Yeelirrie Uranium Project

Response to Submissions

Attachment 3

Revised subterranean fauna avoidance, minimisation, mitigation and offset measures

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Executive Summary

The Yeelirrie calcrete is the most extensively studied calcrete in the Yilgarn, with more than 850 deliberate subterranean fauna samples collected over eight rounds of sampling between 2009 and 2015. In total, 73 species of stygofauna and 45 species of troglofauna are known from the study area. 11 stygofauna and one troglofauna species are currently only known from the impact area. With guidance from EAG 12, Cameco has provided discussion that supports likely range extensions of the 12 species, which should be considered when assessing the predicted impacts of the Project.

In summary, Cameco has utilised the following hierarchy of controls to manage the impact of the Project on subterranean fauna through:

- Avoidance:
  - No abstraction wells will be located within the palaeochannel to the northwest of the pit. While this area is potentially an excellent source of groundwater, it also supports approximately 50 stygofauna species. Therefore, the Project would impact more than 68% of all known species if water was obtained from this area.
  - Establishing a Troglofauna Protection Area within the economic orebody in order to avoid four of the five troglofauna species only known from within the orebody.
- Minimise:
  - Abstraction wells have been relocated throughout the groundwater supply area in order to reduce groundwater impact. Cameco believes that there are a number of opportunities to continue to minimise this impact and these will be explored during the Definitive Feasibility Study, which must be undertaken prior to making the Final Investment Decision. Optimisation of the groundwater model indicates that drawdown can be minimised to avoid impact to another three species of stygofauna.
  - The TSF has been designed to also minimise the impact to the stygofauna population and aid the potential recovery of the palaeochannel to the south east of the mine pit.
- Mitigate/Manage:
  - A Groundwater Management Plan will be implemented so that abstraction wells are actively managed in relation to both groundwater drawdown and groundwater quality in order to protect critical habitat.
  - The area of PEC that will not be impacted by the Project will be managed as an exclusion zone and will not be impacted by excavation activities, groundwater abstraction or surface infrastructure.
  - Following the completion of mining, groundwater levels are expected to gradually recover to a pre-mining state, so that within 50 years, impact to the PEC habitat will be limited to 30% of the pre-mining state.
  - Cameco will undertake further targeted drilling and sampling to demonstrate the extensions of habitat and confirm the likely range extensions.
- Offsets:
  - An appropriate offsets package to be negotiated with relevant government agencies to counteract the residual uncertainty associated with stygofauna habitat and range distributions.

Cameco has revised its management approach and has proposed additional avoidance, minimisation, mitigation and offset measures to reduce impacts and risks to subterranean fauna.

Implementation of these updated measures will reduce the impact of the project to a level that in Cameco's view, meets the EPA's objective for Subterranean Fauna.

1. Introduction

As discussed in the PER, subterranean fauna is a significant issue and a key environmental factor for the Yeelirrie Uranium Project (the Project). As a result of public submissions on the PER, discussions with government agencies and additional information, Cameco has revised its management approach and has proposed additional avoidance, minimisation, mitigation and offset measures to reduce impacts and risks to subterranean fauna.

Implementation of these updated measures, which are discussed in detail below, will further reduce the Project's impact on subterranean fauna and help to preserve habitat. Cameco is strongly committed to implementing the presented measures, exploring further opportunities to reduce impact prior to Project implementation and actively managing areas of the PEC (critical habitat) that will not be impacted.

2. Overview

2.1 PEC

The study area contains PEC No. 49 '*Yeelirrie calcrete groundwater assemblage type on Carey palaeodrainage on Yeelirrie Station*'. At the time of preparing the PER, the PEC was defined spatially as a buffered area (see Figure 9-10 in the PER), without any delineation of the core area (the Yeelirrie saturated calcrete) containing the ecological community of interest, from the surrounding buffer, although the Yeelirrie calcrete is the focus of the listing. As a result of submissions to the PER and requests from the Department of Parks and Wildlife (DPaW) Cameco has presented a refined PEC boundary (Attachment 2 to response to submissions). It is now proposed, based on species distribution, that the PEC can be defined by the extent of saturated calcrete. Thus, the core habitat of the proposed Yeelirrie stygofauna PEC extends from just inside the eastern end of the proposed mine pit to the north-western extent of saturated calcrete 27.7 km away (Attachment 2 Figure 5). The proposed PEC occupies an area of approximately 4184 ha. Groundwater salinity within the proposed Yeelirrie PEC varies within a fine-scale heterogeneous mosaic but falls mostly within the range of 4,000-30,000 µS/cm. All salinity ranges within the PEC are represented outside the area of impact.

2.2 Species

A total of 73 species of stygofauna and 45 species of troglofauna are now known from the study area. While it is almost impossible to collect all invertebrate species occurring within a large, species-rich area without a very intense sampling program across the whole area, importantly for this assessment, the intensive sampling within the area of proposed groundwater drawdown appears to have recorded most of the stygofauna species occurring within this impact area. In total 25 stygofauna species have been collected from the area of drawdown, whereas species richness estimator algorithms applied to the dedicated stygofauna sampling results from the same area predicted only 23 species were expected to occur. The slightly different habitats accessed during the troglofauna sampling yielded a few extra species so that more species were collected than predicted to occur but the overall picture is of high sampling adequacy.

2.3 Sampling

The Yeelirrie calcrete is the most extensively studied calcrete in the Yilgarn. There were nearly 800 deliberately collected subterranean fauna samples collected from Yeelirrie by Subterranean Ecology (2011) (448 troglofauna samples and 347 stygofauna samples) collected over six rounds of sampling between 2009 and 2010. The Subterranean Ecology samples were collected in accordance with GS54A, which conforms to the approaches described in EAG12. Subsequently, Bennelongia (2015) collected a further 66 samples of stygofauna in two rounds of sampling in 2015, in accordance with EAG12.

In general, subterranean fauna sampling at Yeelirrie faced two constraints. The first is the restricted network of bores and drill holes. The location of the holes drilled between 2009 and 2011 were almost entirely confined to existing exploration drill lines. While these drill lines were 0.6-1 km apart within the proposed mine pit and intensively sampled at the western end, they were up to 7 km apart across the wider Yeelirrie calcrete with the result being that the proposed mine pit was sampled at a higher density than the area outside of the pit. Thus the stygofauna and troglofauna species present were much more likely to be recorded within the proposed mine pit than in the wider calcrete outside it, including the area outside the predicted drawdown. Figure 1 shows all stygofauna sampling locations.

