Appendix L
Stygofauna Survey Report

REPORT FOR GUNSON RESOURCES LTD

COBURN MINERAL SAND PROJECT

AMY ZONE OPERATION

- STYGOFAUNA PILOT SURVEY -

April 2005

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EXECUTIVE SUMMARY

This Report relates to a proposal by Gunson Resources Limited to develop the Coburn Mineral Sand Project, located 250 km north of Geraldton, Western Australia. The project is situated within the Carnarvon Basin. This Pilot Survey was undertaken to assess the presence of stygofauna which if found would trigger current legislation protecting subterranean groundwater environments.

The principle findings of this Pilot Study are as follows:

1) Thirteen bores were visited on site in October, 2004, but only seven were found to be suitable for sampling.
2) No stygofauna were found.
3) Two species of terrestrial origin only were found.
4) Results are only relevant for the Northern Region of the Amy Zone Project Area, part of the Coburn Mineral Sand Project.
5) The results presented here cannot be used to predict reliably whether species of stygofauna occur in areas adjacent to the immediate area of sampling covered by this Report, and should mining operations extend beyond this area, each additional area will need to be surveyed.

Follow-up studies recommended to address the following gaps in the present study:

1) Bores in the southern area of operations should be located and sampled.
2) If such bores are not already in existence, then bores should be installed according to a strategic sampling plan.
3) Both northern and southern bores will need to be sampled on at least two further occasions (i.e. all bores should be sampled on at least three occasions) in order to:
    a) Account for seasonal variation and abundance.
    b) Be spaced temporally to overcome adverse affects from installation, and sampling replication.
    c) Gender confidence in negative results.

SCOPE OF THIS SUBMISSION

Gunson Resources Limited is proposing to develop the Coburn Mineral Sand Project, some 250 km north of Geraldton, Western Australia. This Report relates to the need to identify whether any species of stygofauna occur in the area to be developed for the sand mining operation.

The proposed mining area occurs in the south-western corner of the Carnarvon Basin, one of the major sedimentary basins of Western Australia. Limestone formations of the North West Cape and Cape Range areas of the Carnarvon Basin are known to harbour a diverse and zoologically important stygofauna associated with its groundwater, and it is pertinent to question whether stygofauna occur further south within the area of the Amy Zone Operation.

Consequently, this study was undertaken to ascertain whether stygofauna occur in the area proposed for sand mining in the Amy Zone. This research was undertaken in anticipation of the expectation that, should any stygofauna occur within the proposed mining and dewatering areas, the Environmental Protection Authority would need to be assured that no species will be driven to extinction through mining activities.

STYGOFAUNA PILOT SURVEY OF THE AMY ZONE OPERATION AREA

Discussions between staff of URS, on behalf of Gunson Resources Ltd., and zoologists from The University of Western Australia (UWA) were held on Tuesday 27 July, 2004, in the Hyatt Centre. The outcome of this meeting led to listing the following objectives by the proponent:

1. Sample 5-7 bores for stygofauna utilising three sampling methods (bailing, sieving and trapping) at the Amy Zone. The bores to be sampled were identified by URS and the UWA personnel were subsequently informed. All bores which could be located both inside and outside the project area were sampled.
2. Identification of any stygofauna found from any of the bores sampled.
3. Analysis and interpretation of data collected including species occurrence and distribution, and the differences/or significance of species of stygofauna identified within the Project Area compared with any collected from outside the Project Area.
4. Identification of relevant impacts and proposed management issues resulting from dewatering activities for all species of stygofauna found. Recommendations concerning additional surveys required should be included, if necessary.
5. Preparation of a stand alone report summarising the objectives, methodology, results, discussion and conclusions of the stygofauna survey undertaken to a standard suitable for appending to a Public Environmental Review.

The present Report is a summary of the sampling for stygofauna in the northern-most portion of the area proposed for mining areas.

1. INTRODUCTION

Gunson Resources Limited is proposing to develop a mineral sand project north of Geraldton, Western Australia. This Report relates to the need to identify whether any stygofauna occur in the area to be developed for the sand mining operation, the Amy Zone Operation, Coburn Mineral Sand Project, which is some 250 km north of Geraldton on the undulating Victoria Sand Plain District closely adjacent to the southern limit of Shark Bay (Figure 1).

The presence of any stygofauna needs to be resolved because the proposed mining area occurs in the south-western corner of the Carnarvon Basin, one of the major sedimentary basins of Western Australia (Palfreyman 1984). There is a diverse and zoologically important stygofauna associated with the groundwater in the limestone formations of the North West Cape and Cape Range areas of the Carnarvon Basin, and in the northern parts of the Basin (Humphreys 1993a; Bradbury and Williams 1997) including Barrow Island (Bradbury and Williams 1996). Within the study area of this Report, there are four major confined aquifers underlying the project area, of which that closest to the land-surface occurs in the Windalia Sandstone Member, a stratum with a thickness of 32 m in the study area. The water salinity typically varies between 6,500-7,000 mg L^{-1} but the aquifer apparently is of limited extent. Limited areas of saturated dunal sands form local superficial, unconfined aquifers, which also are potential sites of stygofauna. There is an extensive and diverse stygofauna in aquifers capped with calcrete deposits through the Pilbara and Eastern

Goldfield regions of Western Australia (Humphreys 2001; Cooper *et al*. 2002; B Knott unpublished results).

Consequently, this study was undertaken to ascertain whether stygofauna occur in the area proposed for sand mining in the Amy Zone. This research was undertaken in anticipation of the expectation that, should any stygofauna occur within the proposed mining and dewatering areas, the Environmental Protection Authority (EPA) would need to be assured that no species will be driven to extinction through mining activities. Particularly, it can be expected that the EPA will require that mining operations maintain the abundance, diversity and geographical distribution of subterranean fauna.

