7.7 Fauna

7.7.1 Terrestrial Vertebrate Fauna

To date, 11 vertebrate fauna surveys have been carried out over various areas of the Eastern Ridge mining operations. A total of 322 terrestrial vertebrate fauna species, comprising eight amphibian species, 94 reptile species, 172 bird species and 48 mammal species (including 12 introduced) have been recorded within the vicinity of the mining operations (Aston, 2015). Twenty-four species of conservation significant fauna were identified as potentially occurring within the Eastern Ridge mining operations, of which five have been recorded (Figure 11). These species include:

- Pilbara Olive Python (*Liasis olivaceus barroni*) (EPBC Act Vulnerable; WC Act Schedule 3);
- Peregrine Falcon (*Falco peregrinus*) (WC Act Schedule 7);
- Rainbow Bee-eater (*Merops ornatus*) (EPBC Act Migratory; WC Act Schedule 5);
- Ghost Bat (*Macroderma gigas*) (WC Act Schedule 3; DPaW Priority 4); and
- Western Pebble-mound Mouse (*Pseudomys chapmani*) (DPaW Priority 4).

Twelve introduced vertebrate fauna species have been recorded in the vicinity of the Eastern Ridge mining operations (Astron, 2015).

Eight fauna habitats and their importance to fauna were mapped within the Eastern Ridge mining operations (Astron, 2015), including:

- Gorge/Gully (high);
- Hill Crest/Slope (moderate);
- Stony Plain (low);
- Sand Plain (high);
- Mulga (moderate);
- Drainage Area (moderate);
- Major Drainage Line (high); and
- Minor Drainage Line (high).

The habitats ranked as ‘high’ support or provide core habitat for a number of conservation significant and locally significant fauna. All habitats ranked as ‘high’ also occur outside the Eastern Ridge mining operations (Biologic 2014a).

7.7.2 Conservation significant fauna

The Eastern Ridge mining operations is considered to have negligible potential impacts to the Peregrine Falcon, Rainbow Bee-eater, Ghost Bat and Western Pebble-mound Mouse. The Peregrine Falcon and Rainbow Bee-eater are both highly mobile species and widespread throughout the Pilbara. No suitable day roosts for the Ghost Bat have been identified from within the mining operations. With only one potential feeding roost identified from within the mining area the Ghost Bat may forage in the area however it is not expected to roost (Astron, 2015). The Western Pebble-mound Mouse and its preferred habitat are well represented throughout the Pilbara. Suitable habitat for all four species occurs adjacent to and beyond the mining operations.

The Pilbara Olive Python has the potential to be impacted by the Eastern Ridge mining operations. At the Eastern Ridge mining operations, the Pilbara Olive Python has been recorded at semi-permanent waterholes from within the minor drainage line habitats, particularly around the northern edge of Orebody 24 and from within Orebody 25 West (Biologic, 2014a). This population may be considered an ‘important population’ as defined by the DER as it is at the southern extent of its geographic range (Astron, 2015). The Minor Drainage Line habitat extends north with connectivity beyond the mining operations area, which presents an opportunity movement of this species out of the disturbance area (Astron 2015). As part of the proposed Eastern Ridge Revised Proposal, to be formally referred in December 2015 (BHP Billiton Iron Ore, 2015a), future proposed changes to existing Orebody 24 and

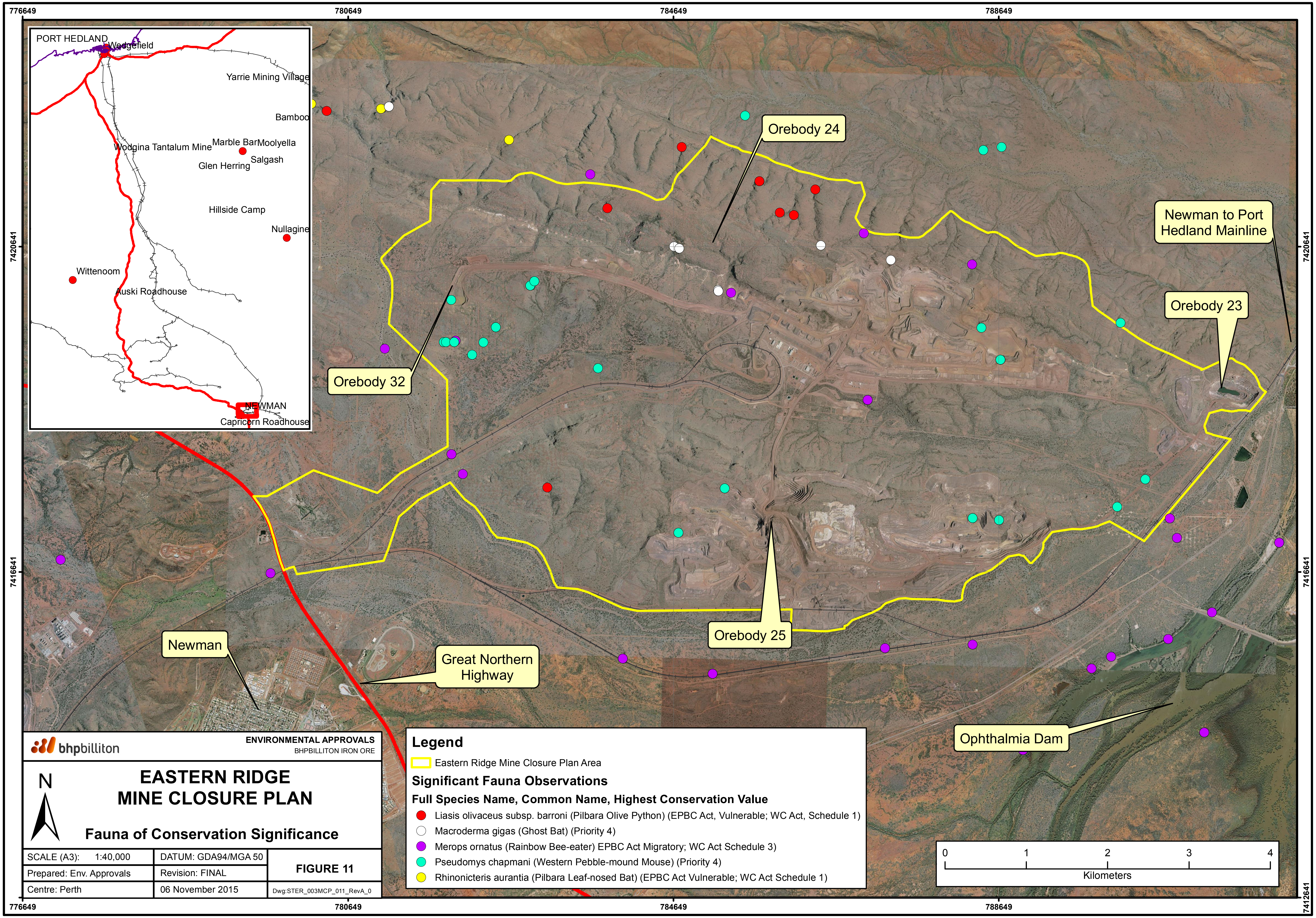
Orebody 25 West operations have been modified to avoid some of the known locations of the Pilbara Olive Python habitat (specifically semi-permanent waterholes) to minimise direct impacts to this species where practicable.

7.7.3 Short-range endemic species

After numerous short-range endemic (SRE) invertebrate fauna species surveys, both within the mining operations and surrounds, no confirmed SRE species have been recorded from within the Eastern Ridge mining operations (Biologic 2015b). Eight potential SRE invertebrate fauna species have been recorded from within the mining operations. These include:

- Aurecocrypta `MYG315-DNA` (mygalomorph spider);
- Buddelundia `16NM` (isopod);
- Buddelundia ‘49’ (isopod);
- Buddelundia `78` (isopod);
- Buddelundiinae `OB24` (isopod);
- Cethegus ‘MYG299-DNA’ (mygalomorph spider);
- Conothele `MYG385-DNA` (mygalomorph spider); and
- Karaops `ARA005-DNA` (selenopid spider) (Biologic 2015a, Biologic 2015b).

Two key SRE habitat zones were mapped from within the mining operations: the Steep Gullies/ Ridges habitat zone, and the Main Ranges/ Slopes habitat zone. These key habitat zones occur widely beyond the Eastern Ridge mining operations, particularly to the west of Orebody 24. All eight potential SRE species and their habitats have all been recorded beyond the mining operations throughout the local or wider regional area (Biologic 2015, Biologic 2014b).



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PORT HEDLAND
Wedgefield
Yarrie Mining Village
Bamboo
Wodgina Tantalum Mine
Marble Bar
Moolyella
Salgash
Glen Herring
Hillside Camp
Nullagine
Wittenoom
Auski Roadhouse
NEWMAN
Capricorn Roadhouse
Orebody 24
Newman to Port Hedland Mainline
Orebody 23
Orebody 32
Orebody 25
Newman
Great Northern Highway
Ophthalmia Dam
Legend
Eastern Ridge Mine Closure Plan Area
Significant Fauna Observations
Full Species Name, Common Name, Highest Conservation Value
Liasis olivaceus subsp. barroni (Pilbara Olive Python) (EPBC Act, Vulnerable; WC Act, Schedule 1)
Macroderma gigas (Ghost Bat) (Priority 4)
Merops ornatus (Rainbow Bee-eater) EPBC Act Migratory; WC Act Schedule 3)
Pseudomys chapmani (Western Pebble-mound Mouse) (Priority 4)
Rhinonicteris aurantia (Pilbara Leaf-nosed Bat) (EPBC Act Vulnerable; WC Act Schedule 1)
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ENVIRONMENTAL APPROVALS
BHPBILLITON IRON ORE
N
EASTERN RIDGE
MINE CLOSURE PLAN
Fauna of Conservation Significance
SCALE (A3): 1:40,000
DATUM: GDA94/MGA 50
FIGURE 11
Prepared: Env. Approvals
Revision: FINAL
Centre: Perth
06 November 2015
Dwg:STER_003MCP_011_RevA_0

7.7.4 Subterranean fauna

Subterranean fauna surveys at the Eastern Ridge mining operations have been undertaken as part of a broad-scale subterranean fauna survey known as the Regional Subterranean Fauna Sampling Program (RSFSP) that began in November 2007. To date, the RSFSP has resulted in survey of more than 30 mining and exploration areas across the Pilbara. More recent surveys have been undertaken at Orebody 24, Orebody 25, Orebody 25 West and Orebody 32. The surveys across the Eastern Ridge mining operations were conducted in accordance with the recommendations of EPA Environmental Assessment Guideline 12 and Guidance Statement 54A.

Troglofauna

The direct loss of individuals and/or loss of potential troglofauna habitat through the creation of pits at the Eastern Ridge mining operations, is considered unlikely to impact the persistence of known trolofauna species throughout the region. No additional impacts to troglofauna are expected to result from closure activities.