The second constraint was the complexity of subterranean fauna habitat, both horizontally and vertically. Lenses of clay and alluvium occur within the calcrete and the type of calcrete varies from karstic through to powdery or cemented. It is considered that most stygofauna occur in karstic calcrete close to the watertable but some species avoid being near the watertable or prefer fine interstitial spaces and thus will occur in non-karstic microhabitats and perhaps in pockets of alluvium within or below the calcrete.

Salinities are often lower near the watertable surface than at depth and also vary spatially, according to whether surface recharge occurs locally and various other factors such as the extent of surface vegetation and soil type. Most sampling of stygofauna occurred in cased, slotted bores using a haul net to collect animals from beneath the calcrete layer through to the top of the watertable. This collecting process provided no information about the microhabitats in which particular stygofauna species occur. The lack of habitat information made it very difficult to demonstrate the wider range of apparently restricted species by sampling other areas containing their preferred microhabitat. Not only were preferred habitats unknown, there was also no capacity to predict where particular microhabitats might be located across the calcrete because of the fine-scale spatial complexity.

3. Impact Assessment

3.1 Habitat loss from groundwater drawdown

Habitat loss represents the most significant potential threat to subterranean fauna and is considered the principal threatening process.

Loss of stygofauna habitat at Yeelirrie will occur mainly through groundwater drawdown. The main considerations for determining the acceptable threshold drawdown levels were:

- Long-term natural falls in groundwater levels;
- Saturated calcrete thickness; and
- Ability to monitor and manage groundwater drawdown across the Project area.

It is common practice when examining relatively deep and uniform aquifers to assume that only drawdowns of greater than 2 m over and above natural fluctuations will have significant conservation impacts on stygofauna. At Yeelirrie, where the thickness of saturated calcrete habitat in the drawdown area is between 3 to 5 m thick and up to 13 m thick in the north-west, a more precautionary threshold of greater than 0.5 m was identified as the point when groundwater drawdown may result in enough loss of stygofauna habitat to have conservation effects. Cameco considers 0.5 m to be an acceptable threshold drawdown limit given the groundwater monitoring data available, depth of saturated calcrete and the need to be able to monitor and manage any impact. It is noted that a drawdown threshold of 0.5 m was used in the assessment of the Toro Wiluna Uranium Project.

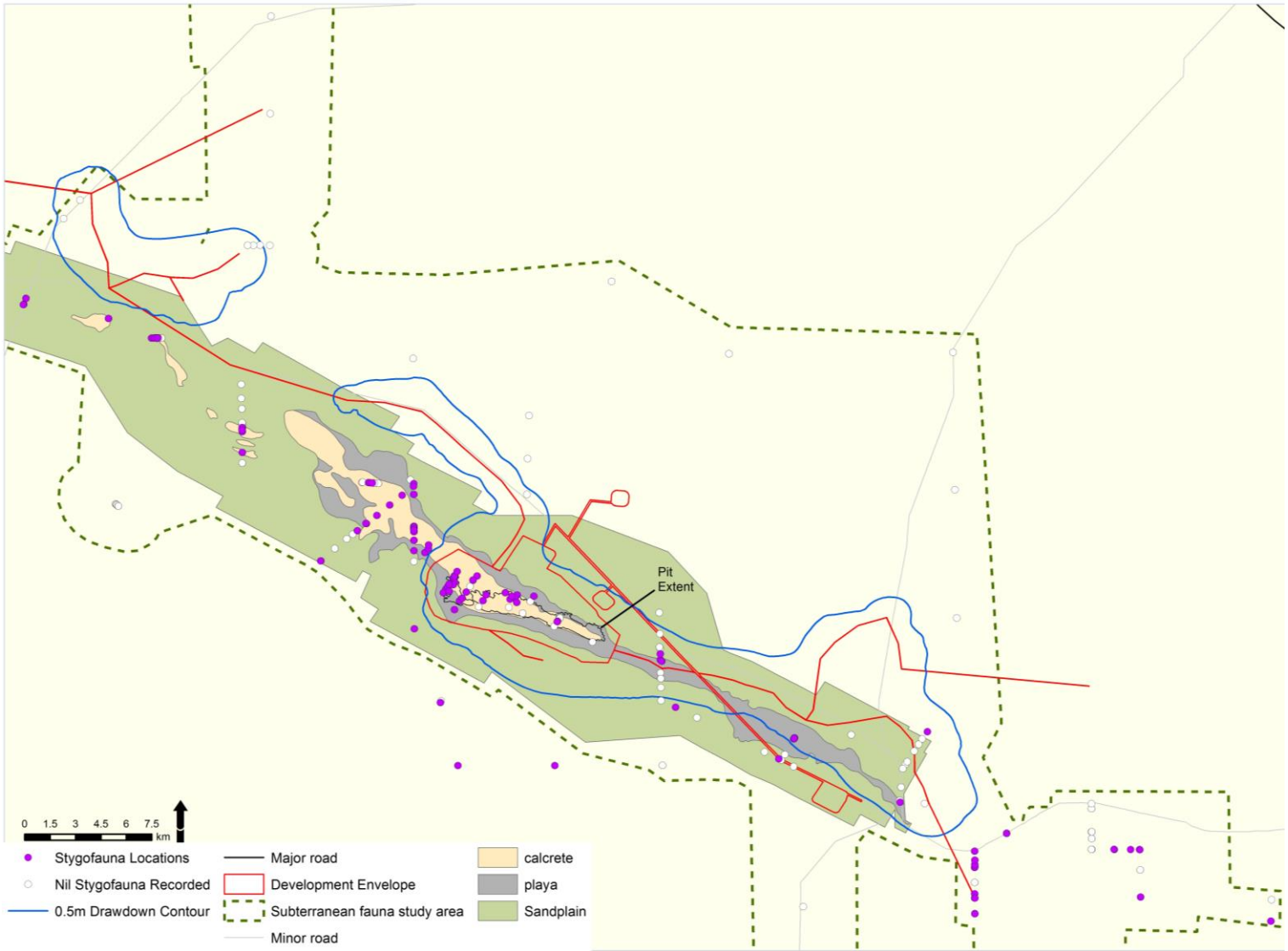

Figure 1: Stygofauna Sampling Locations

3.2 Habitat loss from mining

Loss of troglofauna habitat at Yeelirrie will also occur through excavation for the mine pit. In addition there may be a small area around the mine pit (extending only a few metres) in which drying of habitat and the effects of mine pit activities will reduce habitat quality sufficiently to have conservation effects. Outside the proposed mine pit and this narrow buffer, there should be no significant loss of habitat.

