Wingellina Nickel Project

Pilot Stygofauna Survey

July 2008

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Executive Summary

Outback Ecology was commissioned by Metals X Limited to conduct a stygofauna (subterranean fauna) survey of the Wingellina Nickel Project, within exploration tenement E69/535, in Western Australia. The stygofauna survey was one component of a broader study undertaken concurrently by Outback Ecology, including the assessment of vegetation and flora, terrestrial fauna, soils, and waste materials within the project area.

The project area is approximately 8 km south-west of Surveyor Generals Corner, within the Wingellina Hills, which lie to the north of the Musgrave Ranges in the Ngaanyatjarra Lands Indigenous Protected Area. The project area lies within the Mann-Musgrave subregion of the Central Ranges bioregion.

A comprehensive list of bores was provided by the client but, on inspection, few were found suitable for the collection of stygofauna. As a result, only 12 bores were sampled during the April 2008 survey. Bores were classified as control or impact according to their location within the proposed project layout. At the time of sampling, the control bores were those located in areas that would not be affected by the mining activities, while impact bores were in areas where the aquifer, and therefore the stygofauna habitat, would be affected by the project. Of the 12 bores, three were designated as control bores, with the remainder classified as impact bores.

A slight variation of the groundwater physicochemical parameters was observed between the bores during April 2008. The pH of the groundwater was found to range from circum-neutral to alkaline (6.81 – 8.72). Salinity, measured as electrical conductivity, was considered fresh with the majority of the bores with groundwater less than 3 500 µS/cm. The dissolved oxygen (DO) of the groundwater was low, ranging from 0.7 to 4.74 ppm, which is often the case with deep aquifers. The temperature of the groundwater was consistent ranging from 25 to 28 °C. Overall, the aquifer appeared fairly homogenous in terms of water quality with the greatest variability observed in the groundwater from Inco Bore. This bores is located at the town rubbish disposal area and the elevated salinity, high pH (alkalinity) and low DO, despite the SWL being much higher than the other bores, may have been the result of nutrient enrichment.

A total of 12 invertebrate taxa were identified in the survey, with only two of the 12 bores that did not yield any specimens. Taxa from four different phyla; Arthropoda, Annelida, Nematoda and Rotifera, were identified, the greatest diversity displayed within the Arthropoda. While the phyla recorded were consistent with those found in other stygofauna communities in Western Australia, the specimens collected from Wingellina were not *stygobitic* (true stygofauna), the exception being the copepod nauplius. The invertebrates collected were either terrestrial forms that ended up in the groundwater, or they were *stygoxenes*, invertebrates that live in both surface and groundwater. Stygoxenes are not obligate subterranean fauna (stygobites) and do not rely on subterranean habitats for their survival. The Acarina, Collembola and larval dipterans were all stygoxenes collected from Wingellina in April 2008.

While diversity and abundance was low, stygofauna were present in the Wingellina groundwater. Identification to species level was not possible for the majority of the specimens collected. Rotifera and Nematoda identifications were limited to phylum due to the lack of taxonomic keys available. This limitation has been recognised and accepted by the EPA. The Oligochaete, Enchytraeidae, is found in subterranean waters throughout the Pilbara, but in the absence of reliable keys, identification is limited to the family level. The only group with sufficient taxonomic resources was the copepod. Only one specimen was collected and was at naupliar stage. It was therefore too young to display distinct morphological characteristics needed for identification. It must be noted that the Copepod was collected at the Inco bore which is located at the current Wingellina refuse facility. The presence of the Copepod may be the result of a modified environment with nutrient enrichment.

In terms of the objectives stated for this survey:

- *In situ* physicochemical groundwater data were collected for 12 bores. This survey found that many of the exploration bores had collapsed and only those with casing could be sampled. The number of control bores was less than the impact bores, a reflection of the land use with few pastoral bores available. In terms of habitat type, without site specific hydrogeological information and detailed bore lithology, the aquifer(s) could not be delineated and the subterranean habitat described.
- Stygofauna were collected from bores within the area likely to be impacted from the activities of the mining project (E69/535). Diversity and abundance was low, with only 10 of the 12 bores yielding stygofauna. The specimens collected were predominantly terrestrial taxa with few true stygofauna (stygobites). Of the aquatic forms, most were stygoxenes, and taxonomic constraints prevented identifications to be taken higher than order.
- In the absence of higher taxonomic resolution it is difficult to assess whether any of the specimens identified were of conservation significance and at risk from the mining project. From this survey the results indicate the area may not have high importance for stygofauna communities. From the hydrogeological information extrapolated, the survey area does not display characteristic stygofauna habitats with small, unconsolidated sedimentary aquifers or fractured rock aquifers of low yield. Although limited, the results from this preliminary survey suggest that the risk to the stygofauna community, being poorly formed, from the mining activities within E69/535 may be low.

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1.0 Introduction

1.1 Project Background

Outback Ecology was commissioned by Metals X Limited to conduct a stygofauna (subterranean fauna) survey of the Wingellina Nickel Project, within exploration tenement E69/535 in Western Australia. The stygofauna survey was one component of a broader study undertaken concurrently by Outback Ecology, including assessment of vegetation and flora, terrestrial fauna, soils, and waste materials within the project area.

The project area is defined by the E69/535 tenement boundary, approximately 8 km south-west of Surveyor Generals Corner (**Figure 1**) within the Wingellina Hills, which lie to the north of the Musgrave Ranges in the Ngaanyatjarra Lands Indigenous Protected Area. The area lies within the Man-Musgrave subregion of Central Ranges bioregion, one of the 85 biogeographic regions of the Interim Biogeographic Regionalisation for Australia (IBRA).

