Review of Impact of Pit Lakes upon Fauna

Browns Range Project

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15th June 2014

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1 Introduction

1.1 Background

Northern Minerals Limited (NML) is currently seeking approval to develop the Browns Range Rare Earth Project (the Project), a proposed rare earths mine and mineral processing operation. The Project is located approximately 160 km southeast of Halls Creek, Western Australia. The Project proposes to use beneficiation and hydrometallurgical facilities to process raw materials and produce rare earth oxide. The EPA has identified mine closure, including post-closure impacts of final mine voids, as a preliminary key factor for the assessment of the Browns Range Project.

1.2 Concerns raised by the EPA

The Office of the EPA raised comments in relation to the potential impacts of pit lakes to migratory birds and food chains. Bamford Consulting Ecologists (BCE) was requested to assess the following:

- Migratory species that could occur in the area.
- Likelihood that these species (and other fauna) would utilise pit lakes (including drinking or foraging from lakes).
- Risk posed by water quality within pit lakes, including any toxic metals or contaminants, on migratory species (and other fauna), either through direct effects (drinking) or through bioaccumulation (foraging in the lake ecosystem).

With respect to the risk to fauna and especially waterbirds, the main questions that were addressed are:

- Will fauna be attracted to the lakes (this is a function of their context and structure);
- Will fauna be able to drink the lake water and, if so, will the water quality pose a risk to them if they do drink it; and
- Will the lakes support ecosystems of algae and other aquatic vegetation, and therefore invertebrates, upon which waterbirds may feed, and which may therefore pose a risk from toxic bio-accumulation.

1.3 Description of Pits

The proposed mine includes five open pits which will form pit lakes after project closure: Wolverine, Gambit East, Gambit Central, Gambit West, Area 5. The pits vary in size and are deep (44 m to 152 m) with steep slopes. The largest pit (Wolverine) has a diameter of about 425 m at its maximum extent. Two pits (Wolverine and Area 5) have slopes greater than 100% (steeper than 45º), two pits (Gambit Central and Gambit West) have slopes close to 100% with the remaining pit (Gambit East) having a slope less than 100% (less steep than 45º). Two deposits (Wolverine and Gambit) will also have underground mining operations. Further project details and related studies are provided in the Browns Range API (Northern Minerals, 2014).

1.4 Regional Geography

The Project is located in the Tanami subregion of the Tanami Interim Biogeographic Regionalisation of Australia (IBRA) region, at the northern edge of the Tanami Desert. Rock outcrops in the project area comprise Browns Range Metamorphics and Gardiner Sandstone (NML 2014).

The Project is located in the upper reaches of a minor tributary located centrally within the Sturt Creek drainage catchment. Several small, ephemeral watercourses drain from the Project site to join the Sturt Creek some 140 km upstream from Lake Gregory. The significance of Lake Gregory for waterbirds is discussed in Section 2.3 below. All of the Sturt Creek watercourses are ephemeral and typically flow following large or prolonged rainfall events (NML 2014). There are no permanent or semi-permanent water bodies located in the vicinity of the project area.

Groundwater quality in the project area is fresh to brackish, with an average total dissolved solids concentration of about 2000 mg/L (Klohn Crippen Berger 2014). However, one part of the mining tenement area has much higher salinity at 20,000 mg/L, but this is remote from proposed mining activity. Groundwater pH ranges from slightly acidic to slightly alkaline.

1.5 Bioaccumulation

Bioaccumulation of heavy metals and radionuclides becomes a concern for fauna when the capacity of species to regulate the internal concentration of metals is lost. This can occur through direct ingestion of heavy metals or ingestion of contaminated organisms. This results in the impairment of physiological functions required for normal growth and survival, with documented effects on development and survival of aquatic macroinvertebrates (Dias *et al.* 2008, Khun *et al.* 2002, Muscatello and Liber 2010), frogs (Marques *et al.* 2008, Lefcort *et al.* 1998) and mice (e.g. Domingo 2001). Accumulation of heavy metals and radionuclides can seriously alter the aquatic environment, affecting the survival of some fauna (Lottermoser and Ashley 2005, Jarvis and Younger 1997, Antunes *et al.* 2007, Pyle *et al.* 2001, Muscatello *et al.* 2008, deRosemond *et al.* 2005).

