Western Australia Iron Ore

Eastern Ridge Revised Proposal Hydrological Change Assessment

Department: Resource Planning - Hydrology

Contents

Executive Summary

This hydrological assessment has evaluated the cumulative hydrological effects associated with the Eastern Ridge Revised Proposal (the Proposal), the existing mining operations Orebody 23 (OB23) and Orebody 25 (OB25), surplus water management within Ethel Gorge, and the Ophthalmia and Homestead potable water supply borefields.

The assessment predicts the range of cumulative hydrological change in the vicinity of identified environmental receptors and groundwater resources and outlines the appropriate management options to prevent the impacts to these receptors through operations and into closure.

The assessment follows the Environmental protection Authority's (EPA) framework for environmental principles, factors, and objectives with respect to Inland Waters Environmental Quality and Hydrological Processes (EPA, 2015).

The Proposal considers OB24 below water table mining and Orebody 25 West (OB25W).

Assessment findings identified that the predicted cumulative impacts from dewatering at Orebody 24 (OB24) and OB25W are considered insignificant in relation to the total hydrological change predicted from existing water affecting activities such as dewatering and borefield pumping in the broader area of influence.

Furthermore, the assessment demonstrates that the predicted range of additional hydrological change and impacts expected during operations and closure can be managed and mitigated through the existing regional management plans and any residual long term impact are likely to be within natural variance and reasonable numerical error. The existing Eastern Pilbara Water Resource Management Plan (BHP Billiton Iron Ore, 2015) and the Newman Drinking Water Source Protection Plan (DoW, 2014) provide the basis for adaptive management and a risk based approach to mitigate the predicted impacts to hydrological conditions.

Water effecting activities

The Proposals considers the following water effecting activities:

- Dewatering of up to 24 gigalitres per year (GL/yr) from OB23 and OB25 (existing) and new below water table pits OB25W and OB24;
- The management of up to 19 GL/yr of surplus water generated by the dewatering which includes return of surplus water back to the subsurface via seepage from Ophthalmia Dam and associated infiltration basins and recharge ponds;
- Water supply pumping from Homestead and Ophthalmia borefields for the town of Newman;
- Interruption of existing surface water flow patterns, ponding, and reduction in flow volumes to downstream ecosystems due to mining infrastructure;
- The diversion and interception of Homestead Creek tributaries, and
- Closure related effects such as pit lakes.

Assets of value

Three primary water-related environmental and water resource assets that exist within the broader area of influence and could potentially be impacted by mining activities at Eastern Ridge are:

1. The Ethel Gorge aquifer Stygobiont community (a Threatened Ecological Community, or TEC);
2. Riparian vegetation along the Homestead Creek and Upper Fortescue River drainage line; and
3. The local groundwater resource, in particular the town of Newman drinking water borefields (Ophthalmia and Homestead borefields).

The hydrological changes associated with the identified water effecting activities have been evaluated in relation to potential impacts to the three key water-related environmental and water resource assets.

Groundwater abstraction and changes to groundwater levels – The change to regional groundwater levels resulting from OB24 and OB25W dewatering activities are localized to the mining area, and the cumulative regional groundwater drawdown is dominated by the abstraction from the Homestead borefield during the operational periods. The extent of the additional drawdown from the two proposed below water table mining operations (OB24 and OB25W) is minimal, representing around 20% of the total abstraction in the assessment and less than 5% of the total drawdown contribution beneath Homestead Borefield.

A number of closure scenarios have been evaluated as part of the assessment to predict the extent of long term impacts and to inform subsequent studies outlined in the Closure Plan. The assessment identified that the post closure recovery timeframes will depend upon the closure options considered. The extent of water resource change is not considered to be significant regardless of pit void or backfill closure scenarios and predicted changes to water quality are likely to be localized to the pit void. However, closure related studies will need to continue as mining progresses and more data becomes available to evaluate the potential changes to water chemistries at closure in and surrounding the pits and the likely impacts to the surrounding aquifers. These studies will inform the ultimate closure option as outlined in the Closure Plan.

Impacts to Ethel Gorge aquifer – The cumulative effects of the existing and proposed changes to operations on groundwater levels in Ethel Gorge is consistent with respect the original impact assessment for Eastern Ridge and are to remain within natural variance during operational periods owing to the Ophthalmia Dam recharge system maintaining water levels within the Ethel Gorge aquifer. The final post closure groundwater levels in Ethel Gorge will depend upon the closure scenarios and whether complete backfilling of below water table mines occurs. However, without complete backfill of Ob, there is a potential that a small residual drawdown (around 1m) will remain in part of the designated Ethel Gorge TEC boundary. This residual is considered to be within model error and unlikely to impact the stygofauna community.

The introduction of surplus water into the Ethel Gorge aquifer via Ophthalmia Dam and surrounding infiltration basins and recharge ponds is an existing management approach which will continue to assist in maintaining groundwater levels within historical ranges and prevent impacts to Ethel Gorge TEC habitat. However, the discharge of surplus water into these facilities also has the potential to modify the hydrological conditions to unacceptable levels during operations and closure in the Ethel Gorge aquifer, potentially impacting the TEC or riparian vegetation. The management of water levels in Ethel Gorge is outlined in the Eastern Pilbara Water Resource Management Plan (BHP Billiton Iron Ore, 2015a).

Ophthalmia Dam has the potential to increase salinity over time due to evaporative concentration of salts. The subsequent seepage of elevated TDS into the shallow groundwater could impact the Ethel Gorge TEC further downstream, although 35 years of historical monitoring does not demonstrate an increase to the TDS in the shallow aquifer of Ethel Gorge. Water quality monitoring will be undertaken in accordance with the adaptive management approach outlined within the Eastern Pilbara Water Resource Management Plan to identify such conditions as they start to develop to allow timely mitigation to be implemented prior to any significant impacts occurring.

Potential Impacts to Regional Water Quality – The groundwater across the assessment area is generally fresh with salinity values typically below 2,000 mg/L total dissolved solids (TDS). Changes to surface or groundwater quality from water rock interaction in the immediate area of the pit void and waste rock (producing acidity and metalliferous seepage) are unlikely to have an impact on the regional groundwater quality owing to low potentially acidic forming material, proposed waste rock management and handling techniques during operations, monitoring and adaptive post closure management plans.

Surface water resources – The percentage loss of surface water from the broader catchment area owing to the new operations represents around 6.2% of the Homestead Creek catchment and 0.4% of the Fortescue River system catchment at Ethel Gorge. The extent of hydrological change and interception to the surface water flow volumes and resources is considered to a minor in relation to the total catchment flow and the extent of hydrological change is unlikely to result in impacts to the downstream water resource and dependent environments.

1. Introduction

Project Overview and Description

The Eastern Ridge mining operation is located approximately eight kilometres (km) east of Newman Township in the Pilbara region of Western Australia (Figure 1). The project area consists of Orebody 23 (OB23), Orebody 24 (OB24), Orebody 25 (OB25), Orebody 25 West (OB25W), and Orebody 32 (OB32) within Mineral Lease ML244SA, which is subject to the Iron Ore (Mount Newman) Agreement Act 1964 (Newman Agreement Act).

BHP Billiton Iron Ore Pty Ltd (BHP Billiton Iron Ore) is proposing to amalgamate the Eastern Ridge mining operations under a single Ministerial Statement through referral as a Revised Proposal. The Eastern Ridge operations involve conventional open pit mining, with ore then crushed at the OB24 and OB25 crushers or a moveable crusher and railed to Newman Hub, or directly to port based on business requirements.

The current mining operations include:

- Orebody 23 (OB23) operated under Ministerial Statement 478;
- Orebody 24 (OB24) operated under Ministerial Statement 834;
- Orebody 25 (OB25) operated under Ministerial Statement 712; and
- Orebody 32 (OB32) currently under assessment by the EPA.

The elements of the Eastern Ridge Revised Proposal (the Proposal) that are considered in this impact assessment are mining below water table at OB24 and OB25W.

Current environmental approvals allow BHP Billiton Iron Ore to mine OB24 above water table under Ministerial Statement 834. Approval is being sought to mine below the water table.

Approval is also being sought for the OB25W mining operation which will require both above and below water table mining methods.

Amalgamating Ministerial Statements 712 and 834 as part of the proposed Eastern Ridge referral will provide environmental and water management consistency. OB23 (Ministerial Statement 478) is not included in this approvals process.

The consolidated Eastern Ridge mining operations will then be bounded by a single Development Envelope (Figure 1), with a single Key Characteristic Table, contemporary Ministerial conditions, and a regional approach to Management Plans. The Eastern Ridge mining operations will comprise OB24, OB25, OB25W and OB32 mining operations (Figure 1).

Hydrological Assessment Area

The key hydrological features surrounding the Eastern Ridge mining area are presented on Figure 1.

The hydrological assessment area extends beyond the Development Envelope approximately 10km west to include the upper Homestead Creek catchment and 10km south and east to include Ethel Gorge and Ophthalmia Dam.

The Ethel Gorge Aquifer Stygobiont Threatened Ecological Community (TEC) is located immediately east of the Eastern Ridge operations within the upper Fortescue river system. The TEC has been identified as a key environmental receptor as it represents a diverse assemblage of stygofauna.

The Ophthalmia Dam system which comprises the dam, two infiltration basins and three recharge ponds and connecting drainage system is located to the southeast of the Eastern Ridge hub (Figure 2). The dam, basins and, ponds overly the Ethel Gorge aquifer which hosts the stygofauna TEC. The system was installed to maintain water levels within the Ethel Gorge aquifer to support the Ophthalmia Borefield which provided drinking water supplies to the Newman Town. The borefield continues to provide around 50% of Newman's town water supply and falls within the Newman P1 Drinking Water Reserve (DoW, 2009 and 2014).

The Homestead borefield, located about 3km west of OB25W, complements the Ophthalmia borefield and provides the other 50% of the Newman town water supply. The borefield is located within the Newman P1 Drinking Water Reserve and is included in the associated Source Protection Plan.

The Ophthalmia Dam system continues to maintain water levels within Ethel gorge for the purpose of protecting the TEC and also provides a discharge location for surplus water from the mines within the Eastern Pilbara, including OB23 and OB25.

Homestead Creek is the primary hydrological feature which flows through the assessment area (Figure 1) and conveys surface water flow from the upper catchment area south of OB25 to the Upper Fortescue River. The Homestead creek and Fortescue River converge at Ethel Gorge between OB23 and OB25.

Other relevant nearby operations include the Newman Joint Venture (NJV) hub, located approximately two km west of Newman Township, which consists of Mount Whaleback and Orebodies 29, 30 and 35 and the Jimblebar hub which includes OB31, located approximate 40 km east of Newman Township. Both hubs are relevant from an overall Eastern Pilbara water balance perspective in that historically surplus water from Eastern Ridge was transferred to NJV and in the future all three hubs are projected to have a water surplus.

Scope of this document

This assessment report presents a summary of the hydrological change that may result from below water table mining, mine dewatering, surplus water management, and the disturbance or alteration of surface water due to mining activities at Eastern Ridge. A number of technical studies have been completed to support the assessment, and these are detailed in appendices and summarised below. Although the primary focus of this assessment was for the proposed dewatering operations at OB24 and OB25W and the potential to impact the environment and water resources, the potential cumulative effects from current and future operations and facilities were also considered, including currently approved OB23 and OB25 mining operations, plus Homestead and Ophthalmia Borefields which supply drinking water to the town of Newman.

Three primary water-related environmental assets have been identified that may be impacted by mining activities at Eastern Ridge:

1. The Ethel Gorge aquifer Stygobiont community (a Threatened Ecological Community, or TEC);
2. Riparian vegetation along the Homestead Creek drainage line; and
3. The local groundwater resource and the associated town of Newman Homestead and Ophthalmia Water Supply Borefields.

The hydrologic studies carried out were completed specifically to assess the potential hydrological change (such as water level, flow and quality) associated with the proposed mining activities on these three water-related assets.

2. Strategic Regional Management Approach

The strategic approach to manage the water related impacts from the range of mining related activities and water risks are outlined in two key documents:

1. The Eastern Pilbara Water Resource Management Plan (EPWRMP) (BHP Billiton Iron Ore, 2015a), and
2. The Newman Water Reserve Drinking Water Source Protection Plan (DoW 2014).

Eastern Pilbara Water Resource Management Plan

To meet our legal commitments and sustainability obligations, the EPWRMP has been developed to provide a regionally consistent methodology for identifying and managing water related environmental and community risks, considering:

- Hydrological changes (baseline, current and future conditions of groundwater, soil moisture and surface water) resulting from BHP Billiton Iron Ore dewatering operations;
- Receiving receptors (water resources, environment, social and third-party operations), identified value and hydrological dependency (groundwater, soil moisture and/or surface water);
- Potential impacts (predicted and actual) attributable to BHP Billiton Iron Ore mining activities; and
- Required risk-based adaptive management techniques that are feasible (tested and practicable) to mitigate potential impacts to acceptable levels during operations and closure.

The regional water management approach iteratively collates the key findings of eco-hydrogeological technical studies to inform the required adaptive management to enable achievement of outcome-based objectives. The adaptive management is risk based and is expected to proactively counteract, mitigate or manage potential impacts (both predicted and actual) to an acceptable level.

The approach addresses the overall water catchment management area and the specific BHP Billiton Iron Ore operations within the catchment (eastern Pilbara Hub). It applies catchment scale water management principles, allows for future approval processes and will simplify and provide transparency on water management criteria, risks, controls and water licenses.

The regional water management approach requires that specific regulatory commitments are linked to outcome-based objectives and adaptive management methods for significant receptors if impacted by BHP Billiton Iron Ore operations. The BHP Billiton Iron Ore adaptive management process for water in the Pilbara is detailed in Figure 3.

The Eastern Ridge hydrological change assessment considers the above adaptive approach. The hydrological changes associated with OB24 and OB25W have been evaluated as a new stress entering the management process for the existing mines and borefields. The impact assessment methodology addressed below considers the hydrological change assessment to determine whether the existing mitigation controls to prevent impacts to the key receptors remain effective and valid.

Newman Drinking Water Source Protection Plan

The purpose of this plan is to provide a source protection and management of potable water in the Newman Water Reserve. This plan provides the strategy to protect the current supply bores, modify the pumping configurations owing to land use change and establish systematic requirements for future potable supply bores. The Plan also provides direction on monitoring, procedures and accountabilities.

BHP Billiton's Western Australian Iron Ore (WAIO) operates the bores and water treatment plant, while the Water Corporation operates the reticulated supply scheme and is the licensed water service provider.

This Plan has been prepared in accordance with internal standards and the Australian Drinking Water Guidelines (NHMRC, NRMMC 2011) and in consultation with the Department of Water, Department of Health and the Water Corporation of WA.

3. Change Assessment Methodology

The following methods were used to carry out this hydrological change assessment in order to determine whether there are likely to be unacceptable impacts to hydrological processes environmental assets and:

- Identification of water related environmental assets and community receptors such as the two Newman drinking water borefields (Ophthalmia and Homestead borefields);
- Identification and quantification of water affecting activities associated with the proposed and existing mining operations (e.g. abstraction for dewatering purposes) ;
- Description and conceptualization of geological and hydrogeological environments including baseline conditions. This included dedicated drilling and hydraulic testing programs at the new proposed below water table pits;
- Change assessment including assessment of potential cumulative impacts from new and already approved operations and existing and proposed surplus water management techniques. This included a predictive cumulative change assessment to groundwater levels on a regional or catchment scale using a 3-dimensional numerical groundwater flow model;
- Groundwater and potential surface water quality change from ARD and metals were evaluated as part of the closure assessment study;
- Impacts from surplus water discharge on the groundwater system were evaluated as part of the cumulative numerical model and potential changes to the water quality was evaluated through salt balance modeling;
- Surface water change was evaluated by estimating the reductions in surface water flow volumes to downstream ecosystems and creeks.
- Evaluation of the potential hydrological changes in relation to the current groundwater and surface management approach and the determination whether the management methods were still valid and applicable to mitigate unacceptable impacts during operations or closure.

4. Summary of Water Affecting Activities

There are a number of mining related activates that currently take place or are planned which have the potential to affect surface and groundwater quantity and quality. These 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 mine dewatering purposes. Dewatering commenced in 2006 at OB23 and OB25 and additional dewatering is proposed to enable below water table mining at OB24 and OB25W.
- 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 basins and recharge ponds.
- Exposure of potential acid forming material in pit void walls during mining operations and closure.
- 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.

5. Assets of Value

5.1. Ethel Gorge Threatened Ecological Community (TEC)

The Ethel Gorge TEC has been identified as a key Eastern Pilbara environmental asset which is listed by the Department of Parks and Wildlife (DPaW). There have been at least 82 species recorded to date, 40 of which are considered core endemics to the Ethel Gorge Aquifer and/or associated neighbouring aquifer systems in the local Newman area (Bennelongia 2015).

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. The current spatial extent of the TEC is illustrated on Figure 1, as defined by DPaW, this boundary is understood to be based on the surface expression of calcrete in the area. A more detailed description of the Ethel Gorge TEC and associated stygofauna assemblage are provided in Bennelongia 2015.

5.2. Riparian Vegetation

Two native tree species, Eucalyptus camaldulensis subsp. *refulgens* and *Eucalyptus victrix*, occur within the Homestead Valley and Ethel Gorge areas and have been identified as having local significance (Onshore, 2015). In Pilbara ecosystems both species are considered to have the ability to opportunistically use groundwater (i.e. are facultative phreatophytes) although *Eucalyptus victrix* may also function in some environments as a vadophyte (primarily use water held in the vadose zone (unsaturated) that occurs above the water table) (Onshore, 2015). Potential impacts could occur to the vegetation if they are accessing groundwater and groundwater levels are lowered sufficiently beyond natural variability.

It is worth noting that during the 1970s (before the construction of the Ophthalmia Dam) water levels within the Homestead Valley (south of OB25) and Ethel Gorge were much lower than those observed today due to potable water supply pumping from Ophthalmia borefield. In some areas, saturated thickness was reduced to less than 50%.

5.3. Groundwater Resource

Eastern Ridge sits within the Newman Water Reserve P1 public drinking water source area, which covers the aquifers that feed the Newman town potable supply. Active mining operations at OB24 and OB25 occur within 5 km of the Homestead and Ophthalmia water supply borefields. Potential impacts to the groundwater resource could result from aquifer depletion due to excessive drawdown from mine dewatering or changes in water quality associated with chemical contaminant release (e.g. hydrocarbons) or increased salinity from surplus discharge to Ophthalmia Dam.

6. Predicted Water Balance

An integrated water balance assessment has been carried out which takes into account the key water activities across the Eastern Pilbara operations. The water balance includes the existing and proposed Eastern Ridge operations. An integrated approach was considered necessary owing to cumulative water effects and water sharing between BHP Billiton operations. These include:

- groundwater and surface water abstraction via bores and in-pit sumps for dewatering purposes;
- groundwater abstraction via bores for potable water supply;
- use of dewatering water for ore processing, dust suppression, and construction purposes;
- transfer of surplus water to Ophthalmia dam and return of groundwater to subsurface via infiltration basins and recharge ponds; and
- discharge of surplus water to surface drainage (trial at OB31).

Water balance modelling shows that the collective water balance for the Eastern Pilbara operations will present a significant net surplus over the next 15 years. The surplus volume reflects operations which extend over a distance of 45 km, including from Whaleback (OB29, OB30, and OB35), Eastern Ridge (OB23, OB25 and OB24), OB31 and Jimblebar. The total surplus is estimated to range between 20 and 55 ML/d (BHP Billiton Iron Ore, 2015b). The volume is approximated and the surplus is anticipated to vary monthly and annually due to mine plan changes, short term dewatering efforts and seasonal water demand fluctuations.

Ophthalmia Dam and the adjacent recharge ponds are key tools for the management of surplus water across the Eastern Pilbara operations as these mechanisms allow for the return of water to which is aligned with the Department of Water's hierarchical controls for surplus water management (DoW, 2013).

The operation of Ophthalmia Borefield is a another key mechanism that can be used to manage water levels within the Ethel Gorge TEC as pumping can be increased or decreased (balanced by abstraction from Homestead Borefield) to either draw water levels down during periods when the Dam receives high inflows (both natural flows and surplus discharge) or to allow water levels to be maintained or to even recover during periods of low inflows to the Dam.

A local water balance for Eastern Ridge which details estimated dewatering rates for the various pits, water demand across the site (i.e. volume used on site for processing, dust suppression, etc), and corresponding water surplus is shown in Table 1. The dewatering rate projections are based on numerical modelling results, short term aquifer tests, and historic dewatering rates at OB23 and OB25. The estimates will vary depending upon changes to the mine plan schedules and vertical development rate and the numbers presented below are for impact prediction purposes only and may vary from year to year resulting from mine development variations. Note: the water balance presented in Table 1 assumes that dewatering continues at OB23 and OB25 (pits 1 and 3) through FY21 even though these operations will have finished mining. Therefore the water balance represents an upper estimate for surplus that will need to be managed and that the actual volumes will likely be lower as dewatering is scaled back and ultimately stopped at those pits (OB23 and OB25).

Table 1: Water balance estimates for Eastern Ridge FY16-21.

Component	Water Balance (GL/yr)
OB23 dewatering	4-5
OB24 dewatering	3-5
OB25 Pit 1 dewatering	1
OB25 Pit 3	8-10
OB25 West	1-3
ER Total Dewatering (GL/yr)	**17-24**
ER Demand (GL/yr)	**4-5**
ER Surplus (GL/yr)	**12-20**

7. Hydrogeological Characterisation and Baseline

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 Eastern Ridge (e.g. OB25 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 throughflow from the alluvial system (e.g. OB23) with lesser amounts of recharge occurring from direct rainfall infiltration. Ophthalmia Dam and the associated infiltration basins and recharge 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 545 m AHD across the mining areas towards Ethel Gorge at about 510 m 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 OB23 and OB25 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.

Details of local hydrogeological conditions for the mining areas and water supply borefields are presented below.

Orebody 24 Hydrogeology

The main OB24 range consists primarily of outcropping Brockman Iron Formation (Figure 4). To the south the Dales Gorge Member is conformably underlain by the Mount McRae Shale and the Mount Sylvia Formation. Dolerite and BIF of the Weeli Wolli Formation occur to the north of OB24. Detrital cover is thin at OB24 consisting usually of <1 m of scree. There is deeper cover to the south and north of the deposit.

OB24 has a moderate level of structural complexity in comparison to other Eastern Ridge and Homestead orebodies. The folding style is similar to OB25, with the regional D2, D3 and D5 events (Kneeshaw, 2008) having a major role in the development of structures at OB24 (Figure 5). Well-described regional faulting occurs in close proximity to OB24 which includes the Whaleback and Fortescue River Faults (Kneeshaw, 2008). The Fortescue River Fault truncates the stratigraphy and Whaleback Fault east of OB24, separating it from OB23 (Figure 4).

The hydrogeological conceptual model for OB24 is based on a dedicated hydrogeological drilling and aquifer testing field program which was undertaken in 2014 (BHP Billiton Iron Ore, 2014a), ongoing regional groundwater monitoring as well as historic dewatering operations at nearby Brockman Iron Formation deposits, primarily OB23 and OB25.

The field program at OB24 comprised the following:

- Drilling of 13 exploration bores to assess the hydrogeological properties of the aquifer(s) (airlift yields, groundwater levels and quality) and the geology;
- Installation of 10 standpipe piezometers for use during short term test pumping and long term water level monitoring;
- Drilling and construction of two production bores;
- Construction of six piezometers in suitable, existing RC holes;
- Test pumping of the two production bores to estimate aquifer properties. The test pumping comprised short term step-rate and longer term constant-rate tests (up to 5 days duration); and
- Collection of water samples from each production bore at the end of test pumping for laboratory analyses of major ions, as well as Total Dissolved Solids (TDS), pH and a range of metals.
- Collation and interpretation of the regional groundwater levels within the aquifers and water bearing formations around OB24.

Hydrogeological units have been defined largely in terms of geology and the degree of iron mineralisation, as the primary hydraulic properties are influenced by these characteristics.

