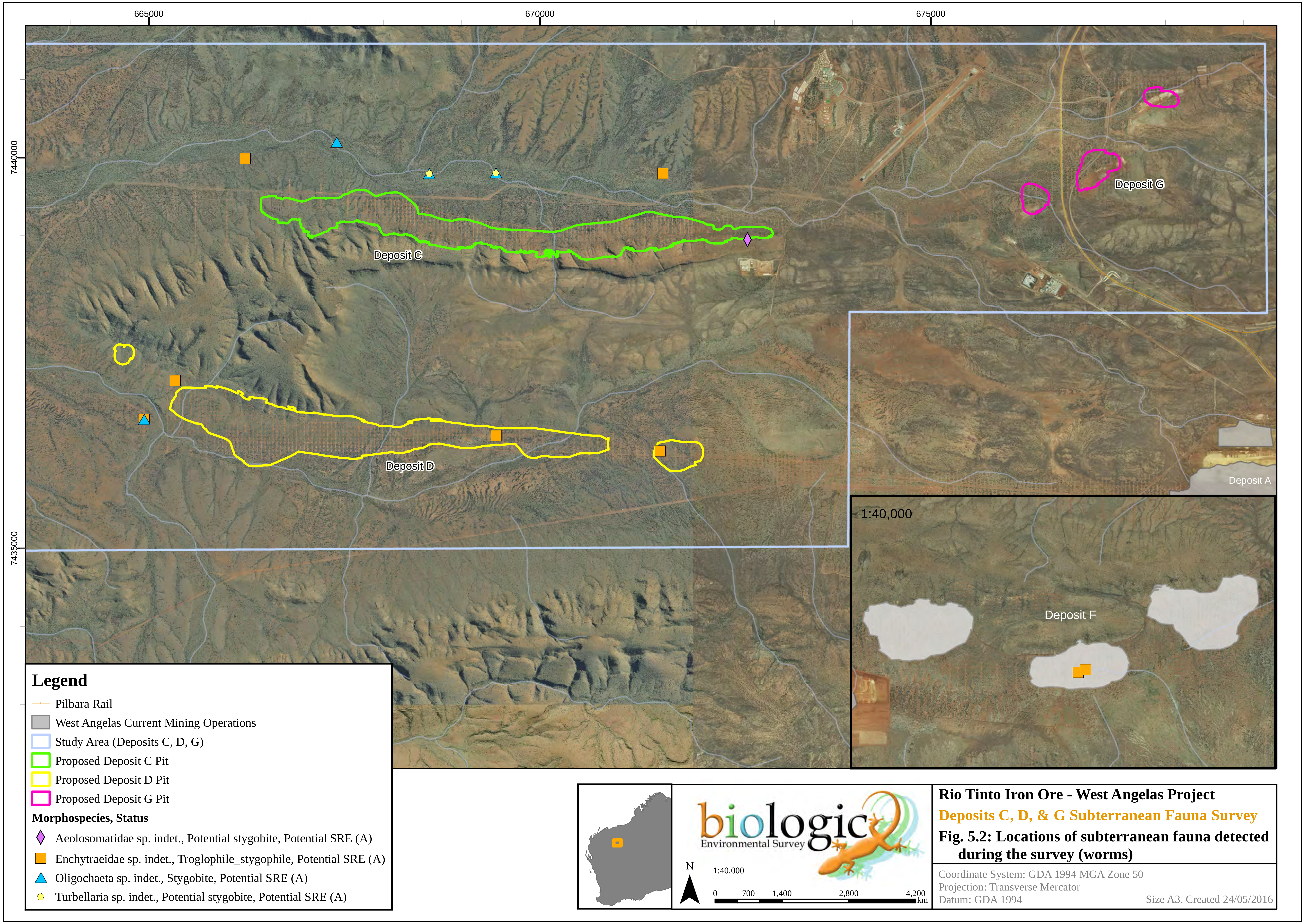

665000
670000
675000
7440000
7435000
Deposit C
Deposit D
Deposit G
Deposit A
1:40,000
Deposit F
Legend
Pilbara Rail
West Angelas Current Mining Operations
Study Area (Deposits C, D, G)
Proposed Deposit C Pit
Proposed Deposit D Pit
Proposed Deposit G Pit
Morphospecies, Status
Aeolosomatidae sp. indet., Potential stygobite, Potential SRE (A)
Enchytraeidae sp. indet., Troglophile_stygophile, Potential SRE (A)
Oligochaeta sp. indet., Stygobite, Potential SRE (A)
Turbellaria sp. indet., Potential stygobite, Potential SRE (A)
biologic
Environmental Survey
N
1:40,000
0 700 1,400 2,800 4,200 km
Rio Tinto Iron Ore - West Angelas Project
Deposits C, D, & G Subterranean Fauna Survey
Fig. 5.2: Locations of subterranean fauna detected during the survey (worms)
Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
Size A3. Created 24/05/2016

Aeolosomatids are polychaete worms that are often found in high numbers in surface aquatic habitats but are rarely collected from groundwater (E. Volschenk pers. comm. 2016). The taxonomy of the group is poorly known, but as all specimens were collected from a single hole (in the eastern part of Deposit C) they may be assumed to belong to the same species. The hole in question (RC15WAC0276) intercepted very little water (approximately 1.5 m) at a depth of approximately 43 mbgl; however, a stygofaunal amphipod was also detected. Along with the depth from surface, this suggests that Aeolosomatidae sp. indet. is potentially stygobitic, although to what extent they may be SRE is currently uncertain (E. Volschenk pers. comm. 2016, Appendix E). Further taxonomic resolution of this group is limited by the poorly developed state of taxonomy and the lack of regional collections with which to compare material from the Study Area.

Oligochaete worms were detected from four holes near Deposits C and D. Preliminary identifications indicated that these specimens may belong to the Naididae or the Phreodrillidae, but without more detailed taxonomic information, it is uncertain whether one or more species may occur (E. Volschenk pers. comm. 2016). Stygofaunal representatives of both of these families occur throughout the region, and regional genetic studies (Brown *et al.* 2015) have shown that, while the majority of species in these families are distributed throughout the major catchments, a number of regionally widespread species and a few SRE species distributions also occur.

One potential explanation offered for these distribution patterns was dispersal by surface water flows (particularly during flood events), and Brown *et al.* (2015) suggested that it remains unclear whether Pilbara groundwater oligochaetes are stygophilic or stygobitic. Brown *et al.* (2015) found other cases where closely related species were detected in the same catchment or locality. Without more detailed taxonomic information, it is uncertain whether the oligochaetes previously collected at West Angelas (in the central plateau, refer Table 5.3) may represent the same species as the current specimens. The regionally widespread species *Insulodrilus angela* (Phreodrilidae) is also known to occur nearby at Angelo River (approximately 10 km south), along with another distinct haplotype (Phreodrilidae 1-1), which was also found at Weeli Wolli Creek (Brown *et al.* 2015).

Turbellarians (flatworms) were detected from two holes in nearby areas north of Deposit C. The current specimens lacked eye-spots associated with some epigean taxa, but this is not regarded as a definitive stygomorphism as other flatworm taxa always lack eye-spots (E. Volschenk pers. comm. 2016). This group has been found at West Angelas during previous surveys (Ecologia 1998, Biota 2003) although, owing to the poorly developed taxonomy of the group, it is unclear whether these may represent the same species. Turbellarians were only found in two holes within a drainage line to the north of Deposit C, in close proximity to the surface (<5 mbgl). This suggests that the morphospecies may be associated with near-surface hyporheic habitats, and may be able to disperse throughout surface waters during flood events. Nevertheless, without further information (which may be limited, owing to the lack of regional collections for this group), it remains unclear to what extent Turbellaria sp. indet. may be SRE (E. Volschenk pers. comm. 2016, Appendix E).

5.3.2 Crustaceans

Eleven morphospecies of crustaceans were detected at Deposits C, D and nearby drill holes, comprising two amphipods, two bathynellaceans, three cyclopoid copepods (plus indeterminate/ unidentified cyclopoid specimens), two harpacticoid copepods, an ostracod, and an isopod (Table 5.6, Figures 5.3 and 5.4).

Table 5.6: Crustaceans detected within each deposit and nearby areas during the survey

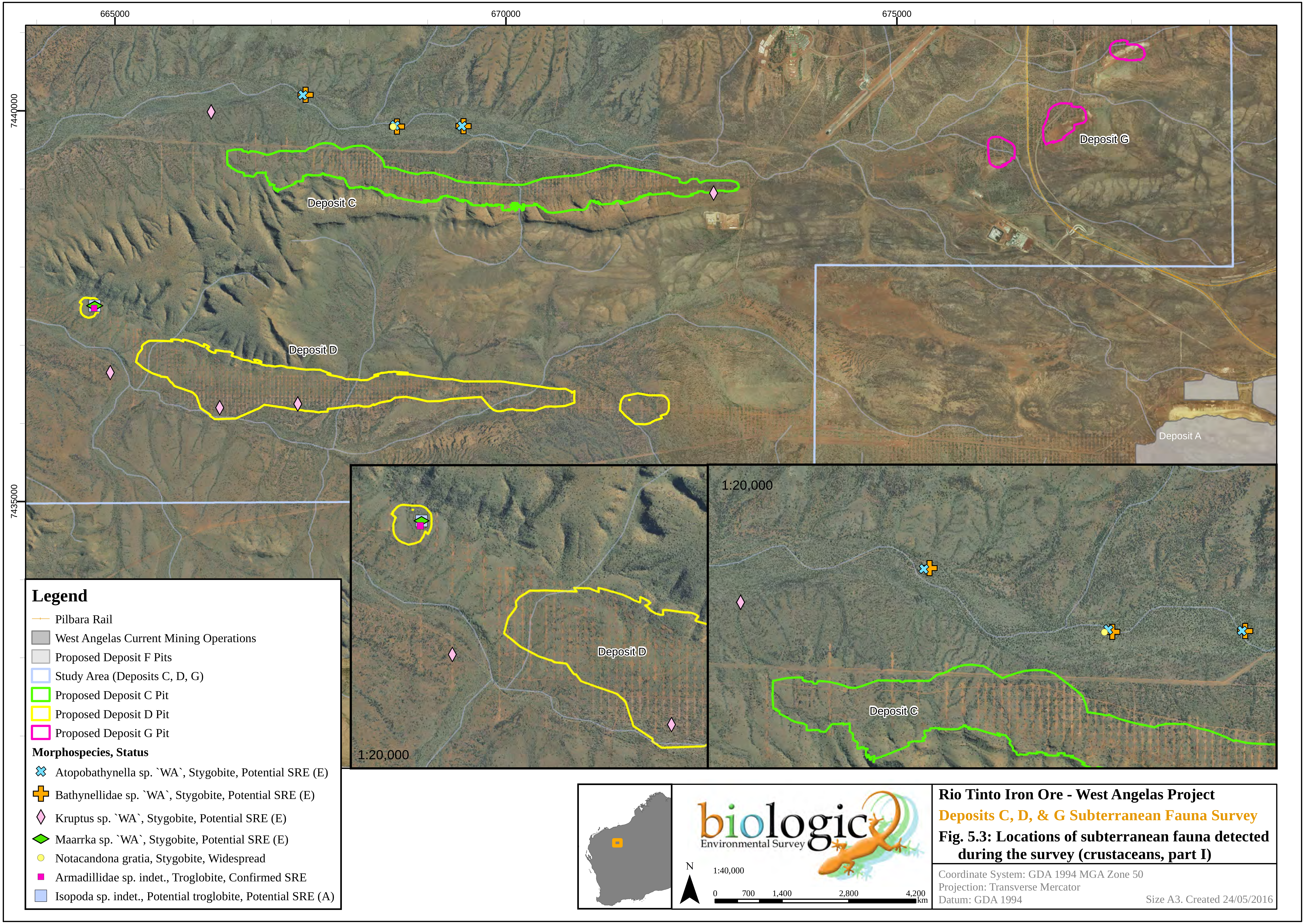
Taxon	C inside	C nearby	D inside	D nearby	Total	Subterranean status	SRE Status
Amphipoda							
Kruptus sp. \`WA\`	1	6	3	1	11	Stygobite	Potential SRE (E)
Maarrka sp. \`WA\`			1		1	Stygobite	Potential SRE (E)
Bathynellacea							
Atopobathynella sp. \`WA\`		200			200	Stygobite	Potential SRE (E)
Bathynellidae sp. \`WA\`		87			87	Stygobite	Potential SRE (E)
Cyclopoida							
Metacyclops sp. \`B01\` (nr. pilbaricus)		1			1	Stygobite	Widespread
Microcyclops varicans		219			219	Stygobite	Widespread
Thermocyclops sp. \`WA\`		4			4	Stygobite	Potential SRE (E)
'Cyclopoida indet.'		174			174	Stygobite	Potential SRE (A)
Harpacticoida							
Australocamptus sp. \`B13\`		89			89	Stygobite	Potential SRE (E)
Parastenocaris sp. indet.		1			1	Stygobite	Potential SRE (A)
Ostracoda							
Notacandona gratia		1			1	Stygobite	Widespread
Isopoda							
Armadillidae sp. indet.			1		1	Troglobite	Confirmed SRE (previous regional sequencing)
Isopoda sp. indet. (damaged)			1		1	Potential Troglobite	Potential SRE (A)
Total	**1**	**608**	**6**	**1**	**616**		

Note: Grey font indicates indeterminate cyclopoid specimens that could not be allocated to the other existing morphospecies.

The indeterminate taxon ‘Cyclopoida indet.’ represents the remaining cyclopoid specimens that could not be allocated to one of the other known cyclopoid species from the same drill holes. Owing to the large number of specimens collected, and the need for dissection and slide mounting to obtain species level identifications, the cyclopoid specimens were sub-sampled for identifications and these were allocated to the remaining specimens in each sample using a parsimonious approach. Where only one species/ morphospecies was identified per sample, the remaining specimens were inferred to be the same. Where more than one morphospecies was identified per sample, the remaining specimens were grouped together as ‘Cyclopoida indet.’ As a result, the indeterminate cyclopoid material may represent more than one species, (although it is likely that the three current species would be most highly represented in this material) and therefore this taxon is not included in the species counts.

Two species of stygal paramelitid Amphipods (*Kruptus* sp. \`WA\` and *Maarka* sp. \`WA\`) were sampled at Deposits C and D (plus nearby holes) (Table 5.6, Figure 5.3). Although *Maarka* sp. \`WA\` was morphologically similar to *M. weeliwollii* and *M. etheli* (respectively known from Weeli Wolli calcrete approximately 70 km north east and Ethel Gorge calcrete approximately 120 km east) (Finston *et al.* 2011), some of the characters of the current specimen did not match either of these species (G. Perina pers. comm. 2016, Appendix F). As such, in the context of considerable distances between the locations of the known *Maarka* species and the Study Area, *Maarka* sp. \`WA\` was regarded as a potentially new species (G. Perina pers. comm. 2016, Appendix F). Under this scenario, *Maarka* sp. \`WA\` is only known from one hole in Deposit D and may be regarded as a Potential SRE (research and expertise) (G. Perina pers. comm. 2016, Appendix F).

The remaining paramelitid specimens tentatively aligned to the genus *Kruptus* (some juvenile specimens were more difficult to assess), which is known to occur at Angelo River 25 km south east (*K.* sp. \`AR\`), and also Spearhole Creek (*K. linnaei*), approximately 60 km east (Finston *et al.* 2008). Although some of the morphological characters were not well-defined in some of the specimens, there was enough difference between this and other known species of *Kruptus* to suggest that *K.* sp. \`WA\` is a distinct species (G. Perina pers. comm. 2016, Appendix F). Under this scenario, *K.* sp. \`WA\` is only known from three holes within Deposits C and D and two holes in nearby areas (Figure 5.3), and is regarded as a Potential SRE (research and expertise) (G. Perina pers. comm. 2016, Appendix F).


665000
670000
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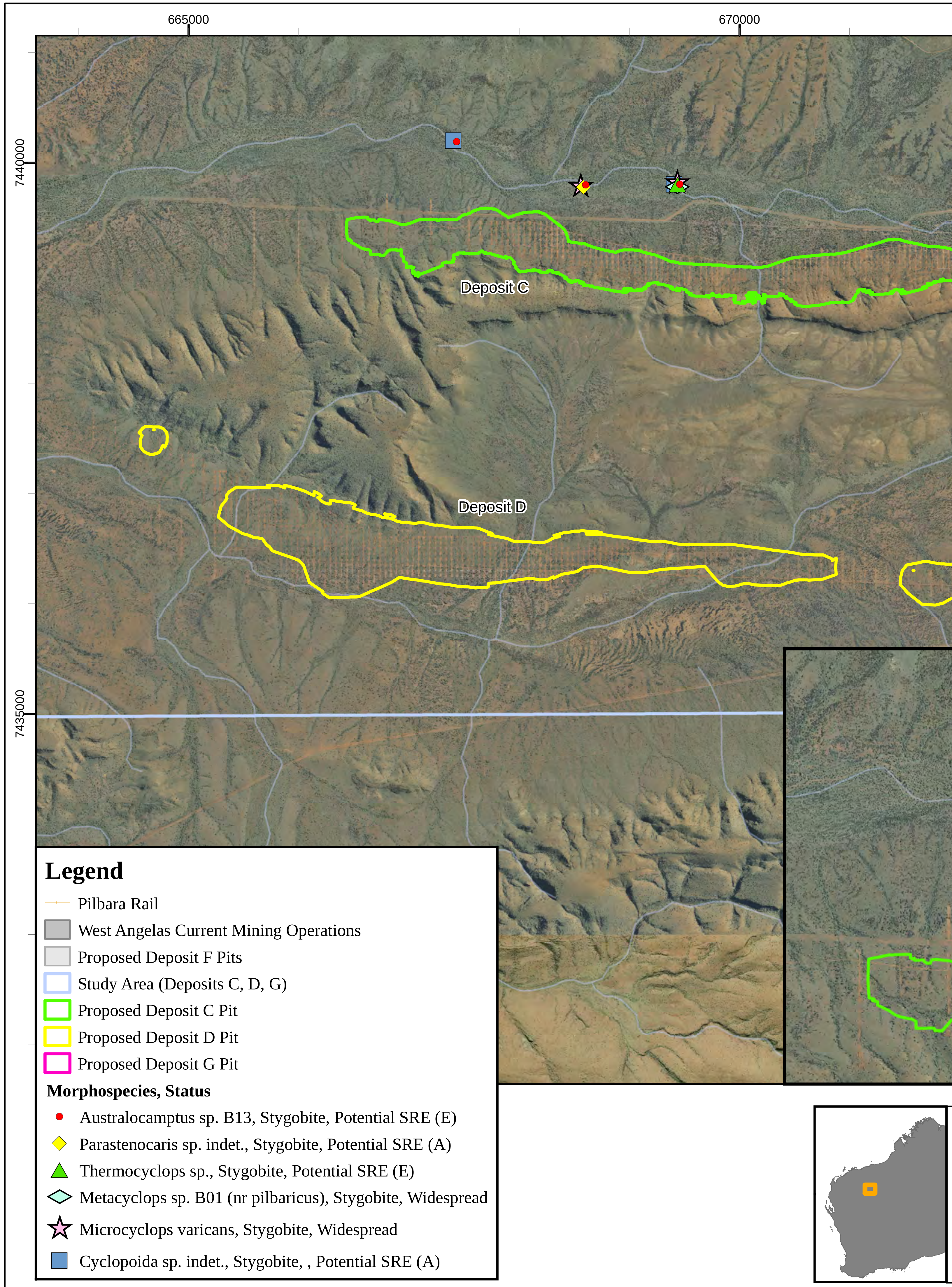
7435000
Deposit C
Deposit D
Deposit G
Deposit A
1:20,000
1:20,000
Deposit D
Deposit C
Legend
Pilbara Rail
West Angelas Current Mining Operations
Proposed Deposit F Pits
Study Area (Deposits C, D, G)
Proposed Deposit C Pit
Proposed Deposit D Pit
Proposed Deposit G Pit
Morphospecies, Status
Atopobathynella sp. `WA`, Stygobite, Potential SRE (E)
Bathynellidae sp. `WA`, Stygobite, Potential SRE (E)
Kruptus sp. `WA`, Stygobite, Potential SRE (E)
Maarrka sp. `WA`, Stygobite, Potential SRE (E)
Notacandona gratia, Stygobite, Widespread
Armadillidae sp. indet., Troglobite, Confirmed SRE
Isopoda sp. indet., Potential troglobite, Potential SRE (A)
biologic
Environmental Survey
N
1:40,000
0 700 1,400 2,800 4,200
km
Rio Tinto Iron Ore - West Angelas Project
Deposits C, D, & G Subterranean Fauna Survey
Fig. 5.3: Locations of subterranean fauna detected during the survey (crustaceans, part I)
Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
Size A3. Created 24/05/2016



Rio Tinto Iron Ore - West Angelas Project

Deposits C, D, & G Subterranean Fauna Survey

Fig. 5.4: Locations of subterranean fauna detected during the survey (crustaceans, part II)

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
Size A3. Created 24/05/2016

Two morphospecies of bathynellaceans (also known as syncarids) were detected from three reference holes to the north of Deposit C (Figure 5.3); *Atopobathynella* sp. `WA`, and Bathynellidae sp. `WA`. Bathynellaceans are entirely stygobitic, and despite the limitations to species-level taxonomy (particularly within the Bathynellidae), many range-restricted species and morphospecies are known to occur in the region (G. Perina pers. comm. 2016, Appendix F). Species of *Atopobathynella* have been previously sampled at Munjina and Marillana Creek (approximately 70-80 km north), while other parabathynellid genera have been recorded at Boundary Ridge (nr. *Billibathynella*, approximately 10 km north) and Wonmunna (approximately 20 km east) (WAM database records 2016). Meanwhile, the nearest known records of bathynellids were detected at South Flank, approximately 35 km north east (WAM database records 2016), but this is unlikely to be the same species, owing to the range-restricted nature of this group. Based on current regional trends, both of the bathynellacean morphospecies are regarded as Potential SREs (research and expertise) (G. Perina pers. comm. 2016, Appendix F).

Three cyclopoid copepod taxa and two harpacticoid copepod taxa were detected in three drill holes to the north of Deposit C (Figure 5.4). The majority of the specimens (219 out of 398 total cyclopoid specimens) were identified as the widespread species *Microcyclops varicans* (J. McRae pers. comm. 2016). The likelihood of range-restricted cyclopoid species from the Pilbara is generally considered low, as the majority of species from the region are widespread (J. McRae pers. comm. 2016), as are the majority of species of the harpacticoid copepod *Parastenocaris*, which was found in the same holes north of Deposit C. Nevertheless, some SRE species of *Parastenocaris* are known to occur, therefore the current taxon may have some potential to be SRE (E. Volschenk pers. comm. 2016, Appendix E).