Extensive troglofauna surveys have been undertaken within the Eastern Ridge mining operations and the local vicinity. These surveys have resulted in the collection of at least 32 troglofauna species (representing 16 orders) from within the Eastern Ridge mining operations (Bennelongia 2015a). All but two of these species are known to occur beyond the proposed or approved mine pits (?*Buddelundia* sp. B01 and *Dampetrus* sp. B03) (Bennelongia 2015a). Based on results from other species suggest that troglofaunal species in the Eastern Ridge mining operations area are relatively widespread and have ranges that do not coincide closely with the pattern of iron ore, particularly because the area landform lacks major barriers to movement of species (Bennelongia 2015a). It is considered unlikely that ?*Buddelundia* sp. B01 and *Dampetrus* sp. B03 would be restricted to the proposed or approved pit areas of the Eastern Ridge mining operations (Bennelongia 2015a).

Stygofauna

Stygofauna surveys have resulted in a collection of 49 species from within the Groundwater Assessment Area (the area where modelled groundwater drawdown is greater than or equal to two meters over and above the natural climatic fluctuations) at the Eastern Ridge mining operations (Bennelongia 2015b). Only five of these species have known ranges that might potentially cause them to be impacted from groundwater drawdown. These are the enchytraeid worm Enchytraeidae sp. OB3, the ostracod *Pilbaracandona* ?`OST002`, the phreodrilid worm Phreodrilidae sp. WAM indet. 1, and two syncarids *Bathynella* sp. B12 and Bathynellidae sp. WAM indet. 1 (Bennelongia 2015b).

The ranges of Enchytraeidae sp. OB3 and Phreodrilidae sp. WAM indet. 1 are considered likely to extend beyond the Groundwater Assessment Area. This is based on the distributions of similar species elsewhere in the Pilbara, and the wider distribution of more abundant endemic species in the Ethel Gorge/Upper Fortescue area. The ranges of *Pilbaracandona* `OST002`, *Bathynella* sp. B12 and Bathynellidae sp. WAM indet. 1, are considered moderately likely to extend beyond the Groundwater Assessment Area (Bennelongia 2015b).

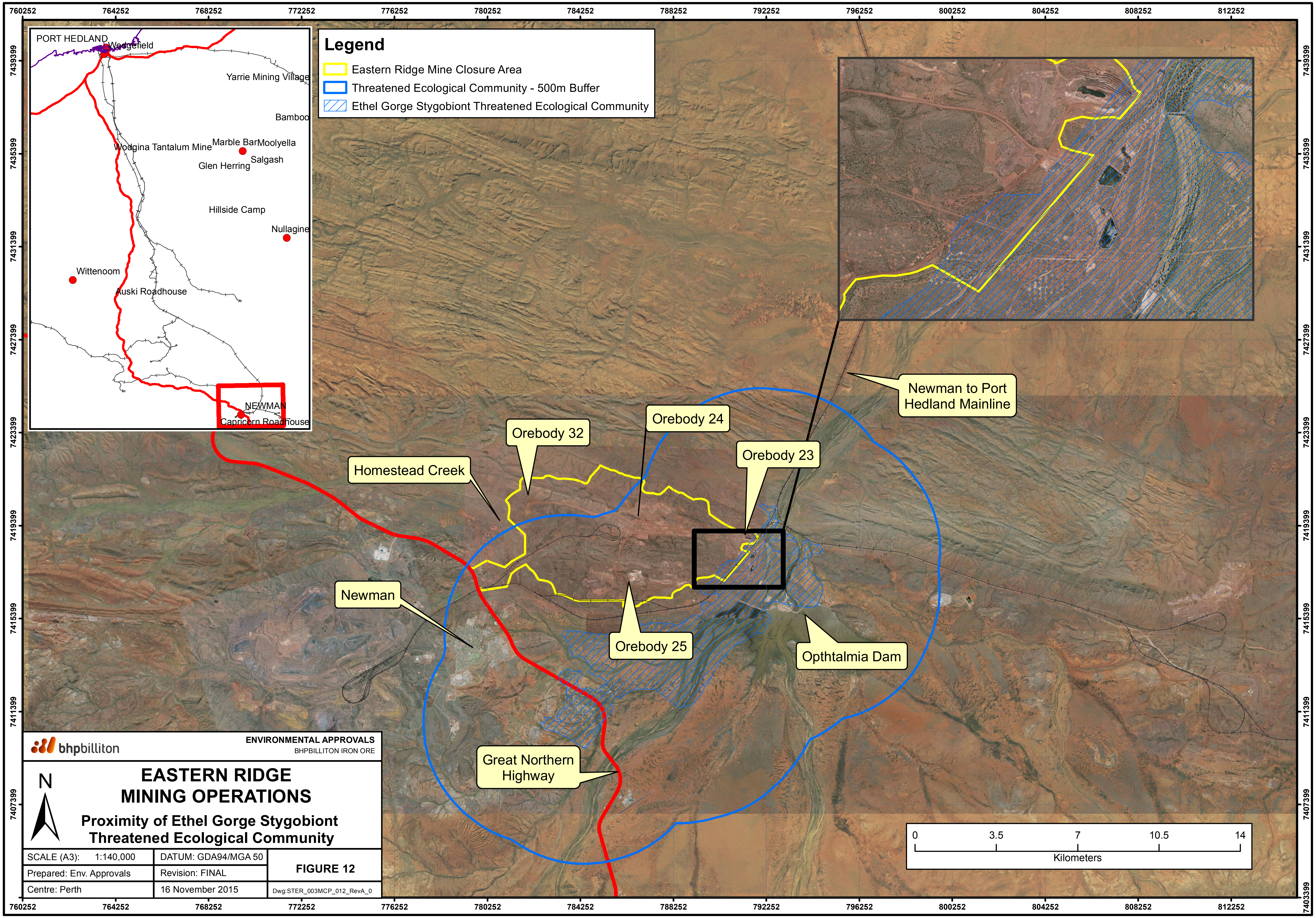
Following mine closure, there will be a slow recovery of groundwater levels in the Eastern Ridge mining operations area, eventually reaching pre-mining levels.

7.7.5 Threatened or Priority Ecological Communities

The Ethel Gorge Aquifer Stygobiont Community is listed as an Endangered Threatened Ecological Community (TEC) endorsed by the Western Australian Minister for Environment. The majority of the Eastern Ridge mining operations are located within the buffer zone of the Ethel Gorge Aquifer Stygobiont Community, with a small section of the mining operations intersecting the designated TEC boundary (Figure 12). The Ethel Gorge Aquifer Stygobiont Community has the potential to be impacted from changes in groundwater level and water quality post closure. This is further discussed in Section 0.

7.7.6 Threatened or Priority Ecological Communities

Knowledge gaps, which have impacts on closure outcomes, relate to eco-hydrological relationships and have been identified are discussed in Section 7.8.4.



bhpbilliton

ENVIRONMENTAL APPROVALS
BHPBILLITON IRON ORE

EASTERN RIDGE MINING OPERATIONS

Proximity of Ethel Gorge Stygobiont Threatened Ecological Community

SCALE (A3): 1:140,000	DATUM: GDA94/MGA 50	FIGURE 12
Prepared: Env. Approvals	Revision: FINAL	
Centre: Perth	16 November 2015	Dwg:STER_003MCP_012_RevA_0

7.8 Hydrology

7.8.1 Conceptual understanding

7.8.1.1 Surface Water

The Eastern Ridge mining operations are located within the Homestead Creek catchment in the Upper Fortescue River catchment. Homestead Creek is an ephemeral tributary of the Fortescue River. It drains an area of approximately 300 km2 and enters the Fortescue River just downstream of Ophthalmia Dam. The main channel of the creek is located approximately 4 km north of the Newman Township at its closest point. For approximately 6 km of its length, Homestead Creek runs adjacent to BHP Billiton Iron Ore's Orebody 25 mining operations. Homestead Creek also passes by the Orebody 23 operation near the Marble Bar Road crossing. The western boundaries of Orebody 25 West and Orebody 32 pits are located within 100 m of Homestead Creek.

Whaleback Creek is located to the south of Homestead Creek. Whaleback Creek is not impacted by Eastern Ridge mining operations, however post-closure there is the potential during extreme flood events for the Homestead Creek floodplain to comingle with the Whaleback Creek floodplain (discussed further below).

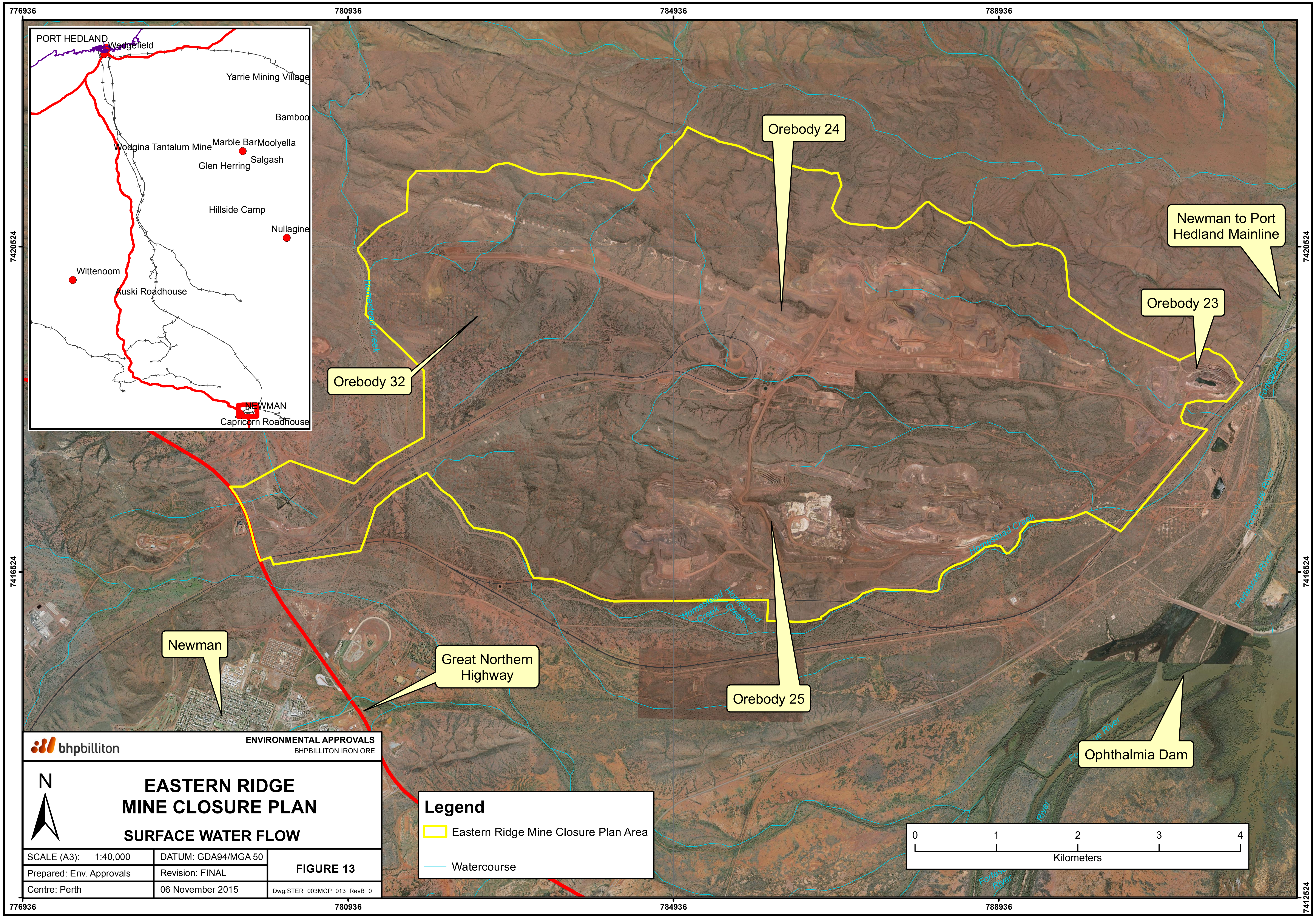
The northern slope of Ophthalmia Range (Orebody 24) drains into an unnamed creek that flows east into the Fortescue River and the remainder of the Eastern Ridge mining operations flowing either directly or indirectly via drainage lines into Homestead Creek. Surface water drainage from future mining operations within the Eastern Ridge mining operations will continue to be dominated by Eastern Ridge and Ophthalmia Range.

