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South Flank MAR subterranean fauna desktop assessment

This memo presents available biological, geological and hydrogeological information and provides a preliminary assessment of potential conservation issues surrounding subterranean fauna species in relation to managed aquifer recharge (MAR) at South Flank. The area proposed for construction of groundwater reinjection bores is referred to as 'the Study Area'.

Project Description

The Study Area, located immediately to the south of South Flank mine pits, north of Mt Robinson and covering an area of approximately 12.3 km^2, is the proposed location for the disposal of surplus water from the Mining Area C operations (MAC) north of South Flank. The results of numerical modelling for various MAR scenarios, in terms of mounding height and spatial area of influence ('the mounding area'), are provided in BHPBIO (2018). Mounding above the existing water table in a range of key locations over the life of mine (LOM) for various MAR scenarios tested is shown in Figure 1. The actual reinjection locations and volumes are yet to be finalised and it is understood that the magnitude of mounding will vary with these parameters.

This assessment is based on the scenario in which dolomite transmissivity is 500 m^2/d and assumes that there is hydraulic connectivity between the South Flank Valley detrital aquifer and the South Flank Marra Mamba Formation (MMF) deposits. Under these conditions the model suggests that peak mounding occurs around 10 years after the commencement of reinjection and is expected to exceed the ground surface (approximately 80 m above the current water table) in the central wellfield and approximately 25 m above the current water table in the eastern and western portions of the wellfield (Figures 2 and 3). Mounding is anticipated to attenuate faster to the north of the wellfield than to the east and west and a large proportion of northern South Flank mine pit areas will remain uninfluenced. However, significant mounding is expected throughout the southern portion of the mining area (BHPBIO 2018).

Existing Subterranean Environment

Previous subterranean fauna assessments have described the subterranean environment across MAC and South Flank deposits (Bennelongia 2016a, b) and further information on the geological and hydrogeological setting for South Flank is given in South Flank Hydrogeological Investigation Program Report (Resource Engineering WAIO 2017), although information pertaining directly to the Study Area is limited. Geology at the scale of 1:20,000 around MAC and South Flank is mapped in Figure 4.

In brief, the mining areas cover part of two parallel ranges, the Packsaddle and Jirrpalpur Ranges which lie north and south of the Northern Flank Valley, respectively. South Flank lies to the south of the Jirrpalpur Range. Both North Flank and South Flank are formed by the weathering of the relatively soft Wittenoom Formation (BHP 2008). The dissolution of Dolomite (a member of the Wittenoom Formation) is likely to have led to the formation of large pores, voids and cavities (BHP 2008) that are prospective for troglofauna. There are four major subterranean habitats present: detritals, including quaternary and tertiary deposits, both of which are variable but are considered to provide prospective habitat in places; hardcap, which prospective due to the occurrence of frequent voids; mineralised rock, including banded ironstone formations (BIF) containing voids and cavities that are considered prospective; and host rock, which is generally not considered to be prospective habitat due to lacking subterranean spaces (Bennelongia 2016b).

It is generally considered that subterranean species in detritals tend to be at least moderately widespread owing to more extensive habitat connectivity than in other subterranean environments, such as mineralised formations and calcrete islands, with the caveat that demonstrating notional widespread distributions through field collections can be problematic due to spatial constraints on sampling, low population densities and resultant low yields.

Measurements taken during previous subterranean fauna survey demonstrate that the water table is relatively deep throughout the Study Area and surrounds (Figure 2), ranging from 26–127 metres below top of collar (mbtc) throughout South Flank and groundwaters are fresh, with conductivities at the water table rarely exceeding 1,000 µS cm^{-1}.

Species in the Study Area and Surrounds: Troglofauna

Bennelongia records show that at least 3,073 holes have been sampled for troglofauna via scraping or trapping (or both) within a search area of 100 km x 100 km surrounding the study area including at least 330 samples[1] from 132 holes in the mounding area. Besides higher order identifications that may belong to other recorded species, at least 28 species of troglofauna have been recorded inside the mounding area (Table 2). While 17 of these species have been recorded outside the mounding area and proposed mine pits, in some cases having either locally or regionally extensive ranges, 11 species are only known from holes that are either within the mounding area or within both the mounding area and mine pits. The ranges and conservation issues relating to MAR of these 11 species are discussed below and collection locations are shown in Figure 5.

- *Draculoides* sp. B16. This schizomid has been collected in three scrapes (above 62 m) and two traps (10–11 mbtc) across four holes in the Central portion of South Flank over a linear range of about 1.8 km. Two of the collection holes are within the South Flank mine pit area but outside the mounding area. The other two holes (SF0154R and SF0095R), which based on previous measurements of water levels in nearby holes have groundwater levels of 73–78 mbtc, are out of pit but are expected to receive mounding of approximately 45 m and 65 m, respectively. Based on modelling the water table in hole SF0095R, in which *Draculoides* sp. B16 was collected at 11 mbtc, will rise to about 8 metres below surface. However, assuming that across its range the species occupies depths of around 10 m, habitat will remain for this species around hole SF0154R where the water table will rise to approximately 33 m. Based on collection data and sampling effort is reasonable to assume that this schizomid has a confined distribution and a significant proportion of its habitat may be removed.

- *Cryptops* sp. B16. This species of centipede has been recorded from two holes outside the mounding area but within South Flank mine pit area (SF0422R and SF0495R, collection depths unknown) and from one hole outside of mine pits but within the mounding area (SF0095R, trap depth 11 mbtc). Based on previous measurements in nearby holes the water table in SF0095R probably stands at around 73 m and after mounding will rise to 8–13 m.

