



Federation Project

Groundwater Impact Assessment

Hera Resources Pty Limited

22 November 2021

GHD Pty Ltd | ABN 39 008 488 373

GHD Tower, Level 3, 24 Honeysuckle Drive

Newcastle, New South Wales 2300, Australia

T +61 2 4979 9999 | **F** +61 2 9475 0725 | **E** ntlmail@ghd.com | **ghd.com****Document status**

Status Code	Revision	Author	Reviewer		Approved for issue		
			Name	Signature	Name	Signature	Date
S4	0	I Gilmore	S Gray		S Gray		19/11/2021
S4	1	I Gilmore	S Gray		S Gray		22/11/2021

© GHD 2021

This document is and shall remain the property of GHD. The document may only be used for the purpose for which it was commissioned and in accordance with the Terms of Engagement for the commission. Unauthorised use of this document in any form whatsoever is prohibited.

Executive summary

Hera Resources Pty Limited (Hera Resources) is a wholly owned subsidiary of Aurelia Metals Limited (Aurelia). Hera Resources currently own and operate the Hera Mine located approximately 80 km south-east of Cobar and approximately 5 km south of the township of Nymagee in western NSW.

Hera Resources is evaluating the development of the Federation Project (the Project), a proposed underground metalliferous mine development. The Project comprises underground mining activities and surface infrastructure at the Federation Site (Federation), mining approximately 6.95 million tonnes (Mt) of ore over a period of 12 to 14 years, amendments at Hera Mine to facilitate processing of ore from Federation, a Services Corridor connecting Federation with Hera Mine and a proposed borefield to supplement water supply. Federation is located approximately 15 km south of the Nymagee township and 10 km south of the Hera Mine.

This Groundwater Impact Assessment (GIA) has been prepared to form part of an Environmental Impact Statement (EIS). The key objective of the GIA is to assess the potential impacts of the Project on the groundwater environment by addressing the relevant Secretary's environmental assessment requirements (SEARs) for the Project and relevant government agency requirements.

The indurated Palaeozoic sediments constitute a fractured rock aquifer where groundwater is stored and transmitted via fractures, joints and other discontinuities within the rockmass. The fractured rock groundwater source is classified as 'less productive' in accordance with the criteria specified in the NSW Aquifer Interference Policy (i.e. the yield is typically less than 5 L/s and/or the total dissolved solids concentration is typically greater than 1,500 mg/L).

The fractured and porous groundwater sources are managed under the water sharing plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources. Groundwater levels at the site are deep at 45 m to 75 m below ground level (bgl) at Hera Mine and Nymagee Copper Mine, and from 75 m to 90 m bgl at Federation. Based on monitoring data collected at the Nymagee Copper Mine, Hera Mine and Federation, groundwater flow is east north-east to west south-west.

There is no evidence of either a perched shallow aquifer or any alluvial aquifers in the vicinity of Federation, Hera Mine and proposed borefield. The shallow colluvium has been dry throughout exploration drilling and bores that are located in the paleochannel near Federation that were installed as part of the Project were also dry. Watercourses in the vicinity of the Federation Site are unnamed tributaries of Sandy Creek. These watercourses are located approximately 1 km from the proposed Federation mine workings. These watercourses are ephemeral. Due to the low rainfall and deep water table, it is considered unlikely that there is any alluvial aquifer associated with these watercourses.

Registered groundwater use in the vicinity of Federation is low. The majority (19) of registered bores identified within 20 km of Federation and Hera Mine (total of 34) were bores associated with operations at Hera Mine. This does not include the Nymagee Town Bore. The Nymagee Town Bore is an unregistered bore located in the township of Nymagee, approximately 5 km north of Hera Mine. The closest registered stock and domestic bores to Hera Mine include GW017385 which is located approximately 3 km north of Hera Mine and GW017386 which is located approximately 2.5 km south of Hera Mine and is 650 m from the nearest Hera Mine groundwater production bore (WB11). The closest registered stock and domestic bores to Federation are GW020714 and GW017386 which are located 6.4 km and 7.4 km from Federation respectively. The closest registered stock and domestic bores to the proposed borefield are GW017386 and GW20714 which are located 4.5 km and 5 km from the borefield respectively.

It is considered unlikely that there are any Groundwater Dependent Ecosystems (GDEs) in the vicinity of Federation due to the deep water table. There are no GDEs within or near the Project that are classified as 'high priority' listed in the relevant Water Sharing Plan.

Groundwater monitoring at Hera Mine monitoring bores commenced in 2011. Monitoring data shows the impacts mining at Hera Mine and extraction from Hera Mine production bores have had on groundwater levels. The monitoring data indicates that underground mining may have resulted in drawdown of up to 4 m at a distance of 1.5 km from Hera Mine. Monitoring data do not show any impact from operations at Hera Mine on groundwater quality or the beneficial use category of groundwater. Groundwater monitoring at Federation commenced in July 2020 and monthly baseline monitoring has been undertaken since that time.

Changes (levels and flows) to groundwater sources and impacts on groundwater sources as a result of the Project have been predicted using a calibrated three dimensional numerical hydrogeological model. The numerical groundwater model was developed based on the conceptualisation of the hydrogeological environment. The numerical groundwater model was calibrated to observed groundwater level trends and observed groundwater inflows at Hera Mine. This adds confidence to predictions of the model of the Project. The numerical groundwater model has been used to predict:

- Changes in groundwater inflows to the Hera Mine workings
- Groundwater inflows to the Federation workings
- Changes in groundwater level due to mining at Federation, continued dewatering of the Hera Mine workings and proposed production bores
- Drawdown due to the Project at landholder bores

The hydrogeological model has been used to predict impacts from the approved mining at Hera Mine and the cumulative impact of the approved mining at Hera Mine and the Project. The incremental impact directly attributable to the Project has also been determined from the difference between cumulative and approved impacts.

Based on model predictions, groundwater inflows into the proposed Federation mine workings are predicted to peak at 0.34 ML/day in 2028. Based on model predictions, groundwater inflows into the existing Hera Mine workings are predicted to remain relatively constant and approximately equal to the current rate of groundwater inflow throughout the period of continued dewatering.

The hydrogeological model predicts that the approved mining at Hera Mine will result in drawdown of the water table of about 1 m up to approximately 4.5 km from the Hera Mine workings. The hydrogeological model predicts that under proposed conditions, the continued dewatering of the Hera Mine workings will result in drawdown of the water table of about 1 m up to approximately 6.2 km from the Hera Mine workings. The hydrogeological model predicts that the proposed mining at Federation will result in drawdown of the water table of about 1 m up to 8 km to the west and 10.5 km to the east of the Federation workings. Some of the drawdown to the east of the Federation mine workings is attributable to the proposed production bores.

Landholder bores within the radius of drawdown have been identified. Four registered landholder bores that were not associated with operations at Hera Mine and monitoring at the Federation Site were located within the radius of drawdown. Two unregistered bores, the Nymagee Town Bore and Harland's Bore, were located within the radius of drawdown. Modelled drawdown was less than 2 m under proposed and approved conditions at all of these bores with the exception of bores GW017385 and GW020714.

The maximum modelled drawdown at GW017385 is approximately 3.5 m under approved conditions and approximately 4 m under proposed conditions. Drawdown at GW017385 is attributable to mining at Hera Mine. The additional drawdown at GW017385 under proposed conditions is attributable to the continued dewatering of the Hera Mine workings. The maximum modelled drawdown at GW020714 is 2.7 m under proposed conditions. Drawdown at GW020714 is negligible (less than 0.1 m) under approved conditions. Drawdown at GW020714 is attributable to mining at Federation. As drawdown at GW017385 and GW020714 is predicted to be greater than 2 m, make good provisions will apply at these bores under the Level 1 minimal impact considerations outlined in the NSW Aquifer Interference Policy (AIP).

For the 14 years of mining at Federation, the dewatering would result in the potential exposure of acid generating geological materials. The dewatering of mine workings, however, would also result in a sink or depression forming in the regional water table, and therefore there is a tendency for acid / metalliferous drainage being collected or its movement hydraulically controlled and managed by the dewatering operations. Following the end of dewatering, the workings will be sealed and the site will continue to be a groundwater sink until groundwater levels start to recover and reach equilibration. Post-closure contours indicate that modelled groundwater levels will have recovered to within 2 m of pre-mining groundwater levels within approximately 65 years of the end of mining at Federation. Oxidation will cease once the portal and vent rises are sealed. The back-filling of the Federation mine workings with tailings paste will also reduce the likelihood of oxidation occurring. As a result, acid mine drainage post closure is unlikely to be a significant risk.

Review of groundwater quality data at Federation indicated that groundwater is slightly brackish to saline (2,000 $\mu\text{S}/\text{cm}$ to 10,000 $\mu\text{S}/\text{cm}$). Therefore, groundwater at Federation is only suitable for stock watering or industrial use. Leachate from the tailings paste backfill (forming a permanently cemented matrix where oxidation of sulfide minerals is significantly limited) or the potentially acid forming rock is considered unlikely to change the beneficial use category of groundwater at Federation.

It is considered unlikely that there are any GDEs in the vicinity of Hera Mine, Federation and proposed production bores due to the depth to water table. The depth to water table varies from 45 m to 75 m bgl at Hera Mine and Nymagee Copper Mine, and 75 m to 90 m bgl at Federation, which is well below the expected depth of any root systems. There are no high priority GDEs or culturally significant sites listed in the relevant water sharing plan within 20 km of Federation Site. Therefore, potential impacts on high priority GDEs and culturally significant sites are within the Level 1 minimal impact considerations for GDEs from the NSW AIP.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.8 and the assumptions and qualifications contained throughout the Report.

Glossary

Aquifer	A groundwater bearing formation sufficiently permeable to transmit and yield groundwater.
Australian Height Datum	A common national surface level datum approximately corresponding to mean sea level.
Bore	Constructed connection between the surface and a groundwater source that enables groundwater to be transferred to the surface either naturally or through artificial means.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site.
Cumulative Rainfall Departure	Monthly accumulation of the difference between the observed monthly rainfall and long term average monthly rainfall.
Dewatering	The removal or pumping of water from an above or below ground storage, including the mine water within the water collection system of mine workings. Water removed from mine workings is regarded as dewatering unless the workings are flooded and at equilibrium with the surrounding strata (in which case the removal is considered groundwater extraction).
Discharge	The quantity of water per unit of time flowing in a stream, for example cubic metres per second or megalitres per day.
Drawdown	A reduction in piezometric head within an aquifer.
Ephemeral	Stream that is usually dry, but may contain water for rare and irregular periods, usually after significant rain.
Fracture	Cracks within the strata that develop naturally or as a result of underground works.
Groundwater	Subsurface water that occurs in soils and geological formations.
Groundwater extraction	For the purposes of this assessment, groundwater extraction has been defined as the removal of groundwater from a groundwater source or aquifer, either via direct removal for use via a production bore or via incidental flow of groundwater from the aquifer into the mine workings during and after mining. Groundwater extraction includes the pumping of underground water from flooded mine workings in equilibrium with the surrounding strata as well as the removal of water from perched aquifers recharged directly from rainfall infiltration.
Hydrogeology	The area of geology that deals with the distribution and movement of groundwater in soils and rocks.
Hydrograph	A graph which shows how a water level (either surface or underground) at any particular location changes with time.
Hydrology	The study of rainfall and surface water runoff processes.
Infiltration	The downward movement of water into soil and rock. It is largely governed by the structural condition of the soil, the nature of the soil surface (including presence of vegetation) and the antecedent moisture content of the soil.
Licensed Discharge Point	A location where a licensed operation discharges water to the environment in accordance with conditions stipulated within the site Environment Protection Licence.
Quadtree	Method of partitioning a two-dimensional space by recursively subdividing it into four quadrants or cells.
Run of Mine	Raw mineral production (unprocessed).
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Strata	Geological layers below the ground surface.
Structure	The combination or spatial arrangement of primary soil particles (clay, silt, sand, gravel) into aggregates such as peds or clods, and their stability to deformation.
Stope	The process of extracting the ore from the underground mine, leaving behind an open space known as a stope.
Surface Water	Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks and drainage lines.
Tailings	Fine reject material produced as a result of the mineral processing.

Abbreviations

AHD	Australian Height Datum
AEM	Airborne Electromagnetic Survey
AIP	Aquifer Interference Policy
Aurelia	Aurelia Metals Limited
bgl	Below ground level
BOM	Bureau of Meteorology
CRD	Cumulative rainfall departure
DA	Development Application
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
EPL	Environment Protection Licence
EVP	Equivalent Porous Medium
GDE	Groundwater Dependent Ecosystem
GHB	General Head Boundary
GHD	GHD Pty Ltd
GIA	Groundwater Impact Assessment
GMS	Groundwater Modelling System
ha	Hectares
Head change	Observed groundwater drawdown
Heads	Observed GW levels
Hera Resources	Hera Resources Pty Ltd
km	kilometre
m	Metres
MB	Monitoring bore
MDB	Murray-Darling-Basin
MF-USG	Modflow USG
ML	Megalitre, Mining Lease
ML/day	Megalitre per day
mm	Millimetres
MOP	Mine Operation Plan
Mt	Million tonnes
Mtpa	Million tonnes per annum
NAF	Non-acid forming
NRAR	Natural Resources Access Regulator
PA	Project Approval
PAF	Potential-Acid forming
PGM	Peak Gold Mine
RMS	Root Mean Square Error
ROM	Run of Mine

SEARs	Secretary's environmental assessment requirements
SILO	Scientific Information for Land Owners
SRMS	Scaled Root Mean Square Error
SSD	State significant development
SWIA	Surface water Impact Assessment
t	Tonnes
TSF	Tailings Storage Facility
µS/cm	MicroSiemens
USGS	United States Geological Survey
WAL	Water Access Licence
WSP	Water Sharing Plan

Contents

1.	Introduction	1
1.1	Overview	1
1.2	Background	1
1.3	Project overview	1
1.4	Transitional period	4
1.5	Federation project detailed overview	5
1.6	Purpose of this report	7
1.7	Objectives and scope of work	7
1.8	Limitations	9
2.	Legislation and policy	10
2.1	Legislation	10
2.1.1	Environmental Planning and Assessment Act 1979	10
2.1.2	Protection of the Environment Operations Act 1997	10
2.1.3	Water Management Act 2000	10
2.1.3.1	Water sharing plans	11
2.1.3.2	Hera Mine	11
2.1.3.3	Water Management (General) Regulation 2018	11
2.2	Policies	11
2.2.1	NSW Aquifer Interference Policy	11
2.2.2	NSW State Groundwater Policy	12
2.2.2.1	NSW Groundwater Quantity Protection Policy	12
2.2.2.2	NSW Groundwater Quality Protection Policy	12
2.2.2.3	NSW Groundwater Dependent Ecosystems Policy	12
3.	Hydrogeological conceptualisation	13
3.1	Climate	13
3.2	Topography	15
3.3	Hydrology	15
3.4	Geology	15
3.4.1	Regional geology	15
3.4.2	Local geology	15
3.4.3	Airborne electromagnetic (AEM) survey	16
3.5	Groundwater receptors	21
3.5.1	Landholder bores	21
3.5.2	Groundwater dependent ecosystems	25
3.5.2.1	Occurrence within the region	25
3.6	Historical and current mining operations	28
3.6.1	Hera mining operations	28
3.6.2	Nymagee Mine	29
3.7	Groundwater monitoring program	29
3.7.1	Hera Mine	29
3.7.1.1	Monitoring bores	29
3.7.1.2	Monitoring program	29
3.7.2	Federation	33
3.7.2.1	Monitoring bores	33
3.7.3	Nymagee Copper Mine	34
3.8	Groundwater monitoring results	34
3.8.1	Groundwater levels	34
3.8.1.1	Hera Mine	34

	3.8.1.2	Federation	35
	3.8.1.3	Nymagee Mine	35
	3.8.2	Groundwater quality	36
	3.8.2.1	Hera Mine	36
	3.8.2.2	Federation	36
	3.8.2.3	Nymagee Mine	38
	3.8.3	Hera Mine groundwater inflows	38
3.9		Aquifer testing	42
	3.9.1	Pumping tests	42
	3.9.1.1	Hera mine aquifer investigation – test pumping analysis (EMM, 2020)	42
	3.9.1.2	Hera Mine test pumping support and analysis (EMM, 2021)	42
	3.9.1.3	Hera Project – Groundwater Assessment (Impax Group, 2011)	42
	3.9.1.4	Hydrogeological Assessment of Skirka's Bore at 'The Peak' Station (Geoterra, 2005)	43
	3.9.1.5	Supplementary Assessment of Groundwater Availability, Hera Project (Aquade, 2015)	43
	3.9.1.6	Assessment of Potential Groundwater Impacts due to North Pod Expansion of Hera Project (Aquade 2016)	43
	3.9.2	Permeability testing	44
3.10		Groundwater extraction	44
3.11		Recharge and evapotranspiration	45
3.12		Groundwater flow directions	45
3.13		Schematic conceptual model	48
4.		Groundwater Modelling set-up	50
	4.1	Overview	50
	4.2	Hydrogeological domain	50
	4.3	Software selection	52
	4.4	Model complexity and target confidence level classification	52
	4.5	Model domain	52
	4.6	Boundary conditions	55
	4.6.1	General head boundaries	55
	4.6.2	Recharge and evapotranspiration	57
	4.6.3	Hera Mine	57
	4.6.4	Production bores	57
5.		Calibration	58
	5.1	Calibration approach	58
	5.2	Steady state calibration	58
	5.2.1	Calibration parameters	58
	5.2.2	Calibration targets	58
	5.2.3	Steady state calibration model parameters	59
	5.2.4	Steady state calibration results	60
	5.2.5	Steady state calibration flow budget	61
	5.3	Transient calibration	62
	5.3.1	Transient calibration model setup	62
	5.3.2	Calibration targets	62
	5.3.3	Calibration process	62
	5.3.4	Calibration performance	63
	5.3.4.1	Comparison of observed and calibrated hydrographs	66
	5.3.4.2	Transient calibration scatter plot	66
	5.3.4.3	Transient calibration Hera mine inflows	68
	5.4	Calibration phase flow budget	69
	5.5	Modelled groundwater contours	69

6.	Predictive model set-up	71
6.1	Overview	71
6.2	Set-up	71
6.2.1	Operational phase model	71
6.2.2	Post-closure phase model	72
6.3	Model performance	72
7.	Model predictive results and impact assessment	74
7.1	Impact assessment scenarios	74
7.2	Impact assessment criteria	74
7.3	Flow budget and predictive model flow terms	76
7.4	Predicted effect on piezometric heads	77
7.4.1	Mine inflow	86
7.5	Groundwater dependant ecosystems	86
7.6	Landholder bores	87
7.6.1	Overview	87
7.6.2	Landholder bore drawdown predictions	87
7.7	Water quality	90
7.8	Summary of impacts	94
8.	Model Complexity and confidence level classification	95
9.	Licencing review and mitigation measures	97
9.1	Water sharing plan licensing requirements	97
9.2	Mitigation measures	97
9.2.1	Flow monitoring	97
9.2.2	Groundwater monitoring	98
9.2.3	Hydrogeological model	98
10.	Uncertainty analysis	100
11.	Conclusions and recommendations	101
11.1	Model confidence level and set-up	101
11.2	Model predictions	101
11.3	Impact assessment	101
11.4	Water licensing	101
11.5	Recommendations	102
11.6	Model limitations	102
12.	References	103

Table index

Table 1.1	Detailed project overview	5
Table 1.2	Assessment requirements	8
Table 2.1	Hera Mine groundwater approvals and licences	11
Table 3.1	Registered bore details	22
Table 3.2	Hera Mine monitoring bores and production bores	31
Table 3.3	Hera Mine – groundwater monitoring program	33
Table 3.4	Federation groundwater monitoring bores	33
Table 3.5	Nymagee Mine monitoring bore details	34
Table 3.6	Nymagee groundwater quality	38
Table 3.7	Summary of Hera Mine workings progress and groundwater inflow (Aquade 2015)	40
Table 3.8	Pumping test derived aquifer parameters (EMM, 2020)	42
Table 3.9	Pumping test derived aquifer parameters (EMM, 2021)	42
Table 3.10	Pumping test results (Impax Group, 2011)	43
Table 3.11	Summary of aquifer property interpretations (Aquade, 2015)	43
Table 3.12	Permeability testing results	44
Table 3.13	Volumes pumped from production bores October 2013 to June 2015 (Aquade, 2015)	44
Table 3.14	Production bores – March 2015 to December 2020	45
Table 4.1	Model layers	54
Table 5.1	Steady state material properties	59
Table 5.2	Steady state calibration residual summary	60
Table 5.3	Steady state calibration flow budget	61
Table 5.4	Calibrated material properties	63
Table 5.5	Comparison of calibrated horizontal hydraulic conductivity and aquifer testing results	66
Table 5.6	Transient calibration model flow budget	69
Table 6.1	Proposed production bores	72
Table 6.2	Material parameters for the predictive phase of modelling	72
Table 7.1	Predictive model flow budget	76
Table 7.2	Comparison of Federation groundwater quality and leachate quality	92
Table 8.1	Australian Groundwater Monitoring Guidelines (Barnett et al, 2012)	96
Table 9.1	Summary of groundwater take – year 2028	97
Table 9.2	Proposed groundwater monitoring bores	98

Figure index

Figure 1.1	Locality and site context	2
Figure 1.2	Project overview	3
Figure 3.1	Historical rainfall record	13
Figure 3.2	Rainfall CRD curve	14
Figure 3.3	Monthly average evaporation and rainfall	14
Figure 3.4	Regional geological map	17
Figure 3.5	Location of paleochannel	18
Figure 3.6	AEM survey cross section at Hera Mine	19
Figure 3.7	AEM survey cross section at Federation	20

Figure 3.8	Landholder bores	26
Figure 3.9	Groundwater dependant ecosystems	27
Figure 3.10	Hera Mine workings (Aquade, 2016)	28
Figure 3.11	Groundwater monitoring network	30
Figure 3.12	Piper diagram	37
Figure 3.13	Groundwater inflow – Hera Mine	39
Figure 3.14	Monthly groundwater inflow – Hera Mine	39
Figure 3.15	Groundwater inflows into Hera Mine – May 2013 to July 2014 (Aquade 2015)	41
Figure 3.16	Groundwater level contours – pre-mining	46
Figure 3.17	Groundwater level contours – current conditions	47
Figure 3.18	Conceptual Hydrogeological Model	49
Figure 4.1	Hydrogeological domain	51
Figure 4.2	Model domain and mesh	53
Figure 4.3	General head boundaries	56
Figure 5.1	Steady state calibration scatterplot	61
Figure 5.2	Calibrated horizontal hydraulic conductivity values versus depth	65
Figure 5.3	Calibration scatter plot	67
Figure 5.4	Modelled and observed Hera Mine inflows	68
Figure 5.5	Modelled groundwater contours – end of transient calibration period	70
Figure 6.1	Proposed production bores	73
Figure 7.1	Maximum drawdown – water table – approved conditions	79
Figure 7.2	Maximum drawdown – water table – proposed conditions	80
Figure 7.3	Maximum drawdown – water table – incremental drawdown	81
Figure 7.4	Drawdown at end of mining at Federation – water table – proposed conditions	82
Figure 7.5	Drawdown 20 years following the end of mining at Federation	83
Figure 7.6	Drawdown 100 years following the end of mining at Federation	84
Figure 7.7	Drawdown 1000 years following the end of mining at Federation	85
Figure 7.8	Modelled mine groundwater inflows (operation phase)	86
Figure 7.9	Landholder bores and maximum modelled drawdown – proposed conditions	88
Figure 7.10	Modelled drawdown – GW017385	89
Figure 7.11	Modelled drawdown – GW020714	89
Figure 9.1	Proposed groundwater monitoring bores	99

Appendices

Appendix A	Groundwater level monitoring data
Appendix B	Groundwater quality data
Appendix C	Production bores and groundwater levels
Appendix D	Model discretisation
Appendix E	Transient calibration information
Appendix F	Drawdown Hydrographs
Appendix G	Uncertainty analysis

1. Introduction

1.1 Overview

Hera Resources Pty Limited (Hera Resources) is a wholly owned subsidiary of Aurelia Metals Limited (Aurelia). Hera Resources currently own and operate the Hera Mine located approximately 80 km south-east of Cobar and approximately 5 km south of the township of Nymagee in western NSW as shown in Figure 1.1. Aurelia owns and operates the Peak Gold Mine (PGM) near Cobar in western NSW.

Hera Resources is evaluating the development of the Federation Project (the Project), a proposed underground metalliferous mine development. The Project comprises underground mining activities and surface infrastructure at the Federation Site (Federation), amendments at Hera Mine to facilitate processing of ore from Federation and a Services Corridor connecting Federation with Hera Mine and a proposed borefield to supplement water supply. Federation is located approximately 15 km south of the Nymagee township and 10 km south of the Hera Mine.

The Federation Project will be a State Significant Development (SSD) (the Project) as defined by the State Environmental Planning Policy (State and Regional Development) 2011 (the SRD SEPP).

1.2 Background

Hera Mine has been operational since 2012 and produces gold and silver doré (unrefined bars) and a zinc/lead concentrate. Waste rock and metalliferous ore are extracted using underground open stope mining methods and underground load and haul operations. Hera Mine is approved to process up to 505,000 tonnes of ore on site annually, with lead/zinc concentrate transported to the Hermidale rail siding located approximately 75 km to the north-east. The Hera Mine Project Approval was modified (Modification 6) in June 2021 to allow for operations up to 31 December 2025.

In April 2019 high grade lead, zinc and gold mineralisation was discovered at the Federation deposit. Subsequent surface drilling programs have delineated a substantial gold-lead-zinc-copper-silver mineral deposit. Hera Resources is evaluating the development of a satellite underground mine at Federation that leverages established infrastructure at the Hera Mine to minimise environmental impacts and allow for the continuation of mining operations in the Nymagee area. Mining of the Federation deposit will allow for a transition of mining operations from Hera Mine to Federation, as ore from the Federation deposit replaces ore from the Hera Mine.

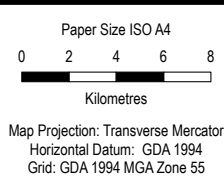
1.3 Project overview

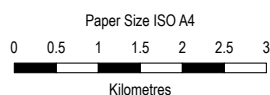
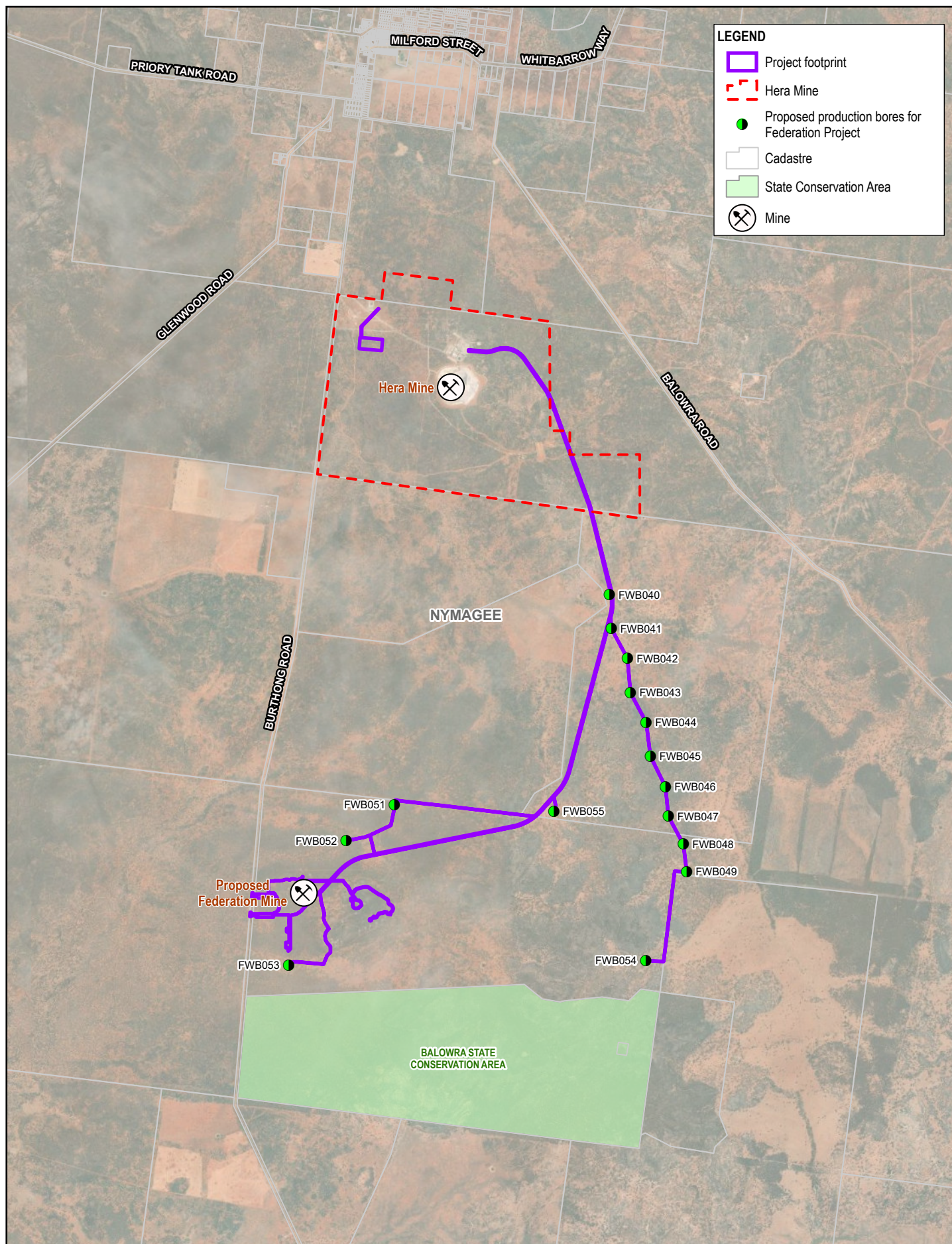
The Project, as shown in Figure 1.2 comprises:

- The establishment and operation of underground gold and metalliferous mining activities, with supporting surface infrastructure, mining approximately 6.95 million tonnes (Mt) of ore over a period of 12 to 14 years, referred to as Federation.
- Amendments at the Hera Mine to facilitate mining and processing of Federation ore, including new process plant and disposal of tailings in the Hera Mine tailings storage facility (TSF).
- Services Corridor between Federation and Hera Mine, including powerline, water pipeline, access track and potentially a tailings pipeline.
- Borefield connected to the water pipeline to supplement water supply.

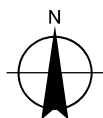
Total ore production from Federation is approximately 6.95 Mt over the life of the mine. The majority of ore produced will be sent to Hera Mine for processing. However up to 200 ktpa will be transported to PGM during the initial 4 years of processing (total of 750 kt over this period), whilst the new processing plant at Hera Mine is being commissioned and ramped up.

Access to the underground mine will be via a portal developed through the base of a box cut. The main decline will be developed to gain access to all production levels, where stopes will be excavated. The loosened ore from the stopes will be brought to the surface via underground truck and placed on the Federation Run of Mine (ROM) ore stockpile near the boxcut. Ore will then be transported by surface trucks via Burthong Road to the Hera Mine ROM stockpile at the Hera Mine process plant.





Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

Project No. 12534191
Revision No. 0
Date 08/11/2021

Project overview

Figure 1-2

Hera Mine infrastructure is proposed to be modified to facilitate the Project including a new 750 ktpa processing plant and solar farm. The existing processing plant will continue to operate at Hera Mine until the commissioning of the new plant. The new plant will be within the existing approved footprint of Hera Mine. The new processing plant will produce silver and gold doré and separate lead, zinc and copper concentrates.

A total of 5.8 Mt of tailings will be generated from the processing of the ore from Federation. Of this approximately 5.2 Mt will be produced at Hera Mine, with the remaining 0.6 Mt at PGM. Approximately 60% of total tailings produced will be returned to Federation to backfill underground stopes.

Hera Mine and Federation will be connected by a Services Corridor. The nominated width of the corridor is 23 m with an approximate length of 14.3 km. Clearing of existing vegetation will be required to install the proposed services infrastructure, including a power transmission line, water pipeline, access track and potentially a tailings slurry pipeline. The access track will be used for maintenance and inspection requirements and will not be used for haulage or ore.

Concentrate from Hera Mine will be trucked to the Hermidale rail siding for transport, as per the current concentrate transport methods and truck sizing. Concentrate from PGM will be transported to Hermidale or Dubbo rail sidings, as per the current concentrate transport methods and truck sizing.

1.4 Transitional period

It is anticipated that approval for the Federation Project will be obtained in early 2023. Prior to the construction and operation of the Federation Project, an Exploration Decline Program will be undertaken. This activity will be undertaken under a separate approval to that being sought for the Federation Project. The main objectives of the Exploration Decline Program are to further define the mineral resources associated with the Federation deposit, including permitting drilling of exploration drill holes from underground.

Key components of the Exploration Decline Program include:

- Establishment of a Surface Infrastructure Area required to support the exploration decline.
- Development of a box cut, portal, exploration decline, two ventilation rises and one escapeway.
- Transportation to and storage of waste rock within the Surface Infrastructure Area, with subsequent transport of waste rock to Hera Mine.
- Establishment and use of an approximately 14.8 km surface pipeline to transfer water from the exploration decline to Hera Mine.
- Exploration drilling from the exploration decline.
- Extraction of one or more bulk samples together totalling no more than 20,000 t and transportation of that material to Hera Mine processing plant via Burthong Road.

It is anticipated that the Exploration Decline Program will commence in November 2021 with the Surface Infrastructure Area established and waste rock being generated from the decline. It is anticipated that ore from the bulk sample will be mined and processed between the third quarter of 2022 and first quarter of 2023. Based on the current schedule for the Federation Project, there will be a transitional period between Exploration Decline Program activities, mining operations at Hera Mine, and Federation Project construction and operations. Following approval of the Federation Project:

- Construction of Federation Project infrastructure (including the new process plant) will commence in the first half of 2023.
- Exploration Decline Program activities will transition into mining operations at Federation.
- Hera Mine operations may continue over a period of 6 to 12 months.

From early 2024, it is anticipated that all activities will be related to the Federation Project operations. The operational workforce numbers will be transitioned from Hera Mine operations to Federation Project operations.

1.5 Federation project detailed overview

Provided in Table 1.1 is a detailed overview of aspects of the Federation Project.

Table 1.1 Detailed project overview

Project Aspect	Project Details
Tenements	Hera Mine and Federation Projects Mining Lease 1686 Mining Lease 1746 Exploration Licence 6162 Exploration Licence 7447
Current Approvals	Hera Mine Major Project Approval – (PA) 10_0191 Environment Protection Licence – 20179 Hera Mine Accommodation Village Development Consent 2012/LD-0004 Development Consent 2021/LD-00010
Federation Deposit	The total potential mineralisation is 7 Mt.
Mining Method	Underground mine stoping method. Access to the underground mine will be via a portal developed through the base of a box cut and decline. The proposed mining method requires excavation via drilling to a depth of approximately 530 m to access areas of economically viable mineral resource deposits. Once the mineral deposit is accessed, stopes will be excavated via drilling and blasting. Bench stopes will be progressively backfilled with waste rock. Tailings from Hera Mine will either be placed within the approved Hera Mine tailings storage facility (TSF) or returned to the Federation Site where they will be processed by a pastefill plant for underground backfilling of mined stopes.
Processing	A new 750 ktpa process plant design is proposed to be commissioned at Hera Mine. The existing processing plant will continue to operate at Hera until the completion of the new plant. The new plant will be within the existing approved footprint of Hera Mine. The new processing plant involves: – Three stages of crushing followed by ball milling with hydrocyclone classification – Gravity separation to recover gold from the milling circuit recirculating load, followed by cyanide leaching of the gravity concentrate. – Sequential flotation to produce separate copper, lead and zinc concentrates. – Concentrate thickening and filtration. – Tailings thickening and disposal by underground backfill placement in the stopes at Federation and surface storage in the Hera Mine TSF. The primary difference between the proposed plant and the current plant, is that each concentrate (e.g. zinc concentrate) will be produced through dedicated processing circuits.
Waste Rock Management	Two waste rock stockpiles will be located at Federation to store waste rock generated from the development of the boxcut, decline and the lateral and vertical development. One stockpile will be for the storage of potential acid forming (PAF) materials and the other for mixed non-acid forming (NAF) and PAF materials. Should a greater proportion of waste rock be identified as PAF material, all or part of the NAF waste rock stockpile area will be managed as a PAF waste rock stockpile. PAF waste rock will be stored on surface with drainage to a lined leachate pond and used as backfill underground during or post mine life. NAF waste rock will be stored on surface for later use in rehabilitation, such as backfilling the box cut.
Ore Transport	Ore from the Federation deposit, that will be processed at Hera Mine, is proposed to be transported approximately 11 km along Burthong Rd. Ore proposed for processing at PGM will be transported along Burthong Rd, Priory Tank Rd and Kidman Way (the same as the currently approved alternate concentrate haulage route). Ore will be transported in trucks with an approximate 50 t payload.
Tailings Storage	The approved Hera Mine TSF will continue to be used to store tailings from the Hera processing plant which will process ore from Federation. It is estimated over the life of the Project 5.2 Mt of tailings will be produced from Federation, of which 3.5 Mt will be returned to Federation to be used as backfill. The remaining 1.7 Mt will be placed into the approved TSF.

Project Aspect	Project Details
Surface Infrastructure – Federation	Site roads, laydown and access control Explosives magazines x 2 Mobile equipment maintenance workshop and warehouse Hydrocarbon storage Heavy and light vehicle washdown facilities Administration building Change house and laundry Sewerage treatment plant Potable Water Treatment Plant Substation Soil stockpiles Pastefill Plant Batch Plant Communications Tower Quarry
Water Supply	Water will primarily be supplied from dewatering of the underground workings. As part of the mine development, a new borefield will be established for the supply of water from production bores. There are existing water supply bores supplying water to Hera Mine, which will continue to operate. Aurelia holds WAL 43173, which permits the extraction of 543 ML of water annually. There is no planned increase to this limit as part of the Project.
On-site water management	The Project will have an integrated water management system across Federation and Hera Mine. A water pipeline within the Services Corridor, and pumps at Federation and Hera Mine, will allow for transfer of water. Water management infrastructure to be constructed at Federation includes: – Mine water dam for dewatering the underground workings with approximate dimensions of 50 m x 50 m with a capacity of 10 ML. – Leachate ponds for collection of runoff from the waste rock pads and ROM pad. Water from the leachate ponds will be pumped to the mine water dam. – Stormwater retention dam designed to collect runoff from disturbed areas that do not contain contaminants. The dam has been sized to collect a 1% AEP 72-hour design rainfall event. – Potentially other minor sediment dams, which would flow to the primary sediment dam. – Drainage infrastructure to separate clean water, sediment water and potentially contaminated water. The catchment areas, which store potentially contaminating materials such as the fuel, hydrocarbons or PAF waste rock will have their own contained catchments and have been limited in extent to minimise the generation of contaminated surface run-off.
Concentrate Transport	Concentrate from Hera Mine will be trucked to the Hermidale rail siding for transport, as per the current concentrate transport methods and truck sizing (50 tonne payload). Concentrate from PGM will be transported to Hermidale or Dubbo rail sidings, as per the current concentrate transport methods and truck sizing.
Hours of Operation	Construction activities will be undertaken 7 days per week during daylight hours, unless a particular aspect of construction requires 24/7 activities. Transport of ore along Burthong Road will be undertaken during daylight hours. Operations at Federation and Hera Mine will be 24 hours per day 7 days per week.
Workforce	It is estimated that a workforce of approximately 100 people will be employed during construction, with a workforce of 200 - 250 for Project operations, depending on the mining and processing production rates. There is a workforce of approximately 150 people for the current Hera Mine operations. Other than the 12 month construction phase, the Project maintains a reasonably consistent workforce, with some increases in the transition from Hera Mine to the Project.

Project Aspect	Project Details
Mining Equipment	Twin boom jumbo Production drill rig 50 t trucks 17 t loaders Shotcrete sprayer Shotcrete agitator Explosives charging unit Integrated toolcarrier (IT) Service truck Grader Water truck Truck and Loader
Decommissioning and Rehabilitation	Rehabilitation and decommissioning of the Project, including the Hera Mine site, would be undertaken on completion of extraction of the Federation deposit, with underground exploration and water extraction continuing at Hera Mine during extraction from the Federation deposit. Backfilling of the stope voids will occur throughout operations. A Rehabilitation Management Plan will be developed for the Project which will outline the rehabilitation objectives and final landform for the project.

1.6 Purpose of this report

The purpose of this report is to provide a groundwater impact assessment to support the EIS for the Federation Project.

1.7 Objectives and scope of work

The key objective of the GIA is to determine the potential impacts of the Project on the groundwater environment by addressing the relevant Secretary's environmental assessment requirements (SEARs) for the Project and relevant government agency requirements. The relevant SEARs and additional requirements are presented in Table 1.2, along with a reference to where each has been addressed in the GIA.

The scope of works of the investigation included:

- A review of available background hydrogeological data.
- A review of available mining data at Hera Mine.
- Review of relevant statutory requirements and development of impact assessment criteria.
- Identification and description of groundwater sources within the project boundary.
- Search of the Water NSW All Groundwater Map to identify licensed groundwater users in the anticipated radius of groundwater drawdown.
- Identification of potential groundwater dependent ecosystems (GDEs) within the project boundary.
- Development of a MODFLOW hydrogeological model to predict potential impacts on groundwater sources (quantity) as a result of the proposed underground mine
- Identification of potential groundwater impacts resulting from the construction and operation of the Project, based on the NSW Aquifer Interference Policy minimal impact considerations.
- Assessment of potential impacts of the Project on GDEs, licensed groundwater users and basic landholder rights.
- Identify groundwater licensing requirements.
- Develop measures to avoid, minimise and mitigate potential impacts of the Project and provide recommended management, monitoring and reporting requirements.

Table 1.2 Assessment requirements

Assessment requirement	Where addressed
The EIS must address the following specific issues with the level of assessment of likely impacts proportionate to the significance of, or degree, of impact on, the issue, within the context of the project location and the surrounding environment and having regard to applicable NSW Government policies and guidelines. Water – including:	
An assessment of the likely impacts of the development on the quantity and quality of surface, and groundwater resources, having regard to the <i>NSW Aquifer Interference Policy</i> ;	Section 7 Refer to SWIA (GHD, 2021a) for surface water resources
An assessment of the hydrological characteristics of the site and downstream;	Section 3
An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure and systems and other water users, including impacts to water supply from dams, and riparian and licensed water users;	Section 7.6 Refer to SWIA (GHD 2021a) for watercourses, riparian land and surface water users
A detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply and transfer infrastructure and water storage structures, and measures to minimise water use;	Refer to SWIA (GHD 2021a)
Demonstration that water for the construction and operation of the development, for the life of the project, can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant <i>Water Sharing Plan</i> (WSP), and include an assessment of the current market depth where water entitlement is required to be purchased;	Section 9.1
A description of the measures proposed, including monitoring activities and methodologies, to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo;	Section 3.7, Section 9.1, Section 9.2.1 and Section 9.2.2
A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts;	Section 3.7 and Section 9.2 Refer to SWIA (GHD 2021a) for details on the whole water management system
An assessment of the potential flooding impacts of the project;	Refer to SWIA (GHD 2021a)

1.8 Limitations

This report: has been prepared by GHD for Hera Resources Pty Limited and may only be used and relied on by Hera Resources Pty Limited for the purpose agreed between GHD and Hera Resources Pty Limited as set out in Section 1.6 of this report.

GHD otherwise disclaims responsibility to any person other than Hera Resources Pty Limited arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Hera Resources Pty Limited and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

2. Legislation and policy

The following section provides a brief overview of the legislation, policies and guidelines relevant to this groundwater impact assessment.

2.1 Legislation

2.1.1 Environmental Planning and Assessment Act 1979

The EP&A Act is the core legislation relating to planning and development activities in NSW and provides the statutory framework under which development proposals are assessed. The EP&A Act aims to encourage the proper management, development and conservation of resources, environmental protection and ecologically sustainable development.

The GIA has been developed to address the groundwater components of the SEARs and accompanying government agency requirements for the Project, which are reproduced in Table 1.2, along with a reference to where each requirement has been addressed within this report.

2.1.2 Protection of the Environment Operations Act 1997

The NSW *Protection of the Environment Operations Act 1997* (POEO Act) is administered by the NSW Environment Protection Authority (EPA), which is an independent statutory authority and the primary environmental regulator for NSW. The objectives of the POEO Act are to protect, restore and enhance the quality of the environment, by mechanisms including programs to reduce pollution at the source and monitoring and reporting on environmental quality. The POEO Act regulates and requires licensing for environment protection, including for waste generation and disposal and for water, air, land and noise pollution.

Under the POEO Act, an environment protection licence (EPL) is required for premises at which a 'scheduled activity' is conducted. Hera Mine is currently licensed for the scheduled activities of crushing, grinding or separating, mineral processing and mining for minerals under EPL 20179. Groundwater monitoring at Hera Mine is undertaken in accordance with EPL 20179. Details of the Hera Mine groundwater monitoring program are provided in Section 3.7.1.

2.1.3 Water Management Act 2000

The aim of the *Water Management Act 2000* (WM Act) is to ensure that water resources are conserved and properly managed for sustainable use benefiting both present and future generations. It is also intended to provide formal means for the protection and enhancement of the environmental qualities of waterways and in-stream uses as well as to provide for protection of catchment conditions.

Historically, the *Water Act 1912* was the main legislation for managing water resources in NSW, however, this Act has been progressively phased out and replaced by water sharing plans (WSPs) under the WM Act. Once a WSP commenced, existing licences under the *Water Act 1912* were converted to water access licences (WALs), water supply works and use approval (controlled activity approvals) under the WM Act. All new WALs and controlled activity approvals are also issued under the WM Act.

Section 4.41 of EP&A Act details that a water use approval under Section 89, a water management work approval under Section 90 or an activity approval (other than an aquifer interference approval) under Section 91 of the Water Management Act 2000 is not required where an SSD approval is given. A water management work approval includes a water supply works approval, drainage work approval and flood work approval. An activity approval includes a controlled activity approval and an aquifer interference approval.

WALs are issued in accordance with Part 2 Division 2 of the WM Act. Aurelia currently holds a WAL which is detailed in Section 2.1.3.2. Additional WAL are not predicted to be required for the Project (Section 9.1); however if an additional WAL was required application would be made in accordance with Section 61 of the WM Act.

2.1.3.1 Water sharing plans

Fresh water sources throughout NSW are managed via WSPs under the WM Act. Provisions within WSPs provide water to support the ecological processes and environmental needs of GDEs and waterways. WSPs also regulate how the water available for extraction is shared between the environment, basic landholder rights, town water supplies and commercial uses. Key rules within the WSPs specify when licence holders can access water and how water can be traded.

The Federation deposit falls within the porous and fractured groundwater sources of the Lachlan Fold Belt Murray Darling Basin (MDB) groundwater source, a sub-area of the WSP for the NSW MDB Fractured Rock Groundwater Sources. This WSP commenced in July 2011 and was updated in June 2020 and regulates the interception and extraction of groundwater within the defined WSP area. Hera Mine and Federation are located outside the Great Artesian Basin.

Therefore the interference and extraction of groundwater at Federation will be required to be licensed under a WAL under the WM Act.

2.1.3.2 Hera Mine

Aurelia holds a WAL administered under the WM Act for groundwater extraction from the Lachlan Fold Belt MDB groundwater source, in which groundwater associated with the Project, Hera Mine and Nymagee Copper Mine are located. Table 2.1 summarises the groundwater works approvals and WAL currently held for Hera Mine under the WM Act. The excavation in Table 2.1 refers to the underground workings at Hera Mine. There are no surface water approvals or licences at Hera Mine.

Table 2.1 Hera Mine groundwater approvals and licences

Works approval	Details	Location	Water Access Licence (WAL)	Share components (ML/year)
85WA752586	10 bores 1 excavation	Lot 664, DP 761702	WAL43173	543
85WA752816	1 bore	Lot 1, DP 665073		

The NSW MDB Fractured Rock Groundwater Sources WSP allows for the carryover of 10% of the remaining entitlement from one year to the next.

An assessment has been undertaken to determine if Hera Resources holds sufficient WAL volume to share in extracting groundwater from the Lachlan Fold Belt MDB groundwater source that is encountered in the Project (Section 9.1). The assessment concluded that the WAL volume held by Aurelia is sufficient volume for encountered groundwater.

2.1.3.3 Water Management (General) Regulation 2018

Section 91 of the WM Act details the requirements for controlled activity approval to carry out work on waterfront land, which includes the bed of any river, lake or estuary and any land within 40 m of its high water mark. The Federation mine workings are located greater than 40 m of any mapped watercourse. Additionally, clause 42 of the Water Management (General) Regulation 2018 exempts activities carried out in accordance with any lease or licence under the *Mining Act 1992*. Furthermore, an activity approval under Section 91 of the WM Act is not required where an SSD approval is given.

Thus, controlled activity approvals will not be required for the drilling and construction of the proposed mine workings. However, it remains an offence to harm waterfront land when carrying out an exempt controlled activity.

2.2 Policies

2.2.1 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy (AIP) was finalised in September 2012 and clarifies the water licensing and approval requirements for aquifer interference activities in NSW, including the taking of water from an aquifer in the course of carrying out mining.

The Policy outlines the water licensing requirements under the WM Act. A water licence is required whether water is taken for consumptive use or whether it is taken incidentally by the aquifer interference activity (such as groundwater filling a void), even where that water is not being used consumptively as part of the activity's operation. Under the WM Act, a water licence gives its holder a share of the total entitlement available for extraction from the groundwater source. The WAL must hold sufficient share component and water allocation to account for the take of water from the relevant water source at all times.

Sufficient access licences must be held to account for all water taken from a groundwater or surface water source as a result of an aquifer interference activity, both for the life of the activity and after the activity has ceased. Many mining operations continue to take water from groundwater sources after operations have ceased. This take of water continues until an aquifer system reaches equilibrium and must be licensed.

The NSW AIP requires that potential impacts on groundwater sources, including their users and GDEs, be assessed against minimal impact considerations, outlined in Table 1 of the Policy. If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable. The adopted Level 1 minimal impact considerations for this project are discussed in Section 7.2.

2.2.2 NSW State Groundwater Policy

The objective of the NSW State Groundwater Policy Framework Document is to manage the State's groundwater resources so that they can sustain environmental, social and economic uses for the people of NSW. The NSW groundwater policy has three parts:

- NSW Groundwater Quantity Protection Policy.
- NSW Groundwater Quality Protection Policy.
- NSW Groundwater Dependent Ecosystems Policy.

2.2.2.1 NSW Groundwater Quantity Protection Policy

The principles of this policy include:

- Maintain total groundwater use within the sustainable yield of the aquifer from which it is withdrawn.
- Groundwater extraction shall be managed to prevent unacceptable local impacts.
- All groundwater extraction for water supply is to be licensed. Transfers of licensed entitlements may be allowed depending on the physical constraints of the groundwater system.

2.2.2.2 NSW Groundwater Quality Protection Policy

The objective of this policy is the ecologically sustainable management of the State's groundwater resources so as to:

- Slow, halt or reverse any degradation in groundwater resources.
- Direct potentially polluting activities to the most appropriate local geological setting so as to minimise the risk to groundwater.
- Establish a methodology for reviewing new developments with respect to their potential impact on water resources that will provide protection to the resource commensurate with both the threat that the development poses and the value of the resource.
- Establish triggers for the use of more advanced groundwater protection tools such as groundwater vulnerability maps or groundwater protection zones.

2.2.2.3 NSW Groundwater Dependent Ecosystems Policy

This policy was designed to protect ecosystems that are dependent on groundwater as a primary water source so that the ecological processes and biodiversity of these ecosystems are maintained or restored for the benefit of present and future generations. It provides guidance on how to protect and manage groundwater dependent ecosystems in a practical sense.

Analysis of the application of the NSW GDEs Policy to this groundwater assessment is outlined in Section 3.5.2.

3. Hydrogeological conceptualisation

3.1 Climate

A historical record of climate data was obtained in the form of a point data set from the Scientific Information for Land Owners (SILO) database operated by the Queensland Department of Environment and Science (DES). SILO point data is based on spatially interpolating observed historical data from surrounding Bureau of Meteorology (BOM) stations (DSITI, 2021).

Data have been obtained from SILO grid point -32.2 (latitude) and 146.35 (longitude). This point is located approximately 4.5 km from Federation and approximately 10 km from Hera Mine. The period of rainfall data used for this assessment extended from January 1901 to April 2021.

The historical SILO rainfall data between 1901 and 2021 are shown in Figure 3.1.

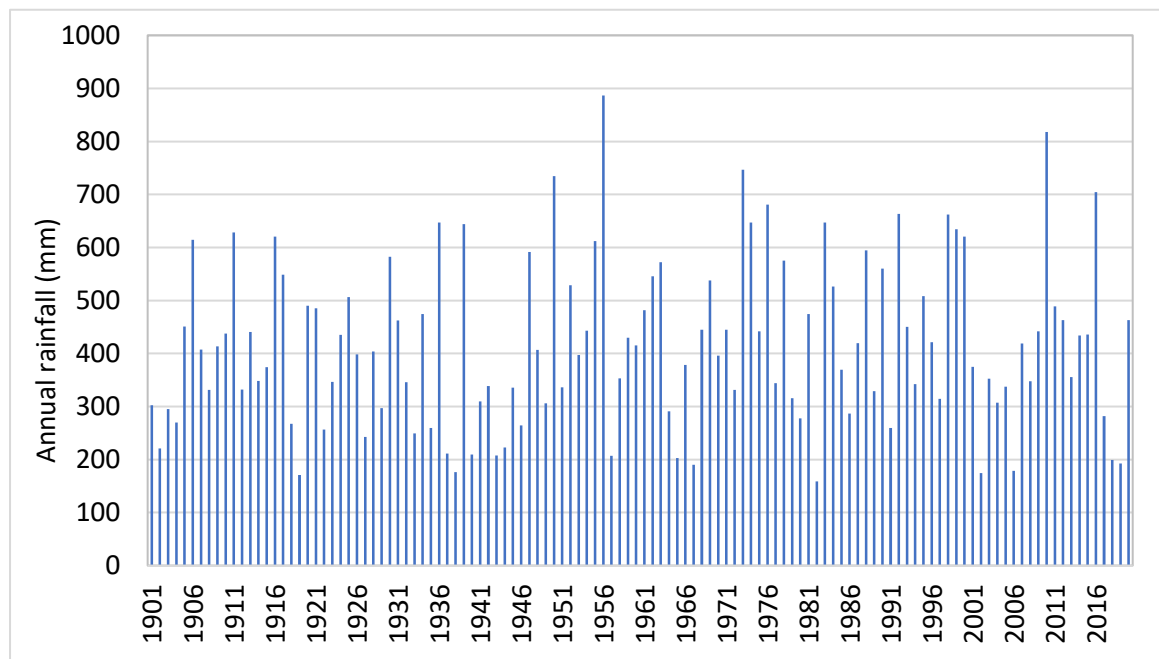


Figure 3.1 Historical rainfall record

The monthly rainfall dataset was used to generate a Cumulative Rainfall Departure (CRD) curve. CRD is the monthly accumulation of the difference between the observed monthly rainfall and the long-term average monthly rainfall. Any increase in the CRD reflects above average rainfall while a decrease in CRD reflects below average rainfall. A constant or steady CRD curve represents average rainfall. The CRD curve only deviates from zero due to atypical (above and below average) rainfall. The CRD over the period 1901 to 2020 is shown in Figure 3.2.

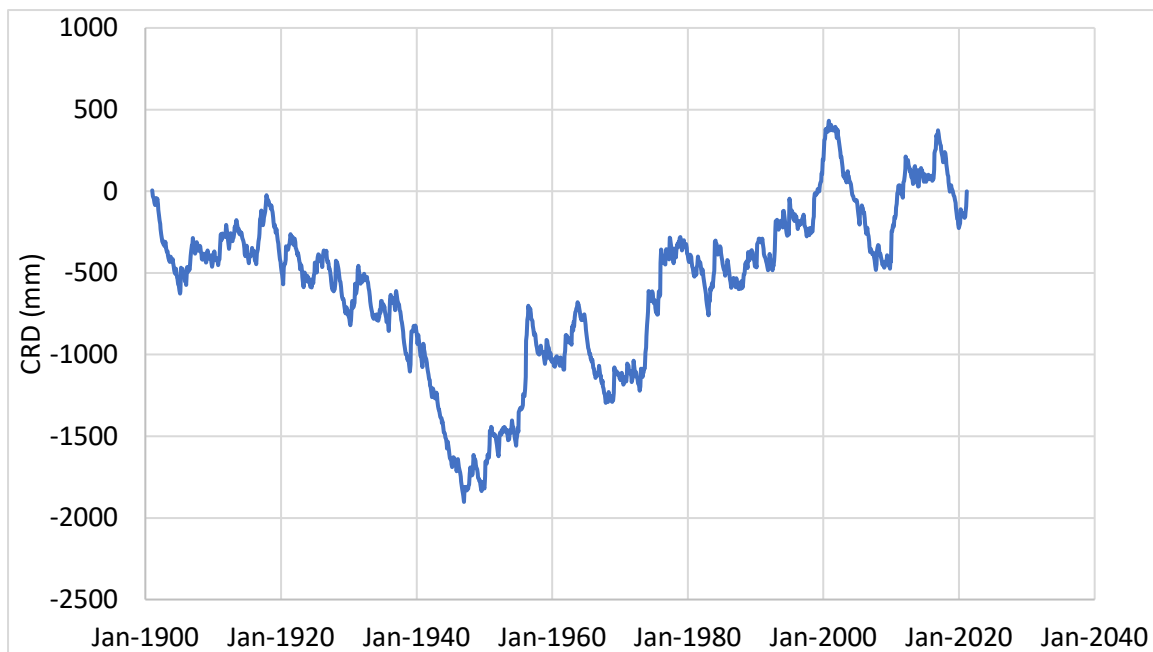


Figure 3.2 Rainfall CRD curve

The CRD curve was generally decreasing between mid-2016 and early 2020 indicating below average rainfall conditions. This reflects the recent drought conditions in western NSW. The CRD has been increasing since early 2020, reflecting a period of above average rainfall.

A plot of average monthly evaporation is compared to average monthly rainfall from the historical record in Figure 3.3.

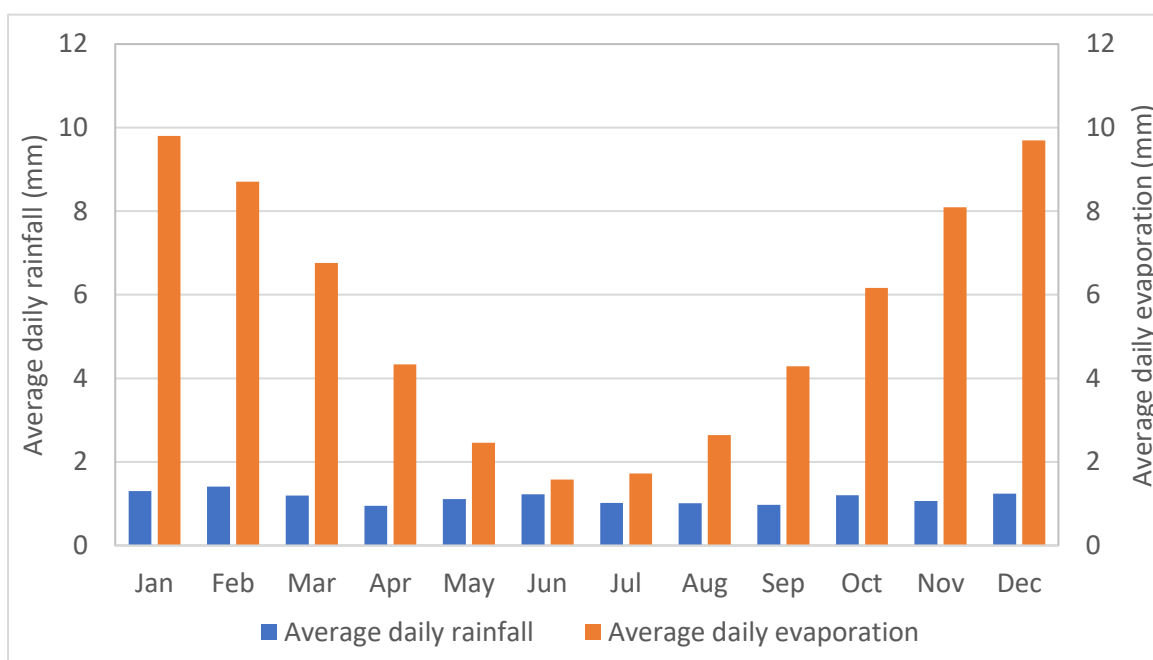


Figure 3.3 Monthly average evaporation and rainfall

As shown in Figure 3.3 evaporation varies seasonally, having higher records in summer compared to winter. The site has an average monthly net rainfall deficit for all parts of the year.

3.2 Topography

The topography at Federation is generally flat. Local relief ranges from approximately 315 to 320 m AHD. The elevation rises to the east of Federation to over 380 m AHD.

3.3 Hydrology

Federation and Hera Mine are located in the Murray Darling Basin. Watercourses at Federation and Hera Mine are ephemeral. Watercourses at Federation are unnamed tributaries of Sandy Creek. Watercourses in the immediate vicinity of Federation flow to the west. The closest watercourses are located approximately 1 km to the north and to the south of Federation. These unnamed watercourses flow into Sandy Creek approximately 19 km west of Federation. The location of Sandy Creek is shown in Figure 1.1. Regional catchment boundaries are shown in Figure 7-3 of the Surface Water Impact Assessment (SWIA) (GHD 2021a).

Watercourses at Hera Mine generally flow to the north west. These watercourses are unnamed tributaries of Box Creek and flow into Box Creek approximately 3 km north west of Hera Mine.

The boundary of the Barwon River catchment lies approximately 9 km east of Federation and 6.5 km east of Hera Mine. Area to the east of this catchment boundary drains towards the Barwon River. Federation and Hera Mine, located to the west of this catchment boundary, are within the catchment of the Darling River.

3.4 Geology

3.4.1 Regional geology

The Federation deposit, Hera Mine and the proposed borefield are located on the eastern margin of the Cobar Basin. Federation is covered by a thin layer of Quaternary alluvial and colluvial sediments and underlain by Palaeozoic rocks (Devonian age) of the Amphitheatre and Mouramba Groups (MacRae, 1988).

The Amphitheatre Group is divided into the Upper Amphitheatre and the Lower Amphitheatre (MacRae, 1988). According to Aurelia Metals (2020), the mineralisation occurs primarily within the Lower Amphitheatre Group. The Lower Amphitheatre outcrops to the east of Federation (MacRae, 1988). As indicated by the *Nymagee 1:100,000 Geological Map* (MacRae, 1988), shown in Figure 3.4, the Lower Amphitheatre Group also outcrops further to the north of the area while the Mouramba Group outcrops further to the east.

The Amphitheatre Group conformably overlies the upper parts of the Mouramba Group. The Mouramba Group is further subdivided into the Roset Sandstone and Burthong Formation. The Burthong Formation consists of fine to very fine sandstone interbedded with siltstone. The Roset Sandstone consists of a sequence of fine to medium-grained sandstone interbedded with fine to very fine sandstone. The proposed Federation mine workings and the existing Hera Mine workings do not reach the base of the Amphitheatre Group.

The Project is located outside the Great Artesian Basin.

3.4.2 Local geology

The host rock at Federation comprises of alternating layers of siltstone and sandstone to depth. Exploration drilling at Federation has not identified the full extent of the mineralisation. Exploration drilling at Federation has identified a paleochannel. The location of the paleochannel is shown in Figure 3.5. The depth of the paleochannel is generally less than 20 m. As part of this GIA two bores were drilled into the paleochannel in the vicinity of Federation. Both these bores have been consistently dry since installation.

The bedrock at Federation and Hera Mine includes an oxidised zone (saprolite), partially oxidised zone and fresh rock. Based on exploration drilling, in the immediate vicinity of Hera Mine and Federation, the depth of the oxidised zone is approximately 45 m below ground level (bgl) and the base of the partially oxidised zone/top of fresh rock is approximately 75 m bgl.

The *Nymagee 1:100,000 Geological Map* (MacRae 1988) was reviewed to identify faulting in the vicinity of Hera Mine and Federation. The review identified the Rookery Fault that runs from north north-west to south south-east. The Rookery Fault lies approximately 1 km east of Hera Mine and 6 km east of Federation. A number of monitoring bores and production bores at Hera Mine (WB3, WB4, WB10, WB28, PWB004 and PWB006) are installed along the Rookery Fault. Additional production bores are proposed along the Rookery Fault and near Federation.

Exploration drilling undertaken by Hera Resources has identified faulting and shearing associated with the intrusive ore body at Federation and Hera Mine. The ore body is limited to the extent of the existing and proposed workings at Federation and Hera. The ore body is of Devonian age.

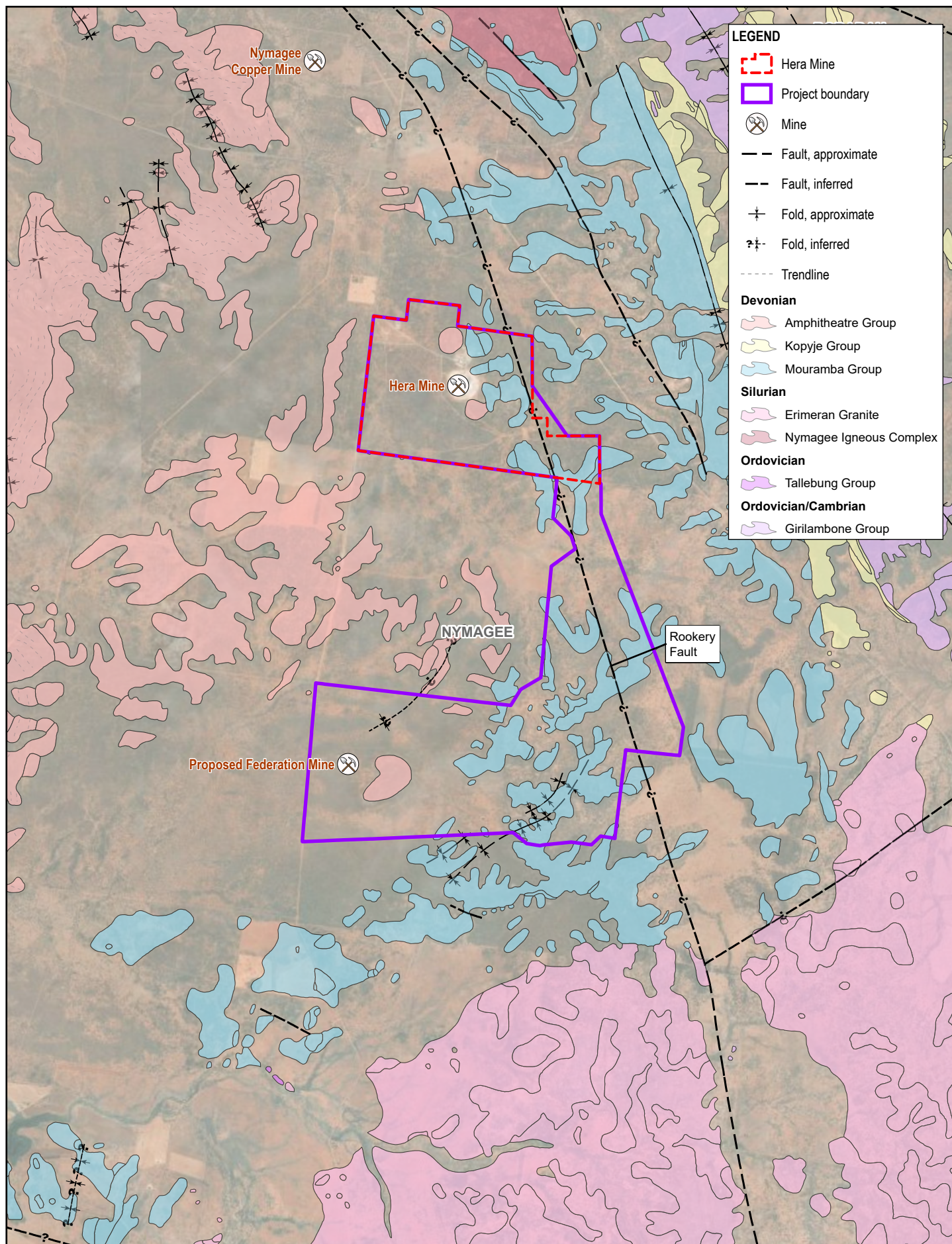
3.4.3 Airborne electromagnetic (AEM) survey

The MinEx CRC Cobar Airborne Electromagnetic (AEM) Survey was commissioned by Geoscience Australia. Results from the MinEx CRC Cobar AEM Survey (Geoscience Australia, 2020) have been reviewed to identify geological features and potential aquifers. Interpretation of results of the AEM Survey presented by Geological Survey of NSW (Carlton, 2020) have also been reviewed. Cross sections of the AEM survey in the vicinity of Hera Mine and Federation is shown in Figure 3.6 and Figure 3.7 respectively.

The AEM survey is able to detect changes in ground conductivity. Areas of high conductivity may be associated with certain strata including red soils/regolith saprolite, clay, shale, graphite or iron and copper minerals, while areas of low conductivity may be associated with granite, volcanic rock or quartzite strata. Additionally, areas of high conductivity may be associated with saline groundwater and areas of low conductivity may be associated with fresh groundwater.

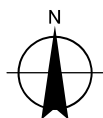
The exploration drilling at Federation and Hera Mine is limited to the vicinity of the ore bodies. The AEM survey has been reviewed to identify the base of saprolite on a regional basis. Review of the AEM survey indicates that the saprolite varies from 60 m in the vicinity of Hera Mine, from 50 m to 60 m in the vicinity of Federation and 50 m to 80 m in the vicinity of the proposed borefield. This generally corresponds with the depth of the saprolite encountered during exploration drilling at Hera Mine and Federation.

The AEM survey has also been reviewed to confirm the location of faulting as indicated by geological mapping. The AEM survey indicates a feature in the vicinity of the Rookery Fault at Hera Mine, however the AEM survey does not indicate any features in the vicinity of the Rookery Fault at Federation.



Paper Size ISO A4
0 1 2 3 4
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

Project No. 12534191
Revision No. 0
Date 08/11/2021

Surface geology map

Figure 3-4



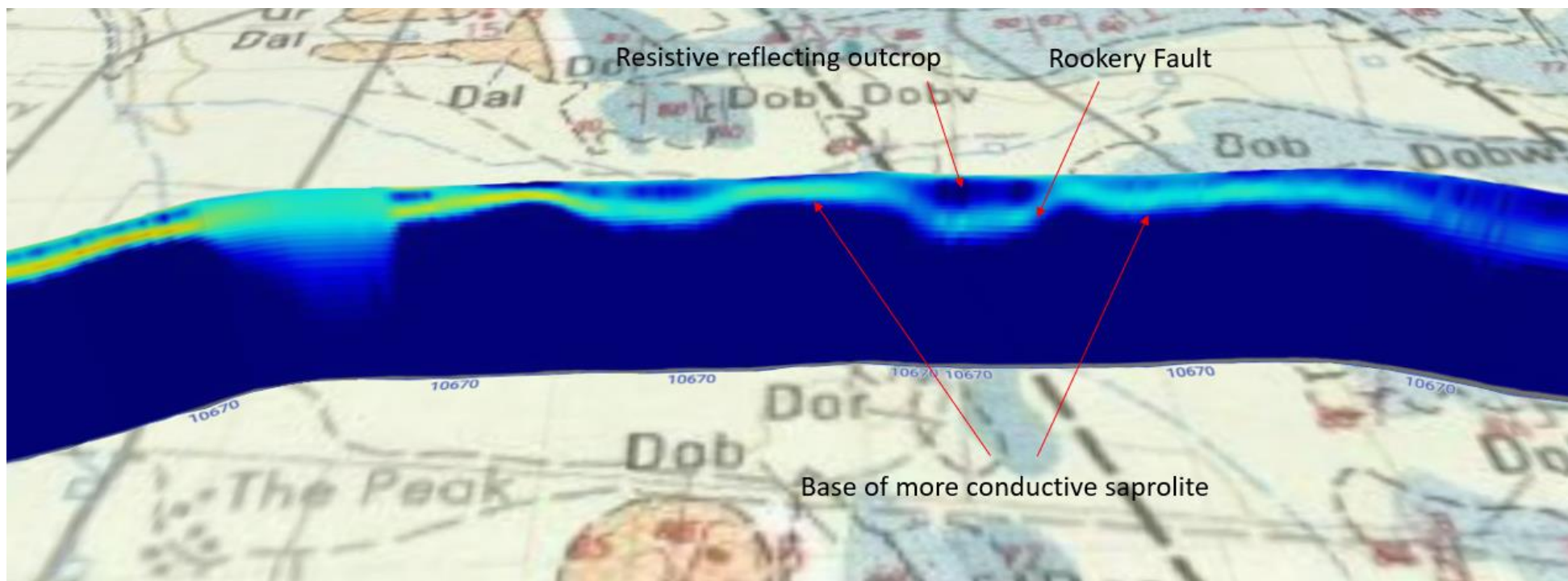


Figure 3.6 AEM survey cross section at Hera Mine

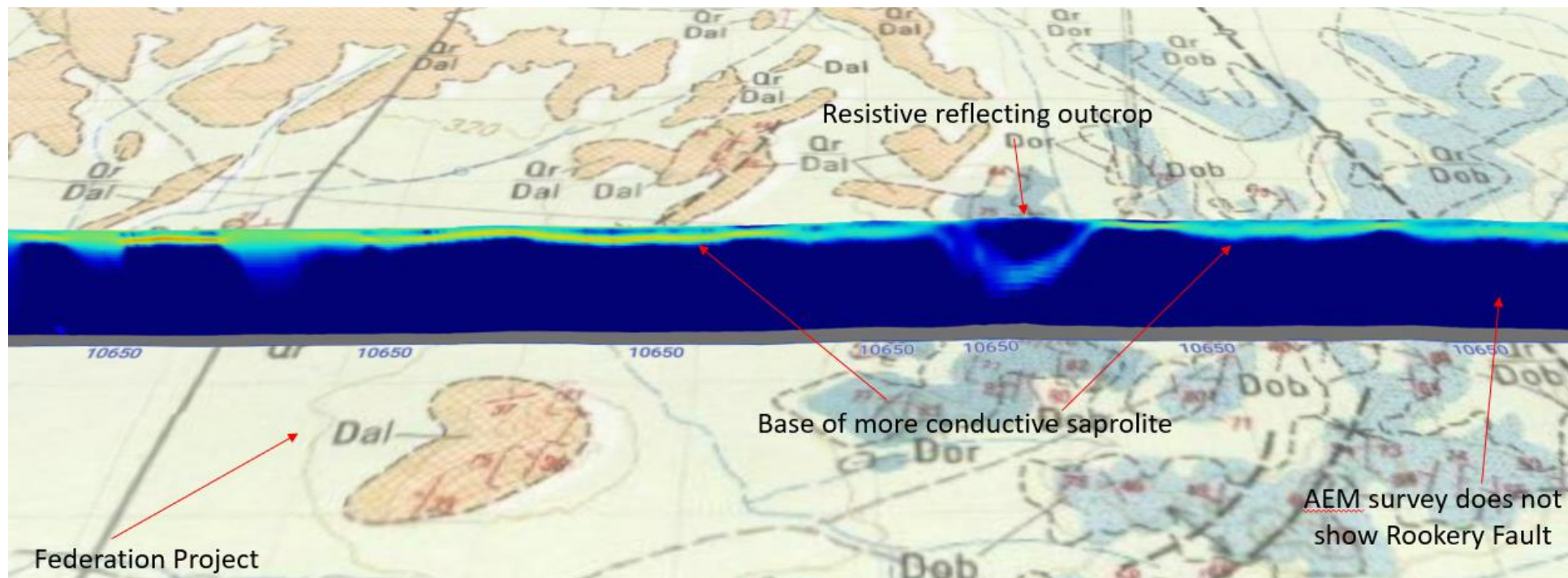
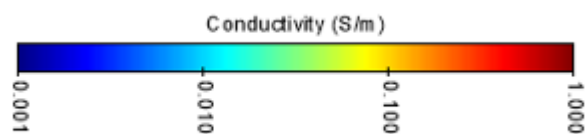


Figure 3.7 AEM survey cross section at Federation

Note to figure: AEM survey data extends from surface level to -200 m AHD

Legend



3.5 Groundwater receptors

3.5.1 Landholder bores

A search of the Australian Groundwater Explorer (BoM 2019a) and Water NSW Real Time Data (Water NSW 2021) was undertaken to identify registered bores near Federation, Hera Mine and the proposed borefield. The search identified 34 bores within an approximate 20 km radius.

Registered bores are shown in Figure 3.8 and bore details are summarised in Table 3.1. Eighteen bores are registered as monitoring or mining purposes, and form part of the monitoring network and production bore network for Hera Mine. Three of these monitoring bores are reported to be abandoned.

The Nymagee Town Bore was not identified in the searches. This bore was reported by Aquade (2017) to be located approximately one kilometre east of Nymagee Mine. The approximate location of Nymagee Town Bore is shown in Figure 3.8. Records of extraction and water level monitoring at the Nymagee Town Bore were not available.

It is noted that bore FWB030/ GW850057 has been installed by Hera Resources for the purposes of exploration. It has been used solely for the purposes of exploration predominately associated with the Federation Project. Bore GW850057 was drilled in October 2019 to a depth of 114 m. A water bearing zone of 1 m was reported to have been encountered between 103 m and 104 m depth. The bore is screened between 102 m and 108 m, with a standing water level of 84 m. The bore is estimated to yield approximately 1.5 L/s. This bore has been incorporated into the Federation groundwater monitoring network, discussed in Section 3.7.2.

The majority of the remaining registered bores are associated with mining and water supply operations at Hera Mine. Stock and domestic bores that are not associated with operations at Hera Mine include:

- GW014111, GW014217, GW015819, GW015820, GW017183, GW017469, GW020714, GW021543 and GW022674 located over 15 km from Hera Mine.
- GW017385 which is located approximately 3 km north of Hera Mine.
- GW017386 is located approximately 2.5 km south of Hera Mine and is 650 m from the nearest groundwater production bore (WB11).
- GW018014 is located approximately 10 km southwest of the Hera Mine underground workings and 8.3 km from the nearest groundwater production bore (WB11).

The closest stock and domestic bores to Federation are GW020714 and GW017386 which are located 6.4 km south and 7.4 km north from Federation respectively.

Table 3.1 *Registered bore details*

Bore	Depth (m)	Purpose	SWL (m)	Yield (L/s)	Salinity	Strata	Radial distance from Federation (km)	Radial distance from Hera Mine (km)	Radial distance from proposed borefield (km)	Hera bore name/ notes
GW014111	54.3	Stock	39.6	0.13	Brackish	Limestone, granite	20.4	30.1	19.2	
GW014217	55.5	Stock	–	–	Brackish	Slate	20.3	30.2	19.0	
GW015819	25.9	Unknown	–	–	–	Sandstone	17.7	24.3	17.1	
GW015820	50.3	Stock	–	–	–	–	18.9	25.1	18.3	
GW017183	91.4	Stock	48.8	0.73	Over 14000 ppm	Sandstone, slate	12.7	18.3	12.3	
GW017385	61	Stock	46.6	0.51	501-1000 ppm	Schist, slate	12.7	3.0	8.3	
GW017386	100.9	Stock	58.2	0.25	1001-3000 ppm	Slate	7.4	2.5	4.6	
GW017469	100.9	Stock	58.2	0.25	1001-3000 ppm	Slate	18.8	22.3	12.6	
GW018014	82.9	Stock	15.2	0.51	3001-7000 ppm	Quartzite	8.2	9.7	8.3	
GW020656	74.1	Stock	55.8	0.63	1001-3000 ppm	Slate, quartzite bands	8.7	2.8	2.9	Back Bore
GW020657	74.1	Stock, domestic	54.3	0.63	–	Slate, quartzite bands	10.3	1.2	6.8	House Bore
GW020714	109.73	Stock	36.6	0.21	Salty	Quartzite	6.4	16.3	5.1	
GW021543	75.6	Stock	45.7	0.59	Over 14000 ppm	Slate	13.4	18.8	13.1	
GW022674	90.8	Stock, domestic	45.7, 39.6	0.63	10001-14000 ppm	Slate	12.7	21.6	11.6	
GW802946	85	Stock, industrial	65	1.1	–	Siltstone	10.5	0.6	6.1	Skirka's Bore (abandoned)
GW804183	108	Monitoring bore	100	2.5	–	Siltstone	11.6	2.2	7.8	

Bore	Depth (m)	Purpose	SWL (m)	Yield (L/s)	Salinity	Strata	Radial distance from Federation (km)	Radial distance from Hera Mine (km)	Radial distance from proposed borefield (km)	Hera bore name/ notes
GW804184	108	Monitoring bore	–	0.6	–	Siltstone	11.7	2.4	5.9	WB3
GW804185	120	Monitoring bore, test bore	52.78	1	–	Siltstone	9.1	3.1	2.8	WB4
GW804534	116	Mining	70.66	3.5, 2.5	–	Sandstone, siltstone, minor quartz veins	8.5	2.7	3.0	
GW804600	150	Monitoring bore, test bore	–	–	–	Sandstone, siltstone	10.6	0.9	6.0	Obs Bore 3
GW804601	120	Monitoring bore, test bore	–	–	–	Sandstone, siltstone	8.1	2.3	3.5	Obs Bore 2
GW804602	120	Monitoring bore, test bore	–	–	–	Sandstone, siltstone	8.6	2.9	2.9	Obs Bore 1
GW804603	150	Monitoring bore, test bore	–	0.5	Slightly salty	Siltstone	10.4	0.6	6.0	Decline Bore
GW804604	103	Monitoring bore, test bore	–	–	–	Shale, siltstone, sandstone	9.9	3.3	3.3	Abandoned
GW804605	140	Monitoring bore, test bore	70	7.5	–	Sandstone, siltstone	8	2.5	3.3	WB8
GW804606	115	Monitoring bore, test bore	–	–	–	Shale, siltstone, sandstone	9.8	1.7	4.3	Abandoned
GW804607	90	Mining	58	0.6	–	Shale, siltstone, sandstone	10.9	2.5	4.8	WB10
GW804608	122	Mining	63	5	–	Sandstone, siltstone	8	1.9	5.1	WB21
GW804609	96	Monitoring bore, test bore	60	0.4	–	Sandstone, siltstone	9.3	1.1	6.2	WB12/WB17
GW804610	108	Mining	72	3.5	3001-7000 ppm	Sandstone, siltstone	9.9	0.3	5.5	WB13
GW805641	117	Monitoring bore	78	0.3	–	Siltstone	11.7	2.3	7.9	WB15

Bore	Depth (m)	Purpose	SWL (m)	Yield (L/s)	Salinity	Strata	Radial distance from Federation (km)	Radial distance from Hera Mine (km)	Radial distance from proposed borefield (km)	Hera bore name/ notes
GW805642	120	Mining	75	4.2	–	Sandstone, siltstone	8.5	2.7	3.0	
GW805643	135	Industrial	66	3	–	Siltstone	9.3	1.1	6.2	WB12/WB17
GW850057	–	Stock, domestic	–	–	–	–	–	10.4	1.1	FWB030

3.5.2 Groundwater dependent ecosystems

A GDE is an ecosystem which has its species composition and natural ecological processes determined by groundwater. That is, GDEs are natural ecosystems that require access to groundwater to meet all (obligatory), or some (facultative) of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services. If the availability of groundwater to GDEs is reduced, or if the quality is allowed to deteriorate, these ecosystems might be impacted.

It is widely acknowledged that a poor understanding exists in recognising GDEs, or understanding the hydrogeological processes affecting GDEs, or their environmental water requirements. GDEs can be broadly grouped into three categories:

- Ecosystems that depend on the surface expression of groundwater:
 - Swamps and wetlands can be sites of groundwater discharge and may represent GDEs. The sites may be permanent or ephemeral systems that receive seasonal or continuous groundwater contribution to water ponding or shallow water tables. Tidal flats and inshore waters may also be sites of groundwater discharge. Wetlands can include ecosystems on potential acid sulphate soils and in these cases maintenance of high water levels may be required to prevent waters from becoming acidic.
 - Permanent or ephemeral stream systems may receive seasonal or continuous groundwater contribution to flow as baseflow. Interaction would depend upon the nature of stream bed and underlying aquifer material and the relative water level heads in the aquifer and the stream.
- Ecosystems that depend on the subsurface presence of groundwater. Terrestrial vegetation such as trees and woodlands may be supported either seasonally or permanently by groundwater. These may comprise shallow or deep-rooted communities that use groundwater to meet some or all of their water requirements. Animals may depend upon such vegetation and therefore indirectly depend upon groundwater. Groundwater quality generally needs to be high to sustain vegetation growth.
- Ecosystems that reside within a groundwater resource. These are referred to as hypogean ecosystems. Micro-organisms in groundwater systems can exert a direct influence on water quality, for example, stygofauna typically found in karstic, fractured rock or alluvial aquifers.

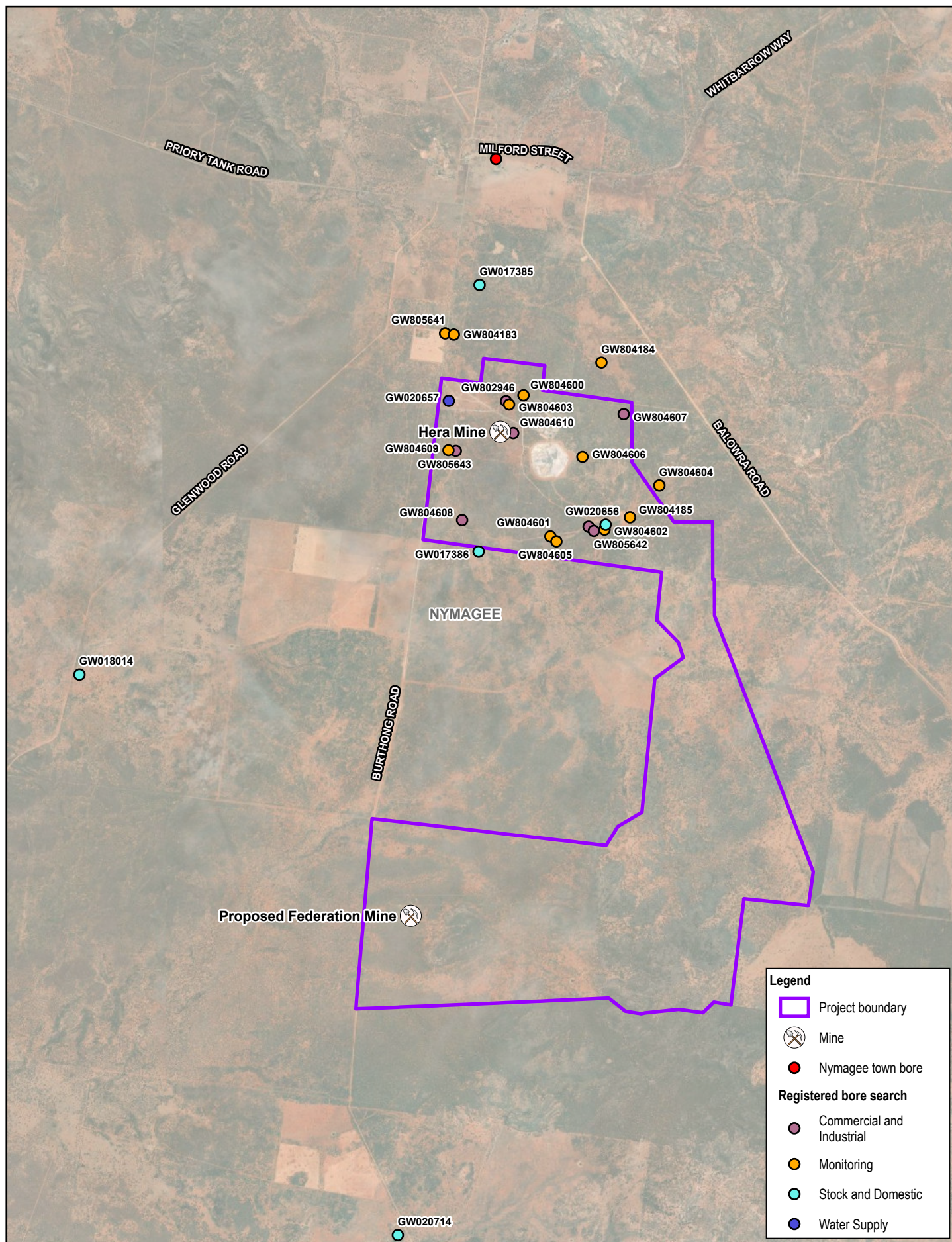
3.5.2.1 Occurrence within the region

A search of the Groundwater Dependent Ecosystem Atlas (BoM 2019b) was undertaken to identify GDEs within 20 kilometres of Federation. There were no known aquatic GDEs identified within 20 kilometres of Federation. This is not unexpected, given the deep groundwater levels identified at the site.

Potential GDEs are identified based on regional assessments of groundwater levels, remote sensing of vegetation and surface topography. The mapping (BoM 2019b) generally identifies potential GDEs based on regional mapping and therefore the potential GDEs often correspond with areas of vegetation. The search identified a number of potential terrestrial GDEs in the vicinity of Federation. The location of these potential GDEs are shown in Figure 3.9. Figure 3.9 shows that Federation lies in a low potential GDE – national assessment occurrence zone. The proposed borefield lies within moderate potential GDE – national assessment. It is considered highly unlikely that these vegetative communities are GDEs given the deep-water levels identified at the site.

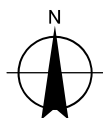
The Balowra State Conservation Area lies to the immediate south of the Project. The State Conservation Area is considered unlikely to contain GDEs given the deep-water levels at the site.

The background document for the Murray-Darling Basin Fractured Rock Groundwater Sources Water Sharing Plan (DPIW 2012) was also reviewed to identify any high priority GDEs within the Lachlan Fold Belt groundwater source. There were no listed high priority GDEs within or near Federation.



Paper Size ISO A4
 0 0.75 1.5 2.25 3
 Kilometres

Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 55

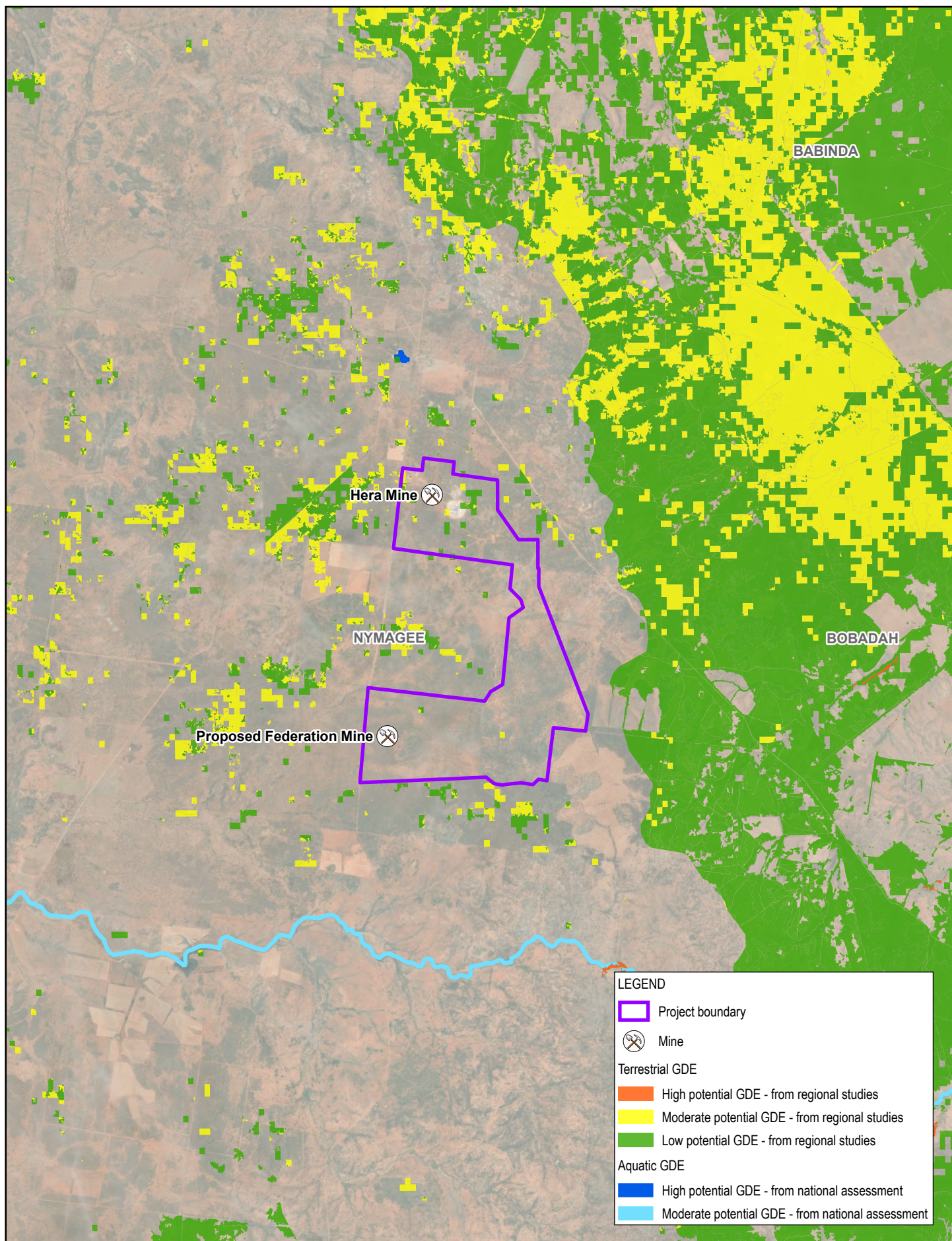


Hera Resources Pty Ltd
 Federation Project
 Groundwater Impact Assessment

Project No. 12534191
 Revision No. 0
 Date 08/11/2021

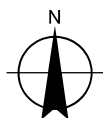
Registered bore search

Figure 3-8



Paper Size ISO A4
0 1.5 3 4.5 6
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

**Groundwater
dependent ecosystems**

Project No. 12534191
Revision No. 0
Date 07/12/2021

Figure 3-9

3.6 Historical and current mining operations

Current and historical mining operations in the hydrogeological domain include the active Hera Mine and the historical Nymagee Mine. There are no other known mining operations in the hydrogeological domain.

3.6.1 Hera mining operations

Development of the decline at Hera Mine commenced in January 2013. The first zinc-lead concentrate was produced on 24 August 2014 and the first gold was poured on 12 September 2014. The mine workings at Hera Mine are actively dewatered to allow mining to occur. Groundwater inflows at Hera Mine are currently metered. Details regarding the monitoring of groundwater inflows is provided in Section 3.8.3. Mining at Hera Mine is ongoing. Plan view of Hera Mine workings (Aquade 2016) are shown in Figure 3.10.

Operations at Hera Mine also include extraction from several production bores. Extractions from the production bores are used in site activities and commenced in mid-2012. Details regarding the production bores are provided in Section 3.10.

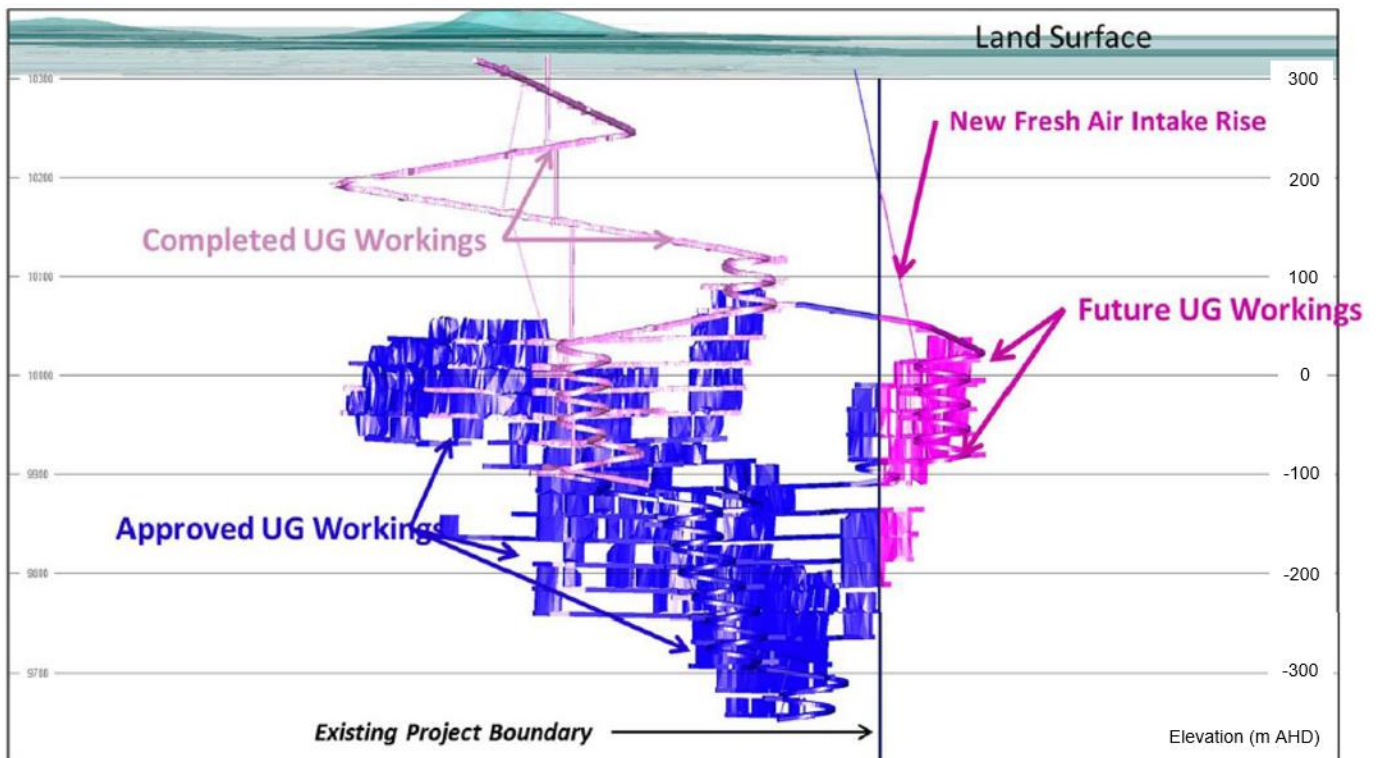


Figure 3.10 Hera Mine workings (Aquade, 2016)

Note to figure: the future workings are predominantly completed

3.6.2 Nymagee Mine

The Nymagee Mine is located approximately 1 km west of the Nymagee township and approximately 4.5 km north north-west of Hera Mine. The location of Nymagee Mine is shown in Figure 1.1.

As reported by R.W. Corkery (2019) the Nymagee Mine commenced operations in 1880, with 13 shafts constructed and extensive surface disturbance by 1890. A fire underground in 1920 resulted in closure of the Nymagee Mine and subsequent relinquishment of the Mining Leases by 1947.

On 24 December 1951, ML5295 and PLL847 were granted, with additional Mining Leases granted in 1962 and 1975. During that period, unsuccessful attempts were made to recommence mining operations, with all mining ceasing by 1975.

The Nymagee Mine workings are now flooded. There has been some limited dewatering of the historical flooded Nymagee Mine workings between April 2019 and July 2020. This dewatering was as part of investigations into the Nymagee Mine workings as a potential water source for Hera Mine. Dewatered volumes from the Nymagee Mine workings are discussed in Section 3.10. The investigation identified that the water in the Nymagee workings was of poor quality and was not a suitable water source without treatment. Therefore, there has not been any further extraction of groundwater from the Nymagee workings since July 2020. However, the Nymagee Mine workings remain a potential future source of water.

Aurelia holds various Mineral Authorities that cover Nymagee Mine.

3.7 Groundwater monitoring program

3.7.1 Hera Mine

3.7.1.1 Monitoring bores

The groundwater monitoring program at Hera Mine includes a number of groundwater monitoring bores and production bores. Extraction from Back Bore and Skirka's Bore for exploration activities commenced as early as 2005. Extraction from the production bores for use in construction and mining activities commenced in mid-2012 with the volume extracted from each bore varying over time. All production bores are fitted with meters to monitor the volume extracted. Monitoring has ceased at a number of bores at Hera due to production bores ceasing operation due to becoming dry.

The monitoring network at Hera Mine also includes a number of shallow Tailings Storage Facility (TSF) monitoring bores. These shallow TSF bores are not relevant to underground mining and are therefore not discussed further in this report.

With the exception of the shallow TSF bores, all bores target the upper portion of the aquifer. There are no monitoring bores or production bores deeper than 160 m.

Details of groundwater monitoring bores are provided in Table 3.2 and locations are shown in Figure 3.11.

3.7.1.2 Monitoring program

Groundwater monitoring at Hera Mine is undertaken in accordance with Environmental Protection Licence (EPL) 20179. The groundwater monitoring program at Hera Mine is summarised in Table 3.3.

