NORTHERN STAR RESOURCES LTD

WORKS APPROVAL SUPPORTING DOCUMENT

HERCULES GOLD MINE

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1 Introduction

1.1 Background and Context

Hercules Gold Mine (Hercules or the Project) is part of Northern Star Resources (NSR or Northern Star) South Kalgoorlie Operations (SKO) and is located approximately 30 Km south of the City of Kalgoorlie-Boulder (**Figure 1**). The Project is adjacent to several existing open pits and waste rock landforms which were mined and constructed in the early 1990s.

Hercules will consist of an open pit which is expected to deliver approximately 10,400,000 tonnes of ore over a 57-month period, before transitioning to an underground mining operation. A waste rock landform will be constructed from the 76,700,000 tonnes of waste rock extracted over the current projected life of the Project. A cut-back of an existing open pit (Penfolds), is also proposed which is expected to produce 900,000 tonnes of ore and 15,000,000 tonnes of waste rock.

Dewatering of the gold deposits will be required to safely access ore below the groundwater table. No processing will be undertaken at the Project site. Ore will be temporarily stockpiled and transported by road train via existing haulage routes to the nearby Kanowna Belle or Fimiston processing facilities. Subject to approvals, the Project is planned to commence in Q3 FY2026 (i.e., Jan - Mar 2026).

1.2 Works Approval Application

NSR is seeking a Works Approval to authorise construction and operation of the following:

Mine dewatering infrastructure (Prescribed Activity: Category 6 – Mine dewatering):
- Four saline water dams/ turkeys nests (dewatering effluent emissions points);
- The following open pits as an emission points (dewatering effluent): Erebus north and south, Fuji, Greenback and Penfolds; and
- Dewatering pipelines connecting the existing open pits, saline water dams and an existing borefield network to the north (KCGM).

Landfill (Prescribed Activity: Category 89 - Putrescible landfill site):
- Landfill to be located in the waste rock landforms.

1.3 Applicant Details

The Landholdings and Holders associated with Hercules can be found in **Table 1** below.

Table 1: Landholding and Holder information

Landholding	Holder
M 15/740	NORTHERN STAR (SOUTH KALGOORLIE) PTY LTD
M 15/663	NORTHERN STAR (SOUTH KALGOORLIE) PTY LTD
M 15/938	NORTHERN STAR (SOUTH KALGOORLIE) PTY LTD
M 15/937	NORTHERN STAR (SOUTH KALGOORLIE) PTY LTD
M 15/469	NORTHERN STAR (SOUTH KALGOORLIE) PTY LTD
M 15/726	NORTHERN STAR (SOUTH KALGOORLIE) PTY LTD
EEL-53 (Lot 105, DP 40396)	NORTHERN STAR (HAMPTON GOLD MINING AREAS) LIMITED

The proponent is Northern Star Resources Limited, the parent company of the following wholly owned subsidiaries: Northern Star (South Kalgoorlie) Pty Ltd and Northern Star (Hampton Gold Mining Areas) Limited.

With respect to the proposed dewatering pipeline joining the existing KCGM South Lakes Borefield network to the north of the Project, the existing borefield network infrastructure is situated on Miscellaneous Licence L 15/154 held by Northern Star (KLV) Pty Ltd and Northern Star (Saracen Kalgoorlie) Pty Ltd, both wholly owned subsidiaries of Northern Star Resources Limited. KCGM is owned and operated by NSR.

1.4 Relevant Approvals

Table 2: Required approvals for the Hercules Gold Mine Project.

Agency	Approval	Status
Department of Water and Environmental Regulation (DWER)	Works Approval	This document; Submitted to DWER for assessment and approval.
Department of Water and Environmental Regulation (DWER)	Prescribed Premises Licence	Once the Works Approval has been executed, the existing SKO Licence L5107/1988/13 will be amended to include the Hercules Project.
Department of Water and Environmental Regulation (DWER)	Groundwater Abstraction Licence	Existing SKO Groundwater Abstraction Licence GWL106836 (9) will be amended to include the Hercules Project.
Department of Mines, Petroleum and Exploration (DMPE)	Native Vegetation Clearing Permit	Purpose Permit **CPS 11105/1** is under assessment.
Department of Mines, Petroleum and Exploration (DMPE)	Mining Development and Closure Proposal	Mining Development and Closure Proposal is in preparation.

1.5 Location

The Project area is located approximately 30 km south of the City of Kalgoorlie-Boulder (CKB) in the Goldfields region of Western Australia. The site is located in the Shire of Coolgardie and is centred at MGA GDA20 (Zone 51) coordinates 349,680 E and 6,568,911 N.

Hercules sits within the Woolibar Pastoral Lease (**Figure 1**). The nearest residential premises is the Woolibar Homestead located approximately 24 km to the south-east. There are no identified sensitive receptors or high value ecosystems within or in close proximity to the Project area.

1.6 Site Plan

The Hercules Gold Mine site plan is shown in **Figure 1** below.

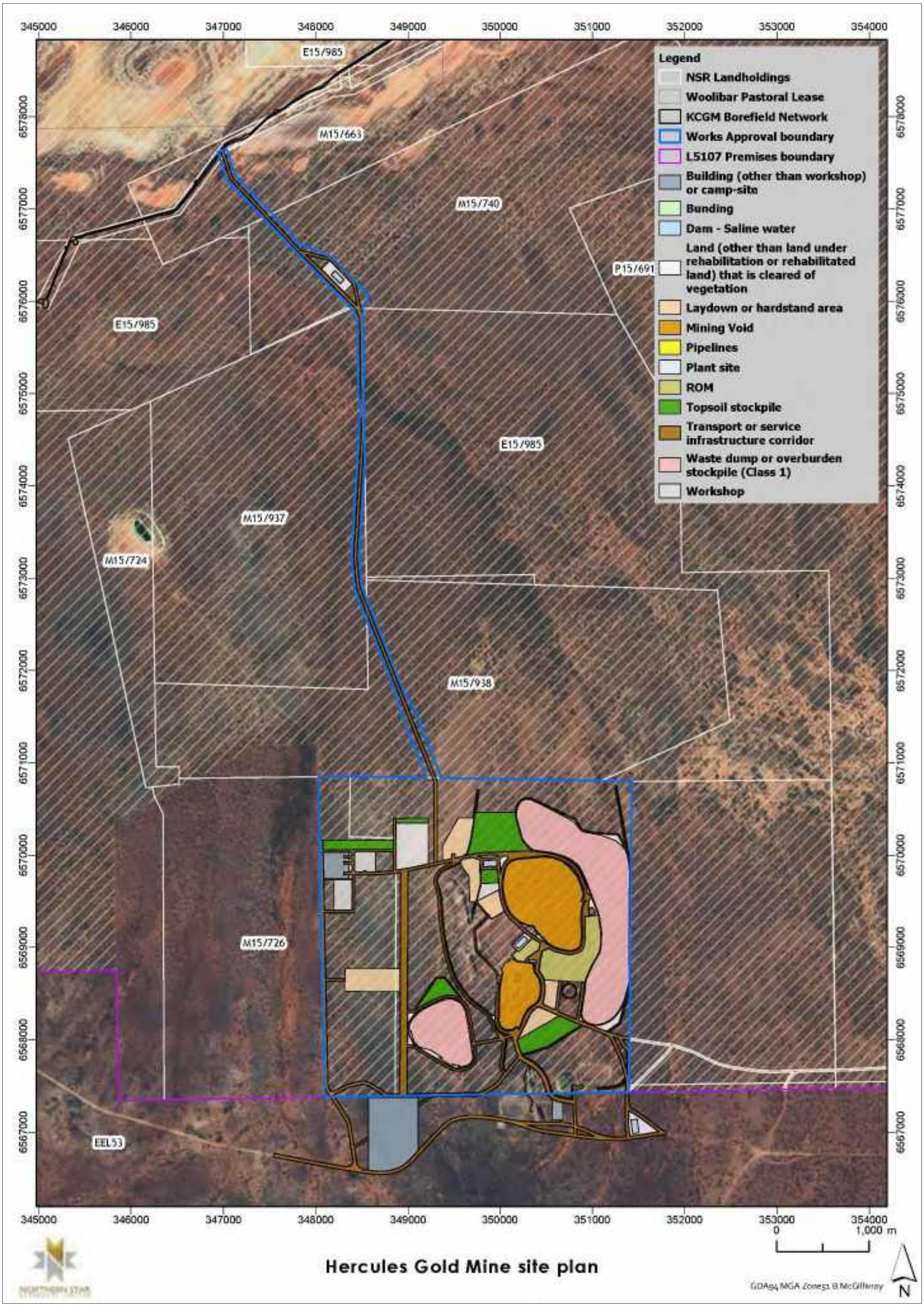

Figure 1. Hercules Gold Mine site plan.

2 Proposed Activities

2.1 Mine dewatering infrastructure

The Hercules Project will involve the construction of a new open pit and subsequent underground mine to a depth below the localised groundwater table, as well as a cut-back of the existing Penfolds open pit. In order to safely access the ore at both mines, dewatering will be required. A hydrogeological investigation was completed for the Project with modelled dewatering estimates of up to 2 GL per annum. Dewatering requirements have been discussed in more detail in **Section 3.1.2** and the full investigation report can be found in **Appendix A**.

Dewatering effluent will be first discharged into existing open pits for clarifying/ settling and from there pumped to the four HDPE lined saline water dams (turkeys nests) for reuse. The water will be reused for mining operations and dust suppression at the mining and transport areas, as well as the unsealed sections of the haulage route to either the Kanowna Belle or KCGM Processing Plants. The saline dam (turkeys nests) design specifications can be found in **Appendix C**.

The total available capacity of the existing open pits to 3-meters below crest level (proposed freeboard limit), is approximately 3,000,000 kL. An overview map showing the open pit locations is provided in **Figure 2**.

Water excess to storage capacity and usage requirements will be directed to the KCGM Fimiston Mills via the existing pipelines used in the KCGM South Lakes Borefield to the north of Hercules (**Figure 3**).

The potential risks/ unwanted events associated with mine dewatering activities and infrastructure, including proposed management measures/ controls, can be found in **Table 3** below.

Table 3. Potential risk/ unwanted events associated with mine dewatering activities/ infrastructure and proposed controls.

Item	Potential risks/ unwanted events	Proposed management measures/ controls
Saline water dam (turkeys nest).	• Seepage of saline dewatering effluent into immediate surroundings. • Spills due to overtopping/ overfilling.	• Lined with HDPE to minimise seepage. • Maintain minimum operational freeboard of 300 mm.
Dust suppression (saline water).	• Overspray & overuse - Damage to surrounding vegetation.	• Dribble bars and directional sprays to minimise overspray. • Dust suppression only where and when required.
Dewatering pipeline.	• Spills due to pipe damage/ failure.	• Bunding/ secondary containment sufficient to contain any spill for a period equal to the time between routine inspections; or • Equipped with telemetry systems, flow meters or pressure sensors along pipelines to allow the detection of leaks and failures; and • Equipped with automated cut-outs in the event of a pipe failure. • Pipeline to be buried at northern drainage line to reduce the risk of pipeline damage from flooding and to allow surface water to flow unimpeded.

Item	Potential risks/ unwanted events	Proposed management measures/ controls
Open pit emissions point.	• Spills due to overtopping/ overfilling. • Seepage of saline dewatering effluent into vegetation rooting zone. • Groundwater contamination.	• Maintain minimum operational freeboard of 3 meters below top of pit crest. • Pit lake elevation measurements at monthly frequency when discharging. • Periodic vegetation condition assessments. • Periodic sampling and analyses of dewatering effluent (parameters in Table 5). • Periodic sampling and analyses of pit lake, if safely accessible (parameters in Table 5).

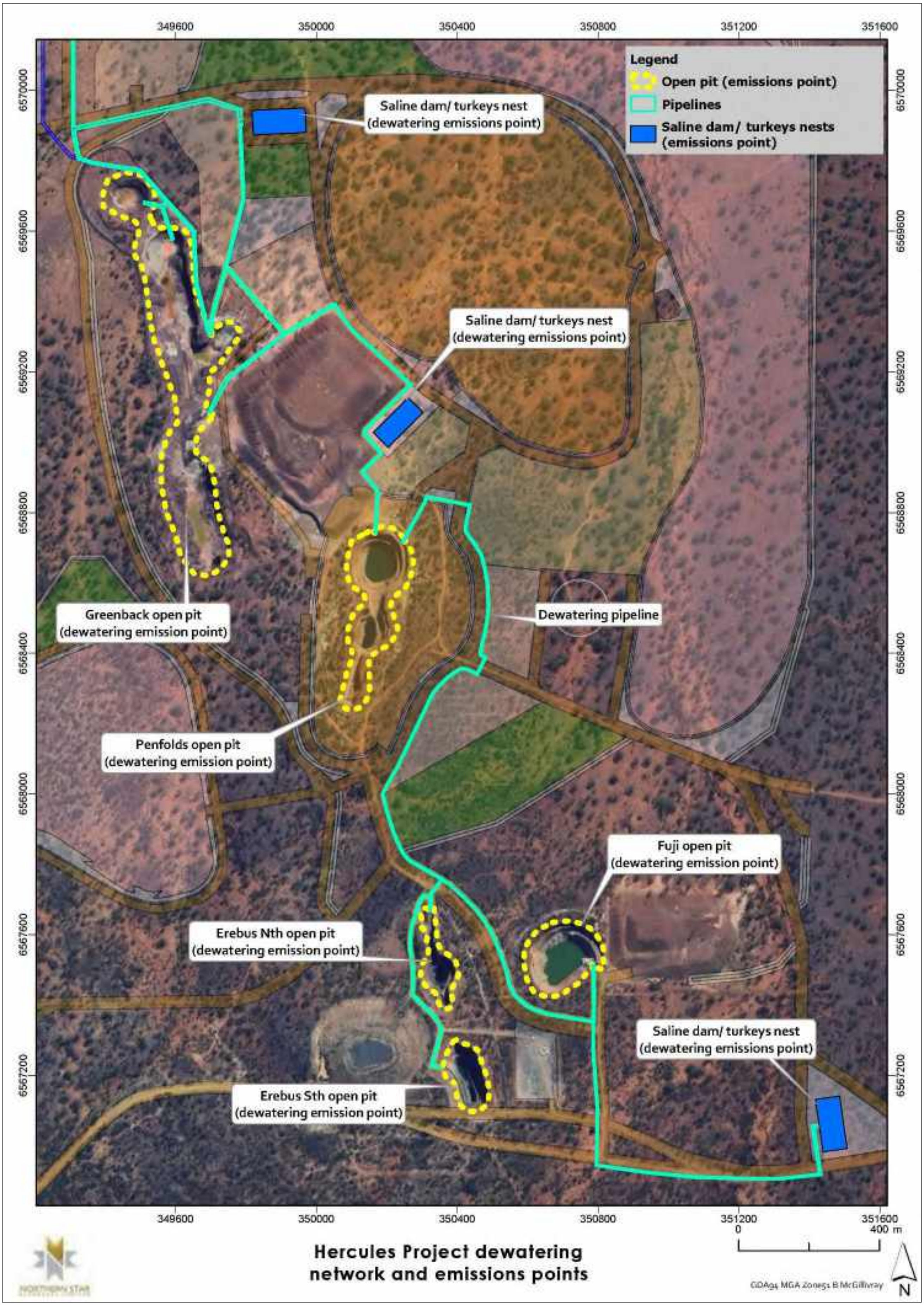

Figure 2. Hercules dewatering infrastructure and emissions points.

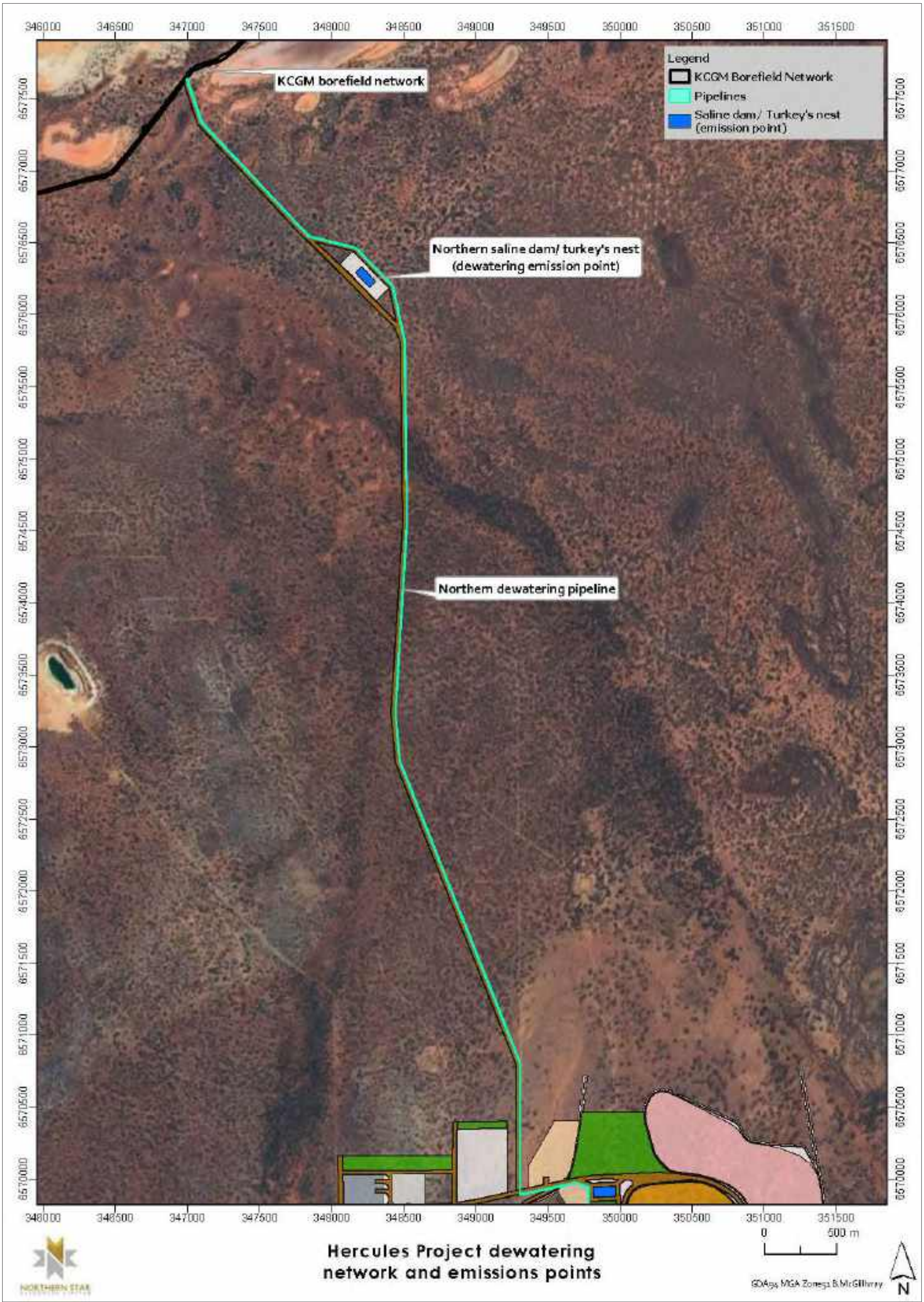

Figure 3. Hercules northern dewatering infrastructure and emissions points.

2.2 Landfill

To allow flexibility in managing waste generated at the Hercules Project, Northern Star are proposing to establish a Class II putrescible landfill at the site located within the new waste rock landforms (WRLs). The landfill site shall only accept inert waste types 1 and 2, putrescible waste and clean fill. Controlled wastes will be managed and transported offsite via a licenced carrier as per the *Environmental Protection (Controlled Waste) Regulations 2004*. The landfilling of waste tyres will be managed in accordance with Part 6 of the *Environmental Protection Regulations 1987*. Recycling programmes will be implemented to reduce waste volumes reporting to the landfill.

Based on anticipated volumes, it is expected that waste generated from the Project will not be greater than 5,000 tonnes per year. Approximate volumes (or tonnes) of waste disposed in the landfill will be recorded for reporting purposes.

Given the landfill will be situated on the Hercules and Penfolds (existing and/ or new) WRLs (**Figure 4**), the separation distance between the base of the landfill and the highest groundwater level will be greater than 20 metres. Additionally, the mine waste from the open pits consists primarily of clayey-oxide material of naturally low permeability which will limit leachate seepage.

Landfill compounds with built up sides and back will be constructed. The dimensions will be an approximate depth of 2 - 5 meters with 5 - 10 meter sides and a maximum 30 meter tipping face. This will allow personnel to drive down to the tipping face and make it more efficient to cover the waste from behind the tipping face. Once the landfill has reached capacity it will be covered level with the surrounding waste landform and a new compound constructed. Mine waste windrows/ bunds will be constructed to divert storm water away from the landfill compound.

The potential risks/ unwanted events associated constructing and operating a landfill, including proposed management measures/ controls, can be found in **Table 4** below.

Table 4. Unwanted events associated with site landfills and proposed controls.

Item	Potential risks/ unwanted events	Proposed management measures/ controls
Landfill	• Windblown rubbish. • Odour. • Exposed rubbish.	• Semi-enclosed compound built from mine waste. • Maximum tipping face width 30 meters. • Covered with mine waste at monthly frequency and when required.
	• Stormwater inundation.	• Windrows/ bunds constructed using mine waste to divert stormwater away from the landfill compound.
	• Leachate seepage.	• The mine waste from the open pit consists primarily of clayey-oxide material of naturally low permeability. • Compaction of landfill base is expected during construction via heavy earthmoving equipment use and ongoing vehicle traffic.

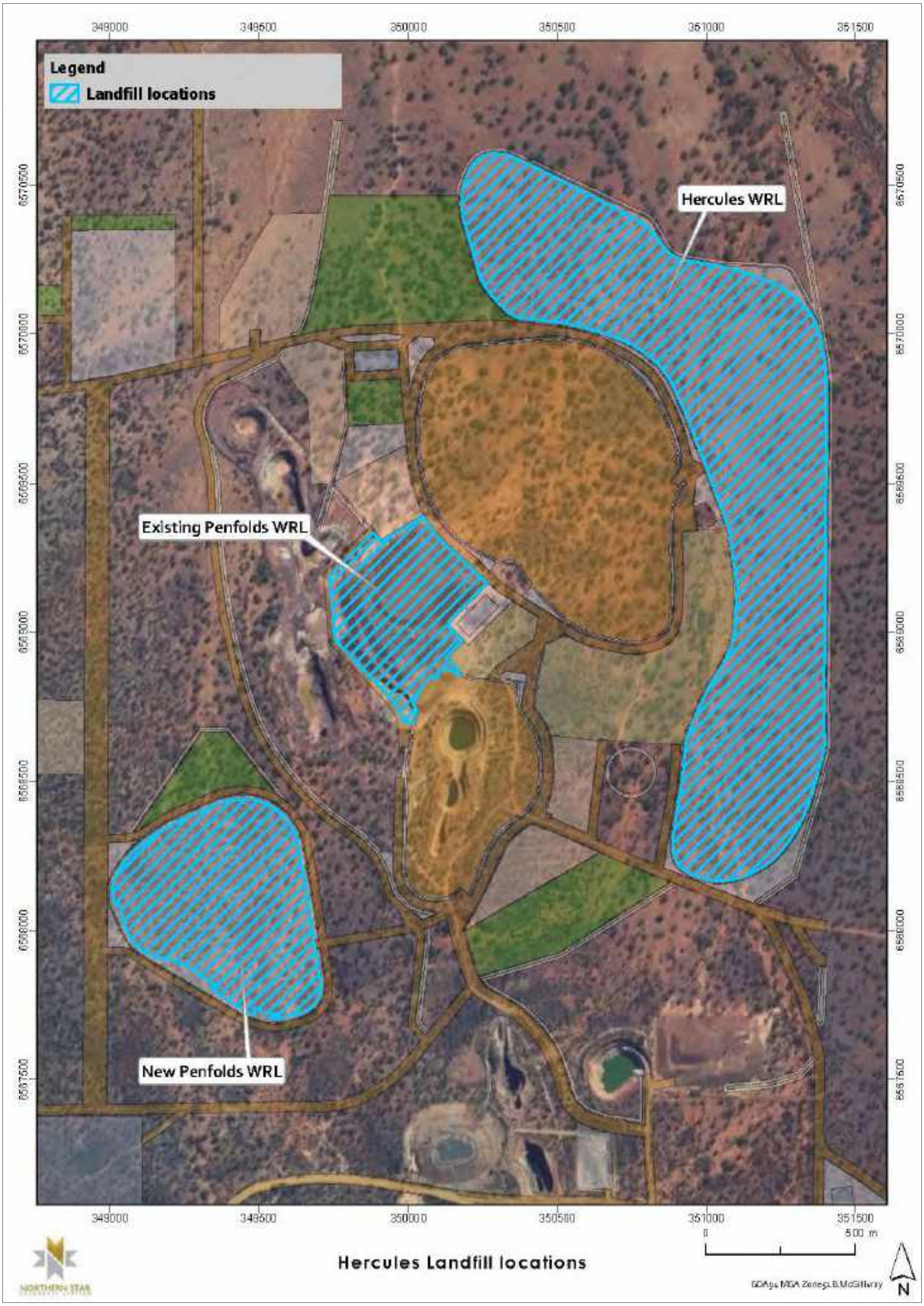

Figure 4. Landfill locations within Hercules and Penfolds waste rock landforms (WRL).

3 Environmental Risks and Management

3.1 Hydrogeology

A hydrogeological assessment of Hercules was undertaken by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) in June 2024 to predict potential dewatering rates during the stages of mining the open pit. The final report can be found in **Appendix A.**

3.1.1 Groundwater Quality

The water quality at Hercules is near-neutral and hypersaline, with Total Dissolved Solids (TDS) concentrations of around 100,000 mg/L. The very high salinity is typical of groundwater resources in the Kalgoorlie region. The results of water quality analyses for the two bore holes and the Penfolds pit lake are shown in **Table 5**. It should be noted that the other open pit lakes connected to the local groundwater system could not be safely accessed for sampling; However, given this connection the water quality is assumed to be similar to that of Hercules and the Penfolds pit lake.

Table 5. Hercules groundwater quality from bores HMB02 and HPB01A as well as Penfolds Pit.

Parameter	Unit	HPB01A	HMB02	Penfolds pit lake
Physical parameters				
pH Value	pH Unit	7.11	7.00	7.3
Electrical conductivity @ 25°C	µS/cm	84,100	108,000	165,000
Total Dissolved Solids @180°C Total	mg/L	67900	89200	144,000
Hydroxide alkalinity as CaCO3	mg/L	<1	<1	<1
Bicarbonate alkalinity as CaCO3	mg/L	236	194	70
Carbonate alkalinity as CaCO3	mg/L	<1	<1	<1
Total alkalinity as CaCO3	mg/L	236	194	70
Major ions				
Chloride	mg/L	30,200	40,400	80,300
Sulphate as SO4 – Turbidimetric dissolved	mg/L	4,290	5,320	4,200
Calcium dissolved	mg/L	664	856	2940
Magnesium dissolved	mg/L	2,410	3,310	5,180
Sodium dissolved	mg/L	16,600	21,800	39,900
Potassium dissolved	mg/L	143	239	1330
Ionic balance	%	1	1	0.24
Total cations	meq/L	957	1,270	2340
Total anions	meq/L	946	1,250	2,350
Nutrients				
Nitrite as N	mg/L	<0.01	<0.01	44.6
Nitrate as N	mg/L	<0.01	<0.01	0.35
Nitrite + Nitrate as N	mg/L	<0.01	<0.01	44.9
Dissolved metals				
Mercury dissolved	mg/L	<0.0002	<0.0002	<0.0005
Arsenic dissolved	mg/L	<0.010	<0.010	<0.020
Zinc dissolved	mg/L	0.524	0.15	<0.100
Selenium dissolved	mg/L	<0.10	<0.10	<0.20
Cadmium dissolved	mg/L	0.0061	<0.0010	0.0054
Nickel dissolved	mg/L	0.376	0.185	0.122
Copper dissolved	mg/L	0.095	0.152	<0.020
Lead dissolved	mg/L	<0.010	<0.010	<0.020
Cobalt dissolved	mg/L	0.367	0.297	<0.020

Parameter	Unit	HPB01A	HMB02	Penfolds pit lake
Manganese dissolved	mg/L	13.6	11.6	0.785
Dissolved metals				
Aluminium dissolved	mg/L	<0.10	<0.10	<0.20
Chromium dissolved	mg/L	<0.010	<0.010	<0.020
Iron dissolved	mg/L	<0.50	8.12	<1.00

3.1.2 Dewatering

Proposed groundwater abstraction for mine dewatering purposes will likely comprise the use of new production bores outside of the pit in conjunction with in-pit sump pumping within both the existing Penfolds pit and new Hercules pit, as required. If constructed, production bores will be utilised initially to assist with depressurisation of the system and dewatering ahead of underground mining. In-pit sump pumping will commence after mining progresses to depths where groundwater seeps and drains into sumps excavated within the open pit.

A numerical groundwater flow model was developed to estimate dewatering requirements for the planned pit and underground workings. The modelling results indicate that total dewatering pump flow from the Hercules pit peaks at 4,100 m^3/day after year 1.5 and decrease to 500 m^3/day at the end of open pit mining and commencement of underground mining (**Figure 5**).

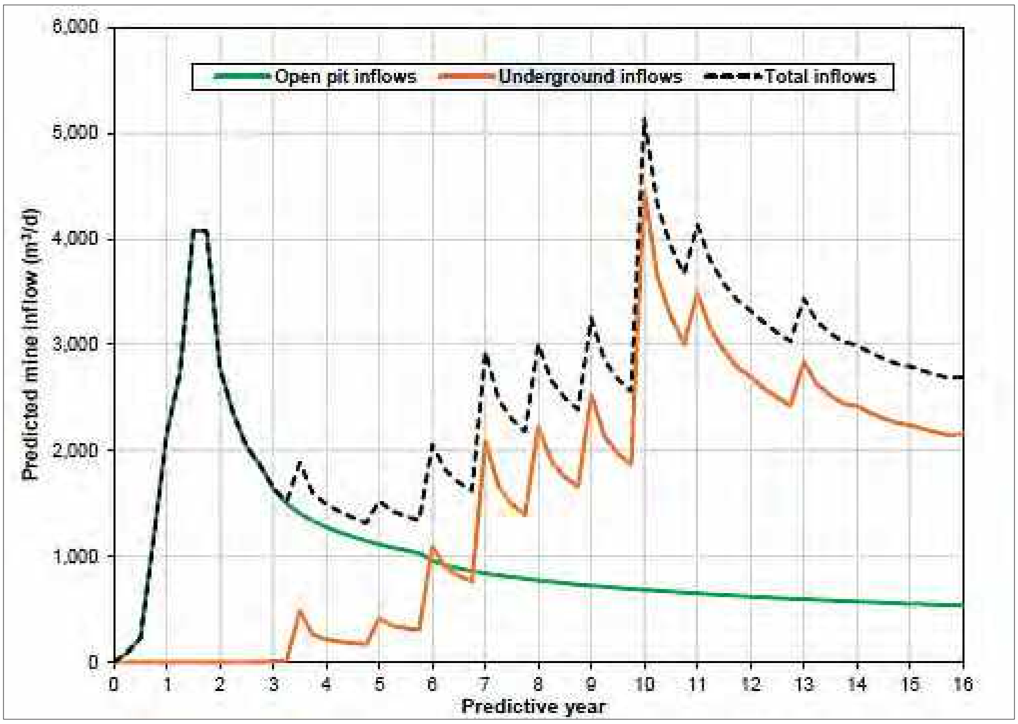

Figure 5. Total predicted inflows to the proposed Hercules open pit and underground mine

The underground mine is planned to be mined over 11 years with stoping extending from 280 mAHD down to -455 mAHD (735 metres below ground level). Modelling results suggest that peak groundwater flows to the underground workings are expected to peak after 10 years of mining with a flow rate of 4,500 m^3/day. This value should be taken as approximate only. Short-term flows could be substantially higher when the workings first intersect shear zones and faults such as the Aquifer Fault.

Model sensitivity analyses indicate that the peak average flows are unlikely to reach above 6,300 m3/day for the open pit and unlikely to exceed 5,000 m^3/day for underground mining with predictions showing 1,400 m^3/day or more from year 1 onwards.

When assessing the zone of 1 m of drawdown at the end of underground mining at Hercules (year 16), the extent of 'very unlikely' impacts extends about 9 to 11 Km radially while the extent of 'about as likely as not' of 1 m drawdown extends about 3 to 4 km radially.

On completion of mining, the open pit and underground voids will be left to fill with groundwater which will be followed by rising in-pit water levels to a new static level. The Hercules pit is calculated to recover to static levels of 336 mAHD, 200 years post mining. The rate of water level recovery is likely to be very slow and stabilise at an elevation that is substantially lower than that of the regional water table. Salinity will continue to increase as result of evaporation. The pit will act as a groundwater sink, preventing any flow of highly saline pit lake water into the surrounding country rocks, noting that this is already very saline.

3.2 Surface water

A surface water assessment was undertaken by AQ2 Pty Ltd (AQ2) in June 2025 to identify potential impacts to the surface water regime and operations at Hercules. The full report, featuring a risk assessment component, can be found in **Appendix B**.

The Project lies just north and east of a small range of low hills. General drainage in the area is northward and surface water runs off the site in shallow waterways with flat grades into the salt lakes. The Hercules site is located between two larger unnamed creeks/ drainage lines (nominally named West Creek and East Creek for the assessment) and a smaller unnamed creek/ drainage line that passes directly through the site (nominally named Middle Creek for the assessment), all of which area ephemeral. The mine disturbance area extends into subcatchments of these three creeks, which all merge together downstream of the Project and subsequently drain to the chain of small salt lakes located north of the Project area (**Figure 6**).

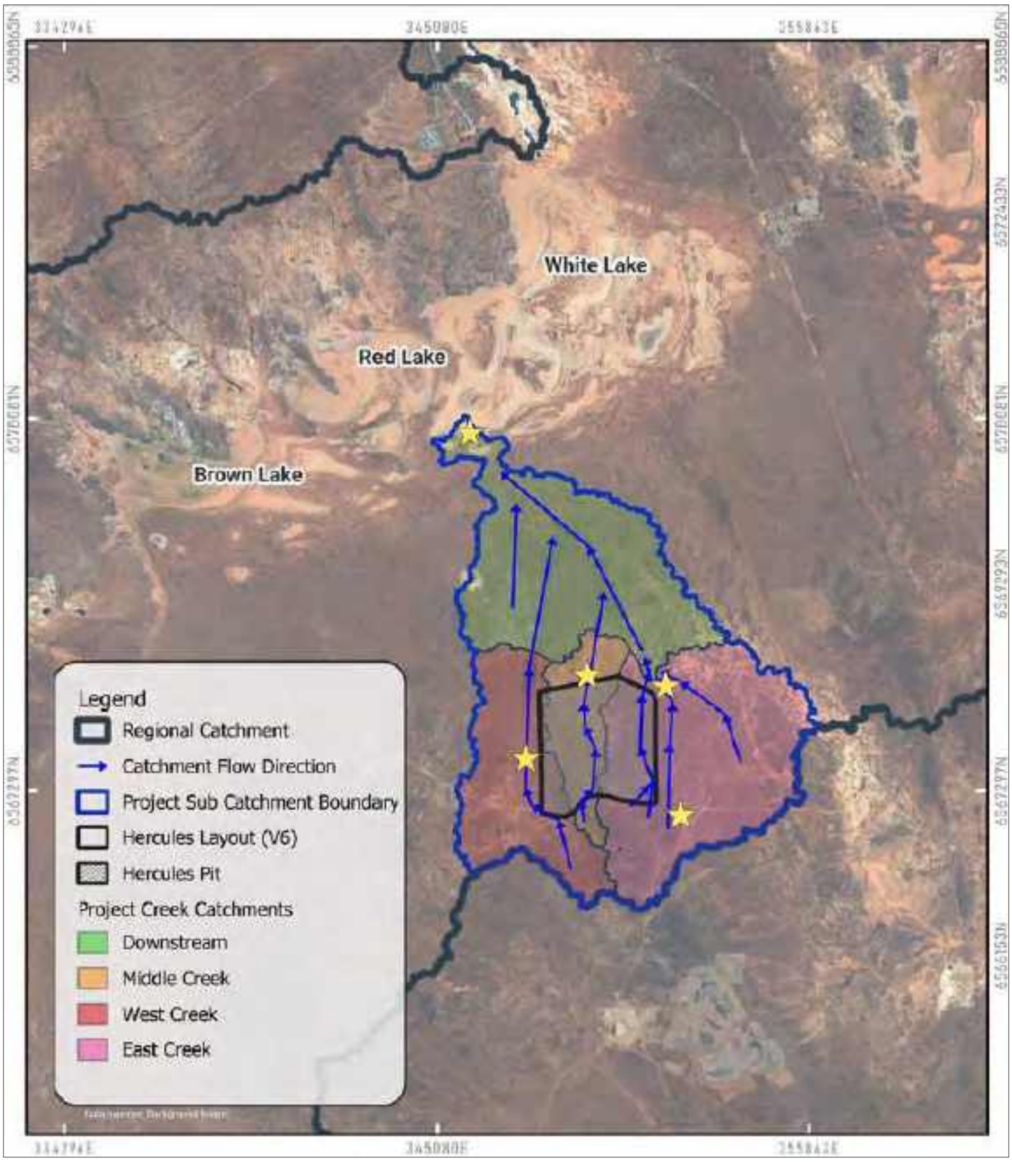

Figure 6. Project sub and main catchments showing direction of surface water flow (AQ2, 2025).

Pre-development hydrological conditions, such as the location and characteristics of flooding throughout the planned mine development footprint, have been predicted using a 2D flood model. Based on this modelling, a hydrological risk assessment was completed which identified the project risks which need to be mitigated. The main mitigation measures proposed (**Figure 7**) include:

- Diversion of East Creek around the south and eastern side of the proposed Hercules Waste Dump footprint;
- Minor diversions around Penfold Waste Dump, plus minor diversions around hardstand and plant areas;
- Dirty water containment ponding around sediment generating disturbance areas (including the waste rock dump, ROM pad and stockpile areas), to divert dirty water runoff to sediment basins for treatment prior to discharge to the downstream environment;
- Runoff from some of the disturbance areas to be directed to the pit void; and
- Pipeline to be buried at northern drainage line to reduce the risk of pipeline damage from flooding and to allow surface water to flow unimpeded.

A post-development flood model was prepared to predict the magnitude and extent of potential surface water changes from a 1% AEP design runoff event with the proposed mitigation measures accounted for.

The residual hydrological risks for the project were re-assessed to be "low" or "insignificant" considering the results from the post-development flood model.

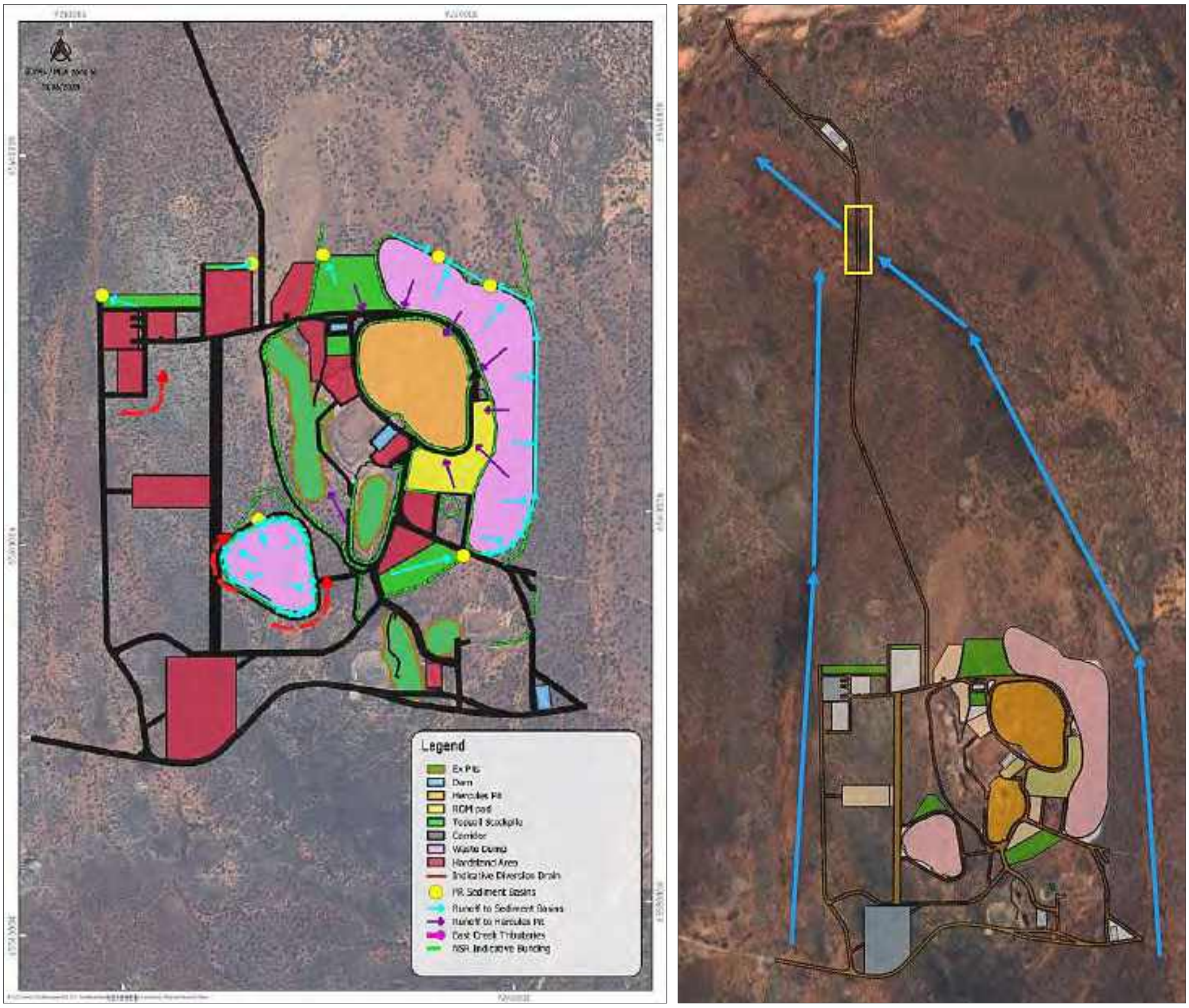

Figure 7. Proposed surface water mitigation infrastructure (AQ2, 2025) and dewatering effluent transfer pipeline buried section at northern drainage line crossing.

3.3 Ecosystem Conservation Values

The land systems and landscape units of the Hercules Project area and its surrounds are well represented throughout the Goldfields region. None of the vegetation communities identified were found to be of National Environmental Significance or include Threatened or Priority Ecological Communities. The study area is considered to have relatively low value as habitat for significant fauna species potentially occurring in the vicinity, including Threatened, Migratory, Specially Protected and Priority vertebrates and SRE invertebrates. No Environmentally Sensitive Areas, Threatened Ecological Communities or Priority Ecological Communities occur within the study area.

The nearest environmentally sensitive areas (ESA) are the Rowells Lagoon System roughly 85 kms to the north-west and the Goongarrie National Park (A Class Reserve), approximately 95 km to the north. These ESA are under the control and management of the Department of Biodiversity, Conservation and Attractions (DBCA).

3.4 Land Clearing

Approximately 560 hectares of new clearing will be required for the Project. As listed in **Section 1.4** of this document, CPS 11105/1 is under assessment by the DMPE. All clearing will be undertaken as per the Conditions listed in the Permit, once granted. A map showing the clearing permit area have been provided in **Figure 8.**

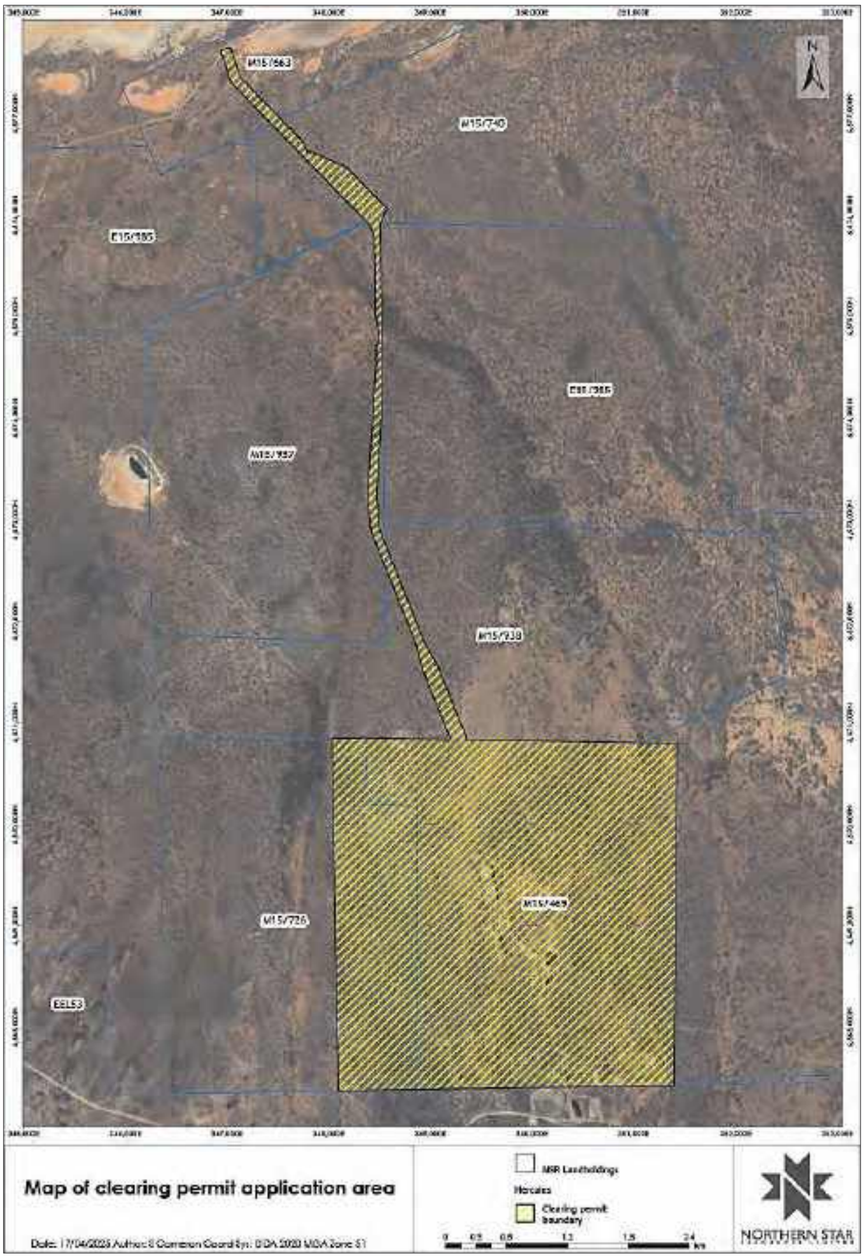

Figure 8. Map of the boundary of the area within which clearing may occur (CPS 11105/1).

3.5 Dust and Noise Emissions

Potential sources of dust are mining and vehicle movement along haul roads and other hardstand areas such as ROM pads. Water trucks will be utilised within the mining operations and along haul roads to minimise dust. Dust emissions are monitored and managed in accordance with the *Work Health and Safety Act 2020* and the *Work Health and Safety (Mines) Regulations 2022*.

Noise emissions are managed in accordance with the *Work Health and Safety Ac*t 2020, the *Work Health and Safety (Mines) Regulations 2022* and the *Environmental Protection (Noise) Regulations 1997*. The nearest noise sensitive receptor to the main operational areas of the Project is the Woolibar homestead located approximately 24 km south-east.

It is not anticipated that the proposed activities will elevate dust and noise emissions above those current. Any stakeholder complaints relating to dust or noise emissions will be acted on immediately and management measures reviewed accordingly.

3.6 Waste & Hazardous Materials Management

Waste materials generated during construction and ongoing operations will be collected, transported, stored and disposed of in a manner which minimises environmental harm and in accordance with relevant Acts and Regulations.

General waste will be taken to the onsite landfill or offsite to an approved facility for disposal. Controlled waste (hydrocarbon-contaminated materials, waste oil, coolants etc.,), will be collected and removed from site by a licenced carrier as per the *Environmental Protection (Controlled Waste) Regulations 2004*. All paper, cardboard, plastics, scrap metal and other recyclables will removed from site for processing, where possible.

