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ENVIRONMENTAL SCIENCES

Python and Gwardar Iron Ore Deposits Stygofauna Survey

FerrAus Pilbara Project

Prepared for FerrAus Ltd
December 2010

Final Report

Python and Gwardar Iron Ore Deposits Stygofauna Survey: FerrAus Pilbara Project

Prepared for FerrAus Limited by Phoenix Environmental Sciences Pty Ltd

Final Report

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EXECUTIVE SUMMARY

In February 2010, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by FerrAus Ltd (FerrAus) to undertake a third (Round 3) stygofauna survey of the Python and Gwardar deposits (the study area) for the FerrAus Pilbara Project (the Project). The study area is located approximately 80km south-east of Newman and lies at the junction of the Gascoyne, Pilbara and Little Sandy Desert bioregions.

Phoenix previously conducted stygofauna surveys in the study area during November 2008 (Round 1) and March 2009 (Round 2). These prior surveys collected mostly juvenile forms of stygofauna, precluding species level identification of many specimens. Three new stygofauna species were also recorded. The limited identifications from the first two survey rounds prevented an adequate assessment of the risk to stygofauna species and habitats from the Project.

Further sampling was undertaken in March 2010 with the aim of providing more comprehensive species identifications and distributional data. This report summarises the results of the first two survey rounds and documents the results of the third.

The completion of preliminary hydrogeological modelling for the study area (Aquaterra 2009) made it possible to more-clearly define the impact area (the area of drawdown) for site selection for the Round 3 survey. The Round 3 survey targeted available additional bores both inside and outside the proposed extent of the drawdown (as per 2009 modelling). The Round 3 study area covered approximately 200ha and represented three major geologies (Marra Mamba, Jerrinah and Wittenoom), encompassing seven Land Systems.

A total of 38 vertical bores were sampled in Round 3, comprising 23 within the impact area and 15 outside of the impact area, as modeled by Aquaterra (2009). Following sampling, a revision was made to the proposed pit size and shape. Aquaterra (2010) subsequently revised the modeled drawdown contour and all but two of the sampled bores fall within the revised impact area (defined by the drawdown contours).

A total of 96 specimens were collected over the three survey rounds from November 2008 to March 2010. These included ten morpho-species from three classes: Oligochaeta (oligochaetes or worms); Malacostraca (amphipods and syncarids) and the Maxillopoda (copepods).

Three new species were recorded in the surveys and are presently known only from within the proposed impact area:

- *Kruptus* sp. 'DC', a new species of parameletid amphipod;
- Parabathynellidae sp. 'DC', a new syncarid species; and
- *Fierscyclops (Pilbaracyclops)* sp. 'DC', a new copepod species.

Kruptus sp. 'DC' was collected from the southern boundary of the impact area in Round 1 and Round 2 surveys (dry and wet season) from the Newman Land System. Parabathynellidae sp.'DC' was collected from the southern (and possibly also northern and eastern) boundary of the proposed pit, from the Newman and Divide Land Systems. *Fierscyclops* (*Pilbaracyclops*) sp. 'DC' was only collected during Round 2 on the south-western boundary of the proposed pit, from the alluvial aquifer of the Fortescue Land System. No significant species were collected in Round 3.

It is possible that the three new species occur more broadly than the proposed impact area. Further sampling is required upstream (to the south of the proposed Python/Gwardar pit), downstream along the Davidson creekline, and along the Marra Mamba formation to the east of the study area, to confirm broader species distributions. Genomic analysis of specimens collected and those from future sampling may also be required.

1.0 INTRODUCTION

In February 2010, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by FerrAus Limited (FerrAus) to undertake an additional stygofauna survey round in relation to the proposed Python/Gwardar deposits (the study area) of the FerrAus Pilbara Project (the Project), following two prior survey rounds within the study area (November 2008 and March 2009) (Phoenix 2009a).

The Project aims to develop an iron ore mine approximately 100km south east of Newman (Figure 1-1). The Project includes: open cut pits, crushing and screening plants, a residual storage facility and associated mine infrastructure. The crushed ore will be transported via a rail spur to port infrastructure for loading onto ships for export.

Within the FPP boundaries, the following specific Project areas are defined:

- Python/Gwardar (formerly known as Davidson Creek) deposit (Figure 1-2);
- process and rail load out infrastructure area: e.g. residue storage facility, waste stockpile, process plant, rail loop, stockpiles etc (the process area);
- King Brown (formerly known as Robertson Range) deposit (ML52/1034);
- King Brown deposit infrastructure area (the infrastructure area): 358ha in area, immediately west of ML52/1034 (see Figure 1-2); and
- haul road and services corridor to the King Brown deposit in M52/1034 (the services corridor).

This report summarises the results of the two previous stygofauna surveys and documents the results of the third stygofauna survey, undertaken in March 2010.

1.1 BACKGROUND

Both the Pilbara and Gascoyne bioregions are classed as “Group 2” areas by the Environmental Protection Authority (EPA 2003, 2007). Within these groups, any disturbance to an area greater than 50ha requires a “Level 2” biological survey. These guidelines are not specifically appropriate for stygofauna surveys. Therefore the survey methodology and sampling effort instead adhere to the more appropriate Guidance Statement No. 54a: *Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia* (EPA 2007) and the earlier EPA Guidance Statement No. 54: *Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in* Western Australia (EPA 2003).

A number of subterranean biological surveys have been undertaken previously for the Project at King Brown, formally referred to as the ‘Robertson Range Project’ (ecologia 2008, 2009a, b); and Python/Gwardar, formally known as the Davidson Creek Project (Phoenix 2009a, b).

1.2 SCOPE OF WORK AND SURVEY OBJECTIVES

In February 2010, FerrAus Limited requested that Phoenix undertake a third stygofauna survey for the proposed Python/Gwardar deposit.

A significant portion of the Python/Gwardar ore body is below the water table therefore dewatering is planned during the life of the mine. As noted in Guidance Statement 54, mining and dewatering have the potential to impact on stygofauna inhabiting the groundwater predominantly through:

- Groundwater abstraction and associated drawdown;
- Changes in water quality or contamination of the groundwater;
- Compaction of sediment from equipment altering infiltration rates; and

- Direct removal of habitat.

This third stygofauna survey round was intended to provide additional information on the presence of stygofauna species occurring in both impact and non-impact areas of the study area, as defined by the extent of the preliminarily modeling of groundwater drawdown contours available at the time of survey design (Aquaterra 2009).

The scope of work for the Round 3 survey was to:

- Conduct additional stygofauna sampling (20 sites) inside the impact area;
- Conduct additional stygofauna sampling (20 sites) outside the impact area and within the study area; and
- Provide a technical report summarising the results of the three stygofauna surveys conducted for the study area.

Primary objectives of the Round 3 survey were:

- To resample bores which recorded stygofauna in previous rounds; and
- To sample as many survey area and regional bores as possible, beyond the modeled impact area as defined by the preliminary hydrogeological report (Aquaterra 2009).

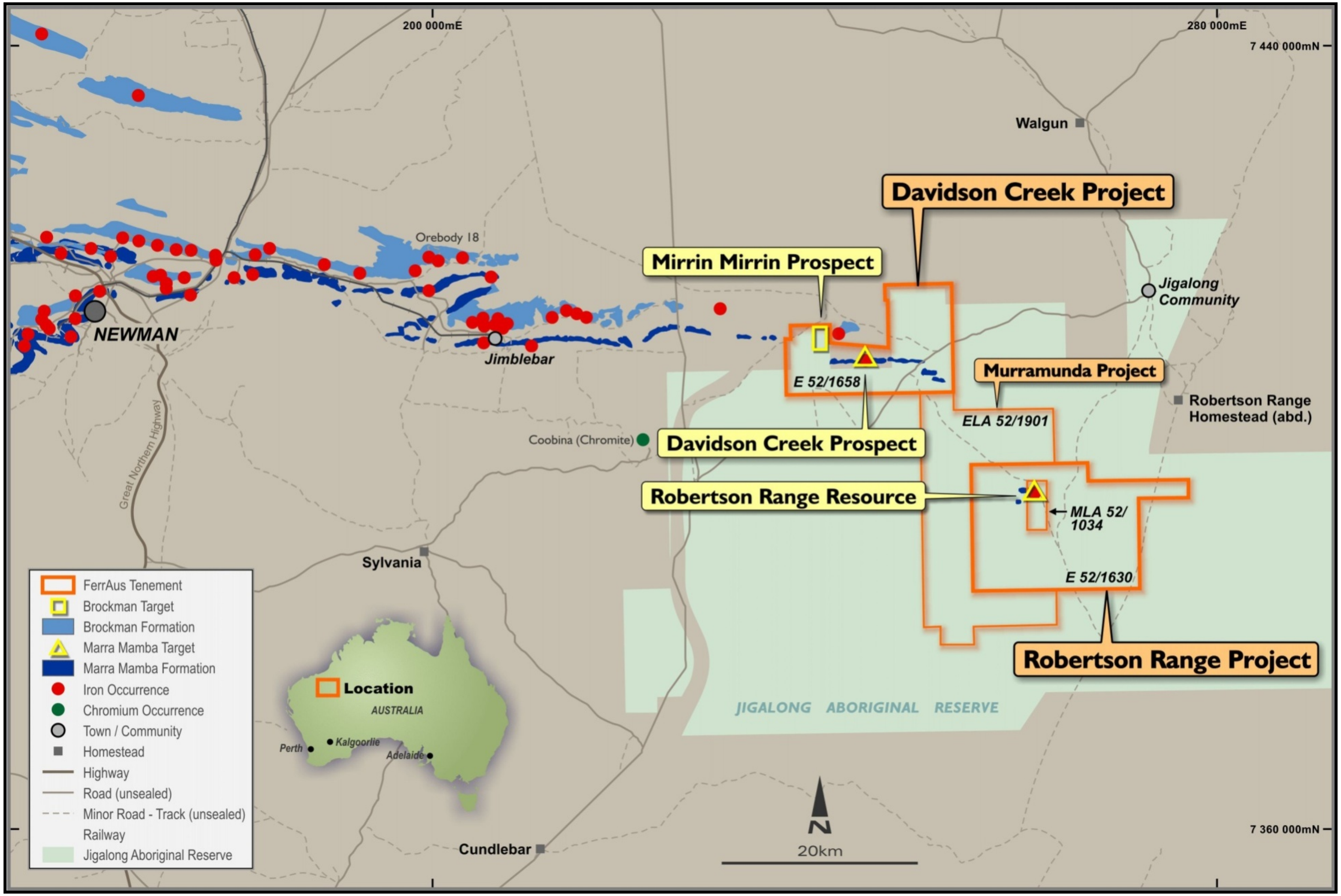

Figure 1-1 Location of the study area

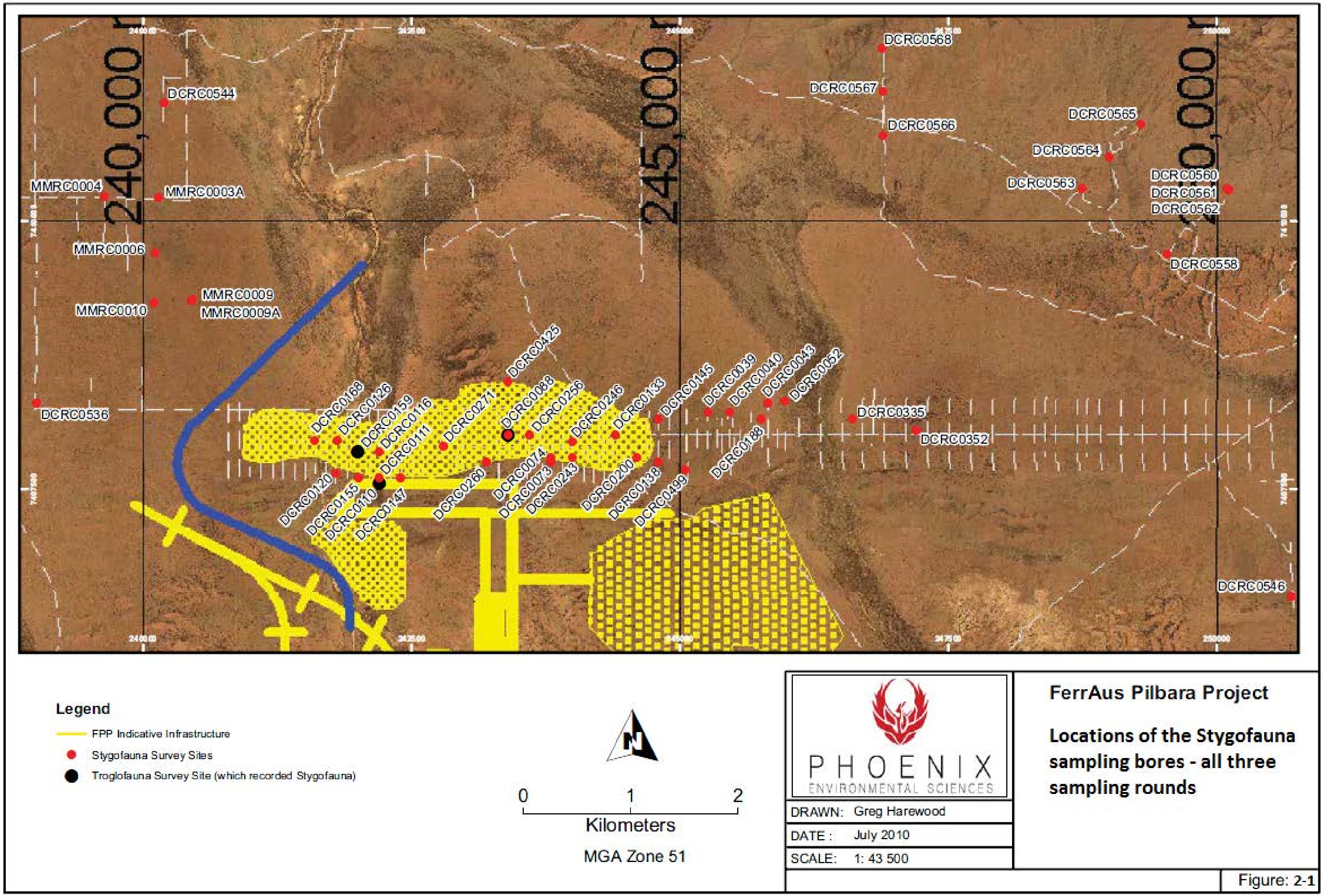

Figure 1-2 Location of the stygofauna survey areas within the Python and Gwardar Deposits

1.3 SUBTERRANEAN FAUNA - STYGOFAUNA

Stygofauna are aquatic subterranean animals, predominantly crustaceans, which inhabit groundwater, such as alluvial, calcrete and fractured rock aquifers. A high proportion of subterranean fauna (including stygofauna) have geographically restricted ranges, often being confined to highly restricted habitats or individual geological features (Cooper et al 2005; Eberhard and Halse 2004; Eberhard 2004; Humphreys 1999). Such taxa are defined as short-range endemics, whose restricted ranges make them vulnerable to adverse disturbance (Harvey 2002). Typical stygobitic species can be seen in Figure 1-3.

