SULPHUR SPRINGS ZINC-COPPER PROJECT

EPA REFERRAL SUPPORTING DOCUMENT

PREPARED FOR:

VENTUREX RESOURCES LIMITED

DECEMBER 2016

PREPARED BY:

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Distribution List:

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Venturex Resources Limited	John Nitschke, Managing Director James Pollock, Project Manager Emma Bamforth, Sustainability Coordinator	[01]	9 December 2016

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First Draft Report	Karen Ganza	Lucy Sands	27 October 2016
Second Draft Report	Karen Ganza	Lucy Sands	24 November 2016
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Final Report	Karen Ganza	Lucy Sands	9 December 2016

EXECUTIVE SUMMARY

The Sulphur Springs Zinc-Copper Project (Sulphur Springs) is located approximately 144 km southeast of Port Hedland and 57 km west of Marble Bar (by road) in the Pilbara Region of Western Australia. Venturex Resources Limited (Venturex) owns this project; Venturex acquired the project tenements from CBH Sulphur Springs Pty Ltd (CBH) in 2011.

In 2013 Venturex submitted a Mining Proposal for a 1.0 Mtpa underground mine, 1.0 Mtpa processing plant and dry stack tailings storage facility (TSF) to the Department of Mines and Petroleum (DMP). The DMP consulted with the Office of the Environmental Protection Authority (OEPA) during the assessment of this Mining Proposal and the project was approved by the DMP in April 2014 (REG ID 40542). No activities approved under this Mining Proposal (and associated clearing permit CPS 5658/1) have been carried out to date.

During 2015 and 2016 Venturex investigated mining and processing options for the project and identified a number of opportunities that would improve its financial viability. Venturex now wishes to progress Sulphur Springs as follows:

- Develop an open pit to mine the top portion of the orebody.
- Develop a 1.5 Mtpa underground mine (accessed via a portal within the pit) to mine the remainder of the orebody.
- Construct a 1.5 Mtpa conventional processing plant which will produce separate copper and zinc concentrates for sale.
- Store tailings in a 'valley fill' Tailings Storage Facility (TSF) with a combined High Density Polyethylene (HDPE) and compacted low permeability sub-base liner.
- Construct a copper heap leach facility within the same valley storage area as the TSF. The heap leach pad design includes a combined HDPE and compacted low permeability sub-base liner. The HDPE liner will be welded to the TSF liner to form a continuous liner under the entire heap leach / TSF facility area.
- Construct a copper Solvent Extraction & Electrowinning Plant (SX-EW) adjacent to the processing plant.
- Construct a permanent waste rock dump (WRD).
- Construct additional supporting elements such as internal roads, material stockpiles, surface water management, accommodation village and power station.

Primary infrastructure such as the processing plant, underground mine, site access road and accommodation village remain similar to that approved under Mining Proposal REG ID 40542. Key changes to existing approvals include development of an open pit, storage of tailings in a dual lined 'valley fill' TSF and construction of a copper heap leach, solvent extraction and electrowinning facility. Combined project elements will require a total land disturbance of approximately 321.9 ha within a Development Envelope of 848.3 ha. This represents an additional 128.9 ha to that approved under the previous mining proposal and clearing permits for the project area.

This document has been prepared to inform and assist in determining the appropriate environmental assessment and approval pathway for Sulphur Springs under Part IV of the *Environmental Protection Act 1986 (EP Act).* A large number of baseline and environmental impact studies conducted over the past 14 years by Venturex and previous tenement holders have contributed significantly to the scientific understanding of the area and allowed Venturex to design the proposed changes in a way that identifies, prevents and minimises adverse environmental impacts.

Preliminary assessment of the proposed changes has identified the following preliminary environmental factors as being relevant:

- Flora and Vegetation.
- Terrestrial Fauna.
- Rehabilitation and Decommissioning.

With respect to Flora and Vegetation, the project has been designed so that the proposed changes do not impact on any known locations of the Threatened (Declared Rare Flora) *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4). This will be confirmed by a Targeted survey during detailed design. With respect to Terrestrial Fauna, the project has been designed so that the proposed changes have minimal impact on potential habitat for the State and Federally listed Endangered Northern Quoll (*Dasyurus hallucatus)*. Venturex believes that through the implementation of management plans for both these species it can meet the EPA objectives for the key factors of Flora and Vegetation and Terrestrial Fauna.

Rehabilitation and decommissioning of the project will, as a minimum, use accepted industry practices and will be managed in accordance with the Mine Closure Plan Guidelines jointly published by the EPA and DMP. Venturex will also trial technologies as they emerge that might help to mitigate the long term environmental impacts of the project. In addition, designs for the WRD and a TSF/heap leach facility with a combined HDPE and compacted low permeability sub-base liner have incorporated key learnings from other such facilities within Western Australia and internationally, ensuring an industry best practice approach to the construction, operation, rehabilitation and long term stability of these mine waste structures.

Venturex believes the risk for each of these factors can be adequately assessed and implementation monitored through provisions of the *Mining Act* and Part V provisions of the *EP Act*. Venturex therefore believes that formal assessment of Sulphur Springs is not required under Part IV of the *EP Act*.

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1. INTRODUCTION

1.1 BACKGROUND

The Sulphur Springs Zinc-Copper Project (Sulphur Springs) is located approximately 144 km southeast of Port Hedland and 57 km west of Marble Bar (by road) in the Pilbara Region of Western Australia. Venturex Resources Limited (Venturex) owns this project; Venturex acquired the project tenements from CBH Sulphur Springs Pty Ltd (CBH) in 2011.

The project has undergone several changes in ownership and development concepts since the feasibility study was conducted in 2002. The first financially viable feasibility study was completed by CBH Sulphur Springs Pty Ltd (CBH) in 2007. A Public Environmental Review (PER) for this contemplated development, with an indicative footprint of 590 ha (55 % greater than current proposed project), was submitted to the Environmental Protection Authority (EPA) by CBH in November 2007 (EPA Assessment No. 1664). Key environmental factors identified for the CBH project included acid mine drainage, groundwater dependent ecosystems (GDEs), flora and vegetation, vertebrate and subterranean fauna and mine closure. The assessment process was terminated by the EPA at the request of Venturex on 2 July 2012 shortly after the company purchased the project (Appendix 1).

Venturex completed a feasibility study on the project in early 2013 and submitted a Mining Proposal for the revised design to the Department of Mines and Petroleum (DMP) during 2014. DMP consulted with the Office of the Environmental Protection Authority (OEPA) during the assessment of this Mining Proposal and no key environmental factors were identified. The Mining Proposal was approved under the *Mining Act* 1978 in April 2014.

As summarised in Table 1, several other approvals under the *Mining Act 1978* and the *Environmental Protection Act 1986* have also been granted for the site.

Table 1: Existing Approvals under the *Mining Act 1978* and *Environmental Protection Act 1986*

Year	Proponent	Existing Approvals	
		Mining Act 1978	***EP Act 1986***
2007	CBH	REG ID 19227 Panorama Project Temporary Exploration Camp Low-Impact Mining Proposal	
2013	Atlas Iron Ltd	REG ID 37527 Abydos DSO Project: Proposed Abydos Link Project	Clearing Permit 5343/1
2014	Venturex	REG ID 40542 Venturex Sulphur Springs Pty Ltd. Sulphur Springs Copper-Zinc Project	Clearing Permit 5658/1

Clearing and construction activities associated with Mining Proposals REG ID 19227 and REG ID 37527 are complete. No activities approved under Mining Proposal REG ID 40542 and CPS 5658/1 have been carried out to date.

During 2015, Venturex completed an optimisation study on Sulphur Springs that identified the opportunity to improve the financial viability of the project by utilising an open pit mine to extract the top portion of the deposit and an underground mine to extract the lower portion. Further geological modelling in 2016 has also identified a copper rich supergene zone near the top of the orebody which is expected to be amenable to recovery via heap leach and solvent extraction/electrowinning.

Subject to approval, Venturex now wishes to progress Sulphur Springs as follows:

- Develop an open pit to mine the top portion of the orebody.
- Develop an underground mine (accessed via a portal within the pit) to mine the remainder of the orebody.
- Construct a conventional processing plant which will produce separate copper and zinc concentrates for sale.
- Store tailings in a 'valley fill' Tailings Storage Facility (TSF) with a combined High Density Polyethylene (HDPE) and compacted low permeability sub-base liner.
- Construct a heap leach facility within the same valley storage area as the TSF for recovery of copper from supergene and oxide ores. The heap leach will only be operational during the early stages of the project and will be segregated from the active TSF surface by a perimeter bund. The leach pad liner will be a combined HDPE and compacted low permeability sub-base layer. Adjacent leach solution ponds will include an intermediate drainage layer between two HDPE liners, over a compacted low permeability sub-base layer. HDPE liners from the heap leach pad and solution ponds will be welded to the TSF liner to form a continuous liner under the entire heap leach / TSF facility area.
- Construct a Solvent Extraction & Electrowinning Plant (SX-EW) adjacent to the processing plant.
- Construct a waste rock dump (WRD) and additional elements such as internal roads and material stockpiles.
- Construct support infrastructure including an accommodation village, waste water treatment plants, mine water treatment plant, surface water management structures and power station.

The project has a substantially smaller footprint than that proposed by CBH and more detailed information regarding environmental values (at both a local and regional scale) and mine waste characterisation is now available. This has provided greater confidence in the assessment of potential impacts. Preliminary environmental factors identified for the proposed project include flora, fauna and rehabilitation. These factors can be adequately mitigated through implementation of well thought out designs and management measures, as outlined in this document.

Venturex seeks a decision from the EPA as to whether the proposal, which includes aspects already approved under Mining Proposal REG ID 40542 and Clearing Permit CPS 5658/1, and additional features such as the open pit, heap leach and SX-EW, requires formal assessment under part IV of the *EP Act*.

Information contained in this document will allow the EPA to understand the potential environmental impacts associated with these activities and to determine if the impacts can be adequately managed to meet the EPA objectives for environmental factors.

1.2 PROPONENT DETAILS

The manager and proponent of Sulphur Springs is Venturex Resources Limited. Venturex is a company incorporated in Australia and has shares listed on the ASX (VXR). Venturex is the owner of all tenements associated with Sulphur Springs.

All compliance and regulatory requirements regarding this assessment document should be forwarded by email, fax, post or courier to the following address:

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1.3 LOCATION AND LAND TENURE

Sulphur Springs is located approximately 144 km southeast of Port Hedland and 57 km west of Marble Bar (by road) in Western Australia (Figure 1). The site is accessed via the sealed Marble Bar Road from Port Hedland, followed by an unsealed private haul road (Abydos Link) and an unsealed site access road (Figure 1 and Figure 2).

Venturex currently holds a number of Mining and Miscellaneous Licenses over the area (Table 2 and Figure 2). Proposed elements will sit wholly within mining leases M45/494, M45/653 and M45/1001 and miscellaneous licences L45/166, L45/170, L45/173 and L45/189.

Table 2: Sulphur Springs Tenement Summary

Tenement	Area (ha)	Grant Date	Expiry Date
M45/494	972	22/10/1990	21/10/2032
M45/653	497	29/09/1995	28/09/2037
M45/1001	873	22/01/2008	21/01/2029
L45/189	1808	20/11/2009	19/11/2030
L45/170	688	18/09/2009	17/09/2030
L45/173	40	24/08/2012	23/08/2033
L45/166	2,183	01/05/2009	30/04/2030
L45/179	636.9	01/04/2011	31/03/2032
L45/287	117	28/09/2012	27/09/2033

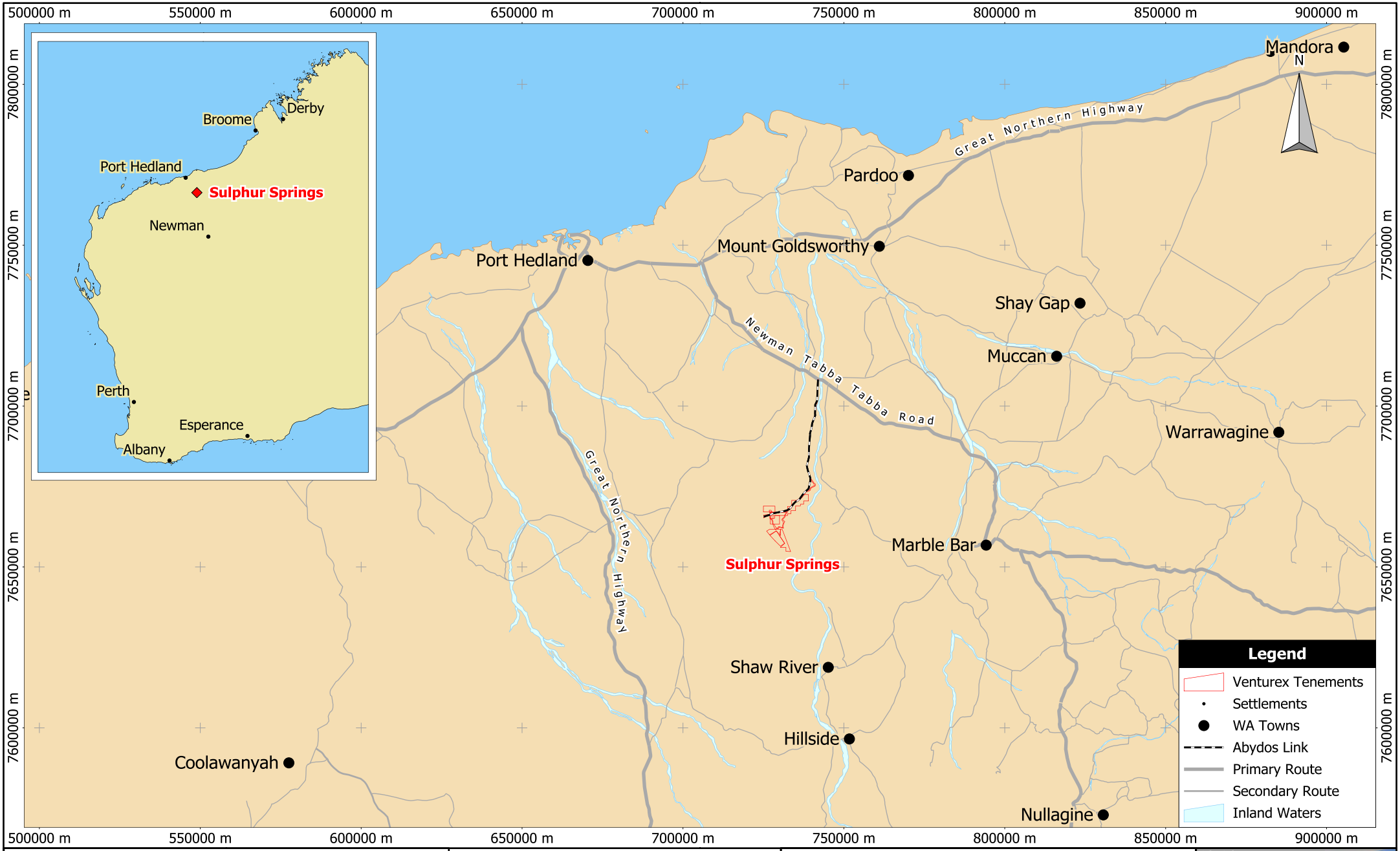
The majority of the project lies within Unallocated Crown Land, but the northern section of the site access road and accommodation village lie within the Panorama and Strelley Pastoral leases.

1.4 PROJECT SCHEDULE

The proposed schedule for Sulphur Springs is described in Table 3.

Table 3: Proposed Schedule for Sulphur Springs

Project Description	Schedule
Feasibility Study	Q1 2017
Construction	Q4 2017
Operations	Q2 2018



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Venturex Resources Limited
Sulphur Springs Project

Figure 1

Location Plan

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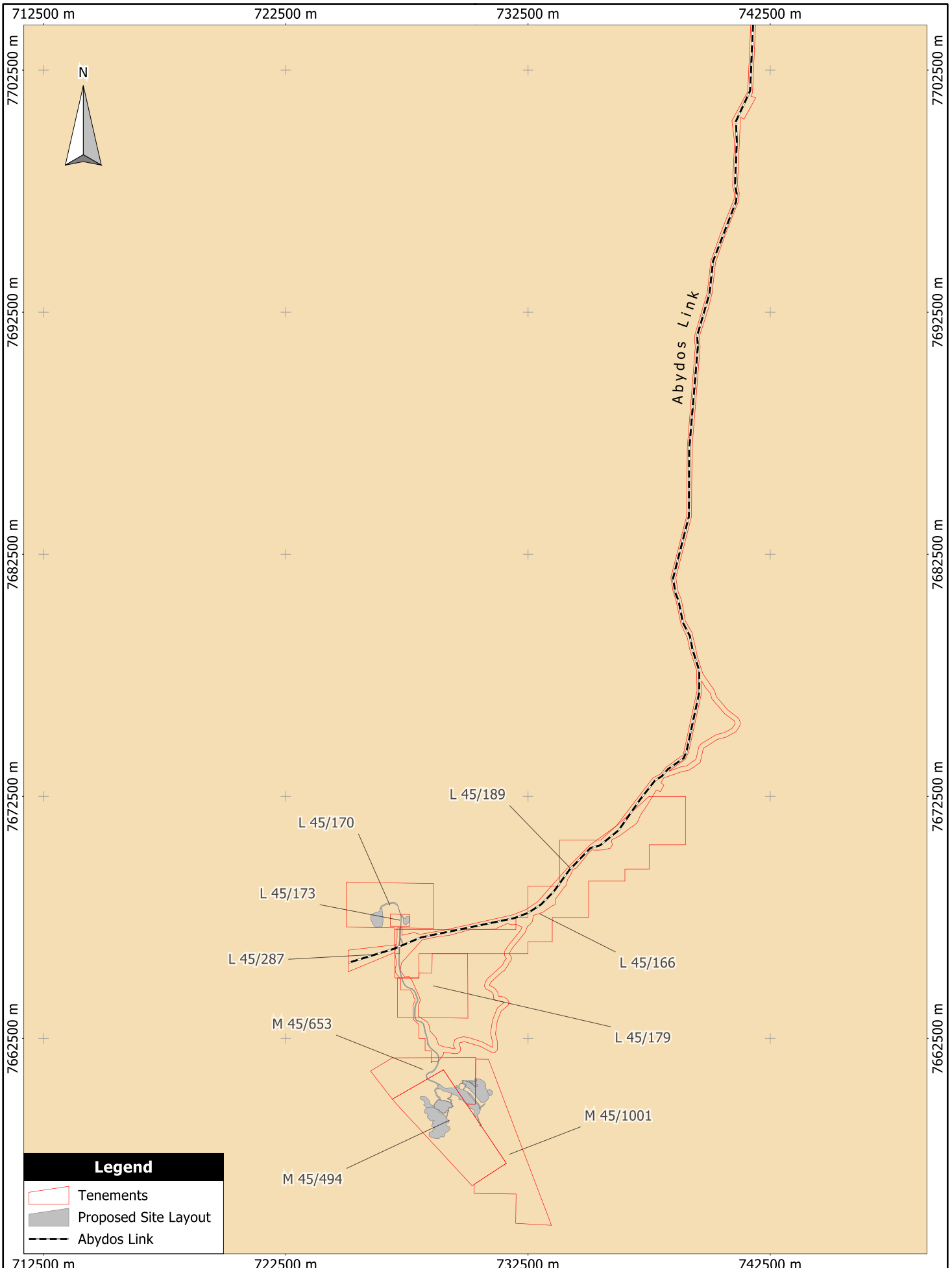

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Venturex Resources Limited
Sulphur Springs Project

Figure 2

Tenement Plan

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2. PROJECT DESCRIPTION

2.1 PROJECT OVERVIEW

Sulphur Springs is located in a remote greenfields area historically used for pastoral activities and mineral exploration. A large number of baseline and environmental impact studies conducted over the past 14 years by Venturex and previous tenement holders have contributed significantly to the scientific understanding of the area and allowed Venturex to design the project in a way that identifies, prevents and/or minimises adverse environmental impacts.

Sulphur Springs is a volcanogenic massive sulphide copper-zinc deposit in the mid-eastern area of the Abydos Plain and incorporates a small portion of the Gorge Range. Base metal sulphide mineralisation was first discovered at the site in 1991. Since this time, a number of exploration programs, studies and reviews have been conducted to further define the resource and develop a viable project development concept. These studies include:

- A feasibility study by Outokumpu Zinc Australia and Sipa Resources Limited in 2002, which proposed an underground operation at Sulphur Springs. This project did not proceed to development as it was not economically viable at the time.
- A detailed feasibility study of the project by CBH in 2007, which identified that the total resource could be economically mined by a 43 million Bank Cubic Metre (BCM) open pit mine and associated WRDs with an indicative project footprint of 590 ha. CBH submitted a PER for the development to the EPA in 2007. Following the purchase of CBH by Toho, the project was sold to Venturex in 2010. Venturex terminated the PER assessment process in July 2012 as part of its own feasibility study of the project.
- A detailed feasibility study of the project by Venturex in 2012, based on mining the total resource using an underground mine. A Mining Proposal for this option was assessed and approved by DMP in 2014 (REG ID 40542) and included the following elements:
  - A 1.0 Mtpa underground mine.
  - A 1 Mtpa processing plant and associated elements to produce exportable copper and zinc concentrate.
  - Several site access roads and transport corridors.
  - Accommodation village and associated elements.
  - Mine support facilities.
  - Water services.

  The DMP consulted with the Office of the Environmental Protection Authority (OEPA) during the assessment of this Mining Proposal. No activities approved under MP Reg ID 40542 (and associated clearing permit CPS 5658/1) have been carried out to date.
- An optimisation study by Venturex in 2015, based on mining the resource using a combination of a 17 m BCM open pit and associated WRD with a footprint of 70 ha and an underground mine together with adoption of a conventional 'valley fill' TSF with a combined HDPE and compacted low permeability sub-base liner would result in a significant reduction in the financial and operational risks associated with the implementation and ongoing operation of the project.
- Development of a new geological model and Resource estimate in 2016, which identified a supergene resource in the upper section of the orebody containing approximately 800,000 t grading 4.2 % Cu. An initial desktop review has confirmed the viability of a separate heap leach process stream to recover copper from the supergene and oxide deposits. The next phase of work will include metallurgical testwork to verify the material's amenability to copper recovery via heap leach and SX-EW.

Venturex now wishes to progress Sulphur Springs as follows:

- Develop an open pit to mine the top portion of the orebody.
- Develop a 1.5 Mtpa open pit and underground mine (access to the underground will be via a portal within the pit) to mine the remainder of the orebody.
- Construct a 1.5 Mtpa conventional processing plant which will produce separate copper and zinc concentrates for sale.
- Store tailings in a 'valley fill' Tailings Storage Facility (TSF) with a combined High Density Polyethylene (HDPE) and compacted low permeability sub-base liner
- Construct a copper heap leach facility within the same valley storage area as the TSF. The leach pad liner will be a combined HDPE and compacted low permeability sub-base layer. Adjacent leach solution ponds will include two HDPE liners, with an intermediate drainage layer, over a compacted low permeability sub-base layer. HDPE liners from the heap leach pad and solution ponds will be welded to the TSF liner to form a continuous liner under the entire heap leach / TSF facility area.
- Construct a copper Solvent Extraction & Electrowinning Plant (SX-EW) adjacent to the processing plant.
- Construct a permanent waste rock dump (WRD).
- Construct additional supporting elements such as site access road, internal roads, material stockpiles, surface water management, accommodation village and power station.

The conceptual site layout is shown in Figure 3. The footprint of these changes is compared to the existing approved Mining Proposal REG ID 40542 in Figure 4. Table 4 compares the current project elements with previous submissions. All proposed infrastructure has been designed to avoid known Declared Rare Flora (DRF) populations and minimise impact to habitat for conservation-significant fauna.

Table 4: Comparison Between Existing Project and Previous Submissions

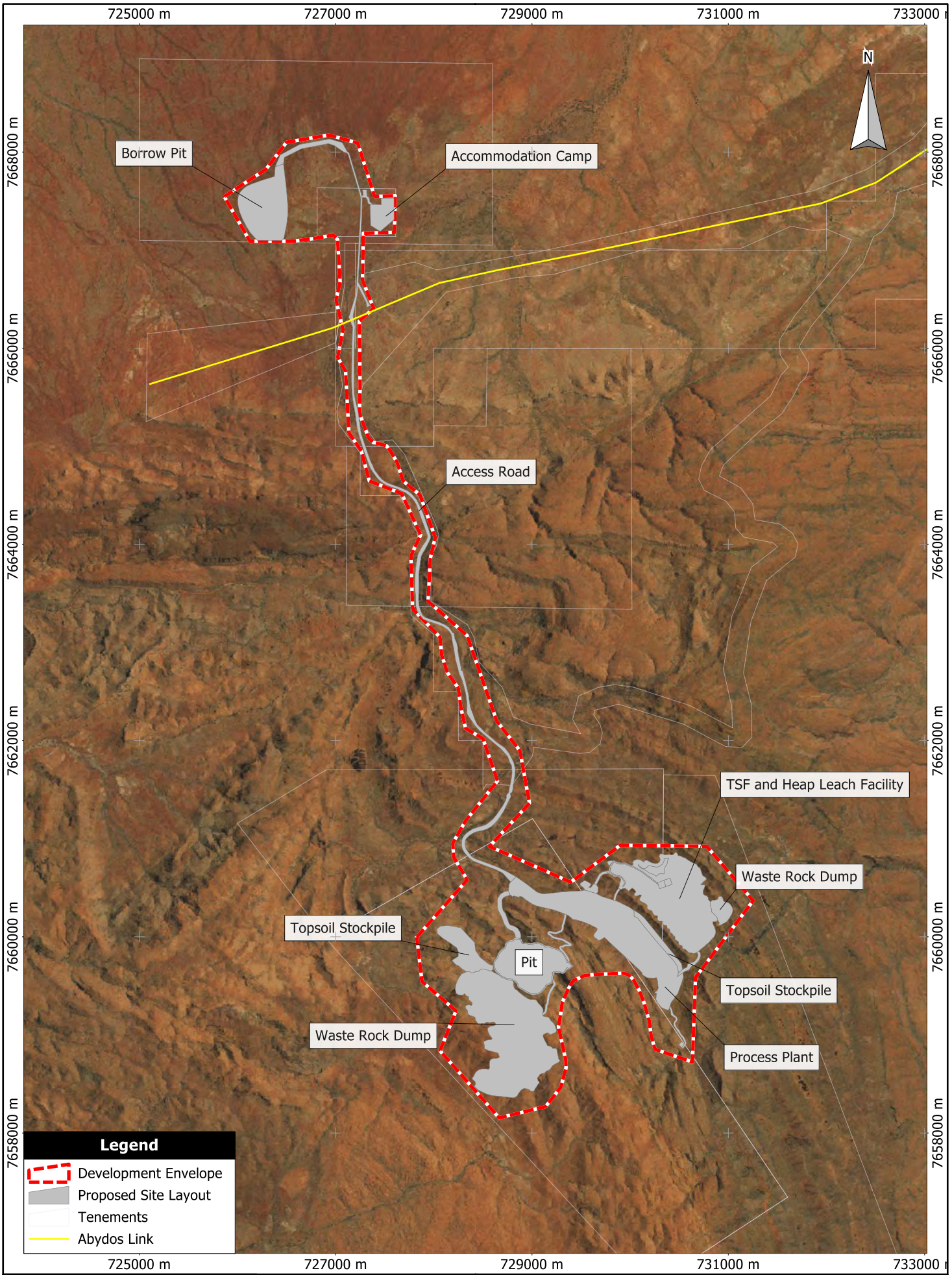
	PER (EPA Assessment No. 1664)	Mining Proposal REG ID 40547 & CPS5658/1	Proposed Project
Year	2007	2014	2016
Proponent	CBH	Venturex	Venturex
Primary Infrastructure	• 1.5 Mtpa, 40 ha open pit.	• 1 Mtpa underground mine.	• 1.5 Mtpa, 28.9 ha open pit and underground mine.
	• 1.5 Mtpa processing plant.	• 1 Mtpa processing plant.	• 1.5 Mtpa processing plant including SX-EW facility.
	• A 72 ha clay lined "valley fill" TSF.	• A 27.6 ha clay lined 'dry stack" TSF.	• A 58.9 ha lined (HDPE and compacted low permeability sub-base) 'valley fill" TSF and copper heap leach facility.
	• Two permanent WRDs (184 ha).	• Temporary WRD.	• One 79.6 ha permanent WRD. • Temporary WRD.
	• A 39 ha airstrip. • Evaporation ponds. • Miscellaneous supporting elements.	• A 35.7 ha airstrip. • Miscellaneous supporting elements.	• Miscellaneous supporting elements.
Proposed Footprint (ha)	590	193 (within an Application Area of 1,194 ha).	321.9 (within a Development Envelope of 848.3 ha).
Key Potential Environmental Issues	• Acid mine drainage. • Potential for impacts on Groundwater Dependent Ecosystems (GDEs). • Flora and vegetation. • Vertebrate fauna (Northern Quoll, Mulgara and Pilbara Leaf-nosed Bat). • Subterranean fauna. • Mine closure	• Flora and vegetation. • GDEs. • Subterranean fauna. • Vertebrate fauna. • Mine closure	• Flora and vegetation. • Vertebrate fauna (Northern Quoll). • Mine Closure

Potential impacts to environmental factors assessed during the CBH PER have been substantially reduced for the proposed project by:

- Additional baseline flora and fauna studies conducted since submission of the CBH PER and the approved Mining Proposal (at both a local and regional level).
- Investigations carried out on GDE's and subterranean fauna as part of the approved Mining Proposal and at a regional level.
- A much smaller open pit combined with water-shedding cover designs for the TSF and a store and release cover for the WRD.
- Completion of waste characterisation studies commenced by CBH and development of a detailed model of waste products produced by the open pit.

- Careful siting of infrastructure to avoid or minimise clearing of conservation significant habitats.
- Adoption of an industry best practice design TSF (dual-lined - HDPE and compacted low permeability sub-base).
- An improved understanding of acid mine drainage management over the past ten years.

This has provided more confidence in the assessment of impacts conducted to support this Referral.



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Venturex Resources Limited
Sulphur Springs Project

Figure 3

Conceptual Site Layout

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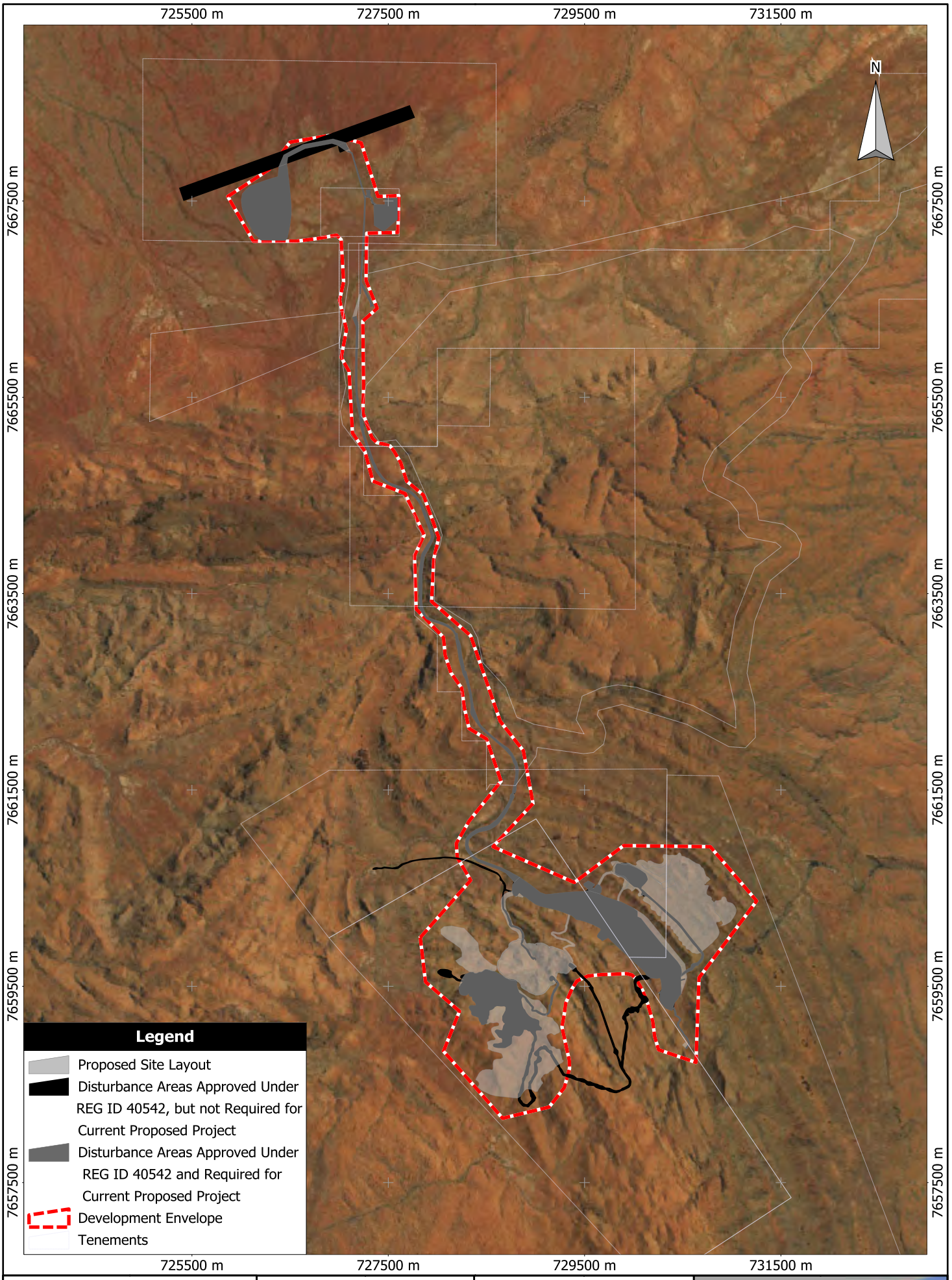

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Sulphur Springs Project

Figure 4

Comparison between Approved and Proposed Site Layout

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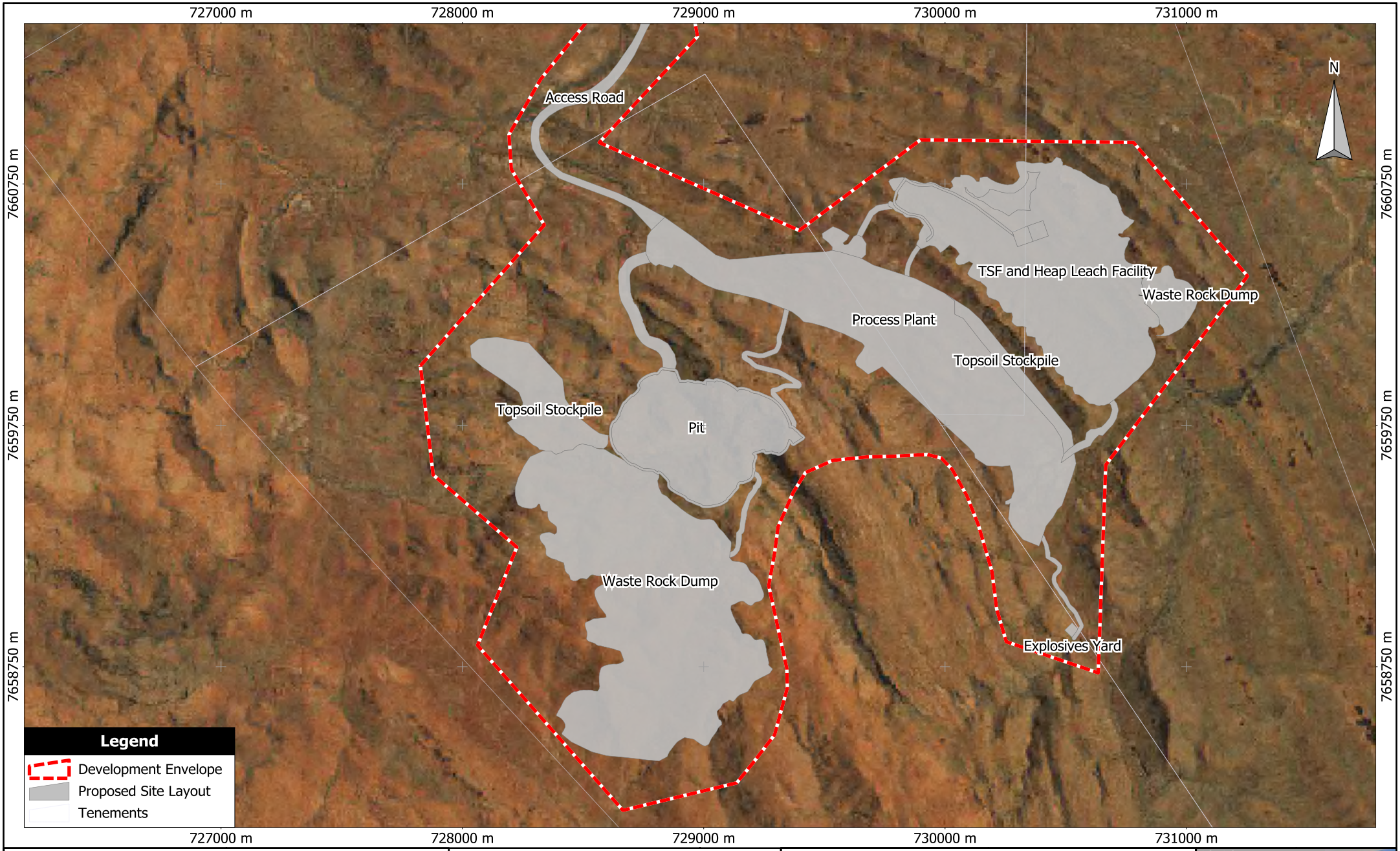
2.2 KEY PROPOSAL CHARACTERISTICS

Key proposal characteristics in accordance with Environmental Assessment Guideline (EAG) 1 (EPA 2012) are shown in Table 5 and the Development Envelope and conceptual site layout plan is shown in Figure 3 and Figure 5. Figure 6 provides a comparison between the proposed project and disturbance approved under Mining Proposal REG ID 40542.

Table 5: Key Proposal Characteristics

Summary of the Proposal		
Proposal Title	Sulphur Springs Zinc-Copper Project (Sulphur Springs)	
Proponent Name	Venturex Resources Limited	
Short Description	Sulphur Springs is located approximately 57 km east of Marble Bar in Western Australia. This proposal relates to construction of the following: • An open pit mine. • A 1.5 Mtpa open pit and underground mine • A 1.5 Mtpa processing plant. • A 'valley fill' tailings storage facility with a combined high density polyethylene and compacted low permeability sub-base. • A copper heap leach facility with a combined high density polyethylene and compacted low permeability sub-base installed above a secondary high density polyethylene liner that will adjoin the tailings storage facility liner. • A solvent extraction/electrowinning plant. • A permanent waste rock dump. • Associated mine elements (stormwater management infrastructure (bunds and drains), internal mine roads, site access road, topsoil and vegetation stockpiles, construction material stockpiles, power station, accommodation village and mine support facilities). The project will produce separate copper and zinc concentrates and copper cathode. These final products will be transported to Port Hedland for sale.	
Element	**Conceptual Location**	**Proposed Extent Authorised**
Physical Elements		
Open Pit, Waste Rock Dump, Processing Plant, SX-EW, Ponds, Explosives Storage, Accommodation Village, and Associated Mine Elements	Figure 3	Clearing no more than 263.0 ha within the 848.3 ha Development Envelope.
Tailings Storage Facility and Heap Leach Facility	Figure 5	Clearing no more than 58.9 ha within the 848.3 ha Development Envelope.
Operational Elements		
Mining Waste Rock	Figure 5	Disposal of no more than 17.5 million loose cubic metres (LCM) in a permanent surface WRD.
Heap Leach	Figure 5	Deposition of no more than 1.07 Mt in a lined (HDPE and compacted low permeability sub-base) heap leach facility.
Process Tailings	Figure 5	Disposal of no more than 1.30 Mtpa in a 'valley fill' dual lined (HDPE and compacted low permeability sub-base) TSF.



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Venturex Resources Limited
Sulphur Springs Project

Figure 5

Conceptual Site Layout (Mine Area)

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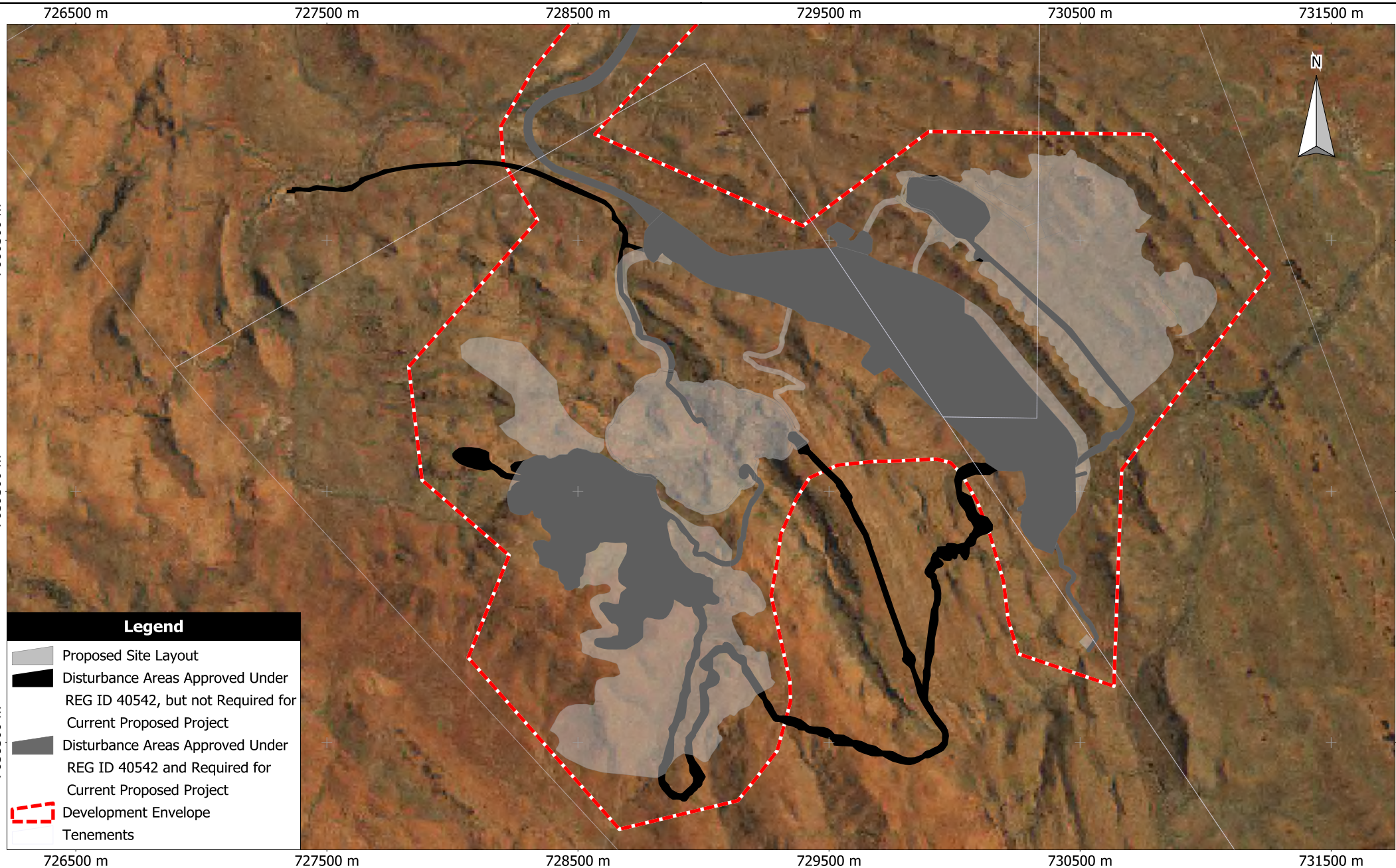
W:\Venturex Resources\Sulphur Springs\Projects\EPA Referral V2\Drawings\Sulphur Springs EPA Referral V4.map 23/11/2016 F5 Conceptual Site Layout (Mine Site) Layout



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Venturex Resources Limited
Sulphur Springs Project

Figure 6

Comparison between Approved and Proposed Site Layout (Mine Area)

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2.3 PROPOSED LAND DISTURBANCE

Land disturbance for the proposal is estimated to be 321.9 ha. The total Development Envelope is 848.3 ha as shown in Table 6 and Figure 3. Disturbance will be located wholly within mining leases M45/494, M45/653 and M54/1001 and miscellaneous licences L45/166, L45/170, L45/173, and L45/189.

Table 6: Estimated Land Disturbance for Key Project Components

Project Component	Estimated Total Disturbance Area (ha)
4WD Access Track[1]	1.7
Access Road	29.4
Borrow Pit	28.0
Explosives Compound	0.2
Haul Road	6.3
Heap Leach Access	0.9
TSF and Heap Leach Facility	58.0
Pit	28.9
Plant Site	60.4
Pond	0.9
Temporary WRD	4.1
Topsoil Stockpile	17.2
Village	6.3
Waste Rock Dump	79.6
Grand Total	**321.9**

2.4 MINING

2.4.1 Open Pit Mine

The top portion of the Sulphur Springs deposit is proposed to be mined via an open pit. The pit will be developed in two stages, with the first stage providing access to ore in the top of the western lode of the deposit and the second stage taking the pit to its final limit and providing access to the portal and ventilation shaft positions.

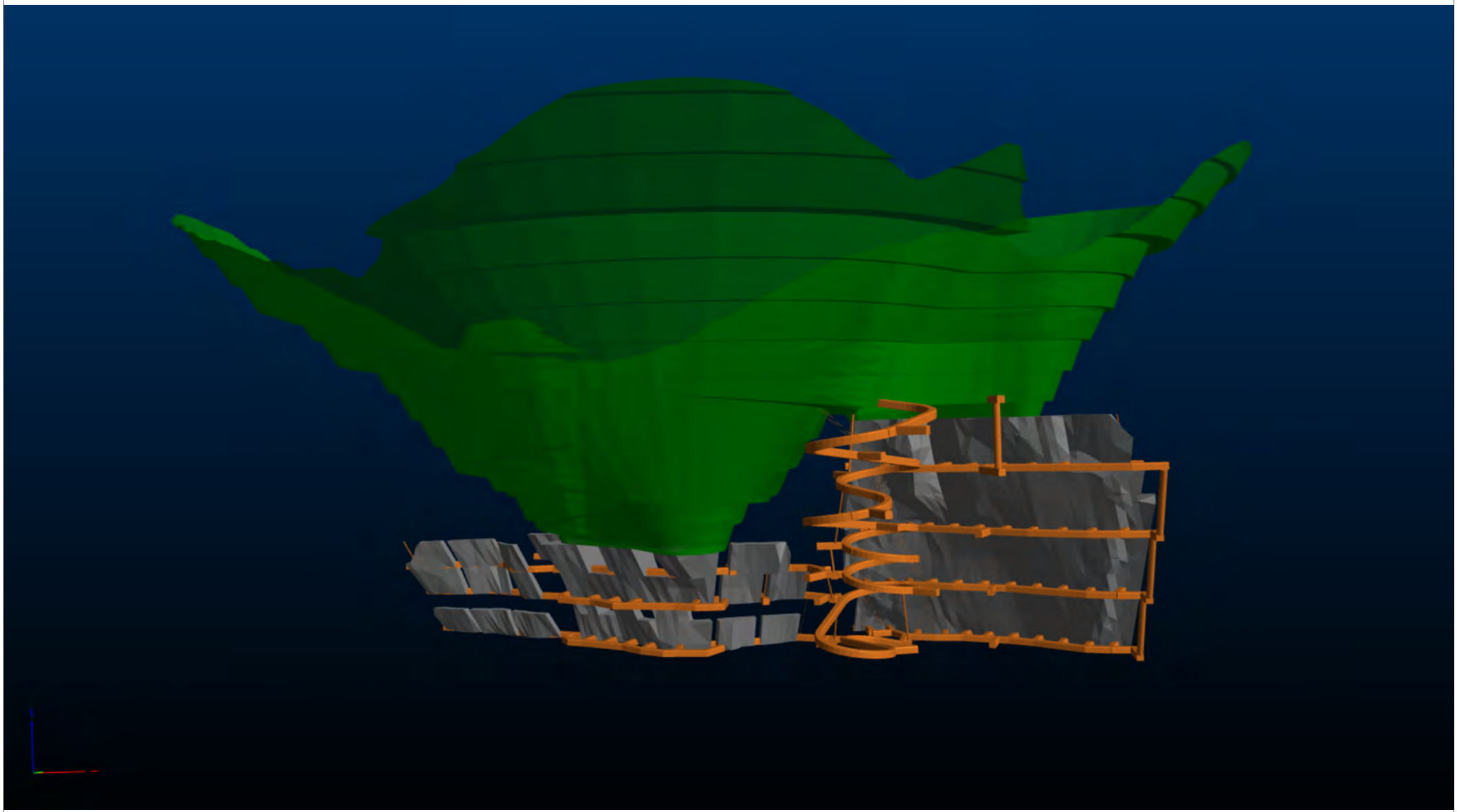
Depending on the stage of development, Run of Mine (ROM) ore will be carted directly to the heap leach facility or to a ROM pad adjacent to the processing plant. Low grade ore will be carted to a separate stockpile adjacent to the processing plant. Both the ROM pad and low grade stockpile will be engineered so as to reduce the seepage of any acid mine drainage into the environment, contain and direct any contaminated runoff into dedicated site runoff ponds and ensure that uncontaminated runoff will be diverted away from these areas.

The open pit will be approximately 735 m long by 520 m wide. Final pit floor elevations will be 1,100 mRL and 1,190 mRL in the western and eastern zones respectively. A long section of the proposed pit and Sulphur Springs orebody is shown in Figure 7.

[1] This is an exploration track that has already been cleared under existing POWs. No additional disturbance for this track is required for the proposed project.

Surface water runoff from outside the pit will be diverted by permanent stormwater structures designed and operated to convey and withstand a one in 100-year storm event.

Approximate locations for elements associated with the project such as the heap leach facility, TSF, WRD, topsoil and vegetation stockpiles and haul roads are shown in Figure 5.



Not to Scale
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Source: Entech 2016

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Figure 7

Sulphur Springs Pit Outline

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\\mbsserver\working\Venturex Resources\Sulphur Springs\Projects\EPA Referral\Drawings\Venturex EPA Referral Map.map 18/04/2016 F5 Pit Outline Layout

2.4.2 Underground Mine

The lower portion of the deposit will be mined using conventional mechanised mining methods similar to those approved under Mining Proposal REG ID 40542. A portal will be located at 1,190 mRL in the eastern zone of pit to provide access into the underground mine. The collars of the main exhaust raises will also be located on this level.

It is proposed to use a core and shell mining method working from the top down to extract the eastern lode of the underground mine. The mining void generated will be filled with waste rock.

It is proposed to use open stoping mining from the bottom up to extract the western lode below the deeper section of the open pit. The mining void generated will be filled with de-slimed tailings. The disposal of tailings from the plant to underground will be maximised.

2.4.3 Waste Rock Disposal

Extensive geochemical characterisation studies including column leaching have been carried out on mine waste samples. A new resource model has been generated that includes waste as well as economic mineralisation and sulphur grades as well as economic metals. The characterisation of waste materials and their disposition is now well understood.

Venturex proposes to produce 19.6 million LCM of waste rock. The likely composition (non-acid forming (NAF) or potentially acid forming (PAF)) and storage location of this material is summarised in Table 7.

Table 7: Mining Waste Rock Disposal Summary

Waste Type	Category	Volume (kLCM)	Disposal Location
Open Pit			
Oxidised Waste	NAF	1,200	Stockpiled in integrated landform at TSF for use in TSF embankment and closure of the structure.
Oxidised Waste	NAF	7,300	Encapsulation of PAF waste rock in WRD or used for construction (roads, footings, etc.).
Hanging Wall Chert	NAF	1,960	Encapsulation of PAF in WRD.
Hanging Wall Siltstones and Breccia	NAF	3,100	Encapsulation of PAF in WRD.
Foot Wall Felsic Volcanics	PAF[1]	340	Waste Rock Dump/Underground if possible.
Rhyolite Stockwork	PAF[1]	600	Waste Rock Dump/Underground if possible.
Disseminated Mineralisation	PAF[1]	1,300	Waste Rock Dump/Underground if possible.
Waste associated with Massive Mineralisation	PAF[2]	300	Temporary PAF Waste Stockpile on WRD then underground or in open pit void.
Underground			
Waste	PAF[2]	150	All placed underground or in open pit void.

[1] *PAF waste rock not immediately associated with the orebody.*

[2] *PAF waste rock immediately associated with the orebody that will have a higher pyrite content than other PAF waste.*

The WRD will be constructed in proximity to the pit for disposal of approximately 17.5 million LCM of waste rock. The proposed location for this landform is shown in Figure 5. It has been designed and located in order to:

- Avoid detrimental geotechnical conditions.
- Avoid potential mineralised areas.
- Minimise footprint and vegetation disturbance.
- Maximise the portion of the footprint within the surface water catchment of the open pit.
- Avoid watercourses and areas of potential flooding.
- Avoid heritage sites or areas of cultural importance.
- Avoid impacts on conservation significant flora and fauna.

Waste material associated with massive mineralisation is pyritic and has high potential to generate acid. All of this waste will be disposed of in the underground mine or open pit void, where it will be below the predicted pit lake water level.

Less than 14% of the waste rock from the open pit to be placed on the WRD will be PAF. Where the mine schedule allows, this material will be used as fill in the mining void formed by the core and shell mining method.

PAF waste designated for permanent storage in the WRD will be encapsulated in cells so as to limit the potential for oxidation. Cells will have a minimum 5 m thick base, a minimum 10 m wide selvage on the outer edges and a minimum cover of 5 m. The base, selvage and cover will be constructed of NAF material placed in layers less than 3 m thick and compacted by heavy vehicle traffic. Further design features for the WRD are shown in Table 8.

Table 8: Waste Rock Dump Design Details

Dimension	WRD
Height	No higher than surrounding topography
Length	Approximately 1,400 m
Width	Approximately 1,000 m
Volume	17,500,000 LCM
Final Batter Angles	16º
Waste Type	PAF encapsulated in engineered cells within NAF material.

Surface water runoff from outside the WRD will be diverted away by permanent stormwater structures designed and operated to convey and withstand a one in 100-year storm event.

2.5 SUPERGENE AND OXIDE ORE PROCESSING

2.5.1 Copper Heap Leach, Solvent Extraction and Electrowinning

A desktop assessment to identify a process route for the supergene deposit and a small oxide deposit at Sulphur Springs was conducted by Knight Piésold Pty Limited (KP) in October 2016 (KP 2016). The assessment determined the most effective location to construct a heap leach pad was within the confines of the TSF envelope. The intent is to recover contained copper in these ore sources via a heap leach facility, solvent extraction and electrowinning plant (SX-EW), to produce copper cathodes.

Venturex anticipates that leaching will commence approximately one month prior to commissioning the processing plant and continue for 14 months.

2.5.2 Heap Leach Facility

2.5.2.1 Location

The KP assessment (KP 2016) investigated options for siting the heap leach facility and determined the most effective location would be within the TSF envelope. The two facilities will be contained in the same valley storage area and thus interaction between them has been incorporated into the design. Constructing the heap leach within the TSF envelope reduces the overall liner requirements, reduces the disturbance footprint for the project and simplifies encapsulation of the facility within the TSF at closure. Figure 8 shows the heap leach facility layout (adjacent to the TSF) at the time of construction of the first heap leach cells. This figure also shows the extent of tailings deposition for the first TSF lift (Stage 1), which is scheduled to be complete approximately four months after leaching terminates. Figure 9 shows the heap leach facility within the final TSF footprint at completion of the project.

2.5.2.2 Design

Heap Leach Pad

The heap leach pad will be constructed in two lifts; two cells in the first lift and three cells in the second. Each lift will be approximately 6 m high. Supergene and oxide ores will be mined, crushed on the ROM pad and hauled to the heap leach facility where they will be end dumped onto the active leach cell. On completion of ore deposition onto a designated cell, ore will be leached in two stages using a sulphuric acid leach solution. Pregnant liquor will be pumped to the SX-EW plant for copper extraction. Barren SX-EW solution will be dosed with sulphuric acid and returned to the heap leach for ongoing leaching. The heap leach configuration is shown in Table 9.

Table 9: Heap Leach Pad Configuration

Lift	Cells	Base RL (m)	Top RL	Area (ha)
1	1 and 2	1,256	1,262	3.0
2	3, 4 and 5	1,261	1,276	5.0

The heap leach pad liner will consist of a 1.5 mm HDPE textured liner over a compacted low permeability sub-base. A cushion layer will be placed on the liner as puncture protection. A corrugated, perforated drain pipe network placed on the cushion layer with outfall pipes for solution collection will be covered by selected drainage media providing a minimum 200 mm cover depth to pipes. The HDPE liner will be welded to the TSF liner to form a continuous liner under the entire heap leach / TSF facility area.

Solution Channels

Each leach cell has a dedicated outfall or secondary collector pipe comprising a 450 mm diameter HDPE discharge pipe connected to two conveyance pipes or tertiary solution collection pipes for pregnant and intermediate solution respectively. Each HDPE conveyance pipe (600 mm) either reports directly to the solution channel or is connected to outfall pipes by a launder.

For the launder system, tertiary collector pipes form the primary lining system for solution channels. Secondary lining comprises 1.5 mm HDPE liner on the channel base and sides. A tertiary lining comprises 0.3 m of compacted low-permeability sub-base constructed below the HDPE liner. Conveyance pipes will have sufficient capacity to for minor storms but major events will discharge from launders via a spillway into the HDPE lined channel.

Solution Ponds

Solution ponds will comprise a pregnant leach solution pond (PLS) and intermediate leach solution pond (ILS). The PLS pond holds copper-enriched solution from the pad prior to processing in SX-EW. The intermediate pond stores copper-bearing solution that is too low in grade to process. This solution is re-circulated through the heap leach pads to increase copper concentration. Pond design details are summarised in Table 10.

Table 10: Solution Pond Design Details

	PLS	ILS
Storage Volume (m^3)	4,000	4,000
Base Size (m x m)	30 x 35	30 x 35
Freeboard Allowance (m)	0.5	0.5

PLS and ILS ponds will be interconnected by an overflow weir. In an extreme rainfall event, the PLS pond will overflow into the ILS pond, and then to the dual-lined TSF, which will act as a stormwater pond for such an event. The TSF has been designed with sufficient capacity to hold a 1 in 100 year 72 hr storm volume over both the TSF and heap leach facility areas, with a 300 mm freeboard.

Leak Collection and Recovery System

The PLS and ILS ponds and solution channels connecting these structures to the heap leach pads will incorporate leak collection and recovery systems (LCRS). The LCRS will be formed by a drainage layer between two HDPE liners, comprising a geonet layer in areas of potentially high flow and a sand layer in potentially low flow areas. The drains will lead to a sump where leaks will be detected and solution removed. In the PLS and ILS ponds a double LCRS and triple liner will prevent leaks escaping. Liner systems will comprise:

- A primary 1.5 mm HDPE liner and secondary 1.0 mm HDPE liner on the base.
- A layer of geonet placed to form a primary leak detection drain.
- A lower liner of conditioned and compacted soil subgrade.

LCRS systems are critical to detect leaks and reduce solution losses until the liners are repaired.

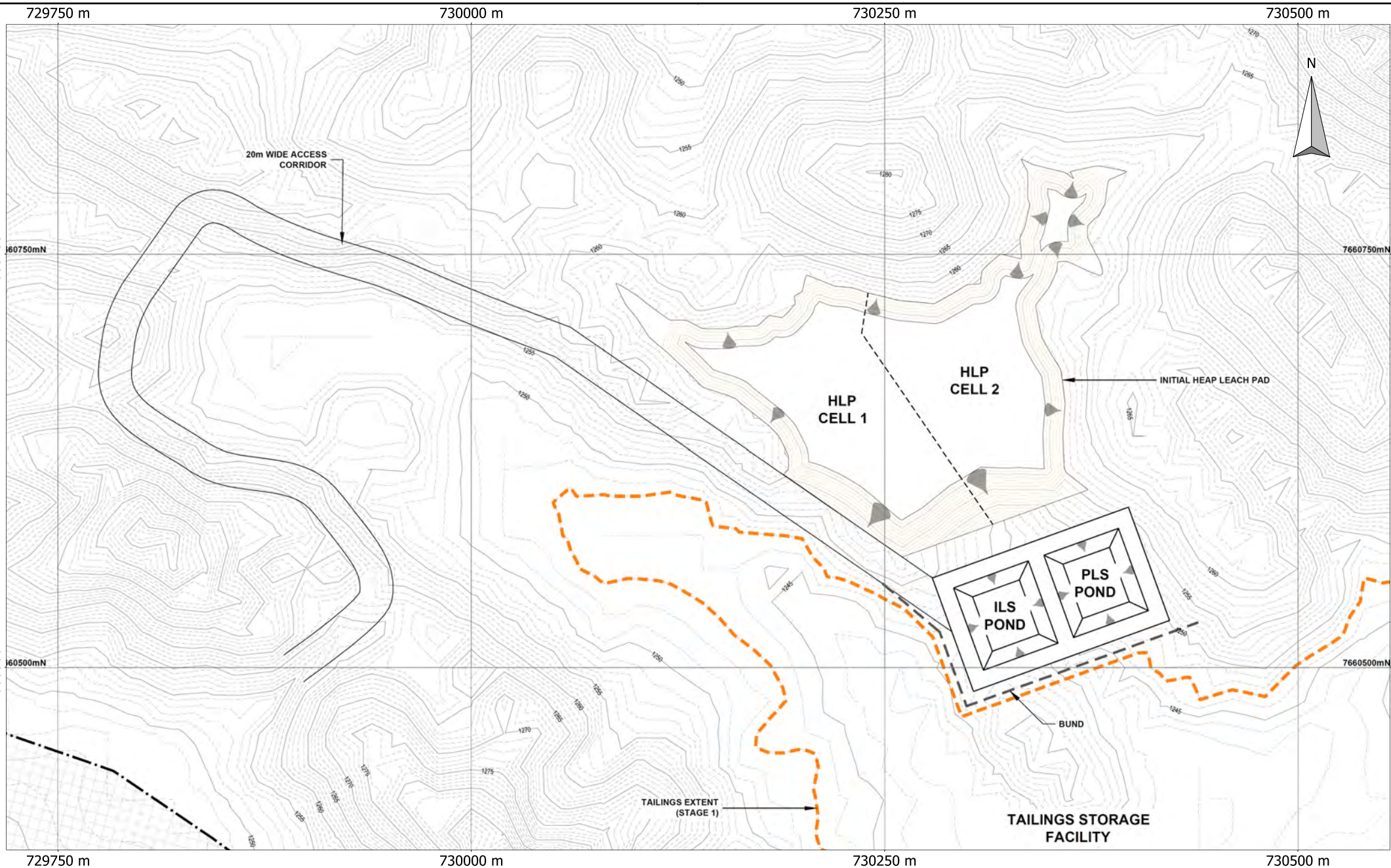
HDPE liners will be welded to the TSF liner to form a continuous liner under the entire heap leach / TSF facility area.

Perimeter Bund

A perimeter bund will be constructed on the downstream (eastern and southern) sides of the solution ponds (Figure 8). The bund will be constructed to a height of 1,248.9 m RL with a 3 m crest width and side slopes of 1V:3H.

PLS and Raffinate Pipeline Corridor

Two HDPE pipelines will be installed between the heap leach facility and SX-EW. The first will transfer PLS to SX-EW and the second will transfer leach solution (raffinate following sulphuric acid addition) to the heap leach pads. Both pipelines will be contained within a single HDPE lined channel, with a 300 mm low-permeability sub-base constructed below the liner. A leak detection system will be installed on both pipelines.



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Source: Knight Piésold 2016
Grid: MGA94(50)

0 100 m

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Figure 8

Initial Heap Leach Facility Layout (Cells 1 and 2)

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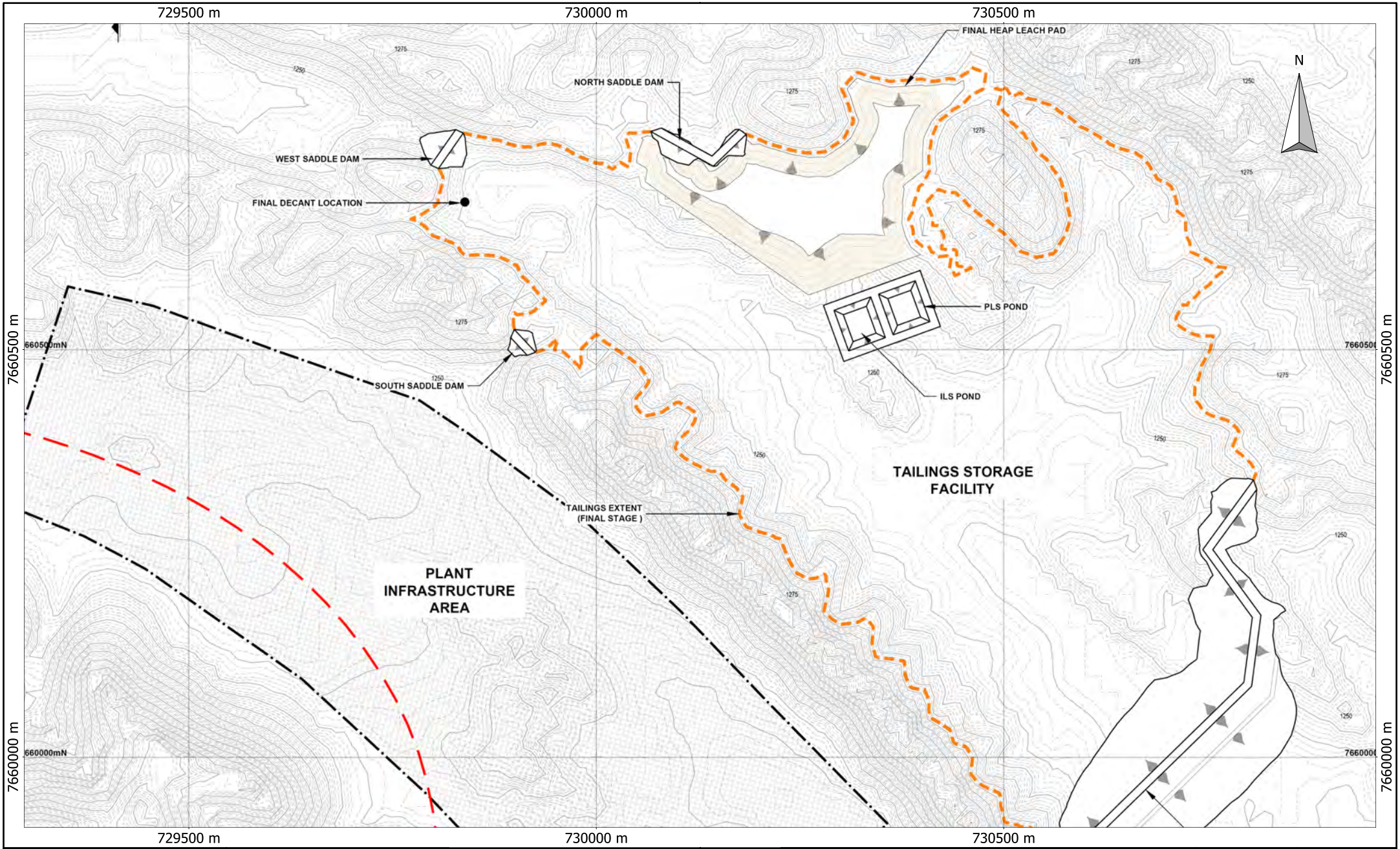

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Source: Knight Piésold 2016
Grid: MGA94(50)

0 200 m

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Figure 9

Heap Leach Facility within TSF at Project Completion

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W:\Venturex Resources\Sulphur Springs\Projects\EPA Referral V2\Drawings\Sulphur Springs EPA Referral V4.map 16/11/2016 F9 Heap Leach Facility within TSF at Project Completion Layout

2.5.3 Solvent Extraction and Electrowinning Plant

The SX-EW is a closed circuit process with all liquid streams being contained and recirculated within the system. Pregnant leach solution from the PLS pond is pumped to the plant where it is mixed with an organic phase containing an extractant which selectively extracts copper from the solution. The copper rich solution is mixed with an aqueous solution containing high concentrations of sulphuric acid (spent electrolyte). The high sulphuric acid concentrations draw copper cations into the aqueous phase. This aqueous phase is then passed through electrowinning cells where copper is electrolytically plated to cathodes and recovered as copper metal. The spent solution flows to the raffinate pond adjacent to SX-EW where the sulphuric acid is added prior to the solution being recycled back to the leaching process.

The SX-EW site will be compacted and lined with plastic prior to construction of concrete bunding. Plant infrastructure will be contained within a concrete bund capable of holding 110% of the largest vessel and 25% of the total volume according to *Australian Standards AS1940 and AS1692*

The raffinate pond will be constructed with a dual liner (HDPE over compacted clay base) and sulphuric acid distribution lines will be double-sleeved where pipe sections pass through unbunded areas.

2.5.4 Temporary Power Supply

Power will be supplied temporarily from a portable diesel power generating plant prior to commissioning of the main power station (refer Section 2.9.1). This will generate power for the SX-EW plant, crushing, agglomeration, conveying and stacking systems.

2.6 SULPHIDE ORE PROCESSING

The processing plant footprint and operation will be similar to that approved under Mining Proposal REG ID 40542. The plant has been designed to take Run of Mine (ROM) ore and concentrate the copper and zinc bearing minerals to produce separate copper and zinc concentrates and a barren tailings stream. Process facilities will include the following:

- Crushing.
- Semi-Autogenous Grinding (SAG) and Ball Milling combination (SAB).
- Flotation.
- Thickening.
- Filtration.
- Product Handling.
- Tailings Disposal.
- Reagents.
- Services and Ancillaries.