[1]A whole troglofauna sample comprises a scrape and trap (or double trap) in a single hole.

Assuming that trap depth in this hole is indicative of the habitat occupied by *Cryptops* sp. B16, some habitat will remain for the species above the water table in the vicinity of SF0095R. Moreover, collection depths and mapped geology around SF0095R (Figure 5) suggest that this species may occupy detritals. The continuation of detritals from SF0095R beyond the mounding area (as shown in Figure 5), as well as its in known minimum linear range of 6.2 km, suggest that *Cryptops* sp. B16 is unlikely to be restricted to either the mounding area or mining areas.

- Parajapygidae `DPL023`. This species of dipluran has been collected in a stygofauna net sample outside the mounding area but within South Flank mine pits in hole SF0259R, as well as in a scrape in hole SF0050R, which is within both the mine pit and mounding area. Mounding in the vicinity of SF0050R is expected to be in the order of 10–15 m and, considering the depth to the water table (based on holes within 500 m) is likely to be at least 60 m, the layers occupied by this species are unlikely to be flooded. Parajapygidae `DPL023` was previously assessed unlikely to be restricted to mining areas, having been collected from detritals that extend south beyond mine pits (Bennelongia 2016b).

- Pselaphinae sp. B12. This species of staphylinid beetle has only been recorded in a single hole that is outside of South Flank mine pits but within the mounding area. It was recorded in a trap at 20 mbtc in hole SF0095R where the water table is likely to currently sit at around 73 m and mounding is expected in the order of 65 m. Based on the collection depth and complementary geological information this species occupies habitat in the Mount Newman member (BIF, carbonates and shales). Troglofaunal staphylinid species have highly variable ranges that probably depend on ecology and the extent of available habitat. Further information on habitat connectivity is necessary to infer the wider occurrence of Pselaphinae sp. B12.

- Sciaridae sp. B05. This species of fungus gnat was recorded in a scrape in hole SF0120R outside of South Flank mine pits but within the mounding area. The water table in the vicinity of this hole sits at around 60 mbtc and mounding is expected in the order of 35–40 m. While the precise collection depth of this species is unknown, it is generally considered that troglofaunal sciarid species are troglophiles and likely to occupy a range of depths within one location, including detritals. They may also have moderately extensive geographic distributions. The geological profile in SF0120R comprises detritals (3–30 m) and West Angela Member (interbedded shales, BIF and dolomite, 30–58 m). Mounding is unlikely to significantly threaten this species.

- *Trinemura* sp. A singleton juvenile female of this silverfish was recorded in a scrape in hole SF0119R, outside South Flank mine pits, but within the mounding area and is the only record of this genus from the Study Area. Congeneric specimens have been recorded outside mine pits and mounding areas in both South Flank and MAC, with the nearest congeneric record coming from 2.5 km west of SF01195 (*Trinemura* sp. B09, hole SF4057R). While the specimen collected from SF0119R may belong to a species recorded elsewhere in the vicinity, most probably *Trinemura* sp. B09 which has a known linear range of 10.7 km, the specimen from SF0119R could not be identified to species-level and confirmation of its alignment with a species recorded in non-disturbance areas would require molecular work. Halse and Pearson (2014) reported a median range for troglofauna silverfish species in the Pilbara of 11 km^2 and, based on records in the Bennelongia database of 22 congeners that have been collected from two or more holes in the Pilbara, species of *Trinemura* have a median linear range of 7.2 km. There is also evidence for some troglofauna silverfish having moderately extensive ranges, including *Dodecastyla crypta*, which has been recorded within 2 km of SF0119R and has an east-west linear range of at least 20 km across the Packsaddle and Jirrpalpur Ranges (Smith and McRae 2014). Therefore, while the *Trinemura* specimen from SF0119R is currently treated

conservatively as having an unknown and potentially small range, it is considered more likely that it has a range extending beyond the influence of mounding.

- *Troglarmadillo* sp. B14. This species of slater has been recorded in a scrape and two traps (9 m and 12 m) in hole GSR0020 (within both South Flank mine pit and mounding areas) and approximately 11.2 km east in a scrape in hole GRS0017 (outside mounding but in pit). It was previously assessed as unlikely to be restricted to South Flank mining areas, although it probably has a small geographic distribution (Bennelongia 2016b). Depth to the water table (based on measurements in nearby holes) in the vicinity of hole GSR0020 is around 80–90 M and mounding in the order of 70–75 m is expected. Depending on the depth of detritals this could equate to a significant localised loss of habitat for *Troglarmadillo* sp. B14. The collection of the species outside the mounding area and its moderately large known linear range provides evidence for its persistence following MAR, provided that it does in fact occur outside the pit area around GRS0017.

- *Troglarmadillo* sp. B37. This species of slater has been collected in a trap in hole SF0042R (40 m) and two traps in hole SF0150R (11 m and 22 m). Both holes are out of mine pits but within the mounding area: depth to the water table is approximately 59 m in SF0042R, with mounding in the order of 20–25 m expected; while depth to water is approximately 75 m in SF0150R, with mounding of 45–50 m expected. The geological profiles of the collection holes indicate that *Troglarmadillo* sp. B37 occupies detritals in both TD2 and TD3 unit and while a significant proportion of these habitats within the known range of *Troglarmadillo* sp. B37 will be flooded, much of the detrital layers will remain above the water table. Although species of *Troglarmadillo* typically have small ranges (Halse and Pearson 2014), species in detritals tend to have distributions related to the extent of habitat. Mapped geology indicates that the alluvial unit around SF0042R and SF0150R extends beyond the mounding area and mine pits.