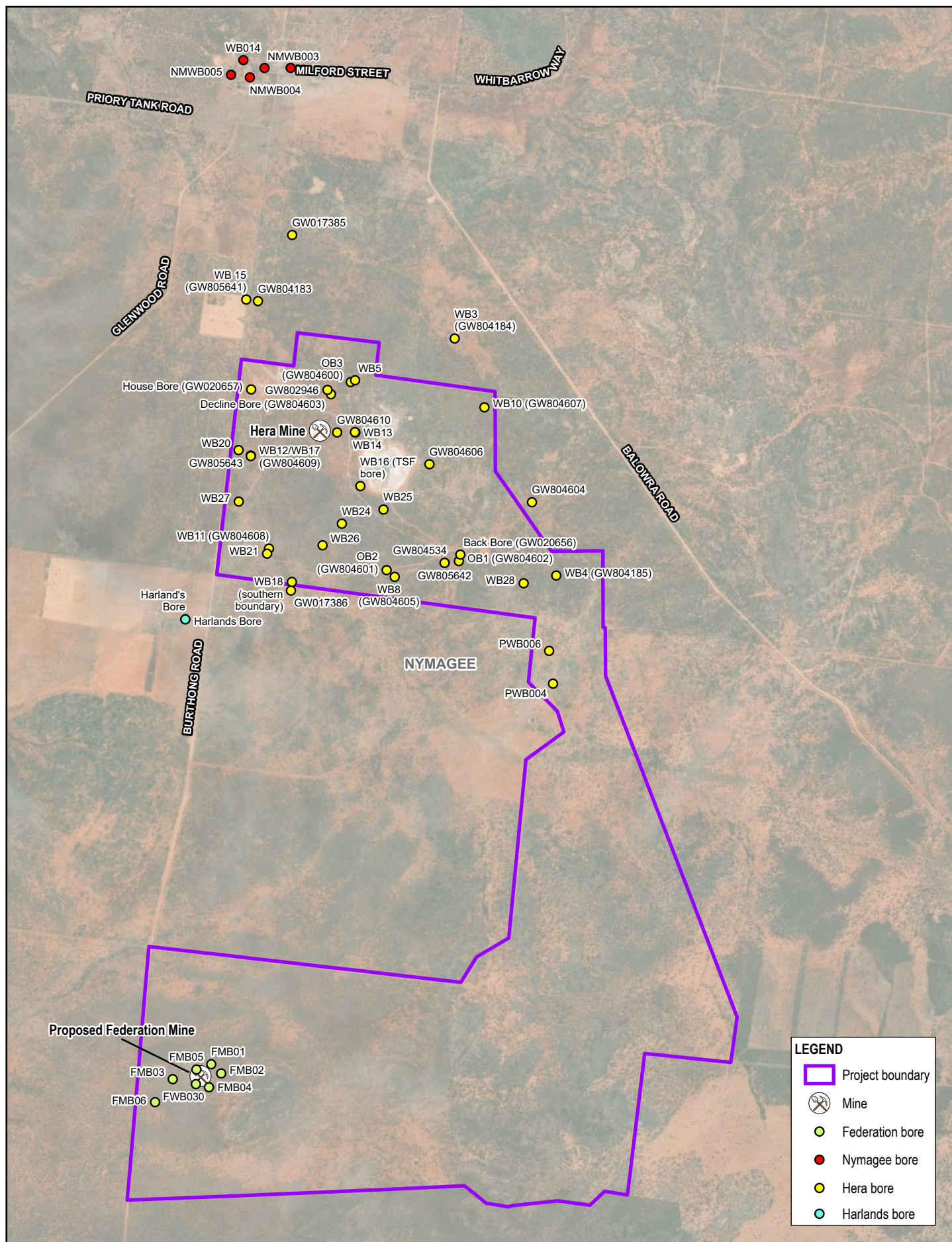


Table 3.2 *Hera Mine monitoring bores and production bores*

Bore	Alternative bore name	Type	Easting	Northing	Period of monitoring	TOC (m AHD)	Bore depth (m)	Screen interval (m bgl)	Gravel pack (m bgl)
PWB004	GW850084	Production bore	439402	6442866	Mar 2020 – current	331.852	108	96-108	94-108
PWB006	GW850085	Production bore	439423	6443350	Mar 2020 – current	338.975	160	148-160	140-160
WB26	EX001	Production bore	436064	6444938	Mar 2020 – current	313.038	130	118-124	116-130
WB27	EX009	Production bore	434778	6445593	Mar 2020 – current	307.113	154	136-148	134-154
WB28	EX010	Production bore	439047	6444369	Mar 2020 – current	336.173	97.5	64-70, 88-94	62-97.5
Nymagee Mine Shaft		Mine shaft	434742.35	6452196.35	Jan 2020 – current				
WB15	Hay Bore	Monitoring bore	434888.788	6448621.179	Apr 2015 – current	304.9	117	101-109	
WB18	Southern Boundary	Monitoring bore	435574.798	6444391.972	Mar 2015 – current	309	120	106-112	
WB20		Monitoring bore	434772.385	6446669.136	Nov 2015 – current	324.061	120	103-116	
WB10		Production and monitoring bore	438458.205	6447002.986	Dec 2011 – current	320.463	90	72-84	66-90
WB25	WB23	Production bore	437221.752	6445330.264	Feb 2020 - current	328.711	124	106-123	
House Bore	HO	Production bore	434943.239	6447257.73	-	303.819	74.1	30-74 (open hole)	
Back Bore	BB	Inactive production bore	438080	6444868	Nov 2011 – Mar 2019	321	120	104-118	
Decline Bore	DB	Inactive production bore	436171	6447198	Nov 2011 – Nov 2017	313.222	148	136-148	
OB1		Inactive monitoring bore	438073	6444704	Mar 2012 – Apr 2016	312.348	150	138-150	
OB2		Monitoring bore	436993	6444569	Mar 2012 – Mar 2019	319.43	150	138-150	
OB3		Monitoring bore	436454	6447385	Mar 2012 – Nov 2017	317.91	150	138-150	
WB12	WB17	Production bore	434958.2453	6446282.831	Apr 2012 - Oct 2015	303	136	84-96	82-136
WB13		Inactive production bore	436518.086	6446633.201	Nov 2011 – May 2015	316	106	90-102	80-106

Bore	Alternative bore name	Type	Easting	Northing	Period of monitoring	TOC (m AHD)	Bore depth (m)	Screen interval (m bgl)	Gravel pack (m bgl)
WB16	TSF Bore	Monitoring bore	436591.719	6445841.405	Mar 2015 – current	308.209	114	98-106	
WB21		Production bore	435217.004	6444908.376	Mar 2019	312.708		97-109	
WB22	WB24	Production bore	437222.712	6445325.255	Jan 2016 – Mar 2019	316.18	124		
WB23	WB25	Production bore	436329.13	6445294.802	Feb 2016 – Mar 2019	324.758	96		
WB3		Monitoring bore	437915.4317	6447986.187	Mar 2015 – Mar 2019	316.647	108	88-108	
WB4		Monitoring bore	438698.7184	6445130.511	Mar 2012 – current	324.76	120	114-120	
WB5			436521.12	6447411.129	Mar 2012 – Jun 2016	320.38	150	144-150	
WB8		Production bore	437111.268	6444463.128	Nov 2011 – Nov 2017	316.65	140	98-104, 110-122, 128-134	79-140
Harland's Bore	HARWB		433978	6443829	Apr 2013 – Jan 2016	347			
GW017386	Pat Dunne's Bore	Landholder bore/ monitoring bore	435560.0526	6444259.617	Jul 2017 – Sept 2018			41-101	
WB11			435230.962	6444891.489	-	308.06	122	98-116	62-122
Skirka's Bore	GW802946	Inactive production bore	436108.977	6447266.271	Jan 2006 – Mar 2006		85	71-77	71-85

Note to table:
TOC: top of casing
m bgl: metres below ground level
MGA: Map grid of Australia

Table 3.3 Hera Mine – groundwater monitoring program

Location	Frequency	Parameter
EPL monitoring points		
WB4 (EPA 7)	Quarterly	Standing water level (SWL), Electrical conductivity (EC), pH, Total dissolved solids (TDS), Sb, As, HCO ₃ , B, Cd, Ca, CO ₃ , Cl, Cr, Cu, Cyanide (free, total & WAD), Fe, Pb, Mg, Hg, Mo, Ni, K, Ag, Na, Sn, Zn
WB8* (EPA 9)		
House bore* (EPA 19)		
WB15 (EPA 27)		
WB16 (EPA 28)		
WB18 (EPA 29)		
WB20 (EPA 30)		
WB21* (EPA 31)		
WB24* (EPA 32)		
WB25* (EPA 33)		
WB10 (EPA 40)		
*SWL not required to be measured in production bores		

3.7.2 Federation

3.7.2.1 Monitoring bores

The groundwater monitoring program at Federation includes seven groundwater monitoring bores, with most of these being installed in mid-2020. The groundwater monitoring network includes one bore installed for the purposes of exploration (FWB030/GW850057). Groundwater monitoring bore details are included in Table 3.4 and locations shown in Figure 3.11.

Table 3.4 Federation groundwater monitoring bores

Bore	TOC (m AHD)	Depth (m bgl)	Screened interval (m bgl)	Gravel pack interval (m bgl)	MGA Zone 55 Co-ordinates		Monitoring period
					Easting	Northing	
FMB001	323.754	120	111-117	96-120	434361	6437163	Jul 2020 – current
FMB002	328.115	180	162-174	88-180	434511	6437027	Jul 2020 – current
FMB003	316.734	120	105-109, 114-117	103-120	433780	6436947	Aug 2020 – current
FMB004	327.118	120	111-117	88-120	434339	6436818	Jul 2020 – current
FMB005	323.248	120	111-117	88-120	434146	6437092	Jul 2020 – current
FMB006	312.228	150	100-103, 144-147	98-150	433476	6436614	Oct 2020 – current
FWB030/GW850057	321.463	114	102-108	100-114	434136	6436866	Jul 2020 – current

Note to table:

m bgl: metres below ground level

MGA: Map grid of Australia

The monitoring bores are monitored monthly for groundwater levels and quality. The monitoring results are discussed in Section 3.8.1.2.

3.7.3 Nymagee Copper Mine

A groundwater monitoring program has been implemented at Nymagee Copper Mine (Nymagee Mine) with four monitoring bores installed around the Nymagee Mine (NMWB003, NMWB004, NMWB005 and NMWB006). Monitoring data are also collected at production bore WB014. The monitoring details are summarised in Table 3.5 and the location of these bores are shown in Figure 3.11.

All monitoring bores and the production bore at Nymagee Mine are installed in the fractured rock aquifer.

Table 3.5 Nymagee Mine monitoring bore details

Bore	Easting (MGA zone 55)	Northing (MGA zone 55)	Monitoring period	Elevation (m RL)	Depth (m)	Screen intervals (m)
WB014	434846.59	6452207.09	Apr 2013 – current	321.6	102	1 – 102
NMWB003	435163.83	6452088.42	Sep 2018 – current	308.0	140	50 – 62, 128 – 134
NMWB004	434945.22	6451947.44	Sep 2018 – current	306.0	142	57 – 63, 124 – 136
NMWB005	434661.40	6451986.69	Sep 2018 – current	309.0	125	60 – 66, 97 – 109
NMWB006	435556	6452090	Oct 2020 – current	309.125	150	56 – 62, 102 – 108, 138 – 144

Groundwater monitoring commenced at NMWB003, NMWB004 and NMWB005 in September 2018. NMWB006 is located between the Nymagee Mine workings and the Nymagee Town Bore. NMWB006 was installed in mid-2020 to monitor for potential impacts of extraction of water from the Nymagee Mine workings on the Nymagee Town Bore. Monitoring at WB014 commenced in April 2013.

3.8 Groundwater monitoring results

3.8.1 Groundwater levels

Groundwater levels are very deep at Hera Mine, Federation and Nymagee Mine. Depth to groundwater typically ranges from 45 m to 75 m below ground level (bgl) at Hera Mine and Nymagee Mine, and from 75 m to 90 m bgl at Federation. At Hera Mine and Nymagee Mine the groundwater table appears to generally lie within the partially weathered strata, while at Federation, the water table is approximately equal to or approximately 10 m below the base of the partially weathered strata.

3.8.1.1 Hera Mine

Groundwater levels have been monitored at Hera Mine since 2011. Aquade (2015a) identified a baseline groundwater flow gradient across the Hera Mine site from east-north-east to west-south-west.

Drawdown in groundwater levels has been observed with decline development in early 2013 and groundwater extraction from production bores. Observed trends in groundwater levels are discussed below. Hydrographs at Hera Mine have been plotted with CRD in Appendix A. Relevant hydrographs are plotted with extraction from production bores in Appendix C.

3.8.1.1.1 Review of groundwater level trends

When not influenced by mining activities or extraction from production bores, available data indicates that groundwater levels are very constant. This indicates that recharge rates are very low. Low recharge rates would be expected owing to the depth of the water table and low rainfall.

The monitoring bores WB5, OB3 and the Decline Bore are all located within 100 m of the Hera Mine workings. All of these bores displayed drawdown commencing in 2013 following the commencement of the Hera Mine decline. Monitoring bore WB13 is located within 300 m of the Hera Mine workings. Drawdown at WB13 occurred in mid-2013 following the commencement of the Hera mine decline.

Groundwater monitoring data indicates that the radius of drawdown from the Hera Mine workings has increased over time. Groundwater monitoring at WB16 commenced in March 2015. Monitoring bore WB16 is located approximately 1 km to the south of the Hera Mine workings. Review of the hydrograph at WB16 indicates that drawdown due to Hera Mine corresponds with the commencement of monitoring at this site. Monitoring bore WB20 is located 1.5 km to the south west of the Hera Mine workings. Groundwater levels at WB20 are relatively constant until early 2018 when groundwater levels start to decline. In early 2018 the closest operational bore to WB20 was WB21 which is located approximately 1.8 km away. Therefore this drawdown at WB20 is attributable to the Hera Mine workings. In 2020, production bore WB17, located 450 m to the south south-east, commenced operation. Review of the hydrograph for WB20 indicated that the rate of drawdown increased in mid-2020. This increase in the rate of drawdown may be partially attributable to extraction at WB17.

WB15 is located approximately 1.5 km to the north west of Hera Mine. Review of the hydrograph indicates that groundwater levels at WB15 started to decline in 2018. There are no known production bores within 2 km of WB15. Therefore, the drawdown observed at WB15 is attributable to the Hera Mine workings.

Groundwater drawdown has been observed at all of the production bores including Back Bore, House Bore, WB8, WB10, WB17, WB21, WB24, WB25, WB26, WB27 and WB28, PWB004 and PWB006.

3.8.1.2 Federation

Groundwater levels in the fractured rock aquifer have been monitored at Federation since July 2020. Observed groundwater levels are shown in Appendix A.

Groundwater levels have been plotted with daily rainfall and CRD. Visual review of the groundwater hydrograph indicates that groundwater levels do not display any response to periods of rainfall. This is to be expected given the low recharge rates and the depth to groundwater. The drop in groundwater levels at Federation monitoring bores in October 2020 is due to pumping from FWB030. Pumping from FWB030 has resulted in drawdown at all Federation monitoring bores. Over 20 m in drawdown has been observed at FWB030. All Federation monitoring bores are located within 200 m to 700 m of FWB030. Drawdown at all other Federation bores has been less than 2 m.

Comparison of the depth to groundwater and the bore construction details indicates that groundwater levels are confined at Federation with groundwater levels at FMB001, FMB003, FMB005, FMB006 and FWB030 above the level of the gravel pack. Groundwater levels at FMB002 and FMB004 are at the top of the gravel pack indicating confined groundwater conditions may also exist at these locations.

3.8.1.3 Nymagee Mine

Groundwater monitoring data have been collected quarterly since September 2018 at NMWB003, NMWB004 and NMWB005. Longer records of groundwater monitoring data were available for WB014 from September 2017 to March 2019. Monitoring data at the Nymagee Mine are presented in Appendix A.

Review of groundwater level monitoring data indicates a drop in groundwater level of 21 m at WB14 between November 2018 and April 2020. There was also drawdown of 0.8 m at NMWB03, 4.5 m at NMBW04 and 2.8 m at NMBW05 over this period. As discussed in Section 3.6.2, this period corresponds with groundwater extraction from the Nymagee workings. WB14 is the closest of the Nymagee monitoring bores to the Nymagee workings. Prior to November 2018, there was variation in groundwater levels at WB14 in accordance with CRD. It is possible that rainfall and runoff is entering the shaft at Nymagee Mine and groundwater levels at WB14 are varying in accordance with water level in the historical workings.

3.8.2 Groundwater quality

3.8.2.1 Hera Mine

Groundwater at Hera Mine monitoring bores and production bores is circumneutral and slightly brackish to brackish (generally 2,000 $\mu\text{S}/\text{cm}$ to 8,000 $\mu\text{S}/\text{cm}$) with some variation in EC. Groundwater quality data at Hera Mine is shown in Appendix B. Dissolved metals concentrations in groundwater at Hera Mine are generally low. Some variability has been observed in dissolved boron at WB20 and WB15, dissolved iron at WB21, dissolved nickel at WB5, WB8, WB16 and WB24; and dissolved zinc at WB8 and WB16. This variability is typically displayed as one off spikes with concentrations returning to typical values in the following monitoring round.

No cyanide has been observed in any groundwater bores.

3.8.2.2 Federation

Groundwater at Federation varies from very slightly acidic to very slightly basic (6.6 pH units to 7.6 pH units) and varies from slightly brackish to saline (2,000 $\mu\text{S}/\text{cm}$ to 10,000 $\mu\text{S}/\text{cm}$).

Dissolved metal concentrations in groundwater at Federation are generally low. Some variability has been observed in dissolved iron and dissolved manganese. Dissolved iron concentrations of up to 5 mg/L and manganese concentrations of generally less than 2 mg/L have been observed at monitoring bores at Federation. Groundwater quality data at Federation are shown in Appendix B.

Groundwater quality at Federation has been compared with groundwater quality at Hera Mine in a piper diagram, shown in Figure 3.12. As shown in the piper diagram groundwater quality at Hera Mine is generally relatively similar to groundwater quality at Federation. Groundwater at Federation and Hera Mine is generally sodium chloride water type. Some sites at Hera Mine are a sodium chloride-sulfate water type such as WB24, WB23, WB22 and the Decline Bore.

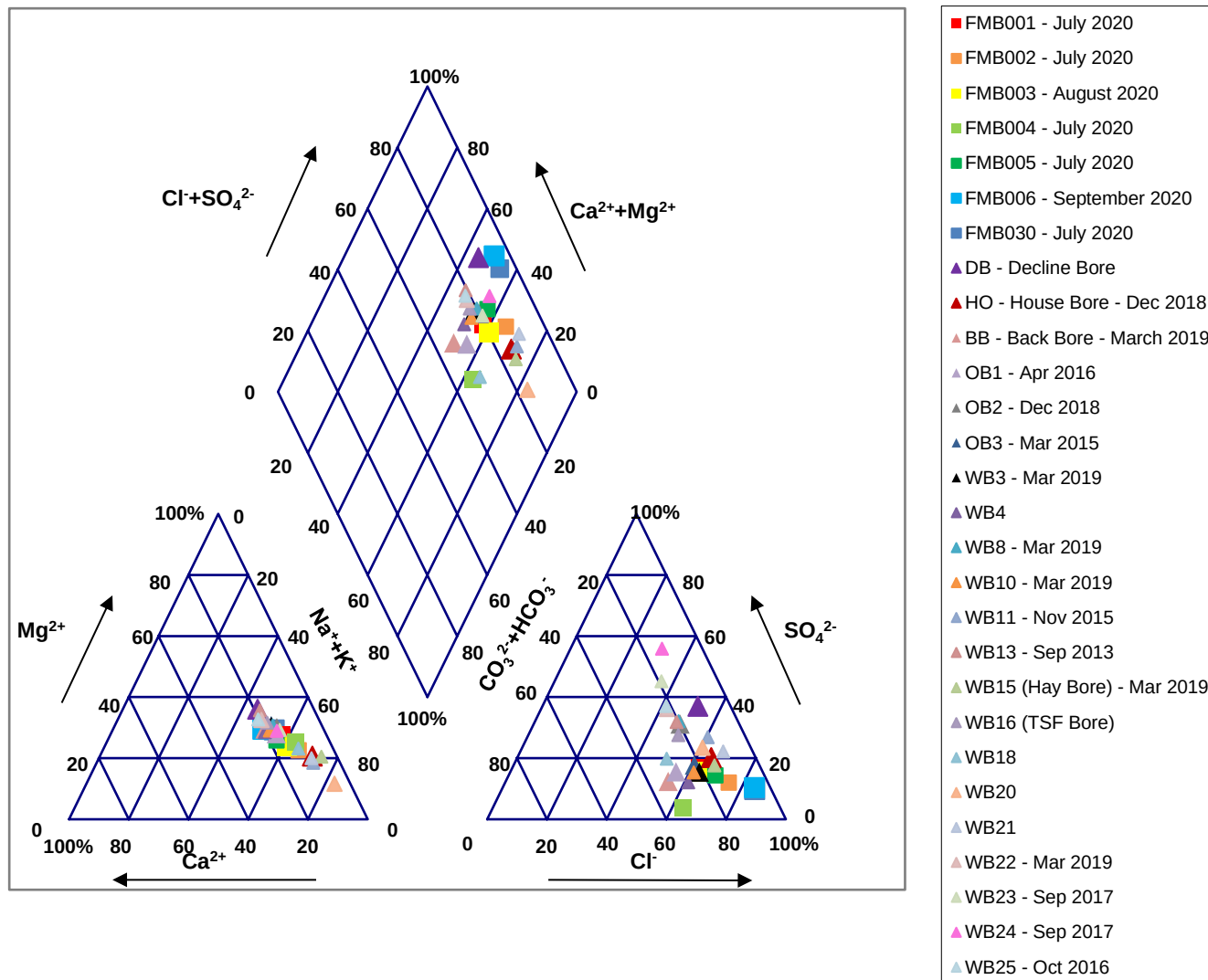


Figure 3.12 Piper diagram

Note to figure: Data from Federation bores are shown with squares, data from Hera Mine bores are shown with triangles

3.8.2.3 Nymagee Mine

Groundwater pH and EC are the only measures of groundwater quality available at Nymagee Mine. Based on the three monitoring bores at Nymagee, measured EC levels ranged between 2,560 and 6,010 $\mu\text{S}/\text{cm}$. Groundwater at WB014 was fresher and more acidic than the three monitoring bores. WB014 is located closer to the mine shaft compared to the monitoring bores and the groundwater quality may be influenced by possible rainfall or runoff entering the shaft. Groundwater pH and EC are summarised in Table 3.6.

Table 3.6 Nymagee groundwater quality

Bore	Average pH	Range pH	Average EC (mS/cm)	Range EC ($\mu\text{S}/\text{cm}$)
NMWB003	7.0	6.9 – 7.0	4.9	3,620 – 6,010
NMWB004	7.4	7.2 – 7.6	3.1	2,560 – 3,810
NMWB005	8.4	7.0 – 10.8*	3.6	2,930 – 4,050
WB014	5.3	3.3 – 6.7	1.69	1,500 – 1,840

*Measurement was confirmed with sampler

Compared to groundwater quality data at Federation and Hera Mine, groundwater at Nymagee bores NMWB003 and NMWB004 is generally consistent in terms of physiochemical parameters. However, the average pH and EC are considerably lower at WMB014, in comparison to the data at both Federation and Hera bores. NMWB005 average pH is more alkaline in comparison to available data at Federation and Hera Mine bores. The recorded EC is slightly lower than the average at both Federation and Hera Mine bores.

3.8.3 Hera Mine groundwater inflows

Calculated groundwater inflows into Hera Mine are shown in Figure 3.13. Development of the decline commenced in January 2013. Over the period of monitoring, groundwater inflows into the mine workings are typically 300 m^3/day to 500 m^3/day (3.5 L/s to 5.8 L/s). In mid-2014, prior to the commencement of metering of groundwater, inflows into Hera Mine were observed to be approximately 25 L/s (2,100 m^3/day) (pers comms.).

In mid-2014, the underground workings at Hera Mine were at a level of 200 m bgl. There was a spike in groundwater inflows between October 2017 to March 2018 to over 1,000 m^3/day as shown in Figure 3.13. This spike in groundwater inflows occurred when the Hera Mine workings extended to approximately 550 m bgl, however, the water was observed to be predominately flowing from several drill holes that had originated from the surface and intersected the decline.

Groundwater inflows are calculated as dewatering from the mine less water transferred into the underground workings. For a period in March 2017 dewatering from the mine was less than water transferred into the underground workings. Therefore in Figure 3.13 groundwater inflows are shown as negative over this period.

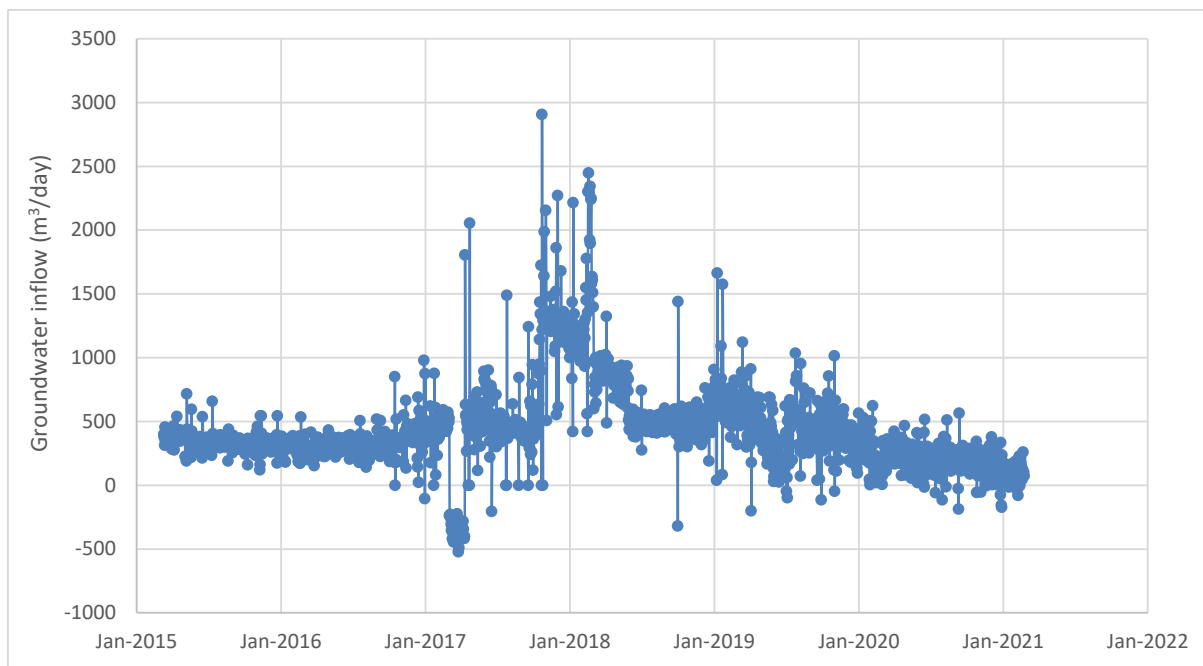


Figure 3.13 Groundwater inflow – Hera Mine

The daily average groundwater inflow was calculated on a monthly basis and is presented in Figure 3.14. The depth of the Hera Mine workings is also shown in Figure 3.14. The decreasing trend inflow between 2019 and 2021 may be due to the mine workings extending into areas that have already been dewatered by the existing workings. The rate of decreasing inflows is in accordance with the conceptualisation of the aquifer that fracturing of the aquifer decreases with depth. This decreasing fracturing would result in lower hydraulic conductivity and lower rate of groundwater inflow.

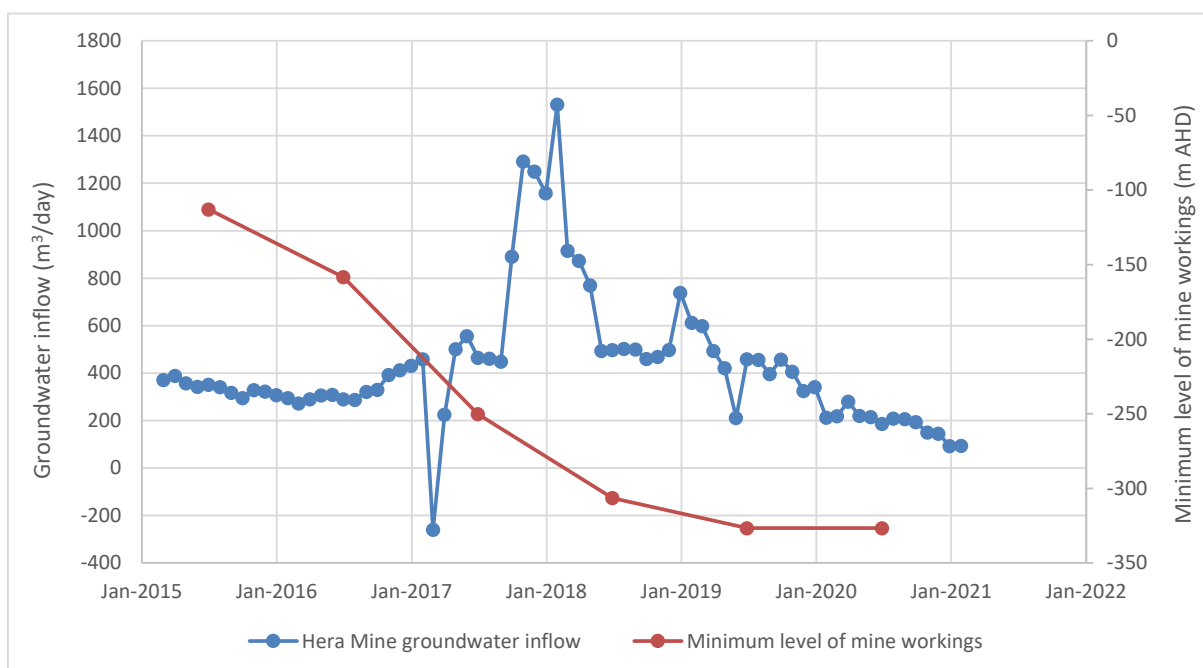


Figure 3.14 Monthly groundwater inflow – Hera Mine

Aquade (2015) undertook a review of groundwater inflow rates into the decline up to February 2015. Metering data of inflows into the Hera Mine workings was not available between July 2014 and February 2015 due to issues with the meter.

Table 3.7 *Summary of Hera Mine workings progress and groundwater inflow (Aquade 2015)*

Decline level	Date when decline reached this level	Approximate level of mine workings (m AHD)	Net inflow observations	Comments
Northern (first corner)	20 May 2013	250 (75 m below portal)	Rate of approximately 350 m ³ /day then trailed off over the following month to approximately 200 m ³ /day	Mine workings at base of weathering
Southern (second corner)	27 July 2013	192 (133 m below portal)	1000+ m ³ /day for several days, then trailed off	Elevated inflow coming from mineralised zone
February 2015 level	February 2015	-100 (425 m below portal)	Approximately 350 to 400 m ³ /day, with decreasing trend	Decline was halted at this level for 4 months

Review of metered data between May 2013 and July 2014 indicates that initial rate of groundwater inflow in May 2013 was 350 m³/day as shown in Table 3.7 and Figure 3.15. Groundwater inflows then gradually declined to approximately 200 m³/day at the start of July 2013. Groundwater inflows then increased to approximately 550 m³/day by early October 2013. Groundwater inflows remained relatively constant at 550 m³/day until July 2014.

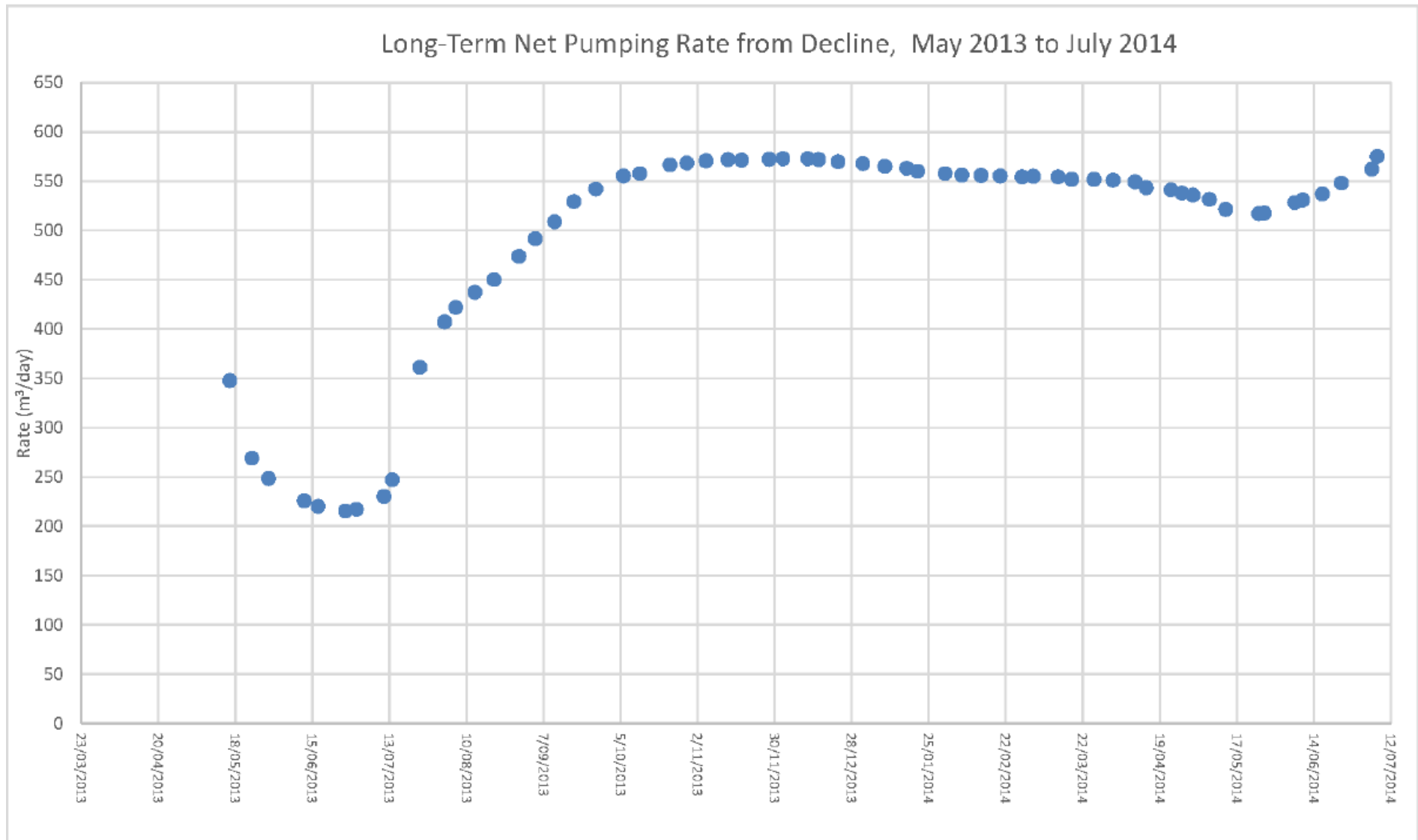


Figure 3.15 Groundwater inflows into Hera Mine – May 2013 to July 2014 (Aquade 2015)

3.9 Aquifer testing

3.9.1 Pumping tests

Pumping testing has been undertaken on a number of bores. The results of the pumping testing are outlined below.

3.9.1.1 Hera mine aquifer investigation – test pumping analysis (EMM, 2020)

EMM (2020) undertook pumping testing and analysis of three bores (WB26, WB27 and WB28) at Hera Mine. The results of the analysis of the pumping testing are summarised in Table 3.8.

Table 3.8 Pumping test derived aquifer parameters (EMM, 2020)

Bore name	Solution	Transmissivity (m ² /day)	Hydraulic conductivity (m/day)	Drawdown (m)
WB26	Leaky confined aquifer, partial penetration	37.8	0.9	12.02
	Confined aquifer, partial penetration	44.2	1.1	
WB27	Confined aquifer, partial penetration	18.8	0.2	51.24
WB28	Unconfined aquifer	8.9	0.3	21.98
	Leaky confined aquifer, partial penetration	27	0.8	

3.9.1.2 Hera Mine test pumping support and analysis (EMM, 2021)

EMM (2020) undertook pumping testing and analysis of two bores (PWB004 and PWB006) at Hera Mine. The results from the analysis of the pumping tests are summarised in Table 3.9.

Table 3.9 Pumping test derived aquifer parameters (EMM, 2021)

Bore	Solution	Transmissivity (m ² /day)	Hydraulic conductivity (m/day)	Drawdown (m)
PWB004	Leaky-confined aquifer, partial penetration	7.64	0.16	25.3
	Confined aquifer, partial penetration	11.35	0.23	
PWB006	Leaky-confined aquifer, partial penetration	13.31	0.15	45.6
	Confined aquifer, partial penetration	17.25	0.19	

3.9.1.3 Hera Project – Groundwater Assessment (Impax Group, 2011)

Aquifer pumping tests were undertaken at six bores (Back Bore, Decline Bore, WB8, WB11 and WB13) at Hera Mine by The Impax Group (2011). The results from the analysis of the pumping tests are summarised in Table 3.10.

Table 3.10 Pumping test results (Impax Group, 2011)

Bore	Transmissivity (m ² /day)	Effective aquifer permeability (m/day)	Storativity (-)
Back Bore	6.7	0.129	6.7×10^{-4}
Decline Bore	3.0	0.038	9.0×10^{-4}
WB8	19.3	0.351	1.7×10^{-3}
WB10	1.3	0.076	N/A
WB11	10.2	0.443	2.8×10^{-4}
WB13	4.8	0.40	N/A

Notes:

N/A: Storage not calculated as observation bores were not used during the test.

3.9.1.4 Hydrogeological Assessment of Skirka's Bore at 'The Peak' Station (Geoterra, 2005)

Geoterra (2005) undertook a pumping test of Skirka's Bore. The test monitored drawdown and recovery of the bore itself, with no observation bores available. The test included a 24 hour pumping test and a 24 hour recovery test. A transmissivity of 5.9 m²/day was estimated based on analysis of pumping test results.

3.9.1.5 Supplementary Assessment of Groundwater Availability, Hera Project (Aquade, 2015)

Aquade (2015) utilised the Theis model (Theis, 1935) to determine aquifer properties based on the available groundwater extraction rate and drawdown in production bores. The assessment considered the possibility of a no flow boundary to the east of WB8. Aquade (2015) noted that transmissivity of the aquifer may be lower to the east of WB8 than to the west of WB8, but there is not a true no-flow boundary to the east of WB8. A summary of the interpreted aquifer parameters is provided in Table 3.11.

Table 3.11 Summary of aquifer property interpretations (Aquade, 2015)

Observation bore	Pumping wells	Aquifer boundaries simulated	Transmissivity (m ² /day)	Storage coefficient (-)
OB2	WB8, WB11, Back Bore	No boundaries	9.6	0.005
	WB8, WB11, Back Bore	One north-south boundary 100 m east of WB8	21	0.005
OB1	WB8, WB11, Back Bore	No boundaries	1.1	0.0036
WB5	Hera mine workings	No boundaries	5.2	0.0088

3.9.1.6 Assessment of Potential Groundwater Impacts due to North Pod Expansion of Hera Project (Aquade 2016)

Aquade (2016) utilised the Theis model (Theis, 1935) to determine aquifer properties based on rate of groundwater extraction from the Hera Mine workings and the observed drawdown at WB5. The results of the assessment calculated transmissivity of 3.8 m²/day and storage coefficient of 0.0088.

3.9.2 Permeability testing

Triaxial permeability testing was undertaken on core samples at Hera Mine and Federation. The results of the triaxial permeability testing are summarised in Table 3.12. The results indicate that the hydraulic conductivity of the Palaeozoic strata is low, less than 1.4×10^{-6} m/day. The results indicate that the hydraulic conductivity of the host rock likely decreases with depth.

Table 3.12 Permeability testing results

Sample depth (m)	Number of samples	K min (m/day)	K max (m/day)
175	2	8.6×10^{-7}	1.4×10^{-6}
400	2	1.0×10^{-7}	5.7×10^{-7}
700	2	2.7×10^{-7}	5.5×10^{-7}

3.10 Groundwater extraction

Exploration activities commenced in 2005 (potentially earlier). These exploration activities including pumping from Skirka's Bore and Back Bore. A licence for Skirka's Bore was issued in 2004 for 1.5 ML/year (GeoTerra, 2005). Additionally, GeoTerra (2006) discusses an application to increase this licence to 18.5 ML/year.

Metered extraction from the production bores at Hera Mine is available from March 2015 onwards. This is because all flow meters on the production bores were replaced in March 2015. From October 2013 to March 2015 some groundwater extraction data are available from previous reporting. Aquade (2015) undertook a review of extraction from production bores from October 2013 to June 2015. The results of the review of extraction from the production bores are summarised in Table 3.13.

Table 3.13 Volumes pumped from production bores October 2013 to June 2015 (Aquade, 2015)

Bore	Cumulative volume pumped between October 2013 and June 2015 inclusive (ML)	Maximum sustained (days to weeks) pumping rate between October 2013 and June 2015 (m ³ /day)	Nearby observation bore	Maximum drawdown in nearby observation bore between October 2013 and June 2015 (m)
WB8	53	250	OB2	6.3
WB11	34	180	WB18	Insufficient data – WB18 installed during this monitoring period
Back Bore	36	64	OB1	9.4
House Bore	1.2	26	N/A	N/A
WB10	0.4	20	N/A	N/A

Details of production bores in operation from March 2015 are summarised in Table 3.14. In addition to the bores listed in Table 3.14, PWB004 and PWB006 are production bores at Hera Mine.

Table 3.14 *Production bores – March 2015 to December 2020*

Bore	Period of operation	Cumulative volume pumped between March 2015 and December 2020 (ML)	Maximum monthly pumping rate between March 2015 and December 2020 (m ³ /day)
Back Bore	May 2015 – May 2019	23.7	236
House Bore	Nov 2019 – current	6.4	26.7
WB8	Mar 2015 – current	295.1	241
WB10	Apr 2020 – current	2.3	12
WB17	Apr 2020 – current	3.0	17
WB21	Nov 2015 – current	146.6	162
WB24	Mar 2016 – current	40.0	119
WB25	Feb 2016 – current	153.6	321
WB26	May 2020 – current	12.0	59
WB27	May 2020 – current	18.4	107
WB28	Apr 2020 – current	23.8	108
Nymagee Mine Workings	Apr 2019 – July 2020	24.3	124
FWB030	Oct 2020 – current	39.4	Unknown – manual meter reading only

Hydrographs for production bores have been plotted with metered groundwater extraction data in Appendix C. Additionally, hydrographs at a number of monitoring bores that are adjacent to production bores, have been plotted with the relevant metered groundwater extraction data. Review of the hydrographs indicates that groundwater drawdown at a number of monitoring bores (OB2; NMWB003 to NMWB006; FMB001 to FMB006) is due to extraction from the production bores.

Review of extraction data indicates that groundwater yields may be gradually decreasing at a number of the production bores including WB8, WB21, WB24 and WB25. This decrease started to occur between 12 months and 4 years of operation.

3.11 Recharge and evapotranspiration

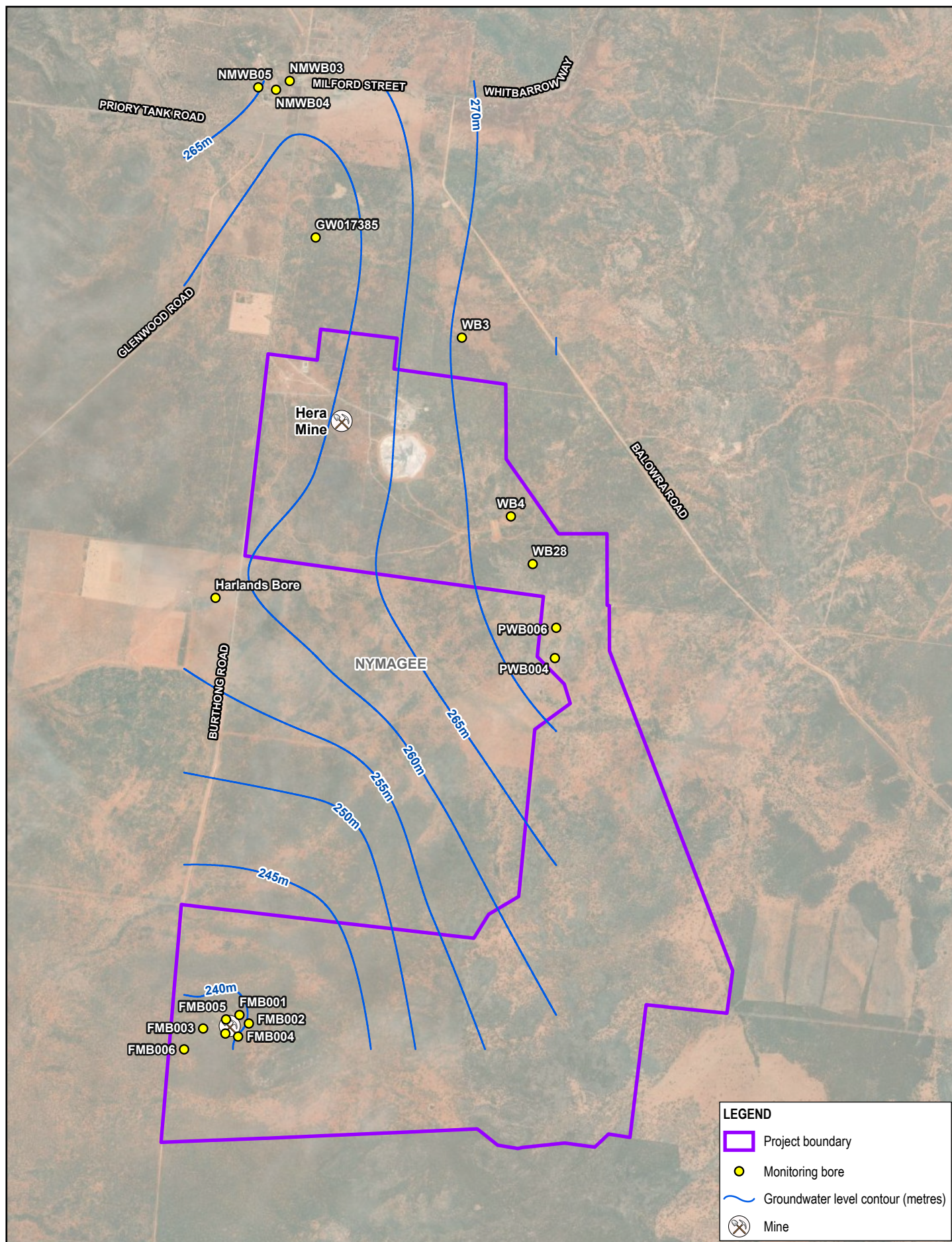
Given the depth to water in the bedrock and low annual rainfall volumes, recharge rates are likely to be very low, and potentially have some lag, owing to the long migration pathway through the unsaturated zone. Groundwater level monitoring data does not show any influence from rainfall recharge, with groundwater levels very constant at bores that are not impacted by mining and groundwater extraction.

Groundwater is very deep at Federation and Hera Mine, generally greater than 45 m bgl. Considering the deep groundwater levels at Federation and Hera Mine, evapotranspiration is likely to be negligible.

3.12 Groundwater flow directions

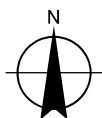
Groundwater levels at Nymagee Mine, Hera Mine and Federation have been reviewed to determine groundwater flow directions in the vicinity of Federation. Groundwater contours have been plotted for pre-mining conditions (i.e. pre Hera Mine commencement) and for current conditions (i.e. with Hera Mine but pre Federation deposit mining) in Figure 3.16 and Figure 3.17 respectively. Pre-mining contours were plotted using data collected from monitoring bores that commenced monitoring prior to mining at Hera Mine; and at Nymagee Mine and Federation bores as they were considered unlikely to be impacted by operations at Hera Mine. Groundwater contours for current conditions were plotted using the latest available monitoring data at each bore.

The pre-mining groundwater contours show that the groundwater flow direction is generally east north-east to west south-west. The groundwater contours for current conditions display the impact of mining and groundwater extraction at Hera Mine. The groundwater contours show drawdown in groundwater levels centred on the OB3 (Hera Mine workings) and WB22 (due to groundwater extraction).



Paper Size ISO A4
0 0.5 1 1.5 2 2.5
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

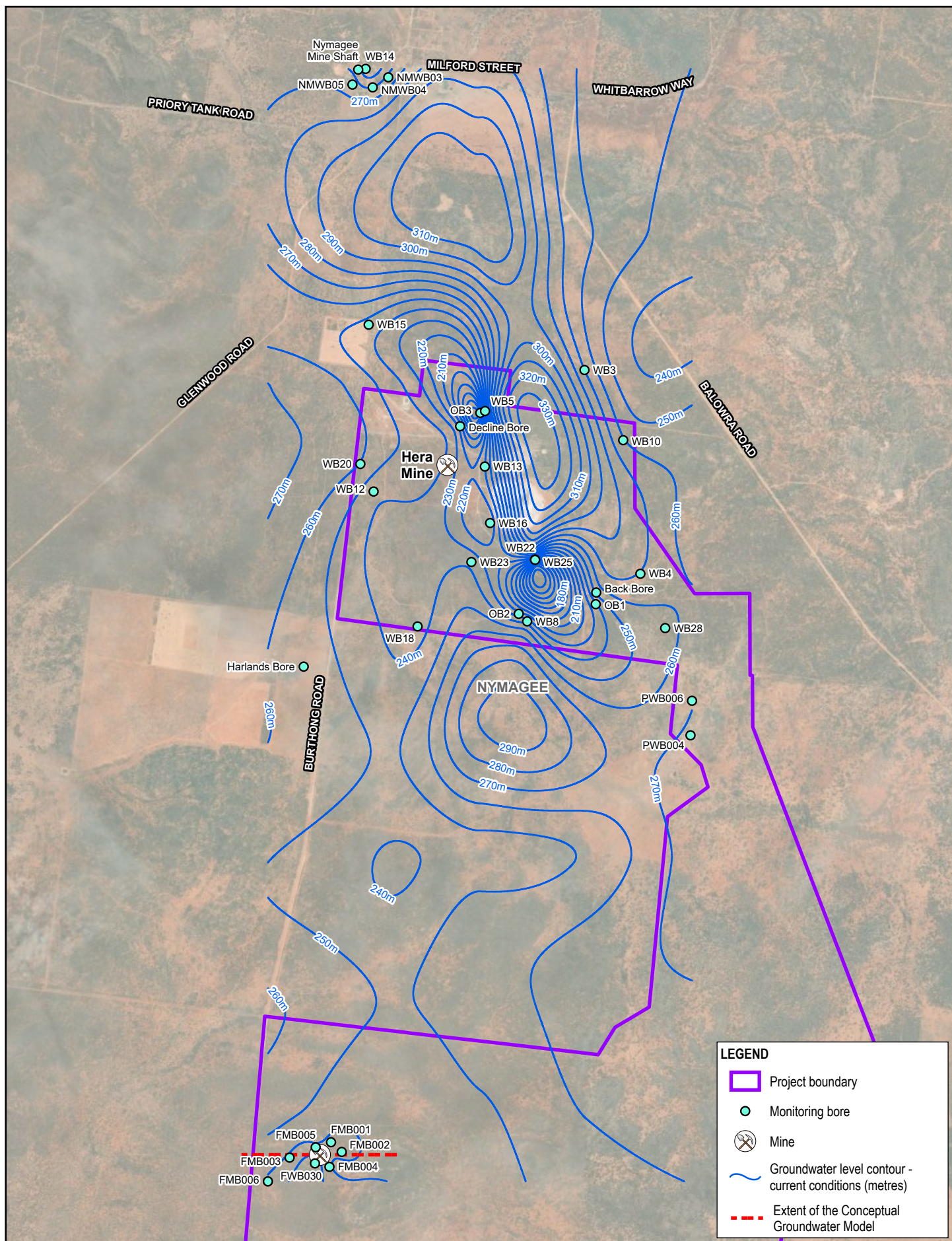


Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

Groundwater level contours
– pre-mining

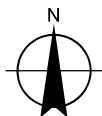
Project No. 12534191
Revision No. 0
Date 08/11/2021

Figure 3-16



Paper Size ISO A4
0 0.5 1 1.5 2
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

**Groundwater level contours
– current conditions**

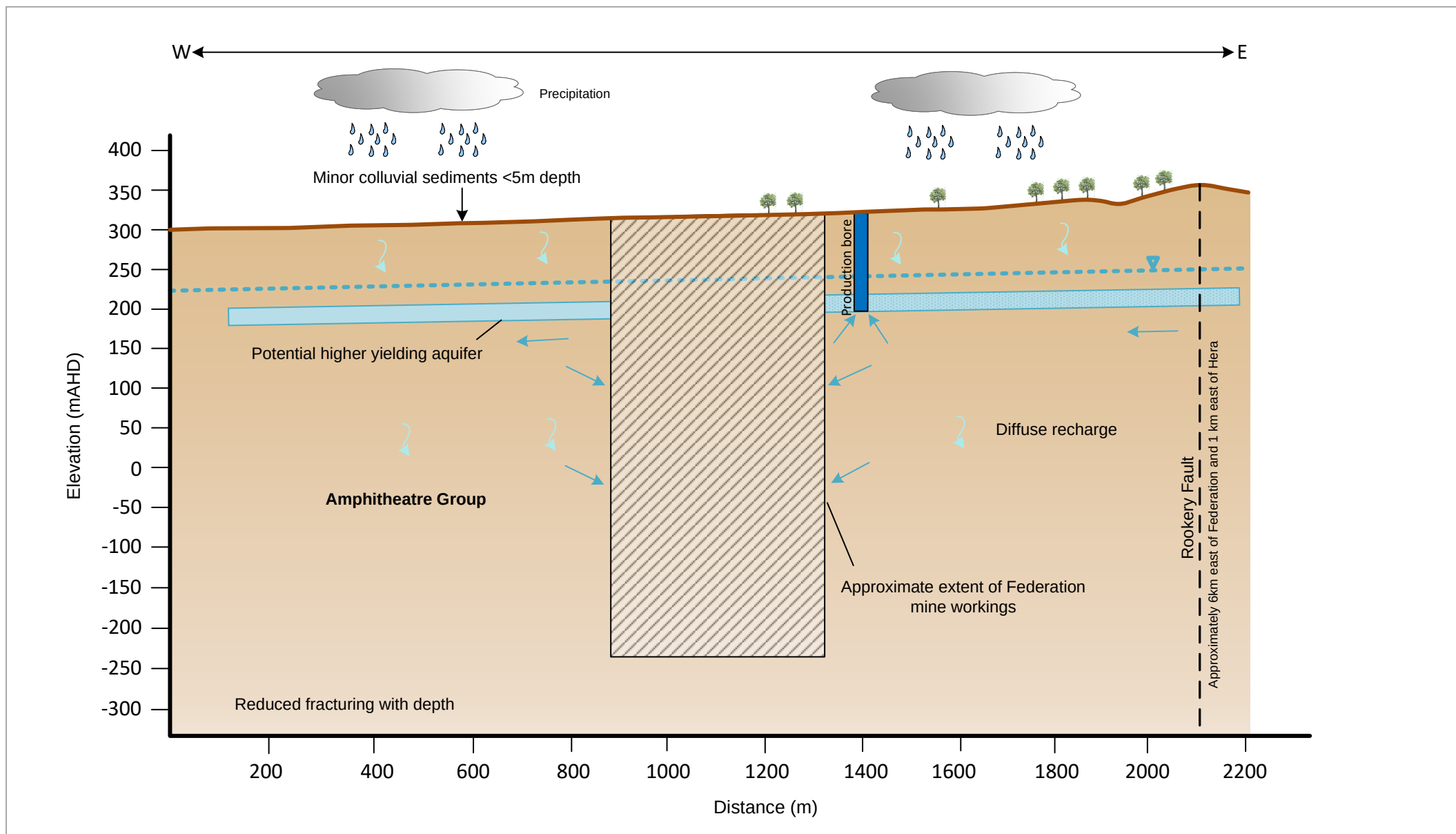
Project No. 12534191
Revision No. 0
Date 08/11/2021

Figure 3-17

3.13 Schematic conceptual model

A conceptual groundwater model has been developed for Federation and is shown in Figure 3.18. The approximate extent of the conceptual groundwater model is shown in Figure 3.17. The conceptual model summarises the information provided in the preceding sections. The conceptual model displays the deep groundwater levels within the Devonian strata at Federation discussed in Section 3.8.1 and the east to west groundwater flow direction indicated by the groundwater monitoring data (Section 3.12). The conceptual model indicates that the highest yielding portion of the aquifer is near the water table. The conceptual model shows that the fracturing of the strata reduces with depth. The reduced fracturing with depth is conceptualised to result in reduced hydraulic conductivity as depth increases.

The conceptual model includes the likely stressors on the groundwater environment attributable to the Project. Mining at Federation and extraction from proposed production bores will depressurise the adjacent strata, inducing changes to groundwater flow in the vicinity of the mining area and the production bores.



Legend

-  Groundwater flow direction
-  Groundwater table
-  Production bore
-  Fault line
-  Recharge



Federation Project
Groundwater Impact Assessment

Conceptual groundwater model

Project No. 12534191
Revision No. 0
Date 08/11/2021

FIGURE 3-18

Created by: Jean Macatanong

4. Groundwater modelling set-up

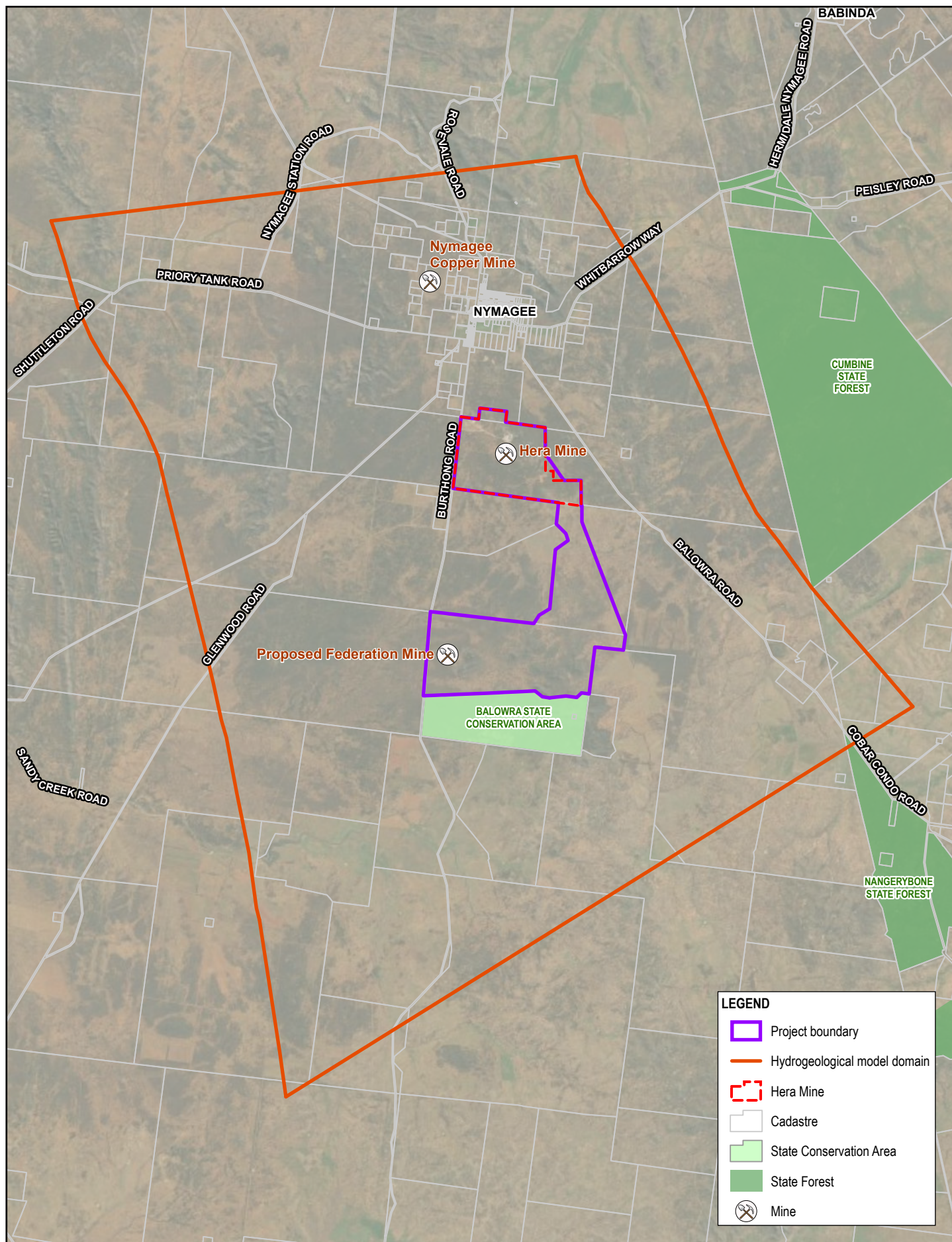
4.1 Overview

Mining at Federation and extraction from proposed production bores will depressurise the adjacent strata, inducing changes to groundwater flow in the vicinity of the mining area and the production bores. Groundwater modelling described in this section has been conducted at a scale commensurate with the scale of the mine and the expected area of influence. In tight rocks of Western NSW, groundwater typically flows along discrete fractures. In regional scale modelling it is not feasible to explicitly simulate discrete fracture flows without adequate supporting data. The generally accepted approach is therefore to represent hydrostratigraphic units as zones of equivalent porous medium (EVP) with spatially averaged hydrogeological properties consistent with the scale of the model.

4.2 Hydrogeological domain

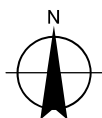
The hydrogeological domain defines the extent of the study area and ultimately the boundary of the numerical groundwater model. It should be large enough to capture key stresses on the groundwater system and their area of influence, both in the context of past and future activities.

Figure 4.1 presents the hydrogeological domain, placing Hera Mine and Federation approximately in the centre. The eastern boundary follows a regional anticline as shown in regional geological mapping (MacRae 1988). The western boundary follows the Woorara Fault as shown in regional geological mapping (MacRae 1988). The eastern and western boundaries are both over 8 km from Hera and Federation and approximately 8 km from the proposed borefield. The northern and southern boundaries are located arbitrarily so as to be at least 10 km from Hera and Federation.



Paper Size ISO A4
0 1.5 3 4.5 6
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

Project No. 12534191
Revision No. 0
Date 08/11/2021

Hydrogeological domain

Figure 4-1

4.3 Software selection

MODFLOW-USG (MF-USG) has been selected as the most appropriate groundwater modelling software for this study. MF-USG is an unstructured grid version of the industry standard MODFLOW code developed and maintained by the United States Geological Survey (Panday et al, 2013). Advantages of MF-USG include flexible meshing for efficient refinement of model cells in the area of interest and robust handling of saturation and desaturation of model cells for tracking the location of the water table. MODFLOW-USG version 1.5.00 was utilised. The MF-USGs model has been prepared using the graphical user interface GMS Version 10.4.

4.4 Model complexity and target confidence level classification

The modelling effort required to meet the study objective is guided by the target confidence level and complexity of the model. Confidence in model predictions depends fundamentally on the availability of data, whether or not sufficient data are available to characterise the groundwater flow processes of interest and whether or not sufficient information is available to inform hydrogeological parameters that have the greatest influence on model predictions. Complexity of the model reflects the level of sophistication of modelling techniques such as the mesh design, degree of parameterisation and choice of boundary conditions. The target model classification for this Project is a medium confidence model. This consideration is guided by the availability of data to support model development and calibration, as well as the intended use of the model to enable prediction of groundwater impacts to support environmental approvals. Further details on the achieved confidence level classification are presented in Section 8.

4.5 Model domain

The MF-USG grid is shown in Figure 4.2. The extent of the model is the same as the hydrogeological domain defined in Section 4.2, where the model boundaries follow hydrogeologically sensible boundaries and are located far enough away from the mine and production bores to minimise boundary-induced effects. The grid is a layered quadtree mesh with the same level of cell refinement in all model layers. The cell size has been refined to 50 m in the area around mine workings, monitoring bores, production bores and landholder bores, and 100 m at faults, the boundary of the paleochannel and the model boundary. The cell size increases to 800 m away from areas of refinement.

The model has 27 layers with 10,998 cells per layer, giving a total of 296,946 cells. It has an area of approximately 904 km².

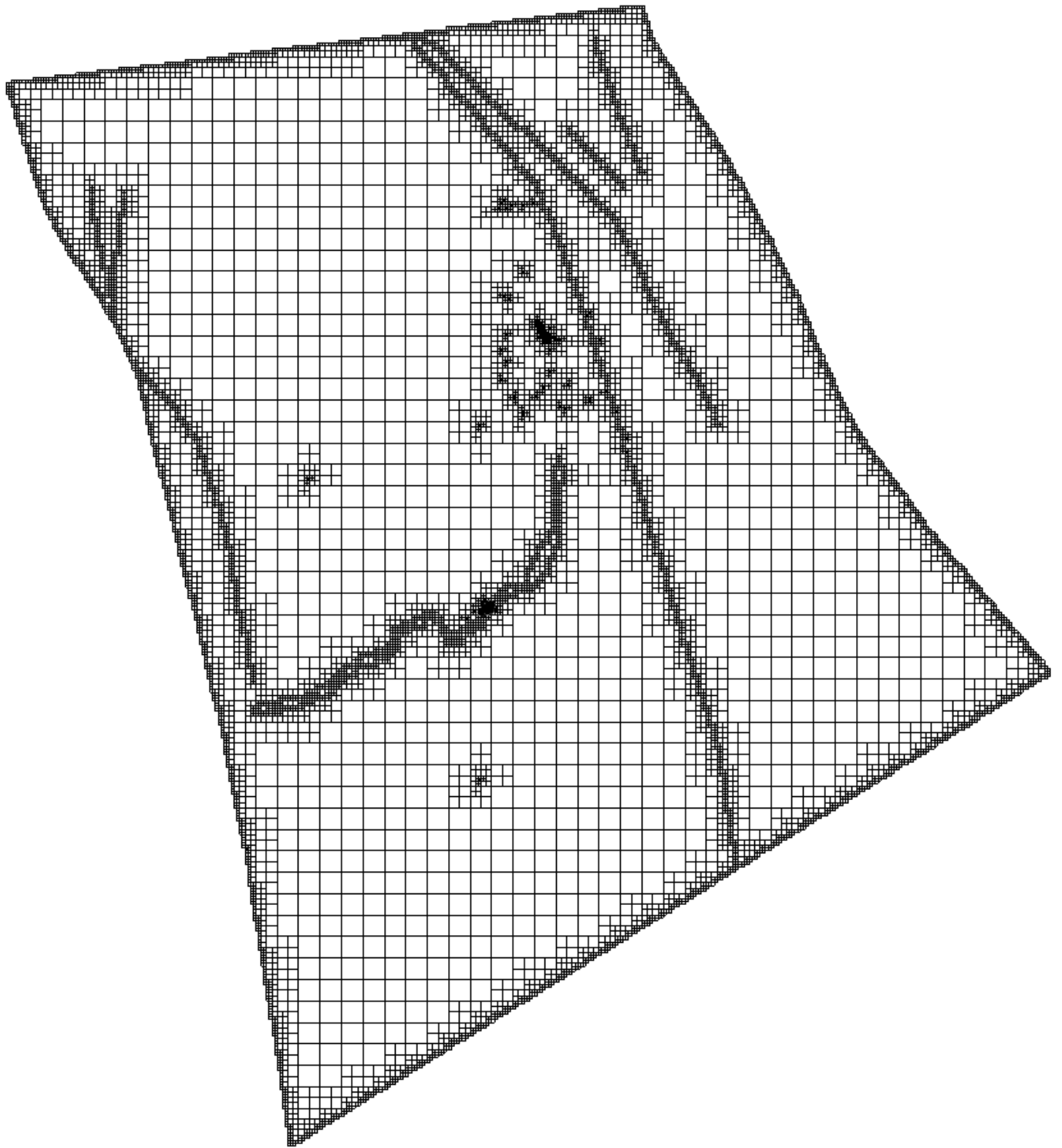


Figure 4.2 *Model domain and mesh*

Thickness of the model layers is presented in Table 4.1. Topographic data were used to assign the model cell elevations for the top of layer 1. Topographic data included LiDAR data provided by Hera Resources. The LiDAR data extended 25 km to the east and west of Hera, 34 km to the south and 10 km north of Hera Mine. To the east, west and south of Hera Mine the LiDAR data extended beyond the model boundary. The very northern portion of the model domain (approximately 50 km²) was not covered by LiDAR data. Topographic contours from Geoscience Australia (FSDF, 2021) were utilised in the area of the model domain where LiDAR was not available.

Geological data collected by Hera Resources is limited to the immediate vicinity of the ore body at Federation and Hera Mine. Where available, geological data have been used to assign thickness of the geological units that define the model layers. Model layer 2 represents the fully weathered zone and model layer 3 represents the partially weathered zone of the bedrock. The thickness of layer 2 and layer 3 are based on the typical depth of the fully weathered zone and the partially weathered zone respectively from exploration drilling data. Model layer 4 to layer 27 represent the unweathered rock. The thickness of model layers 4 to layer 24 have been assigned based on the mine workings at Hera Mine and Federation. Review of the mine plan indicated that there are levels of Hera Mine approximately every 25 m. Therefore, the thickness of layers 4 onwards is generally 25 m.

Table 4.1 *Model layers*

Model layer	Typical layer thickness (m)
1	5
2 (fully weathered)	45
3 (partially weathered)	30
4 (fresh rock – layers 4 to 27)	40
5	50
6	25
7	25
8	25
9	25
10	25
11	25
12	25
13	25
14	25
15	25
16	25
17	25
18	10
19	15
20	25
21	25
22	25
23	33
24	44
25	10
26	13
27	25

4.6 Boundary conditions

Boundary conditions were applied according to the following:

- General head boundaries (GHBs) were applied to the Palaeozoic rocks commensurate with the pre-mining observed head discussed in 3.12 extrapolated to the model boundaries.
- No flow boundary conditions are assumed elsewhere including the northern and southern boundaries, where the boundary is parallel to the expected groundwater flow direction.
- The mine workings at Hera Mine were represented using drain cells.
- Pumping from Hera Resources production bores was represented using the WEL package.

The setup of the boundary conditions is further discussed in the following sections. Pumping from landholder bores is not simulated in the model as there are a limited number of landholder bores in the vicinity of Hera Mine and Federation and potential pumping from these bores is assumed to have negligible effect of model flow budgets.

4.6.1 General head boundaries

GHBs have been applied along the edge of the model domain. Head values have been assigned based on an extrapolation of observed groundwater levels at Federation and Hera Mine. Based on this extrapolation, head value of 302 m AHD was applied to the eastern model boundary and a head value of 183 m AHD was applied to the western model boundary. GHBs were assigned to the eastern and western model boundaries from Layer 4 to Layer 27. GHBs were not assigned to Layer 2 and Layer 3 as this would have resulted in some GHBs being assigned to below the base of some cells.

As discussed in Section 3.7.1 and 3.7.2, all of the monitoring bores at Hera Mine and Federation target the water table and there are no bores deeper than 150 m. Therefore, it is unknown what the vertical hydraulic gradient of the groundwater system may be. In the absence of any information regarding the vertical hydraulic gradient, it was decided to assign head values that were constant from Layer 4 to Layer 27.

Perimeter boundary conditions are displayed in Figure 4.3.

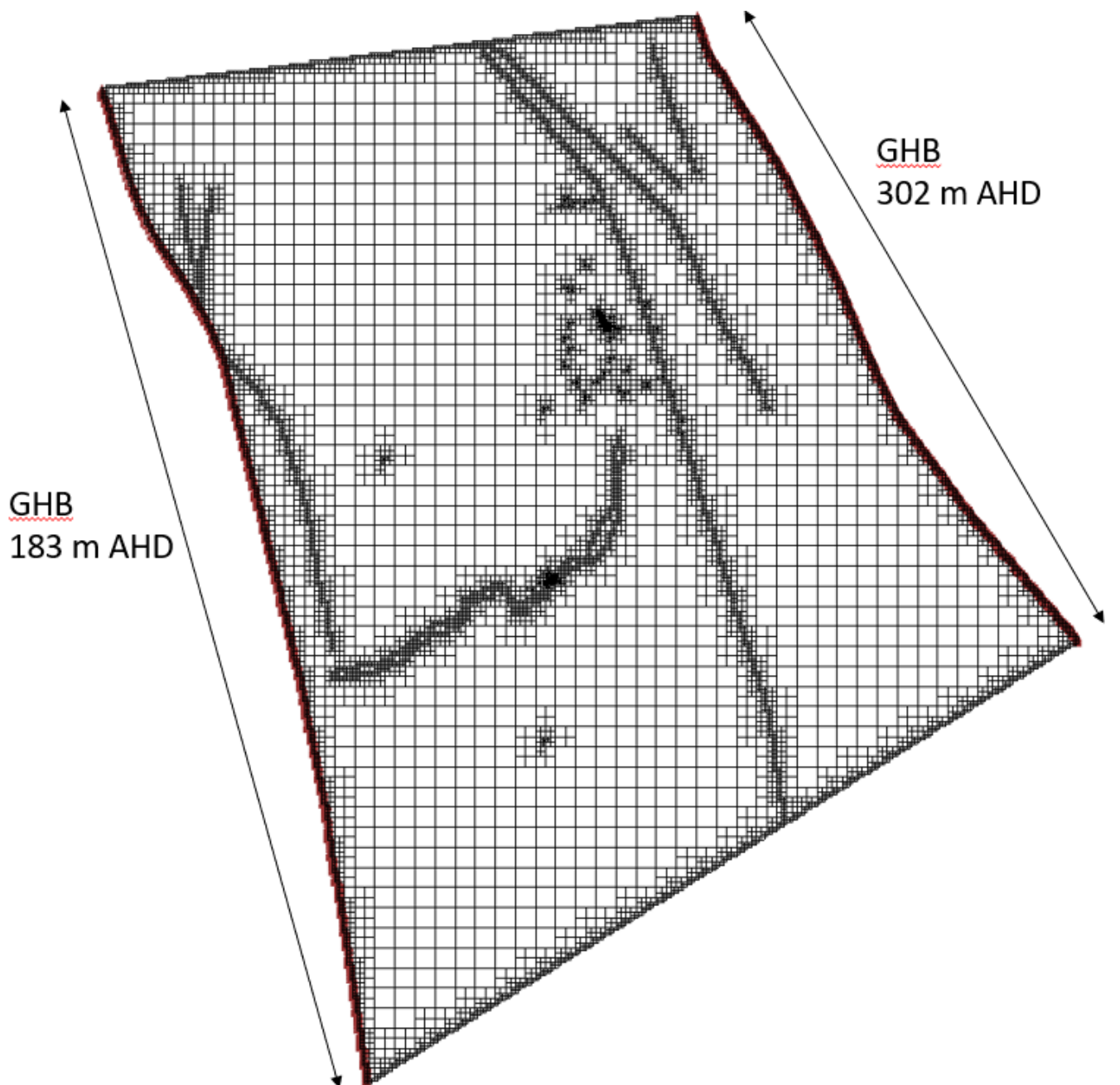


Figure 4.3 General head boundaries

4.6.2 Recharge and evapotranspiration

As discussed in Section 3.11, rainfall recharge in the vicinity of Hera Mine and Federation is very low, therefore rainfall recharge within the model domain was assumed to be zero.

Similarly, as discussed in Section 3.11, the water table within the model domain is very deep, typically greater than 60 m. Therefore, as the water table is so deep and as the root systems will not reach the water table, evapotranspiration within the model domain was assumed to be zero.

4.6.3 Hera Mine

Drain cells were utilised to simulate historical mining at Hera Mine within the calibration model. Drain cells were assigned based on the extent, depth and progression of mining provided by Hera Resources. Drain cells were assigned to Layers 2 to 24. The drain cell elevation was assigned to the floor of each model cell.

Based on the mining schedule provided by Hera Resources, mining commenced in July 2014. Hera Resources provided the development of mining at Hera Mine on an annual basis. Therefore, drain cells were activated on an annual basis to represent the progression of mining at Hera. A drain cell conductance of 0.1 m²/day was adopted.

4.6.4 Production bores

Existing production bores at Hera Mine and Federation have been included in the calibration model using the WEL package. Additionally, the extraction from the Nymagee Mine workings has been simulated using the WEL package.

The pumping rate was determined based on a review of available extraction data, summarised in Section 3.10 and shown in Appendix C. The pumping rate was calculated as the average pumping rate for each stress period. As discussed in Section 3.10 daily extraction data were available from March 2015 onwards at the majority of production bores. From October 2013 to March 2015 there is some available pumping data based on previous reports (Aquade 2015). From October 2013 to March 2015 the reported total groundwater take (Aquade, 2015) was averaged over the reporting period to calculate the average pumping rate.

The pumping rate was assigned to a cell based on the location of the production bore and the elevation of the well screen. All of the existing production bores are located in Layer 4 or Layer 5. The screen elevation for bores WB24 and WB25 was unknown. The screen was assumed to correspond to the base of these bores and therefore the pumping rate for these bores was assigned to Layer 4. The pumping rate at the Nymagee Mine workings was assigned from Layer 3 to 5.

Prior to October 2013, there was no available pumping data. Modelled pumping rate prior to October 2013 at all production bores was assumed to be zero. Review of groundwater levels at production bores indicates that pumping at Back Bore and pumping in the vicinity of WB14 commenced earlier than this.

5. Calibration

5.1 Calibration approach

Model calibration involves changing the values of model parameters within bounds until the model outputs fit historical measurements, such that the model can be accepted as a reasonable representation of the physical system of interest (Barnett *et al.* 2012). The calibration targets are observed groundwater levels (heads) and groundwater drawdown (head change).

The calibration implemented a two-stage process of running the steady state model first, to obtain a sensible set of initial heads, followed by the transient model to simulate temporal variations in groundwater levels. The transient calibration period commences in January 2010. While exploration activities, including groundwater extraction from production bores, started earlier than this date, January 2010 was selected as the start date for the transient calibration period as groundwater monitoring at a number of bores (WB5, WB8, WB10, WB12, WB13, OB1, OB2, OB3 and Decline Bore) started in 2011-2012. Monthly monitoring data were available at the majority of monitoring bores. Therefore, monthly stress periods were adopted throughout the transient calibration period from January 2010 to the end of December 2020, giving a total of 132 stress periods.

5.2 Steady state calibration

5.2.1 Calibration parameters

Steady state calibration has been undertaken using a manual calibration process. The steady state calibration included modifying hydraulic conductivity values and also varying GHB values. These parameters were varied manually to improve the fit between observed and modelled groundwater heads.

As part of steady state calibration parameters were assigned on a layer by layer approach. This approach was considered to be in accordance with the hydrogeological conceptualisation where the hydraulic conductivity of the strata decreases as depth increases.

5.2.2 Calibration targets

The steady state model was intended to represent pre-mining groundwater levels, to obtain a sensible set of starting heads for the transient calibration model. Monitoring bores at Hera Mine, Nymagee Mine and Federation were used in the calibration. Calibration was completed against 18 head measurements. Not all bores at Hera Mine were used in the calculation of steady state calibration statistics. This was because many bores Hera Mine are in the vicinity of mining and groundwater extraction that occurred prior to/concurrent to monitoring commencing.

Bores excluded from the steady state calibration included:

- WB20 excluded due to proximity to historical pumping at House Bore (612 m away).
- OB1 excluded due to proximity to historical pumping at Back Bore (167 m).
- OB3 excluded due to proximity to historical pumping at Skirka's Bore (368 m).
- WB5 excluded due to proximity to historical pumping at Skirka's Bore (438 m).
- Decline Bore excluded due to proximity to historical pumping at Skirka's Bore (93 m).
- WB13 excluded due to proximity to historical pumping at Skirka's Bore (754 m).
- WB26 and WB27 excluded as they were installed in 2020 and are assumed to be impacted by historical mining.
- WB12 excluded due to proximity to House bore and Skirka's bore (980 m and 1510 m respectively).
- OB2 and WB8 excluded due to historical pumping at Back Bore (approximately 1050 m away).

5.2.3 Steady state calibration model parameters

Steady state calibration model parameters are shown in Table 5.1.

Hydraulic conductivity values in the steady state model are generally lower than material properties determined from aquifer testing (Section 3.9). Hydraulic conductivity in Layer 4 and Layer 5 is generally lower than but within one to two orders of magnitude of hydraulic conductivity values determined from aquifer testing. The bores utilised in aquifer testing are installed in Layer 4 or Layer 5 of the model.

Based on the conceptual model, as the depth of the strata increases the hydraulic conductivity decreases. Therefore, it is expected that Layer 6 and below have hydraulic conductivities less than results from aquifer testing. Between Layer 4 and Layer 27 it was assumed that hydraulic conductivity decreased linearly with depth.

Table 5.1 Steady state material properties

Layer	Horizontal hydraulic conductivity (m/day)	Vertical anisotropy (-)
Layer 1	0.1	10
Layer 2	0.1	10
Layer 3	0.1	10
Layer 4	0.01	10
Layer 5	9.13×10^{-3}	10
Layer 6	8.69×10^{-3}	10
Layer 7	8.26×10^{-3}	10
Layer 8	7.82×10^{-3}	10
Layer 9	7.39×10^{-3}	10
Layer 10	6.96×10^{-3}	10
Layer 11	6.52×10^{-3}	10
Layer 12	6.09×10^{-3}	10
Layer 13	5.65×10^{-3}	10
Layer 14	5.21×10^{-3}	10
Layer 15	4.78×10^{-3}	10
Layer 16	4.35×10^{-3}	10
Layer 17	3.91×10^{-3}	10
Layer 18	3.74×10^{-3}	10
Layer 19	3.48×10^{-3}	10
Layer 20	3.04×10^{-3}	10
Layer 21	2.61×10^{-3}	10
Layer 22	2.17×10^{-3}	10
Layer 23	1.60×10^{-3}	10
Layer 24	8.35×10^{-4}	10
Layer 25	6.61×10^{-4}	10
Layer 26	4.35×10^{-4}	10
Layer 27	1.00×10^{-6}	10

5.2.4 Steady state calibration results

Summary of residuals from the steady state model is presented in Table 5.2 and calibration scatterplot is shown in Figure 5.1. The root mean squared (RMS) error is 3.1 m and the scaled RMS (SRMS) is 9.2%.

Table 5.2 *Steady state calibration residual summary*

Bore	Observed head (m AHD)	Modelled head (m AHD)	Residual (m)
FMB001	239.78	241.63	1.85
FMB002	240.07	242.04	1.97
FMB003	239.73	238.43	-1.30
FMB004	240.03	240.80	0.77
FMB005	239.62	240.43	0.81
FMB006	238.86	236.40	-2.46
FWB030	239.81	239.96	0.15
GW017385	256.90	265.64	8.74
Harlands Bore	258.85	254.06	-4.79
NMWB03	263.31	266.41	3.10
NMWB04	262.69	265.56	2.87
NMWB05	265.43	264.64	-0.79
PWB006	273.08	272.13	-0.95
WB10	266.98	273.09	6.11
WB28	273.07	271.88	-1.19
WB3	270.94	272.22	1.28
WB4	272.15	271.29	-0.85
PWB004	272.37	271.62	-0.75

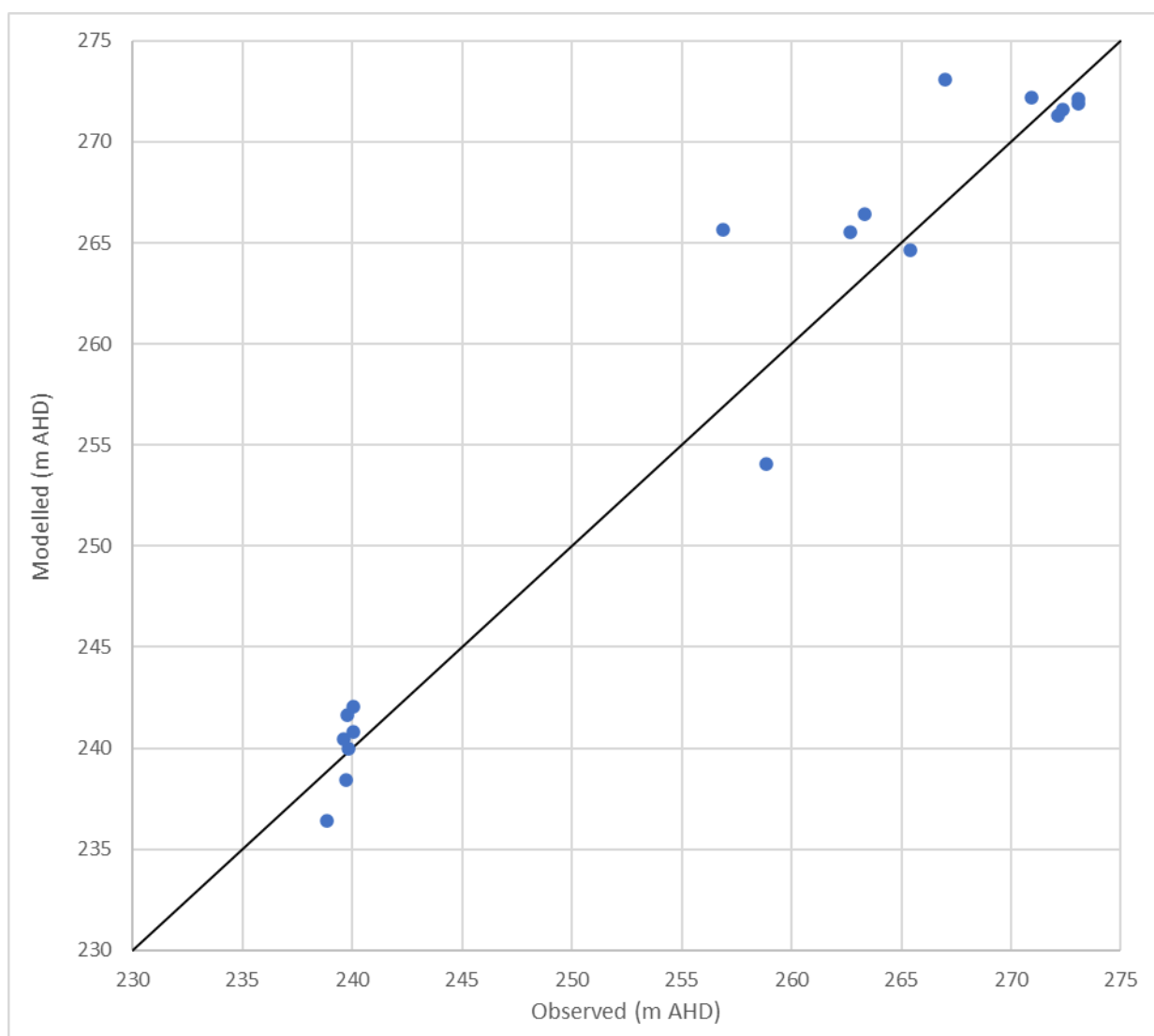


Figure 5.1 Steady state calibration scatterplot

5.2.5 Steady state calibration flow budget

The steady state calibration flow budget is shown in Table 5.3. A cumulative water balance error of 0.11% was recorded for the steady-state model.

Table 5.3 Steady state calibration flow budget

Component	Average flow (m ³ /day)
Inflow	
General head boundaries	77.7
Total	77.7
Outflow	
General head boundaries	77.6
Total	77.6

5.3 Transient calibration

5.3.1 Transient calibration model setup

The transient model was developed to reflect historical operations at Hera Mine. Groundwater monitoring at a number of bores at Hera (WB5, WB8, WB10, WB12, WB13, OB1, OB2, OB3 and Decline Bore) commenced in 2011-2012. The transient calibration model commences January 2010 as there is limited monitoring data prior to this date. Transient calibration runs until the end of 2020 (current conditions). Monthly stress periods were adopted based on the frequency of monitoring data at the majority of groundwater monitoring bores, giving a total of 132 stress periods.

5.3.2 Calibration targets

The model was calibrated against observed groundwater levels (head). Calibration was completed against 2,781 head measurements at 35 bores at Hera Mine, Nymagee Mine and Federation. Calibration targets are summarised in Table E-1 of Appendix E. Calibration locations are shown in Figure 3.11. Note that of the bores shown in Figure 3.11, Skirka's Bore and House Bore were not used in calibration as there were no monitoring data during the transient calibration period. Monitoring bore GW017386 was not used in the calibration as there was no survey data for this bore.

As part of model calibration, consideration was also given to fit between modelled and observed Hera Mine inflows.

5.3.3 Calibration process

Transient calibration was undertaken using manual calibration process. The transient calibration included modifying hydraulic conductivity values, vertical anisotropy, specific yield and specific storage values. These parameters were varied manually to improve the fit between observed and modelled groundwater heads and between observed and modelled inflows into the Hera Mine workings.

As part of model calibration, it was identified that in order to reasonably match mine inflows into the Hera Mine workings, drawdown at bores impacted by mining and Hera Mine production bores, zones of material properties were required to be added to the model. These zones of material properties corresponded to the ore body at Hera Mine, the ore body at Nymagee Mine, the region around a number of production bores at Hera Mine to the south of the Hera Mine workings, a zone around the active production bore at Federation, and the Rookery Fault. Material properties were varied in each of these zones to improve the fit of modelled and observed groundwater levels and Hera Mine groundwater inflows. The locations of these zones of material properties are shown in Appendix D.

Mine inflows into the Hera Mine workings were sensitive to hydraulic conductivity and specific yield. In general, hydraulic conductivity at Hera Mine ore body was required to be lower than the surrounding strata to provide a reasonable fit between modelled and observed mine inflows. The vertical hydraulic conductivity of the strata surrounding the ore body was required to be lowered (via increasing vertical anisotropy) to match observed drawdown due to mining at WB15, WB20 and WB3. Specific storage was lowered at ore body and the strata surrounding the ore body in order to assist in matching modelled and observed mine inflows. A low specific yield was adopted (0.1%) to match modelled and observed groundwater inflows. Vertical hydraulic conductivity had to be higher at the production bores (compared to the strata surrounding the mine). Lowering vertical hydraulic conductivity (via raising anisotropy) at production bores to match the host rock strata resulted in model instability due to drying cells. Therefore, anisotropy at production bores was maintained at 10. Hydraulic conductivity was increased at production bores to match modelled and observed groundwater level drawdown trends at production bores.

5.3.4 Calibration performance

The performance of calibration is often assessed against a predefined value of goodness of fit between observed and computed data, such as the scaled root mean squared (SRMS) error. Other measures of calibration performance are also pertinent, such as low water balance errors, model stability, whether or not the numerical model is behaving in a manner consistent with the conceptual model and representation of key observed hydrological processes, such as water level trends.

Calibrated material properties are shown in Table 5.4. The zones of these materials are shown on a layer by layer basis in Appendix D. As shown in Appendix D, the Rookery Fault is represented by Pumping Zone 1.

Table 5.4 *Calibrated material properties*

Material	Horizontal hydraulic conductivity (K_h) (m/day)	Vertical anisotropy	Specific storage (1/m)	Specific yield (-)
Layer 1 - colluvium	0.1	10	0.00001	0.1
Layer 2 - completely weathered	0.1	10	0.00001	0.1
Layer 3 - partially weathered	0.04 4.0×10^{-2}	50	0.000001	0.1
Layer 3 - Nymagee reduced anisotropy	0.04 4.0×10^{-2}	10	0.000001	0.1
Layer 3 - Pumping Zone 1	0.1	10	0.00001	0.1
Layer 3 - Pumping Zone 2	0.8	10	0.00001	0.1
Layer 3 - Pumping Zone 3	1	10	0.00001	0.1
Layer 3 - Federation pumping zone	3	10	0.00001	0.1
Layer 4	0.004 4.0×10^{-3}	50	0.000001	0.001
Layer 4 - Nymagee reduced anisotropy	0.004 4.0×10^{-3}	10	0.000001	0.001
Layer 4 - Pumping Zone 1	0.01 1.0×10^{-2}	10	0.00001	0.001
Layer 4 - Pumping Zone 2	0.08 8.0×10^{-2}	10	0.00001	0.001
Layer 4 - Pumping Zone 3	0.1	10	0.00001	0.001
Layer 4 - Federation pumping zone	1	10	0.00001	0.001
Layer 5	3.65×10^{-3}	50	0.000001	0.001
Layer 5 - Nymagee reduced anisotropy	3.65×10^{-3}	10	0.000001	0.001
Layer 5 - Pumping Zone 1	9.13×10^{-3}	10	0.00001	0.001
Layer 5 - Pumping Zone 2	7.30×10^{-2}	10	0.00001	0.001
Layer 5 - Pumping Zone 3	9.13×10^{-2}	10	0.00001	0.001
Layer 5 - Federation pumping zone	0.274	10	0.00001	0.001
Layer 6	3.48×10^{-3}	50	0.000001	0.001
Layer 6 - Nymagee reduced anisotropy	3.48×10^{-3}	10	0.000001	0.001
Layer 6 - Pumping Zone 1	8.69×10^{-3}	10	0.00001	0.001
Layer 6 - Pumping Zone 2	6.96×10^{-2}	10	0.00001	0.001
Layer 6 - Pumping Zone 3	8.70×10^{-2}	10	0.00001	0.001
Layer 6 - Federation pumping zone	0.261	10	0.00001	0.001
Layer 7	3.30×10^{-3}	50	0.000001	0.001
Layer 7 - Nymagee reduced anisotropy	3.30×10^{-3}	10	0.000001	0.001
Layer 7 - Pumping Zone 1	8.26×10^{-3}	10	0.00001	0.001
Layer 7 - Pumping Zone 2	6.61×10^{-2}	10	0.00001	0.001
Layer 7 - Pumping Zone 3	8.26×10^{-2}	10	0.00001	0.001
Layer 7 - Federation pumping zone	0.248	10	0.00001	0.001

Material	Horizontal hydraulic conductivity (K_h) (m/day)	Vertical anisotropy	Specific storage (1/m)	Specific yield (-)
Layer 8	3.13×10^{-3}	50	0.000001	0.001
Layer 8 - Nymagee reduced anisotropy	3.13×10^{-3}	10	0.000001	0.001
Layer 8 - Pumping Zone 1	7.83×10^{-3}	10	0.000001	0.001
Layer 8 - Pumping Zone 2	6.26×10^{-2}	10	0.000001	0.001
Layer 8 - Pumping Zone 3	7.83×10^{-2}	10	0.000001	0.001
Layer 8 - Federation pumping zone	0.235	10	0.000001	0.001
Layer 9	2.96×10^{-3}	50	0.000001	0.001
Layer 9 - Nymagee reduced anisotropy	2.96×10^{-3}	10	0.000001	0.001
Layer 9 - Pumping Zone 1	7.39×10^{-3}	10	0.000001	0.001
Layer 9 - Pumping Zone 2	5.91×10^{-2}	10	0.000001	0.001
Layer 9 - Pumping Zone 3	7.39×10^{-2}	10	0.000001	0.001
Layer 9 - Federation pumping zone	0.148	10	0.000001	0.001
Layer 10	2.78×10^{-3}	50	0.000001	0.001
Layer 10 - Nymagee reduced anisotropy	2.78×10^{-3}	10	0.000001	0.001
Layer 10 - Pumping Zone 1	2.32×10^{-4}	10	0.000001	0.001
Layer 10 - Pumping Zone 2	5.56×10^{-2}	10	0.000001	0.001
Layer 10 - Pumping Zone 3	6.96×10^{-2}	10	0.000001	0.001
Layer 10 - Federation pumping zone	0.139	10	0.000001	0.001
Layer 11	5.22×10^{-3}	10	0.000001	0.001
Layer 11 Ore Body	5.43×10^{-5}	10	0.000001	0.001
Layer 12	4.87×10^{-3}	10	0.000001	0.001
Layer 12 Ore Body	5.07×10^{-5}	10	0.000001	0.001
Layer 13	4.52×10^{-3}	10	0.000001	0.001
Layer 13 Ore Body	4.71×10^{-5}	10	0.000001	0.001
Layer 14	4.17×10^{-3}	10	0.000001	0.001
Layer 14 Ore Body	4.34×10^{-5}	10	0.000001	0.001
Layer 15	3.83×10^{-3}	10	0.000001	0.001
Layer 15 Ore Body	3.99×10^{-5}	10	0.000001	0.001
Layer 16	3.48×10^{-3}	10	0.000001	0.001
Layer 16 Ore Body	3.62×10^{-5}	10	0.000001	0.001
Layer 17	3.13×10^{-3}	10	0.000001	0.001
Layer 17 Ore Body	3.26×10^{-5}	10	0.000001	0.001
Layer 18	2.99×10^{-3}	10	0.000001	0.001
Layer 18 Ore Body	3.12×10^{-5}	10	0.000001	0.001
Layer 19	2.78×10^{-3}	10	0.000001	0.001
Layer 19 Ore Body	2.90×10^{-5}	10	0.000001	0.001
Layer 20	2.43×10^{-3}	10	0.000001	0.001
Layer 20 Ore Body	2.54×10^{-5}	10	0.000001	0.001
Layer 21	2.09×10^{-3}	10	0.000001	0.001
Layer 21 Ore Body	2.17×10^{-5}	10	0.000001	0.001
Layer 22	1.74×10^{-3}	10	0.000001	0.001

Material	Horizontal hydraulic conductivity (K_h) (m/day)	Vertical anisotropy	Specific storage (1/m)	Specific yield (-)
Layer 22 Ore Body	1.81×10^{-5}	10	0.000001	0.001
Layer 23	1.28×10^{-3}	10	0.000001	0.001
Layer 23 Ore Body	1.33×10^{-5}	10	0.000001	0.001
Layer 24	6.68×10^{-4}	10	0.000001	0.001
Layer 24 Ore Body	6.96×10^{-6}	10	0.000001	0.001
Layer 25	5.29×10^{-4}	10	0.000001	0.001
Layer 26	3.48×10^{-4}	10	0.000001	0.001
Layer 27	8.0×10^{-7}	10	0.000001	0.001

Comparison of calibrated horizontal hydraulic conductivity values and depth is shown in Figure 5.2. The relationship between hydraulic conductivity and depth developed by Mackie (2009) for NSW coal measures is shown in Figure 5.2, with the upper and lower bounds of the hydraulic conductivity and depth relationship shown in blue. As shown in Figure 5.2, with the exception of one datapoint, the calibrated hydraulic conductivity values lie within the expected range of hydraulic conductivity reported by Mackie.

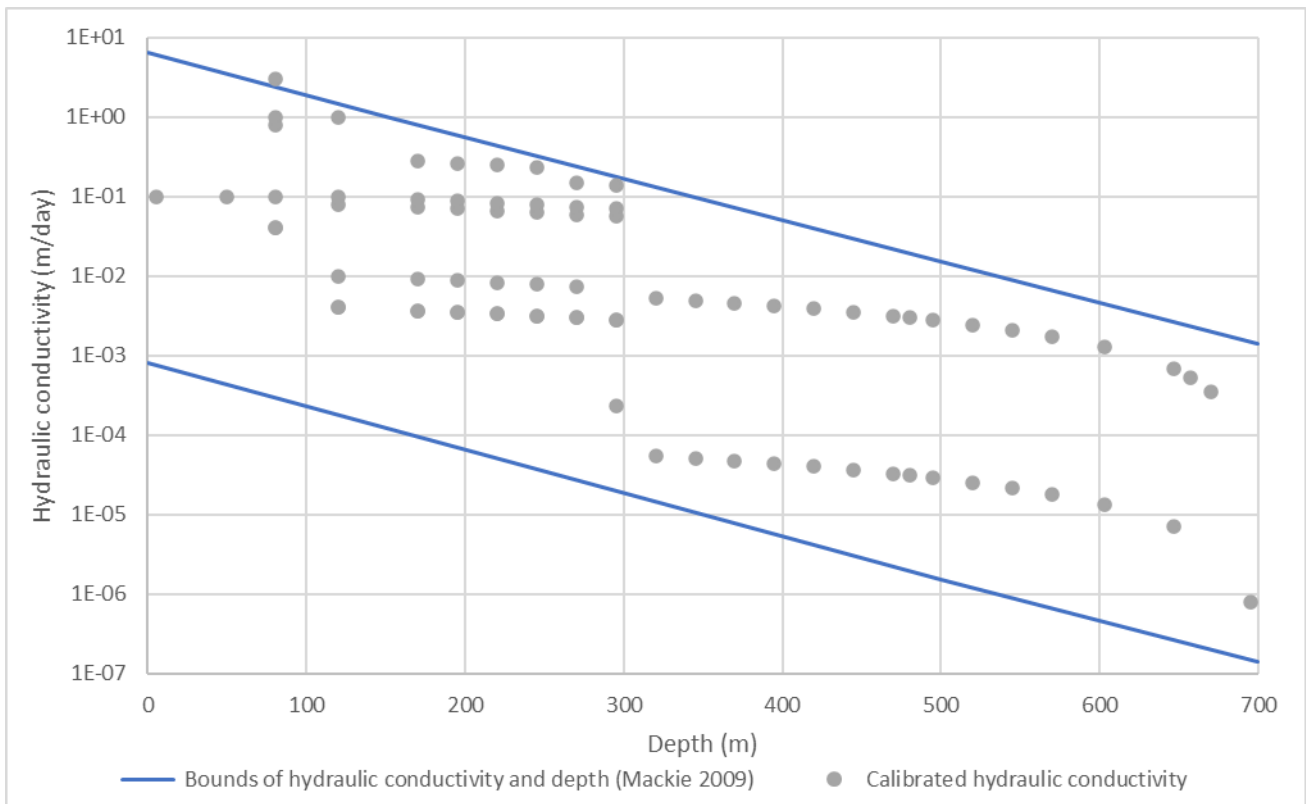


Figure 5.2 Calibrated horizontal hydraulic conductivity values versus depth

Table 5.5 compares calibrated hydraulic conductivity values from Layer 3 to 6 against material properties determined from aquifer testing and previous reporting (Section 3.9). The comparison indicates that calibrated hydraulic conductivity values are generally lower than material properties determined from aquifer testing. Note that the bores utilised in aquifer testing are installed at a depth that corresponds with Layer 4 or 5 of the model. Calibrated horizontal hydraulic conductivity in Layer 3 and Layer 6 is generally within one to two orders of magnitude of hydraulic conductivity values determined from aquifer testing.

Table 5.5 Comparison of calibrated horizontal hydraulic conductivity and aquifer testing results

Testing methodology	Aquifer testing – hydraulic conductivity (m/day)		Modelled hydraulic conductivity (m/day)	
	Minimum	Maximum	Minimum	Maximum
Pumping test	0.038	1.1	0.0035 ¹	0.04 ²

Notes:

1. Modelled hydraulic conductivity for Layer 6

2. Modelled hydraulic conductivity for Layer 4

5.3.4.1 Comparison of observed and calibrated hydrographs

Observed and modelled hydrographs are shown in Appendix E. Model calibration has provided replication of both drawdown due to pumping from extraction bores and drawdown from mining at Hera Mine.

There are a number of bores where the data available for set-up of the model has resulted in discrepancies between modelled and observed groundwater levels.

The mine plan for historical mining at Hera Mine was provided on an annual basis. Based on the mine plan provided by Hera Resources, mining commenced in July 2014. Therefore, initial drain cells simulating mining at Hera Mine in the transient calibration model were activated in July 2014. However review of drawdown hydrographs at bores surrounding Hera Mine displays drawdown earlier than July 2014 indicating that drawdown commenced earlier than this which resulted in a lag between modelled and observed drawdown at monitoring bores OB3, Decline Bore, WB13 and WB5.

As discussed in Section 3.10, accurate metering of groundwater extraction commenced in March 2015, however extraction from the production bores at the site commenced earlier than this. There are a number of bores where the modelled replication of observed trends due to groundwater extraction is limited by the available extraction bore data. Bores where the fit between observed and modelled groundwater levels is impacted by the available groundwater extraction data include Back Bore, OB1, OB2, WB14, PWB004 and PWB006.

At Back Bore and WB8 and adjacent monitoring bores OB1 and OB2, there are pumping data from the period October 2013 to June 2015 based on previous reports (Section 3.10) (Aquade, 2015). The total groundwater extracted over this reporting period has been averaged to calculate the daily pumping rate. While this has resulted in the modelled hydrographs displaying some drawdown over this period, the model is not replicating the dynamic responses in groundwater levels at these bores from periodic pumping from October 2013 to June 2015.