- Mineralised Dales Gorge hydrogeological unit is moderately permeable with airlift yields between 5 and 10 L/sec. Estimated Transmissivities range between 100 to 275 m^2/d and horizontal hydraulic conductivity of about 2-4 m/d. The vertical hydraulic conductivity is likely about 2 to 10 times less permeable based on the strongly bedded nature of the unit however local faulting may enhance the vertical permeability. Specific yield has been estimated at 5% (RPS, 2013). Water quality from this unit is fresh with TDS <400 mg/L and pH around 7-8.
- Submineralised Dales Gorge hydrogeological unit is designated herein as having a Fe content between 32-48% by weight; less than 32% is considered unenriched, and hence expected to have a relatively low hydraulic permeability. This unit comprises shale, BIF and chert with variable silica content. The thickness of this unit can exceed 100m at OB24, although frequently is less as mineralised Dales Gorge often extends down to Mt McRae shale and close to the top of the Dales Gorge Member. Airlift yield data for this unit show generally lower yields, but include the highest yield measured in the hydrogeological field program at 18 L/s. Based on the testing undertaken to date, the unit is moderately permeable, with a horizontal hydraulic conductivity (K_h) value of 1-2 m/d. Estimated K_h values from field data for this unit is significantly higher than that adopted for previous studies (e.g. RPS, 2013). Permeability is interpreted to be associated with fractured or faulted zones. Unit porosity is expected to be moderate to high in places, in the range of 5 to 20%. Specific yield is expected to be lower than the mineralised unit and is estimated to be around 2 or 3%.
- Mt McRae Shale and Mt Silvia Formation; relatively little hydraulic data is available for these units within OB24. Testing and regional water level data, including some holes at nearby OB23, indicates zones of potentially higher permeability then what would otherwise be estimated for these units (RPS, 2013). This likely reflects enhanced permeability along structures associated with folding and faulting.

The current water table ranges from about 517 m AHD in the west of OB24 to 515 m AHD in the east and flows in an ESE direction along the deposit towards the east and Upper Fortescue River. A step change (~35m) has been identified in water levels in the vicinity of mapped dolerite intrusions near OB23 associated with the Fortescue River Fault (Figure 6). This water level variance indicates the intrusions are likely to be of low permeability and presents a barrier to groundwater flow thus limiting the western extent of drawdown that has occurred from almost 10 years of OB23 dewatering activities.

The dewatering rates required for OB24 are estimated to be moderate (3-5 GL/yr) based on the hydro drilling and test pumping results to date as well as the hydrostratigraphy of the area in which the ore body aquifer is generally in contact with low permeability material. However, several cross-cutting faults have been recently been identified (post hydro drilling and test pumping) in resource drill holes which have the potential to allow connection (enhanced permeability) across units resulting in potentially higher dewatering rates. This is to be investigated further by longer term test pumping.

OB23 and OB25 Hydrogeology

The main aquifers at OB23 and OB25 are the unconfined to semi-confined fractured–basement rock aquifer of the Dales Gorge Member and the unconfined alluvial aquifer within the Homestead Creek valley. These two aquifers are generally in direct contact and are considered to be hydraulically connected. However, zones of variable hydraulic connection exist in some areas, such as the OB25 Pit 3 south wall, where multi-level groundwater monitoring points demonstrate that the vertical hydraulic connection between the alluvial aquifer and the deeper orebody aquifer is constrained due to intervening, low-permeability weathered shale and clay sequences (Schlumberger, 2013).

In addition, at OB25, while the mineralised Dales Gorge Member constitutes the main aquifer, the mineralised Joffre Member forms an aquifer with moderate to high permeability.

The alluvial aquifer at OB23 and OB25 forms part of the east dipping alluvium-filled palaeovalley beneath Homestead Creek, which is up to 90 m thick and which has been eroded into the basement rocks of the Brockman Iron Formation, Mt McRae Shale, Mt Sylvia Formation and Wittenoom Formation. Some dissected zones of chemically deposited calcrete form part of the upper alluvial aquifer succession within the upper 50m. The calcrete is characterised by secondary porosity, with karstic features developed through partial dissolution by percolating surface water and groundwater movement. The calcretes outcrop in sections of the south wall of OB25 Pit 3 and the southwestern corner of OB23, which creates a hydraulic connection between the upper section of the alluvial aquifer and the pit voids. Water discharging into the pit from the calcrete is collected in drains and removed via sumps.

The northern walls of OB25 Pit 3 and of OB23 are comprised of the low-permeability Yandicoogina Shale Member of the Brockman Iron Formation and the Weeli Wolli Formation respectively, and historical groundwater levels within these units demonstrate limited hydraulic connectivity to the north (Figure 4).

Orebody 25 West Hydrogeology

The OB25W deposit geology comprises members of the Brockman Iron Formation (Yandicoogina Shale Member through to the Dales Gorge Member), the Mount McRae Shale, Mount Sylvia Formation, and the Wittenoom Formation (Bee Gorge Member). To the north, the Weeli Wolli Formation and Wongarra Rhyolite are also present (Figure 7). Tertiary Detrital cover (TD3 and TD2) overlies bedrock sequences off the ridge to the south and the north, however, the majority of the deposit is confined to the ridge itself. OB25W is structurally complex; the stratigraphy is overturned in places, tightly folded and faulted. The folding and faults are considered consistent with features along strike at OB25 that have been truncated by the Whaleback Fault (Figure 7).

The hydrogeological conceptual model for OB25W is based on a dedicated hydrogeological drilling and monitoring bore field program which was undertaken in 2013 (BHP Billiton Iron Ore, 2014b) as well as reviewing groundwater level responses to surrounding stresses such as historic dewatering operations at OB25 and water supply pumping from the Homestead Borefield. OB25W is expected to have around 40m of below water table ore.

The field program at OB25 West comprised the following:

- Drilling of 9 exploration bores to assess the hydrogeological properties of the aquifer(s) (airlift yields, groundwater levels and quality) and the geology;
- Installation of 9 standpipe piezometers for use of long term water level monitoring; and
- Construction of 10 piezometers in suitable, existing RC holes within both mineralized and sub mineralized rocks.

Although no aquifer tests have been completed at OB25W the following hydrogeological assumptions have been made based on airlift yields, water levels, local geology, geotechnical logging, and nearby dewatering operations in similar geological settings:

- Potential groundwater bearing formations at OB25W include the mineralised and submineralised ore body aquifers of the Dales Gorge and Joffre Members. These units exhibit moderate permeability with horizontal hydraulic conductivity values ranging between 1 and 3 m/d. Highly permeable zones are interpreted to be associated with fractured or faulted zones.
- Mt McRae Shale, Mount Silvia Formation, Yandicoogina Shale and Jeerinah Formation are likely to represent lower permeability units which would contribute minor inflows to pit voids and also limit the extent of lateral drawdown away from the primary deposit.

Groundwater levels at OB25W are highest within the J1 pit area, at approximately 525 mAHD, and lowest towards the open pit at OB25, at approximately 494 mAHD, these latter levels are likely affected by dewatering at OB25 Pit 1 located to the east-southeast. Water levels in the vicinity of the D1 pit are at approximately 514 mAHD.

A step-change in groundwater level is present on the southern side of the J1 pit area, where groundwater levels on the upthrown (southerly) side of a thrust fault are approximately 20m lower than those on the northern side. It is likely that these measurements indicate that the thrust fault is a barrier to southern groundwater flow. Dewatering activities at OB25 have however, effected groundwater levels on the upthrown side of the fault. The change in water table is shown on Figure 7.

Ethel Gorge/Ophthalmia Borefield Hydrogeology

Ethel Gorge is located on the Fortescue River 15 km north east of Newman and downstream (north) of the confluence of Homestead, Shovelanna and Warrawandu Creeks within the Fortescue River. The gorge occurs where the Fortescue River flows through the Ophthalmia Range in a northerly direction. Downstream of Ethel Gorge, the ephemeral river flows in a braided channel system (up to 30 m wide) to the north and then onto a broad flood plain and ultimately into the Fortescue Marsh (RPS, 2014a).

Ethel Gorge aquifers have been used for town and mine water supplies for Newman since the Ophthalmia Borefield (formerly the Ethel Gorge Borefield) was developed in 1969. Abstraction from the borefield steadily increased during the 1970s, leading to concerns regarding the long term sustainability of the resource. A managed aquifer recharge scheme – namely Ophthalmia Dam - was constructed on the Fortescue River and started operation in 1982. The dam is 5 km upstream of Ethel Gorge and was constructed to enhance recharge and augment groundwater resources in the Ethel Gorge area. The dam impounds water much of the time and forms a largely permanent surface water body in close proximity to Ethel gorge. Although historically the dam was built to sustain a drinking water aquifer, it now also has an important management control function to support the eco hydrology of Ethel Gorge (RPS, 2014a).

The Ethel Gorge groundwater system occurs in valley sediments bounded by predominantly low permeability basement rocks (except where the Tertiary aquifer is in contact with the weathered dolomite) (Figure 8). It consists of a highly permeable alluvial aquifer comprising an upper unit of sandy alluvium and calcrete (upper alluvial aquifer) and a lower unit of gravelly alluvium (deep aquifer). The two units are discontinuously separated in some areas by a laterally deposited lower permeability leaky aquitard sequence comprising silts and clays. Orebody aquifers, hosted in the Brockman, may have varying levels of hydraulic connection with the upper alluvial and deep aquifers respectively (evident by piezometric responses from OB25 monitoring bores) where the mineralised zone occurs on the flanks of the valley and is in direct contact with the valley fill.

The hydraulic behavior of the Ethel Gorge groundwater system is dominated by both the Ophthalmia Dam and the Homestead Creek drainage system during periods of high streamflow. The dam serves to detain surface water flow to increase groundwater recharge to the down gradient upper and lower alluvial aquifers.

The upper alluvial aquifer is unconfined and receives recharge from direct infiltration associated with river flow events along the Fortescue River and Homestead Creeks. In addition to seasonal recharge along the river channels, the upper aquifer also receives water seeping from Ophthalmia Dam and this supports long-term trends in the volume of water stored in the aquifer and associated water levels.

Groundwater levels in the upper alluvial aquifer are within 10 metres below ground level across the entire valley floor area. This provides a substantial saturated thickness in the upper alluvium and calcrete, which constitutes the main extent of prospective stygofauna habitat.

The lower alluvial aquifer is largely confined by the overlying aquitard and is predominantly subject to sustained recharge from Ophthalmia Dam. Bore data indicates that the lower aquifer has piezometric heads which commonly equal or exceed water levels in the upper alluvial aquifer, particularly close to the Dam.

Recharge to the groundwater systems in the Ethel Gorge area occurs predominantly as seepage from Ophthalmia Dam at a rate up to 50 ML/d (Figure 8). Other sources of recharge include direct infiltration upstream of Ethel Gorge from channel flow events (along the Fortescue River channel when the dam overflows and above the area of impoundment) and also along Homestead Creek and Shovelanna Creek which are unregulated. Total recharge from infiltration along creek channels upgradient from Ethel Gorge is approximately 24 ML/d (average) on an almost annual basis. There is also a small component of throughflow into the Ethel Gorge area from the upstream catchments; estimated to be approximately 2 ML/d in total.

Recharge volumes mainly replenish the shallow alluvial aquifer. Percolation into the lower aquifer is restricted by the lower permeability aquitard and the hydraulic loading (pressurisation) of the deep aquifer.

Groundwater discharge occurs as throughflow along Ethel Gorge (estimated to be around 3 ML/d), evapotranspiration from riparian vegetation communities (approximately 14 ML/d) downstream of the dam and pumping (approximately 10 ML/d) for pre-dewatering steady state conditions.

Homestead Borefield Hydrogeology

A brief description of the Homestead Borefield hydrogeology is presented as potential impacts from the borefield due to abstraction was considered as part of the cumulative impact assessment, particularly in the vicinity of OB25W (Figure 1).

Pumping from Homestead Borefield commenced in September 2013 at a rate of about 2.5 GL/year.

The major aquifer units in the Homestead area comprise fractured rock aquifers of the Brockman and Marra Mamba Iron Formations (both Banded Iron Formation (BIF) units) and the dolomite aquifer of the Wittenoom Formation (comprising the Bee Gorge and Paraburdoo Members). Valley infill material (alluvium and colluvium) are of sufficient thickness and extent to potentially form local aquifers.

The Marra Mamba and Brockman Iron Formation aquifers are considered to form discreet localised aquifers of variable extent, whereas the Paraburdoo dolomite of the Wittenoom Formation typically forms the most regionally significant aquifer unit in the Pilbara, especially when karstic features are present. However, in the Homestead Borefield no significant karst development was intersected during field investigations.

8. Hydrological Change Assessment

Hydrologic changes that could result in an impact to the key environmental assets in the area (Ethel Gorge TEC, groundwater resource, and riparian vegetation) from the water effecting activities outlined above include:

1. Changes to regional groundwater levels which includes drawdown or elevated groundwater levels down gradient of Ophthalmia Dam;
2. Groundwater quality change;
3. Changes to surface water flow volumes or water quality

These hydrologic changes and associated potential impacts to the environmental assets have been considered for both operational and mine closure timeframes. The assessment considers hydrological change from OB24 and OB25W and also incorporates the cumulative effects resulting from activities from approved mining areas (OB23 and OB25) and nearby operating borefields (Ophthalmia and Homestead).

A regional numerical groundwater model (the model) has been developed (Appendix 1) which includes the Eastern Ridge mining operations, the Ethel Gorge TEC, Ophthalmia Dam, and the Homestead and Ophthalmia water supply borefields. The model has been used to estimate radial extent of drawdown during operations, the required dewatering volumes to enable the mine plan, and to assess the long term recovery of water levels during mine closure time frames.

The model calibration and outputs are sensitive to a number of hydrogeological controls. The most significant of these include the geometry and hydraulic parameters assigned to the various alluvium layers in Ethel Gorge and the orebodies, the seepage rate through the base of Ophthalmia Dam and the evapotranspiration characteristics of vegetation within Ethel Gorge.

8.1. Changes to Groundwater Level - Mine Dewatering

OB24

The pre-mining water table at OB24 is approximately 515 mAHD. Water levels will need to be lowered by up to 35 m to enable below water table mining conditions to 484 mAHD. Below water table mining is currently scheduled to occur over about a 5 year period from 2017 to 2021 (Q3 YEJ2021).

The numerical groundwater model was used to estimate the drawdown associated with dewatering at OB24. Figure 9 shows the estimated drawdown due to dewatering at OB24 when the base of below water table mining has been reached (Q3 YEJ2021). Inspection of Figure 9 illustrates that water levels are expected to be lowered up to 35 m at OB24 with the 1 m drawdown contour extending out radially for about 2 km from the base of the pit and to within about 1km of the designated Ethel Gorge TEC boundary. This drawdown extent is limited by lower permeability strata surrounding OB24 as well as the relatively small magnitude and timeframe of below water table mining and pumping which is required at OB24. The maximum dewatering for OB24 is estimated to be about one-half which has historically occurred at OB23 and one-third of that which has occurred to date at OB25 Pit 3.

Radial drawdown from dewatering at OB24 will be relatively local in extent and will not occur within any regional scale aquifers that are considered to have environmental value as a groundwater resource.

Dewatering rates will vary owing to the vertical mine development rate. The dewatering is anticipated to be up to 5 GL/y but is likely to average around 2.5 GL/y.

OB25W

Below water table mining is planned in two pits at OB25W. The Dales pit is located in the southwestern portion of OB25W and water levels are currently at about 515 mAHD and will only need to be lowered by about 24 m to enable mining of the below water table portion of the pit. The Joffre pit is located in the northern part of OB25W and the water table is currently at about 525 mAHD and will need to be lowered by up to 40 m to allow dry mining conditions to the 484 mAHD. Below water table mining in the Joffre pit is currently scheduled to occur over a three year period from 2018 to 2021.

Figure 10 shows the estimated drawdown due to dewatering at OB25W once the final pit depth has been reached (Q3 YEJ2021). In general, the zone of drawdown is confined to a radius of about 1 km from the base of the Joffre pit with the exception being in the westerly direction in which the model indicates it may extend out to a distance of 4 km. This is the result of drawdown propagating outwards within the Wittenoom Formation which in the model has a relatively high permeability and which needs to be verified with actual pumping data.

OB25W is located within 5 km of Homestead Borefield and drawdown could occur with the regional dolomite aquifer system to the west of the ore body. However the amount of estimated drawdown that will occur is small (1-2m) compared to the overall thickness (>150m) of the regional aquifer in this area and within the range of seasonal water table fluctuations.

Dewatering rates will vary owing to the vertical mine development rate. The dewatering is anticipated to be up to 3 GL/y, although the average dewatering rate is expected to be around 1.5 GL/y.

8.2. Changes to Groundwater Level - Cumulative

Water level data collected since the mid-1970's shows the aquifer that supports the TEC is highly responsive and dependent on the Dam water level and abstraction from the Ophthalmia water supply borefield with up to 15 m of fluctuation having occurred with the lowest water levels occurring in the early 1980's prior to the construction of Ophthalmia Dam and the highest water levels occurring in the early 2000's after a period of significant rainfall and prior to pumping at OB23 and OB25 Pit 3. Hydrographs of selected monitoring bores located within the TEC and near OB23 and OB25 Pit 3 are shown in Figures 11 and 12. As discussed previously (see Eastern Pilbara Predicted Water Balance section), the Dam and adjoining recharge ponds and infiltration basins are used for the management of surplus water generated from dewatering from multiple existing mines (OB23 and OB25) and proposed discharge activities from OB31 and Jimblebar. The dam and adjoining basins and ponds are designed to recharge the underlying aquifer that supports the TEC mitigating any potential drawdown that may be caused by dewatering at Eastern Ridge.

Numerical modelling was used to predict cumulative drawdown from both future dewatering operations (OB24 and OB25W) and existing approved operations which includes dewatering at OB23 and OB25 and water supply abstraction from the Ophthalmia and Homestead borefields. The scenario that was developed to predict cumulative drawdown affects is considered to be conservative (i.e. likely to over predict) due to:

- The inherent uncertainty in the dominant hydraulic recharge stressors in proximity to the TEC not being included; including Ophthalmia Dam recharge facilities.
- Dewatering continues from OB23 and OB25 Pit 3 post-mining operations which is unlikely to occur as the mines transition into closure state which will require no dewatering.

The resulting predicted cumulative drawdown extent in the vicinity of the TEC, as depicted by the 2m drawdown contour (Figure 13), is consistent with respect to the original impact assessment for Eastern Ridge hydrological change (Aquaterra, 2008).

Modelled cumulative drawdown in the vicinity of OB25W is shown in Figure 14. The drawdown represents the cumulative change in water levels resulting from dewatering at OB25W and abstraction from the Homestead Water Supply Borefield. It can be seen from comparing the drawdown shown in Figures 9 and 14 that dewatering at OB25W will contribute a relatively small proportion to the overall drawdown with the majority of change resulting from abstraction at the Homestead Borefield. A 30% reduction in the aquifer thickness (~50m drawdown) in the vicinity of Homestead borefield has been established as the 5C Licence investigation threshold to monitor and manage the potential impacts to the groundwater resource (BHP Billiton Iron Ore, 2015c).

8.3. Changes to Water Quality

Mining Areas

A geochemical assessment has been completed by SRK and is reported in the Closure Plan. The majority of material to be encountered during mining of OB24 and OB25W has a low to negligible potential to generate acidity.

At OB24 there is a moderate potential for acid and metalliferous drainage (AMD) in pit wall runoff from exposed Mt McRae Shale units; however, these units contribute only a small proportion (1.6%) of the total pit wall surface area.

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 the Closure Plan.

Ophthalmia Dam and Ethel Gorge

The key water quality parameter considered in the impact change assessment and the EPWRMP is total dissolved solids (TDS), although it is recognised that a number of other water quality and physical parameters may be important for the sustainability of the stygofauna community, including nutrients and dissolved oxygen.

Average TDS in the Ethel Gorge aquifer that hosts the TEC currently ranges between about 700 mg/L and 2,000 mg/L with localised areas exceeding 3,000mg/L.

Water and salt balance studies for Ophthalmia Dam and Ethel Gorge (RPS, 2014b) indicate that groundwater salinity has the potential to increase over time without the appropriate management. Dam salt level could increase due to evaporative concentration process ultimately resulting in the salinity increase of the underlying aquifer.

Modelling demonstrates that the TDS increases with distance from the dam and time, owing primarily to evaporative concentration effects over the mid to long term. It is predicted that the TDS could potentially exceed thresholds outlined within the EPWMP within about 20 years. However, the timeframe of such an occurrence is dependent upon the actual volume of surplus water delivered to the dam, natural recharge of fresh runoff water and primarily dependent upon the frequency of the dam overtopping. Dam overtopping and flushing is designed for a 1 in every 2.5 year event.

Water quality monitoring will be undertaken in accordance with the adaptive management approach outlined within the Eastern Pilbara Water Resource Management Plan.

8.4. Changes to Water Level and Quality - Mine Closure

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 (RPS, 2015) 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 premining water level and
- **Scenario B (voids):** empty voids at OB24, OB25W, and OB25 Pit 3 and completely infilled pits at OB25 Pit 1 and OB23**.**

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 OB25 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 about 40 years.

Water level recovery is slower away from Ophthalmia Dam, in the vicinity of OB24 and OB25W, 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 15).

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. This risk and potential management actions will be assessed in more detail as part of the Eastern Ridge Mine Closure Plan.

Scenario B (void)

The modelling suggests that permanent pit lakes will form in OB25 Pit 3 and OB25 West. The void in OB24 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 2) 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 2: 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)
OB25W Joffre	460	526	480	470	490
OB25W Dales	492	527	523	510	525
OB25 Pit 3	380	510	507	480	510
OB24	484	522	Dry	Dry	500

Similar to Scenario A, groundwater levels in OB25 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.

The permanent voids at OB24 and OB25W 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 (Figure 16) being established after about 200 to 300 years.

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 (Figure 16).

8.5. Changes to Surface Water

A surface water change assessment was conducted to assess the potential for surface water impacts from mining operations at Eastern Ridge, and the potential significance of these impacts in relation to surface water in the region (Appendix 1).

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

The entire Eastern Ridge Development Envelope lies within the Homestead Creek catchment. An assessment has been made of the loss of catchment area to Homestead Creek due to the Eastern Ridge Development Envelope proposal. 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 Development Envelope is provided in the Table 3.

Table 3: Estimated Areas Impacted by Mining in the Eastern Ridge Development Envelope

Location	Development Area (ha)	Adopted Runoff Loss	Catchment Area Loss Estimate (ha)	% Catchment Area Loss
OB24 (existing & future operations) - Pits	350	100%	350	1.2%
OB24 (existing & future operations) - OSA & Stockpiles	505	50%	253	1.2%
OB25 (existing operations) - Pits	320	100%	320	0.8%
OB25 (existing operations) - OSA & Stockpiles	400	50%	200	1.1%
OB25W (future operations) - Pits	150	100%	150	0.7%
OB25W (future operations) - OSA	111	50%	56	0.5%
OB32E (future operations) - Pits	240	100%	240	0.2%
OB32E (future operations) - OSA	130	50%	65	1.2%
SUBTOTAL	*2206*		*1633*	*5.4%*
Contingency Area	15%		245	
GRAND TOTAL			1878	6.2%

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 1,878 ha from the Homestead mining areas corresponds to about 6.2% of the Homestead Creek catchment.

The catchment loss of 1,878 ha from the Eastern Ridge Development 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.

9. Eastern Pilbara Water Resource Management Plan

BHP Billiton Iron Ore has formulated and operates under a regional water management strategy that delivers sustainable, feasible and cost effective measures to address our existing and future challenges. Importantly, the approach prepares the business for various and changing water balance scenarios and directs proactive management measures to mitigate potential impacts relating to hydrological change on a regional scale.

The objective is to enable sustainable water resource management for below water table mining operations and operations which intercept surface water flow by setting outcome-based conditions and adaptive management techniques to mitigate and offset our operational effects on water levels and quality through 1) preferentially returning surplus dewater to the aquifer and 2) maintaining baseline hydrological conditions at the key environmental receptors.