Thermocyclops specimens from the survey were tentatively regarded as a potential new species, as few previous records of this genus exist in the vicinity of the Study Area (J. McRae pers. comm. 2016), except for one record of *T. aberrans* at South Flank (WAM database records 2016). *Thermocyclops* sp. `WA` was tentatively regarded to be a Potential SRE (data deficient), although its occurrence within near surface hyporheic groundwater habitats associated with the drainage line to the north of Deposit C suggests that it could occur further downstream within the drainage catchment. The harpacticoid copepod *Australocamptus* sp. `B13` was also considered to represent a new, unique species (J. McRae pers. comm. 2016) and owing to this group's known dispersal limitations and the occurrence of other range-restricted harpacticoids in the region, it was considered to be a Potential SRE (research and expertise).

The ostracod *Notacandona gratia* was detected from one hole to the north of Deposit C. Despite other range-restricted ostracods occurring in the Pilbara region, this species is known to occur around Newman (J. McRae pers. comm. 2016, WAM database records 2016) and is therefore regarded as widespread.

Two troglobitic isopod specimens (Armadillidae sp. indet. and Isopoda sp. indet.) were detected from a hole in the far western end of Deposit D. Both specimens showed a high degree of troglomorphy including eyelessness and lack of pigment, although as one of Armadillidae sp. indet. was juvenile, and Isopoda sp. indet. was damaged, their species-level identifications are unresolved. Owing to their collection within the same drill hole at approximately the same time (one from a scrape sample, the other from a trap), it is possible that they may belong to the same species, although some of the taxonomic characters that remained intact on the damaged specimen (Isopoda sp. indet.) did not appear to match Armadillidae sp. indet. (E. Volschenk pers. comm. 2016, Appendix E).

Troglobitic isopods in the genus *Troglarmadillo* (Armadillidae) have been collected throughout the region, with the closest known record being Wonmunna, approximately 10 km east. Previous surveys detected *Pseudodiploexochus* at West Angelas Deposit H (Ecologia 2013), and the WAM database records (2016) showed unidentified isopods from two sites 1.5 km south and 3 km south east of Deposit D (Figure 5.1). Based on current knowledge of troglobitic isopods, and previous DNA studies showing multiple SRE species in the Armadillidae (Bennelongia 2011d, 2015, E. Volschenk pers. comm. 2016), Armadillidae sp. indet. is considered likely to be a Confirmed SRE, and Isopoda sp. indet. is regarded as a Potential SRE (data deficient).

Previous surveys at West Angelas collected representatives of all these same crustacean groups (amphipods, bathynellaceans, copepods, ostracods and isopods), as well as Oligochaete and Turbellarian worms at sites throughout the central plateau (Jeerinah Formation), near the current mining deposits, and at Turee Creek Bore field approximately 15 – 35 km south west (refer Figure 5.1). At the current time, this material is unable to be compared to specimens from the current survey due to a lack of species level identifications.

5.3.3 Arachnids

Five morphospecies of arachnids were detected at Deposits C, D, and G (and nearby areas), comprising two spiders (Araneae), two pseudoscorpions (Pseudoscorpiones) and a schizomid (Schizomida) (Table 5.7, Figure 5.5).

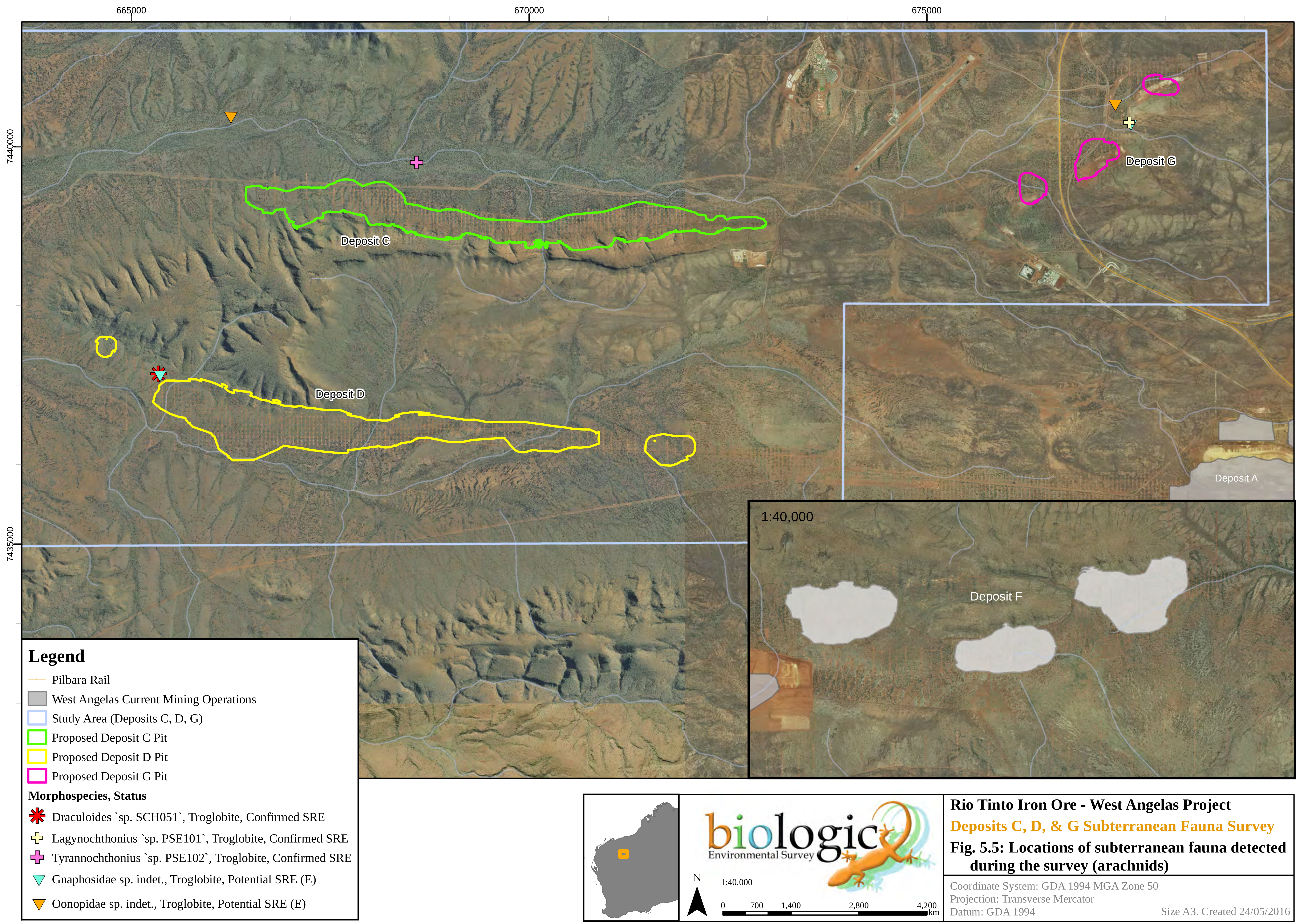
All of the arachnid taxa showed a range of troglomorphic features such as eyelessness, elongated appendages and sensory hairs, a lack of pigment, and softening of the cuticle which are strongly indicative of troglobitic species. The four spider specimens (Gnaphosidae sp. indet. and Oonopidae sp. indet.) were all juveniles or female specimens, therefore they were not able to be identified to species-level using morphology alone (T. Moulds pers. comm. 2016, Appendix G). Troglobitic arachnids are generally considered to have a very high likelihood of being SRE, and the identification of any strongly troglomorphic arachnid that is distinct from other morphospecies within the WAM usually results in the morphospecies being regarded as a Confirmed SRE (T. Moulds pers. comm. 2016, Appendix G).

Table 5.7: Arachnids detected within each deposit and nearby areas during the survey

Taxon	C nearby	D nearby	G nearby	Total	Subterranean status	SRE Status
Araneae						
Gnaphosidae sp. indet.		1	1	2	Troglobite	Potential SRE (A & E)
Oonopidae sp. indet.	1		1	2	Troglobite	Potential SRE (A & E)
Pseudoscorpiones						
Lagynochthonius sp. \`PSE101\`			1	1	Troglobite	Confirmed SRE
Tyrannochthonius sp. \`PSE102\`	1			1	Troglobite	Confirmed SRE
Schizomida						
Draculoides sp. \`SCH051\`		1		1	Troglobite	Confirmed SRE
Total	**2**	**2**	**3**	**7**		

The two pseudoscorpions (*Lagynochthonius* sp. \`PSE101\` and *Tyrannochthonius* sp. \`PSE102\`) and the schizomid (*Draculoides* sp. \`SCH051\`) were allocated unique WAM morphospecies numbers on the basis that they were all adult specimens, collected from an area where no subterranean members of their groups have been previously recorded. As a result, these three taxa are all regarded as potentially new, Confirmed SRE species (T. Moulds pers. comm. 2016, Appendix G). Meanwhile, the two spider morphospecies were regarded as troglobitic due to a range of strong troglomorphic features and, despite being indeterminate (due to juvenile specimens), both taxa were considered to be Potential SREs (data deficient and research/ expertise) (T. Moulds pers. comm. 2016, Appendix G).

None of the arachnid morphospecies from the current survey were detected inside the deposit boundaries, although *Draculoides* sp. \`SCH051\` and Gnaphosidae sp. indet. were detected near the western boundary of Deposit D (Figure 5.5). Previous sampling detected a troglobitic oonopid spider of the genus *Prethopalpus* at Deposit H (Ecologia 2013), but without further investigation it remains uncertain whether this taxon might be the same as the oonopid specimens detected near Deposits C and G.



Rio Tinto Iron Ore - West Angelas Project

Deposits C, D, & G Subterranean Fauna Survey

Fig. 5.5: Locations of subterranean fauna detected during the survey (arachnids)

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 24/05/2016

5.3.4 Hexapods

Six morphospecies of hexapods were detected at Deposits C and D (and nearby areas), comprising indeterminate taxa of bristletails (Diplura), plant bugs (Hemiptera), silverfish (Thysanura) and springtails (Collembola) (Table 5.8, Figure 5.6).

Table 5.8: Hexapods detected within each deposit and nearby areas during the survey

Taxon	C inside	C nearby	D inside	D nearby	Total	Subterranean status	SRE Status
Diplura							
Campodeidae sp. indet.		2			2	Potential troglobite	Potential SRE (A)
Hemiptera							
Meenoplidae sp. indet.	2		1		3	Potential troglobite	Potential SRE (A)
Thysanura							
Atelurinae sp. indet.				1	1	Potential troglobite	Potential SRE (A)
Collembola							
Cyphoderidae sp. indet.	9				9	Potential troglobite	Potential SRE (A)
Sminthuridae sp. indet.		5			5	Potential troglobite	Potential SRE (A)
Total	**11**	**7**	**1**	**1**	**20**		

Diplura are a poorly studied group of hexapods that are always small, eyeless and pale, therefore it is often unclear whether they represent troglofauna or soil fauna when collected in drill holes. The species-level taxonomy of the group is under-developed but several families are recognised, including the Campodeidae, to which the current morphospecies belongs (E. Volschenk pers. comm. 2016, Appendix E). Two specimens were collected in holes to the north of Deposit C (Figure 5.6), where habitat information on troglofauna was limited, but it appeared that groundwater levels were much deeper (ranging from 39 – 48 mbgl) than some of the other holes in this area (minimally 1.9 mbgl). Based on the limited information currently available, this morphospecies is considered to be a potential troglobite (although the possibility that this morphospecies could be soil fauna cannot be excluded), and a Potential SRE (data deficient) (E. Volschenk pers. comm. 2016, Appendix E).

Plant bugs (Hemiptera) of the family Meenoplidae feed on tree roots underground and are often considered to be trogloxenic/ troglophilic where adults show fully developed wings (Subterranean Ecology 2011a, 2011b). Some troglobitic species are also known to occur in Western Australia, in particular a species of *Phaconeura* from Cape Range that had vestigial wings and highly depigmented eye spots (Hoch and Asche 1993). The adult specimens from the current survey (detected within Deposit D) showed a range of troglomorphic characters such as highly reduced eyes and a soft, pale cuticle, but with fully-formed wings, which complicated the assessment of subterranean status. Previous genetic studies have shown a variety of widespread and more restricted distributions throughout the region, even in meenoplid taxa considered highly troglomorphic (Bennelongia 2015, E. Volschenk pers. comm. 2016, Appendix E). As such, this morphospecies is considered to be a Potential SRE (data deficient) and, although the current specimens (collected at Deposits C and D) appear to belong to the same species, it is unclear whether this species is the same as specimens previously collected at Deposits G and H (Ecologia 2013).

Silverfish in the subfamily Atelurinae are known to mainly inhabit soil habitats within ant nests and termite nests (Smith 1998), although three potentially troglobitic species have been recently described from deeper subterranean habitats in the Pilbara region (Smith and McRae 2014). The current survey collected Atelurinae just beyond the western boundary of Deposit D, while previous sampling detected specimens from the same sub-family within the central part of Deposit D (Ecologia 2013). Based on the available habitat data, it would be reasonable to assume that these specimens could belong to the same species, although this is unconfirmed by morphological comparisons at the current time. Based on limited ecological and taxonomic knowledge, it remains unclear whether Atelurinae sp. indet. may be regarded as potentially troglobitic or soil fauna, and this taxon is regarded as a Potential SRE (data deficient) (E. Volschenk pers. comm. 2016, Appendix E).

Epigean or soil dwelling Collembola are often caught as by-catch during subterranean fauna surveys, although some troglobitic taxa are known to occur (Greenslade 2002, E. Volschenk pers. comm. 2016). The specimens from the current survey showed some troglomorphic characters such as elongated antennae and appendages (Cyphoderidae sp. indet.), eyelessness and depigmentation (Sminthuridae sp. indet.), suggesting at least reasonable potential to be troglofauna (E. Volschenk pers. comm. 2016, Appendix E). Members of both of these families are known from caves in other parts of Australia; however, the only troglobitic collembolan described from the Pilbara is from Cape Range (Greenslade 2002). Various soil dwelling species from these families are also known to occur in the region (Greenslade in Biota 2006), therefore the subterranean status of the current specimens remains unclear and they are regarded as Potential SREs (data deficient) (E. Volschenk pers. comm. 2016, Appendix E). Cyphoderidae sp. indet. was detected from one hole within Deposit C, while Sminthuridae sp. indet. was detected from one hole outside Deposit C (Figure 5.6).

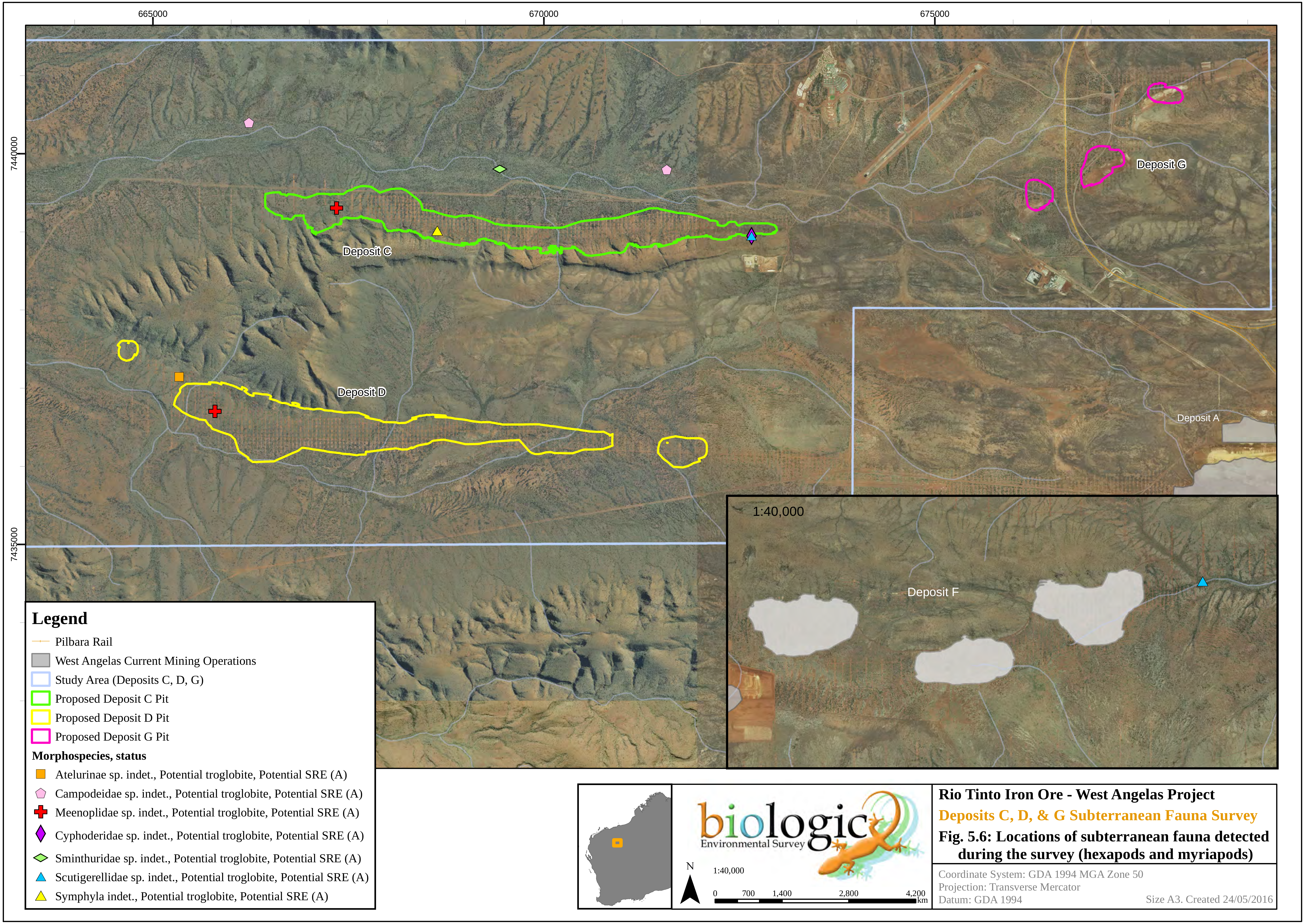


Fig. 5.6: Locations of subterranean fauna detected during the survey (hexapods and myriapods)

5.3.5 Myriapods

Two morphospecies of symphylans (Symphyla) were detected at Deposit C and nearby areas (Table 5.9, Figure 5.6), plus an epigean/ soil dwelling species of pin-cushion millipede (Lophoproctidae: *Lophoturus madecassus*) at Deposit D and G (T. Moulds pers. comm. 2016, Appendix G). A revision of Western Australian polyxenid specimens recently found that the family Lophoproctidae was represented solely by the widespread species *Lophoturus madecassus* (T. Moulds pers. comm. 2016). This species was detected within and near Deposit D during the current survey, while previous surveys (Ecologia 2013) detected lophoproctids at Deposits C, D, and G (Figure 5.1) that can be inferred to belong to the same, widespread species.

Table 5.9: Myriapods detected within each deposit and nearby areas during the survey

Taxon	C inside	D inside	G Inside	Total	Subterranean status	SRE Status
Symphyla						
Scutigerellidae sp. indet.	17			17	Potential troglobite	Potential SRE (A)
Symphyla indet.	1			1	Potential troglobite	Potential SRE (A)
Total	**18**			**18**		

The species-level taxonomy of Symphyla is poorly developed, but several families are recognised, including the Scutigerellidae, to which all but one (damaged specimen) of the current specimens belong. Given the proximity of the damaged specimen to the other Scutigerellidae specimens in Deposit C, it is possible that it may also belong to the same species. WAM database records (2016) showed troglofaunal Symphyla have previously been detected nearby at Wonmunna (E. Volschenk pers. comm. 2016), and indeterminate Scutigerellidae were also collected during the concurrent survey at West Angelas Deposit F (Biologic 2016) (Figure 5.6). Recent regional comparisons (morphological and genetic) have shown that troglobitic symphylans are among the most highly range restricted subterranean fauna groups in the Pilbara region (Bennelongia 2015, E. Volschenk pers. comm. 2016). Based on current information, the Symphyla from Deposit C are regarded as Potential SREs (data deficient), and potential troglobites (E. Volschenk pers. comm. 2016, Appendix E).

6 SUBTERRANEAN HABITAT ASSESSMENT

Information on the subterranean habitats sampled within the Study Area is based upon available geological and hydrogeological reports, drill logs, and geological cross sections at each of the deposits. Few groundwater physicochemistry measurements were able to be taken at the time of survey, owing to the limitations of bailer sampling, but some previous physicochemical measurements were available from hydrological reports.

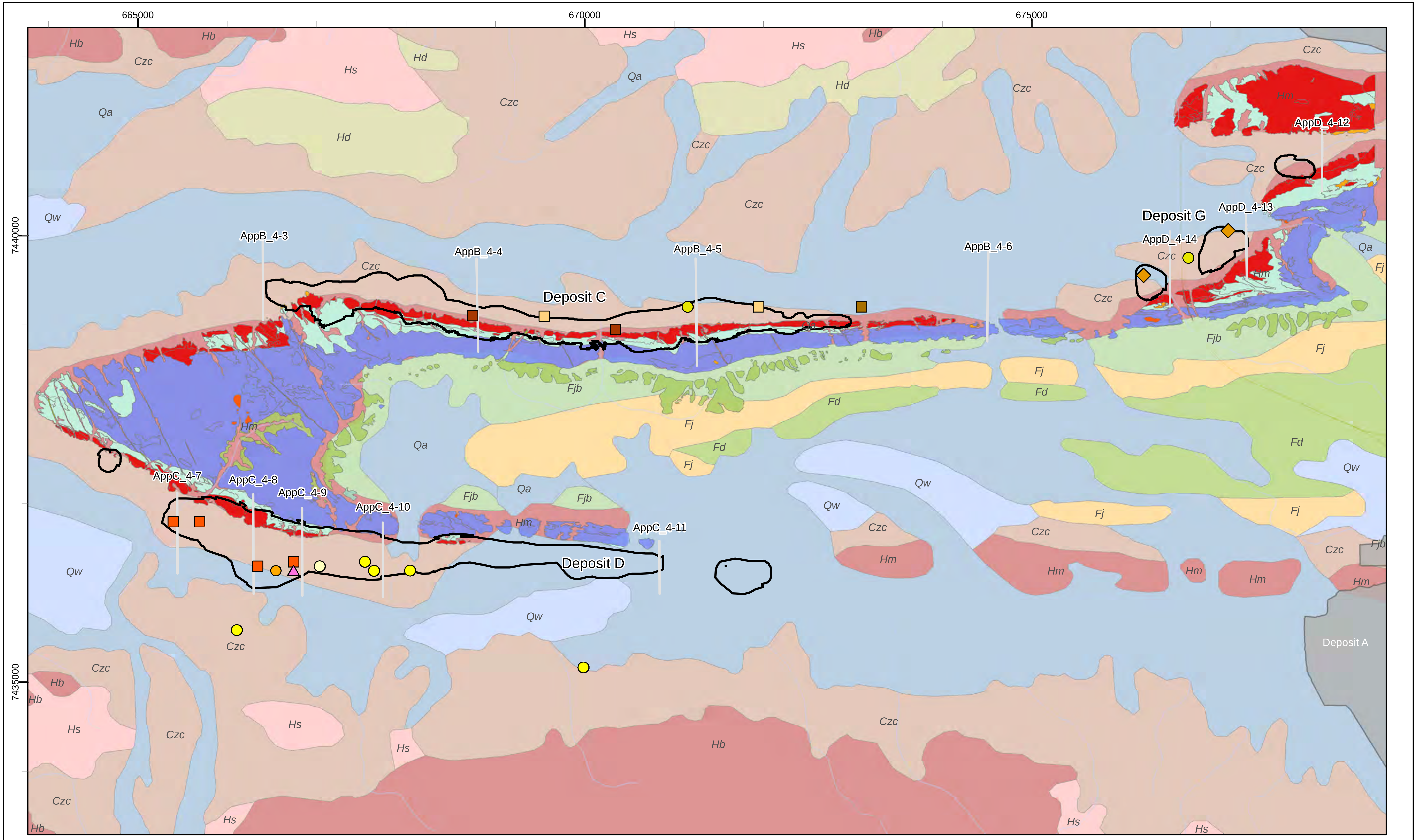
6.1 Geological/ hydrogeological habitats

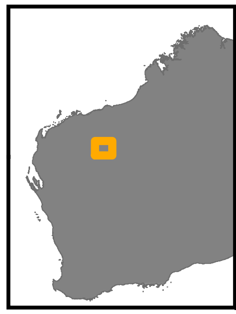
Potential habitats for subterranean fauna (*i.e.* caves, cracks, cavities, vugs, and pores within rock formations above the water table for troglofauna, and below the water table for stygofauna) could occur within numerous strata at Deposits C, D, and G. Geology alone is not a precise predictor of suitable habitat, although in the Hamersley Range it can be reasonably assumed that certain lithologies will usually support sufficient cavities for subterranean fauna where found within approximately 150 m of the surface (below which cavities are rarer due to pressure) (J. Barnett pers. comm. 2016). Cavities are common within secondarily weathered, iron-enriched layers such as 'high grade' ore zones, which occur in the upper layers of BIFs, and often feature a more highly weathered 'hydrated' hardcap. Where exposed near the surface and/or faulted and folded, deep fractures within BIF may also provide suitable habitat for subterranean fauna. Secondary detrital deposits such as calcrete and pisolite (channel iron deposits (CID) and duricrust) are also known to provide highly suitable habitats due to high levels of secondary weathering.