Figure 1-3 **Examples of typical Pilbara stygofauna taxa (paramelitid amphipod left, melitid amphipod right)**

The EPA has estimated the likely presence of subterranean fauna in different regions and geologies of Western Australia (Table 1-1). The likelihood of Stygofauna presence is very high in most geologies of the Pilbara.

Table 1-1 **Likelihood of presence of subterranean fauna in different regions and geologies of Western Australia (adapted from EPA 2003, 2007)**

Region	Geology	Likelihood of	
		Stygofauna	Troglofauna
Kimberley	Karst, limestone sandstone, alluvium islands	High	High
Pilbara	Most geologies	Very high	High
	Barrow Island	Very high	Very high
Inland deserts	Calcrete, alluvium	High	Low
Gascoyne / Murchison	Calcrete, alluvium, banded ironstone	High	High
	Cape Range	Very high	Very high
Yilgarn / Goldfields	Calcrete, alluvium, banded ironstone	Very high	High
South-West	Most geologies	Low	Low
	Karst	High	High
Nullarbor	Karst	High	Very high

The Pilbara contains one of the world's more diverse stygofaunal assemblages (Eberhard et al 2005; Eberhard et al 2004). The Pilbara Biodiversity Survey identified 350 species across the major catchments of the Pilbara and at least 550 are estimated to occur in total.

2.0 EXISTING ENVIRONMENT

2.1 INTERIM BIOGEOGRAPHIC REGIONALISATION OF AUSTRALIA (IBRA) REGION

The study area is located on the borders of the Pilbara, and Gascoyne bioregions as defined by the IBRA (Thackway and Cresswell 1995). More specifically, the study area is situated within the Fortescue Plains subregion of the Pilbara bioregion, and the Augustus subregion of the Gascoyne bioregion.

The Fortescue Plains subregion is characterised by alluvial plains and river frontages, extensive salt marsh, mulga-bunch grass and short grass communities on alluvial plains (eastern end). River Gum woodlands fringe the drainage lines (DEWHA 2009). The Augustus subregion is characterised by rugged low Proterozoic sedimentary and granite ranges divided by broad flat valleys with extensive areas of alluvial valley-fill deposits. Dominant vegetation includes mulga woodland with spinifex on the rises and mulga parkland on the plains (CALM 2002).

2.2 LAND SYSTEMS

The Department of Agriculture has mapped the Land Systems of the region from aerial photography, providing the largest-scale interpretation of vegetation units for the study area (Van Vreeswyk et al 2004). The following ten Land Systems occur within the study area:

- **Boolgeeda** - stony lower slopes and plains found below hill systems, supporting hard and soft spinifex grasslands and mulga shrublands. Predominantly deposition surfaces of very gently inclined stony slopes and plains becoming almost level further downslope.
- **Cadgie –** depositional surfaces; hardpan plains supporting mulga shrublands with soft and hard spinifex. Flat to very gently inclined wash plains with sandy and loamy soils over hardpan, and sandy banks with relief up to 5m.
- **Divide** – level to gently undulating sandplains and occasional small dunes. Generally depositional surfaces. Hard spinifex vegetation that is subject to regular burning. This Land System dominates the northern aspect of the study area.
- **Fortescue –** predominantly depositional flood plains, alluvial plains and river channels, non-saline clay and duplex soils that support patchy grassy woodlands and shrublands, and tussock grasslands.
- **Jamindie –** depositional non-saline plains; gently undulating hardpan wash plains with ironstone grit mantle and pebbles, minor stony plains, low rises and occasional low ridges with relief up to 30m. Supports groved mulga shrublands, occasionally with spinifex understorey.
- **Newman** - rugged jaspilite plateaux and ridges with hard spinifex grassland. Erosional surfaces with moderately spaced tributary drainage; narrow valleys and gorges with narrow drainage floors and channels. The majority of bores sampled in this survey occur in the Newman Land System.
- **River** - active floodplains and terraces flanking major rivers and creeks, supporting riverine woodlands and tussock and hummock grasslands; associated with the Fortescue River system. Flood plains and river terraces are subject to fairly regular overbank flooding from major channels and watercourses, sandbanks and poorly defined levees and cobble plains.

- **Robertson –** erosional hills, ridges and plateaux mainly of sandstone in the east of the area and extending into the sandplain and dune terrain of the Little Sandy and Great Sandy Deserts, relief up to 80m. Supports hard spinifex grasslands and other low shrubs and tussock grasses which are prone to grazing and potentially, degradation.
- **Sylvania** - level to gently undulating gritty surfaced plains and low rises on granite and tributary drainage floors, relief up to 20m. Supports *Acacia-Eremophila-Cassia* shrublands which are prone to grazing and potentially, degradation. This Land System dominates the southern aspect of the study area.
- **Washplain** - depositional, level wash plains and tracts supporting groved mulga shrublands. More concentrated through flow is received with prominent grove patterns of vegetation. Dominated by loamy and clayey soils of variable depth over hardpan, relief less than 10m.

Bores sampled in the Round 1 and 2 surveys were located within the Divide, Fortescue, Newman and Sylvania Land Systems. In the Round 3 survey, these four Land Systems were re-sampled and additional bores were sampled within the Boolgeeda, River and Washplain Land Systems (Figure 2-1).

2.3 CLIMATE

The Pilbara region has a semi-desert to tropical climate with highly variable, mostly summer rainfall occurring as a result of cyclonic activity. The average rainfall over the broader Pilbara area ranges from about 200mm to 350mm, although rainfall may vary widely from the average from year to year (DEWHA 2009).

The nearest Bureau of Meteorology (BOM) weather station is located at Newman, approximately 75km west of the study area. Newman has the highest maximum mean monthly temperature (39°C) in January, the lowest maximum mean annual temperature (22.3°C) in July and an average annual rainfall of 310mm (BOM 2009).

2.4 LAND USE

Pastoral grazing activities comprise the only economic land use in the study area. Overgrazing in the arid grasslands of Western Australia has been shown to have major impacts on invertebrate (Binks et al 2005), vertebrate and floristic diversity and condition (Van Vreeswyk et al 2004).

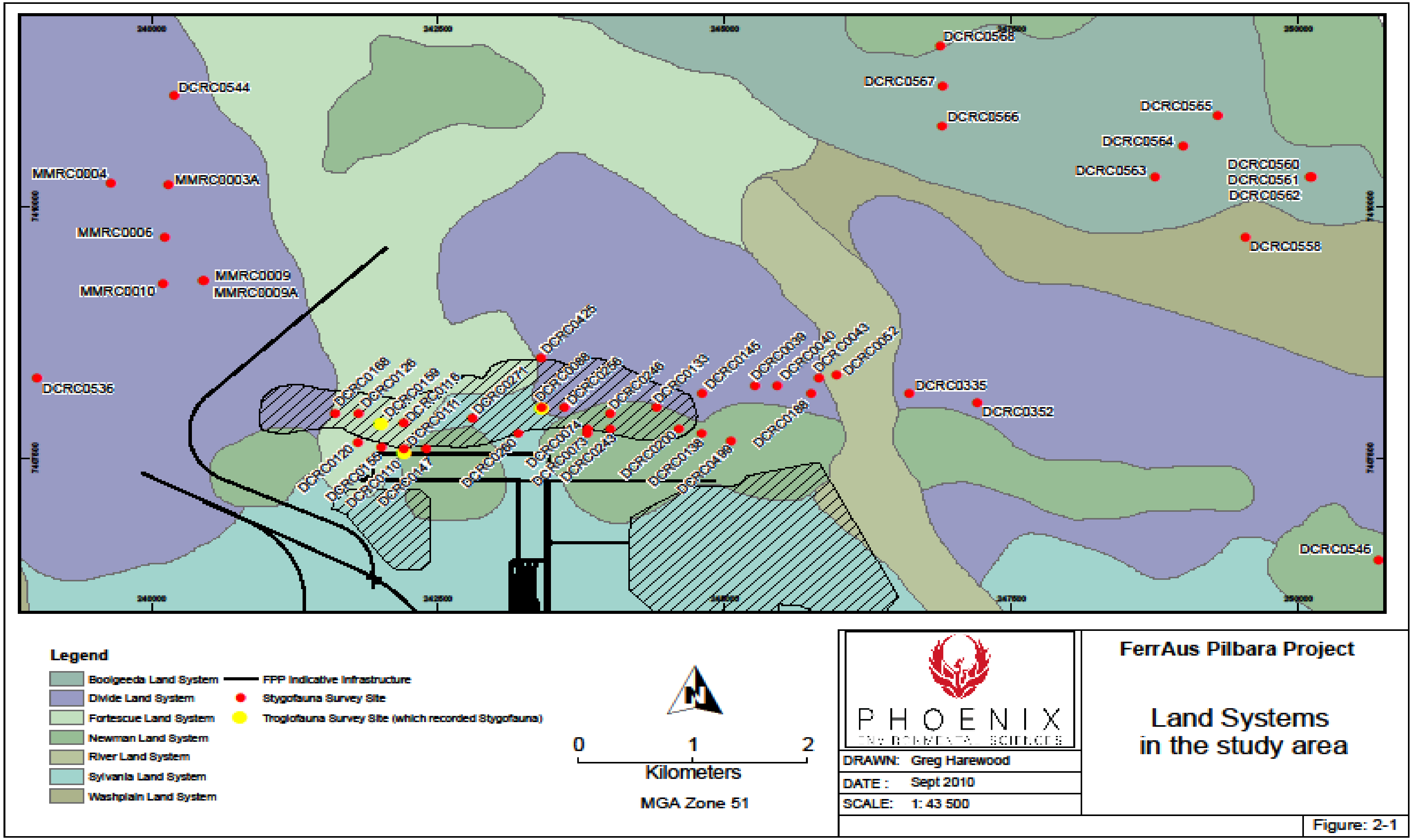

Figure 2-1 Land Systems in the study area

2.5 GEOLOGY

The study area is located on the eastern margin of the Hamersley Province of the Pilbara Craton. The Hamersley province consists predominantly of late-Archaean and Lower Proterozoic (2800-230 Million years ago) sedimentary rocks situated between the large Yilgarn Craton and Pilbara Craton (MacLeod 1966).

Within the study area, the Marra Mamba Iron Formation (MMIF) outcrops as a low east-west ridge. The Formation is divided into the Nammuldi, McLeod and Mount Newman Members. The Mt. Newman Member is the primary host unit for the iron ore mineralisation within the study area. It consists of a thick succession of BIF (Banded Iron Formation), shale and carbonate rocks. The Mount Newman Member is typically poorly exposed at surface, with most of the ore body below Cainozoic colluvial and alluvial material (MacLeod 1966). Overlying the Mount Newman Member and also below the Cainozoic cover, is stratigraphy of the Wittenoom Formation, which forms a more impermeable barrier between the overlying alluvial/colluvial aquifers layer and the MMIF iron hosting unit below (pers comm. FerrAus 2010).

The stratigraphy of the study area is tilted such that the West Angela shale (Wittenoom Formation) overlies the MMIF and forms the northern face of the proposed pit, whilst the Jerrinah Formation underlies the MMIF and forms the southern face of the proposed pit. The MMIF therefore forms the eastern and western faces of the pit and extends along strike in an east west direction from the proposed pit (Aquaterra 2009).

2.6 HYDROGEOLOGY

The groundwater level within the study area at the proposed Python/Gwardar pit lies between 18 and 24m below ground level (mbgl) and to the north of the pit and north west near the Mirrin Mirrin area, the water table lies 10 – 15mbgl within the alluvial and colluvial deposits on the floodplain (Aquaterra 2009). In the study area, the groundwater flow is south to north with limited recharge from rainfall in the upstream catchment. Greater recharge is expected following cyclonic events or seepage from stream flow than from regular rainfall events (Aquaterra 2010).

