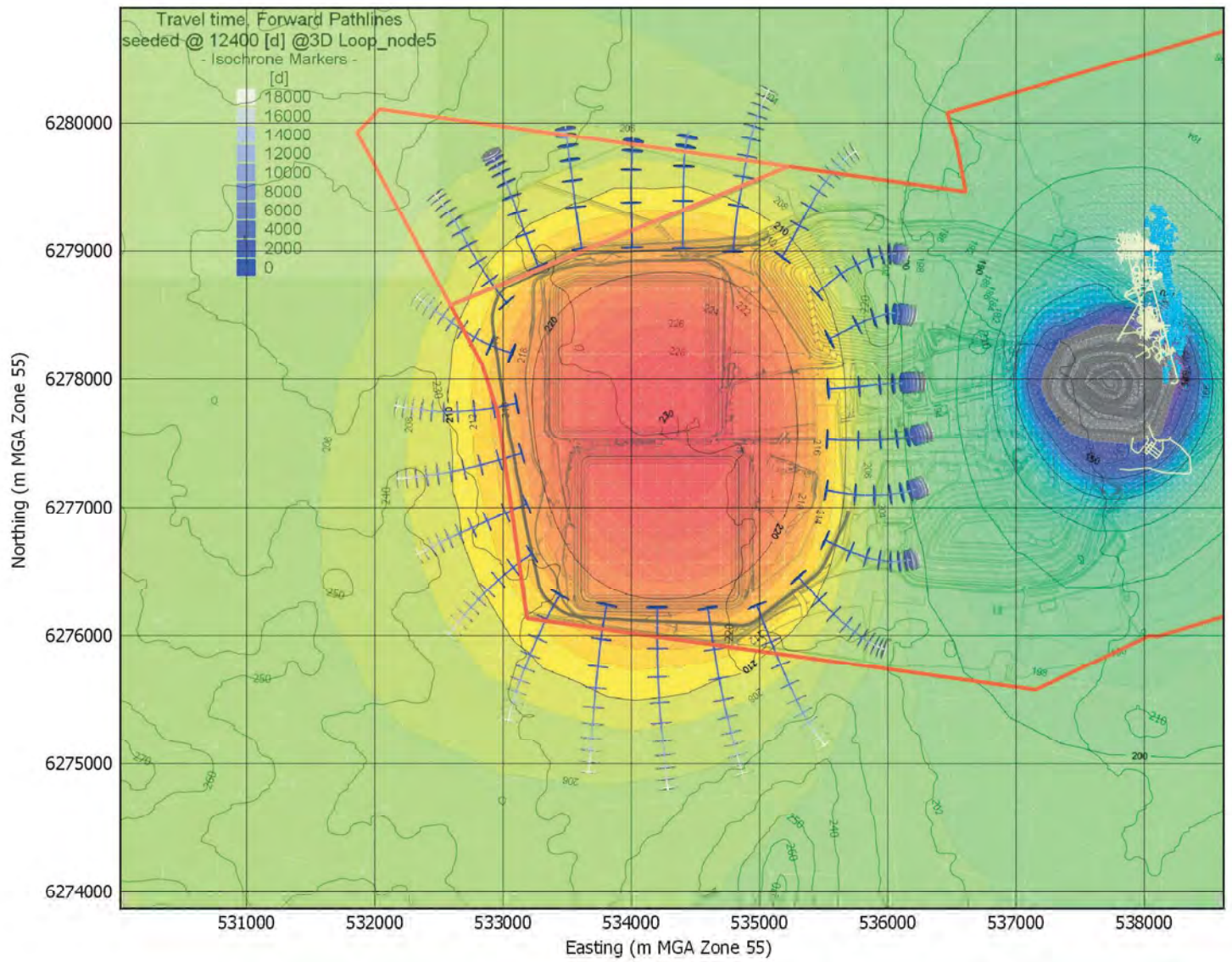




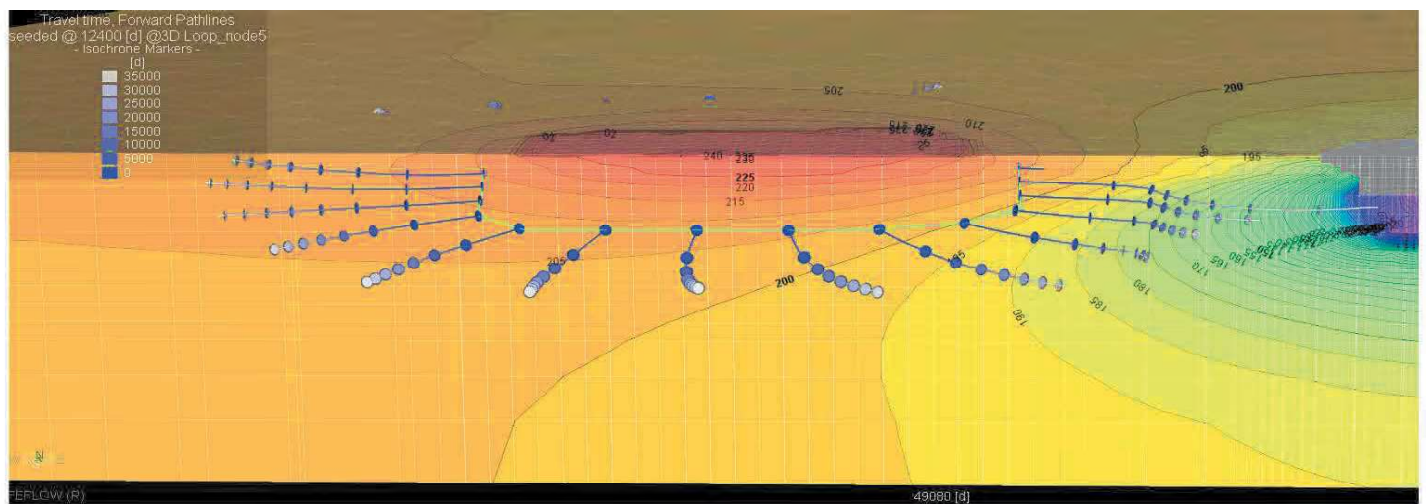
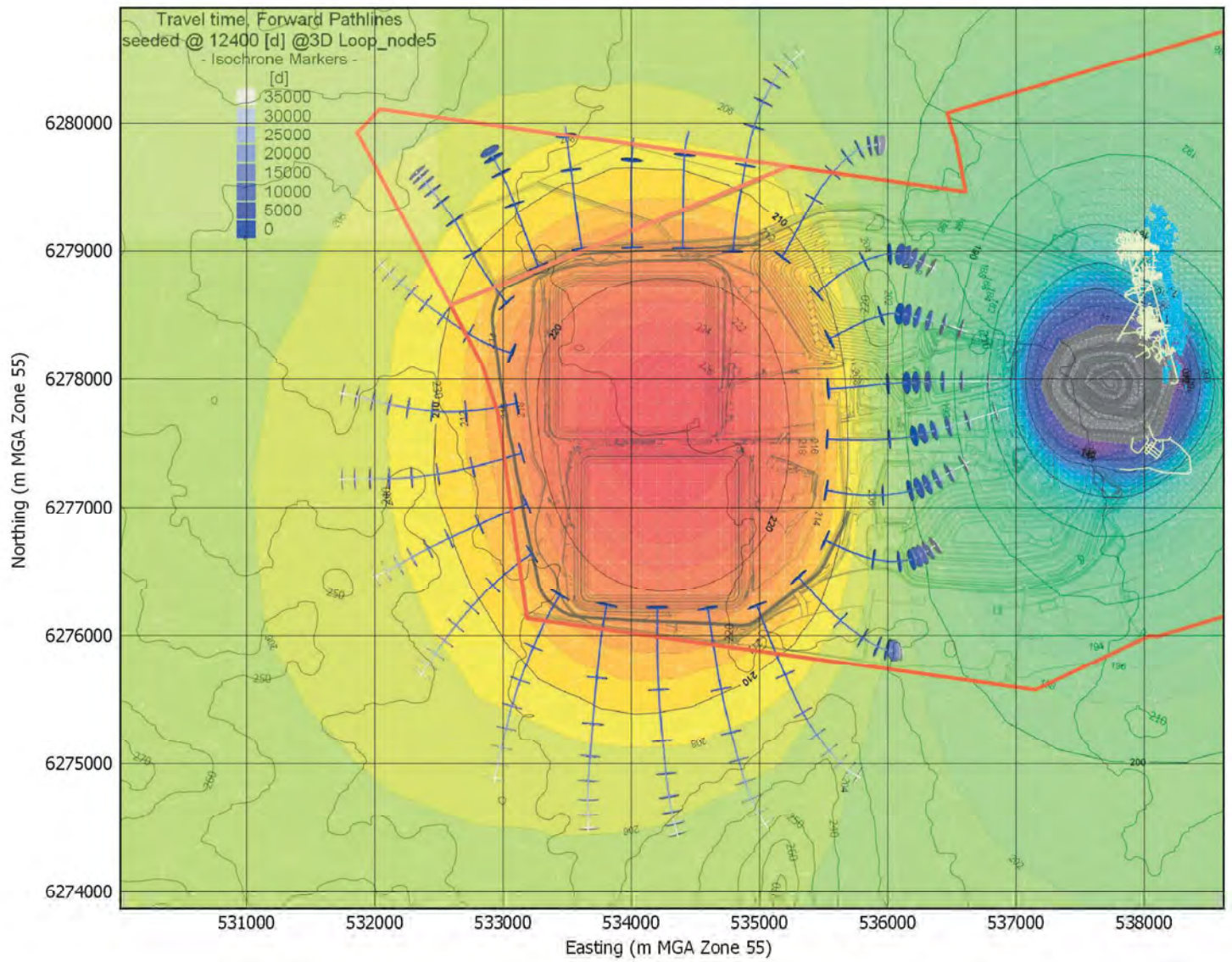
## **Appendix D - Particle tracking**



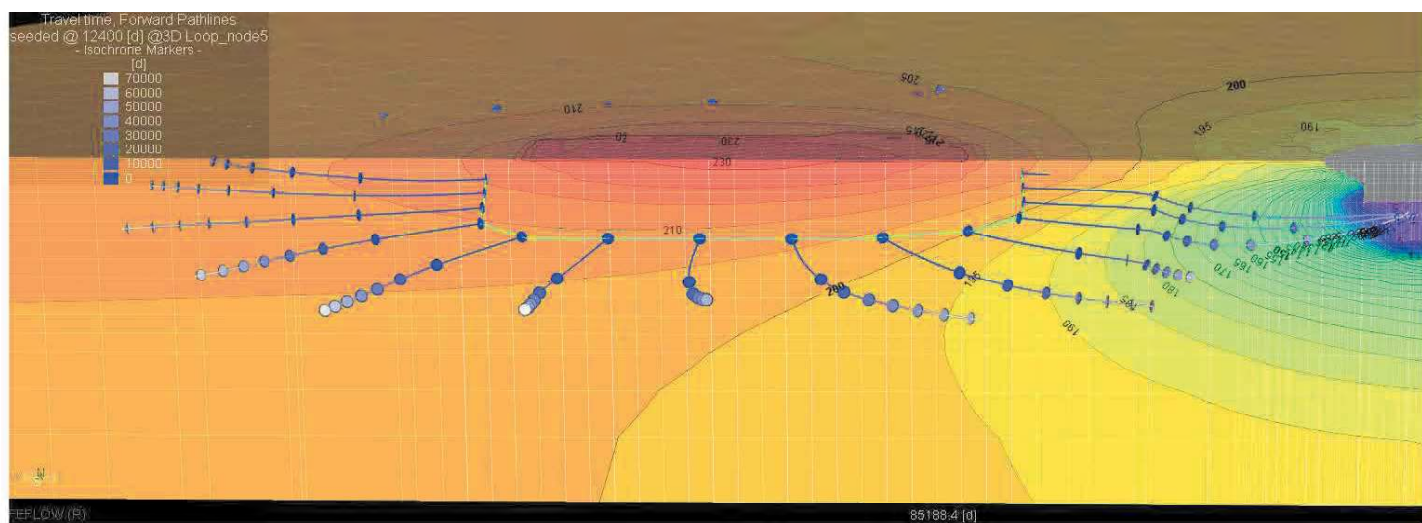
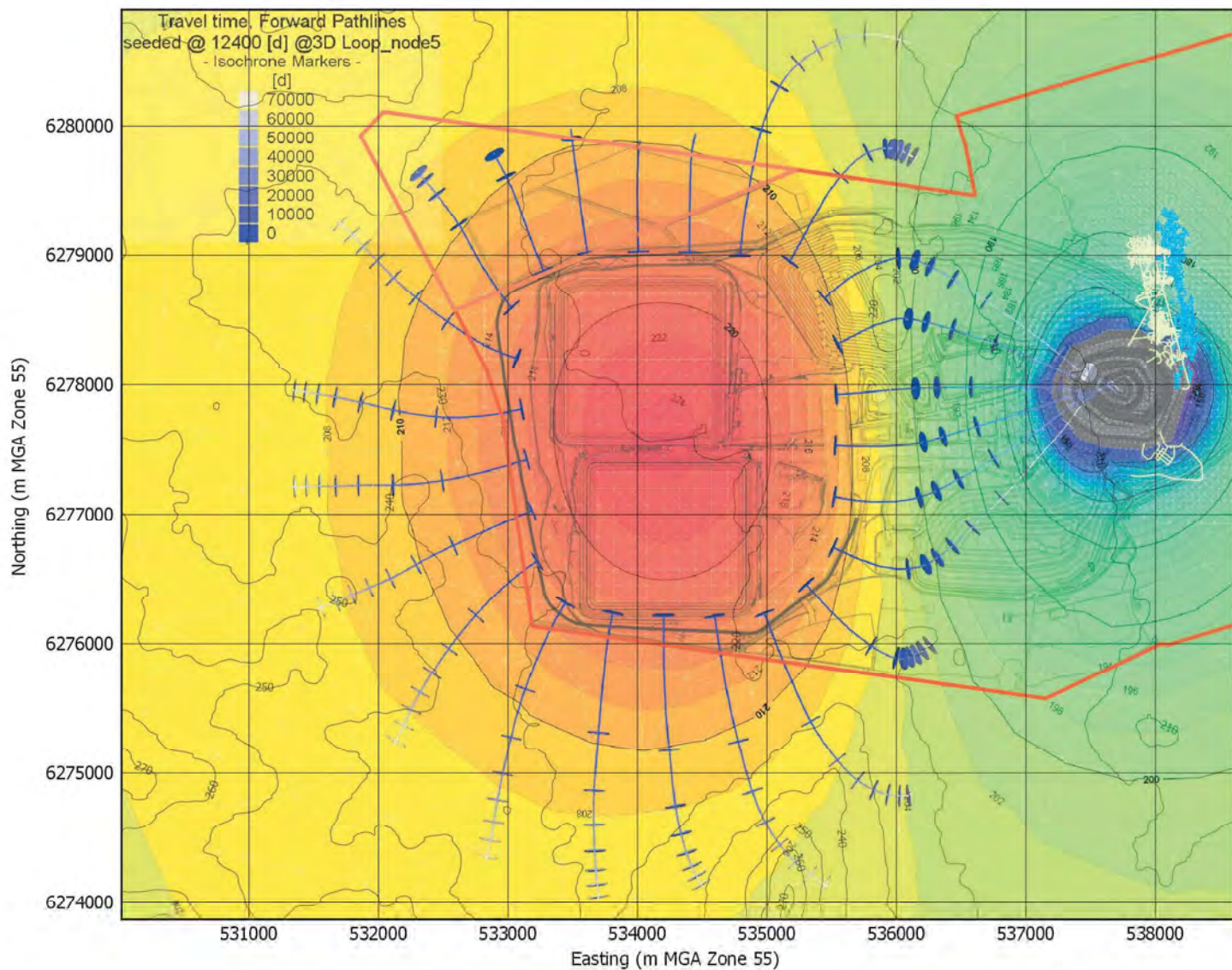








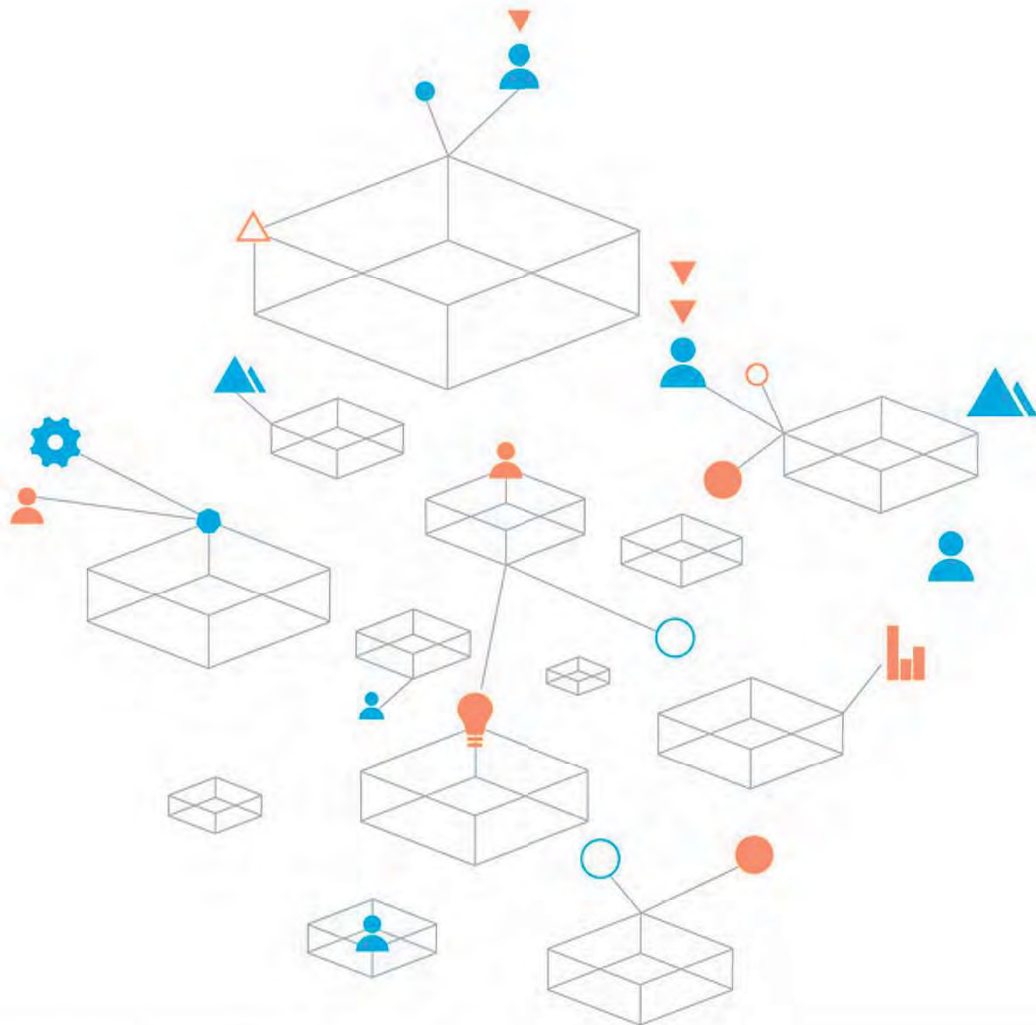




## **Appendix E - Field investigations report**

**EMM Consulting Pty Ltd**  
**CGO Underground Development EIS**  
**Groundwater site investigations report**

6 April 2020



Trust is the  
cornerstone  
of all our  
projects



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# CGO Underground Development EIS

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6 April 2020

Groundwater site investigations report

SYDGE206418-3-AJ

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# 1. Background

Cowal Gold Operations (CGO) is an existing open cut mine site, which has been operational since commencement in 2005, located adjacent to the ephemeral lake, Lake Cowal. The mine is owned and operated by Evolution Mining (Cowal) Pty Limited (Evolution Mining). Evolution Mining seeks to extend mining operations at the CGO by way of an underground development, which would be wholly contained within Mining Lease (ML) 1535. The Underground Development proposal seeks to introduce an underground mine using stope mining practices, in addition to the existing open cut mine, to exploit an identified ore deposit.

The CGO Underground Development includes the development of an underground mining operation beneath Lake Cowal via underground stope mining methods (this would be non-subsiding and no surface expressions of subsidence are anticipated). An exploration decline, GRE46, was constructed by Evolution Mining to explore conditions adjacent to the proposed underground operation. Figure 1 shows the proposed location of the underground operation and exploration decline GRE46 in relation to the existing open cut mine.

A hydrogeological assessment was undertaken by Coffey Services Australia Pty Ltd (Coffey) to assess potential impacts on the groundwater system under the proposed Cowal Gold Operations (CGO) Underground Development (Coffey Report No. SYDGE206418-3-AD, dated 3 February 2020 (Draft)). The assessment employed predictive numerical modelling based on an existing numerical groundwater flow model, taking into account the proposed underground mining to the north of the existing open pit.

To provide evidence in support of groundwater level and hydraulic conductivity assumptions adopted for the hydrogeological assessment, a field investigation program was carried out between 28 January and 29 February 2020. This report presents the results of the field investigations.

The results provide information on:

- Thickness and composition of the lake bed sediments near the proposed CGO Underground Development.
- Groundwater levels to the north of the existing open pit within Lake Cowal.
- Hydraulic properties of the bedrock.
- An assessment of groundwater levels near the exploration decline.
- An assessment of the change in permeability (and extent of the zone of altered permeability) due to stress changes in the rock caused by the tunnelling.

Figure 1 shows the mine site including the proposed CGO Underground Development and the exploration decline to the north east of the open pit.

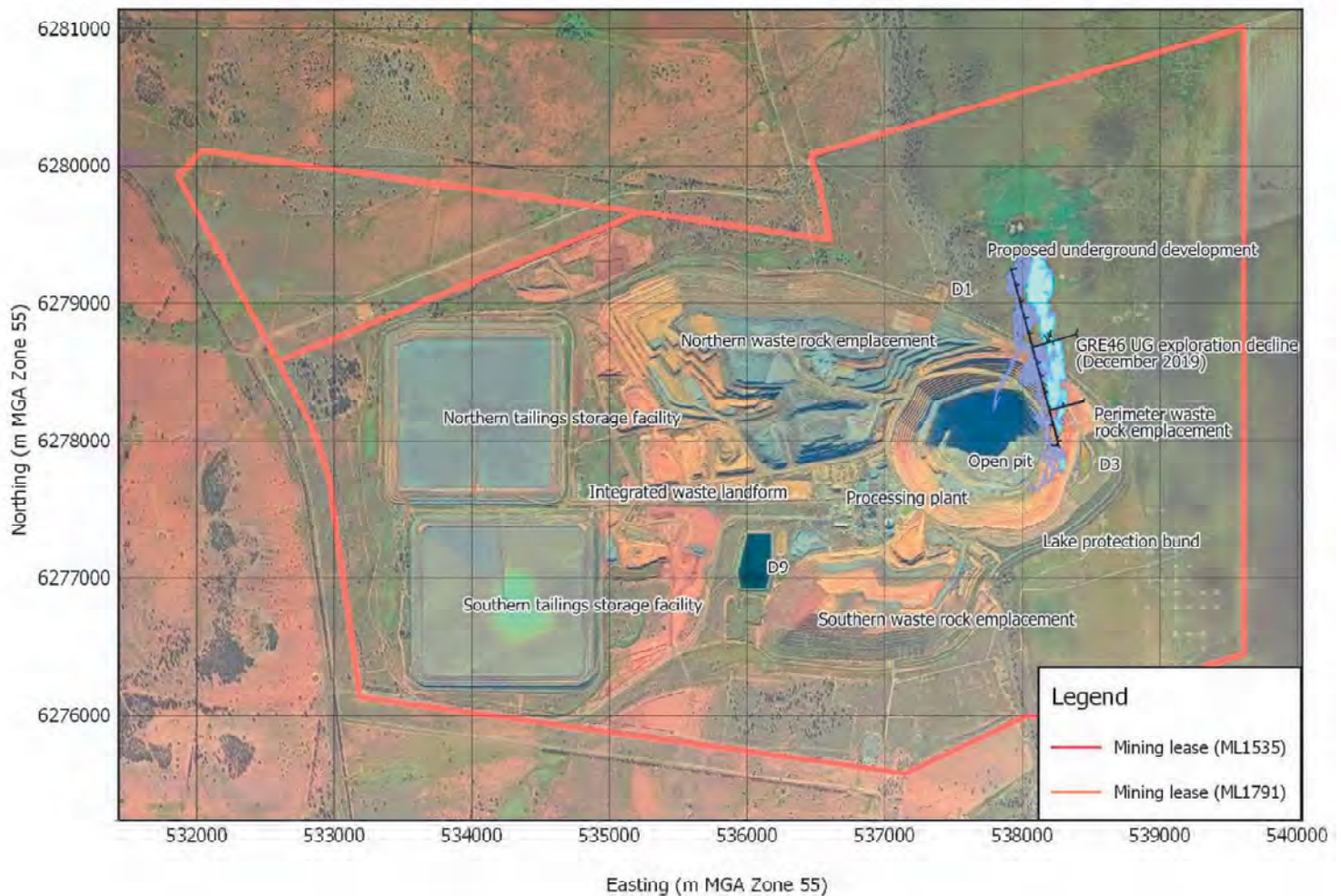


Figure 1: Mine site (Aerial imagery provided by Evolution Mining)

## 2. Regional geology

The Forbes 1:250,000 Geological Map shows that the regional geological setting is dominated by the Gilmore Fault Zone also called the Gilmore Suture, a structurally and lithologically complex feature that trends north-south through ML1535, approximately 500 m west of the CGO open pit.

The fault separates a Late Ordovician volcanoclastic 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 ML1535 and thick Quaternary lacustrine sediments underlie Lake Cowal.

The geology of the CGO site and surrounds is illustrated in Figure 2 and Figure 3.



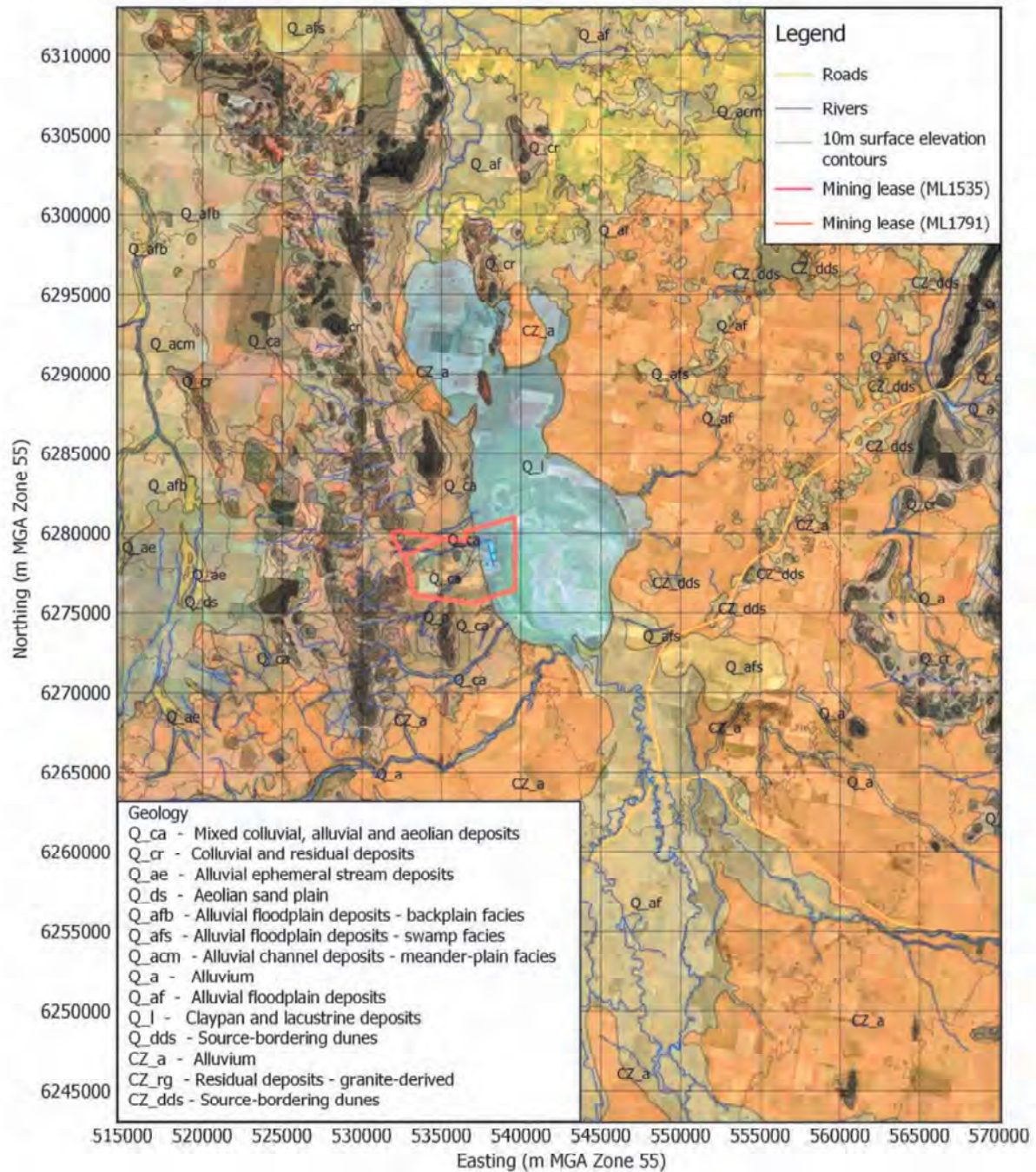


Figure 2: Quaternary and Tertiary geology (Source: Seamless Geology of NSW)



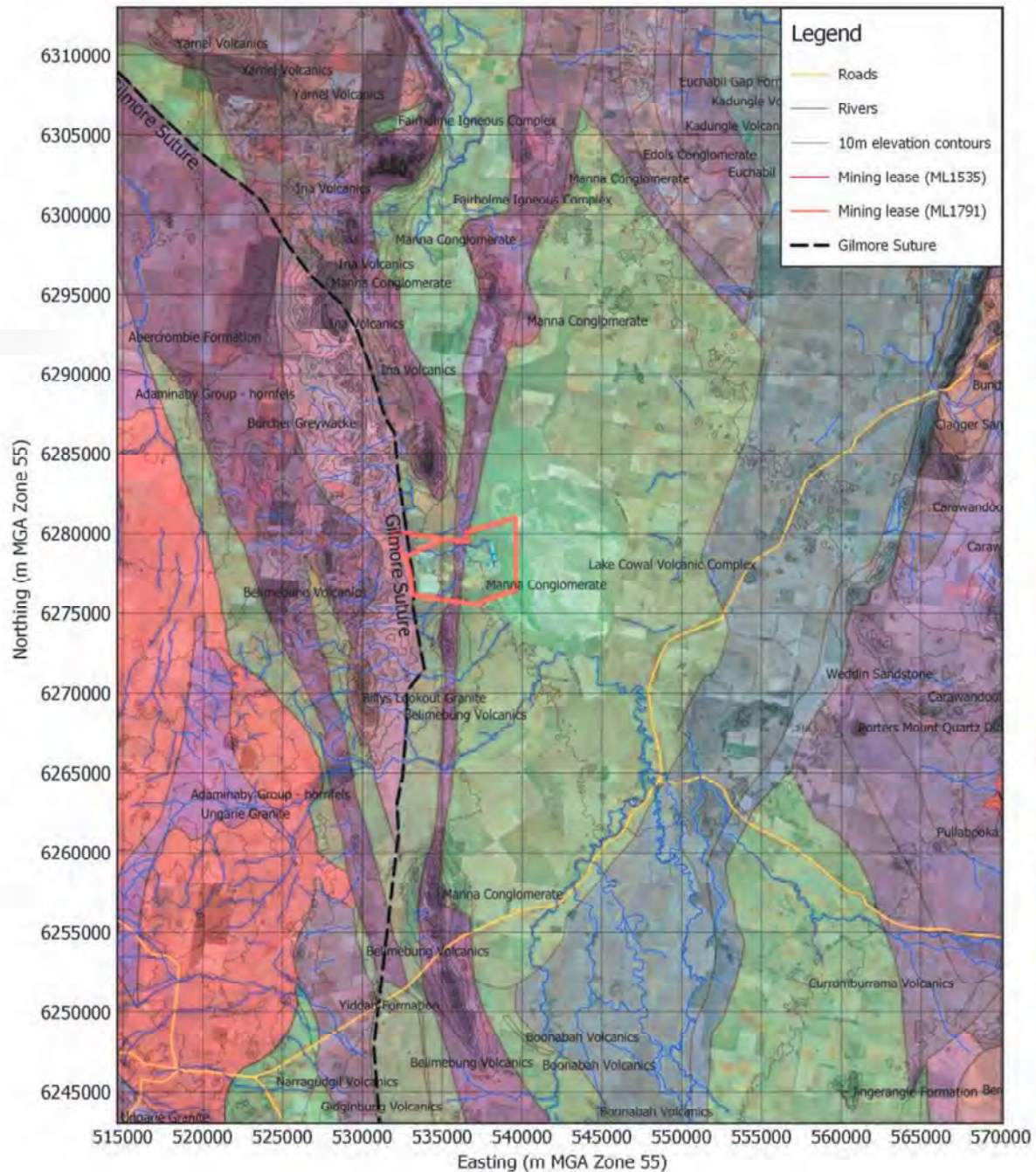


Figure 3: Devonian and Ordovician geology (Source: Seamless Geology of NSW)

### 3. Hydrogeology

#### 3.1. 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 a depth of up to approximately 50 m. It is present 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.
- 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 ML1535, but that the Lachlan Formation did not extend into ML1535. Pre-mining groundwater flow within ML1535 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 Bland Creek Palaeochannel Borefield to the north-east of the CGO site and from the Bland Creek system to the south-east of the CGO site have also been used in characterising the regional hydrogeology.

## 3.2. Mine site hydrogeology

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

- The Lake Sediments or Transported 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 Australia Limited, 2010).
- The Saprolite unit: Underlies the Transported unit and is of relatively low hydraulic conductivity. The unit comprises extremely weathered rock, often weathered to clay.
- The Saprock unit: Underlies the Saprolite unit and occurs in the weathered fractured surface of the Lake Cowal Volcanics. The unit comprises highly to moderately weathered rock with some zones of clay.
- The Primary Rock unit: Consists of the slightly weathered to fresh rock underlying the Saprock unit. This unit is generally considered to be less fractured and less permeable than the Saprock.

Note that the boundaries between the weathered rock units are gradational and weathering profiles may extend over 50 m or more.

Figure 4 presents a conceptual hydrogeological model of the mine site.