Cross-comparisons of surface geology (Figure 3.2), bore logs (Figures 6.1 and 6.2), and geological cross sections (Appendices B, C and D) revealed a number of lithologies that could provide suitable habitat within the deposits and surrounding areas. These units are listed below in a generalised stratigraphic sequence from the surface. The presence/ absence of these layers at each of the deposits, relative to the water table is noted below, and indicated via the locations of bore logs in Figures 6.1 and 6.2, and geological cross sections in Appendices B, C and D.

6.1.1 Surficial detritals (Quaternary alluvium/ colluvium)

This layer comprises alluvial and colluvial gravels, sands, silt, and clays that generally lack suitable pore spaces for subterranean fauna (coloured green and labelled "DET WASTE" or "DW" in Appendices B-D). Within each of the deposits, the surficial detritals did not appear to extend down to the water table, although north of Deposit C the water table was much closer to the surface (within 2 m) and in this area, saturated alluvial gravels following the creek line (hyporheos) would be expected to support stygofauna.





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0 700 1,400 2,800 4,200 km

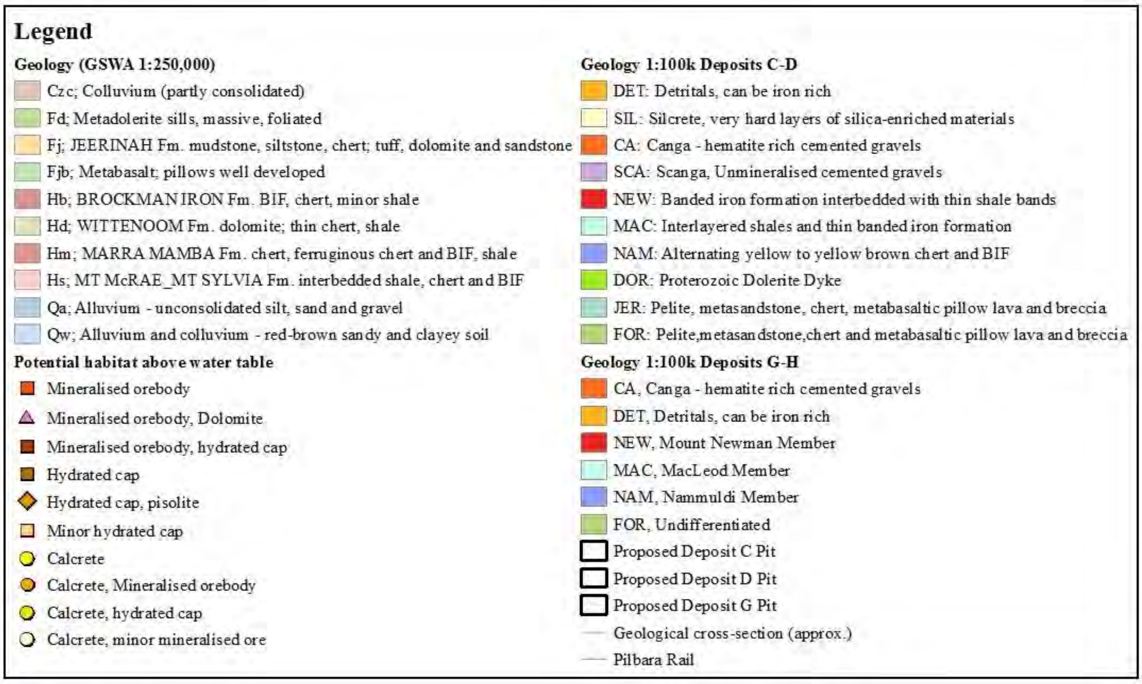
Rio Tinto Iron Ore - West Angelas Project

Deposits C, D, & G Subterranean Fauna Survey

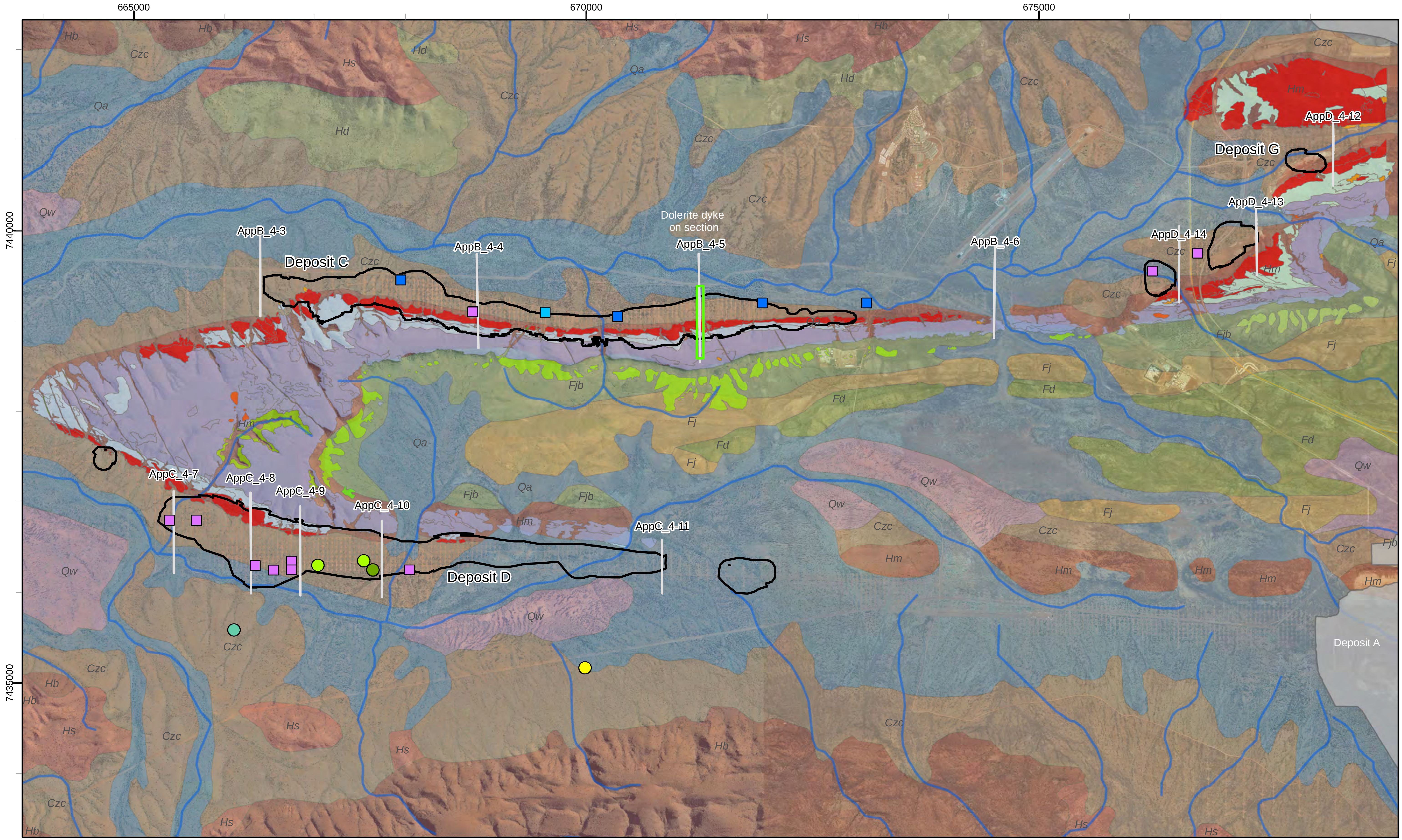
Fig. 6.1: Indicative troglofauna habitats (above water table) based on bore log information

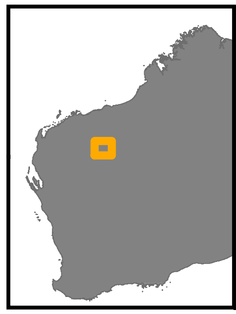
Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 24/05/2016



Legend for Figure 6.1





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0 700 1,400 2,800 4,200 km

Rio Tinto Iron Ore - West Angelas Project

Deposits C, D, & G Subterranean Fauna Survey

Fig. 6.2: Indicative stygofauna habitats (below water table) based on bore log information

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 24/05/2016

Legend

Geology (GSWA 1:250,000)
- Czc; Colluvium (partly consolidated)
- Fd; Metadolerite sills, massive, foliated
- Fj; JEERINAH Fm. mudstone, siltstone, chert; tuff, dolomite and sandstone
- Fjb; Metabasalt; pillows well developed
- Hb; BROCKMAN IRON Fm. BIF, chert, minor shale
- Hd; WITTENOOM Fm. dolomite; thin chert, shale
- Hm; MARRA MAMBA Fm. chert, ferruginous chert and BIF, shale
- Hs; MT McRAE_MT SYLVIA Fm. interbedded shale, chert and BIF
- Qa; Alluvium - unconsolidated silt, sand and gravel following drainage lines
- Qw; Alluvium and colluvium - red-brown sandy and clayey soil

Potential Stygofauna habitat
- Mineralised orebody
- Mineralised orebody, hydrated cap
- Hydrated cap
- Calcrete
- Calcrete, dolomite
- Calcrete, mineralised orebody
- Calcrete, mineralised orebody, dolomite

Geology 1:100k Deposits C-D
- DET: Detritals, can be iron rich
- SIL: Silcrete, very hard layers of silica-enriched materials
- CA: Canga - hematite rich cemented gravels
- SCA: Scanga, Unmineralised cemented gravels
- NEW: Banded iron formation interbedded with thin shale bands
- MAC: Interlayered shales and thin banded iron formation
- NAM: Alternating yellow to yellow brown chert and BIF
- DOR: Proterozoic Dolerite Dyke
- JER: Pelite, metasandstone, chert, metabasaltic pillow lava and breccia
- FOR: Pelite,metasandstone,chert and metabasaltic pillow lava and breccia

Geology 1:100k Deposits G-H
- CA, Canga - hematite rich cemented gravels
- DET, Detritals, can be iron rich
- NEW, Mount Newman Member
- MAC, MacLeod Member
- NAM, Nammuldi Member
- FOR, Undifferentiated
- Proposed Deposit C Pit
- Proposed Deposit D Pit
- Proposed Deposit G Pit
- Geological cross-section (approx.)
- Pilbara Rail

Legend for Figure 6.2

Some troglofauna species (such as nocticolid cockroaches) have been known to occur in near-surface, unconsolidated detrital formations such as alluvial fans and scree slopes where sufficient pore spaces exist (E. Volschenk pers. comm. 2016), but this would not be expected to form a major habitat for troglofauna at West Angelas.

6.1.2 Pisolite/ Calcrete (Cainozoic detrital formations)

Pisolite and calcrete deposits occurring deeper within the detrital layers can provide highly suitable habitats for troglofauna where above the water table, and stygofauna below the water table. While these two detrital formations are structurally and chemically different, they generally both provide highly suitable habitats because of the high degree of secondary weathering and porosity, and because their location near the surface enables rapid transport of nutrients and oxygen from the surface.

Appendices B-D show pisolite layers coloured orange and labelled “DET MIN” or “DM”, while calcrete was coloured yellow and not labelled. Pisolite was only present above water table in drill logs at Deposit G (Figure 6.1, Appendix D), while calcrete was present at all deposits both above and below the water table (in minor amounts at Deposit C and G, and in greater amounts at Deposit D) (Figures 6.1, 6.2). Geological cross-sections suggested a large calcrete deposit to the north of Deposit C, immediately beneath the surficial detritals (Appendix B). Both of these lithologies would be considered highly suitable for troglofauna (above the water table), and stygofauna (below water table).

6.1.3 West Angela Member (shale, dolomite, chert, BIF)

The West Angela Member of the Wittenoom formation (labelled ‘ANG’ and coloured beige in Appendices B-D) overlies the Marra Mamba Formation, comprising mainly shale and dolomite, with minor chert, BIF and shale near its base. Dolomite within the Wittenoom Formation may have potential to provide host cavities where extensive weathering or karstic formations occur (Woodward-Clyde 1998), but this is not expected to be the case in the vicinity of the deposits. Drill logs in each of the deposits showed a higher prevalence of shale rather than dolomite, which is known to be of much lower permeability (aquiclude) and non-cavernous (tight/ fresh), except in the immediate vicinity of major faults or fractures. At Deposit D, dolomite was recorded above the water table in only one bore log, but below the water table in several other bore logs at depths >100 m, often overlain by shale (Figures 6.1, 6.2). Assuming a lack of karstic features in the dolomite or widespread fracturing of the shale/ BIF and chert, the West Angela Member would be regarded as relatively unsuitable for subterranean fauna.

6.1.4 Hydrated hardcap

At Deposits C and G, the mineralised zone is overlain by a 'hydrated' hardcap (coloured deep brown and labelled 'BEDDED HYD' or 'HYD' Appendices B-D), which is inferred as being more highly weathered and cavernous, therefore more highly suitable for troglofauna and stygofauna. The hydrated cap outcrops in the mid slopes of the central part of Deposit C and then dips below the surface down slope and at the eastern and western ends (where it is thinner and overlain by detritals). At Deposit G, the hydrated zone is thicker and lies more consistently along the lower slopes and in the valley beneath the surficial detritals. Bore logs at Deposit C show the hydrated zone both above and below the water table, whereas at Deposit G it is mainly above water table.

6.1.5 Mineralised 'high grade' ore zone

Secondary oxidation and chemical weathering has produced a significant mineralised zone (appearing as martite-goethite) above the Nammuldi Members of the Marra Mamba Formation at each of the deposits, which is inferred as the main target for mining (iron concentrations >60 %). These weathering processes form interconnected cavities in the rock that provide habitat for subterranean fauna, therefore this layer is among the most highly suitable for troglofauna and stygofauna. The thickness of this layer varied between each deposit and along the length of the deposits (coloured red and labelled 'BEDDED MIN' or 'MIN' in Appendices B-D). The mineralised zone was generally thickest in the centre of Deposits C and D, whereas at the eastern and western margins it was shallower, and split into smaller pods. At both Deposit C and D, the mineralised zone occurred above and below water table, while at Deposit G it was above water table. As this enriched zone plunges to greater depths in the central parts of Deposits C and D, it would be expected to become less likely to provide suitable cavities for subterranean fauna habitat (J. Barnett pers. comm. 2016).

6.1.6 Mt Newman Member (non-mineralised/ 'low grade' BIF)

The Mt Newman Member is the top-most layer of the Marra Mamba Formation in the vicinity of the deposits, and therefore the most likely to have undergone fracturing or weathering required to create subterranean fauna habitat. Appendices B-D show the Mt Newman Member as a series of layers coloured medium blue and labelled 'N2U', 'N2L', and 'NE1'. Fractured bedrock habitats may occur where significant folding or faulting has deformed the Mt Newman Member such as the eastern and western margins of Deposits C and D, or where it has been intruded by dolerite dykes in central Deposit C and western Deposit D (coloured bright green in Appendices B-C). Significant fracture zones are also likely to occur where BIFs outcrop higher in the landscape towards the centre of the Anticline (north of Deposit D, south of Deposit C) (J. Barnett pers. comm. 2016).

Significant aquifers are known to form in BIF fractures, and there is potential to support stygofauna, although these habitats may be less well connected and more restricted than those in detrital formations. Groundwater drawdown in such habitats tends to transmit along fracture trends, or in unpredictable patterns, and may be constrained by less permeable strata. Above the water table, fractured BIF may provide suitable habitat for troglofauna, but this type of habitat would be expected to be less well-connected than secondarily weathered lithologies, and the frequency and size of fractures would be expected to decline at depth (J. Barnett pers. comm. 2016).

6.1.7 MacLeod/ Nammuldi Members (chert/ BIF/ shale bedrock)

The underlying MacLeod and Nammuldi Members of the Marra Mamba Formation (respectively coloured light blue and dark blue in Appendices B-D, and labelled 'MAC' and 'NAM') are expected to comprise mostly fresh chert, BIF, and shale in the vicinity of the deposits. Occurring below the mineralised orebody and Mt Newman BIF layers, these lithologies are expected to comprise mainly fresh rock and would not be regarded as suitable habitat for subterranean fauna; however, where they outcrop higher in the landscape towards the centre of the Wonmunna Anticline, they could become sufficiently fractured to support troglofauna (J. Barnett pers. comm. 2016). Aerial photography shows deep gorges occurring at regular intervals along stress lines in the central/ western part of the anticline, which is highly indicative of deep fracture zones within these BIF layers (Figure 6.2, J. Barnett pers. comm. 2016). Such areas could potentially form a secondary habitat for troglofauna, but would not be expected to be as extensive or well-connected as the primary habitats within the mineralised orebodies and calcrete/ pisolite deposits.

6.1.8 Geomorphological features

Particularly where occurring near the water table, intrusive formations such as dykes (coloured bright green and labelled 'DOR' in Appendices B-D) and geomorphological features such as folding and faulting can produce sudden, localised changes in permeability/ porosity. This can have the effect of dividing the more porous subterranean habitats (creating a geomorphological barrier between layers or areas of suitable habitats) and affecting groundwater flows (J. Barnett pers. comm. 2016). Geological and hydrogeological reports (RTIO 2015a, b) indicated the presence of a dolerite dyke that is assumed to form a barrier to groundwater flow in the middle of Deposit C (Figure 6.2). Large fault zones are also apparent from cross sections at the far eastern and western ends of Deposit C (Appendix B). Although these do not appear to have affected the secondarily weathered units expected to be most suitable for subterranean fauna (*i.e.* the mineralised zone, hardcap, and calcrete layers), they may have produced fracture zones in the underlying BIF, which could affect groundwater flows and/ or the suitability of subterranean habitats. Cross sections at Deposit D also showed a number of dykes throughout the profile in the far eastern and western ends, as well as minor faulting (Appendix C).

6.2 Groundwater characteristics

The aquifer at Deposit C is assumed to be associated with the mineralised zone of the Mount Newman Member, as well as fractures within the MacLeod Member, and the overlying Wittenoom Formation. Measurements from piezometers installed in 2014 suggest the water table sits between approximately 55 mbgl in the east and 67 mbgl in the west of Deposit C. Secondary permeability within the valley detritals to the north of Deposit C is well developed, and the water table is much closer to the surface (within approximately 2 mbgl beneath the creek bed at hole RC15WAC0416 at the time of survey).

The aquifer at Deposit D is also assumed to be associated with the mineralised zone of the Mount Newman Member, as well as fractures within the MacLeod Member and the Wittenoom Formation. Measurements from piezometers suggest the water table sits at approximately 58 mbgl throughout the deposit, with a relatively flat gradient.

No water table elevation data was available for Deposit G, although one hole sampled during the survey did intercept groundwater at approximately 63 mbgl.

Groundwater data was available from only a limited number of holes during the survey due to the practical difficulties of bailer sampling at depth. Table 6.1 shows the physicochemical measurements taken from each hole during the survey. The physicochemical conditions measured were within the ranges commonly found where stygofauna communities are known to occur within the Pilbara region (Halse *et al.* 2014, Humphreys 2008, Humphreys *et al*. 2009); namely neutral to slightly alkaline (pH 6-8), fresh water (EC <1500 µS/cm), with high levels of dissolved oxygen (>75% saturation), and positive redox potential (Table 6.1).

Table 6.1: Groundwater physicochemical measurements recorded during the survey (where bailer sampling was possible)

Deposit	C (ref)	C (ref)	D (ref)	D (dep)	D (ref)	G (dep)
Bore code	RC15 WAC0416	RC15 WAC0413	RC14 WAD0346	RC13 WAD0297	RC12 WAD0200	MB15 WAG0002
Groundwater depth (mbgl)	1.92	4.8	45.12	47.52	71.52	30.24
Total depth of hole (mbgl)	24	19.2	46.56	52.32	76.8	55.68
pH	7.06	6.62	7.01	7.34	7.52	7.25
EC µS/cm	193.3	228	874	1172	1241	1429
Diss O_2 (ppm)	6.42	7.19	6.06	6.3	6.26	7.82
Diss O_2 (% sat)	84.9	97.6	77.4	80.3	82.1	90.4
ORP (mV)	105	160		133	143	136
Notes	High turbidity, possible O_2 malfunction	Turbid water				

7 RISK ASSESSMENT

7.1 Types of impacts to troglofauna

Direct impacts on troglofauna occur as a result of the removal of habitat during mining. The potential direct impact area for troglofauna is therefore the proposed pit boundaries at each of the deposits. Although indirect impacts such as shock and vibration from blasting, or desiccation from excavation and groundwater drawdown may extend beyond the pit boundaries, the available project information currently precludes assessment of these risks, therefore this section has focussed on the direct impacts of mining only.

