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BHPB Nickel West - Mt Keith Satellite Operations

Section 38 referral supporting document

Prepared for
BHP Billiton Nickel West
by Strategen

May 2017

strategen
ENVIRONMENTAL

BHPB Nickel West - Mt Keith Satellite Operations

Section 38 referral supporting document

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May 2017

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Client: BHP Billiton Nickel West

Report Version	Revision No.	Purpose	Strategen author/reviewer	Submitted to Client	
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1. Introduction

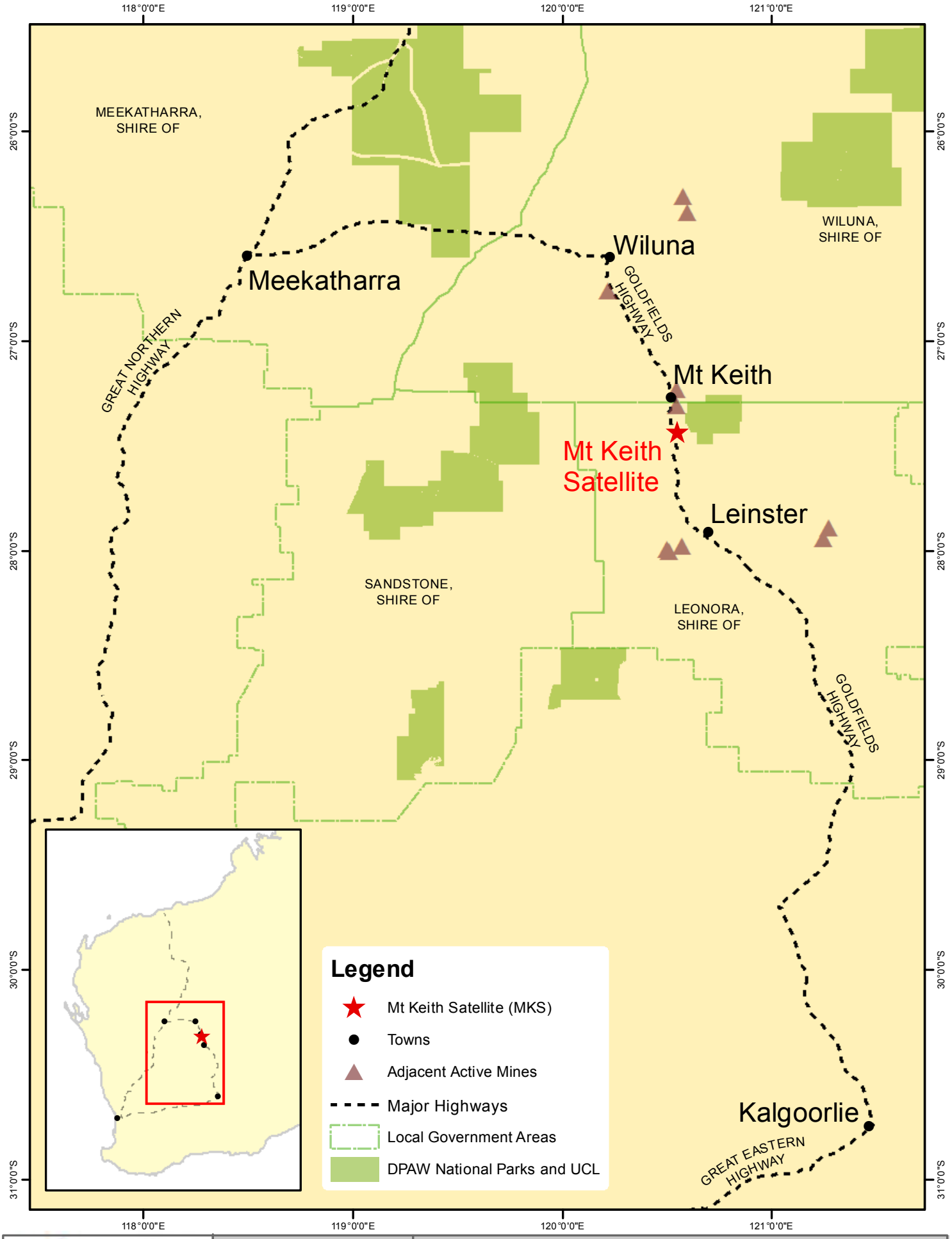
BHP Billiton Nickel West (BHPB) proposes to develop the Mt Keith Satellite Proposal (the Proposal), approximately 80 km north of Leinster in the Shire of Leonora (Figure 1). The Proposal is located within the following Mining Act 1978 (Mining Act) tenure M36/422, M36/399, M36/288, M36/286, M36/285, M36/246, M36/185, M36/184, M36/183, M36/677, L36/206, M36/658, M53/217 and M53/218 (Figure 2), which is all held by either BHP Billiton Nickel West Pty Ltd (the Proponent) or its wholly owned subsidiary BHP Billiton Yakabindie Nickel Pty Ltd (Appendix 1: Table 1). The Proposal is located within the Yakabindie Pastoral Lease, which is held by BHPB. Portions of those Pastoral Leases are sublet to a third party for the conduct of pastoral activities.

The Proposal has a Disturbance Footprint 842 ha within a Development Envelope of 1242 ha and involves the development of two mine pits (Six Mile Well and Goliath), a waste rock landform, associated support infrastructure and a 20 km transport corridor north to the existing Mt Keith Mine (Figure 3).

The Proposal will use facilities at the existing Mt Keith Mine, including processing and storage of tailings.

This document has been prepared to support the referral of the Proposal under s 38 of the Environmental Protection Act 1986 (EP Act). This document provides additional supporting information to describe:

- approvals context
- identification of Preliminary Key Environmental Factors
- studies and investigations undertaken
- stakeholder consultation.



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Nickel West	**Date:** 15/03/2017
	Scale: 1:2,575,000
Map Projection: GDA 1994	**Figure No: 1**
Map ID: Regional_Overview_New103.mxd	

Regional Context

Mount Keith Satellite

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Kilometres

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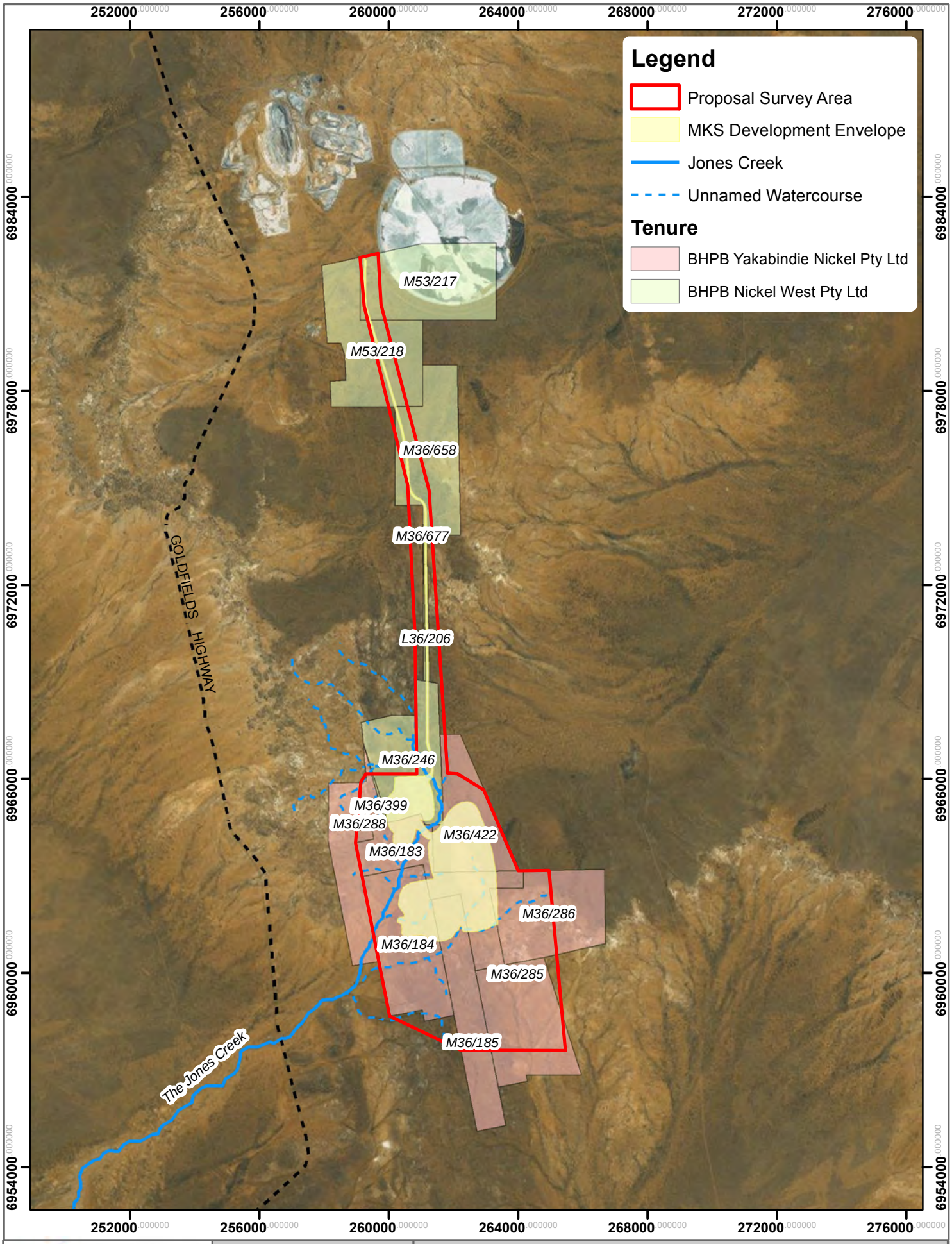

bhpbilliton	**Author:** SJM
Nickel West	**Date:** 03/05/2017
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Map ID: Tenure_Context_Referral103.mxd	**Figure No:** 2

Tenure Context

Mount Keith Satellite

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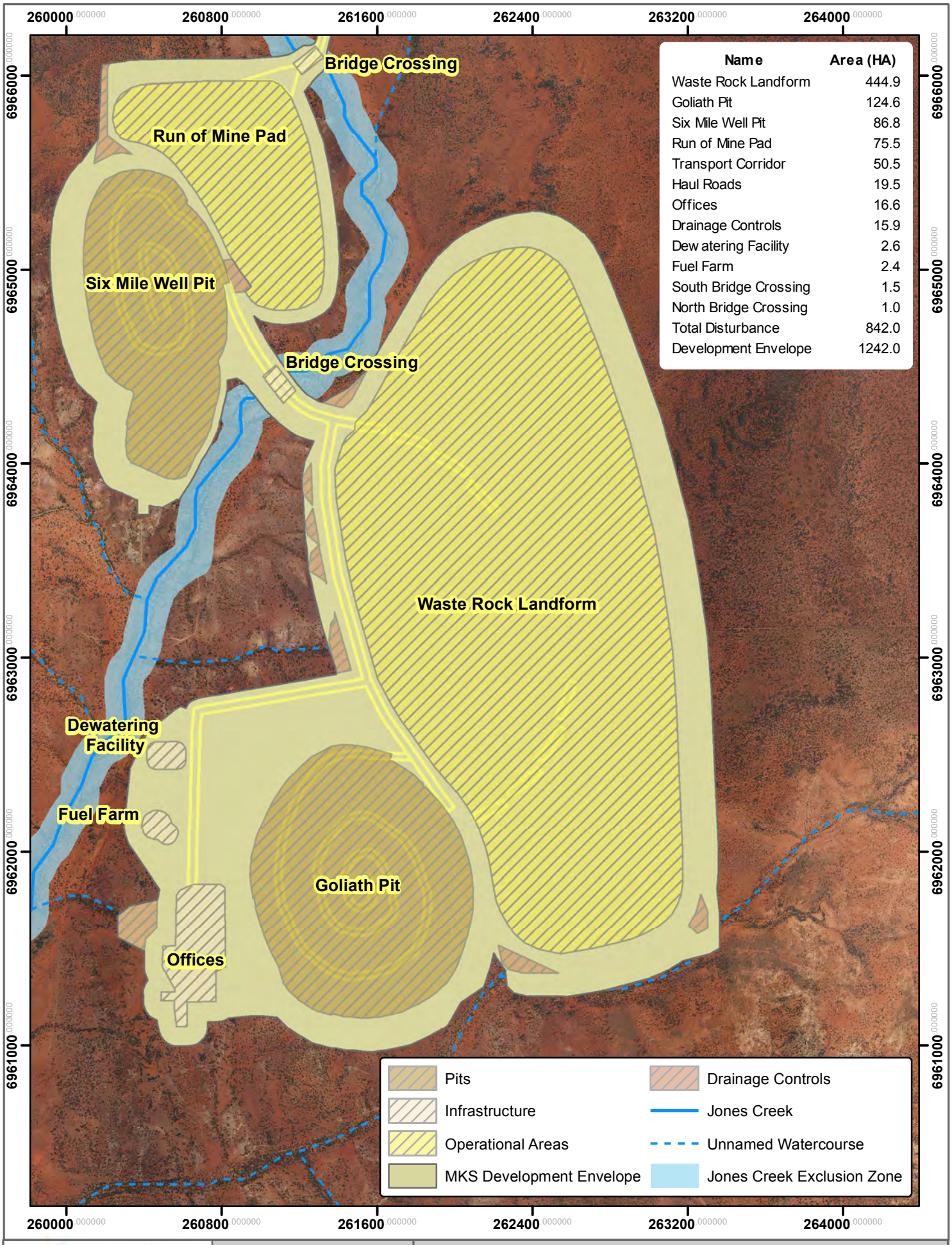

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Nickel West

Projection Details: MGA Zone 51

Author: SJM

Date: 04/05/2017

Scale: 1:25,000

Figure No: 3

Map ID: DetailedProposal103.mxd

Detailed Proposal
Mount Keith Satellite

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2. Approvals context

2.1 Yakabindie Nickel Proposal

In February 1990, Dominion Mining Limited (Dominion) referred a proposal to the EPA for the development of the Yakabindie Nickel Proposal (YNP). YNP proposal comprised open cut mining and processing of a low grade nickel sulphide orebody to produce approximately 6 million tonnes per annum (Mtpa) of ore and 25 Mtpa of waste rock. While the Proposal involves mining the same nickel orebody as the YNP the two proposals are substantially different. A summary of the differences between the two proposals is provided in Section 2.2.

The EPA set the level of assessment for the YNP at Consultative Environmental Review (CER). EPA Bulletin 444 identified that the major environmental issues considered during the assessment of the YNP were:

- location of the facilities such as waste dumps, processing plant and the tailings dam
- the environmental impact on the Jones Creek System
- impacts on the Wanjarri Nature Reserve
- rehabilitation of the operation and the pit itself as a permanent feature
- the impact of utilising groundwater for processing
- cumulative impacts such as transport and water supply associated with the proposed Mount Keith Nickel Proposal.

The EPA recommended approval of the YNP with conditions in August 1990 and it was approved by the Minister for the Environment in December 1990 (Statement 117). Subsequent to Statement 117, the YNP has been subject to six reviews under s46 of the EP Act (Table 1). These reviews related to changes to the proposal, changes to the conditions of the approval and extensions of the time limit of approval.

In 1994, Dominion entered into a joint venture with North Limited and completed a detailed feasibility study. Further work was conducted and changes of ownership occurred from 1995 to 2005 that resulted in Western Mining Corporation (WMC) taking ownership. In 2005, BHPB conducted a takeover of WMC and commenced the mine planning and environmental investigations to update previous work. However, for commercial reasons, the YNP was not constructed and the EPA approval applying to the YNP proposal subsequently expired on 21 October 2007.

Table 1: Summary of approvals for the Yakabindie Nickel Proposal

Year	Statement	EPA Assessment	EPA Bulletin	Comments
1990	117	352	444	Assessment and approval of the original YNP by Dominion.
1991	142	352-A	509	Inquiry under s 46 to amend Condition 1 of Statement 117 to allow for implementation of the proposal including documented modification of 20 February 1991.
1993	302	765	668	Inquiry under s 46 to incorporate a new open pit and associated waste dump area, and an expansion of the Six Mile pit.
1995	388	957	781	Inquiry under s 46 to allow an extension of time. All previous conditions were replaced.

Year	Statement	EPA Assessment	EPA Bulletin	Comments
1996	430	989	827	Inquiry under s 46 regarding a request to alter the existing environmental conditions to accommodate the following three changes: • extension of the eastern waste rock dump into a section (Six Mile Well block) of the Wanjarri Nature Reserve under an arrangement with the State which involves the permanent addition of a similar area of land to the nature reserve and eventual return of the Six Mile Well Block to the Wanjarri Nature Reserve • establishment of a downstream hydrometallurgical processing plant within the currently approved concentrator area • integration of the tailings dam with the Goliath North waste dump so as to form a single operating unit • an extension of time was also granted.
2001	574	1387	1022	Inquiry under s 46 to allow an extension of time. Condition 11 was amended to allow for the time limit on approval to be extended.
2003	623	1450	1079	Inquiry under s 46 to allow an extension of time. Condition 11 was amended to allow for the time limit on approval to be extended to 21 October 2007.

2.2 Comparison of the Proposal with Yakabindie Nickel Proposal

As shown in Figure 4 the Proposal is a substantially simplified and dissimilar Proposal compared with the YNP. The differences between the YNP and the Proposal are also summarised in Table 2.

Table 2: Comparison of differences between the YNP and the Proposal

Element	Description of key YNP elements	Difference between the Proposal and YNP
Total area	The YNP approval is for an area of up to 5000 ha.	Proposal is limited to a Development Envelope of approximately 1242 ha.
Mine Pit	The YNP mine pit was located on Jones Creek, requiring the diversion of the creek.	The Proposal's Six Mile Well Pit avoids Jones Creek (excepting creek crossings).
Waste rock landforms	The YNP required the construction of two waste dumps (with the West Waste Dump extending outside the area of mine tenure held by the Proponent).	The Proposal only includes one waste rock landform.
Plant	The YNP included a processing plant to the west of the pit and would include crushing, grinding, conditioning and flotation to produce a nickel-rich concentrate.	The Proposal does not involve processing of ore (ore will be transported to the existing Mount Keith processing facility via a transport corridor).
Tailing Storage	A Tailings Storage Facility (TSF).	The proposal does not include a TSF (ore will be transported to the existing Mount Keith processing facility which includes a TSF).

2.3 Requirement for new assessment

The Proponent has conducted a review of the YNP proposal and the current Proposal and an analysis of how those proposals are different. The Proponent has also held pre-referral consultations with the Office of the Environmental Protection Authority (OEPA).

As discussed above, following that review, the proponent has assessed the current Proposal as being substantially different to the YNP proposal. Accordingly, assessment of the current Proposal is required as a new proposal under s 38 of the EP Act.

2.4 Consideration of closure requirements

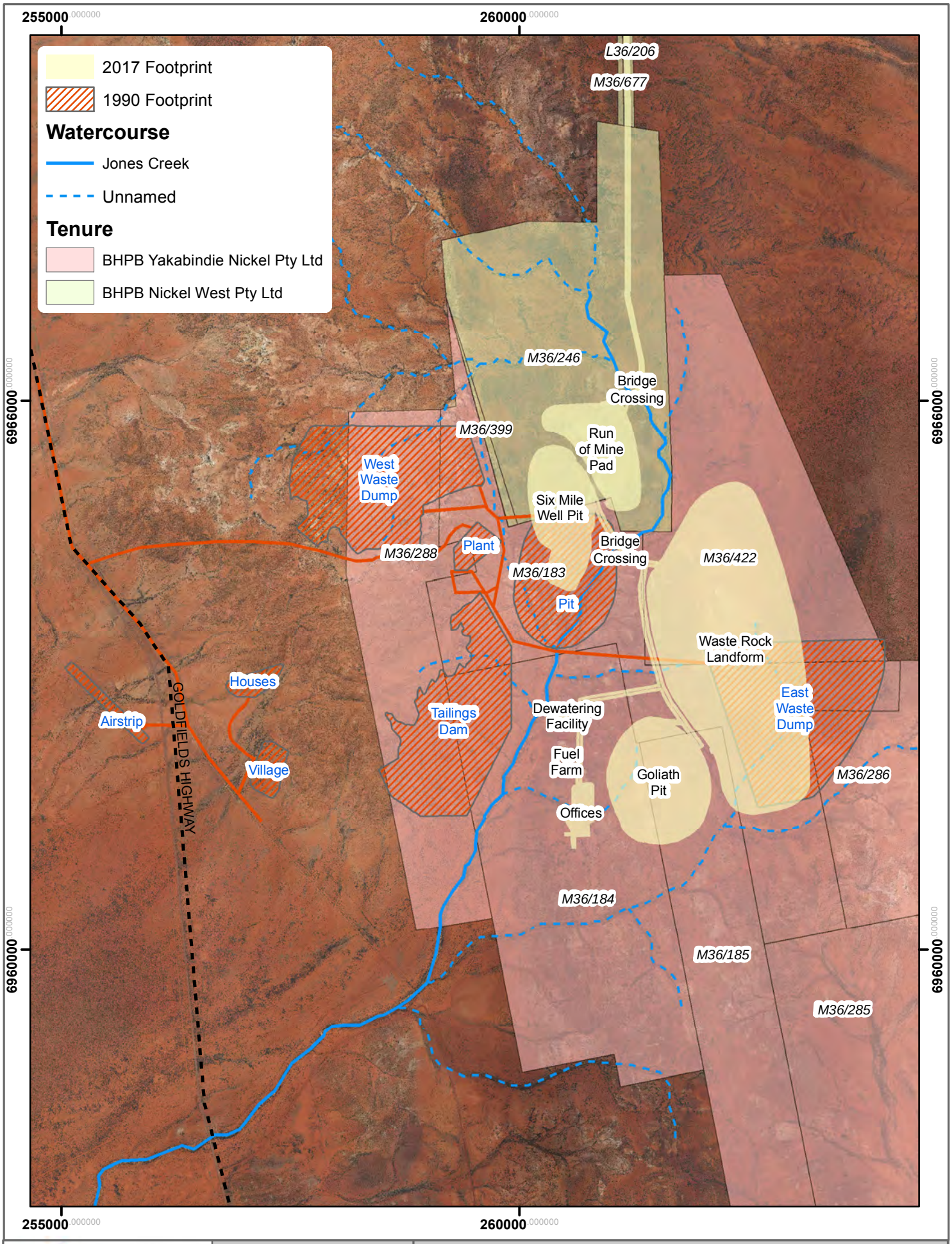
In December 2016 the EPA released revised policies and guidelines for environmental impact assessment. The new guidelines included *Statement of Environmental Principles, Factors and Objectives* (EPA 2016). A key change in the new guideline is the removal of closure as a factor, with closure to be considered in other relevant factors. As Section 4 of this document has been structured in accordance with the EPA (2016) this section has been prepared to provide an overview of how closure has been considered.

Preliminary closure planning has been considered for the Proposal as part of the engineering design and environmental planning. The Proponent is confident that site closure can be implemented successfully and consistent with statutory guidelines and it is therefore not considered likely to be a significant risk for the development of this Proposal.

The Proponent will prepare a Mine Closure Plan (MCP), consistent with "Guidelines for Preparing Mine Closure Plans" (EPA and DMP 2015), for the Proposal and submit this in conjunction with its Mining Proposal application. While it is recognised the Proposal is connected with the existing Mount Keith Operations, the Proposal will have a standalone MCP.

The proposed post-mining land-use will not adversely impact surrounding land-uses including those pastoral and conservation (Wanjarri Nature Reserve) and be agreed to with regulators and other key stakeholders, as relevant. Post-mining land-use will take into account the pre-mining land-use(s), key stakeholder expectations, Goldfields experience in successful mining rehabilitation outcomes and predicted impacts from forecast changes in climate on the long-term viability of the land-use(s). The proposed end land-use may vary over time to respond to changes in stakeholder expectations, Nickel West and industry mine rehabilitation experience and environmental conditions.

The Proponent will develop completion criteria for the proposed development in consultation with stakeholders and regulators, and will ensure that these are Specific, Measurable, Attainable, Relevant and Time-specific (SMART) to allow a reasonable, finite and objective measurement of success.



bhpbilliton	**Author:** SJM
Nickel West	**Date:** 03/05/2017
Projection Details: MGA Zone 51	**Scale:** 1:53,000
Map ID: OldvsNewApproval103.mxd	**Figure No: 4**

1990 vs 2017 Approval Footprint
Mount Keith Satellite

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Kilometres

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3. Identification of potential key environmental factors

The potential key environmental factors were determined based on the Proposal elements. As described in Section 1 the Proposal consists of the following main elements that have the potential to result in environmental impacts:

- mining below the water table in two mine pits requiring dewatering of groundwater
- construction of waste rock landforms
- construction of a 20 km haul road (transport corridor).

Based on the main elements of the Proposal the environmental impacts of greatest potential concern (i.e. with the potential to result in a significant environmental impact) are associated with:

- disturbance of native vegetation and therefore Flora and Vegetation is considered a potential key environmental factor
- dewatering to safely access ore, which will modify local groundwater values and therefore Hydrological Processes is considered a potential key environmental factor
- removal of potential habitat for Subterranean Fauna as a result of mining and dewatering and therefore this is considered a potential key environmental factor.

The Proposal has the potential to affect other environmental factors; however, they are not considered to have a potential significant impact.

Section 4 summarises baseline studies and investigations completed for the potential key environmental factors (Section 4.1 to 4.3) as well as other environmental factors (Section 4.4). `

4. Studies and investigations

4.1 Flora and Vegetation

The Proposal Study Area has been subject to extensive field surveying since 1990 as listed in Table 3. Western Botanical (2017) most recently surveyed approximately 5422 ha encompassing the Proposal Study Area; comprised of 841 ha of Disturbance Footprint within 1242 ha of Development Envelope.

Table 3: Flora and vegetation assessments completed

Author	Title	Date	Scope
Western Botanical	Flora and Vegetation Assessment of the Mt Keith Satellite Operations Study Area	March 2017	Review and update of the previous baseline flora and vegetation report (2012) following a revision of the area surveyed including supplementary field works conducted during November-December 2016. Area survey covers 5422 ha. The report has been prepared to meet the EPA's Guidance Statement 51 and Technical Guide – Terrestrial Flora and Vegetation Surveys for EIA.
Western Botanical	Flora and Vegetation Assessment, Yakabindie Nickel Proposal	September 2016	A review and update of all data relating to flora and vegetation, including review of previous reports relating to the Mount Keith Satellite Operations Study Area inclusive of the Six Mile and Goliath pits and related infrastructure and produce an updated report meeting the requirements of EPA Guidance Statement 51 and Technical Guide – Flora and Vegetation Surveys for Environmental Impact Assessment.
Western Botanical	Baseline review and statistical analysis of the flora and vegetation of the NDS1 mine and corridor study area.	2012	A review and synthesis of previous works and addition of quadrat-based vegetation assessment and analysis, to meet the criteria of a Level 2 Survey. Includes Six-mile and Goliath orebody areas, waste rock storage area, and associated transport corridor based on additional field works implemented in 2011.
Western Botanical	Assessment of flora and vegetation, Yakabindie Proposal (draft report)	2009	Level 1 assessment commissioned for the purposes of applying for a Native Vegetation Clearing Permit (NVCP) for the YNP.
Western Botanical	Flora, vegetation and habitats of the Yakabindie tenements 2004-2005	2006a	Level 1 assessment inclusive of the initial review of flora, vegetation, and conservation values of Yakabindie tenements and surrounding local areas. This represents the most comprehensive and extensive works conducted at the MKSO Study Area inclusive of vegetation mapping, habitat descriptions and species profiles.
Western Botanical	Review of flora, vegetation, landscapes and conservation values of the Six-mile and Sir Samuel blocks, Wanjarri Nature Reserve and Yakabindie Station	2006b	Level 1 assessment of a section of Wanjarri Nature Reserve and a section of Sir Samuel block, in preparation for a land swap to facilitate mining at YNP.
Landcare Services	Review of *Hemigenia exilis* (S. Moore)	2001	Combined all data including WMC, Anaconda Nickel and CALM sources to review the status of *Hemigenia exilis* (DRF) resulting total of 46,005 plants from 66 populations and reduction to Priority 4 status.
Landcare Services	A review of *Hemigenia exilis* (S. Moore) populations at The Mt Keith Operation and within the north-eastern Goldfields	1996	Targeted survey and review of Hemigenia exilis local and regional populations, incorporating data supplied by Anaconda Nickel.
Ecologia	Yakabindie Nickel Proposal: *Hemigenia exilis* survey and management plan	1996	Targeted survey and management of *Hemigenia exilis*, previously ranked as Declared Rare Flora, at the Yakabindie Nickel Proposal.

Author	Title	Date	Scope
Ecologia	Yakabindie nickel mine Proposal, Six Mile Well – Mt Pasco blocks: environmental assessment	1995	Unknown.
Mattiske Consulting Pty Ltd	Summary of *Hybanthus floribundus* subsp. *chloroxanthus* E.M. Benn. (Priority 3) Populations, Yakabindie	September 2011	Confirmation of the identification of populations previously recorded in the Proposal area and abundance of the populations of *Hybanthus floribundus* subsp. *chloroxanthus* (Priority 3) outside immediate impact areas.
Ecologia Ecological Consultants	*Yakabindie Nickel Mine Proposal Consultative Environmental Review: Flora and Fauna Survey*	March 1990	Documentation of existing biota, delineation of the main ecological units, map the area and integration of previously published and unpublished vegetation information.

4.1.1 Flora

In the vicinity of the Proposal Study Area a total of 393 species (and putative hybrids) from 140 genera and 51 families of endemic flora have been recorded. Of these, the majority are common, widespread in distribution and are highly representative of the flora of eastern Murchison and western Great Victoria Desert biogeographic regions. Dominant genera were *Acacia* (53 species inclusive of 31 species and numerous putative hybrids of Mulga species); *Eremophila* (37 species), *Maireana* (18 species) *Senna* (14 species), *Sida* (11 species) and *Eragrostis* (7 species). Six weed species were also recorded, all in small scattered populations of low numbers (Western Botanical 2017).

No Threatened Flora as listed under the *Wildlife Conservation Act 1950* are known within or nearby the surveyed area (Western Botanical 2017).

Priority Flora

Twelve Priority Flora species occur in the Proposal Study Area, including one Priority 1, eight Priority 3 and three Priority 4 listed species (Western Botanical 2017). Although two of the Priority species, *Aristida aff. jerichoensis* subsp. *subspinulifera* (P3) and *Paspalidium aff. distans* (P3), have been identified based on less than optimal material.

Four species have minor populations within the Development Envelope. These species are expected to have less than 2% of their known regional populations affected. These are *Eremophila pungens* (P4), *Grevillea inconspicua* (P4), *Hemigenia exilis* (P4) and *Thryptomene* sp. Leinster (P3) (Western Botanical 2017).

A small proportion of the overall local populations of *Hybanthus floribundus* subsp. *chloroxanthus* (P3), is likely to be affected by the Proposal with individuals within the proposed Development Envelope, representing 10.05% of the known regional population (Western Botanical 2017).

One further species, *Tribulus adelacanthus* (P3) is a poorly known annual, and while one record lies within the Development Envelope (six populations known in total in WA), it is not possible to make a meaningful assessment of proportional impacts on this species (Western Botanical 2017).

Several species of interest have been identified in the Proposal Study Area. The majority of these are well known and widespread in distribution within the region; however some species require formal vouchering or taxonomic review (Western Botanical 2017).

Hibbertia aff. *exasperata* is noted as a species with both taxonomic and conservation interest as the material available for identification to date is less than optimal (Western Botanical 2017). No material was available for collection during the 2016 surveys.

Based on the potential occurrence of Priority Flora in the Development Envelope a survey was conducted to confirm the populations of *Hybanthus floribundus* subsp. *chloroxanthus* (Priority 3) in areas beyond the Development Envelope. Two other Priority Flora species, *Hemigenia exilis* (P4) and *Grevillea inconspicua* (P4) were also recorded. The study confirmed large populations of both Priority 3 species occurred outside the Development Envelope (Mattiske 2011).

4.1.2 Vegetation

Twenty six Vegetation Associations and three Vegetation Association Complexes have been recognised in the 5422 ha area surveyed (Figure 5). The Vegetation Associations have been grouped according to the dominating underlying geology / regolith which strongly influence the vegetation association species composition (Western Botanical 2017). The majority of Vegetation Associations impacted by the Development Envelope are well represented in the Proposal Study Area.

Vegetation Associations on Sandplains and Colluvial and Alluvial Landforms are widely distributed in the Murchison Biogeographic region. Vegetation Associations of the Limonitic Landforms and Basalt geology of the Perseverance fault line, and some of the colluvial slopes associated with these, are less widely distributed but still well represented between Mount Keith and Leinster. Based on regional surveys conducted for the Proposal Study Area the disturbance of vegetation units and flora species is not expected to be significantly impacted at a regional scale (Western Botanical 2017).

Vegetation condition outside the existing exploration areas and access tracks is generally of Excellent or Pristine condition with little evidence of pastoral activities. Areas having been disturbed in previous exploration works are regarded as being in Excellent condition while completely cleared areas were recorded as Completely Degraded (Western Botanical 2017).

Weed populations were found in small, isolated populations with low numbers of individuals present. Three species, *Rumex vesicarius* (Ruby Dock), *Cenchrus ciliaris* (Buffel Grass), *Cenchrus setiger* (Birdwood Grass) have the potential to be highly invasive. A further three species, *Bidens bipinnata* (Tick Weed), *Lysimachia arvensis* (Pimpernel) and *Mesembryanthemum nodiflorum* (Slender Iceplant) pose a lesser environmental risk.

Priority Ecological Community

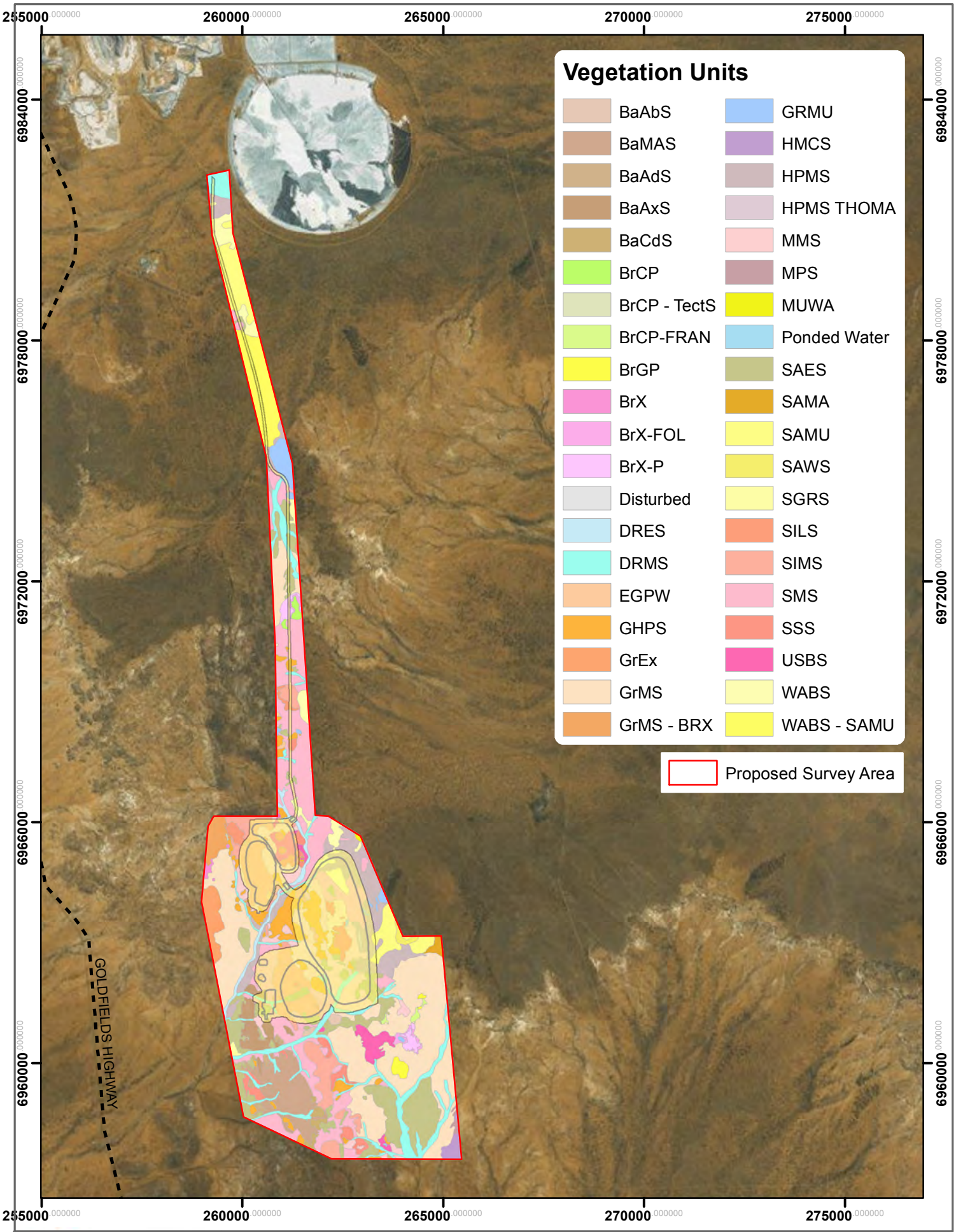
A portion of the Proposal Study Area is located within the 19 256 ha *Violet Ranges (Perseverance Greenstone Belt) vegetation complexes (banded ironstone formation)* Priority 1 Priority Ecological Community (PEC) (Figure 6). The majority of the geology within the Violet Ranges PEC is basalt, gabbro and granite with only minor Banded Ironstone Formation (BIF), chert and quartz outcrops with associated laterite capping (Western Botanical 2017).

The Development Envelope occupies approximately 8% of the Violet Ranges PEC (Western Botanical 2017).

Additional adjacent areas of similar basalt geology and associated vegetation types lie within the Mt Keith Perseverance-greenstone belt / fault line but outside the current PEC boundaries. These areas extend in a discontinuous fashion both northward (north of the Mt Keith nickel mine) and southward (to the Leinster nickel mine) for an overall inclusive length of approximately 82 km. The Violet Ranges PEC represents around 40% of this overall range (Western Botanical 2017).

Wanjarri Nature Reserve

The vegetation within the Wanjarri Nature Reserve is contiguous with the eastern margin of the Proposal Study Area. The vegetation is reflective of underlying granitoid landscapes with extensive Aeolian sandplains, extensive Archaean granite breakaways and associated saline footslopes and hardpan plains being present. These landscape units are widespread and are well represented both within and outside Wanjarri Nature Reserve. Components of the Violet Ranges PEC are not represented within the Wanjarri Nature Reserve (Western Botanical 2017).



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Nickel West

Projection Details: MGA Zone 51

Author: SJM

Date: 02/05/2017

Scale: 1:120,000

Figure No: 5

Map ID: Vegetation103.mxd

Vegetation Mapping
Mount Keith Satellite

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Kilometres

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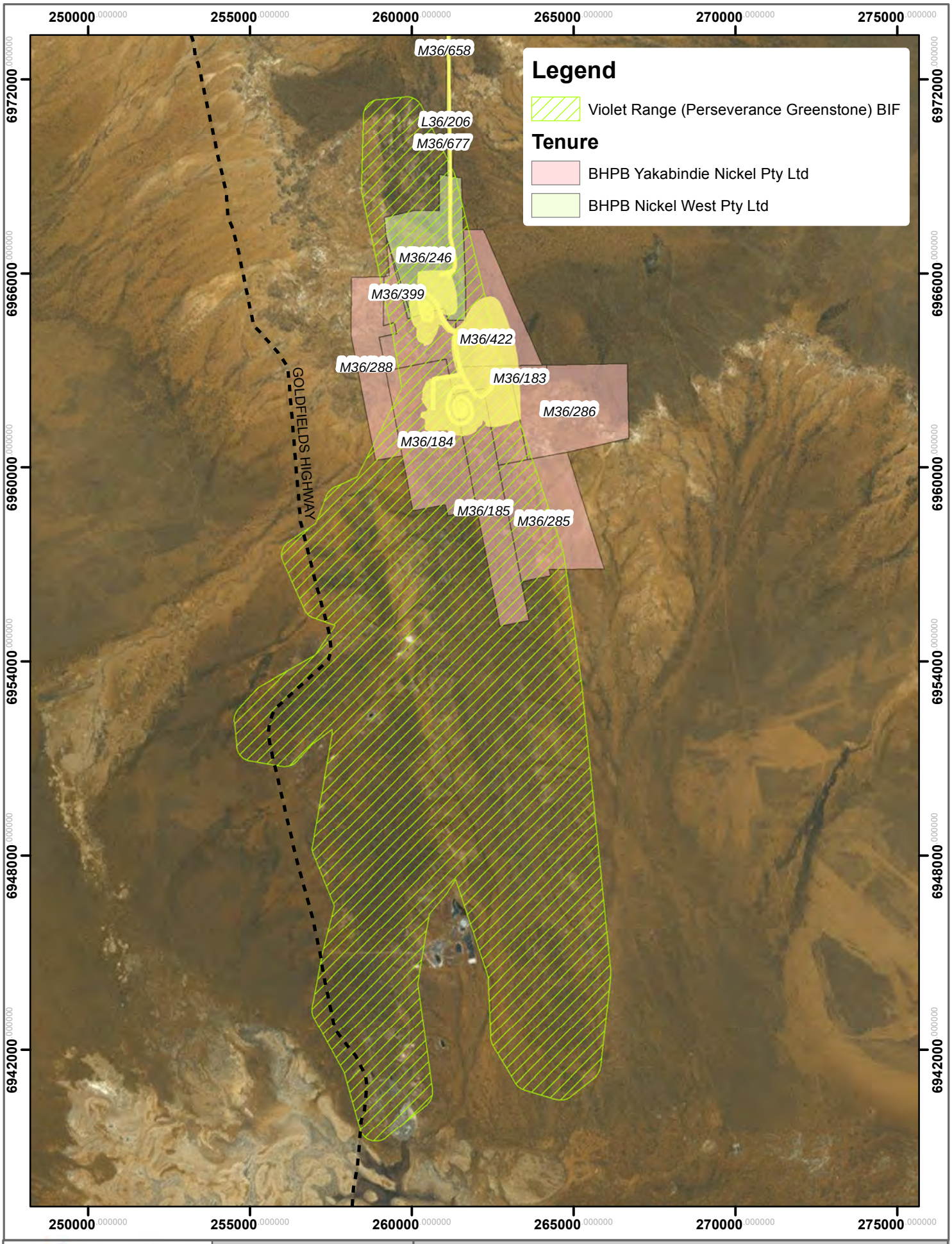

bhpbilliton

Nickel West

Author: SJM

Date: 02/05/2017

Scale: 1:150,000

Projection Details: MGA Zone 51

Figure No: 6

Map ID: TEC_103.mxd

Priority Ecological Communities - Flora

Mount Keith Satellite

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Kilometres

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4.2 Hydrological Processes

The hydrology of the Six Mile Well and Goliath deposits have been evaluated in detail a number of times since the Dominion Mining Feasibility study in 1990 (Table 4). The most recent study was undertaken by MWES in 2016.

Table 4: Hydrological processes studies completed

Author	Title	Date	Scope
MWES 2016	Mt Keith Satellite Pits Proposal – Water Aspects and Impacts	2016	Evaluation of the direct risks of the proposed Proposal on water resources and indirect risks to the ecology of habitats sustained by the water resources.
Outback Ecology Services	Not available	2011	A study of the baseline aquatic fauna, water quality and sediment characteristics within the Jones Creek system.
SKM	WMC Yakabindie - Jones Creek Stream Sediment Characterisation	2005	Baseline modelling and characteristics of Jones Creek.
Wetland Research and Management	Baseline aquatic biology and water quality study of Jones Creek, including the southwest claypan area. Yakabindie Nickel Proposal	2005	A study to determine the baseline aquatic fauna and physico-chemical parameters at eight sites along Jones Creek and one in the southwest claypan.
Hydro-Resources	Potable Water Supply Yakabindie Nickel Proposal and Exploratory and Test Dewatering Drilling. Serp Hill. Yakabindie Nickel Proposal	1997	Hydrology of the area with a strong emphasis on dewatering rates and water supply opportunities.
Woodward Clyde	Yakabindie Proposal: Six Mile and Goliath North Dewatering Review	1995	
Coffey Partners	Yakabindie Nickel Proposal: potable water supply	1991	
Coffey Partners	Yakabindie Nickel Proposal: pit dewatering	1990	

4.2.1 Surface water

The majority of the Development Envelope occurs within the Jones Creek Upper Catchment. During large flood events water is rapidly shed from the upper part of the catchment into the creek. An evaluation of the water resources in the Proposal Study Area determined that creek flow is highly intermittent and water quality can be highly variable (MWES 2016). Sedimentation of Jones Creek is particularly sensitive to catchment conditions between rainfall events and largely unrelated to the proposed mining operation (MWES 2016).

4.2.2 Groundwater

The aquifers in the Proposal Study Area are of limited lateral and vertical extent and surrounding rocks exhibit very low permeability (MWES 2016). Most of the bedrock lithologies have practically no primary or secondary porosity and drilling across a majority of the area generates no groundwater yield. The oxide zone over the dunite ultramafic pod at Six Mile Well pit is the main aquifer, where high permeability and porosity occurs in the oxide silica-carbonate zone which extends to about 50 m below ground level (BGL) (MWES 2016).

Depth to the water table varies from a minimum of about 15 m in the south west, to 16 to 17 m in the vicinity of Jones Creek, and 25 to 35 m outside the creek beds. The groundwater extends down to approximately 50 m (MWES 2016). At such depths, it is considered that groundwater does not sustain surface vegetation (MWES 2016). There is expected to be limited recharge potential and natural groundwater level fluctuations are likely to be minor, and not relevant to the proposed dewatering (MWES 2016).

Groundwater salinity in the aquifer at Six Mile Well pit is brackish (3000 to 8000 mg/L TDS) and neutral pH. Groundwater in the isolated country rock fractured zone in surrounding areas is also brackish but of lower salinity (700-5400 mg/L TDS) (MWES 2016).

There is a high degree of similarity between the proposed satellite pits and the Mt Keith pit, of which the hydrogeology and dewatering requirements are well understood. MWES (2017) identified the following impacts as a result of mining:

1. At the Goliath pit the low permeability will result in very limited drawdown. The dry conditions at Goliath and absence of any pathway or receptor for groundwater impacts negate the requirement of drawdown modelling.
2. Groundwater drawdown extent at the Six Mile Well pit is expected to be less than 1 km from the pit perimeter.

There is potential for changed water quality in the backfilled Six Mile Well pit after closure and for movement of the impacted water laterally away from the backfilled pit. However, investigations on the geochemical characteristics of host rocks and low grade ore indicate that the waste rocks have meagre abundances of sulphide materials dispersed throughout the groundmass with a moderate to high capacity to consume acid (Graeme Campbell and Associates 2005). The limited distribution of elevated sulphide material in the pit walls and the overwhelming high acid neutralising capacity (ANC) for most wall rocks means that there is no possibility of acidification of the Six Mile Well backfill groundwater or the Goliath pit lake (MWES 2016).

4.3 Subterranean Fauna

Subterranean fauna assessments that have been conducted within the Proposal Study Area are listed in Table 5.

Table 5: Subterranean fauna studies completed

Author	Title	Date	Scope
Bennelongia Environmental Consultants	Peer Review Mount Keith Satellite Operations Subterranean Fauna Assessment	2017	A peer review of the MWH 2016 subterranean fauna assessment.
MWH	Mount Keith Satellite Operations Subterranean Fauna Assessment	2016a	An assessment to determine if the removal or modification of potential habitat and groundwater drawdown will place subterranean fauna at risk.
Outback Ecology Services	BHP Billiton Nickel West NDS1 Proposal: Lake Way Borefield Subterranean Fauna Assessment	2012	A desk-top and field based study to define the subterranean fauna values present in the Proposal area.
Biota Environmental Sciences	BHP Billiton Northern Nickel Proposals Stygofauna assessment	2006	A regional survey of the Yakabindie, Lake Way and Albion Downs areas.

4.3.1 Stygofauna

Stygofauna in the Pilbara and Yilgarn predominantly occur within calcrete associated groundwaters. However, the Proposal Study Area consists of regolith and fractured rock aquifers and does not contain any calcrete. As described in the in Section 4.2.2, groundwater occurrence is generally associated with alluvial and/or colluvial deposits, that represent transported or weathered regolith horizons.

The extent of possible stygofauna habitat extends from approximately 25 m bgl to approximately 50 m bgl.

Stygofauna reconnaissance surveys have involved the collection of samples in 21 bores over five sampling rounds between 2006 and 2012 (MWH 2016a). The stygofauna sampling identified the following key findings (MWH 2016a):

- Six Mile Well pit: two syncarids (*Atopobathynella* sp. OES8, *Atopobathynella* sp. OES11) were only recorded within the footprint of the mine; an ostracod (*Gomphodella* sp. IK2,) was recorded within the predicted extent of drawdown; and an unidentified worm (oligochaete) that was also required in the outside the likely groundwater drawdown area
- Goliath pit stygofauna: an amphipod species (*Neoniphargidae* sp.) which was recorded in the footprint of the pit and the predicted drawdown area immediate outside the pit; and an unidentified worm (oligochaete) that was also required in the outside the likely groundwater drawdown area.

It is unlikely that stygofauna is associated with Jones Creek near the proposed Six Mile Well pit because in this area Jones Creek is erosional and incised in bedrock and there is no alluvium associated with the creek (MWH 2016a).

Two stygofauna species were also collected from outside the Development Envelope (MWH 2016a).

Peer review process

A peer review of the MWH (2016a) subterranean fauna assessment has been conducted and confirmed the conclusions of the assessment. The peer review noted that most Yilgarn sampling programs have shown that stygofauna usually only have limited occurrence in the regolith and fractured rock aquifers that host the stygofauna found in the Proposal Study Area (Bennelongia 2017).

The peer review suggests sampling of additional bores is required to show accurate distribution of stygofauna abundance in the Proposal Study Area (Bennelongia 2017).

Further sampling

Based on the reconnaissance survey reports and peer review recommendations, further sampling work is being undertaken to better describe the potential stygofauna assemblages within the Proposal Study Area and confirm assumptions related to groundwater quantities (Figure 7).

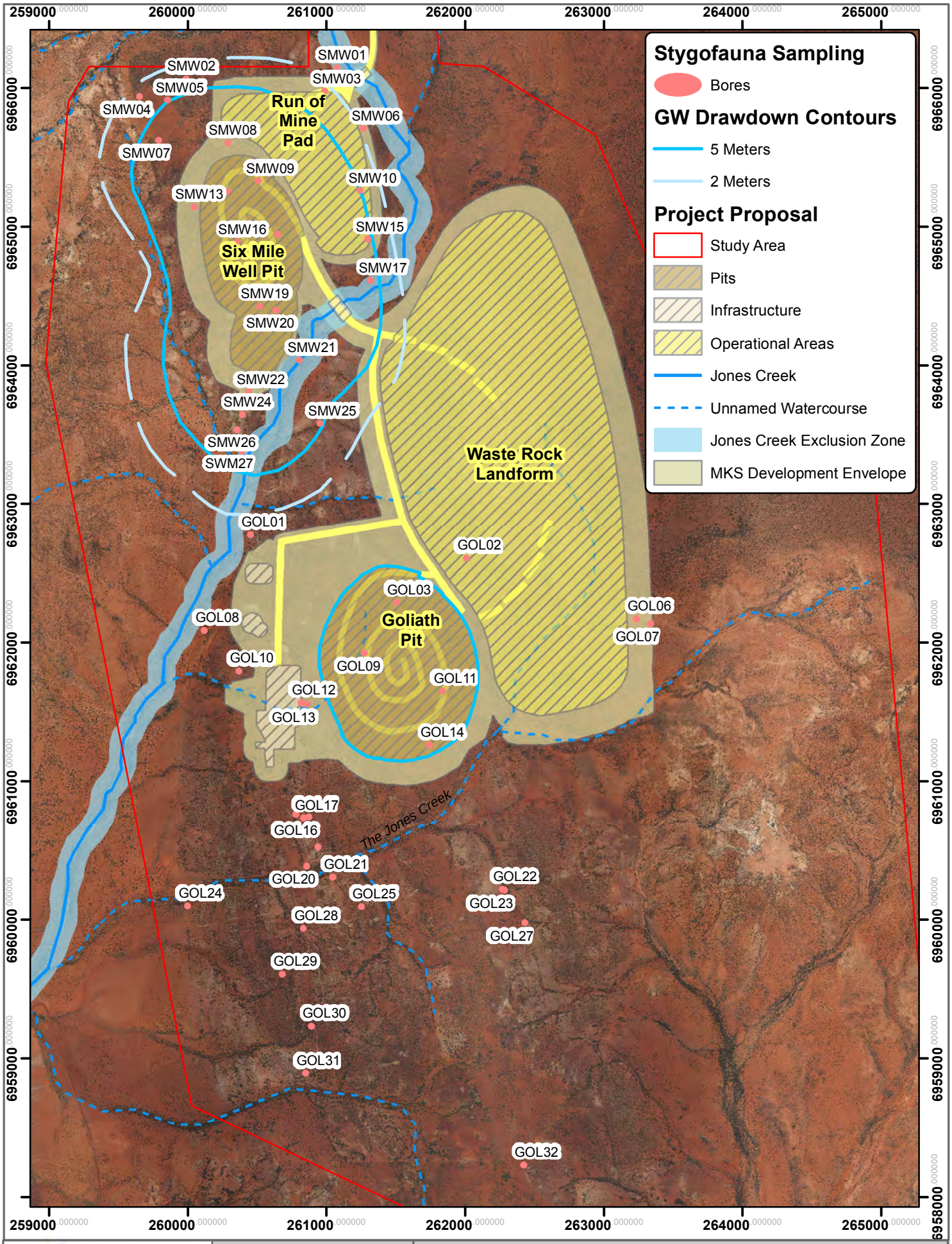
A habitat assessment will also be completed to assess where the occurrence of stygofauna might occur along the Perseverance-Greenstone belt outside the Proposal Study Area to determine stygofauna distribution and abundance outside the zone of impact.

The results of the sampling program are expected mid 2017.

4.3.2 Troglofauna

Two rounds of troglofauna surveys were conducted in 2011, sampling 37 bores. The survey found two species, however these were not found within the Development Envelope (MWH 2016a).

Troglofauna are not considered an assessment issue and no further troglofauna sampling is required (MWH 2016a). The peer review also supported the conclusion that troglofauna are not an assessment issue.



bhpbilliton	**Author:** SJM
Nickel West	**Date:** 03/05/2017
Projection Details: MGA Zone 51	**Scale:** 1:35,000
Map ID: StygofaunaSampling103.mxd	**Figure No:** 7

Stygofauna Sampling Plan
Mount Keith Satellite

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4.4 Other Environmental Factors

While the Proposal is likely to have minimal effect on the following environmental factors, the following work has been undertaken to describe the environmental baseline.

4.4.1 Terrestrial Environmental Quality

A soil and landform survey was conducted in the Proposal Study Area to provide baseline information and assist in the planning of soil resource management and rehabilitation. Soil samples were collected from 30 survey sites to a maximum profile depth of 2 m (Outback Ecology 2012a).

The physical and chemical characteristics of all soils sampled were considered to be generally non-problematic, with little consistent variation in soil properties identified between the soils from the different soil management units (Outback Ecology 2012a).

The top 0 to 25 cm of the soil profile is considered potential “topsoil” and deeper soils could potentially be used as a rehabilitation resource (Outback Ecology 2012a).

4.4.2 Terrestrial Fauna

Terrestrial fauna objectives aim to protect biological diversity and ecological integrity within the Proposal area. Extensive vertebrate and short range endemic fauna surveys have been completed for the Proposal Study Area, including a number of habitat specific assessments relevant to species of conservation significance. These assessments have identified four mammal species and two short range endemic (SRE) species with elevated conservation significance that could potentially occur within the Proposal Study Area. Of these only one mammal (Brush-tailed Mulgara (*Dasycercus blythi*)) and two SRE species have the potential to be affected by the Proposal. Significant habitat exists outside the proposed Development Envelope for each of these species and a substantial portion of this habitat is located within conservation estate. This reduces the risk of significant impact to populations of these species from the development of the Proposal, as such Terrestrial Fauna is not considered a potential key environmental factor.

Vertebrate

Extensive vertebrate fauna and habitat surveys have been completed at the local and regional level since 1990. These assessments have provided a detailed picture of vertebrate fauna populations and available habitat within the region.

To date, nine separate vertebrate fauna surveys, conducted between Mount Keith and Leinster, have been completed. Of these, five vertebrate fauna assessments included or were specific to the Proposal Study Area, between 1990 and 2010. These surveys were documented in the following reports:

- a biological assessment of the Yakabindie Nickel Mine Proposal: Six Mile Well – Sir Samuel Blocks 33 (Ecologia Environmental Consultants (Ecologia) 1990);
- an ecological assessment of the Yakabindie Nickel Mine Proposal: Six Mile Well / Mount Pascoe (Ecologia 1995);
- a fauna assessment of the Yakabindie area (ATA Environmental (ATA) 2005a and 2005b);
- surveys associated with the Wanjarri Nature Reserve Land Swap Proposal (Biota 2006a)
- Part 10 (Sandstone–Sir Samuel and Laverton–Leonora study areas) of the biological survey of the Eastern Goldfields of Western Australia (Hall et al. 1994);
- a fauna survey of the Lake Way Borefields near Mount Keith (Biota 2006b);
- a fauna survey of the Mount Keith Mine expansion area (Biota 2006c);
- a survey of fauna habitats and the fauna assemblage of the Albion Downs Borefield Pipeline area (Biota 2008);
- a detailed fauna assessment of the Yeelirrie Proposal area in 2009 and 2010 (Bamford Consulting Ecologists (BCE) 2011).

A significant number of trapping sites were established within the region. Biota conducted four surveys between 2006 and 2008, establishing 65 systematic trapping sites, 30 sites were established as part of the Mount Keith study by UWA, and ATA established 16 sites within and adjacent to the Proposal Study Area as part of the Yakabindie appraisal in 2005.

In total, this survey effort has recorded 215 vertebrate fauna species, comprising 36 mammal species, 106 bird species, 67 reptile species and six frog species (Biota 2016). The 2016 Biota Terrestrial Fauna Review builds on the previous reports to provide an overall summary of survey efforts since 1990.

Three mammal species of conservation significance (Priority 4) could potentially occur within the Proposal Study Area; the Brush-tailed Mulgara (*Dasycercus blythi*), the Long-tailed Dunnart (*Sminthopsis longicaudata*) and the Central Long-eared Bat (Nyctophilus major tor) (Biota 2016). The Brush-tailed Mulgara, Long-tailed Dunnart and Central Long-Eared Bat are Priority 4 under the *Wildlife Conservation Act 1950*. The fourth mammal species (Schedule 2 - Endangered) the Black-footed Rock-wallaby (*Petrogale lateralis laterals*) was recorded outside of the Proposal Study Area.

The Proposal Study Area contains grass dominated undulating plains, and hills which is suitable habitat for the Brush-tailed Mulgara and slopes / sclerophyll shrublands which is suitable habitat and the Long-tailed Dunnart (Biota 2010). Evidence of Brush-tailed Mulgara has been recorded from the northern end of the Proposal Study Area; however, no individuals have been documented. The Long-tailed Dunnart and Central Long-Eared Bat have not been recorded in fauna surveys within the Proposal Study Area. These habitats are well represented in the surrounding areas in the Barr Smith Range and included in conservation tenure in the Wanjarri Nature Reserve, with significantly more habitat available outside the Proposal Study Area.

The Brush-tailed Mulgara habitat is primarily located within the Bullimore Land System (Pringle et. al. 1994) with only minor occurrences within the Development Envelope. There is over 4 000 000 ha of Bullimore land system habitat within the region and only 70 ha of this area transects the Proposal Study Area. This habitat is well represented in conservation tenure in the Wanjarri Nature Reserve with 29,873 ha located within the A Class Nature Reserve.

Previous surveys have not definitively indicated that these species of conservation significance occur within the Development Envelope, despite significant terrestrial fauna surveys effort. Furthermore the remaining available habitat in the region and a proximity to protected habitat within the Wanjarri Nature Reserve reduces the risk of significant impact to local and regional populations of Conservation Significance species.

Short range-endemic (SRE) invertebrate fauna

Within the Proposal Study Area, the internal drainage and creek line habitats were considered to have a high potential of supporting SRE species.

A SRE invertebrate fauna survey was conducted and was followed by a replicated survey effort and targeted survey in 2012 (Outback Ecology 2012b). The following invertebrate groups prone to short-range endemism were targeted during this assessment: mygalomorph spiders, araneomorph spiders (selenopids), scorpions, pseudoscorpions, millipedes, slaters and terrestrial snails.

The survey identified nine broad fauna habitat types were identified within the Proposal Study Area:

- Drainage Line - Moderate potential to support SRE (11.8% of extent in Development Envelope)
- Mulga over Spinifex on Sand Plain - Moderate potential to support SRE (10% of extent in Development Envelope)
- Mulga over Wanderrie grass - Moderate potential to support SRE (11.7% of extent in Development Envelope)
- Calcrete Plain - Low potential to support SRE
- Stony Plain - Low potential to support SRE
- Sparse Mulga Woodland - Low potential to support SRE
- Playa - Low potential to support SRE

- Acacia Shrubland - Low potential to support SRE
- Annual Shrubland - Low potential to support SRE.

The vegetation habitat considered to have a moderate potential to support SRE in the Proposal Study Area are all well represented outside the Development Envelope. All of the habitats identified are known to also occur outside of the Proposal Study Area.

The survey yielded a total of 1682 invertebrate specimens from 49 species. Slaters were the most numerous group to be collected (832 individuals from eight species), followed by pseudoscorpion. Two of the species collected were well known and well represented in the region. Four of the species collected were considered likely SREs (a group will poor taxonomic resolution or a lack of specimens in reference collections). Eight of the species collected were considered to be potential SREs where identification may not be possible because specimens are an inappropriate sex or life stage to allow comparisons with reference collections (BHP Billiton 2016). A mygalomorph spider recorded was determined by the Dr Mark Harvey of the WA Museum to be (*Idiosoma* 'MYG018') and not *Idiosoma nigrum*, which is recognised as a SRE species.

A fauna review conducted by Biota (2016) concluded that the broad habitats identified are not confined to the Proposal Study Area and is therefore unlikely to support any highly restricted terrestrial fauna species.

4.4.2 Inland Waters and Environmental Quality

The majority of the Proposal Study Area occurs within the Jones Creek Upper Catchment. A study was conducted to assess the ecological values of Jones Creek and the associated southwest terminal claypans (MWH 2016b). Previous studies of Jones Creek were also carried out in 2011 following a major flood event (Outback Ecology 2012c) and aquatic ecology studies in 1992 and 2005.

Jones Creek exhibits freshwater, with neutral to alkaline pH with low nutrients and metals. The riparian vegetation was highly degraded with understorey of grasses and herbs and overstorey of *Eucalyptus* (MWH 2016b).

There were no communities or species of conservation significance found during database searches of relevance to the aquatic ecosystem (MWH 2016b).

The field study results indicate Planktonic algae are abundant and diverse in the clear pools of the creek (MWH 2016). Opportunistic, transient insect groups were characteristic of the invertebrate fauna assemblage of Jones Creek and were associated with habitat availability and the limited residence time of surface water pools. Vertebrate fauna were limited to frogs, with most species occurring along the length of the creekline into the claypan beyond the Proposal footprint. The majority of organisms identified during the study were found to have a broader, cosmopolitan distribution throughout Western Australia and Australian inland waters (MWH 2016).

A 100 m exclusion zone around Jones Creek (excepting creek crossings) will be implemented and appropriate engineering designs and construction protocols will mitigate any potential impact the Proposal may have on Jones Creek. In addition, a series of bunds, silt traps and cleanwater diversion drainage controls will be constructed at strategic locations and a suitable monitoring program will detect potential impacts along the creek (MWH 2016).

4.4.3 Landforms

The soil and landform survey concluded salvaged topsoils and sub soils were relatively stable and suitable for use in landform design and rehabilitation. The use of surface soil and subsoil, with a high percentage of coarse material, is suitable for sloped landforms. The final design of constructed landforms will depend upon the requirements for encapsulation of potentially hostile waste material and landforms to be visually consistent with the surrounding landscape. Additional benign waste rock may be required to augment the surface armouring potential of the surface soils over the proposed constructed landforms (Outback Ecology 2012a).

4.4.4 Air Quality

Air dispersion modelling has been undertaken to assess the potential ambient air quality concentrations and dust deposition that may occur due to proposed mining and transport activities. The assessment focussed on fugitive emissions from major dust generating activities (Ramboll 2017).

The modelling indicated that without the use of watering dust controls on the transport corridor, predicted concentrations are below the nominated standards at the receptors, except at the Mount Keith camp. Exceedances of total suspended particles, PM_{10} and $PM_{2.5}$ were predicted to occur. The modelling also indicated that when watering controls were applied to the transport corridor, concentrations at camp were predicted to fall below the nominated standards (Ramboll 2017).

The Proposal Study Area is likely to exhibit native vegetation with a degree of tolerance to elevated, relatively inert, dust and dust deposition levels due to the dry environment (Ramboll 2017).

Nitrogen and sulphur dioxide emissions were not included in the air dispersion modelling as it was anticipated that the air quality impacts associated with these pollutants will be small at sensitive receptors due to the remote location of the proposed development (Ramboll 2017).

4.4.5 Social Surroundings

Given the Proposal Study Area is adjacent to the Wanjarri Nature Reserve and the Goldfields Highway, the visual amenity of the proposed landform has been assessed. The height of the proposed waste landform has been determined on the basis of minimising Disturbance Footprint and associated Development Envelope and height above the surrounding landscape. There are some viewpoints where the proposed landform will be partially visible through gaps in the trees, such as the Wanjarri Picnic Area and Wanjarri Sleeping Quarters, however, these areas are fairly well screened by the surrounding vegetation (Land Services 2011).

Visual impacts post-closure will be reduced from the rehabilitation of mining landforms. Rehabilitation design will consider the potential for visual impacts and feedback from key stakeholders. Rehabilitation activities will be conducted in accordance with relevant statutory requirements.

Heritage

The Proponent and previous tenement holders have worked with Traditional Owner Groups to develop a detailed understanding of the heritage values of the Proposal Study Area, with the aim of understanding how the Proposal's impact on heritage sites can be minimised.

The Groups that have participated in heritage surveys include the Ngalia, Wutha, Wunmulla, Sir Samuel and Koara. In 2012 the Tjiwarl native title claim was registered, and in December 2016 the Tjiwarl were subsequently granted native title over lands which include the Proposal Study Area. The Tjiwarl are made up of individuals from the above groups.

Over the development history of the Proposal, 46 different heritage (archaeological or ethnographic) surveys have been conducted over land that forms part of the Proposal and its surrounds. Through this engagement, Jones Creek and the Barr Smith Range have been identified as being the places of most importance to Traditional Owners. The previously approved Proposal impacted the Barr Smith Range and required a significant diversion of Jones Creek.

The referred Proposal differs from the previously approved Proposal in a number of significant respects which mitigate impacts to these identified heritage sites, including;

- Nickel West has completed the Wanjarri Land swap which enabled the relocation of the waste rock dump to the eastern side of the pits, thereby avoiding impact to the Barr Smith Range;
- The size of the Six Mile Well pit forming part of the referred Proposal is such that diversion of Jones Creek is not required.

Despite these measures a small number of identified heritage sites are unable to be avoided and will be impacted by implementation of the Proposal. In accordance with the requirements of the *Aboriginal Heritage Act 1972*, Nickel West hold the necessary s18 approvals which allows for disturbance of the land on which these sites are located (Figure 8).

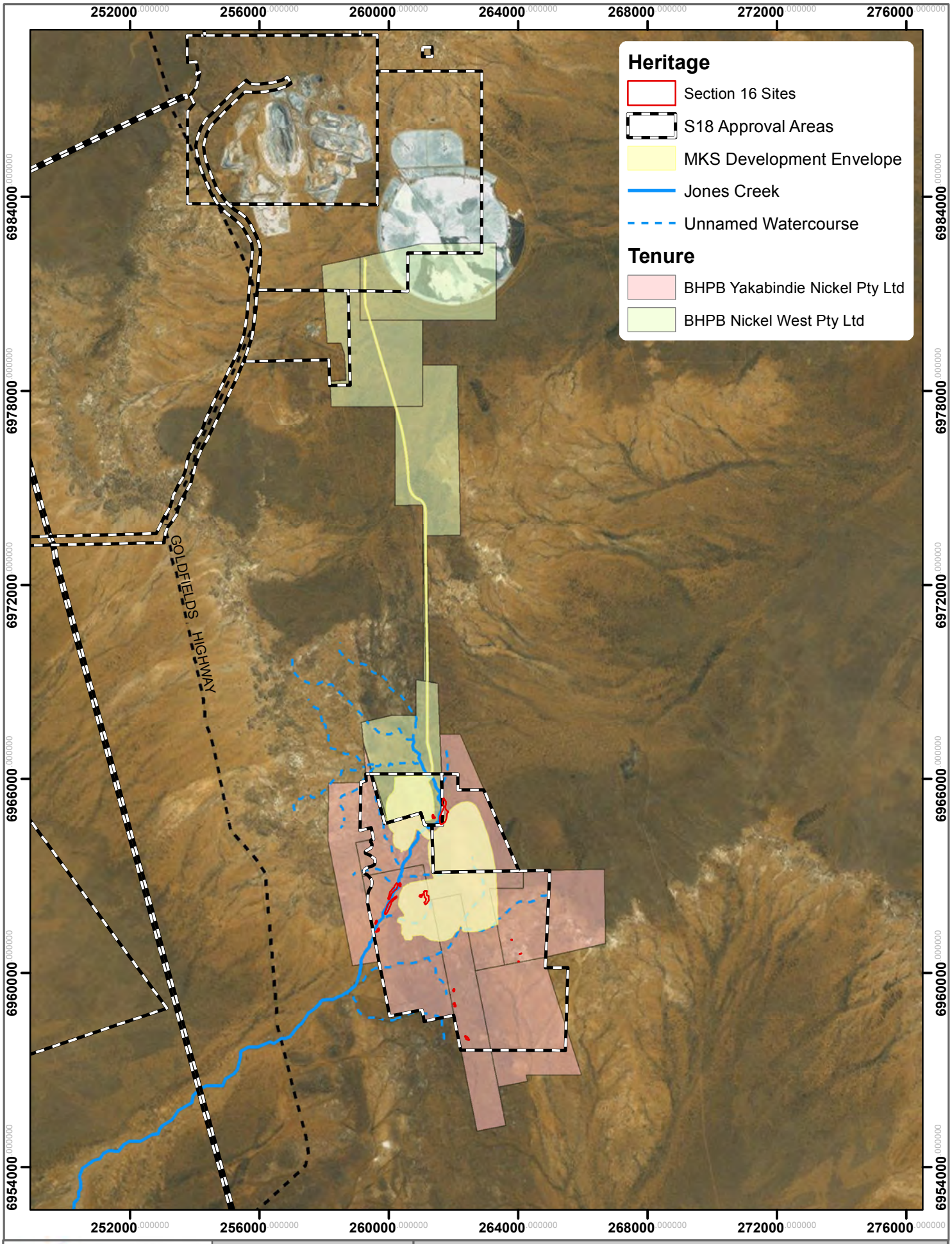
The Proponent will undertake this authorised disturbance of impacted heritage sites in accordance with the conditions of the granted section 18s. Those sites that are outside of the Development Envelope will be protected from impact via Nickel West's existing land disturbance authorisation process.

The Proponent has notified the Tjiwarl of its desire to meet with them and negotiate a land use agreement with them over the Proposal.

4.4.6 Human Health

A noise impact assessment which focused on the more extensive mining and processing activities than the current Proposal has been conducted (by SVT Engineering 2011). The screening assessment determined if further detailed noise modelling was necessary and was based on the closest noise sensitive receptor being the Shearing Sheds in the Wanjarri Nature Reserve, 7 km away. The screening assessment indicated that noise emissions during day were within the criterion; however, night-time construction noise and operational noise was above the criterion. Further acoustic calculations were conducted. The results of the additional calculations indicate that received noise levels from both construction and operations are below the night-time noise level limits (SVT Engineering 2011).

Vibrations from blasting events are identified to be negligible because mining from Six Mile Well and Goliath pits will not occur at the same time. A vibration study found that the ground vibration levels at the Shearing Shed would only be an issue if blasting operations occur at night and if the proposed charge mass from the blasting operations exceeds 7 tonnes at any one time, or 3 tonnes for 9 in 10 consecutive blasts (SVT Engineering 2011).



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Nickel West

Projection Details: MGA Zone 51

Author: SJM

Date: 03/05/2017

Scale: 1:150,000

Figure No: 8

Map ID: Heritage_Referral103.mxd

Section 18
Mount Keith Satellite

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5. Stakeholder consultation

Nickel West aims to consult with all identified stakeholders throughout and beyond the approvals process. The objectives for this communication are as follows:

- engage appropriately with stakeholders to ensure that all stakeholders understand the potential aspects and benefits of the development of the Proposal and the approvals required to successfully develop the Proposal
- ensure that stakeholders understand that the approvals being sought are for the development of a satellite deposit to sustain the existing Mt Keith operation
- communicate with stakeholders in a clear and timely manner, consider the interests of and impacts on our stakeholders.

A Communications and Consultation plan has been developed to enable Nickel West to meet these objectives and outline the appropriate stakeholder engagements at each phase of the Proposal.

5.1 Pre-Referral

Pre-referral discussions have been undertaken with Department of State Development (DSD), the OEPA, Department of Parks and Wildlife (Parks and Wildlife), Department of Mines and Petroleum (DMP) and Department of Environmental Regulations (DER) regarding the Proposal scope and the proposed preliminary key environmental factors as outlined in Table 6.

Pre-referral discussions covering scope and/ or previous findings were also undertaken with Parks and Wildlife Ecosystem Management Branch for the following potential key factors:

- Flora and Vegetation
- Hydrological Processes
- Subterranean Fauna
- Terrestrial and SRE Fauna
- Social Surrounds.

Pre-referral discussions with Parks and Wildlife provided feedback relating to Flora and Vegetation Terrestrial Fauna and Social Surrounds. Parks and Wildlife were satisfied with the scope for further Flora and Vegetation assessments prior to submitting a referral. Conservational Significant fauna species identified within the Proposed Study Area were not of concern due to the proximity to significant protected habitat (Wanjarri Nature Reserve). Parks and Wildlife highlighted the need to consider the aspects of amenity as part of the social surrounds factor.

Further consultation with Parks and Wildlife regarding alternative public access to the Wanjarri Nature Reserve was undertaken in November 2016. The Proponent role in this process is to assist Parks and Wildlife to identify appropriate alternative access and advise of any concerns regarding access to the Proposal Development Envelope.

The OEPA is aware of the additional stygofauna sampling that is currently being undertaken.

Pre-referral discussions were also undertaken with the DMP to ensure that the department was aware of the Proposal prior to the submission of a referral. DMP clarified the requirements for meeting the Mining Proposal approvals required but did not have any concerns related to environmental impacts.

An initial briefing session has been scheduled (May 2017) with the Traditional Owners (Tjiwarl) to provide a Proposal overview and identify an appropriate frequency for further consultation on the detailed aspects of the Proposal.

5.2 Post-Referral

Ongoing consultation, as required, will be undertaken with OEPA, Parks and Wildlife, DoW, DMP, local communities and other relevant stakeholders throughout the planning, design and approval stages of the Proposal.

Table 6: Stakeholder Engagement

Stakeholder	Date	Topic/Issue	Proponent Response/Outcome
DSD	29/07/2016	Initial scoping discussion regarding MKS Proposal and the importance of the Proposal to the future of Nickel West. DSD approved of the Proposal outcomes for Nickel West and requested that Nickel West update DSD further as required.	BHPB Nickel West will keep DSD updated as required.
Parks and Wildlife	21/10/2016	MKS Proposal Technical discussion - all aspects. Parks and Wildlife indicated there was nothing related to the Proposal that would cause them concern at this time. The black flanked wallaby has significant habitat in this area and so Parks and Wildlife do not consider this an issue. Parks and Wildlife suggested that BHPB Nickel West follow up regarding Idiosoma sp. as the taxonomy has recently been reviewed,	BHPB Nickel West followed up regarding Idiosoma sp. as the taxonomy has recently been reviewed, Mike Harvey of the WA Museum has confirmed that the species identified in Wanjarri and the Proposal area are not threatened. Parks and Wildlife have indicated that further consultation can wait until planned flora and vegetation assessments have been completed or referral has been submitted.
EPA	27/10/2016	WAIO session introducing BHPB and requesting a pre-scoping session. EPA indicated that Richard and Rob Hughes would work with BHPB for the assessment process.	Follow up with Renelle Thorpe on the pre-scoping session.
Parks and Wildlife	3/11/2016	Wanjarri Alternative access discussion. Parks and Wildlife indicated that the previous agreement signed in 2007 outlines the requirements BHPB must adhere to. Parks and Wildlife is looking for this signed version. Discussed proponent of the Gas Pipeline to access the pipeline corridor.	BHPB to follow up regarding access. Access assessment trip is planned for March 2017 – BHPB Nickel West representatives will attend to assist with access assessment.
EPA	27/11/2016	Pre-scoping session. Proposal scope discussed in detail. Discussion regarding previous approval and existing Ministerial Statements. EPA is of the opinion that the previous approval is still valid and that the Proposal is a revised proposal.	Review undertaken by BHPB legal has identified risks and therefore certainty of a formal assessment is sought.
EPA	28/12/2016	Pre-scoping session. Discussion concentrated on the previous Statement and approval conditions. The EPA indicated that the condition related to the expiry of the approval was not valid.	As above.
EPA	7/02/2017	Legal discussion s 38 vs s 46. The EPA indicated that an s46 is the way in which expansions are done to date. However, if the Proposal scope is vastly different then a new proposal under s 38 would be required. The other item of discussion was the condition found in the active Statement for the 1990 approval indicating that the approval is not valid.	BHPB to compare the scope of the original 1990 approval with current proposed scope for review at the next session.
EPA	14/02/2017	Legal aspects associated with a revised or new proposal. EPA acknowledged that it could understand risk of s 46 approach and that BHPB should ultimately pursue whichever path it is comfortable with. EPA BHPB to submit the referral to allow EPA to form its view on appropriate approval path.	Submit s38 referral in March 2017.
EPA	20/02/2017	Discussion and presentation regarding stygofauna to date and planned sampling program.	Send presentation to EPA. Submit a referral in March. Feedback on the proposed sampling program will be delivered in the scoping document phase of the approval. Meet again after round 1 sampling reporting is completed.
Shire of Wiluna	02/03/2017	Initial consultation regarding the MKS Proposal was raised as part of ongoing stakeholder engagement activities with the Shire of Wiluna. A number of issues were discussed including the Shire being supportive of the Proposal as a potential income within the Shire. Environmental assessments completed were presented and updates requested by the Shire at future sessions.	BHPB Nickel West will keep DSD updated as required.
DMP	7/03/2017	Initial consultation and discussion regarding timing for approvals, closure plans requirements and other detail. DMP indicated that they will require a closure plan for the Proposal with the Mining Proposal.	DMP indicated that further consultation is not required until preparation to submit Mining Proposal application is scheduled.

6. Potential key environmental factors and impact assessment

Table 7: Assessment of potential key environmental factors

Potential key environmental factor	EPA objective	Policy and guidance	Potential impact	Mitigation strategies	Outcomes
Flora and Vegetation	To protect flora and vegetation so that biological diversity and ecological integrity are maintained.	• Environmental Factor Guideline – Flora and vegetation • Technical Guidance - Flora and Vegetation Surveys for Environmental Impact Assessment.	• Clearing of native vegetation within the Development Envelope: • Clearing of up to 1251 ha of vegetation that is generally widespread in the area • Minor clearing of vegetation units associated with the Violet Range PEC • Minor clearing of Priority 3 and Priority 4 species • Possible spread or introduction of weeds due to movement of mining related vehicles.	Avoid: • Design of the mine footprint to reduce disturbance of conservation significant flora. Minimise: • Rationalisation of the Development Envelope to reduce overall clearing requirements. • Exclusion or buffer areas placed around the Jones Creek riparian vegetation (100m buffer) and conservation significant flora outside the mining footprint (50m buffer). • Internal disturbance approvals process required prior to land clearance (Environment and Heritage Impact Assessment process). Rehabilitate: • Waste dumps and general disturbance areas will be rehabilitated in accordance with closure planning requirements.	Residual Impact: • The majority of Vegetation Associations Complexes are impacted to a negligible level on a regional scale. • Disturbance of 8% of the PEC. Offset: • Based on the expectation that the clearing will not have a significant impact, no offsets are proposed.