Metals X Limited (Metals X) is the owner of the Wingellina Nickel-Cobalt oxide deposit which lies within Exploration License E69/535 within the Central Musgrave Ranges, situated at the Western Australia, South Australian and Northern Territory borders (**Figure 1; Figure 2**). Metals X has completed significant exploration work on the titles since acquisition including over 50 000 meters of drilling which has a resource with the vast majority currently sitting within measured and indicated categories under JORC.

The Wingellina deposit is substantial in scale, occurring over widths of up to 600 m, along a strike length of some 9 km and to depths of up to 200 m (typically 80 – 100 m). The mineralised system remains open along the strike and there is significant potential for depth extensions in many areas of the deposit that were only previously tested by shallow drilling.

1.2 Project Area

The Wingellina Nickel Project is located in central Australia and lies within the Central Ranges bioregion, one of the biogeographic regions of the Interim Biogeographic Regionalisation for Australia (IBRA). It is bounded to the south by the Great Victoria Desert and to the north by the Great Sandy Desert. The Central Ranges occupies upland areas within the Western Australian, South Australian and the Northern Territory borders (**Figure 1; Figure 2**). Within this bioregion are further subregions and the project area lies within the Mann-Musgrave Block.

The majority of the Central Ranges bioregion is Aboriginal freehold land, with only a very small percentage of the area used for pastoral purposes (Graham and Cowan 2001). The bioregion occupies upland areas within the Western Australian, South Australian and the Northern Territory borders.

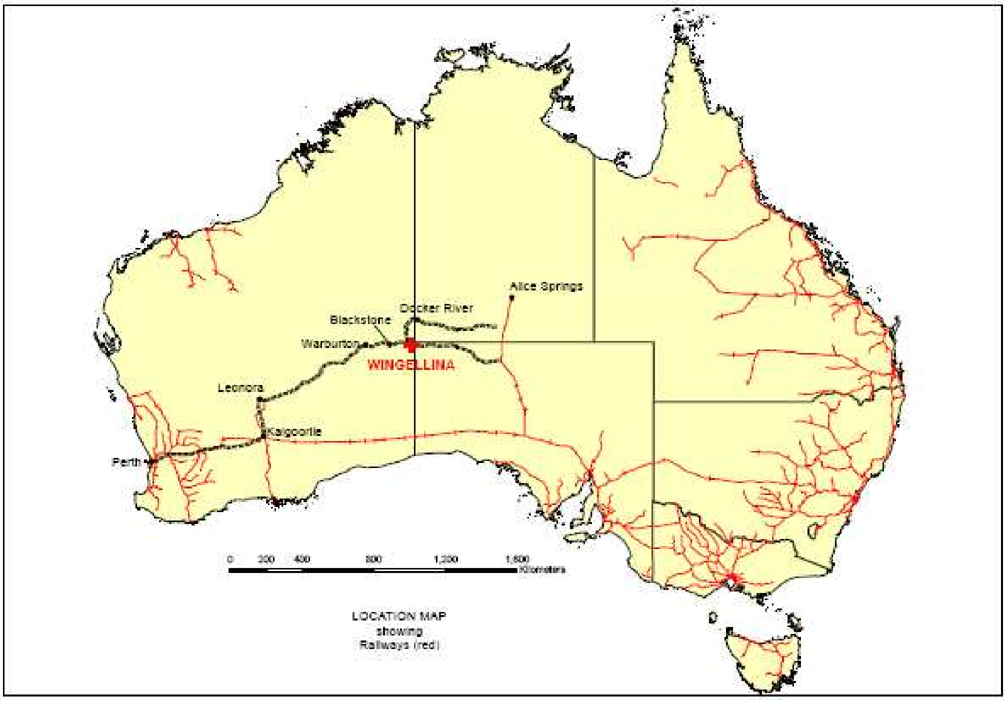

Figure 1: Location of Wingellina project area (Source: Metals X).

