# West Angelas Subterranean Fauna Assessment

## Report Excerpt

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# Abbreviations

| Abbreviation | Description |
|---|---|
| BoM | Bureau of Meteorology |
| DEC | Department of Environment and Conservation |
| DPaW | Department of Parks and Wildlife |
| ELA | Eco Logical Australia |
| EPA | Environmental Protection Authority |
| EP Act | Environmental Protection Act 1986 |
| EPBC Act | Environment Protection and Biodiversity Conservation Act 1999 |
| SRE | Short Range Endemic |
| WAM | Western Australian Museum |
| WC Act | Wildlife Conservation Act 1950 |

# Executive summary

Rio Tinto Iron Ore is proposing to develop additional ore source to sustain current production from the existing West Angelas iron ore operations (West Angelas Project) in the Pilbara region of Western Australia. The Proposal includes the development of Deposit A west and Deposit F, using existing infrastructure at the West Angelas Project.

Ecologia Environment (*ecologia*) completed a single-phase subterranean fauna (troglofauna and stygofauna) pilot survey of the Greater West Angelas area (17,565 ha; the Survey Area) in 2012. The *ecologia* (2013) *Greater West Angelas Subterranean Fauna Assessment* survey and report was completed in broad accordance with the Environmental Protection Authority (EPA) Guidance Statements 54 and 54a (EPA 2003 and EPA 2007). This report has been prepared as an excerpt from the *Greater West Angelas Subterranean Fauna Assessment* (*ecologia* 2013). The survey area and findings discussed in this excerpt report are restricted to the Deposit A west and Deposit F Study Area (approximately 5,640 ha; the Study Area).

Of the 55 potential sites within the Study Area, approximately 38 were suitable for troglofauna sampling and four were suitable for stygofauna sampling. The remainder of the sites were unable to be sampled, due to the inability to locate the bore, a blockage close to the surface or difficulties associated with the plug.

Troglofauna were sampled using custom designed leaf litter traps positioned approximately two meters above the water or a blockage. To maximise troglofauna colonisation, they were left in situ for 91 days. Stygofauna were sampled using modified haul nets. Groundwater physico-chemistry of a single bore was analysed to provide data on the aquifer conditions and their suitability for stygofauna. All specimens were sorted in the *ecologia* Perth laboratory and were classified to the lowest taxonomic resolution possible, prior to being sent to taxonomic experts for further identification.

24 invertebrate specimens (two taxa from the orders Embioptera and Diplopoda) were collected during the survey of Deposit A west and Deposit F. Of these specimens, while none were classified as stygofauna, one was identified as troglobitic, *Embioptera* 'sp. indet.' This species was located at Bore ID DExt13 in Deposit A west outside the proposed disturbance area, in sedimentary rock 270 m north of the proposed Deposit A west Pit location. This specimen was unable to be classified to family level as it was a juvenile; only adult males can be taxonomically identified to this level. This specimen was considered to represent a potential short range endemic (SRE) species, as the troglobitic Embioptera are known to have a narrow distribution and appear to be geographically restricted.

While the *ecologia* (2013) pilot survey and report was completed in broad accordance with the EPA Guidance Statements 54 (EPA 2003) and 54A (EPA 2007), there were survey limitations associated with the survey adequacy of the stygofauna sampling, the water quality sampling method efficiency, the timing (seasonality) of the survey and the resolution of species identification. Capture rates of subterranean fauna may have been affected by survey effort, seasonality, and presence of drilling and bulldozing activities (in Deposit A west only) during the troglofauna survey.

# 1 Introduction

## 1.1 Project Overview

Rio Tinto Iron Ore is proposing develop additional ore source to sustain current production from the existing West Angelas iron ore mining operation (West Angelas Project), which is located approximately 130 km northwest of Newman in the Pilbara region of Western Australia. The Proposal includes the development of Deposit A west and Deposit F for iron ore mining above and below the water table, using existing infrastructure at the West Angelas Project.

A single phase subterranean fauna (troglofauna and stygofauna) pilot survey of the Greater West Angelas Study Area (17,565 ha; the Survey Area) was undertaken in 2012 (*ecologia* 2013). This report provides an excerpt of the *ecologia* (2013) report, *Greater West Angelas Subterranean Fauna Assessment*, to address findings in the Deposit A west (referred to as D extension in *ecologia* (2013)) and Deposit F, the subject of the West Angelas Revised Proposal. The regional location of the 5,640 ha Deposit A west and Deposit F Study Area is presented in Figure 1.

## 1.2 Legislative Framework

Federal and State legislation applicable to the conservation of native fauna include, but are not limited to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), the *Wildlife Conservation Act 1950* (WC Act) and the *Environmental* Protection Act 1986 (EP Act).

The *Greater West Angelas Subterranean Fauna Assessment* report (*ecologia* 2013) was prepared to satisfy the requirements of:

- The EPA Guidance Statement No. 54: *Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia* (EPA 2003); and
- The EPA Guidance Statement No. 54a (Technical Appendix to Guidance Statement no. 54): *Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia* (EPA 2007).

## 1.3 Survey Objectives

The primary objective of the *ecologia* (2013) survey was to provide sufficient information to assess the impact of the Proposal on subterranean fauna in the context of the following EPA objectives:

- Maintain the abundance, species diversity and geographical distribution of subterranean invertebrate fauna; and
- Avoid impacts to Specially Protected (Threatened) fauna, consistent with the provisions of the WC Act.

## 1.4 Subterranean Fauna Overview

Subterranean fauna are highly specialised to their environment and share the following characteristics (*ecologia* 2013 from Gilbert and Deharveng 2002):

1. High endemism but low local diversity relative to regional diversity;
2. A relatively small number of genetic lineages resulting in species dissimilar in appearance to related groups;
3. Many relicts from previous climatic conditions; and

4. Truncated food webs.

Western Australia's subterranean fauna is considered globally significant due to its high level of species richness and endemism (EPA 2012). It has been estimated that 4140 subterranean fauna taxa occur in the western half of Australia, predominantly in arid and semi-arid regions. With 403 species described (and an additional 367 species awaiting further taxonomic description), it is predicted that less than 20 % of the stygofauna taxa present are yet to be sampled (Guzik et al. 2010). With a high level of endemism and restricted distributions, many subterranean fauna are classified as short range endemics (SREs).

## 1.5 Troglofauna Overview

Troglofauna are air-breathing subterranean fauna occurring in underground cavities, fissures and interstitial spaces. Troglofauna are categorised as either troglobites (obligate subterranean species), troglophiles (facultative subterranean species) or trogloxenes (regularly use the subterranean environment for refuge but usually return to the surface to feed). Accidentals are species that stray into the subterranean environment from the surface, either through open boreholes or other access points, but cannot survive there.

Troglobitic species possess morphological/behavioural characteristics that restrict the species to subterranean habitats; these can include reduced or loss of pigmentation, wings or eyes, a slender body, elongated appendages, a lower metabolism and/or lack of circadian rhythm.

The geological characteristics of their subterranean environment can restrict these species from dispersing; thus levels of endemism are high and the range of distribution is low. Most troglofauna species are considered SREs (*ecologia* 2013).

## 1.6 Stygofauna Overview

Stygofauna are obligate groundwater dwelling subterranean fauna. Like troglobites, stygofauna possess adaptations to their environment, such as a reduction or total loss of pigmentation or eyes, elongated appendages, and a filiform body shape.

The distribution of stygofauna is associated with the hydrogeological aquifer type; with compact aquifers (aquitards) having a lower taxonomic richness or a total absence of stygofauna. This is due to the reduced pore spaces within the aquifer material (associated with clay, loess, fine sands and compact rocks), and thus a low hydraulic conductivity and surface water exchange. Stygofauna communities are more likely to be located in open aquifers, with continuous surface water exchange providing food and oxygen and a greater abundance of living space. These aquifers have at least moderate hydraulic conductivity, and comprise of porous, fractured and karstic geologies (*ecologia* 2013).