In the pit lakes, bioaccumulation of toxic chemicals could occur if the lake is considered productive enough to support algal growth, aquatic vegetation, and associated organisms such as zooplankton which could provide foraging opportunities for visiting fauna.

2 Waterbird Assemblage in the Project Area

The 2008 National Waterbird Survey (Kingsford *et al.* 2011) emphasised the importance of the Kimberley region as a staging area and over-wintering site for migratory shorebirds. The survey also discussed the significance of ephemeral wetlands of inland Australia to waterbirds, especially duck species, even during dry years. In assessing the likelihood of the Browns Range project area for supporting resident, visitor or migratory waterbirds, waterbird counts from nearby lakes and from wetlands in the northern Tanami Desert were examined.

In the 2008 National Waterbird Survey, four of the top five ranked wetlands in terms of waterbird abundance were located in the Kimberley (Kingsford *et al.* 2011).The Browns Range Project is located between two of these sites (Lakes Gregory and Argyle). The project area is located approximately 200 km northeast of Lake Gregory, approximately 400 km south of Lake Argyle, and approximately 120 km southwest of Nongra Lake. There have been numerous studies conducted on waterbird usage at the former two lakes, with some data from the latter lake. As it is likely that waterbirds moving between these three sites (which essentially form a triangle around the project area) may utilise the water bodies present in the project area, waterbird data from these lakes are considered.

2.1 Tanami Desert

The Project lies on the edge of the northern Tanami Desert and can be expected to support similar waterbird populations. The Tanami Desert provides refuge for some of Australia's rare and endangered species, with significant bird species including the Grey Falcon *Falco hypoleucos*, Australian Painted Snipe *Rostratula benghalensis*, and Freckled Duck *Stictonetta naevosa* (Gibson 1986). In a 2006 survey of 19 wetlands over an area of 17,700 ha in the northern Tanami Desert, 56 waterbird species were reported with 200,000 individuals estimated across the region (Reid *et al.* 2006). In this survey, the most abundant species reported were the Whiskered Tern (60% of the total waterbirds records), the Black-winged Stilt (13% of total) and Grey Teal (6% of total). The authors reported a "very large waterbird breeding event" during the survey, with at least 18 species breeding.

2.2 Nongra Lake

Nongra Lake is an internationally significant ephemeral wetland located in the northern Tanami Desert in the Northern Territory (DoE 2014), approximately 120 km northeast of the Browns Range Project site. It supports large number of waterbirds when nearby wetlands are dry (DoE 2014).

In separate surveys conducted in 1993 and 2002, 29 (Jaensch 1994), and 41 (Gole 2005) waterbird species were recorded; a combined total of 46 species. The latter survey recorded the Freckled Duck (Australia's rarest duck) which has also been reported from Lake Gregory and situated in a similar arid to sub-tropical transitional zone (Halse *et al.* 1998a). This species is rarely reported from elsewhere in the northern part of Australia (eg. Barrett *et al.* 2003), so inland freshwater bodies, such as those which may develop in the project area, may be important habitat for them in the area. Similarly, the Blue-billed Duck is rarely recorded in the arid interior and Top End of Australia but was recorded on Nongra Lake in 2002 (Gole 2005). The most abundant species recorded in 2002 were the Grey Teal, Hardhead, Pacific Black Duck and Eurasian Coot (Gole 2005). Nongra Lake has also reported two regionally uncommon birds: Baillon's Crake *Porzana pusilla* and Clamorous Reed-Warbler *Acrocephalus stentoreus* (DoE 2014).