7.2 Risks to troglofauna habitat

The habitat assessment found that suitable primary habitats for troglofauna comprise (where occurring above the water table):

- the pisolite and calcrete formations in the detrital valleys adjacent to the deposits;
- the mineralised ore body and hydrated hardcap, and
- the fractured and weathered upper layers of the Marra Mamba Formation (particularly the Mt Newman Member).

Secondary habitats (*i.e.* strata that may be habitable in certain situations, but wouldn't be expected to be the main habitat for troglofauna) may also occur in the lower Members of the Marra Mamba Formation (*i.e.* MacLeod and Nammuldi) occurring higher in the landscape towards the centre of the Anticline between Deposit C and D, where these layers occur near to the surface and are subject to significant weathering and fracturing.

Based on current information, the primary habitats for troglofauna do not appear to be limited to the proposed deposits. This is due to the wider extent of other adjoining strata such as calcrete, Mt Newman Member BIF, and pisolite, as well as the nearby secondary habitats such as fracture zones within the MacLeod and Nammuldi Member BIF. These primary and secondary habitats are expected to be suitable for any of the troglofauna species occurring within the proposed deposits, and although there may be a degree of heterogeneity inherent within any of these formations, there does not appear to be any clear geological barriers between the primary and secondary habitat layers inside and outside of the proposed deposits.

7.3 Risks to troglofauna species

Nine morphospecies collected during the current and previous troglofauna sampling have only been recorded from within the deposit boundaries at Deposits C, D, and G, comprising:

- two beetles: *Hydrobiomorpha* sp. indet., and Anillini sp. indet.;
- two isopods: Armadillidae sp. indet., and Isopoda sp. indet.;
- a plant bug: Meenoplidae sp. indet.;
- a silverfish: Atelurinae sp. indet.;
- a springtail: Cyphoderidae sp. indet.; and
- two symphylans: Scutigerellidae sp. indet., and Symphyla sp. indet.

Based on current taxonomic and ecological information, and the likely extent of suitable habitats for troglofauna beyond the deposit boundaries, the risks to all of these taxa are considered to be moderate (Table 7.1). Figure 7.1 shows the current records of each of these taxa and the inferred extent of potential troglofauna habitats relative to the proposed deposit boundaries (based on current geological information).

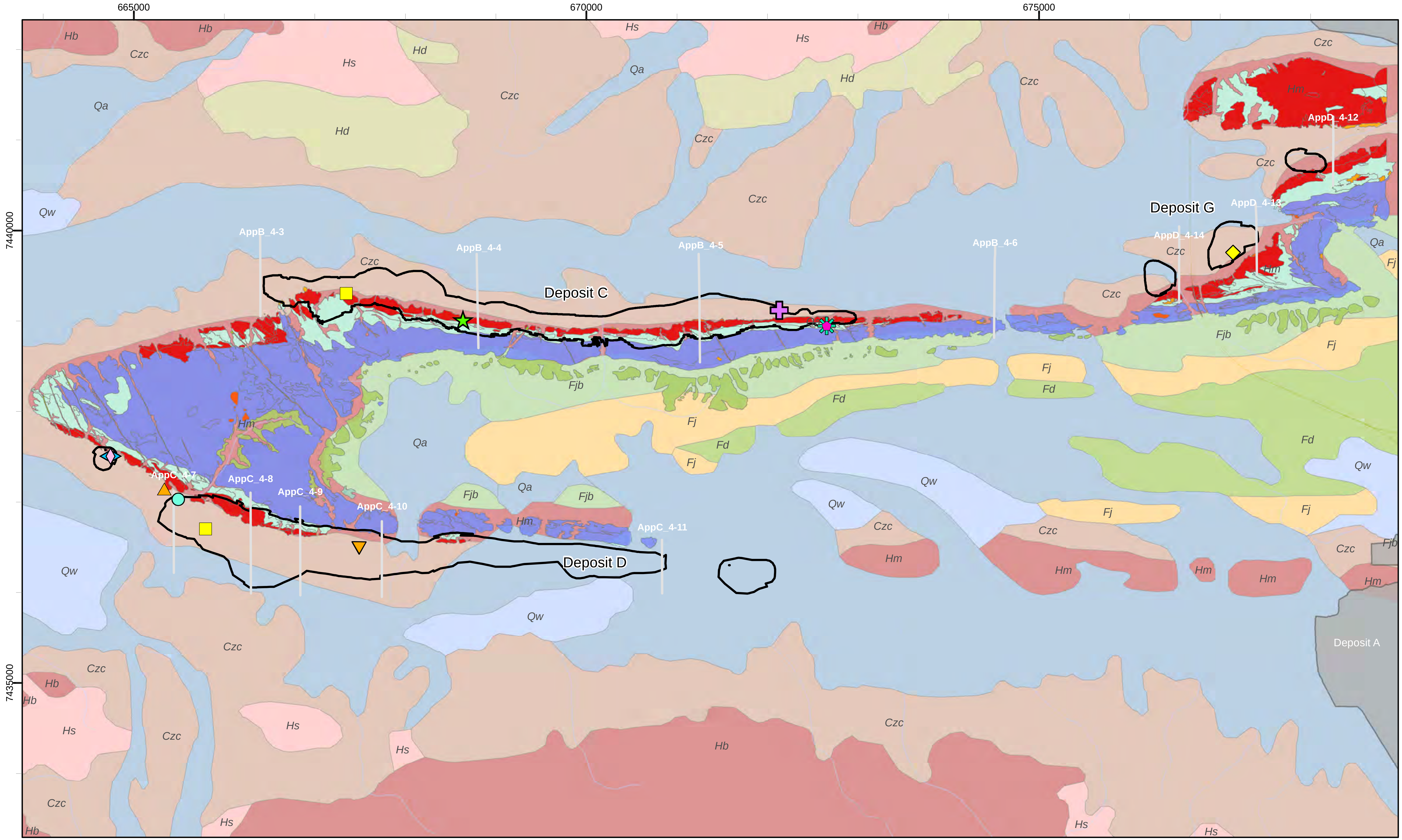
The current occurrence of these nine troglofauna taxa within the proposed deposits is at least partly attributed to sampling artefacts such as the higher numbers of suitable drill holes within deposit boundaries and the prevalence of angled drill holes that preclude scrape sampling, which is known to be complementary to litter trapping (Halse *et al*. 2014). Many troglofauna taxa are rare and difficult to detect, especially when primarily using litter traps, as was the case for the previous survey (Ecologia 2013). Particularly for the rarer and less vagile taxa, detecting a species throughout the full extent of its potential habitat or range can require a very high, repeated survey effort over a long period of time, and even in this case, the extent of sampling is still constrained by the locations of suitable drill holes.

Table 7.1: Troglofauna morphospecies at risk of impact from proposed development of Deposits C, D and G

Taxon	C	D	G	Outside proposed deposits	Subterranean status, regional context	SRE Status, regional context	Likely extent of habitat	Risk of impact
Coleoptera								
Anillini sp. indet.	■				**Troglobite** Many troglobitic species are known to occur	**Potential SRE (A)** Highly restricted species are known to occur	**Beyond Deposit C** Taxon occurs close to boundary, habitat likely throughout Orebody/ Mt Newman Member	Moderate
Hydrobiomorpha sp. indet.		■			**Potential troglobite** No previous records of troglobites in this taxon.	**Potential SRE (A)** No previous records of SREs in this taxon. Possible if troglobitic.	**Beyond Deposit D** Taxon occurs close to boundary, habitat likely throughout Orebody/ Mt Newman Member/ Calcrete	Moderate
Collembola								
Cyphoderidae sp. indet.	●				**Potential troglobite** Few previous records of troglobites in this taxon.	**Potential SRE (A)** Possibly SRE if troglobitic.	**Beyond Deposit C** Taxon occurs close to boundary, habitat likely throughout Orebody/ Mt Newman Member	Moderate
Hemiptera								
Meenoplidae sp. indet.	●	●	*■	Deposit H *■	**Potential troglobite** Both troglobitic and trogloxenic species known to occur	**Potential SRE (A)** Both SRE and widespread species known to occur, even in troglobites	**Beyond Deposits C and D** Taxon occurs across Deposits C and D. Habitat likely throughout Orebody/ Mt Newman Member/ Pisolite/ Calcrete	Moderate
Isopoda								
Armadillidae sp. indet		●			**Troglobite** Many troglobitic species are known to occur	**Confirmed SRE** Highly restricted species are known to occur	**Beyond Deposit D** Taxon occurs close to boundary, habitat likely throughout Orebody/ Mt Newman Member/ Calcrete	Moderate
Isopoda sp. indet.		●			**Potential troglobite** Both troglobitic and soil species known to occur	**Potential SRE (A)** Likely to be SRE if troglobitic	**Beyond Deposit D** Taxon occurs close to boundary, habitat likely throughout Orebody/ Mt Newman Member/ Calcrete	Moderate
Symphyla								
Scutigerellidae sp. indet.	*●			Deposit F *▲	**Potential troglobite** Both troglobitic and soil species known to occur	**Potential SRE (A)** Highly restricted troglobitic species are known to occur	**Beyond Deposit C** Taxon occurs close to boundary, potentially across several deposits. Habitat likely throughout Orebody/ Mt Newman Member	Moderate

Taxon	C	D	G	Outside proposed deposits	Subterranean status, regional context	SRE Status, regional context	Likely extent of habitat	Risk of impact
Symphyla sp. indet.	●				**Potential troglobite** Both troglobitic and soil species known to occur	**Potential SRE (A)** Highly restricted troglobitic species are known to occur	**Beyond Deposit C** Taxon occurs in same habitat as Scutigerellidae sp. indet., likely habitat throughout Mt Newman Member	Moderate
Thysanura								
Atelurinae sp. indet.		*■		Outside Deposit D *●	**Potential troglobite** Both troglobitic and soil species known to occur	**Potential SRE (A)** Both SRE and widespread species known to occur	**Beyond Deposit D** Specimen from current survey is beyond boundary in habitat continuous with previous record inside Deposit D (Orebody/ Mt Newman Member/ Calcrete)	Moderate
Total species	**5**	**5**	**1**	**2**				

Note: '●' indicates specimen detected in current survey; '■' represents specimen detected by Ecologia (2013); '▲' represents specimen detected by Biologic (2016). Asterisk '*' indicates potential taxonomic alignment, yet to be confirmed.



Rio Tinto Iron Ore - West Angelas Project

Deposits C, D, & G Subterranean Fauna Survey

Fig. 7.1: Troglofauna taxa and habitats potentially at risk from mining

biologic Environmental Survey

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0 700 1,400 2,800 4,200 km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 24/05/2016

Legend

- Proposed Deposit C Pit
- Proposed Deposit D Pit
- Proposed Deposit G Pit
- Geological cross-section (approx.)
- Pilbara Rail

Geology (GSWA 1:250,000)

- Czc; Colluvium (partly consolidated)
- Fd; Metadolerite sills, massive, foliated
- Fj; JEERINAH Fm. mudstone, siltstone, chert; tuff, dolomite and sandstone
- Fjb; Metabasalt; pillows well developed
- Hb; BROCKMAN IRON Fm. BIF, chert, minor shale
- Hd; WITTENOOM Fm. dolomite; thin chert, shale
- Hm; MARRA MAMBA Fm. chert, ferruginous chert and BIF, shale
- Hs; MT McRAE_MT SYLVIA Fm. interbedded shale, chert and BIF
- Qa; Alluvium - unconsolidated silt, sand and gravel
- Qw; Alluvium and colluvium - red-brown sandy and clayey soil

Geology 1:100k Deposits G-H

- CA, Canga - hematite rich cemented gravels
- DET, Detritals, can be iron rich
- NEW, Mount Newman Member
- MAC, MacLeod Member
- NAM, Nammuldi Member
- FOR, Undifferentiated

Geology 1:100k Deposits C-D

- DET: Detritals, can be iron rich
- SIL: Silcrete, very hard layers of silica-enriched materials
- CA: Canga - hematite rich cemented gravels
- SCA: Scanga, Unmineralised cemented gravels
- NEW: Banded iron formation interbedded with thin shale bands
- MAC: Interlayered shales and thin banded iron formation
- NAM: Alternating yellow to yellow brown chert and BIF
- DOR: Proterozoic Dolerite Dyke
- JER: Pelite, metasandstone, chert, metabasaltic pillow lava and breccia
- FOR: Pelite,metasandstone,chert and metabasaltic pillow lava and breccia

Troglofauna from previous sampling (Ecologia 2013)

- Anillini sp. indet., Troglobite, Potential SRE (A)
- Atelurinae sp. indet., Potential troglobite, Potential SRE (A)
- Hydrobiomorpha sp. indet., Potential troglobite, Potential SRE (A)
- Meenoplidae sp. indet., Potential troglobite, Potential SRE (A)

Troglofauna from current sampling

- Armadillidae sp. indet., Troglobite, Confirmed SRE
- Atelurinae sp. indet., Potential troglobite, Potential SRE (A)
- Cyphoderidae sp. indet., Potential troglobite, Potential SRE (A)
- Isopoda indet., Potential troglobite, Potential SRE (A)
- Meenoplidae sp. indet., Potential troglobite, Potential SRE (A)
- Scutigerellidae sp. indet., Potential troglobite, Potential SRE (A)
- Symphyla indet., Potential troglobite, Potential SRE (A)

Legend for Figure 7.1

7.4 Types of impacts to stygofauna

Direct impacts on stygofauna comprise the removal of porous strata from mining below the water table, and removal of groundwater by dewatering. The propagation of groundwater drawdown throughout other suitable habitats nearby the mining deposits is also considered to be a direct impact, regardless of whether these habitats feature the same geology as the mining target.

7.5 Risks to groundwater habitats

Until groundwater drawdown modelling is available for each of the various deposits, it is not possible to make a precise assessment of the extent of habitats inside and outside of impact areas. Nevertheless, the indicative direction and extent of drawdown can be broadly outlined on the basis of the current geological and hydrogeological information.

There are three major groundwater habitats of relevance to stygofauna at West Angelas:

1. The central plateau (Jeerinah Formation, occurring between the current deposits and extending eastwards between Deposit A and B);
2. The orebody aquifers at Deposit C and D (Deposit G is omitted as the mining targets in this area appear to be above the water table); and
3. The detrital aquifers in the flanking valleys (to the north of Deposit C and to the south of Deposit D).

Central Plateau

In the central plateau, groundwater levels are much higher than in the flanking valleys (where the deposits occur), and the groundwater habitats of these areas appear to be hydrogeologically separated due to the low permeability of the Jeerinah Formation and Nammuldi Member of the Marra Mamba Iron Formation (MMIF), which contains a high proportion of shale. Previous surveys over multiple rounds of sampling (Ecologia 1998, Biota 2002, 2003, 2005) repeatedly found stygofauna communities within the near-surface aquifers of the central plateau, although due to a lack of species-level identifications the fauna from this area are unable to be compared with current results.

Steep hydraulic gradients on the flanks of the plateau (Woodward-Clyde 1998, Dodson 2006) suggest that dewatering at Deposits C and D would be unlikely to affect groundwater levels in the Jeerinah Formation of the central plateau. As such, stygofauna assemblages in this area may be considered to be less at risk of impact than those in the flanking valleys, although this assumption requires validation when groundwater modelling is available. There is also a chance that some of the stygofauna occurring in the central plateau may represent the same species as those found in the orebodies and flanking valleys, although this cannot be confirmed on the basis of current information.

Orebody Aquifers

The orebody deposits are distributed on the northern and southern limbs of the Wonmunna Anticline, which has an east-west axis and plunges towards the west. Deposits C and D are near the western plunging nose of the Anticline, with Deposit C on the north side and Deposit D on the south. Deposit G is further to the east on the north side of the Anticline, and is above the water table (therefore no dewatering is required).

The ‘orebody aquifers’ occur within the highly permeable mineralised zones in the upper two Members of the Marra Mamba Iron Formation, the Mount Newman and MacLeod Members. Current information (RTIO 2015b) indicates that the water table at Deposit C sits between 55 mbgl in the east and 67 mbgl in the west, with a steep gradient occurring in the middle of the deposit in the area of a dolerite dyke that is assumed to be a barrier to groundwater flow. Based on current mine plans, approximately 53 m of dewatering is required to mine Deposit C (RTIO 2015b). Likewise, the water table at Deposit D sits at approximately 58 mbgl throughout the deposit, and based on current mine plans, approximately 105 m of dewatering is required to mine Deposit D (RTIO 2015b).

Groundwater drawdown within the orebody aquifers is expected to propagate mainly along strike (east-west). This may be complicated by fracture zones within the MMIF or groundwater barriers, such as the dyke reported in the central area of Deposit C (RTIO, 2015d). Transmission of drawdown from the orebody aquifer beyond the two deposits to the west will be limited by the westward-plunging nose of the Wonmunna Anticline, which is overlain by less permeable shales. A high level of connectivity between the aquifers west of Deposit A and throughout Deposit D has been inferred; therefore drawdown from Deposit D would be expected to propagate further eastwards towards the western end of Deposit A, but no further to the east, owing to a series of inferred groundwater barriers (RTIO 2015b, Dodson 2006). There have been no stygofauna species recorded in this area to date.

Transmission of drawdown from the orebody aquifers across strike (north-south) below the flanking valleys (north of Deposit C and south of Deposit D) is expected to be limited by the overlying West Angela Member of the Wittenoom Formation, which is largely composed of low permeability shales; however, where mine-pit boundaries intersect the highly permeable valley-fill detrital deposits, drawdown may propagate throughout the valley, as discussed further below.

Valley Detritals

The valley-fill detrital deposits to the north of Deposit C and to the south of Deposit D comprise mainly calcrete and unconsolidated alluvial gravels (hyporheos) that are highly permeable and provide near-surface groundwater habitats for stygofauna. Where these habitats are intercepted by proposed mine-pits, significant dewatering is expected to be required to facilitate dry mining conditions. Drawdowns from long-term dewatering in the detritals may in time extend across both the valleys north of Deposit C and to the south of Deposit D, as far as the ridges composed of less permeable lithologies (Wittenoom Dolomite, Mount McRae Shale and Brockman Iron Formation) on the far sides of the valleys.

Owing to the rapid transmission of drawdown through highly permeable superficial strata, the detrital deposits adjacent to the pits are likely to be completely dewatered, with drawdown effect progressively declining across the valley, to potentially only a few metres at the far edges. In the absence of any less permeable barriers, such as dykes or shales within the valley-fill detritals to the east and west of the mining deposits, groundwater drawdown would also be expected to propagate throughout the flanking valleys, well beyond the immediate area north and south of the deposits.

7.6 Risks to stygofauna species

Despite the limited groundwater drawdown information available, 11 morphospecies of stygofauna (including Enchytraeidae) occurring within the proposed deposit boundaries and nearby (<1.5 km from the deposits) are expected to be potentially affected by groundwater drawdown, comprising:

- two amphipods: *Kruptus* sp. \`WA\` and *Maarrka* sp. \`WA\`
- two bathynellaceans: *Atopobathynella* sp. \`WA\` and Bathynellidae sp. \`WA\`,
- three copepods: *Australocamptus* sp. \`B13\` and Parastenocaris sp. indet., and *Thermocyclops* sp. \`WA\`; and
- four worms: Aeolosomatidae sp. indet., Enchytraeidae sp. indet.[1], Oligochaeta sp. indet., and Turbellaria sp. indet.

Table 7.2 provides details of the risks to each of these taxa based on current taxonomic and ecological information, and the extent of suitable groundwater habitats for relative to the expected groundwater drawdown (based on available hydrogeological information).

[1] Note: Enchytraeidae are tentatively treated as part of the stygofauna herein, although it is acknowledged that they may also inhabit water films in air-filled subterranean habitats, and thus the risks of groundwater drawdown may not be as pronounced for this taxon.

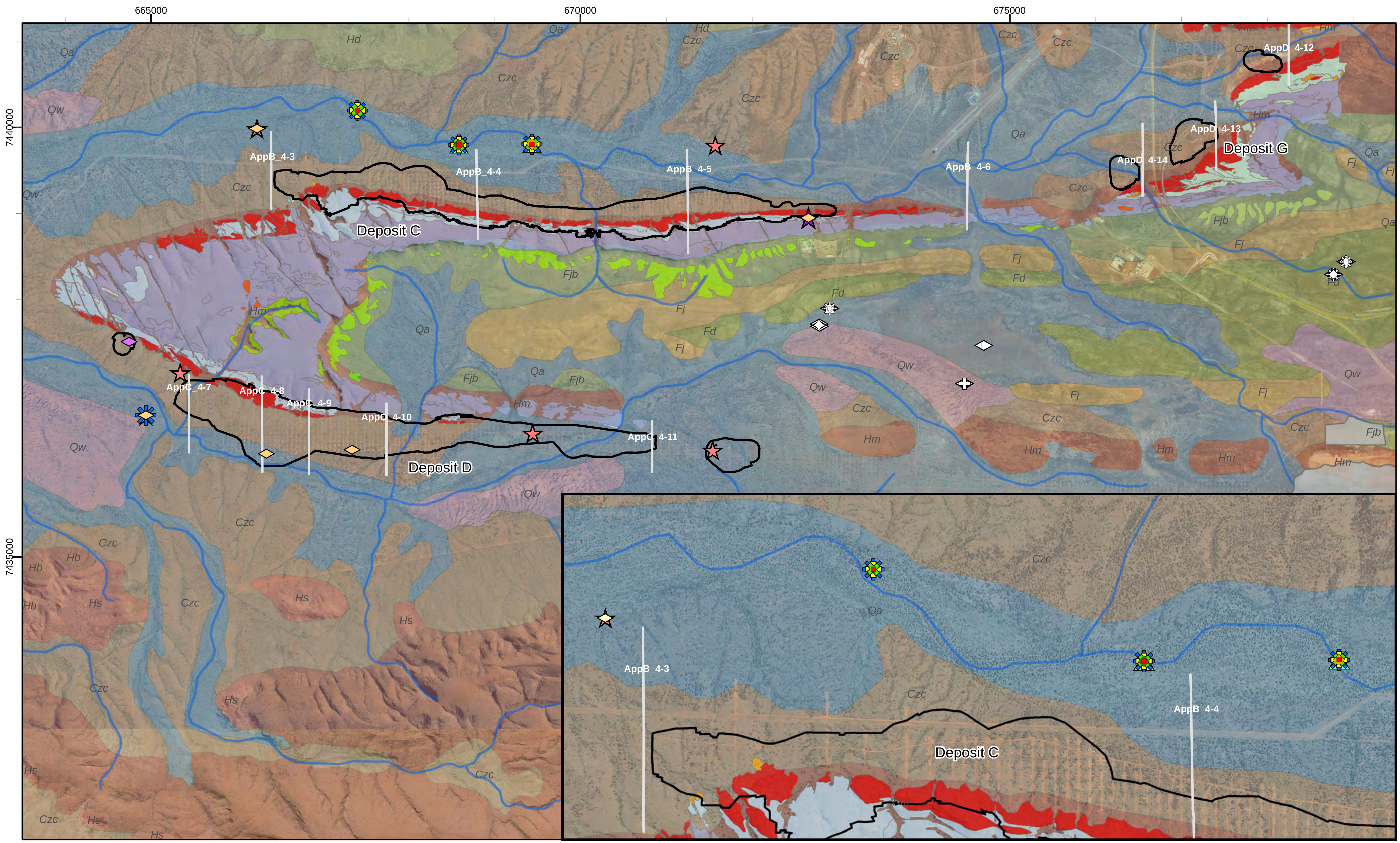
Figure 7.2 shows the occurrence of each of these morphospecies relative to the inferred groundwater habitats within and surrounding the proposed deposits. Groundwater drawdown extent has not been mapped, as this information is not currently available, but notes on the expected direction and propagation of drawdown (based on available hydrogeological information) have been added for each major unit.