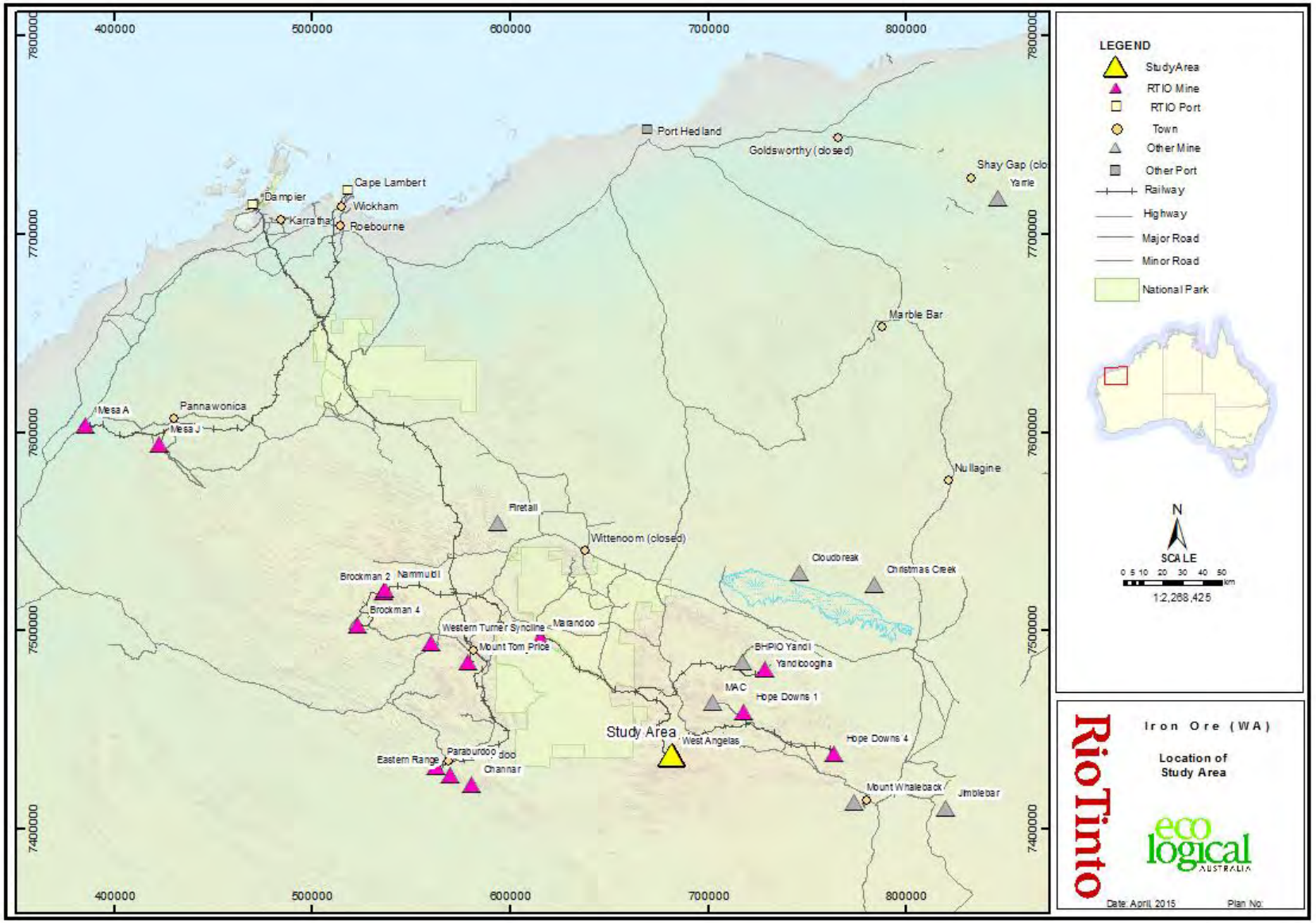


**Figure 1: Regional location of the Deposit A west and Deposit F Study Area.**

# 2 Biophysical Climate

## 2.1 Climate and Weather

The regional climate of the Study Area is semi-arid to semi-tropical with a summer rainfall (wet) season and relatively dry winter season, which varies in frequency and volume from year to year. The summer wet months extend from November to April, with temperatures during this season frequently exceeding 40 °C. The remainder of the year is moderate to warm with a continental effect resulting in low minimum temperatures (less than 10 °C) in June and July. Average annual evaporation can exceed rainfall by as much as 500 mm per year.

The meteorological station closest to the Study Area, Turee Creek Station (Site No. 007083), is located 45.5 km to the south; only rainfall data is available from this site. The closest meteorological station providing climate data for both rainfall and temperature is Paraburdoo Aero (Site No. 007185), located approximately 85 km west of the Study Area. Average monthly rainfall data from the Bureau of Meteorology (BoM) for Turee Creek Station is presented in Figure 2 (BoM 2013, from *ecologia* 2013), with average temperature data used from Paraburdoo Aero.

Annual rainfall is variable, with tropical lows in the wet season producing large regional rainfall events. In the winter dry season, extensive cold fronts occasionally reach the Pilbara from the east, generally only causing light rains. For Paraburdoo Aero, the mean annual rainfall for the period 1974 to 2012 was 312.3 mm, with most precipitation occurring between December and April (coinciding with the cyclone season).

Rainfall in the wet season (November 2011 to March 2012) prior to the survey was higher the the long-term average (163.5 mm), with 298.7 mm recorded during this time at Turee Creek Station (BoM 2013). The succeeding winter season was drier than average, with only 11.4 mm of rainfall recorded in the six months (April – September 2012) prior to troglofauna trap collection on 5th October (long-term average 80.9 mm).

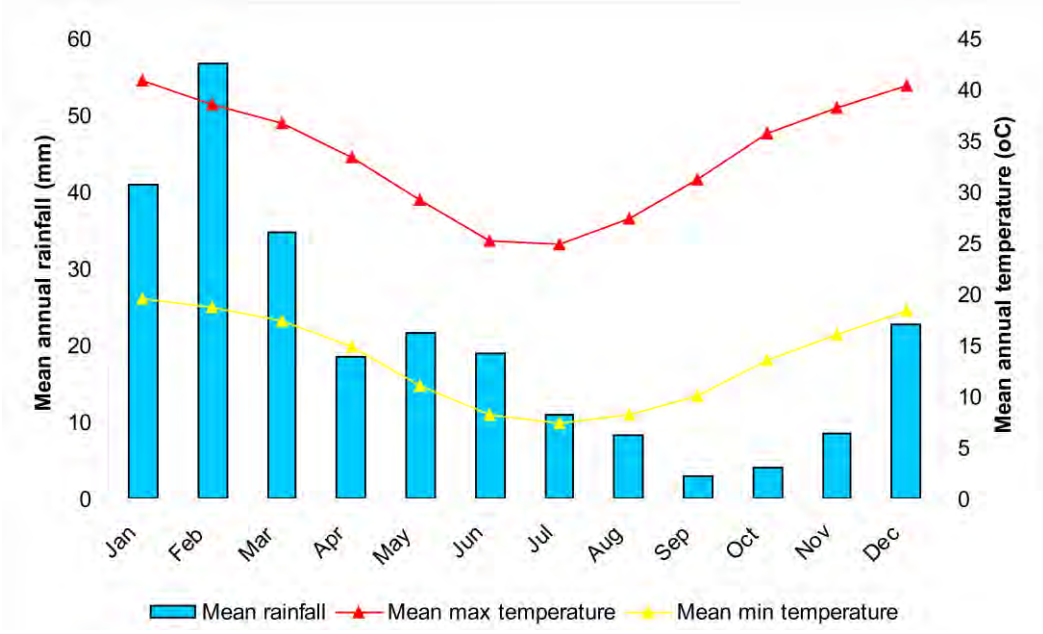


**Figure 2: Mean monthly rainfall (Turee Creek Station) and temperatures (Paraburdoo Aero) near the Study Area. Source: BoM (2013), from *ecologia* (2013).**

## 2.2 Geology

The Deposit A west and Deposit F Study Area was comprised of sedimentary rocks from the Archaean – palaeoproterozoic period (Hickman and Kranendonk 2008).

## 2.3 Land Systems

Land system (rangeland) mapping is based on regional patterns in topography, soils and vegetation (Christian and Stewart 1953). The Study Area crosses the northern boundary of the area surveyed by Payne et al. (1982) in the Regional Inventory of the Ashburton Rangelands and into the area surveyed by Van Vreeswyk et al. (2004) in the Regional Inventory of the Pilbara Rangelands.