3.7 Social Environment

3.7.1 Aboriginal Heritage

Aboriginal people in the Goldfields region come from three diverse cultural groups, the desert people or Wongis from the north-east of Kalgoorlie and Nullarbor, the Gubrun people from the south-east and the Noongar people from the south-west. The area surrounding the towns of Kalgoorlie and Coolgardie is a transitional zone between these groups.

Due to the complex history of the Goldfields, there has yet to be Native Title determined over the areas in which NSR operates. At the time of preparing this document (July 2025), there was one registered Native Title claim in the Kalgoorlie region relevant to the Project:

- **Marlinyu Ghoorlie Claim (WC2017/007).**

The Marlinyu Ghoorlie claim covers the entirety of the Hercules project. Until Native Title is resolved, NSR seeks to work with a diversity of Aboriginal people who have demonstrated relevant cultural knowledge and associate themselves with the region.

Prior to undertaking any ground disturbing activities, Northern Star undertakes heritage surveys involving the Traditional Owners (TO) who have demonstrated relevant cultural knowledge and associate themselves with the area of interest. Numerous ethnographic and archaeological surveys have been conducted in the area surrounding Hercules ranging from the commencement of mining in the South Kalgoorlie Operations (early 1980s) to the present.

The Hercules project area has been surveyed by the relevant TO groups between 2015 and 2024. There have been no Aboriginal cultural heritage values identified within the areas of proposed works.

Two Registered Heritage Sites (DPLH) are located approximately 5.5 km south-west of the proposed disturbance envelop. Information relating to these can be found in **Table 7** below:

Table 6. Registered Aboriginal Heritage sites close to Hercules (DPLH, 2025).

Name	Place ID	Status	Type	Region	Restrictions
Karramindie Soak	15750	Registered	Artefacts/ Scatter; Water Source	Goldfields	No Gender/ Initiation Restrictions
Rod's Soak	15748	Registered	Artefacts/ Scatter; Water Source	Goldfields	No Gender/ Initiation Restrictions

3.8 Non-Aboriginal heritage

The Goldfields region, one of Australia's most prominent and historic mining regions, contains many examples of pastoral, regional development, and early mining practices. As a result of the long-term human occupation of the region, there is a rich array of historic settlements and mining history which began in the 1890's when people flocked to the area when gold was discovered. Many of the abandoned mine workings, shafts and structures are part of the heritage of Western Australia.

There are no listed Non-Aboriginal Heritage sites within the general Hercules area.

3.9 Land Users

The primary land uses of the Eastern Goldfields sub-region are pastoral land (38%), DBCA managed reserves (4.5%), mining and exploration activities with some freehold and unallocated crown land.

The Hercules Mineral Tenement holdings overlap the Woolibar Pastoral Lease. Due to the high level of current and historic mining activity in and around the area, construction and operation of Hercules is not expected to have any material impact on surrounding pastoral activities.

The region has a history dominated by the mining industry and the proposed Hercules Gold Mine is not expected to have any significant effect on the social environment.

Appendix A – Hydrogeological Investigation

Australasian Groundwater & Environmental Consultants

Report on

Hercules Groundwater Assessment

Prepared for
Northern Star (HBJ) Pty Ltd

Project No. HER5001.001
June 2025

ageconsultants.com.au

ABN 64 080 238 642

Document details and history

Document details

Project number	HER5001.001
Document title	Hercules Groundwater Assessment
Site address	Kalgoorlie, WA
File name	HER5001.001 Hercules Groundwater Assessment_v02.01.docx

Document status and review

Edition	Comments	Author	[redacted]	Date
v01.01	Draft for internal review	ZR	[redacted]	07/04/2025
v01.02	Draft for client review	ZR/JB	[redacted]	15/04/2025
v02.01	Final report	ZR/JB	[redacted]	05/06/2025

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Hercules Groundwater Assessment

1 Introduction

Northern Star Resources Ltd (NSRL) is planning on submitting a mining proposal for the proposed open pit and underground mine, Hercules, located approximately 30 km south of Kalgoorlie-Boulder in Western Australia. Hercules is located on mining tenement M15/469 (Figure 1.1). NSRL holds a Groundwater Well Licence (GWL) for the area surrounding including South Kalgoorlie Operations (SKO) (GWL106836(9)) that also includes mining tenement M15/469 for dewatering purposes.

During geological and resource definition drilling at Hercules, the supervising geologists reported that more than expected groundwater volumes were encountered in some drill holes. Following this finding, NSRL requested Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) to assess the hydrogeological conditions and provide recommendations regarding further work to investigate dewatering and water management strategies. AGE proposed this work to be completed in three phases, including:

1. Phase 1 – Desktop data review and gap analysis.
2. Phase 2 – Plan and complete a bore drilling and testing program.
3. Phase 3 – Conceptual and numerical modelling and an impact assessment.

AGE completed Phase 1 and Phase 2, with the drilling of two monitoring bores and one production bore completed which also included test pumping of the production bore and a historically drilled bore. This report represents Phase 3 of the proposed work.

1.1 Objectives and scope of work

The ultimate objective of the groundwater assessment is to predict the types of impacts, the likelihood of impacts, and the magnitude of environmental risk to the groundwater regime posed by the proposed open pit- and underground mining at Hercules. Secondarily, the dewatering rates will be assessed to ensure proper infrastructure planning and water management protocols are to place during the mine's operational phase. AGE developed a scope for Phase 3 and includes the following:

- **Stage 1 – Conceptual model development:** Compilation of the key components of the conceptual model will be undertaken, including topography, geology, climate, groundwater distribution, flow paths, chemical composition, and variability over time.
- **Stage 2 – Numerical groundwater modelling:** Development of a numerical groundwater model, including the conversion of existing conceptual model data to be used as input data to the numerical model.
- **Stage 3** – **Summary water balance.** used to quantify the inflows, outflows, and storage changes. It is done in order to improve the understanding of the groundwater-surface water interactions, estimating recharge rates, and managing water resources sustainably.
- **Stage 4 – Impact assessment**, impact mitigation, and groundwater management approach.
- **Stage 5 – Reporting**: Findings from the stages described above will be amalgamated into one document (this document) and will include an assessment of the potential impacts from the proposed groundwater extraction.

1.2 Report structure and requirements

Table 1.1 provides an overview of the key requirements as part of a Hydrogeological Impact Assessment and corresponding report section(s). For reference, AGE followed the requirements as stated in the Department of Mines, Industry Regulation and Safety (DMIRS) Mining Proposal Guidance (DMIRS, 2023) and Mine Closure Plan Guidance (DMIRS, 2023). Additionally, the Department of Water's (DoW's) Operational policy no. 5.12 - Hydrogeological reporting associated with a groundwater well licence – Appendix A3 - H3 level of assessment (detailed hydrogeological assessment) (DoW, 2009) was used.

Table 1.1 Summary of key requirements and corresponding report section(s)

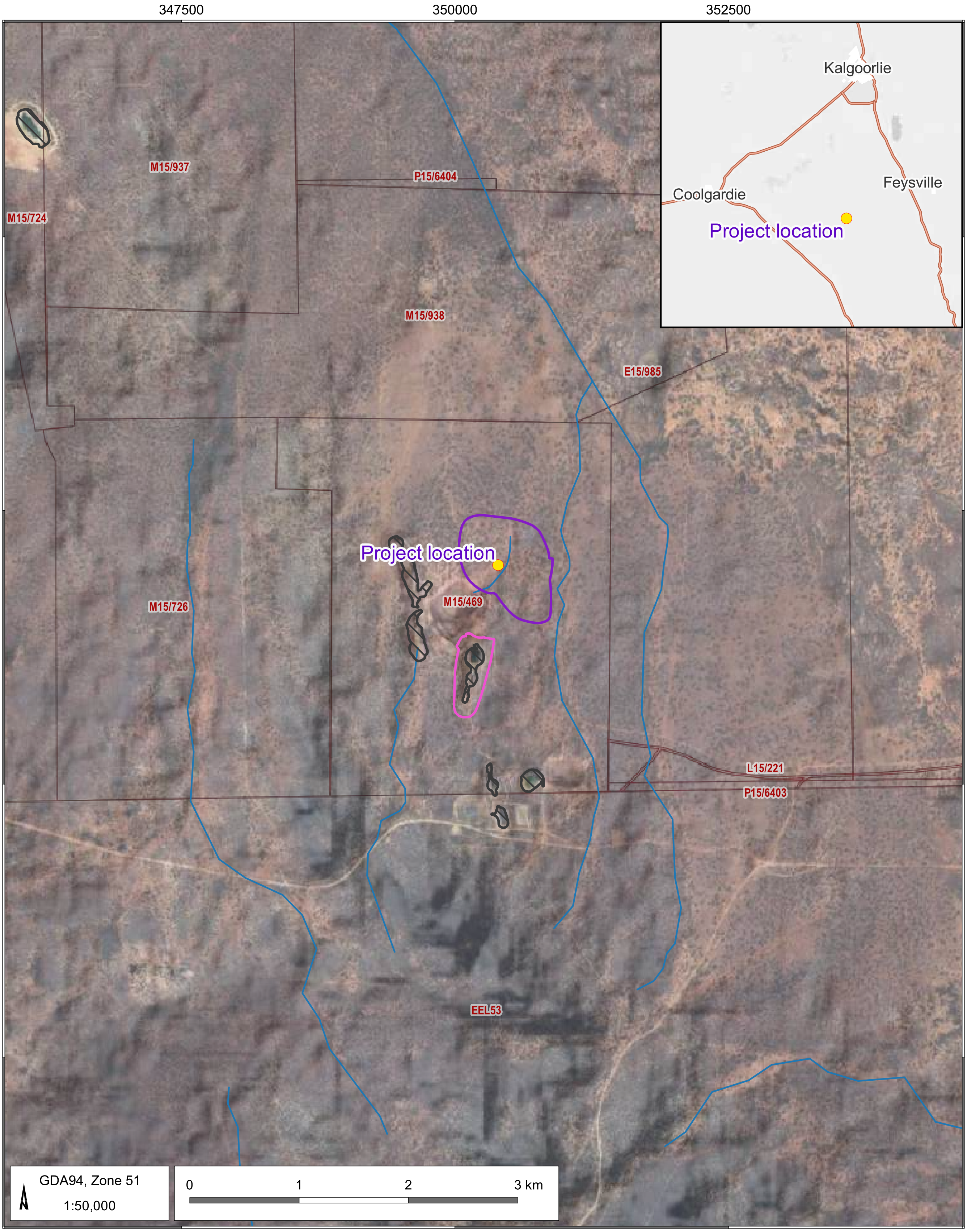
Item	Key requirements	Report section
1	Location of the proposed activity, including groundwater management areas (e.g., groundwater area; subarea).	1.3; 2.1.2
2	Locations of current and proposed production and monitoring bores.	2.4
3	Locations of existing groundwater users and licences.	2.9
4	Location of all potential groundwater dependent ecosystems (GDEs).	2.10
5	Discussion of the climate in the area of the proposed activity.	2.1.1
6	Description of relevant details regarding the groundwater system, including: • an overview of the groundwater system that the aquifer is part of, including recharge and discharge areas, interconnection between aquifers, and connection with GDEs; • identification of the aquifer that is to be developed; • estimates and discussion of groundwater storage and recharge potential.	2.3; 2.6; 2.10
7	Groundwater investigations, including drilling details and test pumping.	2.4; 2.8
8	A groundwater chemistry analysis of the aquifer for proposed abstraction.	2.7
9	An appropriate numerical groundwater model to predict the likely impacts of the proposed groundwater abstraction.	3; 4; 5; 6
10	Any potential impacts on the aquifer, environment, or other groundwater users, that may be caused by the proposed groundwater abstraction and an assessment of impacts.	5.2.1; 6.3.1; 7
11	A proposed groundwater monitoring program should be provided where appropriate to monitor the impacts of ongoing groundwater abstraction upon commencement of operation.	8

1.3 Project overview

The Hercules project consists of a proposed open pit, underground mine, and associated surface infrastructure as presented in Figure 1.2. The proposed life of mine is planned to be 16 years with four years of open pit mining followed by 12 years of underground mining. The current proposed open pit is planned to reach an approximate depth of 245 meters below ground level (mbgl) while the underground mine is proposed to extend from 280 mAHD to -455 mAHD (approximately 735 mbgl).

The surface infrastructure will consist of topsoil stockpiles, waste rock dumps, workshops, and offices (Figure 1.2). At this stage, no processing plant, and associated tailings storage facility (TSF) will be present on site, as all ore is expected be transported off-site for processing.

Historical mining activities have taken place in the vicinity of the proposed open pit and underground mine. The historical Greenback-, Penfolds-, and Erebus pits are located west, southwest, and south of the proposed Hercules open pit, respectively. Historic mine waste rock dumps are located to the west and south-west of the proposed Hercules open pit.



LEGEND

- Town
- Project location
- Drainage
- Road
- Mining tenements
- Proposed Hercules open pit
- Proposed Penfolds open pit
- Historic Open Pit

Hercules Groundwater Assessment (HER5001.001)

Project location

AGE

DATE 05/06/2025

FIGURE No: 1.1

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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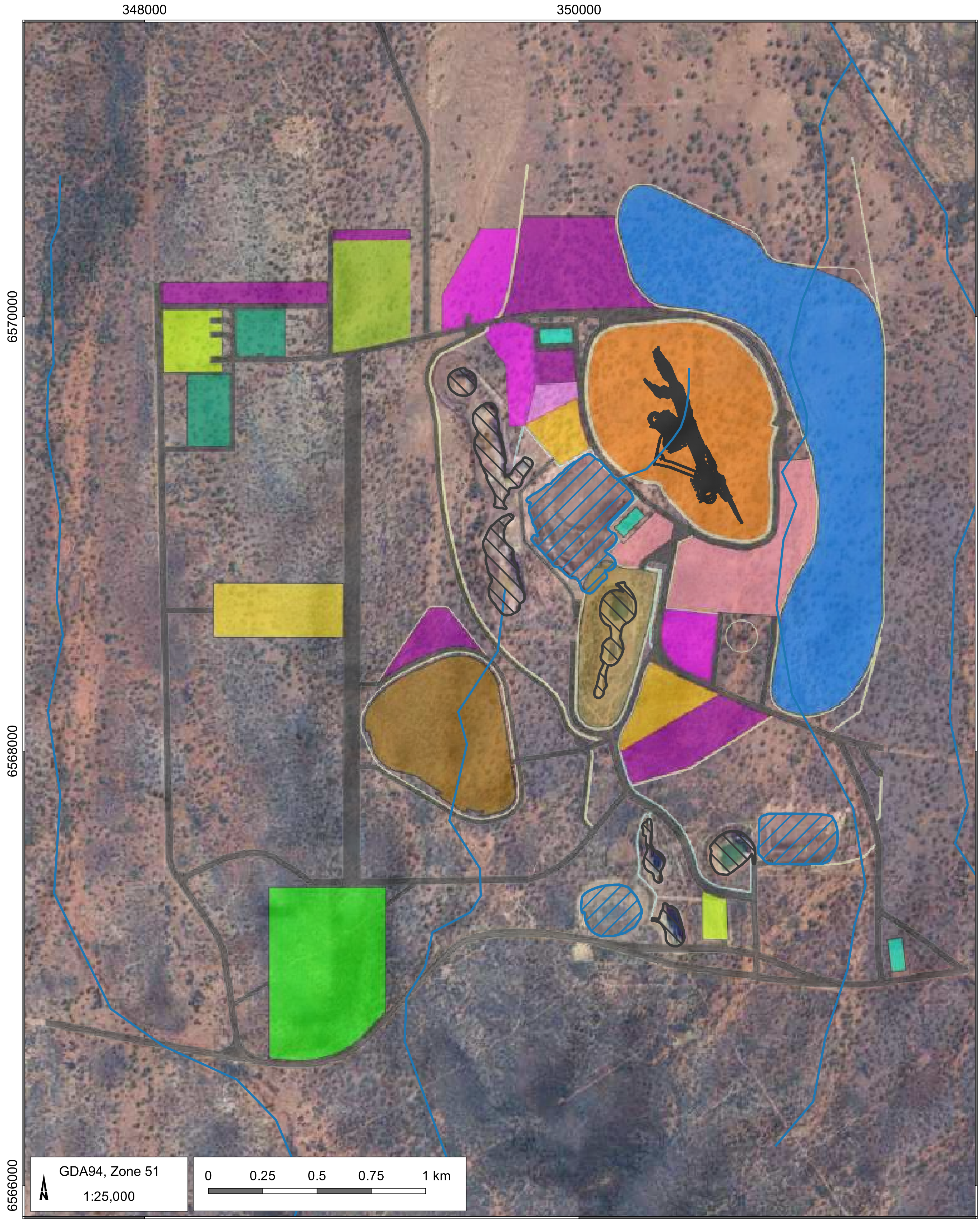

LEGEND

Hecules layout

- Dewatering pipelines
- Flood bunding
- Hercules open pit
- Hercules Village
- Hercules waste rock dump
- Laydown
- Offices
- Paste Sands
- Paste Plant
- Roads
- ROM
- Topsoil Stockpiles
- Turkeys Nest
- UG Power Plant
- UG Workshop & Plant
- Magazine
- Penfolds open pit
- Penfolds waste rock dump
- Hercules underground
- Historic Open Pit
- Historic Waste Rock Dump
- Drainage

Hercules Groundwater Assessment (HER5001.001)

Proposed site infrastructure layout

AGE

DATE 05/06/2025

FIGURE No: **1.2**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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2 Hydrogeological conceptual model

2.1 Environmental setting

2.1.1 Rainfall and evaporation

The climate for the area is generally described as arid to semi-arid with rainfall occurring throughout the year and thunderstorms during summer months. The area experiences hot summers with temperatures regularly reaching 40°C, whereas winters are typically much cooler.

Rainfall data for the project area was sourced from the Scientific Information for Land Owners (SILO)[1] database for the coordinates -31.00°S, 121.45°E, situated in the vicinity of the project area. This database contains patched or infilled climatic data including rainfall, temperature, and evaporation from 1889 to the present day. Actual evaporation data was available from 1957 and thus, long-term average values for the period of 1958 to 2024 have been calculated (Table 2.1). The mean annual rainfall and pan evaporation is 267 mm and 2,413 mm, respectively. The climatic data confirms that pan evaporation greatly exceeds rainfall for each month of the year. This reflects the highly arid climate of the region.

Table 2.1 Summary of climate averages for the period of 1958 to 2025

Month	Mean monthly rainfall (mm)	Minimum monthly rainfall (mm)	Maximum monthly rainfall (mm)	Mean monthly evaporation (mm)	Minimum monthly evaporation (mm)	Maximum monthly evaporation (mm)
January	29.8	0.0	184.9	348.6	95.8	424.2
February	29.9	0.0	197.3	279.3	184.0	351.8
March	24.9	0.0	194.7	243.4	162.7	316.5
April	20.1	0.0	102.5	158.8	91.8	211.4
May	25.1	0.1	115.8	103.9	68.4	152.1
June	26.4	0.6	164.1	73.5	48.7	95.5
July	24.3	0.5	80.9	80.3	53.8	108.9
August	20.9	0.8	75.8	109.2	71.9	162.2
September	12.2	0.0	41.7	159.9	92.6	194.2
October	15.5	0.0	90.1	234.5	169.7	288.9
November	20.5	0.0	88.0	280.3	213.4	351.3
December	17.5	0.0	97.3	340.8	256.2	440.0
Annual	**267.1**	**2.0**	**1433.1**	**2412.5**	**1509.0**	**3097.0**

To place rainfall in the recent years into a historical context, cumulative rainfall departure (CRD) was calculated. The CRD is calculated by subtracting long-term average monthly rainfall from actual monthly rainfall, providing a monthly departure from average conditions before then calculating cumulative totals.

A rising slope in the CRD plot identifies periods of above average rainfall, while a falling slope indicates below average rainfall (Bredenkamp *et al*., 1995). A standard technique for assessing groundwater level trends is to compare the water level hydrographs with a CRD plot. A CRD can be used to assess if changes in groundwater levels are correlated with climatic conditions or other factors such as resource extraction, mining, irrigation, etc.

[1]Scientific Information for Land Owners database: https://www.longpaddock.qld.gov.au/silo/point-data/.

Figure 2.1 shows a CRD plot for SILO rainfall data from 1958 to 2025, and shows that the area's rainfall is cyclic with periods of below and above average rainfall.

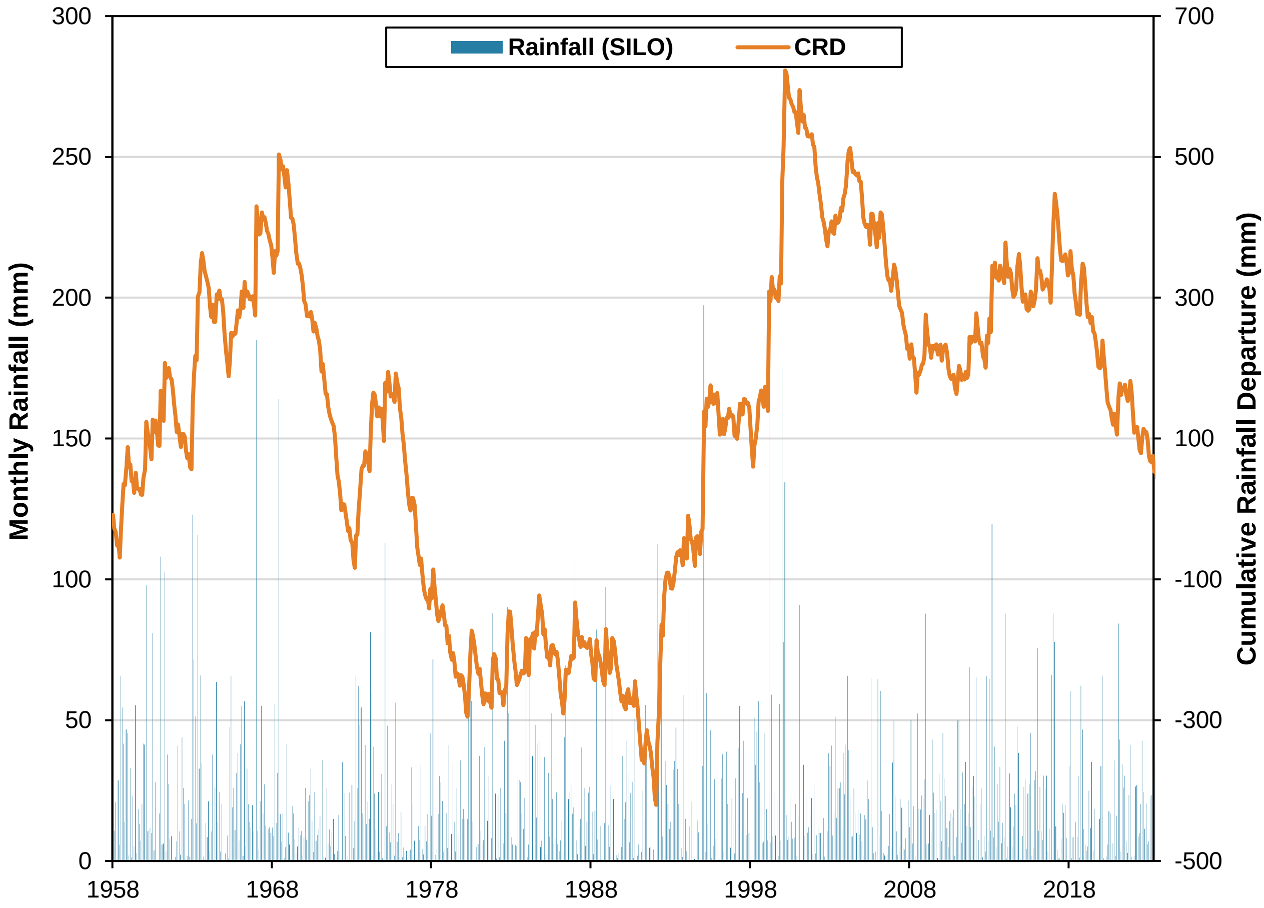
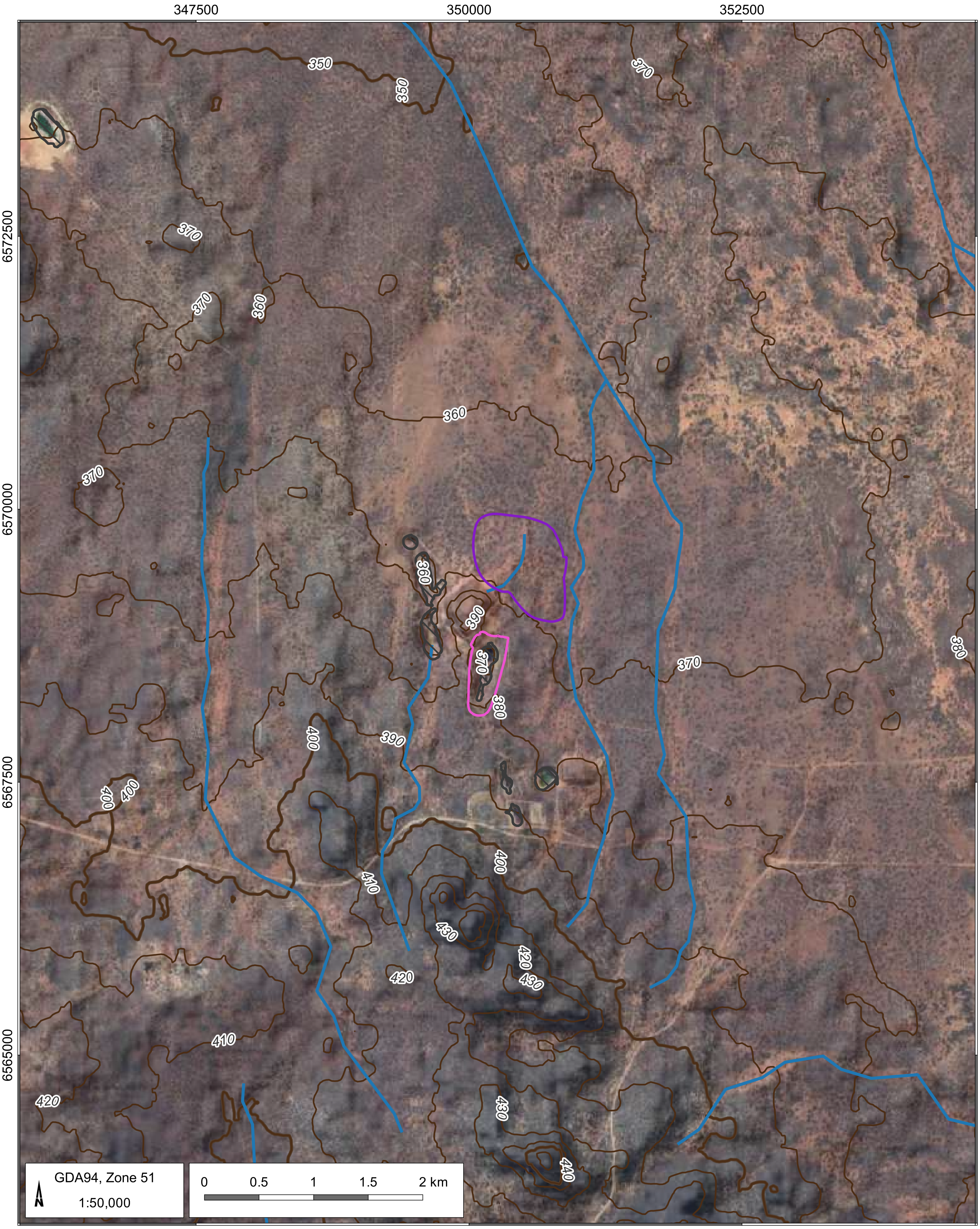


Figure 2.1 Annual rainfall and cumulative rainfall departure (CRD)

2.1.2 Regional terrain and drainage

Figure 2.2 shows the topography and drainage of the Project area. The regional topography consists of undulating hilly terrain associated with eroded basaltic lava flows and vast quaternary deposits where flatter topography dominates. Regionally, surface- and groundwater water flow is towards the major palaeochannels and the ephemeral lakes north of the Project location.

Locally, the topography is generally flat with key anthropogenic features, including the historic open pits and WRDs, changing the topography above and below the natural surface topography. At the Project area, the majority of rainfall runs off the WRDs and into the historic pits or along minor unnamed drainages flowing in a northernly direction.



LEGEND

- Drainage
- 10 m elevation contour (mAHD)
- Proposed Hercules open pit
- Proposed Penfolds open pit
- Historic Open Pit

Hercules Groundwater Assessment (HER5001.001)

Regional terrain and drainage

AGE

DATE 05/06/2025

FIGURE No: **2.2**

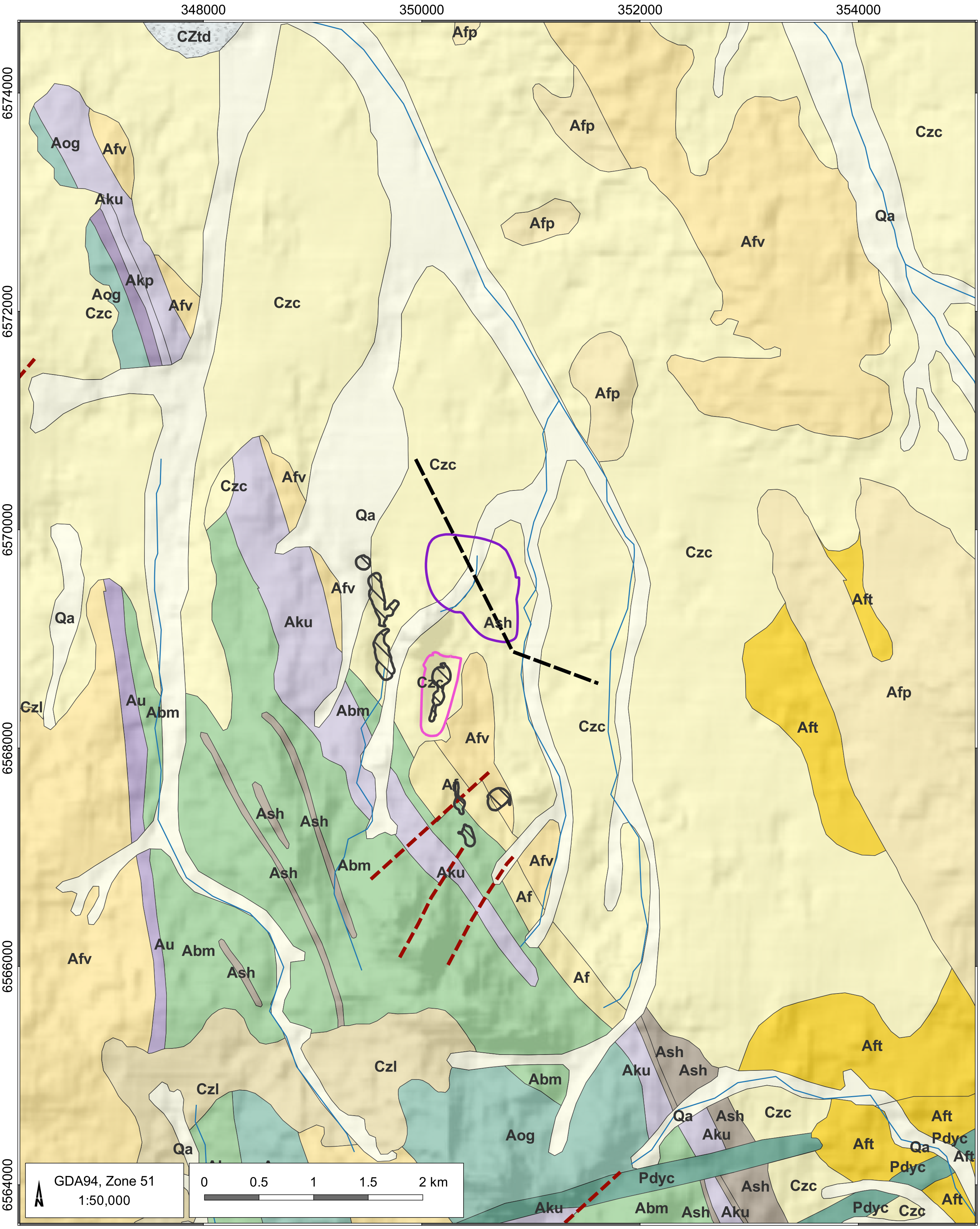
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\HER5001.001 Hercules Groundwater Assessment Phase 3\3_GIS\Workspaces\001_Deliverable1\02.02_HER5001_Regional terrain and drainage.qgz

2.2 Regional and local geology

The proposed Hercules project is situated within the Eastern Goldfields Region of the Archaean Yilgarn Craton which is characterised by northwest trending granite-greenstone belts that display low to medium grade metamorphism. The greenstone belts have been intruded by east-west trending dolerite dykes of Proterozoic age. The sheared and fractured greenstone belts comprise of a range of metamorphic, igneous, and sedimentary assemblages of which the granites tend to be relatively massive, except for locally sheared margins or joints (Hunter, 1993).

Overlying these basement rocks, are mid to late Tertiary sediments originating from erosion of the basement rocks and subsequently deposited in the low-lying areas and palaeochannels. A variety of Cainozoic and Quaternary superficial deposits (alluvials/colluvials, laterites, eolian, and lake deposits) cover the area as well (Swager, 1995).

As shown in Figure 2.3, the proposed Hercules project is underlain by a mafic/ sedimentary contact. To the north-east of the contact the project area is underlain by volcaniclastics comprised of units of felspathic sandstone, polymictic conglomerate and, carbonaceous pyrite and pyrrhotite rich shale. The mafic rocks are found to the south-west of the contact and comprises of two units differentiated by fine- and coarse-grained amphibolite facies. Faulting and fractures are prevalent in the area.



LEGEND

- Locality
- Drainage
- Cross section location
- Fault
- Hercules open pit
- Penfolds open pit
- Historic Open Pit

Geology

- Alluvium (Qa)
- Quartz sand and gypsum dune deposits (CZtd)
- Colluvium (Czc)
- Laterite (Czl)
- Slate and metamorphosed shale (Ash)
- Metamorphosed felsic volcanic rock (Af)
- Metamorphosed intrusive dacite and rhyodacite porphyry (Afp)
- Metamorphosed dacite and rhyolte agglomerate (Aft)
- Metamorphosed felsic volcaniclastic rock (Afv)
- Metamorphosed mafic and ultramafic intrusive rocks (Aog)
- Metamorphosed high-Mg basalt (Abm)
- Metakomatiite (Aku)
- Ultramafic schist (Au)
- Celebration Dyke (Pdyc)

Hercules Groundwater Assessment (HER5001.001)

Geological setting

AGE

DATE
05/06/2025

FIGURE No:
2.3

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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2.3 Hydrostratigraphic units

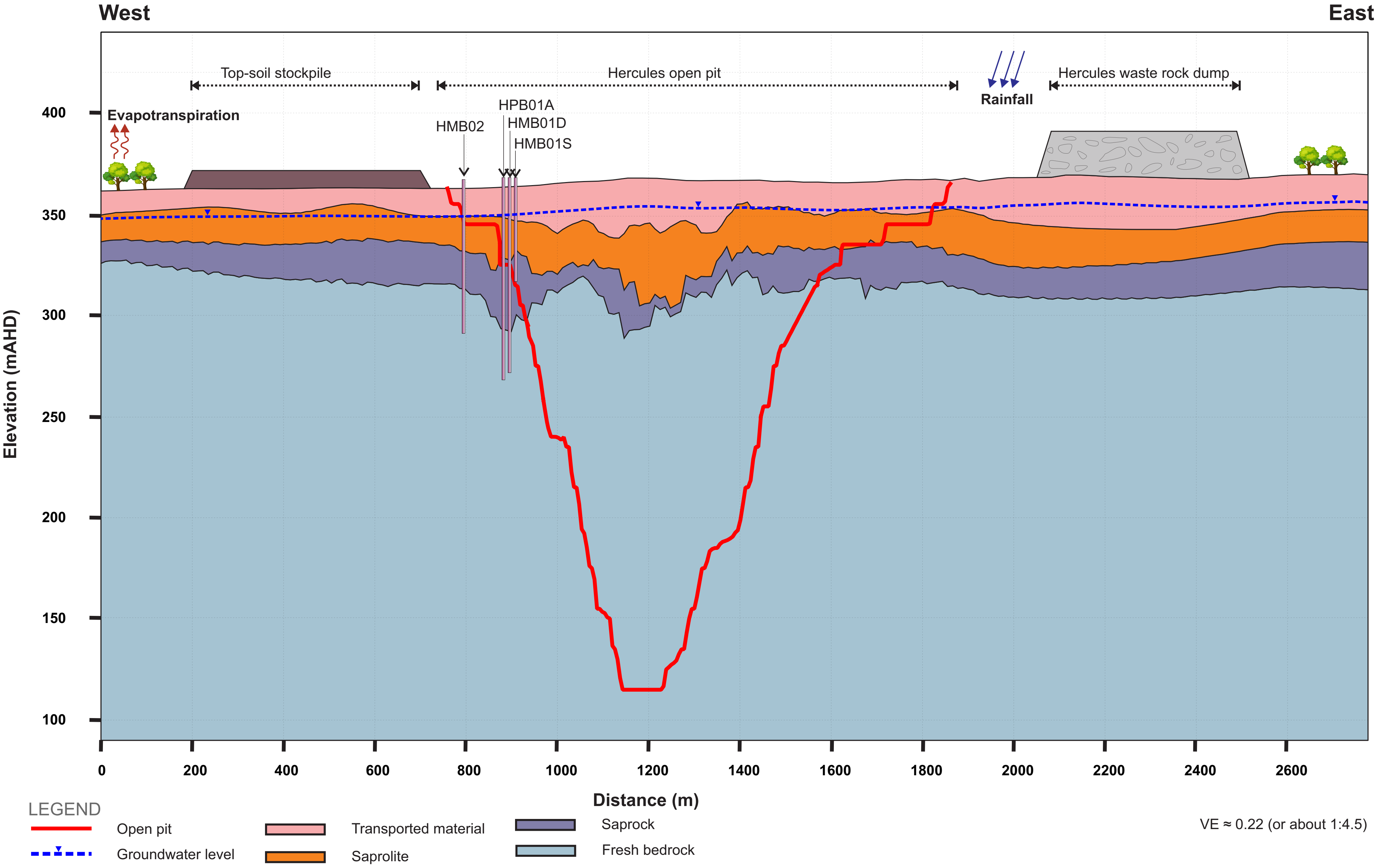
The hydrogeological system at Hercules is likely characterised by a predominantly dual porosity fractured rock environment with confining attributes. The following key hydrostratigraphic units are present within the Project area:

1. transported material consisting of alluvium, colluvium, and residual soils – the layer is likely mostly unsaturated within the Project area;
2. saprolite consisting of clays and silts from highly weathered bedrock material;
3. saprock consisting of partially weathered and fractured bedrock unit underlying the confining saprolite;
4. fractured bedrock rock unit associated with local and regional fracture zones and geological contacts of mafic and volcaniclastic rocks; and
5. bedrock matrix unit containing minor secondary porosity generally determined by the degree and interconnection of fracture-systems.

Peripheral fractures likely also contribute to groundwater flows with varied storage volume, depending on the interconnectivity between fractures and matrix environments. Based on the limited data acquired from four bores tested on site, of which three are in the same vicinity, the fractured rock aquifer could be limited in extent.

The pumping test analysis indicated that the primary groundwater storage in the potentially localised geological structure was limited and was likely also recharged by peripheral fractures or the matrix. During drilling activities, it was noted that the secondary fractures in the fresh bedrock decrease by depth with the weathered material, including silts and clays, overlying the fractured zone. This weathered material is presumed to act as a confining layer above the fractured aquifer zone.

Incorporating the geological data and information presented in Section 2.2, cross sections of the Project area showing the proposed open pit and underground areas are shown in Figure 2.4 and Figure 2.5. These cross sections show that the Project area is overlain by transported material with saprolite and saprock overlying the fresh bedrock. The proposed mining is planned to predominantly intersect the fresh bedrock geology.



Hercules open pit cross section

Figure 2.4

Hercules Groundwater Assessment (HER5001.001)

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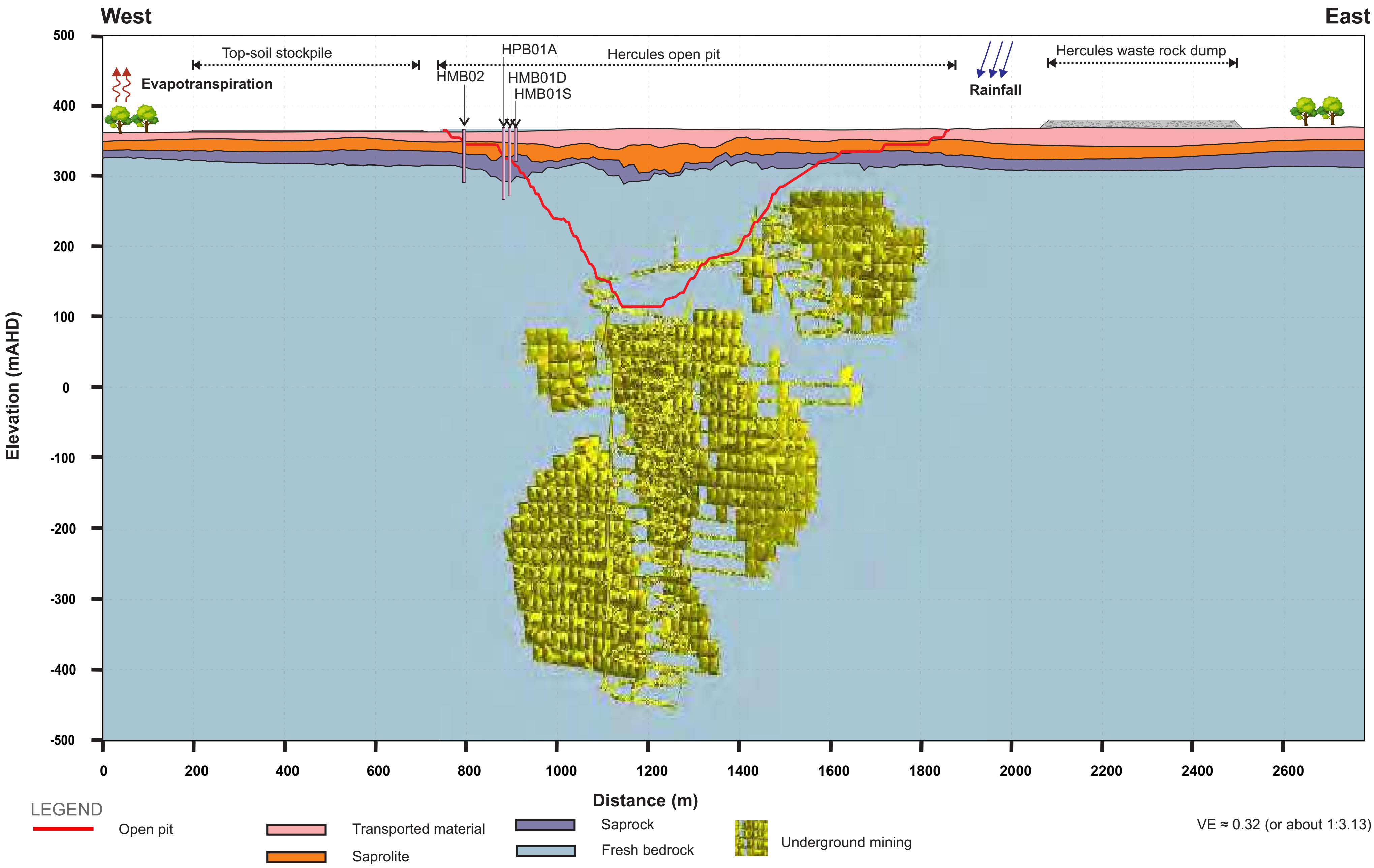

Hercules underground cross section

Figure 2.5

Hercules Groundwater Assessment (HER5001.001)

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2.4 Groundwater bore network

The groundwater bore network at Hercules consists of one production bore, one shallow monitoring bore and two deep monitoring bores. The details for each of the bores is provided in Table 2.2 and the location of the bores is shown in Figure 2.6. The bore logs are available in Appendix A with the full details regarding the drilling and testing campaign reported in AGE (2025).

Table 2.2 Bore installation details

Bore ID	Easting	Northing	Bore type	Ground level (mAHD)	Total depth (mbgl)	Screen depth (mbgl)	Screen stratigraphy	Collar height (m)	Water level (mbgl)	Water level (mAHD)
HMB01S	350462	6569853	Shallow monitoring	363.2	41.5	35.5 - 41.5	Saprock	0.58	18.17	345.03
HMB01D	350428	6569860	Deep monitoring	363.2	84.6	72.6 - 84.6	Volcaniclastics	0.60	18.19	345.01
HPB01A	350466	6569885	Production	362.9	87.0	39 - 87	Volcaniclastics	0.54	17.82	345.08
HMB02	350086	6569820	Monitoring	364.3	71.0	40 - 71	Unknown	0.13	21.37	342.93

Notes: mAHD – meters Australian Height Datum.
mbgl – meters below ground level.

LEGEND

- Newly drilled bore
- Existing monitoring bore
- Drainage
- Mining tenements
- Proposed Hercules open pit
- Proposed Penfolds open pit
- Historic Open Pit

Hercules Groundwater Assessment (HER5001.001)

Groundwater monitoring network

AGE

DATE 05/06/2025

FIGURE No: **2.6**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\HER5001.001 Hercules Groundwater Assessment Phase 3\3_GIS\Workspaces\001_Deliverable1\02.06_HER5001_Groundwater monitoring network.qgz

2.5 Groundwater levels

Depths to groundwater in the bore network range between 17.82 and 21.37 mbgl. A time series graph showing the measured water levels of each of the newly drilled bores and the existing HMB02 is shown in Figure 2.7.

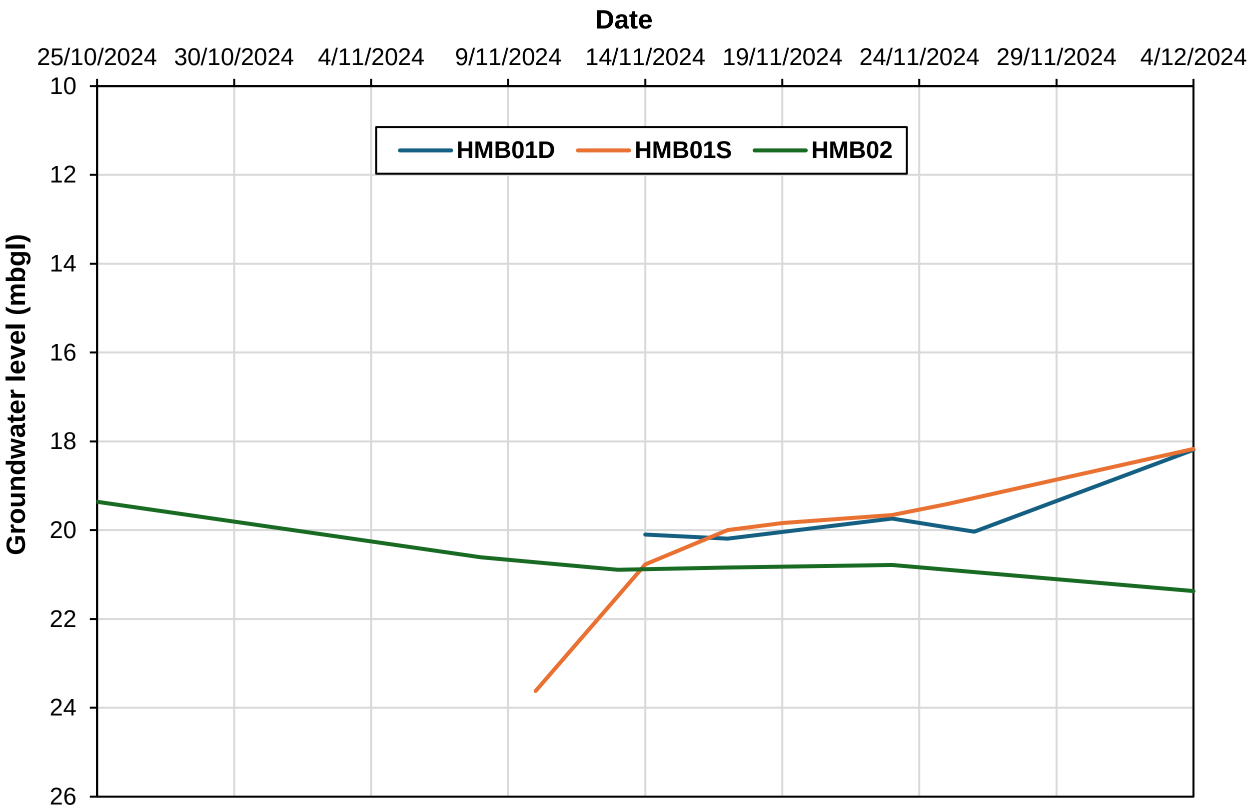


Figure 2.7 Time series groundwater levels for production and monitoring bore

2.6 Groundwater discharge and recharge

The area's rainfall and evaporation are discussed in Section 2.1.1 and shown in Table 2.1. As average rainfall is low and evaporative losses are relatively high in comparison, recharge is likely low. To estimate groundwater recharge, the chloride mass-balance (CMB) method[2] was used based on the chloride concentrations in the monitoring bores at Hercules and compared to the rainfall chloride concentration. Rainfall chloride concentrations for the Project area were reported by Malcolm (1983) at approximately 19.8 mg/L. The recharge estimation using the CMB method was calculated between 0.04% to 0.06%, which is considered low (Figure 2.8).