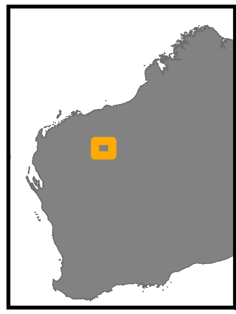
Table 7.2: Stygofauna morphospecies at risk of impact from proposed development of Deposits C, D and G and groundwater drawdown.

Taxon	C inside	C nearby	D inside	D nearby	Other local records	Subterranean status, regional context	SRE status, regional context	Occurrence relative to likely drawdown extent	Risk of impact
Amphipoda					*■ Dep B, CP, TCB				
Kruptus sp. \`WA\`	●	●	●	●		**Stygobite** Stygobitic taxa known throughout the region	**Potential SRE (E)** Stygobitic taxa range from widespread to highly range restricted	All current records likely within drawdown, but may also occur in CP/ TCB/ regionally	Mod - High
Maarrka sp. \`WA\`			●			**Stygobite** Stygobitic taxa known throughout the region	**Potential SRE (E)** Stygobitic taxa range from widespread to highly range restricted	All current records within Deposit D, but may also occur in CP/ TCB/ regionally	Mod - High
Bathynellacea					*■ Dep B, CP, TCB				
Atopobathynella sp. \`WA\`		●				**Stygobite** Obligate stygobitic taxon, known throughout the region	**Potential SRE (E)** Group is almost always highly range restricted	All current records likely within drawdown, but may also occur in CP/ TCB	High
Bathynellidae sp. \`WA\`		●				**Stygobite** Obligate stygobitic taxon known throughout the region	**Potential SRE (E)** Group is almost always highly range restricted	All current records likely within drawdown, but may also occur in CP/ TCB	High
Cyclopoida					*■ CP, TCB				
Thermocyclops sp. \`WA\`		●				**Stygobite** Stygobitic taxa known throughout the region	**Potential SRE (E)** Stygobitic taxa range from widespread to range restricted	All current records likely within drawdown, but may also occur in CP/ TCB/ regionally	Mod - High
Harpacticoida					*■ CP, TCB				
Australocamptus sp. \`B13\`		●				**Stygobite** Stygobitic taxa known throughout the region	**Potential SRE (E)** Group is almost always highly range restricted	All current records likely within drawdown, but may also occur in CP/ TCB	High
Parastenocaris sp. indet.		●				**Stygobite** Stygobitic taxa known throughout the region	**Potential SRE (A)** Stygobitic taxa range from widespread to range restricted	All current records likely within drawdown, but may also occur in CP/ TCB	Mod - High

Taxon	C inside	C nearby	D inside	D nearby	Other local records	Subterranean status, regional context	SRE status, regional context	Occurrence relative to likely drawdown extent	Risk of impact
Polychaeta									
Aeolosomatidae sp. indet.	●					**Potential stygobite** Poorly known regionally, rarely collected from groundwater	**Potential SRE (A)** Limited taxonomic/ ecological information	All current records likely within drawdown, unclear whether restricted to groundwater	Mod - High
Haplotaxida									
Enchytraeidae sp. indet.		●		●	*▲ Dep F, CP	**Stygophile/ Troglophile** Can inhabit groundwater and moist air-filled habitats. May not be restricted to groundwater	**Potential SRE (A)** Regional DNA studies showed widespread and SRE species	All current records likely within drawdown, but may not be restricted to groundwater	Mod-Low
Oligochaeta					*■ Dep B, CP				
Oligochaeta sp. indet.		●		●		**Potential stygobite** Regional DNA studies suggested stygobitic or stygophilic species	**Potential SRE (A)** Regional DNA studies showed widespread and SRE species	All current records likely within drawdown, but may also occur in CP	Mod-High
Turbellaria					*■ Dep B, CP				
Turbellaria sp. indet.		●				**Potential stygobite** Poorly known regionally, but group has been collected from previous surveys	**Potential SRE (A)** Poorly known regionally, but group has been collected from previous surveys	All current records likely within drawdown, but may also occur in CP	Mod-High
Total	**2**	**7**	**2**	**2**	**7**				

Note: '●' indicates specimen detected during current survey; '■' represents specimens detected by Ecologia (1998, 2002, 2005) or Biota (2003, 2008b); '▲' represents specimen detected by Biologic (2016). 'CP' = Central Plateau, 'TCB' = Turee Creek Bore field. Asterisk '*' indicates potential taxonomic alignment, yet to be confirmed.





Rio Tinto Iron Ore - West Angelas Project

Deposits C, D, & G Subterranean Fauna Survey

Fig. 7.2: Stygofauna taxa and habitats potentially at risk from groundwater drawdown

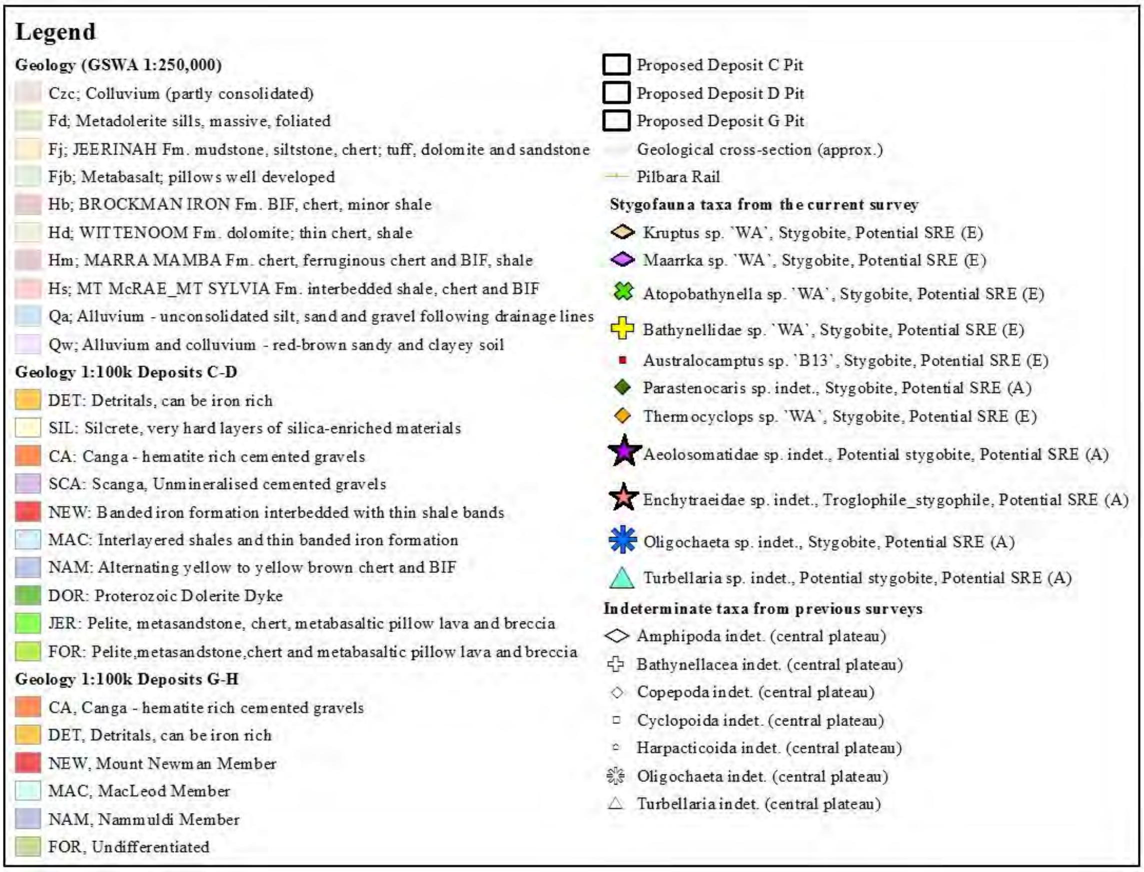
N

1:40,000

0 700 1,400 2,800 4,200 km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Size A3. Created 24/05/2016



Legend for Figure 7.2

8 CONCLUDING REMARKS

The risk assessment for subterranean fauna was based upon the likelihood that any particular species of troglofauna or stygofauna would be restricted to habitats likely to be directly impacted by the proposed development at Deposits C, D, and G. For troglofauna, the direct impact area comprised the proposed deposit boundaries, whereas for stygofauna, the direct impact area included groundwater habitats likely to be affected by drawdown associated with mining (which is yet to be modelled in detail).

Nine morphospecies collected during current and previous troglofauna surveys have only been recorded from within the deposit boundaries at Deposits C, D, and G, comprising:

- two beetles: *Hydrobiomorpha* sp. indet., and Anillini sp. indet.;
- two isopods: Armadillidae sp. indet., and Isopoda sp. indet.;
- a plant bug: Meenoplidae sp. indet.;
- a silverfish: Atelurinae sp. indet.;
- a springtail: Cyphoderidae sp. indet.; and
- two symphylans: Scutigerellidae sp. indet., and Symphyla sp. indet.

The current occurrence of these taxa is at least partly attributed to sampling artefacts such as the high proportion of drill holes within the deposits, and the prevalence of angled holes that preclude scrape sampling (which is known to be complementary to litter trapping). Especially for the rarer and less vagile taxa, detecting troglofauna throughout the full extent of their potential habitat can require a very high, repeated survey effort, and this is inherently restricted to the locations of suitable holes.

Current habitat information suggested that the primary and secondary habitats for troglofauna do not appear to be limited to the proposed deposits. Geological maps and cross sections have shown a range of suitable habitat strata above the water table within and near each of the proposed deposits, including calcrete, pisolite, the mineralised orebodies (and their hydrated hardcap), Mt Newman Member BIF, and potentially, fracture zones within the MacLeod and Nammuldi Member BIF. These lithologies, which are likely to provide suitable habitat for any of the troglofauna species occurring within the deposits, appear to extend well beyond the deposit boundaries at C, D, and G. Although a degree of heterogeneity within and between these strata would be expected, there does not appear to be any clear geological barriers between the various suitable habitat layers inside and outside of the proposed deposits.

Based on current taxonomic and ecological information, and the likely extent of a range of suitable geological habitats beyond the deposit boundaries, the risk of impact to any of the troglofauna morphospecies currently known from within the proposed deposits is considered to be moderate.

For stygofauna, the risk assessment is currently constrained by the lack of groundwater drawdown modelling. As such, the current assessment is based on the inferred direction and rate of drawdown propagation (based on available hydrogeological data) within the three major groundwater habitats at West Angelas, comprising:

- the central plateau, composed of the Jeerinah Formation in the middle of the Wonmunna Anticline – this area is hydrogeologically separated from the proposed deposits and is unlikely to be affected by drawdown;
- the orebody aquifers at Deposits C and D, along the northern and southern flanking slopes of the Wonmunna Anticline – likely to be dewatered to a depth approximately 5-10 m below the pit floor (approximately 53 m and 105 m below current water levels at C and D respectively). Groundwater drawdown in the orebody aquifers should mainly propagate along strike (east-west) and be contained within the Wonmunna Anticline; and
- the detrital aquifers (calcrete, pisolite, and unconsolidated alluvials) in the valleys to the north of Deposit C and to the south of Deposit D – likely to be intercepted by excavation of pits and thereby dewatered in the vicinity of the deposits, with groundwater drawdown propagating radially throughout the valley to an unknown extent.

Previous surveys within the central plateau recorded a range of indeterminate stygofauna taxa (amphipods, bathynellaceans, copepods, ostracods, oligochaetes), of the same higher order taxa as the specimens from the current survey, but species-level identifications are unresolved. These taxa are not expected to be affected by drawdown from the proposed development.

On current information, 11 stygofauna morphospecies (including Enchytraeidae) occur within the orebody and valley detrital aquifers (within 1.5 km from the deposits) that are expected to be affected by groundwater drawdown, comprising:

- two amphipods: *Kruptus* sp. \`WA\` and *Maarrka* sp. \`WA\`
- two bathynellaceans: *Atopobathynella* sp. \`WA\` and Bathynellidae sp. \`WA\`,
- three copepods: *Australocamptus* sp. \`B13\` and Parastenocaris sp. indet., and *Thermocyclops* sp. \`WA\`; and
- four worms: Aeolosomatidae sp. indet., Enchytraeidae sp. indet., Oligochaeta sp. indet., and Turbellaria sp. indet.

While it would be reasonable to assume that some, if not all, of these stygofauna morphospecies may occur further afield within the valley detrital aquifers beyond the Study Area (particularly to the west, following the direction of groundwater flow), the extent to which this area would be affected by groundwater drawdown is currently unclear. There is also a reasonable likelihood that some of these morphospecies may have been previously collected from the central plateau, although this is unable to be confirmed at the current time due to a lack of species-level identifications.

Based on current information, the risks of impact to stygofauna taxa found at or near the proposed deposits range from moderate-high to high (with the exception of Enchytraeidae sp. indet.), based mainly on the likelihood of SRE species within their taxonomic groups, as follows:

- High risk: *Atopobathynella* sp. \`WA\`, Bathynellidae sp. \`WA\`, *Australocamptus* sp. \`B13\` (higher taxa almost always found to be Confirmed SREs);
- Moderate – high risk: *Kruptus* sp. \`WA\`, *Maarrka* sp. \`WA\`, Parastenocaris sp. indet., *Thermocyclops* sp. \`WA\` and Oligochaeta sp. indet. (higher taxa contain a variety of distributions from widespread to Confirmed SRE);
- Moderate – high risk: Aeolosomatidae sp. indet., and Turbellaria sp. indet. (relatively poorly known taxa, but regarded as Potential SREs when stygobitic); and
- Moderate – low risk: Enchytraeidae sp. indet. (higher taxon contains widespread and Potential SRE species, but may not be restricted to groundwater habitats).

This assessment may be subject to change with further information on the extent of groundwater drawdown and/ or further taxonomic resolution of previously sampled specimens from West Angelas.

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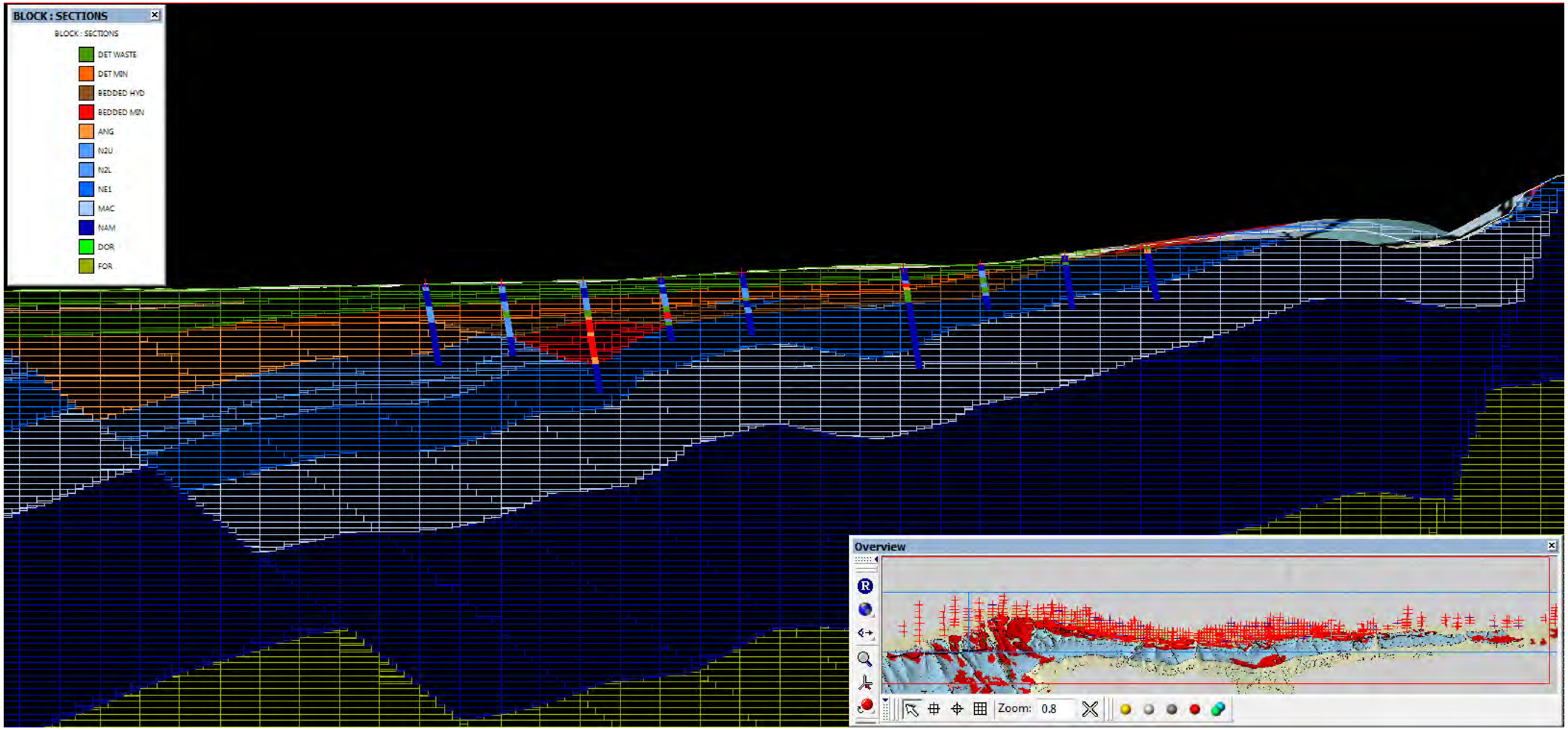
10 APPENDICES

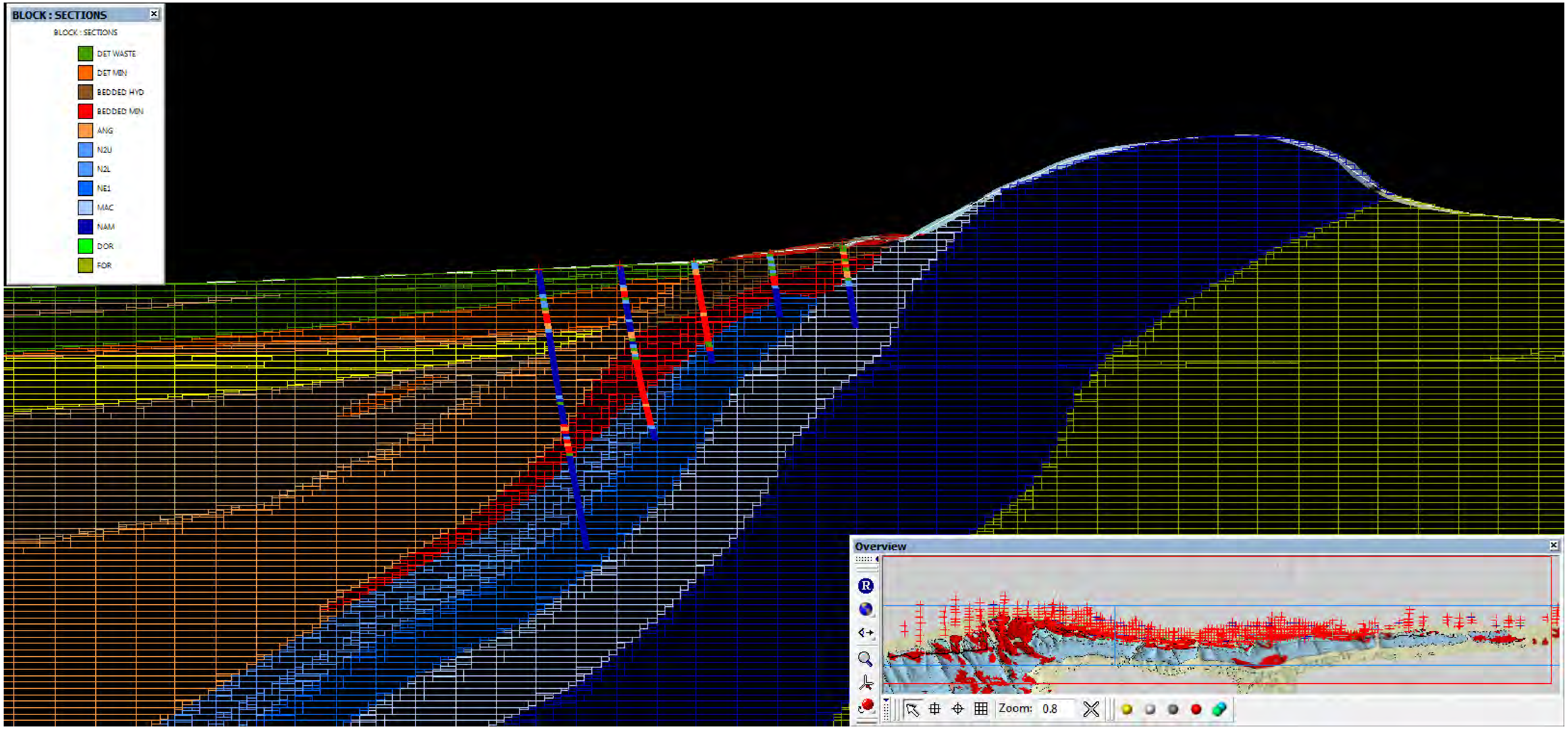
10.1 Appendix A – Conservation categories

IUCN Categories	Definition
Extinct (EX)	A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Extinct in Wild (EW)	A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalised population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Critically Endangered (CE)	A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered as per IUCN (2012) Red List Categories and Criteria, and it is therefore considered to be facing an extremely high risk of extinction in the wild.
Endangered (EN)	A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered as per IUCN (2012) Red List Categories and Criteria, and it is therefore considered to be facing a very high risk of extinction in the wild.
Vulnerable (VU)	A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable as per IUCN (2012) Red List Categories and Criteria, and it is therefore considered to be facing a high risk of extinction in the wild.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future
Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.
EPBC Act	**Definition**
Extinct (EX)	Taxa not definitely located in the wild during the past 50 years.
Extinct in Wild (EW)	Taxa known to survive only in captivity.
Critically Endangered (CE)	Taxa facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (EN)	Taxa facing a very high risk of extinction in the wild in the near future.
Vulnerable (VU)	Taxa facing a high risk of extinction in the wild in the medium-term future.
WC Act Categories	***Definition***
Schedule 1 (S1)	Rare and Likely to become Extinct.
Schedule 2 (S2)	Extinct.
Schedule 3 (S3)	Migratory species listed under international treaties.
Schedule 4 (S4)	Other Specially Protected Fauna.
DPaW Categories	Definition
Priority 1 (P1)	Taxa with few, poorly known populations on threatened lands.
Priority 2 (P2)	Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.
Priority 3 (P3)	Taxa with several, poorly known populations, some on conservation lands.
Priority 4 (P4)	Taxa in need of monitoring. Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change.