The Pilbara Water Resource Management Strategy (BHP Billiton Iron Ore, 2014c) is underpinned by three regional water plans. Specifically, for the management of the potential impacts and changes to hydrological conditions resulting from BHPBIO activities in the eastern Pilbara mines, an Eastern Pilbara Water Resource Management Plan (EPWRMP) has been developed. It is proposed that the Eastern Ridge mines will operate under this management plan.

The EPWRMP aims to provide a consistent method to identify:

1. the hydrological changes (groundwater and surface water quantity, levels and quality) resulting from BHPBIO mining and closure activities,
2. the receiving receptors (water resources, environment, social and third party operations),
3. the potential impacts, and
4. the required risk-based adaptive management to mitigate potential impacts to acceptable levels.

The EPWRMP is guided by a water outcome-based objective:

To manage the range of potential hydrological changes (groundwater, surface water and/or soil moisture) resulting from BHPBIO Eastern Pilbara Hub operations impacting on receiving receptors to an acceptable level.

This objective is supported by thresholds to monitor whether a hydrological change can result in an impact to a receiving receptor as a result of BHP Billiton Iron Ore operations. Three receptors have been identified as having the potential to be impacted by changes in hydrological processes associated with the Eastern Ridge proposal, these being the Ethel Gorge TEC, riparian vegetation along Homestead Creek and Ethel Gorge, and the groundwater resource.

Early warning triggers are also defined to provide the point at which water management options must be considered and implemented to avoid potential impact to a receiving receptor; the trigger is intended to operate sufficiently early to allow water management options to be activated well in advance of the breach of a threshold value for the receiving receptor.

During operation of the mines potential impacts at the key receptors (Ethel Gorge TEC) will be managed through the implementation of the Eastern Pilbara Water Resource Management Plan. The management of surplus water generated during below the water table mining will be managed in accordance with the Eastern Pilbara surplus water management plan, and largely transferred to Ophthalmia dam and surrounding facilities for infiltration into the aquifer. The water will support the management of the groundwater levels and quality within the Ethel Gorge TEC. The potential for impacts associated with the infiltration of surplus water are considered to be limited owing to the small contribution from OB24 and OB25W and any additional impacts to the Ethel Gorge TEC can be managed through the EPWRMP.

10. Impact Potential Summary

The change assessment has evaluated the cumulative hydrological effects associated with the new operations at OB24 and OB25W, existing mining operations (OB23 and OB25), existing and future surplus water management techniques within Ethel Gorge, and the Ophthalmia and Homestead water supply borefields.

The hydrological changes associated with the above 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
- Homestead creek riparian vegetation owing to falling groundwater levels.

The resulting impacts from the additional hydrological change on groundwater and surface resources from OB24 and OB25W are considered not to be significant and can be managed through existing management plans (refer Water Resource Management Plan Section).

Groundwater Levels – The change to regional groundwater levels resulting from OB24 and OB25W activities are localized to the mining area, and the cumulative regional groundwater drawdown is dominated by the abstraction from the Homestead borefield during the operational periods. The extent of the additional drawdown from the two below water table mines (OB24 and OB25W) is minimal, representing around 20% of the total abstraction in the assessment and less than 5% of the total drawdown contribution beneath Homestead borefield.

A number of closure scenarios have been evaluated as part of the assessment to predict the extent of long term impacts and to inform subsequent studies outlined in the Closure Plan. The assessment identified that the post closure recovery timeframes will depend upon the closure options considered. The extent of water resource change is not considered to be significant regardless of pit void or backfill closure scenarios and predicted changes to water quality are likely to be localized to the pit void. However, closure related studies will need to continue as mining progresses and more data becomes available to evaluate the potential changes to water chemistries at closure in and surrounding the pits and the likely impacts to the surrounding aquifers. These studies will inform the ultimate closure option as outlined in the Closure Plan.

The cumulative effects of these new operations on groundwater levels in Ethel Gorge remain within natural variance during operational periods and are consistent with respect to the original impact assessment for Eastern Ridge. The ultimate groundwater levels in Ethel Gorge will depend upon the closure scenarios and whether complete backfilling of below water table mines occurs. However, without complete backfill of the pits, there is a potential that a small residual drawdown (around 1m) will occur long term in Ethel Gorge.

Potential impacts to Water Quality – The groundwater across the assessment area is generally fresh with salinity values typically below 2,000 mg/L TDS. The dewatering water quality is consistent with the regional groundwater quality and lends itself to be preferentially returned to the subsurface via recharge ponds and infiltration basins.

The salinity of Ophthalmia Dam has the potential to increase over time due to evaporative concentration of salts and the subsequent seepage of elevated salinity groundwater could impact the Ethel Gorge TEC downstream. Water quality monitoring will be undertaken in accordance with the adaptive management approach outlined within the Eastern Pilbara Water Resource Management Plan to identify such conditions as they start to develop to allow proper mitigation to occur before significant impacts occur.

The majority of material to be encountered during mining the BWT material of the OB24 and OB25W has a low to negligible potential to generate acidity and the likelihood of impacts to surface water or groundwater resources during operations and closure are considered low.

Surplus water – Management and discharge of surplus water into Ethel Gorge will also modify the hydrological conditions (water levels and quality) during operations and well into closure. The introduction of surplus water into the Ethel Gorge aquifer serves to maintain groundwater levels within historical ranges and prevents impacts to Ethel Gorge from cumulative drawdown effects from regional mining and Ophthalmia borefield pumping activities.

Surface water resources – The percentage loss of surface water from the upper catchment owing to the new operations represents around 6.2% of the Homestead creek catchment and 0.4% of the Fortescue River system catchment at Ethel Gorge.

The extent of additional hydrological change on the surface and groundwater resources related to the Proposal to mine below the water table at OB24 and OB25 West is not considered to be significant and is considered unlikely to result in impacts to the water resource or the dependent environment.

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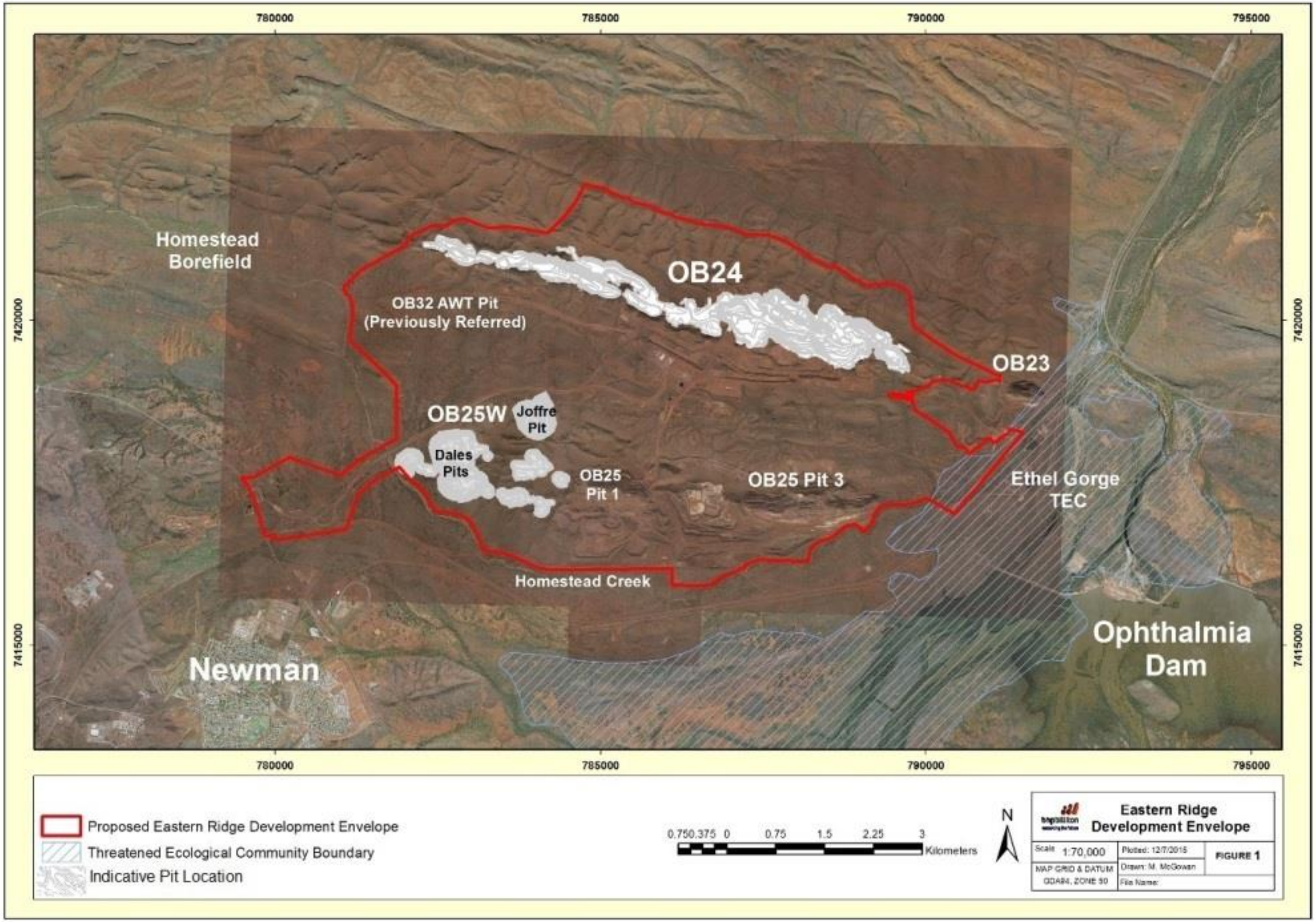
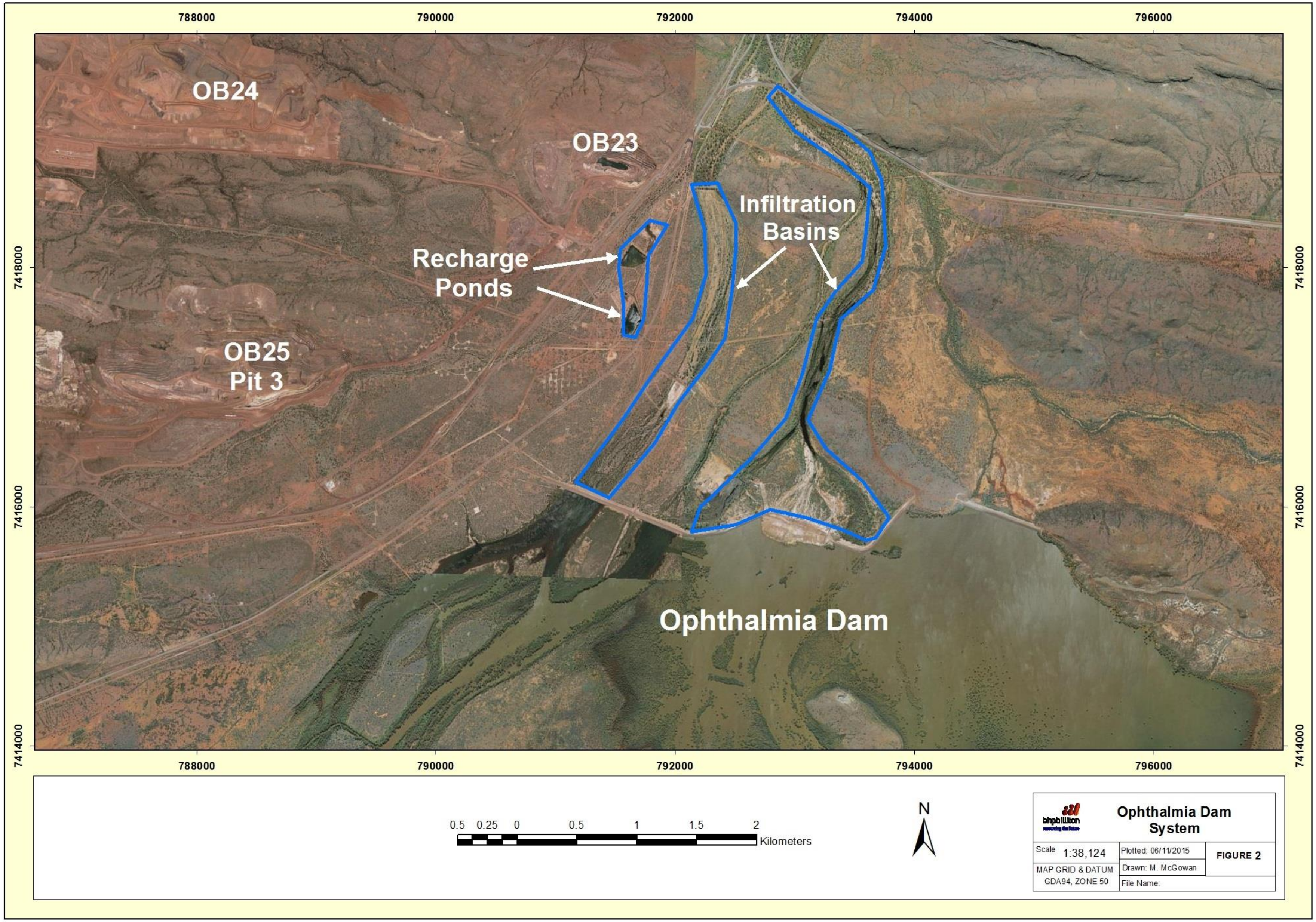
Figures


780000
785000
790000
795000
7420000
7415000
Homestead Borefield
OB24
OB32 AWT Pit (Previously Referred)
OB23
OB25W
Joffre Pit
Dales Pits
OB25 Pit 1
OB25 Pit 3
Ethel Gorge TEC
Homestead Creek
Newman
Ophthalmia Dam
Proposed Eastern Ridge Development Envelope
Threatened Ecological Community Boundary
Indicative Pit Location
0.750.375 0 0.75 1.5 2.25 3
Kilometers
N
Eastern Ridge Development Envelope
Scale 1:70,000
Plotted: 12/7/2015
Drawn: M. McGowan
File Name:
MAP GRID & DATUM GDA94, ZONE 50
FIGURE 1



788000
790000
792000
794000
796000
7418000
7416000
7414000
OB24
OB23
Recharge Ponds
Infiltration Basins
OB25 Pit 3
Ophthalmia Dam
0.5 0.25 0 0.5 1 1.5 2
Kilometers
N
Ophthalmia Dam System
Scale 1:38,124
Plotted: 06/11/2015
FIGURE 2
MAP GRID & DATUM GDA94, ZONE 50
Drawn: M. McGowan
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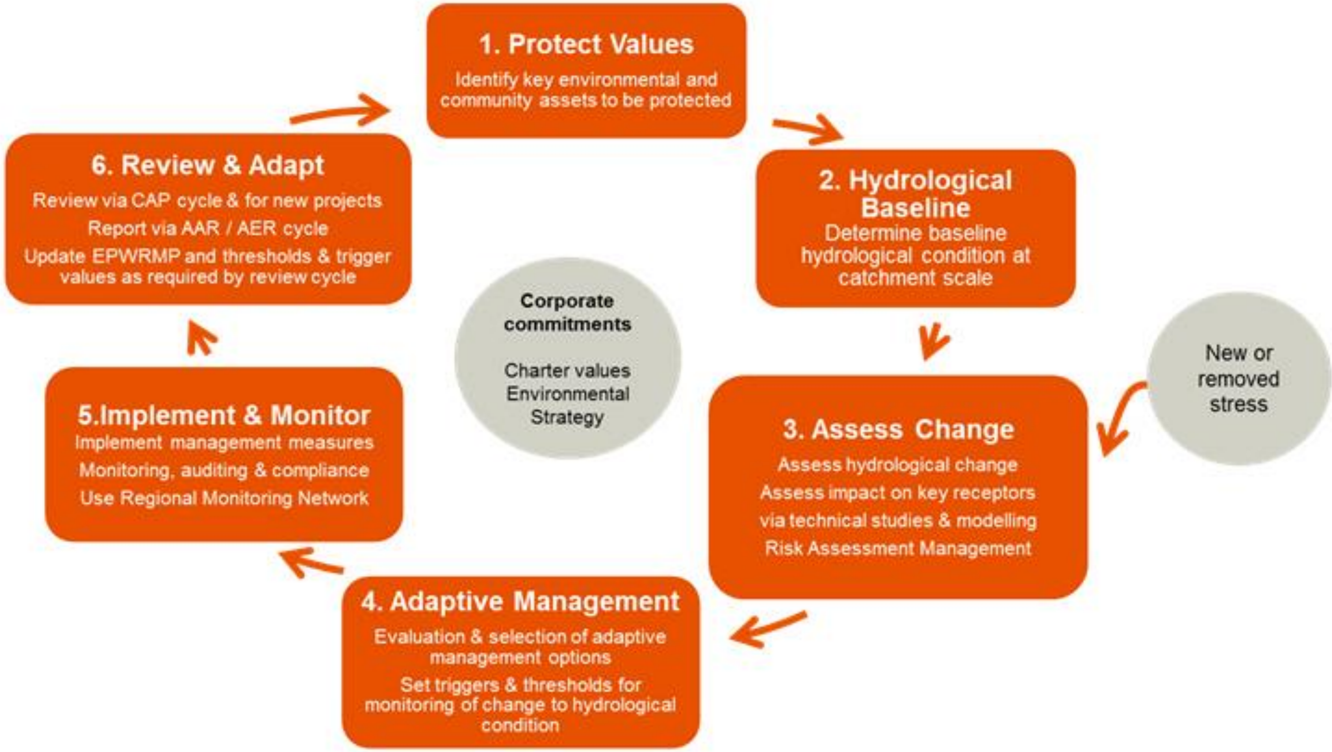
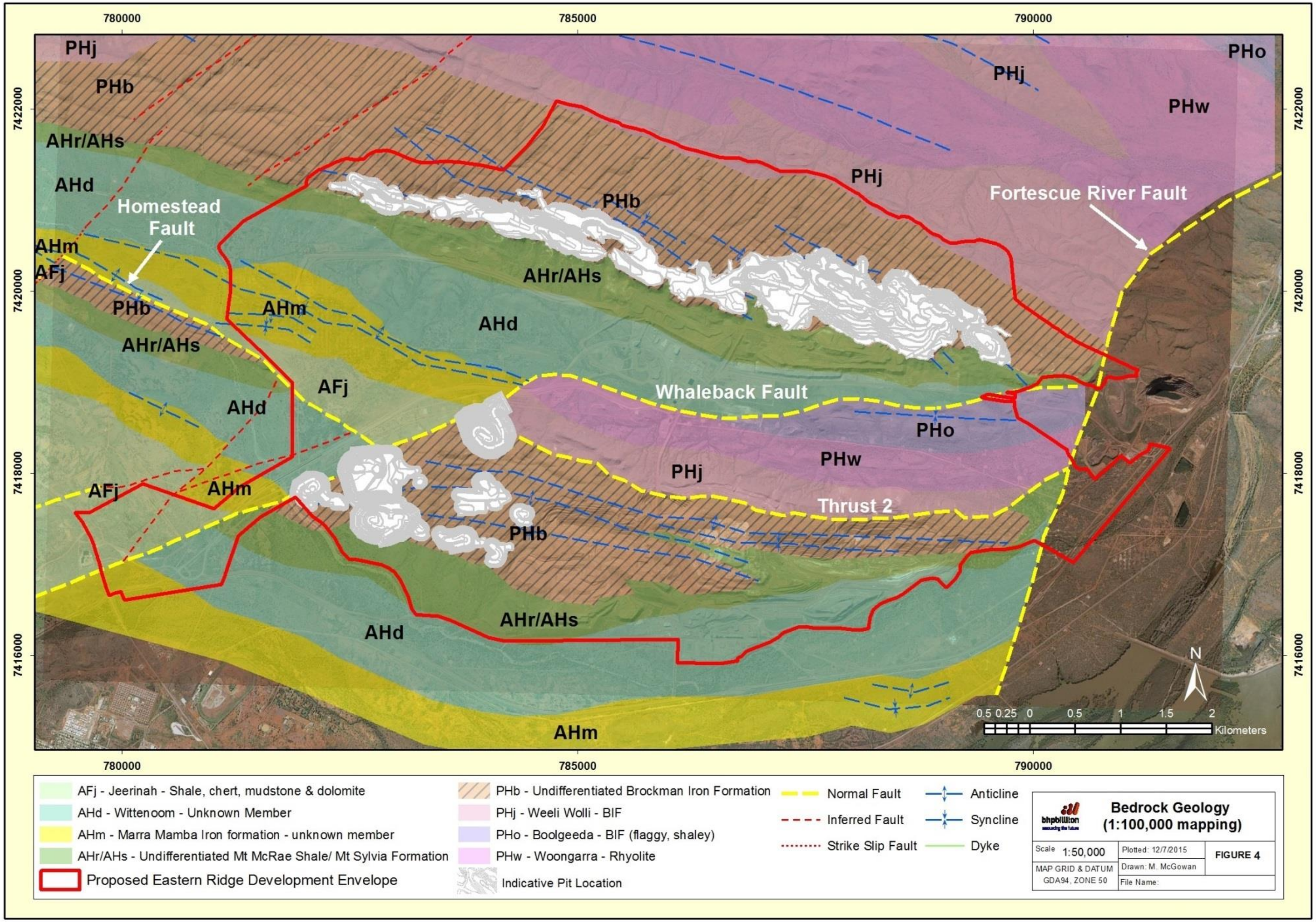


Figure 3 – *A strategic and adaptive management approach has been implemented for water resources within the Pilbara which focuses on key environmental and community assets, sets acceptable change and objectives, and outlines practicable mitigating controls which are proportional and attributable to our impact and appropriate for the level of technical knowledge.*


780000
785000
790000
7422000
7420000
7418000
7416000
PHj
PHb
PHo
PHw
AHr/AHs
AHd
Homestead Fault
AHm
AFj
Fortescue River Fault
Whaleback Fault
Thrust 2
N
0.5 0.25 0 0.5 1 1.5 2
Kilometers
AFj - Jeerinah - Shale, chert, mudstone & dolomite
AHd - Wittenoom - Unknown Member
AHm - Marra Mamba Iron formation - unknown member
AHr/AHs - Undifferentiated Mt McRae Shale/ Mt Sylvia Formation
Proposed Eastern Ridge Development Envelope
PHb - Undifferentiated Brockman Iron Formation
PHj - Weeli Wolli - BIF
PHo - Boolgeeda - BIF (flaggy, shaley)
PHw - Woongarra - Rhyolite
Indicative Pit Location
Normal Fault
Inferred Fault
Strike Slip Fault
Anticline
Syncline
Dyke
Bedrock Geology
(1:100,000 mapping)
Scale 1:50,000
Plotted: 12/7/2015
FIGURE 4
MAP GRID & DATUM
GDA94, ZONE 50
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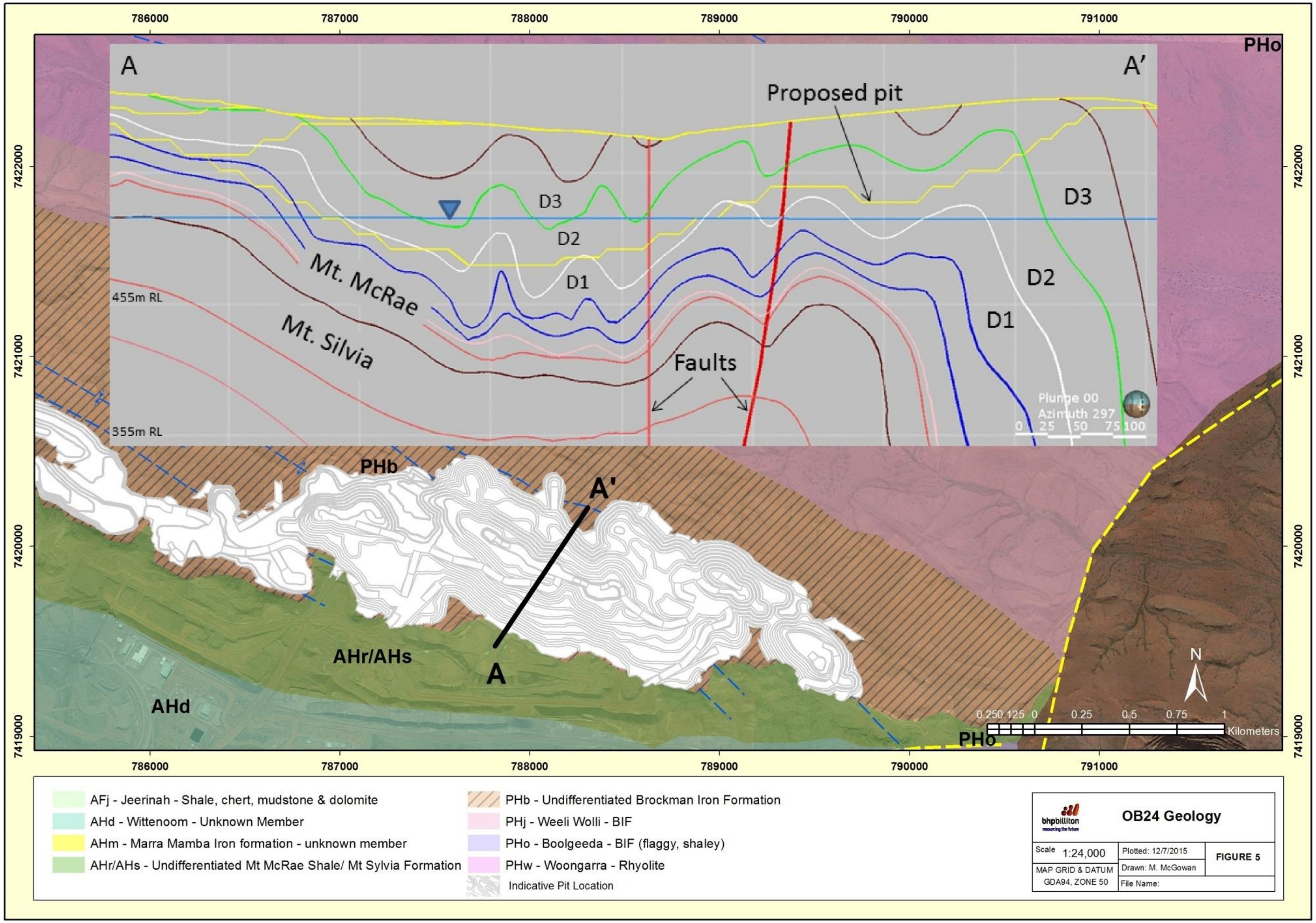
File Name:


A
A'
Proposed pit
D3
D2
D1
Mt. McRae
Mt. Silvia
Faults
455m RL
355m RL
Plunge 00
Azimuth 297
0 25 50 75 100
PHo
PHb
AHr/AHs
AHd
786000
787000
788000
789000
790000
791000
7422000
7421000
7420000
7419000
N
0.25 0.125 0 0.25 0.5 0.75 1 Kilometers
AFj - Jeerinah - Shale, chert, mudstone & dolomite
AHd - Wittenoom - Unknown Member
AHm - Marra Mamba Iron formation - unknown member
AHr/AHs - Undifferentiated Mt McRae Shale/ Mt Sylvia Formation
PHb - Undifferentiated Brockman Iron Formation
PHj - Weeli Wolli - BIF
PHo - Boolgeeda - BIF (flaggy, shaley)
PHw - Woongarra - Rhyolite
Indicative Pit Location
bhpbilliton resourcing the future
OB24 Geology
Scale 1:24,000
Plotted: 12/7/2015
FIGURE 5
MAP GRID & DATUM GDA94, ZONE 50
Drawn: M. McGowan
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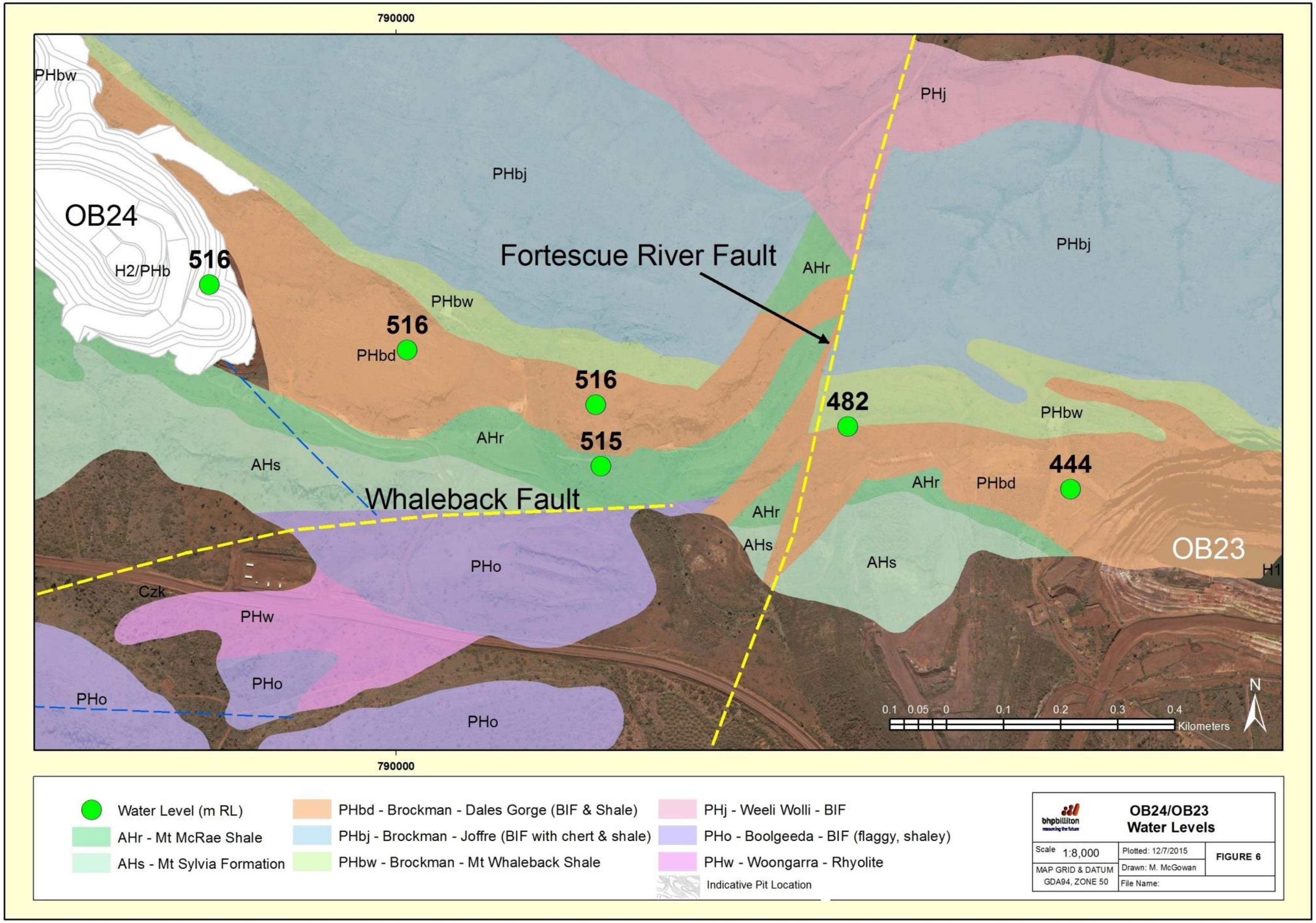
790000
PHbw
OB24
H2/PHb
516
PHbj
Fortescue River Fault
AHr
PHj
PHbj
PHbw
516
PHbd
516
482
PHbw
AHr
515
AHs
Whaleback Fault
AHr
PHbd
444
AHr
AHs
AHs
OB23
H1
PHo
Czk
PHw
PHo
PHo
PHo
0.1 0.05 0 0.1 0.2 0.3 0.4
Kilometers
N
790000
Water Level (m RL)
AHr - Mt McRae Shale
AHs - Mt Sylvia Formation
PHbd - Brockman - Dales Gorge (BIF & Shale)
PHbj - Brockman - Joffre (BIF with chert & shale)
PHbw - Brockman - Mt Whaleback Shale
PHj - Weeli Wolli - BIF
PHo - Boolgeeda - BIF (flaggy, shaley)
PHw - Woongarra - Rhyolite
Indicative Pit Location
bhpbilliton
OB24/OB23
Water Levels
Scale 1:8,000
Plotted: 12/7/2015
FIGURE 6
MAP GRID & DATUM
GDA94, ZONE 50
Drawn: M. McGowan
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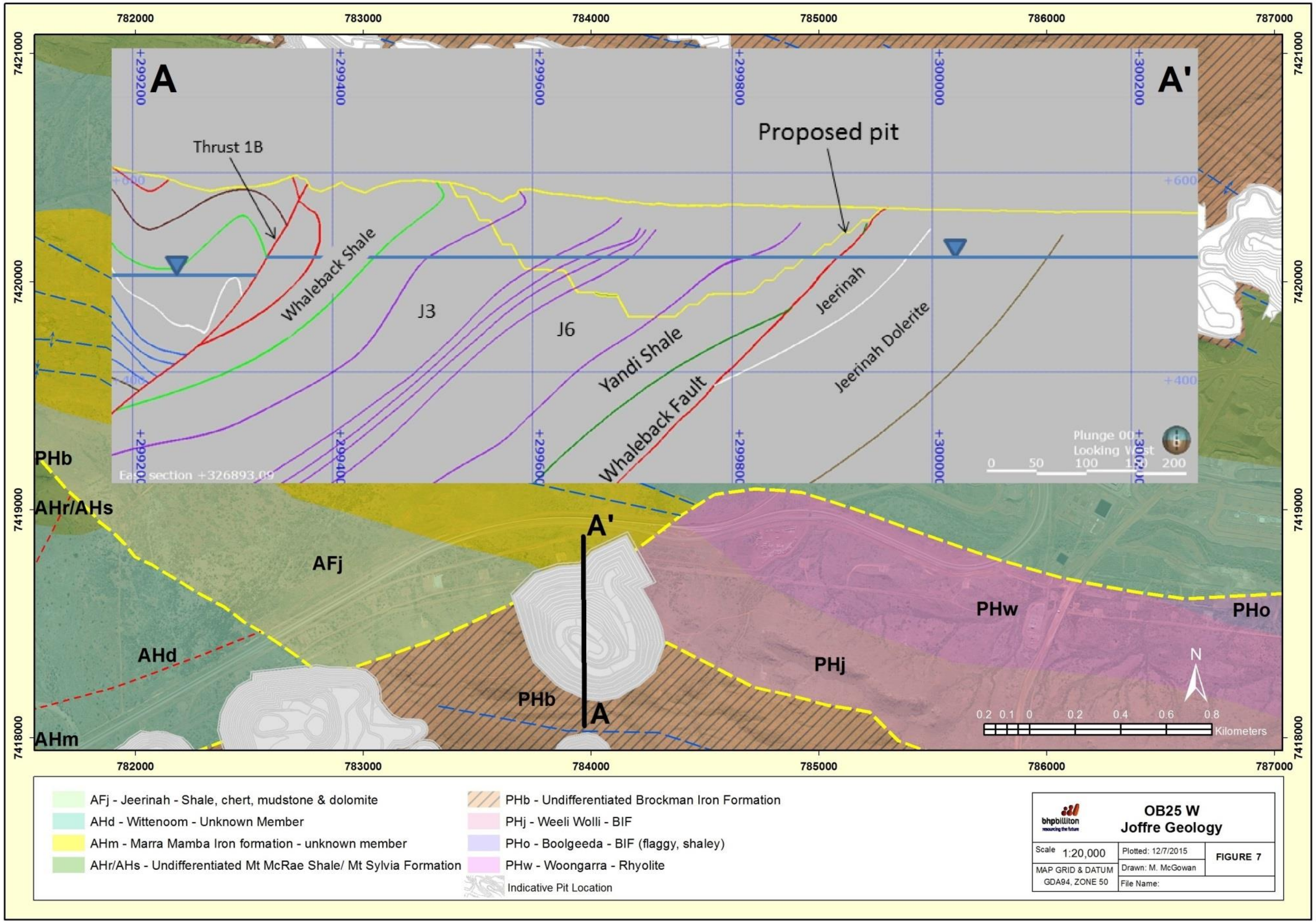
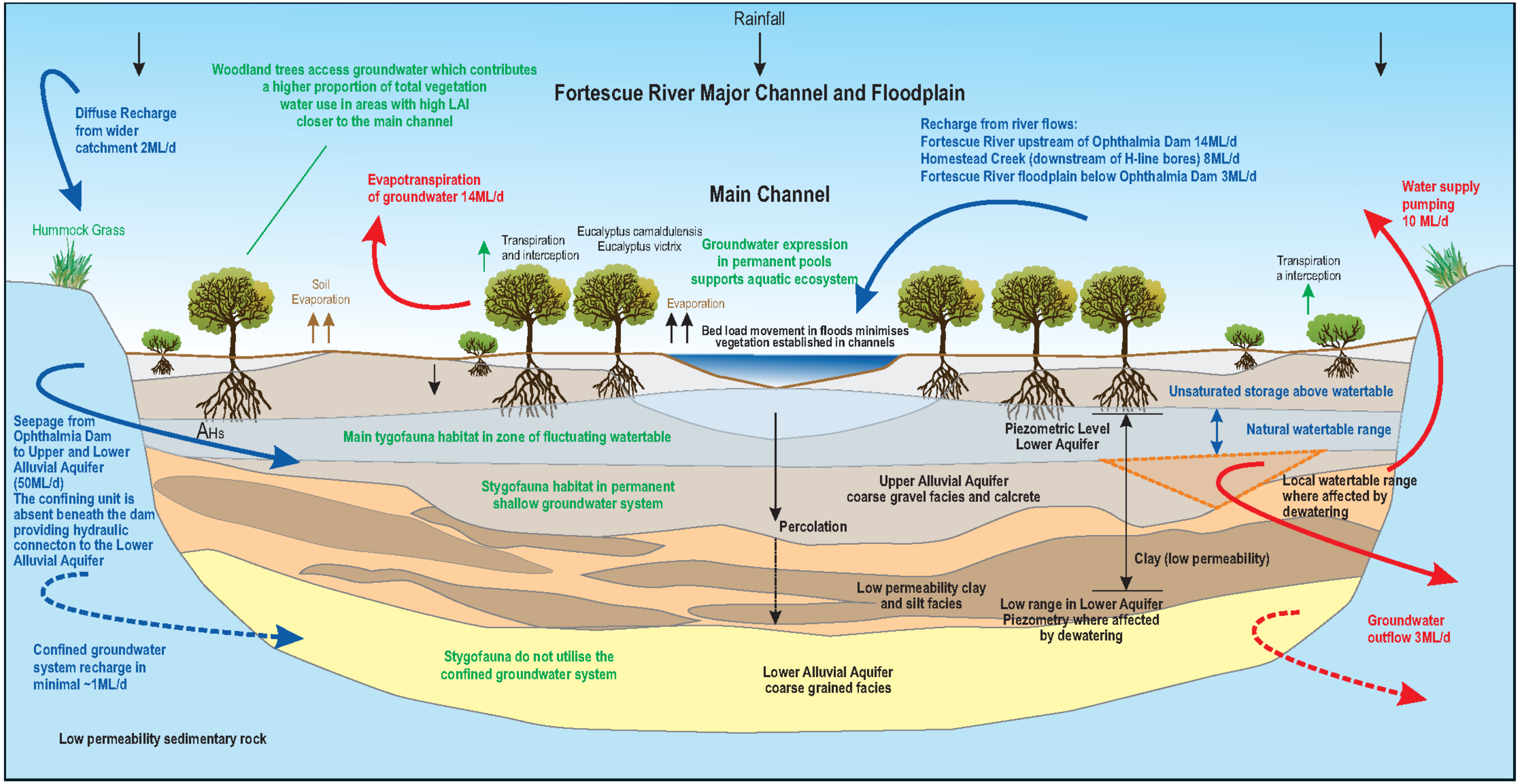

A
A'
Thrust 1B
Proposed pit
Whaleback Shale
J3
J6
Yandi Shale
Whaleback Fault
Jeerinah
Jeerinah Dolerite
+299200
+299400
+299600
+299800
+300000
+300200
+600
+400
Plunge 00
Looking West
0 50 100 150 200
782000
783000
784000
785000
786000
787000
7421000
7420000
7419000
7418000
PHb
AHr/AHs
AFj
AHd
AHm
PHw
PHo
PHj
N
0.2 0.1 0 0.2 0.4 0.6 0.8
Kilometers
AFj - Jeerinah - Shale, chert, mudstone & dolomite
AHd - Wittenoom - Unknown Member
AHm - Marra Mamba Iron formation - unknown member
AHr/AHs - Undifferentiated Mt McRae Shale/ Mt Sylvia Formation
PHb - Undifferentiated Brockman Iron Formation
PHj - Weeli Wolli - BIF
PHo - Boolgeeda - BIF (flaggy, shaley)
PHw - Woongarra - Rhyolite
Indicative Pit Location
OB25 W
Joffre Geology
Scale 1:20,000
Plotted: 12/7/2015
FIGURE 7
MAP GRID & DATUM GDA94, ZONE 50
Drawn: M. McGowan
File Name:



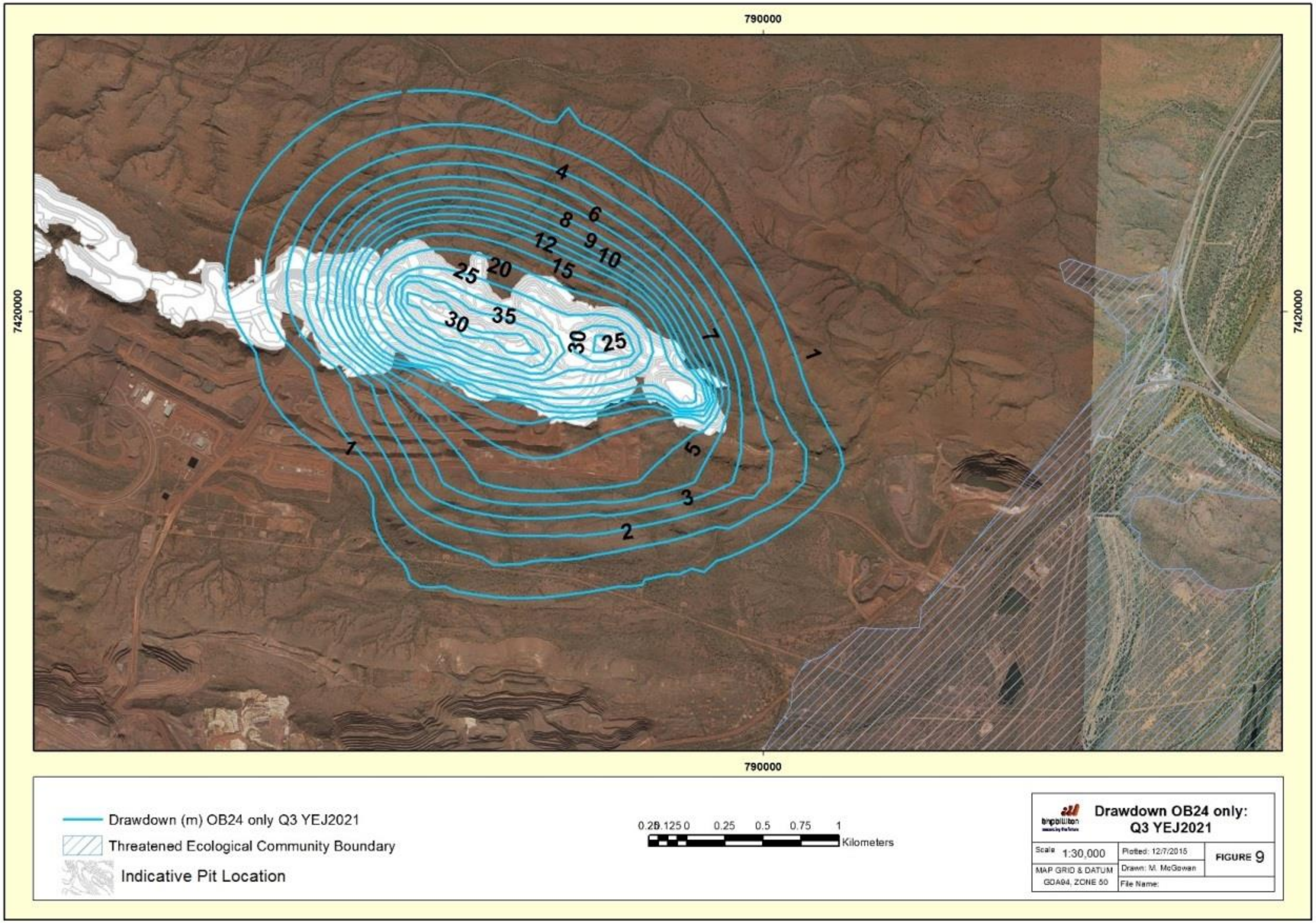
AUTHOR:	JP	REPORT NO:	020a
DRAWN:	RC	REVISION:	a
DATE:	03/02/2014	JOB NO:	1549B