3.3 Impact on the PEC

Table 1 presents the calculated physical impact of the project on the PEC. As presented in Table 1, implementation of the Project will result in permanent loss of 17% (by area) of the PEC through excavation. 42% of the PEC (by area) will experience a drawdown of 0.5 m or greater. However, after mining ceases the watertable will eventually recover (as presented in Section 9.5.5.2 and Appendix I1 of the PER) and eventually 83% (by area) of the PEC habitat will remain.

Table 1: Physical impacts to subterranean fauna habitat

	Area (ha)	Volume (m^3)
Total size of the PEC	4,184	81,963,327
Affected by 0.5m drawdown	1,777 (42%)	35,517,742 (43%)
Not affected by 0.5m drawdown	2,407 (58%)	46,445,585 (57%)
Area excavated for mining	727 (17%)	16,382,466 (20%)
Total habitat remaining after mining	3,457 (83%)	65,580,861 (80%)

3.4 Impact on species

Submissions received on the PER and a review of additional literature have resulted in a minor update to both the number of stygofauna species known in the study area and the number of species currently only known from the impact area.

In total, 73 species of stygofauna are now known from the study area, of which 11 (15%) species are currently only known from the area of impact. 45 species of troglofauna are known from the study area, of which one (2%) species is currently only known from the updated impact area (mine pit).

It is well recognised that sampling for stygofauna is inherently difficult and cannot be considered in the same terms as traditional biological range and population mapping. For example:

- The size of the sample area is very much smaller than normal;
- The habitat varies in three dimensions, and it is not possible to control sample depth;
- The sample point may have unidentified characteristics which may be highly unrepresentative of the habitat; and
- The sample may be unrepresentative of the fauna present.

The complexity of subterranean fauna habitat, both horizontally and vertically also presents significant challenges for sampling at Yeelirrie. Lenses of clay and alluvium occur within the calcrete and the type of calcrete varies from karstic through to powdery or cemented. It is considered that most stygofauna occur in karstic calcrete close to the watertable but some species avoid being near the watertable or prefer fine interstitial spaces and thus will occur in non-karstic microhabitats, perhaps in pockets of alluvium within or below the calcrete.

Salinities are often lower near the surface than at depth and also vary spatially, according to whether surface recharge occurs locally and perhaps various other factors including the extent of surface vegetation and soil type. Most sampling of stygofauna occurred in cased, slotted bores using a haul net to collect animals from beneath the calcrete layer through to the top of the

watertable. This collecting process provided no information about the microhabitats in which particular stygofauna species occur. The lack of habitat information made it very difficult to demonstrate the wider range of apparently restricted species by sampling other areas containing their preferred microhabitat as there is almost no capacity to predict where particular microhabitats might be located across the calcrete because of the fine-scale spatial complexity.

These difficulties are acknowledged in EAG 12, the "Environmental Assessment Guideline for consideration of subterranean fauna in environmental impact assessment in Western Australia", which proposes the use of surrogates to predict the likely range or the presence or absence of species based on common habitat, including for example salinity levels, or the range of similar species, for example.

Given the logistical difficulties associated with the sampling of subterranean fauna at Yeelirrie, ranges of species are likely to be substantially underestimated. This includes species that have ranges extending from the proposed impact area to surrounding areas.

Even if stygofauna and troglofauna species occupy only a small area of habitat outside the predicted impact area, small populations are likely to be viable because of the constancy of subterranean habitat in terms of its structure and climate. For this reason, Cameco believes sufficient consideration has been given to species with a high proportion (but not all) of their known records in the predicted impact area and this group of species are not considered further here.

3.4.1 Stygofauna range extensions

The ranges of individual stygofauna species at Yeelirrie are likely to be determined by the extent of suitable habitat and the life history characteristics of the species. Based on examination of population densities of stygofauna at the nearby Sturt Meadows calcrete (Allford et al. 2008), relative abundances of the stygofauna species at Yeelirrie and published information on minimum viable population sizes of a range of animals (Traill et al. 2007) suggest that even the rarest species at Yeelirrie can persist in an area of <0.5 km^2, assuming that saturated calcrete is 3 m thick. Most, if not all, species are expected to have substantially larger ranges than these minimum areas as illustrated by the ranges of species such as the amphipod nr *Phreatochiltonia* sp. S1, the beetle *Limbodessus* sp. 1, the worm Enchytraeidae sp. Y5 and copepod *Schizopera uranusi* that occur across large parts of the Yeelirrie calcrete.

While current information suggests that some genera are represented by a series of species that are geographical replacements of each other along the Yeelirrie calcrete, this pattern may sometimes be a sampling artefact. This was illustrated by the way collection of a single animal at Sturt Meadows provided a 1 km extension to the range of the amphipod *Stygochiltonia bradfordae* and showed that it and two other amphipod species co-occurred across a 3.5 km^2 grid. All previous records suggested that *Stygochiltonia bradfordae* was restricted to the north end of the grid (Bradford et al. 2013). Although small, differences in reported range of 1 km or so may be quite significant at Yeelirrie and it is worth noting that the outlying *Stygochiltonia bradfordae* population at Sturt Meadows was known from only one animal despite more than 275 samples being collected from within the 3.5 km^2 grid.

Of the 73 species of stygofauna known at Yeelirrie, 11 are currently only known from the impact area. The likely ranges of these species is discussed below, using surrogates in the way described in EAG 12 as the basis for considering wider distributions.

Enchytraeidae sp. Y4: In total, 1133 enchytraeid worms were collected throughout the Yeelirrie calcrete and the Yeelirrie Playa. Identifications were undertaken genetically and there was no

attempt to identify morphotypes prior to DNA analysis. In nearly all cases a single animal from each sample of enchytraeids was analysed. DNA sequencing showed that at least nine species are present at Yeelirrie (Subterranean Ecology 2011).

