

## **Nammuldi Stygofauna Assessment Programme**



Stygal amphipod collected from Homestead Creek



**Hamersley Iron**

**Sampling Programme Design**

**January 2003**



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Cover photo by Terrie Finston, UWA Zoology

# Nammuldi Stygofauna Assessment Programme

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# 1.0 Introduction

## 1.1 Project Background

The Hamersley Iron (HI) Nammuldi iron ore deposits are situated adjacent to the HI Brockman Operations, approximately 55 km to the northwest of the town of Tom Price in the Pilbara region of Western Australia. The Nammuldi project (and the associated Silvergrass iron ore project) was formally assessed by the Environmental Protection Authority (EPA) at the level of Consultative Environmental Review (CER) (Hamersley Iron 2000). The Silvergrass iron ore deposit is located about 12 km to the north of the Nammuldi deposit and the Brockman Operation, and is on the other side of the valley.

One of the issues identified during the Nammuldi Silvergrass assessment was the potential for the dewatering required for mining to affect subterranean groundwater fauna (stygofauna) in the locality (EPA 2000, Hamersley Iron 2000).

The Ministerial Statement (Statement 558) for the Nammuldi – Silvergrass project includes a specific condition in relation to stygofauna sampling:

### 6 Subterranean Fauna Sampling Plan

6-1 *Within twelve months following the issuing of the formal authority to decision making authorities under section 45(7) of the Environmental Protection Act 1986, or at least three years prior to commencing dewatering operations at either the Nammuldi or Silvergrass area, the proponent shall develop a Subterranean Fauna Sampling Plan for the respective area to the requirements of the Environmental Protection Authority on advice of the Department of Environmental Protection, the Department of Conservation and Land Management, and the Western Australian Museum.*

*The objective of this Plan is:*

- *to increase scientific knowledge about subterranean fauna to assist in the conservation of this element of the environment.*

*This Plan shall address:*

- 1 *subterranean fauna surveys of the areas to be affected by dewatering operations to assist in establishing the conservation significance of any species within the affected areas;*
  - 2 *characterisation of subterranean fauna habitats to be affected by dewatering and identification of similar subterranean fauna habitats outside the affected areas;*
  - 3 *subterranean fauna surveys of similar habitats outside the areas to be affected by dewatering operations to assist in establishing the conservation significance of fauna within the areas to be affected; and*
  - 4 *specific measures to record and preserve biological information on any species collected in the project area.*
- 6-2 *The proponent shall implement the Subterranean Fauna Sampling Plan required by condition 6-1.*
- 6-3 *The proponent shall make the Subterranean Fauna Sampling Plan required by condition 6-1 publicly available, to the requirements of the Environmental Protection Authority.*
- 6-4 *The results from the Subterranean Fauna Sampling Plan shall be submitted to the Environmental Protection Authority and the Western Australian Museum.*

6-5 *In the event that the Environmental Protection Authority consider, based on the results of the Subterranean Fauna Sampling Plan, that its objective would be compromised, then the proponent shall develop an action plan to the requirements and timing of the Environmental Protection Authority.*

This document represents the Nammuldi project subterranean fauna sampling plan as required by Condition 6-1 of the project Ministerial Statement. It is submitted to the EPA for approval, subject to the advice of the Department of Conservation and Land Management (DCLM), the Department of Environmental Protection (DEP) and the Western Australian Museum (WAM).

It should be stated that apart from a possible bulk sample (150,000t) from below watertable in the Nammuldi Trial Operation pit, mining of below-watertable ore at Nammuldi is not expected for some years.

This document also presents the results of several phases of sampling at Nammuldi, consistent with the sampling methodology outlined in this report (Section 4.2). These are submitted as the required sampling results for partial clearance of condition clauses 6-4 and 6-5 for the Nammuldi project area only. Sampling design and results for the Silvergrass area will be submitted in a future document.

## 1.2 Industry Collaboration and Data Sharing

HI has worked closely with other industry stakeholders, academic institutions (particularly the University of Western Australia and the University of Adelaide), DCLM and WAM in the design and implementation of its stygofauna sampling work (see Section 2.0). This has also included collaboration and liaison with taxonomic specialists in the eastern states working on stygal taxa. Resources for taxonomic and genetic studies have also been pooled with other regional studies, with the resultant data managed in a consolidated database. This approach will ensure the maximum advances in the understanding of stygal taxa of the region, in addition to enabling the stygofauna of the Nammuldi and Silvergrass areas to be placed into better regional context.

## 1.3 Objective of this Plan

The objective of this subterranean fauna sampling plan is consistent with the requirements of Condition 6-1. That is:

*"to increase scientific knowledge about subterranean fauna to assist in the conservation of this element of the environment."*

HI has incorporated a number of elements into the sampling programme to meet this objective.

## 1.4 Definitions

The following summary provides a general overview of the zoological concepts relating to stygofauna, speciation and taxonomy. It is intended as a generic guide to the type of issues involved with Stygofauna in the Pilbara only. A brief glossary of terms relating to these issues is also provided in Appendix 1.