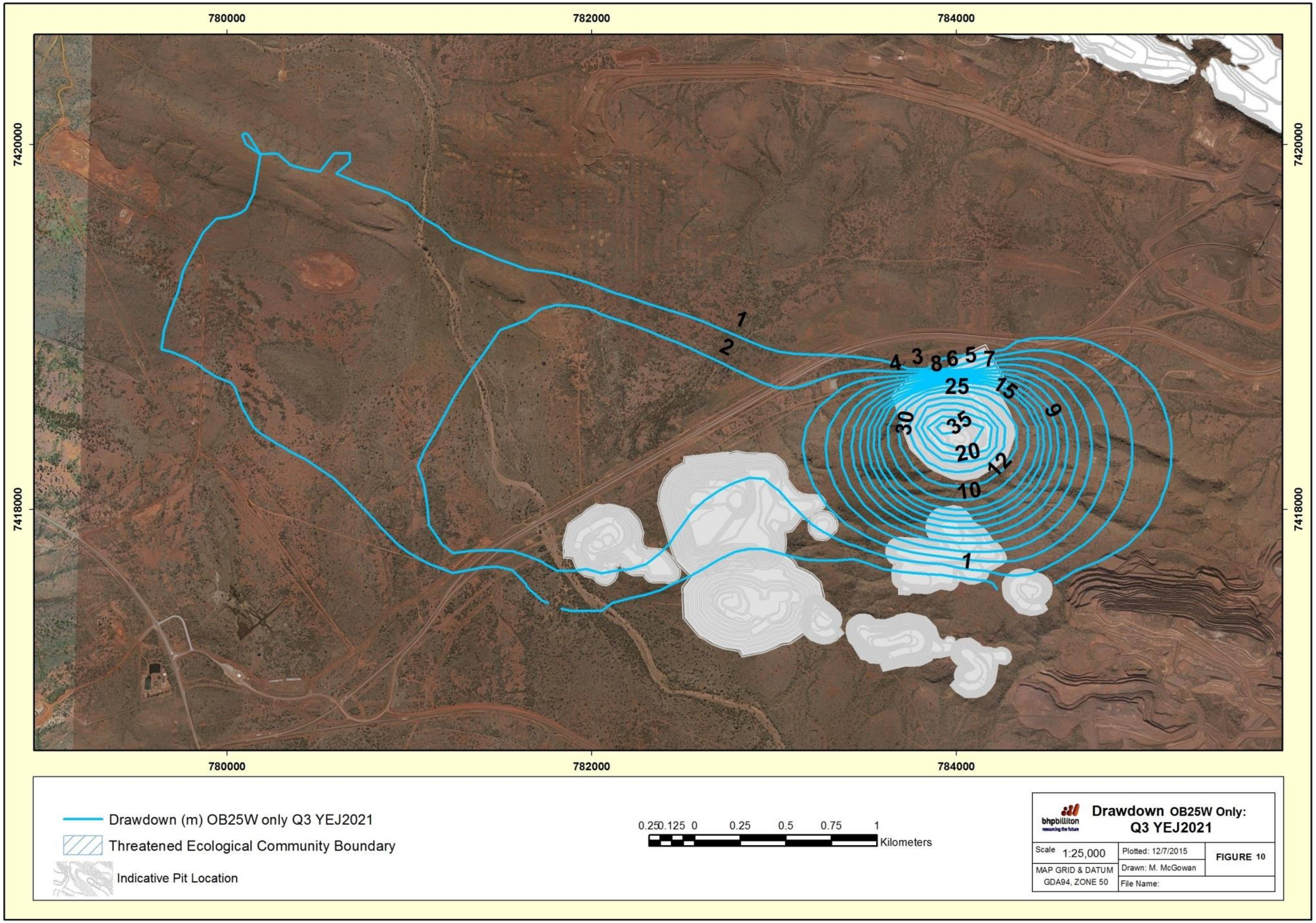
RPS

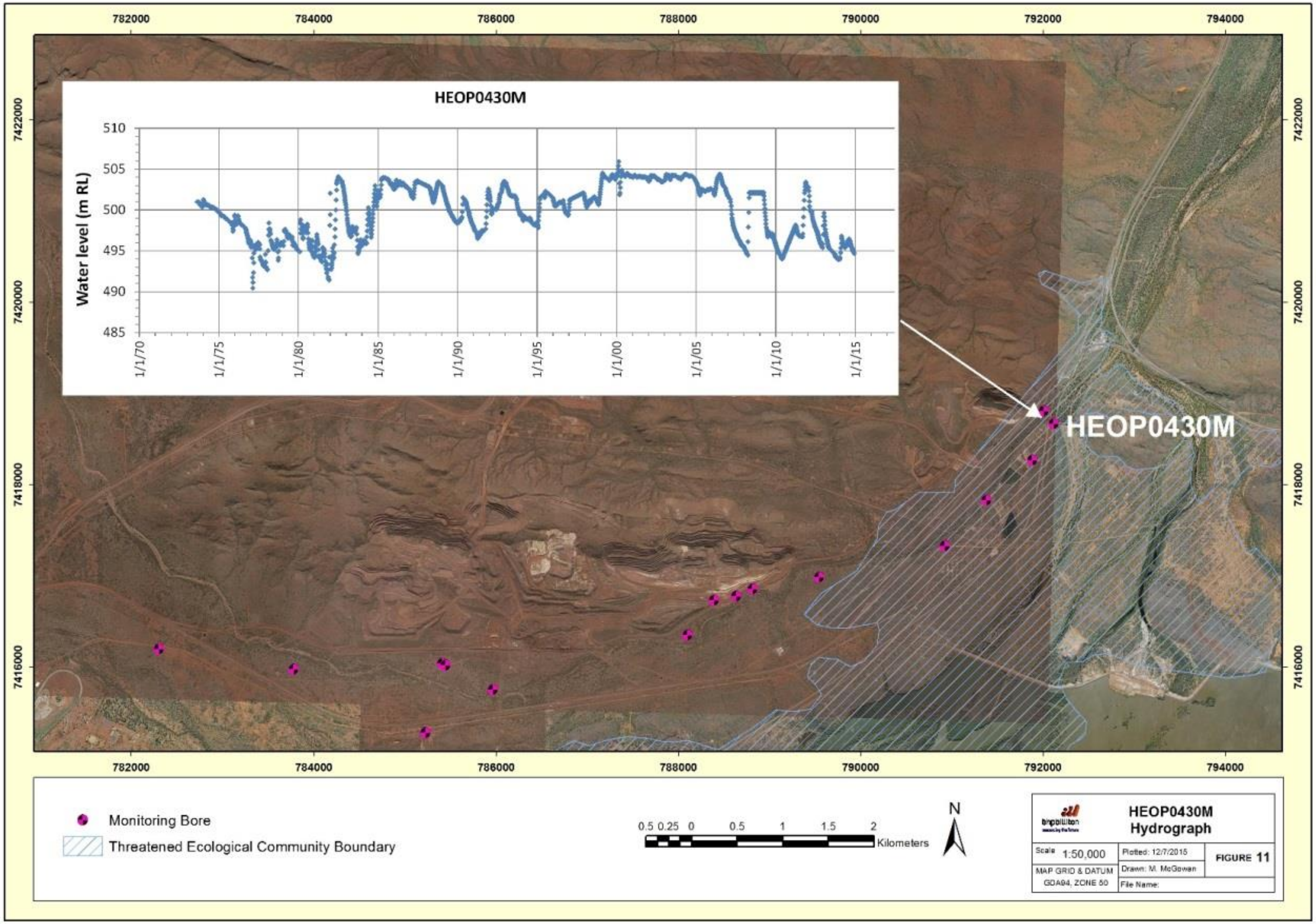
FIGURE 8

Ethel Gorge Ecohydrological Conceptual Model

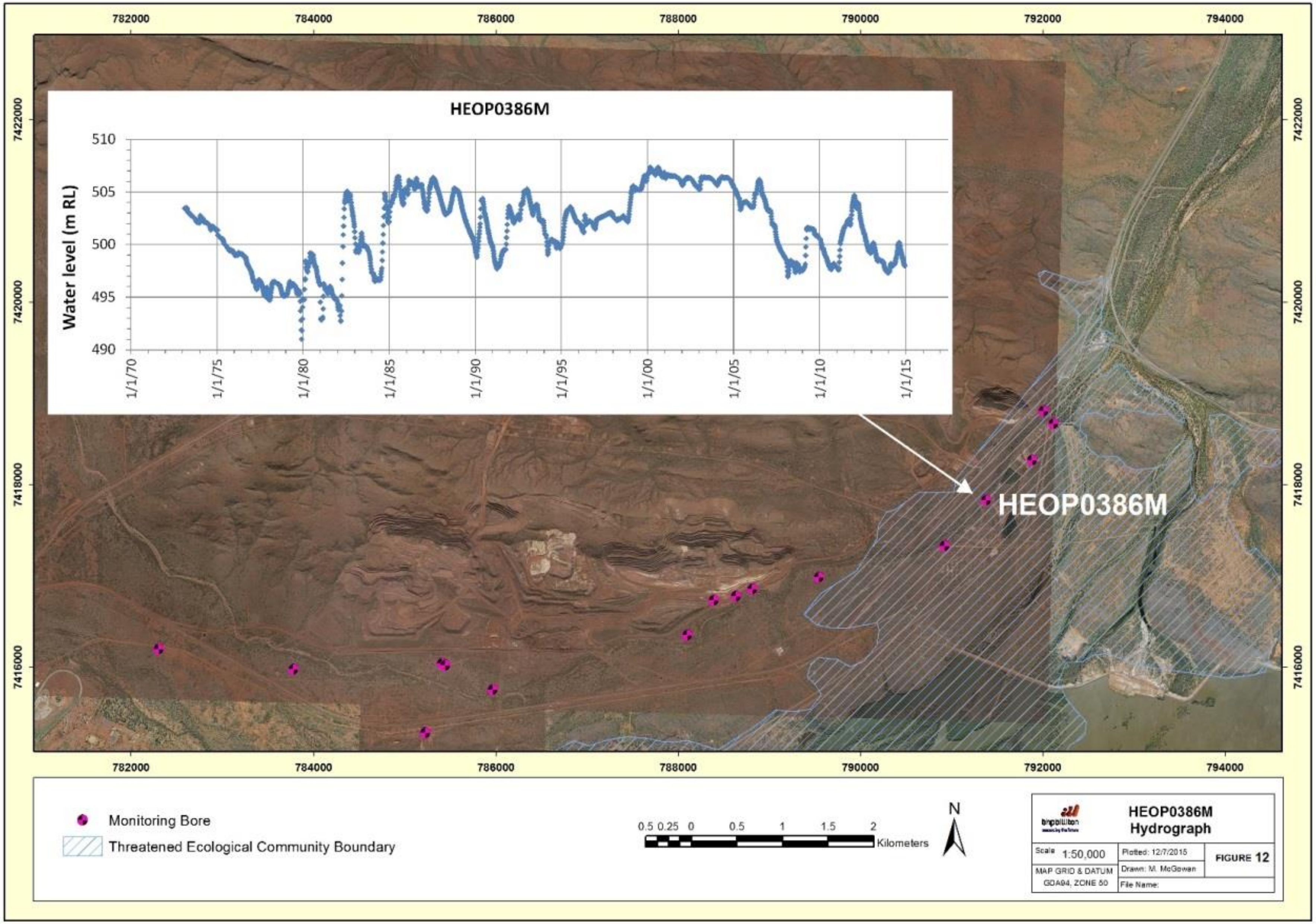
DATA SOURCES:


790000
7420000
4
6
8
9
10
12
15
20
25
30
35
30
25
7
1
1
5
3
2
790000
Drawdown (m) OB24 only Q3 YEJ2021
Threatened Ecological Community Boundary
Indicative Pit Location
0.25 0.125 0 0.25 0.5 0.75 1
Kilometers
bhpbilliton
Drawdown OB24 only:
Q3 YEJ2021
Scale 1:30,000
Plotted: 12/7/2015
FIGURE 9
MAP GRID & DATUM
GDA94, ZONE 50
Drawn: M. McGowan
File Name:

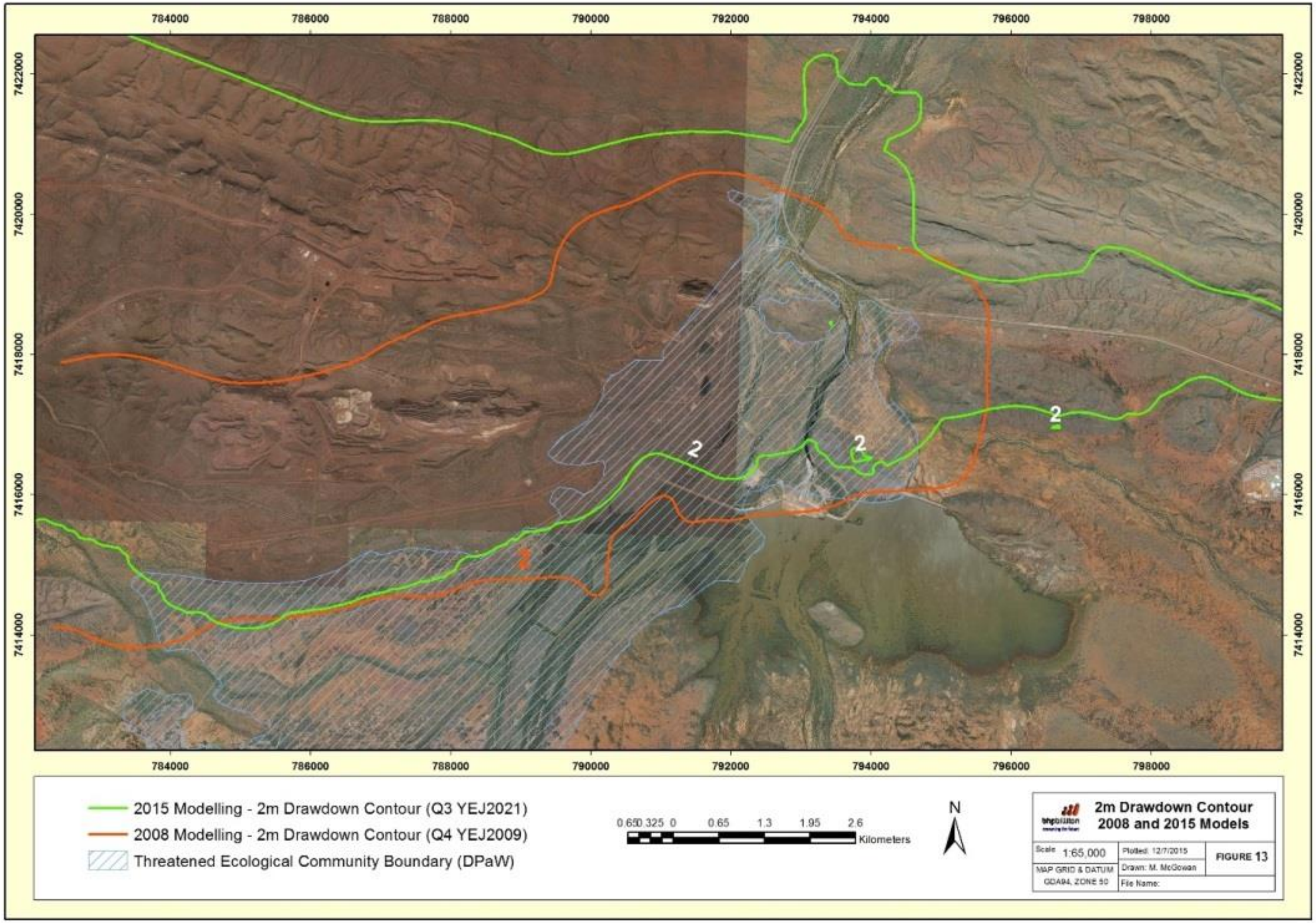

780000
782000
784000
7420000
7418000
1
2
4 3 8 6 5 7
25
15
9
30
35
20
12
10
1
Drawdown (m) OB25W only Q3 YEJ2021
Threatened Ecological Community Boundary
Indicative Pit Location
0.25 0.125 0 0.25 0.5 0.75 1
Kilometers
bhpbilliton
resourcing the future
Drawdown OB25W Only:
Q3 YEJ2021
Scale 1:25,000
Plotted: 12/7/2015
FIGURE 10
MAP GRID & DATUM
GDA94, ZONE 50
Drawn: M. McGowan
File Name:

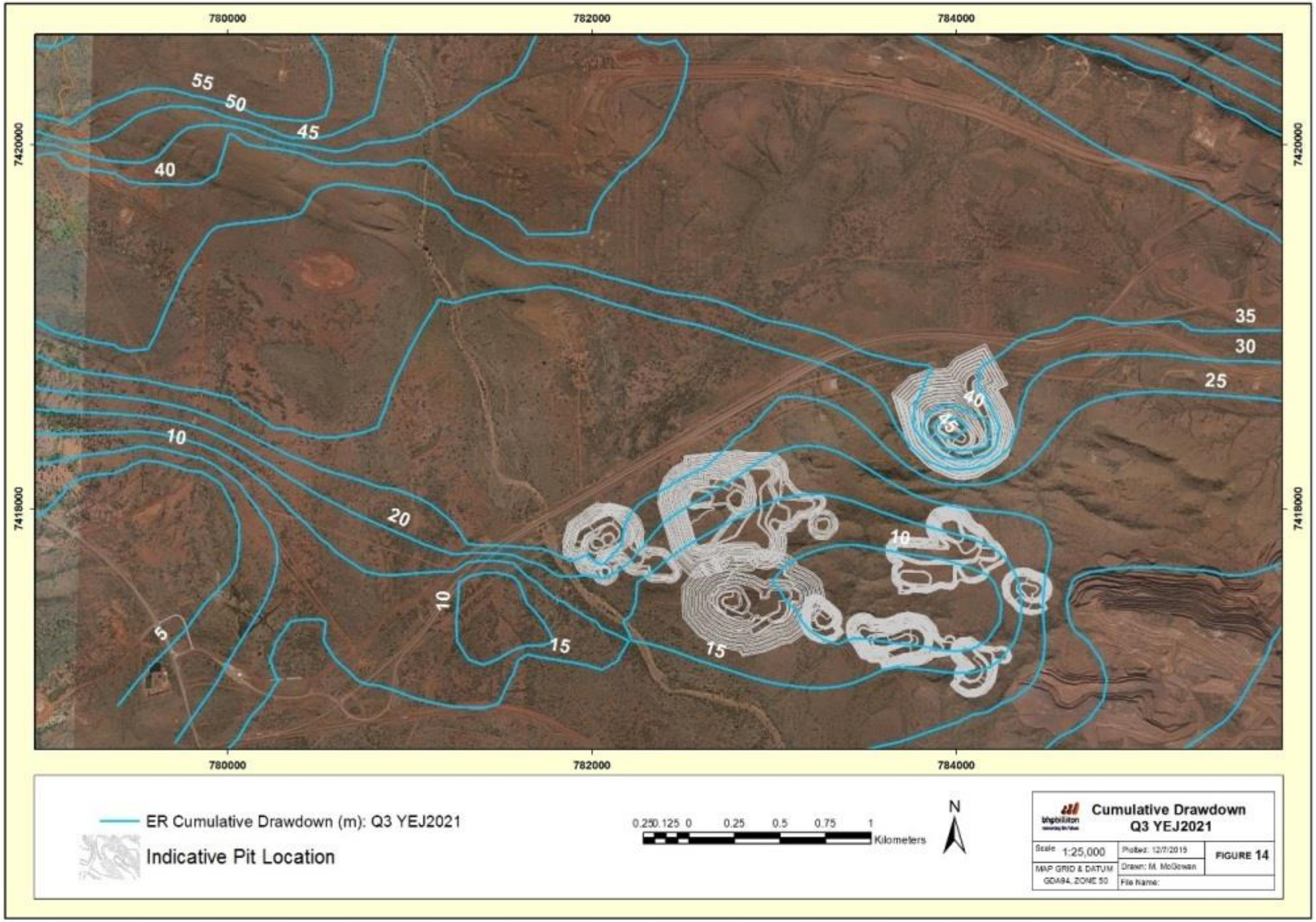


HEOP0430M
Water level (m RL)
510
505
500
495
490
485
1/1/70
1/1/75
1/1/80
1/1/85
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
1/1/15
HEOP0430M
782000
784000
786000
788000
790000
792000
794000
7422000
7420000
7418000
7416000
Monitoring Bore
Threatened Ecological Community Boundary
0.5 0.25 0 0.5 1 1.5 2
Kilometers
N
HEOP0430M
Hydrograph
Scale 1:50,000
Plotted: 12/7/2015
Drawn: M. McGowan
File Name:
MAP GRID & DATUM
GDA94, ZONE 50
FIGURE 11



782000
784000
786000
788000
790000
792000
794000
7422000
7420000
7418000
7416000
HEOP0386M
Water level (m RL)
510
505
500
495
490
1/1/70
1/1/75
1/1/80
1/1/85
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
1/1/15
HEOP0386M
Monitoring Bore
Threatened Ecological Community Boundary
0.5 0.25 0 0.5 1 1.5 2
Kilometers
N
bhpbilliton
HEOP0386M
Hydrograph
Scale 1:50,000
Plotted: 12/7/2015
FIGURE 12
MAP GRID & DATUM
GDA94, ZONE 50
Drawn: M. McGowan
File Name:


784000
786000
788000
790000
792000
794000
796000
798000
7422000
7420000
7418000
7416000
7414000
2
2
2
2
2015 Modelling - 2m Drawdown Contour (Q3 YEJ2021)
2008 Modelling - 2m Drawdown Contour (Q4 YEJ2009)
Threatened Ecological Community Boundary (DPaW)
0.650.325 0 0.65 1.3 1.95 2.6
Kilometers
N
2m Drawdown Contour
2008 and 2015 Models
Scale 1:65,000
Plotted: 12/7/2015
Drawn: M. McGowan
FIGURE 13
MAP GRID & DATUM
GDA94, ZONE 50
File Name:



780000
782000
784000
7420000
7418000
55
50
45
40
35
30
25
20
15
10
5
ER Cumulative Drawdown (m): Q3 YEJ2021
Indicative Pit Location
0.25 0.125 0 0.25 0.5 0.75 1
Kilometers
N
bhpbilliton
Cumulative Drawdown
Q3 YEJ2021
Scale 1:25,000
Plotted: 12/7/2015
FIGURE 14
MAP GRID & DATUM GDA94, ZONE 50
Drawn: M. McGowan
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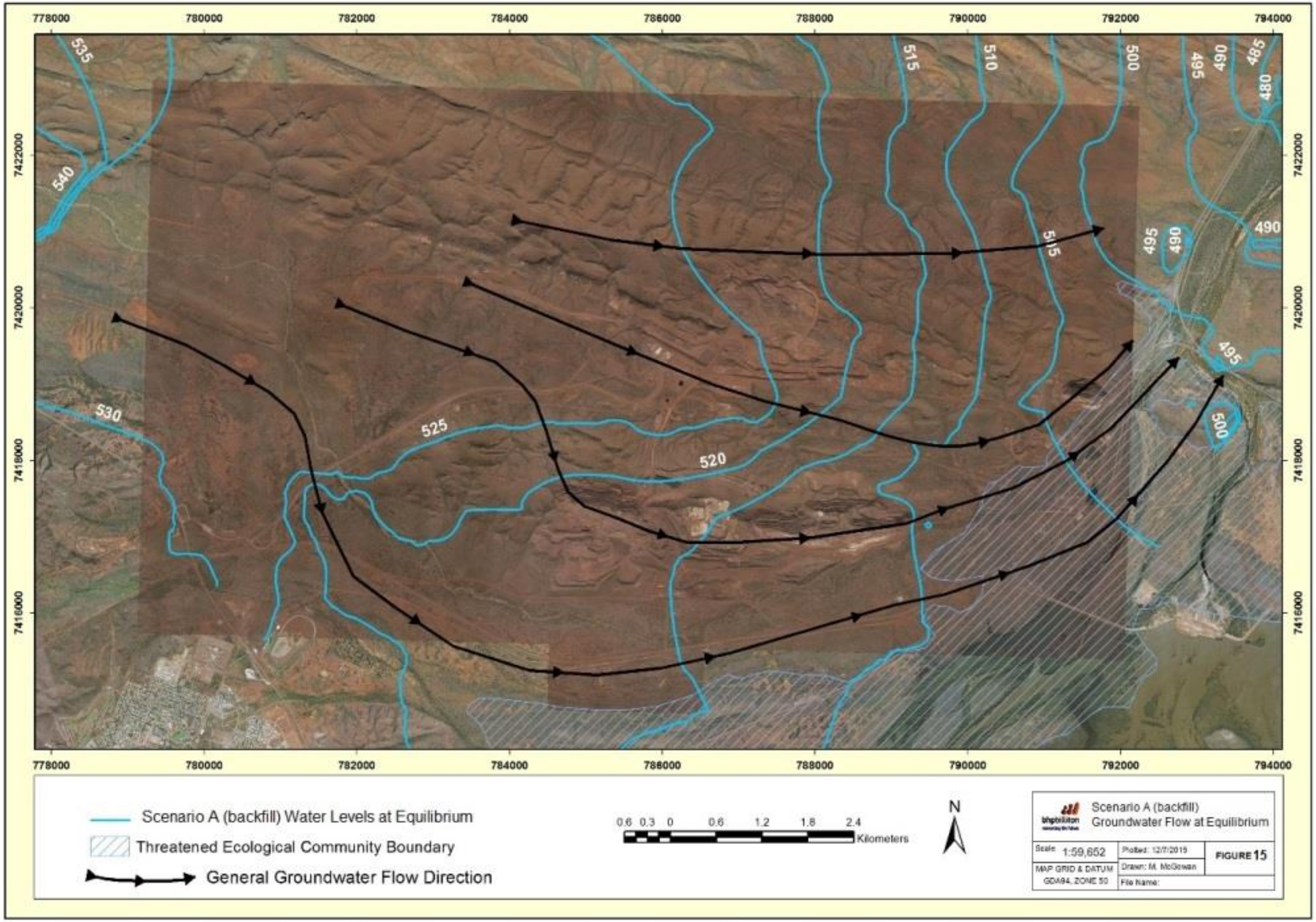
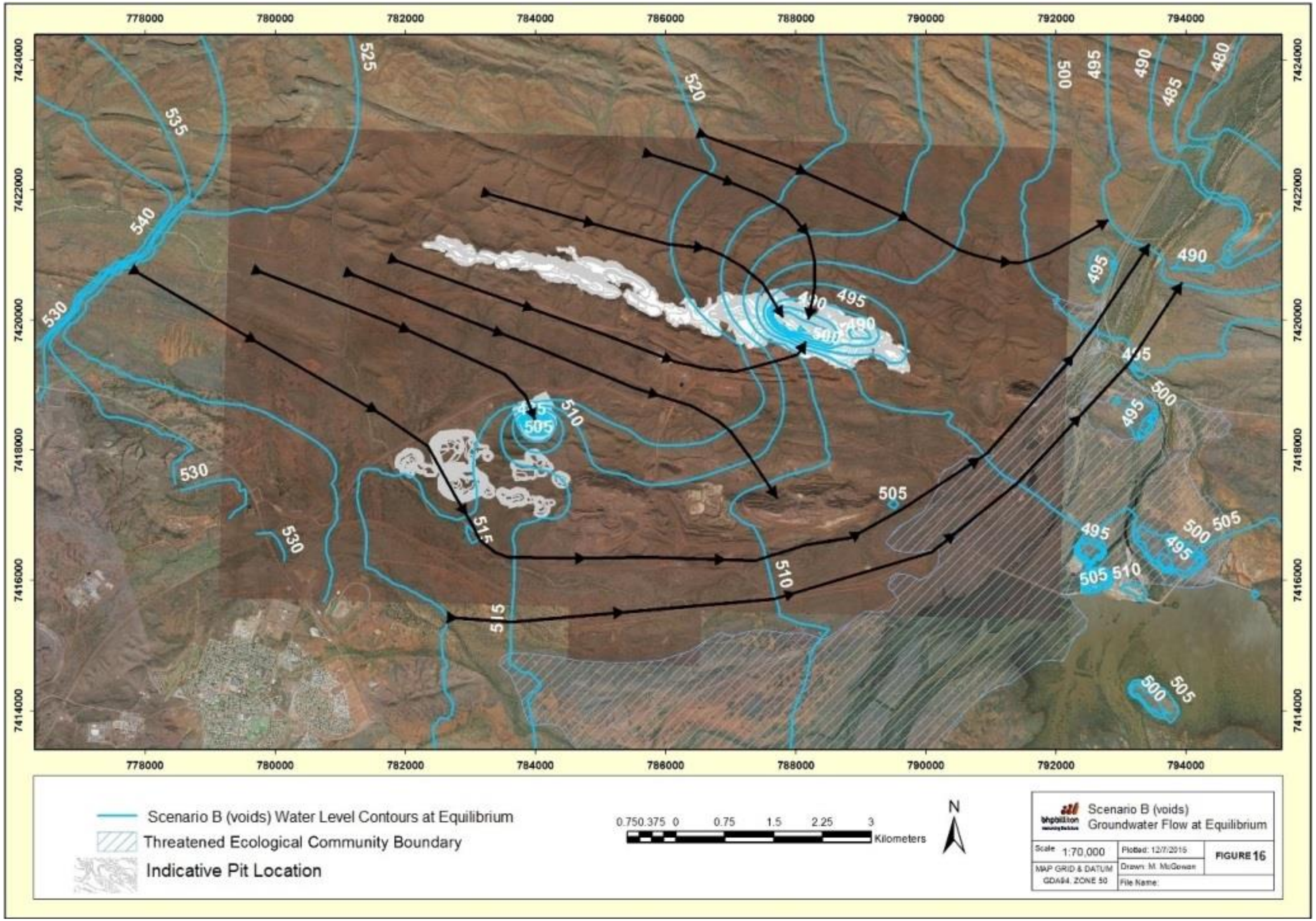