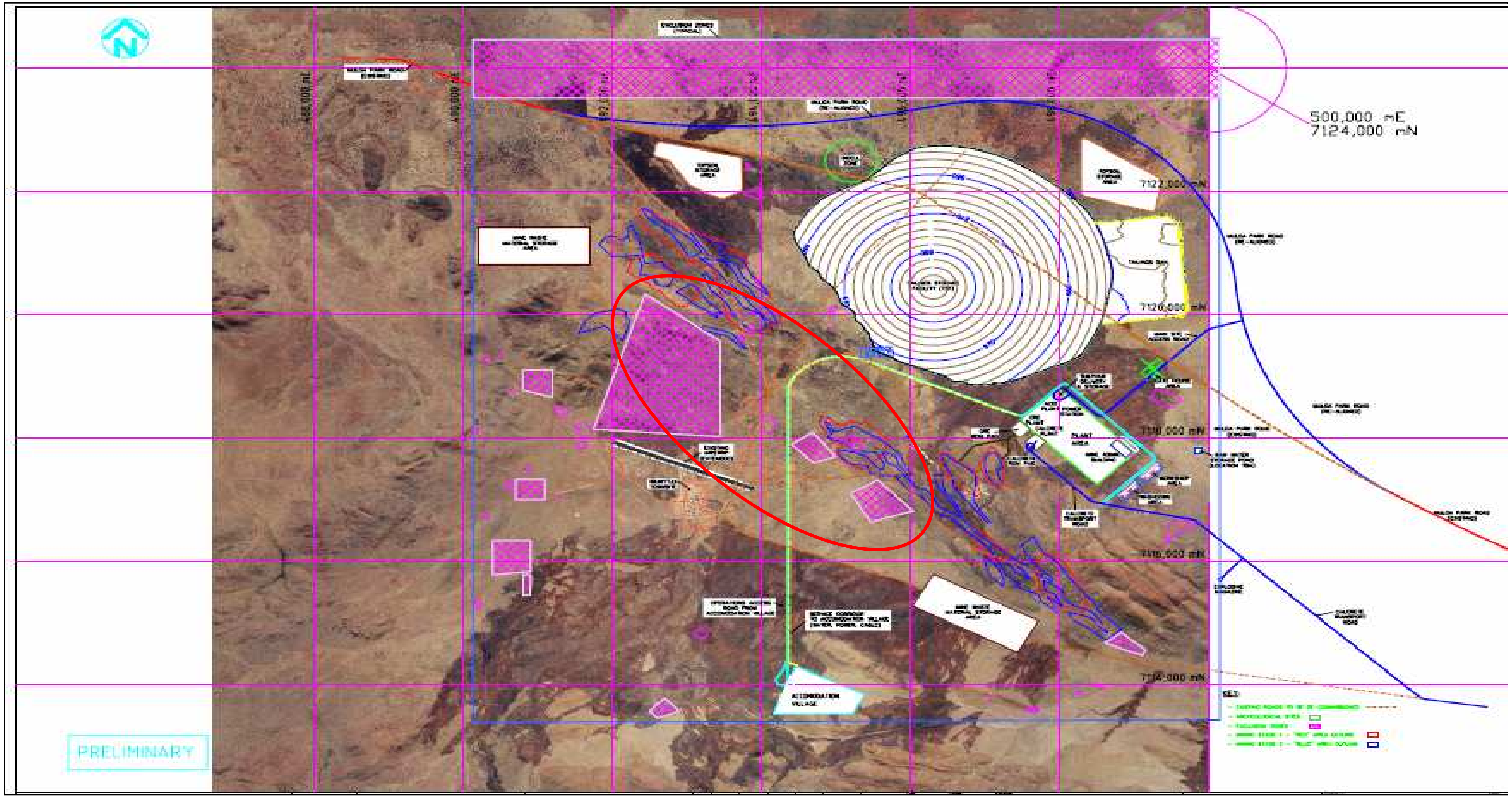

Figure 2: Site plan of the Wingellina project, 2008. Red oval indicates area stygofauna survey area. (Source: Metals X).

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1.3 Climate

The climate of the Central Ranges is characterised as a true arid desert, with hot summers and mild winters. The region is influenced by a northern tropical/summer climatic pattern. Rainfall is variable, however the majority is received during summer, largely due to the movement of low pressure troughs and tropical lows associated with monsoon troughs moving south in the region. Winters are mild and associated with a high pressure subtropical ridge (BOM 2008).

The Giles weather station is the nearest registered meteorological station, located approximately130 km to the north west of the project area. The weather station was established in 1956 by the Australian Weapons Research Establishment (Defence Science and Technology Organisation) (BOM 2008). Mean annual rainfall recorded at Giles is 284 mm, with the majority received between November and March (**Figure 3**). Mean maximum daily temperature of 37.2 ℃ is re corded during January, with the minimum mean temperature of 6.8 °C recorded during July. (BOM 2008)

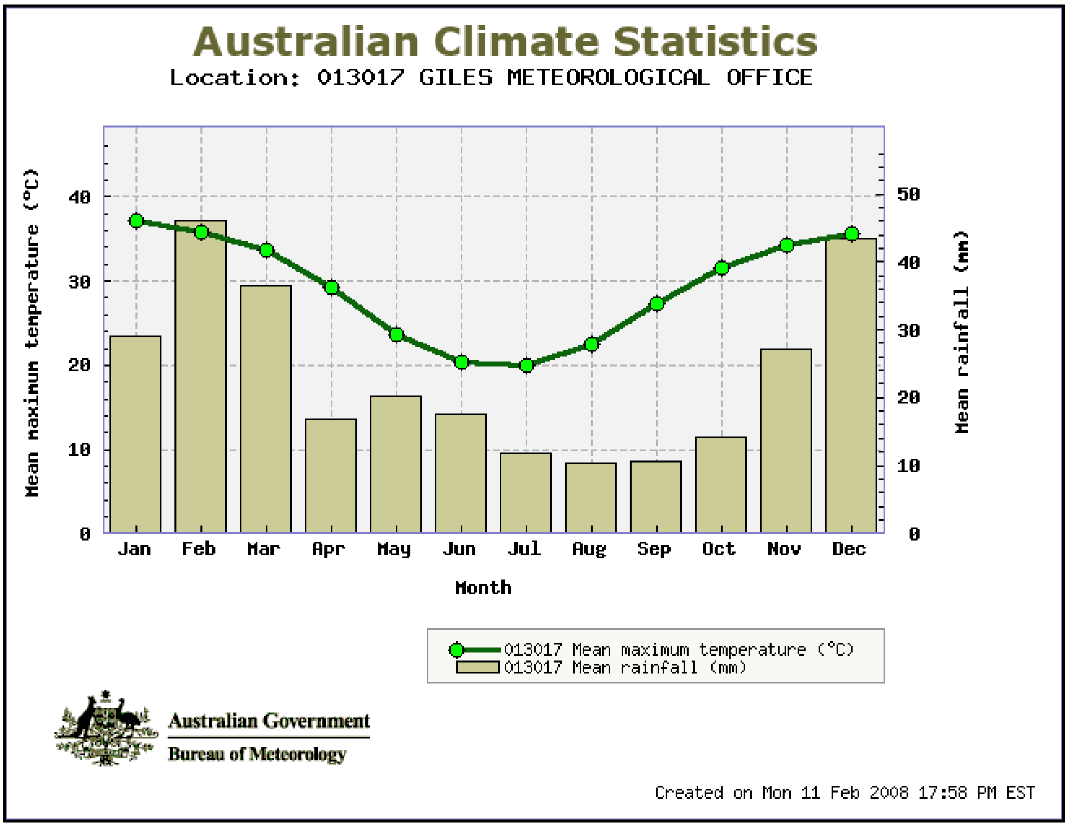

Figure 3: Rainfall averages for the Giles weather station (BOM 2008).