- **Stygofauna**

Stygofauna is the collective term for obligate, groundwater dwelling fauna. They are typically well adapted for the subterranean environment, and are characterised by features such as lack of pigment, elongated appendages and reduced or absent eyes. The

'primitive' features of these fauna indicate their ancestry from those in geological periods when the Pilbara was covered with rainforest. They are therefore regarded as 'relict' fauna that has survived in the aquifer over geological timeframes.

Stygofauna in the Pilbara are commonly represented by crustacean orders including the Isopoda (an order which includes common garden slaters), Copepoda and Amphipoda (see Figure 1). Most are a few millimetres or less in size.



**Figure 1: Generic examples of commonly recorded Pilbara stygofauna orders** (source: Barnes 1987, Bradbury 2000).

- **Taxonomy and Biodiversity**

Fauna are grouped into a variety of levels based on their relatedness and ability to interbreed. Taxonomy is the process of classifying animals and assigning them to these groups in a systematic and hierarchical manner. Taxonomic groups are ordered from Kingdom down through Phylum, Class, Order, Family, Genus to Species, each representing a different taxonomic level. The name of any given species is of the form *Genus species* (eg. *Macropus robustus*, the Euro).

Part of the concern in relation to stygofauna is the potential for studies of this fauna to yield increases in the documented biodiversity of the state at high taxonomic levels. Recent work on stygofauna in Australia, and particularly the northwest, has resulted in the description of new families, and groups identified as new to the southern hemisphere or new to Australia (see review in Humphreys 2000, Biota 2001b). It is relatively unusual to identify new taxa at the species level for most vertebrate fauna groups – with stygofauna new genera are being described routinely (eg. Bradbury 2000).

- **Genetics and Speciation**

DNA is the genetic material that is passed to successive generations and represents the fundamental level of genetic variation. DNA codes for the production of the many proteins that are assembled as the building blocks that comprise the organism. The final expression of this is in the appearance and external features or morphology of the animal. The morphology of any given animal is determined by both this genetic make-up and the environment in which it has developed.

The extent to which the adult morphology or phenotype is influenced by environmental factors varies between groups and between environments. A good biological species must be capable of inter-breeding to produce viable offspring. Decisions about species boundaries are typically made by a taxonomist experienced in a particular group of fauna on the basis of morphological characteristics, population distribution data and other information. It is also possible to test species distinctions with character sets derived from protein and/or DNA markers.

- **Protein Electrophoresis and Mitochondrial DNA Analysis**

Protein electrophoresis is a well established technique of investigating genetic variation in populations of organisms. Different species will produce different forms of the same protein, known as allozymes. If populations of fauna are sufficiently different to be

reproductively isolated (i.e. different species), then many of these allozymes will also differ. Electrophoresis essentially consists of the extraction of a protein rich sample from the subject fauna (or whole animals in the case of stygofauna). This sample is then applied to a small hole at one end of a starch gel and a weak electric field is then applied to it. The proteins will migrate at varying speeds through the gel and suitable stains will then reveal a pattern of different allozymes for each animal sampled. Testing of a range of protein loci enables a 'genetic distance' to be calculated based on the number of shared allozymes. The patterns from these data are compared with that from the morphological investigations, which then allows decisions to be made about species differences.

It is also possible to carry out similar analyses of genetic variation at the level of DNA. At this initial stage however, it may be prudent to commence with allozyme electrophoresis as this procedure will identify species level differences if they exist and is quicker, cheaper and simpler than DNA analysis. This technique has produced clear results on stygofauna in the past. Furthermore, retained similarity that results from shared ancestral polymorphisms can sometimes make interpreting DNA sequences or patterns produced by DNA markers difficult (e.g. Simon et al. 1994). However, DNA markers have proved very useful in numerous studies for providing phylogenetic information at several taxonomic levels, and might be considered as another character set to help interpret species relationships if required as part of future investigations (see Section 3.0).

## 2.0 Approach

The sampling programme has been designed primarily to address the requirements of Condition 6 (Section 1.1). As part of the programme, HI has also adopted an approach of focussing the work to maximise the collective knowledge of stygofauna (Section 1.2). This will be achieved by working in collaboration with other industry proponents in the Pilbara to:

- share data on species distributions;
- jointly support fundamental research into the genetics and ecology of stygofauna; and
- collect and store the resultant data in a consistent format (see Section 1.2).

The following participants and stakeholders, and their broad roles, have been identified in relation to stygofauna research for the Nammuldi project and the wider region:

### **Industry Proponents**

Hammersley Iron (HI)  
BHP Billiton Iron Ore (BHPBIO)  
Hope Downs Management Services (HDMS)

### **Management and Research Organisations**

Biota Environmental Sciences  
Western Australian Museum  
University of Western Australia Zoology Department  
University of Adelaide  
Australian National Museum

### **Decision Making Authorities**

Department of Conservation and Land Management (DCLM)  
Department of Environmental Protection (DEP)  
Environmental Protection Authority (EPA)

A collaborative approach on behalf of all parties will yield the clearest outcomes in relation to speciation and distribution of stygofauna, both at HI sites and in the context of the wider region. This will be useful not only in evaluating the findings of the current stygofauna sampling programme, but also for other sites in the Pilbara.