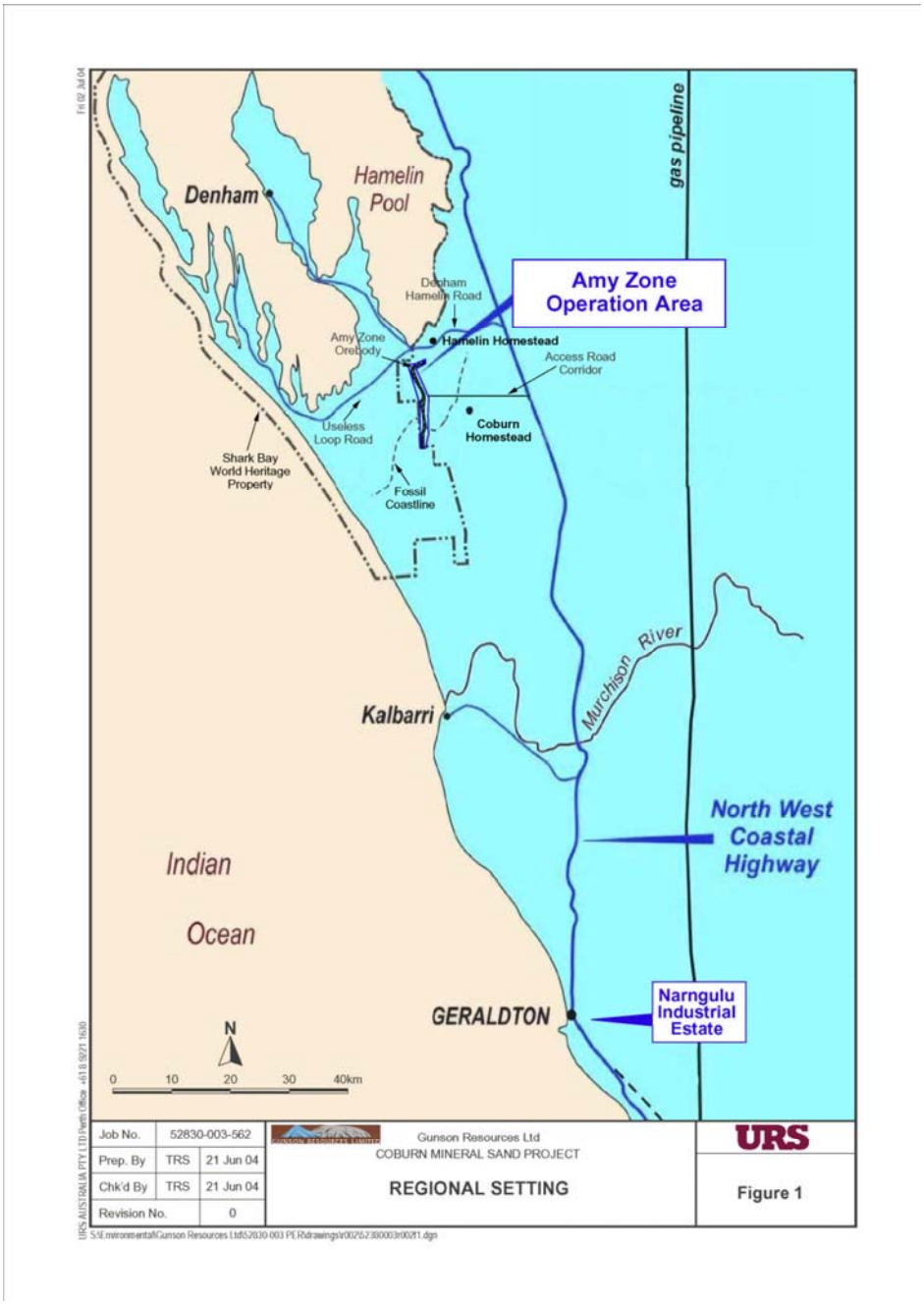

Figure 1: Location of the Amy Zone Operation Area, adjacent to Shark Bay, Western Australia. (Kindly supplied by URS).

2. SUBTERRANEAN FAUNA OF THE CARNARVON BASIN

There is an extensive and diverse stygofauna known from the northern portion of the Carnarvon Basin from karst of Cape Range and the adjacent coastal plains, and extending through the Fortescue River catchment into the Pilbara. Given the propinquity of the Pilbara to the Carnarvon Basin, it is relevant to note that ongoing studies by the Department of Conservation and Land Management (CALM), the Museum of Western Australia (WAM) and UWA, investigating the extent of stygofaunal diversity of the Pilbara region have revealed, to date, an extensive and diverse stygofauna from the Pilbara, with more than 200 species across all taxa being logged (Dr T. Finston, pers. comm.). Crustaceans, amphipods, isopods and copepods particularly constitute the major groups and all are widespread across the region. There is still substantial research effort required to validate the taxonomic status of the stygofauna of the Pilbara, but the zoogeographical significance of the fauna lies in the relictual lineages with Gondwanan, Pangaean and Tethyan affinities: it is an ancient fauna.

The stygofauna of Cape Range peninsula is well documented in a number of papers in the symposium proceedings titled *The Biogeography of Cape Range, Western Australia* (Ed. W. F. Humphreys (1993b). There are at least seven species of macro-stygofauna (i.e. specimens greater than 1 mm in length) associated with fresh groundwater of the coastal plains, with fishes (2 species), atyid shrimps (2 species), a remipede (1 species) a thermosbaenacean (1 species), and a species of amphipod crustacean. Another amphipod occurs at greater elevation in pools in caves on Cape Range (Knott 1993; Bradbury and Williams 1997). In addition, meiofaunal elements (specimens less than 1 mm in length: protists, turbellarians, nematodes, oligochaetes, copepods and acarines) have also been recorded from the area. The macrofaunal elements of the coastal plains, and particularly the fish and shrimp, occur in large spaces/caves in the limestone substrate. The zoogeographical relationships are consistent with those of the stygofauna from the Pilbara, namely there are ancient elements with Gondwanan, Pangaean and Tethyan affinities.

The authors are not aware of any other stygofauna reported from the southern portion of the Carnarvon Basin. Examination of saturated sands at Coral Bay south of Cape Range peninsula within the Carnarvon Basin yielded no stygofauna (B Knott, unpublished).

3. LEGISLATIVE FRAMEWORK

3.1. RELEVANT LEGISLATION

Currently, there are three legislative Acts relevant to the conservation of subterranean ecosystems and their biota. These comprise two Western Australian State Acts and one Federal Act identified below:

- *Environmental Protection Act 1987* (State)
- *Wildlife Conservation Act 1950-1979* (State)
- *Environmental Protection and Biodiversity Conservation Act 1999* (Commonwealth)

3.1.1. *Environmental Protection Act 1986*

The powers of the *Environmental Protection Act 1986* are administered by the Department of Environment (DoE), which in relevant cases advises to the Environmental Protection Authority (EPA). In conjunction with advice from Government departments, the public and

proponents, the role of the EPA is to provide recommendations and independent advice to the Minister for Environment on how best to protect the environment. The Department of Environment delivers the Environmental Protection Program on behalf of the Minister and provides key support to the independent EPA. The jurisdiction of the DoE comprises the protection of environmental systems, pollution prevention and waste management. In particular, the DoE manages and protects rivers, streams, creeks, estuaries, drains, wetlands and groundwater, but not marine waters, of Western Australia. With respect to protecting subterranean biota, the DoE has the power to restrict the abstraction and disposal of groundwater, including dewatering.