The Orebody 32 pit is located within the Homestead Creek catchment between Eastern Ridge and Ophthalmia Range and lies predominately on a hill standing about 45 m above the surrounding terrain. The ground surface elevations at the proposed pit vary from about RL545-590m. The hill deposit naturally drains from the ridge top in all directions.

The loss of surface water volume from the total cumulative catchment loss from the Eastern Ridge mining operations is approximately 2,063ha, or about 7%. This potential catchment loss also represents 0.4% of the Fortescue River catchment area at Ethel Gorge, and 0.07% at the Fortescue Marsh. The potential loss in downstream flow is within the overall seasonal variation of flows downstream.

These changes are not considered to be significant to the overall hydrological system, particularly in comparison to the large natural seasonal variations in catchment runoff.

Figure 13 shows the local tributaries and drainage lines within and around the Eastern Ridge mining operations. Orebody 24 has a number of minor drainage lines which flow into a tributary of Fortescue River. Orebody 25 West has a number of minor drainage lines which flow into Homestead Creek. Orebody 32 has two drainage lines which also flow into Homestead Creek.



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PORT HEDLAND
Wedgefield
Yarrie Mining Village
Bamboo
Marble Bar
Moolyella
Wodgina Tantalum Mine
Salgash
Glen Herring
Hillside Camp
Nullagine
Wittenoom
Auski Roadhouse
NEWMAN
Capricorn Roadhouse
Orebody 24
Orebody 32
Orebody 23
Orebody 25
Newman to Port Hedland Mainline
Newman
Great Northern Highway
Ophthalmia Dam
Homestead Creek
Fortescue River
bhpbilliton
ENVIRONMENTAL APPROVALS
BHPBILLITON IRON ORE
N
EASTERN RIDGE
MINE CLOSURE PLAN
SURFACE WATER FLOW
SCALE (A3): 1:40,000
DATUM: GDA94/MGA 50
Prepared: Env. Approvals
Revision: FINAL
Centre: Perth
06 November 2015
FIGURE 13
Dwg:STER_003MCP_013_RevB_0
Legend
Eastern Ridge Mine Closure Plan Area
Watercourse
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Kilometers

7.8.1.2 Groundwater

The primary aquifers in the assessment area consist of Tertiary detritals associated with the Fortescue River and its main tributaries in the area (Shovelanna, Homestead and Warrawandu creeks) along with the underlying dolomite of the Paraburdoo Member of the Wittenoom Formation. The Tertiary detritals include extensive calcrete, sands and gravels which are up to 90 m thick in some locations. Mineralised Brockman and Marra Mamba Iron Formations are considered to represent local aquifer units (orebody aquifer) which can exceed 200 m thickness in some areas.

Submineralised zones of the Brockman and Marra Mamba Iron Formations, shale rich units of the Mt McRae Shale and Mt Sylvia Formation, and volcanic and BIF's of the Weeli Wolli, Boolgeeda Iron, and Wongarra Formations are in general lower permeability units or aquitards at Eastern Ridge.

Local zones of high permeability occur in many areas of the Eastern Ridge mining operations (e.g. Orebody 25 pit 3) due to enhanced secondary porosity associated with faulting and folding. Such structural features can act as the dominate pathway for local groundwater flow.

Recharge to the alluvial aquifer system occurs primarily from incident rainfall and infiltration in the major drainage lines from surface water flows associated with large rainfall. Recharge to the orebody aquifers can occur via through flow from the alluvial system (e.g. Orebody 23) with lesser amounts of recharge occurring from direct rainfall infiltration. Ophthalmia Dam and the associated infiltration basins and ponds have an influence on the local groundwater regimes in the Ethel Gorge area and recharge from these structures represents water returning to the aquifer from captured runoff and surplus dewatering from mining operations.

Prior to mining, regional groundwater flow directions were similar to the surface water drainage directions, flowing broadly in a west to east direction from the upper Homestead valley at about 545m AHD across the mining areas towards Ethel Gorge at about 510m AHD. Flow directions are then directed northeast through Ethel Gorge at about 500m AHD towards the Fortescue River valley.

Local dewatering activities in the vicinity of Orebody 23 and Orebody 25 and water supply abstraction from the Ophthalmia and Homestead borefields have modified the groundwater flow directions, with groundwater gradients showing local groundwater flow towards the pits and water supply bores.

Groundwater in the assessment area is generally of very good quality with the majority of groundwater having salinity values between 300 and 2,000 mg/L total dissolved solids (TDS) and pH between 6 and 8.

7.8.2 Eco-Hydrological Assets

Three key eco-hydrological assets have the potential to be impacted by the Eastern Ridge mining operations, these are riparian vegetation within Ethel Gorge and Homestead Creek, the Ethel Gorge TEC, previously introduced in Section 7.7.5 and the groundwater resource.

7.8.2.1 *Key Assets – riparian vegetation*

Homestead Creek and Fortescue River comprises surface water dependant and potentially groundwater dependant riparian vegetation communities. It is noted that while BHP Billiton Iron Ore has been operating adjacent to riparian vegetation communities it has monitored the tree health and little change in health of these communities has been observed.

The entire upstream catchment area of Ethel Gorge hosts approximately 3,650 ha of Eucalypt woodland communities including *E. camaldulensis* and *E. victrix*. In Pilbara ecosystems both species are considered to have the ability to opportunistically use groundwater (i.e. are facultative phreatophytes); but also commonly occur in habitats with deep water tables (>20 m bgl) where groundwater is unlikely to be accessed by tree roots. In these situations they are more likely to function as vadophytes.

7.8.2.2 Key Asset – Ethel Gorge TEC

The Ethel Gorge TEC and Ethel Gorge are identified in the EPWRMP (BHP Billiton, 2015b) as key Eastern Pilbara regional biodiversity assets and are considered in more detail as part of the closure assessment of Eastern Ridge mining operations. The TEC is listed by the DPaW with some stygofauna species endemic to Ethel Gorge. The stygofauna habitat comprises saturated calcrete and alluvium aquifers, which underlies the broad Ophthalmia valley and Ethel Gorge, the latter containing the most abundant and diverse community.

Information on habitat requirements for stygofauna, including their distributions within heterogeneous groundwater environments and tolerances of differing water qualities, is very limited in the Pilbara and elsewhere. As a general rule stygofauna are often most abundant and diverse near the watertable, with species richness and abundance decreasing with distance below the watertable in association with decreasing oxygen and nutrients (Stumpp and Hose, 2013). Shallow watertable areas typically have greater stygofauna diversity, where attenuation of organic matter and oxygen by the overlying unsaturated profile is minimised. Areas with a depth to the watertable of less than 15 m from the surface have been found to favour high stygofauna diversity in alluvial aquifers in eastern Australia (Hancock and Boulton, 2008). However the depth at which stygofauna communities can persist is also influenced by different geology. Where transfer of water from the surface to aquifer is rapid, the suitable depth to watertable is likely to be greater (RPS Aquaterra, 2014).

The current spatial extent of the Ethel Gorge TEC was previously illustrated in Figure 12, as defined by DPaW, this boundary is understood to be based on the surface expression of calcrete in the area.

The quality of stygofauna habitat is influenced by the level of connectivity between pores, cavities, and fractures which facilitate fauna movement and dispersal. The zone of watertable fluctuations (i.e. the boundary between unsaturated and saturated zone) may constitute an ecotone with different species assemblages in comparison with constantly saturated and unsaturated zones respectively; however, this has not been confirmed at Ethel Gorge (RPS Aquaterra, 2014).

7.8.2.3 Groundwater Resource

Eastern Ridge sits within the Newman Water Reserve Priority1 public drinking water source area, which covers the aquifers that feed the Newman town potable supply. Active mining operations at Orebody 24 and Orebody 25 occur within 5 km of the Homestead and Ophthalmia water supply borefields.

7.8.2.4 Stressors

There are a number of mining related activates that currently take place or are planned in the future which have the potential to affect surface and groundwater quantity and quality. Following closure these include:

- Exposure of potential acid forming material in pit void walls Interruption of existing surface water flow patterns, ponding, and reduction in flow volumes to downstream ecosystems due to mining infrastructure.
- Development of pit lakes in mine voids during mine closure.

During operations these may include:

- Water supply pumping from Homestead and Ophthalmia borefields for the town of Newman. Pumping from Ophthalmia borefield has occurred since the 1970's with pumping from Homestead starting in 2013.
- Abstraction of groundwater for dewatering purposes. Dewatering commenced in 2006 at Orebody 23 and Orebody 25 and additional dewatering is planned to allow below water table mining at Orebody 24 and Orebody 25 West.
- Seepage from Ophthalmia Dam. The dam was constructed as an infiltration facility in the early 1980's to maintain groundwater levels within the Ethel Gorge aquifer and to support the Ophthalmia Borefield.
- Return of surplus water back to the subsurface via infiltration ponds and basins.

Some of the operational stressors may continue in areas adjacent to the Eastern Ridge mining operations following the closure of the operations or parts thereof. Otherwise, these activities may produce stress on the environment which need to be managed following closure of the site or deposits.

7.8.3 Change Assessment

The hydrological changes associated with the Eastern Ridge mining operations activities have been evaluated in relation to impacts to:

- surface and groundwater resources (including flow, levels and quality);
- groundwater dependent ecosystems, such as stygofauna within Ethel Gorge; and
- riparian vegetation owing to falling groundwater levels.