The plant has been designed in accordance with accepted industry practice and the above facilities are discussed further in the following sections.

2.6.1 Crushing and Coarse Ore Storage

Ore will be reclaimed from the ROM pad by a front-end loader and fed to the ROM bin. The ROM bin will be fitted with a static grizzly to allow diversion of large rocks for subsequent breakage by mobile rock breaker. Ore will be drawn from the ROM bin via a variable speed apron feeder and fed into a single toggle jaw crusher.

Jaw crusher product will discharge onto the primary crusher discharge conveyor, which will feed a surge bin. The surge bin will be designed to overflow onto a stockpile feed conveyor which will discharge onto a static stockpile. This stockpile will be used as the major surge capacity in the event of a crusher shutdown. In normal operation, the milling circuit will be fed from the surge bin and the crusher will be operated to generate an excess of feed which will feed the stockpile. The surge bin will be arranged to allow ore reclaimed from the stockpile by front end loader to re-join the circuit.

A hoist has been provided for servicing the primary crusher area.

The crushing circuit will include a dust collector that will draw dust from the ore transfer points in the process stream.

2.6.2 Grinding

Primary crushed ore from the surge bin will be withdrawn by a single apron feeder and will be conveyed to a Semi-Autogenous Grinding (SAG) mill. Water will be added to the mill together with grinding balls to maintain the desired load. Any pebbles from the SAG mill will be conveyed to a bunker for recycling back onto the SAG mill feed conveyor.

The ground ore which passes through the SAG mill trommel screen will report to a dedicated SAG mill discharge hopper from which it will be pumped to a cluster of classification hydrocyclones. The coarse underflow will gravitate back to the SAG mill. The finer overflow will gravitate to the ball mill discharge hopper.

Slurry from the ball mill discharge hopper will be pumped to a second cluster of classification hydrocyclones and the coarse underflow will gravitate to a ball mill. The discharge from the ball mill will gravitate into the ball mill discharge hopper. Provision for addition of lime to this hopper will be made to assist in depression of pyrite and zinc in the copper float.

Overflow from the second cluster of hydrocyclones, at 35% solids and an 80% passing size (P_{80}) of 63 µm, will gravitate to the copper flotation circuit.

2.6.3 Copper Flotation

Cyclone overflow from the grinding circuit will gravitate to an agitated copper conditioning tank where reagents (including sodium metabisulphite, collector (A3894) and lime) are added to the slurry. Slurry is then directed to the head of the copper flotation circuit where methyl isobutyl carbinol (MIBC) is added to act as a froth stabilising agent. The copper flotation circuit consists of six copper rougher/scavenging cells and two stages of four cleaner cells.

Concentrate from the copper rougher/scavenger cells will gravitate to a horizontal vibrating screen for trash removal, prior to feeding the cleaner flotation circuit, where the concentrate is further upgraded. Oversize from the trash screen will discharge to a bunker and undersize is pumped to the cleaner circuit. Sodium metabisulphite will be added to prevent pyrite flotation. Tailings from the cleaner circuit will be recycled to the rougher/scavenger cells. Concentrate from the second cleaner stage (Cleaner 2) forms the final copper concentrate and will be pumped to the copper concentrate thickener.

Tailings from the copper rougher/scavenger flotation cells will be pumped to the zinc flotation circuit.

2.6.4 Zinc Flotation

Copper rougher/scavenger flotation tailings are directed to the zinc conditioning tank where reagents (including potassium amyl xanthate (PAX), copper sulfate and lime) are added to the slurry. The zinc flotation circuit is similar to the copper circuit. Its configuration includes six rougher/scavenging cells and two stages of four cleaner cells which produce a zinc-rich product and a barren tailing. Tailings from the zinc cleaner circuit are returned to

the zinc rougher/scavenger cells and final concentrate recovered from the second cleaner stage reports to the zinc concentrate thickener.

Tailings from the zinc rougher/scavenger circuit will be pumped to the tailings thickener.

2.6.5 Concentrate Handling

2.6.5.1 Concentrate Thickening and Filtration

Copper concentrate from the flotation circuit will be pumped to a high-rate thickener to increase the solids content to 65% solids by weight and discharged to the copper concentrate storage tank. The thickener overflow will gravitate to the copper flotation water tank for recycling to the flotation circuit. The same process will apply for zinc concentrate from the zinc flotation circuit

Thickened copper concentrate slurry will be pumped from the copper concentrate storage tank to a horizontal plate and frame pressure filter for dewatering. The filter will separate the water and solids to produce a filter cake, containing nominally 10% moisture by weight, and a filtrate solution. During the filtration process the cake can be washed with clean water to remove residual reagents. The filtrate solution will gravitate to the copper concentrate thickener. The copper filter cake will discharge into a concentrate bunker under the filter. The same process will apply for zinc concentrate from the zinc concentrate storage tank.

2.6.5.2 Concentrate Storage and Transport

The entire concentrate facility, including the loading area, will be contained within a shed on a concrete bunded area. The facility will incorporate a weighbridge and has been sized to accommodate four to seven days inventory for all concentrate filter cakes. This will cater for times when the access roadway to site is closed due to inclement weather. The handling of concentrate will take place within the shed and not on open aprons. Entry and exit points will have wheel wash facilities and shed doors will remain closed when not in use.

Risks of self-combustion are assessed as low due to modest rates of oxidation in test-work and concentrate in normal circumstances will not be stored for long periods.

Concentrate will be transported to Port Hedland Port in nominal 120 tonne quad configured road trains using half height containers fitted with lids (Qube Holdings' "Rotabox" containers, as used by others, or similar). The concentrate will be loaded into the half height containers directly onto the road train by wheel loader.

2.6.6 Reagents and Services

2.6.6.1 Reagent Mixing, Storage and Distribution

A number of reagents will be consumed in the process plant. These include the following:

- Lime. Supplied in bulk tankers and transported pneumatically into a 50 t silo on site. This will be mixed to 15% slurry and pumped via a ring main for distribution to the plant.
- Sodium Metabisulphite. Supplied in 1 t bulker bags. This will be mixed to a 15% solution and pumped by individual dosing pumps to the plant.
- A3894 copper collector. Supplied in 150 L drums. This will be mixed to a 15% solution and pumped by individual dosing pumps to the plant.
- Methyl Is Butyl Carbine (MIBC). Supplied in 200 litre drums as a liquid. This will be distributed at full strength by individual dosing pumps to the plant.
- Potassium Amyl Xanthate (PAX) Zinc Collector. Supplied in one t bulker bags. This will be mixed to a 15% solution and pumped by individual dosing pumps to the plant.

- Copper Sulphate Activator. Supplied in 1 t bulker bags as crystals. This will be mixed to a 15% solution and pumped by individual dosing pumps to the plant.
- Flocculant. Supplied in dry powder form in 25 kg bags. This will be mixed using a proprietary mixing plant to 0.25% solution strength and metered direct to the thickeners.
- Sulphuric Acid. Supplied in 98% solution form by tankers. This will be distributed at full strength via a ring main.

All chemical reagents will be stored within tanks in appropriately bunded facilities whereby 110% of the largest vessel is contained and 25% of the total volume is contained according to *Australian Standards AS1940* and *AS1692*. Stocks of reagents will be stored in a designated Reagents Shed, appropriately designed to comply with all relevant legislation.

2.6.6.2 Water Services

A number of water systems will operate in the process plant. These include the following:

- Process Water. Supplied from the tailings thickener overflow and treated decant return and topped up with raw water as required. This will be used for major processing plant dilution, plant washdown and tails line flushing.
- Copper Circuit Water. Supplied from the copper concentrate thickener overflow and topped up with raw water as required. This will be used for dilution, sprays and launder water in the copper flotation circuit.
- Zinc Circuit Water. Supplied from the zinc concentrate thickener overflow and topped up with raw water as required. This will be used for dilution, sprays and launder water in the zinc flotation circuit.
- Raw Water. Supplied from treated mine water, with any make up provided by a local bore (if required). Stored in a HDPE lined pond on site and reticulated for heap leach, SX-EW, power station, crushing and agglomeration area, reagent mixing, thickening and filtration.
- Accommodation Village Potable Water. Supplied from one of the existing bores SSWB036, SSWB038, or SSWB040, which are licenced under GWL 176408(3). A 5 m^3/hr potable water treatment plant will be installed to treat this water, prior to use in the accommodation village.
- Process Plant Potable Water. Supplied from mine dewatering and/or an abstraction bore proposed for the project (SSWB006). A 2 m^3/hr potable water treatment plant will be supplied for the process plant.
- Fire Water. A reserve will be held in the raw water tank and reticulated to the process plant hydrant and hose reel system via a pump skid incorporating electric and diesel pumps.
- Storm Water. Two HDPE lined ponds to capture and store rainfall runoff within site infrastructure areas. The ponds will be sized to contain runoff from plant areas associated with a 1 in 100 year, 72 hour event.

2.6.6.3 Air Services

High and low pressure air will be required on site. Low pressure air will be supplied by three blowers and reticulated to the flotation circuit. High pressure air will be supplied by three compressors and reticulated for filtration and plant air.

2.7 TAILINGS STORAGE FACILITY

Process tailings will be thickened to approximately 60% solids before being pumped to a 'valley fill' TSF with a combined HDPE and compacted low permeability sub-base liner located northeast of the plant as shown in Figure 5. Preliminary designs indicate that approximately 7.4 Mt of tailings will be stored in the TSF over the life of the project with an estimated 0.2 Mt being used for underground fill. The heap leach facility will be integrated within the final footprint of the TSF.

2.7.1 Location

The proposed TSF site (Figure 5) was selected for the following reasons:

- It is adjacent to the processing plant.
- The valley size is suitable to store the full volume of tailings and evaporate excess water within the one location, therefore minimising the requirement for additional associated elements.
- No heritage sites or areas of cultural importance have been identified within the footprint.
- No *Pityrodia sp. Marble Bar* individuals have been identified within the footprint to date.
- Habitats within the footprint consist predominantly of rocky foothills and scree slopes, which are considered widespread throughout the landscape.
- It is more than 500 m from the underground mine so as to prevent any potential interconnection between underground workings and stored tailings.

2.7.2 Design

Geochemical characterisation studies on simulated tailings samples indicate process tailings will be PAF. A rigorous TSF design is therefore proposed to minimise potential impacts to the receiving environment. This design will comply with the *Guide to Departmental Requirements for the Management and Closure of Tailings Storage Facilities* (DMP 2015) and encompass the following:

- A combined liner system across the basin comprising:
  - A 200 mm thick low permeability soil / clay liner sub-base constructed from in situ and imported materials placed in two layers, conditioned and compacted (target permeability of 10^{-8} m/s).
  - A 1.5 mm HDPE liner placed over the compacted low permeability sub-base liner to provide primary containment with a minimum overall permeability of 2×10^{-11} m/s. High standards of construction supervision will be applied during placement of the HDPE liner to ensure that defects are minimised.
- An underdrainage system across the basin, above the HDPE liner. Preliminary designs include a network of finger drains (Draincoil pipes in sand wrapped in geotextile) across the full basin area draining to a collector drain running down the spine of the valley. The collector drain will consist of a sand drain wrapped in geotextile incorporating two larger diameter Draincoil pipes. The collector drain will drain to a sump at the upstream toe of the embankment with a HDPE outlet pipe installed up the upstream embankment face.
- A Leakage Collection and Recovery System (LCRS) installed below the combined HDPE and compacted low permeability sub-base liner, along the spine of the valley to intercept any seepage water which passes through the liner system. Preliminary designs include a 160 mm Draincoil pipe in a 600 mm wide, 500 mm deep trench draining to a LCRS sump. From this sump, water will be returned to the TSF surface for evaporation.
- The TSF embankment will be constructed in a downstream configuration in stages to suit the valley profile and rate of tailings generation. The embankment will be a multi-zoned embankment consisting of a 1.5 mm HDPE liner on the upstream face with an underlying 6 m wide low permeability zone constructed from in situ and imported materials placed, conditioned and compacted with a minimum overall permeability of 10^{-11} m/s. High standards of construction supervision will be applied during placement of the HDPE liner to ensure that defects are minimised. The downstream structural zone will be constructed of selected weathered mine waste from the open pit placed, moisture conditioned and compacted by heavy vehicles traffic (Figure 10).
- Sufficient oxidised NAF waste from the open pit for construction of the TSF embankment and encapsulation of the TSF at the end of its life will be placed adjacent to the TSF in a landform integrated with the initial TSF embankment. This will facilitate rehabilitation of the facility at the end of the mine life or in the event of an unplanned suspension or closure.

- Deposition modelling has been undertaken using the RIFT modelling package. Deposition of tailings will be from the embankment and abutments, driving the pond up the valley to the northwest. Decants will be used to recover water, with the water pumped to a water treatment plant for acid neutralisation and reuse in the processing plant.
- A series of monitoring bores installed to monitor groundwater levels and quality. These bores will be sized such that they can be converted into production bores to abstract water if required.

The conceptual TSF and heap leach facility layout at the final stage of deposition at the end of mine life is shown in Figure 9.

2.7.3 Stability

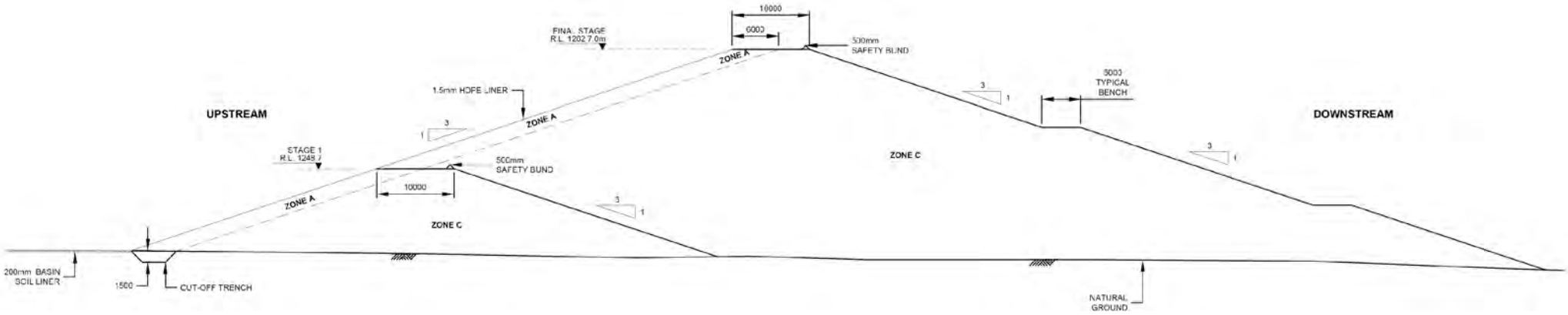
A stability analysis will be conducted as part of the design phase for the project (KP 2016). It is anticipated that stability of the embankment will be acceptable due to the following:

- The embankment is a fully downstream configuration.
- The upstream HDPE liner and low permeability zone will inhibit the movement of water resulting in a low phreatic surface through the embankment.
- The Operating Basis Earthquake (OBE) seismic loading of the embankment is 0.10 g, which is low.

2.7.4 Surface Water Management

To facilitate mining, dewatering of the open pit will commence approximately 11 months prior to commencement of tailings deposition. During this period, mine dewatering will be discharged to the 'valley fill' TSF which sits within a catchment area of approximately 65 ha. After the commencement of tailings deposition, surplus water will be added to the tailings stream.

A water balance has been developed to model changes in the level and surface area of water ponding on the TSF for the project life. This model has considered parameters such as TSF catchment area (Stages 1 to 6), rainfall runoff, evaporation, water treatment plant efficiency and tailings discharge rate (KP 2016). The modelling shows that the pond is the controlling level factor prior to commissioning and for about nine months after the tailings deposition commences. After this period, the pond is smaller than the storage available on the sloping tailings surface and the tailings level controls the embankment design. In order to prevent the tailings and/or the pond in the TSF flooding into the heap leach ponds during the heap leach operating period, a bund will be constructed at the downstream end of the heap leach area. The height of the bund will be a function of the volume of water stored in the TSF plus the volume associated with a one in 100 year, 72 hr rainfall event. A freeboard allowance of 0.3 m was also incorporated to define the required bund level (KP 2016).



Not to Scale Original Size: A4 Source: Knight Piésold 2016	Venturex Resources Limited Sulphur Springs Project	**Figure 10** **Typical Tailings Storage Facility Embankment Section**	4 Cook St West Perth WA 6005 Ph: (08) 9226 3166 Fax: (08) 9226 3177 info@mbsenvironmental.com.au www.mbsenvironmental.com.au

2.8 PROJECT WATER REQUIREMENTS

Project water requirements at the mine site, accommodation village, dust suppression around the entire site and for make-up water at the processing plant (approximately 0.65 GL/yr) will be met by the following:

- Mine dewatering.
- Groundwater abstraction from mine production bore SSWB06 in the vicinity of the mine and processing plant.
- Groundwater abstraction from bores SSWB36, SSWB38 and SSWB40 located along the site access road. Required for the potable water at the camp.

Table 11 provides an indication of annual abstraction volumes from each of the above sources. Mine dewatering will provide the majority of water for the project (approximately 0.64 GL/yr) and the remaining 0.01 GL/yr will be sourced from bores SSWB06, SSWB36, SSWB38 and SSWB40.

Table 11: Sulphur Springs Groundwater Abstraction

Water Source	Approximate Annual Abstraction (GL/yr)
Mine Dewatering	0.64
Bore SSWB06	0.01
Bores SSWB36, SSWB38 & SSWB40	
TOTAL	**0.65**

Additional water, if required, may be sourced from SSWB06 (up to 0.19 GL/yr) and bores SSWB36, SSWB38 and SSWB40 (up to 0.04 GL/yr).

Groundwater modelling conducted by URS (URS 2007a, 2013) estimated the expected groundwater inflow rates during mining, based on both previous studies at the site and the proposed underground mine design and production sequence. Pit dewatering will utilise approximately four strategically located vertical dewatering bore holes equipped with electric submersible pumps. As mining progresses, sub-horizontal drain holes will be drilled in the pit wall to compliment these vertical dewatering bore holes.

Two trailer-mounted, diesel-powered pit dewatering pumps will provide in-pit dewatering from sumps, as required, during mining of the pit.

Groundwater abstraction bores that may be utilised for the project are shown on Figure 11. No water will be discharged from site and any surplus water from mine dewatering will be evaporated within the dual lined TSF or will be reused for processing.

2.8.1 Mine Dewatering

A mine dewatering system will be required to allow safe mining operations. The predicted dewatering volume is approximately 0.64 GL/yr. Dewatering will be effected via a combination of in-pit sumps and groundwater abstraction bores.

2.8.1.1 Groundwater Quality

Groundwater samples collected in the vicinity of the pit indicate mine dewatering will initially be acidic (pH 3.4 to 4.8), saline (1,800 mg/L) and contain elevated concentrations of dissolved metals including arsenic, cadmium, copper, lead, manganese, selenium and zinc. Beyond the vicinity of the pit, groundwater quality data indicates

that there may be finite volumes of comparatively poor, high salinity and acidic groundwater in storage. As these volumes are abstracted during the initial stages of mine dewatering, there will be mixing and dilution with groundwater increasingly derived from broader and un-mineralised source areas. Over time, groundwater quality is therefore likely to be similar to that of the regional aquifer systems which are typically lower in salinity and near-neutral in pH. Water from mine dewatering will report to a water treatment plant for acid neutralisation, prior to use in the processing plant. Any excess mine water will be discharged to the valley fill dual lined (HDPE and compacted low permeability sub-base) TSF where, under the prevailing climatic conditions, it will evaporate quickly.

2.8.1.2 Groundwater Drawdown

The hydrogeology of the mine and project area has been extensively studied and is well understood. Drawdown impacts associated with mine dewatering are predicted to be constrained in distribution and magnitude by country rocks of low transmissivity. Interpreted structures that intersect the underground mine are of limited lateral extent and this aspect provides another constraint that limits the propagation of drawdown. Potential drawdown impacts are summarised as follows (URS 2007a):

- A steep cone of water table drawdown in the immediate vicinity of the underground mine.
- A drawdown cone that is elliptical preferentially propagated along the interpreted solution-cavity zone and the zone near the confluence of the Main, Gorge and Creek faults.
- Drawdown distributions that also preferentially propagate along the two faults that transverse the deposit (Main and Gorge fault).
- Potential drawdowns of magnitude up to 1.0 m that propagate to distances up to about 1.5 km from the underground mine.

2.8.2 Process Makeup Water Production Bores

Water drawn from an existing bore in proximity to the mine and processing plant SSWB006, will be utilised (when required) to supplement supply from mine dewatering and for potable water at the process plant.

Groundwater quality within SSWB006 is predicted to be $MgHCO_3$ and Na-$MgHCO_3$ in type, with the major ions being HCO_3, Mg, Na and Cl (URS 2007a). Measured dissolved silica concentrations are relatively high (in the range 10.9 to 59.2 mg/L). These concentrations may indicate episodes of silicate weathering are influencing the groundwater chemistry in the granite domain. Metal, metalloids and non-metallic inorganics were measured in February 2007. A comparison with trigger values for freshwater ecosystem health show existing soluble Cu and Zn concentrations may exceed the guidelines. Selected groundwater samples also showed concentrations of Cd, nitrate and nitrogen that exceeded guidelines. Results obtained from the existing groundwater quality will be utilised as background water quality levels.

2.8.3 Haul Road South Production Bores

Water drawn from bores adjacent to the Venturex mine access road (from existing bores SSWB036, SSWB038 and SSWB040) will also be used to supply Venturex's accommodation village and the site access road (during construction and for ongoing dust management as required). GWL 176408(3), issued to Atlas Iron Limited (Atlas), permits abstraction of up to 0.315 GL/yr from these bores, which are all located on Venturex tenements. Venturex has collaborated with Atlas to develop a Water Management Plan and a Site Water Operating Plan for the licenced abstraction. Venturex will also discuss licence transfer options with Atlas. No change to the permitted abstraction volume of 0.315 GL/yr is proposed and no additional clearing or infrastructure is required.

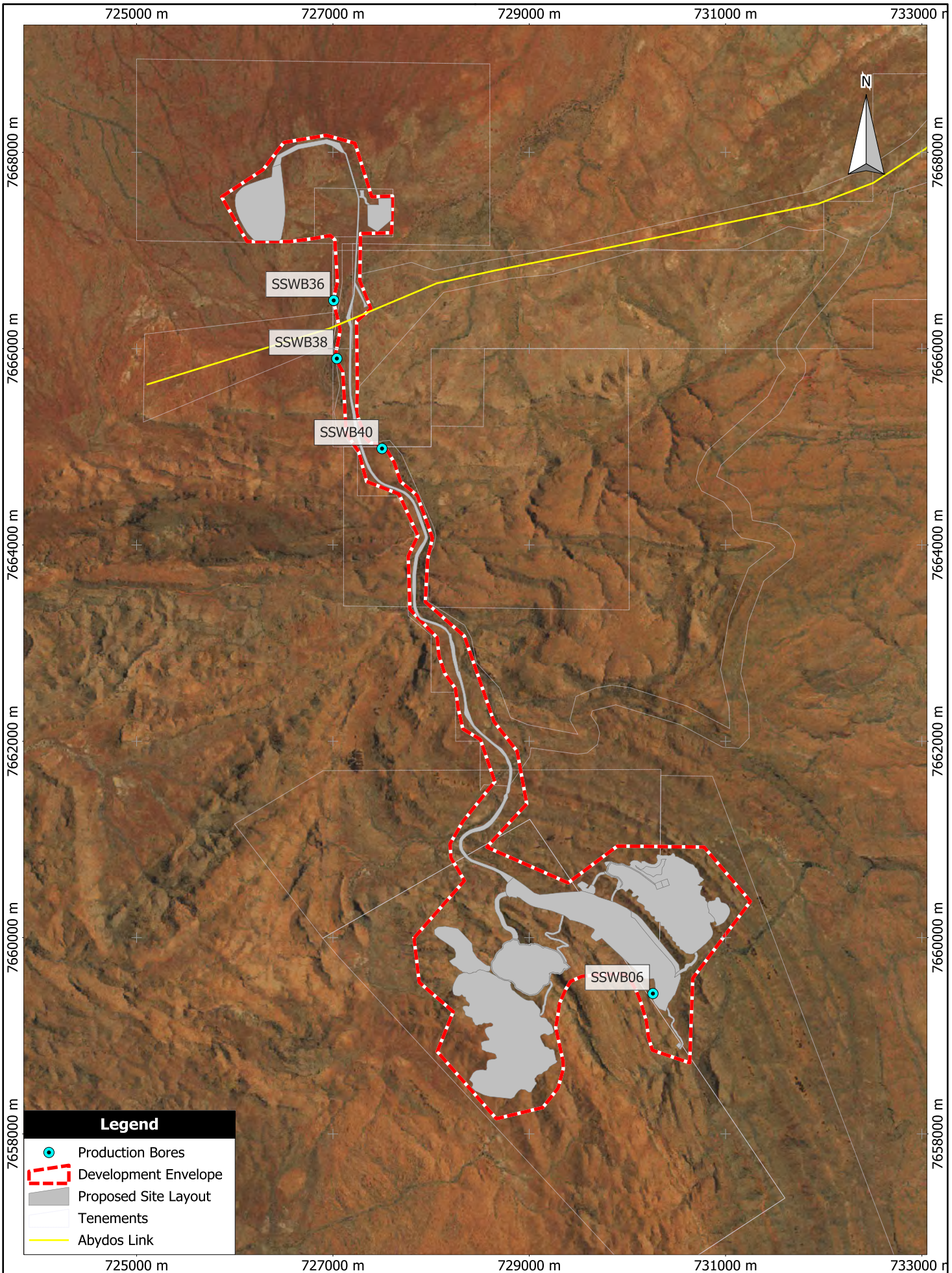
Groundwater quality in the vicinity of these bores was measured in reconnaissance surveys conducted in 2006 and 2007 (RMDSTEM 2013). Salinity concentrations in samples were low and within, or close to, ANZECC 2000 Drinking Water Guidelines humans (436 to 764 mg/L total dissolved solids), with a slightly alkaline pH range (7.1

to 8.2). Groundwater was Mg-HCO_3 in type, with the major ions being bicarbonate, magnesium, sodium and chloride. Dissolved silica concentrations were relatively high (40.7 to 54.8mg/L).

2.8.4 Water Licences

Venturex currently holds Groundwater Licence GWL 165207(4), which permits abstraction of up to 150,000 kL/yr from the fractured rock aquifer within M45/494 for general campsite purposes. Venturex will seek approval from DoW to increase abstraction for the purposes of mining, dust suppression and ore processing.

GWL 176408 (3) is held by Atlas and permits abstraction of up to 1,198,368 kL/yr from nine production bores within the fractured rock aquifer for the purposes of dust suppression, earthworks and construction and potable water supply. Four of these bores (SSWB036, SSWB038, SSWB040 and PAN60) are located on Venturex tenements (L45/188, L45/189 and L45/287) and the associated Site Water Operating Plan (Atlas 2013) stipulates abstraction of up to 0.315 GL/yr from these four bores. As discussed above, Venturex is currently discussing licence transfer options with Atlas, but no change to the water allocation or existing infrastructure is proposed.



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Venturex Resources Limited
Sulphur Springs Project

Figure 11

Groundwater Abstraction Bores

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W:\Venturex Resources\Sulphur Springs\Projects\EPA Referral V2\Drawings\Sulphur Springs EPA Referral V4.map 23/11/2016 F11 Groundwater Abstraction Bores Layout

2.9 SUPPORT FACILITIES

Support facilities proposed for the project are summarised in the sections below. The final location of these facilities will consider factors such as:

- Avoiding potential mineralised areas.
- Landform and topography.
- Presence of conservation significant flora and fauna species and communities.
- Locations of watercourses and associated flood zones.
- Heritage sites.
- Distances to other associated Sulphur Springs elements.
- Separation distances to protect human health.

2.9.1 Power Supply

Power will be supplied from a diesel fired power station. The facility will consist of 5 x 2 MW gensets. Generators will be housed in containers and located on a flat earthen pad and fuel supply will be piped from a day tank and pump.

The power station and associated fuel storage facilities will be located south of the processing facilities to allow easy access for fuel unloading and a clear path for high voltage distribution to the process plant via a piperack. Power will be generated at 11 kV and reticulated to two substations; one at the primary crushing area and one next to the grinding mills. Power will be stepped down to 415 V for reticulation to the remainder of the process plant.

The accommodation camp and remote facilities will be powered by standalone diesel generators.

Open pit mining dewatering will utilise two trailer mounted pumps with a standalone generator.

2.9.2 Fuel Storage

Diesel will be stored onsite in 10 x 110 kL self bunded tanks providing a total storage of 1,100 kL. The facility will include a fuel unloading system, access, lighting and all necessary safety systems. At the reduced power draw this is expected to provide sufficient storage for 20 days use in the power station. Fuel for the powerhouse will be pumped from this storage to the power station day tanks.

A single (110 kL) self bunded diesel tank will be installed at the accommodation village to supply the standalone generator.

All hydrocarbons will be stored within appropriately bunded vessels or within bunded areas. Spill kits will be located at storage areas and in service vehicles and all personnel will be trained in their use. Hydrocarbon storages and machinery will be regularly inspected for leaks and any spills will be cleaned up immediately, with contaminated material disposed of appropriately.

2.9.3 Water Treatment Plant

The accumulation of water in the TSF will require installation and operation of a 25 m^3/hr water treatment plant which will be located in proximity to the processing plant.

2.9.4 Communications System

Communication to the site will be via a microwave system linked to the Atlas Iron Abydos mine infrastructure located 9.5 km from the village. From there, it will be linked via the Atlas Iron microwave network to the Telstra optic fibre network at Wodgina. Systems will include:

- Phone and data
- LAN and IT network
- Two-way radio and PABX
- Fibre optic cabling
- Microwave communications.

2.9.5 Plant Buildings

A number of support buildings including a laboratory, administration office, first aid centre, crib room, mine office, plant office, workshop/warehouse, control room, ablutions and reagent storage will be constructed for the project.

2.9.6 Laydown Areas

Two laydown areas (plant and core yard) will be established for the project.

2.9.7 Accommodation Village

A 200 room permanent village will be established on site and an additional, temporary camp will be installed for construction. The nearly Abydos accommodation village will also be utilised, if required, for any additional accommodation required during construction.

An alternative site for the accommodation camp (closer to the operational area) was considered. However, due to potential impacts on habitat for significant fauna and threatened flora species, this option was discounted.

The project will be operated on a drive-in drive-out basis from Port Hedland. It is expected that a significant portion of the workforce will live in Port Hedland with the remainder commuting from Perth and other regional centres.

2.9.8 Wastewater Treatment

Two 20 m^3 /day package wastewater treatment plants will be installed for the project; one for the accommodation village and one for the processing plant and site office area.

2.9.9 Landfill

Two landfills will be established on site (one for inert waste and one for putrescible waste). The putrescible waste landfill will be established in proximity to the village and the inert waste landfill is likely to be established close to the processing plant.

2.9.10 Washdown Facility

A washdown facility will be constructed, consisting of light/heavy vehicle drive through areas with high pressure spray water for cleaning. Solids and dirty washdown water will drain to a primary settlement sump where the solids settle out. Oily water will overflow to an adjacent cell where oil will be separated using an oil skimmer and the oil will be pumped directly to a small waste oil tank.

Waste oil will be removed from site by a licenced contractor for disposal at a licenced facility in Port Hedland.

Excess water will be pumped to a runoff water pond for either evaporation or reuse.

2.9.11 Roads

A 7.4 km access road (referred to as the valley access road) connecting the mine site to the Abydos link will be constructed along the route shown in Figure 3. Two major creek crossings are required along this route where cross-cutting valleys direct water flows into the main creek system. The crossings have been designed with sufficient drainage pipes to handle predicted creek flows resulting from a rainfall intensity of 5.3 mm/h for a 72 hour 1 in 100 year event, without overtopping. In the event of shorter, higher intensity storms the road may overtop for short periods.

Several additional (internal) site roads will also be required to connect site elements.

Roads shall generally be 12 m wide for two way traffic and constructed with drains on either side to allow for runoff water. The roads will be designed to accommodate heavy vehicles that will be required to supply the project with construction equipment, deliveries of fuel, consumables, reagents and other general goods.

2.10 CLOSURE AND REHABILITATION

A site-wide Mine Closure Plan (MCP) for Sulphur Springs was approved by DMP in April 2014, together with Mining Proposal REG ID 40542. The MCP will be revised to address the changes proposed under this Referral and prepared in accordance with the DMP Guidelines for Preparing Mine Closure Plans (DMP & EPA 2015). The following sections outline specific closure aspects for project.

2.10.1 Open Pit

Hydrogeological studies have indicated that the pit floor will be below existing groundwater levels and if left in this state, a pit lake is predicted to form after closure. Previous modelling (Golder 2007) indicates such a pit lake would exhibit the following characteristics:

- A steady state elevation that is significantly lower than the surrounding groundwater surface. Under such conditions, the lake would remain as an evaporative sink within the confines of the pit with no outflows to the environment.
- More than sufficient freeboard to store water inflow resulting from two consecutive 1 in 100 year 72 hour rainfall events.
- Contained water is likely to be low in pH and contain elevated concentrations of dissolved metals. This is similar to existing surface water in the vicinity of the proposed pit at present. As the pit is expected to remain as an evaporative sump, this water is not predicted to migrate to the receiving environment.

Further modelling based on additional geochemical data and the proposed open pit profile will be conducted as part of the feasibility study.

2.10.2 Waste Rock Dump

The WRD will be constructed as a long term stable land form and surface treatment upon completion will reflect the ongoing land use. Construction details for the WRD have been provided in Section 2.4.3. Closure of the WRD will incorporate an engineered cover, designed to minimise ingress of air (oxygen) and water to the encapsulated PAF cell, therefore reducing the potential to generate AMD.

2.10.3 Tailings Storage and Heap Leach Facility

The primary goals for the combined TSF and Heap Leach Facility closure design are to create a single integrated landform with a final surface that is:

- Water shedding with no potential ponding.
- A spillway located at the lowest relief to allow water shedding.
- Erosion resistant.
- Low in permeability such that the surface infiltration rate is less than the seepage rate out of the base of the facility.

A conservative approach to preliminary designs for the cover of the integrated facility at closure has been taken to minimise potential impacts to the receiving environment. Designs include the following features:

- Underdrainage and leak collection and recovery systems.
- Following drainage and shaping of the tailings and heap leach pad surface, a combined liner system will be installed across the top of the integrated structure comprising:
  - A 200 mm thick sub-base constructed from in situ and imported materials placed, conditioned and compacted with a target permeability of 10^{-8} m/s.
  - A 1.0 mm HDPE liner placed over the compacted sub-base liner to provide primary containment of the tailings. High standards of construction supervision will be applied during placement of the HDPE liner to ensure that defects are minimised.
- A protection layer above the HDPE liner (150 mm) consisting of silt, sand or rounded gravel materials.
- A 300 mm zone of weathered NAF waste rock zone won from the integrated land form adjacent to the TSF.
- A topsoil cover equivalent in thickness to the topsoil removed from the basin area. The topsoil will be integrated with the underlying rock zone to ensure the overall surface is erosion resistant.

The detailed design will comply with the *Code of Practice for Tailings Storage Facilities in Western Australia* (DMP 2013) and *ANCOLD Guidelines on Tailings Dam Planning, Design, Construction, Operation and Closure* (ANCOLD 2012).

Ongoing monitoring of site conditions during operations (such as infiltration rates, underdrainage system seepage volume and quality and groundwater bores in the vicinity of the structure) will allow more rigorous assessment of closure requirements.

2.10.4 Other Site Infrastructure

At the completion of the project, the majority of buildings, plant, pipelines and tanks will be decommissioned, dismantled and removed from site for salvage or scrap. Remaining structures will be demolished for burial in place or in the pit, so that no hazardous structures remain. Any site contamination identified will be remediated such that it poses no threat to public health and safety or the ability to conduct agreed post-closure land uses.

Disturbed areas will be reshaped to be free-draining, with natural drainage reinstated as far as practicable. This work will include filling in the processing plant stormwater drain and pushing in the stormwater containment pond. Areas will be deep ripped to reinstate infiltration and supplementary seed will be spread, if monitoring indicates this is required.

Access to the site will be prevented with bunds across access roads, and signs.

3. EXISTING ENVIRONMENT

3.1 STUDIES AND INVESTIGATIONS

A large number of baseline surveys have been commissioned at Sulphur Springs and as shown in Table 12. The more recent studies have been conducted in accordance with the current EPA guidance statements. These studies compliment the broader regional scale studies that have been conducted throughout the Pilbara.

Venturex has also committed to undertake additional studies prior to any ground disturbing activities and this is discussed further in Section 4.

3.2 REGIONAL SETTING

Sulphur Springs copper/zinc mineralisation is a volcanogenic massive sulfide deposit in the central eastern terrain of the Archaean Pilbara Craton, in the northwest of WA.

The project is located within the Pilbara bioregion, which covers an area of approximately 178,500 km^2. This region is divided into four subregions: Chichester, Fortescue, Hamersley and Roebourne. The project falls within the Chichester subregion, which encompasses 47% of the Pilbara bioregion.

The Chichester subregion is approximately 90,445 km^2 in size and is characterised by undulating Archaean granite and basalt plains including significant areas of basaltic ranges. This region is generally mountainous with elevations up to 1,250 m above sea level, hard alkaline red soils on plains and pediments, and shallow and skeletal soils on ranges (Kendrick and McKenzie 2001).

The basalt plains host a shrub steppe of *Acacia inaequilatera* over *Triodia* spp. hummock grasslands, while tree steppes of *Eucalyptus leucophloia* occur on the ranges. Grazing of native pastures forms the dominant land use in the region with Aboriginal lands and Reserves, Unallocated Crown Land and Crown Reserves, Conservation and Mining Leases also covering significant areas within the landscape (Kendrick and McKenzie 2001). The Chichester sub bioregion lies predominantly inland from the coast.

Table 12: Summary of Studies Undertaken at Sulphur Springs

Aspect	Study Report	Author	Year	Status	Applicable Policy and Limitations
Flora	A flora and vegetation survey of the proposed mine areas and access road for the Panorama Project.	Trudgen et al.	2002	Complete	Declared Rare and Priority Flora List (Atkins 2006)
	Rare Flora searches of a proposed campsite, tailings dam and waste dumps and observations on vegetation condition for the Panorama project.	Trudgen	2006	Complete	Declared Rare and Priority Flora List (Atkins 2006)
	Supplementary Botanical Surveys, Rare Flora Searches, Assessment of Vegetation Condition and Identification of Groundwater Dependent Ecosystems for the Sulphur Springs Project.	Trudgen	2007	Complete	Declared Rare and Priority Flora List (Atkins 2006)
	A Review of the Flora and Vegetation and an Assessment of Groundwater Dependant Ecosystems in the Panorama Project Survey Area.	Mattiske Consulting Pty Ltd	2007	Complete	Guidance Statement No. 51: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (EPA 2004a).
	Venturex Resources Limited Pilbara Copper Zinc Project. Level 1 Vegetation and Flora Survey.	Outback Ecology	2013	Complete	Guidance Statement No. 51: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (EPA 2004a). Three limitations were noted during the survey. These were: • Some areas were inaccessible and unable to be covered by field staff. • Season rainfall was lower than average and the survey did not take place in the peak flowering season due to time constraints. • Some limitations to survey completion were experienced due to limited accessibility on site.
Fauna	Panorama Project Area: Baseline Fauna Study as Part of the Sulphur Springs Feasibility Study.	Bamford Consulting Ecologists	2001	Complete	• Guidance Statement No. 56: Terrestrial Fauna Surveys for Environmental Impact Assessment (EPA 2004b). • Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002).
	Panorama Project: Mine Site and Haul Road	Biota	2007	Complete	• Guidance Statement No. 56: Terrestrial Fauna Surveys for

Aspect	Study Report	Author	Year	Status	Applicable Policy and Limitations
	Corridor Targeted Fauna Survey.				Environmental Impact Assessment (EPA 2004b). • Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002). • Limitations of this study included the fact that sampling was not undertaken as per season guidelines.
	Field Survey for conservation significant bats near Sulphur Springs, Pilbara: field survey and management advice.	MOLHAR Pty Ltd	2007	Complete	N/A
	Pilbara Copper-Zinc Project. Level 1 Terrestrial Fauna Survey.	Outback Ecology	2012	Complete	• Guidance Statement No. 20: Sampling of Short Range Endemic Vertebrate Fauna for Environmental Impact in Western Australia (EPA 2009). • Guidance Statement No. 56: Terrestrial Fauna Surveys for Environmental Impact Assessment (EPA 2004b). • Technical Guide: Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessments (EPA 2010). • Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002).
	Pilbara Copper-Zinc Project. Terrestrial Vertebrate Fauna Impact Assessment	Outback Ecology	2012	Complete	• Guidance Statement No. 56: Terrestrial Fauna Surveys for Environmental Impact Assessment (EPA 2004b). • Technical Guide: Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessments (EPA 2010). • Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002). • Guidance Statement No. 20: Sampling of Short Range Endemic Vertebrate Fauna for Environmental Impact in Western Australia (EPA 2009). • Guidance Statement No. 56: Terrestrial Fauna Surveys for Environmental Impact Assessment (EPA 2004b). • Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002). The only partial limitation noted in this study was due to wet weather the number of targeted search site was reduced by one.
Short Range Endemics	Targeted Terrestrial SRE Invertebrate Fauna Assessment	Outback Ecology	2012	Complete	

Aspect	Study Report	Author	Year	Status	Applicable Policy and Limitations
Subterranean Fauna	Panorama Project Subterranean Fauna Survey Report 2 (Stygofauna phase 2 and 3, Troglofauna Pilot and phase 1)	Subterranean Ecology	2007	Complete	Guidance Statement No. 54: Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Assessment in Western Australia (EPA 2003).
	Panorama Project Subterranean Fauna Report 3: Troglofauna Phase 2 Results and Phase 3 Sites.	Subterranean Ecology	2007	Complete	Guidance Statement No. 54: Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Assessment in Western Australia (EPA 2003).
	Sulphur Springs Panorama Project Subterranean Fauna Report 4: Troglofauna Phase 3 Survey Results	Subterranean Ecology	2007	Complete	Guidance Statement No. 54: Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Assessment in Western Australia (EPA 2003).
	Subterranean Fauna Pilot Survey	Outback Ecology	2012	Complete	• Guidance Statement No. 54: Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Assessment in Western Australia (EPA 2003). • Guidance Statement No 54a: Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (EPA 2007). The only limitation to this study was that specimens could not always be identified to the level of species or morphospecies.
Water	Hydraulic Testing of Bores SSTP01, SSTP03 and SSWB01, Sulphur Springs Prospect.	Hydro-Resources	2002	Complete	State-wide Policy No. 5.12 – Hydrogeological Reporting Associated with a Groundwater Well Licence (DOW2009).
	Panorama Project – Surface Water Hydrology	URS	2007	Complete	N/A
	Water Supply Investigations – Sulphur Springs Project, Pilbara.	Golder Associates	2006	Complete	N/A
	Exploratory and test dewatering bore drilling and hydraulic testing of bore SSDW01 for the Sulphur Springs prospect.	Hydro-Resources	2002	Complete	N/A
	Groundwater Exploration Drilling and Field Reconnaissance June 2007 Panorama Project.	Golder Associates	2007		N/A
	Stage 2 Water Supply Investigations Sulphur Springs Project	Golder Associates	2007		N/A
	Assessment of the Post-Closure Pit Lake Quality – Sulphur Springs Project.	Golder Associates	2007	Complete	N/A

Aspect	Study Report	Author	Year	Status	Applicable Policy and Limitations
	Expanded Groundwater Exploration Target Generation Panorama Project	Golder Associates	2007		N/A
	Panorama Project Groundwater Resources Assessments	URS	2007		Guidelines for Fresh and Marine Water Quality (ANZECC 2000)
Soil and Landform	Panorama-Sulphur Springs Soil Profiling and Clay Classification	URS	2007	Complete	N/A
	Geotechnical Investigation for Plant Site, Panorama Project, Port Hedland	Soil & Rock Engineering	2001		• Geotechnical Site Investigations (SAA 1993) • Method of Testing Soils for Engineering Purposes (SAA 2000)
Geochemical Characterisation	Geochemical Characterisation of Process-Sample (Static Test work): Implications for Process-Tailings Management.	GCA	2002	Complete	N/A
	Geochemical Assessment of Waste Rock and Tailing Materials. Conceptual WRD Design and TSF Cover Design Strategy.	URS	2007	Complete	• Guidelines for Fresh and Marine Water Quality (ANZECC 2000). • Guideline on Investigation Levels for Soil and Groundwater. Groundwater Investigation Levels (NEPC 1999).
	Conceptual design of cover system for Panorama TSF. Letter Report including updated infiltration modelling of TSF cover system.	URS	2007	Complete	N/A
	Geochemical Characterisation of Waste Rock for the Sulphur Springs Project.	RGS	2008	Not Complete	• Technical Guidelines for the Environmental Management of Exploration in Queensland (DME 1995). • Managing Acid and Metalliferous Drainage (DTIR 2007)
	Sulphur Springs Project. Sulphur in Waste Rock	C.H. Lutherborrow	2008	Complete	N/A
	Literature Review and Generic Discussion to Facilitate Conceptual Planning for Process-Tailings Management.	GCA	2011	Complete	N/A
	Geochemical Characterisation of Mine-Waste Samples (Sulphur Springs Deposit) – Implications for Mine-Waste Management.	GCA	2012	Complete	Global Acid Rock Drainage Guide (INAP 2009)
Heritage	Report on an Ethnographic Survey of Seven Exploration Areas within the SIPA-Ashling Joint Venture Panorama Project	R. O'Connor	1993	Complete	N/A

Aspect	Study Report	Author	Year	Status	Applicable Policy and Limitations
	Report on An Archaeological Survey SIPA – Ashling-Joint Venture Panorama Project Area West of Marble Bar	G.S. Quartermaine & C.L. Mattner	1993	Complete	N/A
	An Ethnographic Heritage Survey for the Panorama Joint Venture Project – Njamal Native Title Claimants	Pilbara Native Title Service	2001	Complete	N/A

3.3 CLIMATE

Sulphur Springs is located within the North-West (Pilbara) Climate Zone of Western Australia (Australian Rain and Runoff zoning). The climate is semi-arid to subtropical, typically experiencing high rainfall during the cyclone season between December to April (Table 13). Climatic studies of the project area indicate that the site can expect similar conditions to that of the BoM weather station at Marble Bar Comparison (57 km to the east, BoM station number 004020). Weather data for Marble Bar indicates average daily maximum temperatures peak in December (41.6ºC) and remain above 36ºC between October and April. The lowest average minimum temperature is experienced in July (11.7ºC). Data is summarised in Chart 1.

Average annual rainfall at Marble Bar is 358.4 mm. Mean monthly pan evaporation significantly exceeds rainfall throughout the year, ranging from 170 mm in winter to 400 mm in summer (Table 13 and Chart 1).

Table 13: Monthly Rainfall and Evaporation – Marble Bar Comparison (BOM 2016)

Month	Monthly Rainfall (mm)			Evaporation (mm)
	Decile 1	Mean	Decile 9	Mean
January	15.9	76.3	164.3	350
February	12.2	87.8	179.8	280
March	2.4	56.7	135.5	290
April	0	21.9	59.1	250
May	0	23	70.7	200
June	0	23	74	170
July	0	12.6	41.7	170
August	0	6.4	23.6	200
September	0	0.9	1.8	260
October	0	3.8	7	350
November	0	9.1	30.5	380
December	2	39.6	90.7	400
Annual	190.9	358.4	555.6	3300

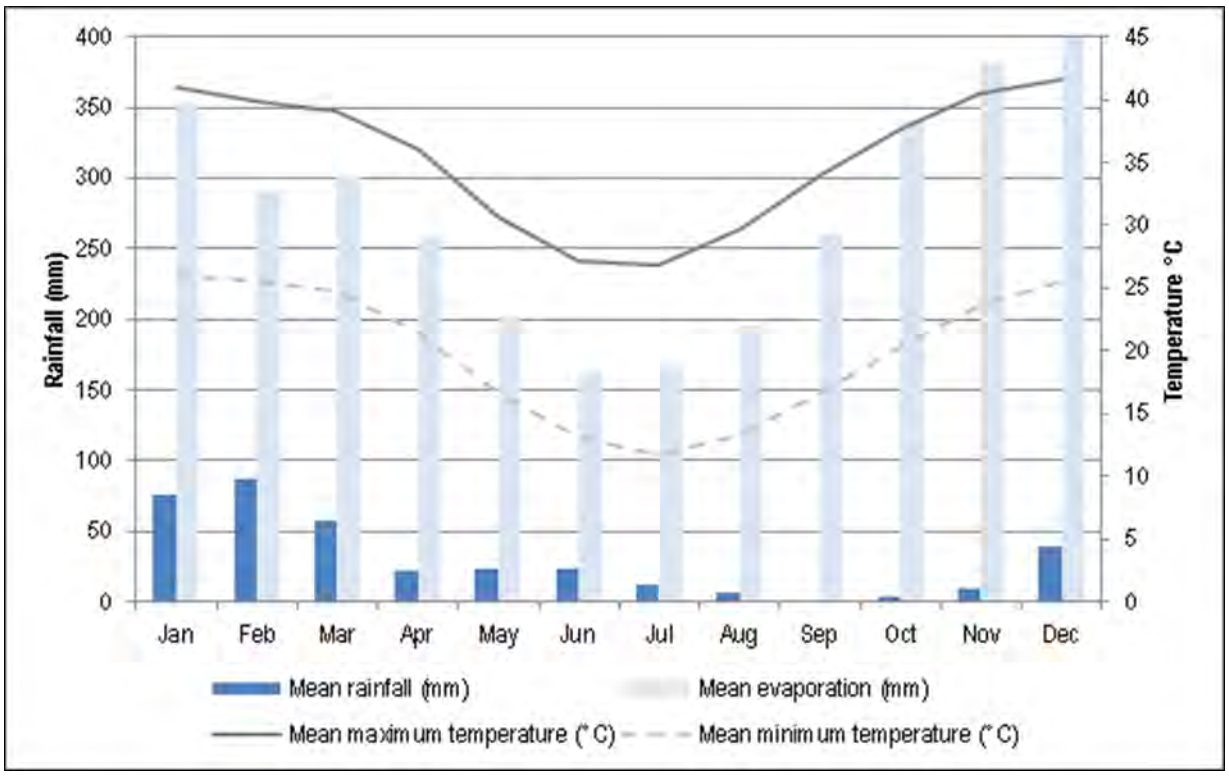


Chart 1: Rainfall and Evaporation Data – Marble Bar Comparison (BOM 2016)

3.4 GEOLOGY

3.4.1 Regional Geology

The Pilbara Craton comprises Archaean and paleo-Proterozoic rocks that outcrop in the Pilbara Region of northwestern Western Australia. The Craton consists of a 250,000 km^2 ovoid segment of terranes and basins. Most of the southern craton is concealed by the Hamersley Basin (URS 2007a).

The northern Pilbara Craton is divided into several types of tectonic elements, following Van Kranendonk (1998). These include lithotectonic terranes, polyphase granitic complexes, individual granitic intrusions, greenstone belts (East Pilbara Terrane only) and sedimentary basins of the De Grey Supergroup (Van Kranendonk et al., 2006 and URS 2007a) subdivided the Pilbara Craton into:

- The 3,650 to 3,200 Maximum Age (Ma) East Pilbara Terrane.
- The 3,270 to 3,060 Ma West Pilbara Superterrane comprising the Karratha, Regal and Sholl Terranes.
- The older-than 3,200 Ma Kurrana Terrane.
- The 3,020 to 2,930 Ma De Grey Superbasin, comprising five later, predominantly siliclastic sedimentary basins – the Gorge Creek, Whim Creek, Mallina, Lalla Rookh and Mosquito Creek Basins.

Sulphur Springs is located in the East Pilbara Terrane, the oldest component of the northern Pilbara Craton. The East Pilbara Terrane is a 'dome-and-basin' granite-greenstone domain in which ovoid granites are flanked by arcuate-shaped volcano-sedimentary packages. This Terrane represents the nucleus of the Pilbara Craton, formed through a succession of mantle plumes (3,530 to 3,230 Ma) that produced a dominantly basaltic volcanic succession, known as the Pilbara Supergroup, on an older sialic basement. Granitic complexes in the East Pilbara Terrane are structural domes that are separated from one another by faults or intervening greenstone belts, or both. Each complex contains several different age components, but many of the components are

common to several complexes, prompting the division of granitic rocks in the East Pilbara Terrane into suites and supersuites rather than by the complex in which they occur (Van Kranendonk et al., 2006).

3.4.2 Sulphur Springs Geology

The proposed Sulphur Springs open pit hosts a copper and zinc orebody linked to volcanogenic massive sulphide deposits. The geology and extent of mineralisation has been interpreted from a number of close-spaced mineral exploration drill holes. Geology flanking the orebody and proposed pit is based on regional mapping and isolated mineral (including groundwater) exploration holes.

The Sulphur Springs Group of the Pilbara Supergroup in the East Pilbara Terrane is host to the deposit mineralisation. Northeast portions of the open pit are also expected to intercept the Soanesville Group successions, which dip 50º to 55º to the northeast. Footwall rocks are predominantly formed of dacite/rhyodacite volcanics of the Kangaroo Caves Formation (Sulphur Springs Group). Sulphide mineralisation is strongly stratabound on the contact between the footwall successions and overlying marker chert beds. Mineralisation is interpreted to occur in association with stratabound shear zones that are concordant with the shear and foliation fabric of the marker chert. Hangingwall rocks include polymict breccias and upper chert beds of the Kangaroo Caves Formation and the overlying siltstone and quartz arenite of the Corboy Formation (Soanesville Group) (URS 2007a).

Sulphide mineralisation is dominated by massive pyrite, which contains enriched horizons of sphalerite and chalcopyrite. Galena is present in minor amounts. The sphalerite rich zone lies towards the top of the massive pyrite lenses. The copper rich zone of the deposit lies towards the base of the influence of the pyrite. The pyrite lenses have a gradational contact with the barren felsic volcanics beneath.

Faults influence the distribution of both the local stratigraphic successions and mineralisation. Most faults are only locally distributed; the Main Fault is different, being a normal fault of northerly strike, 80 m downthrow and mapped strike length of about 3,000 m within the Sulphur Springs Group succession. The Main Fault displaces the mineralisation; forming two distinct Western and Eastern lodes (Figure 7). This fault is not interpreted to propagate into the overlying Soanesville Group.

3.5 LANDFORM AND SOILS CHARACTERISATION

The geomorphology of the region is characterised by numerous rocky hills and gorges that control the flow of surface water. The project area has a diverse landscape, where the differential weathering of basement rocks has developed sharp local changes in relief around 175 m (range: 200 to 375 m AHD). In this landscape, the competent lithologies tend to form topologically high areas (such as ridge lines). In contrast, zones subjected to greater geological stress may preferentially weather and erode and be associated with valley floors. Sulphur Springs sits within three land systems; Boolgeeda, Capricorn and Rocklea. Vreeswyk *et al* (2004) have defined soil types of these land systems and determined their erodibility based on geological properties and landform (Table 14).

In general, soils of the granitic terrain and within the immediate vicinity of granite hills and outcrops across the site are red shallow sands. The hills give way to broad gently sloping plains with red sandy earths, red deep sands and red loamy earths (URS 2007b). Most soil types within the hills have significant to dominant proportions of stone throughout the soil profile and often have a very stony mantle and prominent rock outcrops. Other minor soils include red shallow loams with some red shallow sands. Soils become deeper downslope. In these areas the dominant soils are stony surfaced red loamy earths. The land systems show no sign of degradation or erosion and the condition of perennial vegetation is generally good to very good (URS 2007b).

Soil types of the area are not particularly susceptible to erosion except in cases where the surface mantle or crusting is removed. Shallow red stony earths may be susceptible to water erosion along tracks, and some areas of topsoil where no surface mantle exists may be moderately susceptible to wind erosion once vegetation has been removed.

Table 14: Land Systems of Sulphur Springs

Land System	Landform Types	Soil Types	Erosion Susceptibility
Boolgeeda	Gently inclined Stony Slopes and Plains.	Bare rock, red shallow earth, deep red sands, and channels with riverbed soils.	Vegetation not prone to degradation. Not susceptible to erosion.
Capricorn	Hills and Ridges of sandstone and dolomite with steep rocky upper slopes.	Stony soils, red shallow loams, red shallow sands and riverbed soils.	Vegetation not prone to degradation. Not susceptible to erosion.
Rocklea	Basalt Hills, Plateaux, lower slopes and minor stony plains.	Stony soils and calcareous shallow loams, red shallow sandy duplex soils, shallow red/brown cracking clays, self-mulching cracking clays or the gilgai plains, channels with riverbed soils.	Vegetation not prone to degradation. Not susceptible to erosion.

No landforms within project tenements are listed on the Western Australian Geoheritage Sites database. The large number of baseline surveys conducted across the site (including heritage and ethnographic studies), have not identified any landforms within project tenements that could be considered rare at a local, regional or national level.

3.6 HYDROGEOLOGY

The conceptual hydrogeology for Sulphur Springs has been characterised through interpretations of the Archaean geology, catchment distributions, data obtained during exploratory drilling and groundwater sampling programs (URS 2007a). Groundwater and surface water flow systems in the area are complex, variable and linked. There are strong correlations with topography, geology and structure in both the groundwater and surface water flow systems.

Groundwater type and quality varies across the project area. Groundwater sampling carried out in June 2007 determined that the dominant groundwater type was magnesium bicarbonate ($MgHCO_{3)}$, with minor magnesium – sodium chloride (Mg-NaCl) and magnesium sulfate ($MgSO_4$) groundwaters in upland areas (URS 2007a). There are no clear spatial patterns of groundwater type or electrical conductivity (EC; µS/cm) that indicate a catchment-scale flow path. This supports the conclusion that groundwater flow is compartmentalised.

More detail of aquifer systems and groundwater quality in the vicinity of proposed elements is provided in the following sections.

3.6.1 Open Pit

Local geology, mineralisation and structure are major influences on hydrogeology in the Sulphur Springs open pit area. The proposed pit and immediate hinterland hosts a fractured rock aquifer system that is interpreted to be closely controlled by both mineralisation lodes and occurrence of the marker chert.

3.6.1.1 Aquifer System

The local fractured rock aquifer system is interpreted to be compartmentalised, with groundwater flow strongly linked to transmissive structures. Drawdown distributions during the aquifer tests indicate the aquifer system is anisotropic, with greatest transmissivity along the northwest strike of the orebody (URS 2007a). Drawdown responses also provided indications that the country rock adjoining the ore zone aquifer system is typically low in

transmissivity. This interpretation is supported by the occurrence of steep hydraulic gradients beneath the local slopes.

Site studies have been interpreted in context with topography and positions with respect to watercourses, stratigraphic setting and structure (URS 2007a). This data indicates the following:

- Groundwater flow is strongly aligned with topography, surface water catchments and transmissive structures.
- Recharge occurs beneath ridges and crests.
- Within the proposed pit domain, groundwater flow is from ridges and crests to valley-floor areas. Predominant flow directions are to the northeast and southwest.
- Discharge occurs from the valley floor areas through evaporation and evapotranspiration.
- From the valley floor areas, groundwater flow is towards the northwest along the Sulphur Springs watercourse. This watercourse has a strongly linear character, indicative of alignment along structure.
- Groundwater levels on the valley floor in central areas of the proposed pit are at shallow depths (0 to 3 m) below ground surface. The occurrence of the shallow water table provides indications that the local aquifer system is full. It is also interpreted that the aquifer system is compartmentalised; the catchments are discrete, throughflow is structurally controlled and potentially limited by low-transmissivity flow paths and the topography provides a linear basin-form.
- Downstream of the pit, depth to the water table beneath valley floor areas is commonly less than 5 m. These domains conform with the interpreted compartments linked to the Corboy and Paddy Market Formations.
- The Gorge Fault provides a local influence on groundwater levels by providing a preferred flow path within the central-east portions of the pit.

Overall, the proposed pit area is characterised by steep (1:1) hydraulic gradients beneath steep slopes and comparatively shallow hydraulic gradients beneath valley floors (URS 2007a).

3.6.1.2 Groundwater Quality

Groundwater quality data for samples collected from drilling airlifts and aquifer tests at Sulphur Springs is indicative of a stratified aquifer system, with poor quality groundwater associated with the orebody and the country rock hosting less saline resources (URS 2007a).

The acidity and salinity of the groundwater in this area is high, but as this aquifer is stratified, analyte concentrations are considered to be localised and not characteristic of the groundwater chemistry for the broader area. Primarily due to existing geological occurrences, natural throughflow from the proposed pit to Sulphur Springs Creek is interpreted to contain metals at concentrations that at times exceed ANZECC (2000) Guidelines for Aquatic Ecosystems. The groundwater throughflow may contain concentrations of cadmium, copper, lead, manganese, nickel and zinc that by nature exceed the ANZECC (2000) Guidelines.

3.6.2 Tailings Storage and Heap Leach Facilities

The proposed valley fill dual lined (HDPE and compacted clay) heap leach / TSF facility site overlies a northeast younging interbedded succession of the Corboy Formation and Paddy Market Foundation, Soanesville Group. Locally, the stratigraphy comprises a layered succession of siltstone (Corboy Formation) and shale, with intrusives of peridotite and dolerite of the Daltons Suite (Paddy Market Formation).

The site is located predominantly within the Shaw River Catchment, with a small part of the southern section lying within the Sulphur Springs Creek Catchment. Groundwater is interpreted to flow from the ridges and crests to the valley-floor areas, then broadly to the east. Flow is strongly aligned with topography and surface water

catchments. Comparatively steep hydraulic gradients are expected to occur beneath the ridge slopes and crests. Conversely, the valley-floor areas have water table settings with low hydraulic gradients. Recharge is expected to occur on the slopes and ridge crests, with discharge from the valley floor areas. Discharge is expected to be predominantly controlled by evaporation and evapotranspiration (URS 2007a).

3.7 HYDROLOGY

The project area is located within the Pilbara Surface Water Management Area proclaimed under the *Rights in Water and Irrigation Act 1914*, administered by the Department of Water (DoW). The physical surface characteristics of the site are typical of the Pilbara region with rocky hills, small gorges and gravely loam valleys, with the majority of the watercourses seasonal (URS 2007a).

Surface water flows north from the project area through incised drainage channels to the alluvial flats between the Strelley and Shaw Rivers via Sulphur Springs Creek. The project area is situated on a catchment divide between the Shaw River catchment and the Strelley River catchment. The Sulphur Springs Creek meets Six Mile Creek before merging into the Strelley River, which in turn flows into the De Grey River some 50 km upstream of the Indian Ocean. The Minnieritchie Creek drains into the Shaw River.

DoW considers the Shaw River to be a high median runoff river, along with the Harding, Yule, lower Fortescue, Strelley and DeGrey rivers. These rivers are ephemeral and characteristically flow in their lower courses through extensive floodplains while their upper portions traverse deep gorges. Waterholes within low-lying stretches of the drainage lines may exist for much of the year but most are dry from May to November. After heavy rains the rivers flood and often overflow their banks and inundate the coastal plain. Most of the rivers in the Pilbara region, including the Shaw, have broad alluvial sands or zones of unconsolidated rock saturated with groundwater along their courses (URS 2013).

Surface water sampling to assess the water type and quality of the pools and springs in the Sulphur Springs project area, was carried out in February and July 2007 (Golder Associates, 2007). Interpretation of this data indicates that pools and springs sampled in the upland areas are composed of an increasing component of water fingerprinted to be derived from recent or short residence infiltration from rainfall events (URS, 2007). In the vicinity of the proposed pit, gravity (or descending) springs discharge under unconfined conditions. These are sustained by localised systems, their hydrochemistry also characterised by recent rainfall.

Data suggests changes in surface water chemistry are induced by increased mixing with groundwater along the flow path. In the upland areas, the development of perched springs, characterised by seasonal flow, with low to moderate EC and a sodium chloride fingerprint is favoured. Downgradient near groundwater discharge areas, this fingerprint would be diluted as mixing occurs, with the degree of mixing reflecting local hydrological and hydrogeological processes. Water quality results across the region and in the vicinity of the proposed pit and TSF valley are summarised in Table 15.

Table 15: Surface Water Quality Data

Parameter	Greater Region	Pit Area	TSF Valley Area
TDS	194 to 1,330 mg/L	194 to 1,910 mg/L	1,050 to 1,500 mg/L
pH	5.6 to 8.2	2.8 (near orebody) to 8.2	7.6 to 8.0
Arsenic	0.001 to 0.004 mg/L	<0.001 to 0.007 mg/L	<0.001 to 0.001 mg/L
Copper	0.001 to 0.012 mg/L	0.006 to 4.29 mg/L	0.001 to 0.002 mg/L
Zinc	0.005 to 0.104 mg/L	0.166 to 9.52 mg/L	0.006 to 0.017 mg/L
Nickel	0.002 to 0.265 mg/L	0.003 to 0.031 mg/L	<0.001 mg/L
Lead	<0.001 mg/L	0.002 to 0.02 mg/L	<0.001 mg/L
Cadmium	<0.0001 to 0.007 mg/L	0.0006 to 0.0482 mg/L	<0.0001 mg/L

This data demonstrates that a number of metal and metalloid concentrations at sites across the region and particularly in the vicinity of the proposed pit, currently exceed the ANZECC (2000) Guidelines for Aquatic Ecosystems. This is due to the presence of highly mineralised zones and is to be expected.

3.8 FLORA AND VEGETATION

Six detailed vegetation and flora surveys have been conducted for the project area by M. E. Trudgen and Associates (Trudgen). These surveys include:

- April 2001 – General flora collection survey conducted with 81 quadrats established and recorded along the proposed access road and around the proposed mine and processing areas (including Kangaroo Caves and Bernts areas).
- October 2001 – Vegetation survey of the Project Area (including Kangaroo Caves and Bernts areas) and additional flora collections.
- April 2006 – Rare flora survey of the Project Area.
- May 2006 – Rare flora survey focussing on proposed element locations and a vegetation survey of the previously proposed camp site.
- May 2007 – Vegetation and flora survey of new project areas, around the plant site, that were not covered by previous surveys.
- June 2007 – Vegetation and flora survey of new project areas, including the airstrip and camp that were not covered by previous surveys.

Mattiske Consulting Pty Ltd (Mattiske, 2007) undertook a review of the flora and vegetation survey data and an assessment of the Groundwater Dependent Ecosystems (GDEs), then remapped the vegetation associations prepared by Trudgen *et al*. (2002) and Trudgen (2006; 2007a; 2007b).

Outback Ecology (2013) conducted a Level 1 Vegetation and Flora survey of the Project area in 2012 to review the previous vegetation mapping and search for conservation significant species.

Botanical survey work has been conducted with reference to *Guidance Statement No. 51: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004a) and *Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection* (EPA 2002).

The Mattiske (2007) report remains the most detailed and accurate report summarising the botanical values of the project area and this is included as Appendix 2.

Two other regional Targeted Flora surveys for the North Star Project for *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) are also relevant to the project:

- Ecologia. 2012. *Pityrodia* sp. Marble Bar Targeted Flora Survey. Unpublished report by Ecologia Environment for Fortescue Metals Group Ltd. Ecologia Environment.
- Ecologia. 2016. *Pityrodia* sp. Marble Bar Regional Survey 2015. Unpublished report by Ecologia Environment for FMG Iron Bridge (Aust) Pty Ltd. Ecologia Environment.

The project area is located within the Chichester Interim Biogeographic Regionalisation of Australia (IBRA) subregion of the Pilbara IBRA region. The subregion is characterised by undulating Archaean granite and basalt plains including basaltic ranges. The plains support shrub steppe of *Acacia inaequilatera* over *Triodia wiseana* hummock grasslands, while tree steppes of *Eucalyptus leucophloia* occur on the ranges (Kendrick and McKenzie 2001). The project area is also located within the Fortescue Botanical District of the Eremaean Botanical Province biogeographical region as described by Beard (1990).

Mattiske (2007) reported that a total of 514 plant taxa (including subspecies and varieties) from 161 genera and 58 plant families were recorded within the project area. The most common families recorded included Poaceae (76 taxa), Papilionaceae (61 taxa), Malvaceae (46 taxa) and Mimosaceae (44 taxa).

3.8.1 Conservation Significant Species

Many taxonomic changes have occurred since the Trudgen *et al*. (2002) and Trudgen (2006; 2007a; 2007b) surveys, the Mattiske (2007) review and the Outback Ecology (2013) survey.