The Study Area (Figure 3) is located within six of the 102 land systems described for the Pilbara Bioregion by van Vreeswyk et al. (2004) and Payne et al. (1998):

- Boolgeeda Land System consists of stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands (van Vreeswyk et al. 2004).
- Newman Land System consists of rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands (van Vreeswyk et al. 2004).
- Rocklea Land System consists of basalt hills, plateaux, lowers slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands (van Vreeswyk et al. 2004).
- Elimunna Land System consists of stony plains on basalts supporting sparse Acacia and cassia shrublands and patchy tussock grasslands (van Vreeswyk et al. 2004).
- Platform Land System consists of dissected slopes and raised plains supporting hard spinifex grasslands (van Vreeswyk et al. 2004).
- Egerton Land System consists of dissected hardpan plains supporting mulga shrublands and hard spinifex hummock grasslands (van Vreeswyk et al. 2004).

The land systems and their extent within the Study Area are presented below (Table 1).

**Table 1: Summary of Land Systems present in the Study Area and their regional representation.**

| Land System | Total Area (ha) in Pilbara Bioregion | Area within Study Area (ha) | % of Study Area | Study Area % of land system extent |
|---|---|---|---|---|
| Boolgeeda | 774,800 | 3687.56 | 65.38 | 0.48 |
| Newman | 1,458,000 | 1257.31 | 22.29 | 0.09 |
| Rocklea | 2,299,300 | 459.95 | 8.15 | 0.02 |
| Elimunna | 67,000 | 140.70 | 2.49 | 0.21 |
| Platform | 157,000 | 90.86 | 1.61 | 0.06 |
| Egerton | 46,600 | 4.09 | 0.07 | 0.01 |

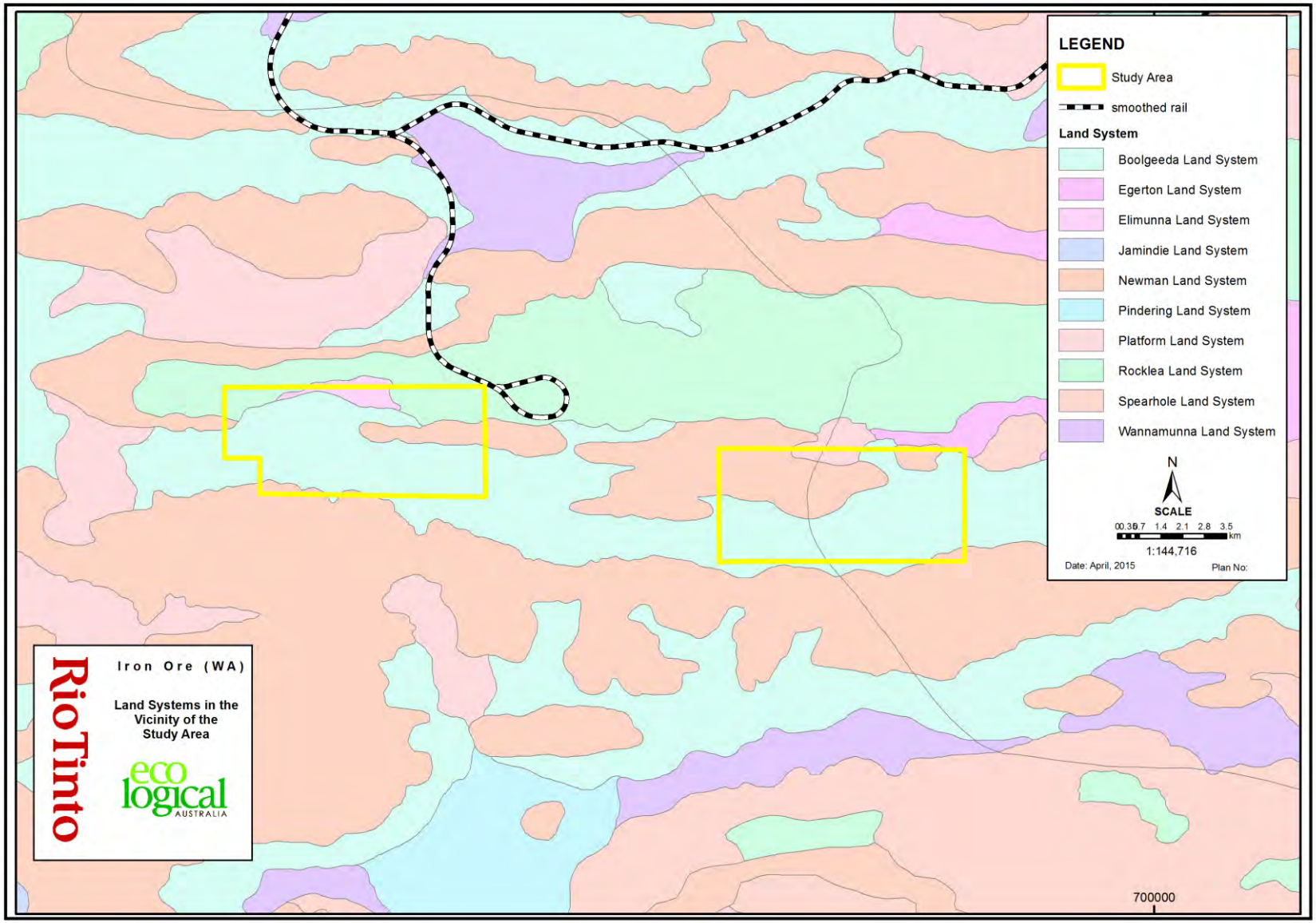


**Figure 3: Land Systems of the Study Area**

## 2.4 Soils

Within the Study Area, two soil units occur (*ecologia* 2013), as classified by Bettenay et al. (1967). The majority of the Study Area contains unit Fa14, which is described as steep hills and steeply dissected pediments on areas of banded jaspilite and chert, along with shales, dolomite, and iron ore formations, with some narrow winding valley plains. The remainder of the Study Area falls within unit Fa13, described as ranges of banded jaspilite and chert, along with shales, dolomites, and iron ore formations. This soil unit has some areas of ferruginous duricrust as well as occasional narrow winding valley plains and steeply dissected pediments. The soils are frequently stony and shallow and there are extensive areas without soil cover.

## 2.5 Hydrology

The Study Area lies in both the Ashburton and the Upper Fortescue River catchment basins (Department of Water 2015). North of the Study Area is the closest river, Turee Creek, which is a sub-tributary of the Ashburton River. Several small, minor ephemeral drainage lines, likely to flow after significant rainfall, are located within the Study Area. The regional hydrology of the Study Area is presented in Figure 4. The Study Area lies approximately 60 km north-west of the Newman Water Reserve and 140 km south-east of the Marandoo Water Reserve.

## 2.6 Hydrogeology

The groundwater in the Central Pilbara is located in the Archaean/Proterozoic basement rocks and the Cainozoic deposits. It is recharged directly from rainfall into basement rock outcrops and indirectly through runoff. Vuggy pisolite (Robe Pisolite) is the main aquifer of the area, and it overlies fractured basement rocks of the Woongarra volcanics and Boolgeeda Iron Formations. The aquifer zone is 50-80 m thick, with an estimated permeability of 40-80 m per day (Johnson and Wright 2001).

## 2.7 Previous Surveys

The following databases and publications were consulted by *ecologia* (2013) in the preparation of potential subterranean fauna lists:

- NatureMap Database;
- WA Museum Crustaceans database;
- WA Museum Molluscs database;
- WA Museum Arachnids/Myriapods;
- *ecologia* internal database;
- *ecologia* (1998);
- Biota (2003); and,
- Biota (2008).

At least 24 subterranean taxa have been identified as occurring within 100 km radius of the original *ecologia* (2013) Survey Area. A list of these taxa is included in Appendix A. A brief summary of the *ecologia* (1998), Biota (2003) and Biota (2008) surveys can be found in Rio Tinto (2015).