Enchytraeidae sp. Y4 was collected from North Bore, near the eastern extent of modelled >0.5 m groundwater drawdown. The depth to watertable was almost 20 m and the bore contained little water at the time of sampling. Although neither salinity nor pH was measured during sampling, modelling suggests groundwater salinity in the area is fresh. Thirty-seven enchytraeid worms were found in the sample and it was assumed that all enchytraeids in the sample belonged to Enchytraeidae sp. Y4. This is common survey practice but it is quite possible other species were also present and not recorded because only one animal was DNA -sequenced.

It is inferred that Enchytraeidae sp. Y4 is likely to be more widespread at Yeelirrie, based on surrogate biological and habitat evidence. There are extensive bands of freshwater along both the north and south side of the palaeochannel that are likely to provide the same habitat for Enchytraeidae sp. Y4 as it occupied at North Bore. The two subterranean enchytraeid species investigated genetically in the Pilbara region by Brown et al. (2015) both had linear ranges of at least 220 km.

Enchytraeidae sp. Y6: This species was collected at a single bore, YYD22, at the western end of the proposed mine pit and near to the limit of >0.5 m groundwater drawdown. Identification was genetic and based on a single animal; the other three enchytaeid worms in the same sample were assumed to be Enchytraeidae sp. Y6. Depth to watertable was about 6 m and groundwater salinity was approximately 10 g/L TDS.

It is inferred that Enchytraeidae sp. Y6 is likely to be more widespread at Yeelirrie, based on surrogate biological and habitat evidence. The related species, Enchytraeidae sp. Y5, has been collected in the north-west sector at depths to groundwater of about 6 m and salinities of 6-25 g/L TDS and in the south-east sector at about 10 g/L TDS. These parameters straddle those of Enchytraeidae sp. Y6, with both species appearing to occupy the same habitat. It appears likely that Enchytraeidae sp. Y6 has a similar distribution. In fact, it is possible that Enchytraeidae sp. Y6 has been collected more widely in existing samples but not identified because of the small numbers of specimens analysed genetically.

***Atopobathynella* sp. 'line K':** This syncarid species was collected from a single bore, YYHC0048KA, on the southern boundary of the eastern part of the groundwater drawdown impact area. Salinity was not measured at the time of collection but modelling suggested it was likely to have been collected at 5-15 g/L TDS.

Syncarids are conventionally considered to have small ranges but it is inferred that *Atopobathynella* sp. 'line K' is likely to be more widespread, based on the distribution of other species of *Atopbathynella* at Yeelirrie. All five of these species occurred in the north-west sector, which appears to be the core habitat for the genus at Yeelirrie. Salinity in the area ranges from fresh to about 15 g/L TDS.

Of the five species, *Atopobathynella* sp. S05 was recorded in 45 samples in the central (i.e. in and around the mine pit) and north-west sectors. *Atopobathynella* sp. Y3 was collected from four samples in the north-west sector. *Atopobathynella* sp. S04 is relatively widespread and, although collected only in two samples, it was recorded at both the Yeelirrie Playa and the north-west sector. *Atopobathynella* sp. Y2 was collected in a single sample from the north-west sector. Given that the modelled salinity where *Atopobathynella* sp. 'line K' was recorded is the same as that to the west of

the mine pit in the north-west sector, it seems very likely that *Atopobathynella* sp. 'line K' has a distribution similar to that of *Atopobathynella* sp. S04 and has at least some of its population in the core *Atopobathynella* habitat outside the area of groundwater drawdown.

***Halicyclops* cf. *eberhardi* sp. B:** The copepod *Halicyclops* cf. *eberhardi* sp. B was collected as 372 specimens in four samples from a single bore, YYAC33, on the periphery of the proposed mine pit and near the western boundary of the area of groundwater drawdown. Identification was based on DNA analysis of a specimen from one sample and it was assumed that animals in other samples from YYAC33 were the same species. Depth to the watertable at YYAS33 was 7 m. Salinity was not measured during sampling, but modelling suggests it was 5-15 g/L TDS.

Two other species of *Halicyclops* cf. *eberhardi* have been collected at Yeelirrie. *H*. cf. *eberhardi* sp. A was collected in 18 samples from five bores (one in the south-eastern part of the groundwater drawdown area, two in the more western part of the drawdown area around the mine pit and two outside the drawdown in the north-west sector). Salinity in the north-west sector is approximately 13 g/L TDS. The second species, *H*. cf. *eberhardi* sp. C was collected in two samples from different bores at Yeelirrie Playa, with one sample having salinity of slightly under 20 g/L TDS.

Bore YYAC33 where *Halicyclops* cf. *eberhardi* sp. B was collected lies more or less in the middle of the known range of *H*. cf. *eberhardi* sp. A at Yeelirrie. This makes it unlikely the species are geographic replacements for each other. It is more likely they occupy different habitats and perhaps have similar overall ranges.

The collection of 372 specimens of *Halicyclops* cf. *eberhardi* sp. B from the one hole suggests that it is unlikely *H*. cf. *eberhardi* sp. B is a low abundance species that was collected from only one bore as a result of chance. Instead it reinforces the hypothesis that *Halicyclops* cf. *eberhardi* sp. B may occur in a microhabitat that has a patchy, and perhaps infrequent, occurrence. Such a microhabitat may occur across a substantial proportion of the Yeelirrie calcrete and be delineated by factors such as an unusual combination of salinity and habitat void/pore size (see Section 9.2.2.4).

In terms of surrogate information from which to infer the likely range of *Halicyclops* cf. *eberhardi* sp. B, the variety of ranges exhibited by different species shows there are no fixed barriers within the subterranean fauna habitat at Yeelirrie that determine species distributions. Modelled salinity suggests that the range of *Halicyclops* cf. *eberhardi* sp. B should extend in a narrow band west of the area of groundwater drawdown, as well as extending further east in the drawdown area.

Kinnecaris lined: One hundred specimens of the copepod *Kinnecaris lined* were collected from a single bore, D-Trog4, in the south-eastern part of the area of groundwater drawdown in fresh water of <1 g/L TDS. Identification was based on DNA sequence data and morphology (Karanovic and Cooper 2011).

