BHP

Orebody 32 below water table: Groundwater impact assessment

August 2022

Authorisation

Version	Description of Version	Position	Date
0	Initial version	Superintendent, Stewardship & Approvals	10 August 2022

Contents

1 Introduction

The purpose of this document is to provide an assessment of the impacts on water resources from the proposed groundwater abstraction for mine dewatering for the Orebody 32 Below Water Table Proposal (OB32 BWT Proposal). The *Eastern Ridge - OB32: Ophthalmia Dam surplus water impact assessment* (BHP 2022a) documents the assessment of the impacts of discharge of surplus mine dewater from the OB32 BWT Proposal to Ophthalmia Dam.

2 Existing environment and environmental values

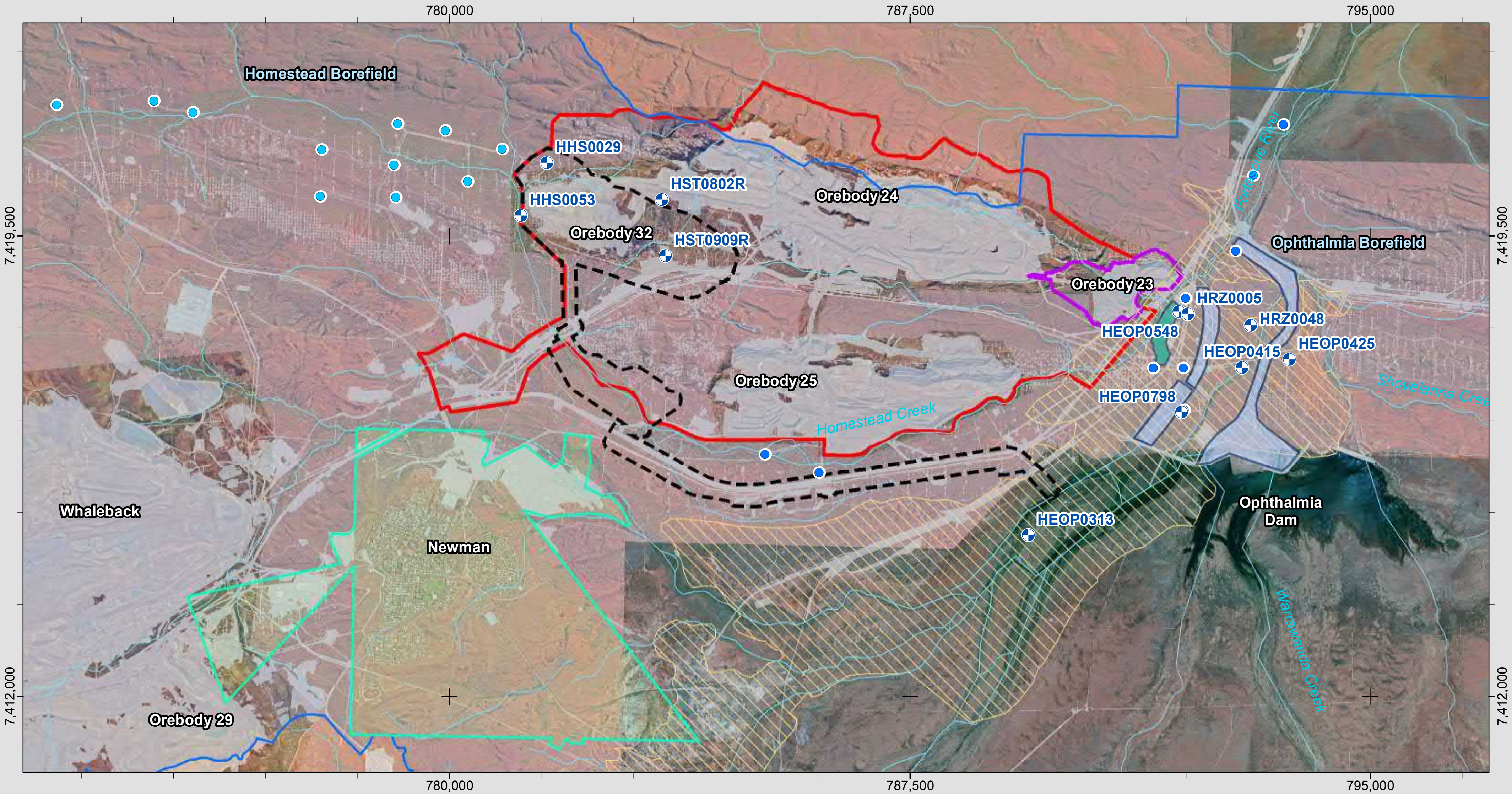
The OB32 above water table (AWT) deposit is part of the existing Eastern Ridge mining operations (Eastern Ridge) which also includes OB23, OB24, OB25 and OB25 West (Figure 1) in the Newman Hub. The Eastern Ridge mine (Eastern Ridge Iron Ore Revised Proposal) was approved under Part IV of the *Environmental Protection Act 1986* (EP Act) by issue of Ministerial Statement 1037 (MS1037) for below water table mining at OB24, OB25 and OB25 West and above water table (AWT) mining at OB32. Below water table mining is also approved at OB23 under MS478 (Figure 1). OB32 is a large orebody that extends from within the proposed Development Envelope 6 km to the west. BHP also refers to the portion of OB32 within the proposed Development Envelope as OB32 East (OB32E). At Eastern Ridge, abstraction for dewatering currently occurs at OB24 and OB25 Pit 3. Abstraction has not commenced at OB25 West. Dewatering has ceased at OB25 Pit 1 and backfilling has commenced. Backfilling has also commenced at OB23 and dewatering is planned to cease by mid-2023.

The OB32 BWT Proposal is located within the Priority 1 Public Drinking Water Source Area of the Newman Water Reserve. Groundwater is abstracted from the BHP operated Ophthalmia and Homestead borefields, to provide drinking water for the Newman town water supply. Southwest of Eastern Ridge are the Mt Whaleback and OB29/30/35 mines (Figure 1). The Homestead Borefield is adjacent to OB32 (to the west) and Ophthalmia Borefield is located to the southeast and east of OB32 (Figure 1), within the Ethel Gorge aquifer. The Ophthalmia Dam system partially overlies the Ethel Gorge aquifer which supports the Ethel Gorge aquifer stygobiont community Threatened Ecological Community (Ethel Gorge TEC). Ophthalmia Dam was commissioned in 1981 as a managed aquifer recharge (MAR) scheme, to maintain groundwater levels within the Ethel Gorge aquifer and to support the Ophthalmia Borefield, which has operated since the 1970s. The Ophthalmia Dam system continues to maintain groundwater levels within the Ethel Gorge aquifer system to protect the Ethel Gorge TEC and also provides a discharge location for surplus water from BHP mines including the OB32 BWT Proposal (BHP 2022a).

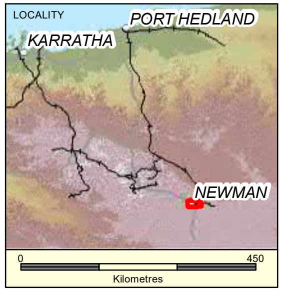
The main water-related environmental values that may be impacted by groundwater abstraction for the OB32 BWT Proposal are (Figure 1):

- local groundwater resource in the Newman Water Reserve, used for town water supply
- Ethel Gorge aquifer (and TEC).

Fortescue Marsh is located approximately 128 km north of Ophthalmia Dam at the terminus of the Fortescue River. The aquifer system underlying Fortescue Marsh is not connected to the OB32 aquifer and will not be impacted by OB32 dewatering.



Proposed Development Envelope
Infiltration Basins
Recharge Ponds
Indicative Cleared Area as at 15 February 2022
Newman Drinking Water Reserve P1
Newman Drinking Water Reserve P3
Watercourses
Homestead Borefield Bores
Ophthalmia Borefield Bores
Monitoring Bore
Eastern Ridge MS1037 Development Envelope
Orebody 23 MS478 Development Envelope
Ethel Gorge Threatened Ecological Community



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Spatial Data - Studies & Access
BHP IRON ORE

OREBODY 32 BELOW WATER TABLE
Local Context

N
0 1 2 3
Kilometres

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator, Datum: GDA 1994, Units: Meter

Scale @ A4: 1:87,500	Prepared: J. Vis	Project No: A1079/057 REV A
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3 Climate

The eco-hydrological change assessment undertaken for the Strategic Proposal (BHP Billiton 2016 - Appendix 7 *Main Report and Maps* and *Appendix D Ecohydrological Conceptualisation for the Eastern Pilbara Region*) provides a summary of climate and climate variability in the Pilbara, based on the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Pilbara Water Resource Assessment (WRA), for which a number of reports were published in 2015. The analyses undertaken for the Strategic Proposal included data up to 2013.

The climate in the Pilbara is semi-arid characterised by high temperatures and low, irregular rainfall. BHP noted in the *Pilbara Public Environmental Review Strategic Proposal* (BHP Billiton 2016) that the Pilbara has experienced a relatively wet 20 year period from the mid-1990s, shown by the 1995-2013 period compared to the previous long-term period at Ethel Gorge using the SILO enhanced climate database (BHP Billiton 2016 - Appendix 7 *Main Report*). For consistency, BHP has used the SILO data at OB32 for rainfall and temperature (Queensland Government 2020).

Figure 2 shows that the average annual rainfall at OB32 since 2014 is lower (336 mm/year) compared to the mean of 391 mm/year from 1995 to 2013. However, it is higher than both the average of 319 mm/year for the WRA baseline period 1961-2012 which climate change scenarios were compared against and the long term average (286 mm). This is also reflected in the 10-year moving average. Therefore, since the 'wet' period referred to in the eco-hydrological change assessment, there does not appear to be a step change to a dry phase.

The annual average monthly maximum temperature shows an increasing trend since the early 1980s, with an average increase of approximately 0.9°C in the 10-year moving average (Figure 3). Interestingly, the period of very high rainfall occurred during the period of temperature rise (Figure 3).

In the WRA for the Upper Fortescue region (where the OB32 BWT Proposal is located), CSIRO noted that groundwater levels in the Upper Fortescue region rose considerably at the turn of the Millennium (~2000) in response to consecutive years of high rainfall and have since gradually declined. CSIRO also noted that local recharge via stream leakage following heavy rainfall and streamflow is an important recharge mechanism in the region. Analysis of rainfall (Station 507005) and streamflow (runoff) data for the Fortescue River - Newman gauging station (708011) indicates that although there was higher runoff during the 'wet' 1995-2013 period, there is not a trend in rainfall and/or runoff decrease to date (Figure 4), which would result in decreased groundwater recharge.

3.1 Future climate predictions

The WRA used the period 1961 to 2012 as the baseline climate period (Scenario A) to compare future climate scenarios (Scenario Cs) as the recent record is likely to be more representative of future climate than early records. The WRA uses a high emissions scenario (RCP8.5) and mid-range scenario (RCP4.5) for predictions. RCP4.5 represents increased emissions of greenhouse gases until about 2040 and then reductions due to the implementation of mitigation, whereas RCP8.5 represents a future with little curbing of emissions and rapidly rising greenhouse gas concentrations. The WRA considered two periods for projected changes to rainfall, temperature and areal potential evaporation (areal PE): C30 to represent changes by 2030 (period 2021 to 2040) and C50 to represent changes by 2050 (period 2041 to 2060). For each of the periods, scenarios were run for the 10th, 50th and 90th percentile rainfall totals (Cdry, Cmid and Cwet) (Charles *et al* 2015).