10.2 Appendix B – Geological Cross Sections - Deposit C



4-3: Deposit C – 666 400E



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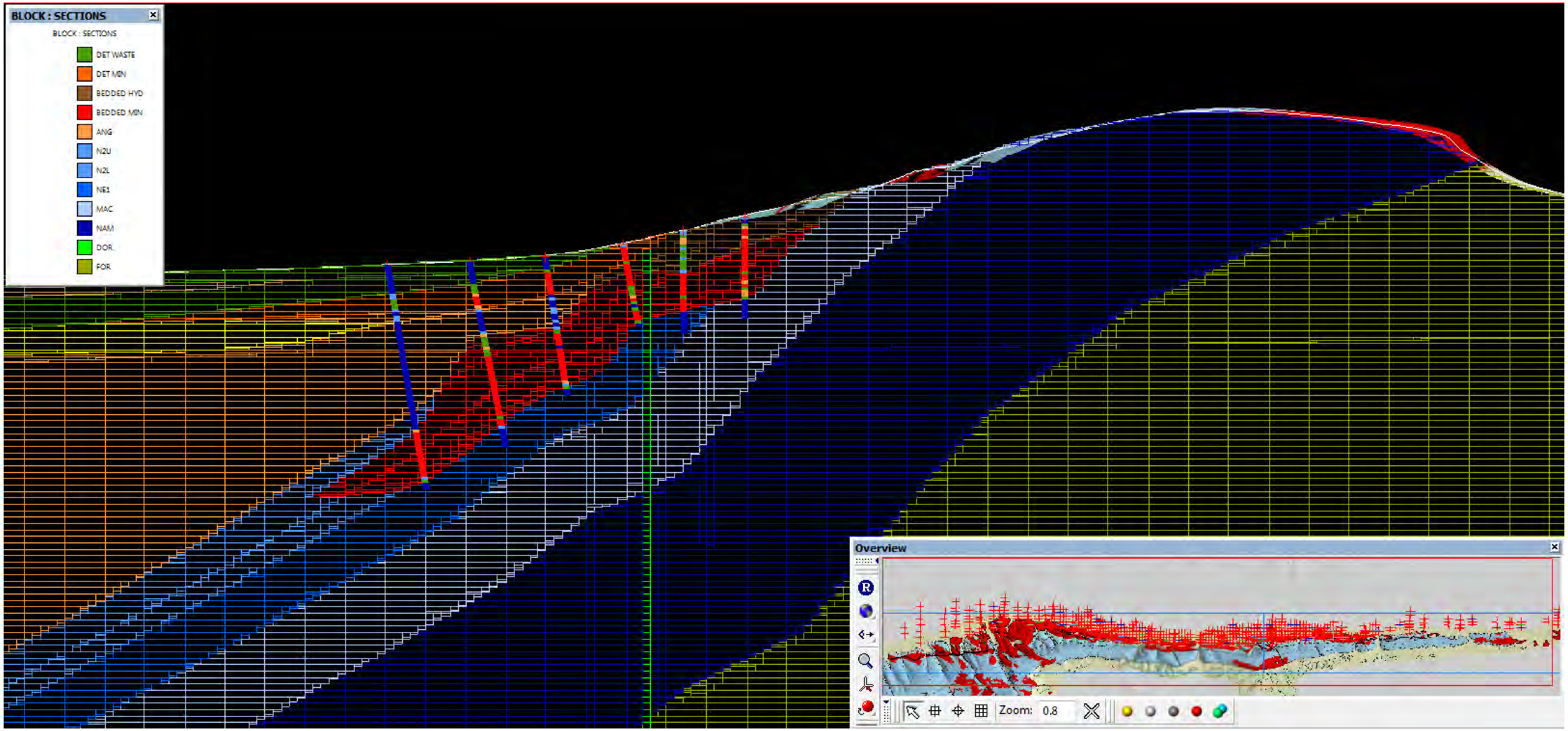
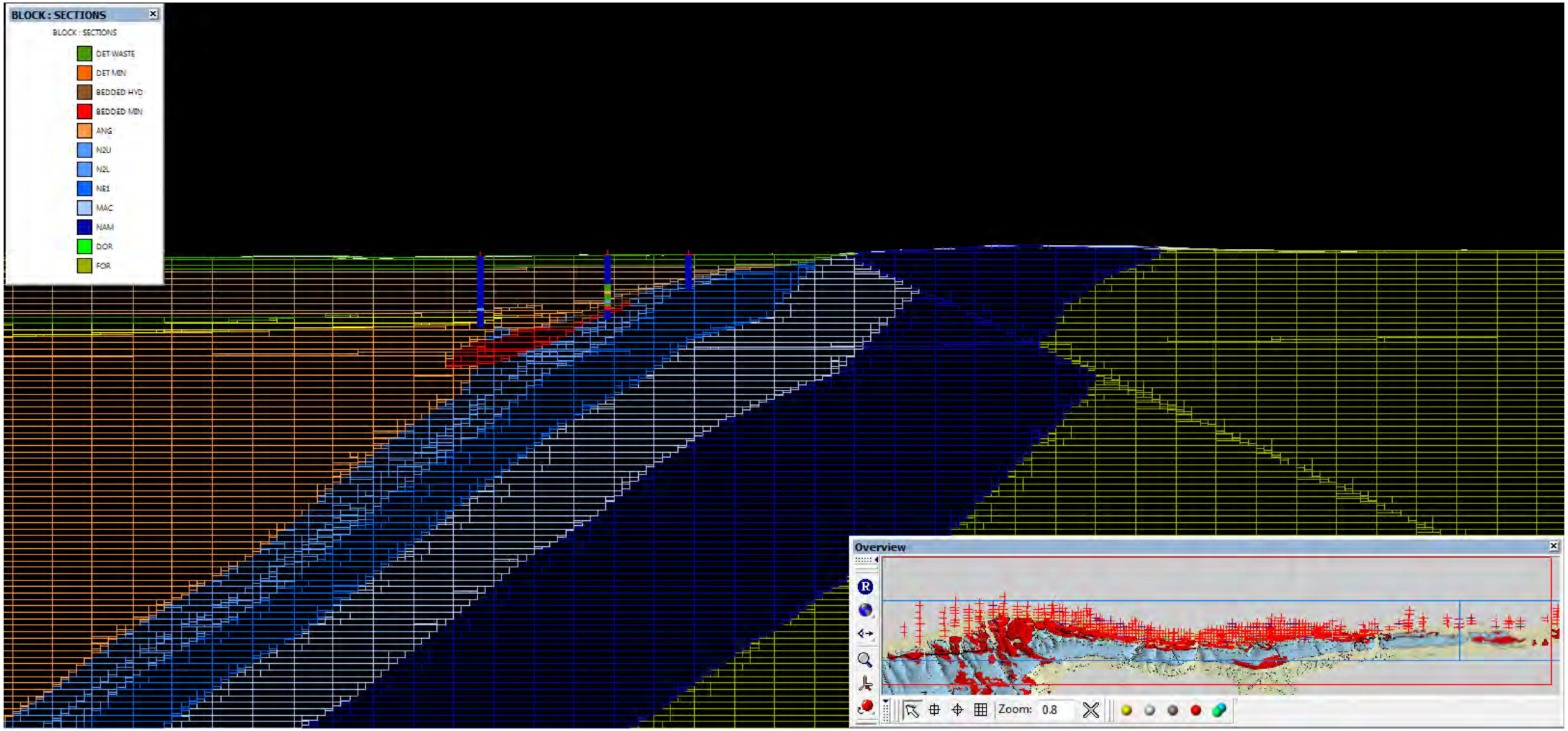
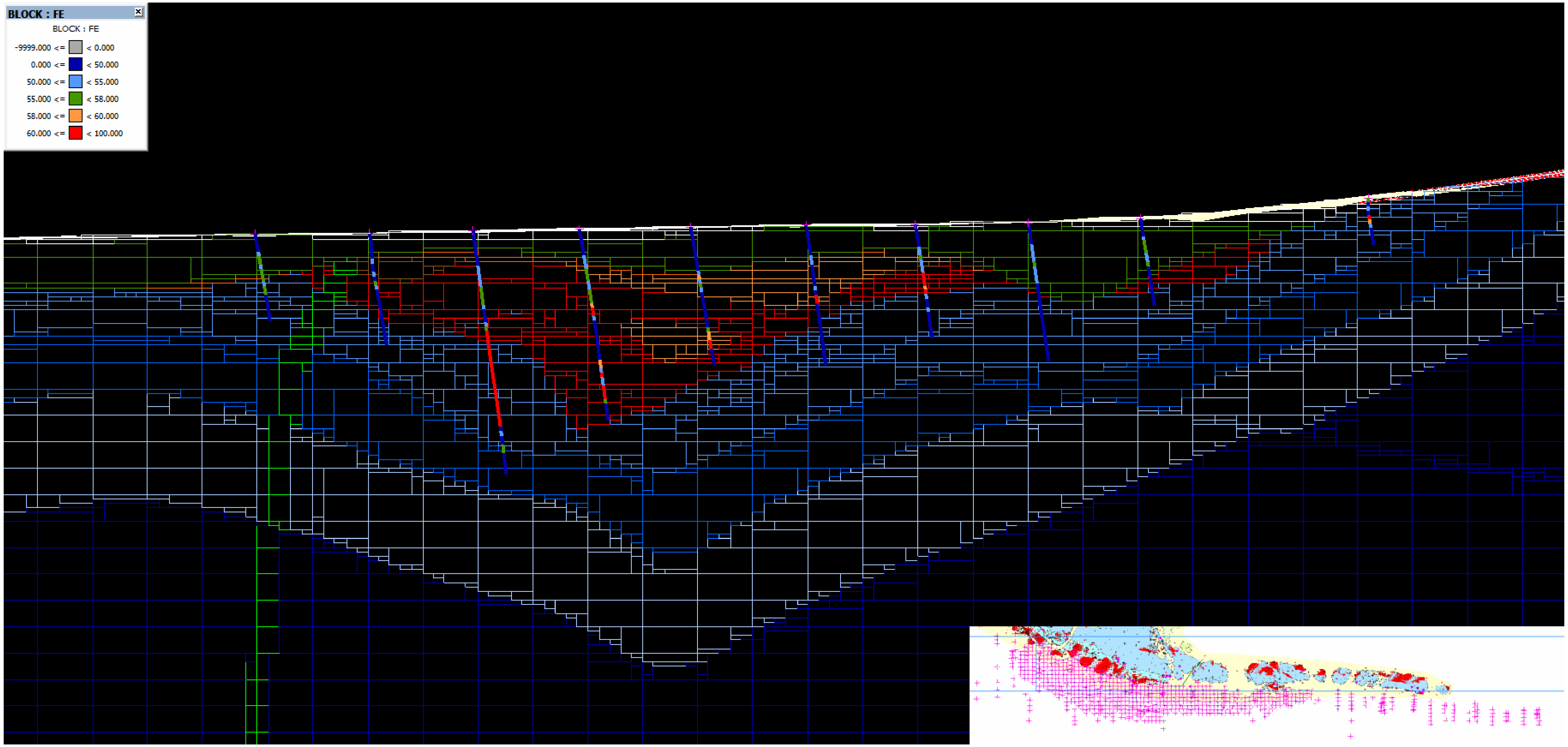


4-5: Deposit C – 671 250E

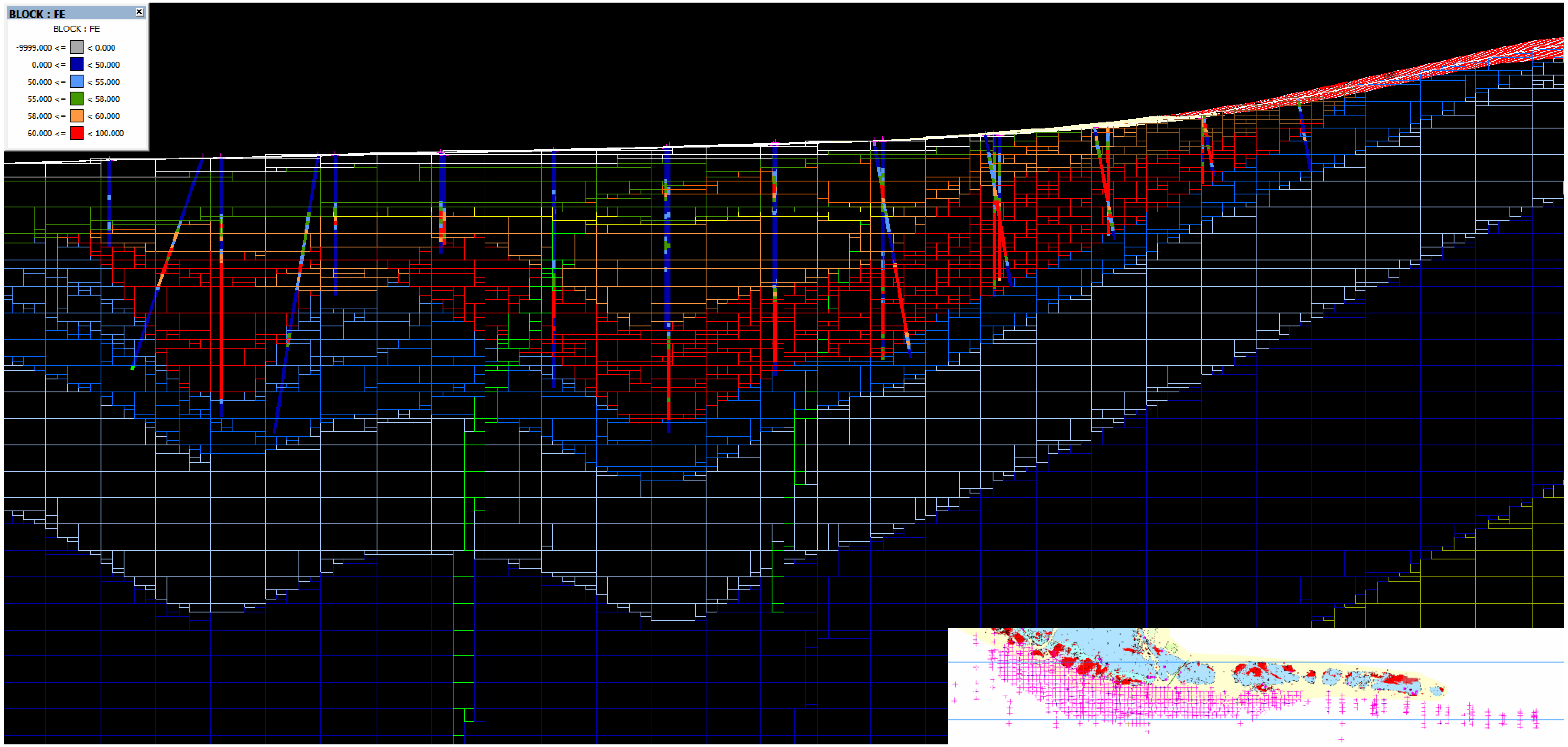


4-6: Deposit C – 674 500E

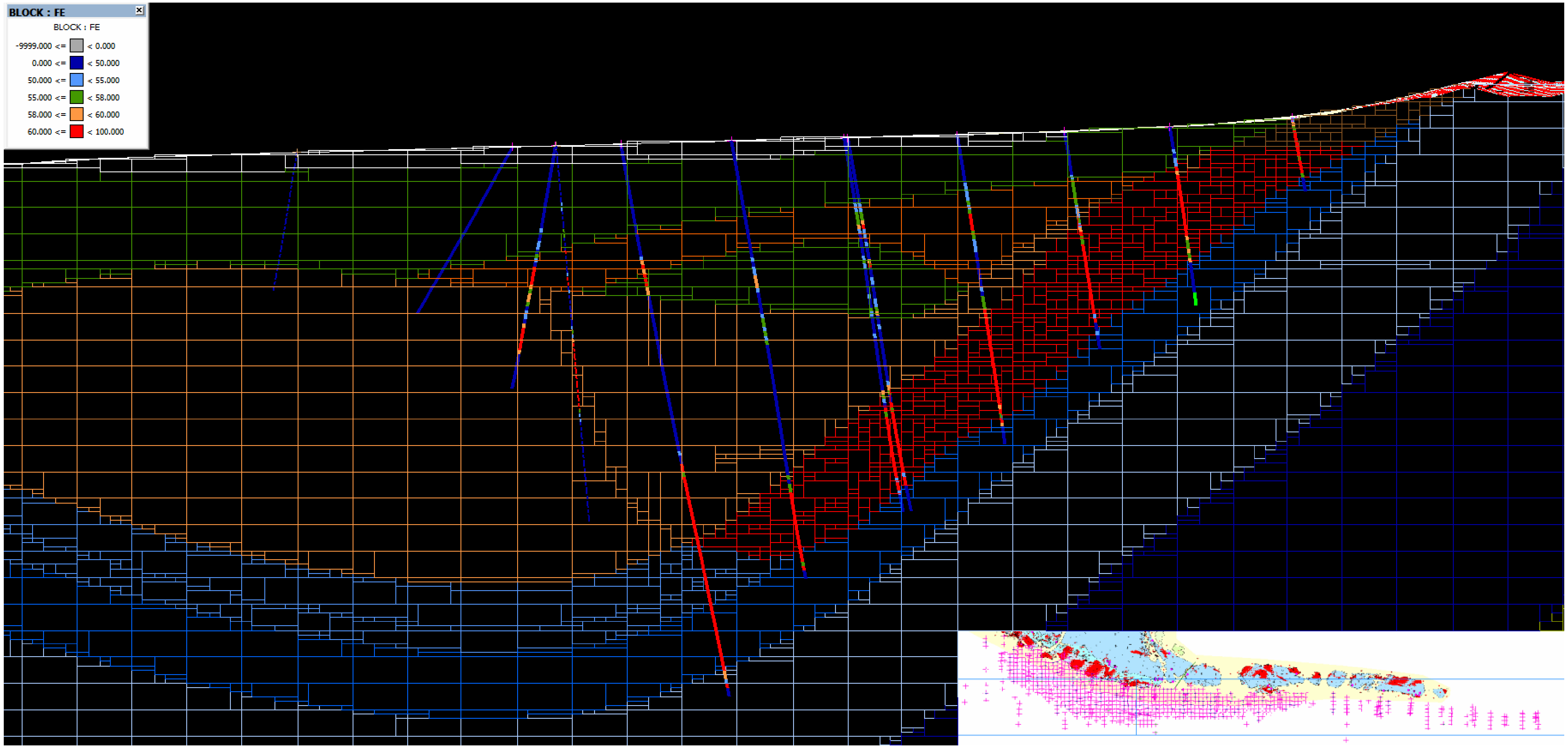
10.3 Appendix C – Geological Cross Sections - Deposit D