1.4 Geology and hydrogeology

The ranges of the Musgrave Block are composed of Middle Proterozoic igneous and metamorphic rocks, primarily gneiss, granite, gabbro and the associated weathering material. The Wingellina Hills consist of predominantly low, northwest-southeast trending ridges with occasional high steep hills and rocky outcrops. These hills are formed by the Wingellina Intrusion, a layered gabbro and ultramafic igneous body. In places the gabbro forms rocky outcrops with bouldery scree slopes on the steeper slopes.

Surface geology consists of Aeolian sands (silica/iron oxide/haematite), magnesite, calcium carbonate and dolomite. At greater depths soils are consolidated, becoming more compact (mainly iron oxide). Ridges in the area consist of gabbro (resistant to erosion), made up of pyroxene, feldspar and minor olivine. Possible crevices/fissures are likely to occur in the top 10 m, although mainly limited to the top 3 m. At greater depths there may be some sheers and pores may be found ranging from approximately 5 to 10 mm.

Hydrogeological information on the Musgrave Province is limited. According to the Australian Natural Resources Atlas (2007) there are no extensive aquifers in the Musgrave Block and are shallow unconsolidated sedimentary aquifers or fractured rock aquifers. They are generally small and low yielding. Many contain old (10 000 years) water that are not recharged.

1.5 Scope of works

Approvals that are required by Metals X in order to mine the Wingellina deposit are:

- The conversion of the existing Exploration Licence to a Mining Lease;
- Environmental approvals from the Western Australian Environmental Protection Authority (EPA), Department of Environment and Conservation (DEC), Department of Industry and Resources (DoIR), Department of Water (DoW);
- Environmental Approval from the Commonwealth Department of Environment and Water Resources.

This document examines the potential impact of the mine on the stygofauna communities (if present) in the aquifers underlying the exploration lease E69/535.

1.6 Relevant legislation

Stygofauna are protected under the same legislation as that of terrestrial fauna, and are governed under three acts:

1. the *Wildlife Conservation Act (1950-1979)*;
2. the *Environmental Protection Act (1987)* (EP Act); and
3. the *Environmental Protection and Biodiversity Conservation Act (1999)* (EPBC Act).

The *Wildlife Conservation Act 1950 – 1979* provides protection for all native fauna species, and is administered by the DEC. Special provision is provided for fauna that are considered rare, threatened with extinction or with high conservation value. This includes subterranean biota, which can be considered for inclusion as Schedule 1 taxa (rare or likely to become extinct).

The *Environmental Protection Act (1987)* is administered by the EPA and includes guidelines for reviewing the environmental factors of proposals that might impact the environment. The Act states that any operation that could potentially have a significant impact on stygofauna or troglofauna habitat will be subject to formal Environmental Impact Assessment (EIA) under the EP Act. The EPA's *Position Statement No. 54* provides specific assessment and management requirements for subterranean fauna and is supported by Guidance Statement 54a, Technical Appendix to Guidance Statement 54.

The *Environmental Protection and Biodiversity Conservation Act (1999)* is administered by the Commonwealth, to regulate protection of matters of national environmental significance. Any action (including projects, developments, undertakings, activity or series of activities) that is likely to have a significant impact on any matter included in Part 3 of the Act, must be referred to the Minister for decisions on whether the proposed action triggers the EPBC Act, and an appropriate level of assessment for approved actions.

1.7 Stygofauna

Stygofauna live in subterranean groundwaters with varying degrees of dependency. Stygobites are obligatory groundwater dwellers and fulfil their entire lifecycle below ground. Stygophiles occur in both above groundwater (epigean) and in below groundwaters (hypogean). Stygoxenes are those that are found in groundwaters and can exist, but have entered there either actively or passively and return to the surface to feed (Thurgate *et al.* 2001). They display characteristics typical of a subterranean existence which include a reduction or absence of pigmentation, absence or reduction of eyes, and the presence of extended locomotory and sensory appendages (Watts and Humphreys 2000).

Stygofauna are considered to be an ancient group with Pangaean, Gondwanan and Thethyan origins and are thought to have sought refuge below ground with the onset of aridity in Western Australia during the Tertiary (Cooper *et al.* 2002; Humphreys *et al.* 2004). The Western Shield is very stable and has remained above sea level since the Palaeozoic. The formation of the palaeorivers in the late Tertiary and the subsequent calcretes, the aquatic invertebrate fauna associated with the rivers and the hyporheic zone (living in between the soil particles of the river bed) took refuge in the subsurface caverns that had formed and remained, evolving into distinct communities (Humphreys 2001). Typical groundwater habitats for stygofauna are megavoids, such as large caves, mesocaverns in karst and basalts, and the interstitial spaces of alluvial aquifers.

An increase in subterranean surveys over the last decade have shown Western Australia to be a stygofauna hotspot with exceptional diversity displayed within a small area (Humphreys *et al.* 2004; Humphreys 2006). Stygofauna diversity is higher within classic karst systems, such as those found in the Cape Range, Western Australia and until recently, it was perceived that stygofauna were confined to these karstic environments. It has since been revealed that calcrete aquifers associated with palaeovalleys of the Australian arid zone also contain a diverse stygofauna population (Karanovic 2004; Humphreys 2006).