Recharge to the aquifers is likely via rainfall infiltration and is thought to be minimal due to high evaporation and transpiration rates. The groundwater discharge of the area is discussed in Section 2.1.2. Due to the flat topography pooling of water is present on site and local drainage is expected to flow towards colluvial channels and unnamed drainages found in the vicinity of the site.

[2] Chloride is regarded as a suitable environmental tracer since it is highly soluble, conservative, and not substantially absorbed by vegetation. Chloride concentration of rainfall is divided by the groundwater chloride concentrations and multiplied by 100 to present a percentage of rainfall recharge.

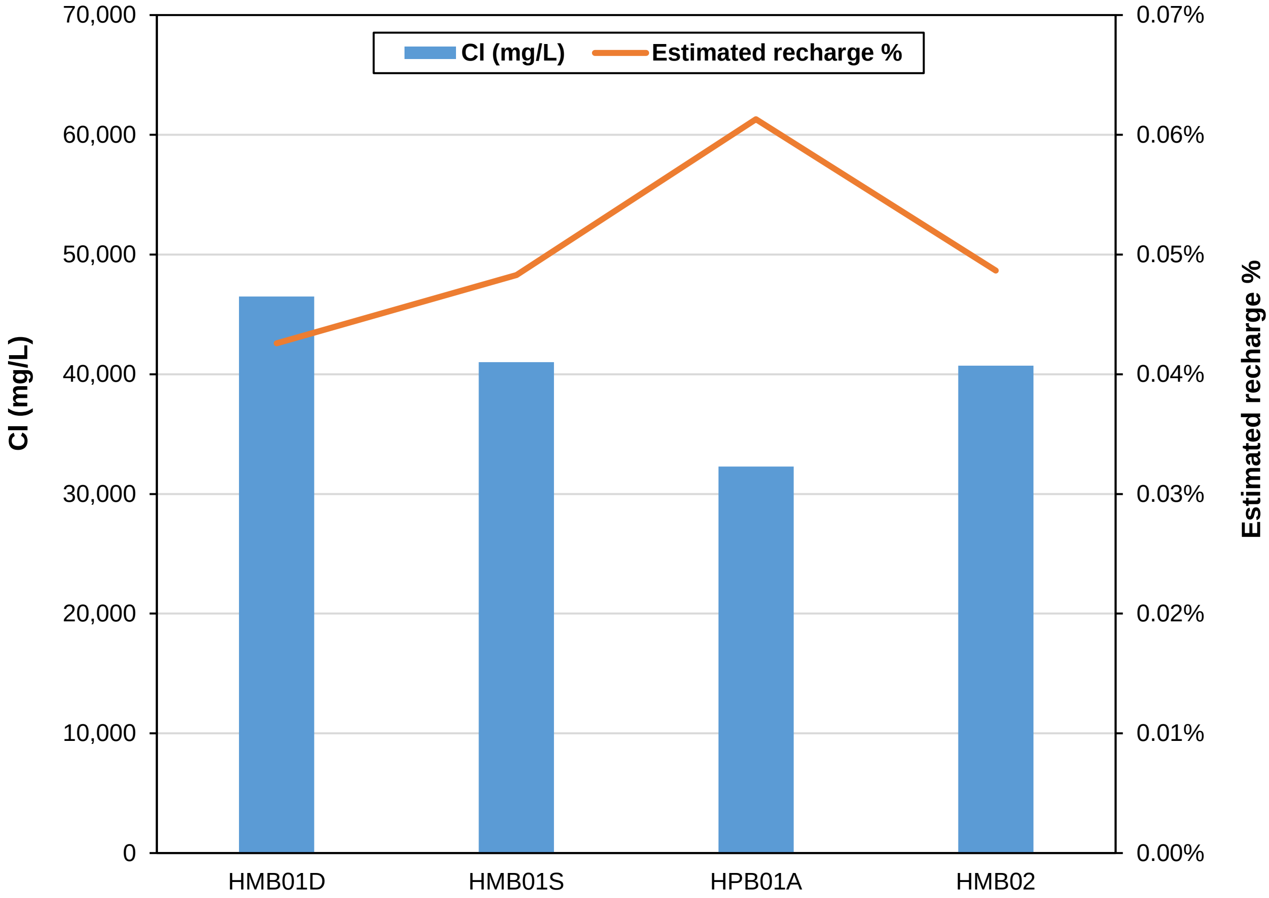


Figure 2.8 Estimated recharge by CMB method for each bore

2.7 Water quality

Water chemistry results for groundwater as well as pit water is available in Appendix B. The water quality results of the samples show neutral pH and high EC and TDS. It is possible to assume that the high EC and TDS, is due to the high salinity of the groundwater which is indicated by the elevated concentrations of sodium and chloride. The hydroxide and carbonate alkalinity are below detection limit, while the bicarbonate alkalinity is relatively elevated, indicating that the groundwater has a neutralising potential. Sulphate concentrations in the groundwater is elevated. The elevated concentrations of manganese could be related to the geology found in the area, as manganese is abundant in mafic rock types[3]. Furthermore, manganese is readily soluble in acidic to neutral pH (pH <7.5) and water that has low oxygen content.

Major cations and anions are presented on a Piper plot in Figure 2.9. The Piper plot shows the ratio of major cations and anions as a single point for each water sample. Different ratios represent different ionic characteristics (i.e., water types). The Piper plot shows the water from all bores are relatively similar and are of a sodium/potassium chloride type. The pit water qualities are shown to be similar for Penfolds 1 and Penfolds 2. The similarity of the Penfolds 1 and 2 water quality with the groundwater quality, shows that the pit water quality and groundwater is in equilibrium. However, the pit water quality for Erebus shows lower concentrations, which could be due to dilution by rainwater.

[3] Schulz, Klaus J., ed. Critical mineral resources of the United States: economic and environmental geology and prospects for future supply. Geological Survey, 2017.

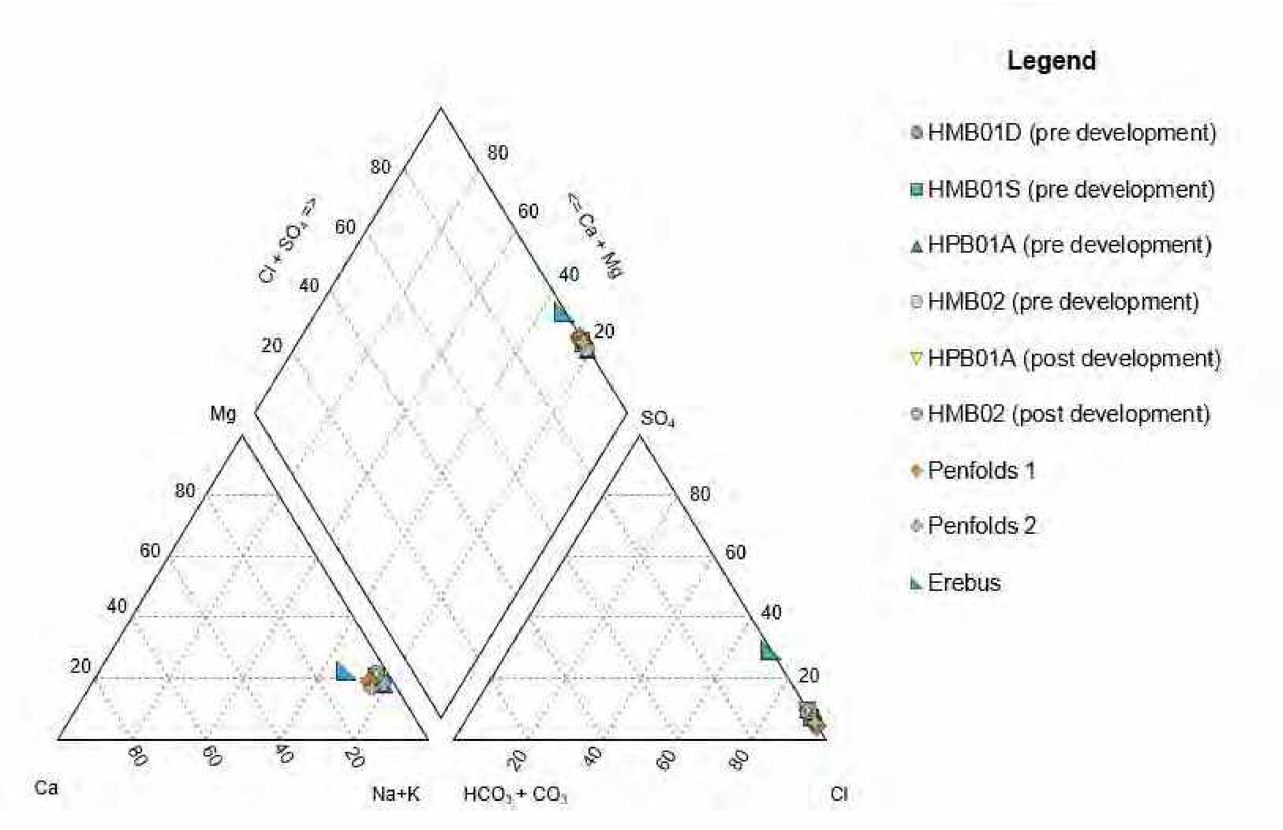


Figure 2.9 Piper water quality plot

2.8 Hydraulic properties

During January 2025, pumping tests were conducted in HPB01A and HMB02 while slug tests were conducted in HMB01D and HMB01S (AGE, 2025a). Aquifer characteristics were determined for each pumping test, including hydraulic conductivity (K) and storativity (S), while hydraulic conductivity was calculated for the slug tests.

The K value (m/d) describes the ease at which water moves through the aquifer. The S of an aquifer is a dimensionless value that represents the volume of water released from storage (or taken into storage), per unit storage area per unit change in hydraulic head (Driscoll, 1986). Specific storage (Ss) values area derived from storativity by dividing the storativity by the aquifer thickness and has a unit of m^{-1}. A summary of the pumping test results is available in Table 2.3 and the slug test results in Table 2.4. Figure 2.10 shows the variable flow rate utilised in the pumping test of HPB01A while Figure 2.11 shows the constant rate discharge results for the pumping test conducted at HMB02.

The conceptual model of the project area shows that there are likely three potential hydrostratigraphic units present in the Project area. The water levels at the site indicate a confined aquifer, as the water strikes were encountered approximately 36 mbgl and the static water level after drilling is approximately 18 to 19 mbgl. However, during drilling highly fractured rocks were encountered with multiple water strikes at deeper depths in some bores indicating a fractured rock aquifer with a dual porosity system consisting of likely both matrix and fracture flow.

Based on observations, the shallow monitoring bore is situated in a fracture, indicated by the high yields encountered during drilling. This bore is likely interconnected to the production bore HPB01A by a secondary fracture. The slower response of HMB01D in comparison to HMB01S indicates that this bore is more likely connected via the matrix. The low yields encountered in HPB01A indicative that the bore's groundwater inflow is likely dominated by secondary fracture and matrix flow.

Table 2.3 Calculated hydraulic conductivities for fractures and matrix

Aquifer type	Confined aquifer												Fractured aquifer			
Equation	Theis/Hantush (1959)				Barker (1988)				Dougherty-Babu (1984)				Moench (1984)			
Hydraulic parameter	T (m/day)	K (m/day)	S	Ss (m^{-1})	T (m/day)	K (m/day)	S	Ss (m^{-1})	T (m/day)	K (m/day)	S	Ss (m^{-1})	T (m/day)	K (m/day)	S	Ss (m^{-1})
HPB01A	2.74E+00	4.00E-02	5.84E-03	8.52E-05	2.02E+00	2.95E-02	4.28E-03	6.24E-05	2.76E+00	4.03E-02	5.04E-03	7.36E-05	2.37E+00	3.46E-02	1.40E-02	2.04E-04
HMB02	6.54E+00	1.33E-01	9.85E-03	2.01E-04	UTC	UTC	UTC	UTC	6.38E+00	1.30E-01	1.29E-02	2.63E-04	4.63E+00	9.43E-02	2.68E+06	5.46E-04

Notes: T – transmissivity (m/day).
K – hydraulic conductivity (m/day).
S – storativity.
Ss – specific storage (m-1).
m – meters.
UTC – unable to calculate due to large Lambda residual.

Table 2.4 Slug test hydraulic conductivity results – monitoring bores

Bore ID	Screened stratigraphy	Solution method	Falling head test period	Falling head test (m/d)	Rising head test period	Rising head test (m/d)	Mean hydraulic conductivity (m/d)
HMB01S	Highly fractured volcaniclastics	Bouwer and Rice	-	3.97E+00	-	7.31E+00	5.22E+00
		Hvorslev	-	3.28E+00	-	7.31E+00	
HMB01D	Fresh volcaniclastics	Bouwer and Rice	Early	1.60E-03	Early	2.60E-03	1.75E-03
			Late	2.30E-03	Late	2.08E-04	
		Hvorslev	Early	1.70E-03	Early	2.80E-03	
			Late	2.60E-03	Late	2.09E-04	

Notes: m/d – meters per day.
N/A – not applicable.

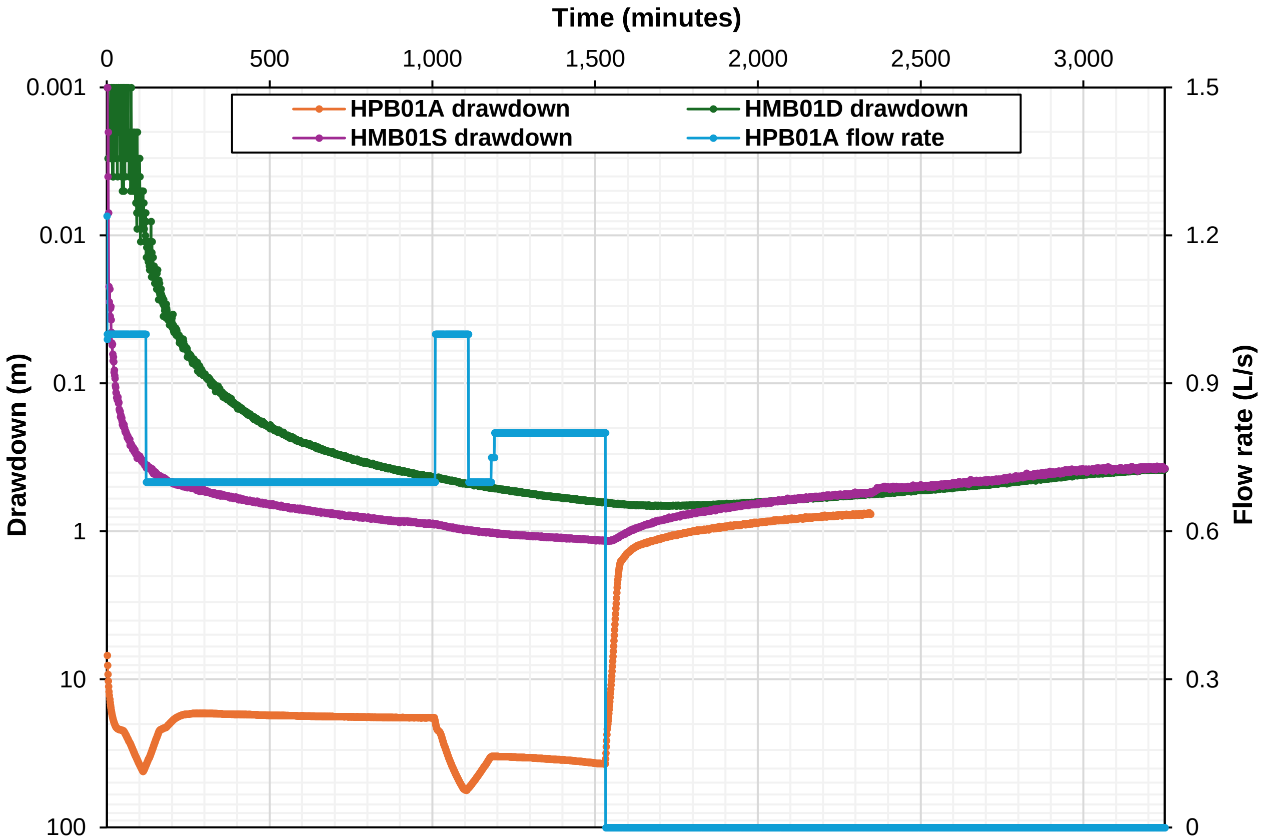


Figure 2.10 Variable rate discharge results – HPB01A

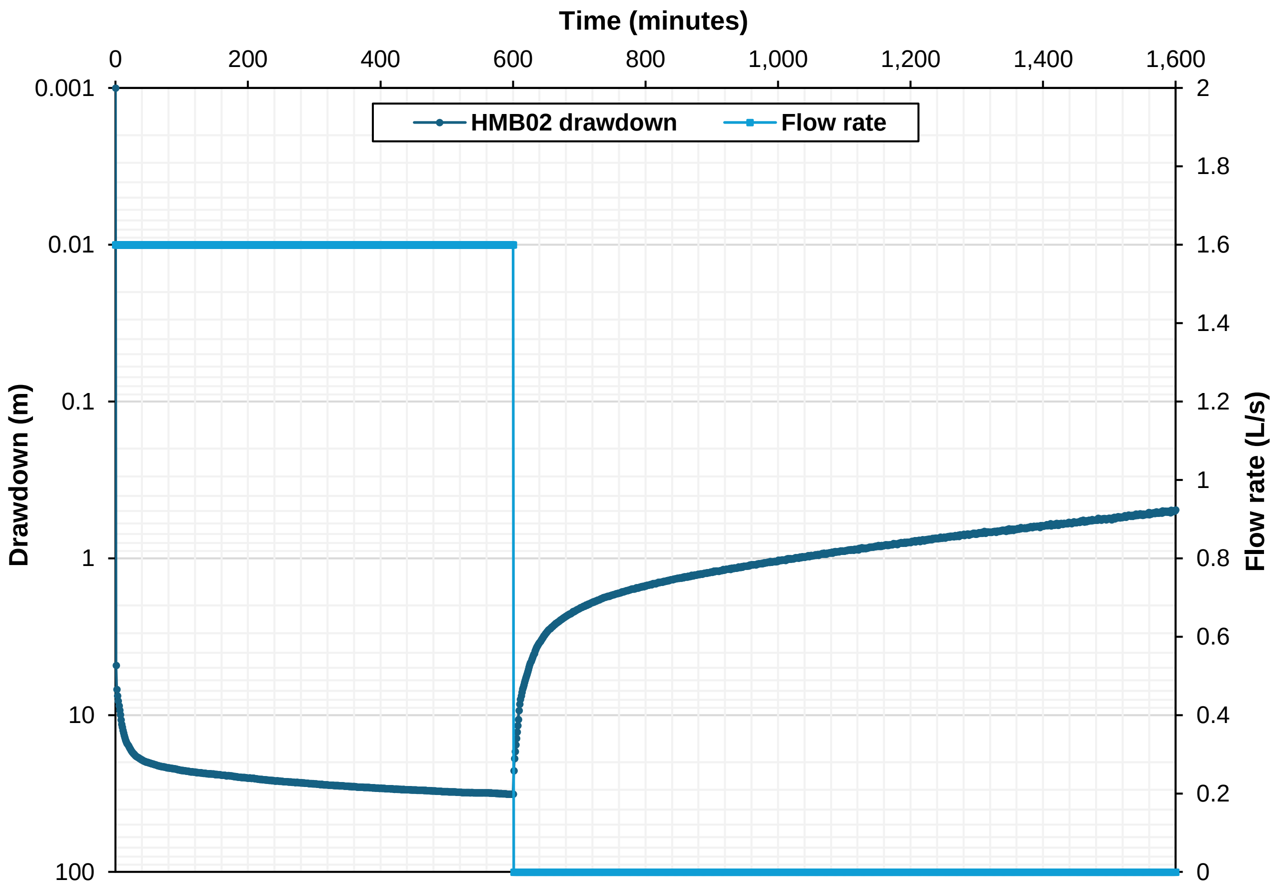


Figure 2.11 Constant rate discharge results – HMB02

2.9 Groundwater users

Information on existing registered bores within a 10 km radius from the Project area has been retrieved from the Water Information Reporting (WIR)[4] database to assess the spatial extent of potential groundwater users. The search identified 12 bores and the location of the registered bores are shown in Table 2.5 and Figure 2.12.

All of the bores identified in Table 2.5 and Figure 2.12 are either owned by NSR or located on NSR tenements and as such managed by NSR.

2.10 Groundwater dependent ecosystems (GDEs)

An evaluation of GDEs in proximity to the project area was conducted using the publicly available GDE Atlas (BoM, 2018). The GDE Atlas is a tool that provides an indication of the potential groundwater dependence of ecosystems across Australia, which was generated using a standardised method (Doody *et al*. 2017). The GDE Atlas was created by applying a catchment scale mapping approach that combined local expert knowledge with the best available spatial data.

GDEs can be classified into the following types (Doody *et al*., 2019):

- Subterranean ecosystems – stygofauna in cave and aquifer ecosystems.
- Aquatic ecosystems – ecosystems dependent on surface expressions of groundwater, e.g. river baseflow, springs, swamps.
- Terrestrial ecosystems – ecosystems dependent on subsurface expressions of groundwater, e.g. some vegetation and riparian communities.

The GDE Atlas contains information about aquatic, terrestrial and subterranean ecosystems. GDEs derived in the GDE Atlas are mapped according to the following classifications:

- high potential for groundwater interaction;
- moderate potential for groundwater interaction; or
- low potential for groundwater interaction.

It should be noted that there may be discrepancies between mapped areas and the actual ecological characteristics on-site, particularly in remote areas. As a result, areas that were mapped as having a low potential for groundwater dependence are not considered to be relevant to this assessment. Subsequently, potential GDEs within a conservative 10 km radius of all production bores were identified for further evaluation. No aquatic and terrestrial GDEs were identified within the 5 km search radius. The GDE Atlas has not analysed the presence of subterranean ecosystems.

2.10.1 Aquatic GDEs

No aquatic GDEs were identified in a 10 km radius of the Project.

2.10.2 Terrestrial GDEs

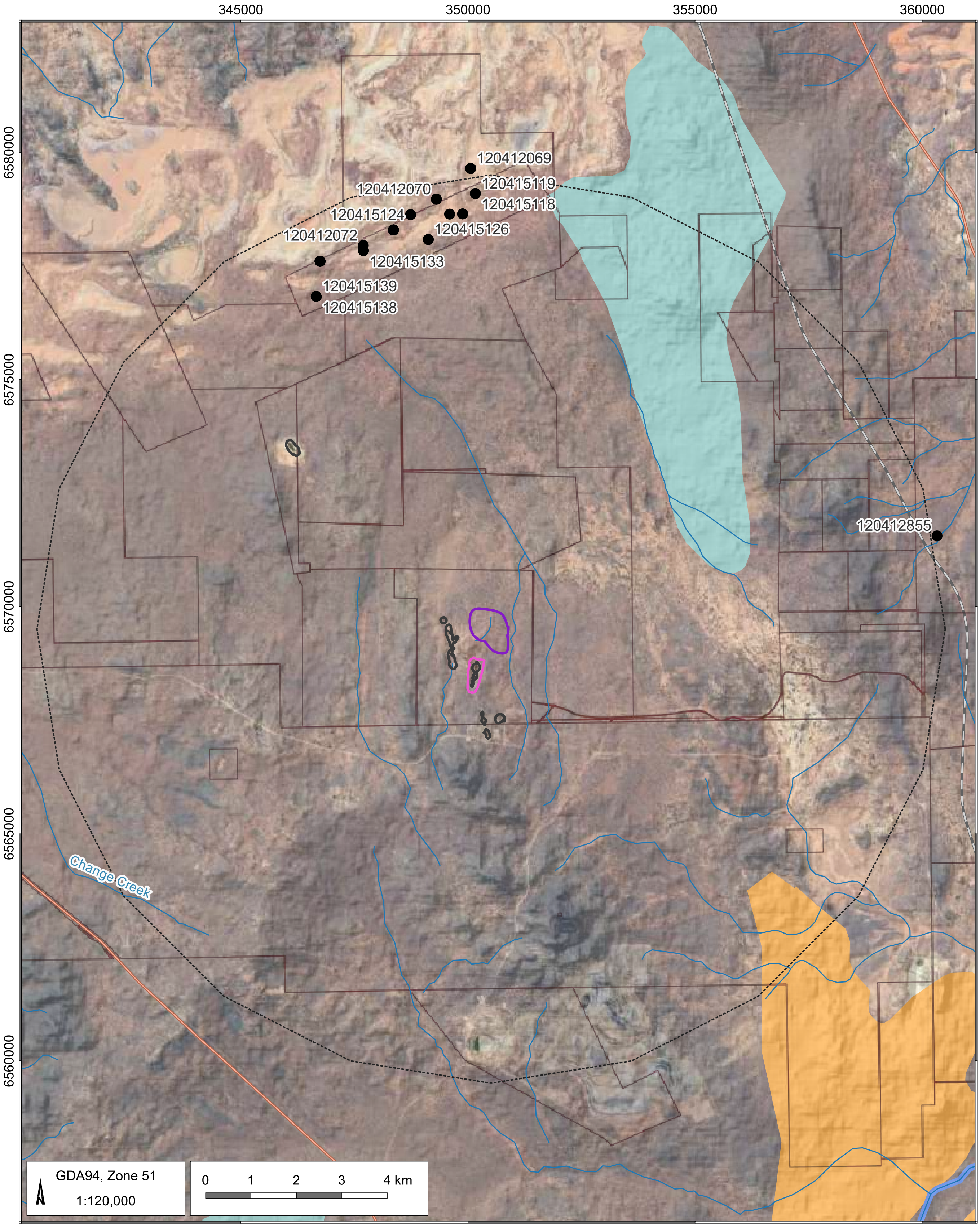
A low potential GDE was identified north-east of the Hercules proposed mine site and a moderate potential GDE was identified south-east (Figure 2.12). The terrestrial GDEs were identified as “undulating plains with some sandplains, ferruginous breakaways; ridges of metamorphic rocks and granitic hills and rises; calcretes, large salt lakes and dunes along valleys”.

[4]Water Information Reporting database https://wir.water.wa.gov.au/Pages/Water-Information-Reporting.aspx.

Table 2.5 Existing groundwater bore network

Site reference	Site name	Easting	Northing	Site type	Owner name	Total Construction Depth (mbGL)	Depth Drilled (mbGL)	Aquifer	Screen top (mbgl)	Screen bottom (mbgl)
120412070	Karramindie - 7	349341.93	6578983.51	Groundwater	Unknown	43	51	Combined Fractured Rock	37	43
120412071	Karramindie - 8	348341.93	6578283.51	Groundwater	Unknown	34.5	46	Combined Fractured Rock	28.5	34.5
120412072	Karramindie - 9	347691.93	6577933.51	Groundwater	Unknown	36	45	Combined Fractured Rock	30	36
120412073	Karramindie - 10	346791.93	6577583.51	Groundwater	Unknown	30.5	42	Combined Fractured Rock	24.5	30.5
120415115	Karramindie - 5A	350102.92	6579683.51	Groundwater	Kalgoorlie Consolidated Gold Mines Pty Ltd	0	48	Combined Fractured Rock	Unknown	Unknown
120415118	Karramindie - 5D	350141.93	6579082.51	Groundwater	Kalgoorlie Consolidated Gold Mines Pty Ltd	0	37	Combined Fractured Rock	Unknown	Unknown
120415121	Karramindie - 6C	349642.93	6578682.51	Groundwater	Kalgoorlie Consolidated Gold Mines Pty Ltd	0	48	Combined Fractured Rock	Unknown	Unknown
120415122	Karramindie - 6B	349891.93	6578623.51	Groundwater	Kalgoorlie Consolidated Gold Mines Pty Ltd	0	47	Combined Fractured Rock	Unknown	Unknown
120415124	Karramindie - 7D	348742.93	6578683.51	Groundwater	Kalgoorlie Consolidated Gold Mines Pty Ltd	0	36	Combined Fractured Rock	Unknown	Unknown
120415126	Karramindie - 7C	349141.93	6578082.51	Groundwater	Kalgoorlie Consolidated Gold Mines Pty Ltd	0	39	Combined Fractured Rock	Unknown	Unknown

Site reference	Site name	Easting	Northing	Site type	Owner name	Total Construction Depth (mbGL)	Depth Drilled (mbGL)	Aquifer	Screen top (mbgl)	Screen bottom (mbgl)
120415131	Karramindie - 9A	347742.93	6577883.51	Groundwater	Kalgoorlie Consolidated Gold Mines Pty Ltd	0	39	Combined Fractured Rock	Unknown	Unknown
120415138	Karramindie - 10B	346641.93	6576883.51	Groundwater	Kalgoorlie Consolidated Gold Mines Pty Ltd	0	42	Combined Fractured Rock	Unknown	Unknown



LEGEND

- NGIS groundwater bore
- Drainage
- Road
- Rail
- Mining tenements
- Proposed Hercules open pit
- Proposed Penfolds open pit
- Historic Open Pit

Aquatic

- Low potential GDE - from national assessment

Terrestrial

- Moderate potential GDE - from national assessment
- Low potential GDE - from national assessment

Hercules Groundwater Assessment (HER5001.001)

Existing registered bores and groundwater dependent ecosystems

AGE

DATE 05/06/2025

FIGURE No: **2.12**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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3 Numerical groundwater model

3.1 Introduction and background

As described in Section 1, NSR are planning to submit a mining proposal for the Hercules Project which requires a hydrogeological impact assessment to be completed. The ultimate objective of the hydrogeological impact assessment is to predict the types of impacts, the likelihood of impacts, and the magnitude of environmental risk to the groundwater regime posed by the proposed open pit- and underground mining at Hercules. Secondarily, the dewatering rates will be assessed to ensure proper infrastructure planning and water management protocols are in place during the mine's operational phase.

Subsequently, three on-site bores were drilled and tested (AGE, 2025a) of which the data was used in the development of a numerical groundwater model.

3.2 Assumptions and limitations

Development, calibration, and the results of predictive simulations from any groundwater model are based on available data characterising the groundwater system under investigation. It is not possible to collect all the data characterising the whole groundwater system in detail, and therefore, various assumptions have been made during the development of the groundwater model. The following assumptions were made using the best available data combined with our technical knowledge with the aim to provide the most accurate prediction:

- Discrete faults and structures were not included in the model development as these faults and structures are subject to a high level of uncertainty and the inclusion thereof would complicate the model.
- The future mining sequence within the Hercules pit and underground has been included in a simplified manner in the numerical groundwater model. Only annual mining progression intervals were used to simulate the mining geometry and sequence.
- Additional model mesh refinement was included in the footprint of the open pit and underground to assist with the representation of the mining progression.
- The future climatic conditions including rainfall, evaporation, and evapotranspiration remain uncertain due to seasonal variability and climate change. The predictive groundwater model has assumed average rainfall, evaporation, and evapotranspiration rates.
- The numerical model has been developed as an impact assessment and decision tool and is not required to include complex geological structure. The model adopts a conservative approach and has been based upon a sound conceptual model and a suitable calibration.

3.3 Model setup

3.3.1 Model uncertainty

Middlemis and Peeters (2018) indicate sources of uncertainty affecting numerical modelling simulations can be grouped as follows:

- structural/conceptual – geological structure and hydrogeological conceptualisation assumptions applied to derive a simplified view of a complex hydrogeological reality (any system that cannot be changed in an automated way in a model);
- parameterisation – hydrogeological property values and assumptions applied to represent complex reality in space and time (any system aspect that can be changed in an automated way in a model via parameterisation);
- measurement error – the combination of uncertainties associated with the measurement of complex system states (heads, discharges), parameters and variability (3D spatial and temporal) with those induced by upscaling or downscaling (site-specific data, climate data); and
- scenario uncertainties – guessing future stresses, dynamics and boundary condition changes (e.g., mining, climate variability, land and water use change).

Each of these sources of uncertainty are discussed within this document within relevant sections below. Where possible, inherent bias is identified and transparently communicated as recommended by Middlemis and Peeters (2018).

3.3.2 Model code

The model utilises the MODFLOW-USG code to simulate groundwater flow in the project region. This model code was considered suitable to meet the model objectives because it:

- allows use of an unstructured mesh where cells can be refined around localised features such as rivers, alluvial aquifers and mining, and larger cells used where refinement is not required;
- does not need layers to be continuous over the model domain, allowing layers to stop where geological units pinch out or outcrop, such as coal seams and alluvium;
- effectively reduces the number of cells with the refinement and pinching options that allow faster model run times and therefore the ability to conduct stochastic uncertainty analysis; and
- better represents flow transfer processes between systems such as bedrock and alluvial groundwater systems through the pinching out of layers.

The input files for the MODFLOW-USG model were created using custom Fortran and Python code, and a MODFLOW-USG edition of the Groundwater Data Utilities by Watermark Numerical Computing (2015). The mesh was generated using Algomesh by HydroAlgorithmics (2020).

3.4 Extent and boundaries

The model grid is presented in Figure 3.1 and covers an area of approximately 227 km^2. The model boundaries are described in detail below:

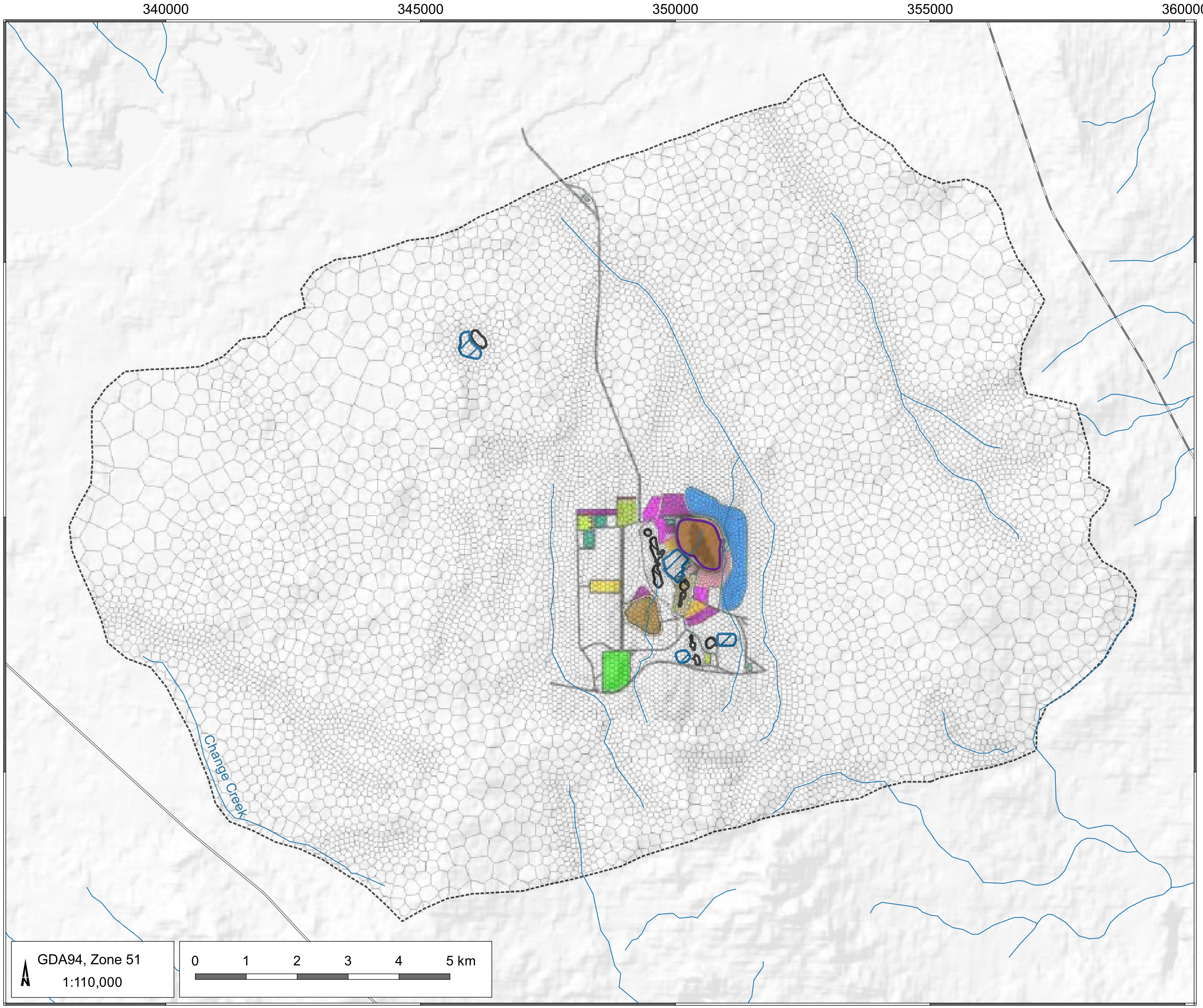
- **Northern boundary**: The northern boundary of the model follows the boundary of the ephemeral lakes which are anticipated to act as a constant head boundary.
- **Eastern boundary**: The eastern boundary follows the topographic boundary east of Hercules, as well as the unnamed non-perennial drainage to the southeast of Hercules. The boundary is anticipated to act as a surface watershed and a groundwater divide.
- **Southern boundary**: The southern boundary follows the geological contact of a northeast, southwest trending dyke which is anticipated to act as a no flow boundary and a groundwater divide.
- **Western boundary**: The western boundary of the model follows the unnamed non-perennial drainage to the southwest of Hercules as well as the topographic boundary northwest of Hercules and is anticipated to act as a surface watershed and a groundwater divide.

3.4.1 Grid

The model domain was discretised and arranged into thirteen layers. The dimensions of the cells varying according to the features that required representation. The following cells dimensions were adopted:

- Hercules pit – approximately 25 x 25 m hexagon cells;
- Hercules underground – approximately 10 x 10 m hexagon cells;
- Hercules waste rock dumps – approximately 75 x 75 m Voronoi cells;
- other mining areas – approximately 50 x 50 m hexagon cells;
- other waste dumps and stockpiles – approximately 75 x 75 m Voronoi cells;
- unnamed watercourses in close proximity to the mining area – approximately 50 x 50 m Voronoi cells;
- remaining watercourses – ranged between approximately 75 x 75 m to 100 x 100 m Voronoi cells;
- mapped alluvium near to the project – approximately 100 x 100 m Voronoi cells;
- mapped alluvium further away from the project – approximately 200 x 200 m Voronoi cells;
- colluvium and regolith in the project area – approximately 200 x 200 Voronoi cells;
- a polygon was delineated around the project area with a refined grid size to allow future updates of the model – approximately 100 x 100 Voronoi cells.

Figure 3.1 shows the cell size adopted in the vicinity of the project to reduce uncertainty associated with the scaling of field data to the model scale. Overall, the model is comprised of 140,462 cells across the thirteen layers, some of which are subject to pinching (refer to Section 3.5).



Hercules Groundwater Assessment (HER5001.001)

Model domain and model mesh

DATE
05/06/2025

AGE

FIGURE No:
3.1

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3.5 Model layers

The key hydrostratigraphic units within the model domain, identified by the conceptual model (refer to Section 2.3), were represented in the numerical model with thirteen separate layers (Table 3.1). Although only four hydrogeologically significant zones were included in the numerical model, the bedrock unit was further discretised to accommodate the inclusion of the underground mining area. The increased vertical discretisation permits more robust underground mining simulations by being able to dewater and rewater vertical columns of cells as required, rather than dewatering an entire column of cells at once, as would be expected from an underground mining environment.

For layer 1, CSIRO depth to regolith (Wilford *et al*., 2015) and the bore log data (Appendix A) for bores within the model boundary were used. The on-site geological model provided vertical data regarding the saprolite, saprock, and top of bedrock. Of the thirteen layers, four layers pinch out and are only present within the mining area while the non-pinched layers include all mining- and non-mining areas. Non-pinching layers and pinching layers comprise up to 13,950 and 3,728 cell nodes in each layer, respectively, as presented in Table 3.1.

Table 3.1 Model layers

Model layer	Hydrostratigraphic unit	Model cells
Layer 1	Weathered material (including alluvium, colluvium, and regolith)	13,950
Layer 2	Saprolite (weathered)	13,950
Layer 3	Saprock (weathered and fractured)	13,950
Layer 4	Bedrock (fresh) - mining (pinched)	3,728
Layer 5	Bedrock (fresh) – mining and non-mining	13,950
Layer 6	Bedrock (fresh) - mining (pinched)	3,728
Layer 7	Bedrock (fresh) - mining and non-mining	13,950
Layer 8	Bedrock (fresh) - mining (pinched)	3,728
Layer 9	Bedrock (fresh) - mining and non-mining	13,950
Layer 10	Bedrock (fresh) - mining (pinched)	3,728
Layer 11	Bedrock (fresh) - mining and non-mining	13,950
Layer 12	Bedrock (fresh) - mining and non-mining	13,950
Layer 13	Bedrock (fresh) - mining and non-mining	13,950

3.6 Timing

The numerical model was calibrated with observation data collected from the pumping tests and subsequent recovery from 11 January 2025 to 16 January 2025. The model timing was optimised to allow for more detailed representation of groundwater drawdown and recovery during the pumping tests conducted for HPB01A and HMB02. The calibration involved an initial steady state calibration to represent pre-pumping test conditions at Hercules, followed by a transient history-matching using water level measurements from the aquifer tests. As the historic mining within the Project area occurred a long time ago, the hydrogeological environment was considered to be in steady state and thus no longer affected by these mining operations. The calibration model stress period's timing was set up as shown in Table 3.2.

Table 3.2 Calibration model stress period timing and counts

Stress period	Stress period count	Stress period intervals (minutes)	Total duration (minutes)
1 (steady state)	1	-	1440
2 – 18	17	15	255
19 – 43	25	30	750
44 – 64	21	15	315
65 – 71	7	30	210
72 – 101	30	1	30
102 – 104	3	10	30
105 – 108	4	30	120
109 – 119	11	60	660
120 – 127	8	360	2,880
128 – 133	6	5	30
134 – 143	10	15	150
144 – 157	14	30	420
158 – 172	15	1	15
173 – 178	6	5	30
179 – 183	5	15	75
184 – 199	16	60	960
Total	**199**	**-**	**6,930**

3.7 Boundary conditions

Model boundary conditions refer to any stresses applied to the model domain that influence the flow of groundwater within the model domain. MODFLOW-USG has different packages to simulate these stresses and is described in the following sections.

3.7.1 Recharge

The MODFLOW-USG recharge package (RCH) was used to represent diffuse rainfall recharge where the model input is a “net” rate of recharge, incorporating evapotranspiration and infiltration, and adopting rate that represents drainage of water below the root zone. Recharge was applied to the highest active (i.e., wet) cell at all locations across the model domain.

Table 3.3 summarises the initial input rate of recharge for each geological unit. These rates were obtained using the CMB method for on-site data, as described in Section 2.6. The input recharge rate applied to the Old pit voids were estimated based on potential seepage and return water volumes from these facilities. The input recharge rate applied to the WRDs was conservatively applied as 20.0%, which is assumed to be high due to the unconsolidated nature of the materials in the dumps.

Figure 3.2 shows the recharge distribution zones represented in the groundwater model, which equate to the locations where various geologies outcrop and where recharge could be received. Variability in recharge rates across these zones were represented with a pilot point multiplying field across the model (refer to Section 4.1.2)

Table 3.3 Recharge zones

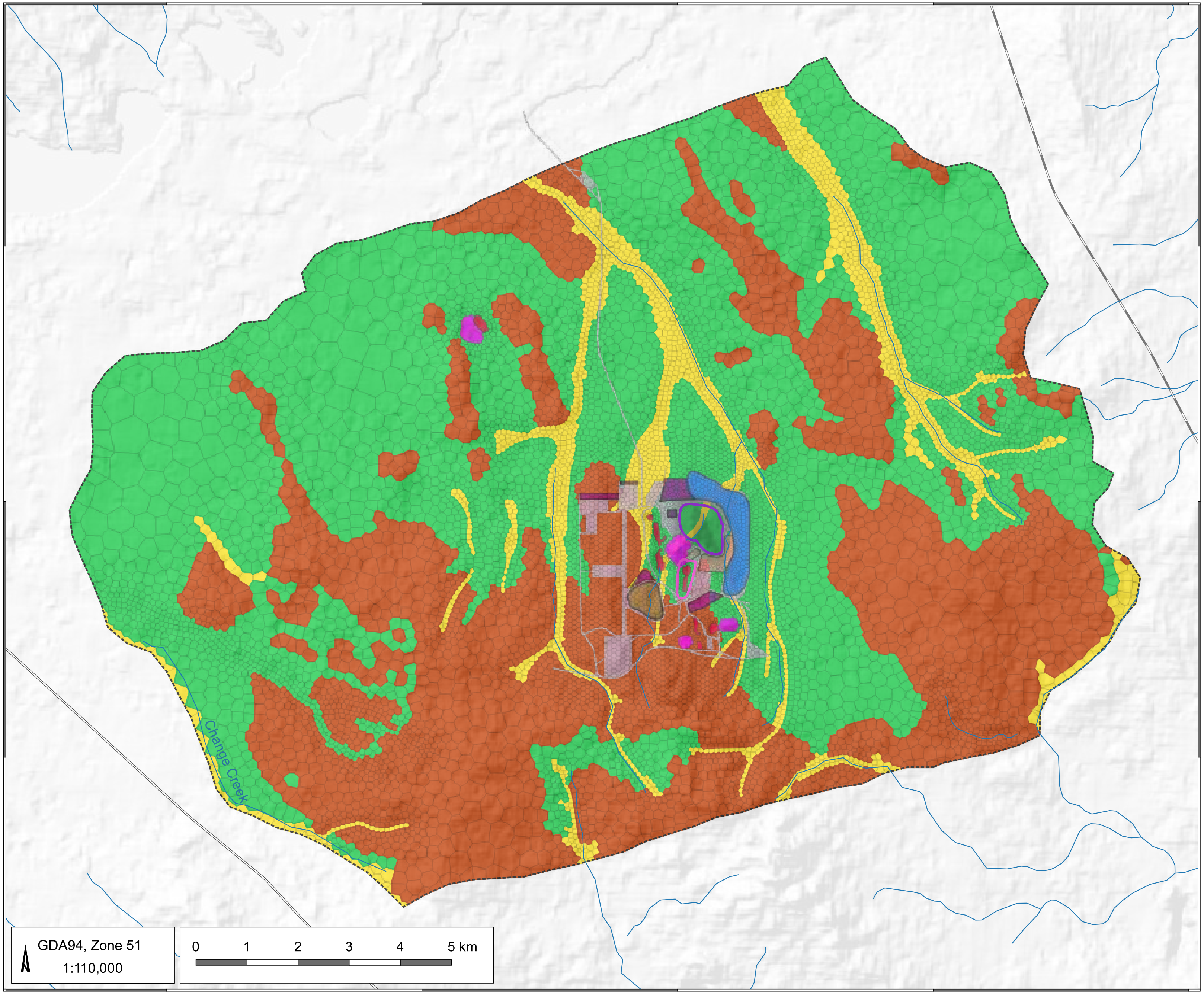
Recharge zone	Average annual recharge (mm/year)	% of net annual rainfall
Colluvium	0.13	0.05%
Alluvium	1.03	0.39%
Regolith	0.13	0.05%
Old pit voids	53.4	20.00%
Old WRDs	53.4	20.00%

3.7.2 Evapotranspiration

Evapotranspiration was represented in the numerical model with the evapotranspiration package (EVT). Areal actual evapotranspiration, obtained from SILO (2025)[5], occurred from the uppermost model cells across the model domain in layer 1 at a mean rate of 2,140 mm/year, decreasing linearly to a maximum depth of 1.0 m below the surface. The evapotranspiration was applied uniformly across all outcropping geological zones, with exception to cells where the river package (RIV) was applied, as described in Section 3.7.3 below. Evapotranspiration rate was constant across all stress periods. In areas where old WRD are located, the extinction depth was increased to 2.0 m. The evapotranspiration zones are shown in Figure 3.2, along with recharge zones (refer to Section3.7.1).