## 3.0 Sampling Programme Design

### 3.1 Overview

The basic design of the sampling programme comprises a subterranean fauna survey of the area to be affected by dewatering for the mine (the Nammuldi areas) and of areas where groundwater levels will not be affected by the Nammuldi dewatering (primarily in areas to the north associated with Homestead Creek).

In summary, the approach to the selection of sampling sites has comprised:

1. A review to identify all available existing bores in the Nammuldi locality.
2. Documentation of the parameters listed in Section 3.2 for all bores to the extent to which records were available.
3. A review of the available bores to categorise them either as those that are within the Nammuldi / Brockman impact area or those that are outside in the wider region (principally to the north at Homestead Creek).
4. Selection of bores for sampling based on this assessment and on other borehole parameters (Section 3.2). The objective of this exercise was to identify bores suitable for sampling in order to maximise the chances of recovering stygofauna and to provide adequate coverage of both the Nammuldi / Brockman impact area and the wider Homestead region.

More detail on the above, and on the implementation of the sampling programme, is provided in the following sections.

### 3.2 Specifics of Borehole Selection

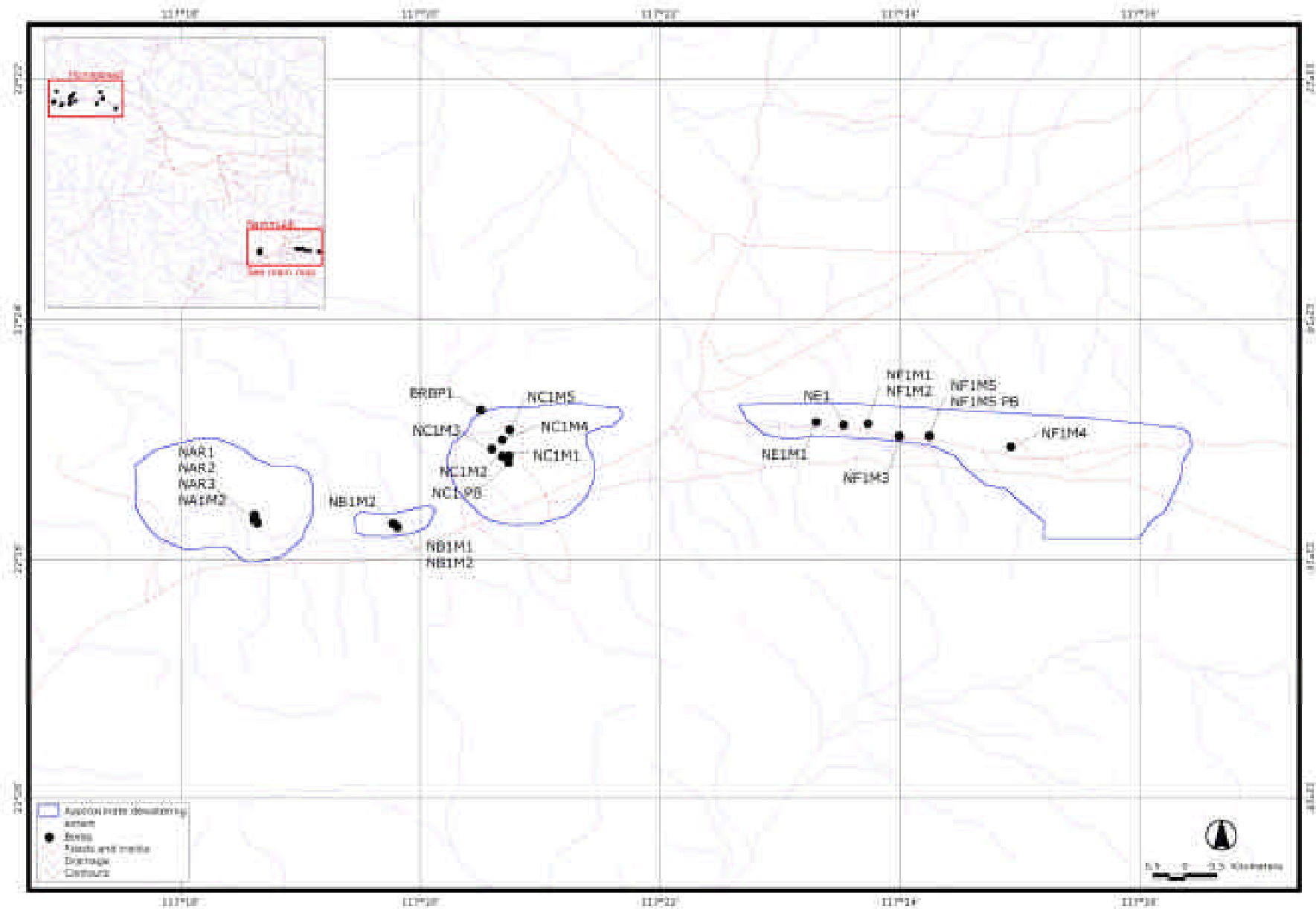
A review was undertaken of the boreholes available in the sampling areas. The objective of this was to select sampling locations to maximise the prospects of collecting stygofauna.