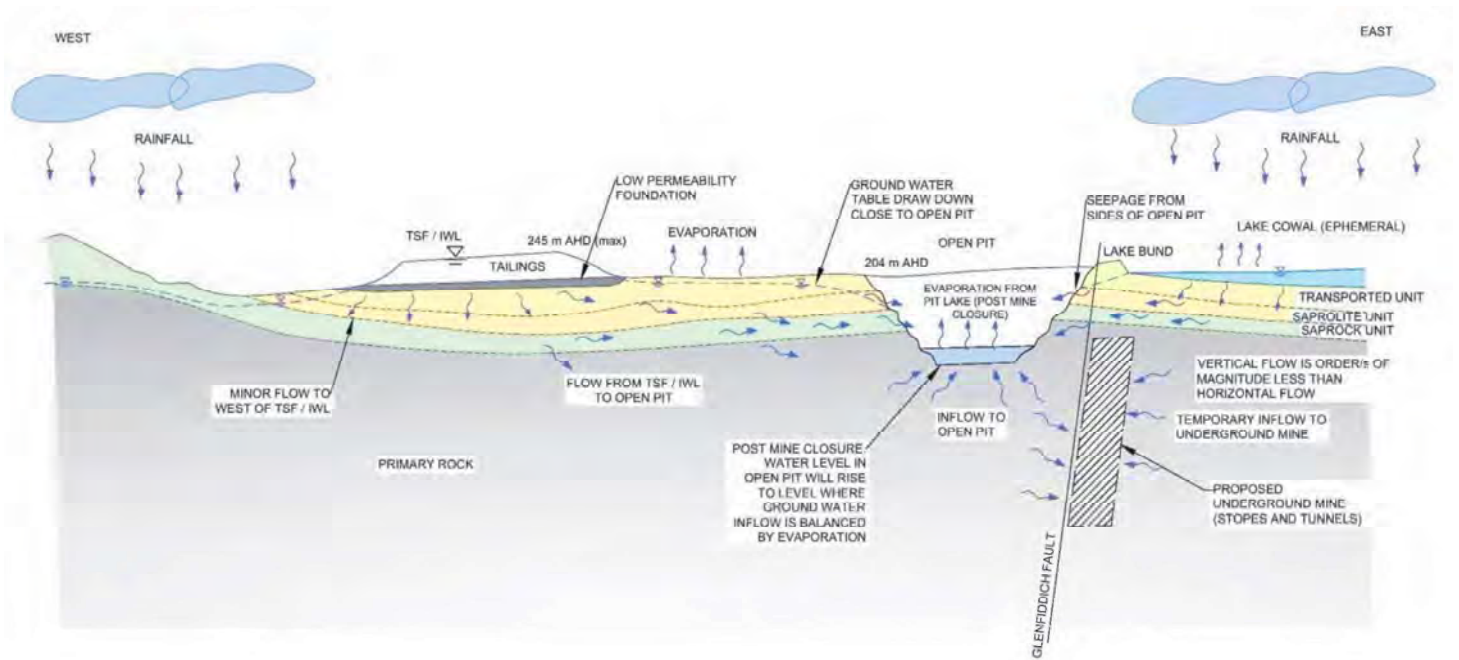


Figure 4: Conceptual hydrogeological model

## 4. Fieldwork

To provide evidence in support of groundwater level and hydraulic conductivity assumptions adopted for the CGO Underground Development EIS, a field investigation program was carried out between 28 January and 29 February 2020. Coffey field engineers attended the CGO mine site from 28 January 2020 to 29 February 2020 to supervise drilling and testing and to complete the piezometer installations associated with the field investigations.

Four vertical boreholes (UG-BH-01, UG-BH-02, UG-BH-03 and UG-BH-04) were drilled on the surface of Lake Cowal. Lake Cowal was dry during the fieldwork and at the time of writing this report (March 2020). Two boreholes were drilled to 70 m and two boreholes were drilled to 100 m depth. Coffey field engineers performed geophysical natural gamma logging. Borehole water pressure (packer) testing was carried out by the drillers at locations nominated by Coffey on selected boreholes. After testing was completed, three strain gauge piezometers were installed in each borehole at varying depths and the boreholes were then backfilled with a bentonite grout mix.

12 sub-horizontal boreholes were drilled in the GRE46 underground exploration decline at three locations, with four boreholes of lengths of 2 m, 4 m, 6 m and 10 m at each location. A strain gauge piezometer was installed at the base of each of these boreholes and the boreholes were then backfilled with a bentonite grout mix. The piezometers were activated one week after grouting and the monitoring data was collected three weeks later.

To provide additional information on the hydraulic conductivity of the bedrock, a Coffey field engineer conducted site observations of the underground decline, mapping observable water inflows and providing an estimate of inflow rates where practicable.

Figure 5 shows the location of the new boreholes, the exploration decline and the location of nearby existing monitoring wells.

### 4.1. Surface borehole drilling

Borehole drilling was conducted by the DDH Drilling company. Drilling was advanced using tungsten carbide bit augers to approximately 5.5m depth, followed by HQ coring to final depth. Table 1

provides the details of the surface (land) boreholes. Horizontal coordinates were surveyed using RTK GPS. Elevations were derived from a topographic survey provided by Evolution Mining.

Table 1: Land borehole details

Borehole	Easting (m MGA zone 55)	Northing (m MGA zone 55)	Elevation (m AHD)	Inclination	End of hole depth (m)
UG-BH-01	537751.6	6278843.8	204.1	Vertical	72.0
UG-BH-02	538180.0	6279593.8	203.8	Vertical	102.8
UG-BH-03	538019.1	6278883.0	203.9	Vertical	72.0
UG-BH-04	538169.0	6278916.0	203.8	Vertical	102.0

Borehole logs and core photos are provided in Appendix A. Note that the core boxes for UG-BH-04 were labelled as UG-BH-05 on site by the drillers.

The borehole logs provided in Appendix A are included for information only are not intended for use in engineering design. For this reason, the borehole logs are marked as DRAFT.

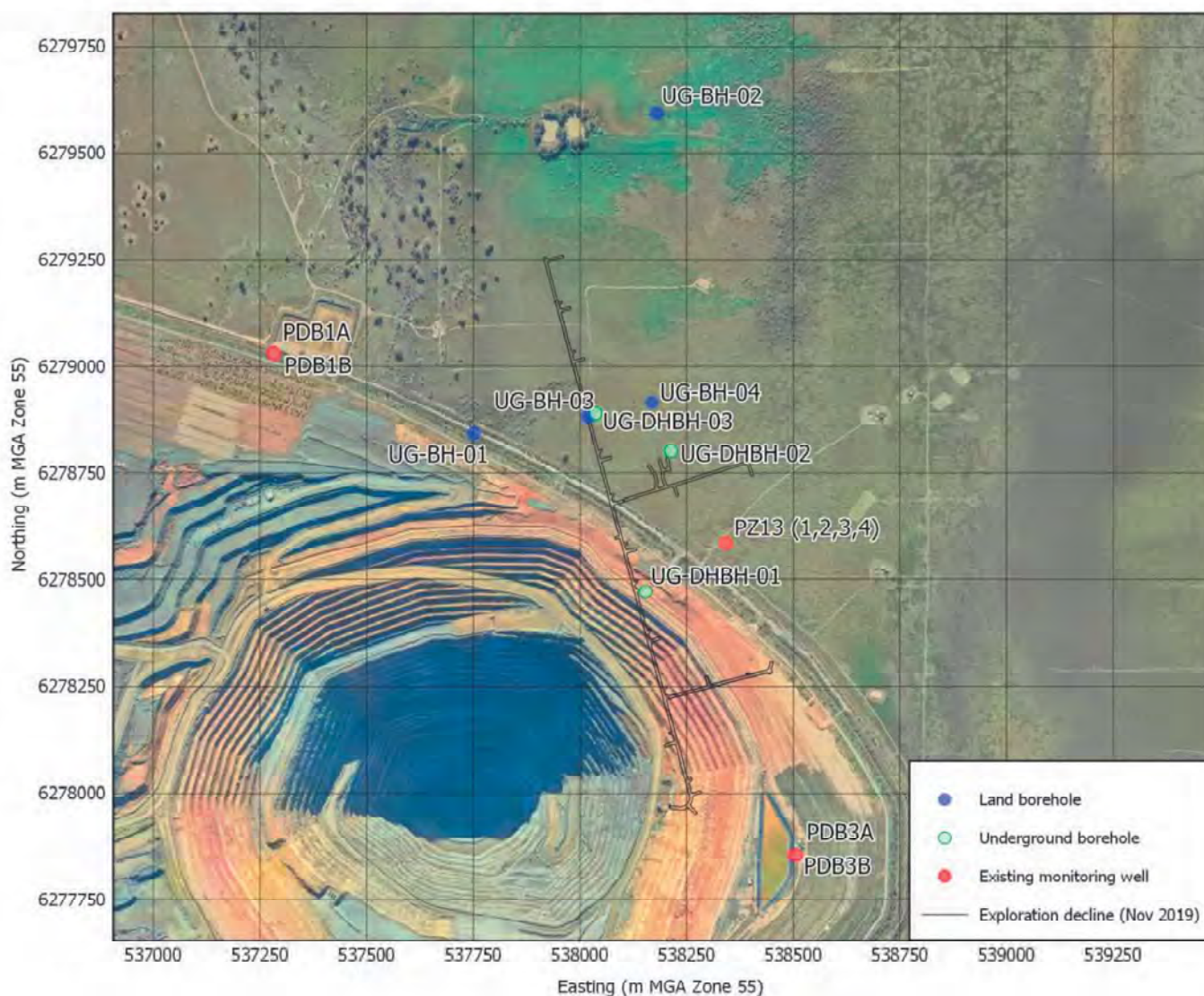


Figure 5: Location plan

### 4.1.1. Observed geological conditions

The following materials were encountered during borehole drilling:

- Lake Sediments: Comprising clays to sandy clays with minor sand layers, overlying;
- Residual soil (Saprolite): Comprising silty to sandy clays, overlying;
- Highly to moderately weathered bedrock (Saprock): Comprising mudstones or andesite, overlying;
- Slightly weathered to fresh bedrock (Primary Rock): Comprising mudstones or andesite.

Table 2 summarises the ground conditions encountered in the boreholes.

Table 2: Ground conditions

Borehole ID	Lake Sediments	Saprolite	Saprock	Primary Rock
UG-BH-01	0 – 18.9 m	18.9 – 37.1 m	37.1 – 72.0 m	Not observed
UG-BH-02	0 – 20.5 m	20.5 – 45.1 m	45.1 – 102.8 m	Not observed
UG-BH-03	0 – 17.3 m	17.3 – 19.0 m	19.0 – 72.0 m	Not observed
UG-BH-04	0 – 10.6 m	10.6 – 15.7 m	15.7 – 66.7 m	66.7 – 102.2 m

## 4.2. Geophysics – Natural gamma logging

Natural gamma logging was carried out at boreholes UG-BH-01, UG-BH-02 and UG-BH-04. The location of these boreholes is shown in Figure 5.

Natural gamma logging is a non-destructive, borehole logging methodology that characterises the subsurface material based upon its radioactive signature. In a lithology, the decay products of thorium, uranium and potassium emit gamma rays (Belknap et al., 1959) and natural gamma logging takes advantage of these naturally occurring circumstances by measuring gamma emission intensity at different depth levels. Radioactive elements that emit gamma radiation (K, U, Th) tend to be associated with clay and shale materials and not sand materials, therefore the natural gamma method can be used to estimate layers of higher sand content where decreases in gamma emission are detected.

Figure 6 shows the typical field setup used which comprised a Mount Sopris manufactured Gamma Ray sonde (1.28m), winch, wireline cable, tripod, and top-side 'Matrix' logger system with a laptop computer to control all components.



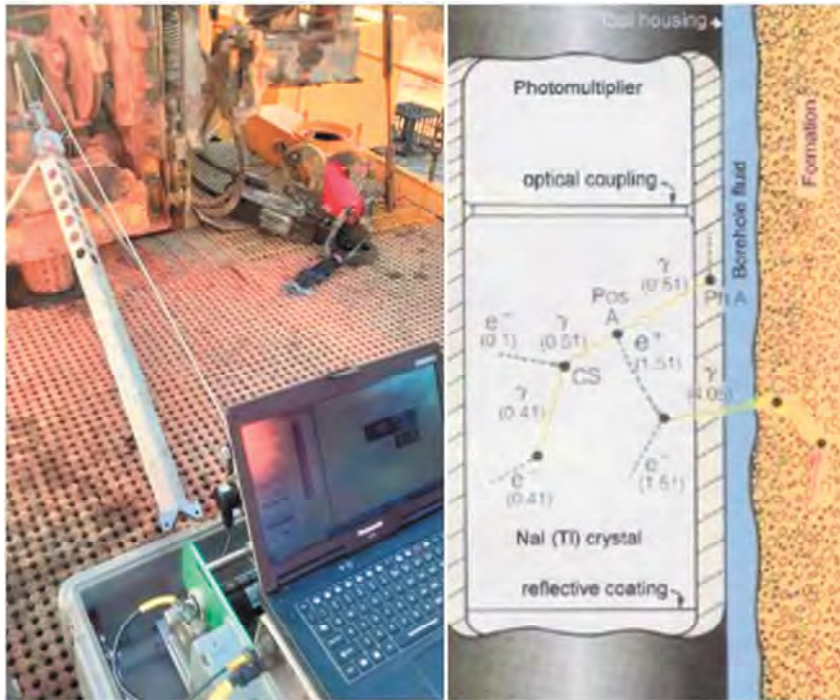


Figure 6: Natural gamma logging setup

Natural gamma logging was conducted to a depth of 50 m in UG-BH-01, UG-BH-02 and UG-BH-04. Due to technical issues with the natural gamma logging equipment during night drilling, UG-BH-03 was not tested.

The results of the natural gamma logging are provided in Appendix B and discussed in Section 5.2.

### 4.3. Packer testing

Following completion of borehole drilling, borehole water pressure testing (packer testing) was conducted to provide information about the hydraulic conductivity of the bedrock. Packer testing involved the insertion into the borehole of a straddle packer (two inflatable balloons or 'packers') which isolated a section of rock, typically 5 m in length. Water was pumped into this section of rock, pressure was applied and held constant for a given time. The rate of water flow from the borehole into the surrounding rock was then monitored using a flow meter.

Each packer test involved five test stages, each at a specified test pressure. The test results were interpreted using the method shown by Burgess (1983). Packer tests results are usually reported in Lugeon values, with one Lugeon being defined as a water loss of 1 L per minute, per metre of rock at 1000 kPa driving pressure. One Lugeon is approximately equivalent to a hydraulic conductivity of  $1 \times 10^{-7}$  m/s

A summary of the packer test results is shown in Table 3. Packer tests were not conducted at UG-BH-01 as a suitable section of non-fractured core to seat the packers was not identified.

The packer test results are provided in Appendix C and discussed in Section 5.1.

Table 3: Packer testing results

Borehole	Depth (m)	Unit	Lugeon value	Hydraulic conductivity (m/s)
UG-BH-02	97.0 – 103.0	Saprock	0.03	$3 \times 10^{-9}$
UG-BH-03	60.0 – 64.0	Saprock	0.01	$1 \times 10^{-9}$
UG-BH-03	65.0 – 72.0	Saprock	0.01	$1 \times 10^{-9}$
UG-BH-04	54.0 – 59.0	Saprock	1.1	$1.1 \times 10^{-7}$
UG-BH-04	63.0 – 68.0	Saprock	0.04	$4 \times 10^{-9}$
UG-BH-04	72.0 – 77.0	Primary Rock	1.2	$1.2 \times 10^{-7}$
UG-BH-04	91.0 – 102.0	Primary Rock	< 0.01	$< 1 \times 10^{-9}$

## 4.4. Installation of piezometers

Following drilling of each surface borehole, three strain gauge piezometers were installed in the borehole at varying depths to monitor groundwater pressures at 6 hr intervals. The boreholes were backfilled with a bentonite grout mix using an approximate ratio (by weight) of 0.3 bentonite to 1 cement to 3 water. The piezometers were connected to telemetry data loggers which enable remote monitoring of the groundwater pressure. Table 4 shows the elevation and hydrogeological unit in which each of each of the piezometers is located. The piezometers are labelled as SG1, SG2 or SG3 in each borehole.

Table 4: Piezometer elevations

Borehole	Piezometer SG1 elevation (m AHD)	Unit	Piezometer SG2 elevation (m AHD)	Unit	Piezometer SG3 elevation (m AHD)	Unit
UG-BH-01	189.1	Lake Sediments	174.1	Lake Sediments	134.1	Saprock
UG-BH-02	190.8	Lake Sediments	160.8	Saprolite	103.8	Primary Rock <sup>1</sup>
UG-BH-03	188.9	Lake Sediments	173.9	Saprolite	133.9	Primary Rock <sup>1</sup>
UG-BH-04	188.8	Lake Sediments	158.8	Saprock	102.3	Primary Rock

1. Piezometer located approximately at the top of primary rock unit

### 4.4.1. Allowance for flooding of Lake Cowal

The telemetry data loggers for the piezometers were installed on poles approximately 1.9 m high. In the event of flooding of Lake Cowal, flood water level is likely to rise above the top of the pole. For this reason, the mounting for the telemetry data loggers has been designed to be easily removable and a tether is provided for attachment to a floatable raft (designed by others), as explained below.

A marine grade stainless steel wire tether has been secured to the top of each post. This may be attached to a floatable raft to allow temporary floating of the data loggers during flooding of Lake Cowal. The data loggers have been mounted onto weather resistant plywood, which can be cut, drilled, screwed or modified as needed to attach to the raft when required. The plywood is mounted onto the pole by two U-bolts, which can be removed with a spanner.

Care was taken when installing the telemetry boxes to ensure that the readout unit was watertight. It should be noted however that it is not designed to be submerged. Figure 7 shows details of the telemetry installation.



Figure 7: Telemetry installation

In the event that Lake Cowal floods, the following steps will need to be taken to ensure that the piezometers continue to function and are not damaged:

1. Cable ties securing wire coils to mounting hooks to be cut to free the cables.
2. Telemetry data logger and plywood backing to be removed from pole by undoing the two large U-bolts with a spanner and then attached to a floatable raft (designed by others).
3. Stainless steel tether to be attached to floatable raft by the eyelet found at the end of the tether.
4. Piezometer cables to be secured to the top of the pole at the D-shackle using a cable tie or similar. This is to reduce the risk of the piezometer cables wrapping around the pole as the floatable raft moves in the water.

After completing the steps above there should be approximately 2 to 3 m of stainless steel wire tether and approximately 3 to 4 m of piezometer cables between the top of the pole and the floatable raft. The stainless steel tether is shorter than the piezometer cables to ensure that the piezometer cables do not carry the load of anchoring the floatable raft.

## **4.5. Piezometer installation in exploration decline**

12 strain gauge piezometers were installed in the exploration decline to gain an understanding of the effect of tunnelling induced stress changes on permeability in the surrounding rock. Three locations were chosen for piezometer installation at different depths in the exploration decline; one in the 1017 arm (17 m AHD), one in the 985 arm (-15 m AHD) and one in the 951 arm (-49 m AHD). These locations are named UG-DHBH-01, UG-DHBH-02 and UG-DHBH-03 respectively. The locations are shown in Figure 5.

At each location, four boreholes were drilled into the surrounding walls of the tunnel at an angle of 20 degrees below horizontal. A Coffey field engineer was not present for the drilling of these boreholes and did not observe any recovered core. The boreholes were drilled to depths of 2 m, 4 m, 6 m and 10 m at each location.

A strain gauge piezometer was placed in the base of each borehole before grouting to the surface using an approximate bentonite grout mix ratio (by weight) of 0.25 bentonite to 1 cement to 2.5 water. One week after grouting, the piezometers were connected to data loggers. This data was downloaded by a Coffey field engineer after three weeks of monitoring.

## **4.6. Mapping of seepage into exploration decline**

A Coffey field engineer conducted a site walkover and drive through the exploration decline on 27 February and 28 February 2020. Observed areas of seepage or dampness of the exposed tunnel face were recorded. Where possible, the rate of seepage was assessed by timing the rate of filling up of a bucket. The entire decline was observed except for a small area where drilling was in progress at the eastern end of the 985 arm. The floor of the decline was not observed as it was not practicable to obtain a clear view due to the presence of disturbed ground, mud or water.

A map showing observed seepage is provided in Appendix D and discussed in Section 5.1.1.



## 5. Discussion of results

### 5.1. Aquifer parameters

The field methodology for packer testing was described in Section 4.3. Packer test results are plotted against depth in Figure 8.

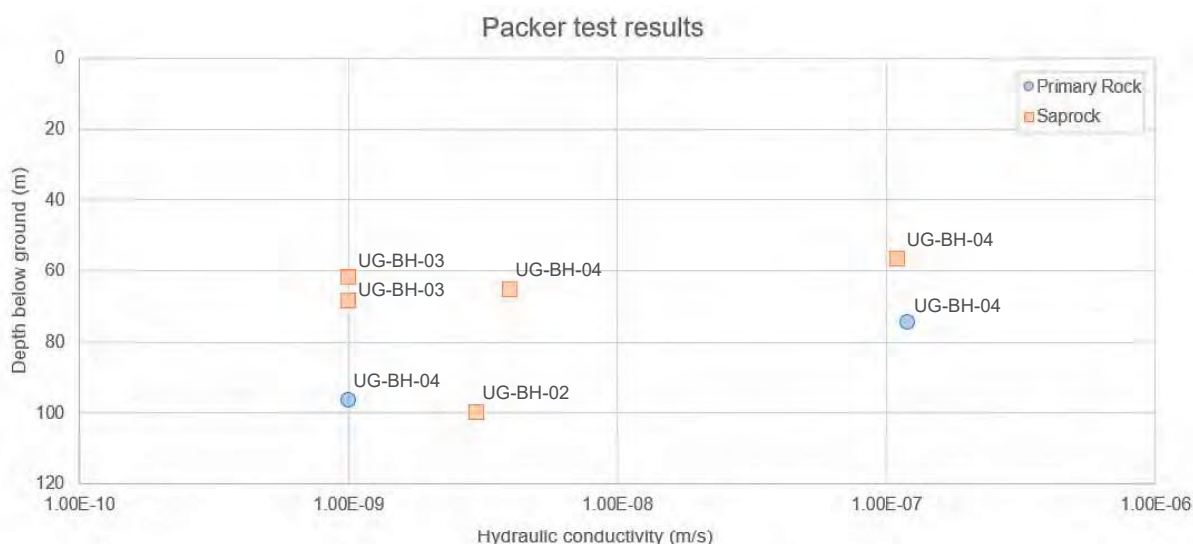


Figure 8: Packer test results

It can be seen from the figure that the majority of packer test results showed hydraulic conductivities below  $1 \times 10^{-8}$  m/s. Three tests showed negligible to no flow and a value of  $1 \times 10^{-9}$  m/s was ascribed to these as a practical minimum level of detection.

#### 5.1.1. Seepage into the exploration decline

Seepage into the exploration decline was mapped by a Coffey field engineer, as described in Section 4.6. The observed seepage and estimated inflows are shown in Table 5. A map showing observed seepage is provided in Appendix D.

Table 5: Observed seepage in exploration decline (27 February 2020)

Category	Approximate flow rate (L/min)	Number observed	Total flow (L/min)	Total flow (L/s)
VVH	25	1	25.0	0.42
VH	7.5	3	22.5	0.38
H	3	6	18.0	0.30
L	1.5	7	10.5	0.18
M	0.2	47	9.4	0.16
TOTAL			85.4	1.42

The seepage inflow rate classifications listed in Table 5 were adopted for this project to cover the range of inflows observed. Even the highest observed inflow rate is considered modest. The total aggregate observed flow into the decline is approximately 1.4 L/s. Doubling this value, to account for areas where seepage could not be observed due to mud and water and for approximations in

assessing flow rates, results in an estimated groundwater inflow rate of 2.8 L/s into the whole exploration decline on 27 February 2020.

An assessment of the hydraulic conductivity required to produce this flow rate was carried out. This was done by assuming an equivalent length tunnel in uniform rock with the same approximate groundwater heads and tunnel elevation profile. The resulting hydraulic conductivity was found to be close to  $5.5 \times 10^{-9}$  m/s. This result is similar to the median of the packer testing results ( $3.5 \times 10^{-9}$  m/s) which are shown in Table 3 and Figure 8.

Note that this method of assessing hydraulic conductivity is approximate, however groundwater inflow rates into the exploration decline serve as an excellent guide to expected groundwater into other excavations nearby such as the proposed stopes and access tunnels for the CGO Underground Development.

Details of the hydraulic conductivity assessment are provided in Appendix D.

### **Influence of faults**

The Glenfiddich fault was observed to cross the exploration decline near its southern portal. The fault zone consists of slightly more fractured rock compared to the surrounding rock and is up to approximately 8 m wide. Some areas of higher inflow were found adjacent to the fault. However, many other areas of higher inflow were found in joints not apparently connected to the Glenfiddich fault or other faults. The widespread and intersecting nature of jointing and faulting observed inside the decline makes it impractical to describe the effect of individual faults on the groundwater flow regime.

It does not appear that the Glenfiddich fault is providing a significant preferential conduit for groundwater when it is considered amongst the surrounding fractured rock at the scale of the CGO Underground Development.

## **5.2. Geophysics - Natural gamma logging**

Natural gamma logging was conducted to assess the variability in the Lake Sediments. The fieldwork methodology was discussed in Section 4.2.

The results of the natural gamma logging are provided in Appendix B. The charts in Appendix B show measured gamma ray emissions from the soil and/or rock versus depth. To assist in interpreting the results, drilling core loss percentages have been plotted as logged in the field. Areas of higher drilling core loss are likely to be areas where the materials contain higher sand content and are often associated with lower GR (natural gamma radiation rate) values. Overall, depths with GR values lower than 80 are interpreted to be likely to contain higher levels of sand.

The following summarises the depths where GR values less than 80 were observed in the Lake Sediments:

- UG-BH-01 (Lake Sediments 0.0 m – 18.9 m):
  - 8.0 m – 8.5 m
  - 15.2 m – 15.8 m
  - 17.0 m – 18.4 m

2.5 m out of 18.9 m (13 %) thickness of Lake Sediments at UG-BH-01 observed to have GR values less than 80.

- UG-BH-02 (Lake Sediments 0.0 m – 20.5 m):
  - 13.0 m – 20.5 m

7.5 m out of 20.5 m (37 %) thickness of Lake Sediments at UG-BH-02 observed to have GR values less than 80.

- UG-BH-04 (Lake Sediments 0.0 m – 10.6 m):

0.0 m out of 10.6 m (0 %) thickness of Lake Sediments at UG-BH-04 observed to have GR values less than 80.

It should be noted that these areas are likely to have a higher sand content than other parts of the Lake Sediments, although the material is likely to still be predominantly a clay. Figure 9 shows a core photo from UG-BH-02. The core run from 14.7 m – 17.8 m, shown in the lower half of the core box, was in a zone where natural gamma GR values were approximately 65 on average. Despite this, the material is still predominantly clay.

Clean sands or gravels were not found in the Lake Sediments in any of the four boreholes.



Figure 9: UG-BH-02 core photo showing Lake Sediments (13.0 m - 18.9 m)

The natural gamma logging, along with the borehole logs, show the Lake Sediments to be predominantly a sandy clay with occasional zones or bands of higher sand content. No obviously high permeability zones (such as clean sands or gravels) were identified in either the borehole logs or the natural gamma logging.

Note that, following advice from Evolution Mining, in-situ permeability testing was not undertaken on the Lake Sediments to minimise risk of environmental contamination of the lake bed with testing water or fluid.

### 5.3. Exploration boreholes

Exploration borehole data was provided in digital format by Evolution Mining. The provided exploration boreholes cover an area of approximately 1.3 km (east-west) by 2.5 km (north-south) above the proposed underground mine. This information was used to obtain elevations for the interfaces between the three hydrogeological units described in Section 3.2. A contouring process (kriging) was used to interpolate between boreholes. Figure 10 shows the interpreted thickness of the Lake Sediments and Saprolite units from the exploration boreholes. The depth below ground refers to the ground surface prior to the open pit being excavated.

In the area above the CGO Underground Development, the thickness of the Lake Sediments can be seen from Figure 10 to be approximately between 15 m and 34 m. It is worth noting that the base of the Lake Sediments can be challenging to identify from borehole drilling. The Saprolite immediately below the base of the Lake Sediments, as observed in UG-BH-01, UG-BH-02, UG-BH-03 and UG-BH-04, often contained sandy clays which appeared very similar to those encountered in the Lake Sediments.



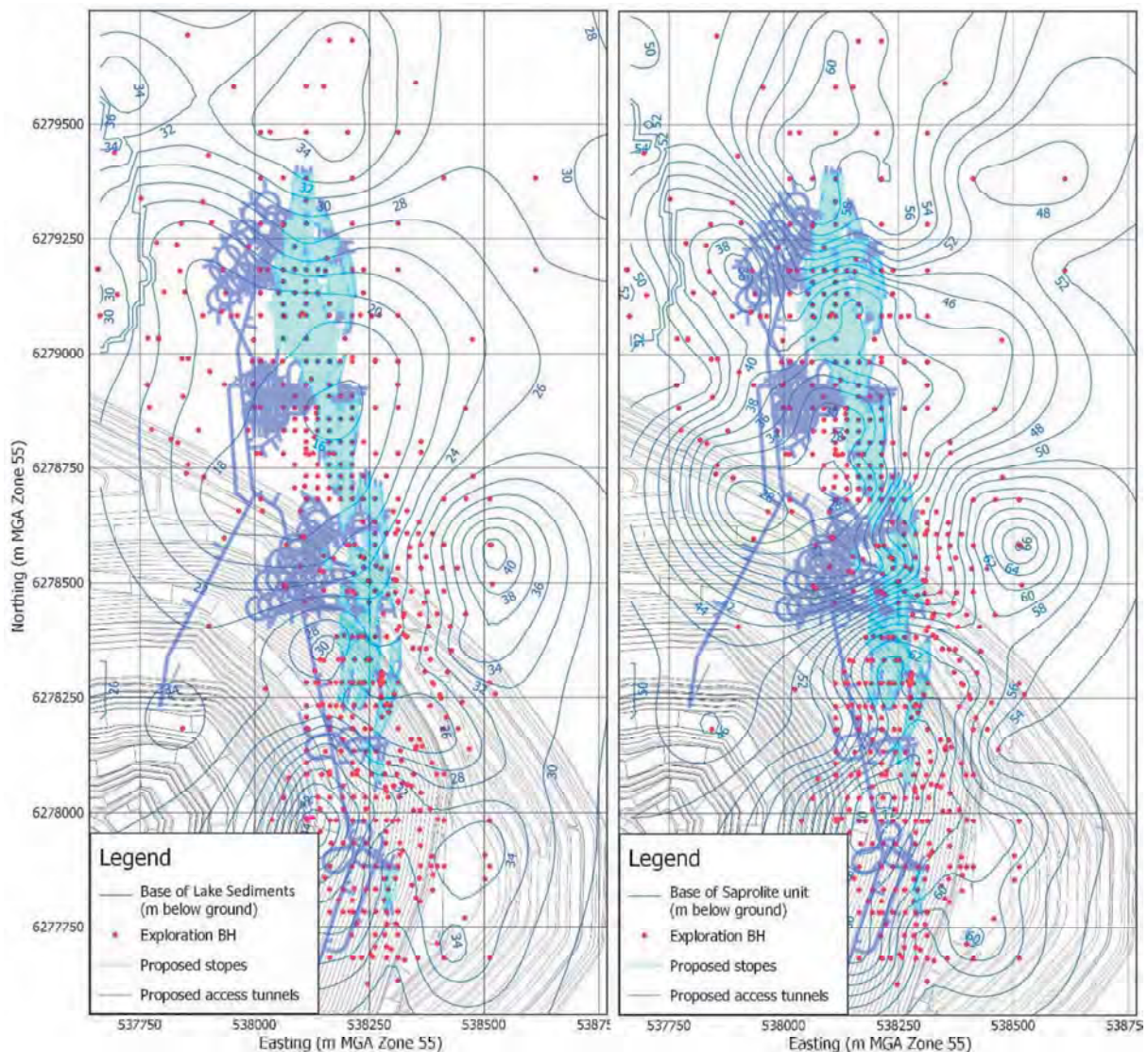


Figure 10: Depth to the base of Lake Sediments and Saprolite units as interpreted from exploration boreholes

## 5.4. Geophysics - gravity survey interpretation

In April 2019, a detailed geophysical gravity survey commissioned by Evolution Mining was carried out by Haines Surveys Pty Ltd (Haines) and presented in a report (Haines Surveys, 2019).

The gravity survey data was provided to Coffey for further analysis and modelling which was carried out in November 2019. The proprietary software program Potent was used. Potent is a Windows-based application in an interactive framework for 3D modelling of potential field data (i.e. gravity and/or magnetics).

The interpretation of the data was calibrated against exploration borehole data, from which the thickness of the Lake Sediments had been observed directly. The majority of boreholes were clustered over the edge of the central eastern part of the survey area above the proposed underground mine. However, four boreholes were obtained from the National Groundwater Information System (NGIS) public borehole database. These boreholes provide lithology logs showing the base of the Lake Sediments. The boreholes are GW703223, GW703225, GW704031 and GW704252. Their locations are shown in Figure 11. There were a number of other boreholes in the NGIS public borehole database for the area covered by the gravity survey, however these did not



provide lithological logs identifying the base of lake sediments or provided logs which were deemed of lesser accuracy and were excluded.

The exploration and selected publicly available boreholes provide a reasonable constraint of the interpretation out to approximately 3 km east of the open pit. The interpreted levels of the base of the Lake Sediments from the gravity survey data are shown in Figure 11 and the interpreted thickness is shown in Figure 12. Figure 12 shows that the Lake Sediments have a thickness generally ranging between 30 m and 50 m in the area east of the open pit, except for a notable area extending north east of the open pit, where the thickness ranges between approximately 15 m and 25 m.

The gravity survey interpretation for areas outside those shown on Figure 11 did not converge in the analysis and so these areas were excluded from reporting. Note also that the gravity survey interpretation was done prior to the fieldwork covered in this report and did not take into account the results of boreholes UG-BH-01, UG-BH-02, UG-BH-03 and UG-BH-04.