Potential key environmental factor	EPA objective	Policy and guidance	Potential impact	Mitigation strategies	Outcomes
Hydrological Processes	To maintain the hydrological regimes of groundwater and surface water so that environmental values are protected.	• Environmental Factor Guideline - Hydrological Processes.	• Dewatering has the potential to affect local hydrological processes resulting in secondary impacts • Groundwater drawdown has the potential to affect subterranean fauna habitat (described in the Subterranean fauna factor below).	Groundwater drawdown cannot be avoided. <u>Minimise:</u> • The mining process consists of mining Goliath Pit to a depth of approximately 410 mbgl, drawdown is required to remove the full extent of the resource. Six Mile Well pit will be mined to approximately 270 mbgl, resulting in the dewatering of approximately 50% of the resource, recharging in 50 years. <u>Mitigate:</u> • Monitoring groundwater levels and quality to minimise impacts • Groundwater from dewatering is planned to be used as dust suppression, and shortfall in water requirements is planned to be met through the Yakabindie borefield 15 km to the south or Mt Keith operations 20 km to the north. <u>Rehabilitate:</u> • The final stage of mining is the completion of Goliath Pit with waste rock to be placed in the Six Mine Well Pit which will assist groundwater recharge of the resource associated with the Six Mile Well pit • A pit lake will form in the Goliath Pit at closure. The water level is expected to gradually stabilise at less than 140 m AHD • Based on the limited porosity of the surrounding geology the formation of a pit lake is not expected to substantially affect hydrological process in the area.	<u>Residual Impact:</u> • Pit lake in Goliath pit to be managed in accordance with Mine Closure Plan requirements under the Mining Act. <u>Offset:</u> • No offset is proposed.

Potential key environmental factor	EPA objective	Policy and guidance	Potential impact	Mitigation strategies	Outcomes
Subterranean Fauna – stygofauna	To protect subterranean fauna so that biological diversity and ecological integrity are maintained.	• Environmental Factor Guideline – Subterranean Fauna • Technical Guidance – Subterranean fauna survey.	• Removal of habitat through excavation of the proposed mining pits, Goliath and Six-Mile Well • Potential drying out of habitat through the lowering of the groundwater table associated with mine pit dewatering • Potential loss of species/ populations at the local level.	Direct impacts cannot be avoided. Minimise: • Design of mine pits has been minimised to avoid unnecessary disturbance. Mitigate: • A sampling program is currently underway to better describe the potential stygofauna assemblages present within the Proposal footprint • Habitat assessment and DNA analysis of specimens will contribute to better understanding and management outcomes • Groundwater dewatering abstraction limits • Groundwater level and quality monitoring to monitor impacts.	Residual Impact: • Removal of stygofauna habitat and loss of species. Offset: • No offset is proposed.
Terrestrial Fauna	To protect terrestrial fauna so that biological diversity and ecological integrity are maintained.	• Environmental Factor Guideline – Terrestrial Fauna • Technical Guidance – Terrestrial fauna surveys.	• Clearing of up to 1251 ha of potential terrestrial fauna habitat that is generally widespread in the area • clearingstephen has the potential to disrupt localised fauna linkages for native fauna or result in the death or injury of terrestrial fauna. • development has the potential to introduce/attract feral animals.	Avoid: • Design of the mine footprint to reduce disturbance of conservation significant flora. Minimise: • Rationalisation of the Development Envelope to reduce overall clearing requirements. • Exclusion or buffer areas placed around the Jones Creek habitat (100m buffer). • Implementing and signposting speed limits for both mining equipment and light vehicles in the Development Envelope and on access roads. • Internal disturbance approvals process required prior to land clearance (Environment and Heritage Impact Assessment process). • Conservation Significant species pre-disturbance clearance survey of preferred habitat within the Development Envelope and relocation of any species identified. Rehabilitate: • Waste dumps and general disturbance areas will be rehabilitated in accordance with closure planning requirements. • Undertaking feral animal control.	Residual Impact: • The terrestrial fauna habitat to be cleared is widespread in the area (including in conservation tenure) and will not significantly reduce the extent of potential habitat • Conservational significant species will not be significantly affected at the local or regional level due to clearance of habitat. • This is not considered a key factor for the proposal as no significant impacts are identified. Offset: Based on the expectation that the clearing of habitat will not have a significant impact, no offsets are proposed.

Potential key environmental factor	EPA objective	Policy and guidance	Potential impact	Mitigation strategies	Outcomes
Social Surrounds	To protect social surroundings from significant harm.	• Environmental Factor Guideline – Social Surroundings	• Potential impacts to Aboriginal heritage sites.	Avoid: • Design of the mine footprint to reduce disturbance of heritage sites Minimise: • Rationalisation of the Development Envelope to reduce overall disturbance requirements. • Exclusion or buffer areas placed around the Jones Creek heritage area (100m buffer) • Internal disturbance approvals process required prior to land clearance (Environment and Heritage Impact Assessment process).	Residual impacts: • Disturbance to Aboriginal heritage sites has been minimised and where disturbance is required will be undertaken in accordance with requirements of s 18 of the *Aboriginal Heritage Act 1972* This is not considered a key factor for the proposal as no significant impacts are identified. The Proponents will continue to liaise with Traditional Owners regarding interaction with Aboriginal heritage sites.

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Appendix 1 – Tenure Detail

Tenement ID	Description	Area (ha)	Grant Date	Expiry/Sale Date	Tenement Holder
L36/206	Conveyor System, Powerline, Pipeline and Road (Mt Keith Satellite Proposal)	42.5	18/08/2011	17/08/2032	BHP BILLITON NICKEL WEST PTY LTD
M36/183	Six Mile Resource (Mt Keith Satellite Proposal)	835.5	26/07/1990	25/07/2032	BHP BILLITON YAKABINDIE NICKEL PTY LTD
M36/184	Serp Hill Mineralisation & Five Creeks Prospect (Mt Keith Satellite Proposal)	886.45	26/07/1990	25/07/2032	BHP BILLITON YAKABINDIE NICKEL PTY LTD
M36/185	Goliath North Resource & Sheba Prospect (Mt Keith Satellite Proposal)	668.5	26/07/1990	25/07/2032	BHP BILLITON YAKABINDIE NICKEL PTY LTD
M36/246	Six Mile North Location, Betheno Mineralisation (Mt Keith Satellite Proposal)	757.6	13/10/1992	12/10/2034	BHP BILLITON NICKEL WEST PTY LTD
M36/285	Mt. Pascoe (Mt Keith Satellite Proposal)	858.85	4/02/1994	3/02/2036	BHP BILLITON YAKABINDIE NICKEL PTY LTD
M36/286	Mt. Pascoe (Mt Keith Satellite Proposal)	839.05	4/02/1994	3/02/2036	BHP BILLITON YAKABINDIE NICKEL PTY LTD
M36/288	Six Mile Well (Mt Keith Satellite Proposal)	521.85	4/02/1994	3/02/2036	BHP BILLITON YAKABINDIE NICKEL PTY LTD
M36/399	Six Mile North Location - Gold Option Tenement (Mt Keith Satellite Proposal)	13.81	10/12/2008	9/12/2029	BHP BILLITON NICKEL WEST PTY LTD
M36/422	Wanjarri Excision Area (Mt Keith Satellite Proposal)	669.35	8/06/2015	7/06/2036	BHP BILLITON YAKABINDIE NICKEL PTY LTD
M36/658	Gold Option Tenement (Mt Keith Satellite Proposal)	864.7	31/07/2006	30/07/2027	BHP BILLITON NICKEL WEST PTY LTD
M36/677	Yakabindie Transport Corridor (Mt Keith Satellite Proposal)	18.58	22/02/2007	21/02/2028	BHP BILLITON NICKEL WEST PTY LTD
M53/217	Tailings Storage Facility	948.80	2/04/1992	1/04/2034	BHP BILLITON NICKEL WEST PTY LTD
M53/218	Includes a minor portion of the Mt Keith Airstrip	924.55	2/04/1992	1/04/2034	BHP BILLITON NICKEL WEST PTY LTD

PEER REVIEW
MOUNT KEITH SATELLITE OPERATIONS SUBTERRANEAN FAUNA ASSESSMENT

Bennelongia Environmental Consults has been asked by BHP Billiton Nickel West to peer review the 2016 report by MWH entitled '*Mount Keith Satellite Operations Subterranean Fauna Assessment*' and also to comment on the planned drilling of additional bores, as well as re-developing of existing bores, for stygofauna sampling. Discussions about location of bores have occurred on several occasions, the most recent being 20 December 2016.

The proposed Mount Keith Satellite Operations consists of the development of two mine pits to the south of Mount Keith at Six Mile Well and Goliath.

In summary, the MWH report appears to be correct in its conclusions that the Project study area does host stygofauna, with an assessment of survey efficiency indicating that additional sampling of the Project area is required to adequately document the stygofauna community. The report is also correct in concluding that troglofauna are not an assessment issue and no further troglofauna sampling is required.

The results of field sampling for stygofauna in the Project area are not what would have been predicted in advance of fieldwork and several aspects of the stygofauna results warrant further comment. There are no issues in relation to troglofauna.

Aquifer geologies in which stygofauna occur
As pointed out by MWH (2016), stygofauna in the Yilgarn are usually collected in calcretes and alluvium/colluvium in palaeochannels or in alluvium of active creeklines. Most Yilgarn sampling programs have shown that stygofauna have limited occurrence in the regolith and fractured rock aquifers that host the stygofauna found in the Project area.

The likely reason for stygofauna occurrence in dunite ultramafics and basalt in the Project area is that these two geologies are weathered and contain an unusually high porosity for their rock types. Based on geology, the area around Six Mile Well would be expected to be more prospective for stygofauna than the area around Goliath

It appears that stygofauna at Six Mile Well occur in a weathered ultramafic aquifer that has reduced porosity at depths >60 mbgl, while at Goliath (and probably to the south) stygofauna are likely to occur in a weathered, but relatively low-yielding and diffuse ultramafic aquifer.

There are unlikely to be any stygofauna associated with Jones Creek in the Six Mile Well area because in this area Jones Creek is erosional and incised in bedrock. There is no alluvium associated with the creek.

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The stygofauna found at Six-Mile Well consisted of syncarids, an ostracod and a worm, Goliath supported an amphipod species and a worm, while the area to the south of Goliath supported a syncarid species and a worm.

Two species have been collected from two or more holes within the Project area (syncarid *Atopobathynella* sp. OES9 and worm Enchytraeidae sp. OES10) and have ranges extending from Six Mile Well to south of Goliath. The linear extent of impacts associated with the two mine pits and their associated drawdown is approximately 5 km. Restricted stygofauna species may have smaller ranges than this, so there is potential for the species currently known only from Six Mile Well or Goliath to be restricted to an area of impact.

The boundary of the area to be potentially impacted by groundwater drawdown at Six Mile Well is defined by the 2 m drawdown contour. The boundary of the area of drawdown around Goliath is defined by the mine pit crest.

Minimum additional sampling

While the total of 64 samples (Table 1) collected from the Project area by Biota (2006) and MWH (2016) seems at first glance to be sufficient to characterize its stygofauna community, EstimateS analyses used by MWH (2016) strongly suggest that this is not be the case and that a relatively speciose fauna occurs at low abundance. It appears that a considerably larger number of samples – including sampling from a greater number of more evenly distributed bores – is required to characterize the fauna. Currently sampling effort is poorly distributed within the Project area because of lack of bores that reached the watertable at the time of sampling.

Table 1. Previous sampling effort in the Project area.

	Six Mile Well	Goliath	Total no. of samples
Impact samples	6	18	24
Reference samples	40		40

In the sampling by Biota (2006) and MWH (2016), only two bores were sampled within the likely impact area (pit and associated groundwater drawdown cone) at Six Mile Well, although six samples were collected from these bores as a result of repeated sampling. It is recommended that at least another four bores within the impact area should be sampled, so that that sampling will have occurred at six bores in the impact area. It is recommended that at least an additional 12 samples should be collected.

At Goliath, 18 samples were collected from six bores in the likely impact area. The number of bores in the impact area (inside mine pit crest) appears to be adequate but it is suggested that at least another six samples should be collected from the existing (or alternative) impact bores.

Altogether, 40 samples were collected from 13 reference area bores that are mostly to the south of Goliath. This review recommends that that at least 30 additional reference samples should be collected from around Six Mile Well, Goliath and farther south (though see next section).

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The early survey work by Biota (2006) collected two species from within the impact area at Goliath. These species were not identified to species level. One was an amphipod Neoniphargidae sp. and the other was a worm Oligochaeta sp. The amphipod is likely to have been mis-identified and is probably a species of *Scutachiltonia* (family Chiltonidae), while the worm may be Enchytraeidae sp. OES10 that is known from reference areas associated with the Project. Re-sampling the two holes yielding these species (CP12/CP12P and 95GPG07) should be a priority to re-collect the two species and provide up to date identifications.

Proposed sampling program

BHP Billiton Nickel West is proposing to conduct additional stygofauna sampling in the Project area.

This will involve the sampling of 58 bores (Table 2). It is planned to sample all 58 bores twice to obtain comprehensive baseline information of the composition of the stygofauna community in the Project area. A third round of targeting sampling is also planned, in which a subset of bores may be sampled to provide more specific information about the stygofauna community and the ranges of individual species.

Six of the bores will be located in the drawdown (impact) area associated with Six Mile Well and six will be located in the Goliath impact area (Table 2). The remaining bores will be distributed from north of Six Mile Well to south of Goliath. The bores have been selected to occur in prospective geologies hosting relatively transmissive aquifers (weathered basalts and ultramafics, especially dunite ultramafics). In the case of reference bores, this maximizes the likelihood of collecting stygofauna and building a picture of the local distribution of the stygofauna species found in the Project area.

The proposed program includes re-sampling the bores CP12/CP12P and 95GPG07, although they have been re-named.

Table 2. Number of samples to be collected in proposed sampling program.

	Round 1	Round 2	Round 3
Six Mile Well impact	6	6	
Goliath impact	6	6	
Reference	46	46	TBA

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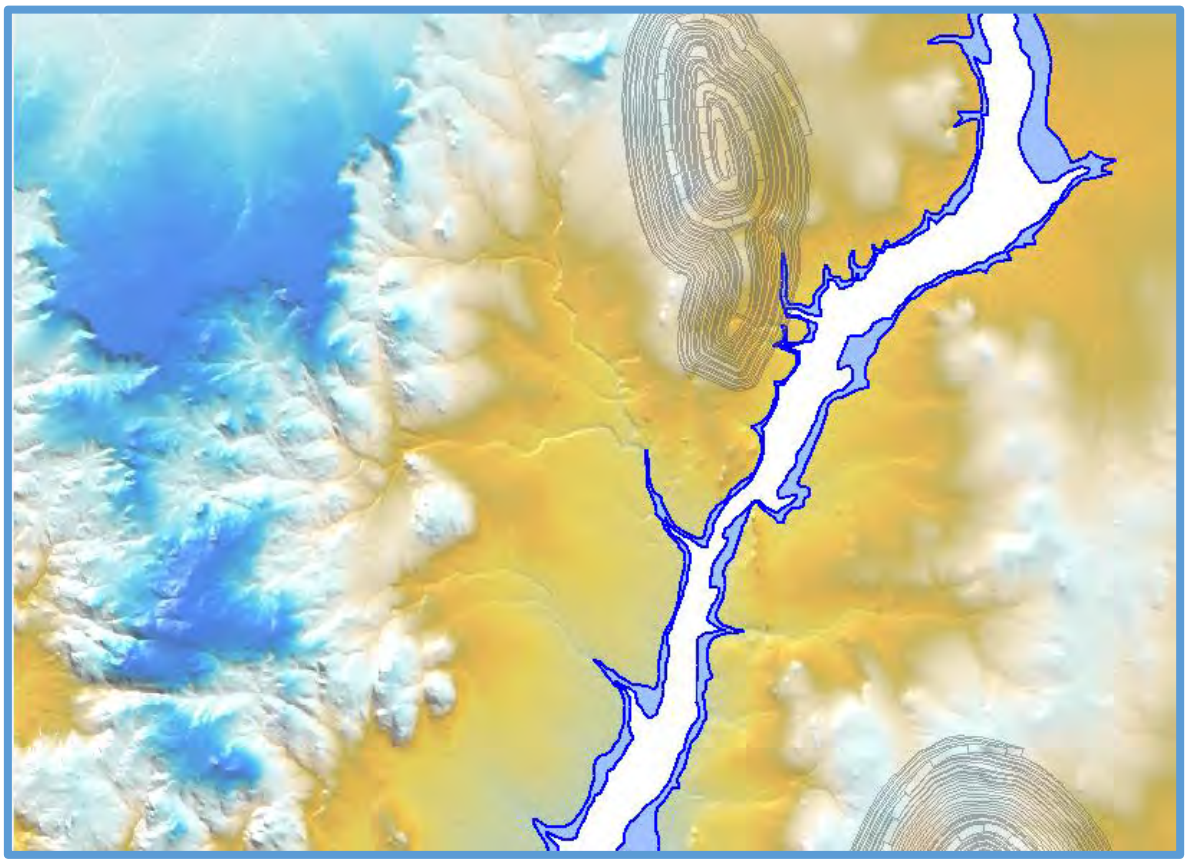
Mt Keith Satellite Operations
Water Aspects and Impacts

BHP BILLITON - NICKEL WEST



MWES CONSULTING

Rev3 - 28 July 2016

EXECUTIVE SUMMARY

This report presents quantitative and qualitative evaluations of water related aspects of the proposed Mt Keith satellite pits mining development. The water related impacts have the potential for direct risks to water resources or indirect risks to the ecology of habitats sustained by the water resources, including:

- Ingress of creek-flow to the mine voids
- Excessive reduction in catchment area and runoff causing a reduction in the frequency/magnitude/duration of flow with significant ecological impacts
- Erosion of the waste rock dump by creek flow
- Excessive increment of creek sediment load causing significant ecological impacts
- Erosion along roadways including Jones Creek crossings
- Vegetation impacts from loss of overland flow along haul roads or "shadowing"
- Dewatering drawdown impact on vegetation and stygofauna habitat
- Sustainability of additional abstraction for Mt Keith concentrator supplies

The proposed development layout is such that the direct water-related risks can be readily mitigated by modest design and operational measures.

For the majority of creek flow events, there is no potential interaction between the flood water and proposed landforms (pits and dump). The potential for interaction only occurs at the margins of extreme flood levels which will occur very rarely and last only a matter of hours. A small amount of permanent bunding will securely isolate the SMW pit void from high-stage creek flow. The small incursions of the WRD onto the Jones Creek flood plain are in areas of low stream velocity.

Catchment scale volumetric impacts have been evaluated and found to be minor. Flow frequency and duration will be practically unaffected. Total catchment discharge reduction will be approximately proportional to the catchment area reduction which will initially be up to 12 %. In most years that intermittent flows in Jones Creek occur, the total annual yield greatly exceeds the capacity of the terminal Clay-pan such that the filling frequency of the Clay-pan will be barely diminished by the development.

A number of measures have been devised to control additional sediment load to the creek system. These include permanent clean stormwater diversions and operational drains and traps to control sediment. The impact is considered to be manageable however, operational controls will be critical to minimising the impact. Operational monitoring of the physical and chemical characteristics stream sediment should provide a robust and direct form of feedback on performance.

Haul routes have been adjusted to minimise impacts where possible and are not problematic from a hydrological perspective. Surface gradients along and across the proposed routes are generally low. Some relatively minor drainage measures, cut slope cladding and road surface profile modifications cladding are detailed.

In support of the overall environmental impact assessment, the report presents a summary of the mine's hydrogeological regime, simulated water level drawdown and recovery, along with an assessment of likely long term pit lake and groundwater quality changes. The main aquifer is the is the regolith-zone aquifer associated with the weathering horizon on the SMW ultramafic orebody. The baseline saturated aquifer thickness is typically about 20 metres and groundwater modelling indicates that significant dewatering drawdown (2-5 metres) will extend up to several hundred metres beyond the pit crest. Mature eucalypts in

Jones Creek adjacent to the SMW Pit and other vegetation are not considered vulnerable to drawdown impacts since baseline water levels are normally at least 15 metres below the creek bed level and pit dewatering will not affect soil/rock moisture in the overlying profile.

The potential for ecological impacts from additional dissolved trace element load to surface and groundwater from all potential sources is considered to be very low, provided appropriate operational practises are undertaken to minimise ore spillage. The ore is generally low grade and relatively low in sulphide and trace metals. Waste rock constitutes the bulk of material movement and has very low levels of mineralisation and the majority has high mechanical and chemical stability ("competence").

After closure, the Goliath pit will partially refill to form a very deep pit lake and minor discharge zone to the generally impermeable country rock. Ongoing evaporative losses mean the pit lake salinity will continue to increase. The backfilled SMW void will refill to a level close to the original static water level over about 50 years and long term water quality is expected to be minimally impacted.

Dewatering rates are expected to be less than operational water requirements creating a modest water supply deficit. Several low impact options to address this deficit are detailed. The viability of the four existing water supplies to the Mt Keith Concentrator has been assessed. It is expected that the borefields will continue to deliver the additional 10 years water supply without substantial modification and that the extension will not create any different environmental outcomes.

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1. INTRODUCTION

Major components of the proposed development include:

- Haul road 15 km north to Mt Keith tenements
- Stage 1 Goliath Pit, 205 M tonnes mined FY20-23 with waste to waste rock dump (WRD)
- Six Mile Well (SMW) pit, 227 M tonnes mined FY23-27 with waste to (WRD)
- Stage 2 Goliath Pit, 362 M tonnes mined FY26-31 with waste to SMW and WRD
- Site haul roads, stockpiles, workshop, office etc.

In support of environmental approvals, Nickel West have requested that MWES address the following scope:

- Climate summary and rainfall-runoff relationships
- Stormwater run-off assessment including:
    - major drains and sediment containment ponds
    - impacts on the downstream Jones Creek hydrograph
- Hydrogeological model of SMW pit for simulation of dewatering, drawdown risks and impacts
- Pit lakes closure models. Predictive model of water level and salinity. Qualitative assessment of ARD and trace element chemistry
- Site water balance, pumping and storage capacity requirements
- Concentrator water supply
- Groundwater management plan including dewatering and monitoring bore layout and monitoring regime
- Stormwater management plan including instrumentation and monitoring regime
- Overall executive summary identifying key water related risks, and control measures

2. CLIMATE, RAINFALL AND RUN-OFF CHARACTERISTICS

Climatic data presented here is largely sourced from the Australian Bureau of Meteorology (BoM) website. General climatic statistics are presented are based on those from Wiluna (BoM station 013012) which is located 100 km north of the site and Leinster Aero (#012314) 50 km to the south. Rainfall data for closer BoM stations was also reviewed.

Long term rainfall averages are slightly higher at Wiluna than some of the closer stations such as Yakabindie Homestead (BoM #12088). The BoM pan evaporation data for Wiluna are inconsistent with wider regional data and values from the BoM regional grid are used here, however the sensitivity of the impacts assessment to any local variations is low.

Rainfall intensity, duration and frequency data are those obtained from the BoM "New IFDs (2013)" and are calculated based on a grid which takes account of local topographic effects.

2.1 Climate

Mt Keith's climate is semi-arid region with cool winters and hot summers. The seasonal range in mean daily minimum temperature is 5 to 23°C and in maximum temperature is 19 to 38°C.

Wind strengths are generally moderate, averaging between 8 to 12 km/hr over most of the year. The prevailing wind direction is from the east to southeast over most of the year. Stronger westerly winds occur in spring, with September average afternoon strengths exceeding 40 km/hr on an average of 1 day per month.

High temperatures and low humidity throughout much of the year produce an average pan evaporation of about 3,200 mm, and average evaporation exceeds average rainfall in all months of the year. The long term average rainfall for the area is about 235 mm.

2.2 Rainfall

Average monthly rainfall is reasonably consistent from December to July (25 to 35 mm) and from August to November (10 to 20 mm). The average number of rain days per year (> 1 mm) is about 32. High intensity rains occur more commonly in summer, caused by localised thunderstorm activity or much larger weather systems associated with cyclones and tropical lows, however high intensity rain can also occur in association with winter weather patterns. Low rainfall intensity and low rainfall totals occur most consistently in the months of September to November.

BoM data indicate that the region has an average annual tropical cyclone frequency of between 0.1 and 0.2. Rainfall intensity-frequency duration relationships for the site are tabulated below. For frequencies of up to 100 years (annual exceedance probability 1%) the data are obtained from the BoM website IFD calculator. Probable maximum precipitation is calculated using the BoM Generalised Tropical Storm Method.

Table 1 – Rainfall Intensity Frequency and Duration (mm) and Probable Maximum Precipitation

	Annual Exceedance Probability							PMP
Duration	**1EY**	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	
1 min	1.1	1.4	2.2	2.8	3.5	4.5	5.3	
2 min	1.9	2.3	3.7	4.7	5.9	7.6	9.1	
3 min	2.7	3.2	5	6.5	8.1	10.4	12.5	
4 min	3.3	4	6.3	8.1	10	12.9	15.4	
5 min	3.9	4.7	7.4	9.5	11.8	15.1	18	
10 min	6	7.2	11.4	14.7	18.2	23.3	27.7	
15 min	7.4	8.9	14.1	18.1	22.4	28.7	34.1	
30 min	9.9	11.9	18.9	24.3	30.1	38.6	45.9	
1 hour	12.7	15.2	24	30.8	38.2	49.1	58.6	
2 hours	15.9	19	29.7	38.1	47.2	60.8	72.6	
3 hours	18.1	21.6	33.7	43.1	53.4	68.7	81.9	
6 hours	22.8	27.1	42.1	53.7	66.3	84.8	100.7	
12 hours	28.7	34.3	53.2	67.6	82.9	105.1	123.9	
24 hours	35.8	42.9	66.7	84.3	102.8	129.1	150.8	832
2 days	43.1	51.8	80.7	101.6	123.1	153.4	177.9	1201
3 days	46.7	56.3	87.6	110.1	133.2	165.4	191.3	1515
4 days	48.8	58.7	91.4	114.8	138.8	172	198.8	1695
5 days	50	60.1	93.5	117.4	141.9	175.8	203.1	1786
7 days	51.1	61.4	95.3	119.6	144.5	179	206.7	

2.3 Peak Stream-flow Rates

A methodology for determination of peak flow was developed for the project (Flavell, 2011). Streamflow data from the relatively steep and rocky (by regional standards) Newton Dam catchment at Kambalda was modelled using RORB to determine runoff characteristics which were then adjusted to local conditions based on comparison of differences in climate, soil and vegetation.

Twelve local catchments were then selected with a variety of sizes/shapes, giving critical storm durations in the range 1 to 6 hours. RORB models were constructed for each of the 12 local catchments using the adjusted runoff coefficients. The models were run for simulation of design storms of various frequencies. Multiple regression analysis of the 2, 5, 10, 20, 50 and 100-year ARI design flood estimates and catchment characteristics was undertaken to derive equations for estimating design flow rates for the area as follows:

$$Q_2 = 0.16\ (AS_e^{0.5})^{0.82}\ (L^2/A)^{-0.35} \quad (1)$$
$$Q_5 = 0.49\ (AS_e^{0.5})^{0.84}\ (L^2/A)^{-0.33} \quad (2)$$
$$Q_{10} = 0.91\ (AS_e^{0.5})^{0.84}\ (L^2/A)^{-0.34} \quad (3)$$
$$Q_{20} = 1.48\ (AS_e^{0.5})^{0.85}(L^2/A)^{-0.33} \quad (4)$$
$$Q_{50} = 2.50\ (AS_e^{0.5})^{0.82}\ (L^2/A)^{-0.36} \quad (5)$$
$$Q_{100} = 3.37\ (AS_e^{0.5})^{0.83}\ (L^2/A)^{-0.35} \quad (6)$$

Where: A = catchment area (km2)
L = mainstream length (km)
Se = equivalent uniform slope (m/km)
Qn = n year flood estimate (m3/sec)
And for $L^2/A < 1.0$, it should be replaced with A/L^2

These equations constitute the Mt Keith Regional Flood Flow Estimation Method (MKRFFEM)

3. HYDROLOGICAL ASSESSMENT AND STORMWATER CONTROLS

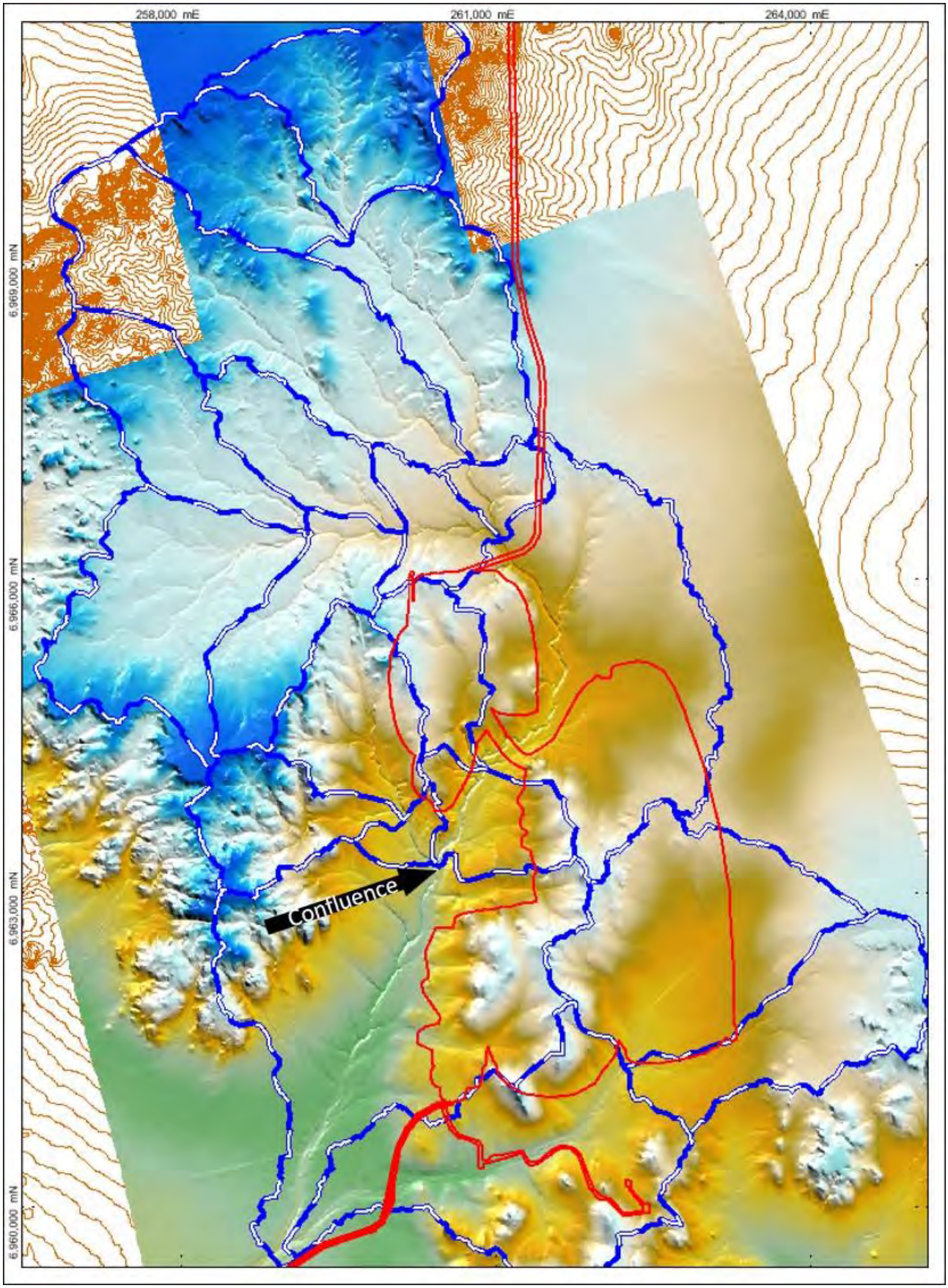
3.1 Jones Creek Flood Levels

3.1.1 Catchments

The baseline catchment model is shown in Figure 1. which shows:

- 20 sub-catchments used in run-off modelling
- Confluence of upstream and western tributary streams
- Proposed disturbance area
- Topographical features
- 5 metre DEM as colour- fill

Figure 1 – Jones Creek Runoff Model Catchments



3.1.2 Flow Rates

Runoff modeling was undertaken using the RORB model and reported by Flavell (2011). Peak flow rates were calculated in site specific RORB models and using the regional peak flow methodology described above. The peak flow rates are tabulated below.

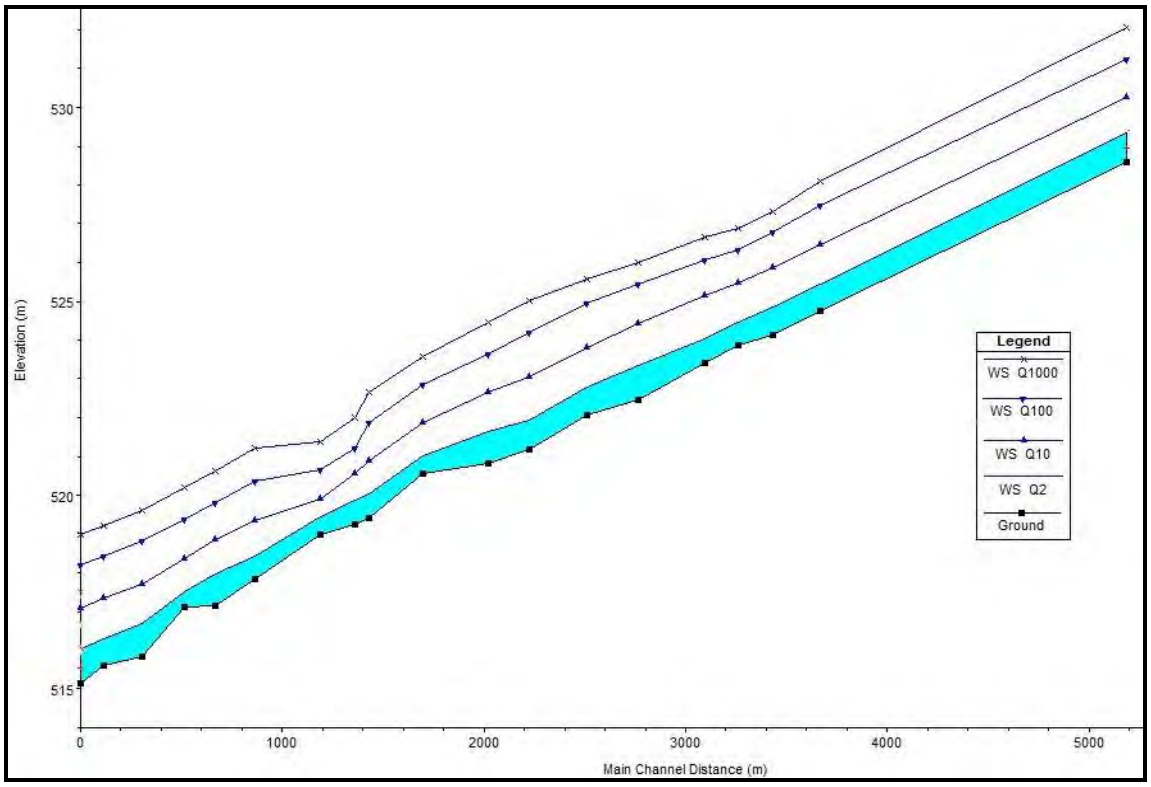
Table 2 – Mainstream Peak Flow Rates

Catchment	Method	A	Se	L	Average Recurrence Interval (years)						
		km^2	m/km	km	2	5	10	20	50	100	1000
					Flow rate (cumecs)						
Upstream of Site	RORB				3.5	11.9	22.6	37.8	53	72.8	160
Upstream of Site	MKRFFEM	28.2	3.9	8.7	3.1	10.3	19.0	32.6	47.3	67.0	
Western Tributary	MKRFFEM				1.1	3.6	6.6	11.1	17.3	23.9	52.5
Confluence	Summation				4.6	15.5	29.2	48.9	70.3	96.7	212.5

3.1.3 Hydraulic Modelling

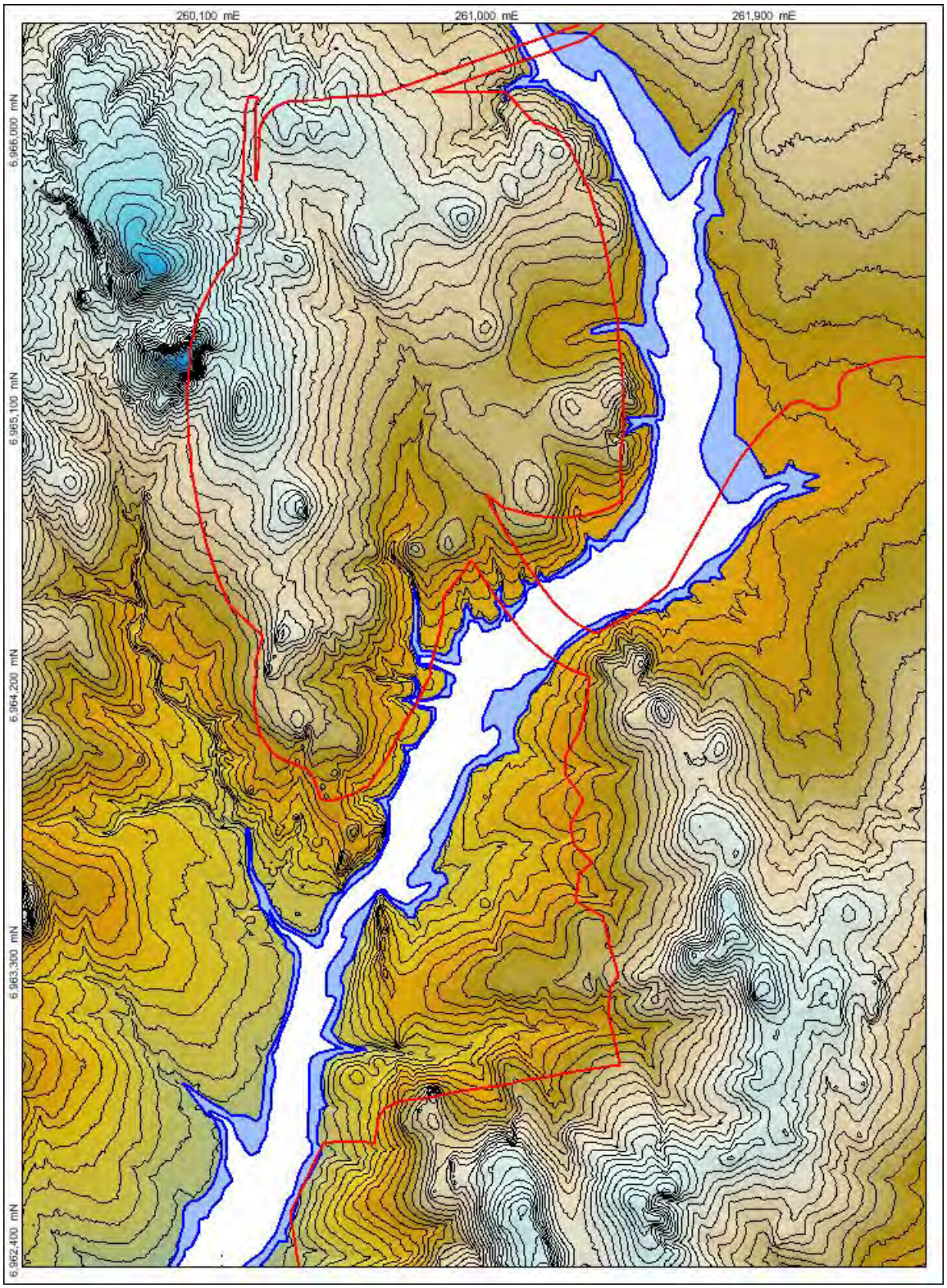
A HEC-RAS (US Army Corps of Engineers, 1997) model was developed that encompassed the mainstream reach through the site (Flavell, 2011). The design floods defined above were applied to the model and the water surface profiles determined. The longitudinal section showing the water surface profiles for the 1:2, 1:10, 1:100 and 1:1000 year ARI events is shown on Figure 2.

Figure 2 – Jones Creek Peak flood level profiles



Modelled and interpolated (between cross sections) peak water levels for the 1:100 year (white) and 1:1000 year (blue) events are shown in Figure 3

Figure 3 – Peak flood levels for 1:100 and 1:1000 year events



Apart from the two Jones Creek crossings there are minor projected incursions of the proposed disturbed area into the extreme flood zone. In these areas control structures will be required to manage interactions and impacts as discussed below.

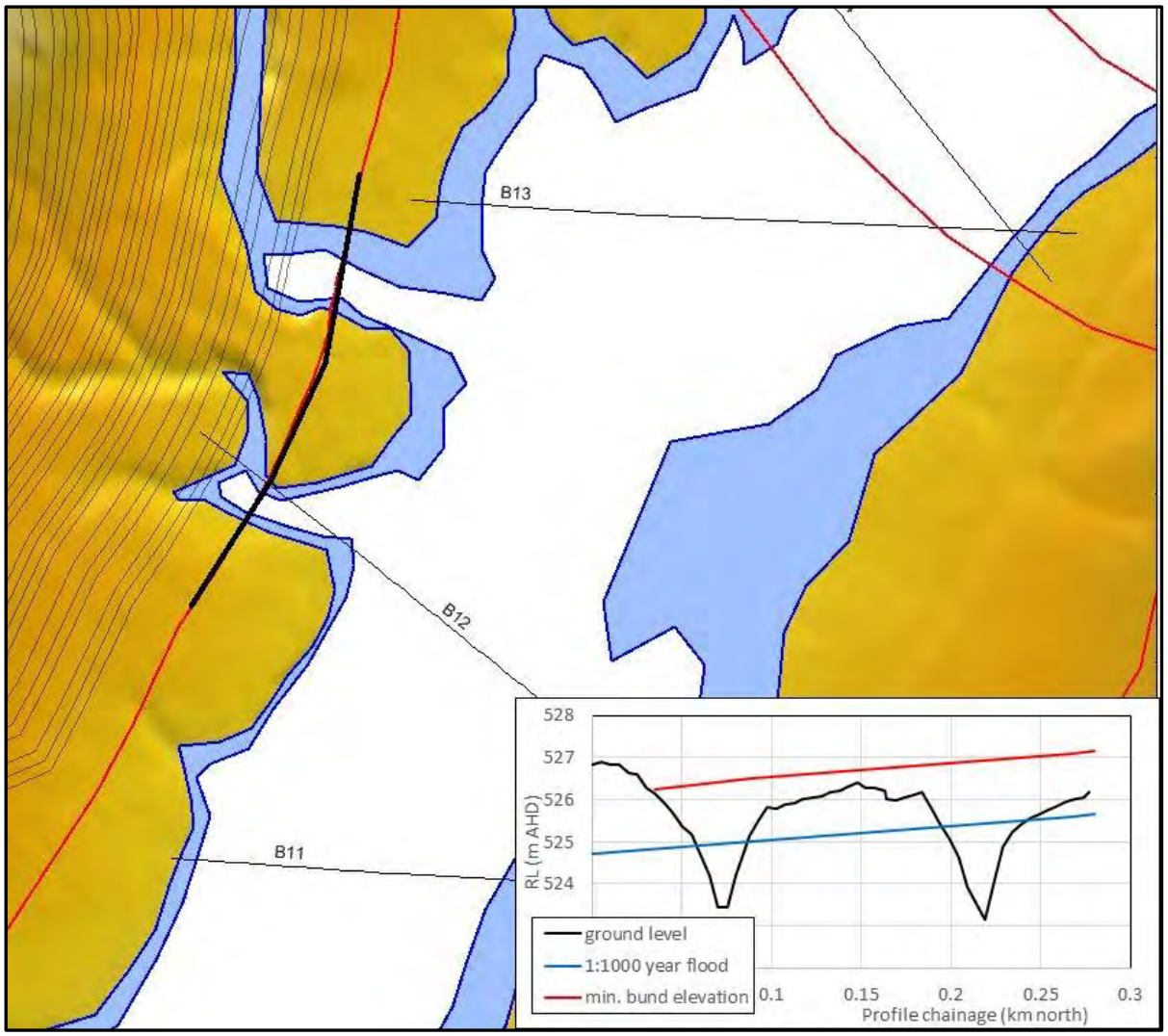
3.2 Stormwater Controls

3.2.1 Jones Creek

Where the development extends beyond the peak flood level there is the potential for flooding of pits resulting in loss of through-flow to the downstream catchment. There is also potential for excessive sediment mobilization. Referring to the incursions of the disturbance area into the extreme flood zone as shown on Figure 3 above and the following locations:

West side of creek-south east corner of SMW pit. Two minor gullies are below the peak flood level at the perimeter of the SMW pit disturbance area. Figure 4 shows the detail, including the flood model cross section lines (B11-B13). The surface profile line (black line) is along a segment of the western edge of the SMW pit disturbance area (red line).

Figure 4 – Jones Creek peak flow level near the SMW pit



The profile shows that the risk of peak flows entering the pit can be managed by short bunds of less than 1.5 metres height. These bunds can be incorporated into the normal operational pit perimeter bund and extended

a further metre above the predicted 1:1000 year level.

East side of creek – northwest corner of waste rock dump. The dump toe will be located 50 metres inside the disturbance area perimeter and up to 500 metres of the dump toe is located on the Jones Creek floodplain and is subject to rare and brief inundation, with the potential risk of erosion of the dump toe. The risk is/can be moderated by the following factors and measures:

- area of interaction is far from the creek line such that flow stream flow velocity will be moderate
- inundation will occur rarely and for brief periods
- the exposed toe segment (500 metres) rock armored to minim elevation of 529 m RL .
- drainage from the northeast of the WRD be routed around the north end of the WRD to the mainstream in a controlled way

3.2.2 Jones Creek Crossings

Potential impacts from the haul road crossings mainly relate to Jones Creek water quality, particularly excessive additional sediment load. When the particle size distribution of the additional load is exotic to the natural stream bed, impacts would be exacerbated. Mechanisms for introducing additional sediment load include:

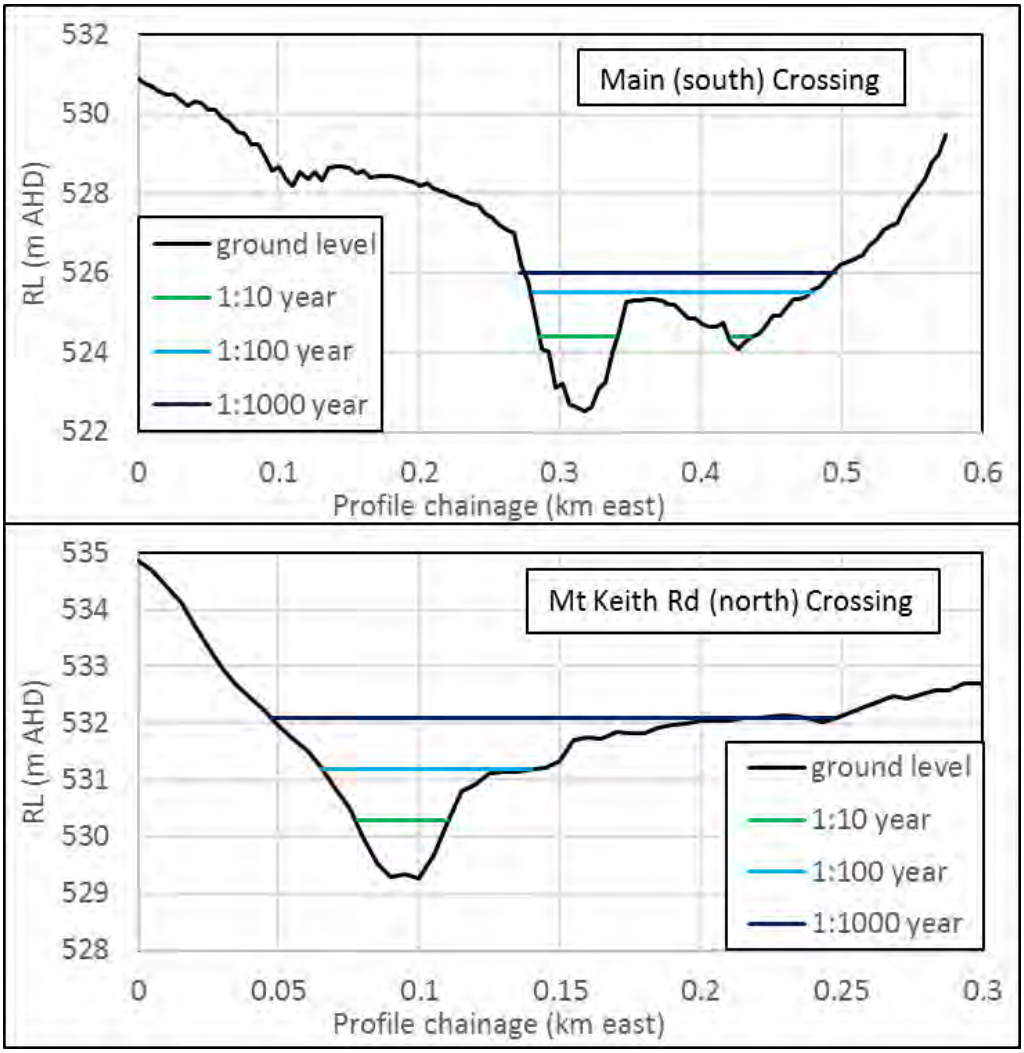
- Construction of crossing – bank cutting to achieve acceptable gradients (max 8% slope)
- Erosion of bank cuttings during flow events
- Erosion of road material during flow events
- Spillage

Impacts may be generally proportional to the magnitude of the flow however the cumulative impact means that more frequent low flow events should also be managed.

The frequency of low flow events is discussed and quantified for the catchment scale assessment in Section 4.2. This assessment shows that, for the upper catchment minor flows can typically be expected following 24-hour rainfall totals of 30 mm. Based on rainfall IFD data the expected flow frequency is slightly more than once per year. Based on observed long term daily rainfall data the show this frequency is close to once per year. Referring to the catchment scale assessment, typical flow duration would be several hours per year with continuous flow for between 48 and 72 hours having a frequency of about 1:100 years.

The surface profiles and major flood elevations are shown in Figure 5.

Figure 5 – Jones Creek crossing profiles



These demonstrate the following:

- The slope of the natural ground surface exceeds 8% over a maximum of about 30 metres horizontally (main crossing - west side). This means that very minor bank cut-backs will be required to achieve suitable grade
- More common flows (greater than 1:10 year frequency) impact short sections of roadway (less than 50 metres)

Considering the low frequency and duration of flow events, a low level "ford" is the appropriate creek-bed crossing. The following measures should be employed to mitigate excess sediment entrainment by intermittent creek flow events:

- Very coarse rock armouring of the bank cut sections up to the 1:100 year flood
- Minimum build up of road surface above natural creek level in mainstream
- Initial construction and maintenance (after flow events) to use stockpile of suitably graded material (minimal fines and particle sizing compatible with creek sediments)
- Best operational practice to minimize vehicle tracking of sediment during wet periods including:
  - Cladding of roads with appropriate materials
  - Road drain and surface maintenance to avoid build up of sediment on roadways
  - Wheel wash as appropriate

3.2.3 Main Drains, Bunds and Silt Traps

Key risks in the implementation of stormwater controls include:

- Excessive stormwater containment on site reducing yield to downstream catchment
- Poor separation of clean and dirty stormwater requiring excessive containment
- Drainage lines intersected by pits and waste dumps
- Unacceptably high additional sediment load to Jones Creek
- Control structures with excessive maintenance requirements and are inadequately maintained

The major control measures are shown on Figure 6. These relate large scale features. Excluded from consideration here is localised drainage and containment, such as relating to specific localised "high risk" potential contaminant point sources (eg workshops) where higher levels of control and containment will need to be specified in detailed design.

Control measures include:

- Clean stormwater drains diverting stormwater flow from un-impacted areas around the site
  - North from NW corner of the SMP pit. Length: 800 m, fall : 550 - 540 m, maximum depth: 2 m
  - South from NW corner of the SMP. Length: 200 m, fall : 545 - 539 m, maximum depth: 0.5 m
  - North around the WRD toe : Length: 1300 m, fall : 531 - 527 m, maximum depth: 1.0 metres
  - South around the WRD toe : Length: 1200 m, fall : 530 - 529 m, maximum depth: 1.0 metres
- Dirty water drains directing stormwater from disturbed areas to silt traps
  - Stockpile area: Length: 1400 m, fall : 540 - 530 m, maximum depth: 2.0 metres
- Clay bunds to prevent stormwater flow down creek-lines blocked by the WRD
  - Northeast and southeast of WRD toe - dump side of main drains
- Coarse dumping on outer surface of WRD to be non-erodible/competent rock
- Flood exclusion bund – southeast side of SMW pit as discussed above
- Silt traps/check dams/rock pads to limit sediment mobilization on selected flow paths
  - small semi-porous embankments (<2.5 metre-high) across key drainage lines
  - unlined, no recovery pumps, water detention not retention
  - partial backfill with loose coarse crushed rock (d_{50} ~ 200mm) of high size uniformity
  - First flush storage capacity with overflow for ongoing run-off
  - Containment for volume equivalent of 4 mm run-off depth across sub-catchment

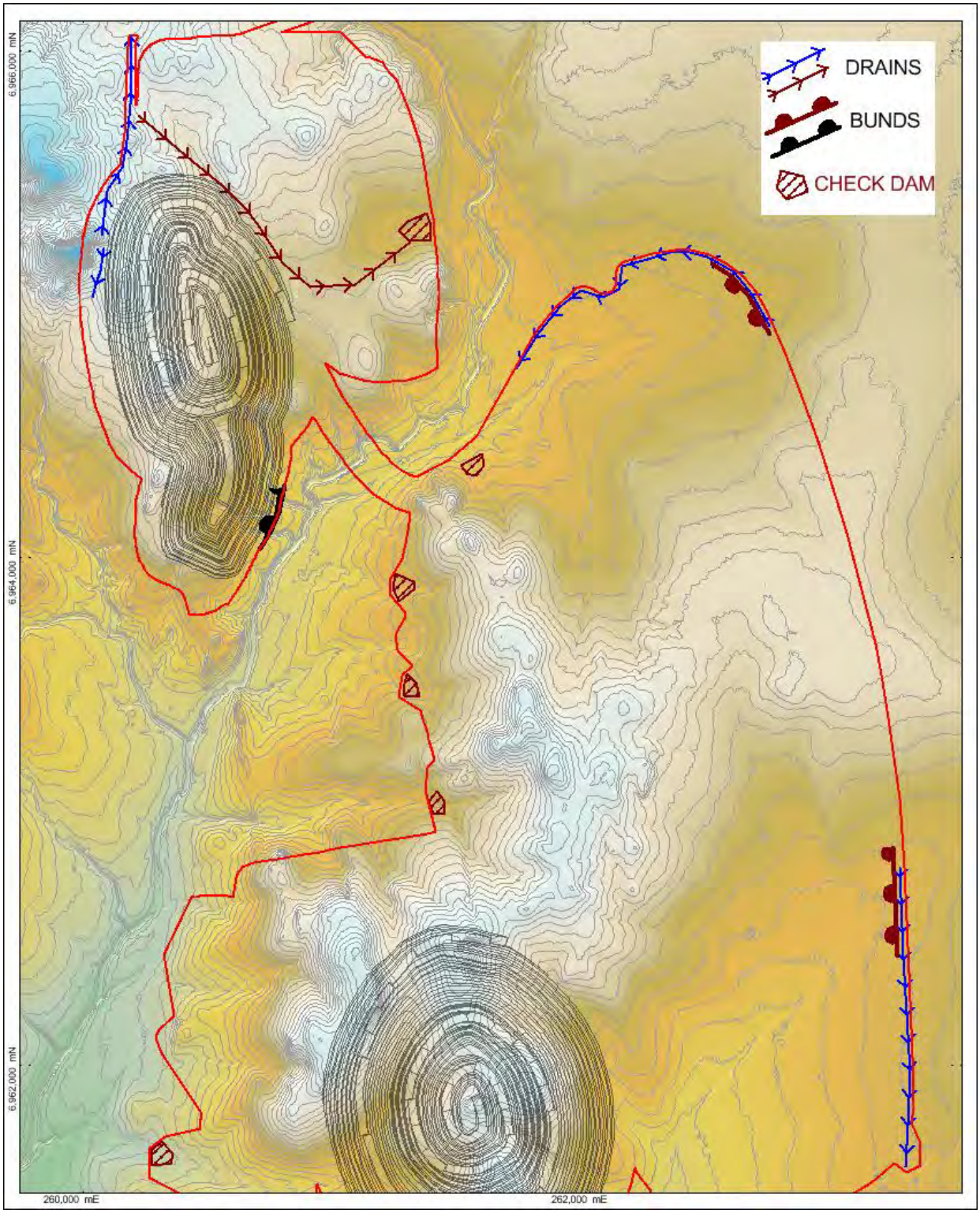
Silt trap locations are preliminary and to be revised based on needs identified from detailed stock-pile and dump sequencing. Key areas for coverage are potential high sediment source areas, including steep concentrated flow paths from areas where oxide material will be stored and exposed continuously over periods of months to years.

The recommended containment capacity "first-flush" depth relates to the relatively large scale and low concentration (diffuse) contaminant source - in particular to practically un-mineralised fine-grained waste rock particles. During rainfall, re-mobilisation of sediment is heavily weighted to the early run-off from higher frequency and higher intensity rain events. On this basis the target event for containment is the 1:2 year frequency, 30 minute duration rain event occurring on a dry (un-flushed) catchment - a rainfall total of 12 mm (Table 1). Based on run-off loss models (Flavell, 2011) the run-off coefficient for such an event is about 10%. Allowing for the smaller and steeper nature of the selected catchment, the recommended

containment capacity for the diffuse sources described above is 4 mm. A portion of the storage should be provided as void space in the back-filled rock pad, to minimize through-flow of sediment.

For example of silt trap sizing, a 30 hectare catchment requires a total water containment volume of 1200 kL For a typical site on a 2% slope and with partial backfill indicative embankment dimensions are 2.0 m high x 50 metres wide.

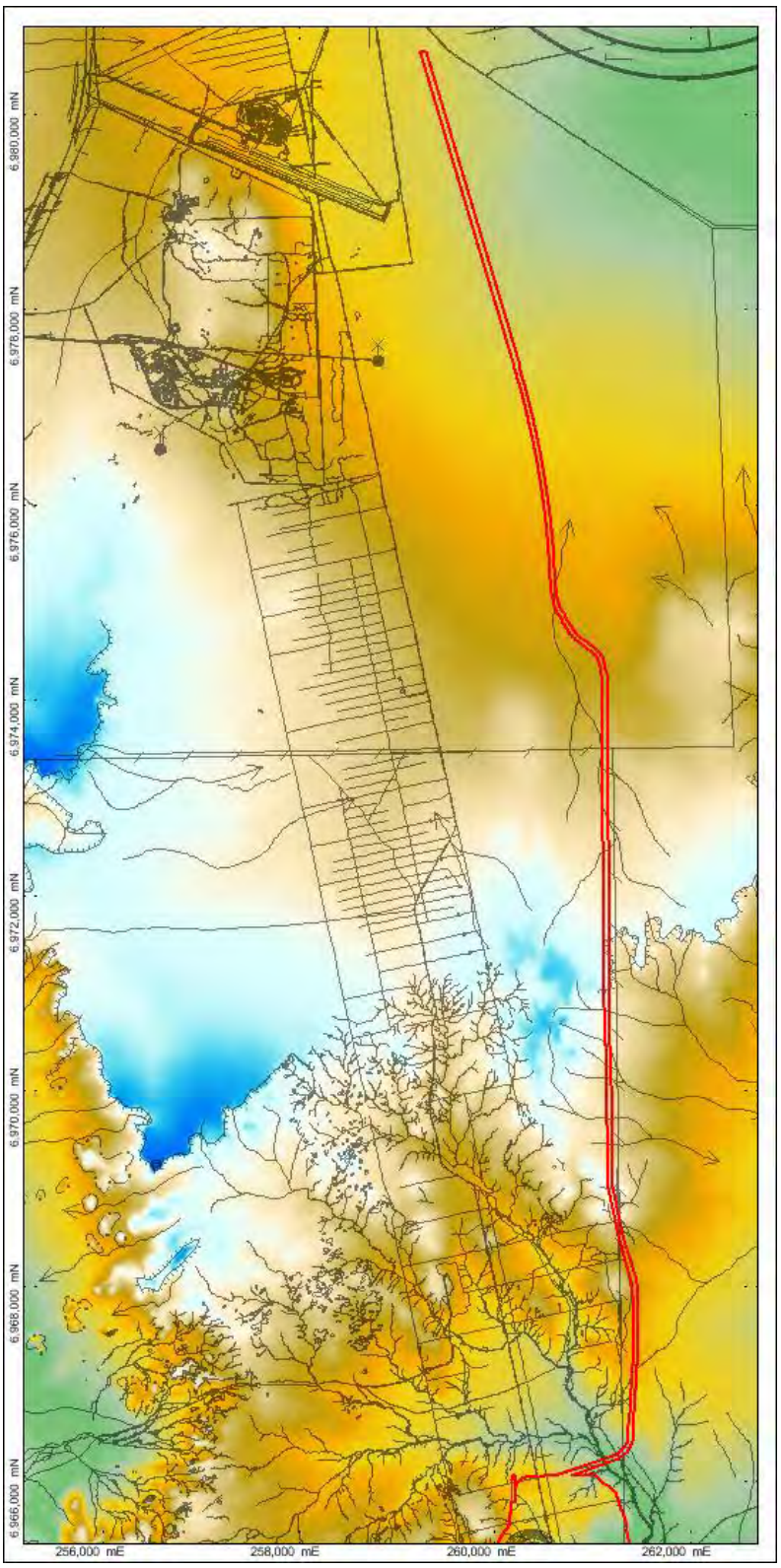
Figure 6 – Major stormwater control structures



3.2.4 Mt Keith Haul Road

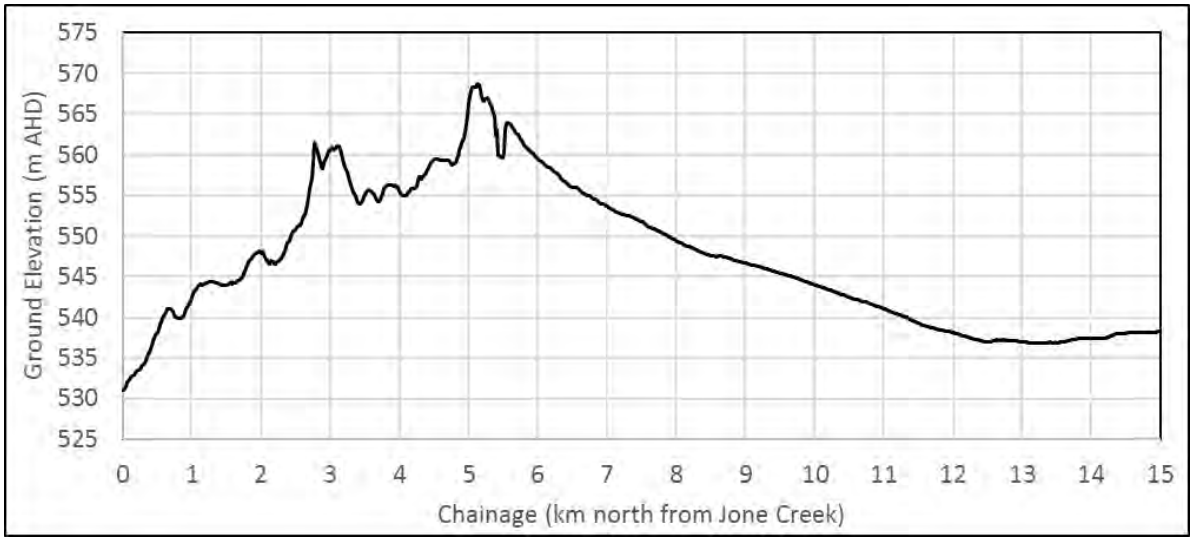
The route is shown on Figure 7, along with exiting topography overlying a colour-fill DEM. Total distance from the Jones Creek crossing to the northern end (located between the M Keith WRD and TSF) is 15 km.

Figure 7 – Mt Keith haul road route



The profile of surface elevation along the route is shown in Figure 8

Figure 8 – Mt Keith haul road profile



From chainage zero at Jones Creek the general route features and gradients are as follows:

0-1.2 km: Ascend directly, traverse at high level, cross ridge line and exit Jones Creek catchment. Route gradient up to 2% and mostly low transverse gradients

1.2-6.4 km: Oblique ascent / high level traverse in east- draining catchment, crossing one lateral spur several minor drainage lines, then enter Mt Keith catchment. Route gradient mostly less than 2% with short sections 4-8% at chainage around 3 km and 5 km (breakaways). Lateral gradients 0-2% to the east.

6.4-15 km: Gradual decent of the south slope of the Mt Keith valley, route turning from direct descent to oblique descent to valley floor traverse. No incised channel drainage features. Route-line gradients less than 1% and lateral gradient to the east at less than 0.5 %.

Potential impacts for consideration in detailed design are as follows:

- Cut to fill at breakaways exposes clay saprolite which to prone to erosion
- Erosion along the roadway margins on steeper sections
- Erosion in drainage line crossings
- Vegetation “shadowing” in areas of lateral gradients

In general, the route poses relatively minor drainage challenges, the risks from the potential impacts are mitigated by the following factors:

- Surface gradients are mostly very low
- Drainage lines are only slightly incised and have small catchment areas
- Cross gradients are generally too low to sustain frequent overland flow which sustains vegetation

Control measures which may be employed in detailed design include:

- Competent rock cladding of material exposed in cuttings and in table drains on steeper sections
- Adequate spacing of cross drains to minimize erosion in the table drain
- Low crown or outfall profile in areas where overland flow needs to maintained

4. CATCHMENT SCALE IMPACTS

4.1 Catchment Setting

Jones Creek is a lateral tributary stream draining southwest into the major regional valley which contains Lake Miranda. The north-east side of the valley is formed by the Barr Smith Range including the Jones Creek catchment. The upper slopes of the valley are relatively steep rocky and sparsely vegetated. From the catchment divide (above 550 m AHD) down to about 515 m AHD there are surface gradients of 1-4%. Short ephemeral creeks drain down the sides of these ranges and flood out onto the sedimentary deposits on the lower slopes of the valley. The lateral creeks terminate on lower slopes of about 0.3% in vegetated distributary alluvial fans (flood-outs) several kilometres short of the valley floor. The one exception is the larger Jones Creek which crosses the lower slopes and discharges to the Clay-pan near the valley axis.

The Jones Creek terminal Clay-pan holds water and sustains a fresh-brackish water ecosystem for several months after stream flow events which is unusual in the Northern Goldfields. The low water salinity and unusually long "hydro-period" defines its potential significance as a habitat or ecological water resource. The potential impacts of the development on the Clay-pan arise from the reduction in catchment area due to the excavation of pits (zero run-off) and construction of waste dumps (practically zero run-off). During extreme rainfall events the Clay-pan fills to overflowing negating any effect of reduced catchment yield. For the more common low –medium intensity rainfall/runoff events, the reduced catchment yield will reduce the volume in storage in the Clay-pan. It is for these smaller and more common (nominally 1 in 2 year to 1 in 5 year average recurrence interval events) that the potential impacts of catchment area reduction will be greatest.

After a flow event, storage in the Clay-pan is gradually depleted by evaporation and seepage so that any reduction in catchment yield will reduce the initial and average depth of water in the Clay-pan and therefore the duration (hydro-period) of inundation. Potential impacts on environmental receptors can be gauged in context of these hydrological impacts.

4.2 Catchment Yield

There is little data to directly support estimation of catchment yield characteristics for the Jones Creek. Anecdotally the creek is reported to flow from moderate to high intensity rainfall of 25 mm or more. Methods described in "Australian Rainfall and Runoff " (1997) for peak flow calculations indicate ongoing losses for relevant catchment type/regions are in the range 3-5 mm/h.

Automated rainfall, channel flow depth and flow velocity instrumentation was operated during an earlier project phase. The observations were made at the Old Highway crossing located 3km upstream from the current Highway bridge. The site has a catchment area of 55 sq km. One substantial flow event was recorded in May 2005. A total of 78 mm was recorded in the single pluviometer, between 00:50 on 4/5/05 and 13:10 on 6/5/05. This included 5.2 mm over 5 hours prior to 9am on the 4/5/05, 1mm on the night of the 4th and 71.4 mm over 9 hours on the night of the 5th. The catchment was dry prior to these events with little rainfall over the preceding six months. Peak rainfall intensity and the corresponding average recurrence intervals for the event are as follows:

- 9.3 mm/hr over 6 hours, ARI = 1 in 12 years (critical duration for peak flow)
- 7.9 mm/hr over 9 hours, ARI = 1 in 15 years (duration of the event)
- 3.0 mm/hr over 24 hours, ARI = 1 in 6 years

Flow velocity and depth were recorded at the channel centre on the old highway causeway crossing. The observed flow depth and velocity data were used to calibrate a HEC-RAS model rating curve for the cross section. The model was also constrained by the hydraulic parameters developed for the HEC-RAS models used in the peak flow assessment (Flavell, 2011. NDS1 Selection Phase Study – Jones Creek Diversion and Transport Corridor Hydrology Study). The monitoring data and rating curve allowed the following determinations:

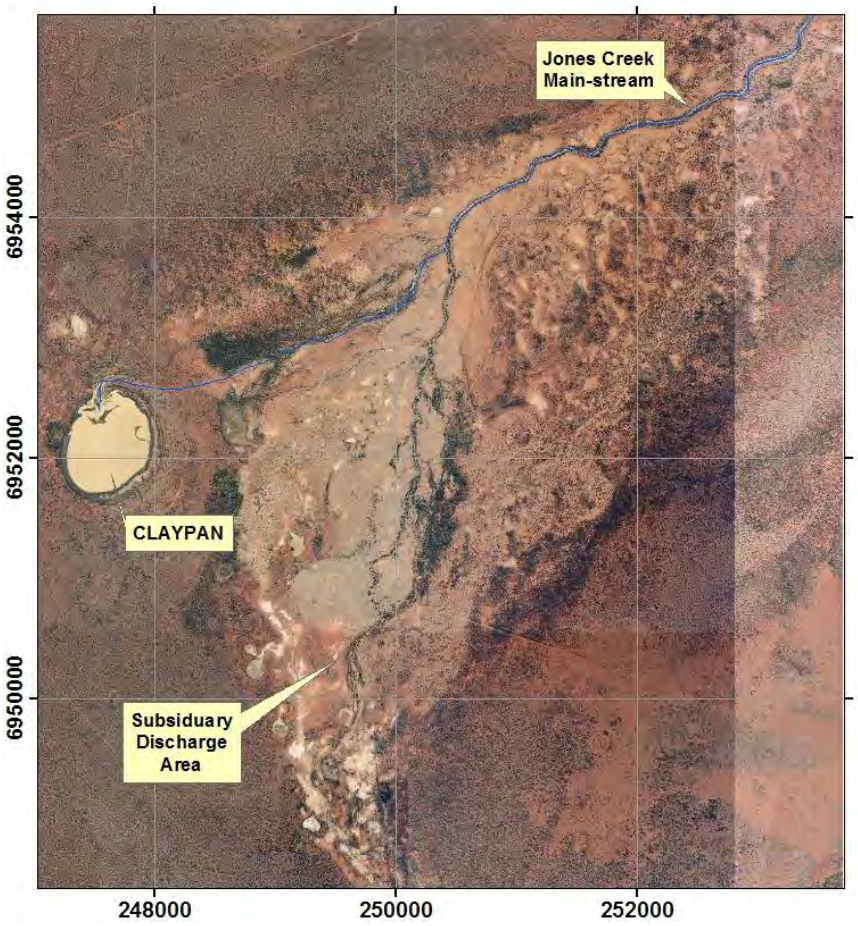
- The 6.5 hour delay from peak rainfall intensity to peak flow rate is consistent with critical duration estimates from previous modelling results
- The peak flow rate for the critical duration 32 cumecs is consistent with peak flow modelling results for the 1 in 12 year ARI
- Calculated total discharge for the event of 700,000 kL amounts to a runoff coefficient of 18% for the 55 sq km catchment

4.3 Terminal Clay-pan Hydro-Period

4.3.1 The Jones Creek Discharge Area

The downstream Clay-pan is part of the broader flood out area which forms at the terminus of the Creek in the valley floor. Aerial photographs show that high flow distribution of the stream flow starts about 7 km upstream from the Clay-pan where there is overbank discharge to the south. The creek bifurcates 3 km upstream of the Clay-pan, with the subsidiary channel discharging to a heavily wooded area and collection of minor clay-pans. (Figure 9).

Figure 9 – Jones Creek discharge area and terminal Clay-pan



The partitioning of flows in the discharge area may be dynamic and subject to slight variations in sedimentation. However, the main Clay-pan elevation is about 2.5 m lower than the elevation in the subsidiary discharge area whilst both are at a downstream distance of about 3 km from the creek bifurcation. This indicates that, for low to moderate flow events the large majority of volume reports to the main Clay-pan, with southern discharge only at very high water levels and/or after the Clay-pan fills and water levels back up the main channel.

4.3.2 Clay-pan Storage Characteristics

In May 2011 the volume in storage in the Clay-pan was investigated at a time of substantial inundation of vegetation at the margins after rains in February 2011. The Clay-pan floor was found to be very flat with most of the area at a water depth of 1.55 m and the 1 metre depth contour located within about 10 metres of the edge of vegetation around the edge. The total surface area in May 2011 was measured at 0.48 sq km and the volume in storage calculated 630,000 kL. The storage versus depth relationship is shown in Figure 10.

Figure 10 – Clay-pan storage curve

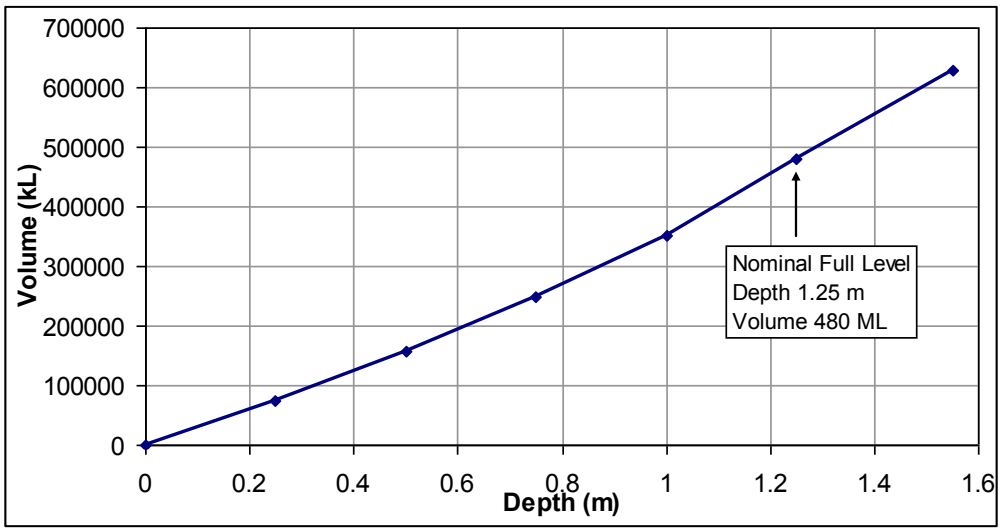


Figure 9 shows the Clay-pan from 2006 imagery with the Clay-pan "full" in the sense that water coverage is to limits of vegetation. The surface area is 0.42 sq. km. Using 2011 depth measurements the typical "full" depth is about 1.25 metres – ie full to limits of vegetation. At this level the volume in storage is about 480,000 kL.

4.3.3 Yield Modelling

Catchment run-off was simulated using a simple one-day time-step model. The model uses a 100 year CLIGEN generated synthetic climate record (Landloch, 2007 – Development of Concave Waste Dump Batter Profiles – Mt Keith Mine). Daily rainfall total and event duration (hours) where used in the model. The model includes initial and ongoing rainfall losses and catchment storage depletion by evapotranspiration.

The adopted parameters were based on local observations, anecdotal evidence and regionally derived parameters. The initial loss term (30mm) and storage depletion by evaporation at 2mm/d imply the creek flows after 30 mm of intense rain and that the upper catchment dries out within 15 days. The ongoing loss rate (4 mm/hr) is based on ARR guidance of 3-5 mm/hour (Australian Rainfall and Runoff, Institution of Engineers

Australia. 1997) and by calibration to the May 2005 event for which the model correctly produces total runoff volume

Modelling of the baseline 64.1 sq km catchment area produces a 100-year runoff record with the following characteristics:

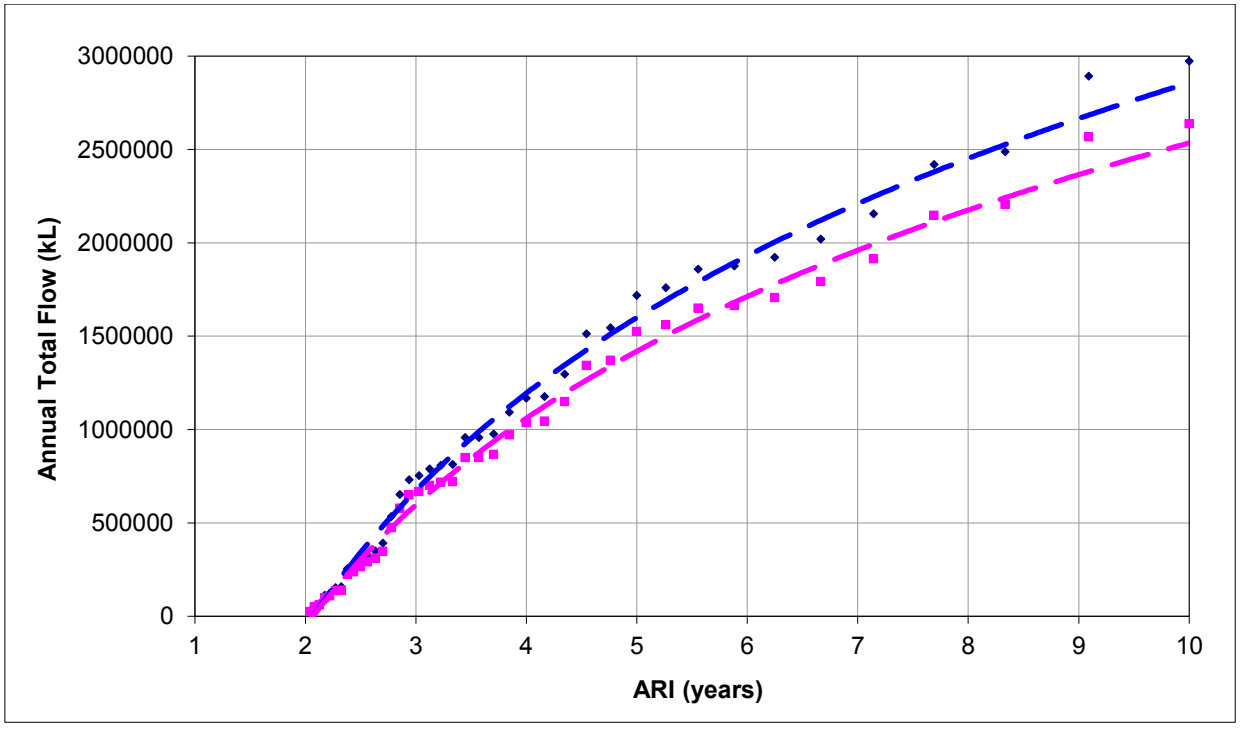
- Flow days 81 per 100 years
- Flow events (ie separated by > 1 day) 76 per 100 years
- Years in which flow occurred 49 per 100 years
- Median total annual flow in flow years 1168 ML/a
- Probability of fill to 1.25 m depth 36 % in any year
- Probability of fill to 0.5 m depth 43 % in any year

The post development catchment area of 56.9 sq km yields the same sequence of flows. The key volumetric parameters change as follows:

- Median total annual flow in flow years 1036 ML/a
- Probability of fill to more than 1.25 m depth 35 % in any year
- Probability of fill to more than 0.5 m depth 42 % in any year

The total annual flow for the 49 flow years are plotted against the average return interval for the 100-year sequence in Figure 11. As described above there is only a very slight reduction in the frequency of flows above a low threshold – ie those which at least partially fill the Clay-pan.

Figure 11 - Jones Creek Yield Frequency



Due to the relatively high rainfall magnitude/intensity threshold before substantial runoff occurs in the catchment and due to the small volumetric capacity of the Clay-pan relative to typical flows, the frequency of filling is not substantially affected by the proposed development. Flows will continue to occur at a frequency 1:2 years and the median annual flow (in flow years), whilst reduced by 11%, remains more than double the

full volume capacity of the Clay-pan.

4.4 Stream Sediments

Since creek flow is highly intermittent, water quality during and between flow events can be highly variable and particularly sensitive to catchment conditions between events and on the rainfall pattern generating the flow. Point or widespread impacts may then be difficult to discern in the broad scatter of data.

It is preferable to focus on the more robust parameters of stream sediment characteristics as an indicator of catchment condition and impacts. In terms of baseline and monitoring evaluation, "robustness" arises from the sediments representing horizontally and time integrated sample that is relatively consistent and repeatable compared to water parameters. As with all environmental parameters these characteristics will also be subject to variations in the catchment area which are un-related to the mining operation.

The baseline characteristics were summarised in by SKM (June 2005). Sampling was undertaken in four characteristic stream reaches and at two sites in the terminal Clay-pan. Samples were subject to particle size distribution and chemical analysis. The results will form part of the baseline for which impacts can be measured and controlled. As with other environmental monitoring further definition of baseline variability will be required as monitoring methodologies are instituted and refined prior to an in the early stages of the development.