Typical parameters that were considered in the selection of bores from amongst those available included:

- spatial location;
- depth;
- construction / casing type;
- age;
- dominant geology targeted;
- extent of saturated calcrete or alluvials/gravels (prospective geology);
- hydrogeological catchment;
- stygofauna presence from previous sampling work; and
- location (either within or outside of the Nammuldi dewatering influence).

Parameters were reviewed to identify bore construction type, lithology and geographical and geological areas most prospective for recovering stygofauna.

The review selected 22 locations (comprising 22 boreholes; Appendix 2, Figure 3.1) within the Nammuldi / Brockman area and 11 locations (comprising 22 boreholes) within the Homestead Creek area (Figure 3.1). This amounts to a total of 44 boreholes amongst 33 locations in the sampling programme. Additional locations were also sampled at Silvergrass to and will be reported as part of a separate compliance document.



**Figure 3.1: Sampling locations in the Nammuldi project area, showing approximate extent of dewatering influence for each deposit and regional sample points at Homestead Creek for context (top left).**

### 3.3 Implementation of the Sampling Programme

The sampling programme methodology is consistent with that currently being applied on other stygofauna survey projects in the Pilbara (Biota 2001a, 2002a, 2002b).

An overview of the field sampling methodology is as follows:

1. Sampling of boreholes, primarily by standard plankton net bailing techniques. Each bore is bailed a minimum of three times per sampling effort. If stygofauna are apparent in the material recovered, then additional bails are carried out at these locations.
2. The use of other specialised pumping techniques or trapping is also considered, with trials of airlift pump techniques having been undertaken by HI at the Nammuldi and Silvergrass sites previously (November 1998).
3. Treatment of the specimens upon recovery depends on the direction followed for the more detailed genetic work (Section 3.4). For protein electrophoresis work, the recovered specimens are stored in a liquid nitrogen flask to ensure that proteins do not denature (which renders the specimens useless). Specimens that are to be utilised for morphological analysis and DNA work are preserved in 100% ethanol.
4. Repeat sampling efforts are conducted to take into account temporal variation. This can yield additional specimens and minimise the risk of recording low frequency species from a single bore only.

The primary sampling method follows established techniques of bore sampling by trawling the column with modified plankton nets. A 200 µm mesh plankton net is used and a range of ring (i.e. aperture) sizes has been manufactured to accommodate the range of bore hole diameters present in the study area (see Appendix 2). Nets are dropped to slightly above the bottom of the sampled holes, allowed to settle for a few minutes, then hauled to the surface. The bore is re-sampled twice more following the same procedure (i.e. three net hauls per bore). On the third bail, the sediments on the bottom of the bore are agitated with the weighted net prior to hauling in an attempt to mobilise sediment fauna. Samples are sorted under a microscope and fauna identified as far as possible (usually order level) in facilities near the study area.

In order to minimise the risks of accidentally transferring collected fauna from one hole to another (and potential cross-contamination of samples) a sampling hygiene procedure is used. This consists of thoroughly washing all nets and sample vials to remove sediment and other material prior to re-use at the next location.

An account of the sampling completed in the Nammuldi project area is provided in Section 4.2.

### 3.4 Specimen Storage and Data Management

Given that a proportion of the specimens recovered are used for allozyme electrophoresis, it is essential that they are returned to Perth frozen at sub-zero temperatures. Frozen specimens are stored in a dewar flask containing liquid nitrogen, with other stygofauna stored in vials containing 100% ethanol. Specimens will initially be utilised as part of research underway at the University of Western Australia, and those parts not consumed will ultimately be lodged with the WAM at the completion of the research programme.

Details of all specimens, including custody, collection location, date, sample number and specimen numbers, are recorded on standard tracking forms and entered into a purpose-designed Microsoft Access database held by Biota. This is of critical importance in the latter parts of the investigations, when data from specimens used in both morphological and

allozymic taxonomic work are corroborated (either parts of the same animal or animals from the same boreholes). Biota's stygofauna database also currently contains capture records from Hamersley Iron's stygofauna work at other sites, along with data from BHPBIO's Orebody 23 and Mining Area C, and the Hope Downs project area.

### **3.5 Specimen Analysis, Identification and Genetics**

The work includes a component that quantifies morphological variation and allozyme variation and may also extend to DNA analyses of selected material. HI is one of the primary initiators and financial supporters of a post-doctoral research project by Dr Terrie Finston at the University of Western Australia's Department of Zoology, which is primarily examining genetic variation in amphipods. Dr Finston's work will be undertaken collaboratively with Dr Brenton Knott and Assoc Prof Mike Johnson, with input from other morphological specialists including Mr John Bradbury (University of Adelaide).