Five other species of *Kinnecaris* occur at Yeelirrie, with the three species with multiple records exhibiting a tenfold variation in known linear range. *K. uranusi*, which was collected in 16 samples from five bores, extends 24 km from the south-eastern part of the groundwater drawdown area to the north-west sector. *K. linel* was collected in five samples from two bores at Yeelirrie Playa that were 2.5 km apart. *K. linesae* was collected in five samples from three bores in the north-west sector that were nearly 8 km apart. Like *K. lined*, *K esbe* and *K*. 'linep' were collected from single bores, the former at Yeelirrie playa and the latter in the north-west sector.

Using the pattern of related species at Yeelirrie to infer the likely distribution of *K. lined* suggests it is likely to have a relatively small range because of an apparent pattern of geographic replacement of

species at Yeelirrie, especially between Yeelirrie and Yeelirrie Playa (Karanovic and Cooper 2011). It should be noted, however, that small ranges are not especially characteristic of *Kinnecaris* species. Two species in nearby calcretes have linear ranges of approximately 50 km (*K. barrambie*) and 30 km (*K. lakewayi*), with only one species present in each of these calcretes.

There is no evidence of strong salinity preferences in *Kinnecaris* species, which instead appear to be tolerant of a range of salinity, with *K. uranusi* and *K. linel* occurring in fresh water through to >10 g/L TDS. This suggests that, while perhaps having a small range, *K. lined* may extend south, or east, of the nearby boundary of groundwater drawdown.

***Novanitocrella* 'araia' sp. n.:** *Novanitocrella* 'araia' sp. n. is known from a single animal collected at the western end of the proposed mine pit in bore YYA35 within the area of groundwater drawdown. The salinity of groundwater was about 12 g/L TDS. Given that the only described species of the genus, *Novanitocrella aboriginesi*, has a known linear range of about 20 km, it is expected that the range of *Novanitocrella* 'araia' sp. n. will extend at least a short distance west of the mine pit in the tongue of groundwater of similar salinity in the north-west sector. The existing record of *Novanitocrella* 'araia' sp. n. is approximately 1.5 km from the 0.5 m groundwater drawdown contour.

***Novanitocrella* 'araia linec' ssp. n.**: This species was collected as 123 animals in three samples from two bores about 400 m apart (YYHC0036C and 37C) in the area of groundwater drawdown to the south-east of the mine pit. Groundwater salinity was about 11-14 g/L TDS.

The distance between records of *Novanitocrella* 'araia' sp. n. and *Novanitocrella* 'araia linec' ssp. n. is about 12 km and it is considered that they represent related species separated by a recent isolation event, so that it is unlikely their ranges overlap. The species appear to have similar salinity preference and the factors controlling their ranges are unknown.

The collection of 123 specimens of *Novanitocrella* 'araia linec' ssp. n. from only two bores suggests it is unlikely that randomness of sampling results is the reason for species being known from such a small part of the Yeelirrie calcrete. As with the apparently restricted *Halicyclops* cf. *eberhardi* sp. B, it is more likely that *Novanitocrella* 'araia linec' ssp. n. occurs in a microhabitat with a patchy, and perhaps infrequent, occurrence. This may have been the mechanism leading to speciation between *Novanitocrella* 'araia' sp. n. and *Novanitocrella* 'araia linec' ssp. n. and would make it difficult to fully document the range of *Novanitocrella* 'araia linec' ssp. n. even with intensive sampling.

***Schizopera akolos*:** In total, 14 species or subspecies of *Schizopera* have been collected from Yeelirrie, including two species recently created by taxonomic revision (Karanovic et al. 2015). Yeelirrie is an area where there has been considerable radiation of this species. Similar radiations have also been observed (albeit to a lesser extent) in some other calcretes in Western Australia.

Schizopera akolos was collected as four animals in two samples from a single bore, YYD22, at the western end of the proposed mine pit within the area of groundwater drawdown. Salinity was not measured during sampling but modelling suggests the species occurred in an area of particularly high salinity (>15 g/L TDS). Similar salinity occurs at Yeelirrie Playa.

It is likely that *Schizopera akolos* occupies a relatively rare microhabitat (see Bradford et al. 2010). Genetic data suggest the high richness of *Schizopera* species at Yeelirrie is the result of multiple invasions of surface species, as well as local speciation (Karanovic and Cooper 2012). DNA data suggest one of the invading species was *Schizopera akolos* and a wide range at Yeelirrie might be expected for such a species unless it has been displaced from this range over time by other species.

Further sampling may show the species occurs outside the area of groundwater drawdown, possibly in high salinity at Yeelirrie Playa.

***Schizopera* emphysema:** Eight animals of *Schizopera emphysema* were collected in four samples from one bore, YYAC1004C, within the proposed mine pit within the area of groundwater drawdown. Salinity was not measured at the time of sampling.

As with *S. akolos*, this species perhaps occupies a discrete microhabitat within the study area because it was not collected from any of the three bores a few metres away (Karanovic and Cooper 2012). Like *Schizopera akolos*, *S. emphysema* belongs to a clade of surface invading species that might be expected to be widespread and it is considered likely the species has a patchy occurrence at Yeelirrie corresponding with occurrences of its preferred microhabitat. Further sampling may show *Schizopera emphsema* occurs outside the area of groundwater drawdown at Yeelirrie in the tongue of groundwater of 5-15 g/L TDS that extends from the drawdown area into the north-west sector.

***Schizopera* sp. 7439:** *Schizopera* sp. 7439, which was identified by genetic analysis of a single animal, was collected in one sample of five animals from bore YYAC1004C within the proposed mine pit. It is a cryptic species and was not recognised morphologically prior to, or after, DNA analysis. It may have occurred in other samples without being recognised and recorded. While identification of the species relies on DNA analysis, which is likely to require screening of large numbers of animals because of the low abundance in which the animal occurs, little can be concluded about its likely distribution. Salinity was not recorded when the animal was collected but it occurs in an area with modelled salinity of 5-15 g/L TDS that extends west into the north-west sector. The species may extend into the north-western sector.

Philosciidae sp. n. Y2: This isopod species was collected as five specimens in four samples from two bore holes (YYD22 and YYAC36) about 400 m apart at the western end of the proposed mine pit and area of groundwater drawdown. Salinity was not measured at either bore.