2.3 Lake Gregory

Lake Gregory has contained water for all but a few years since 1969, with the waterbird population in 1988 estimated at 650,000 (Halse *et al.* 1998a). The importance of Lake Gregory for waterbirds was discovered by several authors (e.g. Smith and Johnstone 1978, Jaensch and Vervest 1990), with detailed surveys conducted from 1988 to 1995 (Halse *et al.* 1998a). A total of 73 waterbird species had been recorded at the lake by 1998, with 21 of these species breeding at the lake (Halse *et al.* 1998a). From 1988 to 1995, the mean annual estimate of waterbirds at Lake Gregory was 203,000. The lake was considered particularly important for species that were recorded in very high abundances, including species such as the Grey Teal, Pink-eared Duck, Hardhead, Little Black Cormorant and Eurasian Coot. Large numbers of palaearctic shorebirds were also recorded in some years. The lake is considered an important staging point for migrating shorebirds which utilise the lake as a stopover; counts of Marsh Sandpipers and Sharp-tailed Sandpipers among the highest in Australia, and more than half the world's known population of Oriental Plovers occurred at the lake in 1989 (Watkins 1993).

Rare species that were recorded at the lake and for which the lake may be significant include the Freckled Duck, Australian Painted Snipe and Long-toed Stint (Halse *et al.* 1998a). Lake Gregory was also considered an important site for cormorant and Eurasian Coot breeding in Australia. The number of breeding species and pairs breeding made Lake Gregory the most important breeding site in the western third of Australia between 1988 and 1995.

Lake Gregory supports more species of waterbird than any other Australian arid zone wetland (Kingsford and Halse 1998), and contains the highest recorded number of invertebrate species (Halse *et al.* 1998b).

2.4 Lake Argyle

Lake Argyle is part of the Lakes Argyle and Kununurra Ramsar site and is an internationally important site for waterbirds (Hale and Morgan 2010). It supports the criteria for waterbirds that critical life stages of migratory shorebirds are supported: it supports in excess of 150,000 waterbirds; and it regularly supports more than one percent of populations of 11 species of birds (Hale and Morgan 2010).

A total of 75 waterbird species, including 22 international migratory species, have been recorded at the site (Hale and Morgan 2010). At Lake Argyle itself a total of 64 waterbird species was recorded in 2007, comprising 17,681 waterbirds of 61 species counted on the ground, and 244,765 waterbirds of 37 species counted from the air (Bennelongia 2007). Similarly, 200,000 waterbirds of 58 species were counted in an aerial count at Lake Argyle by Hassell *et al.* (2006). Earlier counts include a ground count of 181,356 waterbirds of 59 species in 1986 (Jaensch and Vervest 1989) and an aerial count of 4760 waterbirds of 35 species in 1993 (Halse and Pearson unpubl. data, in Bennelongia 2011).

2.5 Waterbirds at the Project Area

The above sections outline the importance of wetlands in the broad vicinity of the project area for waterbirds, with up to 75 waterbird species, including over 20 migratory species, and a conservative number of approximately 200,000 individuals counted on average (at just one of the above lakes) each year. As waterbirds are highly mobile and routinely visit isolated wetlands, the Browns Range project area could be visited by any waterbird species that occurs in the eastern Kimberley. The extent to which waterbirds utilize the pit void lakes, however, will depend upon the characteristics of those lakes.

3 Suitability of Pit Lakes in supporting Fauna

3.1 Shape of Pits

The shape of the pit lakes (steep slopes and deep) is likely to restrict the bird species that will use the pit lakes to waterbirds that can use deep water and do not rely on shores or shallows. Such birds that may use the pits include ducks, grebes, cormorants, terns, osprey and sea-eagles. Some terns, the Eastern Osprey and the White-bellied Sea-Eagle are listed as migratory. Most migratory species, however, are plovers and sandpipers that rely on shallows and shorelines. Similarly, non-migratory waterbirds occasionally abundant in the region, such as the stilts and the Red-necked Avocet, also rely on shallows and shorelines. Such shallows- and shoreline-dependent species may visit the pit lakes as vagrants but in low numbers.