5. MINING IMPACTS ON GROUNDWATER AND THE ULTIMATE VOIDS

5.1 Regional Hydrogeological Setting

5.1.1 Background

The dewatering impact assessment is well constrained by experience at nearby Mt Keith and Leinster, where operating and closed open cut mines are located in similar up-lying strike ridge country with similar host/ore rock sequences. In common, groundwater occurrence is enhanced by the weathering of the dunite (adcumulate) ultramafic ore with partial silica replacement in the regolith zone creating a porous vuggy material, typically at depths of 40-60 metres. The aquifers are of limited lateral and vertical extent and surrounding rocks are of very low permeability. The typical dewatering history for these mines involves a higher rate of pumping to deplete the localised "reservoir" which then stabilising at low ongoing rates. Drawdown extent is localised to less than 1 km from the pit perimeter due to the absence of extensive interconnected aquifers.

Due to the high degree of geological, geographic and mine plan similarity between the satellite pits and the Mt Keith pit (and to a lesser degree Leinster pits), a comparative discussion of the specific discussion of hydrogeology and dewatering is relevant. Particular differences between Mt Keith/NDS1 and Leinster ore-bodies include:

- Leinster ore-bodies have areas of massive nickel sulphide ore in additional to the lower grade disseminated sulphide ore which occurs at Mt Keith/NDS1.
- Late phase talc alteration is more intense at the northern sites than at Leinster

5.1.2 Mt Keith Pit

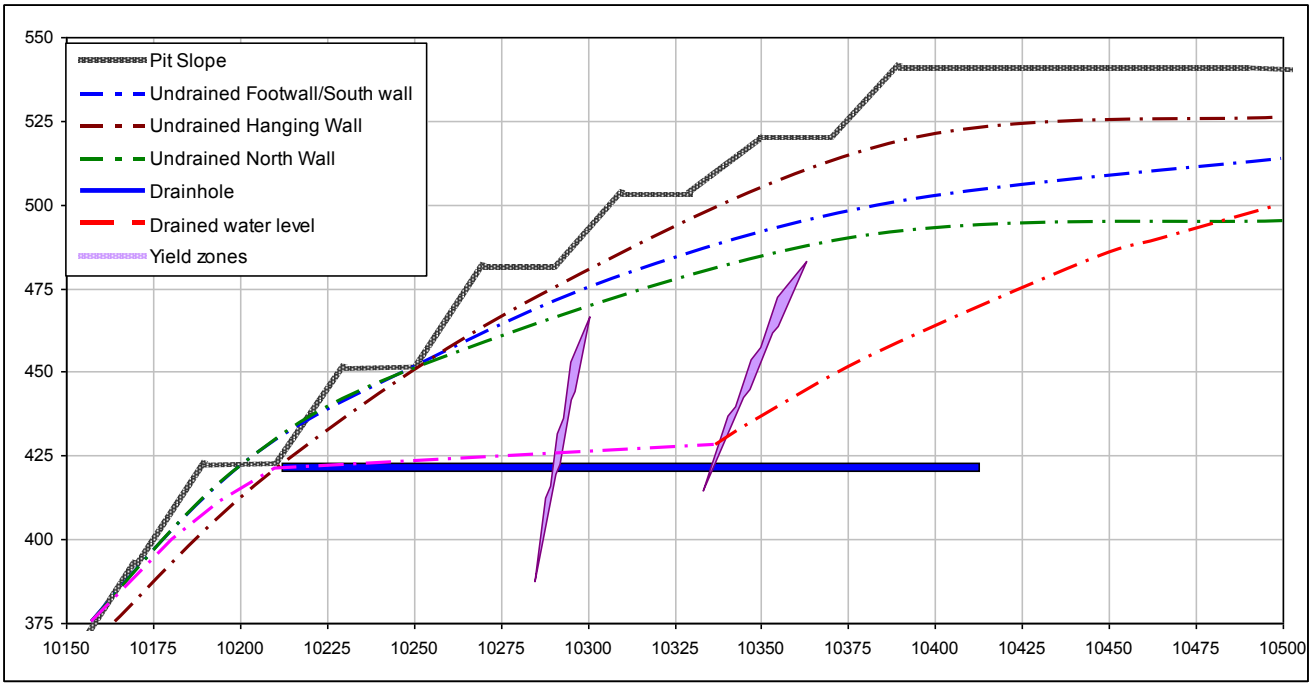
After higher rates of pumping in the first two years of the mine operation (1994-1996), the groundwater inflow rate has been about 12 L/sec. Total groundwater inflow has not changed substantially with various staged increases in the pit size. Stormwater pumpage from the pit catchment is additional with significant runoff occurring during months with a rainfall total of greater than 15 mm.

The hydrogeology is very similar to the satellite pits. The Archean ultramafic unit and flanking volcanics and volcaniclastic sediments into which the pit slopes are mined have practically zero primary porosity or permeability. Groundwater occurrence is limited to secondary features including the weathered zone and structural/lithological discontinuities. Weathered zone groundwater occurs mainly in the saprock interface between weathered and fresh rock. The saprock zone (and overlying saprolite aquitard) can be considered a very low permeability, relatively high storativity unconfined aquifer which is more or less continuous around the pit, with a nominal thickness of about 20 m and typical depth range of between 30 and 70 m BGL.

Natural groundwater levels were at about 520-525m AHD or about 20 metres BGL Piezometers located within or near the pit show the extreme localization of drawdown effects from pit dewatering. Beyond the pit crests on the east and west sides, drawdown is negligible from a geotechnical perspective (less than 5 metres). Drawdown of up to 5-10 m is more extensive along strike to the north and south – up to several hundred metres. The maximum depth to water is about 50 metres in the upper pit slopes. The water table and the pit slopes converge in the lower pit slopes. The configuration of the water table near the pit slopes is shown in Figure 12. The limited radial extent of drawdown induced by dewatering of the Mt Keith pit has led to the use

of horizontal drain holes to depressurise the rock mass within the pit crest limits.

Figure 12 – Generalised water level profiles in the pit slopes at Mt Keith



The mineralogy of the low grade nickel sulphide ore delivered to the MKO concentrator is described by Grguric, (2003). The ultramafic ore comprises mainly high magnesium olivine parent rock type, comprising magnesium silicate hydroxides, hydroxides, carbonates and hydrotalcite. Sulphides are present at relatively low concentrations.

For the range of ore types, the neutralisation capacity and long term trace element solubility effects of sulphuric acid dosing on tailings were evaluated in detail by Graeme Campbell Associates (GCA, May 2001). Acid consumption tests demonstrated very high residual acid neutralising capacity (ANC) being in the range 580-610 kg H2SO4 /tonne. Acid addition rates up to 25-30kg H2SO4/tonne to ground ore was found to result in minor depletion of the reserves of alkalinity and negligible changes to minor ion chemistry. It was concluded that: *"when subjected to alternating cycles of wetting and drying, alkaline and low salinity conditions prevail, due to buffering by gangue phases….The solubility of minor-elements during weathering is very low"*

The regional study of mine voids undertaken by Waters and Rivers Commission (Johnson and Wright, 2003) included a case study of the Mt Keith pit. The hydrological isolation of the pit void was noted. The limited quantities of pyritic chert in the walls of the ultimate pit :

"*suggests there will be no problems with acid mine drainage*".

It was concluded that the pit lake will become more saline over time but will not impact any regional groundwater resource.

5.1.3 Leinster Harmony and Eleven Mile Pit Lakes

Dewatering at the Leinster Nickel Operation's Harmony pit was stopped in mid-2005 and pit flooding recommenced soon after. The recovery of water level in the pit has been monitored. Water level recovery was initially rapid due to low evaporation rates from the small deep pit lake. Water level recovery has since slowed as the pit lake area and surface evaporation has increased. The numerical model of the pit lake water level has proven accurate in describing the water level recovery. This shows the result which is typical for regional pits located in up-lying country, that there is no potential for these pits to fill to a level at which water can impact either surface or groundwater.

The pit lake was sampled in October 2009, four years after closure. Ten surface samples showed consistent results. The difference between the chemistry of groundwater pumped at the late stages of mining (2004) and the 2009 pit lake water are summarised below:

- Salinity – 2009 pit lake salinity was at 6000 mg/L about double the groundwater salinity
- pH – increased from 7.6 to 8.1
- Nickel - increased from 3 to 7 mg/L
- Boron - increased slightly from 1 to 1.3 mg/L
- Cobalt - increased slightly to 0.025 mg/L
- Iron – increased slightly to 0.03 mg/L
- Zinc – increase slightly to 0.05 mg/L
- Arsenic, cadmium, chromium, lead – remaining at very low concentrations

Depth profiles of the pit lake salinity showed that no stratification had developed in the pit lake

Dewatering at the Eleven Mile Well pit was stopped in early 2005 and pit flooding recommenced soon after. Water level recovery at the Eleven Mile Well Pit has been more rapid than at Harmony due to the smaller volume of the pit. The monitoring hydrograph demonstrates a similar trend to that at the Harmony pit - a diminishing rate of water level recovery and gradual stabilisation of water levels. As for the Harmony Pit the water level model has proven accurate in simulating the rise of pit water levels.

The pit lake was sampled in 2007 and 2009. Salinity increased but there was little change in the trace element chemistry of the pit lake water over that period. The difference between the chemistry of groundwater pumped at the late stages of mining and the 2009 pit lake water are discussed below:

- Salinity – increased from 2150 to 3200 mg/L
- pH – increased from 7.8 to 8.1
- Nickel - increased from less than 0.005 mg/L to 0.7 mg/L
- Boron – stable at about 1.3 mg/L
- Arsenic, cadmium, chromium, cobalt, lead, selenium, zinc – remaining at very low concentrations

Depth profiles of the pit lake salinity in 2007 and 2009 showed that no stratification had developed in the pit lake.

Groundwater chemistry and its evolution in the Leinster pit lakes is unremarkable and reflects the chemistry of the inflowing groundwater, with some solute enrichment by evaporation. Acidity has not built up in the pits and concentrations of most metals remain at very low levels, with some enrichment associated with evaporative concentration. Wall rock impacts on pit lake chemistry are limited to some additional alkalinity and possibly minor additional dissolved nickel. Wall rock impacts are expected to decline as the water level rises above the areas of nickel sulphides exposed in the base of the pit. Dissolved nickel concentrations will continue to rise due to evaporative concentration and ongoing release, but at a diminishing rate of increase.

5.2 Satellite Pits Hydrogeological Investigations

5.2.1 BACKGROUND

The hydrogeology of the area was evaluated during the Dominion Mining Feasibility Study with a strong emphasis on dewatering rates and water supply opportunities. Key references include:

- Coffey Partners, 1990
- Coffey Partners, 1991
- Woodward Clyde,1995
- Hydro-Resources, 1997

Figure 13 shows drilling from this phase along with geological mapping and the currently proposed northern SMW and southern Goliath pit outlines.

5.2.2 Geology

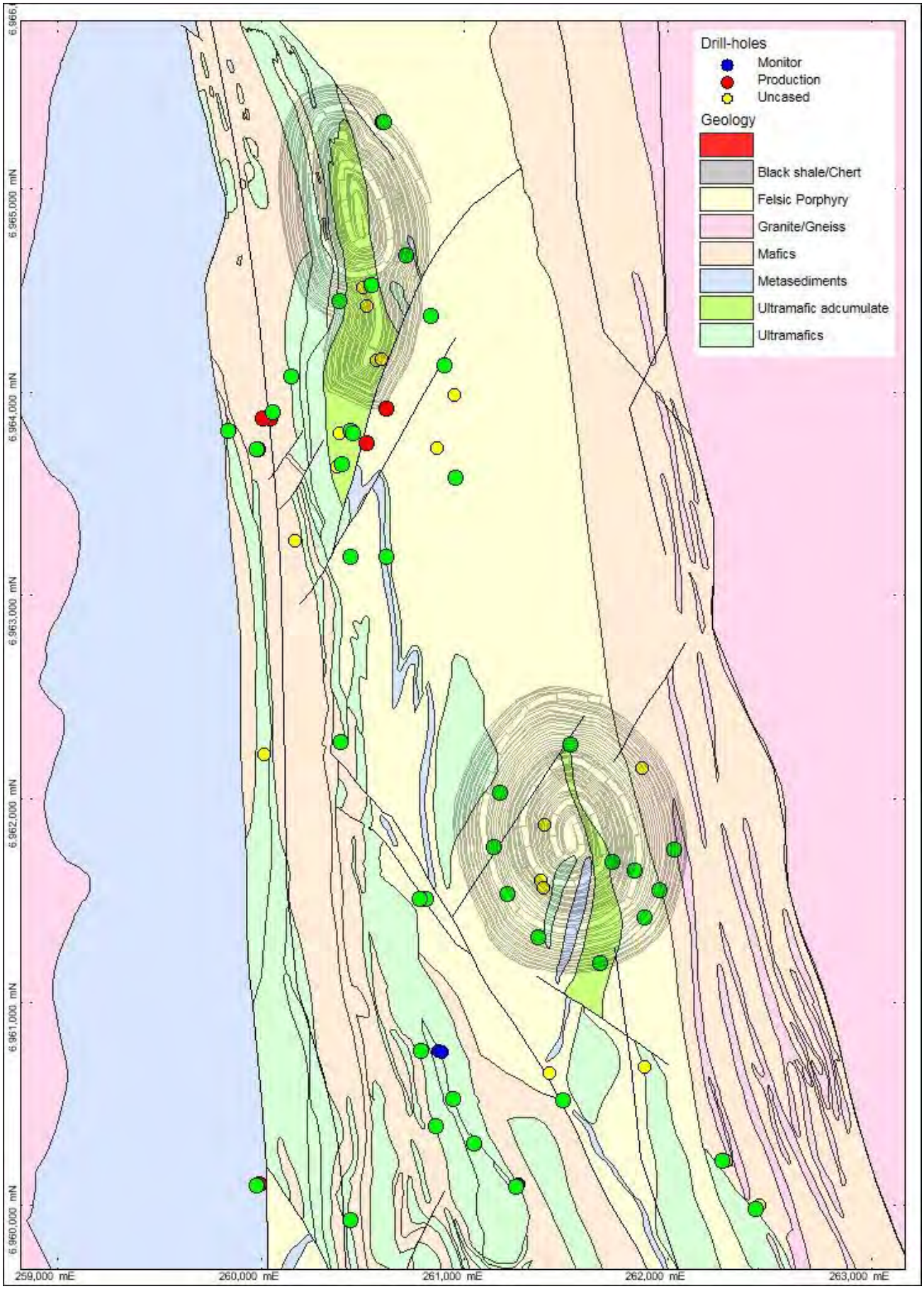
The ultramafic is a peridotite rich (high aluminum, fixed silica and low porosity) with lozenges of adcumulate ultramafic or dunite (olivine rich, low aluminium, silica leaching and high porosity upon weathering). Some of the dunite pods host nickel sulphide orebodies. There is little alluvial or soil cover and the weathering profile comprises:

- Oxide ferruginous – clay altered, local hard pan and nodular iron
- Oxide silica-carbonate – complete oxidation, serpentinite, irregular silicification and carbonate alteration
- Supergene – partial oxidation towards top, serpentine bleached and porous

At SMW, the dunite pod has dimensions of 1500 x 400 m and is nearly vertical. The upper ferruginous oxide is up to 10 m thick. The oxide zone rich in secondary silica-carbonate is patchy depending on original parent rock type as above. The base of Supergene (oxide and transitional material) is at a depth of 90 m to 170 m (360-440 m RL).

The Goliath ultramafic package is smaller and wedge shaped with the footwall sub-vertical and hanging wall dipping to the west. There is a very thin regolith transition zone (oxide-sulphide) with base of oxidation at 30-70 metres depth.

Figure 13 - Geology and Hydrogeological Drill Locations



5.2.3 Groundwater occurrence

Groundwater is relatively scarce in the local region. There is no laterally continuous regolith horizon aquifer due to elevation, depth to water table and erosional denudation. Most of the bedrock lithology's have practically no primary or secondary porosity and drilling across a majority of the area generates no groundwater yield.

The oxide zone over the dunite ultramafic pod at SMW is the main aquifer, where high permeability and porosity occurs in the oxide silica-carbonate zone which extends to about 50 metres BGL. This is a small and localised "caprock aquifer", typically associated with this rock type regionally. Permeability and porosity diminishes with depth and degree of weathering below the main aquifer zone. Low to moderate permeability may also occur to a depth of 60 metres and in highly weathered materials formed in other ultramafic lithology's. No extensive aquifer has been found associated with the Goliath ore-body.

There are isolated fractured rock aquifers occurring at structurally controlled locations within the pit areas and beyond. The fracture zone permeability may range up to moderate- high values, however the fault zones have low porosity and limited lateral extent, which means that storativity is 2 or more orders of magnitude lower than that held on the main SMW regolith aquifer.

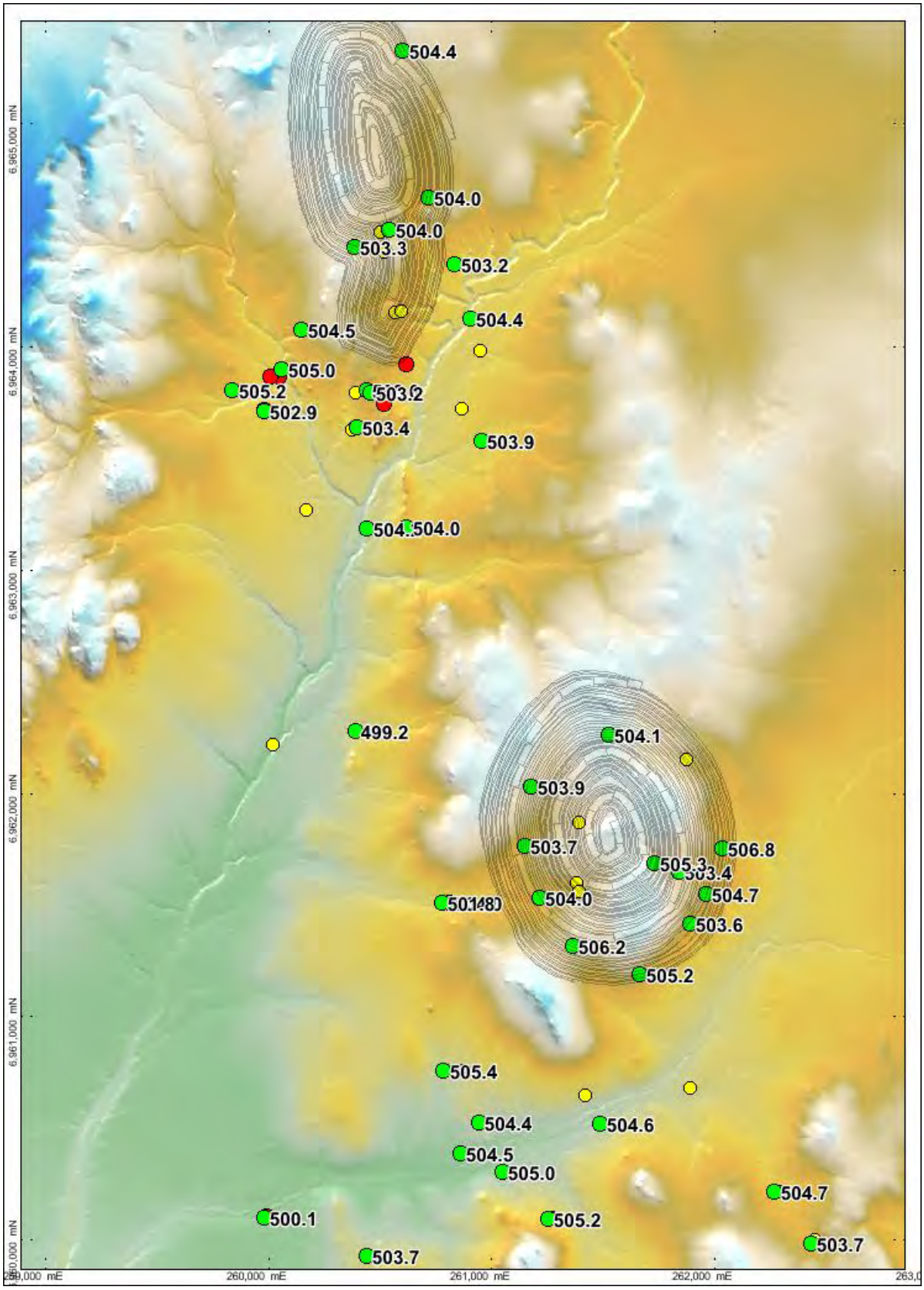
5.2.4 Static water levels

Water levels across the project area are shown on Figure 14. The water levels are primarily from the 1990's phase investigations. Water levels are relatively flat across the area, particularly on the ultramafic bodies. Note the hydraulic gradient south down Jones Creek away from the SMW pit.

Depth to the water table varies from a minimum of about 15 metres near the southwest corner of the mapped area. In the bed of Jones Creek through the SMW pit, the depth to water is at least 16-17 metres. Outside of the creek beds the depth to the water table is typically in the range 25-35 metres. At such depths, it is considered that groundwater does not sustain surface vegetation.

Water level measurements from recent investigations are consistent with the earlier measurements to within 0.5 metres. Due to the depth to water table and limited recharge potential, natural groundwater level fluctuations are likely to be minor and not relevant to the dewatering and impact assessment.

Figure 14 – Static Water Levels



5.2.5 Groundwater Quality

Water salinity on the main caprock aquifer at SMW is well defined in the Coffey (1990) report and is mostly in the range 3000 – 8000 mg/L salinity. Typical major ion analyses showed neutral water with a total salinity 4500 mg/L of predominantly sodium chloride composition, moderately high MgSO4 at 1100 mg/L and alkalinity of 400 mg/L. Dissolved iron concentrations are slightly elevated at up to about 1.0 mg/L reflecting the iron-silicate duricrust host mineralogy. Groundwater exploration in the surrounding area (Coffey Partners, 1991) demonstrates that the isolated country rock fracture zone aquifers contain groundwater of lower salinity at 700-5400 mg/L without measurable dissolved iron.

As mining progresses, the main aquifer will be gradually depleted and groundwater originating from deeper more isolated fracture systems will constitute an increasing proportion of pit pumpage (during periods of dry weather). The groundwater salinity is expected to gradually increase after the first two years of mining, then stabilise with pumping rates.

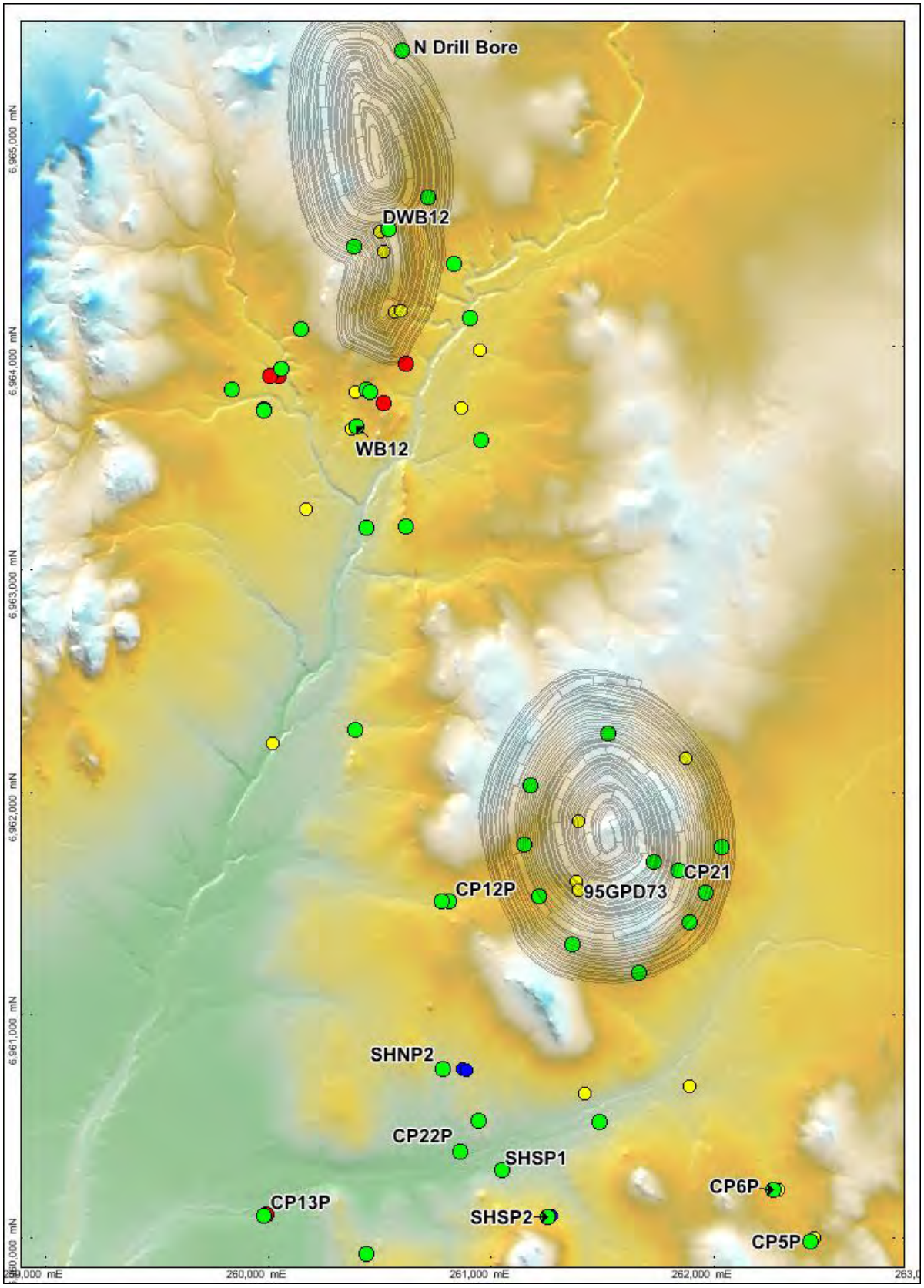
Trace element chemistry sample locations are shown in Figure 15 and results and are summarised in Table 1.

Table 3 - Groundwater trace element chemistry

	EC	pH	As	B	Cr	Co	Cu	Fe	Mn	Ni	Se	Zn
Units	uS/cm		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Detection	<10		<0.005	<0.010	<0.005	<0.005	<0.005	<0.005	<0.001	<0.005	<0.005	<0.005
95GPG11	2020	8.4	0.006	1.9	<0.005	<0.005	<0.005	<0.005	0.008	0.083	0.006	<0.005
CP12P	6410	7.4	0.012	6.2	<0.005	<0.005	<0.005	<0.005	0.002	0.005	0.013	<0.005
CP13P	1060	7.5	0.062	0.35	<0.005	<0.005	<0.005	0.005	0.002	<0.005	<0.005	<0.005
CP21	4170	7.6	<0.005	2.8	<0.005	<0.005	<0.005	<0.005	0.008	<0.005	0.008	<0.005
CP22P	1840	7.7	0.087	0.77	<0.005	<0.005	<0.005	<0.005	0.012	<0.005	<0.005	<0.005
CP5P	1440	7.5	0.007	0.36	<0.005	<0.005	<0.005	0.032	0.013	<0.005	0.006	0.006
CP6P	1120	7.5	0.007	0.36	<0.005	<0.005	<0.005	0.007	0.004	<0.005	<0.005	<0.005
DWB12	4930	7.3	<0.005	2.2	<0.005	0.008	<0.005	<0.005	0.14	0.18	<0.005	<0.005
N DRILL	4290	7.4	<0.005	1.3	<0.005	<0.005	<0.005	<0.005	<0.001	<0.005	0.006	<0.005
SHNP2	3510	7.7	0.043	1.8	<0.005	<0.005	<0.005	0.012	0.007	0.015	<0.005	<0.005
SHSP1	4850	7.7	0.89	2.9	<0.005	<0.005	<0.005	0.4	0.084	0.014	<0.005	<0.005
SHSP2	2570	7	0.04	1.7	<0.005	<0.005	<0.005	3.3	0.6	<0.005	<0.005	<0.005
WB12	9190	7.3	<0.005	6.4	0.011	<0.005	<0.005	<0.005	0.03	0.12	0.01	0.009

Instances where the element concentration exceeds Livestock drinking limits are highlighted in yellow. Groundwater samples show low concentrations of trace elements with chromium copper and zinc mostly at undetectable levels. Bores located further from the mineralised ultramafics (CP5P, CP6P and CP13P) show low concentrations for all elements tested. Highest levels of groundwater mineralisation are in the two bores on the Serp Hill South ultramafic body (SHSP1 and SHSP2).

Figure 15 – Groundwater trace element chemistry sample locations



5.2.6 Test Pumping, Trial Mining and Packer Tests

The 1990 program included a 10 day pumping test on the southern portion of the SMW deposit with a constant rate of 9.6 L/sec from two central bores (Coffey Partners, 1990). Drawdown and recovery patterns showed that the aquifer was highly permeable but of limited lateral extent. This confirms the prognosis based on geological context and mining experience in the region. The pumping test results show a specific yield of about 3.5% for the silica-carbonate weathered dunite material at the centre of the ultramafic body. The results indicate a total storage of about 100 ML within the highly porous central and shallow part of the aquifer. The dewatering prognosis is for abstraction of about 10 L/sec over 6 months to deplete the main storage, with gradually declining groundwater yield to the pit thereafter (Nickel West, April 2006)

Note that the dewatering estimate for the SMW pit excludes additional abstraction from the northern lobe of the SMW pit. It is expected that an additional but lesser silica-carbonate aquifer caprock aquifer will be encountered in this area and additional abstraction of up to 50% may be expected from there.

In 1990 a bulk sampling shaft on the SMW deposit was constructed through the main water bearing zone to 87 m. Dewatering of the shaft was achieved by pumping at 3.6 L/sec.

Coffey Partners reported little indication of substantial groundwater occurrence in the area of the proposed Goliath pit. A single production bore was drilled (CP21) and tested and a sustainable rate of less than 1 L/sec was estimated. Follow up exploration drilling by Woodward Clyde in 1995 confirmed low permeability in the area.

The deeper (sub-regolith) rock mass permeability was investigated at both deposits as part of the 2010 drilling program. At Goliath testing included 17 intervals within three holes. Water take was generally very low at Goliath, with only one tested interval yielding greater than 1 lugeon (1 L/min/metre/1000 kPa). At SMW testing included 29 intervals within six holes. Water take was generally low with some exceptions, mostly at isolated fracture zones which have little significance to overall dewatering volumes. A greater continuity of permeability occurred at the centre of the SMW North deposit indicating substantial groundwater in storage, however the geological context shows that the extent of the aquifer is limited.

5.3 Potential Impacts

Groundwater levels will be maintained at the base of the pit throughout mining operations with dewatering resulting in a cone of drawdown around the pit. After mining is complete, water levels will then gradually rise to equilibrium levels. The SMW pit will be completely backfilled such that the long term equilibrium water levels will return close to the baseline condition. The post-closure Goliath pit will remain a permanent void.

Hydrogeological experience at nearby sites and local investigations described above inform the conceptual hydrogeological model and the requirements for impacts assessment as follows:

- The separation of the two pits is such that the operational and long term drawdown cones for the two pits will remain independent, ie individual assessment of the two pits is appropriate rather than a site-wide ground water model.
- Operational drawdown from the SMW pit will be comparable to the Mt Keith pit, extending of order 100's of metres beyond the pit crest
- After closure and back-filling the drawdown cone will gradually refill

- There is potential for changed water quality in the backfill and for movement of the impacted water laterally away from the backfilled pit (though-flow)
- Drawdown from the Goliath Pit will be of very limited extent due to the absence of permeability
- The dry conditions at Goliath and absence of any pathway or receptor for groundwater impacts negates the requirement of drawdown modelling
- A small lake will develop at the base of the Goliath void

5.4 Six Mile Well Pit Drawdown Extent

5.4.1 Groundwater Model Set-Up

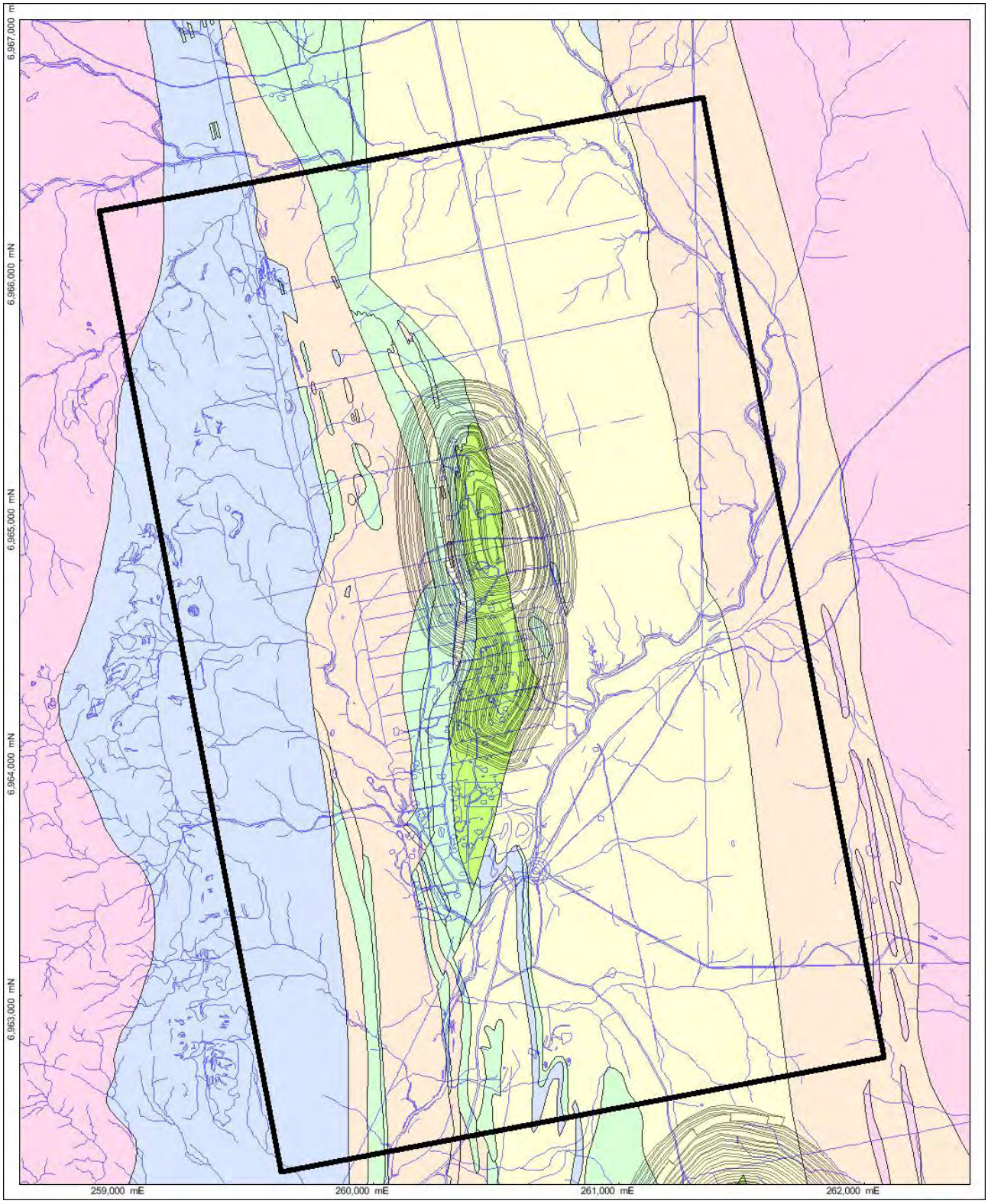
A groundwater flow model was developed to evaluate the pumping requirements and the extent of drawdown around the SMW pit. The conceptual model is based on that developed and calibrated for the existing Mt Keith pit for geotechnical purposes. A four layer model was used, where:

Layer 1 – Ground surface to base of complete oxidation - saprolite
Layer 2 – Base of transitional altered/weathered– saprock including main aquifer on dunite (adcumulate)
Layer 3 - Slightly weathered bedrock
Layer 4 – Fresh bedrock

The base of Layers 1 and 2 are imported geological surfaces defined from the high-density mineral resource drill pattern. Layer 3 was assigned a uniform thickness of 50 metres based on vertical continuity of water occurrence in groundwater investigation holes. The base Layer 4 was set at a constant elevation of 250 m RL, a depth of 250-300 metres, from below which little groundwater is likely to be sourced . The base elevations of Layers 1, 2 and 3 were then adjusted/smoothed to ensure hydraulic continuity.

The model is constructed on a 100 x 100 m spaced rectangular grid extending 4 km north south and 2.5 km east west. Spatial extent is greater than the expected maximum limits of drawdown based on experience at Mt Keith where the drawdown cone is extremely steep, particularly across strike (east-west). The model is aligned with the local grid and the general strike direction of the bedrock formation at about 11 degrees west of north. lateral extent of the SMW pit model is shown in Figure 16.

Figure 16 – Groundwater model domain



Hydraulic boundaries are as follows:

- Northern constant head boundary located 1 km north of the pit boundary and aligning with the west-east reach of Jones Creek crossing the mafic belt
- Southern constant head boundary located 1.4 km south of the pit where mafic belt is crossed by Jones Creek

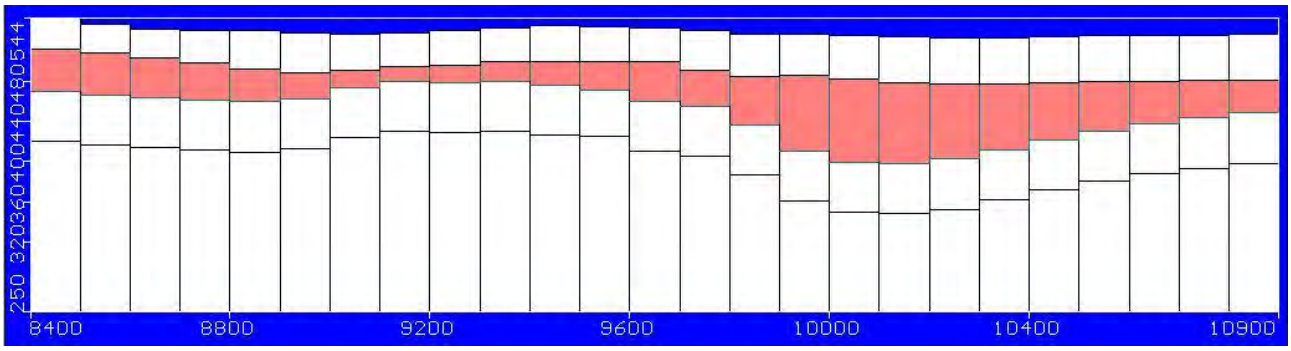
- Rainfall recharge is applied at a regionally uniform rate
- Mixed type boundaries located on the west and east sides of the model representing the maximum cross-strike extent of substantial drawdown
- No flow boundaries at the remaining margins and at the base of Layer 4

The elevation and conductance of the source boundaries at the model limit were adjusted during calibration and the overall water balance was checked during simulation to ensure that the contribution of water from outside the model domain remained a small component.

5.4.2 Layer Geometry

The ground level is at 520-540 m across much the model area and the baseline water level is at about 504 m . Layer 1 thickens from 10-20 metres in the west and south (unsaturated and inactive) to about 40 metres across much of the pit and greater thickness east of the pit. Layer 2 also thickens to the west and deepens to the west. Typical thickness in the pit area is about 30 m and depth extent from 460-490 m RL. Layer 3 has a thickness of about 50 metres and Layer 4 extends to the base of the model at 250 m RL. A typical cross section (east-west) through the centre of the model is shown in Figure 17. The highlighted Layer 2 contains the main aquifer The centre of the pit is located at local grid easting 9600-9800 m East on the section line.

Figure 17 – Groundwater model - typical cross section



5.4.3 Calibration and Hydraulic Parameters

Initial estimates of hydraulic parameters were constrained by test pumping results and packer tests and by guidance from modelling of similar materials in the Mt Keith pit slopes. The parameters were then adjusted during steady-state and transient calibration.

Steady-state calibration was undertaken to develop a set of initial heads which matched the observed heads for use in transient simulation of the pumping test and operational dewatering drawdown. The steady state calibration was primarily achieved by adjusting the recharge rate and downstream constant head elevation. After transient calibration runs, these parameters were further re-adjusted iteratively. The adopted/matched features of the steady sate calibration are as follows:

Up-gradient constant head elevation :	505 m RL
Down-gradient constant head elevation:	499 m RL
Recharge rate (uniform across model):	0.5 mm/year

The configuration generates a north-south water level gradient with water levels at about 504 m in the pit area. These parameters have a relatively minor impact on the transient yield and dewatering simulation, ie the rate of pumpage and extent of drawdown, however the duration of the post closure water level recovery is sensitive to the recharge rate.

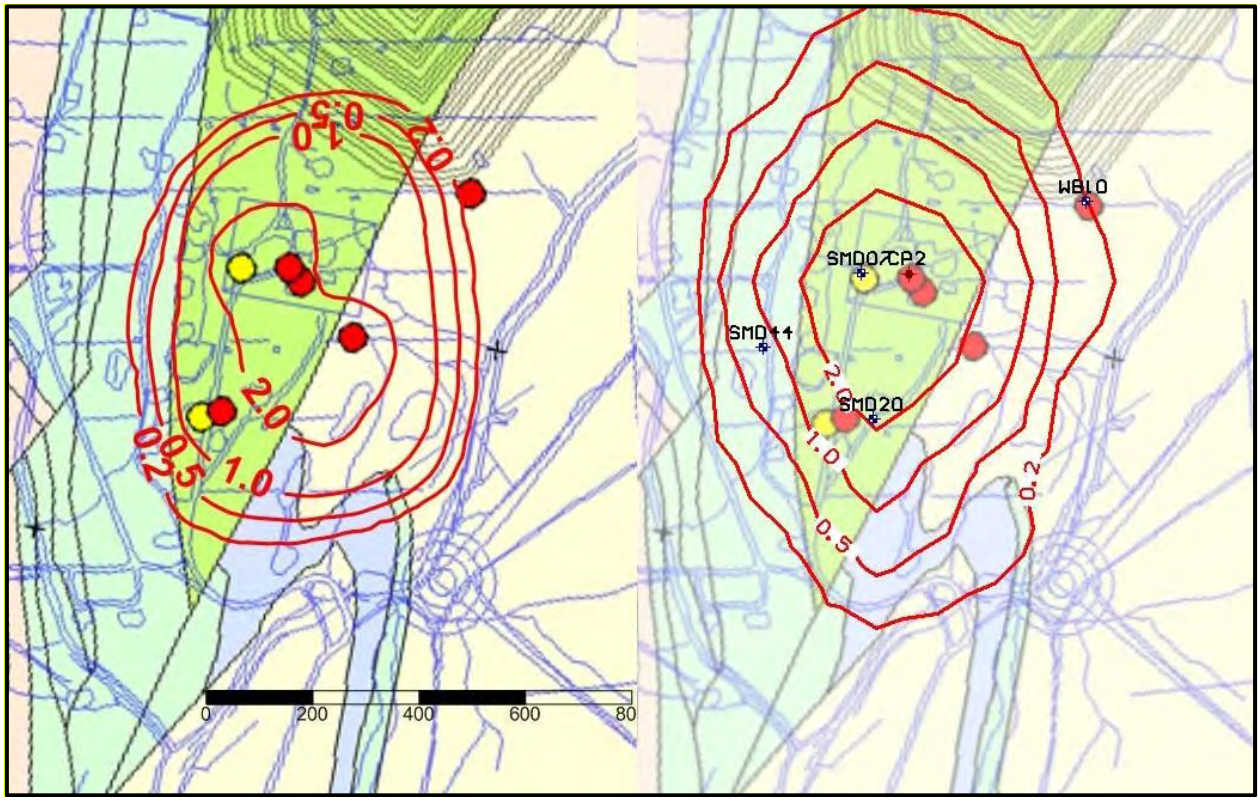
After steady-state calibration with the north and south constant head boundaries in place, the lateral mixed type boundaries were set with elevation equal to the steady state level. The lateral margins are flow parallel/ no flow lines in the steady state condition and become a minor source of lateral inflow to the model domain during the dewatering simulation.

Transient calibration was undertaken using the results of the 10-day pump test reported Coffey Partners (1990). The test involved pumping two adjacent bores located in the dunite aquifer immediately south of the pit at a combined rate of 9.6 L/s with water levels were monitored on an extensive array of bores.

The drawdown cone was analyzed volumetrically which showed that Layer 1 materials with the cone of drawdown responded with a porosity of 3.5 % for the cone of drawdown induced. The remaining model parameters were adjusted to a achieve a match between observed and simulated drawdown.

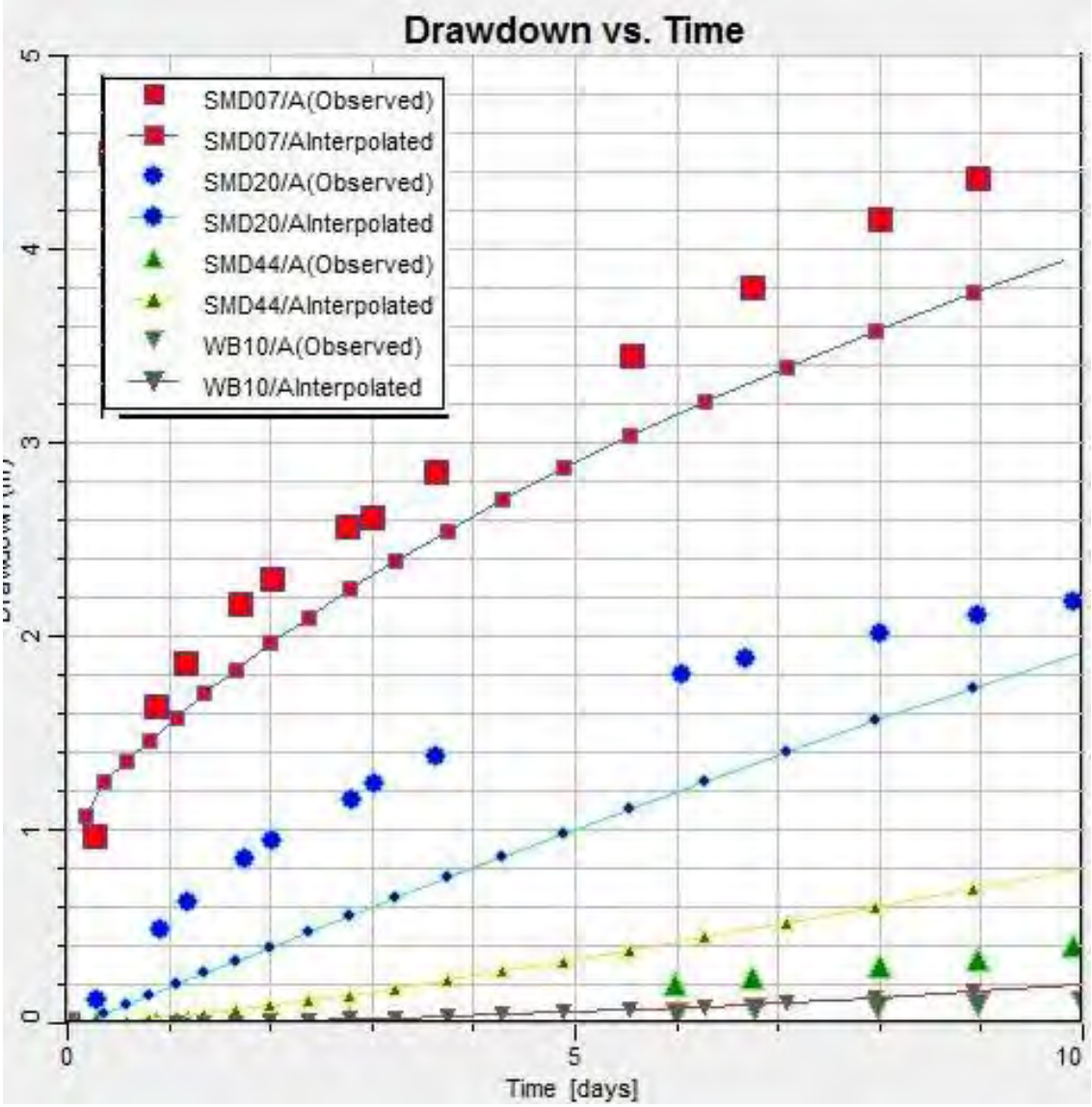
Figure 18 shows the observed (left) and simulated (right) drawdown cone extent after 10 days pumping. The model slightly over-predicts the drawdown extent.

Figure 18 – 10 day pumping test drawdown cone – observed and model simulated



The calibration match of the time series drawdown response is shown in Figure 19 for selected bores at locations shown in Figure 18.

Figure 19 – 10 day pumping test – time series drawdown observed and model simulated



Note that the model under-predicts drawdown close to the pump well and over-predicts drawdown at distance. The markedly flat centre and steep edges of the observed drawdown cone are consistent with extreme hydraulic boundary effects imposed by the geological limits of the dunite aquifer. In essence the aquifer is responding as a "tank" rather than as a continuous field. The model does not fully simulate the extreme bounding, hence operational simulation are expected to generate conservatively large drawdown beyond the pit limits.

The final hydraulic parameters are summarised in Table 4.

Table 4 – Groundwater model parameters

Layer	Zone	Permeability (m/day)	Porosity
1	Adcumulate	0.01	4%
	Other		2%
2	Adcumulate	2.0	4%
	Ultramafic	0.2	2%
	Other	0.1	
3	Adcumulate	0.1	0.5%
	Ultramafic	0.05	
	Other	0.01	
4	All	0.001	0.1%

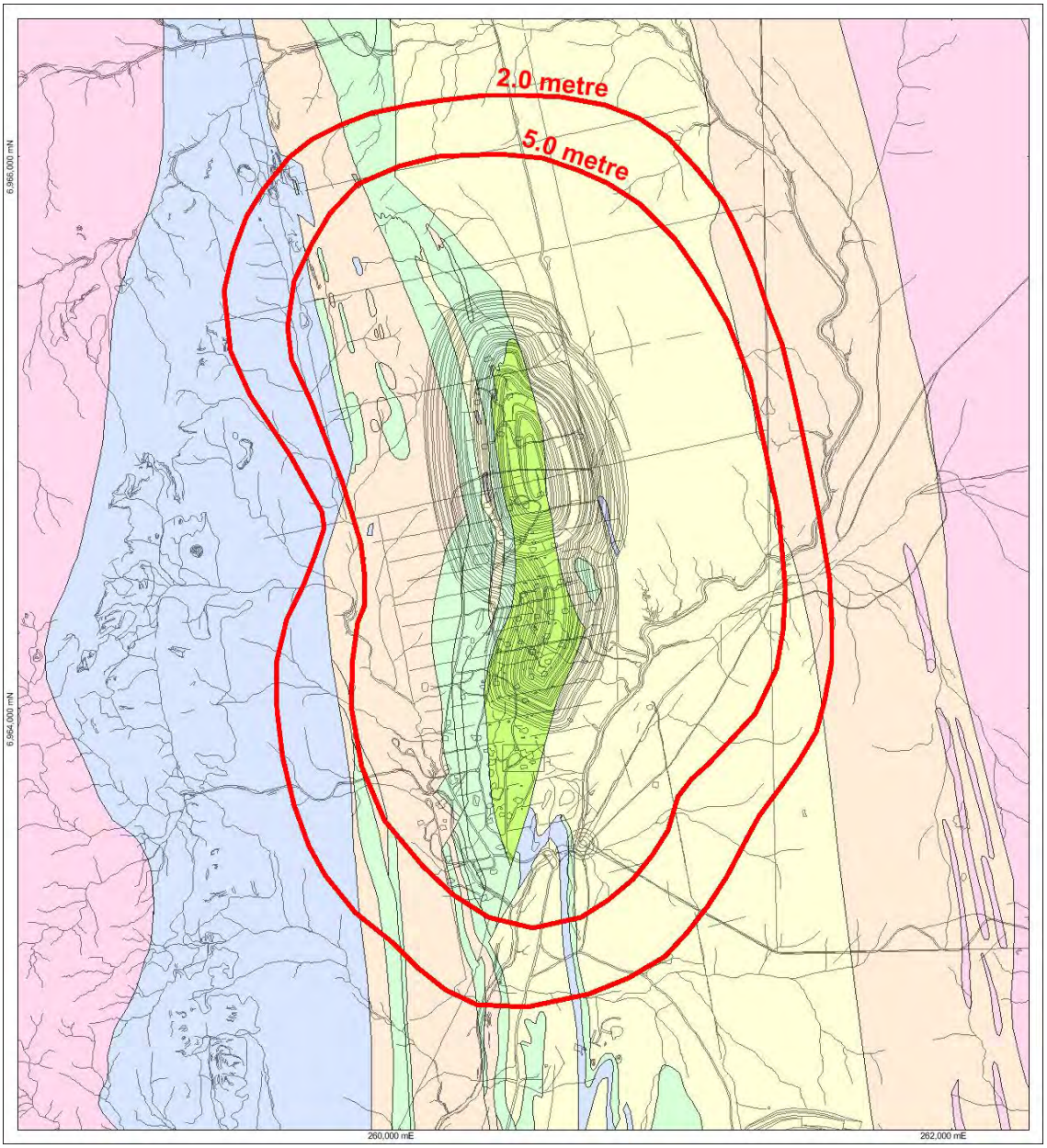
The calibration results show a strong weighting of permeability and porosity to the weathered zone of the ultramafic rock type in particular to the adcumulate ultramafic (dunite).

5.4.4 Simulation of Dewatering Drawdown

Drawdown induced by pit dewatering was simulated by setting constant head mixed type boundary cells at the base of the pit. The pit constant head boundaries are set to decline from water table level to near (slightly above) the base of Layer 2 over the scheduled four year mining period, thereby maximising the simulated flow rate and extent of drawdown.

The simulated extent of drawdown after four years of mine dewatering is shown in Figure 20.

Figure 20 – Groundwater model simulated dewatering drawdown cone



Dewatering is achieved with abstraction at an average rate of 14 L/sec over 4 years. The 5 metre drawdown cone is predicted to extend 500-700 metres from the pit crest along strike and 300-500 metres across strike.

5.5 The Post Closure Water Level Recovery

The evolution of the backfilled void and pit lake after closure is potentially influenced by the following parameters:

- Pit geometry – volume surface area relationships
- Rate of groundwater inflow and through-flow
- Depth range of aquifers
- Water quality of inflowing groundwater
- Rainfall and evaporation rates
- Chemical interactions between water and wall rock/backfill

Following the methodology used for other pit lakes in the region models simulating the post-closure water balance were developed to simulate the recovery of water level after closure. Inputs to the model include geometrical parameters, rainfall, runoff groundwater inflow and evaporation.

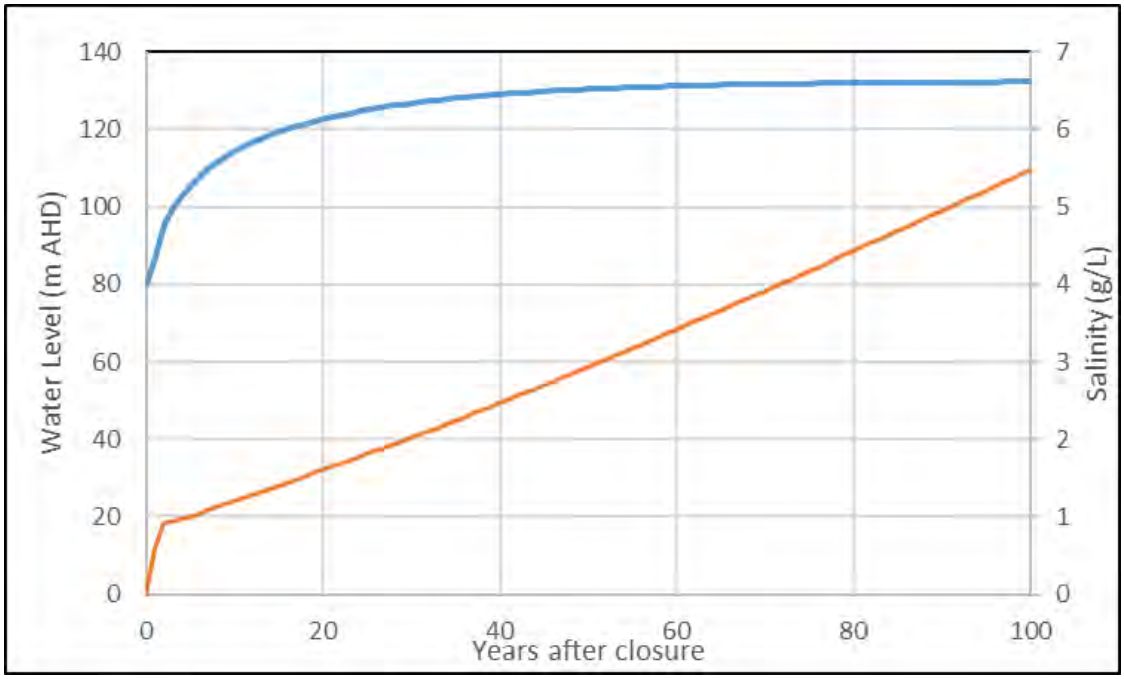
5.5.1 Goliath Pit Lake

From the hydrogeological appraisals made for dewatering the expected long term groundwater inflow rate for the Goliath Pit is 2 L/sec. The main aquifers (such as are present) are at a depth of less than 100 metres, which means that inflow is unchanged while water levels remain below this depth. The assumed long term groundwater salinity for the Goliath pit is 2000 mg/L for the Goliath pit. Regional groundwater quality and host rock mineralogy/geochemistry dictate that salinity will be the dominant parameter in dictating overall groundwater quality characterisation.

Accretion of rainfall (P) from the pit catchment to the pit lake depends on run-off coefficient from the pit slopes and precipitation directly on the lake surface. Drainage models developed for the Mt Keith pit shows a long term average run-off coefficient of about 40%, with much of the low intensity rainfall resulting in little runoff to the pit. Net evaporation (E) from the pit lake surface differs from the simple subtraction of rainfall from evaporation according to pan factor (0.7 adopted) and the brine factor (will remain close to 1.0 for several hundred years then gradually decreases with increasing salt build up in the pit lake.

The results of the model simulation of water level recovery and salinity build-up are shown in Figure 21.

Figure 21 – Goliath Pit Lake Model



From the ultimate pit depth of 450 metres below surface (80 m AHD), the water level gradually stabilises at less than 140 m AHD, which is nearly 400 metres below the pit crest. Short term fluctuations relating to the most extreme rainfall events will result in relatively minor variations from the long term water level trend line, having a magnitude of no more than 2 metres and duration of several months. Salinity reaches 5.5 g/L after 100 years and continues to rise linearly thereafter. Over thousands of years as salinity increases above 50 g/L

then brine factor reductions in pit lake evaporation rate superimpose a very gradual rise in water table level and a very gradual reduction in the rate of salinity increase.

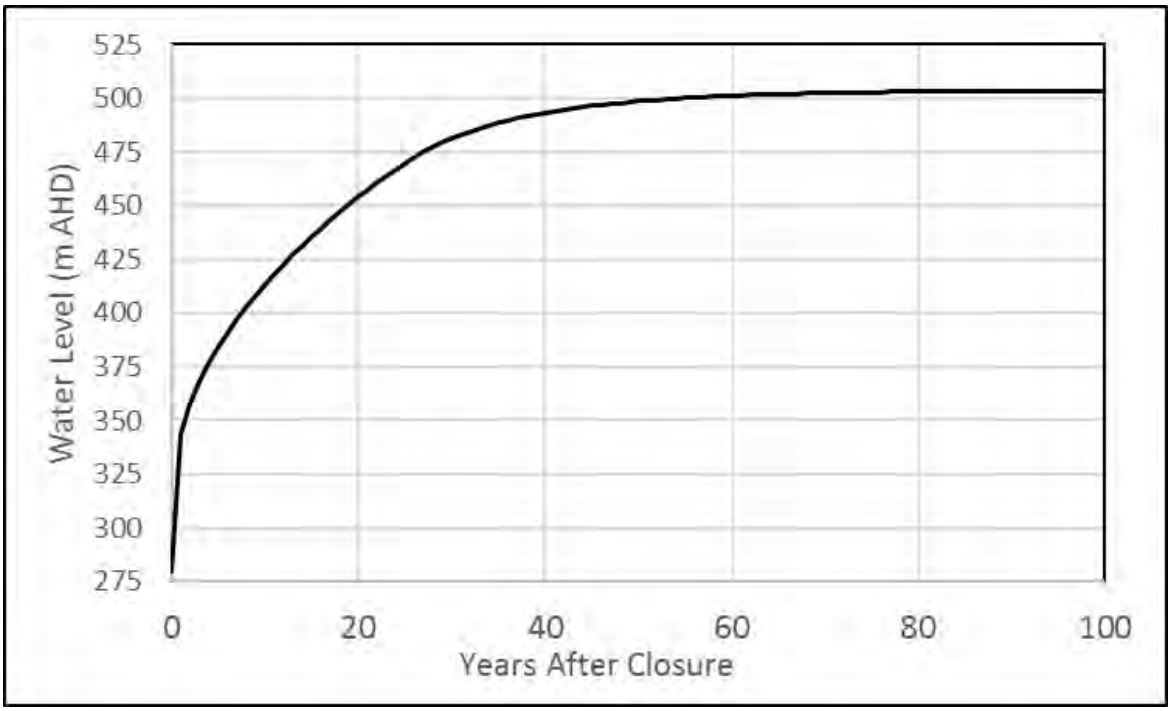
5.5.2 SMW Backfilled Pit

A similar volumetric model to that described above was used. The backfilled pit is not subject to evaporation losses such that groundwater levels will recover, at least to the baseline water table level (503 m AHD). Storage in the backfill is reduced to the residual void space (25%). The maximum (early time) rate of groundwater inflow was based on the results of the numerical flow model. The rate declines linearly after the water level exceeds the base of the main aquifer, to zero at the baseline water level and negative (outflow) at higher water levels.

The final steady-state water level is dependent of the rate of groundwater recharge. The recharge rate through the fill is dependent on run-off and vegetation interception of the final cover. Recharge rates have been estimated based on the assumption of a moderately compacted and gently mounded surface and a low scrub/grass vegetation cover being gradually re-established. Initial recharge rates will be very much higher than baseline conditions, rates will decline as surficial fines are rearranged and vegetation is established but will remain very much greater than baseline conditions (less than 10 mm/year). The assumed recharge rate is 35 mm /annum (15% of rainfall) declining to 12 mm/annum (5 % of rainfall) after 20 years. The early value affects the rate of water level recovery and the later value the final steady rate water level or degree of mounding and additional groundwater through-flow away from the site.

The resulting predicted water level recovery is shown in Figure 22.

Figure 22– SMW Backfilled Void – Simulated Water Level Recovery



The assumed long term recharge rate (5%) results in the steady state water level 0.6 m above the background water level with the additional (increase over baseline) groundwater flux from the backfill of about 0.3 L/sec.

5.6 Chemical Interactions Between Wall Rock, Backfill and Water

Investigations into the geochemical characteristics of host rocks and low grade ore (which occur in small quantities in the pit walls) were reported by Graeme Campbell and Associates (2005). The criteria for potentially acid forming material were established based on:

Sulphide-S: sulphide sulphur content
NAPP: net acid producing potential
ANC: acid neutralising capacity
MPA: maximum potential acidity (calculated by assuming complete oxidation of sulphide-S)
NAPP: net acid producing potential (calculated as MPA-ANC)

The criteria for PAF classification being either:

Sulphide-S $\geq$ 0.3 %, and any positive-NAPP value
Sulphide-S $\geq$ 0.3 %, and a negative-NAPP value with ANC/MPA < 2.0

In general, it was concluded that:

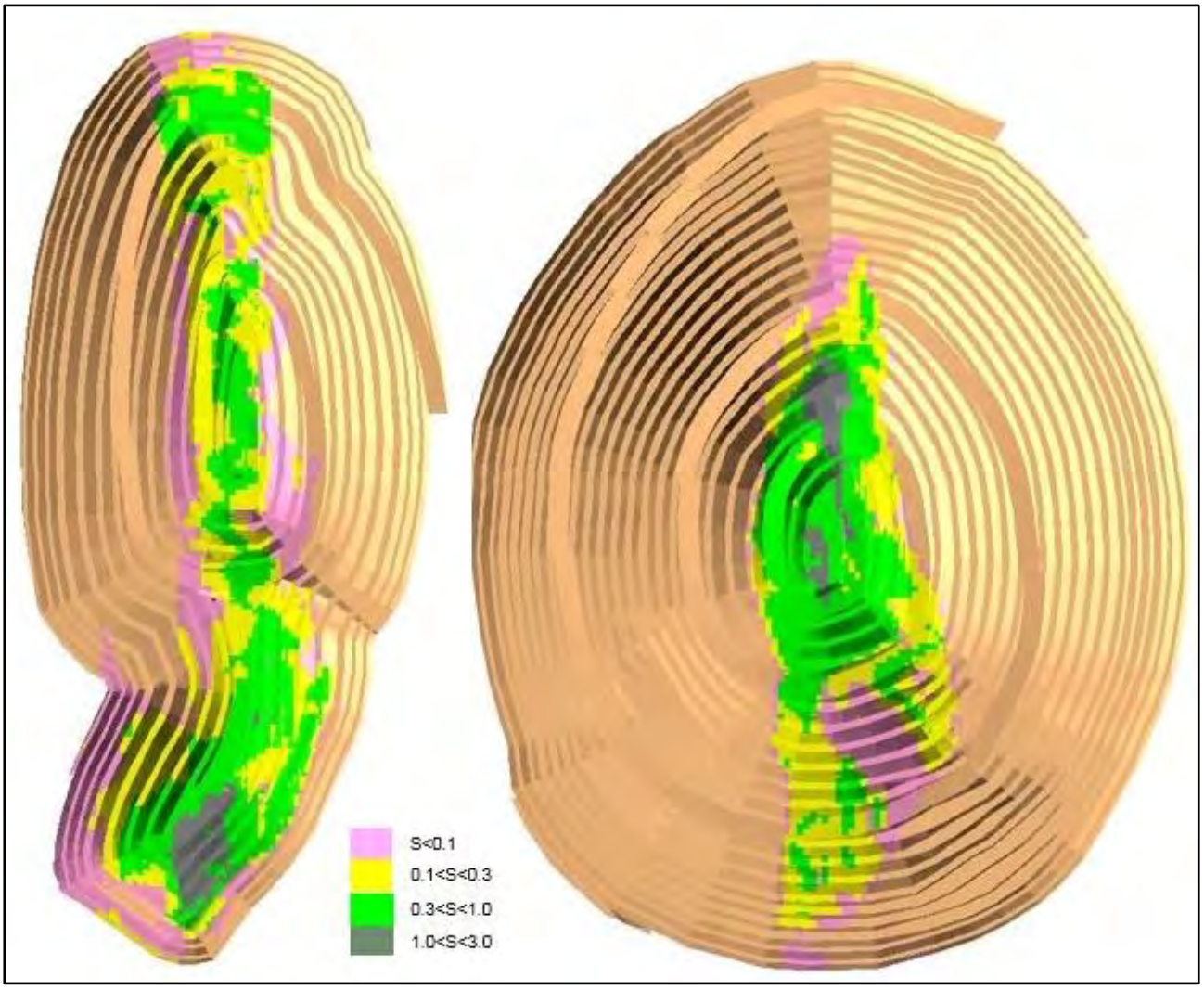
" waste rocks have meagre abundances of sulphide-minerals dispersed throughout a groundmass with moderate-high capacity to consume acid… accordingly the waste bedrocks are classified as non-acid forming".

A notable exception was identified as the volcanic sediments unit which forms a portion of the Chert/Shale (Figure 13). Samples of the volcanic sediment unit contained total-S values of 2.1-16.4%, and despite high ANC the material was classified as potentially acid forming (PAF). This material occurs in thin bands and very low volumes in both pits. The situation is similar to the Mt Keith where large scale mining and co-disposal with high ANC material limit the potential for acid leachate at a significant scale. The slight residual risk can be controlled by using routine operating procedures from Mt Keith, which ensure that high S material is identified during drill and blast cycles and then managed during excavation and WRD emplacement.

Note that subsequent to the geochemical assessment (part of the 2005 impacts assessment), Nickel West have developed improved processing of high talc content ores. This change has resulted in more low grade material being classified as ore, resulting in a further reduction in the mineralisation of material emplaced in the WRD.

Figure 23 shows the distribution of total sulphur (including non-reactive sulphate as well as Sulphide-S) in the walls of the final SMW Pit and the Goliath Pits. Larger areas of elevated sulphur are limited to the central ultramafic unit which is exposed in the floor of the pit and in bands at the north and south ends. Routinely measurable sulphur (>0.1%) is largely absent from the larger west and east walls of the pits. At SMW higher sulphur (1-3%) occurs in the southern wall at 370-460 m RL. At Goliath there is a small zone of higher (1-3%) S wall rock deep in the northern side between the 130 and 160 m RL benches and the large majority of >0.3 % S wall rock below 160 m RL.

Figure 23 - Total Sulphur in the Six Mile Well (left) and Goliath (right) pit shells



The limited distribution of elevated sulphide material in the pit walls and the overwhelming high ANC for most wall rocks means that there is no possibility of acidification of the SMW backfill groundwater or the Goliath pit lake.

After closure, the Goliath pit will partially refill to form a very deep pit lake and minor discharge zone to the generally impermeable country rock. Lake water will initially reflect the chemistry of groundwater, being brackish and with low levels of trace components except for slightly elevated boron. As discussed above, evaporation is the dominant process in controlling changes in water quality and will causing a continuous long term increase in the concentrations of all dissolved constituents and notably increased salinity. Trace element concentrations are unlikely to affect the pit lake water quality categorisation or constrain water use at any time, since increasing salinity will be the dominant constraint.

Groundwater levels in the backfilled SMW void will recover to approach the original static water level after about 50 years. Water levels will then continue to rise and slightly exceed baseline levels (due to increased recharge through the backfill) over about 100 years and long term water quality is expected to be slightly improved. Groundwater is the volumetrically dominant source of water which will re-fill the void, so that void water quality groundwater will reflect the quality of natural groundwater as described above - ie brackish (about 4.5 g/L) and with low levels of trace elements. A very gradual reduction in salinity will occur due to enhanced rainfall recharge through the back-fill.

6. WATER BALANCE

6.1 Site water balance

The estimated requirement for dust suppression, drill and blast operations and to feed to potable supply systems (R/O treatment) is 15 L/sec. Total requirements over ten years are 4.7 GL This excludes dust suppression requirements for the ore haul road to the Mt Keith Concentrator which can be obtained from sources supplying current Mt Keith Operations and do not necessarily constitute a significant overall increase in water supply requirement from current operations.

From a conservative water supply perspective, the SMW aquifer is expected to sustain abstraction of 10 L/sec for about 3 years and 5 L/sec thereafter. For dewatering over four years of operation the minimum contribution from SMW is 1.1 GL (Case A). If the SMW source is used to its' conservatively estimated supply limit,the contribution over 10 years is 2.0 GL Case B). Under Case A, the 10 year supply shortfall is 3.6 GL at a maximum rate of 15 L/sec and under Case B the shortfall is 2.7 GL at a maximum rate of 10 L/sec.

The satellite pits water demand will be strongly seasonal varying in the range 5 to 25 L/sec over periods of several days. To avoid sizing external source capacity to cater for the peak requirement, it will be will be desirable to manage local sources for the summer peak seasonal peaks. Management of the seasonal peak can also be improved by using the Goliath Stage 1 pit for storage after its' completion.

6.2 Make-up water supply options

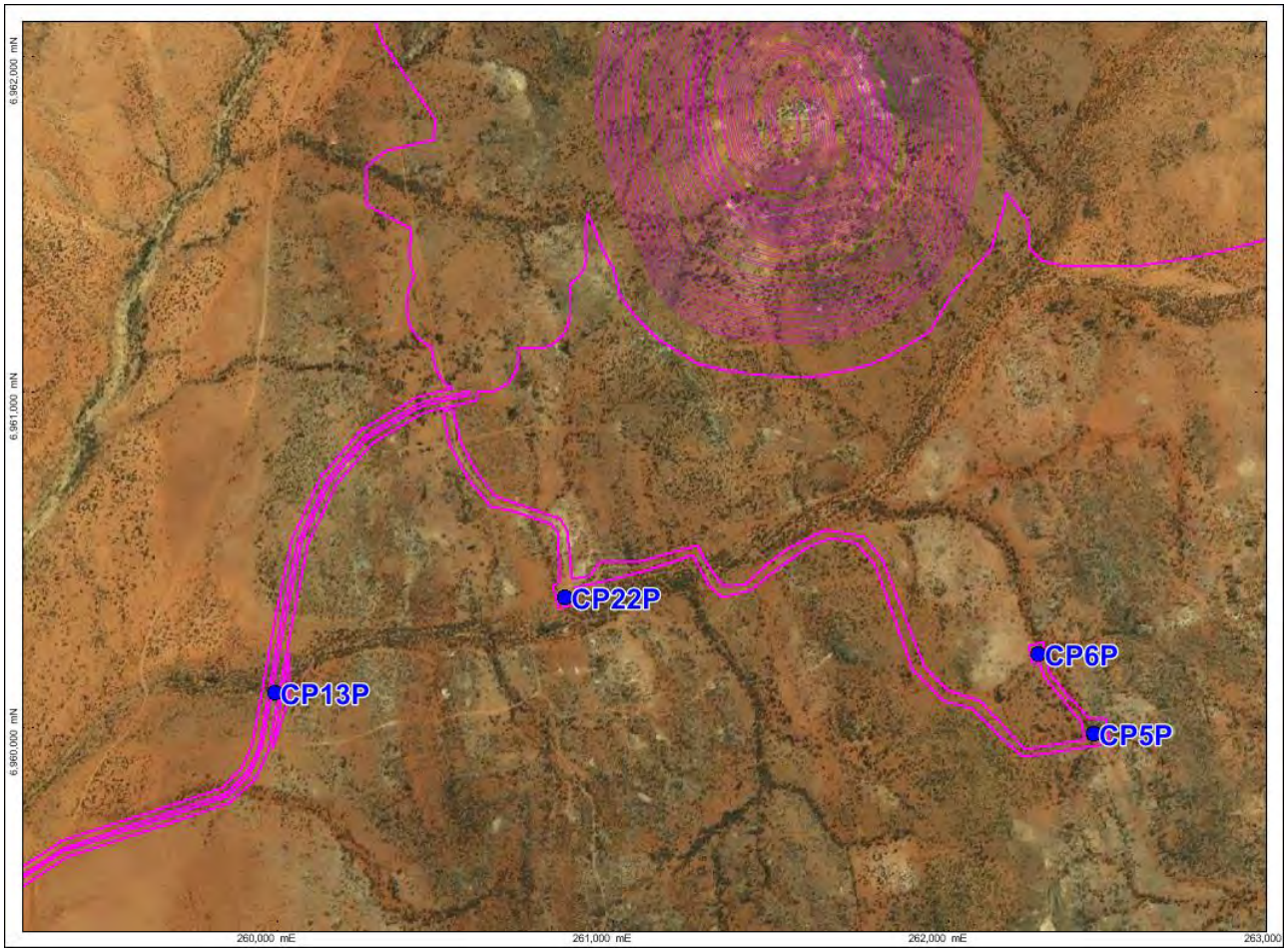
6.2.1 Local Bores

The satellite pits region was explored for groundwater as part of the early 1990's phase of investigation. In general, very low yields were obtained from most drill-holes, however production bores were completed and tested at four locations. These bores intersect minor localised aquifers at the intersection of a structure with a lithological contact. The linear nature and limited extent of the aquifers is evident from the test-pumping results. The aquifers comprise a single narrow and steeply dipping zone of extent 10's to 100's of metres horizontally and 10's of metres vertically. The fracture zone has moderate permeability but very limited storage and long term groundwater is yield is derived from leakage to the fracture zone form very low permeability host rocks.

Bore locations are shown on Figure 24. Pumping test results have be analysed and indicate that a yield of 3 L/sec can be obtained from each of three bores with CP5P and CP6P being so close as to constitute a single site.

The local bores have marginally adequate capacity for the water supply shortfall. Alternatively, the bores could be used to supply part of the supply deficit or used seasonally for demand peaks.

Figure 24 – Local Water Supply Bores



6.2.2 Existing Mt Keith Sources

Current supply sources to the Mt Keith Concentrator are detailed in Section 6.3 below. The two sub-potable borefields have a combined allocation of 4.8 GL/a and typical abstraction of 1.7 GL/a. The South Lake Way borefield capacity was upgraded in 2010. Current installed sub-potable supply capacity is marginally sufficient to accommodate the additional requirements for the satellite pits.

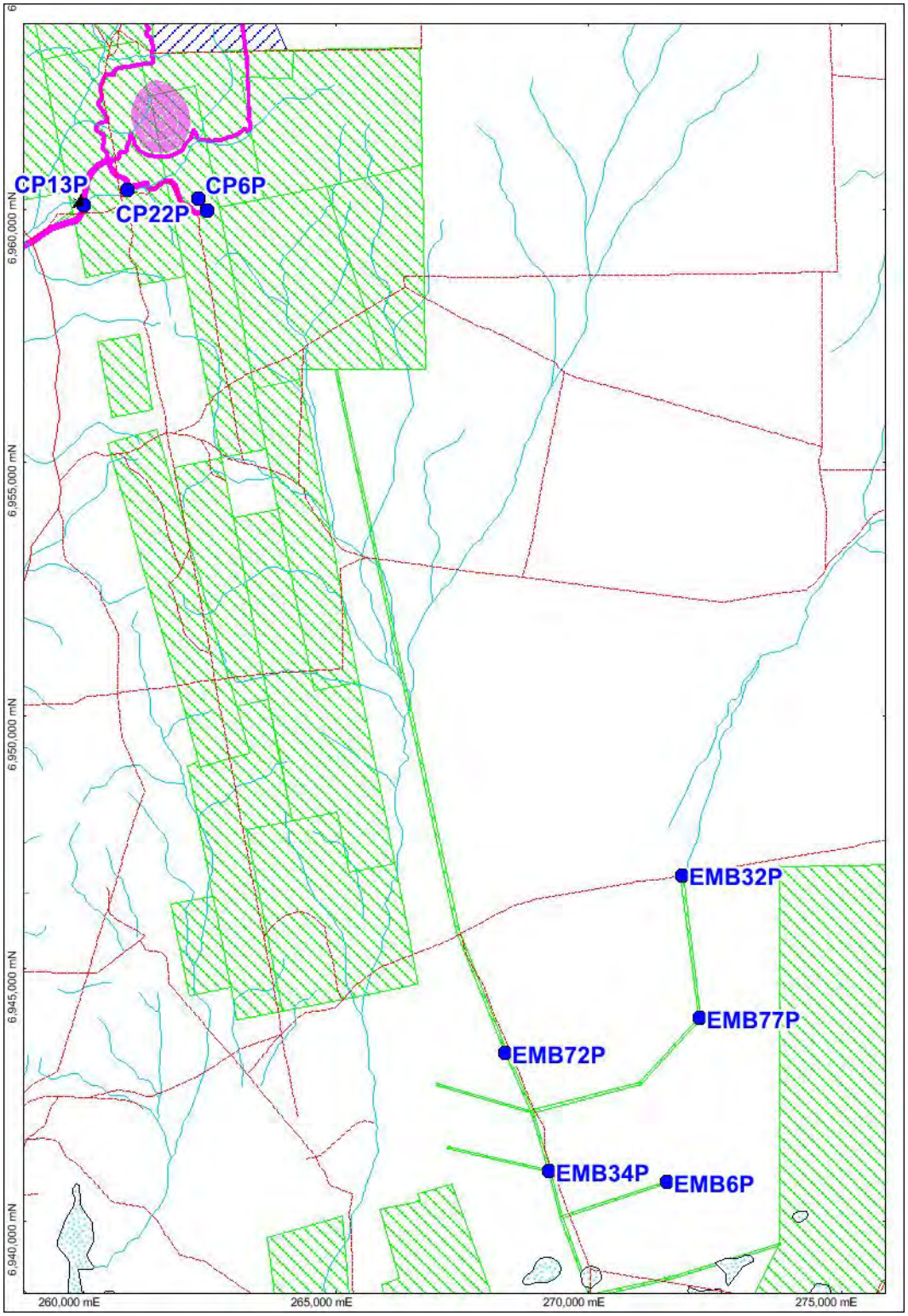
The Cliffs mine, located near the Mt Keith Village and airport has a long term dewatering excess which approximately matches the maximum satellite pits deficit. Currently this water is piped to the Mt Keith Pit or TSF and is not a key component of the Mt Keith supply system. The capacity, location and existing pumping/piping and water quality are favourable for re-directing the pipeline south to the satellite pits.

6.2.3 Southern Borefield

The southern borefield was developed for a previous and superceded project concept which involved constructing a concentrator at the satellite pits. Bores, tenure and DoW licencing have been retained by Nickel West. Under agreement with Nickel West, a portion of the borefield was developed for water supply to the Cosmos mine concentrator in 2000 and operated until the mine closed in 2012. The final and currently licensed configuration has an allocation of 1.5 GL/a (48 L/sec). The operating strategy relating to the current licence includes five production bores, three of which produce sub-potable quality water and two produce saline water.