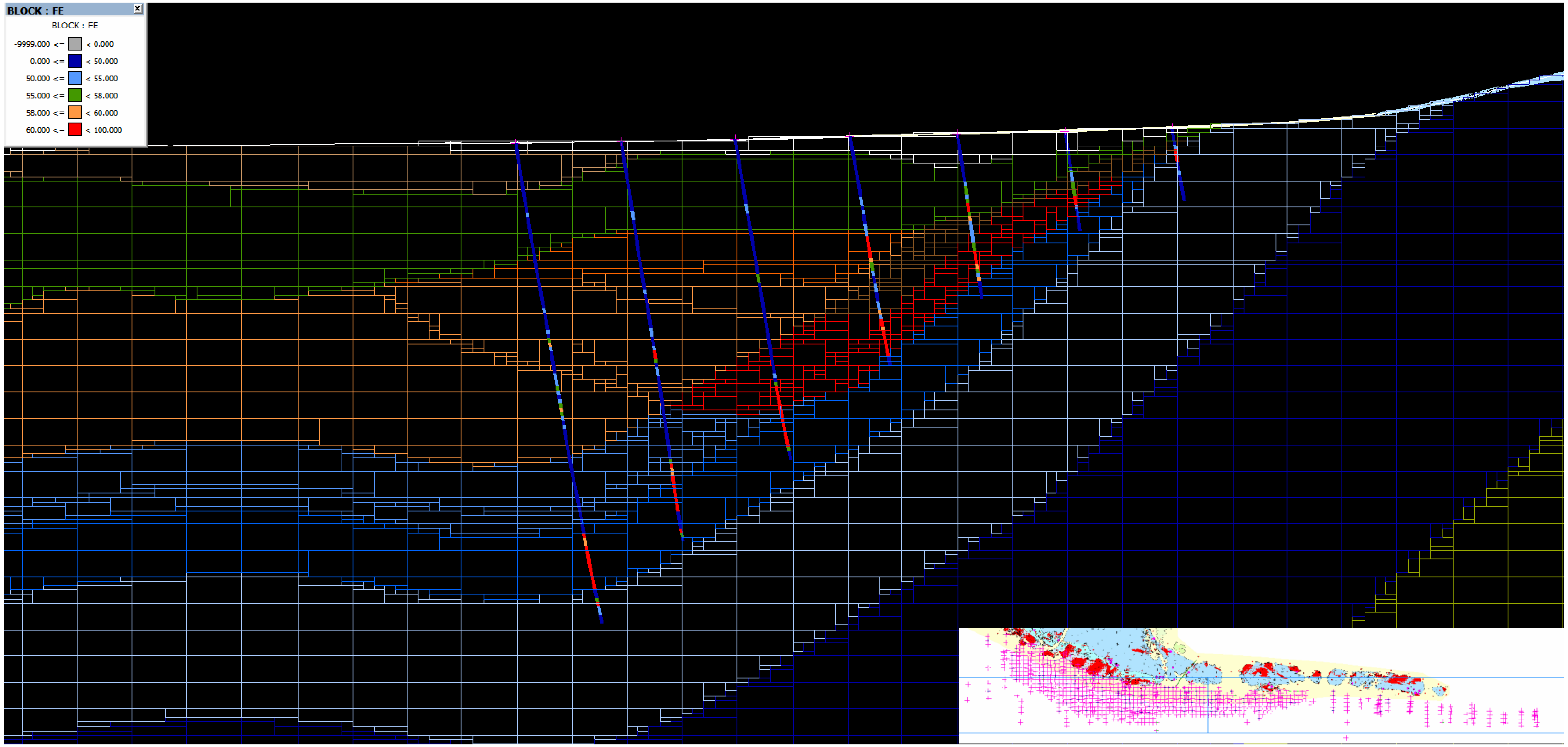
4-7: Deposit D – 665 440E



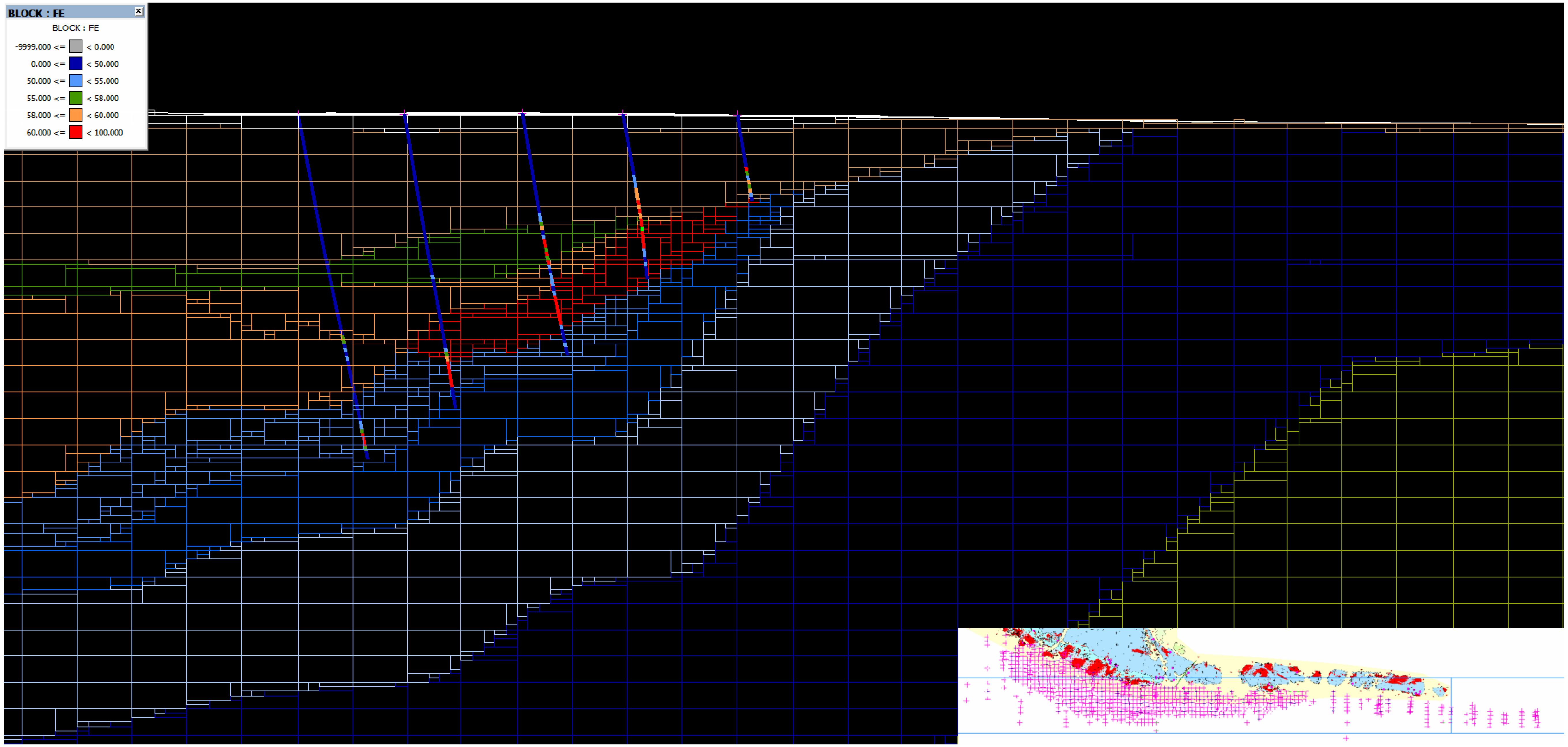
4-8: Deposit D - 666 290E



4-9: Deposit D – 666 840E

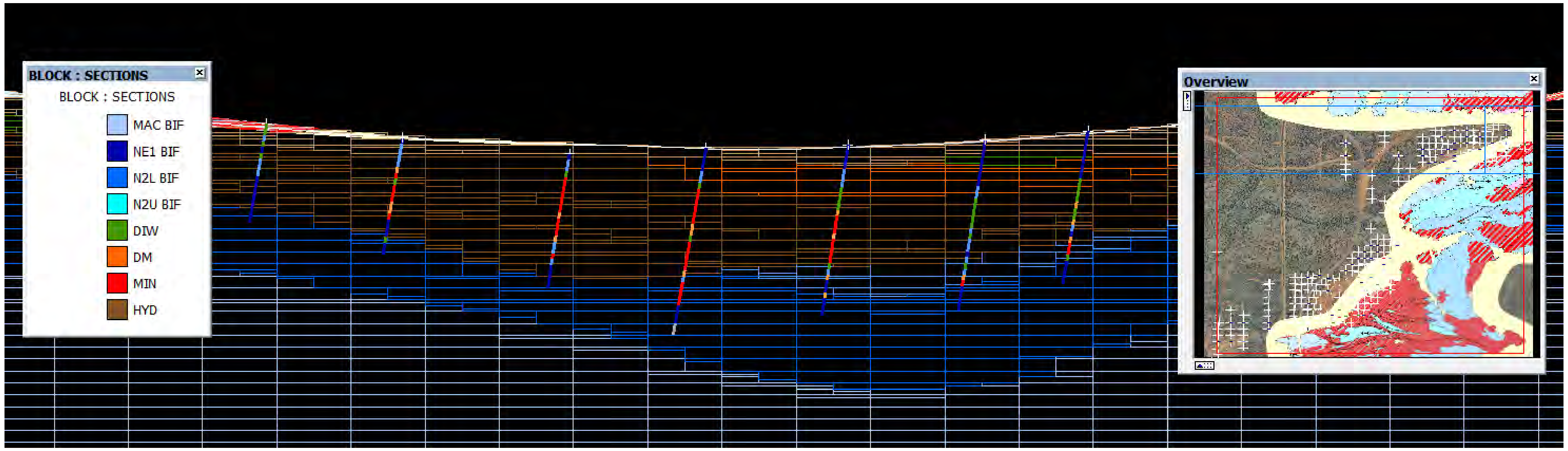


4-10: Deposit D – 667 740E

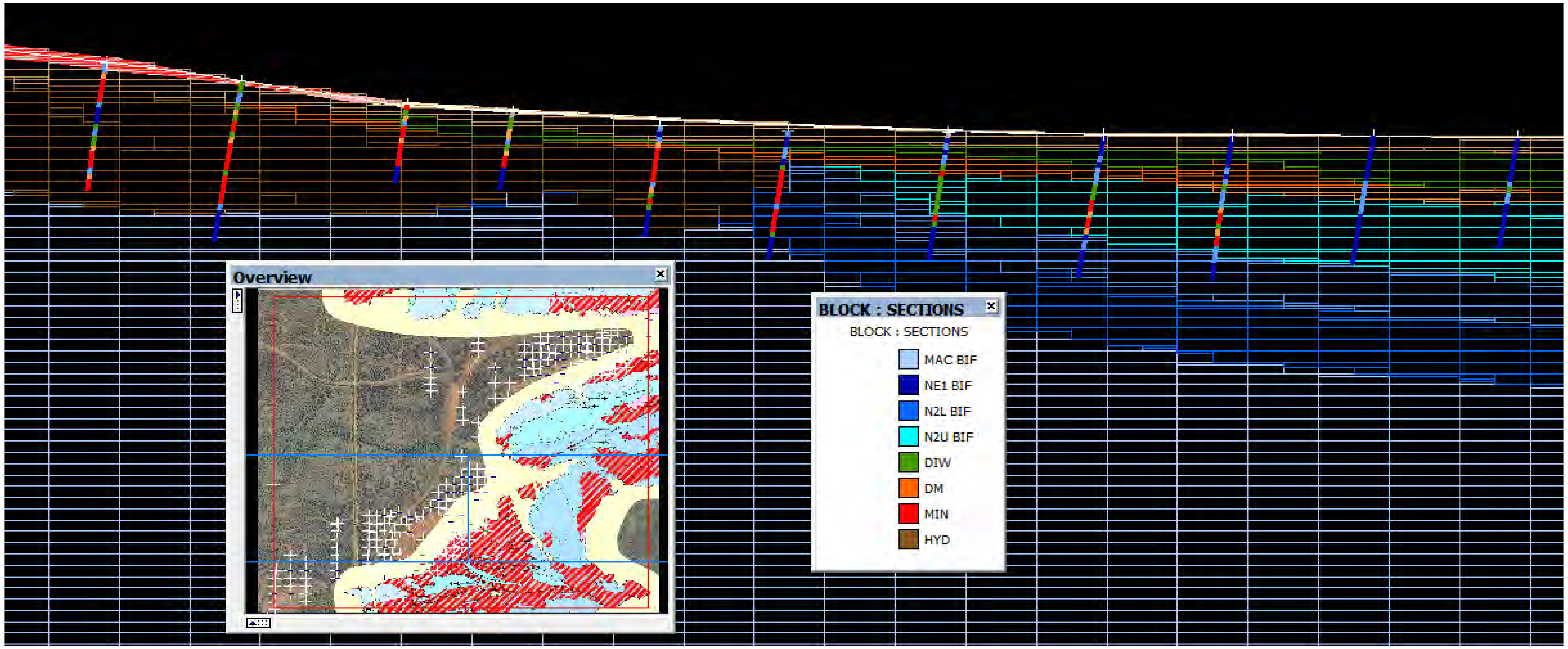


4-11: Deposit D – 670 840E

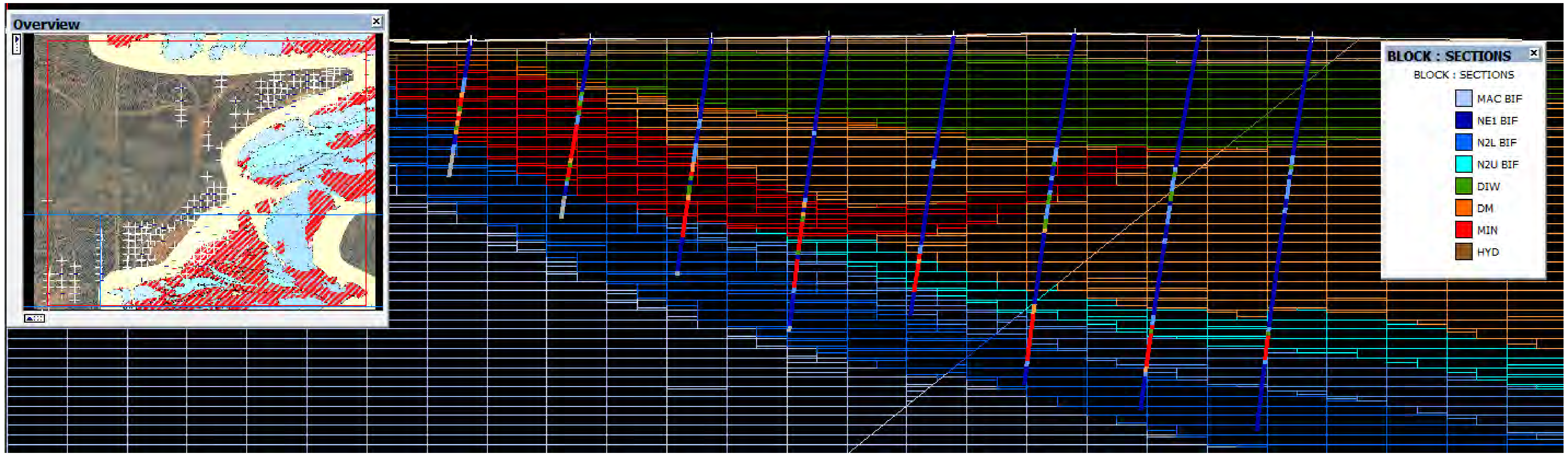
10.4 Appendix D – Geological Cross Sections - Deposit G



4-12: Deposit G (north)



4-13: Deposit G (central)



4-14: Deposit G (south)

10.5 Appendix E – Taxonomic Report (E. Volschenk, Alacran Environmental)

ABN: 33577027061
email: erich@alacranenvironmental.com
phone: 0457111317

MEMO

To:	Shae Callan (Biologic Environmental Survey)
From:	Erich S. Volschenk (Alacran Environmental Science)
Date:	Thursday 30 August 2016
Regarding:	Taxonomy and assessment of short range endemics, troglobites, and stygobites of invertebrates from West Angelas

On the 19th August 2016, Biologic requested that the provision of additional information to supplement a taxonomic 'report' supplied in a previous correspondence (email). Biologic provided a summary table of the species previously identified and requested inclusion of assessments of habitat specialisation such as troglobite, stygobite, soil fauna etc…; as well as an assessment of short-range endemism using the WA Museum SRE ratings. The completed table is supplied at the end of this memo.

Biologic also requested a brief summary of my background in taxonomy and experience undertaking taxonomic services. This is also provided below.

ASSESSMENT OF HABITAT SPECIALISATION

The recognition of obligate subterranean species is heavily reliant on the presence of one or more troglomorphies. These are specialised morphological adaptation that usually occur when organisms are restricted to subterranean existence for many generations. These include, but are not limited to:

- absence or reduction of eyes
- absence or reduction of wings
- absence or reduction of body pigmentation
- elongation of appendages
- thinning of the cuticle

Assessment of troglomorphies is usually made by comparing them with related epigean (surface dwelling) species.

A limitation of this approach is that it is unable to assess taxa that generally possess troglomorphic features; for example, all members of the centipede family Cryptopidae are characterised by the being eyeless and lacking body pigmentation. Some of these groups contain soil fauna; however, it is impossible to distinguish between soil fauna and 'true' troglobites based on their morphology alone.

Several of the species identified from West Angeles fall into this category and are referred to as being 'potential troglobites' or 'potential stygobites'. Assessment of these forms is therefore based on their likelihood of being short-range endemics and most of these species belong to groups that contain SRE's or potential SRE's. In the Pilbara, the absence or rarity of surface dwelling relatives of these species, particularly for potential troglobites, is also an indication that the species in question may be restricted to subterranean habitats.

Management of these species found to be SRE's or potential SRE's will probably be most effective if they are treated as troglofauna, since they are probably susceptible to the same threatening processes.

MY BACKGROUND

My formal training (PhD) is as an Invertebrate Zoologist. I am Australia's only scorpion taxonomist and have also published research on Australian pseudoscorpions. I have worked on subterranean fauna at the academic level as well as environmental consulting. I have provided commercial taxonomic consultation since 2008, and have undertaken assessments of subterranean fauna species since 2011. I also have extensive experience using DNA sequences to assist with species discrimination of both subterranean and surface dwelling SRE's. My laboratory allows me to examine and assess all but the smallest of macroinvertebrates; however, these often represent groups that are poorly known from the Pilbara and for which DNA sequencing is more informative means of assessing species boundaries. I have experience providing taxonomic identifications and SRE assessments for arachnids, myriapods, and some insect groups (Diplura, Thysanura, Blattodea, Hemiptera, Coleoptera, Collembola) and crustacean groups (Amphipoda, Syncarida, Isopoda).

Previous clients for which I have provided taxonomic services include:

- **Environmental consultancies**: Biologic, Phoenix Environmental Sciences, Subterranean Ecology, Biota, Ecologia and Dalcon environmental.
- **Mining/Exploration companies**: BHPIO, BHP Uranium, Rio Iron Ore, Iron Ore Holdings, Hancock Prospecting, Atlas Iron, Dragon energy, Red Hill Iron and Australian Aboriginal Mining Corporation.
- **Government**: WA Museum, WA Department of Agriculture and Food, NSW Department of Environment, Australian Quarantine Service, New Zealand Quarantine Service.

Please see my LinkedIn Profile for more details of my work and research experience:
https://au.linkedin.com/in/erich-volschenk-82784636

AMMENDED REPORT SPECIES IDENTITY REPORT

Taxa	BES numbers	Subterranean status (stygobite/troglobite)	WAM SRE status
Diplura			
Campodeidae sp. indet.	BES:1909, BES:2176	Potential troglobite	Potential SRE: Data deficient
Hemiptera			
Meenoplidae sp. indet.	BES:2139, BES:2356	Troglobite: very reduced eyes	Potential SRE: Data deficient
Thysanura			
Atelurinae sp. indet.	BES:1823	Potential troglobite	Potential SRE: Data deficient
Collembola			
Cyphoderidae sp. indet.	BES:1815	Potential troglobite	Potential SRE: Data deficient
Sminthuridae sp. indet.	BES:1962	Troglobite (blind and pale)	Potential SRE: Data deficient
Symphyla			
Scutigerellidae sp. indet.	BES:2117, BES:2112	Potential troglobite	Potential SRE: Data deficient
Symphyla sp. indet.	BES:2055	Potential troglobite	Potential SRE: Data deficient
Cyclopoida			
Cyclopoida sp. indet.	BES:1976, BES:1979, BES:1973, BES:1902, BES:1972, BES:1774, BES:1960, BES:1822, BES:1980, BES:1997, BES:2236, BES:2034, BES:2023	Stygobite	Potential SRE: Data deficient
Metacyclops sp. `B01` (nr. pilbaricus)	BES:1774	Stygobite	Widespread (not SRE)

Taxa	BES numbers	Subterranean status (stygobite/troglobite)	WAM SRE status
Microcyclops varicans	BES:1972, BES:2022, BES:1980, BES:2236, BES:1960, BES:2034, BES:1979, BES:197	Stygobite	Widespread (not SRE)
Thermocyclops sp. `WA`	BES:1980b, BES:1774	Stygobite	Potential SRE: Expertise (Bennelongia)
Harpacticoida			
Australocamptus sp. `B13`	BES:2022b, BES:1911, BES:2116	Stygobite	Potential SRE: Expertise (Bennelongia)
Parastenocaris sp. indet.	BES:2033	Stygobite	Potential SRE: Data Deficient
Ostracoda			
Notacandona gratia	BES:1967	Stygobite	Widespread (not SRE)
Isopoda			
Armadilidae sp. indet.	BES:1876	Troglobite	Confirmed SRE (based on previous sequencing)
Isopoda sp. indet.	BES:2199	Potential Troglobite	Potential SRE: Data Deficient
Haplotaxida			
Enchytraeidae sp. indet.	BES:2355, BES:2114, BES:1974, BES:2035, BES:1903, BES:1936, BES:1873, BES:2039, BES:1915, BES:1844	Potential troglobite (or stygobite?)	Potential SRE: Data Deficient
Polychaeta			
Aeolosomatidae sp. indet.	BES:2237	Potential Stygobite	Potential SRE: Data Deficient
Oligochaeta			
Oligochaeta sp. indet.	BES:2038, BES:2030, BES:1849, BES:2031, BES:2237	Potential Stygobite	Potential SRE: Data Deficient
Turbellaria			
Turbellaria sp. indet.	BES:1859, BES:2027	Potential Stygobite	Potential SRE: Data Deficient

10.6 Appendix F – Taxonomic Report (G. Perina, WAM/ ECU)

To Shae Callan
Senior Zoologist
Biologic Environmental Survey

Amphipoda and Bathynellacea stygofauna identifications for West Angelas Project

Prepared by Giulia Perina

The following table represents the Amphipoda and Bathynellacea species recorded and identified at West Angelas:

BES#	ID	Notes
AMPHIPODA		
2352	*Maarrka* sp 'WA'	Cf. *M. etheli* or M. weeliwollii. *M. etheli* occurs in the Ethel Gorge: 125 km E of the study area, while *M. Welliwolly* occurs in the Marillana creek: about 70 km NE from West Angelas (Finston et al, 2011); Morphological characters not well defined.
1812	*Kruptus* sp. 'WA'	*Kruptus* genus has been recorded before in the Pilbara region; *Kruptus linnaei* is described from Spearhole creek about 60 km ESE (Finston et al 2008). Morphological characters not well defined.
1978	*Kruptus* sp. 'WA'	
1764	*Kruptus* sp. 'WA'	
PARABATHYNELIDAE		
2297	*Atopobathynella* sp 'WA'	*Atopobathynella* genus has been recorded before in the Pilbara region
1900	*Atopobathynella* sp 'WA'	
2234	*Atopobathynella* sp 'WA'	
BATHYNELLIDAE		
1996	Bathynellidae sp 'WA'	Currently no species are described for WA, only one species is named from Australia (description based on one specimen only). Taxonomy in progress.
2054	Bathynellidae sp 'WA'	

In the following table, the subterranean and SRE status, and options for further taxonomic resolution is listed for each taxa identified at West Angelas:

	Subterranean status (stygomorphy/ troglomorphy)	**WAM SRE status**	**Options for further taxonomic resolution**
Amphipoda			
Kruptus sp. \`WA\`	Stygobite (depigmented and anophthalmic specimens)	Potential SRE (data deficient: lack of taxonomic information and patchy sampling)	DNA comparison between *Kruptus* WA and other morphologically close related amphipods (*K. linneai* and *K.* AR). Preferable a multigene approach with possibly informative nuclear markers. Extend the sampling area to better understand distribution. *Due to the nature of the habitat (fragmented and sporadically interconnected), this group has high chances to have restricted distribution and therefore to be considered SRE, with distribution well below 10,000 Km^2
Maarrka sp. \`WA\`	Stygobite (depigmented and anophthalmic specimens)	Potential SRE (data deficient: lack of taxonomic information and patchy sampling)	DNA comparison between *Maarrka* sp. \`WA\` and other morphologically close related amphipods (*M. etheli* and *weeliwollii*). Preferable a multigene approach with possibly informative nuclear markers. Extend the sampling area to better understand distribution. *Due to the hydrogeological nature of the area (West Angelas), it is probable that *Maarka* sp 'WA' is different from the other 2 species that occur in the Fortescue River catchment, and therefore potential SRE.
Bathynellacea			
Atopobathynella sp. \`WA\`	Stygobite (depigmented and anophthalmic specimens) - no surface or marine relatives have ever been found (the order Bathynellacea is confined in the interstitial underground environment)	Potential SRE (data deficient: lack of taxonomic information and patchy sampling) - but highly likely SRE	Morphological and molecular comparison with other *Atopobathynella* sp is suggested to better understand the distribution. *Due to the nature of the group (limited dispersal ability, no nauplius stage) and the habitat where they are confined, they can be probably considered SRE, with distribution ranges well below 10,000 Km^2. All previous Bathynellacea species study done in Australia showed very restricted ranges for the members of this order.
Bathynellidae sp. \`WA\`	Stygobite (depigmented and anophthalmic spmns) - no surface or marine relatives have ever been found (the order Bathynellacea is confined in the interstitial underground environment)	Potential SRE (data deficient: lack of taxonomic information and patchy sampling) - but highly likely SRE	Morphological and molecular comparison with other Bathynellidae sp is suggested to better understand the distribution. *Due to the nature of the group (limited dispersal ability, no nauplius stage) and the habitat where they are confined, they can be probably considered SRE, with distribution ranges well below 10,000 Km^2. All previous Bathynellacea species study done in Australia showed very restricted ranges for the members of this order.

My expertise with subterranean fauna:

I have been working with subterranean invertebrates since 2005, gaining a Master degree in Evolutionary Biology with a research on European cave fauna.

For 6 years I've been working for an environmental consulting company, specialised in Australian subterranean fauna, as parataxonomist identifying troglo and stygofauna and collaborating with national and international specialists.