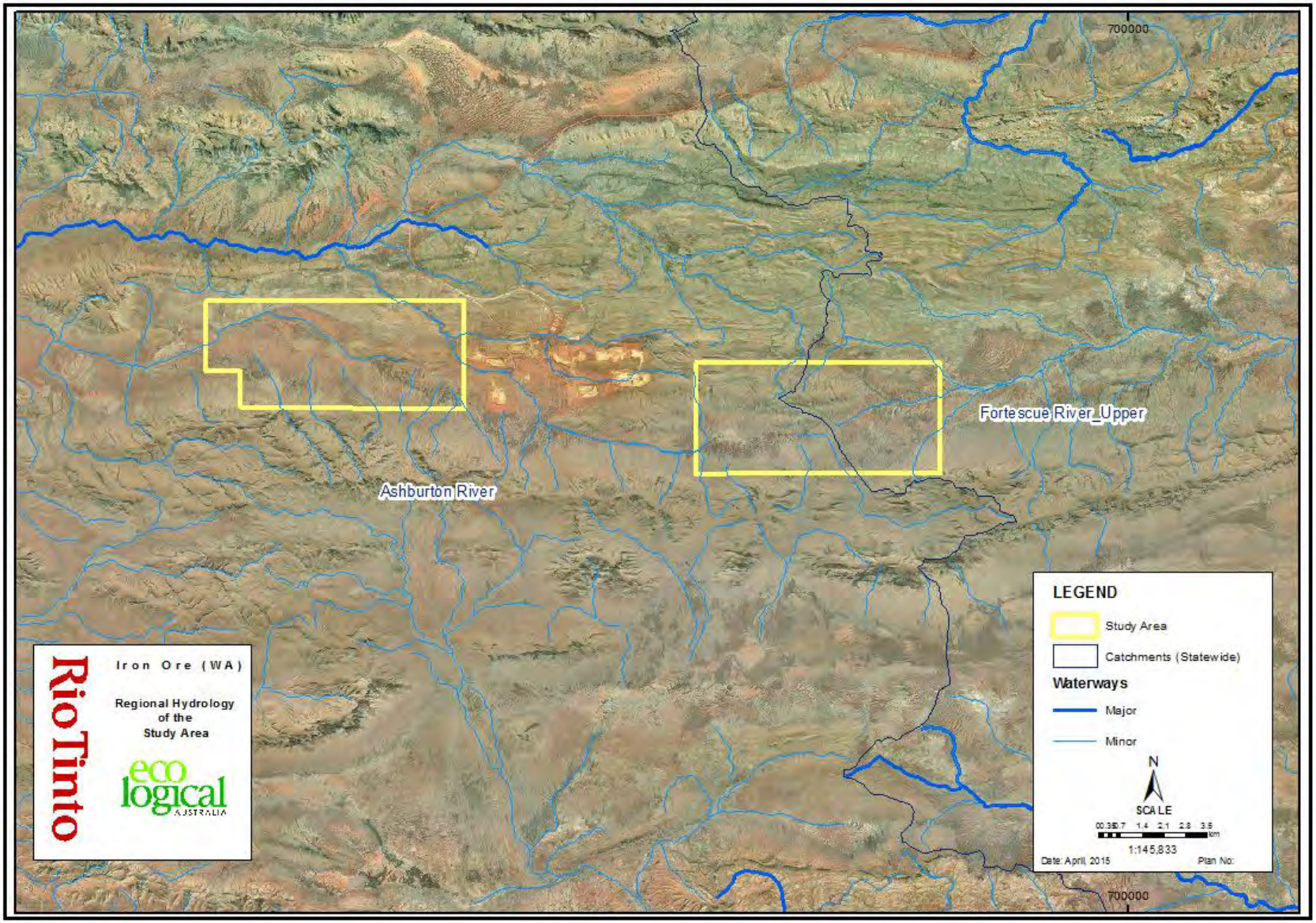


**Figure 4: Regional hydrology of the Study Area**

# 3 Methods

Guidance from the then Department of Environment and Conservation (DEC – now Department of Parks and Wildlife; DPaW) was obtained by *ecologia* prior to the commencement of the survey. While the *ecologia* (2013) pilot survey and report was completed in broad accordance with the EPA Guidance Statements 54 (EPA 2003) and 54A (EPA 2007), there were survey limitations associated with the survey adequacy of the stygofauna sampling, the water quality sampling method efficiency, the timing (seasonality) of the survey and the resolution of species identification. These limitations are described in Section 3.3.

## 3.1 Sampling Methods

Subterranean fauna sampling was undertaken from 9 July to 5 October 2012 as per *ecologia* (2013). The methodology is summarised below.

### 3.1.1 Troglofauna Trapping

55 sampling sites (see Appendix B for further details) were selected within the Study Area prior to the commencement of the field survey to provide good coverage throughout the two deposits (Figure 5). Of these, approximately 38 were sampled; not all drill holes were successfully located or, once discovered, were able to be sampled. Drill holes were only used for sampling if they were sealed and unobstructed.

Leaf litter was prepared eight weeks prior to trap deployment. It was soaked in water, sterilised by microwaving, and stored in an air-tight container until trap deployment. Custom designed traps were filled with the pre-prepared leaf litter and baited with banana, and were lowered to approximately two metres above the water table or blockage (if at a reasonable sampling depth). Traps were positioned against the drill hole wall and were left in situ for a period of 91 days, with the drill hole being re-sealed to reduce contamination from terrestrial fauna and to maintain an appropriate microclimate. Each trapping site was demarcated with flagging tape and clearly signed. Site management was informed of the trap locations to reduce the risk of disturbance. *ecologia* (2013) states two traps were lost during retrieval and the third was accidentally bulldozed in the Greater West Angelas Survey Area; it is unknown if any these traps were located within the Deposit A west or Deposit F Study Area.

Upon trap collection, the leaf litter was placed in sealed plastic bags. Samples were analysed at the *ecologia* laboratory in Perth. Specimens were extracted using Tullgren funnels and placed in 100% ethanol. The leaf litter was then examined using a fluorescent light magnifier for additional dead animals. All specimens were sorted and were classified to the lowest taxonomic resolution possible, prior to being sent to taxonomic experts for further identification.

### 3.1.2 Stygofauna Sampling

Of the approximately38 sampling sites suitable for troglofauna sampling, 12 of these sites had access to water. The water level was determined in each drill hole by a standing water level dip tape to determine its appropriateness for stygofauna sampling; four drill holes were considered suitable. A portable water quality meter was used to sample parameters in situ such as conductivity, turbidity, temperature, Dissolved Oxygen and Redox potential. Sampling was undertaken using haul nets, slowly lowered into the bores with rope. At least six hauls were completed, with at least three performed with a 150 µm mesh net, and three or more undertaken using a 50 µm mesh net. All specimens were washed in a 50 µm sieve and were then preserved in 100 % ethanol. Samples were stored in the dark in a cool

environment. They were analysed back in the Perth *ecologia* laboratory, where they were sorted then sent to the relevant taxonomic experts for further identification.

### 3.2 Short Range Endemic Status

SRE status of subterranean fauna specimens was determined by expert taxonomists based on the current knowledge of the distribution and biology for each taxon. There were five classification categories (*ecologia* 2013):

- No: not considered a SRE.
- Confirmed: current knowledge confirms that this species is a SRE.
- Likely: current knowledge suggests this species is probably a SRE. However, further research is required to confirm status.
- Potential: while current knowledge of this species or group is very limited, there is the potential for this species to represent a SRE. Further research is required to confirm status.
- Unknown; no comment can be made regarding SRE status, usually due to uncertainty over species level due to life stage/sex, and/or lack of taxonomic knowledge.

### 3.3 Survey Limitations

Limitations of the survey are described in Table 2.