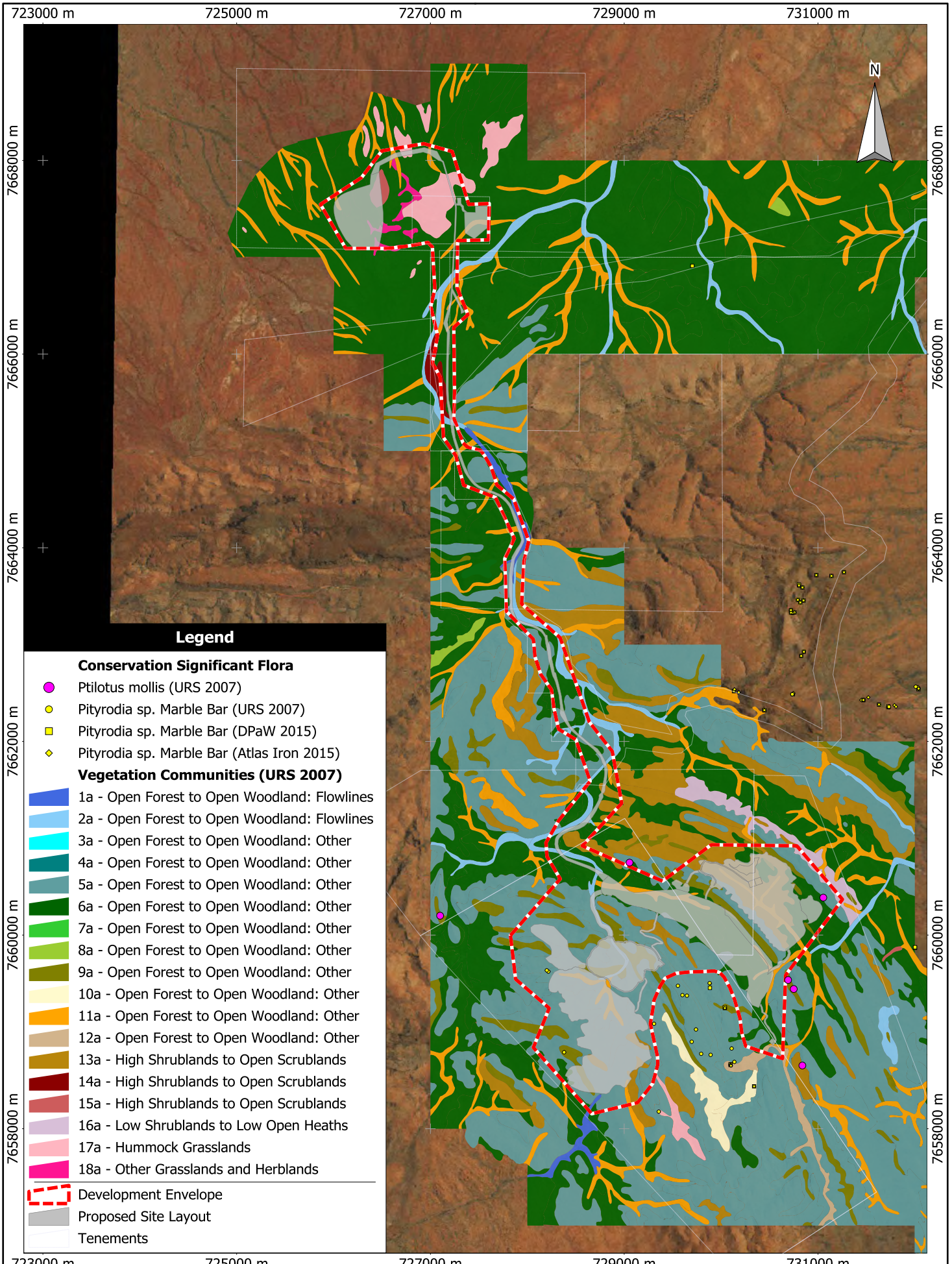
Most notably, Trudgen *et al*. (2002) and Trudgen (2006) identified *Pityrodia* sp. Panorama and *Themeda* sp. Panorama as potentially new flora species within the project area. Ecologia (2012) confirmed that *Pityrodia* sp. Panorama is *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4), now listed as a Threatened (Declared Rare Flora) under the *Wildlife Conservation Act* 1950. *Themeda* sp. Panorama is no longer a species of importance (email correspondence from Stephen van Leeuwen (DPaW) on 11 April 2016).

A further four Priority flora species have been recorded within the wider project area (Table 16). The locations of Conservation Significant Flora in the vicinity of proposed elements are shown in Figure 12. Clearing for the project will not directly impact any Conservation Significant Flora. Potential impacts to *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) are discussed in Section 3.8.1.1.

Table 16: Conservation Significant Species Recorded in the Project Area

Species	CC[2]	Habitat	Recorded	Impacts
Pityrodia sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4)	T[3]	Occurs on sandstone hill slopes with skeletal sandy loams. Favours steep, rocky areas with a southerly or easterly aspect within the Capricorn Land System.	Recorded within and around wider project area.	None. No known plants to be cleared and footprint is outside of surrounding ESA.
Euphorbia clementii	P2[4]	Occurs on gravelly hillsides and stony grounds.	Recorded along access road and in vicinity of airstrip	None
Acacia glaucocaesia	P3[5]	Occurs on loams, sandy loams and clays. Commonly found on floodplains.	Recorded predominately along the access road. Also recorded on road to airstrip.	None
Gymnanthera cunninghamii	P3[5]	Occurs on sandy clay loams and sands. Commonly found on sandplains and drainage lines.	Recorded to the south of mining area.	None
Ptilotus mollis	P4[6]	Occurs on stony hills and screes, common on ironstone ridges but can also occur on siltstone and chert.	Recorded in mining area and to the south	None

[2] Conservation Code
[3] Threatened (Declared Rare Flora)
[4] Priority 2
[5] Priority 3
[6] Priority 4



Scale: 1:51000
Original Size: A4
Source: Landgate Locate Mosaic
Air Photo Date: 2012
Grid: MGA94(50)
0 1000 m

Venturex Resources Limited
Sulphur Springs Project

Figure 12

Locations of Conservation Significant Flora and Vegetation Communities

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W:\Venturex Resources\Sulphur Springs\Projects\EPA Referral V2\Drawings\Sulphur Springs EPA Referral V4.map 8/12/2016 F12 CSS and Veg Comms Layout

3.8.1.1 Pityrodia sp. Marble Bar *(G. Woodman & D. Coultas GWDC Opp 4)*

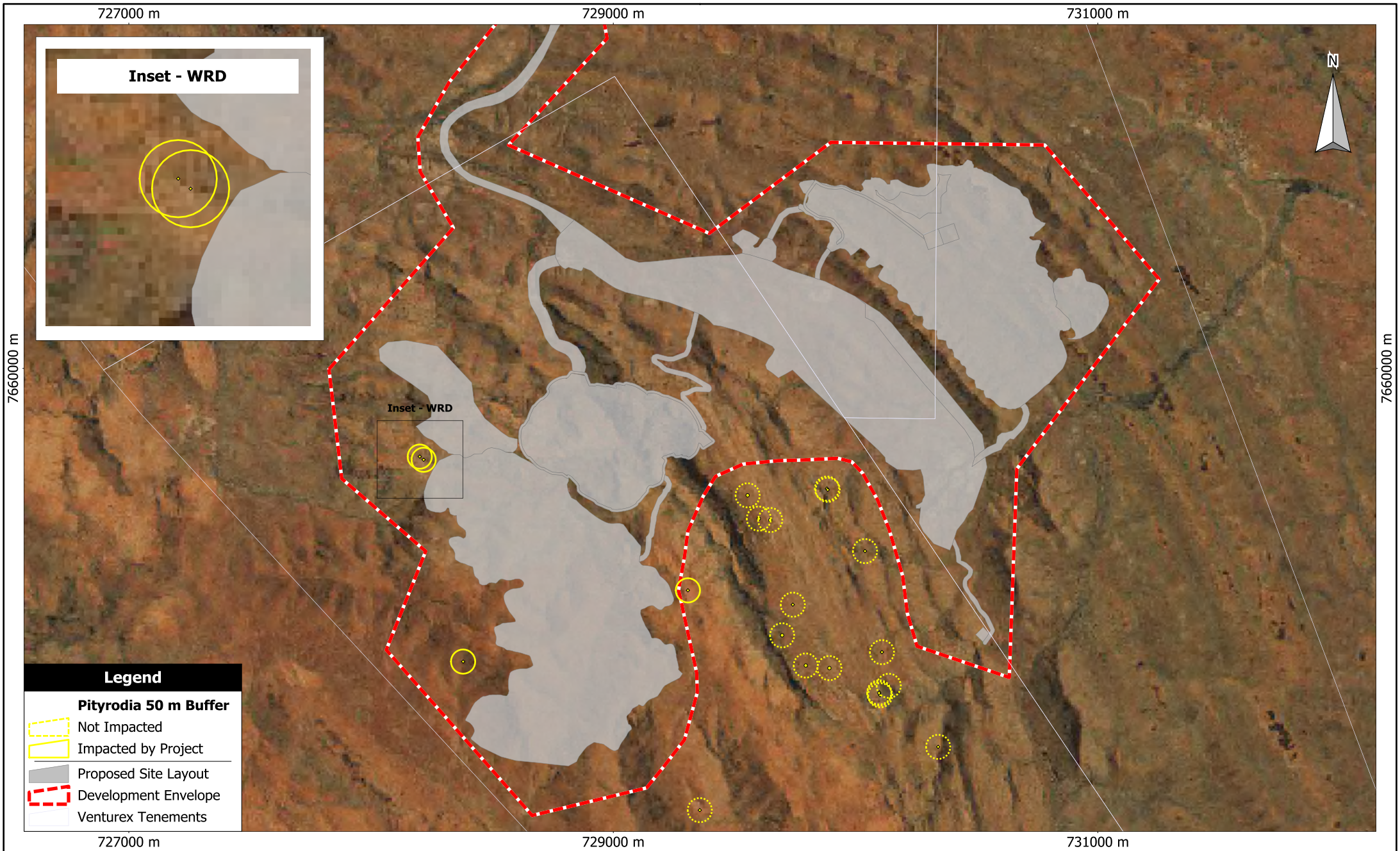
Pityrodia sp. *Marble Bar* (G. Woodman & D. Coultas GWDC Opp 4) recently became listed as a Threatened (Declared Rare Flora) species under the *Wildlife Conservation Act 1950*. It is a member of the Lamiaceae family and is a shrub that grows up to 2 m tall with predominately grey, densely hairy leaves and pink flowers that appear from July to September. It has previously been recorded from sandstone hill slopes with skeletal brown sandy loam. *Pityrodia* sp. *Marble Bar* (G. Woodman & D. Coultas GWDC Opp 4) favours steep, rocky areas with a southerly or easterly aspect within the Capricorn Land System (Ecologia 2016).

Two colour variants have been observed, a "green" (less frequent) variant and a "grey" (more common) variant. "Grey" individuals appear to have an indumentum almost entirely of white hairs, whereas the stem and leaf of "green" individuals have yellow hairs and sepal hairs are pink. The inflorescence structure may also be more open in "green" plants, with possibly a later, albeit overlapping flowering period (Ecologia 2016). Taxonomic studies are currently being conducted to further assess the variants, but at present, assessment will assume they are the one species.

A number of surveys have been conducted across Venturex tenements and the greater region. Relevant results are summarised as follows:

- Ecologia (2016) reported that there is an estimated 9,848 individuals of *Pityrodia* sp. *Marble Bar* (G. Woodman & D. Coultas GWDC Opp 4) within 67 populations known to occur in the Pilbara. Ecologia report (Ecologia 2016) that the actual number of *Pityrodia* sp. *Marble Bar* (G. Woodman & D. Coultas GWDC Opp 4) is likely to be larger as some areas were surveyed by helicopter and some areas were surveyed at a distance from tracks rather than detailed transect traverses typical of a Targeted Flora Survey. *Pityrodia* sp. *Marble Bar* (G. Woodman & D. Coultas GWDC Opp 4) occurs predominately in the Capricorn land system, with only six records recorded in the Rocklea land system.
- Trudgen *et al*. (2002) and Trudgen (2006) identified a total of 257 individual plants of *Pityrodia* sp. *Marble Bar* (G. Woodman & D. Coultas GWDC Opp 4) within the survey area (URS 2007a) (Figure 12, Figure 13).
- Ecologia (2012; 2016) regional surveys for *Pityrodia* sp. *Marble Bar* (G. Woodman & D. Coultas GWDC Opp 4) included parts of the Sulphur Springs project area. Within the mining area, only Population 26 (area between proposed processing plant and WRD), as reported in Ecologia (2016) was revisited, as well as other selected tracks (Figure 12). Ecologia (2016) reported 21 individuals at six sites within Population 26.
- About 1.4 km to the north of the proposed TSF, Populations 20 and 21 contain 16 individuals (Ecologia, 2016).
- Approximately 2.1 km east of the eastern most margin of the proposed TSF, Population 22 has 438 individuals recorded (Ecologia, 2016).

The project has been designed to avoid all known *Pityrodia* sp. *Marble Bar* (G. Woodman & D. Coultas GWDC Opp 4) locations and the 50 m Environmentally Sensitive Area (ESA) surrounding them. There is potential that more *Pityrodia* sp. *Marble Bar* (G. Woodman & D. Coultas GWDC Opp 4) occur within the proposed disturbance areas. Surveys by Trudgen *et al*. (2002) and Trudgen (2007a; 2007b) focused on vegetation mapping and the Outback Ecology study (2013) did not address this species. The Trudgen (2006) survey conducted a Targeted Flora Survey for known impact areas according to the project layout at the time. The Ecologia (2012) survey conducted for the North Star Project revisited some areas within Venturex tenements, but did not encompass all proposed disturbance areas and the Ecologia (2016) survey did not revisit these areas. Therefore, Venturex commits to conducting a Targeted Flora Survey for *Pityrodi*a sp. *Marble Bar* (G. Woodman & D. Coultas GWDC Opp 4) within proposed impact areas prior to development of the project.



Scale: 1:20000
Original Size: A4
Source: Landgate Locate Mosaic
Air Photo Date: 2012
Grid: MGA94(50)

0 1000 m

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Sulphur Springs Project

Figure 13

Pityrodia ESAs

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W:\Venturex Resources\Sulphur Springs\Projects\EPA Referral V2\Drawings\Sulphur Springs EPA Referral V4.map 16/11/2016 F13 Pityrodia ESAs Layout

3.8.2 Vegetation Communities

Given the detail of the vegetation unit in the Trudgen *et al*. (2002) and Trudgen (2006; 2007a; 2007b) reports, Mattiske (2007) reviewed and grouped these smaller site specific vegetation into wider vegetation formations for the purpose of impact assessment.

A total of 18 Vegetation Alliances in six vegetation formations were noted within the Survey Area (Figure 12). Clearing is proposed in 11 Vegetation Alliances, however all impacts are less than 7% of the total mapped area as detailed in Table 17.

Table 17: Vegetation Communities

Code	Description	Total Mapped (ha)	Proposed Clearing Area (ha)	Percentage of Total (%)
Open Forest to Open Woodland: Flowlines				
1a	Open forest to open woodland of *Eucalyptus camaldulensis, Melaleuca argentea* and *Eucalyptus victrix* with scattered tall shrubs of *Indigofera monophylla* over *Schoenus falcatus, Cyperus vaginatus* and *Triodia longiceps* sedgeland/grasslands in river beds.	458.0	1.4	0.30%
Open Forest to Open Woodland: Other				
2a	*Eucalyptus victrix* scattered trees to open woodland which may include *Melaleuca glomerata* and *Melaleuca linophylla* over open to closed scrub in creek beds and low slopes.	177.7	6.4	3.58%
3a	*Corymbia aspera* scattered low trees to low open woodland in creek beds.	4.8	0.0	0.00%
4a	*Acacia tumida* high shrubland to low open forest in creeklines.	58.5	0.0	0.00%
5a	*Eucalyptus leucophloia* scattered low trees over patches of *Acacia* shrubs over hummock grasslands of *Triodia* species, including *T. brizoides, T. wiseana* and *T. epactia* on ridge slopes.	2253.4	111.1	4.93%
6a	*Corymbia hamersleyana* scattered low trees to low open woodland over tall shrubs to open shrubland of *Acacia* spp. and *Grevillea wickhamii* over hummock grasslands on creek banks, flood banks and distributing fans.	7285.8	122.6	1.68%
7a	*Corymbia zygophylla* and *Corymbia hamersleyana* scattered low trees over hummock grasslands on sandplains.	66.8	0.0	0.00%
8a	*Terminalia canescens* scattered low trees to low woodland on creek banks.	26.1	0.0	0.00%

Code	Description	Total Mapped (ha)	Proposed Clearing Area (ha)	Percentage of Total (%)
9a	*Atalaya hemiglauca, Acacia pruinocarpa, Ehretia saligna* var. *saligna, Acacia tumida, Eucalyptus ferriticola* subsp. *ferriticola* and *Ficus platypoda* scattered low trees over high open shrubland on steep, rocky gorge walls.	258.6	15.1	5.85%
High Shrublands to Open Scrublands				
10a	Shrubland to open scrubland of *Acacia* species including *A. tumida, A. acradenia* and *A. orthocarpa* over hummock grasslands on upper and steep slopes.	43.2	0.0	0.00%
11a	Shrubland to closed scrubland of *Acacia* species, including *A. acradenia, A. pyrifolia* and *A. tumida* along small creeklines and on the adjacent parts of valley floors and distributing fans.	818.4	22.2	2.71%
12a	*Acacia inaequilatera* scattered tall shrubs to high open shrubland over *Triodia brizoides* hummock grasslands on ridge slopes and low hills.	36.7	0.0	0.00%
13a	*Acacia inaequilatera* scattered tall shrubs to high shrubland over *Triodia wiseana* hummock grasslands occurring mainly on gentle lower slopes.	569.4	37.9	6.65%
14a	*Acacia ancistrocarpa* high open shrubland to open scrub.	222.4	0.2	0.11%
15a	*Acacia trachycarpa* high open shrubland to high shrublands.	44.8	2.8	6.22%
Low Shrublands to Low Open Heaths				
16a	Low shrublands to low open heath on gentle slopes and undulating plains.	101.2	0.0	0.00%
Hummock Grasslands				
17a	Hummock grasslands on slopes and ridges.	55.1	1.0	1.79%
Other Grasslands and Herblands				
18a	Cracking clay alliance on gentle sloping plains and seasonal damplands.	39.6	1.3	3.18%

3.8.3 Threatened and Priority Ecological Communities

No Threatened Ecological Communities (TECs) as defined by the *Environment Protection and Biodiversity Conservation Act 1999 (*Commonwealth) or the *Wildlife Conservation Act 1950* occur in the project area. No Priority Ecological Communities (PECs) as listed by DPaW (2015) occur within the project area.

3.8.4 Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems (GDEs) are ecosystems that require groundwater in order to maintain their species composition, ecological processes and ecosystem services (SKM 2001). Many ecosystems rely purely on rainfall for their water requirements, but GDEs rely on additional input from groundwater. Changes in the timing, quantity, quality or distribution of groundwater may result in negative impacts on growth and health of vegetation

of a GDE and ultimately lead to plant deaths and changes in ecosystem composition (Eamus 2009, Murray *et al.* 2003).

Phreatophytes (plants dependent upon groundwater) can be divided into two types:

- Obligate phreatophytes rely on groundwater sources for maintenance of some part or all of their ecosystem function. This reliance can be continual, seasonal or episodic. These species are highly sensitive to reduced availability of groundwater.
- Facultative phreatophytes only require access to groundwater in some landscapes, but in other landscapes they can utilise alternate sources of water to maintain ecosystem function. The presence or absence of groundwater is not critical in determining the occurrence of these ecosystems (SKM 2007a).

Astron Environmental Services (2008a) conducted a search of FloraBase on species associated with creeks, depressions, drainage lines, floodplains, seasonally wet areas, swamps and watercourses in the Pilbara resulting in a list of 368 species (trees, shrubs, climbers, herbs and grasses). It was anticipated that these types of habitat were more likely than others to support obligate and facultative phreatophytes (as well as non-groundwater dependent species). The list included trees that characterise the creeks, rivers, banks and floodplains of the Pilbara region: *Eucalyptus camaldulensis*, *E. victrix*, *Corymbia candida*, *C. hamersleyana*, *Melaleuca argentea* and several *Acacia* species. These species were reviewed in detail in order to determine their reliance on groundwater and subsequent potential to act as indicators of the groundwater dependency of vegetation communities.

Mattiske (2007) identified GDEs according to likely groundwater dependent flora species (floristic), structure and position (habitat) of the Vegetation Alliance in the landscape. Groundwater dependent flora species identified from Trudgen et al. (2002) in the Panorama Project Survey Area include *Eucalyptus camaldulensis, Eucalyptus victrix, Melaleuca linophylla, Melaleuca glomerata, Corymbia hamersleyana, Acacia tumida* var. *pilbarensis* and *Terminalia canescens*. A site visit in August 2007 indicated that *Eucalyptus camaldulensis* and *Eucalyptus victrx* are the main groundwater dependent flora species and *Corymbia hamersleyana, Acacia tumida* var. *pilbarensis* and *Terminalia canescens* are more widespread in occurrence in the Survey Area (Mattiske 2007).

Vegetation Alliance 1 was rated as very high GDE probability and Vegetation Alliance 2a was rated with a High GDE probability. All other Vegetation Alliances were rated with a low GDE probability (Mattiske 2007). The impacts to GDEs was previously addressed in Mining Proposal Version 2 (REG ID 40542) approved on 16 April 2014. As the access road has not changed since the 2014 Mining Proposal the potential impacts remain the same. Monitoring of vegetation condition will be undertaken to enable any change in vegetation health to be identified.

3.8.5 Weeds

A weed is a plant growing where it is not wanted or not native to an area. Environmental weeds are problematic as they can potentially cause changes to the structure and species composition of natural ecosystems. Ten introduced (exotic) species have been recorded in the project area (Mattiske 2007). None of the species are listed as Declared Pest Organisms or Prohibited Organisms pursuant the *Biosecurity and Agriculture Management Act 2007* or listed as a Weed of National Significance. Of note is *Cenchrus ciliaris* (Buffel Grass) as this is a particularly invasive species, but is considered to be naturalised in many Pilbara areas.

3.9 TERRESTRIAL FAUNA AND HABITAT

Four fauna surveys have been completed for the greater Sulphur Springs project and haul road corridor development envelope (Bamford 2001, Biota 2007, MOLHAR 2007 and Outback Ecology 2012a), as well as a terrestrial vertebrate fauna impact assessment (Outback Ecology 2012b). Terrestrial Fauna technical studies are included in Appendix 3, Appendix 4 and Appendix 5.

All fauna surveys were completed in accordance with Position Statement No. 3 (EPA 2002), Guidance Statement No. 56 (EPA 2004b) and the Technical Guide for Terrestrial Vertebrate Fauna Surveys (EPA 2010), where relevant.

Surveys have identified up to 151 terrestrial vertebrate fauna species that may occur within the greater study area, including 27 mammals, 83 birds, 34 reptiles, 5 fish and 2 amphibian species. The majority of these species form assemblages that occur across a variety of the habitats present within and surrounding the footprint. These assemblages are also similar to those found in the surrounding landscape.

Three introduced mammals have been recorded within the Sulphur Springs area. These species included the House mouse (*Mus musculus*), Dromedary Camel (*Camelus dromedaries*) and Feral cat (*Felis catus*).

3.9.1 Species of Conservation Significance

The conservation significance of terrestrial vertebrate fauna potentially occurring within the project area is described in the following section; this includes:

- Threatened fauna species (as defined under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (*EPBC Act*) or the *Wildlife Conservation Act 1950* (WA) (*WC Act*).
- Priority fauna recognised by WA Department of Parks and Wildlife (DPaW).
- Migratory species listed under the *EPBC Act* and international agreements, which include the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA), Republic of Korea Australia Migratory Bird Agreement (ROKAMBA) and the Bonn Convention (The Convention on the Conservation of Migratory Species of Wild Animals).

Outback Ecology identified 19 species of conservation significance that have potential to occur within the Sulphur Springs project area (Outback Ecology 2012b). These 19 species are detailed in Table 18. It should be noted that historic scientific reports refer to a total of 24 species; this number has reduced due to changes to the listings of conservation significant fauna under the *EPBC Act* and the *WC Act* since these reports were written.

Species that have been classed as having a high and medium likelihood of occurring in the Sulphur Springs project areas are detailed in Sections 3.9.1.1 to 3.9.1.15. Figure 14 depicts the location of conservation significant fauna observed during fauna surveys covering the Development Envelope.

Table 18: Conservation Significant Fauna Species Potentially Present at Sulphur Springs

Species	Common Name	Conservation Status*			Likelihood to Occur in Sulphur Springs Project Area	Reason for Likelihood
		EPBC Act	*WC Act S1*	*WC Act S4*		
Reptiles						
Aspidites ramsayi	Woma	-	-	P1	Medium (Possible)	• Presence of suitable habitat. • Recent records in surrounding region. • Patchily distributed species.
Ctenotus nigrilineatus	Pin-striped Firesnout Ctenotus	-	-	P1	Low (Unlikely)	• Few records for this species. • Ecology and habitat preferences poorly known.
Ctenotus uber johnstonei	Spotted Ctenotus	-	-	P2	Low (Unlikely)	• Few records for this species. • Ecology and habitat preferences poorly known.
Liasis olivaceus barroni	Olive Python (Pilbara subspecies)	VU	S3	-	Medium (Possible)	• Presence of suitable habitat. • Recent records in surrounding region.
Birds						
Apus pacificus	Fork Tailed Swift	MG MA	S5	-	Medium (Possible)	• Aerial species; may occur within Study area.
Falco peregrinus	Peregrine Falcon	-	S7	-	Medium (Possible)	• Presence of suitable habitat. • Recent records in surrounding region. • Patchily distributed species.
Falco hypoleucos	Grey Falcon	-	S3	-	Medium (Possible)	• Presence of suitable habitat. • Recent records in surrounding region. • Patchily distributed species.
Merops ornatus	Rainbow Bee-eater	MG MA	S5	-	High (Likely)	• Recorded during surveys of the study area.

Species	Common Name	Conservation Status*			Likelihood to Occur in Sulphur Springs Project Area	Reason for Likelihood
		EPBC Act	*WC Act S1*	*WC Act S4*		
Numenius madagascariensis	Eastern Curlew	-	S5	-	Low (Unlikely)	• Presence of suitable habitat.
Pezoporus occidentalis	Night Parrot	EN	S1	-	Medium (Possible)	• Presence of suitable habitat. • Recent records in surrounding region. • Rarely detected species.
Mammals						
Dasycercus blythi	Brush-tailed Mulgara	S1	-	P4	Medium (Possible)	• Recorded within the study area during previous survey but not within the Development Envelope.
Dasyurus hallucatus	Northern Quoll	EN	S2	-	High (Likely)	• Recorded within the Development Envelope and within the impact area.
Lagorchestes conspicillatus leichardti	Spectacled Hare-Wallaby	-	-	P3	Medium (Possible)	• Marginal habitat within study area. • Recorded within the study area during previous survey but not within the Development Envelope
Leggadina lakedownensis	Lakeland Downs Mouse	-	-	P4	Low (Unlikely)	• Patchily distributed species.
Macroderma gigas	Ghost Bat	-	S3	P4	High (Likely) Foraging	• Recorded within the study area during previous survey but not within the Development Envelope. • Presence of suitable foraging habitat.
Macrotis lagotis	Bilby	VU	S3	-	Medium (possible)	• Marginal habitat within Study area. • Recent records within surrounding region but not within the Development Envelope.
Pseudomys chapmani	Western Pebble-mound Mouse	-	-	P4	High (Likely)	• Recorded within the Development Envelope but not within the impact area.
Rhinonicteris aurantia	Pilbara Leaf-nosed Bat	VU	S3	-	High (Likely) Foraging	• Recorded foraging within the Development Envelope.

Species	Common Name	Conservation Status*			Likelihood to Occur in Sulphur Springs Project Area	Reason for Likelihood
		EPBC Act	*WC Act S1*	*WC Act S4*		
Sminthopsis longicaudata	Long-tailed Dunnart	-	-	P4	High (Likely)	• Recorded within the Development Envelope but not within the impact area.

**Explanation of conservation status (Harewood 2016):*

S1 = Wildlife Conservation Act 1950, Schedule 1: Critically endangered species. *S2 = Wildlife Conservation Act 1950, Schedule 2: Endangered species.*

S3 = Wildlife Conservation Act 1950, Schedule 3: Vulnerable species. *S4 = Wildlife Conservation Act 1950, Schedule 4: Presumed extinct species.*

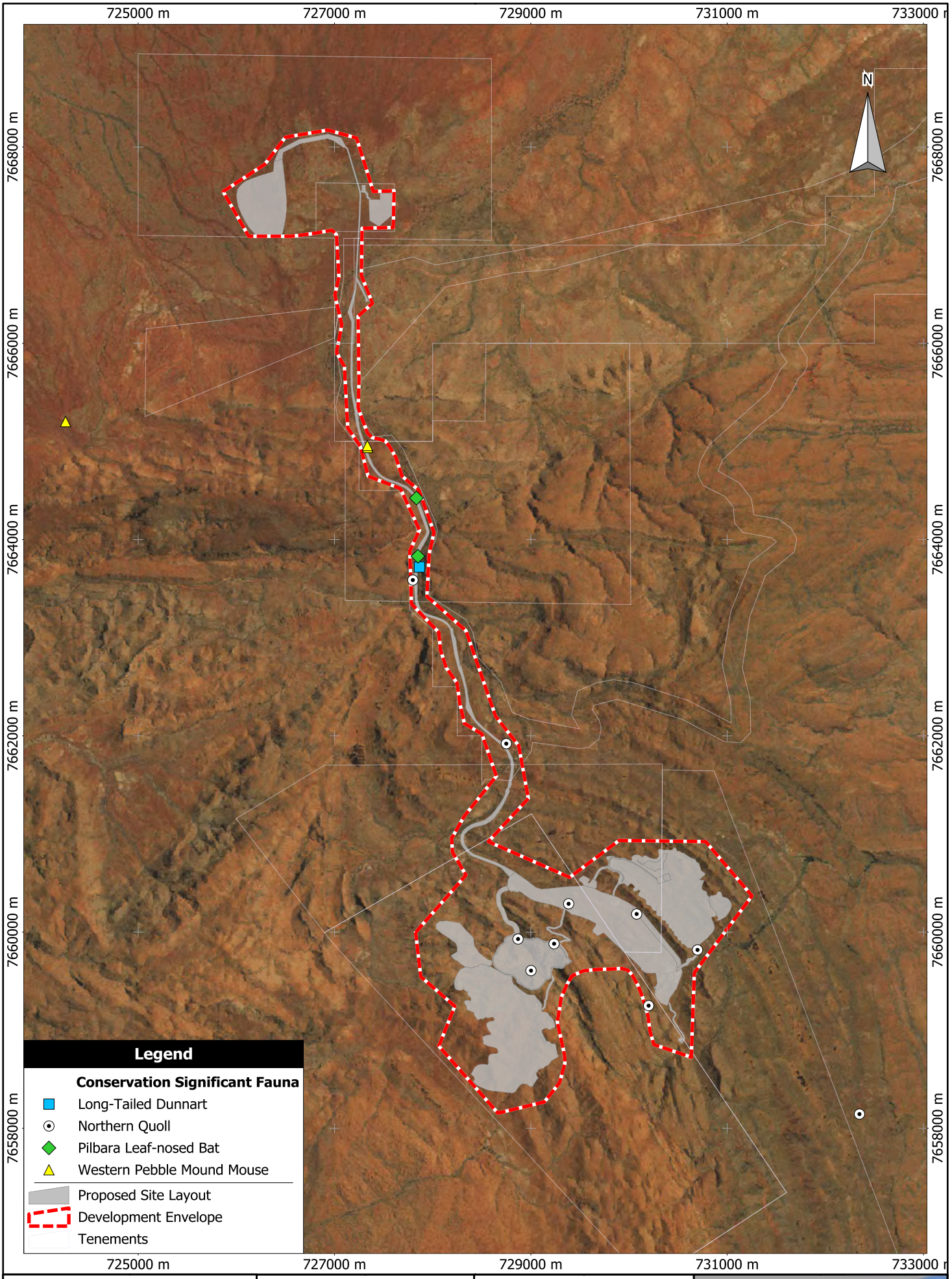
S5 = Wildlife Conservation Act 1950, Schedule 5: Migratory birds protected under an international agreement.

S6 = Wildlife Conservation Act 1950, Schedule 6: Fauna that is of special conservation need as conservation dependent fauna.

S7 = Wildlife Conservation Act 1950, Schedule 7: Other specially protected fauna.

P2 = DPaW Priority 2: Taxa in urgent need of study, known from 5 or less locations some of which under threat. *P4 = DPaW Priority 4: Taxa in need of regular monitoring.*

EN, VU = EPBC Act 1999 Endangered and Vulnerable *MA, MG = EPBC Act 1999 Marine and Migratory species.*



Scale: 1:50000
Original Size: A4
Source: Landgate Locate Mosaic
Air Photo Date: 2012
Grid: MGA94(50) 0 1000 m

Venturex Limited
Resources
Sulphur Springs Project

Figure 14

Conservation Significant Fauna

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3.9.1.1 Woma or Ramsay's Python

The Woma Python (*Aspidites ramsayi*) is listed under Schedule 4 of the *WC Act*. This species occurs in arid zones of Western Australia in woodland, heathland and shrubland habitats often containing spinifex. The southwest Wheatbelt population appears to be threatened as opposed to the northern populations (Storr *et al.* 2002).

This species was not recorded within the study area during surveys (Bamford Consulting Ecologists 2001, Biota 2007) however there is presence of suitable habitat in the surveyed areas.

3.9.1.2 Olive Python

The Pilbara Olive Python (*Liasis olivaceus barroni*) is ranked as Vulnerable under the *EPBC Act* and listed as Schedule 1 and ranked as Vulnerable under the *WC Act*. This species inhabits rocky escarpments, deep gullies and gorges within the Pilbara region and is often recorded near water holes and riverine habitats (Wilson and Swan 2008). Radiotelemetry has found that the Pilbara Olive Python occupies a distinct home range, but males travel long distances during their breeding season from June to July to locate females (Outback Ecology 2012a).

The Pilbara Olive Python has not been recorded during surveys within the study area (Bamford Consulting Ecologists 2001, Biota 2007); however given suitable habitat occurs the presence of the Olive Python is possible within the Sulphur Springs Project area.

The project will directly impact on small areas of Rocky Ridge and Gorge habitat. Although these habitats are uncommon in the landscape, the limited amount of habitat to be removed suggests that the development of the project is likely to have a minimal impact on this species at a localised scale (Outback 2012a).

3.9.1.3 Fork-tailed Swift

The Fork-tailed Swift (*Apus pacificus*) is a nomadic species that may be seen before and after storm fronts or tropical cyclonic events that are associated with an increase in insect activity which the species feeds on (Johnstone and Storr 2004). This species may fly over the study area without specifically utilising the habitats present. The Fork-tailed Swift was recorded during several studies within the surrounding region (Outback Ecology 2012a). It is likely to occur within the study area. The Fork-tailed Swift is almost entirely aerial and is therefore not expected to be reliant on habitat within the project footprint.

3.9.1.4 Peregrine Falcon

The Peregrine Falcon (*Falco peregrinus*) is listed as Schedule 4 under the *WC Act 1950*. It is a nomadic species that utilises a wide range of habitats across Australia, including rocky escarpments and gorges, cliffs, tree lined watercourses, open woodland and *Acacia* shrublands (Pizzey and Knight 2007). This species has a home range of approximately 20 to 30 km throughout the year.

The species may favour Rocky Ridge habitat as it may provide more secure nesting sites than the other habitats within the study area. It is likely that this species would utilise the study area intermittently; however, it is unlikely to be dependent on the habitat given its mobility and the availability of suitable habitat within the region.

The Peregrine Falcon was not recorded during previous surveys within the study area (Bamford Consulting Ecologists 2001, Biota 2007).

Although the species may forage widely over the project area, Outback (2012b) concluded that the area was unlikely to contain many suitable nest sites and thus the Peregrine Falcon is unlikely to be solely reliant on the foraging habitats provided within the project area.

3.9.1.5 Grey Falcon

The Grey Falcon (*Falco hypoleucos*) is listed as Priority 4 by DPaW. This species mainly occurs around inland ephemeral and permanent drainage systems where annual rainfall is less than 500 mm (Garnett and Crowley 2000). The Grey Falcon inhabits lightly wooded countryside especially stony plains and *Acacia* scrublands (Morcombe 2003). This species can be rare, resident or nomadic to most of the semi-arid interior of Western Australia (Birds Australia 2016).

The species was recorded during a survey of the FMG rail corridor (Outback Ecology 2012a) and records for the species exist within databases (Birds Australia 2010, DEC 2010). It is possible that this species may occur within the study area as suitable habitat is present, although this species is patchily distributed and so its presence may be intermittent. This is a wide ranging species that is unlikely to be dependent on habitat within the projects footprint.

3.9.1.6 Rainbow Bee-eater

The Rainbow Bee-eater (*Merops ornatus*) is listed under the *WC Act* as Schedule 3 – Migratory birds protected under an international agreement. It is protected under Japan-Australia Migratory Bird Agreement (JAMBA). Under the *EPBC Act* the species is listed as Migratory. The Rainbow Bee-eater prefers open or lightly timbered areas, often near water. This species has been recorded in dry open sclerophyll forest, open woodlands and shrublands, including mallee, spinifex tussock grassland with scattered trees, chenopod shrubland with scattered trees and riparian or littoral assemblages. It is often seen around disturbed areas such as quarries, road cuttings and mines where exposed bare soil provides suitable breeding sites (Marchant and Higgins 1993). The Rainbow Bee-eater is a migratory bird and will move north from the southern areas of Australia during winter (Johnstone & Storr 1998).

The Rainbow Bee-eater was recorded during previous surveys of the study area (Bamford Consulting Ecologists 2001, Biota 2007) and is common in the surrounding region. Based on the transient nature of this species and the amount of habitat available in and surrounding the Development Envelope it is considered highly probable that this species will occur in other areas.

3.9.1.7 Night Parrot

The Night Parrot (*Pezoporous occidentalis*) is listed as Critically Endangered under the *EPBC Act* and as Schedule 1 under the *WC Act*. There have been very few confirmed records of the Night Parrot, with only 24 specimens in museum collections. The Night Parrot inhabits arid and semi-arid areas that are characterised by having dense, low vegetation. Based on accepted records, the habitat of the Night Parrot consists of *Triodia* grasslands in stony or sandy environments (Department of the Environment 2016).

It is possible that the Night Parrot could occur within the study area, although any estimate of likelihood of occurrence is putative owing to the paucity of data for the species. Additionally no Spinifex Stony Plains will be impacted by the project.

3.9.1.8 Brush-tailed Mulgara

The Mulgara (*Dasycerus blythi*) prefers spinifex grasslands on sandy soils, constructing burrows on the flats between sand dunes (Van Dyck and Strahan, 2008). Introduced grazers namely cattle and rabbits, altered fire regimes and predation by cats and foxes have contributed to the population decline of this species (Maxwell *et al.* 1996, Van Dyck and Strahan 2008).

DPaW threatened and priority fauna database records indicate that the Mulgara has been recorded from Kangan and Port Hedland, with the most recent record being in 2009 (Outback Ecology 2012a). During a Level 1 fauna survey within the Sulphur Springs Study area, numerous diggings by Mulgara were recorded around the Abydos Link Road, with the species also captured along the Site Access Road (Biota 2007).

3.9.1.9 Northern Quoll

The Northern Quoll (*Dasyurus hallucatus*) is listed as Endangered under the *EPBC Act* and as Schedule 1 species under the *WC Act*. Optimal habitat for the Northern Quoll consists of dissected rocky escarpments which provide shelter such as rock crevices and caves and support higher densities of Northern Quolls than habitats such as *Eucalyptus* woodlands and human settlements (Van Dyck and Strahan 2008). Adult male home ranges are over 100 hectares and overlap with female home range (King 1989).

Northern Quolls breed once a year and the majority of adult males die soon after mating at approximately one year of age (Van Dyck and Strahan 2008). Northern Quoll abundance is highly cyclical, with annual reproduction highly synchronised within a population. Breeding seasons may vary by a few weeks between nearby populations (Schmitt *et al.* 1989). Females have a short life span with the oldest female recorded in the wild being three years of age.

The population of Northern Quolls in the Pilbara is at its lowest after the mating season, which occurs in the winter months, as a significant proportion of males have died and young have not yet begun to forage independently. Therefore the population density is expected to be highest in the summer months, prior to the mating season and when juveniles are foraging independently.

Several threatening processes have contributed to the decline in Northern Quoll populations across Australia, such as inappropriate fire regimes, predation, and poisoning as a result of ingesting cane toads (Department of the Environment 2016). The Pilbara is considered to be one of the remaining strong holds of Northern Quolls as the cane toad is encroaching on the Kimberley region and populations in the Northern Territory are known to have been decimated and become locally extinct within a year of contact with cane toads (Van Dyck and Strahan 2008).

Northern Quolls have been observed during previous surveys within the project footprint and within the Development Envelope. Outback 2012a considered two areas within the Development Envelope to be important habitat for the Northern Quoll (Rocky Ridges/Gorge and Ficus Grove). Approximately 27 ha of Rocky Ridges, Gorge and Ficus Grove habitat will be affected by the project as these habitats coincide with the Open Pit development (Figure 15). CPS5658/1 currently permits clearing of up to 2 ha of this habitat. Other infrastructure has been sited to avoid intersecting these habitats, thus leaving substantial Rocky Ridges and Gorge habitat outside of the impact area for this species to colonise.

3.9.1.10 Spectacled Hair-Wallaby

The Spectacled Hare-Wallaby (*Lagorchestes conspicillatus*) is listed as Priority 3 by DPaW. This species inhabits *Triodia* hummock grasslands and *Acacia* shrublands and has declined dramatically within the Pilbara region, possibly due to fox predation and altered fire regimes which have prevented the development of large tussock grasslands required for adequate shelter (Van Dyck and Strahan 2008). The Spectacled Hare-Wallaby has been recorded near the study area at Pilgangoora in 1994 (Department of Environment and Conservation 2010).

Unconfirmed records of the Spectacled Hare-Wallaby were detailed in a survey by Bamford (Bamford 2001) however no confirmed sighting has occurred within the Development Envelope.

3.9.1.11 Ghost Bat

The Ghost Bat (*Macroderma gigas*) is listed as Priority 4 by DPaW. The Ghost Bat is Australia's only carnivorous bat and is known to feed on a variety of vertebrate species including large insects, frogs, lizards, small mammals and other bats. Ghost bats occupy a variety of habitats from the arid Pilbara to the rainforests of Northern Queensland (Van Dyck and Strahan 2008). Ghost Bats roost in undisturbed caves usually with several entrances, in deep fissures or abandoned mine shafts (Menkhort and Knight 2004).

Ghost Bats mate between July and August with females bearing a single young around September. Mothers form nursery colonies and genetic testing has shown that the entire species is centralised upon regional maternity sites, of which approximately ten are known to exist (Van Dyck and Strahan, 2008). In the Pilbara, a number of natural formations are used by the Ghost Bat intermittently as short-term transient roosts and for feeding activity by an

individual or small numbers of individuals, whilst others are used by maternity colonies (Armstrong and Anstee 2000).

The structure of a roost site is largely indicative of its use. The transient day roosts or feeding sites of Ghost Bats are often shallow overhangs and crevices with microclimates similar to ambient conditions, whereas roosts for breeding activity have a relative humidity of above 80% (Armstrong and Anstee 2000). Domed ceilings that create humid microclimates are often present in, but are not exclusive to, maternity caves. Deep, humid and complex mine shafts and deep humid caves with several chambers and dome ceilings are associated with permanent Ghost Bat occupancy and maternity roosts (Hall *et al.* 1997).

The Ghost Bat was recorded by a previous survey within the study area (Bamford Consulting Ecologists 2001). The project is likely to result in clearing of habitat used by this species for foraging, but not for roosting. Foraging habitat within the project footprint is small relative to available foraging habitat within the wider region.

3.9.1.12 Bilby

The Bilby (*Macrotis lagotis*) (Vulnerable – *EPBC Act*, Schedule 1 – *WC Act*) was formerly associated with a variety of inland habitats including desert sandplains and dune fields with hummock grasslands and massive red earths and *Acacia* shrubland (Maxwell *et al.* 1996). Bilbies dig large burrows in the sandy substrates that can reach up to 3 m long and 1.8 m deep (Van Dyck and Strahan 2008). They are not reliant on surface water and receive most of their water requirements from food sources.

Their diet consists of insects, larvae, seeds, bulbs, fruit and fungi (Van Dyck and Strahan 2008). The Bilby has undergone a widespread population decline as a result of altered fire regimes, predation by the European Red Fox (*Vulpes vulp*es) and feral cats and grazing pressure from introduced herbivores and livestock.

Bilby diggings have been recorded at Kangan in 2001 and from Marble Bar in 2006 located approximately 80 and 60 km away from Sulphur Springs respectively. It is possible that the species could occur within the study area where sandy habitat supporting mature hummock grasslands exists, however this species has dispersal capability sufficient to remove itself from the project area where necessary. Additionally habitat within the Development Envelope is minimal when compared to the habitat available in the wider region. Habitat is also well connected which would support re-colonisation by individuals affected by any clearing (Outback Ecology 2012b.

3.9.1.13 Western Pebble-mound Mouse

The Western Pebble-mound Mouse (*Pseudomys chapmani*) is listed as Priority 4 species by DPaW. This mouse constructs mounds out of small pebbles that can cover 0.5 to 9.0 m² (Van Dyck and Strahan 2008). Breeding for this species can occur throughout the year. Females may produce several litters per year of up to four young (Van Dyck and Strahan 2008).

Suitable habitat for the species is patchy, but populations are widespread throughout the ranges of the central and southern Pilbara (Van Dyck and Strahan 2008). Furthermore, evidence of the mouse has been frequently recorded within the region surrounding the study area (Outback Ecology 2012; How and Cooper 2002, How *et al.* 1991).

The Western Pebble-mound Mouse and various mounds were recorded during previous surveys of the study area within the Development Envelope (Bamford Consulting Ecologists 2001, Biota 2007). It is unknown if the mounds recorded during the surveys represent a current population or one that is no longer present.

3.9.1.14 Pilbara Leaf-nosed Bat

The Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*) is classified as Vulnerable under the *EPBC Act*. This species is subject to several threatening processes including flooding and human impacts such as mining. The Pilbara Leaf-nosed Bat has specific habitat requirements occupying warm, very humid roost sites in caves and mines (MOLHAR Pty Ltd 2007, Van Dyck and Strahan 2008). This enables the species to persist in arid temperatures by limiting water loss and energy expenditure. The Pilbara Leaf-nosed Bat is sensitive to human disturbance and the

best method of detection is through recording echolocation calls while it flies from roost sites or forages within gorges (Van Dyck and Strahan 2008).

DPaW records indicate that the Pilbara Leaf-nosed Bat has been recorded from Sulphur Springs and Poondano, near Port Hedland in 2009 (Department of Environment and Conservation 2010). Positive AnaBat echolocation recordings for this species were recorded by previous surveys within the Study area (Bamford 2001 and Biota 2007) although sightings of the species were unconfirmed. Habitat within proposed impact areas assessed as part of the 2011 habitat assessment were deemed unlikely to possess breeding roosts for the species as the rocky ridges did not appear to possess deep caves or crevices required by the species. In the absence of these habitat features, the presence of the species within this habitat is likely to be transitory.

3.9.1.15 Long-tailed Dunnart

The Long-tailed Dunnart (*Sminthopsis longicaudata)* is classified as Priority 4 under the *WC Act*. This species lives in arid rocky areas and has been recorded from flat topped hills, plateaus, granite outcrops and rocky scree slopes. In the winter, the Long-tailed Dunnart feeds entirely on arthropods and under cold conditions this species may utilise torpor as a strategy to conserve energy (Van Dyck and Strahan 2008).

Although suitable rocky habitat for this species occurs within the study area and wider region, the species is only represented by a single record located within the Development Envelope but not within the impact area.

3.9.2 Habitat

Six broad fauna habitats relevant to vertebrates were identified in the project area (Table 19 and Figure 15). Identification of these habitats was based on location, landform, substrate, vegetation community, degree of disturbance (e.g. mining and fire) and the type of habitat that they offer (Outback Ecology 2012a). These habitats are:

- Spinifex Stony Plains.
- Rocky Foothills.
- Scree Slopes.
- Spinifex Sandplains.
- Drainage Lines.
- Rocky Ridges and Gorges.

An additional two fauna habitats of limited extent were identified:

- Rubble Piles.
- Ficus Groves.

All habitat types identified are considered typical of the Pilbara bioregion. They are varied in their potential to support vertebrate assemblages and conservation significant species. Of the habitat types observed, Spinifex Stony Plains, Rocky Foothills, Scree Slope and Spinifex Sandplains are considered widespread throughout the landscape.

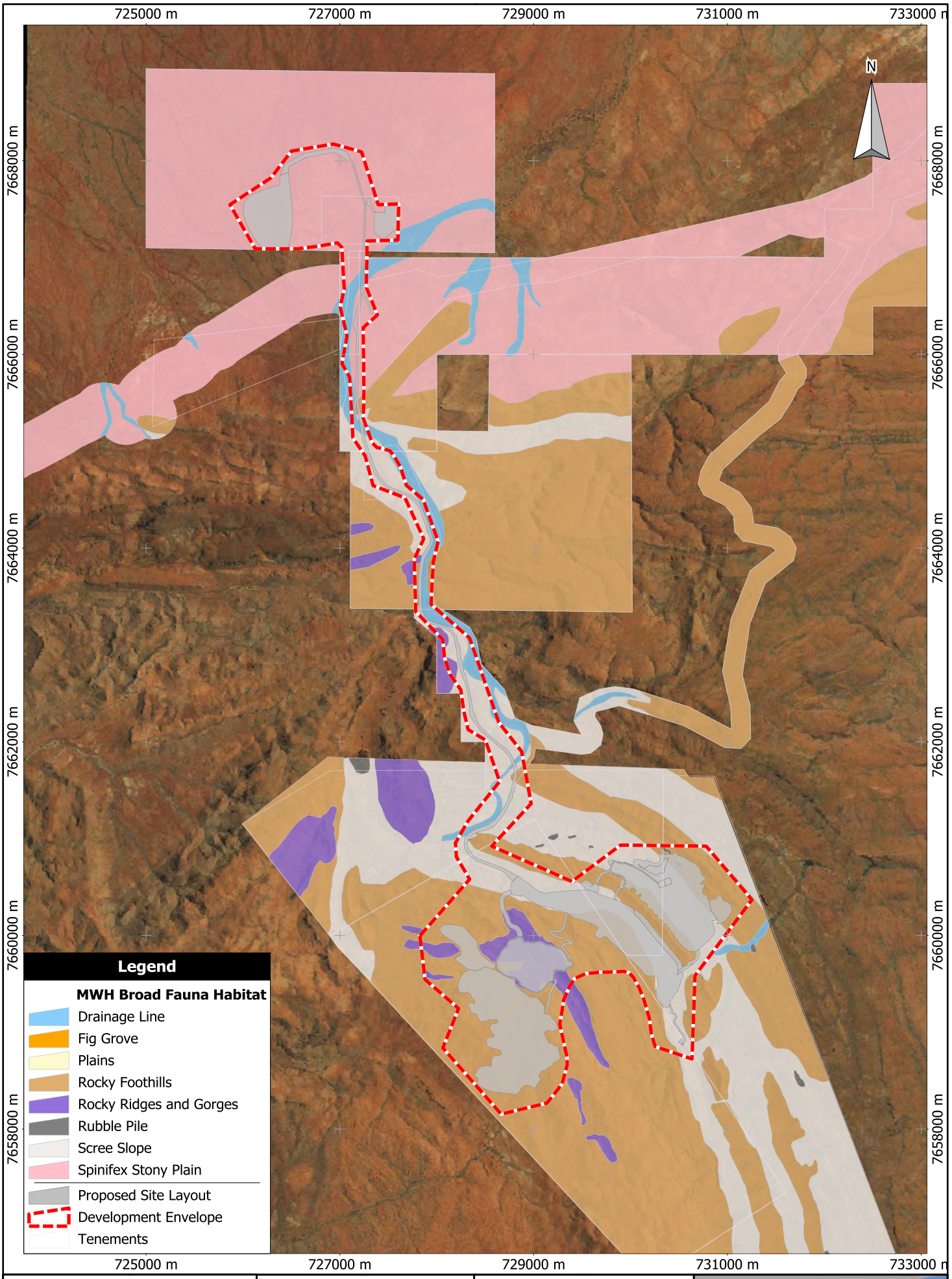
Although the Drainage Line habitat is not extensive in the landscape, it is relatively well connected along its length. Rocky Ridges and Gorges represent the least common habitat within the broader landscape and are comprised specifically of those hills featuring outcropping ironstone formations, fallen boulders, caves, overhangs and crevices (Outback Ecology 2012a).

Habitats encompassed by the project footprint are generally well represented within the wider region and impacts of the project are therefore not likely to be significant. The project will directly impact on small areas of Rocky

Ridge and Gorge habitat. Conservation significant fauna species recorded from such habitat within the greater study area include the Northern Quoll (*Dasyurus hallucatus*), Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*), Pilbara Olive Python (*Liasis olivaceus barroni*) and Ghost Bat (*Macroderma gigas*). The Rocky Ridge and Gorge habitat is less common in the regional landscape, but the limited amount of this habitat-type to be removed suggests the proposed development will have a minimal impact on these and other species at a localised and regional scale.

Table 19: Fauna Habitat of the Sulphur Springs Project Area

Habitat	Regional Context	Total Mapped Area (ha)	Proposed Disturbance (ha)	Proposed Disturbance (%)
Spinifex Stony Plains	Widespread throughout the surrounding landscape. Well represented in the region.	3,064.2	43.8	1.4
Rocky Foothills	Widespread throughout the surrounding landscape. Well represented in the region.	2,487.3	149.3	6.0
Scree Slopes	Widespread throughout the surrounding landscape. Well represented in the region.	1,042.0	96.8	9.3
Drainage Line	Limited in the surrounding landscape but well connected. Well represented in the region.	215.2	4.7	2.2
Rocky Ridges and Gorges	Limited in the surrounding landscape but well connected. Well represented in the region.	210.7	26.9	12.8
Rubble Pile	Limited in the surrounding landscape.	13.1	0.3	2.3
Plains	Widespread throughout the surrounding landscape. Well represented in the region.	590.3	0	0.0
Ficus Grove	Limited in the surrounding landscape.	0.1	0.1	100.0



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Source: Landgate Locate Mosaic
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Figure 15

Fauna Habitats over Conceptual Site Layout

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W:\Venturex Resources\Sulphur Springs\Projects\EPA Referral V2\Drawings\Sulphur Springs EPA Referral V4.map 16/11/2016 F15 Fauna Habitats Layout

3.9.3 Short Range Endemics

A targeted Short Range Endemic (SRE) survey was undertaken by Outback Ecology between 22 and 25 January 2012 (Outback Ecology 2012c). The study encompassed a 27,425 ha parcel of land that surrounds the project and covered tenements held by Venturex as well as neighbouring tenements. Drainage features were previously identified as having potential to support SRE species as they provide sheltered microhabitat that is uncommon in the surrounding landscape (Outback Ecology 2012a). The follow up survey therefore assessed these drainage features and their importance to SRE. The survey results are provided in Appendix 6.

Five drainage habitats were identified within the study area, namely Gorge, Creekline, Riverine, Drainage Line and Floodplain (Figure 16). Results yielded a total of 153 invertebrate specimens from 15 different species. Terrestrial snails were the most numerous group collected, followed by aquatic snails, millipedes, slaters, pseudoscorpions and mygalomorph spiders.

Based on current scientific knowledge, three species collected are considered potential SRE species. These are:

- Antichiropus 'DIP005'.
- Antichiropus 'DIP034'.
- Buddelundia sp. 11.

In addition, a previous biological survey at Sulphur Springs by Biota in August 2006 collected a potential SRE pseudoscorpion (*Feaella 'PSE007'*). Further taxonomic and genetic work is currently in process to determine the status of this specimen.

Table 20 details the potential SRE species and the habitat within which they were recorded.

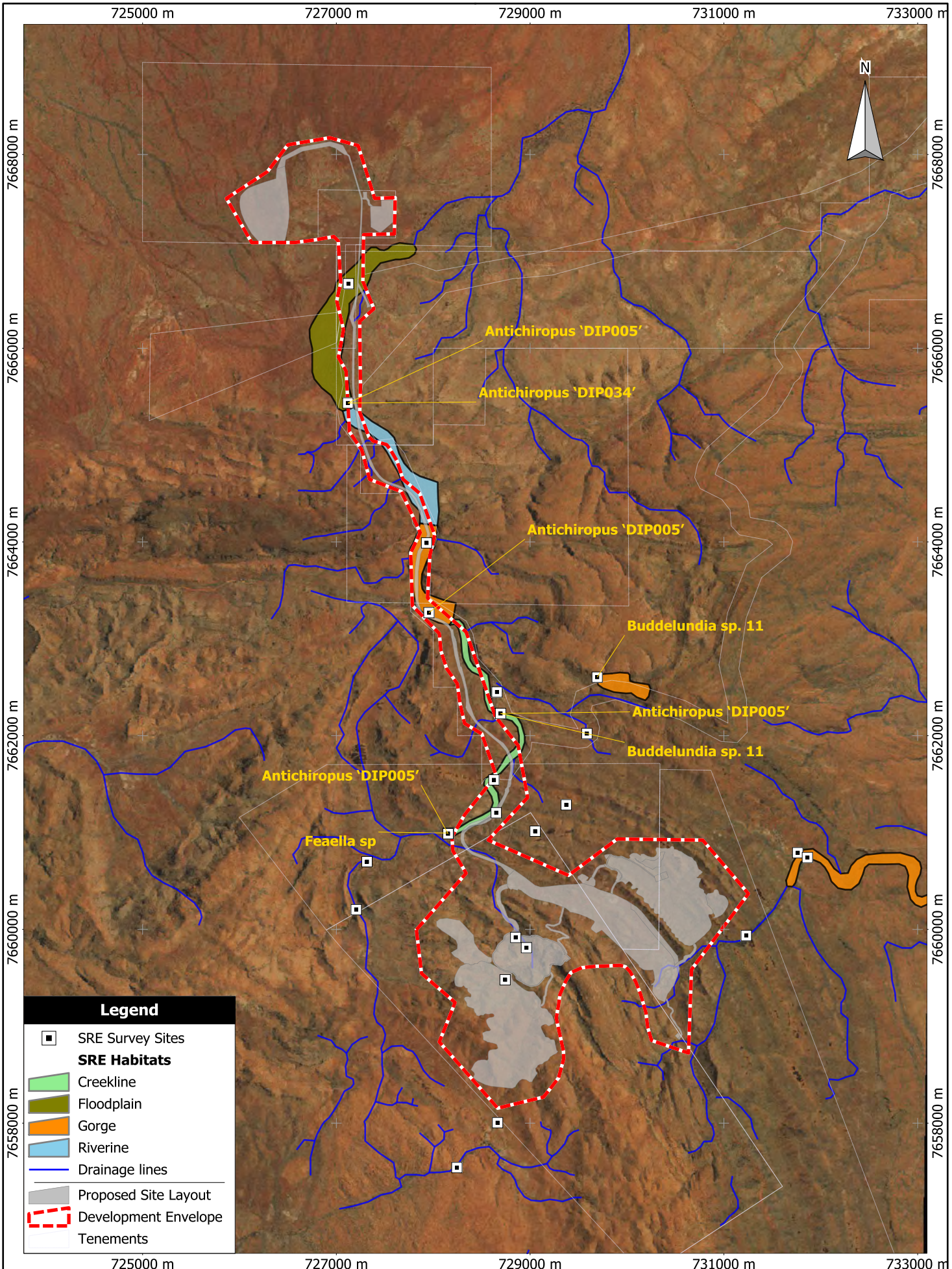
Table 20: Potential SRE Species of the Sulphur Springs Project

Species	Common Name	Location	Habitat
Antichiropus 'DIP005'	Millipede	Sites 1, 2, 3 and 4	Creekline, Gorge and Riverine
Antichiropus 'DIP034'	Millipede	Site 2	Riverine
Buddelundia sp. 11	Slaters	Sites 3 and 8	Creekline and Gorge
Feaella 'PSE007'	Pseudoscorpion	Drainage line	Creekline

Outback Ecology concluded that Gorge and Creekline habitats have the highest potential to support SRE species and thus impacts to these should be minimised where possible. The remaining three habitats are considered to be extensive both within and outside the study area and are thus unlikely to be impacted by the project.

Antichiropus 'DIP005', Antichiropus 'DIP034' and Buddelundia sp. 11 are all known to have a distribution which extends outside of the footprint of the project, both in a local and regional context. Consequently it was determined by Outback Ecology that the project is unlikely to pose a long term conservation risk to any of these species (Outback Ecology 2012c).

Although further information is awaited with regards to Feaella 'PSE007', the proposed project will not impact the collection location of this species. Given that impacts to the Creek Line habitat will be limited, Outback Ecology (2012c) concluded that it would be unlikely that the project would pose a long term conservation risk to *Feaella* PSE007.



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Air Photo Date: 2012
Grid: MGA94(50)
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Figure 16

Potential Short Range Habitat in the Study Area

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3.10 SUBTERRANEAN FAUNA

Subterranean Ecology (Scientific Environmental Services) was contracted during November 2006 to conduct a preliminary survey for stygofauna (Subterranean Ecology 2006). This report identified the occurrence of stygofauna (aquatic subterranean fauna) in the project area, and recommended a second survey to adequately sample and identify the species found, and to assess their distribution and conservation status in relation to potential impacts in the Project area and immediate surrounds.

As part of the second survey, Subterranean Ecology were requested to also undertake an assessment and field survey for troglofauna (terrestrial subterranean fauna) in possible caves or voids within the pit area. The second field survey (stygofauna phase 2 and troglofauna pilot study) was undertaken in February 2007. A follow-up troglofauna survey (phase 2) commenced in May 2007, with the final phase survey being completed in August 2007. The report documenting the findings of the surveys is provided in Appendix 7 and summarised in the following sections.

Surveys were developed and undertaken in accordance with the methodology contained in Guidance Statement No. 54: Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Assessment in Western Australia (EPA 2003) and Draft Guidance Statement 54a '*Sampling Methods for Survey Considerations for Subterranean Fauna in Western Australia'* (EPA 2007). Guidance Statement No. 54 was replaced by Environmental Protection Authority's (EPA) Environmental Assessment Guideline 12 '*Consideration of Subterranean Fauna in Environmental Impact Assessment in Western Australia'* (EPA 2013a) in 2010.

3.10.1 Stygofauna

Three detailed stygofauna surveys have been undertaken for the project area. Surveys were undertaken in 2007 by Subterranean Ecology and concentrated on the project area as a whole (Subterranean Ecology 2007a, 2007 b and 2007c).

Stygofauna were detected at 20 of the 46 sites sampled and collected from both deep and shallow groundwater habitats. The deep groundwater habitats comprised fractured-rock aquifers. Shallow groundwater habitats included alluvium and calcrete, and the hyporheos (porous interstitial) of springs and spring-brooks (Creek Spring in Sulphur Springs Creek).

The detected stygofauna comprised representatives of the major common groundwater taxa known in the Pilbara, including Crustacea (Amphipoda, Copepoda, Ostracoda, and Isopoda), Acariformes, Nematoda and Oligochaeta. More than 1,161 individual specimens were retrieved from samples, with approximately 957 individuals identified to the level of species or the lowest taxonomic rank possible.

Twenty seven taxa were identified, of which 24 were found within the zone of influence of mine dewatering and water supply drawdown. Of these 24 taxa, 20 have distributions recorded outside the zone of influence, either at a local scale or further downstream in the catchments of the Shaw and East Strelley Rivers, and/or regional scale of the Pilbara.

The local distribution patterns of identified (morpho) species were consistent with predictions based on patterns of surface drainage and catchments. Taxa not detected or identified to species level because of taxonomic limitations are likely to display similar distributions related to local patterns in surface drainage and catchments.

The four taxa not collected or otherwise recorded from outside the zone of influence were two species of Oligochaeta and two species of Nematoda. Groundwater Oligochaeta generally display widespread distributions. The taxonomy and distribution of Nematoda is poorly defined, however the collected taxa are considered likely to display similar distribution patterns to the other taxa collected during the survey.

In consideration of potential drawdown impacts to the conservation of stygofauna species within the mining area Subterranean Ecology (2007c) concluded that there was a low likelihood that any stygofauna species would be threatened with extinction as a result of groundwater drawdown impacts given that:

- All taxa identified to the level of (morpho) species were collected and/or previously recorded from areas further downstream in the catchments of the East Strelley and Shaw Rivers, or more widely in the Pilbara region.
- The local distribution patterns of identified (morpho) species were consistent with predictions based on patterns of surface drainage and catchments.
- Taxa not detected or identified to species level because of taxonomic limitations are likely to display similar distributions related to local patterns in surface drainage and catchments.

This conclusion was made on the basis of current available knowledge that most of the deep groundwater habitat will be retained within the zone of fractured rocks that remain saturated below the limits of potential water table drawdown.

3.10.2 Troglofauna

A pilot and first phase survey for troglofauna was undertaken by Subterranean Ecology in July and November 2007 (Subterranean Ecology 2007 a and b) and collected 23 morpho-species of invertebrate specimens in 18 holes situated within the proposed pit void. Considering both surveys, 1,079 specimens comprising 23 morpho-species were collected. The pilot survey in two drill holes collected 275 invertebrate specimens comprising 12 taxa belonging to Acarina (6 morpho-species) and Collembolaand Diptera (1). All of the taxa collected in the pilot study, except one, were recollected in the phase 1 survey. Only one species of cockroach (Blattodea sp. 1) displayed troglomorphic characteristics.

This troglomorphic cockroach was suspected to inhabit shallow subsurface habitats in the regolith. Potentially shallow subsurface habitats are well developed in the colluvium on slopes within the pit area and similar habitas occur extensively and continuously throughout the ranges within the wider region. It was thus considered likely that the distribution of collected fauna (including the cockroach) will unlikely be restricted to the proposed pit disturbance area and will probably occur more widely in similar habitats in the region.

The phase two and three surveys supported this hypothesis with additional cockroach specimens being found in regolith habitats outside the expected zone of influence of the proposed mine within regional areas such as Kangaroo Caves and Bernt's deposits (Phase two) and behind the Outokumpu Camp areas (Phase three).

The presence of this species outside the zone of influence, combined with the extensive and continuous regolith habitat it probably inhabits means this species is of no further conservation significance for the Sulphur Springs deposit area.

3.11 WASTE MATERIAL CHARACTERISTICS

3.11.1 Mine Wastes

Geochemical studies have been conducted on over 2,300 samples representing waste lithologies likely to be encountered during development and operation of the project (Table 21).

Table 21: Waste Rock Geochemical Characterisation Studies

Year	Author	Study Details
2007	URS	Static and kinetic testing on 3 samples collected across the profile of the proposed 2007 pit.
2008	Lutherborrow	Sulphur analysis on 2,248 drill core samples from 118 drill holes, collected across the profile of the proposed 2007 pit.
2008	RGS	Static testing on 60 samples collected across the profile of the proposed 2007 pit and kinetic testing on six composite samples prepared from this sample set. Kinetic leach column tests were monitored over a period of five months.
2012	GCA	Static testing on 17 waste rock samples collected from deeper within the deposit profile. These samples are now likely to be representative of underground waste material

These studies indicate the following:

- Weathered wastes towards the surface of the deposit are unlikely to contain reactive sulphides and are expected to be Non Acid Forming (NAF). These materials account for 50% of the waste volume to be stored in the WRD.
- Acid Neutralising Capacity (ANC) for waste materials is variable, with siltstone and breccia lithologies providing a significant excess of ANC over Maximum Potential Acidity (MPA). These lithologies account for 20% of the waste volume to be stored in the WRD.
- Waste rocks are generally non-sodic, with a low risk of dispersion and erosion.
- Less than 14% of waste rock from the open pit to be stored in the WRD is PAF.

3.11.2 Tailings

Geochemical characterisation testwork has been conducted on two simulated tailings samples produced during bench-scale metallurgical investigations on Sulphur Springs ore (GCA 2002, URS 2007c). The 2002 study involved only static testing, while the 2007 study also included kinetic geochemical testing using leach columns monitored over a five month period. There have been no changes to the proposed process flowsheet since the time of these studies and samples assessed are considered representative of fresh process tailings likely to be produced during operation of the current proposed project.

Assessment results indicated:

- Both simulated tailings samples were classified as Potentially Acid Forming – High Capacity (PAF-HC), with low buffering capacity. Samples contained a high concentration of sulphur (27%), mostly in the sulfide form and therefore capable of generating acidity (URS 2007c).
- Initial supernatant generated from tailings was pH neutral, with selenium the only element to exceed the ANZECC 2000 Guidelines for Fresh and Marine Water Quality (0.32 mg/L versus a guideline of 0.02 mg/L).
- Tailings leachate is likely to become acidic and highly saline following a relatively short period of exposure to oxidising conditions. Corresponding concentrations of soluble aluminium, arsenic, cadmium, cobalt, copper, nickel, lead, selenium, zinc and sulphate are also expected to exceed ANZECC 2000 Guidelines for Fresh and Marine Water Quality under these conditions (URS 2007c).

Despite the above findings, it must be noted that storage of high sulphur tailings within surface TSFs at mining operations throughout Australia is not uncommon and associated risks can be adequately managed via application of a robust series of design, operational and closure measures, such as the use of a HDPE liner and underdrainage system. Design features of the TSF are discussed in Section 2.7.

3.12 SOCIAL ENVIRONMENT

3.12.1 Social Setting

Sulphur Springs is located within the Pilbara region of Western Australia, within the Shire of East Pilbara. This Shire is the largest in Australia covering approximately 372,571 km^2 and mining dominates the Shire's economic landscape followed by pastoral grazing and to a lesser extent tourism. Sulphur Springs is located on three mining leases (M45/494, M45/653 and M45/1001) and six miscellaneous licences (L45/166, L45/173, L45/170, L45/179, L45/189 and L45/287).

The area surrounding the site is sparsely populated compared to the regional centres and major towns. The nearest regional centre, Port Hedland, is located 110 km northwest of the site and Marble Bar is the nearest town located approximately 57 km east of the site (by air).

3.12.2 Mining History

There are no mining-related disturbances at Sulphur Springs except for some historic remains including concrete bearing pads and the septic system and leach drains from a basic exploration camp and laydown area established on M45/1001. Exploration tracks are also present within the project area.

3.12.3 Pastoral

The majority of the project is located on Unallocated Crown Land, but the northern section of the site access road and accommodation village lie within the Panorama and Strelley Pastoral leases.