- Philosciidae sp. B03. This slater is only known from hole GLR002, inside South Flank mine pits and the mounding area. Its high abundance in a single hole indicates that Philosciidae sp. B03 is likely to have a small range and consequently it was previously assessed as being uncertain to occur outside mining areas (Bennelongia 2016b). Trap depths of 20 m and 50 m indicate that the species inhabits the Mt Newman Member. Based on measurements in nearby holes the water table in the vicinity of GLR002 sits at depths of of 65–75 m. Mounding in this area is expected to be in the order of 10–15 m meaning the water table may rise to as high as 50 m below surface. As the proposed pit floor around GLR002 will extend no more than 25 m below surface, suitable habitat should remain *in situ* between 25 m and 50 m following both mining and MAR. Previous work suggests that there is likely to be a considerable amount of suitable habitat for Philosciidae sp. B03 below the pit floor and probably also to the east of the pit in Mount Newman Member (Bennelongia 2017; BHPBIO 2016).

- *Hanseniella* sp. B35. This symphylan is known from a single hole, SF0119R, in the northwest of the Study Area from which it was collected in a scrape. Depth to the water table in this hole is around 60 m and mounding in the order of 35–40 m is expected. The habitat occupied by this species cannot be certain because the precise collection depth is unknown for scrape samples, although it is likely to have been collected from either detritals (0–29.8 m) or West Angela Member (29.8–52.4 m). Although other species of *Hanseniella* known from the vicinity of the Study Area are thought to occupy detritals and are therefore considered unlikely to be confined to mine areas, at least two species of *Hanseniella* recorded by Bennelongia are only known from considerable depths (29 m and 50 m). Many species of *Hanseniella* have small ranges: Halse and Pearson (2014) reported a median range for symphylan species in the Pilbara of 8.3 km^2 and, based on records in the Bennelongia database of 15 congeneric morphospecies that have been collected from two or more holes in the Pilbara, species of *Hanseniella* have a median linear range of 4.5 km. The persistence of *Hanseniella* sp. B35

within the mounding area is based on the assumption that it occupies detritals or other surficial habitats less than about 20 m below surface, although this is uncertain. If *Hanseniella* sp. B35 does occupy detritals it is likely to have a distribution extending beyond both the mounding area and mine pits.

- *Hanseniella* sp. B36-DNA. This species of *Hanseniella* is only known from hole SF0095R in the north of the Study Area where it was collected in a scrape within 20 m of the ground

  surface. The geological profile in this hole comprises surface scree (0–6 m) and Mt Newman Member (6–24 m), although it is unclear which of these is the habitat occupied by *Hanseniella* sp. B36-DNA. The water table in the vicinity of SF095R stands at around 73 m below surface and mounding in the order of 65 m is expected, potentially indicating significant habitat removal around the collection site of *Hanseniella* sp. B36-DNA. As reported above for *Hanseniella* sp. B35, many congeneric species have small ranges.

Stygofauna

Sampling effort targeting stygofauna within the vicinity of South Flank and MAC has also been considerable and Bennelongia have records of at least 2,058 samples from 1,199 holes having been collected within a search area of 100 km x 100 km surrounding the Study Area. Discounting higher order identifications that may belong to other recorded species, at least seven species of stygofauna are known from within the mounding area (Table 3). Six of these species are either known or assumed to have widespread distributions. The remaining species, the syncarid *Bathynella* sp. 2 (South Flank), is known from a single hole (SF3016R) east of the Study Area but within the mounding area. This occurrence of this species outside the mounding area cannot be confirmed based on current data.

Potential Impacts

The potential impacts of mining and related operations on subterranean fauna can be broadly divided into primary impacts, namely the impacts causing possible extinction or threat to the persistence of local populations through direct removal of habitat, and secondary impacts that degrade habitat rather than remove it and therefore, for the most part, only reduce population densities. Secondary impacts include pollutants, altered water chemistry, mine blasting and changes to energy and nutrient pathways. Assessing the threat of secondary impacts usually requires detailed information about the expected environmental changes. The potential threats to subterranean fauna resulting from MAR comprise a mixture of primary and secondary impacts (Table 1) and are considered separately for troglofauna and stygofauna.

The potential primary impact of MAR on troglofauna is habitat loss via flooding due to the increase in piezometric pressure following reinjection and subsequent rise of the water table. The severity of impact on troglofauna species that are confined to the mounding area will be dependent on the height of mounding and the geological habitat preferences of the species.

Table 1. Summary of potential threats to subterranean fauna from managed aquifer recharge.

Fauna	Threat	Primary/secondary	Comments
Troglofauna	Modified groundwater levels	Primary	Increased groundwater levels via recharge may flood troglofauna habitat that currently sits above the watertable causing direct removal of troglofaunal habitat.
Stygofauna	Chemistry changes	Secondary	Moderate changes in chemical composition may cause reductions in stygofauna fitness and population densities. More severe changes could effectively remove suitable habitat (thus being a primary impact) and lead to loss of species and communities.

As discussed, 11 species of troglofauna have only been recorded within disturbance areas (mounding area and mine pits). Despite limited collection data there is some (though not definitive) evidence to

support the notional occurrences of a number of these species outside disturbance areas. The distributions of at least four species outside South Flank disturbance areas (mounding and mine pits) is less certain: these species are *Draculoides* sp. B16, Pselaphinae sp. B12, *Hanseniella* sp. B35 and *Hanseniella* sp. B36-DNA.

In the absence of detailed chemical information for both disposal water and the receiving environment it is considered that the potential impact of MAR on stygofauna is minor. Groundwater parameters that may change as a result of reinjection are the level of salinity and proportions of major ions. There is currently too little information about the chemistry of groundwater in the Study Area to know whether reinjection is likely to result in water quality changes.