Bore locations are shown along with Nickel West tenure on Figure 25.

Figure 25 – Southern Borefield



The satellite pits requirement is very much less than the proven capacity of the licensed portion of the borefield.

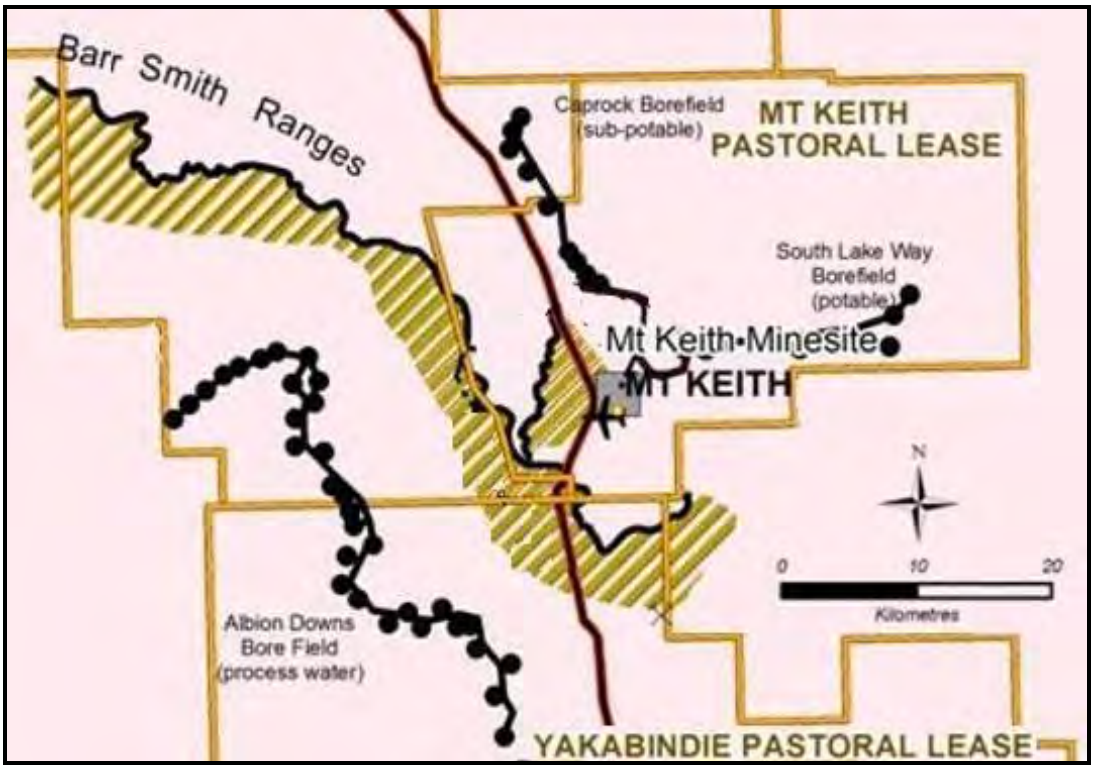
6.3 Concentrator water supply

The project will add 10 years of concentrator operation, with satellite pit ore processed from early in FY21 to early FY32. Existing water supplies to the Mt Keith Concentrator will maintain the supply as follows:

- Process supplies from the Albion Downs Borefield
- Sub-Potable supplies from the Caprock and South Lake Way Borefields
- Village supplies from the Village Borefield
- Additional saline supplies from the Mt Keith Pit and Cliffs Mine
- Minor water harvesting facilities

The general layout of the Mt Keith concentrator water supply borefields is shown below in Figure 26

Figure 26 – Mt Keith concentrator supply borefields



For the additional complete years of operation of the Mt Keith concentrator (FY22-FY30) the total additional throughput of ore is 99.4 MT of ore and the average rate of throughput is 9.8 MTpa. The milling rate and water intensity of milling are expected to be unchanged from the current operational conditions. The project represents a 10-year continuation of the current Mt Keith water demand situation. Existing supplies from the Mt Keith pit will not be required for mining operations and hence provide a minor net positive to the water supply.

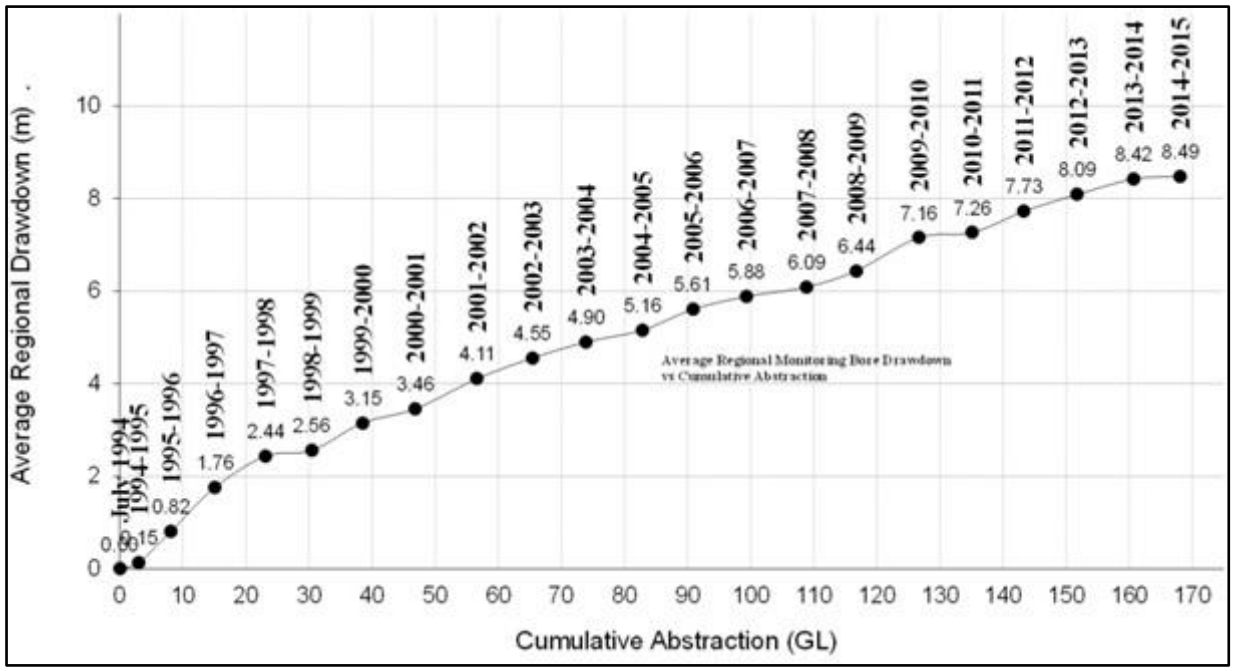
The hydrogeology of the borefields is described in the Groundwater Well Licence Operating Strategy (Nickel West, December 2013) The viability of continuation of the existing water supply sources for an additional 15 years (5 years for Mt Keith pit and 10 additional years) can be determined from the existing borefields annual production summaries and triennial aquifer reviews. The most recent annual production summary includes monitoring results for the period to June 2015 (MWES August 2015). The most recent triennial aquifer reviews complied monitoring results to June 2013 (Nickel West, November 2013).

6.3.1 Albion Downs Process Water Supply

The Albion Downs Borefield is located 30-50 km southwest of Mt Keith mine on the Albion Downs and Yakabindie pastoral leases. The borefield is developed on a typical Yilgarn region palaeochannel/Cenozoic basin sedimentary sequence. Production bores are sited at about 1.5 km intervals along the axis of a major regional palaeochannel aquifer, located within the broader Cenozoic sedimentary basin. The borefield comprises 32 production bores which typically produce a total of about 9000 ML/a or about 80% of the water supplied to Mt Keith. Long term monitoring has shown a steady and predictable rate of drawdown. This response is typical of groundwater abstraction from storage in a bounded aquifer system. The steady rate of drawdown over periods of substantial variation in rainfall, indicates that rainfall recharge to the groundwater aquifer is a very small component of groundwater abstraction.

The basin-wide upper aquifer response is demonstrated by the water level response in approximately 50 regional monitoring bores. The average drawdown of the regional bores is used as an indication of the depletion of water stored in the upper aquifer. Figure 27 shows the average of regional monitor bore drawdown is plotted against cumulative abstraction.

Figure 27 – Albion Downs Borefield - aquifer drawdown response



Based on long term average process water requirement of 0.81 kL/tonne of ore processed, the development will require a total of 80 GL from the Albion Downs Borefield. From measured abstraction of 169 GL to June 2015, the total abstraction will rise to about 210 GL by the commencement of satellite pit ore in early FY21 and to 290 GL by the end of the mine life in FY31. The long term drawdown rate of 0.04 m/GL indicates that average regional upper aquifer drawdown will increase from 8.5 m in 2015 to 10.2 m in FY21 and to 13.4 metres by 2031.

The prognosis for borefield operation and impacts from the extended borefield life is not substantially changed from the most recent aquifer review. Basin delineation drilling at the time of the borefield development showed that the typical saturated thickness of the upper aquifer was 15-20 metres. The residual saturated thickness of 7-12 metres (2015 water levels) should allow will allow ongoing supply from the existing borefield at current rates to 2031. Additional water storage in the aquitard, lower aquifer and surrounding host rocks will provide

further capacity although possibly at diminishing rates. Ongoing localised trends of rising salinity are likely to continue as brackish-saline water in the upper aquifer is further depleted and saline-hypersaline water from the lower aquifer dominates the overall supply. The impacts on the salinity increases on the quality of the aggregate supply are moderated by the fact that many of the bores already deliver water of stable hypersaline quality.

6.3.2 Caprock Borefield Sub-Potable Supply

The Caprock Borefield comprises a 15 km northern pipeline extending north from the Mt Keith Mine and includes 7 operational production bores. Four southern bores tap separate minor bedrock aquifers and three northern bores tap a short segment of a minor palaeochannel. The borefield has typically supplied 40 % of sub-potable requirements. Typical annual total borefield abstraction of about 650 ML is about 6% of the total groundwater supplied to the operations.

The Borefield is a collection of small isolated aquifers. Drawdown is localised by the limited geological extent of the aquifers and the low yield. Monitoring is therefore focused on local water levels without a regional network of monitor bores. The four southern ultramafic rock hosted Caprock bores are operated by partially dewatering the small localised aquifer to maximize leakage into the "reservoir" from the surrounding low permeability country rock. Pumping water levels are well within the aquifer zone at each bore site. The instantaneous/short term pumping capacity of each bore pump generally exceeds the sustainable capacity of the bore and the bores are operated on rotation (over several months) to allow for water level recovery and seasonal variations in mill demand. The three northern palaeochannel bores exploit a more robust aquifer. Since a very small portion of the palaeochannel has been developed, it can be expected that any localised depletion will be ameliorated by flow along the channel from undeveloped areas; i.e. the limited extent of development of the aquifer means that severe/extensive depletion of the aquifer is not possible.

On this basis it is expected that historical rates of supply from the Caprock borefield can be sustained indefinitely. The borefield is currently licensed by the Department of Water for supply of up to 1500 ML/a GL/a until 2022, this licence having been renewed at least 5 times previously. To meet project requirements would require one further licence renewal for the recent customary duration of 10 years. Provided licence conditions continue to be met, it is anticipated that this renewal would be issued in a routine manner.

6.3.3 South Lake Way Sub-Potable Supply

The South Lake Way Borefield extends 20 km east from the NMK site providing 60% of sub-potable process water to the Concentrator, typically about 1000 ML/a or 9% of the total groundwater supply. The borefield is developed in the upper reaches of a typical Yilgarn region palaeochannel/Cenozoic basin sedimentary sequence. There are eight production bores widely spread along 20 km of the east trending palaeochannel. Bores target the axis of a narrow sand-filled channel deposit at the base of the Cenozoic sediments. Mixed sediments of low-moderate permeability form a shallow (up to 50 m deep) broad (2-3 kilometre width of saturated alluvium) unconfined aquifer overlying the palaeochannel axis. This upper basin provides the bulk of water storage to the borefield. To the west of the TSF bores SLW16 and SLW17 are situated upstream of the main palaeochannel axis and tap fractured bedrock underlying low-permeability and shallow alluvium.

For aquifer resource evaluation, the borefield can be considered as three independent components:

SLW16 and SLW17: located west of the TSF are low yielding bores tapping relatively isolated fractured rock. Similar to southern Caprock bores these are operated at high drawdown with pumping water levels near or within the aquifer zone to maximise yield from surrounding rock. There is little potential for extensive drawdown impact and the historical rates of abstraction should be sustainable indefinitely.

SLW02, SLW03 and SLW04: Located east of the TSF these bores tap alluvial aquifers. Water levels are stable or rising indicating that TSF seepage and rainfall recharge are volumetrically dominant over groundwater abstraction so that maintaining the current rates should be possible.

SLW07, SLW08 and SLW09: The eastern bores are located where the palaeochannel and shallow alluvial sedimentary basin is thicker and broader. The main reservoir is the shallow alluvium. The aquifer response is well defined by the average drawdown in regional monitor bores in a similar manner to the Albion Downs borefield, however drawdown at South Lake Way is very much less than at Albion Downs. Abstraction of 8.6 GL from 1994 to June 2013 had induced a drawdown of 2.4 metres and the long term drawdown trend was 0.21 m/GL. The required yield from the area of about 0.5 GL/a will produce a drawdown rate of about 0.1 metre per year which means that the bores can maintain current supply rates for at least several more decades.

The borefield is currently licensed by the Department of Water for supply of up to 3285 ML/a until 2022, this licence having been renewed at least 5 times previously. To meet project requirements would require one further licence renewal for the recent customary duration of 10 years. Provided licence conditions continue to be met, it is anticipated that this renewal would be issued in a routine manner.

6.3.4 Village Borefield

The Village Borefield comprises seven equipped production bores VB01-VB05, VB10 and VB12, located within 3kms of the Mt Keith Village. Typical annual abstraction is about 150 ML or about 1.3% of the total from the five groundwater licences held by NMK. Bores supply near-potable quality water to the Mt Keith Village where it treated by reverse osmosis fir use as a potable supply.

The bores draw water from minor and relatively isolated fractured ultramafic and granitoid hosted aquifers.. As is common for fractured rock aquifers, the bores are operated with relatively high drawdown - i.e. with pumping water levels below the top of the aquifer zone. This allows a maximum amount of leakage to the aquifer zone from surrounding low permeability bedrock. Since the yield is naturally limited by the rate of seepage from surrounding country rock into the fracture system tapped by the bore, there is no potential for long term depletion and current supplies should be available indefinitely.

The borefield is currently licensed by the Department of Water for supply of up to 275 ML/a GL/a until 2022, this licence having been renewed at least 5 times previously. To meet project requirements would require one further licence renewals for the recent customary duration of 10 years. Provided licence conditions continue to be met, it is anticipated that this renewal would be issued in a routine manner.

7. STORMWATER MANAGEMENT PLAN

This section is intended summarise the requirements detailed in this report, which are required for incorporation into revised or additional Mt Keith operating procedures, including environmental and mining procedural documents and management systems. These documents will define additional tasks, training, roles and responsibilities arising from the development.

7.1 Management Objectives and Performance Indicators

The development is located in the unusual and sensitive Jones Creek surface water catchment; hence operations will require a greater focus on stormwater management than is required for existing Mt Keith operations. The primary objectives for design and operation of stormwater controls at the site are:

- Quantity - maintain the existing flow regime and minimise the reduction in clean water yield to the Creek
- Quality - Preserve the stream bed environment by minimising the additional sediment load to the Creek

The objectives will be achieved by appropriate separation of background run-off from impacted stormwater and appropriate control and release of impacted stormwater. Key performance indicators relevant to the management of surface water are as follows:

- No loss of environmental values as a result project related impacts on the flow regime and water quality
- No impacts on third party users

7.2 Risks, Strategy and Management Measures

7.2.1 Pit Flood Protection

On paramount importance is to avoid direct stream flow ingress to the active pits. The overflow of Jones creek or a significant tributary into a mine pit would be dangerous and environmentally unacceptable and must be prevented.

Substantial creek-pit interactions have been prevented by pit design, in particular including the horizontal set-back between Jones Creek and the SMW pit. There remains the potential for pit capture for brief periods at extreme flood levels, the maximum risk is for the capture of a small portion of the total flow for several hours per 100 years. Minor bunding has been detailed to address this residual risk.

7.2.2 Diversion of clean water

The permanent landforms (pits and waste rock dumps) and to a lesser extent temporary features (stockpiles and infrastructure) can result in isolation of portions of the catchment and potentially unnecessary reduction in yield of stormwater to the Creek.

The design layout of these features has been adjusted to minimize this effect and to promote opportunities for clean stormwater to be efficiently routed around the structures. The operational and post-closure diversion of

clean water around major project landforms is a key component of the management strategy and will be incorporated into all project and operational revision and modifications.

Key permanent diversion structures include:

- WRD north drain
- WRD south drain
- SMW pit north drain

These final design capacity of the drains should be the 1:10 year peak flow calculated from the Mt Keith Regional Flood Flow Estimation method described above. The drains should include bunding such that peak flows exceeding 1:100 year level remain on the clean side of the drain. The main drains are expected to have low maintenance requirements, however inspections will be required and will be scheduled into normal site EMS and wet weather procedures.

7.2.3 Control of first-flush impacted water

Areas impacted by mining will accumulate materials subject to remobilization by stormwater as potential contaminants. The volumetrically dominant material is oxidised waste rock which may undergo further weathering resulting in the potential for erosional release of fine-grained suspended solids which can clog and dis-color the exiting coarse grained creek sediments.

The primary control is part of the existing Mt Keith dumping procedure, whereby non-competent waste rock is identified in detailed operational mine plans and scheduled for emplacement centrally within or distant from the edges of the WRD toe.

Additional controls include a series of silt traps. Preliminary locations have been established for revision based on needs identified from detailed stock-pile and dump sequencing. Key areas for coverage are potential high sediment source areas, including steep concentrated flow paths from areas where oxide material will be stored and exposed continuously over periods of months to years. The structures are constructed as low gully spanning embankments. A portion of the storage behind the embankment is as void space in a back-filled rock pad, to minimize through-flow of sediment. The silt trap/check dam/rock pad features include:

- small semi-porous embankments (<2.5 metre-high) across key drainage lines
- unlined, no recovery pumps, water detention not retention
- partial backfill with loose coarse crushed rock (d_{50} ~ 200mm) of high size uniformity
- First flush storage capacity with overflow for ongoing run-off
- Containment for volume equivalent of 4 mm run-off depth across sub-catchment

The silt traps will require regular inspections to ensure the original live storage volume is a maintained. Occasional excavation with a loader will be required.

7.2.4 Creek Crossings

Two main haulage creek crossings are planned. Potential impacts from the haul road crossings mainly relate to Jones Creek water quality, particularly excessive additional sediment load. When the particle size distribution of the additional load is exotic to the natural stream bed, impacts would be exacerbated. M

Minor creek flows can typically be expected following 24 hour rainfall totals of 30 mm or typically about once per year. Based on rainfall IFD data the expected flow frequency is slightly more than once per year flow with typical duration of several hours. Continuous flow for between 48 and 72 hours has an expected frequency of about 1:100 years.

Considering the low frequency and duration of flow events, a low level "ford" is the appropriate creek-bed crossing. The following measures should be employed to mitigate excess sediment entrainment by intermittent creek flow events:

- Very coarse rock (d_{50} = 600 mm) armouring of the bank cut sections up to the 1:100 year flood
- Minimum build up of road surface above natural creek level in mainstream
- Initial construction and maintenance (after flow events) to use stockpile of suitably graded material (minimal fines and particle sizing compatible with creek sediments)
- Best operational practice to minimize vehicle tracking of sediment during wet periods including:
  - Cladding of roads with appropriate materials
  - Road drain and surface maintenance to avoid build up of sediment on roadways
  - Wheel wash as appropriate

7.2.5 Mt Keith Haul Road

The haul route is located relatively high in the catchment. There is little inaction with well-defined natural drainage lines, beyond the crossing of Jones Creek at the south end of the route -which is considered above. The main environmental impacts risks are associated with "shadowing" of vegetation from natural stormwater flow. In addition there is the potential for increased natural erosion where the haul road crosses or traverses close to break-aways where erosion prone regolith materials outcrop and may form the substrate to the road. These issues is mainly controlled at the design stage whereby the following measures have been incorporated:

- Route selection – including adjustments to minimize grade, break-away interactions and swale crossings
- Route selection to minimize clearing and bisecting areas of larger vegetation
- Construction of the road crest close to the natural land surface to minimize impedance of sheet surface water flow

7.3 Monitoring Regime

Characterisation of water quality in highly ephemeral water courses can be problematic since quality is highly sensitive to conditions in the catchment between flows, to the pattern of rainfall causing the flow and to the point in time during the event in which samples are taken. Investigations into ore and waste rock geochemistry show little potential for mined materials to impact the solution chemistry of surface water.

Jones Creek has substantial suspended sediment loads due to the natural erosional conditions in the catchment and due to previous disturbances related to wildfire, pastoral and mining industry activities. Project impacts assessment will focus on identifying changes to stream sediment characteristics.

Operational monitoring will comprise two components:

Inspection of control structures

- Diversion drain condition – visual check for silting and erosion, photograph records as required, re-survey of profile and cross-sections as required
- Silt trap condition and storage capacity – visual check for sediment build up, survey of floor elevation as required, re-excavation as necessary
- Creek crossings – routine reporting of sediment build-up. Scrapping and sweeping as required

Environmental monitoring

Impacts to be determined by sediment sampling in the downstream creek bed by reference to the preliminary baseline assessment report (SKM, June 2005).

- Locations – initial six sites identified in baseline report, plus at least 4 additional sites to be selected between the upstream haul road crossing and the upstream SKM site (#1) and 2 sites upstream of the upstream haul road crossing
- Frequency – two rounds prior to project commencement and following substantial flows thereafter
- Survey, photography and description of channel and upstream/downstream reaches
- Particle size distribution from representative integrated "channel" sample and for selected locally representative fine-grained facies
- Geochemical analysis for the two sediment samples – laboratory methodology and analyte list as per SKM (2005) .

8. GROUNDWATER MANAGEMENT PLAN

The groundwater management plan is synonymous with the legally prescribed "Groundwater Operating Strategy" document where all aspects of groundwater management are required to be specified under groundwater well licensing conditions. It is expected that additional details will be incorporated into revision of the existing Mt Keith Groundwater Operating Strategy document which will support an application for a Department of Water groundwater abstraction license to permit abstraction for dewatering and water supply.

8.1 Management Objectives and Performance Indicators

The main groundwater resource in the project area is the regolith aquifer which is formed by weathering/alteration of the ultramafic which hosts the SMW orebody. The aquifer is a small and isolated brackish water resource and mining will result in it's removal and replacement with coarse waste rock backfill.

8.2 Risks, Strategy and Management Measures

There are no major environmental risks relating to groundwater. The evolution of the pit voids after closure is controlled by a number of hydrogeological and geochemical parameters, however it is demonstrated that these water bodies will not pose a threat to any significant groundwater resource. Natural water levels around the pit area are considered to be too deep to be a primary source to existing vegetation such that further drawdown from mine dewatering should not have impacts. Groundwater conditions in pit slopes may be relevant to pit slope stability assessment which further relates to the long term post-closure pit slope evolution – this being potentially relevant to ensuring pit-creek isolation.

The primary objectives for design and operation of groundwater controls at the satellite pits are:

- Confirm the anticipated drawdown response to the extent required for geotechnical (pit slope stability) assessment
- Capture data to support improved assessment of the post-closure pit lake evolution

These objectives will be meet by operational monitoring.

8.3 Monitoring Regime

Consistent with other nearby pits operated by Nickel West, the monitoring regime will include:

- Metering of total abstraction from each of the pits and bores and collation of monthly abstraction by source
- Annual sampling of discharge from each source for determination of water quality
- Groundwater water level monitoring sufficient for dewatering planning and geotechnical requirements

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MWH

BUILDING A BETTER WORLD

Atopobathynella **sp. OES9**

REPORT

Mount Keith Satellite Operations Subterranean Fauna Assessment

Prepared for BHP Billiton Nickel West

July 2016

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Executive Summary

BHP Billiton Nickel West (Nickel West) is proposing to develop the Mount Keith Satellite Operations (the Project), located approximately 25 km south of Mount Keith in the Northern Goldfields Region of Western Australia. MWH Australia Pty Ltd (formerly Outback Ecology) was commissioned to undertake a subterranean fauna assessment of the proposed Project.

The Project comprises the development of two open-cut pits, Goliath and Six-Mile Well, which will provide nickel disseminated sulphide ore to the Nickel West Mount Keith (NMK) operation. Waste rock will be directed to a waste rock landform adjacent to the mining operations.

The objective of this study reported herein was to investigate the subterranean fauna values of the Project Area and to assess if the removal or modification of potential habitat and groundwater drawdown will place any stygofauna or troglofauna species within the Project Area at risk. The scope of this study encompassed a literature review, database searches and stygofauna and troglofauna surveys of the Project Area.

Stygofauna

The stygofauna survey effort, summarised in **ES Table 1**, involved 64 net haul samples collected over five sample rounds, 2006 (Biota), November 2010, March 2011 June 2011 and February 2012 by MWH.

ES Table 1: Stygofauna survey effort

Area		No. Samples	No. Bores
Inside Proposed Pit Boundaries	Goliath	12	4
	Six-mile Well	4	1
Outside Pits	<500m	8	3
	>500m, <1km	22	6
	>1km	18	7
Totals		**64**	**21**

The Project Area was found to host a stygofauna assemblage of low diversity, with six of the seven species identified known from only one or two individuals. Only one species was collected from more than one bore. Findings, including work conducted by Biota, are summarised as follows:

- four stygofauna species were only recorded from within the proposed impact areas:
  - Goliath: one amphipod species recorded from within from within likely groundwater drawdown zone;
  - Six-Mile Well: two species, *Atopobathynella* sp. OES8 and *Atopobathynella* sp. OES11 from within proposed pit boundary. One species, *Gomphodella* sp. IK2 from within modelled 5m bSWL groundwater drawdown contour.

- two stygofauna species, *Atopobathynella* sp. OES9 and Bathynellidae sp. OES2, were collected from outside the proposed Project impact areas.

An assessment of survey adequacy found that further stygofauna sampling is required to more reliably characterise the stygofauna assemblage present and to provide a higher level of confidence in assessing the potential impacts posed by the proposed Project.

The current findings indicate that the development of the Project will pose a significant conservation risk to four stygofauna species through the removal of habitat by mining excavation and pit dewatering.

Troglofauna

The troglofauna survey effort, summarised in **ES Table 2**, involved sixty seven litter trap samples deployed over two trapping rounds conducted for nine weeks during March to May, 2011, and for seven weeks during May to July, 2011. In addition, 14 net haul scrape samples were also collected.

ES Table 2: Troglofauna survey effort

Area		No. Samples	No. Bores
Inside Proposed Pit Boundaries	Goliath	15	8
	Six-mile Well	8	4
Outside Pits	<500m	8	5
	>500m, <1km	35	13
	>1km	15	7
Totals		**81**	**37**

The Project Area was found to host a troglofauna assemblage of very low diversity and abundance, with only two species collected. Survey findings are summarised as follows:

- *Troglarmadillo* sp. OES3 (known from two specimens only) and Campodeidae sp. OES2 (known from one specimen) were both recorded from outside the proposed Project impact areas;
- no troglofauna species were recorded from inside any Project impact areas; and
- regolith and weathered fractured rock habitat from troglofauna species were collected is extensive and contiguous in the Project Area and surrounding local region.

An assessment of survey adequacy found that no further troglofauna sampling is required to more reliably characterise the assemblage present. The proposed Project is considered to not pose a risk to the long-term survival of any known troglofauna species as no species were collected from the within the proposed impact areas. In addition, the distributions of potentially undetected troglomorphic species are unlikely to be restricted to small areas such as the proposed impact areas because of the continuity and extent of habitat present.

BHP Billiton Nickel West

Mount Keith Satellite Operations Subterranean Fauna Assessment

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1 Introduction

1.1 Project Location and Description

BHP Billiton Nickel West (Nickel West) commissioned MWH Australia (MWH; formerly Outback Ecology) to undertake a subterranean fauna assessment of the proposed Mount Keith Satellite Operations (the Project). The Project is located in the Northeastern Goldfields region of Western Australia, within the Yakabindie and Mt Keith pastoral leases, approximately 25 km south of the existing Mt Keith Nickel Operation and immediately west of the Wanjarri Nature Reserve (**Figure 1-1**).

The Project comprises two proposed open-cut pits at the Goliath and Six-mile Well deposits, a run-of mine (ROM) pad and a waste rock landform. These pits will provide nickel disseminated sulphide ore to the Mt Keith Operation for processing via a proposed transport corridor extending north from the Project. Additional infrastructure will include a bridge across Jones Creek, the ephemeral stream which bisects the Project Area, and a primary access road servicing the Project from the south.

1.2 Assessment Scope and Objectives

The scope of this assessment encompassed a desktop study (literature review and database searches), stygofauna surveys (conducted between 2010 and 2012) and troglofauna surveys (conducted in 2011). The overarching aim was to investigate the subterranean fauna values of the Project Area and assess whether the removal of potential habitat through pit excavation and groundwater drawdown will place any stygofauna or troglofauna within the Project Area at risk. Specific objectives of the assessment were to:

- evaluate the potential of habitat within the proposed mining areas to support subterranean fauna;
- consider the conservation significance of any subterranean fauna assemblage or species occurring within the Project Area; and
- identify any potential risks to obligate subterranean fauna from the proposed mining activities.

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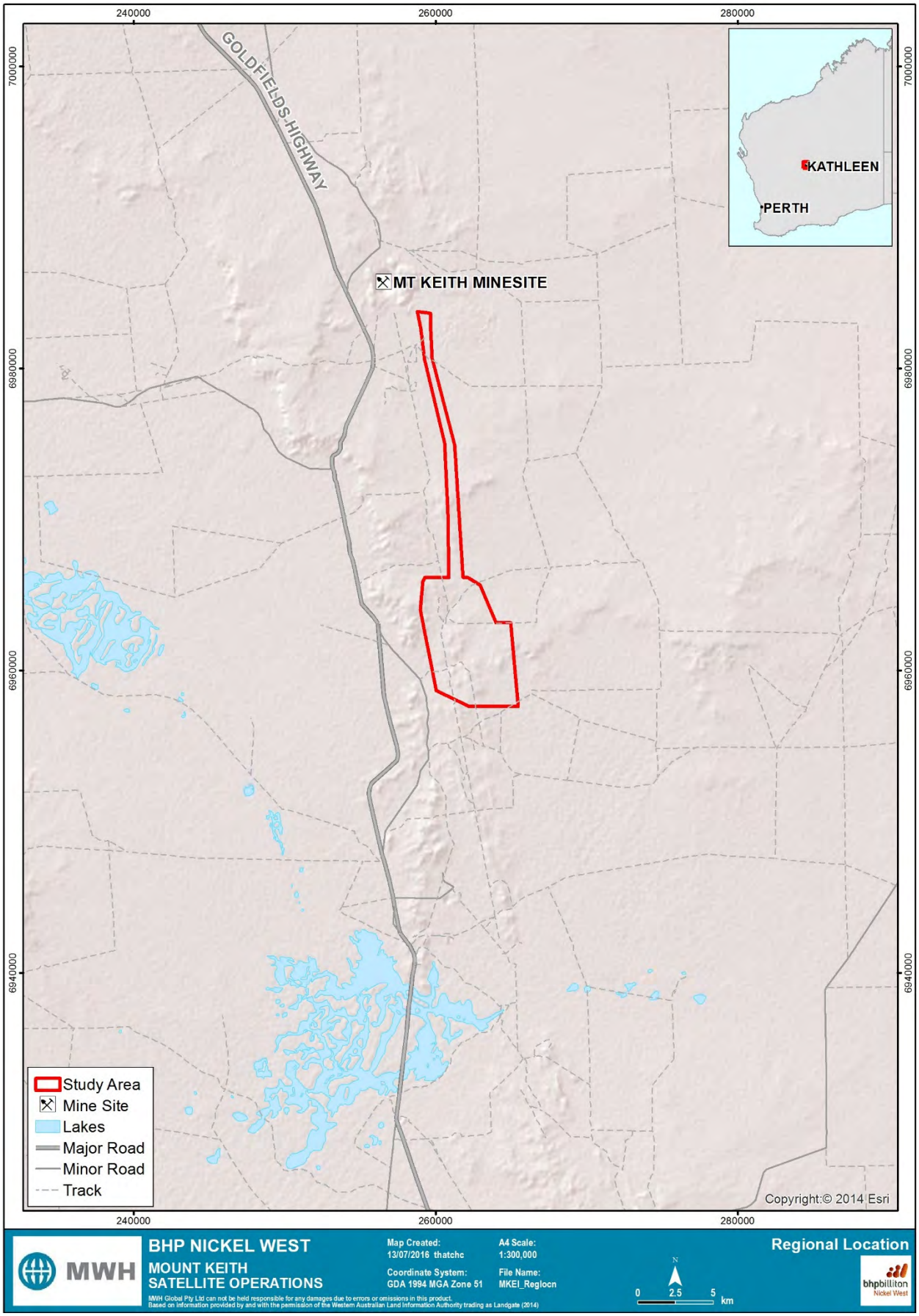

Figure 1-1: Regional location of the Mount Keith Satellite Operations Area.

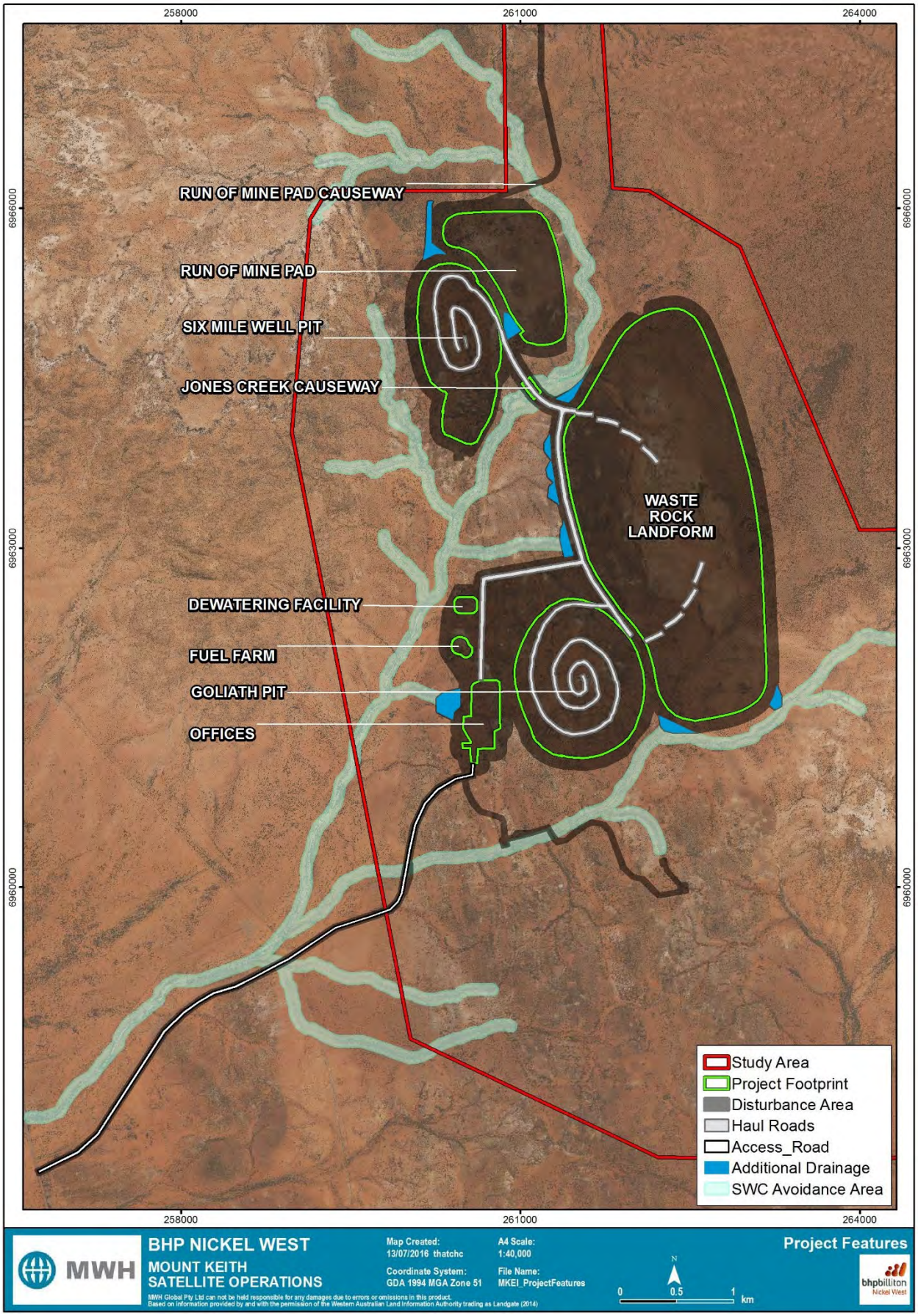

Figure 1-2: The Mount Keith Satellite Operations Area proposed impact footprint.

2 Existing Environment

2.1 Biogeographic Region

As defined by the Interim Biogeographic Regionalisation for Australia (IBRA), the Project Area is located in the East Murchison (MUR1) subregion of the Murchison bioregion in Western Australia (Department of Sustainability Environment Water Population and Communities 2012a, b). This subregion consists of extensive areas of elevated red/red-brown desert sandplains with minimal dune development, breakaway complexes and internal drainage and saline lake systems associated with occluded Palaeodrainage systems which have been found to host diverse subterranean fauna assemblages (Cooper *et al.* 2002, Humphreys 2008, Outback Ecology 2008, 2011a, 2012b, c, d, Subterranean Ecology 2011b).

2.2 Land Use

The dominant land use (85%) within the Eastern Murchison subregion is grazing of sheep and cattle on native pastures (Australian Natural Resources Atlas 2010, Cowan 2001). Other land uses include Unallocated Crown Land (UCL), Crown reserves, and mining (predominantly gold and nickel). Most mining lease areas in the subregion, including the Project Area are still required to be stocked, as they come under the Pastoral Lands Act (Cowan 2001).

The National Land and Water Resources Audit (Australian Natural Resources Atlas 2010) states that just 1.4% of the Murchison bioregion is classified as conservation estate. In 2001, Cowan reported that 1.8% of the Eastern Murchison subregion was classified as conservation estate. Since then, a comprehensive land acquisition program has contributed additional land for conservation, and in 2009 land vested in reserves increased to 8 % (Department of Environment and Conservation 2010).

2.3 Climate

The region has an arid climate, with hot summers and cool winters (Gentilli 1979). Limited annual rainfall, averaging approximately 220 mm, coincides with high evaporation rates (2,400 mm/yr) and is generally characterised by a bimodal distribution (Beard 1976). Winter rainfall is typically associated with low-pressure frontal systems from the south and tends to be widespread and of variable intensity. Summer rainfall is mainly linked to local thunderstorms or the influence of tropical cyclones to the north (Beard 1990, Pringle *et al.* 1994).

Rainfall data from Yakabindie Station (Station no. 012088), the closest weather station to the Project Area, highlights the variability in rainfall patterns within and across years (**Figure 2-1**). While the mean rainfall for the area is approximately 220 mm per annum, rainfall at Yakabindie in 2011 at was greater than 450 mm. Rainfall in September 2010, prior to the first round of stygofauna sampling (November 2010), was more than sixfold that of the long term monthly average (Bureau of Meteorology 2016). Rainfall between December 2010 and February 2011 also well exceeded the monthly averages, in response to large, ex-

tropical, low pressure systems. In particular, February 2011 recorded a monthly rainfall total of 185.7 mm, resulting in the flooding of Jones Creek and the terminal drainage claypans.

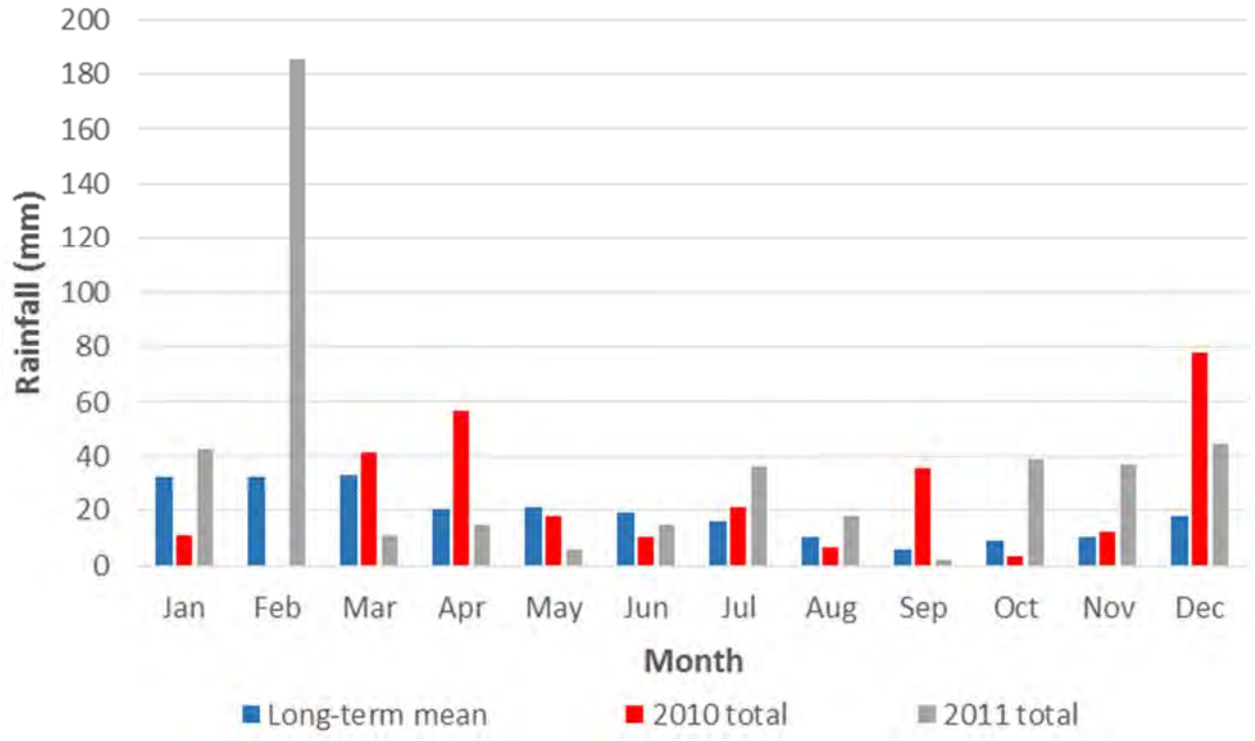

Figure 2-1 Rainfall data collected from Yakabindie Station (Station no. 012088). Long-term data have been calculated from records collected since 1931 (Bureau of Meteorology 2016).

2.4 Hydrology

The main tributary in the Project Area is Jones Creek which is a lateral tributary system, incised into the Barr-Smith Range. The majority of runoff for this ephemeral water course is received from the upper catchment, which covers an area of 64.1 km^2. In large flood events, water is rapidly shed from this part of the catchment into the creek, aided by the rocky nature of the terrain. The terminus for the creek is a large floodplain area to the south west, containing a number of claypans (BHP Billiton Nickel West 2011b). Beyond this, drainage becomes increasingly diffuse, before encountering the Yakabindie calcrete and reaching Lake Miranda, located within the Carey Palaeodrainage system (Wetland Research and Management 2005).

2.5 Geology

The general geology of the Project Area is a low porosity peridotite komatite ultramafic located in the Archean Agnew-Wiluna greenstone belt with lozenges of dunite, some of which host the nickel sulphide deposits (BHP Billiton Nickel West 2011b). There is little alluvial or soil cover with the base of oxidation deeper at the Six-mile Well deposit (90 to 170 m below ground level [bgl]) compared to the Goliath deposit (30 to 70 m bgl). The ultramafic package is larger at Six-mile Well (1,500 x 400 m) compared to Goliath (BHP Billiton Nickel West 2011).

2.6 Hydrogeology

The Project is located within the upper section of the Jones Creek catchment that lies within the larger catchment of an ancient river system, the Carey Palaeodrainage, which once flowed south east into the Eucla Basin currently situated beneath the Nullarbor Plain (Johnson *et al.* 1999). Major fresh and hypersaline aquifers are contained within the palaeodrainage ground waters. Groundwater resources within the Carey Palaeodrainage catchment include calcrete, fractured rock and unconfined regolith (alluvial and colluvial) aquifers, a number of which are important in maintaining local stygofauna assemblages (Outback Ecology 2008, 2012a, b, d, Subterranean Ecology 2011b, Wetland Research and Management 2005).

Groundwater in the Project Area and local region occurs predominately in unconfined shallow aquifers of less than 100 m deep that are not well defined (BHP Billiton Nickel West 2011). The groundwaters are mostly associated with alluvial and/or colluvial deposits, that represent transported or weathered regolith horizons created by erosional and depositional processes, that have formed over the dunite ultramafic caprock aquitard that hosts the nickel deposits (BHP Billiton Nickel West 2011, Wetland Research and Management 2005). The overall static water levels across the Project Area are relatively flat with a slight hydraulic gradient running south down Jones Creek away from the deposit areas (BHP Billiton Nickel West 2011).

3 Subterranean Fauna

3.1 Background

3.1.1 Stygofauna

Stygofauna (groundwater fauna) are predominantly comprised of invertebrates, although some vertebrates, for example eels and fish, can also occur. While crustaceans typically dominate stygofauna community structure, other invertebrate groups including gastropods, insects, arachnids and worms may be represented. Stygofauna can be classified into three main groups according to their level of dependency on the subterranean environment:

- stygoxenes are animals that enter groundwaters passively or accidentally;
- stygophiles inhabit groundwaters on a permanent or temporary basis; and
- stygobites are obligate groundwater dwellers

Stygobites can often be distinguished from surface animals by morphological characteristics typical of a subterranean existence, such as a reduction or absence of pigmentation, absence or reduction of eyes, and the presence of extended locomotory and sensory appendages (Humphreys 2008). They can also be defined by ecological parameters such as longer life history stages, lower metabolisms and fecundity rates (Cooper *et al.* 2002, Danielopol and Pospisil 2000).

Stygobites are restricted to their subterranean environment and as such can have locally-restricted distributions. Taxa with such limited geographical ranges may be further categorised as short range endemic species (SREs) and are considered more vulnerable to extinction (Harvey *et al.* 2011). While a range of less than 10,000 km^2 is generally accepted for short-range endemism (Environmental Protection Authority 2013b, Harvey 2002), the potential adoption of smaller range limits, for example 1000 km^2 or lower has been discussed (Eberhard *et al.* 2009, Harvey *et al.* 2011).

Stygofauna occur in various types of aquifers that exhibit voids of a suitable size to meet biological requirements (Humphreys 2008). In Australia, research efforts and improved sampling techniques have revealed a rich stygal community. Although previously thought to be restricted to karst landscapes, stygofauna have now been found in alluvial sediments, fractured rock aquifers, pisolites and thin regoliths (Guzik *et al.* 2011, Humphreys 2006, 2008, Subterranean Ecology 2008a). In Western Australia, studies have shown that the calcrete and alluvial aquifers associated with palaeodrainage channels of the arid and semi-arid zones contain rich stygofauna communities, with the Pilbara and to a lesser extent the Yilgarn, standing out as global hotspots for stygofauna diversity (Environmental Protection Authority 2007, Humphreys 2008).

3.1.2 Troglofauna

Troglofauna are defined as air-breathing subterranean fauna inhabiting voids or caves (Environmental Protection Authority 2013b). They are often relictual forms related to surface-dwelling (epigean) groups, and can be recognised by characteristics associated with a subterranean existence (Humphreys 2000). Similar to stygofauna, troglofauna can be further divided into:

- *trogloxenes*, which are animals that enter subsurface terrestrial habitats passively or incidentally;
- *troglophiles,* which are animals that carry out part of their lifecycle underground, but are also able to survive in epigean habitats; and
- *troglobites,* which are obligate subterranean inhabitants.

As they are restricted to subterranean environments, troglobites generally lack pigmentation, are blind or have reduced eyes, have elongated limbs, and may possess enhanced non-visual sensory adaptations (Culver *et al.* 1995). Troglofauna are found worldwide and until recently had primarily been investigated as cave-dwelling organisms (Culver and Sket 2000). Consistent with this, significant areas for troglofauna in Western Australia are the Cape Range and Barrow Island karst cave systems, where large and diverse communities have been discovered in extensive cave systems (Hamilton-Smith and Eberhard 2000). However, the discovery of diverse troglofauna communities in subsurface rock fractures in non-karst areas in the 1980's prompted broader consideration of potential habitat (Juberthie 2000). More recent surveys have identified troglofauna from non-karstic geologies such as vuggy pisolite ore beds in the Pilbara region, and calcrete and metamorphic mafic rocks in the Yilgarn (Barranco and Harvey 2008, Bennelongia 2009, Outback Ecology 2011a, Subterranean Ecology 2008c). Distributions are typically restricted, with many troglofauna classified as short range endemic (SRE's) (Harvey *et al.* 2011).

3.2 Risks and Relevant Legislation

Development and operation of new and existing mines in Western Australia poses a number of risks to subterranean fauna and habitat, including:

- lowering the water table, which may cause drying of habitats;
- altering water quality, which may exceed species tolerance limits; and
- direct removal of, or disturbance to, habitats .

Subterranean fauna are protected under State and Federal legislation, governed by three Acts:

- Wildlife Conservation Act 1950 (WA) (WC Act);
- Environmental Protection Act 1986 (WA) (EP Act); and
- Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act).

With this legislation in mind, the Environmental Protection Authority (EPA) has developed Environmental Assessment Guideline (EAG) 12 (2013) and Guidance Statement No. 54A (Environmental Protection Authority 2007) which outline considerations and sampling methods for subterranean fauna in Western Australia. These documents provide advice to proponents and the public on the requirements for environmental impact assessment (EIA) and management of subterranean fauna. The assessment reported here was designed in accordance with both the EAG 12 (Environmental Protection Authority 2013a) and 54A (Environmental Protection Authority 2007).

Mining proposals that will potentially impact on groundwater or hypogean habitats that support subterranean fauna, require a risk assessment to ensure mining operations do not threaten the viability of important species or communities. Proponents must demonstrate that any species existing within potential mine-related impact zones also occur outside this area. For taxa restricted to impact zones, a suitable management plan must be developed, which includes ongoing monitoring of subterranean fauna to ensure the persistence of the species (Environmental Protection Authority 2007).

In accordance with these Guidance Statements, potential impacts to subterranean fauna posed by the Project are related to the following:

- Goliath and Six-mile Well deposits. Mining will involve the physical removal of waste and ore material and the lowering of groundwater levels through mine pit dewatering; and
- ·Waste Rock Landform. As a physical structure, the landform may influence the flow of energy into the subterranean habitat in the immediate area. It may also potentially impact the subterranean habitat during construction (e.g. disturbance of surface material).

Potential, indirect impacts on subterranean fauna assemblages may also include an increase in sediment load in run-off from mining activities. Such an increase that could reduce surface-subsurface water exchange during flow periods (e.g., lessen input of resources) and alter groundwater chemistry (Marmonier 1991).

4 Methods

4.1 Desktop Study

4.1.1 Literature Review

A literature review was conducted to gather existing information on subterranean fauna from within the vicinity of the Project Area. The review included technical reports, scientific journal articles and government publications.

4.1.2 Database searches and lists

Database searches were conducted on relevant government databases to identify any subterranean fauna or threatened and priority communities (TEC or PECs) documented from the Project Area or surrounds (**Table 4-1**). Federal and state government lists were also consulted (**Table 4-2**).

Table 4-1: Summary of databases accessed for the Mount Keith Satellite Operations subterranean fauna desktop assessment

Database	GPS Coordinates	Search Radius	Reference
NatureMap	120°35'13"E, 27°24'55"S	20 km	Department of Parks and Wildlife 2016a
Threatened and Priority Ecological Communities	120°35'13"E, 27°24'55"S	50 km	Department of Parks and Wildlife 2016b
Threatened and Priority Fauna	120°35'13"E, 27°24'55"S	50 km	Department of Parks and Wildlife 2016c
WAM Arachnida and Myriapoda	119°34'13"E, 26°30'39"S (NW corner)	NA	Western Australian Museum 2016a
WAM Crustacea	121°35'53"E, S28°19'02"S (SE corner)		Western Australian Museum 2016b

Table 4-2: Summary of federal and state government lists accessed for the Mount Keith Satellite Operations subterranean fauna desktop assessment

List	Authority	Reference
EPBC Act Threatened Ecological Communities List	Federal	Department of the Environment 2016a
EPBC Act Threatened Fauna List		Department of the Environment 2016b
Threatened Ecological Communities List	State	Department of Parks and Wildlife 2015a
Priority Ecological Communities List		Department of Parks and Wildlife 2015b
Threatened and Priority Fauna List		Department of Parks and Wildlife 2015c
WC Specially Protected Fauna Notice 2015		Department of Parks and Wildlife 2015d

4.2 Groundwater Properties

Basic physicochemical data were collected during the stygofauna surveys. The approximate standing water level (SWL) (m bgl) was measured using a Solinst 101 water level meter. A calibrated TPS 90 FLMV multi-parameter field instrument was used to measure pH, water temperature, dissolved oxygen (DO), electrical conductivity (EC), salinity and reduction-oxidation potential (Redox) of the groundwater. The end of hole (EoH) was estimated using the number of rotations of the sampling winch reel required to retrieve stygofauna nets.

4.3 Stygofauna Assessment

4.3.1 Net Haul Sampling

Stygofauna were sampled using haul nets, which have been found to be the most efficient retrieval method (Allford *et al.* 2008). Sampling was consistent with the procedures outlined in the Guidance Statement No. 54a (EPA 2007). The sampling method was as follows:

- Samples were collected using two weighted haul nets with mesh sizes of 150 µm and 50 µm. Each net was fitted with a collection vial;
- The 150 µm net was lowered first, near to the bottom of the hole;
- Once at the bottom, the net was gently raised up and down to agitate the sediments;
- The net was then raised slowly to minimise the 'bow wave' effect that may result in the loss of specimens, filtering the stygofauna from the water column on retrieval;
- Once retrieved, the collection vial was removed, the contents emptied into a 250 ml polycarbonate vial, and preserved with 100 % undenatured ethanol;
- This process was repeated three times with the 150 µm net and three times using the 50 µm net;
- To prevent cross-contamination, all sampling equipment was washed thoroughly with Decon 90 (2 to 5% concentration) and rinsed with potable water after each site;
- In the field, samples were placed into eskies with ice bricks prior to being transferred into a refrigerated environment on-site at the end of each survey day; and
- Samples were couriered back to the MWH laboratory in Perth, where they were stored in 100% ethanol and refrigerated at approximately minus 20°C.

4.3.2 Stygofauna Survey Effort

A total of 64 stygofauna net haul samples have been collected from 21 bores (**Table 4-3, Figure 4-1, Appendix A: Table A-1**). All known suitable and accessible bores available (i.e. not fully cased, were vertical, not inclined) were sampled in the Project Area. Representative images of bores sampled are shown in **Appendix C**. Of the bores sampled, 16 were cased (slotted below standing water level (SWL)), and 5 were uncased.

Stygofauna sampling has occurred over five sample rounds. The first sample round was undertaken in 2006 with five samples collected by Biota (2006a) (**Table 4-3**; **Appendix A: Table A-1**). The additional four sample rounds were undertaken by MWH (as Outback Ecology): November 16 to 18, 2010; March 28 to 29, 2011; June 17 to 21, 2011; and February 1 to 3, 2012.

The number of impact samples collected from within proposed mine pit boundaries are: Goliath pit, 12 samples from 4 bores; Six-Mile pit, four samples from one bore (**Figure 4-1**). The number of groundwater drawdown impact samples collected is not able to be accurately determined. The Goliath deposit is considered to be associated with a surficial regolith aquifer system that will be completely removed with the development of the Goliath pit (Berry 2016). To what extent (lateral and vertical) groundwater drawdown will occur along associated geological structures of the fractured rock aquifer system

associated with the regolith aquifer present at Goliath is not able to be accurately determined. Therefore, bores that are close to the proposed Goliath pit (e.g. less than 1km away) are not able to be reliably designated as occurring within groundwater drawdown zone or not. For Six-Mile deposit area, the 5m modelled groundwater drawdown below natural SWL encompasses the only bore (CP52) that is near to, but outside of, the proposed pit boundary. As with Goliath, the extent (lateral and vertical) of groundwater drawdown that will occur along associated geological structures of the fractured rock aquifer system associated with the regolith aquifer present at Six-Mile outside of the proposed pit and modelled 5m bSWL contour is not able to be accurately determined.

Table 4-3 Summary of stygofauna survey effort

Area		Biota 2006	November 2010	March 2011	June 2011	February 2012	No. Samples	No. Bores
Inside Proposed Pit Boundaries	Goliath	3	4	3		2	**12**	**4**
	Six-mile Well		1	1	1	1	**4**	**1**
Outside Pits	<500m	2	2	1	1	2	**8**	**3**
	>500m, <1km		6	6	6	4	**22**	**6**
	>1km		5	5	5	3	**18**	**7**
Totals		**5**	**18**	**16**	**13**	**12**	**64**	**21**

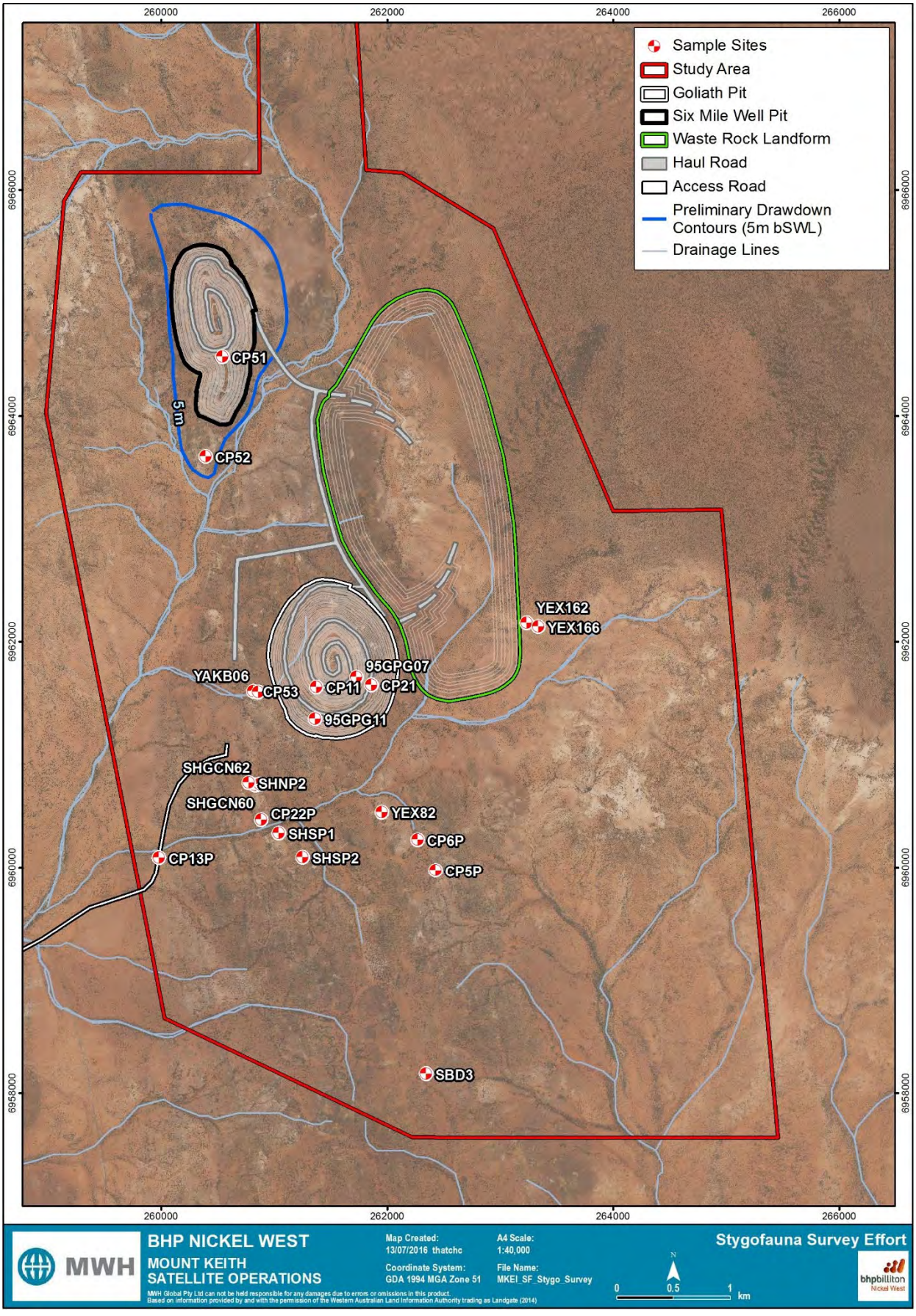

Figure 4-1: Stygofauna survey bore locations in relation to proposed Project footprint.

4.4 Troglofauna Assessment

4.4.1 Litter Trap Sampling

Troglofauna were sampled in accordance with Guidance Statement No. 54a (EPA 2007) using litter traps suspended in bores as follows:

- litter traps were packed with sterilised organic material and sealed to maintain moist, sterile conditions prior to field deployment;
- traps were then wetted with water prior to deployment in bores;
- once installed in the bores, traps were left in place for least six to eight weeks (during each sampling round) to allow adequate time for colonisation by troglofauna; and
- on retrieval, traps were sealed in zip lock bags, labelled, and couriered to the MWH laboratory in Perth for sorting and identification.

In the laboratory, troglofauna specimens were extracted from the litter using Tullgren funnels. Litter was placed into funnels, and light and low heat were applied from overhead lamps to create a temperature gradient of approximately 14°C in the litter. This treatment was applied to encourage any troglofauna, which are light sensitive and prefer humid conditions, to migrate down through the litter as it dried. Troglofauna specimens then fell through a mesh layer into collection vials at the base of the funnels, containing 100% ethanol. After 48 to 72 hours, the litter was removed from the funnels and manually searched under magnification for any remaining troglofauna specimens.

4.4.2 Net Haul Scraping

Net haul scraping has been found to be an efficient method for sampling troglofauna that complements troglofauna trapping (Halse and Pearson 2014, Outback Ecology 2011a, Subterranean Ecology 2008c). Net haul scraping involves:

- lowering a stygofauna net to the bottom of a dry bore, or at least one metre below the standing water level if groundwater was present;
- scraping the net up along the uncased wall surface of the bore on retrieval, with the aim of dislodging and collecting any troglofauna that may be present; and
- repeating the process to a total of four times per borehole, with each scrape sampling a different side of the wall surface of the bore.

In this survey all troglofauna scrape samples were collected as part of stygofauna sampling. Scraping for troglofauna was conducted simultaneously when sampling uncased bores with water present for stygofauna, so that the stygofauna sample also counted as a troglofauna scrape sample. The only difference was that the sample effort was greater, with six net hauls taken per sample rather than four. Stygofauna samples from bores that were fully-cased above the groundwater table were not counted as net haul scrape samples, regardless of whether potential troglofauna taxa may have been collected.

All haul samples were transferred to a 250 ml vial and preserved in 100% ethanol prior to shipment back to MWH's laboratory in Perth for processing. To enhance preservation of specimens and their DNA, samples were kept cool in eskies with ice bricks, then refrigerated at the end of each survey day. All samples were then shipped back to Perth in eskies with ice bricks and placed in freezers to further promote fixation of DNA.

4.4.3 Troglofauna Survey Effort

A total of 81 troglofauna samples (67 litter trap and 14 net haul scrape samples) have been collected from 37 uncased bores (**Table 4-4**, **Figure 4-2**, **Appendix A: Table A-2**). Troglofauna sampling was conducted in refurbished rehabilitated exploration drill holes (referred to herein as bores) that were selected to give good geographical coverage of impact and reference areas within the Project Area. Most of these bores were inclined. Litter trap samples were collected over two trapping rounds conducted from March 26, to May 30, 2011 (9 week duration), and from the May 30, to July 19, 2011 (7 week duration) (**Table 4-4**). Three traps were lost over the entire trapping program due to becoming wedged within bores on retrieval. Representative images of bores sampled are shown in **Appendix B**.

The number of impact samples collected from within proposed mine pit boundaries are: Goliath pit, 15 samples from eight bores; Six-Mile pit, eight samples from four bores (**Table 4-4**). As discussed above, the number of groundwater drawdown impact samples collected is not able to be accurately determined (refer **section 4.3.2**). For Six-Mile deposit area, the 5m bSWL modelled groundwater drawdown encompasses two bores (SMD1187 and SMD1181) that are near to, but outside of, the proposed pit boundary (**Figure 4-2**). For three bores (SMD1178, SMD1180, and YAKAOES03) that are less than 150m from the modelled 5m bSWL groundwater contour, the vertical extent of the potential groundwater drawdown is unknown.

Table 4-4 Summary of troglofauna survey effort

Area		March - May 2011	May - July 2011	February 2012	No. Samples	No. Bores
Inside Proposed Pit Boundaries	Goliath	7	8		**15**	**8**
	Six-mile Well	4	4		**8**	**4**
Outside Pits	<500m	3	5		**8**	**5**
	>500m, <1km	14 (4)	16 (5)	5 (5)	**35 (14)**	**13**
	>1km	6	9		**15**	**7**
Totals		**34 (4)**	**42 (5)**	**5 (5)**	**81 (14)**	**37**

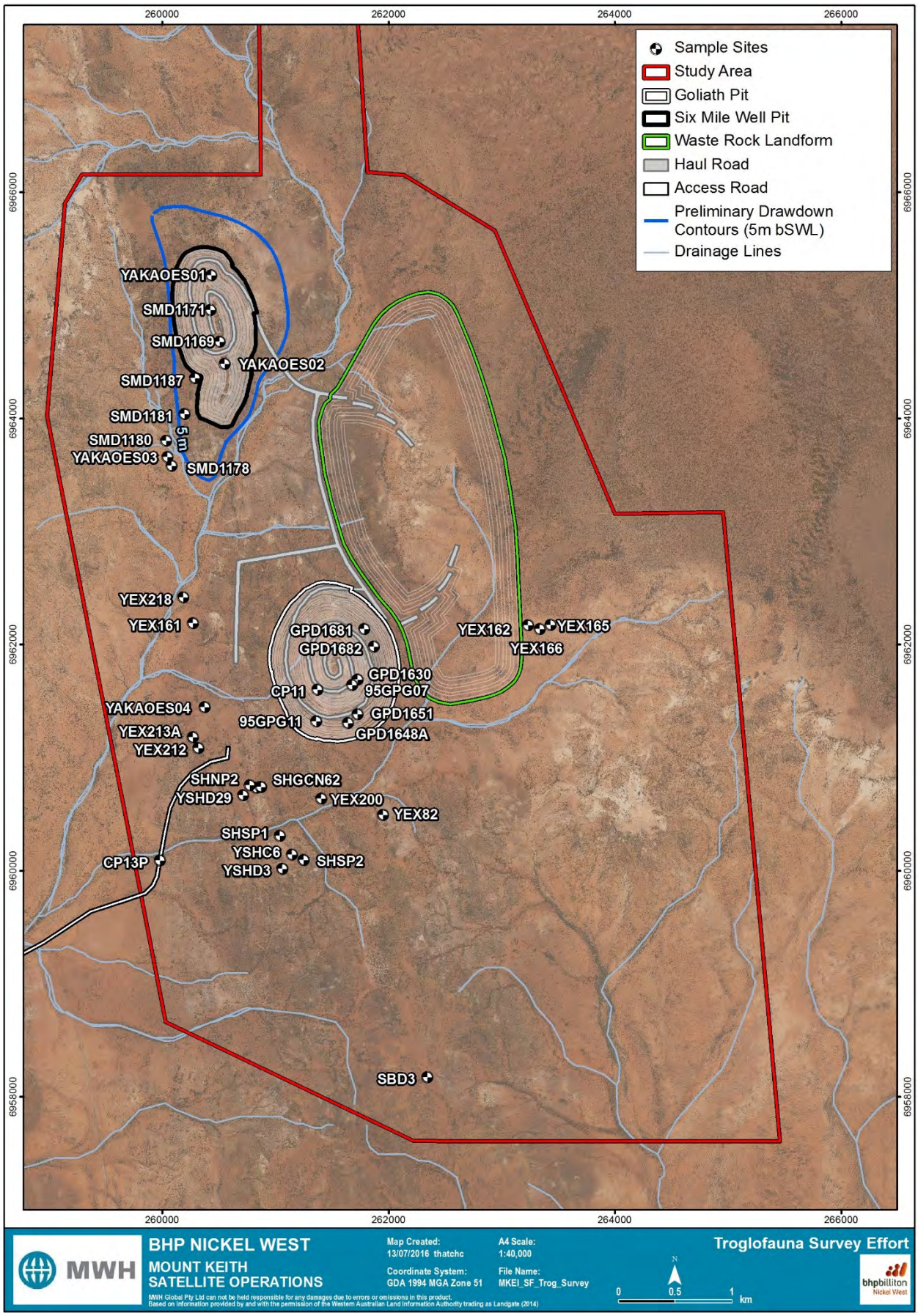

Figure 4-2: Troglofauna survey bore locations in relation to proposed Project footprint.

4.5 Sorting and Identification of Specimens

Preserved samples were sorted manually using Leica MZ6, MZ7.5, M80 and M205C stereomicroscopes by Chris Hofmeester, Syngeon Rodman, and Dr Conor Wilson. Once sorted, any potential subterranean fauna specimens found were preserved in 100% ethanol and stored at approximately minus 18 to 20°C.

Taxa were identified by Dr Jason Coughran, Dr Nicholas Stevens, and Dr Erin Thomas of MWH, using published and unpublished keys and taxon descriptions. Specialist identification for Isopoda and Ostracoda were provided by Dr Rachel King (South Australian Museum) and Prof. Ivana Karanovic (Hanyang University, Seoul), respectively.

4.6 DNA Sequencing

Tissue samples from *Atopobathynella* specimens collected from the Project Area, were sent to Dr Leijs (South Australian Museum) for genetic analyses. The main aims of the molecular analyses were:

- to compare with Lake Way and Lake Maitland material;
- test the robustness of identifications based on morphological characters, including juvenile specimens, and align morphospecies with described and previously sequenced taxa; and
- investigate distribution and phylogeographic patterns of selected taxa to assess the degree of genetic divergence among populations/species across areas sampled within the Project Area.

4.7 Diversity Analysis

The EstimateS software package (Colwell (2013) Version 9.1.0) was used to assess the survey adequacy undertaken by investigating the subterranean fauna diversity recorded in the Project Area. Diversity was analysed using species accumulation rarefaction and extrapolation curves, and species richness estimators (using incidence and abundance data).

The species richness results provide a statistical evaluation of the proportion of the stygofauna and troglofauna assemblages detected. A range in the number of species predicted to form each assemblage was estimated by seven species richness estimators (ACE, Bootstrap, Chao1, Chao2, ICE, Jack 1 and Jack 2). Statistically, it is more robust to show the results of several estimators to provide a range in predicted richness rather than only present one prediction which is not considered statistically sound

4.8 Limitations of the Assessment

Stygofauna sampling was constrained by the lack of suitable holes available throughout the Project Area including within proposed impact zones. The limited number and relatively confined geographical spread of bores can confound the interpretation of sample results of such an intractable habitat, made even more so if the fauna assemblage present exists at low population densities.

Specimens were identified to the lowest taxonomic level where possible. However, specimens could not always be identified to the level of species or morphospecies due to:

- loss or damage of important taxonomic features during collection and/or sorting of specimens;
- lack of adult specimens; or
- limitation in taxonomy, in that the current state of taxonomy for a particular group is insufficiently advanced, and/or relevant taxonomic keys and descriptions are lacking.

While every effort has been made to assess the taxonomy, distribution and conservation significance of the subterranean fauna collected using in-house data collections, publications, publicly available reports, and information provided by specialist taxonomists, some accounts may be limited if specialist information was unavailable.

5 Results and Discussion

5.1 Literature Review

5.1.1 Stygofauna

A number of stygofauna surveys have been undertaken in the area surrounding the Project (≤200 km), predominantly within calcrete associated groundwaters. Calcrete aquifer systems are recognized as providing optimal habitat for stygofauna in the Pilbara and Yilgarn, generally hosting more diverse and abundant assemblages than regolith or fractured rock associated aquifers (Allford *et al.* 2008, Environmental Protection Authority 2007, Humphreys 2008, Outback Ecology 2012d).

Within the surrounding northern Goldfields region, genetic studies have indicated that hydrogeological isolated calcrete systems can represent closed 'subterranean islands' in terms of the species of the stygofauna assemblage present are restricted in distribution to a particular calcrete system only (Cooper *et al.* 2002, Cooper *et al.* 2008, Guzik *et al.* 2008). The Lake Way calcrete systems have been shown to be unique in that genetic data has indicated that for some taxa gene flow does occur among the close neighbouring calcrete systems, particularly among the northern lake associated calcretes, Lake Violet and Uramurdah, and with Millbillillie Bubble Well calcrete. The genetic data was consistent with the hydrogeological assessment. The notion was supported by genetic results reported in Abrams *et al.* (2012) and Outback Ecology (2011, 2012b), that demonstrated the distribution of amphipod, Bathynellacea and dytiscid species to extend from Millbillillie Bubble Well calcrete to Lake Violet and Uramurdah calcretes. In addition, molecular data has shown that *Atopobathynella wattsi* has a distribution extending from the Lake Violet calcrete to the Hinkler Well calcrete (Guzik *et al.* 2008). However, there are instances where hydrogeological data may be inconsistent with the biological data. An example was the molecular investigation of the Browns Range stygofauna assemblage that demonstrated that there was a physical connection between two hydrogeologically distinct fractured rock aquifer systems that were considered isolated from one another, with two bathynellicean species clearly shown to occur in both (Outback Ecology 2014).

Comparative to the diverse calcrete aquifers, few surveys in the area have focused on other aquifer types. Of those, sampling at Cliffs, 22 km north of the Project Area, did not yield any stygofauna from the weathered bedrock zone (Sinclair Knight and Merz 2004). The Project Area specifically, associated with regolith and fractured rock aquifers, was sampled in 2006 (Biota 2006a). Sampling of five bores within the Goliath Project Area collected two amphipod (Neoniphargidae) specimens from YAKB06, 244 m to the west of the proposed Goliath pit boundary (near CP53), and a single oligochaete from CP21 within the proposed Goliath pit (Biota 2006a).

5.1.2 Troglofauna

Information on troglofauna from the area surrounding the Project (≤200 km) is limited in comparison to stygofauna (**Table 5-2**). Most of these troglofauna studies have occurred in calcrete associated habitats and have shown troglofauna to occur in relatively low abundance and diversity compared to stygofauna (Outback Ecology 2011a). This is highlighted by the findings of the current study which identified a low diversity of troglofauna from sampling within the regolith and weathered fractured rock geological facies of the Project Area. In comparison, calcretes in surrounding area including Barwidgee, Yeelirrie and the Lake Way associated calcretes were found to host more diverse troglofauna assemblages (MWH 2015, Outback Ecology 2011a, 2012c, Subterranean Ecology 2011b).

Surveys of non-calcrete associated geologies from the broader Yilgarn region have collected troglofauna from weathered and fractured banded ironstone formations (BIF) and mafic units (Bennelongia 2009, ecologia Environment 2008a, b, Environmental Protection Authority 2010). In Europe, the Azores, and the Canary Islands relatively rich troglofauna assemblages have been found to occur in the 'Milieu Souterrain Superficiel' or mesovoid shallow substratum (MSS) that is characterised as superficial underground compartments beneath the soil profile formed from the cracks and fissures of the weathered bedrock and interstitial spaces within collapsed slopes (Borges 1993, Camacho 1992, Juberthie 1983, Lopez and Oromi 2010).

5.2 Database Searches

There were no threatened or priority subterranean fauna noted in the Project Area or surrounds from a search of the Department of Parks and Wildlife's threatened and priority fauna database (Department of Parks and Wildlife 2016c). A search of the Department of Parks and Wildlife's threatened and ecological communities database did not identify any priority subterranean fauna communities within the Project Area (Department of Parks and Wildlife 2016b). The nearest priority subterranean communities occurred in conjunction with calcrete aquifers to the west and to the south of the Project Area. The Yakabindie calcrete community was the most proximal, the associated buffer zone commencing approximately 16 km south of the proposed pit outlines. The Albion Downs calcrete community and Lake Miranda east and west calcrete communities were each located over 20 km away from the proposed pit outlines, to the west and south, respectively.

A search of the Western Australian Museum's Arachnida and Myriapoda database found close to 100 subterranean fauna records within the region surrounding the Project Area. A sub-set of the most proximal records (occurring within a radius of approximately 50 km) (**Appendix C**) included 40 entries from across eight groups. Araneae (spiders) and pseudoscorpions were well represented with four and nine troglomorphic taxa respectively. Three troglomorphic spider taxa, *Prethopalpus callani* and undescribed species of *Opopaea* and *Desognanops* were recorded from Yeelirrie, approximately 45 km north-west of the Project Area.

The pseudoscorpions primarily belonged to *Tyrannochthonius*, a typically troglobitic genus occurring in calcrete or fractured rock geological facies (Edward and Harvey 2008, Harrison *et al.* 2014). Up to seven undescribed species of *Tyrannochthonius* were collected during sampling in the vicinity of the Miranda East calcrete on Yakabindie Station (25 km south of the Project Area), Lake Maitland/Barwidgee calcrete (45 km north-east of the Project Area) and Yeelirrie. A further two pseudoscorpion taxa, undescribed species of *Austrohorus* and *Beierolpium*, were also collected from Yeelirrie.

Other taxa collected from within the area surrounding the Project and identified as troglofauna included representatives of Cephalostigmata (Symphyla) (Yakabindie Station), geophilid and scolopendrid centipedes (Yeelirrie and Albion Downs, respectively). Troglomorphic palpigrades, particularly *Eukoenenia* sp. and polyxenid millipedes were also recorded from Yeelirrie.

A search of the Western Australian Museum Crustacea database identified over 700 records of subterranean taxa in the region surrounding the Project Area. The closest records (within a radius of approximately 50 km) (**Appendix D**) encompassed stygobitic taxa from groups including amphipods, copepods, isopods, ostracods and syncarids. Records from within the Project Area specifically were limited, comprising two undescribed *Atopobathynella* species (syncarids) and an ostracod (Western Australian Museum 2016b). In general however, subterranean crustaceans in the region were predominantly associated with calcrete habitat in systems such as Yeelirrie, Lake Maitland/Barwidgee, Lake Miranda East and West and Albion Downs. The most proximal of these were troglomorphic

Paraplatyarthrus isopods approximately 25 km south of the Project, within the Lake Miranda calcrete area (Western Australian Museum 2016b).

Differences in taxon diversity between geological units may be partly attributable to sampling bias. However, it is considered to also reflect the more optimal habitable environment hosted within calcrete systems relative to regolith and fractured rock systems.