Calcretes within the Yilgarn have been found to contain stygobitic diving beetle and amphipod species that are restricted in distribution to single calcretes (Cooper *et al.* 2002; Cooper *et al.* 2007) with the lack of connectivity causing the isolation of communities and identified as a possible factor permitting species radiation (evolution). While this remains true for certain taxa, recent intense sampling has found that many species have a broader geographical distribution than previously thought (Karanovic 2004). Stygofauna distribution appears to be primarily affected by hydrological stability, groundwater quality, energy sources, dispersal routes and habitat space (Boulton 2006). Consequently, impacts on these aspects may affect their diversity and abundance.

1.8 Stygofauna – Potential Impacts

The EPA Guidance Statement 54 (EPA 2003) states that mining proposals may "impact stygofauna or troglofauna habitat by:

- lowering of the water table sufficiently to dry out the hyporheic zone in which some species live, or otherwise artificially change water tables, or
- changing the water quality (e.g. increasing salinity levels or altering haloclines, increasing nutrient levels or the availability of organic matter, or introducing other pollutants), or
- destruction of or damaging caves (including changing their temperature and humidity)".

Therefore the design of sampling programs must address these criteria as relevant. The EPA states that proponents of proposed projects must demonstrate a lack of threat by:

- showing that species within the potential impact zone also occur outside this area, and are not restricted to the impact zone,
- providing evidence that likely impacts will not significantly affect species within the potential impact zone,
- producing a management plan for the potential impact zone and species within it, to ensure persistence of those species.

1.9 Objectives of the survey

A pilot survey was proposed for this study, given the uncertainty of the presence of stygofauna in the area or the extent of the aquifers in the project area. In line with these guidance statements, the objectives of this survey were:

- To describe the baseline stygofauna within the potentially-impacted project area,
- To collect and collate *in situ* data such as bore condition, basic water chemistry and habitat data,

- To identify any rare or endemic subterranean taxa,
- To comment on the potential impact of the project with regard to local stygofauna populations.

The resulting report will address the following:

- project area description, a background of stygofauna and any appropriate legislative background within Western Australia,
- sampling methodology,
- sampling results with reference to description of bore holes sampled, species present, bore logs where available and water quality data,
- discussion and recommendations, with reference to distribution and conservation status of all species collected, preliminary identification of potential impacts related to hydrological influences and management recommendations for the potentially-impacted area (if required).

In order to accurately sample for stygofauna the following were required:

- Bores must be vertical holes (it is not possible to sample angled bores),
- Bores are to be cased, packed and capped to ensure the integrity of the bore throughout the sampling program,
- Packing material is to be permeable to allow flow through of water (i.e. not clay or fines),
- Bore casing is to be slotted and placed, at least, into the top level of the main aquifer that is to be impacted,
- Bores are to be evenly spaced throughout the project area where the aquifer will be impacted by drawdown through dewatering,
- Bore casing is to be at least 50 mm in diameter.

With regard to the location and frequency of the sampling programs, the following points are mentioned within the guidance statements:

- It is recommended by the EPA and the DEC that bores are not sampled for a minimum of six months after establishment,
- Stygofauna should be sampled over a minimum of two seasons (i.e. twice within one year and these assessments should be at least three months apart),
- Surveys will need to be carried out until 95 % of species are located (as indicated by the species accumulation curve).

2.0 METHODS

2.1 Sampling sites

An extensive list of exploration bores was provided by Metals X though on inspection few were suitable for stygofauna sampling. A total of 12 suitable bores were sampled during April 2008, although only 3 of these may be considered as control bores, with the remainder located in the impact zone (**Figure 4**). Bores were classified as "control" and "impact" according to their location within the proposed project layout.

Figure 4: Wingellina bores sampled during the April 2008 survey. Control bores = Bore 2, 4, and Inco Bore. All other bores are impact bores. Map base from Google, 2007.

2.2 Groundwater quality

Basic water physicochemistry parameters were measured *in situ* at each bore to identify any differences between the control and impact bores and assess the condition of the groundwater for stygal habitation. Groundwater from each bore was collected by lowering a disposable plastic bailer using a winch below the standing water level (SWL).

Calibrated handheld Windaus meters were used to measure pH, temperature, salinity (using electrical conductivity as a surrogate) and dissolved oxygen (DO) in the water retrieved from the bores. In addition, a Solinst 101 water level meter was used to measure the SWL of each bore.

2.3 Stygofauna sampling and identification

Sampling was consistent with the methodologies outlined in EPA Guidance Statement Number 54a, Technical Appendix (Draft) and the methodology is summarised as follows:

- Samples were collected using two weighted nets with mesh sizes of 150 µm and 50 µm. Each net was fitted with a glass vial with a base mesh of 50 µm.
- The 150 µm net was lowered first to near the bottom of the hole.
- Once at the bottom the net was gently raised up and down three times to agitate the bottom sediment.
- The net was then raised slowly to minimise the ‘bow wave’ effect that may result in the loss of specimens, filtering the stygofauna from the water column on retrieval.
- Once retrieved the collection vial was removed and all the contents emptied into a polycarbonate vial and preserved.
- This process was repeated three times.
- The same procedure was then repeated using the 50 µm net.
- To prevent cross-contamination between bores, all sampling equipment was washed thoroughly with Decon 90 (detergent) and then rinsed with distilled water after sampling each bore.