Conclusions

Based on available numerical modelling of MAR, habitat information and species collection data from the Study Area and relevant regional areas it is concluded that:

- Survey for subterranean fauna in the vicinity of the Study Area has been considerable and has demonstrated the occurrence of a rich troglofauna community. The stygofauna community appears to be less rich but nonetheless significant.
- 28 species of troglofauna have been recorded inside the area expected to be influenced by mounding. Eleven of these species are only known from areas that are within disturbance areas pertaining to mounding and/or mine pits. For some of these species there is limited evidence to support notional occurrences outside disturbance areas.
- Current information probably under-estimates the extent of species' ranges and some species may be able to co-exist with mounding, depending on its vertical extent and their geological habitat preferences.
- Seven species of stygofauna have been recorded in the mounding area although six of these are known or considered to have ranges extending beyond the expected disturbance.
- It is considered that the potential impact of MAR on stygofauna is minor, although more detailed information on the chemistry of disposal water and the receiving environment is needed.

References

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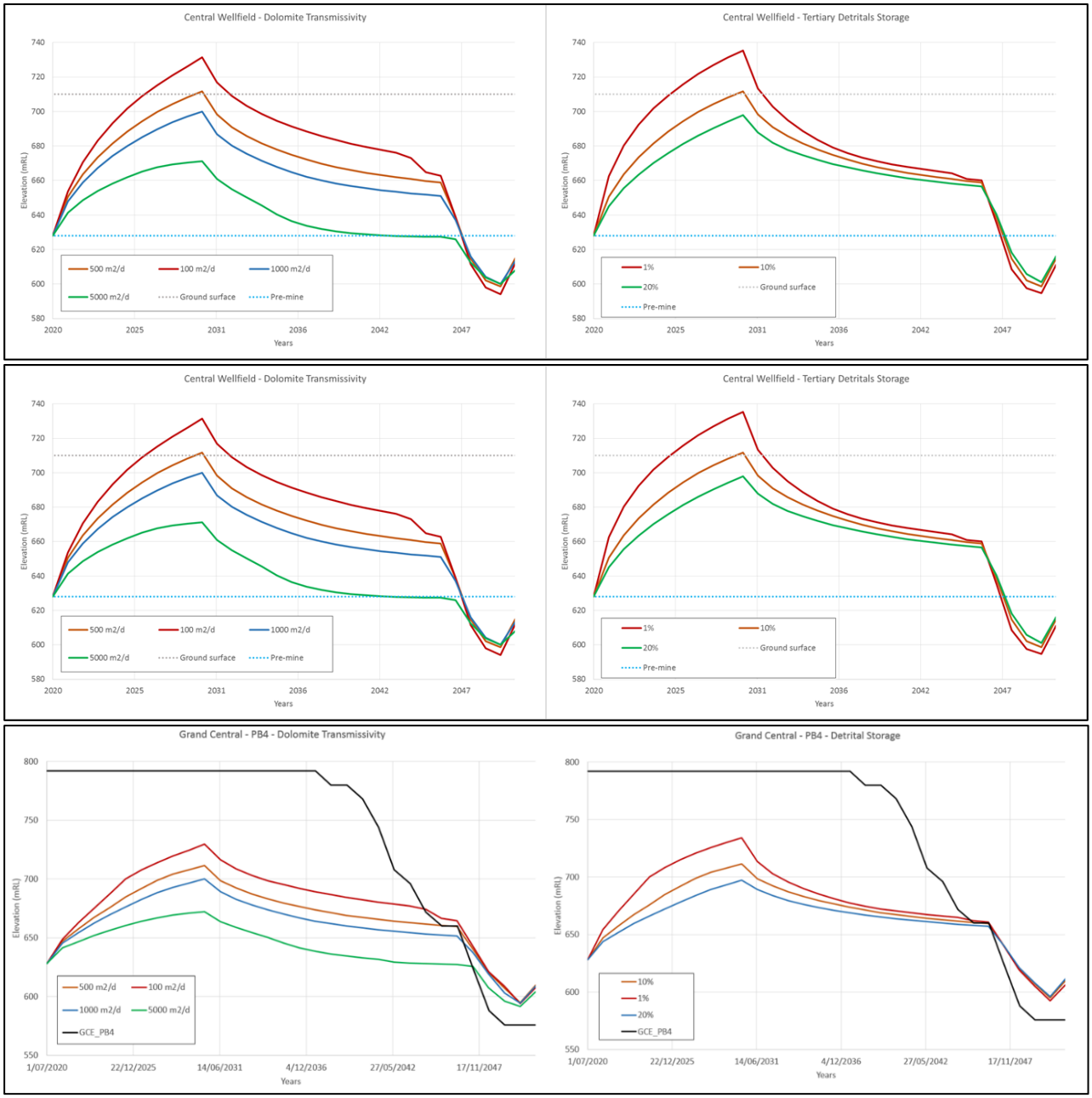
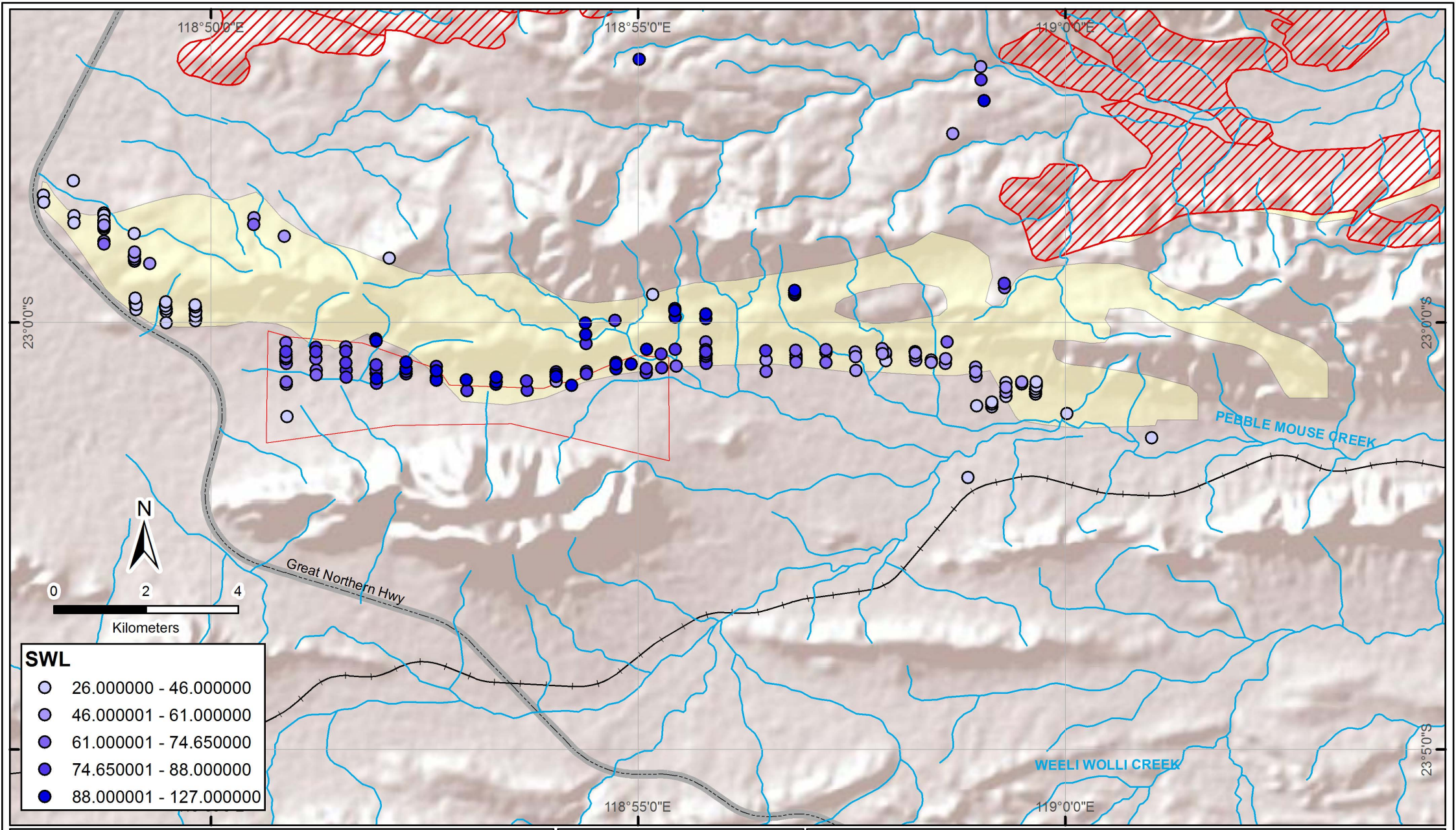