5.3.4.2 Transient calibration scatter plot

Figure 5.3 presents a scatter plot of observed and computed heads. Excluding Decline Bore, OB3, WB13 and WB5 from the calibration (due to discrepancies between modelled and observed drawdown due to assignment of drain cells); and excluding monitoring data prior to March 2015 from Back Bore, WB8, OB1 and OB2 (due to lack of accurate pumping data) results in an RMS equal to 9.8 m and a scaled RMS of 9.6%. Data excluded from the calculation of calibration statistics is shown in Figure 5.3 in grey. Figure 5.3 also provides a split based on monitoring bore location (Hera Mine, Nymagee Mine or Federation).

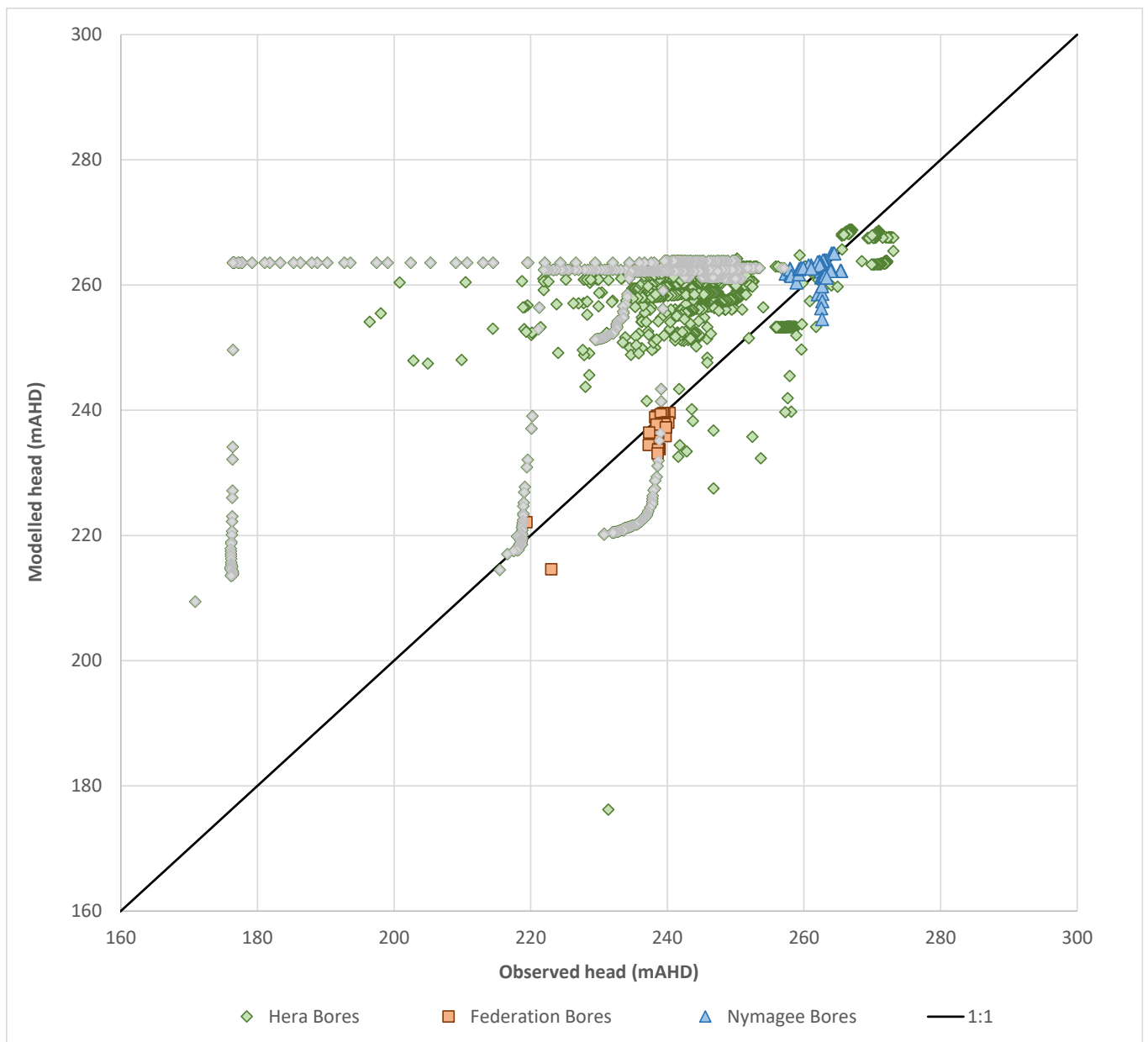


Figure 5.3 Calibration scatter plot

As shown in Figure 5.3, there is a good fit between modelled and observed groundwater levels at Federation and Nymagee Mine, however the model is generally overestimating levels at Hera Mine. The overestimation of levels at Hera in the model may partially be due to the model not including pumping from production bores prior to October 2013, discussed in Section 4.6.4.

Calibration hydrographs, residual summary and spatial plot of average residual are presented in Appendix E.

The match between modelled and observed trends during the transient calibration period is considered reasonable considering the data limitations regarding groundwater extraction and the granularity of the mining progression, which was based on an annual progression compared to monthly stress periods.

5.3.4.3 Transient calibration Hera Mine inflows

Modelled and observed mine inflows into the Hera Mine workings are shown in Figure 5.4. Modelled mine inflows are generally similar to observed mine inflows for the majority of the period over which mine inflow data are available. There is a peak in observed mine inflows from October 2017 to March 2018 which is not replicated by the model. As discussed in Section 3.8.3, this spike in groundwater inflows occurred when the Hera Mine workings extended to approximately 550 m bgl, however, the water was observed to be predominately flowing from several drill holes that had originated from the surface and intersected the decline. The groundwater model does not simulate these drill holes and is therefore underestimating mine inflows over this period.

As shown in Figure 5.4, observed mine inflows have been decreasing since October 2019. However, the model is not replicating this decrease in mine inflows. Therefore, the groundwater model is considered to be conservatively estimating current inflows into the Hera mine workings.

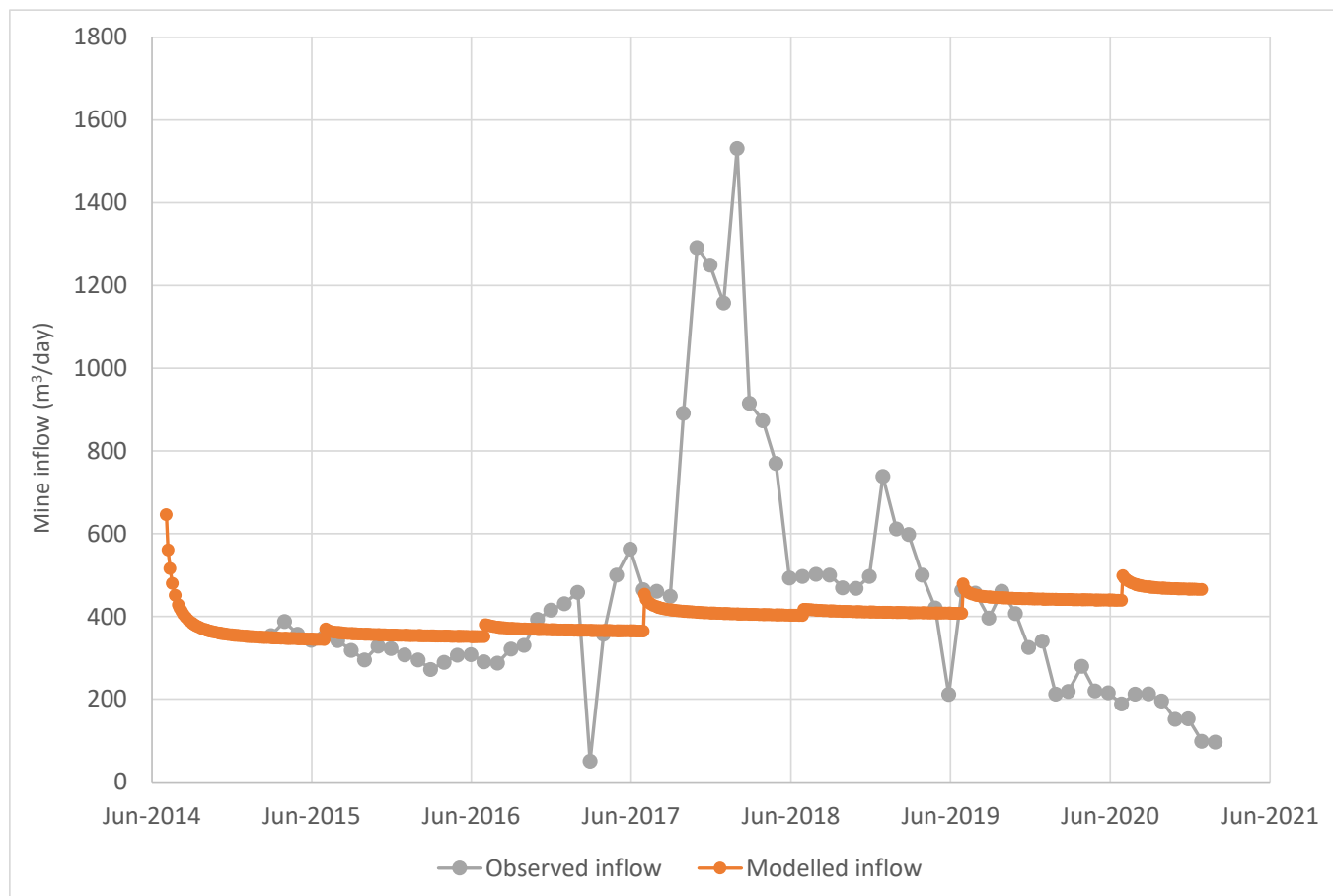


Figure 5.4 Modelled and observed Hera Mine inflows

5.4 Calibration phase flow budget

Table 5.6 presents the flow budget for the transient calibration model. A cumulative water balance error of less than 0.01% was recorded for the transient model, well below the target of 1%. The flow budget presented is averaged for all time steps.

Table 5.6 Transient calibration model flow budget

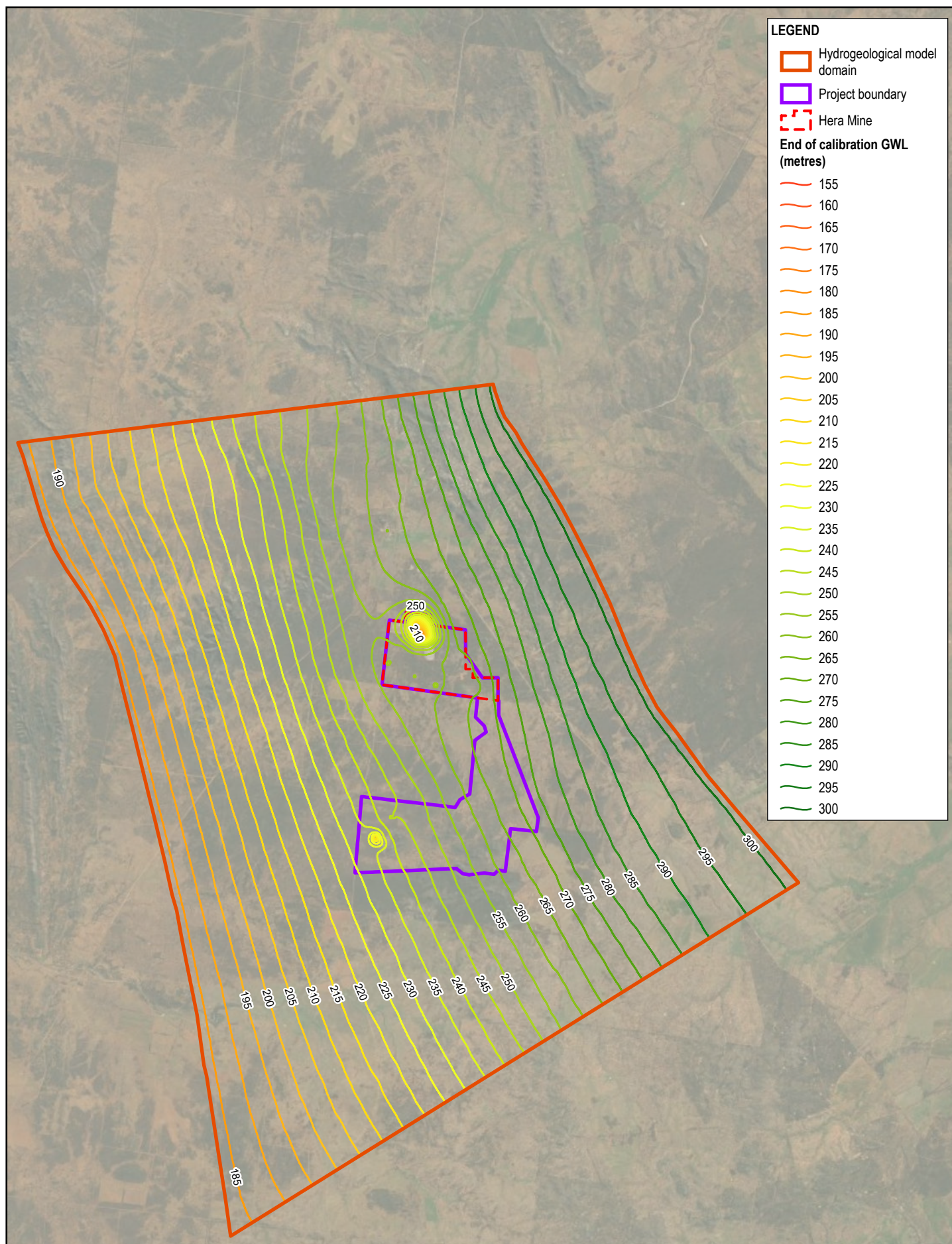
Component	Average flow (m ³ /d)
Inflow	
Storage	486.49 (59.6%)
General Head Boundaries	330.23 (40.4%)
Total	816.72
Outflow	
Storage	25.15 (3.1%)
Wells	214.23 (26.2%)
Drains	246.49 (30.2%)
General Head Boundaries	330.40 (40.5%)
Total	816.72

On the basis on the calibration results, the model has been considered suitably calibrated. The model is providing a good replication of groundwater level and mine inflow trends at Hera Mine. Therefore, on the basis that the geological environment at Federation is similar to Hera, the model is considered to be able to provide a good prediction of impacts from mining at Federation.

5.5 Modelled groundwater contours

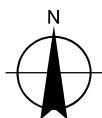
Modelled groundwater contours for the water table from the end of the calibration period (January 2021) are presented in Figure 5.5.

The modelled drawdown contours display the impact of mining at Hera Mine and drawdown at the Hera production bores.



Paper Size ISO A4
0 1.5 3 4.5 6
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

Water table at end of
transient calibration

Project No. 12534191
Revision No. 0
Date 08/11/2021

Figure 5-5

6. Predictive model set-up

6.1 Overview

The purpose of predictive modelling is to predict future groundwater conditions on and surrounding the Project, including inflow rates into the mine, the magnitude and extent of drawdown of piezometric heads, change in groundwater flow conditions and conditions that may impact identified receptors. The prediction model uses the calibrated material parameters and model set-up discussed in Section 4.6 and 5.3 with updates to drain cells and extraction bores to simulate proposed mining and production bores. Additionally, in the post closure phase model changes were made to material properties to represent the backfilled mine workings and void.

Predictive models were established to represent the operational and post-closure phases of the mine as described below:

- **Operational phase model:** the operational phase model has a duration of 15 years. The operational phase model runs from current conditions (January 2021) to the end of mining at Federation. The operational phase model adopts quarterly stress periods which is in accordance with the mine plan provided by Hera Resources with a quarterly progression. The operational phase model simulates proposed mining at Federation, proposed mining at Hera and proposed production bores.
- **Post-closure phase model:** the post-closure model has a duration of 1,000 years. The model includes seventeen stress periods to simulate post-mining conditions. The first five post-closure stress periods are 20 years long, followed by six 50 year stress periods, followed by six 100 year stress periods. The length of the post-closure mining simulation was selected to provide a long-term representation of post-closure conditions.

Initial heads for each successive model were sourced from the final heads of the preceding model.

Further details regarding the set-up of the operational phase model and the post-closure phase model are provided in Section 6.2.1 and Section 6.2.2 respectively.

6.2 Set-up

6.2.1 Operational phase model

Mining at Federation was simulated by progressively assigning drain cells from model layer 2 to model layer 23 in line with the quarterly mine progression provided by Hera Resources. The commencement of the Exploration Decline Program at Federation is simulated to commence in January 2022, with mining commencement following expected approval in early 2023.

Similarly, continued mining at Hera Mine was simulated utilising drain cells. Drain cells from the transient calibration model remained active. Additional mining was simulated by assigning drain cells based on the annual mine progression provided by Hera Resources. Mining at Hera Mine is modelled to be completed in July 2023. Drain cells remained active throughout the operational phase model.

Proposed production bores were simulated using the WEL package. Proposed production bore details are shown in Table 6.1 and locations are shown in Figure 6.1. The location of the majority of proposed production bores corresponds with the Rookery Fault. Details of production bore pumping rates and modelled dates of operation are shown in Table 6.1. It was assumed that the extraction rate of the proposed bores would be equal to the existing production bore at Federation (FWB030). The timing of water production from bores was developed by GHD (2021b) using a water balance approach. The water balance assumed that bores would be active for approximately 4 years, based on a review of the operational life of existing production bores at Hera Mine (Section 3.10). The water balance determined the required number and timing of proposed production bores to supply the required water demand at over the life of mining at Federation.

All proposed production bores were located in Layer 5 of the model.

Table 6.1 *Proposed production bores*

Bore	Easting	Northing	Modelled operational period	Pumping rate (L/s)
PWB004	439402.0	6442866.0	Apr 2021 – Oct 2025	1.5
PWB006	439423.0	6443350.0	Apr 2021 – Oct 2025	1.5
FWB040	439693.0	6442335.0	Apr 2025 – Jul 2029	1.5
FWB041	439726.0	6441730.0	Apr 2025 – Jul 2029	1.5
FWB042	440017.0	6441194.0	Oct 2025 – Jan 2030	1.5
FWB043	440070.0	6440579.0	Oct 2025 – Jan 2030	1.5
FWB044	440351.0	6440043.0	Oct 2025 – Jan 2030	1.5
FWB045	440428.0	6439440.0	Jan 2029 – Jul 2033	1.5
FWB046	440698.0	6438889.0	Jan 2029 – Jul 2033	1.5
FWB047	440850.0	6438361.0	Jul 2029 – Jan 2034	1.5
FWB048	440950.0	6437861.0	Jan 2030 – Jul 2035	1.5
FWB049	441079.0	6437367.0	N/A	N/A
FWB050	435832.0	6438568.0	Jul 2031 – Oct 2035	1.5
FWB051	434966.0	6437922.0	Jan 2033 – Jan 2036	1.5
FWB052	433934.0	6435691.0	N/A	N/A
FWB053	440345.0	6435773.0	Oct 2033 – Jan 2036	1.5
FWB054	438696.0	6438447.0	Oct 2033 – Jan 2036	1.5

N/A denotes extraction from the bore not modelled

6.2.2 Post-closure phase model

Following the completion of mining at Federation, dewatering of the Federation workings and the Hera Mine workings will cease. The Federation and Hera Mine workings will also be backfilled with tailings paste and / or waste rock. Therefore, as part of the post-closure phase model, the drain cells at Federation and Hera Mine were deactivated and the material properties of the Federation and Hera Mine workings were updated to represent the backfill.

Backfill parameters for Federation and Hera Mine were selected with reference to values adopted for tailings at Tomingley Gold Operations (DE Cooper and Associates, 2011). Backfilled material properties adopted in the post-closure model are summarised in Table 6.2.

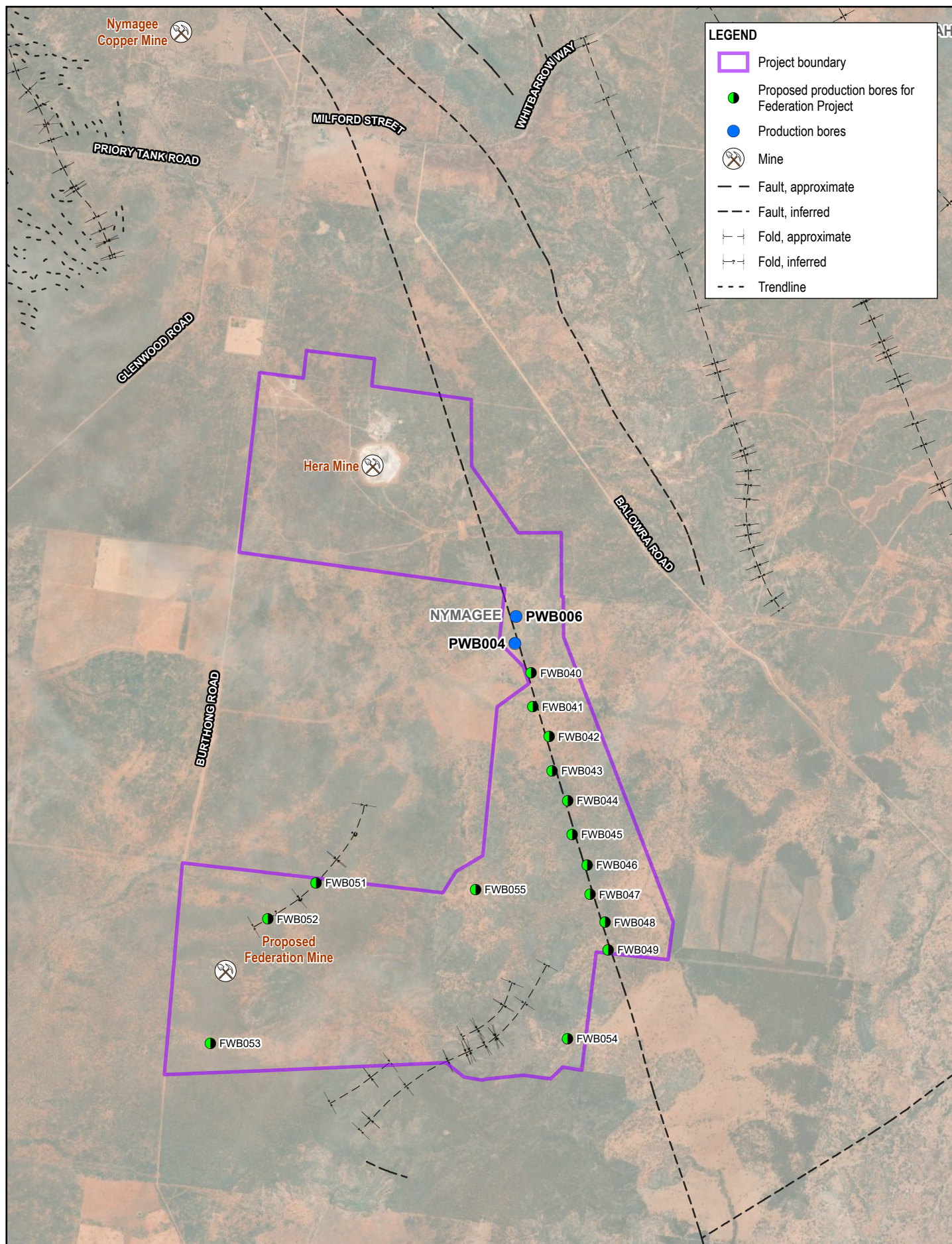
Table 6.2 *Material parameters for the predictive phase of modelling*

Hydrostratigraphic unit	Hydraulic conductivity (m/d)	Vertical anisotropy	Specific Yield (-)	Specific Storage (m ⁻¹)
Backfill	0.0000001	5	0.2	0.00001

The initial heads for the post-closure phase model were based on the piezometric heads computed at the end of the operational phase model.

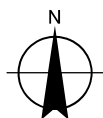
6.3 Model performance

Water balance errors for all stress periods and time steps are all less than 0.1% and deemed acceptable.



Paper Size ISO A4
0 0.5 1 1.5 2 2.5 3
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

Project No. 12534191
Revision No. 0
Date 08/11/2021

Proposed production bores

Figure 6-1

7. Model predictive results and impact assessment

7.1 Impact assessment scenarios

As part of impact assessment, the following scenarios were assessed:

- Approved predictive model – the operational phase model includes life of mining at Hera Mine and Hera production bores (PWB004 and PWB006), followed by a post mining model for approved conditions. Note under approved conditions, the post closure model starts in 2023 when mining at Hera is complete.
- Proposed predictive model – includes life of mining at Hera Mine and Hera production bores, approved exploration decline activities at Federation, proposed mining at Federation, continued dewatering of Hera workings throughout mining at Federation and proposed Federation production bores; followed by a post mining model for proposed conditions. Note under proposed conditions, the post closure model starts in 2036 when mining at Hera is complete.

Impact estimates for the approved and proposed predictive model were based on the difference between the modelled heads and pre-mining heads. Incremental impacts (impacts attributable to Federation) were calculated as the difference between the approved predictive model and the proposed predictive model.

Impact assessment did not require a null (no mining or groundwater extraction) model run as the model does not include natural processes that would result in variation of groundwater levels including rainfall recharge, evapotranspiration or stream flow.

As there are no other proposed mining operations within the model domain, and extraction from landholder bores are assumed to be negligible, the proposed scenario describe above is equivalent to a cumulative impact scenario.

7.2 Impact assessment criteria

The potential impacts have been assessed in accordance with the NSW AIP. The AIP requires that potential impacts on groundwater sources, including their users and GDEs, be assessed against minimal impact considerations, outlined in Table 1 of the policy. If the predicted impacts meet the Level 1 minimal impact considerations, then these impacts will be considered as acceptable.

Based on the hydrogeological environment at the Federation discussed in Section 3.9 and Section 3.8.2, groundwater yield is generally less than 2 L/s and groundwater salinity between 2,000 mg/L and 10,000 mg/L. Level 1 minimal impact considerations for Less Productive Fractured Rock Water Sources have been adopted for the groundwater impact assessment and are defined as follows:

- Water table:
 - Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, at a distance of 40 m from any high priority GDE or high priority culturally significant site listed in the schedule of the relevant WSP. A maximum of a 2 m water table decline cumulatively at any water supply work.
 - If more than 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any high priority GDE; or high priority culturally significant site; listed in the schedule of the relevant WSP then appropriate studies (including the hydrogeology, ecological condition and cultural function) will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2 m decline cumulatively at any water supply work then make good provisions should apply.
- Water pressure:
 - A cumulative pressure head decline of not more than a 2 m decline at any water supply work.
 - If the predicted pressure head decline is greater than the requirement above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.

- Water quality:
 - Any change in groundwater quality should not lower the beneficial use category of the groundwater source, beyond 40 m from the activity.
 - If the above condition is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply work.

7.3 Flow budget and predictive model flow terms

The key aspects of the flow budget for the operational and post-closure models have been summarised in Table 7.1 according to year.

Table 7.1 Predictive model flow budget

Flow term	Year						
	2021	2022	2028	2035	2046	2136	3036
Approved conditions							
Inflow							
Storage	803.6	792.4	123.9	62.6	39.8	11.4	1.1
External boundary inflow	331.1	331.5	333.7	331.1	330.6	330.5	330.8
Total	1134.8	1123.8	457.6	393.7	370.4	341.9	331.9
Outflow							
Storage	128.2	49.2	126.4	63.5	40.2	11.7	1.8
External boundary outflow	330.4	330.4	331.3	330.3	330.2	330.2	330.1
Mine inflow – Hera	480.9	485.0	0	0	0	0	0
Mine inflow – Federation	0.0	0.0	0	0	0	0	0
Wells	195.3	259.2	0	0	0	0	0
Total	1134.8	1123.8	457.6	393.7	370.4	341.9	331.9
Proposed conditions							
Inflow							
Storage	803.6	904.1	1480.2	1531.2	276.5	32.9	1.8
External boundary inflow	331.1	331.5	334.8	335.9	334.0	331.5	332.4
Total	1134.8	1235.6	1814.9	1867.1	610.5	364.4	334.2
Outflow							
Storage	128.2	46.9	19.3	221.8	286.1	41.1	5.7
External boundary outflow	330.4	330.4	331.1	328.5	324.4	323.2	328.5
Mine inflow – Hera	480.9	485.0	476.4	471.0	0	0	0
Mine inflow – Federation	0.0	114.1	338.3	295.8	0	0	0
Wells	195.3	259.2	649.8	550.0	0	0	0
Total	1134.8	1235.6	1814.9	1867.1	610.5	364.4	334.2

Table notes:

2021 relates to current conditions. 2022 is first year of approved Exploration Decline Program activities at Federation, with mining commencing following approval in early 2023. 2028 is the year of modelled maximum mine inflow to Federation, 2035 the last year of mining. 2046, 2136 and 3036 relate to 10, 100 and 1000 years post-closure.

Units are in m³/d

The flow budget indicates the following:

- During the period of mining under both approved and proposed conditions, outflow is dominated by mining at Hera Mine, Federation and extraction from production bores. During mining, outflow from mining and production bores varies from approximately 60% to 65% of outflows under approved conditions; and varies from approximately 60% to 80% of outflows under proposed conditions.
- The most notable impacts on the modelled water budget due to mining are associated with changes in storage.

7.4 Predicted effect on piezometric heads

Contours of the maximum predicted drawdown¹ of the water table for approved and proposed conditions are presented in Figure 7.1 and Figure 7.2 respectively. Incremental drawdown (the difference between proposed and approved drawdown) is presented in Figure 7.3. Therefore, Figure 7.3 displays the modelled impact associated with the Project only. The maximum drawdown plots are composite plots displaying the maximum drawdown over the full duration of model predictions including the calibration period, operational phase and post-closure phase.

Under approved conditions (Figure 7.1), the largest drawdown is predicted at Hera Mine, with steep hydraulic gradients along the edge of the mine, due to the low horizontal hydraulic conductivity of the strata. Drawdown is also centred around the Nymagee Mine workings and at Federation, due to groundwater extraction from the Nymagee Mine workings and production bore FWB030 during the transient calibration period. Drawdown is also centred around bores PWB004 and PWB006 due to extraction from these bores. Under approved conditions, the 1 m drawdown contour extends approximately 4.5 km from Hera Mine.

Under proposed conditions (Figure 7.2), the largest drawdown (composite) is predicted at Hera Mine, Federation and at proposed production bores. Similar to approved conditions, there are steep gradients around the edge of the Hera Mine and Federation workings, due to the low horizontal hydraulic conductivity of the strata. Comparison of modelled drawdown in Figure 7.1 and Figure 7.2 indicates maximum drawdown at the Hera Mine workings is larger under proposed conditions due to the continued dewatering of the Hera Mine workings after the completion of mining. Similarly, the radius of drawdown around the Hera Mine workings is larger, with the 1 m drawdown contour extending up to 6.2 km from Hera Mine. However, as shown in Figure 7.3, the magnitude of incremental drawdown (drawdown under proposed conditions minus drawdown under approved conditions) is less than 1 m at Hera Mine. This indicates while drawdown at Hera Mine is greater under proposed conditions, the magnitude of the additional drawdown is less than 1 m.

Under proposed conditions, the 1 m drawdown contour extends up to 8 km to the west of the Federation Mine workings. Under proposed conditions, the 1 m drawdown contour extends up to 10.5 km to the east of the Federation Mine workings. However, to the east of Federation the drawdown is partially attributable to the proposed production bores.

Under proposed conditions it is predicted that drawdown will extend into the Balowra State Conservation Area to the south of Federation (Figure 1.1). As the deep water levels (45 m to 90 m bgl) in the Palaeozoic sediments are beyond the reasonable limit of tree rooting depths, the Balowra State Conservation Area is not considered to be a GDE. Therefore, the modelled drawdown is not predicted to impact on any GDEs.

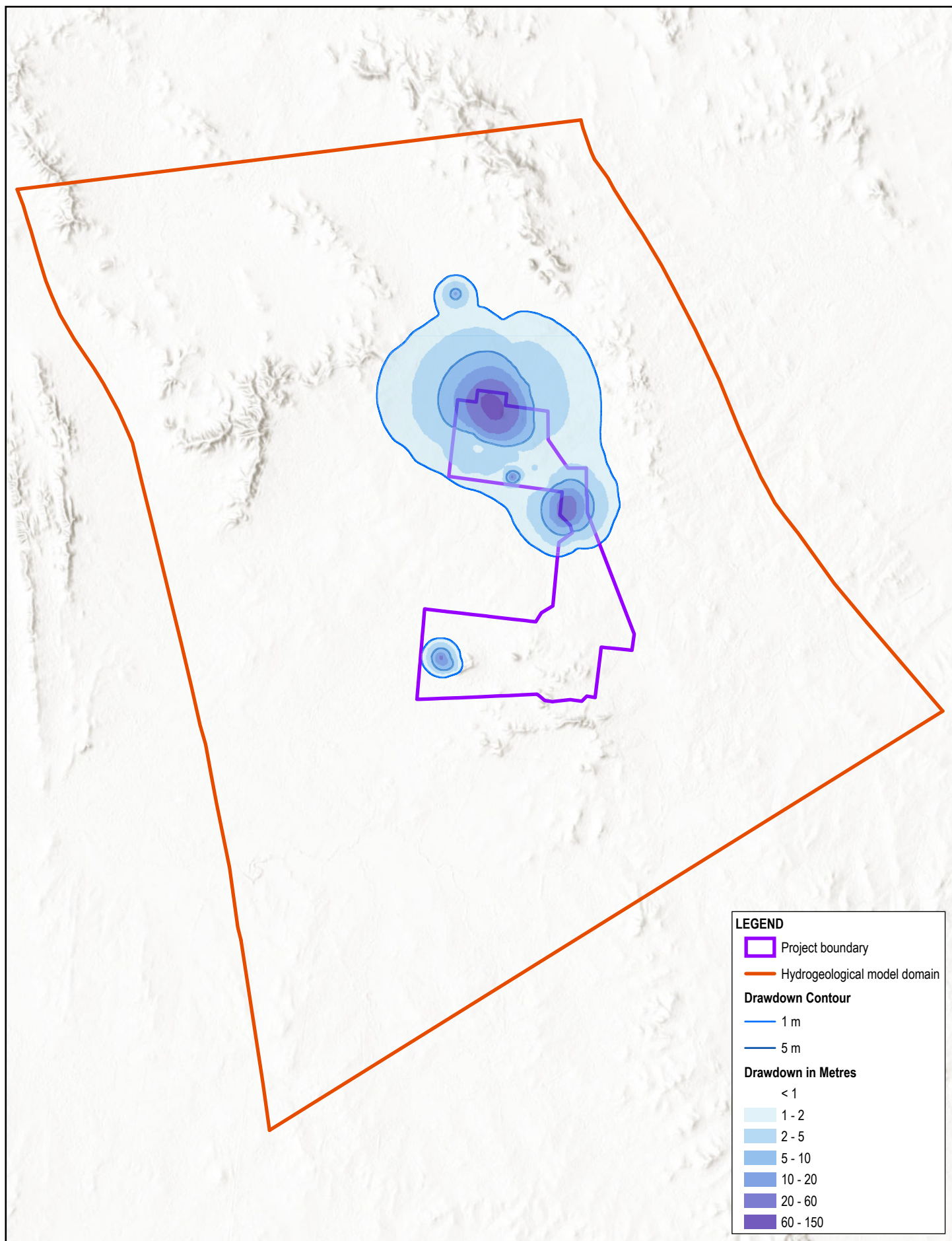
Under proposed conditions, drawdown extends to the model boundary. This is considered due to the low storage and hydraulic conductivity of the strata. Modelled drawdown at the end of proposed mining at Federation is shown in Figure 7.4. As shown in Figure 7.4, drawdown at the end of proposed mining has not extended to the model boundaries. Therefore, drawdown at the model boundaries occurs after the end of proposed mining. Drawdown at the model boundary is low (less than 2 m), and consequently it is unlikely that predicted impacts within the model domain, are restricted by the boundary conditions applied, particularly within the period of mining at Federation.

¹ The maximum drawdown plots are composite plots displaying the maximum drawdown within each model cell over the full duration of model predictions, and accordingly the maximum drawdown may occur at different times in different locations. Maximum drawdown has been calculated as the maximum drawdown over model output corresponding to Apr 2015, Oct 2015, Apr 2018, Sep 2018, Apr 2019, May 2020, Jun 2020, Jul 2020, Sep 2020 and Jan 2021 for the calibration period; 1.5, 3.5, 7.5, 8, 11.5, 12, 13.5 and 14 years since start of mining for the operational phase and 1, 2, 5, 10, 15, 20, 25, 32, 35, 40, 49, 53, 58, 63, 68, 73, 78, 84, 89, 94, 114, 124 and 1000 years for the post closure phase.

Modelled drawdown 20 years after the end of proposed mining at Federation is shown in Figure 7.5. The model results indicate that compared to drawdown at the end of mining, within 20 years of the end of mining the 10 m drawdown contour will have reduced in size, to the immediate extent of the Federation and Hera Mine workings. However, 20 years after the end of mining, the 2 m drawdown contour will have decreased in size around Hera Mine and the proposed borefield but will have extended in size to the south and west of Federation.

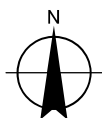
Modelled drawdown 100 years and 1,000 years after the end of proposed mining at Federation is shown in Figure 7.6 and Figure 7.7 respectively. Within 100 years of the end of mining the 2 m drawdown contour is isolated to the immediate extent of the Federation and Hera mine workings. The model results indicate that at 100 years of the end of mining the 1 m drawdown contour associated with the Federation workings has increased in extent to the south of the Federation Site. Following 1,000 years after the end of mining the drawdown associated with mining has largely recovered. At 1,000 years following the end of mining at Federation, there is some remanent drawdown of less than 0.3 m, centred on the Hera Mine workings.

Discussion of drawdown impacts on landholder bores is presented in Section 7.6.



Paper Size ISO A4
0 1.5 3 4.5 6
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

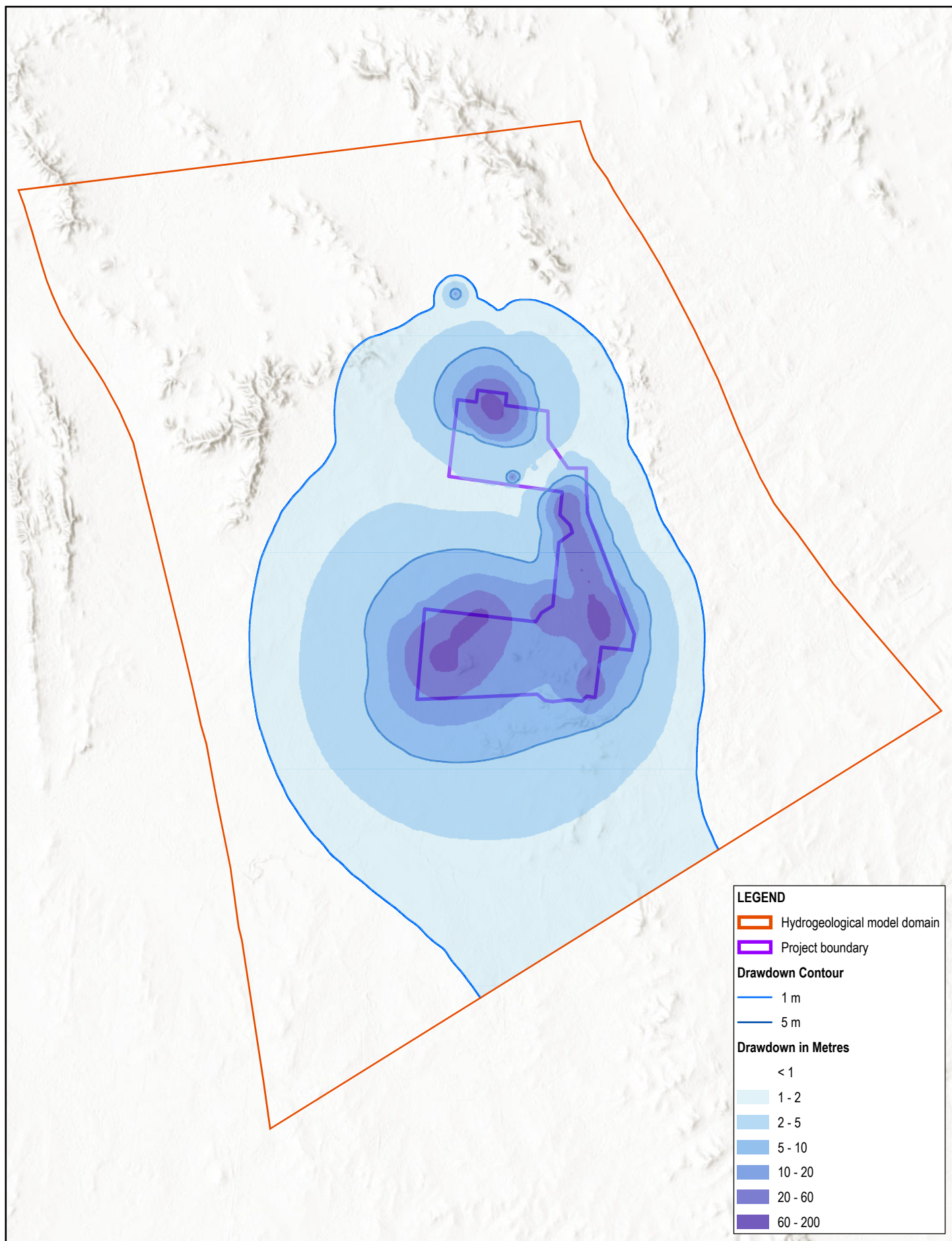


Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

**Maximum drawdown – water table –
approved conditions**

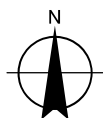
Project No. 12534191
Revision No. 0
Date 10/11/2021

Figure 7-1



Paper Size ISO A4
0 1.5 3 4.5 6
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

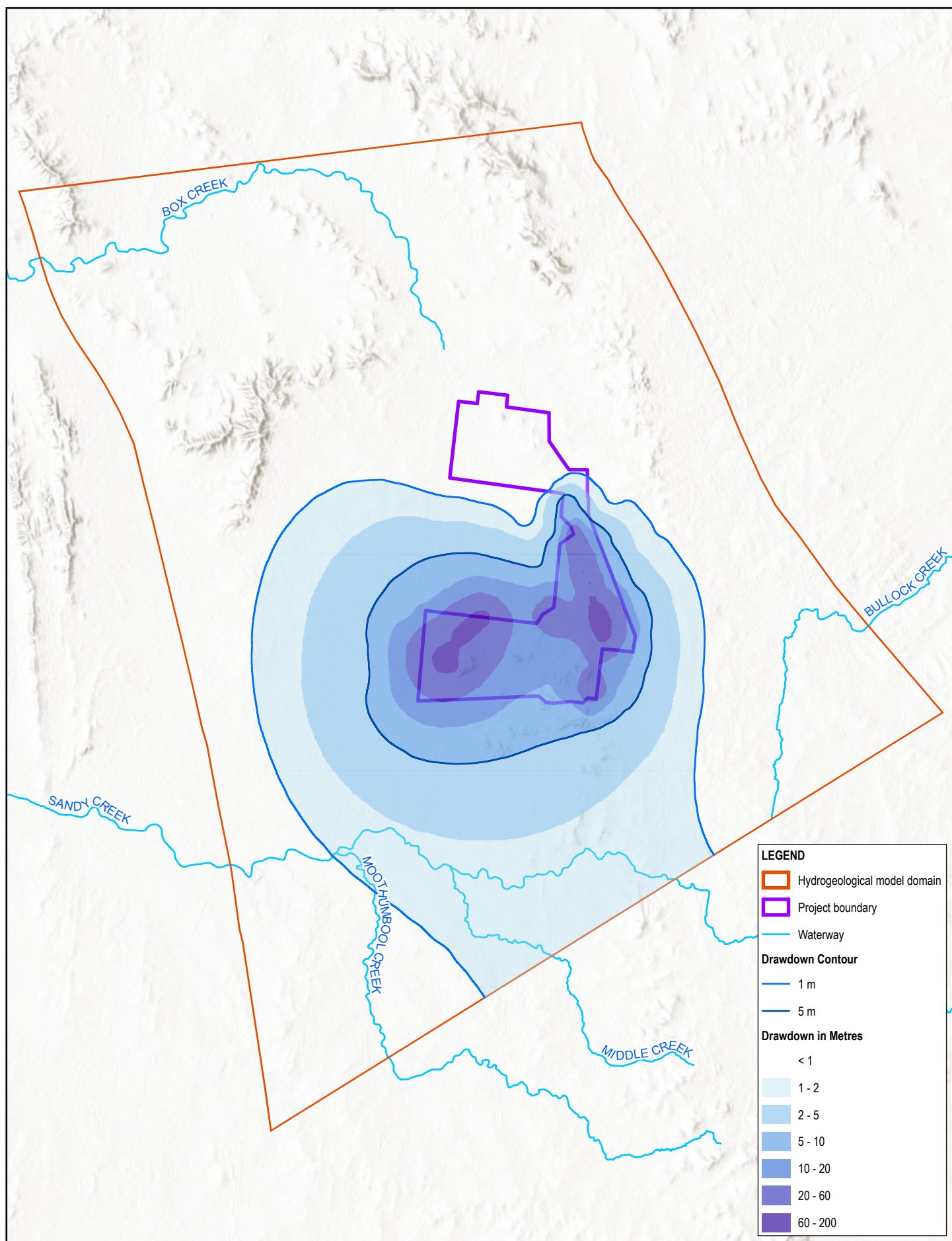


Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

**Maximum drawdown – water table –
proposed conditions**

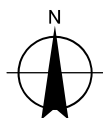
Project No. 12534191
Revision No. 0
Date 08/11/2021

Figure 7-2



Paper Size ISO A4
0 1.5 3 4.5 6
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

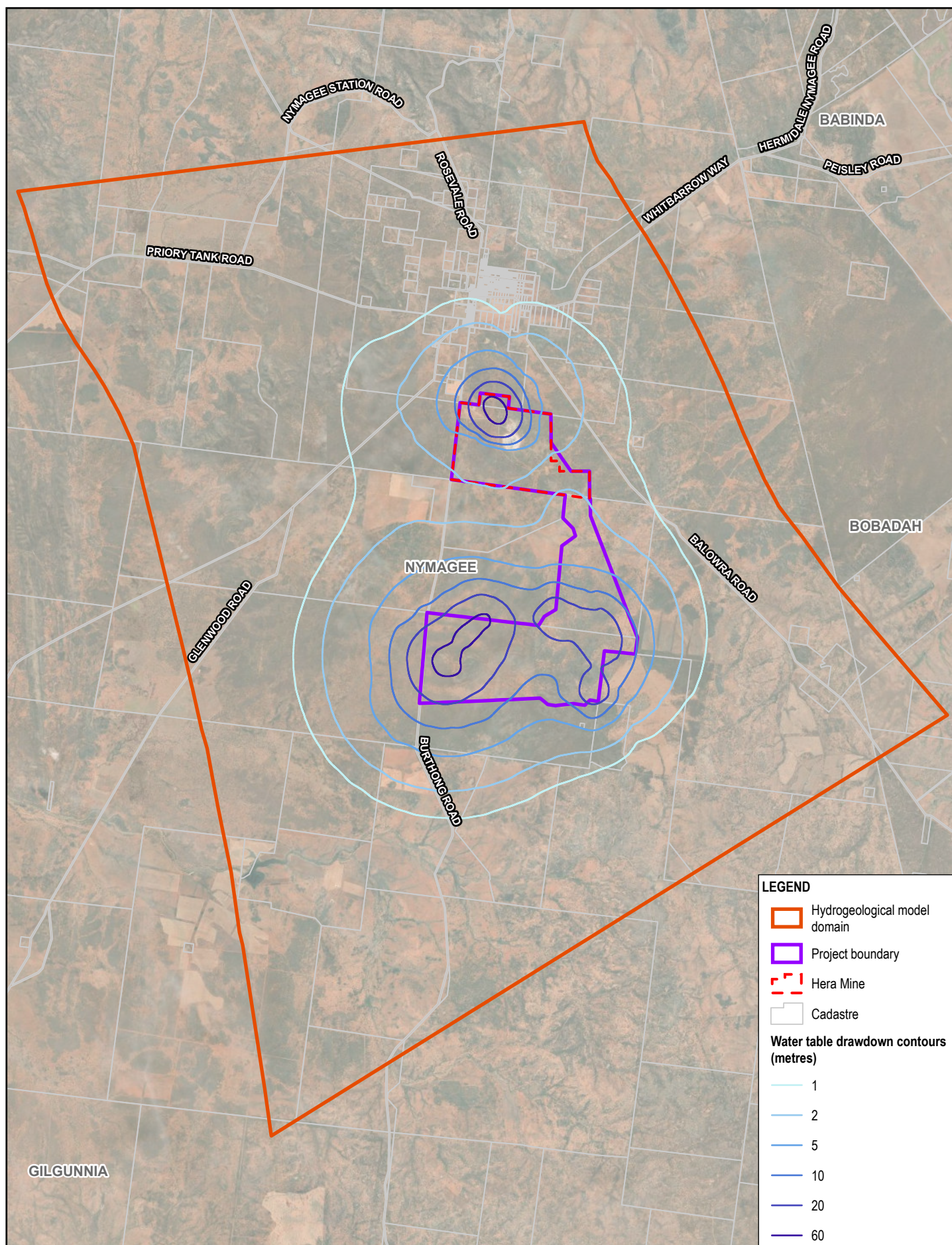


Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

**Maximum drawdown – water table –
incremental drawdown**

Project No. 12534191
Revision No. 0
Date 10/11/2021

Figure 7-3

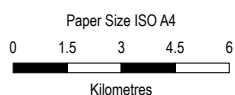


LEGEND

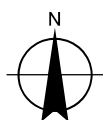
- Hydrogeological model domain
- Project boundary
- Hera Mine
- Cadastre

Water table drawdown contours (metres)

- 1
- 2
- 5
- 10
- 20
- 60



Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

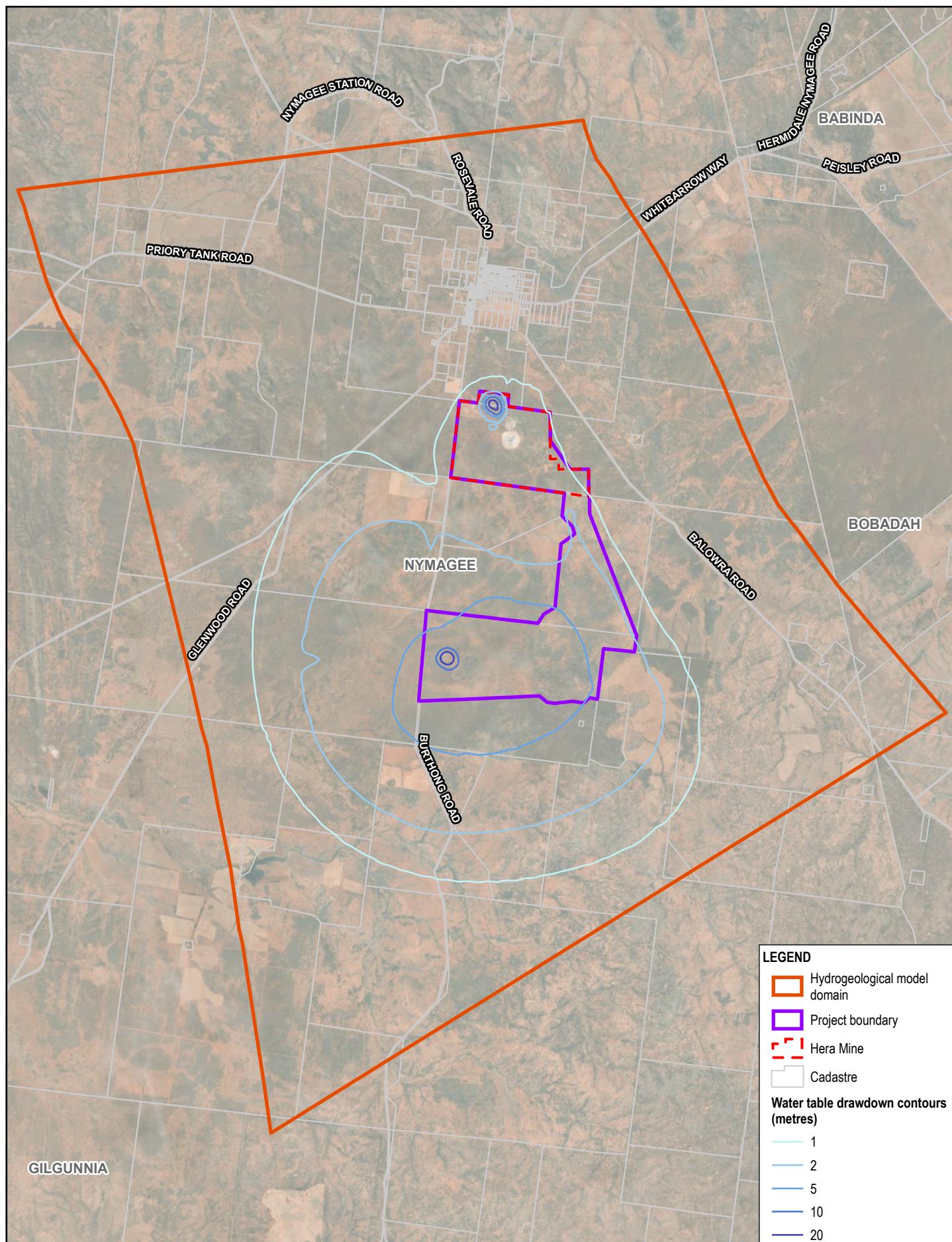


Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

**Water table drawdown at
end of proposed mining**

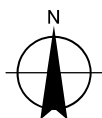
Project No. 12534191
Revision No. 0
Date 08/11/2021

Figure 7-4



Paper Size ISO A4
0 1.5 3 4.5 6
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

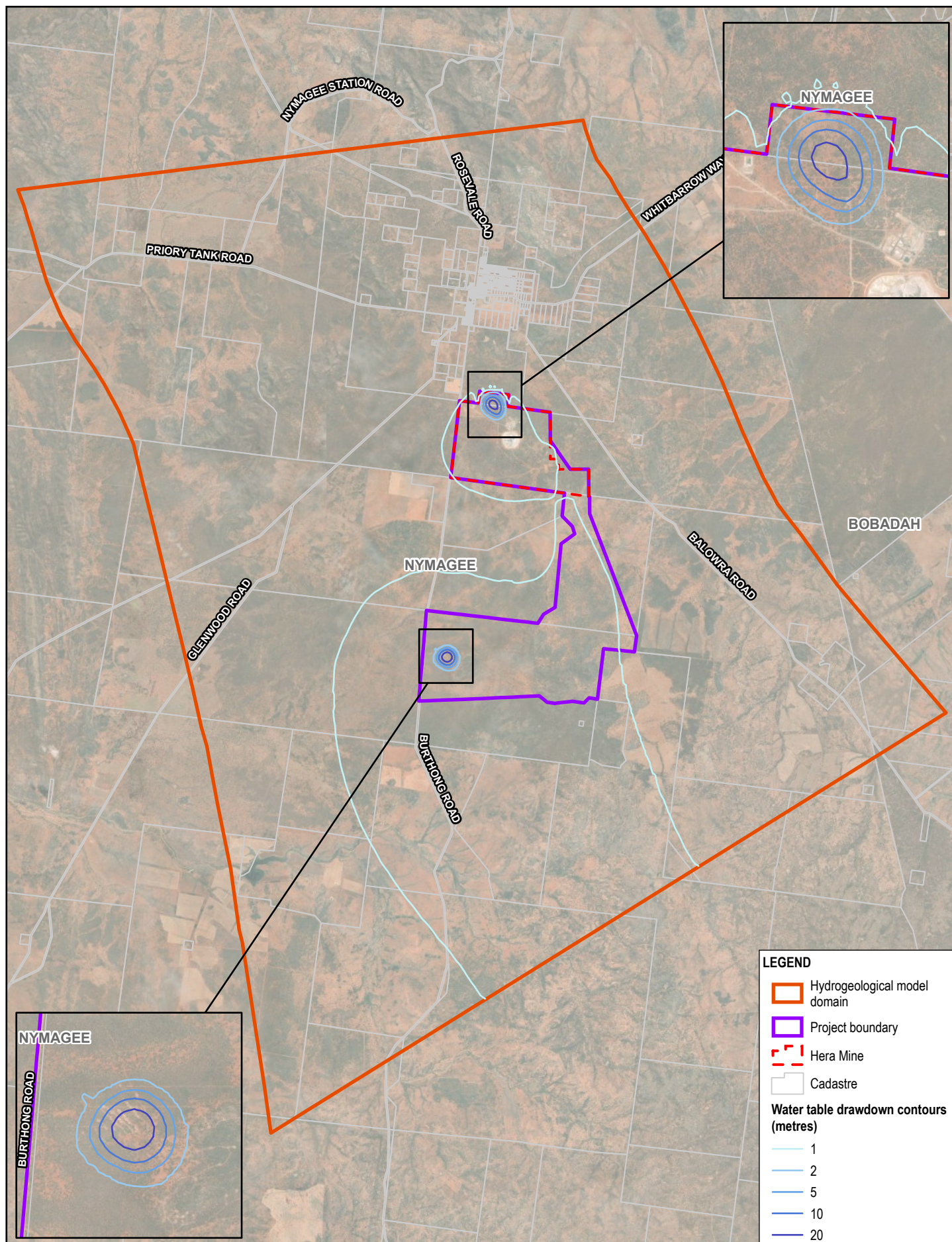


Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

Project No. 12534191
Revision No. 0
Date 08/11/2021

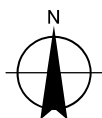
**Water table drawdown 20 years
after the end of proposed mining**

Figure 7-5



Paper Size ISO A4
0 1.5 3 4.5 6
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

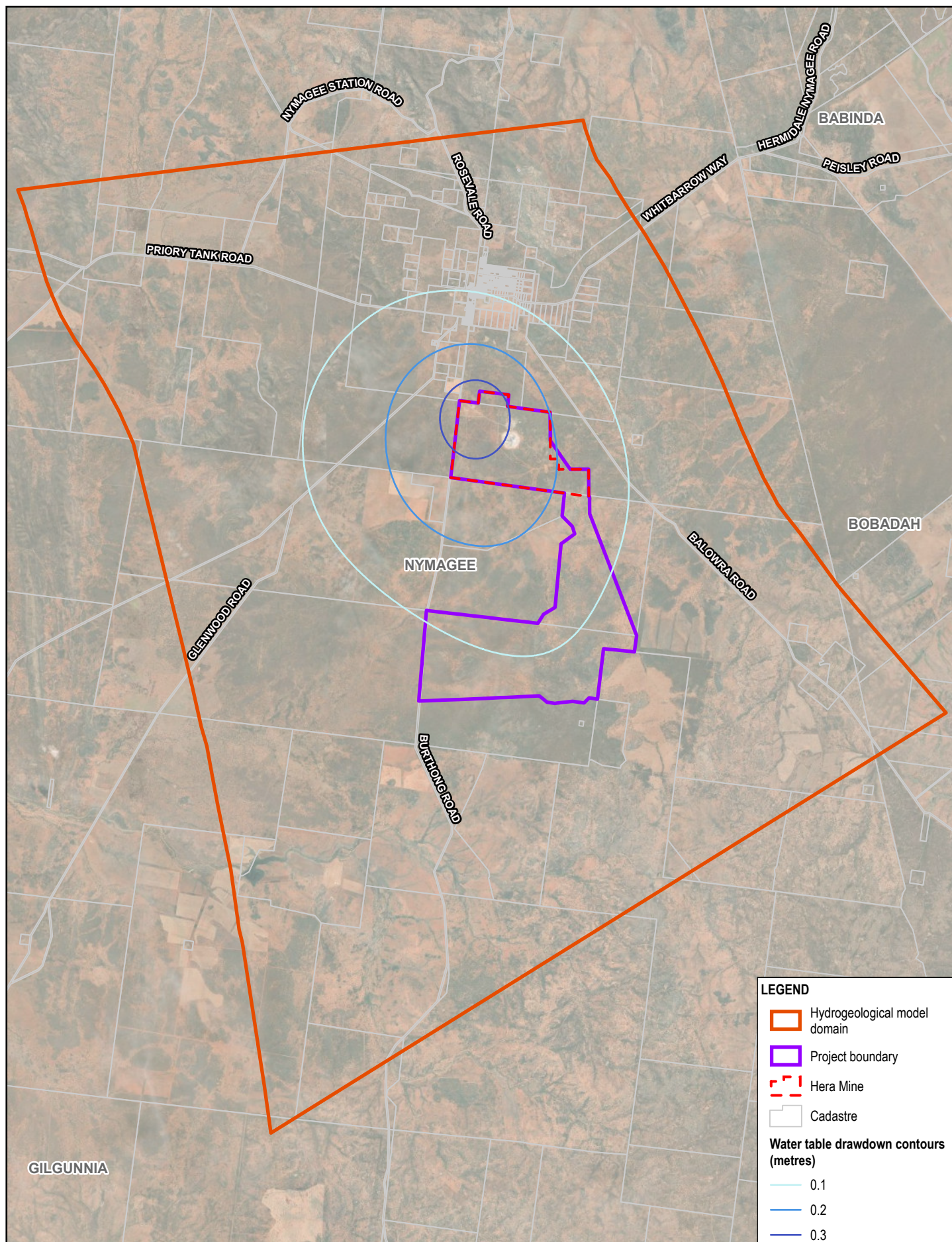


Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

**Water table drawdown 100 years
after the end of proposed mining**

Project No. 12534191
Revision No. 0
Date 08/11/2021

Figure 7-6

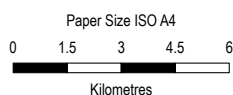


LEGEND

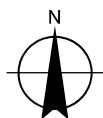
- Hydrogeological model domain
- Project boundary
- Hera Mine
- Cadastre

Water table drawdown contours (metres)

- 0.1
- 0.2
- 0.3



Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

**Water table drawdown 1000 years
after the end of proposed mining**

Project No. 12534191
Revision No. 0
Date 08/11/2021

Figure 7-7

7.4.1 Mine inflow

The groundwater inflow rates are derived from the zone budget for both operational and post-closure phases. A time step multiplier has been used throughout the operational model phase. Therefore while the model may report a high initial rate of inflow at the start of each stress period, this does not necessarily equate to a large volume of groundwater inflow as the initial time step is smaller. Therefore, the volume of groundwater inflow for each stress period has been calculated and this divided by the length of the stress period to calculate the groundwater inflow rate.

The predicted inflow rates into the Hera Mine and Federation mine workings over the period of mining for proposed and approved conditions are shown in Figure 7.8. The predicted mine inflow rate into the Hera Mine workings remains constant throughout the operational mining period. Modelled groundwater inflows into Federation are predicted to increase throughout 2022 and 2023 (first two years of exploration decline activities and mining), with groundwater inflows relatively constant between approximately 300 m³/day and 340 m³/day for the remainder of mining. Groundwater inflows into Federation are predicted to peak in 2027 (year 6 of proposed mining) at 340 m³/day.

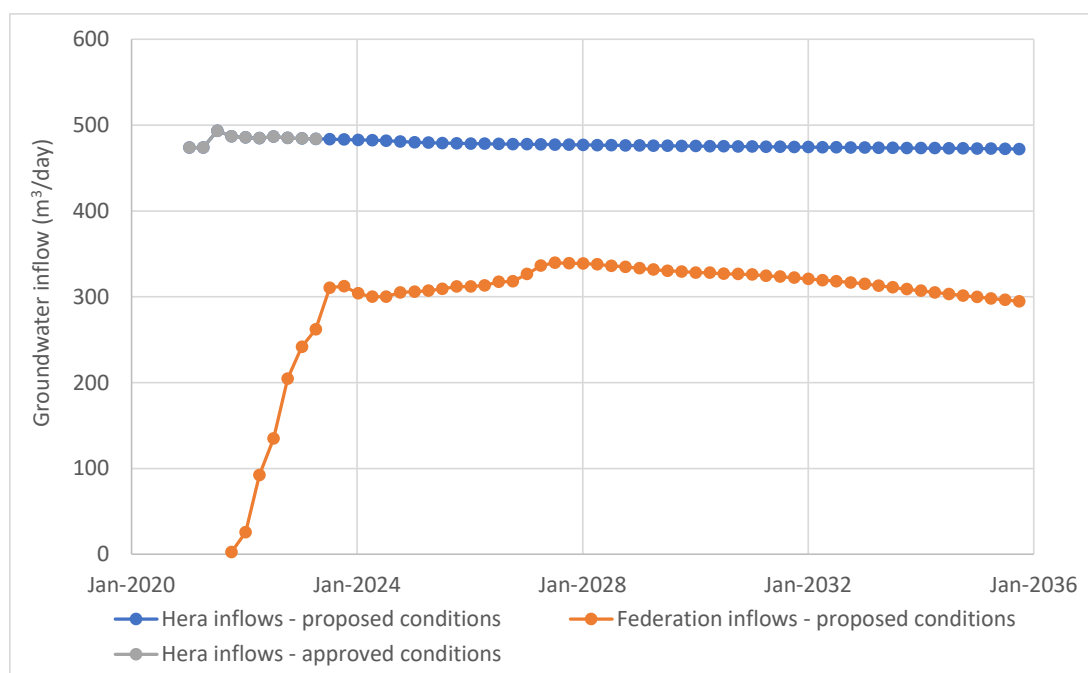


Figure 7.8 Modelled mine groundwater inflows (operation phase)

As discussed in Section 5.3.4.3, the transient calibration model was overestimating current inflows into Hera Mine. The model forecasts that inflows at Hera Mine will remain relatively constant for as long as dewatering of workings continues over the life of the Project, however the actual inflows are likely to be similar to the currently observed inflow volumes (100 m³/day) than the forecasts of the groundwater model.

7.5 Groundwater dependant ecosystems

The outputs of the groundwater model were not utilised to assess impacts on GDEs. This was based upon the following lines of evidence:

- A review of broad scale mapping did not identify any known GDEs within 20 km of the Federation deposit. There are potential terrestrial GDEs in the vicinity of Federation Deposit, however, given the deep water levels it is considered unlikely that these vegetative communities are GDEs.
- The deep water levels (>45 m) in the Palaeozoic sediments are beyond the reasonable limit of tree rooting depths.

It is considered unlikely that a perched aquifer is present considering that exploration drilling has consistently indicated that the shallow strata are dry.

As there are no known GDEs within 20 km of the Federation deposit, potential impacts of the Project are within the Level 1 minimal impact considerations for GDEs from the NSW AIP outlined in Section 7.2.

7.6 Landholder bores

7.6.1 Overview

Groundwater use is discussed in Section 3.5.1. There are 12 registered stock and domestic bores within a 20 km radius of Hera Mine and Federation that are not associated with operations at Hera Mine. These bores include:

- GW014111, GW014217, GW015819, GW015820, GW017183, GW017469, GW020714, GW021543 and GW022674 located over 15 km from Hera Mine.
- GW017385 which is located approximately 3 km north of Hera Mine.
- GW017386 is located approximately 2.5 km south of Hera Mine and is 650 m from the nearest groundwater production bore (WB11).
- GW018014 is located approximately 10 km southwest of the Hera Mine underground workings and 8.3 km from the nearest groundwater production bore (WB11).

Of these bores, the closest stock and domestic bores to Federation are GW020714 and GW017386 which are located 6.4 km south and 7.4 km north from Federation respectively.

There are two known unregistered bore within 20 km of Federation and Hera. The unregistered Nymagee Town Bore is located approximately 1 km east of Nymagee Mine (Aquade 2017). The unregistered Harland's Bore is located approximately 3.9 km south west of Hera Mine. The location of registered bores and the unregistered Nymagee Town Bore is shown in Figure 3.8.

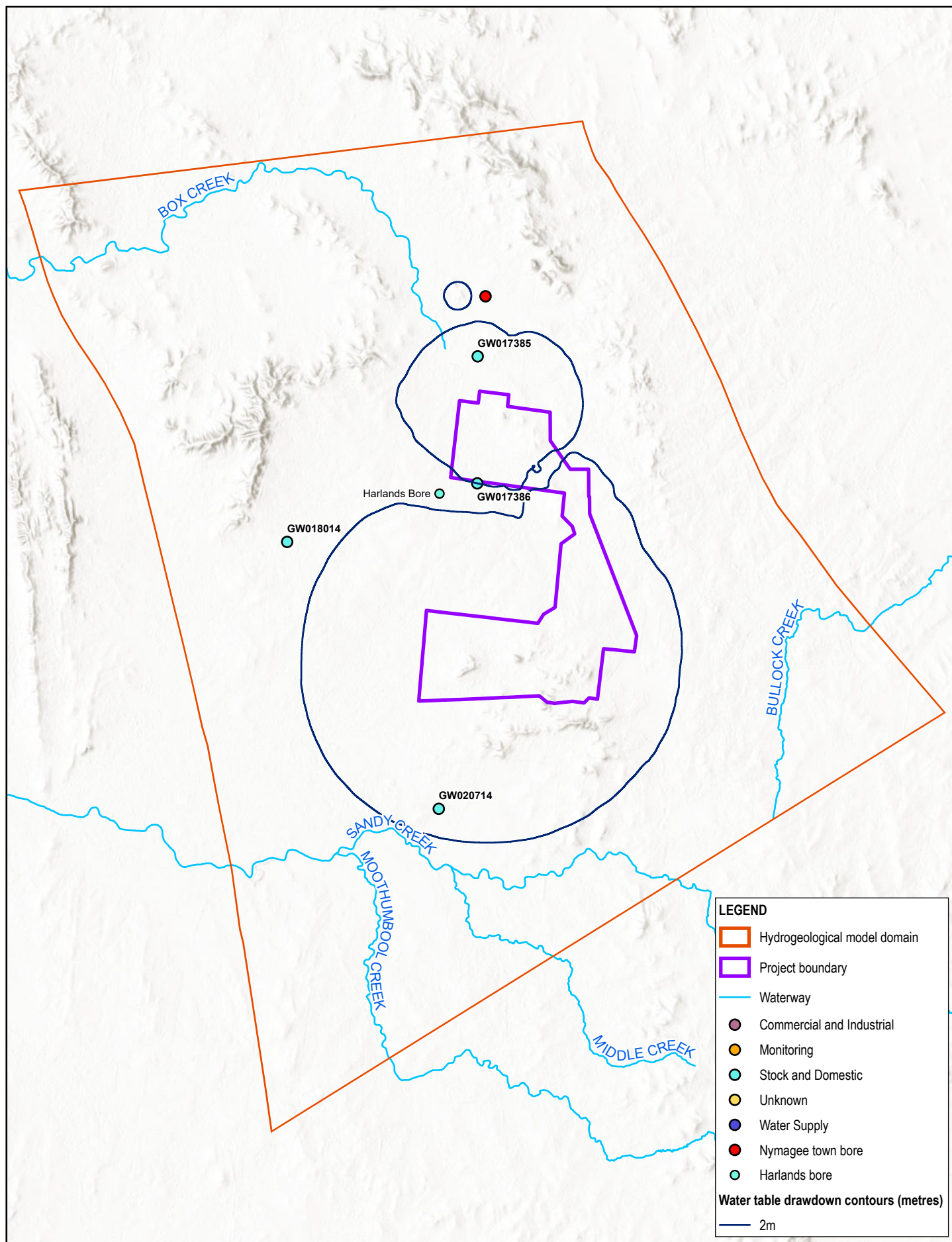
Of these identified bores, the majority (GW014111, GW014217, GW015819, GW015820, GW017183, GW017469, GW021543) are located outside the model boundary. GW022674 is located on the model boundary. Groundwater drawdown plots have been prepared for all other identified bores (GW017385, GW017386, GW018014, GW020714 and Nymagee Town Bore). Groundwater drawdown plots are presented in Appendix F for both proposed and approved conditions. In preparing the groundwater drawdown plots, the depth of each of these bores was reviewed to determine what model layer they were likely installed within. Based on the depth of the bores, they were assumed to be in model layer 5. The depth of the Nymagee Town Bore was unknown. The Nymagee Town Bore was assumed to be installed within model layer 5 based on the depth of the majority of the other landholder bores and the production bores at Hera Mine.

7.6.2 Landholder bore drawdown predictions

As discussed in Section 7.6.1, groundwater drawdown plots have been prepared for landholder bores that are within the model boundary and are not associated with mining operations at Hera Mine. This includes GW017385, GW017386, GW018014, GW020714, Harland's Bore and Nymagee Town Bore. Groundwater drawdown plots are presented in Appendix F. The location of these bores is shown with the 2 m maximum drawdown contour under proposed conditions in Figure 7.9. Of these bores, modelled drawdown at GW017386, GW018014, Harland's Bore and the Nymagee Town Bore is less than 2 m under proposed and approved conditions.

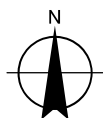
Modelled drawdown at GW017385 and GW020714 is presented in Figure 7.10 and Figure 7.11 respectively. The maximum modelled drawdown at GW017385 is approximately 3.5 m under approved conditions and approximately 4 m under proposed conditions. Drawdown at GW017385 is attributable to mining at Hera Mine. The additional drawdown at GW017385 under proposed conditions is attributable to the continued dewatering of the Hera Mine workings.

The maximum modelled drawdown at GW020714 is 2.7 m under proposed conditions. Drawdown at GW020714 is negligible (less than 0.1 m) under approved conditions. Drawdown at GW020714 is attributable to mining at Federation. At the end of proposed mining at Federation, modelled drawdown is approximately 1.2 m. Maximum modelled drawdown at GW020714 occurs approximately 25 years after the end of mining at Federation.



Paper Size ISO A4
0 1.5 3 4.5 6
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

**Landholder bores
and maximum modelled drawdown**

Project No. 12534191
Revision No. 0
Date 08/11/2021

Figure 7-9

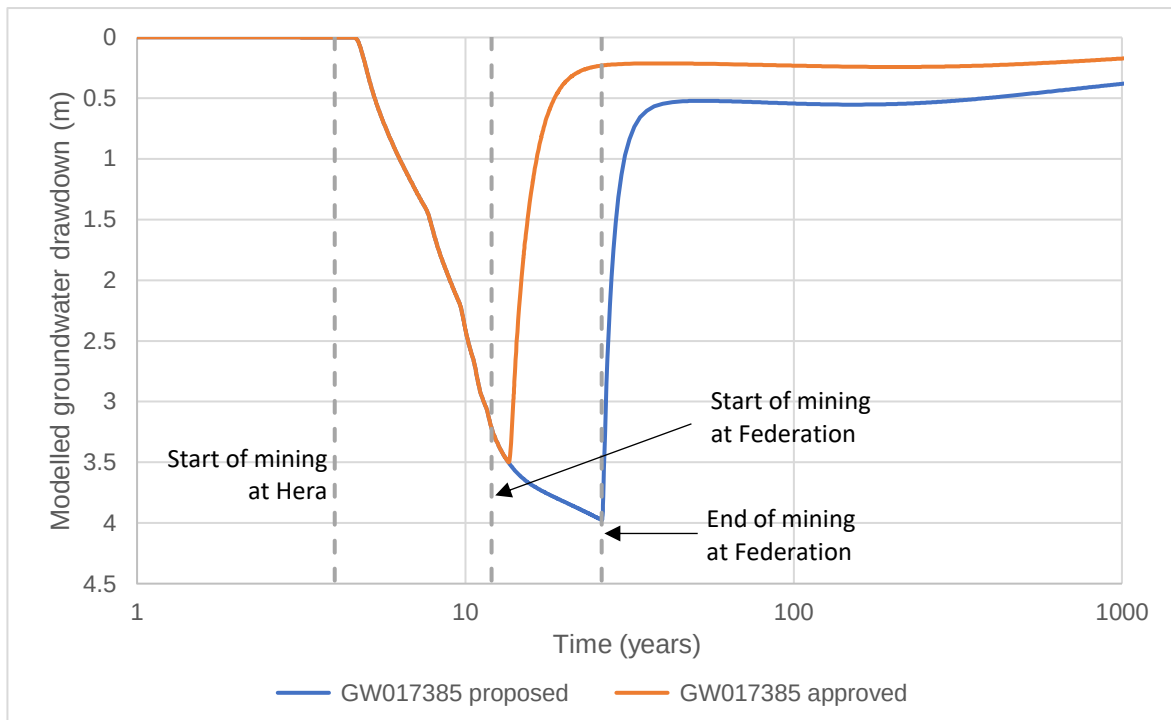


Figure 7.10 Modelled drawdown – GW017385

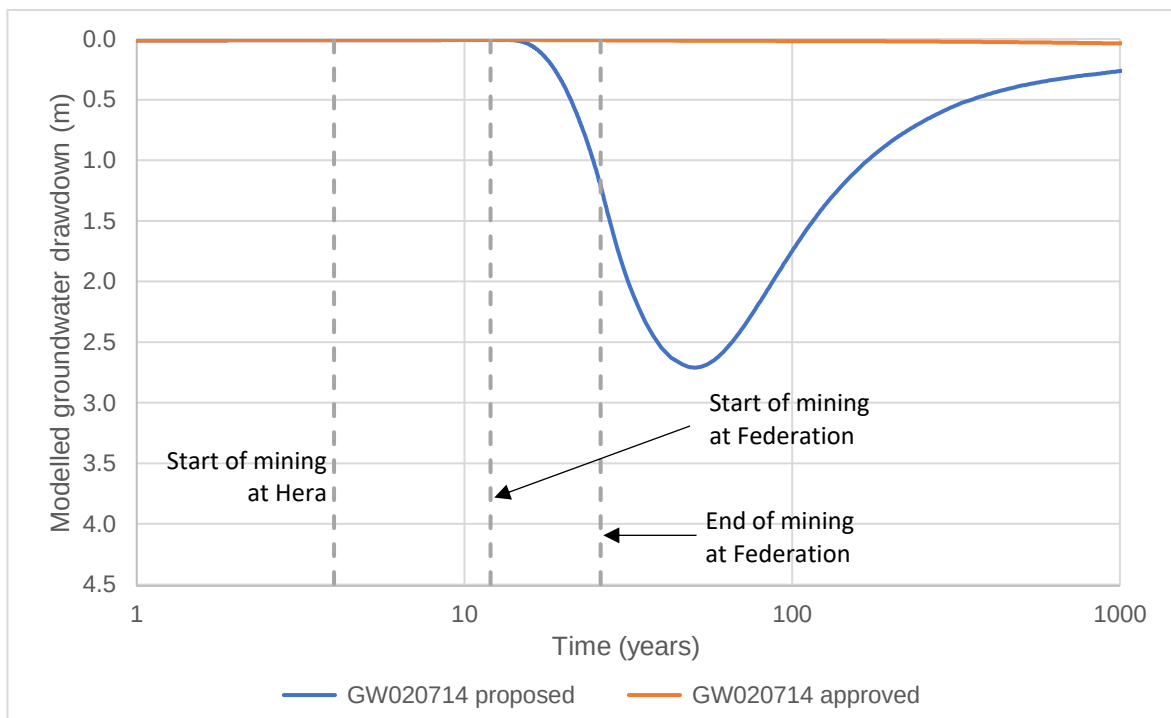


Figure 7.11 Modelled drawdown – GW020714

As modelled groundwater drawdown exceeds 2 m at GW017385 and GW020714, make good provisions will apply under the NSW AIP. Stock bores are used intermittently and therefore loss in the available drawdown may not necessarily result in impact to the operation of landholder bores. If impacts to landholder bores do occur, there are a number of mitigations available for consideration by Hera Resources to ensure a continued supply of water to the landholder:

- Lower the production pump intake (provided there is capacity in the bore)
- Installation of a deeper production bore to replace or supplement the bore
- Provision of an alternate water supply, e.g. tankering supply to the landholder

7.7 Water quality

Potential water quality impacts have not been assessed by the groundwater model. Potential water quality impacts have been qualitatively assessed in this section.

Owing to it being a mineralised province, it is not uncommon for native groundwater to be naturally elevated with heavy metals.

Mineralisation is commonly in the form of metal sulfides, e.g. principally in the form of pyrite. The geological materials are stable when undisturbed or located below the water table. However, when oxygen is introduced, the sulphides oxidise to sulphate, with resultant materials having low pH and potentially high concentrations of the heavy metals. Groundwater leaching through these materials may mobilise pH and heavy metals into the environment. However, there is no decreasing trend in pH at Hera Mine, indicating that pH and heavy metals have not mobilised into the environment at Hera Mine. Therefore, it is considered unlikely that pH and heavy metals will mobilise into the environment due to the Project.

For the 14 years of mining at Federation, the dewatering would result in the potential exposure of acid generating geological materials. The dewatering of mine workings, however, would result in a sink or depression forming in the regional water table, and therefore there is a tendency for acid / metalliferous drainage being collected or its movement hydraulically controlled and managed by the dewatering operations. Following the end of dewatering, the workings will be sealed and the site will continue to be a groundwater sink until groundwater levels start to recover and reach equilibration. Oxidation will cease once the portal and vent rises are sealed. The back-filling of the Federation workings with tailings paste will also reduce the likelihood of oxidation occurring. As a result, acid mine drainage post closure is unlikely to be a significant risk.

The Federation workings will be backfilled with tailings paste. Tailings paste is similar to cement (a mix of general purpose cement and 'slag' will be used as the binder), which hardens within weeks resulting in a concrete-like material, which therefore binds the material into a permanently cemented matrix where oxidation of sulfide minerals is significantly limited. There will also be some potentially acid forming rock placed in the workings. The tailings paste will not contain cyanide. Similar to potential acid / metalliferous drainage, any leachate from the tailings paste and potentially acid forming rock will initially be collected or its movement hydraulically controlled and managed by the dewatering operations.

Modelled drawdown contours 1,000 years after the end of proposed mining (Figure 7.7) indicates that in the long-term post closure, the depression in the regional water table due to mining at Hera Mine and Federation will recover. As recovery occurs, the groundwater flow direction will return to pre-mining conditions, with groundwater flow towards the south west. While impacts with leachate from the tailings paste is unlikely, as oxidation of sulfide minerals is significantly limited by the properties of the paste; under these conditions, any leachate would migrate to the south west. Calculating the likely velocity of the groundwater flow indicates a very low velocity, as shown below. Groundwater flow velocity is calculated as:

$$V = (k \times i) / n$$

Where:

V is groundwater flow velocity (m/day)

k is hydraulic conductivity (m/day); and

i is hydraulic gradient (m/m)

n is porosity (unitless)

Adopting the calibrated hydraulic conductivity for layer 10 (2.78×10^{-3}); hydraulic gradient of 0.005 based on the groundwater contours shown in Figure 3.16 and porosity of 0.1; gives a velocity of 1.4×10^{-4} m/day or 0.05 m/year. This indicates that even over the long term (1000 years or more) the migration of any potential leachate will be isolated to the immediate vicinity of the Hera Mine and Federation workings.

Review of groundwater quality data at Federation (Section 3.8.2.2) indicated that groundwater at Federation is slightly brackish to saline (2,000 $\mu\text{S/cm}$ to 10,000 $\mu\text{S/cm}$). Geochemical analysis of potential tailings and potential waste rock has been undertaken for the Project by Terrenus (2021). Groundwater quality data at Federation has been compared with water extracts from potential tailings and water extracts from potential waste rock in Table 7.2.

The review indicates groundwater at Federation is suitable for stock watering or industrial use. The water leach results suggest that leachate will be slightly more alkaline than natural groundwater with dissolved metals similar to or less than groundwater. Leachate from the tailing backfill (forming a permanently cemented matrix where oxidation of sulfide minerals is significantly limited) or the potentially acid forming rock is considered unlikely to change the beneficial use category of groundwater at Federation.

As the potential impacts on groundwater quality attributable to Federation will not lower the beneficial use category of the groundwater source; impacts on groundwater quality will meet the Level 1 minimal impact considerations for groundwater quality from the NSW AIP as outlined in Section 7.2.

Table 7.2 Comparison of Federation groundwater quality and leachate quality

Parameter	Units	Federation groundwater quality*			Water extracts from potential tailings			Water extracts from potential waste rock		
		Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum
pH	(pH units)	6.53	6.97	7.68	6.90	7.83	8.40	5.50	8.68	9.50
EC	(µS/cm)	1022	4828	10883	284	296	308	52	138	337
TDS	(mg/L)	6.75	3191	7072	-	-	-	-	-	-
Total suspended solids	(mg/L)	2	4162	76000	-	-	-	-	-	-
Total Hardness as CaCO ₃	(mg/L)	343	995	2900	-	-	-	-	-	-
Hydroxide Alkalinity as CaCO ₃	(mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO ₃	(mg/L)	<1	<1	<1	<1	6.7	18.1	1	10.2	39.5
Bicarbonate Alkalinity as CaCO ₃	(mg/L)	237	426	552	122	846	2190	18	288	2500
Total Alkalinity as CaCO ₃	(mg/L)	237	426	552	122	846	2190	18	295.35	2490
Sulfate as SO ₄ - Turbidimetric	(mg/L)	5	281	585	127	148	173	4	18.6	96
Chloride	(mg/L)	431	1340	3600	23	26	29	3	23	100
Calcium	(mg/L)	44	138	391	33	37	41	<2	3	12
Magnesium	(mg/L)	56	158	466	6	6.67	8	<2	2.3	8
Sodium	(mg/L)	282	597	1200	8	9	10	2	15	56
Potassium	(mg/L)	16	23	36	6	10	14	<2	17.5	40
Aluminium	(mg/L)	<0.01	0.02	0.15	<0.02	<0.02	<0.02	<0.02	0.58	1.39
Antimony	(mg/L)	<0.001	0.003	0.022	-	-	-	-	-	-
Arsenic	(mg/L)	<0.001	0.003	0.016	<0.002	<0.002	<0.002	<0.002	0.003	0.01
Beryllium	(mg/L)	<0.001	0.001	0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Barium	(mg/L)	0.032	0.13	0.321	0.009	0.025	0.036	<0.002	0.005	0.018
Cadmium	(mg/L)	<0.0001	0.0001	0.0004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium	(mg/L)	<0.001	0.001	0.002	<0.002	<0.002	<0.002	<0.002	0.002	<0.002
Cobalt	(mg/L)	<0.001	0.005	0.022	<0.002	0.003	0.004	<0.002	0.004	0.038
Copper	(mg/L)	<0.001	0.002	0.009	<0.002	<0.002	<0.002	<0.002	0.002	0.009

Parameter	Units	Federation groundwater quality*			Water extracts from potential tailings			Water extracts from potential waste rock		
		Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Lead	(mg/L)	<0.001	0.002	0.006	<0.002	0.005	0.007	<0.002	0.006	0.036
Manganese	(mg/L)	0.067	0.765	3.72	0.06	0.446	1.15	<0.002	0.020	0.285
Molybdenum	(mg/L)	<0.001	0.001	0.003	<0.002	0.003	0.006	<0.002	<0.002	<0.002
Nickel	(mg/L)	<0.001	0.010	0.027	<0.002	0.003	0.006	<0.002	0.007	0.108
Selenium	(mg/L)	<0.01	0.01	0.01	<0.02	<0.02	<0.02	<0.02	0.021	0.04
Uranium	(mg/L)	<0.001	0.009	0.035	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Vanadium	(mg/L)	<0.01	0.01	0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc	(mg/L)	<0.005	0.040	0.19	0.01	0.16	0.46	<0.01	0.010	0.013
Boron	(mg/L)	0.25	0.44	0.73	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Iron	(mg/L)	<0.05	1.16	5.86	<0.2	<0.2	<0.2	<0.2	0.26	0.5
Mercury	(mg/L)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Free Cyanide	(mg/L)	<0.004	<0.004	<0.004	-	-	-	-	-	-
Total Cyanide	(mg/L)	<0.004	<0.004	<0.004	-	-	-	-	-	-
Weak Acid Dissociable Cyanide	(mg/L)	<0.004	<0.004	<0.004	-	-	-	-	-	-
Nitrite as N	(mg/L)	<0.01	<0.01	<0.01	-	-	-	-	-	-
Nitrate as N	(mg/L)	<0.01	0.02	0.17	-	-	-	-	-	-
Nitrite + Nitrate as N	(mg/L)	<0.01	0.02	0.17	-	-	-	-	-	-
Reactive Phosphorus as P	(mg/L)	<0.01	0.01	0.03	<2	<2	<2	<2	<2	<2
Total Anions	(meq/L)	22	53	119	-	-	-	-	-	-
Total Cations	(meq/L)	19.8	48	111	-	-	-	-	-	-
Ionic Balance	(%)	0.05	6.01	9.92	-	-	-	-	-	-
Fluoride	(mg/L)	0.2	0.5	1.2	0.9	2.7	4.3	0.4	2.6	6.2
Ammonia as N	(mg/L)	<0.01	0.33	1.74	-	-	-	-	-	-

* Federation groundwater quality data for pH, EC and TDS is based on field parameters. For all other parameters, data presented is from lab analysis
In calculating mean values, data less than the limit of reporting (LoR) was assumed to be equal to the LoR.

7.8 Summary of impacts

Potential groundwater impacts predicted by the numerical groundwater model have been assessed against the Level 1 minimal impact considerations outlined in the NSW Aquifer Interference Policy.

The 1 m drawdown contour is modelled to extend 4.5 km and 6.2 km from Hera Mine under approved and proposed conditions respectively. Under proposed conditions, the 1 m drawdown contour extends up to 8 km to the west of the Federation Mine workings. Under proposed conditions, the 1 m drawdown contour extends up to 10.5 km to the east of the Federation Mine workings. However, to the east of Federation the drawdown is partially attributable to the proposed production bores.

There are no high priority GDEs or culturally significant sites listed in the WSP within 20 km of Federation. Therefore potential impacts on high priority GDEs and culturally significant sites are within the Level 1 minimal impact considerations for GDEs from the NSW AIP.

Modelled drawdown at all landholder bores is less than 2 m with the exception of bores GW017385 and GW020714. Modelled drawdown is less than 2 m at the Nymagee Town Bore under approved and proposed conditions. The maximum modelled drawdown at GW017385 is approximately 3.5 m under approved conditions and approximately 4 m under proposed conditions. Drawdown at GW017385 is attributable to mining at Hera Mine. The additional drawdown at GW017385 under proposed conditions is attributable to the continued dewatering of the Hera Mine workings.

The maximum modelled drawdown at GW020714 is 2.7 m under proposed conditions. Drawdown at GW020714 is negligible (less than 0.1 m) under approved conditions. Drawdown at GW020714 is attributable to mining at Federation.

As drawdown at GW017385 and GW020714 is greater than 2 m, make good provisions will apply at these bores under the Level 1 minimal impact considerations outlined in the NSW AIP.

As discussed in Section 7.7, water quality impacts from proposed mining at Federation will not lower the beneficial use category of the groundwater source. Therefore, potential impacts on groundwater quality will meet the Level 1 minimal impact considerations for groundwater quality from the NSW AIP.

8. Model complexity and confidence level classification

The modelling effort required to meet the study objective is guided by the target confidence level and complexity of the model. Confidence in model predictions depends fundamentally on the availability of data, whether or not sufficient data are available to characterise the groundwater flow processes of interest and whether or not sufficient information is available to inform hydrogeological parameters that have the greatest influence on model predictions. Complexity of the model reflects the level of sophistication of modelling techniques such as the mesh design, degree of parameterisation and choice of boundary conditions.

Model characteristics have been compared with the Australian Groundwater Modelling Guidelines (Barnett *et al*, 2012) shown in Table 8.1. According to the Australian Groundwater Modelling Guidelines (Barnett *et al*, 2012), this model has a combination of characteristics of a class 2 (medium confidence) model and a class 3 (high confidence) model.

This model has been classified as medium confidence as this model has been calibrated to transient data, stresses at Hera Mine are similar to those expected at Federation and the calibration period (2011 to 2020) is similar to the predictive period of mining at Federation (14 years of mining). Results should be interpreted in accordance with the expectation of a medium confidence model. The model calibration provides a good replication of historical trends in groundwater levels which adds confidence to the model predictions. It should be noted that even a well-calibrated model can still have significant uncertainty associated with it, as spatial and temporal distribution of hydraulic parameters and boundary conditions are not fully known and by definition groundwater modelling is a simplification of real-world conditions.

Table 8.1 Australian Groundwater Monitoring Guidelines (Barnett et al, 2012)

Class	Data	Calibration	Prediction	Quantitative indicators
1 (simple)	Not much Sparse coverage	Not possible Large error statistic	Timeframe>>> calibration Large stress periods	Timeframe > 10x Stresses >5x
	No metered usage	Inadequate data spread	✓ Poor/no validation	Mass balance > 1% (or one off 5%)
	Low resolution Poor aquifer geometry	Targets incompatible with model purpose	Transient prediction but steady-state calibration	Properties <> field values No review by Hydro/Modeller
	Basic / initial conceptualisation			
2 (impact assessment)	Some	✓ Partial performance	Timeframe > calibration	Timeframe =3-10x
	✓ Ok coverage	Some long term trends wrong	Long stress periods	Stresses = 2-5x
	Some data usage / low volumes	Short term record	Ok validation	✓ Mass balance <1%
	✓ Baseflow estimates some K & S measurements	Weak seasonal match	✓ Transient calibration and prediction	✓ Some properties <> field values review by hydrogeologist
	✓ Some high resolution topographic DEM &/or some aquifer geometry	No use of targets compatible with model purpose (heads & fluxes)	New stresses not in calibration	✓ Some coarse discretisation in key areas of grid or at key times
3 (complex simulator)	Lots, with good coverage	Good performance stats	✓ Timeframe ~ calibration	✓ Timeframe <3x
	✓ Good metered usage info	✓ Most long term trends matched	✓ Similar stress periods	✓ Stresses <2x
	✓ Local climate data	✓ Most seasonal matches ok	Good validation	Mass balance <0.5%
	Kh, Kv, and Sy measurements from a range of tests	✓ Present day data targets	Calibration & prediction consistent (transient or steady state)	Properties ~ field measurements
	High resolution DEM all areas	✓ Head and flux targets used to constrain calibration	✓ Similar stresses to those in calibration	No coarse discretisation in key areas (grid or time)
	Good aquifer geometry			✓ Review by experienced modeller

Note: achieved attributes are shown with a tick

9. Licencing review and mitigation measures

9.1 Water sharing plan licensing requirements

The total WAL entitlement held by Aurelia is 543 ML/year (refer to Section 2.1.3) for the Lachlan Fold Belt MDB groundwater source. An assessment has been undertaken to determine if Hera Resources holds sufficient WAL volume to share in extracting groundwater that is encountered in the Project.

The year of maximum modelled groundwater take from the Federation workings occurs in 2028. The modelled groundwater take in the year 2028 is presented in Table 5.6 and is also summarised below in Table 9.1.

Table 9.1 Summary of groundwater take – year 2028

Water management element	Groundwater take (m3/day)	Groundwater take (ML/year)
Hera Mine groundwater inflow	476.4	174.4
Federation groundwater inflow	338.3	123.8
Extraction from production bores	649.8	237.8
Total	1464.5	536.0

As shown in Table 9.1, total groundwater take in the year of maximum modelled groundwater inflow to Federation is 536 ML/year. This is less than the WAL entitlement held by Aurelia. Therefore Aurelia holds sufficient WAL entitlement for the Project.

Note that based on the site water balance (GHD, 2021), under proposed conditions, extraction from the production bores are likely to be between 250 ML/year and 408 ML/year. Take from production bores will vary in response to actual groundwater inflows. Extractions from production bores will be higher if mine inflows are lower than predicted; and extraction from production bores will be lower if mine inflows are higher than predicted. Total groundwater take will remain below 543 ML/year throughout operations at Federation. Should groundwater take exceed current WAL, there is enough market depth in the Lachlan Fold Belt MDB groundwater source to secure additional entitlement.

9.2 Mitigation measures

With the exception of potential impacts on landholder bores GW017385 and GW020714, all groundwater impacts attributable to the Project have been assessed to be within the Level 1 impact considerations in the NSW AIP. Therefore ongoing measures should focus on monitoring for potential impacts on landholder bores and monitoring to validate groundwater model predictions and provide observation data for future model calibration.

9.2.1 Flow monitoring

The existing flow monitoring program at Hera Mine should be continued. In addition, the flow monitoring program should be expanded as required to include:

- Metering of water transfers into and out of the Federation workings. This will allow the rate of groundwater inflow into the Federation workings to be calculated. The rate of groundwater inflow into the Federation workings will be approximately equal to the difference between water transferred out and water transferred into the Federation workings.
- Metering of groundwater extraction from all proposed production bores.

9.2.2 Groundwater monitoring

The existing groundwater monitoring program at Hera Mine, Federation and Nymagee Mine should be continued. The existing groundwater monitoring program at Hera Mine, Federation and Nymagee Mine is discussed in Section 3.7.

The monitoring bores at Federation are all located within approximately 500 m of the proposed Federation workings. It is recommended that additional bores are located at a greater radial distance from the proposed Federation workings. These additional bores will enable monitoring of the radius of groundwater drawdown due to dewatering of the mine workings. The locations of the proposed bores are summarised in Table 9.2 and locations are shown in Figure 9.1. The proposed monitoring bores are all located within the proposed Project boundary. Monitoring bore FMB009 is located between Federation and landholder bore GW020714. Monitoring of FMB009 will assist in monitoring for potential impacts at GW020714.

Table 9.2 *Proposed groundwater monitoring bores*

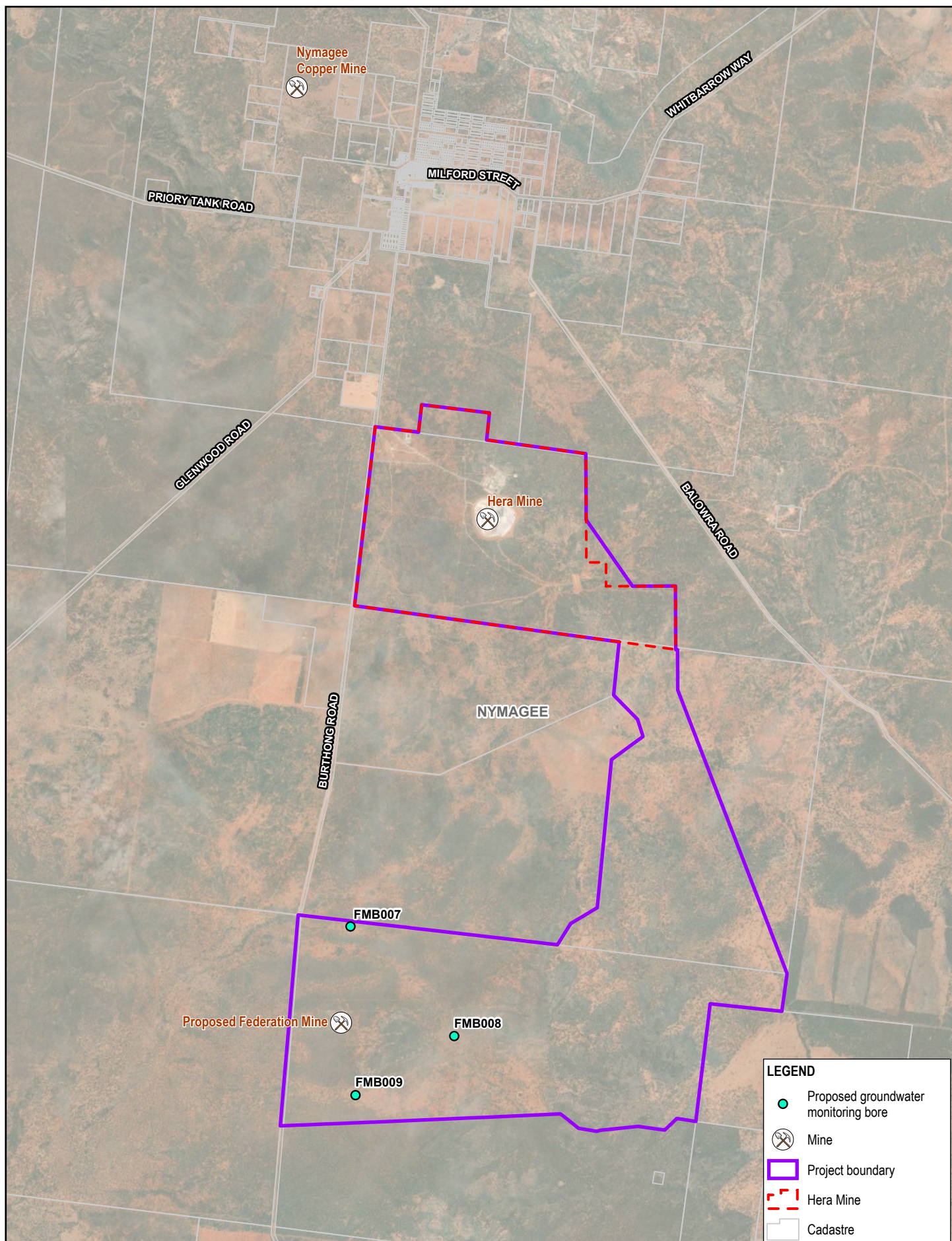
Monitoring bores	Easting	Northing
FMB007	434,375	6,438,720
FMB008	436,245	6,436,745
FMB009	434,465	6,435,680

It is recommended that the proposed groundwater monitoring bores are installed prior to commencement of mining at Federation. It is recommended that the proposed groundwater monitoring bores are incorporated into the Federation groundwater monitoring program discussed in Section 3.7.2.

Landholder bore GW017385 is located approximately 1.9 km north of Hera Mine. Modelled drawdown at GW017385 is attributable to dewatering of the Hera Mine workings. Monitoring bore WB015 is located between Hera Mine and GW017385. Therefore, monitoring bore WB015 is sufficient to monitor for potential impacts at GW017385. Monitoring bore NMWB006 is considered sufficient for monitoring potential impacts on the Nymagee Town Bore.

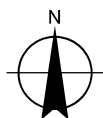
9.2.3 Hydrogeological model

It is recommended that the predictions of the hydrogeological model are reviewed following two years of mining at Federation. The review of the hydrogeological model will include a comparison of modelling results against groundwater monitoring data and mine dewatering volumes. If required, the model should be revised to improve the fit between observed and modelled dewatering volumes and groundwater levels.



Paper Size ISO A4
 0 0.5 1 1.5 2 2.5
 Kilometres

Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 55



Hera Resources Pty Ltd
 Federation Project
 Groundwater Impact Assessment

**Proposed groundwater
 monitoring bores**

Project No. 12534191
 Revision No. 0
 Date 08/11/2021

Figure 9-1

10. Uncertainty analysis

An uncertainty analysis has been developed to support the groundwater modelling undertaken for the Project. Uncertainty analysis outlined in this section is a deterministic scenario analysis with subjective probability assessment. The methodology of uncertainty analysis was chosen with respect to the low number of groundwater receptors resulting in a low level of risk of the Project and with consideration of the IESC Explanatory Note (Middlemis and Peeters, 2018).