A fauna licence (No SF006267) was obtained from the DEC for assessment of stygofauna within the project area and sampling was undertaken by Dr Fiona Taukulis and Ms Brooke Hay.

For preservation and identification of the specimens:

- Samples were placed in 120 mL polycarbonate vials and preserved with 100 % undenatured ethanol in the field. Undenatured ethanol was used to allow for later allozyme electrophoresis and mitochondrial DNA sequencing, if required.
- Samples were couriered back to Outback Ecology’s laboratory in Perth

- Preserved samples were manually sorted with the aid of a Leica MZ6 stereomicroscope and individual specimens placed in specimen vials.
- The specimens were then identified to their lowest possible taxonomic level by Dr Erin Thomas (ET) and Dr Nihara Gunawardene (NRG) of Outback Ecology, using the relevant taxonomic literature, where available. Technical assistance was provided by Richard de Lange (RD) and Kimberly Moiler (KM) of OES.
- Specialist taxonomists were only consulted where necessary.

2.4 Limitations of the study

A description of the subterranean fauna habitat supported by hydrogeological information is required to draw appropriate conclusions from the results of the survey. Without this information the findings of this survey are limited.

Because of the current state of stygofauna taxonomy and the delicate nature of these invertebrates, several specimens could not be identified to species or morphospecies level. To date taxonomic keys are lacking and many new species are yet to be published, thereby making the information publicly available. All specimens were identified to the lowest taxonomic level possible. Many taxa are identified on particular morphological characteristics that are often absent on juveniles or may have been lost or damaged on collection and/or sorting.

3.0 RESULTS and DISCUSSION

3.1 Groundwater Physicochemistry

Generally, little variation was observed in the physicochemical parameters of the groundwater sampled within the Wingellina survey area in April 2008. The pH of the groundwater was found to range from circum-neutral (6.81 at Bore 4) to alkaline (8.72 at WPRC0173) (**Table 1**). The distribution of groundwater fauna can be strongly influenced by the physicochemical characteristics of the aquifers with calcareous systems rich in stygofauna. In the Pilbara the presence of a high number of ostracods in the aquifers was largely determined by pH and carbonate saturation with aquifers of low pH rarely having ostracods present (Reeves 2007).

Salinity, measured as electrical conductivity, was considered fresh with the majority below 3 500 µS/cm. The lowest salinity was recorded at Bore 4 (158 µS/cm) while Inco Bore had a slightly saline groundwater of 3 550 µS/cm. The difference in salinity levels at Inco Bore may have been due to the location of the bore at the local rubbish tip and contamination from refuse causing the increase. In the absence of nutrient and previous data, this cannot be confirmed. Overall there did not appear to be a pattern between the groundwater salinity and location of the bores.

The dissolved oxygen (DO) of the groundwater was low, ranging from 0.7 ppm at Inco Bore to 4.74 ppm at WPRC0334. The standing water levels for the bores were quite deep from 30 m to 54 m. Deeper aquifers tend to have lower DO levels compared to the shallower calcrete aquifers. While dissolved oxygen is considered a factor limiting the presence of stygofauna, Humphreys (2008) found that many stygobitic species are able to tolerate very low DO levels, with many Australia species commonly associated with suboxic waters that have DO levels below 1 mg/L (ppm). The low DO reading at Inco Bore, despite the high SWL, may be caused by excessive nutrients in the groundwater resulting in higher BOD (biological oxygen demand) during bacterial activity.

The groundwater temperature appeared fairly consistent ranging from 25 to 28 °C. Generally, little variation was observed in the physicochemical parameters of the groundwater between the bores and the values fell within ranges displayed in other Western Australia groundwaters, particularly in the Pilbara (OES unpublished data). Salinity and pH are a reflection of the geology. With hydrogeological information the data collected in this survey can be used to assess any changes to the aquifer that may arise during the project life and become a risk to any stygal communities.

Table 1: Details of the Wingellina stygofauna sampling bores and *in situ* physicochemical measurements, April 2008. IBM = internal bore diameter; SWL = surface water level; EoH = end of hole; EC = electrical conductivity; DO = dissolved oxygen.

Bore ID	Area	GPS coordinates	Casing Type	IBD (mm)	SWL (m)	EoH (m)	pH	EC (µS/cm)	DO (ppm)	Temp. (ºC)
Bore 2	Control	52 J 0496751 UTM 7121221	steel	130	31.49	78	7.69	804	3.99	27.40
Bore 4	Control	52 J 0495550 UTM 7119420	PVC	100	38.72	85	6.81	158	0.94	27.00
Inco Bore	Control	52 J 0494425 UTM 7117393	Steel	100	13.90	~15	8.09	3 550	0.70	27.40
Camp Bore	Impact	52 J 0496224 UTM 7117690	Steel/PVC	150	n/a	n/a	7.75	1 776	4.33	28.00
WPRC0102	Impact	52 J 0498727 UTM 7115010	PVC	65	51.00	70	7.33	1 694	7.80	25.00
WPRC0126	Impact	52 J 0491403 UTM 7119910	PVC	65	43.54	76	7.77	1 531	1.63	24.60
WPRC0137	Impact	52 J 0492202 UTM 7120677	PVC	65	38.18	52	7.69	1 831	2.15	26.10
WPRC0171	Impact	52 J 0493722 UTM 7119786	PVC	65	53.63	70	8.07	2 090	1.48	27.40
WPRC0173	Impact	52 J 0492928 UTM 7121235	PVC	65	38.82	70	8.72	2 173	1.65	25.10
WPRC0334	Impact	52 J 0495198 UTM 7118043	PVC	65	52.54	60	8.21	775	4.74	27.00
WPRC0363	Impact	52 J 0496083 UTM 7117099	PVC	65	51.65	60	7.86	1 876	2.10	27.50
WPRC0444	Impact	52 J 0497077 UTM 7116212	PVC	65	48.68	60	7.66	2 251	1.03	25.00
WPRC0658	Impact	52 J 0497133 UTM 7117610	PVC	65	41.82	62	7.62	2 144	1.96	25.50