Figure 1. Outcomes of numerical modelling of groundwater levels in key locations during managed aquifer recharge at South Flank (BHPBIO 2018).



Legend

- South Flank MAR Wellfield
- South Flank mine pits
- MAC approved pits Rev 6
- Rail Lines
- Highway
- Drainage lines

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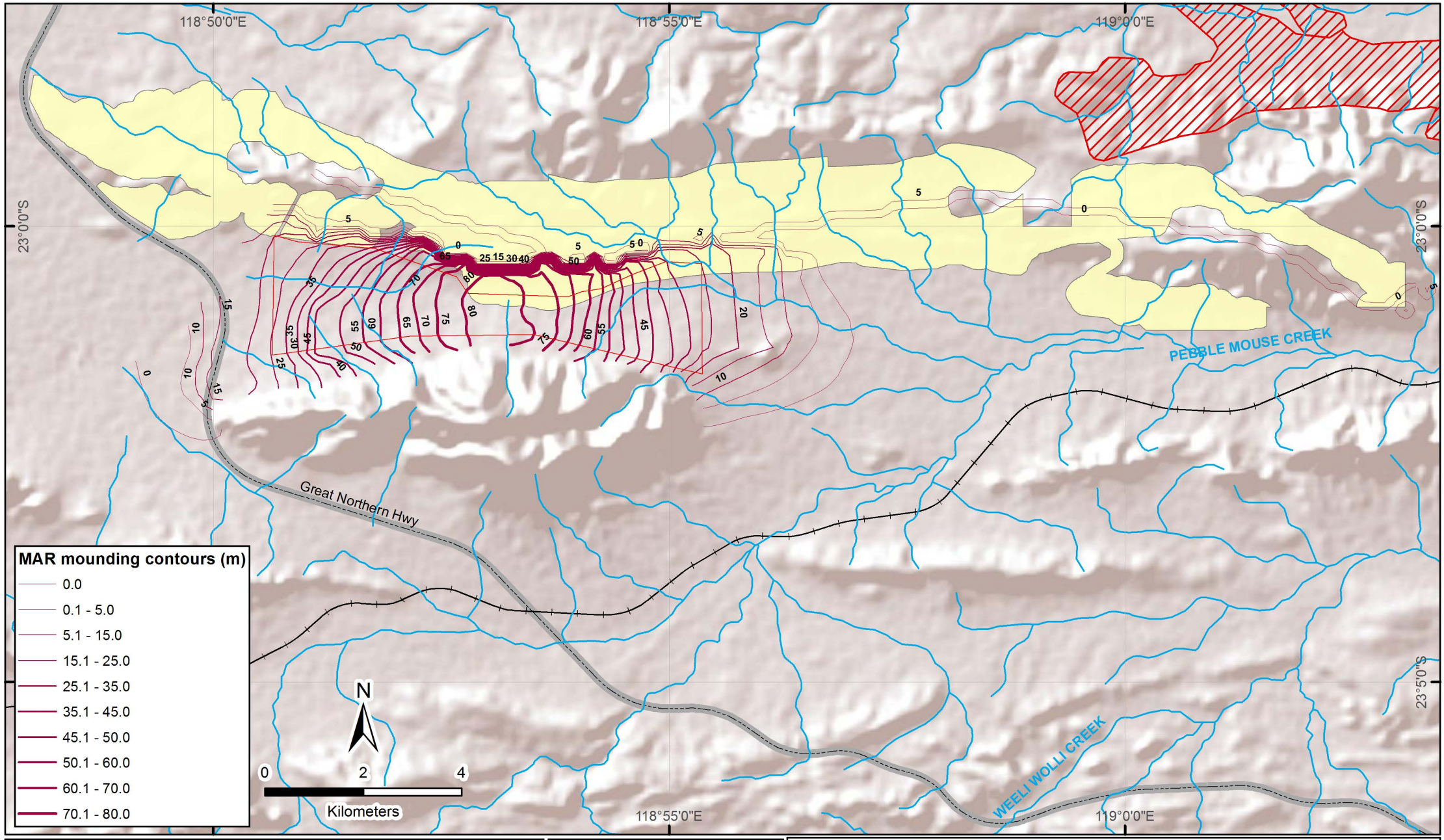
GDA_1994_MGA_Zone_50
Author: A. Mittra
Date: 01-11-2018