The mineralized MMIF (which includes the iron ore hosting Mt Newman member) forms a linear aquifer system which runs east-west continuously in varying saturated thickness over the 4km of known strike length (the iron ore resource) (Aquaterra 2010). The overlying West Angela member shale (Wittenoom formation) at the top of the hosting MMIF forms a barrier to groundwater flow from the alluvial/colluvial aquifers and Wittenoom aquifer to the main Python/Gwardar ore body aquifer. Aquaterra (2010) has assigned a low permeability to this unit.

According to the preliminary groundwater investigations (Aquaterra 2009):

> *It is assumed that the relatively low permeability West Angela and Jerrinah shale rich units form a relatively low permeability envelope around the Marra Mamba Iron Formation, which will restrict the rates of lateral recharge from adjoining aquifer systems, including the alluvial aquifers."*

The MMIF stratigraphy represents the highest yielding aquifer with the greatest porosity. The drawdown contour is expected to be elliptical, with the long axis orientated in an east-west direction. Due to the tilted orientation of the stratigraphy and the relative depth and high transmissivity of the MMIF, it is expected that this sequence will be drawn down to a greater extent to the east and west of the proposed pit. A maximum drawdown of 186m is predicted in the immediate mining area.

The amount of predicted drawdown is expressed in contour drawdown metres from a standing water level of 20mbgl to reflect the reduction (drying out) of potential habitat within the study area (Figure 2-2) for the life of the mine (12 years). In other words, a contour of 5m on Figure 2-2 would reflect a standing water level of 25mbgl after 12 years.

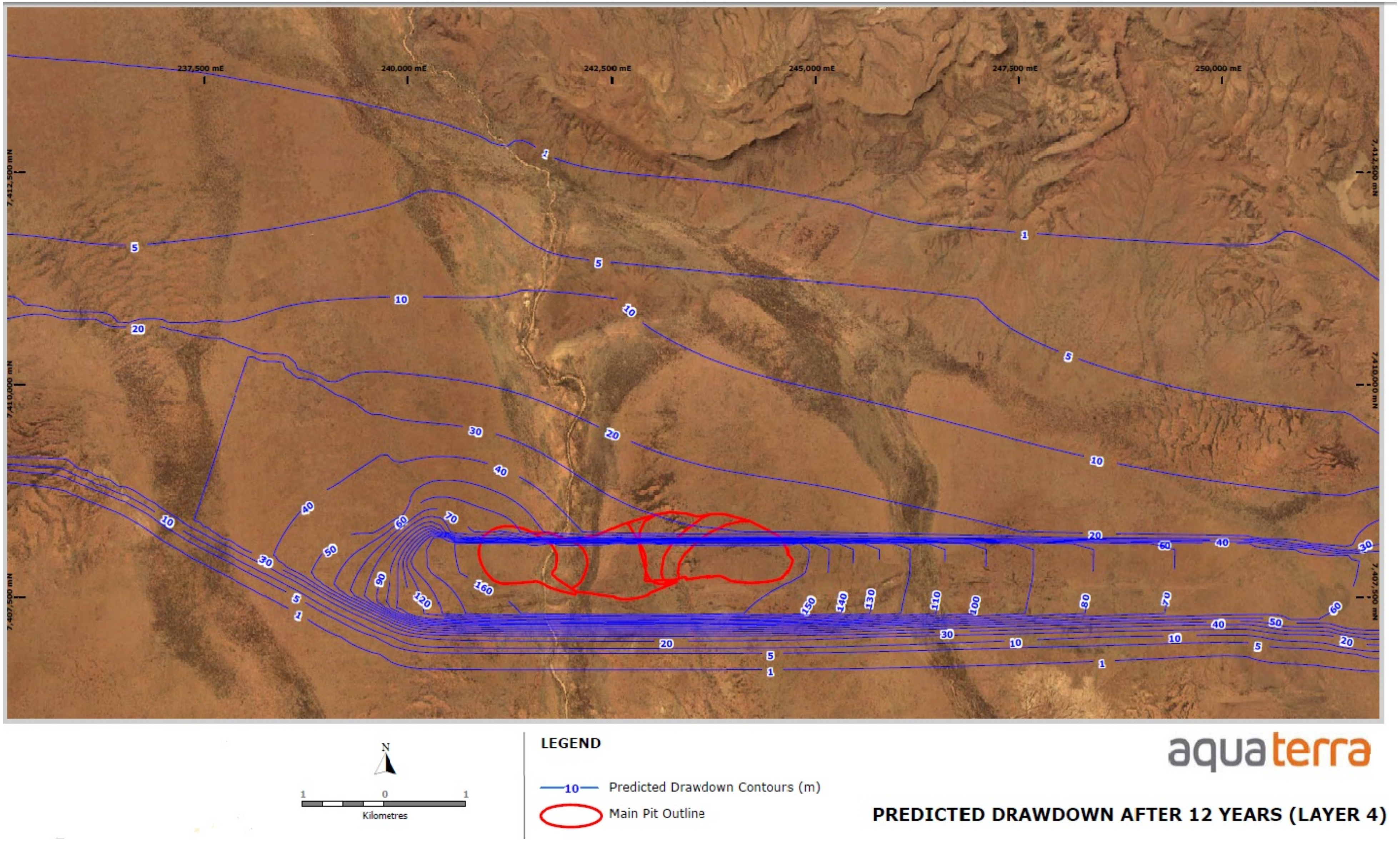

Figure 2-2 Predicted drawdown after 12 year mine life (Aquaterra 2010)

3.0 METHODOLOGY

3.1 HABITAT ASSESSMENT AND SITE SELECTION

A review of geological data, Land System mapping and aerial photography identified four geological types within the study area that were considered prospective habitat for stygofauna:

- Alluvium/colluvium layer (superficial or shallow aquifer);
- The Marra Mamba formation (hosting the economically viable iron ore);
- The Jerrinah formation (initially thought less prospective due to much lower porosity); and
- The Wittenoom formation (initially thought less prospective due to much lower porosity).

A review of the drilling locations and lithography of the study area identified 47 study area and regional bores for sampling that would maximize geographic coverage and geological representativeness (Figure 3-1). Some of these bores were previously sampled in Rounds 1 and 2.

Only 38 of the 47 bores identified were able to be sampled. The remaining nine bores could not be sampled as they were either blocked or dry; they included all regional bores and some study area bores. Of the 38 bores sampled, 25 were previously rehabilitated bores which needed to be dug up and uncapped to be sampled. All 38 bores were vertically orientated.

At the time of site selection and planning for the Round 3 survey round, only preliminary hydrological modelling was available to define the ‘impact area’ and to guide site selection. On that basis, 23 bores were selected for sampling in Round 3 within the impact area and 15 in the non-impact area (Appendix 1). That is, the aim was to resample bores which recorded stygofauna in previous rounds and sample as many bores and regional bores beyond the modeled impact area as defined by the hydrogeological report as possible (Aquaterra 2009).

For the purposes of categorizing sample sites, the degree of impact has been classified in this report into two categories; ‘greater impact area’ and ‘lesser impact area’. The delineation is defined by the extent of the drawdown in the primary geological sequences found below the water table. These include sequences containing the alluvial and colluvial aquifers, and those aquifers found within the Wittenoom Formation and the MMIF (see section 4-2).

The greater impact area includes the area of extraction (direct habitat removal) of the proposed pit to a total depth of 186m and the surrounding geologies which will experience a total drawdown of 160mbgl (closest to the pit boundary). The greater impact area extends to the 30m drawdown contour and is the point at which, after 12 years of operation (the predicted mine life), there is approximately a 50% drawdown of the water in the Wittenoom geological strata, the most likely habitat zones for stygobitic fauna in the study area. It is expected that all stygofauna habitat within the greater impact area will either be removed or experience substantial habitat modification.

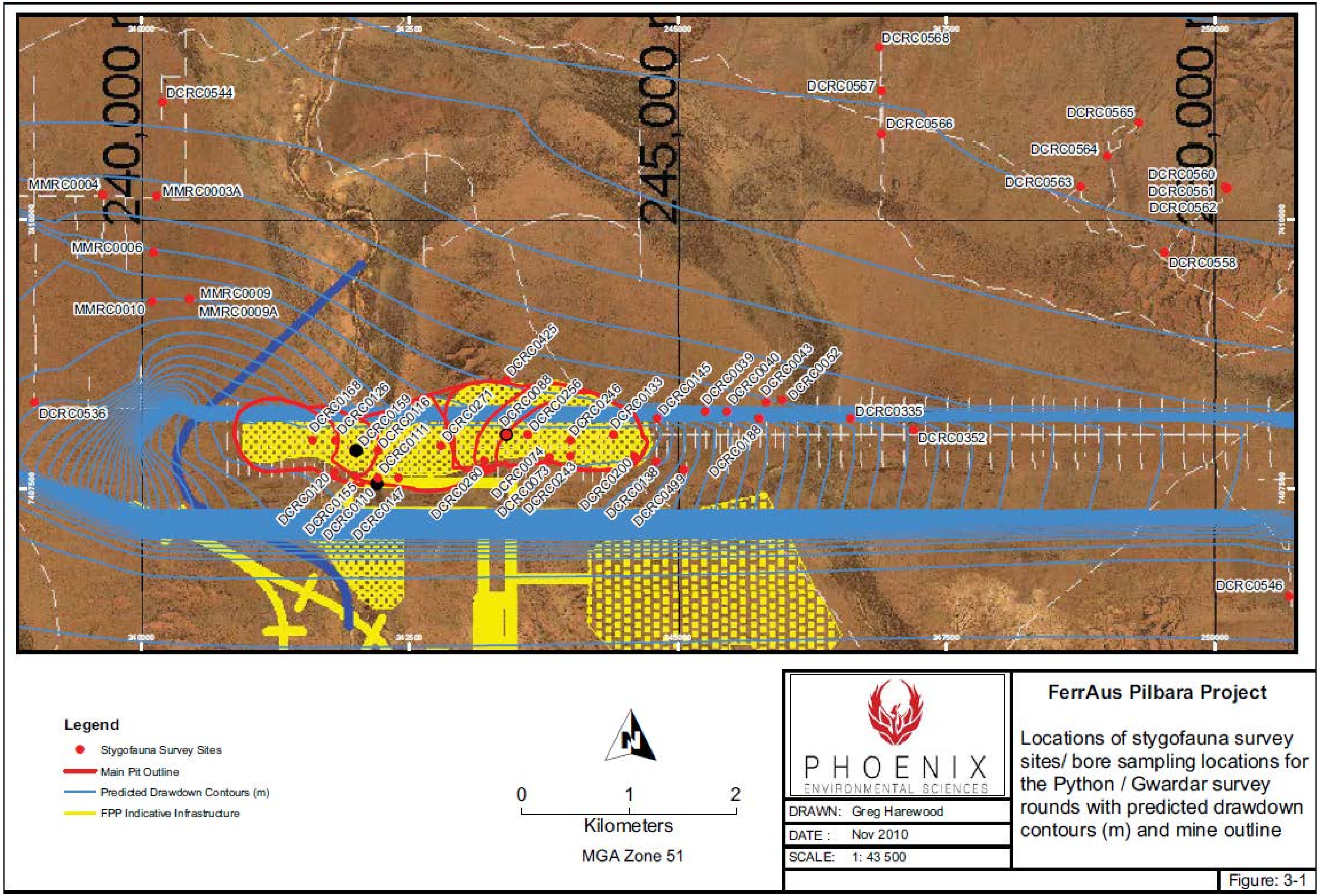

Figure 3-1 **Locations of stygofauna survey sites / bore sampling locations for the three survey rounds**

3.2 SAMPLING EFFORT AND METHODOLOGY

The bores identified for Round 3 required ground-truthing to determine their condition and adequacy for sampling, as the majority of the bores in the study area were previously-rehabilitated.

Within the impact area, a total of 812 net hauls were conducted over the three sampling rounds; 588 in the first two rounds (Table 3-1) and an additional 224 in the third round (Table 3-2).

Table 3-1 Sampling effort for Round 1 and 2 stygofauna surveys

No. sites Round 1 and Round 2 (bores)	No. sampling seasons	No. 150µm net hauls/bore	No. 50µm net hauls/bore	Total sample size (N)
42	2	3 or 5 [a]	3 or 5 [a]	588
TOTAL		147	147	

a – seven bores were sampled five times in the first round of sampling.

Table 3-2 Sampling effort for the Round 3 stygofauna survey

No. sites Round 3 (bores)	No. sampling seasons	No. 150µm net hauls/bore	No. 50µm net hauls/bore	Total sample size (N)
38	1	3 or 0 [a]	3 or 2 [a]	224
TOTAL		111	113	

a – a single bore was only sampled two times due to bore collapse.

In addition to the Round 3 stygofauna survey, three bores from the concurrent troglofauna survey also recorded stygofauna specimens via incidental capture. There is no recorded water parameter information available for these three bores, aside from depth to water (DTW). No physical, chemical or biological data are presented in this report for these troglofauna bores; however, the species collected are recorded in the stygofauna species table and discussed in the results.