**Table 2: Limitations of the *ecologia* (2013) subterranean fauna pilot survey**

| Aspect | Limitation | Comment |
|---|---|---|
| Survey Adequacy | Yes | EPA (2007) recommends that 10-15 troglofaunal and 6-10 stygofaunal samples will be collected for a pilot study.<br><br>Troglofauna sampling sites (n=55) within the Study Area were selected to provide good coverage throughout each deposit. At least 17 bores were unable to be successfully located, or, once discovered, were unable to be sampled. Drilling and bulldozing occurred in Deposit A west during the troglofauna survey. This caused vibration and air pressure changes in subterranean voids and possibly affected capture of troglofauna.<br><br>Stygofauna sampling was limited to four sampling sites in Deposit F as all other boreholes were rehabilitated, did not reach groundwater or were blocked. Survey adequacy is considered a limitation of the stygofauna survey. |
| Method Efficiency | Possible | Survey methods complied with the EPA Guidance Statement 54a (EPA 2007). However, water quality readings were not possible due to the inability to collect water in bailers. |
| Seasonality/Timing | Yes | The EPA (2007) recommend two phases of subterranean fauna sampling be undertaken; if this is impractical, the single phase survey must be completed during the wet season. Troglobitic populations are likely to increase in size during and immediately after wet season, following an influx of nutrients into the underground systems (EPA |

| | | |
|---|---|---|
| | | 2007). Sampling in the *ecologia* (2013) survey was conducted from 9 July 2012 to 5 October 2012, at the end of the dry season, which was drier than average. The previous wet season (November 2011 – March 2012) however recorded higher than average rainfall. |
| Adverse Weather Conditions | No | Weather conditions did not influence the survey |
| Experience of Personnel | No | Field personnel had adequate experience in subterranean surveys. Experts were consulted to identify the specimens, and included Dr Mark Harvey, Mieke Burger, Amber Beavis and Julianne Waldock (arachnids and myriapods; WA Museum 2012), Dr Volker Framenau and Dr Erich Volschenk (troglofauna; Phoenix Environmental 2013) and Dr Simon Judd (Judd 2013; isopods). |
| Species Identification Resolution | Yes | None of the troglobitic specimens collected were identified to species level. The taxonomic resolution of species thus remains one of the largest limitations of the survey. |

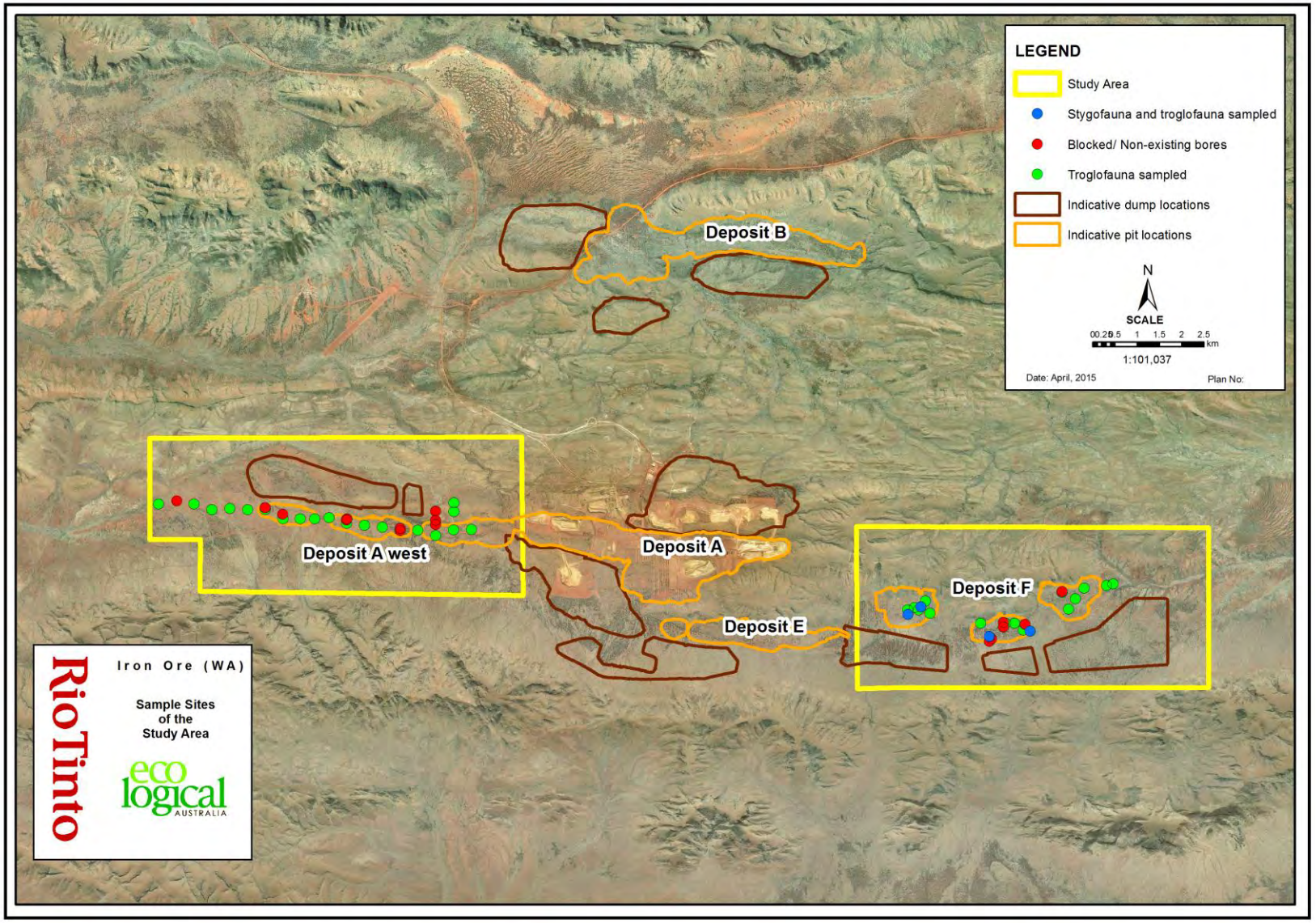


**Figure 5: Sampling sites within the Study Area**

# 4 Results

## 4.1 Field Survey Results

Of the 55 potential sampling bores identified during the desktop assessment, approximately 38 bores were sampled successfully for troglofauna. The remainder of the potential sites could not be sampled, due to the inability to locate the bore, a blockage close to the surface or difficulties with the plug.

24 invertebrate specimens from two taxa (orders Embioptera and Diplopoda) were collected during the survey in Deposit A west and Deposit F (Appendix C). Of these specimens, only one was identified as troglobitic, Embioptera 'sp. indet.'. This species was located outside the proposed disturbance area in Bore ID DExt13 in Deposit A west, approximately 270 m north of the proposed Deposit A west pit location (Figure 6 and Figure 7). This specimen was unable to be classified to family level as it was a juvenile; only adult males can be taxonomically identified. There is limited knowledge of the troglobitic Embioptera; however, as they are known to have a narrow distribution (females are flightless) and morphologically distinct groups appear to be geographically restricted, this species was considered to represent a potential SRE (*ecologia* 2013).

Stygofauna sampling was limited to four sampling sites in Deposit F (WAF1152, WAF2081, WAFRC1089 and WAFRC1992) as all other boreholes were rehabilitated, did not reach groundwater or were blocked. No stygofauna were collected from these bores.

## 4.2 Groundwater Physico-chemistry

Only one water quality reading was obtained during the survey, from bore WAFCR1152 in Deposit F. The water temperature in this bore at the time of sampling was 27.8 $^{o}$C, and the water was fresh (salinity/conductivity = 0.003 mS/cm) and mildly acidic (pH = 6.43), with aerobic conditions (dissolved oxygen = 5.59mg/L at 65 % saturation and positive redox potential = 201 mV).