Figure 2. Depths to groundwater (metres below top of collar) measured during previous survey for subterranean fauna.



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GCS_GDA_1994
Author: A. Mittra
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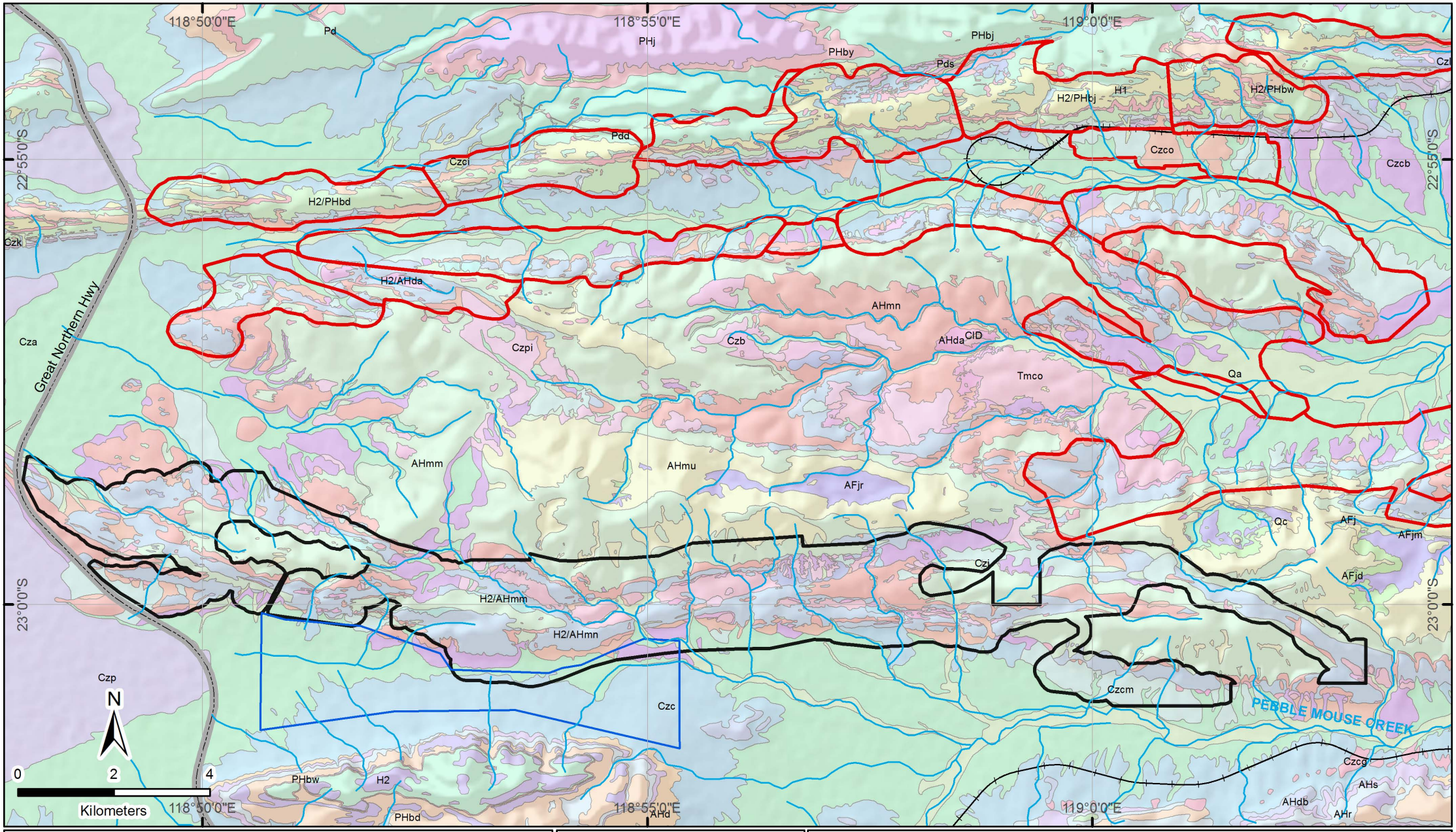
Figure 3. Mounding of the watertable following managed aquifer recharge in the Study Area after 10 years assuming dolomite transmissivity of 500 m2/d