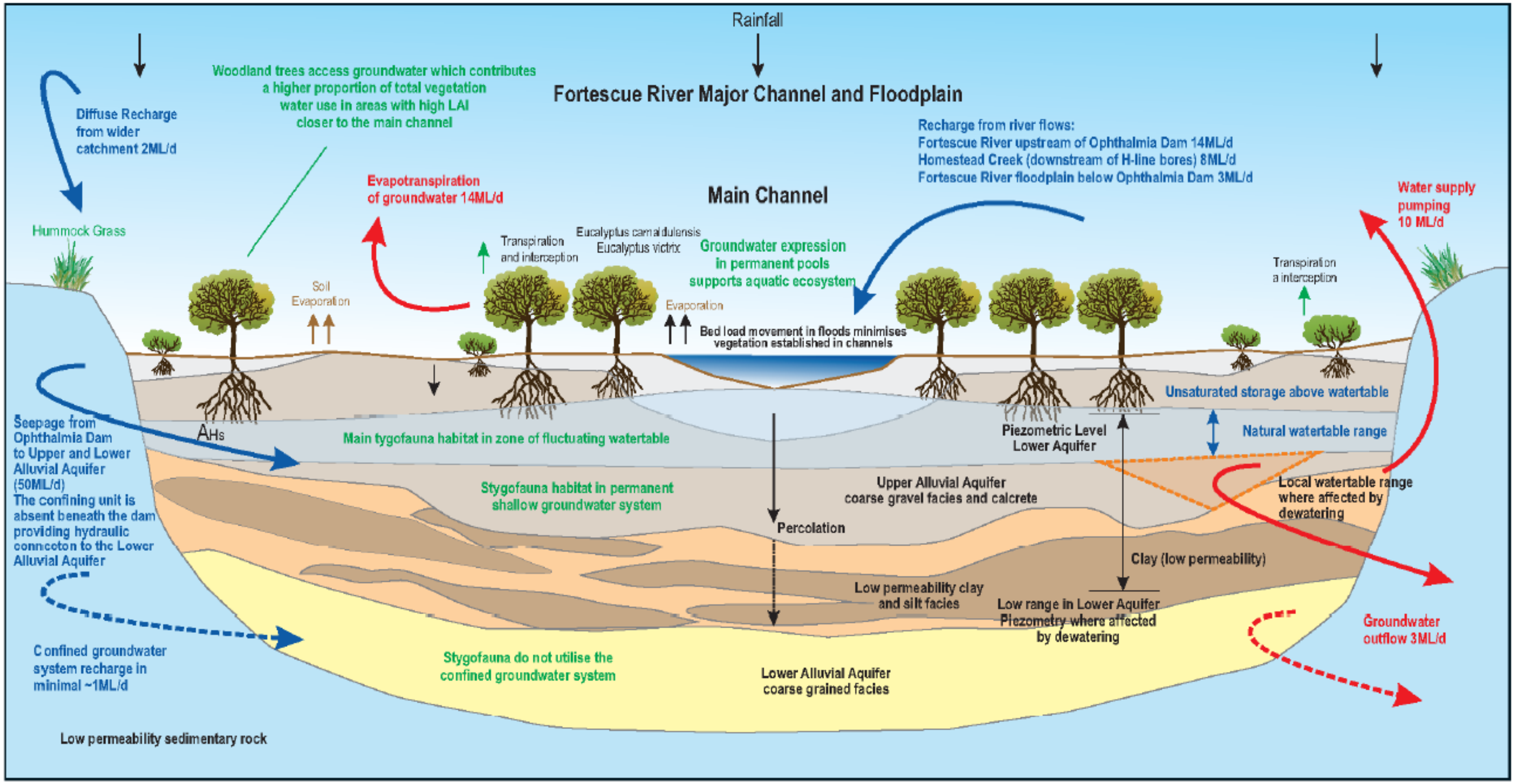


Figure 14: Ethel Gorge Conceptual Eco-hydrological Model (RPS Aquaterra, 2014b)

7.8.3.1 Surface Water

A surface water change assessment was conducted to assess the potential for surface water impacts from activities at the Eastern Ridge mining operations, and the potential significance of these impacts in relation to surface water in the wider region (Appendix C).

Potential surface water impacts include interruption of existing surface water flow patterns, ponding, and reduction in flow volumes to downstream ecosystems.

These impacts can result from:

- loss of surface water run-off where infrastructure or landforms intercept drainage lines;
- natural creek sections adjacent to pits with the potential to capture and reroute drainage; and
- diversion/realignment sections.

Surface Water Run-Off Volumes

The entire Eastern Ridge mining operations lie within the Homestead Creek catchment. The runoff volume is likely to decrease from areas containing pits, OSA's and catchments blocked or trapped by these works.

Runoff volumes from other infrastructure areas (e.g. roofs, hardstands, access roads) may increase, whereas from other infrastructure development areas (e.g. ponds, depressions and interrupted flow areas) runoff volumes may be reduced. Overall runoff volumes from these areas are considered to be effectively unchanged by the planned works.

Non-recovered runoff volume losses have been assumed as follows:

- 100% loss of runoff volume from pit areas;
- 50% loss of runoff volume from OSA developments.

An approximate estimate of the existing and planned relevant pit and OSA / stockpile areas for the Eastern Ridge mining operations is provided in the Table 15.

Table 15: Estimated area impacted by selected operations in the Eastern Ridge mining operations area

Location	Development Area (ha)	Adopted Runoff Loss	Catchment Area Loss Estimate (ha)	% Catchment Area Loss
Orebody 23 (existing operations) – Pits	23	100%	23	0.1%
Orebody 23 (existing operations) – OSA	30	50%	15	0.1%
Orebody 24 (existing & future operations) - Pits	350	100%	350	1.2%
Orebody 24 (existing & future operations) - OSA & Stockpiles	505	50%	253	0.8%
Orebody 55 (existing operations) - Pits	320	100%	320	1.1%
Orebody 25 (existing operations) - OSA & Stockpiles	400	50%	200	0.7%
Orebody 25W (future operations) - Pits	150	100%	150	0.5%
Orebody 25W (future operations) – OSA	111	50%	56	0.2%
Orebody 32E (future operations) - Pits	240	100%	240	0.8%
Orebody 32E (future operations) - OSA	130	50%	65	0.2%
SUBTOTAL	*2,259*		*1,672*	*5.7%*
Extension areas	8.4%		140	0.5%

Location	Development Area (ha)	Adopted Runoff Loss	Catchment Area Loss Estimate (ha)	% Catchment Area Loss
Unplanned developments	15%		251	0.8%
GRAND TOTAL			2,063	7.0%

Allowing 15% contingency for future pits and OSA's, as well as small catchment areas trapped upstream of this infrastructure, the total effective catchment loss of 2, 063 ha from the Homestead mining areas corresponds to about 7% of the Homestead Creek catchment.

The total catchment loss of 2,063 ha Envelope corresponds to 0.4% at Ethel Gorge (Fortescue River catchment area about 4,872 km²); or about 0.06% for the Fortescue Marsh catchment area of 29,700 km².

This potential runoff volume reduction is not considered significant to the overall hydrological systems downstream, particularly when considering the natural seasonal variations in catchment runoff.

<u>Natural creek sections adjacent to pits</u>

Orebody 23 and Orebody 25 Pit 3 were identified as the pits which were in closest proximity to Homestead Creek. Orebody 25 West and Orebody 32 also have pits adjacent to Homestead Creek, but are topographically at less risk as they are generally located uphill from the creek / floodplain.

Pit 3 of Orebody 25 currently extends to within 60 m of the Homestead Creek main channel. The existing flood bunding is designed to protect the pit from flooding during the operational life of the pit; it is not intended for closure conditions in its current form. If floodplain flows spill into an open pit in the post-closure timeframe when no maintenance activities are undertaken, a head cut may form and capture the entire creek flow, trapping all future bed load and all low flows indefinitely.

Tetra Tech (2014) was tasked with conducting a hydrologic analysis of the Homestead and Whaleback Creek catchment areas along with a hydraulic assessment of flow conditions in the vicinity of OB25. An erosion assessment was performed to estimate the extent of head cut migration in the event of flood flows overtopping the banks and discharging into Pit 3. Options were developed for preventing creek capture at closure and ensuring a long-term, stable land form. This informed the approach and closure options chosen in relation to the final landform design of Orebody 23 and Orebody 25 Pit 3.

Whilst the modelling focuses on Orebody 25, the results may be extrapolated to Orebody 23, which is shown to be more susceptible to pit flooding than Orebody 25 under existing conditions.

Hydrologic modelling of Homestead Creek yields a 100-year ARI peak discharge of 608 m^3/s and a 10,000-year ARI peak discharge of 1,611 m^3/s. Additional flow contribution from Whaleback Creek is assessed under the unlikely scenario of coincident peak flows in both creeks. The hydraulic analysis determined that the existing flood bund would overtop only in the event of a flow exceeding the 10,000-year ARI peak discharge in Homestead Creek. Without ongoing maintenance during the post-closure timeframe, the existing flood bund would be expected to deteriorate over time; in order to reflect this condition, a hydraulic analysis was performed under the assumption of complete failure or removal of the bund to the insitu floodplain elevation. Under that scenario, Homestead Creek would begin to overtop and spill into Pit 3 at the approximate peak discharge level associated with a 50-year Average Recurrence Interval (ARI) event in the Homestead Creek catchment.

A series of 100-year to 10,000-year ARI flood events overtopping the channel banks and spilling into the pit was modelled to determine head cut migration rates over a 10,000-year duration. The assessment determined that a single 100-year ARI event would result in sufficient head cut migration to capture the deepest part of the creek or stream bed (thalweg). The flow volume captured by the pit during the event would be sufficient to raise the pit lake elevation from the long-term groundwater table elevation to the level of the ground surface. With the water surface equalised between the creek and the pit, erosion would be slowed during subsequent events until the pit lake water surface recedes back to the long-term groundwater table elevation. Following creek capture and recession of the pit lake elevation to the groundwater table, the entire low-flow discharge of Homestead Creek would be routed into the pit. The probability of this condition occurring under the stated set of assumptions is essentially 100% if the pit is not backfilled. These findings strongly inform the closure management of Orebody 25 Pit 3 and Orebody 23 as outlined in Section 8.

A comparison of available historical aerial photographs showed no discernible change in the path of the creek thalweg in recent years. Observations of the vegetation along the channel banks and the geomorphological characteristics of the system indicate that the potential for creek migration appears to be more likely to occur to the south than to the north toward the pit. The overall potential for large-scale lateral migration appears to be relatively low in this reach of Homestead Creek. Because head cut erosion from creek flows entering the mining pit is effectively a certainty over the 10,000-year assessment period, lateral migration is not assessed quantitatively.

Consultants are currently completing hydrological and hydraulic modelling of Homestead Creek and major tributaries to assess impacts on Orebody 32 and Orebody 25 West pits at closure. The overarching objective of this modelling exercise is to determine the susceptibility of creek capture into closure voids at Orebody 32 and Orebody 25 West, including an analysis of erosion potential and mitigation measures.

This will include a review of existing and life of mine hydrology, hydrological and hydraulic modelling, headcut / erosion analysis and development of concept options to prevent creek capture at closure.