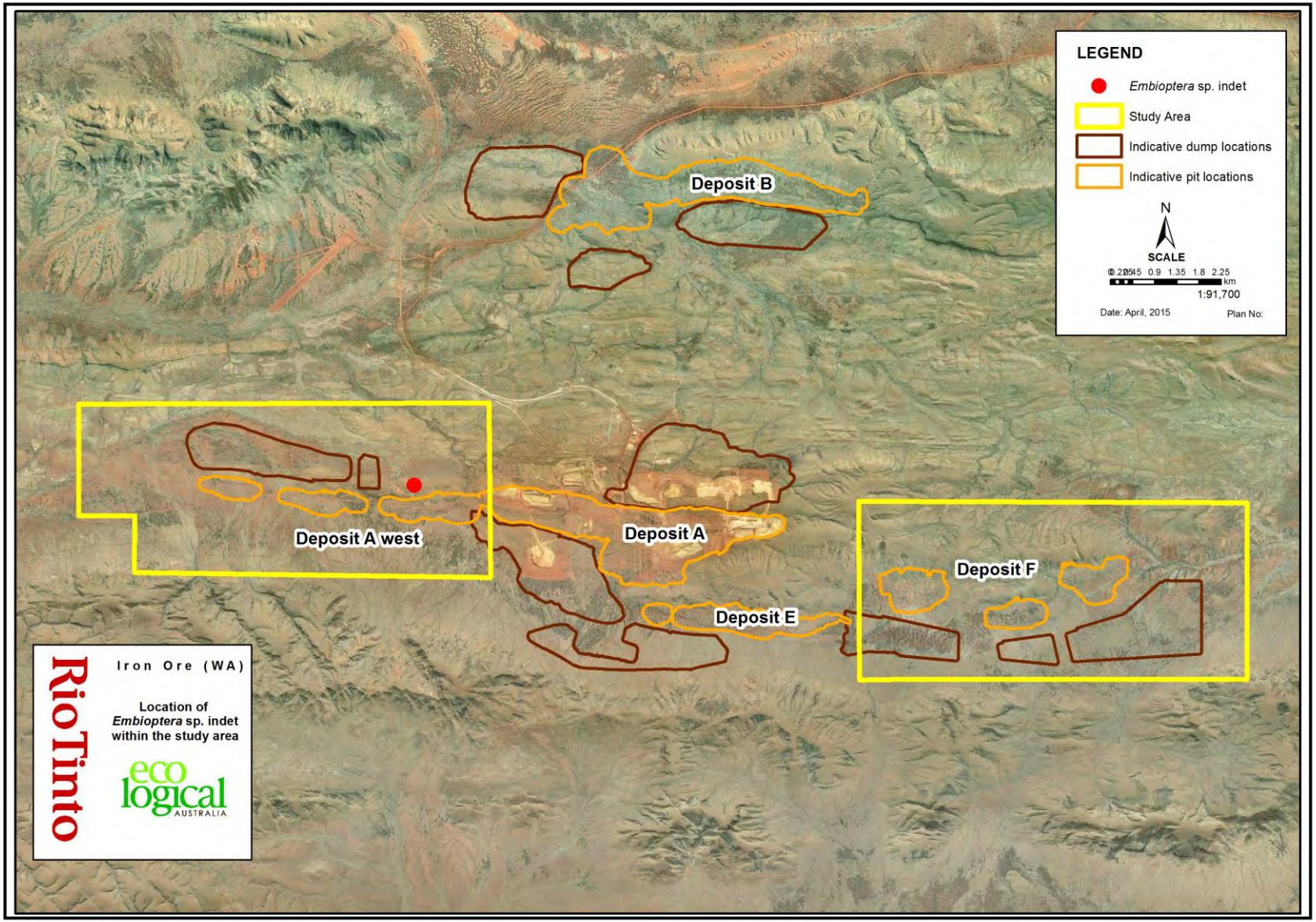


**Figure 6: Location of the troglobite *Embioptera* 'sp. indet.'. collected from the Study Area**

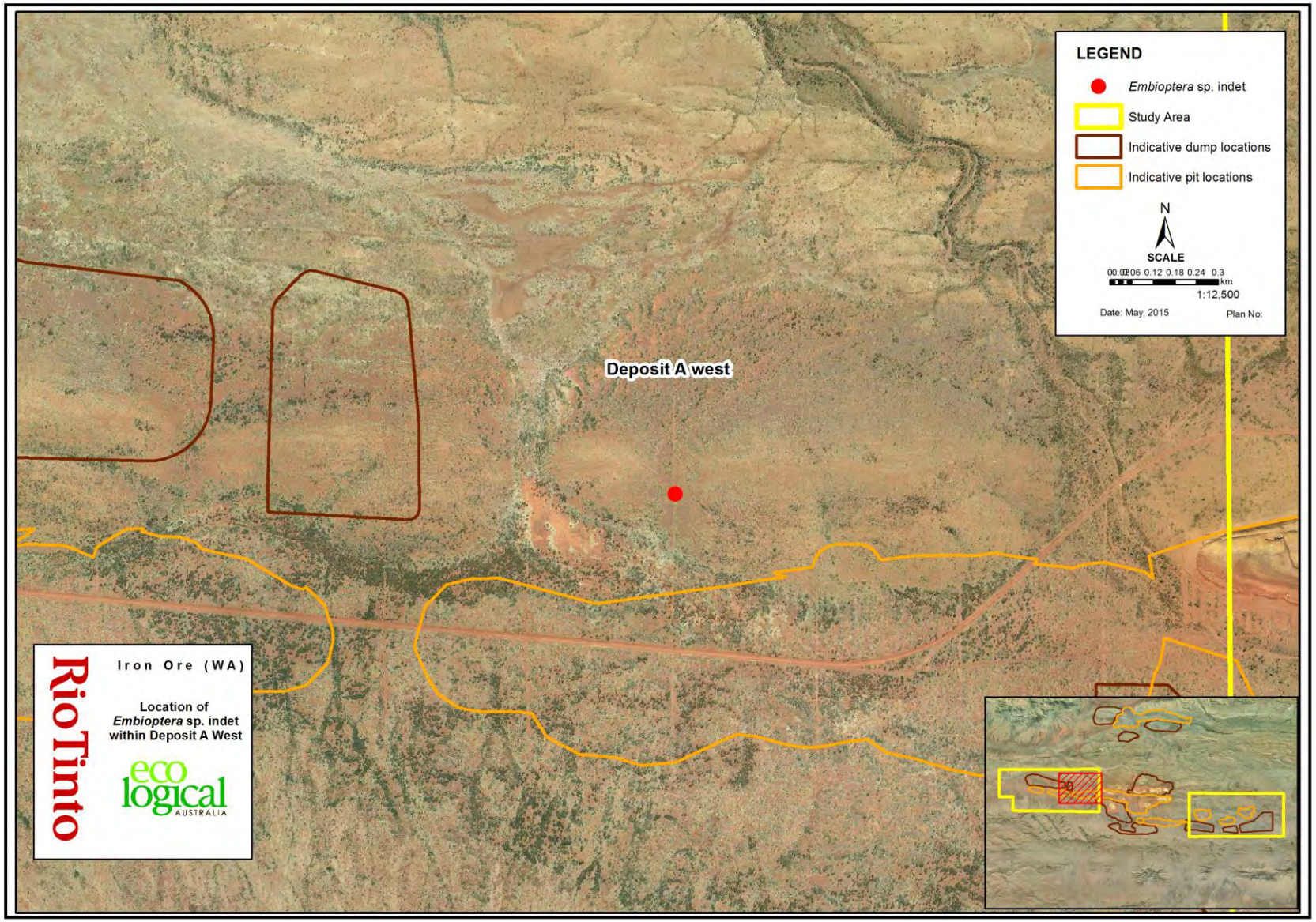


**Figure 7: Location of the troglobite *Embioptera* 'sp. indet.'. within Deposit A west.**

# 5 Discussion

## 5.1 Troglofauna

A sole troglobitic specimen, *Embioptera* 'sp. indet.', was collected during the *ecologia* (2013) survey within the Deposit A west and Deposit F Study Area. This species was located outside the proposed disturbance area in Deposit A west, approximately 270 m north of the proposed Deposit A west pit location. This specimen was a new species record for the Greater West Angelas area. The species was classified as a potential SRE and therefore is considered potentially conservation significant (*ecologia* 2013).

EPA (2007) recommends two phases of subterranean fauna sampling should be undertaken, or if impractical, the single phase survey must be completed during the wet season. Troglobitic populations are likely to increase in size during and immediately after wet season (EPA 2007). While the previous wet season (November 2011 – March 2012) recorded higher than average rainfall, the single phase *ecologia* (2013) survey was conducted at the end of a dry season with less than average rainfall, from 9 July 2012 to 5 October 2012. Seasonality and survey timing was considered a limitation of the survey.