The discussion in this document uses RCP4.5 (assuming there will be emissions reductions from about 2040). The range of projected annual rainfall changes for the Upper Fortescue region for the selected dry and wet scenarios from the 18 global climate models (GCMs) for RCP4.5 is between -6.2% (Cdry) to 3.6% (Cwet) with a median (Cmid) of -0.2% for 2030 and between -7.1% (Cdry) to 4.9% (Cwet) with a median (Cmid) of 0.2% for 2050 (McFarlane (ed.) 2015), emphasising the uncertainty in future rainfall predictions.

The median projected warming relative to the historical climate (mid-point in 1986) for RCP4.5 is 1.5°C for 2030 and 2.1°C for 2050. The areal PE changes are more consistent than those obtained for rainfall as they are a function of the consistently increasing trend in temperature projected by the GCMs. The range of projected annual potential evaporation changes for the Upper Fortescue region for RCP4.5 is 3.3% to 3.8% for 2030 and 4.0% to 4.7% for 2050 (McFarlane (ed.) 2015). Projections indicate that the Pilbara will become warmer and may become slightly drier by 2030 and 2050, although wetter projections cannot be discounted. There is not sufficient confidence in the projections to allow quantification of the probabilities of the wet or dry scenarios occurring in the future (Charles *et al* 2015). Therefore, it is not clear whether it will be wetter or drier. In general, the GCMs suggest that a drier future climate is more probable than a wetter climate (McFarlane (ed.) 2015).