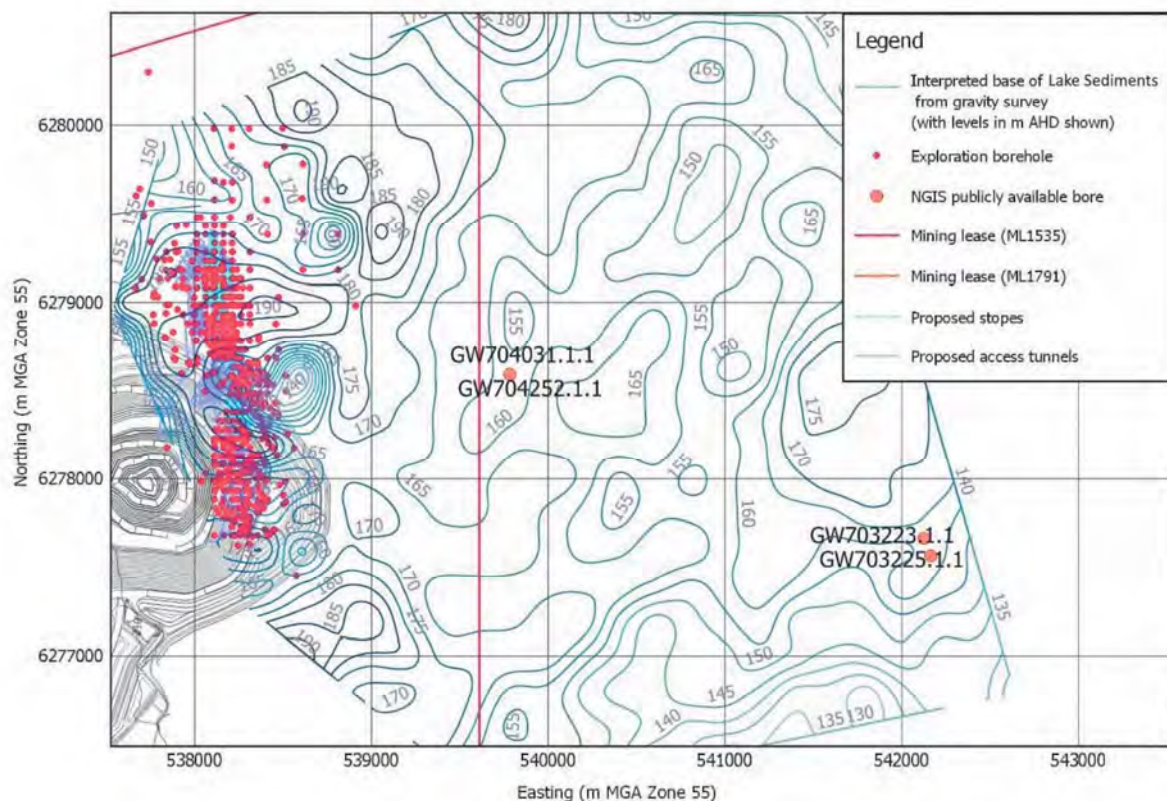


Figure 11: Elevation of the base of the Lake Sediments from gravity survey interpretation

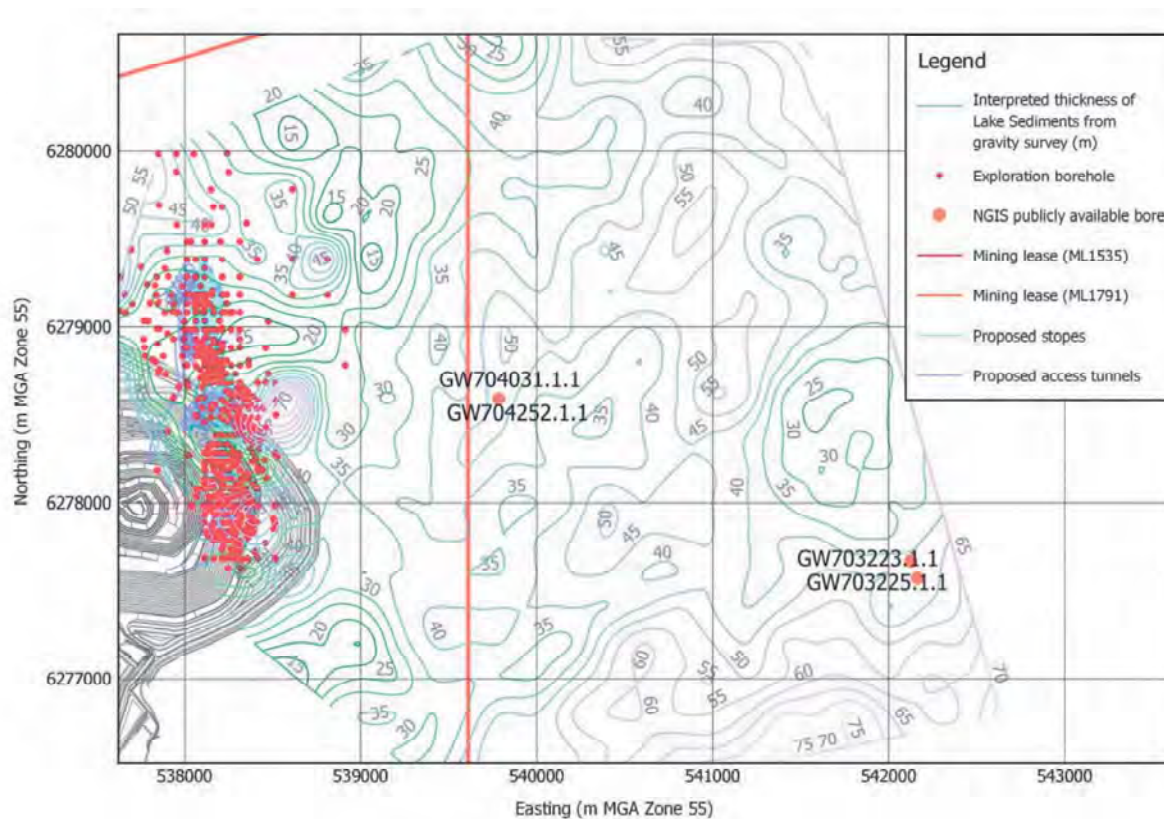


Figure 12: Thickness of the Lake Sediments from gravity survey interpretation

## 5.5. Groundwater levels

Groundwater monitoring was installed at UG-BH-01, UG-BH-02, UG-BH-03 and UG-BH-04. The locations of these boreholes are shown in Figure 5. At each of these locations, three strain gauge piezometers were installed at different depths, as discussed in Section 4.4 and shown in Table 4.

In addition, groundwater monitoring data was provided by Evolution Mining for eight existing piezometers located at boreholes PDB1, PZ13 and PDB3. The locations of these boreholes are also shown in Figure 5. The elevations and hydrogeological units in which these piezometers are screened or located in are shown in Table 6.

Table 6: Existing piezometers near the proposed underground development

Borehole	Piezometer elevation (m AHD)	Unit
PDB1A	126.3	Saprock
PDB1B	194.3	Lake Sediments
PZ13-1	83.8	Primary Rock
PZ13-2	128.8	Saprock
PZ13-3	143.8	Saprock
PZ13-4	171.8	Saprolite
PDB3A	110.3	Saprock
PDB3B	181.2	Lake Sediments

A hydrogeological assessment was undertaken by Coffey to assess potential impacts on the groundwater system under the proposed Cowal Gold Operations (CGO) Underground Development (Coffey Report No. SYDGE206418-3-AD, dated 3 February 2020 (Draft)) (the numerical groundwater model). From the numerical groundwater model, modelled groundwater heads (at January 2020) were extracted at the location of each of the new and existing monitoring locations described above.

The numerical groundwater model did not take into account the exploration decline. Differences between modelled and observed heads may therefore be the result of either effects on groundwater levels associated with the exploration decline and / or may provide an indication of areas where model calibration could be improved.

Modelled and observed groundwater heads at the new and existing groundwater monitoring locations are shown in Figure 13 and Figure 14, respectively. Groundwater heads in the figures are shown for the following dates:

- Modelled groundwater heads are shown for 1 January 2020.
- Observed groundwater heads at UG-BH-01, UG-BH-02, UG-BH-03 and UG-BH-04 are shown for 2 March 2020.
- Observed groundwater heads at PDB1A, PDB1B, PDB3A and PDB3B are shown for 6 December 2020.
- Observed groundwater heads at PZ13 are shown for 1 November 2020.

Groundwater monitoring hydrographs for each of these locations are provided in Appendix E.

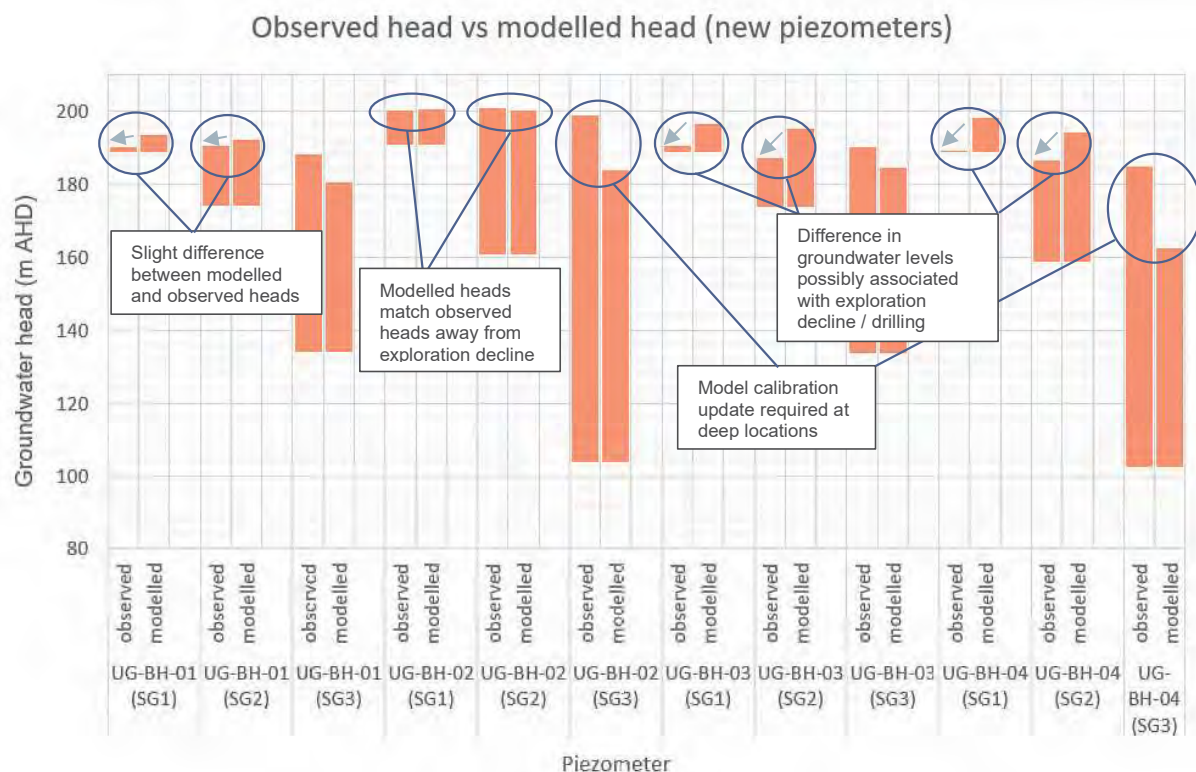


Figure 13: Observed and modelled groundwater head at new piezometers (base of column shows sensor elevation, top of column shows groundwater heads)



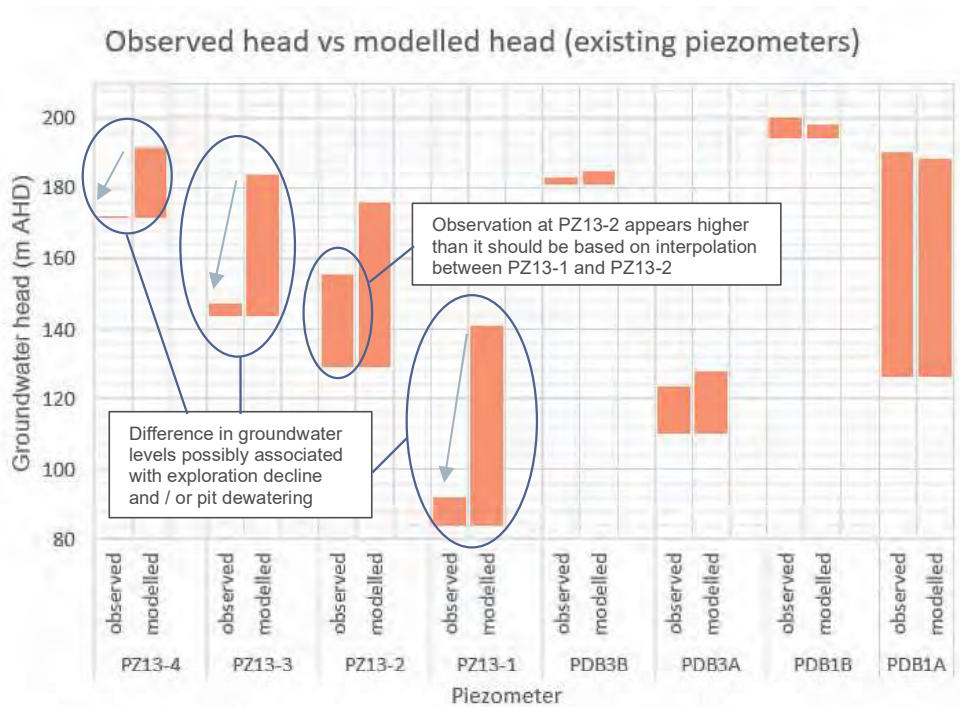


Figure 14: Observed and modelled groundwater head at existing piezometers (base of column shows sensor elevation, top of column shows groundwater heads)

The following observations are made based on the information shown in Figure 7 and Figure 8:

- Groundwater levels away from the decline in the two shallow piezometers at UG-BH-02 provide a close match to predictions from the numerical groundwater model. This indicates that model calibration appears reasonable for the shallower hydrogeological units.
- Groundwater levels for the deeper piezometers observed at all of the new monitoring locations are higher than those predicted by the numerical groundwater model by between 4 m and 10 m. This indicates the potential for improvement to model calibration for the deeper hydrogeological units.
- Groundwater levels observed at UG-BH-03 and UG-BH-04 show that the underground decline and associated exploration drilling may have resulted in groundwater levels in the Lake Sediments and Saprolite being below the modelled values. At UG-BH-01, which is located approximately 250 m west of the exploration decline, differences between modelled and observed heads in the Lake Sediments and Saprolite are less than 2 m.
- Groundwater levels observed at PZ13 are between 10 m and 40 m lower than those predicted by the groundwater model. This large difference might be explained by exploration drilling targeting a shallower zone of potential gold bearing ore in this location and by the higher elevation of the exploration decline in this area. Alternatively, groundwater levels may be affected by rock defects creating preferred pathways towards the open cut mine void.

## 5.6. Groundwater levels adjacent to the exploration decline

As discussed in Section 4.5, strain gauge piezometers were installed at three locations in the exploration decline to monitor groundwater pressures at 2 m, 4 m, 6 m and 10 m distance into the surrounding rock from the tunnel walls. Groundwater monitoring results at the three locations in the underground decline are shown in Figure 15, Figure 16 and Figure 17. The results are summarised as below:



- At UG-BH-01, all of the piezometers were dry over the monitoring period. Pressures of between approximately -2 kPa and -5 kPa observed over the final two weeks of monitoring, indicating unsaturated conditions.
- At UG-BH-02, the piezometer at 2 m distance was dry, showing atmospheric pressure variation. The piezometers at 4 m, 6 m and 10 m showed relatively stable pressures of approximately 1.0 kPa, 0.8 kPa and 10.6 kPa respectively over the final two weeks of monitoring.
- At UG-BH-03, the piezometers at 2 m and 10 m were showing pressures of -95 kPa over the whole monitoring period, indicating that more time may have been required for stabilisation as nearby air pockets fill with water. Interestingly, the piezometer at 4 m distance was similarly showing pressures of -95 kPa for the first two weeks of monitoring until rising rapidly to a near atmospheric condition, as can be observed over the last two days of monitoring. The piezometer at 6 m distance was approximately constant over the monitoring period at around 7 kPa and showed variability similar to atmospheric conditions.

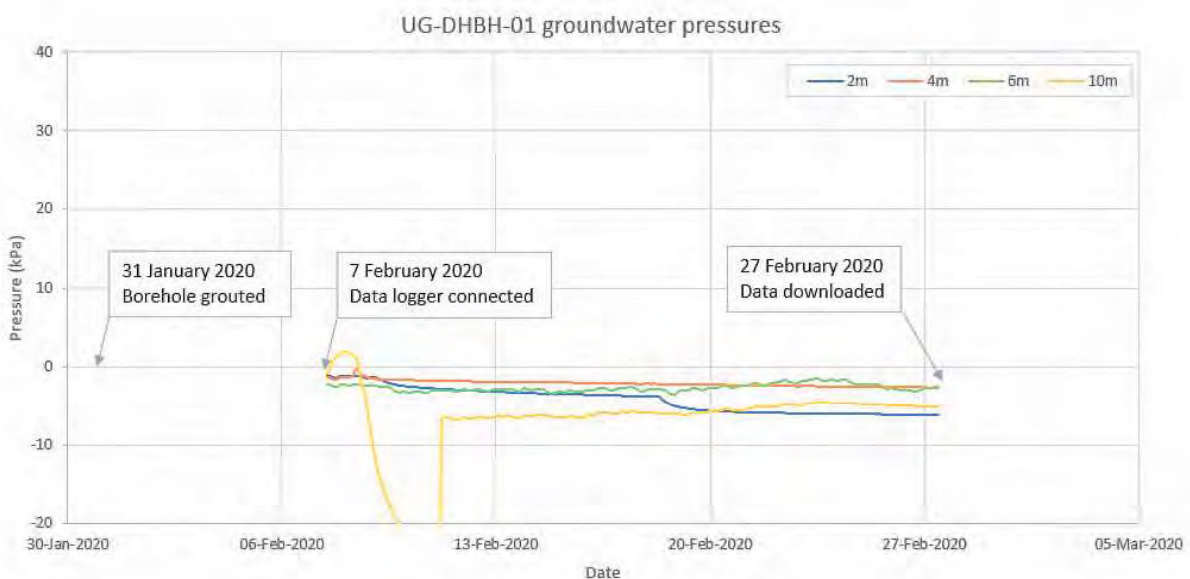


Figure 15: Groundwater pressures at UG-DHBH-01

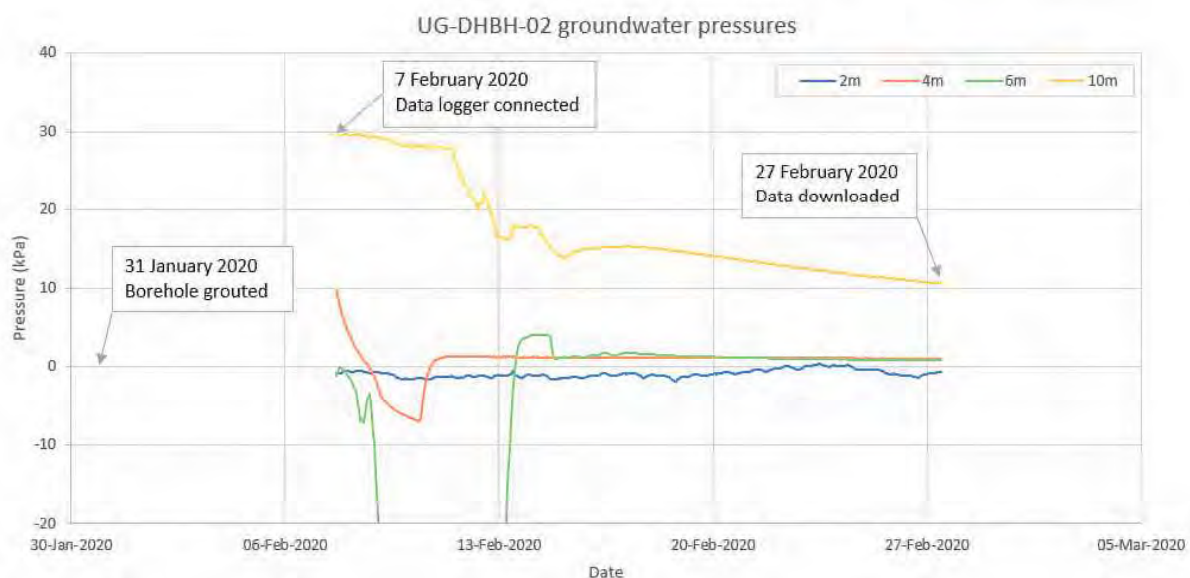


Figure 16: Groundwater pressures at UG-DHBH-02

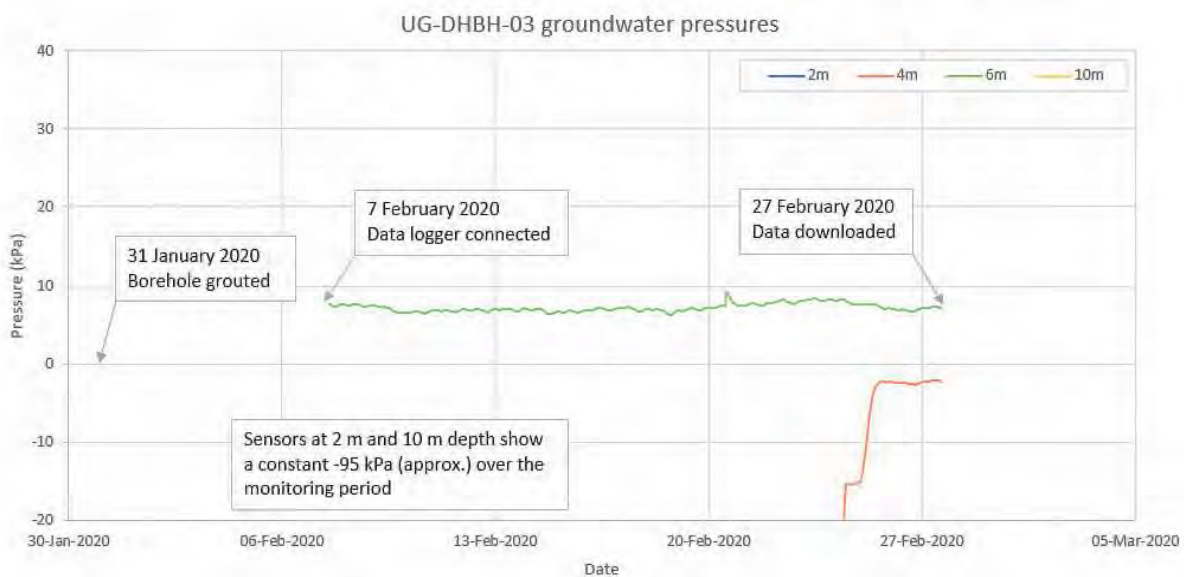


Figure 17: Groundwater pressures at UG-DHBH-03

The results shown in Figure 15, Figure 16 and Figure 17 indicate that groundwater pressures within 10 m from the exploration decline are generally dry or in an unsaturated condition. UG-DHBH-02 is the only location where the majority (three out of four) of piezometers show positive groundwater pressures. At this location, the groundwater pressure at 2m, 4m and 6m is negligible or unsaturated and the groundwater pressure at 10 m is 10 kPa and was falling slowly on 27 February 2020. This may indicate that changes in hydraulic conductivity as a result of stress changes due to tunnelling extend out to somewhere between 6 m and 10 m from the exploration decline at that location. Note however that the drilling of exploration boreholes may have resulted in localised changes to permeability and a lowering of groundwater pressures near the tunnel face in this area and also at UG-DHBH-01 and UG-DHBH-03.

## 6. Summary

The results of fieldwork, undertaken to improve understanding of groundwater conditions in support of the hydrogeological assessment for the CGO Underground Development EIS, have been presented. These include borehole logs, geophysical testing, permeability testing, seepage mapping in the exploration decline and groundwater level monitoring in the area of the proposed CGO Underground Development. The main results from the fieldwork are summarised below:

- The Lake Sediments in the area near the proposed CGO Underground Development were observed to be between 10.6 m and 20.5 m thick at the four boreholes drilled. The Lake Sediments comprised predominantly clays to sandy clays containing minor bands or layers with higher sand content. No clean sands or gravels were observed.
- Following advice from Evolution Mining, in-situ permeability testing was not undertaken on the Lake Sediments to minimise risk of environmental contamination of the lake bed with testing water / fluid.
- In-situ borehole water pressure testing (packer testing) on the Saprock and Primary Rock units, in combination with seepage observations into the exploration decline, showed the horizontal hydraulic conductivity of these units to be in the order of  $1 \times 10^{-9}$  m/s to  $1 \times 10^{-8}$  m/s.
- 12 piezometers were installed at four locations near the proposed CGO Underground development. Initial monitoring results indicate that:

- Observed groundwater levels at UG-BH-02, located away from the exploration decline, provide a reasonable match to predictions from the numerical groundwater model for piezometers in the Lake Sediments and Saprolite
  - Observed groundwater levels at the deepest piezometers in all four locations are higher than those predicted by the numerical groundwater model by between 4 m and 10 m. This indicates the potential for improvement to model calibration for the deeper hydrogeological units. It is recommended to update model calibration in any future revision to the numerical groundwater model
- 12 piezometers were installed at three locations in the exploration decline. Observations at these piezometers indicate that groundwater pressures within 10 m of the excavation decline are generally zero or unsaturated. Results at UG-DHBH-02 which showed groundwater pressure at 10 m distance from the exploration decline and very low to zero pressure at 6 m, 4m and 2m distance suggest that changes to hydraulic conductivity as a result of stress changes due to tunnelling have extended out to somewhere between 6 m and 10 m from the exploration decline at that location.
- Observations of seepage into the exploration decline showed some areas of higher inflow associated with the Glenfiddich fault. Many other areas of higher inflow were found in joints not necessarily connected to faults. The widespread and intersecting nature of jointing and faulting observed inside the decline makes it impractical to describe the impact of individual faults on the groundwater flow regime.

## 7. References

Barrick Australia Limited (2010). Saline Groundwater Assessment – Cowra Aquifer, Cowal Gold Mine, West Wyalong, NSW, Final Report, Project No. BARR010, October 2010.

Belknap, W.B., Dewan, J.T., Kirkpatrick, C.V., Motts, W.E., Peason, A.J., Rabson, W.R., 1959. API calibration facility for nuclear logs, in: Drilling and Production Practice. American Petroleum Institution, pp. 289-316.

Burgess, P.J. (1983) In-situ permeability testing in soil and rock, in: In-situ Testing for Geotechnical Investigations. Balkema, Rotterdam.

Coffey Services Australia Pty Ltd (2006). Cowal Gold Mine, Groundwater Supply Modelling Study, Model Calibration. Report No. S21910/2AK, 15 September 2006.

Haines Surveys (2019), Lake Cowal 3 Gravity Survey, Evolution Mining Ltd, April - May 2019, Job No. 1906.



## **Appendix A – Borehole logs**

# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-01**  
sheet: 1 of 9  
project no: **754-SYDGE206418-3**  
date started: **29 Jan 2020**  
date completed: **01 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance					
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	structure and additional observations
1 2 3	1 2 3							SOIL NAME: plasticity or particle characteristic, colour, secondary and minor components	
					1.0			Sandy GRAVEL: fine to coarse grained, sub-angular to angular, red/brown, sand is fine to coarse grained, with cobbles and boulders up to 300mm.	Outer bund wall
					2.0			Soil not observed from 1.0m to 5.8m due to drilling schedule and method	
					3.0				
					4.0				
					5.0				
					6.0			Start of coring at 5.7m	
					7.0			Sandy CLAY: high plasticity, pale grey mottled orange and red/brown, with fine to coarse grained, sub-angular gravel.	LACUSTRINE SOIL Core Run (5.7-5.9 m): 100% recovery Core Run (5.9-7.7 m): 100% recovery
								CORE LOSS 1.4M.	Core Run (7.7-9.3 m): 13% recovery

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing N nil  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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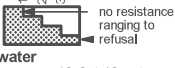
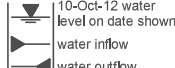
# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-01**  
sheet: 2 of 9  
project no: **754-SYDGE206418-3**  
date started: **29 Jan 2020**  
date completed: **01 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance							
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
	1 2 3							CORE LOSS 1.4M. (continued)			100 200 300 400	LACUSTRINE SOIL
					9.0							
								Sandy CLAY: high plasticity, pale grey mottled orange and red/brown, with fine to coarse grained, sub-angular gravel.				Core Run (9.3-9.7 m): 75% recovery
					10.0			Gravelly CLAY: high plasticity, pale grey mottled red/brown, gravel is fine to coarse grained and sub-angular, with fine to coarse grained sand.				Core Run (9.7-12.2 m): 44% recovery
								CORE LOSS 1.4M.				
					11.0							
								Sandy CLAY: high plasticity, pale grey, sand is fine to coarse grained, with fine to medium grained, sub-angular to sub-rounded gravel.				
					12.0			11.7 m: lenses of clayey SAND, fine to medium grained, red/brown appearing				
								CLAYEY SAND: fine to medium grained, red/brown.				Core Run (12.2-12.8 m): 83% recovery
					13.0			Sandy CLAY: high plasticity, pale grey mottled red/brown, sand is fine to coarse grained, trace fine to medium grained, sub-angular to sub-rounded gravel.				Core Run (12.8-13.4 m): 100% recovery
												Core Run (13.4-14.4 m): 100% recovery
					14.0							
								14.5 m: becoming red/brown mottled pale grey				Core Run (14.4-14.8 m): 100% recovery
					15.0							Core Run (14.8-15.3 m): 100% recovery
								CORE LOSS 0.9M.				Core Run (15.3-16.6 m): 31% recovery

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing N nil  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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# Engineering Log - Borehole


client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-01**  
sheet: 3 of 9  
project no: **754-SYDGE206418-3**  
date started: **29 Jan 2020**  
date completed: **01 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance						
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density
AD	1							<b>CORE LOSS 0.9M. (continued)</b>		
AS	2							<b>Sandy CLAY:</b> high plasticity, pale grey mottled red/brown, sand is fine to coarse grained, trace fine to medium grained, sub-angular to sub-rounded gravel.		
HA	3							<b>CORE LOSS 2.3M.</b>		
W					17.0					
					18.0					
					19.0			caved in material recovered from above 18.9m suggests core loss is likely in a layer of gravelly SAND, fine to coarse grained, red/br. gravel is sub-angular to sub-rounded, fine to coarse grained, with clay		
					20.0			<b>Sandy CLAY:</b> high plasticity, red/brown mottled pale grey and orange, trace fine to medium grained, sub-angular gravel.		
					21.0			19.5 m: becoming pale grey mottled red/brown		
					22.0			19.7 m: pockets of extremely weathered, iron staining, fine to coarse grained, sub-angular gravel appearing		
					23.0					
								23.1 m: pockets of red/brown iron stained clay becoming larger and more frequent		

**LACUSTRINE SOIL**  
Core Run (16.6-17.2 m): 0% recovery  
Core Run (17.2-17.7 m): 0% recovery  
Core Run (17.7-18.1 m): 0% recovery  
Core Run (18.1-18.2 m): 0% recovery  
Core Run (18.2-18.5 m): 0% recovery  
Core Run (18.5-18.6 m): 100% recovery  
Core Run (18.6-18.9 m): 100% recovery  
**RESIDUAL SOIL**  
Core Run (18.9-19.4 m): 100% recovery  
Core Run (19.4-20.7 m): 100% recovery  
Core Run (20.7-21.3 m): 100% recovery  
Core Run (21.3-23.1 m): 100% recovery  
Core Run (23.1-25.1 m): 100% recovery

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore	<b>support</b> M mud C casing <b>penetration</b>  <b>water</b> 10-Oct-12 water level on date shown water inflow water outflow	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear, peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017 <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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\* bit shown by suffix  
e.g. AD/T  
B blank bit  
T TC bit  
V V bit



# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-01**  
sheet: 4 of 9  
project no: **754-SYDGE206418-3**  
date started: **29 Jan 2020**  
date completed: **01 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance				
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	structure and additional observations
AD AS HA W	1 2 3							<b>Sandy CLAY:</b> high plasticity, red/brown mottled pale grey and orange, trace fine to medium grained, sub-angular gravel. <i>(continued)</i>	<b>RESIDUAL SOIL</b>
					25.0				
					26.0				
					27.0				
					27.5			27.5 m: becoming red/brown with pockets of pale grey	Core Run (25.1-27.3 m): 100% recovery
					28.0				Core Run (27.3-30.3 m): 100% recovery
					29.0				
					30.0				Core Run (30.3-31.6 m): 100% recovery
					31.0				Core Run (31.6-33.3 m): 100% recovery

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WL liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-01**  
sheet: 5 of 9  
project no: **754-SYDGE206418-3**  
date started: **29 Jan 2020**  
date completed: **01 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information						material substance								
method & support	penetration			water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
		1	2							<b>Sandy CLAY:</b> high plasticity, red/brown mottled pale grey and orange, trace fine to medium grained, sub-angular gravel. <i>(continued)</i>			100	<b>RESIDUAL SOIL</b>
													200	
													300	
													400	

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing N nil  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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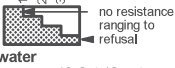
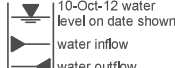
# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-01**  
sheet: 6 of 9  
project no: **754-SYDGE206418-3**  
date started: **29 Jan 2020**  
date completed: **01 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance									
method & support	penetration			water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
		1	2										100	EXTREMELY WEATHERED ROCK
													200	
													300	
													400	

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WL liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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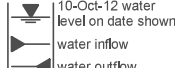
# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-01**  
sheet: 7 of 9  
project no: **754-SYDGE206418-3**  
date started: **29 Jan 2020**  
date completed: **01 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance							
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
	1 2 3										100 200 300 400	
HQ					49.0			<b>Gravelly CLAY:</b> high plasticity, pale grey mottled red/brown and orange, gravel is fine to coarse grained and angular, with fine to coarse grained sand (Extremely to highly weathered rock, very low to low strength, indistinct bedding/foliation at 70°-80°, minor pockets of ironstone/iron-enriched rock). <i>(continued)</i>				<b>EXTREMELY WEATHERED ROCK</b> Core Run (48.1-51.2 m): 100% recovery
C					50.0			<b>Silty CLAY:</b> high plasticity, red/brown mottled pale grey and pale brown, with fine to medium grain sand, trace fine to coarse grained, sub-angular gravel (Highly weathered, low strength rock, massive, pale grey & pale brown).				<b>HIGHLY WEATHERED ROCK</b>  Core Run (51.2-54.0 m): 100% recovery
					51.0							
					52.0			52.2 m: becoming pale brown mottled pale grey and red/brown				
					53.0							
					54.0			<b>ANDESITE:</b> fine to medium grained, pale brown/pale grey, highly weathered, low strength, micro-fractures throughout minor bands of very low strength rock.				<b>HIGHLY WEATHERED IGNEOUS ROCK - POSSIBLY ANDESITE</b> Core Run (54.0-57.0 m): 100% recovery
					55.0							

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud N nil C casing  <b>penetration</b>  no resistance ranging to refusal  <b>water</b> 10-Oct-12 water level on date shown  water inflow water outflow	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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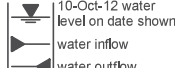
# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-01**  
sheet: 8 of 9  
project no. **754-SYDGE206418-3**  
date started: **29 Jan 2020**  
date completed: **01 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance									
method & support	penetration			water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
	1	2	3										100 200 300 400	
HQ										ANDESITE: fine to medium grained, pale brown/pale grey, highly weathered, low strength, micro-fractures throughout minor bands of very low strength rock. (continued)				HIGHLY WEATHERED ROCK
C							57.0							Core Run (57.0-58.9 m): 95% recovery
							58.0							
							59.0							Core Run (58.9-60.8 m): 100% recovery
							60.0							
							61.0							Core Run (60.8-62.6 m): 100% recovery
							62.0							
							63.0							Core Run (62.6-63.3 m): 100% recovery
										CORE LOSS 1.5M.				Core Run (63.3-66.3 m): 50% recovery