The purpose of the *Environmental Protection Act (1986)* is "...to provide for an Environmental Protection Authority, for the prevention, control and abatement of pollution and environmental harm, for the conservation, preservation, protection enhancement and management of the environment and for matters incidental to or connected with the foregoing". The *Act* requires that proposals "…which, if implemented, may cause significant environmental impact…" must be referred to the EPA for environmental impact assessment. Such proposals are then assessed with regard to the 5 object and principles of the *Act*. Three of these are relevant to the protection of subterranean environments and their biota. These include:

1) the precautionary principle;
2) the principle of intergenerational equity; and,
3) the principle of conservation of biological diversity and ecological integrity.

During the approvals process decisions are based on the broad principles of conserving biodiversity and achieving ecologically sustainable development. Advice provided by the EPA to the Minister for Environment with respect to a proposal is published in a public bulletin, containing recommendations on whether an approval should be granted, and stipulation of any conditions the proposal should be subject to. After consideration of a proposal, advice from the EPA and any appeals, the Minister then issues an approval statement. This statement outlines outcomes from the approval process, including Conditions to be met by the proponent. In most cases, on approval of any proposal, evidence is required to be provided by the proponent to prove that the conditions imposed are being met as the project progresses.

The EPA has released Position Statement No. 54, *Consideration of Subterranean Fauna in Groundwater and Caves* (in accordance with the *Environmental Protection Act 1986*) which outlines the minimum requirements for environmental management expected to be met by the proponent and the public during the assessment process (EPA, 2003). In general any proposal that could potentially have a significant impact on stygofaunal or troglofaunal habitat will trigger a formal EIA under the EP Act if they adversely affect:

1) the water table;
2) water quality; or
3) destroy or damage caves.

Any proponent that does not meet the minimum requirements outlined in the aforementioned Guidance Statement will be expected to scientifically justify to the regulatory authorities any actions to the contrary.

3.1.2. *Wildlife Conservation Act 1950-1979*

Under the *Wildlife Conservation Act 1950-1979* all native fauna to Western Australia are protected. The Act is administered by the Department of Conservation and Land Management (CALM). In particular, fauna considered to be rare, threatened with extinction or with high conservation value are a priority within the Act and specially provided for. The *Wildlife Conservation (Specially Protected Fauna) Notice* released in 1999 identifies 4 Schedules of taxa considered in need of special protection. Of these, Schedule 1 taxa comprises fauna 'which are rare or likely to become extinct'. It is under this Schedule that certain species or communities of subterranean biota are protected within the Act.

The Department of Conservation and Land Management has defined four additional priority codes in an effort to protect fauna of poorly known conservation status or those that may be potentially threatened if environmental conditions were altered. These priority codes vary with respect to the level of knowledge on the populations in question and the level of threat to the lands on which they inhabit. **Priority One** taxa are those with few, poorly known populations on threatened lands not managed for conservation (e.g. pastoral lands, active mineral leases, active Borefields). **Priority Four** taxa are defined as taxa in need of monitoring. These taxa are classified where there have been sight records, or the collection of few specimens, some of which are from lands that are not under immediate threat of habitat destruction or degradation. For both priority listings, taxa are in urgent need of survey to assess their conservation status before they can be declared as threatened fauna.

3.1.3. *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act 1999)*

The Environment Protection and Biodiversity Conservation Act 1999 is a legislative tool that provides protection for 'matters of national environmental significance'. It also regulates specific activities concerning the Commonwealth, Commonwealth areas, wildlife trade and heritage *(EPBC Act 1999)*. Under the *EPBC Act 1999*, approval is required for "any **action** that is **likely** to have a **significant impact** on a matter protected under **Part 3** of the Act". Matters protected under Part 3 include:

1) matters of National Environmental Significance (NES);
2) the environment on Commonwealth land; and
3) the environment in general where the activity in question is to be carried out on Commonwealth land or will be undertaken directly by the Commonwealth or one of its agencies.

One of the seven matters of National Environmental Significance (NES) outlined in the *Act*, concerning the protection of **threatened species** and **threatened ecological communities**, is relevant to the conservation of subterranean biota. Any **action** that **may** have a **significant impact** on a matter protected under **Part 3** must be referred to the Minister to undergo an assessment and approval process. Referral of any action thought to trigger the Act can be made by one of 3 groups:

1) the proponent of the action;
2) any State, Territory of Commonwealth Agency; or
3) a call in by the Minister.

Once an action is referred to the Minister, a decision as to whether or not that action triggers the EPBC Act and requires approval is made. If the action is approved it is called a **controlled action,** with the appropriate **level of assessment** then decided by the Minister. Following assessment and pending approval, conditions are then imposed by the Minister to be met by the proponent.

Note: The **proponent** is obligated to refer any actions that may trigger the Act, where the **action may impact** on **matters of NES**. Failure to do so will incur substantial penalties from the Minister.

4. KEY CHARACTERISTICS OF SUBTERANNEAN FAUNA

A wide range of animals with the necessary pre-adaptations have colonised subterranean habitats, some aquatic, some terrestrial. Some are now restricted to subterranean habitats, some can use them facultatively; some find their way in accidentally. Pertinent to this Report, those aquatic animals which now live obligatorily in subterranean environments are called stygofauna. Although subterranean habitats might not have immediate appeal for humans, being permanently dark, often with very small living spaces, and unreliable supply of food, there may be advantages for the few species able to colonise such habitats: temperatures tend to show minimal fluctuations, and there may be reduced competition for the limited food which is available. Subterranean habitats, considerably diverse (Botosaneanu 1986), possess one salient feature, the absence of plant-driven (photosynthetic) productivity (except in the particular cases where root mats develop and provide nutrients to drive subterranean ecosystems [Jasinska *et al*. 1996; Jasinska and Knott 2000]). (Subterranean systems driven by microbial energy and nutrients are now well known). Presumably as a direct consequence of the absence of light, stygofaunal elements (stygofaunal specimens), particularly of crustaceans, typically are recognisable by possession of a suite of characteristic morphological features:

1) pigmentation is markedly reduced or absent;
2) eyes are markedly reduced or absent; and
3) locomotory and sensory appendages are markedly extenuated, to compensate for the lack of sensory input through eyes.

5. IMPACTS TO SUBTERRANEAN FAUNA AND MANAGEMENT ISSUES

5.1. POTENTIAL IMPACTS OF MINING ON STYGOFAUNA POPULATIONS

There are three major categories of potential impact to stygofaunal habitats from mining activities. These include:

1) Changes to the water balance including dewatering and alterations to the water balance. The immediate impact on stygofauna stems from dewatering. Dewatering frequently produces a cone of dewatered sediment and clearly this removes habitat for aquatic species. The level of impact will depend on the size of the cone, the rate of

water flow through the aquifer and the length of time the cone is evident. Essentially temporary point source cones should not give rise to permanent loss of species.

2) Chemical changes can involve salinity fluctuations, introduction of pollution of the alteration of nutrient levels in the water, may also result from mining activities.

3) Compaction of sediment from heavy equipment, and the building of infrastructure including road access to the site. Habitat can be removed by reduction in the size of interstitial spaces and voids in the underlying strata.