The advantages of this work include:

- developing local Western Australian knowledge of this relatively poorly studied area;
- consolidating data from different locations in the Pilbara to improve sample sizes for analysis; and
- providing a coordinated industry position on this issue and jointly focussing industry resources.

Other stygofaunal groups collected will be identified and their conservation status assessed via the WAM, Australian National Museum, University of Adelaide and other specialist taxonomists as required. The results from this work will be consolidated with the previous work carried out by the University of WA and the WAM, along with the findings of ongoing genetic work for specimens from both Hope Downs and BHPBIO's projects.

A summary of the results from Nammuldi to date are presented in Section 4.2 and is submitted to the DEP/EPA in accordance with the requirements of Condition 6-4.

## 4.0 Evaluation of Results

### 4.1 Evaluation Objectives and Criteria

It is proposed that the evaluation of the results of the programme be carried out within the framework provided by the clauses of Condition 6 (see Section 1.1). A suggested set of objectives and evaluation criteria based on this is provided below for review and approval by the EPA, DCLM and WAM (Table 4.1).

**Table 4.1. Objectives and Evaluation Criteria**

<b>Objective 1: Prepare a subterranean fauna sampling plan</b>	
<b>Requirements</b>	<ol style="list-style-type: none"> <li>1. Conduct subterranean fauna surveys of the areas to be affected by dewatering operations to assist in establishing the conservation significance of any species within the affected areas;</li> <li>2. Characterise subterranean fauna habitats to be affected by dewatering and identify similar subterranean fauna habitats outside the affected areas;</li> <li>3. Conduct subterranean fauna surveys of similar habitats outside the areas to be affected by dewatering operations to assist in establishing the conservation significance of fauna within the areas to be affected; and</li> <li>4. Record and preserve biological information on any species collected in the project area.</li> <li>5. Determine that there is no significant risk of any species of subterranean fauna becoming extinct by mining proceeding in the defined areas.</li> </ol>
<b>Evaluation Criteria</b>	The subterranean fauna sampling plan will meet the identified objectives when it is formally approved as meeting the above requirements by the EPA on advice from CALM that the identified objectives are adequately addressed.
<b>Objective 2: Make the approved sampling plan publicly available</b>	
<b>Requirements</b>	1. The proponent shall make the Subterranean Fauna Sampling Plan publicly available to the requirements of the Environmental Protection Authority.
<b>Evaluation Criteria</b>	This requirement will be met by making the approved sampling plan publicly available by lodging two copies with the Environmental Protection Authority Library, the Tom Price Public Library and the JS Battye Library.
<b>Objective 3: Implement the sampling plan</b>	
<b>Requirements</b>	1. The proponent shall implement the Subterranean Fauna Sampling Plan.
<b>Evaluation Criteria</b>	This requirement will be met by the implementation of the sampling procedures specified in this document for the relevant areas.
<b>Objective 4: Submit the results of the sampling plan to the EPA for consideration</b>	
<b>Requirements</b>	1. The proponent shall submit the results from the Subterranean Fauna Sampling Plan to the Environmental Protection Authority, the Department of Conservation and Land Management, and the Western Australian Museum.
<b>Evaluation Criteria</b>	A report will be prepared summarising the findings of the work and will include the findings of any further investigations carried out on collected material. Distribution and status of the fauna will also be documented to enable evaluation of species extinction to be carried out.

**Table 4.1. Objectives and Evaluation Criteria**

<b>Objective 5: Evaluation of the EPA's objective for the sampling programme</b>	
<b>Requirements</b>	1. In the event that the Environmental Protection Authority considers, based on the results of the Subterranean Fauna Sampling Plan, that its objective would be compromised, then the proponent shall develop an action plan to the requirements and timing of the Environmental Protection Authority.
<b>Evaluation Criteria</b>	The EPA's stated objective for the Subterranean Fauna Sampling Plan is " <i>to increase scientific knowledge about subterranean fauna to assist in the conservation of this element of the environment.</i> " If the EPA considers that this objective would be compromised on the basis of the sampling plan results, and that scientific knowledge has not been increased to assist in the conservation of subterranean fauna, then an 'action plan' will be required. The content of this action plan is not identified at present and would need to be the subject of discussion between the proponent, EPA, DCLM and WAM.

## 4.2 Sampling Effort and Results from Nammuldi

Stygofauna have been sampled from boreholes at Nammuldi on five separate occasions since 1998, typically coinciding with sampling that was undertaken at Silvergrass, Homestead and Farquar. At least 12 boreholes were sampled within the Nammuldi area on each occasion, along with a similar number in the Silvergrass and Homestead Creek areas (data not reported here). Initial sampling in 1998 included trialling a large airlift pump. All other surveys used the modified plankton nets to sample the water column as per the methodology outlined in Section 3.0. Geology and construction for boreholes at Nammuldi is available in PPK (1999).