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WL liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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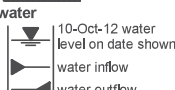
# Engineering Log - Borehole

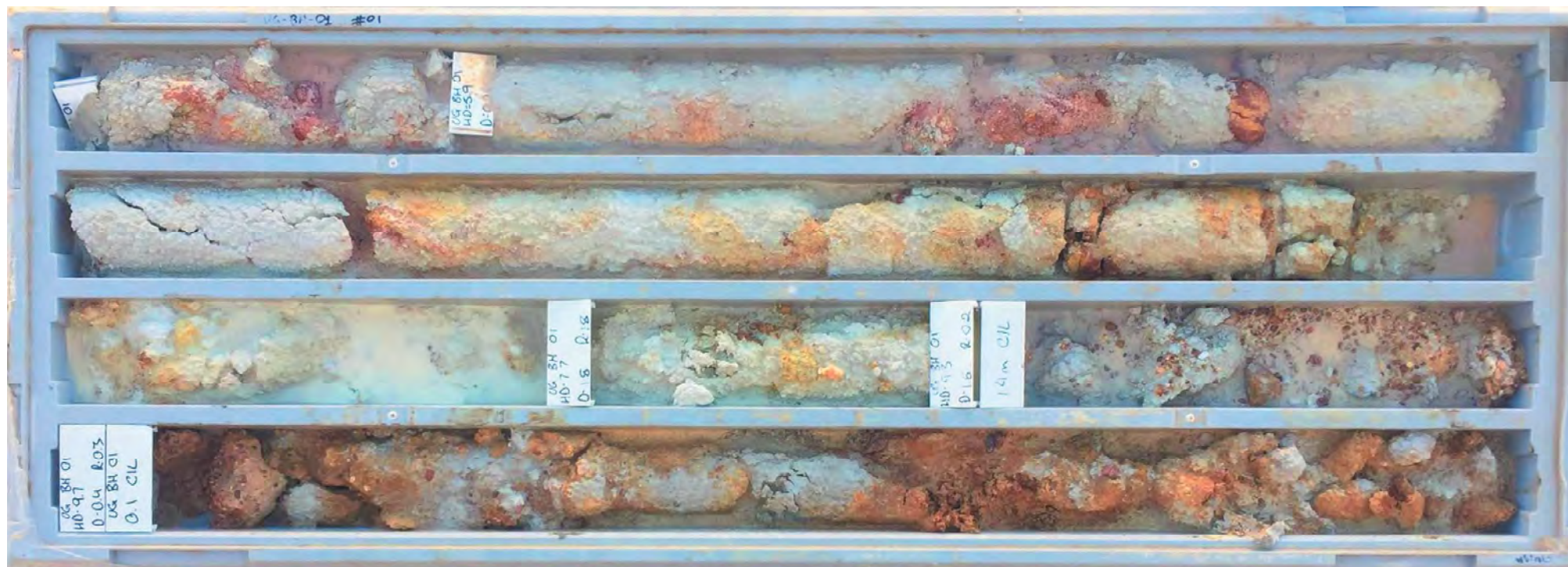
client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-01**  
sheet: 9 of 9  
project no: **754-SYDGE206418-3**  
date started: **29 Jan 2020**  
date completed: **01 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**


position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information						material substance						
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
	1 2 3							CORE LOSS 1.5M. (continued)			100 200 300 400	HIGHLY WEATHERED ROCK
					65.0			ANDESITE: fine to medium grained, pale brown/pale grey, highly weathered, low strength, micro-fractures throughout minor bands of very low strength rock.				
					66.0							
					67.0			ANDESITE: medium grained, pale brown, massive, very low to low strength, extremely to highly weathered, micro-fractures throughout.				Core Run (66.3-66.4 m): 100% recovery Core Run (66.4-66.7 m): 100% recovery Core Run (66.7-68.2 m): 100% recovery
					68.0							Core Run (68.2-69.3 m): 100% recovery
					69.0							Core Run (69.3-70.7 m): 100% recovery
					70.0			70.0 m: bands of highly weathered, very low strength rock up to 100mm thick appearing				Core Run (70.7-72.0 m): 100% recovery
					71.0							
								Borehole UG-BH-01 terminated at 72.0 m Target depth				

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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UG-BH-01 5.70 - 12.20 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 1</b>
original size	A4				rev:	A



UG-BH-01 12.20 - 18.50 m


drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD	
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS	
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>	
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no: <b>FIGURE 2</b>
original size	A4				rev: A







UG-BH-01 18.50 - 21.40 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 3</b>
original size	A4				rev:	A


UG-BH-01 21.40 m - 24.80 m CORE PHOTO NOT AVAILABLE

UG-BH-01 21.40 - 24.50 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-01		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 4
original size	A4				rev:	A




UG-BH-01 24.50 - 28.50 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 5</b>
original size	A4				rev:	A






UG-BH-01 28.50 - 31.60 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 6</b>
original size	A4				rev:	A






UG-BH-01 31.60 - 35.60 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 7</b>
original size	A4				rev:	A




UG-BH-01 35.60 - 39.20 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 8</b>
original size	A4				rev:	A






UG-BH-01 39.20 - 42.60 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 9</b>
original size	A4				rev:	A




UG-BH-01 42.60 - 45.20 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 10</b>
original size	A4				rev:	A






UG-BH-01 45.20 - 49.80 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 11</b>
original size	A4				rev:	A




UG-BH-01 49.80 - 53.20 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 12</b>
original size	A4				rev:	A





UG-BH-01 53.20 - 56.90 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 13</b>
original size	A4				rev:	A


drawn	TBM		client: EMM CONSULTING PTY LTD		
approved	AO		project: CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title: CORE PHOTOGRAPH UG-BH-01		
scale	N.T.S.				
original size	A4		project no: 754-SYDGE206418-3	fig no: <b>FIGURE 14</b>	rev: A



drawn	TBM		client: EMM CONSULTING PTY LTD	
approved	AO		project: CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS	
date	23/03/2020		title: CORE PHOTOGRAPH UG-BH-01	
scale	N.T.S.		project no: 754-SYDGE206418-3	
original size	A4		fig no: <b>FIGURE 15</b>	rev: A




UG-BH-01 63.60 - 68.70 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 16</b>
original size	A4				rev:	A





UG-BH-01 68.70 - 72.00 m


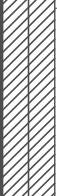
drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-01</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 17</b>
original size	A4				rev:	A


# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-02**  
sheet: 1 of 13  
project no: **754-SYDGE206418-3**  
date started: **02 Feb 2020**  
date completed: **06 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance							
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description  SOIL NAME: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
<div>AD/T</div> <div>150 mm PVC casing</div> <div>HQ</div> <div>PW casing</div>	1	Not Observable			1.0		CH	<b>Silty CLAY:</b> high plasticity, grey, with fine to medium grained sand and trace fine to medium grained, sub-angular quartz gravel.	<Wp	VSt	100	<b>LACUSTRINE</b>
	2				200							
	3				300							
					400							
					6.0			<b>Silty CLAY:</b> high plasticity, grey, with fine to medium grained sand and trace fine to medium grained, sub-angular quartz gravel.				Core Run (5.8-6.2 m): 100% recovery
					7.0							Core Run (6.2-7.3 m): 100% recovery
												Core Run (7.3-9.2 m): 100% recovery
								7.1 m: becoming pale grey mottled orange/brown				
								7.3 m: sand content increasing				

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore	<b>support</b> M mud C casing N nil	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear, peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
<b>penetration</b>  <b>water</b> 10-Oct-12 water level on date shown water inflow water outflow	<b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit			

\* bit shown by suffix  
e.g. AD/T  
B blank bit  
T TC bit  
V V bit



# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-02**  
sheet: 2 of 13  
project no: **754-SYDGE206418-3**  
date started: **02 Feb 2020**  
date completed: **06 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance									
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations		
HQ PW casing	1	Not Observable						<b>Silty CLAY:</b> high plasticity, grey, with fine to medium grained sand and trace fine to medium grained, sub-angular quartz gravel. <i>(continued)</i>			100	<b>LACUSTRINE</b>		
	2						<b>Sandy CLAY:</b> high plasticity, red/brown mottled pale grey, sand is fine to coarse grained, with fine to coarse grained, sub-rounded to sub-angular gravel and silt.	200						
	3										300			
											400			




<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing N nil  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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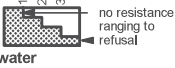
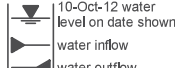
# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-02**  
sheet: 3 of 13  
project no: **754-SYDGE206418-3**  
date started: **02 Feb 2020**  
date completed: **06 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter : PVC150/PW

drilling information						material substance						
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
HQ PW casing	1	Not Observable						<b>Sandy CLAY:</b> high plasticity, red/brown mottled pale grey, sand is fine to coarse grained, with fine to coarse grained, sub-rounded to sub-angular gravel. <i>(continued)</i>			100	<b>LACUSTRINE</b>
	2						<b>CORE LOSS 3.8M.</b>	200				
	3							300				
								400				
	17.0										Core Run (17.8-18.9 m): 0% recovery	
	18.0											
	19.0										Core Run (18.9-21.2 m): 30% recovery	
	20.0											
	21.0					<b>CLAYEY SAND:</b> fine to coarse grained, pale grey mottled pale brown, clay is high plasticity, with fine to coarse grained, sub-rounded gravel and bands of highly weathered, very low strength sandstone up to 40mm thick.					<b>RESIDUAL SOIL</b>	
	22.0						<b>CORE LOSS 2.0M.</b>					
23.0						Core Run (22.1-22.7 m): 0% recovery						
						Core Run (22.7-23.5 m): 63% recovery						
						Core Run (23.5-24.6 m): 64% recovery						
								<b>CORE LOSS 0.4M.</b>				
												

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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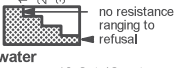
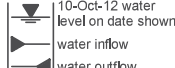
# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-02**  
sheet: 4 of 13  
project no. **754-SYDGE206418-3**  
date started: **02 Feb 2020**  
date completed: **06 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance									
method & support	penetration			water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
	1	2	3										100 200 300 400	
HQ														RESIDUAL SOIL
PW casing							25.0			<b>Sandy CLAY:</b> high plasticity, mottled pale brown/orange and pale grey, sand is fine to coarse grained, with fine to coarse grained, sub-rounded to sub-angular gravel and bands of highly weathered, very low strength sandstone up to 30mm thick. <i>(continued)</i> <b>CORE LOSS 0.9M.</b>				Core Run (24.6-25.7 m): 18% recovery
							26.0			<b>Sandy CLAY:</b> high plasticity, mottled pale brown/orange and pale grey, sand is fine to coarse grained, with fine to coarse grained, sub-rounded to sub-angular gravel. <b>CORE LOSS 2.0M.</b>				Core Run (25.7-26.6 m): 0% recovery
							27.0							Core Run (26.6-26.7 m): 0% recovery Core Run (26.7-26.9 m): 0% recovery Core Run (26.9-27.2 m): 0% recovery
							28.0			<b>Sandy CLAY:</b> high plasticity, mottled pale brown/orange and pale grey, sand is fine to coarse grained, with fine to coarse grained, sub-rounded to sub-angular gravel. <b>CORE LOSS 0.4M.</b>				Core Run (27.2-27.3 m): 0% recovery Core Run (27.3-27.7 m): 0% recovery
							29.0			<b>Sandy CLAY:</b> high plasticity, mottled pale brown/orange and pale grey, sand is fine to coarse grained, with fine to coarse grained, sub-rounded to gravel found in irregular bands up to 100mm thick showing signs of iron oxide staining, and bands of highly weathered, very low strength sandstone up to 30mm thick.				Core Run (27.7-27.8 m): 100% recovery Core Run (27.8-28.0 m): 50% recovery Core Run (28.0-29.1 m): 64% recovery
							30.0							Core Run (29.1-30.2 m): 100% recovery
							31.0							Core Run (30.2-31.2 m): 100% recovery
														Core Run (31.2-31.7 m): 0% recovery
														Core Run (31.7-33.2 m): 100% recovery

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WL liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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**Borehole**

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**Y LTD**

**DEVELOPMENT EIS**

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

CDF 0 9 07 LIBRARY.GLB rev"AU Log COF BOREHOLE: NON CORED 754-SYDGE206418-3.GPJ <DrawingFile>> 27/03/2020 10:49



# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-02**  
sheet: 6 of 13  
project no: **754-SYDGE206418-3**  
date started: **02 Feb 2020**  
date completed: **06 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance									
method & support	penetration			water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
	1	2	3										100 200 300 400	
HQ PW casing														

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing N nil  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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**Borehole**

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**DEVELOPMENT EIS**

location: **COWAL GOLD OPERATIONS**

checked by: **PLV**

casing diameter : PVC150/PW

CDF 0 9 07\_LIBRARY.GLB rev:AU Log COF BOREHOLE: NON CORED 754-SYDGE206418-3.GPJ <<DrawingFile>> 27/03/2020 10:49

# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-02**  
sheet: 8 of 14  
project no. **754-SYDGE206418-3**  
date started: **02 Feb 2020**  
date completed: **06 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial O = diametral a = axial d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
			49.0								
			50.0								
			51.0								
			52.0								
			53.0								
			54.0								
			55.0								
					started coring at 55.60m						
					MUDSTONE: red/brown/grey, distinctly bedded at 25-50°, with clay seams up to 2mm thick.	XW - HW					

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-02**  
sheet: 9 of 14  
project no: **754-SYDGE206418-3**  
date started: **02 Feb 2020**  
date completed: **06 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance					rock mass defects																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
method & support	water	RL (m)	depth (m)	graphic log	material description  ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50					samples, field tests & Is(50) (MPa)  a = axial, d = diametral	core run & RQD	defect spacing (mm)					additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
							VL	J	N	H	VH			EH	30	100	300	1000	3000	particular	general																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
HQ	Not Observable		57.0		MUDSTONE: red/brown/grey, distinctly bedded at 25-50°, with clay seams up to 2mm thick. (continued)	XW - HW																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-02**  
sheet: 10 of 14  
project no: **754-SYDGE206418-3**  
date started: **02 Feb 2020**  
date completed: **06 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance							rock mass defects						
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial O = diametral a = axial, d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)				additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)			
							VL J M H VH EH				30	100	300	1000	3000	particular	general
						XW - HW											
			65.0		CORE LOSS 1.9M.												
			66.0														
			67.0		MUDSTONE: purple/brown, indistinctly bedded 60-80°.	HW											
			68.0														
			69.0		CORE LOSS 1.0M.												
			70.0		MUDSTONE: purple/brown, indistinctly bedded 60-80°.	HW - XW											
					CORE LOSS 0.5M.												
			71.0		MUDSTONE: purple/brown, indistinctly bedded 60-80°.	HW - XW											
					71.30 m: becoming red/brown												

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
---	--	--	---	--	--

# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-02**  
sheet: 11 of 14  
project no. **754-SYDGE206418-3**  
date started: **02 Feb 2020**  
date completed: **06 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial, O = diametral a = axial, d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
							VL J N E SH			30 100 300 1000 3000	particular general
					CORE LOSS 0.7M.						
			73.0		MUDSTONE: red/brown, indistinctly bedded 60-80°.	XW - HW					
			74.0								
			75.0		CORE LOSS 0.4M.						
			76.0		MUDSTONE: red/brown, indistinctly bedded 60-80°.	XW - HW					
			77.0								
					CORE LOSS 0.2M.						
			78.0		MUDSTONE: red/brown/grey, indistinct bedding.	XW - HW					
					78.40 m: becoming purple/brown						
			79.0		CORE LOSS 0.4M.						
					MUDSTONE: purple/brown/grey, indistinct bedding.	XW - HW					
										</	

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-02**  
sheet: 12 of 14  
project no. **754-SYDGE206418-3**  
date started: **02 Feb 2020**  
date completed: **06 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial O = diametral a = axial d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
					MUDSTONE: purple/brown/grey, indistinct bedding. (continued)	XW - HW					
			81.0		CORE LOSS 0.3M.						
					MUDSTONE: purple/brown, indistinctly bedded 60-80°.	XW - HW					JT, 50°, PL, SO, Sandy clay CO
			82.0								
			83.0								
			84.0								
			85.0			HW					
			86.0								JT, 40°, PL, SO, Fe SN
			87.0		CORE LOSS 0.6M.						
					MUDSTONE: purple/brown, indistinctly bedded 60-80°.	XW - HW					

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint CU curved SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-02**  
sheet: 13 of 14  
project no. **754-SYDGE206418-3**  
date started: **02 Feb 2020**  
date completed: **06 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial O = diametral a = axial, d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
							VL J M H VH EH			30 100 300 1000 3000	particular general
			89.0		MUDSTONE: purple/brown, indistinctly bedded 60-80°. (continued)						JT, 70°, PL, SO, Fe SN JT, 70°, PL, SO, Fe SN JT, 50°, PL, SO, Fe SN
			90.0		89.60 m: becoming pale brown, indistinctly bedded at 35-55°  90.10 to 90.80 m: trace of manganese staining around joints	HW - XW					JT, 70°, PL, SO, Fe SN
			91.0		CORE LOSS 2.3M.						
			92.0								
			93.0								
			94.0		MUDSTONE: pale brown, indistinctly bedded 35-55°, minor bands of 'silicified' mudstone.	HW - XW					
			95.0			HW					

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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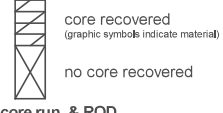
# Engineering Log - Cored Borehole

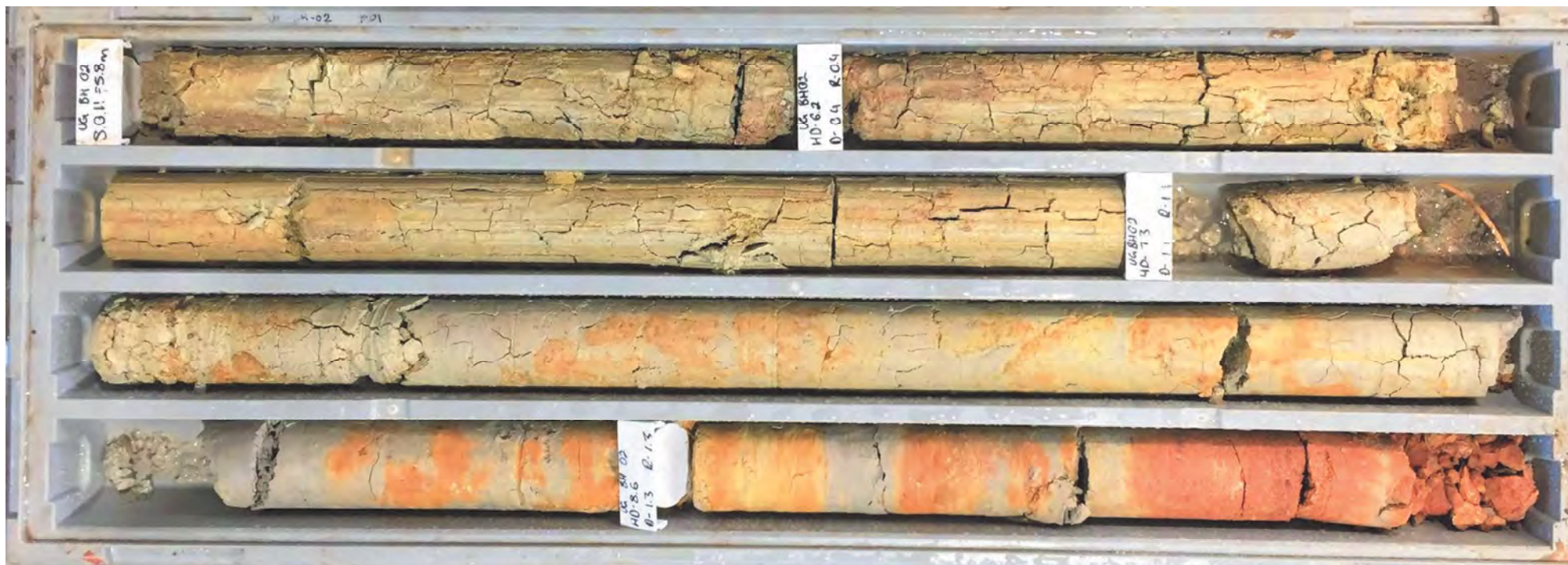
client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-02**  
sheet: 14 of 14  
project no: **754-SYDGE206418-3**  
date started: **02 Feb 2020**  
date completed: **06 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**


position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial O = diametral a = axial, d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
							VL J M H VH			30 100 300 1000 3000	particular general
<div>HQ</div>	Not Observable				MUDSTONE: pale brown, indistinctly bedded 35-55°, minor bands of 'silicified' mudstone. (continued)	HW - XW					
			97.0								
			98.0								
			99.0			HW					
			100.0		99.90 m: becoming grey/purple/brown, distinctly bedded at 20-35°	MW - SW					
			101.0		CORE LOSS 0.4M.						
			102.0		MUDSTONE: grey/purple/brown, distinctly bedded 20-35°.	MW - SW					
			103.0		Borehole UG-BH-02 terminated at 102.80 m Target depth						

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b>  RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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UG-BH-02 5.80 - 9.10 m

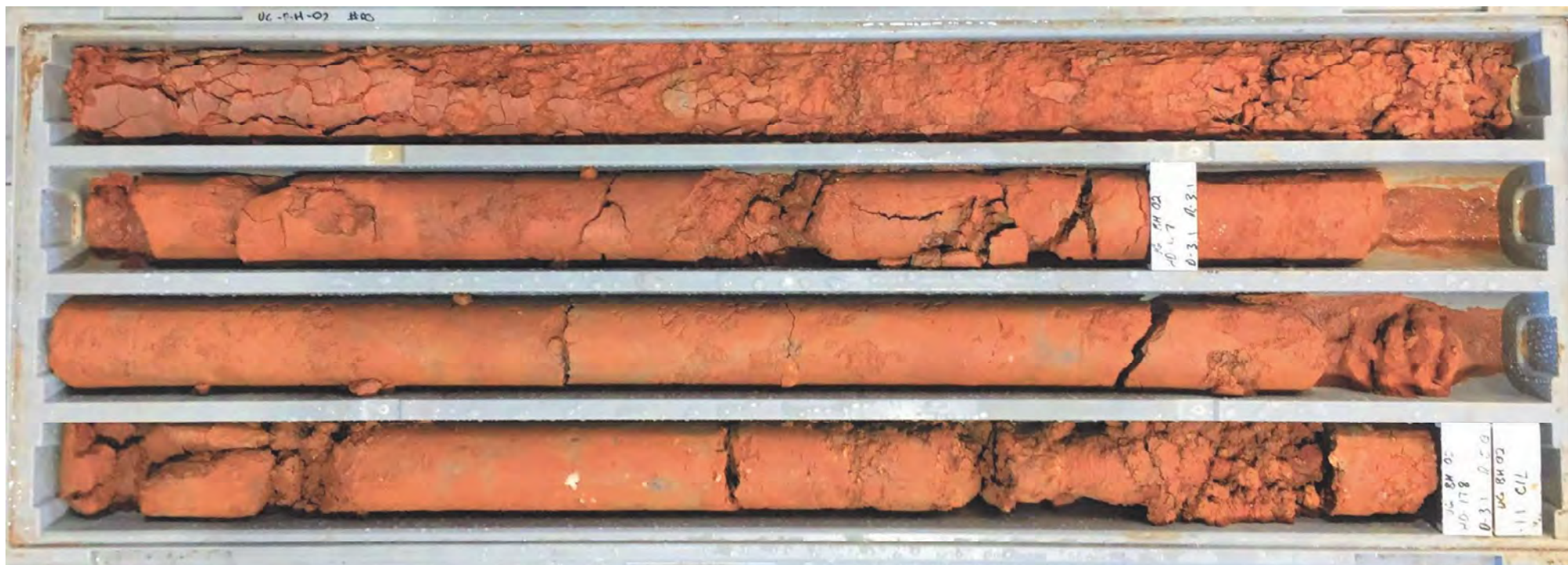
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approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 1</b>
original size	A4				rev:	A






UG-BH-02 9.10 - 13.00 m


drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 2</b>
original size	A4				rev:	A



UG-BH-02 13.00 - 18.90 m


drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 3</b>
original size	A4				rev:	A



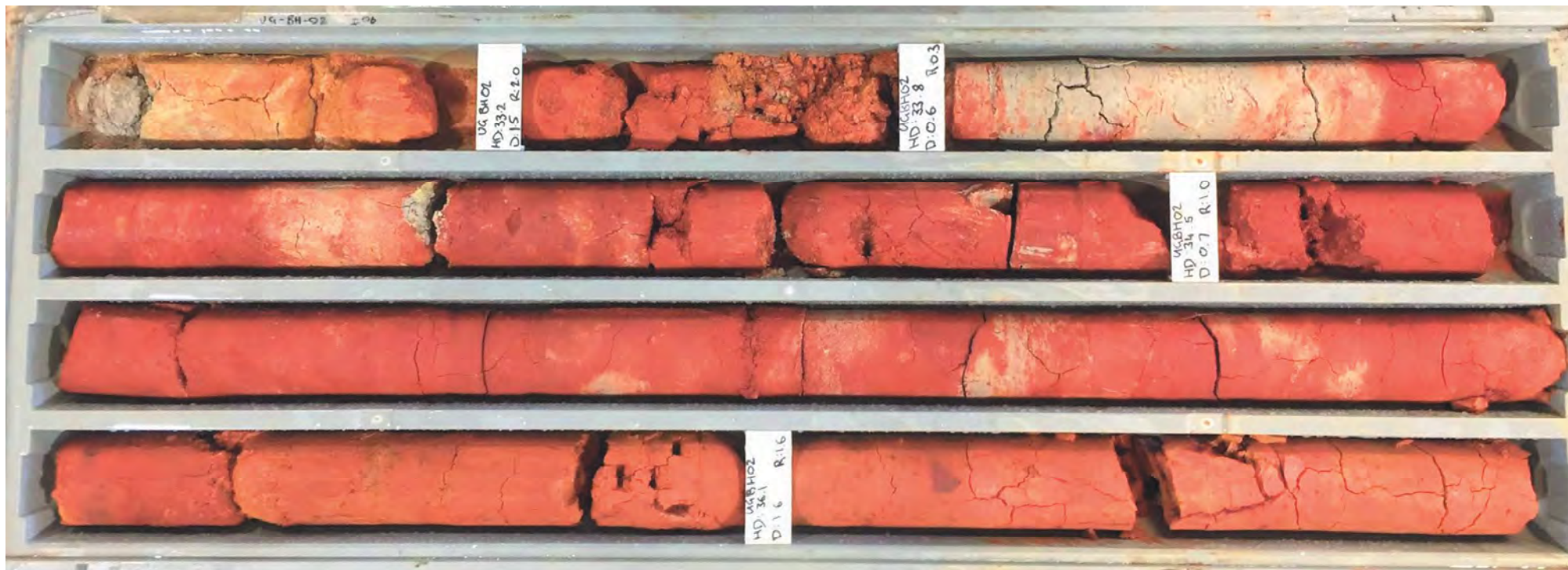
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approved	AO		project: CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title: CORE PHOTOGRAPH UG-BH-02		
scale	N.T.S.		project no: 754-SYDGE206418-3		
original size	A4		fig no: <b>FIGURE 4</b>		rev: A




UG-BH-02 29.30 - 32.90 m

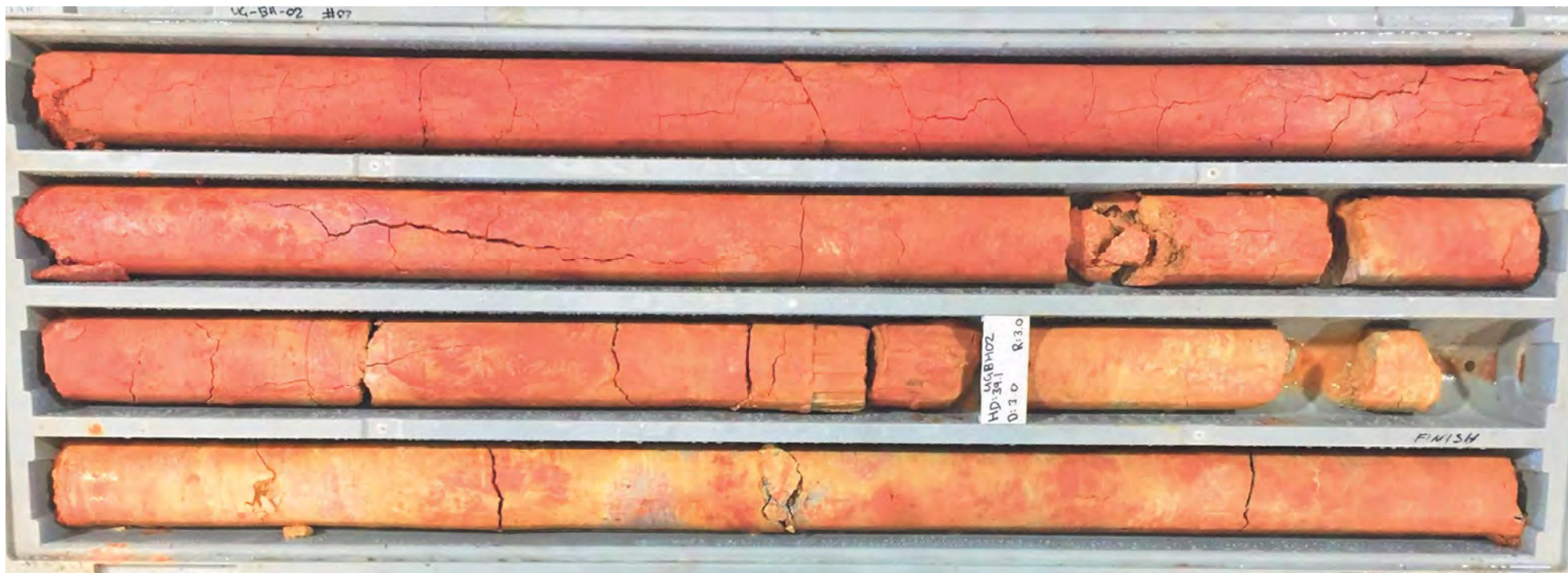
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approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 5</b>
original size	A4				rev:	A






UG-BH-02 32.90 - 36.60 m

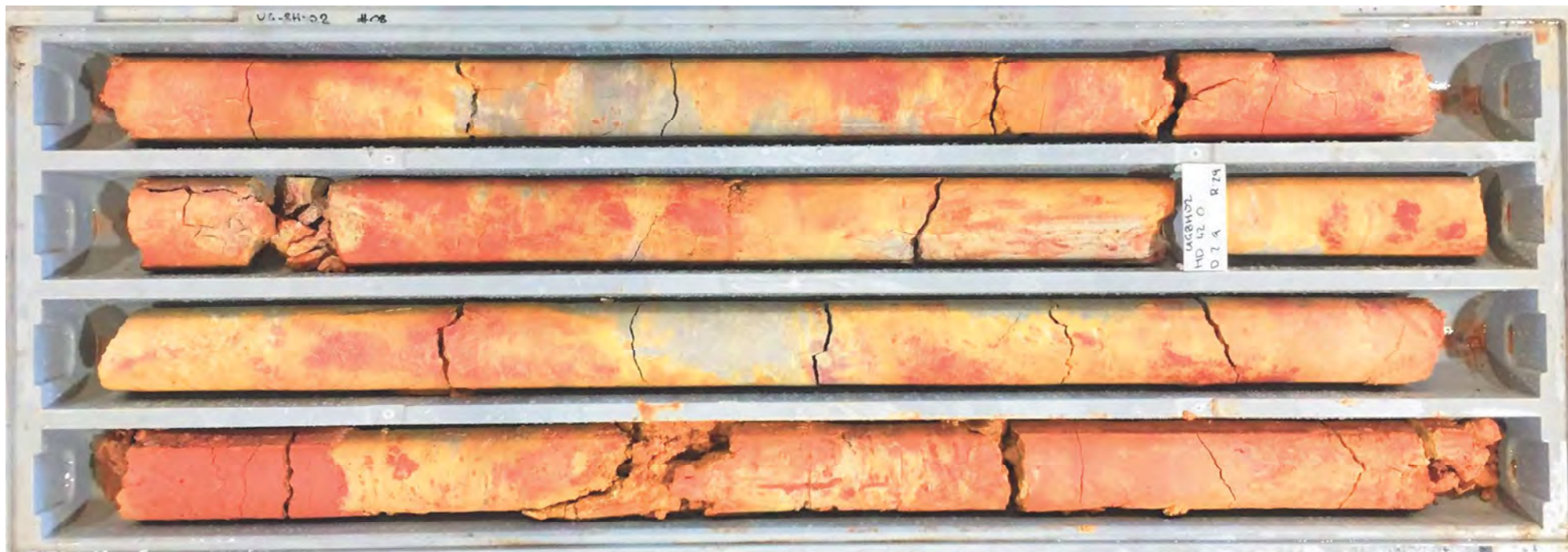
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approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 6</b>
original size	A4				rev:	A




UG-BH-02 36.60 - 40.20 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 7</b>
original size	A4				rev:	A






UG-BH-02 40.20 - 44.30 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 8</b>
original size	A4				rev:	A




UG-BH-02 44.30 - 47.30 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 9</b>
original size	A4				rev:	A






UG-BH-02 47.30 - 51.20 m

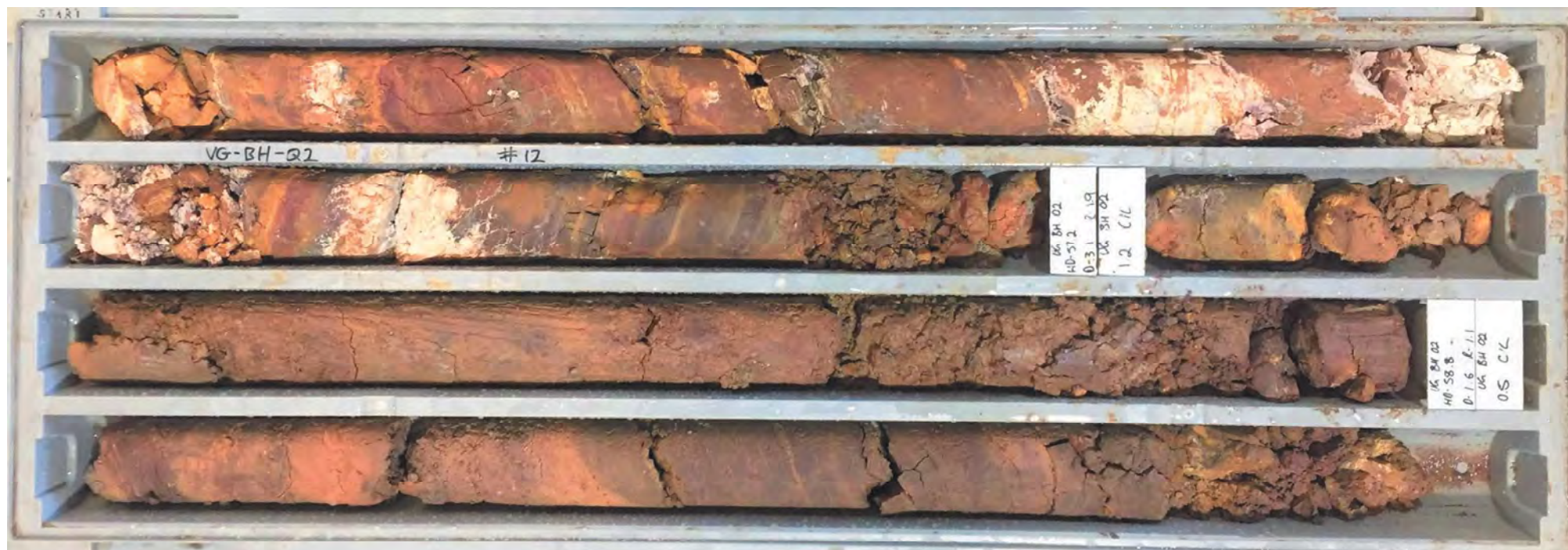
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approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 10</b>
original size	A4				rev:	A