Diversion/realignment sections

Orebody 32 potentially requires diversion of a minor drainage line which flows into Homestead Creek. This would maintain the surface water flow into Homestead Creek (Figure 15 and Figure 16).

Hydraulic modelling (RPS Aquaterra, 2014) was carried out on the pre-development / existing floodplain, and then post-closure with the proposed Orebody 32 pit encroachment into a minor drainage line to the north of Orebody 32 and also the Homestead Creek Floodplain.

Studies have investigated the expected 100 year ARI flow in the minor drainage line to the north of Orebody 32 and the probable maximum flood (PMF) in Homestead Creek. These estimates will inform final diversion and landform designs for any diversions required.

The majority of the Orebody 25 West pits are located on local ridgelines outside the Homestead Creek floodplain with the exception of one pit, which is within the 100 year floodplain and will be bunded during operations. Surface water impacts during closure of this pit and Orebody 32 in particular are currently being modelled.

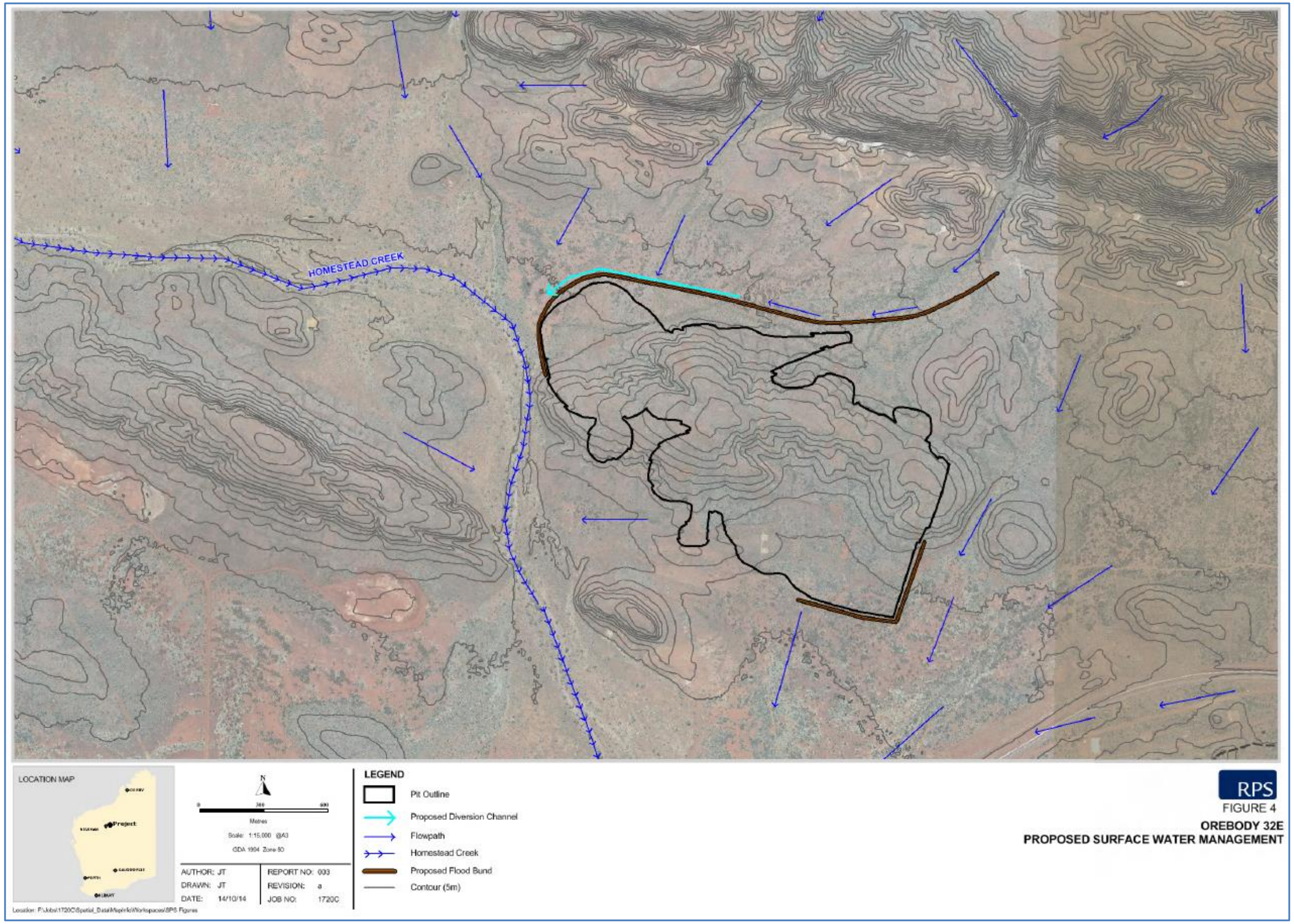


Figure 15: Proposed Surface Water Diversion at Orebody 32 (RPS Aquaterra, 2015a)

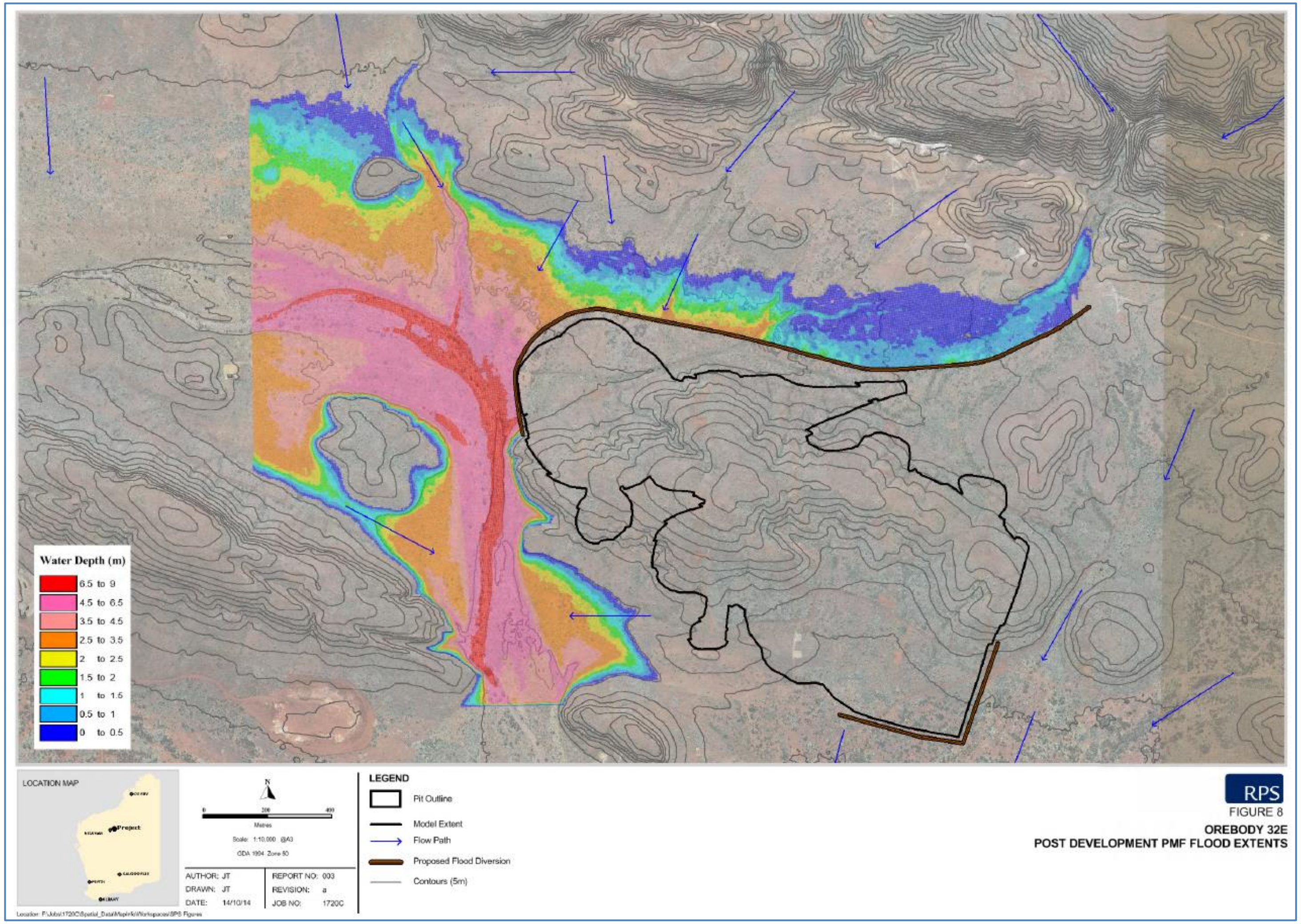


Figure 16: Modelling of Post-Closure PMF Flood Extents with the Surface Water Diversion at Orebody 32 (RPS Aquaterra, 2015a)

7.8.3.2 Groundwater

The purpose of the closure assessment is to determine the long term hydrological impact of different closure management options for Eastern Ridge. The focus of this work is any hydrological impact particularly relating to pit voids and long term impacts to the key environmental receptors.

The Ethel Gorge numerical model (Appendix C) was used to estimate the long term hydrological change using two different closure management options:

- **Scenario A (backfill)**: completely infilled pit voids to 5 m above the pre-mining water level; and
- **Scenario B (voids)**: empty voids at Orebody 24, Orebody 25W, and Orebody 25 Pit 3 and completely infilled pits at Orebody 25 Pit 1 and Orebody 23.

The two closure scenarios represent the likely range of hydrological conditions to develop, one being a full backfill and the other a pit lake. There are a number of other intermediate closure alternatives (such as partial backfill) which have not been considered but are likely to result in hydrological conditions somewhere between the two scenario outcomes. Each of the closure scenarios have been simulated using the numerical model starting from 2021 following the cessation of dewatering at Eastern Ridge.

For the backfilled void scenario (assuming backfilled material of equivalent hydraulic parameters as the ore body aquifer) the water levels will rebound to pre-mining levels after an extended period of time as flow from the regional aquifer and recharge replenishes the storage of the backfilled void. For the empty void, a pit lake develops at a rate governed by the rate of groundwater and surface inflows and loss via direct evaporation. Under the open void scenario rebound to the pre-mining water level is unlikely in the pit void due to the ongoing evaporative loss from the pit lake.

Scenario A (backfill)

Water level recovery at Orebody 25 Pit 3 and within the Ethel Gorge area is relatively quick due the high recharge rates associated with direct infiltration through Ophthalmia Dam and Homestead and Shovelanna Creeks. Full recovery of water levels is estimated to occur within approximately 40 years.

Water level recovery is slower away from Ophthalmia Dam, in the vicinity of Orebody 24 and Orebody 25 West, with about 50% recovery occurring by 2050, 75% by about 2070 and 90% by about 2150. The final 10% of recovery takes longer with full recovery and pre-pumping water levels and flow paths re-established by about 2350 resulting in no permanent changes to the groundwater system (Figure 17). This has previously been discussed in Section 7.2.3

The key hydrologic risk associated with the backfill scenario is the potential for emplacement of non-inert waste into pit voids and the subsequent release of contaminants to the groundwater system.