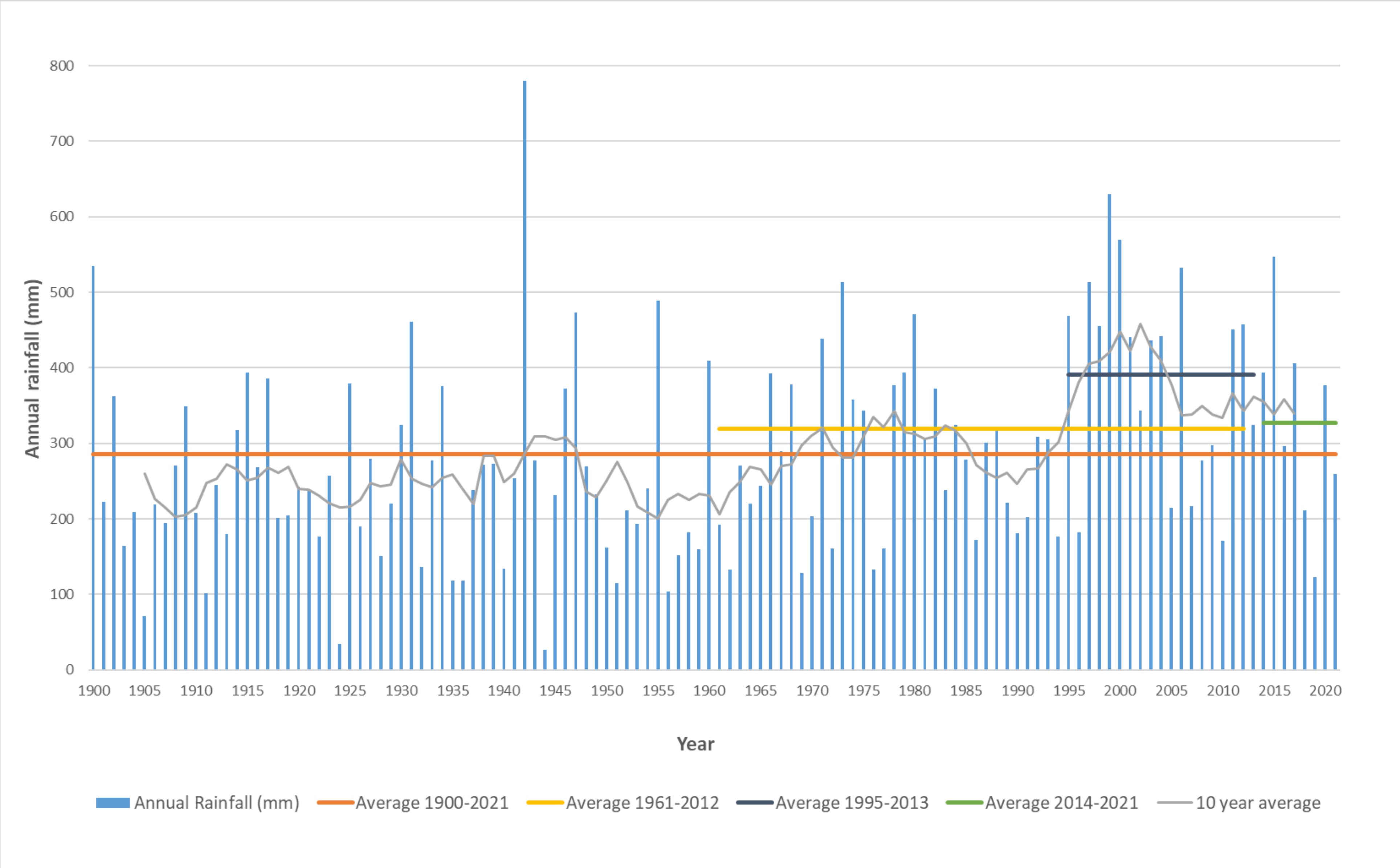


Figure 2: SILO annual rainfall at OB32

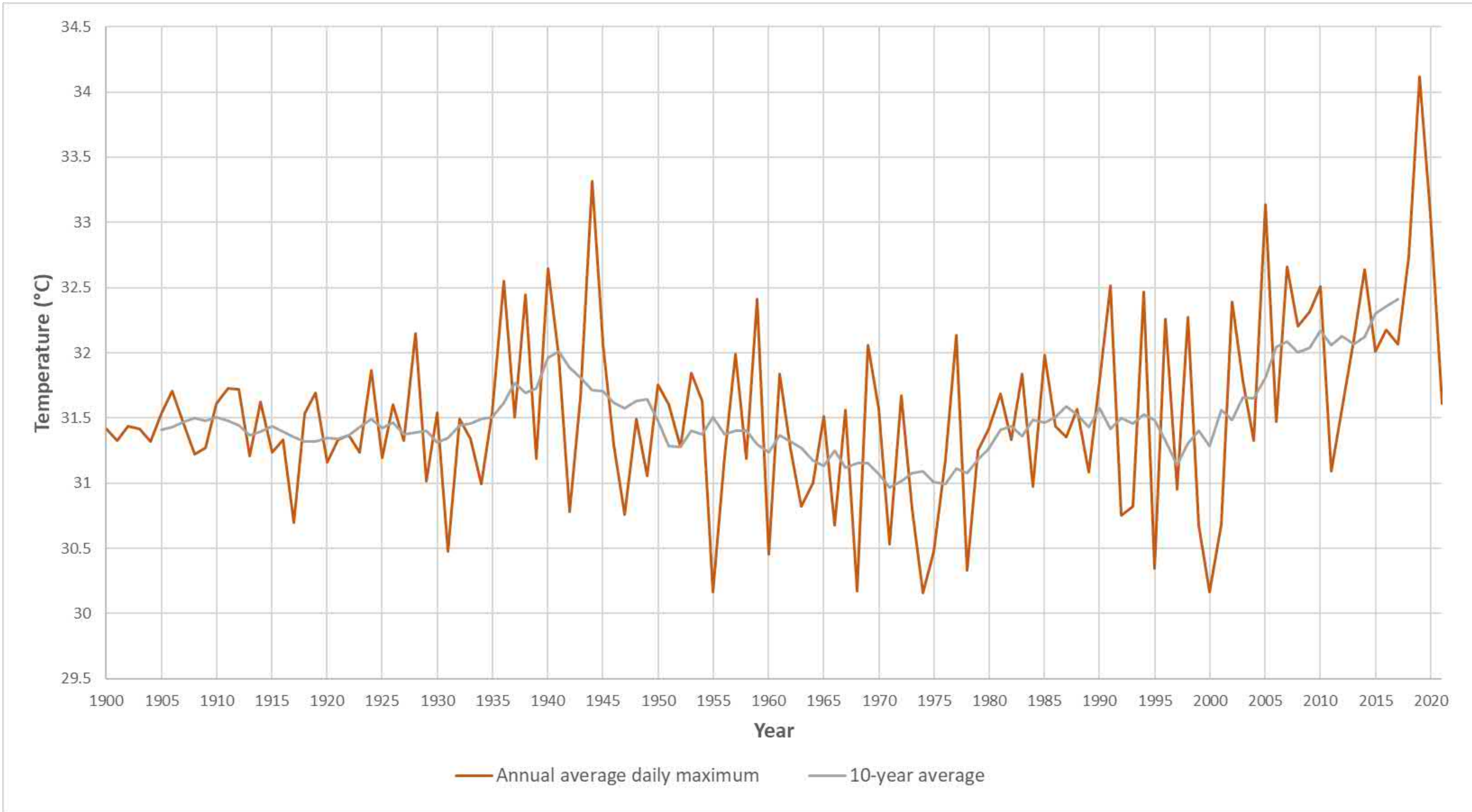


Figure 3: SILO annual temperature at OB32

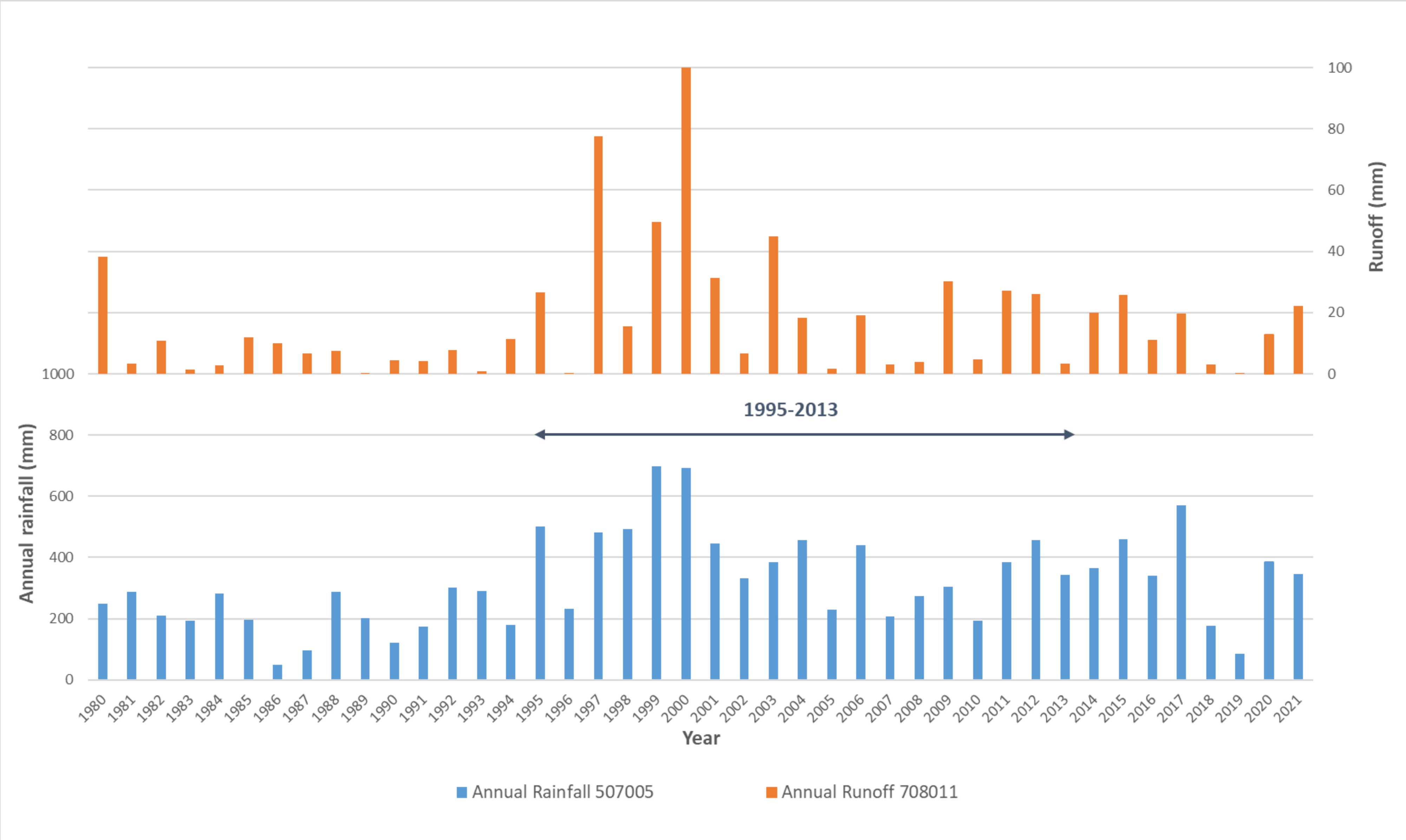


Figure 4: Annual rainfall and runoff at Fortescue River - Newman station

4 Historical abstraction and groundwater levels

The groundwater regime in the Eastern Ridge area has been altered by groundwater abstraction for water supply for Newman since the 1970s from the Ophthalmia Borefield and since 2013 from the Homestead Borefield. Mine dewatering has also altered the local groundwater regime since 2006 at Eastern Ridge (OB23 and OB25 Pit 3). Since the commissioning of Ophthalmia Dam in 1981, the Ethel Gorge aquifer has been recharged by the Ophthalmia Dam system. Since 2006, surplus water from BHP mines (including Eastern Ridge) has been discharged to the Ophthalmia Dam system (BHP 2022a).

Figure 5 shows observed groundwater levels in the Homestead East/ OB32E aquifer in the vicinity of the existing OB32 AWT pit since 2013 when abstraction at the Homestead Borefield started. The data for the OB32 area shows that the groundwater level decline (drawdown) is up to approximately 10 m due to abstraction from the Homestead Borefield. The current groundwater level in the vicinity of the OB32 AWT pit is approximately 515 - 520 mRL.

Figure 6 shows observed groundwater levels in the Ethel Gorge aquifer since the 1970s when abstraction from the Ophthalmia Borefield started. The data for the Ethel Gorge aquifer shows the decline in groundwater levels (drawdown) during the 1970s due to abstraction from the Ophthalmia Borefield for the Newman town water supply (as discussed in Section 2) and the rapid groundwater level response in the early 1980s following the commissioning of Ophthalmia Dam in 1981. Observed groundwater levels in the Ethel Gorge aquifer are generally higher since Ophthalmia Dam was commissioned.

As shown in Figure 6, the drawdown in the vicinity of the Eastern Ridge pits reached a maximum of approximately 130 m at OB25 Pit 3 and 100 m at OB23. However, while there was some response to the dewatering in the Ethel Gorge aquifer, the groundwater level data shows that the observed drawdown in the Ethel Gorge aquifer between 2006 and 2012 was limited to a maximum of 5 m. This occurred downstream of Ophthalmia Dam and adjacent to OB23 (i.e. HEOP0425M, HEOP0415M, HRZ0048M and HRZ0005M) and reduced to less than 2 m upstream of the dam (HEOP0313M) (see Figure 1 for bore locations). Groundwater levels in the vicinity of the OB23 pit have recovered and are approaching the pre-mining groundwater levels (BHP 2021). Since 2006, when abstraction at Eastern Ridge (and the discharge of surplus water from Eastern Ridge to the dam) started, groundwater levels in the Ethel Gorge aquifer have remained within the range of groundwater levels since Ophthalmia Dam was commissioned.

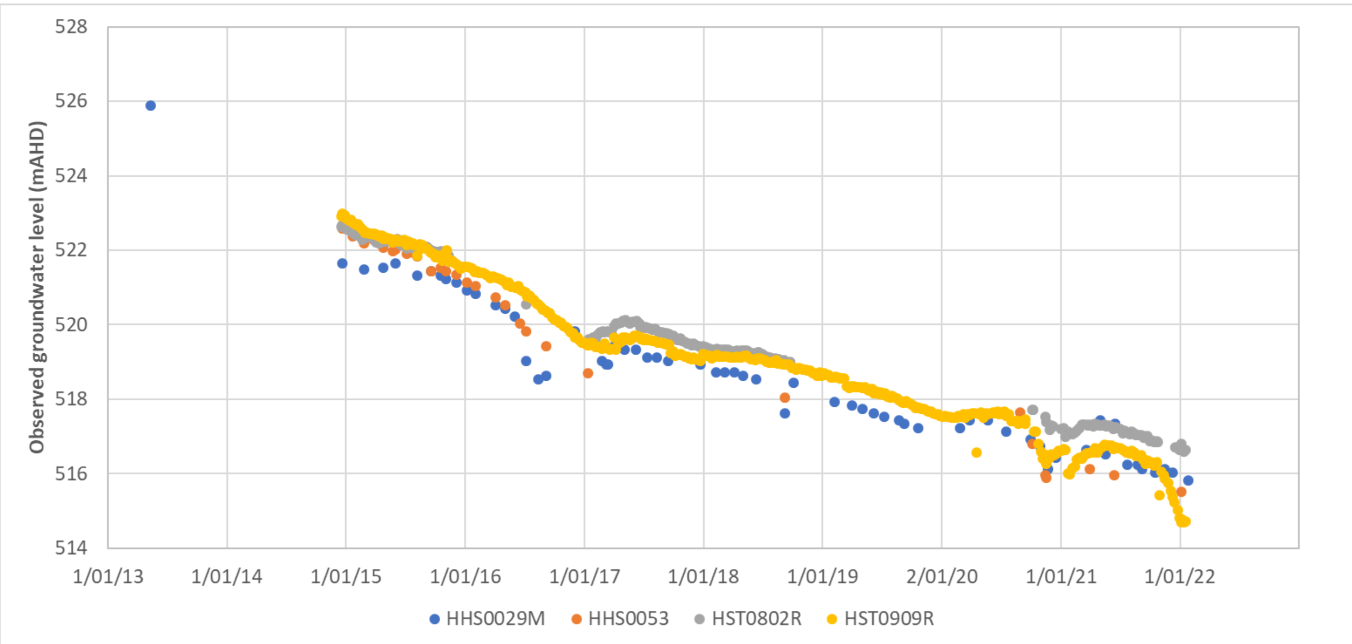
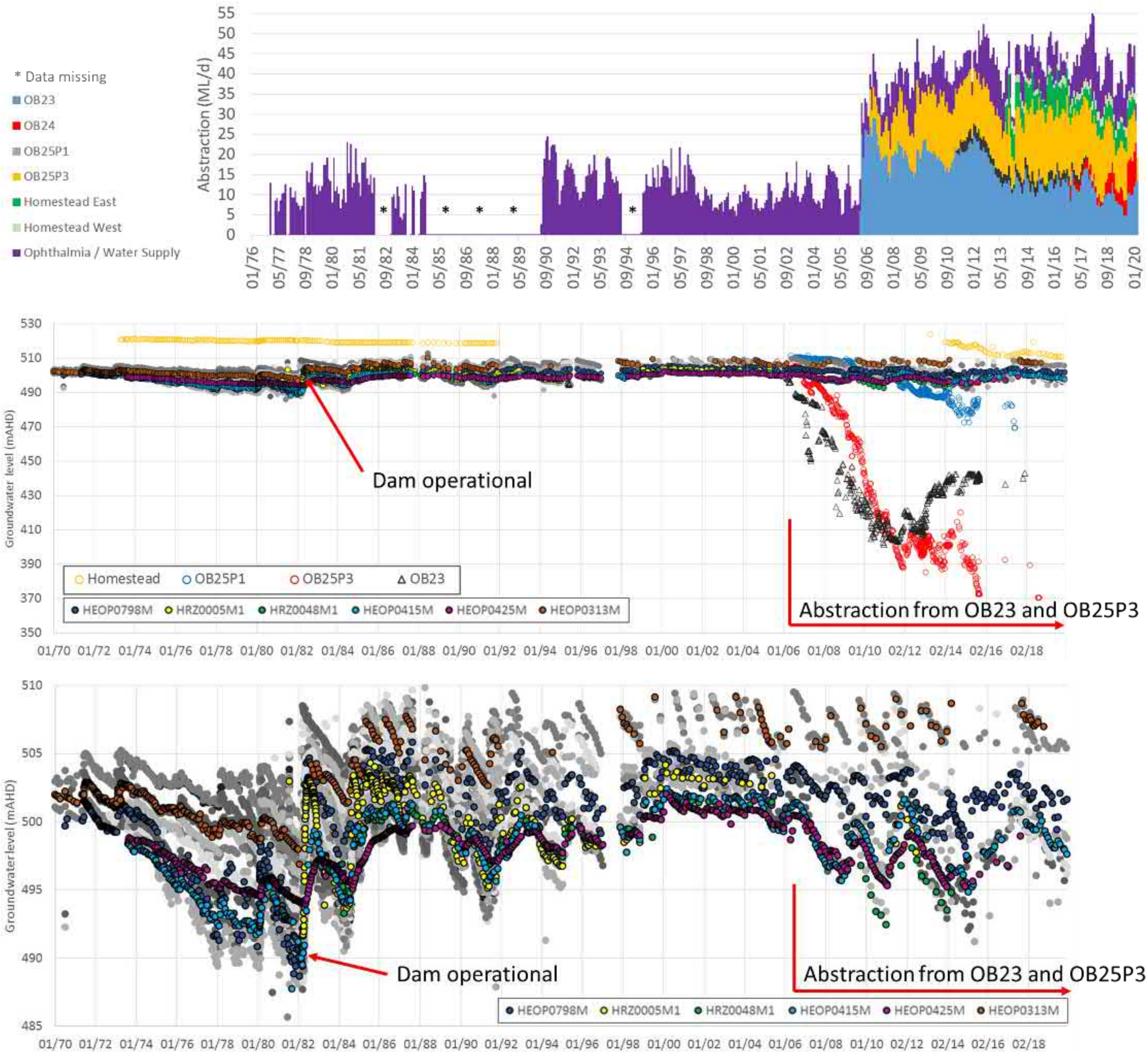


Figure 5: Observed groundwater levels in the Homestead East/ OB32E aquifer



Note: See Figure 1 for pit and bore locations

Figure 6: Dewatering rates and observed groundwater levels in the Ethel Gorge aquifer

5 Groundwater modelling

5.1 2020 Detailed hydrogeological assessment

BHP undertook the *OB32 East and OB25 West Joffre: Detailed Hydrogeological Assessment* (Appendix 1; BHP 2022b) to assess the potential impacts from groundwater abstraction at OB32E (and update predictions at OB25W), to support *Rights in Water and Irrigation 1914* (RiWI) 5C licence and EP Act Part IV approval processes. The numerical model was completed in November 2020 ('2020 model'). As discussed in Section 2, OB32E is the portion of OB32 in the proposed Development Envelope for the OB32 BWT Proposal. As the AWT operation for OB32E is referred to as OB32 in the Part IV MS1037, BHP has referred to OB32 when referring to the orebody and/or proposal and has referred to OB32E when referring to the hydrogeological conceptualisation.