UG-BH-02 51.20 - 55.50 m

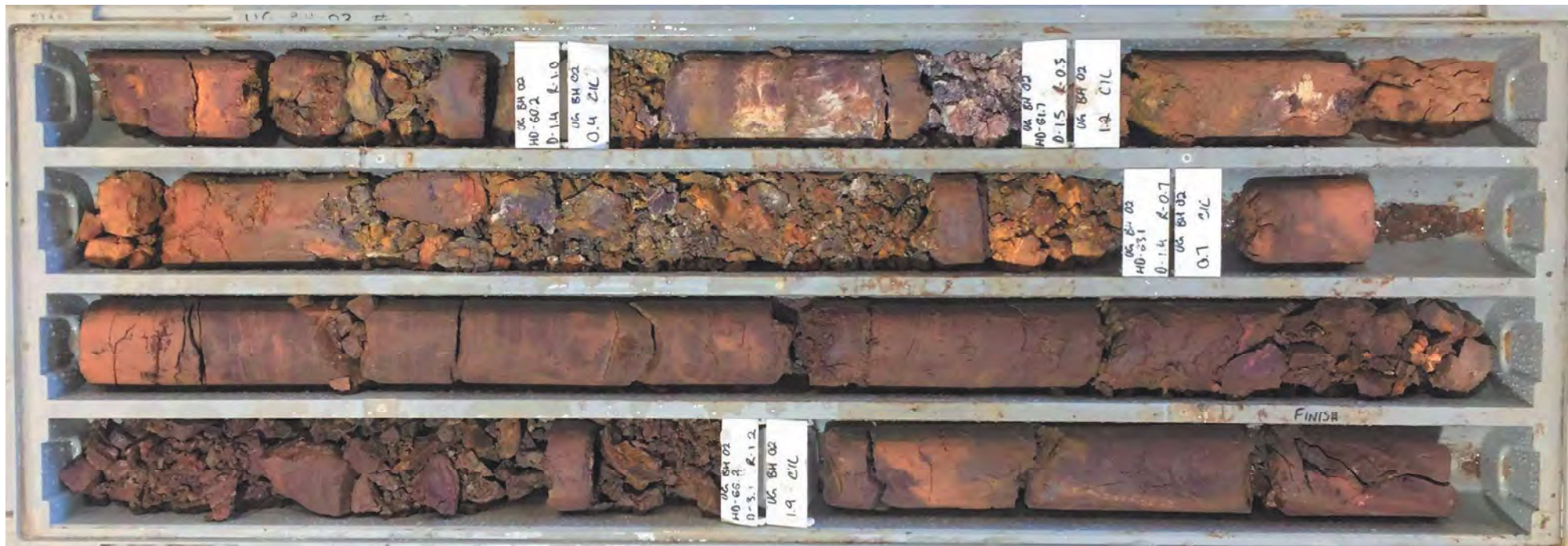
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approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 11</b>
original size	A4				rev:	A






UG-BH-02 55.50 - 59.90 m

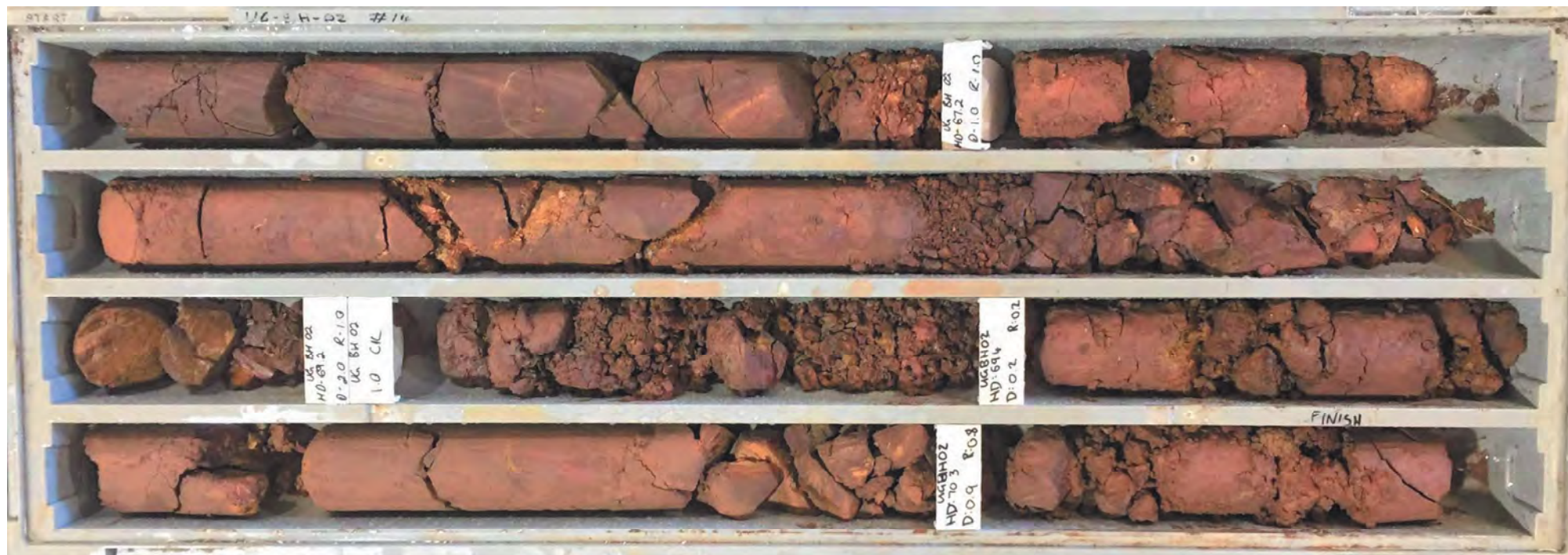
drawn	TBM	 <b>coffey</b> <small>A TETRA TECH COMPANY</small>	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 12</b>
original size	A4				rev:	A




UG-BH-02 59.90 - 66.60 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-02		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 13
original size	A4				rev:	A






UG-BH-02 66.60 - 70.60 m

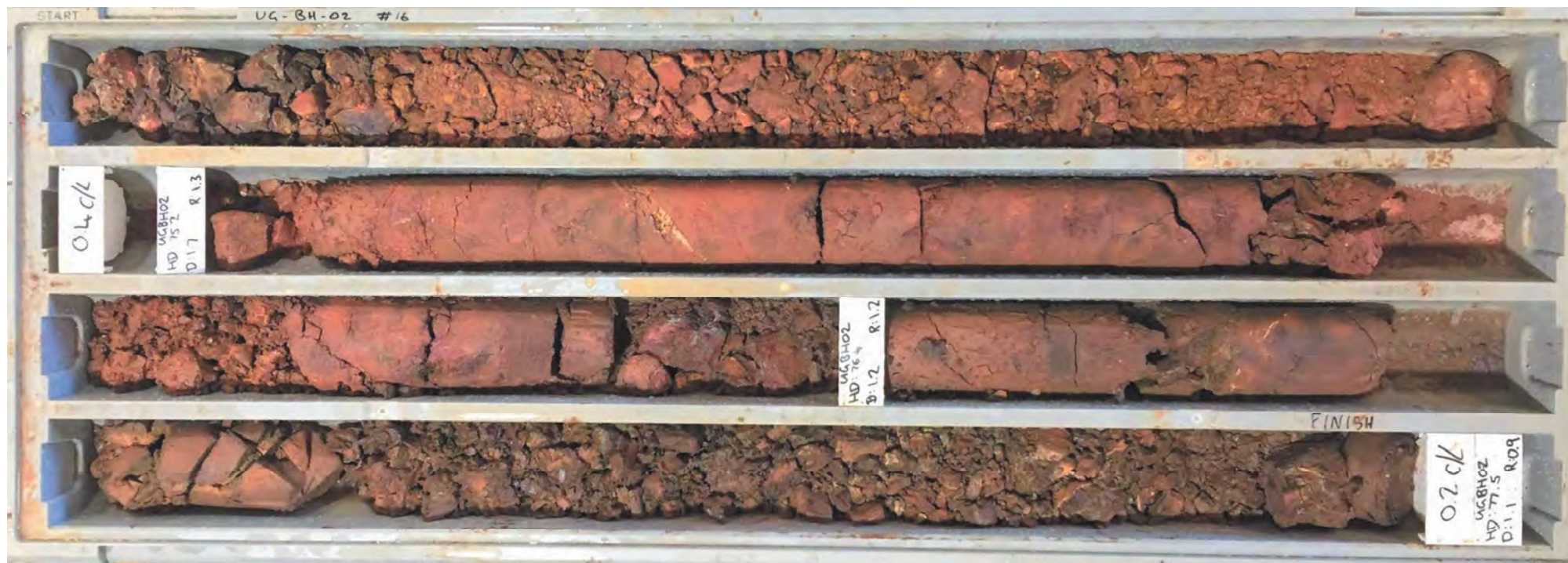
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approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 14</b>
original size	A4				rev:	A




UG-BH-02 70.60 - 74.50 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 15</b>
original size	A4				rev:	A






UG-BH-02 74.50 - 77.50 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 16</b>
original size	A4				rev:	A




UG-BH-02 77.50 - 81.00 m

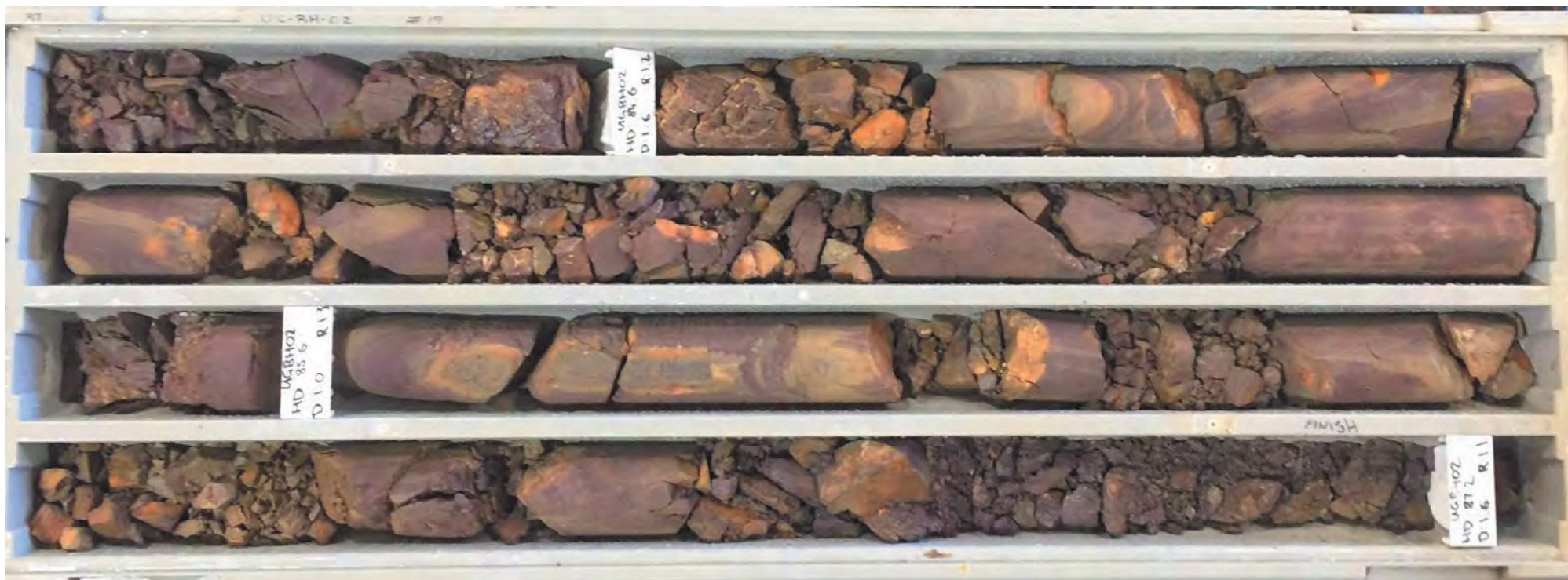
drawn	TBM	 <b>coffey</b> <small>A TETRA TECH COMPANY</small>	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 17</b>
original size	A4				rev:	A






UG-BH-02 81.00 - 84.60 m

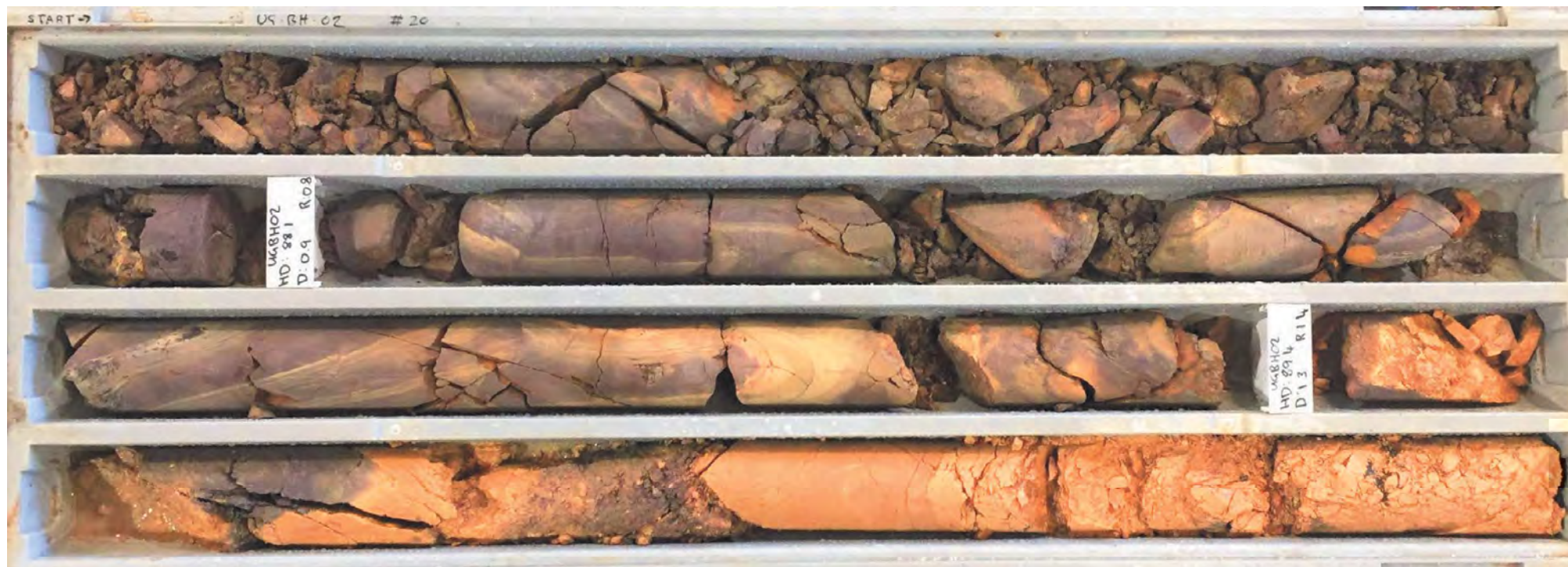
drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 18</b>
original size	A4				rev:	A




UG-BH-02 84.60 - 87.20 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-02		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 19
original size	A4				rev:	A






UG-BH-02 87.20 - 90.50 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 20</b>
original size	A4				rev:	A




UG-BH-02 90.50 - 96.10 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-02		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 21
original size	A4				rev:	A






UG-BH-02 96.10 - 100.40 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-02		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 22
original size	A4				rev:	A



UG-BH-02 100.40 - 102.80 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-02</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 23</b>
original size	A4				rev:	A




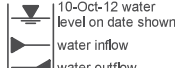
# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-03**  
sheet: 1 of 10  
project no: **754-SYDGE206418-3**  
date started: **16 Feb 2020**  
date completed: **20 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance							
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description  SOIL NAME: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
1 2 3	1 2 3										100 200 300 400	LACUSTRINE
AD/T 150 mm PVC casing					1.0							
Not Observable					2.0							
					3.0							
					4.0							
					5.0							
					6.0			Start of coring at 5.5m				
								CORE LOSS 0.8M.				
					7.0			CLAY: high plasticity, pale grey, with silt and trace fine to medium grained sand.				
								7.1 m: becoming pale grey mottled orange/brown, with fine to medium grained, sub-angular gravel and fine to coarse grained sand				Gravels found amongst orange/brown mottling - likely rich in iron
								7.6 m: horizontal bands of red/brown appearing, with increased gravel content (Gravelly CLAY)				Core Run (7.3-8.3 m)

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-03**  
sheet: 2 of 10  
project no. **754-SYDGE206418-3**  
date started: **16 Feb 2020**  
date completed: **20 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance							
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
	1 2 3										100 200 300 400	

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing N nil  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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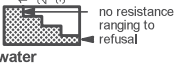
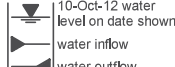
# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-03**  
sheet: 3 of 10  
project no. **754-SYDGE206418-3**  
date started: **16 Feb 2020**  
date completed: **20 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance							
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
HQ	1	Not Observable						finest.			100	LACUSTRINE
	2						CORE LOSS 1.5M.	200				
	3							300				
								400				
	17.0										Core Run (16.7-17.9 m)	
	18.0						Sandy CLAY: high plasticity, red/brown mottled pale grey, with fine to medium grained sand.				RESIDUAL SOIL	
	19.0										Core Run (17.9-19.4 m)	
	19.0						19.0 m: manganese stained veins appearing, recovered sample beginning to show rock-like structure				EXTREMELY WEATHERED ROCK	
	20.0						CORE LOSS 0.4M.				Core loss likely indicates extremely weathered rock is being broken up and lost during drilling	
	21.0						Sandy CLAY: red/brown mottled orange and pale grey, sand is fine to coarse grained, with fine to medium grained, angular gravel, manganese stained joints observed throughout.				Core Run (19.4-21.2 m)	
22.0											Core Run (21.2-24.2 m)	
23.0												
								Sandy CLAY: red/brown mottled orange and pale grey, sand is fine to coarse grained, with fine to medium grained, angular gravel.				

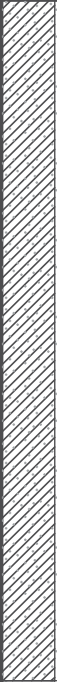
<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WL liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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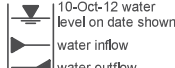
# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-03**  
sheet: 4 of 10  
project no. **754-SYDGE206418-3**  
date started: **16 Feb 2020**  
date completed: **20 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance							
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density	hand penetrometer (kPa)	structure and additional observations
HQ	1	Not Observable						<b>Sandy CLAY:</b> red/brown mottled orange and pale grey, sand is fine to coarse grained, with fine to medium grained, angular gravel. <i>(continued)</i> 24.4 m: becoming brown mottled red/brown   				

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud N nil C casing  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WL liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-03**  
sheet: 5 of 10  
project no. **754-SYDGE206418-3**  
date started: **16 Feb 2020**  
date completed: **20 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial, O = diametral a = axial, d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
HQ			25.0								
			26.0								
			27.0								
			28.0								
			29.0								
Not Observable			29.0		started coring at 28.50m <b>ANDESITE:</b> fine to medium grained, orange/brown, porphyritic, heavily fractured along planes at 0-45° showing extensive iron oxide and manganese staining.	XW - HW					
			30.0		<b>CORE LOSS 0.6M.</b>						
			31.0		<b>ANDESITE:</b> fine to medium grained, orange/brown, porphyritic, heavily fractured along planes at 0-45° showing extensive iron oxide and manganese staining.	XW - HW					
					31.40 m: becoming brown and pale grey						

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-03**  
sheet: 6 of 10  
project no: **754-SYDGE206418-3**  
date started: **16 Feb 2020**  
date completed: **20 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial O = diametral a = axial, d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
					</						

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-03**  
sheet: 7 of 10  
project no. **754-SYDGE206418-3**  
date started: **16 Feb 2020**  
date completed: **20 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial, O = diametral a = axial, d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
					CORE LOSS 1.1M. (continued)						
			41.0		ANDESITE: fine to medium grained, brown and pale grey, porphyritic, heavily fractured along planes at 0-45° showing extensive iron oxide and manganese staining.	XW - HW					
			42.0								
			43.0								
			44.0								
			45.0								
			46.0								
			47.0		CORE LOSS 1.0M.						
						XW - HW					

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-03**  
sheet: 8 of 10  
project no. **754-SYDGE206418-3**  
date started: **16 Feb 2020**  
date completed: **20 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects				
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial, O = diametral a = axial, d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)	
											particular	general
			49.0		ANDESITE: fine to medium grained, brown and pale grey, porphyritic, heavily fractured along planes at 0-45° showing extensive iron oxide and manganese staining. <i>(continued)</i>	XW - HW						
			50.0		49.40 m: bands of highly weathered, medium strength rock appearing up to 150mm thick	XW - HW						
			51.0									
			52.0									
			53.0		CORE LOSS 0.6M.							
			54.0		ANDESITE: fine to medium grained, brown and pale grey, porphyritic, heavily fractured along planes at 0-45°.	HW						
			55.0									

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-03**  
sheet: 9 of 10  
project no. **754-SYDGE206418-3**  
date started: **16 Feb 2020**  
date completed: **20 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is(50) X = axial O = diametral a = axial d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
					ANDESITE: fine to medium grained, brown and pale grey, porphyritic, heavily fractured along planes at 0-45°. (continued)	HW					
			57.0		CORE LOSS 1.2M.						
			58.0		ANDESITE: fine to medium grained, brown and pale grey, porphyritic, heavily fractured along planes at 0-45°.	XW - HW					
					CORE LOSS 0.4M.						
			59.0		ANDESITE: fine to medium grained, brown and pale grey, porphyritic, heavily fractured along planes at 0-45°.	XW - HW					
			60.0								
			61.0								
			62.0			HW					
			63.0			HW - MW					

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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**Cored Borehole**

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**Y LTD**

**DEVELOPMENT EIS**

checked by: **PLV**


location: **COWAL GOLD OPERATIONS**

casing diameter : PVC150/PW

PDF 0 9 07 LIBRARY.GLB rev:AU Log COF BOREHOLE: CORED 754-SYDGE206418-3.GPJ <<DrawingFile>> 27/03/2020 09:21




UG-BH-03 5.50 - 9.90 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-03		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 1
original size	A4				rev:	A






UG-BH-03 9.90 - 13.45 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-03</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 2</b>
original size	A4				rev:	A






UG-BH-03 13.45 - 19.40 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-03</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 3</b>
original size	A4				rev:	A




UG-BH-03 19.40 - 25.60 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-03</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 4</b>
original size	A4				rev:	A






UG-BH-03 25.60 - 28.30 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-03</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 5</b>
original size	A4				rev:	A




UG-BH-03 28.30 - 32.60 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-03</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 6</b>
original size	A4				rev:	A






UG-BH-03 32.60 - 37.60 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-03</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 7</b>
original size	A4				rev:	A




UG-BH-03 37.60 - 41.50 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-03		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 8
original size	A4				rev:	A






UG-BH-03 41.50 - 45.20 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-03		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 9
original size	A4				rev:	A




UG-BH-03 45.20 - 49.20 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-03		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 10
original size	A4				rev:	A






UG-BH-03 49.20 - 52.60 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-03</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 11</b>
original size	A4				rev:	A




UG-BH-03 52.60 - 56.60 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-03		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 12
original size	A4				rev:	A






UG-BH-03 56.60 - 61.40 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-03		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 13
original size	A4				rev:	A




UG-BH-03 61.40 - 64.80 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-03</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 14</b>
original size	A4				rev:	A






UG-BH-03 64.80 - 68.10 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-03</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 15</b>
original size	A4				rev:	A




UG-BH-03 68.10 - 71.10 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-03		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 16
original size	A4				rev:	A





UG-BH-03 71.10 - 72.00 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-03</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 17</b>
original size	A4				rev:	A



# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-04**  
sheet: 1 of 14  
project no: **754-SYDGE206418-3**  
date started: **20 Feb 2020**  
date completed: **23 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance				
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	structure and additional observations
1 2 3	1 2 3								
AD/T	150-RPM (auger screwing)	Not Observable			1.0			<b>Silty CLAY:</b> high plasticity, grey, with fine to medium grained sand and trace fine to medium grained, sub-angular quartz gravel.	<b>LACUSTRINE SOIL</b>
					2.0				
					3.0				
					4.0				
					5.0			Cuttings found at start of hole are presumed to be from cave in, so true depth of material recovered is unknown between 1-5.7m. Material is a clayey SAND, fine to coarse grained, red/brown, clay is highly plastic, with fine grained, sub-rounded gravel	
					5.5			Start of coring at 5.5m	
					6.0			<b>CORE LOSS 0.2M.</b>	Core Run (5.7-6.2 m): 100% recovery
					6.2			<b>CLAY:</b> high plasticity, pale grey mottled orange, with fine to medium grained sand.	Core Run (6.2-8.7 m): 100% recovery
					7.0			7.2 to 7.4 m: iron oxide staining evident	


<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing N nil  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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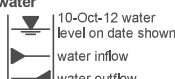
# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-04**  
sheet: 2 of 14  
project no. **754-SYDGE206418-3**  
date started: **20 Feb 2020**  
date completed: **23 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information					material substance								
method & support	1 2 3	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description  SOIL NAME: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	hand penetrometer (kPa) 100 200 300 400	structure and additional observations
HQ			Not Observable			8.6			CLAY: high plasticity, pale grey mottled orange, with fine to medium grained sand. (continued)				LACUSTRINE SOIL
						9.0			8.6 m: becoming red/brown mottled pale grey, sand content varying in lenses of heavily varying thickness				Core Run (8.7-10.0 m): 100% recovery
						10.0							Core Run (10.0-12.4 m): 100% recovery
						11.0			Sandy CLAY: high plasticity, red/brown mottled pale grey, sand is fine to medium grained.				RESIDUAL SOIL
						12.0			12.4 to 14.0 m: trace of manganese staining				Core Run (12.4-14.6 m): 100% recovery
						13.0			13.0 m: bands of higher sand content appearing up to 100mm thick				
						14.0							
						15.0			14.5 m: sand becoming fine to coarse grained, with fine to medium grained, sub-angular to sub-rounded gravel appearing				Core Run (14.6-15.4 m): 63% recovery
									CORE LOSS 0.3M.				
									Sandy CLAY: high plasticity, red/brown mottled pale grey and black, sand is fine to coarse grained, with fine to medium grained, sub-angular to sub-rounded gravel.				Core loss likely indicates higher sand content
			Core Run (15.4-16.8 m): 100% recovery										
				EXTREMELY WEATHERED ROCK									

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud C casing N nil  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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# Engineering Log - Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-04**  
sheet: 3 of 14  
project no. **754-SYDGE206418-3**  
date started: **20 Feb 2020**  
date completed: **23 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance						
method & support	penetration	water	samples & field tests	RL (m)	depth (m)	graphic log	soil group symbol	material description	moisture condition	consistency / relative density
	1 2 3							<b>Gravelly CLAY:</b> high plasticity, red/brown mottled pale grey and pale brown, gravel is fine to coarse grained, sub-angular, with fine to coarse grained sand and magnesium staining in veins/joints. <i>(continued)</i>		
		Not Observable			17.0					
					18.0					
					19.0					
					20.0					
					21.0					
					22.0					
					23.0					
								Borehole UG-BH-04 continued as cored hole		

<b>method</b> AD auger drilling* AS auger screwing* HA hand auger W washbore  * bit shown by suffix e.g. AD/T B blank bit T TC bit V V bit	<b>support</b> M mud N nil C casing  <b>penetration</b>  <b>water</b> 	<b>samples &amp; field tests</b> B bulk disturbed sample D disturbed sample E environmental sample SS split spoon sample U## undisturbed sample ##mm diameter HP hand penetrometer (kPa) N standard penetration test (SPT) N* SPT - sample recovered Nc SPT with solid cone VS vane shear; peak/remoulded (kPa) R refusal HB hammer bouncing	<b>soil group symbol &amp; soil description</b> based on AS 1726:2017  <b>moisture condition</b> D dry M moist W wet Wp plastic limit WI liquid limit	<b>consistency / relative density</b> VS very soft S soft F firm St stiff VSt very stiff H hard Fb friable VL very loose L loose MD medium dense D dense VD very dense
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-04**  
sheet: 4 of 14  
project no. **754-SYDGE206418-3**  
date started: **20 Feb 2020**  
date completed: **23 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial O = diametral a = axial d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
			17.0								
			18.0		started coring at 18.00m						
			18.0		ANDESITE: fine grained, red/brown and pale brown, porphyritic, heavily fractured along planes at 0-45°.	XW - HW					Due to drilling method and extensive weathering of rock, sample is highly fractured and defects are difficult to log. Only major/distinguishable defects will be logged until 54.5m
			19.0								SM, 15°, Clay, 19 mm
			20.0								SM, 20°, Clay, 15 mm
			21.0								SM, 25°, Clay, 120 mm
			22.0								SM, 15°, Clay, 28 mm
			23.0								SM, 20°, Clay, 54 mm
											SM, 30°, Clay, 26 mm
											SM, 10°, Clay, 29 mm
											SM, 40°, Clay, 21 mm
											SM, 70°, Clay, 46 mm

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-04**  
sheet: 5 of 14  
project no: **754-SYDGE206418-3**  
date started: **20 Feb 2020**  
date completed: **23 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial, O = diametral a = axial, d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-04**  
sheet: 6 of 14  
project no: **754-SYDGE206418-3**  
date started: **20 Feb 2020**  
date completed: **23 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance		rock mass defects					
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial O = diametral a = axial d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
					ANDESITE: fine grained, red/brown and pale brown, porphyritic, heavily fractured along planes at 0-45°. (continued)	XVW - HW					
			33.0								
			34.0								
			35.0								
			36.0								
			37.0								
			38.0								
			39.0								

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-04**  
sheet: 7 of 14  
project no. **754-SYDGE206418-3**  
date started: **20 Feb 2020**  
date completed: **23 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial O = diametral a = axial, d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
			41.0		ANDESITE: fine grained, red/brown and pale brown, porphyritic, heavily fractured along planes at 0-45°. (continued)	XW - HW					SM, 0°, Clay, 800 mm
					CORE LOSS 0.3M.						
			42.0		ANDESITE: fine grained, red/brown and pale brown, porphyritic, heavily fractured along planes at 0-45°.	XW - MW					
			43.0								SM, 30°, Clay, 50 mm
			44.0								
			45.0								SM, Clay, 28 mm
			46.0		45.20 m: pale green/pale brown altered rock appearing, particularly around joints/defects						
			47.0		46.60 m: becoming purple brown and pale brown, with green/pale brown alteration found near joints/defects						JT, 45°, IR, SO, SN, and altered PB JT, 70°, IR, SO, SN

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-04**  
sheet: 8 of 14  
project no: **754-SYDGE206418-3**  
date started: **20 Feb 2020**  
date completed: **23 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is(50) (MPa) X = axial O = diametral a = axial d = diametral	samples, field tests & Is(50) (MPa) a = axial d = diametral	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
					ANDESITE: fine grained, red/brown and pale brown, porphyritic, heavily fractured along planes at 0-45°. (continued)	XVW - MW					
			49.0								SM, Clay, 60 mm
			50.0								SM, Clay, 40 mm SM, Clay, 50 mm JT, 50°, PL, RO, Sandy clay CO - SN JT, 60°, PL, RO, Fe SN, Healed JT, 15°, UN, RO, Fe SN, Healed JT, 50°, IR, RO, Fe SN, Healed JT, 30°, PL, SO, Fe SN
			51.0								JT, 45°, PL, SO, Fe SN
			52.0								
			53.0								
			54.0								
			55.0								JT, 50°, PL, SO, SN SM, 10 - 15°, Clay, 22 mm JT, 50°, PL, SO, Fe SN

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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**Cored Borehole**

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**Y LTD**

**DEVELOPMENT EIS**

checked by: **PLV**

casing diameter : PVC150/PW

defect type	planarity
PT parting	PL planar
JT joint	CU curved
SS shear surface	UN undulating
SZ shear zone	ST stepped
CO contact	IR Irregular
CS crushed seam	
SM seam	

roughness	coating
VR very rough	CN clean
RO rough	SN stained
SO smooth	VN veneer
POL polished	CO coating
SL slickensided	



# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-04**  
sheet: 10 of 14  
project no. **754-SYDGE206418-3**  
date started: **20 Feb 2020**  
date completed: **23 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is(50) X = axial O = diametral a = axial d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
					ANDESITE: fine grained, red/brown and pale brown, porphyritic, heavily fractured along planes at 0-45°. (continued)	MW					
			65.0		65.00 m: becoming pale brown with red/brown and grey sections						JT, 70°, PL, SO, Fe SN JT, 70°, PL, SO, Fe SN
			66.0								JT, 40°, PL, SO, Fe SN JT, 55°, PL, SO, Fe SN
			67.0			SW - MW					JT, 70°, PL, SO, Fe SN JT, 45°, PL, SO, Fe SN
			68.0								JT, 80°, UN, SO, Fe SN JT, 60°, UN, SO, Fe SN
			69.0								JT, 45°, PL, SO, Fe SN JT, 50°, PL, SO, Fe SN Hight weathered rock/fractured zone
			70.0								JT, 10°, IR, SO, Fe SN - Clay CO JT, 60°, PL, SO, Fe SN - Clay CO
			71.0								JT, 45°, IR, SO, Fe SN SM, 15°, Clay, 7 mm