The uncertainty analysis assessment is documented in Appendix G. The results of the uncertainty analysis do not alter the findings of the base case model.

11. Conclusions and recommendations

11.1 Model confidence level and set-up

A 3D numerical groundwater flow model of the proposed Federation Project has been developed using the industry standard MODFLOW-USG code. The model simulates the key features of the hydrogeological system of the mine site and surrounding area including hydrostratigraphic units, recharge and discharge mechanisms and spatial and temporal distribution of piezometric heads, as well as representing historical mining at the adjacent Hera Mine. The calibrated model parameters are within the bounds of expected values based on literature searches. Modelled inflows at Hera Mine are similar to observed groundwater inflows. The calibrated model is considered to have the characteristics of class 2 confidence level (i.e. moderate confidence), with aspects of a class 3 model (i.e. high confidence), in accordance with the confidence level classification of the Australian Groundwater Modelling guidelines (Barnett *et al*, 2012). Model confidence should be considered lower for predictions of far-future conditions post-mining, where the groundwater system slowly recovers towards a new dynamic equilibrium over potentially many hundreds of years. The confidence in model predictions would be improved by ongoing data collection and revision of the numerical model after the commencement of the mining at Federation. Fundamentally, predictions of mining-induced effects depend on a monitoring network that adequately captures the stress-response relationship.

11.2 Model predictions

The predictive simulations indicate the following:

- Mining at Federation will result in the long-term depressurisation of groundwater levels in all directions from the mine. Drawdown exceeding 1 m is predicted to occur up to 8 km to the west of the Federation mine workings and up to 10.5 km to the east of the Federation mine workings. However, to the east of Federation the drawdown is partially attributable to the proposed production bores.
- Mining at Hera has resulted in the long-term depressurisation of groundwater levels in all directions from the mine. Drawdown exceeding 1 m due to approved mining is modelled to occur up to approximately 4.5 km from Hera Mine. The continued dewatering of Hera Mine as part of the Project will result in the depressurisation of groundwater levels continuing to extend further from Hera Mine. The continued dewatering of Hera Mine as part of the Project results in modelled drawdown exceeding 1 m occurring up to approximately 6.2 km from Hera Mine.
- Drawdown of less than 2 m is predicted at all landholder bores with the exception of GW017385 and GW020714. Drawdown at GW017385 is attributable to mining at Hera Mine. The maximum modelled drawdown at GW017385 is approximately 3.5 m under approved conditions and approximately 4 m under proposed conditions. Drawdown at GW020714 is attributable to mining at Federation. The maximum modelled drawdown at GW020714 due to mining at Federation is 2.7 m.
- Uncertainty analysis results do not change findings of assessment on the basis that uncertainty analysis runs had a poorer calibration performance and results of these runs are less reliable.

11.3 Impact assessment

Predicted impacts have been compared to the Level 1 minimal impact considerations for less productive water sources in the NSW AIP. Predicted impacts are within the minimal impact considerations, with the exception of modelled impacts on landholder bores GW017385 and GW020714. As predicted impacts at these bores exceeds 2 m, make good provisions will apply at these bores.

11.4 Water licensing

Total groundwater take at Hera and Federation in the year of maximum modelled groundwater inflow to Federation (2028 or year 7 of proposed mining) is 536 ML/year. This is slightly less than the WAL entitlement held by Aurelia for the Lachlan Fold Belt MDB groundwater source in which Hera Mine and the Project are located. Therefore, Aurelia holds sufficient WAL entitlement. Should groundwater take exceed current WAL, there is enough market depth in groundwater source to secure additional entitlement.

11.5 Recommendations

The following recommendations are discussed in Section 9.2 and are summarised below:

- The current groundwater monitoring program at Nymagee Mine, Hera Mine and Federation continues.
- The groundwater monitoring program at Federation is expanded as required to include metering of mine inflows and metering of extraction from production bores.
- Additional monitoring bores are installed at Federation to monitor for drawdown from the proposed mine workings. The location of these additional monitoring bores are shown in Figure 9.1. One of these bores should be located between the Federation workings and landholder bore GW020714. This bore will assist in monitoring for impacts on GW020714.
- The predictions of the hydrogeological model are reviewed following 2 years of mining at Federation. The review of the hydrogeological model will include a comparison of modelling results against groundwater monitoring data and mine dewatering volumes. If required, the model should be revised to improve the fit between observed and modelled dewatering volumes and groundwater levels.

11.6 Model limitations

Numerical groundwater models are a mathematical representation of complex natural systems, developed using a finite numbers of cells whose properties must be inferred from a limited number of measurements. Simplifications are necessary in modelling commensurate with the spatial and temporal scales of processes being modelled and the underlying data used to support the development of the model. The outcomes of modelling should be considered within the context these limitations. In particular, model predictions exceed both the duration and scale of stresses replicated in the calibration period, which leads to increased uncertainty in future predictions.

12. References

- Aquade 2015, Hera Mine - Modification 3 - Environmental Assessment Appendix 3 – Supplementary Assessment of Groundwater Availability.
- Aquade 2016, Assessment of Potential Groundwater Impacts due to North Pod Expansion of Hera Project, Nymagee NSW.
- Aquade 2017, Initial Groundwater Conditions and Monitoring, Aurelia Nymagee Mine, NSW.
- Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A, 2012, *Australian groundwater modelling guidelines*, Waterlines report, National Water Commission, Canberra.
- BOM (2021a) Australian Groundwater Explorer. Retrieved from <http://www.bom.gov.au/water/groundwater/explorer/index.shtml>
- BOM (2021b), Groundwater Dependent Ecosystems Atlas, Australian Government Bureau of Meteorology, viewed online 31 March 2021 from <http://www.bom.gov.au/water/groundwater/gde/map.shtm>
- Carlton, A (2020) *Results from the largest airborne electromagnetic survey ever flown in NSW*, Geological Survey of NSW, from <https://vimeo.com/456479160>
- DE Cooper and Associates *Tomingley Gold Project Residue Management Design Report*, prepared for Alkane Resources Limited.
- Department of Science, Information Technology and Innovation (DSITI) (2021), *SILO Data Drill*, Queensland Government. Retrieved from <http://www.longpaddock.qld.gov.au/silo/>
- EMM (2020) *Hera Mine aquifer investigation – test pumping analysis*. Letter report prepared by EMM Consulting for Aurelia Metals Ltd. EMM reference H200112_L1_V2.
- EMM (2021) *Hera Mine test pumping support and analysis (PWB004 and PWB006)*, prepared by EMM Consulting for Aurelia Metals Ltd. EMM reference J200855.
- Environmental Planning and Assessment Act 1979 (NSW) viewed 7 September 2021, from <https://legislation.nsw.gov.au/view/html/inforce/current/act-1979-203>.
- The Foundation Spatial Data Framework (FSDF) 2021, *Elevation Information System (ELVIS)*. Retrieved from <https://elevation.fsdf.org.au/>.
- GHD (2021a) *Surface water impact assessment – Federation Project*, prepared for Hera Resources Pty Limited.
- GHD (2021b) *Federation Project – Groundwater Supply Assessment*, prepared for Hera Resources Pty Limited.
- Geoterra (2005) *Hydrogeological Assessment of Skirka's Bore at 'The Peak' Station*, prepared by Geoterra Pty Ltd for Triako Resources Limited.
- GeoTerra (2006) *Hera Project Groundwater Status Report*, prepared by Geoterra Pty Ltd for Triako Resources Limited.
- The Impax Group (2011), *Hera Project Groundwater Assessment*, prepared for R.W. Corkery and Company Pty Ltd on behalf of Hera Resources Ltd.
- Mackie, CD (2009) *Hydrogeological Characterisation of coal measures and overview of impacts of coal mining on groundwater systems in the Upper Hunter Valley of NSW*, PhD thesis, Faculty of Science, University of Technology, Sydney.
- MacRae, GP 1988, *Nymagee 1:100,000 Geological Sheet 8133*, New South Wales Geological Survey, Sydney, retrieved online 6 May 2019 from <http://gmaps.geoscience.nsw.gov.au/100K/Nymagee/>
- Mining Act 1992* (NSW), viewed 2 May 2016, from <http://www.legislation.nsw.gov.au/#!/view/act/1992/29>
- Middlemis, H and Peeters, LJM (2018) *Explanatory Note, Uncertainty Analysis in Groundwater Modelling*. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy.

NSW DPIW 2012, *Water Sharing Plan Murray-Darling Basin Fractured Rock Groundwater Sources Background Document*, New South Wales Department of Primary Industries

NOW (2012c), *NSW Aquifer Interference Policy*, NSW Office of Water, NSW Department of Primary Industries

NSW DPIW 2012, *Water Sharing Plan Murray-Darling Basin Fractured Rock Groundwater Sources Background Document*, New South Wales Department of Primary Industries

Panday, Sorab, Langevin, C.D., Niswonger, R.G., Ibaraki, Motomu, and Hughes, J.D., 2013, *MODFLOW-USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods*, book 6, chap. A45, 66 p., <https://pubs.usgs.gov/tm/06/a45>.

Protection of the Environment Operations Act 1997 (NSW), viewed 2 May 2016, from <http://www.legislation.nsw.gov.au/#/view/act/1997/156>

RW Corkery & Co 2019, *Statement of Environmental Effects for the Hera Mine Modification 5 PA 10_0191*.

State Environmental Planning Policy (State and Regional Development) 2011 (NSW), viewed 7 September 2021, from <https://legislation.nsw.gov.au/view/html/inforce/current/epi-2011-0511>

Theis, C.V., 1935. *The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage*, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

Water Act 1912 (NSW), viewed 2 May 2016, from <http://www.legislation.nsw.gov.au/#/view/act/1912/44>

Water Management Act 2000 (NSW), viewed 2 May 2016, from <http://www.legislation.nsw.gov.au/#/view/act/2000/92>

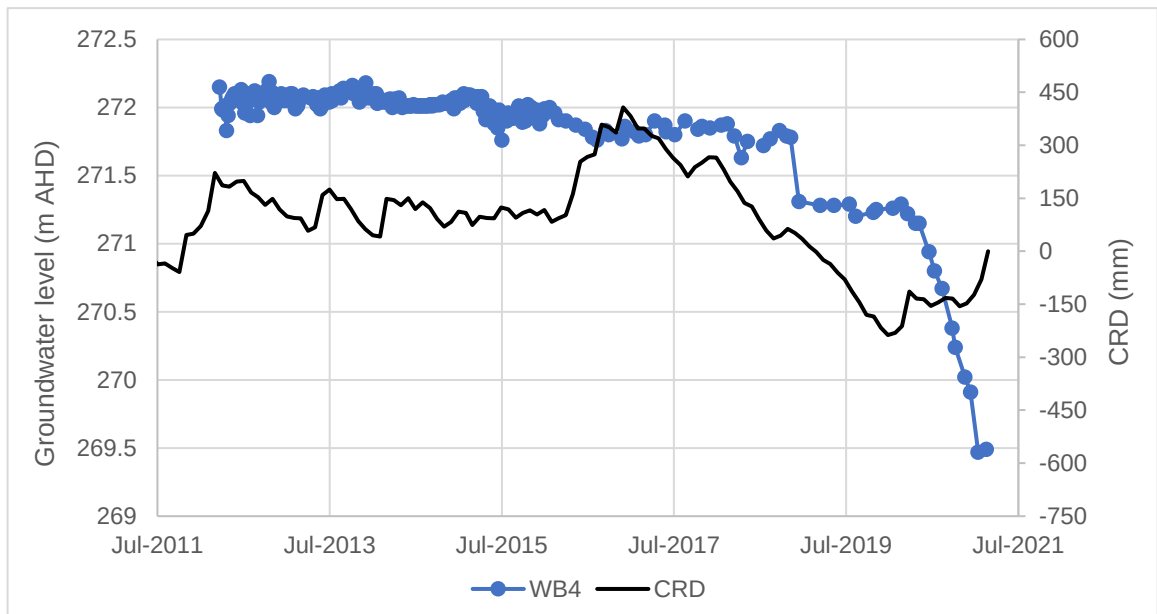
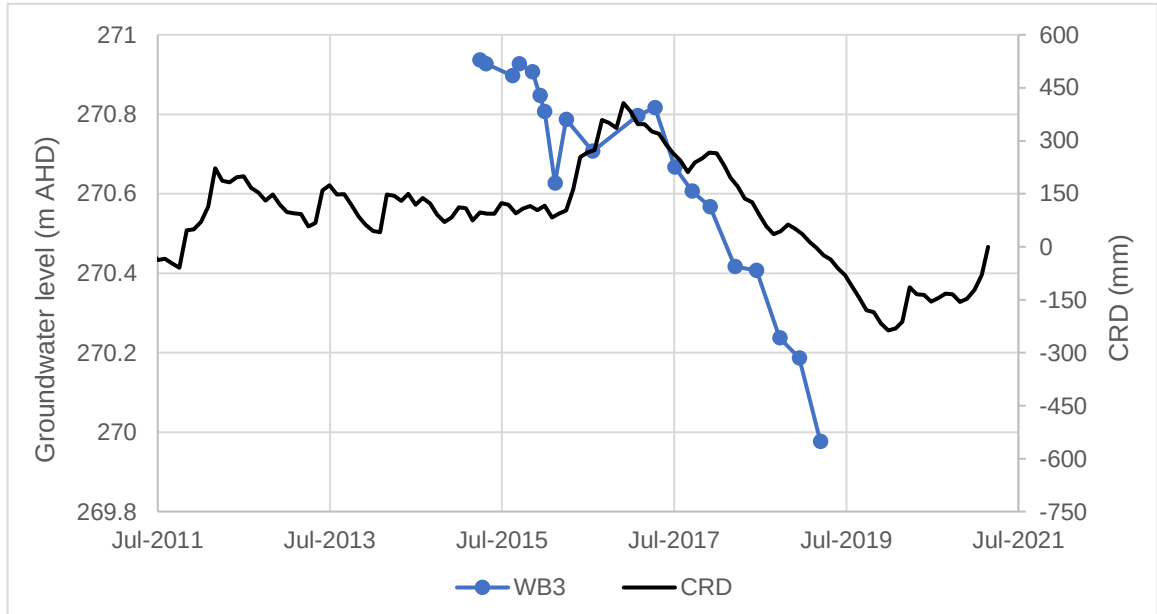
Water NSW (2021) *Real time data*. Retrieved from <https://realtimedata.watnsw.com.au/>

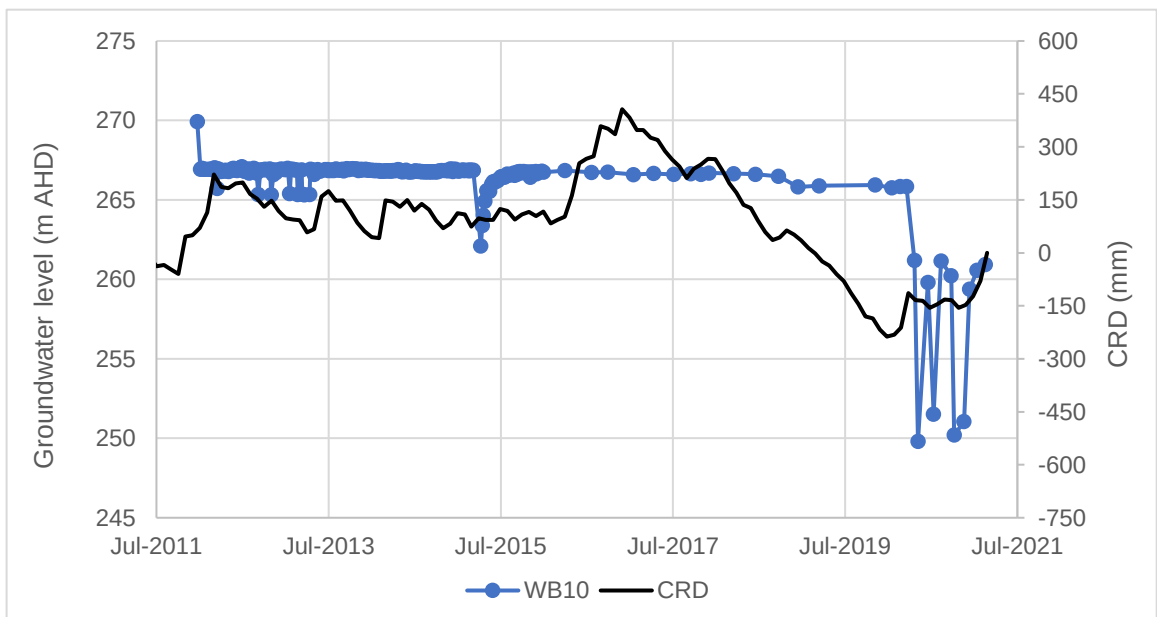
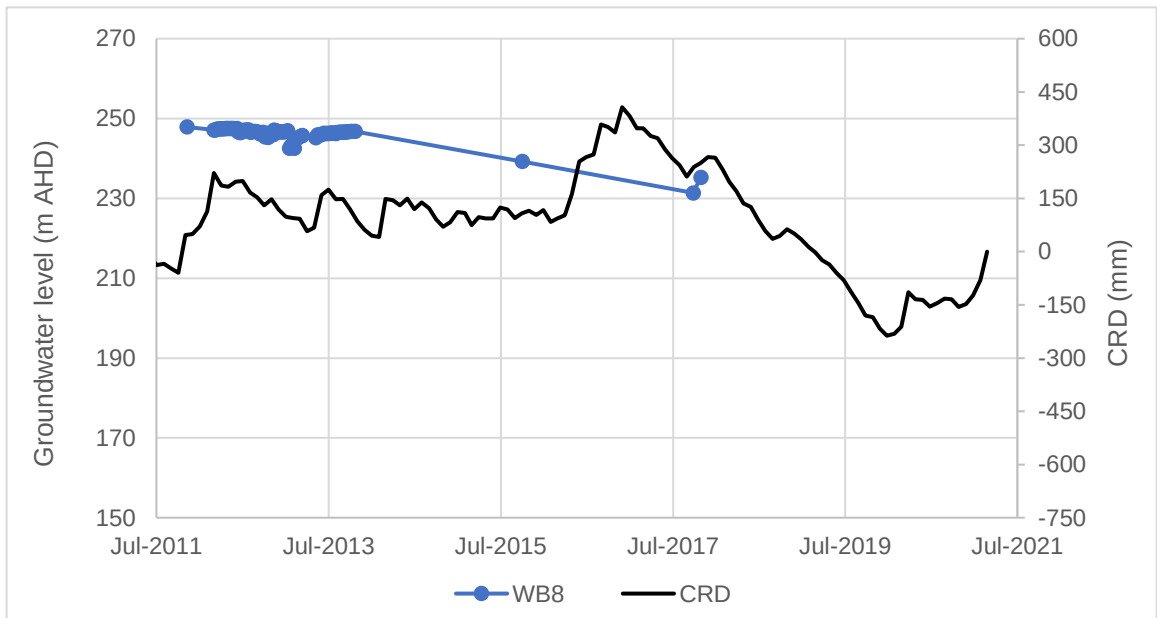
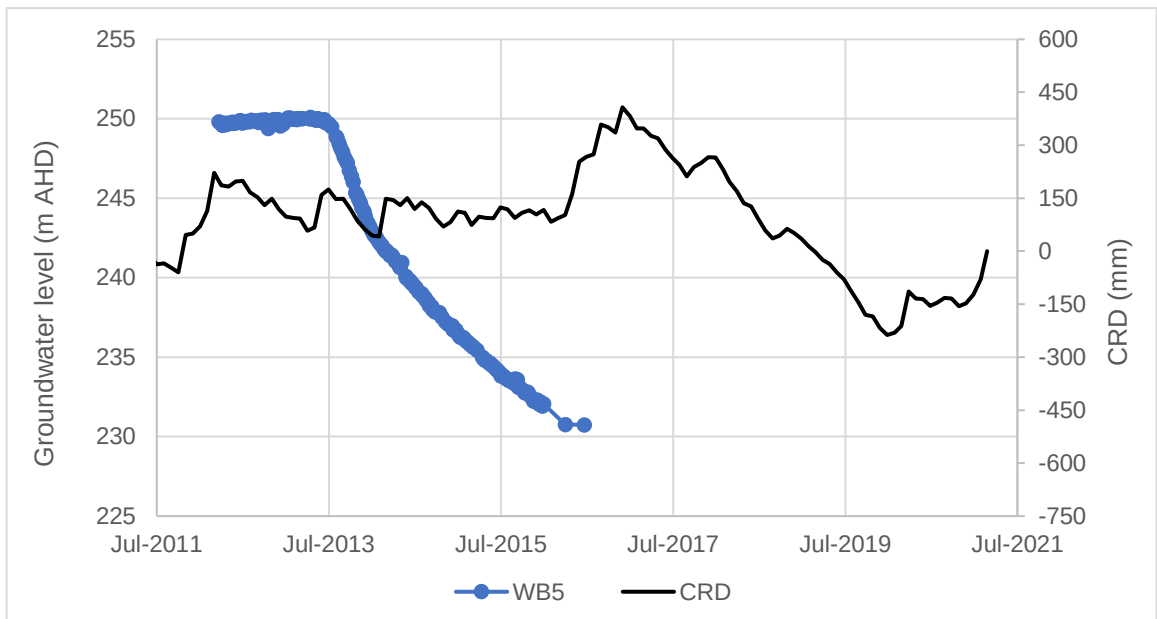
Appendices

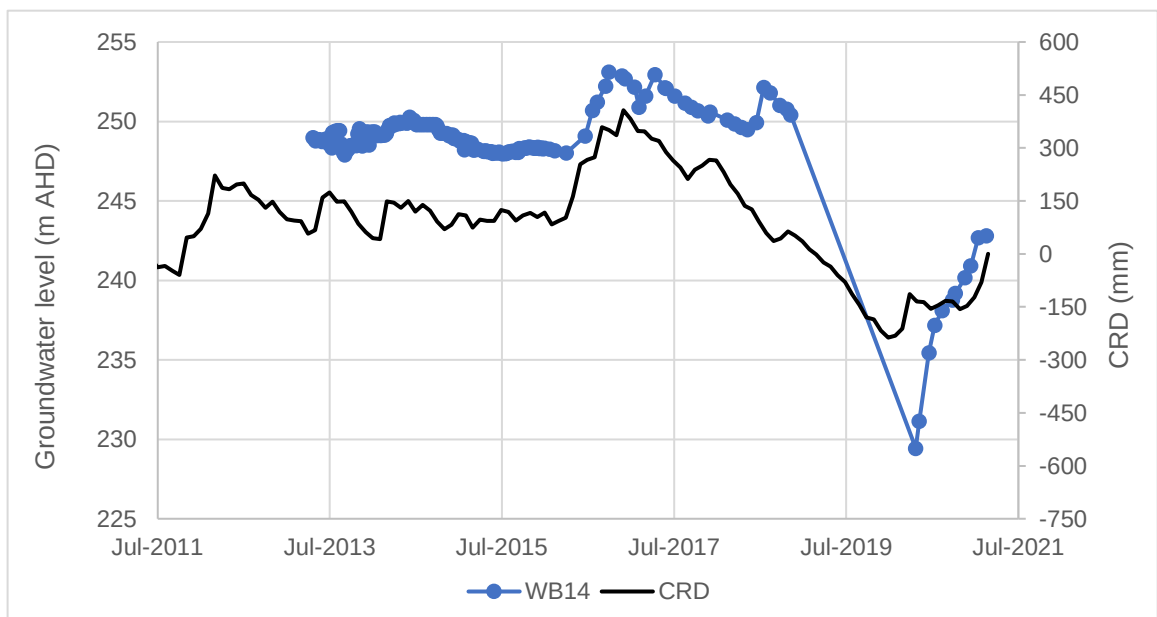
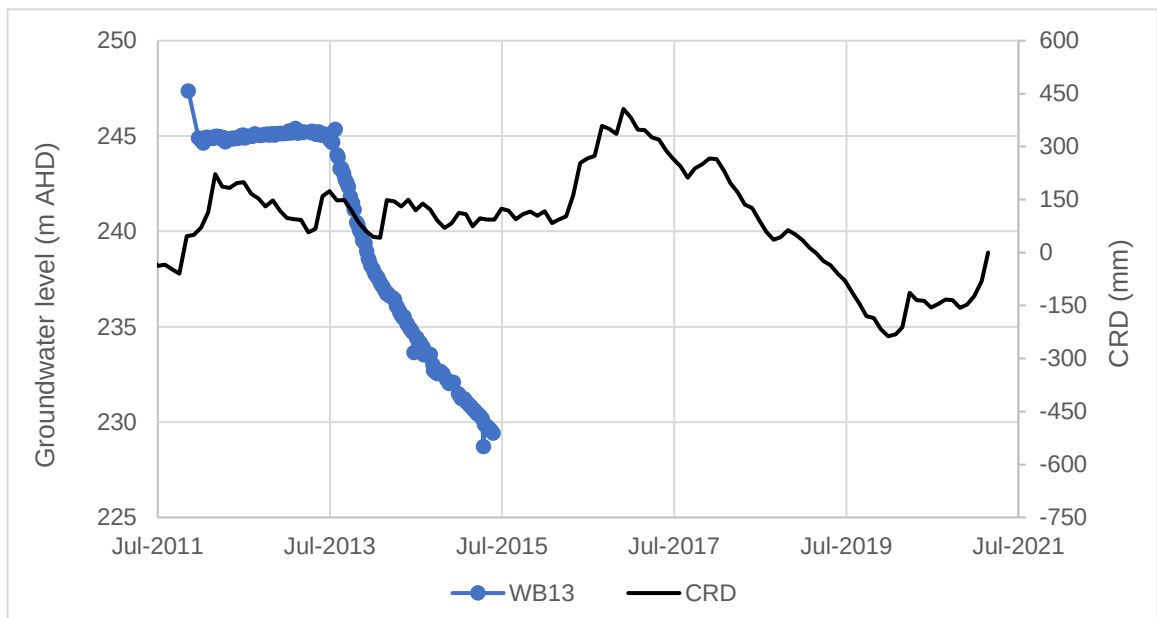
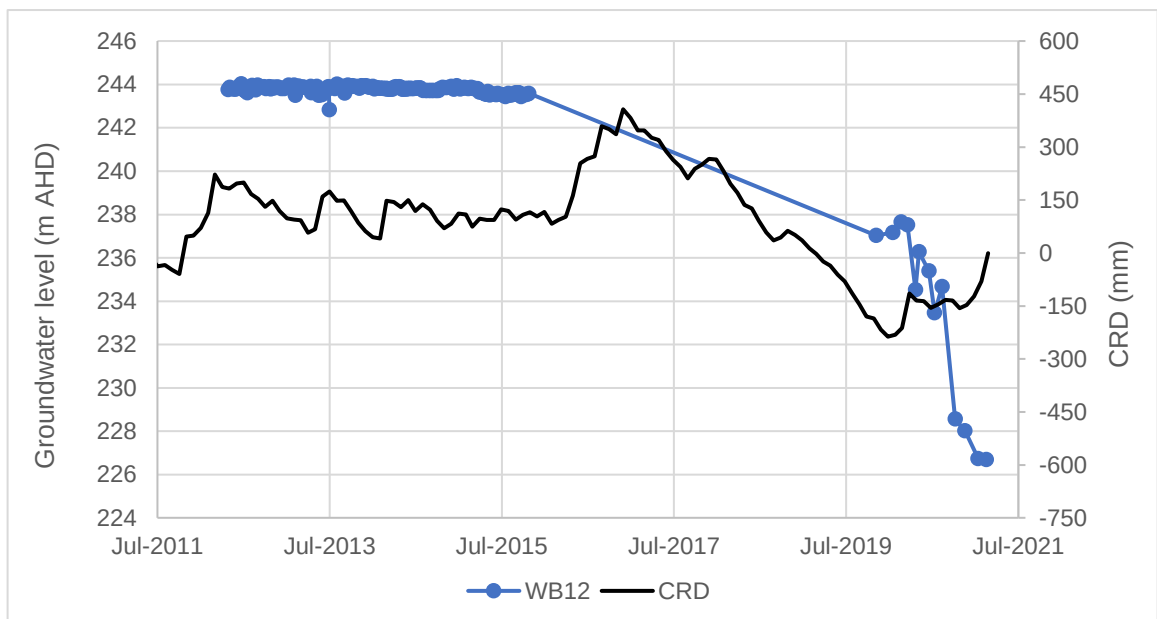
Appendix A

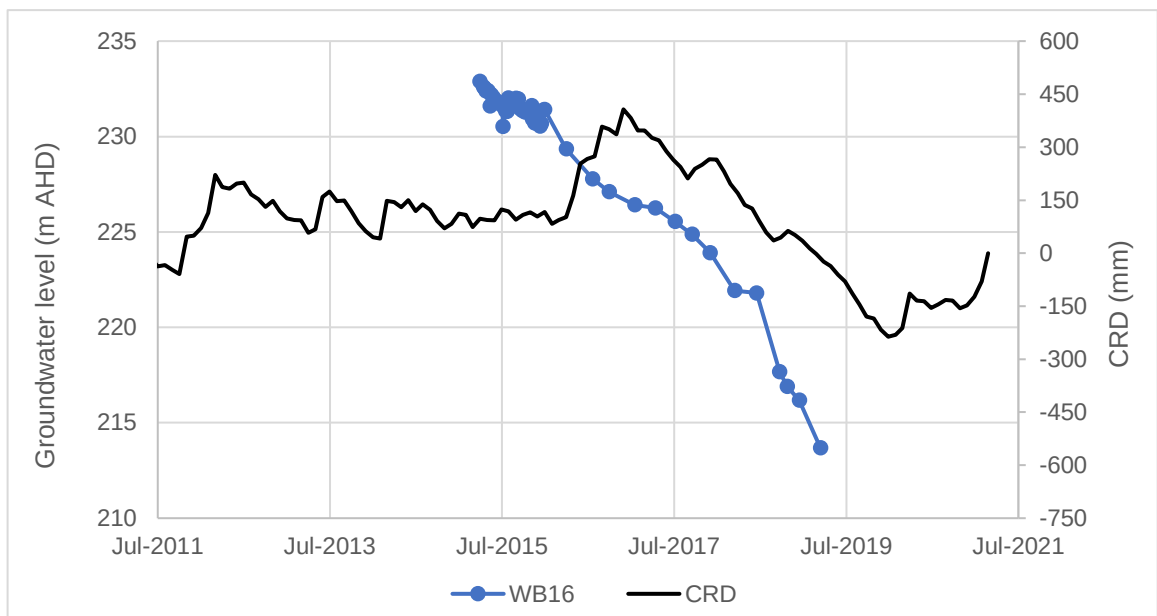
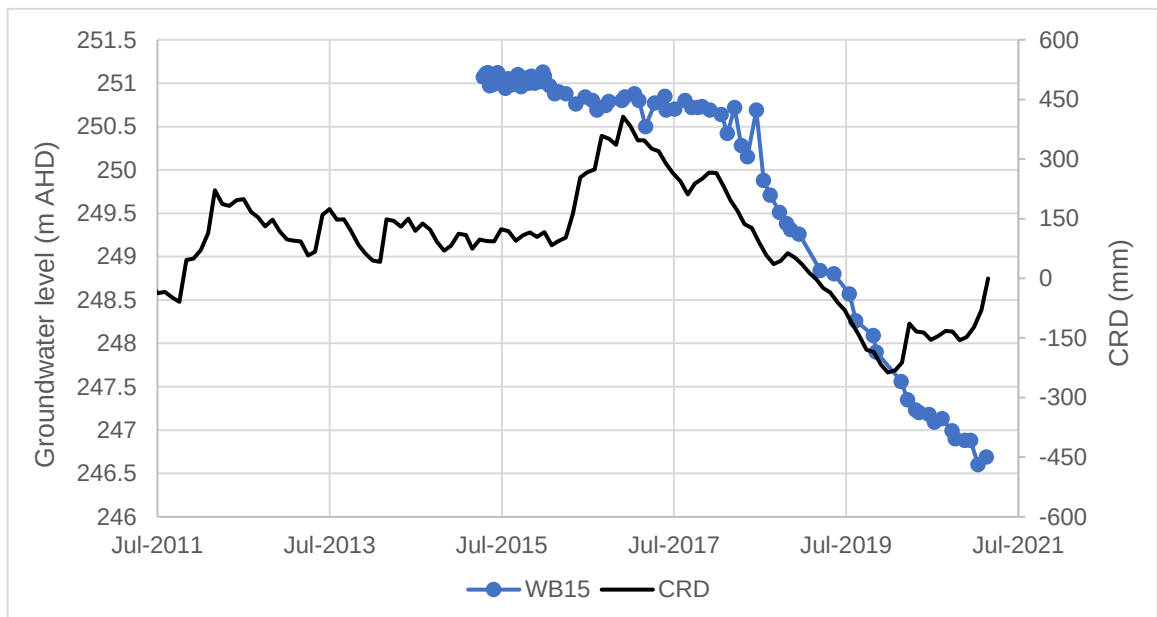
Groundwater level monitoring data

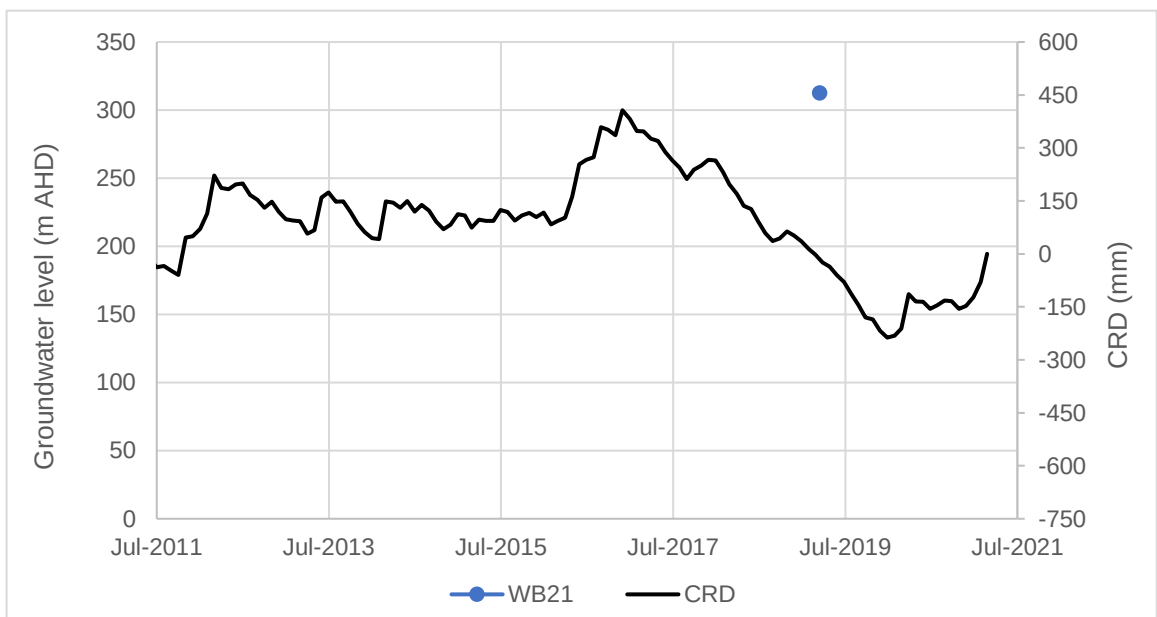
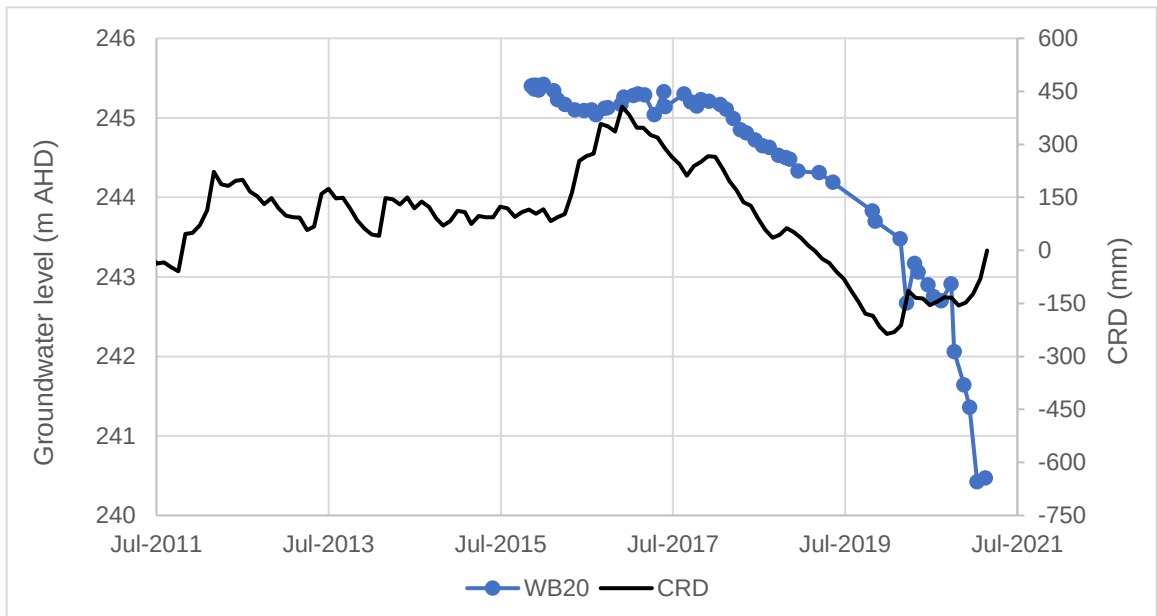
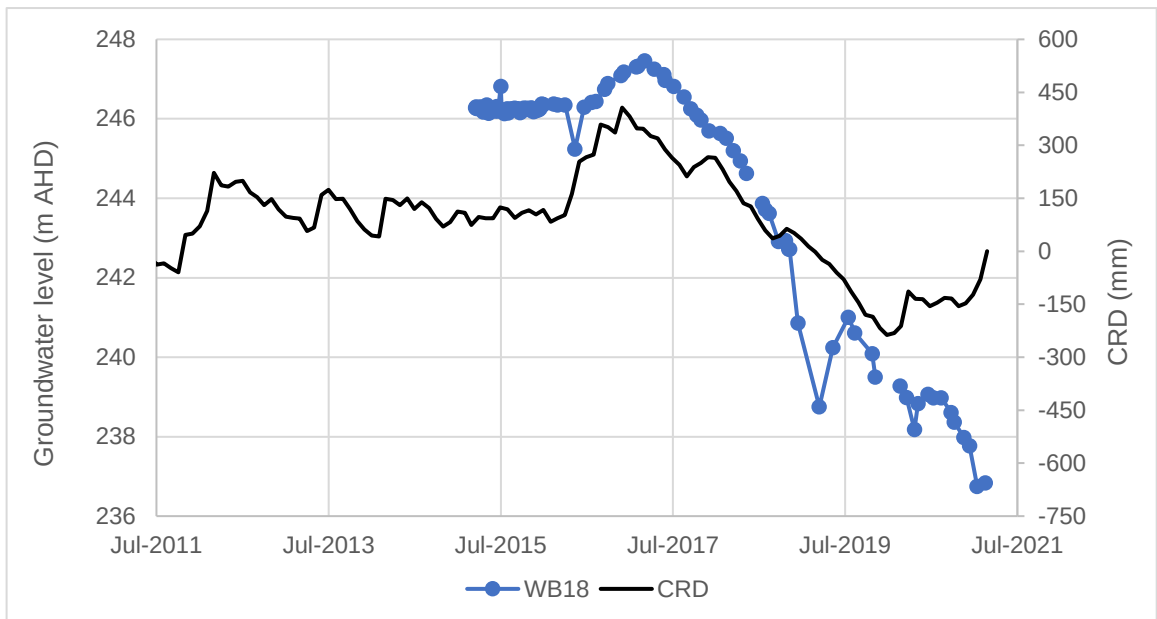
Hera Mine

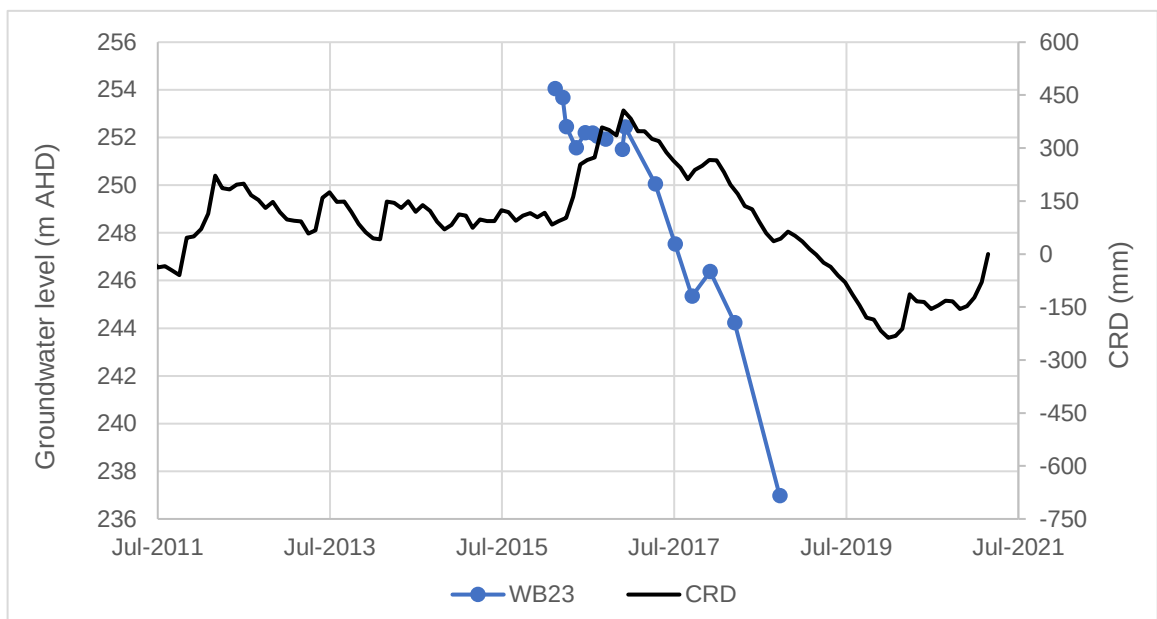
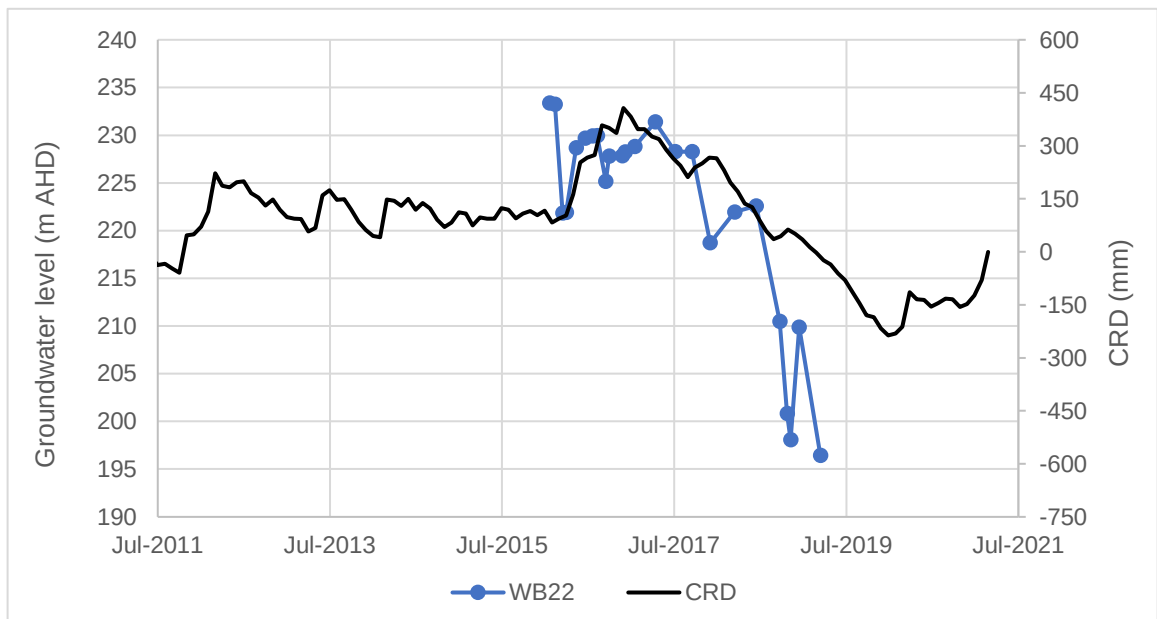


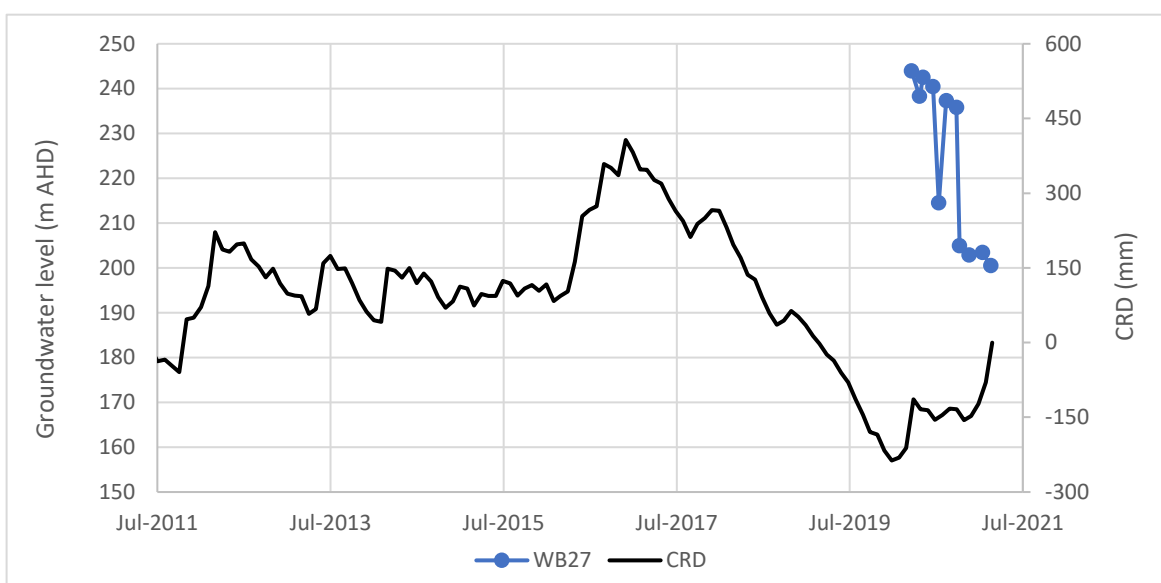
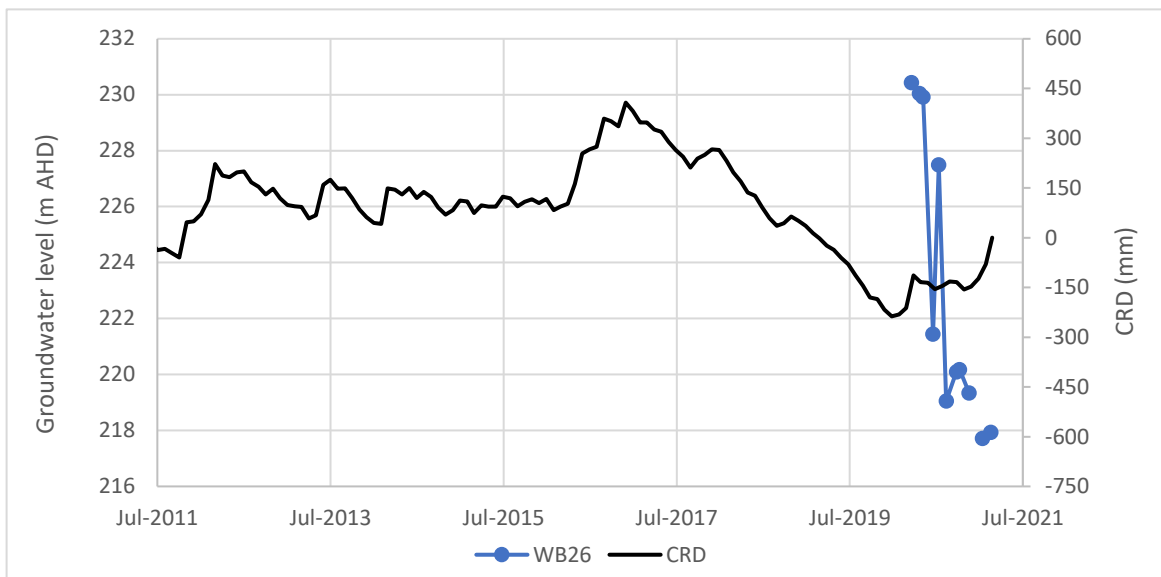
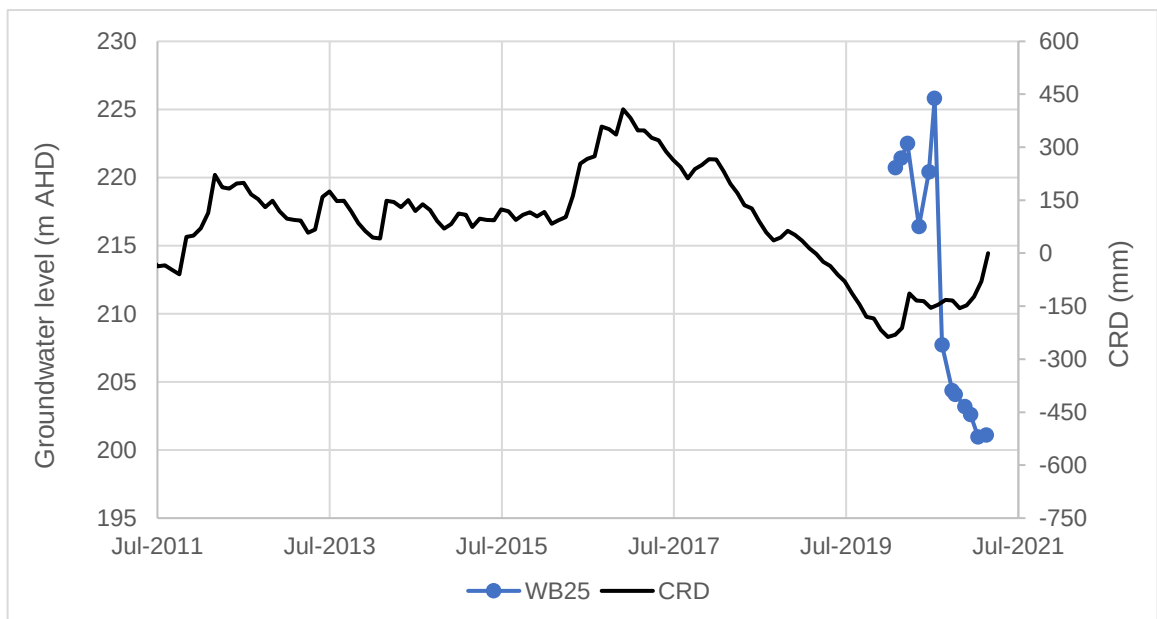


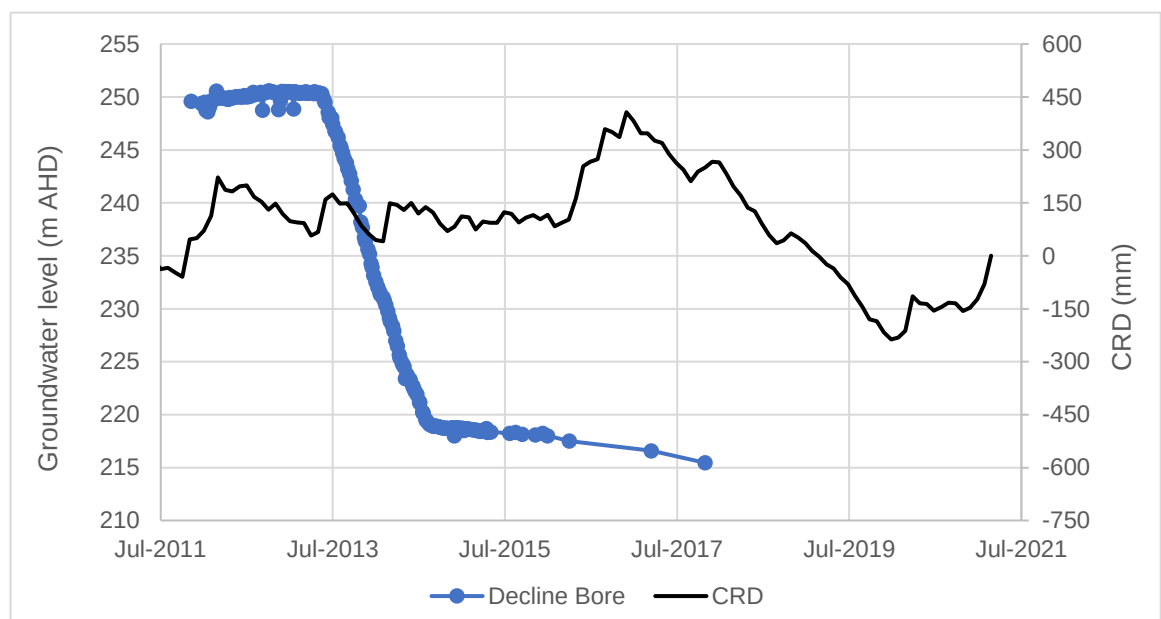
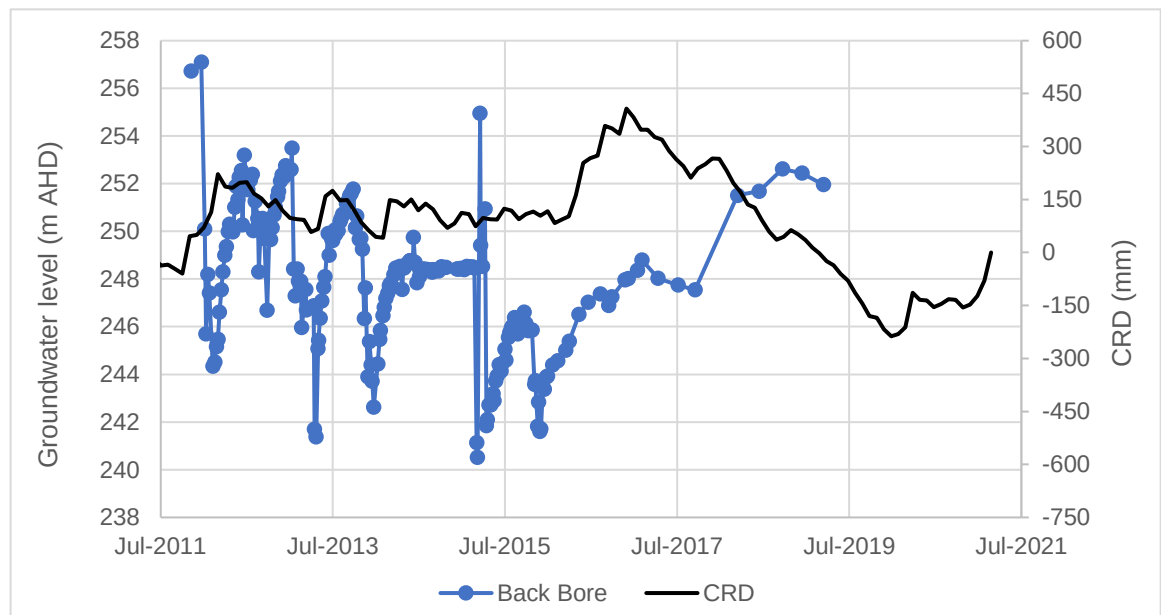
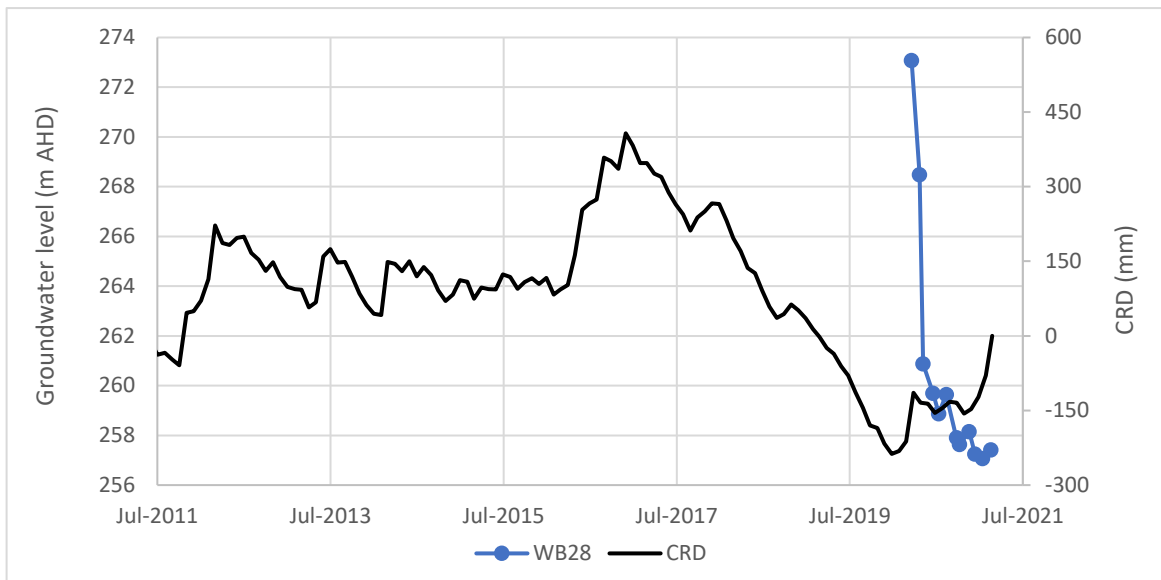


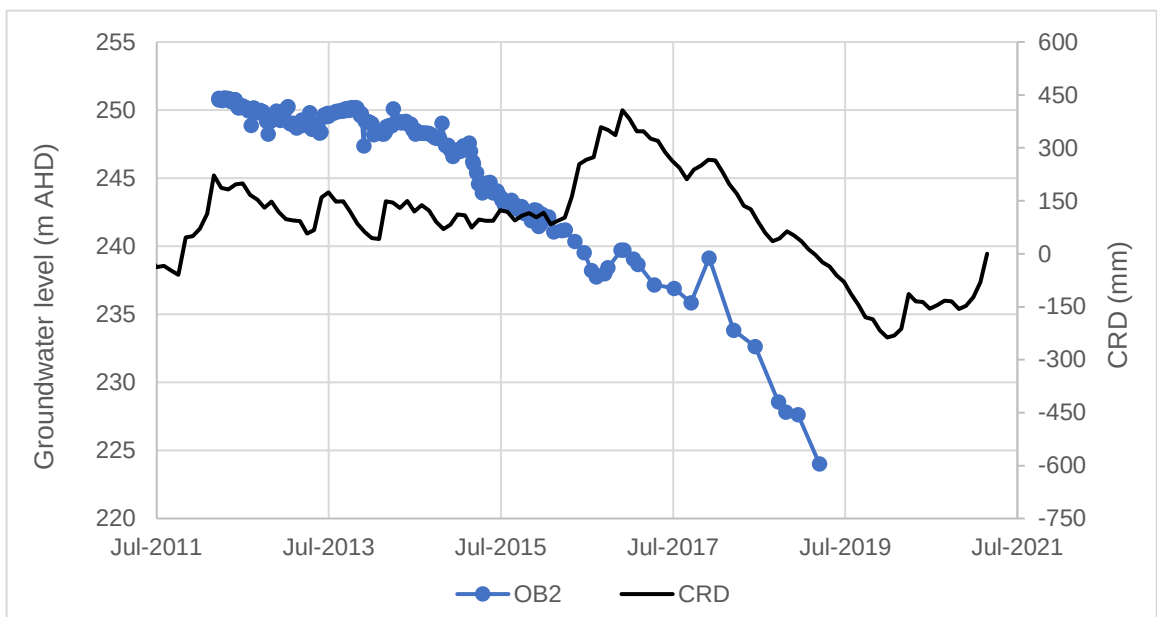
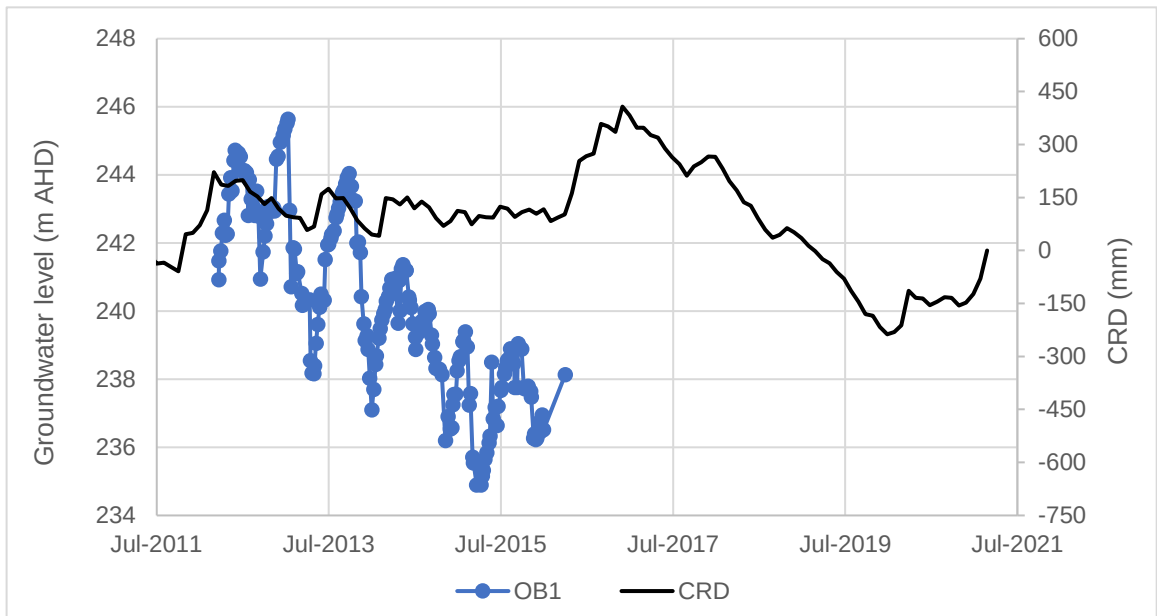
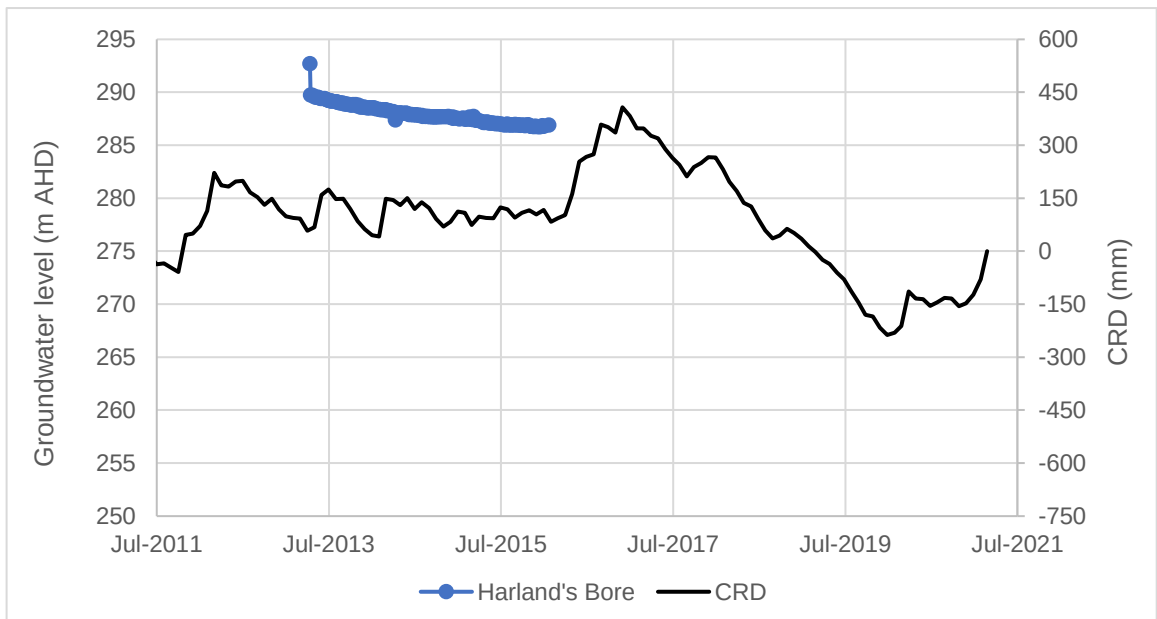


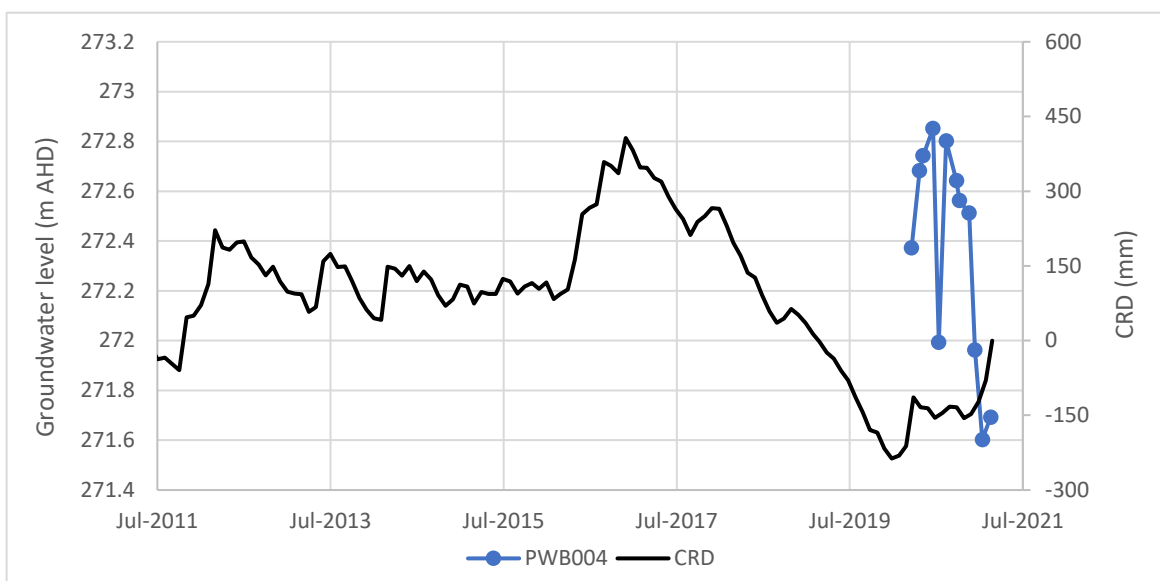
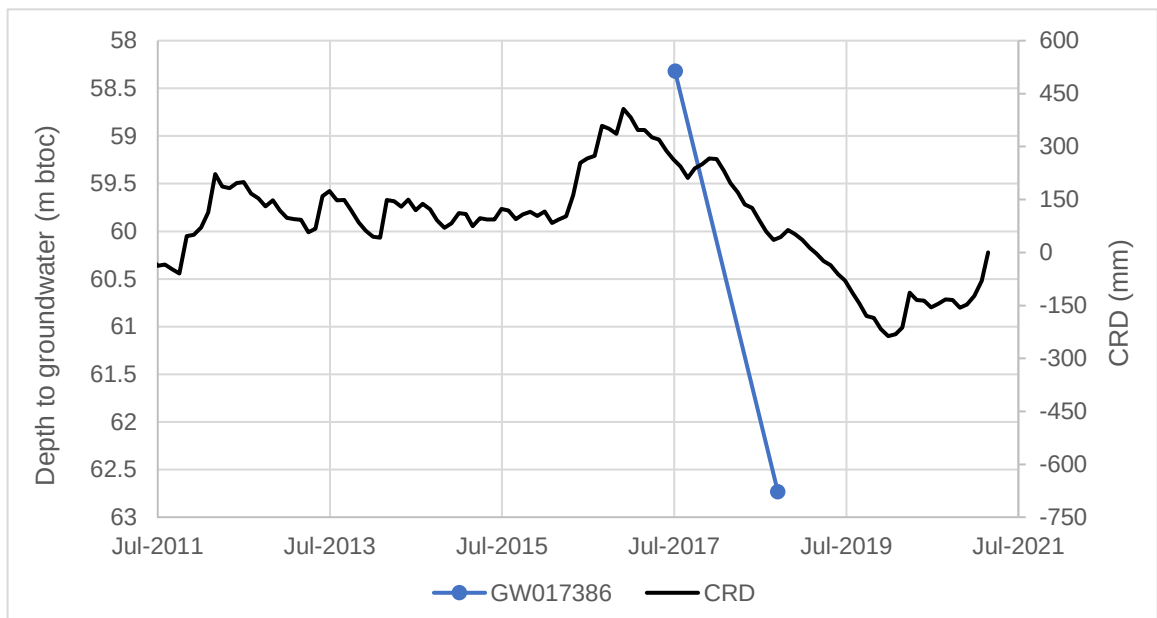
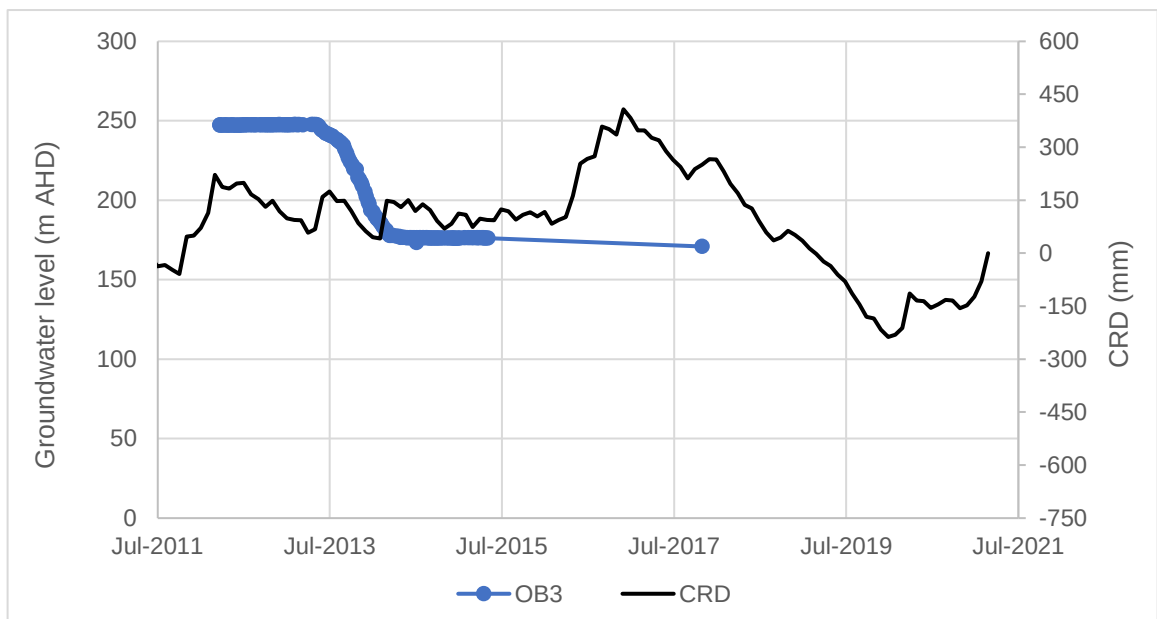


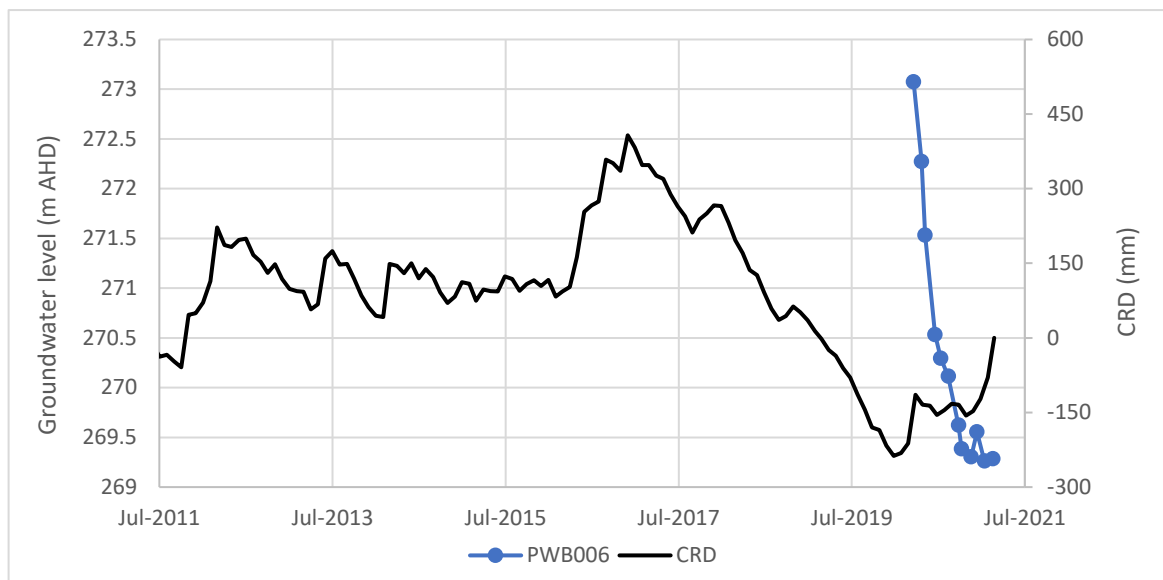




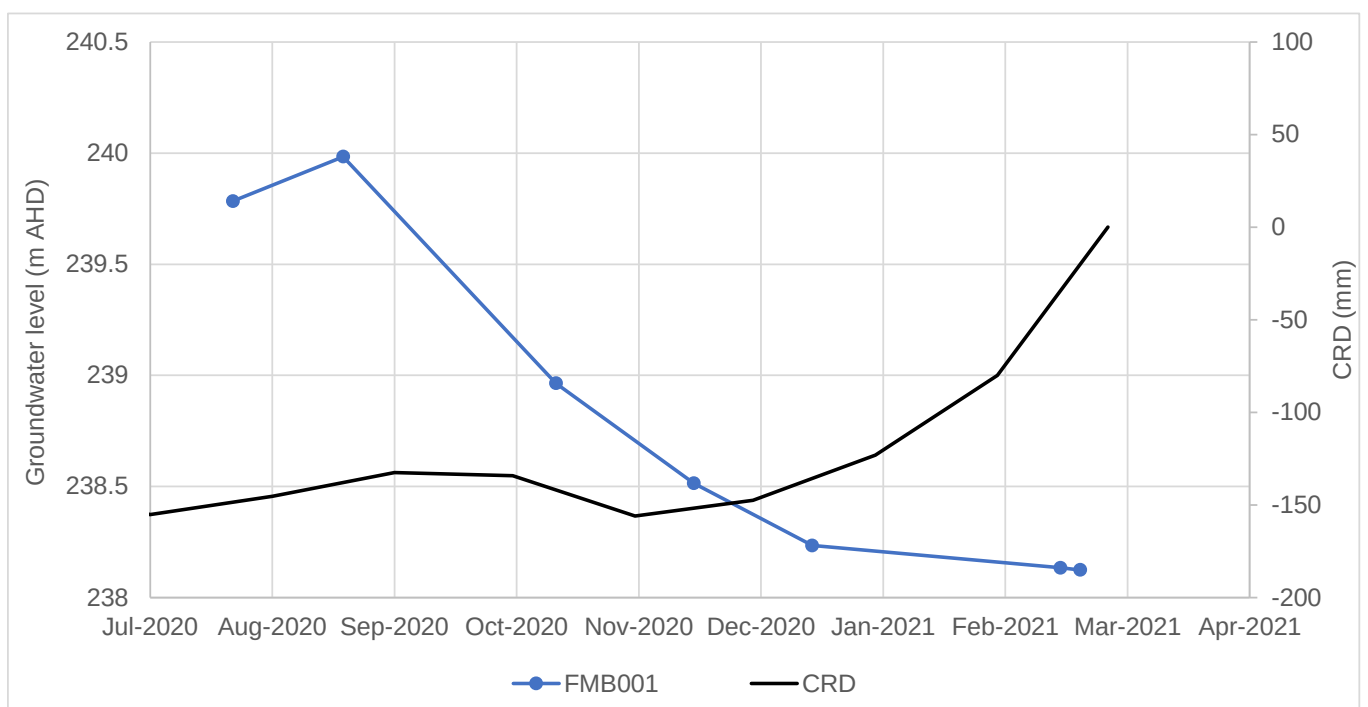


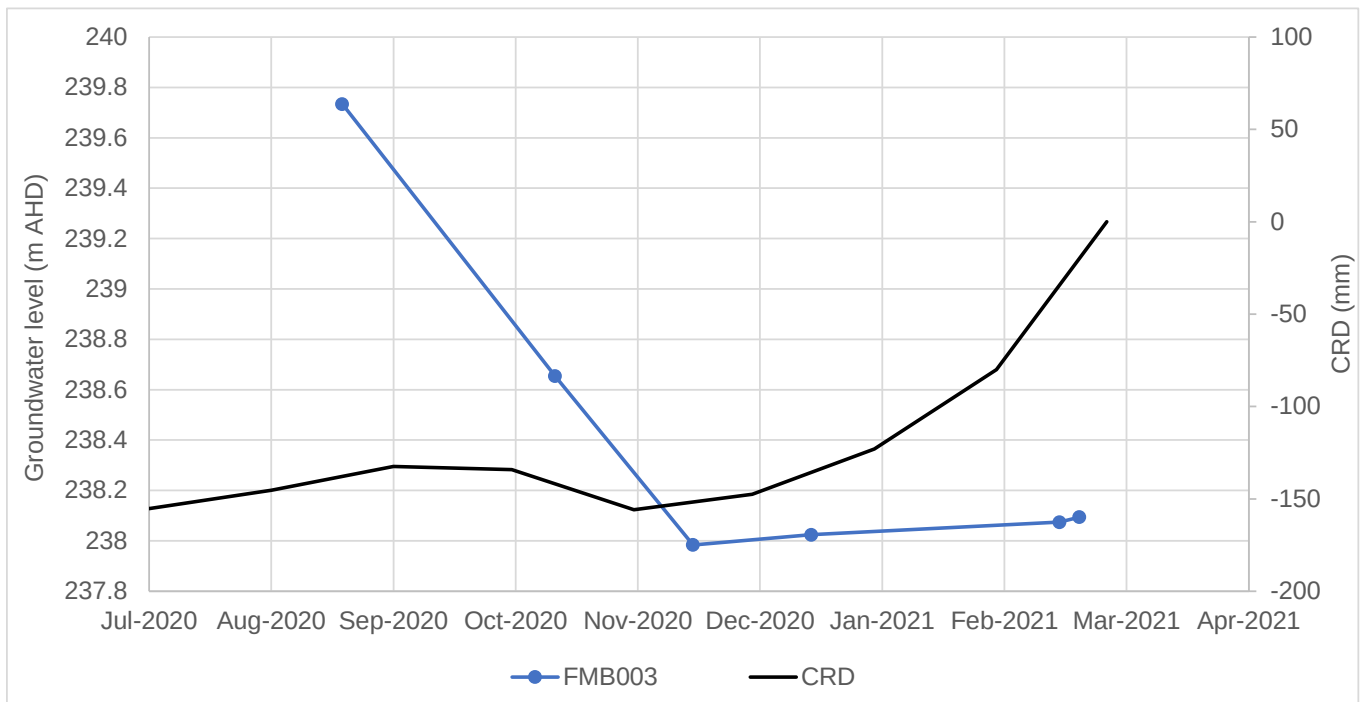
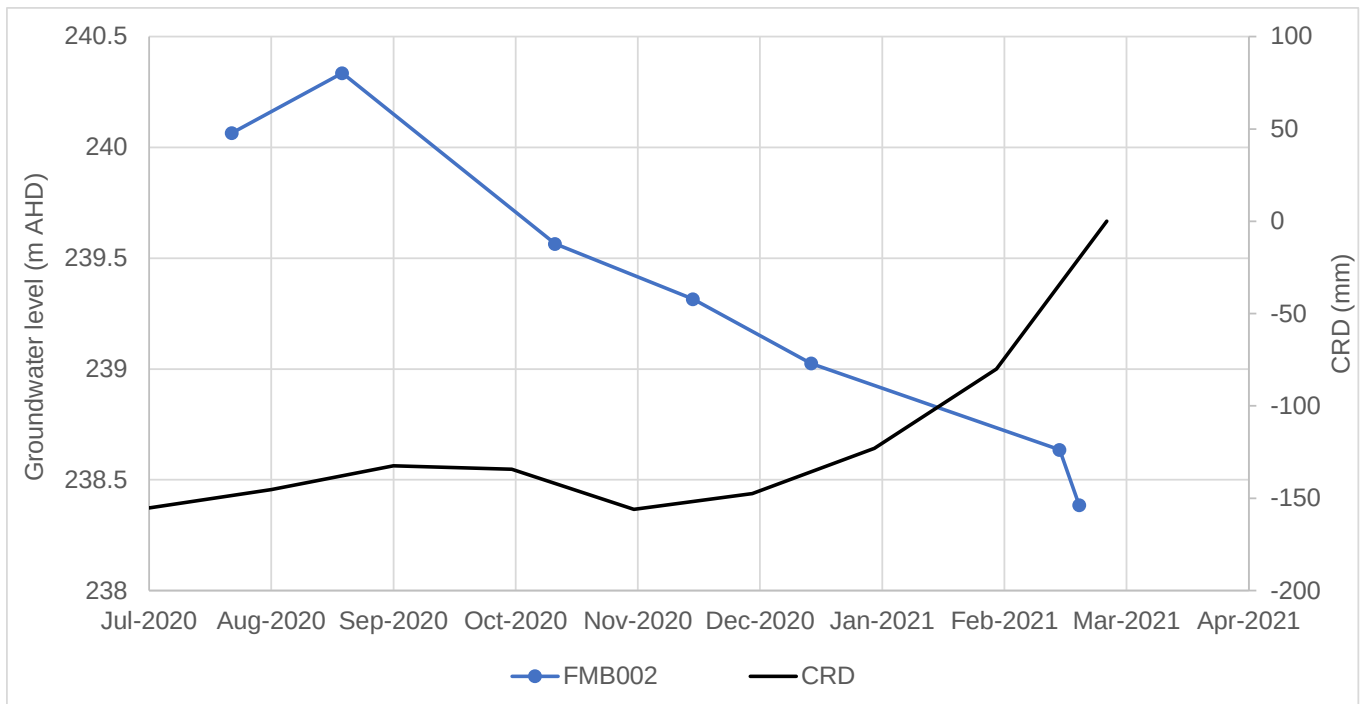


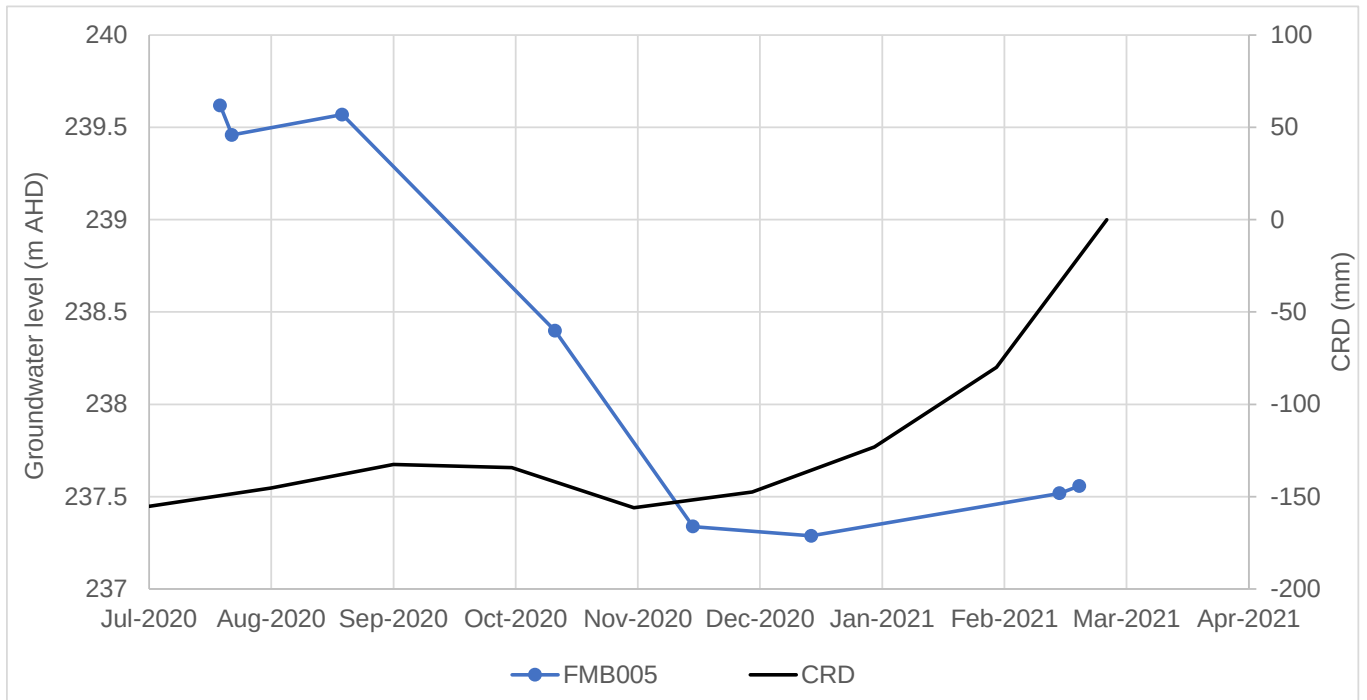
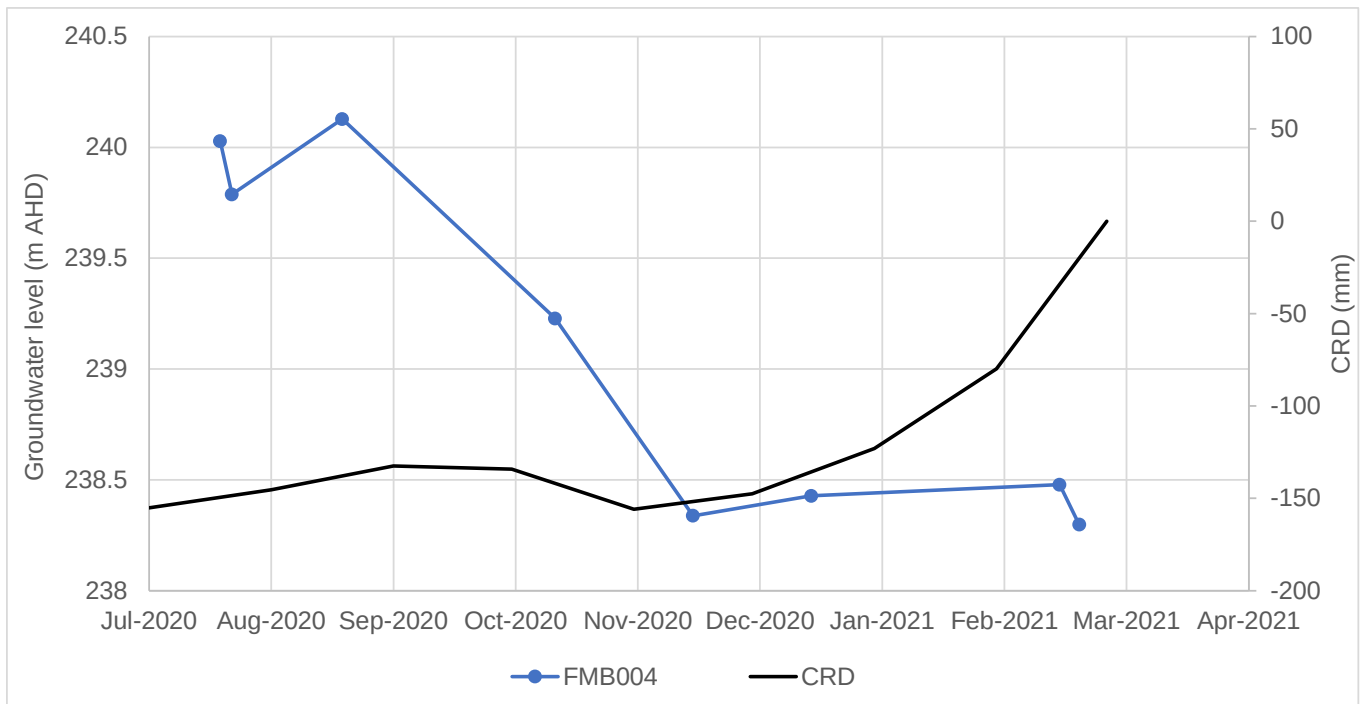


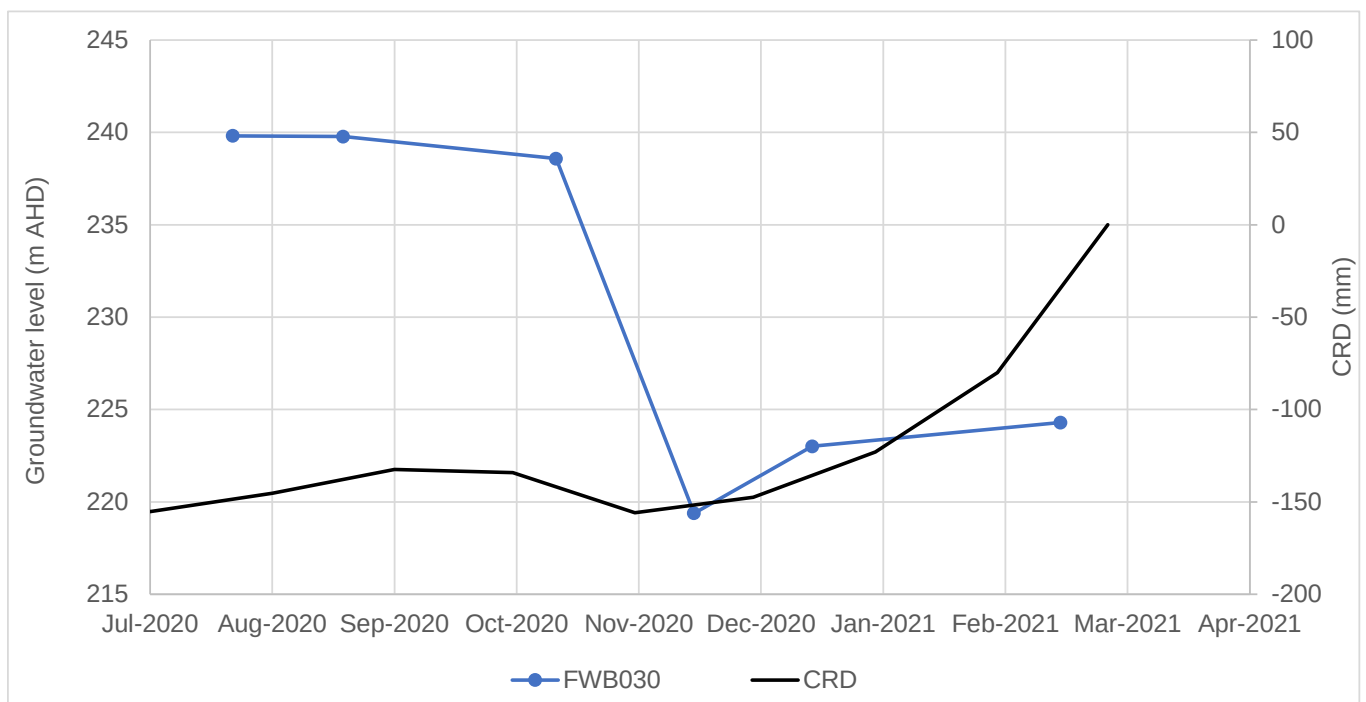
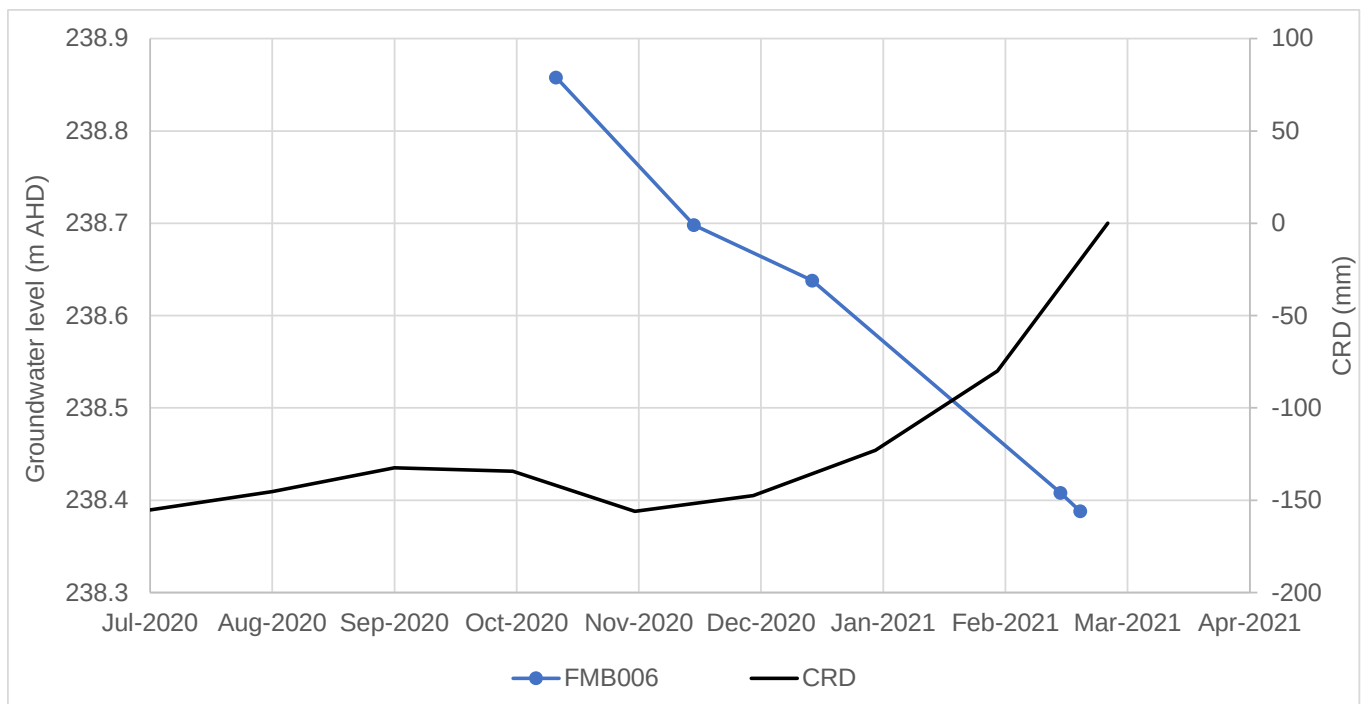


Federation

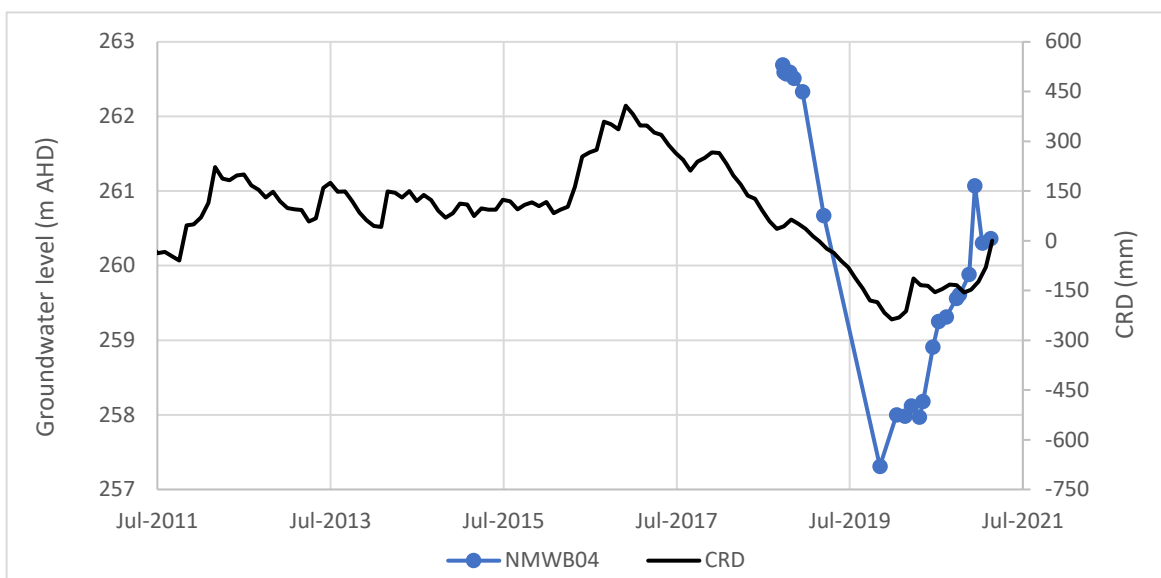
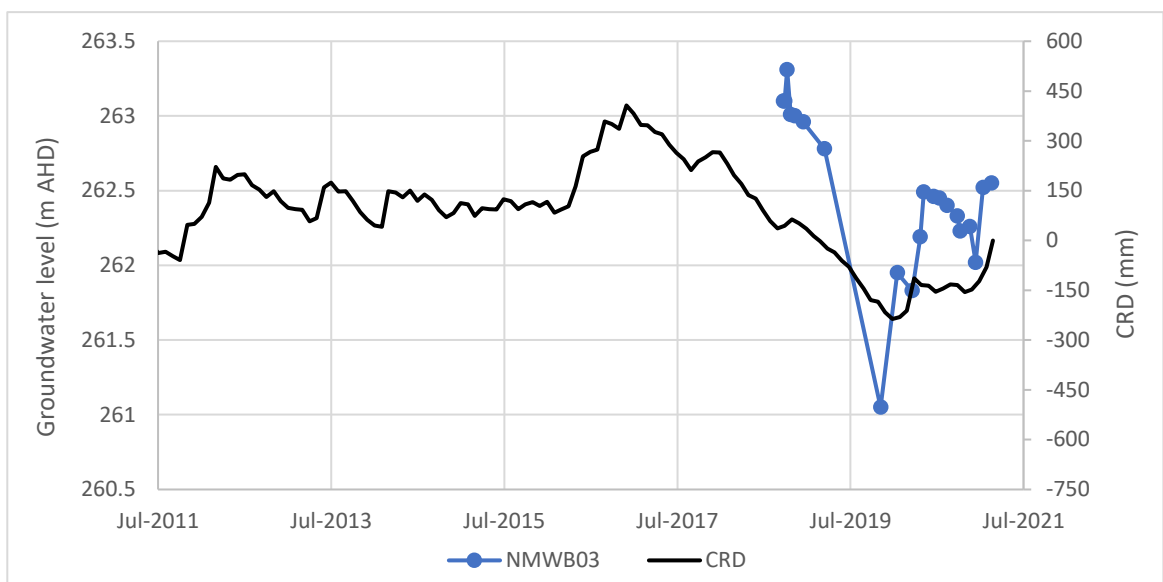
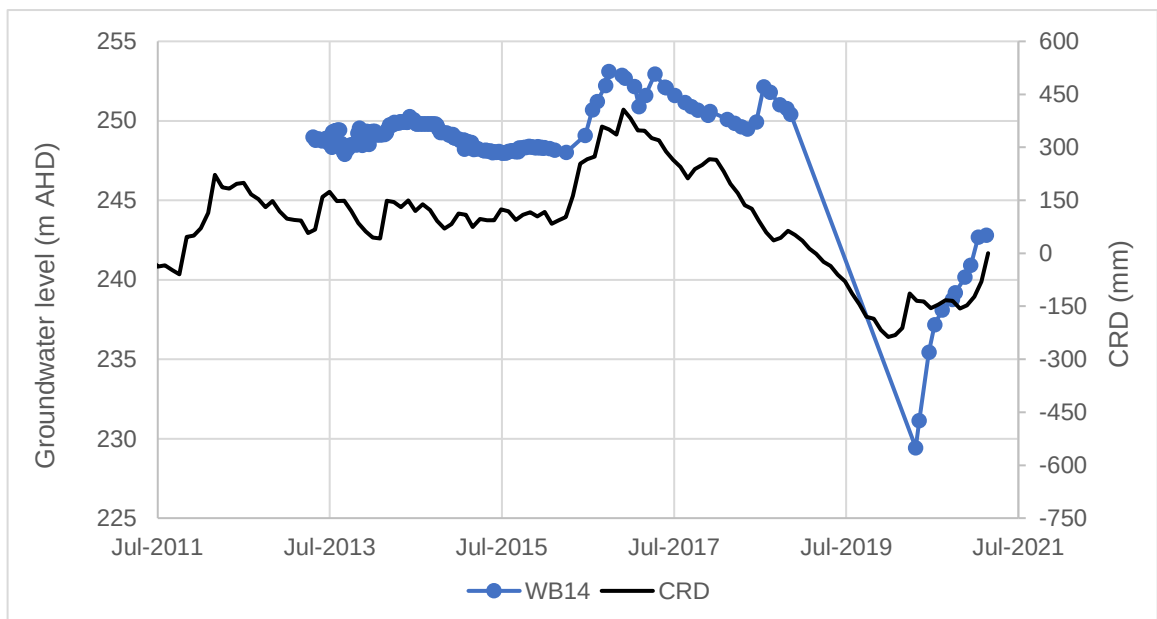