3.12.4 Native Title

The project lies largely within the claimant area of the Njamal people. A Mining Deed was executed on 3 November 2006 with the Njamal people and provides for regular consultation with them and their participation in the provision of cultural awareness training, site clearances, direct employment and provision of contract service to the project together with the payment to them of a NSR based royalty payment. The Warrarn people have an interest in the land to the north of the project.

3.12.5 Heritage

In order to determine the presence of items or sites of State, National or Aboriginal heritage, a search of the following databases were undertaken:

- Australian Heritage Places Inventory.
- Australian Heritage Council of Western Australia.
- Register of the National Estate (RNE).
- Shire of Port Hedland Municipal Inventory.
- National Trust Database.
- Department of Aboriginal Affairs (DAA) Heritage Inquiry System.

No European heritage sites were identified. One registered Aboriginal Heritage Site (site 6046) lies within the Development Envelope but is outside proposed disturbance areas.

A review of five heritage surveys which have been undertaken within the project area between 1992 and 2007 identified a further seven sites of significance in the region. All of these sites are within the Development Envelope but are not impacted by any disturbance by the project. Venturex has committed to implementing a 30 metre exclusion zone surrounding each site for protection from ground disturbing activities, as agreed with the Njamal people.

3.12.6 Air Quality and Noise

The closest community is that of Marble Bar situated approximately 57 km west of Sulphur Springs. Receptors of potential air quality and noise issues associated with the project will only be employees who may be in the area.

Placement of the accommodation camp and work locations have taken into consideration the predominant wind directions and topography of the area to minimise any risk of potential air quality and noise impacts.

4. IDENTIFICATION OF ENVIRONMENTAL FACTORS AND ASSESSMENT OF POTENTIAL IMPACTS

Based on a preliminary assessment, the following is a summary of the preliminary environmental factors identified as being relevant to the proposal:

- Flora and Vegetation.
- Terrestrial Fauna.
- Rehabilitation and Decommissioning.

Secondary factors considered less likely to be impacted by Sulphur Springs include:

- Offsets.
- Terrestrial Environmental Quality.
- Subterranean Fauna.
- Landforms.
- Hydrological Processes.
- Inland Waters Environmental Quality.
- Heritage.

Other factors considered unlikely to be impacted by Sulphur Springs include:

- Air Quality and Atmospheric Gases.
- Amenity.
- Human health.

Information regarding each of the environmental factors including a description of the potential environmental impact and preliminary management and mitigation actions is contained in Table 22. Guidance and policy documents that have been taken into consideration during the assessment of likely impact on environmental factors at the project have also been included in this table.

Table 22: Assessment of Likely Impact on Environmental Factors by Sulphur Springs

Environmental Aspect	Receiving Environment	Potential Impacts	Guidance and Policy	Preliminary Mitigation and Management Actions
Land				
Flora and Vegetation ***To maintain representation, diversity, viability and ecological function at the species, population and community level.***				
• Clearing of native vegetation. • Clearing of Threatened (DRF) Flora. • Groundwater drawdown. • Modification of surface and subsurface flow.	• Threatened (Declared Rare Flora) Flora *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4) recorded within Sulphur Springs project area. No known individuals or the ESA surrounding them will be impacted. • A further four Priority flora species have been recorded within the project area, but none of these will be impacted. • A total of 18 Vegetation Alliances in six vegetation formations were noted within the Survey Area. • Clearing is proposed in 11 vegetation Alliances, however all impacts are less than 7% of the total mapped areas. • No TECs or PECs. • Vegetation Alliance 1 was rated as very high GDE probability and Vegetation Alliance 2a was rated with a High GDE probability.	• Localised loss of vegetation from clearing. • Loss of biological diversity and reduced regional representation of flora and vegetation communities. • Fragmentation of habitat. • Spread of existing weed species and introduction of new weed species due to increased vehicle movement in the local area. • Vegetation damage due to increased fire risk. • Death of vegetation due to low pH, saline or metalliferous water and tailings spills/leaks. • Alteration to vegetation communities resulting from changed drainage patterns. • Reduction in vegetation condition due to dust emissions.	Guidance Statement No. 51: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (EPA 2004a) Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002). *Guidance Statement No. 6: Rehabilitation of Terrestrial Ecosystems.* Guidance for the Assessment of Environmental Factors (EPA 2006). State *Wildlife Conservation Act 1950* *Environmental Protection Act 1986 (Part V – clearing of native vegetation)* Federal *Environment Protection Biodiversity Conservation Act 1999*	• Venturex commits to conducting a Targeted Flora Survey for *Pityrodi*a sp. *Marble Bar* (G. Woodman & D. Coultas GWDC Opp 4) within proposed footprint areas. • Venturex commits to avoiding known *Pityrodi*a sp. *Marble Bar* (G. Woodman & D. Coultas GWDC Opp 4) plants and altering disturbance footprints where practical, should more individuals be recorded. • Local provenance seed collection will be undertaken both prior to vegetation clearing and throughout the project life. • Clearing activities will be managed to ensure clearing is strictly limited to that necessary for the operations. • Disturbance will be minimised through careful design of site layout and mine scheduling. Disturbed areas will be rehabilitated as they become available. • Vehicle and equipment hygiene procedures will be implemented to minimise introduction of and/or distribution of weed and soil borne diseases. • Vehicles will not be permitted to leave access tracks or cleared areas unless otherwise authorised by senior management. • Firefighting equipment will be located on site and in all mine vehicles. • Personnel will be trained in fire response. • Lightning protection equipment will be installed as part of project design where necessary. • Project design will consider location of drainage lines and flood levels with the aim of minimising disturbance of these areas. • Pipes transferring low pH, metalliferous or saline water, or tailings over land will be located within bunds. • Dust control measures will be implemented. • Speed limits will be implemented to minimise dust emissions. • The approved Mine Closure Plan will be amended and implemented. • Closure criteria will consider EPA objectives for this factor.

Environmental Aspect	Receiving Environment	Potential Impacts	Guidance and Policy	Preliminary Mitigation and Management Actions
Terrestrial Fauna ***To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.***				
• Clearing of habitat. • Clearing of Threatened Fauna habitat within project footprint. • Groundwater drawdown. • Modification of surface and subsurface flow. • Fauna mortality due to vehicle strikes.	Baseline studies have identified up to 151 terrestrial vertebrate fauna species that may occur within the greater study area, including 27 mammals, 83 birds, 34 reptiles, five fish and two amphibian species. Of these 19 have been identified to be of conservation significance. Only the habitat provided by the Rocky Gorge (over which the pit sits) provides a potentially important habitat for the Northern Quoll. Several northern quolls were found to occur within the impact area of the project.	• Removal and fragmentation of fauna habitat. • Reduction in connectivity of fauna habitat. • Disturbance of potential conservation significant fauna species by clearing of habitat. • Increased risk of fauna mortality from vehicle strikes. • Potential increase in pest species (populations and number of species) through establishment of domestic waste disposal and permanent water storage facilities. • Death of fauna due to bogging in the TSF or drowning in water storages such as the final pit lake. • Isolation of local habitats for terrestrial invertebrate SRE species. • Altered fire regime resulting in loss, or reduced health and condition, of native fauna and/or habitat.	Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002). Guidance Statement No. 56: Terrestrial Fauna Surveys for Environmental Impact Assessment (EPA 2004b). Guidance Statement No. 20: Sampling of Short Range Endemic Vertebrate Fauna for Environmental Impact in Western Australia (EPA 2009). *Technical Guide - Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment* (EPA 2010). State *Wildlife Conservation Act 1950.* *Environmental Protection Act 1986.* Federal *Environment Protection Biodiversity Conservation Act 1999.*	• As far as is practicable, project elements will be sited to avoid or minimise potential habitat of Northern Quoll. • Clearing activities will be managed to ensure clearing is strictly limited to that necessary for operations. • Pre-clearance surveys for the Northern Quoll will be undertaken of the project area prior to clearing taking place. Venturex will work with DPaW to develop an appropriate relocation program if any quolls are found during these surveys. • Disturbed areas will be rehabilitated as they become available. • Speed limits will be implemented and enforced to minimise fauna mortality due to vehicle strike on all roads, particularly between dusk and midnight when bats are most active. • Vehicles will not be permitted to leave access tracks or cleared areas unless otherwise authorised by senior management. • The use of insect repelling lighting will be considered to reduce the likelihood of bats being attracted to the area. • Education and awareness training will include conservation significant fauna, flora and habitat and discuss standard operating procedures in the event of fauna interactions. • Open holes, trenches, the refuse impoundment and any water holding facilities will be inspected regularly for fauna. • Domestic waste facilities will be fenced and putrescible wastes will be regularly covered. • The site induction program will provide information on fauna of conservation significance including their appearance and habitats. • Access to pit lake will be restricted by establishment of an abandonment bund at closure. • Firefighting equipment will be located on site and in all mine vehicles. • Personnel will be trained in fire response. • Lightning protection equipment will be installed as part of project design where necessary.
Rehabilitation and Closure ***To ensure that premises are closed, decommissioned and rehabilitated in an ecologically sustainable manner.***				
• Pit. • TSF and Heap Leach Facility. • WRD.	No existing or intended areas of conservation estate land are to be found around Sulphur Springs. Rehabilitated land (TSF/Heap Leach Facility and WRD) will be maintained and managed.	• Wind and water erosion of disturbed areas. • Off-site discharge of potential pollutants from un-rehabilitated land. • Ineffective establishment of vegetation and habitat. • Disruption to or poor re-establishment of local drainage paths. • Safety risks associated with project areas and the mine workings.	*Guidelines for Preparing Mine Closure Plans*. (DMP and EPA 2015) *Tailings Storage Facilities in Western Australia – Code of Practice* (DMP 2013). *Guidance Statement No. 6: Rehabilitation of Terrestrial Ecosystems*. Guidance for the Assessment of Environmental Factors (EPA 2006). Environmental Protection Bulletin No 19: *EPA Involvement in Mine Closure* (EPA. 2013). *Assessment and Management of Contaminated Sites (*DER 2014)	• Existing Mine Closure Plan approved by DMP will be amended and implemented to reflect the proposed changes to the project as per DMP and EPA Guidelines for Preparing Mine Closure Plans (2015). • Topsoil will be stripped and stockpiled for later use in rehabilitation activities. • Topsoil stockpiles will be seeded if required to minimise erosion and develop a self-sustaining seedbank. • Borrow pits, if required, will be rehabilitated with slopes battered to a 1:3 slope to reduce water erosion and ponding and blend with the surrounding environment. • Consultation will be undertaken with stakeholders regarding the future use of project roads after mine closure. • Monitoring will be implemented once areas are rehabilitated to ensure progression towards completion criteria.

Environmental Aspect	Receiving Environment	Potential Impacts	Guidance and Policy	Preliminary Mitigation and Management Actions
				• Annual payments will be made to the Mining Rehabilitation Fund.
Terrestrial Environmental Quality **To maintain the quality of land and soils so that the environment values, both ecological and social, are protected.**				
• Clearing of vegetation and stripping topsoil. • Contamination of surface or groundwater.	Land systems show no sign of degradation or erosion and the condition of perennial vegetation is generally good to very good. Soil types of the area are not particularly susceptible to erosion except in cases where the surface mantle or crusting is removed	• Contamination of soils through spillage of reagents, chemicals, hydrocarbons, tailings or metalliferous, acidic or saline water. • Erosion of disturbed areas. • Unplanned seepage of contaminated water from 'valley fill' TSF/heap leach facility with a combined HDPE and compacted low permeability sub-base liner or WRD.	*Environmental Protection Act 1986* (Part V – Works Approvals and Licensing). *Guidance Statement No. 6: Rehabilitation of Terrestrial Ecosystems.* Guidance for the Assessment of Environmental Factors (EPA 2006).	• All hydrocarbon and chemical storages will be designed and constructed in accordance with Australian Standards AS1940 and AS1692. • Pipes transferring low pH, metalliferous or saline water or tailings will be located within bunds, fitted with leak detection systems and routinely inspected. • Reagents and hydrocarbons will be stored and used within bunded areas. • Hydrocarbon wastes will be segregated from other wastes and collected for offsite disposal by a licensed contractor. • Spill kits will be located at strategic locations throughout the project area and employees trained in their use. • Disturbance will be minimised through careful design of site layout and mine scheduling. Disturbed areas will be rehabilitated as they become available. • Topsoil will be stripped and stockpiled for later use in rehabilitation activities. • Topsoil stockpiles will be seeded if required to minimise erosion and develop a self-sustaining seedbank. • Heap leach facility design will include a leak collection and recovery system. • The heap leach pad will include a combined 1.5 mm HDPE and compacted low permeability sub-base liner. • PLS and ILS ponds and solution channels will include a leak collection and recovery system consisting of a primary 1.5 mm HDPE liner, intermediate drainage layer, secondary 1.0 mm HDPE liner, and low permeability sub-base liner • TSF design will include an underdrainage system, a combined 1.5 mm HDPE and compacted low permeability sub-base liner and a leakage collection and recovery system. • All areas where PAF waste rock is stored will be adequately engineered and constructed so as to ensure that unplanned leakage of contaminated water is minimised. • Water storages potentially storing saline or poor quality water will be lined to prevent or minimise seepage. They will be operated with adequate freeboard to store inflows associated with 1 in 100 year, 72 hour rainfall event.

Environmental Aspect	Receiving Environment	Potential Impacts	Guidance and Policy	Preliminary Mitigation and Management Actions
Subterranean Fauna ***To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.***				
• Mining open pit. • Groundwater drawdown and changes in quality for project and accommodation camp.	Baseline studies within the proposed project area identified four species of stygofauna and one troglofauna species. These stygofauna species are indicated to have wide distributions through hydraulic connection within the secondary aquifer system and therefore impacts on stygofauna from open pit development are considered negligible. The troglofauna was found to occur within a regional context and thus was not considered of conservation significance.	• Direct disturbance and potential, localised loss of subterranean fauna habitat due to open pit development. • Alteration of groundwater tables i.e. drawdown associated with pumping and final pit lake.	*Environmental Assessment Guideline 12 'Consideration of Subterranean Fauna in Environmental Impact Assessment in Western Australia'* (EPA 2013a). *Draft Guidance Statement 54a 'Sampling Methods for Survey Considerations for Subterranean Fauna in Western Australia'* (EPA 2007). State *Wildlife Conservation Act 1950*	• Final pit lake modelling will occur as part of closure planning following the commencement of mining.
Landforms ***To maintain the variety, integrity, ecological functions and environmental values of landforms.***				
• Isolated surface water ponds. • Open Pit. • Valley Fill HDPE lined TSF and heap leach facility. • WRD.	• Project area occurs within three land systems; Boolgeeda, Capricorn and Rocklea. • No landforms within project tenements are listed on the Western Australian Geoheritage Sites database. • Baseline studies have not identified any landforms within project tenements that could be considered rare at a local, regional or national level.	• Permanent changes to the landform as a result of development of an open pit and construction of WRD and TSF/heap leach facility. • Short term changes to landform for construction of project elements. Such impacts on landform are only for the life of the project. • Increased erosion within disturbed areas.	*Environmental Assessment Guideline for Environmental Principles, Factors and Objectives*, (EAG 8). (EPA 2015). *Guidance on the EPA Landforms Factor.* Environmental Protection Bulletin Number 23 (EPA 2015).	• Existing Mine Closure Plan approved by DMP will be amended and implemented to reflect the proposed changes to the project as per DMP and EPA Guidelines for Preparing Mine Closure Plans (2015). • Project design has considered minimising landform disturbance and ensuring constructed landforms will be no higher than surrounding hills. • Clearing activities will be managed to ensure clearing is strictly limited to that necessary for the operations. • Disturbed areas will be rehabilitated as they become available.
Water				
Hydrological Processes ***To maintain the hydrological regimes of groundwater and surface water so that existing and potential uses, including ecosystem maintenance, are protected.***				
Groundwater abstraction for mine dewatering and site water supply. Dewatering discharge to 'valley fill' TSF with a combined HDPE and compacted low permeability sub-base liner. Interception of surface water flows across the project area.	The project area is located within the Pilbara Surface Water Management Area. The physical surface characteristics of the site are typical of the Pilbara region with rocky hills, small gorges and gravely loam valleys, with the majority of the watercourses seasonal. Groundwater and surface water flow systems in the area are complex, variable and linked. The local fractured rock aquifer system is interpreted to be compartmentalised, with groundwater flow strongly linked to transmissive structures.	Development of Sulphur Springs has potential to affect hydrological processes through: • Formation of a cone of water table drawdown in the immediate vicinity of the underground mine as a result of mine dewatering. • Impacts to aquifer water quality as a result of mine activities. • Groundwater drawdown which could have an adverse impact on health of GDEs. • Localised reduction in surface water volumes. • Flooding of the project area and associated project elements. • Ponding of water in project areas.	Position Statement 4 – Environmental Protection of Wetlands (EPA 2004c) Department of Water (DoW). 2013. *Western Australia Water in Mining Guideline. Water licensing delivery report series.* Report No. 12. Perth, Western Australia State *Environmental Protection Act 1986* (Part V – Works Approvals and Licensing). *Rights In Irrigation and Water Act 1914*	• The mine dewatering regime will consider water quality, rate of groundwater drawdown, location of impact of drawdown and presence of GDEs. Detailed project design will focus on minimising groundwater drawdown in areas that support GDEs. • A detailed hydrological review and on-going monitoring will be conducted to ensure sustainable groundwater abstraction. • Venturex will seek approval from DoW to increase groundwater abstraction for the project for the purposes of mining, dust suppression and ore processing. • All groundwater abstraction will be conducted in accordance with the *Rights in Irrigation and Water Act 1914.* • The 'valley fill' TSF will be constructed with a combined 1.5 mm HDPE and compacted low permeability sub-base liner. The TSF will have an underdrainage and seepage collection system to minimise adverse impacts to the environment. • The heap leach pad will be constructed with a combined 1.5 mm HDPE and compacted low permeability sub-base liner. • PLS and ILS ponds and solution channels will include a leak collection and recovery system consisting of a primary 1.5 mm HDPE liner, intermediate

Environmental Aspect	Receiving Environment	Potential Impacts	Guidance and Policy	Preliminary Mitigation and Management Actions
				drainage layer, secondary 1.0 mm HDPE liner, and low permeability sub-base liner. • Project design has incorporated surface water diversion measures to minimise risk of flooding or ponding of project areas. • Project design has considered flood levels and made adequate provision to minimise risk of flooding affecting project areas. • Culverts or floodways will be installed where necessary to prevent blockage of drainages. • Engineered PAF cells in the permanent WRD will be preferentially located such that any seepage is directed towards cone of depression associated with the pit. • Groundwater monitoring bores will be installed in accordance with a site wide groundwater management plan to monitor groundwater levels and quality.
Inland Waters Environmental Quality ***To maintain the quality of groundwater and surface water, sediment and biota so that the environmental values, both ecological and social, are protected.***				
• Ore mining. • WRD. • 'Valley fill' TSF and heap leach facility with a combined HDPE and compacted low permeability sub-base liner	Surface water flows north from the project area through incised drainage channels to the alluvial flats between the Strelley and Shaw rivers via Sulphur Springs Creek. The project area is situated on a catchment divide between the Shaw River catchment and the Strelley River catchment	• Contamination of underlying groundwater due to seepage from mine waste landforms (TSF, heap leach facility and WRD). • Contamination of underlying groundwater due to mixing with waters formed in a pit lake after closure. • Contamination of drainage lines from low pH, metalliferous or saline water, tailings or hydrocarbon spills. • Increased sediment entering drainage lines during construction or following periods of high rainfall.	Position Statement 4 – Environmental Protection of Wetlands (EPA 2004c). *Rights In Irrigation and Water Act 1914* Department of Water (DoW). 2013. *Western Australia Water in Mining Guideline. Water licensing delivery report series.* Report No. 12. Perth, Western Australia.	• Project design has considered locations of drainages and minimised disturbance of these. • All PAF waste immediately associated with the orebody mined in the pit will be disposed of underground as part of ongoing operations or at the end of the underground mine life. • Other PAF waste mined in the pit will be preferentially stored underground and the remainder encapsulated in the surface WRD to minimise the potential for oxidation and generation of acid and metalliferous mine drainage. • All waste mined from the underground will be disposed of in the underground mine as part of the ongoing operations. • Tailings will either be used as underground stope fill or be contained within a 'valley fill' TSF with a combined HDPE and compacted low permeability sub-base liner. The TSF will have an underdrainage and seepage collection system to minimise adverse impacts to the environment. • Diversion bunds will be constructed to separate clean and potentially contaminated water. • Potentially contaminated water will be captured and either re-used, transferred to the TSF for evaporation. • Pipes transferring low pH, metalliferous or saline water, or tailings will be located within bunds, fitted with leak detection systems and routinely inspected. • Process solution pipes connecting the heap leach facility and SX-EW will be installed within HDPE-lined bunds. • Sulphuric acid distribution lines will be double-sleeved where pipe sections pass through unbunded areas. • Reagents and hydrocarbons will be stored and used within bunded areas. • Hydrocarbon transfer operations will occur within bunded areas. • Spill kits will be located at strategic locations throughout the project area and employees trained in their use. • Water storages potentially storing saline or poor quality water will be lined to prevent or minimise seepage. • Sediment control measures will be implemented during construction and operation.

Environmental Aspect	Receiving Environment	Potential Impacts	Guidance and Policy	Preliminary Mitigation and Management Actions
Heritage ***To ensure that historical and cultural associations, and natural heritage, are not adversely affected.***				
• Access to site. • Heritage sites.	No known European heritage sites are within the project area. Seven Aboriginal heritage sites of significance are within the Development Envelope, but these sites and associated exclusion zones are not impacted by any disturbance by the project.	Disruption of access to sites of cultural significance.	*Aboriginal Heritage Act (1972).* *Guidance Statement No. 41: Assessment of Aboriginal Heritage (EPA 2004).*	• Project design will take into consideration results of the archaeological and ethnographic surveys and avoid impacts where possible. • Sulphur Springs site inductions will include information on heritage aspects of the project area. • Employees will receive cultural awareness training as part of their induction. This training will address heritage issues associated with the site. • Venturex has committed to implementing a 30 metre exclusion zone surrounding each site for protection from ground disturbing activities, as agreed with the Njamal people.
Offsets ***To counterbalance any significant residual environmental impacts or uncertainty through the application of offsets.***				
• Land clearing. • Groundwater drawdown.	High value assets: • *Pityrodia* sp. Marble Bar (G. Woodman & D. Coultas GWDC Opp 4). • Northern Quoll habitat.	Clearing will include: • 27 ha of potential habitat for Northern Quoll. • Indirect impacts to North Quoll and *Pityrodia*.	*Environmental Protection Bulletin No. 1: Environmental Offsets* (EPA 2014). *WA Environmental Offsets Guidelines.* Perth, Western Australia. (Government of Western Australia 2014). *WA Environmental Offsets Policy.* Perth, Western Australia (Government of Western Australia 2011). Federal *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy (DoE 2012).* *How to Use the Offsets Assessment Guide*: http://www.environment.gov.au/system/files/resources/12630bb4-2c10-4c8e-815f-2d7862bf87e7/files/offsets-how-use.pdf (DoE 2012). *Offset Calculation Excel spreadsheet with embedded formulae*: http://www.environment.gov.au/epbc/publications/environmental-offsets-policy.html.	If the proposal is likely to have any significant residual environmental impacts, identify environmental offsets, consistent with the requirements in the WA *Environmental Offsets Guidelines*, which includes the use of the WA *Environmental Offsets Calculation Spreadsheet* and *EPA Environmental Protection Bulletin No.1: Environmental Offsets*.
Air Quality and Atmospheric Gases ***To maintain air quality for the protection of the environment and human health and amenity, and to minimise the emission of greenhouse and other atmospheric gases through the application of best practice.***				
• Mining. • Transportation.	Sulphur Springs is remote and the nearest sensitive receptor, Marble Bar, is located approximately 57 km east of the project.	Generation of dust via: • Land clearing during construction. • Open pit blasting. • Material handling within the open pit. • Crushing processes. • Erosion from topsoil, waste rock and ore stockpiles. • Vehicle movement on unsealed roads within the project area. Generation of greenhouse gas emissions via engine exhaust emissions from construction	*A Guideline for Managing the Impacts of Dust and Associated Contaminants from Land Development Sites, Contaminated Sites Remediation and Other Related Activities* (DEC 2011). Environmental Protection Bulletin No .24: *Greenhouse Gas Emissions and Consideration of Projected Climate Change Impacts in the EIA Process (*EPA 2015). *National Environmental Protection (Ambient Air Quality) Measure (2003).*	• The accommodation village has adequate separation from mining elements and activities to minimise adverse impacts. • Site roads will be properly formed and compacted with appropriate drainage. • Vehicle traffic will be confined to defined roads and tracks. • Dust suppression measures will be implemented using water sprays and other means, as necessary. • Disturbed areas will be rehabilitated as they become available. • Vehicles and power generation equipment will be maintained to minimise emissions. • Energy efficiency and greenhouse gas emissions will be considered as part of equipment selection and purchase. • The nearest town (Marble Bar) is 57 km away and beyond range of any impacts of the project. • The processing plant crushing circuit will include a dust collector that will draw

Environmental Aspect	Receiving Environment	Potential Impacts	Guidance and Policy	Preliminary Mitigation and Management Actions
		equipment, open pit mining equipment and light vehicles.		dust from the ore transfer points in the process stream. • Concentrate loading will take place in the concentrate storage area using a weighbridge to monitor weight. Covered containers will be used on quad road-trains carrying 120 tonne payload. • Containers will be unloaded in Port Hedland using the ship's cranes and a special tipping unit to discharge directly into the hold with minimum dust generation. Dust suppression sprays will inject a water mist around the hull opening prior to unloading of the containers to further minimise generation of dust.
Amenity ***To ensure that impacts to amenity are reduced as low as reasonably practicable.***				
• Mining (blasting and noise). • Transport.	The project area is remote and is not visited by people other than Traditional Owners. The nearest sensitive receptor, Marble Bar, is 57 km to the east.	Potential Impacts of Sulphur Springs are: • Disruption to traditional use of the land. • Visual scar on the landscape if rehabilitation of disturbed areas is ineffective.	*A Guideline for Managing the Impacts of Dust and Associated Contaminants from Land Development Sites, Contaminated Sites Remediation and Other Related Activities* (DEC 2011). *Health Act (1911).* *Mines Safety and Inspection Act (1995).* *Contaminated Sites Act (2003).*	• The accommodation village has adequate separation from mining elements and activities to minimise adverse impacts. • The nearest town (Marble Bar) is 57 km away and beyond range of any impacts of the project. • Venturex has an agreement with the Traditional Owners of the project area. This agreement provides for regular consultation with, and participation of, the Traditional owners on the proposed project including conducting Cultural Awareness training of operations staff. • Stakeholder consultation will continue to be undertaken. • Existing Mine Closure Plan will be amended and implemented in consultation with Traditional Owners. • Monitoring will be implemented once areas are rehabilitated to ensure progression towards completion criteria.
Human Health ***To ensure that human health is not adversely affected.***				
• Dust. • Noise. • Chemicals and contaminated waters.	The nearest sensitive receptors are the accommodation village (approximately 7 km to the north of the project) and Marble Bar (approximately 57 km to the east of the project).	The project area is remote and is not visited by people other than Traditional Owners. Potential impacts on health of employees relevant to the *EP Act* include: • Noise. • Air quality (particulates). • Chemical exposure.	*Environmental Protection Act 1986* (Part V – Works Approvals and Licensing).	• Project design has considered exposure to noise and dust emissions. The accommodation village has adequate separation to minimise adverse impacts. • Compliance with occupational hygiene requirements for noise, dust and chemicals in operational areas.

Table 23 summarises the reasoning behind the assessment of the environmental factors for Sulphur Springs.

Table 23: Summary of Assessment of Environmental Factors

Environmental Factor	Yes/No	Comments
Flora and Vegetation	**Yes**	No more than 321.9 ha of clearing required. Not located within ESAs, Schedule 1 Areas, or within DPaW managed land. No TECs or PECs. Some Threatened (DRF) *Pityrodia* sp. Marble Bar occur within the development envelope, however infrastructure has been redesigned to avoid all ESAs. Potential impact will be mitigated using standard mining industry practices. CPS5658/1 currently permits clearing of up to 193 ha within the proposed development envelope.
Landforms	No	Not a key factor. No landforms within project tenements are listed on the Western Australian Geoheritage Sites database and baseline studies have not identified any landforms within project tenements that could be considered rare at a local, regional or national level.
Subterranean Fauna	No	Not a key factor. Subterranean fauna found within the project area are likely to occur outside the zone of influence.
Terrestrial Environmental Quality	No	Not a key factor. Project designed to minimise risk of land and soil contamination and preserve soil quality for rehabilitation.
Terrestrial Fauna	Yes	Approximately 321.9 ha of fauna habitat to be cleared. This includes 27 ha of rocky ridges, gorge and ficus grove habitats to be cleared for the pit. Impacts have been minimised by modifying the project footprint to avoid habitat where possible. Impacts can be further mitigated using standard mining industry practices.
Hydrological Processes	No	Not a key factor. The project design has considered surface water flows as well as impacts to groundwater quality and draw down to minimise impacts to GDEs.
Inland Waters Environmental Quality	No	No excess water discharge will be required.
Air Quality and Atmospheric Gases	No	There are no communities in close proximity to the proposal. The nearest community is Marble Bar which is approximately 57 km to the east.
Amenity	No	There are no sensitive receptors given the remoteness of Sulphur Springs.
Heritage	No	Consultation with Traditional Owners has not identified significant issues to date. Traditional Owners will be active participants in the project as employees and providing cross cultural training and contract. Potential impacts will be mitigated by Project design. Potential impacts will be mitigated by Project design.
Human Health	No	There are no communities in close proximity to the proposal. The nearest community is Marble Bar which is approximately 57 km to the east.
Offsets	No	Careful siting and design of project elements means there are no significant residual environmental impacts or risks associated with the project.
Rehabilitation and Decommissioning	**Yes**	The heap leach facility sits within the final footprint of the TSF and the two landforms will be integrated at closure to form a final waste landform. Tailings materials have been identified as PAF and will be stored in a 'valley fill' TSF with a combined HDPE and compacted low permeability sub-base liner and a water-shedding cover installed at closure. Less than 14% of waste rock generated from the pit is predicted to be PAF and will be encapsulated in engineered cells within the WRD.

Environmental Factor	Yes/No	Comments
		Suitable NAF waste rock required for closure of the TSF/heap leach facility will be stored adjacent to this structure to preserve the integrity of this material and reduce costs of rehandling. Good quality competent rock, soils and subsoils are available for rehabilitation.

Chart 2 illustrates the likely significance of each of the environmental factors considering the inherent and residual risk after management and mitigation measures have been applied. From this it can be seen that the residual risk for each factor is considered below the point where formal assessment under the *EP Act* is warranted.

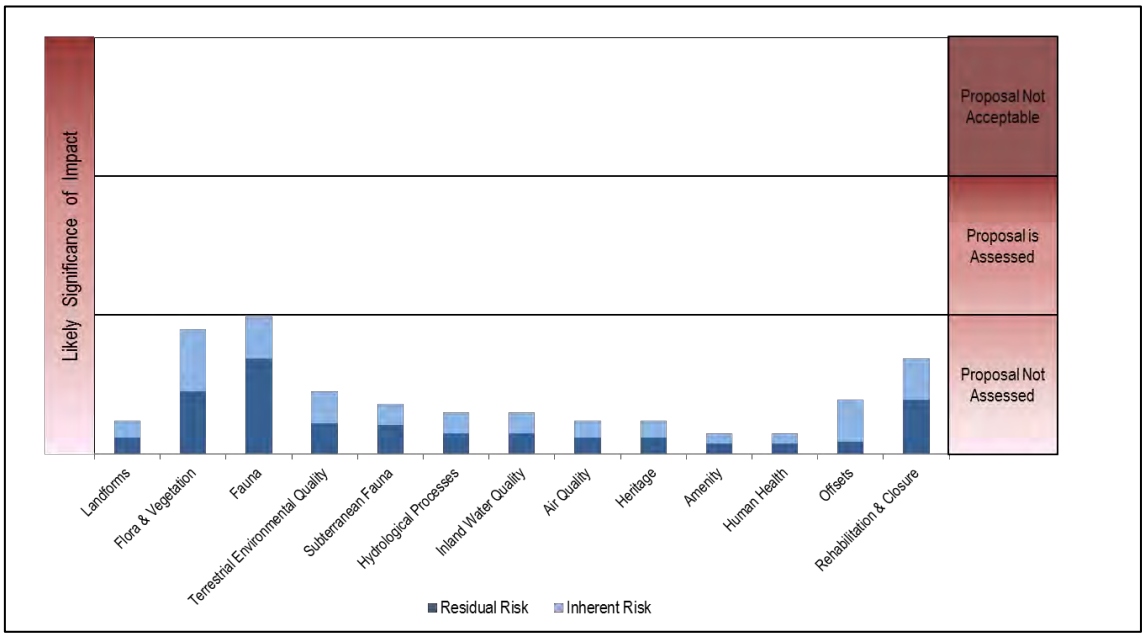

Chart 2: Assessment of Likelihood of Significant Impact by Factor

5. STAKEHOLDER CONSULTATION

5.1 STAKEHOLDER IDENTIFICATION

Venturex is in the process of working to establish economically, environmentally and socially responsible exploration and mining development at Sulphur Springs. The company has engaged the following key stakeholders in this project:

- State government.
- Federal government.
- Aboriginal groups.
- Non-government organisation and Special Interest Groups.
- Pastoral station owner.

Table 24 lists stakeholders identified for Sulphur Springs.

Table 24: Key Stakeholders for Sulphur Springs

Stakeholder Sector	Organisation	Interest
State Government Departments and Agencies	Office of the Environmental Protection Authority (OEPA).	• Administers *EP Act*. • Part IV (*EP Act*) Environmental Impact Assessments.
	Department of Aboriginal Affairs (DAA).	• Indigenous and native title requirements. • Heritage, cultural, ethnographic and archaeological sites.
	Department of Mines and Petroleum (DMP). Mine Safety Inspectorate.	• Administers *Mining Act 1978* (*Mining Act*) and Regulations. • Tenement conditions. • Mining proposals, programs of work. • Mining rehabilitation fund. • Rehabilitation standards. • Safety in resource sector.
	Department of Water (DoW).	• Provision of licences to take and abstract water. • Groundwater quality and quantity.
	Department of Environment Regulation (DER).	Administers Part V (*EP Act*), Industry Regulation and Licensing and *Contaminated Sites Act 2003*.
	Department of Parks and Wildlife (DPaW).	• Administers *Wildlife Conservation Act 1950* (*WC Act*). • Flora, fauna and habitat conservation. • Interest in Projects that are located on DPaW-managed land only. • Baseline surveys and licences to take flora and fauna.
	Department of Fire and Emergency Services (DFES).	• Fire breaks. • Provision of emergency services.
	Department of Health (DoH).	Environmental health, building and planning compliance.
	Pastoral Lands Board (PLB).	Pastoral leases, stations.
	Main Roads Western Australia (MRWA).	Use of public roads.

Stakeholder Sector	Organisation	Interest
Federal Government Departments	Department of the Environment (Commonwealth, Territories and Assessment Branch) (DoE).	Part 7 (Referral) and Part 8 (Assessment) environmental impact assessments of matters of national environmental significance.
Local Government Authorities	East Pilbara Shire	Use of public roads and infrastructure.
Indigenous Groups	Native Title Claimant Group (Njamal Group).	• Access to and use of Traditional Owner land. • Cultural heritage values. • Native Title rights.
Underlying Land/Tenement Owners	Atlas Iron Limited	Land access approvals/agreements use of minor infrastructure.
Environmental Interest Groups	Wildflower Society of Western Australia. Conservation Council of Western Australia (CCWA).	Potential interest in baseline surveys and significance of data.

5.2 CONSULTATION

Stakeholder management has been adopted by senior management with stakeholder registers and meeting minutes being maintained. Stakeholder engagement, consultation and participation strategies are discussed at the senior management level and are implemented as an ongoing process. A copy of the Stakeholder Register is provided in Appendix 8.

The objective of Venturex's consultation program is to enable individuals, groups and agencies with an interest in the proposed project to have access to up-to-date, relevant information regarding Sulphur Springs, as well as providing a means for stakeholders to raise issues and concerns, and Venturex with the means to respond to these.

Venturex carried out extensive direct consultation with neighbours, pastoralists, representatives of interested parties and regulatory agencies during the Feasibility Study and permitting of the project between 2012 and 2014. Presentations and information sessions were held to provide stakeholders with an overview of the project as well as information on potential impacts and how they will be managed. These sessions also provided a mechanism for participant feedback.

Stakeholder consultation has continued since this time, as appropriate, given the downturn in economic conditions for the resource industry.

The project lies largely within the claimant area of the Njamal people. The existing agreement with the Njamal people provides for regular consultation with them and provides for their participation in the provision of cultural awareness training, site clearances, direct employment and provision of contract service to the project together with the payment to them of a net smelter royalty based royalty payment.

Venturex is committed to continuing stakeholder consultation throughout the construction, operation and decommissioning phases of the project. Consultation will be aimed at developing relationships that are mutually beneficial to both parties.

6. EPA PRINCIPLES

The EPA has identified a set of principles for environmental management. Venturex considered these initially in the Sulphur Springs optimisation study. Further consideration of the EPA principles will be given during the Sulphur Springs feasibility study (anticipated to be completed during 2017) when Venturex's environmental design standards will be incorporated and implemented in the engineering specifications for Sulphur Springs. Details of how these have currently been considered in the early stages of project design are provided in Table 25.

Table 25: Principles of Environmental Management

Principle	Application
Precautionary Principle Where there are threats of serious irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, decisions should be guided by: • Careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and • An assessment of the risk-weighted consequences of various options.	Venturex will utilise baseline environmental investigations to identify potential impacts and assess the environmental risk of project implementation on these aspects. Venturex commits to develop and implement measures to avoid serious or irreversible damage to the environment. Where gaps in scientific knowledge may exist Venturex will ensure management measures will adequately cover the broader extent of the potential impact.
Intergenerational Equity The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.	Venturex commits to managing those environmental factors within its control such that future adverse impacts are minimised and that, wherever possible, the quality of the environment is maintained or enhanced. Amendment of the approved Mine Closure Plan will be prepared in consultation with regulatory and Traditional Owner stakeholders to ensure that post mining land use is consistent with agreed stakeholder objectives and so that rehabilitation can be progressively implemented.
Conservation of Biological Diversity and Ecological Integrity Conservation of biological diversity and ecological integration should be a fundamental consideration.	Sulphur Springs site layout, environmental protection measures, and engineering specifications have taken into account conservation of biological diversity. There will be direct impacts from removal of the Rocky Gorge habitat within the pit footprint that Northern Quolls utilise as well as indirect impacts to the Northern Quoll from activities associated with mining as well as the road between the accommodation camp and the mining project. Additionally several species of stygofauna will be impacted by the project pit and groundwater drawdown associated with the mine pit and accommodation camp water requirements. Indirect impacts to Pityrodia are possible, although all known individuals and their surrounding ESAs have been avoided through careful project design.

Principle	Application
	Biological studies undertaken as part of collation of baseline information for Sulphur Springs have greatly assisted the scientific community in understanding the biological diversity of this area. Venturex undertakes to fully assess the effects of its operations, both direct and indirect, on the biological environment and to implement measures to protect remaining biodiversity. This assessment will be documented in the environmental approval submissions provided to regulatory authorities.
Improved Valuation, Pricing and Incentive Mechanisms • Environmental factors should be included in the valuation of assets and services. • The polluter pays principle – those who generate pollution and waste should bear the cost of containment, avoidance or abatement. • The users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any waste. • Environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, which benefit and/or minimise costs to develop their own solutions and responses to environmental problems.	Venturex is committed to implementing proven, practical and economically viable technologies where practical and possible. All engineering designs have been reviewed to identify opportunities for improved energy efficiency and greenhouse gas reduction, and all proven, practical and economically viable opportunities have been implemented. Suppliers and materials with low carbon footprints will be utilised where practicable. Venturex will identify and store suitable NAF waste required for the construction and encapsulation of the TSF adjacent to the facility so as to underwrite its ultimate rehabilitation liability. Venturex recognises that project costs include mitigation, management and closure actions.
Waste Minimisation All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment. Wastes should be managed in accordance with the following order of preference: • Avoidance. • Re-use. • Recycling. • Recovery. • Treatment. • Containment. • Disposal.	Waste minimisation principles have been considered in project design. This includes: • Use of tailings and PAF waste rock as fill underground will be maximised as far as practical. • Minimising the size of the TSF and WRD. • Re-use of topsoil and cleared vegetation in rehabilitation of areas during operations and post-mining. • Disposal of putrescible wastes in a purpose built onsite landfill. • Reduce landfill by reusing and recycling materials where possible. • Minimising packaging wastes associated with reagents by importing in bulk and requiring return of packaging to suppliers.

7. PROJECT ENVIRONMENTAL ASSESSMENT REQUIREMENTS

Sulphur Springs is located in a remote greenfield location within mining leases M45/494, M45/653 and M45/1001 and miscellaneous licences L45/166, L45/173, L45/170, L45/179 and L45/189. Baseline environmental studies undertaken by Venturex and previous owners have significantly contributed to the scientific knowledge of the area and have given Venturex a well-developed understanding of Sulphur Springs, the surrounding environmental aspects and potential impacts.

Venturex has engaged key stakeholders of the area since acquiring tenements in 2012 and intends to continue the stakeholder consultation program as further environmental and engineering investigations are initiated and project design details are refined.

Venturex considers the significant environmental issues associated with Sulphur Springs are limited in nature and extent. Environmental issues can be managed effectively within the following regulatory frameworks:

- **Native Vegetation Clearing Permit**: This is a well-documented assessment process with opportunity for public comment. Impacts of land clearing can be adequately assessed by DMP using this process.
- **Permit to Take Declared Rare Flora (DRF)**: This is a well-documented assessment process managed by the Department of Parks and Wildlife (DPaW). Impacts of removing DRF and monitoring remaining individuals can be adequately assessed by DPaW using this process should it be required.
- **Mining Proposal**: This is a well-documented assessment process managed by DMP Environmental Officers and part of the project has already been assessed and approved under MP Reg ID 40542. DMP Environmental Officers have a strong technical understanding of the potential impacts of mining and associated activities such as ore processing, heap leach, waste disposal, power generation and borefield development to supply water for mining projects and appropriate management measures to safeguard the environment. Requirements for lodgement of an annual Mining Rehabilitation Fund fee will assist in minimising environmental liabilities to the State in the case of unplanned closure. The existing Mine Closure Plan will be amended in accordance with EPA and DMP guidelines, incorporating progressive rehabilitation, closure monitoring and maintenance.
- **Works Approval**: This is a well-documented assessment process with opportunity for public comment. Design of equipment and infrastructure associated with pollution management, specifically discharges to air, land and water, can be adequately assessed by DER using this process.
- **Environmental Licence**: This is a well-documented assessment process with opportunity for public comment. Impacts of discharges to air, land and water during Project operation can be adequately assessed and regulated by DER using this process. DER has powers to assess and ensure compliance with licence conditions.
- **Water Licence**: An application to amend existing GWL 165207(4) for the abstraction and use of water for mine dewatering activities (in accordance with MP Reg ID 40542), will be made during future phases of study. This is part of a well-documented assessment process and impacts on aquifers can be adequately assessed by DoW using this process.

8. CONCLUSION

Sulphur Springs is located in a remote greenfields area historically used for pastoral activities and mineral exploration. A large number of baseline environmental studies conducted over the past 14 years by Venturex and previous tenement holders have contributed significantly to the scientific understanding of the area and allowed Venturex to design the project in a way that identifies, prevents and minimises adverse environmental impacts.

Venturex has engaged key stakeholders since 2012 through an extensive stakeholder consultation program during the exploration, environmental baseline studies, project design and Native Title negotiation processes. Venturex will continue the stakeholder consultation program and effectively engage with key stakeholders throughout the life of the project.

Venturex believes that potential adverse environmental impacts associated with construction and implementation of Sulphur Springs are limited due to well thought-out environmental and engineering project designs. Potential impacts not able to be fully avoided through project design will be able to be effectively managed and minimised using best practice mining industry management and mitigation measures.

Preliminary environmental factors that have potential to be impacted through land disturbance and groundwater abstraction have been identified in order of greatest to least potential impact to be (Table 22):

- Flora and vegetation.
- Terrestrial fauna.
- Rehabilitation and decommissioning.

After application of best practice management and mitigation measures, Venturex believe the EPA objectives for these three environmental factors can be met (Chart 2). Fundamental to achieving this will be the careful and detailed design of the project in order to limit and/or reduce the impact upon Pityrodia and the Northern Quoll. Venturex believes that through the implementation of management plans for both these species and education of the workforce it can meet the EPA objectives for flora and vegetation and terrestrial fauna.

Rehabilitation and decommissioning of the project will, as a minimum, use accepted industry practices and will be managed in accordance with the Mine Closure Plan Guidelines jointly published by the EPA and DMP. Venturex will also trial technologies as they emerge that might help to mitigate the long term environmental impacts of the project.

Venturex does not believe that formal assessment of Sulphur Springs is required under Part IV of the *EP Act*. Venturex believes that environmental impacts can be adequately assessed and implementation monitored through provisions of the *Mining Act* and Part V provisions of the *EP Act*.

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APPENDICES

APPENDIX 1: SULPHUR SPRINGS PER TERMINATION LETTER (PER ASSESSMENT NO. 1664)

GOVERNMENT OF WESTERN AUSTRALIA

Environmental Protection Authority

The Atrium,
Level 8, 168 St Georges Terrace,
Perth, Western Australia 6000.
Telephone: (08) 6467 5000.
Facsimile: (08) 6467 5557.

Postal Address: Locked Bag 33,
Cloisters Square, Perth, Western Australia 6850.
Website: www.epa.wa.gov.au

Ms Liza Carpene
Company Secretary
Venturex Sulphur Springs Pty Ltd
PO Box 1444
WEST LEEDERVILLE WA 6901

Our Ref OEPA2010/001045-1.
Enquiries T Gentle 6467 5433
Email tim.gentle@epa.wa.gov.au

Dear Ms Carpone

PROPOSAL:	**Sulphur Springs (Panorama) Copper Zinc Project**
LOCATION:	**Approximately 160 km south-east of Port Hedland**
PROPONENT:	**Venturex Sulphur Springs Pty Ltd**
LEVEL OF ASSESSMENT:	**PER (Assessment No. 1664)**

Thank you for your letter received by email on 22 June 2012 advising that your company no longer intends to proceed with the above proposal (based on open pit development) and requesting termination of the environmental assessment process.

In response and pursuant to section 40A(1)(a) of the *Environmental Protection Act 1986* (EP Act), the Environmental Protection Authority (EPA) hereby terminates the environmental impact assessment of the proposal to develop the Sulphur Springs (Panorama) Copper Zinc Project (open pit development) which was being assessed at the level of Public Environmental Review.

Please be advised that following termination of an assessment under the EP Act, any subsequent plan to progress the proposal (open pit development) would require a fresh referral to the EPA for assessment under section 38 of the EP Act.

Should you require further clarification on the above, please contact Mr Tim Gentle, the Office of the EPA assessment officer for the project, who can be contacted on telephone number 6467 5433.

Yours sincerely

Dr Paul Vogel
CHAIRMAN

2 July 2012

APPENDIX 2: A REVIEW OF THE FLORA AND VEGETATION AND AN ASSESSMENT OF GROUNDWATER DEPENDENT ECOSYSTEMS IN THE PANORAMA PROJECT SURVEY AREA (MATTISKE 2007)

A REVIEW OF THE FLORA AND VEGETATION AND AN ASSESSMENT OF GROUNDWATER DEPENDENT ECOSYSTEMS IN THE PANORAMA PROJECT SURVEY AREA

Prepared for:
URS Australia Pty Ltd

On behalf of:
CBH Resources Ltd

Prepared by:
Mattiske Consulting Pty Ltd

September 2007

MATTISKE CONSULTING PTY LTD

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1. SUMMARY

The flora and vegetation of the Panorama survey area is reviewed from Trudgen *et al.* (2002) and Trudgen (2006; 2007a; 2007b). As they stand, these reports are highly technical and specialist botanical documents, which are not easy for a non-scientific audience to understand. Mattiske Consulting Pty Ltd was commissioned by URS Australia Pty Ltd of behalf of CBH Resources Ltd to review and provide advice on the Trudgen *et al.* (2002) and Trudgen (2006; 2007a; 2007b) reports to facilitate a greater understanding of the flora and vegetation and to assist the Public Environmental Review of the proposed Panorama project.

1.1. Flora

A total of 514 plant taxa (including subspecies and varieties) from 161 genera and 58 plant families were recorded within the Panorama Project Survey Area. The most common families recorded included Poaceae (76 taxa), Papilionaceae (61 taxa), Malvaceae (46 taxa) and Mimosaceae (44 taxa). Ten introduced (exotic) species were recorded within the Panorama Project Survey Area (Appendix A). No Declared Plant species pursuant to section 37 of the *Agricultural and Related Resources Protection Act 1976* [WA] were recorded in the Panorama Project Survey Area.

No Declared Rare Flora species pursuant to Subsection 2 of Section 23F of the *Wildlife Conservation Act 1950* [WA] and listed by the Department of Environment and Conservation (2007a) were located during the survey.

No Endangered or Vulnerable taxa, pursuant to s179 of the *Environment Protection and Biodiversity Conservation Act 1999* [Commonwealth] were located during the survey.

Other species of conservation significance that may exist, but have not been recorded in the Panorama Project Survey Area include two Declared Rare Flora species, *Lepidium catapycnon* (R) and *Thryptomene wittweri* (R) according to the *Environment Protection and Biodiversity Conservation Act 1999* [Commonwealth] and eight Priority Flora species.

Seven Priority Flora species were recorded within or may occur within the Panorama Project Area: *Euphorbia clementii* (P2), *Gonocarpus ephemerus* (P2), *Olearia fluvialis* (P2), *Abutilon trudgenii* (ms) (P3), *Acacia glaucocaesia* (P3), *Gymnanthera cunninghamii* (P3) and *Ptilotus mollis* (P4).

Two new flora species were recorded within Panorama Project Survey Area: *Pityrodia* sp. Panorama and *Themeda* sp. Panorama. Only a few records of *Pityrodia* sp. Panorama were located within Panorama Project Survey Area and should therefore be treated as having a Declared Rare status until it can be investigated further. *Pityrodia* sp. Panorama is therefore considered by Trudgen *et al.* (2002) and Trudgen (2006; 2007b) to be the most conservation significant taxa within the Panorama Survey Project Area. Four locations of *Pityrodia* sp. Panorama occur within the Panorama Project footprint area. *Themeda* sp. Panorama was recorded at a range of sites, including ten sites in the Kangaroo Caves and Bernts areas. Therefore *Themeda* sp. Panorama appears to be less restricted than the *Pityrodia* sp. Panorama. Both of these taxa require further research into their taxonomic status and also conservation status.

Other flora species of conservation significance include five species that require further investigation and are possibly geographically restricted; nine species that require further investigation but are not geographically restricted and eleven species now with a wider distribution according to Trudgen (2006; 2007b). Of these species, seven occur within the Panorama Project footprint area.

1.2. Vegetation

Eighteen Vegetation Alliances in six Vegetation Formations were summarised from the detailed botanical surveys of the Panorama Project Survey Area (Trudgen *et al*. 2002). Thirteen of these were considered to be locally significant due to the presence of Priority Flora species, species of conservation significance or restricted occurrence in the wider Panorama Project Survey Area. No Threatened Ecological Communities (TEC) as defined by the *Environment Protection and Biodiversity Conservation Act 1999* [Commonwealth] were observed in the Panorama Project Survey Area. However, *Themeda* grasslands of the Pilbara Region are listed as a Vulnerable TEC according to the Department of Environment and Conservation's (2007b) TEC database. Whilst *Themeda* grasslands were not found within the Panorama Project Survey Area, these grasslands could potentially occur there and care should be taken where *Themeda* species, in particular *Themeda* sp. Panorama, are a dominant part of the vegetation.

In general, the vegetation of the Panorama Project Survey Area was categorised as "very good" or "excellent" in condition, except where directly impacted by the existing access road. There was one area of vegetation in "poor" to "very poor" condition along the access road which was infested with **Cenchrus ciliaris* (Buffel Grass).

1.3. Groundwater Dependent Ecosystems (GDE)

Two ecosystems in the Pilbara Region are recognised nationally as Groundwater Dependent Ecosystems (GDEs) (Sinclair Knight Merz, 2001). These are:

- Pilbara spring systems, which are entirely dependent on groundwater and have a high conservation value; and

- Pilbara river pool ecosystems, which are highly dependent on groundwater and have a moderate conservation value.

In general, the spring ecosystems and river pool ecosystems of the Pilbara are recognised as groundwater dependent ecosystems and are protected under state legislation according to the *Environmental Protection Act 1986* [WA] and the *Rights in Water and Irrigation Act 1914* [WA] (Water and Rivers Commission 2000; Sinclair Knight Merz 2001).

Mattiske conducted an assessment of the probability of groundwater dependence of the vegetation within the Panorama Project Survey Area. Vegetation Alliance 1a was rated as having a Very High probability of being a GDE and Vegetation Alliance 2a as having a High probability of being a GDE. All other Vegetation Alliances were rated with a low GDE probability. Locally within the Panorama Project Survey Area, Vegetation Alliance 1a and 2a could be potentially recognised as spring or river pool systems, given the location of these GDEs along flowlines and on lower slopes.

2. INTRODUCTION

In July 2007, URS Australia Pty Ltd commissioned Mattiske Consulting Pty Ltd on behalf of CBH Resources Ltd to review and provide advice on the Trudgen *et al.* (2002) and Trudgen (2006; 2007a; 2007b) reports of the Panorama Project Survey Area. Six detailed vegetation and flora surveys have been conducted for the proposed Project by M. E. Trudgen and Associates (Trudgen). These surveys comprised:

- April 2001 – General flora collection survey conducted with 81 quadrats established and recorded along the proposed access road and around the proposed mine and processing areas (including Kangaroo Caves and Bernts areas).
- October 2001 – Vegetation survey of the Project Area (including Kangaroo Caves and Bernts areas) and additional flora collections.
- April 2006 – Rare flora survey of the Project Area.
- May 2006 – Rare flora survey focussing on the proposed infrastructure locations and a vegetation survey of the previously proposed camp site.
- May 2007 – Vegetation and flora survey of new infrastructure areas, around the plant site, that were not covered by previous surveys.
- June 2007 – Vegetation and flora survey of new infrastructure areas, including the airstrip and camp that were not covered by previous surveys.

These reports are specialist botanical documents on the local flora and vegetation. The Panorama Project Survey Area is in the Pilbara region of Western Australia. It is situated approximately 160 kilometres south-south-east of Port Hedland and south-west of the Port Hedland - Marble Bar Road, to the west of the Shaw River.

3. BACKGROUND

3.1. Vegetation

Regionally, the Panorama Project Survey Area falls within the Fortescue Botanical District (Beard 1990). Trudgen *et al.* (2002) and Trudgen (2006; 2007a; 2007b) document in fine detail the flora and vegetation of the Panorama Project Survey Area. As they stand, these reports are highly technical documents and are not easy for a non-scientific audience to understand. The vegetation survey of the Panorama Project Survey Area involved both flora descriptions and vegetation mapping, in addition to floristic analysis using the PATN computer package; to enable comparison of the vegetation within the Survey Area with vegetation of other areas in the Fortescue Botanical District (Trudgen *et al.* 2002). Later reports provide further information and clarification on the flora and vegetation (Trudgen 2007; 2007a) and Trudgen (2007b) details information on additional areas (the proposed airstrip location and the NW extension) which were not included in the 2002 report. In summary, these reports document the flora and mapped vegetation units, detail the floristic analysis of the flora and associated communities and assess the conservation value of the flora and vegetation.

3.2. Rare and Priority Flora

Species of flora and fauna are defined as Rare or Priority conservation status where their populations are restricted geographically or threatened by local processes. The Department of Environment and Conservation (2007a) recognises these threats of extinction and consequently applies regulations towards population and species protection.

Rare Flora species are gazetted under subsection 2 of section 23F of the *Wildlife Conservation Act 1950* [WA] and therefore it is an offence to "take" or damage rare flora without Ministerial approval. Section 23F of the *Wildlife Conservation Act 1950* [WA] defines "to take" as "… to gather, pick, cut, pull up, destroy, dig up, remove or injure the flora to cause or permit the same to be done by any means."

Priority Flora are under consideration for declaration as 'Rare Flora', but are in urgent need of further survey (Priority One to Three) or require monitoring every 5-10 years (Priority Four). Table 1 presents the definitions of Declared Rare and the four Priority ratings under the *Wildlife Conservation Act 1950* [WA] as extracted from Department of Environment and Conservation (2007a).

Table 1: Definition of Rare and Priority Flora Species (Department of Environment and Conservation 2007a)

Conservation Code	Category
R	**Declared Rare Flora – Extant Taxa** "Taxa which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection and have been gazetted as such."
P1	**Priority One – Poorly Known Taxa** "Taxa which are known from one or a few (generally <5) populations which are under threat, either due to small population size, or being on lands under immediate threat. Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey."
P2	**Priority Two – Poorly Known Taxa** "Taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but urgently need further survey."
P3	**Priority Three – Poorly Known Taxa** "Taxa which are known from several populations, and the taxa are not believed to be under immediate threat (i.e. not currently endangered), either due to the number of known populations (generally >5), or known populations being large, and either widespread or protected. Such taxa are under consideration for declaration as 'rare flora' but need further survey."
P4	**Priority Four – Rare Taxa** "Taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every 5-10 years."

3.3. Threatened Flora Species and Ecological Communities

Threatened flora species are a matter of national environmental significance under the *Environment Protection and Biodiversity Conservation Act 1999* [Commonwealth]. A person must not take an action that has, will have, or is likely to have a significant impact on a listed threatened species or an ecological community, without approval from the Commonwealth Minister for the Environment and Water Resources. Table 2 presents the definitions of the categories of threatened species under the *Environment Protection and Biodiversity Conservation Act 1999* [Commonwealth].

Communities are described as 'Threatened Ecological Communities' (TEC's) if they have been defined by the Western Australian Threatened Ecological Communities Scientific Advisory Committee and found to be Presumed Totally Destroyed (PD), Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) (Department of Environment and Conservation 2007b). For further definitions of TEC categories and criteria refer to English and Blyth (1997, 1999). Some Western Australian TEC's have also been listed as "Threatened Ecological Communities" under the *Environment Protection and Biodiversity Conservation Act 1999* [Commonwealth](Department of .the Environment and Water Resources 2007).

3.4. Vegetation Condition

Vegetation condition of communities in the Panorama Project Survey Area was assessed according to a condition scale from Trudgen (1988) (Table 3).

3.5 Local and Regional Significance

Flora or Vegetation may be locally or regionally significant in addition to statutory listings by the State or Federal Government.

In regards to Flora; species, subspecies, varieties, hybrids and ecotypes may be significant other than as Declared Rare Flora (DRF) or Priority Flora, for a variety of reasons, including:

". a keystone role in a particular habitat for threatened species, or supporting large populations representing a significant proportion of the local regional population of a species;
. relic status;
. anomalous features that indicate a potential new discovery;
. being representative of the range of a species (particularly, at the extremes of range, recently discovered range extensions, or isolated outliers of the main range);
. the presence of restricted subspecies, varieties, or naturally occurring hybrids;
. local endemism/a restricted distribution;
. being poorly reserved" (Environmental Protection Authority 2004: 29 – 30).

Vegetation may be significant because the extent is below a threshold level and a range of other reasons, including:

". scarcity;
. unusual species;
. novel combinations of species;
. a role as a refuge;
. a role as a key habitat for threatened species or large populations representing a significant proportion of the local to regional total population of a species;
. being representative of the range of a unit (particularly, a good local and/or regional example of a unit in "prime" habitat, at the extremes of range, recently discovered range extensions, or isolated outliers of the main range);
. a restricted distribution" (Environmental Protection Authority 2004: 30).

Vegetation communities are locally significant if they contain Priority Flora species or contain a range extension of a particular taxon outside of the normal distribution. They may also be locally significant if they are very restricted to one or two locations or occur as small isolated communities. In addition, vegetation communities that exhibit unusually high structural and species diversity are also locally significant (Mattiske *pers. comm*.).

Vegetation communities are regionally significant where they are limited to specific landform types, are uncommon or restricted plant community types within the regional context, or support populations of Declared Rare Flora (Mattiske *pers. comm*.).

Determining the significance of flora and vegetation may be applied at various scales, for example, a vegetation community may be nationally significant and governed by statutory protection as well as being locally and regionally significant.

Table 2: Categories of Threatened Species (*Environment Protection and Biodiversity Conservation Act 1999* [Commonwealth])

Category Code	Category
Ex	**Extinct** A native species is eligible to be included in the **extinct** category at a particular time if, at that time, there is no reasonable doubt that the last member of the species has died.
ExW	**Extinct in the Wild** A native species is eligible to be included in the **extinct in the wild** category at a particular time if, at that time (a) it is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or (b) it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
CE	**Critically Endangered** A native species is eligible to be included in the **critically endangered** category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
E	**Endangered** A native species is eligible to be included in the **endangered** category at a particular time if, at that time (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
V	**Vulnerable** A native species is eligible to be included in the **vulnerable** category at a particular time if, at that time (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium term future, as determined in accordance with the prescribed criteria.
CD	**Conservation Dependent** A native species is eligible to be included in the **conservation dependent** category at a particular time if, at that time, the species is the focus of a specific conservation program, the cessation of which would result in the species becoming vulnerable, endangered or critically endangered within a period of 5 years.

Table 3: Vegetation Condition Scale from Trudgen (1988)

Condition Code	Category
E = Excellent	Pristine or nearly so, no obvious signs of damage caused by the activities of European man.
VG = Very Good	Some relatively slight signs of damage caused by the activities of European man. Eg. some signs of damage to tree trunks caused by repeated fire and the presence of some relatively non-aggressive weeds such as *Ursinia anthemoides* or *Briza* species, or occasional vehicle tracks.
G = Good	More obvious signs of damage caused by the activities of European man, including some obvious impact on the vegetation structure such as caused by low levels of grazing or by selective logging. Weeds as above, possibly plus some more aggressive ones.
P = Poor	Still retains basic vegetation structure or ability to regenerate to it after very obvious impacts of activities of European man such as grazing or partial clearing (chaining) or very frequent fires. Weeds as above, probably plus some more aggressive ones such as *Ehrharta* species.
VP = Very Poor	Severely impacted by grazing, fire, clearing or a combination of these activities. Scope for some regeneration but, not to a state approaching good condition without intensive management. Usually with a number of weed species including aggressive species.
D = Completely Degraded	Areas that are completely or almost completely without native species in the structure of their vegetation. Ie. Areas that are cleared or "parkland cleared" with their flora comprising weed or crop species with isolated native trees or shrubs.

3.6. Groundwater Dependent Ecosystems (GDEs)

Groundwater Dependent Ecosystems (GDEs) are ecosystems that depend on groundwater, which include:

- Aquifer and cave ecosystems where stygofauna reside;
- Ecosystems dependent on the surface expression of groundwater (such as baseflow rivers and streams, wetlands and some floodplains); and
- Ecosystems dependent on the subsurface presence of groundwater (Eamus *et al.* 2006).

Within a GDE, water use is likely to vary according to vegetation structure (ie tree water use versus shrub water use). The dependence of an ecosystem on groundwater may also be variable: infrequently utilised such as during plant establishment or in periods of drought; or continual dependence but facultative (ie species will utilise groundwater if present, but are not groundwater dependent for survival) (Eamus *et al.* 2006).

Key indicator species, such as *Melaleuca argentea* in the Daly River catchment in the Northern Territory (O'Grady *et al.* 2006) or *Banksia* sp. on the Swan Coastal Plain (Eamus *et al.* 2006), can be used to identify GDEs. However it has been shown that groundwater use varies according to the position in the landscape and trees at lower elevations closer to rivers are highly dependent compared to opportunistic groundwater use by trees at higher elevations (O'Grady *et al.* 2006).

The groundwater dependence of ecosystems is rated according to the depth to the water table:

0 – 10 m	Groundwater dependent
>10 m	Reduced dependence on groundwater
10 – 20 m	Possible groundwater dependence, although negligible
> 20 m	Groundwater dependence low (Eamus *et al.* 2006).

Due to the variability of groundwater use as mentioned above, the response of a GDE to groundwater drawdown will not be uniform. Hence determining the ecological water requirements (EWRs) and the subsequent statutory ecological water provisions (EWPs) according to the *Environmental Protection Act 1986* [WA] and the *Rights in Water and Irrigation Act 1914* [WA], necessary for the maintenance of the structure and function of GDEs is complex (Water and Rivers Commission 2000; Sinclair Knight Merz Pty Ltd 2001; Eamus and Froend 2006; Eamus *et al.* 2006).

Monitoring ecosystems over long-term periods are necessary to determine the impacts of lowering groundwater availability, prior to and during pumping. Monitoring can indicate if GDEs are more resilient than predicted or determine if the ecosystem condition falls below acceptable levels, and then EWPs can be adjusted where required. However, ecosystems may respond proportionally or show a threshold response to declining water availability. Often ecosystems do not respond immediately and the "lag" effects on ecosystem health may result in exponentially declining condition. Changes in understorey species and an increase in introduced (exotic) species may indicate disturbances in the short-term within GDEs. Whilst overstorey species tend to be more resilient to changes in groundwater levels and are good long-term indicators of GDEs.

In summary, to assess the impacts of altered groundwater levels as a result of EWPs set in Water Allocation Plans; monitoring should include an assessment of:

- species diversity;
- species cover and abundance;
- "weediness";
- density of indicator species;
- community distribution (change in aerial extent);
- canopy health;
- water quality; and
- soil moisture (Eamus *et al*. 2006; Loomes *et al*. 2006; Water and Rivers Commission 2000).

4. OBJECTIVES

Mattiske Consulting Pty Ltd was commissioned by URS Australia Pty Ltd on behalf of CBH Resources Ltd to review and provide advice on the Trudgen *et al.* (2002) and Trudgen (2006; 2007a; 2007b) reports on the flora and vegetation of the Panorama Project Survey Area. The specific objectives of this report are to

- Review and simplify the flora and vegetation of the Panorama Project Survey Area for a Public Environment Review;
- Identify and assess potential Groundwater Dependent Ecosystems (GDEs) within the Panorama Project Survey Area; and
- Prepare a report on the findings.

5. METHODS

The results of Trudgen *et al.* (2002) and Trudgen (2006; 2007b) were crosschecked and combined to update the flora and vegetation results. In undertaking this review the authors of the Mattiske Consulting Pty Ltd report accept no responsibility for the previous work undertaken by Trudgen on the Panorama project area. The data and information as extracted is based on the reports and information as provided and any further re-interpretation of the vegetation and aerial photographs and the mapping units as defined by Trudgen (2007b). The potential impacts of clearing were assessed according to the project footprint as at the August 15th 2007.

5.1. Flora

All taxa were checked on the Department of Environment and Conservation (2007a) "Florabase" database to ensure listings were current, in particular for all Declared Rare and Priority Flora (see Table 1). Additionally, all introduced (exotic) species were checked on the Department of Agriculture and Food's (2007) "Declared plants" database. Mattiske Consulting Pty Ltd has electronic access to the Department of Environment and Conservation (2007a) database through licensing and an annual fee payment.

A list of species recorded within the Panorama Project Survey Area in Trudgen *et al.* (2002) and Trudgen (2006; 2007b) was reviewed and updated according to the Department of Environment and Conservation (2007a) "Florabase" database. Several changes were made including updating name changes since 2002 and removal of now excluded flora species names. Flora species names with a collection or site number were treated as different taxa. If a species name had been misused for more than one species, the distributions of the flora species were checked to determine the species name used in this report. Flora species that were not found on the "Florabase" database (Department of Environment and Conservation 2007a) were included in Appendix A and treated as different taxa.

Fungi species, *Pisolithus tinctorius*, was listed in Appendix 9 of Trudgen (2007b), however it has been excluded from the count of taxa and Appendix A. *Convolvulus angustissimus* subsp. *angustissimus* was mentioned in Section 3.6 in Trudgen (2007b), however it was not in corresponding Appendix 7, or in Appendix 14. It has been included in the count of taxa and Appendix A. Several *Euphorbia* species were identified as *Euphorbia* sp. though it was unable to differentiate between these during the review of the flora collections.

The GPS locations of species of conservation significance within the Panorama Project Survey Area were compiled from Trudgen *et al.* (2002) and Trudgen (2006; 2007b) and updated where appropriate. Quadrat and releve site data given in Trudgen *et al.* (2002) and Trudgen (2006; 2007b) was used to check location data of species of conservation significance. If a species was recorded in any of the studies (Trudgen *et al.* 2002; Trudgen 2006; 2007a; 2007b), the site was recorded in the list of locations in the results.

5.2. Vegetation

The vegetation of the Panorama Project Survey Area was remapped utilising aerial photographs and a re-interpretation of the mapping units as defined by Trudgen *et al.* (2002) and Trudgen (2007b). Areas mapped in Trudgen *et al.* (2002) and Trudgen (2007b) were overlayed onto aerial photographs of the Panorama Project Survey Area. Vegetation Alliances were aligned to the underlying topography and vegetation and remapped using the vegetation codes from Trudgen *et al.* (2002) and Trudgen (2007b) in addition to knowledge of the Pilbara vegetation (Mattiske, *pers. comm.*).

The complexity of the vegetation communities was simplified. The ten Vegetation Formations and 52 Vegetation Alliances that were mapped in Trudgen *et al.* (2002) and Trudgen (2007b) were reduced to six Vegetation Formations and 18 Vegetation Alliances. This was conducted using both the results of the floristic analysis as conducted by Trudgen *et al.* (2002) and using standard vegetation mapping techniques as per Beard (1990). That is, further details on the habitats of Vegetation Alliances were added from the quadrat and releve descriptions. Vegetation Alliances were then grouped according key species (floristic), structure and location in the landscape (habitat).