Scenario B (void)

The modelling suggests that permanent pit lakes will form in Orebody 24 and Orebody 25 West (Figure 18). The void in Orebody 24 is modelled to be dry as the rate of groundwater inflow is estimated to be less than the rate of evaporation. A range of upper and lower pit lake levels however has also been included with the modelled pit lake levels (Table 16) to reflect uncertainty in the modelled level and also which takes into account local hydrogeology, proximity to recharge zones such as Ophthalmia Dam, and the size of the pit void (magnitude of area susceptible to evaporation).

Table 16: Pit void predicted lake levels.

Pit	Void Base (mRL)	Pre-dewatering groundwater level (mRL)	Predicted lake level (mRL)	Lower bound Lake level (mRL)	Upper bound Lake level (mRL)
Orebody 25 West Joffre	460	526	480	470	490
Orebody 25 West Dales	492	527	523	510	525

Orebody 25 Pit 3	380	510	507	480	510
Orebody 24	484	522	Dry	Dry	500

Similar to Scenario A, groundwater levels in Orebody 25 Pit 3 and within Ethel Gorge recover quickly (within 40 years) once dewatering and abstraction from Ophthalmia Borefield cease due to high recharge rates associated with Ophthalmia Dam and Homestead and Shovelanna Creeks.

Closure Strategy Scenario

A final mine void closure scenario was modelled with Orebody 23 and Orebody 25 Pit 3 being backfilled and permanent voids at Orebody 24 and Orebody 25 West pits showing residual groundwater levels once equilibrium has been reached (Figure 20).

The permanent voids at Orebody 24 and Orebody 25 West Joffre pits have the most significant effect on groundwater levels in the Eastern Ridge mining area. Although final lake levels are reached quickly (within 10 years) the recovery of the entire groundwater system is longer (particularly within vicinity of Homestead borefield) with water level equilibrium and corresponding groundwater flow regime being established after about 200 to 300 years.

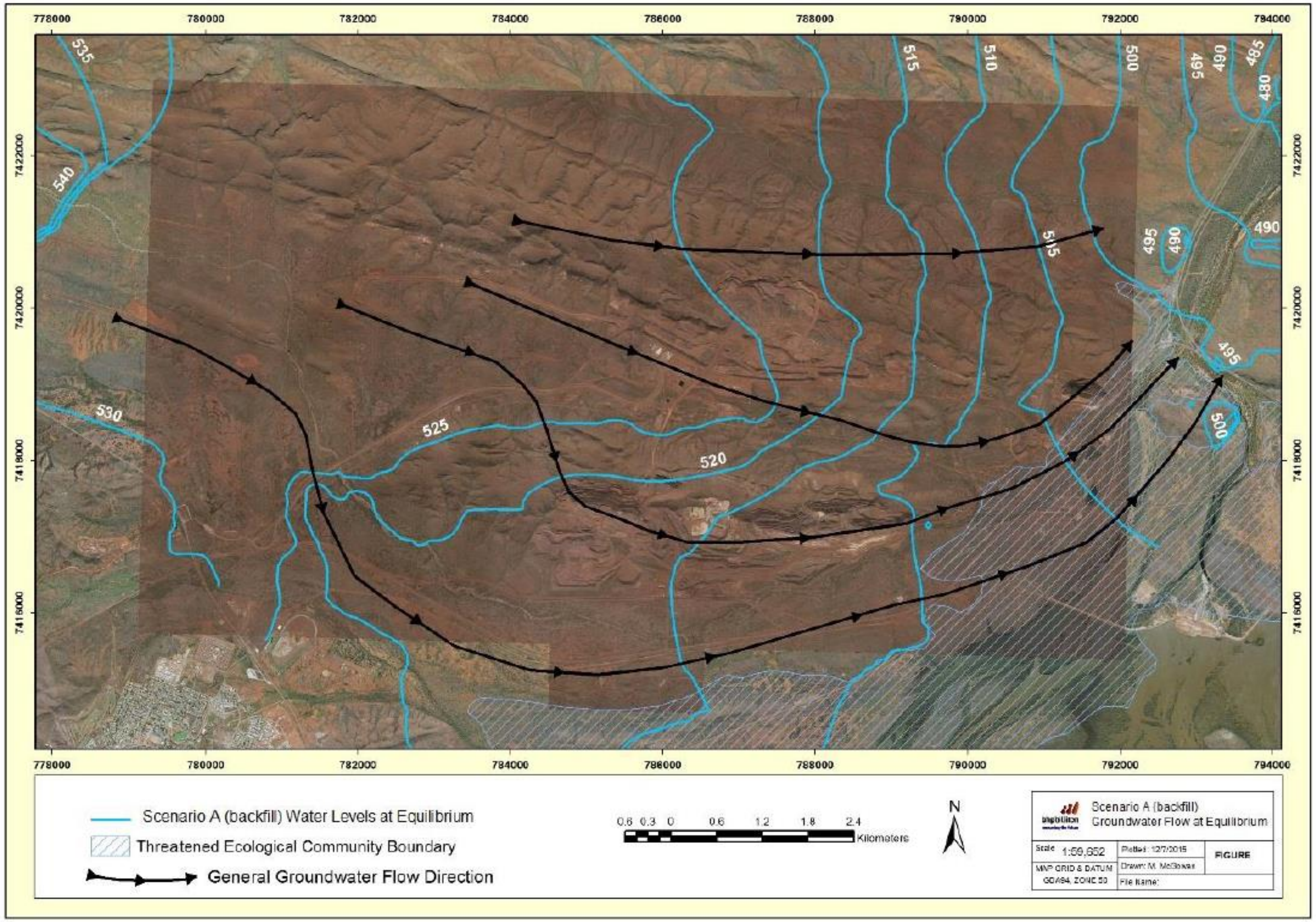


Figure 17: Scenario A (backfill) Groundwater Levels at Equilibrium

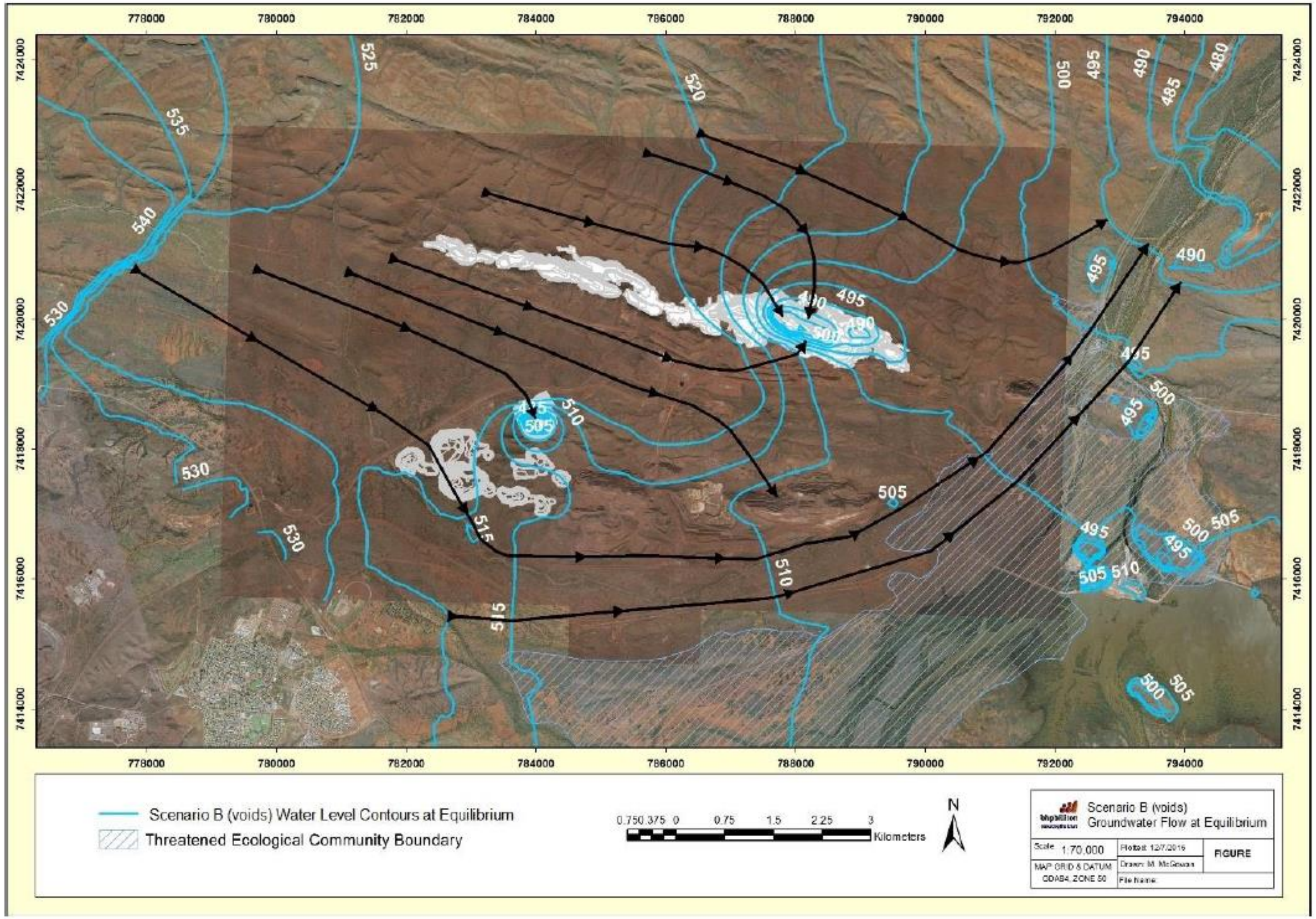


Figure 18: Scenario B (Voids) Groundwater Flow at Equilibrium

Water Quality - Mine voids approaching closure

For mine voids approaching closure (Orebody 23 and Orebody 25 Pit 3) the AMD risk assessment included scoping level pit water quality modelling to provide comparison of potential water quality impacts associated with alternative mine void closure strategies. Two options were considered; pit lakes and backfill (SRK, 2015b).

If pits are backfilled to above the long term regional groundwater table, groundwater flow would be re-established and flow would pass through backfill. Upon inundation, oxygen supply to the backfill would be reduced to very low levels and oxidation will essentially cease. Readily soluble solutes contained in the backfill placed below the final water table (i.e generated prior to inundation) would be released to the groundwater following inundation. The total potential for solute release would depend on the degree of oxidation (i.e. the duration of exposure) of sulfide minerals prior to inundation. After inundation residual sulphide minerals would no longer react and generate solutes. Solute generation would be expected to continue in reactive materials (backfill and wall rocks) that remain above the water table.

Should pits remain as open voids post closure (or be backfilled to below the long term groundwater elevation), they could act as indefinite sinks for groundwater and would capture some seepage and runoff from OSAs that fall within the drawdowns that would occur around the voids. Under this scenario, although the pit lakes would be anticipated to salinize over time due to evapo-concentration, impacts on the key environmental receptors would be unlikely.