Table 5-1: Summary of stygofauna surveys undertaken within the region surrounding the Project Area

Deposit / Area	Distance from Yakabindie Project	Stygofauna	Geology / Habitat	Reference
Yakabindie	Within	Amphipods, oligochaetes, syncarids	Regolith	Biota 2006a, current report
Cliffs	22 km north	No stygofauna present	Weathered bedrock	Sinclair Knight Merz 2004
Albion Downs	30 km north	Amphipods, copepods, mites	Calcrete	Biota 2006a
Lake Maitland/ Barwidgee	55 km north-east	Amphipods, copepods, isopods, oligochaetes, ostracods, syncarids	Surficial aquifers, often calcrete	Golder Associates 2010, Cooper *et al* 2007, Outback Ecology 2012a
Lake Way South	60 km north	Amphipods, copepods, oligochaetes, syncarids	Alluvium and dune deposits	Biota 2006a, Outback Ecology unpublished data
Lake Darlot	65 km south-east	Copepods	Specific geology unknown	Western Australian Museum 2016b
Depot Springs	75 km south-west	Amphipods, syncarids, copepods	Colluvium and calcrete	Environmental Protection Authority 2001, Cooper *et al* 2007
Lake Way (Hinkler Well)	75 km north-west	Amphipods, dytiscid beetles, copepods, isopods, oligochaetes, syncarids	Calcrete	Taiti and Humphreys 2001, Karanovic 2004, Cho *et al* 2006, Cooper *et al* 2007, Cooper *et al* 2008, Watts and Humphreys 2009, Cho and Humphreys 2010, Outback Ecology 2012c, MWH 2015
Lake Way (Lake Violet)	90 km north-west			
Lake Way (Uramurdah)	90 km north-east			
Lake Way (Millbillillie)	135 km north			
Yeelirrie	85 km north-west	Amphipods, annelids, copepods, dytiscid beetles, isopods, ostracods, syncarids	Calcrete	Subterranean Ecology 2011, Bennelongia 2015
Jaguar	110 km south	No stygofauna recorded during preliminary investigations	Specific geology unknown	Department of Mines and Petroleum 2010
Marshall Creek Borefield	110 km south	Copepods	Silcrete and alluvial sand	Environmental Protection Authority 2001
Sandstone South Borefield	125 km south-west	Copepods	Highest numbers - calcrete/silcrete	
Sturt Meadows	140 km south	Amphipods, copepods, dytiscid beetles, oligochaetes	Calcrete	Environmental Protection Authority 2001, Bradford *et al* 2010, King *et al* 2012
Paroo Station	160 km north	Amphipods, aphanoneurans, dytiscid beetles, copepods, isopods, oligochaetes, ostracods, rotifers, syncarids	Calcrete, chert	De Laurentiis et al 2001, Cho et al 2006, Cooper *et al* 2007, Watts and Humphreys 2009, Biota 2006b, Outback Ecology 2008, 2010, Bennelongia 2013

Table 5-2: Summary of troglofauna surveys undertaken within the region surrounding the Project Area

Deposit / Area	Distance from Yakabindie Project	Stygofauna	Geology / Habitat	Reference
Yakabindie	Within	Isopods	Regolith, fractured rock	Current report
Lake Miranda (East and West)	25 km south	Isopods	Calcrete	Javidakar 2014, Western Australian Museum 2016b
Yakabindie Station	25 km south	Pseudoscorpions, symphylans	Specific geology unknown - likely calcrete	Western Australian Museum 2016a
Lake Maitland/Barwidgee	45 km north-east	Chilopods, hemipterans, isopods, pauropods, pseudoscorpions	Calcrete, alluvium, colluvium	Outback Ecology 2012b
Lake Way (Hinkler Well)	75 km north-west	Diplurans, pauropods, pseudoscorpions, isopods, polyxenid millipedes, silversfish, spiders, symphylans	Calcrete/alluvium	Platnick 2008, MWH 2015, Western Australian Museum 2016a
Lake Way (Lake Violet)	90 km north-west			
Lake Way (Uramurdah)	90 km north-east			
Millbillillie Bubble Well	110 km north-west	Pseudoscorpions	Specific geology unknown - likely calcrete	Western Australian Museum 2016a
Depot Springs	70 km south-west	Spiders	Specific geology unknown	Western Australian Museum 2016a
Yeelirrie	85 km north-west	Diplurans, hemipterans, isopods, myriapods, palpigrades, pseudoscorpions, spiders, silverfish	Calcrete	Subterranean Ecology 2011, Bennelongia 2015
Sturt Meadows	140 km south	Palpigrades, pseudoscorpions	Calcrete	Barranco and Harvey 2008, Edward and Harvey 2008

5.3 Stygofauna Habitats

5.3.1 Aquifers

Groundwater in the Project Area and local region occurs predominately in unconfined shallow aquifers of less than 100 m deep that are not well defined (BHP Billiton Nickel West 2011). The groundwaters are mostly associated with alluvial and/or colluvial deposits, that represent transported or weathered regolith horizons created by erosional and depositional processes, that have formed over the dunite ultramafic caprock aquitard that hosts the nickel deposits (BHP Billiton Nickel West 2011, Wetland Research and Management 2005). To a lesser degree, groundwater is also present within deeper isolated fractured rock aquifers occurring at structurally controlled locations (BHP Billiton Nickel West 2011). From an economic resource perspective, these groundwater bodies were not considered of significance to the groundwater resources of the region because they did not form a regionally continuous aquifer system, being minor and hydraulically isolated (Wetland Research and Management 2005). However, from an ecological perspective, the spatial and temporal extent of connectivity via the 'interstitial highway' (Ward and Palmer 1994) among the surficial regolith and fractured rock aquifers within the upper Jones Creek catchment could be relatively extensive and sufficient for gene flow to occur among potential stygofauna populations.

The groundwater associated with the thin regolith of the Goliath deposit was not considered a substantial aquifer. Test pumping demonstrated a low permeability in the area with a sustainable pump rate of less than one litre per second (L/sec) estimated (Coffey Partners 1990, Woodward Clyde 1995). Testing of the deeper, sub-regolith aquitard, showed water take was generally very low with yields of greater than 1 lugeon (1 L/min/metre/1000kPa) only recorded once.

The regolith aquifer associated with the Six-mile Well deposit forms the main aquifer in the Project Area and is estimated to contain one to two orders of magnitude more in water storage than the fractured rock aquifers in the proposed pit area (BHP Billiton Nickel West 2011). Within the main surficial aquifer, high permeability and porosity extends to 44 m below the ground surface (BHP Billiton Nickel West 2011). Low to moderate permeability may occur to depths of 60 m and in highly weathered materials formed in other ultramafic lithologies (BHP Billiton Nickel West 2011). The permeability of the fractured rock zone can range from moderate to high but the porosity of the fault zones are low and with limited lateral extent (BHP Billiton Nickel West 2011). Pump testing in the southern area of the Six-mile Well deposit recorded a constant rate of 9.6 L/sec and indicated a total storage of about 100 megalitres (ML) within the highly porous central and shallow part of the aquifer (Coffey Partners 1990). The drawdown and recovery patterns indicated high permeability of the aquifer but with limited extent. The saturated extent of the main regolith aquifer declines to the south outside of the proposed pit boundary as the more deeply weathered ultamafic ore-bodies gives way to less permeable fresh bedrock (BHP Billiton Nickel West 2011).

The overall static water levels across the Project Area are relatively flat with a slight hydraulic gradient running south down Jones Creek away from the deposit areas (BHP Billiton Nickel West 2011). The static

water levels within the Six-mile Well deposit range from 16 to17 m bgl within the bed of Jones Creek, and 25 to 35 m bgl outside of the creek beds (BHP Billiton Nickel West 2011). Within the Goliath deposit, static water levels range from approximately 25 to 35 m bgl.

5.3.2 Groundwater Properties

Recorded groundwater quality parameters across the Project Area during the 2010/11 surveys were suitable for stygofauna habitation. Salinity ranged from fresh (280 parts per million [ppm]) to hyposaline (7,730 ppm), sensu Hammer (1986), and was particularly variable within the Goliath area (**Table 5-3**). There was seasonal variation in salinity among bores, with the lower salinity levels recorded corresponding with recharge from winter rainfall and the higher concentrations occurring in the drier months of March and June (**Appendix E**). The ranges recorded were generally consistent with salinity levels previously recorded for the area. The salinity of the main regolith aquifer at Six-mile Well mostly ranged from 3,000 to 8,000 ppm (Coffey Partners 1990) with surrounding isolated fractured rock aquifers generally of lower salinity ranging from 700 to 5,400 ppm (Coffey Partners 1991). Overall, the groundwater pH ranged from circumneutral (6.5-7.5) to alkaline (>7.5). The most diverse stygal communities inhabit calcareous environments between pH 7.2 and 8.2 (Humphreys 2008), and while low pH can restrict distribution, some ostracods have been documented from pH as low as 4.4 (Reeves *et al.* 2007).

Dissolved oxygen levels ranged from anoxic (2.78 ppm) to oxygenated (7.77 ppm). While concentrations below 5 ppm may adversely affect surface aquatic biota, stygofauna have been documented from sub-oxic conditions well below 1 ppm in coastal environments (Chapman and Kimstach 1996, Humphreys 2008). Groundwater temperature fluctuated with seasonal variations (ranging from 18.7 to 28.1°C) with minimal differences across the Project Area for the same sample round (**Appendix E**).

The variation in standing water level (SWL) among bores reflected the local topography across the Project Area, particularly within the Goliath region (**Table 5-3**). Generally the SWL were closer to the surface to the south of Goliath at Serpentine Hill (15 m bgl), with the area situated within a valley floor. The remaining bores were situated within regions of higher elevation, where the distance to groundwater was greater, averaging SWL's between 20 to 25 m bgl. On the whole, there was little variation in SWL among sample rounds, with most fluctuations less than 0.5 m (**Appendix E**). The greatest fluctuations recorded were between 0.5 to 1.5 m. Fluctuations were inconsistent among sample rounds. In many instances, the November 2010 and/or June 2011 SWL's recorded were greater than recorded for March 2011 despite the large amount of rainfall in February 2011. In other instances, the March SWL's were greater. The standing water levels measured against the Australian Height Datum (AHD) were shown to be relatively flat across the Project Area (range: Six-mile Well deposit 502.9 to 505 m AHD; Goliath deposit 503.6 to 506.8 m AHD) with a slight hydraulic gradient running south down Jones Creek away from the deposit areas (499.2 m AHD) (BHP Billiton Nickel West 2011b).

Table 5-3 Summary of groundwater properties within the Project Area. DO = dissolved oxygen; EoH – end of hole; m bgl = metres below ground level; n = number of samples; SWL = standing water level.

Project Area	Value	D.O. (ppm)	Temp (°C)	Salinity (ppm)	pH (unit)	Redox (mV)	SWL (m bgl)	EoH (m bgl)
Goliath	Min	3	18.70	283.00	7.18	24	8.45	30.60
	Max	6.75	26.80	7730.00	8.06	193	45	200
	Mean	4.87	25.09	1636.00	7.68	124.87	25.90	69.46
	n	16	12	12000	16	15	17	19
Six-mile Well	Min	3.37	23.80	2360.00	6.71	-192	10	36.90
	Max	6.30	27.30	4860.00	7.65	154	28.80	78.30
	Mean	5.10	25.68	3395.00	7.13	54.83	21.84	53.79
	n	6	4	4000	6	6	9	8
Waste Rock Landform	Min	4.05	23.10	482.00	8.23	152	20	49.50
	Max	4.09	23.90	482.00	8.25	181	24.30	81
	Mean	4.07	23.50	482.00	8.24	166.50	22.43	61.65
	n	2	2	1000	2	2	3	4
Serpentine Hill	Min	2.78	21.70	4.390	6.98	-63	10.80	36.90
	Max	6.83	26.60	2070.00	8.56	188	20.85	99
	Mean	5.04	24.71	1389.27	7.75	102.67	14.86	61.89
	n	21	20	16000	21	21	22	21
Sheba	Min	6.63	28.10	1176.00	7.74	124	26.04	90
	Max	7.77	28.10	1176.00	7.77	132	27.10	99
	Mean	7.20	28.10	1176.00	7.76	128	26.57	95
	n	2	1	1000	2	2	2	2
Overall	Min	2.78	18.70	4.390	6.71	-192	8.45	31
	Max	7.77	28.10	7730.00	8.56	193	45	200
	Mean	5.04	24.83	1735.05	7.67	107.54	20.46	63.80
	n	47	46	30000	47	46	53	55

5.4 Stygofauna Survey

5.4.1 Stygofauna Findings

In total, 75 stygofauna specimens, representing at least seven species (potentially eight) from four higher level taxonomic groups (Amphipoda, Bathynellacea, Oligochaeta, and Ostracoda) were collected from six of the 21 bores sampled in the Project Area (**Table 5-4**, **Figures 5-1 & 2, Appendix F: Tables F-1 & 2**). The Bathynellacea was the most diverse group with four species recorded, all of which are singletons (known from a single specimen only). The Oligochaeta was the most abundant group with 68 specimens collected. The Oligochaeta may likely to be represented by one morphospecies Enchytraeidae sp. OES10, however, the material collected by Biota in 2006 was not identified to family level and the specimen could not be located for further examination.

The findings for each of the proposed pit areas are summarised as follows:

- Goliath — No stygofauna taxa were collected from within the proposed Goliath pit boundary during the 2010 to 2012 stygofauna sample rounds. Previous sampling by Biota (2006a) did record an unidentified oligochaete species from bore CP21, within the proposed pit boundary (**Figure 5-3 & 4,Table 5-4, Appendix F**). There is a likelihood that this unidentified species could be the same morphospecies as Enchytraeidae sp. OES10 that has also been recorded from within the proposed Six-Mile Well pit boundary as well as from outside likely groundwater drawdown impact area.

  An amphipod, identified as a Neoniphargidae species, was also recorded in 2006 from bore YAKB06 that is located less than 200 m outside the proposed pit boundary (**Figure 5-3**). As discussed above (refer **Section 4.3.2**) the extent of the groundwater drawdown that would be associated with the mining of the Goliath pit is not known. However, it is considered likely that there would be a significant drawdown occurring at this site located close to the pit. Therefore, the only recorded location of the Neoniphargidae species is considered to be within the groundwater drawdown impact zone associated with the dewatering of the Goliath pit.

- Six-Mile Well — Three species, *Atopobathynella* sp. OES8, *Atopobathynella* sp. OES11 and Enchytraeidae sp. OES10, were collected from within the proposed Six-Mile Well pit boundary from Boer CP51 during the 2010 to 2012 stygofauna sample rounds (**Figure 5-3**). The distributions of both *Atopobathynella* sp. OES8 and *Atopobathynella* sp. OES11 have not been demonstrated to occur outside the proposed pit impact area. Enchytraeidae sp. OES10 was the only species to have been recorded from outside the proposed pit having also been collected from within the proposed Goliath pit boundary as well as from outside the likely groundwater drawdown impact area.

  The Ostracoda species, *Gomphodella* sp. IK2, was collected on a single occasion from Bore CP52 within the modelled 5m bSWL groundwater drawdown impact area associated with the dewatering of Six-Mile Well pit (**Figure 5-3**).

Of the seven identified species, three species, *Atopobathynella* sp. OES9, Bathynellidae sp. OES2, and Enchytraeidae sp. OES10, have been recorded from outside proposed impact areas. The remaining four species, *Atopobathynella* sp. OES8, *Atopobathynella* sp. OES11, *Gomphodella* sp. IK2 and Neoniphargidae sp., are of conservation concern as their distributions have not been demonstrated to extend beyond proposed impact areas.

Table 5-4: Stygofauna taxon diversity and distribution. Orange shaded cells indicate taxa recorded from within the pit outlines only; Yellow shaded cells indicate taxa recorded from areas of likely groundwater drawdown only.

Subterranean Fauna	Abundance	Area	Bore ID	Location	Comments
Stygofauna Taxa					
Amphipoda					
Neoniphargidae sp. (Biota 2006)	2	Goliath	YAKB06	Near pit (<200m)	Of conservation concern. Undescribed species collected by Biota (2006a). Specimen could not be found for further examination. No additional amphipod material collected in later surveys.
Bathynellacea					
Atopobathynella sp. OES8	1	Six-mile Well	CP51	Inside pit	Of conservation concern. DNA sequencing failed but morphologically distinct from other *Atopobathynella* species.
Atopobathynella sp. OES9	1	Serp Hill South	CP22P	Outside pits (>500m, <1km)	Not of conservation concern. DNA analysis demonstrated that distinct from other *Atopobathynella* species
Atopobathynella sp. OES11	1	Six-mile Well	CP51	Inside pit	Of conservation concern. DNA analysis demonstrated that distinct from other *Atopobathynella* species.
Bathynellidae sp. OES2	1	Serp Hill South	CP22P	Outside pits (>500m, <1km)	Not of conservation concern. DNA analysis demonstrated that distinct from other Atopobathynella species
Oligochaeta					
Enchytraeidae sp. OES10	67	Six-mile Well, Serp Hill South	CP13P, CP21, CP51	Inside & Outside pits (>1km)	Not considered to be of conservation concern. Enchytraeidae species generally considered widespread in distribution and not stygobitic, more stygophiles or stygoxenes. Can be semi-aquatic.
Oligochaeta sp. (Biota 2006a)	1	Goliath	CP21	Inside pit	Undescribed species collected by Biota (2006a). Specimen could not be found for further examination. There is likelihood that may be same species as Enchytraeidae sp. OES10. However, this cannot be verified. Conservation status not clear.
Ostracoda					
Gomphodella sp. IK2	2	Six-mile Well	CP52	Near pit (>300m, <500m)	Of conservation concern.

Amphipoda

Stygobitic amphipods, particulary chiltoniid species, have been relatively commonly recorded from many of the northern Yilgarn calcretes sampled (Bradford *et al.* 2013, Bradford *et al.* 2010, Cooper *et al.* 2007, Guzik *et al.* 2011, Subterranean Ecology 2011b). However, we are not aware of stygobitic amphipod species been collected from fractured rock aquifer systems in the northern Yilgarn area. Within well studied calcrete systems (e.g. Barwidgee, Lake Way associated calcretes, Laverton Downs, Sturt Meadows, and Yeelirrie), molecular phylogenetic analyses have revealed that many of the commonly collected amphipod species possessed relatively broad distributions (Bradford *et al.* 2013b, Guzik *et al.* 2011, (MWH 2015, Outback Ecology 2012b, d), Subterranean Ecology 2011). The single chiltoniid species commonly recorded from the Yeelirrie calcrete system was shown to have a distribution that ranged for approximately 70 km from the most north-western survey line (P) down through many of the Yeelirrie calcretes to the south-east of the Yeelirrie salt lake playa (Subterranean Ecology 2011). This may represent one of the broadest distributions recorded from a stygobitic amphipod in the Yilgarn or Pilbara regions. The molecular analysis did reveal a relativley high haplotype diversity present and suggested that there is likely to be a degree of gene flow restriction between geographically distant populations (Finston and Berry (2011) in Subterranean Ecology 2011).

Bathynellacea

All species of Bathynellacea globally are considered to be stygobitic. The domination of the stygofauna assemblage at the Project Area by bathynellacean diversity is similar to studies undertaken in north-western and north-eastern Australia that have also found bathynellaceans to be most commonly collected component of other fractured rock and alluvial aquifers (Hancock and Boulton 2008, Outback Ecology 2014). A genetic study as part of the Browns Range Project, in the south eastern Kimberley region, identified 15 bathynellacean species from fractured rock aquifer systems with five species found to be relatively widespread with distributions extending for further than 10 km (Outback Ecology 2014). Two of these widespread species were found to have distributions that spanned what were considered hydrogeologically to be two separate fracture rock aquifer systems within the Browns Range Metamorphics and the surrounding Gardiner Sandstone geological unit. The genetic analysis confirmed that there existed subterranean habitat connections between these two distinct geological units.

Tissue of all bathynellacean taxa collected from the Project Area were sent for molecular analysis. Amplification of DNA sequence from the CO1 gene was successful for all taxa except *Atopobathynella* sp. OES8, which was morphologically distinct from the other *Atopobathynella* species based on morphological characteristics considered important in determining species limits (Cho *et al.* 2006). *Atopobathynella* species from the Project Area were found to be highly divergent from Lake Way, Lake Way South, Barwidgee and Yeelirrie species (Outback Ecology 2012a).

Oligochaeta

The taxonomy and ecology of the Enchytraeidae is poorly known, with no stygal species described to date (Pinder 2009, Pinder 2007). These worms are commonly recorded in subterranean fauna surveys, and occur in both surface and subterranean aquatic systems (freshwater and marine), or semi-aquatic and terrestrial habitats (Outback Ecology 2011a, Rota *et al.* 2007, van Vliet *et al.* 1997). Genetic analyses of Enchytraeidae material commonly collected at Browns Range revealed that it represented one, widely distributed species (Outback Ecology 2012a).

It is not known whether Enchytraeidae sp. OES10 is an aquatic (inhabiting the aquifer), semi-aquatic or terrestrial oligochaete species. Terrestrial invertebrate fauna are often collected in stygofauna nets having either being dislodged from the soil profile during retrieval of the nets or collected from the water column into which they may have fallen (Outback Ecology 2011a, Outback Ecology unpublished data, Subterranean Ecology 2008b, c). Some Enchytraeidae species have been demonstrated to not be obligate groundwater inhabitants, with genetic data showing material collected in troglofauna traps were conspecific (same species) with material collected from stygofauna net hauls (Leijs 2013, Outback Ecology 2011b). However, no Enchytraeidae sp. OES10 material was collected from the relatively substantial trapping effort conducted. It is for this reason that Enchytraeidae sp. OES10 is considered a putative stygofauna species.

Ostracoda

Ostracods are commonly collected in stygofauna surveys with many species considered to be stygophiles or stygoxenes. The genus *Gomphodella* is endemic to Australia and is composed of both surface water and groundwater dwelling species (Karanovic 2009). *Gomphodella* sp. IK2 was identified from juvenile material as a stygobitic species (Outback Ecology 2012a).

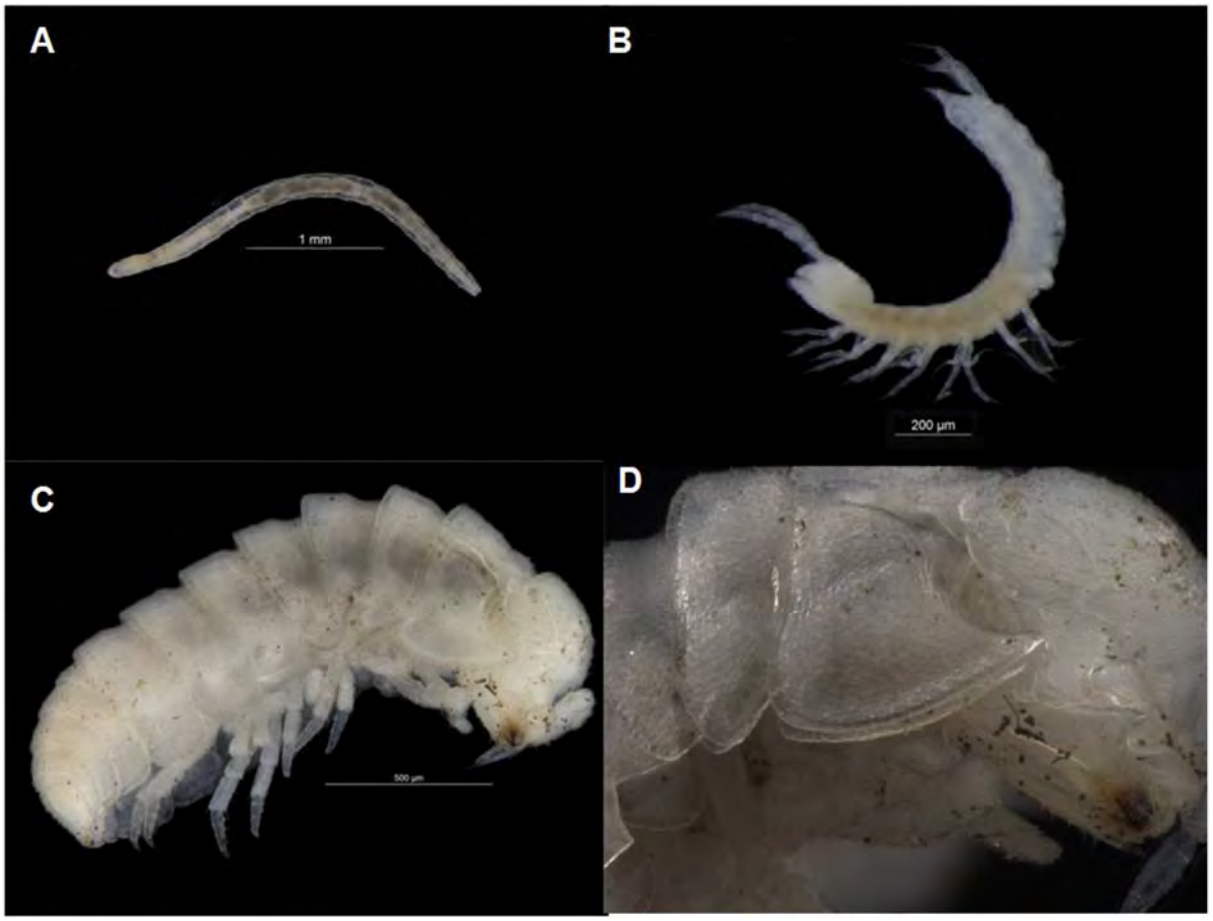

Figure 5-1: Representative stygofauna and troglofauna taxa collected from subterranean fauna sampling. A) Enchytraeidae sp. OES10; B) *Atopobathynella* sp. OES9; C) & D) *Troglarmadillo* sp. OES3.

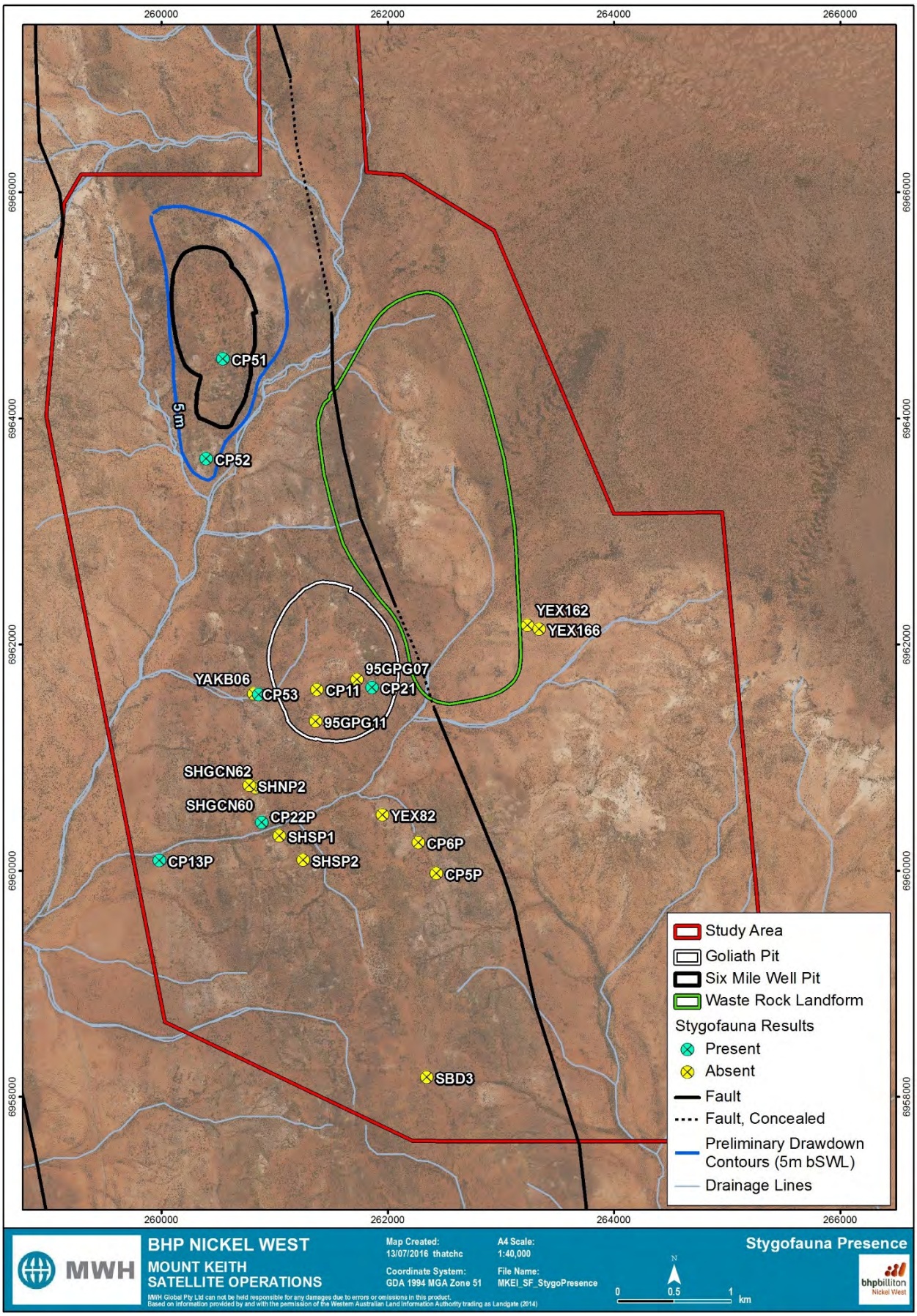

Figure 5-2: Overview of stygofauna sample sites indicating recorded presence or absence.

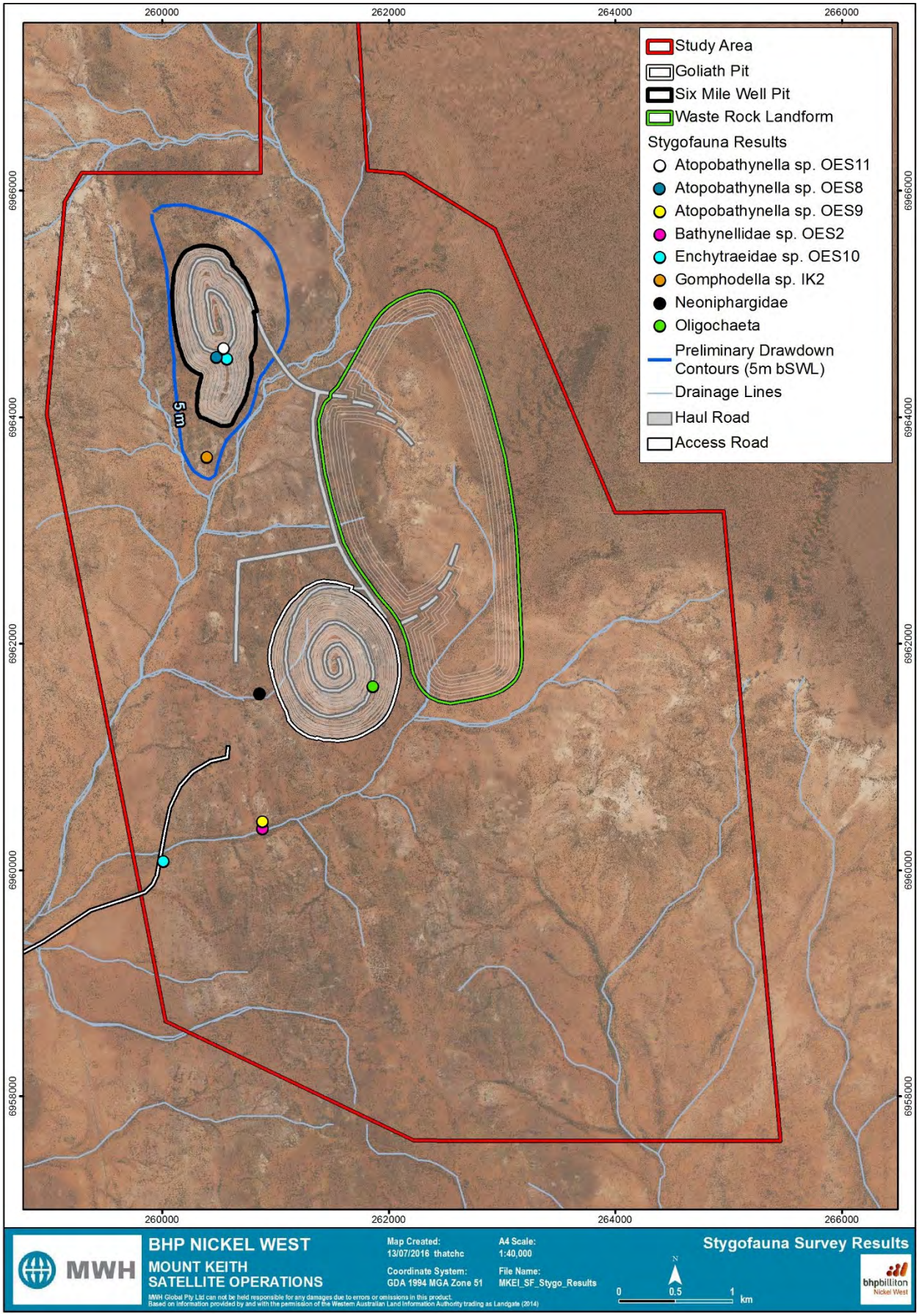

Figure 5-3: Distribution of stygofauna recorded.

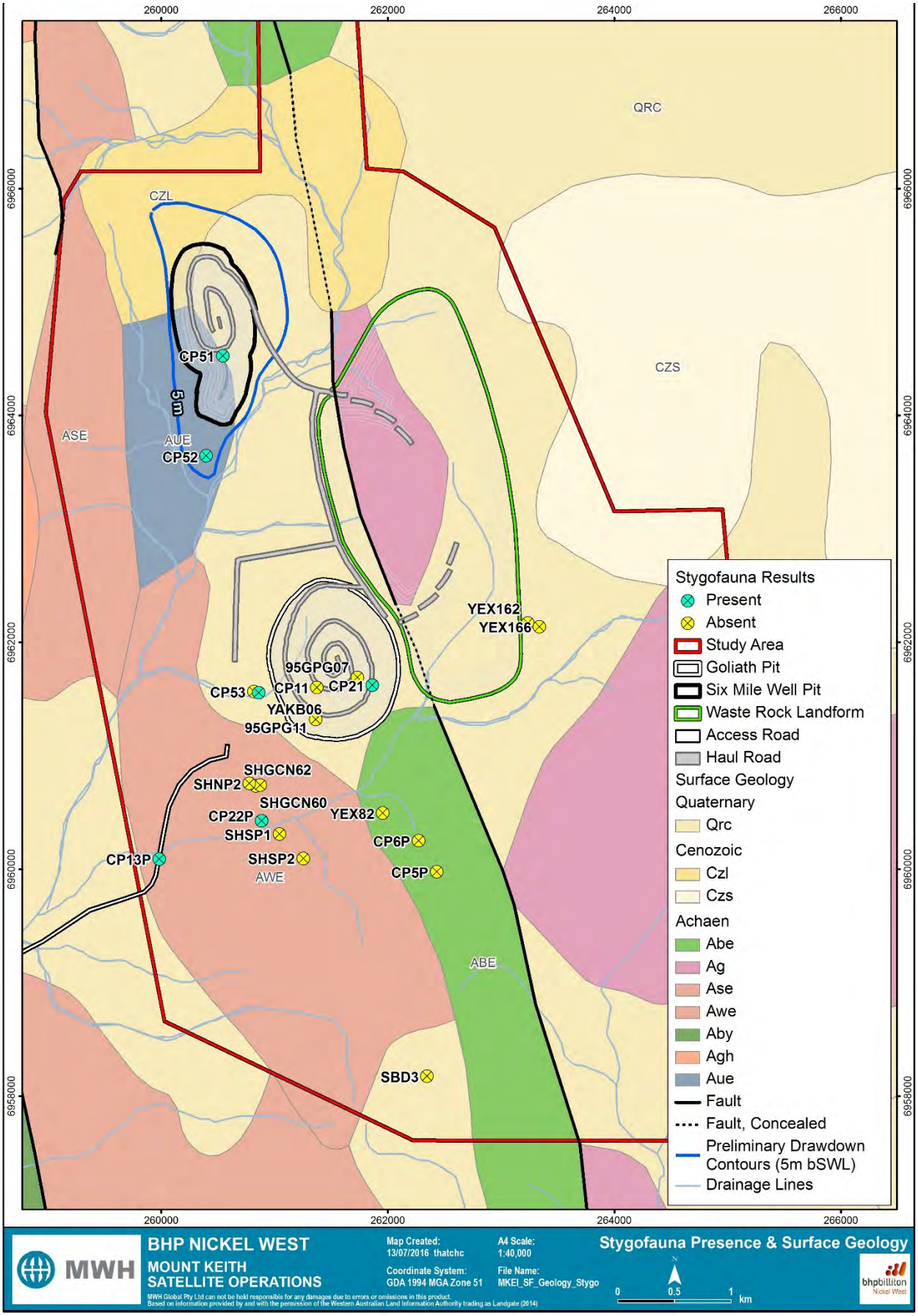

Figure 5-4: Distribution of stygofauna recorded in relation to subsurface geology.

5.4.2 Stygofauna Survey Adequacy

Regulatory Guidelines

The EPA EAG 12 (2013) stipulates that the appropriate level of survey required depends on the likely presence of subterranean fauna, the degree of impact proposed, and adequacy to reliably inform decisions as part of the EIA process as to whether a proposal meets the EPA's objective and is tailored to the circumstances of the proposal. The sampling effort conducted to date has exceeded the minimum requirements of 6 to 10 samples recommended by the EPA Guidance statement 54a (2007) for a Level 1 (pilot) survey and was more than sufficient in providing a reliable indication that stygofauna are present in the Project Area. The presence of stygofauna in the area, in conjunction with the high degree of impact proposed, means that a comprehensive Level 2 (baseline) survey would be required to provide a reliable characterisation of the stygofauna assemblage present in the Project Area and in relation to the proposed direct impact zones (pits associate groundwater drawdown).

The EPA Draft Guidance statement 54a (2007) recommends that in areas that are likely to host 'significant stygofaunal values', a minimum of 40 samples for a comprehensive Level 2 (baseline) survey are required to be collected from at least 10 bores within the proposed impact area. The definition of 'significant values' is not specified but has been interpreted to relate to the species richness present in or associated with the proposed development area. In addition, the minimum survey effort is considered to relate to an impact area on a connected aquifer system (i.e. a single, interconnected habitat), not a collated impact survey effort of separate aquifer systems that are each likely to host distinct stygofauna assemblages with no, or restricted, gene flow occurring among each system.

The number of samples collected for this assessment from within each of the proposed pit areas, and associated groundwater drawdown zone, does not exceed the minimum recommended survey intensity of 40 samples. The survey intensity undertaken to date is considered to be insufficient to achieve a high level of knowledge of the stygofauna assemblage present in the Project Area and, therefore, does not provide a high level of confidence in assessing the potential impacts posed by the proposed Project in accordance with EPA EAG 12 (2013a).

Species Diversity Analysis

A total of eight stygofauna taxa were considered to have been collected from the Project Area (treating Oligochaeta sp. as a separate species to Enchytraeidae sp. OES10). The species richness predicted to occur across the Project Area ranged from 10.6 to 50.8 species (**Figure 5-5, Table 5-5**). The species accumulation curves for all of the species richness estimators are still trending upwards with ICE and Chao 2 approaching exponential increases. None of the estimators are approaching a plateau. The stygofauna sampling undertaken to date is estimated to have recorded between 15.8 to 75.7 percent of the assemblage predicted to exist. The high species richness predicted by ICE (50.8) is considered to be an unreliable estimate as the species richness of many well studied calcrete systems do not come close to exceeding this, with Yeelirrie the only known exception. The extrapolation to 130 samples predicts that

a 100 percent increase in survey effort will result in the collection of an additional six species from the Project Area.

The species accumulation curves indicate that the survey intensity undertaken has not been sufficient in providing a high level of knowledge of the stygofauna assemblage present in the Project Area and therefore, does not provide a high level of confidence in assessing the potential impacts posed by the proposed Project in accordance with EPA EAG 12 (2013a).

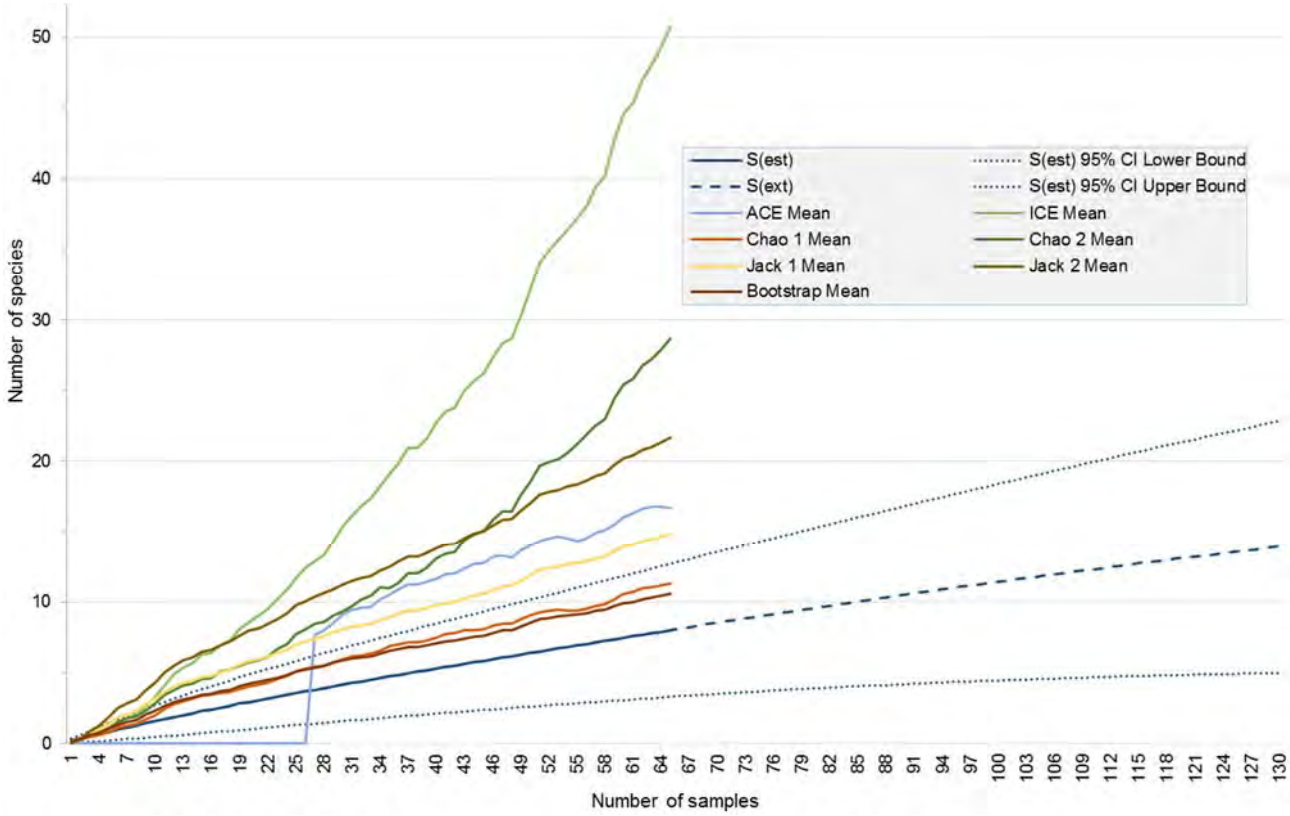

Figure 5-5: Stygofauna species accumulation curves for observed (S(est)), extrapolated (S(ext); to 130 samples), and various diversity estimators (EstimateS (Colwell 2013)) based on all recorded results (including Biota (2006)) from 2006 to 2012 sample rounds for the Mount Keith Satellite Operations Area.

Table 5-5: Observed stygofauna species diversity recorded from 2006 to 2012 sample rounds (including Biota (2006)) of the Mount Keith Satellite Operations Area compared to estimated diversity using EstimateS (Colwell 2013) diversity estimators.

Observed vs Estimated		Obs. & Pred. spp richness	% Predicted collected
Obs.	Sobs	8	
	Extrapolated (130 samples)	14.0	57.2%
Diversity estimators	Bootstrap Mean	10.6	75.7%
	Chao 1 Mean	11.3	70.9%
	Jack 1 Mean	14.9	53.7%
	ACE Mean	16.8	47.8%
	Jack 2 Mean	21.7	36.9%
	Chao 2 Mean	28.7	27.9%
	ICE Mean	50.8	15.8%
Range		10.6 — 50.8	15.8 — 75.7%

5.5 Troglofauna Survey

5.5.1 Troglofauna Findings

Two troglofauna species, Campodeidae sp. OES2 (Diplura) and *Troglarmadillo* sp. OES3 (Isopoda) were collected from two of the 37 bores sampled (**Table 5-6, Figure 5-1, Figure 5-6, Appendix F: Tables F-1 & 2**). A single specimen of *Troglarmadillo* sp. OES3 was collected in litter traps each sample round from the same bore, YSHD29, within the Serpentine Hill area, more than 900 m to the south west of the proposed Goliath pit boundary (**Figure 5-7**). The dipluran, Campodeidae sp. OES2, was collected in a scrape sample from bore SHGCN62, near to where the isopod was recorded, close to 900 m to the south west of the proposed Goliath pit boundary.

No troglofauna species were collected from within the proposed Goliath and Six-Mile Well pit boundaries or likely associated groundwater drawdown impact areas. Therefore, the proposed Project does not pose a risk to the long-term survival of any known species of troglofauna. The results of the troglofauna survey demonstrated that the interstitial spaces within the regolith and weathered fractured rock geologies in and near to the Project Area do not harbour a diverse or abundant troglofauna assemblage. The potential habitats associated with these subsurface geologies are widespread and contiguous throughout the Project Area and surrounding region (**Figure 5-8**). Therefore, the distributions of potentially undetected troglomorphic species are unlikely to be restricted to a small area only because of the continuity and extent of habitat present.

Table 5-6: Troglofauna taxon diversity and distribution.

Subterranean Fauna	Abundance	Area	Bore ID	Location	Comments
Troglofauna Taxa					
Diplura					
Campodeidae sp. OES2	1	Serp Hill South	SHGCN62	Outside pits (>500m, <1km)	Not of conservation concern.
Isopoda					
Troglarmadillo sp. OES3	2	Serp Hill South	YSHD29	Outside pits (>500m, <1km)	Not of conservation concern.

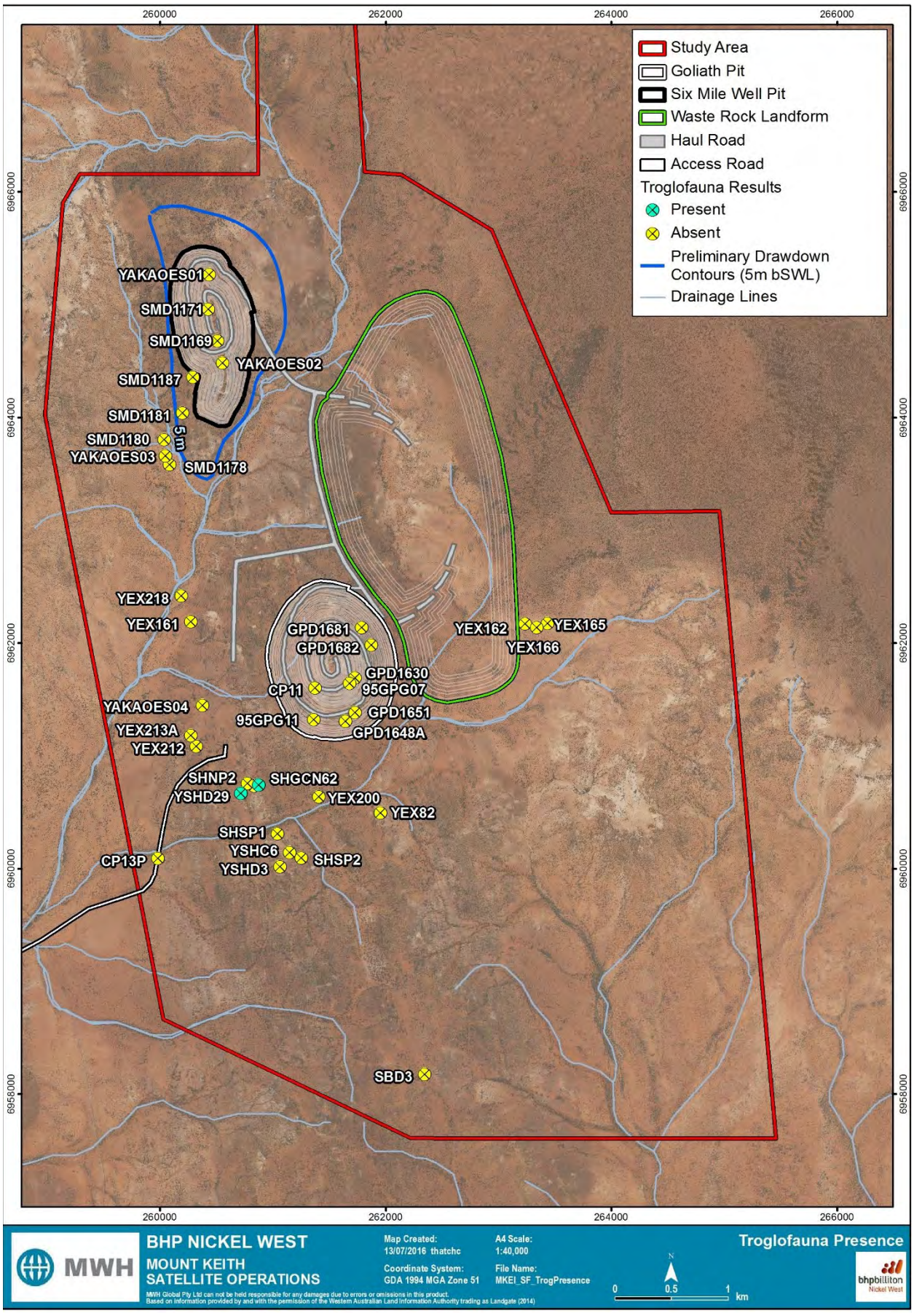

Figure 5-6: Overview of troglofauna sample sites indicating recorded presence or absence.

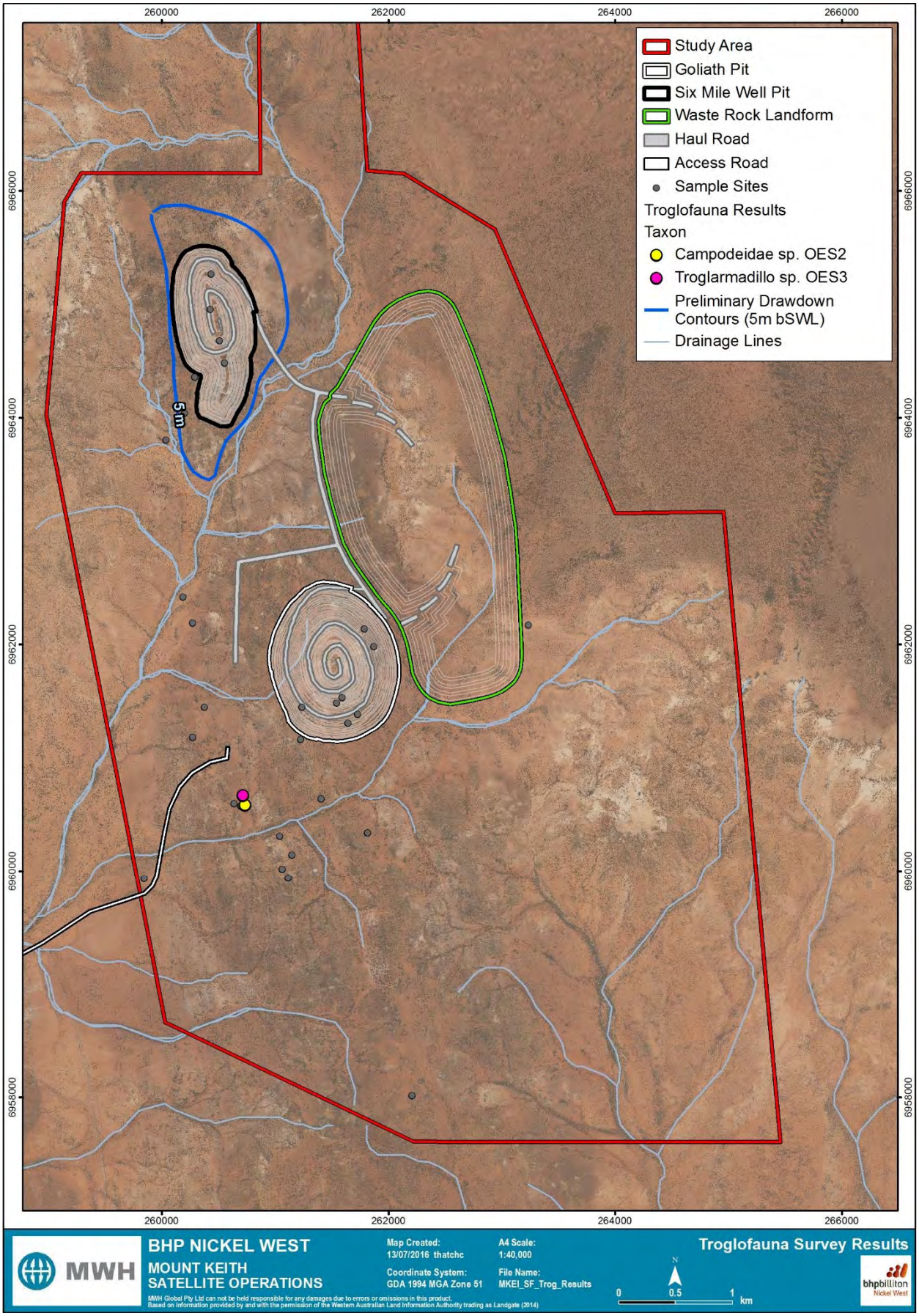

Figure 5-7: Distribution of troglofauna recorded.

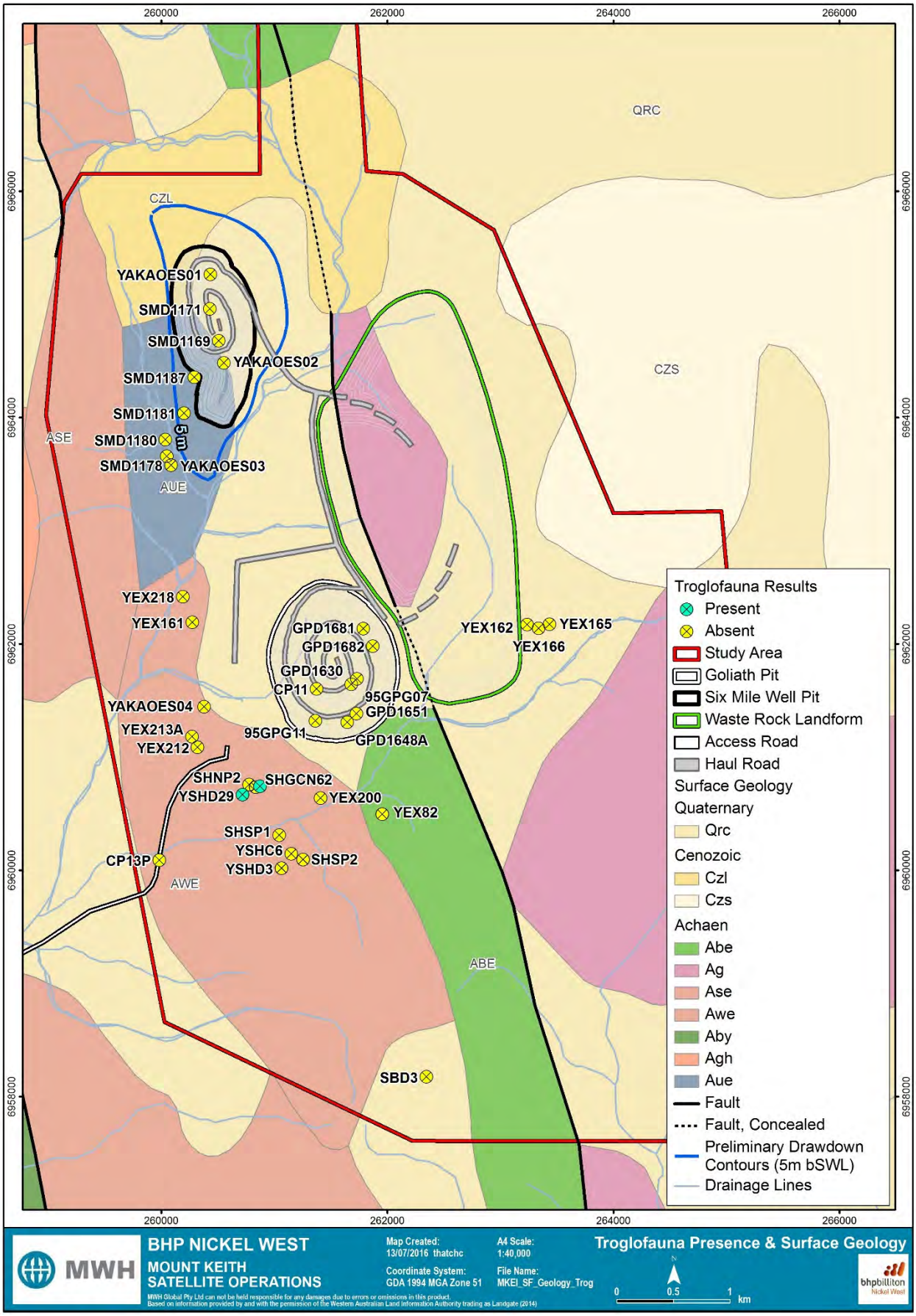

Figure 5-8: Distribution of troglofauna recorded in relation to subsurface geology.

5.5.2 Troglofauna Survey Adequacy

Regulatory Guidelines

The EPA EAG 12 (2013) stipulates that the appropriate level of survey required depends on the likely presence of subterranean fauna, the degree of impact proposed, and adequacy to reliably inform decisions as part of the EIA process as to whether a proposal meets the EPA's objective and is tailored to the circumstances of the proposal. The EPA Guidance statement 54a (2007) recommends that for Level 2 (baseline) surveys in areas that are likely to host 'significant troglofaunal values', a minimum of 60 samples deployed over two rounds for a minimum of six weeks each are required. The sampling effort conducted to date within the proposed pit impact areas has exceeded the minimum requirements of 6 to 10 samples recommended by the EPA Guidance statement 54a (2007) for a Level 1 (pilot) survey. This sample effort was more than sufficient in providing a reliable indication that troglofauna were not present within the proposed pit boundaries. The total number of samples collected as part of this assessment of an area that was demonstrated to have limited prospective habitat for troglofauna, exceeded the recommended baseline minimum with 89 samples. The comprehensive Level 2 (baseline) survey undertaken does provide a reliable characterisation of the troglofauna assemblage present in the Project Area and in relation to the proposed direct impact zones (pits and associate groundwater drawdown).

Species Diversity Analysis

A total of two troglofauna taxa were collected from the Project Area. The species richness predicted to occur across the Project Area ranged from 2 to 3 species (**Figure 5-9, Table 5-7**). The species accumulation curves for five of the seven species richness estimators have reached a plateau or are trending downwards. Only ACE and ICE are still trending upwards. The troglofauna sampling undertaken to date is estimated to have recorded between 66.7 to 100 percent of the assemblage predicted to exist. The extrapolation to 162 samples predicts that a 100 percent increase in survey effort will result in the collection of an additional 0.4 species from the Project Area.

The species accumulation curves indicate that the survey intensity undertaken has been sufficient in providing a high level of knowledge of the stygofauna assemblage present in the Project Area and therefore, does provide a high level of confidence in assessing the potential impacts posed by the proposed Project in accordance with EPA EAG 12 (2013a).

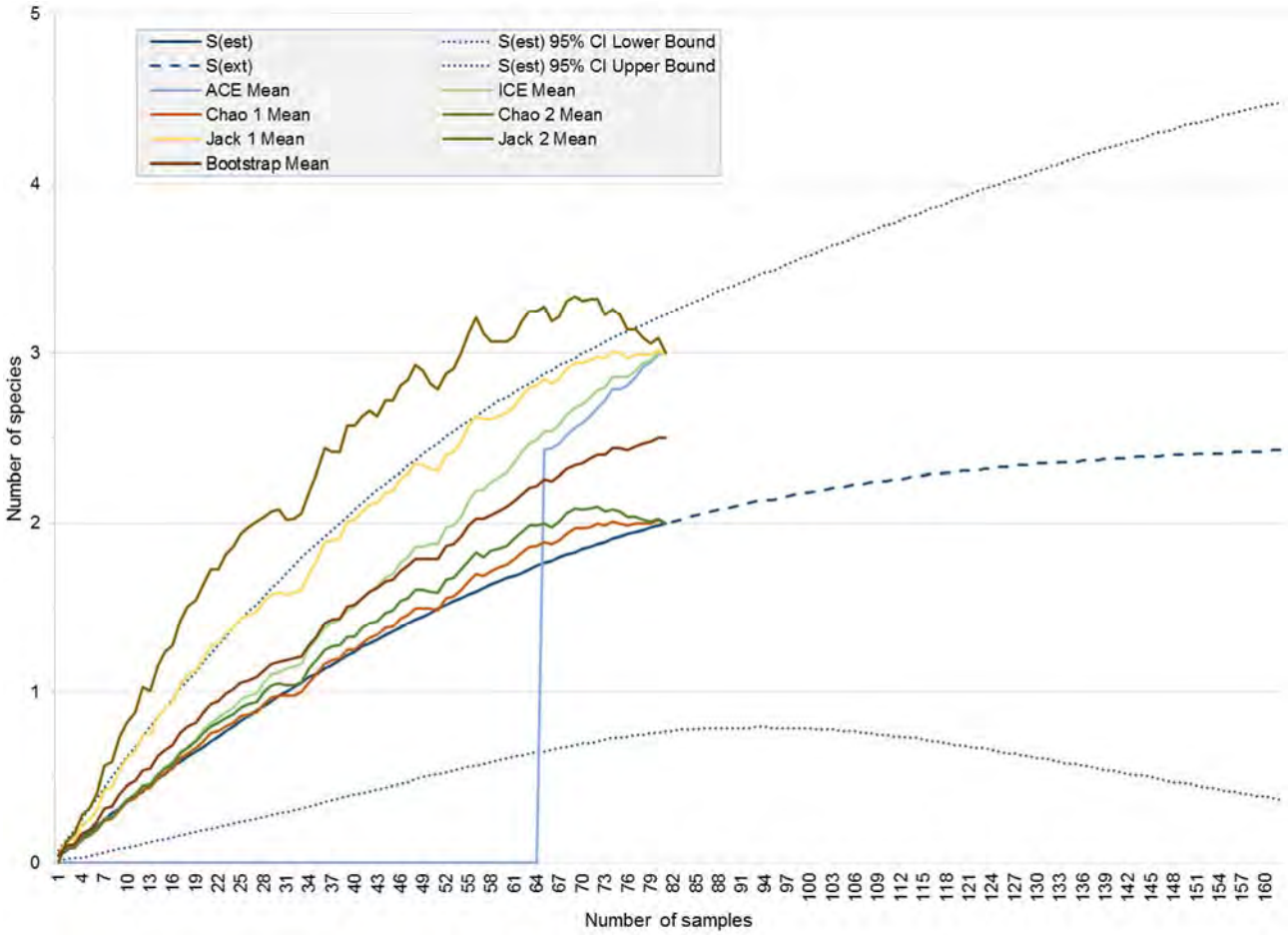

Figure 5-9: Troglofauna species accumulation curves for observed (S(est)), extrapolated (S(ext); to 162 samples), and various diversity estimators (EstimateS (Colwell 2013)) based on all recorded results from 2010 to 2012 sample rounds for the Mount Keith Satellite Operations Area.

Table 5-7: Observed troglofauna species diversity recorded from 2010 to 2012 sample rounds of the Mount Keith Satellite Operations Area compared to estimated diversity using EstimateS (Colwell 2013) diversity estimators.

Observed vs Estimated		Obs. & Pred. spp richness	% Predicted collected
Obs.	Sobs	2	
	Extrapolated (162 samples)	2.4	82.3%
Diversity estimators	Chao 1 Mean	2	100.0%
	Chao 2 Mean	2	100.0%
	Bootstrap Mean	2.5	80.0%
	Jack 1 Mean	2.99	66.9%
	ACE Mean	3	66.7%
	ICE Mean	3	66.7%
	Jack 2 Mean	3	66.7%
	Range	2 — 3	66.7 — 100%

6 Risk Assessment

The two main direct potential impacts on subterranean fauna associated with the development of the Project are:

- removal of habitat through excavation of the proposed mining pits, Goliath and Six-Mile Well; and
- drying out of habitat through the lowering of the groundwater table associated with mine pit dewatering.

The removal of habitat through mining excavation poses the greater risk to the conservation of stygofauna and troglofauna species relative to the lowering of the groundwater table only. Groundwater drawdowns are considered to have greater impacts on stygofauna compared to troglofauna because lowering of the groundwater table can directly reduce the extent of habitat available. In the case of troglofauna, the lowering of the water table may result in portions of saturated geology containing suitable habitable voids becoming unsaturated and potentially available for colonisation.

Both pit excavation and lower groundwater levels pose varying degrees of risk to the conservation of four of the seven identified stygofauna species that were restricted in distribution to within the proposed mining areas or modelled/ likely groundwater drawdown zones. The risk assessment outlined below focuses on stygofauna, as no species of troglofauna were found to be of conservation concern in the context of the development of the proposed Project.

Potential indirect impacts posed by proposed mining developments that could impact on aquifers inhabited by stygofauna include:

- fuel spills; and
- increase in sediment load in run-off from mining activities that could reduce surface-subsurface water exchange during flow periods (e.g., lessen input of resources) and alter groundwater chemistry (Marmonier 1991).

These potential indirect impacts to groundwater quality are not considered further here as part of this risk assessment because they can be greatly reduced or avoided through project design and best practice environmental management procedures. Appropriate management and mitigation measures will need to be addressed in the relevant approvals documentation and related environmental management plan in relation to potential indirect impacts.

6.1 Species of Conservation Concern

Of the seven identified stygofauna species recorded from the Project area, four species of the assemblage are of conservation concern because they have each only been recorded from within proposed pit boundaries or modelled/likely groundwater drawdown zones. The four species of conservation concern within proposed direct impact areas are as follows:

- The direct removal of habitat through mining excavation poses a risk to *Atopobathynella* sp. OES8 and *Atopobathynella* sp. OES11 within the proposed Six-Mile Well pit boundary.
- The direct removal of habitat through groundwater drawdown associated with mine dewatering poses a risk to *Gomphodella* sp. IK2 (Six-Mile Well pit) and Neoniphargidae sp. (Goliath).

Six of the stygofauna species, including all species of conservation concern, were only recorded from one bore with four species identified from a single specimen only (**Table 5-4**). It is not possible to reliably assess the distribution range of stygofauna species that are known only from limited records. Sampling the full extent of their likely range is often not possible as access to the subterranean habitat can often be constrained by the lack of bores available. Ecologically, there are many factors that influence the distribution of stygofauna at a range of habitat and temporal scales (Boulton 2000). Some of the more influential factors at the microhabitat (sediment) scale include suitable interstitial pore size (i.e. provision of connected network of habitable cavities), inflow rates of energy resources (e.g. organic carbon, biofilm growth, prey), and water quality parameters such as water temperature, pH, dissolved oxygen and organic carbon levels. At the mesohabitat (catchment) scale, factors include flow patterns along a water course influencing zones of upwelling and downwelling of energy resources or dissolved oxygen according to geomorphological features, as well as interactions with riparian and parafluvial sediments (Boulton *et al.* 1998). In addition, there are temporal variations in assemblage diversity when sampling as demonstrated with the continuation of the discovery of new species from previously relatively well sample areas (Guzik *et al.* 2010) or species only recorded intermittently over the course of an extensive survey program (Karanovic and Cooper 2012, MWH 2015). The seemingly restricted distribution of a taxon to a single bore, may likely be an artefact of sampling a species occurring at low population densities with a patchy, irregular distribution within the aquifer in response to varying micro- and mesohabitat factors, seasonality, biological interactions and availability of energy resources, rather than the actual distribution being confined to one limited area that was intercepted by a single bore.

The low and sporadic incidence of stygofauna present within the Project Area correlates with the overall hydrogeological assessment that the surficial and fractured rock aquifers present in the area are minor and relatively hydraulically isolated (refer Section 5.3.1). To the south of the main Six-mile Well deposit surficial aquifer, outside of the proposed pit boundary along Jones Creek, the more deeply weathered saturated regolith and bedrock layers become much thinner as the geology progresses into less permeable fresh bedrock (BHP Billiton Nickel West 2011a). Beneath and along side Jones Creek, a thin alluvial aquifer of several metres is considered to remain within the weathered zone above the saturated, less permeable bedrock(BHP Billiton Nickel West 2011a). The collection of *Atopobathynella* sp. OES9

and Bathynellidae sp. OES2, from outside the Project impact area, indicates that suitable habitat does exist for stygofauna outside of the regolith aquifers associated with each deposit.

Alluvial aquifers are an important ecological component of river systems including ephemeral streams (Harvey and Wagner 2000). The hyporheic zone forms an important transition zone connecting alluvial aquifer ecosystems to surface aquatic ecosystems (Boulton 2000). The hyporheic zone is defined as an ecotone that occurs within the bed and banks of a water course where surface and groundwater interact (Boulton *et al.* 1998). In arid environments, the hyporheic zone in ephemeral water courses is heavily dependant on associated groundwater within the saturated alluvial sediments and weathered strata, that can provide refugia for many epigean and stygobitic species during not only dry periods but also during flood events (Boulton and Stanley 1996, Boulton *et al.* 1992, Clinton *et al.* 1996, Cooling and Boulton 1993). Through the hyporheic zone, alluvial aquifers can provide an important linkage among rivers and ephemeral streams and can be conceptualised as forming the core of Ward and Palmer's (1994) 'interstitial highway' (Tomlinson and Boulton 2010).

From an ecological perspective, the spatial and temporal dimensions (Dole-Olivier *et al.* 1994, Ward 1989) of the extent of connectivity among the shallow alluvial aquifers associated with Jones Creek and its tributaries, could provide an 'interstitial highway' sufficient for gene flow to occur among stygofauna populations. Molecular sequence data confirmed the wider distribution of stygofauna species *Atopobathynella wattsi* and amphipod Chiltoniidae sp. SAM1, demonstrating that the alluvial aquifers associated with the northern Carey palaeodrainage channel provided interstitial corridors enabling these comparatively large species, to move among multiple calcrete systems over distances of more than 25 km (Outback Ecology 2011a). Similarly, a diverse stygofauna assemblage was found to disperse amongst the alluvial aquifers of the Coondiner Creek drainage system in the south eastern Pilbara (Outback Ecology 2009). In addition, the diverse stygofauna assemblage

Interconnected with the alluvial aquifers, likely providing refugia and potentially contributing to the interstitial highway, would be components of the fractured rock aquifer systems in the project area, associated with geological structures such as faults, fractures and shear zones. Molecular analysis demonstrated that many species in Browns Range stygofauna assemblage possessed relatively widespread distributions throughout the fractured rock and associated alluvial aquifer systems present within the Browns Range Metamorphics and surrounding Gardiner Sandstone geological units (Outback Ecology 2014).

The discussion above regarding potential habitat interconnectedness and extents remains purely conjecture as the survey results to date provide no empirical evidence to support the suppositions proposed. There is the possibility that the habitat sampled represents the peripheral upper distribution limits of a more widespread Jones Creek catchment stygofauna assemblage. However, suitable bores were not available along the main Jones Creek line further down the catchment to test if the assemblage was present and more diverse and abundant to the south of the Project Area. It is unlikely that only

sampling the same bores that have already been sampled on multiple occasions as part of this study will provide a much clearer picture of the Jones Creek catchment stygofauna assemblage. These bores are set in or adjacent to minor ephemeral stream beds that form the very upper extent of the headwaters of the Jones Creek catchment area. Therefore, the habitat sampled may likely to represent the outer distribution limits or periphery of the stygofauna assemblage within the Jones Creek catchment. During the 2010 to 2012 surveys there were no known available bores along the main Jones Creek drainage line within the Project Area downstream of Six-mile Well or Goliath impact areas. This prevented further assessment of the stygofauna assemblage within the alluvial aquifers associated with the main channel of the Jones Creek catchment. In addition, there were no published papers nor WAM or DEC database records of stygofauna from the catchment area, including from the large floodplain area at the terminus of Jones Creek and from the calcrete systems associated with Lake Miranda, to provide any additional knowledge regarding species diversity and distribution.

From the stygofauna results collected from the Project Area to date it is not possible to achieve a high level of knowledge of the stygofauna assemblage present in the Project Area. Based on current results the implementation of the proposed Project would put at risk the conservation of four stygofauna species, *Atopobathynella* sp. OES8, *Atopobathynella* sp. OES11, Gomphodella sp. IK2, and Neoniphargidae sp.

7 Conclusion

The subterranean fauna assessment undertaken has revealed that the Project study area does host a low stygofauna and troglofauna diversity with the stygofauna assemblage dominated by bathynellacean taxa. Genetic analysis demonstrated that the bathynellacean taxa were highly divergent from other northern Yilgarn bathynellacean fauna assemblages. Four of the seven stygofauna species recorded were found from within proposed impact areas only and so are of conservation concern. The two troglofauna species recorded were from non-impact areas only so are not of conservation concern. An assessment of survey adequacy found that further stygofauna sampling is required but that no further troglofauna sampling is needed.

The current findings indicate that the development of the Project will pose a significant conservation risk to four stygofauna species through the removal of habitat by mining excavation and pit dewatering. .

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9 Glossary

alluvium – sediment deposited by a stream or river

aquatic – relating to water

aquifer – a body of permeable rock or sediment capable of storing groundwater

arid – a region characterised by a severe lack of available water, to the extent that the growth and development of biota is hindered or prevented

bedrock – consolidated rock attached to the earth's crust

biodiversity – the diversity of biota in a particular environment or region

calcrete – carbonate deposits that form in arid environments, as a result of groundwater evaporation

cave – a subsurface cavity of sufficient size that a human could enter

dissolved oxygen – a measure of the amount of gaseous oxygen dissolved in a solution

distribution range – the overall geographic area that a species is known to occur in

divergence – degree of separation from a common ancestor

diversity – species richness

drawdown – the lowering of the adjacent water table or piezometric surface as a result of groundwater extraction

ecotone – zone of transition among different ecosystems

electrical conductivity – an estimate of the total dissolved salts in a solution, or salinity

endemic – having a distribution restricted to a particular geographic region

epigean – pertaining to the surface zone

fractured rock – a rock formation characterized by separation or discontinuity, usually as a result of geological stress (e.g. faulting)

freshwater – salinity less than 5,000 µS/cm (3,000 mg/L)

geological ages (e.g. Cainozoic) – distinct time periods within the geological history of the earth

groundwater – water occurring below the ground surface

habitat – an ecological or environmental area that is inhabited by a particular animal or plant species

hypogean – pertaining to the subterranean zone

hyporheic zone – spatially fluctuating ecotone within the bed of a river or stream between surface and groundwater. Considered important component of groundwater ecosystems and involved in the 'interstitial highway', forming hyporheic corridor linking associated aquifers.

invertebrates – animals lacking vertebrae

karst – a region of limestone or other soluble rock, characterized by distinctive features such as caves, caverns, sinkholes, underground streams and springs

lineage – a group of organisms related by descent from a common ancestor

molecular – pertaining to the genetic characteristics of an organism or group

morphology – the specific form and structure of an organism or taxon

morphospecies – a general grouping of organisms that share similar morphological traits, but is not necessarily defined by a formal taxonomic rank

palaeoriver, palaeochannel, palaeodrainage – a remnant of a stream or river channel cut in older rock and filled by the sediments of younger overlying rock

pH – a measure of the hydrogen ion concentration of a soil or solution (values below pH of 6.5 are 'acidic', and those above pH 7.5 are 'alkaline')

relictual – having survived as a remnant

salinity – the concentration of all dissolved salts in a solution

semi-arid – a climatic region that receives low annual rainfall (250 – 500 mm)

species – a formal taxonomic unit defining a group or population of organisms that share distinctive characters or traits, are reproductively viable and/or are otherwise identifiable as a related group

species diversity – the number of species present in a particular habitat, ecosystem or region

species accumulation curve – a model used to estimate species diversity or richness

standing water level – the depth to groundwater from a particular reference point (e.g. in a monitoring bore)

stygal, stygo – pertaining to groundwater habitat or biota

stygobite – an obligate aquatic species of groundwater habitats

stygobiont – another term used to describe obligate inhabitants of groundwater systems

stygofauna – a general term for aquatic groundwater fauna

stygophile – an aquatic species that temporarily or permanently inhabits groundwater habitats

stygoxene – an aquatic species that has no fixed affinity with groundwater habitats, but may nonetheless occur in groundwater habitats

taxon – an identifiable group of organisms, usually based on a known or inferred relationship or a shared set of distinctive characteristics

troglobite – an obligate terrestrial species of subterranean habitats

troglofauna – a general term for terrestrial subterranean fauna

troglomorphic features – morphological characteristics resulting from an adaptation to subterranean habitats (e.g. a reduction in pigment)

troglophile – a terrestrial species that temporarily or permanently inhabits subterranean habitats

trogloxene – a terrestrial species that has no fixed affinity with subterranean habitats, but may nonetheless occur in subterranean habitats

void – a pore space in the rock or stratum

Yilgarn – pertaining to the Yilgarn Craton, a 65,000 km^2 body of the earth's crust in south-western Australia that dates back to the Archaean period, 2.6 to 3.7 million years ago

Appendix A Survey Effort and Bore Data

Table A-1: Stygofauna survey effort (including Biota 2006) and bore data recorded. Blue shaded rows indicate stygofauna recorded.

Project Area	Bore Code	Latitude (DMS)	Longitude (DMS)	UTM (51J)		Sample Date	Elevation	SWL		EoH		Location
				Easting	Northing		(AHD)	(m bgl)	(AHD)	(m bgl)	(AHD)	
Goliath	95GPG07	27°26'56"S	120°35'16"E	261591	6961532	2006	537	NA				Inside pit
Goliath	95GPG07	27°26'56"S	120°35'16"E	261591	6961532	18-Nov-10	537	33.15	503.85	72.9	464.1	Inside pit
Goliath	95GPG07	27°26'56"S	120°35'16"E	261591	6961532	29-Mar-11	537	33.3	503.7	75.6	461.4	Inside pit
Goliath	95GPG11	27°27'08"S	120°35'03"E	261225	6961161	18-Nov-10	530	27.4	502.6	57.6	472.4	Inside pit
Goliath	95GPG11	27°27'08"S	120°35'03"E	261225	6961161	29-Mar-11	530	26.1	503.9	59.4	470.6	Inside pit
Goliath	CP11	27°26'59"S	120°35'03"E	261235	6961444	2006	532	NA				Inside pit
Goliath	CP11	27°26'59"S	120°35'03"E	261235	6961444	18-Nov-10	532	26.06	505.94	58.5	473.5	Inside pit
Goliath	CP11	27°26'59"S	120°35'03"E	261235	6961444	29-Mar-11	532	26.1	505.9	32.4	499.6	Inside pit
Goliath	CP11	27°26'59"S	120°35'03"E	261235	6961444	2-Feb-12	532					Inside pit
Goliath	CP21	27°26'58"S	120°35'21"E	261724	6961463	2006	532	NA				Inside pit
Goliath	CP21	27°26'58"S	120°35'21"E	261724	6961463	18-Nov-10	532	29.1	502.9	61.2	470.8	Inside pit
Goliath	CP21	27°26'58"S	120°35'21"E	261724	6961463	2-Feb-12	532					Inside pit
Goliath	CP53	27°26'59"S	120°34'43"E	260678	6961407	2006	523					Near pit (<200m)
Goliath	CP53	27°26'59"S	120°34'43"E	260678	6961407	18-Nov-10	523	20.93	502.07	64.8	458.2	Near pit (<200m)
Goliath	YAKB06	27°26'55"S	120°34'50"E	260859	6961556	2006	531		531			Near pit (<200m)
Goliath	YAKB06	27°26'55"S	120°34'50"E	260859	6961556	3-Feb-12	531					Near pit (<200m)
Goliath South	CP5P	27°27'52"S	120°35'40"E	262292	6959817	16-Nov-10	534	25.25	508.75	69.3	464.7	Outside pits (>1km)
Goliath South	CP5P	27°27'52"S	120°35'40"E	262292	6959817	28-Mar-11	534	25.45	508.55	66.6	467.4	Outside pits (>1km)
Goliath South	CP6P	27°27'52"S	120°35'40"E	262132	6960091	16-Nov-10	528	21.84	506.16	33.3	494.7	Outside pits (>1km)
Goliath South	CP6P	27°27'52"S	120°35'40"E	262132	6960091	28-Mar-11	528			31.5	496.5	Outside pits (>1km)
Goliath South	CP6P	27°27'52"S	120°35'40"E	262132	6960091	21-Jun-11	528	21.77	506.23	30.5	497.5	Outside pits (>1km)
Goliath South	CP6P	27°27'52"S	120°35'40"E	262132	6960091	1-Feb-12	528					Outside pits (>1km)
Goliath South	YEX82	27°27'35"S	120°35'23"E	261816	6960336	16-Nov-10	527	19.8	507.2	66.6	460.4	Outside pits (>500m, <1km)
Goliath South	YEX82	27°27'35"S	120°35'23"E	261816	6960336	28-Mar-11	527			30.6	496.4	Outside pits (>500m, <1km)
Goliath South	YEX82	27°27'35"S	120°35'23"E	261816	6960336	21-Jun-11	527	20.06	506.94	30.5	496.5	Outside pits (>500m, <1km)
Goliath South	YEX82	27°27'35"S	120°35'23"E	261816	6960336	1-Feb-12	527					Outside pits (>500m, <1km)
Serp Hill South	CP13P	27°27'47"S	120°34'11"E	259844	6959931	18-Nov-10	509	11.08	497.92	79.2	429.8	Outside pits (>1km)
Serp Hill South	CP13P	27°27'47"S	120°34'11"E	259844	6959931	28-Mar-11	509	10.8	498.2	59.4	449.6	Outside pits (>1km)
Serp Hill South	CP13P	27°27'47"S	120°34'11"E	259844	6959931	17-Jun-11	509	11.6	497.4	62.4	446.6	Outside pits (>1km)
Serp Hill South	CP13P	27°27'47"S	120°34'11"E	259844	6959931	2-Feb-12	509					Outside pits (>1km)
Serp Hill South	CP22P	27°27'36"S	120°34'45"E	260748	6960268	16-Nov-10	526	12.17	513.83	51.3	474.7	Outside pits (>500m, <1km)
Serp Hill South	CP22P	27°27'36"S	120°34'45"E	260748	6960268	28-Mar-11	526	11.7	514.3	46.8	479.2	Outside pits (>500m, <1km)
Serp Hill South	CP22P	27°27'36"S	120°34'45"E	260748	6960268	21-Jun-11	526	11.9	514.1	50.5	475.5	Outside pits (>500m, <1km)

Table A-1 (cont.): Stygofauna survey effort (including Biota 2006) and bore data recorded. Blue shaded rows indicate stygofauna recorded.