5.3. Groundwater Dependent Ecosystems (GDEs)

Groundwater Dependent Ecosystems (GDEs) within the Panorama Project Survey Area were identified according to likely groundwater dependent flora species (floristic), structure and position (habitat) of the Vegetation Alliance in the landscape. Key groundwater dependent flora species identified from Trudgen *et al.* (2002) in the Panorama Project Survey Area include *Eucalyptus camaldulensis*, *Eucalyptus victrix*, *Melaleuca linophylla*, *Melaleuca glomerata*, *Corymbia hamersleyana*, *Acacia tumida* var. *pilbarensis* and *Terminalia canescens.* Remapping of the vegetation and a site visit in August 2007 indicated that *Eucalyptus camaldulensis* and *Eucalyptus victrx* are the main groundwater dependent flora species and *Corymbia hamersleyana*, *Acacia tumida* var. *pilbarensis* and *Terminalia canescens* are more widespread in occurrence in the Panorama Project Survey Area.

The 18 Vegetation Alliances were rated according to their groundwater dependence:

- Very High: groundwater very important for maintenance of ecosystem;
- High: groundwater important for maintenance of ecosystem;
- Medium: groundwater may be important for maintenance of ecosystem; and
- Low: groundwater likely to be unimportant for maintenance of ecosystem.

6. RESULTS

6.1. Flora

A total of 514 plant taxa (including subspecies and varieties) from 161 genera and 58 plant families were recorded within the Panorama Project Survey Area (Appendix A). The most common families recorded included Poaceae (76 taxa), Papilionaceae (61 taxa), Malvaceae (46 taxa) and Mimosaceae (44 taxa). Of these, ten are introduced (exotic) species (Department of Environment and Conservation 2007). No Declared Plant species pursuant to section 37 of the *Agricultural and Related Resources Protection Act 1976* were recorded in the Project Area.

No Declared Rare Flora species, pursuant to subsection (2) of section 23F of the *Wildlife Conservation Act 1950* [WA] and as listed by the Department of Environment and Conservation (2007) was located during the survey. No plant taxa pursuant to section 179 of the *Environment Protection and Biodiversity Conservation Act 1999* were located in the survey area.

Priority Flora species, new flora species and species of conservation significance, including species that require further investigation and are possibly geographically restricted, species that require further investigation but are not geographically restricted, and species now with a wider distribution according to Trudgen (2006; 2007b), are described in detail below (also see Appendix B and Figures 3a to 3c).

The GPS locations of species of Priority Flora species and flora species with conservation significance within the Panorama Project Survey Area are given in Appendix C.

6.2 Priority Flora Species

There are seven Priority Flora species recorded within the wider Panorama Project Survey Area (Appendices B and C). Of these species, six Priority Flora species are known to occur within or may occur within the Panorama Project Area.

Table 4: Priority Flora species known or possibly occurring in the Panorama Project Area. SCC = State Conservation Code for Priority Flora Species, see Table 1 for explanation (Department of Environment and Conservation 2007a)

Species	SCC	Comments
Euphorbia clementii	P2	This small annual herb was recorded in Vegetation Alliance 6a. A large population has been recorded adjacent to the Access Road and a scattered population was recorded in the vicinity of the proposed airstrip. This species was recorded outside the Project Area at five locations.
Gonocarpus ephemerus	P2	This species was recorded in Vegetation Alliance 6a adjacent to the Access Road. This species was recorded outside the Project Area at one location.
Olearia fluvialis	P2	This small perennial shrub was recorded at one location outside of the Project Area.
Abutilon trudgenii (ms)	P3	This species was recorded in Vegetation Alliance 13a in the TSF area and in communities 6a, 11a and 14a on the Access Road. This species was recorded at seven locations outside the proposed Project footprint area. Trudgen (2007b) comments that this species should be removed from the Priority Flora list.
Gymnanthera cunninghamii	P3	This species was collected from four locations outside of the Project Area and occurs at scattered locations in the Pilbara Region and two of the adjacent IBRA regions.
Acacia glaucocaesia	P3	This species was found in Vegetation Alliances 6a and 11a on the Access Road. This species was recorded outside the Project Area at eleven locations.
Ptilotus mollis	P4	This species was recorded in Vegetation Alliance 13a within the TSF area and at six locations outside of the Project Area.

6.3 New Flora Species

Two new flora species were recorded within Panorama Project Survey Area, *Pityrodia* sp. Panorama and *Themeda* sp. Panorama (Appendix B). Of these, *Pityrodia* sp. Panorama is considered the most important species of conservation significance within the Panorama Project Survey Area. This species appears to be rare within this area and should be reviewed as a Declared Rare by the Department of Environment and Conservation (2007a) (Trudgen *et al.* 2002; Trudgen 2006).

Two previously undescribed flora species were recorded within the wider survey area. These species are:

- *Pityrodia* sp. Panorama. This species was recorded at fifteen locations. Four of these locations occurred within Vegetation Alliances 5a, 6a and 9a in the proposed waste dumps and at two other proposed disturbance sites within the Project Area. This species appears to be rare within this area and Trudgen *et al.* (2002) and Trudgen (2006) suggested that this species is considered for classification as Declared Rare Flora.

- *Themeda* sp. Panorama. This species was recorded at ten locations in the Kangaroo Caves and Bernts areas to the south of the main Project Area.

If the project proceeds as proposed, both these species will not be impacted significantly by the proposed development. However these taxa require further research into their taxonomic status and also conservation status.

6.4 Species that require further investigation

A number of other flora species recorded within the wider survey area and are of interest because they:

- are classified as DRF or Priority Flora species and may occur within the Panorama Project Survey Area based on DEC database searches;
- may be geographically restricted, but require further investigation;
- may have conservation significance, but require further investigation; or
- are species that now have a wider distribution than previously recorded.

Of these species, the following occur within the proposed Project footprint. These species are:

- *Acacia* aff. *drepanocarpa* subsp. *drepanocarpa*. This species was recorded at seven locations. Five of these locations occurred within the proposed Project footprint area within Vegetation Alliances 11a and 13a. These locations occurred within the TSF and Evaporation Pond areas.
- *Acacia* sp. Barklys was recorded at four locations. All of these locations occurred within the Evaporation Pond area within the proposed Project footprint area within Vegetation Alliance 13a.
- *Cullen* aff. *lachnostachys* (MET 15, 154) was recorded at six locations, of which two occurred within the proposed Project footprint. This species occurred within Vegetation Alliance 5a (waste dump) and 11a (access road).
- *Sida* aff. *fibulifera* (PAN10-6) was recorded at one location within Vegetation Alliance 6a on the access road.
- *Tephrosia* aff. *supina* (HD88-4) was recorded at two locations. One of these locations was within Vegetation Alliance 6a on the access road and one was outside the proposed Project footprint.
- *Triodia angusta* (Shale form) was recorded at one location within Vegetation Alliance 6a in proposed disturbance areas within the proposed Project footprint.
- *Triumfetta* aff. *chaetocarpa* (Panorama form) was recorded at seven locations. Two of these locations occurred within Vegetation Alliances 6a (access road) and 13a (other proposed disturbance areas) of the Project footprint.

Acacia sp. (PAN M48), *Corchorus* aff. *walcottii* (H251-3), *Euphorbia* sp. (PAN5-15), *Mallotus ?dispersus* and *Rhynchosia* sp. King Bay were recorded in the wider survey area, but not in the proposed Project footprint area.

6.5 Species now with a wider distribution (Trudgen 2006)

As a result of the later survey by Trudgen (2006) there are eleven species of conservation significance according to Trudgen *et al.* (2002) which have a potentially wider distribution after further investigation (see Appendix B):

- *Corchorus* aff. *laniflorus* (PAN 76),
- *Corchorus* sp. Panorama,:
- *Eriachne* sp. Port Headland,
- *Indigofera monophylla* (PAN57-9),
- *Indigofera monophylla* (PAN58-17),
- *Indigofera monophylla* (PAN65-14),
- *Triodia angusta* (Panorama form),

- *Triodia angusta* (Shaw River form),
- *Triodia melvillei*,
- *Triumfetta* aff. *chaetocarpa* (PAN3/4), and
- *Vigna* sp. Harding Dam.

6.6 Potential Rare and Priority Species

Two Declared Rare Flora species, *Lepidium catapycnon* (R) and *Thryptomene wittweri* (R), were not recorded, but potentially occur within the Panorama Project Survey Area (see Appendix B) (Department of Conservation and Environment 2007a). These Declared Rare Flora species are also listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* [Commonwealth] (Department of the Environment and Water Resources 2007).

A description of these species is given below.

- *Lepidium catapycnon* (R), is a perennial, herb or shrub species, 0.2–0.3 m high that has white flower in October, and occurs on skeletal soils on hillsides (Department of Conservation and Environment 2007a). There are nine collections held at the Western Australian Herbarium from the Nullagine, Newman, Wittenoom and Hamersley Ranges areas (Department of Conservation and Environment 2007a).

- *Thryptomene wittweri* (R), a shrub species, 0.5–1.5 m high that has white and cream flowers from April to August, and occurs on skeletal red stony soils on breakaways and stony creek beds. There are ten collections held at Western Australian Herbarium from the Carnarvon Range, Karijini National Park, Mount Meharry, Mount Augustus and White Cliffs Station areas (Department of Conservation and Environment 2007a).

Ptilotus appendiculatus var. *minor* (P1), *Gomphrena pusilla* (P2), *Bulbostylis burbidgeae* (P3), *Fimbristylis sieberiana* (P3), *Goodenia nuda* (P3), *Goodenia pascua* (P3), *Hibiscus brachysiphonius* (P3) and *Phyllanthus aridus* (P3), were not recorded but potentially occur within the Panorama Project Survey Area. A description of these species is given below.

- *Ptilotus appendiculatus* var. *minor* (P1), is a perennial herb or shrub species that has only one record location according to the Western Australian Herbarium (Department of Conservation and Environment 2007a). This specimen occurred near Boodarie in the Pilbara (Department of Conservation and Environment 2007a).

- *Gomphrena pusilla* (P2) is an annual herb species to 0.2 m high with white flowers between March to June, and occurs on fine beach sand behind foredunes and on limestone (Department of Conservation and Environment 2007a). Five collections are held at the Western Australian Herbarium and were recorded in the Pilbara and Dampierland regions (Department of Conservation and Environment 2007a). As these habitat types do not occur within the Panorama Project Survey Area, it is unlikely that this species occurs there.

- *Bulbostylis burbidgeae* (P3), is a sedge species 0.03–0.25 m high with brown flower in March to August, and occurs on granitic soils and outcrops and at cliff bases (Department of Conservation and Environment 2007a). Nine collections are held at the Western Australian Herbarium and were recorded near Port Headland, Newman, the George Ranges, Mount Edgar Station and in the north Pilbara (Department of Conservation and Environment 2007a).

- *Fimbristylis sieberiana* (P3), is a sedge species 0.25–0.6 m high with brown flower from May to June, and occurs on mud and skeletal soil pockets, at pool edges and on sandstone cliffs (Department of Conservation and Environment 2007a). Fourteen collections are held at the Western Australian Herbarium and were recorded in the Great Sandy Desert, Pilbara, Central Kimberley, Dampierland and Ord-Victoria Plains regions (Department of Conservation and Environment 2007a).

- *Goodenia nuda* (P3), is a herb species to 0.5 m high with yellow flowers from April to August (Department of Conservation and Environment 2007a). Ten collections from the Pilbara region are held at the Western Australian Herbarium (Department of Conservation and Environment 2007a).

- *Goodenia pascua* (P3), is a herb species to 0.5 m high with yellow flowers from May to August, and occurs on red sandy soils and basaltic plains (Department of Conservation and Environment 2007a). Nine collections are held at the Western Australian Herbarium and were recorded in the Hamersley Range, Mount Brockman, Roebourne, Port Headland and Onslow areas (Department of Conservation and Environment 2007a).

- *Hibiscus brachysiphonius* (P3), is a perennial herb or shrub species 0.1–0.3 m high with pink flowers from August to October, and occurs on clay in creeklines and on clay flats (Department of Conservation and Environment 2007a). Fourteen collections are held at the Western Australian Herbarium and were recorded in the Exmouth Gulf, Newman, Paraburdoo and Hamersley Ranges areas (Department of Conservation and Environment 2007a).

- *Phyllanthus aridus* (P3), is a shrub species to 0.25 m high with cream and green flowers from May to June, and occurs on sandstone, gravel and red sand (Department of Conservation and Environment 2007a). Twenty collections are held at the Western Australian Herbarium and were recorded in the Great Sandy Desert, Pilbara, Central Kimberley, Dampierland, Northern Kimberley, Ord-Victoria Plains and Victoria Bonaparte regions (Department of Conservation and Environment 2007a).

6.7 Introduced (exotic) species

There are ten introduced (exotic) species recorded within the Panorama Project Survey Area. These are; **Cenchrus ciliaris* (Buffel Grass), **Cynodon dactylon* (Couch Grass), **Setaria verticillata* (Whorled Pigeon Grass), **Aerva javanica* (Kapok Bush), **Portulaca oleracea* (Purslane), **Argemone ochroleuca* (Mexican Poppy), **Vachellia farnesiana* (Mimosa Bush), **Ricinus communis* (Castor Oil Plant), **Solanum nigrum* (Black berry nightshade) and **Cucumis melo* subsp. *agrestis* (Ulcardo Melon) (Appendix A). Trudgen (2007a) also states that **Malvastrum americanum* (Spiked Malvastrum) may also be present in a flora survey is conducted in another season or after sufficient rain.

No Declared Plant species pursuant to section 37 of the *Agricultural and Related Resources Protection Act 1976* were recorded in the Panorama Project Survey Area (Department of Agriculture and Food 2007).

**Cenchrus ciliaris* (Buffel Grass) is a particularly invasive introduced (exotic) species that is now naturalised in many Pilbara habitats (Van Vreeswyk *et al.* 2004). The invasion of **Cenchrus ciliaris* (Buffel Grass) is a major concern for flora and ecosystem conservation of the Pilbara due to negative effects on biodiversity (Van Vreeswyk *et al.* 2004). **Cenchrus ciliaris* (Buffel Grass) was recorded at 38 locations within the Panorama Project Survey Area. **Cenchrus ciliaris* (Buffel Grass) is particularly invasive at 21 locations within the wider survey area.

6.8 Vegetation

A total of 18 Vegetation Alliances in six vegetation formations were noted within the Panorama Project Survey Area (Appendix D and Figures 1a to 1f).

Open Forest to Open Woodland: Flowlines

Vegetation Alliance 1a - Open forest to open woodland of *Eucalyptus camaldulensis, Melaleuca argentea* and *Eucalyptus victrix* with scattered tall shrubs of *Indigofera monophylla* over *Schoenus falcatus, Cyperus vaginatus* and *Triodia longiceps* sedgeland/grasslands in river beds.

Open Forest to Open Woodland: Other

Vegetation Alliance 2a - *Eucalyptus victrix* scattered trees to open woodland which may include *Melaleuca glomerata* and *Melaleuca linophylla* over open to closed scrub in creek beds and low slopes.

Vegetation Alliance 3a - *Corymbia aspera* scattered low trees to low open woodland in creek beds.

Vegetation Alliance 4a - *Acacia tumida* high shrubland to low open forest in creeklines.

Vegetation Alliance 5a - *Eucalyptus leucophloia* scattered low trees over patches of *Acacia* shrubs over hummock grasslands of *Triodia* species, including *T. brizoides, T. wiseana* and *T. epactia* on ridge slopes.

Vegetation Alliance 6a - *Corymbia hamersleyana* scattered low trees to low open woodland over tall shrubs to open shrubland of *Acacia* spp. and *Grevillea wickhamii* over hummock grasslands on creek banks, flood banks and distributing fans.

Vegetation Alliance 7a - *Corymbia zygophylla* and *Corymbia hamersleyana* scattered low trees over hummock grasslands on sandplains.

Vegetation Alliance 8a - *Terminalia canescens* scattered low trees to low woodland on creek banks.

Vegetation Alliance 9a - *Atalaya hemiglauca, Acacia pruinocarpa, Ehretia saligna* var. *saligna, Acacia tumida, Eucalyptus ferriticola* subsp. *ferriticola* and *Ficus platypoda* scattered low trees over high open shrubland on steep, rocky gorge walls.

High Shrublands to Open Scrublands

Vegetation Alliance 10a - Shrubland to open scrubland of *Acacia* species including *A. tumida, A. acradenia* and *A. orthocarpa* over hummock grasslands on upper and steep slopes.

Vegetation Alliance 11a - Shrubland to closed scrubland of *Acacia* species, including *A. acradenia, A. pyrifolia* and *A. tumida* along small creeklines and on the adjacent parts of valley floors and distributing fans.

Vegetation Alliance 12a - *Acacia inaequilatera* scattered tall shrubs to high open shrubland over *Triodia brizoides* hummock grasslands on ridge slopes and low hills.

Vegetation Alliance 13a - *Acacia inaequilatera* scattered tall shrubs to high shrubland over *Triodia wiseana* hummock grasslands occurring mainly on gentle lower slopes.

Vegetation Alliance 14a - *Acacia ancistrocarpa* high open shrubland to open scrub.

Vegetation Alliance 15a - *Acacia trachycarpa* high open shrubland to high shrublands.

Low Shrublands to Low Open Heaths

Vegetation Alliance 16a - Low shrublands to low open heath on gentle slopes and undulating plains.

Hummock Grasslands

Vegetation Alliance 17a - Hummock grasslands on slopes and ridges.

Other Grasslands and Herblands

Vegetation Alliance 18a - Cracking clay alliance on gentle sloping plains and seasonal damplands.

6.9. Local and Regional Significance

Thirteen of the eighteen Vegetation Alliances recorded within the wider Panorama Project Survey Area are locally significant due to the presence of Priority Flora species, species of conservation significance or are restricted to isolated areas within the wider survey area. There are no regionally significant Vegetation Alliances within the Panorama Project Survey Area. Vegetation Alliances that are locally significant are listed in Appendix E and described below.

- **Vegetation Alliance 1a**

Vegetation Alliance 1a is classified as locally significant due its structure as a wetland area and the potential for habitat trees. *Schoenus falcatus*, which is uncommon in the Pilbara Region was recorded in this alliance. Vegetation Alliance 1a consists of an open forest to open woodland of *Eucalyptus camaldulensis, Melaleuca argentea* and *Eucalyptus victrix* with scattered tall shrubs of *Indigofera monophylla* over *Schoenus falcatus, Cyperus vaginatus* and *Triodia longiceps* sedgeland/grasslands in river beds.

- **Vegetation Alliance 2a**

Vegetation Alliance 2a is classified as locally significant due its structure as a wetland area and the potential for habitat trees. Vegetation Alliance 2a consists of an open forest to open woodland of *Eucalyptus victrix* which may include *Melaleuca glomerata* and *Melaleuca linophylla* over open to closed scrub in creek beds and low slopes.

- **Vegetation Alliance 3a**

Vegetation Alliance 3a is classified as locally significant as it is restricted to small areas along the access road, near the Marble Bar Road. Vegetation Alliance 3a consists of a woodland of *Corymbia aspera* scattered low trees to low open woodland in creek beds.

- **Vegetation Alliance 5a**

Vegetation Alliance 5a is classified as locally significant due to the occurrence of patches of species of conservation significance (including one occurrence of *Cullen* aff. *lachnostachys* (MET 15, 154) and two occurrences of *Pityrodia* sp. Panorama). Vegetation Alliance 5a consists of an open woodland of *Eucalyptus leucophloia* scattered low trees over patches of *Acacia* shrubs over hummock grasslands of *Triodia* species, including *T. brizoides, T. wiseana* and *T. epactia* on ridge slopes.

- **Vegetation Alliance 6a**

Vegetation Alliance 6a is classified as locally significant due to the occurrence of patches of Priority Flora and species of conservation significance (including three occurrences of *Abutilon trudgenii* (ms) (P3) one occurrence of *Acacia glaucocaesia* (P3), one occurrence of *Euphorbia clementii* (P2), two occurrences of *Gonocarpus ephemerus* (P2), one occurrence of *Pityrodia* sp. Panorama, one occurrence of *Sida* aff. *fibulifera (*PAN10-6), one occurrence of *Tephrosia* aff. *supina* (HD88-4), one occurrence of *Themeda augusta* (Shale form), eighteen occurrences of *Triodia* sp. Panorama and one occurrence of *Triumfetta* aff. *chaetocarpa* (Panorama form). Vegetation Alliance 6a consists of a low open woodland

of *Corymbia hamersleyana* over tall shrubs to open shrubland of *Acacia* spp. and *Grevillea wickhamii* over hummock grasslands on creek banks, flood banks and distributing fans.

- **Vegetation Alliance 7a**

Vegetation Alliance 7a is classified as locally significant due to the restricted occurrence of this alliance along the access road near the Marble Bar Road. Vegetation Alliance 7a consists of a an open woodland of *Corymbia zygophylla* and *Corymbia hamersleyana* scattered low trees over hummock grasslands on sandplains.

- **Vegetation Alliance 8a**

Vegetation Alliance 8a is classified as locally significant due to the restricted occurrence of this alliance along the access road within the wider survey area.. Vegetation Alliance 8a consists of an open woodland of *Terminalia canescens* scattered low trees to low woodland on creek banks.

- **Vegetation Alliance 9a**

Vegetation Alliance 9a is classified as of locally significant due to the presence of species of conservation significance (including one occurrence of *Pityrodia* sp. Panorama within the proposed waste dump areas). Vegetation Alliance 9a consists of an open low woodland of *Atalaya hemiglauca, Acacia pruinocarpa, Ehretia saligna* var. *saligna, Acacia tumida, Eucalyptus ferriticola* subsp. *ferriticola* and *Ficus platypoda* scattered low trees over high open shrubland on steep, rocky gorge walls.

- **Vegetation Alliance 11a**

Vegetation Alliance 11a is classified as locally significant due to the presence of Priority Flora and species of conservation significance (including one occurrence of *Abutilon trudgenii* (ms) (P3), one occurrence of *Acacia* aff. *drepanocarpa* subsp. *drepanocarpa*, one occurrence of *Acacia glaucocaesia* (P3), one occurrence of *Cullen* aff. *lachnostachys* (MET 15, 154) and two occurrences of *Triodia* sp. Panorama). Vegetation Alliance 11a consists of a shrubland to closed scrubland of *Acacia* species, including *A. acradenia, A. pyrifolia* and *A. tumida* along small creeklines and on the adjacent parts of valley floors and distributing fans.

- **Vegetation Alliance 13a**

Vegetation Alliance 13a is classified as locally significant due to the presence of Priority Flora and species of conservation significance (including one occurrence of *Abutilon trudgenii* (ms) (P3), four occurrences of *Acacia* aff. *drepanocarpa* subsp. *drepanocarpa*, four occurrences of *Acacia* sp. Barklys, one occurrence of *Ptilotus mollis* (P4) and one occurrence of *Triumfetta* aff. *chaetocarpa* (Panorama form). Vegetation Alliance 13a consists of shrublands of *Acacia inaequilatera* scattered tall shrubs to high shrubland over *Triodia wiseana* hummock grasslands occurring mainly on gentle lower slopes.

- **Vegetation Alliance 14a**

Vegetation Alliance 14a is classified as locally significant due to the presence of Priority Flora (including one occurrence of *Abutilon trudgenii* (ms) (P3)). Vegetation Alliance 14a consists of shrublands of *Acacia ancistrocarpa* high open shrubland to open scrub.

- **Vegetation Alliance 16a**

Vegetation Alliance 16a is classified as locally significant due to the presence of Priority Flora (including two occurrences of *Ptilotus mollis* (P4)) and some areas of the Alliance are restricted to small areas of Shale ridges (including near the Kangaroo Caves area, which is outside the project area). Vegetation Alliance 16a consists of low shrublands to low open heath on gentle slopes and undulating plains.

- **Vegetation Alliance 18a**

Vegetation Alliance 18a is classified as locally significant due to the restricted occurrence of the alliance along the access road. Vegetation Alliance 18a consists of grasslands and herblands on cracking clay alliance on gentle sloping plains and seasonal damplands.

6.10 Threatened Ecological Communities (TECs)

No Threatened Ecological Communities (TECs) as defined by the *Environment Protection and Biodiversity Conservation Act 1999* [Commonwealth] were observed in the Panorama Project Survey Area.

However, *Themeda* grasslands of the Pilbara Region are listed as a Vulnerable Threatened Ecological Community according to the Department of Environment and Conservation's (2007b) Threatened Ecological Community's database. This category means that *Themeda* grasslands in the Pilbara region exists as largely "modified occurrences that are likely to be capable of being substantially restored or rehabilitated" (Department of Environment and Conservation 2007b).

Four *Themeda* species occur within the Panorama Project Survey Area: *Themeda* aff. *triandra* (MET 16,046), *Themeda avenacea*, *Themeda* sp. Panorama and *Themeda triandra* (Appendix A).

6.11 Condition of the Flora and Vegetation Communities

The vegetation of the Panorama Project Survey Area was generally "very good" or "excellent" in condition (see Table 3) (Trudgen *et al.* 2002). There was one area of vegetation in "poor" condition. Along the access road, approximately 42.85 km from the Marble Bar Road, quadrat PAN 032 (Vegetation Alliance 2) was assessed as being in "poor" to "very poor" condition with **Cenchrus ciliaris* (Buffel Grass) invasion. Trudgen *et al.* (2002) explains that the reduction in vegetation condition at this site is due to grazing of cattle and the associated introduction of **Cenchrus ciliaris* (Buffel Grass).

Some of the slopes of the gorge area were assessed to be in "good" condition but were burnt recently (Trudgen *et al.* 2002). The vegetation condition recorded at these sites was lowered because of the (then) recent fire. Most of the vegetation of the gorge area is in "very good" or "excellent" condition, except where it has been impacted by the access track.

Areas associated with mineral exploration were assessed as "completely degraded" due to creation of access tracks, camp sites, gridlines and drill pads. At these sites the vegetation has been completely removed and soil compaction and topsoil removal has inhibited rehabilitation. Other impacts include direct impacts from grazing cattle and camels, pastoral impacts such as increase in fire frequency to improve pasture and **Cenchrus ciliaris* (Buffel Grass) invasion (Trudgen *et al.* 2002, Trudgen 2006; Trudgen 2007b).

7. GROUNDWATER DEPENDENT ECOSYSTEMS (GDE)

7.1. Nationally recognised GDEs

Two ecosystems in the Pilbara Region are recognised nationally as Groundwater Dependent Ecosystems (GDEs) (Sinclair Knight Merz, 2001). These are:

- Pilbara spring systems, which are entirely dependent on groundwater and have a high conservation value; and
- Pilbara river pool ecosystems, which are highly dependent on groundwater and have a moderate conservation value.

Both GDEs list mining, water resources and agricultural as potential threats (Sinclair Knight Merz Pty Ltd 2001).

7.2. Panorama Project Survey Area: Potential GDEs

The GDE rating (from Low to Very High) of the 18 Vegetation Alliances within the Panorama Project Survey Area are given in Appendix D and Figures 2a to 2f. Besides Vegetation Alliances 1a and 2a, all other Vegetation Alliances were rated with a low GDE probability. Locally within the Panorama Project Survey Area, Vegetation Alliance 1a and 2a could be potentially recognised as spring or river pool systems, given the location of these GDEs along flowlines and on lower slopes.

Very High GDE Probability

Vegetation Alliance 1a in the Open Forest to Open Woodland: Flowlines Vegetation Formation was rated with a Very High GDE probability (Appendix D):

Vegetation Alliance 1a - Open forest to open woodland of *Eucalyptus camaldulensis, Melaleuca argentea* and *Eucalyptus victrix* with scattered tall shrubs of *Indigofera monophylla* over *Schoenus falcatus, Cyperus vaginatus* and *Triodia longiceps* sedgeland/grasslands in river beds.

High GDE Probability

Vegetation Alliance 2a in the Open Forest to Open Woodland: Other Vegetation Formation was rated with a High GDE probability (see Appendix D):

Vegetation Alliance 2a - *Eucalyptus victrix* scattered trees to open woodland which may include *Melaleuca glomerata* and *Melaleuca linophylla* over open to closed scrub in creek beds and low slopes.

8. DISCUSSION

8.1. Flora and Vegetation

The flora and vegetation of the Panorama Project Survey Area is complex and varies over small distances according to the geology and the range of habitats surveyed. In general, the flora and vegetation is typical of that in the Fortescue Botanical District. However, the Panorama Project Survey Area also contains some locally and regionally significant flora; including new, Priority Flora and other species of conservation significance.

Pityrodia sp. Panorama. This species was recorded at fifteen locations. Four of these locations occurred within Vegetation Alliances 5a, 6a and 9a in the proposed waste dumps and at two other proposed disturbance sites within the Project Area. This species appears to be rare within this area and Trudgen *et al.* (2002) and Trudgen (2006) have suggested that this species be considered for classification as DRF. The other new species - *Themeda* sp. Panorama was recorded at ten locations in the Kangaroo Caves and Bernts areas to the south of the main Project Area.

Seven current Priority Flora species were recorded within or may occur within the Panorama Project Area: *Euphorbia clementii* (P2), *Gonocarpus ephemerus* (P2), *Olearia fluvialis* (P2), *Abutilon trudgenii* (ms) (P3), *Acacia glaucocaesia* (P3), *Gymnanthera cunninghamii* (P3) and *Ptilotus mollis* (P4). Trudgen *et al*. (2002) comments that the conservation value of some of these Priority Flora species is low to moderate as they are not "genuinely uncommon". Moreover, Trudgen (2007b) believes that *Abutilon trudgenii* (ms) (P3) should be removed from the Priority Flora species list. Despite this, *Abutilon trudgenii* (ms) (P3) and all Priority Flora species should be avoided wherever possible in any developments.

There are a number of other flora species recorded within the wider survey area and are of interest because they are classified as DRF or Priority Flora species and may occur within the Project Area based on DEC database searches; may be geographically restricted, but require further investigation; may have conservation significance, but require further investigation; or are species that now have a wider distribution than previously recorded. Some of these are recorded within the proposed Project footprint and may require further clarification.

Other conservation significant species that may exist, but have not been recorded in Panorama Project Survey Area, include two Declared Rare Flora species, *Lepidium catapycnon* (R) and *Thryptomene wittweri* (R) according to the *Environment Protection and Biodiversity Conservation Act 1999* [Commonwealth]. Further searches for Declared Rare Flora may confirm their presence or absence in the Panorama Project Survey Area.

Trudgen *et al*. (2002) mapped 52 Vegetation Alliances (or vegetation mapping units), reflecting the structural and floristic diversity. These vegetation mapping units were simplified to 18 Vegetation Alliances in the Panorama Project Survey Area by Mattiske (see Appendix D). Some of the Vegetation Alliances are locally significant.

No Threatened Ecological Communities (TEC) as defined by the *Environment Protection and Biodiversity Conservation Act 1999* [Commonwealth] were observed in the Panorama Project Survey Area. However, *Themeda* grasslands of the Pilbara Region are listed as a Vulnerable TEC according to the Department of Environment and Conservation's (2007b) TEC database. Whilst *Themeda* grasslands were not found within the Panorama Project Survey Area, these grasslands could potentially occur there and care should be taken where *Themeda* species, in particular *Themeda* sp. Panorama, are a dominant part of the local vegetation.

In general, the vegetation of the Panorama Project Survey Area can be classified as being "very good" or "excellent" in condition, except where directly impacted by the existing access road. There was one area of vegetation in "poor" to "very poor" condition along the access road which was infested with **Cenchrus ciliaris* (Buffel Grass).

8.2. GDEs

There is a suite of GDEs present within the Panorama Project Survey Area. In general, the spring ecosystems and river pool ecosystems of the Pilbara are recognised nationally and protected under state legislation according to the *Environmental Protection Act 1986* [WA] and the *Rights in Water and Irrigation Act 1914* [WA] (Water and Rivers Commission 2000; Sinclair Knight Merz 2001). Locally within the Panorama Project Survey Area; Vegetation Alliance 1a, rated with a Very High probability of being a GDE, and Vegetation Alliance 2a, rated with a High probability of being a GDE, could be potentially recognised as spring or river pool systems, given the location of these GDEs along flowlines and on lower slopes (see Appendix D). Given the groundwater dependence of these vegetation alliances, the EWRs need to be determined prior to any groundwater pumping. It is recommended that EWRs allow a buffer for groundwater drawdown given the likely large variability in ecosystem response.

Further site specific surveys are required to tightly constrain the findings reported herein. For example, determining the rooting depths of key flora species in GDEs can enable reliable determination of EWRs. Furthermore, determining seasonal changes in the depth to the watertable is important for long-term ecosystem function (see Eamus *et al.* 2006). Establishment of a detailed groundwater monitoring program prior to and during pumping is necessary to determine the impacts of altered groundwater levels on GDEs within the Panorama Project Survey Area. Additionally monitoring should include an assessment of: the abundance and distribution (especially in regard to indicator species but also in terms of aerial extent); character; and condition of GDEs to provide further detail reported herein (Eamus *et al*. 2006; Loomes *et al*. 2006; Water and Rivers Commission 2000).

9. LIST OF PERSONNEL

The following personnel of Mattiske Consulting Pty Ltd were involved in this project:

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Senior Ecologist
Dr F. Itzstein-Davey

Botanists
Ms K. Rose
Ms F. De Wit
Mr C. Blackburn
Mr T. Sleigh

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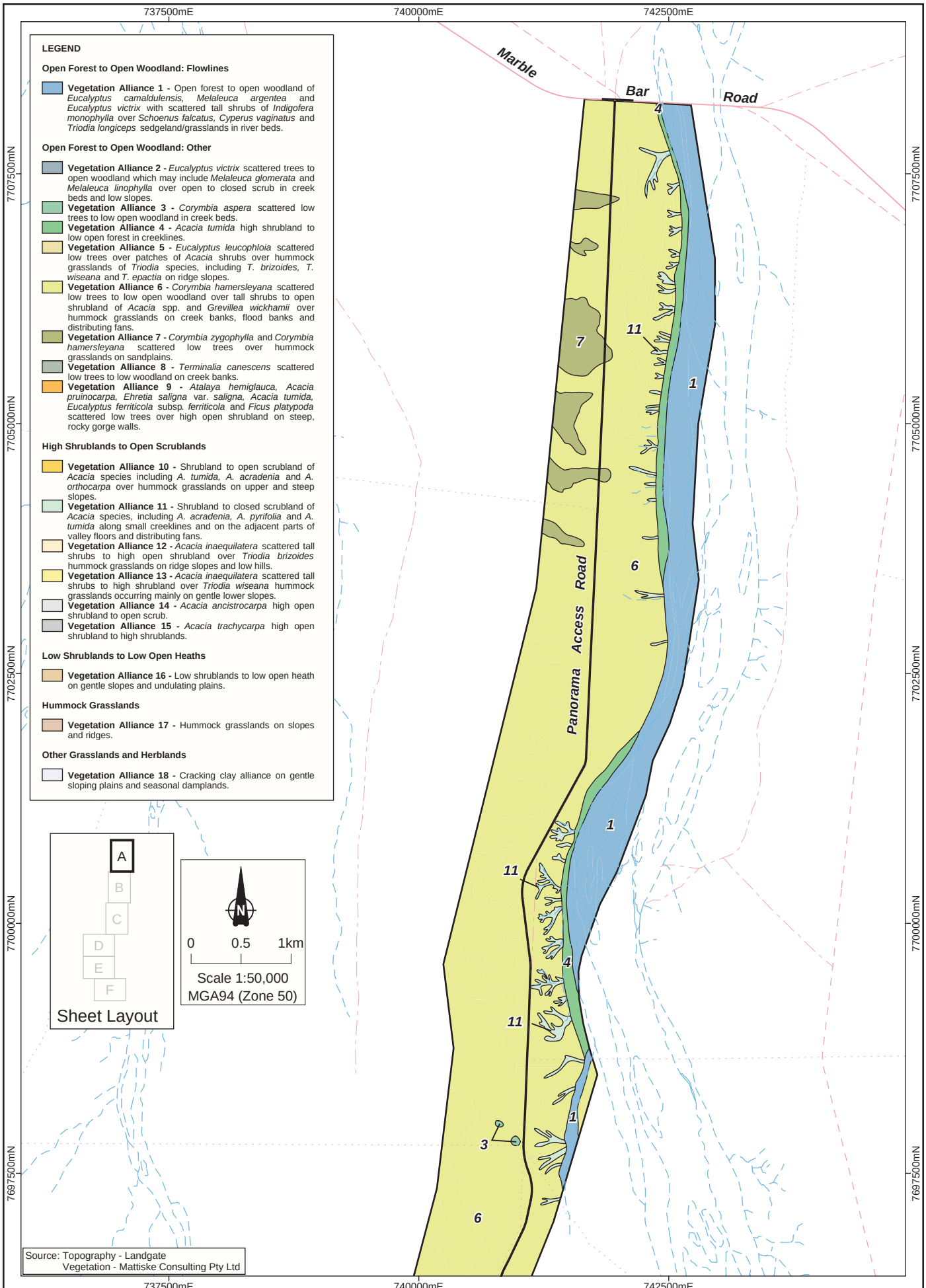

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PANORAMA PROJECT

Vegetation Communities Project Area

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Drawn: CAD Resources

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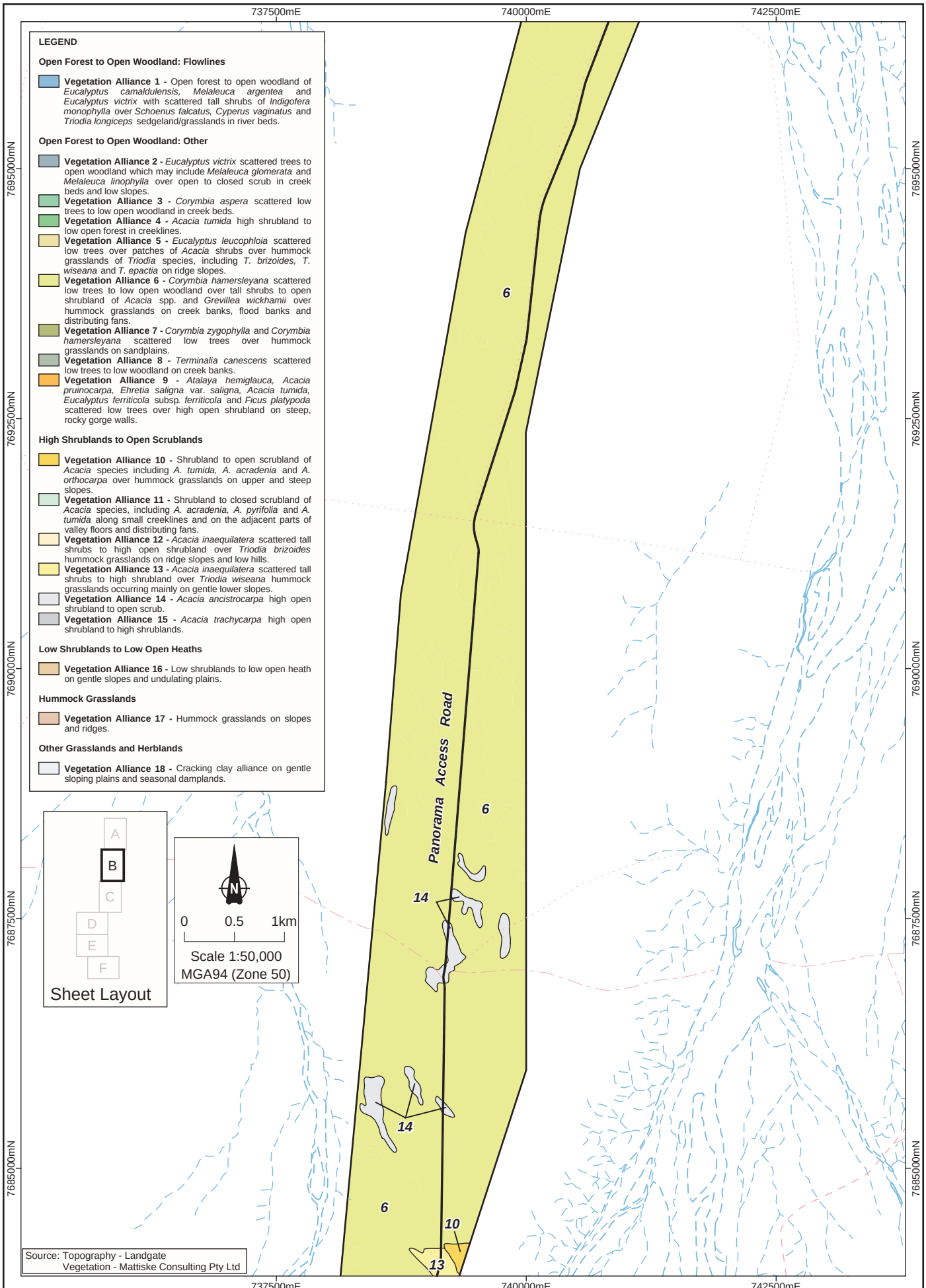
Figure No: 1a



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Vegetation Communities Project Area

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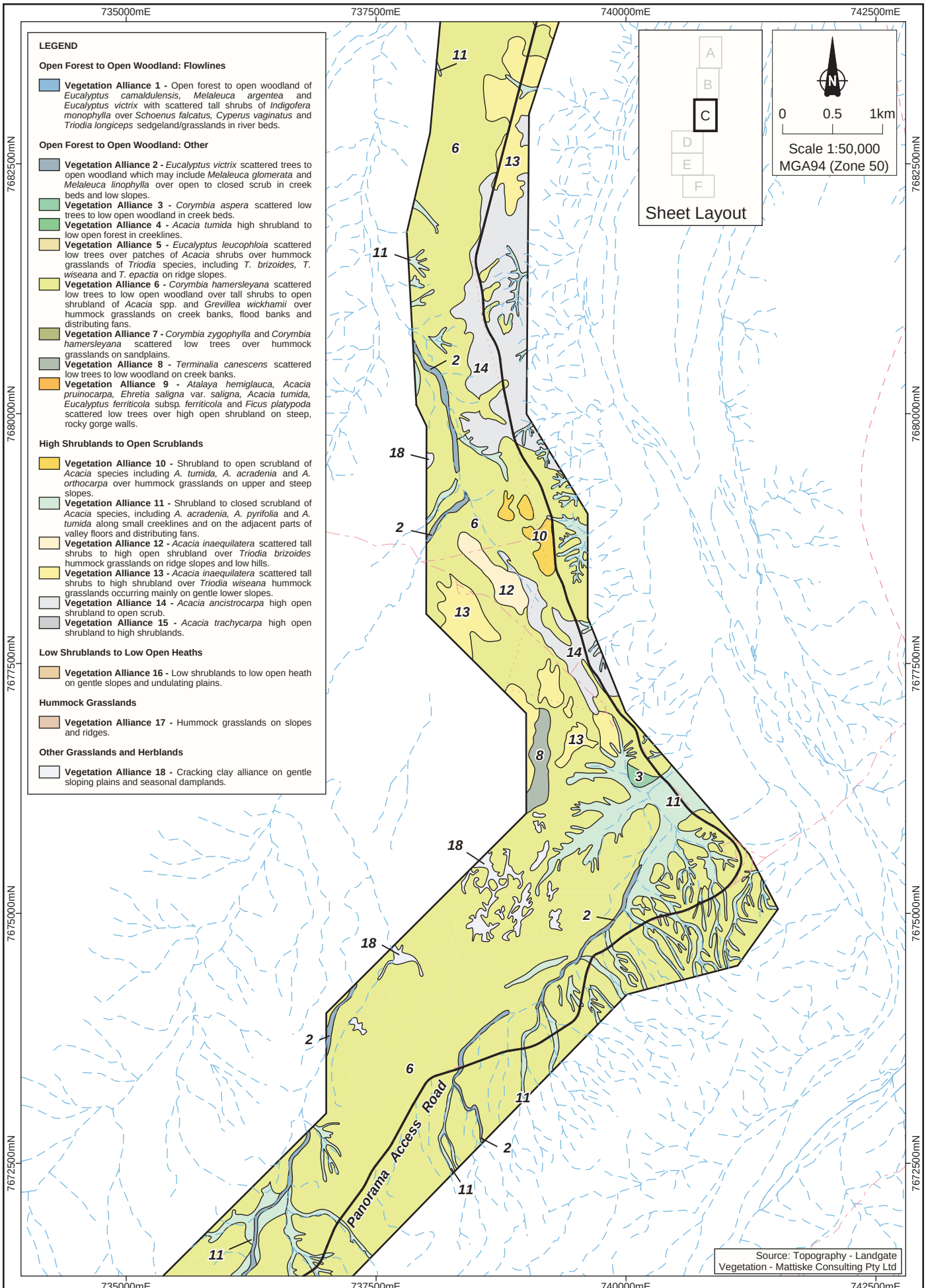

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Vegetation Communities Project Area

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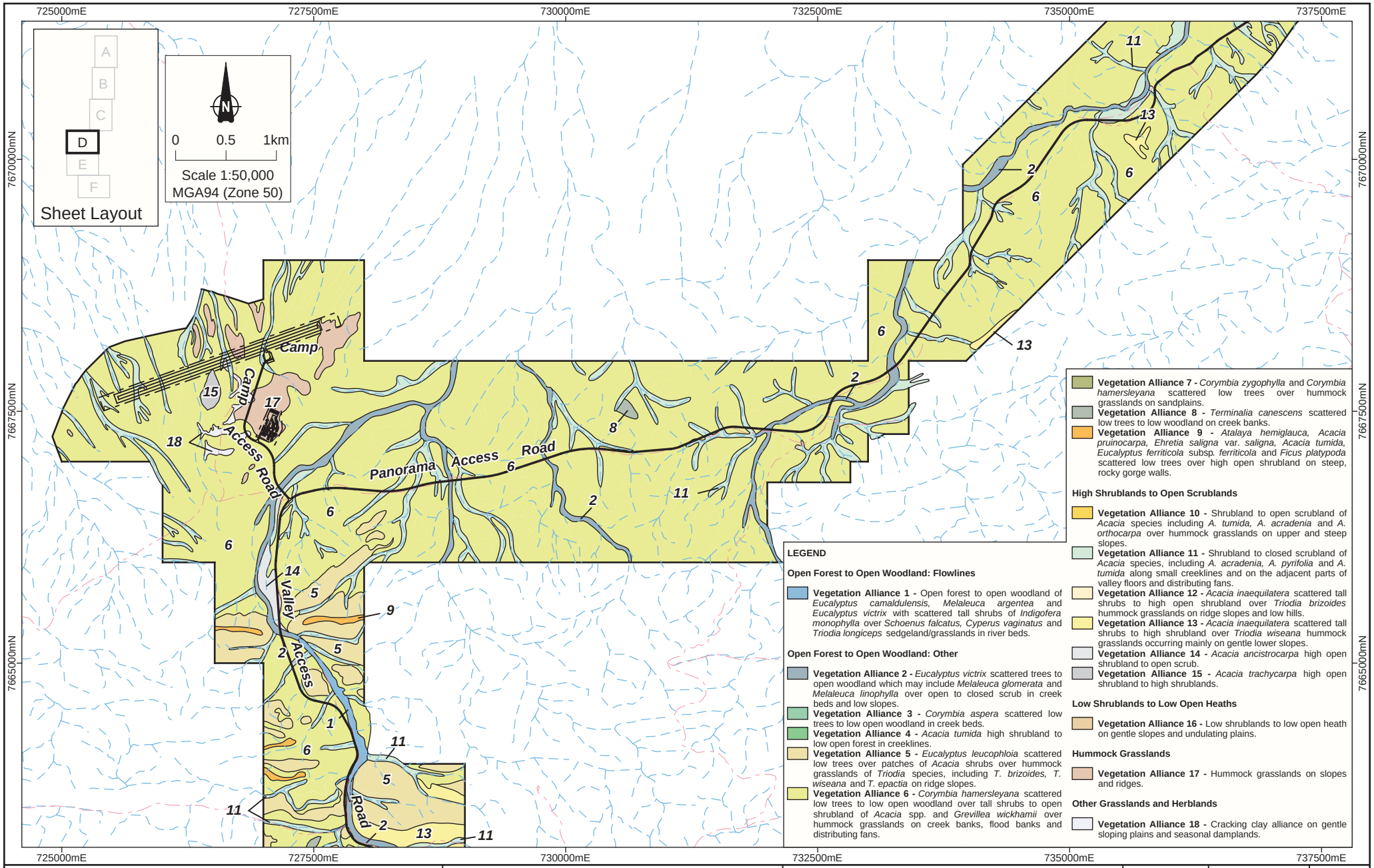

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Vegetation Communities Project Area

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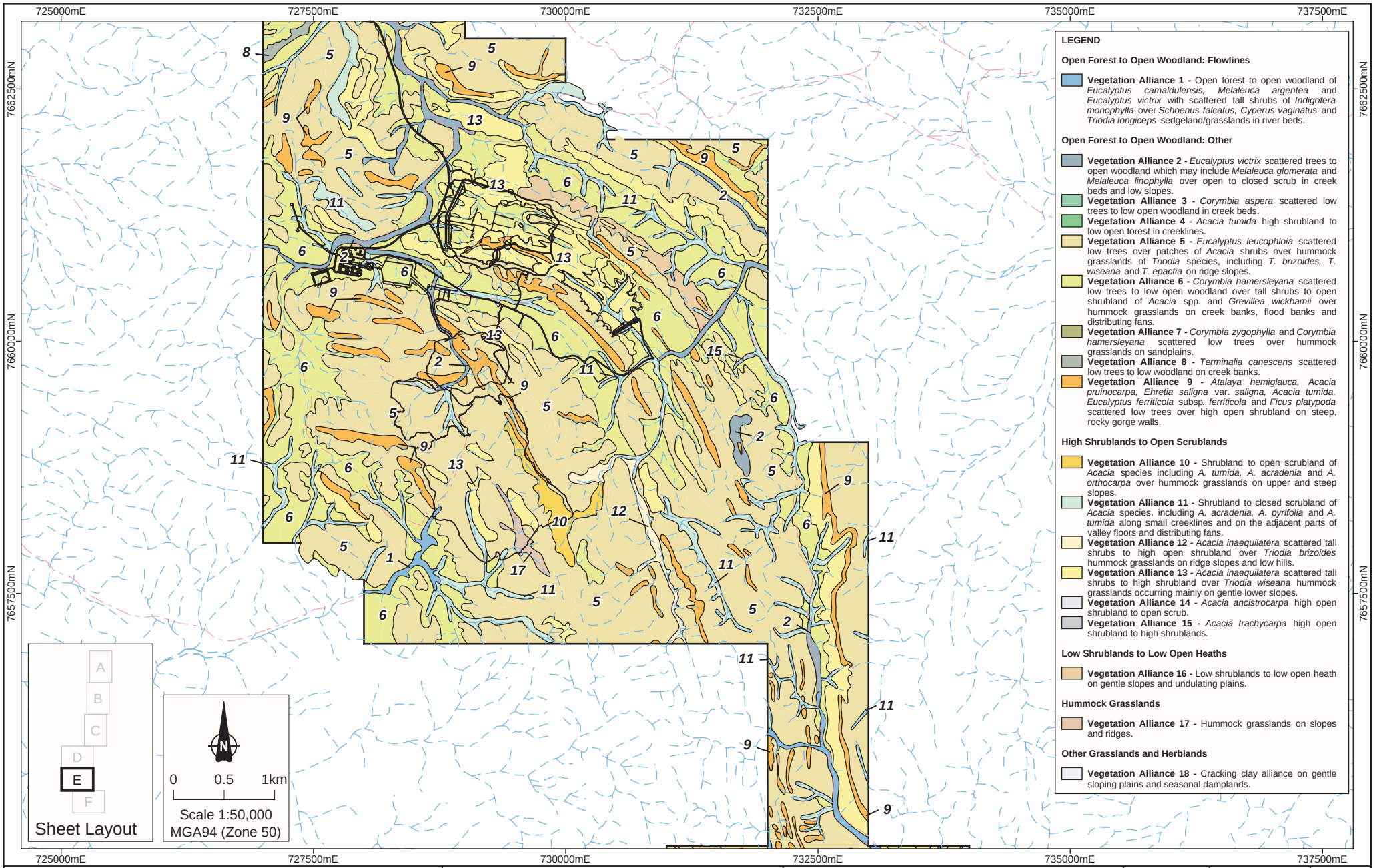

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Vegetation Communities Project Area

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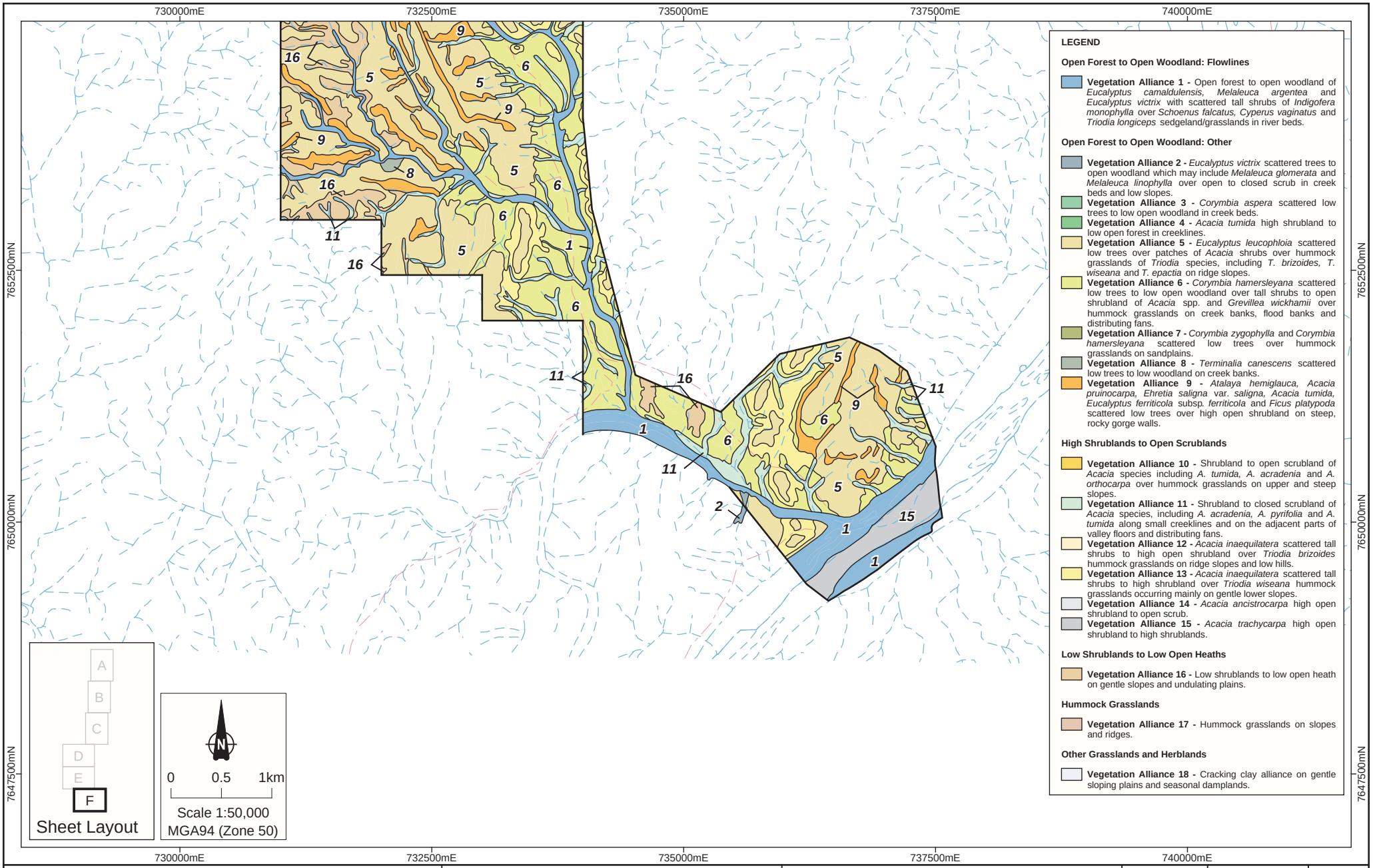

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Vegetation Communities Project Area

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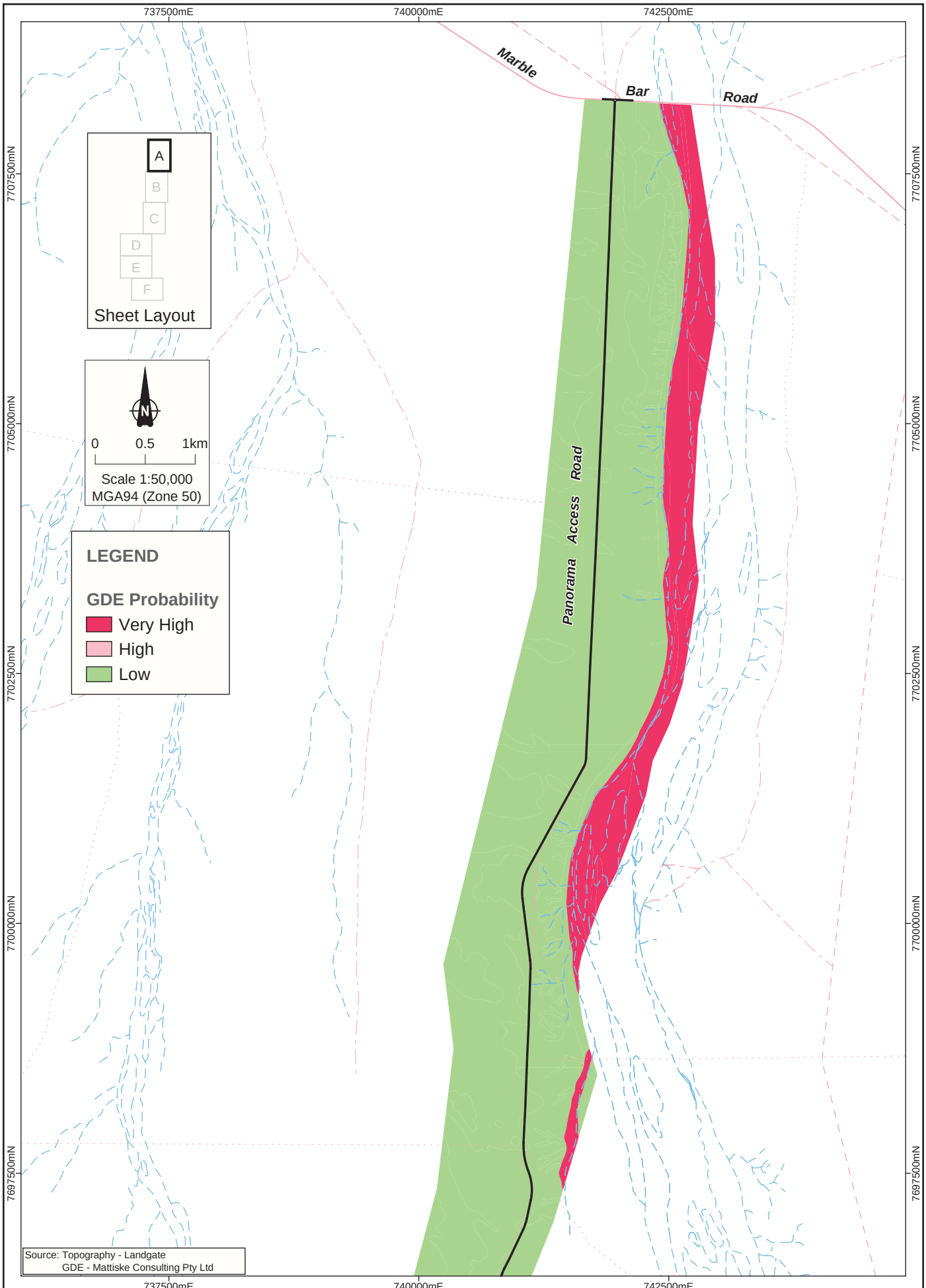

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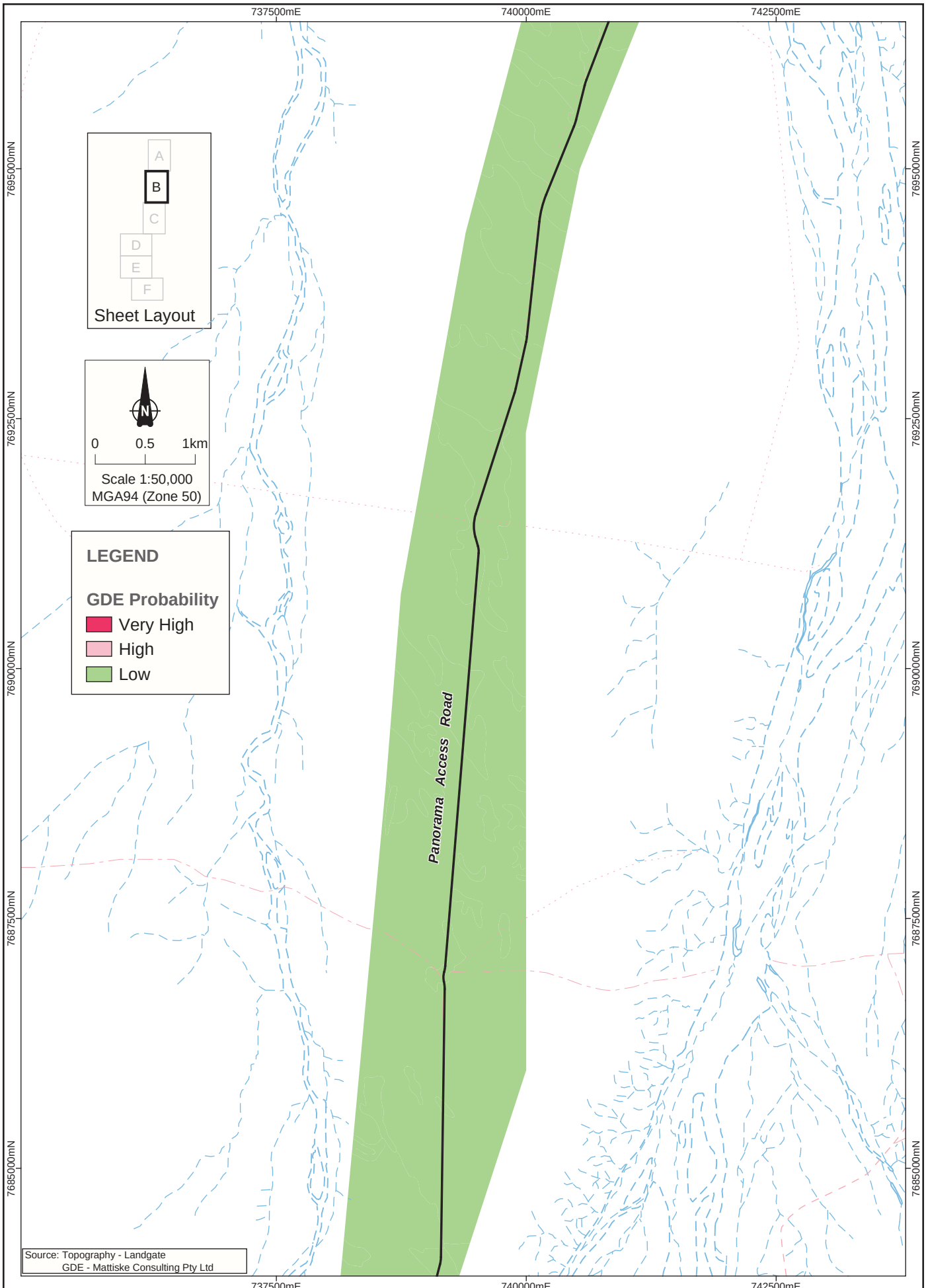

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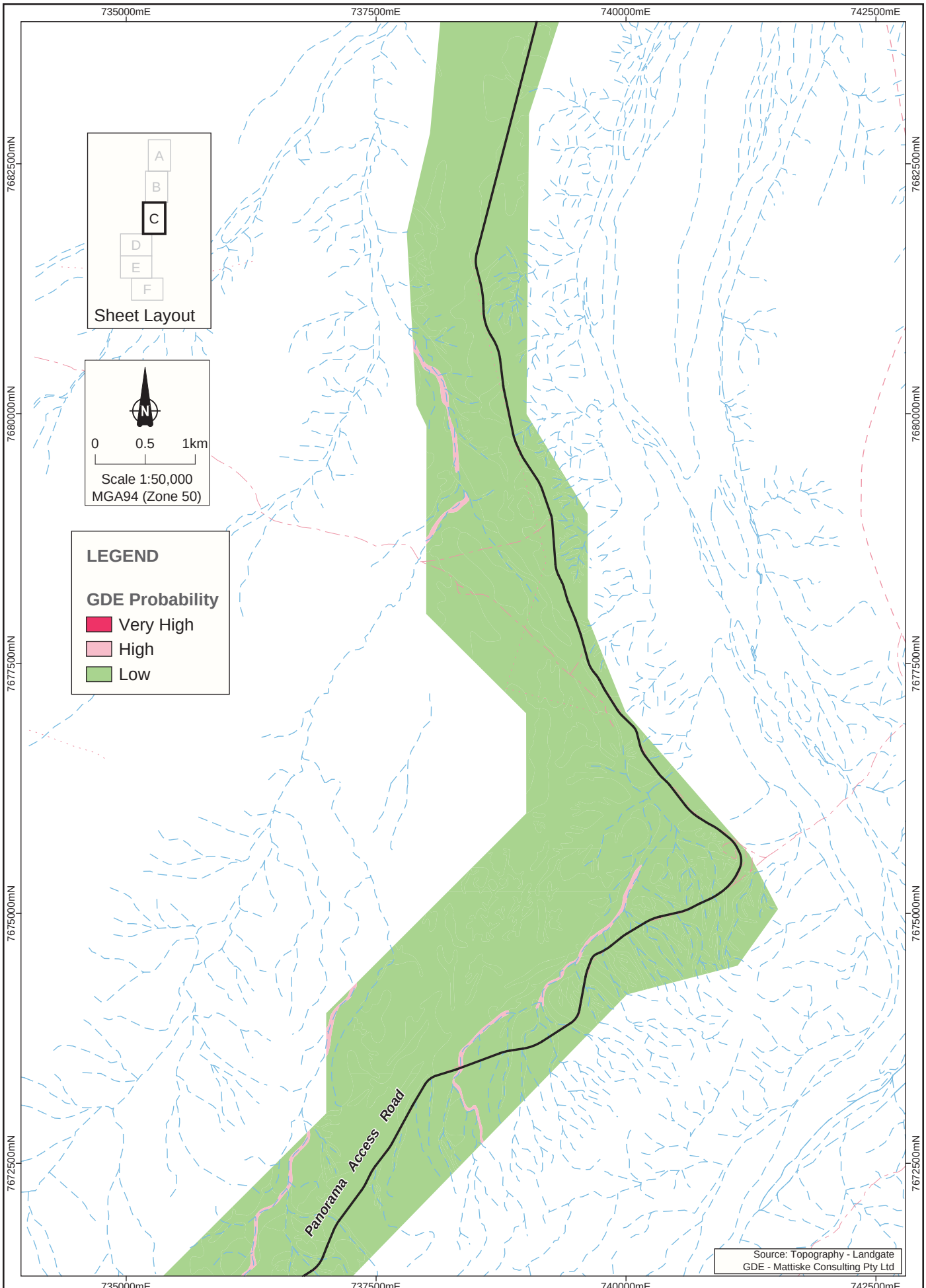

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Groundwater Dependent Ecosystems

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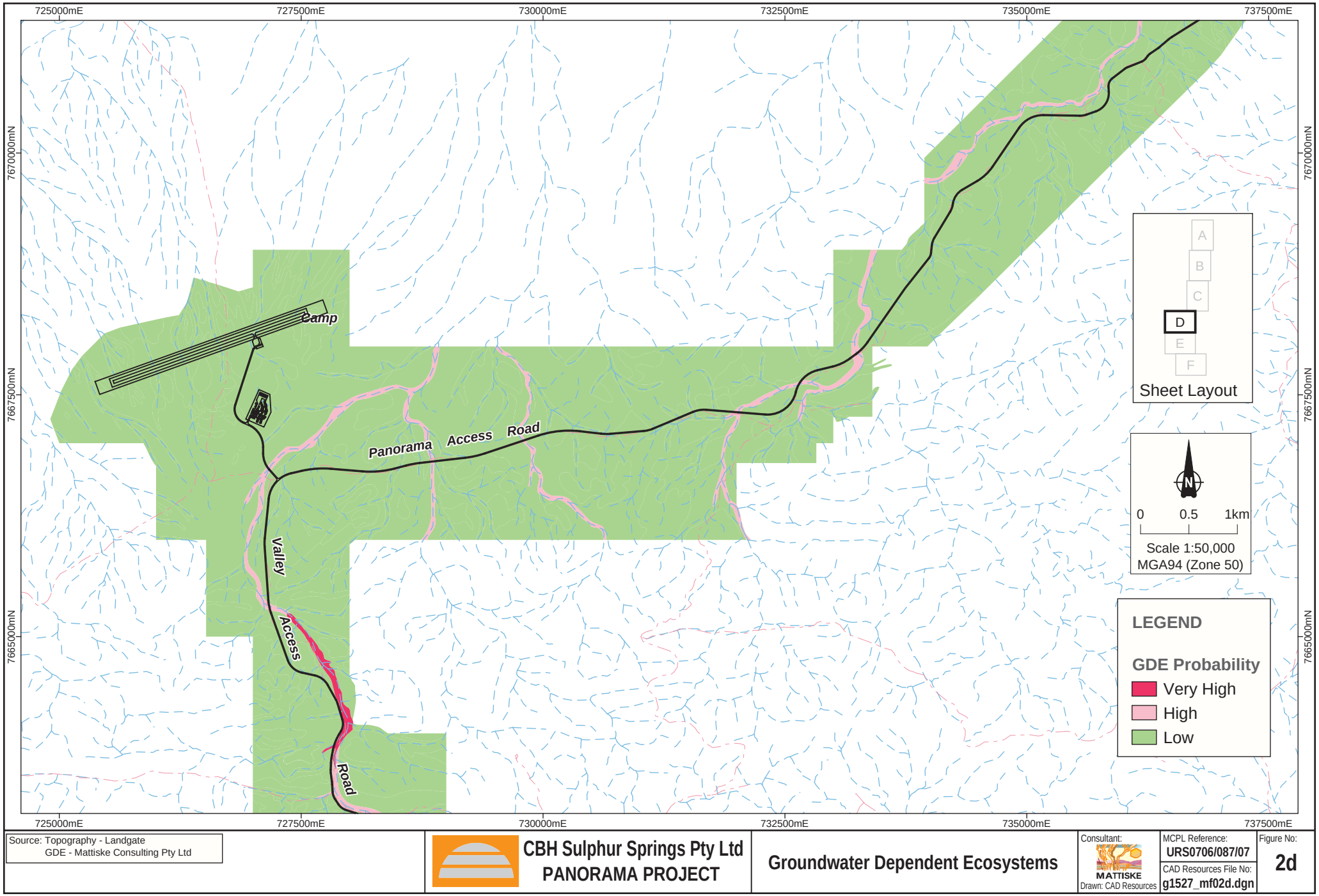