Changes to any of the above issues may trigger the Acts outlined in Section 6 of this Report.

5.2. STYGOFAUNA SAMPLING STRATEGIES AND CONSTRAINTS

Sampling of subterranean aquatic fauna typically is constrained by difficulty in access. Caves, where they open to the surface, may provide good access for sampling underground water bodies. However, in areas such as that of the study area, the Amy Zone, caves are unknown and bores provide access to the ground water. In outback areas of Western Australia, many pre-existing bores were installed to provide access to water for human consumption and/or pastoral purposes; however, their placement was not driven by needs for scientific studies. This can restrict the effectiveness of preliminary sampling programs for stygofauna using pre-existing bores. Bores are expensive to install and preliminary sampling programs often rely on these old windmills and pastoral bores as sampling sites for data collection.

Using pre-existing bores is not without its problems. Some practical problems encountered when interpreting the presence f stygofauna include:

1) Variation of bore chronology / construction type / materials used. With many older bores there is insufficient information about bore details and it is only on-site experience that can reveal whether water can be extracted. However, information on slot size and casing type may remain a mystery, rendering interpretations of faunal-strata relationships inconclusive.

2) Water quality and physico-chemical environment within bore. Bores are often points of entry of surface derived organisms and detrital material which can cause stagnation within the bore.

3) Stratigraphy intersected by bore. Where a bore intersects more than one aquifer it may be difficult to identify which aquifer is harbouring a species of stygofauna.

4) Variation in water volume sampled. This can give rise to reliability of interpreting results, particularly negative results. What volume of water must be sampled before a negative result is reliable?

5) Variation in sampling design and techniques imposed by logistical and physical constraints. In a State the size and with the geological structure of WA, a study area often can cover large areas which are not well documented with respect to defining landmark features, and importantly positions of bores in relation to tracks. Thus locating bores can be difficult and time consuming. It is imperative to have accurate up-to-date maps to expedite an efficient sampling program.

6. METHODOLOGY

6.1. SAMPLE SITE SELECTION

Potential sites for stygofauna monitoring, within the boundaries of the Amy Zone Operation of the Coburn Mineral Sand Project, were identified by URS in a meeting with UWA staff prior to the commencement of field surveys. All bores were selected with the intention of sampling within, or adjacent to, the area of Exploration Lease E 09|939. In all, 7 bores were identified to be sampled, including: SMB 1A, SMB 1B and SMB 1C, SMB 2, SMB 3, SMB 4 and H 21 (Table 1). Of these bores, SMB 2, SMB 3 and SMB 4 each were comprised of a shallow and deep bore, designed to intersect both the superficial and underlying aquifers, respectively. It was requested that both components be sampled. Information concerning the location and structural characteristics of each bore was provided to UWA staff by URS. Subsequently, all bores sampled were located within the northern end of the mining lease.

Three additional bores were added to the sampling program in the field by the URS field staff. The exact co-ordinates of these bores were unknown but their location within the Shark Bay World Heritage Property and potential for yielding stygofauna were considered important to the client. Thus, the accumulative number of bores projected to be sampled totalled 13 (Figure 2).

Table 1: Bores identified to be sampled for stygofauna, Amy Zone, October, 2004.

BORE	DATE INSTALLED	TOTAL DEPTH (m)	STATIC WATER LEVEL (m)	COMMENT
SMB 1A shallow	~1985	~7	3	(Sampled)
SMB 1B shallow	~1985	~7	3	(Sampled)
SMB 1C	~1985	~7	3	(Sampled)
SMB 2 (shallow)	4-5/8/04	23.88	24.68	Insufficient water to sample for stygofauna
SMB 2 (deep)	4-5/8/04	40.55	24.68	Sand/calcrete (slightly to well cemented) 2.5-6 m; Clay 26-31 m (Sampled)
SMB 3 (shallow)	1-2/8/04	30	dry	
SMB 3 (deep)	1-2/8/04	43	30.14	Clay 32 m to bottom (Sampled)
SMB 4 (shallow)	2-3/8/04	30.49	dry	
SMB 4 (deep)	2-3/8/04	42.74	37.1	Sand/calcrete (slightly to well cemented) 8-10 m; Clay 30.5-34 m (Sampled)
Hamlin 21 (H 21)	20 years?	Very deep. Beyond 200 m rope (potentially to base of the Talunga Formation?)	30	(Sampled)
WH 1	Unknown	6.72	6.52	Potentially decommissioned DoE bore – insufficient water to sample
WH 2	Unknown	Unknown		Potentially decommissioned DoE bore – insufficient water to sample
WH 2a	Unknown	6.56	dry	Potentially decommissioned DoE bore – insufficient water to sample