**Table 4.2. Summary of stygofauna sampling and results in the Nammuldi project area.**

<b>Date</b>	<b>Locations sampled</b>	<b>Nammuldi Holes</b>	<b>Fauna collected at Nammuldi</b>
November 1998	Nammuldi (plus Brockman - Silvergrass - Homestead)	NAR1 NAR2 NAR3 NF1M2 NF1M3 NF1M4 NF1M5 NF1M5 PB NC1 PB NC1M1 NC1M2 NC1M3 NC1M4 NC1M5 BRPB1	None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded
May 1999	Nammuldi (plus Brockman - Silvergrass - Homestead)	NE1 NE1M1 NF1M2 NF1M3 NF1M5 NF1M5 PB NC1 PB NC1M1 NC1M2 NC1M3 NC1M4 NC1M5 BRPB1	None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded 8 x Collembola, 1 x Copepod, 2 x Amphipoda (families Bogidiellidae and Melitidae)

**Table 4.2. Summary of stygofauna sampling and results in the Nammuldi project area.**

Date	Locations sampled	Nammuldi Holes	Fauna collected at Nammuldi
October 1999	Nammuldi (plus Brockman - Silvergrass - Homestead)	NE1 NE1M1 NF1M2 NF1M3 NF1M5 NF1M5 PB NC1 PB NC1M1 NC1M2 NC1M3 NC1M4 NC1M5 NAR3  NB1M1 BRPB1	None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded 1 x Copepod (HI 130) 1 x Chelicerata (terrestrial spider; HI 131) 1 x Unknown (HI 132) 'worm' (possible oligochaete; HI 129) None recorded
May 2001	Nammuldi (plus Brockman - Silvergrass - Homestead, Farquar)	NE1 NE1M1 NF1M2 NF1M3 NF1M5 NF1M5 PB NC1 PB NC1M1 NC1M2 NC1M3 NC1M4 NC1M5	None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded Not located None recorded None recorded
June 2001	Nammuldi	NAR1  NAR3 NA1M2  NA1M3 NA1M5 NB1 NB1M1 NB1M2 NB1M3 NB1M4 BRPB1	1 x amphipod (? <i>Pilbarus millsii</i> - HI643) None recorded 1 x amphipod (family Melitidae:- HI644) None recorded None recorded None recorded None recorded None recorded None recorded None recorded None recorded

Five sampling exercises over a three year period recorded no stygofauna from the majority of the boreholes in the project area (Table 4.2). Of the five visits to Nammuldi, only four individual stygal specimens have been recorded from the core Nammuldi area, each record being from a separate hole that yielded only one (or in one case two) stygal specimens. Two individual amphipods were recorded from the Nammuldi area. One individual, from NAR1, was a juvenile, making taxonomic designation difficult. However, it was compared against slide-mounted material from the paramelitid *Pilbarus millsii* (which is known from a number of other sites in the Pilbara) and appeared to correspond to this species (T. Finston, UWA, pers. comm.). The other was a mature melitid amphipod probably belonging to the genus *Nedsia* which was recorded from NA1M2 (T. Finston, UWA, pers. comm.). Both were collected in June 2001 and both locations are within the dewatering influence of Pit A. The remaining two specimens were from boreholes NAR3 (a copepod) and NB1M1 (a worm, possibly an oligochaete) (see Table 4.2).