The detailed hydrogeological assessment (BHP 2022b) describes the hydrogeology and conceptualisation of the OB32E area in detail. As shown in Figure 7, there are several distinct groundwater aquifer compartments in the area. The orebody, dolomite and alluvial aquifers of the Homestead East, OB32E and OB25W Joffre areas form a single, well connected, aquifer compartment (Homestead East / OB32E aquifer compartment). Analysis of long-term and recent monitoring data undertaken for the detailed hydrogeological assessment provides evidence that the Homestead East / OB32E aquifer compartment has high transmissivity and high storage. There are several aquifer systems to the north, south and west of the Homestead East / OB32E aquifer compartment. The hydraulic connection (and groundwater flow) between the compartments is variable and controlled by the following factors:

- Connection with aquifers to the north of OB32 is restricted due to the low permeability geology between OB32 and OB24 and the low permeability geology to the north of OB24 (in effect a double barrier).
- Connection with the aquifers to the west of the Homestead East / OB32E aquifer compartment is restricted due to a flow barrier (Lone Ranger Dyke).
- Connection to the OB33 aquifer compartment may be impeded by low permeability geology (Mt McRae and Mt Sylvia Formations) and the significant thickness of low permeability geology (Jeerinah Formation) directly to the south of OB32.

There is no location at which the Homestead East / OB32E aquifer and the Ethel Gorge aquifer compartments are in direct contact. There is however, evidence that groundwater flows south into the OB33 aquifer compartment from the Homestead East / OB32E aquifer compartment and then continues into the Ethel Gorge aquifer compartment. The connection between the OB33 and Ethel Gorge aquifer compartments is constrained by a flow barrier (Whaleback Fault (BHP 2022b)).

The 2020 model was run for 27 years from Financial Year (FY) 2022 to FY2049 to:

- predict the likely dewatering rates required to achieve the OB32E and OB25W Joffre target water levels (lowering groundwater levels by 200 m, to allow dry mining)
- predict the vertical and lateral extent of drawdown as a result of the dewatering
- provide a high level understanding of potential groundwater level recovery times post mining.

As the Ethel Gorge aquifer and Ophthalmia Dam are outside of the model domain, the groundwater modelling did not consider the increase in groundwater levels through MAR from the Ophthalmia Dam system. Changes to groundwater levels from the Ophthalmia Dam MAR scheme were modelled separately as part of the Eastern Pilbara Hub water balance model review (EMM 2020) (BHP 2022a). However, the groundwater model was used to predict the changes to groundwater flow between the Homestead East / OB32E aquifer and the Ethel Gorge aquifer compartments during OB32 dewatering and after dewatering ceases (post-mining), to estimate the groundwater level change in the Ethel Gorge aquifer (see Section 6).

5.2 Numerical model review

Since the 2020 detailed hydrogeological assessment was undertaken, the numerical model was updated to support the OB24 5C licence amendment in February 2022 ('2022 model'). Major changes were made to the model to incorporate the OB24 orebody aquifer and calibrate the model to OB24 groundwater level data. A more detailed description of the 2022 model is in *Eastern Ridge – OB24 Hydrogeological Assessment* (BHP 2022c).

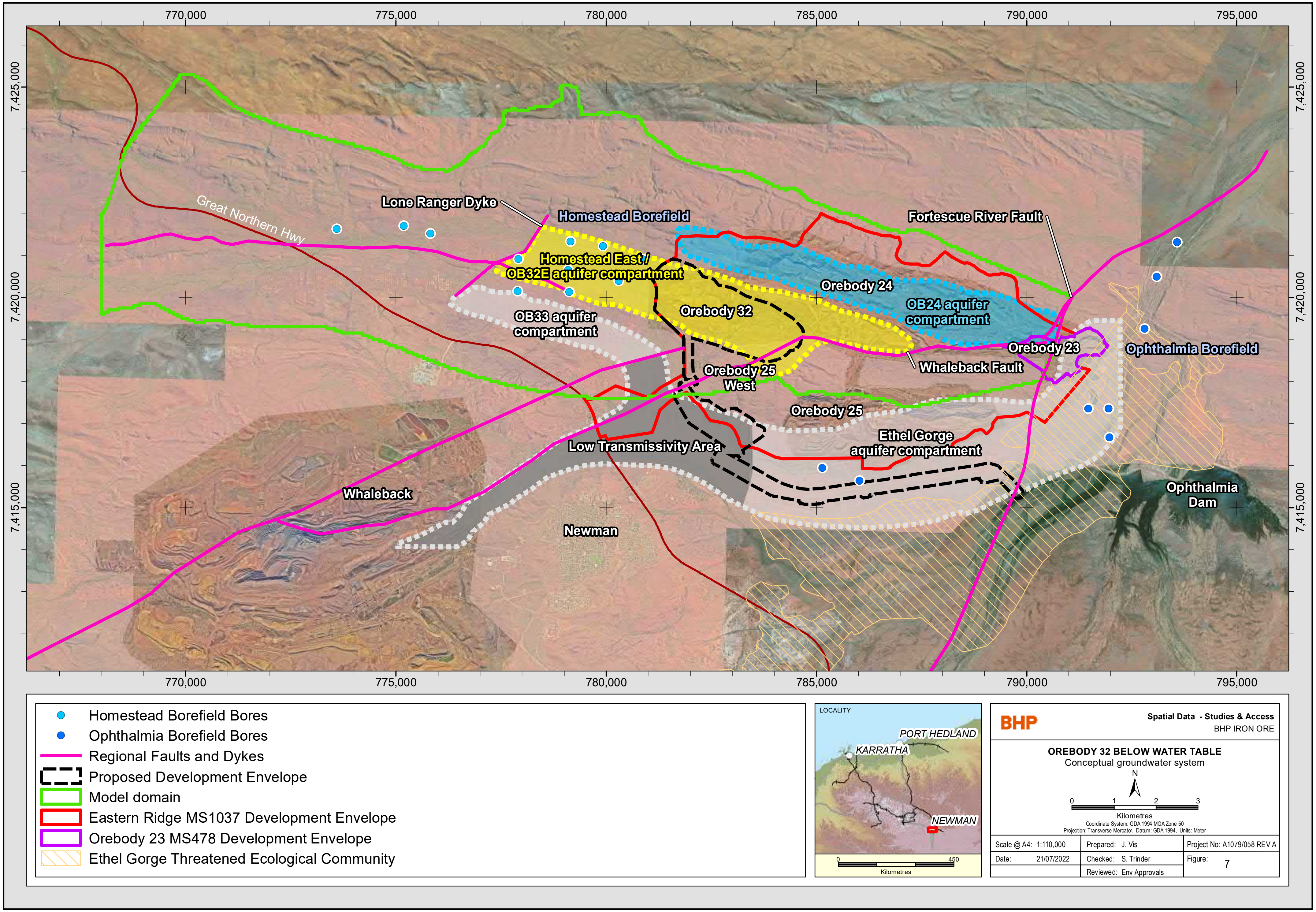
5.3 2022 Modelling update

The *Technical Memorandum: OB32E groundwater modelling update* (Appendix 2; BHP 2022d) provides a summary of the 2022 model update and calibration.

The following changes were made to the 2020 model:

- The numerical model domain was extended to the east to incorporate the full aquifer compartment associated with OB24 (Figure 7).
- The geology was updated based on latest mining, geological and resource models. This included delineating the very low permeability Mt McRae / Sylvia Formations between the OB24 orebody aquifer and the regional dolomite to the south (which is hydraulically connected to the OB32E orebody) and extending the low permeability Lone Ranger dyke to the northeast and southwest.
- Homestead Borefield abstraction was extended to October 2021 and abstraction for OB24 dewatering was included.
- The storage (Specific Yield) was increased and the hydraulic conductivity was decreased in the regional dolomite and OB32E orebody aquifer, to rectify the over-prediction of observed drawdown in the OB32 / Homestead East area from the geological changes and improve the calibration.

As major changes were made to the numerical model, the 2020 predictions were reviewed. The 2022 model was run to update the predicted dewatering rates and drawdown extent produced from the 2020 model.



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5.4 Predicted abstraction rates and drawdown

Figure 8 shows the predicted dewatering rates from the 2022 and 2020 models for the calibrated and uncertainty runs. The results show that the calibration runs are similar; however, the uncertainty run which represents the highest dewatering rate is higher for the 2022 model compared to the 2020 model. The 2022 model predicted that a peak dewatering rate at OB32 of between 52.9 ML/d and 70.4 ML/d would be required. To be conservative, BHP has assumed that a peak dewatering rate of up to 70.4 ML/d (equivalent to 25.7 GL/a) will be required and has evaluated the potential impact of dewatering based on the 2022 uncertainty run.

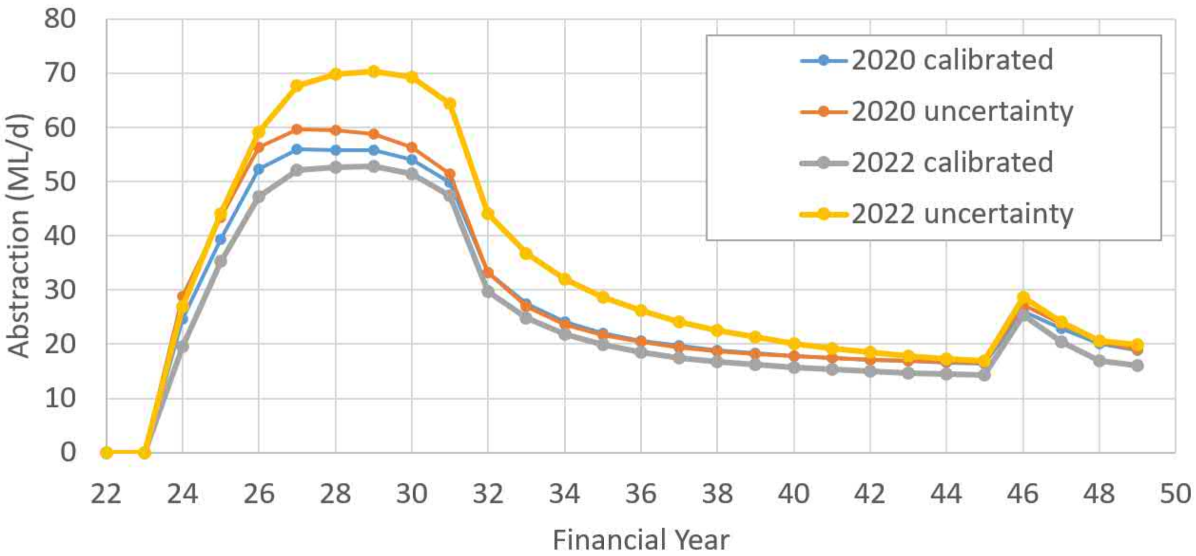
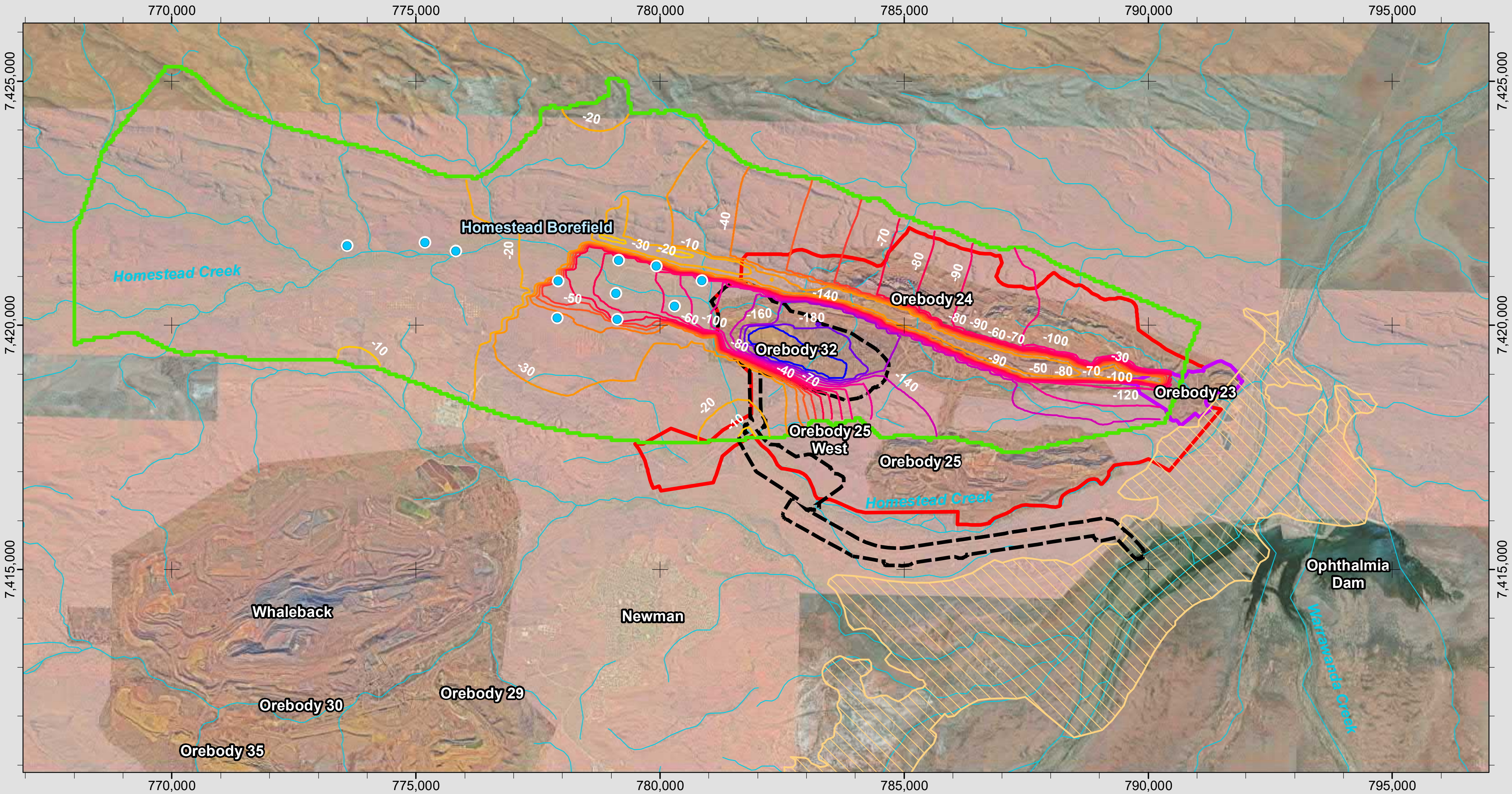