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Groundwater Dependent Ecosystems

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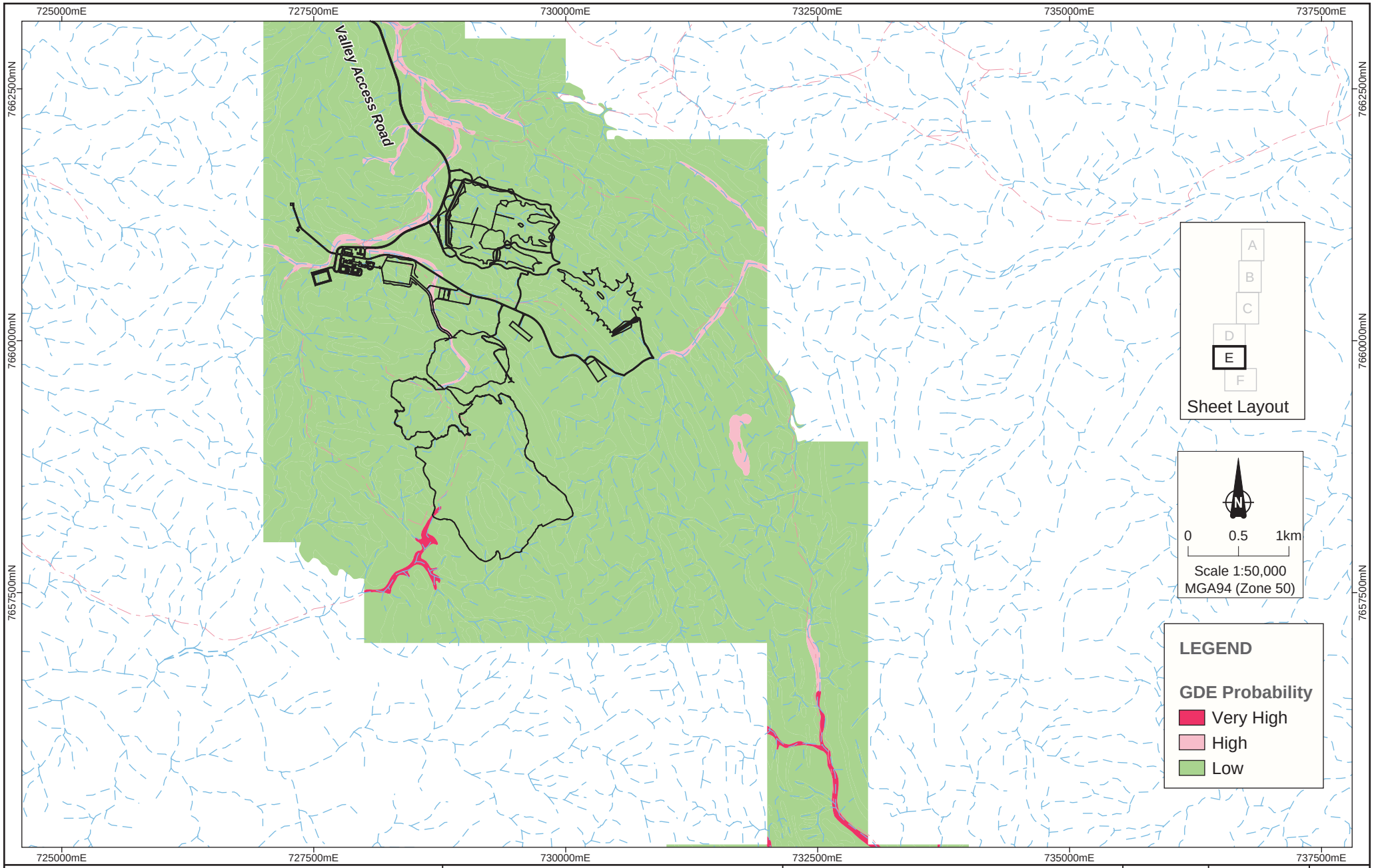

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Groundwater Dependent Ecosystems

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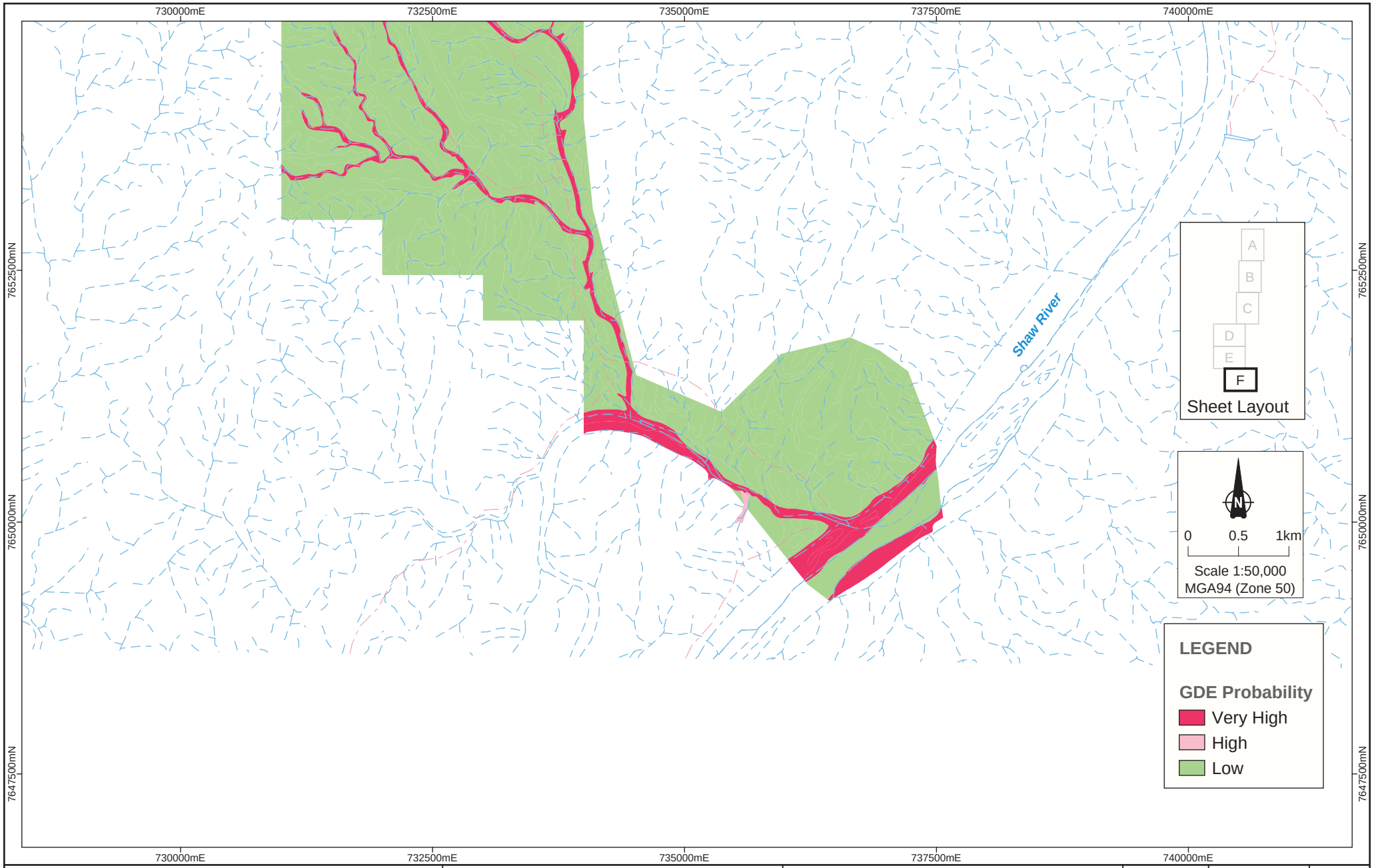

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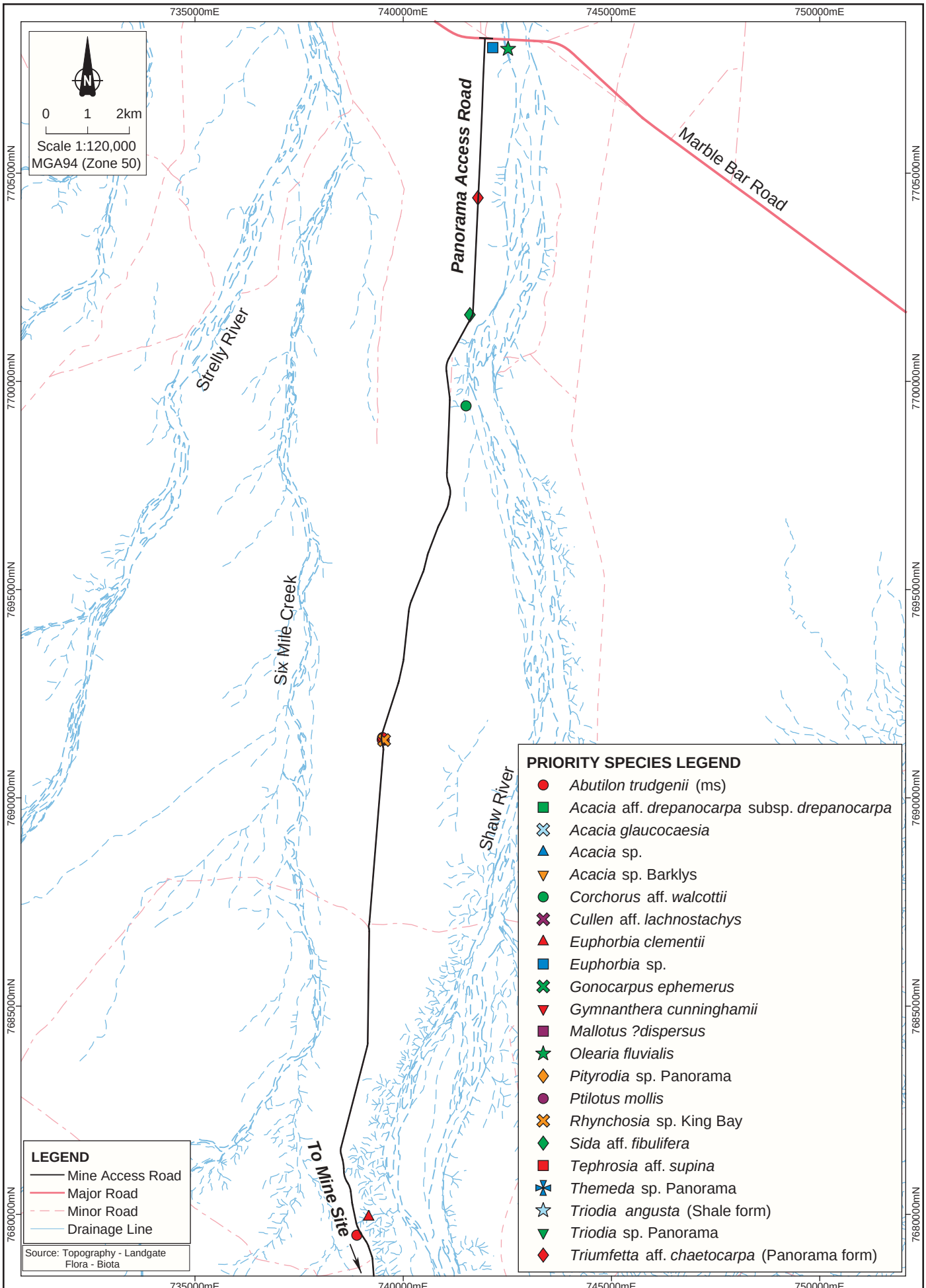
PANORAMA PROJECT

Groundwater Dependent Ecosystems

Consultant: MATTISKE
Drawn: CAD Resources

MCPL Reference: URS0706/087/07
CAD Resources File No: g1527_mf02f.dgn

Figure No: 2f



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PANORAMA PROJECT

Species of Conservation Significance

Consultant: MATTISKE
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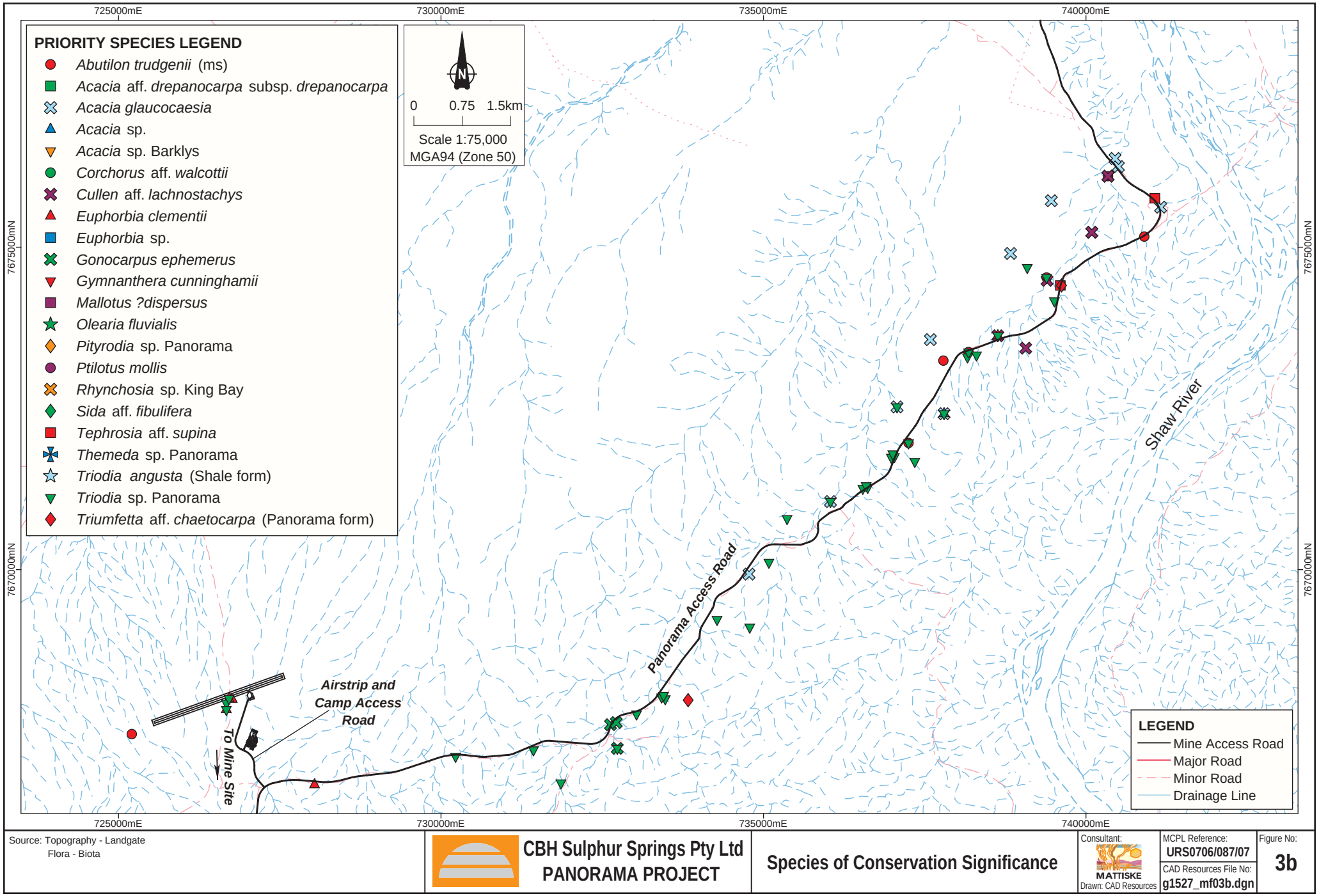
MCPL Reference: URS0706/087/07
CAD Resources File No: g1527_mf03a.dgn

Figure No: 3a



Source: Topography - Landgate
Flora - Biota

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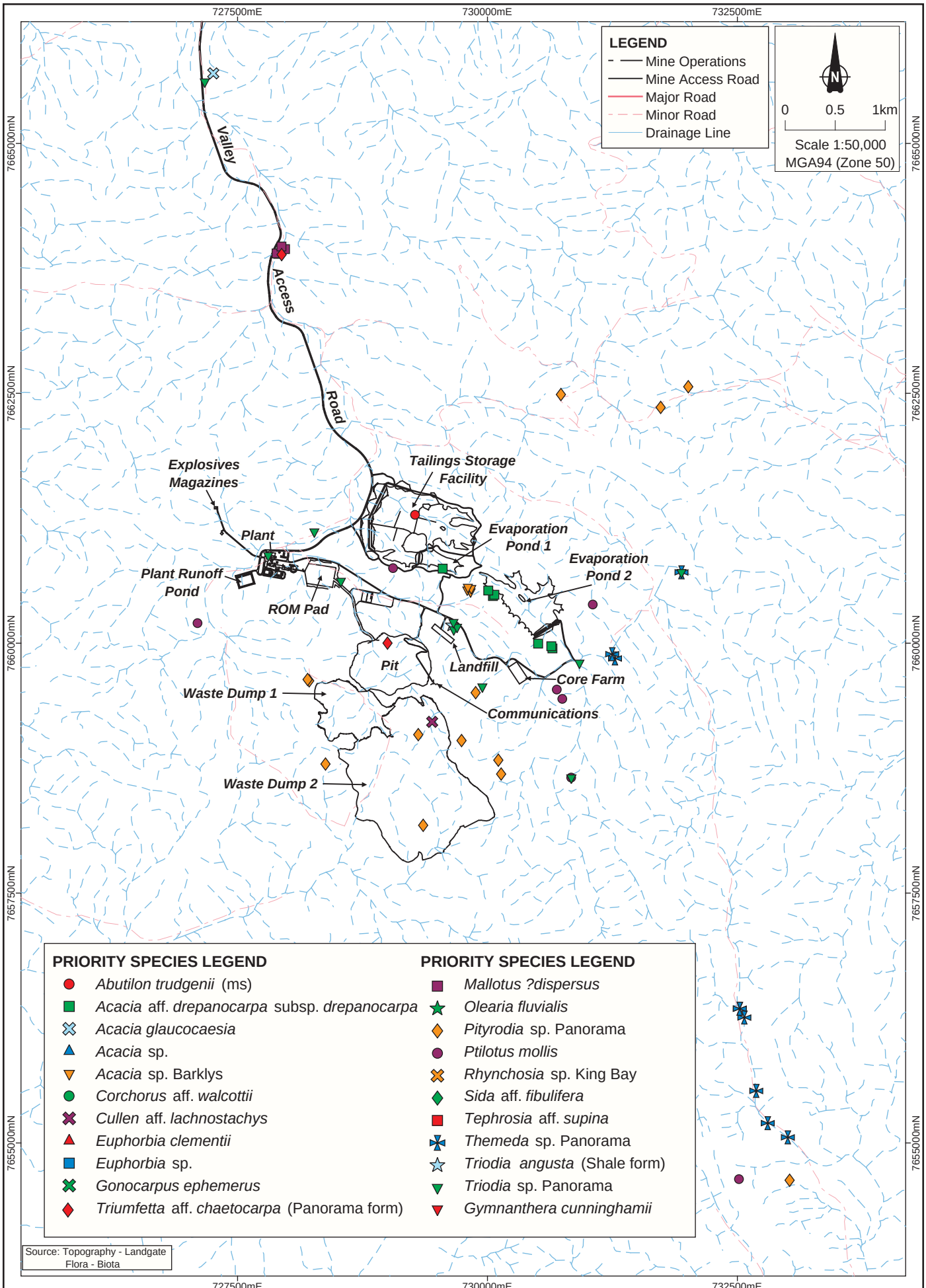
Species of Conservation Significance

Consultant: MATTISKE
Drawn: CAD Resources

MCPL Reference: URS0706/087/07
CAD Resources File No: g1527_mf03b.dgn

Figure No: 3b



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PANORAMA PROJECT

Species of Conservation Significance

Consultant: MATTISKE
Drawn: CAD Resources

MCPL Reference: URS0706/087/07
CAD Resources File No: g1527_mf03c.dgn

Figure No: 3c

APPENDIX A: SUMMARY OF VASCULAR PLANT SPECIES RECORDED WITHIN THE PANORAMA PROJECT SURVEY AREA

Note: * denotes introduced species; P1, P2, P3 and P4 denote - Priority Flora Species (DEC, 2007a)

FAMILY	SPECIES
ADIANTACEAE	*Cheilanthes austrotenuifolia*
	Cheilanthes lasiophylla
	Cheilanthes sieberi
MARSILEACEAE	*Marsilea hirsuta*
TYPHACEAE	*Typha domingensis*
POACEAE	*Aristida contorta*
	Aristida holathera var. *holathera*
	Aristida holathera var. *latifolia*
	Aristida hygrometrica
	Aristida latifolia
	Aristida sp.
	Bothriochloa sp.
	Brachyachne convergens
	Brachyachne prostrata
	* *Cenchrus ciliaris*
	Chrysopogon fallax
	Cymbopogon ambiguus
	Cymbopogon obtectus
	Cymbopogon procerus
	* *Cynodon dactylon*
	Dactyloctenium radulans
	Dichanthium fecundum
	Dichanthium sericeum subsp. *humilius*
	Digitaria brownii
	Elytrophorus spicatus
	Enneapogon caerulescens
	Enneapogon caerulescens var. *caerulescens*
	Enneapogon lindleyanus
	Enneapogon sp.
	Eragrostis cumingii
	Eragrostis eriopoda
	Eragrostis ?*leptocarpa*
	Eragrostis olida
	Eragrostis tenellula
	Eragrostis xerophila
	Eriachne aristidea
	Eriachne benthamii
	Eriachne ciliata
	Eriachne aff. *festucacea*
	Eriachne mucronata (typical form)
	Eriachne obtusa
	Eriachne sp. Port Hedland
	Eriachne pulchella
	Eriachne pulchella subsp. *dominii*
	Eriachne pulchella subsp. *pulchella*
	Eriachne tenuiculmis
	Eriachne sp. aff. *festucacea*

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FAMILY	SPECIES
POACEAE (continued)	*Eulalia aurea*
	Heteropogon contortus
	Iseilema dolichotrichum
	Iseilema eremaeum
	Iseilema macratherum
	Leptochloa fusca subsp. *fusca*
	Panicum decompositum
	Paraneurachne muelleri
	Paspalidium clementii
	Paspalidium rarum
	Paspalidium tabulatum (Whim Creek form)
	Schizachyrium fragile
	Setaria dielsii
	* *Setaria verticillata*
	Sorghum plumosum
	Sporobolus actinocladus
	Sporobolus australasicus
	Themeda avenacea
	Themeda sp. Panorama
	Themeda triandra
	Themeda aff. *triandra* (MET 16,046)
	Triodia angusta (Panorama form)
	Triodia angusta (Shale form)
	Triodia angusta (Shaw River form)
	Triodia basedowii
	Triodia brizoides
	Triodia epactia
	Triodia lanigera
	Triodia longiceps
	Triodia melvillei
	Triodia sp. Panorama
	Triodia schinzii
	Triodia wiseana
	Triodia wiseana var. *brevifolia* ?
	Yakirra australiensis var. *australiensis*
CYPERACEAE	*Bulbostylis barbata*
	Cyperus cunninghamii subsp. *cunninghamii*
	Cyperus hesperius
	Cyperus iria
	Cyperus squarrosus
	Cyperus vaginatus
	Cyperus viscidulus
	Eleocharis atropurpurea
	Fimbristylis dichotoma
	Fimbristylis littoralis
	Fimbristylis microcarya
	Fimbristylis simulans
	Fimbristylis sp.
	Fuirena ciliaris

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FAMILY	SPECIES
CYPERACEAE (continued)	*Lipocarpha microcephala*
	Schoenoplectus litoralis
	Schoenus falcatus
MORACEAE	*Ficus brachypoda*
	Ficus opposita
	Ficus opposita var. *indecora*
	Ficus platypoda var. D
PROTEACEAE	*Grevillea pyramidalis*
	Grevillea pyramidalis subsp. leucadendron
	Grevillea wickhamii subsp. *aprica*
	Grevillea wickhamii subsp. *hispidula*
	Hakea chordophylla
	Hakea lorea subsp. *lorea*
SANTALACEAE	*Santalum lanceolatum*
	Santalum spicatum
LORANTHACEAE	*Lysiana casuarinae*
CHENOPODIACEAE	*Dysphania rhadinostachya* subsp. *rhadinostachya*
	Dysphania sphaerosperma
	Salsola tragus
	Salsola tragus var. *tragus*
	Sclerolaena hostilis
AMARANTHACEAE	* *Aerva javanica*
	Alternanthera nana
	Alternanthera nodiflora
	Amaranthus aff. *pallidiflorus* (WAS1127)
	Amaranthus undulatus
	Amaranthus sp.
	Gomphrena canescens
	Gomphrena cunninghamii
	Gomphrena leptoclada subsp. *leptoclada*
	Ptilotus aervoides
	Ptilotus arthrolasius
	Ptilotus astrolasius var. *astrolasius*
	Ptilotus auriculifolius
	Ptilotus axillaris
	Ptilotus calostachyus var. *calostachyus*
	Ptilotus clementii
	Ptilotus exaltatus var. *exaltatus*
	Ptilotus fusiformis
	Ptilotus fusiformis var. *fusiformis*
	Ptilotus gaudichaudii var. *gaudichaudii*
	Ptilotus gomphrenoides var. *gomphrenoides*
	Ptilotus incanus
	Ptilotus incanus var. *elongatus*
	Ptilotus mollis (P4)
	Ptilotus murrayi var. *murrayi*

APPENDIX A: SUMMARY OF VASCULAR PLANT SPECIES RECORDED WITHIN THE PANORAMA PROJECT SURVEY AREA

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FAMILY	SPECIES
NYCTAGINACEAE	*Boerhavia burbidgeana*
	Boerhavia coccinea
	Boerhavia gardneri
	Boerhavia repleta
	Boerhavia sp. (M92-7)
GYROSTEMONACEAE	*Codonocarpus cotinifolius*
AIZOACEAE	*Trianthema aff. triquetra* (M3.35)
	Trianthema oxycalyptra var. *oxycalyptra*
	Trianthema pilosa
	Trianthema triquetra
	Trianthema sp.
MOLLUGINACEAE	*Mollugo molluginea*
PORTULACACEAE	*Calandrinia pumila*
	* *Portulaca oleracea*
CARYOPHYLLACEAE	*Polycarpaea corymbosa* var. *corymbosa*
	Polycarpaea holtzei
	Polycarpaea involucrata
	Polycarpaea longiflora
	Polycarpaea longiflora (Whim Creek form, WC147-7)
	Polycarpaea longiflora (White form, M13-7)
	Polycarpaea sp.
MENISPERMACEAE	*Tinospora smilacina*
LAURACEAE	*Cassytha capillaris*
PAPAVERACEAE	* *Argemone ochroleuca*
CAPPARACEAE	*Cleome uncifera*
	Cleome uncifera subsp. *uncifera*
	Cleome viscosa
BRASSICACEAE	*Lepidium pholidogynum*
MIMOSACEAE	*Acacia acradenia*
	Acacia adoxa var. *adoxa*
	Acacia ampliceps
	Acacia ancistrocarpa
	Acacia arida
	Acacia sp. Barklys
	Acacia bivenosa
	Acacia colei
	Acacia coriacea
	Acacia coriacea subsp. *pendens*
	Acacia dictyophleba
	Acacia aff. *drepanocarpa* subsp. *drepanocarpa* (BM:C16)

APPENDIX A: SUMMARY OF VASCULAR PLANT SPECIES RECORDED WITHIN THE PANORAMA PROJECT SURVEY AREA

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FAMILY	SPECIES
MIMOSACEAE (continued)	*Acacia elachantha*
	Acacia ericifolia
	Acacia glaucocaesia (P3)
	Acacia hilliana
	Acacia holosericea
	Acacia inaequilatera
	Acacia maitlandii
	Acacia melileodora
	Acacia orthocarpa
	Acacia orthocarpa (wispy form)
	Acacia sp. (PAN M48)
	Acacia pruinocarpa
	Acacia ptychophylla
	Acacia pyrifolia
	Acacia pyrifolia (slender, white)
	Acacia sabulosa
	Acacia sclerosperma subsp. *sclerosperma*
	Acacia sericophylla
	Acacia sphaerostachya
	Acacia spondylophylla
	Acacia stellaticeps
	Acacia synchronicia
	Acacia trachycarpa
	Acacia trachycarpa x *tumida* var. *pilbarensis*
	Acacia ?*trachycarpa* (PAN12-4)
	Acacia tumida
	Acacia tumida var. *pilbarensis*
	Acacia victoriae
	Acacia sp.
	Dichrostachys spicata
	Neptunia dimorphantha
	* *Vachellia farnesiana*
CAESALPINIACEAE	*Cassia glaucifolia* x *glutinosa*
	Cassia glutinosa x *luerssenii*
	Cassia aff. *oligophylla* (BMor 152)
	Cassia 'symonii'
	Cassia sp.
	Petalostylis labicheoides
	Senna artemisioides subsp. *helmsii*
	Senna artemisioides subsp. *oligophylla*
	Senna artemisioides subsp. *oligophylla* (Panorama form)
	Senna artemisioides subsp. *oligophylla* x *helmsii*
	Senna artemisioides subsp. x *artemisioides*
	Senna artemisioides subsp. x *artemisioides* (Panorama form)
	Senna aff. *artemisioides* subsp. x *artemisioides* (thinly sericeous)
	Senna glaucifolia
	Senna glutinosa
	Senna glutinosa subsp. *charlesiana*
	Senna glutinosa subsp. *glutinosa*
	Senna glutinosa subsp. *luerssenii*
	Senna glutinosa subsp. x *luerssenii*

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FAMILY	SPECIES
CAESALPINIACEAE (continued)	*Senna glutinosa* subsp. *pruinosa*
	Senna notabilis
	Senna oligoclada
	Senna symonii
	Senna venusta
	Senna sp.
PAPILIONACEAE	*Alysicarpus muelleri*
	Cajanus cinereus
	Cajanus marmoratus
	Crotalaria cunninghamii
	Crotalaria dissitiflora subsp. *benthamiana*
	Crotalaria medicaginea (Burrup form; B65-11)
	Crotalaria medicaginea
	Crotalaria ramosissima
	Cullen lachnostachys
	Cullen aff. *lachnostachys* (MET 15,154)
	Cullen leucanthum
	Cullen leucochaites
	Cullen martinii
	Cullen pogonocarpum
	Cullen stipulaceum
	Desmodium filiforme
	Desmodium muelleri
	Indigastrum parviflorum
	Indigastrum parviflorum (Whim Creek form; W138-3)
	Indigofera colutea
	Indigofera linifolia
	Indigofera linnaei
	Indigofera monophylla
	Indigofera monophylla (small calyx form)
	Indigofera monophylla (PAN20-2)
	Indigofera monophylla (PAN57-9)
	Indigofera monophylla (PAN58-17)
	Indigofera monophylla (PAN65-14)
	Indigofera rugosa
	Indigofera trita
	Isotropis atropurpurea
	Rhynchosia cf. *minima*
	Rhynchosia minima var. *australis*
	Rhynchosia sp. King Bay (B181-13)
	Sesbania cannabina
	Sesbania formosa
	Swainsona formosa
	Templetonia hookeri
	Tephrosia bidwillii
	Tephrosia aff. *bidwillii* (HD153-5)
	Tephrosia sp. B Kimberley Flora (C.A.Gardner 7300)
	Tephrosia sp. Bungaroo Creek (M.E.Trudgen 11601)
	Tephrosia clelandii ms
	Tephrosia clementii
	Tephrosia aff. *clementii* (11)

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FAMILY	SPECIES
PAILIONACEAE (continued)	*Tephrosia rosea* var. *clementii*
	Tephrosia rosea var. *rosea*
	Tephrosia aff. *rosea* (HD292-37)
	Tephrosia simplicifolia
	Tephrosia spechtii
	Tephrosia stipuligera
	Tephrosia supina
	Tephrosia aff. *supina*
	Tephrosia aff. *supina* (HD205-10)
	Tephrosia aff. *supina* (HD237-23)
	Tephrosia aff. *supina* (HD88-4)
	Tephrosia aff. *supina* (MET 12,357)
	Tephrosia aff. *uniovulata* (HD76)
	Tephrosia sp.
	Vigna lanceolata var. *lanceolata*
	Vigna sp. Harding Dam (HD189-12)
	Zornia chaetophora
ZYGOPHYLLACEAE	*Tribulopis angustifolia*
	Tribulus hirsutus
	Tribulus platypterus
	Tribulus suberosus
POLYGALACEAE	*Polygala* aff. *isingii*
	Polygala linariifolia
EUPHORBIACEAE	*Euphorbia australis*
	Euphorbia aff. *australis*
	Euphorbia aff. *australis* (B191)
	Euphorbia biconvexa
	Euphorbia clementii (P2)
	Euphorbia coghlanii
	Euphorbia aff. *drummondii* (HD195-16)
	Euphorbia aff. *drummondii* (MET 15,030)
	Euphorbia sp. (PAN1-14B)
	Euphorbia sp. (PAN5-15)
	Euphorbia sp. (site 1089)
	Euphorbia tannensis subsp. *eremophila* (Panorama form)
	Euphorbia sp.
	Euphorbia wheeleri
	Flueggea virosa subsp. *melanthesoides*
	Leptopus decaisnei
	Leptopus decaisnei var. *decaisnei*
	Mallotus ?*dispersus*
	Phyllanthus erwinii
	Phyllanthus maderaspatensis
*	*Ricinus communis*
SAPINDACEAE	*Atalaya hemiglauca*
	Dodonaea coriacea
RHAMNACEAE	*Ventilago viminalis*

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FAMILY	SPECIES
TILIACEAE	*Corchorus* sp. A Kimberley Flora (K.F.Kenneally & B.P.M.Hyland 10421)
	Corchorus aff. *aestuans*
	Corchorus elachocarpus
	Corchorus incanus
	Corchorus aff. *laniflorus* (PAN 76)
	Corchorus aff. *laniflorus* (PAN 78)
	Corchorus sp. (M.E. Trudgen 21,247)
	Corchorus sp. Panorama
	Corchorus parviflorus
	Corchorus aff. *walcottii* (H251-3)
	Corchorus aff. *walcottii* (K.J. Atkins 570)
	Corchorus sp.
	Triumfetta chaetocarpa
	Triumfetta aff. *chaetocarpa* (PAN3/4)
	Triumfetta aff. *chaetocarpa* (Panorama form)
	Triumfetta clementii
	Triumfetta maconochieana
	Triumfetta propinqua
	Triumfetta sp.
MALVACEAE	*Abutilon dioicum*
	Abutilon aff. *dioicum* (HD72-14)
	Abutilon sp. aff. *dioicum*
	Abutilon fraseri
	Abutilon aff. *hannii*
	Abutilon aff. *hannii* (1)
	Abutilon aff. *hannii* (2)
	Abutilon aff. *lepidum* (1) (MET 15 352)
	Abutilon aff. *lepidum* (4)
	Abutilon otocarpum
	Abutilon trudgenii (P3)
	Abutilon sp.
	?*Abutilon* sp. (P62)
	?*Abutilon*
	Gossypium australe (Burrup Peninsula form)
	Gossypium australe (Whim Creek form)
	Gossypium robinsonii
	Hibiscus brachychlaenus
	Hibiscus coatesii
	Hibiscus aff. *coatesii*
	Hibiscus aff. c*oatesii* (MET 15012)
	Hibiscus aff. c*oatesii* (site 693)
	Hibiscus goldsworthii
	Hibiscus leptocladus
	Hibiscus platychlamys
	Hibiscus aff. *platychlamys* (site 1139)
	Hibiscus sturtii var. *campylochlamys*
	Hibiscus sturtii var. aff. c*ampylochlamys* (MET 15,957)
	Hibiscus sturtii var. aff. c*ampylochlamys* (site 1398)
	Hibiscus sturtii var. *platychlamys*
	Hibiscus sp.

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FAMILY	SPECIES
MALVACEAE (continued)	*Sida* sp. A Kimberley Flora (P.A.Fryxell & L.A.Craven 3900)
	Sida cardiophylla
	Sida clementii
	Sida echinocarpa
	Sida hackettiana
	Sida aff. *fibulifera*
	Sida aff. *fibulifera* (PAN 10-6)
	?*Sida* sp. (M58)
	Sida pilbarensis ms
	Sida pilbarensis ms (Ferruginous form)
	Sida aff. pilbarensis
	Sida aff. Pilbarensis (EOB46-01B)
	Sida rohlenae subsp. *rohlenae*
	Sida spinosa
	Sida subarticulata ms
	Sida sp. (?no match)
	?Sida sp.
STERCULIACEAE	*Keraudrenia nephrosperma*
	Keraudrenia velutina subsp. *elliptica* ms
	Melhania sp. Burrup
	Waltheria indica
	Waltheria virgata
ELATINACEAE	*Bergia pedicellaris*
	Bergia trimera
VIOLACEAE	*Hybanthus aurantiacus*
THYMELAEACEAE	*Pimelea ammocharis*
LYTHRACEAE	*Ammannia auriculata*
	Ammannia baccifera
	Rotala diandra
COMBRETACEAE	*Terminalia canescens*
MYRTACEAE	*Corymbia ferriticola* subsp. *ferriticola*
	Corymbia flavescens
	Corymbia hamersleyana
	Corymbia sp. (PAN39-18)
	Corymbia zygophylla
	Eucalyptus camaldulensis var. *obtusa*
	Eucalyptus leucophloia
	Eucalyptus leucophloia subsp. *leucophloia*
	Eucalyptus victrix
	Melaleuca argentea
	Melaleuca glomerata
	Melaleuca linophylla
ONAGRACEAE	*Ludwigia perennis*

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FAMILY	SPECIES
HALORAGACEAE	*Gonocarpus ephemerus* (P2)
	Haloragis gossei
APIACEAE	*Trachymene didiscoides*
	Trachymene hemicarpa
	Trachymene oleracea
	Trachymene aff. *oleracea* (B61)
LOGANIACEAE	*Mitrasacme connata*
APOCYNACEAE	*Carissa lanceolata*
ASCLEPIADACEAE	*Gymnanthera cunninghamii* (P3)
	Marsdenia angustata
	Sarcostemma viminale subsp. *australe*
CONVOLVULACEAE	*Bonamia* sp. (HD94-6)
	Bonamia linearis
	Bonamia media var. *villosa*
	Bonamia pannosa
	Bonamia rosea
	Bonamia sp.
	Convolvulus angustissimus subsp. *angustissimus*
	Convolvulus sp.
	Evolvulus alsinoides var. *villosicalyx*
	Ipomoea muelleri
	Operculina aequisepala
	Polymeria ambigua
	Polymeria aff. *ambigua* (PAN 26B-20)
	Polymeria calycina
	Polymeria aff. *calycina*
	Polymeria sp. (PAN1-16)
	Polymeria sp. (PAN4-14)
	Polymeria sp.
	Porana commixta
BORAGINACEAE	*Ehretia saligna* var. *saligna*
	Heliotropium chrysocarpum
	Heliotropium cunninghamii
	Heliotropium aff. *cunninghamii* (P65-12)
	Heliotropium curassavicum
	Heliotropium heteranthum
	Heliotropium ovalifolium
	Heliotropium paniculatum
	Heliotropium skeleton
	Heliotropium tanythrix
	Heliotropium tenuifolium
	Heliotropium sp.
	Trichodesma zeylanicum var. *zeylanicum*
VERBENACEAE	*Clerodendrum floribundum* var. *angustifolium*
	Clerodendrum floribundum var. *floribundum*

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FAMILY	SPECIES
VERBENACEAE (continued)	*Clerodendrum tomentosum*
CHLOANTHACEAE	*Pityrodia* sp. *Panorama* (BMor 151)
SOLANACEAE	*Nicotiana benthamiana*
	Solanum beaugleholei
	Solanum diversiflorum
	Solanum ellipticum
	Solanum ?*ellipticum*
	Solanum horridum
	* *Solanum nigrum*
	Solanum phlomoides
SCROPHULARIACEAE	*Stemodia grossa*
	Stemodia viscosa
	Striga curviflora
BIGNONIACEAE	*Dolichandrone heterophylla*
RUBIACEAE	*Oldenlandia crouchiana*
	Oldenlandia galioides
	Synaptantha tillaeacea var. *tillaeacea*
CUCURBITACEAE	* *Cucumis melo* subsp. *agrestis*
	Mukia maderaspatana
	Mukia cf. *maderaspatana*
	Mukia sp. D Flora of Australia
	Mukia sp. Panorama
	Trichosanthes cucumerina
CAMPANULACEAE	*Wahlenbergia tumidifructa*
LOBELIACEAE	*Lobelia quadrangularis*
GOODENIACEAE	*Dampiera candicans*
	Goodenia cusackiana
	Goodenia lamprosperma
	Goodenia microptera
	Goodenia muelleriana
	Goodenia ?*muelleriana*
	Goodenia stobbsiana
	Goodenia sp.
	Scaevola amblyanthera var. *centralis*
	Scaevola parvifolia subsp. *pilbarae*
ASTERACEAE	*Centipeda minima*
	Flaveria australasica
	Olearia fluvialis (P2)
	Pentalepis trichodesmoides
	Pluchea dentex
	Pluchea dunlopii
	Pluchea ferdinandi-muelleri

APPENDIX A: SUMMARY OF VASCULAR PLANT SPECIES RECORDED WITHIN THE PANORAMA PROJECT SURVEY AREA

Note: * denotes introduced species; P1, P2, P3 and P4 denote - Priority Flora Species (DEC, 2007a)

FAMILY	SPECIES
ASTERACEAE (continued)	*Pluchea rubelliflora*
	Pluchea tetranthera
	Pterocaulon sp. (PAN1-47)
	Pterocaulon serrulatum
	Pterocaulon sphacelatum
	Pterocaulon sphaeranthoides
	Pterocaulon sphaeranthoides x *sphacelatum*
	Rhodanthe margarethae
	Streptoglossa bubakii
	Streptoglossa decurrens
	Streptoglossa macrocephala
	Streptoglossa odora
	Streptoglossa sp.
	Vittadinia virgata

APPENDIX B: SUMMARY OF RECORDED AND POTENTIAL DECLARED RARE, PRIORITY AND CONSERVATION SIGNIFICANT SPECIES RECORDED WITHIN THE PANORAMA PROJECT SURVEY AREA

SCC - State Conservation Codes (Department of Environment and Conservation 2007a)
FCC - Federal Conservation Codes (Environmental Protection and Biodiversity Conservation Act, 1999)

Family	Species	SCC	FCC
Priority Species Recorded in the Panorama Project Area			
AMARANTHACEAE	*Ptilotus mollis*	P4	
MIMOSACEAE	*Acacia glaucocaesia*	P3	
EUPHORBIACEAE	*Euphorbia clementii*	P2	
MALVACEAE	*Abutilon trudgenii* (ms)	P3	
HALORAGACEAE	*Gonocarpus ephemerus*	P2	
ASCLEPIADACEAE	*Gymnanthera cunninghamii*	P3	
ASTERACEAE	*Olearia fluvialis*	P2	
New Species Recorded in the Panorama Project Area			
POACEAE	*Themeda* sp. Panorama		
LAMIACEAE	*Pityrodia* sp. Panorama (BMor 151)		
Species that require further investigation and possibly geographically restricted			
POACEAE	*Triodia* sp. Panorama *Triodia angusta* (Shale form)		
MIMOSACEAE	*Acacia* sp. Barklys		
EUPHORBIACEAE	*Mallotus* ?*dispersus*		
TILIACEAE	*Triumfetta* aff. *chaetocarpa* (Panorama form)		
Species that require further investigation			
MIMOSACEAE	*Acacia* aff. *drepanocarpa* subsp. *drepanocarpa* *Acacia* sp. (PAN M48)		
PAPILIONACEAE	*Cullen* aff. *lachnostachys* (MET 15,154) *Rhynchosia* sp. King Bay *Tephrosia* aff. *supina* (HD88-4)		
EUPHORBIACEAE	*Euphorbia* sp. (PAN1-14B) *Euphorbia* sp. (PAN5-15)		
TILIACEAE	*Corchorus* aff. w*alcottii* (H251-3)		
MALVACEAE	*Sida* aff. *fibulifera* (PAN10-6)		

APPENDIX B: SUMMARY OF RECORDED AND POTENTIAL DECLARED RARE, PRIORITY AND CONSERVATION SIGNIFICANT SPECIES RECORDED WITHIN THE PANORAMA PROJECT SURVEY AREA

SCC - State Conservation Codes (Department of Environment and Conservation 2007a)
FCC - Federal Conservation Codes (Environmental Protection and Biodiversity Conservation Act, 1999)

Family	Species	SCC	FCC
Rare Species Potentially in the Panorama Project Area			
BRASSICAEAE	*Lepidium catapycnon*	R	Vulnerable
MYRTACEAE	*Thryptomene wittweri*	R	Vulnerable
Priority Species Potentially in the Panorama Project Area			
CYPERACEAE	*Bulbostylis burbidgeae*	P3	
	Fimbristylis sieberiana	P3	
AMARANTHACEAE	*Gomphrena pusilla*	P2	
	Ptilotus appendiculatus var. *minor*	P1	
EUPHORBIACEAE	*Phyllanthus aridus*	P3	
MALVACEAE	*Hibiscus brachysiphonius*	P3	
GOODENIACEAE	*Goodenia nuda*	P3	
	Goodenia pascua	P3	

APPENDIX C: GPS LOCATIONS OF CONSERVATION SIGNIFICANT SPECIES RECORDED WITHIN THE PANORAMA PROJECT SURVEY AREA

Note: P1, P2, P3 and P4 denote - Priority Flora Species (DEC, 2007a).
All GPS locations are in the AMG projection, WGS84 datum and in zone 50k

Species	Easting	Northing	Project Disturbance Area	Project Area
Priority Species Recorded in the Panorama Project Area				
Ptilotus mollis (P4)	729055	7660749	TSF	13a
Ptilotus mollis (P4)	732516	7654639		
Ptilotus mollis (P4)	730839	7658653		
Ptilotus mollis (P4)	730750	7659443		
Ptilotus mollis (P4)	730692	7659536		
Ptilotus mollis (P4)	727100	7660200		
Ptilotus mollis (P4)	731055	7660387		
Acacia glaucocaesia (P3)	740342	7676101	Road	11a
Acacia glaucocaesia (P3)	734776	7669930	Road	6a
Acacia glaucocaesia (P3)	727257	7665700		
Acacia glaucocaesia (P3)	736039	7671056		
Acacia glaucocaesia (P3)	737800	7672418		
Acacia glaucocaesia (P3)	737071	7672523		
Acacia glaucocaesia (P3)	737588	7673567		
Acacia glaucocaesia (P3)	738831	7674903		
Acacia glaucocaesia (P3)	740091	7675231		
Acacia glaucocaesia (P3)	741158	7675620		
Acacia glaucocaesia (P3)	739463	7675721		
Acacia glaucocaesia (P3)	740503	7676251		
Acacia glaucocaesia (P3)	740451	7676376		
Euphorbia clementii (P2)	728040	7666664	Road	6a
Euphorbia clementii (P2)	726672	7667830		
Euphorbia clementii (P2)	726765	7667989		
Euphorbia clementii (P2)	726714	7668001		
Euphorbia clementii (P2)	738634	7673626		
Euphorbia clementii (P2)	739170	7679939		
Abutilon trudgenii (ms) (P3)	740342	7676101	Road	11a
Abutilon trudgenii (ms) (P3)	729276	7661285	TSF	13a
Abutilon trudgenii (ms) (P3)	738886	7679499	Road	14a
Abutilon trudgenii (ms) (P3)	737249	7671964	Road	6a
Abutilon trudgenii (ms) (P3)	738180	7673374	Road	6a
Abutilon trudgenii (ms) (P3)	740904	7675164	Road	6a
Abutilon trudgenii (ms) (P3)	725207	7667451		
Abutilon trudgenii (ms) (P3)	737789	7673242		
Abutilon trudgenii (ms) (P3)	739389	7674531		
Abutilon trudgenii (ms) (P3)	741069	7675759		
Abutilon trudgenii (ms) (P3)	739541	7691388		
Abutilon trudgenii (ms) (P3)	739493	7691397		
Abutilon trudgenii (ms) (P3)	739508	7691444		

APPENDIX C: GPS LOCATIONS OF CONSERVATION SIGNIFICANT SPECIES RECORDED WITHIN THE PANORAMA PROJECT SURVEY AREA

Note: P1, P2, P3 and P4 denote - Priority Flora Species (DEC, 2007a).
All GPS locations are in the AMG projection, WGS84 datum and in zone 50k

Species	Easting	Northing	Project Disturbance Area	Project Area
Priority Species Recorded in the Panorama Project Area (continued)				
Gonocarpus ephemerus (P2)	732628	7667595	Road	6a
Gonocarpus ephemerus (P2)	732718	7667628	Road	6a
Gonocarpus ephemerus (P2)	732734	7667228		
Gymnanthera cunninghamii (P3)	736592	7650011		
Gymnanthera cunninghamii (P3)	736661	7650011		
Gymnanthera cunninghamii (P3)	736592	7650036		
Gymnanthera cunninghamii (P3)	736653	7650037		
Olearia fluvialis (P2)	742517	7707983		
New Species Recorded in the Panorama Project Area				
Themeda sp. Panorama	733005	7655055		
Themeda sp. Panorama	732804	7655197		
Themeda sp. Panorama	732689	7655520		
Themeda sp. Panorama	732541	7656061		
Themeda sp. Panorama	732570	7656254		
Themeda sp. Panorama	732524	7656342		
Themeda sp. Panorama	732524	7656342		
Themeda sp. Panorama	731276	7659847		
Themeda sp. Panorama	731248	7659889		
Themeda sp. Panorama	731941	7660708		
Pityrodia sp. Panorama	729741	7659025	Other	5a
Pityrodia sp. Panorama	728380	7658790	Waste Dumps	5a
Pityrodia sp. Panorama	729882	7659504	Other	6a
Pityrodia sp. Panorama	729308	7659084	Waste Dumps	9a
Pityrodia sp. Panorama	732326	7653399		
Pityrodia sp. Panorama	732282	7653420		
Pityrodia sp. Panorama	733023	7654626		
Pityrodia sp. Panorama	729357	7658177		
Pityrodia sp. Panorama	730137	7658690		
Pityrodia sp. Panorama	730109	7658829		
Pityrodia sp. Panorama	728217	7659623		
Pityrodia sp. Panorama	728201	7659636		
Pityrodia sp. Panorama	731733	7662358		
Pityrodia sp. Panorama	730735	7662487		
Pityrodia sp. Panorama	732009	7662565		

APPENDIX C: GPS LOCATIONS OF CONSERVATION SIGNIFICANT SPECIES RECORDED WITHIN THE PANORAMA PROJECT SURVEY AREA

Note: P1, P2, P3 and P4 denote - Priority Flora Species (DEC, 2007a).
All GPS locations are in the AMG projection, WGS84 datum and in zone 50k

Species	Easting	Northing	Project Disturbance Area	Project Area
Species that require further investigation and possibly geographically restricted				
Triodia sp. Panorama	729663	7660135	Other	11a
Triodia sp. Panorama	737030	7671751	Road	11a
Triodia sp. Panorama	729949	7659563	Other	6a
Triodia sp. Panorama	729696	7660160	Other	6a
Triodia sp. Panorama	729660	7660208	Other	6a
Triodia sp. Panorama	731434	7667204	Road	6a
Triodia sp. Panorama	733032	7667760	Road	6a
Triodia sp. Panorama	733477	7667996	Road	6a
Triodia sp. Panorama	733421	7668024	Road	6a
Triodia sp. Panorama	733451	7668049	Road	6a
Triodia sp. Panorama	736540	7671259	Road	6a
Triodia sp. Panorama	736616	7671274	Road	6a
Triodia sp. Panorama	736592	7671300	Road	6a
Triodia sp. Panorama	736982	7671741	Road	6a
Triodia sp. Panorama	737005	7671794	Road	6a
Triodia sp. Panorama	737249	7671964	Road	6a
Triodia sp. Panorama	738163	7673296	Road	6a
Triodia sp. Panorama	738303	7673327	Road	6a
Triodia sp. Panorama	738180	7673374	Road	6a
Triodia sp. Panorama	739510	7674167	Road	6a
Triodia sp. Panorama	732125	7653619		
Triodia sp. Panorama	730839	7658653		
Triodia sp. Panorama	730839	7658653		
Triodia sp. Panorama	730920	7659801		
Triodia sp. Panorama	728534	7660620		
Triodia sp. Panorama	731941	7660708		
Triodia sp. Panorama	727807	7660877		
Triodia sp. Panorama	728268	7661114		
Triodia sp. Panorama	727172	7665616		
Triodia sp. Panorama	731860	7666691		
Triodia sp. Panorama	730226	7667103		
Triodia sp. Panorama	732734	7667228		
Triodia sp. Panorama	726672	7667830		
Triodia sp. Panorama	726674	7667928		
Triodia sp. Panorama	726714	7668001		
Triodia sp. Panorama	734787	7669107		
Triodia sp. Panorama	734280	7669226		
Triodia sp. Panorama	735084	7670113		
Triodia sp. Panorama	735366	7670791		
Triodia sp. Panorama	736039	7671056		
Triodia sp. Panorama	737346	7671676		
Triodia sp. Panorama	737800	7672418		
Triodia sp. Panorama	737071	7672523		
Triodia sp. Panorama	738634	7673626		
Triodia sp. Panorama	739389	7674531		
Triodia sp. Panorama	739090	7674684		

APPENDIX C: GPS LOCATIONS OF CONSERVATION SIGNIFICANT SPECIES RECORDED WITHIN THE PANORAMA PROJECT SURVEY AREA

Note: P1, P2, P3 and P4 denote - Priority Flora Species (DEC, 2007a).
All GPS locations are in the AMG projection, WGS84 datum and in zone 50k

Species	Easting	Northing	Project Disturbance Area	Project Area
Species that require further investigation and possibly geographically restricted (continued)				
Triodia angusta (Shale form)	729645	7660178	Other	6a
Acacia sp. Barklys	729831	7660514	EP2	13a
Acacia sp. Barklys	729798	7660533	EP2	13a
Acacia sp. Barklys	729838	7660548	EP2	13a
Acacia sp. Barklys	729804	7660560	EP2	13a
Mallotus ?*dispersus*	727907	7663894		
Mallotus ?*dispersus*	727891	7663899		
Mallotus ?*dispersus*	727975	7663942		
Mallotus ?*dispersus*	727939	7663968		
Triumfetta aff. *chaetocarpa* (Panorama form)	729000	7660000	Other	13a
Triumfetta aff. *chaetocarpa* (Panorama form)	739620	7674407	Road	6a
Triumfetta aff. *chaetocarpa* (Panorama form)	736384	7650836		
Triumfetta aff. *chaetocarpa* (Panorama form)	736462	7650954		
Triumfetta aff. *chaetocarpa* (Panorama form)	727941	7663887		
Triumfetta aff. *chaetocarpa* (Panorama form)	733832	7667975		
Triumfetta aff. *chaetocarpa* (Panorama form)	741792	7704409		
Species that require further investigation				
Acacia aff. *drepanocarpa* subsp. *drepanocarpa*	730507	7659995	EP2	11a
Acacia aff. *drepanocarpa* subsp. *drepanocarpa*	730055	7660471	EP2	13a
Acacia aff. *drepanocarpa* subsp. *drepanocarpa*	730069	7660484	EP2	13a
Acacia aff. *drepanocarpa* subsp. *drepanocarpa*	730008	7660526	EP2	13a
Acacia aff. *drepanocarpa* subsp. *drepanocarpa*	729552	7660745	TSF	13a
Acacia aff. *drepanocarpa* subsp. *drepanocarpa*	730650	7659947		
Acacia aff. *drepanocarpa* subsp. *drepanocarpa*	730639	7659969		
Acacia sp. (PAN M48)	737800	7672418		

APPENDIX C: GPS LOCATIONS OF CONSERVATION SIGNIFICANT SPECIES RECORDED WITHIN THE PANORAMA PROJECT SURVEY AREA

Note: P1, P2, P3 and P4 denote - Priority Flora Species (DEC, 2007a).
All GPS locations are in the AMG projection, WGS84 datum and in zone 50k

Species	Easting	Northing	Project Disturbance Area	Project Area
Cullen aff. *lachnostachys* (MET 15,154)	740342	7676101	Road	11a
Cullen aff. *lachnostachys* (MET 15,154)	729447	7659212	Waste Dumps	5a
Cullen aff. *lachnostachys* (MET 15,154)	739066	7673434		
Cullen aff. *lachnostachys* (MET 15,154)	738634	7673626		
Cullen aff. *lachnostachys* (MET 15,154)	739397	7674485		
Cullen aff. *lachnostachys* (MET 15,154)	740091	7675231		
Rhynchosia sp. King Bay	739541	7691388		
Species that require further investigation (continued)				
Tephrosia aff. *supina* (HD88-4)	739602	7674407	Road	6a
Tephrosia aff. *supina* (HD88-4)	741069	7675759		
Euphorbia sp. (PAN1-14B)				
Species that require further investigation (continued)				
Euphorbia sp. (PAN5-15)	742149	7708015		
Corchorus aff. *walcottii* (H251-3)	741504	7699409		
Sida aff. *fibulifera* (PAN10-6)	741600	7701600	Road	6a

APPENDIX D: SIMPLIFIED VEGETATION FORMATIONS AND ALLIANCES AND THEIR CORRESPONDING GROUNDWATER DEPENDENT ECOSYSTEM (GDE) PROBABILTY IN THE PANORAMA PROJECT SURVEY AREA

Vegetation Formation	Vegetation Alliance (Mattiske 2007)		Vegetation Alliances (Trudgen *et al.* 2002; Trudgen 2007b)		GDE probability			
	No.	Vegetation Alliance Description	No.	Vegetation Alliance	Low	Medium	High	Very High
Open Forest to Open Woodland - Flowlines	1a	Open forest to open woodland of *Eucalyptus camaldulensis, Melaleuca argentea* and *Eucalyptus victrix* with scattered tall shrubs of *Indigofera monophylla* over *Schoenus falcatus, Cyperus vaginatus* and *Triodia longiceps* sedgeland/grasslands in river beds	1	*Eucalyptus camaldulensis* var. *obtusa* open to closed forest				+
	1a		2	*Eucalyptus camaldulensis, Melaleuca argentea* and *Eucalyptus victrix* open forest over scattered tall shrubs of *Schoenus falcatus, Cyperus vaginatus* and *Triodia longiceps* sedgeland/grasslands				+
	1a		3	*Melaleuca argentea* low woodland to woodland				+
	1a		4	*Eucalyptus camaldulensis* var. *obtusa* open woodland to high open woodland in riverbeds (gravelly and sandy)				+
	1a		38	*Indigofera monophylla* low shrublands to low open heath on lower slopes and valley floor areas				+
Open Forest to Open Woodland - Other	2a	*Eucalyptus victrix* scattered trees to open woodland which may include *Melaleuca glomerata* and *Melaleuca linophylla* over open to closed scrub in creek beds and low slopes	5	*Eucalyptus victrix* scattered trees to open woodland over *Melaleuca glomerata* and *Melaleuca linophylla* over open to closed scrub in creek beds and low slopes			+	
	2a		11	*Eucalyptus victrix* scattered low trees to open woodland along major creeklines			+	
	3a	*Corymbia aspera* scattered low trees to low open woodland in creek beds	6	*Corymbia aspera* scattered low trees to low open woodland in creek beds	+			
	4a	*Acacia tumida* high shrubland to low open forest in creeklines	7	*Acacia tumida* high shrubland to low open forest in creeklines	+			
	5a	*Eucalyptus leucophloia* scattered low trees over patches of *Acacia* shrubs over hummock grasslands of *Triodia* species, including *T. brizoides, T. wiseana* and *T. epactia* on ridge slopes	8	*Eucalyptus leucophloia* scattered low trees over *Triodia brizoides* hummock grasslands on ridge slopes	+			
	5a		9	*Eucalyptus leucophloia* scattered low trees over *Triodia wiseana* hummock grasslands on ridge slopes	+			
	5a		10	*Eucalyptus leucophloia* scattered low trees over *Triodia epactia* hummock grasslands on ridge slopes	+			
	5a		28	*Acacia orthocarpa* shrubland to open scrub over hummock grasslands on steep slopes (gravelly and pebbly)	+			
	5a		34	*Acacia hilliana* low shrublands to low open heath on gentle slopes	+			

APPENDIX D: SIMPLIFIED VEGETATION FORMATIONS AND ALLIANCES AND THEIR CORRESPONDING GROUNDWATER DEPENDENT ECOSYSTEM (GDE) PROBABILTY IN THE PANORAMA PROJECT SURVEY AREA

Vegetation Formation	Vegetation Alliance (Mattiske 2007)		Vegetation Alliances (Trudgen *et al.* 2002; Trudgen 2007b)		GDE probability			
	No.	Vegetation Alliance Description	No.	Vegetation Alliance	Low	Medium	High	Very High
Open Forest to Open Woodland - Other	5a	*Eucalyptus leucophloia* scattered low trees over patches of *Acacia* shrubs over hummock grasslands of *Triodia* species; including *T. brizoides, T. wiseana* and *T. epactia* on ridge slopes	35	*Acacia ptychophylla* low shrubland to low open heath on slopes on a low ridge	+			
	5a		40	*Triodia angusta* (Shaw River form) hummock grasslands on ridges	+			
	5a		44	(scattered tall shrubs over) *Triodia melvillei* hummock grasslands on	+			
	5a		46	*Triodia wiseana* hummock grasslands on mid slopes	+			
	5a		47	*Aristida holathera* var. *holathera* and *Triodia epactia* hummock grassland on sand dunes	+			
	6a	*Corymbia hamersleyana* scattered low trees to low open woodland over tall shrubs to open shrubland of *Acacia* spp. and *Grevillea wickhamii* over hummock grasslands on creek banks, flood banks and distributing fans	12	*Corymbia hamersleyana* scattered low trees to low open woodland over *Acacia acradenia, Cajanus cinereus* and *Petalostylis labicheoides* open scrublands on creek banks, flood banks and distributing fans	+			
	6a		13	*Corymbia hamersleyana* scattered low trees over *Triodia angusta* (Shaw River form) hummock grasslands on low slopes and creeks	+			
	6a		14	*Corymbia hamersleyana* scattered low trees over scattered tall shrubs to high open shrubland over *Triodia epactia* hummock grasslands on valley floor , lower slopes and distrubuting fans	+			
	6a		15	*Corymbia hamersleyana* low scattered trees over *Triodia wiseana* hummock grasslands on mid to lower slopes and valley floors	+			
	6a		27	*Grevillea wickhamii* subsp. *aprica* high open shrubland to high shrubland on gently undulating plains	+			
	6a		29	High shrublands over *Triodia schinzii* hummock grasslands on sandplains	+			
	6a		37	*Acacia stellaticeps* low shrubland to low open heath on undulating plains	+			

APPENDIX D: SIMPLIFIED VEGETATION FORMATIONS AND ALLIANCES AND THEIR CORRESPONDING GROUNDWATER DEPENDENT ECOSYSTEM (GDE) PROBABILTY IN THE PANORAMA PROJECT SURVEY AREA

Vegetation Formation	Vegetation Alliance (Mattiske 2007)		Vegetation Alliances (Trudgen *et al.* 2002; Trudgen 2007b)		GDE probability			
	No.	Vegetation Alliance Description	No.	Vegetation Alliance	Low	Medium	High	Very High
Open Forest to Open Woodland - Other	7a	*Corymbia zygophylla* and *Corymbia hamersleyana* scattered low trees over hummock grasslands on sandplains	16	*Corymbia zygophylla* and *Corymbia hamersleyana* scattered low trees over hummock grasslands on sandplains	+			
	8a	*Terminalia canescens* scattered low trees to low woodland on creek banks	18	*Terminalia canescens* scattered low trees to low woodland on creek banks	+			
	9a	*Atalaya hemiglauca, Acacia pruinocarpa, Ehretia saligna* var. *saligna, Acacia tumida, Eucalyptus ferriticola* subsp. *ferriticola* and *Ficus platypoda* scattered low trees over high open shrubland on steep, rocky gorge walls.	20	*Atalaya hemiglauca, Acacia pruinocarpa, Ehretia saligna* var. *saligna, Acacia tumida* and *Ficus platypoda* scattered low trees over high open shrubland on steep, rocky gorge walls	+			
	9a		17	*Corymbia ferriticola* subsp. *ferriticola* scattered low trees to low open woodland on rocky breakaways	+			
	9a		19	*Acacia coriacea* subsp. *pendens* scattered low trees on rockpiles	+			
High Shrublands to Open Scrubs	10a	Shrubland to open scrubland of *Acacia* species including *A. tumida, A. acradenia* and *A. orthocarpa* over hummock grasslands on upper and steep slopes	21	*Acacia tumida* high shrubland to open scrub on upper slopes of ridges	+			
	10a		22	*Acacia acradenia* high shrubland to open scrub on ridge slopes	+			
	11a	Shrubland to closed scrubland of *Acacia* species, including *A. acradenia, A. pyrifolia* and *A. tumida* along small creeklines and on the adjacent parts of valley floors and distributing fans	23	*Acacia acradenia* shrubland to closed scrub along small creeklines and on the adjacent parts of valley floors and distributing fans	+			
	11a		24	*Acacia pyrifolia* high shrubland to open scrub on flowlines	+			
	11a		26	*Acacia tumida* high shrubland to open scrub over *Triodia lanigera* hummock grassland in creek beds	+			
	12a	*Acacia inaequilatera* scattered tall shrubs to high open shrubland over *Triodia brizoides* hummock grasslands on ridge slopes and low hills	30	*Acacia inaequilatera* scattered tall shrubs to high open shrubland over *Triodia brizoides* hummock grasslands on ridge slopes and low hills	+			

APPENDIX D: SIMPLIFIED VEGETATION FORMATIONS AND ALLIANCES AND THEIR CORRESPONDING GROUNDWATER DEPENDENT ECOSYSTEM (GDE) PROBABILTY IN THE PANORAMA PROJECT SURVEY AREA

Vegetation Formation	Vegetation Alliance (Mattiske 2007)		Vegetation Alliances (Trudgen *et al.* 2002; Trudgen 2007b)		GDE probability			
	No.	Vegetation Alliance Description	No.	Vegetation Alliance	Low	Medium	High	Very High
High Shrublands to Open Scrubs	**13a**	*Acacia inaequilatera* scattered tall shrubs to high shrubland over *Triodia wiseana* hummock grasslands occurring mainly on gentle lower slopes.	**31**	*Acacia inaequilatera* scattered tall shrubs to high shrubland over *Triodia lanigera* hummock grassland on gentle slopes (gravelly and pebbly)	+			
	13a		**32**	*Acacia inaequilatera* scattered tall shrubs over *Triodia wiseana* hummock grasslands occurring mainly on the slopes of low rises and the colluvial spurs and lower slopes of high ridges	+			
	14a	*Acacia ancistrocarpa* high open shrubland to open scrub	**25**	*Acacia ancistrocarpa* high open shrubland to open scrub on very gentle lower slopes	+			
	15a	*Acacia trachycarpa* high open shrubland to high shrublands	**33**	*Acacia trachycarpa* high open shrubland to high shrublands	+			
Low Shrublands	**16a**	Low shrublands to low open heath on gentle slopes and undulating plain	**36**	*Acacia spondylophylla* low shrublands on mid to upper slopes	+			
	16a		**39**	*Corchorus* aff. *lanifloris* (PAN 76), *Dampiera candicans* and *Ptilotus mollis* low shrubland over *Triodia melvillei* and *Eriachne mucronata* (typical form) very open to open hummock grasslands on mid to upper slopes	+			
Hummock Grasslands	**17a**	Hummock grasslands on slopes and ridges	**41**	Other *Triodia brizoides* hummock grasslands on slopes and spurs of ridges and on low rises	+			
	17a		**42**	*Triodia epactia* hummock grasslands on sandplains and lower slopes of hills	+			
	17a		**43**	Other *Triodia lanigera* hummock grasslands on flat to gentle slopes	+			
	17a		**45**	(Scattered tall shrubs over) *Triodia* sp. Panorama hummock grasslands on flat to gentle slopes	+			

APPENDIX D: SIMPLIFIED VEGETATION FORMATIONS AND ALLIANCES AND THEIR CORRESPONDING GROUNDWATER DEPENDENT ECOSYSTEM (GDE) PROBABILTY IN THE PANORAMA PROJECT SURVEY AREA

Vegetation Formation	Vegetation Alliance (Mattiske 2007)		Vegetation Alliances (Trudgen *et al.* 2002; Trudgen 2007b)		GDE probability			
	No.	Vegetation Alliance Description	No.	Vegetation Alliance	Low	Medium	High	Very High
Other Grasslands and Herblands	18a	Cracking clay alliance on gentle sloping plains and seasonal damplands	48	Cracking clay alliance on gentle sloping plains	+			
	18a		50	*Chrysopogon fallax* tussock grassland on cracking clay	+			
	18a		51	*Triodia* sp. Panorama grasslands on cracking clay (seasonal damplands)	+			
	18a		52	*Iseilema macrantherum* grasslands and herblands on cracking clay (seasonal damplands)	+			
	18a		49	**Cenchrus ciliaris* tussock grassland along creek lines	+			

APPENDIX E: LOCAL AND REGIONAL SIGNIFICANCE OF VEGETATION ALLIANCES WITHIN THE PANORAMA PROJECT SURVEY AREA

Formation	Vegetation Alliance	Occurs within Project Footprint	Contains Priority Flora	Contains Conservation Significant Flora Species	Contains Dominant Conservation Significant Flora	Restricted Habitat	Locally Significant	Regionally Significant	Comments
OPEN FOREST - OPEN WOODLAND: FLOWLINES	**1a**	**Access Road, Waste Dumps**					X		Potential habitat trees for some species, includes some patches of *Schoenus falcatus* (which is uncommon)
OPEN FOREST - OPEN WOODLAND: OTHER	**2a**	**Pit, Plant, Access Road, TSF**					X		Potential habitat trees for some species
	3a	**Access Road**				X	X		Restricted occurrence in survey area, near Marble Bar Road
	4a								
	5a	**Pit, Plant, Access Road, TSF, Waste Dumps**		X	X		X		Presence of conservation species
	6a	**Plant, Access Road, TSF, Waste Dumps**	X	X	X		X		Presence of Priority species and conservation species
	7a	**Access Road**				X	X		Restricted occurrence in survey area
	8a					X	X		Restricted occurrence in survey area
	9a	**Pit, TSF, Waste Dumps**		X	X		X		Presence of conservation species

APPENDIX E: LOCAL AND REGIONAL SIGNIFICANCE OF VEGETATION ALLIANCES WITHIN THE PANORAMA PROJECT SURVEY AREA

Formation	Vegetation Alliance	Occurs within Project Footprint	Contains Priority Flora	Contains Conservation Significant Flora Species	Contains Dominant Conservation Significant Flora	Restricted Habitat	Locally Significant	Regionally Significant	Comments
HIGH SHRUBLANDS TO OPEN SCRUBS	10a	Access Road, Waste Dumps							
	11a	Pit, Plant, Access Road, TSF, Waste Dumps	X	X	X		X		Presence of Priority species and conservation species
	12a								
	13a	Pit, Access Road, TSF, Waste Dumps	X	X	X		X		Presence of Priority species and conservation species
	14a	Access Road	X		X		X		Presence of Priority species
	15a								
LOW SHRUBLANDS	16a	TSF				X	X		Presence of Priority species and can be restricted to small areas of shale ridges (Trudgen *et al.* 2002)
HUMMOCK GRASSLANDS	17a	Access Road, Waste Dumps							
OTHER GRASSLANDS AND HERBLANDS	18a					X	X		Restricted occurrence in survey area and supports range of grass species that are locally significant

APPENDIX 3: TERRESTRIAL FAUNA SURVEYS STUDIES (BAMFORD 2001, BIOTA 2007 AND MOLHAR 2007)

PANORAMA PROJECT AREA:

BASELINE FAUNA STUDY AS PART OF THE SULPHUR SPRINGS FEASIBILITY STUDY.