Terrestrial isopods often have restricted ranges (Judd *et al*. 2003) and subterranean philosciids have sometimes been shown to be restricted to single calcretes or to have mine-scale distributions (Cooper *et al*. 2008; Taiti and Humphreys 2001). Bore YYD22 contained two other species known only from the drawdown area (Enchytraeidae sp. Y6 and *Schizopera emphysema*), which suggests an unusual habitat may have been sampled (nine species of stygofauna were recorded in it altogether) and Philosciidae sp. n. Y2 may have a patchy distribution because of its occurrence in this unusual habitat. Based on modelled salinity, the range of Philosciidae sp. n. Y2 would be expected to extend west into the north-west sector but other factors may also be involved in determining the distribution of the species.

3.4.2 Troglofauna range extensions

Management measures, in particular, the proposed establishment of the Troglofauna Protection Area have reduced the number of troglofauna species at risk to one.

***Trichorhina* sp. n. F:** Three of the four species of the isopod *Trichorhina* collected in the study area are known from single bores, with *Trichorhina* sp. n. F being represented by a single animal within the proposed mine pit. The fourth species, *Trichorhina* sp. n. G occurs in multiple bores in the northwest part of the Yeelirrie calcrete with a linear range of about 14 km. Characterising habitat within the calcrete body in sufficient detail to document species habitat preferences and enable predictions of species ranges was not feasible. *Trichorhina* sp. n. F may have a small range but further sampling may show it occurs outside the mine pit due to the fact that the related *Trichorhina*

sp. n. G occurs in multiple bores in the northwest part of the Yeelirrie calcrete with a linear range of about 14 km.

3.5 Impact from the TSF

It is predicted that contaminant plumes associated with the tailings storage facility (TSF) will have no significant effect on subterranean fauna. The contaminant with most capacity to travel is chloride (salinity) and, based on a realistic infiltration rate from the sealed TSF of 0.1% of annual rainfall, Cl concentration will be elevated beyond baseline for a distance of approximately 55 km east of the TSF. However, concentrations will be increased by <5 mg/L throughout this distance, which represent increases with no adverse biological effect. Changes would need to be two orders of magnitude larger to potentially affect freshwater species and three orders of magnitude larger to affect species occurring in the salinities typical of baseline conditions downstream of Yeelirrie (Attachment 2 – Figure 6). The three heavy metals mostly likely to be contaminants (U, V, Mo) will travel only tens of metres beyond the sealed TSF and will be contained within the area of groundwater drawdown. This applies under all recharge scenarios. Cameco considers that all other potential deleterious effects on stygofauna will be also confined to the area of modelled groundwater drawdown.

4. Avoidance, Minimisation, Mitigation and Offsetting of Impacts/Risks

4.1 Groundwater Model and Location of Abstraction Wells

As detailed in Section 9.5 of the PER, Cameco undertook an extensive review of previous hydrological studies prior to developing the Cameco groundwater model. The development of the Cameco Model was based on the previous URS Model, however it was modified (to consider the increase in the rate of mining and processing and the updated groundwater abstraction well locations) and expanded to include solute transport modeling. Prior to commencement of the Cameco Model a decision was made to not locate any abstraction wells within the palaeochannel to the northwest of the proposed mine pit in order to reduce impact to the stygofauna population and maintain a significant amount of saturated calcrete habitat within the palaeochannel. This area is an excellent source of groundwater, but also supports many stygofauna species and is the location of likely range extension for the species currently only known from the impact area. It is estimated that over 50 species of stygofauna would experience drawdown of greater the 0.5 m if abstraction wells were located within the palaeochannel to the northwest of the proposed mine pit.

Cameco has also removed a number of planned abstraction wells from the Western Brackish Wellfield in the palaeochannel. Despite not having a benefit to species currently only known from the area of impact it has resulted in a reduced impact to the palaeochannel and the PEC.

Since the PER was submitted Cameco has also optimised the groundwater model in order to further reduce impact. Optimisation results indicate that drawdown at the location of some of the species currently only known to the southeast of the mine (*Atopobathynella* sp. 'line K', *Enchytraeidae* sp. Y4 and *Kinnecaris* 'lined' sp. n.) can be reduced to less than 0.5 m. Cameco will undertake further optimisation of the model during the Definitive Feasibility Study (DFS) to confirm if significant impact to these species can be avoided. This work will be completed prior to commencement of any dewatering activities.

Cameco believes that the impact to both stygofauna species and potentially suitable habitat can be further reduced through pumping optimisation and the strategic location of abstraction wells, however this cannot be confirmed at this stage of the Project. Cameco is committed to undertaking further testing and modelling of the wellfields during the DFS in order to reduce impact to both habitat and species. During the DFS, Cameco will also investigate alternative water sources outside the palaeochannel and away from preferred stygofauna habitat.

4.2 Troglofauna Protection Area

In the PER, five troglofauna species were identified as being known only from within the mine pit impact zone. Cameco now proposes to establish a Troglofauna Protection Area in the northwest corner of the mine pit, as presented in Figure 2. The proposed Troglofauna Protection Area contains four of the five troglofauna species that are currently only known from the mine pit (*Tyrannochthonius* sp. n. Y1, *Austrohorus* sp. n. Y1, *Pauropoda* sp. S6B and *Symphyla* sp. Y7) and provides a minimum 50 m buffer to the known location of each species. Covering an area of 10.5 ha and containing approximately 1% of the total resource, the protection area will be maintained for the life of mine unless additional habitat mapping confirms that suitable habitat extends past the area of impact for the four species of troglofauna. If additional habitat mapping is successful in demonstrating range extensions for the four species then Cameco will seek approval to mine the additional 10.5ha. This strategy was originally considered and rejected within the PER, as the four species are considered likely to not be restricted to the mine footprint and because of the associated economic impacts to the Project, however it is now proposed as a further conservation measure.

Cameco is aware that the proposed water reinjection point is within close proximity to the Troglofauna Protection Area and could also impact on the species. Cameco is committed to developing a comprehensive groundwater monitoring program, as part of the Subterranean Fauna and Groundwater Management Plans, which will include monitoring of water reinjection and developing agreed trigger levels to ensure protection of specific troglofauna species.

The establishment of the protection area now means that only one troglofauna species (*Trichorhina* sp. n. F) is only known from the impact area. *Trichorhina* sp. n. F is represented by a single animal within the proposed mine pit. As discussed above, *Trichorhina* sp. n. F may have a small range but further sampling may show it occurs outside the mine pit due to the fact that the related *Trichorhina* sp. n. G occurs in multiple bores in the northwest part of the Yeelirrie calcrete with a linear range of about 14 km.