Scenario A (backfill) Water Levels at Equilibrium
Threatened Ecological Community Boundary
General Groundwater Flow Direction
Kilometers
N
Scenario A (backfill)
Groundwater Flow at Equilibrium
Scale 1:59,652
Plotted: 12/7/2015
Drawn: M. McGowan
File Name:
MAP GRID & DATUM GDA94, ZONE 50
FIGURE 15



Scenario B (voids) Water Level Contours at Equilibrium
Threatened Ecological Community Boundary
Indicative Pit Location
0.75 0.375 0 0.75 1.5 2.25 3
Kilometers
N
Scenario B (voids)
Groundwater Flow at Equilibrium
Scale 1:70,000
Plotted: 12/7/2015
FIGURE 16
MAP GRID & DATUM GDA94, ZONE 50
Drawn: M. McGowan
File Name:

Appendix

RPS

EASTERN RIDGE MINING OPERATIONS AMALGAMATION: SURFACE WATER ENVIRONMENTAL IMPACT ASSESSMENT

EASTERN RIDGE MINING OPERATIONS AMALGAMATION: SURFACE WATER ENVIRONMENTAL IMPACT ASSESSMENT

Prepared by:

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Our ref: 1744B/004e
Date: 24 September 2015

Prepared for:

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Perth WA 6000

Document Status

	Issue Date	Purpose of Document
Revision a	4 June 2015	Draft for Comments
Revision b	6 July 2015	Final
Revision c	9 July 2015	Final – Incorporating Client Comments
Revision d	11 September 2015	Final – Incorporating Client Comments
Revision e	24 September 2015	Final – Incorporating Client Comments

	Name	Position	Signature	Date
Author	Rhod Wright Kai Tan	Principal Civil / Water Engineer Water Resources Engineer		24 Sep 2015
Reviewer	D Monaghan	Principal Water Resources Engineer		24 Sep 2015

EXECUTIVE SUMMARY

BHP Billiton Iron Ore is proposing to amalgamate the “Eastern Ridge” mining operations under a single new Ministerial Statement. The current mining operations are all located on Mineral Lease 244SA and comprise of three existing Ministerial Statements:

- Orebody 23 operated under Ministerial Statement 478;
- Orebody 24 operated under Ministerial Statement 834;
- Orebody 25 operated under Ministerial Statement 712.

Ministerial Statements 712 and 834 are to be amalgamated, while Orebody 23 / Ministerial Statement 478 is not included in the proposal.

The consolidated Eastern Ridge mining operations will then be bounded by a single Development Envelope, with a single Key Characteristic Table, contemporary Ministerial conditions, and a regional approach to Management Plans. The mining operation will comprise Orebody 24, Orebody 25, Orebody 32 and the new Orebody 25 West mining operations.

The new single Development Envelope will mostly consist of a combination of existing approved Development Envelopes (4036ha) and five additional minor areas (372ha). The Development Envelope is located within the Homestead Creek catchment in the Upper Fortescue River catchment. This creek is a large ephemeral tributary of the Fortescue River which in turn drains to the Fortescue Marsh.

Potential surface water impacts associated with mining operations at the consolidated Eastern Ridge mining operations include discharge of dewatering from the pit, interruption of existing surface water flow patterns, ponding, and reduction in flow volumes to downstream ecosystems.

Surface water quality in Homestead Creek / Eastern Ridge area and adjacent creek systems may be characterised as fresh, with the proposed changes not expected to impact on water quality, given the following:

- Disposal of dewatering flows has the potential to impact the receiving waterbody unless consideration is given to management of volume and water quality, duration, frequency and seasonal variability.
- Potential surface water impacts also include the increased risk of erosion and sedimentation from disturbed mining areas unless appropriate control measures are implemented to mitigate these impacts.
- The use of chemicals and hydrocarbons at the site has the potential to impact water quality unless they are appropriately managed in accordance with regulation and best practice approaches.

The planned mining development works will cause some loss of catchment area and runoff volume to the downstream drainage system due to areas containing pits, OSA’s and catchments blocked or trapped by these works. The total cumulative loss of catchment area contributed by the mining operations within the proposed single Development Envelope is estimated at up to 6.8% of the Homestead Creek catchment, of which the new additional extension areas contribute up to 0.5% equivalent catchment loss. It is assumed the loss in catchment area produces the same proportionate loss in runoff volume.

This potential runoff volume loss lies within the overall seasonal variation of Homestead Creek flows and makes up a minimal portion of the runoff to environmental receptors such as Ethel Gorge and Fortescue Marsh. Implementation of appropriate engineering structures (e.g. diversion, bunds, culverts) would help to further minimise flow interruption, ponding and changes to runoff volumes by the planned works.

No significant changes to surface water drainage or quality are anticipated, where the risk cannot be appropriately managed and mitigated. Consistent with the EPA objective for Hydrological Processes and Inland Waters Environmental Quality, it is anticipated that the Eastern Ridge Development Envelope proposal and associated alterations to surface runoff and drainage should not adversely impact the existing surface water regime and ecosystems.

TABLE OF CONTENTS

TABLES

FIGURES (compiled at end of report)

1. INTRODUCTION

1.1 Project Description

BHP Billiton Iron Ore Pty Ltd (BHP Billiton Iron Ore) is proposing to amalgamate the “Eastern Ridge” mining operations under a single new Ministerial Statement (Figure 1 and Figure 2). The Eastern Ridge operations involve conventional open pit mining, with ore then crushed at the Orebody 24 and Orebody 25 crushers and railed to Newman Hub, or directly to port based on business requirements.

The current mining operations are located on Mineral Lease 244SA and operate under three existing Ministerial Statements:

- Orebody 23 operated under Ministerial Statement 478;
- Orebody 24 operated under Ministerial Statement 834;
- Orebody 25 operated under Ministerial Statement 712.

Ministerial Statements 712 and 834 are to be amalgamated, while Orebody 23 / Ministerial Statement 478 is not included.

The consolidated Eastern Ridge mining operations (Figure 2 and Figure 3) will then be bounded by a single Development Envelope, with a single Key Characteristic Table, contemporary Ministerial conditions, and a regional approach to Management Plans. The mining operation will comprise Orebody 24, Orebody 25, Orebody 25 West and Orebody 32 mining operations:

- The Orebody 24 deposits are located on a parallel ridge line (Ophthalmia Range) immediately to the north of Eastern Ridge;
- The Orebody 25 deposits are located on a ridge line about 7km long (Eastern Ridge). To date mining has been carried out on the eastern two-thirds of the ridgeline;
- Orebody 25 West operations are located on the western third of Eastern Ridge;
- The future Orebody 32 mining operation is on a hill west of Eastern Ridge.

The new single Development Envelope will consist of mostly a combination of pre-existing development envelopes (totalling 4036ha) and five additional minor areas (totalling 372ha) (refer Figure 3 and Table 1.1).

Table 1.1: Consolidated Eastern Ridge Development Envelope

Description of Components	Area (ha)
OB24:	
Approved	2,283
New – Area 1	24
New – Area 2	209
New – Area 3	59
New – Area 4	28
OB25:	
Approved (including OB25 West)	1,340
OB32:	
Under assessment	413
New – Area 5	52
Proposed TOTAL (single Eastern Ridge Development Envelope)	4,408

These mining operations lie approximately 6-9km north-east of Newman township and 12km north-east of the Newman Hub (which includes Mount Whaleback and Orebody's 29, 30 and 35 mining operations).

The mining operations in any part of the Eastern Ridge mining operations include new pits or extension of existing pits, Overburden Storage Areas, construction and use of haul and access roads, various topsoil, run-of-mine and low grade ore stockpiles and ancillary infrastructure.

Consolidated mining operations include:

- Current approved operations (i.e. Orebody 24 and Orebody 25);
- Proposed mining operations referred but not yet approved (i.e. Orebody 32);
- Proposals not yet referred (i.e. new mining operations, Orebody 25 West).

1.2 Objectives and Purpose of Report

This surface water report has been prepared to support the Environmental Impact Assessment (EIA) process for the proposal. This report describes the potential for surface water impacts from the proposal associated with amalgamated and new mining operations, and describes the potential significance of these impacts in relation to surface water in the region.

Stormwater management, surface water discharges and activities that discharge to the environment are regulated under the Environmental Protection Act (EPA).

The EPA applies the following objective to the assessment of proposals that may affect key surface water (a) Hydrological Processes and (b) Inland Waters Environmental Quality:

- To maintain the hydrological regimes of groundwater and surface water so that existing and potential uses, including ecosystem maintenance, are protected;
- To maintain the quality of groundwater and surface water, sediment and biota so that the environmental values, both ecological and social, are protected.

1.3 Applicable Guidelines and Standards

The protection of water quality is primarily governed by Part V of the EPA, which, among other matters, regulates activities with potential to cause pollution or environmental harm. Regulation of potentially polluting activities is primarily through Works Approvals and associated discharge licensing provisions of the EPA and regulations.

Applicable Guidelines and Standards include:

- ANZECC / ARMCANZ Guidelines;
- Water Quality Protection Notes and Guidelines for mining and mineral processing applied by the Department of Water (DoW) and Department of Mines and Petroleum (DMP);
- State Water Quality Management Strategy.

2. BASELINE HYDROLOGY

2.1 General

The Pilbara area is characterised by an arid-tropical climate receiving summer rainfall. Cyclones can occur during this period, bringing heavy rain.

2.2 Temperature

The Pilbara climate is arid and experiences two main seasons: hot summers and mild and dry winters. The mean maximum temperatures average 36-37°C from November to April, up to 50°C. Temperatures over the May to October period are milder, with mean maximum temperatures averaging 28-29°C and cooler nights, particularly in inland desert regions, with mean minimums of around 6-9°C in July, dropping to lows of 0°C.

The nearest Bureau of Meteorology (BOM) climate station to Eastern Ridge is at Newman Aero (Site Number 007176). The average monthly temperatures at Newman (1981-2015) are provided in Table 2.1.

Table 2.1: Newman - Average Monthly Temperatures (2015)

Average Temperature [°C]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Maximum	39.2	37.2	34.9	31.7	26.9	22.9	23.0	26.2	30.5	35.1	37.4	38.9
Minimum	24.9	24.0	21.6	17.4	11.9	7.0	6.2	7.8	12.2	17.7	20.9	23.8

2.3 Rainfall and Evaporation

Rainfall in the Pilbara is generally low (270-400mm per annum) and variable throughout the year. The annual average rainfall for Newman is 326.8mm (BOM, Newman Aero, Site Number 007176). Annual variability is high with recorded rainfall varying between 153mm (1976) and 619mm (1999).

Rainfall is greatest during summer, resulting from moist storms from the north which bring sporadic and drenching thunderstorms. With the exception of these large events, rainfall can be erratic and localised due to thunderstorm activity (rainfall from a single site may not be representative of the spatial variability of rainfall over a wider area). High summer temperatures and humidity seldom occur together, giving the Pilbara its very dry climate.

The Pilbara coastline lies within the most tropical cyclone-prone region of the Australian coast (Broome to Exmouth). On average, two tropical cyclones cross this coastline each year, mainly from January to March, and capable of producing destructive winds.

During May and June, cold fronts move east across WA, sometimes reaching the Pilbara region, producing light winter rains.

On average, the driest months are August to October, and January / February are the wettest months. Average monthly rainfall for Newman (1981-2015) is provided in Table 2.2.

Table 2.2: Average Monthly Rainfall at Newman and Evaporation at Wittenoom (2015)

Average Rainfall/Evap	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rainfall [mm]	65.3	73.7	42.5	20.6	19.5	14.5	15.2	7.2	4.2	5.6	13.1	38.2
Evaporation [mm]	353	274	279	228	177	135	152	189	258	344	372	384

Average monthly pan evaporation rates are shown in Table 2.2 with a mean annual pan evaporation rate of about 3100mm, as measured at the BOM meteorological site (005026) at Wittenoom (190km north-east of Newman). These evaporation rates vary from a minimum of 135mm in June to a maximum of 384mm in December on average.

2.4 Rainfall Intensities

Design rainfall intensity data for the Eastern Ridge area are given in Table 2.3 ("Australian Rainfall and Runoff", Engineers Australia, 2013). These data provide for various rainfall durations and average exceedance probabilities (AEP).

Table 2.3: Eastern Ridge - Average Rainfall Intensities [mm/hr]

Rainfall Duration	20% AEP*	10% AEP	5% AEP	2% AEP	1% AEP
1 hour	34.0	41.3	48.5	58.0	65.2
6 hours	63.6	79.9	97.1	121.9	142.5
12 hours	81.6	104.4	129.1	165.8	197.2
24 hours	101.8	131.6	164.1	213.0	255.4
48 hours	119.3	153.9	191.3	246.7	294.0
72 hours	126.7	162.4	200.3	255.5	301.9

* Note that 1% AEP is equivalent to 100 year Average Recurrence Interval (ARI) i.e. AEP Ξ 100 / ARI

2.5 Streamflow

Streamflow in the Pilbara region is typically correlated with rainfall, with the majority of streamflow occurring during the summer months. Streamflow in smaller flow channels is typically of short duration, and ceases soon after the rainfall passes. In the larger river channels, runoff can persist for several weeks and possibly months following major rainfall events, such as tropical cyclones.

Streamflow gauging stations are widely spaced in the Pilbara region. A gauge is located on the Fortescue River near Newman (Department of Water [DoW] Station 708011, catchment area 2,822km^2). Available gauging data from 1980 indicates an average annual runoff volume of 5.4% of the annual rainfall over the catchment. However, the variability of annual runoff is high, with annual runoff varying between 0-15% of the average rainfall.

Due to relative catchment sizes, streamflow data recorded at this gauging station does not necessarily represent the runoff characteristics in the Eastern Ridge area.

Homestead Creek flows through the Eastern Ridge area, and into the Fortescue River.

2.6 Climate Change

2.6.1 Definition

Climate change is generally defined as a change in average, long term, global weather patterns. It commonly suggests increases in temperature, greater or lesser precipitation at any given location, and occurrences of extreme weather events (Department of Environment, 2015).

2.6.2 Temperature

Australia's climate has warmed since national records began in 1910, especially since 1950, and average daytime maximum and overnight minimum temperatures have warmed by 0.8°C and 1.1°C respectively. The Pilbara region is becoming warmer, with more hot days and less cold nights.

Modelling predicts about 1°C (above 1990 temperatures) average warming across Australia by 2030 (0.7-0.9°C in coastal areas and 1.0-1.2°C inland). By 2070, average warming is expected to be between 2.2-5.0°C across Australia, depending on the emissions scenario adopted or endorsed.

2.6.3 Rainfall

Average annual rainfall over Australia has increased since national records began in 1900, largely due to increases in rainfall from October to April, and most markedly across the north-west of the country. Rainfall trends in the Pilbara have similarly also shown a substantial increase since 1950.

Global climate models show uncertainty in regard to future Pilbara rainfall trends, but predict a decrease in the total number of tropical cyclones, but a likely increase in the proportion of more intense cyclones (by 2030 there may be a 60% increase in intensity of the most severe storms, and a 140% increase by 2070). Hence, more extreme storm events and flash flooding are predicted, along with more frequent and severe droughts (Department of Environment, 2015).

The adoption of a 5% increase in rainfall intensity per degree temperature increase is under consideration by the BOM. With regards to the most extreme precipitation events, the BOM has concluded that it is not possible to confirm that Probable Maximum Precipitation will definitely increase under a changing climate (Engineers Australia, 2011).

3. EXISTING ENVIRONMENT

3.1 Homestead Creek

The amalgamated Eastern Ridge mining operation is located within the Homestead Creek catchment in the Upper Fortescue River catchment, as shown in Figure 2.

Homestead Creek is a large ephemeral tributary of the Fortescue River. The creek rises in the Ophthalmia Range about 20km west of Newman and drains eastwards, passes along the southern side of Eastern Ridge, crosses the Marble Bar Road and ultimately discharges into the Fortescue River 3km downstream of Ophthalmia Dam. The Homestead Creek catchment is about 302km² at the Fortescue River.

3.2 Fortescue River System

The Upper Fortescue River catchment is a closed system with a total catchment area of ~29,700km^2, draining to the Fortescue Marsh formed by the Goodiadarrie Hills at the western downstream end. The lower Fortescue River drains north-west to the ocean south of Karratha.

The Fortescue Marsh is an extensive intermittent wetland (about 100km long, 10km wide) with an elevation of about RL400m. Following a large rainfall event, runoff from the various catchments drains to the marsh. A major flood event may be sufficient to flood the whole marsh area, while in smaller runoff events, isolated pools form on the marsh surface opposite the main drainage inlets.

Surface water runoff to the marsh has low salinity and turbidity, though the turbidity typically increases significantly during flood peaks. Water stored on the marsh slowly dissipates through evaporation and seepage. Evaporation increases salinity in the ponded water and as the flooded areas recede, traces of surface salt can be seen. The ponded water seeps into the valley floor alluvial deposits, and groundwater below the marsh is believed to be saline to hypersaline.

3.3 Existing Surface Water Quality

Surface water quality monitoring is regularly conducted by BHP Billiton Iron Ore when rainfall has resulted in surface water being present in the creek systems. Monitoring results are available at Homestead Creek between 1998 and 2015, at a point just west of Eastern Ridge (OB25SW001, upstream) and another (OB25SW003, downstream) located on Homestead Creek near the junction with the Fortescue River. Based on this water quality sampling:

- pH of the water in Homestead Creek is neutral, typically pH6-8;
- An Electrical conductivity (EC) field measurement taken on 3 March 2015 read 100 µS/cm (upstream) and 50 µS/cm (downstream), equivalent to about TDS of 60 mg/L and 30 mg/L;
- TDS has been measured on 28 occasions with results of 25-350mg/L (upstream); and 3 occasions with results of 76-155mg/L (downstream);
- TDS readings at the Fortescue River (Newman) gauging station typically vary from 20-100mg/L after a major flow event, with an average of about 40mg/L;
- Salinity readings can be highly variable depending on the flow preceding the water sample date and the flow at the time of sampling;
- Electrical conductivity (EC) and Total Dissolved Solids (TDS) are measures of salinity. Monitoring results have been compared with ANZECC assessment levels for Tropical Upland Rivers, as detailed in the ANZECC Guidelines for Tropical Australia Aquatic Ecosystems, where full trigger values for salinity (indicative of slightly disturbed ecosystems in tropical Australia) are 20-250 µS/cm or 15-170mg/L respectively;
- Total Suspended Solids (TSS, mg/L) was measured as 4-18,000mg/L on 37 occasions at the upstream site; and 11-920mg/L on 7 occasions at the downstream site. TSS readings can also be variable, and may be expected to be particularly high when the creek is in flood.
- With pH approximately neutral and TDS typically <350mg/L, the surface water quality measured in Homestead Creek may be characterised as “fresh”.

4. SURFACE WATER HYDROLOGY

4.1 General

Homestead Creek drains east along a broad valley. Near Orebody 32, Ophthalmia Range and Eastern Ridge are about 2km apart. The creek turns south at Orebody 32 for 2.7km and then passes around the western end of Eastern Ridge (refer Figure 2), and then along the southern side of Eastern Ridge.

Homestead Creek is a relatively large creek with a formed channel typically about 20m wide in the vicinity of Eastern Ridge (but commonly wider), with a mobile (sand / gravel) bed. The creek has a typical bed slope of about 0.3%.

The consolidated Eastern Ridge Development Envelope is located in the Homestead Creek catchment as shown on Figure 2 and 3. During the establishment of the Development Envelope, a 50m buffer was applied to Homestead Creek.

4.2 Current and Future Mining Operations

Current disturbed areas represent about 10% of the proposed consolidated Eastern Ridge Development Envelope area. The surface drainage patterns in the area are dominated by Eastern Ridge and Ophthalmia Range (refer Figure 2), where operations lie on both the north and south ridge slopes (approximately 150m high above the valley floor between the two ridges). This drainage pattern will continue throughout future mining operations.

Surface water drainage from Orebody 25 mining activities on Eastern Ridge is mainly south, directly into Homestead Creek.

Surface water drainage from Orebody 24 mining activities on Ophthalmia Range is mainly to the south into the valley between the ranges; this valley mainly drains eastward to meet Homestead Creek at the eastern end of Eastern Ridge. The western end of the rail loop represents a high point or crest in the valley from where the valley drains eastward and westward (into Homestead Creek at different locations).

The north slope of Ophthalmia Range drains into an unnamed creek that flows east into the Fortescue River.

Surface water drainage from future mining operations within the Eastern Ridge Development Envelope will continue to be dominated by Eastern Ridge and Ophthalmia Range. The proposed operations will be located on both the north and south slopes of both ridges.

4.3 Future Mining Operations – Orebody 25 (Figure 4)

Surface water runoff from current mining activities on the south slope of Eastern Ridge drains directly into Homestead Creek. The proposed minor changes to the existing Pit 1 are also located on the south side of the ridgeline. These developments will have minimal impact on current drainage regimes and as such, will not be reassessed as part of the scope in this Environmental Impact Assessment.