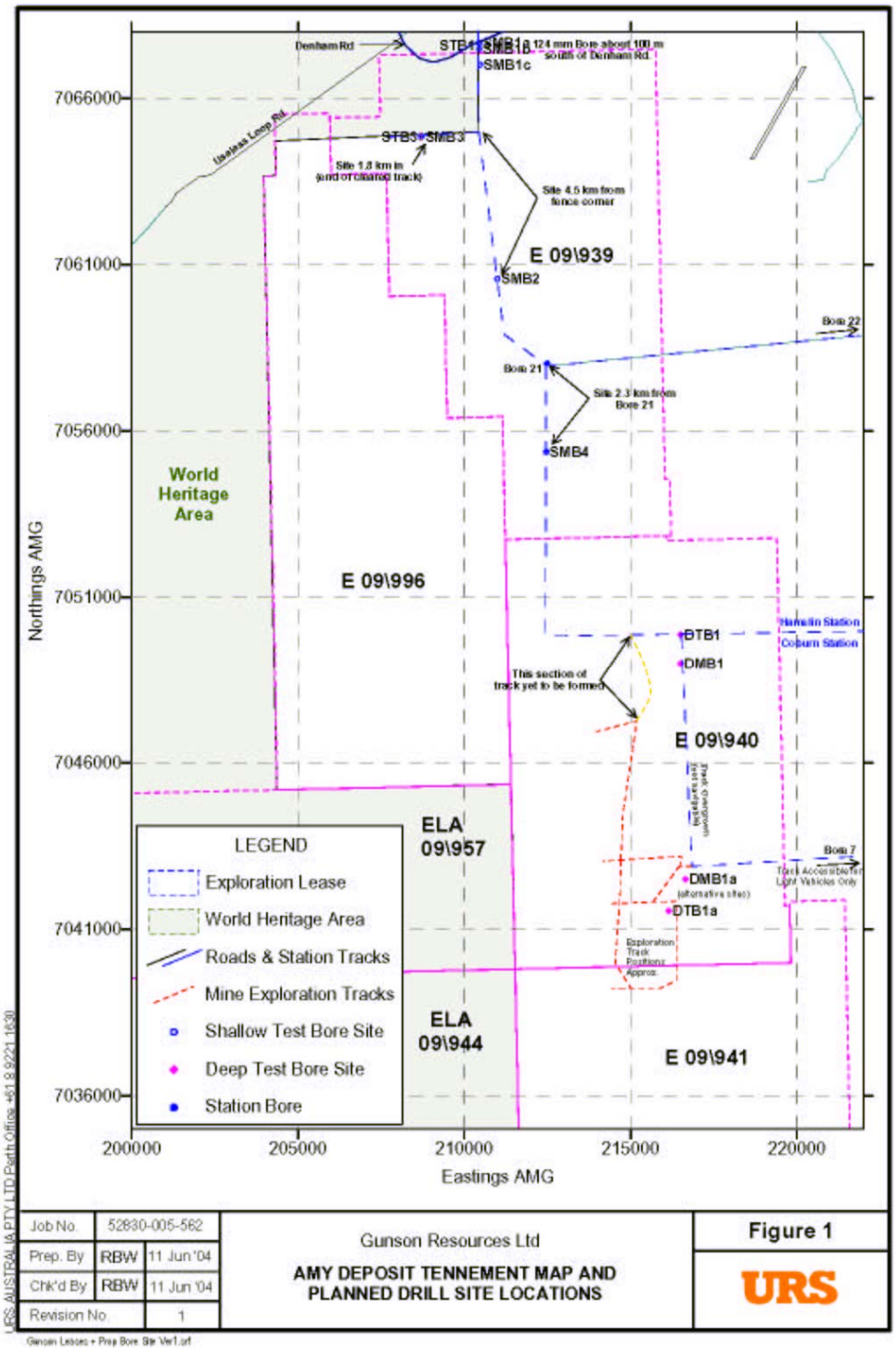

Figure 2: **Bore locations sampled during, October 2004, and property boundaries in the north-western region of the Amy Zone Operation Site, immediately south of Shark Bay, Western Australia.** (Map drawn by URS. The additional 3 bores occur within the World Heritage Area, beyond the northern limits of the map).

6.2. FIELD SAMPLING

All sites located with adequate water levels were sampled for stygofauna using three separate sampling techniques:

1. bailing;
2. netting; and
3. baiting/trapping

6.2.1. Bailing

The first replicate at each site was taken using a (1000 ml) bailer lowered on a 200 m rope and reel device to sample from the surface waters of the bore (Plate 1). Each sample was obtained from below the level of water in the bore (the water table or static water level, SWL) at a depth just sufficient to fill the bailer to maximum capacity. The water recovered was sieved through a 53 µm Endecotts sieve to remove any residual animals and/or debris. A 200 ml sample was abstracted for water quality analysis (see section 9.3) and the remaining isotonic water used for washing further samples from that bore. Two additional replicate samples were recovered using the same bailing technique and added to the initial Endecotts sieve. All three samples were then washed with the pre-sieved isotonic water into pre-labelled sample vials, kept cool in an insulated cooler box and returned live to Perth for live-sorting.

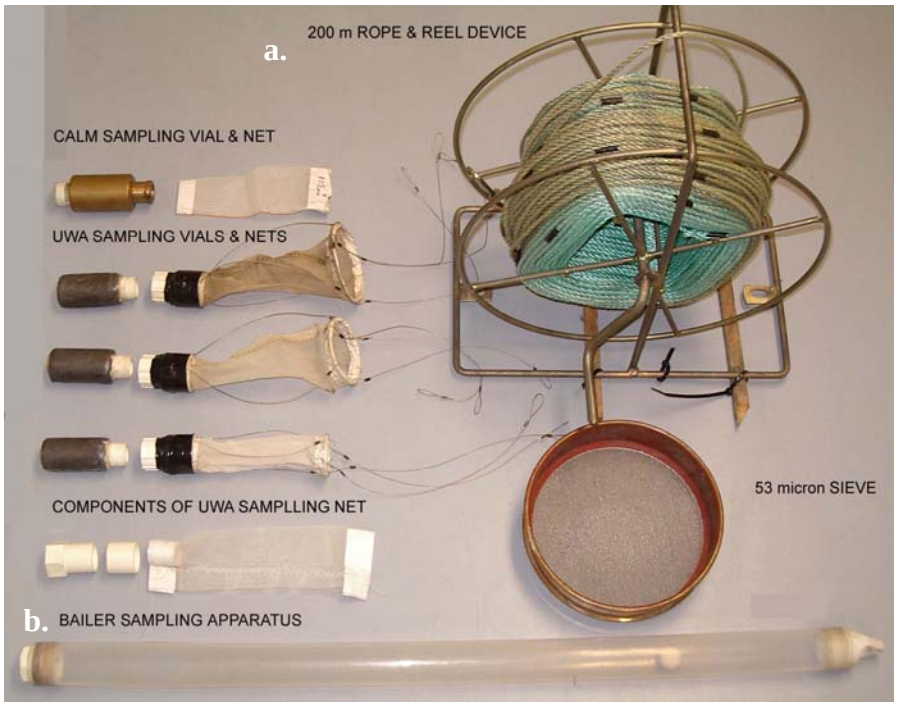

Plate 1: Equipment used in sampling for stygofauna.
Equipment used in 2 of the 3 sampling techniques during this study is illustrated, comprising: a. rope & reel device used to lower sampling equipment; b. 1000 ml –40 mm diameter bailer; and c, sampling nets modified from nets as used by CALM and BIOTA.

6.2.2. Netting

Netting for stygofauna involved taking replicates using a weighted net constructed from 50 µm plankton netting and a lead-weighted vial (Plate 1). For this purpose, the appropriately

sized (for the diameter of the bore) net was lowered to the bottom of each bore on a 200 m rope and reel device. The rope was then raised and lowered approximately 1 m on six separate occasions to agitate the bottom sediment and any animals present. The net then was raised through the water column very slowly to minimise the formation of a bow wave immediately above the top of the net which might trigger avoidance by any animals present. At the top of the bore, the net was then moved directly over the same 53 µm Endecotts sieve used during the previous sampling process. The lead-weighted sample vial was removed and emptied into the sieve. Isotonic water was used to flush the net and vial and ensure that all debris, organic matter and animals were transferred to the sieve. The contents of the sieve were then washed into pre-labelled plastic vials using the ambient water, kept in an insulated cooler box and returned live to Perth for live-sorting.

6.2.3. Baiting / Trapping

It is common experience that animals can be attracted to bait. So, too, with stygofauna. The problem is knowing which bait will work most effectively at a particular site and different baits might be required for different types of animal. Identifying an effective bait, therefore, will usually entail trial and error testing. The principle is simple: bait is added to a sample vial with holes through which fauna can enter. In the present study, one such vial was baited using a mouldy cheese, lowered down each bore on a hand-line and then raised approximately 1 m from the bottom of the bore (Plate 2). The bore was then sealed (capped) and left for a period of no more than 24 hr to prevent bacterial contamination of the water. On retrieval, the contents of the vial were carefully decanted into a 50 µm Endecotts sieve and scanned by eye for evidence of stygofauna. Due to the condition of the sample and logistics of transporting the sample retrieved, if no stygofauna were observed, the sample was disposed of in the field.