Figure 8: Predicted dewatering rates

BHP estimates that groundwater levels would need to be lowered by up to 200 m at OB32 (BHP 2022b). Figure 9 shows the predicted drawdown in FY49 from the 2022 model uncertainty run to achieve this target groundwater level. The model predicts that OB32 dewatering results in a maximum vertical drawdown of up to approximately 100 m at the northern boundary of the model domain, 140 m at the south-eastern boundary, 20 m at the southern boundary and 10 - 20 m at the western boundary.

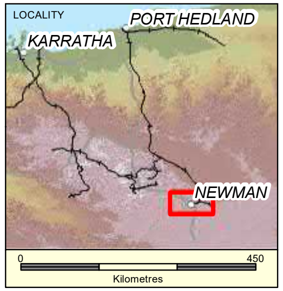
The predicted depth of drawdown from the OB32 BWT Proposal is greater than the predicted drawdown from approved BHP activities (water supply and dewatering abstraction) assessed for the approved Eastern Ridge proposals (BHP Billiton 2015). The Homestead Borefield is adjacent (to the west) of the OB32 BWT Proposal and the Homestead East bores are located within the Homestead East / OB32E aquifer compartment. Therefore, the increased drawdown depth in the Homestead East / OB32E aquifer compartment may impact water availability at bores within the Homestead Borefield. However, the migration of drawdown beyond the Homestead East / OB32E aquifer compartment will be restricted due to the low permeability geology north of OB24, the Lone Ranger dyke to the west, and the Whaleback Fault and low permeability of the Jeerinah Formation to the south. Changes to groundwater levels to the east (in the Ethel Gorge aquifer compartment) are discussed in Section 6.



Proposed Development Envelope
Watercourse
Homestead Borefield Bores
Model domain
Eastern Ridge MS1037 Development Envelope
Orebody 23 MS478 Development Envelope
Ethel Gorge Threatened Ecological Community

Predicted drawdown (m)

-200, -180, -160, -140, -120, -100, -90, -80, -70, -60, -50, -40, -30, -20, -10



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Spatial Data - Studies Planning & Access
BHP IRON ORE

OREBODY 32 BELOW WATER TABLE
Predicted OB32 groundwater drawdown

N
0 1 2 3
Kilometres

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator, Datum: GDA 1994, Units: Meter

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5.5 Post-mining groundwater level recovery

The recovery of post-mining groundwater levels was considered for both backfill (i.e. above pre-development groundwater level) and partial or no-backfill (i.e. void) scenarios. The 2020 model was used for the post-mining analysis as the model settings relating to closure (rainfall recharge and inflow to the Ethel Gorge aquifer compartment) were not changed in the 2022 model (BHP 2022d).

5.5.1 Backfill above pre-development water level

The 2020 model predicted that for the backfill scenario groundwater levels would return to pre-development (i.e. prior to dewatering at OB32) levels within 50 to 200 years post-mining. The main uncertainty is the level of hydraulic connection between the Homestead East / OB32E aquifer and the Ethel Gorge aquifer compartments (i.e. better connection results in quicker water level recovery). A fully backfilled OB32 pit is not expected to result in any permanent changes in groundwater levels in the Ethel Gorge aquifer (BHP 2022b).

5.5.2 Partial / no backfill

The response of the groundwater system for the scenario if a permanent void remains at OB32 is more difficult to predict as it incorporates many more variables and uncertainties. The main controlling variables are discussed in the detailed hydrogeological assessment (BHP 2022b). If a permanent pit void remains at OB32 when mining and dewatering ceases, and there is enough groundwater inflow from the surrounding area, then a pit lake will form. The water level in the pit void will correspond to the level where evaporation and groundwater inflow / rainfall runoff balance. An approach was adopted that combined simple pit lake evaporation potential and direct rainfall recharge estimates with numerical model estimates of regional groundwater levels and flows (BHP 2022b).

This water balance approach indicates that a pit lake will form after dewatering ceases, with a final elevation at equilibrium between 470 and 480 mAHD. This is lower than the pre-development groundwater level at OB32 prior to abstraction from the Homestead Borefield (526 mAHD) and in the Ethel Gorge aquifer (500 mAHD). Because the final water level in the pit is predicted to be lower than the surrounding groundwater level, the pit lake will be a sink, where groundwater will flow into the pit lake (Figure 10). Therefore, there is little potential for lower quality (i.e. saline) water to travel away from the pit lake towards the Ethel Gorge aquifer. The regional flow will always be from the direction of Ethel Gorge to the pit void, and any local flow reversals will be temporary. The numerical modelling suggested that the full backfill scenario would take between 50 to 200 years for groundwater levels to recover. It follows then that the water level in the pit void would take a similar time to reach equilibrium.

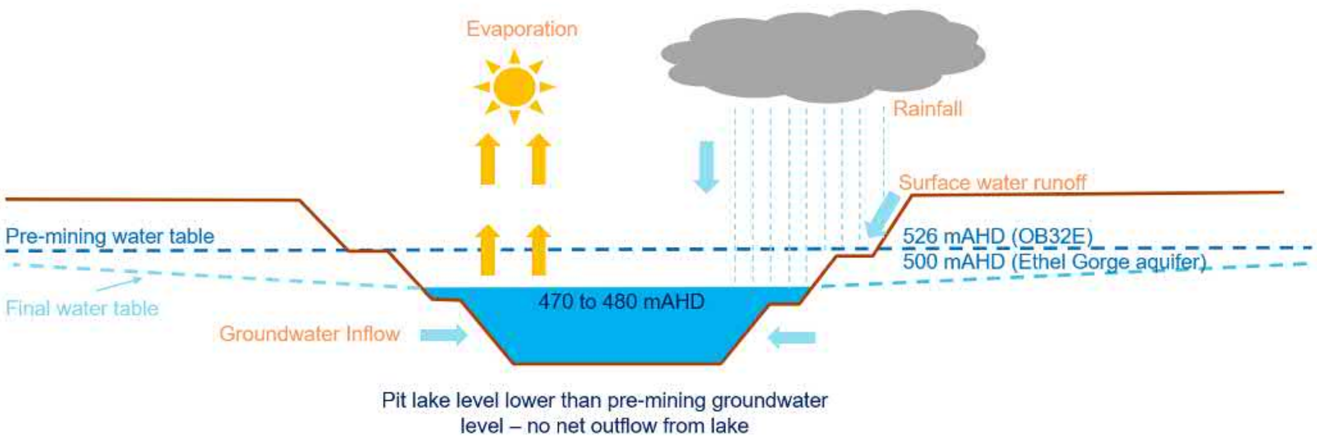


Figure 10: Conceptual pit lake diagram - sink

6 Change assessment

The results from the 2020 and 2022 numerical modelling (BHP 2022b and 2022d), the conceptual model of the groundwater system and observed data were used to assess the change in groundwater flows and groundwater levels in the Ethel Gorge aquifer. To understand the cumulative drawdown extent, BHP considered the predicted drawdown from OB32 (see Section 5.4) in the context of other approved activities in the Newman Hub.

6.1 Change in groundwater flows and groundwater levels

The Ethel Gorge aquifer compartment is outside of the numerical model domain. The groundwater model does however, predict the change in flow that will occur between the Homestead East / OB32E aquifer and the Ethel Gorge aquifer compartments in response to OB32 dewatering and post-mining (partial / no backfill scenario). This information was used with historical groundwater level observations of the response of the Ethel Gorge aquifer compartment to water supply abstraction (Ophthalmia Borefield) and dewatering (OB23 and OB25 Pit 3) to estimate the effects that the predicted changes in flow will have on groundwater levels in the Ethel Gorge aquifer compartment.

Specifically, the numerical groundwater model predicts that:

- Pre-development (i.e. prior to groundwater abstraction for water supply, mine dewatering and surplus water discharge to Ophthalmia Dam), groundwater flow towards the Ethel Gorge aquifer compartment (via the OB33 aquifer compartment) from the Homestead East / OB32E aquifer compartment was approximately 2 ML/d.
- The groundwater flow direction will reverse in response to OB32 dewatering (i.e. there will be groundwater flow into the Homestead East / OB32E aquifer compartment from the Ethel Gorge aquifer compartment). At its peak, the groundwater flow is predicted to be between 0 and 15 ML/d. This means that the net loss of groundwater flow to the Ethel Gorge aquifer compartment would be 2 to 17 ML/d (including the loss of groundwater flow that pre-development was towards the Ethel Gorge aquifer compartment (2 ML/d)). The wide range in the prediction is due to the uncertainty in the hydraulic parameters, and the length of the flow path from OB32 to the Ethel Gorge aquifer compartment.
- Post-mining after dewatering ceases, if the OB32 pit is left as a void, this reversal in groundwater flow direction is likely to remain. However, the groundwater flow from the Ethel Gorge aquifer compartment will reduce to approximately 3.5 ML/d (a net loss of 5.5 ML/d including the loss of groundwater flow that pre-development was towards the Ethel Gorge aquifer compartment).