4.4 Future Mining Operations – Orebody 24 (Figure 4 and 5)

Pre-existing drainage patterns on the south slope of Ophthalmia Range flow into the Ophthalmia / Eastern valley. However, existing and future mining activities will extend over about 7km and will largely mine out the south slope of Ophthalmia Range. Any (minor) catchments trapped between the pit and crest of the Ophthalmia Range ridgeline would enter the pit unless bunding and / or diversions are installed.

Existing and future operational areas, haul roads, etc, downstream of the pits and OSA's will continue to drain into the Ophthalmia / Eastern valley.

The proposed Area 1 extension to the OB24 boundary is located to the north west of the OB24 development, and intercepts a minor catchment that will already be intercepted by the OB24 pit development in the future.

The proposed Area 2 extension to the OB24 boundary is located on the north slope of Ophthalmia Range, where surface water drains north into a creek line (outside the Development Envelope), which in turn drains east into the Fortescue River. It is anticipated that any trapped catchments within this area will be minor and stormwater runoff will pond against any OSA's that will be constructed in this area, or where possible, pass directly north out of the Development Envelope and outside the Homestead Creek catchment.

The proposed Area 3 extension to the OB24 boundary is located on the eastern end of Ophthalmia Range. The majority of this area drains into Homestead Creek south of Orebody 23. A small portion drains to the north and outside the Homestead Creek catchment.

The proposed Area 4 extension to the OB24 boundary is located to the south west of the OB24 development and intercepts a minor catchment which drains past Orebody 32 and into the valley to the west and eventually to Homestead Creek.

4.5 Future Mining Operations – Orebody 25 West (Figure 4 and 6)

Orebody 25 West mining activities are located on both sides of Eastern Ridge. The pits will only intercept minor catchments on their upstream side, and therefore surface water drainage will have minimal impact. Runoff from these minor catchments cut off by pits can either be permitted to enter the pits, or diverted along existing watercourses between the pits and into Homestead Creek.

The proposed Orebody 25 West Joffre OSA will also (eventually) intercept a small catchment on its south side.

The 10,000 year Homestead Creek flood extents are shown in Figure 3 and encroach in places into the Proposed Development Envelope. The location of operational infrastructure within the Development Envelope can be typically compared against the 100 year flood extents in major creek systems, given there is a probable chance of this event occurring during the life of the mine. All the proposed infrastructure developments remain non-flood affected with the possible exception of a single pit located on the western edge of the Development Envelope. In this case, suitable flood bund protection can be applied at the edge of the pit.

4.6 Future Mining Operations – Orebody 32 (Figure 4 and 7)

The future Orebody 32 mining activities lie predominately on a hill standing about 45m above the surrounding terrain, and located just south of Ophthalmia Range. At the western end, the planned pit development area naturally drains from the ridge top in all directions. The lower areas of the pit (depending on pit outline) are potentially impacted by flooding in Homestead Creek. The pit also disrupts surface water runoff from Ophthalmia Range.

At the eastern end of the proposed pit, the north side cuts off a flow path from Ophthalmia Range and the valley drainage, a catchment area of about $8km^2$. This upstream catchment will be impacted by planned developments in Orebody 24 and 32, reducing the effective catchment area.

The proposed Area 5 extension to the OB32 boundary is located on the same $8km^2$ catchment discussed above.

4.7 Future Mining Operations – Access and Haul Roads

A network of haul roads currently link pits and OSA's to the wider network of roads for access to Orebody 24 and 25 Ore Handling Plants. This network will be extended in keeping with the proposed extension of mining operations within the Eastern Ridge Development Envelope. The proposed network extension of roads will cross numerous watercourses.

5. POTENTIAL MINE SITE IMPACTS

5.1 Potential Impacts from Mining Activities

5.1.1 General

The proposed mining infrastructure is outside the Homestead Creek main channel, although the western most Orebody 25 West pit is within the 100 year flood extent. Some of the proposed developments also intercept, or are within the floodplain of several tributaries to Homestead Creek. As a result, the potential impacts of the proposed Eastern Ridge Development Envelope include modifications in watercourse flow patterns, causing changes to surface flow volumes and water quality downstream (through erosion and sedimentation from disturbed areas, and chemical spills and wastewater).

Potential surface water impacts associated with mining operations at the overall Eastern Ridge Development Envelope are:

5.1.2 Dewatering of Pits

- Where dewatering discharge to environment is required, the quality, duration and frequency of the discharge and seasonal variability of the receiving water quality can significantly alter the state of the receiving waterbody and affect its normal ecosystem function (water quality, biota, light penetration) as well as downstream uses of the water;
- Discharge water containing high solids load or a high concentration of contaminants, or differing substantially in nature from the receiving waterbody, can affect regional water quality;
- A change in the volume of water in the receiving waterbody may also impact on its normal ecosystem function;
- Mine dewatering may cause an expansion of area of drawdown, potentially affecting any groundwater dependent ecosystems that may be present in the drawdown area.

5.1.3 Interruption of Existing Surface Water Flow Patterns

- The proposed developments are not expected to intercept the main channels of any major creeks or drainage lines.
- However, mine pits and OSA's / stockpiles and service infrastructure (including linear infrastructure such as roads and pipelines) may interrupt minor surface water flow patterns by diverting watercourses through and around the infrastructure. This can result in capturing rainfall within mining areas, reducing the contributing catchment area to downstream flows (and potentially shadowing) resulting in a runoff loss to the downstream environment;
- Changes to the natural hydrological regime can be minimised by locating infrastructure outside the main channel of major drainage lines where possible;
- If this is not feasible, intercepted watercourses that require diversion should be redirected into the same drainage lines. Roads that intercept drainage lines should be culverted to allow runoff to continue downstream.

5.1.4 Runoff Loss to Downstream Environment

- Mine areas are typically designed to be internally draining during operations to minimise potential downstream water quality impacts from turbidity and contamination. However, the effect of this drainage design isolates the mine area from the catchment area of downstream creek lines;
- Mining structures therefore have the potential to reduce the surface water runoff volumes received by downstream ecosystems;
- An open pit and its trapped catchment upstream are a direct catchment loss;
- OSA's characteristically reduce surface water runoff due to the uneven surface created and porous uncompacted surface of the material. Runoff is typically generated by the sloped

faces, and absorbed by the flat benches;

- Where pits are within the floodplains of major drainage lines, bunding should be installed to prevent flooding of the pit and to minimise loss of runoff to the downstream environment.

5.1.5 Increased Risk of Erosion and Sedimentation from Disturbed Areas

- Rainfall and surface water runoff from all disturbed mining areas has the potential to increase erosion and transmit sediment laden water to the environment / natural drainage systems downstream. The main potential sediment sources are OSA's and stockpiles;
- The diversion of watercourses around mine infrastructure may result in changes to flow velocities, concentrate sheet flow and potentially increase local flow velocities and soil erosion;
- Where mining occurs on or near the top of ridgelines, sediment laden water also has the potential to drain away from controlled drainage systems into undisturbed areas. Particular attention should be given to manage areas where runoff drains to the undisturbed environment outside the Homestead Creek catchment.

5.1.6 Ponding

- The diversion of watercourses around mine infrastructure may result in changes to flood extents;
- Diversion of watercourses can result in temporary changes in flow depth (decreased in some areas and increased in other areas). Some areas which would be expected to receive flows in particular rainfall events may now become dry, and other areas that would be expected to be dry may now receive flows (ponding);
- The construction of mining infrastructure can also trap surface water runoff from catchments upstream of the infrastructure.

5.1.7 Contamination of Surface Water by Chemicals or Hydrocarbons

Spills and inappropriate use and disposal of chemicals and hydrocarbons can have direct and indirect surface water environmental impacts as follows:

- Soil contamination;
- Contamination of groundwater resulting in a reduction in water quality;
- Contamination of surface water resulting in a reduction in water quality.

5.2 Assessment of Runoff Loss to the Downstream Environment

5.2.1 General

The entire Eastern Ridge Development Envelope lies within the Homestead Creek catchment. An assessment has been made of the loss of catchment area to Homestead Creek due to the Proposed Development Envelope as a whole (cumulative impacts); and due to the proposed new mining extension areas only.

The runoff volume is likely to decrease from areas containing pits and OSA's due to the reduction in catchment area from the infrastructure footprints and catchments blocked or trapped by these works. In comparison, runoff volumes from infrastructure areas such as roofs, hardstands and access roads may increase from concentration and redirection of flows.

Only pit and OSA areas have been considered to contribute to non-recovered runoff volume. Indicative future pit and OSA areas were based on layouts provided by BHP Billiton Iron Ore on 06/05/2015. The runoff volumes from other infrastructure areas are considered to remain effectively unchanged (neutral).

On this basis, 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.

5.2.2 Cumulative Surface Water Runoff Loss in the Homestead Creek Catchment

An approximate estimate of the total planned relevant pit and OSA / stockpile areas for the Proposed Development Envelope is provided in the table below. The table also shows the loss in catchment area from the pits and OSA's / stockpiles compared to the overall Homestead Creek catchment area of 302km^2.

Table 5.1: Estimated Area Impacted by Mining in the Eastern Ridge Development Envelope

Location	Indicative Pit/OSA Areas (ha)	Adopted Runoff Loss	Catchment Area Loss Estimate (ha)	% Catchment Area Loss
OB24 (existing & future operations) - indicative Pits	350	100%	350	1.2%
OB24 (existing & future operations) – indicative OSA & Stockpiles	505	50%	253	0.8%
OB25 (existing operations) - indicative Pits	320	100%	320	1.1%
OB25 (existing operations) - indicative OSA & Stockpiles	400	50%	200	0.7%
OB25W (future operations) - indicative Pits	150	100%	150	0.5%
OB25W (future operations) - indicative OSA	111	50%	56	0.2%
OB32 (future operations) - indicative Pits	240	100%	240	0.8%
OB32 (future operations) - indicative OSA	130	50%	65	0.2%
SUBTOTAL	***2,206***		***1,633***	***5.5%***
Extension areas	8.4%		137	0.5%
Unplanned developments	15%		245	0.8%
GRAND TOTAL			**2,015**	**6.8%**

The existing and planned indicative future pits and OSA's are estimated to reduce the catchment by up to 1,633ha or 5.5% of the Homestead Creek catchment. Assuming the reduction in catchment area is directly proportional to the reduction in runoff volume, a 5.5% potential reduction in runoff volume is not expected to be environmentally significant, particularly when considering the natural seasonal variations in catchment runoff.

The five new extension areas make up 8.4% of the total area in the consolidated Development Envelope (372ha of 4,408ha, refer Table 1.1). No development plans are currently available for these areas. Hence, the effective catchment loss from the extension areas has been assumed to also be 8.4% of the estimated existing and planned area impacted by mining (1,633ha). This is equivalent to an additional 137ha of catchment lost, or 0.5% of the Homestead Creek catchment, which is not considered significant.

A nominal 15% contingency has been added for unplanned future pits and OSA's, as well as small catchment areas trapped upstream of these infrastructure. This is equivalent to an additional 245ha of catchment area lost, or 0.8% of the Homestead Creek catchment, which is not considered significant.

The total effective catchment area loss due to the Proposed Development Envelope mining areas is estimated to be about 2,015ha. This is equivalent to a reduction in runoff volumes of about 6.8% to the Homestead Creek catchment, 0.4% to Ethel Gorge (catchment area 4,872km^2) and 0.07% to Fortescue Marsh (catchment area 29,700km^2), as shown in Figure 1. This total potential reduction in runoff volume is not expected to be environmentally significant.

5.3 Closure

Mine closure requires the remaining landforms to be safe, stable and non-polluting against any potential surface water impacts that could occur over an extended period of time.

The surface water system at closure will be designed to meet the closure principle of no significant impact on baseline surface water quality and flow regimes in nearby waterways. Key considerations will include an assessment of the likelihood that mine voids will 'capture' creek lines, or that major climatic events will result in damage to surface water controls (including those on constructed landforms) that may in turn impact future groundwater/surface water interactions and hence, long term water balances.

This requires assessment of landforms against events greater than a 100 year flood event typically applied for operational purposes, which has a 1% probability of occurring in 100 years. Consistent with the Department of Mines and Petroleum / Environmental Protection Authority Guidelines for Preparing Mine Closure Plans (2015), a risk based approach is applied. For example, for high risks, the 1,000 years, 10,000 year or Probable Maximum Flood (PMF) may be adopted as a design criterion and/or to sensitivity testing for closure.

5.3.1 Pits

Of the existing Eastern Ridge pits, Orebody 25 Pit 3 and Orebody 23 are located the closest to Homestead Creek and are the most susceptible to flooding. Current closure work has primarily focused on Pit 3. External consultants have completed hydraulic modelling of Homestead Creek (MWH 2014) and assessed a number of different closure scenarios to determine the most suitable surface water closure strategy for Pit 3. The results of the hydraulic modelling show that the proposed development envelope generally remains above the 10,000 year flooding level in Homestead Creek (Figure 3). However, if the existing access road adjacent to the southern crest of Pit 3 is removed or eroded over time, there will be substantial overflow into the pit. A headcut would reach the Homestead Creek streambed within a single event exceeding the 100 year ARI flood and flows from Homestead Creek would be routed into Pit 3 thereafter. The hydraulic model also extended to Orebody 23, which was found to be more susceptible to pit flooding than Orebody 25 under existing conditions.

Options that were considered to mitigate the risk of creek capture by Pit 3 included using a combination of backfill and flood levees. Backfill options varied from none, partial (for pit wall stabilisation and/or pit lake depth control) or full backfill. The proposed closure strategy that is being progressed is full backfill to the lowest free draining level. It is noted that current ministerial conditions require Pit 3 to be backfilled based on potential groundwater and stygofauna impacts in closure.

For other pits that may be impacted by Homestead Creek flooding e.g. Orebody 32 and Orebody 25 West, similar creek capture considerations apply. For pits that are unlikely to be impacted by Homestead Creek flooding, structures may still be required to manage impacts associated with inundation of the pit void from local surface water runoff. Potential impacts and available mitigation measures are summarised in Table 5.2.

Sufficient material is available to achieve the backfill options if this is determined as necessary during the closure landform design development. Where final voids remain, closure will need to focus on ensuring geotechnical and geochemical stability as well as public safety.

Table 5.2: Potential Impacts and Mitigation Options for Pits in Closure

Event	Causes	Potential Environmental Impacts	Mitigation Options
Reduction of downstream flows	Pit has a large in-pit catchment area Pit intercepts a main flow path or large external catchment area	Negative impact on ecosystems sensitive to surface water runoff volumes e.g. mulgas Reduced downstream groundwater recharge	External bunding and diversions to direct runoff downstream Backfill pit to pre-mining ground level to reinstate original drainage patterns
Pit lake forms and becomes a groundwater sink	Pit mined below water table Rate of evaporation > groundwater and surface water inflow	Increased salinity of pit lake water Potential for acid mine drainage to form	Backfill pit to at least regional water table level
Pit lake forms and allows groundwater throughflow	Pit mined below water table Rate of evaporation < groundwater and surface water inflow	Transfer of potentially saline or acidic pit lake water into the aquifer	Backfill pit to at least regional water table level

5.3.2 Overburden Storage Areas

Surface water management around OSA's during operations can have implications during closure. The scope of this assessment addresses the topographical implications of the mine closure design.

Site selection prior to construction will ensure no major drainage lines are interrupted during operations and closure. As noted in Section 5.1 there is not anticipated to be significant interception of major drainage lines as a result of pits or OSA's.

OSA's are prone to erosion and require management methods that are self-sustaining during closure. The Department of Mines and Petroleum (2009) recommends that OSA's in arid regions have profiles that are designed to be water retaining. Impoundments on the flat surfaces to hold the design rainfall event and ripping at intervals on the sloping surface will generally achieve the necessary control. This is being trialled at other WAIO operations including Whaleback in the form of store and release cells on the top surfaces of some OSA's.

6. CONCLUSION

The proposed mining infrastructure is outside the Homestead Creek main channel, although the western most Orebody 25 West pit is within the 100 year flood extent. Some of the proposed developments also intercept or are within the floodplain of several tributaries to Homestead Creek. As a result, the potential impacts of the proposed Eastern Ridge Development Envelope include discharge of dewatering flows from the pit, interruption of existing surface water flow patterns, ponding, and reduction in flow volumes to downstream ecosystems.

Disposal of dewatering flows where necessary has the potential to impact the receiving waterbody unless consideration is given to volume and water quality, duration and frequency of the discharge and seasonal variability.

Potential surface water impacts also include the increased risk of erosion and sedimentation from disturbed mining areas unless appropriate control measures are implemented to mitigate these impacts. Particular attention should be given to managing areas where runoff drains to the undisturbed environment outside the Homestead Creek catchment.

The use of chemicals and hydrocarbons at the site has the potential to impact water quality unless they are appropriately managed in accordance with regulation and best practice approaches. This may include the required approvals and licences, risk assessments, training and equipment, storage, bunding, oily water treatment, etc.

Interruption of existing flow patterns is minimal and not expected to have a significant environmental impact provided appropriate engineering structures e.g. diversion, bunds, culverts are used to enable flow to continue downstream. These structures will also assist to ensure runoff volumes remain largely unchanged by the planned works. Some reduction in surface runoff volume may occur due to the pit and OSA developments in particular, however the potential loss in downstream flow volume may be considered less than the natural overall seasonal variation of local creek flows.

No significant changes to surface water drainage or quality are anticipated where the risk cannot be appropriately mitigated. Consistent with the EPA objective for Hydrological Processes and Inland Waters Environmental Quality, it is anticipated that the Eastern Ridge Development Envelope proposal and associated alterations to surface runoff and drainage should not adversely impact the existing surface water regime and ecosystems.

7. REFERENCES

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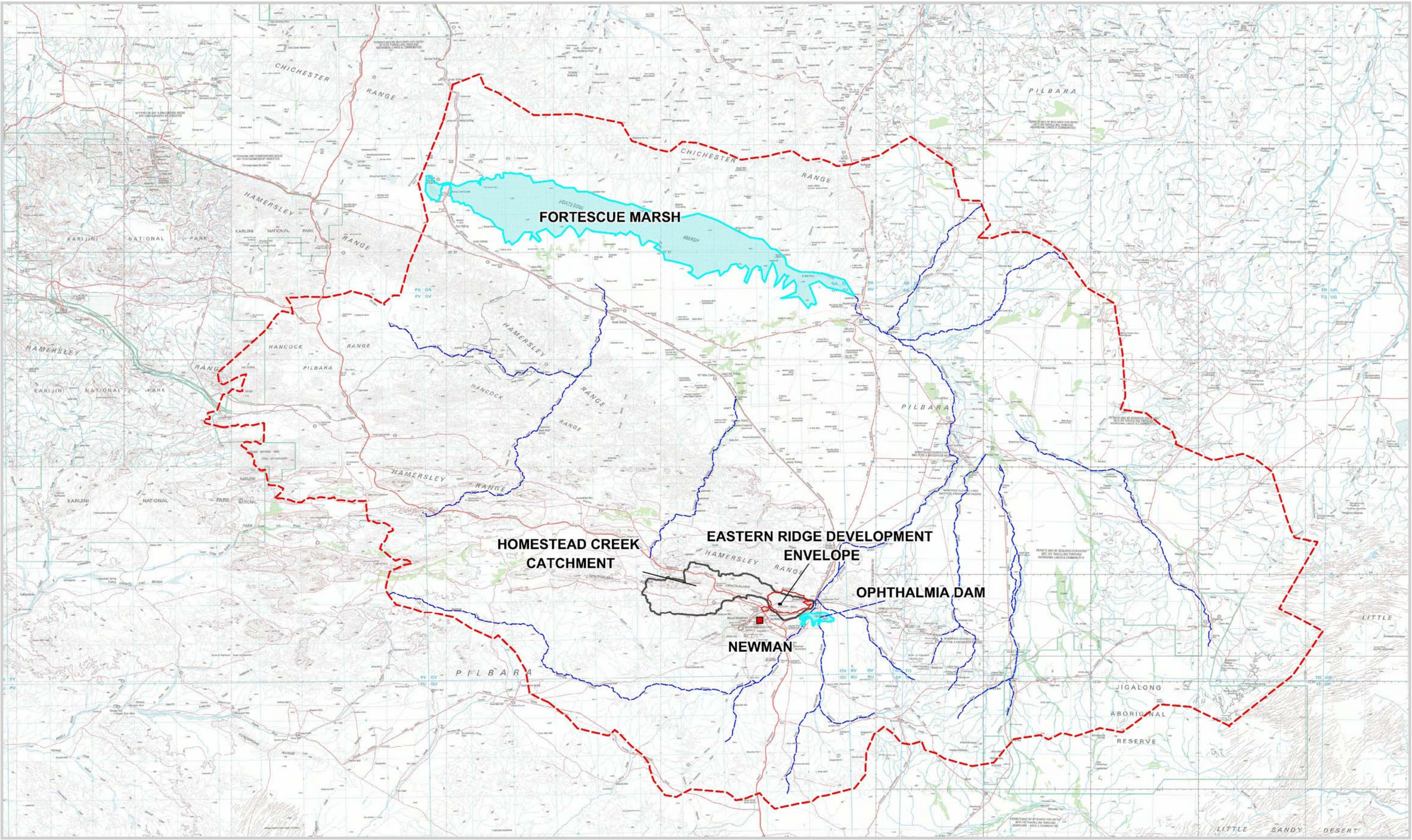
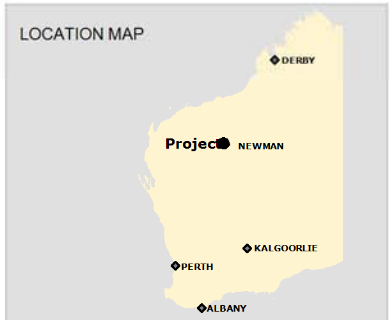
FIGURES





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GDA 1994 Zone 51

AUTHOR: RW	REPORT NO: 004
DRAWN: KT	REVISION: A
DATE: 07/09/15	JOB NO: 1744B

LEGEND

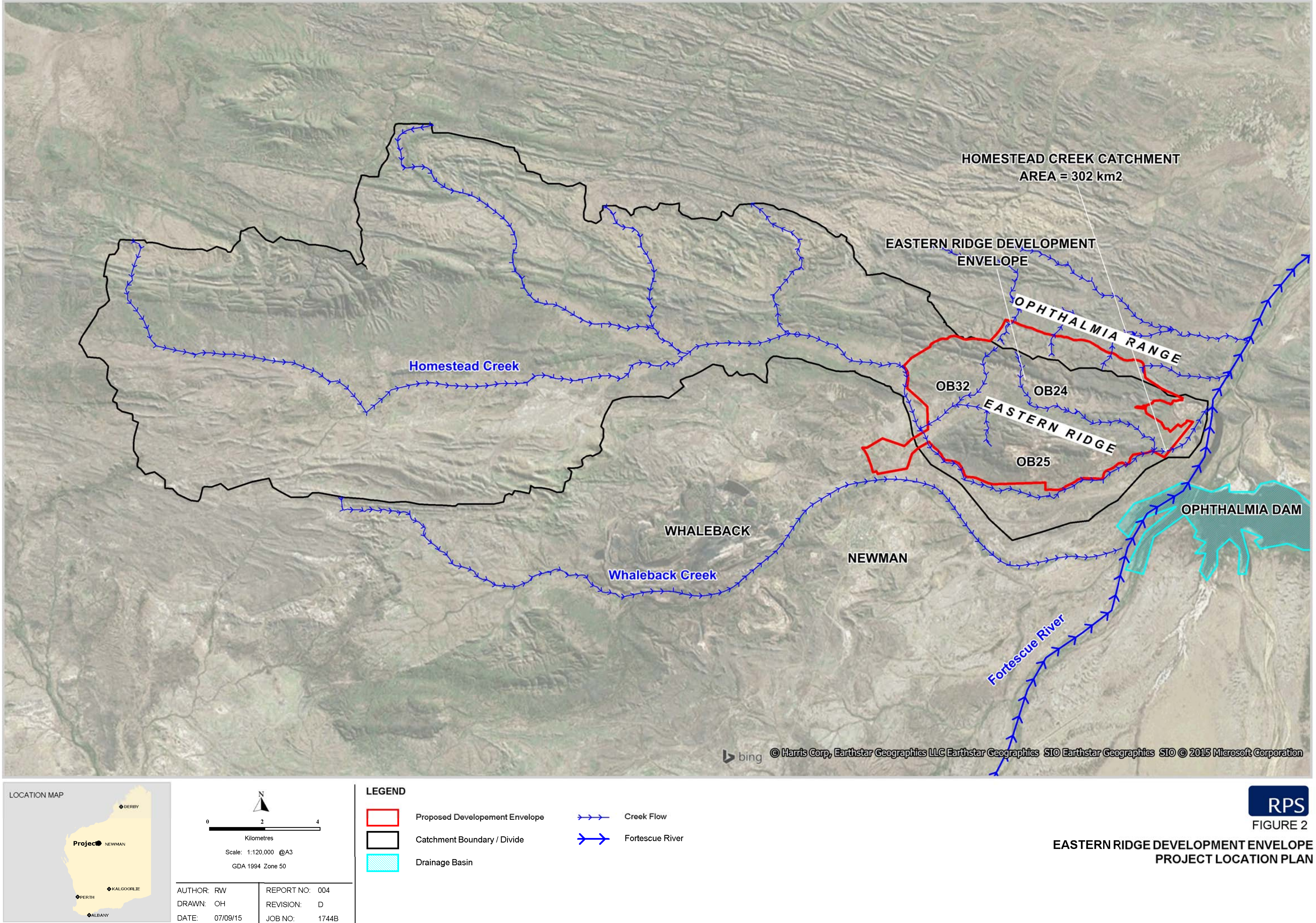
- Fortescue Marsh Catchment Boundary
- Creek Flow
- Homestead Creek Catchment Boundary
- Proposed Development Envelope
- Drainage Basin