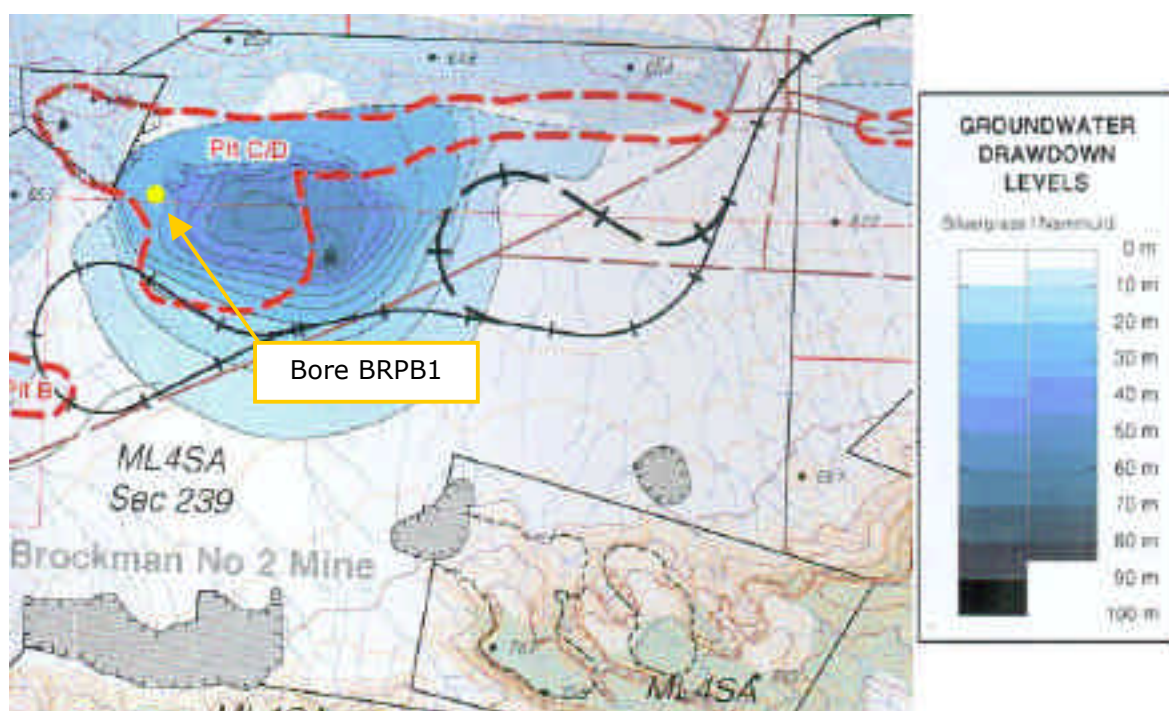
Despite the fact that identification of three specimens from Nammuldi could not be confirmed and could not be compared to regional samples (barring DNA analysis), Dr Terrie Finston (pers. comm.) has found that similar stygal assemblages can occur over a

range of approximately 20 km within a single catchment where suitable habitat is available (e.g. Paraburdoo mine and Paraburdoo townsite along 7 Mile Creek, and Homestead and Silvergrass along Caves Creek). Therefore, these three unidentified specimens may also occur outside the impact area.

The results at Nammuldi contrast with those from Homestead and Silvergrass where stygofauna representing several crustacean groups and other invertebrates have been collected from most bores (Appendix F of Hamersley Iron 2000; Biota 2002c). The taxonomic diversity and abundance of most groups was relatively high in some bores at these reference locations (Appendix F of Hamersley Iron 2000; Biota 2002c). The difference in results between the two locations is not surprising given that a large alluvial drainage system, such as Caves Creek at Homestead / Silvergrass, is absent from Nammuldi, with drainage being limited to minor drainage incised lines. In a regional context then, the stygofauna values of the Nammuldi area appear to be low in comparison to both local sites (Homestead, Silvergrass) and other locations in the region (eg. Ethel Gorge (Eberhard and Humphreys 1999, Biota 2001a), Weeli Wollie Creek (Biota, in prep.)).

One hole from the nearby Brockman borefield (associated with the existing Brockman mine) also yielded specimens during sampling undertaken in May 1999 (see Table 4.2). The fauna collected was mostly surface in origin (collembolans typically being leaf-litter or edaphobitic fauna and not stygal), with the exception of one copepod specimen and two amphipods. These amphipods appeared to belong to the families Bogidiellidae and Melitidae (T. Finston, UWA Zoology, pers. comm.) but were too minute or immature to be identifiable to the species level. Many of the features required to key out this fauna require mature specimens of good size and condition for diagnostic features to be assessed.

Borehole BRP1 at Brockman is situated on the outer margin of the Nammuldi C/D pit (Figure 4.1). This location will be removed with the full development of the Nammuldi C/D pit and would be subject to 20-30m drop in groundwater levels.



**Figure 4.1: Location of hole BRPB1 in the context of modelled drawdown levels for the Nammuldi C/D pit.**

In summary then, the results of the sampling work conducted at Nammuldi indicate that there is a relatively low risk of any regionally significant stygal communities being affected by

dewatering. Three years of repeat sampling have found no evidence of stygofauna in the majority of sample sites (17 of 22 holes; 77%), with collections from each of the other holes generally being only single individuals on single occasions. Three of the four amphipod specimens collected from the impact area were too small and immature to be definitively identified to the species level, but one appeared to be a species known from other locations in the Pilbara. The remaining individual was preliminarily placed in the genus *Nedsia*, which is also represented amongst stygal specimens collected from the Homestead Creek area (Biota, 2002c).

HI's research work on stygofauna genetics in the Nammuldi-Silvergrass-Homestead area, and other regional sites, indicate that the same species appear to be generally distributed locally within a catchment, but different species occur between catchments (T. Finston, UWA, pers. comm.). This suggests that the few individuals collected at Nammuldi may be represented elsewhere in the local catchment (outside of the dewatering influence) but were not collected due to the limited number and distribution of sampling points. It should also be noted that this summary statement, and the results of this programme generally are limited by the factors typically associated with this type of investigation. That is, factors such as bore construction, age, the depth of drilling and the portion of the aquifer that the casing is open to, can all affect the likelihood of stygofauna colonising the bore.