To estimate what these changes in groundwater flow will have on the groundwater levels in the Ethel Gorge aquifer compartment, the following historical datasets of groundwater levels were used:

- Pre-development data (1970 to 1972) was used to understand the groundwater flow directions prior to OB32 dewatering.
- Data between June 2006 and December 2012 in the Eastern Ridge area was used to estimate the change during OB32 dewatering (Figure 11).
- Data between 1996 and 2006 from the Ophthalmia Borefield (i.e prior to dewatering at Eastern Ridge) was used to estimate the change post-mining after OB32 dewatering ceases, if OB32 is left as a pit void (Figure 11).

Pre-development

Figure 12 shows the direction of groundwater flows before large-scale water management in the catchment started (i.e. prior to groundwater abstraction for water supply, mine dewatering and surplus water discharge to Ophthalmia Dam (‘pre-development’)). Groundwater in the Ethel Gorge aquifer compartment was recharged by rainfall and inflow from upstream aquifer compartments (OB29/30/35, OB33 and aquifers to the east of the Ethel Gorge aquifer compartment). From the Homestead East / OB32E aquifer compartment groundwater flow was predominantly in the south and southeast direction, and therefore towards the Ethel Gorge aquifer compartment. The total flow out of the OB33 aquifer compartment into the Ethel Gorge aquifer compartment was predicted to be approximately 2 ML/d (Figure 12).

Proposed OB32 dewatering

The period between June 2006 and December 2012 corresponds to the maximum average rate of dewatering from both OB23 (20 ML/d) and OB25 Pit 3 (12 ML/d), in addition to abstraction from the Ophthalmia Borefield (8 ML/d). As all these operations are within the Ethel Gorge aquifer compartment, this abstraction resulted in flow directly out of the Ethel Gorge aquifer. Operational data suggests that at least 75% of the dewatering volumes from OB23 and OB25 Pit 3 (compared to orebody storage) and 100% of the Ophthalmia Borefield abstraction came from the Ethel Gorge aquifer compartment. Therefore, as shown on Figure 13, between June 2006 and December 2012, at least 32 ML/d was estimated to flow out of the Ethel Gorge aquifer compartment due to groundwater abstraction, comprising:

- 15 ML/d from OB23 dewatering (representing 75% of the total from this orebody)
- 9 ML/d from OB25 Pit 3 dewatering (representing 75% of the total from this orebody)
- 8 ML/d from Ophthalmia Borefield abstraction (representing 100% of the total).

During this time, groundwater levels in the Ethel Gorge aquifer compartment stabilised at between approximately 492 and 502 mAHD (Figure 11). As discussed in Section 4, despite the high rates of abstraction during this period, groundwater levels in the Ethel Gorge aquifer remained within historical levels, due to the infiltration of water from the Ophthalmia Dam system into the Ethel Gorge aquifer.

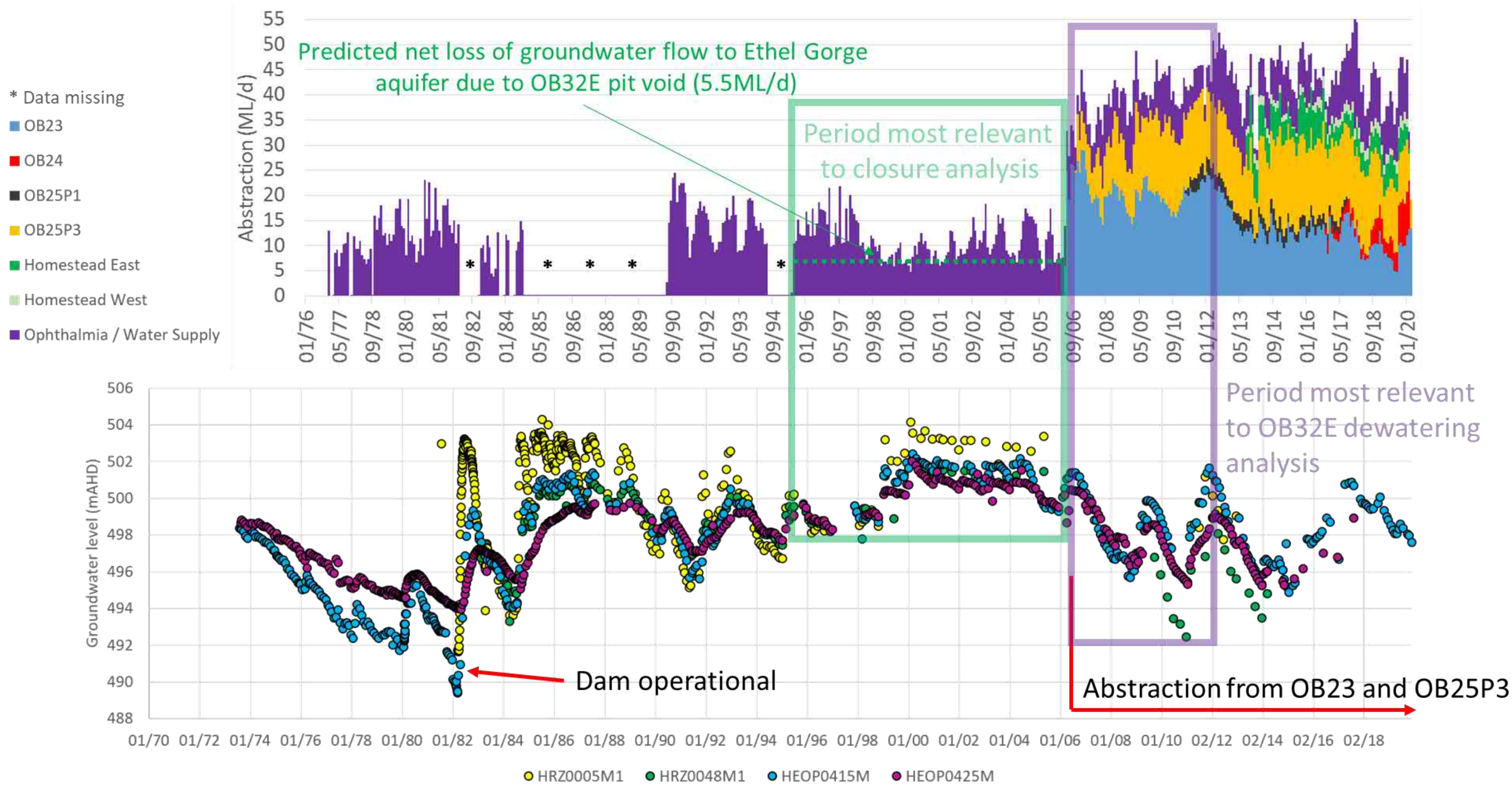
At its peak, the groundwater flow out of the Ethel Gorge aquifer compartment is predicted to be between 0 and 15 ML/d due to OB32 dewatering, i.e the predicted net loss of groundwater flow to the Ethel Gorge aquifer compartment is 2 to 17 ML/d (Figure 14). Even at the highest point of this range, the historical dewatering between 2006 and 2012 was almost double this value (32 ML/d). Therefore, with the continued operation of Ophthalmia Dam, groundwater levels in the Ethel Gorge aquifer are predicted to remain within historical levels during dewatering of OB32, and most likely towards the upper part of the 492 to 502 mAHD range.

Post-mining: OB32 pit lake

The Ophthalmia Borefield was the only abstraction operation that was active between 1996 and 2006. During this period the average abstraction was 11 ML/d, and, as this abstraction was from the Ophthalmia Borefield, 100% of this groundwater came from the Ethel Gorge aquifer compartment. During this period, Ethel Gorge aquifer groundwater levels were stable at around 498 to 504 mAHD (Figure 11). This period can therefore be used to predict with confidence the changes that a pit void at OB32E will have on the Ethel Gorge aquifer compartment groundwater levels (with continued operation of Ophthalmia Dam).

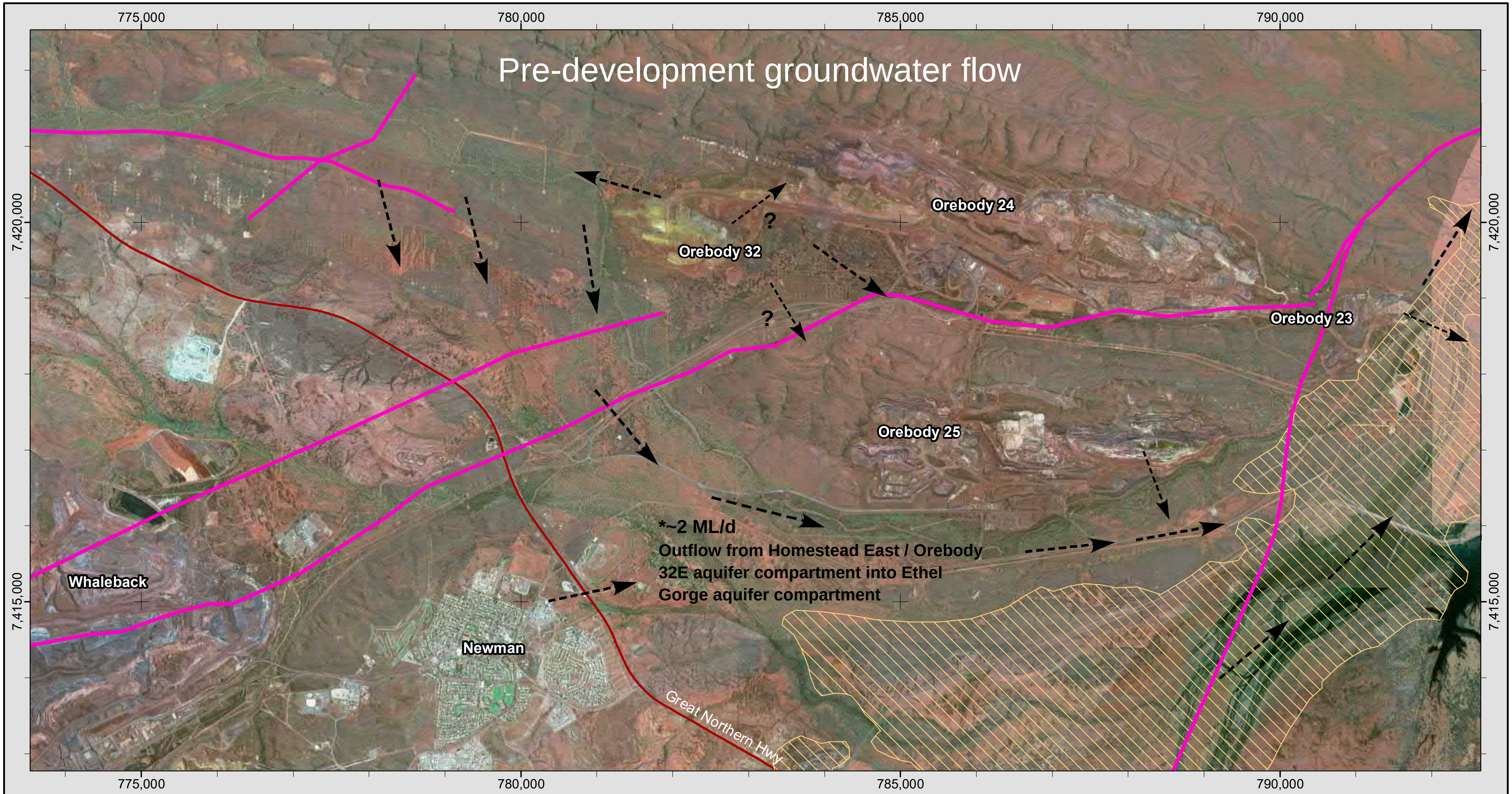
As discussed in Section 5.5.2, post-mining of OB32 BWT, a pit lake is predicted to form if the OB32 pit remains as a void and the pit lake will be a sink (i.e. groundwater will flow into the pit lake). The post-mining analysis (BHP 2022b) indicates that approximately 3.5 ML/d of groundwater will flow from the Ethel Gorge aquifer compartment to the OB32 pit lake in response to evapo-transpiration from the pit lake (Figure 15).