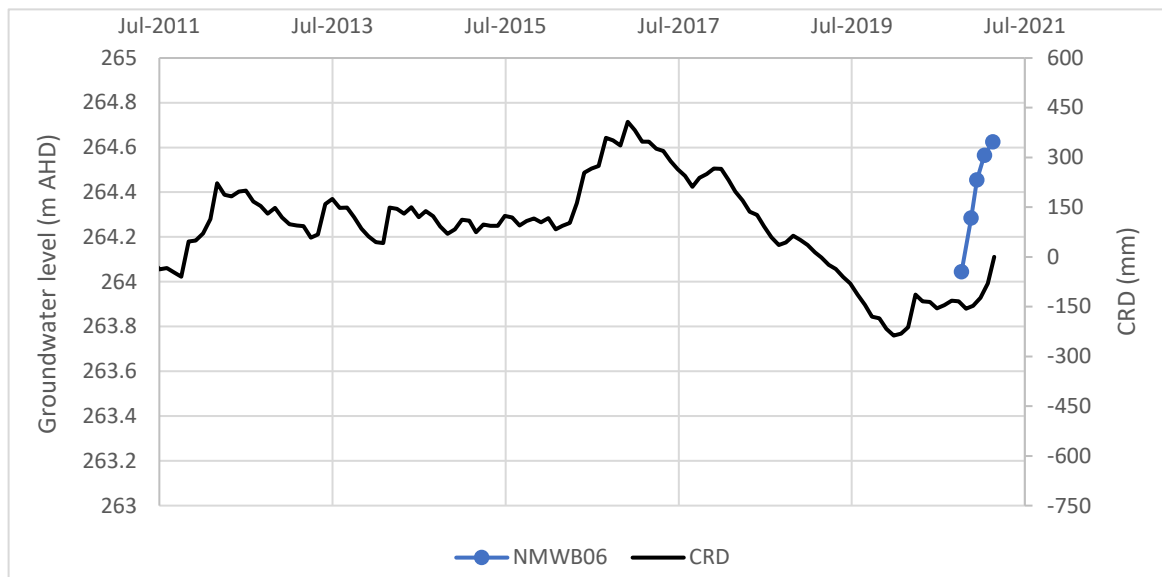
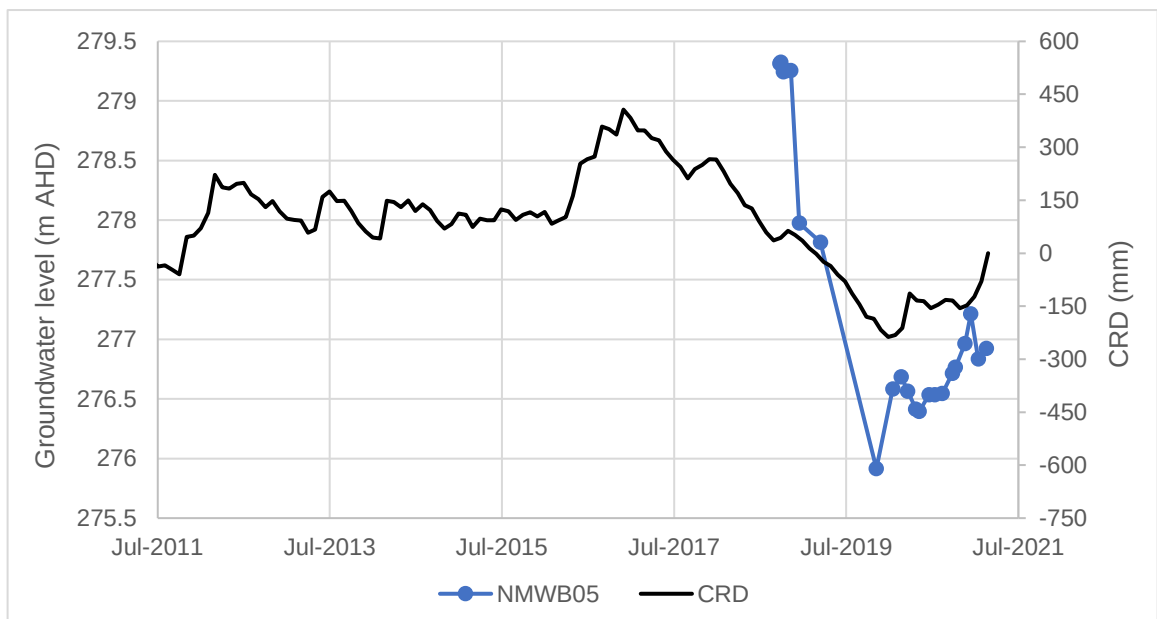






Nymagee Mine



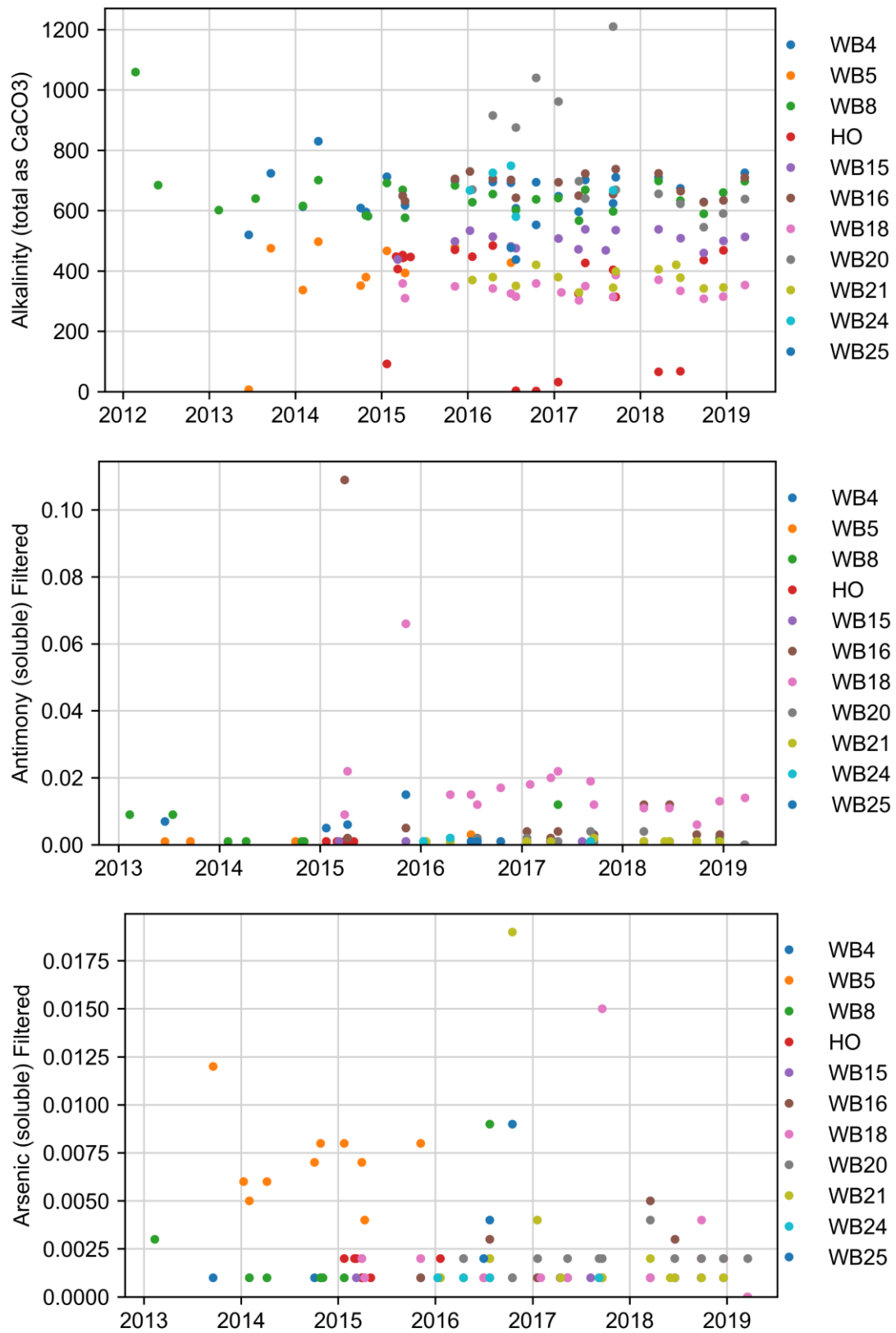


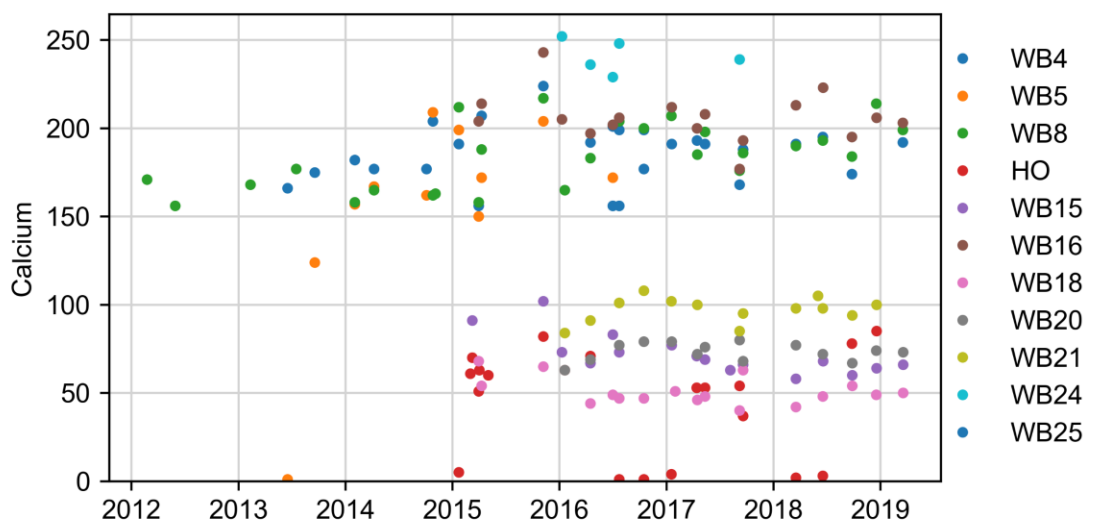
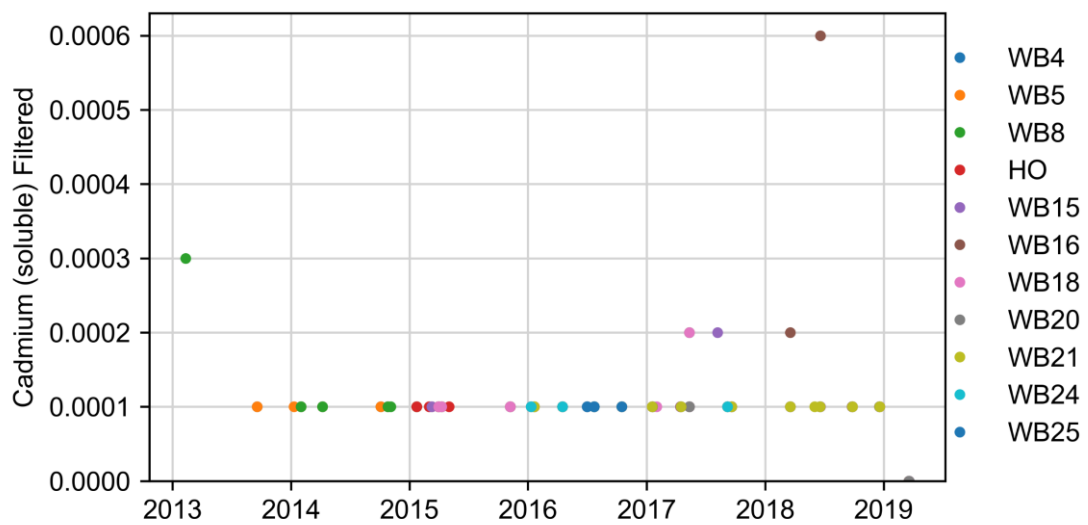
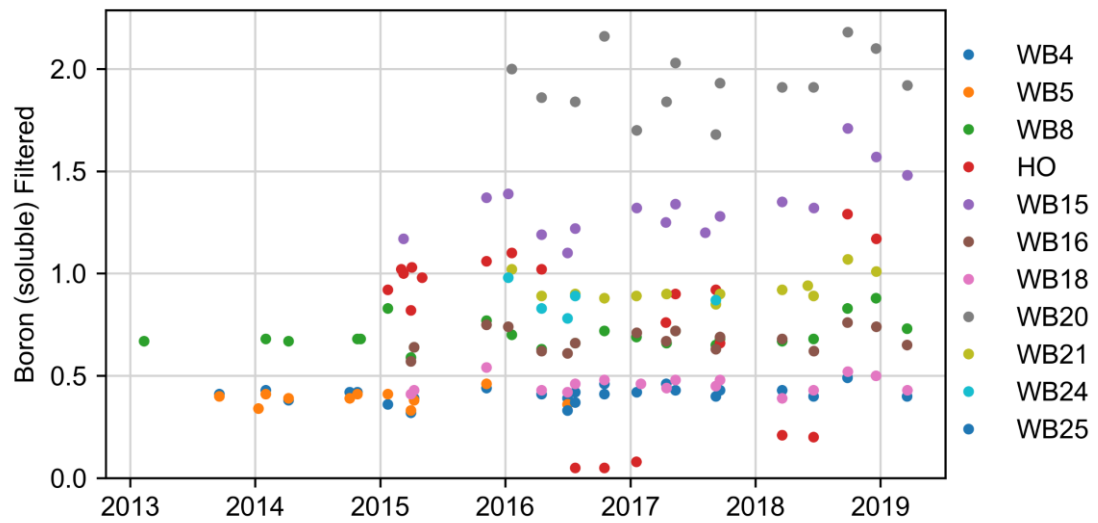
Appendix B

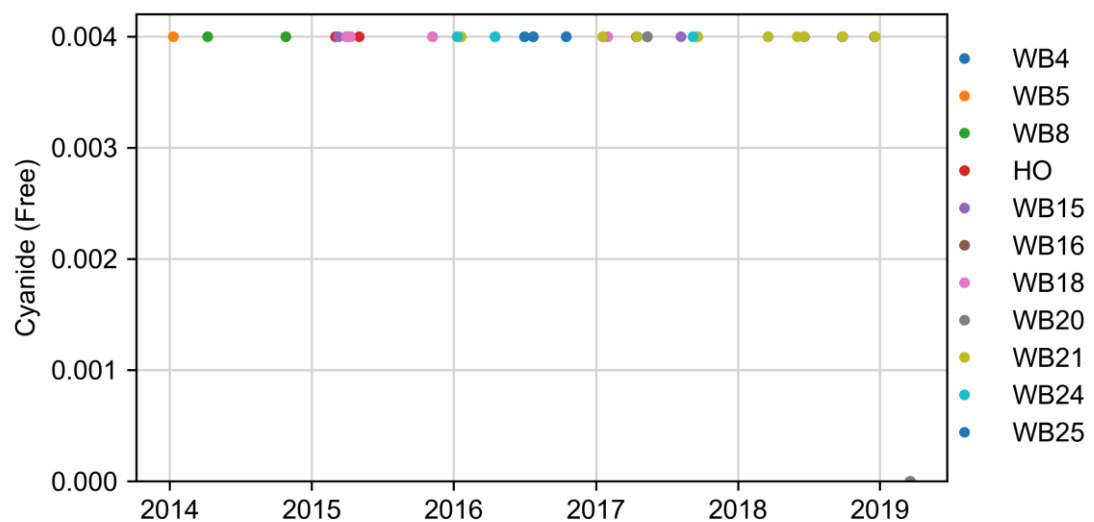
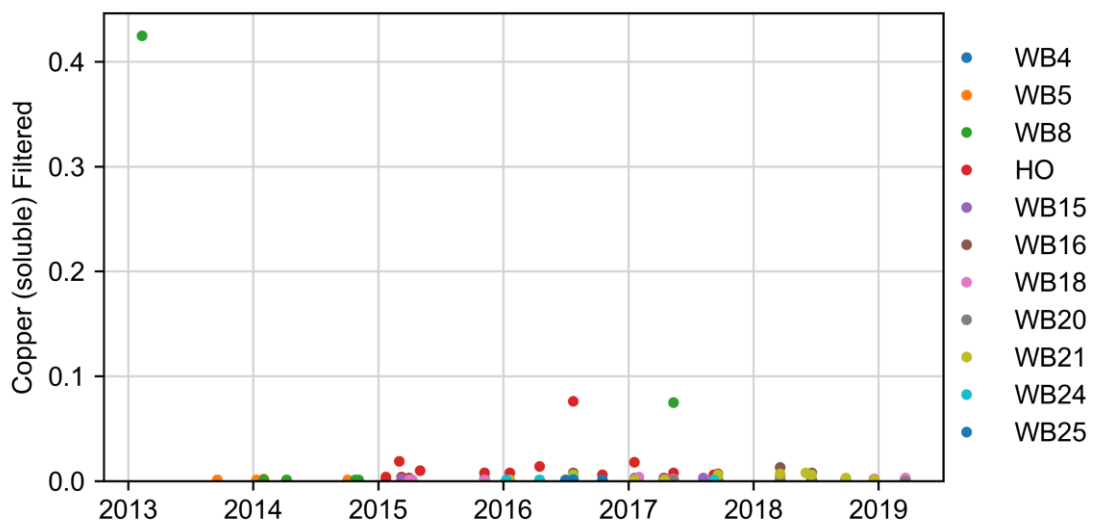
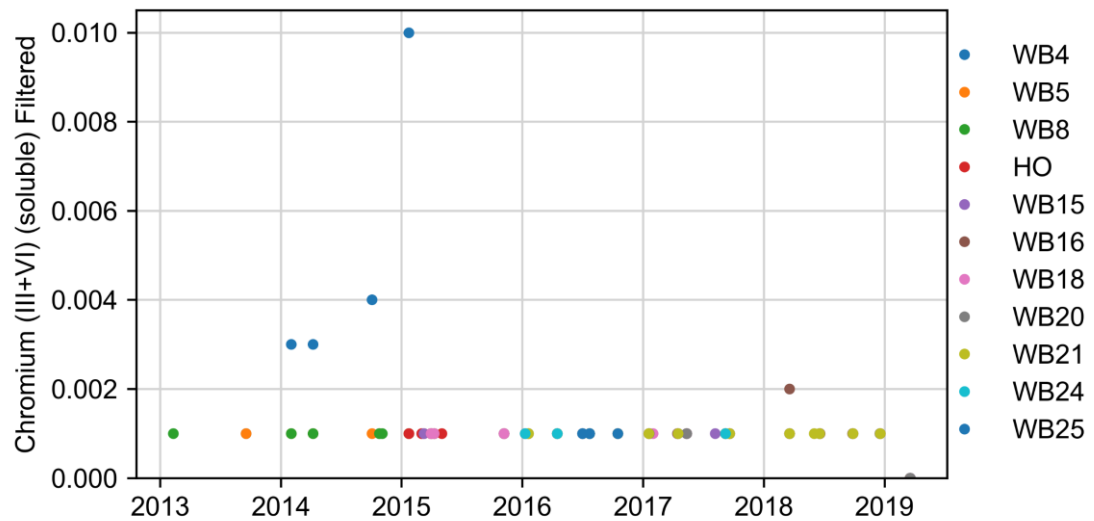
Groundwater quality data

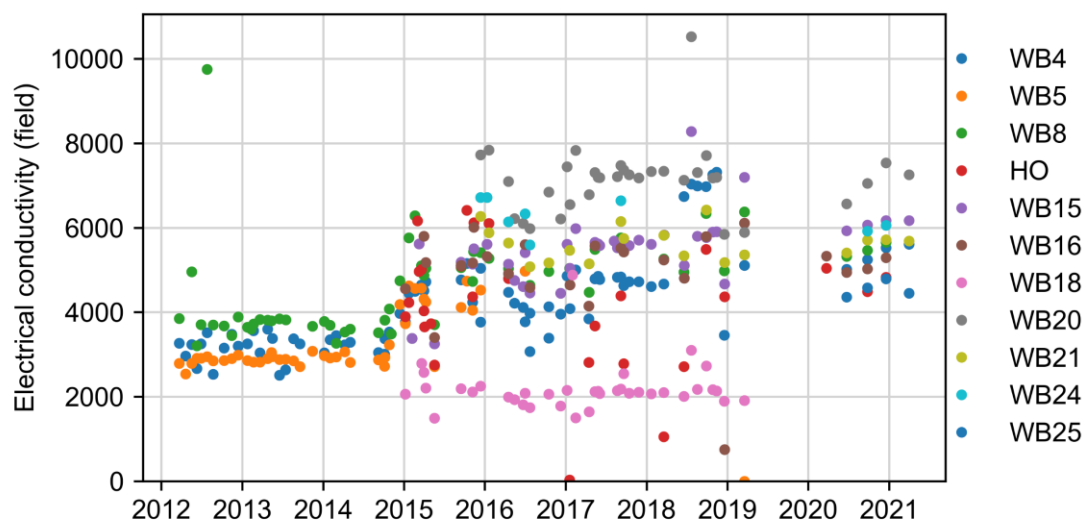
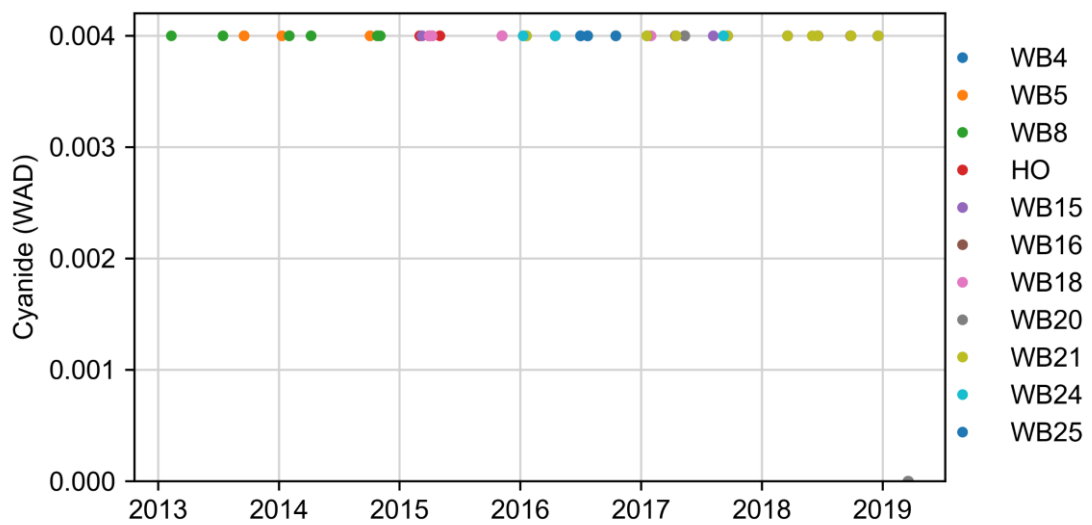
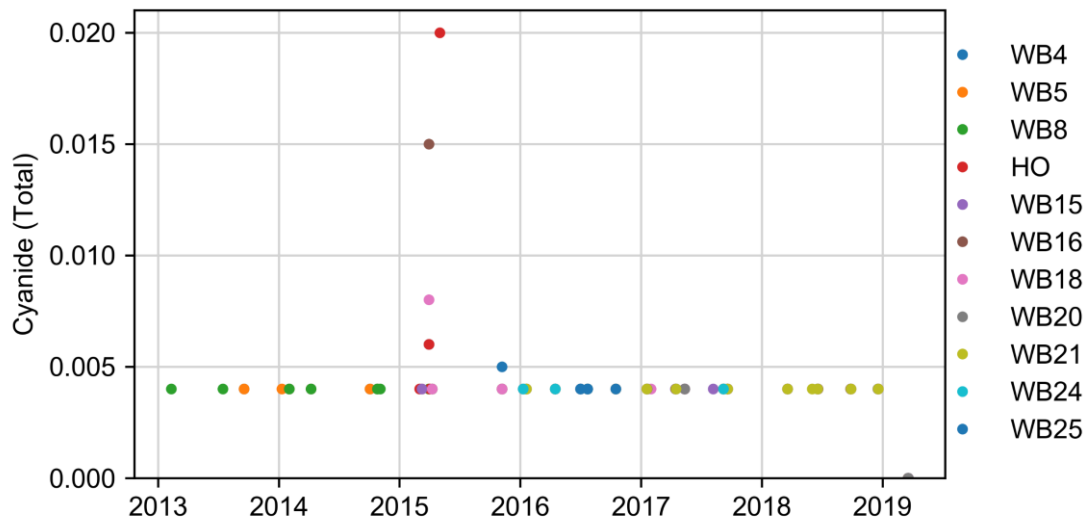
Hera Mine

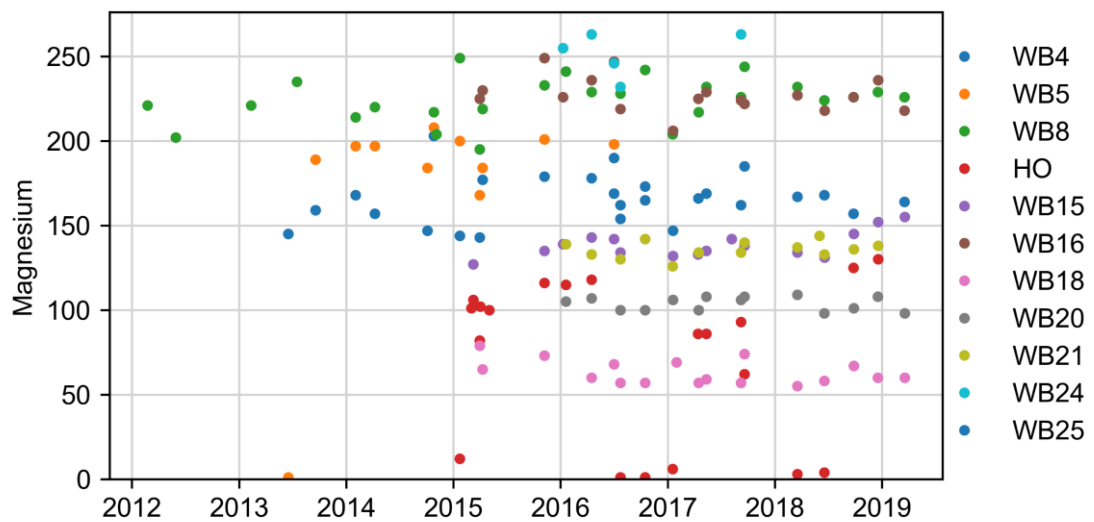
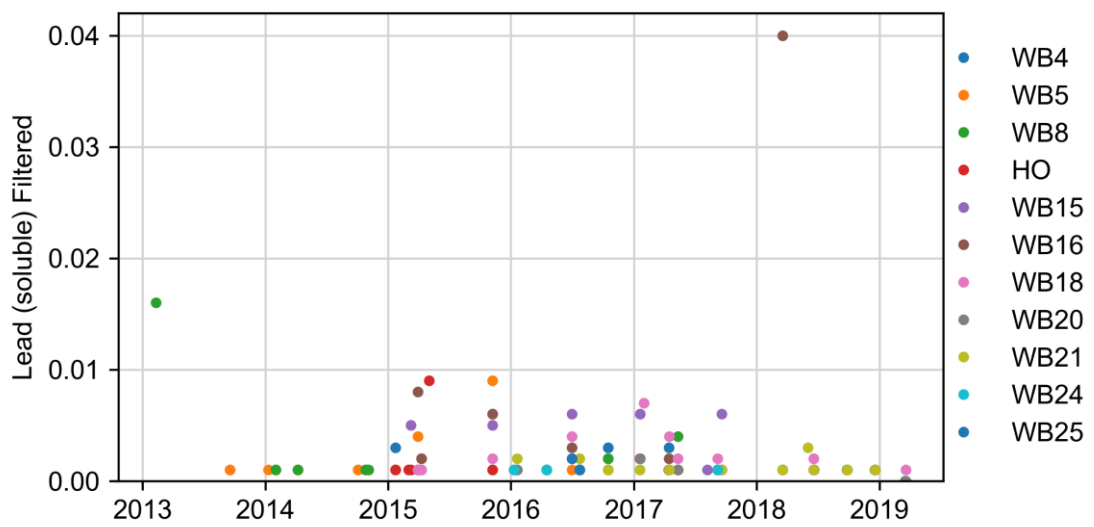
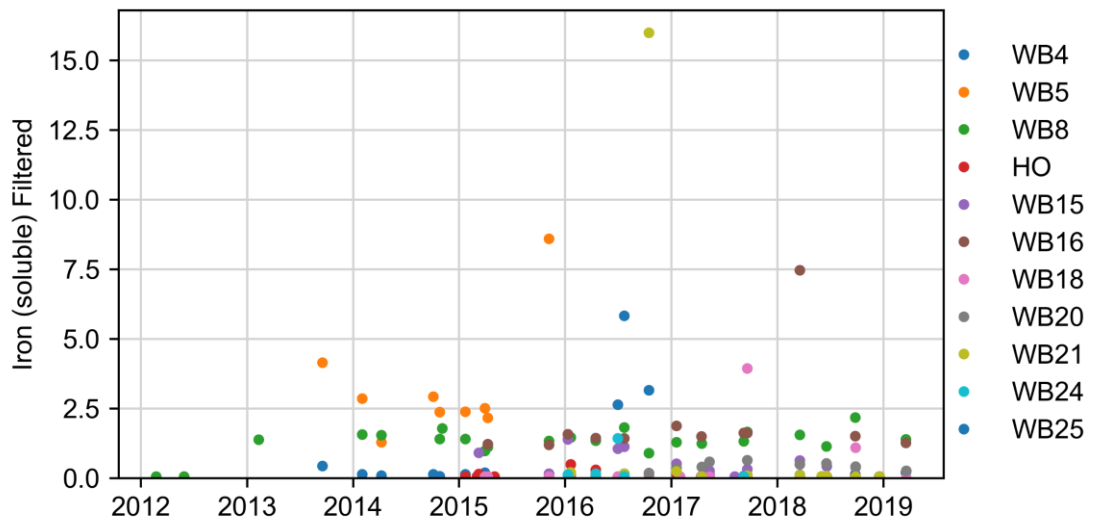
Note: in all plots HO is House Bore

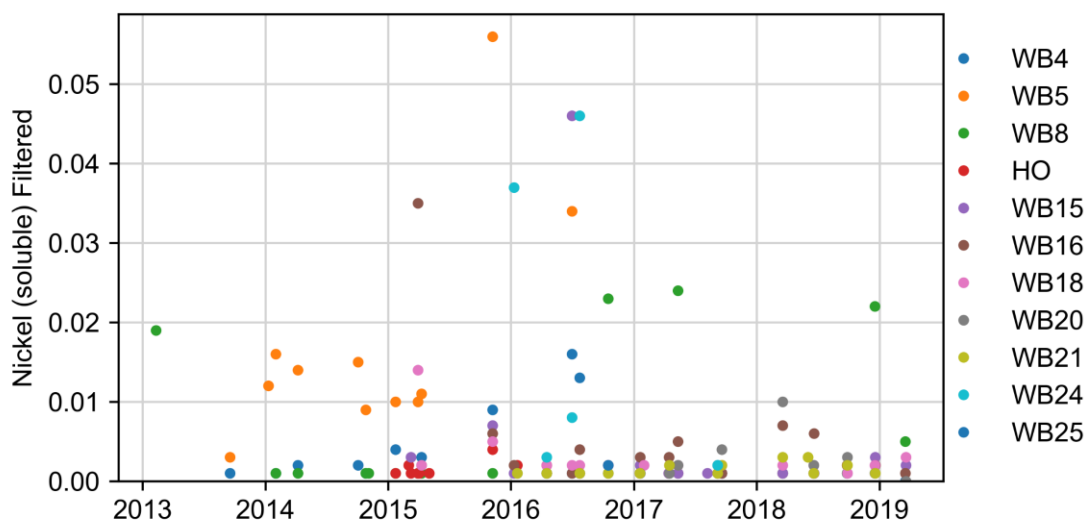
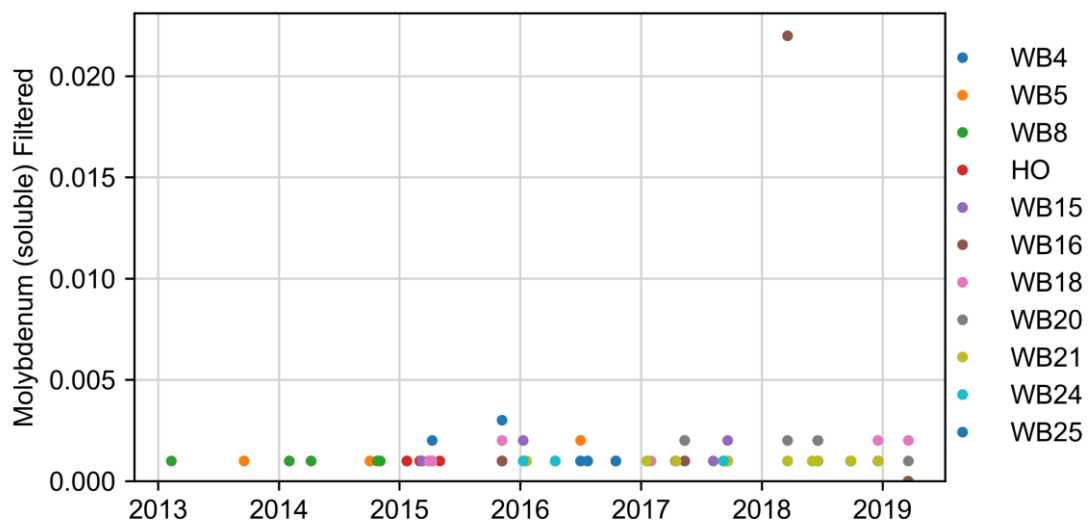
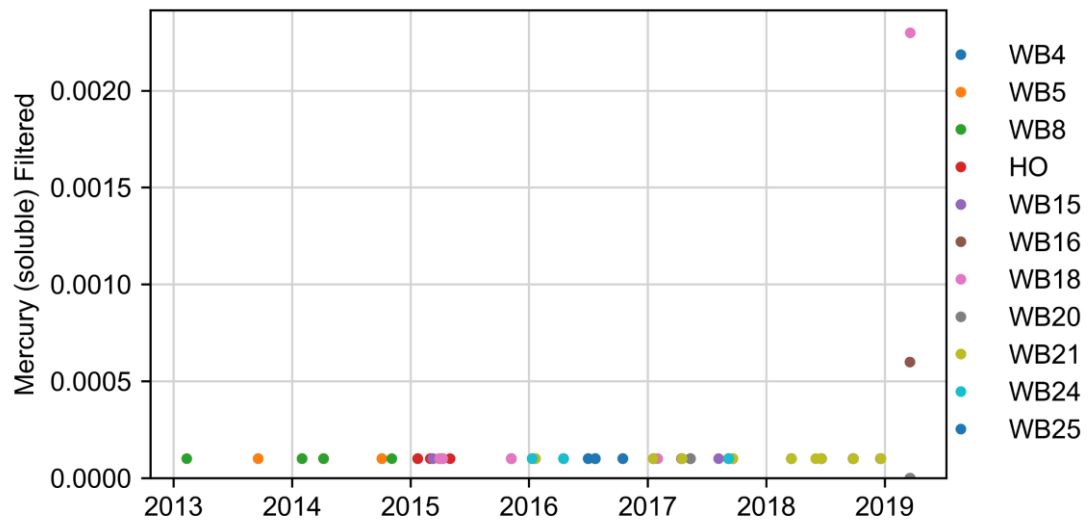


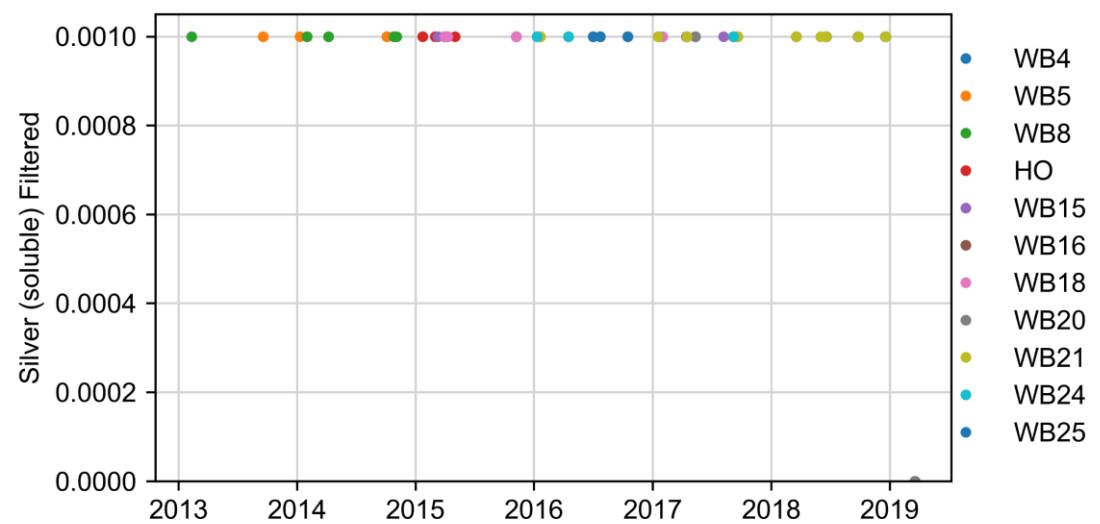
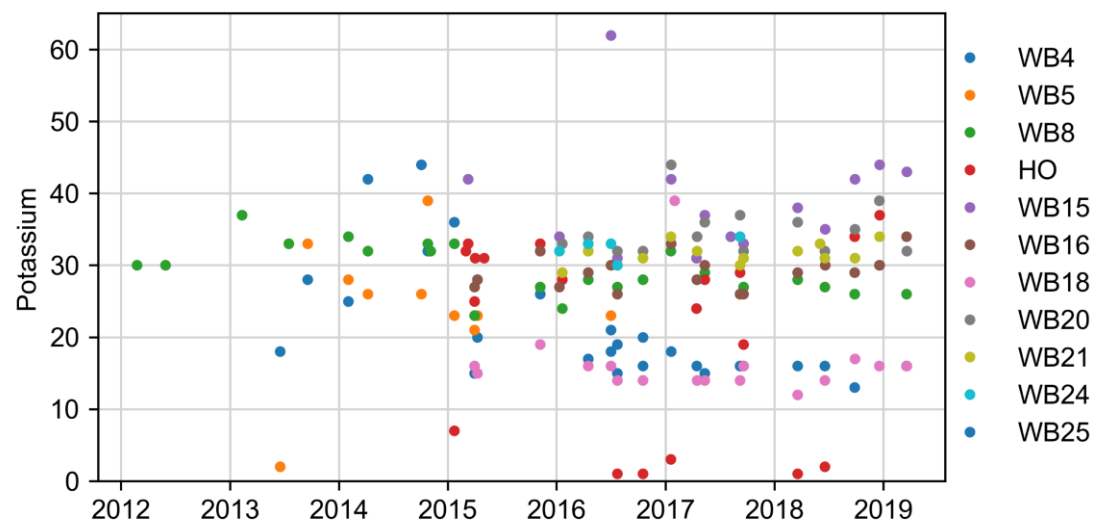
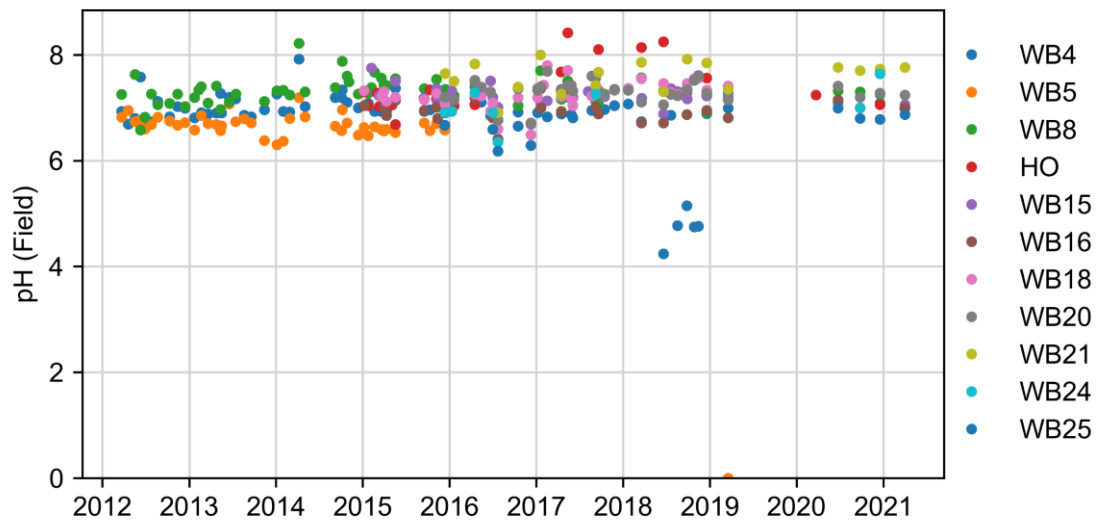


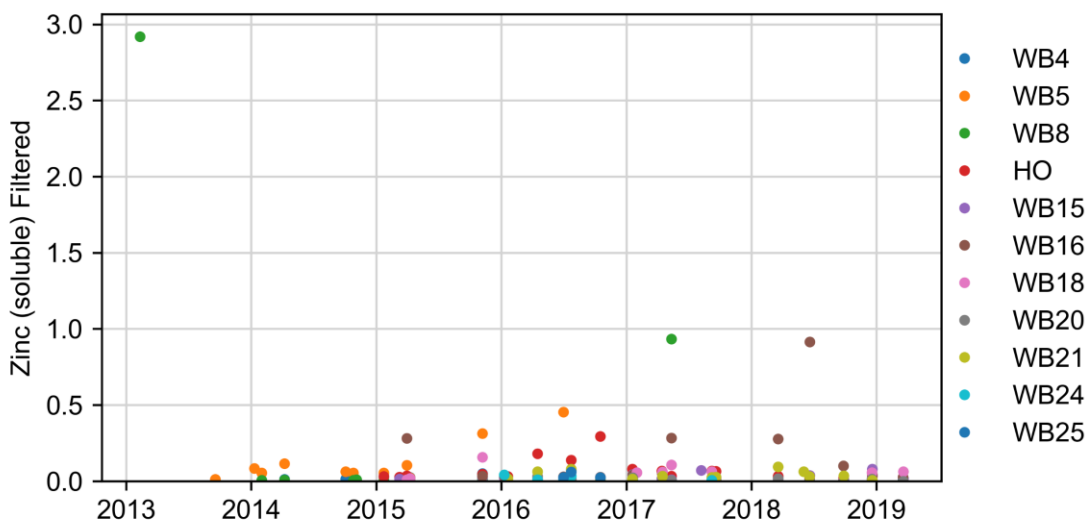
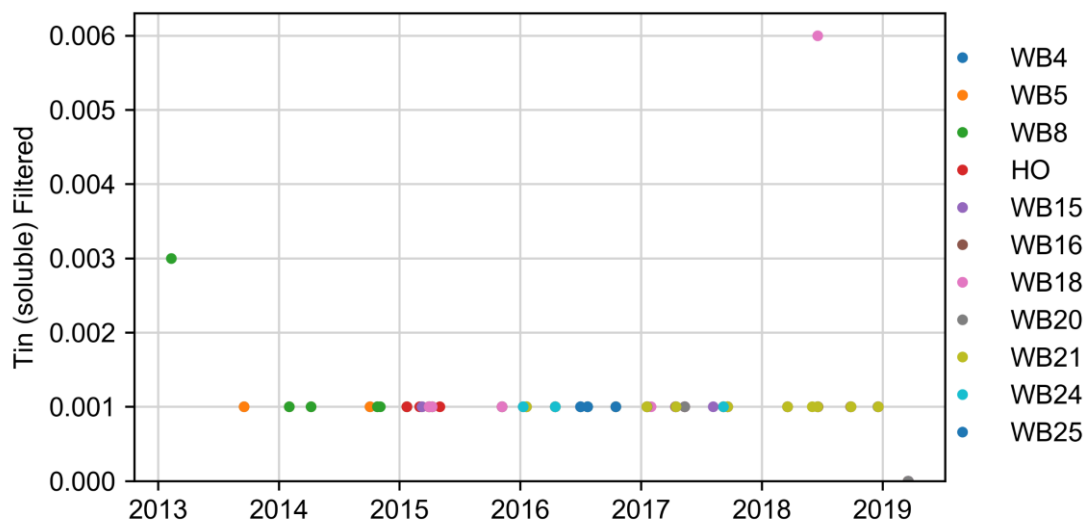
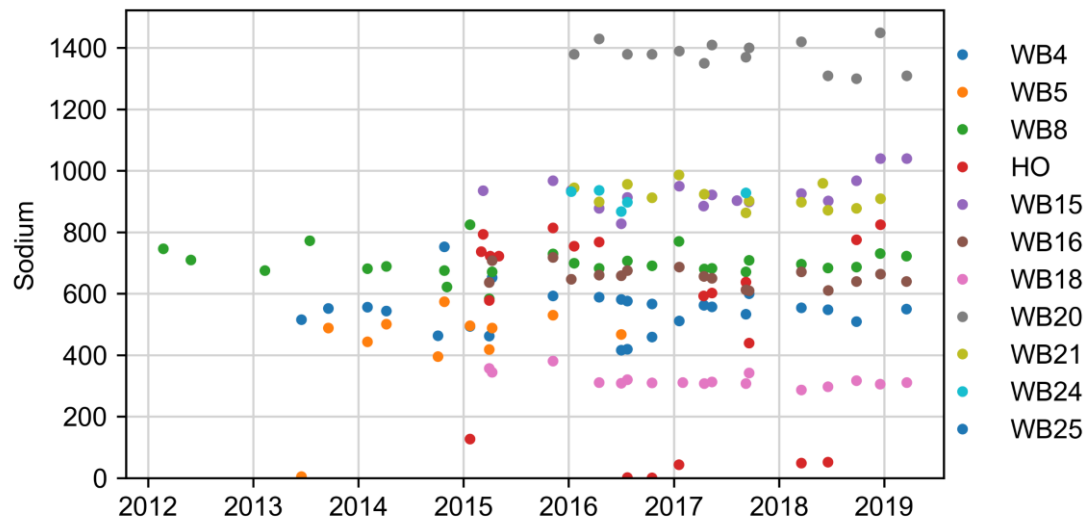




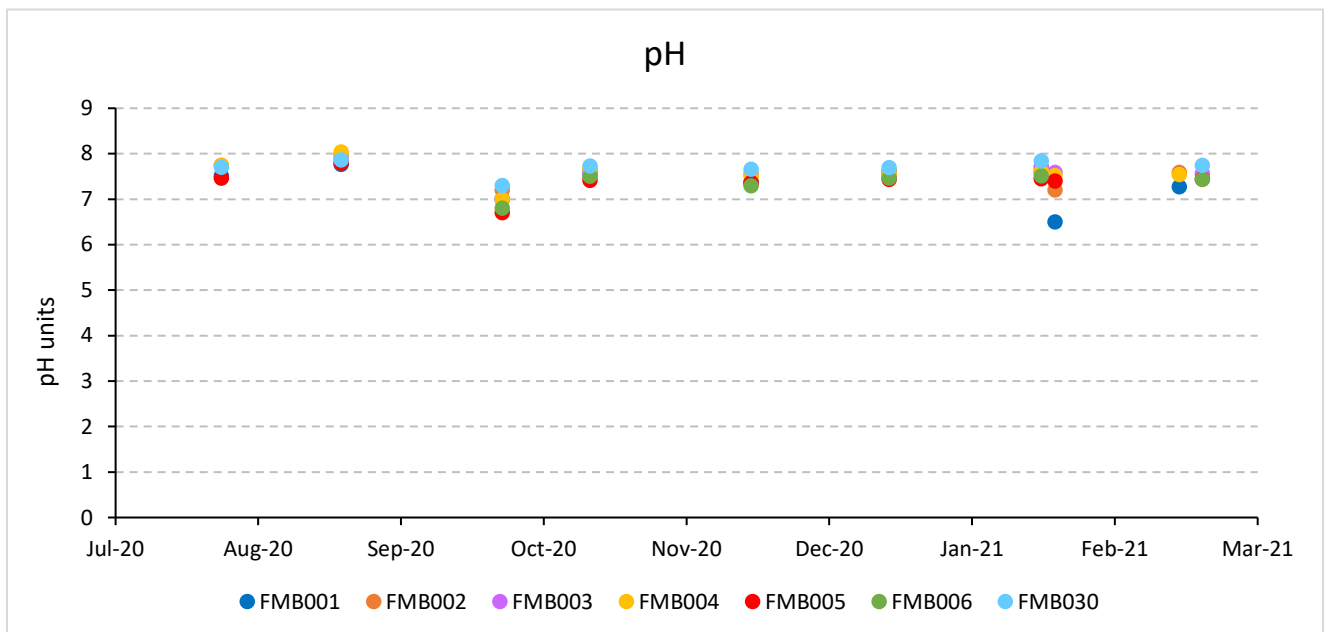
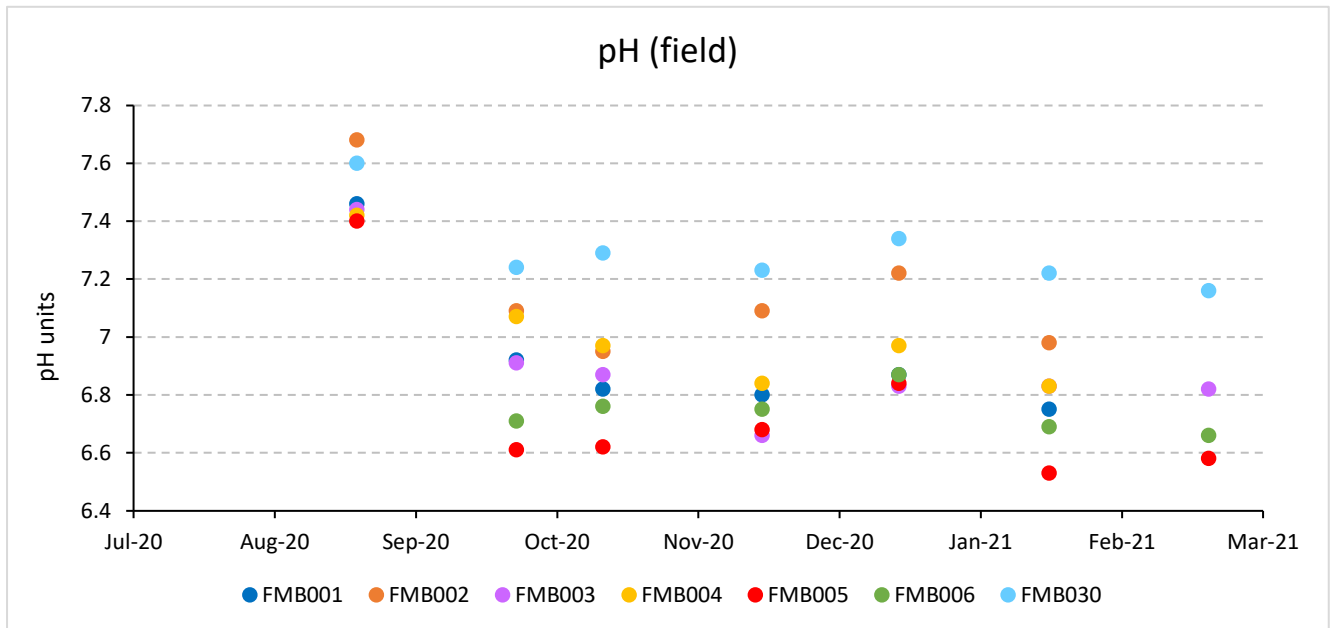


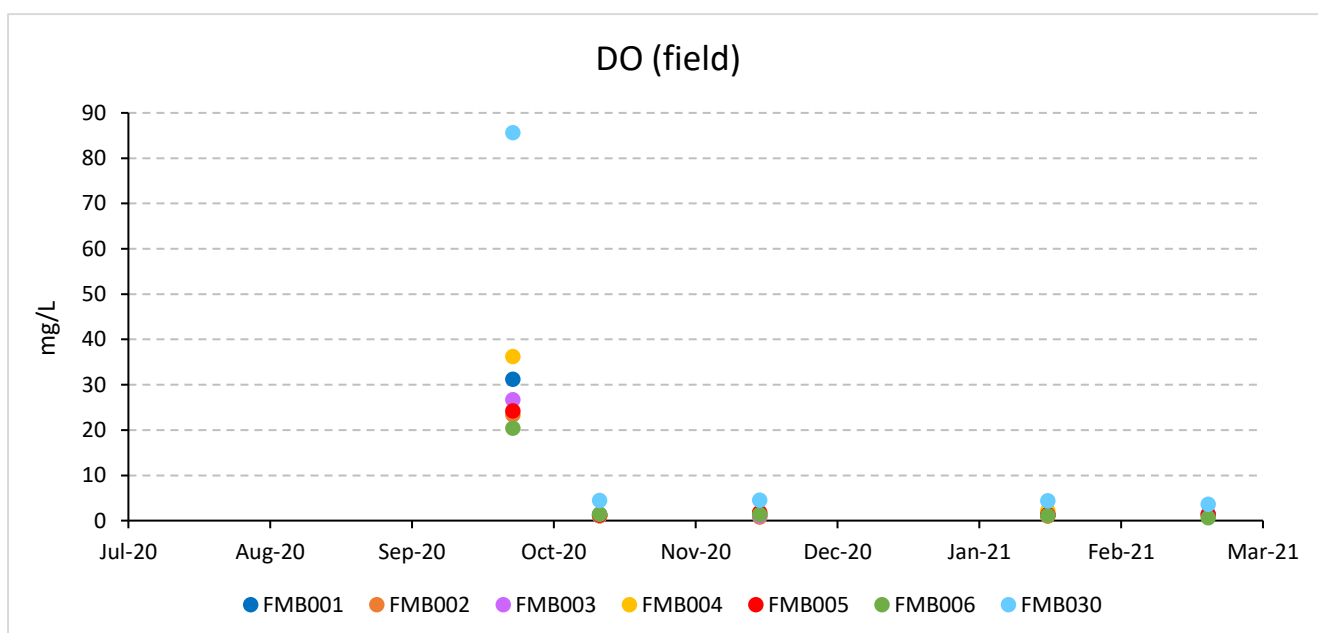
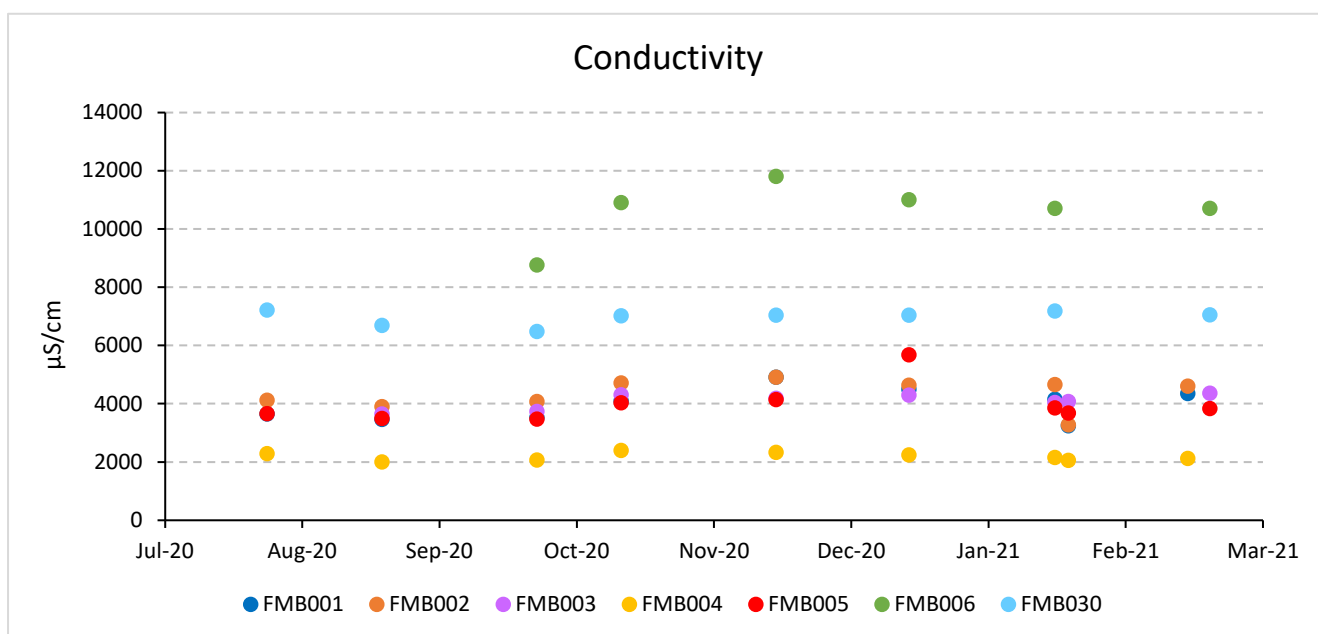
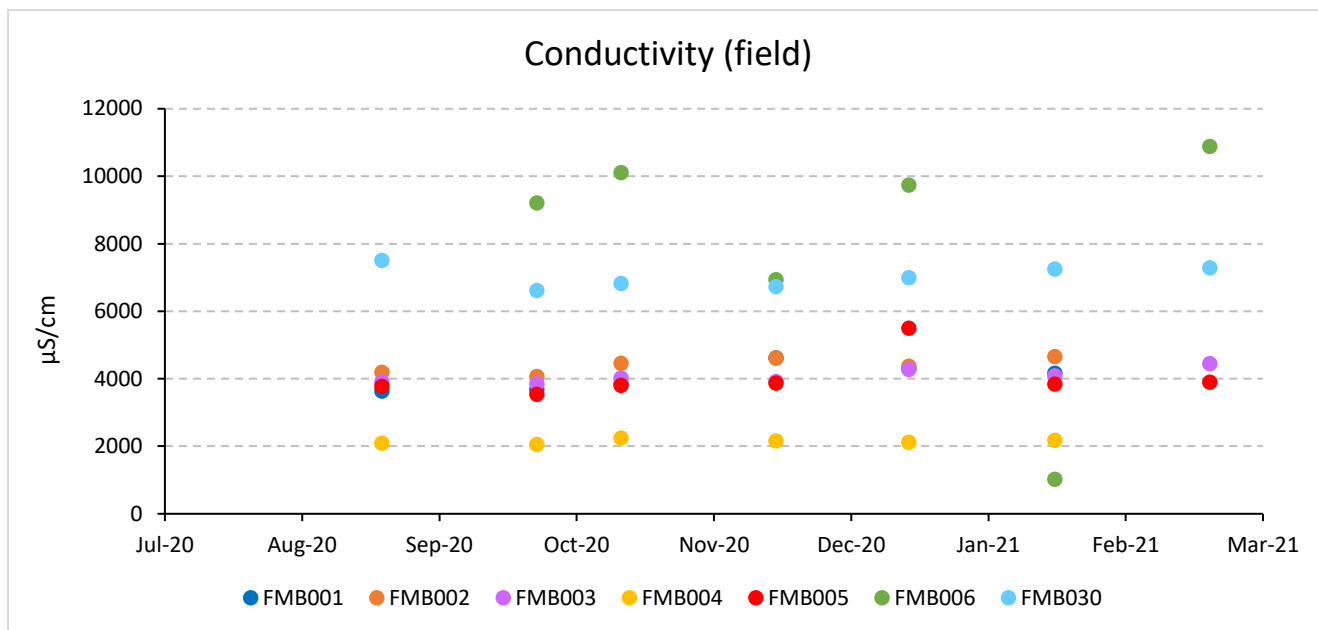


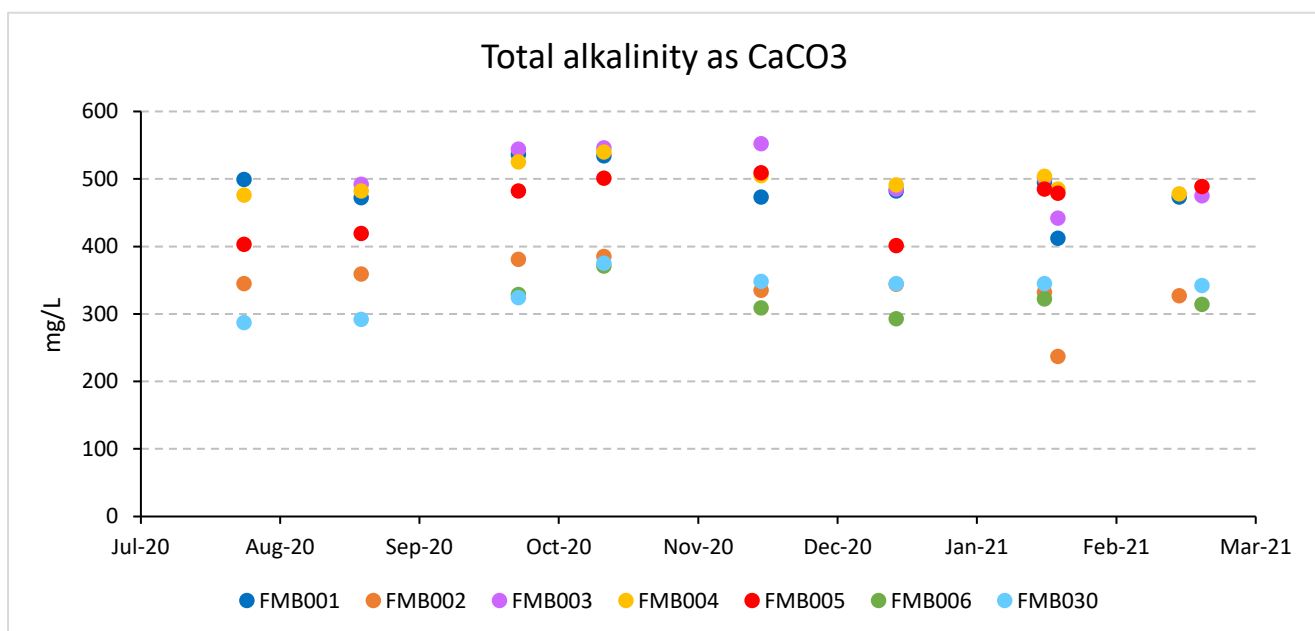
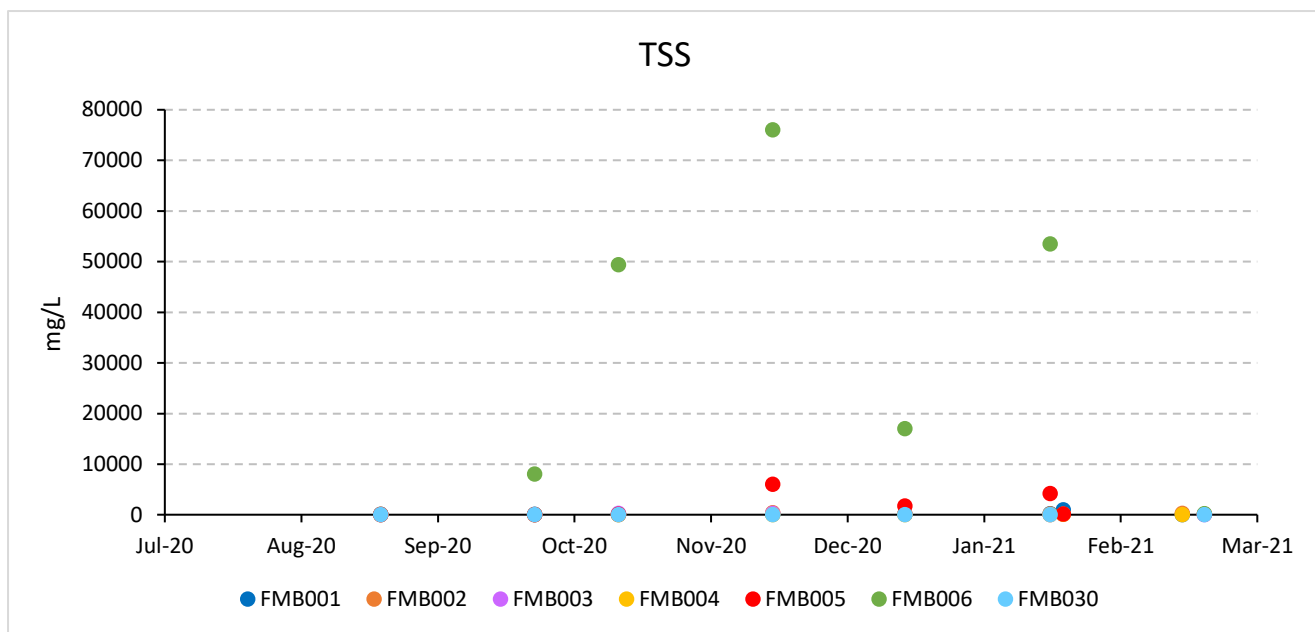
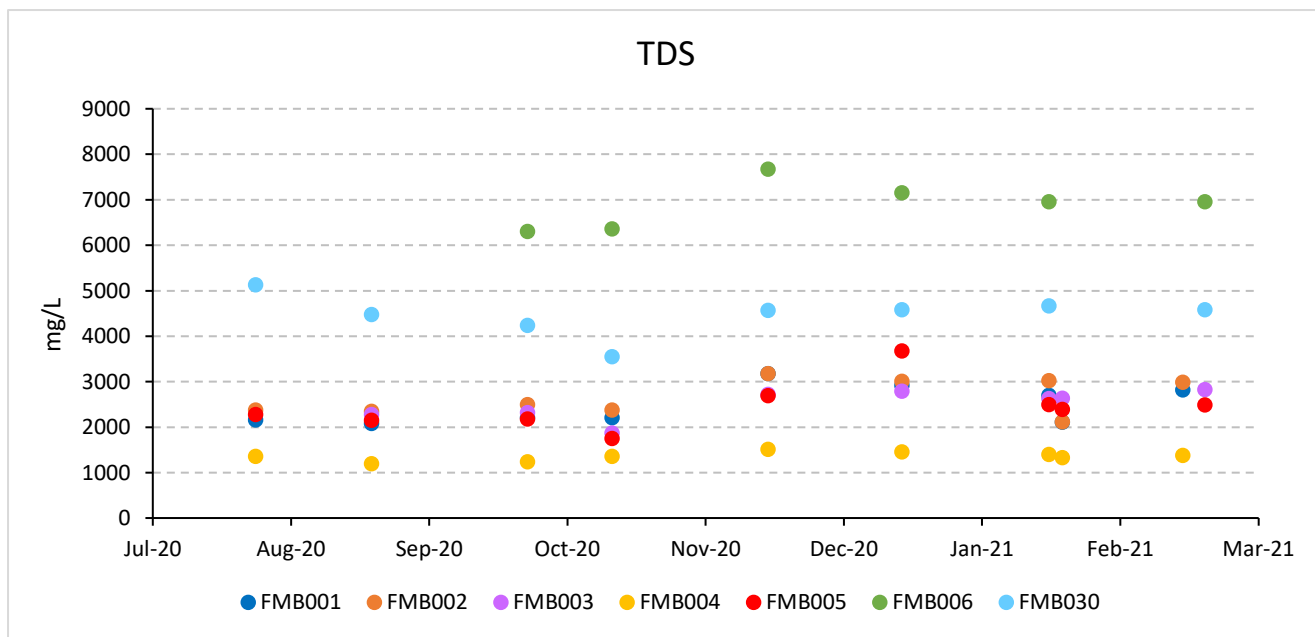


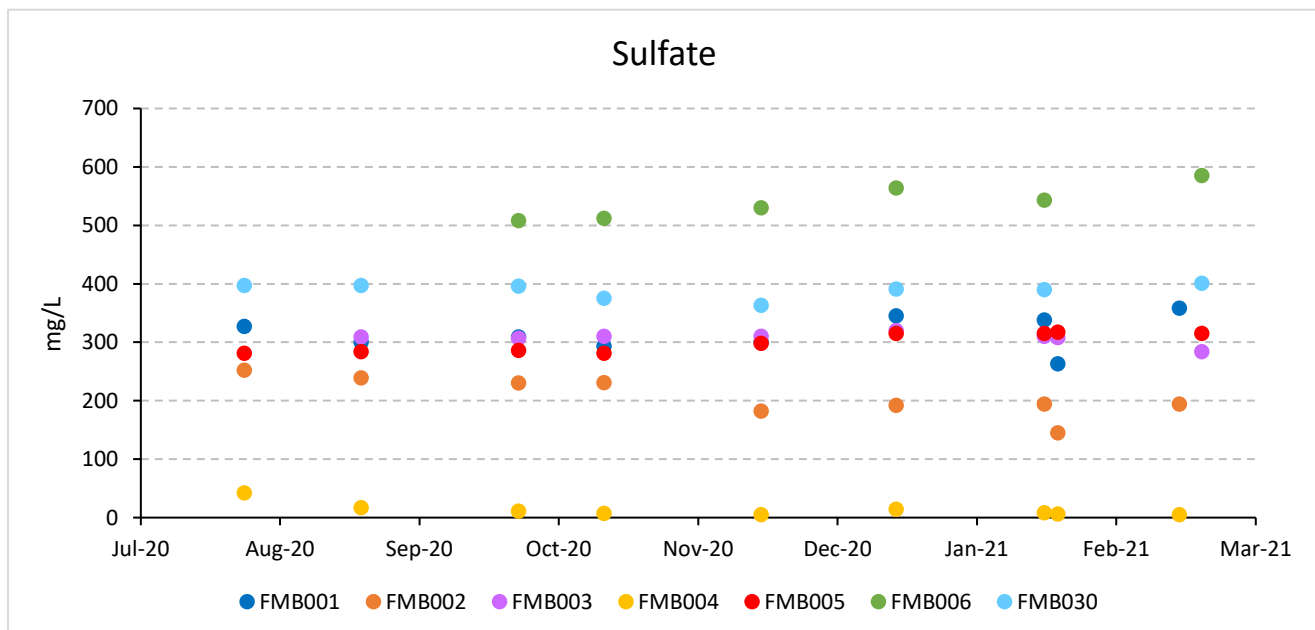
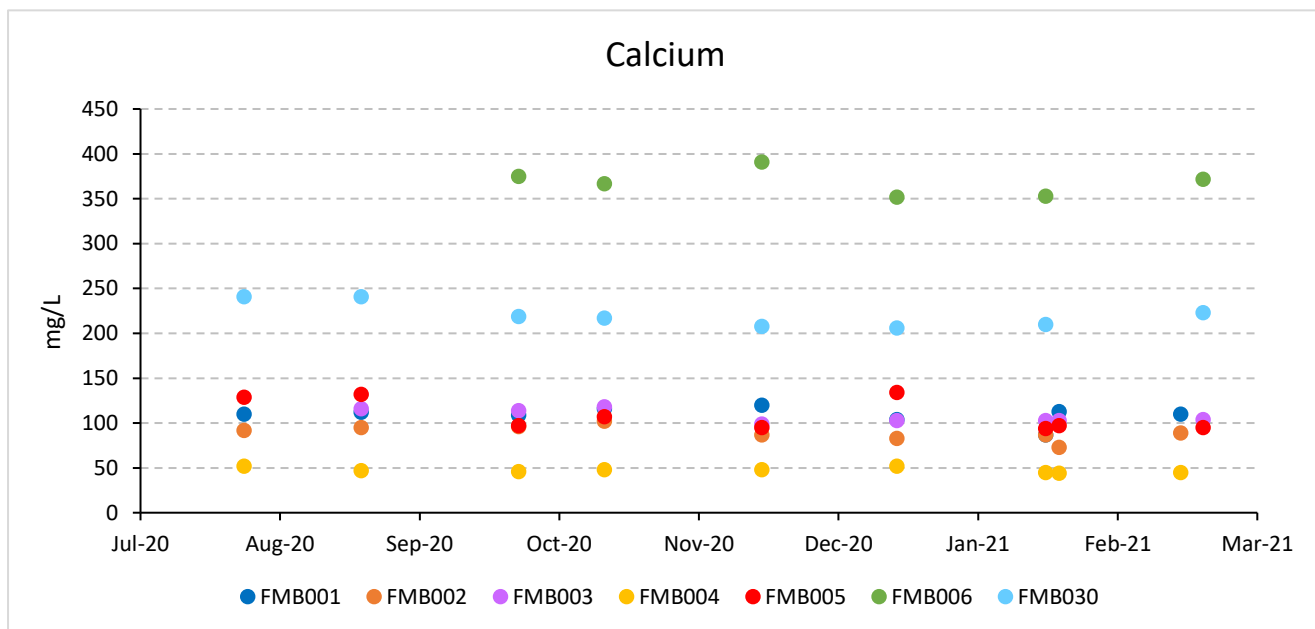
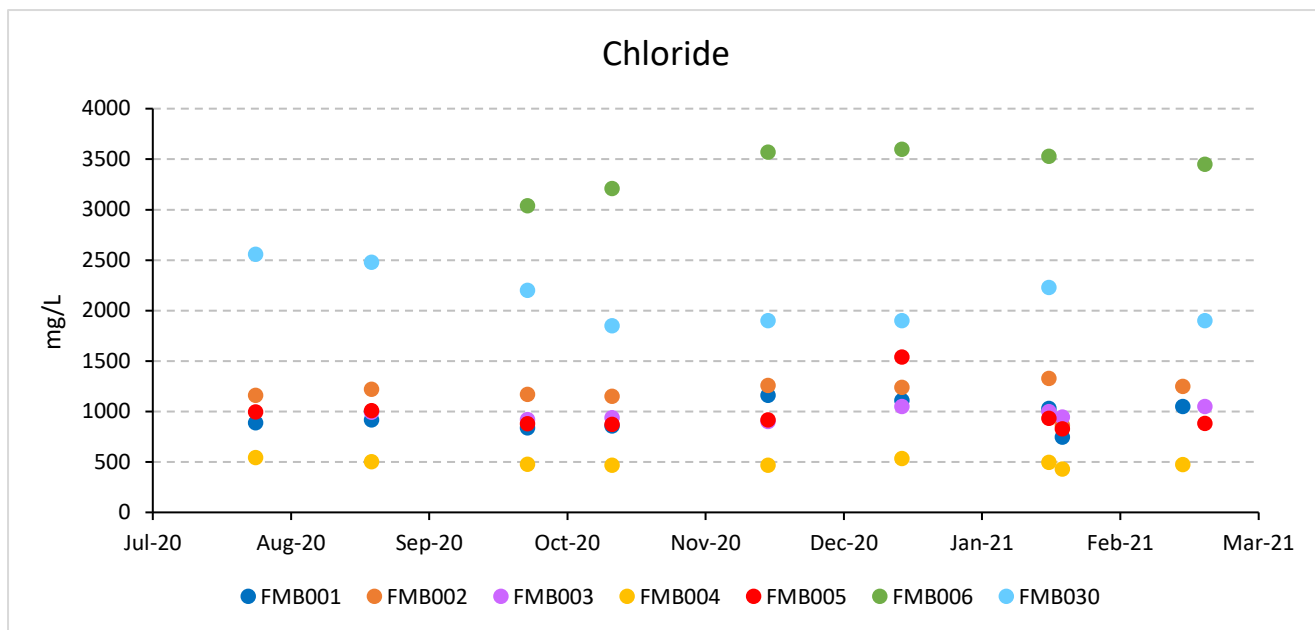


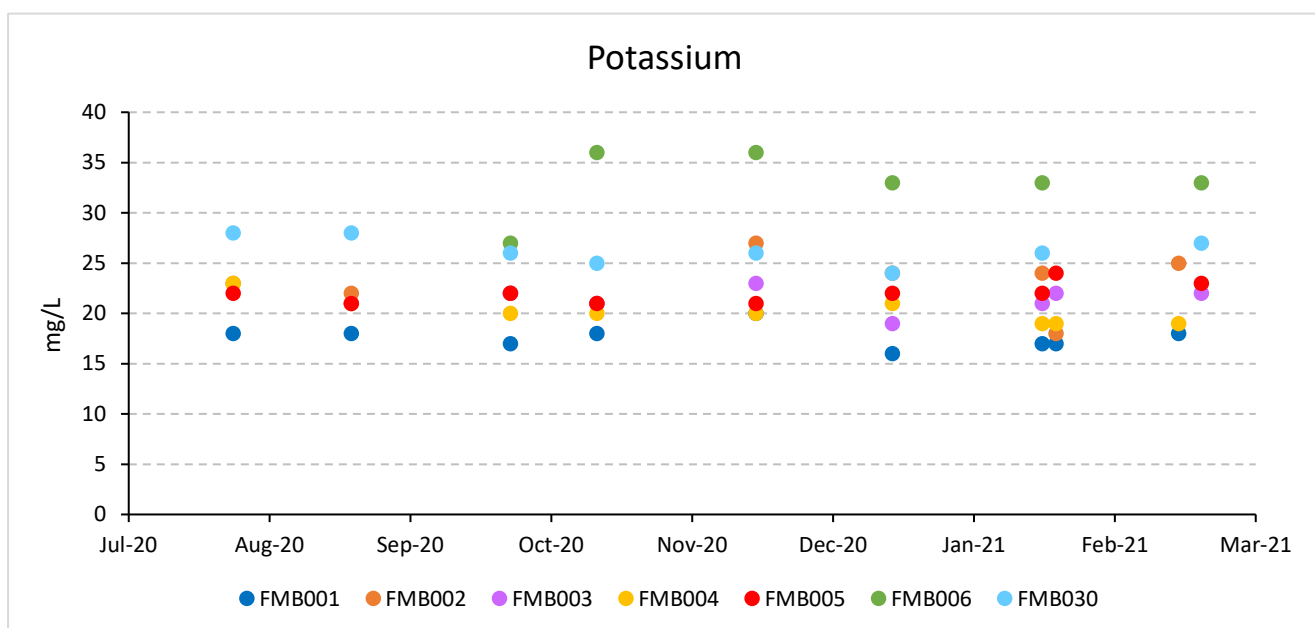
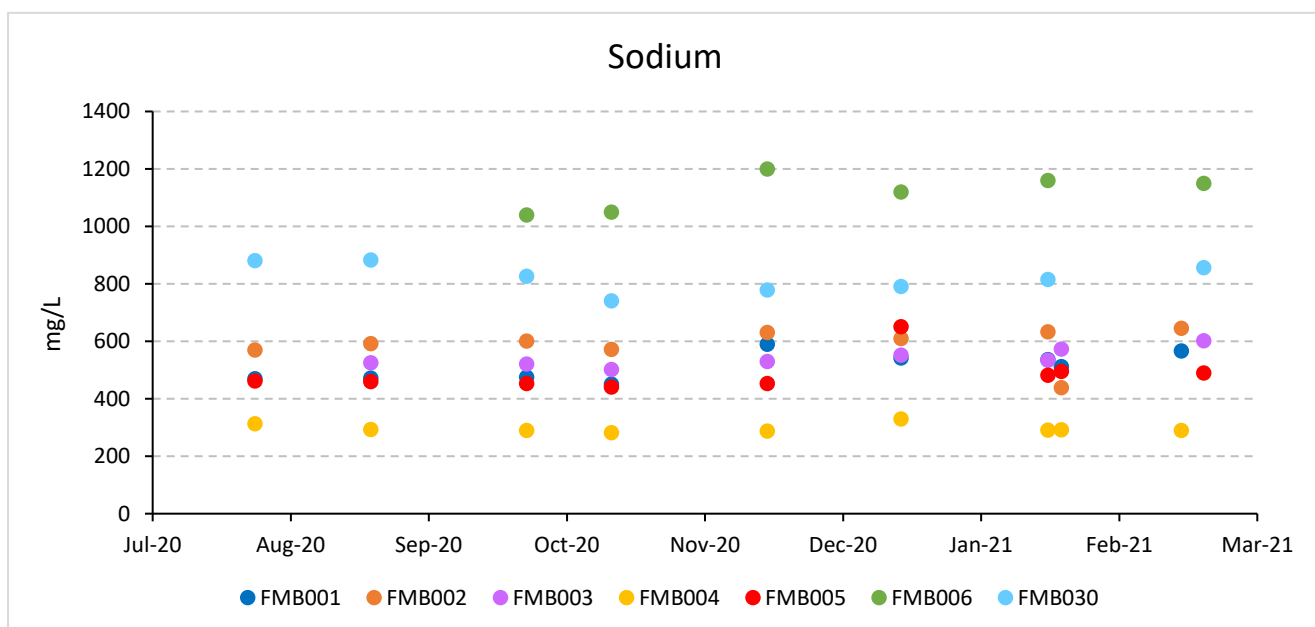
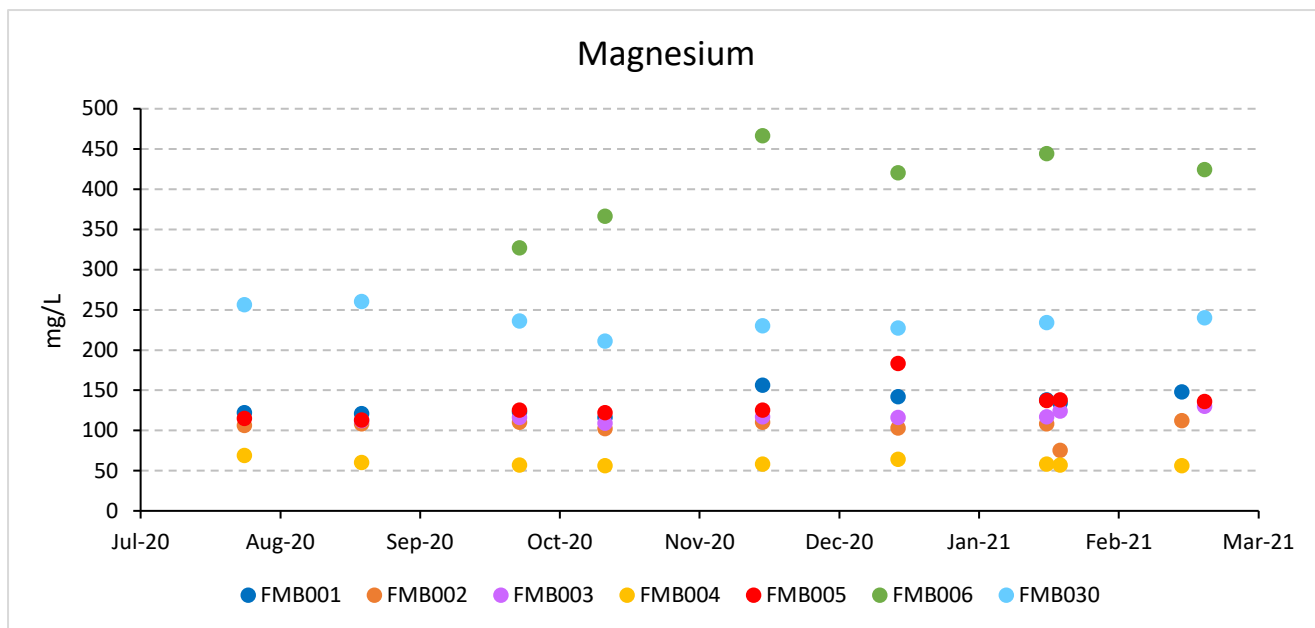
Federation

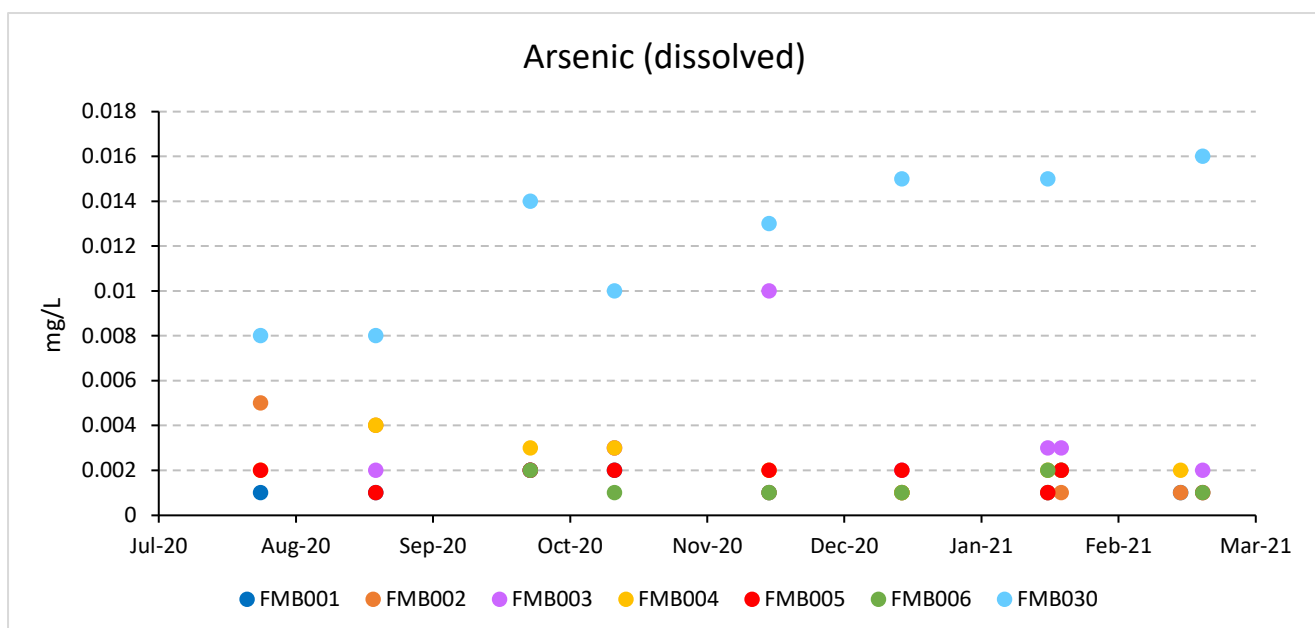
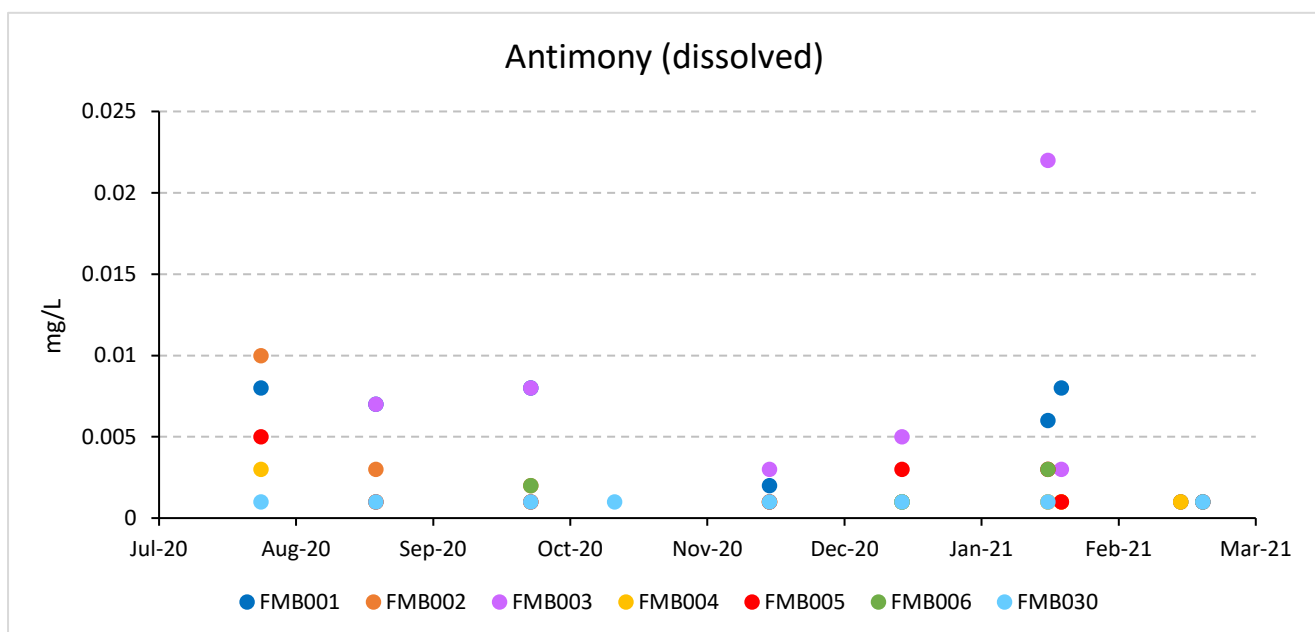
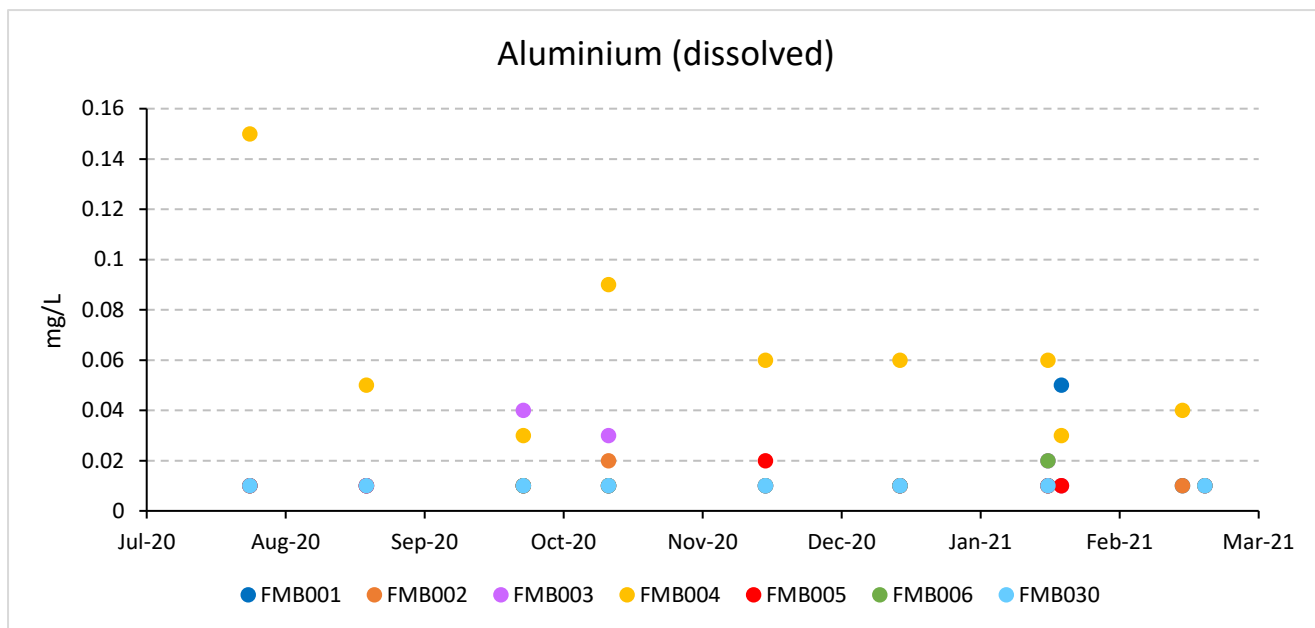


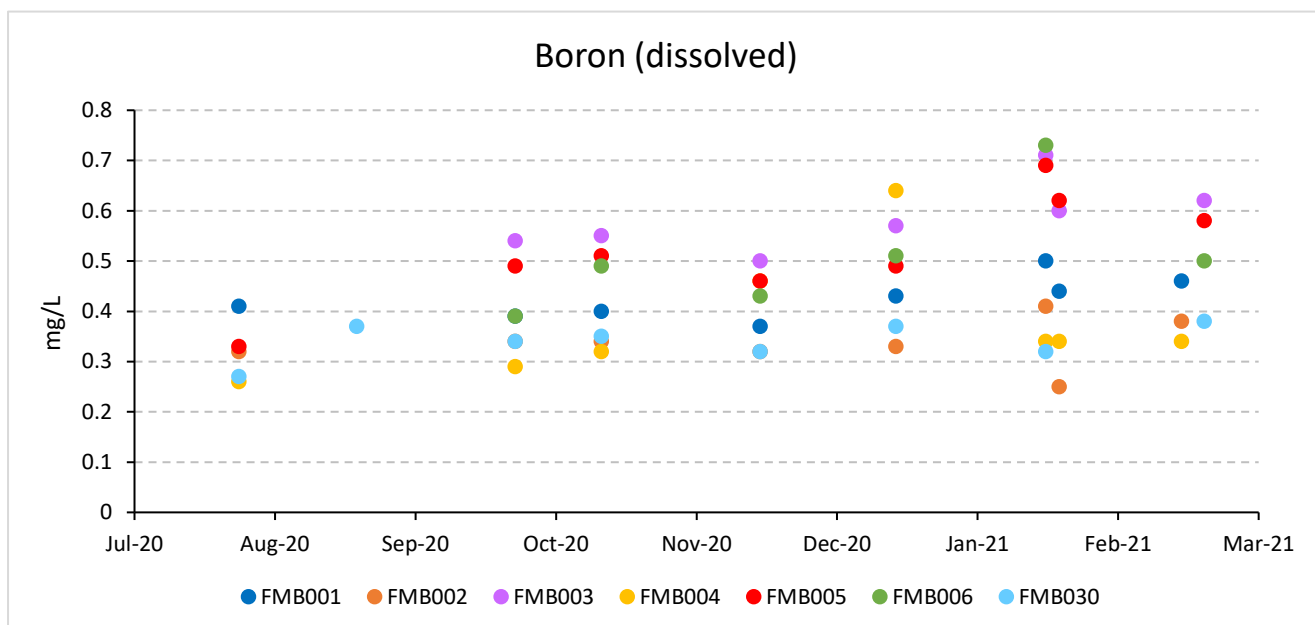
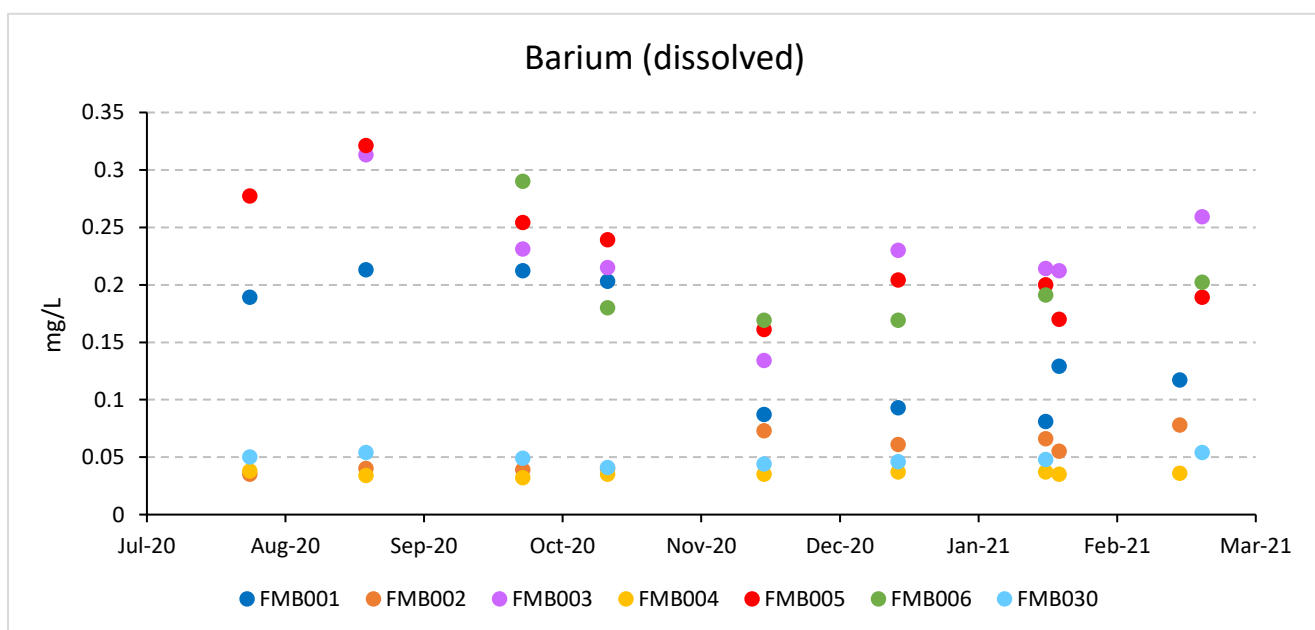
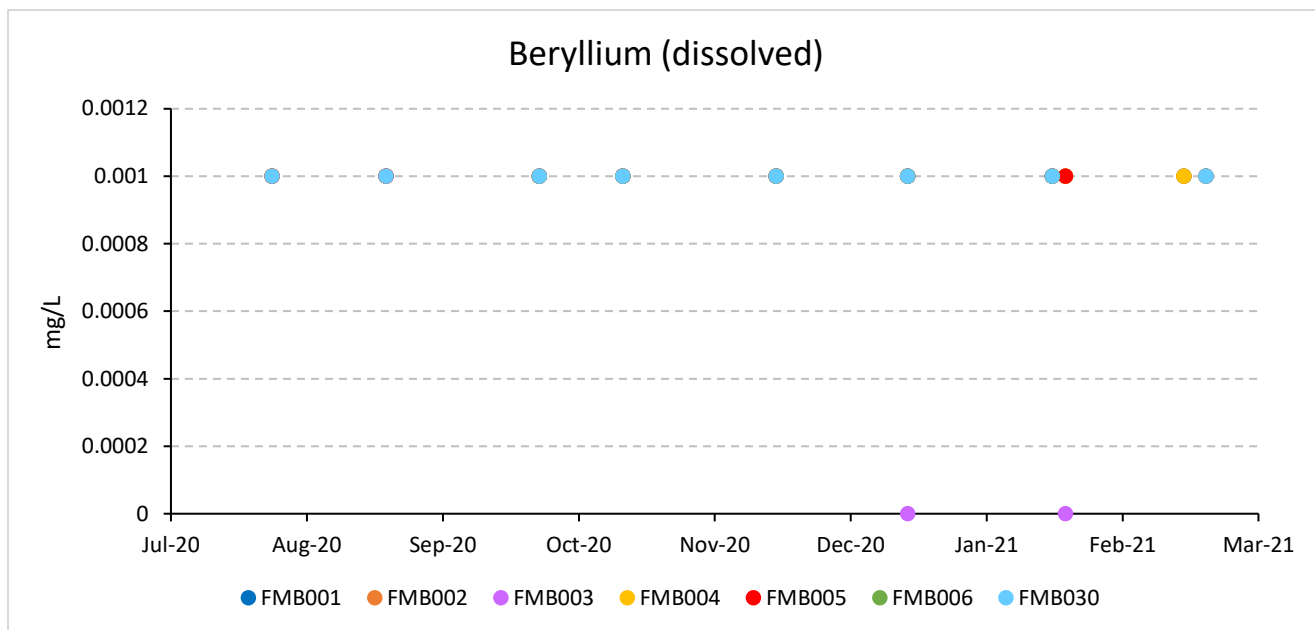


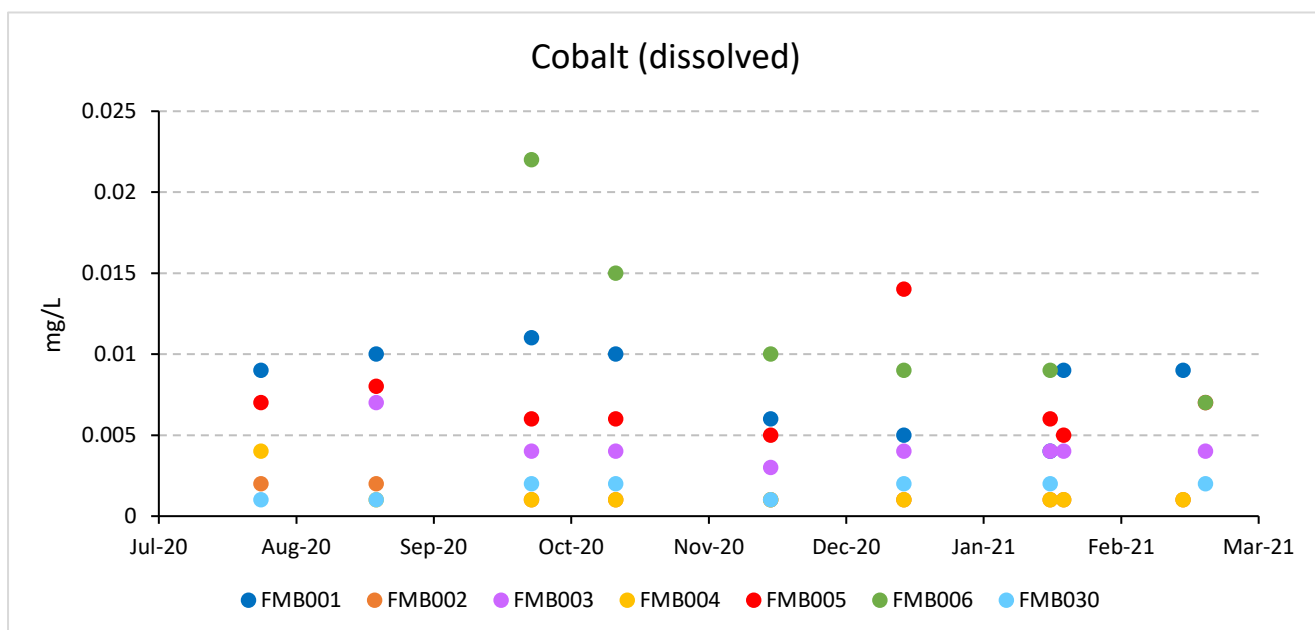
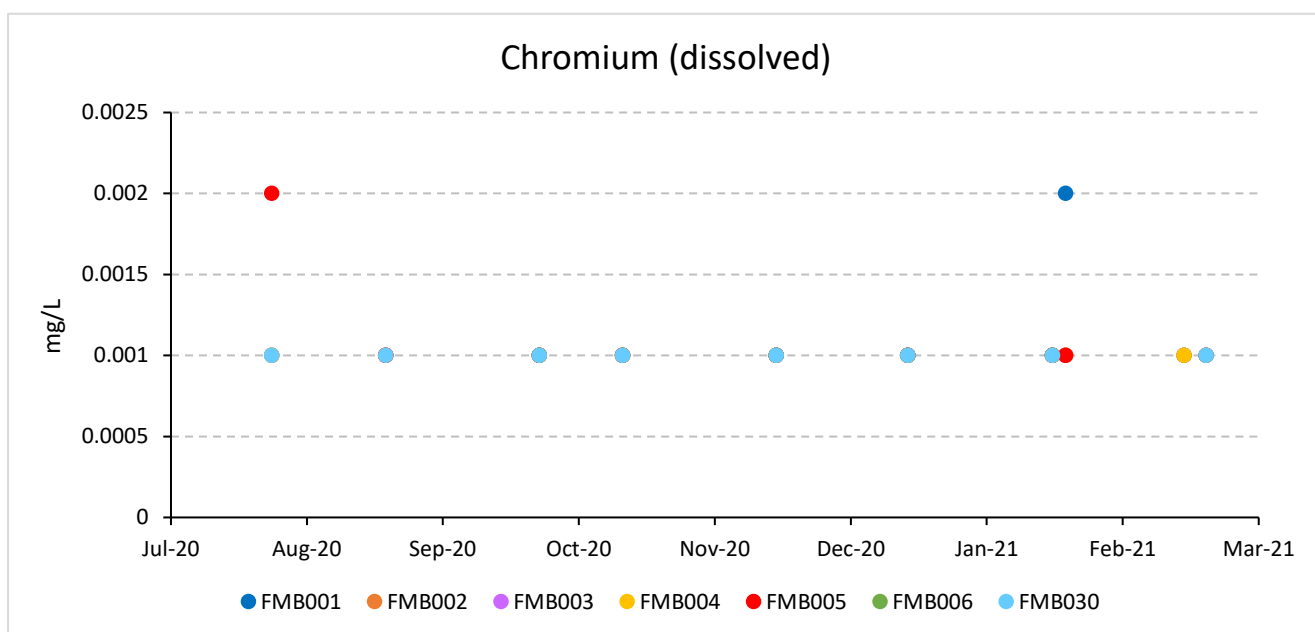
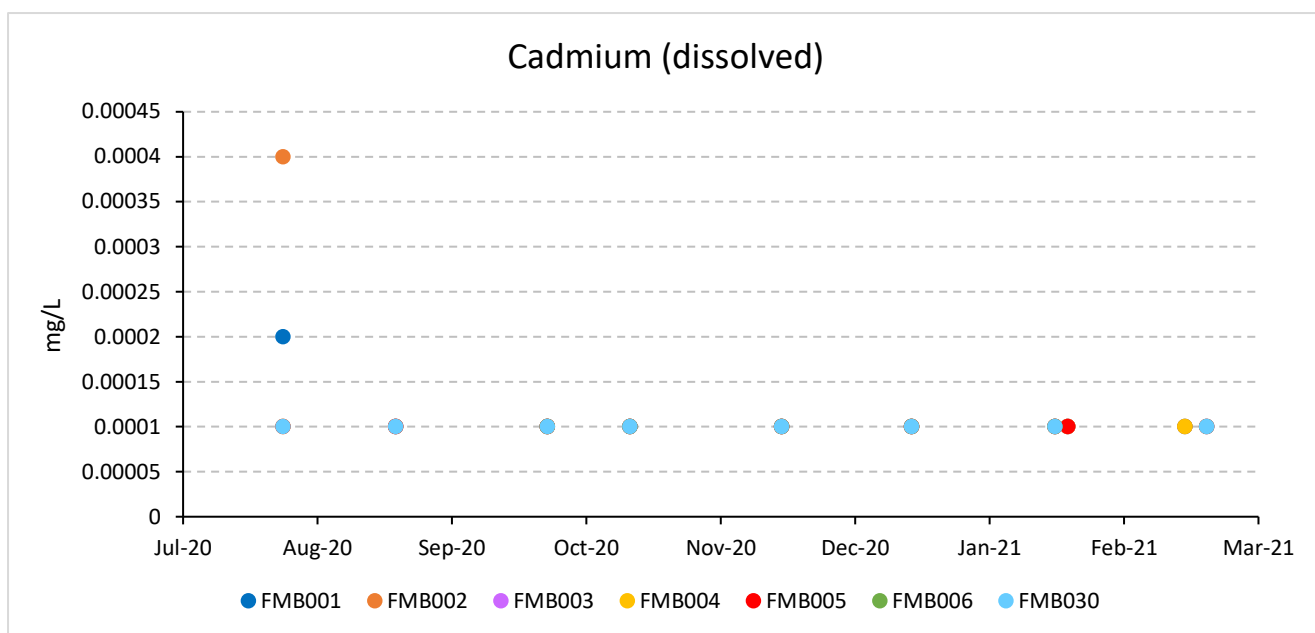