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-04**  
sheet: 11 of 14  
project no. **754-SYDGE206418-3**  
date started: **20 Feb 2020**  
date completed: **23 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is(50) X = axial O = diametral a = axial d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
					ANDESITE: fine grained, red/brown and pale brown, porphyritic, heavily fractured along planes at 0-45°. (continued)	SW - MW					particular
			73.0								general
			74.0		74.00 m: becoming grey, manganese stained fracture planes every 5-10mm becoming less obvious						JT, 10°, PL, SO, Fe SN JT, 50°, PL, SO, Fe SN - Clay CO JT, 50°, PL, SO, Fe SN - Clay CO JT, 50°, PL, SO, Fe SN - Clay CO JT, 50°, PL, SO, Fe SN - Clay CO JT, 70°, PL, SO, Clay CO JT, 70°, PL, SO, Fe SN Vein quartz, 45°, 20 mm JT, 10°, UN, SO, Clay CO
			75.0		75.44 m: trace pyrite crystals up to 1mm wide appearing, particularly amongst quartz veins 75.73 m: manganese stained fracture planes no longer visible	SW					JT, 65°, UN, SO, Fe CO JT, 55°, PL, SO, Fe CO JT, 15°, PL, SO, Fe CO JT, 25°, PL, SO, Fe SN - Clay CO JT, 15°, PL, SO, Clay VN, Healed JT, 45°, IR, SO, Sandy clay VN JT, 45°, PL, SO, Fe SN
			76.0			FR					JT, 20°, PL, SO, Fe SN JT, 70°, UN, SO, Fe SN JT, 50°, UN, SO, Fe SN
			77.0								JT, 30°, PL, SO, Fe SN
			78.0								JT, 65°, PL, SO, Calcite VN
			79.0		79.45 m: becoming grey, with sporadic green/pale brown alteration near select joints						Vein quartz, 30°, PL, 4 mm JT, 85°, PL, SO, CN JT, 35°, PL, SO, CN JT, 70 - 85°, IR, SO, CN JT, 45°, IR, SO, CN JT, 65°, PL, SO, Healed

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID. **UG-BH-04**  
sheet: 12 of 14  
project no. **754-SYDGE206418-3**  
date started: **20 Feb 2020**  
date completed: **23 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial O = diametral a = axial d = diametral	samples, field tests & Is(50) (MPa)	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)
					ANDESITE: fine grained, grey, porphyritic, with quartz and calcite veins 0-90° up to 5mm thick. 80.20 m: becoming grey, with no alteration observed	FR					
			81.0								JT, 15°, PL, SO, Clay VN, Healed JT, 80°, UN, SO, CN JT, 60°, PL, SO, Clay CO JT, 60°, PL, SO, Clay CO
			82.0								JT, 90 - 80°, UN, SO, Calcite VN JT, 45°, PL, SO, Calcite VN
			83.0								JT, 10°, PL, SO, Calcite VN JT, 30°, PL, SO, Calcite VN JT, 30°, IR, SO, Calcite VN
			84.0		84.24 m: pyrite vein approximately 8mm thick, 50°						JT, 40°, PL, SO, Calcite VN JT, 30°, PL, SO, Calcite VN JT, 50°, PL, SO, CN
			85.0								
			86.0								
			87.0								

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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# Engineering Log - Cored Borehole

client: **EMM CONSULTING PTY LTD**  
principal: **Evolution Mining**  
project: **CGO UNDERGROUND DEVELOPMENT EIS**  
location: **COWAL GOLD OPERATIONS**

Borehole ID: **UG-BH-04**  
sheet: 13 of 14  
project no: **754-SYDGE206418-3**  
date started: **20 Feb 2020**  
date completed: **23 Feb 2020**  
logged by: **TBM**  
checked by: **PLV**

position: Not Specified surface elevation: Not Specified angle from horizontal: -90°  
drill model: Sandvik DE840, Truck mounted drilling fluid: PAK-R casing diameter: PVC150/PW

drilling information				material substance				rock mass defects			
method & support	water	RL (m)	depth (m)	graphic log	material description ROCK TYPE: grain characteristics, colour, structure, minor components	weathering & alteration	estimated strength & Is50 X = axial, O = diametral	samples, field tests & Is(50) (MPa) a = axial, d = diametral	core run & RQD	defect spacing (mm)	additional observations and defect descriptions (type, inclination, planarity, roughness, coating, thickness, other)

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none <b>water</b> 10/10/12, water level on date shown water inflow complete drilling fluid loss partial drilling fluid loss water pressure test result (lugeons) for depth interval shown	<b>graphic log / core recovery</b> core recovered (graphic symbols indicate material) no core recovered <b>core run &amp; RQD</b> barrel withdrawn RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR irregular <b>coating</b> CN clean SN stained VN veneer CO coating
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**Cored Borehole**









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**Y LTD**

**DEVELOPMENT EIS**


checked by: **PLV**

casing diameter : PVC150/PW

<b>method &amp; support</b> AS auger screwing AD auger drilling CB claw or blade bit W washbore RR rock roller NMLCNMLC core (51.9 mm) NQ wireline core (47.6mm) HQ wireline core (63.5mm) PQ wireline core (85.0mm)	<b>support</b> C casing M mud N none  <b>water</b>  10/10/12, water level on date shown  water inflow  complete drilling fluid loss  partial drilling fluid loss   water pressure test result (lugeneos) for depth interval shown	<b>graphic log / core recovery</b>  core recovered (graphic symbols indicate material)  no core recovered  <b>core run &amp; RQD</b>  barrel withdrawn  RQD = Rock Quality Designation (%)	<b>weathering &amp; alteration*</b> RS residual soil XW extremely weathered HW highly weathered MW moderately weathered SW slightly weathered FR fresh *W replaced with A for alteration <b>strength</b> VL very low L low M medium H high VH very high EH extremely high	<b>defect type</b> PT parting JT joint SS shear surface SZ shear zone CO contact CS crushed seam SM seam  <b>roughness</b> VR very rough RO rough SO smooth POL polished SL slickensided	<b>planarity</b> PL planar CU curved UN undulating ST stepped IR Irregular  <b>coating</b> CN clean SN stained VN veneer CO coating
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UG-BH-04 5.10 - 8.90 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-04		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 1
original size	A4				rev:	A






UG-BH-04 8.90 - 12.30 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 2</b>
original size	A4				rev:	A




UG-BH-04 12.30 - 16.00 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 3</b>
original size	A4				rev:	A






UG-BH-04 16.00 - 19.40 m

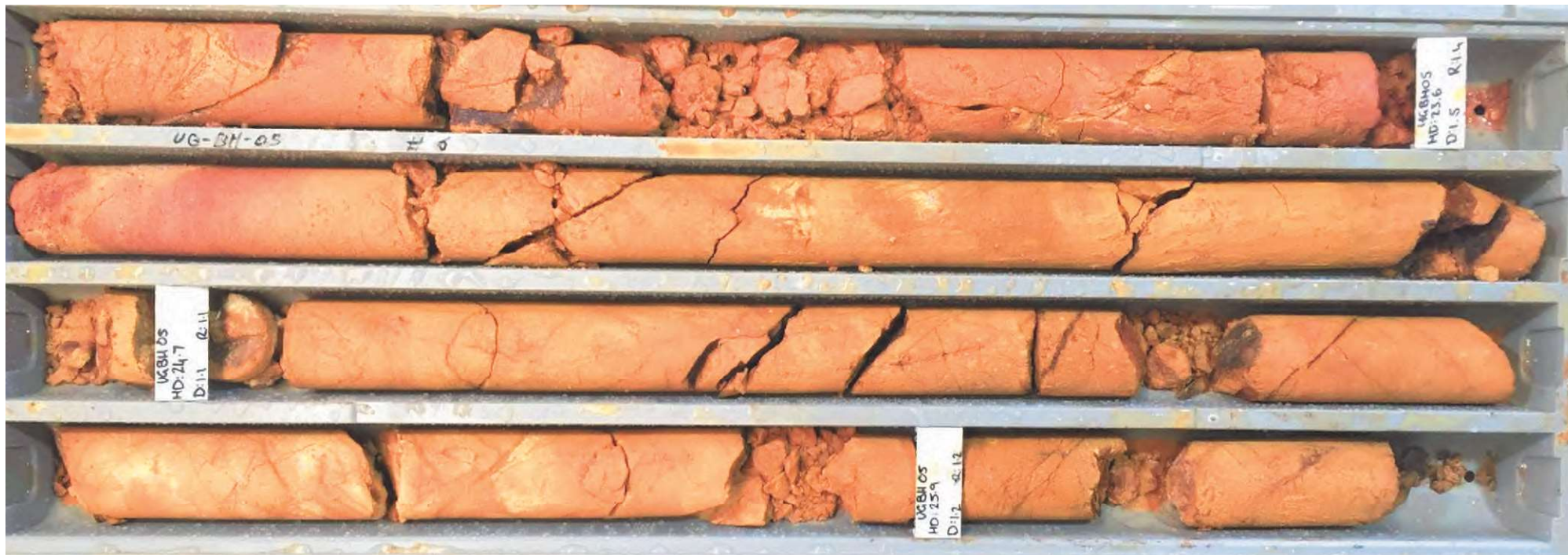
drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 4</b>
original size	A4				rev:	A






UG-BH-04 19.40 - 22.80 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 5</b>
original size	A4				rev:	A




UG-BH-04 22.80 - 26.20 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 6</b>
original size	A4				rev:	A






UG-BH-04 26.20 - 29.70 m

drawn	TBM	 <b>coffey</b> <small>A TETRA TECH COMPANY</small>	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 7</b>
original size	A4				rev:	A






UG-BH-04 29.70 - 32.80 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 8</b>
original size	A4				rev:	A




UG-BH-04 32.80 - 36.45 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 9</b>
original size	A4				rev:	A






UG-BH-04 36.45 - 39.60 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 10</b>
original size	A4				rev:	A






UG-BH-04 39.60 - 43.00 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 11</b>
original size	A4				rev:	A



UG-BH-04 43.00 - 46.70 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-04		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 12
original size	A4				rev:	A




drawn	TBM		client: EMM CONSULTING PTY LTD		
approved	AO		project: CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title: CORE PHOTOGRAPH UG-BH-04		
scale	N.T.S.				
original size	A4		project no: 754-SYDGE206418-3	fig no: FIGURE 13	rev: A






UG-BH-04 49.90 - 53.50 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 14</b>
original size	A4				rev:	A




UG-BH-04 53.50 - 56.40 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 15</b>
original size	A4				rev:	A

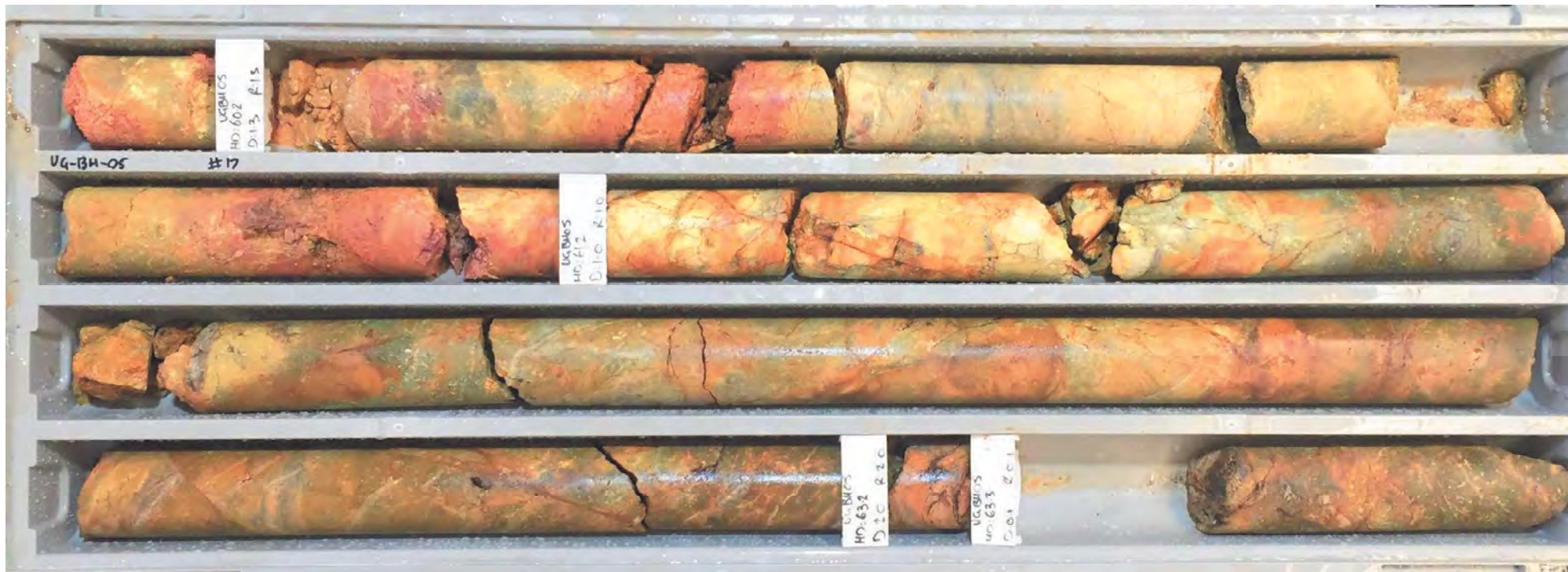





UG-BH-04 56.40 - 60.10 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 16</b>
original size	A4				rev:	A






UG-BH-04 60.10 - 63.60 m

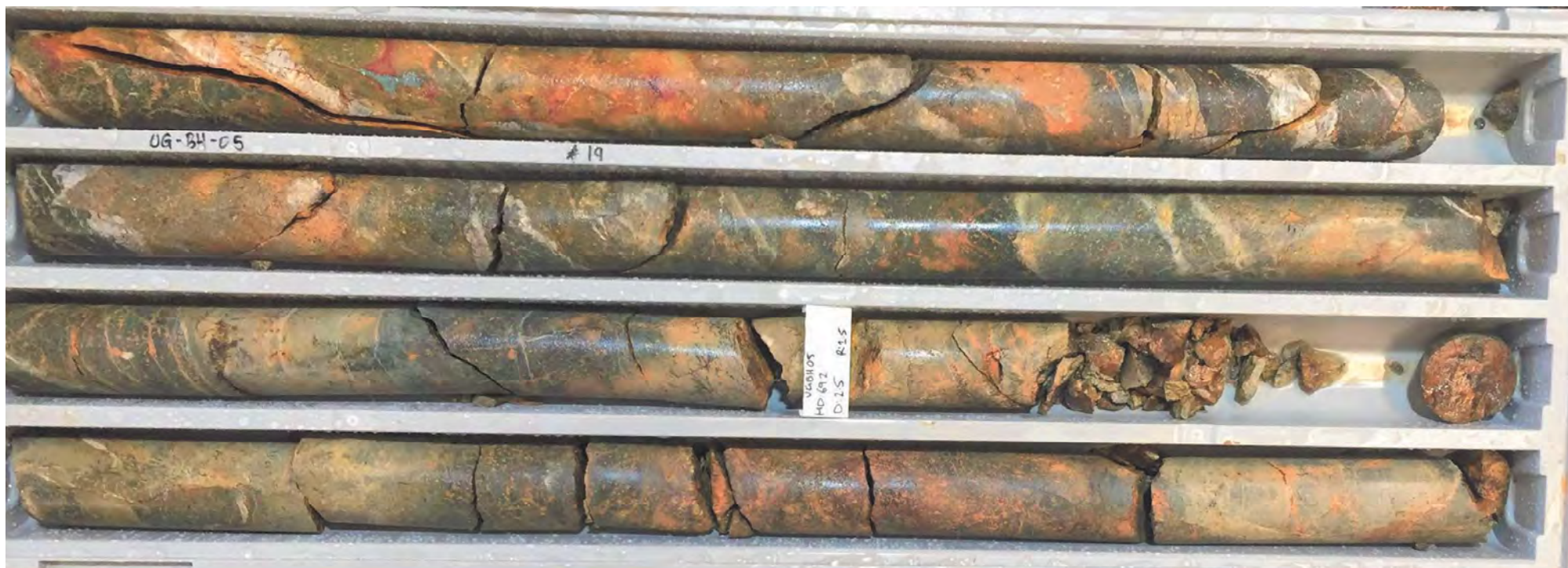
drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 17</b>
original size	A4				rev:	A




UG-BH-04 63.60 - 67.00 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-04		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 18
original size	A4				rev:	A

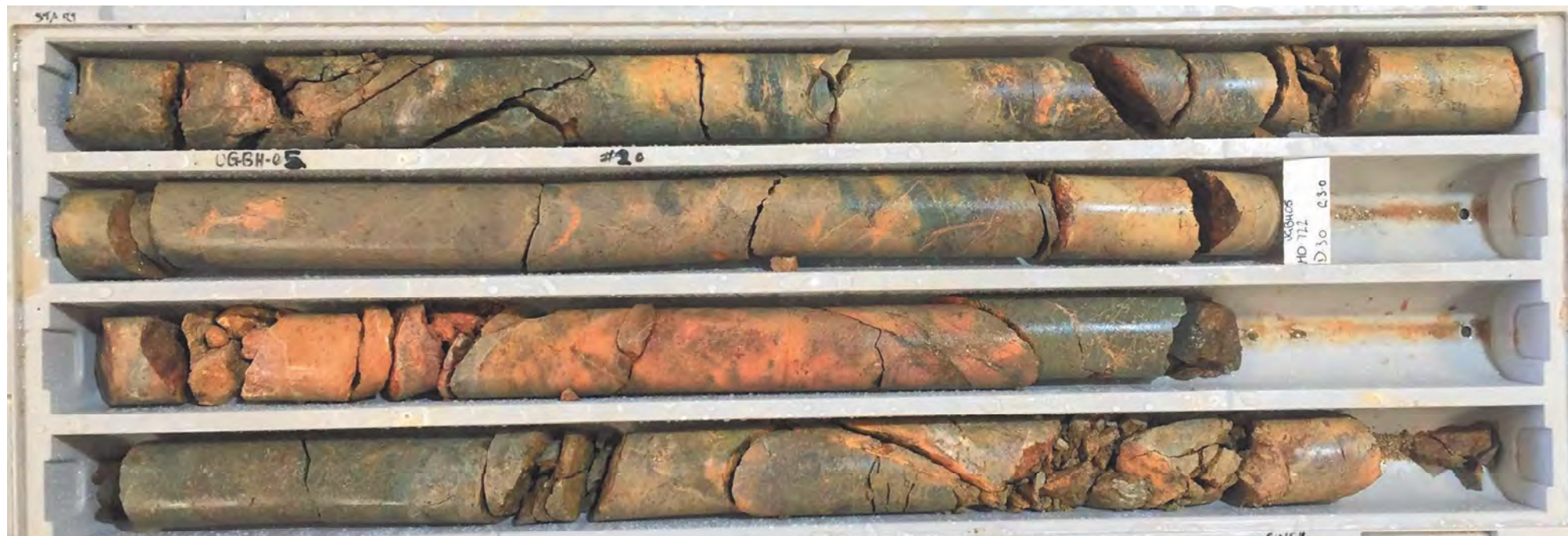





UG-BH-04 67.00 - 70.65 m

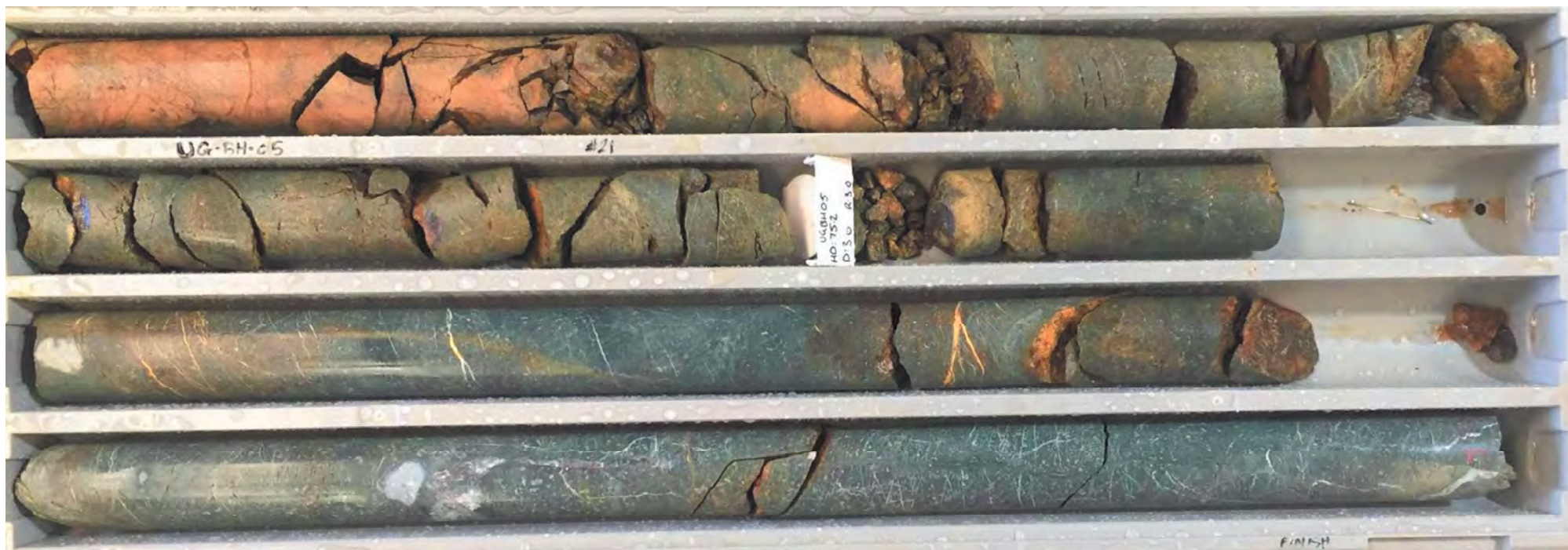
drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 19</b>
original size	A4				rev:	A






UG-BH-04 70.65 - 74.70 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 20</b>
original size	A4				rev:	A




UG-BH-04 74.70 - 77.20 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 21</b>
original size	A4				rev:	A






UG-BH-04 77.20 - 80.70 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 22</b>
original size	A4				rev:	A






UG-BH-04 80.70 - 84.20 m

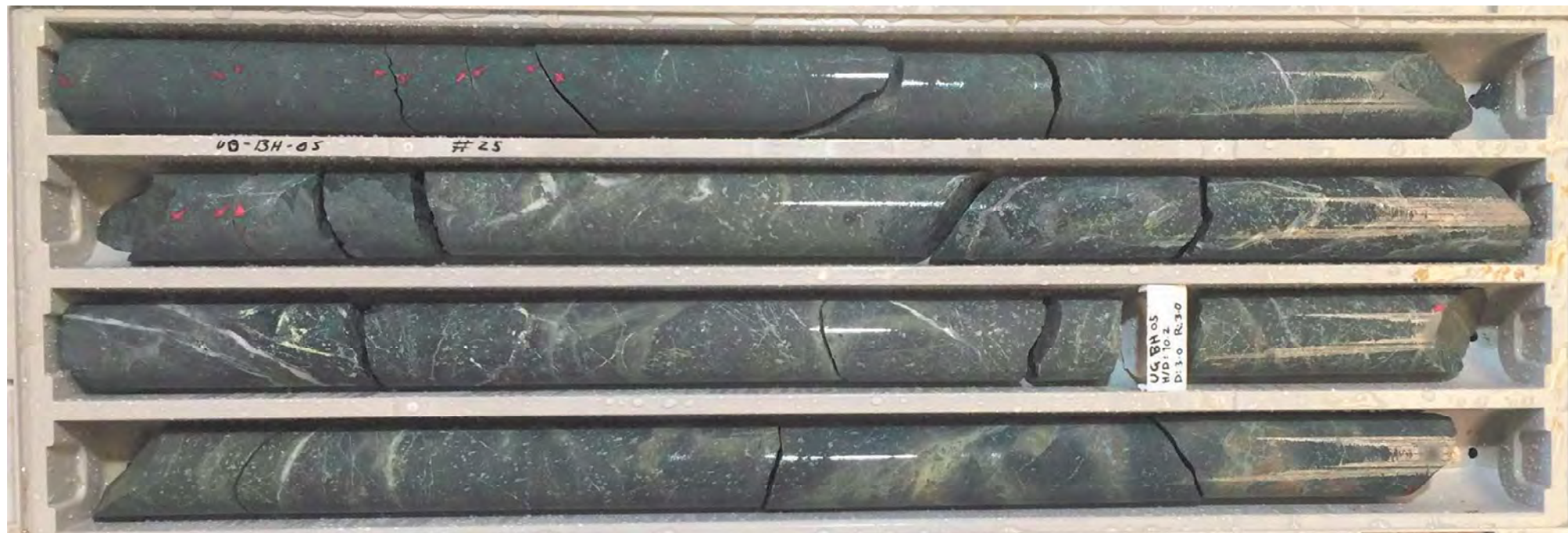
drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 23</b>
original size	A4				rev:	A




UG-BH-04 84.20 - 87.75 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 24</b>
original size	A4				rev:	A






UG-BH-04 87.75 - 91.15 m

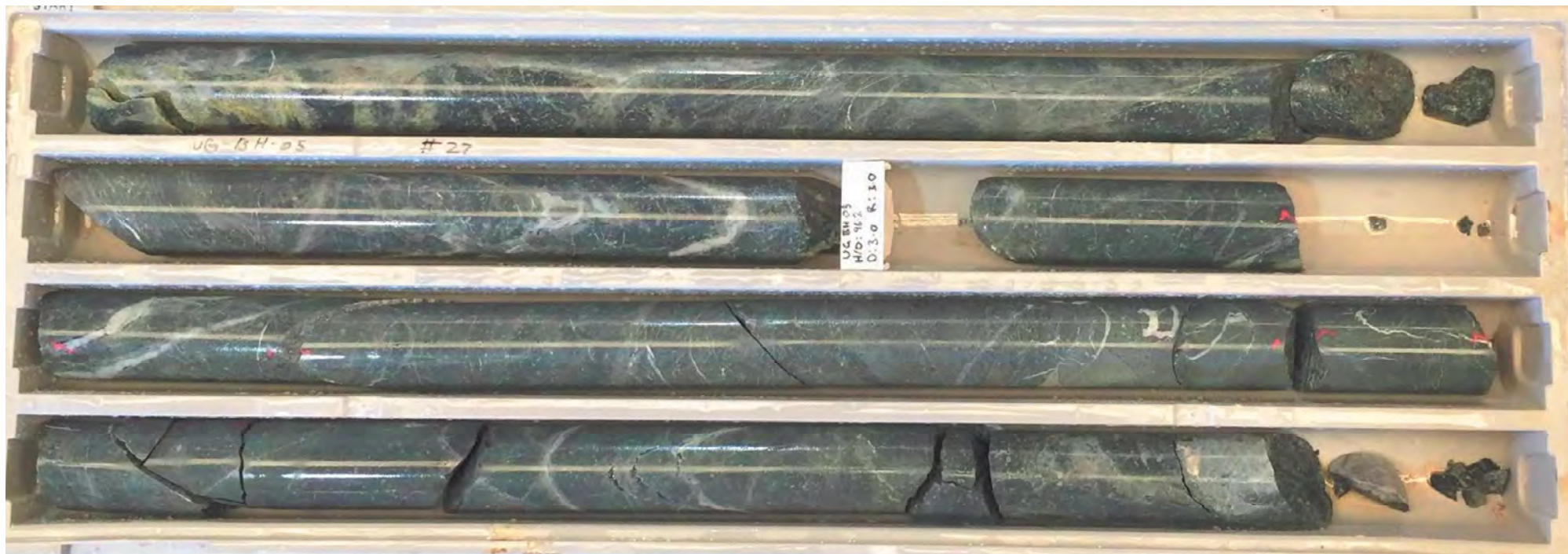
drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 25</b>
original size	A4				rev:	A






UG-BH-04 91.15 - 94.00 m

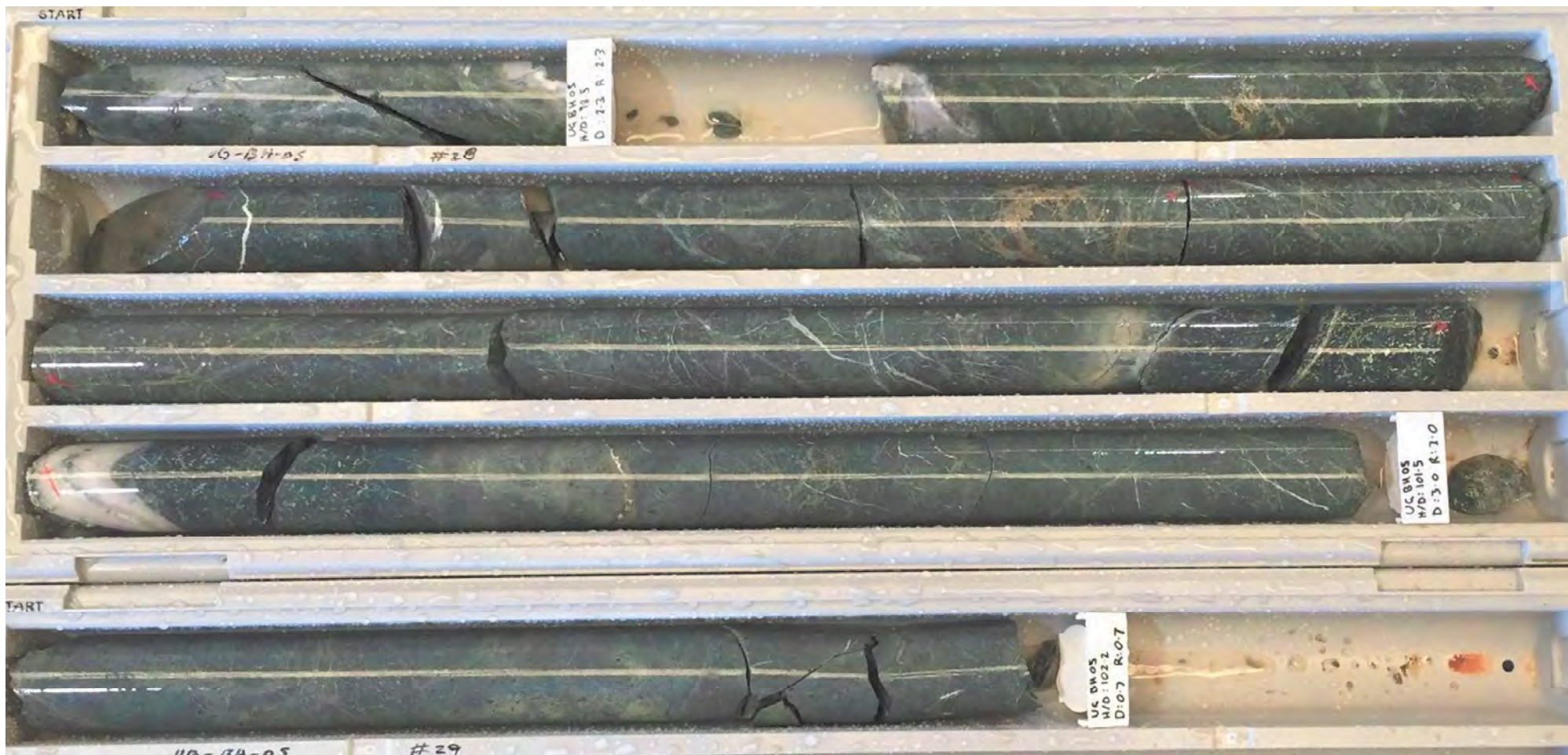
drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 26</b>
original size	A4				rev:	A




UG-BH-04 94.00 - 98.00 m

drawn	TBM		client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	<b>CORE PHOTOGRAPH UG-BH-04</b>		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	<b>FIGURE 27</b>
original size	A4				rev:	A