The predicted net loss of groundwater flow to the Ethel Gorge aquifer compartment due to the OB32 pit void is 5.5 ML/d. The historical abstraction from the Ophthalmia Borefield between 1996 and 2006 was double this value (11 ML/d). Therefore, with the continued operation of the Ophthalmia Dam system, this indicates that groundwater levels in the Ethel Gorge aquifer will stabilise within the upper part of the range of 498 to 504 mAHD.



Note: See Figure 1 for pit and bore locations

Figure 11: Historical groundwater level analysis



Regional Faults and Dykes

Ethel Gorge Threatened Ecological Community

Groundwater flow direction

? Uncertainty in groundwater flow direction

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OREBODY 32 BELOW WATER TABLE

Pre-development groundwater flow

N

0 1 2 3

Kilometres

Coordinate System: GDA 1994 MGA Zone 50

Projection: Transverse Mercator, Datum: GDA 1994, Units: Meter

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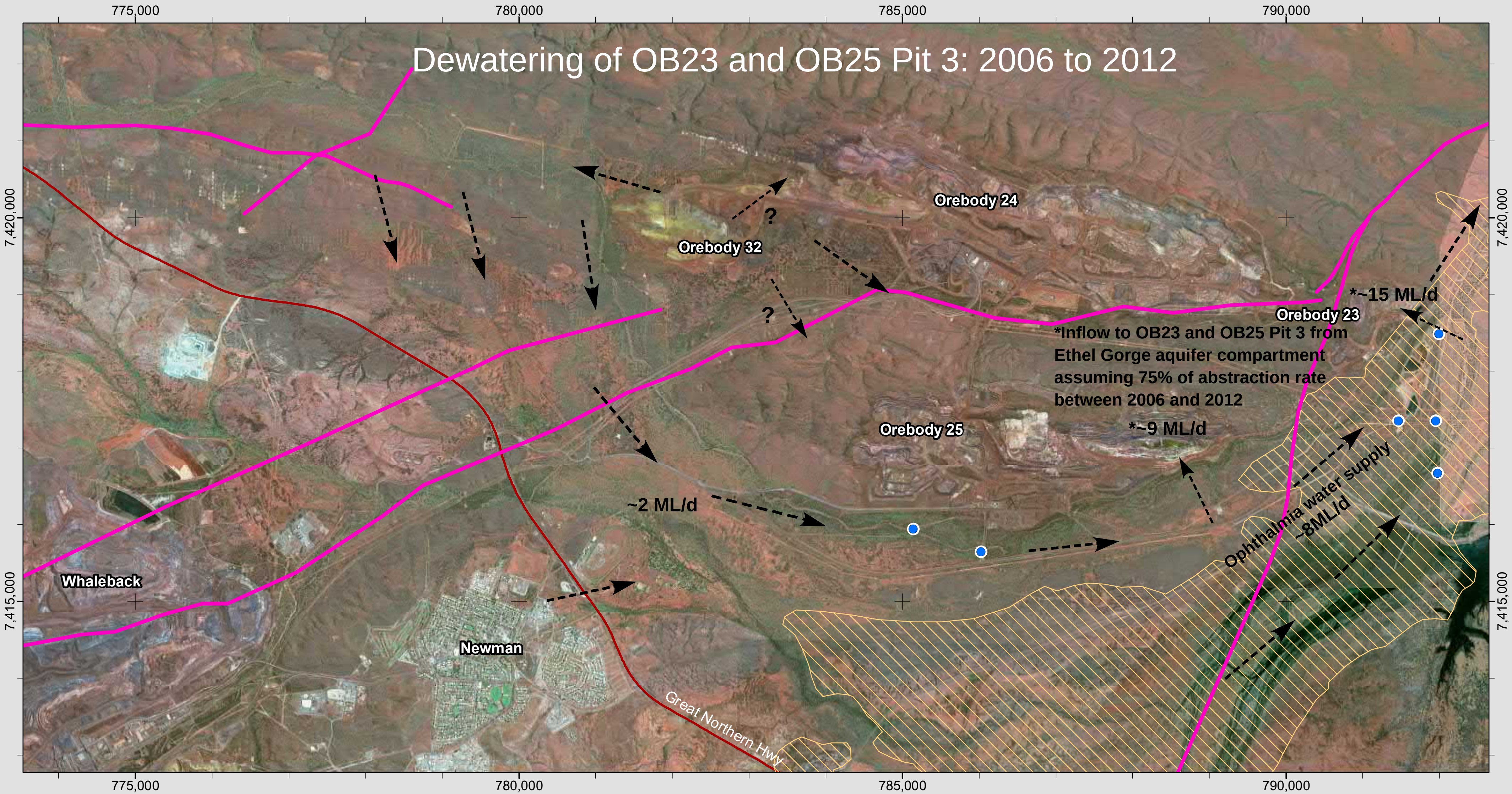
	Reviewed:	



- Ophthalmia Borefield Bores
- Regional Faults and Dykes
- Ethel Gorge Threatened Ecological Community
- Groundwater flow direction
- ? Uncertainty in groundwater flow direction

Environment Approvals
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OREBODY 32 BELOW WATER TABLE

Dewatering of OB23 and OB25 Pit 3: 2006 - 2012

N

0 1 2 3
Kilometres

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator, Datum: GDA 1994, Units: Meter

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Date: 24/06/2022	Checked:	Figure: 13
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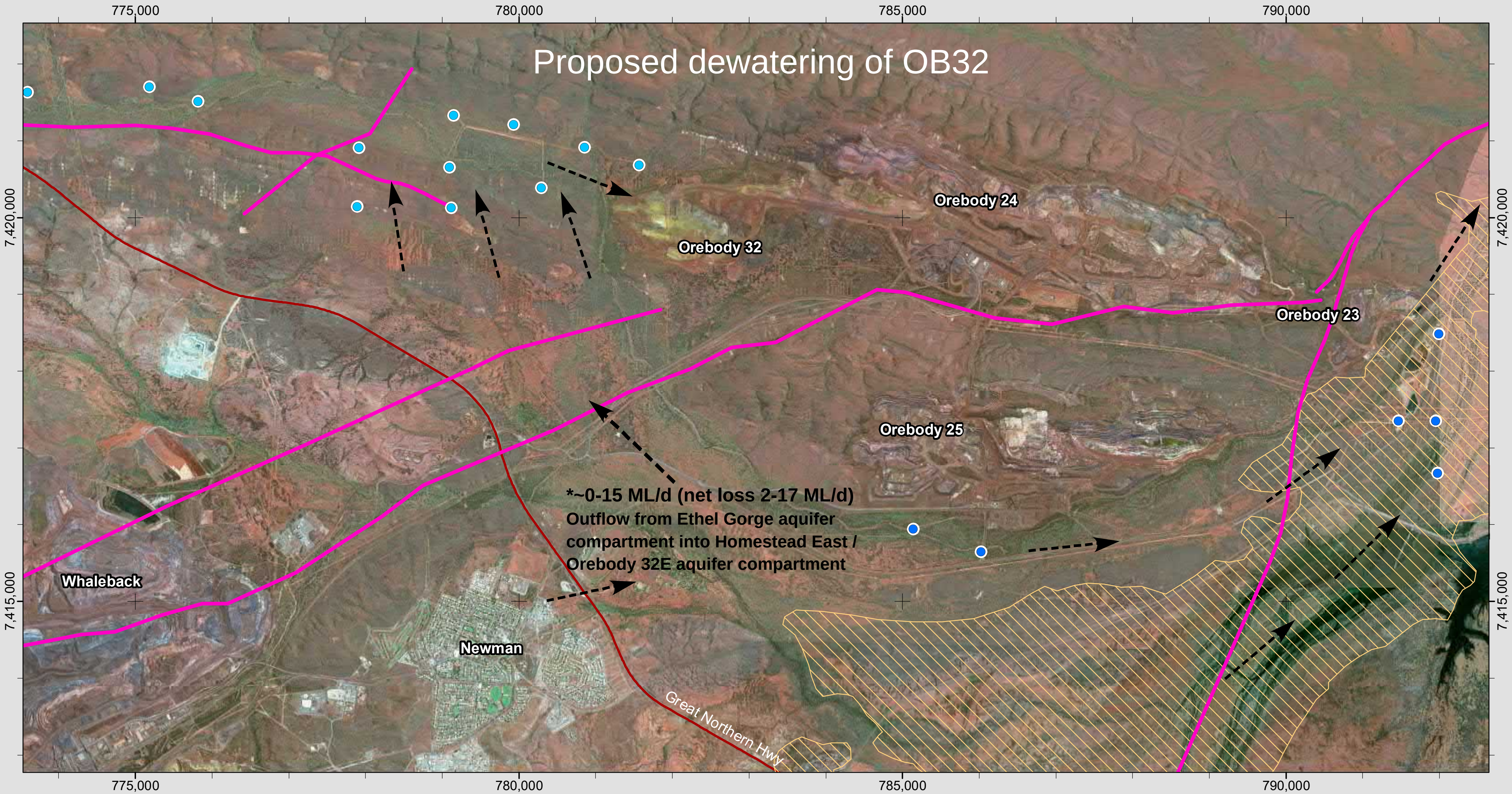

Homestead Borefield Bores
Ophthalmia Borefield Bores
Regional Faults and Dykes
Ethel Gorge Threatened Ecological Community
Groundwater flow direction
? Uncertainty in groundwater flow direction

BHP

Environment Approvals
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OREBODY 32 BELOW WATER TABLE

Proposed dewatering of OB32

N

0 1 2 3
Kilometres

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator, Datum: GDA 1994, Units: Meter