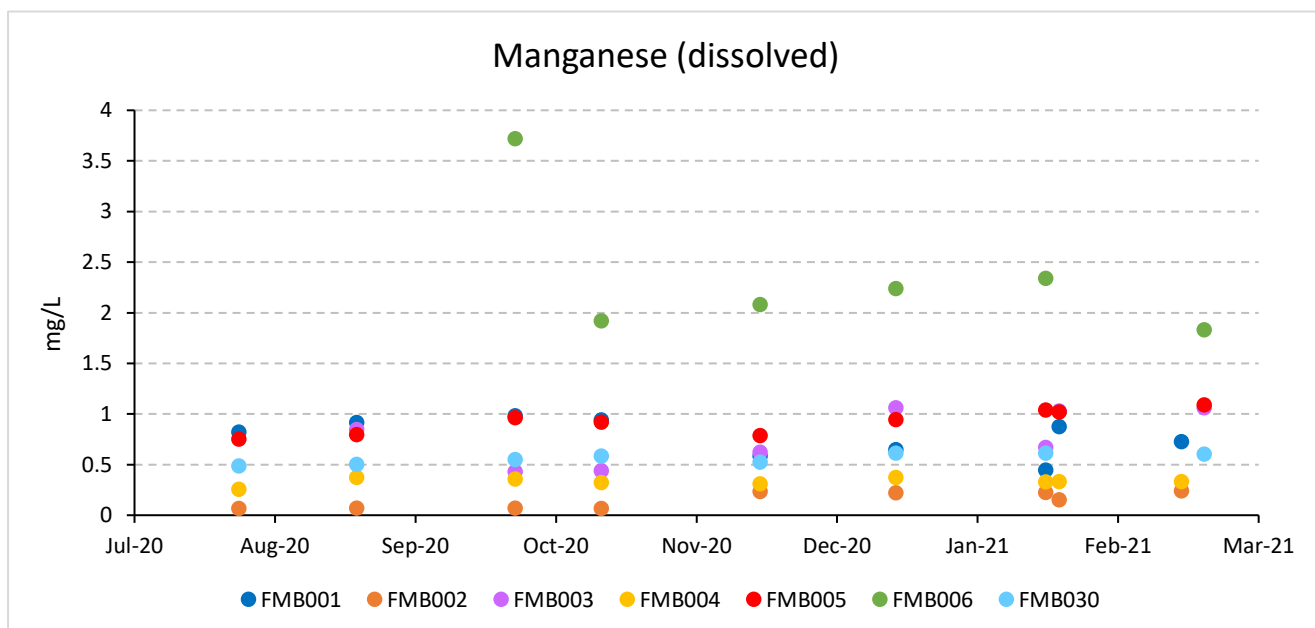
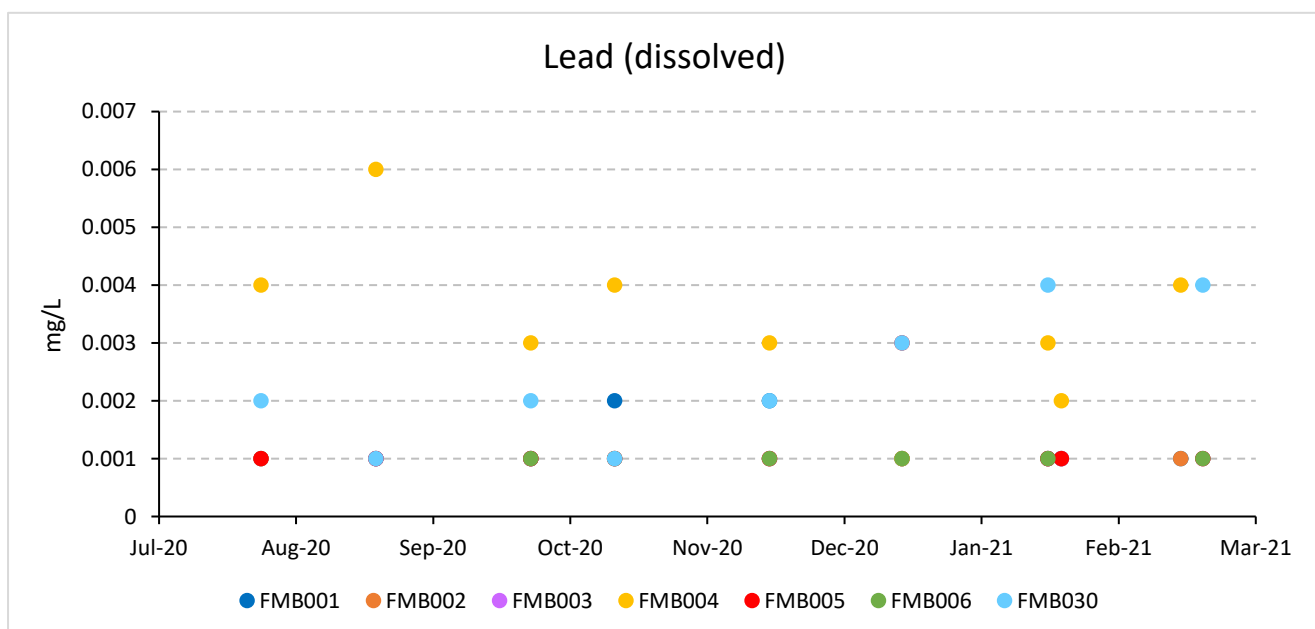
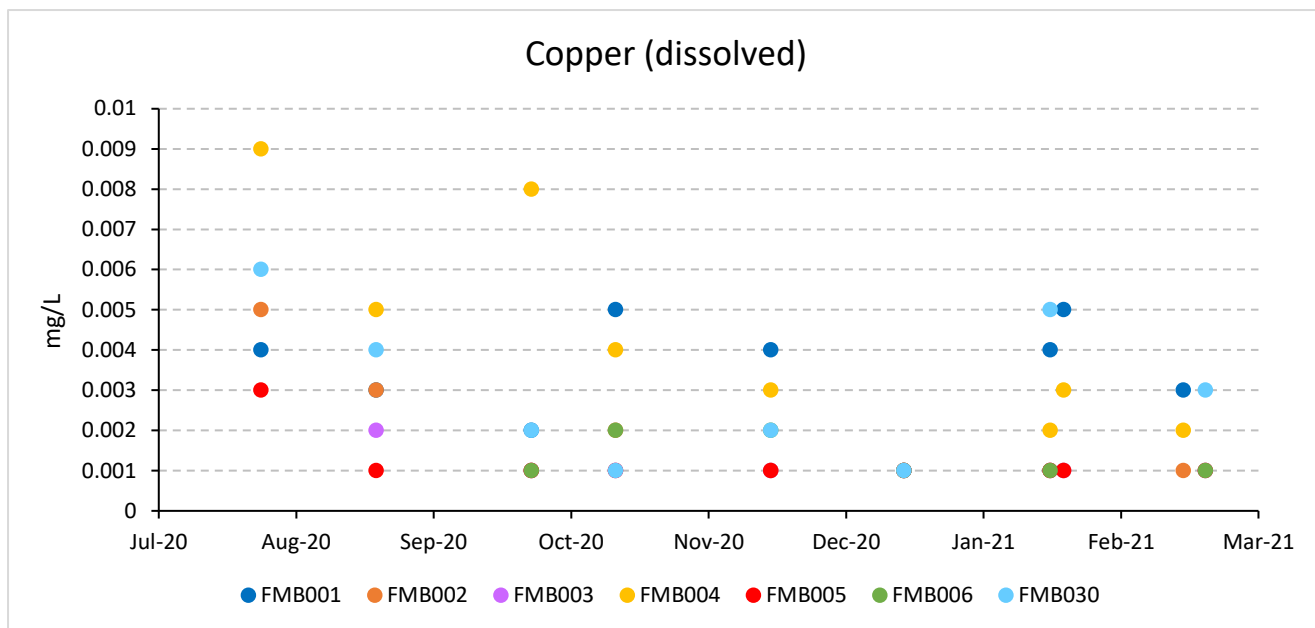


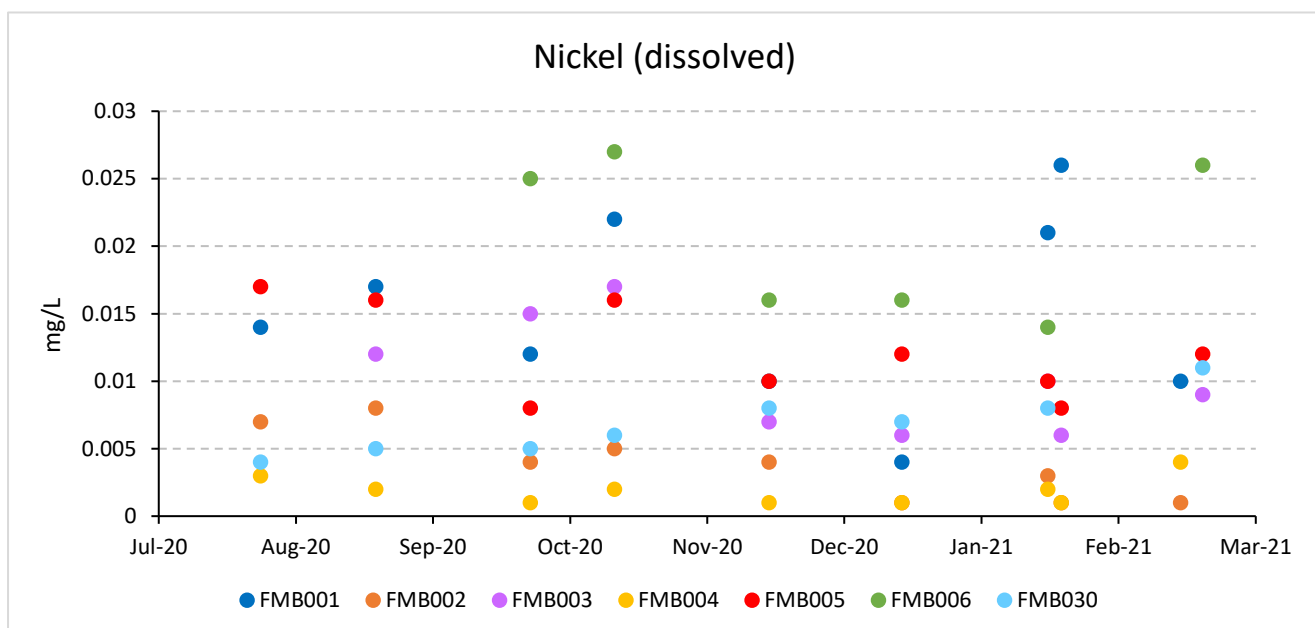
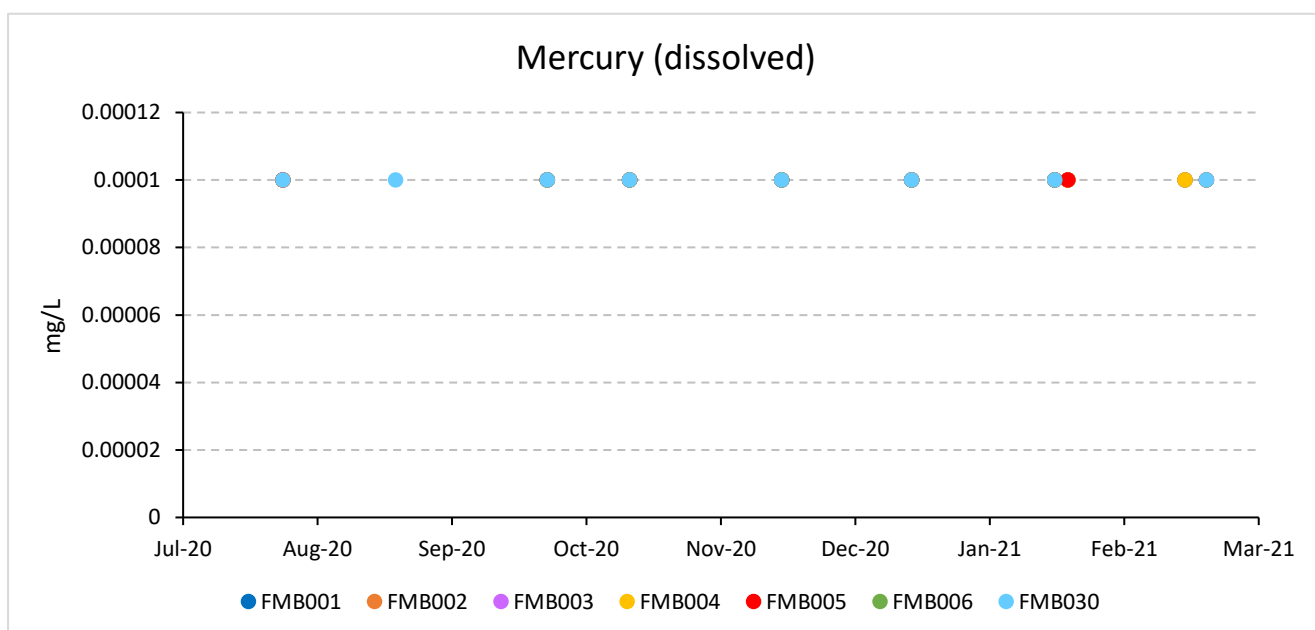
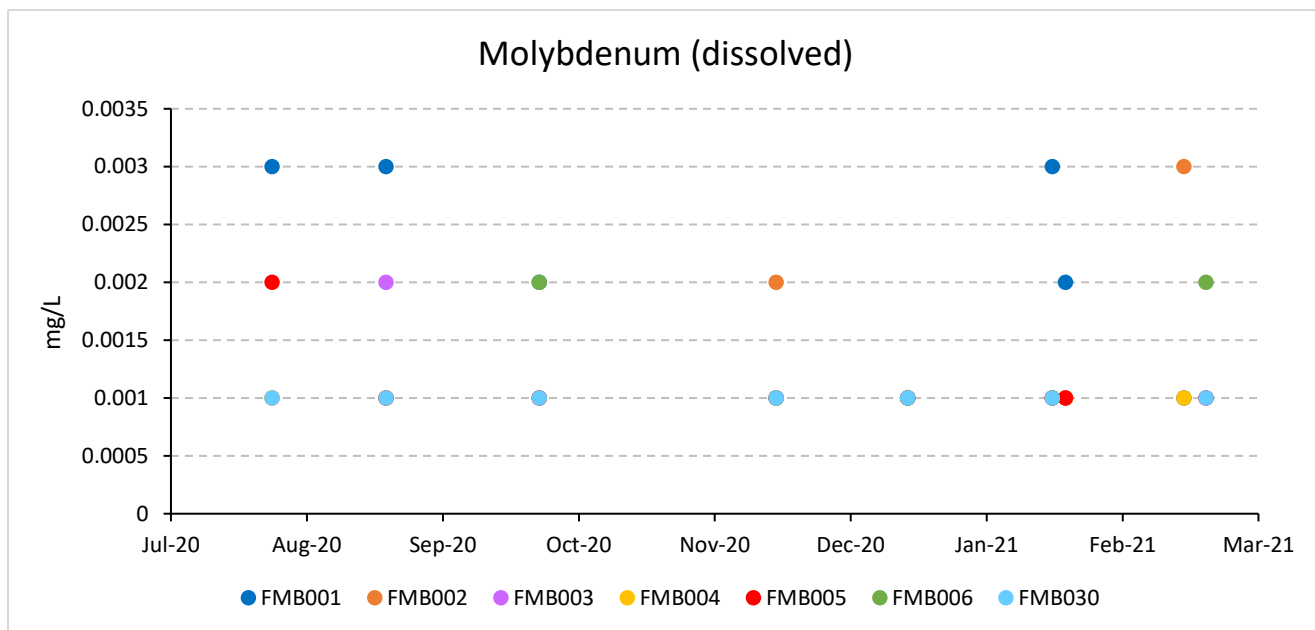


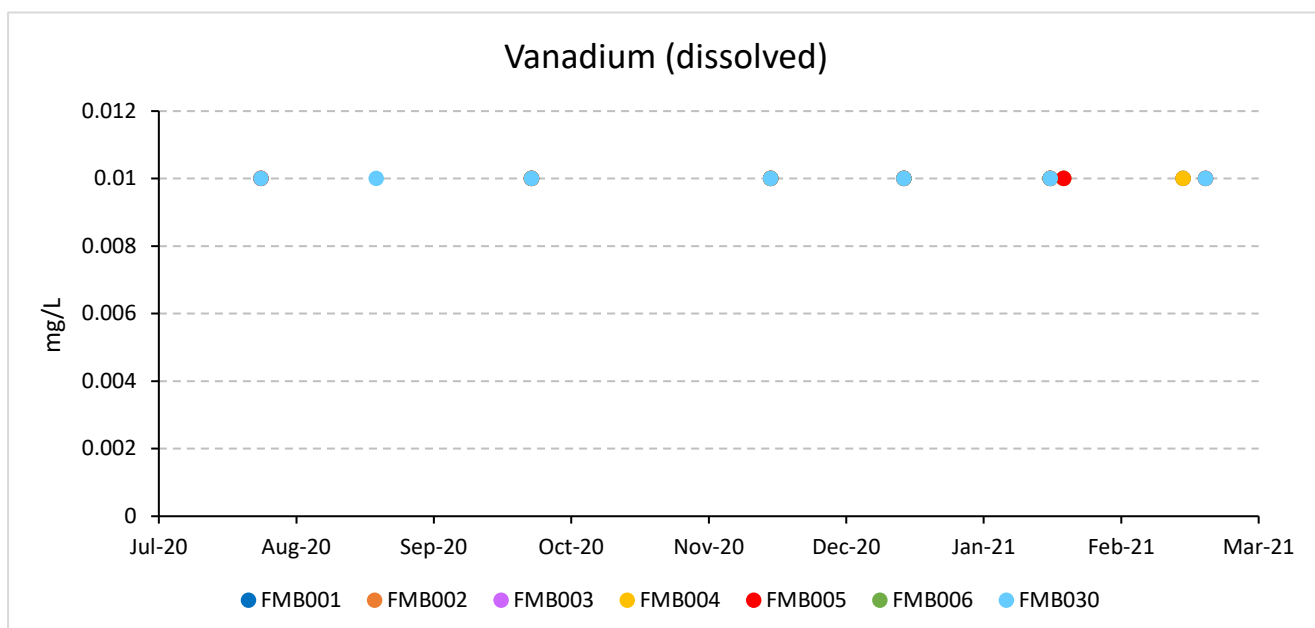
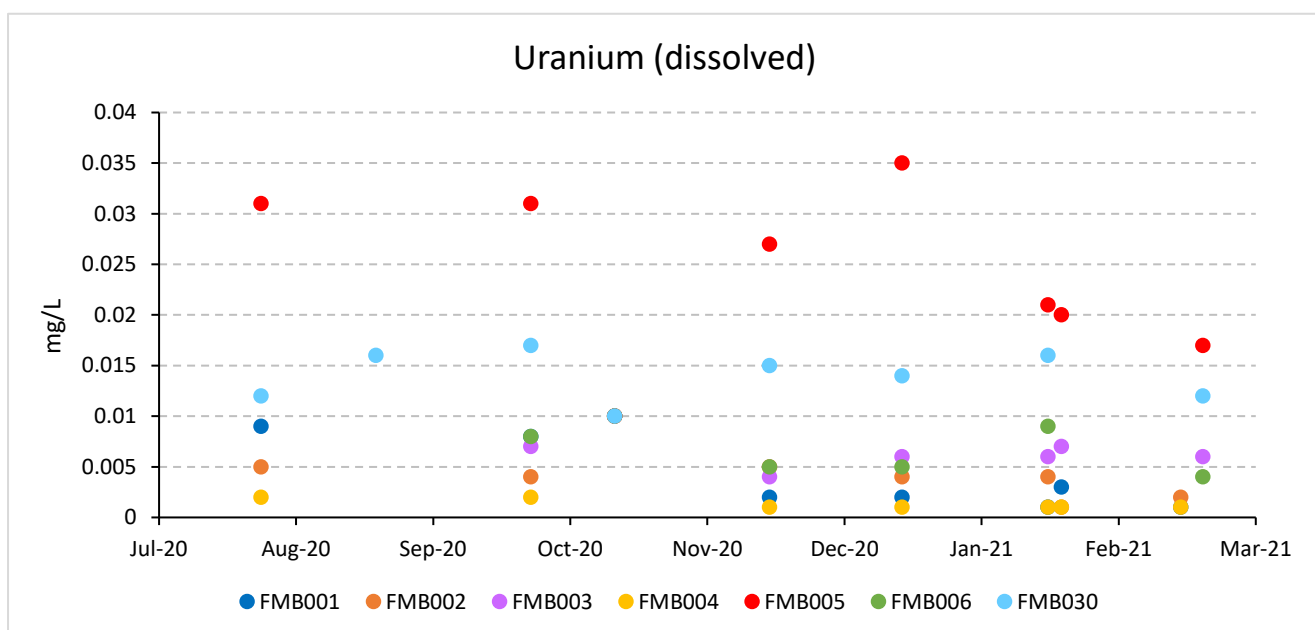
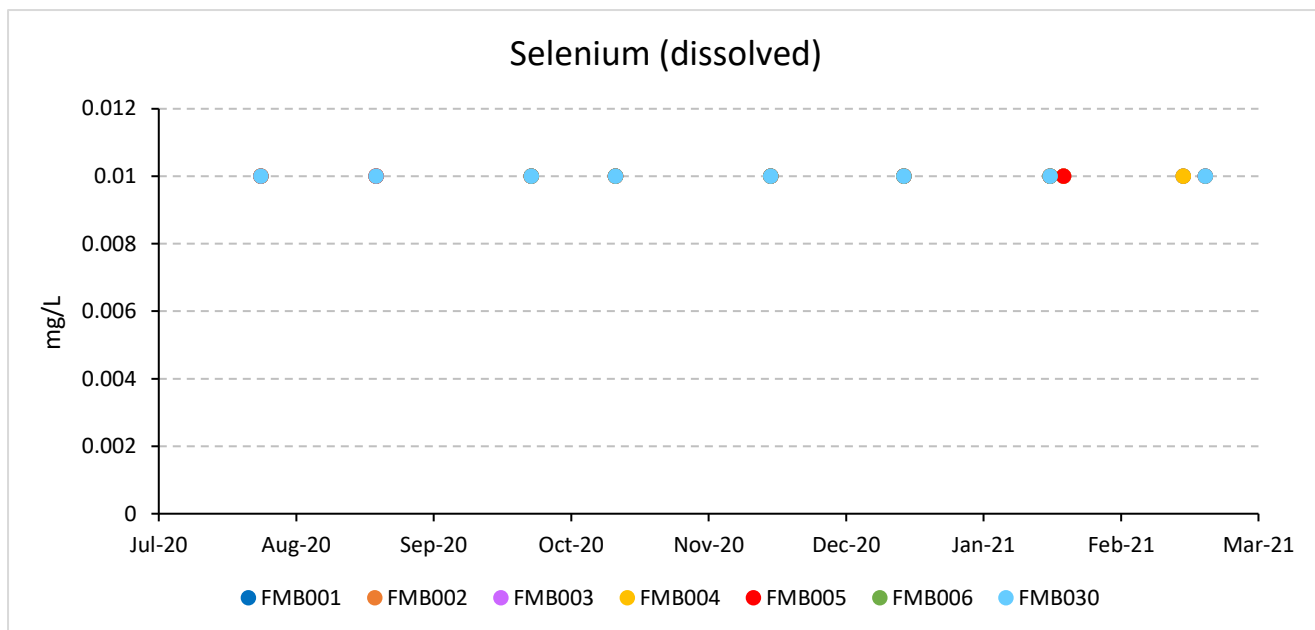


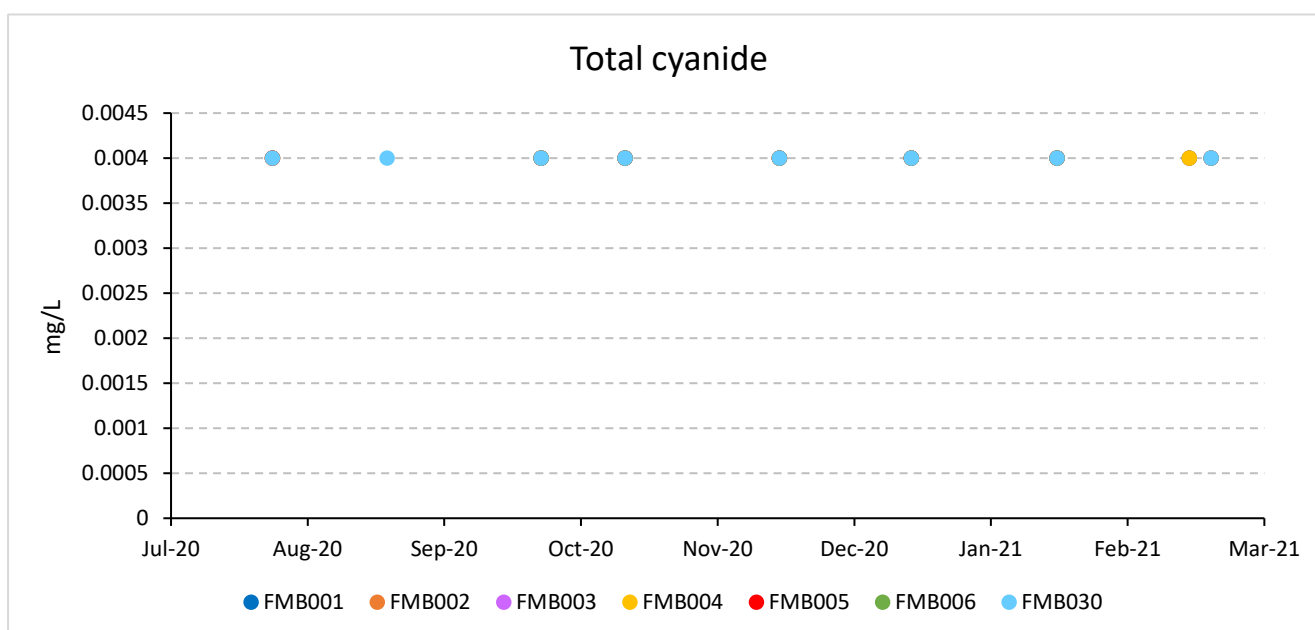
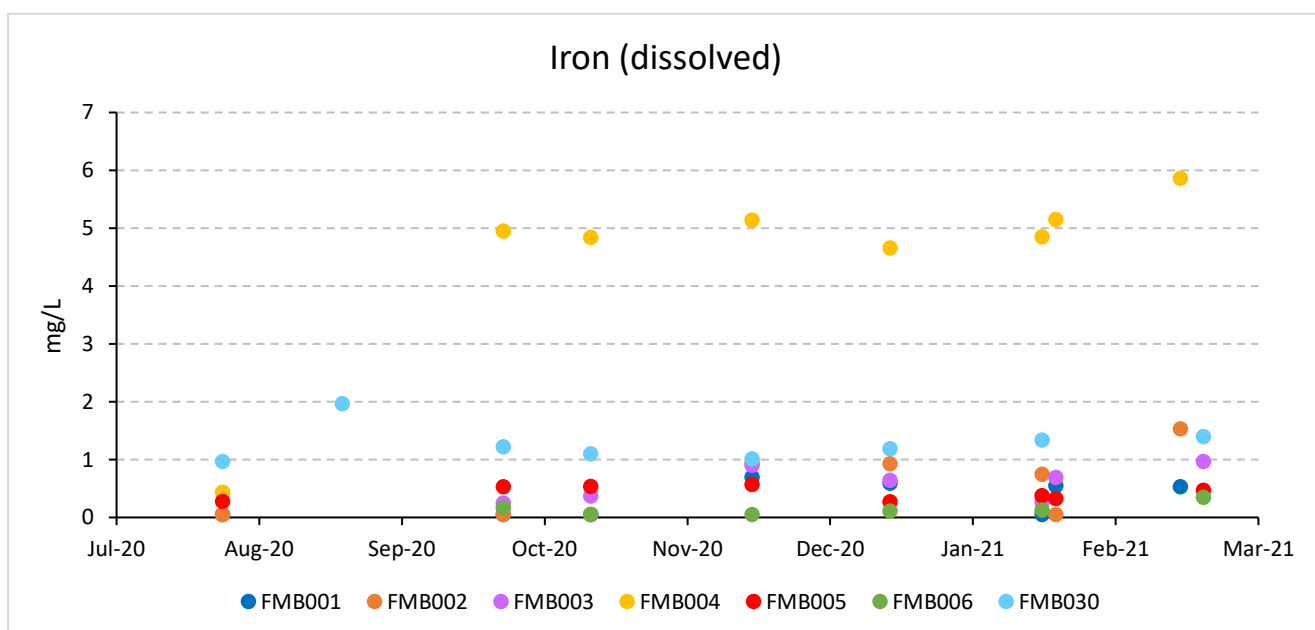
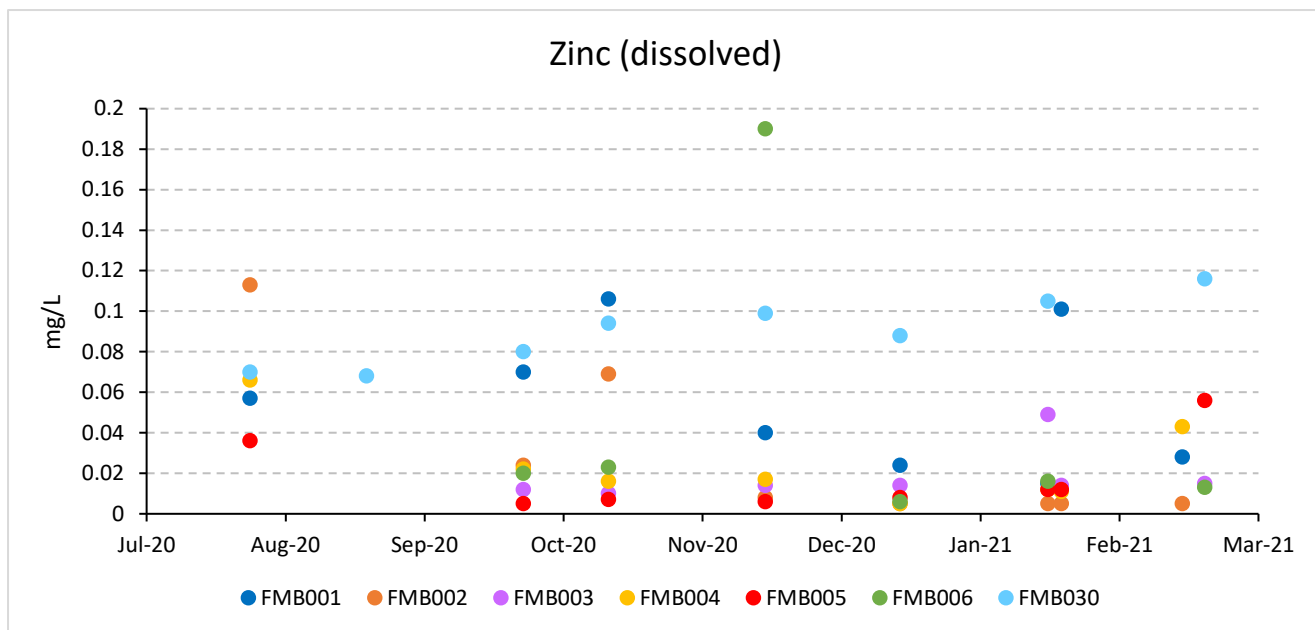


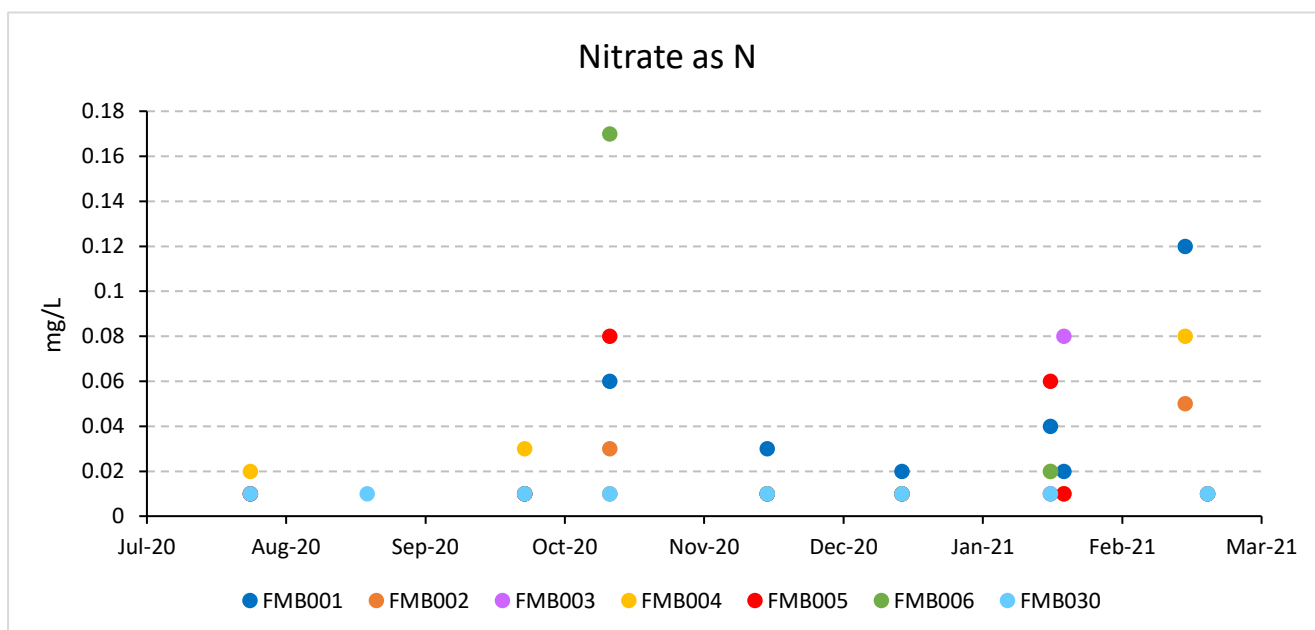
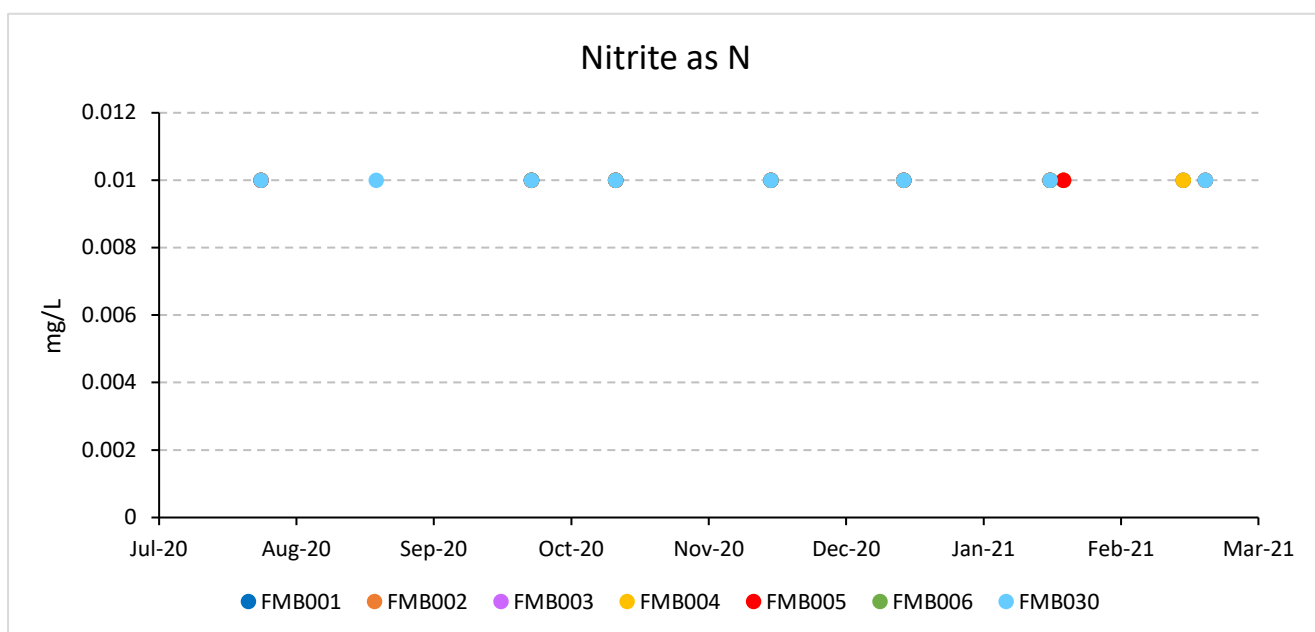
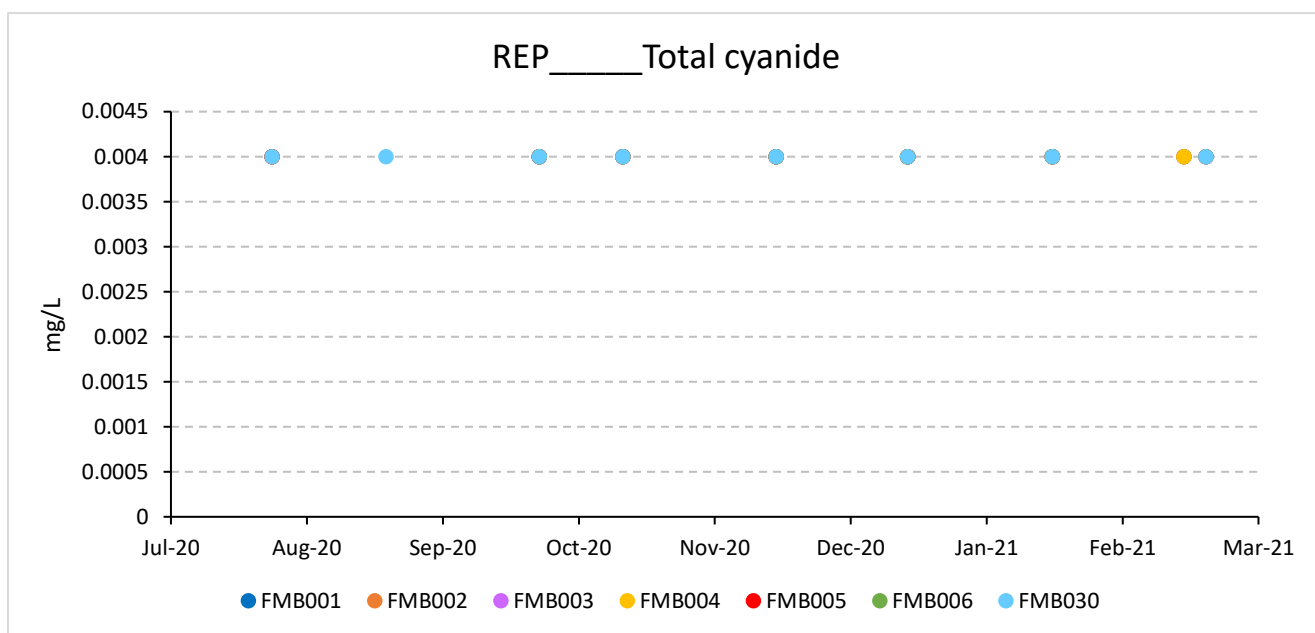


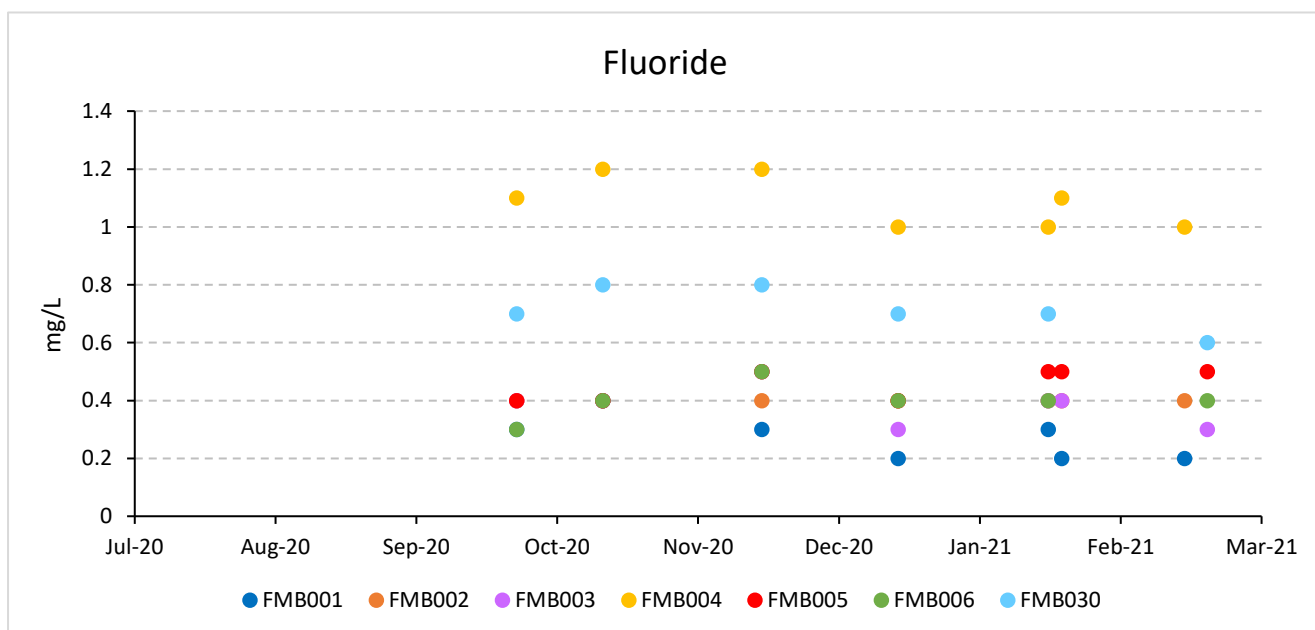
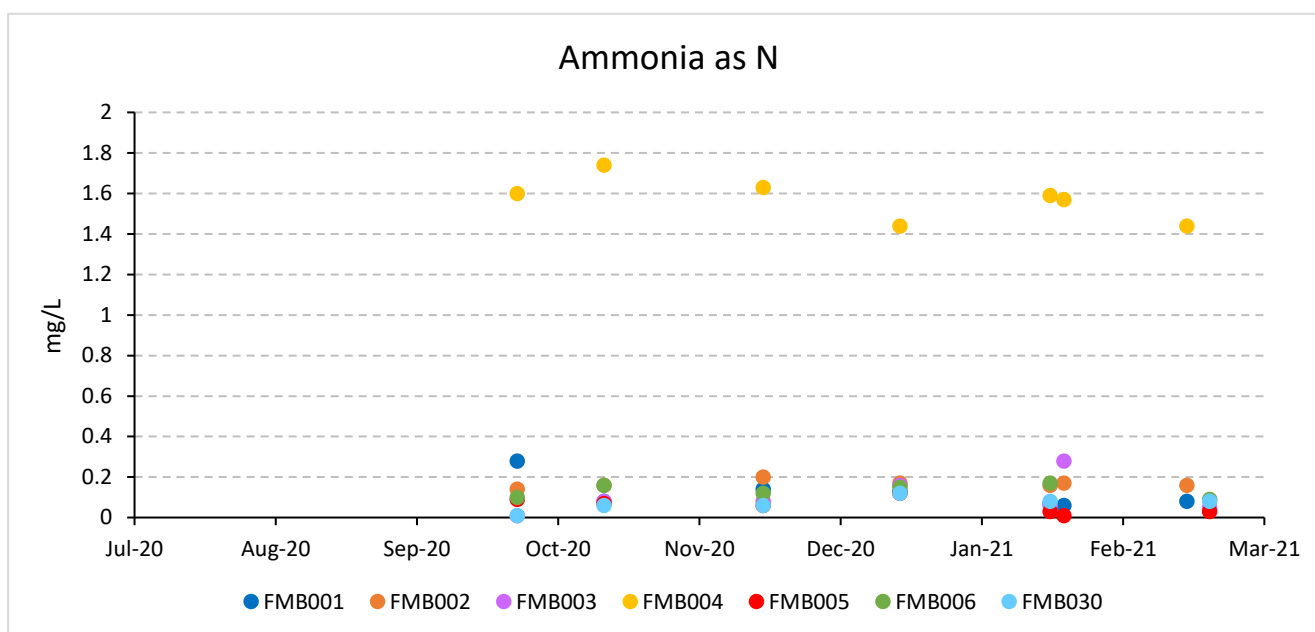
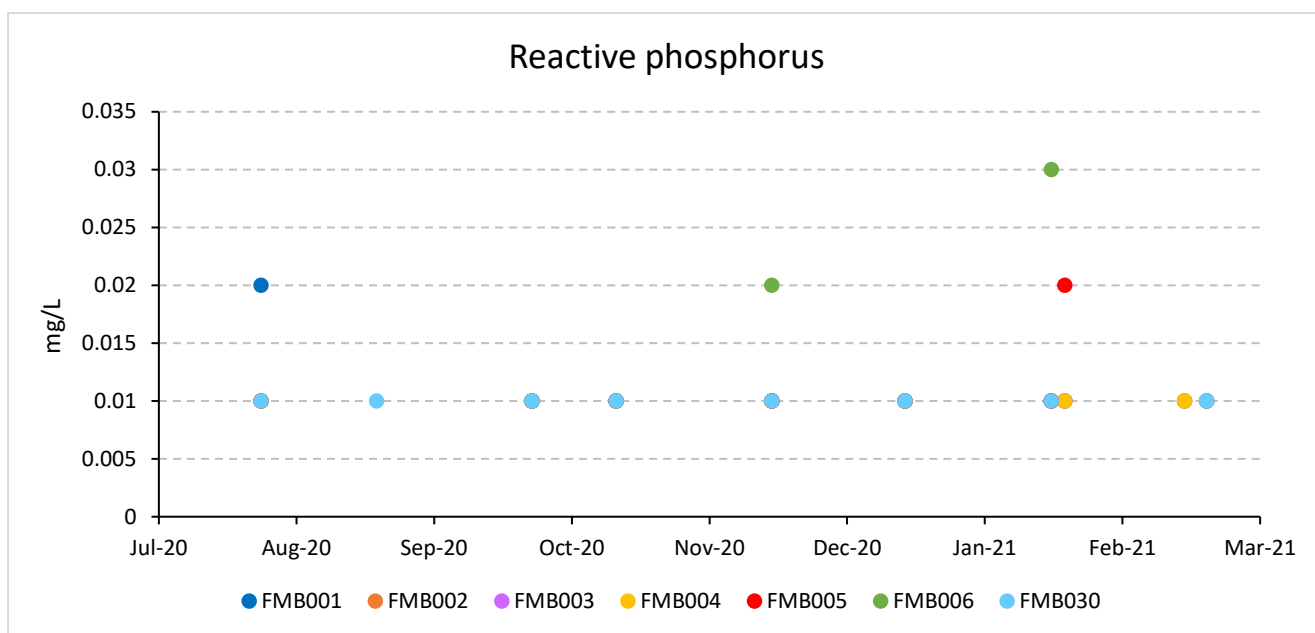






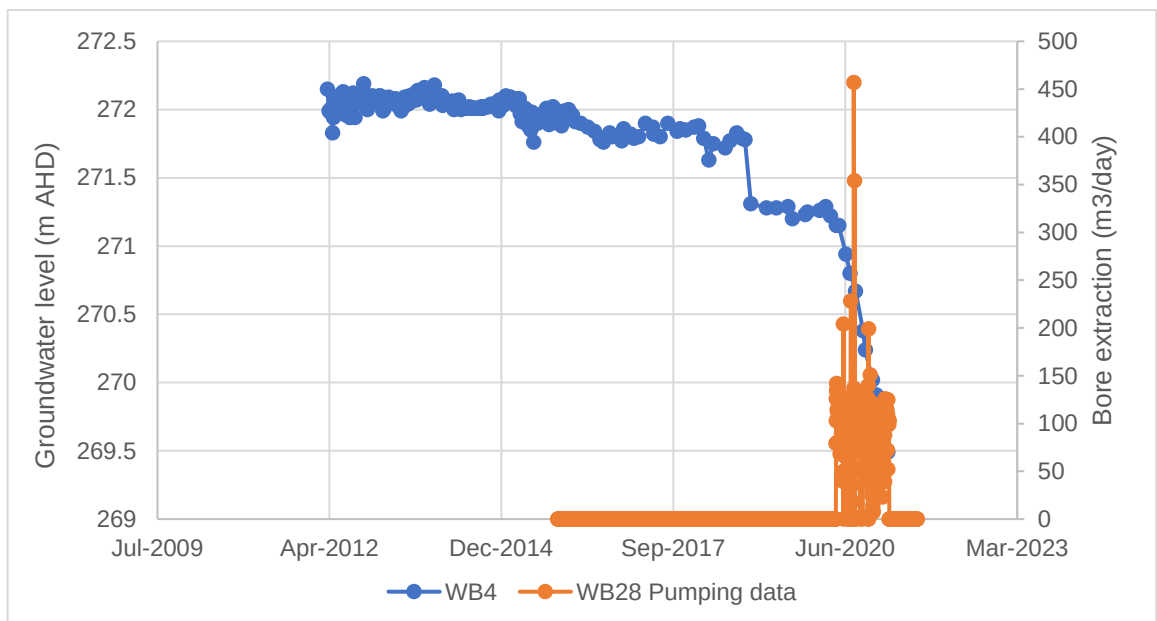




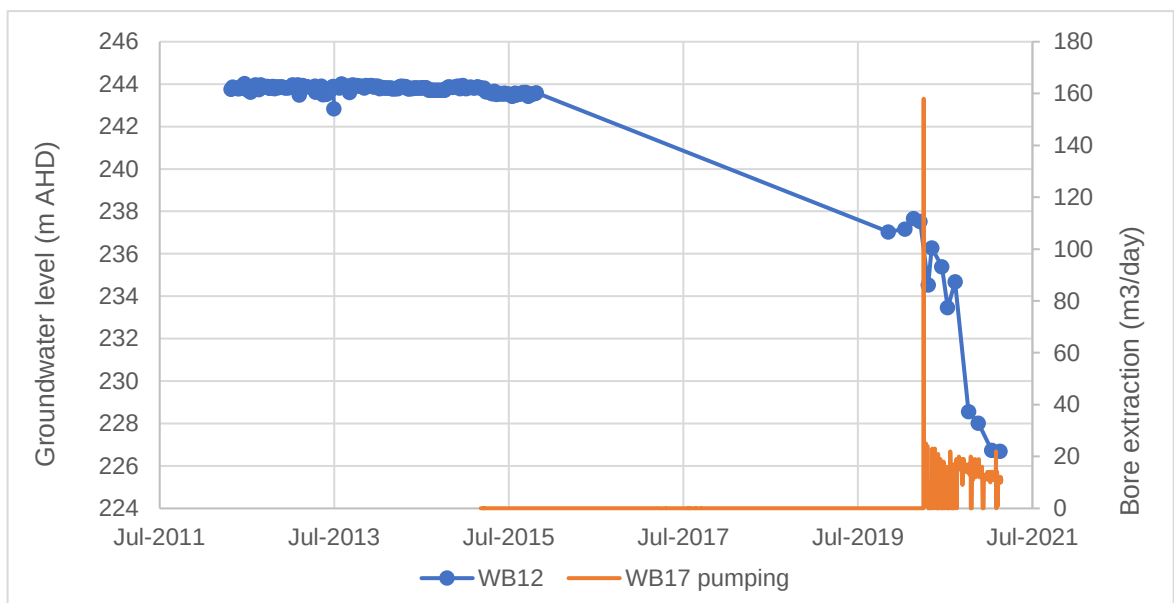
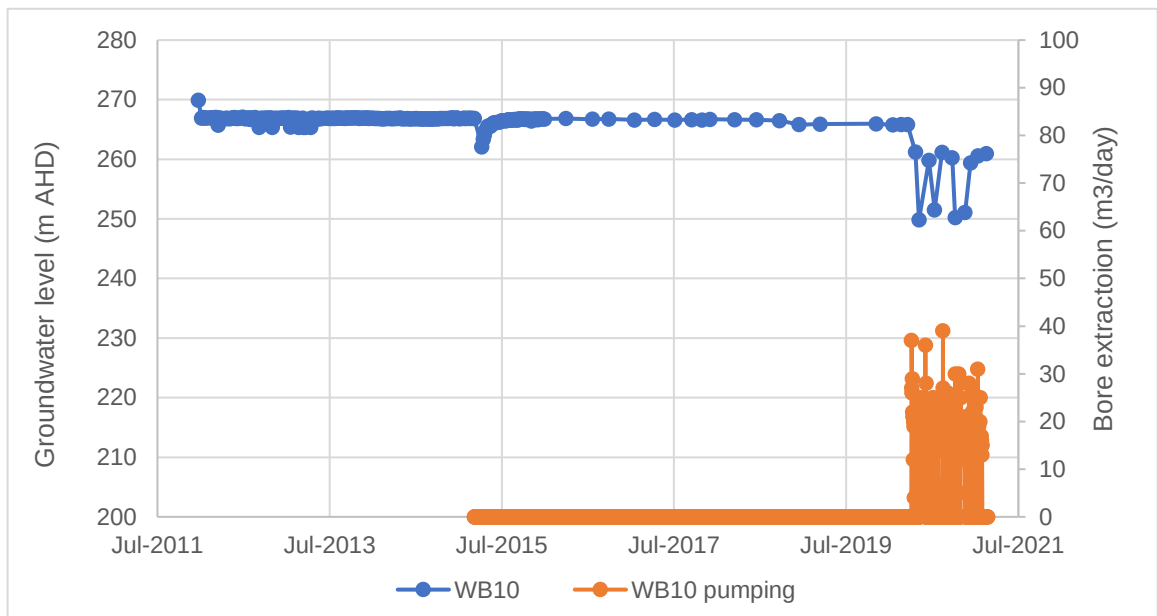


Appendix C

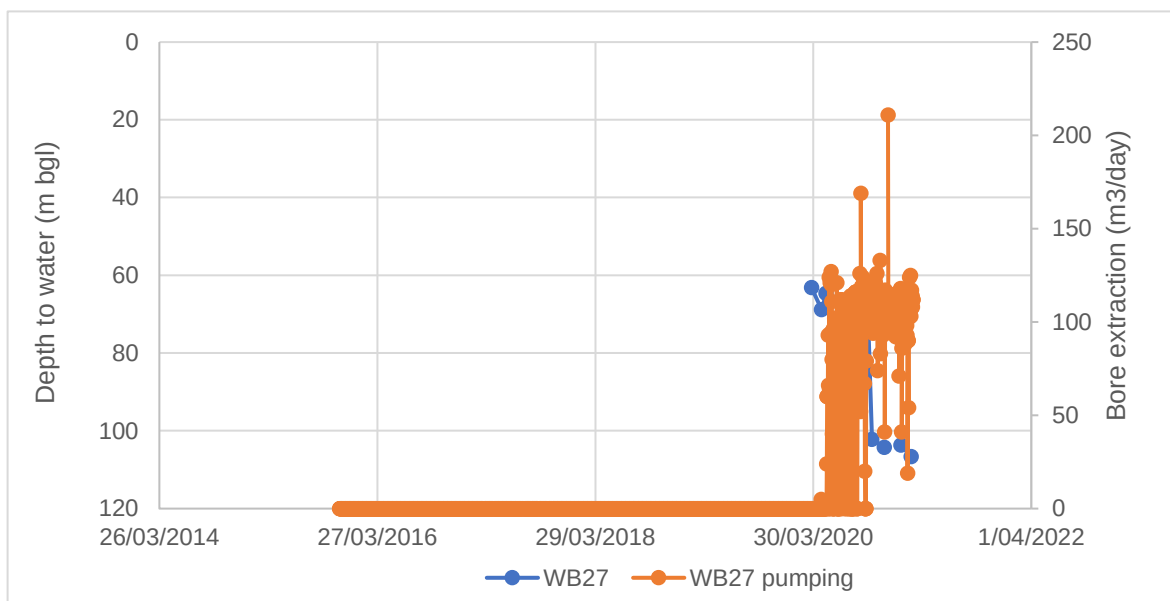
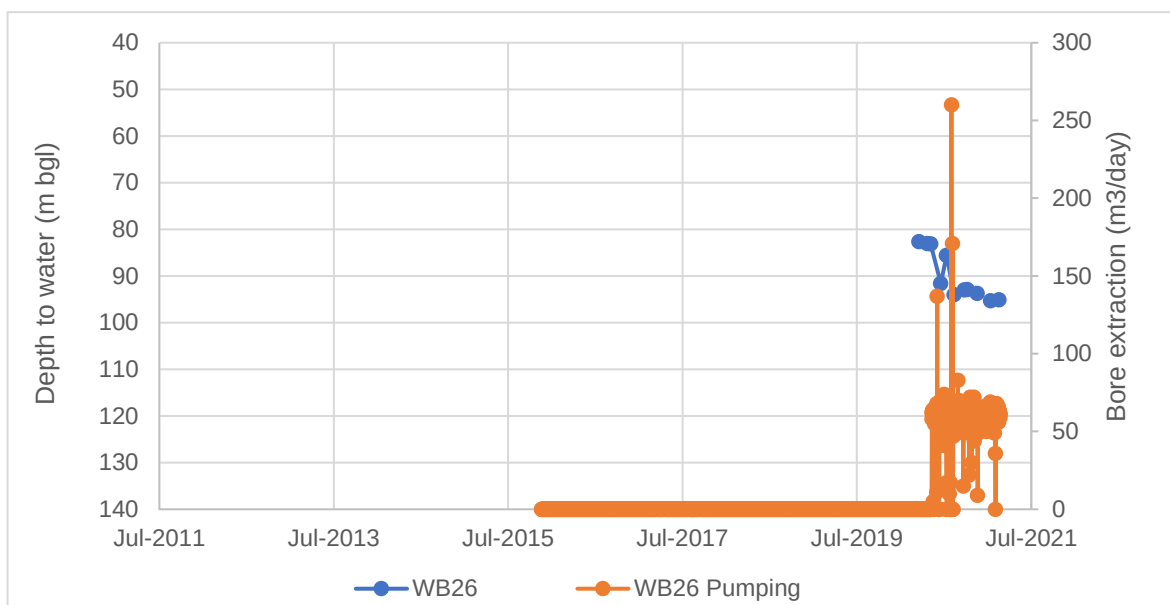
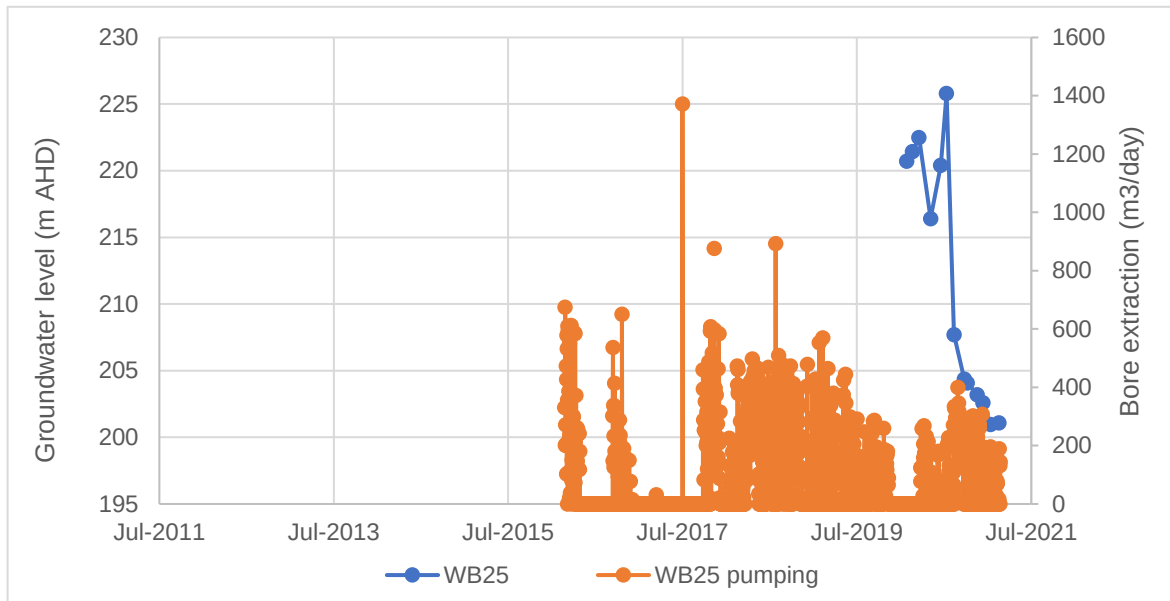
Production bores and groundwater levels

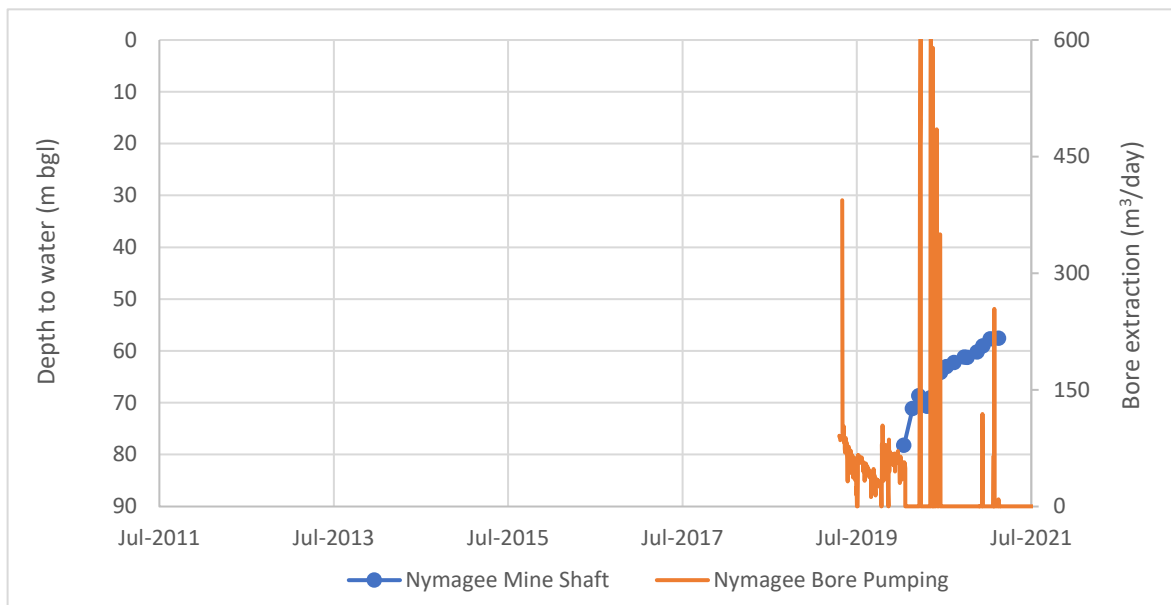
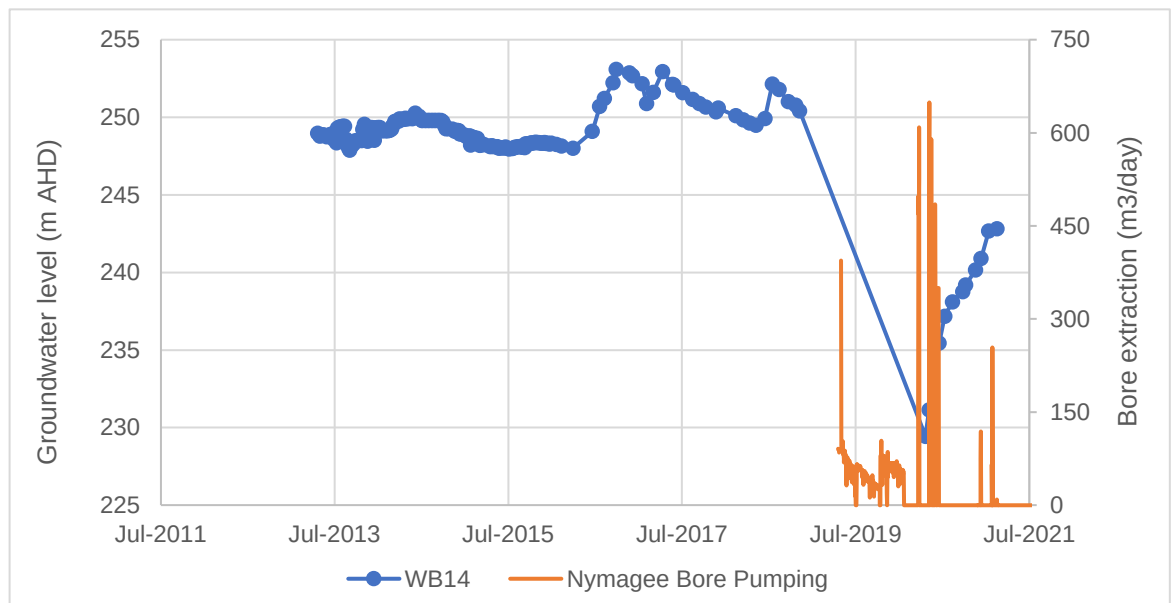
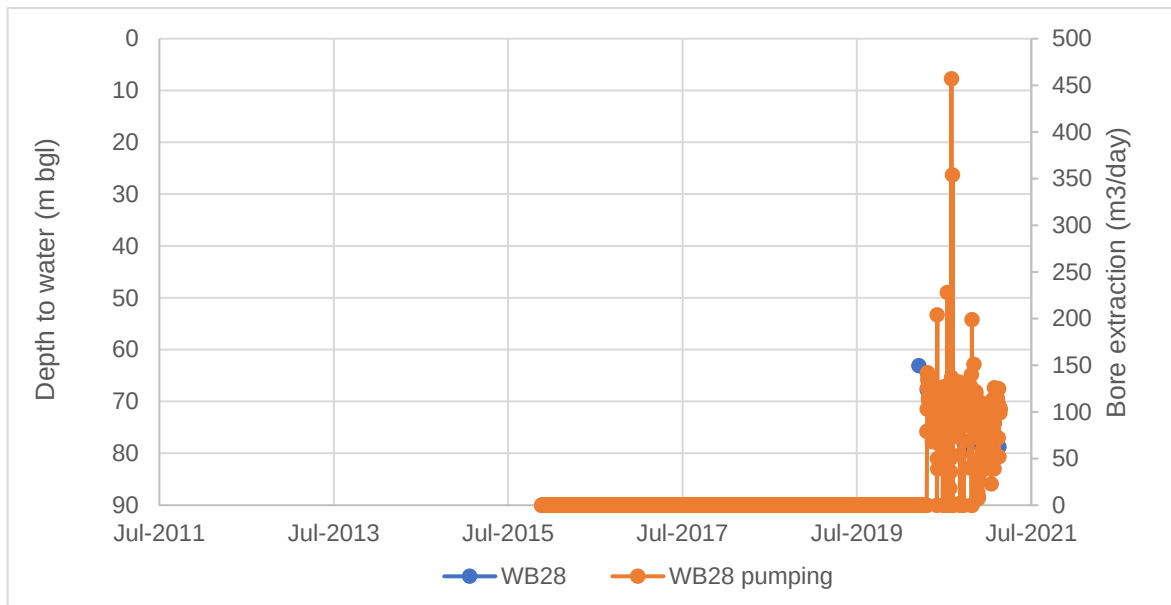


Note: WB28 0.84 km from WB4

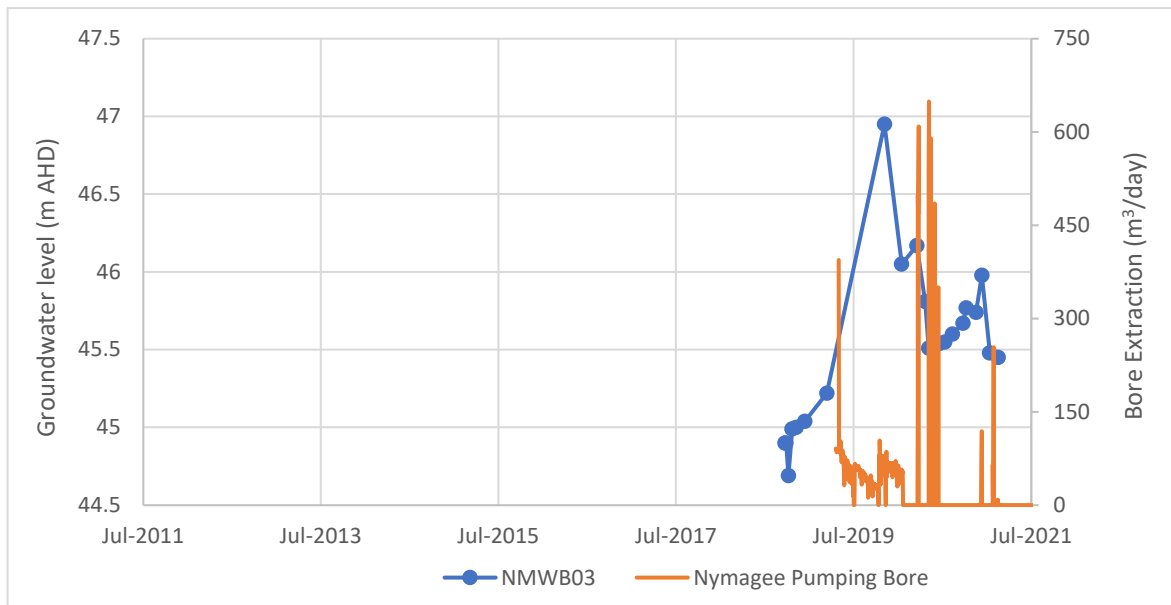


Note: WB17 in vicinity of WB12

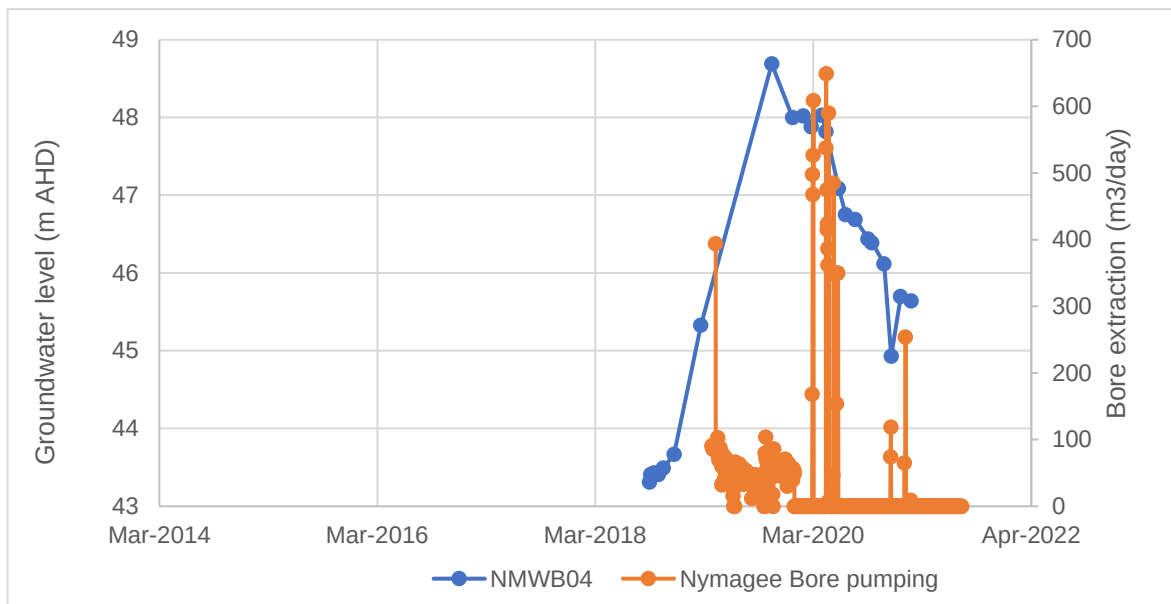




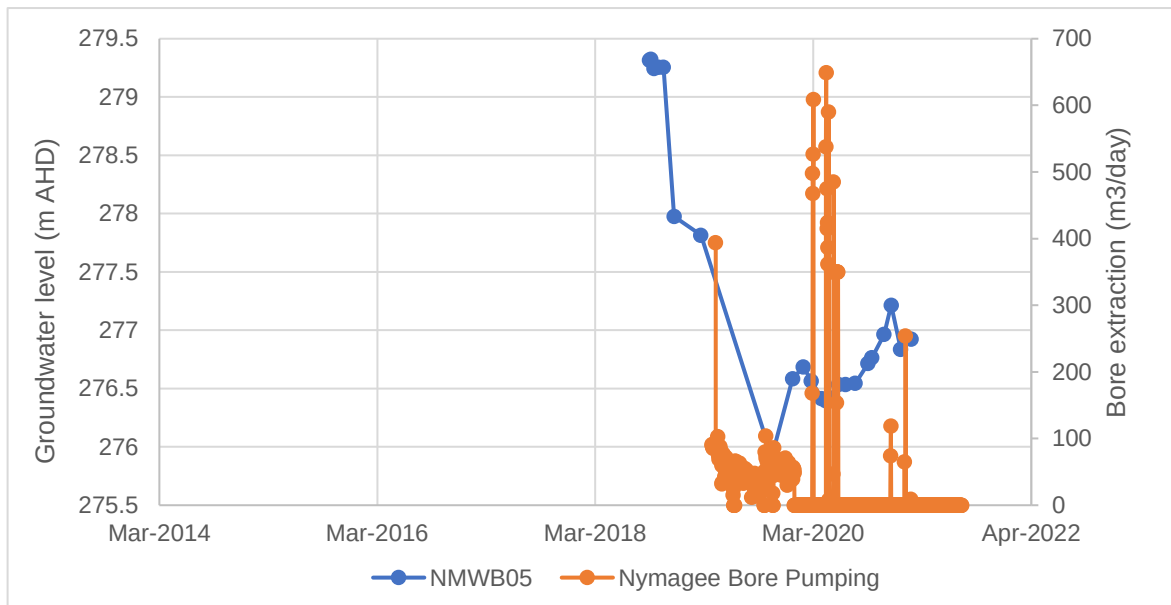
Note: Nymagee Bore 0.11 km from Nymagee Mine Shaft



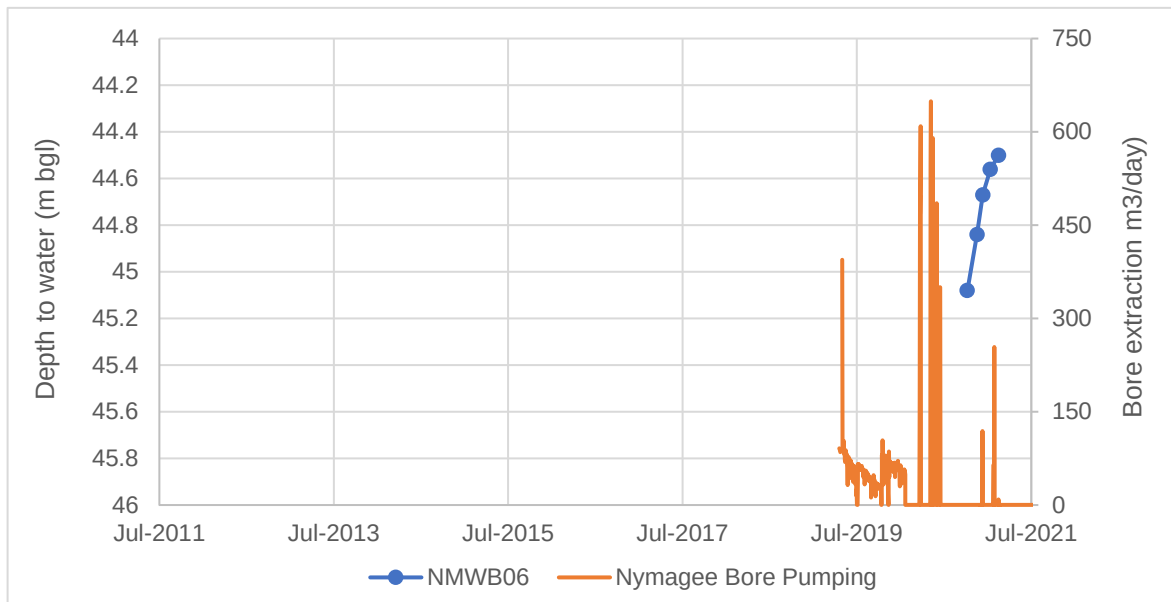
Note: Nymagee Bore 0.34 km from NMWB03



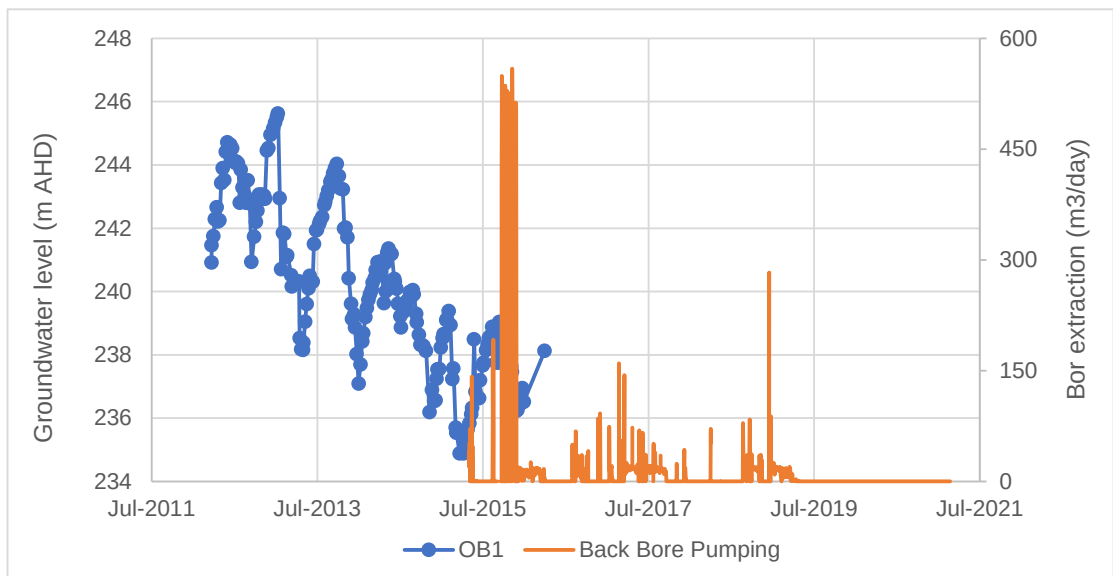
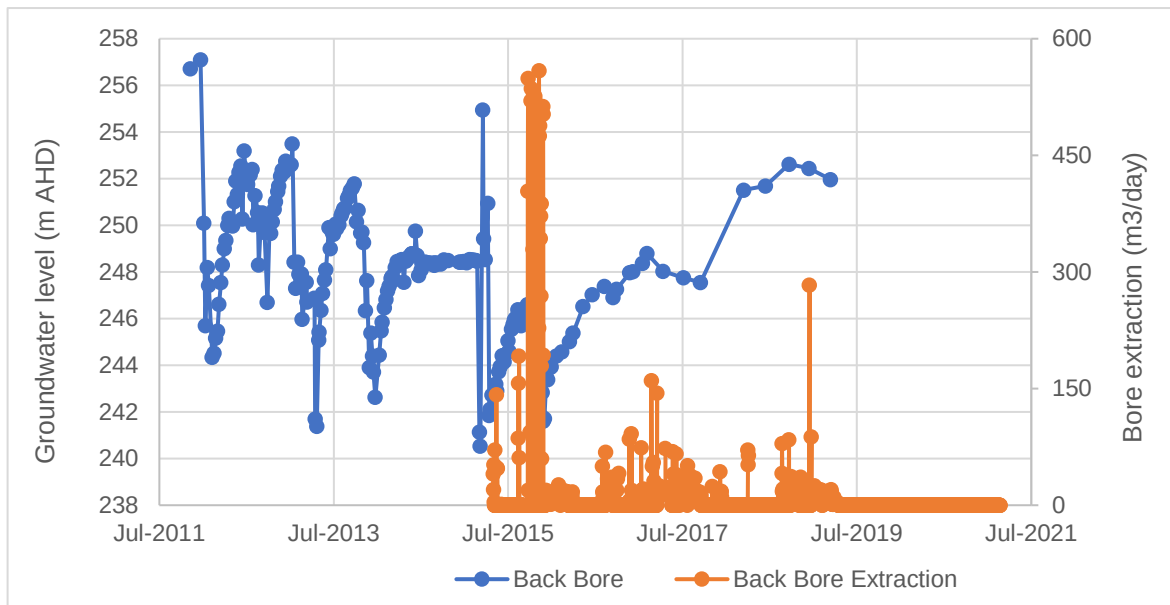
Note: Nymagee Bore 0.28 km from NMWB04



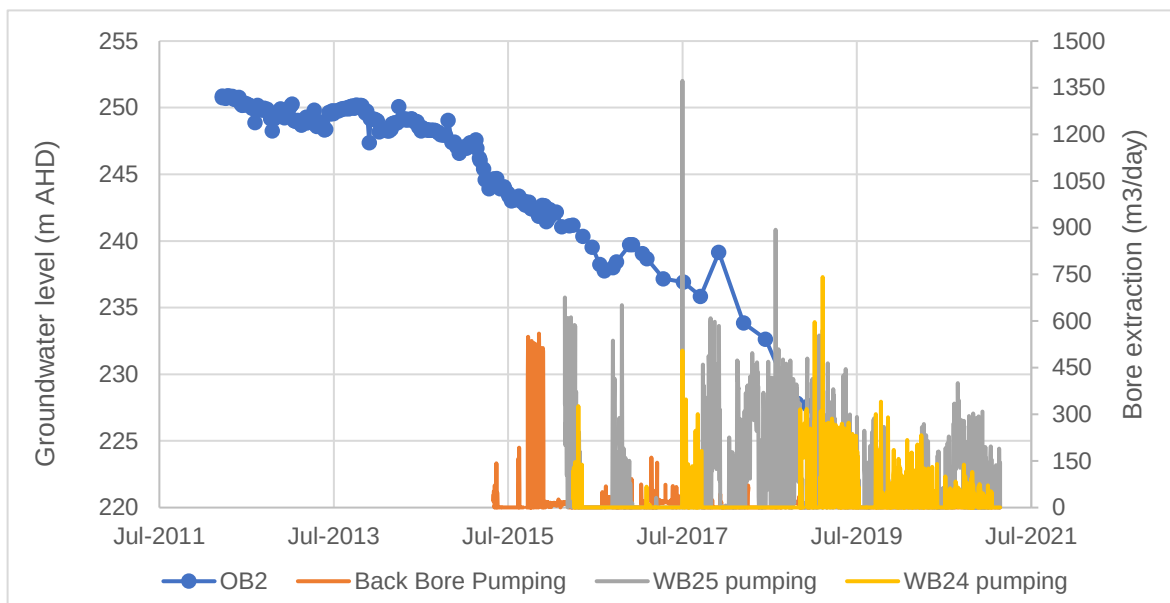
Note: Nymagee Bore 0.28 km from NMWB05



Note: Nymagee Bore 0.72 km from NMWB06

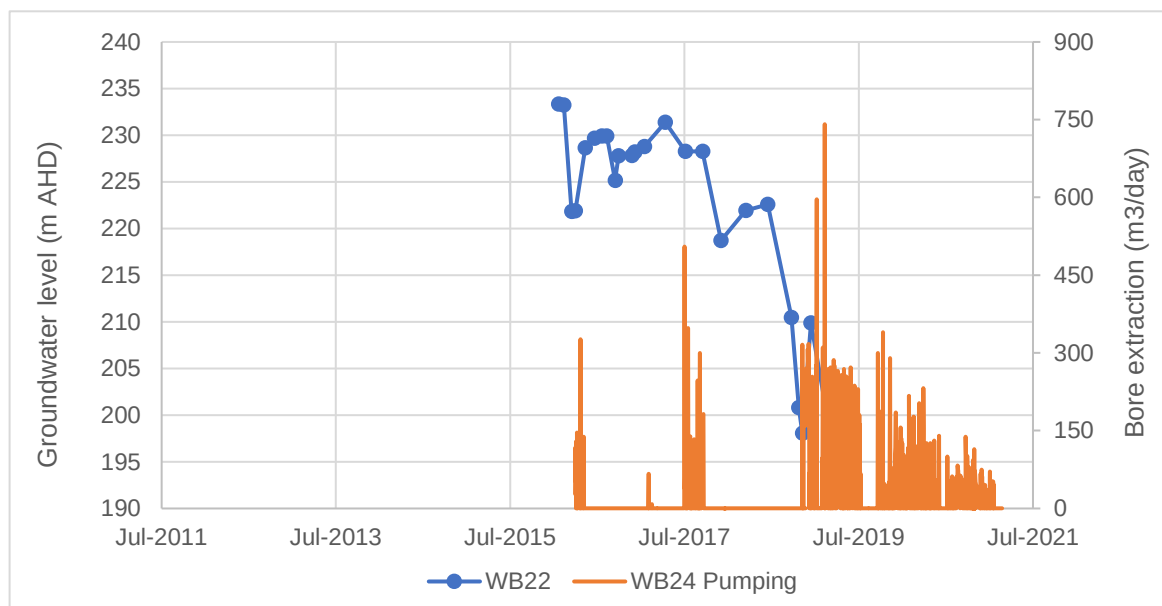


Note: Back Bore 0.16 km from OB1



Note:

Back Bore 1.1 km from OB2
WB25 1.0 km from OB2
WB22 0.8 km from OB2



Note: WB24 in vicinity of WB22

Appendix D

Model discretisation

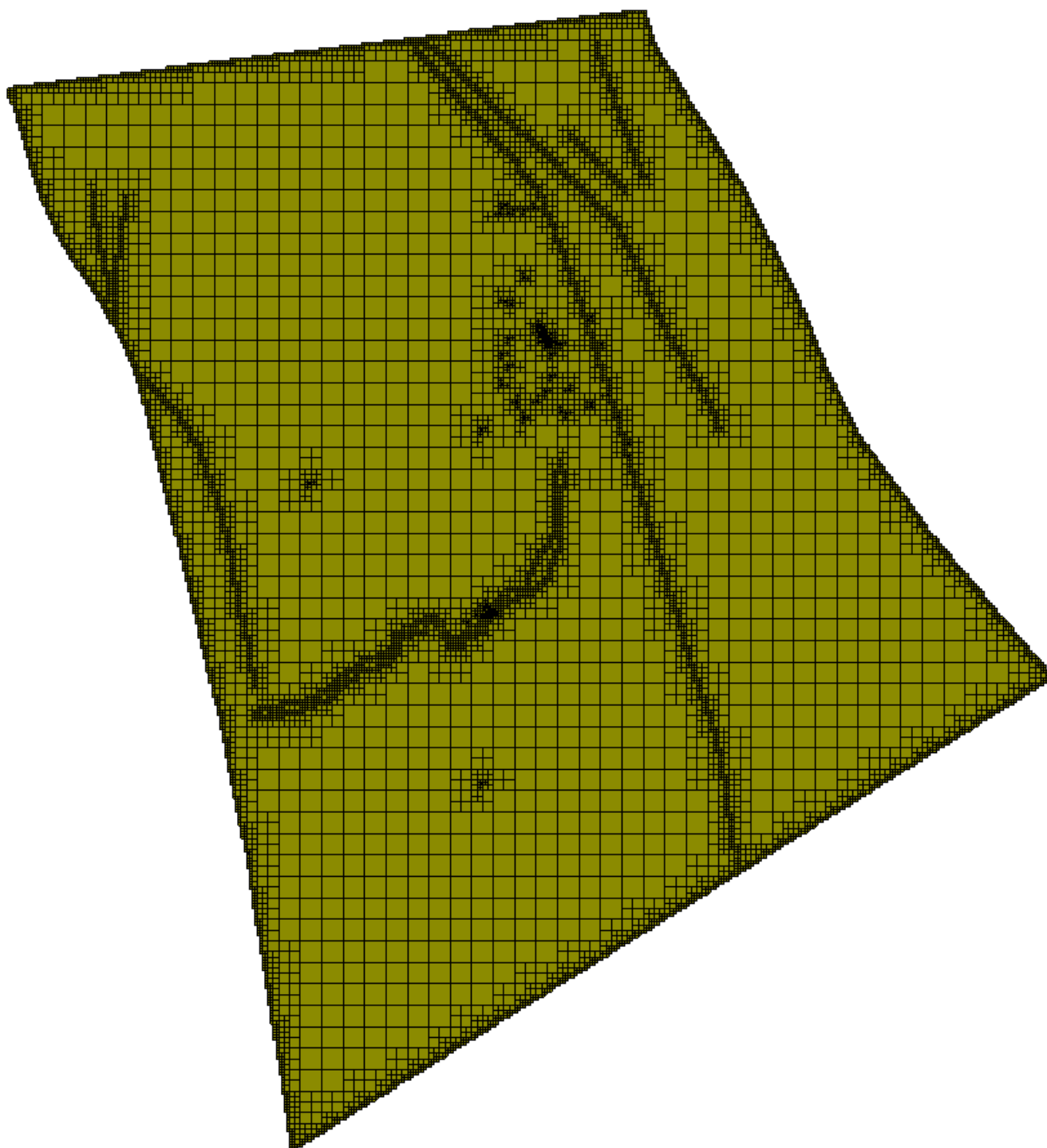


Figure D.1 *Model layer 1*

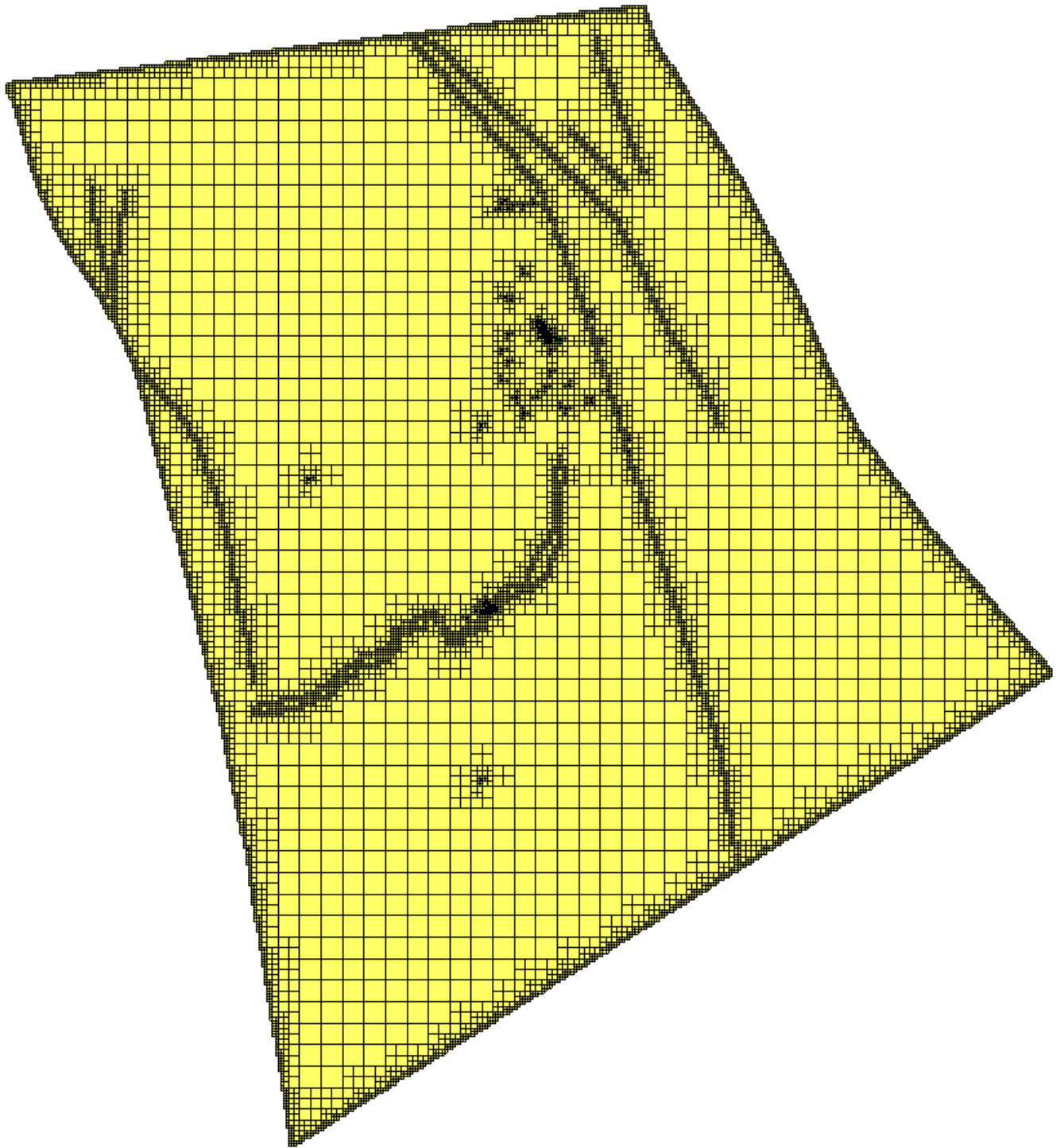


Figure D.2 Model layer 2

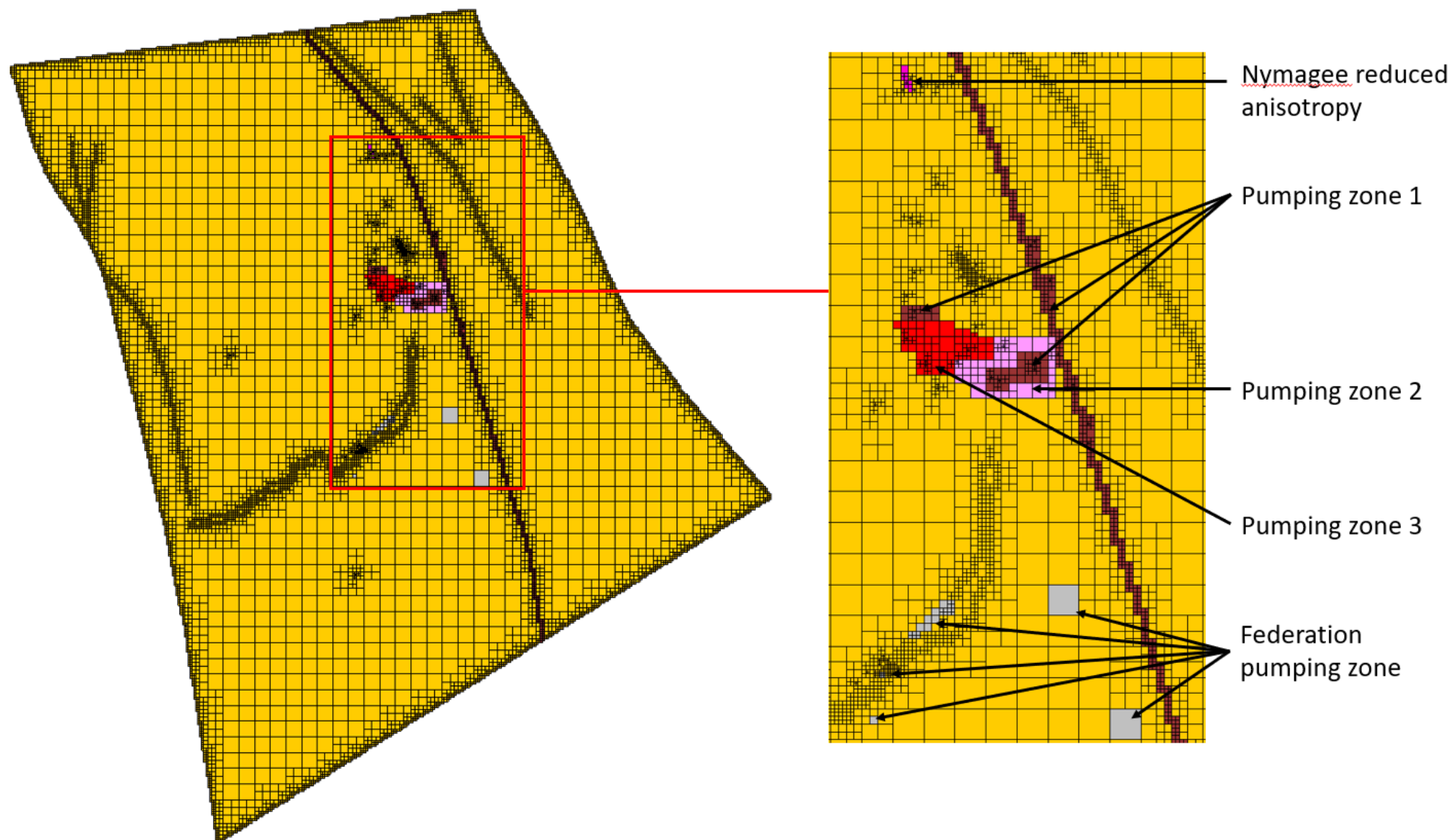


Figure D.3 Model layer 3

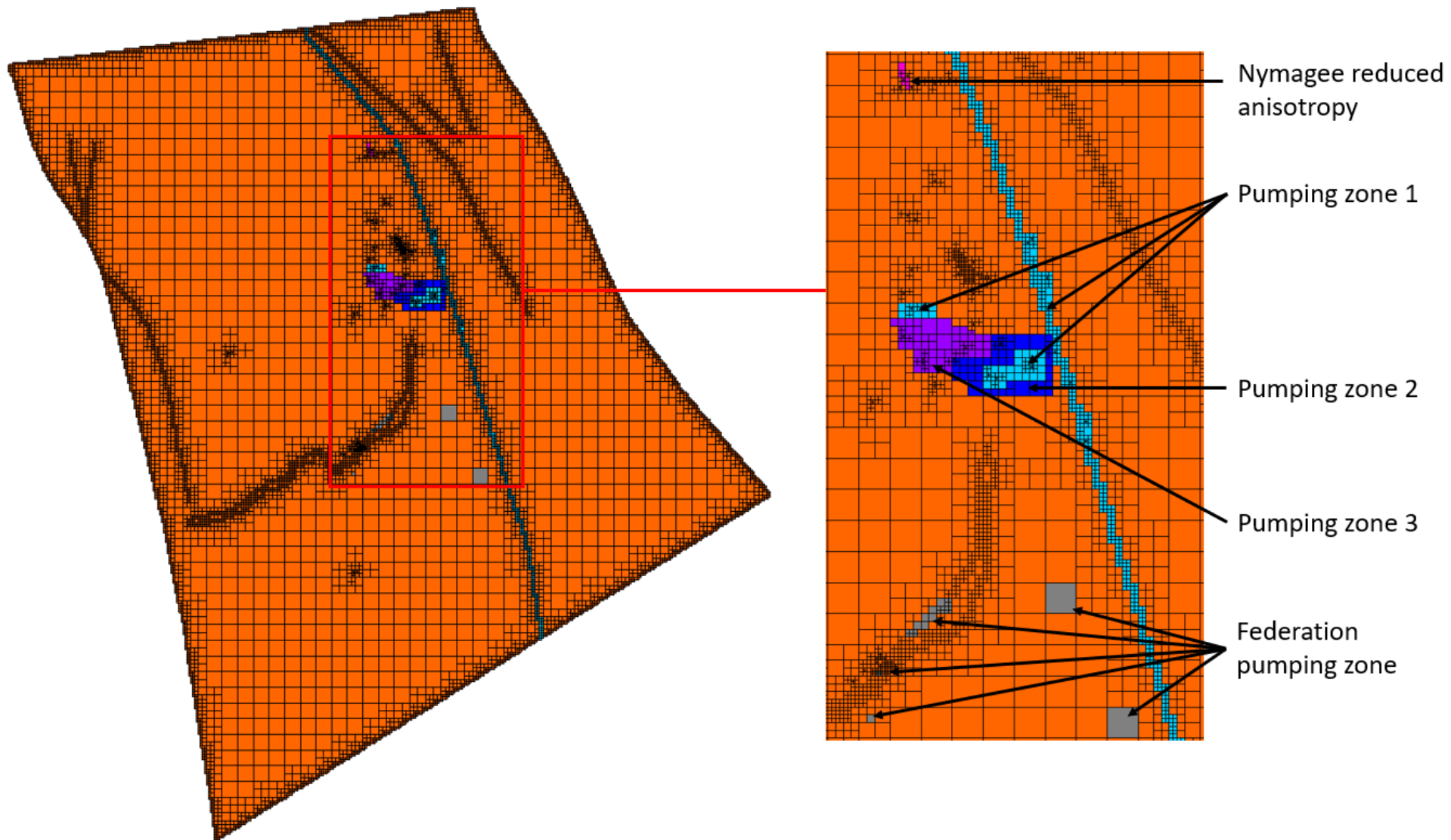


Figure D.4 Model layer 4

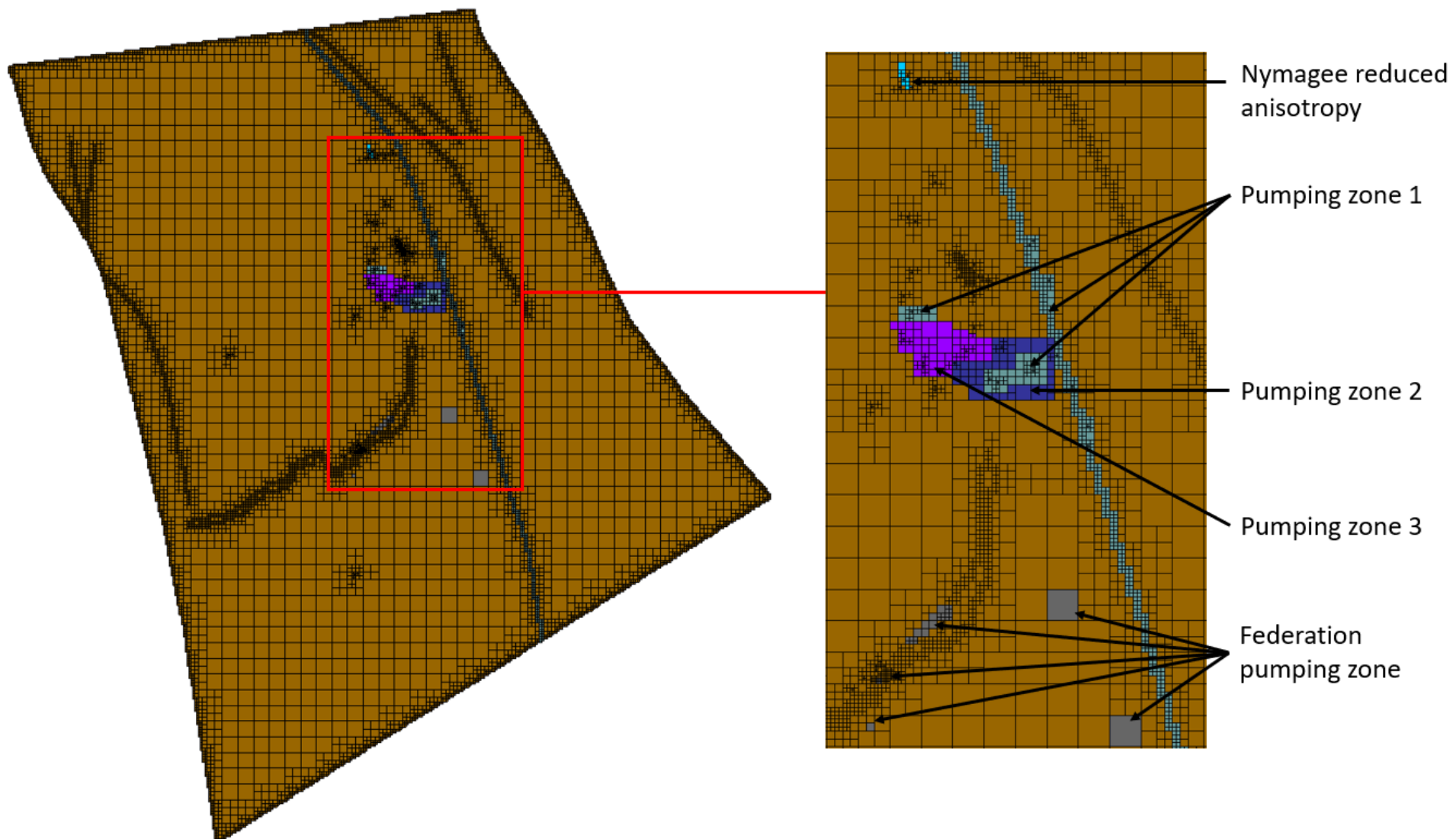


Figure D.5 Model layer 5

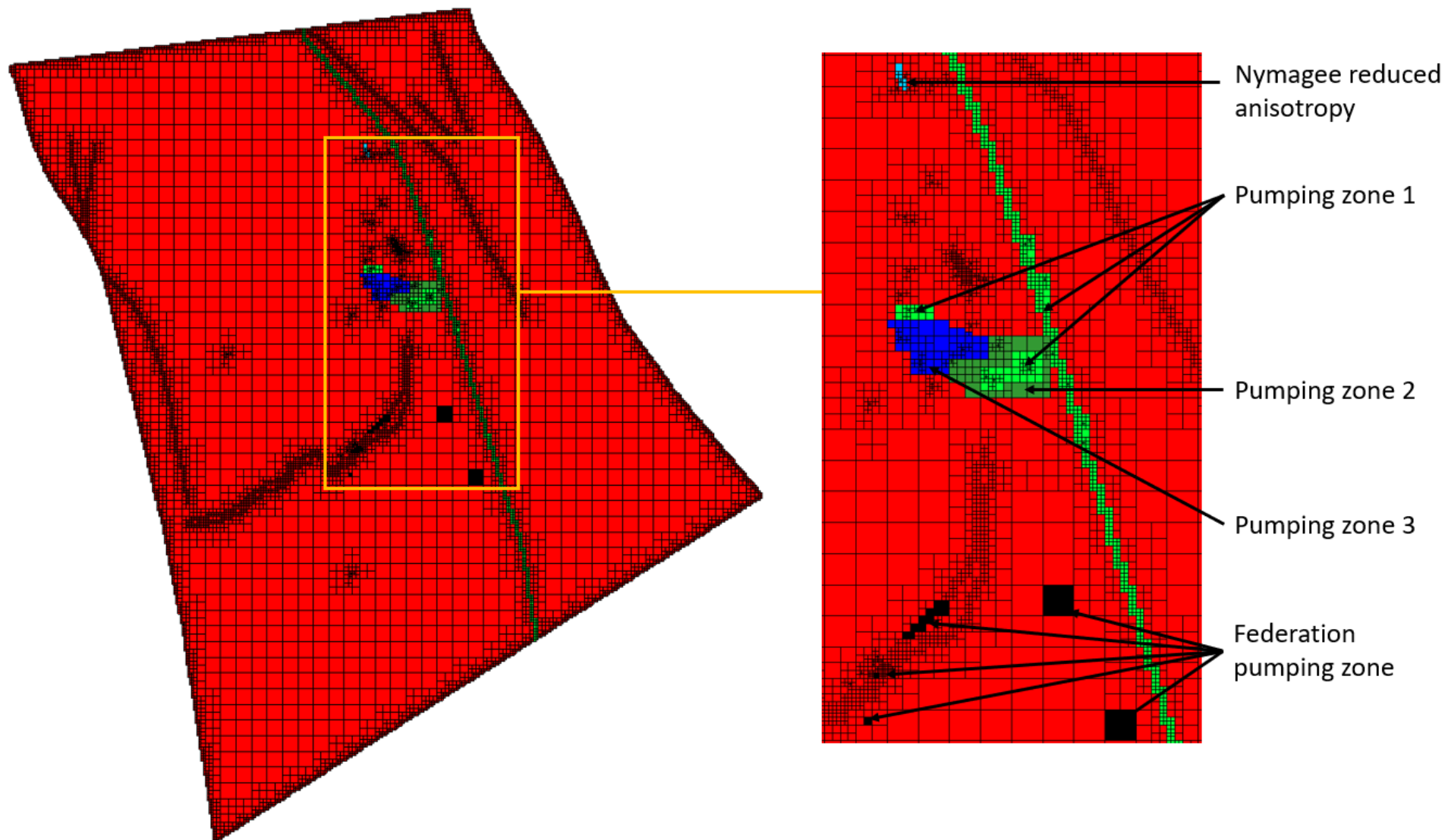


Figure D.6 Model layer 6

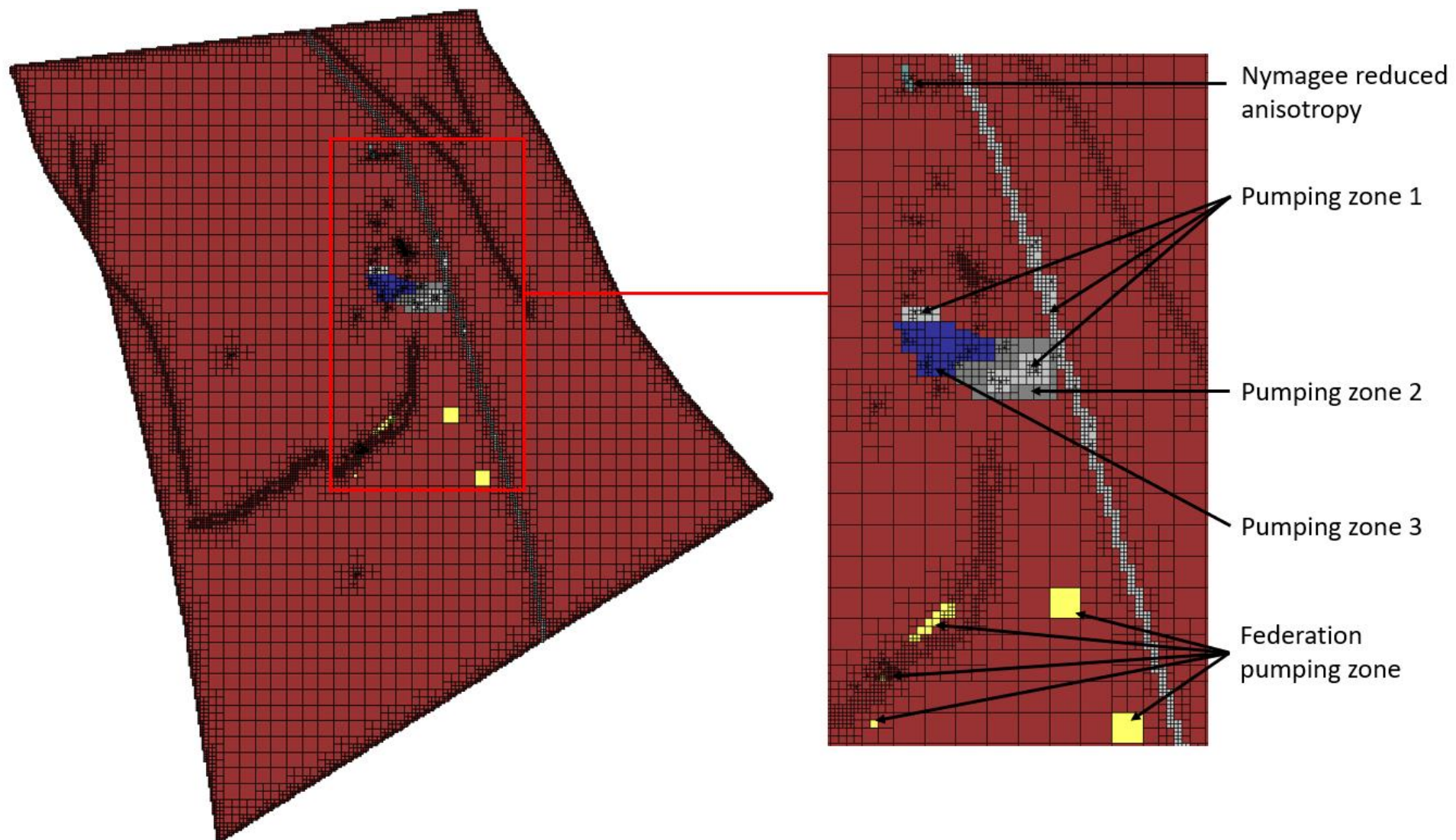


Figure D.7 Model layer 7

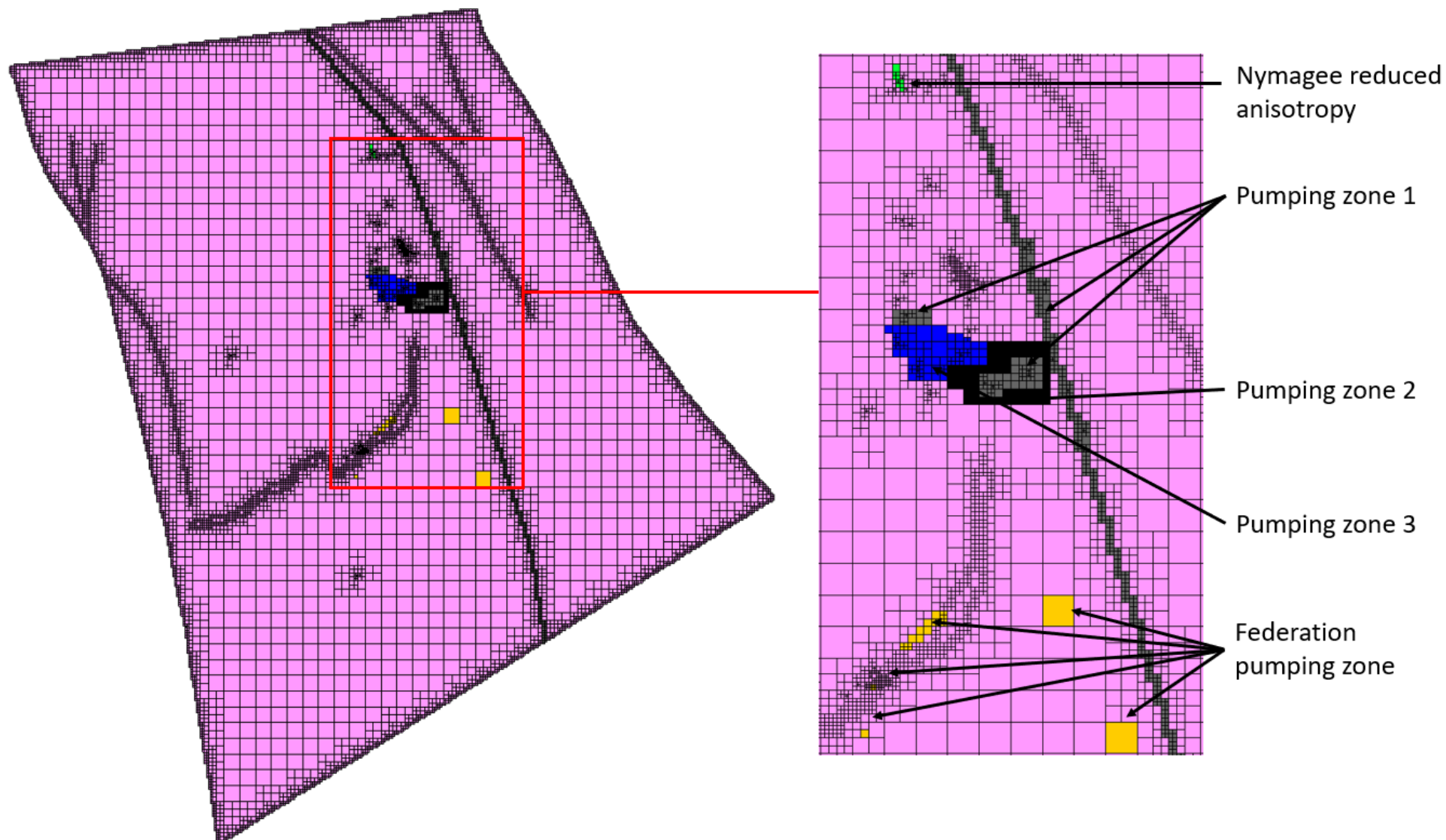


Figure D.8 Model layer 8

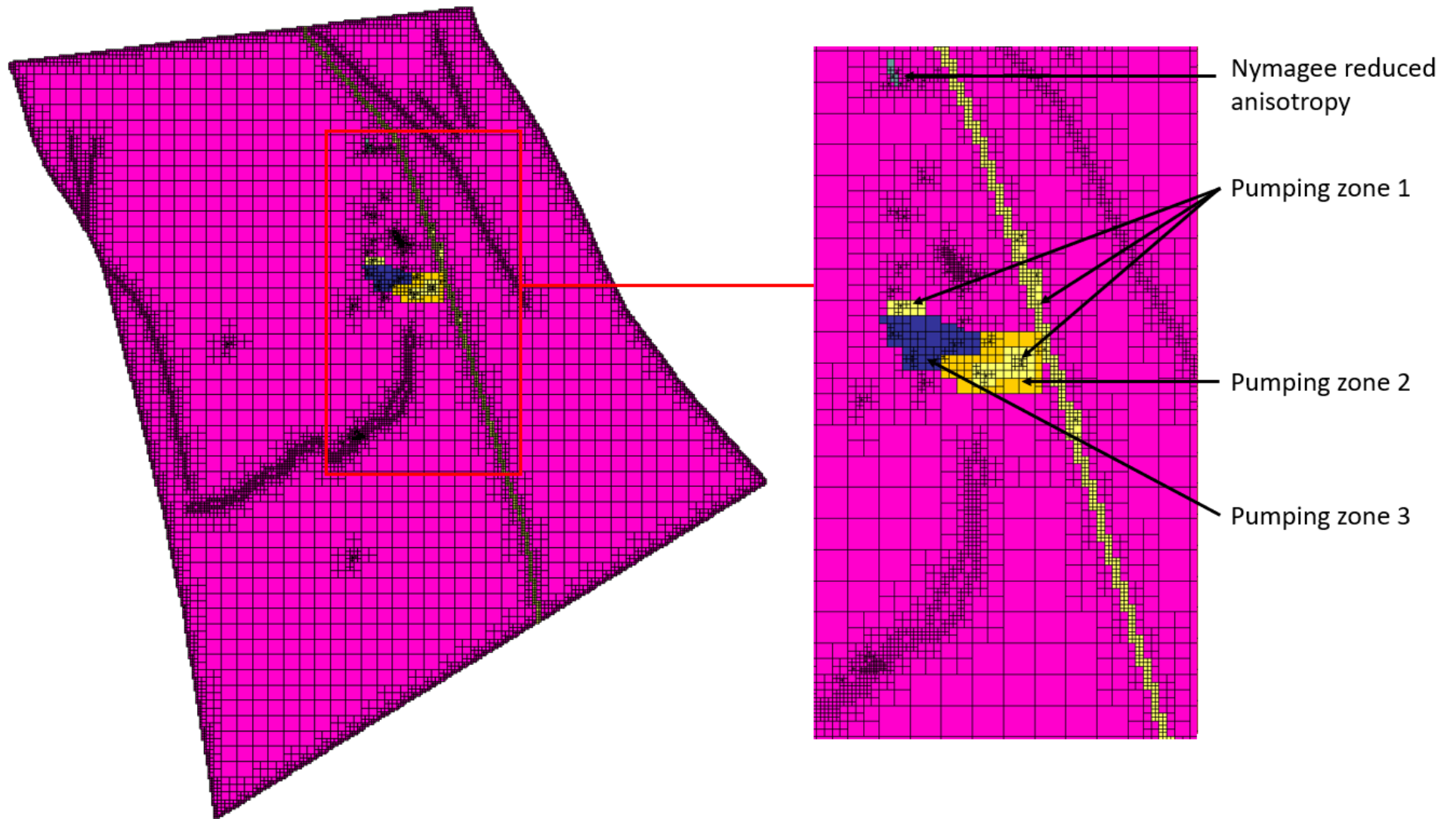


Figure D.9 Model layer 9

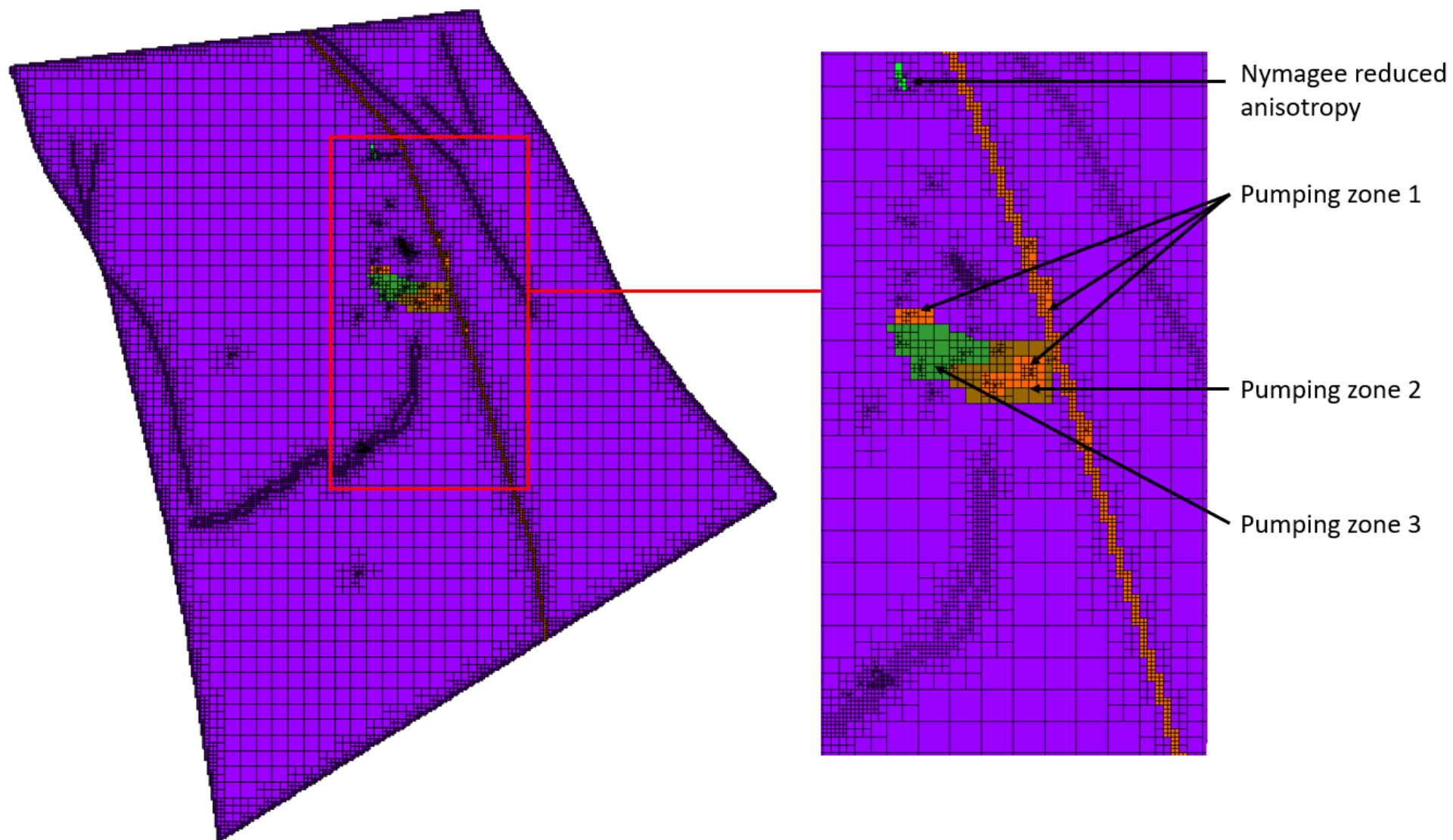


Figure D.10 Model layer 10

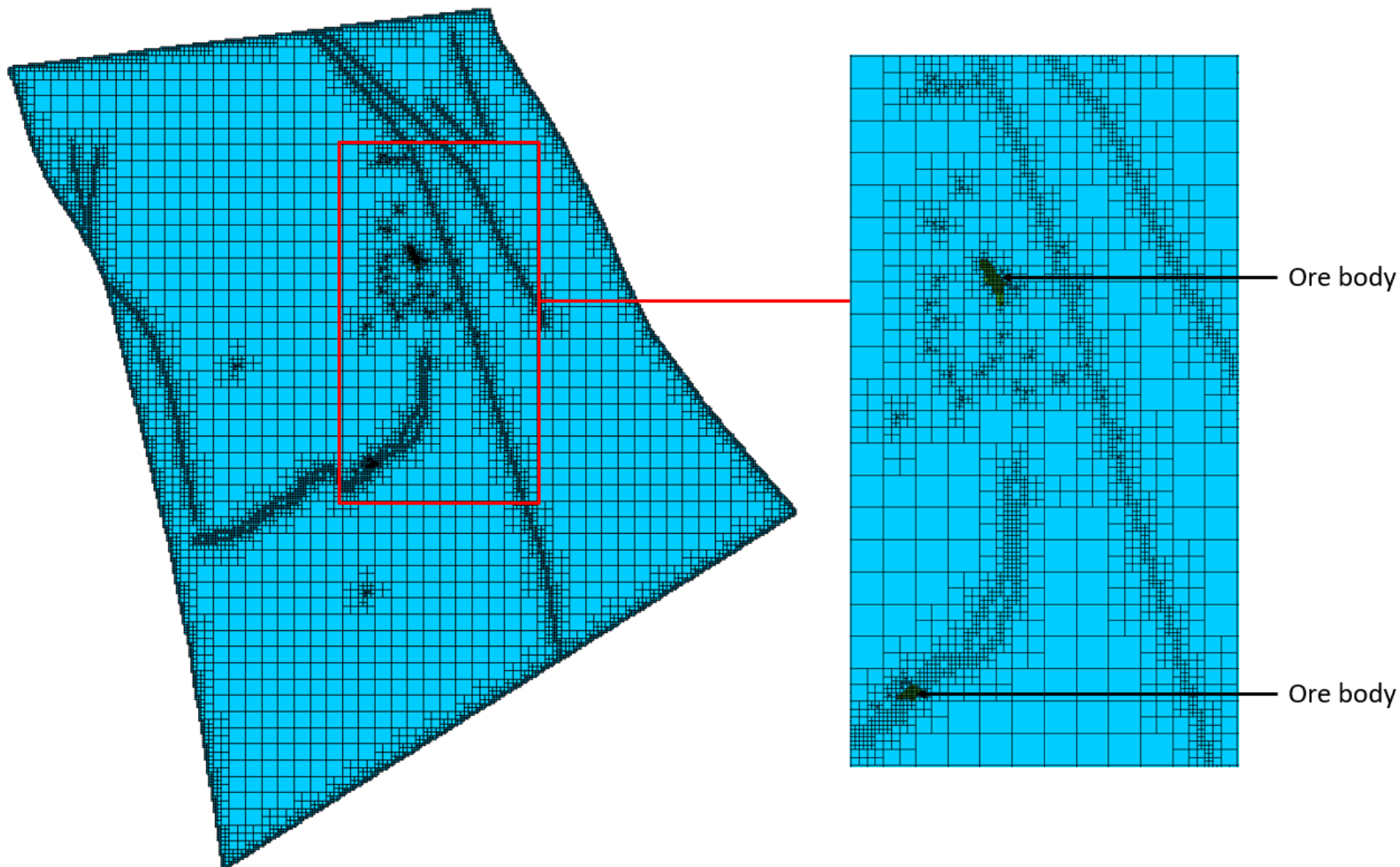


Figure D.11 Model layer 11

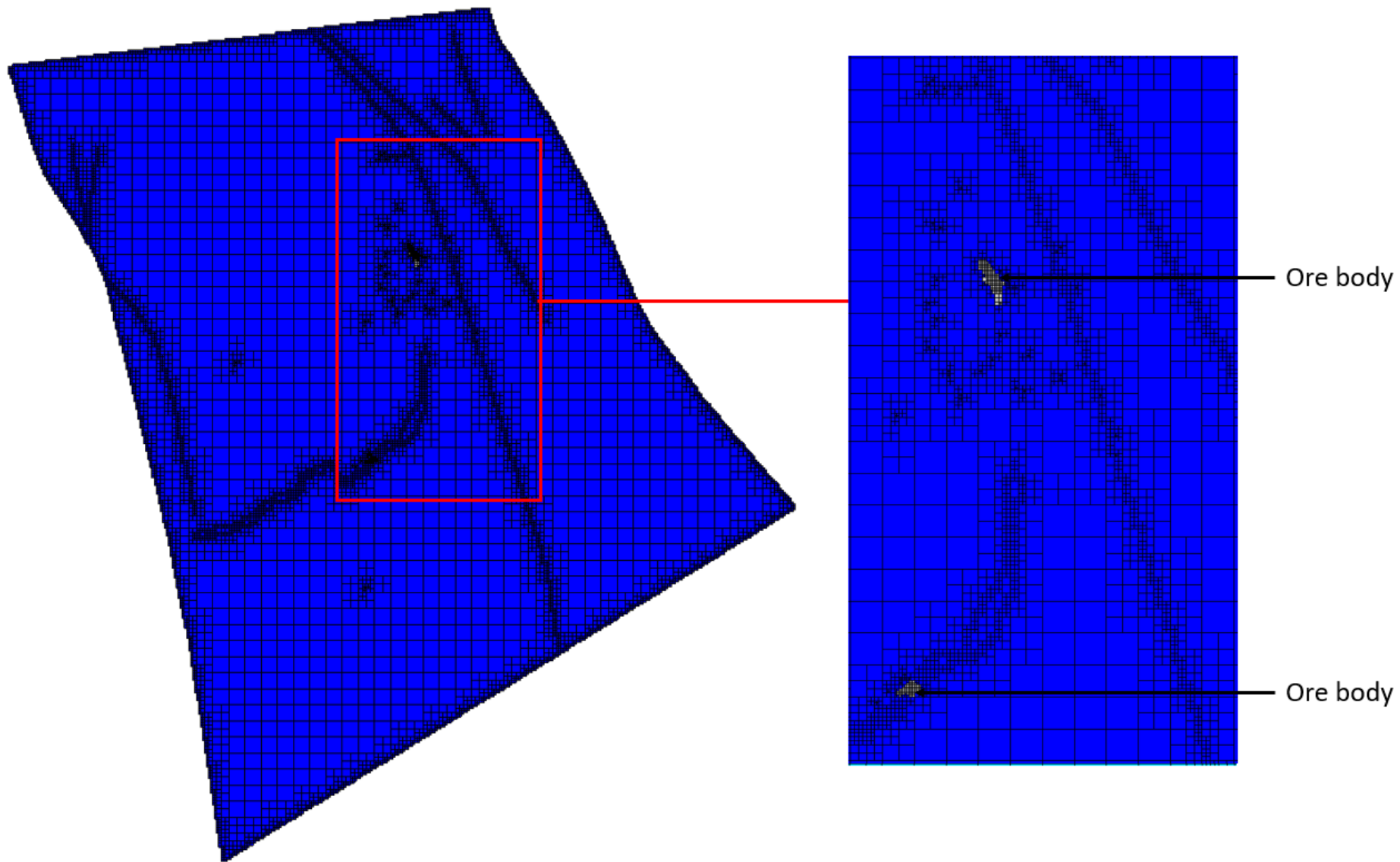


Figure D.12 Model layer 12

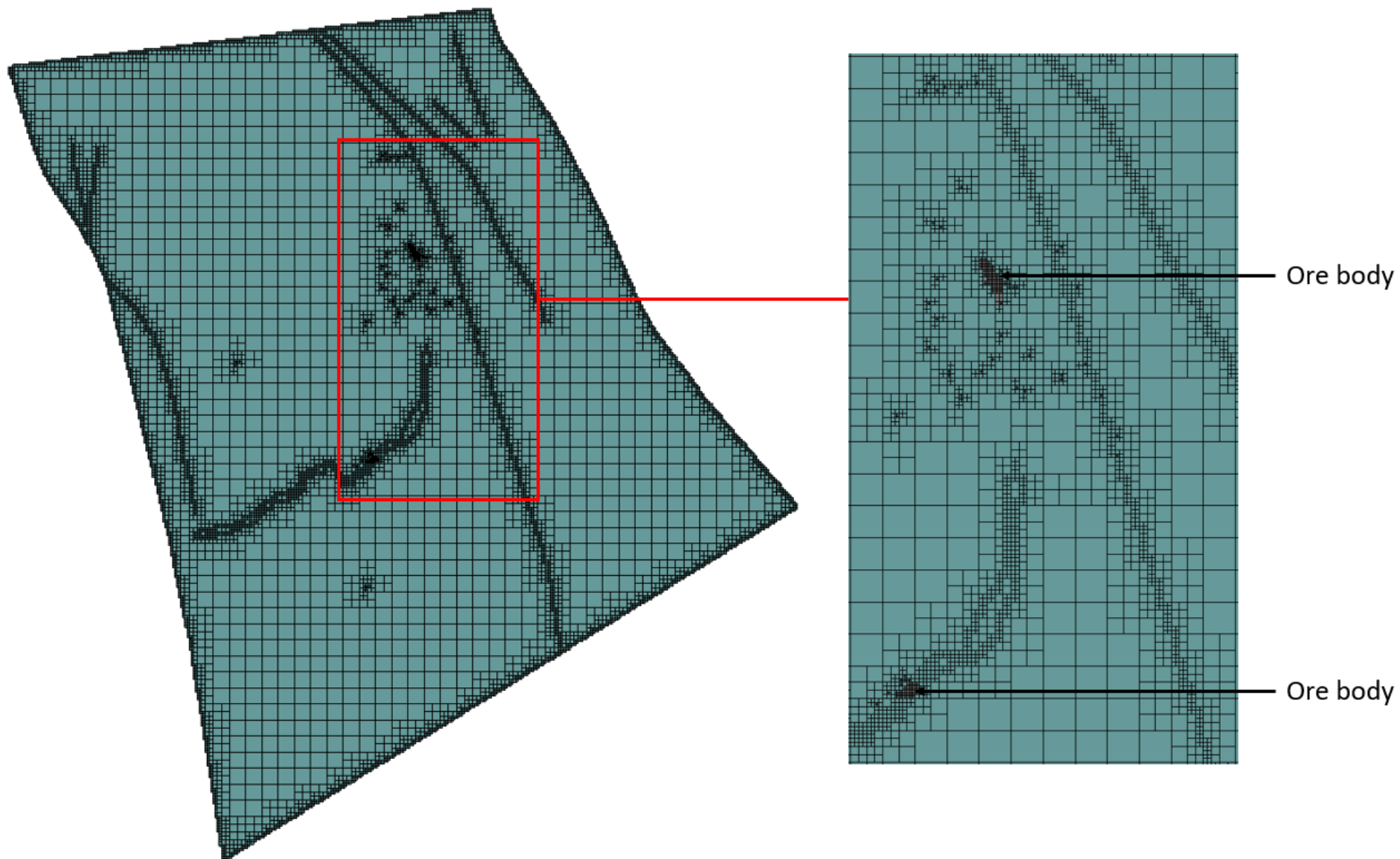


Figure D.13 Model layer 13

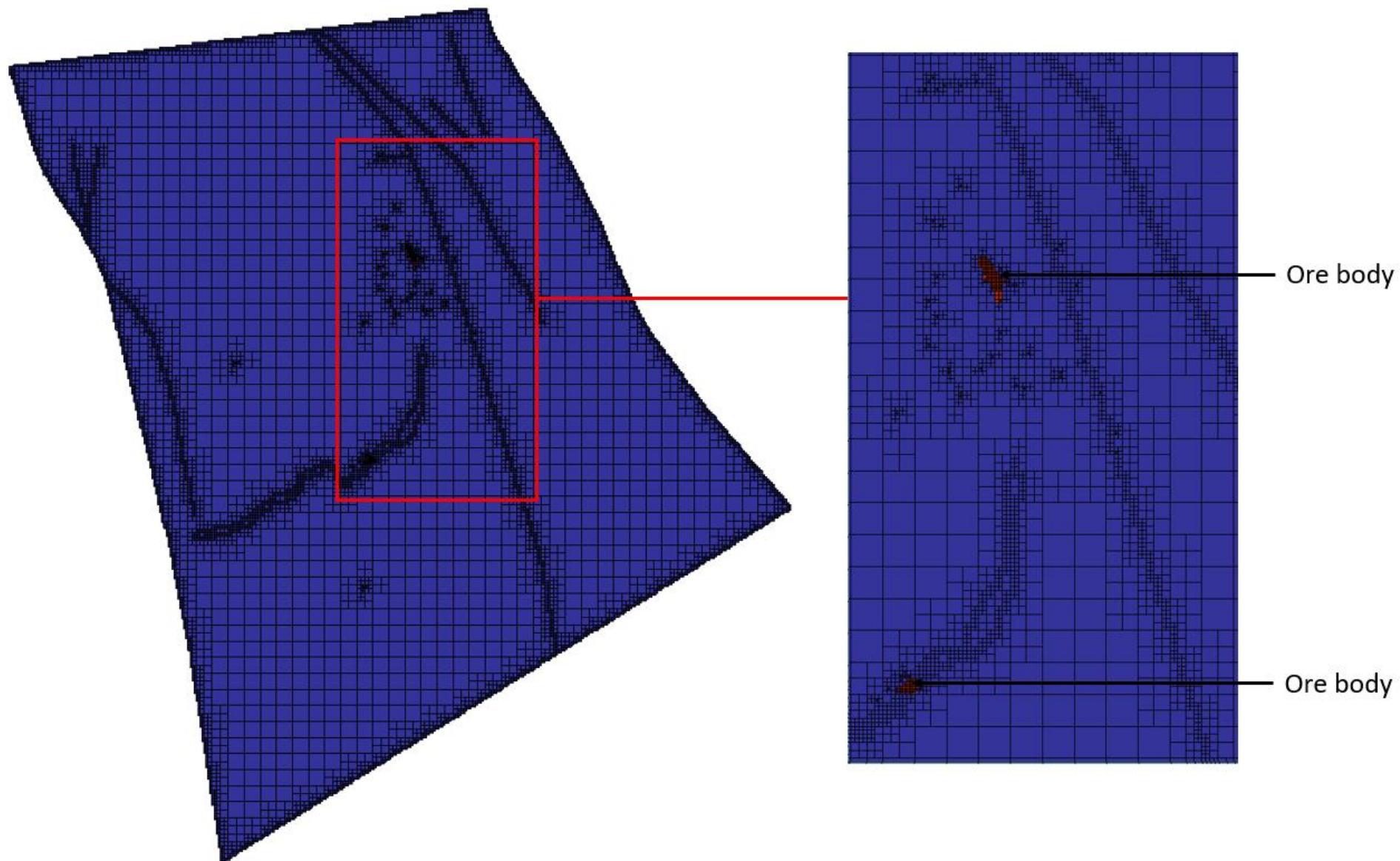


Figure D.14 Model layer 14

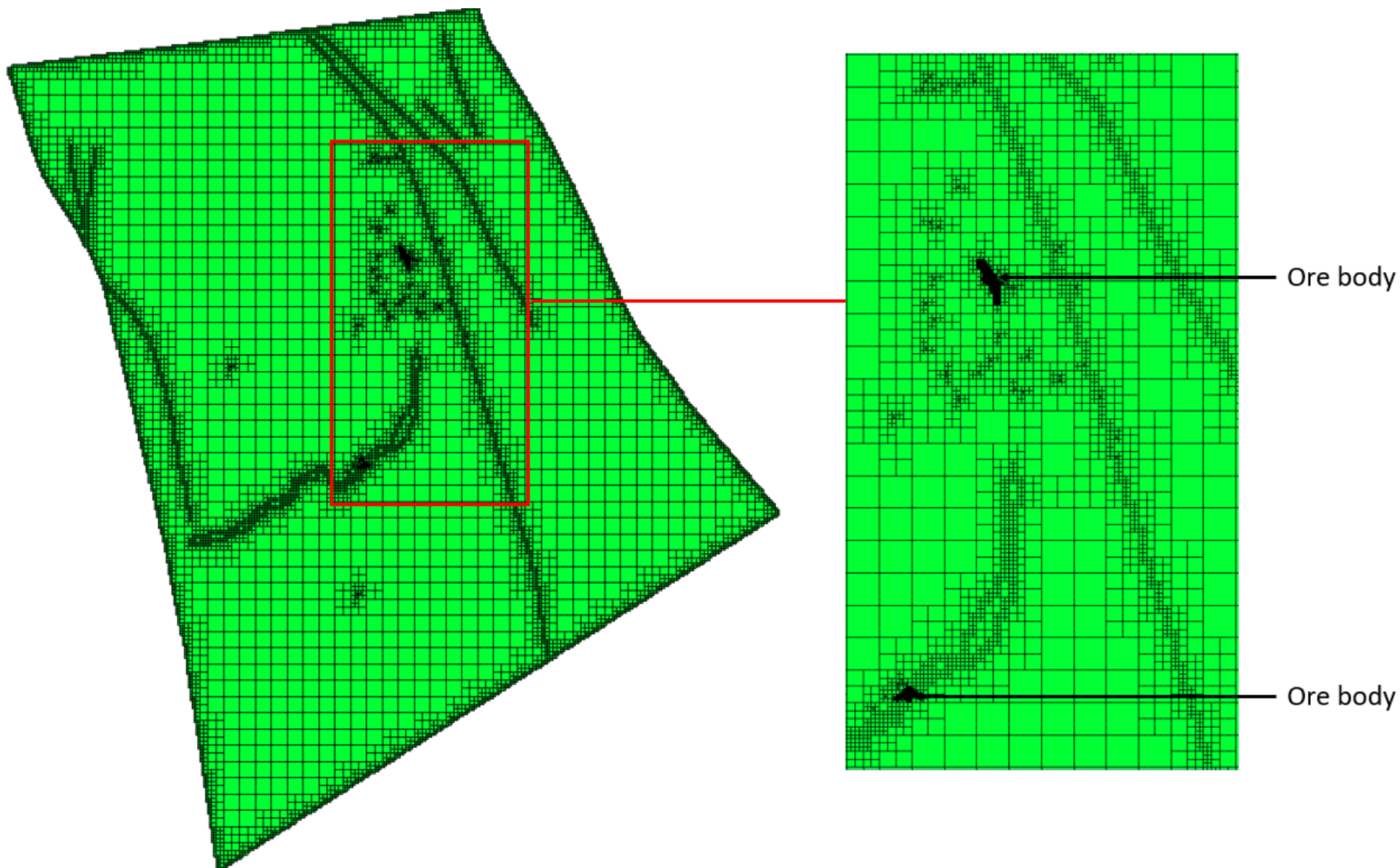


Figure D.15 Model layer 15

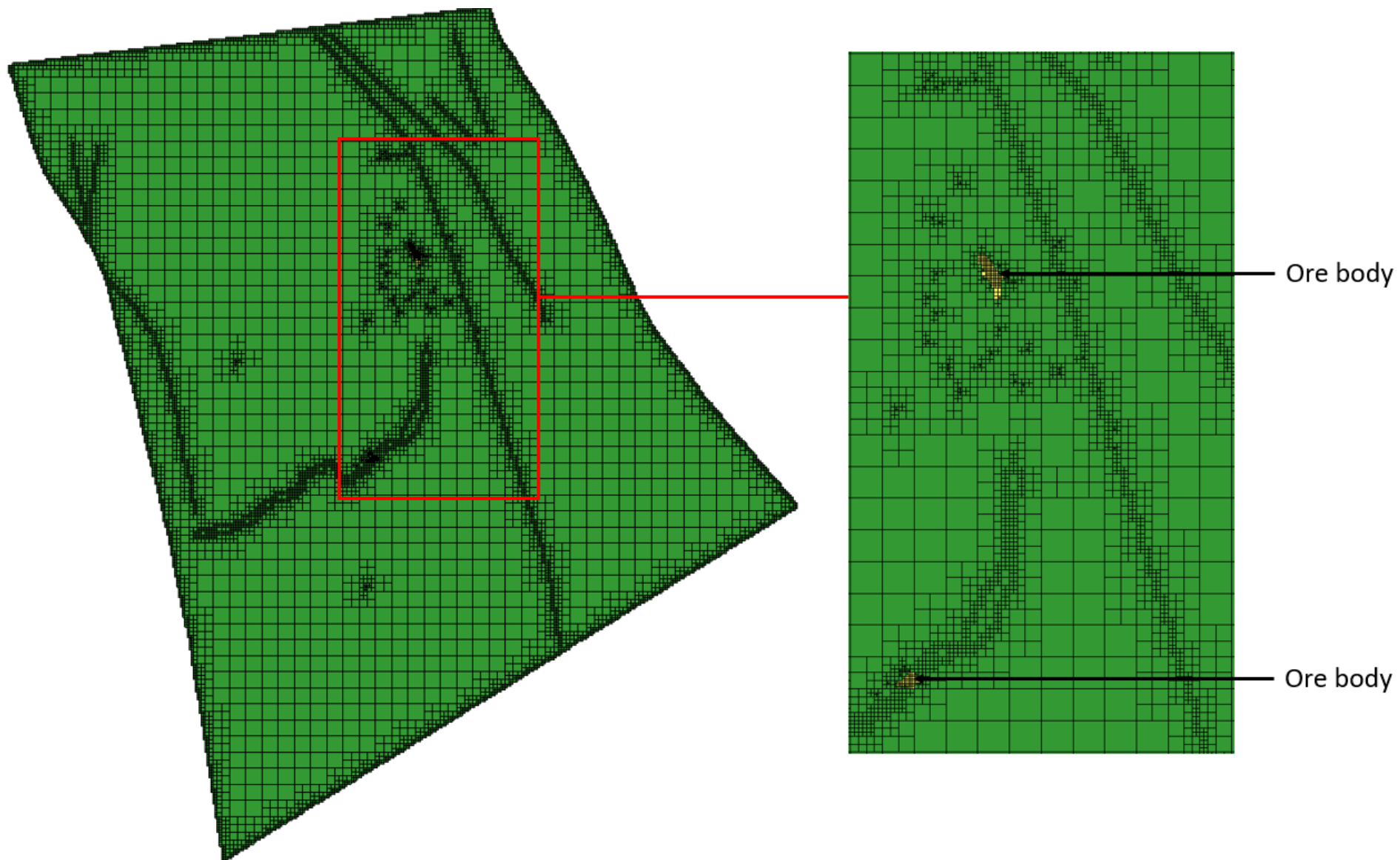


Figure D.16 Model layer 16

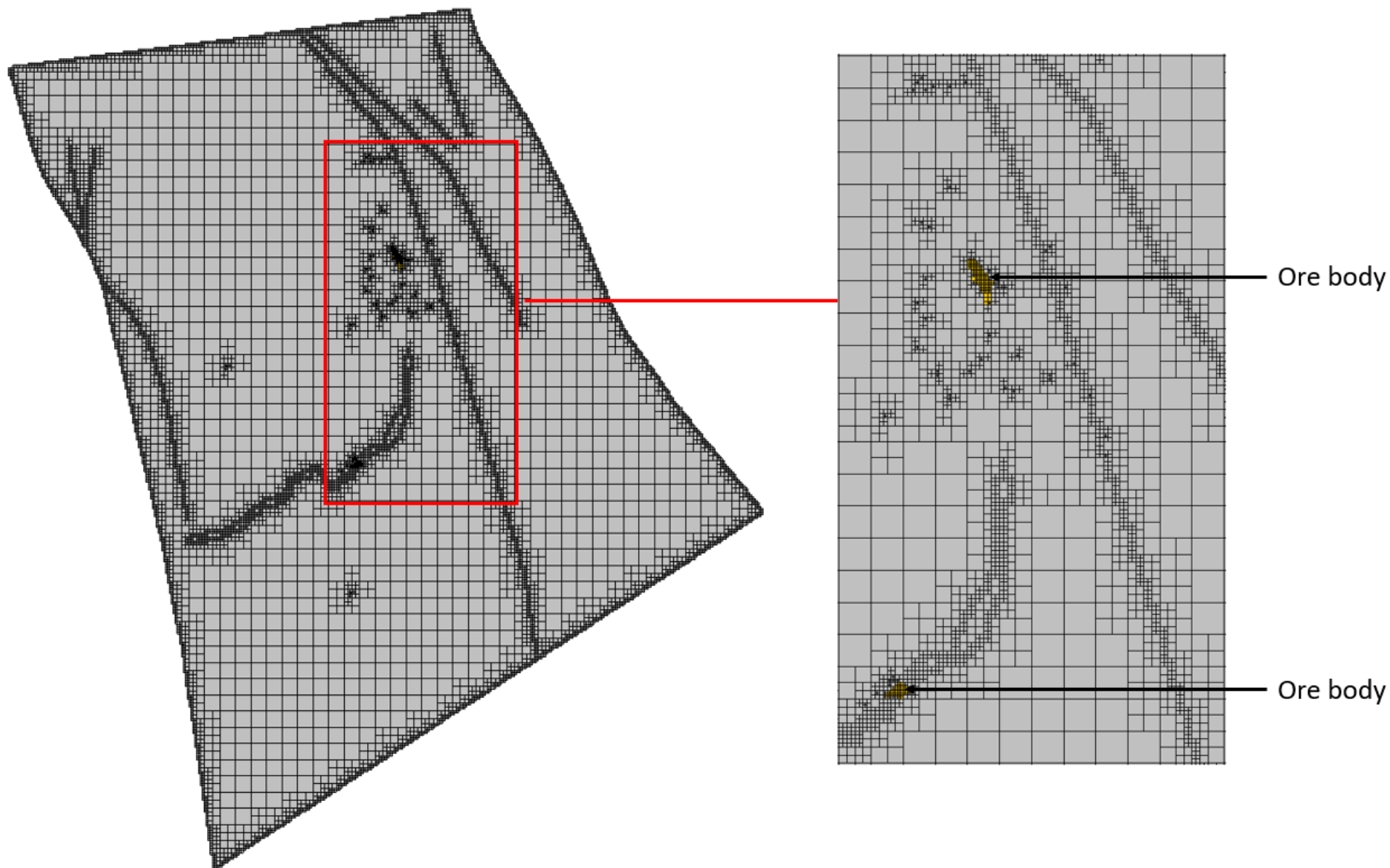


Figure D.17 Model layer 17

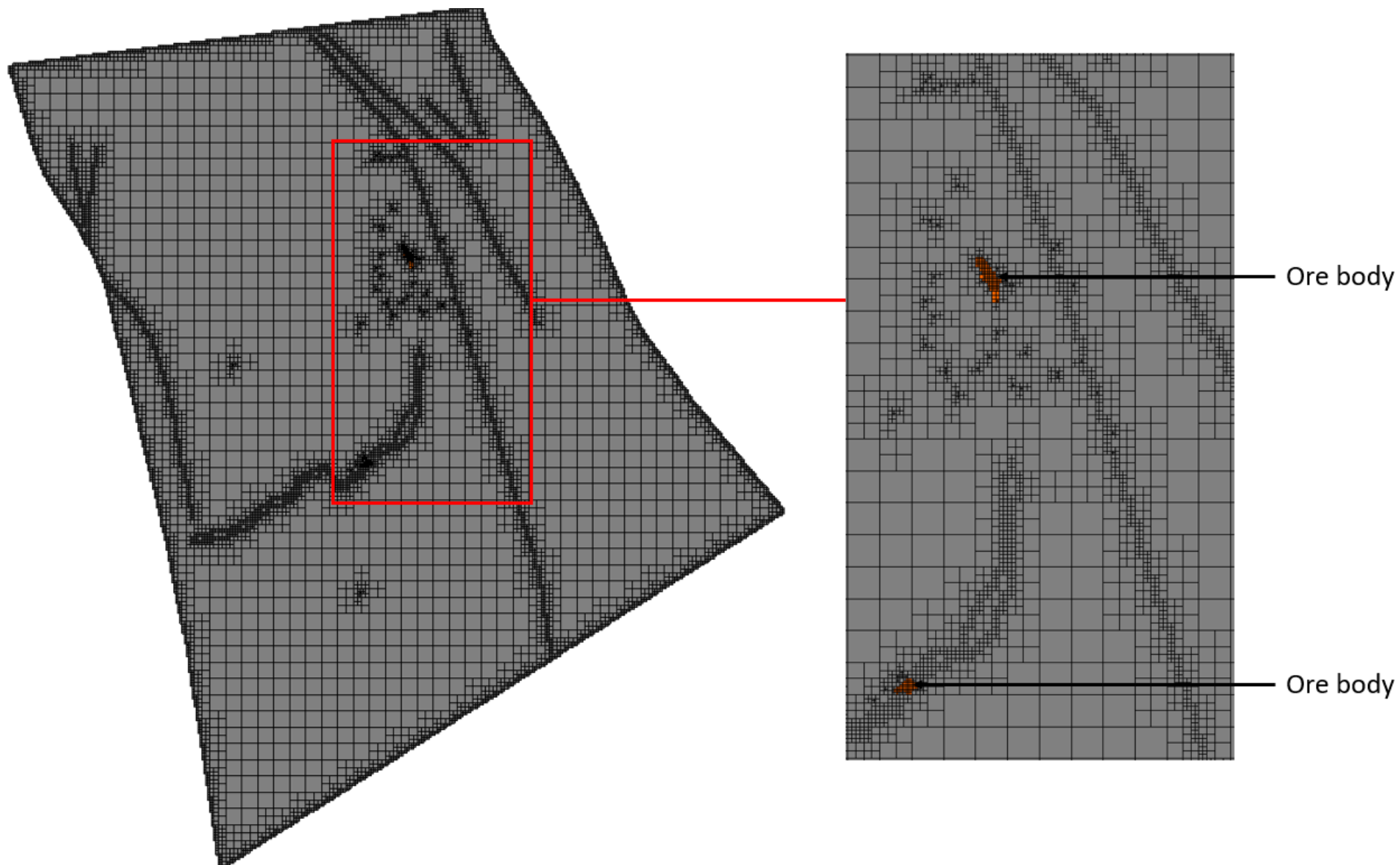


Figure D.18 Model layer 18

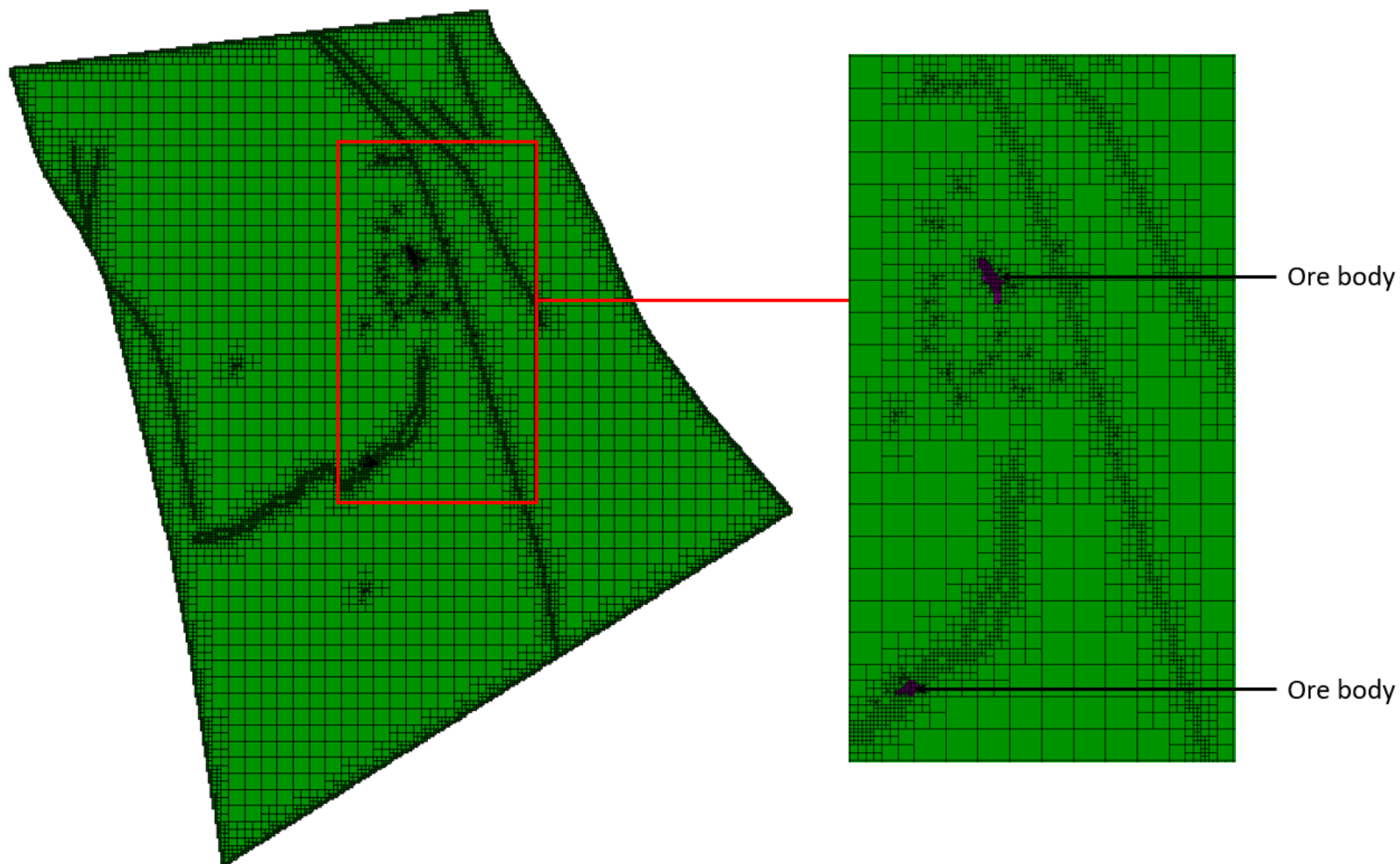


Figure D.19 Model layer 19

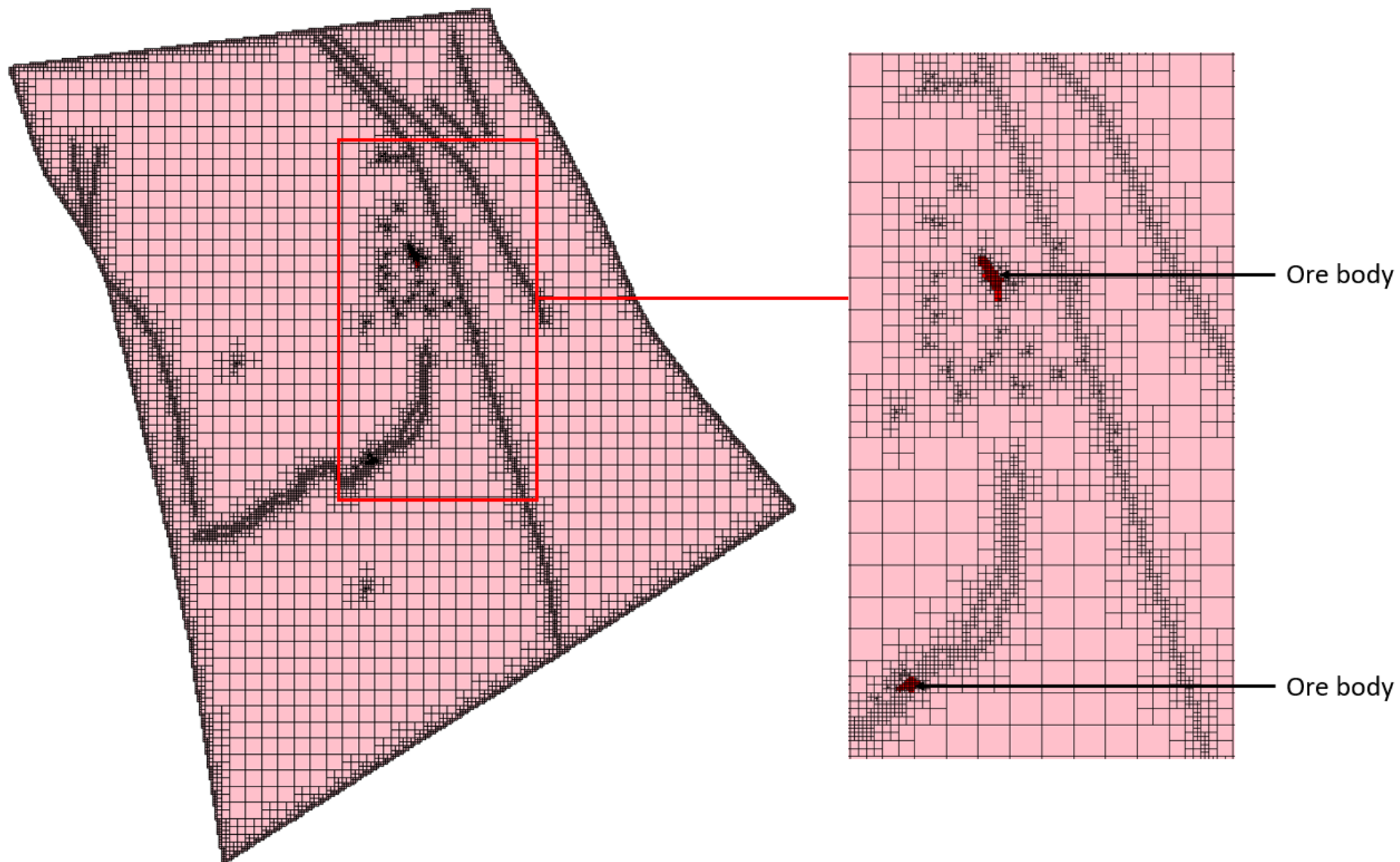


Figure D.20 Model layer 20

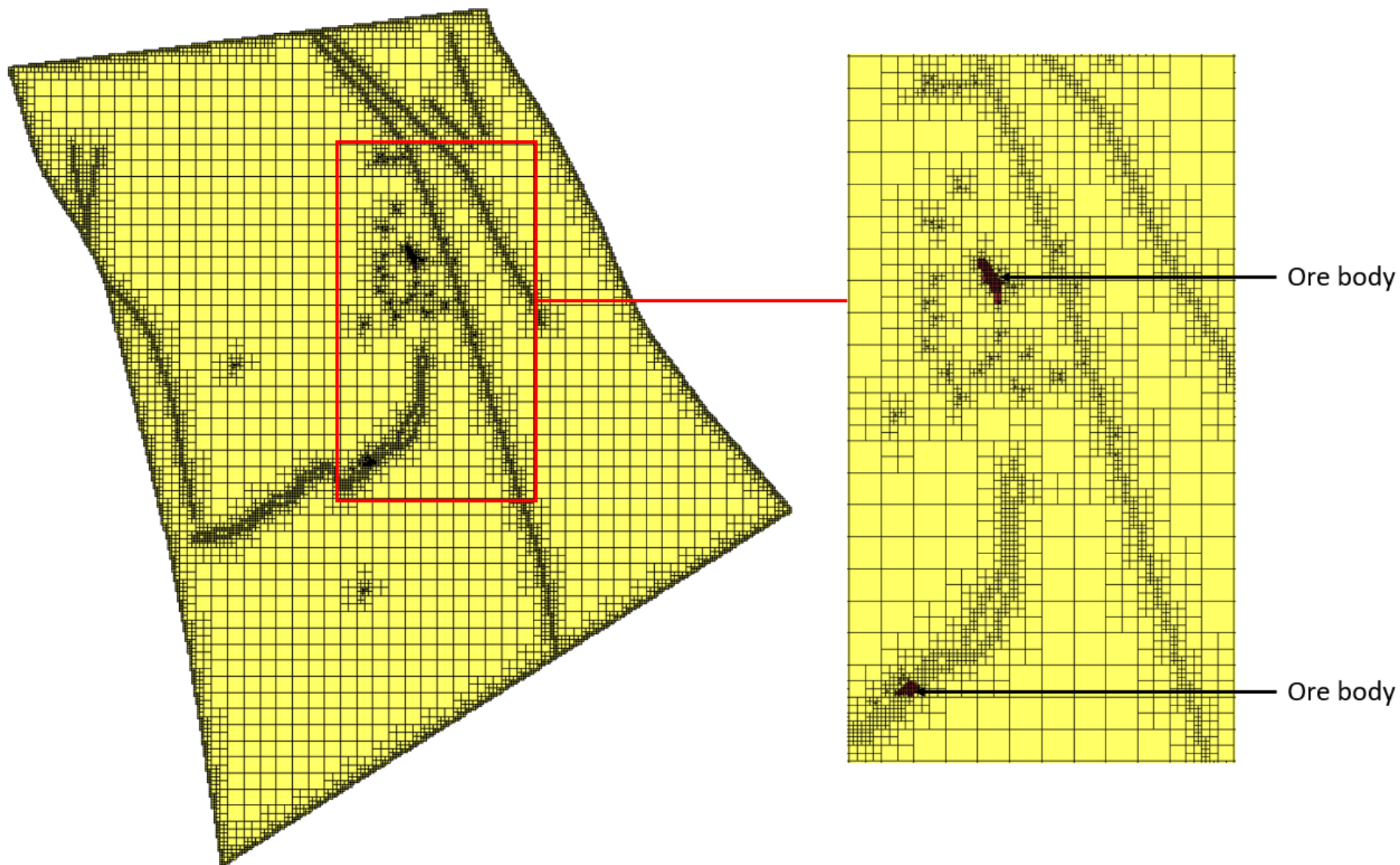


Figure D.21 Model layer 21

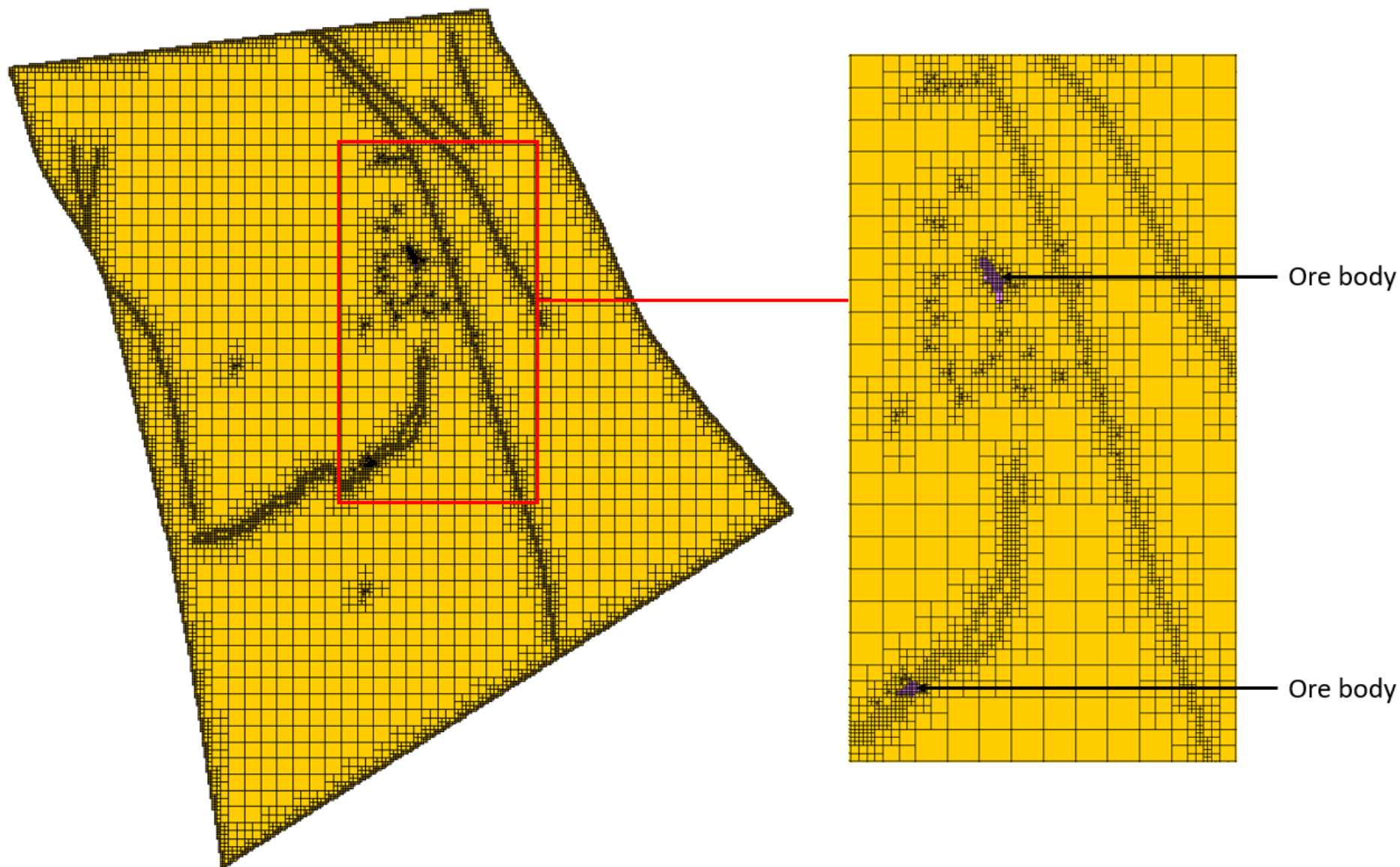


Figure D.22 Model layer 22

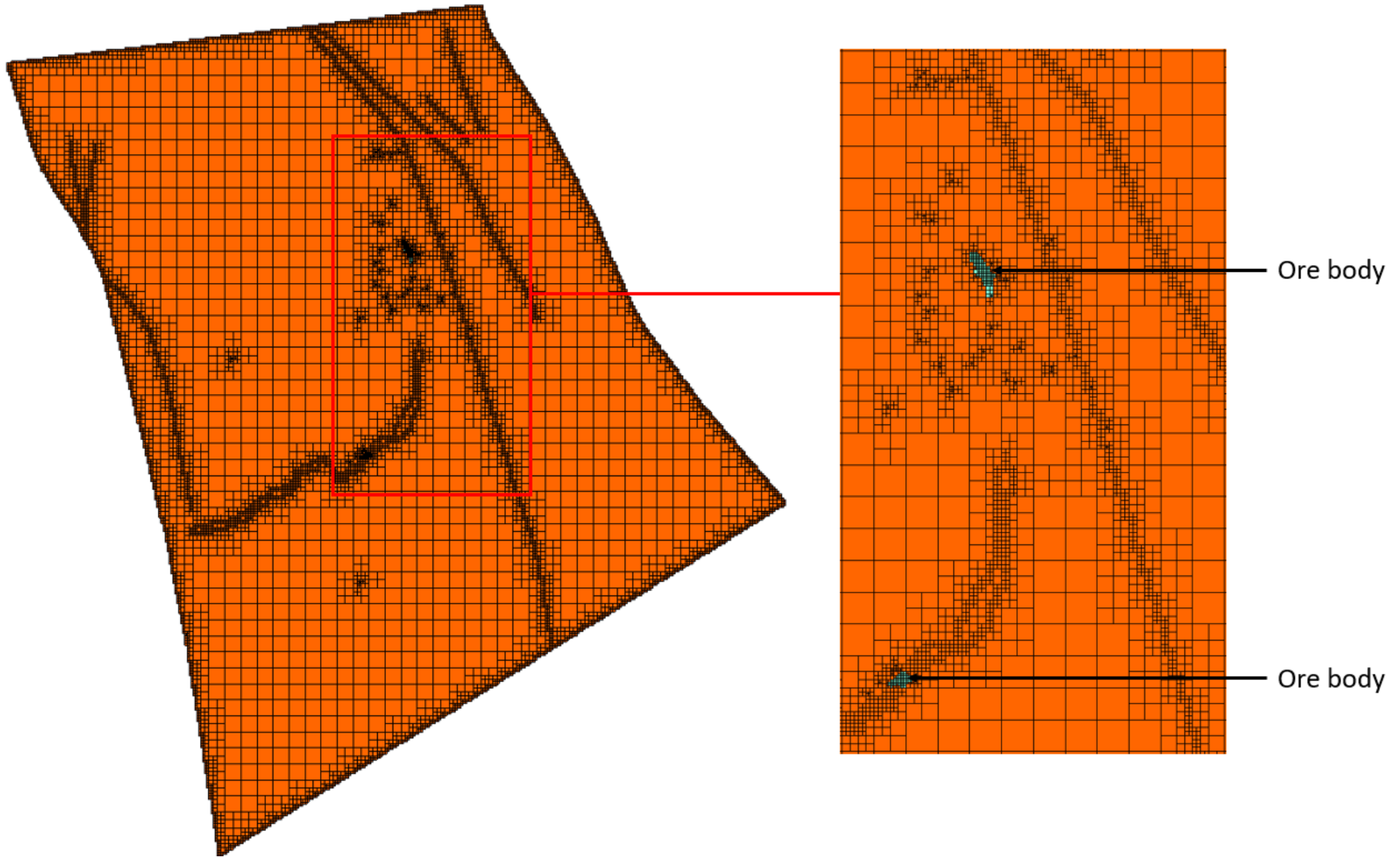


Figure D.23 Model layer 23

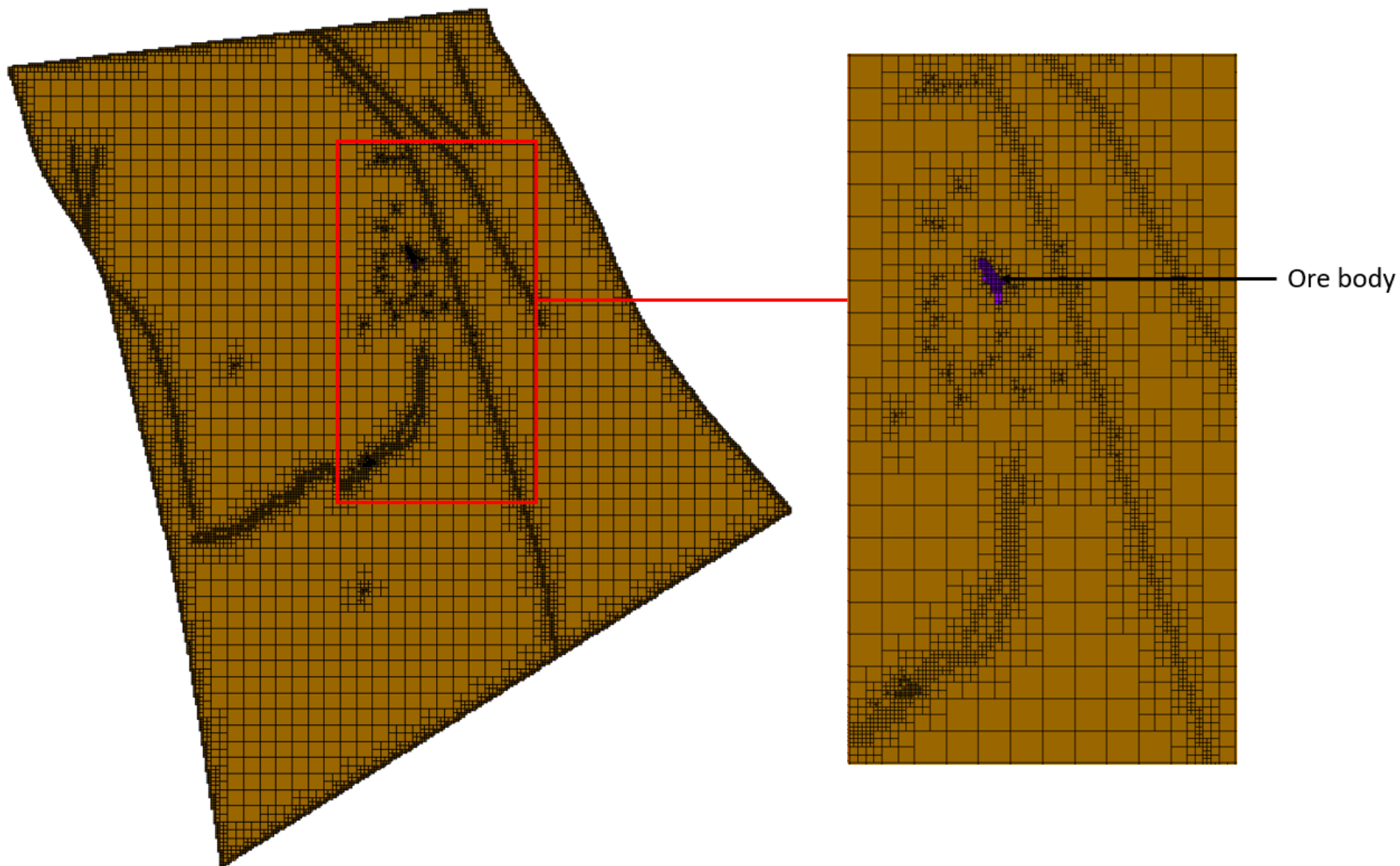


Figure D.24 Model layer 24

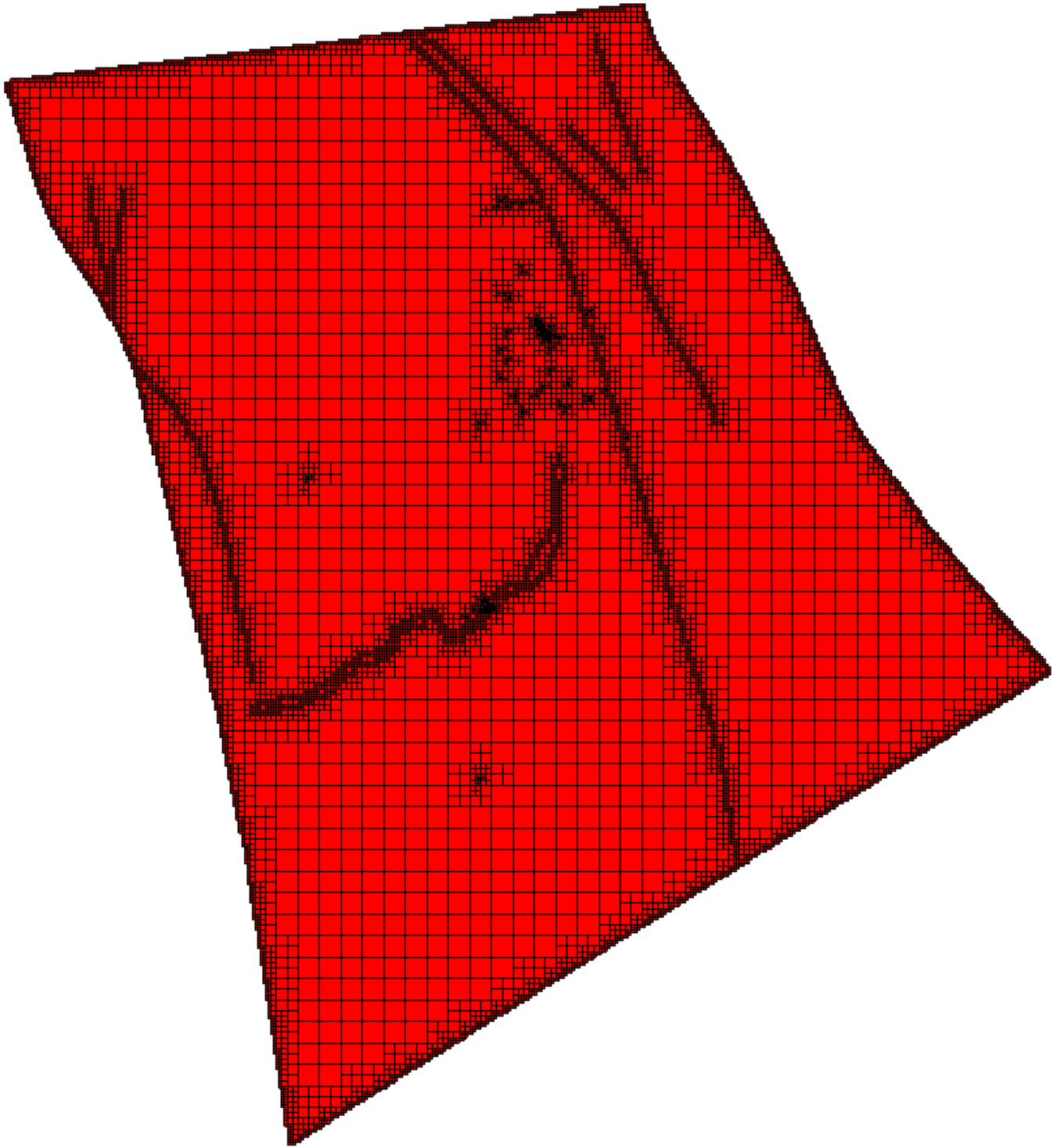


Figure D.25 *Model layer 25*

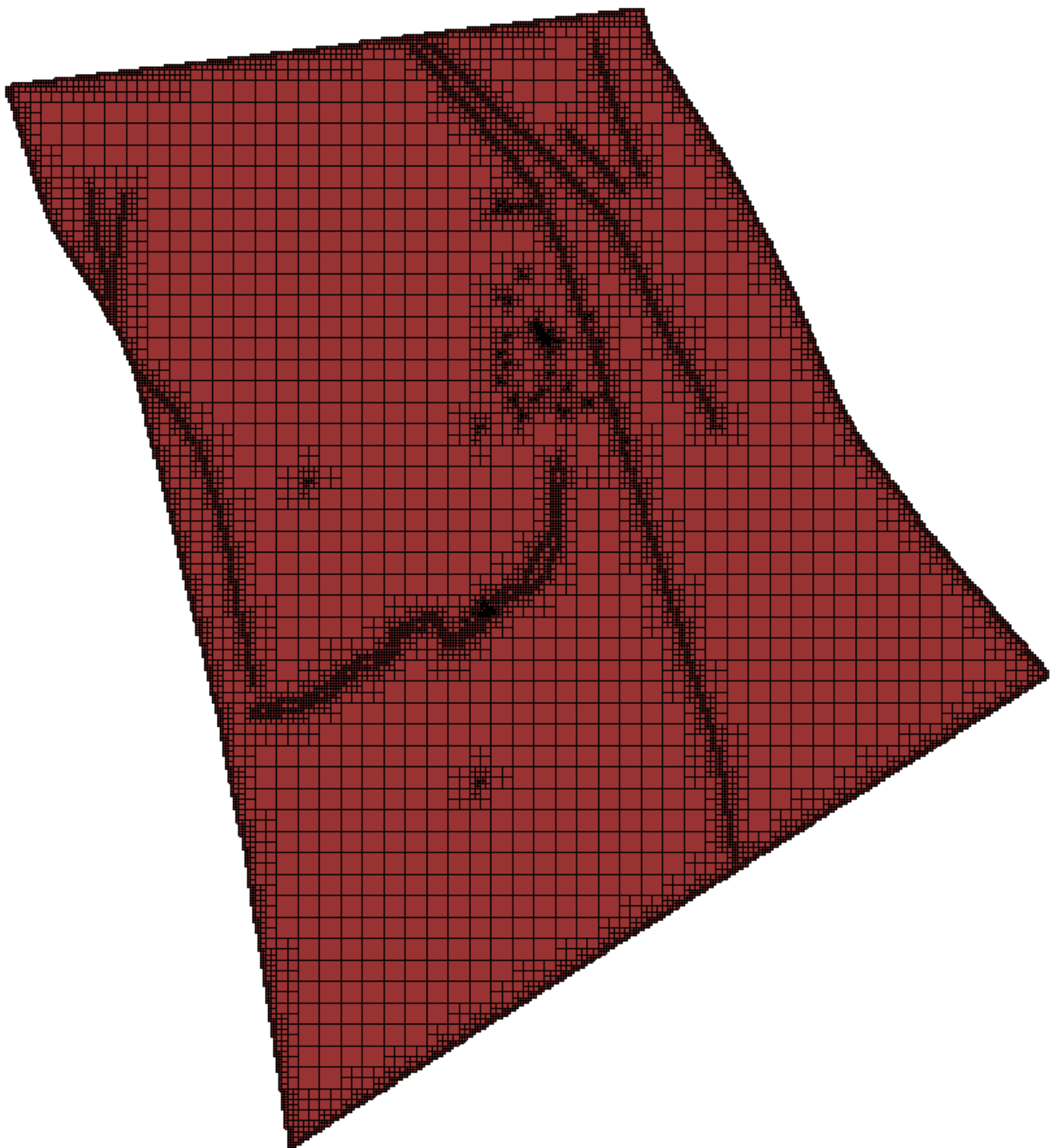


Figure D.26 Model layer 26

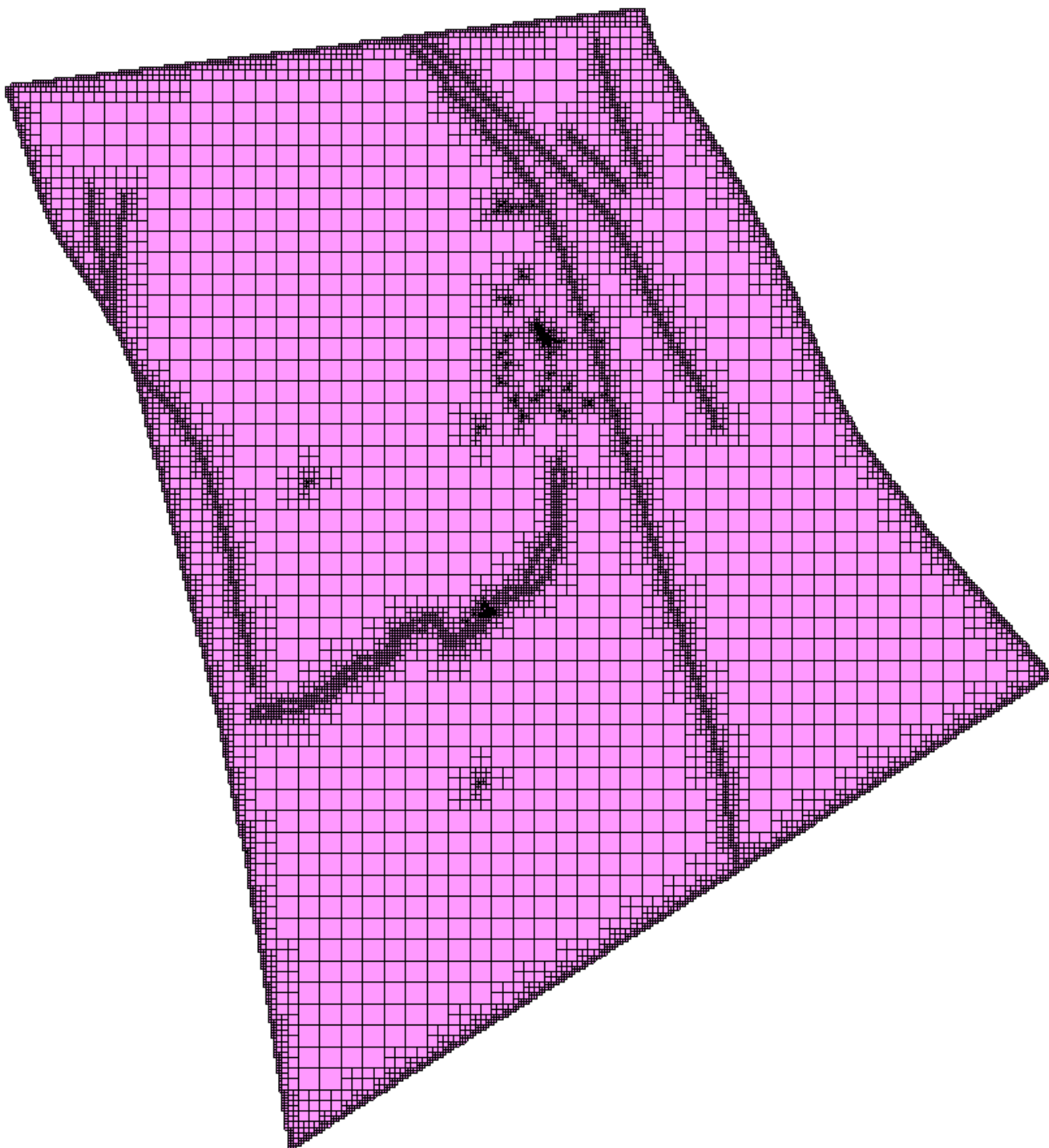
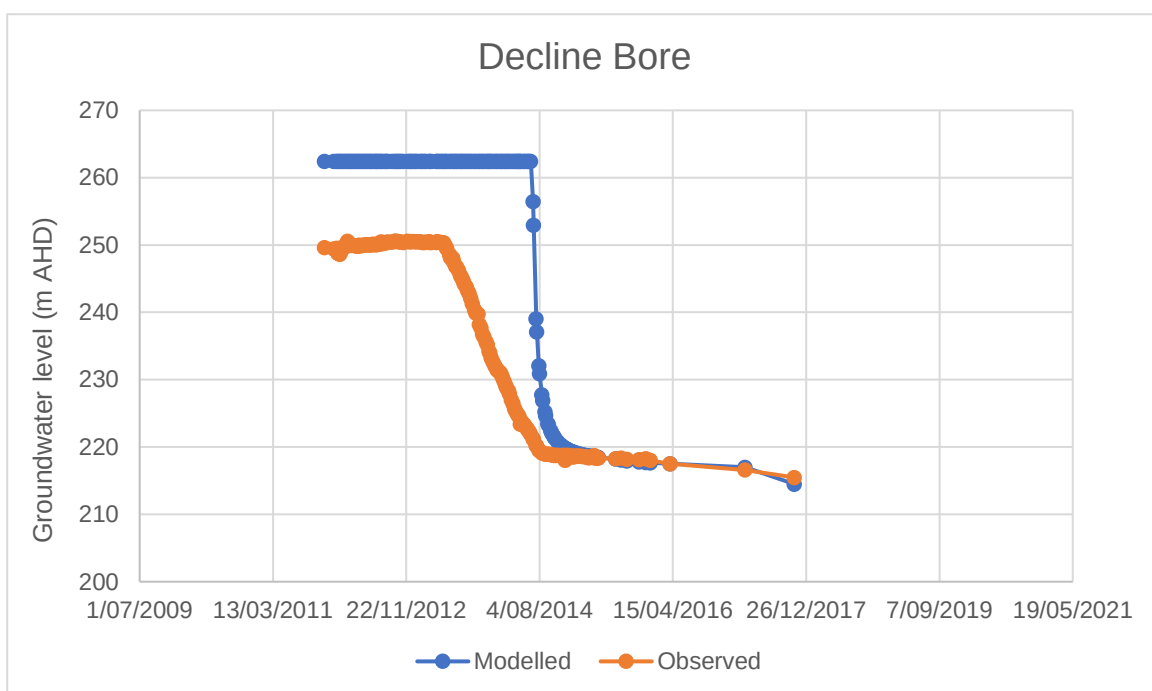
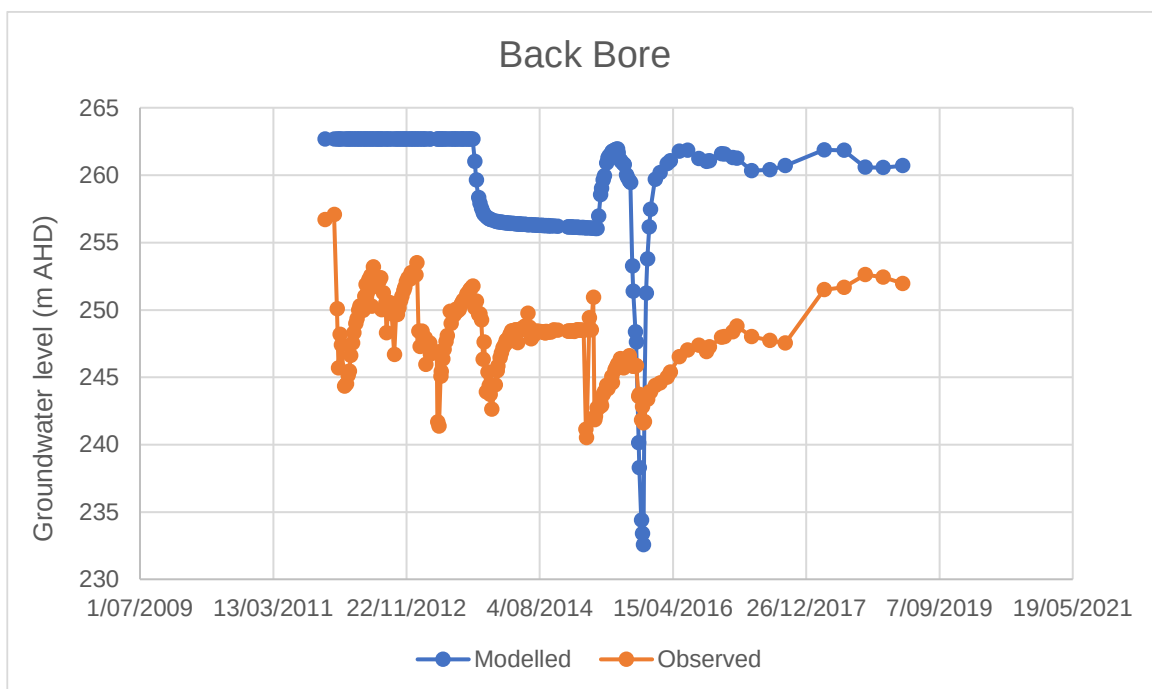


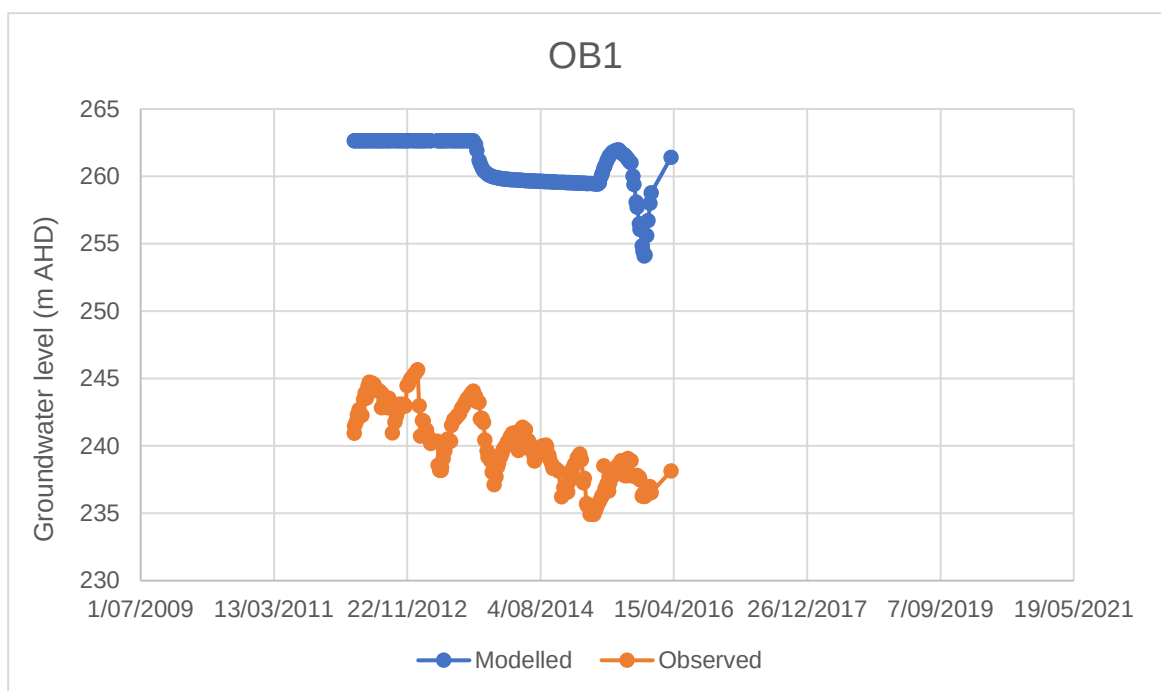
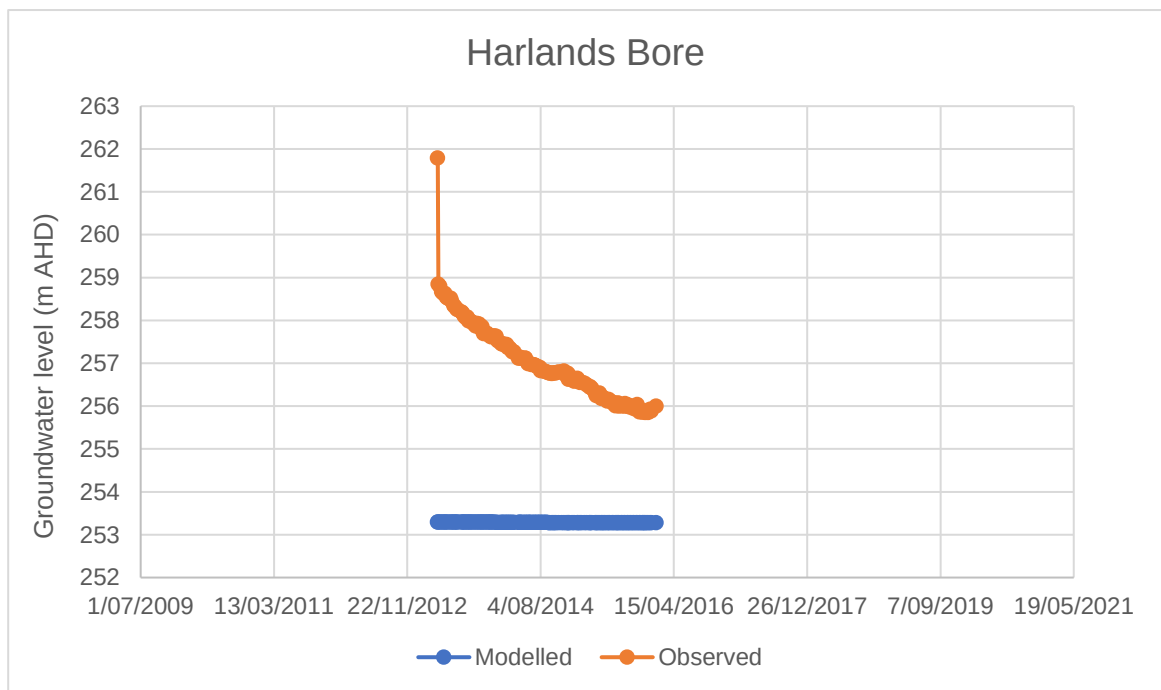
Figure D.27 Model layer 27

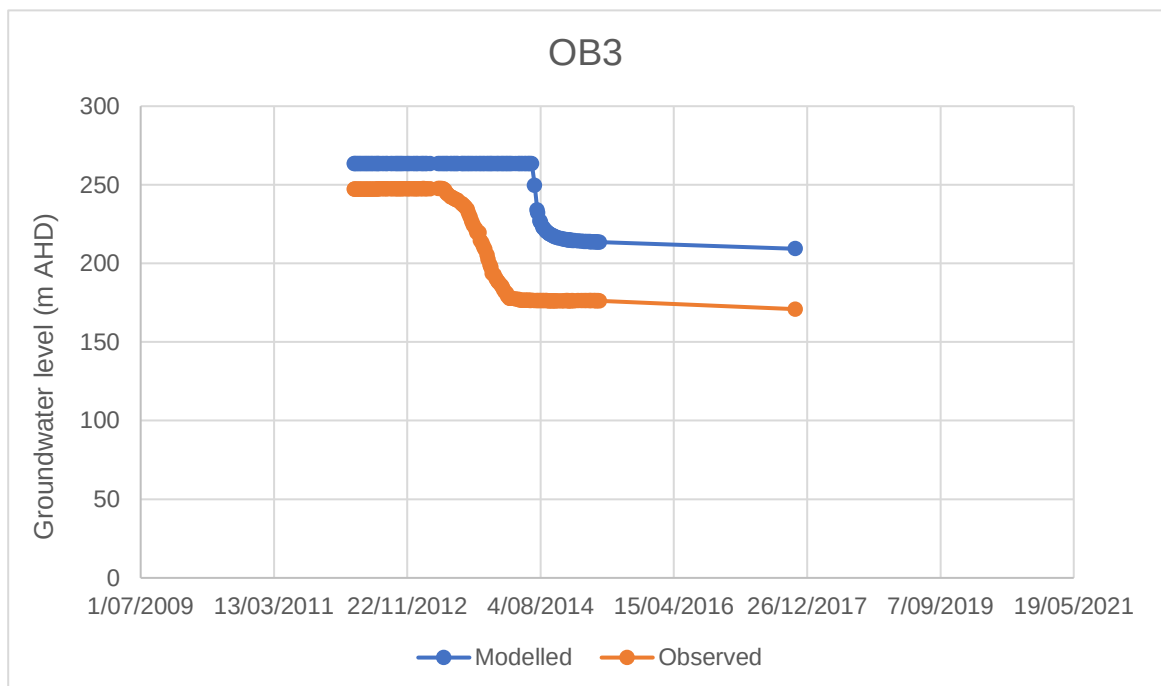
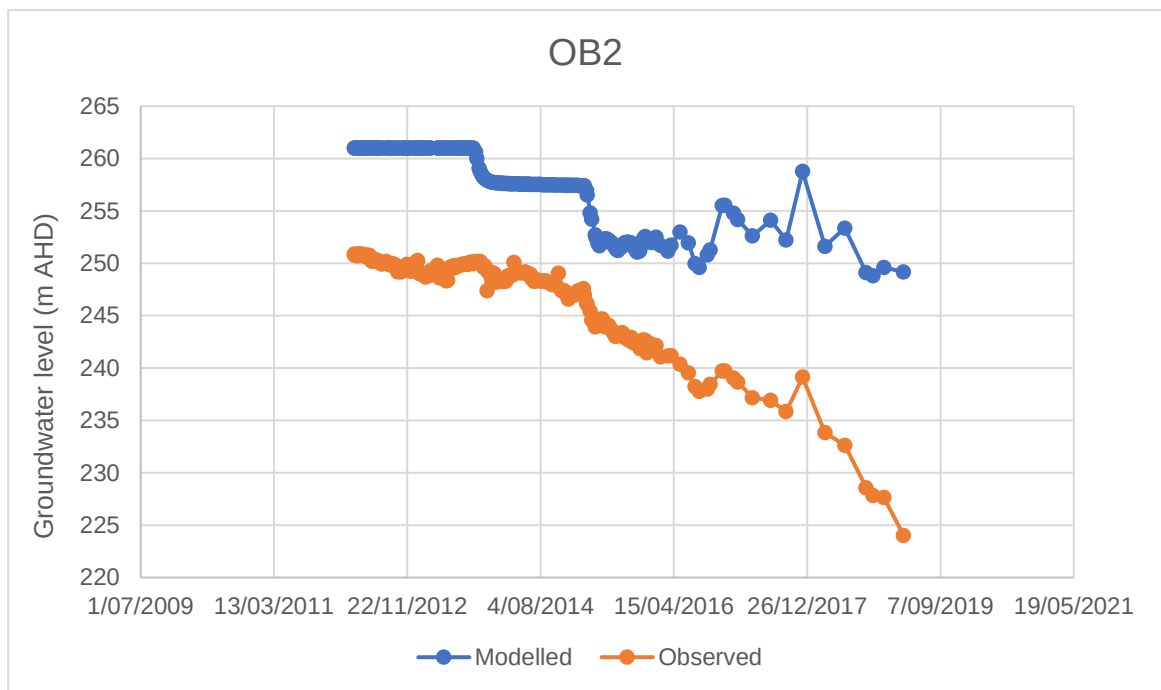
Appendix E