RPS

FIGURE 1

EASTERN RIDGE DEVELOPMENT ENVELOPE
REGIONAL LOCATION PLAN

Location: F:\Jobs\1744\Spatial_Data\MapInfo\Workspaces\004d\004d Figure 1



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GDA 1994 Zone 50

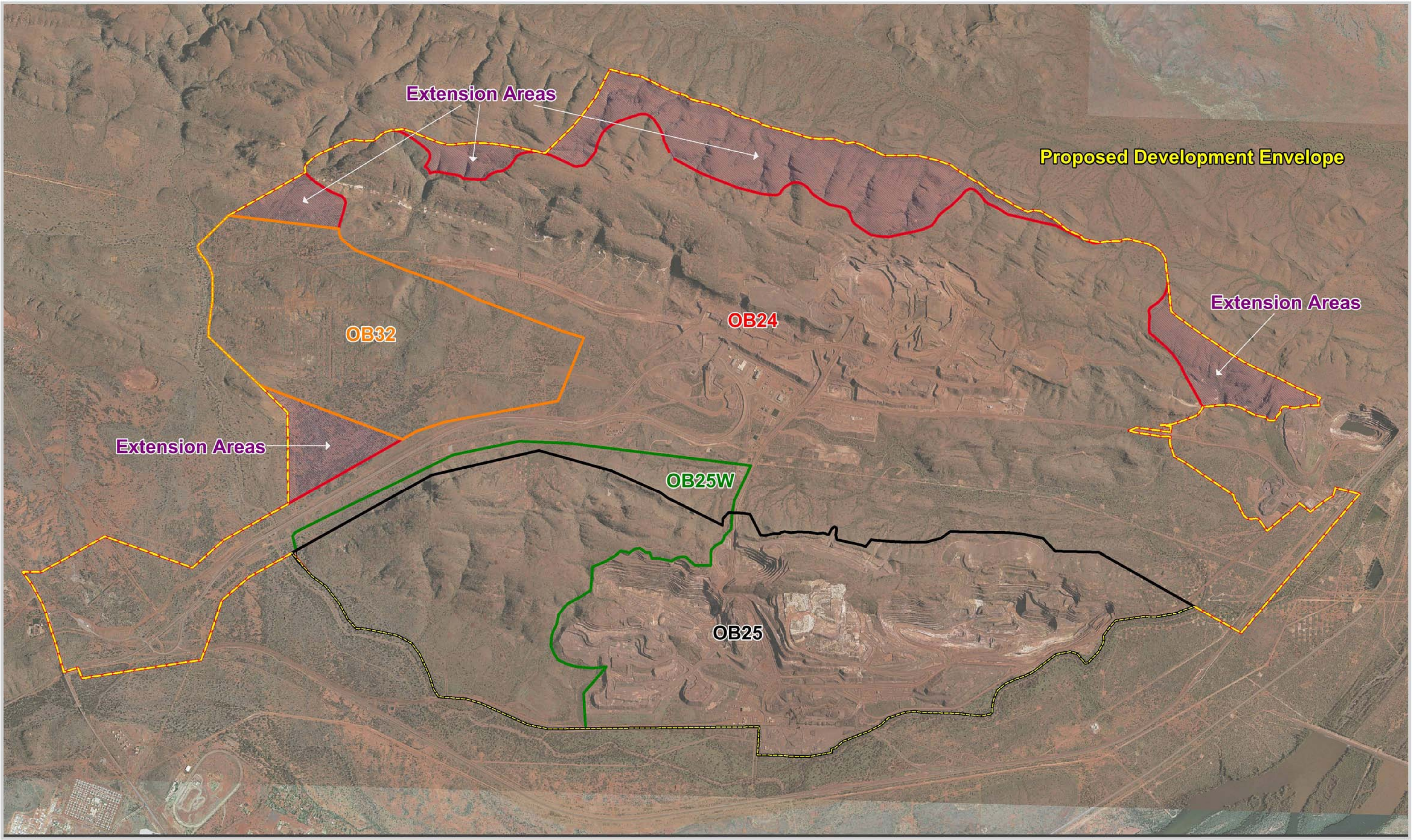
AUTHOR:	RW	REPORT NO:	004
DRAWN:	OH	REVISION:	D
DATE:	07/09/15	JOB NO:	1744B

Location: F:\Jobs\1744\Spatial_Data\MapInfo\Workspaces\004d\004d Figure 2

RPS

FIGURE 2

EASTERN RIDGE DEVELOPMENT ENVELOPE
PROJECT LOCATION PLAN



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GDA 1994 Zone 50

AUTHOR: RW	REPORT NO: 004
DRAWN: KT	REVISION: D
DATE: 09/09/15	JOB NO: 1744B

Location: F:\Jobs\1744\Spatial_Data\MapInfo\Workspaces\004d\004d Figure 3

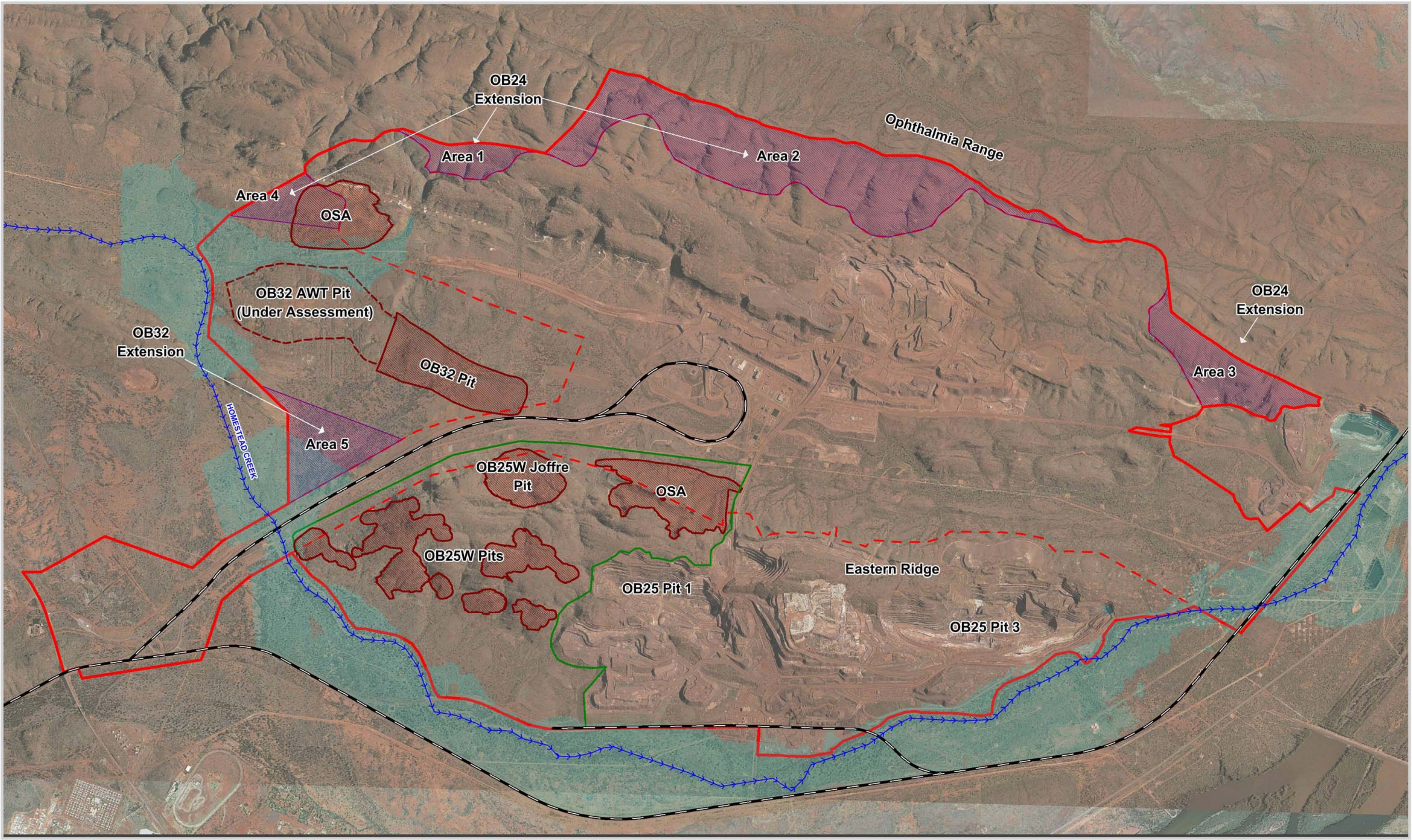
LEGEND

- Proposed Development Envelope
- Extension Areas
- Orebody 24
- Orebody 25
- Orebody 25 West
- Orebody 32

RPS

FIGURE 3

EASTERN RIDGE DEVELOPMENT AREAS



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GDA 1994 Zone 50

AUTHOR:	RW	REPORT NO:	004
DRAWN:	KT	REVISION:	D
DATE:	09/09/15	JOB NO:	1744B

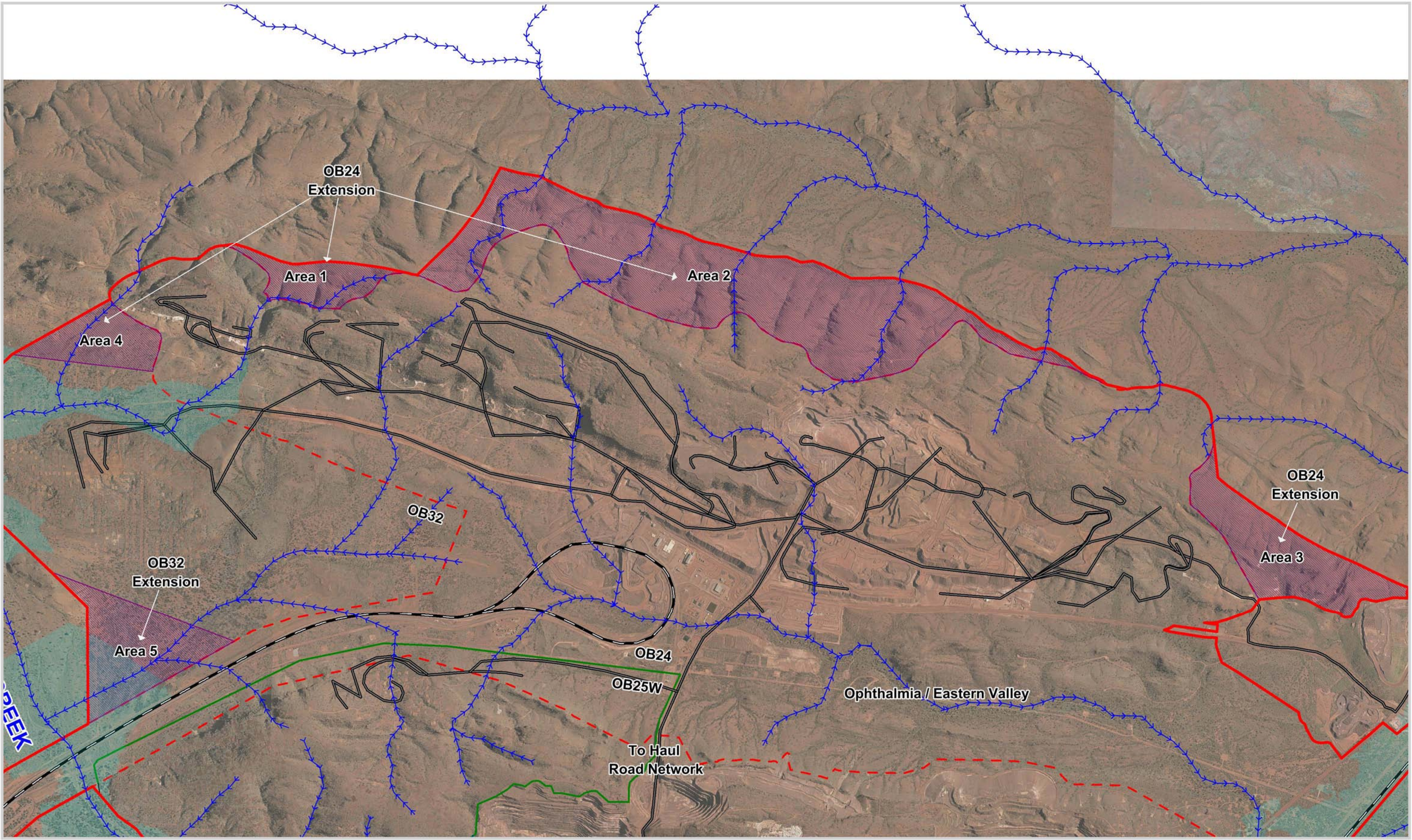
Location: F:\Jobs\1744\Spatial_Data\MapInfo\Workspaces\004d\004d Figure 4

LEGEND

- Proposed Development Envelope
- Existing Approved Boundaries
- Extension Areas
- Indicative Infrastructure
- Railway
- OB25 West Operations
- Creek Flow
- Homestead Creek 10,000 Year ARI Flood Extent

RPS

FIGURE 4
EASTERN RIDGE DEVELOPMENT ENVELOPE



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GDA 1994 Zone 50

AUTHOR: RW	REPORT NO: 004
DRAWN: KT	REVISION: D
DATE: 09/09/15	JOB NO: 1744B

Location: F:\Jobs\1744\Spatial_Data\MapInfo\Workspaces\004d\004d Figure 5

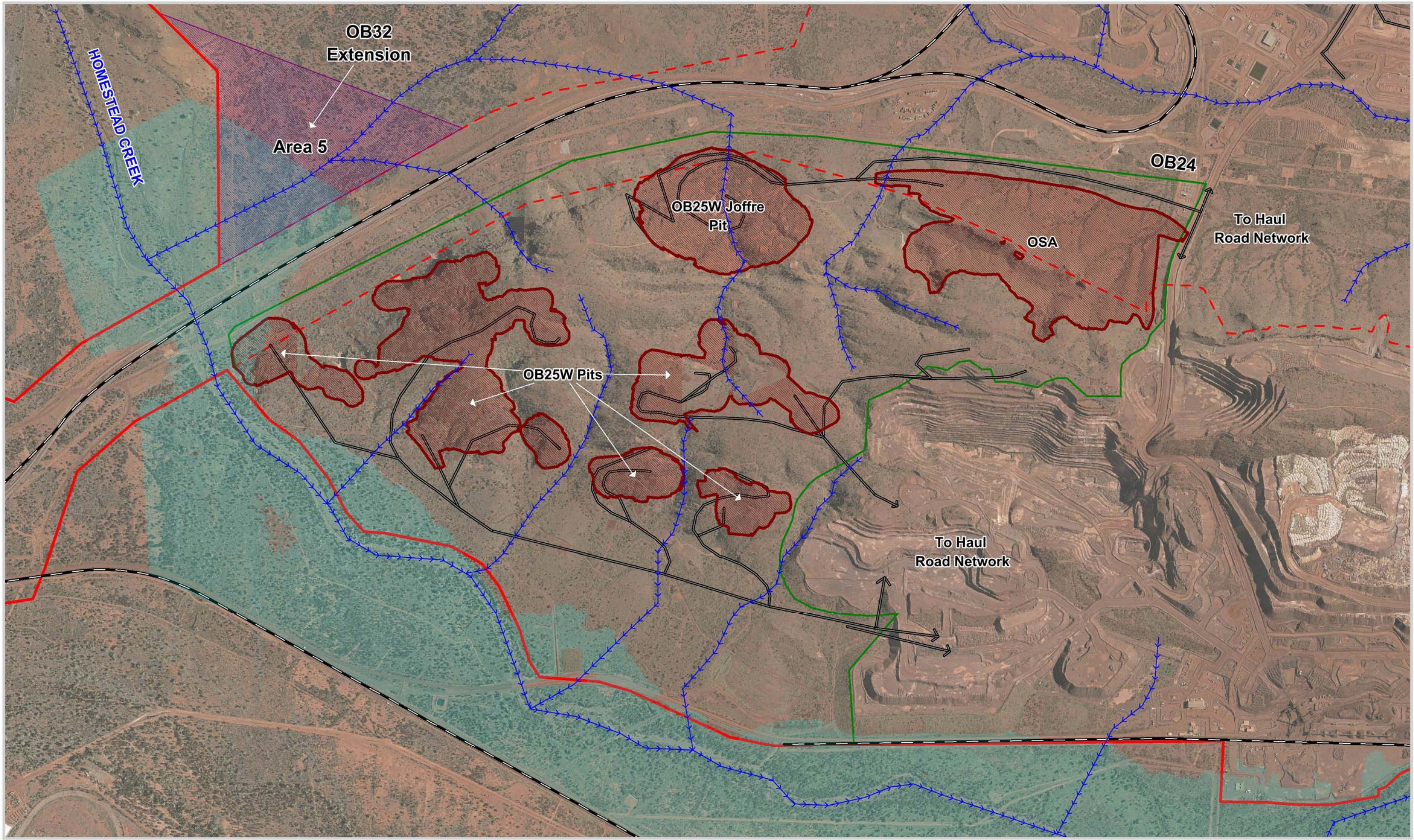
LEGEND

- Proposed Development Envelope
- Existing Approved Boundaries
- Extension Areas
- Indicative Infrastructure
- Railway
- OB25 West Operations
- Creek Flow
- Homestead Creek 10,000 Year ARI Flood Extent
- Indicative Haul Roads

RPS

FIGURE 5

EASTERN RIDGE (OB24) SURFACE WATER



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Scale: 1:15,000 @A3
GDA 1994 Zone 50

AUTHOR:	RW	REPORT NO:	004
DRAWN:	KT	REVISION:	D
DATE:	09/09/15	JOB NO:	1744B

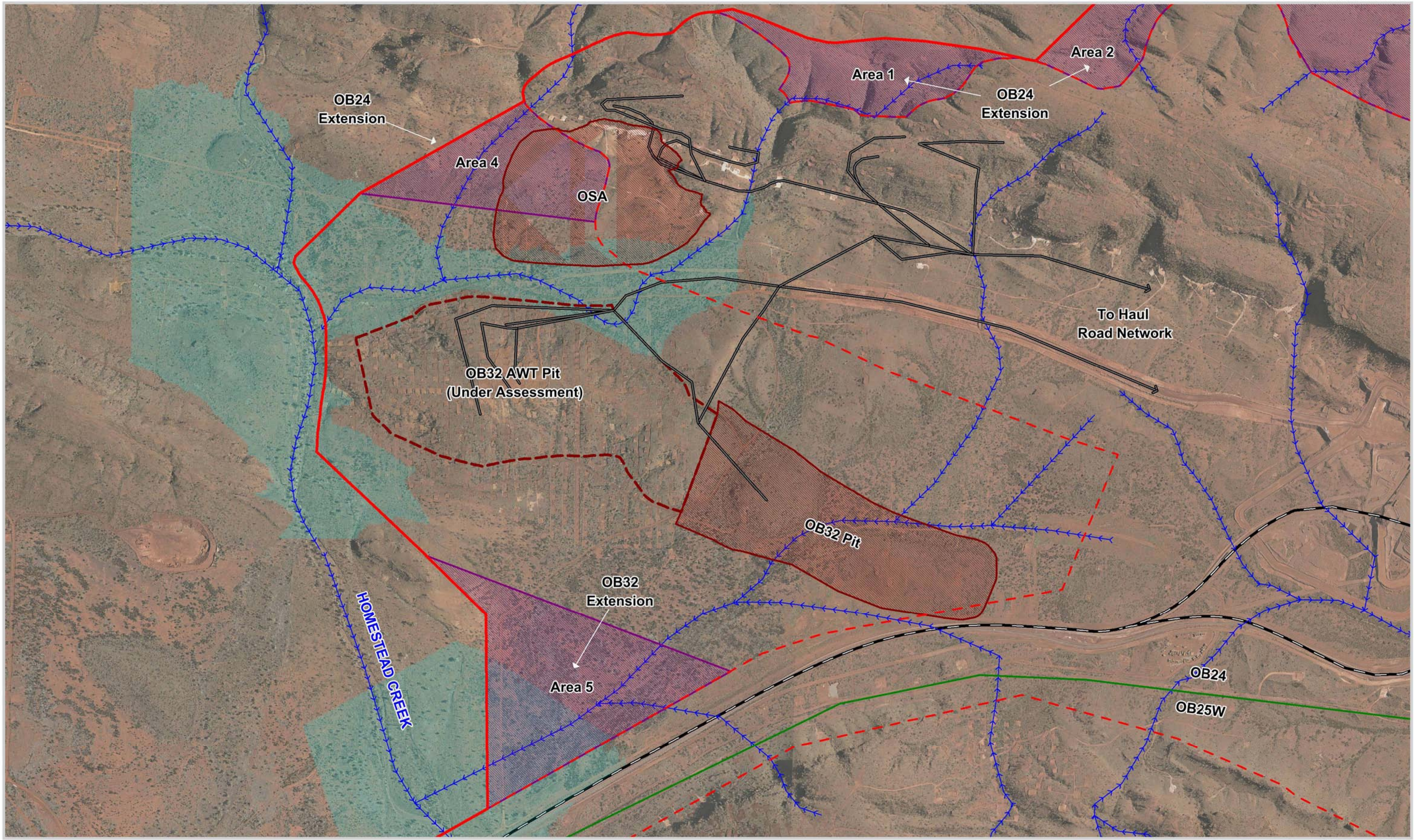
LEGEND

- Proposed Development Envelope
- Existing Approved Boundaries
- Extension Areas
- Indicative Infrastructure
- Railway
- OB25 West Operations
- Creek Flow
- Homestead Creek 10,000 Year ARI Flood Extent
- Indicative Haul Roads

RPS

FIGURE 6
EASTERN RIDGE (OB25W) SURFACE WATER

Location: F:\Jobs\1744\Spatial_Data\MapInfo\Workspaces\004d\004d Figure 6



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GDA 1994 Zone 50

AUTHOR:	RW	REPORT NO:	004
DRAWN:	KT	REVISION:	D
DATE:	09/09/15	JOB NO:	1744B

LEGEND

- Proposed Development Envelope
- Existing Approved Boundaries
- Extension Areas
- Indicative Infrastructure
- Railway
- OB25 West Operations
- Creek Flow
- Homestead Creek 10,000 Year ARI Flood Extent
- Indicative Haul Roads

RPS

FIGURE 7

EASTERN RIDGE (OB32) SURFACE WATER

Location: F:\Jobs\1744\Spatial_Data\MapInfo\Workspaces\004d\004d Figure 7