Evapotranspiration, like recharge, also varies spatially and is a function of similar factors including soils, land-use, geology, topography, and depth to water table. Whilst there is inherent uncertainty in the volume of water removed by evapotranspiration from the water table, the process is only represented in the numerical model where the water table is within 1.0 m of the land surface. The water table is only close to the land surface in the numerical model in a riparian zone near creeks and rivers, and therefore evapotranspiration only potentially influences groundwater levels in these areas.

[5] Scientific Information for Land Owners database: https://www.longpaddock.qld.gov.au/silo/point-data/.



LEGEND

- Drainage
- Road
- Rail
- Model grid
- Model boundary
- Alluvium
- Colluvium
- Regolith
- Proposed Hercules open pit
- Proposed Penfolds open pit
- Waste rock dump
- Other pit
- Other mine activities

Hercules layout

- Hercules waste rock dump
- ROM
- Topsoil Stockpiles
- Penfolds waste rock dump

Hercules Groundwater Assessment (HER5001.001)

Recharge and evapotranspiration zones

DATE
05/06/2025

AGE

FIGURE No:
3.2

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3.7.3 Surface-groundwater interaction

Groundwater interaction with surface drainage was simulated using the MODFLOW-USG river package (RIV). The cells assigned to this package in the model were divided into zones to represent each of the drainage lines in the model domain and are illustrated in Figure 3.3.

The stream water level above the riverbed (i.e., stage height) was set at 0.0 m for all river cells. This allows the cells to act as gaining streams when groundwater levels are above the bed of the river. The locations of the river cells in the groundwater model were assumed to be at the highest active layer in the model.

Table 3.4 provides an overview of the riverbed parameters. Uncertainty in the representation of the rivers is introduced to the model through the adopted riverbed conductance. The riverbed conductance, which represents the connectivity of surface water with groundwater, was not measured but was determined as suitable during the calibration.

Table 3.4 Modelled river (RIV) bed parameters

RIV zone	Vertical hydraulic conductivity Kv (m/d)	Width (m)	Incised depth (m)	Bed depth (thickness) (m)
All drainages	0.1	5	1	1

3.7.4 General head boundary

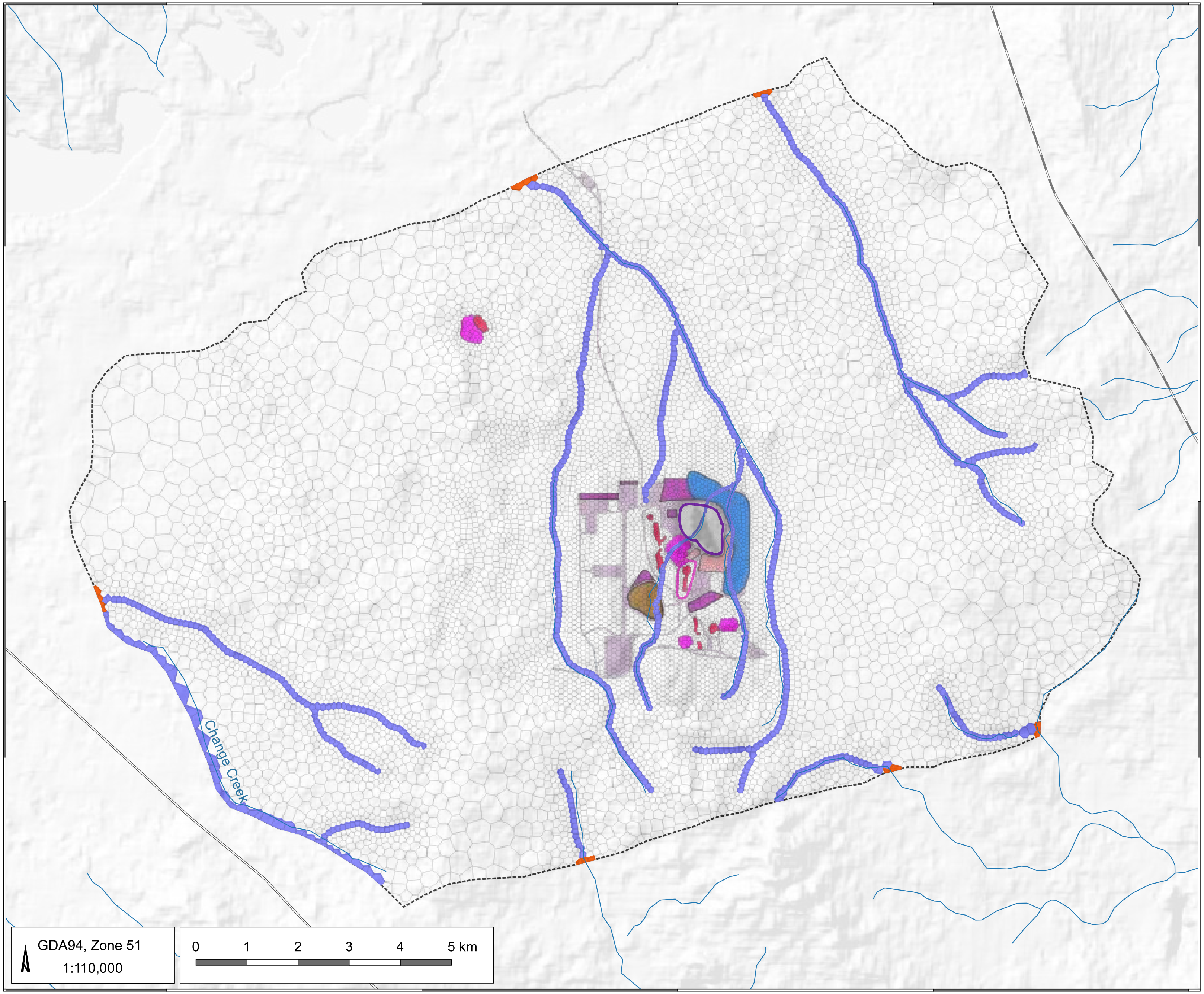
The edge of a MODFLOW-USG model is normally a “no-flow” boundary that does not transmit or receive groundwater from outside of the model domain. While the model layers do terminate at the domain boundary, the boundary is not considered to be no-flow in reality. Boundaries across the model extents are therefore represented using the MODFLOW-USG general head boundary package (GHB) assigned to the highest consistently saturated layer cells in certain areas and are shown in Figure 3.3.

GHB simulates groundwater entering or leaving the model by assigning a potentiometric head to boundary cells. General head boundaries utilise a conductance rate calculated using the dimensions of the model cells, the distance to the neighbouring cell, and the calibrated horizontal hydraulic conductivity.

The potentiometric head in each GHB cell was calculated by deriving an equation for approximate height of the water table, as a function of topographic elevation, using recorded water levels at the project’s monitoring bores. The equation used is:

$$h = 0.004t2 + 0.5222t - 0.3554$$

- where h is potentiometric head; and
- t is topographic elevation.



LEGEND

- Locality
- Drainage
- Road
- Rail
- Proposed Hercules open pit
- Proposed Penfolds open pit
- Waste rock dump
- Other pit
- Model grid
- Model boundary
- General head boundary
- River cells

Hercules layout

- Hercules waste rock dump
- ROM
- Topsoil Stockpiles
- Penfolds waste rock dump
- Other mine activities

Hercules Groundwater Assessment (HER5001.001)

River and GHB cells

DATE
05/06/2025

AGE

FIGURE No:
3.3

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3.7.5 Groundwater abstraction

The model represents any groundwater abstraction that took place during the pumping tests from the production bore (HPB01A) and monitoring bore (HMB02), as presented in Table 2.2, using the MODFLOW-USG well package (WEL). Abstraction rates were included and spilt between layers (3 and 4) due to the screens of some bores intersecting one or more model layers (refer to Table 2.2). The locations of the bores from which abstraction was simulated are shown Figure 2.6.

3.7.6 Mining

The model represents the dewatering due to mining using the MODFLOW-USG drain package (DRN), with the progression of mining over time based on the schedules provided by NSR. Only future pit shells and underground workings were used to simulate the mining geometry and sequence as the primary purpose of the numerical groundwater model is to predict potential impacts from mining activities.

Within the project mining area, drain boundary conditions were applied to all intersected model cells with reference elevations set to the floor of each cell down to the base of pit shells provided. The drains were set up to remain active within the mining areas before being turned off during the care and maintenance period.

No mining was included in the calibration model and only in the predictive model with further detail provided in Section 5.1.5 regarding the DRN parameters and properties.

3.7.7 Input hydraulic properties

The input hydraulic properties applied are shown in Table 3.5. The hydraulic conductivity for each geological zone (Figure 3.2) was determined by using data from existing bore logs and the geological model data. Average data was applied for each layer, including data from the pumping tests.

Table 3.5 Input hydraulic parameters

Layer	Zone	Hydrostratigraphic unit description	Horizontal hydraulic conductivity (m/d)	Vertical hydraulic conductivity (m/d)	Specific yield (%)	Specific storage (m-1)
Layer 1	1	Alluvium	2.50E+00	2.50E-01	0.10	2.50E-06
	2	Colluvium	5.00E-01	2.50E-02	0.05	2.50E-06
	3	Regolith	5.00E-01	2.50E-02	0.05	2.50E-06
	4	Old pit voids	1.00E-01	5.00E-03	0.10	2.50E-06
	5	Old WRD	1.00E-01	5.00E-03	0.05	2.50E-06
Layer 2	6	Saprolite	1.00E-02	3.00E-03	0.05	1.00E-06
Layer 3	7	Saprock	1.00E+00	1.50E-01	0.10	1.00E-06
Layer 4	8	Fresh - mining area only	4.00E-02	4.00E-03	0.005	7.30E-06
Layer 5	9	Fresh - entire model domain	4.00E-02	4.00E-03	0.005	7.30E-06
Layer 6	10	Fresh - mining area only	1.00E-02	1.00E-03	0.005	7.30E-06
Layer 7	11	Fresh - entire model domain	1.00E-02	1.00E-03	0.005	7.30E-06
Layer 8	12	Fresh - mining area only	1.00E-03	1.00E-04	0.005	7.30E-06
Layer 9	13	Fresh - entire model domain	1.00E-03	1.00E-04	0.005	7.30E-06

Layer	Zone	Hydrostratigraphic unit description	Horizontal hydraulic conductivity (m/d)	Vertical hydraulic conductivity (m/d)	Specific yield (%)	Specific storage (m-1)
Layer 10	14	Fresh - mining area only	1.00E-03	1.00E-04	0.005	7.30E-06
Layer 11	15	Fresh - entire model domain	1.00E-03	1.00E-04	0.005	7.30E-06
Layer 12	16	Fresh - entire model domain	5.00E-04	5.00E-05	0.005	7.30E-06
Layer 13	17	Fresh - entire model domain	1.00E-04	1.00E-05	0.005	7.30E-06

4 Model calibration

4.1 Calibration method

The groundwater model was calibrated with a steady state run followed by a transient run (11 January 2025 to 16 January 2025) using available groundwater level and drawdown data. The model was calibrated by adjusting aquifer parameters and stresses to produce the best match between the observed and simulated water levels. Manual testing and automated parameterisation software (PEST_HP, Doherty, 2015) were used to determine optimal hydraulic parameters and recharge rates to achieve the best history match to the available water level measurements from monitoring bores and streamflow data.

As with all models the resulting calibration is non-unique. That is, an alternative set of parameters could produce an equally valid calibration, especially where simulations are sensitive to parameter combinations that lie within the calibration null space. The calibration null space refers to the model parameters and parameter combinations that are not informed by the available observed measurements. A model calibrated in this way is classified as conditionally calibrated (verified) in that it has not yet been falsified by tests against observation data (Middlemis and Peeters. 2018).

4.1.1 Calibration targets

Middlemis and Peeters (2018) suggest groundwater assessments consider the uncertainty around measurements used during the modelling process. The groundwater levels within the monitoring network during the pumping tests were measured manually with electronic water level dippers as well as by water level loggers and the water level converted to an elevation based on surveyed levels at the measurement point, which is usually the top of the bore casing. Modern electronic water dippers are expected to be accurate to within ±1 cm, and with the measurement point elevation also ±1 m to 10 cm depending on the method of surveying. The measurement of water levels within the monitoring network is therefore considered unlikely to have introduced any significant uncertainty to the model predictions.

For model calibration purposes, the observation bore water level records were weighted as follows:

- obviously anomalous measurements were removed; and
- datapoints for each location were weighted according to the formula, where w is the weight of the datapoint, and n is the number of datapoints for that monitoring point:

$$w=1/\sqrt{n}$$

Using this method, bores with longer records have a lower weighting per datapoint, but the location contributes equally with other locations in the combined dataset.

The model was calibrated to the observed water levels (refer to Section 2.8), with the 'best calibrated' model returning the lowest objective function (phi) value (i.e., the lowest statistical difference between the observed and modelled values across the chosen dataset).

In total, there are four observation points from which water levels and drawdown data was used to calibrate to. These observation points yielded a total of 590 observations. As two of these four observations points were used as pumping bores during the pumping tests, these two pumped bores (HPB01A and HMB02) were assigned lower weightings during the calibration. The lower weighting means that the automated parameterisation software (PEST) will use a scale for the proportion of data to be used based on scaled residual head (phi) after each iteration.

The key motivation why the two pumped bores' observations were assigned lower weightings is due to that observations from pumping bores are often subject to increased uncertainty from factors such as well bore storage and extract volumes of water abstracted via the bore's screens.

4.1.2 Pilot points

The water level responses recorded in the pumping and monitoring bores vary depending on a range of factors including geology, location, and climatic conditions. Water levels recorded in the bores indicate heterogeneous hydraulic properties and recharge rates. To represent heterogeneity within the model domain and provide a degree of flexibility during the calibration, a series of pilot points were added to each model layer as a basis to define spatial variability. The locations of the pilot points in the groundwater model are shown in Figure 4.1.

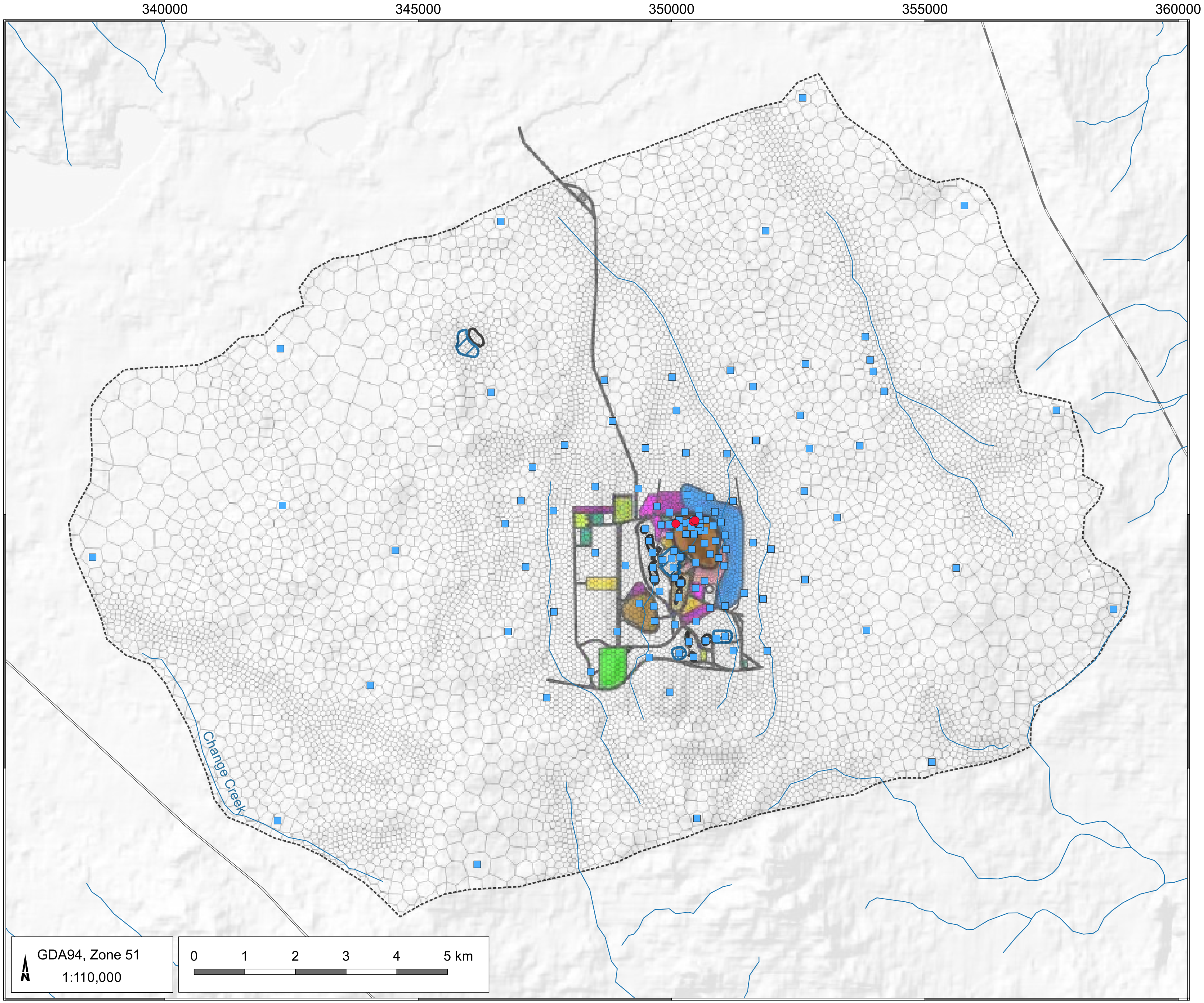
Pilot points distant from the project area were fixed as they are not near to monitoring points or mining activities. The calibration process therefore focused on water level and drawdown observations from pumping and monitoring bores around the Project area, where the pilot points remained adjustable.

The pilot points were interpolated across the model domain in each layer of the model using ordinary automatic Kriging through PLPROC (Watermark Numerical Computing, 2015). Horizontal hydraulic conductivity was adjusted, and the absolute values were capped to ensure maximum and minimum values did not exceed appropriate ranges for each unit. Specific storage (Ss) values are constrained by literature values derived from regional studies of similar strata. The starting point for all pilot point multipliers was assumed to be 1.

Table 4.1 presents the general parameter constraints applied to all geological units present within the model layers.

Table 4.1 General parameter constraints

Unit	Min Kh (m/d)	Max Kh (m/d)	Max Kv:Kh	Min Sy (%)	Max Sy (%)	Min Ss (m^{-1})	Max Ss (m^{-1})
Alluvium	1.00E-04	2.00E+02	1.00E+00	1.00E-01	4.00E-01	1.30E-07	3.70E-05
Colluvium	1.00E-08	1.00E+01	1.00E+00	1.00E-03	2.00E-01	1.30E-07	3.70E-05
Regolith	1.00E-08	5.00E+01	1.00E+00	1.00E-03	5.00E-01	1.30E-07	3.70E-05
Old pit voids	1.00E-08	5.00E+01	1.00E+00	1.00E-03	5.00E-01	1.30E-07	3.70E-05
Old WRD	1.00E-08	5.00E+01	1.00E+00	1.00E-03	5.00E-01	1.30E-07	3.70E-05
Saprolite	1.00E-08	1.00E+01	1.00E+00	1.00E-03	2.00E-01	1.30E-07	3.70E-05
Saprock	1.00E-08	1.00E+02	1.00E+00	1.00E-03	3.00E-01	1.30E-07	3.70E-05
Bedrock	1.00E-10	5.00E+01	1.00E+00	1.00E-03	2.00E-01	1.30E-07	3.70E-05



LEGEND

- Drainage
- Road
- Rail
- Model grid
- Model boundary

Hercules layout

- Dewatering pipelines
- Flood bunding
- Hercules open pit
- Hercules Village
- Hercules waste rock dump
- Laydown
- Offices
- Paste Sands
- Paste Plant
- Roads
- ROM
- Topsoil Stockpiles
- Turkeys Nest
- UG Power Plant
- UG Workshop & Plant
- Magazine
- Penfolds open pit
- Penfolds waste rock dump
- Historic Open Pit
- Historic Waste Rock Dump

Hercules Groundwater Assessment (HER5001.001)

Locations of pilot points

DATE
05/06/2025

AGE

FIGURE No:
4.1

G:\Projects\HER5001.001 Hercules Groundwater Assessment Phase 3\3_GIS\Workspaces\001_Deliverable1\04.01_HER5001_Locations of pilot points.qgz

4.2 Calibration results

Figure 4.2 and Figure 4.3 represents the observed versus simulated groundwater levels determined from the calibration in a scattergram where a perfect match between simulated and observed water levels would show the data points directly on the diagonal line.

The calibrated steady state model's unweighted scaled root mean square (SRMS) was 16.95% (Figure 4.2) Although the calibrated steady state model's unweighted SRMS for all four observations points is high, the total root mean square was only 0.71 m. The calibrated steady state model's squared correlation (R^2) value for only the two monitoring bores (HMB01S and HMB01D) was 100% and thus represents a good fit.

The transient state scattergram of observed versus simulated groundwater levels are shown in Figure 4.3 and shows an unweighted SRMS calculated at 5.18% and R^2 value of 94% for all of the observation data. This is about half of the SRMS target of <10% suggested in the Australian Modelling Guidelines (Barnett, 2012), which represents an excellent comparison. Appendix C presents the calibration hydrographs, showing the fit between modelled and observed groundwater levels during the calibration period.

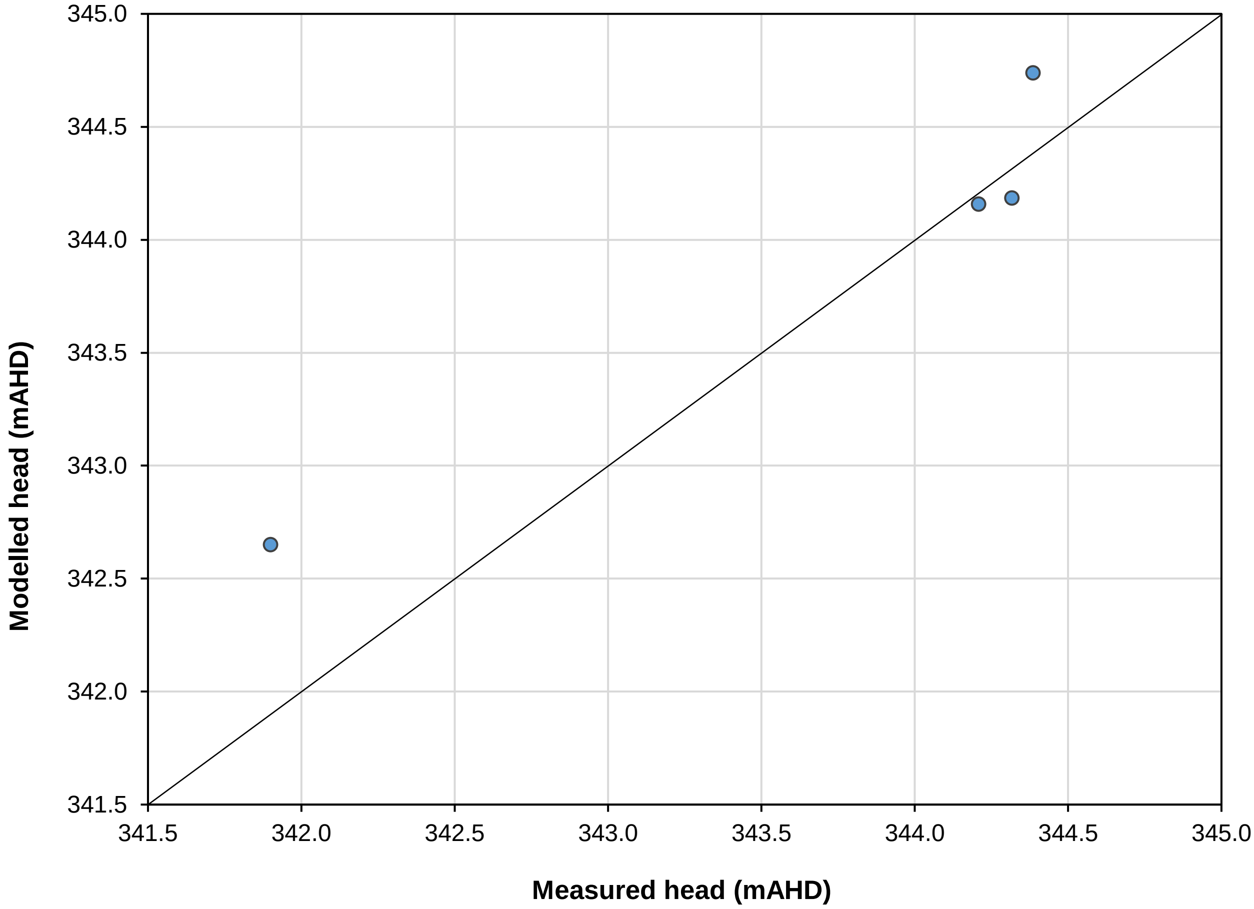


Figure 4.2 Steady state calibration – modelled vs observed groundwater levels

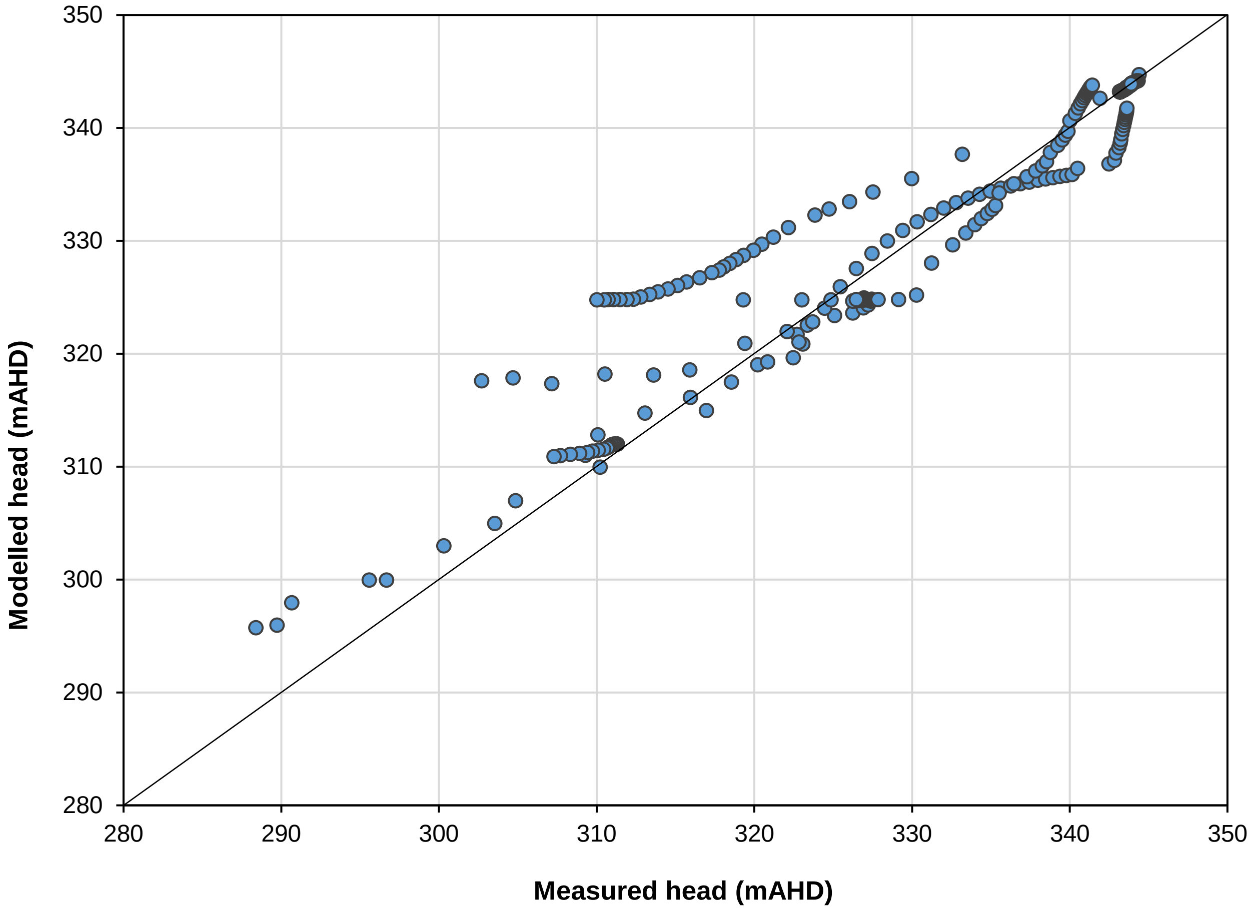
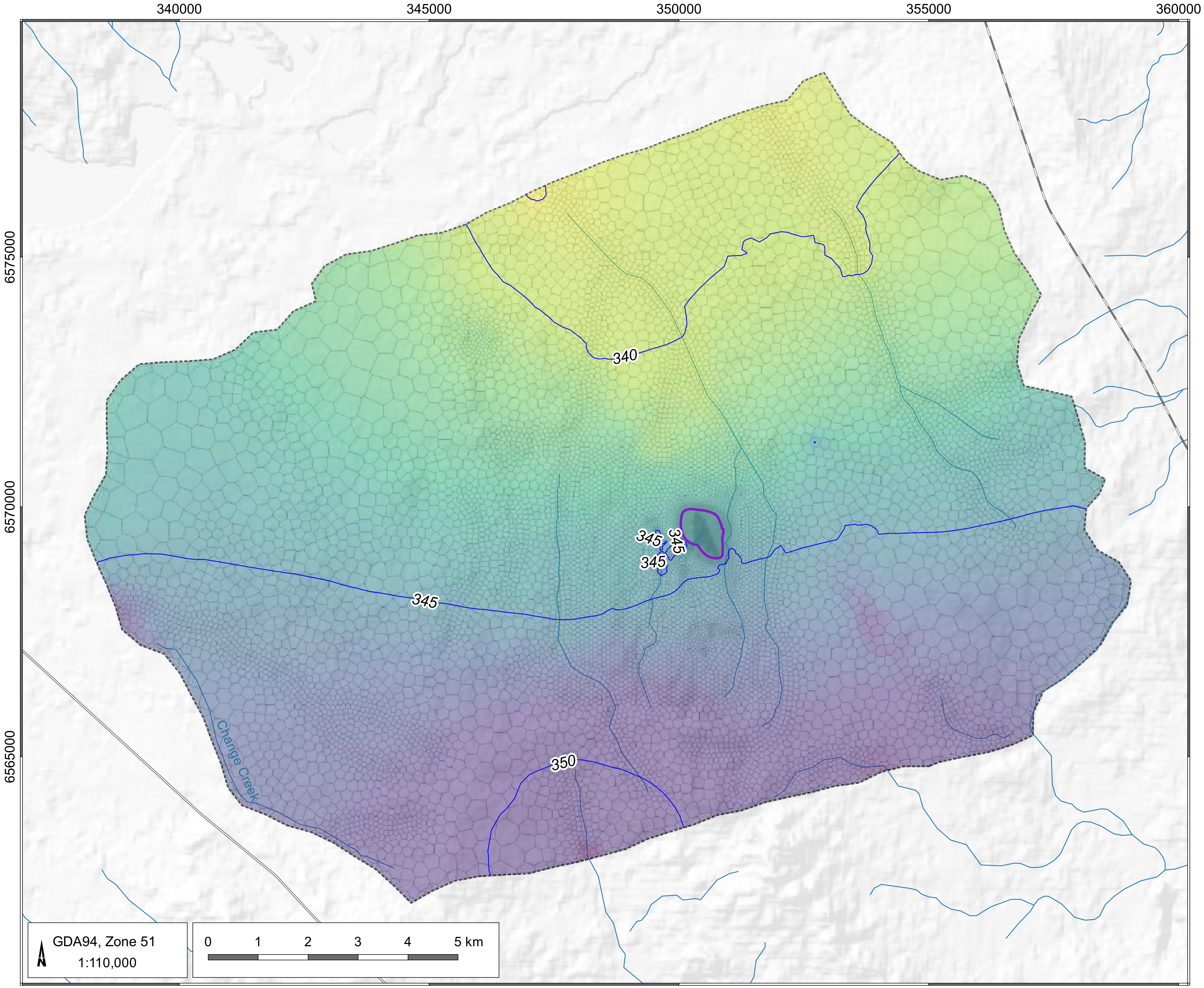


Figure 4.3 Transient calibration – modelled vs observed groundwater levels

4.2.1 Calibration heads

The calibrated steady state groundwater levels, representative for January 2025, are presented in Figure 4.4 and show groundwater levels that generally follow topography and flow in a northernly direction. Varying groundwater levels are evident near the historic mining areas including the historic open pits and WRD west of the proposed Hercules open pit.



LEGEND

- Drainage
- Road
- Rail
- Open pit outline
- Model grid
- Model boundary
- Predicted groundwater level contour (mAHD)

Predicted groundwater levels (mAHD)

- 334
- 340
- 342
- 343
- 344
- 345
- 346
- 347
- 385

Hercules Groundwater Assessment
(HER5001.001)

Predicted steady state model (January 2025) groundwater levels (mAHD)

DATE
14/04/2025

AGE

FIGURE No:
4.4

G:\Projects\HER5001.001 Hercules Groundwater Assessment Phase 3\3_GIS\Workspaces\001_Deliverable1\04.04_HER5001_Predicted steady state model (January 2025) groundwater levels (mAHD).qgz

4.2.2 Hydraulic parameters

Table 4.2 summarises the calibrated average hydraulic conductivity value for each of the hydrostratigraphic units within the model domain for a set of depth ranges for each layer. The values presented are the base case value for each layer.

Table 4.2 Calibrated hydraulic conductivity results

Layer	Zone	Hydrostratigraphic unit description	Horizontal hydraulic conductivity (m/d)	Vertical hydraulic conductivity (m/d)	Specific yield (%)	Specific storage (m-1)
Layer 1	1	Alluvium	1.35E+01	2.75E-02	2.79E-02	1.76E-05
	2	Colluvium	3.98E-01	5.29E-02	7.74E-02	2.24E-05
	3	Regolith	2.80E-01	1.38E-01	3.57E-01	2.01E-05
	4	Old pit voids	1.32E-01	7.98E-02	4.79E-02	1.54E-05
	5	Old WRD	7.70E-02	3.97E-02	6.14E-02	1.61E-05
Layer 2	6	Saprolite	9.95E-04	2.59E-01	2.98E-02	2.83E-05
Layer 3	7	Saprock	1.63E-01	3.97E-01	8.90E-02	8.34E-06
Layer 4	8	Fresh - mining area only	2.63E-02	7.72E-01	1.29E-02	1.44E-05
Layer 5	9	Fresh - entire model domain	4.09E-03	2.53E-02	6.16E-03	1.27E-05
Layer 6	10	Fresh - mining area only	4.72E-03	4.76E-02	3.86E-03	3.29E-05
Layer 7	11	Fresh - entire model domain	3.20E-03	8.23E-02	3.31E-02	1.57E-05
Layer 8	12	Fresh - mining area only	1.77E-03	7.05E-02	1.07E-03	1.59E-05
Layer 9	13	Fresh - entire model domain	5.14E-04	1.38E-01	1.06E-02	2.69E-05
Layer 10	14	Fresh - mining area only	4.90E-03	6.40E-02	3.83E-03	2.59E-05
Layer 11	15	Fresh - entire model domain	1.18E-03	4.11E-02	4.07E-03	2.03E-05
Layer 12	16	Fresh - entire model domain	8.88E-04	1.32E-01	4.39E-03	2.19E-05
Layer 13	17	Fresh - entire model domain	6.41E-05	5.93E-02	1.24E-02	2.86E-05

4.2.3 Recharge

The recharge zones determined during the steady state and transient calibration have been summarised and discussed in Section 3.7.1. Generally, the recharge rates shown in Table 4.3 derived during the calibration are low for each recharge zone, but higher than the initially calculated recharge rates.

Table 4.3 Calibrated recharge zones

Recharge zone	Average annual recharge (mm/year)	% of net annual rainfall
Alluvium	0.43	0.16%
Colluvium	0.19	0.07%
Regolith	0.15	0.06%
Old pit voids	1.69	0.63%
WRDs	1.69	0.63%

4.2.4 Water budget

The mass balance error is the difference between calculated model inflows and outflows. This was 0.0% at the completion of the steady state calibration. The maximum percent discrepancy at any time step in the simulation was also 0.0%. This value indicates that the model is stable and achieves an accurate numerical solution. Table 4.4 shows the water budget for the steady state model and averages from the transient model for the period 11 January 2025 to 16 January 2025.

Table 4.4 Steady state and transient water budgets

Parameter	Steady state model			Transient model average		
	In (m^3/day)	Out (m^3/day)	In-Out (m^3/day)	In (m^3/day)	Out (m^3/day)	In-Out (m^3/day)
Storage	-	-	-	161.0	-34.5	126.4
Rainfall recharge	77.0	0.0	77.0	0.0	0.0	0.0
River	0.0	0.0	0.0	0.0	0.0	0.0
Evapotranspiration	0.0	-17.6	-17.6	0.0	-17.6	-17.6
General head boundary	108.3	-167.7	-59.4	108.4	-167.7	-59.3
Wells	-	-	-	-	-49.4	-49.4
Total	**185.4**	**-185.3**	**0.0**	**269.3**	**-269.3**	**0.0**

Note: "-" indicates not applicable.

5 Model predictions

Following the calibration period, the model simulation was extended to include the 16 years of proposed mining at the Hercules open pit and underground as well as an additional 2,500 years to predict the Hercules open pit final void equilibrium water level. The proposed Penfolds open pit extension was not included in the predictive model.

5.1 Predictive model setup

5.1.1 Stress periods

The predictive model was extended by 16 years during the operational phase and 2,500 years during the post-closure phase with stress periods as listed in Table 5.1 below.

Table 5.1 Predictive model stress period timing and counts

Stress period	Stress period count	Stress period intervals (days)	Total duration (days)
200	1	0.54	0.54
201	1	14	14
202	1	59	59
203 – 271	69	90 to 92 (1 quarter)	6,300
272 – 274	3	365 to 366 (1 year)	1,096
275 – 277	3	1,826 to 1,827 (5 years)	5,479
278 – 281	4	3,652 to 3,653 (10 years)	14,609
282 – 306	25	36,524 to 36,525 (100 years)	913,106
Total	**107**	**-**	**940,663.54**

5.1.2 Recharge

As noted in Section 5.1.1, the predictive model was extended by 2,516 years with stress periods as listed in Table 5.1. The average rainfall was calculated for each stress period using the historic rainfall presented in Table 2.1 and then adopted for the recharge inputs for the predictive.

5.1.3 Evapotranspiration

The constant evapotranspiration rate of 2,140 mm/year was assigned across the model domain, consistent with the constant rate applied in the calibration model.

5.1.4 Groundwater abstraction

The predictive model assumed no groundwater abstraction for existing or future production bores.

5.1.5 Mining

As described in Section 1.3, the proposed Hercules open pit mining was simulated for the first four years followed by 12 years of underground mining. The current proposed open pit is planned to reach an approximate depth of 245 meters below ground level (mbgl) while the underground mine is proposed to extend from 280 mAHD to -455 mAHD (approximately 735 mbgl).

5.1.6 Modelling scenarios

For the predictive model, three scenarios were set up to simulate the potential groundwater environment with- and without the proposed mining activities. The different modelling scenarios were set up with identical boundary conditions, with the only exception being that the no mine scenario did not include any mining activities and the closure scenario includes a long post-mining period where groundwater levels are permitted to recover to a level of post-mining equilibrium.

The different scenarios are described further below:

1. *No mine (null) scenario*: This predictive model excludes the proposed open pit and underground mining at Hercules.
2. *Mine scenario (base case)*: This predictive model includes the proposed open pit and underground mining at Hercules.
3. *Closure scenario*: This predictive model includes no mining activities beyond the proposed 16 years of mining at Hercules and the groundwater environment is allowed to recover to provide prediction regarding long-term equilibrium water levels within the Hercules open pit void and the surrounding groundwater levels.

5.2 Predictions

5.2.1 Drawdown during mining

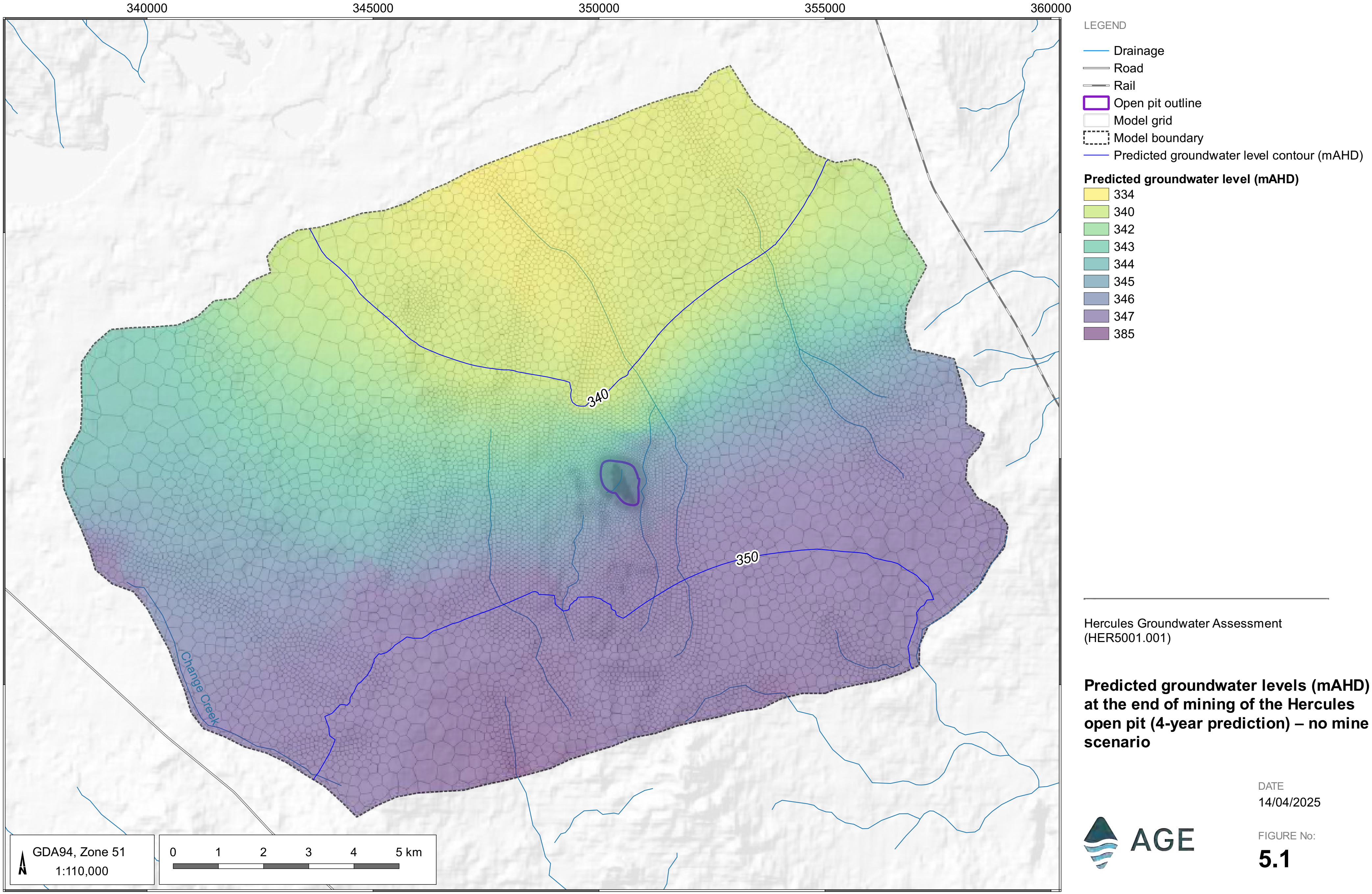
On average, the rate of groundwater seepage into the proposed Hercules open pit will exceeds the rate at which the surrounding aquifers can recharge. This process will lead to drawdown of the groundwater potentiometric surface (i.e., drawdown) in the strata surrounding the proposed mining area, including the underground mine.

The water table's groundwater levels at the end of predictive year 4, following completion of the proposed open pit, for both the no mine and mine scenarios are shown in Figure 5.1 and Figure 5.2, respectively. The regional groundwater levels for both scenarios are very similar while the local groundwater levels surrounding the proposed Hercules open pit shows deeper groundwater levels at the end of predictive year 4.

The predicted extent of groundwater drawdown, based on the 1 m contour, in the water table directly attributable to the proposed Hercules open pit is illustrated on Figure 5.3 which shows the maximum drawdown following completion of the proposed open pit reaching approximately 245 m. The radius of influence from drawdown extends approximately 3 km radially around the mining area.

The water table's groundwater levels at the end of predictive year 16, following completion of the proposed underground mine, for both the no mine and mine scenarios are shown in Figure 5.4 and Figure 5.5, respectively. The regional groundwater levels for both scenarios are very similar while the local groundwater levels surrounding the proposed Hercules mining area shows deeper groundwater levels at the end of predictive year 16.

The predicted extent of groundwater drawdown, based on the 1 m contour, in the water table directly attributable to the proposed Hercules open pit and underground mine is illustrated on Figure 5.6 which shows the maximum drawdown following completion of the proposed open pit reaching approximately 480 m. This deeper drawdown is focussed within the centre of the proposed pit where the underground infrastructure, including the portal, penetrate into the subsurface and thus depressurises the water table. The radius of influence from drawdown extends approximately 5 to 7 km radially around the mining area.