Two post closure periods were considered; transient phase (cumulative impact period) during which the pits would be affected by active dewatering at nearby sites, and the long term post closure phase when groundwater inflow volumes and rates would reach steady state.

For both pit lake and backfilled scenarios, calculations examined the evolution of pit water chemistry over a period of 100 years following mine closure. Base case values for key parameters (e.g. Oxidation rate, leachable content of backfill and evaporation rate) were used along with sensitivity analysis to evaluate the effect of key input parameters on the outcomes. Figure 19 illustrates the final pit lithologies for Orebody 25 Pit 3 and Orebody 23.

Orebody 23

For many assumed conditions, the calculated water chemistry in the pit resembled the inflowing groundwater. Significant deviations from baseline groundwater resulted from;

- Evaporative losses leading to increasing concentrations in the pit lake scenarios
- Leachable content of the backfill materials. For long term flow through conditions (backfill) salinity would be flushed out gradually.
- Sulfidic materials (pit walls or backfill) reacting at a high rate resulted in increased salinity.
- Run off or seepage from the nearby OSA reporting to the pit in quantities sufficiently high to influence the pit water chemistry.

Due to the significant alkalinity in the inflowing groundwater, acidic condition would not be expected to develop within the pit void. Only for very extreme assumptions (e.g. oxidation rates) could the acidity produced within the pit void exceed the alkalinity. Any acidic conditions that developed would be expected to be transient because once the sulphide source is depleted, acid production would cease. Ultimately neutral pH conditions would return due to the continued inflow of alkaline groundwater. In the unlikely event that any acidic water should migrate away from the pit, it is expected that neutralisation would take place within a short distance of the pit boundary due to the presence of carbonate-rich rock formations along the typical groundwater flow paths.

Orebody 25 Pit 3

As for most conditions in Orebody 25 Pit 3, the calculated water chemistry in the pit (irrespective of being backfilled or not) resembled the inflowing groundwater. Inputs that had the strongest influence on the outcomes included:

- duration of the cumulative impact period in which water table is suppressed;
- assumed distribution of sulphides and oxidation rates;
- contribution of OSA seepage; and
- leachable content of backfill

In the pit lake scenario the water quality would deteriorate, solutes would be contained indefinitely within the confines of the pit. Due to significant ongoing alkalinity in the groundwater inflow, acidic conditions would not be expected to develop.

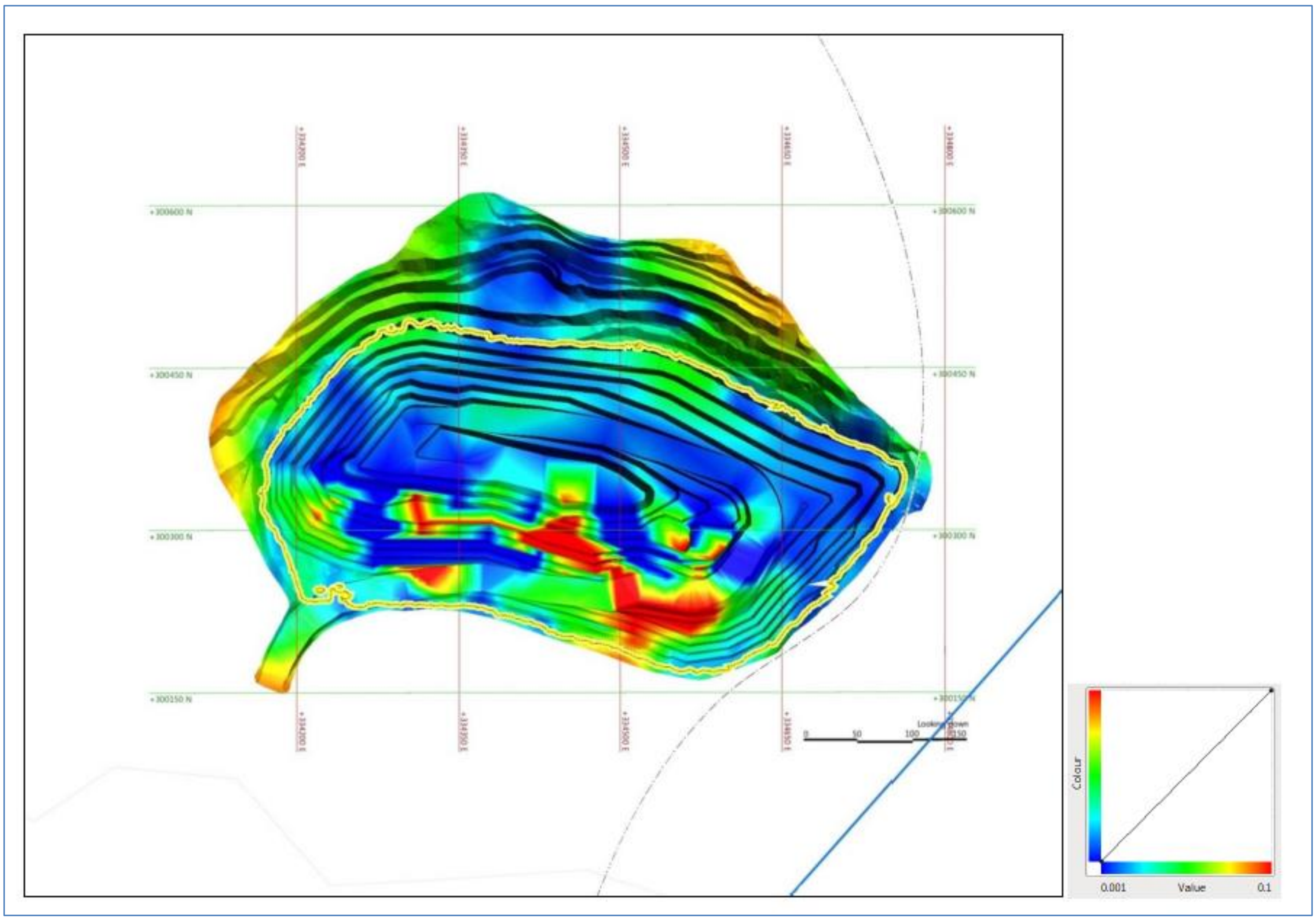
In the backfill scenario, peak concentrations related to the OSA seepage influence and salts flushing downward through unsaturated backfill. Over the long term, once the through flow system has developed, continuous flushing of the backfill by groundwater would result in water quality returning to baseline conditions. Under certain conditions there was a risk of onset of acidic conditions in the backfilled pit, however the calculations did not consider the neutralising capacity of the saturated backfill.

Orebody 25 West and Orebody 24 BWT

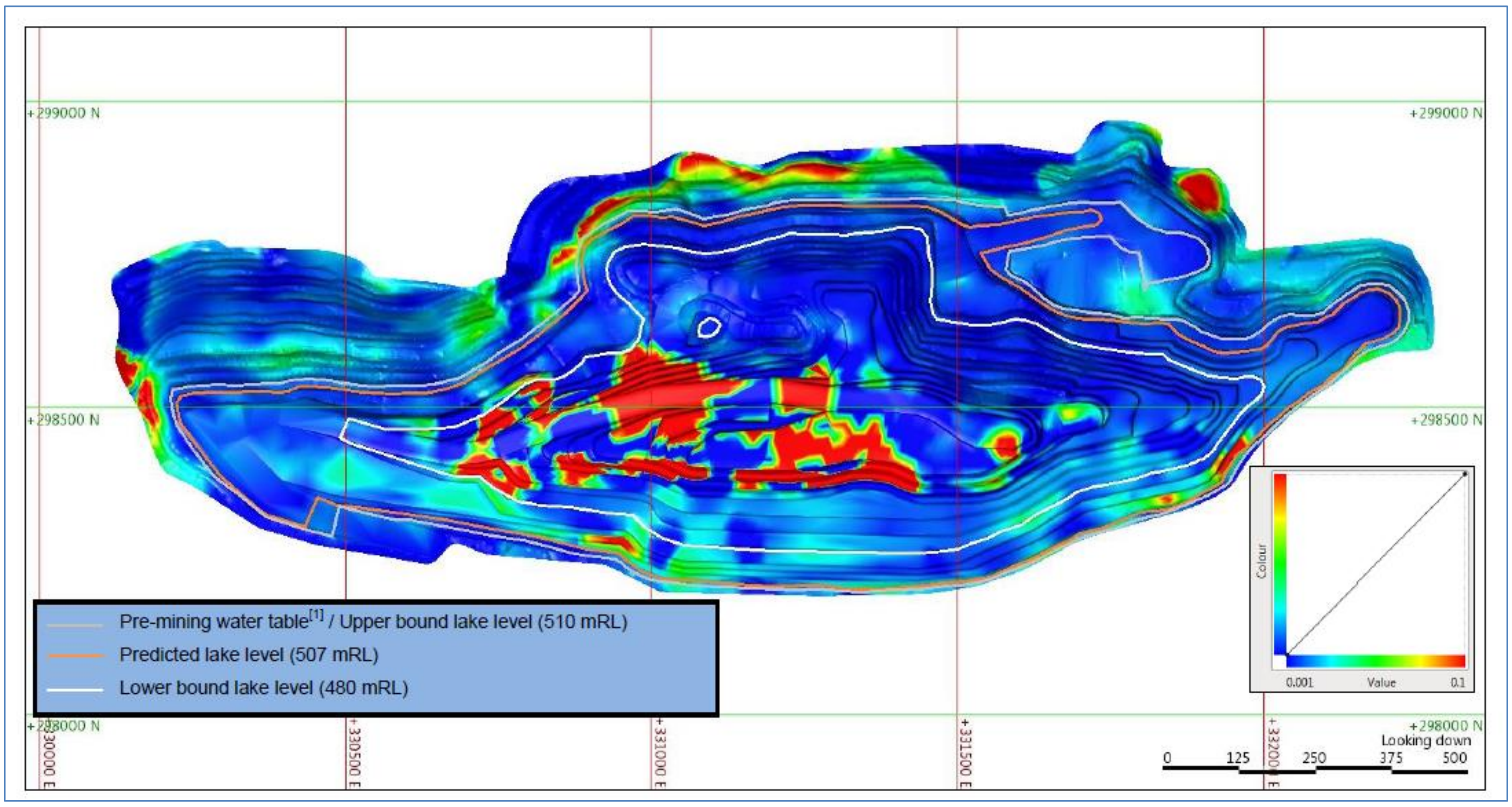
Any resulting pit lakes are likely to become saline due to evaporation concentration of salts. However, the pit lake scenario creates a local groundwater sink in which the final pit lake water level is lower than the regional water table and therefore groundwater discharges to the pit lake containing the poor quality water within the pit.

Risks to water quality are considered low. However, potential impacts from site drainage to surface water bodies and groundwater cannot be ruled out and therefore the management of the residual risk of impact during operations are outlined in Section 8.4.