Legend

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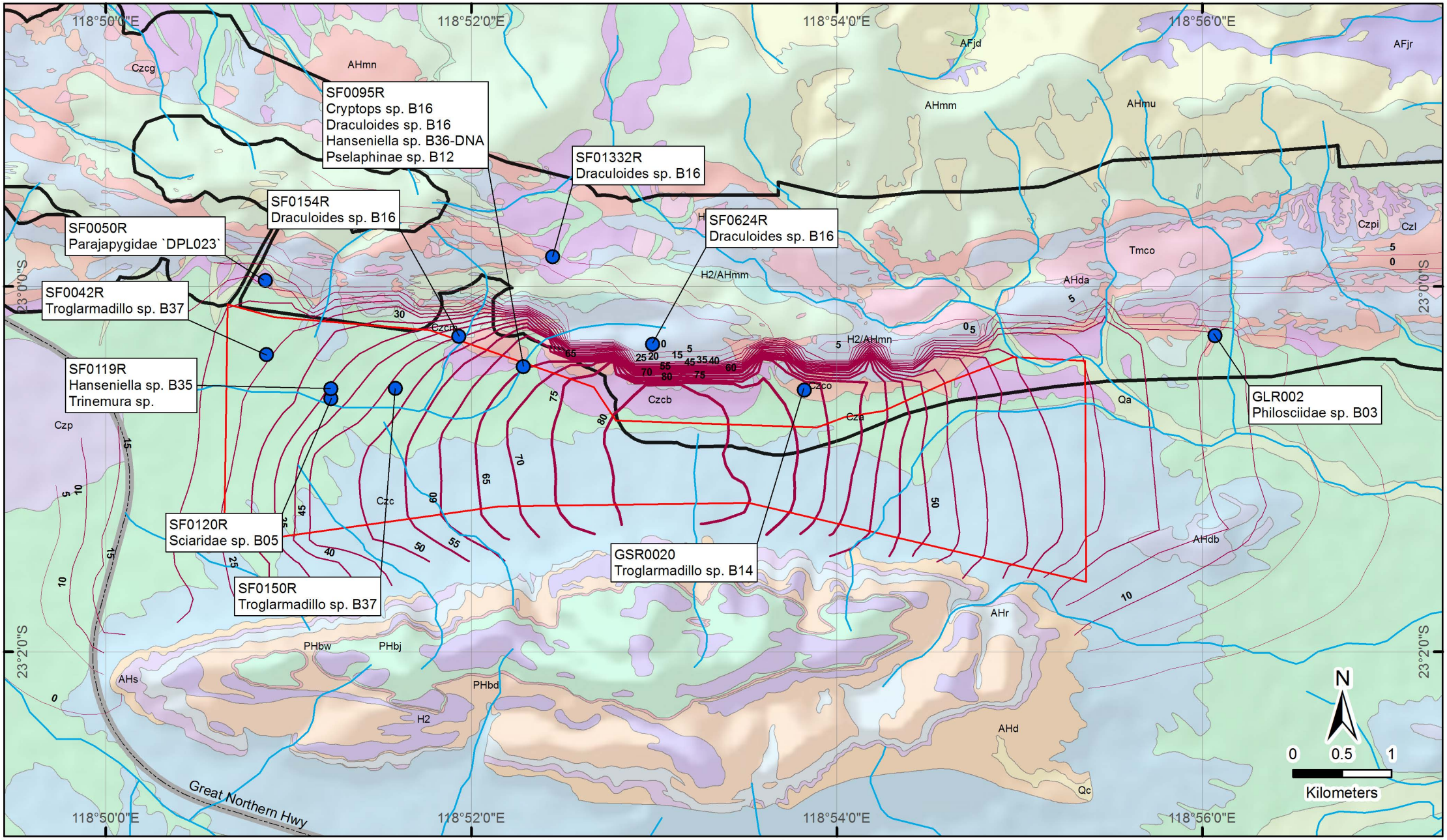
GCS_GDA_1994
Author: A. Mittra
Date: 20-11-2018

Figure 4. Geology in and around MAC and South Flank mapped at the 1:20,000 scale (provided by BHP). Units are labelled according to GSWA codes.



Legend

- Troglofauna
- South Flank MAR wellfield
- South Flank mine pits
- Rail_Lines
- Highway
- Drainage lines

Bennelongia Environmental Consultants

GCS_GDA_1994
Author: A. Mittra
Date: 20-11-2018

Figure 5. Collection locations of troglofauna species known only from holes within the modelled mounding area (dolomite transmissivity 500 m2/day, 10 years)

Geology mapped at the 1:20,000 scale and labelled according to GSWA codes

Table 2. Troglofauna species known from within the mounding area of influence and their known distributions.
Grey shading indicates that the species is only known from within the mounding area, proposed pits, or both.