The following sampling methodology was employed at each site and closely follows guidelines recommended by the EPA (2007):

1. Physical characteristics were recorded (Appendix 1):
    a. Geographic coordinates by handheld GPS
    b. Bore diameter (mm)
2. A standing water level (SWL) meter and a Hack Multi parameter water quality meter were used to record:
    a. Depth to water (mbgl)
    b. Total depth of bore (m) from ground level
    c. pH (pH units)
    d. Salinity (mg/L)
    e. Electrical conductivity (µS/cm)
    f. Dissolved oxygen (mg/L)
    g. Dissolved oxygen (% sat.)

h. Oxidation reduction potential (ORP) (mV)

i. Temperature (ºC).

All water chemistry parameters were measured from a water sample collected from the bore using a bailer, prior to the collection of stygofauna. Single-use bailers were used at each bore to prevent cross-contamination between sites.

3. Stygofauna sampling was undertaken using stygofauna nets of two different mesh sizes, 50µm and 150µm following (EPA 2007). A minimum of three net 'hauls' were conducted at each bore with each type of net, except at one site where the bore collapsed during the sampling effort. For each haul, the net was lowered to the bottom of the bore, gently agitated, and then raised slowly to minimise the 'bow wave' effect. Where the bore was obstructed with a casing, five net hauls were made between the bore wall and casing.
4. Following each haul, the vial at the base of the net was immediately unscrewed and the contents transferred directly into a jug filled with 2L of water. The nets were then thoroughly rinsed into the same jug. This process was repeated for all hauls within a site. The nets were thoroughly rinsed with deionised water prior to reinsertion into the bore.
5. Once net hauling was completed, the contents of the jug were poured through a 50 µm stainless steel sieve. The contents of the sieve were then transferred into labeled vials containing 100% ethanol.
6. Between sites, the net and vial were washed with a toothbrush in a bucket containing detergent (Decon90®) and then rinsed thoroughly in deionised water and allowed to dry.
7. At the completion of the survey, all specimens were transported to Perth for sorting and identification.

3.3 SURVEY TIMING AND WEATHER

Guidance Statement No.54a (EPA 2007) recommends that stygofauna surveys be carried out over two seasons and preferably encompass both wet and dry seasons, with post-wet season sampling being most critical, as stygofauna exhibit a biological response to rainfall. Seasonal sampling events must be three months apart as a minimum.

In accordance with these recommendations, the first two survey rounds were conducted at the study area from the 9 - 13 November 2008 (dry season, Round 1) and the 13 – 17 March 2009 (wet season, Round 2). The third survey round was conducted from 15 – 22 March 2010 (providing a second preferred wet season sample).

Daily maximum and minimum temperatures at Newman ranged from 35.4 – 41.6°C and 17.2 – 27.9°C respectively during the Round 3 survey (Figure 3-2). During the survey period, 5.4mm of rainfall was recorded at Newman (BOM 2010).

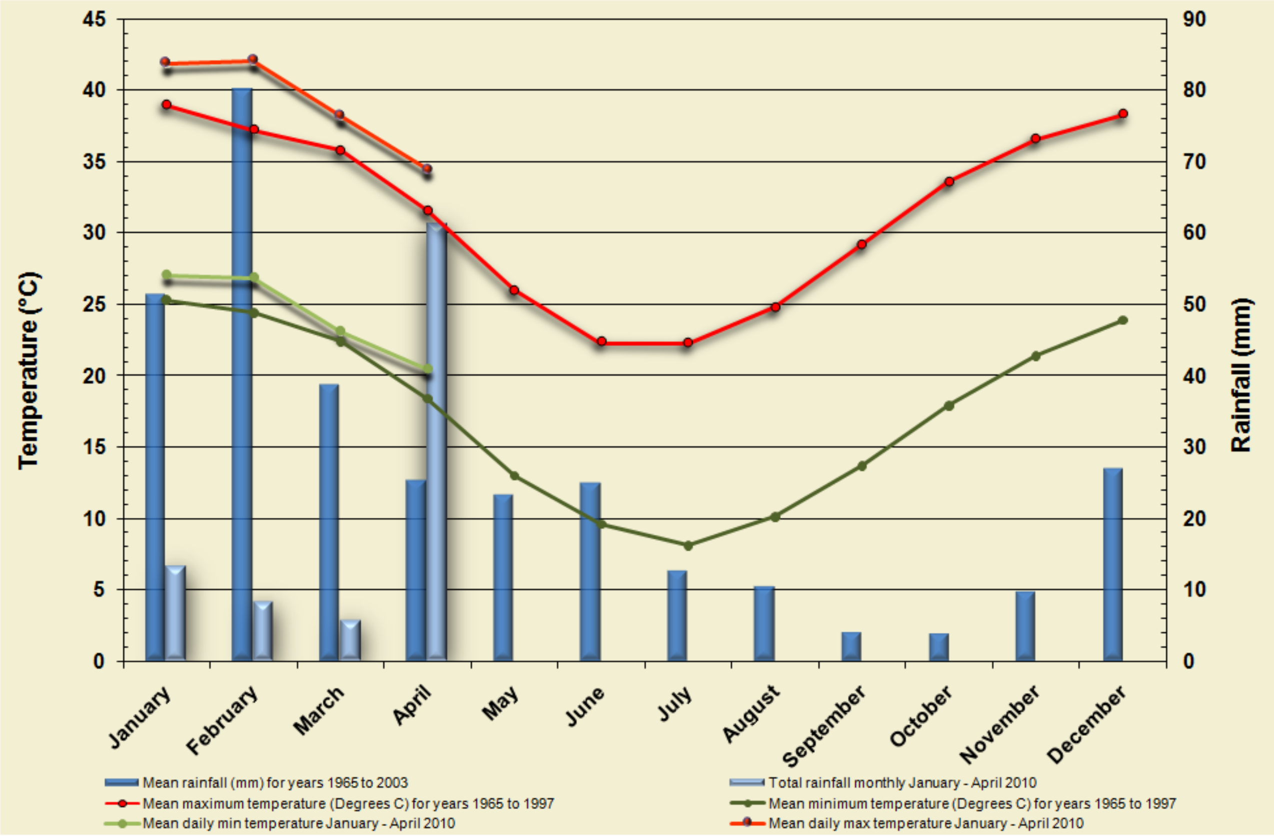

Figure 3-2 Rainfall and temperature data for the Round 3 survey compared with seasonal trends

Source: BOM.

3.4 TAXONOMY AND NOMENCLATURE

Sample processing and order-level identifications were completed by Phoenix staff. Species-level identifications of annelid worms were completed by Mike Scanlon (Bennelongia). All remaining species-level identifications were completed by Prof. Brenton Knott and Danny Tang (UWA). All specimens from the third round of sampling were submitted for identification in April 2010. No results are pending at the time of writing, all identifications have been completed.

3.5 SURVEY PERSONNEL AND ACKNOWLEDGEMENTS

A summary of the personnel involved in the survey is provided in Table 3-3. Phoenix also gratefully acknowledges Prof. Brenton Knott and Mike Scanlon for assisting with the taxonomic identifications.

Table 3-3 Survey personnel

Person	Title	Qualifications
Mr Jarrad Clark	Senior Invertebrate Biologist	B. Sc. (Environmental Management)
Ms Conor O'Neill	Environmental Scientist	B. Sc. (Sustainable Development and Conservation Biology)
Ms Andrea Bending	Biologist	B. Sc. (Marine Science and Environmental Biology)
Mr Simon Pynt	Zoologist	B. Sc. (Zoology)

4.0 RESULTS

Of the thirty eight bores sampled in the Round 3 survey, 15 were previously sampled in Rounds 1 and 2, and 26 bores (including three troglofauna bores which recorded stygofauna by-catch) were sampled for the first time in Round 3. In total, across the three survey rounds, 42 bores were sampled two to three times and 26 bores were sampled once (Appendix 1).

The Round 3 survey extended across seven Land Systems (Boolgeeda, Divide, Fortescue, Newman, River, Sylvania and Washplain) and the bores collectively passed through three major geologies; Marra Mamba, Jerrinah and Wittenoom formations. The Round 3 survey recorded a single additional specimen, Enchytraeidae pilbara sp.2 which was not previously recorded in Round 1 and Round 2.

Sixty seven specimens representing at least nine stygofauna species were recorded during the first two survey rounds from bores located within the proposed impact area. Three of the species were previously unrecorded in the region and represent new species records. All Round 1 and 2 sampling sites are located within the impact area. The absence of hydrogeological data at the time of sampling prevented definition of the impact area.

The sampling effort for the Round 3 survey aimed to provide additional information concerning stygobitic abundance and distribution, with the ultimate aim of extending species records outside of the impact area, both north of strike and further along strike to the east in particular. Recent resource extension and subsequent remodelling of the hydrogeology of the Python/Gwardar deposits resulted in significant changes to the original drawdown contours (Aquaterra 2010), on which the survey design for the third round of stygofauna sampling was based. Consequently no sampled bores are located outside of the revised modeled impact area.

The latest modelling suggests that after 12 years of mining (the predicted mine life) the maximum drawdown (‘drawdown cone’) will extend approximately 1km to the south, 4.5km to the north. Definitive data on the drawdown extent along the main body of the aquifer to the east and west was not available at the time of writing (pers. comm., Gary Bounds, Aquaterra November 2010).

4.1 STYGOFAUNA

The Round 1 and 2 surveys recorded at least nine stygobitic species, representing three classes, four orders, six families and eight genera. In the Round 3 survey, five stygobitic species were recorded, including four species collected in previous rounds and a single additional species from the same family as juveniles recorded in Rounds 1 and 2. The single additional species takes the total number of stygofauna recorded through the three survey rounds to ten species, representing three classes, four orders, seven families and nine genera (Table 4-1, Table 4-2). Records for all ten species are from inside the impact area only.

In the Round 1 and 2 surveys, 51 of the 67 individuals collected were of juvenile form, so definitive morphological identifications were not possible. In the Round 3 survey, only three of the 45 individuals collected were juveniles. In the case of the oligochaetes, adult specimens belonging to the family Enchytraeidae were collected in the third round. This enabled morphological identification to define a distinct species (Enchytraeidae pilbara sp.2) in the family Enchytraeidae from the three survey rounds. The species, Enchytraeidae pilbara sp.2 was collected in both adult and juvenile forms in Round 3 and may or may not represent the juveniles collected in Round 1 and 2 (Table 4-1, Table 4-2). Genetic sequencing to determine movement patterns within the aquifers will enable this to be clearly resolved, although this is outside the scope of the current study.

Of the 65 individual bores that were sampled over the three survey rounds, 24 (36.9%) contained stygofauna. The Round 1 survey (a dry season survey) yielded 21 individuals from six bores (14%). A higher number of individuals was recorded in the two wet season surveys, with 48 individuals collected from 12 bores (28.5%) in the Round 2 survey and 45 individuals collected from 11 bores (28.9%) in the Round 3 survey. The proportionate number of sampled bores yielding stygofauna were slightly lower than is typical of Pilbara surveys (usually around 38%) (Eberhard et al 2004).

Only two bores (DCRC0138, DCRC0074) recorded the same stygofauna species in two or more surveys, with the majority of re-sampled bores recording variability in assemblages between the three surveys.

Total abundance was highest in bores DCRC0040 and DCRC0246 in the Round 1 and 2 surveys, respectively (see location in Figure 4-1). In Round 3 abundance was greater per bore compared to earlier surveys, with 6-9 individuals being collected from bores DCRC0116, DCRC0335, DCRC0425 and DCRC0110 (Table 4-2).