Capture rates may have been affected by survey effort; during the single phase survey, 17 of the 55 proposed survey sites were unable to be used for sampling. Drilling and bulldozing activities conducted as part of the Proposal exploration also occurred in Deposit A west during the troglofauna survey, causing vibration and change in air pressure in subterranean voids and possibly reducing the likelihood of troglofauna capture. The geology of Deposit A west and Deposit F is dominated by sedimentary rocks, which can range from solid and compact (e.g. shale) to loose (e.g. breccia) and/or cavernous (e.g. karst limestone), and thus may potentially provide habitat suitable for troglofauna (*ecologia* 2013). *ecologia* (2013) recommend further sampling be undertaken to clarify the composition and the extent of the troglobitic assemblage in the study, its potential restriction to the geological units and the impact that the Project may have on the species.

## 5.2 Stygofauna

The survey was restricted to four accessible bores in Deposit F; no stygofauna were collected from these locations. The EPA Guidance Statement 54a (EPA 2007) states that while the design of pilot studies varies according to the situation, it is expected that 6-10 stygofaunal samples will be collected for a pilot study. *ecologia* (2013) considered the current sampling effort was inadequate due to the low number of bores sampled and limited spatial coverage. They suggest that further sampling is recommended, particularly in Deposit A west.

However, the *ecologia* (2013) results were consistent with previous surveys in Deposit A west and Deposit F, which did not yield any stygofauna taxa (RTIO 2015). Biota (2008) assessed Deposit A as containing a closed aquifer (aquitard), and likely to be unsuitable for stygofauna. Given the similar geology in the Study Area, the sedimentary rock in Deposit A west and Deposit F may have similar low hydraulic conductivity and thus be less suitable for stygofauna. The geologies located outside the Study Area are comprised of dolerites and gabbros and extrusive igneous rocks (mafic volcanics) and may be more appropriate for stygofauna (*ecologia* 2013).

# 6 Conclusions

A summary of the findings of the West Angelas Subterranean Fauna Assessment in the Deposit A west and Deposit F Study Area are as follows:

- No species listed under the EPBC Act, WC Act or on threatened or priority DPaW lists were recorded during the survey.
- Out of the 55 potential survey sites, approximately 38 were able to be sampled for troglofauna. The troglofauna survey yielded 24 invertebrate specimens representing two taxa from orders Embioptera and Diplopoda.
- One taxa was identified as troglobitic; the webspinner *Embioptera* 'sp. indet.'. This conservation significant taxon has the potential to be an SRE and was a new record for the Greater West Angelas area.
- While the *ecologia* (2013) pilot survey and report was completed in broad accordance with the EPA Guidance Statements 54 (EPA 2003) and 54A (EPA 2007), there were limitations associated with the survey adequacy of the stygofauna sampling, the water quality sampling method efficiency, the timing (seasonality) of the survey and the resolution of species identification.
- EPA Guidance Statement 54a (EPA 2007) recommend 6-10 stygofaunal samples are taken during a pilot study. An insufficient number of stygofauna samples were collected during the *ecologia* (2013) survey, with the stygofauna survey limited to four accessible bores in Deposit F. No specimens were collected from these bores. *ecologia* (2013) recommended further sampling be undertaken, particularly in Deposit A west.
- Troglofauna capture rates may have also been affected by drilling and bulldozing activities conducted as part of the Proposal exploration in Deposit A west during the survey.

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# Appendix A Previous Subterranean Fauna Results

The following subterranean fauna were recorded in previous surveys and in databases within a 100 km radius of the *ecologia* Greater West Angelas Survey Area (Table from Appendix C, *ecologia* 2013).

| Class (order) | Family | Taxa |
|---|---|---|
| Arachnida (Prostigmata) | | |
| | Bdellidae | not specified |
| Arachnida (Oribatida) | | |
| | not specified | not specified |
| Arachnida (Trombidioidea) | | |
| | not specified | not specified |
| Arachnida (Palpigradida) | | |
| | not specified | not specified |
| Arachnida (Schizomida) | | |
| | Hubbardiidae | not specified |
| Arachnida (Pseudoscorpiones) | | |
| | Olpiidae | Sub-adult |
| Chilopoda (Scolopendrida) | | |
| | Cryptopidae | *Cryptops* sp. |
| Diplopoda (Polyxenida) | | |
| | not specified | not specified |
| | Polyxenidae | not specified |
| Insecta (Hemiptera) | | |
| | Emesinae | not specified |
| Insecta (Coleoptera) | | |
| | not specified | not specified |
| Insecta (Blattodea) | | |
| | Nocticolidae | *Nocticola* sp. |
| Malacostraca (Bathynellacea) | | |
| | Parabathynellidae | not specified |
| Malacostraca (Amphipoda) | | |
| | not specified | not specified |
| Malacostraca (Bathynellacea) | | |
| | Bathynellidae | not specified |
| | Parabathynellidae | *Billibathynella* new species 3 |
| | | *Billibathynella* n. sp. 2 & 3 |
| Malacostraca (Isopoda) | | |
| | not specified | not specified |
| | Oniscoid | not specified |

| Class (order) | Family | Taxa |
|---|---|---|
| Oligochaeta (Haplotaxida) | | |
| | Phreodrilidae | *Insulodrilus angela* |
| | Phreodrilidae | immature |
| | Enchytraeidae | spp. |
| Pauropoda (Pauropodina) | | |
| | | *Allopauropus* n. sp. 2 |
| | | *Allopauropus* n. sp. 1 |

# Appendix B Survey Sites

Survey sites within the Deposit A west and Deposit D Study Area. This table was adapted from Appendix A, *ecologia* 2013.

| Deposit Bore Name | Latitude | Longitude | Easting | Northing | Zone | Trog Trap Depth (m) | Total Bore Depth (m) | Depth to Water (m) | Notes |
|---|---|---|---|---|---|---|---|---|---|
| **Deposit A west** | | | | | | | | | |
| WAC197 | 23°10`39.036``S | 118°42`32.592``E | 674934 | 7435802 | 50 | 20 | 28 | | |
| WAD235 | 23°10`41.951``S | 118°43`14.85``E | 676135 | 7435698 | 50 | 40 | 59 | | |
| WAD328 | 23°10`26.984``S | 118°41`13.943``E | 672702 | 7436199 | 50 | | | | plug stuck |
| WAD379 | 23°10`25.013``S | 118°39`49.898``E | 670312 | 7436287 | 50 | 50 | 64 | 61 | |
| WAD379B | 23°10`24.959``S | 118°40`17.702``E | 671103 | 7436280 | 50 | 40 | 50 | | |
| WAD383 | 23°10`28.511``S | 118°41`14.000``E | 672703 | 7436152 | 50 | 30 | 68 | | |
| WAD396 | 23°10`41.472``S | 118°43`42.918``E | 676933 | 7435704 | 50 | 50 | 70 | | |
| WAD400 | 23°10`40.942``S | 118°43`57.244``E | 677341 | 7435715 | 50 | 40 | 75 | | |
| WAD439 | 23°10`28.597``S | 118°41`0.132``E | 672308 | 7436154 | 50 | 30 | 39 | | |
| WAD441 | 23°10`27.917``S | 118°40`46.074``E | 671909 | 7436179 | 50 | 40 | 82 | 80 | |
| WAD447 | 23°10`28.869``S | 118°40`32.076``E | 671510 | 7436155 | 50 | 20 | 83 | 76 | |
| WADRC0425 | 23°10`34.547``S | 118°41`53.246``E | 673817 | 7435953 | 50 | 60 | 64 | | |
| WADRC0432 | 23°10`34.684``S | 118°41`41.914``E | 673494 | 7435953 | 50 | 40 | 94 | 86 | |
| WADRC0436 | 23°10`31.627``S | 118°41`28.052``E | 673101 | 7436051 | 50 | | | | plug stuck |
| WADRC438 | 23°10`34.848``S | 118°41`28.215``E | 673105 | 7435952 | 50 | 50 | 89 | 78 | |
| DExt01 | 23°10`33.656``S | 118°42`4.581``E | 674139 | 7435977 | 50 | 30 | 35 | | |
| DExt02 | 23°10`34.484``S | 118°42`18.786``E | 674543 | 7435947 | 50 | | | | could not be located |
| DExt03 | 23°10`35.23``S | 118°42`18.599``E | 674538 | 7435924 | 50 | | | | plug blocked |
| DExt04 | 23°10`37.788``S | 118°42`18.607``E | 674537 | 7435845 | 50 | 50 | 60 | | |
| DExt05 | 23°10`40.086``S | 118°42`46.741``E | 675336 | 7435765 | 50 | 50 | 61 | | |