Management for AMD materials across BHP Billiton Iron Ore's Pilbara sites is outlined at a high-level in the WAIO AMD Management Standard (See Section 8.4.1 for further detail).



Orebody 23 pit shell (as adapted from SRK Consulting, 2015b)



Orebody 25 Pit 3 pit shell (as adapted from SRK Consulting, 2015b)

Figure 19: Final pit shells illustrating the distribution of sulfur and the position of the long-term water level after rebound for Orebodies 23 and 25 Pit

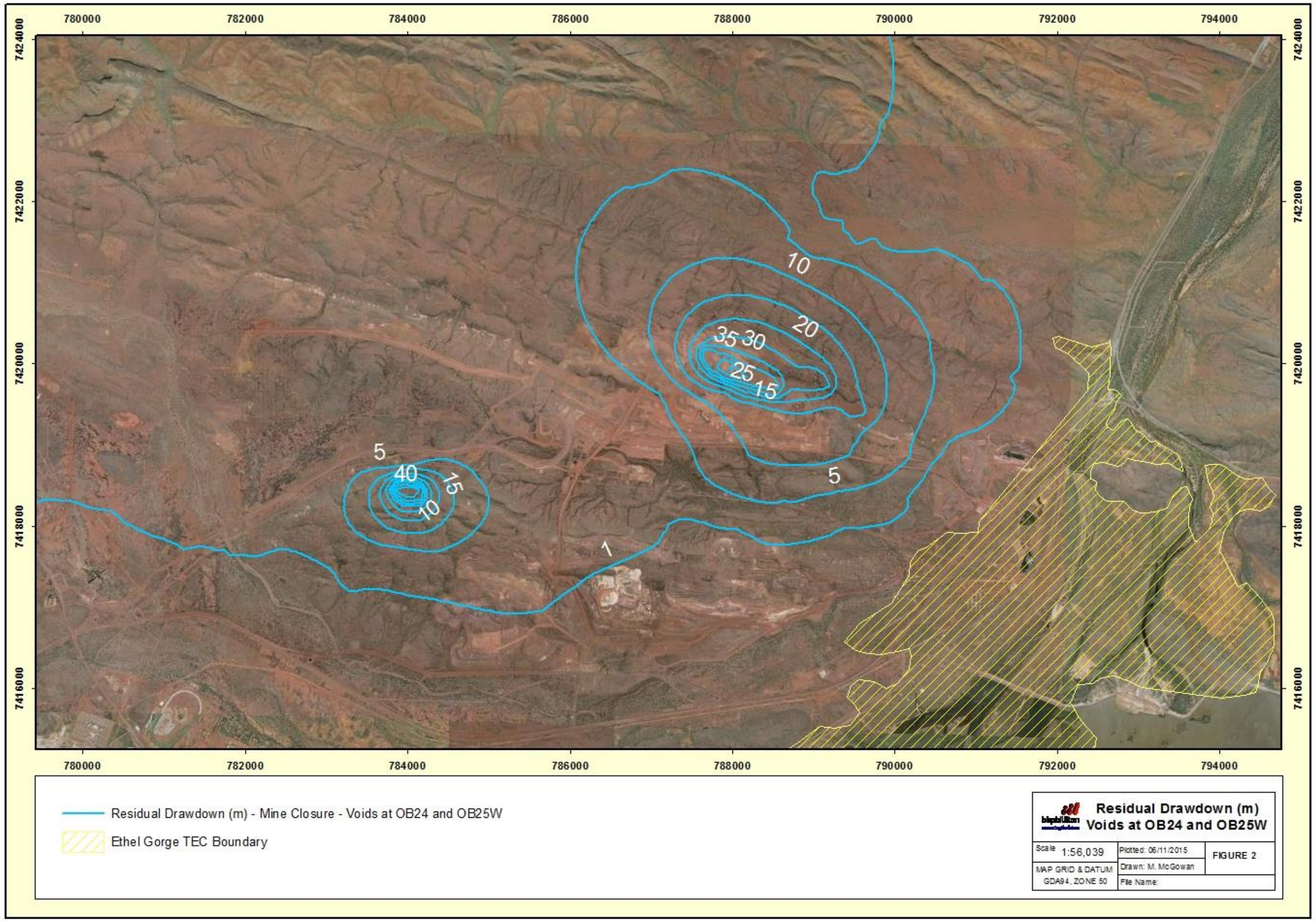


Figure 20: Closure Strategy Scenario – Residual Groundwater Level Change at Equilibrium

7.8.3.3 *Impacts to Eco-hydrological Receptors*

A number of closure scenarios have been evaluated to estimate some of the long term impacts and to direct subsequent studies and closure management plans. Post closures, the recovery timeframe and extent will depend to some extent on the closure options considered. However, the extent of water resource change is considered to be insignificant regardless of a pit void or backfill closure scenarios.

Riparian Vegetation

The risk from cumulative groundwater drawdown along the major length of Homestead Creek supporting *Eucalyptus victrix* is determined to be low, while the risk for the localised section of Homestead Creek immediately west of Orebody 25 West supporting *Eucalyptus camaldulensis* subsp. *refulgens* is determined to be moderate (Onshore, 2015).

The risk from cumulative groundwater drawdown to vegetation supporting the species *Eucalyptus victrix* and Eucalyptus *camaldulensis subsp*. *refulgens* at Fortescue River and Ethel Gorge is determined to be low to moderate (Onshore, 2015).

Measurements of leaf water potential from riparian trees in the Homestead Creek system collected since 2009 suggest that *Eucalyptus camaldulensis* subsp. *refulgens* and *Eucalyptus victrix* trees in the Upper Homestead Creek area are likely to rely on vadose zone water, and are unlikely to have any groundwater dependence (AQ2, 2015).

Tree health monitoring along Homestead Creek found no evidence that dewatering associated with existing operations has had an unacceptable negative impact on vegetation at monitored sites and that no monitoring triggers have been breached (Astron 2015).

As such impacts are not expected to impact the health of the riparian vegetation post-closure.

Ethel Gorge TEC

Over 40 years of monitoring data demonstrates that groundwater levels in this area fluctuate by up to 6 m in response to seasonal rainfall and runoff variations; however, habitat for stygofauna is considered to be maintained by zones of permanent saturation in the shallow alluvial groundwater system.

The cumulative effects of these new operations on groundwater levels in Ethel Gorge remain within natural variance during operational periods. The ultimate groundwater levels in Ethel Gorge show that with complete backfilling of Orebody 23 and Orebody 25 Pit 3 there is no residual drawdown predicted to occur long term in Ethel Gorge TEC (Figure 20).

During the transition period from operations to closure (when groundwater level may be influenced by surrounding operations dewatering) solute transport (from backfilled mine pits) beyond the mine void is a potential risk, however continuous dilution and flushing during large hydrologic events (e.g. cyclones) is expected to limit the transport of elevated solutes levels to the Ethel Gorge TEC. During the transition period, recovery of the groundwater table may be managed through aquifer recharge (if required) to reduce the accumulation of solutes and subsequent flushing of solute spikes

Groundwater Resource

The extent of long term impacts to the water resource during closure is not considered to be significant regardless of pit void or backfill closure scenarios. This is due to the relatively small magnitude of residual drawdown that would occur near any pit voids and because the voids would create localised groundwater sinks therefore containing any poor water quality within the pit.

7.8.4 Knowledge Gaps

The following knowledge gaps which have impacts on closure outcomes have been identified:

- Surface water assessment for other pits that may be impacted by Homestead Creek flooding e.g. Orebody 32 and Orebody 25 West, to inform closure design requirements.

- Better definition of the mine development plans for the pit and OSA areas to enable final designs for surface water.
- Fate and transport of solutes in groundwater from the backfilled mine voids of Orebody 23 and Orebody 25 pit 3 in relation to Ethel Gorge TEC.
- Better understanding of the Ethel Gorge Stygobiont Community.

7.9 Site Contamination

The Eastern Ridge mining operations has eight known or suspected contaminated sites, which are managed in accordance with BHP Billiton Iron Ore Contaminated Sites Management (Work Instruction). The sites are listed in Table 17 below and illustrated in Figure 21.

Remediation of free-phase product has commenced at the Orebody 25 former fuel farm facility with the installation of an active extraction system removing diesel contamination from the water table. This system was installed in the Financial Year (FY) 2016 following a trial period that indicated removal of the product from the surface of the water table would be a viable remediation option. Remediation activities at this site are ongoing, with the system anticipated to operate for two years.

Table 17: Eastern Ridge mining operations known/suspected contaminated sites

Contaminant	Reference
Hydrocarbon	Orebody 25 Former Fuel Farm
Hydrocarbon	Orebody 25 Bioremediation Landfarm
Hydrocarbon	Orebody 25 Ore-handling plant bunded area
Hydrocarbon	Orebody 25 Maintenance Workshop
Hydrocarbon	Orebody 24 Landfarm adjacent to Valley Haul Road
Hydrocarbon	Orebody 24 Inert Landfill facility
Hydrocarbon/Asbestos	Orebody 24 Historic Landfill facility
Hydrocarbon	Orebody 25 Existing Fuel Farm

Further contaminated sites investigations are proposed at the Eastern Ridge mining operations to determine the severity of contamination and define any remedial works. Prioritisation of investigations is based on risk as discussed with the DER.

7.9.1 Knowledge Gaps

The following knowledge gaps which have impacts on closure outcomes have been identified:

- Contamination assessments are incomplete for known and suspected contaminated sites.

7.10 Visual Amenity

The Eastern Ridge mining operations are located approximately three kilometres north-east of the Newman Township. Aside from Mount Whaleback it is the closest mining operation to the Newman Township. Newman is considered a Newman is considered a hub for a large proportion of Western Australia's mining workforce, both those residing in the town and those in transit on the way to other operations in the Central Pilbara.

A Landscape and Visual Impact Assessment (LVIA) has been carried out (360 Environmental, 2015) to assess the levels of potential impact to both visual amenity and landform values of Newman and its surroundings as a result of the Eastern Ridge mining operations.

Field surveys and a desktop review identified five 'key' viewpoints out of a total of ten identified sensitive receptors; Radio Tower Hill, Bubbacurry Loop, the Parnpajinya Aboriginal Community, the Newman Race Course and the Great Northern Highway.

The assessment suggested that potential impacts to the composition of views (and amenity values associated with them) is unlikely to change substantially from existing compositions.

The LVIA also assessed the potential cumulative impacts on land systems following cessation of operations and noted that impact levels for these systems were still relatively low (<3% of pre-European have been impacted). It should also be noted that impact statistics for the Eastern Ridge mining operations were calculated using a conceptual worst-case scenario (360 Environmental, 2015).

In summary, it was found that given the levels of existing impact, Eastern Ridge mining operations is unlikely to significantly affect the visual amenity values of Newman. Levels at the broader landform and landscape scale are also relatively small given that only a fractional percentage of landscape and landform types may be affected.

Potential impacts can be managed through standard operating and post-closure rehabilitation procedures.

7.10.1 Knowledge Gaps

No knowledge gaps have been identified.