Table 4-1 Number of stygofauna species records per bore (Rounds 1 and 2)

Bore	Land System	Class	Superorder/ Order	Family	Genus	Species	Abundance	Comment
Round 1 Nov-08 (21 specimens – 19 juvenile)								
DCRC0074	Newman	Malacostraca	Amphipoda	Paramelitidae	*Kruptus*	sp. 'DC'	1	Juvenile
DCRC0425	Divide	Malacostraca	Syncarida	Parabathynellidae		sp. 'DC'	1	Adult
DCRC0425	Divide	Malacostraca	Amphipoda	Could not be identified due to damage			1	Adult
DCRC0039	Divide	Oligochaeta	Tubificida	Enchytraeidae		sp. (juv)	5	Juvenile
DCRC0040	Divide	Oligochaeta	Tubificida	Enchytraeidae		sp. (juv)	12	Juvenile
DCRC0138	Newman	Oligochaeta	Tubificida	Phreodrilidae		sp. (juv)	1	Juvenile
Round 2 Mar-09 (46 specimens – 32 juvenile)								
DCRC0120	Fortescue	Could not be identified due to damage					1	
DCRC0073	Newman	Malacostraca	Amphipoda	Paramelitidae	*Kruptus*	sp. 'DC'	2	2 Juvenile, 1 damaged
DCRC0200	Fortescue	Malacostraca	Syncarida	Parabathynellidae		sp. 'DC'	1	Adult
DCRC0111	Fortescue	Maxillopoda	Cyclopoida	Cyclopidae	*Microcyclops*	*varicans*	4	Adult
DCRC0111	Fortescue	Maxillopoda	Cyclopoida	Cyclopidae	*Mesocyclops*	*brooksi*	1	Adult
DCRC0111	Fortescue	Maxillopoda	Cyclopoida	Cyclopidae	*Fierscyclops (Pilbarocyclops)*	sp. 'DC'	1	Adult
DCRC0116	Fortescue	Maxillopoda	Cyclopoida	Cyclopidae	*Microcyclops*	*varicans*	1	Adult
DCRC0116	Fortescue	Maxillopoda	Cyclopoida	Cyclopidae	*Mesocyclops*	*brooksi*	1	Adult
DCRC0116	Fortescue	Oligochaeta	Tubificida	Naididae	*Pristina*	*longiseta*	4	Adult
DCRC0126	Fortescue	Oligochaeta	Tubificida	Enchytraeidae		sp. (juv)	2	Juvenile
DCRC0147	Newman	Oligochaeta	Tubificida	Phreodrilidae		sp. (juv)	3	Juvenile
DCRC0243	Newman	Oligochaeta	Tubificida	Phreodrilidae		sp. (juv)	1	Juvenile
DCRC0246	Newman	Oligochaeta	Tubificida	Enchytraeidae		sp. (juv)	12	Juvenile
DCRC0256	Newman	Oligochaeta	Tubificida	Enchytraeidae		sp. (juv)	5	Juvenile
DCRC0260	Sylvania	Oligochaeta	Tubificida	Phreodrilidae		sp. (juv)	6	Juvenile
DCRC0138	Newman	Oligochaeta	Tubificida	Phreodrilidae		sp. (juv)	1	Juvenile

Table 4-2 Number of stygofauna species records per bore (Round 3)

Bore	Land System	Class	Superorder/ Order	Family	Genus	Species	Abundance	Comment
Round 3 Mar-10 (45 specimens – 3 juvenile)								
DCRC0040	Divide	Maxillopoda	Cyclopoida	Cyclopidae	*Microcyclops*	*varicans*	1	Adult
DCRC0074	Newman	Malacostraca	Amphipoda	Paramelitidae	*Kruptus?*	sp. 'DC'	2	Adult
DCRC0088*	Divide	Oligochaeta	Tubificida	Enchytraeidae		sp. (juv)	1	Juvenile
DCRC0116	Fortescue	Oligochaeta	Tubificida	Naididae	*Pristina*	*longiseta*	6	Adult
DCRC0145	Divide	Oligochaeta	Tubificida	Enchytraeidae		sp. (juv)	2	Juvenile
DCRC0335	Divide	Oligochaeta	Tubificida	Enchytraeidae		*pilbara* sp.2	9	Adult
DCRC0425	Divide	Oligochaeta	Tubificida	Enchytraeidae		*pilbara* sp.2	9	Adult
DCRC0159*	Fortescue	Oligochaeta	Tubificida	Enchytraeidae		*pilbara* sp.2	3	Adult
DCRC0110*	Fortescue	Oligochaeta	Tubificida	Enchytraeidae		*pilbara* sp.2	8	Adult
MMRC0004	Divide	Maxillopoda	Cyclopoida	Cyclopidae	*Microcyclops*	*varicans*	1	Adult
MMRC0004	Divide	Oligochaeta	Tubificida	Naididae	*Pristina*	*longiseta*	1	Adult
MMRC0006	Divide	Oligochaeta	Tubificida	Enchytraeidae		*pilbara* sp.2	2	Adult

*indicates a troglofauna sampled bore which recorded a stygobitic species.

Table 4-3 Stygofauna species records with respect to Land Systems

Species	Round 1	Round 2	Round 3	TOTAL
Amphipoda		-		
Kruptus sp. 'DC'	Newman	Newman	Newman	**1**
Amphipoda sp. indet	Divide	Newman	-	**2**
Copepoda				
Fierscyclops (Pilbarocyclops) sp. 'DC'	-	Fortescue	-	**1**
M. varicans	-	Fortescue	Divide	**2**
M. brooksi	-	Fortescue	Divide	**2**
Oligochaeta				
Enchytraeidae sp. (juv)	Divide	Fortescue / Newman	Fortescue / Divide	**3**
Enchytraeidae pilbara sp.2	-	-	Fortescue / Divide	**2**
Pristina longiseta	-	Fortescue	Fortescue / Divide	**2**
Phreodrilidae sp. (juv)	Newman	Newman/Sylvania	-	**2**
Syncarida				
Parabathynellidae sp. 'DC'	Divide	Fortescue	-	**2**

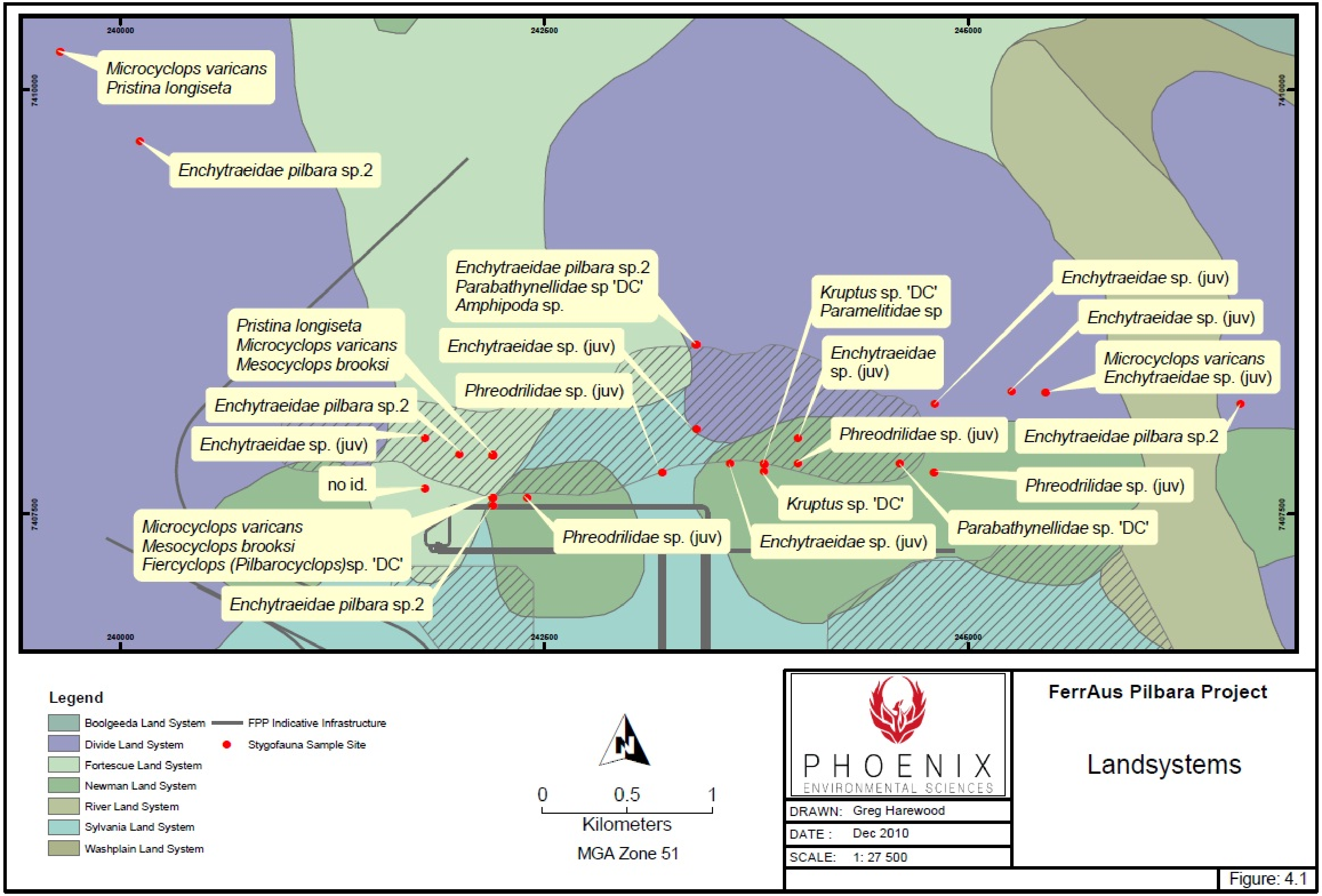

Figure 4-1 Location of stygofauna records from survey Rounds 1 to 3

Species richness in Rounds 1 and 2 were highest in bores DCRC0111 and DCRC0116, with three species recorded from each bore. In Round 3 the greatest species richness (two species) was recorded in bore MMRC0004 (the Mirrin Mirrin prospect ~4km to the north of the Python/Gwardar proposed pits). This is quite low as a richness of 5.4 species per bore is typical for bores sampled twice in the Pilbara (Eberhard et al 2004).

Three bores (DCRC0040; DCRC0116; and DCRC0425) recorded different assemblages between sampling rounds, while others (e.g. DCRC0138, DCRC0074 and DCRC0040) recorded the same species in two or more rounds. The variability in abundance and species assemblages over time suggests there may be a high degree of mobility and therefore a more permeable alluvial and colluvial aquifer, despite the limited permeability of the MMIF unit as suggested by Aquaterra (2010).

The majority of species collected in the surveys are known from elsewhere in the Pilbara; however, of the ten species collected which are discussed below, three are considered to be new species

4.1.1 Amphipoda

A single new species of Amphipod belonging to the family Parameletidae, was collected in all three survey rounds, the species was tentatively placed in the genus *Kruptus* and named *Kruptus* sp. 'DC'. This species was represented by two specimens from bores DCRC0073 and DCRC0074 located very close to one another. These bores are also adjacent to a nearby alluvial channel on the southern boundary of the pit (within the area of proposed impact) (Figure 4-1; Table 4-3). The Paramelitidae family is well represented across the Goldfields and Pilbara regions however this species has not been recorded previously.

At present *Kruptus* sp. 'DC' is known only from within the study area, in the greater impact area.

One damaged and juvenile amphipod specimen (Amphipoda sp. indet) could not be identified as they were damaged.

4.1.2 Copepoda

Three copepods, *Fierscyclops (Pilbarocyclops)* sp. 'DC', *Microcyclops varicans* and *Mesocyclops brooksi* were recorded in the study area. *Fierscyclops (Pilbarocyclops)* sp. 'DC' was only collected in the Round 3 survey, while *M. varicans* and *M. brooksi* were collected during the wet season surveys (Rounds 2 and 3).

Fierscyclops (Pilbarocyclops) sp. 'DC' is a new species. It was collected from a single bore on the southwest margin of the proposed pit, within the Fortescue Land System. This location is within the greater impact area.

The other two recorded copepods (*Microcyclops varicans* and *Mesocyclops brooksi*) are surface water forms (i.e. not obligate groundwater fauna) that have broad Pilbara distributions (Bennelongia 2010).

4.1.3 Oligochaeta (worms)

Oligochaete specimens were collected in all three survey rounds and were the most abundant (41 specimens) and widespread (19 of the 24 bores) group recorded in both dry (Round 1) and wet season rounds (Rounds 2 and 3) (Table 4-1, Table 4-2). Of the stygofauna collected, the Oligochaeta were the most diverse group, with three species morphologically identified in addition to juvenile specimens from all three rounds which could not be morphologically assigned.

The diversity and distribution of oligochaete records, and their basic ecology suggests that the stygobitic worms are abundant within the study area, and likely to occur beyond the study area boundaries.

Enchytraeidae sp.(juv) could not be assigned to a particular genus as morphological identification requires an adult specimen. It is suggested that these juveniles could belong to the identified species Enchytraeidae pilbara sp. 2 (Mike Scanlon pers comm. 2010) however planned genomic (genetic sequencing) analysis to assess the movement of stygofauna will determine this in the upcoming work.

Enchytraeidae pilbara sp. 2 is an oligochaete that was recorded from the Fortescue and Newman Land Systems in Round 1 and 2 surveys, and was also found well north of the ore hosting unit, in Round 3 (Fortescue and Divide Land Systems). It is recorded in both the greater and lesser impact areas. While not yet formally described, this species has been recorded in the Pilbara biological survey and is well represented across the Pilbara region (Bennelongia 2010). Representatives of the Enchytraeidae also recorded distribution across the south coast of Western Australia (Rockwater 2006a, b) and other areas of the Pilbara, such as the coastal basin in Port Hedland (OES 2008). This species is considered to have a broad distribution.

An unidentified Phreodrillidae species was recorded from four sites along the length of the proposed pit within the greater impact area in both Rounds 1 and 2. It was not recorded in Round 3.

Phreodrillids occur in ground and surface waters and specimens have been recorded from various drainage basins within the Pilbara region (Pinder 2008). Additionally, phreodrillids are considered widespread throughout Western Australia and have also been recorded from groundwaters of the Yilgarn and Murchison Like the Enchytraeidae (OES 2009). Although this species is lacking in data, it is considered to have a broad distribution

Pristina longiseta (Ehrenberg, 1828) is a cosmopolitan species that is known from Australia, Europe and North America (Pinder & Brinkhurst 1994; Tang et al. 2008). It was recorded in Round 2 and Round 3 in the Fortescue/Newman and Divide Land Systems respectively from within both the lesser and greater impact areas. This species is common and is known to have a broad distribution

4.1.4 Syncarida

A single unidentified species of parabathynellid syncarid, tentatively classified as Parabathynellidae sp.'DC', was collected in Rounds 1 and 2. This form is previously unrecorded and represents a new species. The collection in Round 1 was from the northern boundary of the pit in the Divide Land System and the Round 2 collection was from the south-eastern boundary of the pit collected in the Fortescue Land System. It was not recorded in Round 3 and collections remain restricted to the greater impact area of the study area.