3.2 Stygofauna

A total of 12 invertebrate taxa were identified from the Wingellina survey area (**Table 2**) with only two bores that did not yield any specimens (**Table 3**). Taxa from four different phyla; Arthropoda, Annelida, Nematoda and Rotifera, were identified with the greatest diversity displayed within the Arthropoda. While these groups are consistent with those found in other stygofauna communities in Western Australia and globally (Eberhard *et al.* 2005), the specimens yielded do not appear to be stygobitic (true stygofauna). Many were either terrestrial taxon or were surface water (epigean) groups such as the Acarina, Collembola and larval dipterans. Collembola are springtails that live in leaf litter, their affinity with water means they inhabit the edges of rivers and creeks and are often washed into watercourses after the rains which assists in their dispersal. When conditions become dry springtails will burrow into the moist soil and enter dormancy (Gooderham and Tsyrlin 2002) which is why they are often collected in stygofauna samples. Larval dipterans (flies) are widely dispersed and are only aquatic for a portion of their lifecycle (Williams 1980). Stygobites (true stygofauna) are obligate subterranean fauna and complete their entire lifecycle below ground, restricting their distribution.

The Acarina, or mites, recorded from the project area all belonged to predominantly terrestrial groups (Williams 1980; Pearse *et al.* 1987; Halse *et al.* 2000) while the Hydracarina, the water mites, was not represented. Low level taxonomic identifications of mites, other than Hydracarina, are not required according to the EPA's Guidance Statement 54a due to the absence of referencing material.

Of the truly aquatic specimens collected, the Rotifera, Copepoda, Annelida and Nematoda are possibly stygobites. The phylum Rotifera is a group of invertebrates found predominantly in freshwater environments but can also live in damp terrestrial habitats. They are all microscopic, rarely greater than 0.5 mm, and make up 2 % of the described stygofauna in the world (Eberhard *et al*. 2005). Because of taxonomic difficulties association with the Rotifera, the EPA accepts that this group cannot be identified to species level (EPA Guidance Statement 54a). The cladoceran, Bosminidae, was another truly aquatic taxon and, while predominantly a surface water group, stygal cladocerans are known (Brancelj and Mori 2004).

A recent survey by the DEC in the Central Ranges revealed a number of new stygobitic diving beetles and also recorded a number of stygal copepods (Pearson *et al.* 2007). These are typical of groundwaters in central Australia and in the Yilgarn Region of Western Australia (Karanovic 2004; Watts and Humphreys 2006). Even though the study was in the Central Ranges, it appears to have been some distance from Wingellina and sampling may have been from calcretes rather than unconsolidated aquifers. Stygal diversity is much higher in classic karst systems where subterranean voids are well developed (Humphreys 2006). The subterranean environment of Wingellina may not have well developed, limiting the number of stygofauna in the area. Many of the stygal taxa are relicts with ancient lineages that sought refuge during the late Tertiary as the surface waters dried with the onset of aridity. Therefore the greatest diversity of stygofauna is often found in the palaeovalleys and the associated calcretes, remnants of the ancient river system. Mapping of any palaeovalleys in the Wingellina area will indicate the location of other potential stygofauna habitats which may yield higher numbers than was found in the fractured rock aquifers of Wingellina.

Table 2: Distribution and taxonomic identification of specimens yielded from haul net sampling of Wingellina bores, April 2008.

Phylum	Class	Superorder/Order	Lowest Taxonomic Identification	Bore Code	Distribution
Arthropoda	Arachnida	Acarina	Astigmata	Inco Bore, WPRC0102	Mostly terrestrial. Large order of mites, containing over 80 families, generalisation difficult
			Mesostigmata	Inco Bore, WPRC0126, WPRC0137, WPRC0334	Diverse, cosmopolitan group of terrestrial mites
			Oribatida	WPRC0444	Oribatida are widely distributed, occurring in surface water, subterranean and terrestrial habitats.
			Acarina	WPRC0137	No further taxonomic determination possible
	Branchiopoda	Cladocera	Bosminidae	Bore 4	Two genera are recognised from Australia, the species collected is most likely to have an affinity to *Bosmina meridionalis* which is common throughout S.E. Australia (Shiel 1995).
	Collembola	Arthropleona	Isotomidae	Inco Bore, WPRC0102, WPRC0658	Mostly recorded from terrestrial habitats but can occur in aquatic environments (Hawking and Smith 1997). Few truly aquatic species have been recorded (Greenslade 1991)
		Symphypleona	Sminthuridae	WPRC0171	Almost all species from the three families are known to be epigaeic, with only *Sminthurides* is aquatic (Greenslade 1991).
	Insecta	Diptera	Diptera larva	Inco Bore	No further taxonomic determination possible from specimen
	Maxillopoda	Copepoda	Copepoda nauplius	Inco Bore	No further taxonomic determination possible from specimen
Nematoda			Nematoda	WPRC0126, WPRC0334	No further taxonomic determination required
Annelida	Oligochaeta	Tubificida	Enchytraeidae	WPRC0137	Very large group of microdrile oligochaetes, found in terrestrial and aquatic environments. In subterranean waters have been collected from areas such as Barrow Island and the south-coast region near Albany. Recorded also from De Grey in Pilbara.
Rotifera			Rotifera	Bore 4, Camp Bore, WPRC0173	Rotifera are common in subteraanean waters, make up 2% of described stygofauna globally. No further taxonomic determination required.