Plate 2: **Traps used for baiting stygofauna, Amy Zone, Western Australia. October, 2004.**

The three main components of the bait / trap equipment used in this study are illustrated, and comprise: a. a threaded capped sample vial with pre-drilled holes at the upper margins of the vial; b. a swivel & weighted end for attachment to the trap; and c. a hand-line.

6.2.4. Preservation and Decontamination

Where samples were obtained, care was taken to ensure that each vial was filled to only half of the total vial capacity, thereby ensuring that enough oxygen was present to maintain any animals alive for transport to the laboratory. On completion of sampling at each bore, all sampling equipment used were decontaminated by scrubbing thoroughly in water with a toothbrush and then round brush, rinsed with clean water and hung to dry. Each net was then sprayed with methylated spirits (*sensu* WRC, 2003) to ensure that:

- no transfer of animals occurred between sampling sites;
- nets were dry during transport between bores; and
- to reduce the risk of any chemical-induced damage to the nets.

6.2.5. Laboratory Sorting and Identification

Small aliquots from each sample vial were decanted into a Petri dish until the full sample had been scanned for stygofauna. Each subsample in the Petri dish was immersed in the water from the vial (i.e. isotonic water with the original bore water), and scanned for stygofauna in the laboratory using a dissecting microscope at 40x magnification.

6.2.6. Limitations

Limitations of the stygofauna sampling process that need to be considered include:

1. avoidance by strongly mobile (swimming) specimens;
2. bow wave produced by net;
3. loss of sample in transfer process;
4. different sample procedures where obstructions were encountered; and,
5. the presence of reducers within bores which will alter water volume calculations.

6.3. WATER QUALITY

Water quality data were noted in the field using hand-held meters for the interest of UWA staff only. These measurements are not conclusive as they were measured from water samples obtained during the first bailer haul, which was in turn decanted into a beaker. This process most likely will have resulted in water mixing and may have altered readings, rendering them inconclusive with respect to exact conditions experienced by stygofauna in the water column. As such, the measurements are considered to be indicative of conditions at the time of sampling only, and will not be discussed in details within this report.

However, if, in future, a detailed stygofauna monitoring program is established for the Amy Zone Operation Area, it is recommended that *in situ* water quality data of pH, dissolved oxygen, conductivity, salinity and temperature be recorded using a multi-probe data logger. This will be necessary in order to establish a baseline data set and to comply with EPA Guidelines (EPA 2003) for sampling subterranean fauna. Additionally, water parameters of static water level (SWL), total water column depth and water volume sampled should also be noted.

7. RESULTS

The bores sampled are listed in Table 1 (see Methods) and information on bore details, field observations and images are collated in the Appendix. The nature of the sediment is listed in Table 2. Meiofauna, comprising Collembola and Acarina, was recorded from one bore only, namely H 21, when bailing. Collembola are not aquatic hexapods, but typically are attracted to water and, once within a bore, are unlikely to escape. Unable to escape, they presumably establish colonies at the air-water interface in bores. Those from bore H 21 are pigmented and with reduced eyes. The acarines, also heavily pigmented and not showing morpho-facies typical of stygofauna (eyeless, lacking in pigment, extenuation of limbs and sensory structures), may be predatory upon the Collembola.

It is significant that the water and sediment from a number of the bores smelled strongly of hydrogen sulphur. Invertebrates generally, and stygofauna particularly, typically avoid and/or are not able to function in water high in sulphurous products (B Knott, numerous unpublished observations). This may support the suggestion that the two groups were sampled from the bore column above the water level. Very small ciliates were observed in one bailer sample from SMB 2 and 3. The conclusion is that no stygofauna were collected from bores in and adjacent to the area of the Amy Zone Operation in October, 2004.

Table 2. Summary of the characteristics of the sediments returned to be sorted, Amy Zone, October, 2004.

BORE	SEDIMENT
SMB 1A	Sand, with filaments ?of feather. Numerous remains of pigmented, winged insects; flocculent detritus.
SMB 1B	Sand (with orange-red precipitates). Numerous remains of pigmented, winged insects; much flocculent detritus.
SMB 1C	Strong sulphurous smell; fine dark silt + angular particles; numerous remains of pigmented, winged insects.
SMB 1C(B)	Sand, with orange-red precipitates. Numerous remains of pigmented, winged insects; flocculent detritus.
SMB 2	Strong sulphurous smell; white/ brown/black sediment + grey crystalline 'balls'; some plant detritus; numerous ciliates present.
SMB 3	Sand (with orange-red deposits); few ciliates; numerous remains of pigmented, winged beetles
SMB 4	Strong sulphurous smell; very fine black silt, white/ brown/black fine sediment + grey crystalline 'balls'.
H 21	Strong sulphurous smell; fine dark silt + angular fine sediment. Collembola, Acarina present; plant filamentous detritus.

8. DISCUSSION

The lack of any stygofauna in the samples was not unexpected. The saturated sediments near Coral Bay, sampled in similar geomorphological conditions and also close to the coastline, failed to yield any stygofauna. Indeed, the major occurrence of stygofauna within the Carnarvon Basin occurs in karst formation in limestone. No such geological features occur near the present study site. Further, experience sampling meiofauna from beaches, indicates that no sandy beach interstitial meiofauna occurs in beaches of south-western Australia containing numerous small, black particles likely to be heavy minerals. The black particles in the samples sorted through here may also be of heavy metals, although no analyses have been performed to verify this suggestion. The grey 'balls' noted in the sediment while examining the samples for fauna were crystalline and, although neither abundant nor identified, nevertheless probably resulted through precipitation of some metallic ion present in the ground water in high concentrations; similar particles are not conspicuous in sediments where stygofauna is present.

The observation of plant detritus, but more particularly of the remains of numerous winged, pigmented insects, clearly of surface origins, indicates connections between the surface and the ground water. The insect bodies might have served as a good source of carbon for any aquatic animals present and so may have served as bait for stygofauna, but none was found. Consequently, it is reasonable to conclude that no stygofauna occurs in the bores of, and adjacent to, the area of the Amy Zone sampled in October, 2004. It is appropriate to note, however, that bores SMB 2, 3 and 4 were installed only very recently prior to the sampling, and were unlikely to have developed into efficient sampling points for stygofauna in the intervening two months. Consequently, we recommend at least two further samplings of the bores, the first to capture any faunal changes which might result from seasonal impacts.