Based on the data gained from this sampling programme, the EPA's objective has been met as it applies to Nammuldi through the implementation of the sampling methodology, resultant improvements on knowledge of stygofauna distribution, morphology and population genetics, and the lack of apparent risks with regards to regional conservation values with respect to stygofauna. An evaluation of the results for the site against the criteria set out in Section 4.1 is provided below in Table 4.3.

**Table 4.3: Evaluation of Nammuldi Stygofauna Sampling against objectives based on Ministerial Condition 6**

<b>Objective 1: Prepare a subterranean fauna sampling plan</b>	
<b>Evaluation</b>	This document represents the sampling plan addressing the requirements of Objective 1 of Table 4.1 and clause 6-1 of Ministerial Condition 6.
<b>Objective 2: Make the approved sampling plan publicly available</b>	
<b>Evaluation</b>	This document will be lodged with the Environmental Protection Authority Library, the Tom Price Public Library and the JS Battye Library, once approved by EPA on advice from the relevant agencies.
<b>Objective 3: Implement the sampling plan</b>	
<b>Evaluation</b>	Sampling has been completed at Nammuldi on five occasions in accordance with the procedures outline in this sampling.
<b>Objective 4: Submit the results of the sampling plan to the EPA for consideration</b>	
<b>Evaluation</b>	Section 4.2 of this document outlines the results of the sampling work at Nammuldi and is submitted as required for EPA review on advice from the relevant agencies.
<b>Objective 5: Evaluation of the EPA's objective for the sampling programme</b>	
<b>Evaluation</b>	Given the apparent lack of a significant stygal community at Nammuldi it appears unlikely there are any significant stygofauna at risk from future dewatering activities proceeding at this site.

## 5.0 References

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**Glossary of Terms**

## Glossary

Allozyme	Alternative forms of the same protein coded for by different genes at the same locus.
DNA	Deoxyribonucleic Acid – the fundamental genetic material.
Electrophoresis	A lab technique for separating proteins based on their different mobility through an electric field.
Gene	A sequence of DNA that codes for a specific protein or other function.
Genotype	The genetic make-up of an organism with respect to a particular locus or the whole genetic material.
Locus	The place at which a particular gene resides on the DNA or genetic map.
Phenotype	The observable characteristics of an individual arising from interaction between the genotype and the environment.
Species	Groups of interbreeding natural populations that are reproductively isolated from other such groups.
Stygofauna	Obligate, groundwater dwelling fauna.

**Details of Sample Boreholes**

### Boreholes for Nammuldi Stygofauna Sampling Programme.

Bore	Easting	Northing	Depth (m)	Casing Details	Target Geology
NAR1	531811.36	7519953.42	7	Slotted over entire length	Alluvials
NAR2	531782.27	7519962.86	6	Slotted over entire length	Alluvials
NAR3	531789.819	7519984.03	5	Slotted over entire length	Alluvials
NA1M2	531793.33	7519983	24	Cased to 24m, slotted 12-24	Alluvials, calcrete
NA1M3	531787	7520045	24	Cased to 22.5m, slotted 10.5-22.5	Alluvials, calcrete
NA1M5	531826	7519912	72	Cased to 72m, slotted 54-72	Fractured NEW min
NB1M1	533840.53	7519849.7	36	Cased to 36m, slotted 30-36	Calcrete
NB1M2	533775	7519903	90	Cased to 87m, slotted 57-87	Detritals, NEW min
NC1 PB	535440.912	7520848.04	234	Steel production well, cased to 234m, slotted 54-60, 78-90, 102-108, 120-126 and 138-234	Detritals, calcrete, NEW min
NC1M1	535446.578	7520941.48	-	Cased to 90 m, slotted 60-90	-
NC1M2	535349.527	7520942.43	138	Cased to 138m, slotted 124-138	Overthrust NEW min
NC1M3	535200.166	7521054	-	Cased to 82 m, slotted 45-85	Overthrust NEW min
NC1M4	535351.412	7521193.45	-	Cased to 70m, slotted 52-70	Detritals
NC1M5	535459.74	7521343.64	81	Cased to 81m, slotted 51-81	Underthrust NEW min
NE1	540250.3	7521405.64	111	Cased to 110, slotted 38-110	Detritals, NEW min
NE1M1	539858.28	7521456.75	90	Cased to 90m, slotted 60-90	ANG min, NEW min
NF1M1	540598.531	7521424.18	70	Cased to 69m, slotted 57-69	-
NF1M2	540597.9	7521423.69	93	Cased to 55m, slotted 43-55	-
NF1M3	541049.054	7521237.52	57	Cased to 57m, slotted 45-57	Calcrete, detritals
NF1M4	542652.518	7521067.84	118	Cased to 118m, slotted 82-118	NEW min
NF1M5	541478.401	7521232.45	128	Cased to 88m, slotted 46-88	Detritals, NEW min
NF1M5 PB	541478.401	7521232.45	129	355mm steel production well to 47m, 219mm steel case to 129, blank 0-51m, slotted 51-129	NEW min
BRBP1	535042	7521654	-	Brockman borefield water bore	-