3.2 Water Chemistry

3.2.1 Salinity

The geochemical characters of the pit lakes were modelled by Klohn Crippen Berger (KCB) (2014). Predicted lake water salinity in the first hundred or so years following cessation of mining is estimated to range from approximately 1000mg/L to 10,000mg/L, depending upon the pit configuration and the rate of groundwater inflow. The natural groundwater TDS in the project area is fresh to brackish, averaging approximately 2000 mg/L.

Based on the 1000 year water quality simulations, the pit lakes will become more saline as they get much older. Based on this long-term modelling, Gambit Central and Area 5 will eventually have salinities greatly in excess of seawater, but others will have salinities similar to (or less than) seawater. Marine waterbirds, including sandpipers and plovers, often live in environments where the only available drinking water is seawater but will drink water of lower salinity if available.

A review of salinity impacts to freshwater aquatic communities concluded that biota are affected by salinity, but there is limited understanding of increased salinity on species interactions and food chains; little is also known on the salinity thresholds that prevent semi-aquatic and terrestrial fauna from using an aquatic body (Kimberley *et al.* 2003).

3.2.2 Metals and other Contaminants

Golder Associates (2014) examined KCB's 100-year water quality predictions against ecological guidelines Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000) trigger values for protection of aquatic ecosystems and trigger values for livestock drinking water. Exceedences of the 100 year predicted metal concentrations against the above guidelines were seen across all of the chemicals, including mercury and selenium. However, this depended on the input water concentrations: inputs from SFE modelling were below ANZECC ecological thresholds and indicated acceptable risk; inputs from NAG modelling (for selenium and mercury) were above ANZECC thresholds and indicated potential risks to fauna.

There are insufficient data to comment on toxicity of other substances in the water. The two sets of modelled results (100 year water quality data) do indicate exceedences of the ANZECC guideline trigger values (for livestock drinking water) for Boron, Cadmium, Chromium, Mercury, Molybdenum, Selenium, Sulphate and Uranium. None of the contemporary chemical parameters measured in the groundwater for the five pits exceeded the ANZECC guidelines (where guideline values are available).

Some of these substances are toxic when in soluble form (Boron, Cadmium, Chromium, Mercury, Molybdenum, Selenium and Uranium) and may accumulate in the tissues of primary producers and secondary consumers. The degree of bioaccumulation which may occur or its impact on waterbirds is unknown, as the quoted ANZECC guidelines are based on mammalian physiology, however poisoning as a result of the bioaccumulation of a toxin or toxic substance generally occurs after ingestion of organisms which have directly consumed a large amount of organisms containing the toxin (e.g. humans consuming shellfish – algal toxins) or through the consumption of high order consumers where there has been a significant amplification (e.g. humans consuming sharks – mercury). However, the quoted ANZECC guidelines do refer to direct ingestion (drinking) of water by livestock so it is possible that some of these toxic substances may be directly toxic to waterbirds. It should be noted, however, that none of these substances is currently present in concentrations exceeding the ANZECC guidelines in the groundwater and most results for these parameters were below detection.

3.3 Lake Productivity

Productivity in the lakes can be predicted by examining nutrient levels as these determine the growth of organisms such as algae, aquatic vegetation, zooplankton and other aspects of an aquatic ecosystem. Lake productivity will therefore determine the extent of foraging opportunities available for visiting fauna and the risk of toxic bioaccumulation.

Phophorus and Nitrogen levels are available for groundwater in the proposed pit areas, and Phosphorus levels are predicted at 100 and 1000 years for the proposed pits (Klohn Crippen Berger 2014). For all lakes, Phosphorus levels are predicted to be extremely low (ultra-oligotrophic, all <0.004 mg/L) at 100 years, but extremely high (eutrophic, >0.01 mg/L) at most wetlands at 1000 years. Only at Wolverine based on one input (NAG) do Phosphorus levels remain low at 1000 years.