I'm currently a PhD student (3rd year) focussing on one particular group of stygofauna (Bathynellidae), studying the biodiversity, distribution and phylogeny, mainly in the Pilbara bioregion, though integrative taxonomy (using molecular and morphological tools). I'm working with the Bathynellacea world specialist (Dr Ana Camacho, Madrid, Spain) on different species/genera in the Pilbara, trying to better understand the subterranean variability (at aquifer and region level) and distribution of this group.

Ms Giulia Perina
PhD student
Centre for Ecosystem Management
School of Science
Edith Cowan University
Joondalup
Western Australian Museum

10.7 Appendix G – Taxonomic Report (T. Moulds et al. WAM)

WAMTS434:

Arachnids from West Angelas, Western Australia

(Project *West Angelas Subterranean Fauna*)

Report to Biologic

23 June 2016

Timothy Moulds, Kym Abrams, Julianne Waldock, Mark S. Harvey

Department of Terrestrial Zoology, Western Australian Museum,

Locked Bag 49, Welshpool DC, Western Australia 6986, Australia

SUMMARY

WAMTS434 specimens were submitted to the Western Australian Museum on the 17th June 2016. The project contained: Acarina from the family Anisitsiellidae (n=1); Pseudoscorpiones from the family Chthoniidae (n=2); Schizomida form the family Hubbardiidae (n=1); spiders from the families Gnaphosidae (n=2) and Oonopidae (n=2); Centipedes from the family Cryptopidae (n=1) and pin cushion millipedes form the family Lophoproctidae (n=2). A summary of specimen identifications together with their SRE status may be found in Table 1. A full explanation of the SRE categories used by the Western Australian Museum may be found in Appendix 1.

Table 1. Summary of WAMTS434 specimen identifications and SRE status.

ORDER	FAMILY	GENUS	SPECIES	# OF SPECIMENS	SRE STATUS	SRE SUB-CATEGORY
Trombidiformes	Anisitsiellidae	*Rutacarus?*	*sp. indet.*	1	Potential SRE	(A) Data Deficient
Schizomida	Hubbidariidae	*Draculoides*	*sp. SCH051*	1	Confirmed SRE	
Pseudoscorpionida	Chthoniidae	*Tyrannochthonius*	*sp. PSE102*	1	Confirmed SRE	
Pseudoscorpionida	Chthoniidae	*Lagynochthonius*	*sp. PSE101*	1	Confirmed SRE	
Araneomorpha	Gnaphosidae		*sp. indet.*	1	Potential SRE	(A) Data Deficient
Araneomorpha	Gnaphosidae		*sp. indet.*	1	Potential SRE	(A) Juvenile
Araneomorpha	Oonopidae		*sp. indet.*	2	Potential SRE	(A) Data Deficient
Scolopendromorpha	Cryptopidae	*Cryptops*	*sp. indet.*	1	Potential SRE	(A) Data Deficient
Polyxenida	Lophoproctidae	*Lophoturus*	*madecassus*	22	Widespread	

SHORT-RANGE ENDEMISM

The terrestrial invertebrate fauna of inland Australia contains a plethora of species, and just the arthropods were recently estimated to consist of more than 250,000 species (Yeates, Harvey et al. 2004; Chapman 2009). The vast majority of these are found within the Insecta and Arachnida, although significant numbers of millipedes are to be expected. For many years, the prospect of including invertebrates in assessments of biological systems subject to modification proved daunting because of the large numbers of unknown species. These animals were largely ignored, as they were too diverse and their taxonomy too little known for them to be considered in environmental surveys that require a rapid turn-around time.

In a recent publication, the issue of Short-Range Endemism in the Australian invertebrate fauna was examined (Harvey 2002). Species that could be defined as Short-Range Endemics (SRE) were those that had a naturally small range of less than 10,000 km^2. Harvey (2002) found that those species possessed a series of distinct ecological and life-history traits that contributed to their limited distributions, including:

- poor powers of dispersal;
- confinement to discontinuous habitats;
- usually highly seasonal, only active during cooler, wetter periods; and
- low levels of fecundity.

A number of major invertebrate groups have a high proportion of individual species that show these traits and can be considered SRE's. The Western Australian fauna contains a number of SRE taxa, including millipedes, land snails, trap-door spiders, some pseudoscorpions, slaters, and onychophorans and these represent focal groups in Environmental Impact Assessment studies in the state (EPA 2009). The south coast region is relatively well known compared with other regions of the state (Framenau, Moir et al. 2008), but there are many poorly known species and gaps in our understanding of the distributions of many species.

METHODS

Specimens collected by *Biologic* were submitted to the Western Australian Museum on the 17th June 2016. The specimens were examined at the WA museum using Leica dissecting microscopes (MZ6, MZ205). The SRE status of each taxonomic group was given using the SRE categorisation system developed and implemented by the Western Australian Museum. A full explanation of the WAM SRE categories is available in Appendix 1.

SIGNIFICANT OUTCOMES

The significant findings of WAMTS434 are summarised below.

ARACHNIDA

ORDER Schizomida

Family Hubbardiidae

1. *Draculoides sp. SCH051*
    - **SRE Category: Confirmed SRE.**
    - *This species is from a location where the WAM has no other collections of schizomids and represents a new species. It has been assigned a putative WAM schizomid species code of SCH051. Previous collections of schizomids from both Draculoides and Paradraculoides in the Pilbara has shown all are SRE species and hence this specimen should be considered an SRE species until shown by direct evidence to be otherwise.*

ORDER Pseudoscorpiones

Family Chthoniidae

2. *Laygnochthonius sp. PSE101.*
    - **SRE Category: Confirmed SRE.**
    - *This specimen represents a new species and it has been assigned a putative WAM pseudoscorpion species code of PSE101. Due to the troglomorphic nature of the species and that subterranean chthoniids are unable to disperse this specimen should be considered an SRE species until shown by direct evidence to be otherwise.*
3. *Tyrannochthonius sp. PSE102.*
    - **SRE Category: Confirmed SRE.**
    - *This specimen represents a new species and it has been assigned a putative WAM pseudoscorpion species code of PSE102. Due to the troglomorphic nature of the species and that subterranean chthoniids are unable to disperse this specimen should be considered an SRE species until shown by direct evidence to be otherwise.*

ORDER Araneae

Family Gnaphosidae

4. *Genus and species in det.*
    - **SRE Category: Potential SRE; (A) Data Deficient.**
    - *These specimens could not be identified beyond family level due to the specimens being female or juvenile. Due to the specimens troglomorphisms they are considered to be potential SRE taxa.*

Family Oonopidae

5. *Genus and species in det.*
    - **SRE Category: Potential SRE; (A) Data Deficient.**
    - *These specimens could not be identified beyond family level due to the specimens being female. Due to the specimens troglomorphisms they are considered to be potential SRE taxa.*

APPENDIX 1. WAM SHORT-RANGE ENDEMIC CATEGORIES

	Taxonomic Certainty	Taxonomic Uncertainty
Distribution < 10 000km^2	**Confirmed SRE** • *A known distribution of < 10 000km^2.* • *The taxonomy is well known.* • *The group is well represented in collections and/ or via comprehensive sampling.*	**Potential SRE** • *Patchy sampling has resulted in incomplete knowledge of the geographic distribution of the group.* • *We have incomplete taxonomic knowledge.* • *The group is not well represented in collections.* • *This category is most applicable to situations where there are gaps in our knowledge of the taxon.* **Sub-categories for this SRE designation are outlined below**
Distribution > 10 000km^2	**Widespread (not an SRE)** • *A known distribution of > 10 000km^2.* • *The taxonomy is well known.* • *The group is well represented in collections and/ or via comprehensive sampling.*	

SRE SUB-CATEGORIES

If a taxon is determined to be a "Potential SRE", the following sub-categories will further elucidate this status.

A. *Data Deficient:*
- There is insufficient data available to determine SRE status.
- Factors that fall under this category include:
  - New species.
  - Lack of geographic information.
  - Lack of taxonomic information.
  - The group may be poorly represented in collections.
  - The individuals sampled (e.g. juveniles) may prevent identification to species level.

B. *Habitat Indicators:*
- It is becoming increasingly clear that habitat data can elucidate SRE status.
- Where habitat is known to be associated with SRE taxa and vice versa, it will be noted here.

C. *Morphology Indicators:*
- A suite of morphological characters are characteristic of SRE taxa.
- Where morphological characters are known to be associated with SRE taxa and vice-versa, it will be noted here.

D. *Molecular Evidence:*
- If molecular work has been done on this taxon (or a close relative), it may reveal patterns congruent or incongruent with SRE status.

E. *Research & Expertise:*
- Previous research and/ or WAM expertise elucidates taxon SRE status.
- This category takes into account the expert knowledge held within the WAM.

APPENDIX 2. SPECIMEN DATA FOR ARACHNIDS AND MYRIAPODS COLLECTED FROM WEST ANGELAS, PILBARA

REGNO	FLDNO	ORDER	INFRAORDER	FAMILY	GENUS	SPECIES	AUTHORITY	STATE	SITE	LATITUDE	LONGITUDE	M	F	JUV	TOT
140997	BES:2353	Trombidiformes	Parasitengona	Anisitsiellidae	*Rutacarus*?	\`sp. indet.\`		W.A.	West Angelas c.a. 113 km WNW of Newman	23°08\`31.0"S	118°39\`17.67"E				1
140998	BES:1840	Araneae	Araneomorphae	Gnaphosidae	\`in det.\`	\`sp. indet.\` (juvenile)		W.A.	West Angelas c.a. 113 km WNW of Newman	23°09\`58.97"S	118°36\`54.62"E			1	1
140999	BES:1899	Araneae	Araneomorphae	Gnaphosidae	\`in det.\`	\`sp. indet.\`		W.A.	West Angelas c.a. 104 km WNW of Newman	23°08\`11.8"S	118°44\`02.58"E		1		1
141000	BES:2029	Araneae	Araneomorphae	Oonopidae	\`in det.\`	\`sp. indet.\`		W.A.	West Angelas c.a. 104 km WNW of Newman	23°08\`03.77"S	118°43\`55.54"E		1		1
141001	BES:2294	Araneae	Araneomorphae	Oonopidae	\`in det.\`	\`sp. indet.\`		W.A.	West Angelas c.a. 113 km WNW of Newman	23°08\`12.89"S	118°37\`24.69"E		1		1
141002	BES:2020	Schizomida		Hubbardiidae	*Draculoides*	\`sp. *SCH051*\`		W.A.	West Angelas c.a. 113 km WNW of Newman	23°09\`58.97"S	118°36\`54.62"E	1			1
141003	BES:1816	Pseudoscorpiones		Chthoniidae	*Lagynochthonius*	\`sp. PSE101\`		W.A.	West Angelas c.a. 104 km WNW of Newman	23°08\`11.8"S	118°44\`02.58"E	1			1
141004	BES:1913	Pseudoscorpiones		Chthoniidae	*Tyrannochthonius*	\`sp. PSE102\`		W.A.	West Angelas c.a. 113 km WNW of Newman	23°08\`31.53"S	118°38\`47.74"E	1			1
141005	BES:1933	Scolopendromorpha		Cryptopidae	*Cryptops*	\`sp. indet.\`		W.A.	West Angelas c.a. 90 km WNW of Newman	23°11\`14.25"S	118°52\`42.0"E				1
141006	BES:2172	Polyxenida		Lophoproctidae	*Lophoturus*	*madecassus*	Marquet and Condé, 1950	W.A.	West Angelas c.a. 113 km WNW of Newman	23°10\`25.5"S	118°40\`54.05"E				18
141007	BES:1977	Polyxenida		Lophoproctidae	*Lophoturus*	*madecassus*	Marquet and Condé, 1950	W.A.	West Angelas c.a. 113 km WNW of Newman	23°10\`21.35"S	118°39\`36.79"E				4

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Biologic Environmental Survey Pty Ltd
PO Box 179 Floreat
Western Australia

6 April 2017

Carly Nixon

Rio Tinto Iron Ore – Central Park

152-158 St Georges Tce

PERTH WA 6000

RE: Results of DNA analysis of subterranean fauna collected at West Angelas Deposits C, D, and G

Dear Carly,

Rio Tinto Iron Ore requested genetic identification of certain troglofauna and stygofauna taxa sampled throughout West Angelas Deposits C, D and G, and comparisons with pre-existing regional sequences to determine whether the species found at West Angelas matched others from elsewhere in the region.

- Based on the results of the West Angelas Deposits C, D and G subterranean fauna survey (Biologic 2016), as requested and approved by RTIO, 26 specimens from 10 taxonomic groups were chosen for sequencing, comprising Bathynellacea (4), Amphipoda (5), Haplotaxida (Enchytraeidae) (6), Oligochaeta (3), Isopoda (2), Hemiptera (Meenoplidae) (2), Thysanura (1), and Symphyla (3) (Table 1).
- Specimens and species were chosen based on the following criteria: A) taxa that have a broad regional context available in the form of multiple previous regional sequences throughout the Pilbara region, B) taxa that were only found within potential impact areas (pits and/ or potential drawdown areas), or taxa that were found both inside and outside of potential impact areas at West Angelas, and C) taxa that had some degree of taxonomic uncertainty regarding their morphological identifications at the species level.
- Analyses/ comparisons were limited to those that would most quickly and adequately address the following hypotheses: 1) does the material from West Angelas represent a single species or multiple different species; and 2) does the material from West Angelas match any previously recorded species from the Pilbara region (based on available sequences). Deeper phylogenetic relationships between material recorded at West Angelas and previous regional material were not investigated and cannot be inferred from the types of neighbour-joining cluster analysis used.

Table 1. Details of specimens sent for DNA analysis (1 specimen per record)

Specimen code	HIGHER TAXON Family	Preliminary ID	Bore/hole name	UTM E z50 GDA94	UTM N z50 GDA94
	BATHYNELLACEA				
BES:1900	Parabathynellidae	*Atopobathynella* sp. 'WA'	RC15WAC0416	668584.57	7439798.37
BES:2297	Parabathynellidae	*Atopobathynella* sp. 'WA'	RC15WAC0413	669436.13	7439804.66
BES:1996	Bathynellidae	Bathynellidae sp. 'WA'	RC15WAC0413	669436.13	7439804.66
BES:2054	Bathynellidae	Bathynellidae sp. 'WA'	RC15WAC0384	667401.98	7440199.63
	AMPHIPODA				
BES:1812	Paramelitidae	*Kruptus* sp. 'WA'	RC13WAD0287	667339.68	7436249.24
BES:1910	Paramelitidae	*Kruptus* sp. 'WA'	RC15WAC0387	666231.13	7439987.54
BES:1966	Paramelitidae	*Kruptus* sp. 'WA'	RC14WAD0346	664939.59	7436650.84
BES:1971	Paramelitidae	*Kruptus* sp. 'WA'	RC15WAC0276	672654.61	7438949.45
BES:2352	Paramelitidae	*Maarrka* sp. 'WA'	RC12WAD0295	664742.89	7437505.38
	HAPLOTAXIDA				
BES:1844	Enchytraeidae	Enchytraeidae sp. indet.	RC12WAD0189	671538.78	7436245.02
BES:1936	Enchytraeidae	Enchytraeidae sp. indet.	RC15WAC0387	666231.13	7439987.54
BES:2035	Enchytraeidae	Enchytraeidae sp. indet.	RD14WAF0003	689191.74	7433400.35
BES:2039	Enchytraeidae	Enchytraeidae sp. indet.	RC14WAF0066	689286	7433433.84
BES:2114	Enchytraeidae	Enchytraeidae sp. indet.	RC14WAD0350	665336.97	7437144.78
BES:2355	Enchytraeidae	Enchytraeidae sp. indet.	RC15WAC0380	671570.22	7439796.36
	OLIGOCHAETA				
BES:1849		Oligochaeta sp. indet.	RC14WAD0346	664939.59	7436650.84
BES:2030		Oligochaeta sp. indet.	RC15WAC0384	667401.98	7440199.63
BES:2031		Oligochaeta sp. indet.	RC15WAC0413	669436.13	7439804.66
	ISOPODA				
BES:1876	Armadillidae	Armadillidae sp. indet.	RC12WAD0295	664742.89	7437505.38
BES:2199		Isopoda sp. indet.	RC12WAD0295	664742.89	7437505.38
	HEMIPTERA				
BES:2139	Meenoplidae	Meenoplidae sp. indet.	RC15WAC0377	667347.98	7439303.55
BES:2356	Meenoplidae	Meenoplidae sp. indet.	RC14WAD0217	665792.22	7436703.79
	THYSANURA				
BES:1823	Nicoletiidae	Atelurinae sp. indet.	RC14WAD0350	665336.97	7437144.78
	SYMPHYLA				
BES:2112	Scutigerellidae	Scutigerellidae sp. indet.	RC14WAF0072	692251.8	7434505.65
BES:2117	Scutigerellidae	Scutigerellidae sp. indet.	RC15WAC0276	672654.61	7438949.45
BES:2055		Symphyla sp. indet.	RC15WAC0197	668634.6	7439014.15

METHODS

The DNA sequencing and comparisons were conducted by Helix Molecular Solutions. A full account of the methods and detailed results can be found in Appendix I. The following details are provided in summary (from Helix 2016):

- Sequencing of the mitochondrial gene cytochrome oxidase subunit 1 (COI) and the nuclear gene 12s was conducted using multiple primers.

- Sequences were edited using GENEIOUS software, while alignments were conducted using CLUSTAL W software.
- Genetic distances were calculated using uncorrected p-distances (total percentage of nucleotide differences between sequences) and trees were constructed using neighbour–joining in MEGA 6.0 software.
- Based on published data, lineages were defined as haplotypes (or groups of haplotypes) differing by >3% sequence divergence (COI), while the thresholds for species-level divergence were defined on a taxon-by taxon basis, acknowledging that a vast majority of species- pairs differ from each other by >8% (COI), following Hebert et al. (2003). For this reason, divergences <3% (COI) were regarded as the same lineage within a species, and >8% (COI) were regarded as likely to be different species, however divergences between 3% – 8% were generally regarded as an intermediate zone between interspecific and intraspecific variability.

RESULTS

Table 2 shows the results of the genetic analyses within each of the groups of taxa. Overall, the analyses found that:

1. Several sequences in the Oligochaeta (*Pristina longiseta* and Phreodrillidae `OLP012`), Haplotaxida (Enchytraeidae `OLE026`), and Hemiptera (Meenoplidae `HEM003`) aligned to previously recorded species or lineages that are known to occur widely in the Pilbara;
2. Sequences of the Bathynellidae, Parabathynellidae, Amphipoda, Isopoda, and Symphyla were all unique regionally, with high levels of genetic divergence between any of the available regional material from these taxonomic groups and the samples from West Angelas;
3. Three specimens, respectively from the Bathynellidae, Oligochaeta, and Thysanura did not sequence successfully, therefore the identifications of these specimens have not changed; and
4. Additional putative species were revealed within the Amphipoda (*Kruptus* `AMP045`, Paramelitidae `AMP036`, and *Maarka* `AMP037`), Haplotaxida (Enchytraeidae `OLE026`, `OLE028`, `OLE029`, and `OLE030`), Oligochaeta (*Pristina longiseta* and Phreodrillidae `OLP012`), and Symphyla (Scutigerellidae `SYM027`, `SYM028`, and `SYM029`). The implications for the remaining specimens within these groups that have not been sequenced are discussed in further detail below.

Figure 1 shows the locations of subterranean fauna sequences from Deposits C, D, and G, and the resulting genetic identifications of the taxa.

Table 2: Summary of local and regional genetic alignment results.

Specimen code	HIGHER TAXON Family	Preliminary ID	Bore/hole name	Local match	% div. COI	Regional match	% div. COI	Nominal species-level ID	Comment
BATHYNELLACEA									
BES:1900	Parabathynellidae	*Atopobathynella* sp. 'WA'	RC15WAC0416	BES:2297	0.3%	No	>10%	***Atopobathynella* `BAP027`**	Regionally distinct species of Parabathynellidae. Likely *Atopobathynella* following G. Perina morphological ID, August 2016.
BES:2297	Parabathynellidae	*Atopobathynella* sp. 'WA'	RC15WAC0413	BES:1900					
BES:1996	Bathynellidae	Bathynellidae sp. 'WA'	RC15WAC0413	No		No	>19%	**Bathynellidae `BAB018`**	Regionally distinct species of Bathynellidae
BES:2054	Bathynellidae	Bathynellidae sp. 'WA'	RC15WAC0384						Sequence failed
AMPHIPODA									
BES:1812	Paramelitidae	*Kruptus* sp. 'WA'	RC13WAD0287	BES: 1910, 1966	0.3 - 0.9%	No	>15%	***Kruptus* `AMP035`**	Regionally distinct species of Paramelitidae. Likely *Kruptus* following G. Perina morphological ID, August 2016.
BES:1910	Paramelitidae	*Kruptus* sp. 'WA'	RC15WAC0387	BES: 1812, 1966					
BES:1966	Paramelitidae	*Kruptus* sp. 'WA'	RC14WAD0346	BES: 1812, 1910					
BES:1971	Paramelitidae	*Kruptus* sp. 'WA'	RC15WAC0276	No	>17%	No	>15%	**Paramelitidae `AMP036`**	Regionally distinct species of Paramelitidae. Juvenile specimens only, uncertain morphological ID. Unable to be placed to genus on current information.
BES:2352	Paramelitidae	*Maarrka* sp. 'WA'	RC12WAD0295	No	>17%	No	>15%	***Maarka* `AMP037`**	Regionally distinct species of Paramelitidae. Likely *Maarka* following G. Perina morphological ID, August 2016.
HAPLOTAXIDA									
BES:1936	Enchytraeidae	Enchytraeidae sp. indet.	RC15WAC0387	BES:2355	1.2%	OLE26	2.8% - 3.4%	**Enchytraeidae `OLE026`**	Genetic alignment to a species (OLE26) previously sampled elsewhere in the Pilbara (Helix 2016).
BES:2355	Enchytraeidae	Enchytraeidae sp. indet.	RC15WAC0380	BES:1936					
BES:1844	Enchytraeidae	Enchytraeidae sp. indet.	RC12WAD0189	No	>16%	No	>12%	**Enchytraeidae `OLE028`**	Regionally distinct species of Enchytraeidae.
BES:2114	Enchytraeidae	Enchytraeidae sp. indet.	RC14WAD0350	No	>7.5%	Possibly	5.7%	**Enchytraeidae `OLE029`**	Potentially distinct, but moderate divergences indicate more information required to separate distinct species. Occurs in a large species complex found across a wide area and multiple catchment boundaries (Helix 2016).
BES:2035	Enchytraeidae	Enchytraeidae sp. indet.	RD14WAF0003	BES:2039	1.6%	Possibly	7.8%	**Enchytraeidae `OLE030`**	Potentially distinct, but moderate divergences indicate more information required to separate distinct species. Occurs in a large species complex found across a wide area and multiple catchment boundaries (Helix 2016).
BES:2039	Enchytraeidae	Enchytraeidae sp. indet.	RC14WAF0066	BES:2035					