| Deposit Bore Name | Latitude | Longitude | Easting | Northing | Zone | Trog Trap Depth (m) | Total Bore Depth (m) | Depth to Water (m) | Notes |
|---|---|---|---|---|---|---|---|---|---|
| DExt06 | 23°10`42.577``S | 118°43`0.872``E | 675737 | 7435684 | 50 | | | | could not be located |
| DExt07 | 23°10`40.895``S | 118°43`0.872``E | 675738 | 7435735 | 50 | | | | blocked at surface |
| DExt08 | 23°10`28.127``S | 118°43`28.733``E | 676535 | 7436119 | 50 | | | | blocked at surface |
| DExt09 | 23°10`34.625``S | 118°43`28.728``E | 676532 | 7435919 | 50 | | 2 | | blocked |
| DExt10 | 23°10`37.733``S | 118°43`28.837``E | 676534 | 7435823 | 50 | | | | blocked at surface |
| DExt11 | 23°10`45.763``S | 118°43`28.985``E | 676535 | 7435576 | 50 | 60 | 73 | | |
| DExt12 | 23°10`21.704``S | 118°43`42.995``E | 676943 | 7436312 | 50 | 10 | 17 | | |
| DExt13 | 23°10`28.278``S | 118°43`43.149``E | 676945 | 7436109 | 50 | 10 | 14 | | |
| DExt14 | 23°10`26.977``S | 118°41`14.029``E | 672704 | 7436199 | 50 | | | | could not be located |
| DExt15 | 23°10`22.727``S | 118°40`4.089``E | 670717 | 7436353 | 50 | | | | could not be located |
| **Deposit F** | | | | | | | | | |
| DFRC001 | 23°11`44.748``S | 118°51`0.044``E | 689340 | 7433604 | 50 | 40 | 62 | | |
| F475 | 23°11`44.593``S | 118°51`7.167``E | 689543 | 7433606 | 50 | 40 | 64 | | |
| F98 | 23°11`14.903``S | 118°52`24.61``E | 691756 | 7434492 | 50 | 30 | 72 | | |
| WAF1098 | 23°11`45.23``S | 118°51`15.499``E | 689779 | 7433584 | 50 | | 16 | | original depth 120m |
| WAF1152 | 23°11`33.555``S | 118°49`53.001``E | 687438 | 7433973 | 50 | | 111 | 96.4 | Stygofauna sampled: 6 hauls 90mm nets |
| WAF2081 | 23°11`50.139``S | 118°51`19.55``E | 689892 | 7433431 | 50 | | 127 | 117 | Stygofauna sampled: 6 hauls 90mm nets |
| WAFPLF438 | 23°11`47.315``S | 118°50`58.35``E | 689291 | 7433526 | 50 | | 104 | | |
| WAFRC1076 | 23°11`34.233``S | 118°49`47.883``E | 687292 | 7433954 | 50 | 80 | 118 | 95 | |
| WAFRC1089 | 23°11`54.473``S | 118°50`47.448``E | 688978 | 7433310 | 50 | 80 | 160 | 113 | Stygofauna sampled. 6 hauls 90mm nets |
| WAFRC1141 | 23°11`35.81``S | 118°49`51.144``E | 687384 | 7433904 | 50 | 40 | 87 | | |
| WAFRC1159 | 23°11`29.294``S | 118°49`56.619``E | 687542 | 7434102 | 50 | 40 | 64 | | |
| WAFRC1164 | 23°11`38.105``S | 118°50`0.216``E | 687641 | 7433830 | 50 | 40 | 58 | | |
| WAFRC1267 | 23°11`44.023``S | 118°50`58.42``E | 689294 | 7433627 | 50 | | 56 | | |
| WAFRC1299 | 23°11`56.185``S | 118°50`49.313``E | 689030 | 7433256 | 50 | | 76 | | original depth 124m |

| Deposit Bore Name | Latitude | Longitude | Easting | Northing | Zone | Trog Trap Depth (m) | Total Bore Depth (m) | Depth to Water (m) | Notes |
|---|---|---|---|---|---|---|---|---|---|
| WAFRC1361 | 23°11`49.511``S | 118°51`14.114``E | 689738 | 7433453 | 50 | 80 | 124.8 | 116 | |
| WAFRC1464 | 23°11`21.563``S | 118°51`44.4``E | 690610 | 7434301 | 50 | 20 | 35 | | original depth 52m |
| WAFRC1510 | 23°11`33.688``S | 118°51`49.612``E | 690754 | 7433926 | 50 | 60 | 106 | | |
| WAFRC1558 | 23°11`26.142``S | 118°51`54.978``E | 690909 | 7434157 | 50 | 80 | 88 | | |
| WAFRC1590 | 23°11`18.382``S | 118°52`1.745``E | 691105 | 7434393 | 50 | 20 | 30 | | original depth 52m |
| WAFRC1640 | 23°11`16.213``S | 118°52`19.395``E | 691608 | 7434453 | 50 | 40 | 80 | | |
| WAFRC1902 | 23°11`45.002``S | 118°50`40.37``E | 688780 | 7433604 | 50 | 10 | 12 | | original depth 40m |
| WAFRC1991 | 23°11`35.875``S | 118°49`42.502``E | 687138 | 7433905 | 50 | 80 | 130 | 92 | |
| WAFRC1992 | 23°11`39.252``S | 118°49`42.705``E | 687143 | 7433801 | 50 | | 111 | 91 | Stygofauna sampled. original depth 112m, 6 hauls 90mm nets |
| WAFRC821 | 23°11`21.015``S | 118°51`44.474``E | 690613 | 7434318 | 50 | | | | could not be located |
| WFPC1297 | 23°11`58.026``S | 118°50`47.585``E | 688980 | 7433200 | 50 | | 93 | | blocked |

# Appendix C Invertebrate Specimens Collected

The following invertebrate specimens were collected with the Study Area. This table was adapted from Appendix B, *ecologia* 2013.

| Bore ID | Embioptera 'sp. indet.' (order Embioptera) *Troglobitic* | Lophoproctidae (order Diplopoda) *Not troglobitic* |
|---|---|---|
| **Deposit A west** | | |
| WAC197 | 0 | 0 |
| WAD235 | 0 | 0 |
| WAD379 | 0 | 7 |
| WAD379B | 0 | 0 |
| WAD383 | 0 | 0 |
| WAD396 | 0 | 0 |
| WAD400 | 0 | 0 |
| WAD439 | 0 | 0 |
| WAD441 | 0 | 0 |
| WAD447 | 0 | 3 |
| WADR0425 | 0 | 0 |
| WADR0432 | 0 | 0 |
| WADRC438 | 0 | 0 |
| DExt01 | 0 | 0 |
| DExt05 | 0 | 0 |
| DExt11 | 0 | 1 |
| DExt12 | 0 | 0 |
| DExt13 | 1 | 3 |
| **Deposit F** | | |
| DFRC001 | 0 | 0 |
| F475 | 0 | 0 |
| F98 | 0 | 0 |
| WAFRC1076 | 0 | 0 |
| WAFRC1089 | 0 | 0 |
| WAFRC1141 | 0 | 0 |
| WAFRC1159 | 0 | 8 |
| WAFRC1164 | 0 | 0 |
| WAFRC1267 | 0 | 0 |
| WAFRC1361 | 0 | 0 |
| WAFRC1464 | 0 | 0 |
| WAFRC1510 | 0 | 0 |
| WAFRC1558 | 0 | 0 |
| WAFRC1590 | 0 | 0 |
| WAFRC1640 | 0 | 0 |

| | | |
|---|---|---|
| WAFRC1902 | 0 | 1 |
| WAFRC1991 | 0 | 0 |
| WAFRC1992 | 0 | 0 |
| WFPC1297 | 0 | 0 |

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