4.2 STYGOFAUNA HABITAT

For the purposes of conducting an impact assessment, the impact area was defined by the groundwater drawdown across the study area and was divided into two scales of impact; referred to as 'greater impact area' (greater drawdown zone) and 'lesser impact area' (lesser drawdown zone) (Figure 4-2).

The geology of the 11 bores sampled in the greater impact area outside the pit boundary is represented on the left hand side of Figure 4-3. This figure also highlights the level of drawdown in the bores of the greater and lesser impact areas. In the greater impact area, all of the bores will experience 100% drawdown of the alluvial/colluvial sequence and 82% of the sampled bores in this zone will experience 100% drawdown of the known extent of the Wittenoom strata. Each bore will also have a percentage drawdown within the iron hosting Marra Mamba formation (unmapped) (Figure 4-3).

In the lesser impact area, the boundary closest to the greater drawdown area will experience up to 100% drawdown of the alluvial/colluvial sequence, up to 50% drawdown in the Wittenoom strata and a lesser drawdown of the aquifer hosted by the Marra Mamba unit. Habitat toward the outer margins of the lesser impact area in the regional bores sampled will experience much less drawdown in each geological sequence than those in closer proximity to the greater impact zone (central columns of Figure 4-3). It is expected that some stygofauna habitat will be modified in the lesser impact area.

Of the eighteen bores sampled in the lesser impact area, only two recorded stygofauna species are present (represented in columns outlined in red in Figure 4-3). These two bores are located in the Mirrin Mirrin area to the northeast of the proposed Python/Gwardar pit. This area also contains a Marra Mamba iron hosting formation, with an associated aquifer. It is likely that drawdown from the Python/Gwardar pit will affect 100% of the alluvial/colluvial zone and up to 50% of the Wittenoom strata.

The interaction between the Mirrin Mirrin and Python/Gwardar aquifers is untested (Aquaterra 2010).

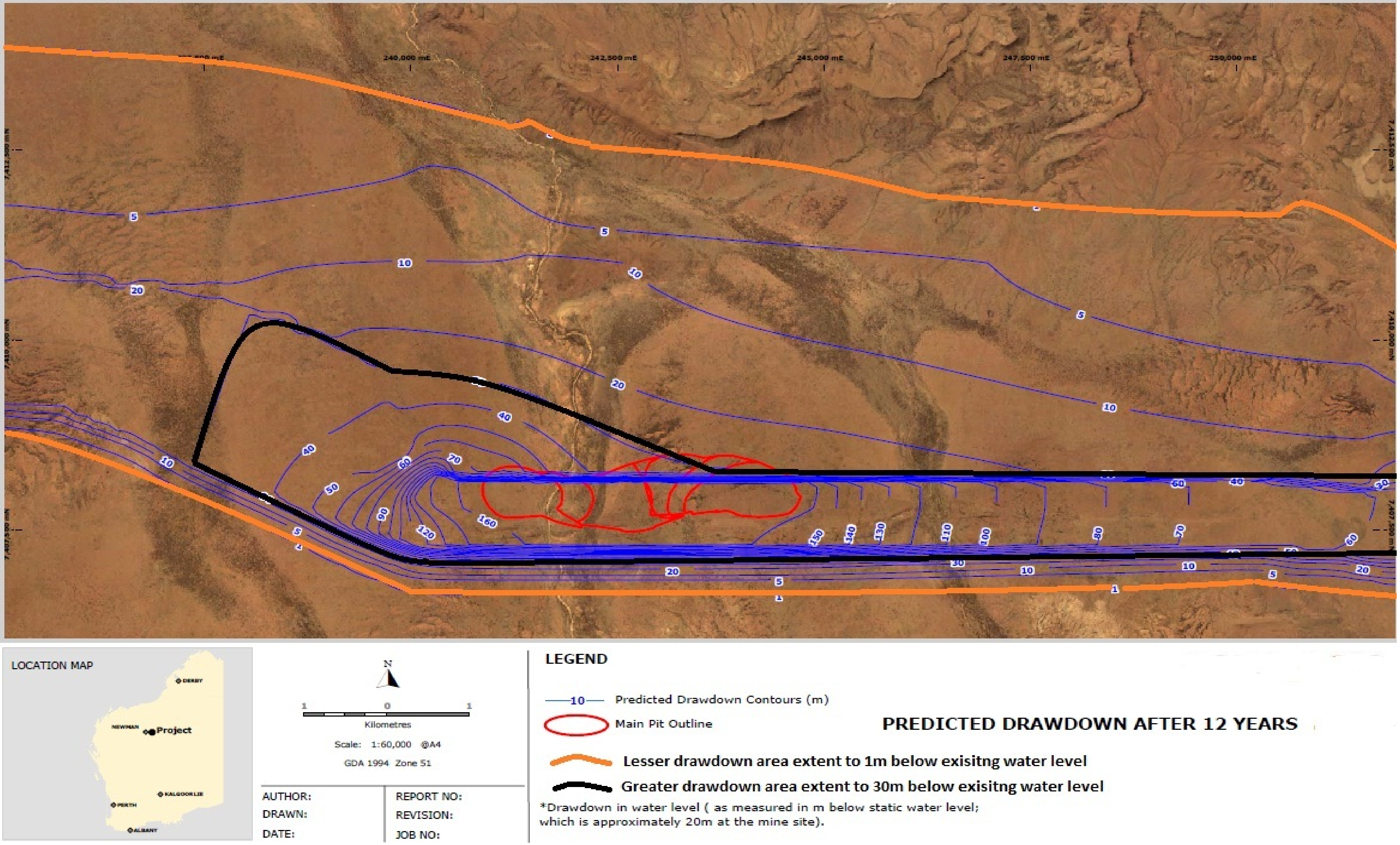

Figure 4-2 **Greater and lesser drawdown zones for the study area predicted after 12 years**

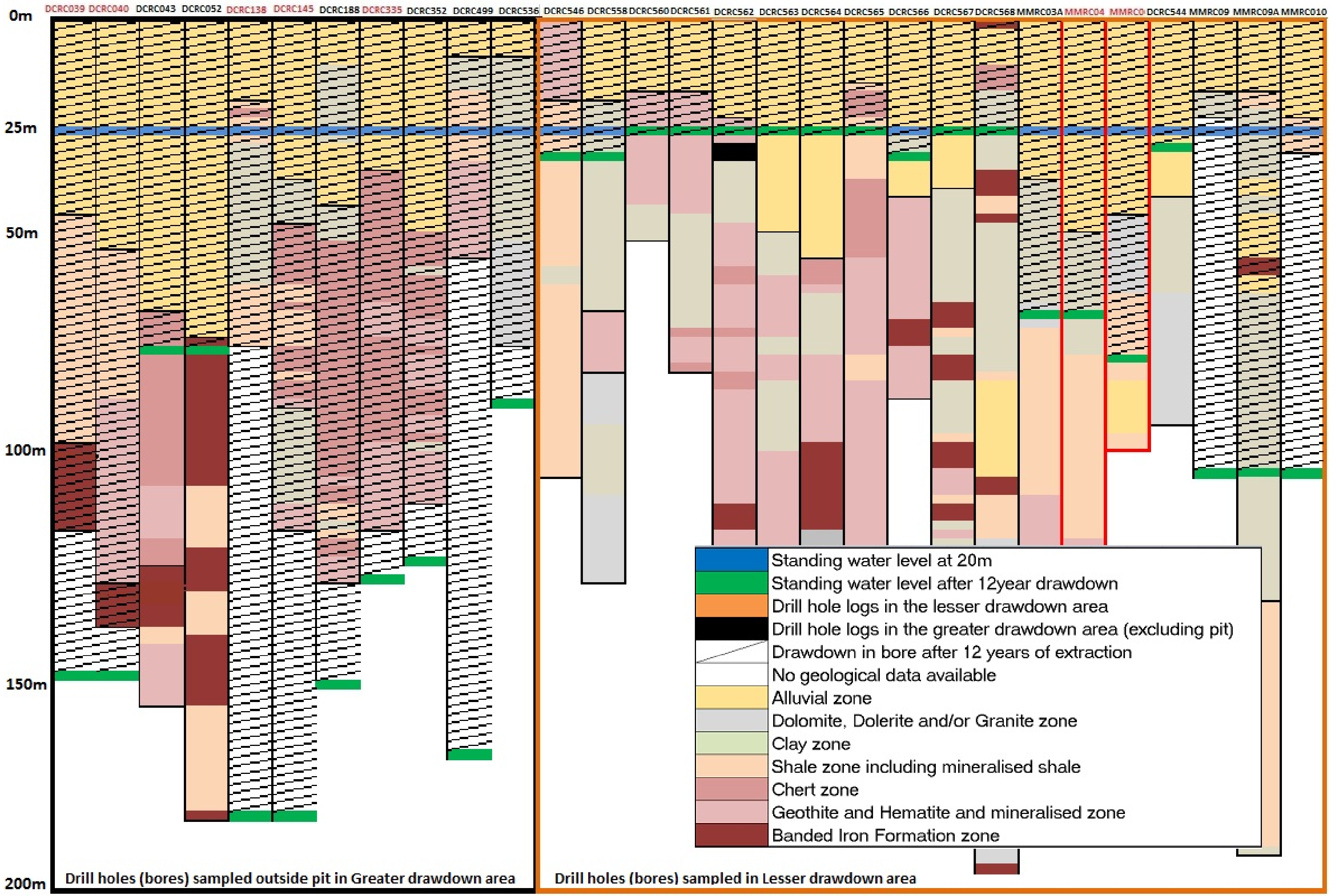

Figure 4-3 Bore data for drawdown extent in greater impact area (left hand columns) and lesser impact area (right hand columns). Bores numbers in red font recorded stygofauna

4.3 WATER QUALITY

Groundwater in all sampled bores across all survey rounds was fresh to brackish, with salinities being less than 1.5g/L on average, and electrical conductivities being 2,408µS/cm on average. Notably, the highest electrical conductivities recorded in Rounds 1 and 2 were 6680µS/cm and 6370 µS/cm respectively, compared to a maximum in Round 3 of 8230µS/cm recorded from one of the newly-added Mirrin Mirrin bores (Table 4-4 and Table 4-5).

The pH of the aquifers ranged from acidic (5.7) to slightly alkaline (8.45) throughout Rounds 1 to 3.

Dissolved oxygen was low (e.g. 0.7mg/L, 7.9% saturation) in the majority of bores and increasingly saturated (19.2mg/L, 192% saturation) in others. For the three sampling rounds, the median dissolved oxygen was 3.5mg/L or 45.0% saturation.

Oxidation reduction potential (ORP) was variable in both Rounds 1 and 2, ranging from a low of -125mV in March 2009 to a high of 303mV in November 2008. In the March Round 3 survey, the ORP ranged from a low of -292mV to a high of 187mV, which is a smaller range than was recorded in the first two survey rounds (Table 4-4, Table 4-5).

The rainfall received between the Round 1 and 2 surveys appears to have had an effect on the groundwater parameters measured. Median salinity and conductivity were slightly lower after a rainfall event in Round 2.

Average alkalinity rose from November 2008 (Round 1) to March 2010, and the pH range across the bores was broader. The same was true of dissolved oxygen. The median ORP fell between November 2008 and March 2009, and again in Round 3.