Final Report

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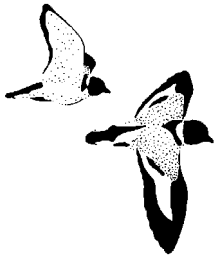


17/11/'01

EXECUTIVE SUMMARY

As part of the Environmental Impact Assessment being carried out for a zinc mine in the Panorama Project Area in the northern Pilbara, proposed by Outokumpu Mining Australia Pty Ltd, a comprehensive fauna survey is being undertaken. This consists of a review of available information on fauna of the region and two field surveys: one in June 2001 and a second in September 2001. This report presents the results of the information review and the field surveys. The objectives of a comprehensive fauna survey are:

- to produce a fauna list, containing both species recorded during the field surveys and species predicted to occur in the project area on the basis of known patterns of distribution and habitats present on the site;
- to identify species of conservation significance that are or may be present;
- to identify significant or sensitive habitats and locations on the site and;
- to make management recommendations to minimise impacts upon fauna.

The two surveys took place over the periods 2nd to 11th June and 22nd to 28th September 2001 and work included:

- Systematic trapping for amphibians, reptiles and mammals at 5 sites distributed across the main habitat types;
- Censussing for birds in conjunction with systematic trapping;
- Spotlighting for nocturnal reptiles, birds and mammals;
- The use of mist-nets, a harp-trap and an ultra-sonic detector for bats;
- Searching for reptiles, mainly under dead spinifex along tracks, and searching for cave fauna such as bats;
- The keeping of opportunistic records at all times.

The Panorama Project Area includes the Sulphur Springs, Kangaroo Caves and Bernt's Areas and the landscape is typical of the northern Pilbara with rocky hills, small gorges, mostly seasonal watercourses and gravelly loam valleys. Access to the area, however, is across the loam Abydos Plains, while the Bernt's Area is close to the alluvial soils associated with the Shaw River and Honeyeater Creek. Therefore, although field-work focussed on the main Project Area of Sulphur Springs, Kangaroo Caves and Bernt's, adjacent areas were visited and included in the review.

As a result of the diversity of habitats present, the vertebrate fauna is likely to consist of: at least 4 species of fish, 8 species of frogs, 78 species of reptiles, 126 species of birds and 47 species of mammals. Of these, 4 fish, 2 frogs, 29 reptiles, 80 birds and 22 mammals were recorded in the field surveys. Significant features of the faunal assemblage are as follows.

Freshwater fish
All species depend upon permanent water and therefore either disperse into the Project Area seasonally or rely on refuge pools within the Project Area. None of the fish species is of conservation significance.

Frogs
Of the 8 expected species, 2 may occur only in adjacent areas with loam soils but the remaining 6, including the 2 species recorded, should be present throughout the main

Project Area, especially near seasonal watercourses. None of the frog species is of conservation significance.

Reptiles
Of the 78 expected species, 19 may occur only in adjacent areas with loam soils, but this still suggests a reptile fauna in the main Project Area of about 60 species. Results from trapping were inadequate to draw firm conclusions concerning the relative importance of different habitats, but there is information available on habitat preferences in the literature. This suggests that some of the reptile species will be confined to habitats that occupy only a small part of the project area, such as steep, rocky slopes and clifflines, and riparian environments along the larger watercourses, while other species will be widespread. One of the species that, if present, is likely to be restricted to riparian environments where water is permanent, is the Pilbara Olive Python *Morelia olivacea barroni*. This is also the only reptile species observed or expected that is of conservation significance, being listed as Vulnerable.

Birds
Although only 80 of the 126 expected bird species were recorded, the expected list includes some species that may only be irregular visitors. The abundance of most bird species was low, with only 26 species recorded in censussing, but a lot of records were made opportunistically. Therefore, observations, combined with information on habitat preferences in the literature, were useful in developing an understanding of local patterns of distribution of birds. Some species were widespread, but a lot of species were associated with particular habitat types. The most significant of those are species that occur around habitats that occupy only small parts of the Project Area, such as riparian vegetation around watercourses. There were also species associated with rocky hills and gorges, while the Striated Grasswren was found in dense, long unburnt spinifex. Seven bird species of conservation significance may be present but only two of these, the Australian Bustard and Bush Stone-curlew, were recorded.

Mammals
The expected mammal fauna of 47 species is rich because it contains Pilbara species, species more typical of the nearby Great Sandy Desert but that may occur in areas of loam soil adjacent to the main Project Area, as well as some Kimberley species that are known from the northern Pilbara. Trapping and observations on mammals were affected by unseasonally cool weather throughout the June survey, and at night in September, which is almost certainly why few bat species were observed, but 23 mammal species in total were recorded and some measures of abundance were obtained. For example, the Northern Quoll *Dasyurus hallucatus* and the Common Rock-Rat *Zyzomys argurus* were trapped in rocky areas as expected on the basis of their known habitat preferences, and both were clearly abundant. However, a number of other mammal species for which the rocky hills appeared to provide suitable habitat were not recorded, although levels of abundance can vary seasonally and annually, so these species may still be present.

The most significant observations on mammals included regular sightings of Rothschild's Rock-Wallaby *Petrogale rothschildi* and several sightings of the Ghost Bat *Macroderma gigas*, including one roosting in a cave close to the proposed mine site and a maternity colony of at least 163 animals in a mine shaft at Lalla Rookh. There were also several unconfirmed sightings of the Orange Leaf-nose Bat

Rhinonicteris aurantius, a species known to share roost caves with the ghjost Bat because the two have similar environmental requirements. The Ghost Bat is listed as Priority 4 by the Department of Conservation and Land Management, while the Orange Leaf-nose Bat is classed as Vulnerable under the WA Wildlife Conservation Act. Mounds of the Western Pebble-mound Mouse or Ngadji *Pseudomys chapmani* were found alongside the access road both north and south of Lalla Rookh. The Ngadji is listed as Priority 4 by the Department of Conservation and Land Management. There were unconfirmed sightings of the Priority 3 Spectacled Hare Wallaby *Lagorchestes conspicillatus* north of Lalla Rookh and a further 4 significant mammal species may be present.

Conclusions

Despite disappointing numbers of captures, particularly of reptiles, the field surveys did confirm the presence of many expected species and made it possible to review the expected faunal assemblage in terms of the habitats present. With respect to minimising impacts of the development proposal upon this fauna, the following points should be considered.

- The main Project Area lies high in the landscape and the possibility therefore exists of downstream impacts from mining activities.
- The watercourse on which the proposed mine area and existing access road are located is one of the most distinctive environmental features of the Project Area and it is important for many species of fauna. As a general principle, impacts on fauna in a region can be minimised by minimising impacts on locally uncommon habitats. This principle needs to be considered when designing and constructing the access route to the mine, and by ensuring that mining activity does not affect the watercourse downstream of the mine.
- The current access road passes close to Lalla Rookh mine where a significant maternity colony of the Ghost Bat is located, and where the Orange Leaf-nose Bat may also be present. The access road also passes through areas of gravelly plain where active mounds of the Ngadji were found and through sandy areas where there were unconfirmed sightings of the Spectacled Hare-Wallaby. Development of the access road near Lalla Rookh could lead to increased disturbance of the Ghost Bat and therefore access to the mine site should be restricted. Barbed wire fencing in the vicinity of the colony should not be used, and should be removed where it already exists. It is recommended that non-intrusive monitoring of the Ghost Bat colony be carried out in order to develop an understanding of when the colony is used each year, and detect any adverse impacts upon the colony should they occur. In addition, it is recommended that surveys for active Ngadji (Pebble-mound Mouse) mounds and for the Spectacled Hare-Wallaby be undertaken to determine their distribution along the access road. Although development of the access road only requires upgrading of the existing road, it is important to identify significant locations so that they can be avoided, such as when finding sources for road materials and realigning sections of the existing road that are dangerously curved.
- Other uncommon habitats in the area that require protection to minimise impacts upon fauna include groves of trees and flowering bushes, and permanent pools along the Strelley and Shaw River systems. Such pools were found to be used by waterbirds, are a refuge for freshwater fish and may support significant fauna such as the Olive Python.

- The proposed mine area is located adjacent to a particularly well-developed gorge, steep cliffs and a deep cave found to contain a Ghost Bat (in June). Rothchild's Rock-Wallaby and Northern Quoll are also abundant at this location. While loss of habitat in this area due to mining in inevitable, the actual area of disturbance should be minimised.
- Increased human activity associated with the mine can lead to a number of environmental issues that may need to be addressed as part of the overall environmental management plan for the project. These include:
    - illegal hunting;
    - an increase in fires;
    - an increase in feral animals;
    - an increase in recreational activities in surrounding areas that could be especially significant at locations such as Strelley Pool and Lalla Rookh Ghost Bat colony and;
    - firewood collection.

CONTENTS

INTRODUCTION

As part of the Environmental Impact Assessment being carried out for a zinc mine in the Panorama Project Area in the northern Pilbara, proposed by Outokumpu Mining Australia Pty Ltd, we have been commissioned by Astron Environmental to undertake a comprehensive fauna survey of the project area. This fauna survey consisted of a review of available information on fauna of the region and two intensive field surveys: one in June 2001 and a second in September 2001. This report presents the results of the information review and the two field surveys.

The objectives of a comprehensive fauna survey are as follows:

- produce a fauna list, containing both species recorded during the field surveys and species predicted to occur in the project area on the basis of known patterns of distribution and habitats present on the site;
- identify species of conservation significance that are or may be present;
- identify significant or sensitive habitats and locations on the site and;
- make management recommendations to minimise impacts upon fauna.

METHODS

Site Description

The Panorama Project Area lies in the northern Pilbara and consists of three areas of interest: Sulphur Springs Area (at about 21 09'S, 119 12' 30"E; 729,000 mE, 7,660,000 mN), Kangaroo Caves Area (at about 21 12' 30"S, 119 14'E; 732,000 mE, 7,665,300 mN) and Bernt's Area (at about 21 13' 15"S, 119 17'E; 736,000 mE, 7,660,500 mN). In addition and for the purposes of the fauna survey, the Project Area is considered to include the access road from the main road between Port Hedland and Marble Bar. Detailed grid references of all locations visited within and between these areas are listed in Appendix 1 and Figure 1 presents a sketch map of the area. Grid references were determined with a hand-held GPS. The Sulphur Springs area included the Sulphur Springs Camp and Finn's Camp, and is the site for the proposed mining area, processing mill and tailings dam. Therefore, most intensive field-work was conducted in this area and a base camp was set up at the existing Sulphur Springs Camp.

The Project Area is a region of high rocky hills between the upper reaches of the Strelley and Shaw Rivers. An independent assessment of the vegetation of the study area is being carried out, but for the purposes of the fauna assessment, the main landform and habitat features are as follows:

- The access road to the project area, from the Port Hedland to Marble Bar Road, traverses the Abydos Plain, a landscape of low relief with soils of loam and gravelly loam, and vegetation consisting largely of spinifex (*Triodia* spp. and *Plectrachne* spp.) with some areas of shrubland, particularly associated with watercourses. Although outside the mining leases, this existing access road may be upgraded for haulage and therefore some observations on fauna were made in the region. The access road passes the abandoned Lalla Rookh

Mine on Lalla Rookh Station. In this report, this section of the access road is referred to as the Plains Access Road.

- From the base of the rocky hills, the access road largely follows a creek until well into the Sulphur Springs Area and close to Finn's Camp. Although part of this track is outside the Sulphur Springs Area, sites at several locations along the track were visited as the track is considered an option for a haulage route. The creek was flowing during both field surveys although the water was mainly in a series of large pools. The creek occupies a small gorge with distinct riparian vegetation, with the surrounding hills being rocky and supporting mostly spinifex on shallow, rocky soil. In this report, this section of the track is referred to as the Creek Access Road.
- Within the Sulphur Springs, Kangaroo Hills and Bernt's Areas, the landscape had several distinct components as follows:
    - Seasonal watercourses, sometimes associated with small gorges and with distinct riparian vegetation. These included sites such as Harp Trap Creek, one of the sampling locations used in the field surveys, and the gorge located adjacent to the proposed mine site.
    - Undulating plains of gravelly loam with spinifex and scattered shrubs.
    - Rocky foothills with spinifex in shallow soil and patches of exposed rock, including basaltic rock piles. The proposed tailings dam occupies an area of undulating plain and rocky foothills.
    - Rocky ridges and hills, supporting spinifex on shallow soil, with a lot of exposed rock along ridges and cliff-lines, sometimes forming overhangs, breakaways and small caves.

There was little difference in the general landscape of the three areas, all being dominated by rocky ridges and hills, with rocky foothills and undulating plains. Bernt's Area, however, was adjacent to the Shaw River and Honeyeater Creek, two major watercourses lined with eucalypts and with broad bands of alluvial soils.

Field Survey Programme

Field-work in the Panorama Project Area took place from 2nd to 11th June 2001, and from 22nd to 28th of September 2001. Field personnel were: Dr M. Bamford, Mr P. Smith, Mr B. Metcalf (June and September) and Ms J. Wilcox (June only). Assistance in setting up trapping sites was received from Dr P. Kendrick of the Department of Conservation and Land Management. Work carried out in the field included:

- Systematic trapping for amphibians, reptiles and mammals;
- Censussing for birds in conjunction with systematic trapping;
- Spotlighting for nocturnal reptiles, birds and mammals;
- The use of mist-nets, a harp-trap and an ultra-sonic detector for bats;
- Searching for reptiles, mainly under dead spinifex along tracks, and searching for cave fauna such as bats;
- The keeping of opportunistic records at all times.

Methods employed for these components of the field project are described in the following sections. Table 1 provides descriptions of the systematic trapping and bird censussing sites and the timetable of work at these sites. Table 2 summarises the

daily programme of all other field-work. In general, the same level and range of sampling was undertaken on the two field trips.

Systematic Trapping for Amphibians, Reptiles and Mammals

Systematic trapping for amphibians, reptiles and mammals took place at 5 sites. These sites are described in Table 1. All were located in the Sulphur Springs Area and they were arranged to sample the range of habitats as described above.

At each sampling site, the trapping layout consisted of:

- 10 assisted pitfall traps placed at approximately 20 m intervals, each 15 cm in diameter and 60 cm deep, with a 25 cm high driftfence extending 3m to either side of the pitfall. The pitfalls had a flywire base to prevent animals digging out the bottom.
- 20 medium Elliott Traps, with one placed at each end of the driftfence.
- wire cage traps, located in the vicinity of every alternate pitfall except at Site 3, where the cage traps were located in an area of rocks and small caves about 100 m further up the gorge from the pitfall and Elliott Traps. Five cage traps were used at each site in June but only 4 were available for each site in September.

The pitfall traps were deployed in a transect at all sites except Site 2, where steep slopes restricted access and the pitfalls were arranged in a loose grid, although still with approximately 20 m between each trap.

Specimens caught were identified, some basic measurements were taken, notes were made on reproductive status and they were marked if they were released. Reptiles were marked with a permanent felt pen while mammals received an individual ear-clip. Voucher specimens were collected and lodged with the WA Museum where identification was in doubt or where specimens represented a possible range extension. All trapping and collection was carried out under a Licence to Take Fauna for Scientific Purposes SF 003481.

Bird Censusing

Bird surveys were carried out at each of the five trapping sites in the Sulphur Springs Area whenever the traps were checked. They thus took place in the mornings from 7th–11th June and 23rd-28th September. The order of checking traps was varied so that the bird censussing was not carried out at the same time of day at each site on every morning, although all bird censussing was carried out between 0630 hours (about half an hour after sunrise) and 1030 hours. During the bird surveys, all birds observed from the trapping site were counted and each bird survey had a duration of 20-30 minutes. The number of censusses carried out corresponded to the number of mornings each trapping site was checked. Therefore in June each site was surveyed for birds 5 times, and in September Sites 1-3 were surveyed 6 times and Sites 4 and 5 were surveyed 5 times. Observations on birds were also gathered opportunistically (see below).

Spotlighting

Spotlighting took place on most nights (see Table 2) and was carried out either on foot using head-torches (referred to as head-torching) or from a vehicle using the vehicle headlights and a hand-held spotlight.

Head-torching began approximately half an hour after sunset, when it was fully dark, and involved three or four people for a period of about 45 minutes. All animals seen were counted, identified and, if necessary for identification, captured. Head-torching tended to focus on areas where trapping was not possible, such as the rocky sides of gorges at Site 3 and around waterholes.

Spotlighting from a vehicle took place whenever travel at night was undertaken, such as when driving out to and back from sites for head-torching (see Table 2). In addition, on both field trips long spotlighting runs were undertaken from the Bernt's Area back to Sulphur Springs Camp and from Lalla Rookh Mine back to Sulphur Springs Camp. The total distance travelled when spotlighting by vehicle was 49.8 km in June and 95.8 km in September, although one 22.5 km run in September took place behind another vehicle, and therefore disturbance may have reduced the number of observations made. During spotlighting, the speed was maintained at about 15 kph or less. When spotlighting by vehicle, notes were made whenever an animal was seen, including the odometer reading, and the location of especially significant sightings was recorded with a hand-held GPS unit.

Bat Surveys

Bats were surveyed through the use of mist-nets, a harp-trap, an Anabat II ultrasonic detector, when spotlighting (both visually and aurally) and by searching for roosting sites in caves (see Table 2). The harp-trap was based on the design of Tidemann and Woodside (1978) and was located at the end of a pool on Harp-Trap Creek, near Site 1, for six nights from 3rd – 9th June and from 23rd-27th September, and for one night in a gorge near Site 3 (9th June). Two mist-nets (1 x 12m and 1 x 18 m) were placed across a pool on Harp-Trap Creek on the evening of 7th June for three hours, while 1 mist-net was placed across a pool on Honeyeater Creek on the evening of 25th September for two hours.

The ultrasonic detector was used on virtually all occasions when night-work was being carried out, and was also left operating at night around the Sulphur Springs Camp. When the ultrasonic calls of a bat were heard through the detector, they were recorded for later analysis in the hope that the species could be identified.

Searching for bat roosts was carried out in three main areas: along a rocky ridge east of Site 5, in the complex of gorges around Site 3 and along the gorge of the Creek Access Road. This involved moving along gorges, clifflines and breakaways, and examining caves and crevices with torches. At the same time, searches were undertaken for evidence of bats, such as smell and droppings, and evidence of other mammals, such as droppings of rock-wallabies. On both field trips, time was also spent at Lalla Rookh to observe bats emerging from mine shafts in the evening.

Searching for Reptiles

During the June survey in particular, reptile captures in the pitfall traps were expected to be low, as they are dependent upon high levels of reptile activity usually associated with warm weather of spring and summer. Therefore, intensive searching for reptiles was undertaken. This focussed on dead spinifex along the edges of tracks, as a lot of reptile species shelter under spinifex, while the clumps of spinifex along the sides of tracks provide very good shelter for reptiles and are readily accessible. This searching for reptiles was carried out in three principal areas: along a disused track that skirted the northern edge of the Sulphur Springs Project Area (hereafter referred to as the Bypass Track), along the Kangaroo Caves Road near Site 5 and around Finn's Camp. Searching for reptiles was also undertaken under debris around Sulphur Springs Camp and opportunistically elsewhere. Searching for reptiles focussed on locations where it was anticipated that reptiles could be readily found and was therefore not directed at the regular sampling sites. Some searching was undertaken in September, but high daytime temperatures (maxima in the shade of 40 C were recorded) made this strenuous. Furthermore, very few reptiles were observed as during hot weather, reptiles tend to shelter deep in the soil and be hard to locate (M. Bamford pers. obs.).

Opportunistic surveys

At all times, observations of fauna were noted when they contributed to the accumulation of information on the fauna of the Project Area. These included such casual observations as birds seen while we were travelling between sites or from the Sulphur Springs Camp, and freshwater fish observed in pools while setting up and dismantling the harp-trap and mist-nets.

Sources of Information

Because even an intensive field study cannot be expected to record all species present in an area, the survey results were supplemented with records from a number of sources. These included publications that provide information on general patterns of distribution of frogs (Tyler *et al.* 2000), reptiles (Storr *et al.* 1983, 1986, 1990 and 1999), birds (Blakers *et al.* 1984 and Johnstone and Storr 1998), and mammals (Strahan 1995). In addition, specimen records of frogs, reptiles and mammals held by the WA Museum were obtained for the region bounded by 20^{o} 45' to 21^{o} 30'S, and 118^{o} 45' to 119^{o} 45'E. The Department of Conservation and Land Management's Threatened Fauna Database was also searched for records from this region. The Threatened Fauna Database includes threatened invertebrates but no threatened invertebrates were listed for the area.

These supplementary sources of information were used to create lists of species expected to occur at the site. As far as possible, expected species are those that are very likely to utilise the project area, and such lists exclude species that have been recorded in the general region as vagrants. Particularly among the birds, for example, vagrants can be recorded almost anywhere.

For the determination of conservation significance, the conservation status of fauna species is assessed under Federal and State Acts such as the Commonwealth Environmental Protection and Biodiversity Conservation Act (EPBC Act) and the WA Wildlife Conservation Act. These use levels of significance recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN) and reviewed by Mace and Stuart (1994), although the WA Act also has a category of "Other Specially Protected Fauna" that has no equivalent IUCN level. These categories are described in Appendix 2. In addition, Environment Australia has supported the publication of reports on the conservation status of reptiles (Cogger *et al.* 1993) and birds (Garnett and Crowley 2000), while the Threatened Species and Communities Section of Environment Australia has produced a list of Threatened Australian Fauna (Environment Australia 1999). These publications also use the IUCN categories, although those used by Cogger e*t al.* (1993) differ in some respects as this report pre-dates Mace and Stuart's review.

In Western Australia, the Department of Conservation and Land Management has produced a supplementary list of Priority fauna, being species that are not considered Threatened under the IUCN categories but for which the Department feels there is cause for concern. Levels of Priority are described in Appendix 2.

In addition to the assessment of fauna under CALM's Priority list and the IUCN categories, some fauna are recognised under international treaties such as the China Australia Migratory Bird Agreement (CAMBA) and the Japan Australia Migratory Bird Agreement (JAMBA). Species listed under these agreements are mostly migrants that spend part of the year in each country, although some of the species are non-migrants but occur in both countries. Species that are not listed under any of the above categories can be considered of regional significance if they are at the limit of their distribution or are common but within a very restricted range.

Taxonomic orders and names used in this report generally follow Tyler *et al.* (1984) for amphibians, Storr *et al.* (1983, 1986, 1990 and 1999) for reptiles, Strahan (1983) for mammals and Christidis and Boles (1994) for birds. Where recent taxonomic revisions have occurred, earlier names are given in parenthesis.

FAUNA OF THE PANORAMA PROJECT AREA

Tables 3, 4 and 5 list the vertebrate fauna known from the general region of the Panorama Project Area, based on general patterns of distribution, and indicate those recorded by the WA Museum (frogs, reptiles and mammals), by Blakers *et al.* (1984) (birds), and that were recorded during the field surveys. The results of the field surveys are presented in Tables 6, 7, 8 and 9, while annotated species lists of all species recorded in the field surveys appear in Appendices 3, 4 and 5.

Freshwater Fish

At least four species of freshwater fish were present and a further two species could occur in the area (Table 3). The Bony Bream were recorded only in a pool in a flooded section of the Creek Access Road outside the Sulphur Springs Area in June,

but the remaining species were widespread in pools in both the Sulphur Springs and Kangaroo Caves Areas. No pools were located in the Bernt's area, but the nearby Honeyeater Creek contained water and at least the Western Rainbowfish was present.

All these species require permanent water but disperse along seasonal watercourses when the opportunity arises. Therefore, permanent pools are vital to the persistence of these fish in a region, but it is not known which, if any, of the pools observed in the Panorama Project Area act as dry season refuges. Although water remained even in minor creeks during 2001, the region experienced unusual rains and it is possible that in most years the system of watercourses dries out. In this event, fish would colonise annually during the wet season from Honeyeater Creek to the south and Strelley River to the west.

None of the freshwater fish recorded in the project area is of conservation significance.

Amphibians

Of the 8 frog species listed in Table 3, only 2 species were recorded: *Uperoleia russelli* and *Litoria rubella*. *U. russelli* was found at Harp-trap Creek, was trapped at Site 3, in the gorge near the mine area, as was abundant along the Creek Access Road, where it was calling in September. *L. rubella* was found in the Sulphur Springs Camp, in Harp-trap Creek, along the Creek Access Road and in the Shaw River.

Of the remaining 6 frog species, both *L. spenceri* and *N. nichollsi* are associated with sandy soils so may only be present along the Plains Access Road and associated with alluvial soils of Honeyeater Creek south of Bernt's Area. Other species may be associated with watercourses throughout the project area and may disperse into adjacent habitats.

None of the frogs recorded or expected in the project area is of conservation significance.

Reptiles

Of the 78 species of reptile expected in the general region of the Panorama Project Area, 41 appear in the specimen records of the WA Museum for the area defined above (see Methods), while 29 were recorded in the field surveys (Table 3). Note that of these species recorded, 12 were not listed by the WA Museum. The incompleteness of the WA Museum record for the area was expected and was one of the reasons why an intensive field programme was required.

The large number of species expected in the Project Area reflects the richness of the Pilbara region overall for reptiles, but is also related to the diversity of habitats present. Habitats range from rocky hills and gorges to gravelly loams within the Sulphur Springs, Kangaroo Caves and Bernt's Areas, and extend to alluvial plains along the Plains Access Road through Lalla Rookh Station and along Honeyeater Creek. The vegetation is also an important component of the habitat, for while

spinifex is present almost throughout, the presence/absence of trees and shrubs, including eucalypts and acacias, can influence the abundance of some reptile species.

WA Museum publications on reptiles of Western Australia (Storr *et al.* 1983, 1986, 1990 and 1999) provide some information on habitat preferences of reptile species, particularly with reference to soil type, and it is therefore possible to list 41 of the expected species that are likely to be restricted or largely restricted to either sandy soils or rocky hills (see Table 10).

Although similar numbers of species in each landscape type are expected, no sandy soil species and 12 rocky hills species were recorded during the field surveys, reflecting the largely rocky nature of the main study area where trapping and intensive searching were carried out. It is likely that within the Sulphur Springs, Kangaroo Caves and Bernt's Areas, species associated with sandy soils are scarce or absent, while in much of the region traversed by the Plains Access Road, these species will be abundant but species associated with rocky hills will be scarce or absent.

Four of the reptile species were recorded by trapping during the June survey, whereas trapping yielded 16 reptile species in September (Table 6). This reflected the greater reptile activity during the warm conditions experienced in September. A total of 18 reptile species were recorded in the traps, with the remaining 11 species being found during hand-searching and by opportunistic observation.

Although the numbers of reptile captures in traps were too low to warrant detailed statistical analyses, some patterns were apparent. For example, species associated with rocky environments, such as *D. savagei*, *H. spelea*, *G. punctata*, *V. acanthurus*, *C. rubicundus* and *C. saxatilis*, were recorded only at Sites 3 and 4. Two of these species, the geckoes *G. punctata* and *H. spelea*, were also recorded during head-torching only in rocky areas (Table 7), although *G. punctata* was also present in the buildings at Sulphur Springs Camp. One of the most abundant species in pitfall traps, the gecko *H. binoei*, was caught only at Site 1 (Table 6), but hand-searching found it to be moderately widespread (Table 7).

Numbers of reptile captures in traps over the two field surveys were especially low in Sites 2 (2 specimens) and 4 (6 specimens), and high in Site 3 (15 specimens). This may reflect a real difference in the abundance of reptiles with habitats such as that at Site 3 being more important than some other habitats, but intensive field work is required to draw conclusions concerning local patterns of distribution. For example, the effectiveness of traps can vary with the environment. Similarly, the results of hand-searching in June (Table 7) may be biased, as the recorded presence and abundance of species are directly related to the availability of habitat that can be searched under. For example, the capture of large numbers of some species, such as ten *P. reginae* along the Bypass Track and near Site 5, resulted from the species being easy to find in this area, not necessarily because it was especially abundant. Hand-searching in September (Table 7) resulted in the capture of very few reptiles.

Very few reptiles were found when spotlighting from a vehicle, with only a single *H. binoei* located in this way in June, and a single *A. perthensis* in September. This is often an effective means of locating reptiles, especially geckoes and pythons, but the weather was cool in June with the lowest minimum recorded being 12 C. In addition,

anecdotal evidence suggests that spotlighting for reptiles is more effective on bitumen than gravel roads, possibly because the bitumen retains warmth and therefore is attractive to the animals.

Results of the systematic trapping and the collection of other data on reptiles make it difficult to draw conclusions concerning important habitats for reptiles within the Project Area. However, as a general principle, habitats that make up a limited proportion of the total area of a site are likely to be more significant than habitats that make up a large proportion of a site's area. In this respect, rocky gorges are limited in area and may be the only locations where the most specialised rock-haunting reptile species, such as *H. spelea*, occur. There was also some suggestion that such rocky gorges support more reptile species and individuals than other environments in the area. Gorges containing permanent pools, if present, are potentially of special significance as they may support the Pilbara Olive Python *Morelia olivacea barroni*. Such sites are most likely to be along the Creek Access Road where it follows the gorge from the plains of Lalla Rookh Station up to the Sulphur Springs Area. Strelley Pool and pools along Honeyeater Creek may also be suitable habitats. This is the only reptile species of conservation significance expected in the Project Area; it is listed as Vulnerable under the WA Wildlife Conservation Act and EPBC Act.

Birds

Of the 126 bird species expected to occur in the Panorama Project Area, 80 were recorded: 64 in June and 71 in September (Table 4). Three of the species that were recorded were seen only along the Plains Access Road on Lalla Rookh Station, north of Lalla Rookh Mine, while most of the waterbird species were confined to Honeyeater Creek and Strelley Pool.

More species were recorded in the Sulphur Springs Area than in the Kangaroo Caves and Bernt's Areas (see Appendix 4), but this reflected the greater effort expended around Sulphur Springs. The similarity of habitats in the three areas suggests that the same suite of bird species would be present in them, with the only major habitat difference that might be significant being the juxtaposition of Bernt's Area with Honeyeater Creek and the Shaw River.

Most of the bird species were widespread but at low densities, and this is reflected in the censussing results made while checking traps at Sites 1 to 5 (Table 8). Many species were recorded only once at a site, even though over 2 hours were spent checking traps at each site over the course of each field trip, while only 3 species, the Grey-headed Honeyeater, Torresian Crow and Painted Firetail, were recorded at all sites over the course of the two trips. Site 4 was the poorest for birds, with only 8 species and 37 individuals recorded over the two field trips, while Site 1 supported the most species (15) with the most records (107). This result was probably influenced by Site 1 being close to Harp-trap Creek, as riparian vegetation along watercourses was important for birds.

Despite the low numbers of birds recorded during censussing, there were some clear habitat associations among the birds based upon censussing and general observations. While a few species, such as the Grey-headed Honeyeater, Painted Firetail, Black-

faced Woodswallow and Willie Wagtail were present virtually everywhere, and species such as birds of prey were recorded too infrequently to be linked with any specific habitat, a lot of species were associated with particular habitats.

Honeyeaters were concentrated in areas where nectar-bearing plants were flowering, such as some eucalypts along creek-lines (flowering in September) and *Grevillea wickhami* (flowering in June) that was abundant in the gravelly loam valley soils around Site 5. The White-plumed Honeyeater was recorded only in eucalypts along creeklines as is typical for this species (Higgins *et al.* (2001), and the only records of the Black-chinned Honeyeater were also among eucalypts.

As would be expected, the waterbirds recorded were along creeklines with the exception of birds flying overhead when travelling between wetlands, with such records generally being made at night. Other birds associated with creeklines, or with vegetation along creeklines, were the Diamond Dove, Pheasant Coucal, Variegated Fairy-wren and Blue-winged Kookaburra. The Barking Owl, although not recorded, is also commonly associated with large eucalypt and paperbark trees along watercourses in the Pilbara (Johnstone and Storr 1998). There were sections along the Creek Access Road that appeared suitable for this species, while Honeyeater Creek and the Shaw River had large tracts of this sort of riverine forest.

The Western Bowerbird and Little Woodswallow were recorded only near rocky areas, with both species being abundant in the proposed mine area near Site 3. The Bowerbird is typically associated with the Rock Fig in the Pilbara (Johnstone and Storr 1998).

The Striated Grasswren was notable as it appeared to occur mainly in dense, tall spinifex, usually on steep slopes, while all records of the feeding platelets (circular scrapes in the soil) of the Little Button-quail where amongst spinifex in gravelly-loam soil, such as at Site 5 and along the Bypass Track. These were the only species that were recorded regularly but appeared to have a very narrow focus on spinifex. In some parts of its range, the Striated Grasswren is associated with long unburnt spinifex and is threatened by broad scale fires, but has increased in abundance where mosaic burning has created a range of fire-age spinifex stands (Garnett and Crowley 2000).

A number of the bird species recorded or expected are of conservation significance as follows:

- Square-tailed Kite (Priority 4 according to CALM, but listed as Least Concern by Garnett and Crowley 2000). Although recorded occasionally in the Pilbara, Johnstone and Storr (1998) consider it to be a rare transient in the region, so it is likely to be a rare, non-breeding visitor to the Project Area.
- Peregrine Falcon (Other Specially Protected Fauna under the WA Wildlife Conservation Act but Least Concern according to Garnett and Crowley 2000). If present in the Project Area, the Peregrine Falcon is likely to forage widely but nesting sites, most likely on cliffs, would be significant. Suitable nest sites may be present in the mining area and along the Creek Access Road. This is normally a conspicuous species, so the absence of records suggests that it was not present during the periods of the surveys.

- Grey Falcon (Priority 4 according to CALM and Near-Threatened according to Garnett and Crowley 2000). While this species could be present anywhere within the Project Area, Garnett and Crowley (2000) note that it favours plains with acacia shrubland and tree-lined water-courses. It is therefore most likely to occur outside the Project Area, such as along Honeyeater Creek and the Shaw River.
- Australian Bustard (Near-Threatened according to Garnett and Crowley 2000). Recorded on Lalla Rookh Station along the Plains Access Road and probably only an occasionally visitor to the main Project Area. Hunting is a threat to this species in the region and any increase in human activity is likely to lead to an increase in hunting pressure. The species is clumsy when taking off and may collide with vehicles and overhead powerlines.
- Bush Stone-curlew (Priority 4 according to CALM and listed as Near-Threatened by Garnett and Crowley 2000). Locally common in the Project Area, on the loam soils along the Plains Access Road and at several locations within the Sulphur Springs Area, typically where there is open ground such as along tracks and gravel beds of broad watercourses. The main threatening processes listed by Garnett and Crowley (2000) for this species are loss of habitat and predation by Foxes.
- Flock Bronzewing (Near-Threatened according to Garnett and Crowley 2000). Historically known from the Pilbara, especially around waterholes on sandplains, but the species has declined and is now recorded only as a vagrant in the region (Johnstone and Storr 1998). If ever still present in the region of the Panorama Project Area, it is likely only on the plains traversed by the Access Road south of the Port Hedland to Marble Bar Road.
- Night Parrot (Critically Endangered under the WA Wildlife Conservation Act and according to Garnett and Crowley 2000; Endangered under the EPBC Act). An enigmatic species about which little is known, but it has been recorded in the Pilbara historically and is sometimes associated with spinifex grassland. Little can be concluded about the status of this species in the Project Area but any sightings or suspected sightings should be reported to CALM.

In addition to these significant species, a number of the birds are listed under international conservation treaties. These are migrants such as some of the sandpipers (Scolopacidae) and the Rainbow Bee-eater (Table 4). However, sandpipers are likely to be present only in low numbers, and generally only along the major river systems nearby. Bee-eaters were found breeding in banks along the Creek Access Road.

Mammals

Mammal species recorded or expected in the Project Area are listed on Table 5. The mammal fauna predicted to occur on the site reflects the location of the area on the northern edge of the Pilbara, as it contains elements typical of the Pilbara, elements associated with the sandy deserts to the north and east and some species with distributions that centre on the Kimberley but that are known from the northern Pilbara. Species associated with the rocky hills include: *Dasykaluta rosamondae, Pseudantechinus roryi*, the Long-tailed Dunnart *Sminthopsis longicaudata*, bat species associated with caves (Ghost Bat *Macroderma gigas*, Orange Leaf-nose Bat *Rhinonicteris aurantius* and the sheathtail-bats), the Pebble-Mound Mouse or Ngadji

Pseudomys chapmani and the Common Rock-Rat *Zyzomys argurus*. In contrast, few species associated with sandy soils are expected, but there is a possibility of the Mulgara *Dasycercus cristicauda*, the Spectacled Hare-Wallaby *Lagorchestes conspicillatus*, the Bilby *Macrotis lagotis* and the Tarrkawarra *Notomys alexis* occurring in areas of mostly loam soil such as along the Plains Access Road and along major rivers. Similarly, the Sandy Inland Mouse or Mingkiri and Pale Field-Rat are also likely to be in loam soils if they are present at all. Species more commonly associated with the Kimberley but that are known from the northern Pilbara include bats such as *Nyctophilus bifax* and *N. arnhemensis*.

Of the 47 species expected to occur in the Panorama project area, 16 were recorded during the June survey period and 19 in September (Table 5, see Table 6 for captures on Sites and Table 9 for observations made while spotlighting). A total of 21 mammal species were recorded, eight of which were caught through the trapping programme, with other species being observed, mainly through observation during searching and spotlighting. The Harp-Trap caught no bats despite being used for 7 nights in June and 4 nights in September. Low temperatures and a full moon in June may have suppressed bat activity (Churchill 1998), while nights were cool in September despite generally hot days. Most bats were found by searching in caves, when spotlighting or by mist-netting over a mine-shaft at Lalla Rookh Mine (see Appendix 5 for notes on observations on each mammal species).

The Northern Quoll and Common Rock Rat are both rock-haunting species and were caught only in rocky areas. The Rock-Rat was not caught in the rocky gorge at Site 3, where the Quoll was abundant, but was common on Site 4, the top of the hill beside Site 3, where the Quoll was also present. The Quoll was also caught around Sulphur Springs Camp, where they were living among and underneath the buildings. Quolls were caught at Site 2 only in June, and observations of Quolls drinking suggests that they may prefer to have access to free water during the hotter part of the year. They are therefore likely to concentrate along watercourses.

All of the bat species recorded and several of those expected shelter in caves, and roosts were found at the following locations:

21 09’ 02”S, 119 12’ 19”E. (June). In a cave in a small gorge leading away from the proposed mine area, a single Ghost Bat and about 10 Common Sheathtail Bats. This was a deep cave with a shaft angling up for about 5 m.
21 09’ 48”S, 119 14’ 16”E. (June). In a cave on a ridge east of Site 5, Common Sheathtail Bats.
21 03’ 20”S, 119 16’ 25”E. (June). Vertical mineshaft at the abandoned Lalla Rookh Mine, dozens of Common Sheathtail Bats flying in and out in the evening. *Vespadelus finlaysoni* was probably also present. In September, an old mine shaft about 100 m to the north was found to contain at least 163 Ghost Bats in a probable maternity colony as well as Common Sheathtail Bats and *V. finlaysoni*.
21 06’ 54”S, 119 11’ 33”E. (September). Caves on slopes above Creek Access Track containing small groups of Common Sheathtail Bats and *V. finlaysoni*.
21 10’ 53”S, 119 14’ 17”E. (September). A large cave on ridge near Site 5 was being used by a single Ghost bat and a single *V. finlaysoni.*

Given the nature of the country, with many kilometres of rocky ridges, clifflines and breakaways, there are potentially hundreds of small caves that may be used by roosting bats, although the very deep cave in which the Ghost Bat was located was unusual. Other bat species, such as the White-striped Bat and the three long-eared bats, tend to roost in hollow trees and may therefore roost amongst eucalypts along watercourses. While the Common Sheathtail Bats were recorded only at roost sites, the White-striped Bat, Ghost Bat, Orange Leaf-nose Bat (unconfirmed) and *V. finlaysoni* were observed when foraging. These observations are presented in Appendix 5. The records of the Orange Leaf-nose Bat are not definite as while a small, orange and fast-flying bat was seen on three occasions (Appendix 5), recordings made at two of these sightings were inconclusive.

Other species observed or expected that use rocky habitats include *D. rosamondae, P. roryi*, the Long-tailed Dunnart, Northern Brush-tailed Possum, Euro, Rothschild's Rock-Wallaby and the Pebble-Mound Mouse. Of these, *P. roryi*, the Euro, Rock-Wallaby and Pebble-mound Mouse were recorded. Euros were widespread, sheltering in caves and foraging often well away from rocky areas, whereas all Rock-Wallaby records were either along the Creek Access Track or in the gorge near Site 3. Rothschild's Rock-Wallaby is a shy and cryptic species, so the regular sightings indicate that the species is present in moderate numbers at least along the gorges occupied by the Creek Access Road and around the mine area. The species is probably widespread in suitable habitats in the region, but may be limited to where gorges are sufficiently developed to support vegetation around at least semi-permanent pools where the Rock-Wallabies can forage.

Pebble-mound Mouse records were not in the rocky hills but on the gravelly foothills between Strelley Pool and the vicinity of Lalla Rookh Mine. Active mounds were especially concentrated about 4-8 km north-east of Lalla Rookh (see Figure 1) but are probably present right along the Plains Access Road where it traverses the foothills of the plateau.

Ningaui timealyi, *Planigale* sp., the introduced House Mouse, *P. delicatulus* and *P. desertor* were absent from the very rocky Sites 3 and 4. *P. desertor* has been noted to have increased in abundance in the Pilbara in recent years (P. Kendrick pers. comm.). Previously, it was scarce in the area and until recently it was considered to be a rare and possibly threatened species associated with mesic refugia in sandy desert environments (Happold 1983). In the Project Area, it may be confined to gravelly loam soils (such as at Site 5) and adjacent foothills (Site 1).

Dingo tracks were common throughout the Panorama Project Area, and Dingoes are reported to suppress and even exclude some introduced species such as the Goat *Capra hircus* (P. Kendrick pers. comm.). The only introduced species recorded were the Feral Cat, Feral Donkey (possibly) and Camel. Domestic Cattle (not included in species lists) were present in the Kangaroo Caves and Bernt's Areas. Fresh tracks of the Camel were common along the Plains Access Road in both June and September, but one animal had recently walked along the track through the Sulphur Springs Area in September.

A number of the mammal species recorded or expected within the Project Area are of conservation significance. These include:

- Long-tailed Dunnart (Priority 4 according to CALM). This species has an apparently disjunct distribution from the Pilbara and across parts of inland Western Australia and the rocky hills of the Project Area appear suitable for it. Although not recorded, it is important to realise that trapping, even for extensive periods, cannot guarantee the capture of a species, especially in arid environments where levels of abundance can vary annually.
- Bilby (Vulnerable under the WA Wildlife Conservation Act and the EPBC Act). According to CALM's threatened fauna database, there is a 1962 record of a Bilby in the general vicinity of the Project Area. Generally associated with sandy soils, the Bilby is known to persist on the northern edge of the Pilbara and is abundant in some parts of the Great Sandy Desert (M. Bamford, unpub. data). If present, it is only likely along the Plains Access Road on Lalla Rookh Station and in areas of alluvial soil along Honeyeater Creek and the Shaw River. Searching was carried out along the Plains Access Road for the distinctive tracks of Bilbies, but they were not found and much of the area is heavily disturbed by cattle. Any sightings of this species should be reported to CALM.
- Spectacled Hare-Wallaby (Priority 3 according to CALM). According to CALM's threatened fauna database, there is a population in the general region of the Project Area but it is declining due to extensive fires and predation by Feral Cats. Most likely to be present in areas of loam soil. M. Trudgeon (pers. comm.) observed what appeared to be this species at 737 162 mE, 7 672 416 mN and 739 289 mE, 7 690 704 mN, and collected droppings from a shelter under spinifex that appeared consistent with photographs of droppings of the Spectacled Hare-Wallaby presented in Triggs (1996). Both these locations are along the Plains Access Road north of Lalla Rookh mine in an area with at least some long-unburnt spinifex and the more southerly location is indicated on Figure 1. Very extensive fires that remove the mosaic of burnt and unburnt spinifex have been implicated in the decline of a number of mammal species such as hare-wallabies (Burbidge and McKenzie 1989).
- Ghost Bat (Priority 4 according to CALM). Listed for the area in CALM's threatened fauna database and presence confirmed. The apparent maternity colony in Lalla Rookh Mine is one of the largest known in the Pilbara and fewer than 10 such colonies have been documented by CALM. It also appears that Ghost Bats are scattered throughout the area were small caves provide shelter. This species only congregates in maternity colonies for part of the year, and disperses widely through adjacent areas at other times (J. Toop. pers. com.).
- Orange Leaf-nose Bat (Vulnerable under the WA Wildlife Conservation Act). The Pilbara population of this species is isolated and three unconfirmed sightings were made. This bat roosts in caves and apparently suitable roost sites appeared to be present, especially the mine shaft being used by Ghost Bats, as the two species require similar conditions of temperature and humidity.
- Pebble-mound Mouse (Priority 4 according to CALM). Active mounds found in the stony foothills along the Plains Access Track in the vicinity of Lalla Rookh Mine and close to Strelley Pool (see Figure 1).

In addition to these species of conservation significance that were recorded or may be present, several species are almost certainly locally extinct. These include the Boodie

Bettongia lesueur (the mainland race is extinct, while island races are classed as Vulnerable under the WA Wildlife Conservation Act and the EPBC Act) and the Golden Bandicoot or Wintarru *Isoodon auratus* (Vulnerable).

CONCLUSIONS

The June and September field trips to the Panorama Project area made it possible to prepare detailed lists of species expected to be present in the area and to confirm the presence of many of these, including some of conservation significance. The field programme also provided some measures of abundance and made it possible to comment upon the relative value for fauna of different habitats present.

Significant features of the Project Area and its fauna can be summarised as follows:

- The main Project Area, consisting of the Sulphur Springs, Kangaroo Caves and Bernt's Areas, consists of typical Pilbara landscape with rocky hills, small gorges and undulating plains of gravelly loam in broad valleys. However, it lies high in the landscape between the Strelley and Shaw Rivers with associated alluvial soils, while the access road crosses the loam and gravelly loam soils of the Abydos Plain. Therefore, the fauna of the main Project Area can be expected to be typical of the rocky Pilbara landscape, but adjacent landscapes that could also be impacted by the proposed development can be expected to support a different suite of fauna. Bernt's Area in particular is close to Honeyeater Creek and the Shaw River, while the access road from the Port Hedland to Marble Bar Road runs parallel with the Shaw River for much of its length.
- Watercourses and associated riparian vegetation occupy a very small part of the landscape but are critical for species including freshwater fish, waterbirds and some landbirds of dense, riparian vegetation. In addition, the Northern Quoll may require access to water for part of the year, while Rothschild's Rock-Wallaby may depend upon riparian vegetation for browsing. If any permanent pools are present in the Project Area, they will be refuges for freshwater fish and the Vulnerable Pilbara Olive Python.
- Rocky gorges, hills and clifflines are the principal habitat for a number of reptile, bird and mammal species. Although extensive in the Project Area, some species require particular and rare features within this habitat, such as Ghost Bats needing deep caves and Western Bowerbirds being associated with the Rock Fig. Although no Peregrine Falcons were located, they would also be expected to depend upon a limited number of nesting sites along clifflines. The proposed mine site is located in what appears to be one of the best developed systems of cliffs and caves at least within the Sulphur Springs area where most work was carried out.
- Many of the bird species recorded were reliant upon a few species of scattered plants that were flowering, notably eucalypts and grevilleas along watercourses and in broad valleys of undulating gravelly loam.
- Introduced species that compromise the conservation value of some areas, such as Goats and the Fox, were not recorded and are either scarce or absent. In the case of the Goat and possibly the Fox, this has been attributed to predation by the Dingo. The scarcity/absence of these introduced species may

be important for species such as Rothschild's Rock-Wallaby and the Bush Stone-curlew.
- The Striated Grasswren appeared to be particularly abundant, possibly due to the presence of long-unburnt patches of spinifex.
- The presence of a probably maternity colony of the Ghost Bat in an old mine at Lalla Rookh is highly significant. This is one of the largest such colonies known in the Pilbara and although not in the mining area, it is within 300 m of the existing access road.
- The Pebble-mound Mouse appears to be common along some sections of the existing access road.
- A population of the Spectacled Hare-Wallaby appears to be present along the existing access road north of Lalla Rookh.

These significant features indicate where impacts on fauna may occur and suggest ways that impacts can be managed. For example:
- The main project area lies high in the landscape within the catchment areas of the Strelley and Shaw Rivers. The possibility therefore exists, no matter how remotely, of downstream impacts from mining activities.
- The proposed mine area and existing access road are on a watercourse that is part of the Strelley system. This watercourse is one of the most distinctive environmental features of the Project Area, and the watercourse/gorge environment has a rich fauna. As a general principle, impacts on fauna in a region can be minimised by minimising impacts on locally uncommon habitats, particularly habitats that are identified as being important for a range of species. This principle needs to be considered when designing and constructing the access route to the mine. For example, if no alternative exists but to have the haul road follow the existing route of the Creek Access Road along the gorge, then the haul road should be designed so as not to impede water flow and to minimise loss of riparian vegetation. This has been achieved in a similar situation in Karijini National Park by having a low profile, concrete road-way in the base of a gorge.
- The proposed mine area is located adjacent to a particularly well-developed gorge, steep cliffs and a small cave found to contain a Ghost Bat. This cave is probably too close to the mine area to escape disturbance. Although there are probably many such small caves used by Ghost Bats in the region, every attempt should be made to minimise disturbance of clifflines where small caves are present.
- Increased human activity associated with the mine may lead to illegal hunting, such as of the Australian Bustard, and an increase in fires. Fires *per se* are not the problem so much as the potential for very extensive or frequent fires. It may even be desirable to implement a programme of mosaic burning around the mine infrastructure to reduce the risk of extensive fires.
- Mining operations in remote areas sometimes result in an increase in feral animals. Feral animals should not be encouraged, even inadvertently.
- Another impact of mining operations in remote areas can be increased recreational activity in surrounding areas. Such activities tend to focus on significant features such as waterholes. Strelley Pool, for example, is an attractive feature but is also a focus for waterbirds in an otherwise seasonally arid landscape. Education of personnel and even management of recreational

locations may be necessary. The collection of firewood for "recreational" campfires can also result in impacts, as the sort of timber that is collected often includes hollow limbs that are important shelter for some animals.

- The existing access road passes through areas occupied by Ngadji or Pebble-mound Mice and the Spectacled Hare-Wallaby. It also passes within 300 m of the Lalla Rookh Ghost Bat colony. The following recommendations should be considered:
    - A survey should be undertaken to locate active mounds of the Ngadji or Pebble-mound Mouse so that these can be avoided during road works and especially when identifying sources of road materials.
    - A survey of the Spectacled Hare-Wallaby should be undertaken to determine the distribution of the population. The potential for road-kills due to operations along the haul road exists, but the greatest threat to the population may be from an increase in fire frequency. A fire management plan in the vicinity of the hare-wallaby population could be developed in consultation with the Department of Conservation and Land Management.
    - The potential exists for the Lalla Rookh Ghost Bat colony to be disturbed as a result of hauling activities. Discussions on this topic were held with Dr J. Toop of the Queensland Department of the Environment, a recognised expert in the study and management of Ghost Bats, and the major concern identified was disturbance resulting from increased visitation to the site. There are apparently Ghost Bat Colonies less than 300 m from major roads which are unaffected by the noise and vibration cased by traffic. It was suggested that a buffer of 1 km from the haul road to the Ghost Bat colony would be ideal, but discussions with Outokumpu staff and Dr M. Trudgeon (botanist) concluded that realigning the haul road in the vicinity of Lalla Rookh would require crossings over several seasonal watercourses. Potentially, therefore, increasing the distance between the haul road and the bat colony would increase other environmental impacts. To control incidental visitation of the site that could disturb the bats, the mine site should be fenced to exclude visitors from the shafts containing bats. Fencing should be with plain wire only, as the bats become entangled in barbed wire, and any existing barbed wire fences on the site should be removed. Some non-intrusive monitoring of the Ghost Bat colony should be considered to develop an understanding of patterns of seasonal usage and variation of the site. Such monitoring could also be used to detect any impacts of nearby activities.

TABLE ONE. Descriptions of fauna sampling sites. In June, all traps were operated for 5 nights from 6th –11th June, while bird censussing was carried out on the mornings when traps were checked from 7th – 11th June. In September, all traps were also operated for 5 nights at all sites from 23rd –28th September. In addition, however, the pitfall and Elliott Traps at Sites 1, 2 and 3 were operated on the night of 22nd September. Bird censussing was carried out on the mornings that the traps were checked from 23rd-28th September for Sites 1, 2 and 3, or 24th-28th September for Sites 4 and 5. Grid references of sampling sites are given in Appendix 1.

Site 1
Rocky foothills and valley of the proposed tailings dam area. Undulating ground with a number of small gullies, soil of fragmented rock. The vegetation is spinifex with scattered shrubs.

Site 2
Rocky ridge that forms one side of the proposed tailings dam area. It has a soil surface covered in scree and small rocks, with exposed outcrops, break-aways and shallow caves. The vegetation is spinifex with scattered shrubs.

Site 3
The small gorge leading up to the Sulphur Springs mine area. The side of the gorge is covered with small to medium rocks, with exposed rocks, caves and crevices. The steep slopes are vegetated with low spinifex and acacia thickets.

Site 4
The top of a rocky hill in the mine area. The hill-top is very rocky and uneven, with lots of exposed rock and little soil. The vegetation is spinifex with scattered small shrubs.

Site 5
An undulating plain of gravelly loam dissected by small creek-lines and with scattered outcrops of exposed rock. The vegetation consists of tall spinifex and thickets of acacias and *Grevillea wickhami*.

TABLE TWO-A. Table of events for hand-searching for reptiles, spotlighting, area inspections and searching for bats in caves, June 2001.

Date	Procedure	Location
03/06/01	Hand-searching for reptiles	Bypass Track, under dead Spinifex.
03/06/01	Spotlighting from vehicle	Harp-trap Creek (near Site 1) to Sulphur Springs Camp. 2 km.
03/06/01	Head-torching	At Harp-trap creek (2030-2130).
03/06/01	Harp-trap for bats	At Harp-trap Creek near Site 1.
04/06/01	Spotlighting from vehicle	From Sulphur Springs Camp to Site 2 along road, and back. 4 km.
04/06/01	Head-torching	At ridge on Site 2 (2100-2130).
04/06/01	Harp-trap for bats	At Harp-trap Creek near Site 1.
05/06/01	Spotlighting from vehicle	From Sulphur Springs Camp to Site 3 and back. 7 km.
05/06/01	Head-torching	Along gorge near Site 3 (2115-2145).
05/06/01	Harp-trap for bats	At Harp-trap Creek near Site 1.
06/06/01	Harp-trap for bats	At Harp-trap Creek near Site 1.
07/06/01	Hand-searching for reptiles	Bypass Track, under dead Spinifex.
07/06/01	Harp-trap for bats	At Harp-trap Creek near Site 1.
07/06/01	Mist-nets for bats	At Harp Trap Creek near Site 1.
08/06/01	Searching for bats in caves	In hills by Kangaroo Caves Road near Site 5.
08/06/01	Hand-searching for reptiles	Along Kangaroo Caves Road from Site 5 and south along the road.
08/06/01	Area inspection	Kangaroo Caves and Bernt's areas
08/06/01	Spotlighting from vehicle	From Shaw River along Kangaroo Caves Road, past Site 5 and Site 1 to Sulphur Springs Camp. 14.4km
08/06/01	Harp-trap for bats	At Harp-trap Creek near Site 1.
09/06/01	Hand-searching for reptiles	Around Finn's Camp and along the road nearby.
09/06/01	Area inspection	Creek Access Road and Plains Access Road on plain from Sulphur Springs Camp to Lalla Rookh mine.
09/06/01	Mist-nets for bats	At Lalla Rookh (abandoned) mine over an open vertical shaft.
09/06/01	Spotlighting from vehicle	From Lalla Rookh mine along access roads to Sulphur Springs Camp. 22.4 km
09/06/01	Harp-trap for bats	In gorge near Site 3.
10/06/01	Hand-searching for reptiles	Under dead Spinifex along road in gorge at Site 3.
10/06/01	Searching for bats in caves	In gorge system near Site 3.
10/06/01	Head-torching	In gorge at Site 3.

TABLE TWO-B. Table of events for hand-searching for reptiles, spotlighting, area inspections and searching for bats in caves, September 2001.

Date	Procedure	Location
22/09/01	Spotlighting from vehicle	From Sulphur Springs camp to Lalla Rookh Mine. Following another vehicle for much of distance so disturbance a factor. 22.5 km
23/09/01	Spotlighting from vehicle	Sulphur Springs Camp to Site 3 and return. 7 km.
23/09/01	Head-torching	At Site 3 (2015-2115).
24/09/01	Spotlighting from vehicle	From Gorge Track to Sulphur Springs Camp. 9 km.
24/09/01	Area inspection	Along Creek Access Road.
24/09/01	Head-torching	Along Creek Access Road.
24/09/01	Harp-trap for bats	At Harp-trap Creek near Site 1.
25/09/01	Area inspection	Kangaroo Caves and Bernt's area. Also searched around waterholes along Honeyeater Creek and Shaw River nearby.
25/09/01	Mist-netting for bats	Over waterhole on Honeyeater Creek.
25/09/01	Spotlighting from vehicle	From Shaw River along Kangaroo Caves Road, past Site 5 and Site 1 to Sulphur Springs Camp. 14.7 km
25/09/01	Harp-trap for bats	At Harp-trap Creek near Site 1.
26/09/01	Hand-searching for reptiles	Bypass Track, under dead spinifex.
26/09/01	Searching for bats in caves	In hills along Kangaroo Caves Road south of Site 5, therefore extending from where searching carried out in June.
26/09/01	Harp-trap for bats	At Harp-trap Creek near Site 1.
27/09/01	Bird censussing	Along Creek Access Road, to supplement bird censussing at main study sites.
27/09/01	Spotlighting from vehicle	From Lalla Rookh mine along access road to Sulphur Springs camp. 22.7 km
27/09/01	Harp-trap for bats	At Harp-trap Creek near Site 1.
28/09/01	Area inspection	Strelley Pool
28/09/01	Spotlighting from vehicle from just before sunset	Strelley Pool to Sulphur Springs Camp. 18.2 km
29/09/01	Opportunistic observations while travelling	Sulphur Springs Camp to Headland-Marble Bar Road

TABLE THREE. Species of freshwater fish, frogs and reptiles expected to occur in the Panorama project area on the basis of general patterns of distribution, indicating those recorded by the WA Museum (see Methods) and those recorded in the June and September 2001 field surveys.

Species		Recorded by WA Museum	Recorded:	
			June 2001	Sept 2001
Plotosidae (eel-tailed catfish)				
Pilbara Tandan	*Neosilurus hrytlii*		+	
Clupeidae				
Bony Bream	*Nematalosa erebi*		+	
Melanotaeniidae (rainbowfish)				
Western Rainbowfish	*Melanotaenia splendida australis*		+	+
Teraponidae (grunters)				
Barred Grunter	*Amniataba percoides*			
Spangled Grunter	*Leiopotherapon unicolor*		+	+
Eleotridae (gudgeons)				
Sleeper Gudgeon	*Oxyeleotris lineolatus*			
Myobatrachidae (ground frogs)				
	Limnodynastes spenceri	+		
	Neobatrachus centralis			
	Notaden nichollsi			
	Pseudophryne douglasi			
	Uperoleia glandulosa			
	Uperoleia russelli		+	+
Hylidae (tree-frogs)				
	Cyclorana maini			
Inland Tree-Frog	*Litoria rubella*	+	+	+
Gekkonidae (geckoes)				
Clawless Gecko	*Crenadactylus ocellatus*		+	+
Northern Spiny-tailed Gecko	*Strophurus ciliaris*			
Fat-tailed Gecko	*Diplodactylus conspicillatus*			
	Diplodactylus jeanae			
	Diplodactylus elderi		+	
	Diplodactylus savagei	+		+
	Diplodactylus stenodactylus			
Tree Dtella	*Gehyra variegata*	+	+	+
Pilbara Dtella	*Gehyra pilbara*	+	?	?
Spotted Dtella	*Gehyra punctata*	+	+	+
Bynoe's Gecko	*Heteronotia binoei*	+	+	+
	Heteronotia spelea			
	Nephrurus levis			
	Nephrurus wheeleri			
	Oedura marmorata			
Beaked Gecko	*Rhynchoedura ornata*			

Table 3 (cont.)

Species		Recorded by WA Museum	Recorded:	
			June 2001	Sept 2001
Pygopodidae (legless-lizards)				
	Delma borea			
	Delma elegans	+		+
	Delma haroldi			
	Delma nasuta	+	+	+
	Delma pax	+	+	
	Delma tincta	+		
Burton's Legless-Lizard	*Lialis burtonis*	+		+
Hooded Scalyfoot	*Pygopus nigriceps*	+		
Agamidae (dragon lizards)				
Ring-tailed Dragon	*Ctenophorus caudicinctus*	+	+	+
Military Dragon	*Ctenophorus isolepis*	+		
Central Netted Dragon	*Ctenophorus inermis*	+		
	Diporiphora winneckei			
Long-nosed Water-Dragon	*Gemmatophora longirostris*	+	+	+
Bearded Dragon	*Pogona minor*			
Varanidae (goannas or monitor lizards)				
Spiny-tailed Goanna	*Varanus acanthurus*		+	+
Pygmy Goanna	*Varanus brevicauda*	+		
	Varanus eremius	+		
Perentie	*Varanus giganteus*			+
Gould's Goanna or Bungara	*Varanus gouldii*			
Black-headed Tree Goanna	*Varanus tristis*			
Scincidae (skink lizards)				
	Carlia munda		+	+
	Cryptoblepharus plagiocephalus		+	+
	Ctenotus grandis	+		
	Ctenotus pantherinus	+		
	Ctenotus piankai	+		
	Ctenotus rubicundus	+		+
	Ctenotus saxatilis	+	+	+
	Ctenotus serventyi			
	Cyclodomorphus melanops		+	+
	Egernia depressa	+		
	Egernia formosa			+
	Eremiascincus richardsonii	+		
	Lerista bipes			
	Lerista muelleri	+	+	
Dwarf Skink	*Menetia greyii*	+		
	Menetia surda		+	
	Morethia ruficauda		+	+
	Notoscincus ornatus			+
	Proablepharus reginae		+	+
Desert Bluetongue	*Tiliqua multifasciata*	+		

Table 3 (cont.)

Species		Recorded by WA Museum	Recorded:	
			June 2001	Sept 2001
Typhlopidae (blind snakes)				
	Ramphotyphlops diversus			
	Ramphotyphlops grypus	+		
	Ramphotyphlops hamatus			
Boidae (pythons)				
Pygmy Python	*Antaresia perthensis*	+		+
Stimson's Python	*Antaresia stimsoni*	+		
Black-headed Python	*Aspidites melanoscaphus*	+		
Woma	*Aspidites ramsayi*			
Olive Python	*Morelia olivacea barroni*	+		
Elapidae (front-fanged snakes)				
Desert Death Adder	*Acanthophis pyrrhus*			
Pilbara Death Adder	*Acanthophis wellsi*	+		
Yellow-faced Whip-Snake	*Demansia psammophis*			
Rufous Whip-Snake	*Demansia rufescens*	+		+
Moon Snake	*Furina ornata*	+		
Mulga Snake	*Pseudechis australis*	+		
Ringed Snake	*Pseudonaja modesta*	+		
Gwarder	*Pseudonaja nuchalis*	+		
Rosen's Snake	*Suta (Denisonia) fasciata*	+		
Monk Snake	*Suta (Rhinoplocephalus) monachus*			
Spotted Snake	*Suta (Rhinoplocephalus) punctatus*			
	Simoselaps (Vermicella) approximans			
	Vermicella snelli	+		
Number of fish species expected (recorded):			6 (4)	6 (2)
Number of frog species expected (recorded):		8 (2)	8 (2)	8 (2)
Number of reptile species expected (recorded):		78 (41)	78 (21)	78 (25)

TABLE FOUR. Bird species observed or expected to occur in the Panorama Project Area based on general patterns of distribution, indicating species observed in the June and September field trips. Species observed only on the access road north of Lalla Rookh mine are indicated by (+).

Species		June 2001	Sept 2001
Dromaiidae (emus)			
Emu	*Dromaius novaehollandiae*		
Phasianidae (pheasants and quails)			
Brown Quail	*Coturnix ypsilophora*	?	+
Anatidae (swans and ducks)			
Pacific Black Duck	*Anas superciliosus*		+
Anhingidae (darters)			
Darter	*Anhinga melanogaster*		+
Phalacrocoracidae (cormorants)			
Little Pied Cormorant	*Phalacrocorax melanoleucos*		+
Little Black Cormorant	*Phalacrocorax sulcirostris*		+
Pelcanidae (pelicans)			
Australian Pelican	*Pelecanus conspicillatus*		+
Ardeidae (herons and egrets)			
White-faced Heron	*Egretta novaehollandiae*	+	+
White-necked Heron	*Ardea pacifica*		+
Great Egret	*Ardea alba*		+
Nankeen Night Heron	*Nycticorax caledonicus*	+	+
Threskiornithidae (ibis and spoonbills)			
Straw-necked Ibis	*Threskiornis spinicollis*		+
Ciconiidae (storks)			
Black-necked Stork or Jabiru	*Ephippiorhynchus asiaticus*		+
Accipitridae (kites, hawks and eagles)			
Black-shouldered Kite	*Elanus notatus*	+	+
Square-tailed Kite	*Lophoictinia isura*		
Black-breasted Buzzard	*Hamirostra melanosternon*		
Black Kite	*Milvus migrans*		
Whistling Kite	*Haliastur sphenurus*	+	+
Spotted Harrier	*Circus assimilis*	(+)	+
Brown Goshawk	*Accipiter fasciatus*	+	
Collared Sparrowhawk	*Accipiter cirrhocephalus*	+	+
Wedge-tailed Eagle	*Aquila audax*	+	+
Little Eagle	*Hieraaetus morphnoides*	+	+
Falconidae (falcons)			
Black Falcon	*Falco subniger*		
Peregrine Falcon	*Falco peregrinus*		
Australian Hobby	*Falco longipennis*		
Grey Falcon	*Falco hypoleucos*		
Brown Falcon	*Falco berigora*	+	+
Nankeen Kestrel	*Falco cenchroides*	+	+
Turnicidae (button-quails)			
Little Button-quail	*Turnix velox*	+	+

Table 4 (cont.)