Hercules Groundwater Assessment (HER5001.001)

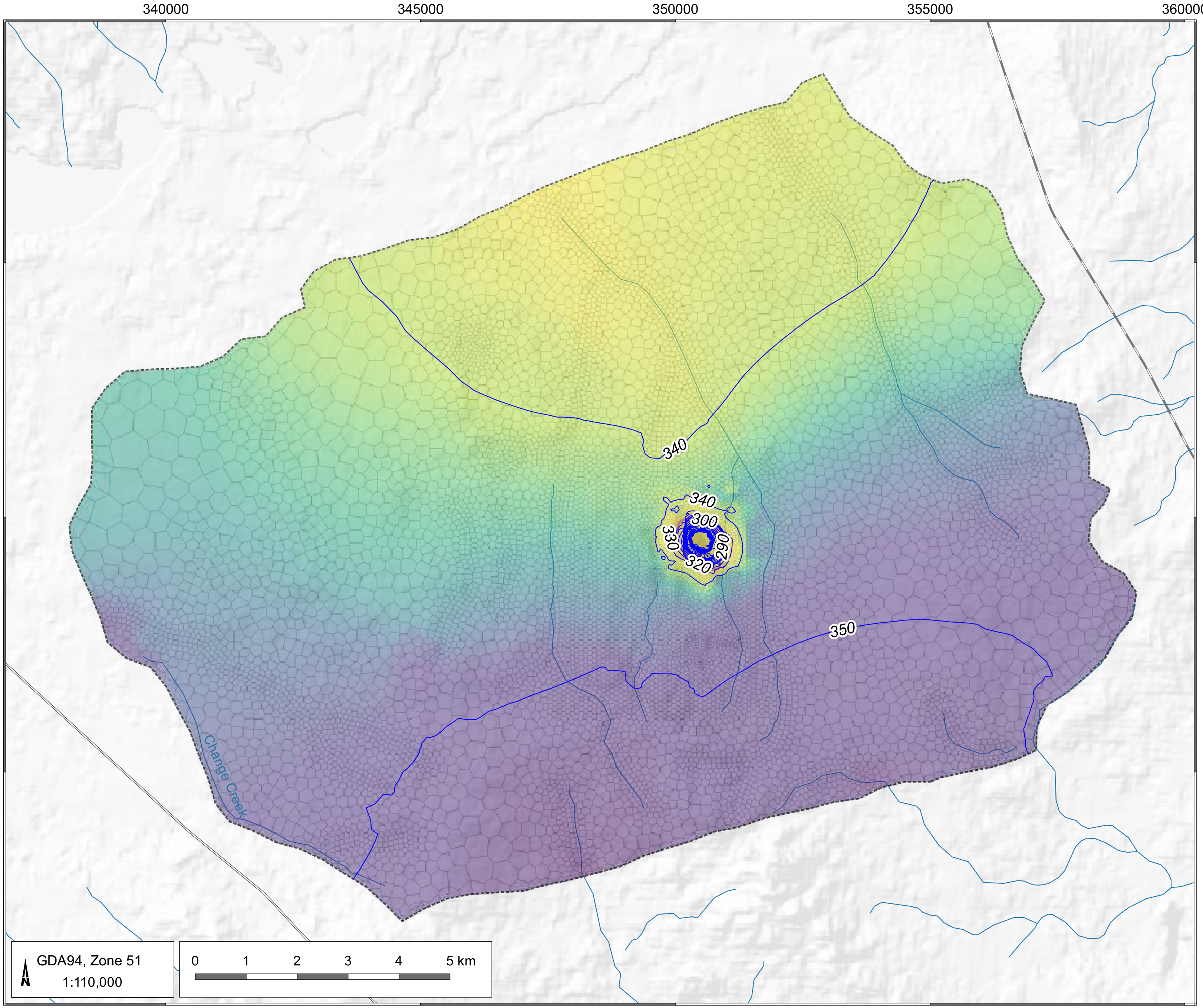
Predicted groundwater levels (mAHD) at the end of mining of the Hercules open pit (4-year prediction) – no mine scenario

DATE
14/04/2025

AGE

FIGURE No:
5.1

G:\Projects\HER5001.001 Hercules Groundwater Assessment Phase 3\3_GIS\Workspaces\001_Deliverable1\05.01_HER5001_Pred GWLs end of mining at Hercules OP (4-year prediction) – NM sce.qgz



LEGEND

- Drainage
- Road
- Rail
- Open pit outline
- Model grid
- Model boundary
- Predicted groundwater level contour (mAHD)

Predicted groundwater level (mAHD)

- 334
- 340
- 342
- 343
- 344
- 345
- 346
- 347
- 385

Hercules Groundwater Assessment (HER5001.001)

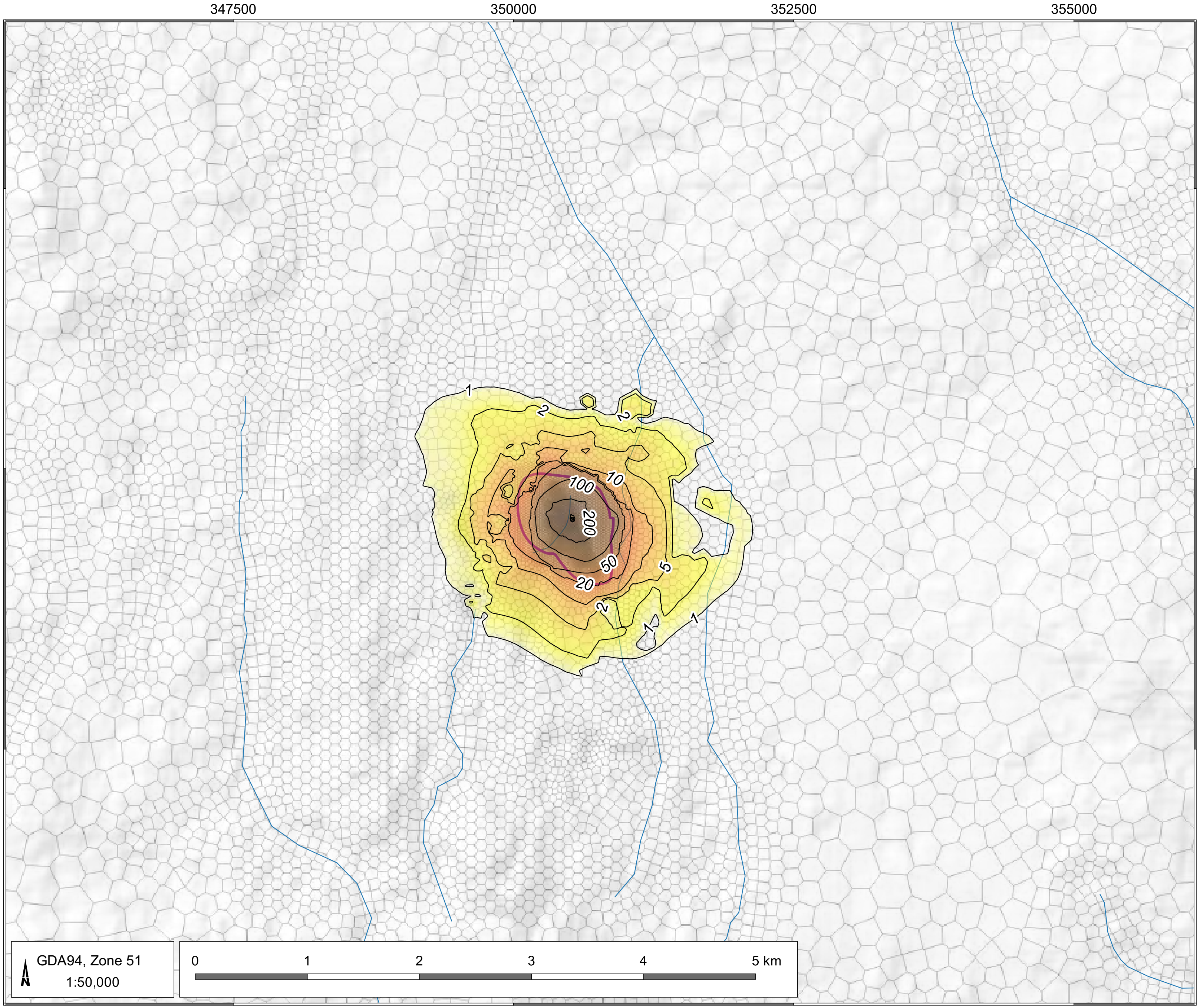
Predicted groundwater levels (mAHD) at the end of mining of the Hercules open pit (4-year prediction) – mine scenario

DATE
14/04/2025

AGE

FIGURE No:
5.2

G:\Projects\HER5001.001 Hercules Groundwater Assessment Phase 3\3_GIS\Workspaces\001_Deliverable1\05.02_HER5001_Pred GWLs end of mining at Hercules OP (4-year prediction) – mine sce.qgz



LEGEND

- Drainage
- Road
- Rail
- Open pit outline
- Model grid
- Model boundary
- Predicted drawdown contour (m)

Predicted drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200

Hercules Groundwater Assessment
(HER5001.001)

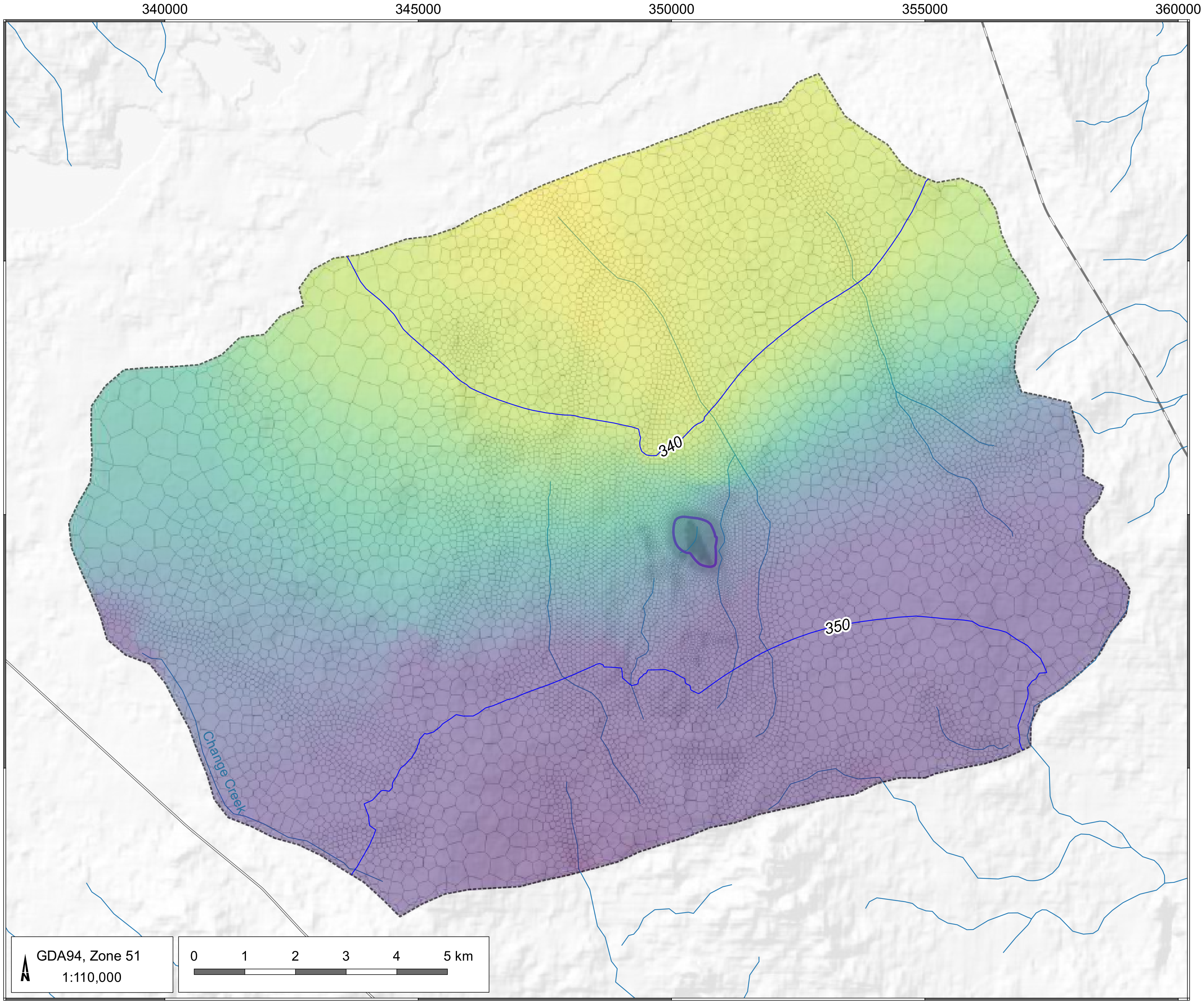
Predicted water table drawdown (m) at the end of mining of the Hercules open pit (4-year prediction)

AGE

DATE
14/04/2025

FIGURE No:
5.3

G:\Projects\HER5001.001 Hercules Groundwater Assessment Phase 3\3_GIS\Workspaces\001_Deliverable1\05.03_HER5001_Predicted DD at the end of mining of the Hercules OP (4-year prediction).qgz



LEGEND

- Drainage
- Road
- Rail
- Open pit outline
- Model grid
- Model boundary
- Predicted groundwater level contour (mAHD)

Predicted groundwater level (mAHD)

- 334
- 340
- 342
- 343
- 344
- 345
- 346
- 347
- 385

Hercules Groundwater Assessment (HER5001.001)

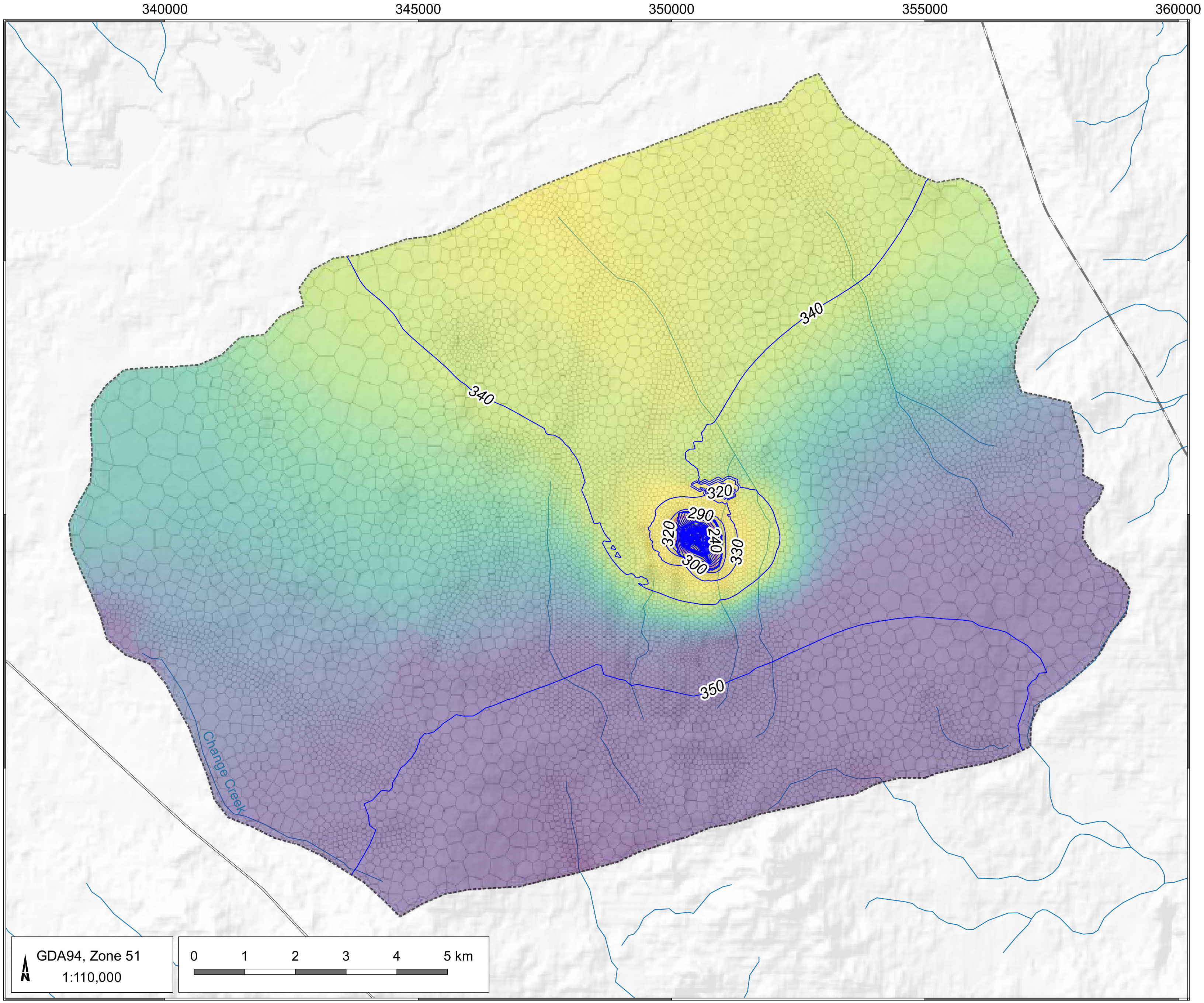
Predicted groundwater levels (mAHD) at the end of mining of the Hercules underground (16-year prediction) – no mine scenario

DATE
14/04/2025

AGE

FIGURE No:
5.4

G:\Projects\HER5001.001 Hercules Groundwater Assessment Phase 3\3_GIS\Workspaces\001_Deliverable1\05.04_HER5001_Pred GWLs end of mining at Hercules UG (16-year prediction) – nm sce.qgz



LEGEND

- Drainage
- Road
- Rail
- Open pit outline
- Model grid
- Model boundary
- Predicted groundwater level contour (mAHD)

Predicted groundwater level (mAHD)

- 334
- 340
- 342
- 343
- 344
- 345
- 346
- 347
- 385

Hercules Groundwater Assessment (HER5001.001)

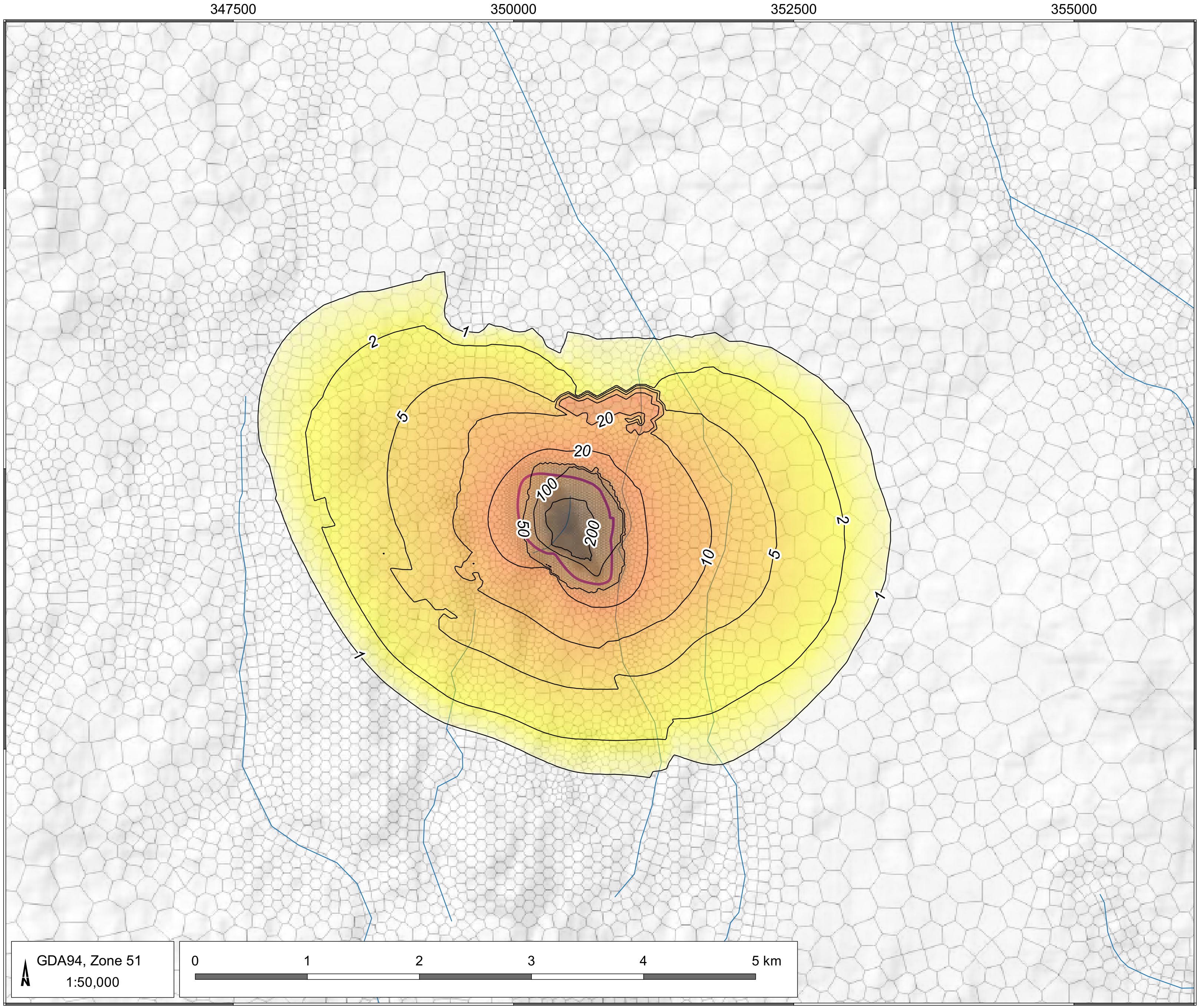
Predicted groundwater levels (mAHD) at the end of mining of the Hercules underground (16-year prediction) – mine scenario

DATE
14/04/2025

AGE

FIGURE No:
5.5

G:\Projects\HER5001.001 Hercules Groundwater Assessment Phase 3\3_GIS\Workspaces\001_Deliverable1\05.05_HER5001_Pred GWLs end of mining at Hercules UG (16-year prediction) –mine sce.qgz



LEGEND

- Drainage
- Road
- Rail
- Open pit outline
- Model grid
- Model boundary
- Predicted drawdown contour (m)

Predicted drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200

Hercules Groundwater Assessment
(HER5001.001)

Predicted water table drawdown (m) at the end of mining of the Hercules underground (16-year prediction)

DATE
14/04/2025

AGE

FIGURE No:
5.6

G:\Projects\HER5001.001 Hercules Groundwater Assessment Phase 3\3_GIS\Workspaces\001_Deliverable1\05.06_HER5001_Predicted DD at the end of mining of the Hercules underground (16-year prediction).qgz

5.2.2 Mine inflows

The volume of water predicted to flow into the proposed Hercules open pit and underground was calculated per model stress period using the drain boundary condition in MODFLOW-USG. As mentioned in Section 3.7.6, the drain boundary condition represents the dewatering of the open pit and underground mining areas and thus provides a prediction of the total inflow from the geological layers above the pit floor and adjacent to the underground mining development. As the model prediction does not include evaporation from the open pit area during active mining, the actual water volumes reporting and pumped from a pit sump will differ.

The predicted open pit inflows peak after approximately 1.5 years of mining, with approximately 4,100 m^3/day expected to seep into the proposed open pit, as shown in Figure 5.7. Following completion of the active open pit mining, dewatering is assumed to remain in place to ensure a safe and dry working environment for the underground mine where open pit inflows decrease to about 500 m^3/day at the end of the underground operations.

The predicted underground mine inflows peak after approximately 10 years of mining, with approximately 4,500 m^3/day expected to enter the underground mining area, as also shown in Figure 5.7. The total mine inflows over the proposed life of mine are variable depending on the area being mined with the model predictions showing 1,400 m^3/day or more inflows from mining year 1 onwards.

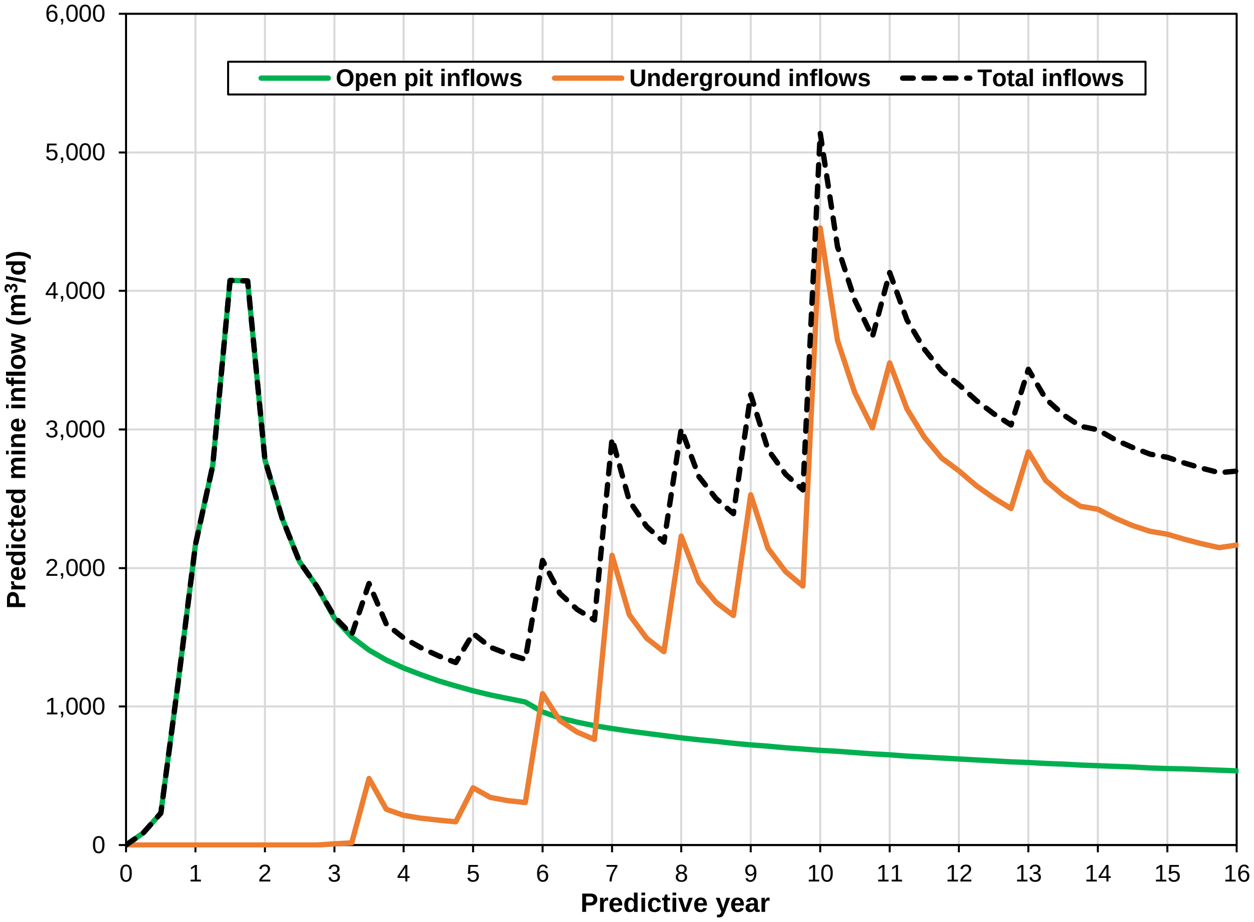


Figure 5.7 Total predicted inflows to the proposed Hercules open pit and underground mine

5.2.3 Post-closure void recovery water level

At the completion of mining, dewatering of the Hercules open pit and underground will cease and the final void will be left to flood, which will be followed by rising in-pit water levels to a new static level. Away from the mine, the propagation of drawdown outwards away from the mine will continue, but the rate of that propagation will diminish as groundwater levels at the mine workings rise and the gradient back to the mine reduces.

To simulate the groundwater level rebound, post closure pit inflows, and long-term equilibrium water levels, all drains were removed from the model at the end of prediction year 16. The hydraulic properties adopted in the post-mining groundwater model simulation are summarized in Table 5.2.

Table 5.2 Post mining model setup

Model Feature	Adopted Value
Void $K_{h\,\&\,y}$	1,000 m/day
Void Recharge	110% of rainfall to account for direct rainfall into the void as well as surface runoff.
Void EVT	Up to 2,413 mm/year
Void S_s	5E-06 m^{-1} (~compressibility of water)
Void Sy	1.0

Figure 5.8 shows the simulated Hercules open pit void recovery water level obtained from the groundwater model. The groundwater model's long-term Hercules void water level reaches an equilibrium at about 336 mAHD approximately 200 years post mining. The groundwater model does not simulate long-term transient climatic influences including rainfall and evaporation, and as such, the long-term void equilibrium water level does not indicate any seasonal or cyclical fluctuations.

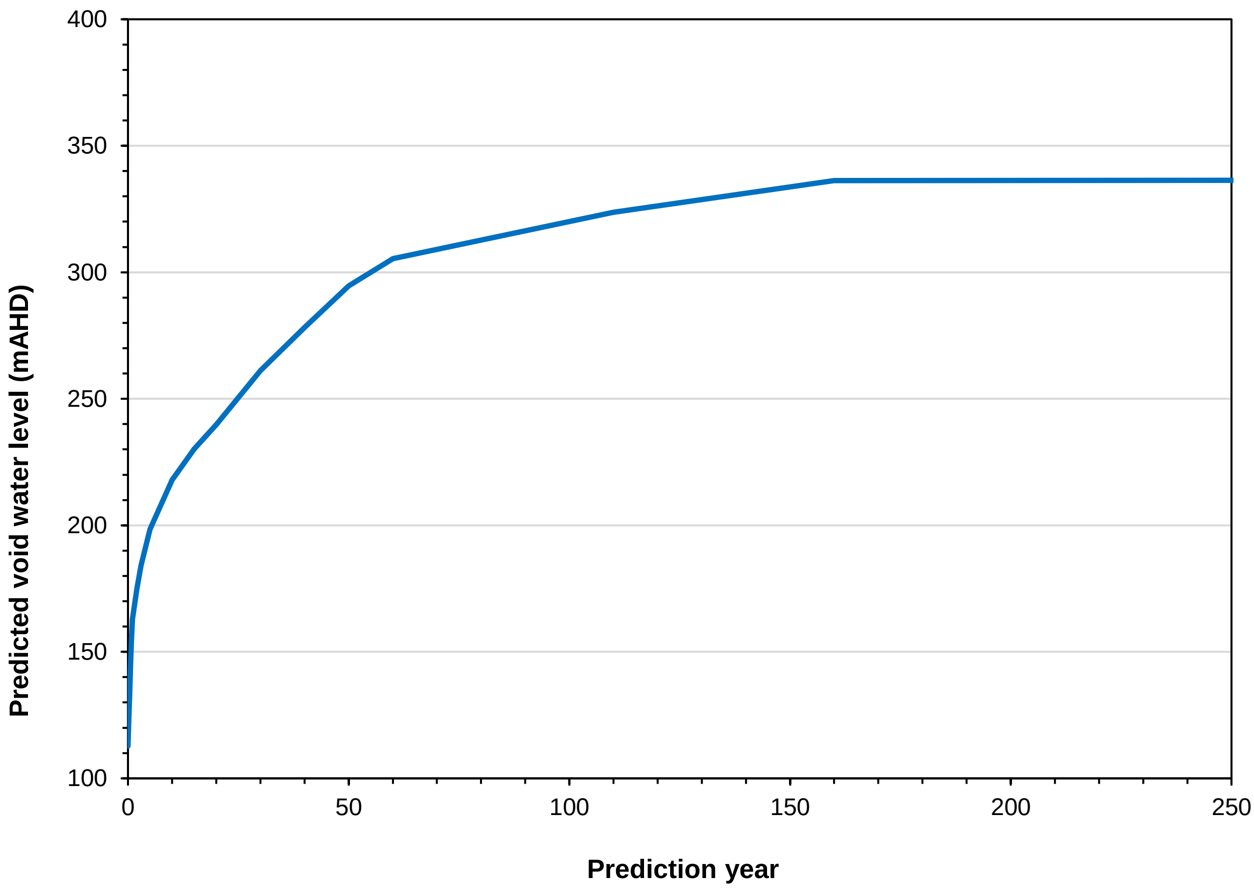


Figure 5.8 Predicted Hercules void recovery water level

6 Uncertainty Analysis

Groundwater models represent complex environmental systems and processes in a simplified manner. This means that predictions from groundwater models, like so many other environmental models, are inherently uncertain. When considered in a risk management context, a single calibrated model is insufficient to fully predict the range of potential impacts and their likelihood. A robust uncertainty analysis is therefore important for regulatory decision-making to ensure management options and approaches are appropriate to the level of risk and its likelihood for any particular impact.

The sections below describe the methodology and results of the uncertainty analysis completed for the Hercules numerical model.

6.1 Methodology

A calibration constrained Monte Carlo uncertainty analysis was undertaken to quantify the magnitude of uncertainty in the future impacts predicted by the model. This type of analysis produces probability distributions for the prediction by ranking a range of predicted inflows based on calibrated models with different parameter combinations.

This uncertainty analysis was undertaken as a three-part process. To begin, the logical range for each parameter was determined, and then 500 model realisations were created, each having differing values of key parameters. The realisations were tested and the models that failed to converge or could not achieve adequate calibration were rejected. Outputs from the uncertainty modelling were processed in accordance with the risk-based calibrated language proposed in Middlemis & Peeters (2018). The ranges adopted are shown in Table 6.1.

Table 6.1 Calibrated uncertainty modelling language

Narrative descriptor	Probability class	Description	Colour code
Very likely	90 – 100 %	Likely to occur even in extreme conditions	
Likely	67 – 90 %	Expected to occur in normal conditions	
About as likely as not	33 – 67 %	About an equal change of occurring as not	
Unlikely	10 – 33 %	Not expected to occur in normal conditions	
Very unlikely	0 – 10 %	Not likely to occur even in extreme conditions	

6.2 Parameter generation

A suite of 500 unique model realisations was generated, with each parameter randomly selected within the assigned range, which is documented in Table 6.2 through to Table 6.6. The parameters were assumed to possess a log-normal distribution with a mean value, or the most probable value, derived from the model calibration exercise.

Table 6.2 Uncertainty range – Horizontal hydraulic conductivity (Kh)

Layer	Zone	Hydrostratigraphic unit description	Horizontal hydraulic K (m/day) Lower	Horizontal hydraulic K (m/day) Optimum	Horizontal hydraulic K (m/day) Upper
Layer 1	1	Alluvium	1.30E+00	1.35E+01	1.30E+02
	2	Colluvium	3.87E-02	3.98E-01	3.87E+00
	3	Regolith	2.14E-02	2.80E-01	2.14E+00
	4	Old pit voids	1.02E-02	1.32E-01	1.02E+00
	5	Old WRD	9.51E-03	7.70E-02	9.51E-01
Layer 2	6	Saprolite	8.28E-05	9.95E-04	4.14E-02
Layer 3	7	Saprock	5.97E-03	1.63E-01	3.73E+01
Layer 4	8	Fresh - mining area only	5.09E-04	2.63E-02	2.54E-01
Layer 5	9	Fresh - entire model domain	1.45E-04	4.09E-03	7.27E-02
Layer 6	10	Fresh - mining area only	4.85E-05	4.72E-03	4.85E-02
Layer 7	11	Fresh - entire model domain	2.84E-05	3.20E-03	2.84E-02
Layer 8	12	Fresh - mining area only	1.59E-04	1.77E-03	1.59E-02
Layer 9	13	Fresh - entire model domain	5.49E-05	5.14E-04	5.49E-03
Layer 10	14	Fresh - mining area only	4.76E-04	4.90E-03	4.76E-02
Layer 11	15	Fresh - entire model domain	9.66E-05	1.18E-03	9.66E-03
Layer 12	16	Fresh - entire model domain	7.73E-05	8.88E-04	7.73E-03
Layer 13	17	Fresh - entire model domain	5.71E-06	6.41E-05	5.71E-04

Table 6.3 Uncertainty range – Vertical hydraulic conductivity (Kz)

Layer	Zone	Hydrostratigraphic unit description	Vertical hydraulic K (m/day) Lower	Vertical hydraulic K (m/day) Optimum	Vertical hydraulic K (m/day) Upper
Layer 1	1	Alluvium	5.41E-03	3.71E-01	2.71E+01
	2	Colluvium	2.17E-04	2.10E-02	1.09E+00
	3	Regolith	2.86E-04	3.86E-02	1.43E+00
	4	Old pit voids	9.18E-05	1.05E-02	4.59E-01
	5	Old WRD	3.41E-05	3.05E-03	1.70E-01
Layer 2	6	Saprolite	1.90E-06	2.58E-04	4.14E-02
Layer 3	7	Saprock	2.34E-04	6.48E-02	3.73E+01
Layer 4	8	Fresh - mining area only	3.08E-05	2.03E-02	2.54E-01
Layer 5	9	Fresh - entire model domain	6.15E-07	1.03E-04	1.54E-02
Layer 6	10	Fresh - mining area only	2.42E-07	2.25E-04	1.21E-02
Layer 7	11	Fresh - entire model domain	2.62E-07	2.64E-04	1.31E-02
Layer 8	12	Fresh - mining area only	9.35E-07	1.25E-04	4.68E-03
Layer 9	13	Fresh - entire model domain	7.88E-07	7.07E-05	3.94E-03
Layer 10	14	Fresh - mining area only	2.65E-06	3.14E-04	1.32E-02
Layer 11	15	Fresh - entire model domain	5.02E-07	4.83E-05	2.51E-03
Layer 12	16	Fresh - entire model domain	1.12E-06	1.17E-04	5.62E-03
Layer 13	17	Fresh - entire model domain	3.55E-08	3.80E-06	1.78E-04

Table 6.4 Uncertainty range – Specific yield (Sy)

Layer	Zone	Hydrostratigraphic unit description	Specific yield (-) Lower	Specific yield (-) Optimum	Specific yield (-) Upper
Layer 1	1	Alluvium	3.66E-03	2.79E-02	5.00E-01
	2	Colluvium	6.92E-03	7.74E-02	5.00E-01
	3	Regolith	7.22E-03	3.57E-01	5.00E-01
	4	Old pit voids	5.17E-03	4.79E-02	5.00E-01
	5	Old WRD	7.25E-03	6.14E-02	5.00E-01
Layer 2	6	Saprolite	2.66E-03	2.98E-02	2.00E-01
Layer 3	7	Saprock	4.72E-03	8.90E-02	5.00E-01
Layer 4	8	Fresh - mining area only	1.18E-03	1.29E-02	3.00E-01
Layer 5	9	Fresh - entire model domain	5.85E-04	6.16E-03	3.00E-01
Layer 6	10	Fresh - mining area only	3.96E-04	3.86E-03	3.00E-01
Layer 7	11	Fresh - entire model domain	2.61E-03	3.31E-02	3.00E-01
Layer 8	12	Fresh - mining area only	1.73E-04	1.07E-03	3.00E-01
Layer 9	13	Fresh - entire model domain	7.03E-04	1.06E-02	3.00E-01
Layer 10	14	Fresh - mining area only	4.51E-04	3.83E-03	3.00E-01
Layer 11	15	Fresh - entire model domain	4.98E-04	4.07E-03	3.00E-01
Layer 12	16	Fresh - entire model domain	4.40E-04	4.39E-03	3.00E-01
Layer 13	17	Fresh - entire model domain	1.16E-03	1.24E-02	3.00E-01

Table 6.5 Uncertainty range – Specific storage (Ss)

Layer	Zone	Hydrostratigraphic unit description	Specific storage (m^{-1}) Lower	Specific storage (m^{-1}) Optimum	Specific storage (m^{-1}) Upper
Layer 1	1	Alluvium	1.30E-07	1.76E-05	3.70E-05
	2	Colluvium	1.30E-07	2.24E-05	3.70E-05
	3	Regolith	1.30E-07	2.01E-05	3.70E-05
	4	Old pit voids	1.30E-07	1.54E-05	3.70E-05
	5	Old WRD	1.30E-07	1.61E-05	3.70E-05
Layer 2	6	Saprolite	1.30E-07	2.83E-05	3.70E-05
Layer 3	7	Saprock	1.30E-07	8.34E-06	3.70E-05
Layer 4	8	Fresh - mining area only	1.30E-07	1.44E-05	3.70E-05
Layer 5	9	Fresh - entire model domain	1.30E-07	1.27E-05	3.70E-05
Layer 6	10	Fresh - mining area only	1.30E-07	1.29E-05	3.70E-05
Layer 7	11	Fresh - entire model domain	1.30E-07	1.57E-05	3.70E-05
Layer 8	12	Fresh - mining area only	1.30E-07	1.59E-05	3.70E-05
Layer 9	13	Fresh - entire model domain	1.30E-07	2.69E-05	3.70E-05
Layer 10	14	Fresh - mining area only	1.30E-07	2.59E-05	3.70E-05
Layer 11	15	Fresh - entire model domain	1.30E-07	2.03E-05	3.70E-05
Layer 12	16	Fresh - entire model domain	1.30E-07	2.19E-05	3.70E-05
Layer 13	17	Fresh - entire model domain	1.30E-07	2.86E-05	3.70E-05

Table 6.6 Uncertainty range – Recharge factor

Layer	Zone	Hydrostratigraphic unit description	Recharge factor Lower	Recharge factor Optimum	Recharge factor Upper
Layer 1	1	Alluvium	0.01%	0.16%	5.53%
	2	Colluvium	0.01%	0.07%	2.86%
	3	Regolith	0.01%	0.06%	2.74%
	4	Old pit voids	0.07%	0.63%	30.00%
	5	Old WRD	0.09%	0.63%	30.00%

6.3 Results

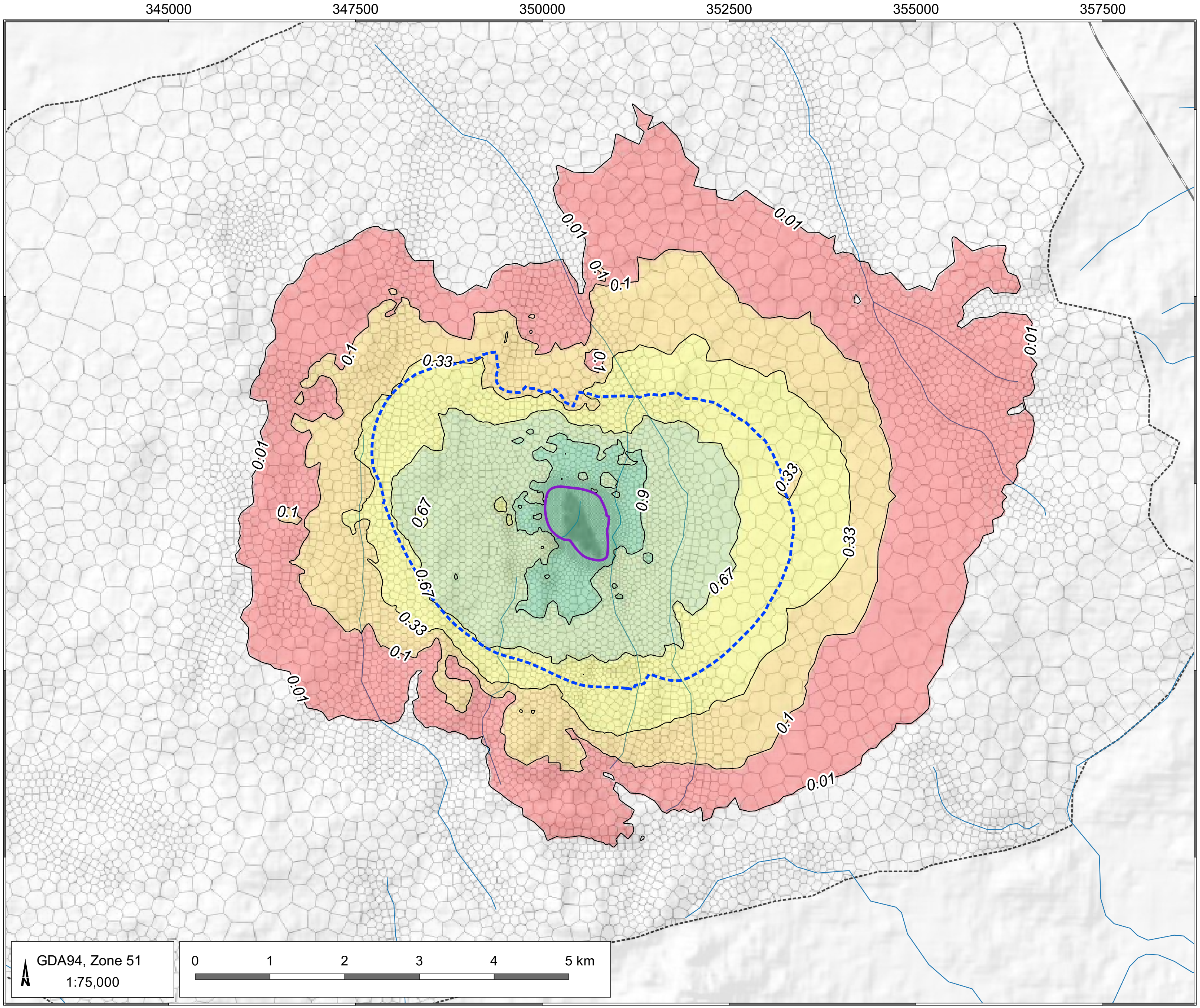
As noted previously, a total of 500 models were generated and set to run. Of the 500 models run, 269 models did not converge or produce acceptable calibration statistics, leaving 231 models for the uncertainty calculations.

6.3.1 Zone of 1 m drawdown during mining

The extent of the zone of 1 m of additional drawdown at the end of underground mining at Hercules (year 16) was assessed for each of the 231 successful model runs. The total number of times a model cell had drawdown >1 m within the water table was tallied and converted to a percentile and shown in Figure 6.1.

The uncertainty plot (Figure 6.1) should be interpreted as the probability that the 1 m difference limit is further out than that location. The green coloured zone indicates that the probability is very likely that 1 m drawdown will occur within that area. Likewise, the pink areas indicate where it is very unlikely that the 1 m contour of difference from the mining at Hercules is outside of this area.

For the water table, the current calibrated base case is on the cusp of the ‘unlikely’ and ‘about as likely as not’ zone, indicating the predicted 1 m contour is more likely to be within the adopted predicted base case extent. This could in part be a function of the saturation levels in these areas, but also a result of a conservative approach where parameters are more uncertain.



LEGEND

- Drainage
- Road
- Rail
- Open pit outline
- Model grid
- Model boundary
- Mine scenario 1 m drawdown contour

Exceedance probability (%)

- 0-10% (Very unlikely)
- 10-33% (Unlikely)
- 33-67% (About as likely as not)
- 67-90% (Likely)
- 90-100% (Very likely)

Hercules Groundwater Assessment (HER5001.001)

Uncertainty in incremental predicted water table drawdown (1 m) at the end of underground mining at Hercules

DATE
14/04/2025

AGE

FIGURE No:
6.1

G:\Projects\HER5001.001 Hercules Groundwater Assessment Phase 3\3_GIS\Workspaces\001_Deliverable1\06.01_HER5001_Uncertainty in incremental predicted water table drawdown at the end of underground mining at Hercules.qgz

6.3.2 Mine inflows

Figure 6.2, Figure 6.3, and Figure 6.4 shows the probability of various rates of predicted groundwater inflow to the proposed Hercules open pit and underground as well as combined, respectively. The calibrated model inflows to the open pit and underground are predicted to be between the 10th and 50th percentiles, or 'about as likely as not'.

For the proposed Hercules open pit, it is unlikely that the predicted inflows will reach above 6,300 m³/day and very unlikely that maximum inflows of 39,500 m³/day will occur as shown in Figure 6.2. Similarly, for the proposed Hercules underground, it is unlikely that the predicted inflows will reach above 5,000 m³/day and very unlikely that maximum inflows of 12,000 m³/day will occur as shown in Figure 6.3.

Figure 6.4 shows the combined inflows from the open pit and underground mining which shows predicted inflows reaching 5,200 m³/day and very unlikely that minimum total inflows of below 1,500 m³/day occur.