4.3 TSF Design

The operation and closure of the TSF will not have a significant impact on the Yeelirrie stygofauna population. The design of the TSF also increases the potential for some species to re-establish post mining. As detailed in the PER, Section 6.5 and Appendix D, the proposed TSF has been designed to provide safe and permanent storage of tailings in a way that minimises potential environmental impacts and risks. The intent of the closure design is to provide an erosion-resistant and non-polluting facility that is stable in the long term. TSF embankments close to the pit walls would be constructed of clay-based materials originating from the development of the pit. The permeability of the pit floor and the TSF cell embankments would be very low, with an estimated permeability of 1 x 10^{-9} m/sec, similar to the permeability of a geosynthetic liner. Seepage from the TSF has been modelled and the results and discussion is presented in Section 9.5 of the PER. Very little seepage from the TSF is anticipated because of the proposed tailings drying cycle, which locks the solutes into the tailings matrix. The TSF would also be operated in a way to reduce potential seepage, including:

- drying the tailings during the deposition cycle hence limiting mobility of the pore solutes;
- consolidating the tailings hence ensuring very low permeability and leachate flux ;
- covering the tailings as soon as possible after filling a cell to prevent infiltration that would mobilise potential contaminants in leachate;
- providing suitable drainage within and around the TSF to prevent groundwater from re-entering the stored tailings; and
- including design elements to facilitate the monitoring the groundwater levels and quality and providing contingency measures to abstract any polluted groundwater before a harmful impact occurs.

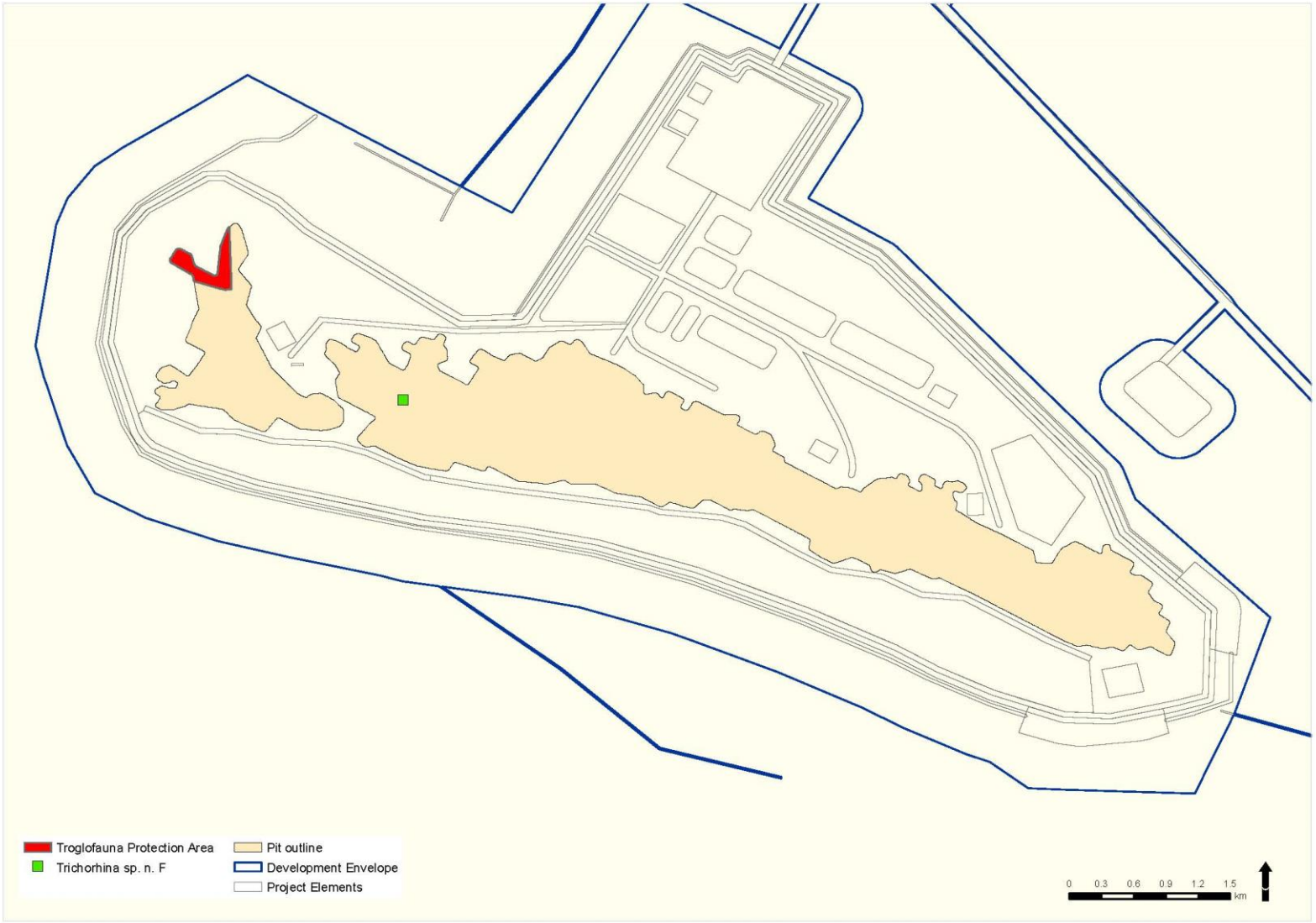

Figure 2: Proposed Troglofauna Protection Area

4.4 Operational Management

4.4.1 Northwest of the Mine Pit

Cameco is committed to reducing the Project impact to subterranean fauna and providing long-term protection of the palaeochannel northwest of the mine pit. As discussed in the response to submissions this area represents 58% of the PEC and is likely to host a number of the species currently only known from the impact area. Cameco will provide long-term protection of this area by:

- Developing an outcome-based Subterranean Fauna Management Plan in accordance with EAG 17, which will be closely integrated with the Groundwater Management Plan, and will include the following:
  - the location of production and monitoring bores;
  - a detailed monitoring program for both water quality and groundwater level;
  - baseline data for both water quality and absolute water level at the monitoring bore locations;
  - internal trigger criteria, threshold criteria and associated contingency actions; and
  - reporting.
- Not exceeding the 0.5 m drawdown contour as presented in the PER (Figure 9-17);
- Not exceeding the groundwater quality or absolute groundwater level threshold criteria, which will be established in the Subterranean Fauna Management Plan, beyond the mapped 0.5 m drawdown contour; and
- Not having a significant impact on the recharge pattern of the palaeochannel to the northwest of the mine pit.