Table 4-4 Water chemistry of bores sampled in survey Rounds 1 and 2

		Round 1 - November 2008									Round 2 - March 2009									
	Bore	Total Depth (m)	Depth to Water (m. bgl):	pH	Salinity (mg/L)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%) sat.)	ORP (mV)	Temperature (°C)	Total Depth (m)	Depth to Water (m):	pH	Salinity (mg/L)	Conductivity (µs/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)sat.)	ORP (mV)	Temperature (°C)	Land System
1	DCRC0031	>100	22.5	7.0	0.3	525	3.5	39.7	144	28.5	100	21.5	7.0	0.3	599	1.1	16.5	-107	30.8	Divide
2	DCRC0036	Could not acquire water									No resample attempted									Divide
3	DCRC0037	100	20.4	6.6	0.7	1162	4.9	65.7	113	31.3	100	20.4	6.5	0.1	227	3.1	35.6	108	27.9	Divide
4	DCRC0039*	85	19.9	7.0	0.4	590	5.5	66.3	128	27.6	82	19.9	6.8	0.3	569	1.5	19.2	146	30.2	Divide
5	DCRC0040*	>100	19.9	6.7	0.8	1309	3.9	47.3	168	30.5	100	19.8	7.5	0.0	0.4	4.1	50.0	111	31.1	Divide
6	DCRC0064	>100	29.7	6.9	2.4	3830	3.2	40.5	123	28.3	100	29.9	7.2	2.0	3800	5.6	58.0	111	28.8	Newman
7	DCRC0066	>100	24.0	6.9	2.1	3270	3.8	49.4	143	32.2	100	23.9	7.0	1.5	2800	4.0	56.6	160	32.3	Newman
8	DCRC0073*	50	25.0	6.9	2.9	4510	1.8	29.6	152	29.2	81	26.8	7.1	1.7	3190	19.2	130.0	176	31.2	Newman
9	DCRC0074*	>50	25.6	6.8	1.4	2120	1.7	22.3	235	32.1	68	25.5	7.1	2.5	4560	13.0	92.5	170	31.7	Newman
10	DCRC0093	59	20.6	6.3	1.6	2580	1.5	19.0	217	29.5	55	20.6	7.2	0.3	5990	4.2	50.4	118	28.7	Sylvania
11	DCRC0095	Could not acquire water									No resample attempted									Sylvania
12	DCRC0100	57	25.8	6.8	3.3	5130	10.1	141.9	214	30.9	57	26.8	7.3	2.8	5190	3.8	48.7	154	30.0	Newman
13	DCRC0105	>100	19.1	6.6	0.6	966	5.9	85.6	303	30.2	100	21.3	8.0	0.0	77	4.0	54.7	120	29.9	Newman
14	DCRC0110	25	16.5	6.8	4.2	6680	1.9	23.6	90	27.8	26	17.0	7.0	3.5	6370	4.8	55.1	84	29.2	Newman
15	DCRC0111*	>100	18.1	6.9	3.6	5660	4.6	55.1	69	29.1	100	17.9	7.7	0.6	1310	6.5	82.3	53	30.2	Fortescue
16	DCRC0116*	>100	18.1	6.8	0.9	1356	5.8	75.1	138	30.7	100	18.0	7.4	0.4	735	4.7	54.9	46	29.1	Fortescue
17	DCRC0120*	39	18.7	6.9	4.0	6210	2.5	32.8	176	25.4	38	18.7	7.2	3.2	5750	2.3	29.2	126	30.9	Fortescue
18	DCRC0126*	30	18.5	7.2	0.4	660	10.6	142.1	183	29.4	34	18.8	7.7	0.3	610	2.2	25.3	135	29.0	Fortescue
19	DCRC0127	Could not acquire water									No resample attempted									Fortescue
20	DCRC0138*	68	23.8	7.0	1.7	2570	4.2	61.2	170	31.1	66	23.8	6.7	0.1	242	1.5	19.1	120	30.4	Newman
21	DCRC0142	86	22.5	6.8	1.2	1900	2.5	30.4	142	26.8	80	22.4	6.7	0.2	315	1.4	17.7	135	30.3	Divide
22	DCRC0147	50	22.0	6.9	3.5	5500	2.2	31.1	152	31.8	72	22.3	7.3	3.1	5650	13.8	192.0	160	31.1	Newman
23	DCRC0153	70	18.8	7.1	1.2	1810	0.7	7.9	-171	28.2	68	18.4	7.4	0.9	1770	4.1	45.0	-125	29.6	Fortescue
24	DCRC0155	40	20.2	6.8	3.8	5860	3.3	44.0	163	30.9	38	20.3	7.0	0.8	1554	3.2	37.8	124	30.2	Fortescue
25	DCRC0200*										74	24.3	6.5	1.1	2190	1.4	16.5	152	29.1	Newman
26	DCRC0202	92	23.6	6.0	0.4	670	3.5	47.6	179	29.7	89	23.5	5.7	0.3	513	4.7	60.2	206	28.0	Newman

		Round 1 - November 2008									Round 2 - March 2009									
	Bore	Total Depth (m)	Depth to Water (m. bgl):	pH	Salinity (mg/L)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%) sat.)	ORP (mV)	Temperature (ºC)	Total Depth (m)	Depth to Water (m):	pH	Salinity (mg/L)	Conductivity (µs/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)sat.)	ORP (mV)	Temperature (ºC)	Land System
27	DCRC0243*	>50	27.9	7.0	2.4	3800	2.7	35.5	151	29.1	55	26.9	7.2	2.1	3890	5.8	55.4	137	31.0	Newman
28	DCRC0245	>50	23.3	6.9	1.8	2840	2.3	31.2	187	30.6	100	23.5	7.2	1.6	3020	5.0	58.1	102	28.7	Newman
29	DCRC0246*	>50	23.0	6.7	1.1	1790	3.0	45.0	238	32.1	100	22.4	7.0	0.8	1430	4.5	58.0	145	30.1	Newman
30	DCRC0251	50	23.0	6.9	2.9	4560	1.4	19.1	185	32.1	86?	23.0	7.2	2.5	4640	2.2	28.0	127	31.3	Newman
31	DCRC0256*	40	20.8	6.5	1.2	1810	2.8	36.7	222	29.4	39	19.7	6.9	0.9	1810	6.7	75.2	128	30.0	Newman
32	DCRC0260*	69	20.7	7.1	2.8	4380	3.4	39.9	182	28.3	67	20.7	7.2	2.3	4320	3.3	42.2	130	28.8	Sylvania
33	DCRC0264	34	20.3	7.0	0.9	1402	6.5	84.0	287	29.2	34	19.6	7.4	0.2	320	3.2	42.0	113	30.2	Sylvania
34	DCRC0267	77	22.0	6.9	3.4	5300	2.0	27.3	156	31.4	77	21.9	7.2	2.8	5150	2.3	29.0	165	28.7	Newman
35	DCRC0270	>100	19.7	6.3	0.5	787	4.8	65.2	295	33.4	100	19.7	7.4	0.1	208	3.6	42.2	162	25.3	Sylvania
36	DCRC0344	25	15.0	6.7	0.7	1113	5.9	77.6	161	29.4	Could not acquire water									Divide
37	DCRC0345	83	21.3	6.7	2.3	3660	1.3	17.2	215	30.51	Could not acquire water									Divide
38	DCRC0371	40	18.0	6.8	0.4	631	6.2	93.3	230	30.5	35	16.6	6.8	0.2	500	4.4	48.1	121	29.3	Divide
39	DCRC0372	67	16.9	6.5	0.3	519	7.6	100.3	203	30.0	66	17.0	6.7	0.2	473	5.4	69.7	154	29.9	Divide
40	DCRC0425*	50	18.0	6.8	0.4	619	5.5	68.4	196	27.8	50	17.9	7.5	0.3	559	3.7	49.1	131	28.6	Divide
41	DCRC0451	100	23.8	6.4	0.8	1191	6.2	86.2	216	30.1	100	23.8	6.5	0.9	1720	4.9	60.7	156	29.3	Divide
42	DCRC0501										30	23.4	6.3	0.3	620	5.7	64.0	167	29.1	Divide
	Mean	**67.2**	**21.3**	**6.8**	**1.7**	**2683.0**	**4.0**	**53.7**	**171.8**	**29.9**	**71.7**	**21.6**	**7.1**	**1.1**	**2234.4**	**4.7**	**53.2**	**119.5**	**29.7**	
	Max.	**100.0**	**29.7**	**7.2**	**4.2**	**6680.0**	**10.6**	**142.1**	**303.0**	**33.4**	**100.0**	**29.9**	**8.0**	**3.5**	**6370.0**	**19.2**	**192.0**	**206.0**	**32.3**	
	Min.	**25.0**	**15.0**	**6.0**	**0.3**	**519.0**	**0.7**	**7.9**	**-171.0**	**25.4**	**26.0**	**16.6**	**5.7**	**0.0**	**0.4**	**1.1**	**16.5**	**-125.0**	**25.3**	
	Std. Dev.	**25.8**	**3.2**	**0.2**	**1.2**	**1930.9**	**2.3**	**31.8**	**77.8**	**1.7**	**25.6**	**3.2**	**0.4**	**1.1**	**2052.1**	**3.6**	**32.7**	**65.1**	**1.3**	

*Indicates that stygofauna were recorded from this bore.

Table 4-5 Water chemistry of bores sampled survey Round 3

	Bore	ID	Rehabilitated and uncovered?	Total Depth (m)	Depth to Water (m. bgl):	pH (pH units)	Salinity (g/L)	Electrical Conductivity (µs/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%sat.)	ORP (mV)	Temperature (°C)	Land System
		Round 3 - March 2010											
1	DCRC0126	DCRC	Yes		17.71	7.7	0.4	590	3.55	44.1	126	28.77	Fortescue
2	DCRC0120	DCRC	Yes		16.4	7.24	4	6200	3.1	36.1	118	30.11	Fortescue
3	DCRC0116*	DCRC	Yes		17.64	7.48	0.8	1219	3.91	45.3	104	24.65	Fortescue
4	DCRC0111	DCRC	Yes		19.04	7.45	3.7	5700	3.7	44.3	137	28.49	Newman
5	DCRC0147	DCRC	Yes		18.71	7.11	0.2	359	4.11	53.6	89	32.8	Newman
6	DCRC0260	DCRC	Yes		20.66	7.61	2.9	4530	4.21	49.1	119	28.16	Sylvania
7	DCRC0256	DCRC	Yes		23.6	6.85	1.1	1720	4.7	59.3	140	29.3	Divide
8	DCRC0074*	DCRC	Yes		25.5	7.28	3	4700	3.51	42.5	121	28.68	Newman
9	DCRC0073	DCRC	Yes		24.32	7.48	2.7	4170	4.16	47	100	27.77	Newman
10	DCRC0246	DCRC	Yes		21.99	7.1	1.2	1810	5.6	61.2	135	29.81	Newman
11	DCRC0200	DCRC	Yes		23.08	6.8	1.5	2460	3.83	44.6	133	32.51	Newman
12	DCRC0040*	DCRC	Yes		17.79	7.17	0.6	919	3.12	37.2	110	30.64	Divide
13	DCRC0425*	DCRC	Yes		17.91	6.49	0.4	608	4.74	65.3	157	33.45	Divide
14	DCRC0052	DCRC	No		18.72	7.21	0.4	560	3.31	38.2	162	28.61	River
15	DCRC0335*	Aquaterra	No		20.55	7.85	0.7	1125	7.2	88.1	106	27.11	Divide
16	DCRC0352	Aquaterra	No		18.95	7.57	1.5	2390	7.34	76.3	111	28.53	Divide
17	DCRC0188	Aquaterra	No		20.31	7.09	0.9	1428	4.48	57.7	162	30.42	Divide
18	DCRC0145*	Aquaterra	No		21.07	7.22	0.2	314	2.06	35.8	118	28.15	Divide
19	DCRC0133	Aquaterra	No		22.7	6.91	0.6	853	5.13	63.4	130	28.5	Newman
20	DCRC0271	Aquaterra	No		19.44	6.7	0.5	749	4.55	58.1	138	30.4	Sylvania
21	DCRC0168	Aquaterra	No		18.95	7.19	1.1	1750	4.33	51.2	175	32.1	Fortescue
22	DCRC0536	Aquaterra	No		10.63	7.54	1.6	2480	9.93	118	97	30.63	Divide
23	DCRC0544	Aquaterra	No		11.23	7.43	1.3	1950	7.33	79	131	30.91	Divide
24	DCRC0546	Aquaterra	No		36.8	7.24	1.5	2400	3.31	37.5	128	30.11	Newman
25	DCRC0558	Aquaterra	No		20.31	7.51	0.8	1283	4.17	50	139	28.12	Washplain
26	DCRC0155	Aquaterra	No		18.95	7.22	1	1550	2.4	27.4	-251	29.46	Fortescue

	Round 3 - March 2010												
	Bore	**ID**	**Rehabilitated and uncovered?**	**Total Depth (m)**	**Depth to Water (m. bgl):**	**pH (pH units)**	**Salinity (g/L)**	**Electrical Conductivity (µs/cm)**	**Dissolved Oxygen (mg/L)**	**Dissolved Oxygen (%sat.)**	**ORP (mV)**	**Temperature (ºC)**	**Land System**
27	MMRC003A	Mirrin Mirrin	Yes		15.01	7.33	2.1	3300	3.11	32.6	147	27.51	Divide
28	MMRC0004*	Mirrin Mirrin	Yes		17.35	7.57	2	3150	5.99	68.1	135	27.82	Divide
29	MMRC0006*	Mirrin Mirrin	Yes		16.23	7.32	2.1	3270	4.1	48.2	149	28.24	Divide
30	MMRC0009	Mirrin Mirrin	Yes		16.3	7.59	0.6	972	4.52	52.8	124	28.78	Divide
31	MMRC0009A	Mirrin Mirrin	Yes		17	6.65	0.7	1027	6.01	69.5	187	29.18	Divide
32	MMRC0010	Mirrin Mirrin	Yes		16.45	8.45	5.3	8230	4.15	44.7	97	29.52	Divide
33	DCRC0563	Regional	Yes		20.67	7.33	1.8	2790	2.43	27.2	79	31.84	Boolgeeda
34	DCRC0564	Regional	Yes		24.12	7.37	1.2	1890	1.63	19.8	-292	32.19	Boolgeeda
35	DCRC0566	Regional	Yes		20.83	7.29	2.4	3730	3.74	53.1	77	35.55	Boolgeeda
36	DCRC0568	Regional	Yes		36.15	7.33	1.4	2170	2.17	105	161	32.27	Newman
37	DCRC0499	DCRC	Yes		29.59	7.5	1.5	2410	2.41	63.7	36.5	31.2	Newman
38	DCRC0043	DCRC	Yes		19.77	7.22	0.6	942	0.942	80	149	30.55	Divide
Mean					**20.32**	**7.29**	**1.48**	**2307**	**4.18**	**54.6**	**104.8**	**29.81**	
Max.					**36.8**	**8.45**	**5.3**	**8230**	**9.93**	**118**	**187**	**35.55**	
Min.					**10.63**	**6.49**	**0.2**	**314**	**0.942**	**19.8**	**-292**	**24.65**	
Std. Dev.					**5.32**	**0.35**	**1.14**	**1775**	**1.69**	**20.45**	**94.59**	**2.06**	

*Indicates that stygofauna were recorded from this bore.