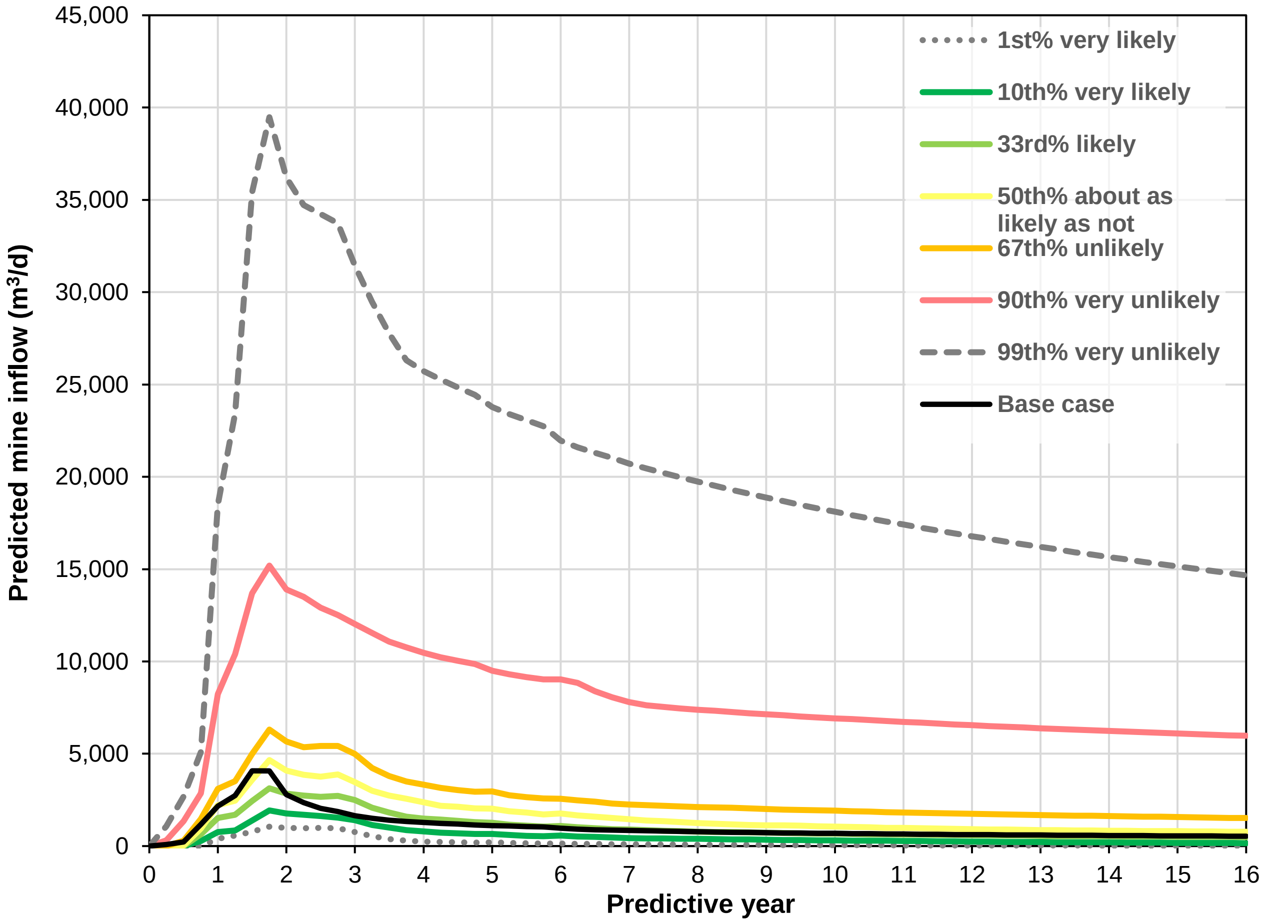


Figure 6.2 Probability of predicted groundwater inflow rates – Hercules open pit

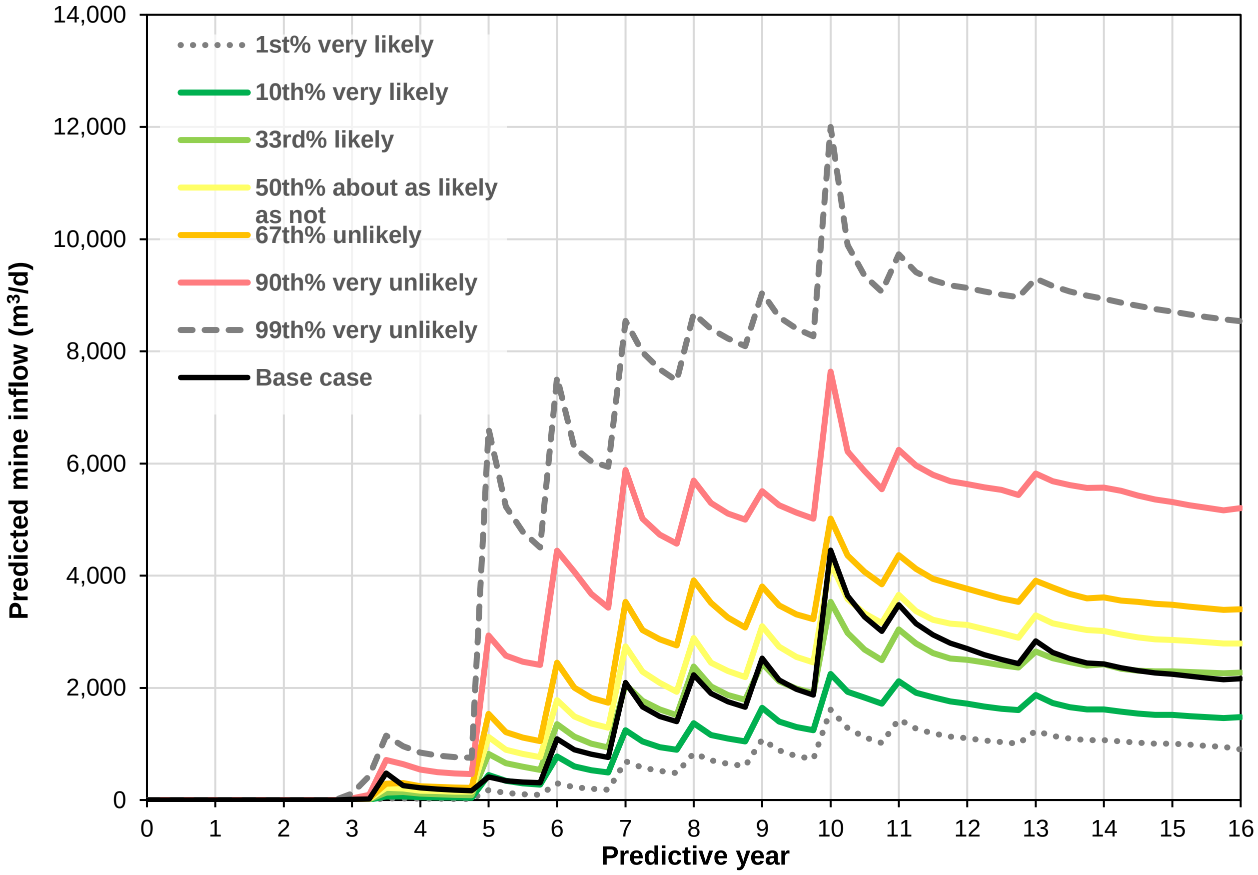


Figure 6.3 Probability of predicted groundwater inflow rates – Hercules underground

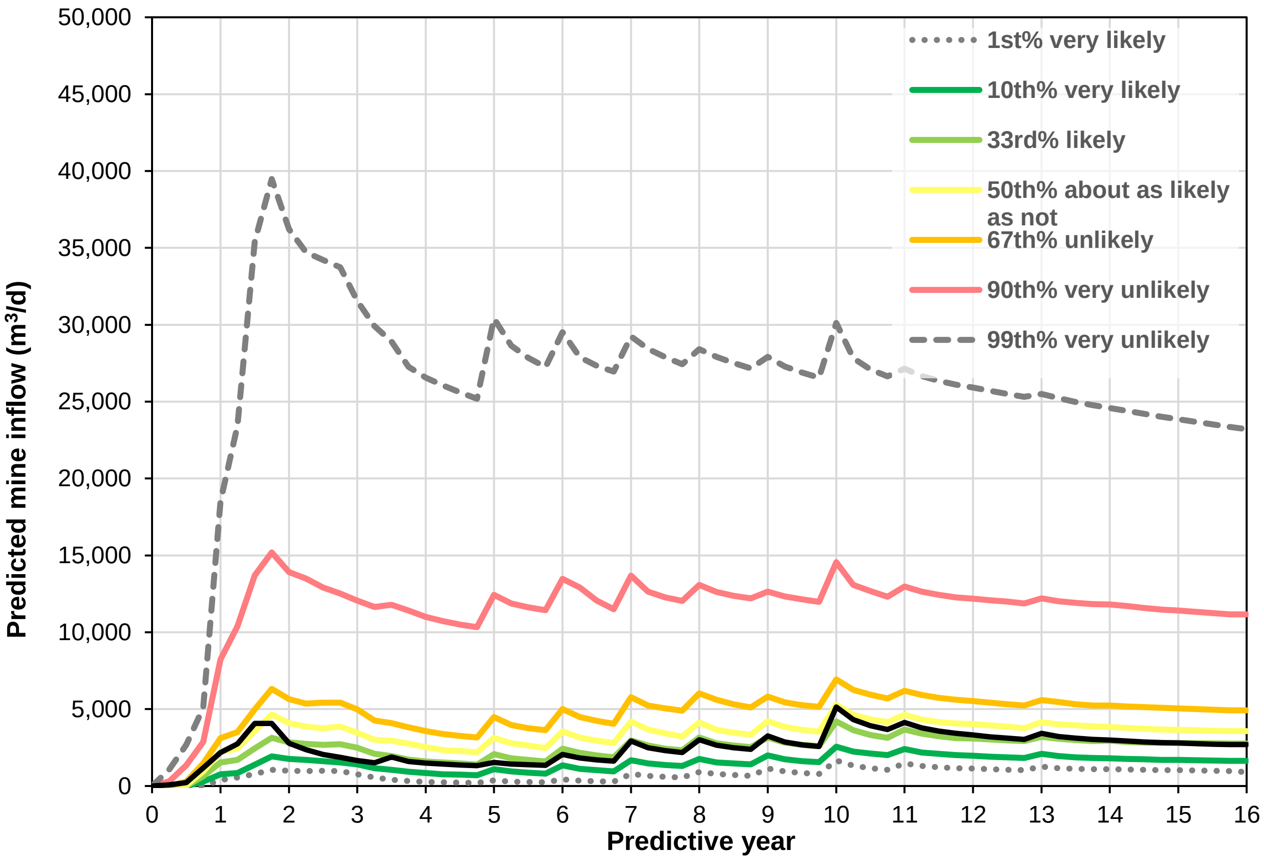


Figure 6.4 Probability of predicted groundwater inflow rates – Hercules open pit and underground

7 Impacts summary

The numerical groundwater model was developed to inform and predict potential impacts from mining via a proposed open pit and underground mine. Additionally, the model was also used to predict potential inflows into the mining operations to assess water management options.

When comparing Figure 2.12, Figure 5.6, and Figure 6.1, potential impacts to GDEs resultant from groundwater level drawdown over the next 16 years, is considered negligible to low, i.e., no adverse effects from simulated mining activities is expected. When assessing the zone of 1 m of drawdown at the end of underground mining at Hercules (year 16), the extent of ‘very unlikely’ impacts extends about 9 to 11 km radially while the extent of ‘about as likely as not’ of 1 m drawdown extends about 3 to 4 km radially.

No registered bores are affected by any potential predicted impacts simulated while most of the potential drawdown is contained within NSR leases.

Predicted inflows for the proposed Hercules open pit and underground operations are unlikely to exceed 6,300 m^3/day and 5,000 m^3/day, respectively, with maximum inflows considered very unlikely. Combined inflows from both operations are expected to reach around 5,200 m^3/day, with total inflows below 1,500 m^3/day considered very unlikely.

The groundwater model’s long-term Hercules void water level reaches an equilibrium at about 336 mAHD approximately 200 years post mining.

8 Groundwater monitoring and management approach

As this is a newly proposed mining operation, a Groundwater Operating Strategy (GWOS) should be implemented upon operations to monitor potential impacts while assisting with best practise site water management. The purpose of the GWOS will be to set in place a monitoring protocol to be followed to assist with site water management. Especially for newly proposed mining sites, baseline and background data is important to be collected for any future uses including sites assessments and expansions, investigation of potential impacts, and altering of any on-site water management procedures. Furthermore, the collected data can help inform any potential mitigation measures if any significant impacts are identified.

Ideally, the GWOS needs to use the findings and recommendations for this assessment combined with the existing conditions of the SKO (GWL106836(9)). The current SKO GWOS contains trigger limits, which would not be recommended to be included for Hercules unless significant impacts are observed, or additional groundwater users are identified that need to be managed. Until a site-specific GWOS is created the SKO GWOS can be used as guidance for Hercules.

As part of the GWOS, it will be important to install an appropriate network of monitoring bores surrounding Hercules to measure and monitor changes in groundwater levels. As previously mentioned, it is important to collect sufficient background data near and distal to the proposed mining operations to ensure early detection of potential impacts.

SKO's GWL (GWL 106836(9)) permits the total abstraction of 6,188,195 m^3/year. As recent as 2024 (AGE, 2025b), SKO only utilised 11% of this licence allocation and even when considering potential inflows as high as 15,000 m^3/day, it remains unlikely that the licence allocation needs to be increased. It is recommended to review this licence allocation every 12 months for the first three years of operations and conduct early investigation if the licence allocation needs to be increased.

In the event where excess water is available from pit dewatering, the nearby Greenback-, Penfolds-, and Erebus pits have sufficient storage capacity to store up to roughly 3,000,000 m^3 considering a 3 m freeboard. As applicable at SKO (AGE, 2025b), provision needs to be made to keep groundwater levels below 3 mbgl to ensure vegetation isn't adversely affected by rising water levels.

9 Conclusions and recommendations

The following conclusions can be made for this impact assessment:

- Proposed mining consists of an open pit and underground mine with a proposed life of mine planned to be 16 years with four years of open pit mining followed by 12 years of underground mining.
- The current proposed open pit is planned to reach an approximate depth of 245 mbgl while the underground mine is proposed to extend from 280 mAHD to -455 mAHD (approximately 735 mbgl).
- Calculated hydraulic parameters obtained from pumping tests are variable, as would be expected from fractured (dual-porosity) aquifer environments.
- The numerical model calibration was considered good with the calibrated transient state model's unweighted scaled root mean square being 5.18% with R^2 (correlation) value of 94% between all observed- and simulated groundwater levels.
- After 16 years of potential mining, potential impacts to GDEs resultant from groundwater level drawdown is considered negligible to low, i.e., no adverse effects from simulated mining activities are expected.
- When assessing the zone of 1 m of drawdown at the end of underground mining at Hercules (year 16), the extent of 'very unlikely' impacts extends about 9 to 11 km radially while the extent of 'about as likely as not' of 1 m drawdown extends about 3 to 4 km radially.
- Predicted inflows for the proposed Hercules open pit and underground operations are unlikely to exceed 6,300 m^3/day and 5,000 m^3/day, respectively, with maximum inflows considered very unlikely. Combined inflows from both operations are expected to reach around 5,200 m^3/day, with total inflows below 1,500 m^3/day considered very unlikely.
- No registered bores are affected by any potential predicted impacts simulated while most of the potential drawdown is contained within NSR leases.
- The groundwater model's long-term Hercules void water level reaches an equilibrium at about 336 mAHD approximately 200 years post mining.

The following recommendations are made following this impact assessment:

- Additional drilling must be undertaken to assess the extent of the fractured environment. Drilling should consist of test (production) bores with appropriately located monitoring bores of which the test bores should be subjected to pumping test.
- Near mine and distal monitoring bores should be drilled.
- Update the numerical groundwater model 12 months after commencement of mining or if significant changes are made to the mining layout such aerrs the addition of the proposed Penfolds open pit extension.
- Compile a site-specific Groundwater Operating Strategy for the site once the mining proposal is approved.
- Continue monitoring bores quarterly by means of collecting groundwater levels and analysing hydrochemical samples until operations commence or a GWOS is implemented.
- Assess whether the groundwater abstraction licence allocation needs to be increased based on the results of this assessment.

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Appendix A

Bore construction logs

AGE Australasian Groundwater & Environmental Consultants Pty Ltd

46 B Angove Street, North Perth, Western Australia 6006

BOREHOLE LOG

HMB01D

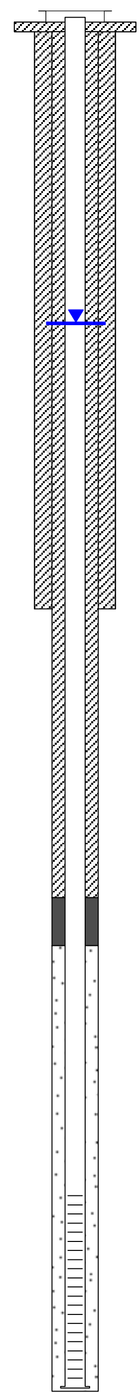
PROJECT No: **HER5000.001**	DRILLING COMPANY: **Acqua Drill**	EASTING: **350428 mE**
PROJECT NAME: **Hercules**	DRILLER: [redacted]	NORTHING: **6569860 mN**
DATE DRILLED: **14/11/2024**	DRILLING METHOD: **Mud rotary / Rotary air**	DATUM: **MGA51**
LOGGED BY: [redacted]	DRILL RIG: **Versa-Drill 2000ADP**	RL: **363.20 mAHD**
		TD: **85 mBGL**

COMMENTS: **Deep monitoring bore.**

Stratigraphic Cloumn	Soil or Rock Field Material Description	Depth (mBGL)
CLAY	CLAY: high plasticity, clay, lithic clasts, well graded, clay matrix, light reddish red, residual soil, dry,	0 – 3
CLAY	CLAY: high plasticity, clay, lithic clasts, well graded, clay matrix, light reddish red / white, residual soil, dry,	3 – 19
CLAY	CLAY: high plasticity, clay, lithic clasts, well graded, clay matrix, light yellowish yellow / white / orange, residual soil, dry, Moisture in clays	19 – 36
CLAY	CLAY: medium plasticity, clay, lithic clasts, well graded, clay matrix, light orange / red, residual soil, dry,	36 – 39
SANDY CLAY	SANDY CLAY: medium plasticity, fine sand, lithic clasts, clay matrix, light greyish grey / white, extremely weathered, wet,	39 – 43
SAND	SAND: fine sand, sub-angular, lithic clasts, poorly graded, dark greyish grey / white, distinctly weathered wet,	43 – 47
SAND	SAND: fine sand to medium sand, sub-angular, lithic clasts, poorly graded, dark greyish grey, fresh, wet,	47 – 85

Depth scale (mBGL): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90

Bore Construction



Bore Description

Protective lockable steel collar: +0.6 m
Stick up: +0.37 m

304 mm Dragbit: 0 m to 22 m (Mud rotary)

SWL: 18.19 mbgl (4/11/2024) - clear, no odour, no turbidity

304 mm Tricone: 22 m to 36 m (Mud rotary)

203 (mm) Steel surface casing: 0 m to 36 m

Bentonite grout (5 %): 0 m to 55 m

152 mm Hammer: 36 m to 85 m (Air Rotary)

Water strike at 47 m.

50 mm uPVC Class 18 blank casing: 0 m to 72.6 m

Bentonite seal: 54 m to 57 m

1.6 - 3.2 mm washed, rounded, quartz gravel pack: 57 m to 84.6 m

50 mm uPVC Class 18 machine slotted casing, slot aperture: 1 mm, 72.6 m to 84.6 m

End of hole: 85 m BGL

Hole collapse: 84.6 m to 85 m

Bore development: 3 hr 15 mins; EC: 100 uS/m; pH: 7.42

Very little water for airlift, only sufficient volume to collect samples.

Australasian Groundwater & Environmental Consultants Pty Ltd

46 B Angove Street, North Perth, Western Australia 6006

BOREHOLE LOG

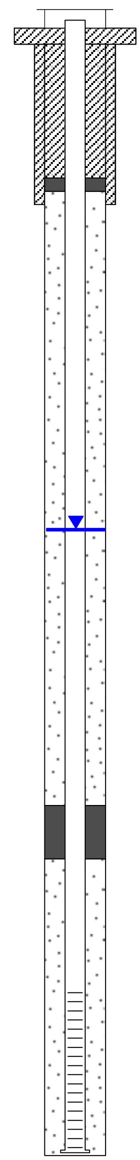
HMB01S

PROJECT No: **HER5000.001**	DRILLING COMPANY: **Acqua Drill**	EASTING: **350462 mE**
PROJECT NAME: **Hercules**	DRILLER: [redacted]	NORTHING: **6569853 mN**
DATE DRILLED: **28/10/2024**	DRILLING METHOD: **Rotary air**	DATUM: **MGA51**
LOGGED BY: [redacted]	DRILL RIG: **Versa-Drill 2000ADP**	RL: **363.20 mAHD**
		TD: **151 mBGL**

COMMENTS: Bore drilled at a larger diameter as it was intended to be installed as a production bore. Due to hole collapse, the bore was installed as a shallow monitoring bore.

Stratigraphic Cloumn	Soil or Rock Field Material Description	Depth (mBGL)
CLAY	CLAY: medium plasticity, clay, lithic clasts, uniform, clay matrix, dark reddish red, residual soil, soft, dry, massive, massive,	0
CLAY	CLAY: medium plasticity, clay, lithic clasts, uniform, clay matrix, mottled whitish red / white, residual soil, soft, dry, massive, massive,	
CLAY	CLAY: medium plasticity, clay, lithic clasts, poorly graded, clay matrix, light reddish red, residual soil, soft, dry, massive, massive,	10
CLAY	CLAY: medium plasticity, clay, lithic clasts, uniform, clay matrix, light whitish red / white, residual soil, soft, dry, massive, massive,	
SAPROLITE	SAPROLITE: clay, lithic clasts, uniform, clay matrix, light orangey brown / yellow, distinctly weathered soft, wet, bedded, massive,	20
SAPROLITE	SAPROLITE: fine sand, lithic clasts, uniform, light greyish grey, medium strength, slightly weathered, firm, wet, bedded, granular,	30–40
SANDSTONE	SANDSTONE: fine sand, lithic clasts, poorly graded, mottled greyish grey / mottled / red, medium strength, fresh, stiff, wet, bedded, granular,	50

Bore Construction



Bore Description

Protective lockable steel collar: +0.58 m
Stick up: +0.37 m

444 mm Hammer: 0 m to 6 m (Air Rotary)

305 (mm) Steel surface casing: 0 m to 6 m

Bentonite grout (5 %): 0 m to 5 m

50 mm uPVC Class 18 blank casing: 0 m to 35.5 m

301.5 mm Hammer: 6 m to 42 m (Air Rotary)

SWL: 18.17 mbgl (4/11/2024) - clear, no odour, no turbidity

Bentonite seal: 28.5 m to 30.5 m

1.6 - 3.2 mm washed, rounded, quartz gravel pack: 30.5 m to 41.5 m

Water strike at 35 m

50 mm uPVC Class 18 machine slotted casing, slot aperture: 1 mm, 35.5 m to 41.5 m

End cap
Hole collapse: 41.5 m to 151 m

152 mm Hammer: 42 m to 151 m (Air Rotary)

End of hole: 151 m BGL

Bore development: 30 min; EC: 90.6 uS/m; pH: 7.38

Airlift flow rate: 0.1 L/s

Stabilized parameters and sediment sufficiently removed.

Australasian Groundwater & Environmental Consultants Pty Ltd

46 B Angove Street, North Perth, Western Australia 6006

BOREHOLE LOG

HPB01

PROJECT No: **HER5000.001**
PROJECT NAME: **Hercules**
DATE DRILLED: **9/11/2024**
LOGGED BY: [redacted]

DRILLING COMPANY: **Acqua Drill**
DRILLER: [redacted]
DRILLING METHOD: **Rotary air**
DRILL RIG: **Versa-Drill 2000ADP**

EASTING: **350444 mE**
NORTHING: **6569876 mN**
DATUM: **MGA51**
RL: **363.20 mAHD**
TD: **101 mBGL**

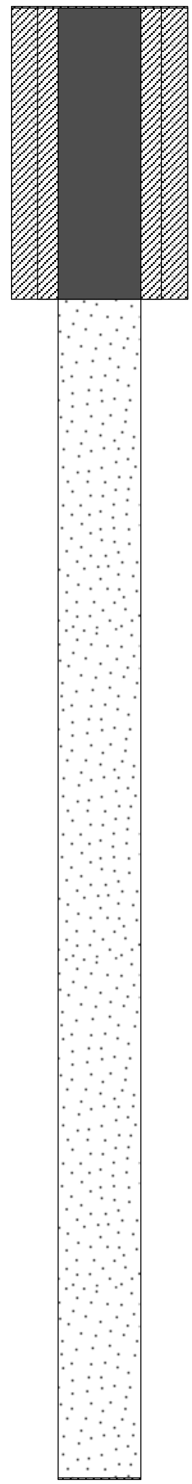
COMMENTS: Bore abandoned as a result of difficult ground- and drilling conditions that led to continuous collapse.

Stratigraphic Cloumn	Soil or Rock Field Material Description
CLAY	CLAY: lithic clasts, well graded, clay matrix, dark reddish red, residual soil, dry, massive,
CLAY	CLAY: clay, lithic clasts, well graded, clay matrix, dark reddish red / white, residual soil, dry, massive,
CLAY	CLAY: clay, lithic clasts, well graded, clay matrix, light whitish white / red, residual soil, dry, massive,
CLAY	CLAY: clay, lithic clasts, well graded, clay matrix, light brownish brown / red / white, residual soil, dry, massive,
CLAY	CLAY: clay, lithic clasts, well graded, clay matrix, light yellowish yellow / white, residual soil, moist, massive,
SAPROLITE	SAPROLITE: fine sand, sub-angular, lithic clasts, gap graded, clay matrix, light greyish grey / yellow, extremely weathered, wet,
SANDSTONE	SANDSTONE: medium sand, sub-angular, lithic clasts, poorly graded, dark greyish grey / mottled, fresh, wet,

Depth (mBGL): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

Graphic Log | R.L. (mAHD)

Bore Construction



Bore Description

381 mm Dragbit: 0 m to 22 m (Air Rotary)

305 (mm) Steel surface casing: 0 m to 20 m

Hole collapse: 20 m to 101 m

Hole abandoned due to collapse, surface casing filled with grout.

Waterstrike with insignificant yield at 28 m.

301.5 mm Hammer: 22 m to 101 m (Air Rotary)

Drilling airlift flow rate: 11.5 - 12.5 L/s

End of hole: 101 m BGL

Australasian Groundwater & Environmental Consultants Pty Ltd
46 B Angove Street, North Perth, Western Australia 6006

BOREHOLE LOG

HPB01A

PROJECT No: **HER5000.001**
PROJECT NAME: **Hercules**
DATE DRILLED: **29/11/2024**
LOGGED BY: [redacted]

DRILLING COMPANY: **Acqua Drill**
DRILLER: [redacted]
DRILLING METHOD: **Mud rotary / Rotary air**
DRILL RIG: **Versa-Drill 2000ADP**

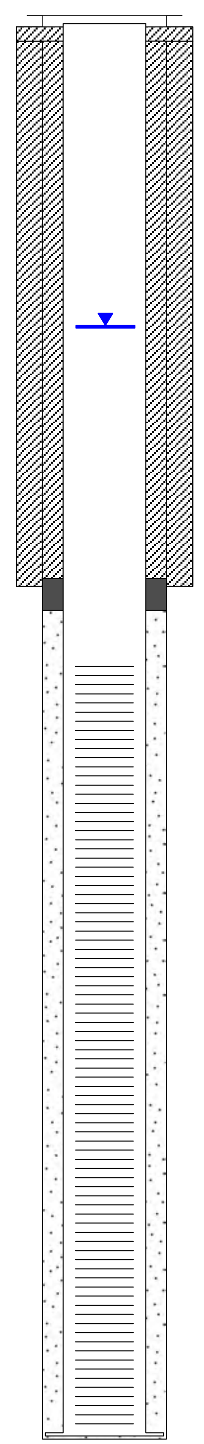
EASTING: **350466 mE**
NORTHING: **6569885 mN**
DATUM: **MGA51**
RL: **362.91 mAHD**
TD: **87 mBGL**

COMMENTS: **Production bore.**

Stratigraphic Cloumn	Soil or Rock Field Material Description
CLAY	CLAY: high plasticity, clay, lithic clasts, uniform, clay matrix, dark reddish red, residual soil, soft, dry, massive,
CLAY	CLAY: high plasticity, clay, lithic clasts, uniform, clay matrix, light reddish red / white, residual soil, soft, dry, massive,
CLAY	CLAY: medium plasticity, clay, lithic clasts, well graded, clay matrix, light red / white, residual soil, firm, dry, massive,
SAPROLITE	SAPROLITE: medium plasticity, clay, lithic clasts, gap graded, clay matrix, light red / white / brown, residual soil, dry, massive,
SAPROLITE	SAPROLITE: clay to fine sand, lithic clasts, well graded, clay matrix, light greyish grey, distinctly weathered dry, massive,
SAPROLITE	SAPROLITE: fine sand, lithic clasts, poorly graded, clay matrix, dark greyish grey, fresh, wet, massive,

Graphic Log | Depth (mBGL) / R.L. (mAHD): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90

Bore Construction



Bore Description

Protective lockable steel collar: +0.54 m
Stick up: +0.41 m

305 (mm) Steel surface casing: 0 m to 36 m
Bentonite grout (5 %): 0 m to 33.5 m

444 mm Tricone: 0 m to 37 m (Mud rotary)

SWL: 17.82 mbgl (4/11/2024) - clear, no odour, no turbidity

203 mm uPVC Class 18 blank casing: 0 m to 38.2 m

Bentonite seal: 33.5 m to 35.5 m

301.5 mm Tricone: 37 m to 87 m (Mud rotary)

1.6 - 3.2 mm washed, rounded, quartz gravel pack: 35.5 m to 86.2 m

203 mm uPVC Class 18 machine slotted casing, slot aperture: 1 mm, 38.2 m to 86.2 m

Airlift flow rate: 1 - 3 L/s

Hole collapse: 86.2 m to 87 m

End of hole: 87 m BGL

End cap

Bore development: 16 hr 30 mins; EC: - µS/m; pH: -

Airlifting done by drilling contractors, no field parameters measured.

Appendix B

Laboratory water chemistry results

Table B 1 Groundwater chemistry results

Parameter	Unit	*LOR**	HMB01D (pre development)	HMB01S (pre development)	HPB01A (pre development)	HMB02 (pre development)	HPB01A (post development)	HMB02 (post development)
Physical parameters								
pH Value	pH Unit	*0.01*	7.59	7.66	7.65	7.53	7.11	7.00
Electrical conductivity @ 25°C	µS/cm	*1*	97,000	90,600	82,100	110,000	84,100	108,000
Total Dissolved Solids @180°C Total	mg/L	*10*	81,100	74,000	63,700	91,800	67900	89200
Hydroxide alkalinity as CaCO3	mg/L	*1*	<1	<1	<1	<1	<1	<1
Bicarbonate alkalinity as CaCO3	mg/L	*1*	190	190	247	219	236	194
Carbonate alkalinity as CaCO3	mg/L	*1*	<1	<1	<1	<1	<1	<1
Total alkalinity as CaCO3	mg/L	*1*	190	190	247	219	236	194
Major ions								
Chloride	mg/L	*1*	46,500	41,000	32,300	41,000	30,200	40,400
Sulphate as SO4 - Turbidimetric dissolved	mg/L	*1*	4,460	4,110	4,690	5,870	4,290	5,320
Calcium dissolved	mg/L	*1*	1040	1040	556	890	664	856
Magnesium dissolved	mg/L	*1*	2,980	2,790	2,040	3,380	2,410	3,310
Sodium dissolved	mg/L	*1*	23,200	21,400	16,900	27,100	16,600	21,800
Potassium dissolved	mg/L	*1*	240	198	73	142	143	239
Ionic balance	%	*0.01*	6.55	2.53	4.17	7.96	1	1
Total cations	meq/L	*0.01*	1240	1,180	933	1500	957	1,270
Total anions	meq/L	*0.01*	1,410	1240	1,010	1280	946	1,250
Nutrients								
Nitrite as N	mg/L	*0.01*	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	*0.01*	0.01	0.1	0.01	<0.01	<0.01	<0.01
Nitrite + Nitrate as N	mg/L	*0.01*	0.01	0.11	0.01	<0.01	<0.01	<0.01
Dissolved metals								
Mercury dissolved	mg/L	*0.0001*	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Arsenic dissolved	mg/L	*0.001*	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Zinc dissolved	mg/L	*0.005*	0.078	0.052	<0.050	<0.050	0.524	0.15
Selenium dissolved	mg/L	*0.01*	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium dissolved	mg/L	*0.0001*	0.001	<0.0010	0.0055	<0.0010	0.0061	<0.0010
Nickel dissolved	mg/L	*0.001*	0.094	0.316	0.326	0.093	0.376	0.185
Copper dissolved	mg/L	*0.001*	<0.010	<0.010	0.073	0.016	0.095	0.152
Lead dissolved	mg/L	*0.001*	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt dissolved	mg/L	*0.001*	0.176	0.32	0.301	0.153	0.367	0.297
Manganese dissolved	mg/L	*0.001*	13.8	12.8	14	10.3	13.6	11.6
Aluminium dissolved	mg/L	*0.01*	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Chromium dissolved	mg/L	*0.001*	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron dissolved	mg/L	*0.05*	<0.50	<0.50	<0.50	<0.50	<0.50	8.12

Table B 2 Pit water chemistry results

Parameter	Unit	*LOR**	Penfolds 1	Penfolds 2	Erebus
Physical parameters					
pH Value	pH Unit	*0.01*	7.3	4.46	4.31
Electrical conductivity @ 25°C	µS/cm	*1*	165,000	139,000	25,100
Total Dissolved Solids @180°C Total	mg/L	*10*	144,000	115,000	17,900
Hydroxide alkalinity as CaCO3	mg/L	*1*	<1	<1	<1
Bicarbonate alkalinity as CaCO3	mg/L	*1*	70	<1	<1
Carbonate alkalinity as CaCO3	mg/L	*1*	<1	<1	<1
Total alkalinity as CaCO3	mg/L	*1*	70	<1	<1
Major ions					
Chloride	mg/L	*1*	80,300	61,800	6,450
Sulphate as SO4 - Turbidimetric dissolved	mg/L	*1*	4,200	4,910	3,550
Calcium dissolved	mg/L	*1*	2940	2550	576
Magnesium dissolved	mg/L	*1*	5,180	3,810	747
Sodium dissolved	mg/L	*1*	39,900	32,300	4,230
Potassium dissolved	mg/L	*1*	1330	1060	80
Ionic balance	%	*0.01*	0.24	0.74	3.83
Total cations	meq/L	*0.01*	2340	1,870	276
Total anions	meq/L	*0.01*	2,350	1840	256
Nutrients					
Nitrite as N	mg/L	*0.01*	44.6	32.2	<0.01
Nitrate as N	mg/L	*0.01*	0.35	0.12	<0.01
Nitrite + Nitrate as N	mg/L	*0.01*	44.9	32.3	<0.01
Dissolved metals					
Mercury dissolved	mg/L	*0.0001*	<0.0005	<0.0005	<0.0001
Arsenic dissolved	mg/L	*0.001*	<0.020	<0.020	0.01
Zinc dissolved	mg/L	*0.005*	<0.100	0.14	21.8
Selenium dissolved	mg/L	*0.01*	<0.20	<0.20	<0.02
Cadmium dissolved	mg/L	*0.0001*	0.0054	<0.0020	0.0694
Nickel dissolved	mg/L	*0.001*	0.122	0.443	2.47
Copper dissolved	mg/L	*0.001*	<0.020	<0.020	1.33
Lead dissolved	mg/L	*0.001*	<0.020	<0.020	<0.002
Cobalt dissolved	mg/L	*0.001*	<0.020	0.416	1.26
Manganese dissolved	mg/L	*0.001*	0.785	12.3	20.2
Aluminium dissolved	mg/L	*0.01*	<0.20	10.8	43.4
Chromium dissolved	mg/L	*0.001*	<0.020	<0.020	0.007
Iron dissolved	mg/L	*0.05*	<1.00	<1.00	7.02

Appendix C

Hydrographs

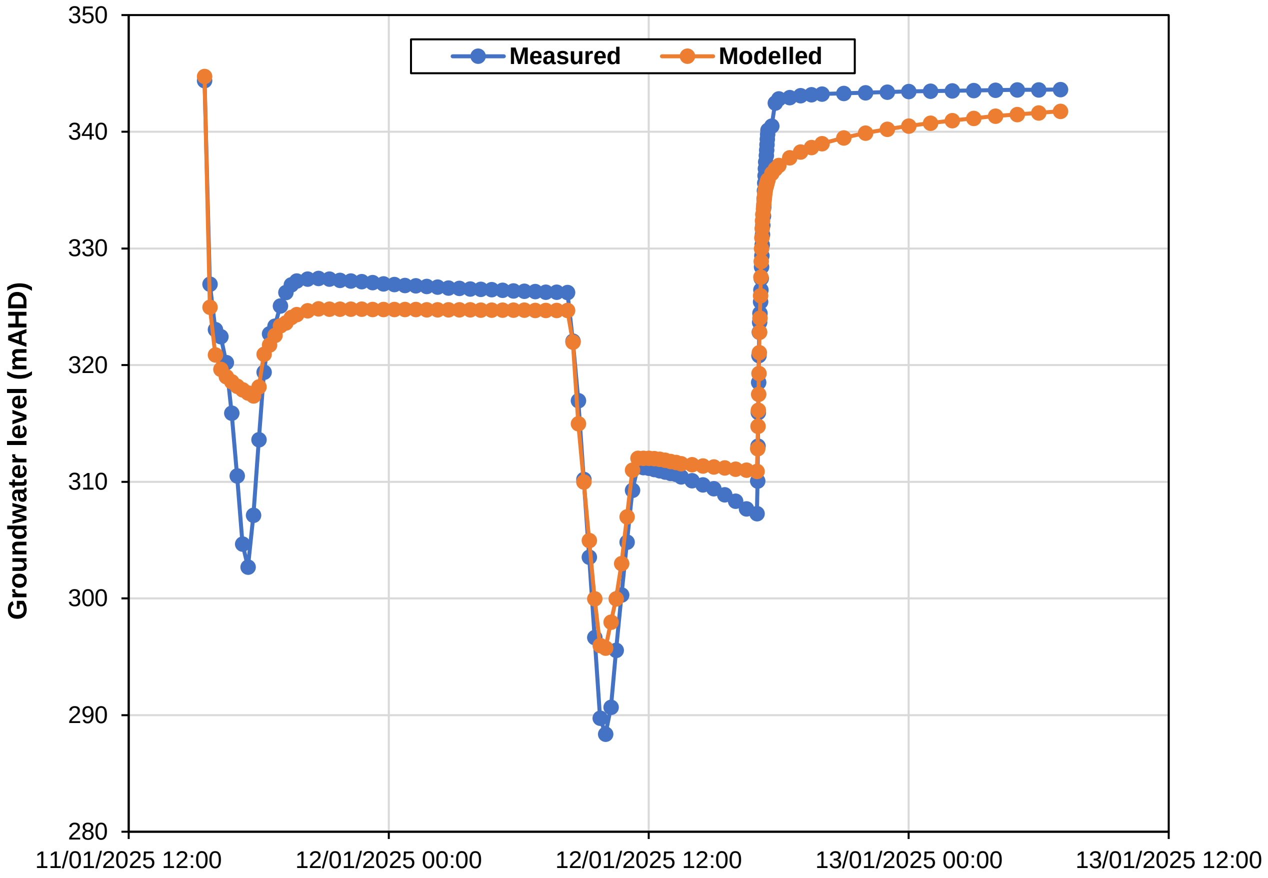


Table C 1 Calibrated groundwater levels at HPB01A

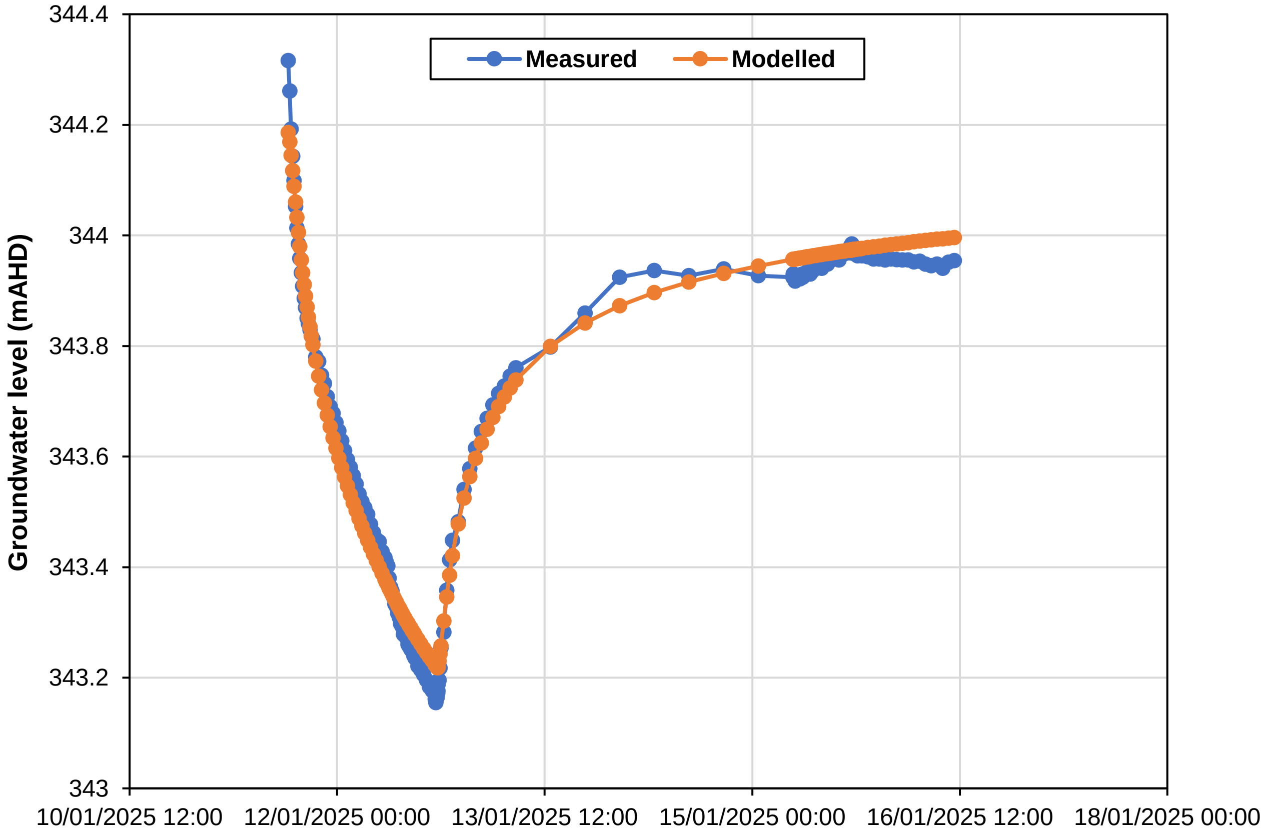


Table C 2 Calibrated groundwater levels at HMB01S

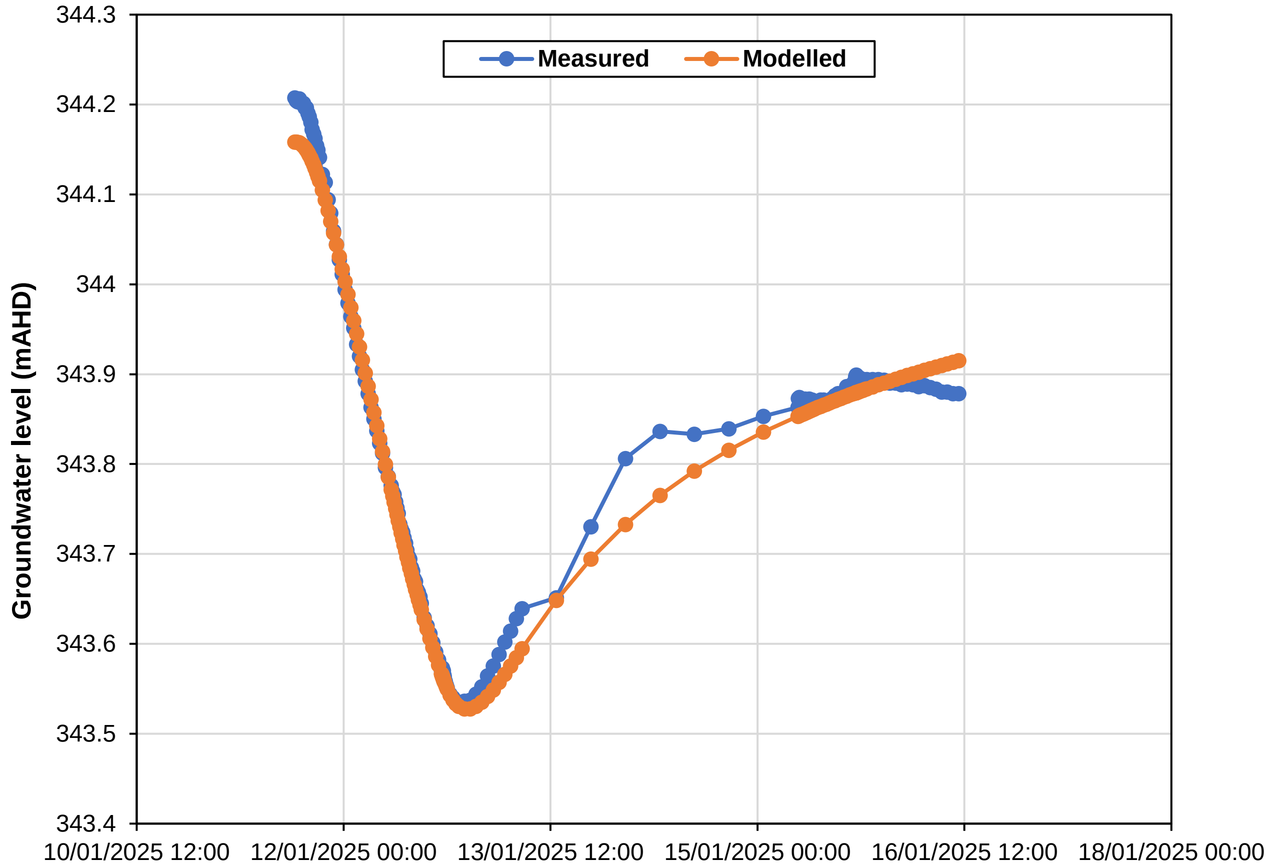


Table C 3 Calibrated groundwater levels at HMB01D

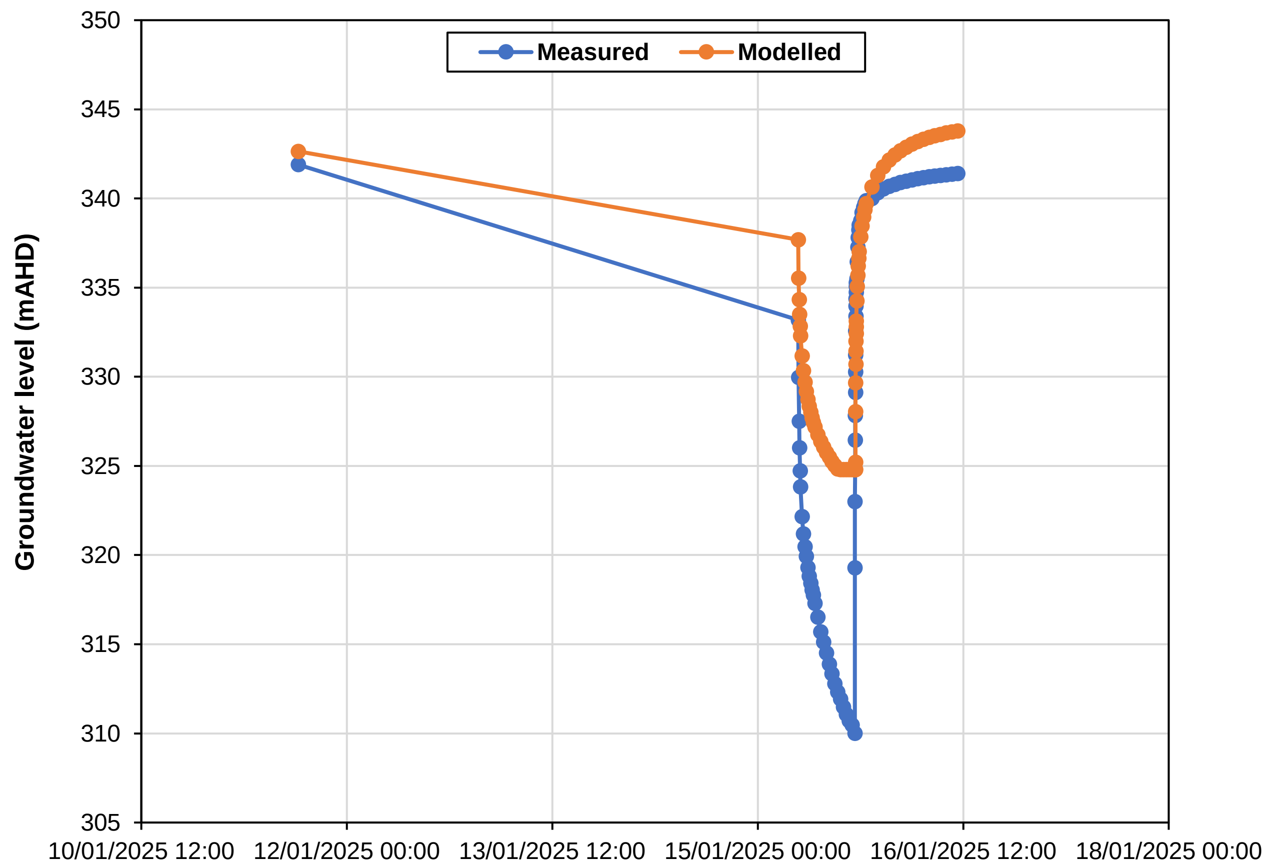


Table C 4 Calibrated groundwater levels at HMB02

Appendix B – Surface Water Assessment

Surface Water Assessment
Hercules Project

Prepared for:

Northern Star Resources

June 2025

[redacted]

[redacted]

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1. INTRODUCTION

1.1 Background

The Hercules project is located south of Kalgoorlie in the Goldfields region, Western Australia (WA). Northern Star Resources (NSR) proposes to develop the Hercules open-pit and underground mine, within trucking distance to the Company's processing facilities.

Northern Star Resources requires a surface water assessment for the proposed Hercules open-pit and underground mine, to support a Mining Development and Closure Proposal (MDCP) submission to the Department of Energy, Mines, Industry Regulation and Safety (DEMIRS). An MDCP is set to replace the existing requirement for two separate documents (Mining Proposal / Mine Closure Plan).

1.2 Project Overview

The NSR Kalgoorlie Operations currently comprise two separate mining areas, Kanowna Belle (KB) and South Kalgoorlie Operations (SKO). Ore from both operations are processed at the Kanowna Belle Mill.