Project Area	Bore Code	Latitude (DMS)	Longitude (DMS)	UTM (51J)		Sample Date	Elevation	SWL		EoH		Location
				Easting	Northing		(AHD)	(m bgl)	(AHD)	(m bgl)	(AHD)	
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260697	6960575	18-Nov-10	519	16	503	60.5	458.5	Outside pits (>500m, <1km)
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260697	6960575	28-Mar-11	519	15.3	503.7	59.4	459.6	Outside pits (>500m, <1km)
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260697	6960575	21-Jun-11	519	15.63	503.37	64	455	Outside pits (>500m, <1km)
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260697	6960575	3-Feb-12	519					Outside pits (>500m, <1km)
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260735	6960583	16-Nov-10	524	16.24	507.76	59.5	464.5	Outside pits (>500m, <1km)
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260735	6960583	28-Mar-11	524	15.3	508.7	81	443	Outside pits (>500m, <1km)
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260735	6960583	21-Jun-11	524	16.12	507.88	60.3	463.7	Outside pits (>500m, <1km)
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260735	6960583	3-Feb-12	524					Outside pits (>500m, <1km)
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	260637	6960597	18-Nov-10	515	15.17	499.83	74.6	440.4	Outside pits (>500m, <1km)
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	260637	6960597	28-Mar-11	515	16.2	498.8	51.3	463.7	Outside pits (>500m, <1km)
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	260637	6960597	21-Jun-11	515	15.22	499.78	38.7	476.3	Outside pits (>500m, <1km)
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	260637	6960597	2-Feb-12	515					Outside pits (>500m, <1km)
Serp Hill South	SHSP1	27°27'35"S	120°34'55"E	261042	6960308	16-Nov-10	529	12.95	516.05	62.1	466.9	Outside pits (>500m, <1km)
Serp Hill South	SHSP1	27°27'35"S	120°34'55"E	261042	6960308	28-Mar-11	529	13.5	515.5	45	484	Outside pits (>500m, <1km)
Serp Hill South	SHSP1	27°27'35"S	120°34'55"E	261042	6960308	21-Jun-11	529	12.77	516.23	38.7	490.3	Outside pits (>500m, <1km)
Serp Hill South	SHSP2	27°27'47"S	120°34'58"E	261114	6959936	16-Nov-10	529	20.85	508.15	54.9	474.1	Outside pits (>1km)
Serp Hill South	SHSP2	27°27'47"S	120°34'58"E	261114	6959936	28-Mar-11	529	19.8	509.2	50.4	478.6	Outside pits (>1km)
Serp Hill South	SHSP2	27°27'47"S	120°34'58"E	261114	6959936	21-Jun-11	529	20.7	508.3	36.9	492.1	Outside pits (>1km)
Serp Hill South	SHSP2	27°27'47"S	120°34'58"E	261114	6959936	2-Feb-12	529					Outside pits (>1km)
Sheba	SBD3	27°28'51"S	120°35'36"E	262207	6958015	16-Nov-10	534	27.1	506.9	60.3	473.7	Outside pits (>3km)
Sheba	SBD3	27°28'51"S	120°35'36"E	262207	6958015	28-Mar-11	534	26.04	507.96	65.6	468.4	Outside pits (>3km)
Six-mile Well	CP51	27°25'23"S	120°34'35"E	260404	6964368	18-Nov-10	535	27.54	507.46	38.7	496.3	Inside pit
Six-mile Well	CP51	27°25'23"S	120°34'35"E	260404	6964368	29-Mar-11	535	28.8	506.2	38.7	496.3	Inside pit
Six-mile Well	CP51	27°25'23"S	120°34'35"E	260404	6964368	17-Jun-11	535	26.35	508.65	36.9	498.1	Inside pit
Six-mile Well	CP51	27°25'23"S	120°34'35"E	260404	6964368	2-Feb-12	535					Inside pit
Six-mile Well	CP52	27°25'52"S	120°34'29"E	260256	6963486	18-Nov-10	525	23.03	501.97	64	461	Near pit (>300m, <500m)
Six-mile Well	CP52	27°25'52"S	120°34'29"E	260256	6963486	29-Mar-11	525	23.4	501.6	60.3	464.7	Near pit (>300m, <500m)
Six-mile Well	CP52	27°25'52"S	120°34'29"E	260256	6963486	17-Jun-11	525	22.42	502.58	60.3	464.7	Near pit (>300m, <500m)
Six-mile Well	CP52	27°25'52"S	120°34'29"E	260256	6963486	2-Feb-12	525					Near pit (>300m, <500m)
Waste Rock Landform	YEX162	27°26'36"S	120°36'16"E	263235	6962170	17-Jun-11	527	22.99	504.01	49.5	477.5	Outside pits (>1km)
Waste Rock Landform	YEX166	27°48'16"S	120°35'52"E	263338	6922137	17-Jun-11	566	24.3	541.7	62.1	503.9	Outside pits (>1km)

Table A-2: Troglofauna survey effort undertaken and bore data recorded. Orange shaded rows indicate troglofauna recorded.

Project Area	Bore Code	Latitude (DMS)	Longitude (DMS)	UTM (51J)		Sample Start Date	Sample End Date	Trap Depth (mbgl)	Location
				Easting	Northing				
Goliath	95GPG07	27°26'56"S	120°35'16"E	261591	6961532	29-Mar-11	30-May-11	25	Inside pit
Goliath	95GPG07	27°26'56"S	120°35'16"E	261591	6961532	23-May-11	19-Jul-11	25	Inside pit
Goliath	95GPG11	27°27'08"S	120°35'03"E	261225	6961161	29-Mar-11	30-May-11	20	Inside pit
Goliath	95GPG11	27°27'08"S	120°35'03"E	261225	6961161	23-May-11	19-Jul-11	20	Inside pit
Goliath	CP11	27°26'59"S	120°35'03"E	261235	6961444	23-May-11	19-Jul-11	16	Inside pit
Goliath	GPD1630	27°26'52"S	120°35'19"E	261542	6961484	29-Mar-11	30-May-11	12	Inside pit
Goliath	GPD1630	27°26'52"S	120°35'19"E	261542	6961484	23-May-11	19-Jul-11	12	Inside pit
Goliath	GPD1648A	27°27'03"S	120°35'18"E	261644	6961307	26-Mar-11	30-May-11	31	Inside pit
Goliath	GPD1648A	27°27'03"S	120°35'18"E	261644	6961307	23-May-11	19-Jul-11	29	Inside pit
Goliath	GPD1651	27°27'01"S	120°35'21"E	261726	6961383	26-Mar-11	30-May-11	6	Inside pit
Goliath	GPD1651	27°27'01"S	120°35'21"E	261726	6961383	23-May-11	19-Jul-11	6	Inside pit
Goliath	GPD1681	27°26'37"S	120°35'24"E	261787	6962135	26-Mar-11	30-May-11	9	Inside pit
Goliath	GPD1681	27°26'37"S	120°35'24"E	261787	6962135	23-May-11	19-Jul-11	9	Inside pit
Goliath	GPD1682	27°26'42"S	120°35'27"E	261870	6961980	26-Mar-11	25-May-11	9	Inside pit
Goliath	GPD1682	27°26'42"S	120°35'27"E	261870	6961980	23-May-11	19-Jul-11	9	Inside pit
Goliath South	YEX82	27°27'35"S	120°35'23"E	261816	6960336	28-Mar-11	30-May-11	15	Outside pits (>500m, <1km)
Goliath South	YEX82	27°27'35"S	120°35'23"E	261816	6960336	30-May-11	19-Jul-11	15	Outside pits (>500m, <1km)
Serp Hill North	YAKAOES04	27°26'58"S	120°34'32"E	260377	6961444	25-Mar-11	30-May-11	15	Outside pits (>500m, <1km)
Serp Hill North	YAKAOES04	27°26'58"S	120°34'32"E	260377	6961444	23-May-11	19-Jul-11	15	Outside pits (>500m, <1km)
Serp Hill North	YEX212	27°27'10"S	120°34'30"E	260320	6961085	23-May-11	19-Jul-11	10	Outside pits (>500m, <1km)
Serp Hill North	YEX213A	27°27'07"S	120°34'28"E	260271	6961180	26-Mar-11	30-May-11	10	Outside pits (>500m, <1km)
Serp Hill North	YEX213A	27°27'07"S	120°34'28"E	260271	6961180	23-May-11	19-Jul-11	12	Outside pits (>500m, <1km)
Serp Hill South	CP13P	27°27'47"S	120°34'11"E	259844	6959931	28-Mar-11	30-May-11	10	Outside pits (>1km)
Serp Hill South	CP13P	27°27'47"S	120°34'11"E	259844	6959931	30-May-11	19-Jul-11	10	Outside pits (>1km)
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260697	6960575	18-Nov-10		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260697	6960575	28-Mar-11		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260697	6960575	28-Mar-11	30-May-11	14	Outside pits (>500m, <1km)
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260697	6960575	30-May-11		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260697	6960575	30-May-11	19-Jul-11	14	Outside pits (>500m, <1km)
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260697	6960575	21-Jun-11		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHGCN60	27°27'26"S	120°34'43"E	260697	6960575	03-Feb-12		Scrape	Outside pits (>500m, <1km)

Table A-2 (cont.): Troglofauna survey effort undertaken and bore data recorded. Orange shaded rows indicate troglofauna recorded.

Project Area	Bore Code	Latitude (DMS)	Longitude (DMS)	UTM (51J)		Sample Start Date	Sample End Date	Trap Depth (mbgl)	Location
				Easting	Northing				
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260735	6960583	16-Nov-10		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260735	6960583	28-Mar-11		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260735	6960583	28-Mar-11	30-May-11	15	Outside pits (>500m, <1km)
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260735	6960583	30-May-11	19-Jul-11	10	Outside pits (>500m, <1km)
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260735	6960583	21-Jun-11		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260735	6960583	03-Feb-12		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHGCN62	27°27'26"S	120°34'44"E	260735	6960583	03-Feb-12		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	261114	6959936	18-Nov-10		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	261114	6959936	28-Mar-11		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	261114	6959936	21-Jun-11		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHNP2	27°27'26"S	120°34'41"E	261114	6959936	02-Feb-12		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHSP1	27°27'26"S	120°34'41"E	261114	6959936	16-Nov-10		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHSP1	27°27'26"S	120°34'41"E	261114	6959936	28-Mar-11		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHSP1	27°27'26"S	120°34'41"E	261114	6959936	21-Jun-11		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261114	6959936	16-Nov-10		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261114	6959936	28-Mar-11		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261114	6959936	28-Mar-11	30-May-11		Outside pits (>500m, <1km)
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261114	6959936	30-May-11		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261114	6959936	30-May-11	19-Jul-11	9	Outside pits (>500m, <1km)
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261114	6959936	21-Jun-11		Scrape	Outside pits (>500m, <1km)
Serp Hill South	SHSP2	27°27'26"S	120°34'41"E	261114	6959936	02-Feb-12		Scrape	Outside pits (>500m, <1km)
Serp Hill South	YEX200	27°27'25"S	120°35'09"E	261407	6960636	26-Mar-11	30-May-11	10	Outside pits (>500m, <1km)
Serp Hill South	YEX200	27°27'25"S	120°35'09"E	261407	6960636	30-May-11	19-Jul-11	10	Outside pits (>500m, <1km)
Serp Hill South	YSHC6	27°27'41"S	120°34'59"E	261148	6960143	26-Mar-11	30-May-11	14	Outside pits (>1km)
Serp Hill South	YSHC6	27°27'41"S	120°34'59"E	261148	6960143	30-May-11	19-Jul-11	9	Outside pits (>1km)
Serp Hill South	YSHD29	27°27'24"S	120°34'44"E	260717	6960666	26-Mar-11	30-May-11	15	Outside pits (>500m, <1km)
Serp Hill South	YSHD29	27°27'24"S	120°34'44"E	260717	6960666	30-May-11	19-Jul-11	15	Outside pits (>500m, <1km)
Serp Hill South	YSHD3	27°27'45"S	120°34'56"E	261062	6960016	26-Mar-11	30-May-11	14	Outside pits (>1km)
Serp Hill South	YSHD3	27°27'45"S	120°34'56"E	261062	6960016	30-May-11	19-Jul-11	14	Outside pits (>1km)
Sheba	SBD3	27°28'51"S	120°35'36"E	262207	6958015	28-Mar-11	30-May-11	25	Outside pits (>3km)
Sheba	SBD3	27°28'51"S	120°35'36"E	262207	6958015	28-Mar-11	30-May-11	25	Outside pits (>3km)
Sheba	SBD3	27°28'51"S	120°35'36"E	262207	6958015	30-May-11	19-Jul-11	20	Outside pits (>3km)

Table A-2 (cont.): Troglofauna survey effort undertaken and bore data recorded. Orange shaded rows indicate troglofauna recorded.

Project Area	Bore Code	Latitude (DMS)	Longitude (DMS)	UTM (51J)		Sample Start Date	Sample End Date	Trap Depth (mbgl)	Location
				Easting	Northing				
Six-mile Well	YEX161	27°26'34"S	120°34'29"E	260272	6962189	25-Mar-11	30-May-11	10	Outside pits (>500m, <1km)
Six-mile Well	YEX161	27°26'34"S	120°34'29"E	260272	6962189	23-May-11	19-Jul-11	10	Outside pits (>500m, <1km)
Six-mile Well	YEX218	27°26'26"S	120°34'26"E	260187	6962417	25-Mar-11	30-May-11	9	Outside pits (>500m, <1km)
Six-mile Well	YEX218	27°26'26"S	120°34'26"E	260187	6962417	23-May-11	19-Jul-11	9	Outside pits (>500m, <1km)
Six-mile Well	SMD1169	27°25'13"S	120°34'39"E	260507	6964678	25-Mar-11	30-May-11	20	Inside pit
Six-mile Well	SMD1169	27°25'13"S	120°34'39"E	260507	6964678	23-May-11	19-Jul-11	20	Inside pit
Six-mile Well	SMD1171	27°25'04"S	120°34'36"E	260427	6964954	25-Mar-11	30-May-11	25	Inside pit
Six-mile Well	SMD1171	27°25'04"S	120°34'36"E	260427	6964954	23-May-11	19-Jul-11	25	Inside pit
Six-mile Well	SMD1178	27°25'49"S	120°34'23"E	260084	6963579	23-May-11	19-Jul-11	8	Near pit (>300m, <500m)
Six-mile Well	SMD1180	27°25'41"S	120°34'21"E	260035	6963804	25-Mar-11	30-May-11	19	Near pit (>300m, <500m)
Six-mile Well	SMD1180	27°25'41"S	120°34'21"E	260035	6963804	23-May-11	19-Jul-11	19	Near pit (>300m, <500m)
Six-mile Well	SMD1181	27°25'34"S	120°34'27"E	260200	6964039	25-Mar-11	30-May-11	17	Near pit (<200m)
Six-mile Well	SMD1181	27°25'34"S	120°34'27"E	260200	6964039	23-May-11	19-Jul-11	17	Near pit (<200m)
Six-mile Well	SMD1187	27°25'24"S	120°34'31"E	260291	6964355	23-May-11	19-Jul-11	8	Near pit (<200m)
Six-mile Well	YAKAOES01	27°24'54"S	120°34'37"E	260433	6965265	25-Mar-11	30-May-11	14	Inside pit
Six-mile Well	YAKAOES01	27°24'54"S	120°34'37"E	260433	6965265	23-May-11	19-Jul-11	14	Inside pit
Six-mile Well	YAKAOES02	27°25'20"S	120°34'40"E	260552	6964483	25-Mar-11	30-May-11	6	Inside pit
Six-mile Well	YAKAOES02	27°25'20"S	120°34'40"E	260552	6964483	23-May-11	19-Jul-11	5	Inside pit
Six-mile Well	YAKAOES03	27°25'46"S	120°34'21"E	260046	6963658	25-Mar-11	30-May-11	14	Near pit (>300m, <500m)
Six-mile Well	YAKAOES03	27°25'46"S	120°34'21"E	260046	6963658	23-May-11	19-Jul-11	14	Near pit (>300m, <500m)
Waste Rock Landform	YEX162	27°26'36"S	120°36'16"E	263235	6962170	26-Mar-11	30-May-11	9	Outside pits (>1km)
Waste Rock Landform	YEX162	27°26'36"S	120°36'16"E	263235	6962170	23-May-11	19-Jul-11	9	Outside pits (>1km)
Waste Rock Landform	YEX165	27°26'36"S	120°36'24"E	263434	6962172	26-Mar-11	30-May-11	18	Outside pits (>1km)
Waste Rock Landform	YEX165	27°26'36"S	120°36'24"E	263434	6962172	23-May-11	19-Jul-11	18	Outside pits (>1km)
Waste Rock Landform	YEX166	27°48'16"S	120°35'52"E	263338	6922137	26-Mar-11	30-May-11	16	Outside pits (>1km)
Waste Rock Landform	YEX166	27°48'16"S	120°35'52"E	263338	6922137	23-May-11	19-Jul-11	16	Outside pits (>1km)

Appendix B Representative Survey Area Bores

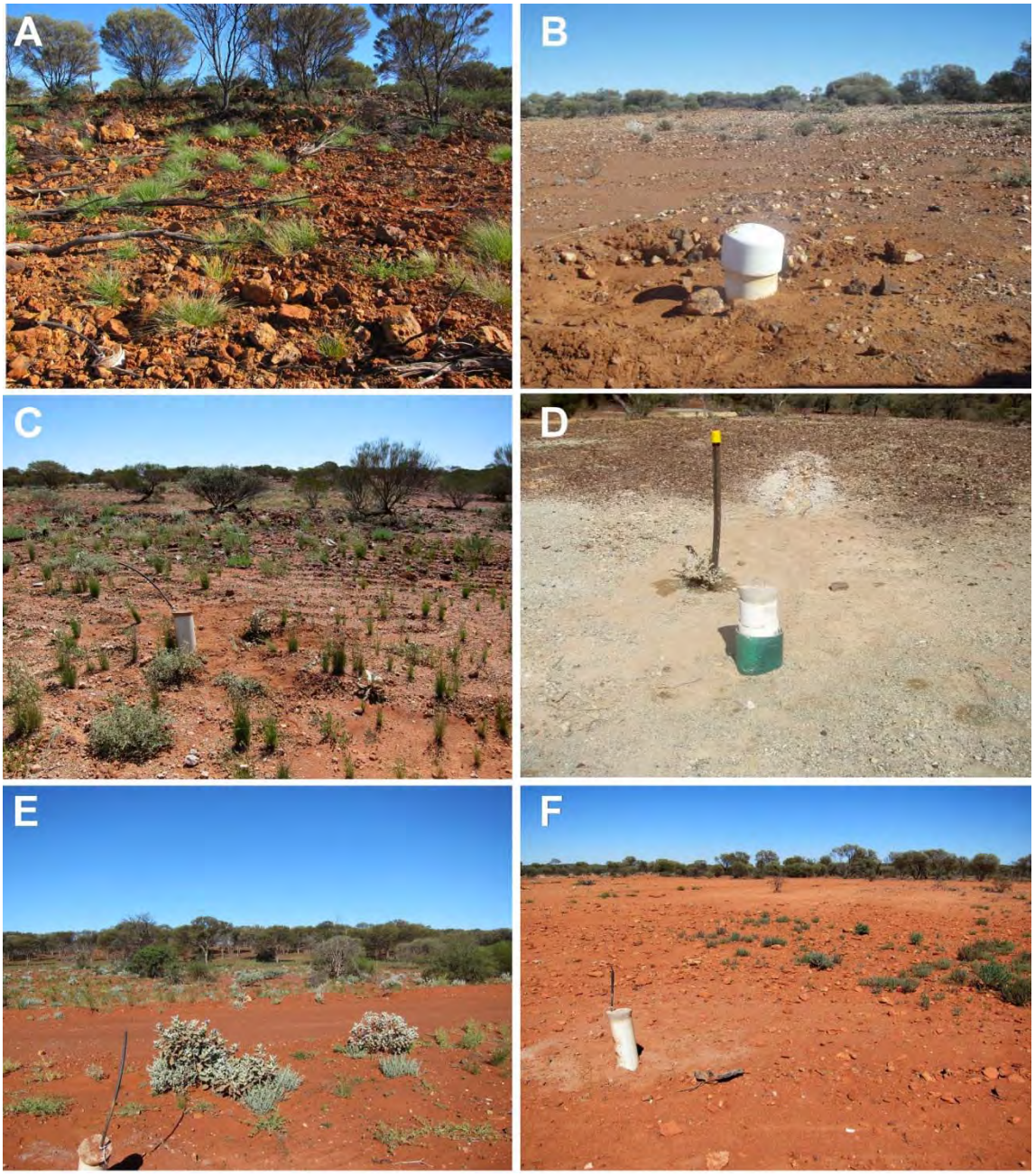

Figure B-1: Representative Project survey area bores; A) GPD1648A, Goliath; B) SHGCN60, Serpentine Hill South; C) YSHD29, Serpentine Hill South; D) CP52, Six-mile Well; E) YEX161, south of Six-mile Well; F) YEX162, Waste Rock Landform.

Appendix C Western Australian Museum (WAM) Arachnida and Myriapoda Database

GROUP	FAMILY	GENUS	SPECIES	SITE	LATITUDE (DECIMAL)	LONGITUDE (DECIMAL)	DATE
				Yeelirrie, 87 km S. of Wiluna	-27.317	120.151	12/01/2010
Araneae	Oonopidae	Opopaea	\`sp. nov.\`	Yeelirrie, 87 km S. of Wiluna, bore YYHC0048H	-27.3166	120.151	17/03/2010
Araneae	Oonopidae	Prethopalpus	callani	Yeelirrie, 87 km S. of Wiluna, bore YYHC0048H	-27.3166	120.151	17/03/2010
Araneae	Sparassidae	Pediana	tenuis	23.7 km SW. of Mt Keith, Albion Downs Borefields, site ADB06B-P6	-27.4025	120.353	/03/2008
Araneae	Trochanteriidae	Desognanops	\`sp. nov. Yeelirrie\`	Yeelirrie Station, bore YYHC0049E	-27.3396	120.151	13/11/2010
Cephalostigmata				Yakabindie Station, MEB site 78	-27.7466	120.524	19/09/2006
Geophilida	Geophilidae			Yeelirrie, 87 km S. of Wiluna	-27.3166	120.151	17/03/2010
Geophilida	Geophilidae			Yeelirrie, 87 km S. of Wiluna	-27.2819	120.111	18/09/2010
Palpigradi				Yeelirrie Station, Yeelirrie Deposit, bore hole SB14-MT (MKC06)	-27.3428	120.242	10/03/2009
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	18/09/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	18/09/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3065	120.218	12/01/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	12/01/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	12/01/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	12/01/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	12/01/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	12/01/2010
Palpigradi	Eukoeneniidae	Eukoenenia	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3161	120.151	18/09/2010
Polyxenida				Yeelirrie, 87 km S. of Wiluna	-27.3405	120.151	12/01/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`OES4\`	LT107 / WAM1, 50 km SW. of Wiluna	-27.1374	120.953	20/09/2011
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`OES4\`	LT107, 95 km NE. of Leinster	-27.1374	120.953	18/07/2011
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`OES5\`	LMTF0027 / LMAC0523, 95 km NE. of Leinster	-27.1674	121.084	13/11/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`OES6\`	LT105 / WAM3, 50 km SW. of Wiluna	-27.1377	120.946	20/09/2011
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`OES6\`	LT107, 95 km NE. of Leinster	-27.1374	120.953	18/07/2011
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp. indet. (juvenile)\`	Barwidgee Station, bore troglofauna site 105	-27.1375	120.945	20/07/2008
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp. nov. Yakabindie Station\`	Yakabindie Station, bore troglofauna site 54	-27.6639	120.61	22/07/2008
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp. nov. Yeelirrie\`	Yeelirrie, 87 km S. of Wiluna	-27.3161	120.151	12/01/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3065	120.238	18/09/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3161	120.151	12/01/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3145	120.151	12/01/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3065	120.238	12/01/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3444	120.308	11/03/2010
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3396	120.151	13/11/2009
Pseudoscorpiones	Chthoniidae	Tyrannochthonius	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3145	120.151	13/11/2009
Pseudoscorpiones	Olpiidae	Austrohorus	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3145	120.151	12/01/2010
Pseudoscorpiones	Olpiidae	Beierolpium	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3145	120.151	12/01/2010
Pseudoscorpiones	Olpiidae	Beierolpium	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3065	120.238	12/01/2010
Pseudoscorpiones	Olpiidae	Beierolpium	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.298	120.168	14/01/2010
Pseudoscorpiones	Olpiidae	Beierolpium	\`sp.\`	Yeelirrie, 87 km S. of Wiluna	-27.3145	120.151	18/03/2010
Scolopendrida	Scolopendridae	Scolopendra	morsitans	13.3 km NW. of Mt Keith, Albion Downs Borefields, site ADB17A	-27.2458	120.428	/03/2008

Appendix D Western Australian Museum (WAM) Crustacea Database Search

GROUP	FAMILY	GENUS	SPECIES	SITE	LATITUDE (DECIMAL)	LONGITUDE (DECIMAL)	DATE
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.2479	120.055	18/09/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.2476	120.055	14/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.2476	120.055	14/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.2476	120.055	20/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.2476	120.055	18/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.2476	120.055	18/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	14/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	18/09/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	16/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	18/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	14/11/2009
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	14/11/2009
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	12/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3299	120.151	12/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.31	120.15	18/09/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.316	120.151	18/09/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3156	120.151	18/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3444	120.308	11/03/2009
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3443	120.308	12/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3443	120.308	12/01/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3444	120.308	18/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3444	120.308	18/09/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3444	120.308	16/03/2010
Amphipoda	Chiltoniidae	nr. Phreatochiltonia	sp. S1		-27.3444	120.308	12/01/2010
Amphipoda	Chiltoniidae		sp. OES1	Leinster	-27.1378	121.034	17/08/2010
Amphipoda	Chiltoniidae		sp. SAM3	Wiluna	-27.1375	120.949	31/01/2012
Amphipoda	Chiltoniidae		sp. SAM4	Leinster	-27.1852	121.066	8/03/2010
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; WAM1-LT107	-27.1358	120.954	18/07/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; Little Well	-27.1338	121.004	14/03/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; LMST008	-27.1377	121.034	14/03/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; LMST008	-27.1377	121.034	18/07/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; LMST012	-27.1558	121.036	15/03/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; LMST012	-27.1558	121.036	18/07/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; LMST007	-27.1472	121.062	15/03/2011
Amphipoda	ORDER: Amphipoda			130km south east of Wiluna; LMST002	-27.1652	121.064	16/03/2011

GROUP	FAMILY	GENUS	SPECIES	SITE	LATITUDE (DECIMAL)	LONGITUDE (DECIMAL)	DATE
Bathynellecea	Parabathynellidae	Atopobathynella	sp. OES8	Mt. Keith	-27.423	120.576	18/11/2010
Bathynellecea	Parabathynellidae	Atopobathynella	sp. OES9		-27.4587	120.5805	27/03/2011
Copepoda				LMST014	-27.165	121.048	15/03/2011
Copepoda				Lake Way South; 50km SE of Leinster	-26.9849	120.643	18/06/2011
Copepoda				Lake Way South; 50km SE of Leinster	-27.0012	120.745	27/03/2011
Copepoda				Lake Way South; 50km SE of Leinster	-27.0012	120.745	27/03/2011
Copepoda				Lake Way South; 50km SE of Leinster	-27.0011	120.745	18/06/2011
Cyclopoida	Cyclopidae	Halicyclops	microeberherdi n. sp.	LMST008	-27.1333	121.033	17/08/2010
Cyclopoida	Cyclopidae	Halicyclops	microeberherdi n. sp.	LMST014	-27.165	121.048	17/08/2010
Cyclopoida	Cyclopidae	Halicyclops	microeberherdi n. sp.	LMST004	-27.1666	121.05	17/08/2010
Cyclopoida	Cyclopidae	Halicyclops	microeberherdi n. sp.	LMST006	-27.15	121.05	17/08/2010
Cyclopoida	Cyclopidae	Mesocyclops	brooksi	Site 419, "The Other Home Well", Yeeleerie Station	-27.2816	120.093	27/06/2000
Cyclopoida	Cyclopidae	Mesocyclops	brooksi	Townsend Well, Yakabindie Station	-27.655	120.687	29/06/2000
Cyclopoida	Cyclopidae	Microcyclops	varicans	6 Mile Bore	-27.0361	121.062	18/08/2010
Cyclopoida	ORDER: Cyclopoida			130km south east of Wiluna; WAM1-LT107	-27.1358	120.954	18/07/2011
Cyclopoida	ORDER: Cyclopoida			130km south east of Wiluna; Little Well	-27.1338	121.004	18/07/2011
Cyclopoida	ORDER: Cyclopoida			130km south east of Wiluna; LMST012	-27.1558	121.036	18/07/2011
Cyclopoida	ORDER: Cyclopoida			130km south east of Wiluna; LMACW69	-26.9808	121.092	18/07/2011
Cyclopoida				TB18	-26.982	120.676	1/02/2012
Cyclopoida				LMST008	-27.1333	121.033	14/03/2011
Cyclopoida				LMST012	-27.1558	121.036	15/03/2011
Cyclopoida				LT105	-27.1362	120.948	31/01/2012
Cyclopoida				LT104	-27.1361	120.951	31/01/2012
Cyclopoida				LT107	-27.1359	120.954	31/01/2012
Cyclopoida				SCP1111	-26.9849	120.643	17/11/2011
Cyclopoida				TB1-8	-26.982	120.676	17/11/2011
Cyclopoida				Lake Way South	-27.0011	120.745	27/03/2011
Cyclopoida				WAM3	-27.1362	120.948	18/11/2011
Cyclopoida				WAM1	-27.1359	120.954	22/09/2011
Cyclopoida				WAM1	-27.1359	120.954	18/11/2011
Cyclopoida				Little Well	-27.1338	121.004	14/03/2011
Cyclopoida				Little Well	-27.1338	121.004	9/03/2010
Cyclopoida				EH01	-27.1852	121.066	8/03/2010

GROUP	FAMILY	GENUS	SPECIES	SITE	LATITUDE (DECIMAL)	LONGITUDE (DECIMAL)	DATE
Harpacticoida	Ameiridae	Nitocra	lacustris	Little Well	-27.1338	121.004	18/08/2010
Harpacticoida	Ameiridae	Nitokra	esbe	bore SB14-1	-27.3443	120.308	18/03/2010
Harpacticoida	Ameiridae	Nitokra	esbe	bore SB14-1	-27.3443	120.308	18/03/2010
Harpacticoida	Ameiridae	Nitokra	esbe	bore SB14-1	-27.3443	120.308	18/03/2010
Harpacticoida	Ameiridae	Nitokra	yeelirrie	Bore line N, bore YYHC0067B, Yilgarn region	-27.3064	120.225	23/09/2010
Harpacticoida	Ameiridae	Nitokra	yeelirrie	bore YYHC0067B, bore line N	-27.3064	120.225	23/09/2010
Harpacticoida	Ameiridae	Nitokra	yeelirrie	Bore line K, bore YYHC085B	-27.2478	120.055	20/03/2010
Harpacticoida	Ameiridae	Nitokra	yeelirrie n. sp.	Yeelirrie station	-27.3441	120.308	10/03/2009
Harpacticoida	Miraciidae	Schizopera	akation	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	akation sp. nov.	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	akation sp. nov.	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3297	120.151	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3297	120.151	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3297	120.151	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa	Yeelirrie station	-27.3297	120.151	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa n. sp.	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa s. str	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	analspinulosa s.str	Yeelirrie station	-27.3441	120.308	18/03/2010
Harpacticoida	Miraciidae	Schizopera	dimorpha n. sp.	LMST011	-27.1472	121.054	18/08/2010
Harpacticoida	Miraciidae	Schizopera	dimorpha n. sp.	LMST006	-27.15	121.05	17/08/2010
Harpacticoida	ORDER: Harpacticoida			130km south east of Wiluna; WAM1-LT107	-27.1358	120.954	18/07/2011
Harpacticoida	ORDER: Harpacticoida			130km south east of Wiluna; Little Well	-27.1338	121.004	18/07/2011
Harpacticoida	ORDER: Harpacticoida			130km south east of Wiluna; LMST008	-27.1377	121.034	18/07/2011
Harpacticoida	ORDER: Harpacticoida			130km south east of Wiluna; LMST012	-27.1558	121.036	18/07/2011
Harpacticoida	Parastenocarididae	Kinnecaris	esbe sp. nov.	SB14-1	-27.3443	120.308	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	esbe sp. nov.	SB14-1	-27.3443	120.308	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	esbe sp. nov.	SB14-1	-27.3443	120.308	18/03/2010

GROUP	FAMILY	GENUS	SPECIES	SITE	LATITUDE (DECIMAL)	LONGITUDE (DECIMAL)	DATE
Harpacticoida	Parastenocarididae	Kinnecaris	lined	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	lined sp. nov.	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	lined sp. nov.	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	lined sp. nov.	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	lined sp. nov.	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	lined sp. nov.	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	lined sp. nov.	bore line D	-27.2828	120.111	23/09/2010
Harpacticoida	Parastenocarididae	Kinnecaris	linel sp. nov.	bore line L, Snake Well	-27.3073	120.151	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	linel sp. nov.	bore line L, Snake Well	-27.3073	120.151	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	linel sp. nov.	bore line L, Snake Well	-27.3073	120.151	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	linel sp. nov.	bore line L, Snake Well	-27.3073	120.151	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	linel sp. nov.	bore line L, Snake Well	-27.3073	120.151	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	linel sp. nov.	bore line L, Snake	-27.3073	120.151	18/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	uranusi	bore line K	-27.2478	120.055	20/03/2010
Harpacticoida	Parastenocarididae	Kinnecaris	uranusi	bore line K	-27.2478	120.055	20/03/2010
Harpacticoida				LMST012	-27.1558	121.036	17/08/2010
Harpacticoida				SCP1111	-26.9849	120.643	31/01/2012
Harpacticoida				LT105	-27.1362	120.948	31/01/2012
Harpacticoida				LT107	-27.1359	120.954	18/11/2011
Harpacticoida				LT107	-27.1359	120.954	21/09/2011
Harpacticoida				LT107	-27.1359	120.954	31/01/2012
Harpacticoida				1109D	-26.9673	120.638	17/11/2011
Harpacticoida				SCP1111	-26.9849	120.643	17/11/2011
Harpacticoida				TB1-8	-26.982	120.676	17/11/2011
Harpacticoida				Lake Way South	-27.0005	120.745	17/11/2010
Harpacticoida				Lake Way South	-27.0011	120.745	17/11/2010
Harpacticoida				Lake Way South	-27.0011	120.745	27/03/2011
Harpacticoida				TB7-7	-27.0011	120.745	16/11/2011
Harpacticoida				TB7-7	-27.0011	120.745	16/11/2011

GROUP	FAMILY	GENUS	SPECIES	SITE	LATITUDE (DECIMAL)	LONGITUDE (DECIMAL)	DATE
Harpacticoida				WAM3	-27.1362	120.948	18/11/2011
Harpacticoida				WAM2	-27.1361	120.951	18/11/2011
Harpacticoida				Little Well	-27.1338	121.004	9/03/2010
Harpacticoida				EH01	-27.1852	121.066	8/03/2010
Harpacticoida				LMST012	-27.1558	121.036	15/03/2011
Isopoda	Paraplatyarthridae	Paraplatyarthrus	cooperi sp. nov.	Lake Miranda East calcrete	-27.664	120.61	8/08/2011
Isopoda	Paraplatyarthridae	Paraplatyarthrus	cooperi sp. nov.	Lake Miranda East calcrete	-27.664	120.61	8/08/2011
Isopoda	Paraplatyarthridae	Paraplatyarthrus	cooperi sp. nov.	Lake Miranda East calcrete	-27.664	120.61	8/08/2011
Isopoda	Paraplatyarthridae	Paraplatyarthrus	cooperi sp. nov.	Lake Miranda East calcrete	-27.664	120.61	8/08/2011
Isopoda	Paraplatyarthridae	Paraplatyarthrus	cooperi sp. nov.	Lake Miranda East calcrete	-27.664	120.61	8/08/2011
Isopoda	Paraplatyarthridae	Paraplatyarthrus	cooperi sp. nov.	Lake Miranda East calcrete	-27.664	120.61	8/08/2011
Isopoda	Scyphacidae	Haloniscus	sp. OES1	Leinster	-27.1528	121.082	24/05/2007
Isopoda	Scyphacidae	Haloniscus	sp. OES12	Leinster	-27.1566	121.093	24/05/2007
Ostracoda				130km south east of Wiluna; Little Well	-27.1338	121.004	18/07/2011
Ostracoda				CP52	-27.431	120.575	2/02/2012
Ostracoda				WAM3	-27.1362	120.948	18/11/2011
Ostracoda				Little Well	-27.1338	121.004	9/03/2010
Ostracoda				LMST006	-27.15	121.05	17/08/2010
Syncarida				130km south east of Wiluna; WAM3-LT105	-27.1363	120.948	18/07/2011

Appendix E Groundwater Physico-chemical Data

Table E-1: Recorded groundwater parameters. DO = dissolved oxygen; Temp = temperature; SWL = standing water level; EoH = end of hole.

Project Area	Bore ID	Date	D.O. (ppm)	Temp (°C)	Salinity (ppm)	pH	Redox (mV)	SWL (m bgl)	EoH (m bgl)
Goliath	95GPG07	18/11/2010	4.66	26.5	7730	7.35	174	33.15	72.9
Goliath	95GPG07	29/03/2011	4.13	25.5		7.35	135	33.3	75.6
Goliath	95GPG11	18/11/2010	4.91	25.7	1055	7.87	147	27.4	57.6
Goliath	95GPG11	29/03/2011	5.48	24.8		7.74	87	26.1	59.4
Goliath	CP11	18/11/2010	4.91	26	824	7.84	159	26.06	58.5
Goliath	CP11	29/03/2011	5.05	26.1		7.67	24	26.1	32.4
Goliath	CP21	18/11/2010	6.75	26.1	2120	7.71	155	29.1	61.2
Goliath	CP53	18/11/2010	4.03	26.6	2250	7.39	149	20.93	64.8
Goliath South	CP5P	16/11/2010	6.64	26.8	848	7.98	101	25.25	69.3
Goliath South	CP5P	28/03/2011	4.65			7.4		25.45	66.6
Goliath South	CP6P	16/11/2010	4.35	26.1	425	7.46	110	21.84	33.3
Goliath South	CP6P	28/03/2011	4.59	24.3		7.18	176		31.5
Goliath South	CP6P	21/06/2011	5.64	21.1	283	7.92	90	21.77	200
Goliath South	YEX82	16/11/2010	4.55	26.6	1310	7.99	109	19.8	66.6
Goliath South	YEX82	28/03/2011	4.6	24.9		8.01	193		30.6
Goliath South	YEX82	21/06/2011	3	18.7	1180	8.06	64	20.06	200
Serp Hill South	CP13P	18/11/2010	5.68	24.9	857	7.93	188	11.08	79.2
Serp Hill South	CP13P	28/03/2011	6.12	25.5		7.33	156	10.8	59.4
Serp Hill South	CP13P	17/06/2011	6.16	24.1	4.39	7.61	53	11.6	90
Serp Hill South	CP22P	16/11/2010	3.33	26.3	1370	7.49	121	12.17	51.3
Serp Hill South	CP22P	28/03/2011	6.05	25.7		7.31	113	11.7	46.8
Serp Hill South	CP22P	21/06/2011	3.92	21.7	1089	7.51	63	11.9	90
Serp Hill South	SHGCN60	18/11/2010	5.09	25.2	2070	7.72	182	16	81.9
Serp Hill South	SHGCN60	28/03/2011	5.55	26.2		7.68	134	15.3	59.4
Serp Hill South	SHGCN60	21/06/2011	6.83	22	1930	7.88	88	15.63	64
Serp Hill South	SHGCN62	16/11/2010	2.78	26.6	1122	7.51	121	16.24	45
Serp Hill South	SHGCN62	28/03/2011	4.61	26		7.87	133	15.3	81
Serp Hill South	SHGCN62	21/06/2011	3.65	23.3	1490	8.14	74	16.12	60.3
Serp Hill South	SHNP2	18/11/2010	5.62	26	1840	8	172	15.17	81
Serp Hill South	SHNP2	28/03/2011	5	25.8		7.93	134	16.2	51.3
Serp Hill South	SHNP2	21/06/2011	6.82	22.6	1820	8.4	73	15.22	38.7

Project Area	Bore ID	Date	D.O. (ppm)	Temp (°C)	Salinity (ppm)	pH	Redox (mV)	SWL (m bgl)	EoH (m bgl)
Serp Hill South	SHSP1	16/11/2010	6.03	26.4	1168	8.33	87	12.95	62.1
Serp Hill South	SHSP1	28/03/2011	4.71	26.2		8.04	109	13.5	45
Serp Hill South	SHSP1	21/06/2011	5.8	21.7	1148	8.56	83	12.77	38.7
Serp Hill South	SHSP2	16/11/2010	4.31	26.1	1270	7.15	47	20.85	54.9
Serp Hill South	SHSP2	28/03/2011	4.14	26		6.98	88	19.8	99
Serp Hill South	SHSP2	21/06/2011	3.57	21.9	1610	7.3	-63	20.7	36.9
Sheba	SBD3	16/11/2010	6.63	28.1	1176	7.74	124	27.1	60.3
Sheba	SBD3	28/03/2011	7.77	23.6		7.77	132	26.04	90
Six-mile Well	CP51	18/11/2010	3.37	27.1	2550	6.87	136	27.54	38.7
Six-mile Well	CP51	29/03/2011	3.7	22.3		6.71	119	28.8	38.7
Six-mile Well	CP51	17/06/2011	5.71	23.8	2360	7.08	-192	26.35	36.9
Six-mile Well	CP52	18/11/2010	6.3	27.3	4860	7.28	154	23.03	64
Six-mile Well	CP52	29/03/2011	6.25	22.7		7.21	71	23.4	60.3
Six-mile Well	CP52	17/06/2011	5.27	24.5	3810	7.65	41	22.42	60.3
Waste Rock Landform	YEX162	17/06/2011	4.09	23.1		8.23	181	22.99	49.5
Waste Rock Landform	YEX166	17/06/2011	4.05	23.9	482	8.25	152	24.3	62.1

Appendix F Subterranean Fauna Survey Results

Table F-1: Subterranean fauna survey results (including Biota 2006) sorted by taxon.

Group	Family	Taxon	No. Individuals	Project Area	Bore Code	Eastings (51 J)	Northings (51 J)	Location	Sample Start Date	Sample End Date	Sampling method
Stygofauna Results											
Amphipoda	Neoniphargidae	Neoniphargidae	2	Goliath	YAKB06	260859	6961556	Near pit (<200m)	2006		Net Haul
Bathynellacea	Bathynellidae	Bathynellidae sp. OES2	1	Serp Hill South	CP22P	260886	6960426	Outside pits (>500m, <1km)	21-Jun-11		Net Haul
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES11	1	Six Mile Well	CP51	260404	6964368	Inside Pit	2-Feb-12		Net Haul
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES8	1	Six Mile Well	CP51	260542	6964526	Inside Pit	18-Nov-10		Net Haul
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES9	1	Serp Hill South	CP22P	260886	6960426	Outside pits (>500m, <1km)	21-Jun-11		Net Haul
Oligochaeta		Oligochaeta	1	Goliath	CP21	261724	6961463	Inside Pit	2006		Net Haul
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	3	Six Mile Well	CP51	260542	6964526	Inside Pit	17-Jun-11		Net Haul
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	7	Serp Hill South	CP13P	259844	6959931	Outside pits (>1km)	2-Feb-12		Net Haul
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	7	Six Mile Well	CP51	260542	6964526	Inside Pit	18-Nov-10		Net Haul
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	50	Six Mile Well	CP51	260404	6964368	Inside Pit	2-Feb-12		Net Haul
Ostracoda	Limnocytheridae	*Gomphodella* sp. IK2	2	Six Mile Well	CP52	260256	6963486	Near pit (>300m, <500m)	2-Feb-12		Net Haul
Troglofauna Results											
Diplura	Campodeidae	Campodeidae sp. OES2	1	Serp Hill South	SHGCN62	260735	6960583	Outside pits (>500m, <1km)	3-Feb-12		Scrape
Isopoda	Amardillidae	*Buddelundia* sp. OES3	1	Serp Hill South	YSHD29	260717	6960666	Outside pits (>500m, <1km)	26-Mar-11	30-May-11	Litter trap
Isopoda	Amardillidae	*Buddelundia* sp. OES3	1	Serp Hill South	YSHD29	260717	6960666	Outside pits (>500m, <1km)	30-May-11	19-Jul-11	Litter trap

Table F-2: Subterranean fauna survey results (including Biota 2006) sorted by Project Area and bore.

Project Area	Bore Code	Eastings (51 J)	Northings (51 J)	Location	Sample Start Date	Sample End Date	Sampling method	Group	Family	Taxon	No. Individuals
Stygofauna Results											
Goliath	CP21	261724	6961463	Inside Pit	2006		Net Haul	Oligochaeta		Oligochaeta	1
Goliath	YAKB06	260859	6961556	Near pit (<200m)	2006		Net Haul	Amphipoda	Neoniphargidae	Neoniphargidae	2
Serp Hill South	CP13P	259844	6959931	Outside pits (>1km)	2-Feb-12		Net Haul	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	7
Serp Hill South	CP22P	260886	6960426	Outside pits (>500m, <1km)	21-Jun-11		Net Haul	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES9	1
Serp Hill South	CP22P	260886	6960426	Outside pits (>500m, <1km)	21-Jun-11		Net Haul	Bathynellacea	Bathynellidae	Bathynellidae sp. OES2	1
Six Mile Well	CP51	260542	6964526	Inside Pit	18-Nov-10		Net Haul	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	7
Six Mile Well	CP51	260542	6964526	Inside Pit	18-Nov-10		Net Haul	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES8	1
Six Mile Well	CP51	260542	6964526	Inside Pit	17-Jun-11		Net Haul	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	3
Six Mile Well	CP51	260404	6964368	Inside Pit	2-Feb-12		Net Haul	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES11	1
Six Mile Well	CP51	260404	6964368	Inside Pit	2-Feb-12		Net Haul	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES10	50
Six Mile Well	CP52	260256	6963486	Near pit (>300m, <500m)	2-Feb-12		Net Haul	Ostracoda	Limnocytheridae	*Gomphodella* sp. lK2	2
Troglofauna Results											
Serp Hill South	YSHD29	260717	6960666	Outside pits (>500m, <1km)	26-Mar-11	30-May-11	Litter trap	Isopoda	Amardillidae	*Buddelundia* sp. OES3	1
Serp Hill South	YSHD29	260717	6960666	Outside pits (>500m, <1km)	30-May-11	19-Jul-11	Litter trap	Isopoda	Amardillidae	*Buddelundia* sp. OES3	1
Serp Hill South	SHGCN62	260735	6960583	Outside pits (>500m, <1km)	3-Feb-12		Scrape	Diplura	Campodeidae	Campodeidae sp. OES2	1

Western Botanical

Flora and Vegetation Assessment of the Mt Keith Satellite Proposal Study Area

March 2017

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Executive Summary

BHP Billiton Nickel West Australia (NiW) proposes to develop the Mt Keith Satellite operation (MKS), approximately 680 km north-east of Perth. Several field assessments and reports have been produced for the MKS project between 1990 and 2011 in support of a Level 2 Survey of flora and vegetation, consistent with EPA Guidance Statement 51 (Environmental Protection Authority, 2004). Western Botanical was engaged by NiW to review and update the previous baseline flora and vegetation report (Western Botanical, 2012) following a revision of the MKS project scope. Supplementary field works were commissioned and conducted during May, November and December 2016 to support the update of the flora and vegetation assessment report. This report presents the updated baseline flora and vegetation assemblages covering the revised MKS project footprint and regional context (Proposal Study Area). This report has been prepared to meet the requirements for Environmental Impact Assessment in accordance with the EPA's Guidance Statement 51 and the recent Environmental Protection Authority and Department of Parks and Wildlife (2015) Technical Guide – Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment.

In summary, the following findings are relevant to the MKS Proposal Study Area:

Flora

The consolidated cumulative species list for the MKS Proposal Study Area now contains 393 species (and putative hybrids) from 140 genera and 51 families of endemic flora. Of these, the majority are common, widespread in distribution and are highly representative of the flora of eastern Murchison and western Gt Victoria Desert biogeographic regions. This compares with 279 species recorded in previous surveys at the MKS Proposal Study Area to the end of 2015 and 301 species recorded in the spring 2016 assessments with 176 species recorded in both periods.

Dominant families include Fabaceae (76 species incl. putative hybrids), Poaceae (47 species), Chenopodiaceae (46 species), Scrophulariaceae (37 species), Asteraceae (30 species), Malvaceae (22 species) and Myrtaceae (20 species). Dominant genera were *Acacia* (53 species inclusive of 31 species and numerous putative hybrids of Mulga species); *Eremophila* (37 species), *Maireana* (18 species) *Senna* (14 species), *Sida* (11 species) and *Eragrostis* (7 species). Excluding putative hybrids, the Proposal Study Area supports 13 species of Mulga.

Six weed species were also recorded, all in small scattered populations of low numbers.

While no Threatened Flora as listed under the *Wildlife Conservation Act 1950* are known within or nearby the Proposal Study Area, Twelve Priority Flora species are known within the areas assessed. These include one Priority 1, eight Priority 3 and three Priority 4 listed species.

Priority Flora species

Anacampseros sp. Eremaean (F. Hort, J. Hort & J. Shanks 3248) P1 (Associated with Archaean granitoid domains).

Aristida aff. jerichoensis var. *subspinulifera* P3 (1 record in Jones Creek).

Eremophila pungens complex P4, inclusive of *E.* sp. Leinster (R.J. Cranfield 6767) (low numbers, widespread in the MKS Development Envelope and Proposal Study Area, associated with Archaean granite breakaways, ironstone hills and upper colluvial slopes).

Grevillea inconspicua P4 (low numbers, widespread in the MKS Development Envelope and Proposal Study Area, associated with basalt outcrop and subcrop).

Gunniopsis propinqua P3 (several records in the MKS Development Envelope and Proposal Study Area, associated with saline sites).

Hemigenia exilis P4 (low numbers, widespread in the MKS Development Envelope and Proposal Study Area, associated with volcaniclastic sediments and Wiluna Hardpan).

Hibiscus krichauffianus P3 (three records within the MKS Development Envelope and Proposal Study Area, associated with ironstone and quartz outcrops).

Hybanthus floribundus subsp. *chloroxanthus* P3 (scattered populations in the MKS Development Envelope and Proposal Study Area, associated with tributaries of Jones Creek).

Sida picklesiana P3 (MKS Development Envelope and Proposal Study Area, associated with Archaean granite breakaways).

Thryptomene sp. Leinster (B.J. Lepschi & L.A. Craven 4362) P3 (MKS Development Envelope and Proposal Study Area, associated with Archaean granite breakaways, SIMS and SILS communities).

Tribulus adelacanthus P3 (one record within the MKS Development Envelope on colluvial slopes)

Verticordia jamiesonii P3 (MKS Development Envelope and Proposal Study Area, associated with Archaean granite breakaways).

One of these species, *Aristida aff. jerichoensis* subsp. *subspinulifera* P3 has been identified based on less than optimal material and re-collections for confirmation of the identifications of this species is required.

Small proportions of the overall local population of *Hybanthus floribundus* subsp. *chloroxanthus* P3, *Hemigenia exilis* P4, *Grevillea inconspicua* P4 and *Thryptomene* sp. Leinster P3 will be impacted by the development of the mine voids and wastedumps while *Thryptomene* sp. Leinster P3 and *Verticordia jamiesonii* P3 will be impacted by the development of haul road alignment.

Species of Interest

Species of Interest are defined as (i) undescribed species which are not formally recognised as yet and represent species new to science but are widespread and not of conservation significance; (ii) undescribed species with limited known distribution which may warrant conservation review and (iii) species of uncertain taxonomy which do require specialist inputs and may warrant conservation review.

Widely distributed undescribed species

Eight undescribed species with informal names that do not appear on the Census of Vascular Flora, and therefore are not shown on the DPaW Florabase website, are known from the MKS Proposal Study Area. The majority of these are well known, represented by numerous specimens at the WA Herbarium (albeit under names other than listed below) and widespread in distribution within the Murchison, Pilbara or Gt Victoria Desert biogeographic regions. These do not warrant conservation consideration. These species listed below require (i) formal vouchering at the WA Herbarium and (ii) taxonomic and differentiation within the broad species complexes that they currently reside within. All belong to species complexes that are acknowledged by the relevant specialist taxonomists as requiring further review.

Acacia oswaldii (long phyllode variant) (G Cockerton & S. Cockerton WB38622).

Maireana tomentosa - (Type 1 breakaway foot slopes) (G Cockerton & D Brassington WB38650);

Olearia sp. Sherwood Breakaways (A. Taylor 25552);

Olearia xerophila sens. lat. (G. Cockerton & P. Goodman WB38116);

Ptilotus obovatus (typical Goldfields form) (G. Cockerton, G. Grehan, L. Trotter, J. Symington 15213);

Ptilotus obovatus (upright form) (G. Cockerton, G. Grehan, L. Trotter, J. Symington LCH 15206);

Scaevola spinescens (broad leaf, non-spiny form); and

Scaevola spinescens (narrow leaf, spiny form)

A further twelve well known but as yet undescribed species are also known within the Proposal Study Area. These are well represented in collections at the WA Herbarium, appear on the Census of Vascular Flora and are shown on the DPaW Florabase website. These are listed in the Systematic Species List for the MKS Proposal Study Area.

Undescribed species with limited distribution

One species, *Eremophila* sp. long pedicels (G. Cockerton 1975), is known from few specimens in the Lake Way and Lake Maitland Catchments in the Wiluna area. A recent review of the taxon has found additional material in the region, however, a review of the relevant WA Herbarium specimens by Western Botanical does not support the inclusion of material outside the Lake Way and Lake Maitland catchments in this species. A small number of individuals of *Eremophila* sp. long pedicels lie within the proposed haul road alignment to Mt Keith, representing a negligible proportion of the overall known regional population.

Species with uncertain taxonomic status, requiring further review

The taxonomic status of six (to seven) species is not well understood and will require the attention of specialist taxonomists in those genera. These are:

Acacia aff. *doreta* (narrow pod form) (G. Cockerton & S. Cockerton WB38633);

Acacia aff. *subtessarogona* (flat pod form) (G. Cockerton WB38658);

Acacia aff. *xanthocarpa* (terete to flat phyllode, resinous margins complex, inclusive of *Acacia* sp. East Murchison Basalt (G. Cockerton 38064));

Hibbertia aff. *exasperata* (G. Cockerton & G. O'Keefe 11911);

Olearia sp. Sherwood Breakaways (A. Taylor 25552), currently within *Olearia stuartii*; and

Olearia xerophila sens. lat. (G. Cockerton & P. Goodman WB38116), currently within *Olearia xerophila*.

The *Acacia* species noted above will require an extensive and complex review of the abundant specimen material available following the 2016 round of field works. Preliminary works in this regard have commenced in March 2017.

The *Hibbertia* aff. *exasperata* (G. Cockerton & G. O'Keefe 11911) requires collection of suitable flowering and fruiting material to effect unambiguous identification. There is sufficient material available of the two *Olearia* species to conduct the taxonomic reviews required.

Hibbertia aff. *exasperata* (G. Cockerton & G. O'Keefe 11911) remains a species with both taxonomic and conservation interest as the material available for identification to date is

inadequate and the disjunction from potentially related taxa is significant, with the MKS populations being some 200 km north-east of the closest related species, Figure 48. A large proportion of the small population of round 92 plants within the MKS Proposal Study Area is to be impacted by the proposed haul road alignment.

The broad leaved, non-hairy pod form of the *Acacia xanthocarpa* complex, here termed *Acacia* sp. East Murchison Basalt (G. Cockerton 38064), lies within the MKS wastedump footprint with few records outside this area.

Some of these species may warrant conservation consideration, based on current knowledge of occurrences in the Wiluna – Leinster region.

Species occurring at limits of known range or representing range extensions

Eight species records at the MKS Proposal Study Area represent slight range extensions of known distributions. These species are well represented within Western Australia and do not warrant further conservation consideration.

Acacia brachystachya;

Eremophila platycalyx subsp. Neds Creek (N.H. Speck 1228);

Aristida aff. jerichoensis var. *subspinulifera* P3;

Chondropyxis halophila;

Muelleranthus trifoliolatus;

Maireana melanocoma;

Olearia xerophila sens. lat. (G. Cockerton & P. Goodman WB38116); and

Sida sp. spiciform panicles (E. Leyland s.n. 14/8/90).

Vegetation

Vegetation of the MKS Proposal Study Area and the proposed MKS Borefield were mapped at scales of 1:10,000 and 1:25,000 respectively to NVIS Level 5 *Association* level. Terminology for the Vegetation Associations in the sandplain and granitoid communities closely follows that of Pringle *et. al.* (1994) while communities in other geological or regolith domains have novel, project-specific community codes developed, conforming to NVIS Level 5 protocols.

Thirty Eight Vegetation Associations and 2 Vegetation Association Complexes, have been recognised in the MKS Proposal Study Area. The Vegetation Associations have been grouped into 6 sub-units according to the dominating underlying geology / regolith which strongly influences the vegetation association species composition, Table 7.

Those vegetation associations on (i) Sandplains (5 communities) and (ii) Colluvial and Alluvial Landforms are widely distributed in the Murchison Biogeographic region. Vegetation Associations of the (iii) Limonitic Landforms, the (iv) fresh rock Basalt geology of the Perseverance fault line and (v) carbonate soils derived from weathered basalt geology as well as some of the colluvial slopes associated with these are less widely distributed and, based on information available to date, are constrained within the Perseverance fault line and within the boundaries of the Violet Ranges Priority Ecological Community. While narrow in an east-west orientation, these landforms extend for over 80 km in a north-south orientation while the Violet Ranges PEC represents a subset of this overall range.

The majority of Vegetation Associations individually represent less than 10% of the area of occupancy within the MKS Proposal Study Area. Two Vegetation Associations represent greater than 10%: Stony Mulga Shrubland, SMS, (14.09% of the MKS Proposal Study Area) and Granitic Mulga Shrubland, GrMS, (18.26% of the MKS Proposal Study Area). Large areas of SIMS, with the associated colluvial lower slopes, has been extensively mapped near both Mt Keith and Leinster (Western Botanical, 2016). The GrMS Vegetation Association is widespread in the region and in found extensively outside the MKS Proposal Study Area in both an eastern direction (within the Wanjarri Nature Reserve) and western direction (within Yakabindie, Mt Keith, Albion Downs and Yeelirrie Stations and beyond), in association with the Archaean granitoid Barr-Smith Range.

Six Vegetation Associations will be impacted at levels of between 20% and 50% of their area mapped within the MKS Proposal Study Area . These are the SMS (21.55%), HPMS (22.81%), EGPW (43.13%), USBS (35.39%), SSS (41.89%) and GHPS (43.13%). The SMS, HPMS and EGPW communities are well represented outside the MKS Proposal Study Area while the USBS, SSS and GHPS communities are largely known from within the MKS Proposal Study Area.

The SIMS, SMS and HPMS-Thoma communities are impacted to High (SIMS, 57.98%) and Very High (SMS, 75.22%, HPMS-Thoma 100%) proportions of their mapped areas within the

MKS Proposal Study Area. However, SIMS is widespread within the Bevon Land System between Leinster and Mt Keith and HPMS-Thoma community is very closely aligned with the wider-spread HPMS community (separated only by the inclusion of *Acacia thoma* as a dominant species). *Acacia thoma* is known from four locations within the MKS Proposal Study Area and also at Leinster and regionally to the Pilbara region.

Vegetation Condition, Weeds and Grazing

The MKS tenements have been extensively explored in the past and post exploration rehabilitation was found to have been largely effective. Vegetation condition outside the areas directly impacted by exploration and track maintenance can be regarded as being in Pristine (i) condition with little evidence of pastoral activities. Areas having been disturbed in previous exploration works are regarded as being in Excellent (ii) condition while completely cleared areas were recorded as Completely Degraded (vi).

Weed populations were always found in small, isolated populations with low numbers of individuals present. Three species, *Rumex vesicarius* (Ruby Dock), *Cenchrus ciliaris* (Buffel Grass), *Cenchrus setiger* (Birdwood Grass) have the potential to be highly invasive and should be actively managed. A further three species, *Bidens bipinnata* (Tick Weed), *Lysimachia arvensis* (Pimpernel) and *Mesembryanthemum nodiflorum* (Slender Iceplant) pose a lesser risk to the project and do not warrant active management.

While the MKS project lies largely within the Yakabindie Pastoral Lease and grazing of cattle has historically been the main pastoral activity in the past 20 years (D. Brownlie pers. comm.), little evidence of grazing pressure on vegetation is apparent. Specifically, the Mulga and associated vegetation shows little evidence of grazing by cattle and the canopies of most vegetation is intact and reflects normal seasonal conditions.

Wanjarri Nature Reserve

The Wanjarri Nature Reserve is contiguous with the eastern margin of the MKS tenements. Here, the vegetation is reflective of underlying granitoid landscapes with extensive Aeolian sandplains, extensive Archaean granite breakaways and associated saline footslopes and hardpan plains being present. These landscape units are widespread and prevalent in the north-eastern Goldfields region and are well represented both within and outside the adjacent Wanjarri Nature Reserve. Components of the Violet Ranges PEC are not represented within the Wanjarri Nature Reserve. The development of the MKS project will not directly impact on the Wanjarri Nature Reserve as currently defined.

Priority Ecological Community

The MKS Proposal Study Area lies approximately centrally within the 19,256.2 ha *Violet Ranges (Perseverance Greenstone Belt) vegetation complexes (banded ironstone formation)*

Priority 1 Priority Ecological Community. This PEC extends for approximately 32 km in a north-south orientation and approximately 11 km in an east-west orientation at it's widest point.

The MKS Proposal Study Area intersects 3,248.5 ha or 16.87 % of the 19,256.2 ha Violet Ranges PEC and the MKS proposed Development Envelope represents 1242 ha or 5.87 % of the Violet Ranges PEC as currently mapped. Minimal historical impacts to the Violet Ranges PEC have occurred to date with clearing for pastoral tracks and fences as well as historical, now decommissioned, Bellevue mining activities on the north-shore of Lake Miranda being the major contributors.

Additional adjacent areas of similar basalt geology and associated vegetation types that lie within the Mt Keith - Perseverance greenstone belt / fault line, but outside the current PEC boundaries. These areas extend in a discontinuous fashion both northward (north of the Mt Keith nickel mine) and southward (to the Leinster nickel mine) directions for an overall inclusive length of approximately 82 km. If found to be representative of the PEC, the definition and the area of occupancy the Violet Ranges PEC should be reviewed to incorporate these areas.

If the expanded area between the Leinster Nickel Mine and to the north of the Mt Keith Nickel Mine was to be considered as representing similar vegetation associations aligned with the intent of the Violet Ranges PEC, then the proportional impact of the MKS project on the PEC would be approximately halved to between 4% and 5%. However, the cumulative impacts of both the Leinster and Mt Keith Nickel mines would have to be taken into consideration. This broadened analysis, incorporating a validation of the assertion of the increased area of the PEC, has not been undertaken as yet.

1. Introduction

1.1. Project Background

BHP Billiton Nickel West Australia (NiWest) proposes to develop the Mt Keith Satellite Operation (MKS), approximately 680 km north-east of Perth. Several field assessments and reports have been produced for the MKS Project between 1990 and 2011 in support of a Level 2 Survey of flora and vegetation, in accordance with EPA Guidance Statement 51 (Environmental Protection Authority, 2004). This report has been prepared to meet the requirements for Impact Assessment in accordance with the EPA's Guidance Statement 51 and the recent Environmental Protection Authority and Department of Parks and Wildlife (2015) Technical Guide – Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment.

In mid 2016, Western Botanical was engaged by NiWest to review and update the previous baseline flora and vegetation report (Western Botanical, 2012) following a revision of the MKS Proposal Study Area. Supplementary field works were conducted during May 2016 to support the production of the updated flora and vegetation assessment report (Western Botanical, 2016).

Following this, Western Botanical was engaged to conduct work to address identified gaps in previous work conducted on behalf of NiWest. This report presents the updated baseline flora and vegetation study conducted over the revised MKS Proposal Study Area, inclusive of the proposed Six Mile and Goliath pits, wastedumps, infrastructure areas and the haul road alignment to the Mt Keith minesite. Results of field surveys presented here are current to end November 2016 with taxonomic status of flora current to end February 2017.

1.2. Location

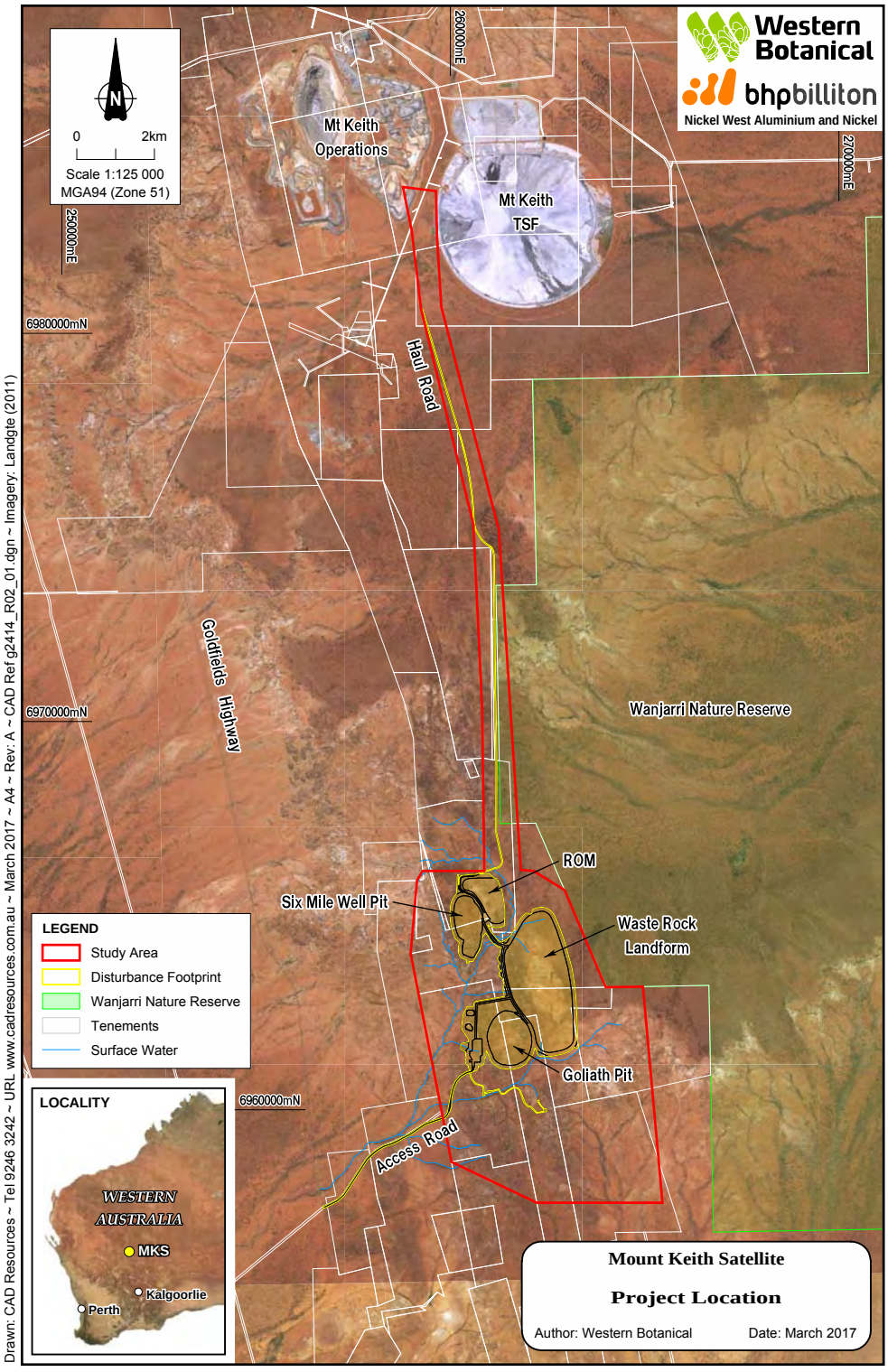
The MKS Project is located in the north-eastern Goldfields of Western Australia, 52 km north-north-west of Leinster, around 25 km south of the Mount Keith Mine, and 3 km east of the Goldfields Highway,

Figure 1. The MKS Proposal Study Area lies immediately adjacent to the western boundary of the Wanjarri Nature Reserve (WNR) but does not directly impact on the Reserve.

The North-eastern Goldfields region lies in the north-eastern corner of the Archaean Yilgarn Block. As defined by Beard (1990), the project falls within the Wiluna sub-region of the Austin Botanical District of the Eremaean Botanical Province. The Interim Biogeographic Regionalisation for Australia (Department of the Environment, 2013) places the MKS Project in the eastern portion of the Murchison Biogeographic Region (MUR01).

Figure 1. Project Location Map

Insert Figure map



1.3. Previous surveys

The MKS Proposal Study Area (previously referred to as the NDS1 Project and the Yakabindie Nickel Project) has been the focus of multiple flora and vegetation survey reports since 1990. Previous reports addressed two aspects of the overall project. Works A, B, F to N assess the flora and vegetation values of the proposed MKS Proposal Study Area including orebodies, infrastructure areas and the proposed haul road to Mt Keith. These were progressively conducted to fulfil the requirements of a Level 2 Survey, in accordance with EPA Guidance Statement 51 (Environmental Protection Authority, 2004). Works D and F to refer to the flora and vegetation conservation values of the south-western portion of the WNR and an area within Yakabindie Station which were the subject of a successful land swap aimed at excising a portion of the Wanjarri Nature Reserve in order to facilitate mining at the MKS Proposal Study Area. Table 1 summarises previous surveys and reports related to the MKS Proposal Study Area.

Table 1. Previous Reports Relating to the Flora and Vegetation of the MKS Proposal Study Area.

#	Author	Title	Summary
A	Western Botanical (2016) WB860 V2	Flora and Vegetation Assessment, Yakabindie Nickel Project September 2016	Review and update of all data relating to flora and vegetation, including review of previous reports relating to the MKS Proposal Study Area. Included supplementary field work mapping weeds and vegetation condition. Discussed 263 endemic flora, four weed species, 10 Priority flora (four P3 and two P4 taxa) and seven Species of Interest. Presented vegetation maps and significant species records and incorporated a vegetation condition map and weed populations. Conducted an analysis of vegetation units between Leinster, MKS and Mt Keith, finding that all three were significant different
B	Western Botanical (2012) WB701	Baseline review and statistical analysis of the flora and vegetation of the NDS1 mine and corridor Proposal Study Area	A review and synthesis of previous works and addition of quadrat-based vegetation assessment and analysis, to meet the criteria of a Level 2 Survey. Includes Six-mile and Goliath orebody areas, waste rock storage area, and associated transport corridor of the YNP based on additional field works implemented in 2011. Discussed impacts at Land System and Vegetation Community levels. Discussed 295 endemic flora species, seven Priority species, 13 undescribed species and eight Species of Interest. Discussed potential impacts to two species with or likely to have conservation significance, within the Proposal Study Area.
C	Western Botanical (2011) WB730	Flora and Vegetation of the Proposed Yakabindie Borefield, March 2012	Presented Level 1 assessment vegetation maps within a 1 km wide corridor centred on the proposed borefield alignment. Discussed 111 endemic flora, one Priority 3 species and two Species of Interest.
D	Western Botanical (2010) WB658	Assessment of conservation values of the flora and vegetation of Wanjarri Excision Area, ELA36/739 and EL3/570	Assessment of a section of Wanjarri Nature Reserve and the Sir Samuel block, in preparation for a land swap to facilitate mining at YNP. Discussed the relative conservation values of each parcel of land including land systems, vegetation units, 10 Priority Species and three undescribed Species of Interest.

E	Western Botanical (2009) WB563	Assessment of flora and vegetation, Yakabindie Project (draft report)	Commissioned for the purposes of applying for a Native Vegetation Clearing Permit (NVCP) for the YNP Section 18 Area. Discussed 219 endemic flora, 11 Priority Species and two species of Interest.
F	Western Botanical (2008) WB491	Vegetation, flora and conservation values of the north-western corner of the Wanjarri Nature Reserve	Assessment of a small section (87 ha) of the Wanjarri Nature Reserve, known as the Yanganoo Block, as an addition to a land swap from WNR into mining tenement. Listed land systems, 4 Priority Flora and vegetation as well as the conservation values of the area assessed.
G	Western Botanical (2006b) WB254	Flora, vegetation and habitats of the Yakabindie tenements 2004-2005	Initial review of flora, vegetation, and conservation values of Yakabindie and surrounding local areas. This represented the most comprehensive and extensive works conducted at the MKS Proposal Study Area inclusive of vegetation mapping, habitat descriptions and species profiles to date. Listed 204 vascular flora, 4 Priority Flora and 5 undescribed species.
H	Western Botanical (2006c) WB347	Review of flora, vegetation, landscapes and conservation values of the Six-mile and Sir Samuel blocks, Wanjarri Nature Reserve and Yakabindie Station.	Assessment of a section of Wanjarri Nature Reserve and a section of Sir Samuel block, in preparation for a land swap to facilitate mining at YNP. Assessed a small portion of the WNR and listed endemic species, vegetation associations and land systems.
I	Landcare Services (2001)	Review of *Hemigenia exilis* (S. Moore) November 2001	Combined all data including WMC, Anaconda Nickel and CALM sources to review the status of *Hemigenia exilis* (DRF) resulting total of 46,005 plants from 66 populations and in reduction to Priority 4 status.
J	Landcare Services (1996)	A review of *Hemigenia exilis* (S. Moore) populations at The Mt Keith Operation and within the north-eastern Goldfields.	Review of *Hemigenia exilis* local and regional populations, incorporating data supplied by Anaconda Nickel. Noted 22,862 plants of *Hemigenia exilis* (DRF) at approximately in 49 populations south of Mt Keith.
K	Ecologia (1996)	Yakabindie Nickel Project: *Hemigenia exilis* survey and management plan	Survey and management of *Hemigenia exilis*, previously ranked as Declared Rare Flora, at the Yakabindie Nickel Project.
L	Ecologia (1995)	Yakabindie nickel mine project, Six Mile Well – Mt Pasco blocks: environmental assessment	Not sighted by the authors

M	Ecologia (1991)	Declared Rare Flora Assessment Survey: Distribution and conservation status of the Cue *Grevillea*, *Grevillea inconspicua*.	Regional assessment of *Grevillea inconspicua*, a species previously ranked as Declared Rare Flora.
N	Ecologia (1990)	Yakabindie Nickel Mine Project: Six Mile Well – Sir Samuel 33 Biological Assessment Survey	Early assessment of flora and fauna for the YNP.

Several flora and vegetation assessments of the MKS area were conducted between 1990 and 2009 (Ecologia, 1990, 1991, 1996 and Western Botanical, 2006b, 2008, 2009). In order to meet EPA Guidance Statement 51 for a Level 2 survey (EPA, 2004), NiW commissioned further works in 2010. The 2010 Scope of Works included establishment of quadrats, a statistical analysis of this data, a review of the flora and a review of the conservation status of species. The Western Botanical (WB701, 2011) report includes a revised organisation of vegetation communities (formerly referred to as habitat units) within the landscape and the introduction of Landform Systems, revised floristics including annual flora species encountered in April 2011, a revised discussion of conservation significant species and a statistical analysis of the quadrat data. Importantly, the vegetation associations of the Proposal Study Area were mapped at a scale of 1:25,000 on relatively coarse satellite imagery.

The portions of Jones Creek that lie outside and downstream of the mine area were mapped at low resolution by Western Botanical in 2004-2005 (Western Botanical, 2006b).

The earlier surveys of *Hemigenia exilis* and *Grevillea inconspicua* (Ecologia, 1996 & 1991) mapped the occurrence of these two species at both a local and regional scale. These works, in association with works commissioned by WMC Resources (Landcare Services, 1996, 2001) and Anaconda Nickel on the regional occurrences of *Hemigenia exilis* were adequate at that time to reassess the conservation significance of each species of those Threatened Species with resulting reduction to Priority 4 for both taxa. The Ecologia 1990 and 1995 reposts provided initial assessments of flora and vegetation for smaller, discrete parts of the MKS Proposal Study Area.

1.4. Current Survey

The current survey addresses the Scope for the MKS Proposal Study Area (inclusive of proposed pits, wastedumps, infrastructure areas and transport corridor to the existing Mt Keith Nickel Mine), Figure 1, as amended during the works program, including the following:

1. Re-mapping the entire MSKO Proposal Study Area at 1:10,000 scale using excellent quality satellite imagery sourced from the Department of Land Administration (DLI) and a series of Relevés describing the vegetation communities;

2. Re-assessing all quadrats previously established within the Proposal Study Area by DPaW (formerly CALM, DEC) (9 quadrats);

3. Re-visiting all 89 Quadrats previously established by Western Botanical, re-scoring a subset of these (64 quadrats) and establishing a further 50 new quadrats and 58 Relevés (total of 261 sites) to define the Vegetation Associations of the Proposal Study Area;

4. Updating the flora, and specifically the Mulga varieties (*Acacia aneura* sens. lat. and associated species), known within the Proposal Study Area;

5. Reassessing the impacts of the proposed MKS development on the vegetation communities of the proposed MKS Development Envelope within the Proposal Study Area;

6. Briefly assessing the Violet Range PEC description, boundaries and vegetation units with similarity to those of the MKS Proposal Study Area; and

7. Evaluating the condition of the vegetation of the Proposal Study Area with respect to weeds and grazing impacts.

1.5. Physical Environment

1.5.1. Climate

The Murchison bioregion has an arid climate and rainfall can occur at any time of year. The average annual rainfall is approximately 210 mm and is variable throughout the region (Pringle *et al.,* 1994). Summers are hot and dry with infrequent, high intensity seasonal thunderstorms and occasional cyclonic events. Maximum temperatures across the region exceed 40°C during the summer months and winters are mild with cool nights (Bureau of Meteorology, 2017).

The Leinster Aero weather station (site number 012314) located approximately 77 km to the south is the closest Bureau of Meteorology data collection site to the Proposal Study Area. At this location, the mean annual rainfall recorded from 1994 – 2016 is 260.3 mm; the lowest average rainfall of 139.8 mm was recorded in 2009 and the highest of 439.4 mm was recorded in 1997, (Bureau of Meteorology, 2017). The historical average annual rainfall recorded during the summer months (December to February) is 105.3 mm with January recording the highest mean monthly rainfall of 41.1 mm. During the winter months (June to August) the average rainfall received is 42.7 mm (Bureau of Meteorology, 2017).

1.5.2. Geology

The Proposal Study Area occurs at the northern end of the Yilgarn Craton in the Eastern Goldfield Province. The Yilgarn Craton, with an age of approximately 2.5 gigaannum (Ga) (Griffin, 1990), encompasses a large portion of the Western Australian landmass of 657,000 km2. The Eastern Goldfield Province is a typical Archaean granite-greenstone terrain

characterised by large areas of granitic lithology and generally narrow, linear belts of greenstone (Griffin, 1990). Alluvial soils and sands mantle the granitic-greenstone units of the Yilgarn Craton. the soils in low areas is a red-brown siliceous hardpan (Curry et al., 1994). In the eastern half of the bioregion the soils are typically calcareous red earth soil, lithosols, duplex soil and clays and red sands, (Australian Natural Resources Atlas, 2007).

The MKS lies within the Keith – Kilkenny lineament geological anomaly which was interpreted and mapped from early reconnaissance data as a single fault line (GSWA, 1974 in AGSO Research Newsletter 20). This has been more recently described as not constituting a single simple continuous fault, but rather, is an artefact made up of separate, genetically unrelated segments, (AGSO Research Newsletter 20). This may account for some of localisation of habitat units within the MKS with lies within the Mt Keith – Perseverance fault zone within this alignment. The Yakabindie Greenstone belt is one of three distinct greenstone components of the Mt Keith – Perseverance fault (Liu *et. al.,* 2002).

"The Yakabindie greenstone belt comprises a layered sequence of the Kathleen Valley Gabbro overlain by the massive tholeiitic Mount Goode Basalt. The Agnew greenstone belt comprises a lower sequence of metamorphosed ultramafic, mafic, felsic volcanic, and sedimentary rocks, which is exposed in the Lawlers and Leinster Anticlines. The upper sequence, as exposed in the Mount White Syncline area, consists of metabasalt, metagabbro and metasedimentary rocks. Metamorphosed ultramafic, mafic, felsic volcanic and sedimentary rocks in the Perseverance area extend farther north to west of Mount Pasco. From Six Mile Well, ultramafic, sedimentary, and felsic volcanic/volcaniclastic rocks correlate with the greenstone sequences from Mount Keith to Wiluna. The Jones Creek Conglomerate represents a late clastic sequence and is restricted to a narrow, fault-bounded zone between the Yakabindie greenstone belt and granitoid in the west and the Mount Keith–Perseverance and Agnew greenstone belts to the east." (Liu *et. al.,* 2002).