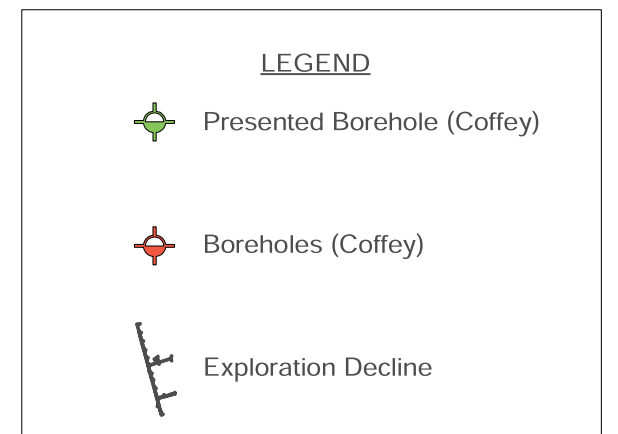
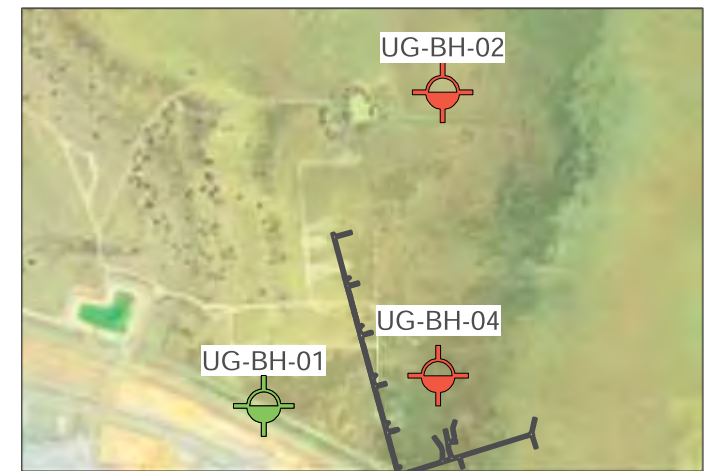
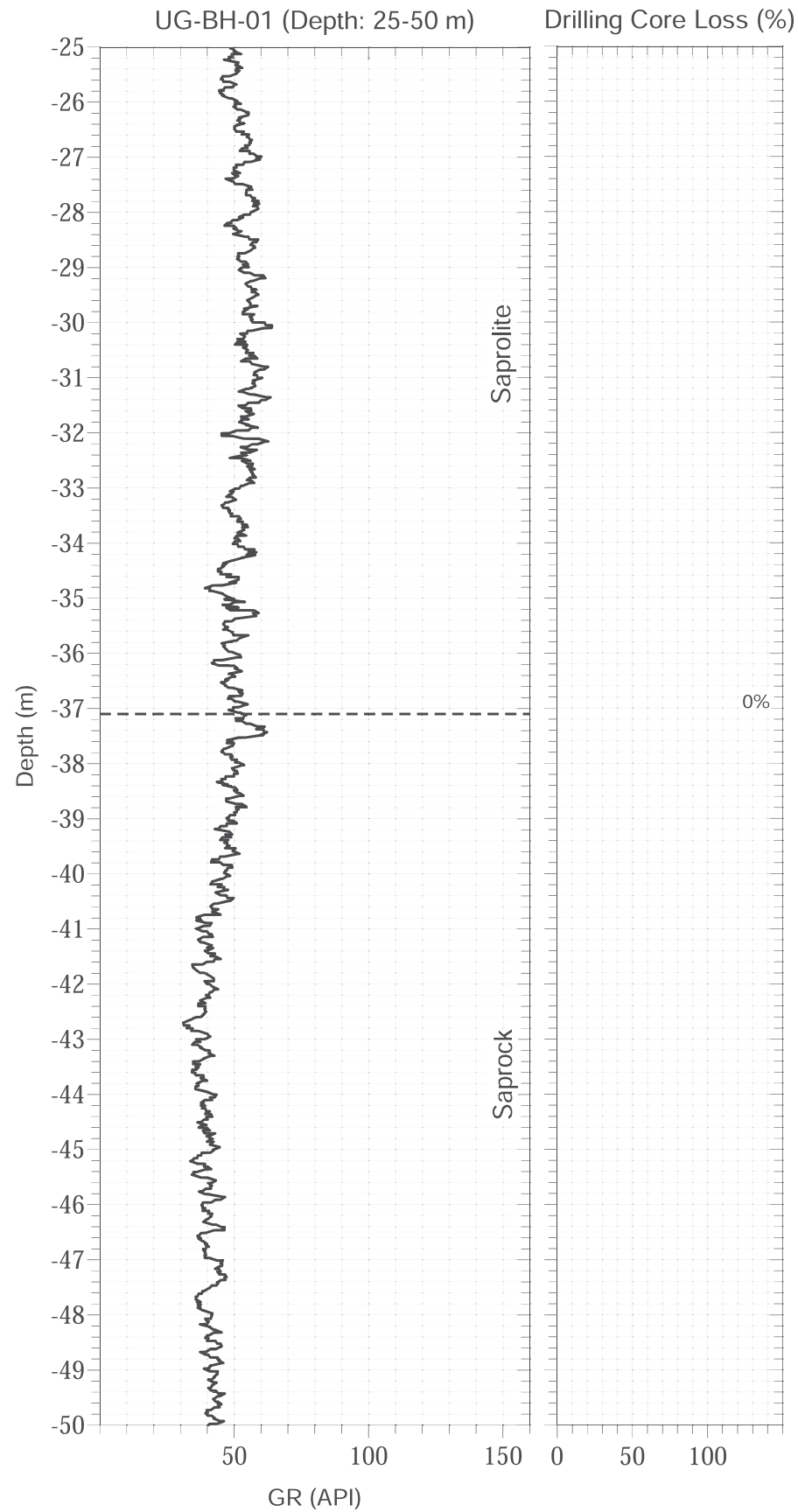
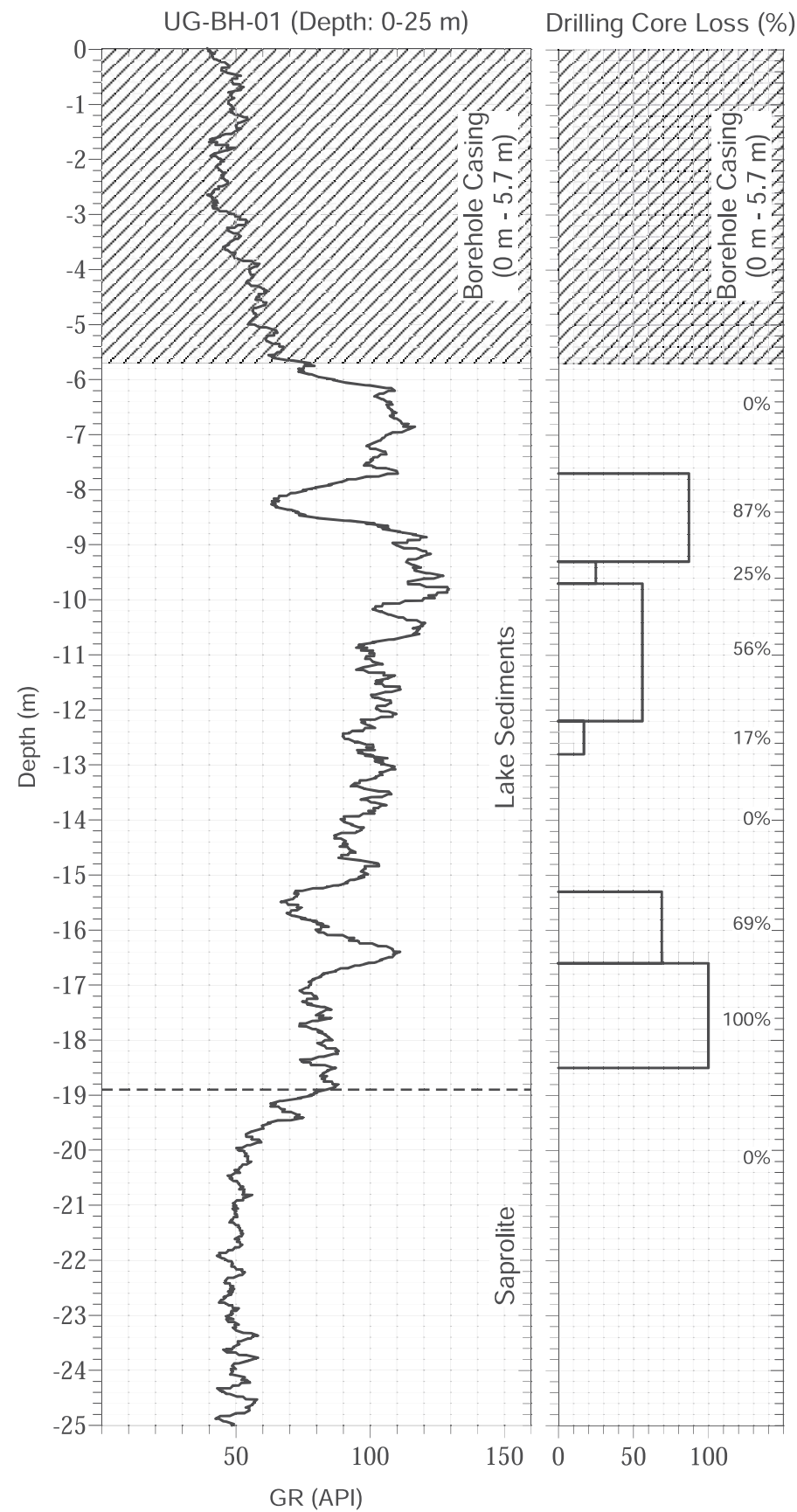


UG-BH-04 98.00 - 102.00 m

drawn	TBM	 A TETRA TECH COMPANY	client:	EMM CONSULTING PTY LTD		
approved	AO		project:	CGO UNDERGROUND DEVELOPMENT EIS COWAL GOLD OPERATIONS		
date	23/03/2020		title:	CORE PHOTOGRAPH UG-BH-04		
scale	N.T.S.		project no:	754-SYDGE206418-3	fig no:	FIGURE 28
original size	A4				rev:	A



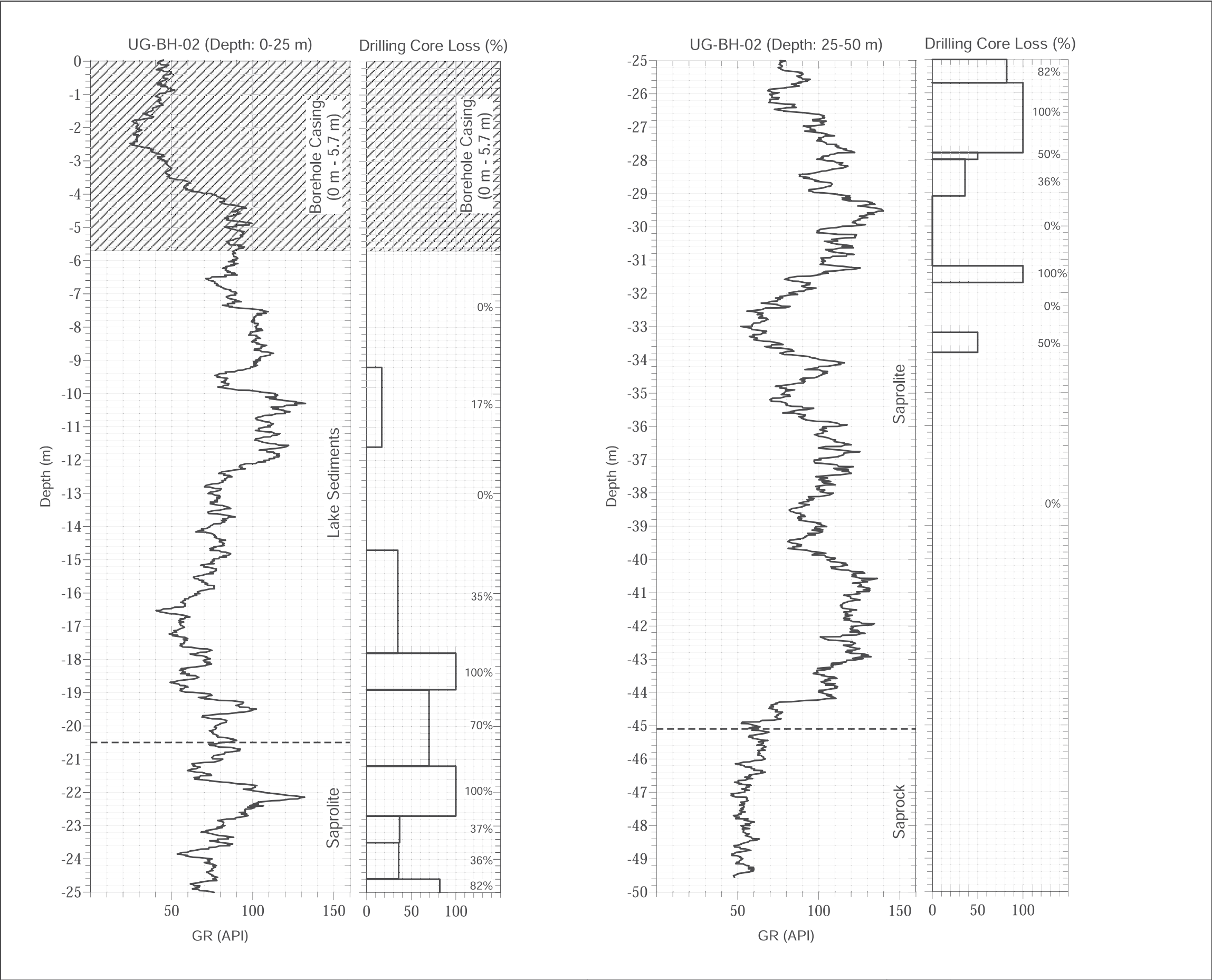
## **Appendix B – Natural gamma logging**



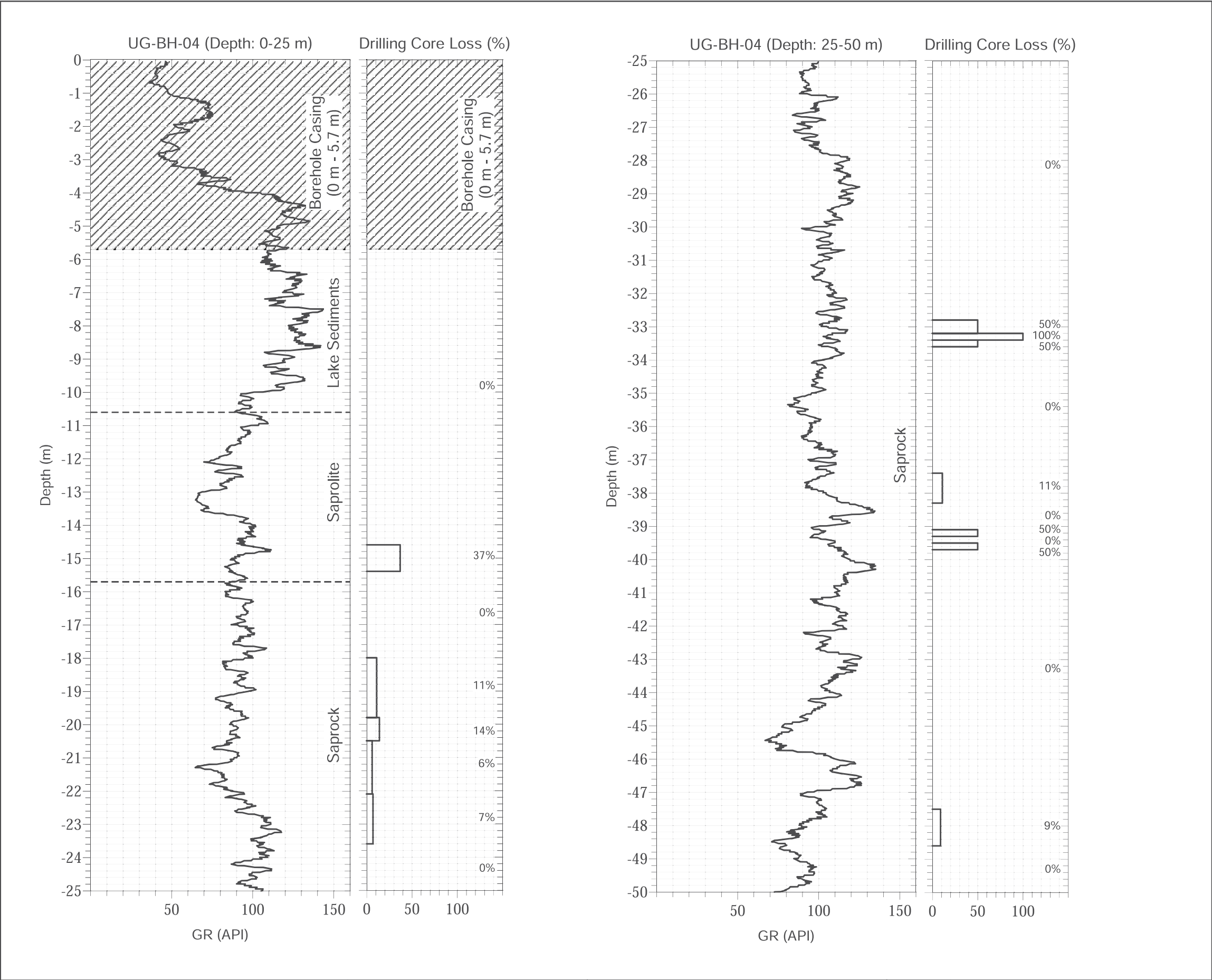
Well Name:	UG-BH-01
Easting:	537751.6
Northing:	6278843.8
Location:	Cowal Gold Mine
Operator:	BS
Log Measured From:	Ground Level

GEODETIC PARAMETERS	
Geodetic Datum:	MGA1994
Coordinate System:	MAP GRID of AUSTRALIA 1994
Projection:	Universal Transverse Mercator (UTM) Zone 55
Semi Major Axis:	6378137.0000m
Inverse Flattening (1/f):	298.25722210
Central Meridian:	147°00'00 East
Reference Latitude:	00°00'00 North
Scale Factor at CM:	0.9996
False Easting:	500,000m
False Northing:	10,000,000m

revision	no.	description	drawn	approved	date		drawn	BS		client:	EMM CONSULTING PTY LTD		
	01	FINAL	BS	SS	17 / 03 / 2020		approved	SS		project:	CGO UNDERGROUND DEVELOPMENT EIS		
							date	17 / 03 / 2020		title:	NATURAL GAMMA RAY PROFILING: UG-BH-01		
							scale	NTS		project no:	SYDGE206418-3	figure no:	FIGURE B1
							original size	A3		rev:	01		







LEGEND

Presented Borehole (Coffey)

Boreholes (Coffey)

Exploration Decline

Well Name:	UG-BH-04
Easting:	538169
Northing:	6278916
Location:	Cowal Gold Mine
Operator:	TM
Log Measured From:	Ground Level

revision	no.	description	drawn	approved	date		drawn	BS	<div><div>A TETRA TECH COMPANY</div></div>	client:	EMM CONSULTING PTY LTD		
	01	FINAL	BS	SS	17 / 03 / 2020		approved	SS		project:	CGO UNDERGROUND DEVELOPMENT EIS		
							date	17 / 03 / 2020		title:	NATURAL GAMMA RAY PROFILING: UG-BH-04		
							scale	NTS		project no:	SYDGE206418-3	figure no:	FIGURE B3
							original size	A3		rev:	01		

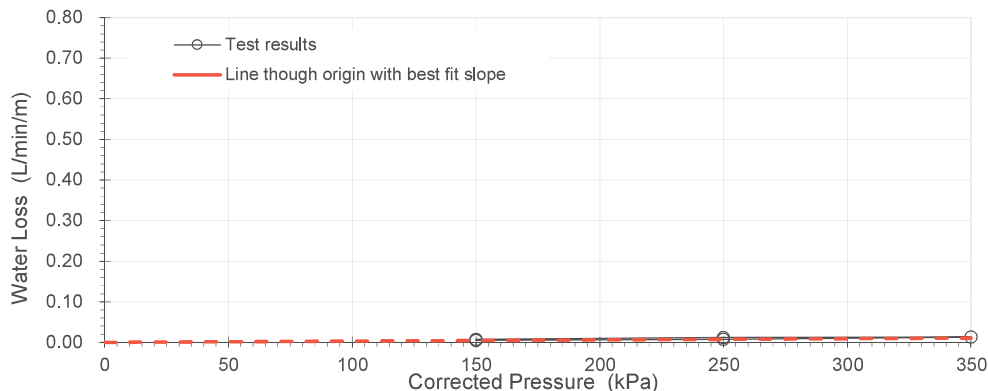
## **Appendix C – Packer test results**

## Borehole Water Pressure Test

Client **EMM CONSULTING PTY LTD**  
Principal **Evolution Mining**  
Project **CGO UNDERGROUND DEVELOPMENT EIS**  
Location **North east of open pit outside lake bund**

Borehole **UG-BH-02**  
Depth Interval **97.00-103.00 m**  
Job No. **SYDGE206418-3**  
Test date **6-2-2020**  
Interpreted by **AO**  
Checked **RJB**

Test Details		Packer type <b>Pneumatic</b>	Borehole diam. <b>96 mm</b>			
		Type of pump <b>Drill rig</b>	Borehole inclination <b>90 degrees</b>			
		Pressure gauge <b>Accu-Drive DD504N28-150D</b>	Test interval length <b>6.00 m</b>			
time interval (min)	gauge pressure (kPa)	water loss (L)	flow rate (L/min)	pressure correction (kPa)	water loss rate (L/min/m)	corrected pressure (kPa)
1	150	0.1	0.14	0	0.02	150
1	150	0.1	0.08	0	0.01	150
1	150	0.1	0.08	0	0.01	150
1	150	0.1	0.10	0	0.02	150
1	150	0.1	0.06	0	0.01	150
5	150	0.2	0.05	0	0.01	150
1	250	0.1	0.12	0	0.02	250
1	250	0.1	0.09	0	0.02	250
1	250	0.1	0.10	0	0.02	250
1	250	0.1	0.09	0	0.02	250
1	250	0.1	0.06	0	0.01	250
5	250	0.4	0.07	0	0.01	250
1	350	0.1	0.12	0	0.02	350
1	350	0.1	0.08	0	0.01	350
1	350	0.1	0.09	0	0.02	350
1	350	0.1	0.08	0	0.01	350
1	350	0.1	0.10	0	0.02	350
5	350	0.4	0.08	0	0.01	350
1	250	0.0	0.04	0	0.01	250
1	250	0.1	0.06	0	0.01	250
1	250	0.1	0.05	0	0.01	250
1	250	0.1	0.06	0	0.01	250
1	250	0.0	0.04	0	0.01	250
5	250	0.2	0.05	0	0.01	250
1	150	0.0	0.03	0	0.00	150
1	150	0.0	0.03	0	0.01	150
1	150	0.0	0.04	0	0.01	150
1	150	0.0	0.02	0	0.00	150
1	150	0.0	0.03	0	0.00	150
5	150	0.2	0.03	0	0.01	150



Interpreted Lugeon Permeability: **0.03 uL** (L/min/m @ 1000 kPa)

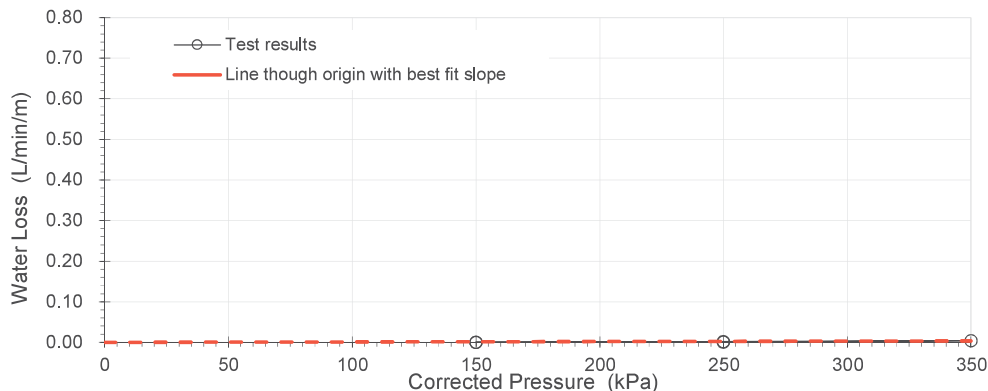


## Borehole Water Pressure Test

Client **EMM CONSULTING PTY LTD**  
Principal **Evolution Mining**  
Project **CGO UNDERGROUND DEVELOPMENT EIS**  
Location **North east of open pit outside lake bund**

Borehole **UG-BH-03**  
Depth Interval **60.00-64.00 m**  
Job No. **SYDGE206418-3**  
Test date **19-2-2020**  
Interpreted by **AO**  
Checked **RJB**

Test Details	Packer type	<b>Pneumatic</b>		Borehole diam.	<b>96 mm</b>	
	Type of pump	<b>Drill rig</b>		Borehole inclination	<b>90 degrees</b>	
	Pressure gauge	<b>Accu-Drive DD504N28-150D</b>		Test interval length	<b>4.00 m</b>	
time interval (min)	gauge pressure (kPa)	water loss (L)	flow rate (L/min)	pressure correction (kPa)	water loss rate (L/min/m)	corrected pressure (kPa)
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.01	0	0.00	150
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
5	150	0.0	0.00	0	0.00	150
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.00	0	0.00	250
5	250	0.0	0.01	0	0.00	250
1	350	0.0	0.02	0	0.00	350
1	350	0.0	0.02	0	0.00	350
1	350	0.0	0.02	0	0.00	350
1	350	0.0	0.02	0	0.00	350
1	350	0.0	0.01	0	0.00	350
5	350	0.1	0.02	0	0.00	350
1	250	0.0	0.01	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.01	0	0.00	250
5	250	0.0	0.00	0	0.00	250
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
5	150	0.0	0.00	0	0.00	150



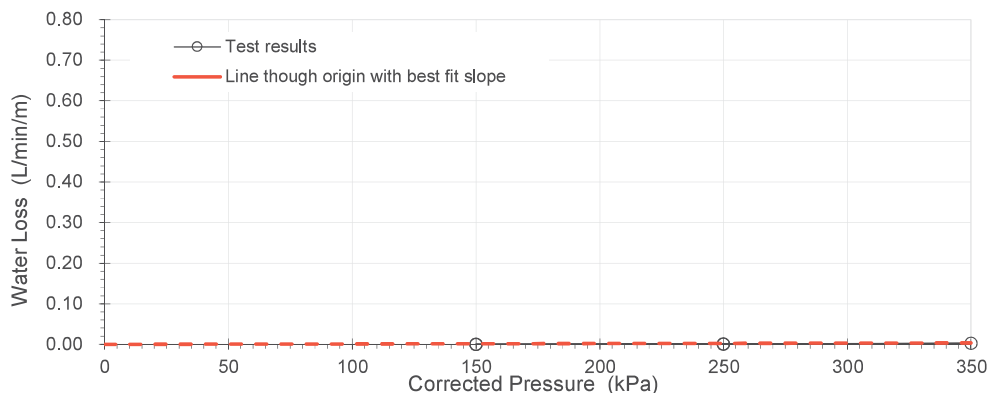
Interpreted Lugeon Permeability: **0.01 uL** (L/min/m @ 1000 kPa)

## Borehole Water Pressure Test

Client **EMM CONSULTING PTY LTD**  
Principal **Evolution Mining**  
Project **CGO UNDERGROUND DEVELOPMENT EIS**  
Location **North east of open pit outside lake bund**

Borehole **UG-BH-03**  
Depth Interval **65.00-72.00 m**  
Job No. **SYDGE206418-3**  
Test date **20-2-2020**  
Interpreted by **AO**  
Checked **RJB**

Test Details	Packer type	<b>Pneumatic</b>		Borehole diam.	<b>96 mm</b>	
	Type of pump	<b>Drill rig</b>		Borehole inclination	<b>90 degrees</b>	
	Pressure gauge	<b>Accu-Drive DD504N28-150D</b>		Test interval length	<b>7.00 m</b>	
time interval (min)	gauge pressure (kPa)	water loss (L)	flow rate (L/min)	pressure correction (kPa)	water loss rate (L/min/m)	corrected pressure (kPa)
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.01	0	0.00	150
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.01	0	0.00	150
5	150	0.0	0.00	0	0.00	150
1	250	0.0	0.01	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.01	0	0.00	250
1	250	0.0	0.01	0	0.00	250
1	250	0.0	0.00	0	0.00	250
5	250	0.0	0.01	0	0.00	250
1	350	0.0	0.02	0	0.00	350
1	350	0.0	0.03	0	0.00	350
1	350	0.0	0.02	0	0.00	350
1	350	0.0	0.03	0	0.00	350
1	350	0.0	0.02	0	0.00	350
5	350	0.1	0.02	0	0.00	350
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.01	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.00	0	0.00	250
5	250	0.0	0.00	0	0.00	250
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
5	150	0.0	0.00	0	0.00	150



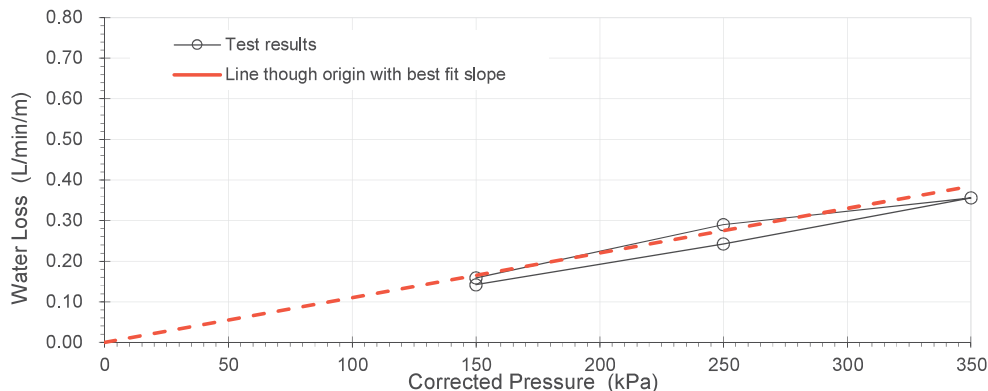
Interpreted Lugeon Permeability: **0.01 uL** (L/min/m @ 1000 kPa)

## Borehole Water Pressure Test

Client **EMM CONSULTING PTY LTD**  
Principal **Evolution Mining**  
Project **CGO UNDERGROUND DEVELOPMENT EIS**  
Location **North east of open pit outside lake bund**

Borehole **UG-BH-04**  
Depth Interval **54.00-59.00 m**  
Job No. **SYDGE206418-3**  
Test date **23-2-2020**  
Interpreted by **AO**  
Checked **RJB**

Test Details	Packer type	<b>Pneumatic</b>		Borehole diam.	<b>96 mm</b>	
	Type of pump	<b>Drill rig</b>		Borehole inclination	<b>90 degrees</b>	
	Pressure gauge	<b>Accu-Drive DD504N28-150D</b>		Test interval length	<b>5.00 m</b>	
time interval (min)	gauge pressure (kPa)	water loss (L)	flow rate (L/min)	pressure correction (kPa)	water loss rate (L/min/m)	corrected pressure (kPa)
1	150	1.1	1.15	0	0.23	150
1	150	0.7	0.65	0	0.13	150
1	150	0.9	0.92	0	0.18	150
1	150	1.1	1.10	0	0.22	150
1	150	0.8	0.76	0	0.15	150
5	150	3.5	0.71	0	0.14	150
1	250	1.4	1.39	0	0.28	250
1	250	1.1	1.12	0	0.22	250
1	250	1.4	1.36	0	0.27	250
1	250	1.2	1.15	0	0.23	250
1	250	1.3	1.34	0	0.27	250
5	250	6.1	1.21	0	0.24	250
1	350	2.4	2.38	0	0.48	350
1	350	2.3	2.33	0	0.47	350
1	350	1.8	1.82	0	0.36	350
1	350	2.2	2.17	0	0.43	350
1	350	1.9	1.94	0	0.39	350
5	350	8.9	1.78	0	0.36	350
1	250	1.6	1.61	0	0.32	250
1	250	1.6	1.65	0	0.33	250
1	250	1.7	1.70	0	0.34	250
1	250	1.6	1.64	0	0.33	250
1	250	1.7	1.69	0	0.34	250
5	250	7.3	1.45	0	0.29	250
1	150	1.1	1.11	0	0.22	150
1	150	1.2	1.23	0	0.25	150
1	150	1.3	1.26	0	0.25	150
1	150	0.7	0.67	0	0.13	150
1	150	0.8	0.82	0	0.16	150
5	150	4.0	0.79	0	0.16	150



Interpreted Lugeon Permeability: **1.1 uL** (L/min/m @ 1000 kPa)

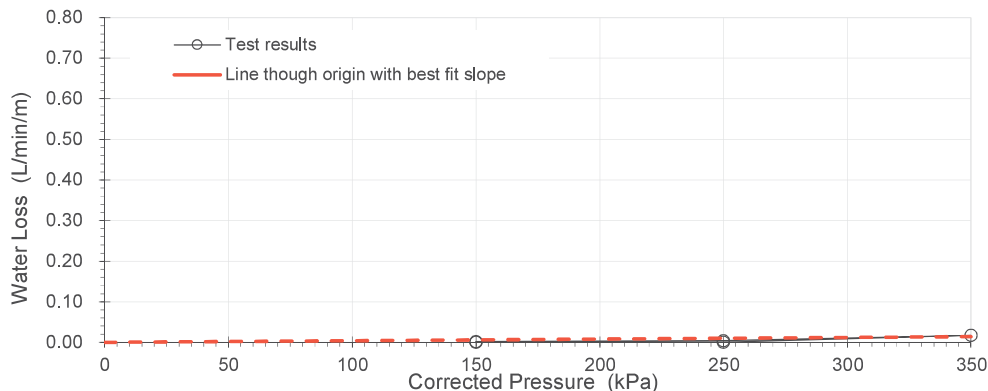


## Borehole Water Pressure Test

Client **EMM CONSULTING PTY LTD**  
Principal **Evolution Mining**  
Project **CGO UNDERGROUND DEVELOPMENT EIS**  
Location **North east of open pit outside lake bund**

Borehole **UG-BH-04**  
Depth Interval **63.00-68.00 m**  
Job No. **SYDGE206418-3**  
Test date **23-2-2020**  
Interpreted by **AO**  
Checked **RJB**

Test Details	Packer type	<b>Pneumatic</b>		Borehole diam.	<b>96 mm</b>	
	Type of pump	<b>Drill rig</b>		Borehole inclination	<b>90 degrees</b>	
	Pressure gauge	<b>Accu-Drive DD504N28-150D</b>		Test interval length	<b>5.00 m</b>	
time interval (min)	gauge pressure (kPa)	water loss (L)	flow rate (L/min)	pressure correction (kPa)	water loss rate (L/min/m)	corrected pressure (kPa)
1	150	0.1	0.08	0	0.02	150
1	150	0.1	0.14	0	0.03	150
1	150	-0.2	-0.19	0	-0.04	150
1	150	0.0	0.01	0	0.00	150
1	150	0.0	-0.01	0	0.00	150
5	150	0.0	0.01	0	0.00	150
1	250	0.0	0.02	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.1	0.08	0	0.02	250
1	250	0.0	0.05	0	0.01	250
1	250	0.0	0.01	0	0.00	250
5	250	0.1	0.02	0	0.00	250
1	350	0.1	0.06	0	0.01	350
1	350	0.1	0.07	0	0.01	350
1	350	0.1	0.08	0	0.02	350
1	350	0.1	0.10	0	0.02	350
1	350	0.1	0.07	0	0.01	350
5	350	0.4	0.09	0	0.02	350
1	250	0.0	0.01	0	0.00	250
1	250	0.0	-0.01	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.0	-0.03	0	-0.01	250
1	250	0.0	0.02	0	0.00	250
5	250	0.0	0.00	0	0.00	250
1	150	0.0	0.05	0	0.01	150
1	150	0.0	-0.01	0	0.00	150
1	150	0.0	-0.02	0	0.00	150
1	150	0.0	0.01	0	0.00	150
1	150	0.0	0.00	0	0.00	150
5	150	0.0	0.00	0	0.00	150



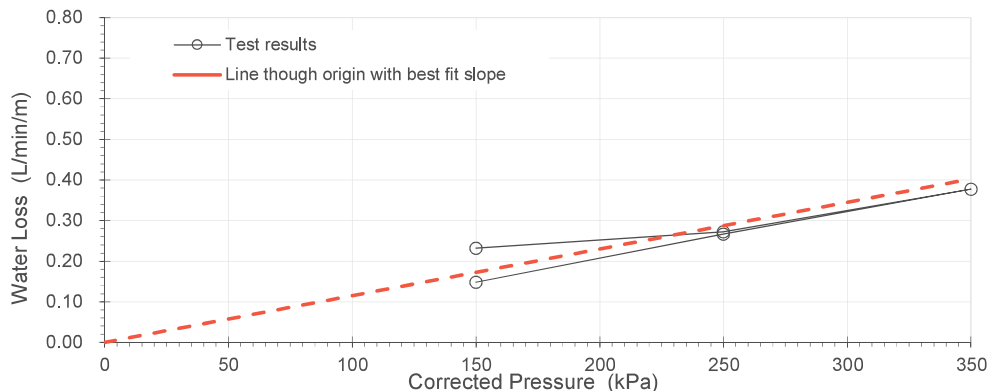
Interpreted Lugeon Permeability: **0.04 uL** (L/min/m @ 1000 kPa)

## Borehole Water Pressure Test

Client **EMM CONSULTING PTY LTD**  
Principal **Evolution Mining**  
Project **CGO UNDERGROUND DEVELOPMENT EIS**  
Location **North east of open pit outside lake bund**

Borehole **UG-BH-04**  
Depth Interval **72.00-77.00 m**  
Job No. **SYDGE206418-3**  
Test date **23-2-2020**  
Interpreted by **AO**  
Checked **RJB**