9. RECOMMENDATIONS

This study has not revealed any stygofauna. However, it cannot be assumed that stygofauna does not occur in the area or in adjacent areas. Proving the absence of an animal is always difficult and confidence in an absence will only be achieved by repeated systematic sampling. The precise area to be sampled will depend on the area of impact predicted for the Amy Zone. Ideally, samples will be collected within and beyond this area of impact. This will enable a reliable judgement on whether, should stygofauna be found within and outside the impact zone, stygofauna is likely to be affected deleteriously.

The difficulties in sampling to detect stygofauna within the Amy Zone Operation are exacerbated by the scarcity of suitable bores and also the inconvenient placement of those already installed with respect to the projected area of impact. From this survey, living aquatic animals were retrieved only from Hamlin 21 (H 21), a deep, long-standing pastoral well/bore. The age of this bore no doubt has enabled the water balance to have achieved equilibrium and for fauna to have had time to colonize the confines of the structure.

In view of these difficulties and the experience of this preliminary pilot survey, we propose the following Recommendations:

1) This pilot survey was undertaken to sample stygofauna in the north-western region of the Amy Zone Operation of the Coburn Mineral Sand Project. The results presented here cannot be used to predict reliably whether species of stygofauna occur in areas beyond the immediate area of sampling covered by this Report. Should mining operations extend beyond this area, each additional area will need to be surveyed.
2) Further sampling for stygofauna should continue. It is suggested at least two more surveys be undertaken commencing **six** months hence, one on a 'winter' season and the other in the 'summer' season experienced at Shark Bay. This should reveal seasonal effects on stygofaunal presence and provide replication of the original findings, respectively.
3) The seeming scarcity of bore details for this survey suggests that searches should be made for other bores which might prove suitable for this purpose. Proven access sites into groundwater likely to yield stygofauna are long-established bores and windmills. However, if no suitable pre-established bores can be found, it is recommended several strategically placed bores should be installed, considering catchment flows and direction.
4) Sites within and outside the areas subject to change as a result of the mining activities, including the zones of dewatering, should be included in future sampling programmes.
5) If further works are to be undertaken, the proponent will need to organise the requisite permits from CALM under Regulation 17 to take Fauna for Scientific Purposes in order to continue its sampling programme on stygofauna.

10. ACKNOWLEDGEMENTS

We acknowledge with appreciation assistance from the following people:

Daniel Lacey
Jenny Becher
Sonia Finucane

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APPENDIX

Table 1: Bore details, field notes and preliminary results from stygofauna pilot survey (page 1 of 4)

This table has been included to provide background information on bore details, sampling conditions, and field observations recorded during the Pilot Survey. It is intended to be used only as an aid for any future stygofuana monitoring that is to be undertaken within the Amy Zone. (Note: Cap ID = Cap Internal Diameter; Stick Length = length of pvc casing above ground; SWL = Static Water Level; WQ = Water Quality)

Bore ID	Feature Type	Easting	Northing	Date sampled	Bore ID (mm)	Casing Type	Stick (mm)	SWL (~m)	Total depth (~m)	Water column (~m)	Depth WQ readings	pH	Ec (ms/cm)	Salinity (ppt)	Temp (ºC)	Mesh size	Ring OD (mm)	Reducer / obstruction
SMB 1A	Bore	3210583	7067731	7/10/2004	125	pvc	390	-	-	-	Surface / available water	9.41	88.00	Convert		50 µm	96	No
SMB 1B	Bore	210584	7067638	7/10/2004	50	pvc	550	3.71	4.29	0.58	Surface / available water	7.37	66.90	Convert	24.5	50 µm	N/A	No
SMB 1C	Bore	210612	7067169	7/10/2004	50	pvc	210	11.35	13.25	1.9	Surface / available water	7.29	11.49	Convert	26.1	50 µm	46	No
SMB 2	Bore	211120	7060721	6/10/2004	50	pvc inside steel casing	520	23.68	40.55	16.87	Surface	7.65	10.80	Convert	27.2	50 µm	46	No
SMB 3	Bore	208687	7065002	6/10/2004	50	pvc inside a steel casing	480	30.12	42.6	12.48	Surface	7.21	10.92	Convert	26.6	50 µm	46	No

Table 1: Bore details, field notes and preliminary results from stygofauna pilot survey (page 3 of 4)

This table has been included to provide background information on bore details, sampling conditions, and field observations recorded during the Pilot Survey. It is intended to be used only as an aid for any future stygofuana monitoring that is to be undertaken within the Amy Zone. (Note: Cap ID = Cap Internal Diameter; Stick Length = length of pvc casing above ground; SWL = Static Water Level; WQ = Water Quality)

Bore ID	Feature Type	Easting	Northing	Date sampled	Bore ID (mm)	Casing type	Stick (mm)	SWL (~m)	Total depth (~m)	Water column (~m)	Depth WQ readings	pH	Ec (ms/cm)	Salinity (ppt)	Temp (ºC)	Net size	Ring OD (mm)	Reducer / obstruction
HAMLIN 21 (H21)	Bore	212585	7058039	6/10/2004	100	steel inside a concrete casing	N/A	22.12	>100	>77.88	Surface	9.04	10.20	Convert	31.4	50 µm	96	No
SMB 4	Bore	212600	7055528	6/10/2004	50	pvc inside a steel casing	530	37.65	42.74	5.09	Surface	6.64	24.40	Convert	27.8	50 µm	46	No
WH 1	Bore	209494	7068884	7/10/2004	50	pvc	14800	6.52	6.72	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N//A	N/A
WH 2	Bore			7/10/2004	50	pvc	480	N/A	6.56	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WH 2A	Bore	209436	7069117	7/10/2004	100	steel	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 1: Bore details, field notes and preliminary results from stygofauna pilot survey (page 2 of 4)

This table has been included to provide background information on bore details, sampling conditions, and field observations recorded during the Pilot Survey. It is intended to be used only as an aid for any future stygofuana monitoring that is to be undertaken within the Amy Zone. (Note: Cap ID = Cap Internal Diameter; Stick Length = length of pvc casing above ground; SWL = Static Water Level; WQ = Water Quality)