1.6. Interim Biogeographic Regionalisation of Australia

The Proposal Study Area is located within the Murchison Biogeographic Region and the East Murchison (MUR1) subregion (Department of the Environment and Energy, 2017), Figure 2. The MUR1 subregion, with an area of 7,847,996 ha, covers northern parts of the 'Southern Cross' and 'Eastern Goldfields' Terranes of the Yilgarn Craton (Cowan, 2001). This subregion is characterised by:

- Internal drainage;
- Extensive areas of elevated red desert sand plains with minimal dune development;
- Salt lake systems associated with occluded Paleodrainage system; and
- Broad plains of red-brown soils and granitic breakaway complexes as well as red sand plains (Cowan, 2001).

The vegetation in this region is dominated by Mulga varieties (*Acacia aneura* sens. lat. and related taxa) shrublands / woodlands often rich in ephemeral species, Spinifex (*Triodia* spp.) hummock grasslands, Saltbush shrublands (*Atriplex* spp.) and Samphire (*Tecticornia* spp.) shrublands. Land use within the Murchison bioregion is predominantly pastoral and mining (often combined) (Cowan, 2001).

Figure 2. The MKS Proposal Study Area and IBRA Subregions of Western Australia with Eastern Murchison (MUR1) shaded.

1.7. Land Systems

In the early 1990's, the Department of Agriculture (DoA) conducted extensive Land System mapping and pastoral condition assessments in the north-eastern Goldfields (Pringle *et al*., 1994). These works broadly mapped vegetation, soils and underlying geology, representing a milestone in the overall understanding of the landscapes, vegetation and flora of the region.

Fourteen Land Systems are present within the confines of the Proposal Study Area, including the transport corridor. These are briefly described in Table 6 while Figure 6 shows their representation in and around the Proposal Study Area.

The Land Systems of the MKS Proposal Study Area are generally well represented in the broader north-eastern Goldfields region. Those Land Systems with the greatest representation within the Proposal Study Area are the Archaean granite breakaways and associated foot slopes of the Sherwood Land System (1136.9 ha); low ironstone (limonitic duricrust) hills of the Bevon Land System (1,785.9 ha); and the extensive orange sandplains of the Bullimore Land System (1,321.6 ha). These represent 0.07%, 0.75% and 0.03% of their respective regional area of occupancy in the north-eastern Goldfields.

The gravely hardpan plains of the Tiger Land System (335.2 ha); the hardpan plains with ironstone gravel mantles of the Jundee Land System (810.1 ha) and the gently undulating stony plains and low rises with quartz mantles on granite of the Windarra Land System (465.7 ha) occupy relatively large areas within the Proposal Study Area and represent 0.31%, 0.12% ad 0.20% of their respective regional area of occupancy in the north-eastern Goldfields, Table 6.

Nine Land Systems are represented by smaller areas, from 10.8 ha being the major creeklines of the Wilson Land System to 235.9 ha within the gently undulating gravelly plains on greenstone, laterite and hardpan of the Violet Land System, each representing less than 0.04% of their respective regional area of occupancy in the north-eastern Goldfields, Table 6.

This analysis does not take into account cumulative impacts in the region.

1.8. Landform Systems

Landform Systems, rather than Land Systems (as described by Pringle *et al*., 1994), were the preferred unit for grouping the vegetation communities recognised in the 2010 and 2011 vegetation surveys for statistical analysis within the Study Area. These reflect local changes in underlying geology, landform and soils, which influence vegetation. This allowed Western Botanical to develop an understanding of habitat sub-groups and flora assemblages existing within the Study Area. Six Landform Systems (Drainage Line and Hardpan with Sheet Flow; Low Rises on Granite; Low Rises on Calcrete; Low Rises on Basalt; Sandplain; and the Lateritic Duricrust) were recognised and defined within the Study Area. These provided a physical context for the Vegetation Communities (Habitat Units) recognised but have not been mapped separately.

The Landform Systems present within the Study Area are not mapped either within or outside the MKS Study Area, but are known by the authors to be widespread within the north-eastern Goldfields, as are many of the Vegetation Communities they support.

Three Landform Systems of the study area are widespread in the region: Drainage Line Hardpan with Sheet Flow Landform System; the Low Rises on Calcrete Landform System; and the Sand Plain Landform System.

Three Landform Systems with accompanying Habitat Units are less widely distributed in the region. These are:

(i) The Lateritic Duricrust Landform System is specifically associated with the Bevon Land System within the Perseverance Greenstone Belt and is not known by the authors to occur outside this alignment;

(ii) The Low Rises on Granite Landform System is associated with the Sherwood Land System which is widespread but of limited area and occurring in disjunct occurrences in the Murchison biogeographic region; and

(iii) Low Rises on Basalt Landform System is associated with the Basalt, mixed Acacia species Shrubland Complex (BaMAS) vegetation complex mapped within the MKS Study Area. Low Rises on Basalt landform system extends further southwards from the MKS Study Area within the Perseverance Greenstone Belt. The regional distribution of the SMBS community is not known to the authors outside the MKS Study Area.

Vegetation communities associated with the Lateritic Duricrust Landform System include the Stony Ironstone Mulga Shrublands (SIMS) site type of Pringle *et al* (1994), the Stony Ironstone Low Shrublands (SILS), and the Stony Senna Shrublands (SSS) communities. The SILS community often supports species with conservation significance including *Thryptomene* sp. Leinster (B.J. Lepschi & L.A. Craven 4362), a P1 species. The SIMS and SILS communities may also support populations of *Eremophila* sp. Leinster (R.J. Cranfield 6767), a Species of Interest. The Basalt, mixed Acacia species Shrubland Complex (BaMAS) sits within the Bevon Land System and supports the newly recognised species *Acacia* sp. East Murchison Basalt (G. Cockerton 38064), a species of interest.

The Breakaway Shrubland (BRX) community associated with the Low Rises on Granite Landform System is a variable community that supports a range of species with conservation significance. These include *Sida picklesiana* P3 and *Verticordia jamiesonii* P3 and the undescribed species *Hibbertia* sp. aff. *H. exasperata* (G. Cockerton & G. O'Keefe 11911) which is poorly known and will likely acquire priority flora status upon assessment. Some areas of SILS community may also be found within this landform system and represent areas where the lateritic duricrust has been in close contact with the underlying granite plateaux.

The *Eucalyptus gypsophila – Eremophila pantonii* Woodland (EGPW) community occurs on eroded carbonate influenced soils with a slight ironstone and quartz pebbly mantle and occupies an area of 15.08 hectares within the MKSO Study area. This is a discrete community within the region and occurs to the north, east and southeast of the Six-mile Well orebody. The EGPW community is not known to be widely distributed and occurrences are discrete and relatively small in area where it occurs. It is known from between the northern boundary of the MKS project and the Mt Keith Nickel mine, west of the proposed MKS transport corridor. West of the proposed haul road alignment and outside the MKS Study Area, the EGPW community as mapped supports the Priority 3 species *Cratystylis centralis*.

The Breakaway Shrublands (BRX) vegetation community, associated with the Archaean granite breakaways of the Sherwood Land System, is highly variable in species composition and occurs in disjunct distributions across the region. It is known to support a wide range of Priority species and the new species *Hibbertia* sp. Sherwood Breakaways aff. *H. exasperata* (G. Cockerton & G. O'Keefe 11451). The MKS Project does not impact on significant areas of the Breakaway Shrublands vegetation community in relation to its local or regional occurrence although the proposed haul road does impact on the known population of *Hibbertia* sp. Sherwood Breakaways aff. *H. exasperata* (G. Cockerton & G. O'Keefe 11451).

1.9. Pre-European Vegetation

Five of Beard *et. al.'s* (2013) Pre-European Vegetation units are present within the Proposal Study Area, Table 5 and Figure 7. The mapping is conducted a high level and the proportional impacts of the MKS project on these is negligible in both a local and regional sense.

2. Methods

2.1. Desktop Survey

Prior to planning and conducting the current works, Western Botanical prepared a review of previous works for the MKS Proposal Study Area (Western Botanical, 2016). This review covered all known previous work related to the Proposal Study Area and included a gap analysis to identify work needed to update previous work and remain current with a modified Proposal Study Area.

2.2. Field Survey

Field work for the current survey period was conducted in November and December 2016. Three trips were undertaken:

Trip 1 2-7 November, 4 personnel, 24 personnel days;

Trip 2 17-25 November, 4 personnel, 36 personnel days;

Trip 3 5-17 December. 2 personnel, 26 personnel days.

These figures include travel, which involved initially taking vehicles to site then flying in/out between field events and driving vehicles back to Perth when field work was concluded. A total of 86 personnel days field work were implemented. The personnel involved in the field works are shown in Table 2.

Table 2. Personnel involved in field works and survey schedule

Name	Experience	Role	Trip 1	Trip 2	Trip 3
Geoff Cockerton	24 years experience	Team Leader	**1**	**1**	**1**
Jonathan Warden	10 years experience	Team Leader	**1**		
Ben Eckermann	13 years experience	Botanist		**1**	
Daniel Brassington	10 years experience	Botanist		**1**	**1**
Steven Cockerton	2 years experience	Field Technician	**1**		
Sarah Smith	10 years experience	Field Technician	**1**	**1**	

Two teams separately conducted (i) vegetation mapping, and (ii) quadrat establishment and quadrat rescoring during the field visits, visiting a total of 181 sites. Fifty-eight of the sites were relevés to aid in vegetation mapping while one hundred and twenty-three quadrats were described. Of these, fifty were newly established quadrats, sixty-four were rescoring quadrats established in 2010, and nine were rescoring DPaW quadrats established in 2010 (Meissner and Wright, 2010).

2.3. Vegetation Mapping

Vegetation mapping was conducted using seven A2 sheets of 10:1000 RGB hard copy laminated colour satellite imagery. Vegetation associations were described at representative locations using Relevés where a complete species list and representative photographs were taken. Samples of the majority of flora were collected for future reference.

Vegetation was described at NVIS Level 5 Association and boundaries were drawn onto field maps whilst in the field. Extensive traverses to investigate the boundaries of communities were made either on foot or in-vehicle to define the margins of communities as closely as possible. Many communities demonstrated relatively broad ecotonal edges and the margins of some may be accurate to within 1+/- 100m.

2.4. Quadrat Establishment and Scoring

Quadrats established were all 20 x 20 m with axes orientated north-south, unless constrained by physical features such as narrow drainage lines. The majority of pre-existing quadrats established by Western Botanical were re-scored with exceptions being those established in in the majority of drainage lines (DRMS communities). The reasoning here was that previous statistical analyses of existing quadrat data (Western Botanical, 2016) showed that DRMS quadrats did not nest together, rather they reflected the adjoining communities more than reflecting a separate cohesive association. As such, and after a cost-benefit review, there was little point in re-evaluating these, other than generating more data on flora species, which was already well represented in existing and currently held data.

All species encountered in quadrats were sampled and retained for verification. Of note. the Mulga trees present were almost all holding mature fruits. This enabled collection of the critically important fruits for identification of the Mulga varieties. All Mulga specimens were keyed and reviewed in relation to the recent published revision of Mulga (Maslin and Reid, 2012).

Quadrats locations were confirmed using GPS and one to two representative photographs at a minimum of 5MP were taken of each site, nominally from the north-western and north-eastern corners, using a digital camera.

2.5. Flora Specimen Identification and Taxonomy

Specimens collected during quadrat survey and vegetation mapping were identified using the Western Botanical reference herbarium and relevant taxonomic keys, with recourse to the WA Herbarium's Reference Herbarium and Research Collection for specimens more difficult to resolve. Some material was referred to specialist taxonomists when necessary.

Plant nomenclature adopted follows that of the Australian Plant Census published by the Council of Heads of Australian Herbaria (2007 onwards) as used by the WA Herbarium as at January

2017. Nomenclature for potentially new species follows informal conventions. Nomenclature for some *Eremophila* species which do not appear on the census of vascular flora follows that advised by Dr. Bevan Buirchell, Mr Andrew Brown and Dr. Steven Dillon.

2.6. Statistical Analysis

Western Botanical uses the PATN v3.12 package of statistical programs developed by Lee Belbin and CSIRO (Blatant Fabrications Pty Ltd, 2004). PATN is a comprehensive software package designed for extracting and displaying patterns in complex multivariate datasets.

Three functions of PATN were used in the investigation;

- Bray and Curtis association.
- Flexible UPGMA classification with results displayed in a dendrogram.
- Semi-Strong Hybrid scaling (SSH) ordination as a measure of analysis strength.
- Two-way Table: this function produced colour coded table displaying the classification of sites and species. In this analysis the two-way table was used to identify the presence or absence of species within quadrats and the subsequent influence this had on the association of quadrats within a dendrogram.

Stress Values

Data analysis generates a Stress Value associated with a dataset. In the context of vegetation analysis as presented here, a Stress Value indicates the similarity or otherwise of floristic composition between vegetation groupings in a dataset. A Stress Value;

- <0.14 indicates strong similarity,
- between 0.14 and 0.16 indicates proportionate similarity within a dataset, meaning that the 'fit' is good but perhaps not exact,
- between 0.16 and 0.18 indicates a similarity with discrepancies, and
- between 0.18 and 0.20 indicates a lack of similarity in a dataset. A value >0.20 indicates little or no similarity at all.

Dataset

The dataset consisted of the field data collected from all quadrats. The data had been collected in the form of percentage foliage cover (PFC) estimates (in terms of the total quadrat cover), and were converted into five cover classes, Table 2.

This created a more equal weighting between abundant and non-abundant species.

Table 2 Percentage foliage cover conversions to Cover Class.

Percentage Cover	Cover Class	N
0	0	31143
> 0 to < 1	1	2756
1 to < 5	2	566
5 to <10	3	160
10 to < 25	4	111
25 to < 50	5	13
50 to < 75	6	3
75 to 100	7	0

Annuals, singletons (species occurring on only one quadrat) and taxa unidentified to species level were removed from the dataset to negate influences that may have skewed the result. To prevent data splitting to a degree involving multiple infraspecific names, infraspecific taxa that occupy similar habitats had their names reconciled to the specific taxon before presentation to PATN.

2.7. Vegetation Condition

Vegetation condition was recorded in May 2016 using the Vegetation Condition Scale presented in Table 3, adapted from Keighery (1994). Adaptation of the Keighery scale was required to account for rehabilitated former exploration sites, which showed capacity for regeneration post disturbance.

Table 3. Adapted Vegetation Condition Scale

Keighery (1994) Code	Keighery (1994) Description	Adapted Description (WB 2016)	Habitat Cond	Seasonal Conditionality	Disturbance to Vegetation or to surface drainage	Weeds	Regenerative Capacity
Pristine (1)	Pristine or nearly so, no obvious signs of disturbance.	**Pristine or nearly so, vegetation in pristine condition and reflecting normal seasonal conditions. No anthropogenic influences.**	**Pristine (i)**	Normal	Intact, no roads, tracks or animal trails	Nil	Normal
Excellent (2)	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.	**Vegetation structure intact, vegetation in a condition that reflects normal seasonal conditions but subject to minor disturbance (eg: light grazing, minor tracks) affecting individual species. No impact to surface drainage. Regenerative capacity retained. No weed species.**	**Excellent (ii)**	Normal	Minor tracks, no evidence of erosion or altered drainage	Nil	Normal
Very Good (3)	Vegetation structure altered, obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback , logging and grazing.	**Vegetation structure intact, vegetation in a condition that reflects normal seasonal conditions but subject to obvious disturbance (eg: grazing, partial clearing, flooding, sheet flow interruption, recent fire events) affecting a wide range of species. Regenerative capacity retained. Weed species in low abundance and are non-invasive.**	**Good (iii)**	Normal	Minor tracks but evidence of altered drainage (erosion or ponding)	Minor, non-invasive species	Reduced

Keighery (1994) Code	Keighery (1994) Description	Adapted Description (WB 2016)	Habitat Cond	Seasonal Conditionality	Disturbance to Vegetation or to surface drainage	Weeds	Regenerative Capacity
Good (4)	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.	**Vegetation structure altered, vegetation in a condition that reflects normal seasonal conditions but subject to obvious disturbance (eg: heavy grazing, partial clearing, flooding, sheet flow interruption, recent fire events) affecting a wide range of species.** **Regenerative capacity reduced** **Weed species in moderate abundance and are invasive.** **Recovery possible with some active management.**	**Poor (iv)**	Normal	Moderate, tracks and larger cleared areas present	Minor, some invasive species	Reduced
Degraded (5)	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing	**Vegetation structure severely altered, vegetation in a condition not reflecting normal seasonal conditions and subject to obvious disturbance (eg: heavy grazing, clearing, flooding, sheet flow interruption, recent fire events) affecting a wide range of species.** **Regenerative capacity significantly reduced.** **Weed species in high abundance and are invasive.** **Recovery possible with active management over long term.**	**Degraded (v)**	Abnormal	Moderate to High	High, invasive species	Significantly reduced

Keighery (1994) Code	Keighery (1994) Description	Adapted Description (WB 2016)	Habitat Cond	Seasonal Conditionality	Disturbance to Vegetation or to surface drainage	Weeds	Regenerative Capacity
Completely Degraded (6)	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as "parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.	**Vegetation structure severely altered, vegetation in a condition not reflecting normal seasonal conditions, subject to obvious disturbance (eg: heavy grazing, clearing, flooding, sheet flow interruption, recent fire events) affecting a wide range of species. Regenerative capacity absent. Weed species may be in high abundance and are invasive.**	**Completely Degraded (vi)**	Abnormal	High	High, invasive species	Absent

3. Results and Discussion

3.1. Desktop Survey

A thorough and wide ranging desktop revision of Conservation Significant Flora and Priority Ecological Communities was conducted earlier in 2016 during production of the Western Botanical (2016) report (report ref WB860). This involved interrogation of relevant publicly available DPaW databases, a revision of taxonomy of all flora known within the MKS Proposal Study Area, including those that were considered to represent newly discovered, undescribed species. With this current information at hand, no further interrogation of DPaW databases was undertaken in preparation for the late 2016 field assessments.

The analysis from the above report is re-presented in Table 4. This shows that the DPaW databases list seven Priority Flora in the region that were found within the MKS Proposal Study Area: *Anacampseros* sp. Eremaean (F. Hort, J. Hort & J. Shanks 3248) P1, *Eremophila pungens* P4, *Grevillea inconspicua* P4, *Hemigenia exilis* P4, *Sida picklesiana* P3, *Thryptomene* sp. Leinster (B.J. Lepschi & L.A. Craven 4362) P3 and *Tribulus adelacanthus* P3. The majority of these are well known within the Proposal Study Area.

Exceptions to this are: (i) *Anacampseros* sp. Eremaean P1 which has only been recorded at three sites outside the proposed Development Envelope, but is known to be associated with granitoid landscapes of the Barr-Smith Range (the breakaway system within the MKS Proposal Study Area and in the Sherwood Land System) and (ii) *Tribulus adelacanthus* P3 which has only been recorded once on colluvial slopes within the MSKO Development Envelope. Both remain poorly known across the state. These and other species with conservation significance are discussed further within this document.

Table 4. DPaW Threatened and Priority Flora List search results for the MKS project.

Taxon	Status	DPaW Region	DPaW District	Distribution	Preferred Habitat	Likelihood of Occurrence within MKS
Atriplex sp. Yeelirrie Station (L. Trotter & A. Douglas LCH 25025)	**T**	GOLD	KALGOORLIE	Yeelirrie Stn., Albion Downs Stn. **IUCN Rank: VU** **IUCN Criteria D2** **EPBC Listing: EN**	Red self-mulching smectite clay in valley floors, specifically within the Yeelirrie paleochannel	Nil
Anacampseros sp. Eremaean (F. Hort, J. Hort & J. Shanks 3248)	P1	GOLD	KALGOORLIE	Yakabindie Station, Wanjarri Nature Reserve	Granitoid landscapes, shallow gritty sand on breakaways, stony plains and exfoliating granite outcrops	Present
Baeckea sp. London Bridge (M.E. Trudgen 5393)	3	GOLD, MWST	KALGOORLIE, GERALDTON	Sandstone, Youanmi	Archaean granitoid landscapes, shallow gritty sand on breakaways	Nil
Baeckea sp. Sandstone (C.A. Gardner s.n. 26 Oct. 1963)	3	GOLD, MWST	KALGOORLIE, GERALDTON	Wiluna, Sandstone, Agnew, Great Victoria Desert,	Aeolian sandplains	Possible
Beyeria lapidicola	1	GOLD	KALGOORLIE	Bulga Downs, Weld Range, Lake Way Stn.	Banded Ironstone Formation outcrops and breakaways on midslopes	Nil
Bossiaea eremaea	3	GOLD	KALGOORLIE	Merolia Stn, Sandstone, White Cliffs Stn	Aeolian sandplains	Possible

Taxon	Status	DPaW Region	DPaW District	Distribution	Preferred Habitat	Likelihood of Occurrence within MKS
Calytrix praecipua	3	GOLD, PILB	KALGOORLIE, KARRATHA	Melita Station, Laverton, Youno Downs, Wanjarri, Marymia, Erong Hmstd, Niagara Dam	Archaean granite breakaways, scree slopes and associated creeklines	Possible
Calytrix verruculosa	3	GOLD, MWST	KALGOORLIE, GERALDTON	Tuchanana Ck, Yoothapina Stn, Mt Hale, Meekatharra, (Leinster, Mt Keith)	Major Banded Ironstone Formation ranges, quartzite scree slopes	Unlikely based on habitat preference and known range
Cratystylis centralis	3	GOLD	KALGOORLIE	Barwidgee Stn, Leonora, Yakabindie Station (WB record)	Carbonate influenced soils derived from basalt	Nil, well known in the local area and mapped adjacent to but outside MKS
Dampiera plumosa	1	GOLD, MWST	KALGOORLIE, GERALDTON	Sandstone, Coolgardie, Lake Barlee	Yellow to orange sandplains	Possible
Eremophila arguta	1	GOLD, MWST	KALGOORLIE, GERALDTON	Mt Augustus Station, Neds Creek, Wiluna	Loamy soils in floodplains, drainage lines	Unlikely
Eremophila congesta	1	GOLD	KALGOORLIE	Wiluna	Lateritic outcrops, quartzite scree slopes	Unlikely, this species has a narrow range of natural distribution at Wiluna
Eremophila flaccida subsp. *attenuata*	3	GOLD, MWST	KALGOORLIE, GERALDTON	Wiluna, Dairy Creek, Glenburgh	Stony quartzite plains over Archaean granite	Unlikely based on distribution, occurs significantly north-west of MKS
Eremophila gracillima	3	GOLD, MWST ,PILB	KALGOORLIE, KARRATHA, GERALDTON	Mt Vernon, Paroo, Wonganoo Station [1]	Stony plains	Unlikely based on distribution, occurs significantly north-west of MKS

[1] Record of *Eremophila gracillima* P3 at Wonganoo Station is erroneous. See note within text.

Taxon	Status	DPaW Region	DPaW District	Distribution	Preferred Habitat	Likelihood of Occurrence within MKS
Eremophila pungens [2]	4	GOLD, MWST	KALGOORLIE, GERALDTON	Eareheedy, Meekatharra, Lake Way, Barwidgee, Wanjarri, Wiluna, Wonganoo, Granite Peak, Lorna Glen Hmstd, Agnew, Leinster, Mooloogool	Stony uplands, Limonitic and Archaean granitic landforms	Present within MKS
Euryomyrtus inflata	3	GOLD	KALGOORLIE	Wiluna, Lake Mason Stn., Youno Downs Stn.	Aeolian sandplains	Possible
Grevillea inconspicua	4	GOLD, MWST	KALGOORLIE, GERALDTON	Cue, Meekatharra, Yakabindie, Sandstone, Melrose, Leinster, Mt Magnet	Outcropping and subcropping basalt	Present within MKS
Hemigenia exilis	4	GOLD	KALGOORLIE	Lake Darlot, Yakabindie, Leinster, Leonora, Mt Keith	Limonitic landforms, volcaniclastic sediments, Wiluna hardpan on margins of creeks	Present within MKS
Hibiscus sp. Wonganoo Station (K. Boladeras 125)	1	GOLD	KALGOORLIE	Wonganoo Stn.	Archaean granitic breakaways, kaolinitic slopes	Possible though unlikely, occurs significantly east of MKS
Homalocalyx echinulatus	3	GOLD	KALGOORLIE	Carnegie Stn, Wiluna, Doolgunna Stn, Weld Range, Mount Hale, Windidda, Wongawal Stn	Granitoid landscapes, shallow gritty sand on Archaean breakaways	Possible
Labichea eremaea	3	GOLD, MWST	KALGOORLIE, GERALDTON	West of Sandstone, Bimbijy, Mt Jackson, Black Range Stn	Aeolian sandplains	Possible

[2] *Eremophila pungens* P4 is inclusive of *Eremophila* sp. Leinster (RJ Cranfield 6767), sp. nov.

Taxon	Status	DPaW Region	DPaW District	Distribution	Preferred Habitat	Likelihood of Occurrence within MKS
Maireana prosthecochaeta	3	GOLD, KIMB, MWST ,PILB	KALGOORLIE, KARRATHA, EAST KIMBERLEY, GERALDTON	Meekatharra, Cue, Mt Phillips Station, Marymia, Bulloo Downs, Lake Way Stn.	Laterite hills, saline expressions	Possible
Micromyrtus chrysodema	1	GOLD	KALGOORLIE	Leinster	Granitoid landscapes, shallow gritty sand on Archaean granitic breakaways	Possible
Mirbelia stipitata	3	GOLD, MWST	KALGOORLIE, GERALDTON	Nth Sandstone, Nth Laverton	Granitoid Archaean landscapes, shallow gritty sand on breakaways	Possible
Neurachne lanigera	1	GOLD	KALGOORLIE	Wiluna, Warburton	Aeolian sandplains, rocky outcrops, hardpan plains	Possible
Olearia arida	4	GOLD	KALGOORLIE	Yeelirrie	Aeolian sandplains	Possible
Olearia mucronata	3	GOLD, PILB	KALGOORLIE, KARRATHA	Hamersley and Chichester Range area, West Angelas, Paraburdoo, Mt Margaret, Mt Keith, Wiluna	Stony uplands, Limonitic and Archaean granitic landforms, shaded and sheltered locations	Possible
Phyllanthus baeckeoides	3	GOLD	KALGOORLIE	Laverton, Merolia Stn, White Cliffs Stn, Windimurra Station, Cashmere Downs Stn, Leinster, Banjawarn Stn	Minor creeklines in stony limonitic uplands	Possible, nearest population is at Leinster
Pityrodia canaliculata	1	GOLD, MWST	KALGOORLIE, GERALDTON	Anketell to Sandstone, Black Range Stn.	Aeolian sandplains	Unlikely, occurs significantly west of MKS
Prostanthera ferricola	3	GOLD, MWST	KALGOORLIE, GERALDTON	Wiluna, Meekathara, Mooloogool, Doolgunna, Lake Way Stn.	Stony uplands, Limonitic landforms, shaded and sheltered locations	Possible

Taxon	Status	DPaW Region	DPaW District	Distribution	Preferred Habitat	Likelihood of Occurrence within MKS
Ptilotus luteolus	3	GOLD, MWST	KALGOORLIE, GERALDTON	Meekatharra, Mt Alice, Mount Magnet,Lake Way Stn.,Doolgunna Stn.Boogardie Stn., Polelle Stn., Glenburg Stn., Milbillillie Stn.	Stony uplands, limonitic, basaltic and dioritic landforms	Possible
Rhagodia sp. Yeelirrie Station (K.A. Shepherd et al. KS 1396)	1	GOLD	KALGOORLIE	Yeelirrie Stn, Pinnacles Stn. Credo Stn.	Claypans and playa margins	Nil
Sauropus sp. Woolgorong (M. Officer s.n. 10/8/94)	3	GOLD, MWST	KALGOORLIE, GERALDTON	Pinegrove Stn, Mt Magnet, Leinster, Yakabindie, Mt Keith.	Aeolian sandplains, granitoid landscapes, shallow gritty sand on Archaean breakaways and low granitic outcrops	Possible
Sida picklesiana	3	GOLD, MWST	KALGOORLIE, GERALDTON	Wiluna, Doolgunna Stn., Lake Way Stn., Ned's Creek Stn.		
Stackhousia clementii	3	GOLD, PILB	KALGOORLIE, KARRATHA	Warburton, Wiluna, Karratha, Little Sandy Desert, NT, SA, Gnaraloo Stn, Burrup Peninsula	Carbonate influenced landforms, calcrete plains and groundwater calcrete outcrops	Possible
Stenanthemum mediale	1	GOLD, MWST	KALGOORLIE, GERALDTON	Yeelirrie Station, Black Hill Stn, Montague Range	Stony uplands, limonitic, landforms, stony chert hills	Possible
Tecticornia sp. Lake Way (P. Armstrong 05/961)	1	GOLD	KALGOORLIE	Wiluna	Lake bed within large saline playa systems	Nil

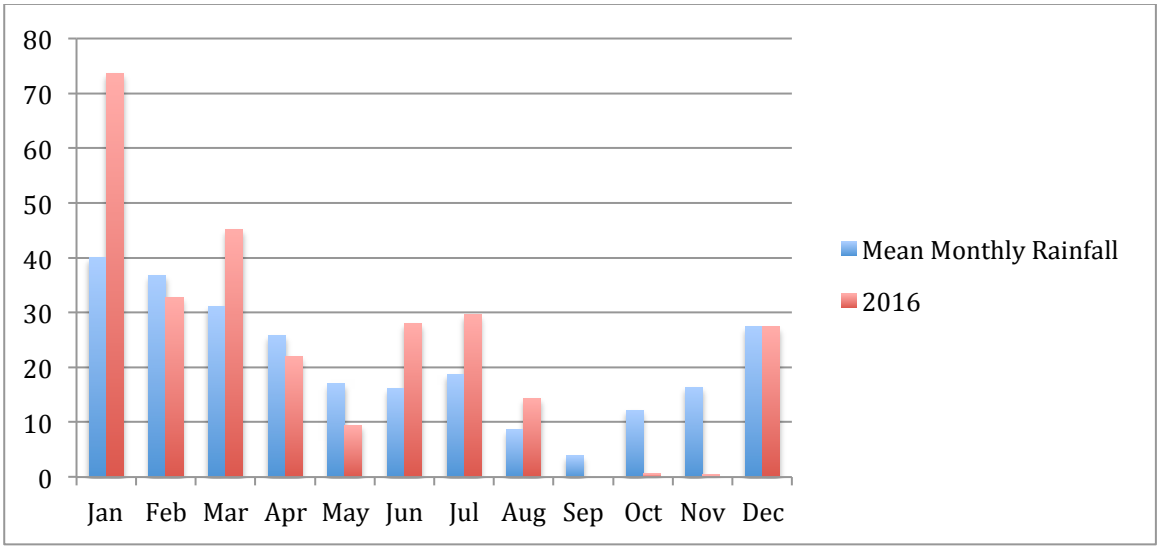
Taxon	Status	DPaW Region	DPaW District	Distribution	Preferred Habitat	Likelihood of Occurrence within MKS
Thryptomene nealensis	3	GOLD	KALGOORLIE	Leinster, White Cliffs Stn, Neale Junction, Gt Victoria Desert	Aeolian sandplains, granitoid landscapes, shallow gritty sand on Archaean breakaways and low granitic outcrops	Possible
Thryptomene sp. Leinster (B.J. Lepschi & L.A. Craven 4362)	3	GOLD	KALGOORLIE	Leinster	Aeolian sandplains, granitoid landscapes, shallow gritty sand on Archaean breakaways and low granitic outcrops	Present within MKS
Tribulus adelacanthus	3	GOLD, MWST	KALGOORLIE, GERALDTON	Wiluna, Robinson Range, Mt Magnet, Mt Keith Stn.	Colluvial stony plains	Present within MKS
Lichen: *Austroparmelina macrospora*	3	GOLD, MWST ,WHTB	KALGOORLIE, GERALDTON, CENTRAL WHEATBELT	Kalgoorlie, Ninghan Stn, Wanjarri NR, Mount Harry, Kathleen, Bullfinch, Kalbarri	On sheltered dry bark on shrubs or sheltered to exposed dry wood on ground	Possible, not assessed
Lichen: *Xanthoparmelia nashii*	3	GOLD, MWST ,PILB, WHTB	KALGOORLIE, KARRATHA, GERALDTON, GREAT SOUTHERN, CENTRAL WHEATBELT	King Rocks, Lorna Glen Stn., Karolin Rock, Eurady Stn., Hamersley Range N.P., Wiluna	Plains, exfoliating granite outcrops, flood plains with brown-grey soils, Archaean granite breakaways with stony scree and outcrops, found on sheltered dry stone on ground	Possible, not assessed

3.2. Field Survey

3.2.1. Seasonal Conditions

Seasonal conditions in the two months prior to the field survey were relatively dry and well below average rainfall for Leinster Aerodrome (Bureau of Meteorology, 2017), Figure 3. The field survey was conducted well after most annual and perennial species had finished flowering. Despite this, fruit was present on the majority of *Acacia* species, reflecting the above average rainfall events in the period June to August, enabling for the first time, identification of the Mulga and some other cryptic species of *Acacia*.

Figure 3. Rainfall, Leinster Aerodrome, 2016 vs monthly average.



The seasonal conditions were not considered a limitation for the effectiveness of field surveys except that annuals and geophytes were largely absent. This only had implications for one Priority Species, *Anacampseros* sp. Eremaean (P1), which is a small geophyte with ephemeral above-ground parts and can only effectively assessed after substantial rainfall.

3.2.2. Flora

The consolidated cumulative species list for the MKS Proposal Study Area now contains 393 species (and putative hybrids) from 140 genera and 51 families of endemic flora. Of these, the majority are common, widespread in distribution and are highly representative of the flora of eastern Murchison and western Gt Victoria Desert biogeographic regions. This compares with 279 species (69%) recorded in numerous previous surveys at the MKS Proposal Study Area to the end of 2015 and 301 species (75%) recorded in the Spring 2016 assessments with 177 species (44%) recorded in both periods. The differences in representativeness of the various survey periods is attributed to seasonality, rainfall and species apparent at the time of surveys.

Dominant families include Fabaceae (76 species incl. putative hybrids), Poaceae (47 species), Chenopodiaceae (46 species), Scrophulariaceae (37 species), Asteraceae (30 species), Malvaceae

(22 species) and Myrtaceae (20 species). Dominant genera were *Acacia* (53 species inclusive of 31 species and numerous putative hybrids of Mulga species); *Eremophila* (37 species), *Maireana* (18 species) *Senna* (14 species), *Sida* (11 species) and *Eragrostis* (7 species). Excluding putative hybrids, the Proposal Study Area supports 13 species of Mulga.

Of these, the majority are common, widespread in distribution and are highly representative of the flora of eastern Murchison and western Gt. Victoria Desert biogeographic regions. A systematic species list is presented in Appendix 1.

A species accumulation curve shows the asymptotic approach of the number of species encountered towards the overall total number of species, Figure 4.

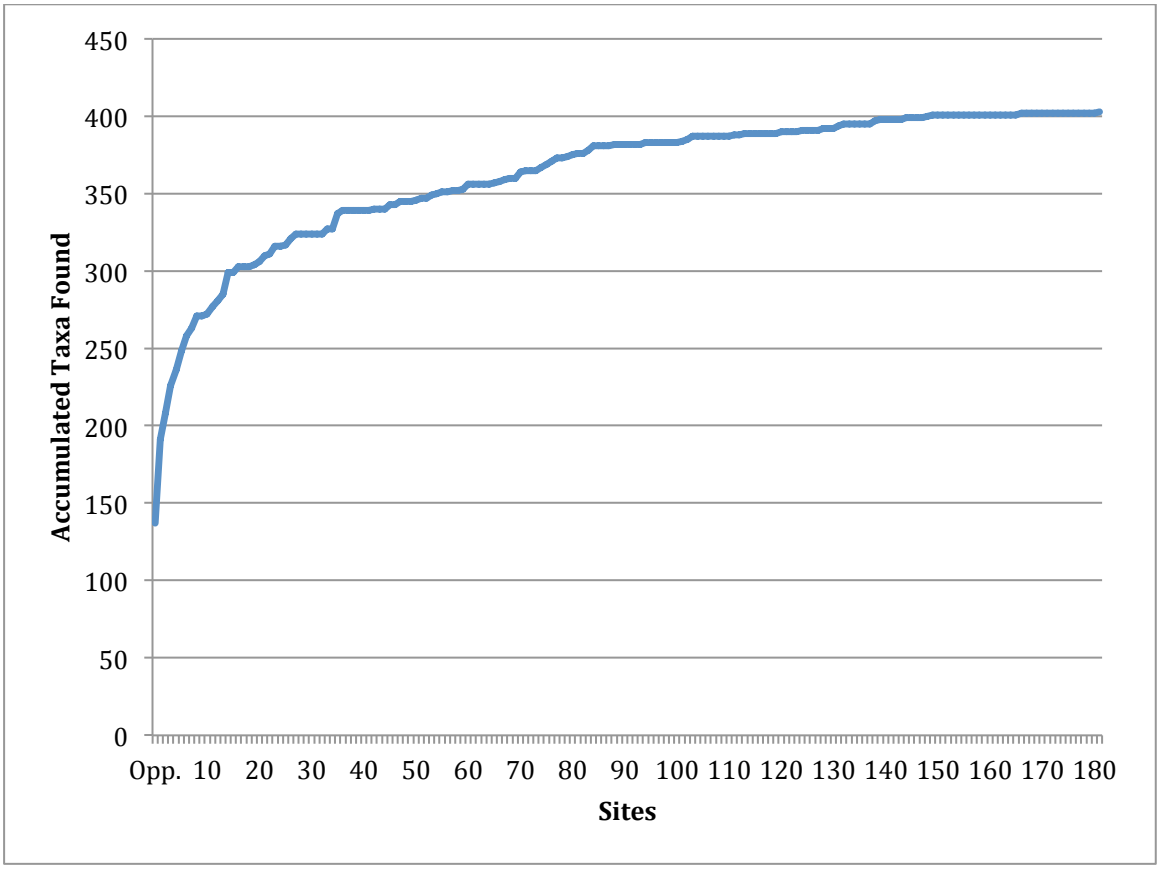


Figure 4. Species Accumulation Curve for the MKS Proposal Study Area, all endemic flora records combined.

The graph in Figure 4 commences at 137 species, which represents the number of opportunistically collected species (Opp.) as a starting point. These are species that were recorded either historically, or were recorded outside quadrats and relevés in the current survey.

Dominant families include Fabaceae (76 species), Poaceae (47 species), Chenopodiaceae (46 species), Scrophulariaceae (37 species), Asteraceae (31 species), Malvaceae (22 species) and Myrtaceae (20 species). Dominant genera were *Acacia* (53 species inclusive of 31 species and numerous putative hybrids of Mulga species); *Eremophila* (37 species), *Maireana* (18 species)

Senna (14 species), *Sida* (11 species) and *Eragrostis* (7 species). Excluding putative hybrids, the Proposal Study Area supports 13 species of Mulga.

Six weed species were also recorded, all in small scattered populations of low numbers.

Conservation - Significant Flora

No Threatened Flora as listed under the *Wildlife Conservation Act 1950* (as amended) are known within or nearby the Proposal Study Area.

Twelve Priority Flora species are known within the areas assessed. These include one Priority 1, ten Priority 3 and three Priority 4 listed species. These are:

Anacampseros sp. Eremaean (F. Hort, J. Hort & J. Shanks 3248) P1 (granitoid domains).

Aristida aff. jerichoensis var. *subspinulifera* P3 (1 record in Jones Creek).*

Eremophila pungens complex P4, inclusive of *E.* sp. Leinster (R.J. Cranfield 6767) (low numbers, widespread in the MKS Development Envelope and Proposal Study Area).

Grevillea inconspicua P4 (low numbers, widespread in the MKS Development Envelope and Proposal Study Area).

Gunniopsis propinqua P3 (several records in the MKS Development Envelope and Proposal Study Area, saline areas). *

Hemigenia exilis P4 (low numbers, widespread in the MKS Development Envelope and Proposal Study Area).

Hibiscus krichauffianus P3 (three records within the MKS Development Envelope and Proposal Study Area). *

Hybanthus floribundus subsp. *chloroxanthus* P3 (scattered populations in the MKS Development Envelope and Proposal Study Area).

Sida picklesiana P3 (MKS Development Envelope and Proposal Study Area, breakaways).

Thryptomene sp. Leinster (B.J. Lepschi & L.A. Craven 4362) P3 (MKS Development Envelope and Proposal Study Area, breakaways, SIMS and SILS communities).*

Tribulus adelacanthus P3 (one record within the MKS Development Envelope)

Verticordia jamiesonii P3 (MKS Development Envelope and Proposal Study Area, breakaways).

Two of these species, *Aristida aff. jerichoensis* subsp. *subspinulifera* P3 and *Paspalidium* aff. *distans* P3, have been identified based on less than optimal material and re-collections for confirmation of the identifications of these is required.

* Species marked with an Asterisk were recorded within the MKS Proposal Study Area for the first time in 2016.

These species are describe and maps showing the distribution of Priority Species within the MKS Proposal Study Area are presented in Appendix 2.

3.3. Taxonomically Significant Flora - Species of Interest

Species of Interest (SOI) are defined as (i) undescribed species which are not formally recognised as yet and represent species new to science but are widespread and not of conservation significance; (ii) undescribed species with limited known distribution which may warrant conservation review and (iii) species of uncertain taxonomy which require specialist taxonomic inputs and may warrant conservation review.

3.3.1. Widely distributed undescribed species

Eight undescribed species with informal names that do not appear on the Census of Vascular Flora, and therefore are not shown on the DPaW Florabase website, are known from the MKS Proposal Study Area. The majority of these are well known, represented by numerous specimens at the WA Herbarium (albeit under names other than listed below) and widespread in distribution within the Murchison, Pilbara or Gt Victoria Desert biogeographic regions. These do not warrant conservation consideration. These species require (i) formal vouchering at the WA Herbarium and (ii) taxonomic and differentiation within the broad species complexes that they currently reside within and are listed below.

Acacia oswaldii (long phyllode variant) (G Cockerton & S. Cockerton WB38622).

Maireana tomentosa - (Type 1 breakaway foot slopes) (G Cockerton & D Brassington WB38650).

Olearia sp. Sherwood Breakaways (A. Taylor 25552).

Olearia xerophila sens. lat.

Ptilotus obovatus (typical Goldfields form) (G. Cockerton, G. Grehan, L. Trotter, J. Symington 15213).

Ptilotus obovatus (upright form) (G. Cockerton, G. Grehan, L. Trotter, J. Symington LCH 15206).

Scaevola spinescens (broad leaf, non-spiny form).

Scaevola spinescens (narrow leaf, spiny form).

A further twelve well known but as yet undescribed species are also known within the Proposal Study Area. These are well represented in collections at the WA Herbarium, appear on the Census of Vascular Flora and are shown on the DPaW Florabase website. These are listed in the Systematic Species List for the MKS Proposal Study Area and are briefly described and discussed in Appendix 3.

3.3.2. Undescribed species with limited distribution

One species, *Eremophila* sp. long pedicels (G. Cockerton 1975), is known from few specimens in the Lake Way Catchment in the Wiluna area. A recent review of the taxon has found additional material in the region, however, investigation of the WA Herbarium specimens by Western Botanical conducted in early March 2017 found many anomalies and those specimens at distance from the Wiluna region are not considered to be the same species. This then indicates that *Eremophila* sp. long pedicels (G. Cockerton 1975) is restricted to the Lake Way and Lake Maitland Catchments at and north-east of the Mt Keith Nickel Mine. This species is briefly described and discussed in Appendix 3.

3.3.3. Species with uncertain taxonomic status, requiring further review

The taxonomic status of six (to seven) species is not well understood and will require the attention of specialist taxonomists in those genera. These are primarily the first four *Acacia* species noted in the list below, which will require an extensive and complex review of the abundant material available following the 2016 round of field works.

Acacia aff. *doreta* (narrow pod form) (G. Cockerton & S. Cockerton WB38633).

Acacia aff. *subtessarogona* (flat pod form) (G. Cockerton WB38658).

Acacia aff. *xanthocarpa* (terete to flat phyllode, resinous margins complex, inclusive of *Acacia* sp. East Murchison Basalt (G. Cockerton 38064)).

Hibbertia aff. *exasperata* (G. Cockerton & G. O'Keefe 11911).

Olearia sp. Sherwood Breakaways (A. Taylor 25552), currently within *Olearia stuartii*.

Olearia xerophila sens. lat.

The *Hibbertia* aff. *exasperata* (G. Cockerton & G. O'Keefe 11911) requires collection of suitable flowering and fruiting material to effect unambiguous identification.

The *Hibbertia* aff. *exasperata* (G. Cockerton & G. O'Keefe 11911) remains a species with both taxonomic and conservation interest as the material available for identification to date is less than optimal and the disjunction in potentially related taxa is significant, with the MKS populations being some 200 km north-east of the closest related species. The largest population of this species assessed to date lies within the proposed haul road alignment and around 92 individuals are know at this stage.

Some of these species may warrant conservation consideration, based on current knowledge of occurrences in the Wiluna – Leinster region. These species are describe in Appendix 4.

3.3.3.1. Species occurring at limits of known range or representing range extensions

Eight species records at the MKS Proposal Study Area represent slight range extensions of known distributions. These species are well represented within Western Australia, do not warrant conservation consideration and are listed in the Systematic Species List in Appendix 1.

Acacia brachystachya

Eremophila platycalyx subsp. Neds Creek (N.H. Speck 1228)

Aristida aff. jerichoensis var. *subspinulifera* P3

Chondropyxis halophila

Muelleranthus trifoliolatus

Maireana melanocoma

Olearia xerophila sens. lat.

Sida sp. spiciform panicles (E. Leyland s.n. 14/8/90)

Species removed from discussion as Species of Interest

The following species have been discussed in previous Western Botanical reports as either Priority Species or Species of Interest (Western Botanical, 2010). However, progress in taxonomic review, conservation status or a review of mapping has led to them no longer being included in discussions. The species and reasons for their removal are noted below.

- *Acacia* sp. Yakabindie Station aff. *A. kempeana* (G. Cockerton & G. O'Keefe 14274) is now regarded fitting within the broader *A. kempeana* sens. lat. group, which is acknowledged as requiring taxonomic review (B. Maslin pers. comm.).
- *Calytrix erosipetala* has been removed from the Priority Flora list.
- *Calytrix uncinata* has been removed from the Priority Flora list.
- *Cratystylis centralis* P3 has been discussed in previous reports (Western Botanical 2012, 2010) and is known north-west of the MKS Proposal Study Area, at the McFarlane's Find abandoned minesite. It is not found within the Proposal Study Area and has been removed from further discussion though is included in descriptions of Priority Flora for reference.
- *Eremophila galeata* x *platycalyx* subsp. Neds Creek Hybrid could not be relocated and has been removed from discussion though is included in descriptions of Species of Interest for reference.
- *Frankenia georgei* (formerly P3) was previously misidentified and is now regarded as the common and widespread *Frankenia interioris.*

- *Templetonia incrassata* has been described (in 2010) and is reasonably widespread in W.A. and South Australia.

3.4. Weeds

Few weeds have been noted within the MKS Proposal Study Area in any of the surveys to date. The original 2004 assessment recorded some *Acetosa vesicaria* (Ruby Dock), west of the Goldfields Highway, outside the current MKS Proposal Study Area. A review of weeds within the MKS Proposal Study Area in May and Nov – Dec 2016 found several minor occurrences of weeds within or near the Proposal Study Area:

Weed populations were always found in small, isolated populations with low numbers of individuals present, Figure 5. Three species of significant weed species were noted:

Rumex vesicarius (Ruby Dock)	An aggressive coloniser species that responds rapidly to rainfall, producing seeds that are readily distributed by wind and water. It is well established at Mt Keith and elsewhere on minesites and in disturbed lands in the north-eastern Goldfields.
Cenchrus ciliaris (Buffel Grass)	An aggressive coloniser that is well established in the Pilbara region but is only recently becoming a problem in the north-eastern Goldfields. It is allelopathic, meaning it supresses other plants growing near it and can be a major management risk to the project.
Cenchrus setiger (Birdwood Grass)	Is similar to Buffel Grass and is an aggressive coloniser that is well established in the Pilbara region but is only recently becoming a problem in the north-eastern Goldfields. It is also allelopathic, meaning it supresses other plants growing near it and can be a major management risk to the project.

These have the potential to be highly invasive and management will be required to maintain these species in low numbers.

Cenchrus ciliaris and *Cenchrus setiger* are in low numbers and only recorded at a few sites. Both are actively promoted by local Pastoralists (Doug Brownlie pers. comm., 2016) as pasture grasses, however, both have the potential to be come highly competitive weeds which respond well to summer rainfall.

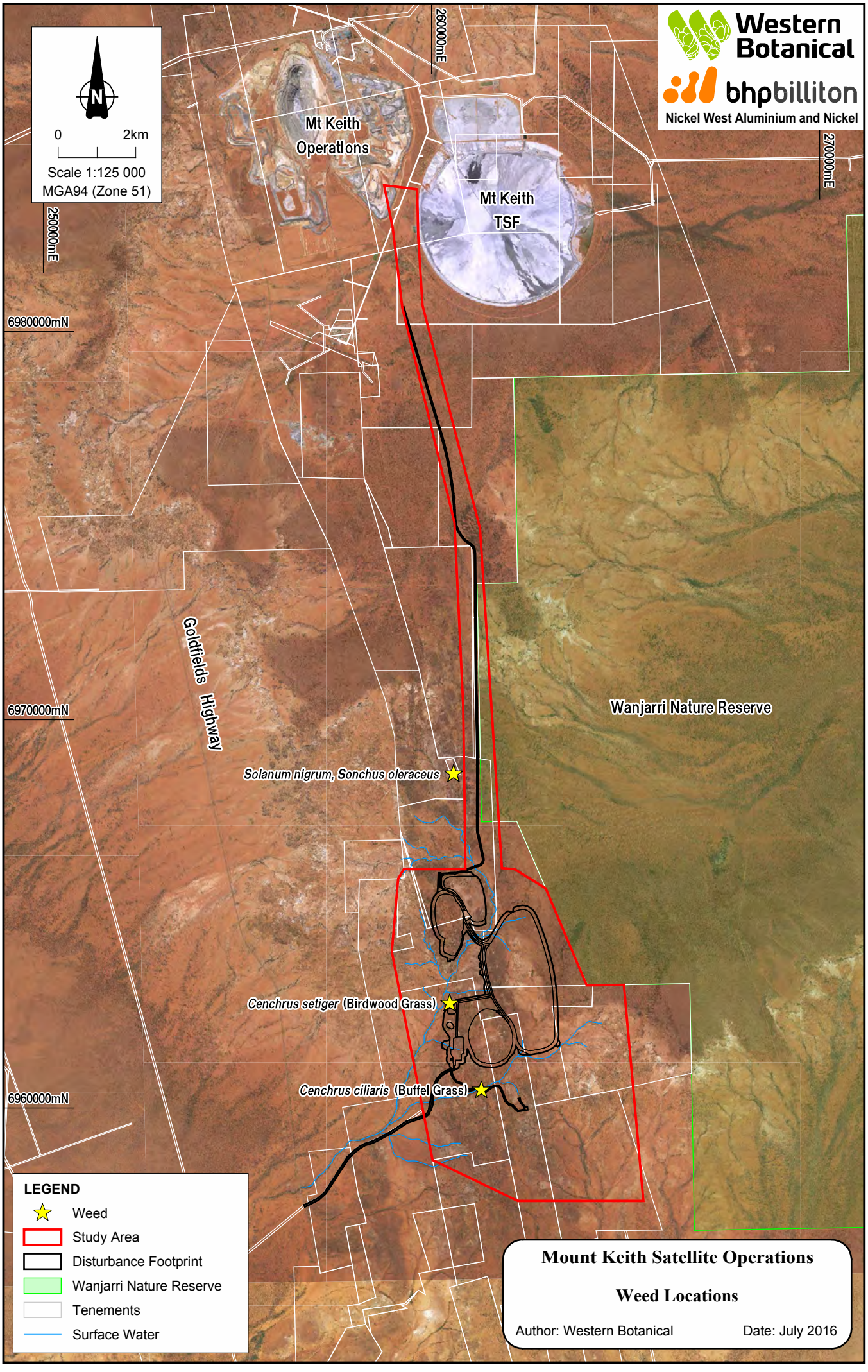
A further three species are known within the MKS Proposal Study Area:

Bidens bipinnata (Tick Weed)	Recorded within the bed of Jones Creek, downstream from the existing main crossing, and lies within the MKS Proposal Study Area. It is a nuisance plant with spiny fruit which cling to clothing and is readily transmitted via stock.
Lysimachia arvensis (Pimpernel)	Recorded at one site within Jones Creek and is a small annual species which has seeds that are readily transported by wind and water.
Mesembryanthemum nodiflorum (Slender Iceplant),	Recorded at one site in the north-west of the Proposal Study Area, associated with a low Archaean granite breakaway. It is a small annual species which has seeds that are readily transported by wind.

These species are widely naturalised in the pastoral regions of Western Australia, pose a lesser risk to the project and do not warrant active management.

A wide range of weed species are now prevalent at the Mt Keith Nickel Mine and were observed in May and Oct – Nov 2016. This lies outside the MKS Proposal Study Area, however, as the two sites will be linked and vehicle transport between the sites will be frequent, a comprehensive and pro-active weed management program should be initiated to prevent weed ingress to the MKS Proposal Study Area from the Mt Keith minesite.

Figure 5. Known Weed Populations within the MKS Proposal Study Area.


Western Botanical
bhpbilliton
Nickel West Aluminium and Nickel
N
0
2km
Scale 1:125 000
MGA94 (Zone 51)
260000mE
270000mE
250000mE
6980000mN
6970000mN
6960000mN
Mt Keith Operations
Mt Keith TSF
Goldfields Highway
Wanjarri Nature Reserve
Solanum nigrum, Sonchus oleraceus
Cenchrus setiger (Birdwood Grass)
Cenchrus ciliaris (Buffel Grass)
LEGEND
Weed
Study Area
Disturbance Footprint
Wanjarri Nature Reserve
Tenements
Surface Water
Mount Keith Satellite Operations
Weed Locations
Author: Western Botanical
Date: July 2016
Drawn: CAD Resources ~ Tel 9246 3242 ~ URL www.cadresources.com.au ~ July 2016 ~ A4 ~ Rev: A ~ CAD Ref g2414_R01_06.dgn ~ Imagery: Landgte (2011)

3.5. Pre-European Vegetation

Pre-European vegetation of Western Australia has been mapped by Beard et. al. (2013). The MKS Proposal Study Area lies within four of the Vegetation Systems mapped. These are (i) Low Mulga Woodlands (Wiluna 18), Mulga Shrublands (Wiluna 39), Hummock Hard Spinifex Grasslands with emergent Mulga and *Eucalyptus kingsmillii* (Wiluna 107) and Mulga and *Acacia quadrimarginea* Shrublands (Wiluna 202). These are impacted to minor degrees by the current proposal with proportional impacts well below 1%. However, these vegetation Systems are mapped a very high levels and an assessment of impacts to these of minimal value.

Table 5. Pre-European Vegetation Systems of the MKS Proposal Study Area

System	Description	MKS Proposal Study Area (ha)	% within MKS Proposal Study Area	Total Remaining (ha)
WILUNA_18	Low woodland; Mulga (Acacia aneura)	2,408.2	0.06%	4,296,026.3
WILUNA_39	Shrublands; Mulga scrub	2,586.2	0.61%	422,110.9
WILUNA_107	Hummock grasslands, shrub steppe; mulga and Eucalyptus kingsmillii over Hard Spinifex	148.8	0.01%	2,739,490.9
WILUNA_202	Shrublands; Mulga & Acacia quadrimarginea scrub	151.4	0.17%	88,101.8
Disturbed		127.5		
TOTAL		5,422.1		

3.6. Land Systems

In the early 1990's, the Department of Agriculture (DoA) conducted extensive Land System mapping and pastoral condition assessments in the north-eastern Goldfields (Pringle *et al*., 1994). These works broadly mapped vegetation, soils and underlying geology, representing a milestone in the overall understanding of the landscapes, vegetation and flora of the region.

Fourteen Land Systems are present within the confines of the Proposal Study Area, including the transport corridor. These are briefly described in Table 6 while Figure 6 shows their representation in and around the Proposal Study Area.

The Land Systems of the MKS Proposal Study Area are generally well represented in the broader north-eastern Goldfields region and specifically within the Eastern Murchison (MUR1) biogeographic region. Those Land Systems with the greatest representation within the Proposal Study Area are the Archaean granite breakaways and associated foot slopes of the Sherwood Land System (1136.9 ha); low ironstone (limonitic duricrust) hills of the Bevon Land System (1,785.9 ha); and the extensive orange sandplains of the Bullimore Land System (1,321.6 ha). These represent 0.07%, 0.75% and 0.03% of their respective regional area of occupancy in the north-eastern Goldfields.

The gravely hardpan plains of the Tiger Land System (335.2 ha); the hardpan plains with ironstone gravel mantles of the Jundee Land System (810.1 ha) and the gently undulating stony plains and low rises with quartz mantles on granite of the Windarra Land System (465.7 ha) occupy relatively large areas within the Proposal Study Area and represent 0.31%, 0.12% ad 0.20% of their respective regional area of occupancy in the north-eastern Goldfields, Table 6.

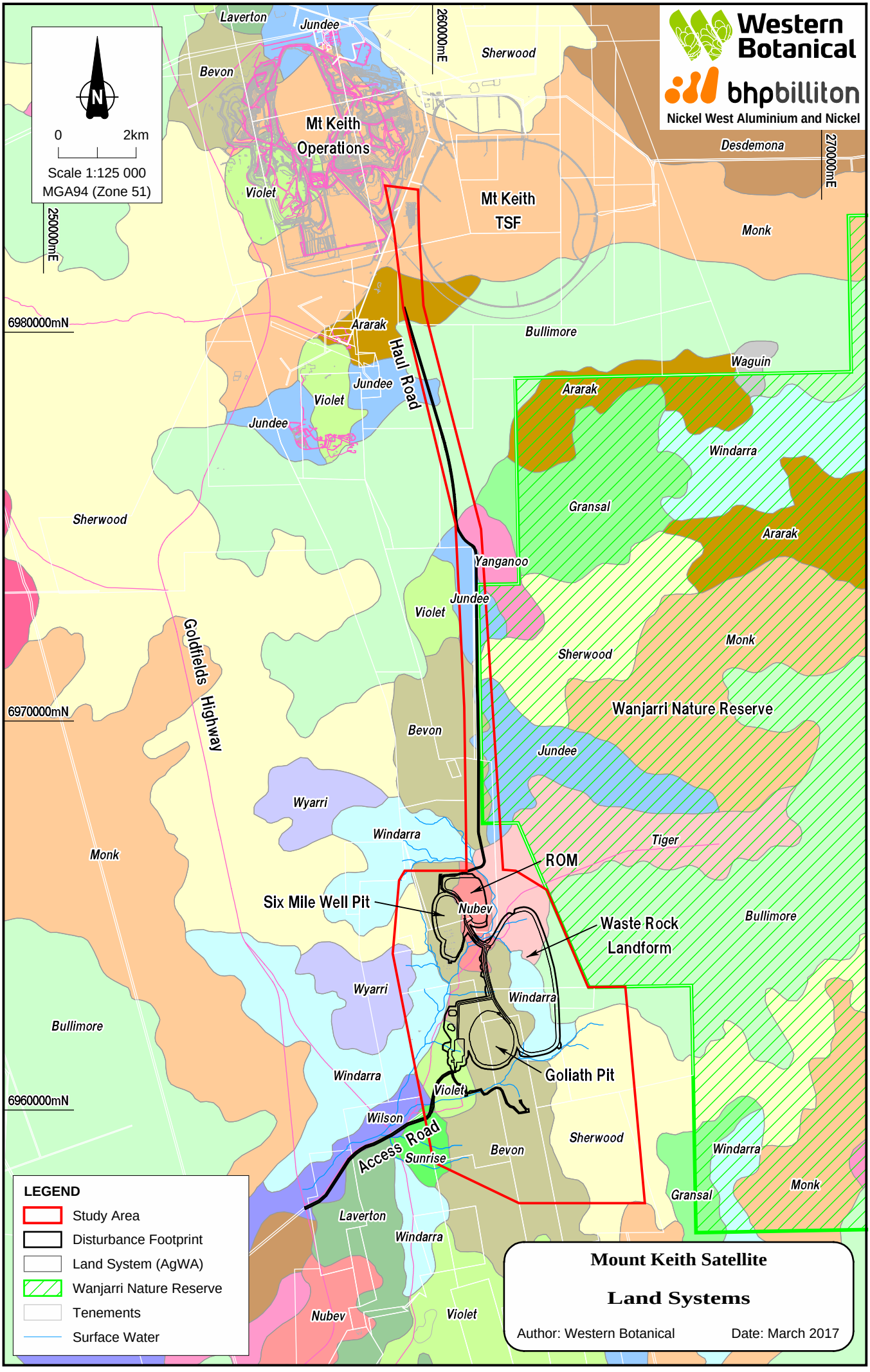
Nine Land Systems are represented by smaller areas, from 10.8 ha being the major creeklines of the Wilson Land System to 235.9 ha within the gently undulating gravelly plains on greenstone, laterite and hardpan of the Violet Land System, each representing less than 0.04% of their respective regional area of occupancy in the north-eastern Goldfields, Table 6.

Table 6. Land Systems of the MKS Proposal Study Area

Name	Description	MKS Proposal Study Area (ha)	Regional Total Area (ha)
Ararak	Broad plains with mantles of ironstone gravel supporting mulga shrublands with wanderrie grasses.	64.1	208,031.70
Bevon	Irregular low ironstone hills with stony lower slopes supporting mulga shrublands.	1,785.90	239,333.90
Bullimore	Gently undulating sandplain with occasional linear dunes and stripped surfaces supporting spinifex grasslands with mallees and acacia shrubs.	542	4,766,266.40
Jundee	Hardpan plains with variable gravelly mantles and minor sandy banks supporting weakly groved mulga shrublands.	342	666,389.20
Monk	Hardpan plains with occasional sandy banks supporting mulga tall shrublands and wanderrie grasses.	155.3	998,651.60
Nubev	Gently undulating stony plains, minor limonitic low rises and drainage floors supporting mulga and halophytic shrublands.	201.9	152,701.90
Sherwood	Breakaways, kaolinised footslopes and extensive gently sloping plains on granite supporting mulga shrublands and minor	1,089.40	1,579,987.80

Name	Description	MKS Proposal Study Area (ha)	Regional Total Area (ha)
	halophytic shrublands.		
Sunrise	Stony plains supporting mulga shrublands.	69.2	36,218.00
Tiger	Gravelly hardpan plains and sandy banks with mulga shrublands and wanderrie grasses.	335.2	109,873.50
Violet	Gently undulating gravelly plains on greenstone, laterite and hardpan, with low stony rises and minor saline plains; supporting groved mulga and bowgada shrublands and occasionally chenopod shrublands.	235.9	549,845.00
Wilson	Large creeks with extensive distributary fans, supporting mulga and chenopod shrublands.	10.8	48,423.70
Windarra	Gently undulating stony plains and low rises with quartz mantles on granite, supporting acacia-eremophila shrublands.	465.7	230,050.20
Wyarri	Granite domes, hills and tor fields with gritty-surfaced fringing plains supporting mulga and granite wattle shrublands.	62.7	88,823.10
Yanganoo	Almost flat hardpan wash plains, with or without small wanderrie banks and weak groving; supporting mulga shrublands and wanderrie grasses on banks.	62	2,013,881.20
	Total Area	**5,422.10**	

Figure 6. Land System Map of the Proposal Study Area



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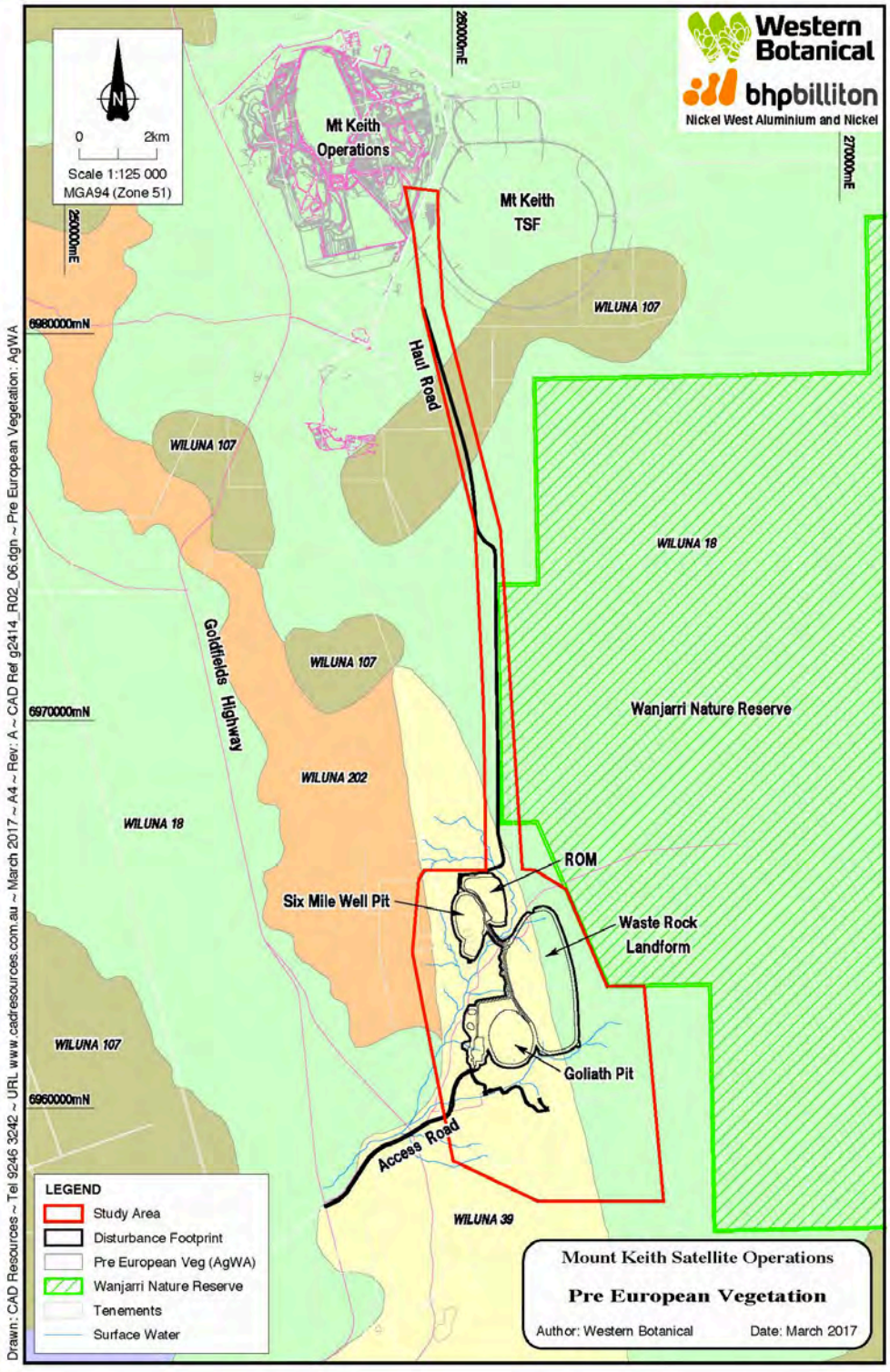
3.7. Pre-European Vegetation

Five of Beard *et. al.'s* (2013) Pre-European Vegetation units are present within the Proposal Study Area, Table 5 and Figure 7. The mapping is conducted a high level and the proportional impacts of the MKS project on these is negligible in both a local and regional sense.

Figure 7. Map of Pre-European Vegetation of the Region.



3.8. Priority Ecological Community

The MKS Proposal Study Area lies approximately centrally within the 19,256.2 ha *Violet Ranges (Perseverance Greenstone Belt) vegetation complexes (banded ironstone formation)* Priority 1 Priority Ecological Community. This PEC extends for approximately 32 km in a north-south orientation and approximately 11 km in an east-west orientation at it's widest point, Figure 8.

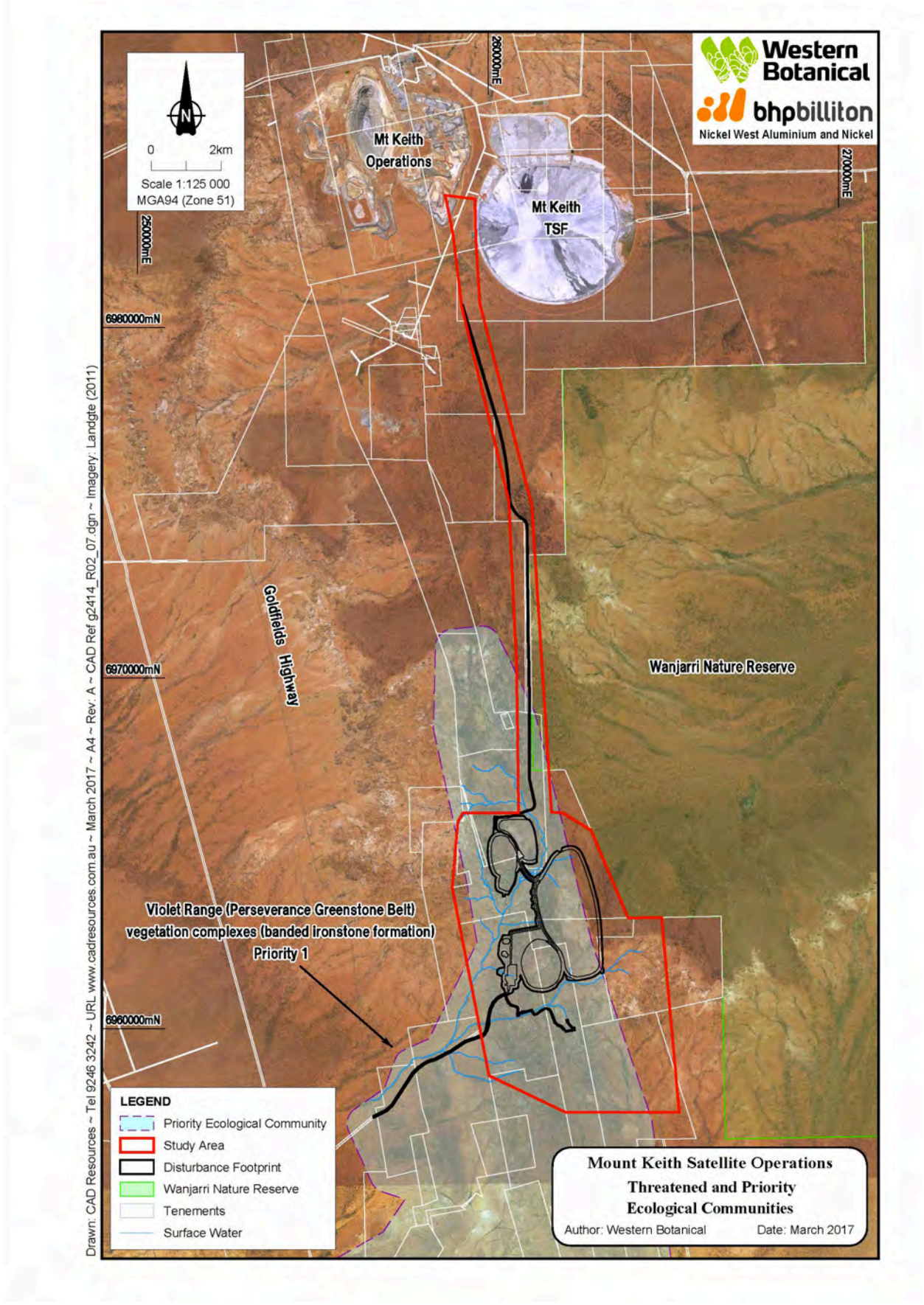
The MKS Proposal Study Area intersects 3,248.5 ha or 16.87 % of the 19,256.2 ha Violet Ranges PEC and the MKS proposed Development Envelope represents 1242 ha ha or 5.87 % of the Violet Ranges PEC as currently mapped. Minimal historical impacts to the Violet Ranges PEC have occurred to date with clearing for pastoral tracks and fences as well as historical mining activities at the decommissioned Bellevue mine site on the north-shore of Lake Miranda being the major contributors.

The majority of the geology within the Violet Ranges PEC is basalt, gabbro and granite with only minor chert and quartz outcrops present with extensive laterite duricrust capping present. The description of the PEC is therefore inaccurate.

In the vicinity of the MKS Proposal Study Area, the vegetation associations associated with the Mt Keith - Perseverance fault line are constrained within the boundaries of the Violet Ranges Priority Ecological Community. However, while narrow in an east-west orientation, these landforms extend beyond the limits of the PEC as currently drawn. These additional areas extend in a discontinuous fashion both northward (north of the Mt Keith nickel mine) and southward (to the Leinster nickel mine) directions for an overall inclusive length of approximately 82 km. The Violet Ranges PEC represents around 40 % of this overall range and the limits of the PEC are therefore inaccurate.

The definition and the area of occupancy the Violet Ranges PEC should be reviewed to incorporate additional adjacent areas of similar basalt geology and associated vegetation types that currently lie within the Mt Keith - Perseverance fault line but outside the current PEC boundaries.

Figure 8. MKS Proposal Study Area and Priority Ecological Communities



3.9. Vegetation Mapping

Vegetation of the MKS Proposal Study Area was mapped at a scale of 1:10,000 to NVIS Level 5 *Association* level. Terminology for the Vegetation Associations in the sandplain and granitoid communities closely follows that of Pringle *et. al.* (1994) while communities in other geological or regolith domains have novel, project-specific community codes developed conforming to NVIS Level 5 protocols.

Thirty Eight Vegetation Associations and 2 Vegetation Association Complexes, have been recognised in the MKS Proposal Study Area. The Vegetation Associations have been grouped into 6 sub-units according to the dominating underlying geology / regolith which strongly influences the vegetation association species composition, Table 7, Figure 9.

Those vegetation associations on (i) Sandplains (5 communities) and (ii) Colluvial and Alluvial Landforms are widely distributed in the Murchison Biogeographic region. Vegetation Associations of the (iii) Limonitic Landforms, the (iv) fresh rock Basalt geology of the Perseverance fault line and (v) carbonate soils derived from weathered basalt geology as well as some of the colluvial slopes associated with these are less widely distributed and, based on information available to date, are constrained within the Perseverance fault line and within the boundaries of the Violet Ranges Priority Ecological Community. While narrow in an east-west orientation, these landforms extend for over 80 km in a north-south orientation while the Violet Ranges PEC represents a subset of this overall range.

Table 7. Vegetation Associations of the MKS Proposal Study Area

Veg Code	Vegetation Association Name	Area (ha)	% of MKS Proposal Study Area
Basalt geology (Fresh Rock)			
BaMAS Complex	**Basalt, mixed Acacia species Shrubland Complex**	182.9	3.37
BaAdS	Basalt, Acacia aff. doreta Shrubland	19.4	0.36
BaAxS	Basalt, Acacia aff. xanthocarpa Shrubland	83.2	1.54
BaAbS	Basalt, Acacia burkittii Shrubland	11.9	0.22
BaCdS	Basalt, Calytrix desolata low Shrubland	22.7	0.42
Carbonate Soils, derived from Weathered Basalt			
GHPS	Weathered Basalt, Hakea leucoptera subsp. sericipes - Eremophila pantonii Shrubland	233.2	4.30
SSS	Stony Senna Shrubland	127.7	2.36
EGPW	Weathered Basalt, Eucalyptus gypsophila - Eremophila pantonii Woodland	11.9	0.22
Limonitic Landforms			
SILS	Stony Ironstone Low Shrubland	27.2	0.50

Veg Code	Vegetation Association Name	Area (ha)	% of MKS Proposal Study Area
SIMS	Stony Ironstone Mulga Shrubland	412.3	7.60
USBS	Upland Small Bluebush Shrubland	92.9	1.71
Archaean granite geology			
BrCP Complex	**Breakaway Chenopod Plain Complex**	12.2	0.23
BrCP - TectS	Breakaway Chenopod Plain Complex - Tecticornia Shrubland	0.6	0.01
BrCP-FRAN	Breakaway Chenopod Plain Complex - Frankenia shrubland	8.5	0.16
BrGP	Breakaway Grassy Plain	18.7	0.34
BrX-FOL	Archaean Granite Breakaway Footslope	15.7	0.29
BrX-P	Archaean Granite Breakaway Plateaux	30.8	0.57
GrEx	Granite, Exfoliating granite outcrops	62.4	1.15
GrMS	Granitic Mulga Shrubland	990.0	18.26
GrMS - BRX Complex	**Granite Mulga Shrubland - Granite Breakaway Plateaux Complex**	48.3	0.89
SAES	Stony Acacia Eremophila Shrubland	484.3	8.93
Sandplain Landforms			
MUWA	Mulga - Wanderrie Grassland	2.8	0.05
SAMU	Sandplain Mulga Spinifex Shrubland	172.0	3.17
SAWS	Sandplain, Acacia species Spinifex Shrubland	11.9	0.22
WABS	Wanderrie Bank Grassy Shrublands	182.2	3.36
WABS – SAMU Complex	Wanderrie Bank Grassy Shrublands / Sandplain Mulga Spinifex Shrubland Complex	153.9	2.84
SAMA	Sandplain, Mallee, Acacia species Spinifex Shrubland	13.3	0.24
Colluvial and Alluvial landforms			
DRMS	Drainage Line Mulga Shrubland	381.5	7.04
GRMU	Groved Mulga Woodland	65.2	1.20
HMCS	Mulga Shrubland with scattered low Chenopod Shrubs	24.0	0.44
HPMS	Hardpan Mulga Shrubland	323.3	5.96
MMS	Mulga over Maireana triptera Shrubland	330.0	6.09
SMS	Stony Mulga Shrubland	763.8	14.09

The majority of Vegetation Associations individually represent less than 10 % of the area of occupancy within the MKS Proposal Study Area. Two Vegetation Associations represent greater than 10%: Stony Mulga Shrubland, SMS, (14.09% of the MKS Proposal Study Area) and Granitic Mulga Shrubland, GrMS, (18.26% of the MKS Proposal Study Area).

The SMS Vegetation Association represents the lower colluvial slopes of the Stony Ironstone Mulga Shrublands (SIMS) community that is centrally focussed within the Bevon Land System which extends from near the Mt Keith minesite to south of Leinster in a discontinuous fashion.

These are both likely to be reasonably widespread within the Violet Range PEC and southwards of the PEC towards Leinster. Large areas of SIMS, with the associated colluvial lower slopes, has been extensively mapped near both Mt Keith and Leinster (Western Botanical, 2016). While the SIMS community is also mapped at both Mt Keith and at Leinster, and was the focus of the Meissner & Wright (2010) assessments, the review of regional data sets presented in Western Botanical (2016) found that the species composition, primarily in the understorey components, differed between the Leinster, Mt Keith and the MKS sites so that the three are not directly comparable due to species turnover.

The GrMS Vegetation Association is widespread in the region and in found extensively outside the MKS Proposal Study Area in both an eastern direction (within the Wanjarri Nature Reserve) and western direction (within Yakabindie, Mt Keith, Albion Downs and Yeelirrie Stations and beyond), in association with the Archaean granitoid Barr-Smith Range.