Higher Classification	Lowest Identification	Comments on Known Distribution
Arthropoda		
Arachnida		
Palpigradi	Palpigradi sp.*	Higher order identification.
	Palpigradi sp. B01	Widespread throughout the Pilbara.
Pseudoscorpiones		
Chthoniidae	Chthoniidae sp.*	Higher order identification.
	Lagynochthonius `PSE039`	Recorded throughout the central Hamersley Range.
	Lagynochthonius sp.*	Higher order identification.
Schizomida		
Hubbardiidae	*Draculoides* `SCH022`	Recorded throughout the central Hamersley Range.
	Draculoides sp. B16	Known from four holes: two within mine pits; and two outside mine pits but within mounding area.
Chilopoda		
Geophilida		
Schendylidae	*Australoschendyla* sp. B06	Known from two holes at South Flank, one of which is outside the mounding area and pits. Previously assessed as being unlikely to be restricted to the impact area.
Scolopendrida		
Cryptopidae	*Cryptops* sp. B16	Known from three holes at South Flank, including one inside the mounding area. The other two holes are inside the proposed pits.
Diplopoda		
Polyxenida		
Lophoproctidae	*Lophoturus madecassus*	Cosmopolitan troglophile.
Entognatha		
Diplura		
Japygidae	Japygidae `DPL002`	Recognised as a species complex, recorded throughout the central Hamersley Range.
Parajapygidae	Parajapygidae `DPL023`	Known from two holes at South Flank, one of which is outside the mounding area but inside proposed pits. Previously assessed as being unlikely to be restricted to the impact area.
Insecta		
Blattodea		
Blattidae	Blattidae sp.*	Higher order identification.
	Blattidae sp. B06 (= sp. S02)	Recorded throughout the central Hamersley Range.
Nocticolidae	*Nocticola cockingi* s.l.	The *cockingi* clade comprises multiple species and is known from throughout the central Hamersley Range.
	Nocticola sp.*	Higher order identification.
Coleoptera		
Carabidae	*Typhlozuphium* sp. B02	Known from three holes at South Flank: two inside mine pits; and one outside pits, but within mounding area.
Zuphiini sp.		
Curculionidae	Curculionidae Genus 1 sp.*	Higher order identification.
	Curculionidae Genus 1 sp. B02 (=Curculionidae sp. S02)	Recorded throughout the central Hamersley Range.

Higher Classification	Lowest Identification	Comments on Known Distribution
Staphylinidae	Pselaphinae sp. B12	Known only from a single hole at South Flank within the mounding area (outside pits).
Diptera		
Sciaridae	Sciaridae sp.*	Higher order identification.
	Sciaridae sp. B01	Recorded throughout the central Hamersley Range.
	Sciaridae sp. B05	Known only from a single hole within the mounding area (outside pits).
Hemiptera		
Meenoplidae	*Phaconeura* sp.*	Higher order identification.
	Phaconeura sp. B02 s.l. (=Meenoplidae sp. S01)	A species complex, currently known from the central Hamersley Range.
	Phaconeura sp. B04	A troglophile that lives underground for part of its life, known from the Pilbara and Goldfields.
	Phaconeura sp. B13	Known from outside mounding area and mine pits (North Flank and South Flank).
Zygentoma		
Nicoletiidae	*Dodecastyla crypta*	Recorded throughout MAC (Packsaddle, North Flank and South Flank)
	Trinemura sp.	Higher order identification from within the mounding area, conservatively treated as being potentially restricted, due to uncertain alignment with species recorded elsewhere including two species from South Flank/MAC.
Malacostraca		
Isopoda		
Armadillidae	*Troglarmadillo* sp. B13	Known from outside mounding area and mine pits at South Flank.
	Troglarmadillo sp. B14	Known from two holes at South Flank: one inside the mounding area and mine pit; the other outside mounding but in pit.
	Troglarmadillo sp. B37	Known from two holes at South Flank, both within the mounding area (outside mine pits).
Philosciidae	Philosciidae sp. B03	Known only from a single hole at South Flank that is within both the mounding area and mine pits.
Pauropoda		
Tetramerocerata		
Pauropodidae	Pauropodidae sp.*	Higher order identification.
	Pauropodidae sp. B14	Known from within mounding/mine pit at South Flank and Packsaddle Range.
Symphyla		
Cephalostigmata		
Scutigerellidae	*Hanseniella* sp. B35	Known from a single hole at South Flank that is inside the mounding area.
	Hanseniella sp. B36-DNA	Known from a single hole at South Flank that is inside the mounding area.

Table 3. Stygofauna species known from within the mounding area and their known distributions.
Grey shading indicates that the species is only known from within the mounding area, proposed pits, or both.

Higher classification	Lowest identification	Comments on distribution
Annelida		
Clitellata		
Haplotaxida		
Phreodrilidae	Phreodrilidae sp. AP DVC s.l.	A species complex, the family is highly diverse (see Brown *et al.* 2015).
	Oligochaeta sp.	Higher order identification.
Arthropoda		
Malacostraca		
Amphipoda		
Paramelitidae	Paramelitidae sp. B03	Known from South Flank, Weeli Wolli, Jinidi, Juna Downs, Mudlark and Yandi. Linear range of 69 km.
Syncarida		
Bathynellidae	*Bathynella* sp. 2 (South Flank)	Only known from hole SF3016R inside the mounding area (but outside mine pits).
Maxillopoda		
Cyclopoida		
Cyclopidae	*Microcyclops varicans*	Widespread throughout WA.
Harpacticoida		
Parastenocarididae	Parastenocarididae sp.*	Higher order identification.
	Parastenocaris sp.	Genus-level identification and range unknown.
	Copepoda sp.	Higher order identification.
Nematoda	Nematoda spp.	Insufficient taxonomic knowledge to assess nematodes in EIA.
Rotifera		
Filiniidae	*Filinia* sp.	Rotifer species are considered widespread.