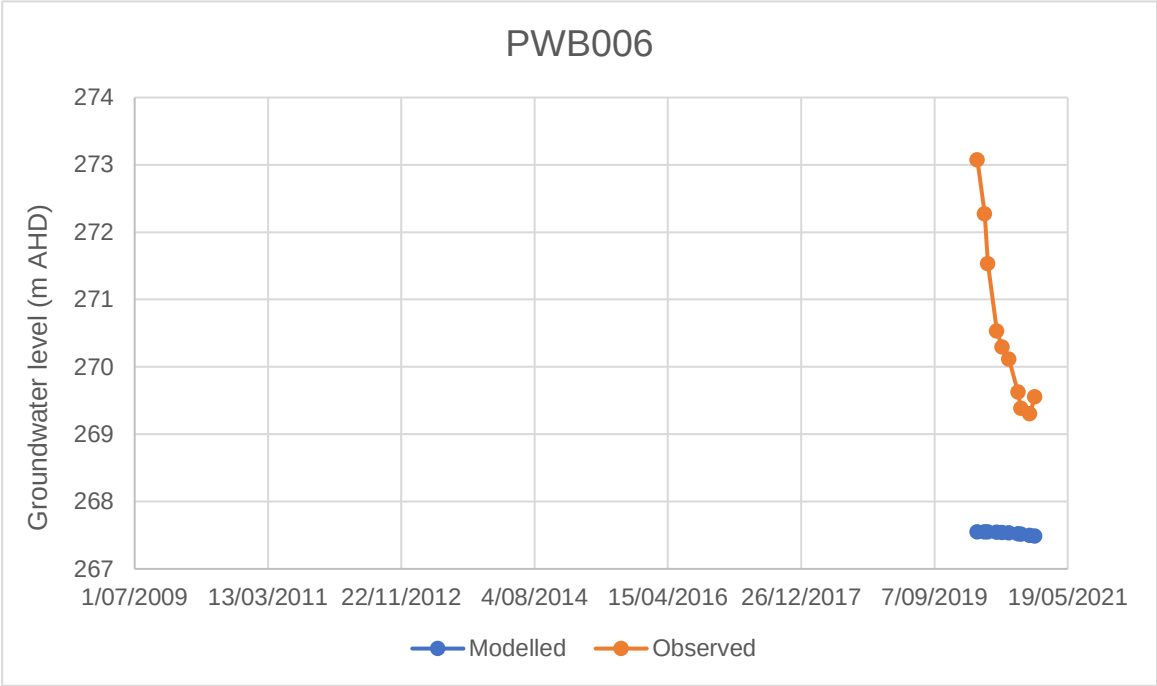
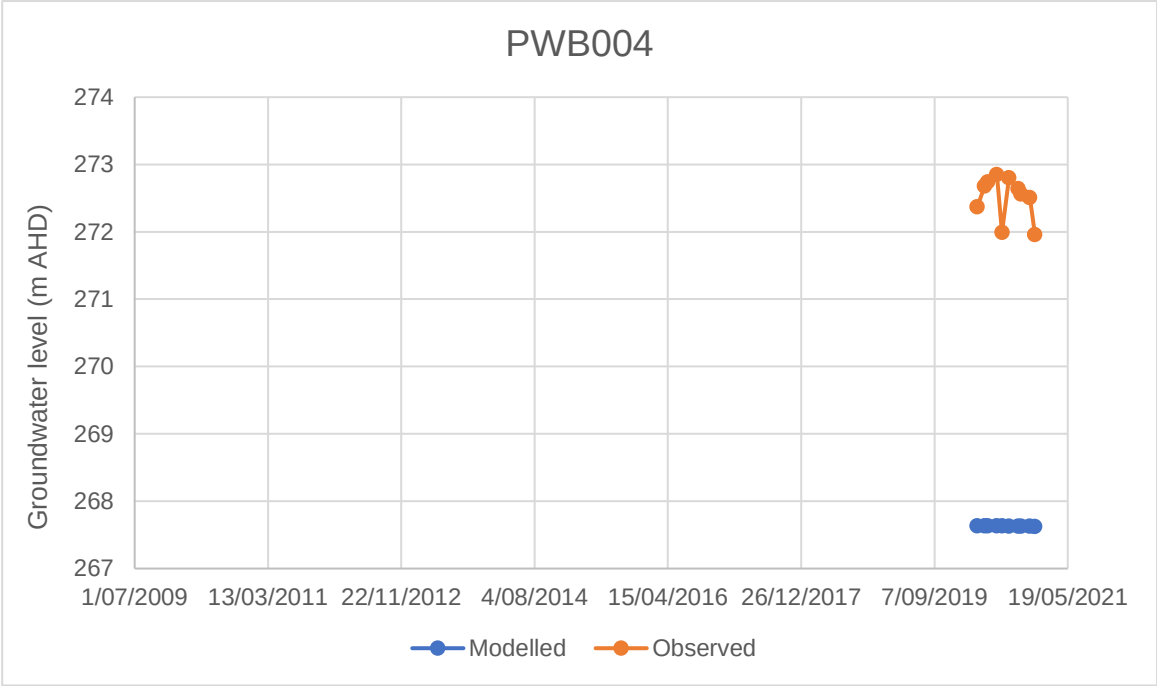
Transient calibration information

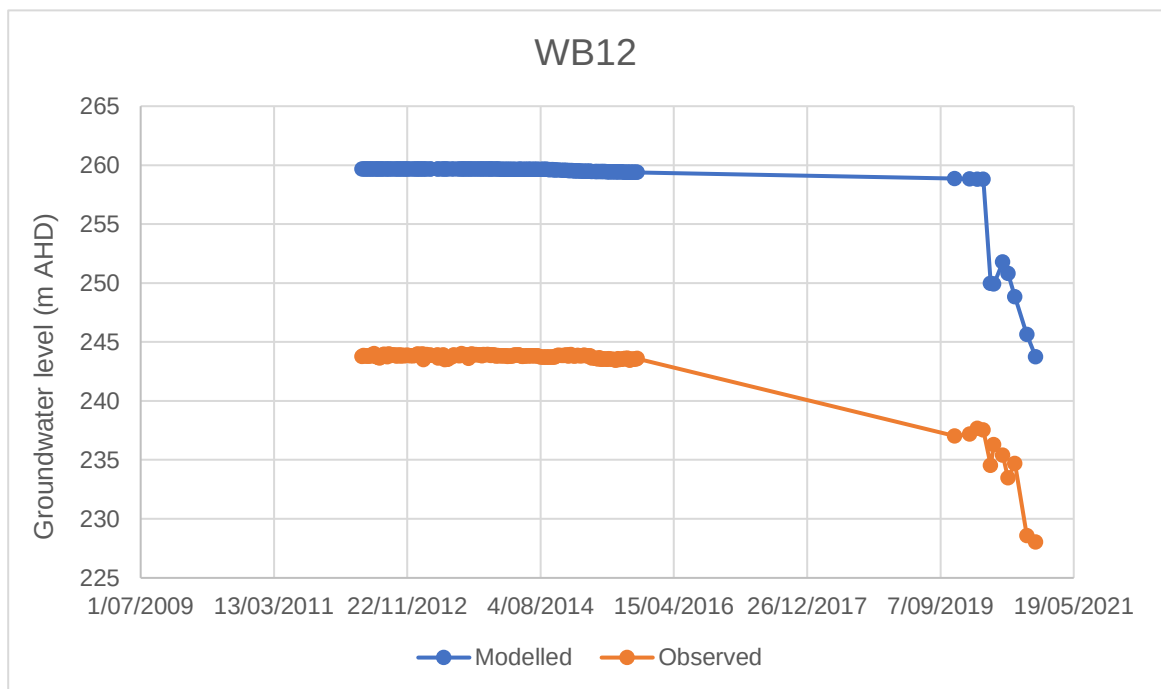
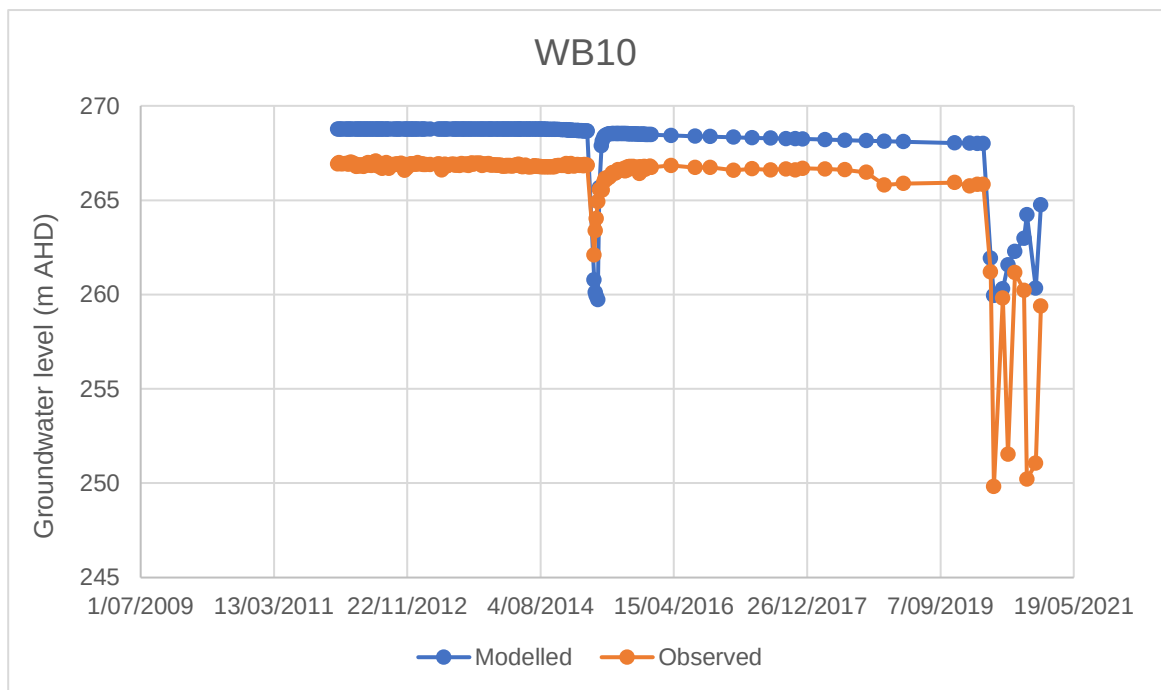
Hera

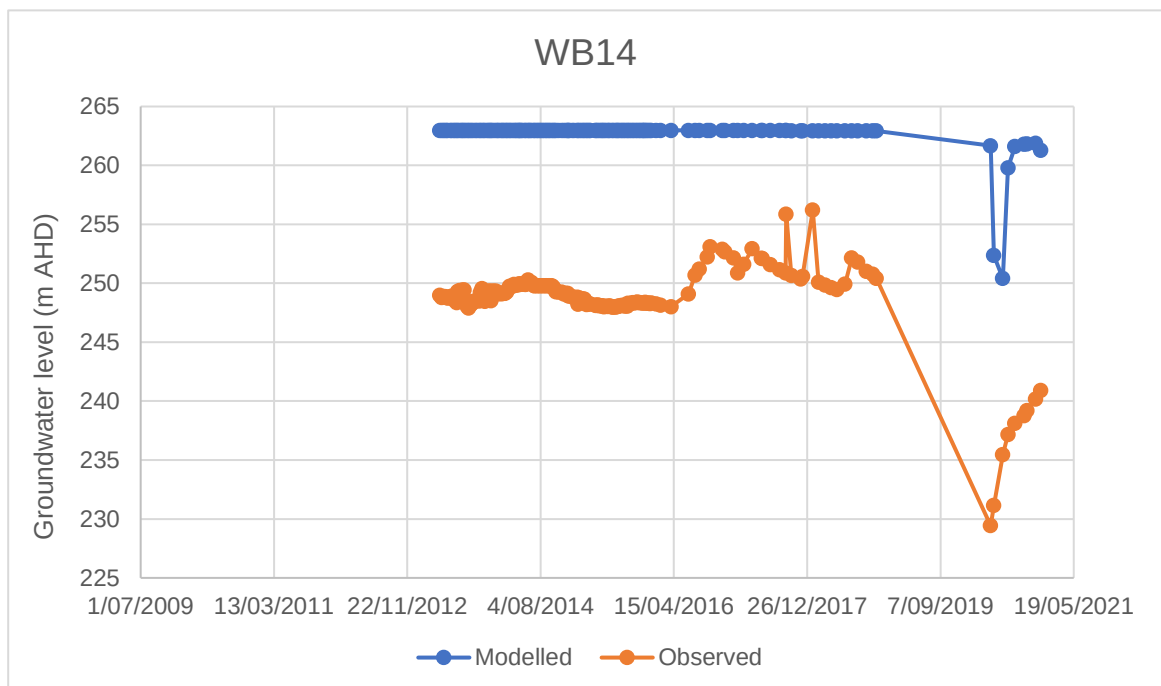
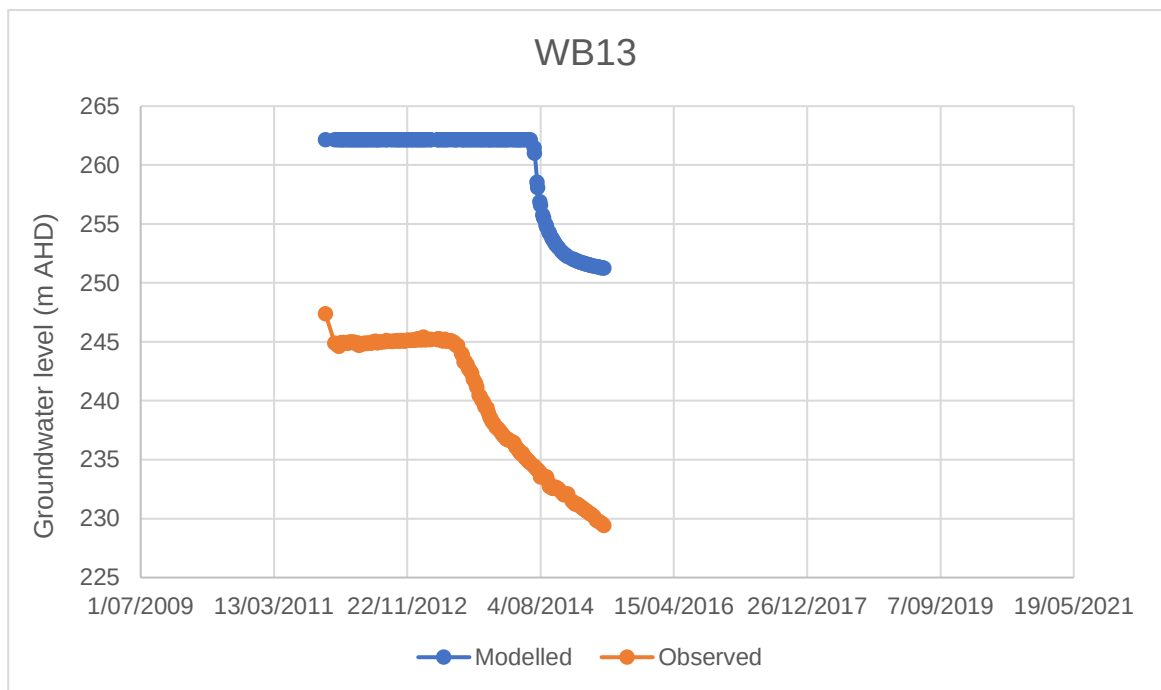


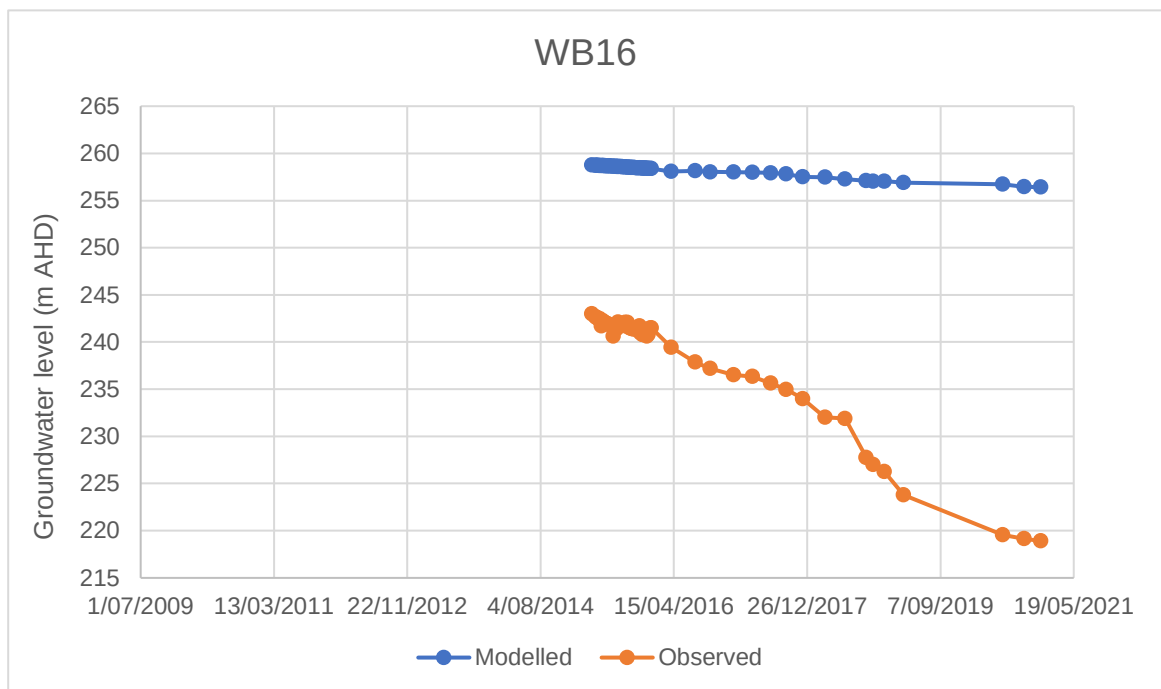
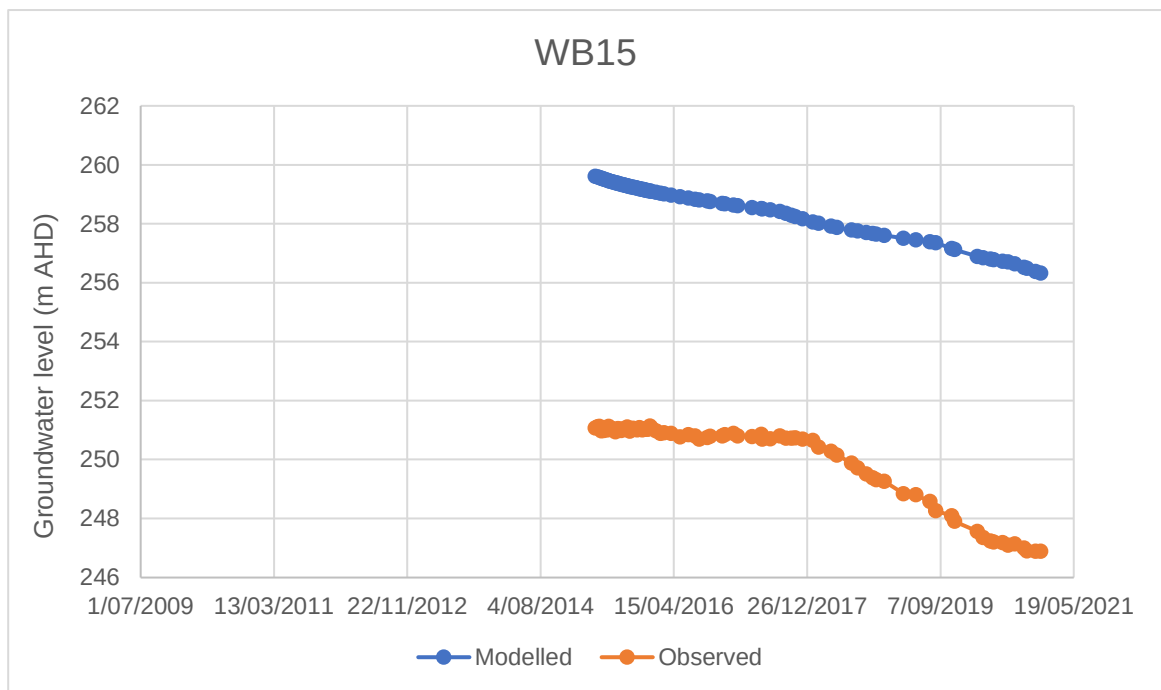


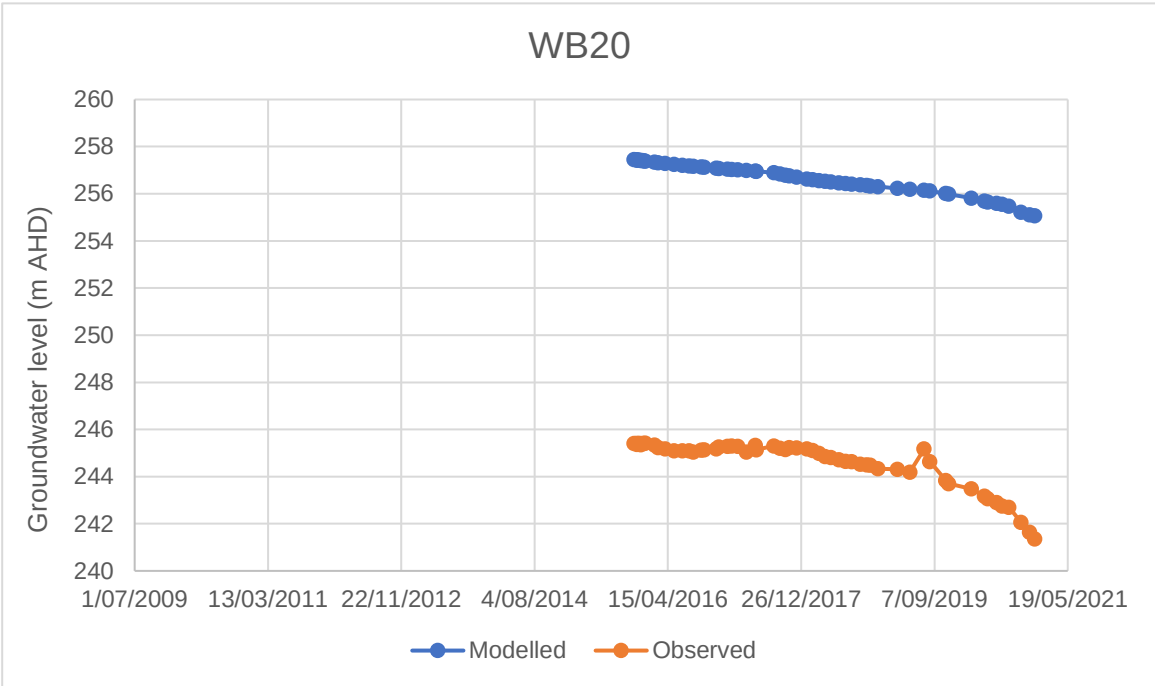
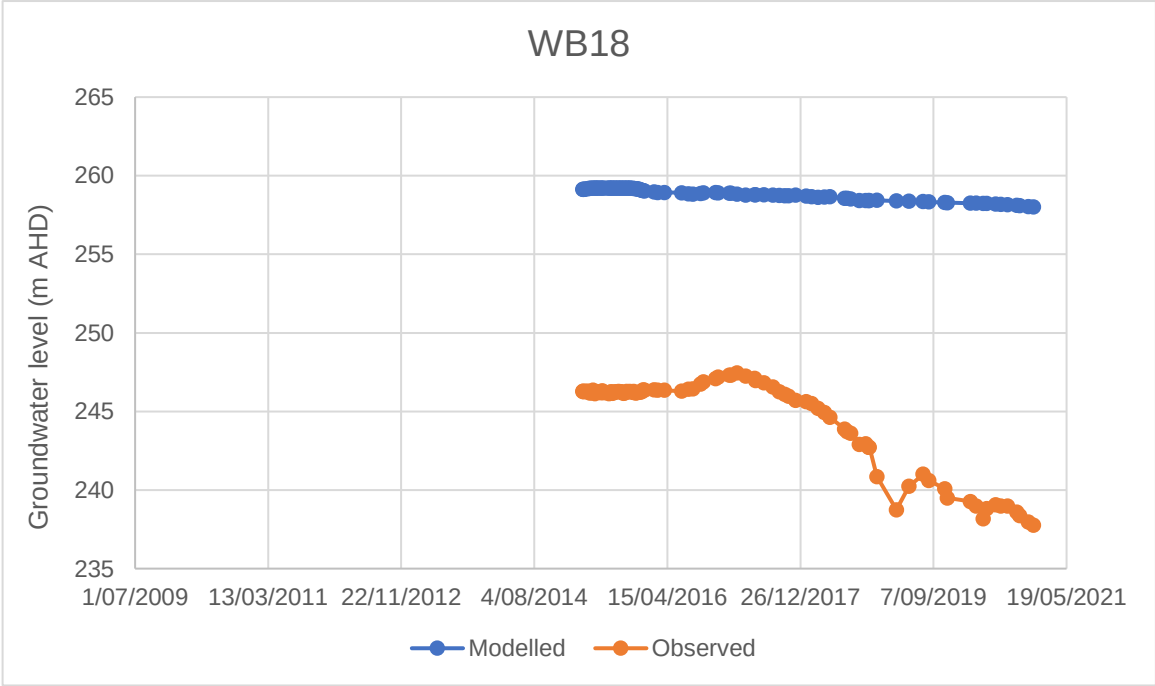


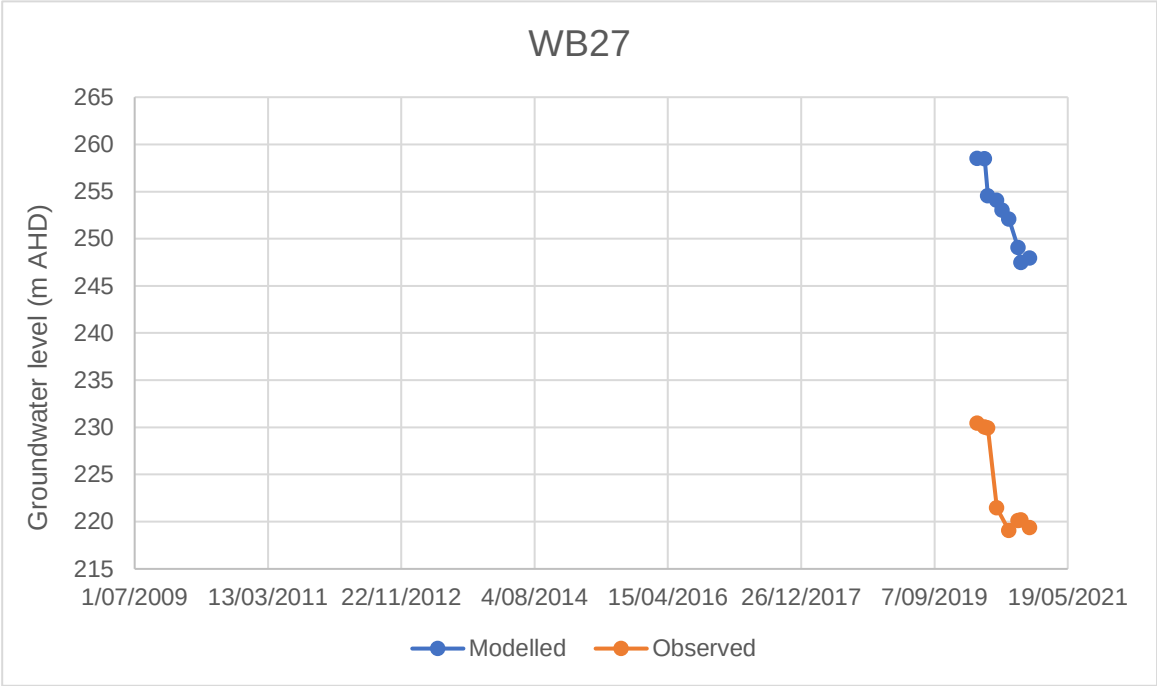
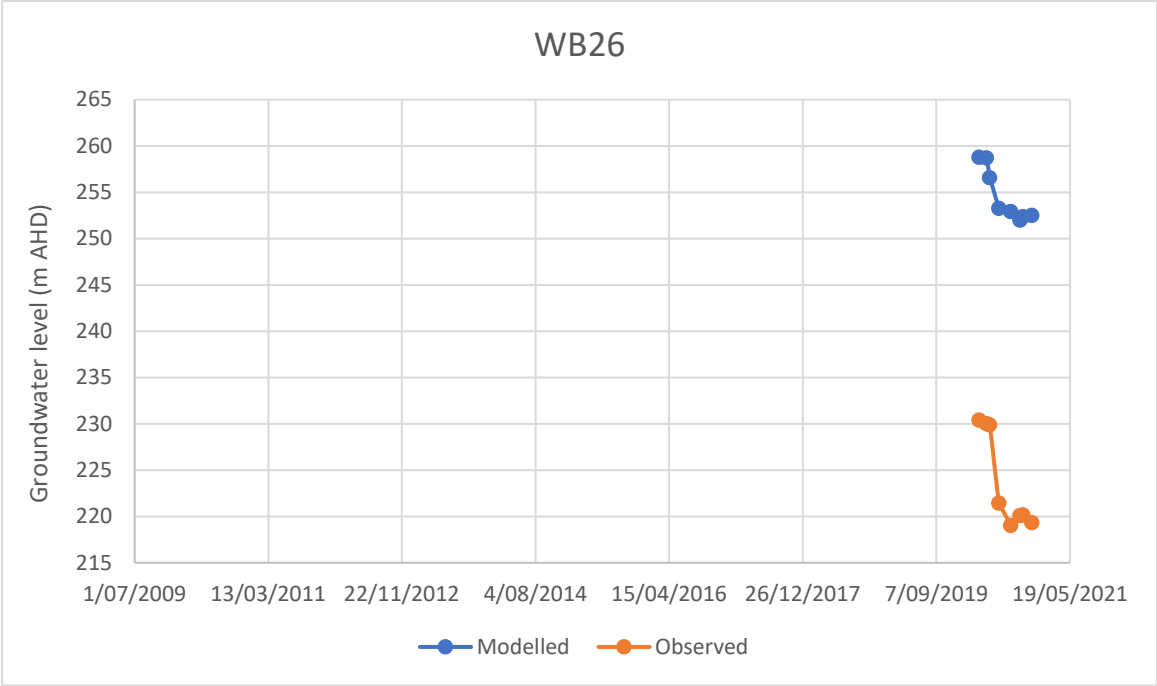


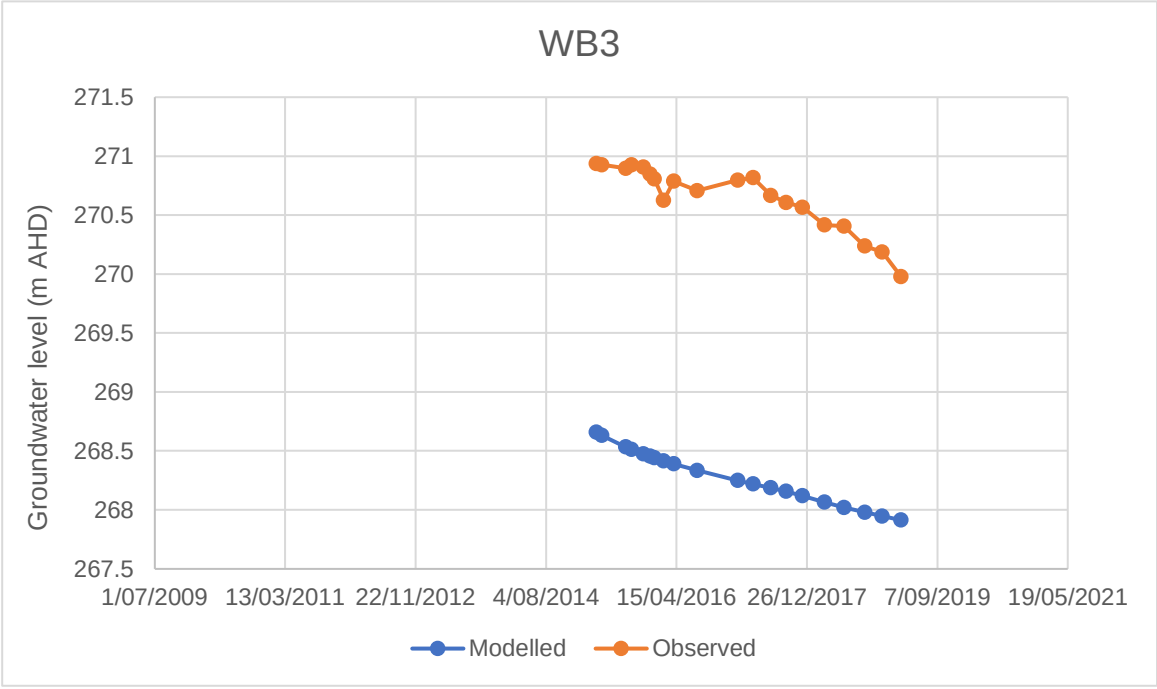
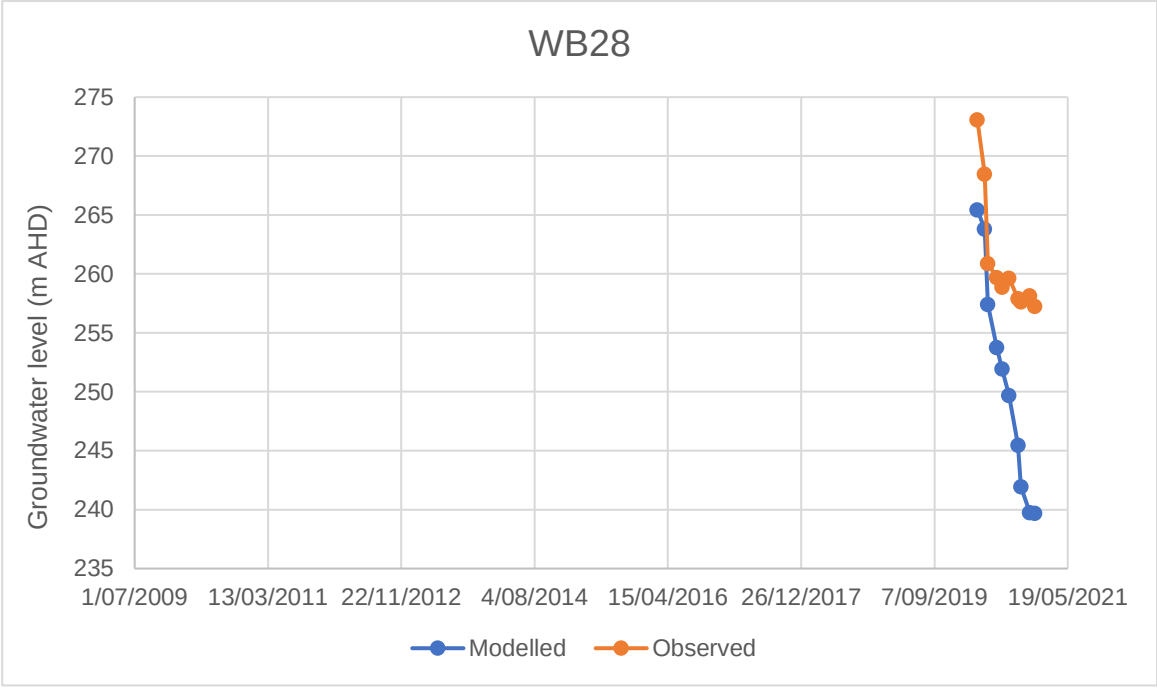


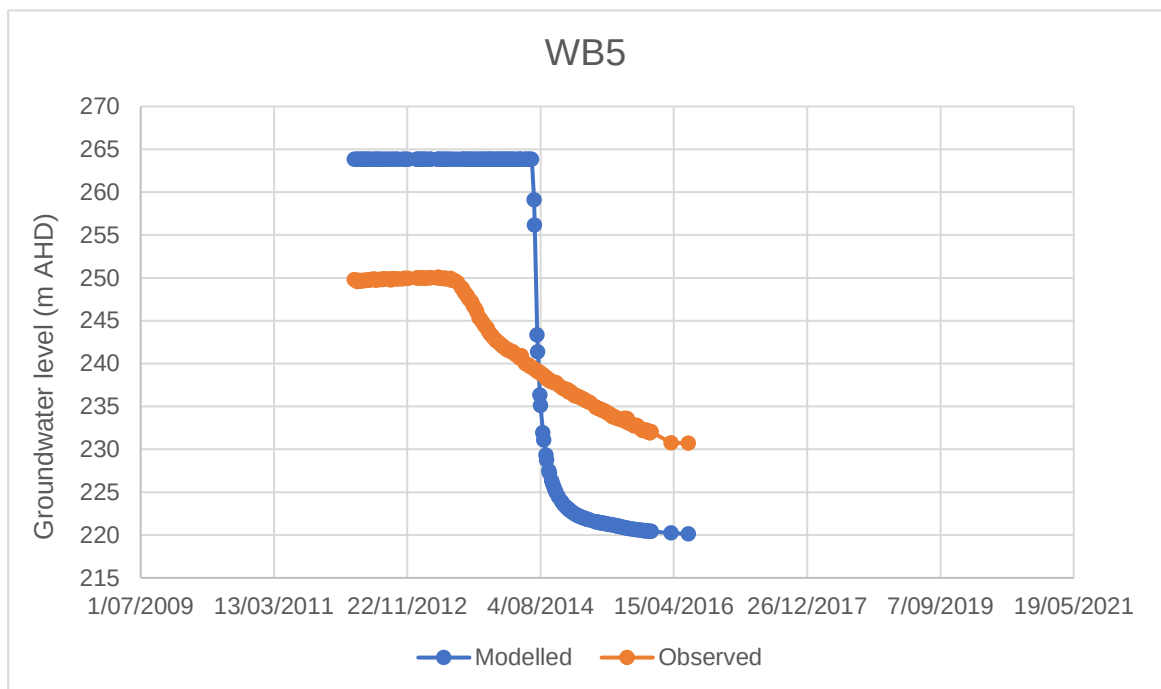
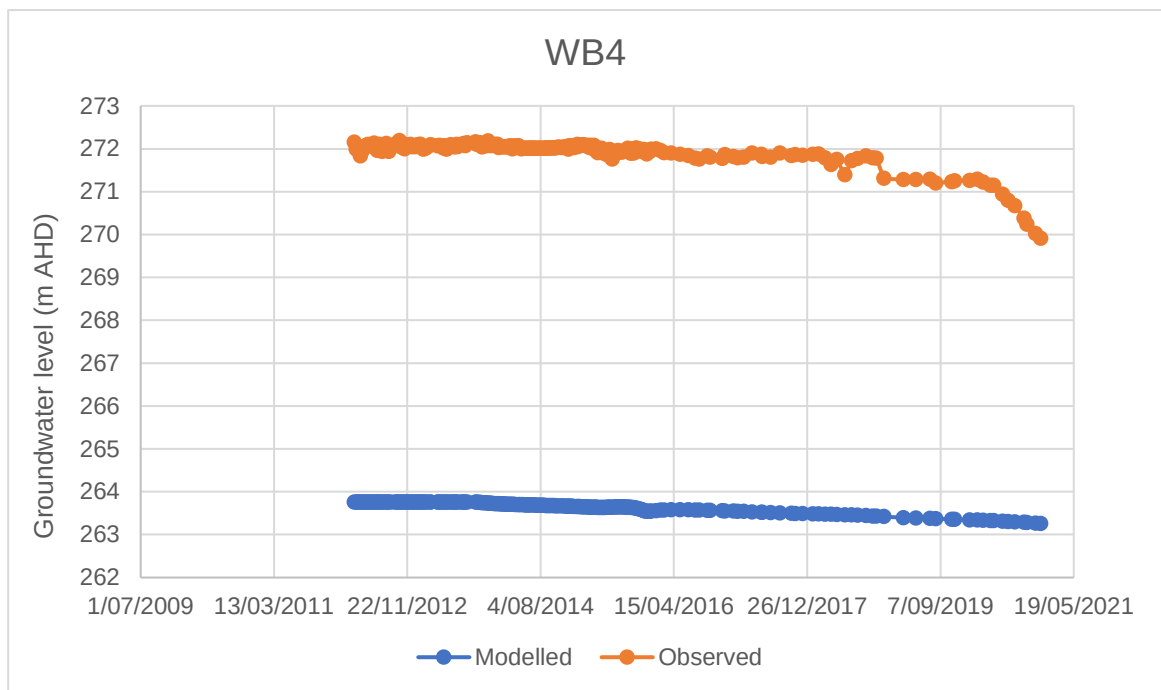


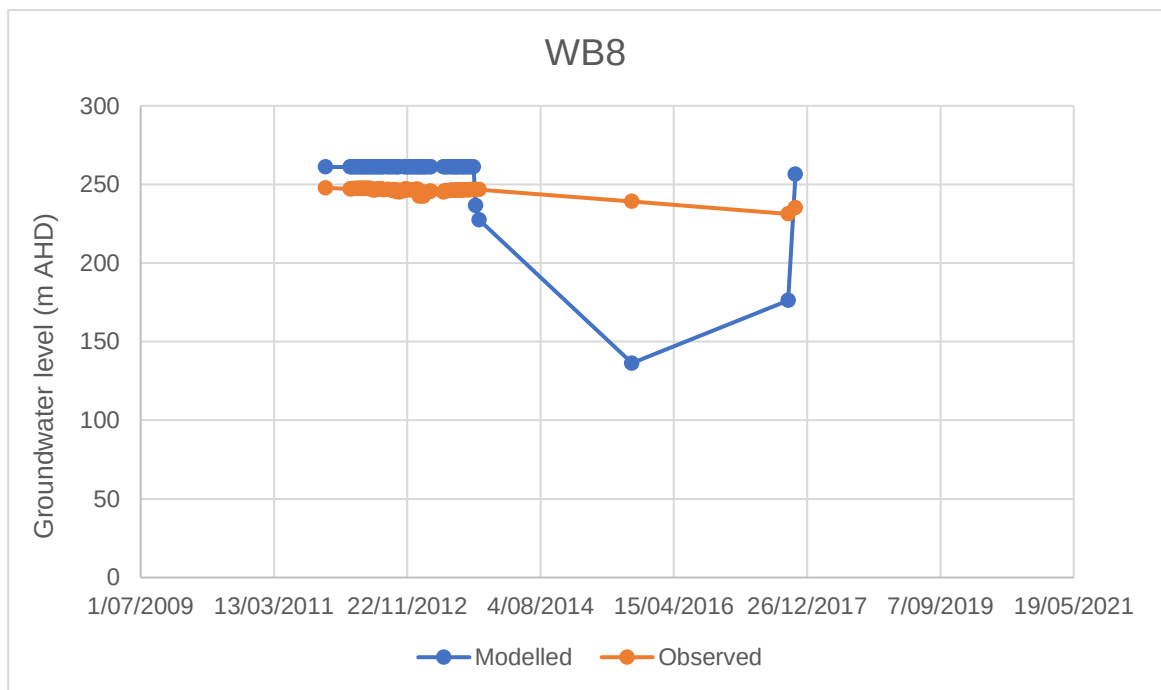




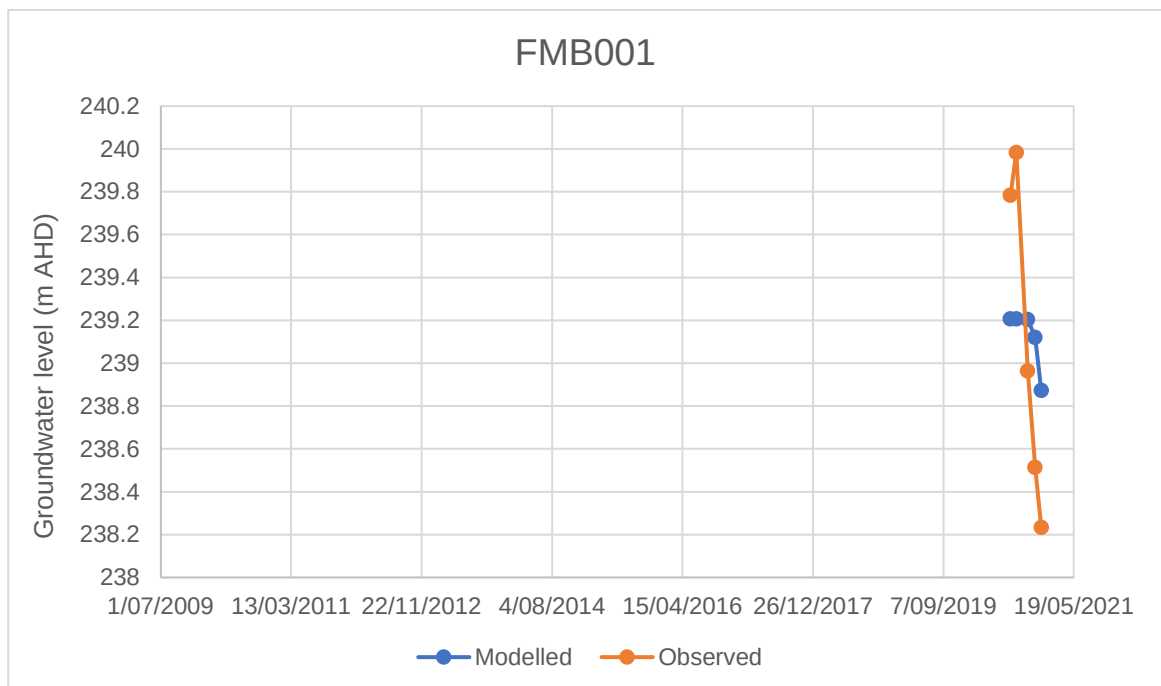


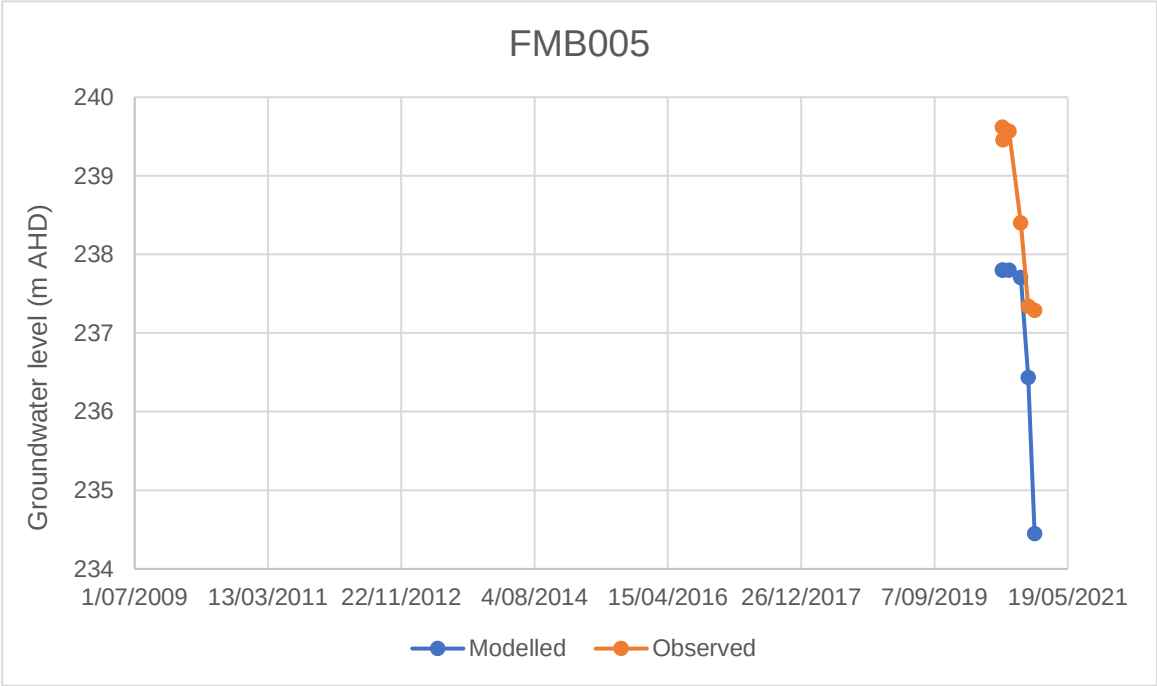
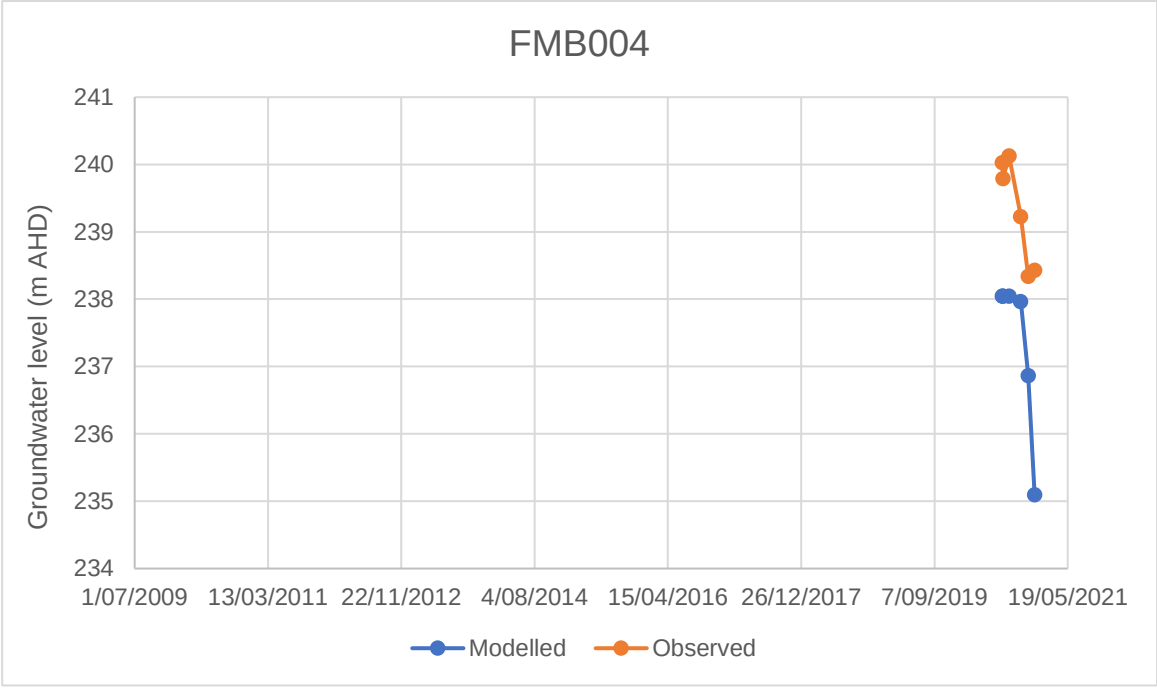


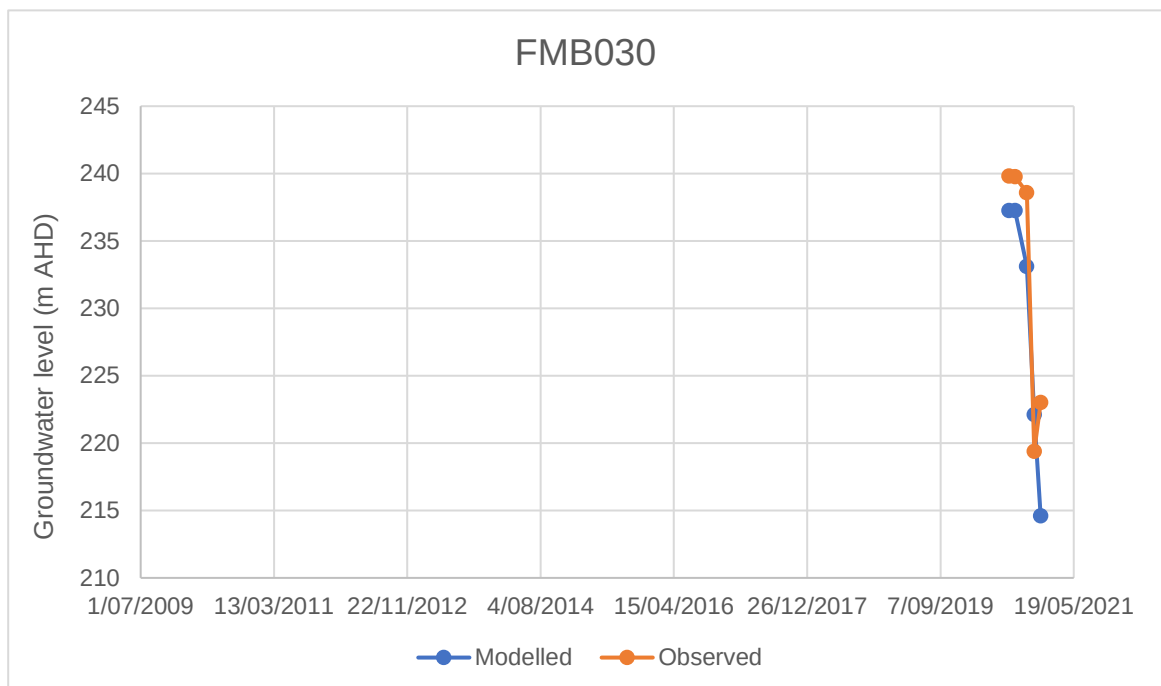
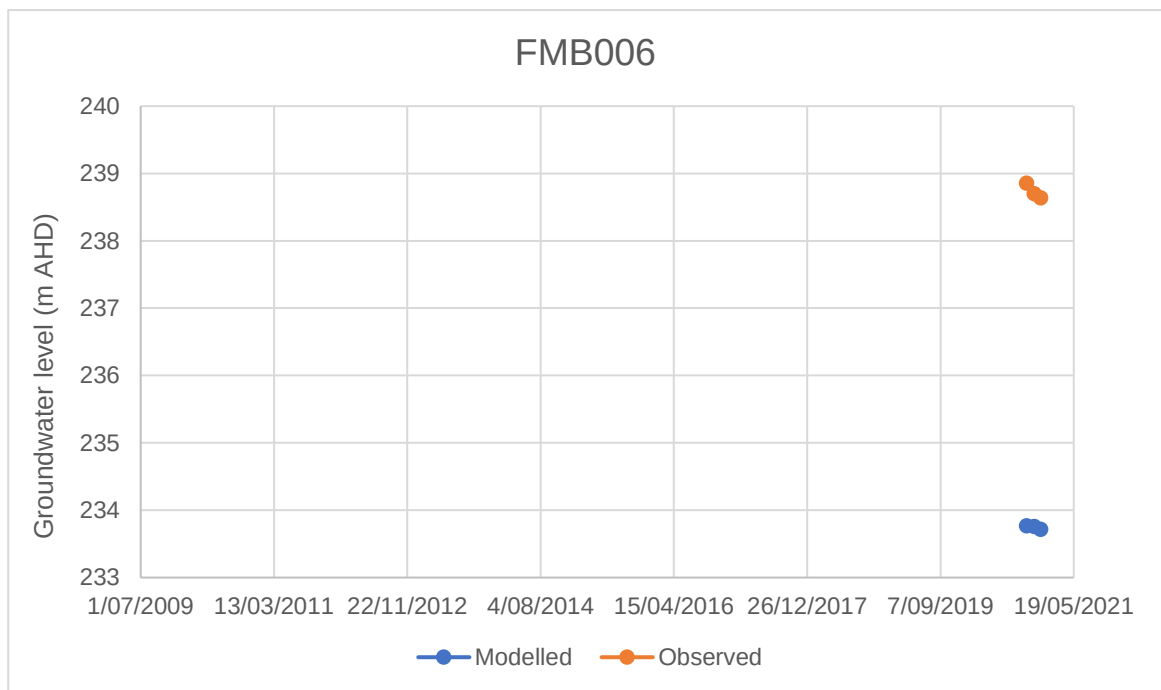




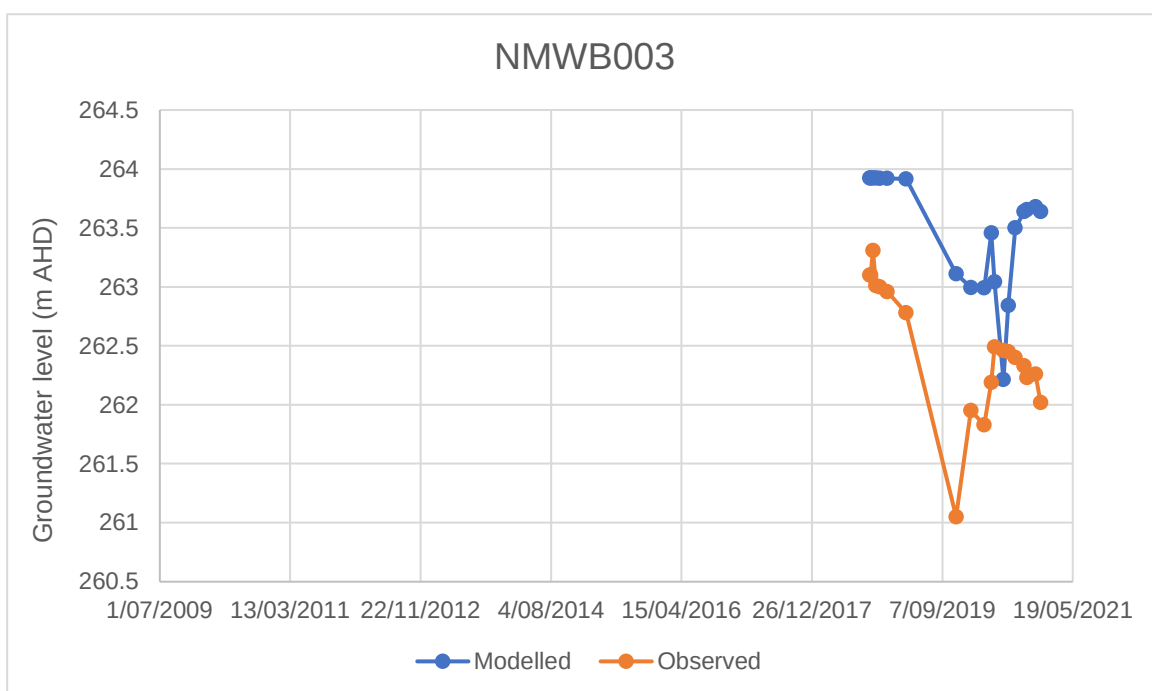
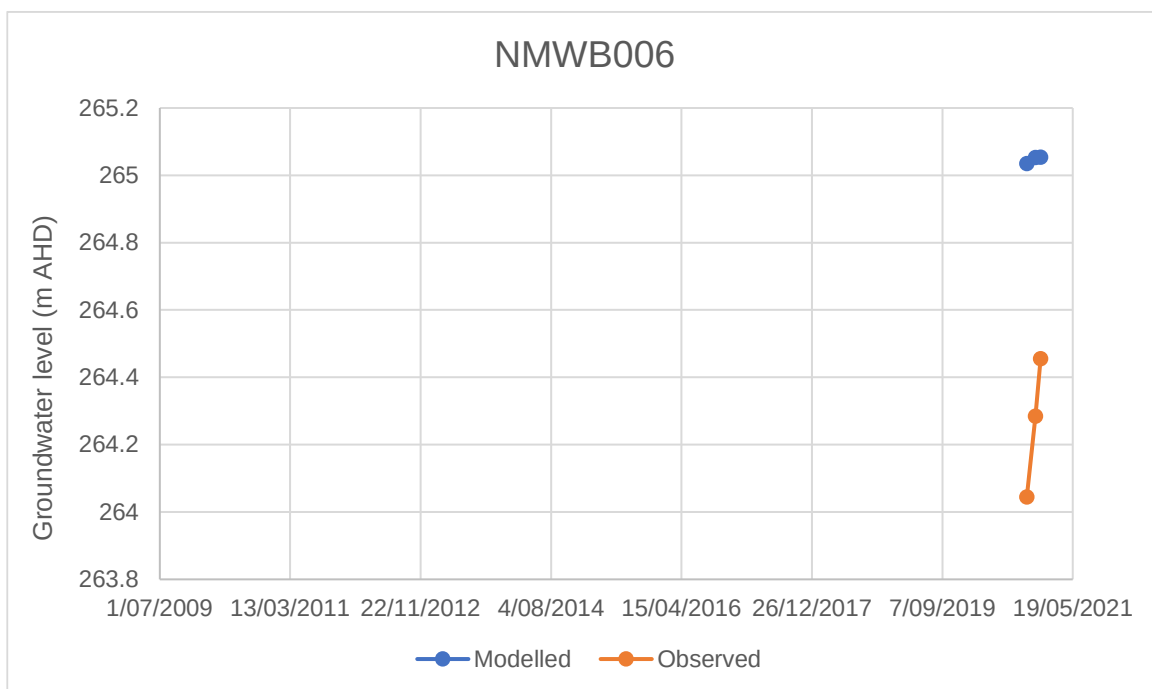
Federation







Nymagee



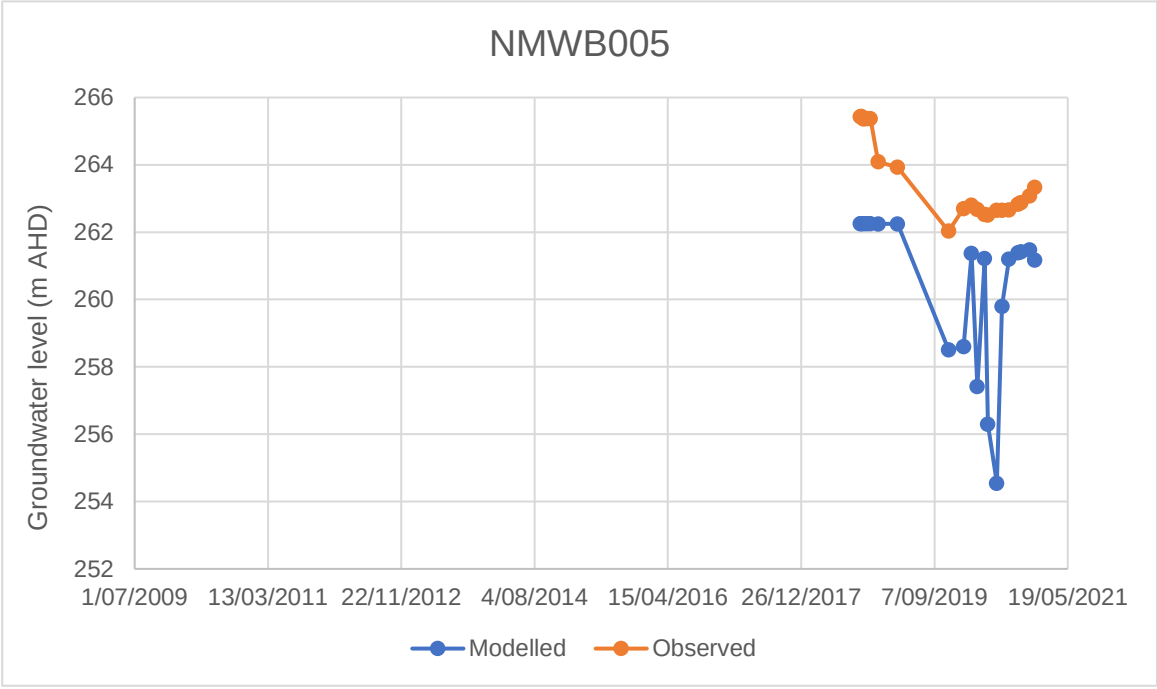
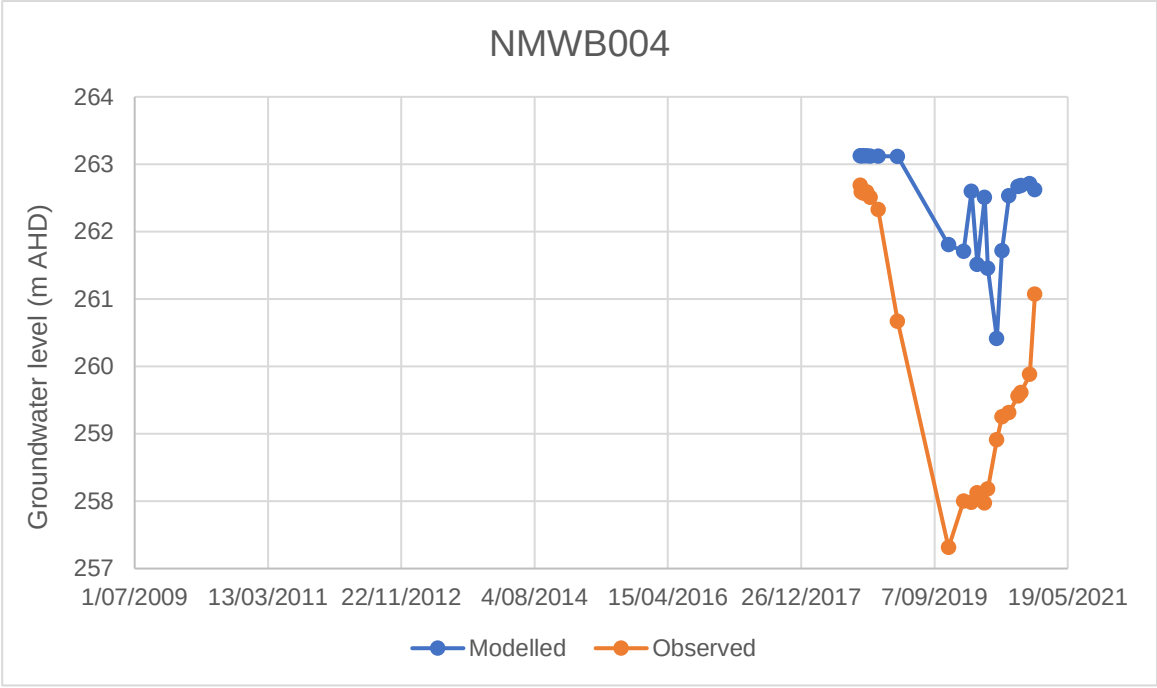
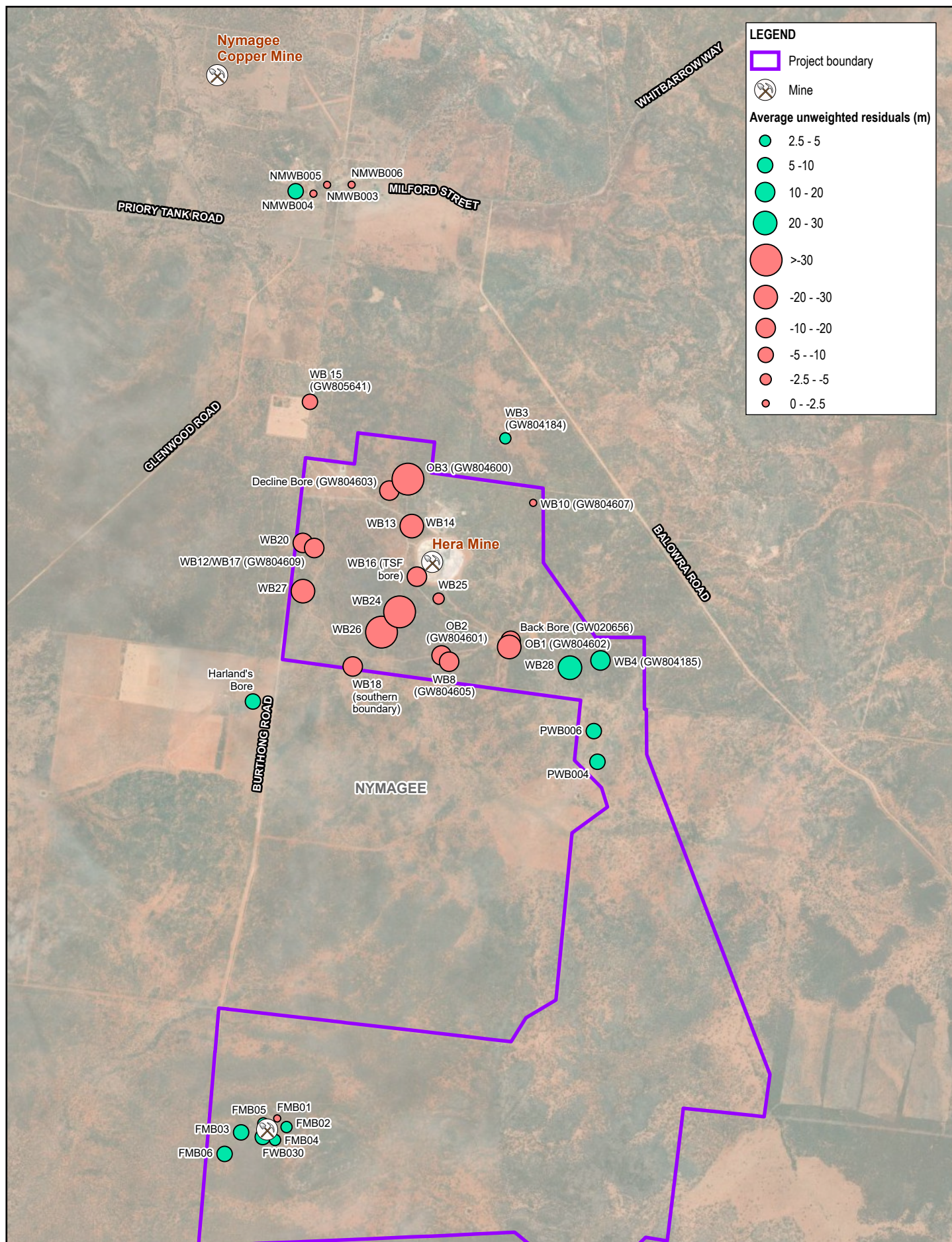


Table E-1 *Calibration target summary*

Bore	Easting	Northing	Model layer	Number of groundwater level observations
Back Bore	438080	6444868	5	216
Decline Bore	436171	6447198	5	175
FMB001	434361	6437163	4	5
FMB002	434511	6437027	4	5
FMB003	433780	6436947	4	4
FMB004	434339	6436818	4	6
FMB005	434146	6437092	4	6
FMB006	433476	6436614	4	3
FWB030	434136	6436866	4	5
Harland's Bore	433978	6443829	4	133
NMWB03	435163.8	6452088	4	19
NMWB04	434945.2	6451947	4	20
NMWB05	434661.4	6451987	4	20
OB1	438073	6444704	5	190
OB2	436993	6444569	5	209
OB3	436454	6447385	5	141
PWB004	439402	6442866	4	10
PWB006	439423	6443350	4	10
WB10	438458.21	6447003	4	216
WB12	434958.25	6446282.8	4	178
WB13	436518.09	6446633.2	4	162
WB014	434846.6	6452207	4	178
WB15	434888.79	6448621.2	5	88
WB16	436591.72	6445841.4	5	57
WB18	435574.8	6444392	5	95
WB20	434772.39	6446669.1	5	58
WB22	437222.71	6445325.3	4	24
WB23	436329.13	6445294.8	4	17
WB26	436064	6444938	5	8
WB27	434778	6445593	5	9
WB28	439047	6444369	4	10
WB3	437915.43	6447986.2	4	20
WB4	438698.72	6445130.5	4	235
WB5	436521.12	6447411.1	5	173
WB8	437111.27	6444463.1	4	76

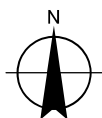
Table E-2 Calibration residual summary

Monitoring bore	Average residual (observed minus modelled)
Back Bore	-11.2
Decline Bore	-14.7
FMB001	-0.03
FMB002	0.16
FMB003	2.89
FMB004	1.98
FMB005	1.61
FMB006	4.98
FWB030	3.25
Harlands Bore	3.73
NMWB006	-0.79
NMWB03	-1.02
NMWB04	-2.38
NMWB05	3.01
OB1	-20.7
OB2	-10.6
OB3	-39.0
PWB004	4.88
PWB006	3.04
WB10	-1.96
WB12	-15.9
WB13	-20.1
WB14	-14.1
WB15	-8.34
WB16	-19.9
WB18	-14.1
WB20	-12.0
WB22	-37.1
WB23	-3.85
WB26	-30.8
WB27	-23.8
WB28	10.3
WB3	2.37
WB4	8.27
WB5	-4.88
WB8	-11.6



Paper Size ISO A4
0 0.55 1.1 1.65 2.2
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

Project No. 12534191
Revision No. 0
Date 08/11/2021

Average Model Residual

Figure E-1

Appendix F

Drawdown Hydrographs

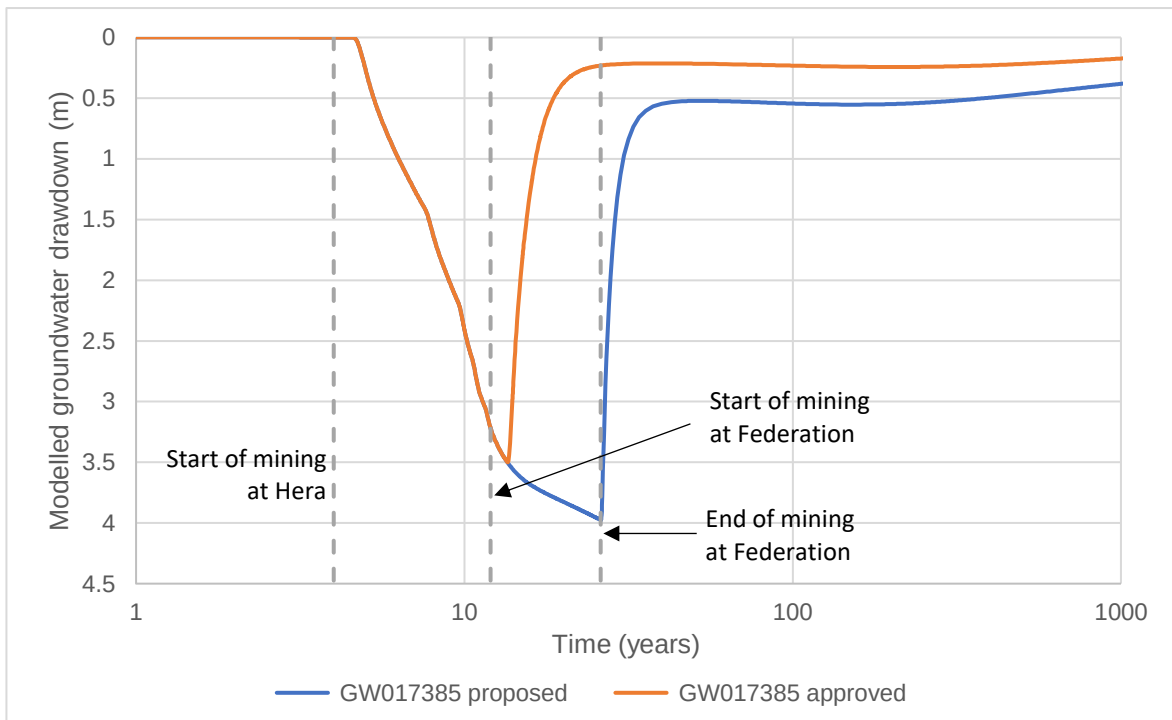


Figure F-1 Modelled groundwater drawdown – GW017385

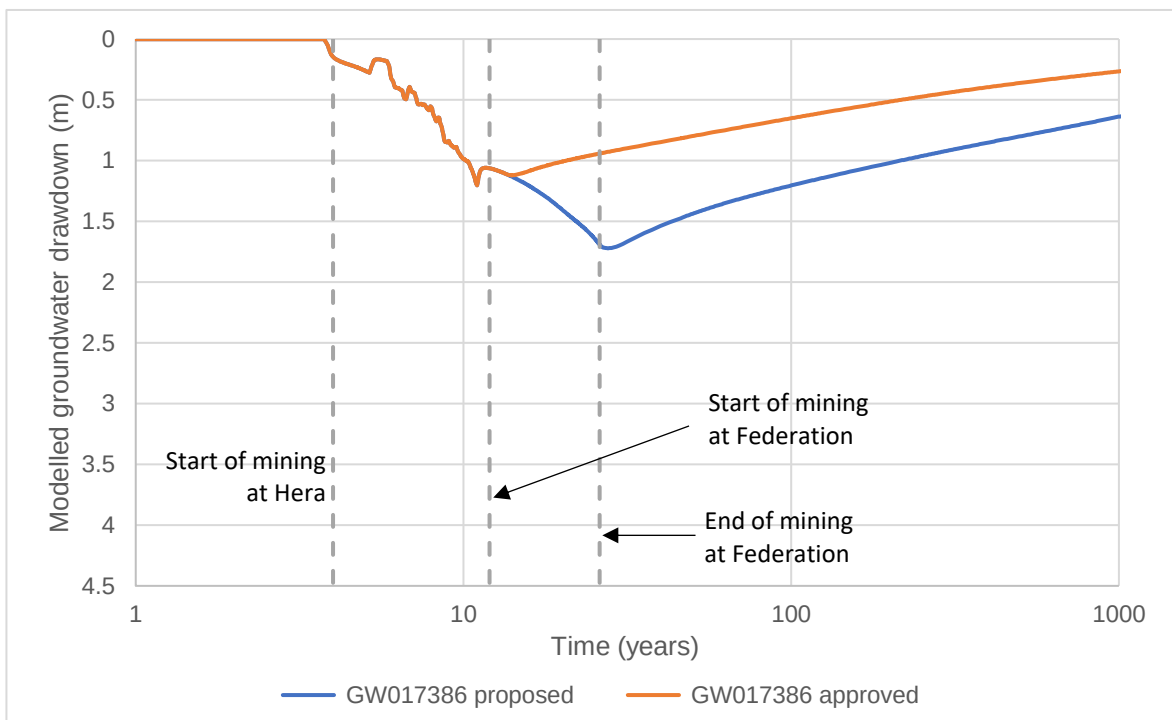


Figure F-2 Modelled groundwater drawdown – GW017386

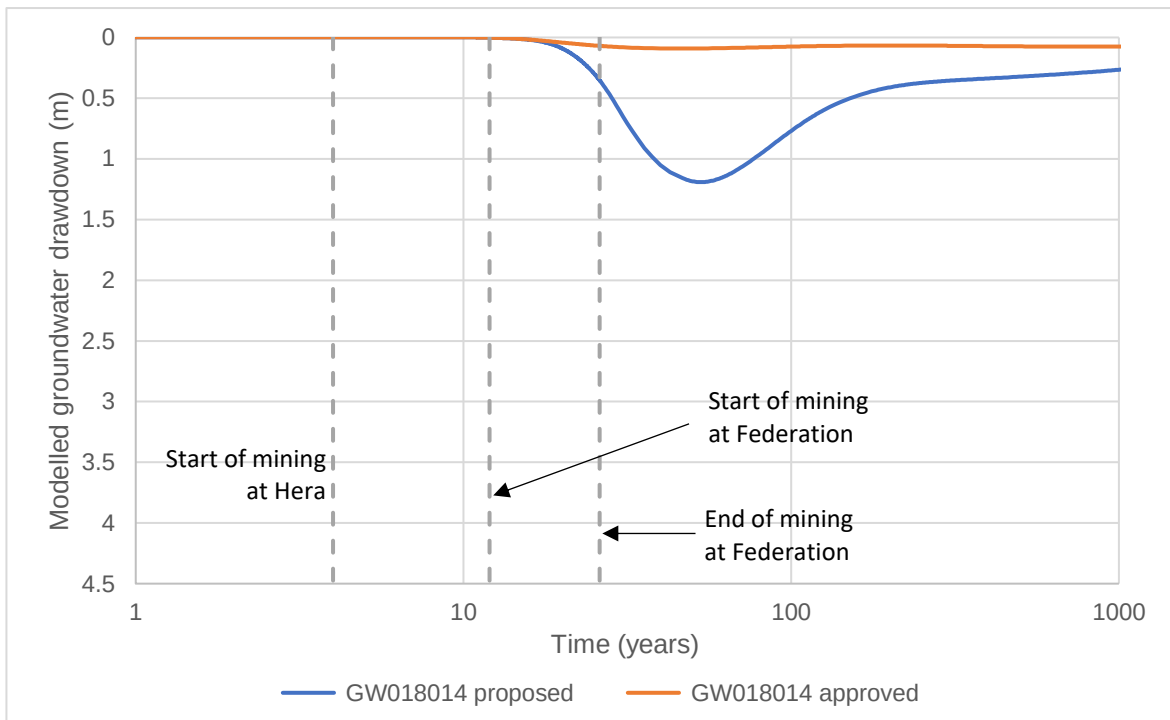


Figure F-3 *Modelled groundwater drawdown – GW018014*

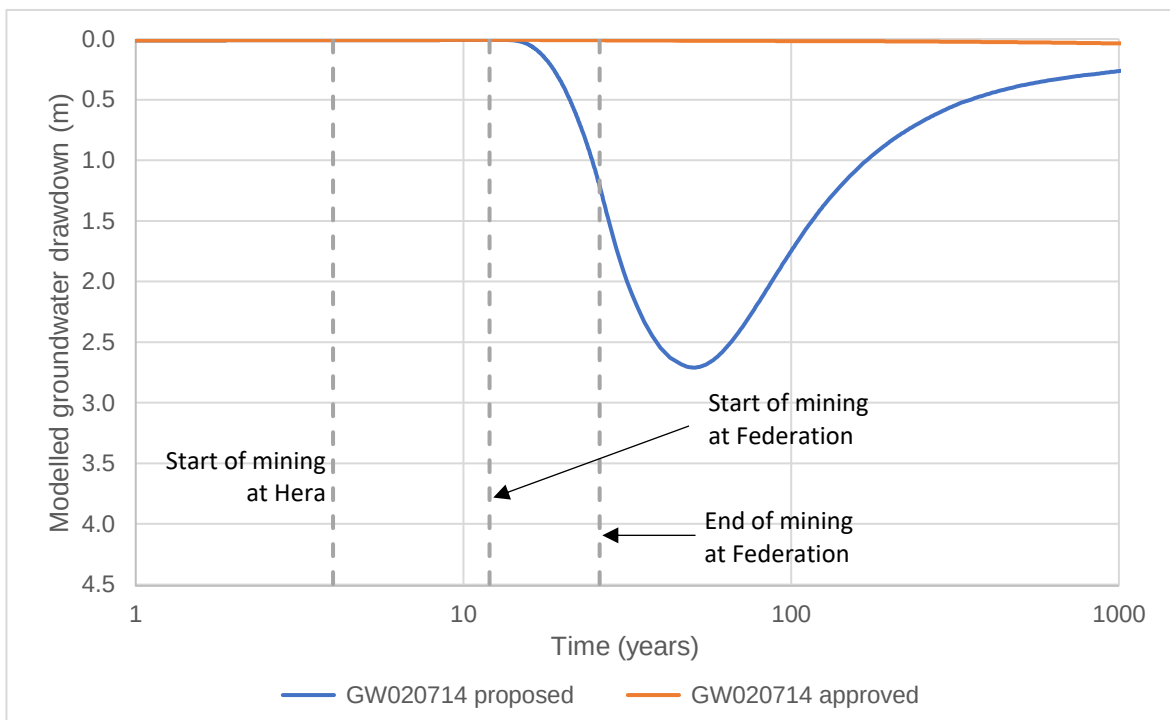


Figure F-4 *Modelled groundwater drawdown – GW020714*

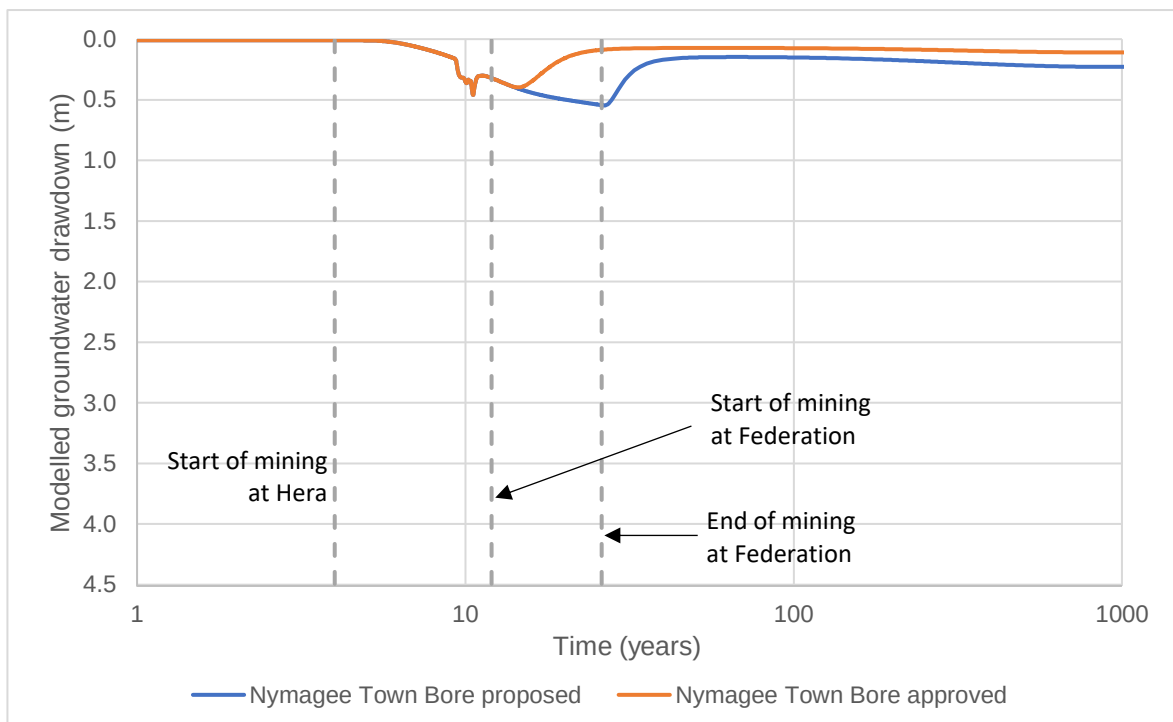


Figure F-5 Modelled groundwater drawdown – Nymagee Town Bore

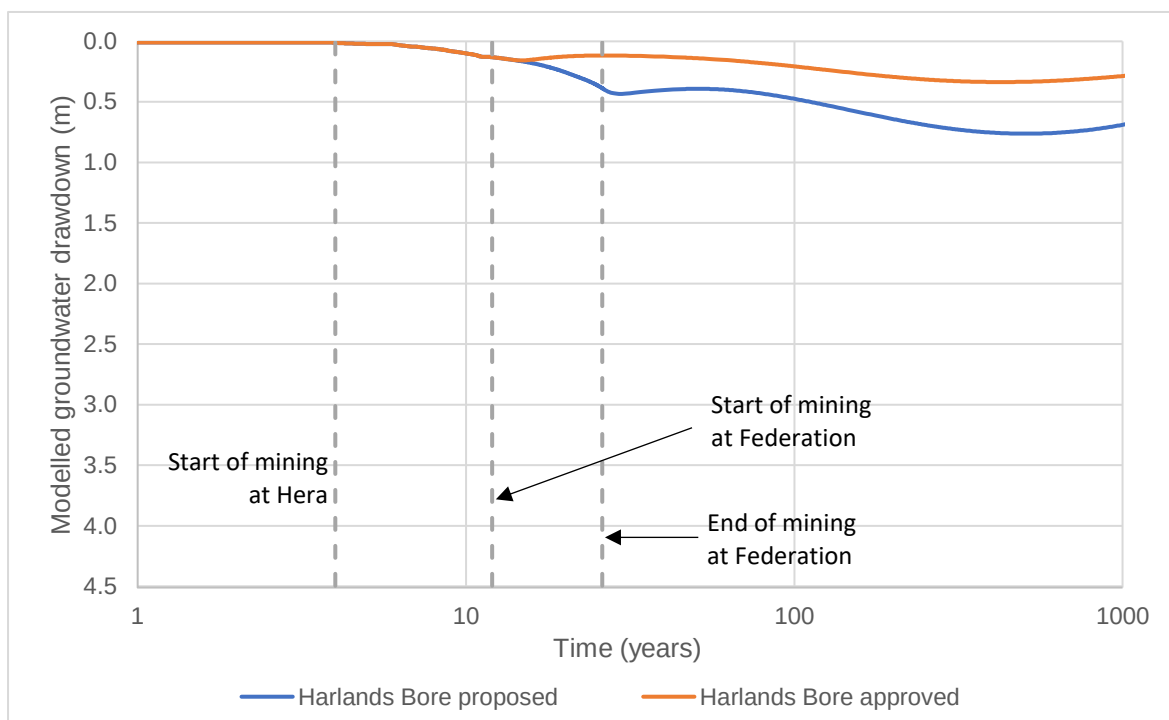


Figure F-6 Modelled groundwater drawdown – Harland's Bore

Appendix G

Uncertainty analysis

Overview

Uncertainty analysis was undertaken to assess the effect of varying model input parameter values on model predictions.

Based on the adopted methodology (Section 10), four uncertainty runs were considered as part of uncertainty analysis. In each of these uncertainty runs, model parameters were varied. The modelled uncertainty runs were as follows:

- Run 1: increase horizontal hydraulic conductivity for ore body and host rock by one order of magnitude
- Run 2: decrease horizontal hydraulic conductivity for ore body and host rock by one order of magnitude
- Run 3: decrease horizontal hydraulic conductivity for ore body and host rock by one order of magnitude and decrease vertical anisotropy (K_h/K_v) of host rock from 50 (base case model) to 100.
- Run 4: Increase specific yield by an order of magnitude.

For each uncertainty run, the model was run for steady state, transient calibration period and for the operational predictive period for proposed conditions.

As part of the operational predictive period, proposed production bores were removed from the model. This was due to instability in the uncertainty analysis model runs. Therefore the base case model (Section 7) was also re-run for the operational predictive period with proposed production bores removed.

Parameters modified as part of the uncertainty analysis were selected with consideration of the likely sensitive model parameters discussed in Section 5.3.3.

Results

Model calibration statistics

Model calibration statistics (including RMS and sRMS) for the base case model and each of the uncertainty runs are summarised in Table G-1. The RMS and sRMS is higher for all of the uncertainty analysis runs and therefore the impacts associated with the uncertainty analysis runs are less likely to be representative of actual impacts.

Table G-1 *Model calibration statistics – uncertainty analysis*

Uncertainty analysis run	RMS (m)	sRMS (%)
Base case	9.8	9.6
Run 1	10.4	10.2
Run 2	11.4	11.1
Run 3	10.4	10.2
Run 4	11.0	10.7

Mine inflow

The modelled mine inflow predictions for each of the uncertainty runs have been compared with the results of the base case model. As discussed above, the results presented in this section for both the base case model and the uncertainty analysis runs exclude the proposed production bores.

Modelled mine inflows into the Hera Mine workings for the base case model and uncertainty analysis scenarios, over the calibration period (2010 to 2021) are shown in Figure G-1. Predicted mine inflows into the Federation workings for the base case model and uncertainty analysis scenarios are shown in Figure G-2.

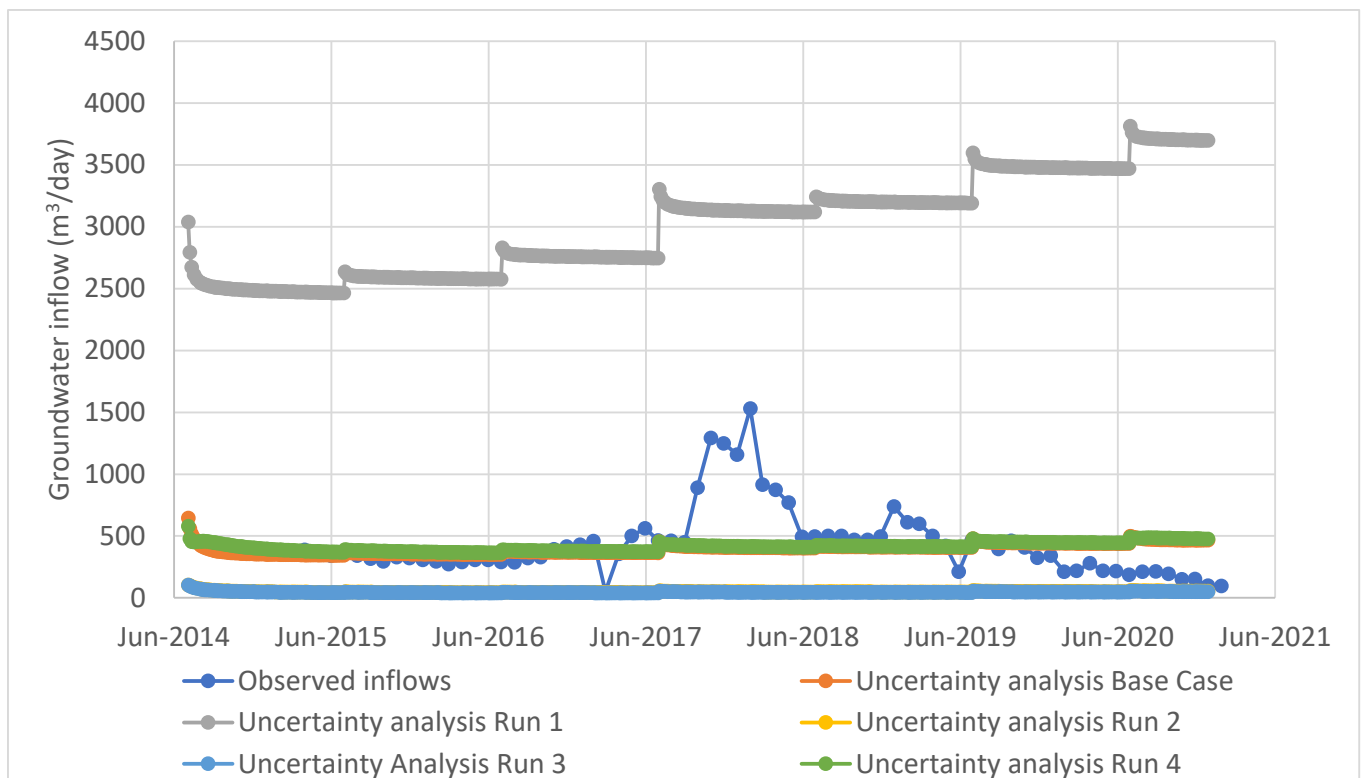


Figure G-1 Modelled Hera Mine inflows – calibration period – uncertainty analysis

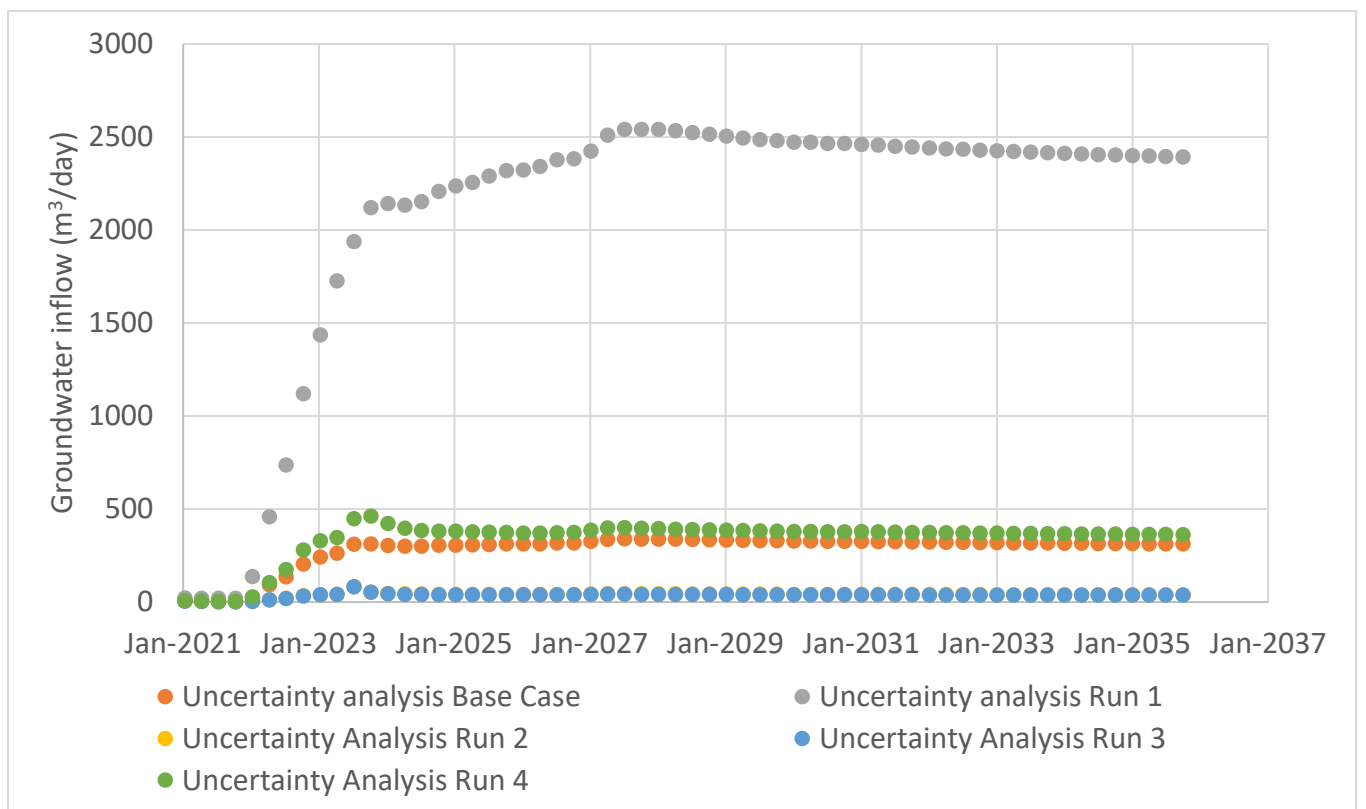


Figure G-2 Modelled Federation inflows – uncertainty analysis

The results indicate that modelled inflows are sensitive to hydraulic conductivity. Increasing hydraulic conductivity resulted in increased modelled mine inflows, while decreasing hydraulic conductivity resulted in lower modelled mine inflows.

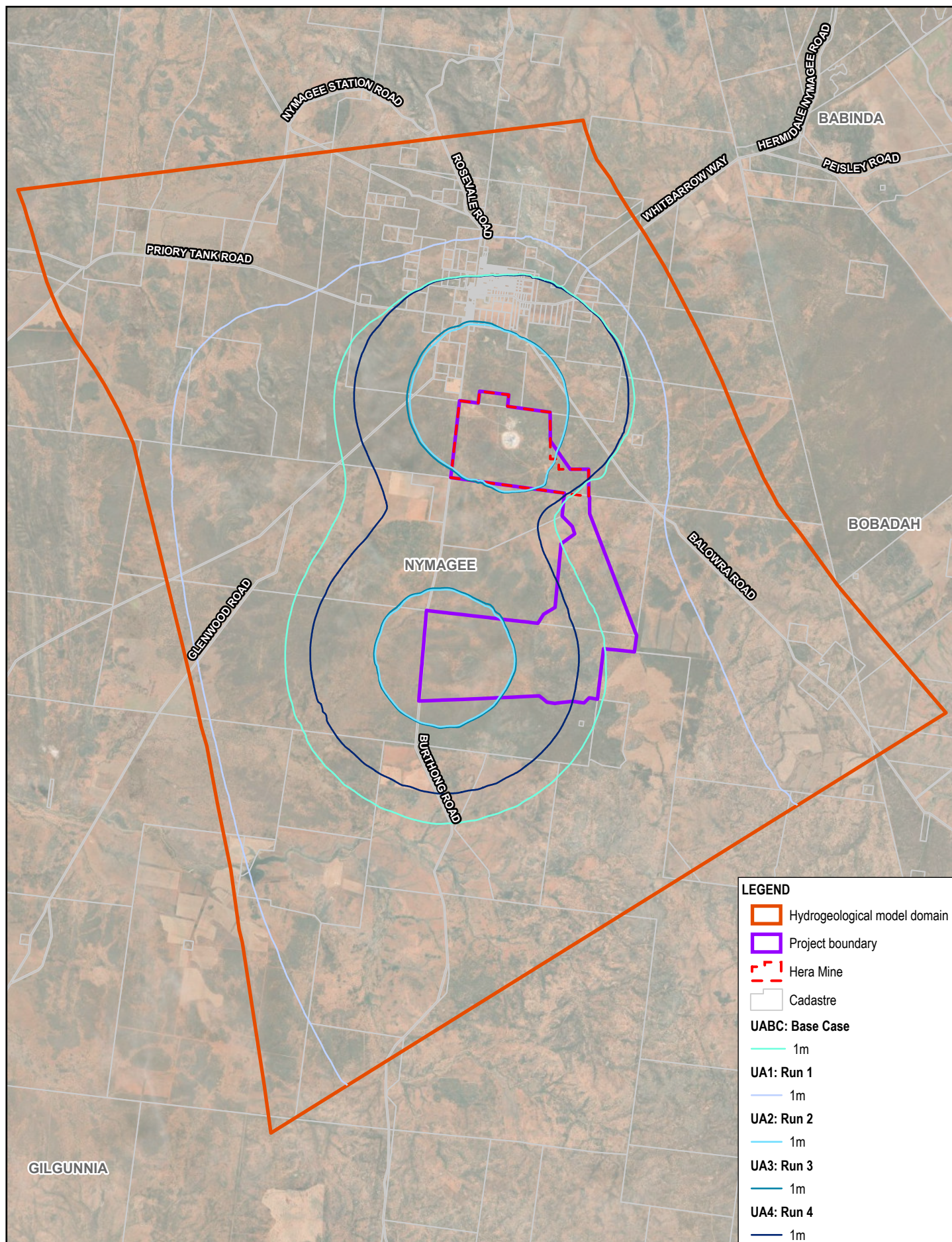
Uncertainty run 1 and uncertainty run 3 are significantly overestimating and underestimating inflows into the existing Hera Mine workings respectively. Therefore, predictions of future impacts of uncertainty run 1 and uncertainty run 3 are considered unlikely to occur. Predictions of mine inflow for uncertainty run 2 and uncertainty run 4 are similar to base case predictions. This indicates that there is unreconciled uncertainty in parameters that were modified in uncertainty run 2 and uncertainty run 4 (minimum horizontal and vertical hydraulic conductivity, and specific yield magnitude).

Effect on groundwater levels

The modelled 1 m drawdown contour at the end of mining for the base case and each of the uncertainty runs has been compared in Figure G-3. Note that these model runs do not include the proposed production bores.

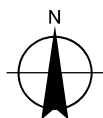
The results indicate that increasing hydraulic conductivity by an order of magnitude results in a larger modelled radius of drawdown. Decreasing hydraulic conductivity resulted in a smaller modelled radius of drawdown. Comparison of the modelled radius of drawdown for uncertainty run 2 and uncertainty run 3 indicates that increasing anisotropy increases the radius of drawdown. Increasing specific yield results in a smaller radius of drawdown compared to the base case.

The results of the uncertainty analysis runs do not alter the findings of the base case model. Uncertainty run 1 does indicate that drawdown at landholder bores and groundwater inflows into the Federation workings may be greater than predicted by the base case model. However, as shown in Figure G-1, uncertainty run 1 is overestimating impacts due to existing mining. Therefore predictions of future impacts of uncertainty run 1 are considered unlikely to occur.



Paper Size ISO A4
0 1.5 3 4.5 6
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55



Hera Resources Pty Ltd
Federation Project
Groundwater Impact Assessment

End of mining 1 m drawdown
contour – uncertainty analysis

Project No. 12534191
Revision No. 0
Date 08/11/2021

Figure G-3



ghd.com

➔ The Power of Commitment