Figure 9. Vegetation Maps of the MKS Proposal Study Area

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Western Botanical

bhpbilliton

Nickel West Aluminium and Nickel

259000mE 260000mE 261000mE 262000mE

6982000mN 6980000mN 6978000mN 6976000mN 6974000mN 6972000mN 6970000mN 6968000mN 6966000mN

N

0 400m

Scale 1:25 000

MGA94 (Zone 51)

Mt Keith
TSF

Wanjarri
Nature Reserve

WABS
DRMS
Disturbed
Ponded Water
HPMS
SAMU
SMS
SAES
WABS - SAMU
Mosaic Complex
GRMU
GrMS
BrX-FOL
BrX-P
BrCP
GHPS
SIMS
EGPW
SILS
SSS
USBS
MMS

Mount Keith Satellite

Vegetation

Sheet 2 of 2

Author: Western Botanical Date: March 2017

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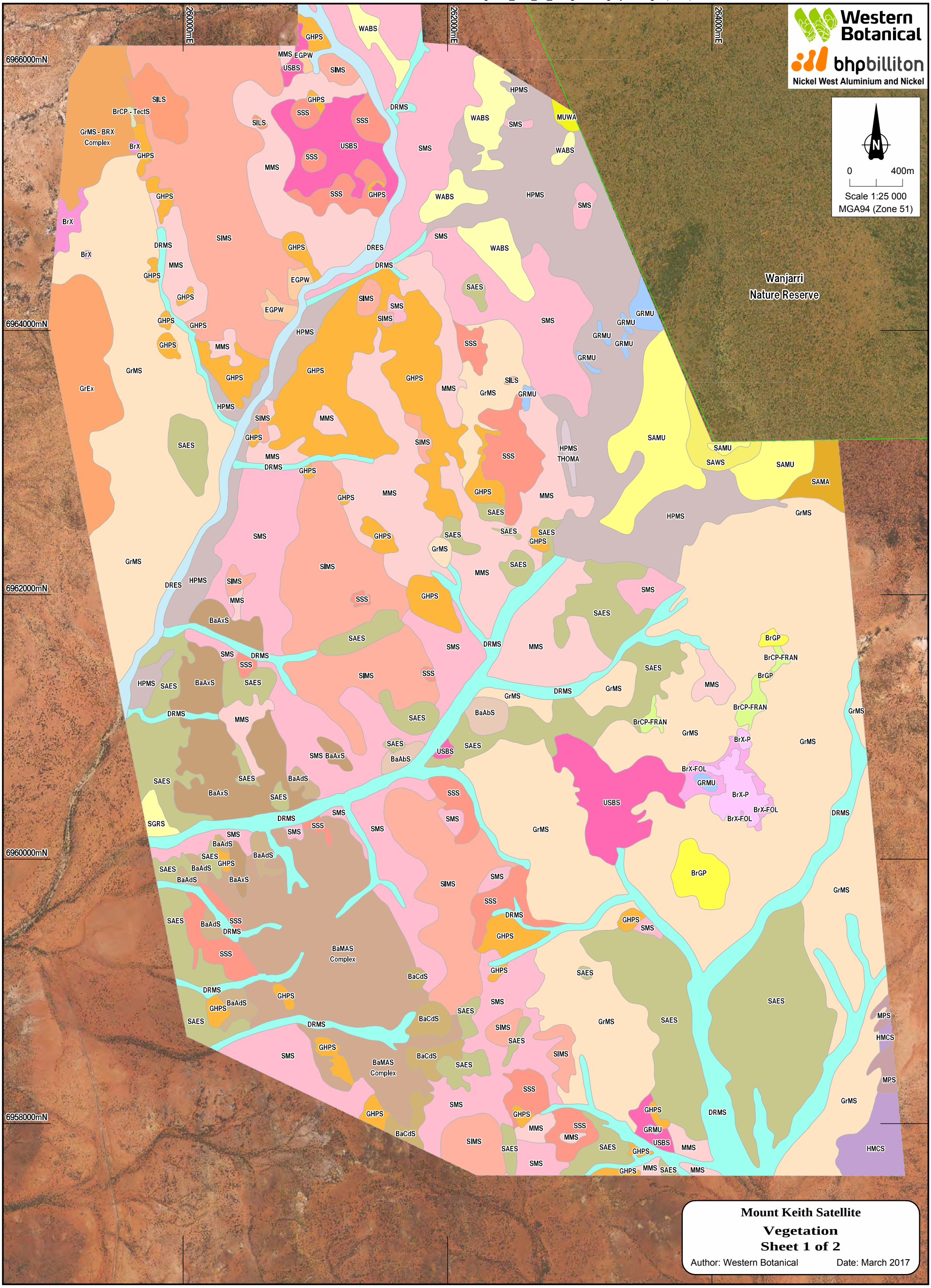
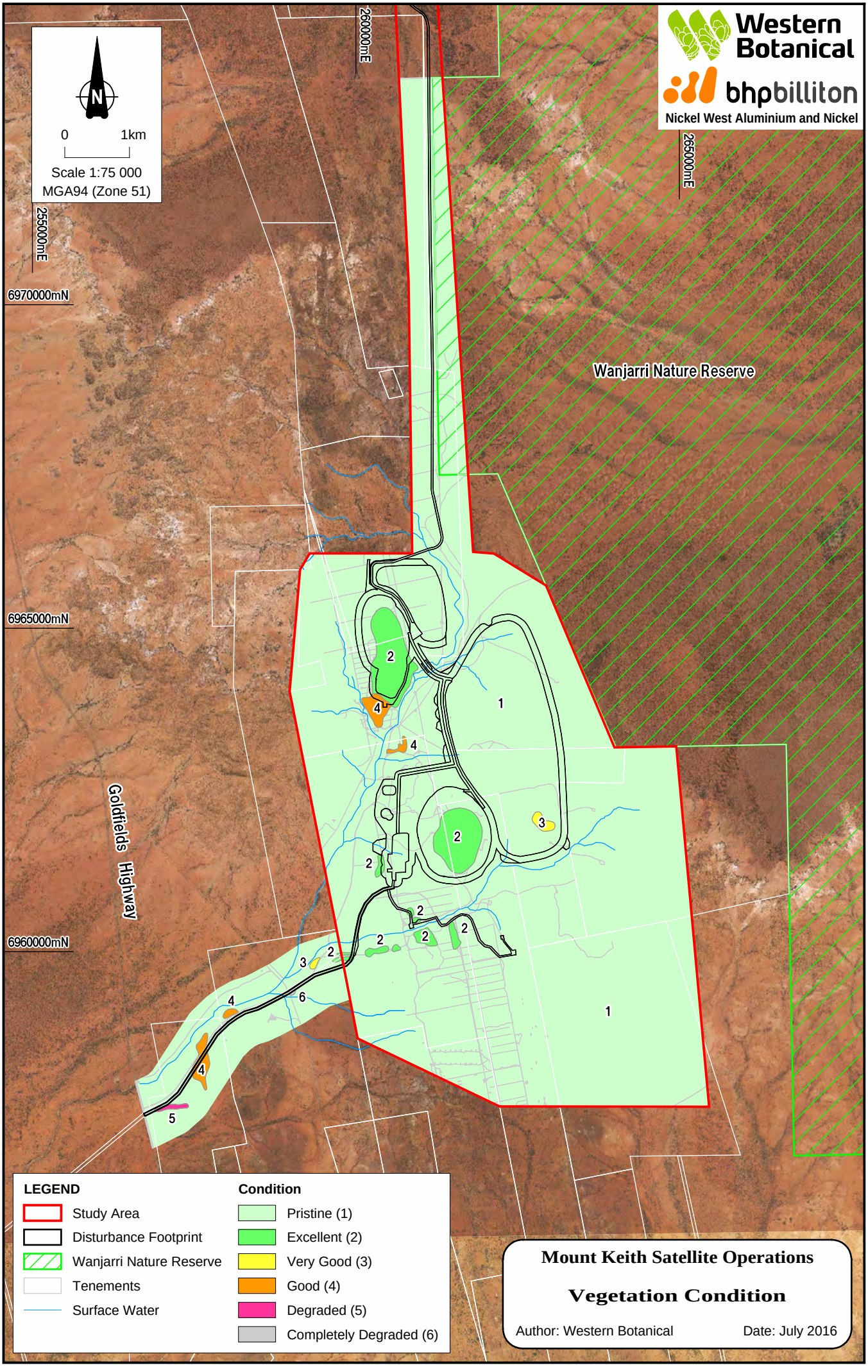


3.10. Vegetation Condition and Grazing

The MKS tenements have been extensively explored in the past and post exploration rehabilitation was found to have been largely effective. Vegetation condition outside the areas directly impacted by exploration and track maintenance can be regarded as being in Pristine (i) condition with little evidence of pastoral activities. Areas having been disturbed in previous exploration works are regarded as being in Excellent (ii) condition while completely cleared areas were recorded as Completely Degraded (vi), Figure 10.

The MKS project lies within the Yakabindie Pastoral Lease and grazing of cattle has historically been the main pastoral activity in the past 20 years (D. Brownlie pers. comm., 2016). While there is evidence of traffic by cattle, this is mostly on the margins and within the sandy bed of Jones Creek. Little evidence of grazing pressure on vegetation is apparent. Specifically, the Mulga and associated vegetation shows little evidence of grazing by cattle and the canopies of most vegetation is intact and reflects normal seasonal conditions in all the surveys that have been conducted to date by Western Botanical and Landcare Services since 1996.

Figure 10. Vegetation Condition Map



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3.11. Impact Assessment – Flora

Priority Flora

Of the fourteen species of Priority Flora known within the MKS Proposal Study Area, two are not directly impacted by the MKS project. These are:

- *Anacampseros* sp. Eremaean ((F. Hort, J. Hort & J. Shanks 3248) P1
- *Sida picklesiana* - P3

Five species have minor populations within the MKS Development Envelope and are impacted at less than 2% of their known regional populations. These are:

- *Eremophila pungens* - P4 (including *Eremophila* sp. Leinster RJ Cranfield 6767): 24 plants, representing 0.61% of the known regional population.
- *Grevillea inconspicua* - P4: 159 plants, representing 1.77% of the known regional population.
- *Hemigenia exilis* - P4: 70 plants, representing 0.31% of the known regional population.
- *Thryptomene* sp. Leinster (B.J. Lepschi & L.A. Craven 4362) - P3: 689 plants, representing 1.19% of the known regional population.
- *Verticordia jamiesonii* - P3, one site of

One priority species, *Hybanthus floribundus* subsp. *chloroxanthus* - P3, is impacted to a moderate extent by the MKS project with approximately 150 plants being within the Six Mile orebody area, representing 10.05% of the known regional population (Western Botanical, 2016).

One further species, *Tribulus adelacanthus* P3 is a poorly known annual, and while one record lies within the MKS Disturbance Envelope (six populations known in total in WA), it is not possible to make a meaningful assessment of proportional impacts on this species.

Significant Flora Species

Of the species listed as Significant Flora, two species present on the Breakaway plateaux of the Sherwood Land System will be impacted by the MKS project, in development of the transport corridor to the Mt Keith Nickel Mine:

- *Olearia* sp. Sherwood Breakaways (A. Taylor 25552).
- *Hibbertia* sp. Sherwood Breakaways aff. *H. exasperata* (G Cockerton & G O'Keefe 11451), representing 1.09% of the known population of 92 plants of this species.

Of these, impacts to the *Hibbertia* sp. Sherwood Breakaways aff. *H. exasperata* (G Cockerton & G O'Keefe 11451) are of greatest concern as this species, based on available data, is likely a new

species, is significantly geographically isolated from other *Hibbertia* species in the south-west of W.A. and may acquire a relatively high conservation listing. Unfortunately the material of this species available for taxonomic review is poor and a re-collection of flowering and fruiting material, a review by a competent *Hibbertia* expert and a local – regional review of abundance and distribution, is required to finalise the assessment of this species.

The *Olearia* sp. Sherwood Breakaways (A. Taylor 25552) is known to be widespread though always occurring in low numbers and is not considered to warrant conservation focus.

One species has no counts of either local or regional populations or maps of the extents of it's occurrence within or outside the MKS Proposal Study Area and impacts to it's populations can not be assessed:

- *Acacia sp. East Murchison Basalt* (G Cockerton 38064)

Acacia sp. East Murchison Basalt is known from three locations on basalt (greenstone) hills between Menzies and Wiluna. The largest population known to date, estimated at several hundred plants occurring over an estimated 2.96 ha occurs within the MKS Proposal Study Area, on the margin of the Golaith orebody pit area and the eastern wastedump (indicative point 51J 261927, 6962350). A small population of fewer than 50 plants is known from a small basalt rise on Barwidgee Station (51J 278048, 7021419) while a small population of a dozen or so plants is known from an area south-west of the MKS Proposal Study Area, south of Lake Miranda (51J 264461, 6929273).

This species complex is currently (March 2017) under review by Mr. Bruce Maslin at the WA Herbarium.

One species, with around 20 individuals within the northern portion of the proposed haul road to Mt Keith, is known to be abundant in the area east of the Mt Keith CDTSF. The population to be impacted has not been assessed in detail.

- *Eremophila* sp. long pedicels (G. Cockerton 1975)

Impacts to this species by the MKS project are considered insignificant though the species may warrant conservation listing as a Priority Species.

3.12. Impact Assessment – Vegetation Associations

For the purposes of Impact Assessment, the degree of impact on the vegetation units has been divided into four categories, Table 8.

Table 8. Impact Assessment Categories for Vegetation Associations

Low Impact	0 to 20% of the vegetation unit to be impacted within the MKS Development Envelope
Moderate Impact	20 to 50% of the vegetation unit to be impacted within the MKS Development Envelope
High Impact	50 to 70% of the vegetation unit to be impacted within the MKS Development Envelope
Extreme Impact	> 70% of the vegetation unit to be impacted within the MKS Development Envelope

Western Botanical (2016) discussed that numerous Vegetation Communities of the MKS Proposal Study Area mapped to 2011 were impacted to a High to Extreme degree, greater than 50%. This, combined with the known relatively coarse level of mapping conducted to that date, regarded as equivalent to what is now regarded as a Level 1 Assessment, led to a review of mapping and the incorporation of re-mapped Vegetation Associations of the MKS Proposal Study Area. The re-mapping was completed using significantly better quality aerial photography at a more detailed scale (1:10,000 vs. the previous mapping at 1:25,000 capture scales).

This proved to be an extremely useful exercise and led to a significant review of vegetation mapping, supported by additional traverses, quadrats and relevés as discussed in Methods. This has resulted in re-classification of many vegetation units and a significantly more accurate depiction of vegetation unit boundaries.

The result of the improved mapping and re-classification of vegetation associations, relying on a greater level of detailed on-ground assessments, is presented in Table 9.

This shows that the majority of Vegetation Associations and Vegetation Association Complexes are impacted to a negligible level, below 10% of their local are of occupancy, compared to the mapped extent of communities within the MKS Proposal Study Area.

Fourteen Vegetation Associations and one Vegetation Association Complexes of the MKS Proposal Study Area will not be impacted at all by the proposed development of the mine voids, infrastructure areas and transport corridor. Twelve Vegetation Associations and one vegetation Association Complex will be impacted to a degree less than 20%. Collectively these are considered Low Impacts and are not discussed further. These cells are shaded in green within Table 9.

Six Vegetation Associations will be impacted at levels of between 20% and 50% of their area mapped within the MKS Proposal Study Area . These are the SMS (21.55%), HPMS (22.81%), EGPW (43.13%), USBS (35.39%), SSS (41.89%) and GHPS (43.13%).

The SMS and HPMS communities represent the colluvial and alluvial slopes associated with the Bevon Land System respectively and both lie downslope of the SIMS community. The SMS community is likely to be more widespread within the Violet Range PEC and also elsewhere in the vicinity of Mt Keith and Leinster. The HPMS Community is widespread in the region, associated with the margins of drainage lines and is considered locally and regionally well represented. One Priority Species, *Tribulus adelacanthus* P3, is known from one record within the SMS Community at MKS and is also known from a similar landscape position near the Mt Keith Nickel mine.

The EGPW, community is associated with the catchment of the upper reaches of the Jones Creek and large areas of this are known outside the MKS Proposal Study Area, in the vicinity of the McFarlane's Find abandoned prospect. The apparent restriction of this community in the local area is an artefact of the boundary of the MKS Proposal Study Area excluding the region inclusive of McFarlane's Find, north-west of the MKS Proposal Study Area. No species with conservation significance are know within this community within the MKS Proposal Study Area. However, west of the MKS Proposal Study Area, *Cratystylis centralis* sens. lat. P3 is known to be strongly associated with the EGPW Community.

The USBS Community is characterised by occasional *Acacia oswaldii* (narrow leaf form) and *Hakea preissii* emergent over a broad range of low annual and perennial halophytic herbs. It was highlighted in Western Botanical (2016) as being impacted at 83.86%. However, in re-mapping the MKS Proposal Study Area, additional areas of USBS were found outside the proposed disturbance envelope, south of the Goliath orebody area. The proportional impact on the USBS community is now calculated at 35.39% and is considered Moderate. No information is available on the regional context of the USBS Community as it has not been encountered at either Leinster or Mt Keith. However, no species with conservation significance are known within this community at MKS.

The SSS Community is characterised as a mid shrubland of *Senna* species with occasional emergent *Hakea preissii* and *Hakea leucoptera* subsp. *sericipes*. It is associated with low stony rises and lies upslope of USBS and is often adjacent to GHPS communities. The SSS Community is impacted at 43.13% within the area mapped in the Proposal Study Area and this is considered a Moderate impact. No species with conservation significance are known within this community.

The SIMS, MMS and HPMS-Thoma communities are impacted to High (SIMS, 57.98%) and Very High (MMS, 75.22%, HPMS-Thoma 100%) proportions of their mapped areas within the MKS Proposal Study Area. However, SIMS is widespread within the Bevon Land System between Leinster and Mt Keith and HPMS-Thoma community is very closely aligned with the

wider-spread HPMS community (separated only by the inclusion of *Acacia thoma* as a dominant species). *Acacia thoma* is known from four locations within the MKS Proposal Study Area and also at Leinster and regionally to the Pilbara region.

The SIMS Community is characterised by Mulga (*Acacia aneura* and it's allies) Shrublands with very little understorey on low, rounded lateritic hills which may include minor chert, quartz and tertiary laterite outcrop. The small and limited outcrops of limonitic material were the focus of the Meissner & Wright (2010) Surveys of vegetation of banded ironstone formations of the Perseverance Greenstone Belt, nine sites of which lie within the MKS Proposal Study Area. SIMS is impacted to a high degree, 57.98% within the area mapped in the MKS Proposal Study Area. While SIMS is also mapped extensively at Mt Keith and Leinster (Landcare Services, 1997 a, b), due to changes in species composition of the understorey, they communities are considered not directly comparable and were separated in the first major branches of the PATN analysis undertaken and presented in Western Botanical (2016). However, they SIMS communities at Mt Keith, MKS and Leinster do contain many species in common including a range of Mulga varieties, *Acacia pruinocarpa*, *Scaevola spinescens* (narrow leaf, spiny form), *Eremophila jucunda* subsp. *jucunda*, *Eremophila latrobei* forms, Eremophila sp. Leinster (RJ Cranfield 6767) within *Eremophila pungens* P4, *Senna* sp. Meekatharra (E. Bailey 1-19) and *Harnieria kempeana* var. *muelleri* as a minor inclusion.

The MMS Community is characterised tall Mulga (*Acacia aneu*ra sens. lat. and related species) over a sparse mid storey of *Sida ectogamma*, *Ptilotus obovatus* (upright form) and a consistently dominant understorey of the halophyte *Maireana triptera*. It forms the some of the lower colluvial slopes downslope of the SIMS community within the Bevon Land System. The MMS Vegetation Association is impacted to a very high level with 75.22% of the known extent of MMS inside the MKS Proposal Study Area being within the proposed development envelope. The combination of Mulga trees over *Maireana triptera* is uncommon outside the MKS Proposal Study Area, with small areas known near Leinster, at the southern end of the Mt Keith – Perseverance lineament. No species with conservation significance are known within this community.

The HPMS-Thoma community is found in two small areas in the eastern part of the MKS Proposal Study Area, within the proposed wastedump footprints and 100% of it's local occurrence is proposed to be taken. It represents a floristic association typical of the broader HPMS community but differs in occurring on low rises, having a shallow sandy mantle present and supporting local populations of *Acacia thoma*. *A. thoma* is known at four locations within the MKS Proposal Study Area and from Leinster to the southern and central Pilbara bioregion. It is uncommon in the landscape in the region between Leinster and Mt Keith. It is however, sufficiently widespread and not of conservation significance. The PATN analysis suggested that HPMS-Thoma was very similar to the more widespread HPMS community discussed above. The HPMS-Thoma Vegetation Association has been retained in this treatment to acknowledge

the presence of this species within that community, it's absence elsewhere at MKS and the relatively scarcity in the Leinster – Mt Keith region.

Table 9. Impacts on Vegetation Associations, MKS Proposal Study Area

Vegetation Code	Description	Area within MKS (ha)	% of MKS Proposal Study Area Total	Area (ha) within Development Envelope	% to be Disturbed
BaAbS	Basalt, Acacia burkittii Shrubland (component of the BaMAS complex)	11.9	0.22%	0.00	0.00%
BaCdS	Basalt, Calytrix desolata low Shrubland	22.7	0.42%	0.00	0.00%
BaMAS	Basalt, mixed Acacia species Shrubland Complex	182.9	3.37%	0.00	0.00%
BrCP - TectS	Breakaway Chenopod Plain Complex - Tecticornia Shrubland (component of the BrCP Complex)	0.6	0.01%	0.00	0.00%
BrCP-FRAN	Breakaway Chenopod Plain Complex - Frankenia shrubland (component of the BrCP Complex)	8.5	0.16%	0.00	0.00%
BrGP	Breakaway Grassy Plain	18.7	0.34%	0.00	0.00%
BrX	Archaean Granite Breakaway	7.1	0.13%	0.00	0.00%
GrEx	Granite, Exfoliating granite outcrops	62.4	1.15%	0.00	0.00%
GrMS - BRX Complex	Granite Mulga Shrubland - Granite Breakaway Plateaux Complex	48.3	0.89%	0.00	0.00%
HMCS	Mulga Shrubland with scattered low Chenopod Shrubs	24.0	0.44%	0.00	0.00%
MPS	Maireana pyramidata Shrubland	6.8	0.13%	0.00	0.00%
MUWA	Mulga - Wanderrie Grassland	2.8	0.05%	0.00	0.00%
Ponded Water	Ponded Water	1.5	0.03%	0.00	0.00%
SAMA	Sandplain, Mallee, Acacia species Spinifex Shrubland	13.3	0.24%		0.00%
SAWS	Sandplain, Acacia species Spinifex Shrubland	11.9	0.22%	0.00	0.00%
BrCP	Breakaway Chenopod Plain Complex	12.2	0.23%	0.00	0.00%
SGRS	Sandy Grantic Mulga Shrubland	5.4	0.10%	0.01	0.17%
BrX-FOL	Archaean Granite Breakaway Footslope	15.7	0.29%	0.22	1.39%
BaAdS	Basalt, Acacia aff. doreta Shrubland (component of the BaMAS complex)	19.4	0.36%	0.64	3.30%
SAMU	Sandplain Mulga Spinifex Shrubland	172.0	3.17%	5.72	3.32%

Vegetation Code	Description	Area within MKS (ha)	% of MKS Proposal Study Area Total	Area (ha) within Development Envelope	% to be Disturbed
GrMS	Granitic Mulga Shrubland	990.0	18.26%	35.38	3.57%
DRES	Drainage Line Eucalypt Woodland	50.5	0.93%	1.87	3.72%
GRMU	Groved Mulga Woodland	65.2	1.20%	2.84	4.35%
BrX-P	Archaean granite geology	30.8	0.57%	1.43	4.65%
WABS - SAMU Mosaic Complex	Wanderrie Bank Grassy Shrublands / Sandplain Mulga Spinifex Shrubland	153.9	2.84%	8.76	5.69%
SILS	Stony Ironstone Low Shrubland	27.2	0.50%	1.58	5.82%
DRMS	Drainage Line Mulga Shrubland	381.5	7.04%	28.44	7.45%
BaAxS	Basalt, Acacia aff. xanthocarpa Shrubland (component of the BaMAS complex)	83.2	1.54%	11.25	13.52%
SAES	Stony Acacia Eremophila Shrubland	484.3	8.93%	66.38	13.71%
WABS	Wanderrie Bank Grassy Shrublands	182.2	3.36%	26.75	14.68%
SMS	Stony Mulga Shrubland	763.8	14.09%	164.59	21.55%
HPMS	Hardpan Mulga Shrubland	323.3	5.96%	73.77	22.81%
EGPW	Weathered Basalt, Eucalyptus gypsophila - Eremophila pantonii Woodland	11.9	0.22%	3.96	33.25%
USBS	Upland Small Bluebush Shrubland	92.9	1.71%	32.89	35.39%
SSS	Stony Senna Shrubland	127.7	2.36%	53.50	41.89%
GHPS	Weathered Basalt, Hakea leucoptera subsp. sericipes - Eremophila pantonii Shrubland	233.2	4.30%	100.57	43.13%
SIMS	Stony Ironstone Mulga Shrubland	412.3	7.60%	239.06	57.98%
MMS	Mulga over Maireana triptera Shrubland	330.0	6.09%	248.23	75.22%
HPMS THOMA	Hardpan Mulga (Acacia thoma) Shrubland	3.0	0.06%	3.02	100.00%
Disturbed	**Disturbed (roads)**	**27.0**		**19.86**	
		5,422.1	**100.00%**	**1,130.73**	

3.13. Impact Assessment – Priority Ecological Community

Violet Range PEC

The MKS Proposal Study Area occupies 5,422.1 ha or 28.16 % of the Violet Range (Perseverance Greenstone Belt) vegetation complexes (banded ironstone formation) P1 Priority Ecological Community. The MKS proposed Development Envelope occupies 1,547.6 ha or 8.04 % of the 19,256.2 ha of the PEC as currently mapped, Figure 11.

Minimal historical impacts to the Violet Ranges PEC have occurred to date with clearing for pastoral tracks and fences as well as historical mining activities at the abandoned Bellevue site on the north-shore of Lake Miranda being the major contributors. The current Cosmos Nickel Mine lies outside the boundary of the Violet Ranges PEC. The MKS project therefore represents the largest proposed impact to the Violet Ranges PEC.

However, it is clear from field investigations conducted in late 2016 as well as historically between Leinster and Mt Keith, that the definition of the Violet Ranges PEC as well as it's extent of occupancy and boundaries are in need of review. The majority of the geology within the Violet Ranges PEC is basalt and gabbro and some granite with only minor Banded Ironstone Formation (BIF), chert and quartz outcrops present with associated tertiary laterite capping present.

In the vicinity of the MKS Proposal Study Area, the vegetation associations associated with the Mt Keith Perseverance fault line are constrained within the boundaries of the Violet Ranges Priority Ecological Community. However, while narrow in an east-west orientation, these landforms extend beyond the limits of the PEC as currently drawn. These additional areas extend in a discontinuous fashion both northward (north of the Mt Keith nickel mine) and southward (to the Leinster nickel mine) directions for an overall inclusive length of approximately 82 km. The Violet Ranges PEC represents around 40 % of this overall range and the limits of the landforms and associated vegetation units within the PEC are therefore inaccurate.

A depiction of areas with similar landform and geology to components of the Violet Range PEC, as well as associated vegetation associations outside the current PEC boundary, with the current PEC shown, is presented in Figure 11. The areas of potential similarity to the Violet Range PEC occupy an area of approximately 18,288 ha, an area almost equivalent to that of the currently mapped PEC.

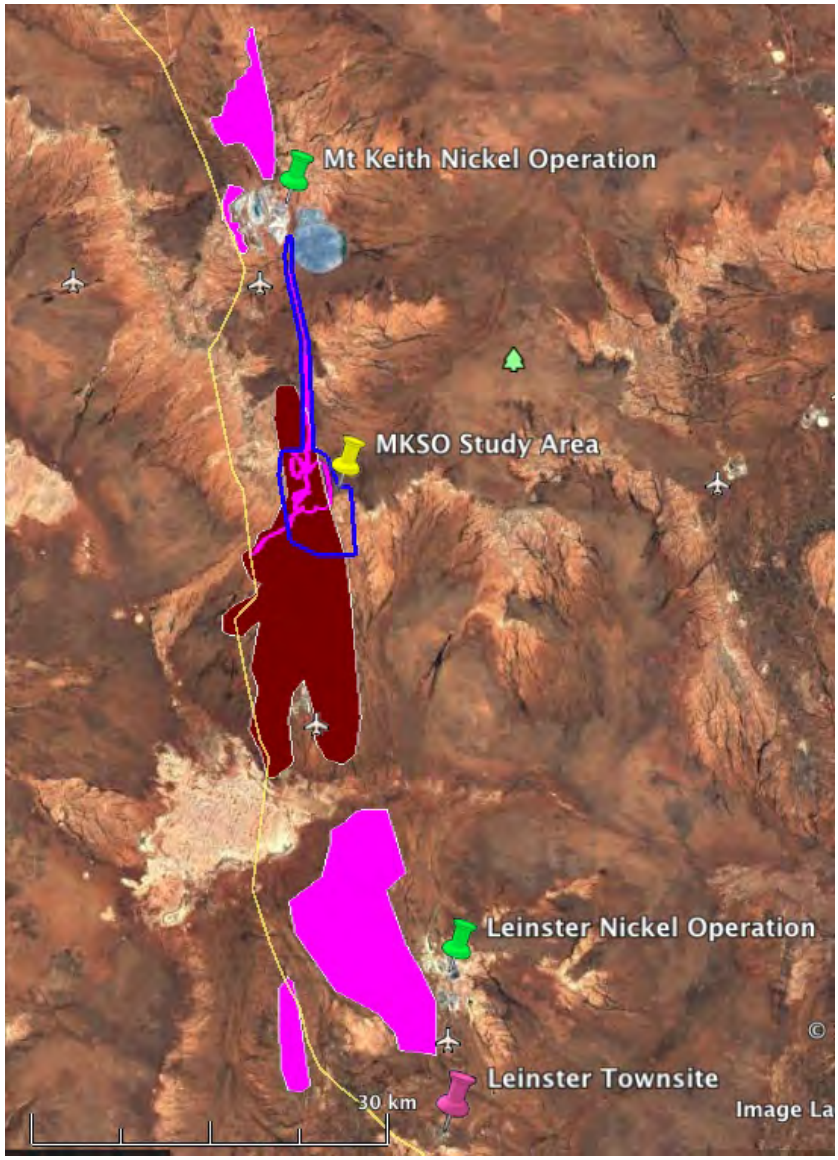


Figure 11. Violet Range PEC current Boundary (Dark Red Polygon) and areas of similar geology, landform and vegetation in the region.

The regional assessment of the flora and vegetation of the Perseverance Greenstone Belt conducted by Meissner & Wright (2010) extend over 6.6 km within the MKS Proposal Study Area and an overall length of 17.5 km within the Perseverance Greenstone Belt. They are located north of Lake Miranda and south of Mt Keith and do not extend to the areas here being suggested as worthy of consideration for inclusion in the expanded PEC, Figure 12.

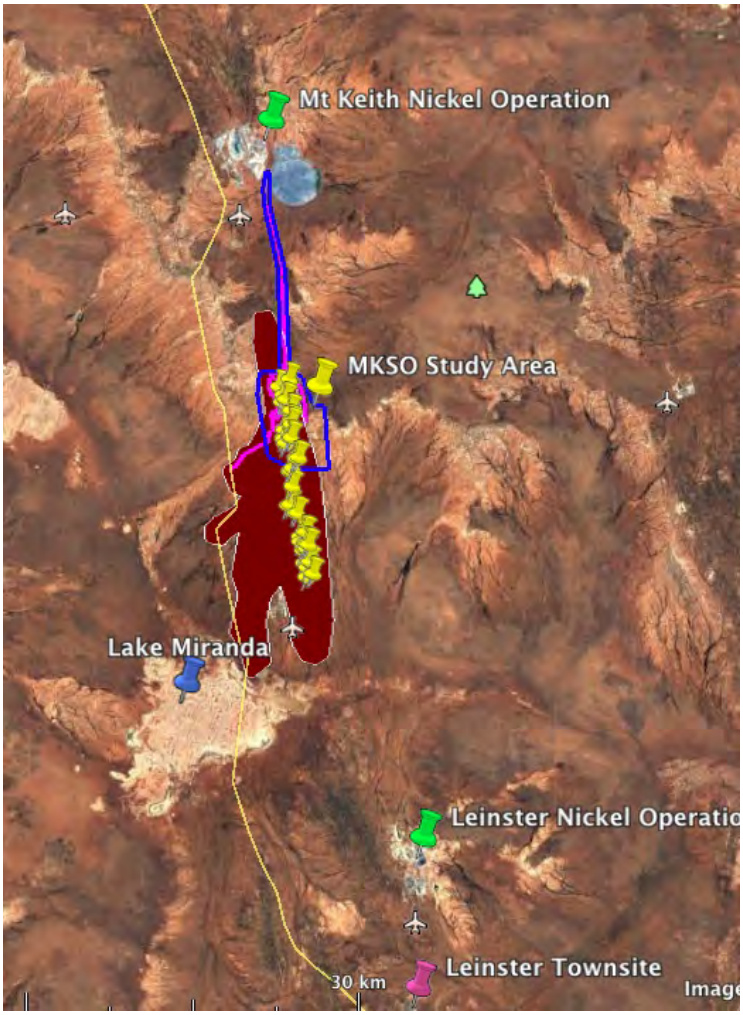


Figure 12. DPaW Quadrats within the Perseverance Greenstone Belt (yellow markers).

The definition and the area of occupancy the Violet Ranges PEC should therefore be reviewed to incorporate additional adjacent areas of similar basalt geology and associated vegetation types that currently lie within the Mt Keith - Perseverance fault line but outside the current PEC boundaries. This task lies outside the scope of this assessment and is not required to establish the low impact on the PEC.

Given the above, and if the expanded area was to be considered as representing similar vegetation associations aligned with the intent of the Violet Ranges PEC, then the proportional impact of the MKS project on the PEC would be approximately halved to between 4% and 5%. However, the cumulative impacts of both the Leinster and Mt Keith Nickel mines would have to

be taken into consideration. This broadened analysis, incorporating a validation of the assertion of the increased area of the PEC, was not part of this scope of work required for the EIA of vegetation units under Guidance Statement 51, and has not been undertaken at this stage.

3.14. Statistical Validation of Vegetation Associations

The PATN statistical analysis, with interrogation and explanation of outputs, supports the majority of Vegetation Associations described within the MKS Proposal Study Area. Ordination of the MKS quadrat and Releve data returned a stress value of 0.2463, which is considered high, and is due to complexity of vegetation within a relatively small area. This stress is higher than the preferred value of 0.2000. This reflects the level of complexity of the vegetation units within the Proposal Study Area and demonstrates a comprehensive level of survey. The vast majority of quadrats grouped well with one outlier Releve (a disturbed site) containing two species, Figure 13.

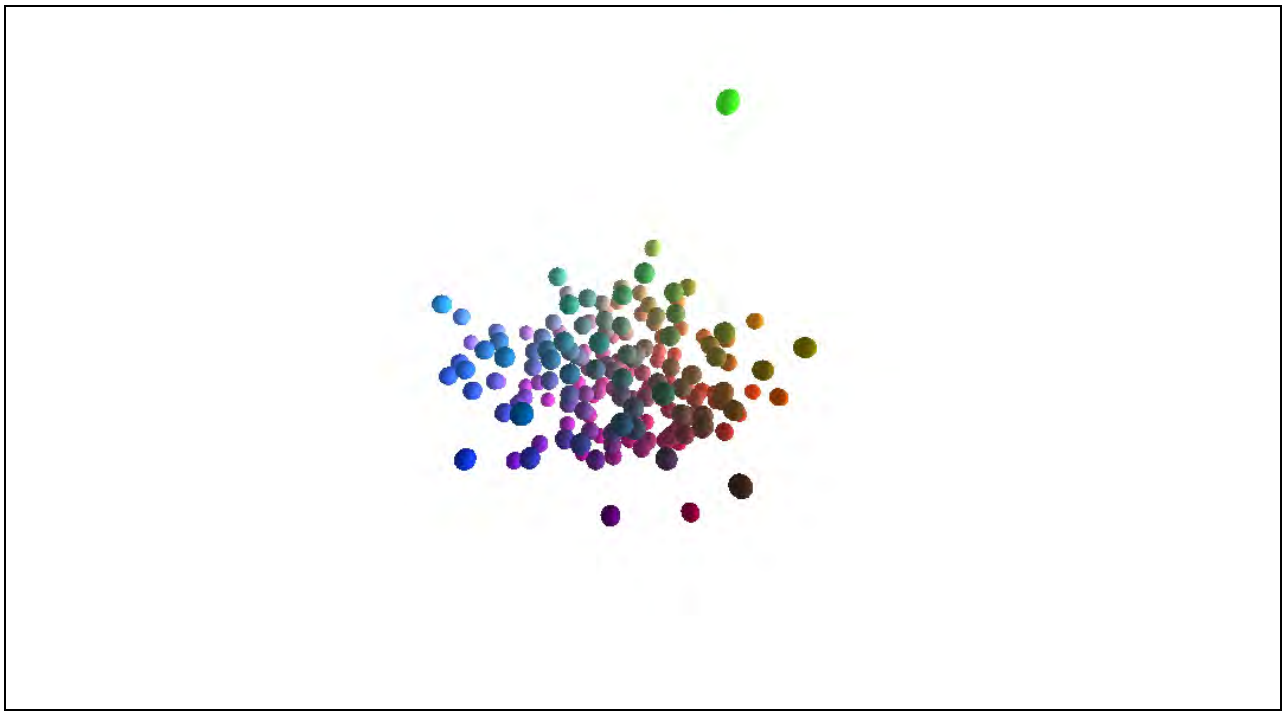


Figure 13. Three-dimensional display of the ordination result of MKS quadrats showing a main cluster of quadrats colour coded by relationship, and a small number of outlier quadrats.

Classification produced a dendrogram, Figure 14, containing groupings of most similar quadrats into branches typically denoting fine-scale local vegetation units.

In preparing data for analysis, the following was undertaken:

- Weeds and annuals were excluded.
- Singletons (taxa only occurring at one site) were excluded.
- Indeterminate species were excluded to avoid false-grouping. E.g. two *Maireana* sp. Indet. specimens may or may not be the same taxa.

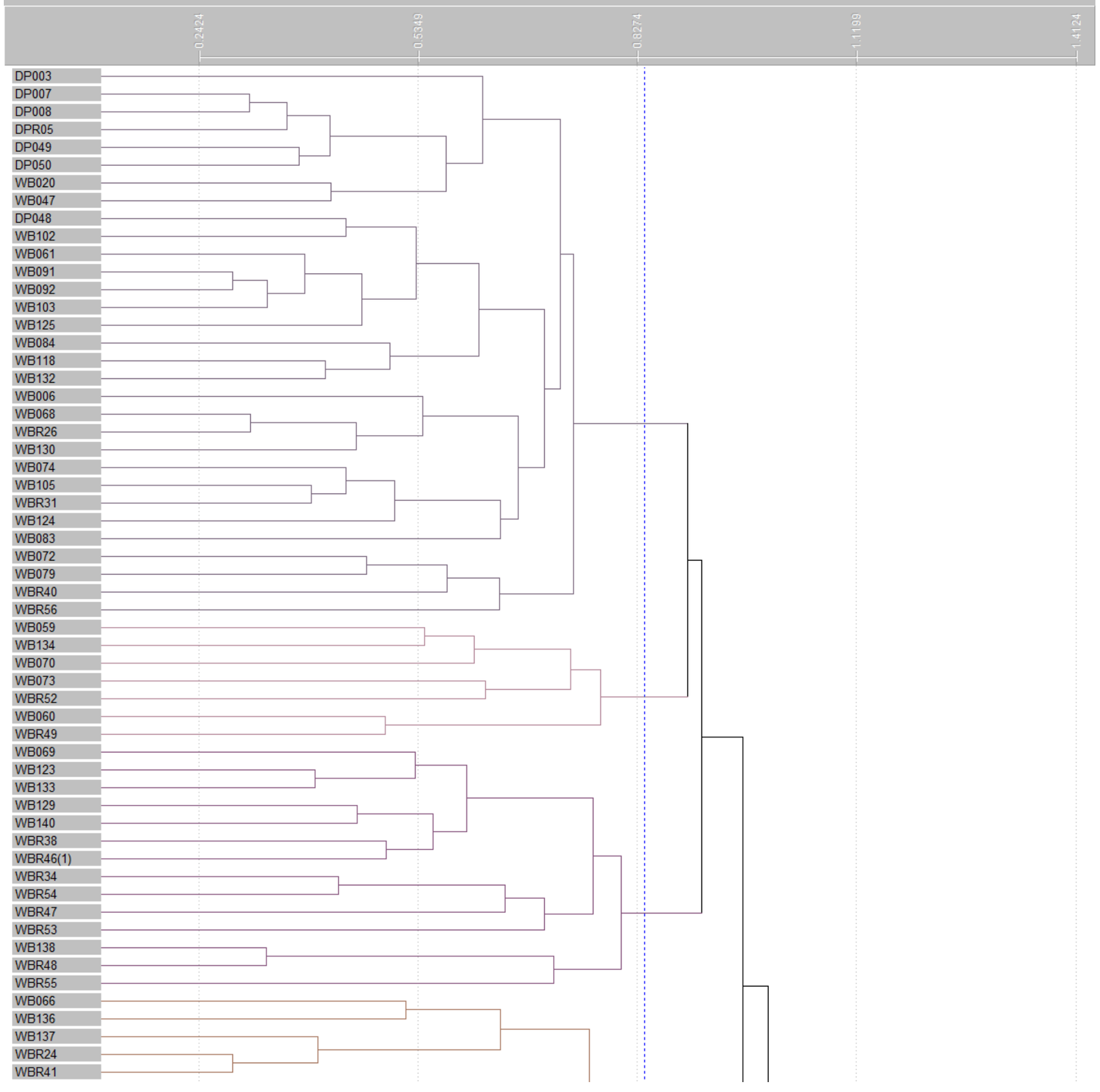
- Mulga varieties within the analysis were treated as per Maslin & Reid (2012). Putative hybrids were lumped into the taxa that they were most related to (the first element of a hybrid listing).

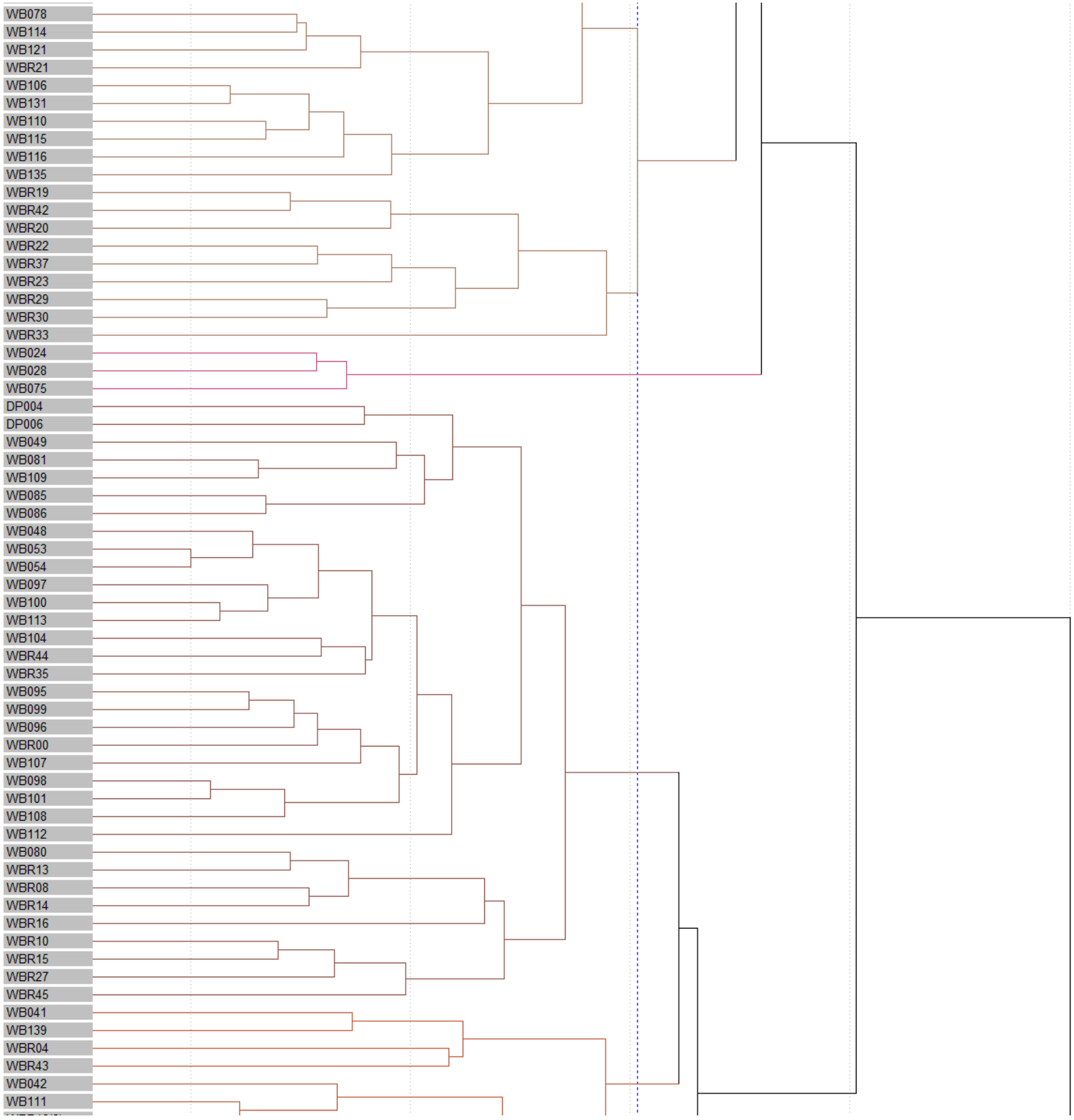
Some notable 'lumpings' of taxa were:

- *Eriachne mucronata* forms - high number of records did not specify which form.
- *Ptilotus obovatus* forms (Typical Goldfields form vs. Upright form) – a high number of records did not specify which form.
- *Scaevola spinescens* forms - high number of records did not specify which form.
- *Eremophila spectabilis* (no subsp.), 1 record, merged into *Eremophila spectabilis* subsp. *brevis*.
- *Maireana planifolia* (typical), 1 record, merged into *Maireana planifolia* (long leaf form).
- *Sida fibulifera* and *Sida* sp. verrucose glands (F.H. Mollemans 2423) - these were often confused during fieldwork (due to poor plant material and dry seasonal conditions) and could not be separated in the data.

Figure 14. Dendrogram showing similarity/dissimilarity of floral composition of the MKS Proposal Study Area.

Row Fusion Dendrogram




WB078
WB114
WB121
WBR21
WB106
WB131
WB110
WB115
WB116
WB135
WBR19
WBR42
WBR20
WBR22
WBR37
WBR23
WBR29
WBR30
WBR33
WB024
WB028
WB075
DP004
DP006
WB049
WB081
WB109
WB085
WB086
WB048
WB053
WB054
WB097
WB100
WB113
WB104
WBR44
WBR35
WB095
WB099
WB096
WBR00
WB107
WB098
WB101
WB108
WB112
WB080
WBR13
WBR08
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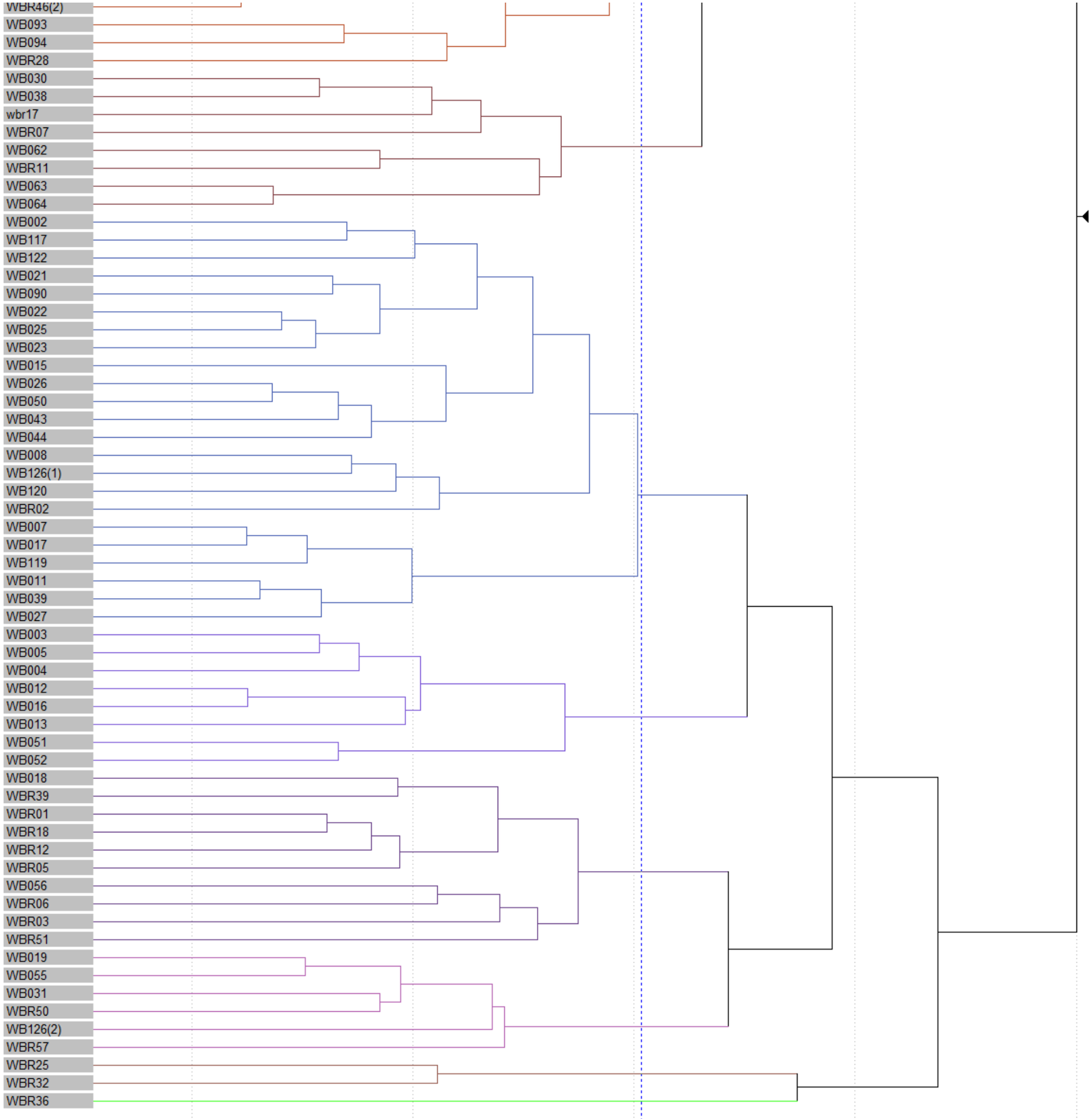
WBR15
WBR27
WBR45
WB041
WB139
WBR04
WBR43
WB042
WB111


WBR46(2)
WB093
WB094
WBR28
WB030
WB038
wbr17
WBR07
WB062
WBR11
WB063
WB064
WB002
WB117
WB122
WB021
WB090
WB022
WB025
WB023
WB015
WB026
WB050
WB043
WB044
WB008
WB126(1)
WB120
WBR02
WB007
WB017
WB119
WB011
WB039
WB027
WB003
WB005
WB004
WB012
WB016
WB013
WB051
WB052
WB018
WBR39
WBR01
WBR18
WBR12
WBR05
WB056
WBR06
WBR03
WBR51
WB019
WB055
WB031
WBR50
WB126(2)
WBR57
WBR25
WBR32
WBR36

Comments on the results of the PATN analysis is presented in Table 10.

Table 10. Comments on the PATN Classification Dendrogram.

Unit	PATN Grouping	Comments
SIMS	Poor	Six sites grouped well into a Minor Branch mostly composed of the DPaW sites. Four sites grouped within a branch related to the secondary GRMS grouping. The remaining 17 sites dispersed throughout the dendrogram. This shows that the SIMS community as mapped is heterogeneous and variable.
MMS	Poor	MMS sites split into two locations on the dendrogram. Four sites formed a Minor Branch, allied to the DRMS branch. The other five sites occurred within the Chenopod Major Branch but mostly separate from each other. This shows that the MMS community, a colluvial community downslope of SIMS, is heterogeneous and variable.
DRMS	Excellent	Three of five sites grouped together within one Minor Sub Branch. The two other sites are validly DRMS but moved elsewhere due to sharing some species of nearby vegetation (commonly occurs with long narrow drainage polygons).
DRES	Perfect	All three sites grouped perfectly as one of the 14 Major Branches.
SAMU	Excellent	All five sites grouped together within one Minor Sub Branch.
SAMA	-	One quadrat. Paired with the single SAWS site as a related branch to SAMU grouping. SAMA, SAWS and SAMU communities are closely allied.
SAWS	-	One quadrat. Paired with the single SAMA site as a related branch to SAMU grouping. SAMA, SAWS and SAMU communities are closely allied.
SAES	Poor	No coherent grouping within the analysis. But retained as a mapped unit due to dominance of *Eremophila galeata* common to SAES sites. High species variability dispersed SAES sites across multiple dendrogram branches. Appears that the SAES community, which is readily noted in the field, is strongly influenced by adjacent communities, with species leakage across margins, making statistical validation of the community difficult.
BaAbS	Excellent	Three of four sites grouped together within a separate Minor Sub Branch. The remaining site is an extreme outlier (forming a Major Branch on its own) that can be validly lumped with other BaAbS sites due to *Acacia* aff. *doreta* being the most dominant species. These sites are strongly influenced by the underlying basalt geology.
BaAdS	Excellent	Three of four sites grouped together within one Minor Sub Branch due to presence of *Acacia* aff. *doreta.* Related to both the BaAbS and BaAxS branches. These sites are strongly influenced by the underlying basalt geology.
BaAxS	Good	Four of eight sites fell within a separate Minor Sub Branch. The other four sites are all within the same outlier branch of relevés that would likely group with the other BaAxS sites if they were quadrats.
BaCdS	Good	Two of the three sites grouped together as one Major Branch. The third site fell as an outlier within the BaAxS grouping due to presence of *Acacia* aff. *xanthocarpa*, but can validly be pulled back in with the two BaCdS sites due to a clear dominance of *Calytrix desolata*. These sites are strongly influenced by the underlying basalt geology.
BrCP	-	One releve site, an outlier to the Major Group containing BaCdS, BaAbs, and BaAxS. Additional sites would likely form a separate dendrogram branch. However, PATN based this assessment on the dominance of two annual species, *Aristida contorta* and *Ptilotus*

Unit	PATN Grouping	Comments
		helipteroides, neither of which are habitat specific and both of which are generalists. The grouping is considered an artefact of the sampling density and the statistical analysis and does not represent a true pattern in the environment.
Qtz	Poor	Two sites that did not pair in analysis, due to low number of Qtz sites and small being small polygons showing a relation to neighbouring polygons. Could be incorporated into vegetation associations surrounding each site.
HPMS	Average	HPMS split to two distant locations on the dendrogram. The primary group consists of six HPMS sites forming a majority of a Major Branch along with four disparate sites (two of which are drainage that have characters of HPMS). The secondary group consists of four HPMS sites allied with GRMU sites due to the presence/dominance of *Acacia ramulosa* subsp. *ramulosa*.
HPMS Thoma	Good	The two HPMS Thoma sites paired within the secondary grouping of HPMS sites, related to GRMU due to dominance of *Acacia ramulosa* subsp. *ramulosa*. The presence of *Acacia thoma* may not warrant separation of this as a community.
HMCS	Good	Two of three sites paired as a relative of the primary HPMS branch. The third site occurred within the primary HPMS branch but is retained as HMCS due to dominance of *Maireana pyramidata* in the understorey.
GRMU	Average	Two of three sites grouped with the secondary grouping of HPMS sites. The third GRMU site grouped strongly within a branch of seven GRMS sites, and may best be labelled as GRMS.
GRMS	Average	GRMS split into two distant locations on the dendrogram. The primary group consists entirely of seven GRMS (one labelled GRMU), all lying within its own Major Group. The secondary group consists of five GRMS sites mixed with four disparate SIMS sites, all lying within its own Major Group. Though separate, both branches share primary dominant species (further exploration would likely bring these two branches together).
BrGP	Poor	Two sites separate but both within the primary grouping of HPMS branch. This unit may be a part of HPMS, but may also pull together with additional BrGP added to the analysis. HPMS and BRGP are similar in structure but differ markedly in soil, landscape position and underlying geology. HPMS may have a range of annual grasses present while BrGP has a marked dominance of *Aristida contorta* in the understorey with few other annual grass species.
BrCP - TectS	Perfect	Four sites (two labelled as TECT) all containing *Tecticornia disarticulata* grouped perfectly as one Minor Branch, related to both BrCP-FRAN and the secondary grouping USBS branch. The BrCP – TectS and BrCP-FRAN communities co-occur as a complex.
BrCP-FRAN	Perfect	All three sites grouped perfectly within one Minor Branch by presence of two *Frankenia* species. This group is closely related to the secondary grouping of the USBS sites which is separate due to presence of Cratystylis subspinescens. BrCP-FRAN and BrCP-Tect often co-occur as a complex.

Unit	PATN Grouping	Comments
USBS	Average	USBS split to two separate locations on the dendrogram. The primary grouping is of five USBS sites together with four non-USBS sites within the Chenopod Major Group. Three USBS Releve sites grouped within a related outlier releve branch and would likely join the primary grouping if they were quadrats. The secondary USBS group consisting of three sites fell together due to presence of *Cratystylis subspinescens*. This secondary USBS group forms half of the *Maireana* Major Group and is related to the BCP-Fran branch. All are saline sites.
EGPW	Perfect	All three sites grouped together well (with one within one unlabelled site) by the presence of *Eucalyptus gypsophila*. Related to the GHPS branch.
GHPS	Average	GHPS sites split to two separate locations on the dendrogram. Both separate groupings are dominated by *Eremophila pantonii*. Four sites grouped due to *Hakea leucoptera* subsp. *sericipes* which is always present within the GHPS but may have lain outside quadrats established. Three other sites grouped with GRMU sites due to *Acacia ramulosa* subsp. *ramulosa*. GHPS and SSS almost always co-occur and are adjacent to each other with much in common.
SSS	Poor	Four SSS sites grouped within a Minor Sub Branch (along with WBR00) and are related to the secondary GHPS grouping. Two more SSS sites appear within an outlier releve branch and would likely join the other SSS sites if they were quadrats. Two SSS sites joined into the primary USBS grouping and may belong there. GHPS and SSS almost always co-occur and are adjacent to each other with much in common.
SILS	Perfect	All four sites grouped perfectly within one Minor Branch due to *Thryptomene* sp. Leinster and *Acacia quadrimarginea*. Part of the greater WABS/SMS Major Branch.
WABS	Good	All five sites grouped within a single Major Group, but split into two separate branches, separated by the closely related primary grouping of SMS sites.
SMS	Poor	SMS split into four locations on the dendrogram. The primary group consists of a branch of four SMS sites separating the two WABS branches. The remaining five sites are within three different Major Branches.
BrX-FOL	Poor	One site was an outlier to the BrX-P Major Branch, one site an outlier to the secondary GRMS grouping branch, a third site forms part of the BrCP-TectS branch.
BrX-P	Good	All 3 BrX-P sites grouped into a single Major Branch with a small number of disparate sites by the presence of *Thryptomene* sp. Leinster and *Calytrix uncinata*.

4. Assessment against the 10 Clearing Principles

Principle (a) – Native vegetation should not be cleared if it comprises a high level of biological diversity.

The MKS Proposal Study Area, inclusive of the proposed haul road to Mt Keith and the MKS Development Footprint on Yakabindie Station, is known to support 393 endemic flora species within 38 Vegetation Associations and two Vegetation Complexes. This is comparable to the species count known at Leinster where 402 endemic species were recorded in studies for WMC Resources. The range of species known within each of the Vegetation Associations at MKS ranges from between 6 and 36 species with a mean of 17 species per Vegetation Association and a standard deviation of 6. This is not considered to be either particularly diverse nor to represent a high degree of endemism for the region, and rather is representative of what may be commonly encountered in the eastern Murchison biogeographic region.

The MKS project is not at variance with this principle.

Principle (b) – Native vegetation should not be cleared if it comprises the whole or a part of, or is necessary for the maintenance of, a significant habitat for fauna indigenous to Western Australia.

While the vegetation of the MKS Proposal Study Area plays a role in providing fauna habitat, none of the Vegetation Associations that are significantly impacted in development of the MKS Project are known to provide habitat critical to the maintenance of fauna species.

The proposed development has been designed to minimize impacts to the eucalypt dominated ephemeral drainage line of Jones Creek which is considered to be the most significant of habitats from a fauna utilization and refuge perspective, in the Proposal Study Area.

The MKS project is not at variance with this principle.

Principle (c) – Native vegetation should not be cleared if it includes, or is necessary for the continued existence of, rare flora.

No Threatened (Declared Rare) flora are known within the MKS Proposal Study Area. Twelve Priority flora are known within the MKS Proposal Study Area (one P1, eight P3 and three P4 species).

The MKS project is therefore not at variance with this principle.

The majority of species known from the overall MKS Proposal Study Area are both common and widespread in the eastern Murchison, western Gt. Victoria Desert biogeographic regions. The MKS Proposal Study Area supports 12 Priority Flora species (one P1, eight P3 and three P4 species). The project has been designed to minimize impacts on Priority Flora and development

of the MKS project will not result in an upgrading of the Conservation Statius of any of these Priority Flora species.

A further eight species which represent undescribed flora that do not as yet appear on the Census of Vascular Flora for Western Australia are known from within the MKS Proposal Study Area. These are species that are widely distributed in the eastern Murchison Biogeographic Region and are known cases of inadequate taxonomy. These species neither have, nor require, conservation focus. One species represents an undescribed taxon with relatively limited range in the Lake Way and Lake Maitland catchments near Wiluna. It also is regarded as being relatively common within it's known range and may not require conservation focus. The MKS development impacts on a negligible proportion of the overall known population this species.

A further group of six (to seven) undescribed species require taxonomic clarification by expert taxonomists. The MKS Project does not impact on the majority of these undescribed taxa. Exceptions to this are (i) *Acacia* sp. East Murchison Basalt (G Cockerton 38064) (flat phyllode, non-hairy resinous pod form), which occurs within the footprint of the proposed waste rock landform; and (ii) *Hibbertia* aff. *exasperata* (G Cockerton & G. O'Keefe 11911), which occurs on a low granite breakaway system within the proposed transport corridor. Both are poorly known species with the majority of their known occurrences within the MKS Proposal Study Area and within the proposed MKS Disturbance Envelope. The conservation status of these two poorly known species has not been assessed.

Principle (d) – Native vegetation should not be cleared if it comprises the whole or a part of, or is necessary for the maintenance of, a threatened ecological community.

No Threatened Ecological Community (TEC) is known within the MKS Proposal Study Area. The MKS Proposal Study Area does lies approximately centrally within the *Violet Ranges (Perseverance Greenstone Belt) vegetation complexes (banded ironstone formation)* Priority 1 Priority Ecological Community. The impacts to the mapped extent of this PEC by the MKS proposal is 8.04%. However, a review of the description and extent of this PEC is recommended to incorporate adjacent areas of similar geology, landform and vegetation. If so incorporated, the proportional impact to the expanded PEC would be approximately halved.

The project is not at variance with this principle.

Principle (e) – Native vegetation should not be cleared if it is significant as a remnant of native vegetation in an area that has been extensively cleared.

The region inclusive of the MKS Proposal Study Area has been subject to extensive pastoralism, some road infrastructure development and the development of numerous mining operations. Overall, on a regional scale within the eastern Murchison biogeographic region, clearing of land by these activities is small and the land has not been extensively cleared.

The project is not at variance with this principle.

Principle (f) – Native vegetation should not be cleared if it is growing in, or in association with, an environment associated with a watercourse or wetland.

While the MKS project is situated adjacent to the Jones Creek, an ephemeral eucalypt lined drainage channel, the development has been designed to minimize impacts on the Jones Creek and it's down-stream playa lake systems. Minimal direct impacts are unavoidable in the formation of one crossing across the creek bed.

The project is at variance with this principle, though to a minor extent.

Principle (g) – Native vegetation should not be cleared if the clearing of the vegetation is likely to cause appreciable land degradation.

Clearing of land for the development of the MSKO project will directly result in the clearing of 1242 ha of land. The boundaries of the MKS project will be managed to prevent disturbance outside the approved development envelope. Through careful design and management, there should be no appreciable land degradation outside the areas of direct clearing for development.

The project is not at variance with this principle.

Principle (h) – Native vegetation should not be cleared if the clearing of the vegetation is likely to have an impact on the environmental values of any adjacent or nearby conservation area.

The MKS development area lies adjacent to the western boundary of the Wanjarri Nature Reserve. No direct impacts to the Wanjarri Nature Reserve will occur. However, it is possible indirect impacts such as dust or aerosol saline water drift may not be fully contained within the development envelope.

The development of the MKS project may impact indirectly on the fauna utilization of the western margin of the Wanjarri Nature Reserve.

Principle (i) – Native vegetation should not be cleared if the clearing of the vegetation is likely to cause deterioration in the quality of surface or underground water.

Not Addressed here.

Principle (j) – Native vegetation should not be cleared if clearing the vegetation is likely to cause, or exacerbate, the incidence of flooding.

Not Addressed here.

5. Limitations

Scope and Time Available for Field Survey

There was adequate time available for field survey allowing a thorough traversing of the majority of the MKS Proposal Study Area. Conditions during the field surveys were favourable, though warm to hot, meaning the majority of fruits were ripening and plants were dehiscing seeds at the time of survey, and we are satisfied that the assessments conducted represent a thorough review of both the vegetation and flora of the MKS Proposal Study Area.

Timing of Surveys and implications for plant identifications and distributions of cryptic species.

The late 2016 survey conducted in late spring 2016 meaning most annuals were either seeding or senescent. Few species that, based on previous records, specifically required collection of flowering and/or fruiting material to address taxonomic issues were neither in flower or fruit. However, many perennial tree species were holding mature fruit, which enabled detailed taxonomic investigation and resolution of the *Acacia aneura* sens. lat. group into their species complexes as well as the collection of fruits of other *Acacia* species enabling a more detailed review of their taxonomic status.

Combined with the May 2016 site visit when many *Acacia* species were in flower and were specifically collected, the late Spring 2016 assessment allowed for the corresponding collection of fruiting material of these species. This will enable the taxonomic status of *Acacia* aff. *xanthocarpa*, *Acacia* sp. East Murchison Basalt, Acacia aff. *subtessarogona* and *Acacia* aff. *doreta* to be thoroughly assessed when the relevant specialist taxonomists are available.

Populations of the Priority 1 *Anacampseros* sp. Eremaean (F. Hort, J. Hort & J. Shanks 3248) are very difficult to assess as the plants are geophytic ephemerals. Timing is the key to effective survey and a very narrow window of opportunity exists following substantial rainfall events to assess this species. The records of *Anacampseros* sp. Eremaean are therefore considered indicative and it is highly likely more exist in both the local and broader region.

Cumulative Species Lists

Overall, the cumulative species list for the MKS Proposal Study Area is considered very extensive and well representative with a total of 393 species, varieties and 18 putative hybrids between varieties of Mulga. It compares with 102 species (excluding species level Mulga varieties) known from a limited area at Mt Keith (Landcare Services, 1997a) and 402 species (excluding species level Mulga varieties) known over an extensive area at Leinster (Landcare Services, 1997b). The extensive MKS species list, generated over many on-ground assessments over numerous years of field survey, is considered highly representative and is therefore not considered a limitation.

Violet Range Priority Ecological Community

The scope allowed for a cursory review of some of the landforms, and vegetation south of the MKS Proposal Study Area within the southern extents of the currently mapped Violet Range PEC. The limited availability of well formed tracks and rough terrain meant that only a few tracks could be traversed safely in the time available. The discussion of the Violet Range PEC outside the MKS Proposal Study Area presented within this document is therefore considered only a reconnaissance level assessment at this stage.

The definition and extents of the Violet Range PEC warrant revision to reflect on-ground observations, however, this lies outside the scope of this assessment.

Taxonomy

The tenuous state of the taxonomy of many flora groups raises numerous queries as to the actual taxonomic status of some species. For example, *Olearia* sp. Sherwood Breakaways (currently included within *Olearia stuartii*) and *Olearia xerophila* sens. lat. are two good examples of where species have highly disjunct distributions across the Australian continental land mass, where TYPE specimens have been collected in either Queensland or New South Wales and yet the species in Western Australia are currently considered the same as those in the eastern states. In reality, this is highly improbable and preliminary evidence suggests that the Western Australian taxa are new species. However, until the taxonomy of these groups is definitively reviewed, there will remain doubt over species relationships and therefore inaccurate conservation assessment of the species in question.

Regional Context for Priority Flora Species

No opportunity existed to gather regional context for Priority Flora or Species of Interest in this assessment other than through desktop reviews and reconnaissance surveys.

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- Dr. Steven Dillon (2016, 2017), Western Australian Herbarium, for review of *Olearia* specimens.

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8. List of Participants

Title	Personnel, Role
Project Manager and Senior Botanist	Geoff Cockerton, Field survey, reporting
Senior Botanists	Jono Warden, Field survey, reporting Ben Eckermann, Field survey Daniel Brassington, Field survey, reporting Dr. David Leach – Statistical analyses, reporting
Field Assistants	Sarah Smith, Field survey Steven Cockerton, Field survey

Appendix 1. Systematic Species List

Family	Species Name	Cons Status	Notes	Prior Record	2016 Collection
Acanthaceae	*Harnieria kempeana* subsp. *muelleri*			1	1
Aizoaceae	*Gunniopsis propinqua*	PRIORITY 3			1
Aizoaceae	*Gunniopsis septifraga*				1
Aizoaceae	*Gunniopsis* sp. 5 carpels				1
Aizoaceae	*Mesembryanthemum nodiflorum* *		Weed		1
Amaranthaceae	*Alternanthera nodiflora*			1	
Amaranthaceae	*Ptilotus aervoides*			1	
Amaranthaceae	*Ptilotus astrolasius*				1
Amaranthaceae	*Ptilotus gaudichaudii* subsp. *gaudichaudii*			1	
Amaranthaceae	*Ptilotus helipteroides*			1	1
Amaranthaceae	*Ptilotus nobilis*		Inclusive of *P. exaltatus*	1	1
Amaranthaceae	*Ptilotus obovatus* (typical Goldfields form) (G. Cockerton, G. Grehan, L. Trotter, J. Symington 15213)		Undescribed, Common and Widespread	1	1
Amaranthaceae	*Ptilotus obovatus* (upright form) (Cockerton G.; Grehan, J.; Trotter, L.; Symington, J. LCH 15209)		Undescribed, Common and Widespread		1
Amaranthaceae	*Ptilotus polystachyus*			1	1
Amaranthaceae	*Ptilotus roei*			1	1
Amaranthaceae	*Ptilotus schwartzii*			1	1
Apocynaceae	*Marsdenia australis*			1	1
Apocynaceae	*Rhyncharrhena linearis*			1	1
Asparagaceae	*Thysanotus manglesianus*				1
Asteraceae	*Actinobole uliginosum*			1	
Asteraceae	*Angianthus* sp. Indeterminate				1
Asteraceae	*Angianthus tomentosus*			1	
Asteraceae	*Bidens bipinnata* *		Weed		1
Asteraceae	*Brachyscome ciliaris*			1	
Asteraceae	*Brachyscome ciliocarpa*			1	
Asteraceae	*Brachyscome iberidifolia*			1	
Asteraceae	*Brachyscome* sp. (indeterminate)				1
Asteraceae	*Calocephalus multiflorus*				1
Asteraceae	*Calotis hispidula*				1
Asteraceae	*Calotis multicaulis*				1
Asteraceae	*Cephalipterum drummondii*			1	1
Asteraceae	*Chrysocephalum puteale*				1
Asteraceae	*Cratystylis subspinescens*			1	1
Asteraceae	*Erymophyllum ramosum*			1	1
Asteraceae	*Gnephosis arachnoidea*			1	1
Asteraceae	*Gnephosis tenuissima*				1
Asteraceae	*Helipterum craspedioides*			1	1
Asteraceae	*Myriocephalus rudallii*			1	

Family	Species Name	Cons Status	Notes	Prior Record	2016 Collection
Asteraceae	*Olearia xerophila sens. lat.*		Undescribed, new species, Range Extension, Widespread in Pilbara WA	1	
Asteraceae	*Olearia* sp. Sherwood Breakaways (A. Taylor WB25552)		Undescribed, Widespread	1	1
Asteraceae	*Pluchea dentex*			1	1
Asteraceae	*Podolepis capillaris*			1	1
Asteraceae	*Podolepis eremaea*		Some records previously reported as *P. canescens*	1	
Asteraceae	*Rhodanthe charsleyae*			1	1
Asteraceae	*Rhodanthe chlorocephala* subsp. *splendida*				1
Asteraceae	*Rhodanthe maryonii*			1	
Asteraceae	*Roebuckiella ciliocarpa*		Previously reported as *Brachyscome ciliocarpa*	1	
Asteraceae	*Senecio magnificus*			1	
Asteraceae	*Streptoglossa liatroides*			1	1
Asteraceae	*Vittadinia sulcata*				1
Boraginaceae	*Trichodesma zeylanicum*			1	1
Brassicaceae	*Lepidium phlebopetalum*				1
Brassicaceae	*Lepidium platypetalum*			1	1
Brassicaceae	*Menkea sphaerocarpa*			1	
Campanulaceae	*Isotoma petraea*			1	
Campanulaceae	*Lobelia heterophylla*				1
Campanulaceae	*Wahlenbergia tumidifructa*				1
Casuarinaceae	*Casuarina pauper*			1	1
Celastraceae	*Stackhousia muricata* subsp. Annual (W.R. Barker 2172)		Undescribed, Common and Widespread	1	
Celastraceae	*Stackhousia* sp. Mt Keith (G. Cockerton & G. O'Keefe 11017)		Undescribed, Common and Widespread	1	1
Chenopodiaceae	*Atriplex codonocarpa*			1	1
Chenopodiaceae	*Atriplex quinii*			1	1
Chenopodiaceae	*Atriplex semilunaris*				1
Chenopodiaceae	*Dysphania glomulifera*		Likely subsp. *eremaea*	1	
Chenopodiaceae	*Dysphania kalpari*			1	
Chenopodiaceae	*Dysphania melanocarpa*			1	
Chenopodiaceae	*Dysphania rhadinostachya*		Likely subsp. *rhadinostachya*	1	1
Chenopodiaceae	*Dysphania rhadinostachya* subsp. *rhadinostachya*				1
Chenopodiaceae	*Enchylaena lanata*				1

Family	Species Name	Cons Status	Notes	Prior Record	2016 Collection
Chenopodiaceae	*Enchylaena tomentosa*			1	
Chenopodiaceae	*Eriochiton sclerolaenoides*				1
Chenopodiaceae	*Maireana carnosa*			1	1
Chenopodiaceae	*Maireana convexa*				1
Chenopodiaceae	*Maireana gardneri*				1
Chenopodiaceae	*Maireana georgei*			1	1
Chenopodiaceae	*Maireana georgei* x *Enchylaena tomentosa* (hybrid)				1
Chenopodiaceae	*Maireana glomerifolia*			1	1
Chenopodiaceae	*Maireana melanocoma*		Range Extension		1
Chenopodiaceae	*Maireana planifolia*		Some records previously reported as *M. radiata*	1	1
Chenopodiaceae	*Maireana planifolia* (long leaf form)				1
Chenopodiaceae	*Maireana pyramidata*			1	1
Chenopodiaceae	*Maireana radiata*				1
Chenopodiaceae	*Maireana thesioides*			1	1
Chenopodiaceae	*Maireana tomentosa* (indeterminate subspecies)			1	1
Chenopodiaceae	*Maireana tomentosa* subsp. *tomentosa*				1
Chenopodiaceae	*Maireana tomentosa* Type 1 Breakaway footslopes (G. Cockerton & D. Brassington WB38650)		Undescribed		1
Chenopodiaceae	*Maireana trichoptera*				1
Chenopodiaceae	*Maireana triptera*			1	1
Chenopodiaceae	*Maireana villosa*		Some records previously reported as *M. radiata*	1	
Chenopodiaceae	*Rhagodia drummondii*			1	1
Chenopodiaceae	*Salsola australis*		some previous records as *S. tragus*	1	1
Chenopodiaceae	*Sclerolaena convexula*				1
Chenopodiaceae	*Sclerolaena cornishiana*			1	
Chenopodiaceae	*Sclerolaena cuneata*			1	1
Chenopodiaceae	*Sclerolaena densiflora*				1
Chenopodiaceae	*Sclerolaena deserticola*			1	
Chenopodiaceae	*Sclerolaena diacantha*			1	1
Chenopodiaceae	*Sclerolaena eriacantha*			1	1
Chenopodiaceae	*Sclerolaena fusiformis*				1
Chenopodiaceae	*Sclerolaena gardneri*		Some previous records as *S. aff. eriacantha*	1	1
Chenopodiaceae	*Sclerolaena lanicuspis*			1	1
Chenopodiaceae	*Sclerolaena lanicuspis* (5 spine variant)				1

Family	Species Name	Cons Status	Notes	Prior Record	2016 Collection
Chenopodiaceae	*Sclerolaena obliquicuspis*				1
Chenopodiaceae	*Sclerolaena patenticuspis*				1
Chenopodiaceae	*Tecticornia disarticulata*			1	1
Colchicaceae	*Wurmbea deserticola*			1	
Colchicaceae	*Wurmbea tenella*				1
Convolvulaceae	*Bonamia erecta*		Previous records as *B. rosea*	1	
Convolvulaceae	*Cuscuta planiflora*				1
Convolvulaceae	*Duperreya commixta*				1
Convolvulaceae	*Duperreya sericea*			1	1
Crassulaceae	*Crassula colorata* var. *acuminata*				1
Cupressaceae	*Callitris columellaris*			1	1
Cyperaceae	*Bulbostylis barbata*			1	
Cyperaceae	*Cyperus centralis*			1	1
Cyperaceae	*Cyperus iria*			1	
Dilleniaceae	*Hibbertia* aff. *exasperata* (G. Cockerton & G. O'Keefe 11911)		Undescribed	1	1
Euphorbiaceae	*Euphorbia boophthona*			1	
Euphorbiaceae	*Euphorbia drummondii*			1	1
Fabaceae	*Acacia* aff. *doreta* (G. Cockerton & S. Cockerton WB38633)		Undescribed, Previously reported as A. grasbyi	1	1
Fabaceae	*Acacia* aff. *subtessarogona* flat pod form (G. Cockerton WB38658)		Undescribed. Previously reported as Acacia cuthbertsonii	1	1
Fabaceae	*Acacia aneura*			1	1
Fabaceae	*Acacia aneura* (hybrid)				1
Fabaceae	*Acacia aneura* sens. lat.		Mulga complex		1
Fabaceae	*Acacia aptaneura*				1
Fabaceae	*Acacia aptaneura* x (hybrid)				1
Fabaceae	*Acacia aptaneura* x *mulganeura* (hybrid)				1
Fabaceae	*Acacia ayersiana*			1	
Fabaceae	*Acacia ayersiana* (narrow phyllode variant)				1
Fabaceae	*Acacia brachystachya*		Range Extension		1
Fabaceae	*Acacia burkittii*			1	1
Fabaceae	*Acacia caesaneura*				1
Fabaceae	*Acacia caesaneura* (hybrid)				1
Fabaceae	*Acacia caesaneura* (narrow phyllode variant)				1
Fabaceae	*Acacia colletioides*			1	
Fabaceae	*Acacia craspedocarpa*			1	1
Fabaceae	*Acacia craspedocarpa* (ovate phyllode variant, hybrid)				1

Family	Species Name	Cons Status	Notes	Prior Record	2016 Collection
Fabaceae	*Acacia effusifolia*		Previously *A. coolgardiensis* subsp. *effusa*	1	1
Fabaceae	*Acacia fuscaneura*				1
Fabaceae	*Acacia fuscaneura* x				1
Fabaceae	*Acacia fuscaneura* x *pteraneura*				1
Fabaceae	*Acacia incurvaneura*				1
Fabaceae	*Acacia incurvaneura* (hybrid)				1
Fabaceae	*Acacia incurvaneura* x *mulganeura*				1
Fabaceae	*Acacia incurvaneura* x *pteraneura*				1
Fabaceae	*Acacia jamesiana*			1	
Fabaceae	*Acacia kempeana*			1	1
Fabaceae	*Acacia macraneura*				1
Fabaceae	*Acacia macraneura* (hybrid)				1
Fabaceae	*Acacia macraneura* x *aneura*				1
Fabaceae	*Acacia macraneura* x *aptaneura*				1
Fabaceae	*Acacia minyura*			1	1
Fabaceae	*Acacia mulganeura*				1
Fabaceae	*Acacia mulganeura* (hybrid)				1
Fabaceae	*Acacia mulganeura* x *caesaneura*				1
Fabaceae	*Acacia oswaldii*			1	1
Fabaceae	*Acacia oswaldii* (long phyllode form) (G. Cockerton & S. Cockerton WB38622)		Undescribed, Common and Widespread. Previously reported as A. oswaldii		1
Fabaceae	*Acacia pachyacra*			1	
Fabaceae	*Acacia paraneura*				1
Fabaceae	*Acacia pruinocarpa*			1	1
Fabaceae	*Acacia pteraneura*				1
Fabaceae	*Acacia pteraneura* (narrow pod variant)				1
Fabaceae	*Acacia quadrimarginea*			1	1
Fabaceae	*Acacia ramulosa* var. *linophylla*			1	1
Fabaceae	*Acacia ramulosa* var. *ramulosa*			1	
Fabaceae	*Acacia rhodophloia*			1	1
Fabaceae	*Acacia* sp. aff. xanthocarpa TYPE 1 (subterete leaf, one red vein, G. Cockerton & S. Cockerton WB38615)		Undescribed, some previous records as *A. xanthocarpa*	1	1
Fabaceae	*Acacia* sp. East Murchison Basalt TYPE 2 (flat leaf, two red veins, hairy pods) (G Cockerton WB38638)		Undescribed		1
Fabaceae	*Acacia* sp. East Murchison Basalt Type 3 (narrow flat leaf, two red veins, glabrous pods (G. Cockerton & S. Cockerton		Undescribed	1	1