The Hercules Project is located 16.5km due west of SKO, and 35km southwest of the Fimiston processing plant at KCGM. It is anticipated ore from Hercules will be hauled to either the Fimiston plant or Kanowna Belle for processing. Refer Figure 1.1 for the project location. The project has three access options, two of the options are existing haul roads off Goldfields Hwy. Currently the preferred access is the most northern haul road called Celebration-Coolgardie Road. The Project can also be accessed from Coolgardie via an existing haul road off Coolgardie Esperance Hwy.

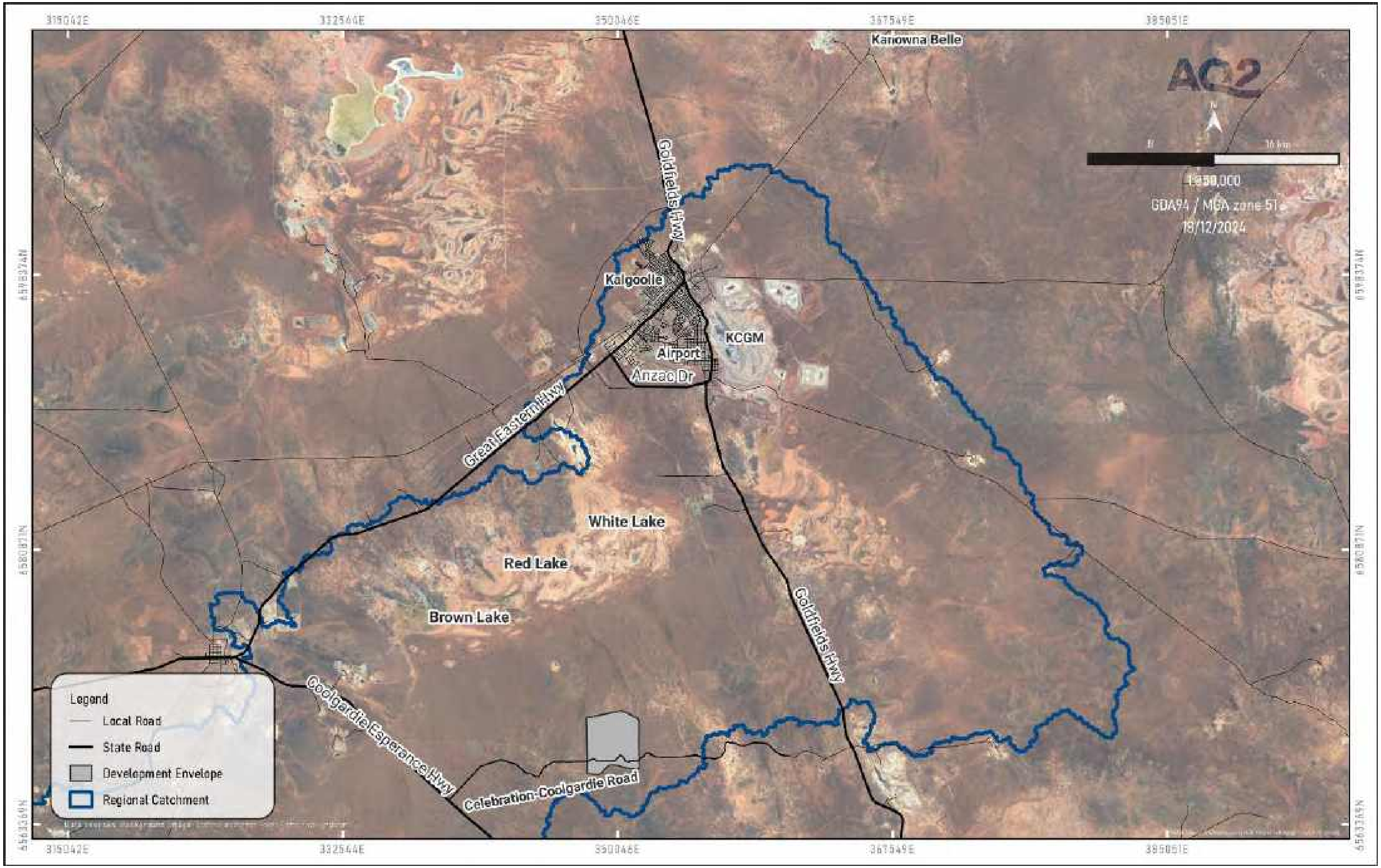


Figure 1.1 Site Location

1.3 Project Layout

The Hercules project development area covers an area of approximately 5km^2. The development area is not a greenfield site with existing mining activities, including historic open cut pits and waste dumps remaining adjacent to proposed development areas.

The proposed Hercules open pit and underground mine will be constructed northeast of the existing pits and waste dump with a new waste dump and topsoil stockpile proposed adjacent to the proposed open cut pit (further northeast). A secondary waste dump is proposed to the southwest of the proposed open cut pit labelled Penfolds waste dump Figure 1.2 A run-of-mine (ROM) pad is proposed at the south end of the proposed Hercules pit and waste dump. Other proposed infrastructure includes various workshops, laydowns, water storages, and accommodation to the south. The Project has the following key mining activities:

- Open pit – mining void (with a depth of at least 5m below ground-water level).
- ROM pad.
- Turkeys nests – saline water or process liquor dams.
- Waste rock dumps and stockpiles.
- Paste plant and plant site.

The Project also has the following miscellaneous mining activities:

- Access roads.
- Pipeline / powerline corridors.
- Abandonment and flood bunding / diversion channels or drains.
- Topsoil stockpiles.
- Workshop/ offices.
- Laydown or hardstand areas.

The proposed site layout plan for the Hercules project is shown in Figure 1.2.

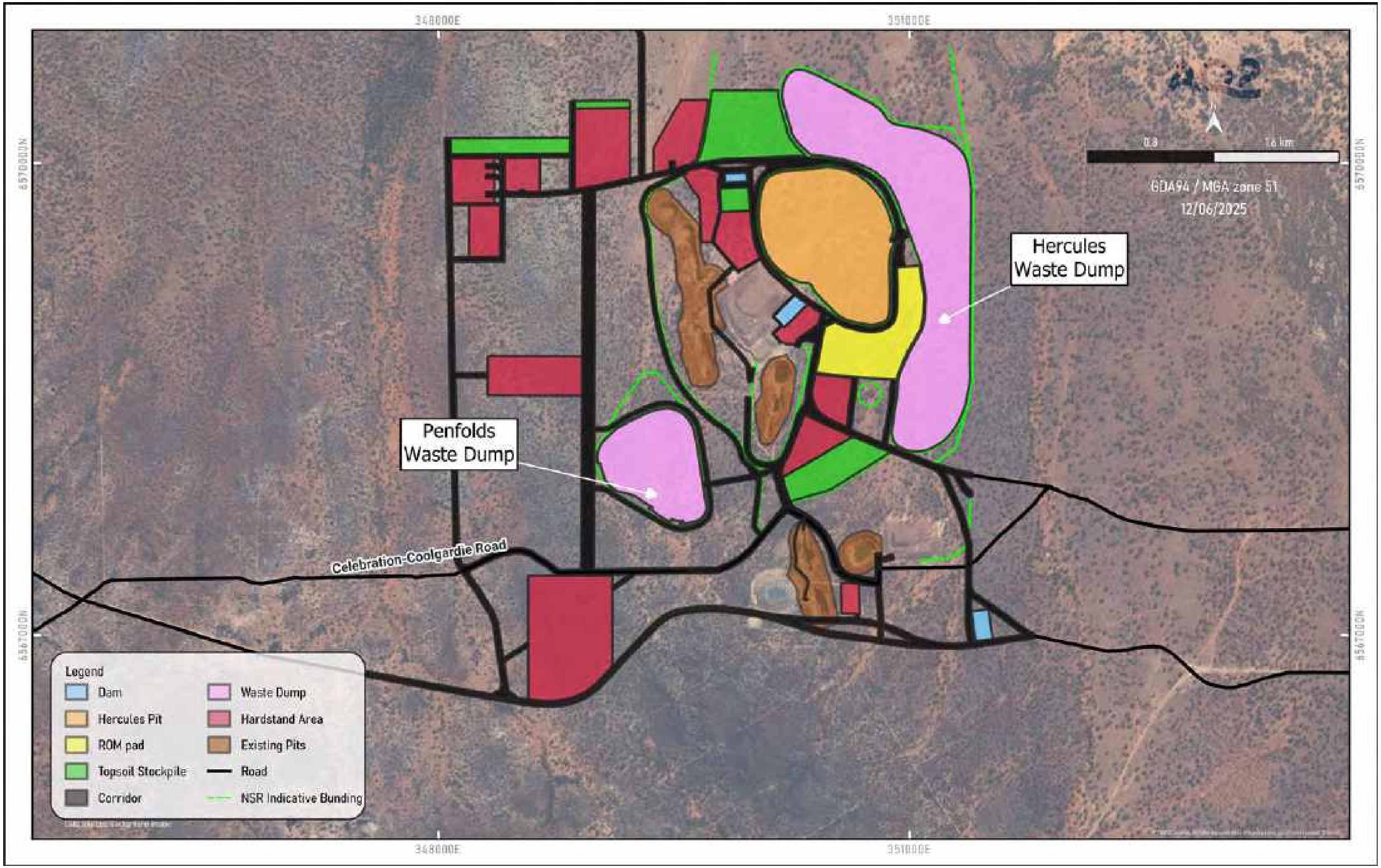


Figure 1.2 Project Layout Plan

2. BASELINE ENVIRONMENTAL DATA

2.1 Current Climate

The climate around the Kalgoorlie region is characterised as semi-arid. Summers are hot and dry, with average daytime temperatures often exceeding 35°C. Heatwaves can push temperatures beyond 40°C. Summer rain is infrequent but can occur in the form of short, intense thunderstorms. Occasionally, moisture from tropical cyclones can bring significant rainfall to the area. Winters in Kalgoorlie are relatively mild, with average daytime temperatures between 15°C to 20°C. Temperatures at night occasionally drop below 5°C, and light frosts may occur during the colder winter nights.

Rainfall data is available from 1939-present at the closest Bureau of Meteorology (BoM) station (012038) at Kalgoorlie-Boulder Airport. Rainfall is low and variable, averaging 265mm per year. Overall, the region experiences a relatively dry climate year-round, with average monthly rainfall evenly distributed throughout the year. However, the summer rainfall is generally a result of large, infrequent rainfall events while the winter rainfall is generally from more frequent, smaller events. There is slightly more rainfall in the late summer months between January and March, with large rainfall events typically a result of ex-tropical lows.

Evaporation rates are high, with monthly average evaporation exceeding monthly average rainfall throughout the year. This contributes to dry soil conditions and limited surface water resources. Evaporation data has been sourced from BoM, which provides an average annual pan evaporation of approximately 2,630mm.

Vegetation in the area is sparse and adapted to drought, with species like saltbush, mulga, and eucalyptus trees dominating the landscape. Winds are common throughout the year, especially during the dry season. Dust storms can occur, particularly when there are strong winds combined with dry conditions.

The climate data for the project is summarised below in Table 2.1.

Table 2.1 Monthly Climate Statistics at Kalgoorlie-Boulder Airport

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Max Temp (°C)	33.7	32.2	29.5	25.3	20.8	17.6	16.9	18.8	22.4	26.0	29.1	32.1	25.4
Mean Min Temp (°C)	18.4	18.0	16.2	12.7	8.7	6.3	5.1	5.8	8.2	11.3	14.2	16.7	11.8
Mean Rainfall (mm)	26.4	31.7	25.6	20.1	24.1	27.7	24.0	21.3	13.4	15.6	18.9	15.9	265
Pan Evaporation (mm)	381	329	262	177	110	79	85	116	177	256	314	366	2628

2.2 Climate Change

The Project lies within the ARR (2019) Australian Rangelands climate region[2]. ARR advises that the impacts of climate change should be considered within surface water assessments to account for the current climate being different to historic climate observations (which rainfall and runoff relationships are based upon) and future climate altered by Climate Change. The rainfall and runoff relationships used in the

Hercules assessment were scaled in accordance with ARR as detailed further in Section 3.2.3. Projected changes relevant to the Hercules life or mine (LOM) due to Climate Change are summarised below[1].

- By 2030, mean annual warming in the South Rangelands (which includes Kalgoorlie) is projected to be about 0.6 to 1.4°C above the 1986-2005 climate across all emission scenarios.
- Extreme temperatures are projected to increase in the future, with more frequent and intense heatwaves.
- There is high confidence that climate change will result in a harsher fire weather climate in the future.
- Winter rainfall is projected to decrease in the South Rangelands with high confidence across all emission scenarios.
- Natural climate variability is expected to remain the major driver of rainfall changes by 2030, with annual mean changes of about 10%, and seasonal-mean changes of about 20%.
- There is high confidence that the intensity of heavy rainfall events will increase under all emissions scenarios.
- The frequency of cyclones has remained relatively stable in WA, but their intensity is thought to have increased. This trend is expected to continue with medium confidence.
- Potential evapotranspiration is expected to increase across all seasons, with significant reductions in soil moisture projected by 2090, particularly during winter months. Despite this, changes to runoff remain uncertain due to complex nature of rainfall and runoff processes in changing climatic conditions.

These climate change projections pose significant challenges for Kalgoorlie and the broader Rangelands region, particularly in terms of water security, bushfire risk management, and adaptation to more extreme weather events.

2.3 Probable Maximum Precipitation Depths

Probable Maximum Precipitation (PMP) rainfall values were calculated for the Project for different duration events using the GSDM (Generalised Short Duration Method), GTSMR (Generalised Tropical Storm Method) and Generalised Southeast Australia Method (GSAM) and are presented in Table 6.1, with the highest calculated value shown for each duration.

Table 2.2 PMP Event Depths

Duration (hours)	PMP (mm)
0.25	180
0.5	260
0.75	330
1	410
1.5	460
2	510
2.5	550
3	580

[1] Department of Water and Environmental Regulation. (2021). Western Australian climate projections summary. Government of Western Australia. https://www.wa.gov.au/system/files/2022-01/Western_Australian_Climate_Projections_Summary.pdf

[2] Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) Australian Rainfall and Runoff: A Guide to Flood Estimation, © Commonwealth of Australia (Geoscience Australia), Version 4.2, 2019.

Duration (hours)	PMP (mm)
12	680
24	730
36	890
48	1040
72	1310
96	1470
120	1540

Note: rainfall depths are rounded to the nearest 10mm.

2.4 Regional Hydrology

The Goldfields region is characterised by dry, flat landscapes adapted to low and variable rainfall, and highly variable hydrology. Water quality characteristics of runoff from undisturbed land are influenced by the arid climate, sparse vegetation cover, and the accumulation of salts in the soil profile (with little flushing due to low rainfall), but which are mobilised during (episodic intense) rainfall events. The quality of surface water runoff is relatively fresh with higher salinity occurring in areas where runoff ponds and evapo-concentration occurs.

Elevation changes are minimal, and contribute to slow and shallow surface water flow, which evaporates or seeps into the ground. Surface drainage is often poorly defined. Water tends to accumulate in shallow basins, the ephemeral salt lakes and clay pans that are typical features of the region.

The salt lakes can remain dry for long periods of time, and hold water temporarily, filling only during periods of significant rainfall. The lakes are often saline and are an end point for surface runoff, with high evaporation rates, leaving behind salt crusts.

2.5 Project Topography

The Hercules project is located north and east of a series of hills with a maximum elevation of approximately RL450m. The elevation in the proposed mining area is in the order of RL355-390m on flat to gently undulating terrain. Approximately 10km north of the project lies a collection of low-lying salt lakes (Brown Lake, Red Lake, White Lake) at RL340m.

2.6 Project Hydrology

The Project lies just north and east of a small range of low hills. General drainage in the area is northward and surface water runs off the site in shallow waterways with flat grades into the salt lakes. The Hercules site is located between two larger unnamed creeks (nominally named West Creek and East Creek for this assessment) and a smaller unnamed creek that passes directly through the site (nominally named Middle Creek for this assessment), all of which area ephemeral. The mine disturbance area extends into sub-catchments of these three creeks, which all merge together downstream of the Project and subsequently drain to the chain of small salt lakes located north of the Project area. Refer Figure 2.1. for the creek catchments in relation to the Hercules project and the overall catchment draining to the chain of small salt lakes.

An overview of the creeks is as follows:

- West Creek: passes a couple of hundred metres west of the proposed development area and continues north towards the salt lakes. The course of the creek becomes relatively undefined once past the site, tending towards overland/sheet flow. West Creek has minimal to no impact on the Project.
- Middle Creek: flows through the central part of the site, west of the existing pits. The creek naturally joins East Creek approximately 3km to the north of the site. The proposed Penfolds waste dump is located within the Middle Creek flow path and is likely to impact its flow. Additionally, the proposed NSR indicative bunding, positioned adjacent to the western side of the existing pits (refer to Figure 1.2), will encroach into the Middle Creek floodplain and surface water management measures may be required to promote positive drainage to convey runoff downstream (discussed in more detail in Section 5).
- East Creek: consists of approximately three tributary channels that converge around 500m north of the site. Downstream of this confluence point, the flow path becomes relatively undefined. One creek tributary directly impacts the southern end of the proposed ROM pad and waste dump footprints and will need to be diverted further east. Indicative bunding and the footprint of the waste dump within the proposed mine layout have been included by NSR to aid drainage of East Creek.
- The peak 1% AEP flow rate was estimated for the West, Middle and East catchments reporting to the 2D hydraulic model downstream boundary which has been developed for the project (refer Section 3.2) using Flavell's 2012[2] flood frequency procedures for the Goldfields region in Western Australia, noting these do not account for the changes in rainfall and runoff processes due to Climate Change. The 2D Model Catchment represents approximately 75% of the total project catchment area. These flows were used to confirm the rainfall loss parameters adopted in the 2D hydraulic flood model were appropriate. The results presented in Table 3.1, indicate the outflow from the 2D hydraulic model should be in the order of 130m^3/s.

Table 2.3 Estimated Peak 1% AEP Flow Rates

Variable	2D Model Catchment
Area (km2)	65.5
Slope (m/km)	3.2
Length (km)	12
1% AEP Flow Rate (m^3/s) (Flavell, 2012)	130

[2] Flavell, D. 2012, "Design flood estimation in Western Australia", Australian Journal of Water Resources, Vol. 16, No. 1, pp. 1-20, http://dx.doi.org/10.7158/W11-865.2012.16.1.

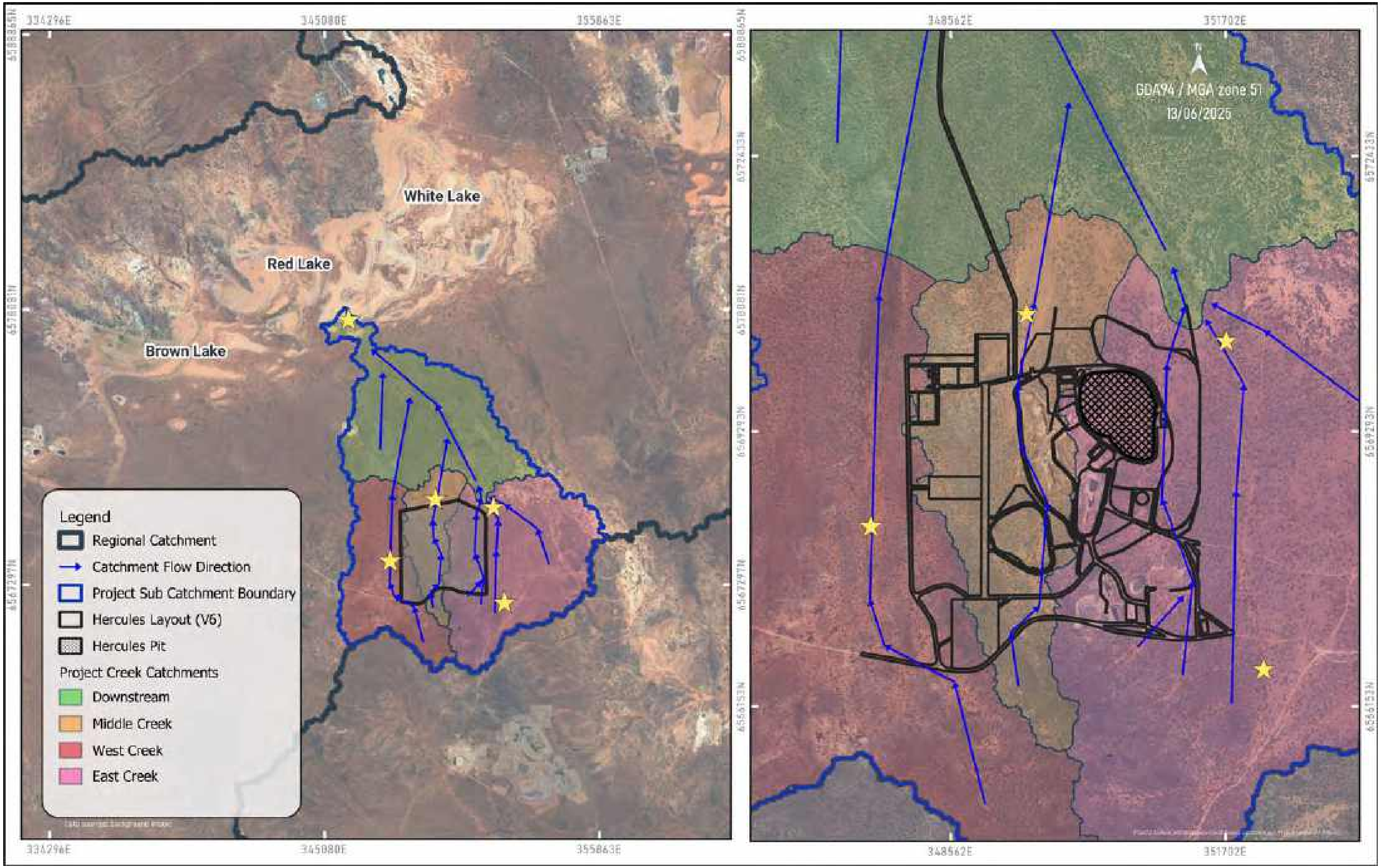


Figure 2.1 Project Hydrology

2.7 Potential Environmental Receptors

Runoff from rain events at the Hercules mine site terminate at the chain of salt lakes north of the site, the downstream receptor for rainfall run-off events. Despite the harsh environment with high salinity and temperatures, salt lakes host a variety of life forms (microbial life and crustaceans), which can remain dormant during dry periods and become active when the lakes fill with water; and aquatic salt-tolerant plants like samphire, which are common around lake margins, stabilising soil and providing a base for the food chain.

Between the Hercules project and the downstream salt lakes, there are no mapped Department of Biodiversity, Conservation and Attractions (DBCA) priority or threatened ecological communities.

3. HYDROLOGICAL MODELLING

3.1 Methodology

To characterise the baseline hydrological regime before the implementation of the Hercules project a pre-development flood model was completed. The pre-development hydrological regime included the impact of existing mine landforms present at the Hercules project location.

3.2 2D Flood Model Set Up

3.2.1 General

Flood modelling was carried out using Hydrologic Engineering Center's River Analysis System (HEC-RAS) software developed by U.S. Army Corps of Engineers. The 2D model was based on a pre-development Digital Terrain Model (DTM) derived from 5m resolution LiDAR data, incorporating the existing mine terrain. To encompass all contributing surface water catchments beyond the DTM area, SRTM data was integrated, and matched to the DTM at the model boundary.

3.2.2 Model Build

The 2D HEC-RAS hydraulic model had the following set up:

- A computational mesh spacing of 30m x 30m was applied to the 2D flow area and refined as required for more detailed modelling.
- A roughness coefficient of 0.1 was adopted across the model domain to simulate the roughness applicable for relatively shallow flow through undefined drainage areas.
- One outflow boundary condition was set up far downstream of the Hercules project using a normal depth energy gradient assumed parallel to the terrain.
- An adaptive timestep was assigned using a maximum Courant Number of 2.
- The 2D full momentum shallow water equation was selected as the solving method.
- A model simulation time of 8 hours was used such that the maximum depths due to the peak flows were simulated at the Hercules project.
- Road embankments at the Hercules project were not simulated.

Runoff is prevented from reporting to the existing pits by simulating glass walls along the alignment of the apparent flood protection bunding in the terrain data and aerial imagery.

3.2.3 Rainfall and Runoff

A nested frequency storm was generated by combining the BoM 1% AEP IFD rainfall depths across all durations into a single storm pattern. A 40% proportional rainfall loss was applied to the nested frequency storm with flow rates predicted by the model approximating those estimated using Flavell's 2012 flood frequency procedures for the Goldfields region (refer Section 2.6).

To account for changes in rainfall and runoff processes due to Climate Change, adjustment factors to the rain-on-grid hydrology simulated in the 2D flood model were applied in accordance with the Australian Rainfall and Runoff (ARR) guidelines[3] for 2030. The BOM 1% AEP rainfall depths were increased by 13% and the 40% proportional loss was increased by 11% to 44%. This was under the following assumptions:

- The current and near-term (2030 period) medium Representative Concentration Pathways 4.5 (RCP4.5) was adopted for the Hercules project given its short LOM timeframe.
- The critical duration of runoff reaching the proposed Hercules development envelope best aligns with the 4.5-hour duration.

3.3 Pre-Development 2D Flood Model Results

The peak 1% AEP flow rates modelled in HEC-RAS for each of the three creek catchments relevant to the site are presented in Table 3.1. The total flows represent runoff from the same catchment area as the 2D Model Catchment which are summarised in Table 2.3.

Table 3.1 Project Catchment Runoff Rate Estimates

Catchment ID	Area (km^2)	1% AEP Flow (m^3/s)
West Creek	18.0	37
Middle Creek	8.60	27
East Creek	32.7	63
Total	59.3	127

The pre-development flood prediction maps for the 1% AEP event are presented in Appendix A (flood depth) and Appendix B (flood velocity).

The flood mapping generally indicates that the Hercules Project is relatively flood free from external catchments except where an East Creek tributary impacts the southern end of the proposed ROM pad and waste dump footprints. Flow from this tributary will need to be diverted further east, and the mine layout plan includes proposed bunding to assist with this. The Hercules project footprint encroaches into the Middle Creek flood plain, most significantly where the Penfolds waste dump is situated, where maximum predicted flood depths in the order of 1.65m occur at the toe of the Penfolds waste dump.

[3] Flavell, D. 2012, "Design flood estimation in Western Australia", Australian Journal of Water Resources, Vol. 16, No. 1, pp. 1-20, http://dx.doi.org/10.7158/W11-865.2012.16.1.

4. POTENTIAL HYDROLOGICAL IMPACTS (GENERAL)

Generally, mining operations can be impacted by external hydrological effects, in particular flooding from local waterways. Mining operations can also impact or modify the environmental values and hydrological behaviour of the surrounding areas as follows:

- Increasing or reducing water availability within the environment.
- Interfering with floodplain capacity and changing flood patterns and flood levels.
- Erosion of disturbed areas (runoff from construction areas, stockpiles, ROM pads and mine voids may increase sedimentation downstream).
- Erosion of undisturbed areas, where flood velocities have increased due to water management around the mine.
- Degradation of water quality through discharge of contaminants (chemicals, hydrocarbons).

4.1 Modification of the Hydrological Regime

Generally, construction of mine pits, waste dumps, haul roads and other associated infrastructure for proposed mines potentially could affect existing surface water drainage features, including creek lines, pools and flood plains. Modification of the existing catchments and drainage channels can reduce the volume and distribution of runoff to some areas, creating water shadows and increasing flows and periods of ponding in others. This disturbance has the potential to adversely impact downstream vegetation due to water starvation, drowning and/or sedimentation.

Haul roads located in relatively flat areas of the floodplain or across shallow drainage areas have the potential to impede flow and create water shadows on the downstream side of the road. The dynamic loads imposed by heavy traffic loads potentially can result in compaction of the subgrade potentially decreasing permeability. The development of mine pits adjacent to or within major drainage channels poses significant flood risk to the mine pits and potential for water starvation downstream. Runoff from waste dumps and cleared or disturbed areas may increase the volume of runoff and adversely impact water quality.

4.2 Sediment Generation

Mining operations will inherently cause ground disturbance related to mining and construction of ancillary landforms, such as ROM pads and crushers, topsoil stockpiles and waste landforms. The impacts of this ground disturbance can be significant, depending on several factors, including the location of the deposit, mine planning, materials of construction and the terrain of the area, among others. The development of these landforms can increase sediment loads transported in runoff and could result in sedimentation of vegetated and other sensitive ecological areas.

4.3 Water Quality

Mine development has the potential for adverse impacts to surface and groundwater quality due to:

- Spillage of hydrocarbons and chemicals stored, handled or transported on site;
- Runoff from the mine pit, stockpiles, ROM pad and waste dump areas containing metals or other elements; and
- Discharge of water used for dust suppression.

Contaminated discharges have the potential to impact on vegetated areas, pools and other sensitive ecological areas downstream if allowed to enter nearby waterways.

5. HYDROLOGICAL RISKS AND MITIGATION MEASURES

5.1 Project Specific Potential Impacts

The identification of potential impacts on the hydrological environment as a result of the Hercules development was completed by comparing pre-development and post-development flow regimes.

5.1.1 Modification of Hydrological Regime

The proposed Hercules development may have the following impacts on the existing hydrological regime without the implementation of appropriate surface water management measures.

The reduction in catchment reporting downstream due to the containment and treatment of water within the Hercules project footprint is summarised in Table 5.1 with an approximate 7% reduction to the salt lake sub catchment, which is impacted by the mine site, on the (conservative) assumption that no runoff from the open cut pit and waste dump areas will report to the downstream salt lakes. This catchment reduction is relatively small, and it is not anticipated to adversely impact the hydrological regime or function of the portion of the catchment downstream of the mine site . In practice, runoff from the waste dumps will pass through sediment basins before returning to the environment post-treatment and contribute water to the catchment.

The salt lakes themselves also receive water from further catchments than those within which the Hercules development sits.

The Hercules project tends to encroach on the Middle Creek floodplain with the implementation of the NSR bunding located adjacent (west) of the existing pits.

Table 5.1 Reduction in Catchment

Catchment ID	Area (km^2)	Reduced Area (km^2)	Percent Reduction (%)
West Creek	18.0	17.6	2
Middle Creek	8.60	6.20	28
East Creek	32.7	29.0	11
Total Catchment Reporting to Downstream Salt Lakes	89.8	83.8	7

5.1.2 Sediment Generation

Runoff from mine disturbance areas, in particular the proposed waste dump, soil stockpiles and ROM pad, may generate sediment if not managed correctly. Runoff from these landforms will either be directed inward into the mine disturbance area (such as towards the pit void) for capture or outward to the downstream side of the mine infrastructure. Proposed measures to reduce potentially sediment laden runoff from the waste dump include wide, reverse grade benching. Containment bunding and sediment basins positioned strategically downstream of mine disturbance areas will intercept and treat the potentially sediment laden runoff before release to the environment.

5.1.3 Water Quality

The project may impact the water quality by saline water spills into the environment due to pipeline leaks or breaks, overfilling of storage dams or from dust suppression activities. Runoff contaminated with hydrocarbons and/or other chemicals that are discharged or washed off site can also result in contamination of the environment.

5.2 Risk Assessment

5.2.1 Introduction

The previous section identified the potential impacts of the Project on the surface water regime. The following section assesses the inherent risk to hydrological and environmental receptors in the surrounding area, and the residual risk following application of proposed mitigation measures are described in Section 5.5.

DEMIRS is the regulatory body overseeing the submission and assessment of mining proposals and uses a risk-based approach to evaluate the environmental and safety impacts of mining operations. The risk matrix is designed to assess the potential risks associated with mining activities by considering both the likelihood of an event occurring and the consequence of that event if it does occur.

In accordance with DEMIRS (2020), the evaluation of inherent risks associated with the Project requires consideration of objectives for different environmental factors as shown in the excerpt below. Of these, the 'Water Resources' factors are the most relevant for this assessment.

Table 1: Objectives for environmental factors

Factor	Objective
Biodiversity	To maintain representation, diversity, viability and ecological function at the species, population and community level.
Water Resources	To maintain the hydrological regimes, quality and quantity of groundwater and surface water to the extent that existing and potential uses, including ecosystem maintenance, are protected.
Land and Soils	To maintain the quality of land and soils so that environmental values are protected.
Rehabilitation and Mine Closure	Mining activities are rehabilitated and closed in a manner to make them physically safe to humans and animals, geo-technically stable, geo-chemically non-polluting/non-contaminating, and capable of sustaining an agreed post-mining land use, and without unacceptable liability to the State.

Source: DEMIRS, 2020

5.2.2 Risk Matrix Descriptors

The hydrological risk assessment has been completed by adopting the NSR semi-quantitative risk matrix template (shown in Appendix D), as provided to AQ2. Application of the matrix involves rating each impact with respect to:

- The plausible consequence of the impact resulting from the proposed infrastructure or activity.
- The likelihood of the adverse impact occurring.

NSR has provided descriptors for each of the consequence and likelihood aspects of the risk assessment, which have been adapted for this assessment. These descriptors are generally consistent with the guidance provided by DEMIRS (2020).

The likelihood of an impact occurring is focused on the frequency or probability of different scale rain events (i.e. Annual Exceedance Probability or AEP) during the expected life of the Project. The Likelihood rating ranges from Rare to Almost Certain.

The likelihood of a flood event exceeding an AEP design criteria over the operational lifetime of the Hercules development (assumed approximately in the order of 6 years) was calculated. The exceedance probability is computed using the following ARR equation:

$$p = 1 - \exp\left(-\frac{L}{Y}\right)$$

Where:

Y = the return period of a given flood event (ARI)

L = the design life in years

P = the exceedance probability during the design life

Table 5.2 Exceedance Probability

Mine Life (years)	Probability of Exceedance (%) for AEP					
	50% (2yr ARI)	20% (5yr ARI)	10% (10yr ARI)	5% (20yr ARI)	2% (50yr ARI)	1% (100yr ARI)
14	99%	93%	75%	50%	25%	13%

With respect to surface water assessments, the likelihood of an event occurring is directly related to the probability that a certain size flood event (% AEP) will occur.

5.2.3 Risk Matrix

An inherent risk matrix using the NSR descriptors of consequence and likelihood was developed for each of the potential impacts identified for the Hercules project. The Hercules risk matrix is presented in Appendix E and includes ratings for both the unmitigated and mitigated impacts.

Several potential impacts to the environment have a medium to high risk of impact to the environment if no surface water mitigation measures are considered. The most significant inherent risks were:

- R1/R2 – Hercules Waste Dump blocking a branch of East Creek during operations and post-closure.
- R4/R5 – Penfolds Waste Dump partially blocking Middle Creek during operations and post-closure.
- R6 – Sediment laden runoff from waste dumps reporting to the environment.

5.3 Proposed Mitigation Measures

5.3.1 General

Surface water runoff around the mine area and associated infrastructure must be managed to limit the environmental impacts of the operations on the surface water regime and reduce the impacts of flooding on the mine operations. To manage the identified risks on the hydrological regime due to the implementation of the Hercules project, surface water management infrastructure should reduce the total risk of an unwanted event to the extent that it becomes an acceptable level. The general management objectives relating to surface water are as follows:

- Maintain the existing hydrological regime to the extent practicable.
- Mitigate impacts on surface water quality from construction and operations and contain or treat any contaminated water on-site.
- Ensure the quality of the water released from the site will not lead to significant deterioration of the water resources, vegetation and other ecological factors in the downstream environment.

Generally, mitigation measures should meet the above objectives and the following design philosophies (where possible/applicable):

- Clean water should be diverted around disturbance footprints and into the downstream environment, to prevent contamination of clean water catchments.
- Dirty water should be captured and treated close to the source of dirty water (i.e. close to the disturbance area) to reduce the volume of water that needs to be treated.
- Return treated water to the same catchment in the downstream environment.
- Take measures to avoid excessive scour, erosion and sediment transport off-site.
- Drainage around operational areas should be designed to prevent prolonged ponding following rainfall events.
- Flood mitigation measures to prevent flood ingress into open pits and mine infrastructure areas should be constructed.

The objective of treatment measures is to reduce the identified risks to acceptable levels.

5.3.2 Project Specific

The greatest potential surface water impacts of the Project, without the implementation of additional diversion features, are associated with the blockage of an East Creek tributary by the proposed Hercules Waste Dump and the obstruction of Middle Creek by the proposed Penfolds Waste Dump. To reduce the risk of ponding and flow stranding in the East Creek and Middle Creek areas, the following of surface water management measures should be implemented.

- East Creek – NSR has proposed diversion bunding to deflect runoff from the impacted tributary to the east of the mine disturbance area. Based on the Post-Development flood modelling completed (refer Section 5.4), the proposed flood protection bund appears adequate to divert the pond. When constructing the bund, the surface around the toe of the bund should be graded to promote positive drainage and prevent ponding in local low lying areas.
- Middle Creek - The post-development flood modelling predicts runoff would pond at two locations along the toe of the proposed Penfolds Waste Dump. Minor diversion drains around the toe of the Waste Dump, as shown in Figure 5.1, would divert this flow around the waste dump. Sediment release - To mitigate the risk of releasing potentially sediment laden runoff from mine disturbance areas such as the proposed waste dump, soil stockpiles and ROM pad, containment bunding around these features directing runoff towards sediment basins are recommended, with conceptual locations of sediment basins shown in Figure 5.1. The basins are generally positioned proximal and downstream of the mine disturbance areas (source of potential contamination) to treat the potentially sediment laden runoff before release to the environment. The containment bunding around the features will ensure that mixing of upstream catchment flow (clean water) and potentially sediment laden runoff will not occur.
- Other – The model also predicts ponding around some of the hardstand and plant areas in the northern section of the mine site. Runoff can either be drained through these areas, or around them (refer to Figure 5.1).

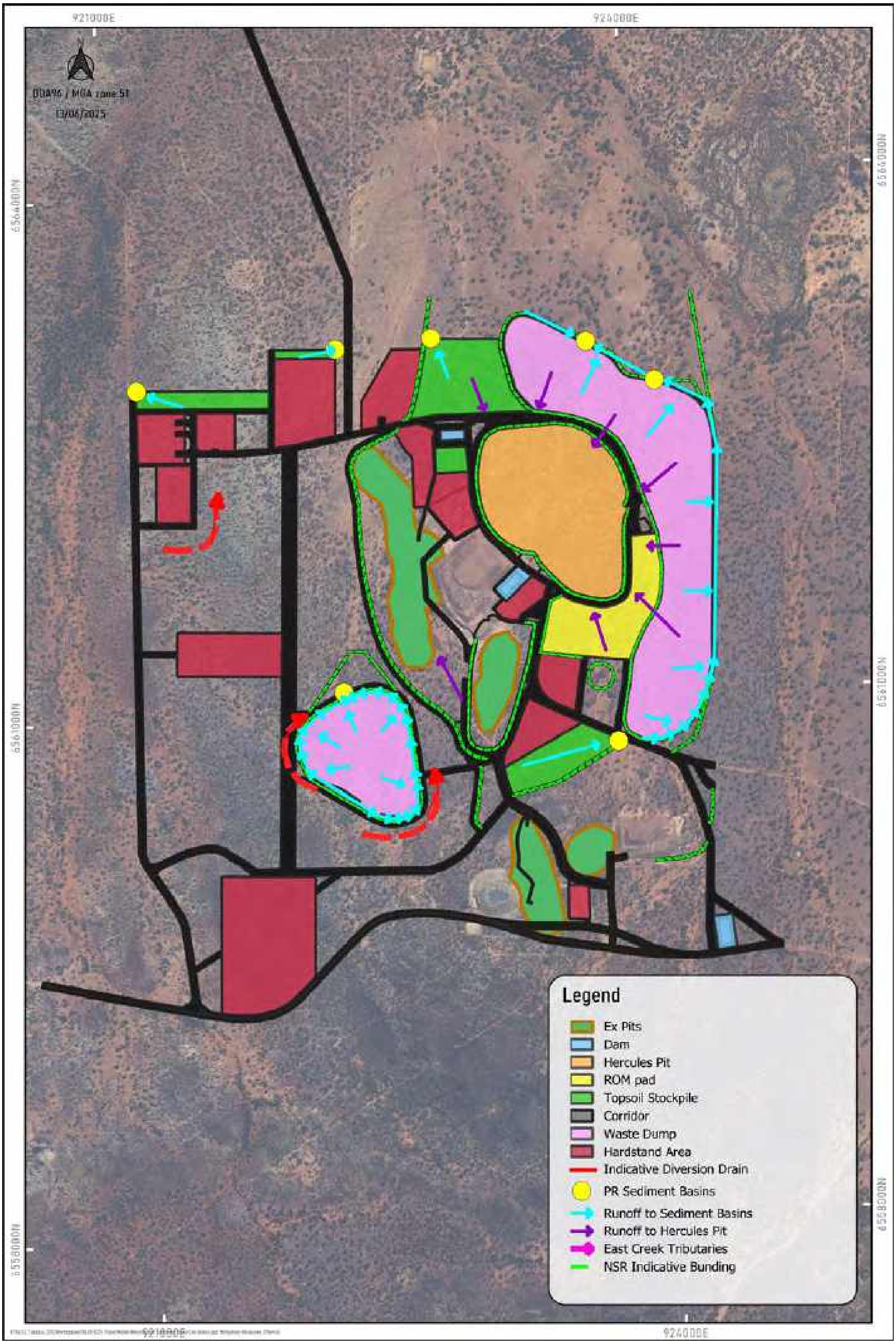


Figure 5.1 Proposed Surface Water Management Measures (Operations)

5.4 Post-Development 2D Model Results

A post-development 2D flood model was prepared to predict the impact of the Project on the flow regime and to reassess the hydrological risks taking into account the LOM development footprint, which includes the NSR proposed flood bunds (but not the minor surface water management measures proposed around Penfold Waste Dump or the hardstand area). The resulting flood map predictions were used to quantify the potential changes to the hydrological regime from the proposed Project. In the post-development 2D flood model, it was assumed that surface water would be contained within the proposed disturbance footprints at the Hercules Project and would therefore not contribute runoff within the model.

The post-development predicted flood depths and velocities with proposed surface water diversion measures (outside of the assumed containment bunding) for the 1% AEP event are presented in Appendix A and B. Difference mapping of the pre and post-development flood depth and velocity predictions are presented in Appendix C.

The greatest apparent risk to the Project (without implementation of any surface water diversion features) arises from the East Creek tributary that is blocked by the Hercules Waste Dump. The proposed NSR Indicative Bunding appears to be suitable to deflect this runoff around the eastern side of the mine development. The post-development flood model shows some areas where localised minor ponding may occur if the ground around the toe of the flood bund isn't graded to promote positive drainage. Culverts will need to be installed beneath roads where they cross the diverted flow path.

The Middle Creek floodplain is constrained by the installation of the proposed bund around the western perimeter of the Hercules mine disturbance area and by the construction of the Penfold Waste Dump. Without simulating any drainage diversions around the Penfold Waste Dump, the post-development model (and the flood difference model) shows water ponding against the toe of the waste dump in two locations.

In the post-development model, the NSR Indicative Bunding around the western side of the Hercules mine disturbance area (and eastern side of the Middle Creek floodplain) tends to laterally displace the flow further west and channelise the flow. As shown in the difference mapping included in Appendix C, the 1% AEP maximum flood depths and velocities are predicted to increase as a result. In both the pre-development and post-development models the maximum depths and velocities do not exceed 1.8 m and 0.7 m/s. The risk of erosion and release of sediment downstream due to increased velocities adjacent to the proposed NSR Indicative Bunding remain low due to the relatively low maximum predicted velocities (max 0.5m/s).

Other observations in the difference mapping include:

- Predictions of flow depths and velocities are increased east of the Hercules Waste Dump due to the East Creek tributary diversion.
- A reduction in the flow depths and velocities, including minor water shadowing, downstream of the mine development envelope which may reduce the surface water runoff available for vegetation and fauna.

5.5 Residual Risk Ratings

The risk matrix shown in Appendix E shows all residual risks to the hydrological regime are reduced to a low rating after the proposed mitigation measures are adopted.

6. SURFACE WATER CLOSURE

6.1 Introduction

The objective of Mine Closure guidelines is to ensure an effective planning process is in place throughout the life of mine, so closure is achieved in an environmentally sustainable manner and without unacceptable liability to the State. General mine closure principles include maintenance of surface and groundwater hydrological patterns / flows, water levels and water quality with no long-term reduction in the availability of water to meet local environmental values.

6.2 Land Disturbance and Rehabilitation

In all regards, mining is a temporary land use and rehabilitation objectives should be consistent with future land use (such as pastoralism and heritage conservation). Sediment-laden runoff from the site must be prevented post-closure without the use of capture or treatment devices, which cannot be maintained into perpetuity. Rehabilitated disturbed areas need to be stable, free draining, non-polluting, visually compatible with the surrounding landscape and vegetated with endemic plant communities similar to those that existed prior to disturbance.

To prevent inadvertent access at the Hercules project post-closure, NSR intends to construct an abandonment bund around the Hercules Pit which will tie into the waste dump landform shape. The abandonment bund will be constructed with dimensions in accordance with DEMIRS Guidelines. The runoff within the abandonment bund footprints will drain towards the Hercules pit void and won't be released downstream.

The northern/eastern flank of the Hercules waste dump will be rehabilitated as part of mine closure to ensure that dump doesn't become a long-term source of sediment. A reduction in runoff from the waste dump will occur through the use of wide, reverse grade benching and revegetated. A similar approach will be taken to the Penfold Waste Dump. In general, disturbance areas will be cleared of infrastructure, reshaped as required, cross ripped and seeded with native species.

6.3 Other Surface Water Considerations

Closure abandonment bunds are required around the pit to mitigate inadvertent access to the pit void and will be constructed to meet the DEMIRS guidelines. A section of the abandonment bund will also be used to divert flow to the east and around the closure landforms. This section will need to be constructed as an engineered flood protection bund to ensure long-term stability of the bund. Post-closure, the reduction in runoff volume reporting to the environment due to the Hercules Pit and waste dump will be reduced, with an effective reduction of <1% of the total catchment reporting to the downstream salt lakes. Assuming the reduction in catchment area is proportional to the reduction in runoff volume, a <1% potential reduction in runoff volumes would not be environmentally significant, particularly when considering the natural seasonal variations in catchment runoff.

6.4 Post Closure 2D Flood Model Results

To simulate the surface water regime post-closure, the PMP event was modelled in HEC-RAS with post-closure landforms from the Hercules project (described in prior section). The PMP depth of 600mm with a 44% proportional rainfall loss was simulated as rain-on-grid hydrology in the 2D post closure flood model for the 4-hour event.

Figure 6.1 shows the predicted maximum flood depths in a post-closure surface water regime for a PMP event. To the south/west of the Hercules closure landform, and adjacent to the abandonment/flood protection bund, the predicted flood depths peak at approximately 3.75m. This area may represent a possible ponding location, that may restrict flows from continuing downstream. It is recommended that a drain is constructed parallel to the abandonment bund (as shown by the indicative arrows on Figure 6.1) to promote positive drainage to convey flows downstream. Considerations for managing erosion risks along this drainage pathway may be required.

The West Creek diversion, around the Penfolds waste dump, will remain upon closure, including any rock armouring required, to ensure the channels remain effective in the long term.

Risk of erosion at the toe of the waste dump in a post-closure environment may also be prevalent and measures to ensure stability should be considered on the western and eastern sides of the waste dump/closure landform.