Another indication of lake productivity is nitrogen, for which there are no predicted data[1]. Although it is likely that nitrogen levels are also low, the nitrogen to phosphorus (N:P) ratio could be significant with respect to what algal groups may be favoured. N:P ratios in excess of 17:1 generally indicate phosphorus limitation whilst N:P ratios below 10:1 generally indicate nitrogen limitation. When nitrogen is the limiting nutrient, the nitrogen-fixing cyanobacteria (blue-green algae) may be favoured and become dominant. However, if the overall nutrient status is low, then algal growth will also be low. There are moderate levels of nitrogen naturally-occurring in the groundwater (L. Chandler, pers. comm.); increased nitrogen levels in the pit lakes may increase lake productivity and consequent bioaccumulation risk and as such predicted nitrogen levels should be examined. It is most likely that the systems will be Phosphorus limited at least in the medium-term (100+ years).

The predicted TDS is not considered high enough to preclude algal growth, however most common freshwater taxa, including potentially toxic freshwater cyanobacteria, may not be able to tolerate these salinities. Nodularia is a genus of blue-green algae known to bloom in brackish waters; it is also a potentially toxic species. It is possible that this species may find the conditions in these pit lakes hospitable, but growth may be initially (for some centuries?) restricted by the limitation of Phosphorus. . The elevated salinity based on the 1000 year predictions will reduce the range of algae that can grow further; this may occur despite the predicted rise in phosphorus. It is possible that other chemical substances in the water may alter and potentially reduce the bioavailability of nutrients available in the lake, and therefore alter productivity and risk of bioaccumulation.

[1] Groundwater Nitrogen levels were made available as this report was being completed but these have not been modelled for the pit water.

In general, when examining both 100 and 1000 year predictions, the elevated levels of salinity and initial low nutrient levels suggest it is likely productivity within the pit lakes will be low for 100+ years, but productivity could rise in the long term. High salinity in Gambit Central and Area 5 pits may limit productivity even then.

4 Risk to Fauna

4.1 Drinking

Based on the predicted salinity levels at the pit lakes (KCB 2014), the lake water will initially be fresh enough to be palatable to a wide range of fauna and is likely to be used as a source of drinking water by waterbirds (and potentially landbirds). The physical structure of the pit lakes may not be attractive to most waterbirds as they have steep slopes and no shallow areas. Therefore the birds may not stay for long periods as there is also limited foraging opportunity (Section 4.2). Other natural water bodies in the region are likely to be preferred sites by fauna due to the presence of fresh water, food, shallow sandy shores and shade. However, the lakes may be visited by fauna as a source of drinking water, including both water and land birds, particularly in the dry season.

Golder Associates (2014) conducted ecotoxicity studies on two species of waterbird (Oriental Plover and Nankeen Night-Heron), examining the impacts of elevated selenium and mercury (metals known to accumulate in the food chain) on the species. They concluded that birds that only drink the pit lake water and do not forage in the lake may not experience adverse effects from mercury and selenium bioaccumulation, although this conclusion depends on the input water concentrations (SFE modelling is acceptable but NAG modelling is not).

Therefore, the risk to fauna from drinking water at the pit lakes is expected to be low.

4.2 Bioaccumulation through Foraging

Golder Associates (2014) concluded that there is a risk of toxic bioaccumulation to waterbirds if they forage within the pit lakes (based on examination of the Oriental Plover) due to accumulation of selenium and mercury through the food chain. This assumed that the lakes would be productive and support an ecosystem of algae, vegetation and invertebrates, and would thus provide foraging opportunities.

Based on the predicted water chemistry at the pit lakes (KCB 2014), however, the overall productivity within the lakes is expected to be low at least initially (see Section 3.3). Aquatic vegetation/macrophyte growth will be unlikely due to the low nutrient levels predicted within the lakes, in addition to the steep slopes and the lack of suitable substrate within the pits. The lakes may support limited secondary production (e.g. zooplankton), but is not expected to offer much foraging opportunities for visiting waterbirds. Some ducks such as the Pink-eared Duck will filter-feed invertebrates from the water, but will require high concentrations of such food which is unlikely to grow. Large rainfall events could create a freshwater lens on top of the brackish water and this may provide a temporary environment for freshwater algal species, providing temporary foraging opportunities (and temporary risk of toxic bioaccumulation) for birds. The potential for mixing of toxic metals through the water column may be of temporary concern, however following a rainfall event birds would have many other freshwater options in the region. The lakes are unlikely to support a high biomass of potentially toxic blue-green algae due to predicted elevated salinity. However, this may be different if predicted nitrogen levels are higher.