Species		June 2001	Sept 2001
Rallidae (crakes and rails)			
Black-tailed Native-hen	*Gallinula ventralis*		
Otidae (bustards)			
Australian Bustard	*Ardeotis australis*	(+)	
Burhinidae (stone-curlews)			
Bush Stone-curlew	*Burhinus grallarius*	+	+
Scolopacidae (sandpipers)			
Marsh Sandpiper	*Tringa stagnatalis*		
Common Greenshank	*Tringa nebularia*		
Wood Sandpiper	*Tringa glareola*		
Common Sandpiper	*Tringa hypoleucos*		
Charadriidae (lapwings and plovers)			
Black-fronted Dotterel	*Elseyornis melanops*	+	+
Red-kneed Dotterel	*Erythrogonys cinctus*		
Glareolidae (pratincoles)			
Oriental Pratincole	*Glareola maldivarum*		
Australian Pratincole	*Stiltia isabella*		
Columbidae (pigeons and doves)			
Peaceful Dove	*Geopelia placida*		+
Common Bronzewing	*Phaps chalcoptera*	+	+
Flock Bronzewing	*Phaps histrionica*		
Crested Pigeon	*Ocyphaps lophotes*	+	
Spinifex Pigeon	*Geophaps plumifera*	+	+
Diamond Dove	*Geopelia cuneata*	+	+
Cacatuidae (cockatoos)			
Red-tailed Black-Cockatoo	*Calyptorhynchus banksii*		
Galah	*Cacatua roseicapilla*	+	+
Little Corella	*Cacatua sanguinea*		+
Psittacidae (lorikeets and parrots)			
Cockatiel (wiero)	*Nymphicus hollandicus*	+	+
Budgerigar	*Melopsittacus undulatus*	+	
Australian Ringneck	*Barnardius zonarius*	+	
Night Parrot	*Pezoporus occidentalis*		
Cuculidae (cuckoos)			
Pallid Cuckoo	*Cuculus pallidus*	+	+
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*	?	+
Black-eared Cuckoo	*Chrysococcyx osculans*		
Pheasant Coucal	*Centropus phasianinus*	+	+
Strigidae (hawk-owls)			
Southern Boobook Owl	*Ninox novaeseelandiae*	+	+
Barking Owl	*Ninox connivens*		
Tytonidae (barn owls)			
Barn Owl	*Tyto alba*		
Podargidae (frogmouths)			
Tawny Frogmouth	*Podargus strigoides*	+	+

Table 4 (cont.)

Species		June 2001	Sept 2001
Aegothelidae (owlet-nightjars)			
Australian Owlet-nightjar	*Aegotheles cristatus*	+	+
Caprimulgidae (nightjars)			
Spotted Nightjar	*Eurostopodus argus*	+	+
Apodidae (swifts)			
Fork-tailed Swift	*Apus pacificus*		
Halcyonidae (forest kingfishers)			
Blue-winged Kookaburra	*Dacelo leachii*	+	+
Red-backed Kingfisher	*Todiramphus pyrrhopygia*	+	+
Sacred Kingfisher	*Todiramphus sanctus*		+
Meropidae (bee-eaters)			
Rainbow Bee-eater	*Merops ornatus*	+	+
Coraciidae (rollers)			
Dollarbird	*Eurystomus orientalis*		
Climacteridae (treecreepers)			
Black-tailed Treecreeper	*Climacteris melanura*		
Maluridae (fairy-wrens)			
Variegated Fairy-wren	*Malurus lamberti*	+	+
White-winged Fairy-wren	*Malurus leucopterus*		
Rufous-crowned Emu-wren	*Stipiturus ruficeps*		+
Striated Grasswren	*Amytornis striatus*	+	+
Pardalotidae (pardalotes)			
Western Gerygone	*Gerygone fusca*	+	
Red-browed Pardalote	*Pardalotus rubricatus*	+	+
Striated Pardalote	*Pardalotus striatus*	+	
Weebill	*Smicrornis brevirostris*		+
Meliphagidae (honeyeaters)			
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*		
Yellow-throated Miner	*Manorina flavigula*	+	+
Singing Honeyeater	*Lichenostomus virescens*		+
Grey-headed Honeyeater	*Lichenostomus keartlandi*	+	+
Grey-fronted Honeyeater	*Lichenostomus plumulus*		
White-plumed Honeyeater	*Lichenostomus penicillatus*	+	+
Black-chinned Honeyeater	*Melithreptus gularis*	+	+
Brown Honeyeater	*Lichmera indistincta*	+	+
Black Honeyeater	*Certhionyx niger*		
Pied Honeyeater	*Certhionyx variegatus*	+	
Crimson Chat	*Epthianura tricolor*	(+)	
Orange Chat	*Epthianura aurifrons*		
Petroicidae (Australian robins)			
Red-capped Robin	*Petroica goodenovii*		
Hooded Robin	*Melanodryas cucullata*		
Pomatostomidae (Australian babblers)			
Grey-crowned Babbler	*Pomatostomus temporalis*		
Cinclosomatidae (quail-thrushes and allies)			
Chiming Wedgebill	*Psophodes occidentalis*		

Table 4 (cont.)

Species		June 2001	Sept 2001
Neosittidae (sittellas)			
Varied Sittella	*Daphoenositta chrysoptera*		
Pachycephalidae (whistlers)			
Crested Bellbird	*Oreoica gutturalis*	+	+
Rufous Whistler	*Pachycephala rufiventris*	+	+
Grey Shrike-thrush	*Colluricincla harmonica*	+	+
Dicruridae (flycatchers)			
Magpie-lark	*Grallina cyanoleuca*	+	+
Grey Fantail	*Rhipidura fuliginosa*		
Willie Wagtail	*Rhipidura leucophrys*	+	+
Campephagidae (cuckoo-shrikes)			
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	+	+
White-winged Triller	*Lalage sueurii*	+	+
Artamidae (woodswallows)			
White-breasted Woodswallow	*Artamus leucorhynchus*		
Masked Woodswallow	*Artamus personatus*		
Black-faced Woodswallow	*Artamus cinereus*	+	+
Little Woodswallow	*Artamus minor*	+	+
Grey Butcherbird	*Cracticus torquatus*		
Pied Butcherbird	*Cracticus nigrogularis*	+	+
Australian Magpie	*Gymnorhina tibicen*	+	+
Corvidae (ravens and crows)			
Little Crow	*Corvus bennetti*		
Torresian Crow	*Corvus orru*	+	+
Ptilonorhynchidae (bowerbirds and catbirds)			
Western Bowerbird	*Chlamydera guttata*	+	+
Alaudidae (larks)			
Singing Bushlark	*Mirafra javanica*		
Motacillidae (pipits and true wagtails)			
Richard's Pipit	*Anthus novaeseelandiae*		
Passeridae (finches and allies)			
Painted Firetail	*Emblema picta*	+	+
Zebra Finch	*Taeniopygia guttata*	+	(+)
Dicaeidae (flower-peckers)			
Mistletoebird	*Dicaeum hirundinaceum*	+	+
Hirundinidae (swallows)			
White-backed Swallow	*Cheramoeca leucosternus*		
Welcome Swallow	*Hirundo neoxena*		
Tree Martin	*Hirundo nigricans*	+	+
Fairy Martin	*Hirundo ariel*		
Sylviidae (Old World warblers)			
Spinifexbird	*Eremiornis carteri*	+	+
Rufous Songlark	*Cincloramphus mathewsi*		+
Brown Songlark	*Cincloramphus cruralis*	(+)	
Number of species expected (recorded): Total recorded: 80		126 (63)	126 (71)

TABLE FIVE. Mammal species observed (+) or expected to occur at the Panorama Project Area. The list includes species associated with sandy soils. Introduced species are indicated by (I).

Species		Recorded by WA Museum	Recorded in:	
			June 2001	Sept 2001
Tachyglossidae (echidnas)				
Echidna	*Tachyglossus aculeatus*			+
Dasyuridae				
Pilbara Ningaui	*Ningaui timealeyi*	+	+	+
	Planigale sp.		+	
Mulgara	*Dasycercus cristicauda*	+		
	Dasykaluta rosamondae	+		
Northern Quoll	*Dasyurus hallucatus*		+	+
	Pseudantechinus roryi			+
	Pseudantechinus woolleyae			
Long-tailed Dunnart	*Sminthopsis longicaudata*			
Stripe-faced Dunnart	*Sminthopsis macroura*			
	Sminthopsis youngsoni			
Thylacomyidae (bilbies or rabbit-eared bandicoots)				
Bilby, Dalgyte or Walpiri	*Macrotis lagotis*			
Phalangeridae (possums)				
Northern Brush-tailed Possum	*Trichosurus arnhemensis*			
Macropodidae (kangaroos and wallabies)				
Spectacled Hare-Wallaby	*Lagorchestes conspicillatus*	+		+?
Euro	*Macropus robustus*	+	+	+
Red Kangaroo	*Macropus rufus*			
Rothschild's Rock-Wallaby	*Petrogale rothschildi*	+?	+	+
Pteropodidae (fruit bats or flying-foxes)				
Black Flying-fox	*Pteropus alecto*			
Little Red Flying-fox	*Pteropus scapulatus*			
Megadermatidae (false vampire bats)				
Ghost Bat	*Megaderma gigas*	+	+	+
Hipposideridae (leaf-nose bats)				
Orange Leaf-nose Bat	*Rhinonicteris aurantius*	+	?+	?+
Emballonuridae (sheathtail bats)				
Yellow-bellied Sheathtail Bat	*Saccolaimus flaviventris*			
Common Sheathtail Bat	*Taphozous georgianus*	+	+	+
Hill's Sheathtail Bat	*Taphozous hilli*			
Mollosidae (mastiff bats)				
White-striped Bat	*Tadarida (Nyctinomus) australis*		+	+
Northern Freetail Bat	*Chaerophon jobensis*			
Beccari's Freetail Bat	*Mormopterus beccarii*			

Table 5 (cont.)

Species	Recorded by WA Museum	Recorded in:	
		June 2001	Sept 2001
Vespertilionidae (vesper bats)			
Gould's Wattled Bat *Chalinolobus gouldii*			
Vespadelus (Eptesicus) finlaysoni	+	+	+
Arnhem Long-eared Bat *Nyctophilus arnhemensis*			
Northern Long-eared Bat *Nyctophilus bifax*			
Lesser Long-eared Bat *Nyctophilus geoffroyi*			
Scotorepens balstoni			
Scotorepens greyii			
Muridae (rats and mice)			
House Mouse *Mus musculus* (I)			+
Tarrkawarra or Spinifex Hopping-Mouse *Notomys alexis*			
Pebble-mound Mouse *Pseudomys chapmani*			+
Pseudomys delicatulus			+
Pseudomys desertor		+	+
Mingkiri or Sandy Inland Mouse	+		
Pseudomys hermannsburgensis			
Pale Field-Rat *Rattus tunneyi*			
Common Rock-Rat *Zyzomys argurus*	+	+	+
Leporidae (rabbits and hares)			
Rabbit *Oryctolagus cuniculus* (I)			
Canidae (foxes and dogs)			
Dingo *Canis lupus dingo*	+	+	+
European Red Fox *Vulpes vulpes* (I)			
Felidae (cats)			
Feral Cat *Felis catus* (I)		+	
Equidae (horses and donkeys)			
Feral Donkey *Equus asinus* (I)		?	
Bovidae (horned ruminants)			
Camel *Camelus dromidarius* (I)		+	+
Number of species expected (recorded):	48 (13)	48 (16)	48 (19)

TABLE SIX. Numbers of captures (excluding recaptures) of frogs, reptiles and mammals at Sites 1 to 5 for June 2001 (A) and September 2001 (B).

A. June 2001. Note that all traps at all sites were operated for 5 nights.

Species	Site 1	Site 2	Site 3	Site 4	Site 5
Amphibians					
Uperoleia russelli	-	-	3	-	-
Reptiles					
Ctenophorus caudicinctus	3	-	-	-	1
Varanus acanthurus	-	-	-	1	-
Gemmatophora longirostris	-	-	1	-	-
Ctenotus saxatilis	-	-	3	-	1
Mammals					
Dasyurus hallucatus	-	2	4	1	-
Ningaui timealyi	2	1	-	-	1
Planigale sp.	1	1	-	-	1
Pseudomys desertor	1	-	-	-	2
Zyzomys argurus	2	-	-	6	-
Number of species	5	3	4	3	5
Number of frog specimens	-	-	3	-	-
Number of reptile specimens	3	-	4	1	2
Number of mammal specimens	6	4	4	7	4

B. September 2001. Note that the pitfall and Elliott traps were operating for 6 nights at Sites 1, 2 and 3, and 5 nights at sites 4 and 5. All cages were operating for 5 nights.

Species	Site 1	Site 2	Site 3	Site 4	Site 5
Amphibians					
Uperoleia russelli	-	-	1	-	-
Reptiles					
Diplodactylus savagei	-	-	1	-	-
Gehyra punctata	-	-	-	1	-
Heteronotia binoei	6	-	-	-	-
Heteronotia spelea	-	-	-	1	-
Varanus acanthurus	-	-	-	1	-
Carlia munda	-	-	-	-	1
Ctenotus rubicundus	-	-	-	1	-
Ctenotus saxatilis	-	-	7	1	-
Egernia formosa	-	-	1	-	-
Morethia ruficauda	2	-	1	1	-
Notoscincus ornatus	1	-	-	-	2
Proablepharus reginae	-	-	-	-	3
Delma elegans	-	1	-	-	-
Delma nasuta	-	-	-	-	1
Lialis burtonis	-	-	1	-	-
Demansia rufescens	-	1	-	-	-
Mammals					
Dasyurus hallucatus	-	-	4	7	-
Mus musculus	5	4	-	-	-
Ningaui timealyi	3	1	-	1	2
Pseudomys delicatulus	1	-	-	-	1
Pseudomys desertor	2	2	-	-	-
Zyzomys argurus	1	1	-	3	-
Petrogale rothschildi	-	-	1	-	-
Number of species	8	6	8	9	6
Number of frog specimens	-	-	1	-	-
Number of reptile specimens	9	2	11	6	7
Number of mammal specimens	12	8	5	11	3

TABLE SEVEN. Numbers of reptiles found during searching and head-torching. Harp Trap Creek was a watercourse with riparian vegetation and water was present, while the Creek Access Track was similar. Sulphur Springs Camp, Finn's Camp and Site 2 were all in a broadly similar landscape of rocky ground, Sites 3 and 4 were in a rocky gorge and the Bypass Track/Site 5 was undulating gravelly loam with tall spinifex.

7A. June 2001.

Species	Harp Trap Creek near Site 1	Sulphur Springs Camp, Finn's Camp, Site 2	Sites 3 & 4	Bypass Track and near Site 5
Uperoleia russelli	1			
Litoria rubella	1			
Crenadactylus ocellatus		7		10
Diplodactylus elderi				3
Gehyra variegata		3	1	
Gehyra punctata		1	4	
Heteronotia binoei		4		17
Heteronotia spelea			1	
Delma nasuta				2
Delma pax		1		1
Ctenophorus caudicinctus		6		4
Gemmatophora longirostris	2	1	1	
Varanus acanthurus		1		
Carlia munda				1
Cryptoblepharus plagiocephalus		1	3	
Ctenotus saxatilis			2	
Cyclodomorphus melanops		7		7
Lerista muelleri				2
Menetia surda		1		1
Morethia ruficauda		1	2	
Proablepharus reginae		1		10

7B. September 2001.

Species	Creek Access Track	Sulphur Springs Camp	Sites 3 & 4	Bypass Track
Uperoleia russelli	Abundant			
Litoria rubella	2	1		
Gehyra variegata		2		
Ctenophorus caudicinctus		2		
Gemmatophora longirostris	3	2	1	
Varanus giganteus	1			
Cyclodomorphus melanops				3

TABLE EIGHT. Summary of daily bird observations for sites 1 to 5 for June 2001 (A) and September 2001 (B). The first value indicates the number of surveys (out of 5 in June; out of 6 for Sites 1, 2 and 3 and out of 5 for Sites 4 and 5 in September) on which a species was recorded at a site, while the value in parenthesis is the total number of that species seen on all occasions at a site.

A: June 2001

Species	Site 1	Site 2	Site 3	Site 4	Site 5
Little Button-quail					1 (1)
Galah	1 (10)				1 (2)
Striated Grasswren		1 (4)			
Red-browed Pardalote				1 (1)	
Striated Pardalote				1 (3)	
Yellow-throated Miner	1 (4)	2 (12)			
Grey-headed Honeyeater	2 (7)	3 (5)	2 (5)	2 (5)	4 (13)
Brown Honeyeater	4 (8)		1 (1)	2 (2)	1 (4)
Crested Bellbird	1 (1)				
Grey Shrike-thrush	1 (1)	1 (1)	1 (1)		1 (1)
Black-faced Cuckoo-shrike			2 (2)		
Black-faced Woodswallow		1 (4)			1 (7)
Little Woodswallow				3 (8)	
Pied Butcherbird					1 (1)
Torresian Crow		1 (2)		1 (2)	1 (2)
Western Bowerbird	1 (1)				
Painted Firetail	5 (10)	3 (12)	3 (22)	2 (4)	4 (18)
Zebra Finch					1 (10)
TOTAL:	**42**	**40**	**31**	**25**	**59**

B: September 2001

Species	Site 1	Site 2	Site 3	Site 4	Site 5
Pallid Cuckoo			1 (1)		
Horsfield's Bronze-Cuckoo	2 (2)				
Common Bronzwing			1 (1)		2 (2)
Spinifex Pigeon	1 (3)		2 (6)		1 (4)
Diamond Dove	1 (1)				1 (2)
Striated Grasswren		2 (4)		1 (4)	
Red-browed Pardalote				2 (2)	
Yellow-throated Miner			1 (3)		
Grey-headed Honeyeater	3 (8)	2 (2)	4 (11)		1 (2)
Brown Honeyeater	1 (1)				
Crested Bellbird	1 (1)	1 (1)			1 (1)
Grey Shrike-thrush	4 (4)	1 (1)	4 (5)		1 (1)
Willie Wagtail			1 (1)		
Magpie-lark			1 (2)		
Black-faced Woodswallow	1 (4)				
Little Woodswallow				1 (2)	
Pied Butcherbird	1 (1)	1 (5)		1 (2)	
Torresian Crow	1 (2)		1 (2)		
Painted Firetail	6 (35)	1 (2)	3 (18)	1 (2)	3 (10)
Spinifexbird	3 (3)	4 (5)	2 (3)		
TOTAL:	**65**	**20**	**53**	**12**	**22**

Summary of bird censussing across the two field trips

	Site 1	Site 2	Site 3	Site 4	Site 5
Number of species	15	10	13	8	14
Number of records	107	60	84	37	81

TABLE NINE-A. Results of spotlighting in June.

1. 03/06/'01. Harp-Trap Creek to Sulphur Springs Camp. 2 km.
2. 04/06/'01. Sulphur Springs Camp to Site 2 and return. 4 km.
3. 05/06/'01. Sulphur Springs Camp to Site 3 and return. 7 km.
4. 08/06/'01. Shaw River to Sulphur Springs Camp. 14.4 km.
5. 09/06/'01. Lalla Rookh Mine to Sulphur Springs Camp. 22.4 km, divided between 13 km along the access road across the plain and 9.4 km along the trac following the gorge and through rocky hills.

Survey 1.	Spotted Nightjar – 1.
	White-striped Bat – 1.
Survey 2.	Owlet Nightjar – 1.
	Bynoe's Gecko – 1.
Survey 3.	Spotted Nightjar – 1.
Survey 4.	Spotted Nightjar – 2.
	Ghost Bat – 1;
	Orange Leaf-nose Bat – 1 (unconfirmed).
	Euro – 4.
Survey 5 (plain)	Spotted Nightjar – 2.
	Bush Stone-curlew – 2.
	Tawny Frogmouth – 1.
Survey 5 (gorge & hills)	Bush Stone-curlew - 2
	Nankeen Night-Heron – 1.
	Rothschild's Rock-Wallaby – 1.
	Euro – 6.
	Orange Leaf-nose Bat – 1 (unconfirmed).
	Common Rock-Rat – 1.

TABLE NINE-B. Results of spotlighting in September.

1. 22/09/'01. Sulphur Springs Camp to Lalla Rookh Mine. 22.5 km.
2. 23/09/'01. Sulphur Springs Camp to Site 3 and return. 7 km.
3. 24/09/'01. Creek Access Track to Sulphur Springs Camp. 9 km.
4. 25/09/'01. Shaw River to Sulphur Springs Camp. 14.7 km.
5. 27/09/'01. Lalla Rookh Mine to Sulphur Springs Camp. 22.7 km, divided between 13 km along the access road across the plain and 9.7 km along the track following the gorge and through rocky hills.
6. 28/09/'01. Strelley Pool to Sulphur Springs Camp. 17.6 km, with the first 8 km just before sunset and the remainder of the survey during twilight.

Survey 1.	Spotted Nightjar:	2.
	Boobook Owl:	1.

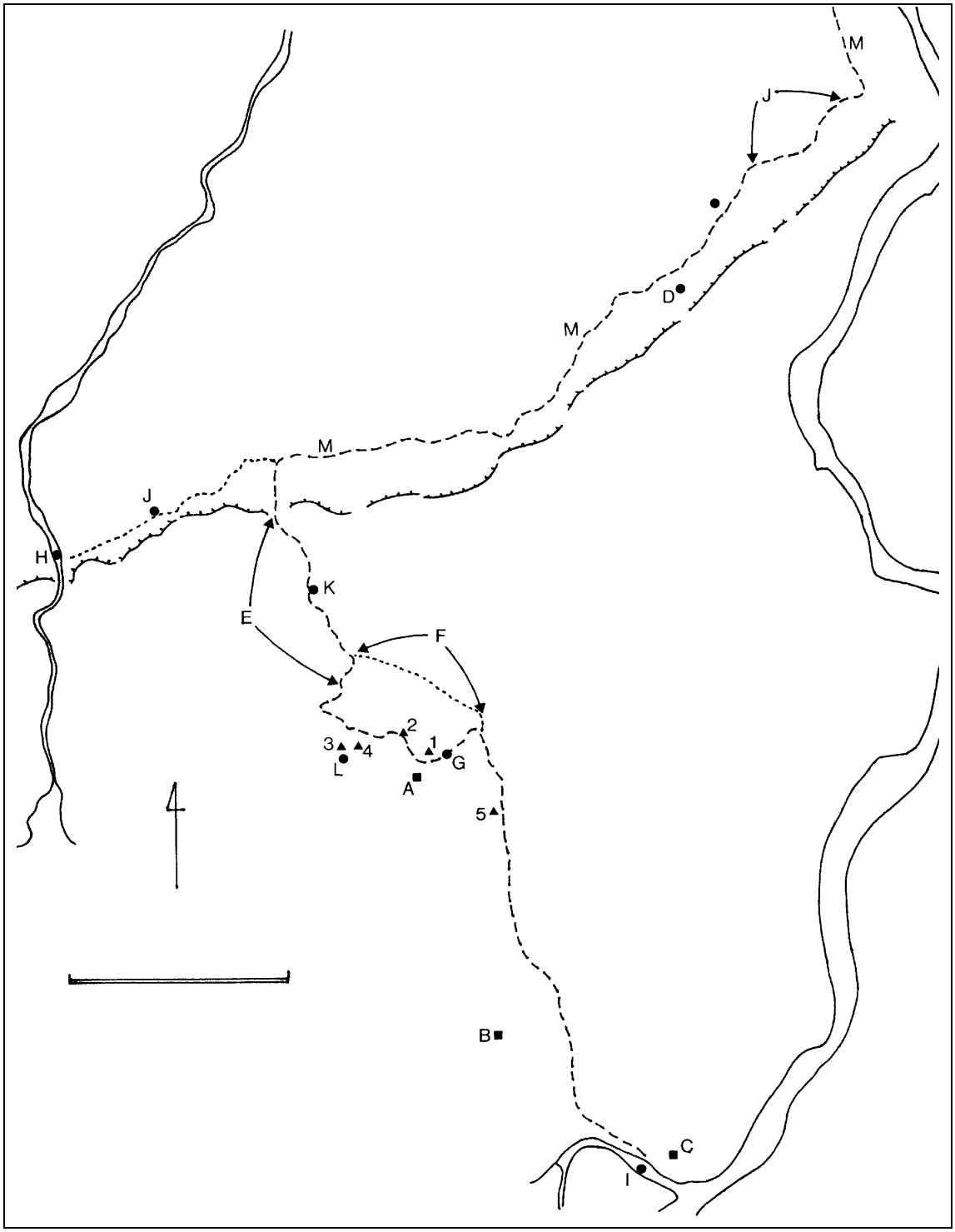
NB. Survey was carried out following another vehicle, so fauna may have been disturbed.

Survey 2.	Euro:	1.
Survey 3.	Bush Stone-curlew:	2.
Survey 4.	Bush Stone-curlew:	1.
	Spotted Nightjar:	5.
	Tawny Frogmouth:	1.
	Northern Quoll:	1.
	Euro:	1.
Survey 5.	Spotted Nightjar:	6.
(plain)	Boobook Owl:	5.
	Pygmy Python:	1.
	Euro:	2.
	Orange Leaf-nose Bat:	1.
Survey 5.	Bush Stone-curlew:	1.
(gorge & hills)	Tawny Frogmouth:	1.
	Rothschild's Rock-Wallaby:	1.
	Euro:	1.
Survey 6.	Nankeen Night-Heron:	1.
	Tawny Frogmouth:	1.

TABLE TEN. Habitat preferences of reptile species, indicating those likely to favour or be restricted to sandy soils and rocky hills (based on information in Storr *et al.* 1983, 1986, 1990 and 1999).

Sandy soils	**Rocky hills**
S. ciliaris	*C. ocellatus*
D. conspicillatus	*D. savagei*
D. jeanae	*G. punctata*
N. levi	*H. spelea*
R. ornata	*N. wheeleri*
P. nigriceps	*O. marmorata*
C. isolepis	*D. elegans*
V. eremius	*D. pax*
V. gouldii	*D. haroldi*
C. pantherinus	*C. caudicinctus*
C. piankai	*V. acanthurus*
C. serventyi	*V. brevicauda*
E. richardsonii	*V. giganteus*
L. bipes	*C. rubicundus*
T. multifasciata	*C. saxatilis*
A. ramsayi	*C. melanops*
A. pyrrhus	*E. depressa*
S. approximans	*A. perthensis*
V. snelli	*A. melanoscaphus*
	M. olivacea barroni
	A. wellsi

FIGURE ONE. Sketch map of the Panorama Project Area, indicating locations mentioned in the text. Grid references are given in Appendix One. The main course of the Shaw River (to the east) and a branch of the Strelley River (to the west) are indicated. Key to locations: A – Sulphur Springs Camp, B – Kangaroo Caves area, C – Bernt's area, D – Lalla Rookh Mine, E – Creek Access Road, F – Bypass Track, G – Harp Trap Creek, H – Strelley Pool, I – pool on Honeyeater Creek, J – locations of Pebble-mound Mouse mounds, K – caves with Rothschild's Rock-Wallabies and bats, L – cave with Ghost Bat and gorge with Rothschild's Rock-Wallaby near the Sulphur Springs mining area, M – Plains Access Road. The scale bar is 5 km.



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APPENDIX ONE. Summary of grid references for key areas in the Panorama Project Area. These areas and locations are presented on Figure One.

Area/Site name	Brief Description	Grid Reference
Sulphur Springs Camp		730 200E 7 659 250N
Finn's Camp		729 385E 7 660 288N
Site 1	Slope and valley of tailings dam	730 698E 7 659 818N
Site 2	Ridge and slope of dam wall	730 078E 7 660 184N
Site 3	Gorge near mine area	728 870E 7 659 929N
Site 4	Rocky hill in mine area	729 237E 7 659 881N
Site 5	Gravelly plain on Kangaroo Caves Road	732 348E 7 658 145N
Ghost Bat Cave and sighting of Rothschild's Rock Wallaby	In gorge near mine area	729 002E 7 659 607N
Bernt's Area		21 14 06S, 119 16 36E
Kangaroo Caves Area		21 12 37S, 119 15 09E
North end of Bypass Track		728 750E 7 661 920N
Lalla Rookh Mine	Abandoned mine on plain, with open vertical shafts	736 252E 7 670 378N
Sightings of Rothschild's Rock-Wallabies and several small caves with bats. Also eastern end of bird census areas along Creek Access Road	In gorge along Creek Access Road	727 730E 7 663 436N
Strelley Pool	Permanent waterhole on plain	722 164E 7 663 893N
Pebble-mound Mouse mound	On track to Strelley Pool	724 260E 7 665 202N
Pebble-mound Mouse mounds in this region	Plains Access Track	738 000E 7 673 000N to 740 000E 7 675 000N
Unconfirmed sighting of Spectacled Hare-Wallaby	On Plains Access Track	737 162E 7 672 416N
Unconfirmed sighting of Spectacled Hare-Wallaby	On Plains Access Track	739 289E 7 690 704N

APPENDIX TWO. Categories used in the assessment of conservation status.

Environmental Protection and Biodiversity Conservation Act and the WA Wildlife Conservation Act (categories from IUCN, based on review by Mace and Stuart (1994)).

Extinct. Taxa not definitely located in the wild during the past 50 years.

Extinct in the Wild. Taxa known to survive only in captivity.

Critically Endangered. Taxa facing an extremely high risk of extinction in the wild in the immediate future.

Endangered. Taxa facing a very high risk of extinction in the wild in the near future.

Vulnerable. Taxa facing a high risk of extinction in the wild in the medium-term future.

Near Threatened. Taxa that risk becoming Vulnerable in the wild.

Conservation Dependent. Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classed as Vulnerable or more severely threatened.

Data Deficient (Insufficiently Known). Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.

Least Concern. Taxa that are not Threatened.

WA Department of Conservation and Land Management Priority species (species not listed under the Conservation Act, but for which there is some concern).

Priority 1. Taxa with few, poorly known populations on threatened lands.

Priority 2. Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.

Priority 3. Taxa with several, poorly known populations, some on conservation lands.

Priority 4. Taxa in need of monitoring.

APPENDIX THREE: Annotated list of amphibians and reptiles observed in the Panorama Project Area during the survey periods 03/06/'01 – 11/06/'01 and 22/09/'01 to 29/09/'01.

- *Uperoleia russelli*

Along watercourses in project area, including Harp-trap Creek and the Creek Access Road, on both field trips. Calling in September. Caught in pitfalls in Site 3 in June and September.

Inland Tree-frog *Litoria rubella*

Harp Trap Creek, Creek Access Road and around Sulphur Springs Camp.

Clawless Gecko *Crenadactylus ocellatus*

Two under dead spinifex along Kangaroo Caves Road on 03/06/01. Six under dead spinifex on north end of Kangaroo Caves bypass track on 07/06/01. Two found by hand-searching under dead spinifex along Kangaroo Cave Road near Site 5 on 08/06/01. Seven found at Finn's Camp on 09/06/01 under dead spinifex. Not found in September.

Diplodactylus savagei

One in pitfall at Site 3 in September.

- *Diplodactylus elderi*

Three specimens found through hand-searching under dead Spinifex. One near north end of Kangaroo Caves bypass road on 07/06/01, and two along Kangaroo Caves Road near Site 5 on 08/06/01. Not found in September.

Tree Dtella *Gehyra variegata*

Several found amongst debris at Sulphur Springs Camp in both June and September. Also found under bark of dead tree near Site 5 (24/09/'01). Several specimens, suspected of being the similar *Gehyra pilbara*, were collected and confirmed by the WA Museum as being *G. variegata*.

Spotted Dtella *Gehyra punctata*

One seen head-torching at Site 2 on 04/06/01. Three found by head-torching at Site 3 on 05/06/01, one of which had a snout to vent length of 67 mm, just over the upper limit recorded for the species by Storr *et al.* (1990). Another very large specimen was caught near Site 3 while head-torching on 10/06/01. Several located in the buildings of the Sulphur Springs Camp. Not located while head-torching in September but one caught in pitfall in Site 4.

Bynoe's Gecko *Heteronotia binoei*

Several under dead spinifex along Kangaroo Caves Road on 03/06/01. One found spotlighting near Sulphur Springs Camp on 04/06/01. Ten found under dead spinifex while hand-searching under dead spinifex along the north end of Kangaroo Caves bypass road. Three found by hand-searching under dead spinifex along Kangaroo Cave Road near Site 5 on 08/06/01. Four found under dead spinifex at Finn's Camp on 09/06/01. Six caught in pitfalls at Site 1 in September.

Heteronotia spelea

One specimen caught in gorge near Site 3 while head-torching on 05/06/01 and one in pitfall at Site 4 in September.

Delma elegans

One in pitfall at Site 2 in September.

- *Delma nasuta*

One found under dead spinifex along the north end of Kangaroo Caves bypass road on 07/06/01. One found by hand-searching under dead spinifex along Kangaroo Cave Road near Site 5 on 08/06/01. One in pitfall at Site 5 in September.

Delma pax

One found under dead spinifex along the north end of Kangaroo Caves bypass road on 07/06/01. One found on 09/06/01 while hand-searching under dead spinifex at Finn's camp.

Burton's Legless-Lizard *Lialis burtonis*

One in pitfall at Site 3 (September).

Ring-tailed Dragon *Ctenophorus caudicinctus*

Numerous sightings along Kangaroo Caves Road near Site 5, and at Site 1. Also caught in pitfalls at Sites 1 and 5. One seen while searching along the north end of Kangaroo Caves bypass road on 07/06/01 and specimens seen regularly around Sulphur Springs Camp. Seen widely in September but none caught.

Long-nosed Water-Dragon *Gemmatophora (Lophognathus) longirostris*

Sightings at Sulphur Springs Camp and Site 3 on 05/06/01. One caught in a pit-trap at Site 3 on 08/06/01. All specimens seen and trapped in June were hatchlings, but adults were also seen in September at Sulphur Springs Camp, Harp-trap Creek, Creek Access Road, Lalla Rookh and Kangaroo Caves area.

Spiny-tailed Goanna *Varanus acanthurus*

One found at Sulphur Springs Camp under sheet metal, and one (hatchling) in a pit-trap at Site 4 on 11/06/'01. One in Elliott Trap at Site 4 in September.

Perentie *Varanus giganteus*

Two seen along Creek Access Road in September, and a third near Strelley Pool.

- *Carlia munda*

One specimen found by hand-searching under dead spinifex along Kangaroo Caves Road on 03/06/01. One in pitfall at Site 5 (September).

Fence Skink *Cryptoblepharus plagiocephalus*

One specimen found at Ghost Bat Cave near Site 3 (June). Specimens observed in rocky areas at Sites 2, 4 and along a rocky ridge near Site 5 (June and September).

- *Ctenotus saxatilis*

Regularly seen and caught in pitfall and Elliott Traps at Site 3 and 4. One caught in a pit at Site 5 on 11/06/01.

Ctenotus rubicundus

One in an Elliott Trap at Site 4 in September.

- *Cyclodomorphus melanops*

Five found while hand-searching along the north end of Kangaroo Caves bypass road on 07/06/01. Two found by hand-searching under dead spinifex near Site 5 on 08/06/01. Seven found under dead spinifex at Finn's Camp on 09/06/01. Also seen when hand-searching in September.

Egernia formosa

One in Elliott Trap at Site 3, September. Specimen collected to confirm identification with WA Museum.

- *Lerista muelleri*

Two found while hand-searching along the north end of the Bypass Track on 07/06/01.

- *Menetia surda*

One found while hand-searching along the north end of the Bypass Track on 07/06/01, and another under dead Spinifex at Finn's Camp on 09/06/01.

- *Morethia ruficauda*

One seen at Site 1 on 05/06/01 and another seen at Site 3 on 11/06/01. One specimen caught below caves at Site 5 on 07/06/01. One seen in gorge near Site 3 on 10/06/01. In September, caught in pitfalls at Sites 1, 3 and 4.

Notoscincus ornatus

Caught in pitfalls at Sites 1 and 5 in September. Colouration variable and in some cases intermediate between the races *N. o. ornatus* and *N. o. wotjulum*, so several specimens collected for WA Museum. Similarity of some specimens to the Kimberley *N. o. wotjulum* confirmed.

Proablepharus reginae

Three under dead Spinifex along Kangaroo Caves Road on 03/06/01. Six found under dead spinifex along north end of Bypass Track on 07/06/01. One found by hand-searching under dead spinifex along Kangaroo Cave Road near Site 5 on 08/06/01. One found under dead Spinifex at Finn's Camp on 09/06/01. Three in pitfalls at Site 3 in September. Note that a number of the specimens had orange-red tails in June but not in September.

Pygmy Python *Antaresia perthensis*

A sloughed skin, probably of this species, amongst rocks along Creek Access Road, and one found during spotlighting along Plains Access Road between Lalla Rookh and the Creek Access Road, both in September.

Rufous Whip-Snake *Demansia rufescens*

One caught in pitfall at site 2 in September.

APPENDIX FOUR. Annotated list of birds observed in the Panorama Project Area during the survey period 03/06/'01 – 11/06/'01 and 22/09/'01 to 29/09/'01.

Brown Quail *Coturnix ypsilophora*
Possible sighting in Kangaroo Caves Area on 08/06/01 and an adult bird with young at Strelley Pool on 28/09/'01.

Pacific Black Duck *Anas superciliosus*
Two birds were regularly seen along flooded sections of the Creek Access Track during the September field trip, and a pair with 5 ducklings on honeyeater Creek on 25/09/'01.

Darter *Anhinga melanogaster*
One perched beside pool on Honeyeater Creek (25/09/'01) and one beside Strelley Pool (28/09/'01).

Little Pied Cormorant *Phalacrocorax melanoleucos*
One seen on several occasions along Creek Access Track in September, one beside pool on Honeyeater Creek (25/09/'01) and one beside Strelley Pool (28/09/'01).

Little Black Cormorant *Phalacrocorax sulcirostris*
One seen along Creek Access Track (23/09/'01), one beside pool on Honeyeater Creek (25/09/'01) and 15 on Strelley Pool (28/09/'01).

Australian Pelican *Pelecanus conspicillatus*
One on pool on Honeyeater Creek (25/09/'01) and 8 on Strelley Pool (28/09/'01).

White-faced Heron *Egretta novaehollandiae*
Two birds flying over Sulphur Springs Camp on 04/06/01. Two had also been seen flying over the Plains Access Road on 02/06/01. Two birds were regularly seen along flooded sections of the Creek Access Track during the September field trip.

White-necked Heron *Ardea pacifica*
One beside pool on Honeyeater Creek (25/09/'01).

Great Egret *Ardea alba*
One beside pool on Honeyeater Creek (25/09/'01) and one beside Strelley Pool (28/09/'01).

Nankeen Night Heron *Nycticorax caledonicus*
One at night on Harp-trap Creek on 07/06/01, and one on Honeyeater Creek near the Bernt's Area on 08/06/01. In September, one on Honeyeater Creek (25/09/'01) and one of Creek Access Track (28/09/'01).

Straw-necked Ibis *Threskiornis spinicollis*
Five foraging around pool on honeyeater Creek on 25/09/'01.

Black-necked Stork (Jabiru) *Ephippiorhynchus asiaticus*
One flying over Honeyeater Creek on 25/09/'01.

Black-shouldered Kite *Elanus notatus*
Several over the Plains Access Road (02/06/01), and one bird near Site 5 on 10-11/06/01. One seen over Harp Trap Creek on 26/09/'01.

Whistling Kite *Haliastur sphenurus*
One over Harp-trap Creek on 10/06/01, and several over Plains Access Road (02/06/01 and 11/06/01). In September, only one sighting, over Site 5 on 23/09/'01, but dozens were present around a fire along the Hedland to Marble Bar Road on 29/09/'01.

Spotted Harrier *Circus assimilis*
Several on the Plains Access Road on 02/06/01 and one over Lalla Rookh on 27/09/'01.

Brown Goshawk *Accipiter fasciatus*
An immature bird over Site 5 on 08/06/01, and one over Sulphur Springs Camp on 09/06/01. A pair seen over the north end of the Bypass Track on 11/06/01.

Collared Sparrowhawk *Accipiter cirrhocephalus*
One female on Harp-trap Creek on 08/06/01, and one in Kangaroo Caves area on 08/06/01. An adult male seen along Harp-trap Creek on 24/09/'01.

Wedge-tailed Eagle *Aquila audax*
One on Plains Access Road on 04/06/01. A single bird and a pair seen over Site 4 (08/06/01). A single bird over Site 5 on 26/09/'01.

Little Eagle *Heiratus morphnoides*
One bird near north end of Bypass Track on 11/06/01, and one near Lalla Rookh Mine on 11/06/01. In September, one over Lalla Rookh Mine on 29/09/'01.

Brown Falcon *Falco berigora*
One over Finn's Camp on 03/06/01. In September, pair on nest above Creek Access Track and a single bird seen over Lalla Rookh Mine on 22/09/'01.

Nankeen Kestrel *Falco cenchroides*
Several seen on Plains Access Road in June and September. One over Site 4 on 06/06/01, a pair over Sulphur Springs Camp on 08/06/01 and one over Lalla Rookh Mine on 22/09/'01.

Little Button-quail *Turnix velox*
Numerous in all areas but especially in gravelly loam soils; many foraging platelets.

Australian Bustard *Ardeotis australis*
One bird on access road on the plain (02/06/01).

Bush Stone-Curlew *Burhinus grallarius*
Three birds at Sulphur Springs Camp on 03/06/01 and possibly same birds seen at Camp throughout the period of 03-10/06/01. At least one bird left tracks near Site 5 08/06/01. Three birds on Plains Access Road while spotlighting on 09/06/01. At least two birds around Sulphur Springs Camp in September, one near Lalla Rookh Mine on 22/09/'01 and several calling around Honeyeater Creek on evening of 25/09/'01.

Black-fronted Dotterel *Elseyornis melanops*
Approximately 10 birds on Creek Access Road near water in both June and September. Also heard flying overhead at night at Sulphur Springs Camp during both field trips. One bird seen on Harp-trap creek near Site 1 on 09/06/01 and about 10 around pools on Honeyeater Creek on 25/09/'01, including at least one chick.

Peaceful Dove *Geopelia placida*
Several around Honeyeater Creek on 25/09/'01.

Common Bronzewing *Phaps chalcoptera*
Regularly seen in singles and in pairs in the Sulphur Springs Area (including the camp) particularly near water.

Crested Pigeon *Ocyphaps lophotes*
Seen along Plains Access Road (02/06/01 and 11/06/01). Not seen in September.

Spinifex Pigeon *Geophaps plumifera*
Widespread and in groups of 2-15. Found particularly in rocky areas.

Diamond Dove *Geopelia cuneata*
In small groups in all areas, especially along Harp Trap Creek.

Galah *Cacatua rosiecapilla*
Flock of 10 at Site 1 on 05/06/01 and 2 birds at Site 5 (09/06/01). Seen more regularly in September, with groups of 2-3 birds seen most days.

Little Corella *Cacatua sanguinea*
Present around Honeyeater Creek (25/09/'01) and about 30 around Strelley Pool on 28/09/'01.

Cockatiel *Nymphicus hollandicus*
A few birds along the Plains Access Road on 04/06/01. A flock of approximately 10 at Site 2 on 05/06/01 and 1 over Sulphur Springs Camp on 09/06/01. Flock of approximately 5 seen over Honeyeater Creek on 29/09/'01.

Budgerigar *Melopsittacus undulatus*
Small flocks over Sulphur Springs Camp on 04/06/01 and 10/06/01. Larger flocks in the low 100s over Plains Access Road (02/06/01).

Australian Ringneck *Barnadius zonarius*
Two birds near Site 5 on 05/06/01.

Pallid Cuckoo *Cuculus pallidus*
One heard near Bernt's area on 08/06/01. In September, heard around Sulphur Springs Camp (23/09/'01) and in Kangaroo Caves area (25/09/'01).

Horsfield's Bronze-Cuckoo *Chrysococcyx basalis*
Unconfirmed sighting near Site 5 in June, but one calling near Sulphur Springs Camp and near Site 1 on 26/09/'01.

Pheasant Coucal *Centropus phasianinus*
One along Plains Access Road on 02/06/01 and one at north end of Bypass Track on 07/06/01. Seen and heard regularly in September with birds in breeding plumage. Recorded at Lalla Rookh, Harp-trap Creek, Creek Access Track, in the Kangaroo Caves area along a watercourse and along Honeyeater Creek.

Southern Boobook Owl *Ninox novaeseelandiae*
One heard on Honeyeater Creek on 08/06/01 and also heard there on 25/09/'01. Several seen along Plains Access Track when spotlighting in September.

Tawny Frogmouth *Podargus strigoides*
One road-killed on the Plains Access Road on 02/06/01. One near Sulphur Springs Camp (spot-lit at night) on 05/06/01. Several seen during spotlighting in September, including at Harp-trap Creek and along the Creek Access Track.

Australian Owlet-nightjar *Aegotheles cristatus*
One bird near Sulphur Springs Camp while spotlighting on 04/06/01. One near Lalla Rookh on 22/09/'01 and one calling around Sulphur Springs Camp on 23/09/'01.

Spotted Nightjar *Eurostopodus argus*
One bird on track near Site 1 on both 03-04/06/01 and 05/06/01 (Spot-lit at night). Several birds in both Kangaroo Caves and Bernt's Areas when spotlighting on 08/06/01, and along Plains Access Road when spotlighting (09/06/01). Also seen regularly when spotlighting in September. A lot of birds calling just after sunset and sometimes before dawn around Lalla Rookh Mine, with smaller numbers calling around Sulphur Spring Camp.

Blue-winged Kookaburra *Dacelo leachii*
Calling near Honeyeater Creek (near Bernt's area) on 08/06/01. One bird seen along Creek Access Road on both 04/06/01 and 09/06/01, and heard at Harp Trap Creek (07/06/01). In September, also seen and heard along Honeyeater Creek, Creek Access Track, Harp-track Creek and around Lalla Rookh Mine.

Red-backed Kingfisher *Todiramphus pyrrhopygia*
One bird along Plains Access Road on 04/06/01. A pair around Sulphur Springs Camp daily. Seen around Lalla Rookh Mine in September.

Sacred Kingfisher *Todiramphus sanctus*
A single bird along Creek Access Track on 23/09/'01, and a pair at Honeyeater Creek on 25/09/'01.

Rainbow Bee-eater *Merops ornatus*
Some near Lalla Rookh Mine on 04/06/01. Approximately 10 birds over Creek Access Road on 09/06/01 and 3 on 11/06/01. A small group over Harp Trap Creek near Site 1 on 10/06/01. In September, seen regularly and breeding in bank along Creek Access Track.

Variegated Fairy-wren *Malurus lamberti*
One group seen on Harp Trap Creek near Site 1 (08/06/01), and another group on the northern end of the Bypass Road (08/06/01). Seen at same locations in September, but also seen in dense riparian vegetation along Creek Access Track and in Kangaroo Caves Area.

Rufous-crowned Emu-wren *Stipiturus ruficeps*
Pair seen on Plains Access Track near the Hedland to Marble Bar Road (22/09/'01), and a small party seen where the Creek Access Track enters the hills on 23/09/'01.

Striated Grasswren *Amytornis striatus*
Scattered parties throughout the Sulphur Springs Area. Heard and fleetingly seen frequently at Sulphur Springs Camp, Site 2, Site 3 and a nest was found on a rocky hill near Site 5. Heard and seen regularly in September, with the birds more vocal and conspicuous than in June.

Western Gerygone *Gerygone fusca*
One bird along Creek Access Road on 09/06/01, and one near Site 5 on 10/06/01.

Red-browed Pardalote *Pardalotus rubricatus*
One calling in creek-line in Sulphur Springs Camp on 04/06/01 and several days thereafter. One seen at Site 4 (09/06/01). Heard regularly in September, particularly from eucalypts along Creek Access Track.

Striated Pardalote *Pardalotus striatus*
Several calling in Sulphur Springs Area on a regular basis (including Camp and Site 4). Some calling at Finn's Camp on 03/06/01. Not observed in September.

Weebill *Smicrornis brevirostris*
Small party seen in eucalypts along Honeyeater Creek on 29/09/'01.

Yellow-throated Miner *Manorina flavigula*
Parties of 6-10 birds at Finn's Camp, Sulphur Springs Camp, Site 1 and Site 2 in June. Present at Bernt's Area on 08/06/01. Seen around Sulphur Springs Camp and Site 3 in September.

Singing Honeyeater *Lichenostomus virescens*
Several at Lalla Rookh Mine on 23/09/'01 and 27/09/'01.

Grey-headed Honeyeater *Lichenostomus keartlandi*
Widespread and common at all sites and areas in both field trips, particularly in concentrations of flowering eucalypt, grevillea and hakea species.

Black-chinned Honeyeater *Melithreptus gularis*
Small groups on several occasions along Harp Trap Creek near Site 1, and in Sulphur Springs Camp on both field trips, and also along Creek Access Track in September.

Brown Honeyeater *Lichmera indistincta*
Numerous at Sulphur Springs Camp and generally abundant along watercourses.

White-plumed Honeyeater *Lichenostomus penicillatus*
Along watercourses including Harp Trap Creek, Creek Access Road, Honeyeater Creek and Strelley Pool.

Pied Honeyeater *Certhionyx variegatus*
One or two birds at Sulphur Springs Camp on 03/06/01 and small numbers on spinifex plain along Kangaroo Caves Road on 04/06/01.

Crimson Chat *Epthianura tricolor*
Some along Plains Access Road near the Headland to Marble Bar Road on 02/06/01 but not in main Project Area and not in September.

Crested Bellbird *Oreoica gutturalis*
Heard at Sites 1 and 5 most days in June; in September heard near Site 2 (23/09/'01) and near Sulphur Springs Camp (24/09/'01).

Rufous Whistler *Pachycephala rufiventris*
One bird along Bypass Track on 04/06/01 and one along Creek Access Road on 09/06/01. One seen around Sulphur Springs camp most days in September.

Grey Shrike-thrush *Colluricincla harmonica*
Throughout all areas, mainly along creek-lines.

Australian Magpie-lark *Grallina cyanoleuca*
Pairs and small groups, particularly around Sulphur Springs Area and near water on the Creek Access Road.

Willie Wagtail *Rhipidura leucophrys*
Single birds and pairs throughout Sulphur Springs Area; also in Kangaroo Caves and Bernt's Areas.

Black-faced Cuckoo-shrike *Coracina novaehollandiae*
Pairs seen occasionally throughout, including along Creek Access Road.

White-winged Triller *Lalage sueurii*
Two birds along Bypass Track on 04/06/01 and near Finn's Camp on 05/06/01. Parties of up to 10 around Site 5. Also in Kangaroo Caves and Bernt's Areas in June. In September, seen only in burnt area along Plains Access Track north of Lalla Rookh Mine (22/09/'01) and near Honeyeater Creek (25/09/'01)..

Black-faced Woodswallow *Artamus cinereus*
Throughout Sulphur Springs Area in parties of 4-6. Also in Kangaroo Caves and Bernt's Areas.

Little Woodswallow *Artamus minor*
In small parties of 2-5 mostly above rocky hills in Sulphur Springs, Kangaroo Caves and Bernt's areas.

Pied Butcherbird *Cracticus nigrogularis*
Widespread in Project Area, including Kangaroo Caves and Bernt's Areas.

Australian Magpie *Gymnorhina tibicen*
Most sightings along the Plains Access Track in both field trips.

Torresian Crow *Corvus orru*
Parties of 2-4 in all areas. Seemed more abundant in June than in September.

Western Bowerbird *Clamydera guttata*
Party of birds (5-10) around Site 3 in gorge on 04/06/01 and 10/06/01, and seen in this area daily in September. Occasional elsewhere and typically associated with Rock Figs growing on steep slopes of gorges.

Painted Firetail *Emblema picta*
Widespread and common throughout. Nest with chicks found near Strelley Pool (28/09/'01).

Zebra Finch *Taeniopygia guttata*
Small parties (4-5) along Bypass Track on 04/06/01 and 07/06/01. Some in Kangaroo Caves area (08/06/01) and a group of 10 at Site 5 on 10/06/01. Seen only along Plains Access Track north of Lalla Rookh Mine in September.

Mistletoebird *Dicaeum hirundinaceum*
Heard at Sulphur Springs Camp and at Kangaroo Caves Area in June, and one in Kangaroo Caves Area in September.

Tree Martin *Hirundo nigricans*
Two near Site 5 on 10/06/01 and two over Sulphur Springs Camp on 26/09/'01. The similar Fairy Martin *Hirundo ariel* was seen only along the Hedland to Marble Bar Road but some old nests of this species were found in caves within the Project Area.

Spinifexbird *Eremiornis carteri*
Heard at Kangaroo Caves Area and seen at Bernt's Area on 08/06/01. Much more conspicuous in September, when birds calling at all sites.

Brown Songlark *Cincloramphus cruralis*
One bird near Lalla Rookh on 11/06/01 and one near Site 3 on 24/09/'01.

APPENDIX FIVE: Annotated list of mammals observed in the Panorama Project Area during the survey period 02/06/01 to 11/06/01 and 22/09/'01 to 29/09/'01.

Pilbara Ningaui *Ningaui timealeyi*
Caught in pitfall traps at Sites 1, 2, 4 and 5. Females with small pouch young in September. One seen on Creek Access Track during spotlighting on 22/09/'01.

Planigale *Planigale* sp.
Caught only in June, with a female in a pit-trap at Site 5, and a male in a pit-trap at Site 2 on 09/06/01, and a male caught in a pit-trap at Site 1 on 10/06/01. The female was not in breeding condition. Probably *Planigale maculata* as this is the only species of planigale recorded from the Pilbara, but identification yet to be confirmed by the WA Museum.

Northern Quoll *Dasyurus hallucatus*
Caught in cage and Elliott Traps at Sites 2, 3 and 4, and at Sulphur Springs Camp. Females with pouch young in September. One animal seen drinking from Harp-trap Creek at night, and tracks abundant around pools along Creek Access Track. Road-killed specimen near Lalla Rookh Mine on 22/09/'01.

Euro *Macropus robustus*
Common and widespread in the Sulphur Springs, Kangaroo Caves and Bernt's Areas, and also around Lalla Rookh Mine.

Rothschild's Rock-Wallaby *Petrogale rothschildi*
Common in gorge at Site 3 and along Creek Access Track, with four seen in one afternoon when searching caves for bats (25/09/'01). One in cage trap at Site 3 on 24/09/'01.

Spectacled Hare-Wallaby *Lagorchestes conspicillatus*
Unconfirmed sightings by M. Trudgeon along Plain Access Road at 737 162E, 7 672 416N and 739 289E, 7 690 704N, on 20th October 2001. Sightings in unburnt spinifex in an area where the branches of the Shaw River may break up fires, creating a mosaic of burnt and unburnt habitat.

Ghost Bat *Megaderma gigas*
In June, one found roosting in a cave just south of mine area on 10/06/01 and specimens seen flying near Bernt's Area on 08/06/01 and near Lalla Rookh Mine (09/06/01). In September, the cave near the mine area was empty, but a single bat was found roosting in a cave near Site 5 on 27/09/'01, while 163 emerged from an old mine shaft at Lalla Rookh Mine on the evening of 27/09/'01. These included juveniles calling after adults and later waiting near the cave entrance for the adults to return. The mine shaft is a rough, elongated working that slopes steeply into the ground rather than one of the more conspicuous, modern shafts in the area. This observation suggests that the shaft contains a maternity colony and it is one of the biggest reported from the Pilbara.

Orange Leaf-nose Bat *Rhinonicteris aurantius*
Possible sighting on 08/06/01 while spot-lighting near Kangaroo Caves Area, and a possible sighting (727 835E, 7664 423N) on Creek Access Road while spotlighting on 09/06/01. Also a possible sighting near Lalla Rookh Mine on 27/09/'01. Recordings of ultra-sonic calls made during these sightings, however, did not appear to be those of the Orange Leaf-nose Bat. The species is reported to often use roosts favoured by Ghost Bats, as the two have similar requirements of temperature and humidity, so it is likely that Orange Leaf-nose Bats are present in Lalla Rookh Mine.

Common Sheathtail Bat *Taphazous georgianus*
Found regularly in small caves and crevices around Site 3, in ridge near Site 5 and along the Creek Access Track. Large numbers (>100?) emerged from a mine shaft at Lalla Rookh Mine in evening of 09/06/01, and smaller numbers emerged from the Ghost Bat Mine Shaft on 27/09/'01.

White-striped Bat *Nyctinemus (Tadarida) australis*
Heard overhead at night at Sulphur Springs Camp and Harp Trap Creek regularly in June, but rarely in September.

- *Vespadelus (Eptesicus) finlaysoni*
Calls of this species recorded at Lalla Rookh Mine (09/06/01). Found roosting in small caves along Creek Access Track (25/09/'01) and several emerged from the Ghost Bat Mine Shaft on 27/09/'01.

Pseudomys delicatulus
Single specimens at Site 1 and 5 in September.

- *Pseudomys desertor*
Three females caught in June at Sites 1 and 5 were lactating. In contrast, specimens caught at Sites 1 and 3 in September were sexually inactive males and females.

Common Rock-Rat *Zyzomys argurus*
Recorded at Sites 1 and 4 in June and Sites 1, 2 and 4 in September. Sexually active specimens only in September.

House Mouse *Mus musculus*
Recorded only in September, with five specimens at Site 1 and four at Site 2.

Dingo *Canis lupus dingo*
Fresh tracks seen regularly wherever soft soil was present.

Feral Cat *Felis catus*
Fresh tracks along Creek Access Road on 09/06/01.

Camel *Camelus dromedarius*
Fresh tracks seen on Plains Access Road on 02/06/01 and 11/06/01, and in September. Fresh track and droppings near Sulphur Springs camp on 23/09/'01.

Donkey *Equus asinus*
Weathered droppings believed to be from a Donkey along Bypass Track (05/06/01).

APPENDIX SIX. Capture records and morphometric data for all frog, reptile and mammal captures in the trapping grids in the Panorama Project Area for the period 06/06/01 – 11/06/01.

Column abbreviations are:
Wt = Weight (g); Crn = Crown (mm); TL = Tail length (mm); HB = head and body length (mm); Pes = Pes length (mm); GW = Gonad Width (mm); SVL = Snout to vent length (mm); Tot = total length (mm).
A number in parenthesis in the 'notes' column is the number with which the specimen was marked (ear-punch, mammals only). An "R" alongside this number indicates that the specimen was a recapture. py = pouch young; npy = no pouch young; vc = vagina closed; vp = vagina perforate; lac = lactating; preg = pregnant. An MJB number indicates that the specimen was collected and lodged with the WA Museum.

A. REPTILES AND AMPHIBIANS – June.

Date	Species	Site No.	Trap Type	SVL	Tot	Notes
07/06	*Ctenophorus caudicinctus*	1	pit 4	32	97	
07/06	*C. caudicinctus*	5	pit 4	39	98	MJB 200
08/06	*Gemmatophora longirostris*	3	pit 4	31	70	MJB 204
09/06	*C. caudicinctus*	1	pit 7	37	110	
09/06	*Ctenotus saxatilis*	3	pit 5			
09/06	*C. saxatilis*	3	ell 5			
10/06	*C. saxatilis*	3	pit 7			
10/06	*Uperoleia russelli*	3	pit 6			
10/06	*U. russelli*	3	pit 6			
11/06	*C. caudicinctus*	1	pit 4	33	98	
11/06	*U. russelli*	3	pit 6			
11/06	*U. russelli*	3	pit 6			
11/06	*Varanus acanthurus*	4	pit 1			hatchling
11/06	*C. saxatilis*	5	pit 6			

B. MAMMALS – June.

Date	Species	Site No.	Trap type	Wt	Crn	TL	HB	Pes	GW	Sex	Notes
07/06	*Ningaui timealeyi*	1	pit 6	4.0	20.9	60	55		6.3	M	MJB 201
07/06	*Dasyurus hallucatus*	2	cg 9	600	84.0			47	23.6	M	(1)
07/06	*D. hallucatus*	3	cg 4	550	66.1			40.8		F	(2) npy
08/06	*Zyzomys argurus*	1	pit 6	20.0	32.0	105				F	MJB 203 white patch on back
08/06	*D. hallucatus*	4	ell 5								(1)
08/06	*Z. argurus*	4	pit 1	26.0	31.6	105				M	flaccid scrotum
08/06	*Z. argurus*	4	?	30.5	33.0	105				F	vc
08/06	*Pseudomys desertor*	5	ell 10	25.5	28.3	85		21		F	(1) preg
09/06	*Planigale* sp.	2	pit 9	6.0	21.1				7.5	M	MJB 211
09/06	*D. hallucatus*	2	cg 10	600						M	(2)
09/06	*D. hallucatus*	3	ell 1	540						F	(2) npy
09/06	*D. hallucatus*	3	cg 2	420						F	(3) npy
09/06	*D. hallucatus*	3	cg 4	500						M	(4)
09/06	*Z. argurus*	4	pit 4							F	(1) lac
09/06	*Z. argurus*	4	pit 10								
09/06	*P. desertor*	5	ell 1	21.5	28.3	85		21		F	(R1) preg
09/06	*planigale*	5	pit 1	4.5	21.6					F	Npy MJB 210
10/06	*Z. argurus*	1	ell 1	37.0	33.2					F	(1) vp lac
10/06	*N. timealeyi*	1	pit 3	6.0	20.0					F	(1) npy
10/06	*Planigale*	1	pit 9	6.0	20.2				7.6	M	
10/06	*P. desertor*	1	ell 2	27.0	29.0					F	(1) vp lac
10/06	*N. timealeyi*	2	pit 4								
10/06	*Z. argurus*	4	ell 7								(3)
10/06	*P. desertor*	5	ell 7	32.0	29.2					F	(2) vp lac
11/06	*D. hallucatus*	3	ell 4							F	(R2)
11/06	*D. hallucatus*	3	cg							F	(R3)
11/06	*D. hallucatus*	4	cg 1								(R1)
11/06	*Z. argurus*	4	pit 7								
11/06	*N. timealeyi*	5	pit 9	6.0	22.5				7.7	M	(1)

APPENDIX SEVEN. Capture records and morphometric data for all frog, reptile and mammal captures in the trapping grids in the Panorama Project Area for the period 22/09/01 – 27/09/01 for Sites 1, 2 and 3, and 23/09/01 – 27/09/01 for Sites 4 and 5.

Column abbreviations are:
Wt = Weight (g); Crn = Crown (mm); TL = Tail length (mm); GW = Gonad Width (mm); SVL = Snout to vent length (mm); Tot = total length (mm).
A number in parenthesis in the 'notes' column is the number with which the specimen was marked (ear-punch, mammals only). An "R" alongside this number indicates that the specimen was a recapture. py = pouch young; npy = no pouch young; vc = vagina closed; vp = vagina perforate; lac = lactating; preg = pregnant. An MJB number indicates that the specimen was collected and lodged with the WA Museum.

A. REPTILES AND AMPHIBIANS – September.

Date	Species	Site No.	Trap Type	SVL	Tot	Notes
24/09	*Uperolea russelli*	3	Pit 6	27		
25/09	*Morethia ruficauda*	1	Pit 4			
25/09	*Heteronotia binoei*	1	Pit 4	38	53	
25/09	*H. binoei*	1	Pit 5	41	84	
25/09	*H. binoei*	1	Pit 5	36	82	
25/09	*Notoscincus ornatus*	1	Pit 5	34	87	MJB 216
25/09	*Egernia formosa*	3	Ell 4	95	240	MJB 215, wt: 25
25/09	*Ctenotus saxatilis*	3	Ell 6	83	237	
25/09	*Lialis burtonis*	3	Pit 8	145	220	
25/09	*C. saxatilis*	4	Ell 9	95	233	
25/09	*Varanus acanthurus*	4	Ell 1	120	325	Wt: 25, male
25/09	*Proablepharus reginae*	5	Pit 1	28	88	
25/09	*P. reginae*	5	Pit 7	29	88	
25/09	*Delma nasuta*	5	Pit 10	96	280	Tail recently dropped
26/09	*H. binoei*	1	Pit 8	40	86	
26/09	*Demansia rufescens*	2	Pit 8		58	
26/09	*C. saxatilis*	3	Pit 6	87	285	
26/09	*C. saxatilis*	3	Pit 5	90	277	
26/09	*C. saxatilis*	3	Pit 4			
26/09	*Heteronotia spelea*	4	Pit 4	55	120	MJB 218, female
26/09	*N. ornatus*	5	Pit 1	30	84	
26/09	*N. ornatus*	5	Pit 3	32	78	MJB 217
26/09	*Carlia munda*	5	Pit 7	34		
26/09	*P. reginae*	5	Pit 9	31	100	
27/09	*M. ruficauda*	3	Pit 9	38	70	Gravid female
27/09	*Diplodactylus savagei*	3	Pit 8	34	48	
27/09	*C. saxatilis*	3	Ell 3			
27/09	*Ctenotus rubicundus*	4	Ell 10	82	176	
27/09	*Gehyra punctata*	4	Pit 7	40	75	MJB 219

(Reptiles and amphibians cont.)

Date	Species	Site No.	Trap Type	SVL	Tot	Notes
28/09	*H. binoei*	1	Pit 1			
28/09	*H. binoei*	1	Pit 1			
28/09	*M. ruficauda*	1	Pit 1			
28/09	*Delma elegans*	2	Pit 3			MJB 220
28/09	*C. saxatilis*	3	Pit 8			
28/09	*C. saxatilis*	3	Ell 4			
28/09	*M. ruficauda*	4	Pit 7			

B. MAMMALS – September.

Date	Species	Site No.	Trap type	Wt	Crn	GW	Sex	Notes
23/09	*Pseudomys desertor*	2	Pit 8	16.0	27.8		F	(4) vc, lost tail
23/09	*Zyzomys argurus*	2	Pit 10		34.2		F	vp, tail damaged
23/09	*Mus musculus*	2	Ell 5	12.0		7.0	M	
24/09	*M. musculus*	1	Pit 4				F	MJB 214
24/09	*Ningaui timealeyi*	1	Pit 8		19.9		F	(16) 5py
24/09	*P. desertor*	2	Ell 7	18.0	28.5		F	(17), vc, half tail missing
24/09	*M. musculus*	2	Pit 9				F	MJB 213, vc
24/09	*Petrogale rothschildi*	3	Cage				M	
24/09	*Z. argurus*	4	Pit 10	31	33.6		M	(16)
24/09	*Z. argurus*	4	Ell 10	50	34.5		F	(17) vp
24/09	*N. timealeyi*	4	Pit 7	9.5	22.4	8.4	M	(16)
24/09	*Dasyurus hallucatus*	4	Ell 5					(16)
24/09	*D. hallucatus*	4	Ell 3				F	4 small py
24/09	*Pseudomys delicatulus*	5	Pit 9	8.6			F	MJB 212 vp
25/09	*M. musculus*	1	Pit 3		22.0		M	
25/09	*P. desertor*	1	Ell 3	29.0	29.8		M	(16)
25/09	*N. timealeyi*	1	Pit 7	7.0	21.2	7.6	M	(17)
25/09	*N. timealeyi*	1	Pit 7	5.0	19.4		F	(18) 2 small py
25/09	*M. musculus*	2	Ell 6		20.8		F	(17) vc
25/09	*D. hallucatus*	3	Ell 7	570	75.0	21.7	M	(16) regurgitated a *C. saxatilis*
25/09	*D. hallucatus*	3	Cage	510	79.0	22.8	M	(17)
25/09	*D. hallucatus*	3	Cage	360			F	(R2) 3 small py
25/09	*D. hallucatus*	4	Ell 7	390	71.5		F	(2B) 2 small py
25/09	*D. hallucatus*	4	Ell 6	560		19.0	M	(R16)
25/09	*D. hallucatus*	4	Ell 2	290			F	(R1) 7 small py
26/09	*Z. argurus*	1	Pit 1		33.3		F	(16) vp
26/09	*M. musculus*	1	Ell 2	8.0			F	vp
26/09	*M. musculus*	1	Ell 5	10.0	22.5		M	(4)
26/09	*N. timealeyi*	1	Pit 6				F	(R18) 1 py – lost one?
26/09	*N. timealeyi*	2	Pit 2				F	(16) npy

(Mammals cont.)

Date	Species	Site No.	Trap type	Wt	Crn	GW	Sex	Notes
26/09	*D. hallucatus*	3	Cage	425	70.0			(R2)
26/09	*D. hallucatus*	3	Cage	480	75.0	24.0	M	(18)
26/09	*D. hallucatus*	4	Ell 10	420	74.2	22.0	M	(17)
26/09	*Z. argurus*	4	Pit 8	36.0	34.5	14.5	M	(18)
26/09	*D. hallucatus*	4	Ell 5		69.5		F	(2a) 6 py
26/09	*D. hallucatus*	4	Ell 3	520		20.0	M	(R16)
26/09	*D. hallucatus*	4	Ell 3		65.0		F	(R1) 7 py
26/09	*N. timealeyi*	5		5.5	19.8		F	(16) npy but active pouch
27/09	*M. musculus*	1	Ell 2	8.5				
27/09	*P. desertor*	1	Pit 6	22.5		11.8		(17)
27/09	*P. delicatus*	1	Ell 10					escaped
27/09	*N. timealeyi*	2	Pit 2		20.9		F	(R16) npy
27/09	*D. hallucatus*	3	Cage					(R2)
27/09	*D. hallucatus*	3	Cage					(R18)
28/09	*N. timealeyi*	2	Pit 1					(R16)
28/09	*M. musculus*	2	Pit 10					
28/09	*D. hallucatus*	3	Cage	480		17.3	M	(R18)
28/09	*D. hallucatus*	4	Ell 7	310			F	(R2a) 6 py
28/09	*D. hallucatus*	4	Ell 1	360	68.2		F	New animal. 7 py
28/09	*N. timealeyi*	5	Pit 6					

BIOta Biota Environmental Sciences

Panorama Project: Mine Site and Haul Road Corridor Targeted Fauna Survey




Prepared for

CBH Resources

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