4.4 SURVEY LIMITATIONS

Limitations of survey Rounds 1 to 3 are outlined in Table 4-6.

Table 4-6 Limitations of survey Rounds 1 to 3

Limitations[1]	Relevant to the three surveys? Yes / no	Comments
Competency / experience of the consultant carrying out the survey.	No	Phoenix has extensive experience in undertaking stygofauna surveys throughout the Pilbara, Midwest, Southwest, Kimberley and Goldfields regions of W.A.
Scope (what faunal groups were sampled, were some sampling methods not able to be employed because of constraints such as weather conditions, e.g. pitfall trapping in waterlogged soils or inability to use pitfall traps).	Yes	Survey was constrained to the impact area in Rounds 1-3. Survey of regional bores constrained by lack of available bores suitable for sampling.
Proportion of fauna identified, recorded and/or collected.	Yes	Given the limited knowledge subterranean fauna of the east Pilbara, it is not possible to confirm that all species were recorded for the study area; further survey work is required outside the impact areas.
Sources of information e.g. previously available information (whether historic or recent) as distinct from new data.	Yes	No stygofauna surveys have previously been conducted within the study area. Stygofauna have been recorded for an iron ore deposit 20km to the south of the study area. The groups recorded were similar (Copepods, Amphipods and Oligochaeta), but distinct species were recorded.
Timing/weather/season/cycle.	No	Data were collected in both wet and dry seasons.
The proportion of the task achieved and further work which might be needed.	Yes	The program was implemented as planned, although some bores could not be sampled because they were blocked or had collapsed. In addition, all of the bores sampled fall within the modeled ‘impact zone’. In Round 3 nearly 50% of those sampled were originally thought to be outside the modeled proposed drawdown and as such they would fall within the ‘lesser impact’ area (the area for which some drawdown would be experienced).
Disturbances (e.g. fire, flood, accidental human intervention etc.) which affected results of survey.	No	Not relevant to any of the three survey rounds.
Intensity (in retrospect, was the intensity adequate?)	Yes	Sampling intensity requires reference sites outside the proposed impact area. Further survey work is required to complete intensity required.
Completeness (was relevant area fully surveyed?)	Yes	Local bores and some regional bores were sampled over Rounds 1 to 3, however a greater proportion fall within the impact area, Further survey work is required upstream and in regional bores.
Remoteness and/or access problems.	No	Not relevant to the surveys.
Availability of contextual (e.g. biogeographic) information on the region.	No	There is a paucity of subterranean information compared with other faunal groups, i.e. vertebrate fauna, however records have expanded markedly with the expansion of mining and associated reporting in the Pilbara; unfortunately most of these records remain unpublished.

[1] EPA (2004)

5.0 DISCUSSION

Guidance Statement 54a: *Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia* (EPA 2007) states that there is a very high likelihood of collecting stygofauna from all geologies in the Pilbara. Prior to sampling by Phoenix in 2008, no previous stygofauna studies had been carried out in the study area. Numerous regional studies have been undertaken in the Pilbara, reporting a diverse array of stygafauna species from geologies similar to the study area (Eberhard and Halse 2004; Eberhard et al 2005).

In the context of other local (Bennelongia 2010; ecologia 2009a) and regional (Biota 2006; OES 2009) stygofauna surveys, stygofauna were expected from the Python/Gwardar iron ore pits. This was confirmed with stygofauna being recorded in all three rounds of survey within the study area.

Sixteen of the sampled bores yielded 67 stygofauna specimens in Rounds 1 and 2, and Round 3 yielded 45 specimens in 11 bores from within both the greater and lesser impact areas. The survey yields of Rounds 1, 2 and 3 (14.0%, 28.5% and 28.9% respectively) were slightly less than that typically recorded in the Pilbara (38%) (Eberhard and Halse 2004). This may be due to the paucity of bores within the study area that were suitable for sampling.

Rounds 1 and 2 recorded primarily juvenile stygofauna forms that precluded species level identification based on morphology. A lack of definitive (species level) identification limits the ability to conduct risk assessment and therefore indicates a need for further sampling and genomic investigations. The third sampling round aimed to provide definitive identifications and increase knowledge of species distribution and abundance in areas beyond the predicted groundwater drawdown boundary.

All specimens recorded in the Round 3 survey were identified to species level. The Round 3 identifications also enabled the identification of some juvenile specimens from the first two survey rounds. The additional collections and identifications have provided greater understanding of species distributions within the study area,

An assessment of Aquaterra's hydrogeological modelling suggests that the MMIF, Wittenoom and Jerrinah Formations are chemically distinct from one another. The difference in transmissivity recorded by Aquaterra further suggests that the hydraulic connectivity of the aquifers within the different formations may be limited (Aquaterra 2009).

The stygofauna results for three sampling events over a 16-month period indicate there is some lateral movement of stygofauna, however the extent to which stygofauna species may be moving between aquifers is unkown. Movement of juveniles between different bores in the study area may occur as many of the species (oligocheates, copepods, parabathenelids) have juvenile forms which are very small. Species with small larval stages are capable of dispersal through smaller space cavities than those with relatively large larval stages such as amphipods (Brusca and Brusca 2003).

The results of the surveys are not sufficient to conduct an impact assessment because:

- A revision to the modeled impact area has resulted in all sampled bores and species records being located within the impact area; and
- Many of the specimens collected were juveniles and not able to be identified to species level.

At present the amphipod, *Kruptus* sp. 'DC' is known only from the greater impact area. Due to its relatively large size, *Kruptus* sp. 'DC' may be restricted in its movement in adult form between aquifers in the study area and may not be located outside of the greater impact area unless moving in larval form. Nearby alluvial channels (including Davidson creekline) may provide conduits for movement of this species if it is present in habitat adjacent to the channels.

Fierscyclops (Pilbarocyclops) sp. 'DC' and Parabathynellidae sp. 'DC' were not recorded in Round 3 and records remain limited to greater impact area of the study area. The hydrogeological modelling (Aquaterra 2009, 2010) suggests an east to west connectivity in the MMIF in which some these species may be able to disperse. They may also be present upstream and downstream of the drainage contours of the study area.

Further sampling is required upstream and downstream of the aquifers of the Python/Gwardar study area to ascertain the broader distribution of the three new species.

Many Pilbara stygofauna species are not yet formally described and so it is also possible that the three new species collected in this survey have been collected from other regional locations, but remain undocumented. DNA sequencing of the specimens collected to date would enable comparison with records from other regional studies and could be a component of future studies for the Project.

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APPENDIX 1: GPS COORDINATES, BORE DIAMETER AND SAMPLING EFFORT

Rounds 1 & 2	Projection: UTM Zone 51 (WGS84)						
Bore Type	Bore number	Zone	Easting	Northing	Bore Diameter (mm)	No. of 150µM Hauls	50µM Hauls
Impact	DCRC0031	51K	245259	7408069	50	3	3
Impact	DCRC0036	51K			50	3	3
Impact	DCRC0037	51K	245659	7408120	50	3	3
Greater Impact	DCRC0039	51K	245259	7408220	50	3	3
Greater Impact	DCRC0040	51K	245459	7408219	50	3	3
Impact	DCRC0064	51K	244199	7407650	50	3	3
Impact	DCRC0066	51K	244200	7407900	50	3	3
Impact	DCRC0073	51K	243800	7407750	50	3	3
Impact	DCRC0074	51K	243799	7407799	50	3	3
Impact	DCRC0093	51K			150	5	5
Impact	DCRC0095	51K			150	5	5
Impact	DCRC0100	51K	242599	7407599	50	3	3
Impact	DCRC0105	51K	242600	7407849	50	3	3
Impact	DCRC0110	51K	242200	7407549	50	3	3
Impact	DCRC0111	51K	242200	7407599	50	3	3
Impact	DCRC0116	51K	242199	7407849	50	3	3
Impact	DCRC0120	51K	241800	7407650	50	3	3
Impact	DCRC0126	51K	241800	7407949	50	3	3
Impact	DCRC0127	51K			50	3	3
Greater Impact	DCRC0138	51K	244800	7407749	50	3	3
Impact	DCRC0142	51K	244800	7407999	50	3	3
Impact	DCRC0147	51K	242399	7407600	50	3	3
Impact	DCRC0153	51K	242399	7407949	50	3	3
Impact	DCRC0155	51K	242000	7407600	50	3	3
Impact	DCRC0200	51K	244599	7407800	50	3	3
Impact	DCRC0202	51K	244599	7407899	50	3	3
Impact	DCRC0243	51K	244000	7407800	50	3	3
Impact	DCRC0245	51K	243999	7407949	50	3	3
Impact	DCRC0246	51K	243999	7407949	50	3	3
Impact	DCRC0251	51K	243600	7407749	50	3	3
Impact	DCRC0256	51K	243599	7407800	150	5	5
Impact	DCRC0260	51K	243199	7407749	50	3	3
Impact	DCRC0264	51K	243199	7407949	50	3	3
Impact	DCRC0267	51K	242799	7407699	50	3	3
Impact	DCRC0270	51K	242800	7407850	50	3	3
Impact	DCRC0344	51K			50	3	3
Impact	DCRC0345	51K	246996	7408048	150	5	5
Impact	DCRC0371	51K	245056	7408322	150	5	5
Impact	DCRC0372	51K	244602	7408402	150	5	5
Impact	DCRC0425	51K	243399	7408501	150	5	5
Non Impact	DCRC0451	51K	248599	7408001	150	5	5
Non Impact	DCRC0501	51K			150	5	5
TOTAL			**42**	**42**		**147**	**147**

Round 3	Projection: UTM Zone 51 (WGS84)					No. of	
Bore Type	Bore ID	Zone	Easting	Northing	Bore Diameter (mm)	150µM Hauls	50µM Hauls
Greater Impact	DCRC0040	51K	245460.25	7408215.29	150	3	3
Greater Impact	DCRC0043	51K	245821.27	7408298.71	150	3	3
Greater Impact	DCRC0052	51K	245975.85	7408322.82	150	3	3
Direct Removal	DCRC0073	51K	243800.16	7407750.43	150	3	3
Direct Removal	DCRC0074	51K	243801.23	7407790.37	150	3	3
Direct Removal	DCRC0088*	51K	243401	7408002	150	-	-
Direct Removal	DCRC0110*	51K	242200	7407550	150	-	-
Direct Removal	DCRC0111	51K	242200.69	7407599.1	150	3	3
Direct Removal	DCRC0116	51K	242200.13	7407850.65	150	3	3
Direct Removal	DCRC0120	51K	241800.7	7407649.26	150	3	3
Direct Removal	DCRC0126	51K	241805.12	7407951.25	150	3	3
Direct Removal	DCRC0133	51K	244402.19	7408000.07	150	3	3
Greater Impact	DCRC0145	51K	244804.3	7408149.61	150	3	3
Direct Removal	DCRC0147	51K	242397.75	7407601.07	150	3	3
Direct Removal	DCRC0155	51K	242003.4	7407604.24	150	3	3
Direct Removal	DCRC0159*	51K	242001	7407850	150	-	-
Direct Removal	DCRC0168	51K	241599.03	7407950.52	150	3	3
Greater Impact	DCRC0188	51K	245754.19	7408147.97	150	3	3
Direct Removal	DCRC0200	51K	244598.08	7407801.23	150	3	3
Direct Removal	DCRC0246	51K	244000.07	7407947.21	150	3	3
Direct Removal	DCRC0256	51K	243600.99	7408003.9	150	3	3
Direct Removal	DCRC0260	51K	243200.48	7407751.25	150	3	3
Direct Removal	DCRC0271	51K	242799.61	7407899.83	150	3	3
Greater Impact	DCRC0335	51K	246610.16	7408151.84	150	3	3
Greater Impact	DCRC0352	51K	247201.59	7408047.53	150	3	3
Direct Removal	DCRC0425	51K	243399.53	7408501.56	150	3	3
Greater Impact	DCRC0499	51K	245052.34	7407673.17	150	3	3
Greater Impact	DCRC0536	51K	239001.8	7408299.79	150	3	3
Non Impact	DCRC0544	51K	240200.66	7411097.93	150	3	3
Lesser Impact	DCRC0546	51K	250700.54	7406493.45	150	3	3
Lesser Impact	DCRC0558	51K	249538.72	7409694.82	150	3	3
Lesser Impact	DCRC0563	51K	248754.7	7410299.92	150	3	3
Lesser Impact	DCRC0564	51K	248999.91	7410594.29	150	3	3
Lesser Impact	DCRC0566	51K	246896.08	7410797.22	150	3	3
Lesser Impact	DCRC0568	51K	246883.69	7411604.25	150	3	3
Lesser Impact	MMRC0003A	51K	240145.7	7410216.55	150	3	3
Lesser Impact	MMRC0004	51K	239644.3	7410228.34	150	3	3
Lesser Impact	MMRC0006	51K	240114.93	7409699.68	150	3	3
Lesser Impact	MMRC0009	51K	240459.57	7409264.99	150	3	3
Lesser Impact	MMRC0009A	51K	240450.9	7409262.03	150	3	3
Lesser Impact	MMRC0010	51K	240098.86	7409238.44	150	0	2
TOTAL			**38**	**38**		**111**	**113**

*Bores that were sampled in the Troglofauna survey that recorded stygobitic species, though not included in the totaled sampled count.