Test Details	Packer type	<b>Pneumatic</b>		Borehole diam.	<b>96 mm</b>	
	Type of pump	<b>Drill rig</b>		Borehole inclination	<b>90 degrees</b>	
	Pressure gauge	<b>Accu-Drive DD504N28-150D</b>		Test interval length	<b>5.00 m</b>	
time interval (min)	gauge pressure (kPa)	water loss (L)	flow rate (L/min)	pressure correction (kPa)	water loss rate (L/min/m)	corrected pressure (kPa)
1	150	1.1	1.08	0	0.22	150
1	150	1.3	1.25	0	0.25	150
1	150	1.1	1.12	0	0.22	150
1	150	1.3	1.25	0	0.25	150
1	150	1.2	1.18	0	0.24	150
5	150	3.7	0.74	0	0.15	150
1	250	1.4	1.36	0	0.27	250
1	250	1.4	1.38	0	0.28	250
1	250	1.4	1.39	0	0.28	250
1	250	1.7	1.65	0	0.33	250
1	250	1.3	1.30	0	0.26	250
5	250	6.7	1.33	0	0.27	250
1	350	1.8	1.81	0	0.36	350
1	350	1.8	1.83	0	0.37	350
1	350	2.0	2.04	0	0.41	350
1	350	1.9	1.92	0	0.38	350
1	350	1.9	1.91	0	0.38	350
5	350	9.4	1.89	0	0.38	350
1	250	1.7	1.74	0	0.35	250
1	250	1.7	1.65	0	0.33	250
1	250	1.5	1.55	0	0.31	250
1	250	1.4	1.43	0	0.29	250
1	250	1.7	1.68	0	0.34	250
5	250	6.8	1.36	0	0.27	250
1	150	1.0	0.97	0	0.19	150
1	150	1.3	1.27	0	0.25	150
1	150	1.2	1.24	0	0.25	150
1	150	1.3	1.29	0	0.26	150
1	150	1.4	1.41	0	0.28	150
5	150	5.8	1.16	0	0.23	150



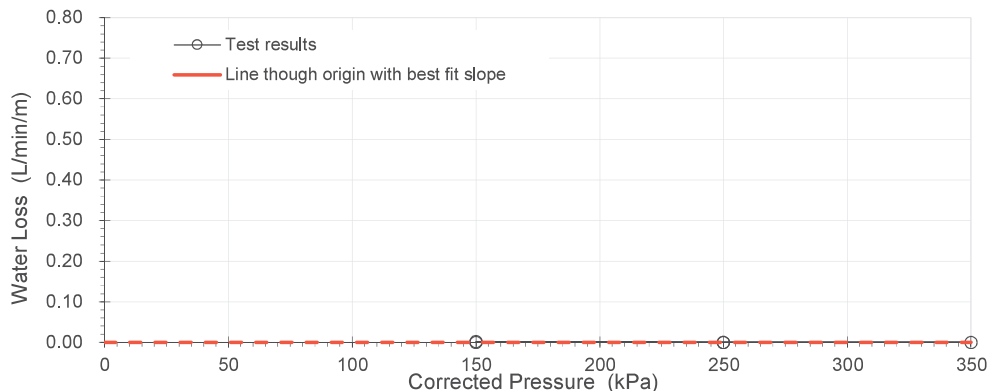
Interpreted Lugeon Permeability: **1.2 uL** (L/min/m @ 1000 kPa)

## Borehole Water Pressure Test

Client **EMM CONSULTING PTY LTD**  
Principal **Evolution Mining**  
Project **CGO UNDERGROUND DEVELOPMENT EIS**  
Location **North east of open pit outside lake bund**

Borehole **UG-BH-04**  
Depth Interval **91.00-102.00 m**  
Job No. **SYDGE206418-3**  
Test date **23-2-2020**  
Interpreted by **AO**  
Checked **RJB**

Test Details	Packer type	<b>Pneumatic</b>		Borehole diam.	<b>96 mm</b>	
	Type of pump	<b>Drill rig</b>		Borehole inclination	<b>90 degrees</b>	
	Pressure gauge	<b>Accu-Drive DD504N28-150D</b>		Test interval length	<b>11.00 m</b>	
time interval (min)	gauge pressure (kPa)	water loss (L)	flow rate (L/min)	pressure correction (kPa)	water loss rate (L/min/m)	corrected pressure (kPa)
1	150	0.0	0.03	0	0.00	150
1	150	0.0	0.04	0	0.00	150
1	150	0.0	0.04	0	0.00	150
1	150	0.1	0.06	0	0.01	150
1	150	0.1	0.07	0	0.01	150
5	150	0.1	0.02	0	0.00	150
1	250	0.0	0.03	0	0.00	250
1	250	0.0	0.03	0	0.00	250
1	250	0.0	0.03	0	0.00	250
1	250	0.0	0.02	0	0.00	250
1	250	0.0	0.00	0	0.00	250
5	250	0.0	0.00	0	0.00	250
1	350	0.0	0.00	0	0.00	350
1	350	0.0	0.00	0	0.00	350
1	350	0.0	0.00	0	0.00	350
1	350	0.0	-0.01	0	0.00	350
1	350	0.0	0.00	0	0.00	350
5	350	0.0	0.00	0	0.00	350
1	250	0.0	0.00	0	0.00	250
1	250	0.0	-0.02	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.00	0	0.00	250
1	250	0.0	0.00	0	0.00	250
5	250	0.0	0.00	0	0.00	250
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
1	150	0.0	-0.02	0	0.00	150
1	150	0.0	0.00	0	0.00	150
1	150	0.0	0.00	0	0.00	150
5	150	0.0	0.00	0	0.00	150



Interpreted Lugeon Permeability: **0 uL** (L/min/m @ 1000 kPa)



## **Appendix D – Seepage into exploration decline**



ANALYTIC ESTIMATE OF GROUNDWATER INFLOW TO EQUIVALENT TUNNEL OF EQUAL LENGTH TO GRE46 EXPLORATION DECLINE

		tunnel lengths (m)	tunnel elev (m AHD)	Tunnel ID
EQUIVALENT TUNNEL		1274	100 to -100	Main tunnel
diameter	6.5	261	60	1057 arm
length	2010 m	350	-15	985 arm (main)
gwl	200 m AHD (average)	125	-15	985 arm (north branch)
		2010 m (total)		

The equation shown below (for example see Best and Parker, 2004) is used to approximate inflow into the tunnel under the assumption that the tunnel is circular (diameter, D) contained within material of uniform hydraulic conductivity (k), and with groundwater head at height (H) above the tunnel centreline.

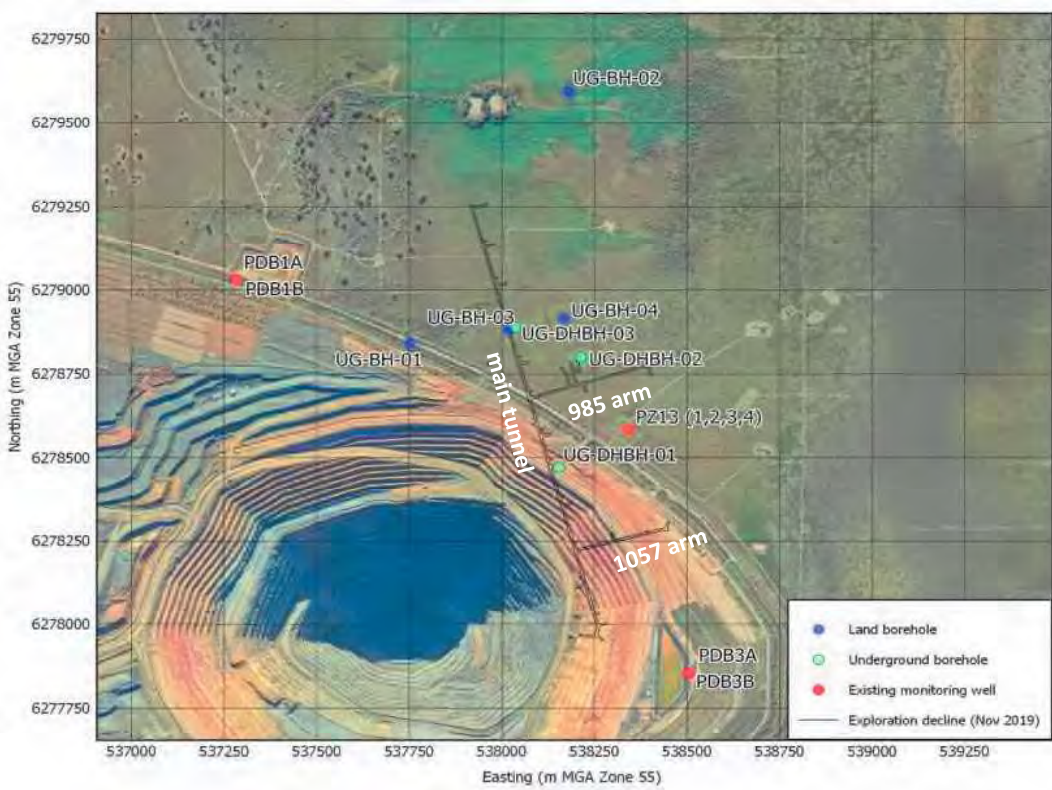
$$q = \frac{2\pi kH}{\ln(\frac{4H}{D})}$$

(inflow volume per m run of tunnel)

Main tunnel					
chainage	Tunnel elev (m AHD)	gwl (m AHD)	H (m)	q m3/m run	Q (m3)
0	100.0	200	100.0	8.39E-07	8.39E-05
100	84.3	200	115.7	9.37E-07	9.37E-05
200	68.6	200	131.4	1.03E-06	1.03E-04
300	52.9	200	147.1	1.13E-06	1.13E-04
400	37.2	200	162.8	1.22E-06	1.22E-04
500	21.5	200	178.5	1.31E-06	1.31E-04
600	5.8	200	194.2	1.40E-06	1.40E-04
700	-9.9	200	209.9	1.49E-06	1.49E-04
800	-25.6	200	225.6	1.58E-06	1.58E-04
900	-41.3	200	241.3	1.67E-06	1.67E-04
1000	-57.0	200	257.0	1.75E-06	1.75E-04
1100	-72.7	200	272.7	1.84E-06	1.84E-04
1200	-88.4	200	288.4	1.92E-06	1.92E-04
1300	-104.1				
				1.81E-03 m3 / s	
				156.66 m3 / day	

Reference:

Best R.J. and Parker C.J. (2004). Groundwater in Sydney – Tunnel inflows and settlement – Theory and experience



Side tunnels		Tunnel elev (m					
name	length	AHD)	gwl (m AHD)	H (m)	q m3/m run	Q (m3)	
1057 arm		261	60	200	140.0	1.09E-06	2.83E-04
985 arm (main)		350	-15	200	215.0	1.52E-06	5.32E-04
985 arm (north branch)		125	-15	200	215.0	1.52E-06	1.90E-04
							1.01E-03 m3 / s
							86.90 m3 / day
k		5.50E-09 m/s		(adopted hydraulic conductivity)			
Resulting flow		243.57 m3 / day					
		2.8 L / s					

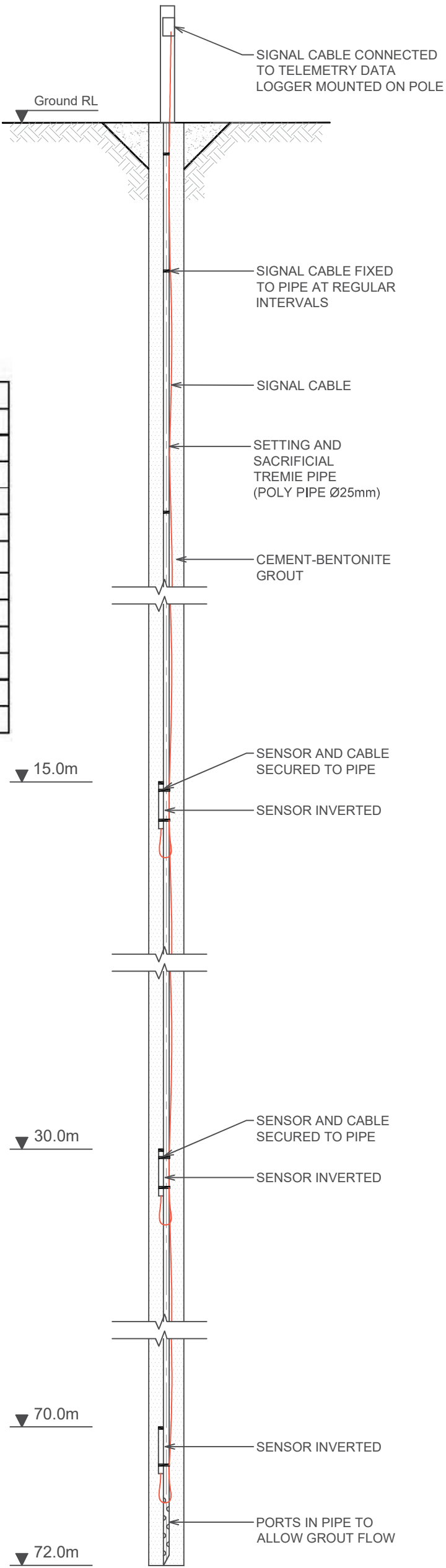


## **Appendix E – Piezometer details and groundwater monitoring hydrographs**

UG-BH-01 - PIEZOMETER CONSTRUCTION

Borehole	UG-BH-01
Hole depth (m)	72.0
Telemetry ID	Coffey3
Telemetry S/N	05011943000056
Phone number for SMS data request (SMS the word 'ETRAIA' to request data)	0436 841 933

Sensor ID		SG1	SG2	SG3
Downhole depth (m)		15.0	30.0	70.0
Sensor model		SGP-3400	SGP-3400	SGP-3400
Sensor serial number		SG00699	SG00700	SG00704
Logger channel		2	3	5
Calibration (in air)	Reading mA	4.013	4.002	4.006
	Temperature (°C)	18	18	19
	Barometer (hPa)	995	995	985
	Date	25-Nov-19	25-Nov-19	28-Nov-19
	Linear factor (kPa per mA)	127.32	127.62	129.26
Grout mix (by weight)	Cement	1		
	Bentonite	0.3		
	Water	3		



PIEZOMETER SECTION

drawn	AO / AW
approved	RJB
date	23/03/2020
scale	N.T.S.
original size	A3

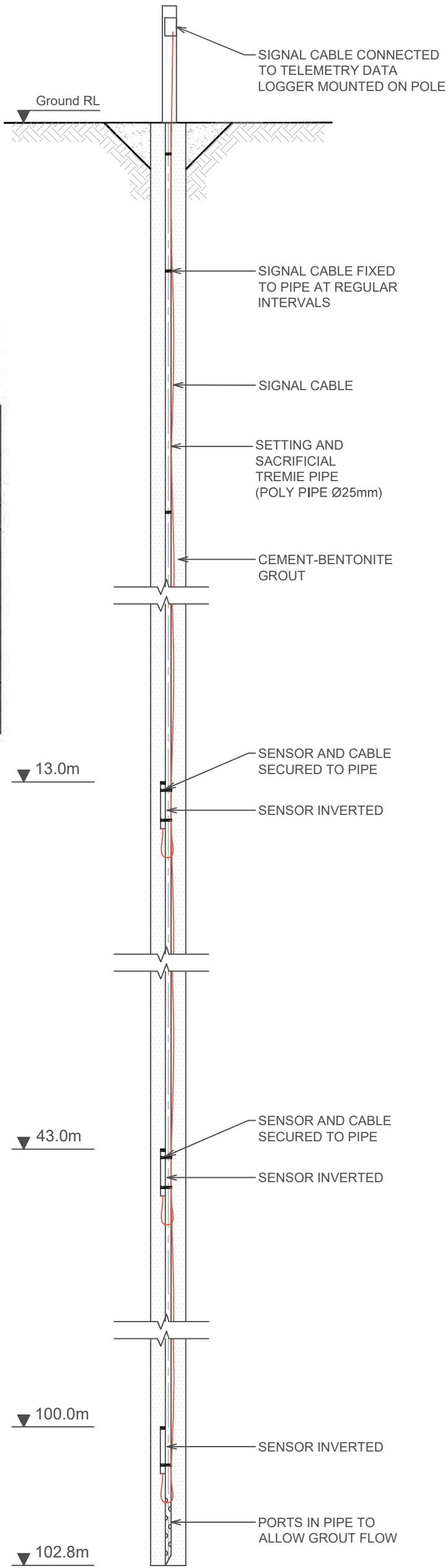


client:	EMM CONSULTING PTY LTD		
project:	CGO UNDERGROUND DEVELOPMENT EIS		
title:	AS-INSTALLED INSTRUMENTATION - UG-BH-01		
project no:	754-SYDGE206418-3-AJ	figure no:	FIGURE E1
		rev:	A

UG-BH-02 - PIEZOMETER CONSTRUCTION

Borehole	UG-BH-02
Hole depth (m)	102.8
Telemetry ID	Coffey4
Telemetry S/N	05011943000055
Phone number for SMS data request (SMS the word 'ETRAIA')	0436 841 932

Sensor ID		SG1	SG2	SG3
Downhole depth (m)		13.0	43.0	100.0
Sensor model		SGP-3400	SGP-3400	SGP-3400
Sensor serial number		SG00698	SG00701	SG00706
Logger channel		2	3	5
Calibration (in air)	Reading mA	4.02	4.009	4.013
	Temperature (°C)	18	18	19
	Barometer (hPa)	995	995	985
	Date	25-Nov-19	25-Nov-19	28-Nov-19
	Linear factor (kPa per mA)	129.42	129.28	129.29
Grout mix (by weight)	Cement	1		
	Bentonite	0.3		
	Water	3		



PIEZOMETER SECTION

drawn	AO / AW
approved	RJB
date	23/03/2020
scale	N.T.S.
original size	A3



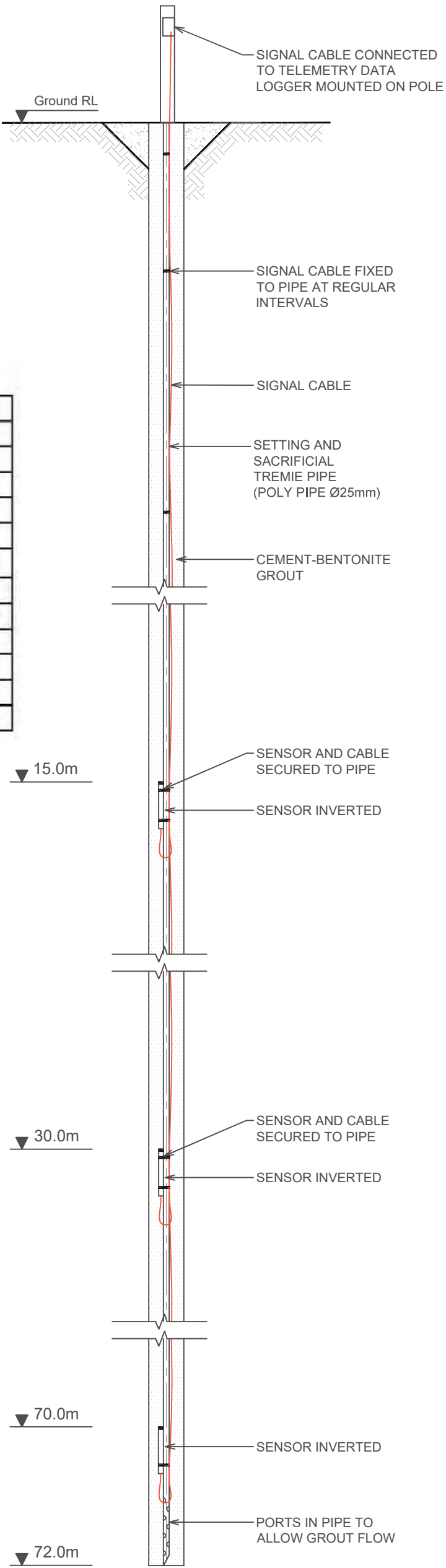
client:	EMM CONSULTING PTY LTD		
project:	CGO UNDERGROUND DEVELOPMENT EIS		
title:	AS-INSTALLED INSTRUMENTATION - UG-BH-02		
project no:	754-SYDGE206418-3-AJ	figure no:	FIGURE E2
		rev:	A



UG-BH-03 - PIEZOMETER CONSTRUCTION

Borehole	UG-BH-03
Hole depth (m)	72.0
Telemetry ID	Coffey2
Telemetry S/N	05011943000054
Phone number for SMS data request (SMS the word 'ETRAIA')	0436 841 938

Sensor ID	SG1	SG2	SG3
Downhole depth (m)	15.0	30.0	70.0
Sensor model	SGP-3400	SGP-3400	SGP-3400
Sensor serial number	SG00696	SG00695	SG00703
Logger channel	2	3	5
Calibration (in air)	Reading mA	4.023	4.005
	Temperature (°C)	18	18
	Barometer (hPa)	995	995
	Date	25-Nov-19	25-Nov-19
	Linear factor (kPa per	129.46	127.41
Grout mix (by weight)	Cement	1	
	Bentonite	0.3	
	Water	3	



PIEZOMETER SECTION

drawn	AO / AW
approved	RJB
date	23/03/2020
scale	N.T.S.
original size	A3

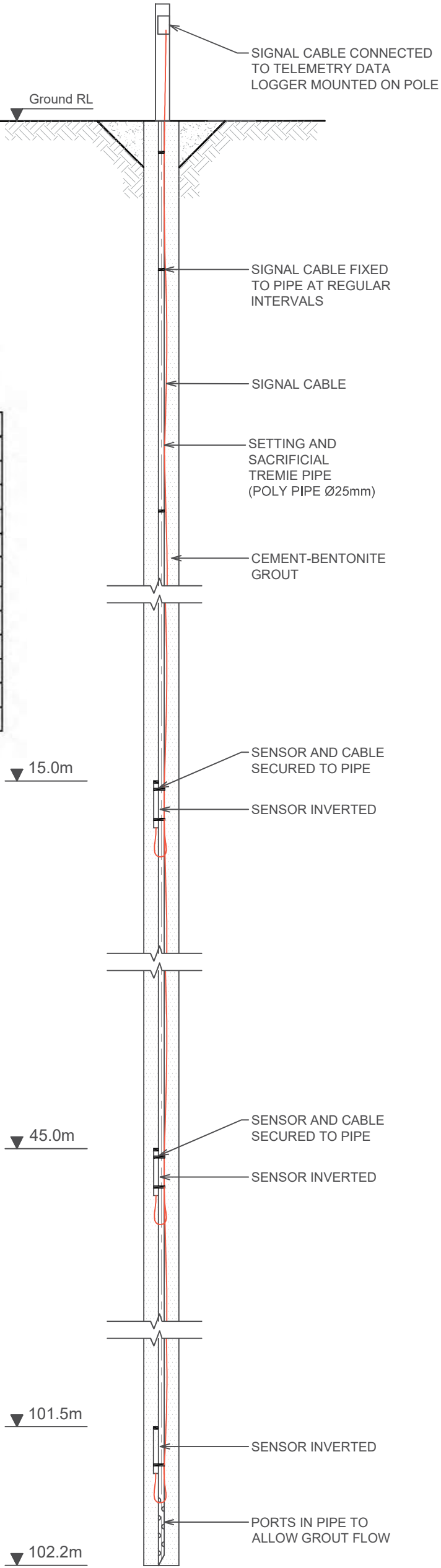


client:	EMM CONSULTING PTY LTD		
project:	CGO UNDERGROUND DEVELOPMENT EIS		
title:	AS-INSTALLED INSTRUMENTATION - UG-BH-03		
project no:	754-SYDGE206418-3-AJ	figure no:	FIGURE E3
		rev:	A


UG-BH-04 - PIEZOMETER CONSTRUCTION

Borehole	UG-BH-04
Hole depth (m)	102.2
Telemetry ID	Coffey1
Telemetry S/N	05011943000053
Phone number for SMS data request (SMS the word 'ETRAIA')	0436 841 939

Sensor ID	SG1	SG2	SG3
Downhole depth (m)	15.0	45.0	101.5
Sensor model	SGP-3400	SGP-3400	SGP-3400
Sensor serial number	SG00697	SG00702	SG00705
Logger channel	2	3	5
Calibration (in air)	Reading mA	4.011	4.019
	Temperature (°C)	18	18
	Barometer (hPa)	995	995
	Date	25-Nov-19	25-Nov-19
	Linear factor (kPa per mA)	129.29	127.30
Grout mix (by weight)	Cement	1	
	Bentonite	0.3	
	Water	3	



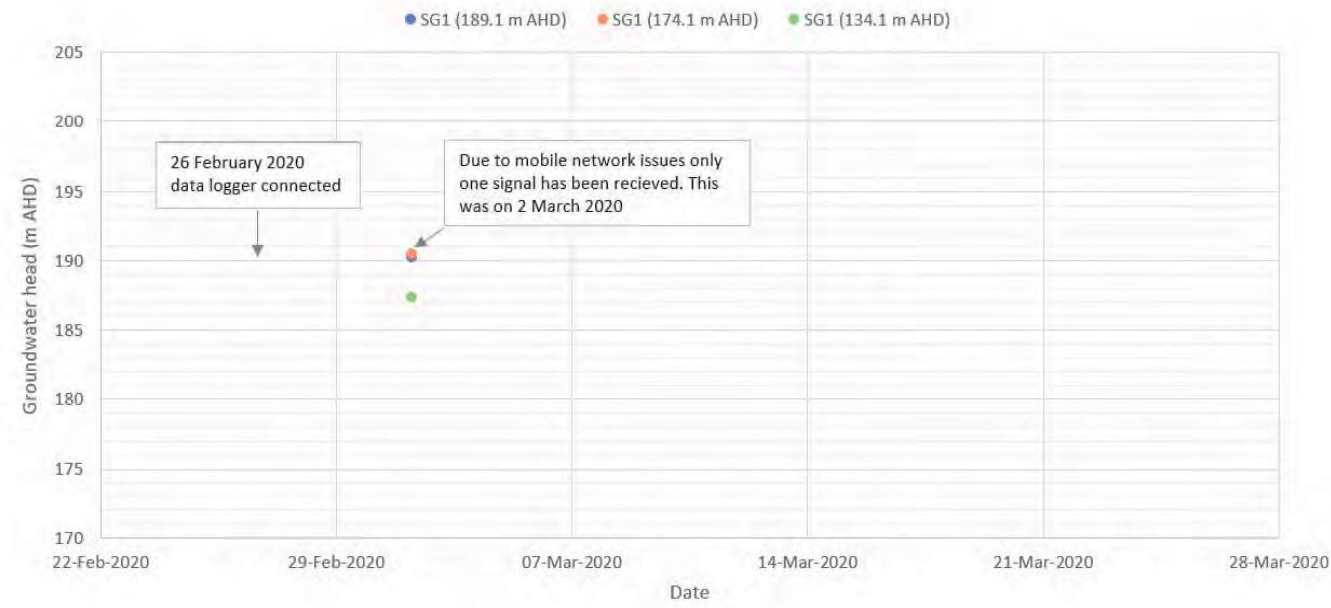
PIEZOMETER SECTION

	drawn	AO / AW	 A TETRA TECH COMPANY	client: EMM CONSULTING PTY LTD		
	approved	RJB		project: CGO UNDERGROUND DEVELOPMENT EIS		
	date	23/03/2020		title: AS-INSTALLED INSTRUMENTATION - UG-BH-04		
	scale	N.T.S.		project no: 754-SYDGE206418-3-AJ	figure no: FIGURE E4	rev: A
	original size	A3				

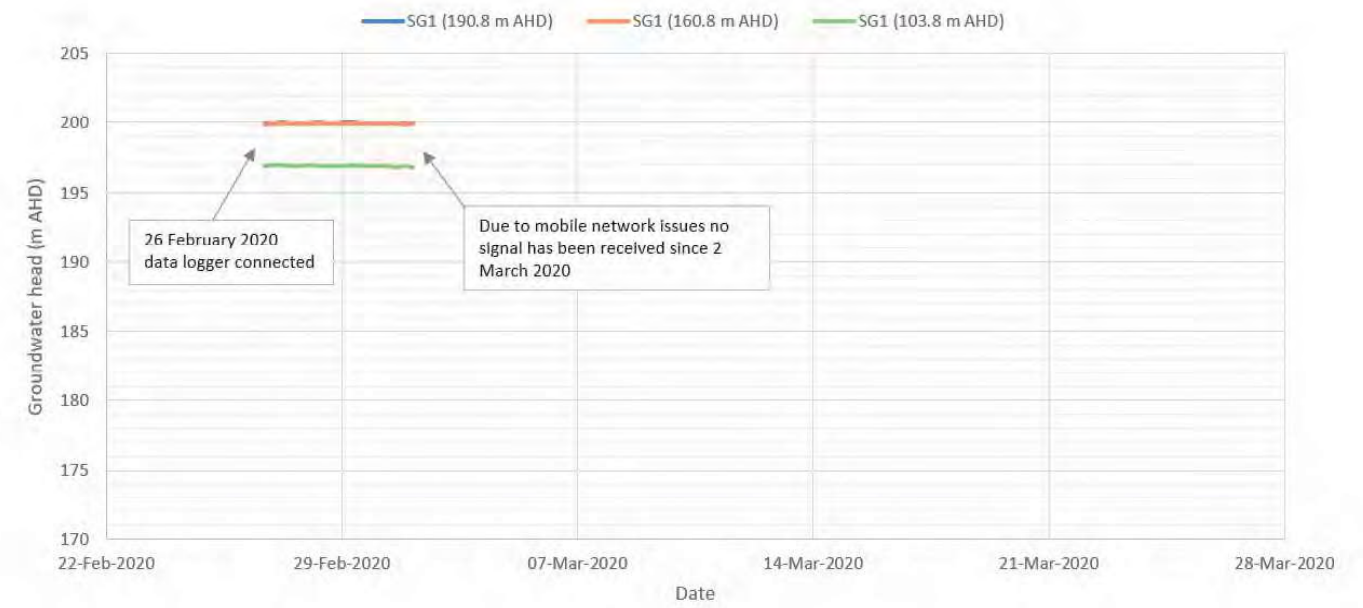


# Groundwater hydrographs - CGO Underground Development EIS

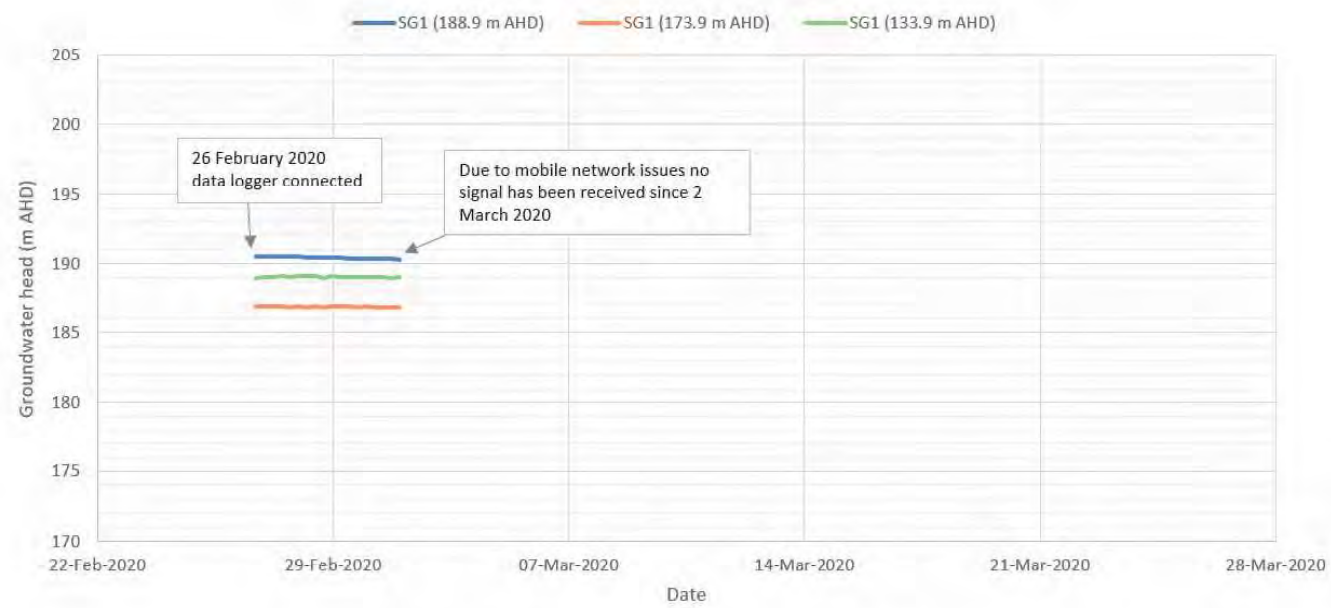
## Groundwater levels - UG-BH-01



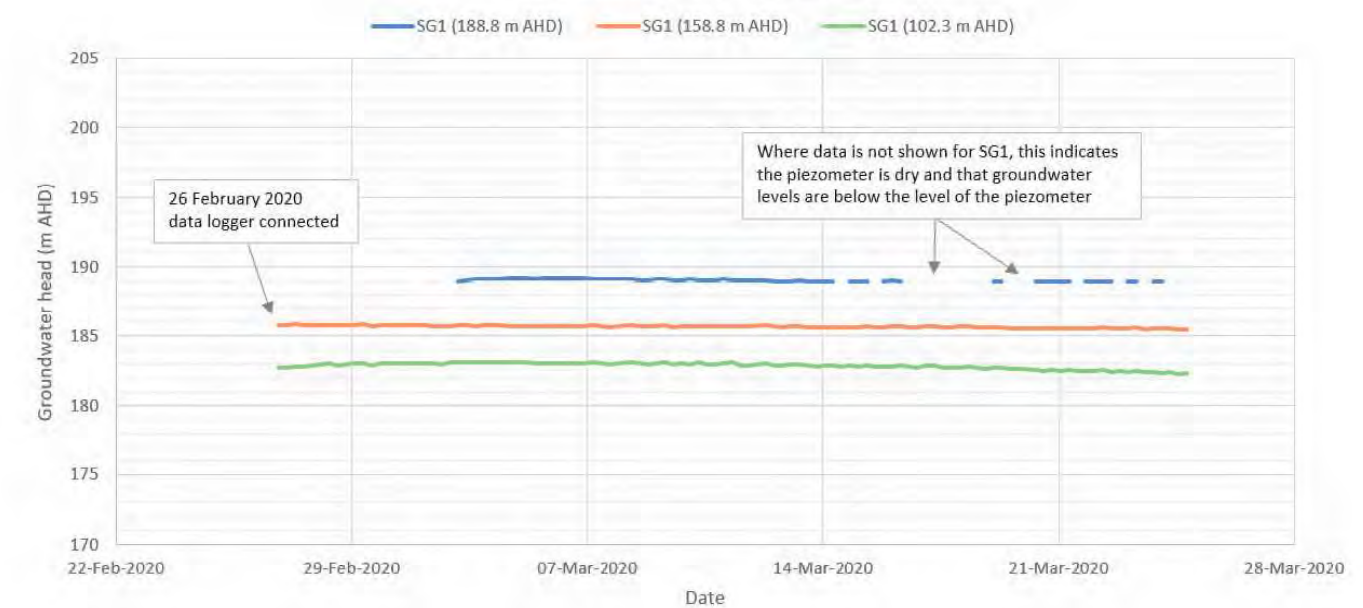
## Groundwater levels - UG-BH-02



## Groundwater levels - UG-BH-03



## Groundwater levels - UG-BH-04



## Groundwater levels - PDB1A/1B and PDB3A/3B



## Groundwater levels - PZ13