4.4.2 Southeast of the Mine Pit

Cameco is committed to reducing the Project impact to subterranean fauna downstream from the mine pit (southeast) and within the palaeochannel. Cameco commits to the following operational management measures in order to reduce Project impact to this area:

- Developing an outcome-based Subterranean Fauna Management Plan;
- Monitoring groundwater quality within the downstream environment; and
- Having specific trigger criteria and management actions in relation to the downstream environment.

4.4.3 Within the Mine Pit

Cameco is committed to maintaining the Troglofauna Protection Area in the northwest corner of the mine pit, as presented in Figure 2. The proposed Troglofauna Protection Area contains four of the five troglofauna species that are currently only known from the mine pit. The area would be mined only if additional habitat mapping is successful in demonstrating range extensions for the four species at which point Cameco will seek approval to mine the additional 10.5ha.

4.5 Recovery of Habitat after Mine Closure

As presented in Table 1, implementation of the Project will result in permanent loss of 17% (by area) of the PEC through excavation. Following the completion of mining, groundwater abstraction will cease and groundwater levels will commence a recovery to pre-mining levels, gradually restoring stygofauna habitat to the areas that have not been excavated. Groundwater modelling undertaken by Cameco and reported in the PER, indicates that 66% (by area) of the critical habitat (PEC) will exist 50 years after mining. This means that 8% of the area impacted by drawdown of at least 0.5 m during mining would have recovered within 50 years. The residual impact to the critical habitat (PEC) 100 years after mining will be 749 ha, consisting of 727 ha of the open pit and 22 ha of area where

groundwater drawdown remains greater than 0.5 m. Calculations on groundwater and habitat recovery are presented in Table 2.

It should also be noted that the majority of the habitat to the southeast of the mine pit, including the Yeelirrie Playa, will also recover within 100 years.

Table 2: Groundwater and habitat recovery

	Area (ha)	Volume (m^3)
Total size of the PEC	4,184	81,963,327
Not impacted by 0.5m drawdown	2,407 (58%)	46,445,585 (57%)
Habitat 20 years after mining (not impacted by 0.5m drawdown)	2,678 (64%)	52,580,954 (64%)
Habitat 50 years after mining (not impacted by 0.5m drawdown)	2,757 (66%)	53,759,042 (65%)
Habitat 100 years after mining (not impacted by 0.5m drawdown)	3,435 (82%)	65,522,623 (80%)
Total habitat to recover	3,457 (83%)	65,580,861 (80%)

4.6 Offsets

Cameco considers that the avoidance, minimisation and mitigation measures outlined above will allow the Project to be operated so that the risk to maintaining the representation, diversity, viability and ecological function at the species, population and assemblage level of subterranean fauna is low and therefore EPA's objective for this key environmental factor will be met. However, Cameco recognises that a level of uncertainty remains about the range of the potentially restricted species and therefore proposes the following offset measure:

- Implementation of a research package developed with input from appropriate agencies to further develop the understanding of the impact on subterranean fauna from mining and groundwater abstraction in this region. It is proposed that this research could be conducted through the newly-established WA Biodiversity Science Institute. The research package could include a desk top study of examples where subterranean fauna populations have recovered following cessation of mining, habitat requirements (salinity, water chemistry etc.) and sampling methodologies including possible use of genomics.

The knowledge gathered by the implementation of such an offset is consistent with one of the EPA's strategic objectives in its Strategic Plan 2013-16, 'Build a science and knowledge base for environmental advice' and would be publicly available to improve planning, management and decision-making by industry and government in this complex area of impact assessment.

5. Management Strategy

In summary, Cameco commits to the following which it expects will be implemented via appropriately worded conditions and/or the key characteristics table:

- Develop and implement an outcome-based Subterranean Fauna Management Plan in accordance with EAG 17, which will be closely integrated with the Groundwater Management Plan. The Subterranean Fauna Management Plan will include the following as a minimum:
    - the location of monitoring bores;
    - a detailed monitoring program for both water quality and groundwater level;
    - baseline data for both water quality and absolute water level at the monitoring bore locations;
    - internal trigger criteria, threshold criteria and associated contingency actions; and
    - reporting.
- Not exceed the impact on both species and the PEC, as presented in the PER and response to submissions, by committing to managing the 0.5 m drawdown contour;
- Not exceed the groundwater quality or absolute groundwater level threshold criteria, which will be established in the Subterranean Fauna Management Plan, beyond the mapped 0.5 m drawdown contour;
- Establish a geo-referenced Troglofauna Protection Area, as presented in Figure 1;
- Undertake additional troglofauna sampling and habitat mapping in order to improve knowledge and confirm surrogacy predictions prior to seeking approval to mine the Troglofauna Protection Area;
- Prior to implementation of the Project, undertake additional stygofauna habitat mapping and additional sampling in order to improve knowledge and confirm habitat and range extensions;
- Undertake further groundwater investigations of the wellfields during the DFS. This information will allow Cameco to further refine the groundwater model and look for opportunities to relocate abstraction wells from the palaeochannel. Potential options include:
    - Locating well fields in the alluvium/weathered bedrock aquifers in the areas north of the valley floor and north of the proposed pit;
    - Investigating additional water sources outside the palaeochannel and not in preferred stygofauna habitat, with the potential for relocating entire well fields; and
    - Increase supply from areas outside the palaeochannel.
- An appropriate offsets package to be negotiated with relevant government agencies to counteract the significant residual uncertainty associated with stygofauna habitat and range distributions.
- Cameco expects that groundwater recovery after 50-100 years and hence stygofauna habitat recovery would also be dealt with in the Mine Closure Plan as closure and relinquishment criteria.

6. Conclusion

Implementation of the revised management, minimisation, mitigation and offset measures to reduce impacts and risks to subterranean fauna will reduce the impact of the project to a level that in Cameco's view, meets the EPA's objective for Subterranean Fauna.

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