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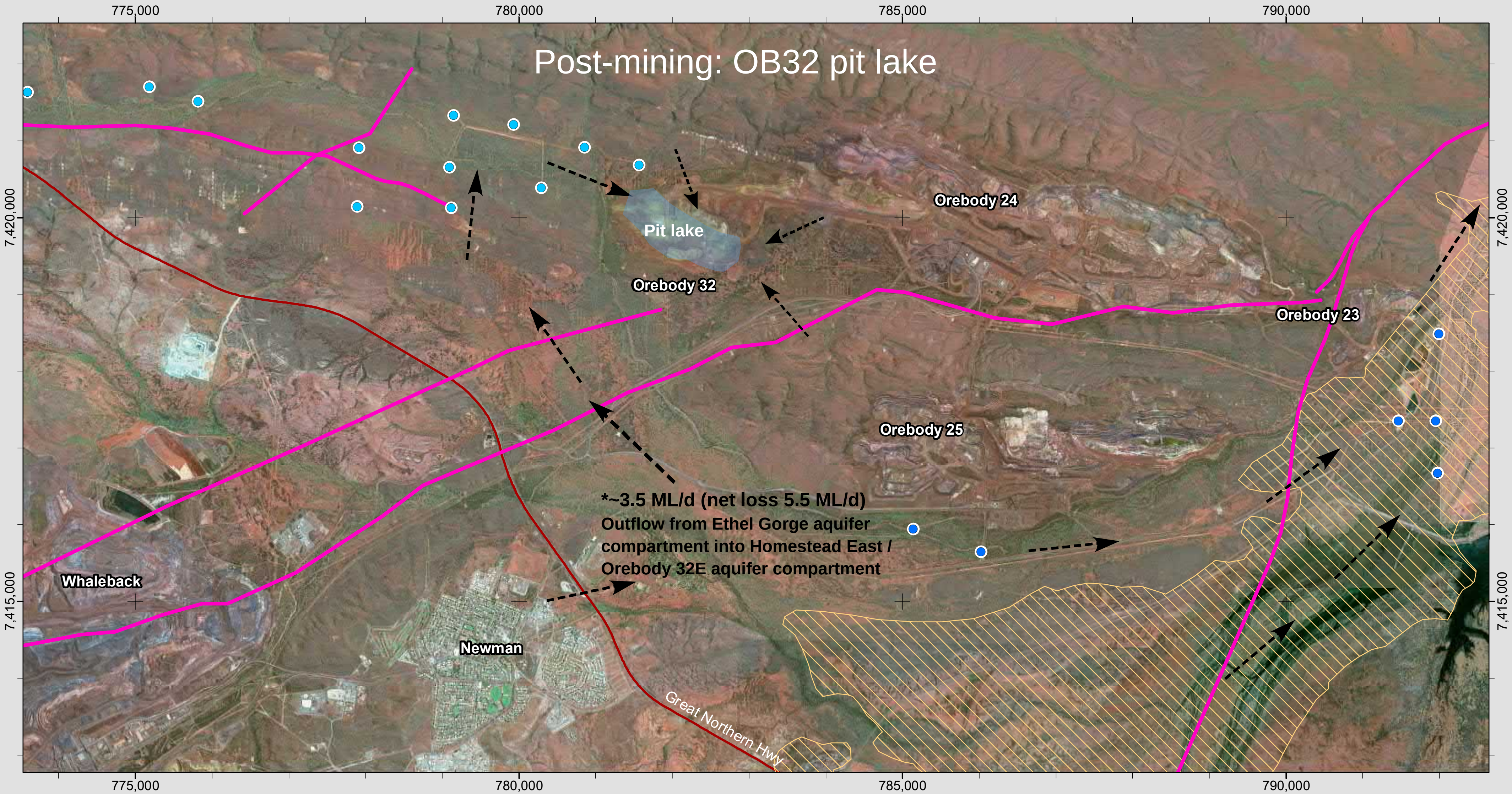
	Reviewed:	



- Homestead Borefield Bores
- Ophthalmia Borefield Bores
- Regional Faults and Dykes
- Ethel Gorge Threatened Ecological Community
- Groundwater flow direction
- ? Uncertainty in groundwater flow direction

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OREBODY 32 BELOW WATER TABLE

Post-mining: OB32 pit lake

N

0 1 2 3
Kilometres
Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator, Datum: GDA 1994, Units: Meter

Scale @ A4: 1:70,000	Prepared: Env. Approvals	Project No:
Date: 24/06/2022	Checked:	Figure: 15
	Reviewed:	

6.2 Cumulative drawdown

As discussed in Section 2, OB32 is located in the Newman Hub where there are existing approved groundwater abstraction activities (for water supply from the Ophthalmia and Homestead borefields and for mine dewatering at Mt Whaleback, OB29/30/35 and Eastern Ridge) and the Ophthalmia Dam MAR system. To understand the cumulative drawdown extent, BHP has considered the predicted drawdown from OB32 in the context of other approved activities in the Newman Hub. Figure 16 shows the following:

- 2015 Eastern Ridge 2 m Drawdown Contour - represents the extent of the assessed and approved drawdown impacts of the Eastern Ridge mining operation (and surplus water management at Ophthalmia Dam) (BHP Billiton 2015b)
- 2013 OB29/30/35 1 m Drawdown Contour - represents the assessed and approved drawdown extent of the OB29/30/35 mine
- 2022 Cumulative Eastern Ridge 2 m Drawdown Contour - represents the estimated maximum lateral extent of the cumulative effect of assessed and approved drawdown impacts at Eastern Ridge and predicted drawdown from OB32 dewatering
- 2022 Additional OB32 Drawdown Extent - represents the predicted drawdown extent of the OB32 BWT Proposal above the assessed and approved drawdown at Eastern Ridge and OB29/30/35.

Other than to the west, the predictions of cumulative drawdown (i.e. considering predicted drawdown from the Eastern Ridge and OB29/30/35 mines and surplus water management at Ophthalmia Dam) from 2015 and 2022 are similar because:

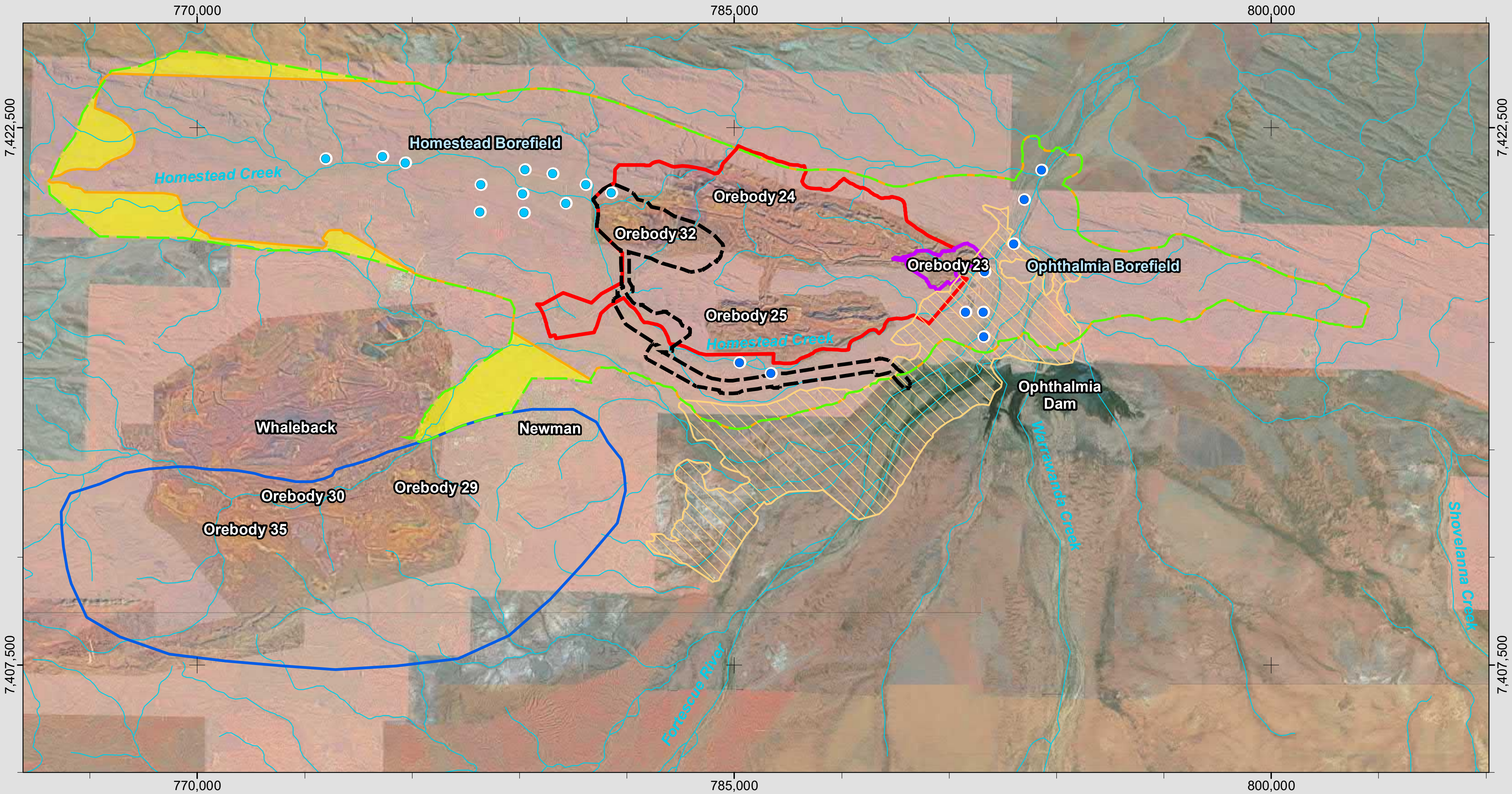
- in both cases, migration of drawdown is restricted south, north and east of the Homestead East / OB32E aquifer compartment due to the presence of structural flow barriers (see Figure 7)
- in both cases, drawdown north of OB24 will be limited by the lower permeability geology surrounding OB24
- as discussed in Section 6.1, even though the dewatering at OB32 is deeper than predicted in 2015, the groundwater level change within the Ethel Gorge aquifer compartment is comparable or less than already encountered during OB23 and OB25 Pit 3 dewatering.

In the west and southwest, the cumulative drawdown predicted by the 2022 model extends further than the 2015 model because:

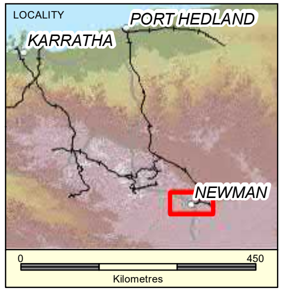
- in the 2022 model, to the west (in the western area of the Homestead Borefield) the additional drawdown from OB32 dewatering has migrated to reach the model boundaries (based on the position of known flow barriers) in this area, whereas in the 2015 model it did not
- to the southwest, the 2022 model assumes that drawdown of up to 2 m will migrate within the low transmissivity Ethel Gorge aquifer compartment towards the OB29/30/35 aquifer compartment; however, the drawdown will not extend beyond the western end of the Ethel Gorge aquifer compartment (shown on Figure 7).

The lateral drawdown extent as a result of dewatering for the OB32 BWT Proposal is predicted to increase by 8.8% compared to the assessed and approved drawdown (2022 Additional OB32 Drawdown Extent shown on Figure 16).

The level of confidence in the drawdown prediction, particularly in the area of the Ethel Gorge aquifer (and TEC), is high based on the observations to date, which are consistent with the predictions from the 2015 Eastern Ridge modelling, both in magnitude and timing of drawdown. There will be no impacts to the Ethel Gorge TEC from the proposed change, as predictions indicate that there will be no increase to the depth and extent of drawdown in the Ethel Gorge aquifer. The conceptual model suggests a limited and tortuous connectivity between OB32 and the Ophthalmia Borefield. Any potential impact to the Ophthalmia Borefield is anticipated to be mitigated by the Ophthalmia Dam MAR scheme (as for the Ethel Gorge aquifer (and TEC)).



Proposed Development Envelope
Watercourse
2013 Orebody 29/30/35 1 m Drawdown Contour
2015 Eastern Ridge Iron Ore Revised Proposal 2 m Drawdown Contour
2022 Cumulative Eastern Ridge 2 m Drawdown Contour
2022 Additional OB32 Drawdown Extent
Homestead Borefield Bores
Ophthalmia Borefield Bores
Eastern Ridge MS1037 Development Envelope
Orebody 23 MS478 Development Envelope
Ethel Gorge Threatened Ecological Community



BHP

Spatial Data - Studies Planning & Access
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OREBODY 32 BELOW WATER TABLE
OB32 and cumulative groundwater drawdown extent

N
0 1 2 3
Kilometres
Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator, Datum: GDA 1994, Units: Meter

Scale @ A4: 1:150,000	Prepared: J.VIS	Project No: A1079/060 Rev A
Date: 12/07/2022	Checked: S.TRINDER	Figure: 16
	Reviewed: ENVIRO A&I.	

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7 References

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Appendices

Appendix 1 OB32 East and OB25 West Joffre: Detailed Hydrogeological Assessment

Appendix 2 Technical Memorandum: Orebody 32 East 2022 groundwater modelling update

Separate documents