Based on the above observations of initial low nutrient levels and limited productivity, the likelihood of toxic bioaccumulation by waterbirds feeding on lakes (whether on aquatic macrophytes or invertebrates) is considered to be low in the 100+ years range. Bioaccumulation may become an issue if fish were introduced into the lakes and fish-eating waterbirds forage in the lakes. In the long term (towards 1000 years), productivity will increase in some lakes and a simple ecosystem consisting largely of phytoplankton and zooplankton could establish. This could attract filter-feeding ducks; unless there is a major change in lake structure due to slumping of the lake walls, the lack of shallows and shoreline will limit foraging opportunities by migratory waterbirds such as sandpipers and plovers. It is not certain to what extent such a simple ecosystem would lead to bio-accumulation since there would only be three trophic levels (phytoplankton, zooplankton, ducks), but the risk is probably low especially as ducks in this region are highly mobile and unlikely to be resident on the lakes. The introduction of fish into lakes would increase the long-term risk of bio-accumulation to a different suite of birds, such as (grebes and cormorants.

5 Conclusions

Conclusions are drawn in reference to questions raised in Section 1.4:

- The Browns Range project area is located in a region that supports a large land and waterbird assemblage, and is likely to be visited by birds, including migratory waterbirds.
- Pit lake water will initially be fresh to slightly brackish, progressively becoming more saline, and even hypersaline in some cases. Nutrient levels will be initially be low but Phosphorus will increase over centuries, with eutrophic levels predicted by 1000 years. Some metals may exceed ANZECC thresholds.
- Fauna are likely to be attracted to the lakes; fauna are likely to drink from them when the water is fresh enough.
- Birds are unlikely to be adversely affected by elevated levels of chemicals in the water if they only drink (and do not forage) from the pit lakes.
- Steep slopes, a hard substrate and few shallows will limit macrophyte growth and discourage many bird species from foraging. Species of waterbirds with greatest potential to forage would be some ducks, cormorants, grebes and possibly some terns, the Osprey and the White-belied Sea-Eagle. Cormorants, the Osprey and the sea-eagle are fish-eaters and would thus not forage successfully in the lakes unless fish were introduced.
- Birds are likely to visit the project area for drinking water but are unlikely to stay for long periods due to lack of foraging opportunities and lack of shallows.
- Productivity at the pit lakes is likely to be low initially due to low nutrient levels and, in some lakes, elevated salinity. Therefore, in the 100+ years range, they are unlikely to support complex ecosystems of algae and other aquatic vegetation, and invertebrates. Productivity on some lakes will increase in the long term (towards 1000 years).
- In the short term (100+ years), pit lakes are likely to provide limited foraging opportunities to visiting fauna, therefore toxic bioaccumulation is unlikely to pose a risk to visiting waterbirds (with temporary exposure following large rainfall events the exception). In the long term (towards 1000 years), some of the lakes can be expected to support a simple

ecosystem of phytoplankton and zooplankton, which could attract filter-feeding ducks. Despite this, the risk of bio-accumulation is likely to be low because of the low number of trophic levels and because the ducks are likely to be visitors only. The introduction of fish could increase the risk of bio-accumulation, but prediction biological outcomes in the long term should be treated with caution.

Note that environmental ecotoxicology is not an exact science and is constrained by many limitations and uncertainties, especially when predicting future environmental states with exposure and toxicity of different receptors. Within this context, accurately assessing the potential risk to fauna can be problematic. Multiple assumptions and scenarios are given in this report which are based on limited data, thus are provided as a guideline only. Further toxicological investigation and monitoring is required to fully quantify the impacts.

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