Table 3: Sample count from the groundwater samples collected from Wingellina survey area, 2008. Green highlight indicates no specimens yielded.

Bore Code	Area	Easting	Northing	Sample Date	Lowest Identification	Count	Identifier
Bore 4	Control	495550	7119420	08/04/2008	Bosminidae	1	KM
Bore 4	Control	495550	7119420	08/04/2008	Rotifera	34	KM
Inco Bore	Control	494425	7117393	09/04/2008	Astigmata	31	RD
Inco Bore	Control	494425	7117393	09/04/2008	Mesostigmata	8	RD
Inco Bore	Control	494425	7117393	09/04/2008	Isotomidae	28	RD
Inco Bore	Control	494425	7117393	09/04/2008	Diptera larva	1	RD
Inco Bore	Control	494425	7117393	09/04/2008	Copepoda nauplius	1	RD
Bore 2	Control	496751	7121221	09/04/2008			RD
Camp Bore	Impact	495550	7119420	09/04/2008	Rotifera	2	KM
WPRC0102	Impact	498727	7115010	08/04/2008	Astigmata	3	RD
WPRC0102	Impact	498727	7115010	08/04/2008	Isotomidae	1	RD
WPRC0126	Impact	491403	7119910	09/04/2008	Mesostigmata	3	RD
WPRC0126	Impact	491403	7119910	09/04/2008	Nematoda	4	RD
WPRC0137	Impact	492202	7120677	09/04/2008	Mesostigmata	15	RD
WPRC0137	Impact	492202	7120677	09/04/2008	Acarina	15	RD
WPRC0137	Impact	492202	7120677	09/04/2008	Enchytraeidae	17	RD
WPRC0171	Impact	493722	7119786	09/04/2008	Sminthuridae	1	RD
WPRC0173	Impact	492928	7121235	09/04/2008	Rotifera	2	RD
WPRC0334	Impact	495198	7118043	09/04/2008	Mesostigmata	3	ET
WPRC0334	Impact	495198	7118043	09/04/2008	Nematoda	1	ET
WPRC0363	Impact	496083	7117099	08/04/2008			RD
WPRC0444	Impact	497077	7116212	08/04/2008	Oribatida	1	RD
WPRC0658	Impact	497133	7117610	08/04/2008	Isotomidae	10	RD

4.0 CONCLUSION and RECOMMENDATIONS

While taxon diversity and abundance was low in the groundwaters of the Wingellina project area, stygofauna were present in the samples yielded. The samples were dominated by stygoxenes, i.e. fauna that only fulfil a portion of their lifecycle below ground or enter groundwater passively, normally feeding on the surface (Thurgate *et al* 2001). Taxonomic verification was difficult for a number of taxa collected due to the lack of suitable specimens. For example, the copepod collected was only a nauplius, at a very early stage in its lifecycle. The taxonomic keys for particular groups were also unavailable. In the absence of higher taxonomic resolution, it was difficult to assess whether any of the specimens identified were of conservation significance, and therefore at risk from the impacts of the mining project. Until the appropriate keys are constructed many will remain unresolved. In terms of juvenile stages being the limiting factor, the collection of adult stages will enable specimens, such as the copepod, to be identified to species level.

In terms of the impacts within this area of the project, according to the information provided during the preparation of this report it is anticipated that the aquifer in this survey area may not be affected as mining will be above the water table. Therefore the effects of drawdown are not expected, though the destruction of certain areas of the aquifers, including the removal of habitat, may still be a consideration. In the absence of hydrogeological information it is difficult to determine if the low numbers of stygofauna present in the groundwater is a result of the habitat type and the lack of connectivity between aquifers, or if the area was never fully colonised by aquatic invertebrates seeking refuge during the late Tertiary.

The physicochemical parameters of the Wingellina groundwater were within the ranges of other stygofauna habitats, and therefore not considered to be a factor limiting the presence of stygofauna. While dissolved oxygen was low, stygobitic taxa have been found to tolerate very low oxygen levels compared to epigean (surface) species and this may no longer be considered a limiting factor (Malard and Hervant 1999). There may have been some influence on the stygofauna from higher nutrient levels at Inco Bore, though it should be noted that the water has not been analysed for nutrients. Stygofauna live in nutrient deficient environments with any carbon source being external. Higher nutrient levels would be an attractant for any subterranean invertebrates and difference in the community structure and abundance may be due to the increased nutrients.

The presence of a number of stygoxenes indicates that there may be some connectivity with the epigean zone, and further hydrological information may assist with this. In order to achieve a 95 % confidence interval for the bores, which would indicate that all the possible stygal taxa that are likely to occur in the groundwater have been recorded, a greater number of bores need to be sampled. The technique adopted using haul nets and performing six hauls per bore has been found to be the most effective in collecting all specimens present in the bore at that time (Allford *et al.* 2008). This has been further increased with the use of two nets of different mesh size. The techniques applied are therefore adequate for collecting the stygofauna, the sampling frequency instead needs to be increased.

In terms of the objectives stated for this survey, baseline data on the stygofauna and the *in situ* physicochemical parameters of the groundwater were collected for 12 bores. This survey found that many of the exploration bores had collapsed and only those with casing could be sampled. The number of control bores available was much less than the impact bores and this is a reflection of the land use with few pastoral bores available. Further surveys, including hydrogeological, are envisaged for the project area which will allow for a more detailed understanding of the stygofauna communities in the Wingellina Project area.

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