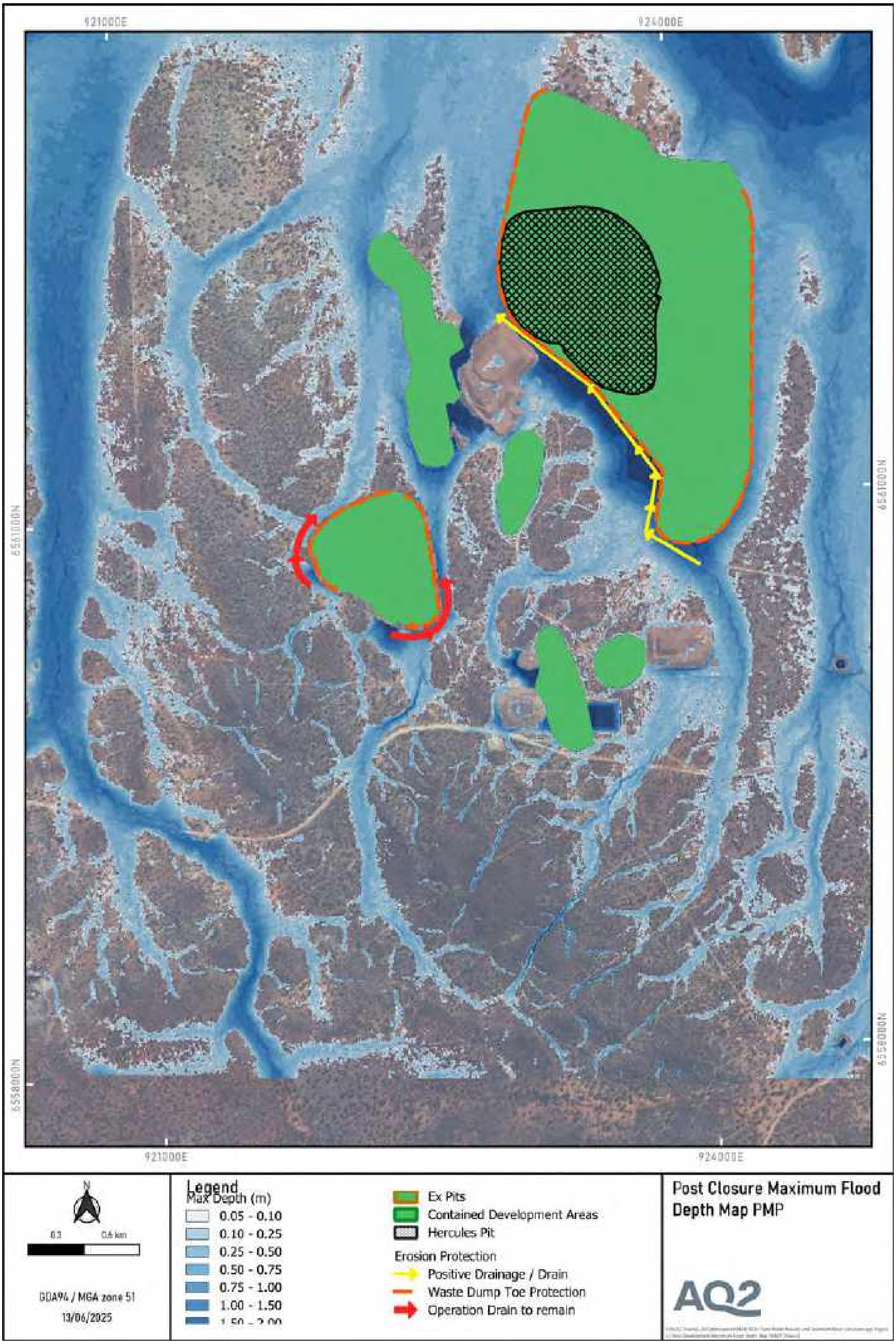


Figure 6.1 Post Closure Maximum Flood Depth Map PMP Event

7. SURFACE WATER MONITORING

Where sampling points can be safely accessed, water quality samples should be collected and analysed to develop a pre-development water quality data set which accounts for natural variations to runoff. Sample collection should include water quality from the drainage lines and from downstream terminal lakes. Given the arid conditions, surface water flow may only occur after significant rainfall events, and monitoring would need to be predominantly event-based. Grab sampling should occur as soon as surface water flow is observed. Continuous monitoring can be installed at key locations to automatically measure certain parameters (e.g. EC, pH) during rainfall events.

During mine operations, a surface water sampling network should be developed to monitor for potential impacts to runoff water quality from the Project. Figure 7.1 provides indicative surface water monitoring locations at the Hercules project. Sampling locations should include upstream sites (to serve as control points), immediate downstream sites, and farther downstream locations to assess and check the spread of any contaminants. Priority should be given to locations where runoff is most likely to collect, such as creek beds, ephemeral watercourses, and low-lying areas near the mining operations.

Parameters such as electrical conductivity (EC), pH, metals, sulfates, nitrates, and total suspended solids (TSS) should be measured, with special attention to contaminants that may arise from mining activities, such as hydrocarbons, metals, and any potential acid drainage.

Post-closure, the monitoring program should continue during the completion period or longer until it can be demonstrated that water quality is stable and comparable to pre-mining conditions. Water quality results should be regularly reported, ensuring compliance with relevant environmental regulations. Results should be compared against both pre-development data and site-specific water quality criteria, with triggers in place to initiate remediation or mitigation actions if significant deviations are observed.

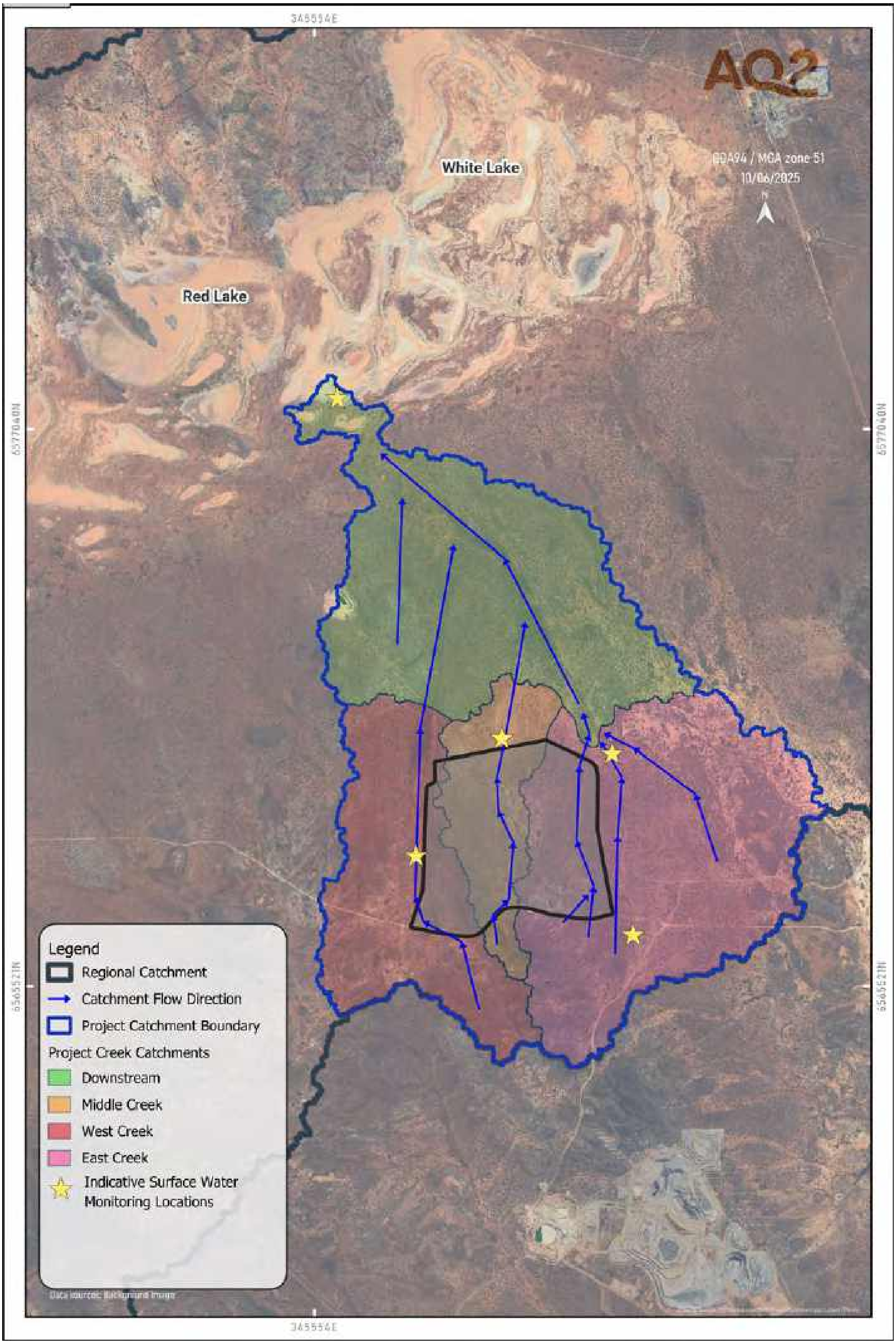


Figure 7.1 Indicative Surface Water Monitoring Locations

8. SUMMARY

The proposed mining activities for the Hercules project are located in the same area as previous operations, with plans to expand the mine to include a new pit, waste dumps, and associated infrastructure.

Pre-development hydrological conditions, such as the location and characteristics of flooding throughout the planned mine development footprint, have been predicted using a 2D flood model. Based on this modelling, a hydrological risk assessment was completed which identified the project risks which need to be mitigated. The main mitigation measures proposed include:

- Diversion of East Creek around the south and eastern side of the proposed Hercules Waste Dump footprint.
- Minor diversions around Penfold Waste Dump, plus minor diversions around hardstand and plant areas.
- Dirty water containment ponding around sediment generating disturbance areas (including the waste rock dump, ROM pad and stockpile areas) to divert dirty water runoff to sediment basins for treatment prior to discharge to the downstream environment.
- Runoff from some of the disturbance areas to be directed to the pit void.

A post-development flood model was prepared to predict the magnitude and extent of potential surface water changes from a 1% AEP design runoff event with the proposed mitigation measures accounted for. The residual hydrological risks for the project were re-assessed to be “low” or “insignificant” considering the results from the post-development flood model.

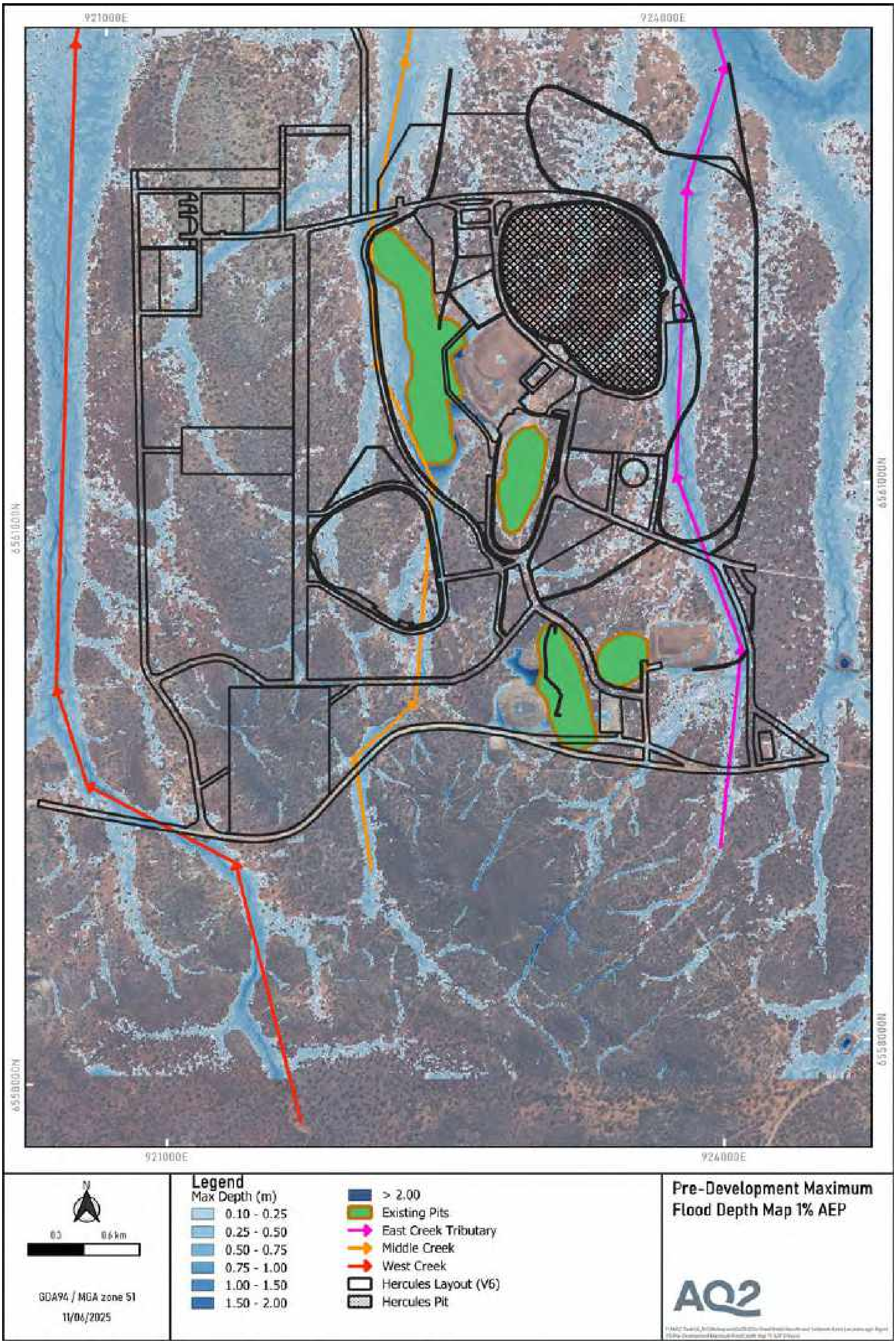
A post-closure flood model was developed and used to assess hydrological risks in the post-closure environment. The assessment resulted in recommendations that:

- A section of the pit abandonment bund, together with a parallel drain, be used to divert flows around the southern/western side of the post-closure Hercules landform.

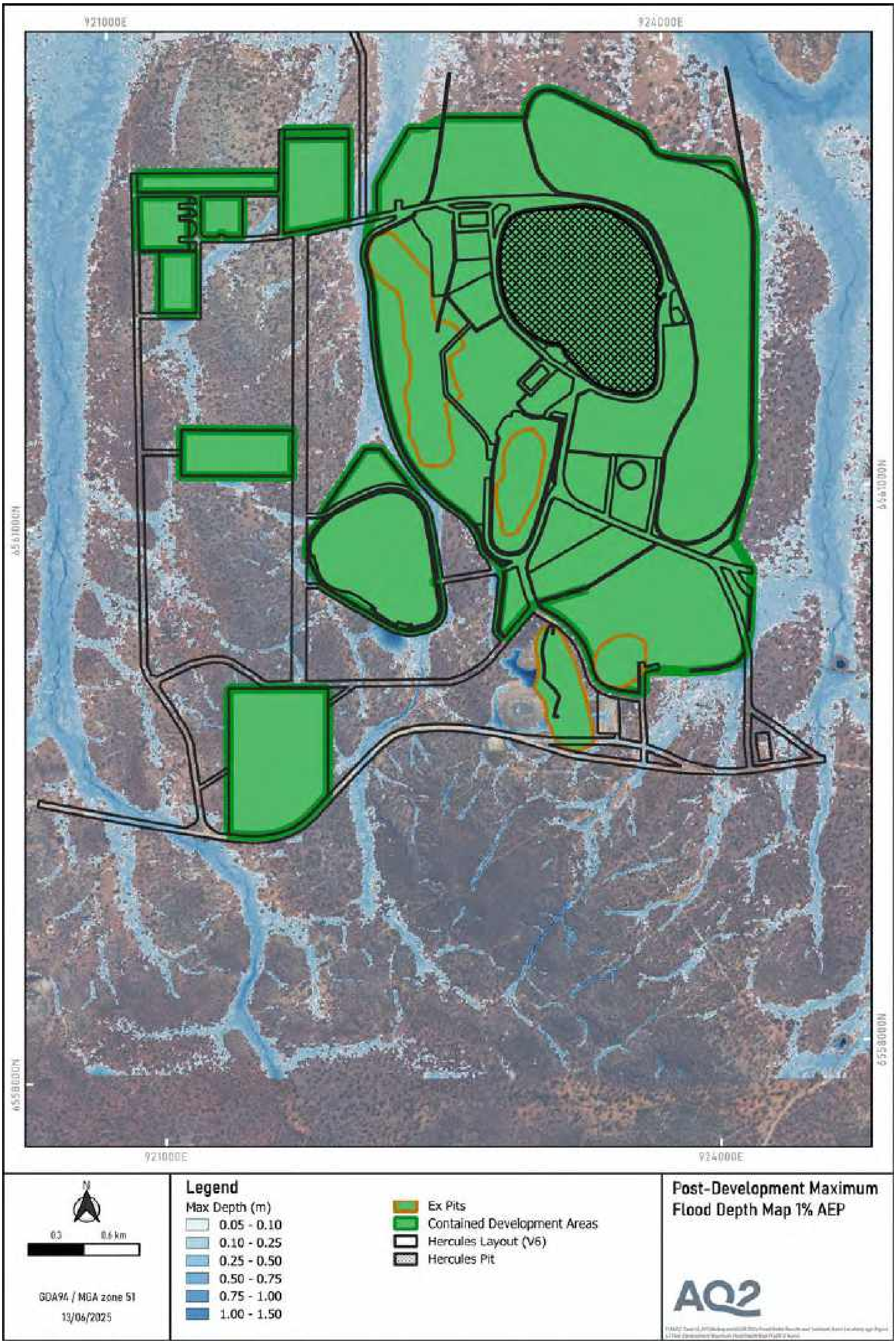
Measures to increase stability along the lengths of the waste dumps should be considered to reduce the risk of toe erosion due to flood flows.

A surface water monitoring network is proposed to allow monitoring of surface water quality during operations and post-closure to identify any potential contamination of runoff from the disturbance areas.

APPENDIX A
PRE-AND POST-DEVELOPMENT FLOOD DEPTH MAPS

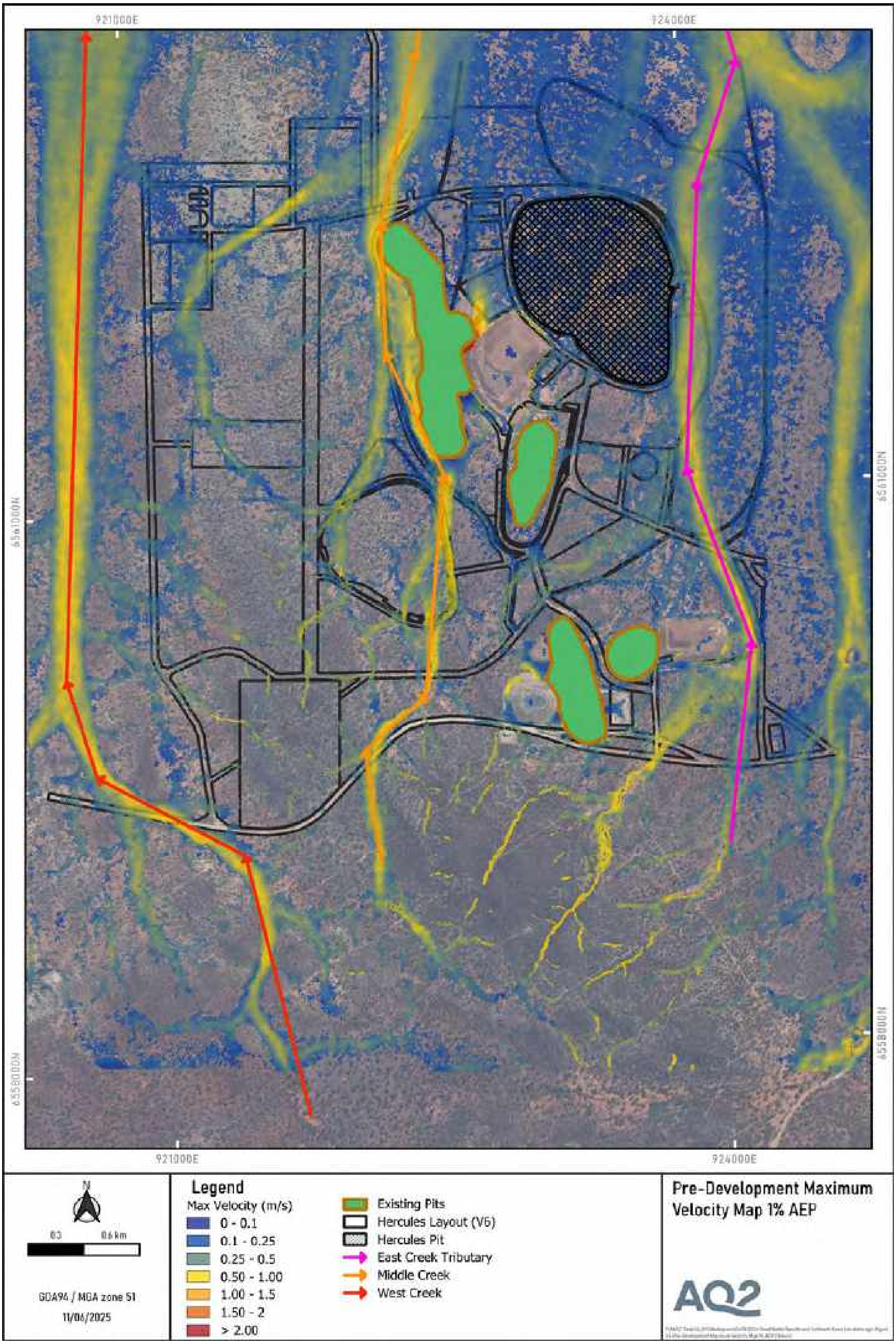


Pre-Development Maximum Flood Depth Map 1% AEP

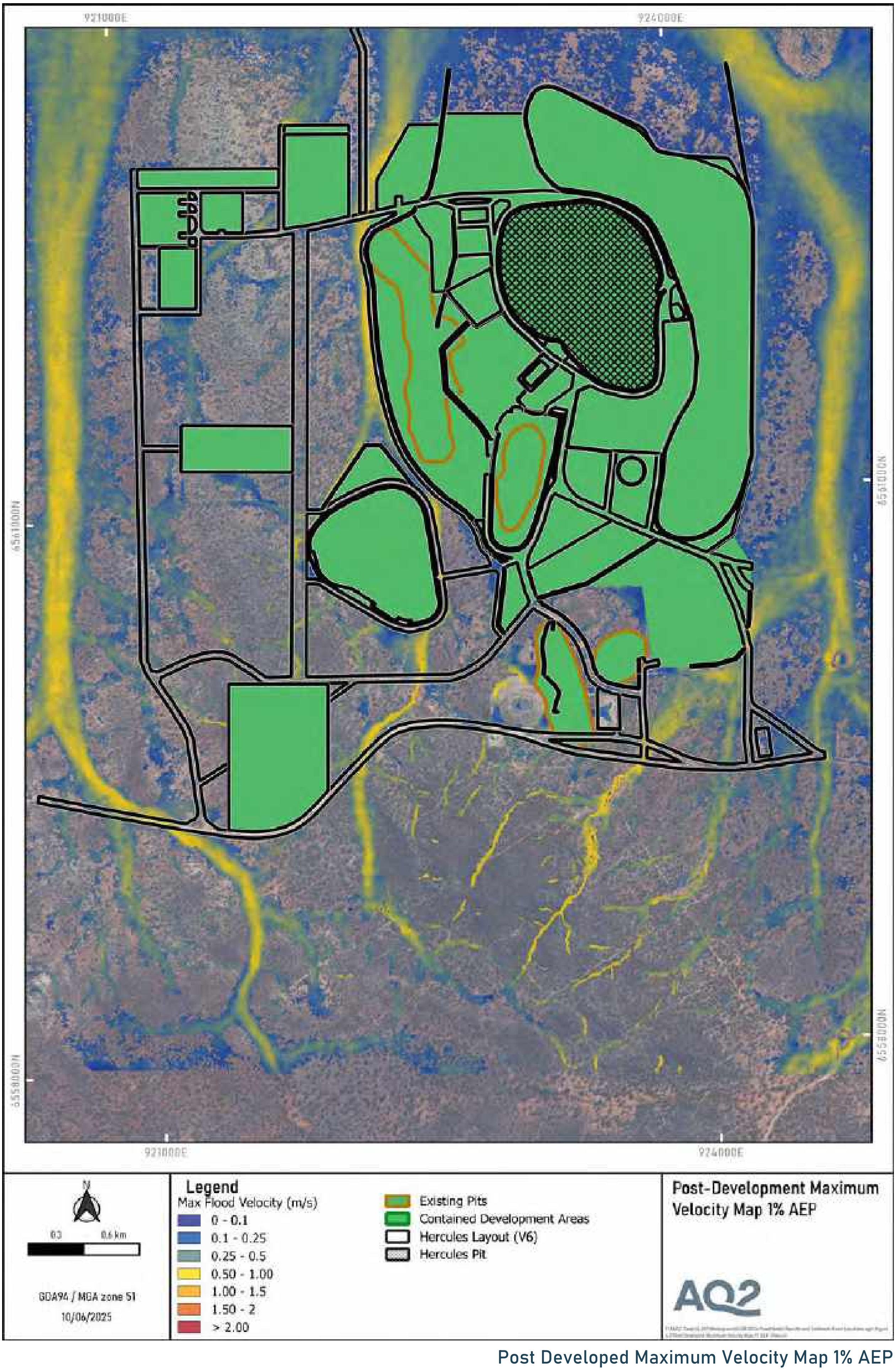


Post-Development Maximum Flood Depth Map 1%AEP

APPENDIX B
PRE-AND POST-DEVELOPMENT FLOOD VELOCITY MAPS

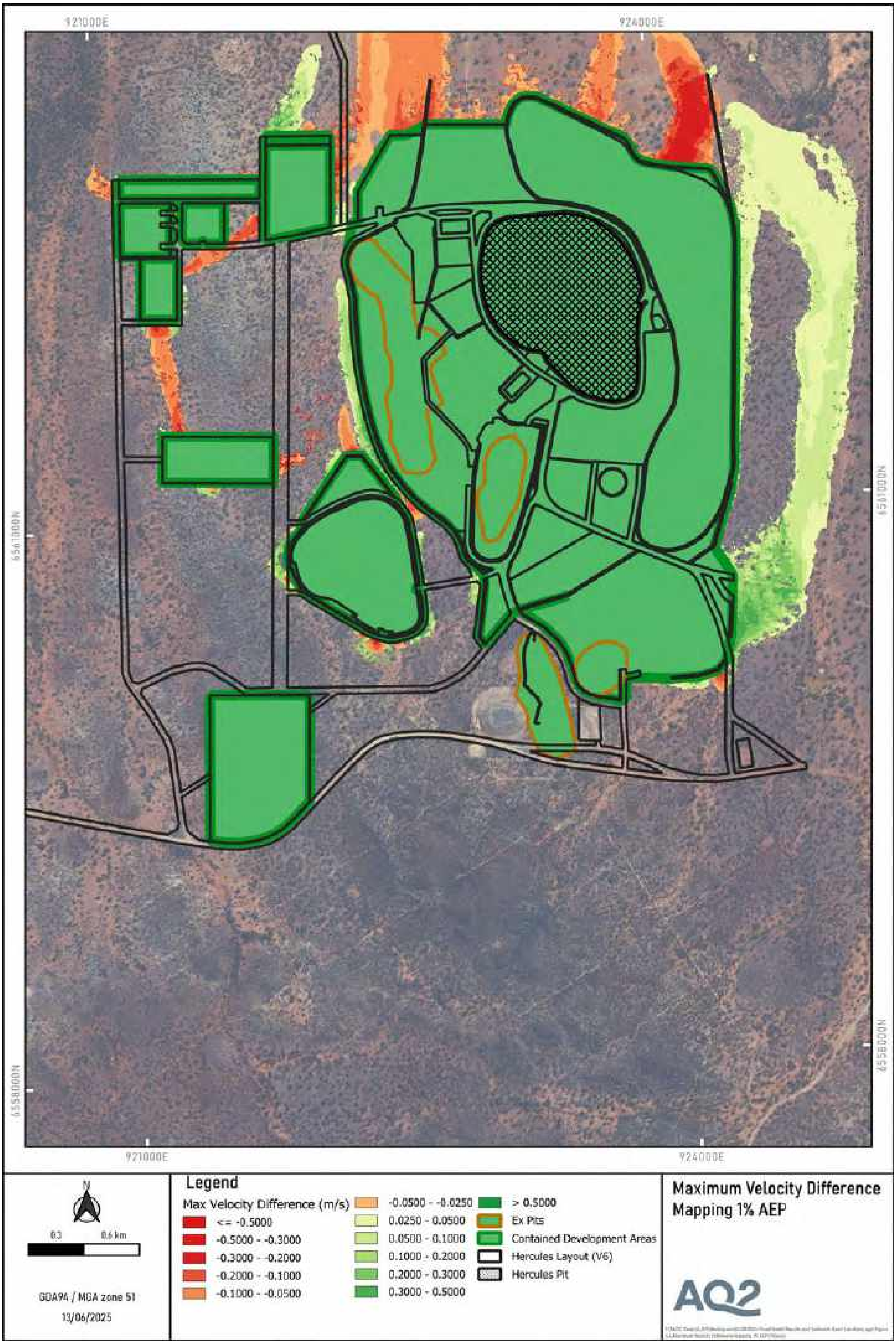


Pre-Development Maximum Velocity Map 1% AEP

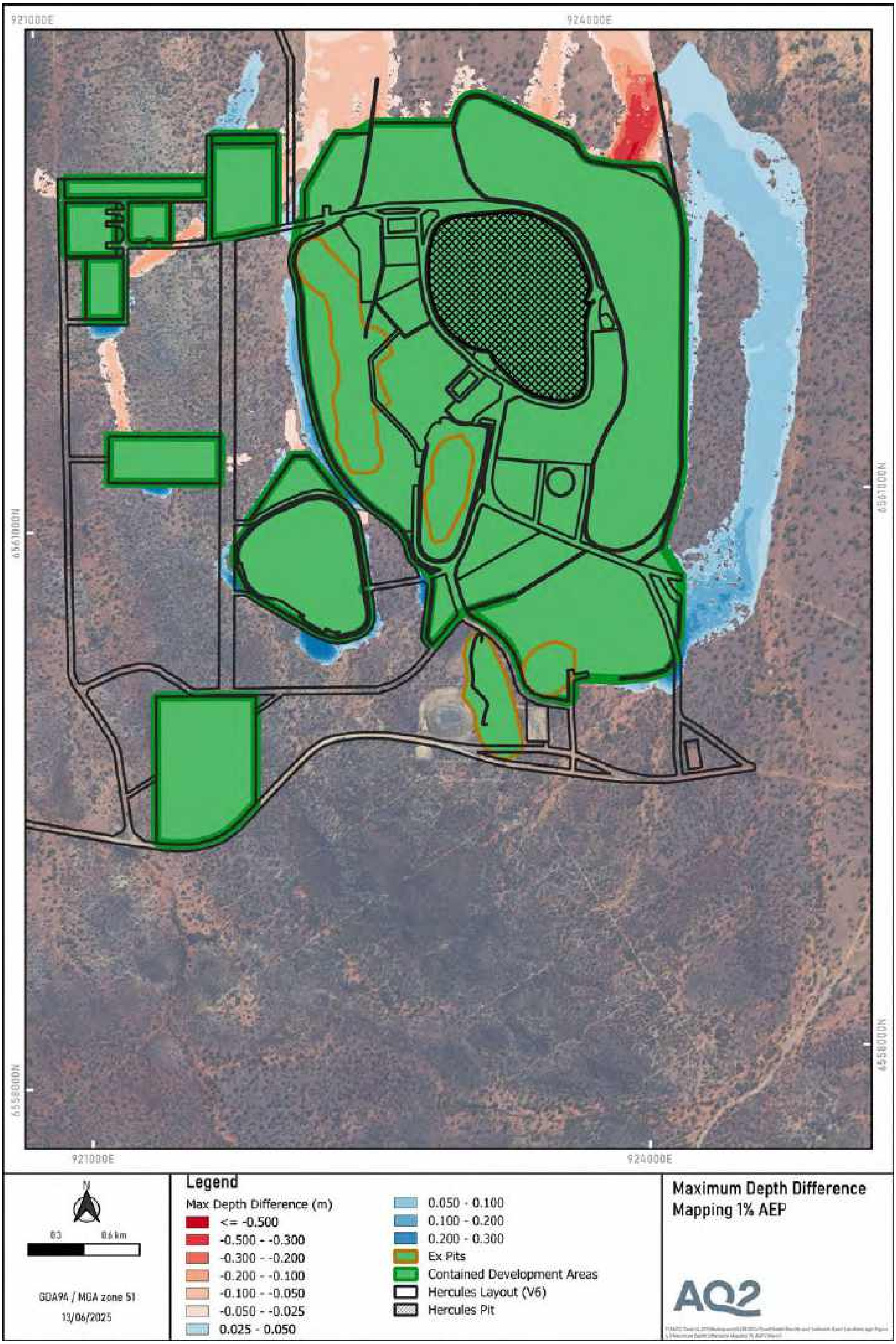


Post Developed Maximum Velocity Map 1% AEP

APPENDIX C
FLOOD DIFFERENCE MAPS



Maximum Velocity Difference Mapping 1% AEP



Maximum Depth Difference Mapping 1% AEP

APPENDIX D
RISK MATRIX DESCRIPTORS

7 Environmental Risk Management

7.1 Methodology

Northern Star has a risk assessment process to identify significant risks and ensure that appropriate management strategies are implemented to reduce potential impacts to people, the environment or community. The risk assessment identifies the hazards associated with planned activities, the likelihood of it occurring and the potential consequence (Tables 15 - 18).

- Risk assessments are utilised to:
- Identify activities that could result in safety, environmental or community impacts;
- Quantify the level of inherent risk (pre-treatment) of the activity i.e. no control measures applied;
- Develop appropriate control measures to reduce the residual risk (post-treatment);
- Document these processes so they form part of the EMS; and
- Routinely monitor and review the effectiveness of these processes and control measures aiming for continuous improvement.

The aim of the process is to reduce the residual risk to 'As Low as Reasonably Practicable' (ALARP). The best way to control a risk is to eliminate the hazard altogether, however this is not always practicable. Northern Star use the 'Hierarchy of Control' which is widely accepted as a systematic approach to risk management. It provides a structure to select the most effective control measures to eliminate or reduce the risk of identified hazards.

Table 15. Likelihood Categories

	Description	Criteria (read as either/ or)
LIKELIHOOD	Almost Certain (A)	The event is expected to occur in most circumstances; Once per week
	Likely (B)	The event will probably occur in most circumstances; Once per month
	Possible (C)	The event could possibly occur at some time; Once per year
	Unlikely (D)	The event could possibly occur at some time but is unlikely; Once every 5-10 years
	Rare (E)	The event may occur in exceptional circumstances; >10 years

Table 16. Consequence Categories

	Insignificant (5)	Minor (4)	Moderate (3)	Major (2)	Catastrophic (1)
Biodiversity	- Negligible localised ecosystem component impact, contained.	- Minor ecosystem component impact within site boundary, contained.	- Moderate ecosystem component impact, extends beyond site boundary, uncontained. - Able to be remediated in short-term.	- Severe ecosystem component impact requiring long-term remediation. - Severe impact to a priority species.	- Severe permanent ecosystem component impact. - Total loss of a priority species.
Water	- Negligible localised surface/ groundwater impact, contained.	- Minor surface/ groundwater impact within site boundary, contained.	- Moderate surface/ groundwater impact, extends beyond site boundary, uncontained. - Able to be remediated in short-term.	- Severe surface/ groundwater impact requiring long-term remediation.	- Severe permanent surface/ groundwater impact.
Land and Soil Degradation	- Negligible localised environmental impact, contained.	- Minor environmental impact within site boundary, contained.	- Moderate environmental impact, extends beyond site boundary, uncontained. - Able to be remediated in short-term.	- Severe environmental impact requiring long-term remediation.	- Severe permanent environmental impact.
Rehabilitation and Mine Closure	- Site is safe. - Stability or pollution issues are localised and contained. - Post-mining land use is not impacted.	- Site is safe. - Stability or pollution issues are localised and contained. - Short-term management required by post-mining land user.	- Site is safe. - Stability or pollution issues require ongoing/ long-term management by post-mining land user.	- Site cannot be considered safe, stable or non-polluting without significant intervention. - Post-mining land use cannot proceed.	- Site is permanently unsafe, unstable and/ or polluting. - Post-mining land use cannot be achieved.

Table 17. Risk Ranking Matrix

			CONSEQUENCE				
			Insignificant	Minor	Moderate	Major	Catastrophic
			5	4	3	2	1
LIKELIHOOD	Almost Certain - Expected occurrences - once per week	A	5A Medium	4A Medium	3A High	2A High	1A High
	Likely - Probable occurrences - once per month	B	5B Medium	4B Medium	3B High	2B High	1B High
	Possible - Possible occurrences - once per year	C	5C Low	4C Medium	3C Medium	2C Medium	1C High
	Unlikely - Unlikely to occur - once every 5-10 years	D	5D Low	4D Low	3D Low	2D Medium	1D Medium
	Rare - May occur in exceptional circumstances - >10 years	E	5E Low	4E Low	3E Low	2E Medium	1E Medium

APPENDIX E
SURFACE WATER RISK MATRIX (INHERENT AND RESIDUAL)

Type	ID	Risk Pathway/Unwanted Event	Description of Impact	Phase(s)	Consequence	Likelihood	Inherent Risk Rating	Risk Treatment / Mitigation Measure	Consequence	Likelihood	Residual Risk Rating
Modification to Hydrological Regime	R1	Proposed Hercules Waste Dump encroachment in the East Creek floodplain (namely the western tributary of East Creek).	Floodplain encroachment will impede creek flow, causing ponding and a reduction in downstream flow.	Operations	Major	Almost Certain	2A	Proposed flood diversion bunding will divert water around the mine disturbance area, passing on the eastern side of the waste dump. Grading around the toe of the bunding may be required to ensure continuous surface water flows to the north.	Minor	Unlikely	4D
	R2	Proposed waste dump and ROM pad encroachment in the East Creek floodplain (namely the western tributary of East Creek).	Floodplain encroachment will impede creek flow, causing ponding and a reduction in downstream flow.	Closure	Major	Almost Certain	2A	Proposed flood diversion bunding will divert water around the waste dump and ROM pad. Grading around the toe of the bunding may be required to ensure continuous surface water flows to the north. Erosion protection of the toe of the bunding will be required to ensure the structure remains stable post-closure.	Minor	Unlikely	4D
	R3	Surface water captured within the Hercules development footprint will reduce runoff to downstream environment.	Runoff collected within the pit, held up on waste dumps, and trapped behind demarcation bunds will reduce runoff downstream. This may impact downstream vegetation / ecology	Operations	Insignificant	Likely	5B	The reduction in catchment reporting to the downstream salt lakes due to the containment and treatment of water within the Hercules project footprint is approximately 7%. Sediment basins should be positioned to return captured and treated surface water in the Hercules development footprint.	Insignificant	Unlikely	5D
	R4	Proposed Penfold Waste Dump partially blocks Middle Creek	Floodplain encroachment will impede creek flow, causing ponding and a reduction in downstream flow.	Operations	Moderate	Almost Certain	3A	Construct a diversions to aid surface water flows around the waste dump.	Minor	Unlikely	4D

Type	ID	Risk Pathway/Unwanted Event	Description of Impact	Phase(s)	Consequence	Likelihood	Inherent Risk Rating	Risk Treatment / Mitigation Measure	Consequence	Likelihood	Residual Risk Rating
	R5	Proposed Penfold Waste Dump partially blocks Middle Creek	Floodplain encroachment will impede creek flow, causing ponding and a reduction in downstream flow.	Closure	Moderate	Almost Certain	3A	Diversions around the Penfold Waste Dump will maintain runoff flow to the downstream area and prevent ponding against the waste dump. Erosion protection of the toe of the bunding will be required to ensure the structure remains stable post-closure.	Minor	Unlikely	4D
Sediment Generation	R6	Sediment-laden runoff from waste dumps, stockpiles and disturbed surfaces	Ongoing sediment release to the downstream environment from small to medium rainfall events adversely impacting downstream water quality (ecology and riparian vegetation)	Construction/ Operations	Moderate	Likely	3B	Trap all sediment laden runoff behind demarcation or specific capture bunds, and direct to sediment basins to settle out coarse silt and sand prior to discharge into the environment. Ensure separation of clean water diversions and dirty water runoff from stockpiles and the waste dump. Direct runoff from some of the Hercules Waste Dump to the Hercules pit.	Insignificant	Unlikely	5D
Sediment Generation	R7	Sediment-laden runoff from face of waste dumps, stockpiles and disturbed areas.	Sediment release to the downstream environment from large rainfall events impacting riparian vegetation and downstream water quality.	Operations	Insignificant	Possible	5C	No treatment proposed other than dilution. Large rain events will overflow capture devices and sediment in overflow waters would be consistent with natural high sediment loads in large floods.	Insignificant	Possible	5C
Sediment Generation	R8	Erosion of waste dumps and stockpiles	Erosion of the waste dump toe, and stockpiles due to flood waters, particularly the East Creek tributary diversion, leading to slope failure and a release of sediment downstream.	Operations	Major	Unlikely	2D	Ensure low velocity flow around infrastructure to reduce the risk of erosion. Provide adequate flood protection, such as rock armouring, to the waste dump toe and stockpiles.	Insignificant	Unlikely	5D
Sediment Generation	R9	Sediment-laden runoff from the remnant waste dump.	Sediment release to the downstream environment from rainfall events impacting riparian vegetation and downstream water quality.	Closure	Moderate	Unlikely	3D	Position a sediment bund at the toe of the waste dump.	Insignificant	Unlikely	5D
Sediment Generation	R10	Erosion of waste dumps and stockpiles	Erosion of the waste dump toe due to flood waters may lead to slope failure and a release of sediment downstream.	Closure	Major	Unlikely	2D	Provide adequate flood protection, such as rock armouring, to the waste dump toe and stockpiles.	Insignificant	Unlikely	5D
Quality	R11	Spillage of hydrocarbons and chemicals	Pollution of downstream environment leading to environmental damage.	Construction/ Operations	Major	Possible	2C	Storage, handling and transport procedures required on site. Runoff from wash bays and fuel storage/handling areas directed to grit & oil separators prior to discharge.	Minor	Unlikely	4D

Type	ID	Risk Pathway/Unwanted Event	Description of Impact	Phase(s)	Consequence	Likelihood	Inherent Risk Rating	Risk Treatment / Mitigation Measure	Consequence	Likelihood	Residual Risk Rating
Water	R12	Dust suppression (saline) water runoff into the environment.	Vegetation adversely affected by (saline) runoff water.	Construction/ Operations	Moderate	Possible	3C	Dust suppression operations to be managed to prevent over-watering of roads.	Minor	Unlikely	4D

Appendix C – Saline dam (turkeys nest) design specifications

Appendix C – Saline Dam (Turkeys Nest) Design Specifications

1. Summary

- Four Turkey's nest will be constructed for excess mine water to be used for dust suppression and re-used for mining operations.
- All dams will be lined with HDPE plastic.
- Maximum level of all dams will be controlled by level sensors and auto shutoff inflow control logic i.e.; the water is shutoff when it reaches the freeboard setpoint of 300m.
- Dam dimensions and storage capacities are identical for all four proposed dams (see **Figures 1-4** below).
- Dam design specifications are outlined in **Table 1** below.

Table 1. Dam design specifications.

Item	Units	Turkeys Nest 1	Turkeys Nest 2	Turkeys Nest 3	Turkeys Nest 4
Dam depth	m	3	3	3	3
Dam length (approximate)	m	140.2	140.2	140.2	140.2
Dam width (approximate)	m	59.4	59.4	59.4	59.4
Wall width (minimum)	m	5	5	5	5
Inner wall slopes	Degrees	30	30	30	30
Outer wall slopes	Degrees	30	30	30	30
Freeboard	mm	300	300	300	300
Estimated storage capacity	m^3	8690	8690	8690	8690
Estimated volume of freeboard	m^3	1230	1230	1230	1230
Total area occupied by dam	m^2	8335	8335	8335	8335
Total area occupied by storage facility	m^2	27202	10425	19758	47299

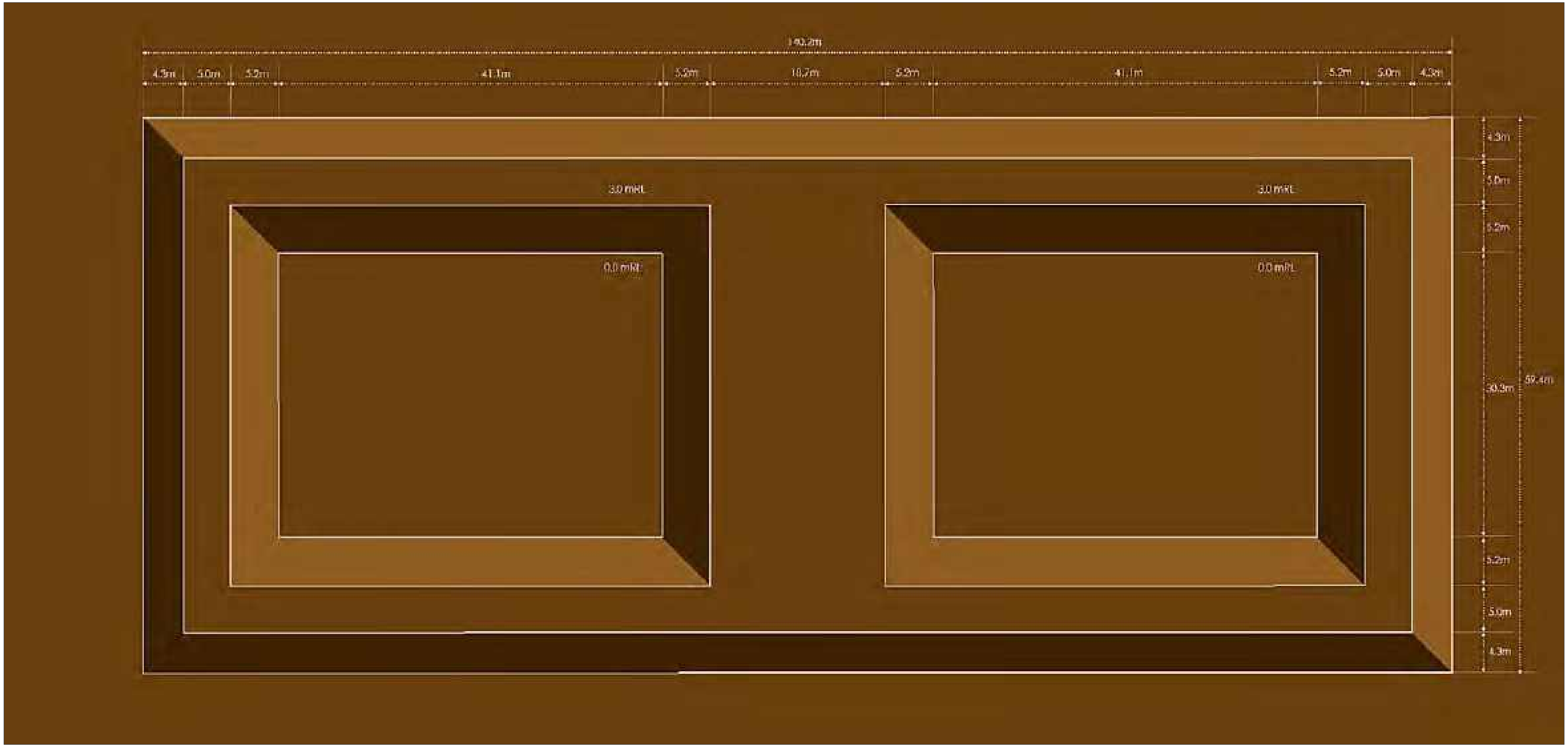


Figure 1. Top down view empty.

Figure 2. Top down view at capacity.

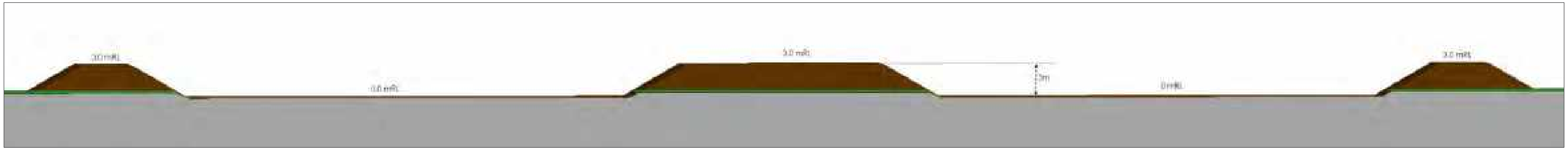


Figure 3. Cross-section empty.

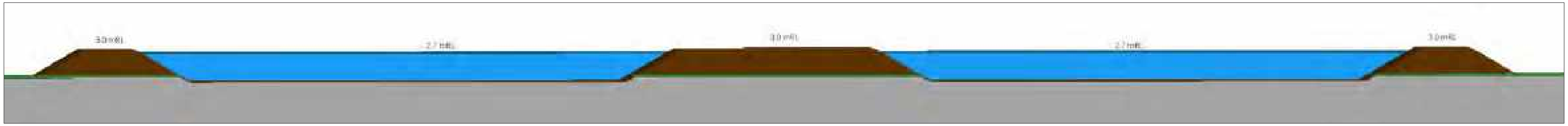


Figure 4. Cross-section at capacity.