Bore ID	Methods used	No. of vials used	stygofauna observed	Stygofauna found	Comment	Photo
SMB 1A	All 3 methods successfully used. This included: 3 x bailer @ water surface; 3 x vertical haul with 50 µm net, and; 1 x Stygofauna bait trap (collected 8/10/2004)	2	No	No	Located approximately 20 m from gate entering lease property on LHS of track. Directly adjacent to World Heritage Area. Larger bore ID than bores SMB 1b and SMB 1c (photo 1). Bore sealed with electrical tape. Thought to be sealed due to incorrect cap size. Situated just inside lease boundaries in open acacia woodland adjacent to World Heritage area. Water quality readings took a long time to stabilize at this site in comparison to other sites (>10 min). Due to putrification of baited trap, the sample was scanned on site only. No stygofauna was observed from this sample.	
SMB 1B	Only 1 x bailer of water could be retrieved filling 1/2 volume capacity of bailer.	1	No	No	Located approximately 150 m from gate entering lease property on LHS of track (photo 1). Situated just inside lease boundaries in open acacia woodland adjacent to World Heritage area. Only enough water in bore to allow for 1/2 a bailer volume to be collected. Recharge was slow preventing application of all 3 sampling methods. Sample with dark sediment/organics and numerous parts of green shiny beetles. Nb/ bailer sample must be taken first to allow for undisturbed water quality readings and obtaining isotonic water for washing sample through Endecott sieve. This bore is not suitable for the purposes of this study and samples should not be compared to other larger bores.	
SMB 1C	All 3 methods successfully used. This included: 3 x bailer @ water surface; 3 x vertical haul with 50 µm net, and; 1 x Stygofauna bait trap (collected 8/10/2004)	2	No	No	Located on LHS - 3rd bore past SMB 1a and SMB 1b on same track heading along lease fence line. Open acacia woodland adjacent to World Heritage area. Bore was bent when located and would not allow for equipment to be lowered into bore. Daniel Lacey of URS straightened the pvc prior to sampling. Water smelt anoxic and was dark in color with brown/black sediment/organics. Small shiny beetle parts and larvae observed in sample. Slow recharge, only just quick enough to be able to sample additionally with net and trap. Bailer removes all of water and therefore habitat was typically disturbed. Not likely to be stygofauna re-entering bore cavity with recharge if strong swimmers. Due to putrification of baited trap, the sample was scanned on site only. No stygofauna was observed from this sample.	
SMB 2	All 3 methods successfully used. This included: 3 x bailer @ water surface; 3 x vertical haul with 50 µm net, and; 1 x Stygofauna bait trap (collected 7/10/2004)	2	No	No	Located past SMB 1a, 1b and 1c through Gates 1 and 2. Pass turn off to SMB 3 at Gate 3 (wire fencing) and keep traveling along fence line. SMB 2 is situated in a large clearing to the LHS of track and consists of a shallow and deep bore that were constructed to intersect and monitor different aquifer bodies. The shallow bore was dry and could not be sampled. The results shown are for the deeper bore at the same location. Note sample contained plastic clay material - refer to bore logs. Due to putrification of baited trap, the sample was scanned on site only. No stygofauna was observed from this sample.	
SMB 3	All 3 methods successfully used. This included: 3 x bailer @ water surface; 3 x vertical haul with 50 µm net, and; 1 x Stygofauna bait trap (collected 7/10/2004)	2	No	No	Located past SMB 1a, 1b and 1c through Gates 1 and 2. Turn right at Gate 3 (wire fencing) and travel to end of track. If come upon SMB 2 you have gone too far and missed the turn off. SMB 3 consists of a shallow and deep bore that were constructed to intersect and monitor different aquifer bodies. The shallow bore was dry and could not be sampled. Therefore the results obtained are for the deeper bore at the same location. Note sample contained plastic clay material - refer to bore logs. Due to putrification of baited trap, the sample was scanned on site only. No stygofauna was observed from this sample.	

Table 1: Bore details, field notes and preliminary results from stygofauna pilot survey (page 4 of 4)

This table has been included to provide background information on bore details, sampling conditions, and field observations recorded during the Pilot Survey. It is intended to be used only as an aid for any future stygofuana monitoring that is to be undertaken within the Amy Zone. (Note: Cap ID = Cap Internal Diameter; Stick Length = length of pvc casing above ground; SWL = Static Water Level; WQ = Water Quality)

Bore ID	Methods used	No. of vials used	stygofauna observed	Stygofauna found	Comment	Photo
HAMLIN 21	All 3 methods successfully used. This included: 3 x bailer @ water surface; 3 x vertical haul with 50 µm net, and; 1 x Stygofauna bait trap (collected 7/10/2004)	2	Potentially small pale animals. Collembola? Not moving, needs further investigation under microscope in lab to confirm - see results	No - see results	Located along same track past SMB 2. Situated on LHS of track approximately 500 m from 90 degree turn in fence line heading east. Opposite old rusted tank in open acacia woodland. Bore was originally used by station owners but has not been used for many years. Large cement platform surrounds steel bore casing. Surprisingly no rust was collected in sample. Well depth beyond 100 m of depth probe capacity. Small animals observed in field to be investigated further. Nb/ sample was left open to elements for over 1 hour due to OSH procedures imposed by URS - sample may have been contaminated by terrestrial species or undergone degeneration during this time. Due to putrification of baited trap, the sample was scanned on site only. No stygofauna was observed from this sample.	
SMB 4	All 3 methods successfully used. This included: 3 x bailer @ water surface; 3 x vertical haul with 50 µm net, and; 1 x Stygofauna bait trap (collected 7/10/2004)	2	No	No	Located past approximately 9 km from SMB 3. Follow fence line to Hamlin 21. Turn right through Gate 4 at water tank and continue along to SMB 4 which is situated in a large clearing to the LHS of track in open acacia woodland and in the base of a gully. SMB 4 consists of a shallow and deep bore that were constructed to intersect and monitor different aquifer bodies. The shallow bore was dry and could not be sampled. The results shown are for the deeper bore at the same location. Note sample contained plastic clay material - refer to bore logs. Due to putrification of baited trap, the sample was scanned on site only. No stygofauna was observed from this sample.	
WH 1	No samples were taken. Insufficient water	N/A	N/A	N/A	The exact locations of bores located in the World Heritage Area were previously unknown. It was suggested that some old decommissioned bores installed by DoE may lay in the area between the proposed mining lease and the coastal marsh/flood plains. After much searching, the bores were all located on a 4WD track entering the reserve just past Useless Loop Rd turn off. WH1 was situated in open accacia woodland with less understorey compared to that of the mining lease (photo 1). Wildflowers and woodland vegetation were scattered across dried algal marsh floodplain ridges. The bore itself was in good condition but contained insufficient water to sample although this may prove possible in the wet season. However, it is strongly adviced for URS to ascertain the legality of sampling in this region. Permits and approval by CALM and local authorities are a must. The stick length may also prove an obsticle.	
WH 2	No samples were taken. Bore dry.	N/A	N/A	N/A	WH2A was situated along the same track past WH1. The bore itself was in good condition but was dry. However, as with WH!, this site may prove suitable for sampling in the wet season. Again, it is strongly advised for URS to ascertain the legality of sampling in this region.	
WH 2A	No samples were taken. Bore dry.	N/A	N/A	N/A	WH2 was situated along the same track past WH2A. The bore itself was steel and is now the home of an owl that has nested inside. It is not thought this bore will ever recover or provide potential for stygofauna monitoring.