In accordance with the Terms of Reference, which instructed the developer to provide a comprehensive analysis of the key line inquiry, Tyhee should put more emphasis on the questions related to the key line of inquiry. To facilitate this, the information requests in part one contain short descriptions of the information gaps that the Review Board identified in the DAR.

IR Number: 1-1-2

Source:	*Mackenzie Valley Review Board*
To:	*Tyhee*
Issue:	***Cyanide Attenuation***

Background

For cyanide Tyhee appears to rely on natural attenuation through volatilization, leaching, and bacterial activity. In the DAR Tyhee identifies temperature, aeration, UV light availability and bacterial growth as factors determining the rate of attenuation. Yet it does not provide evidence that these factors will allow sufficient attenuation at the Yellowknife Gold Project's sub-arctic location, or an explanation how leaching of cyanide will mitigate environmental effects. In addition, the DAR does not contain an analysis of concentrations of cyanide breakdown compounds.

Request

1. *Please submit studies, or relevant excerpts, that support Tyhee's reliance on natural attenuation of cyanide under the conditions prevailing at the proposed mine site.*
2. *Please provide an explanation how leaching of cyanide will mitigate environmental impacts and a description of where leached cyanide will likely end up and any environmental effects associated with it.*
3. *Please provide an analysis of cyanide breakdown compounds, their toxicity, and their concentrations and distribution.*

Tyhee NWT Corp Response

Request

1. *Please submit studies, or relevant excerpts, that support Tyhee's reliance on natural attenuation of cyanide under the conditions prevailing at the proposed mine site.*

Tyhee does not plan to rely exclusively on natural attenuation to reduce cyanide in mine effluent water. As stated in Section 4.11.7 of the DAR, a sulfur dioxide (SO_2)-Air cyanide destruction circuit will be used to reduce cyanide concentrations to MMER required concentrations before discharge to the TCA. Metallurgical work is currently underway to determine the reagent usage in the beneficiation process for Ormsby ore. Optimization work on the cyanide destruction circuit based on the results of metallurgical testing will follow.

The following is a brief description of the cyanide destruction circuit, as described in the DAR, followed by studies and excerpts of cyanide attenuation. The exclusion of Nicholas

Lake Ore is likely to reduce the overall cyanide usage, as a smaller percentage of ore will be entering the concentrate circuit when less sulphide ore is being put through the mill.

The SO_2-Air process is accepted as an effective method of removing soluble cyanides from wastewater. The process was developed approximately 30 years ago by INCO and has been used in over 80 mining operations worldwide. The process has a track record of being able of reducing total cyanide in leach effluents to less than 1 mg per liter (Mudder et.al, no date). Examples include Lac Mineral's Colosseum (0.4 mg/L), Westmin's Premier Gold (< 0.2 mg/L), and Homestake Chevron's Golden Bear (0.3 mg/L).

Tyhee ore will be ground and gold will be separated by froth flotation. This process will concentrate the gold into approximately 10 percent of the original ore volume for cyanide leaching, while the remaining 90 percent will be sent to the TCA as flotation tailings without cyanide.

The barren leached concentrate slurry, consisting of approximately 10 percent of the total mill throughput processed will flow to a process thickener. This device will remove much of the cyanide solution from the slurry for reuse in the process, raising the solids content from approximately 35 percent solids to 50 percent solids. The thickened tailings slurry will then be treated by the SO_2-Air process to reduce the remaining cyanide.

This flotation tailings slurry will be thickened to approximately 50 percent solids (same as the cyanide leach tailings) in another process thickener. As discussed previously (IR 1-1-1), the TCA design currently being considered will deposit flotation tailings to the north and south, and cyanide leach concentrate tailings will be sub-aqueously deposited in the center portion of the berm-divided TCA. The water associated with both tailings streams will preferentially collect in the area of the leached concentrate tailings. Dilution from flotation tailings water, which will be approximately ten times the volume of leach concentrate tailings, combined with the cyanide destruction circuit will produce a cyanide concentration less than 0.1 mg/L well below the MMER cyanide standard of 1 mg/L.

Natural attenuation within the TCA is expected to further reduce TCA concentrations. TCA discharge will mix with meteoric external water, reducing cyanide concentrations even further. If Narrow Lake cyanide concentrations are found to exceed CCME guidelines, that TCA water can be cycled back into the TCA, and additional treatment can be implemented (IR 1-1-3).

The surface effluent testing on flotation tailings (DAR Appendix J) had a pH of 7.99, indicating that the waters in contact with flot tailings is likely to be approximately pH 8. That process water will mix to some degree, with local runoff waters. The average pH of Round, Winter, and Narrow Lakes were 7.43, 7.03, and 7.03, respectively based on monitoring from 2004 through 2010 for water license MV2002L2-0017. If pH in the TCA is maintained below a pH of 8, which is achievable through pH adjustment before discharge if necessary, more than 90 percent of the cyanide anion (CN^-) present will be present as hydrogen cyanide (HCN) (Logsdon et al., 1999, available online).

Examples of Cyanide Natural Attenuation

Natural attenuation of cyanide in tailings ponds is a function of the environmental conditions and has been shown to be effective. Lupin Mine and Colomac Mine, both in Canada's North, are excellent examples of cyanide attenuation in climates similar to Tyhee's Yellowknife Gold Project.

Lupin Mine, NWT (Logsdon et al., 1999); this mine relied solely on natural degradation of cyanide within the TCA, with CN^- entering the TCA at a concentration of 184 mg/L and being discharged from the TCA at a concentration of 0.17 mg/L. This now-closed mine now owned by Elgin Mining (formerly MMG, Kinross and Echo Bay Mines) is located approximately 350 kilometers (km) north of the Yellowknife Gold Project.

The Colomac Mine, NWT, mill was not equipped with a cyanide destruction circuit because the TCA was intended to be a zero discharge facility (due to faulting and poor construction, the facility was not zero discharge). Historic sampling over the period of 1998 through 2001 logged the degradation of cyanide, thiocyanate, and ammonia. Total cyanide concentrations in the Colomac Mine Tailings Lake decreased naturally without any intervention from 38 mg/L in September 1998 to 1 mg/L in September 2001 (Chapman et al., no date, available online). Enhanced Natural Removal was successfully used through the addition of phosphorus as a limiting nutrient to bring cyanide and its breakdown compounds (i.e., thiocyanate, ammonia) down to concentrations acceptable for release to the environment. This mine is located within 50 km west of the Yellowknife Gold Project.

Request

2. *Please provide an explanation how leaching of cyanide will mitigate environmental impacts and a description of where leached cyanide will likely end up and any environmental effects associated with it.*

The use of cyanide leaching in the gold recovery process is described in DAR Section 4.11, and the resultant cyanide concentrations from process and discharge to the TCA are described in DAR Section 6.2.1.2. The predicted concentrations of cyanide and cyanide breakdown compounds in the TCA and TCA discharge are likely to change with the new mine plan. A full description of the environmental impacts and fate of cyanide in the system will be developed once a water balance and metallurgical work have been completed for the new mine plan.

Request

3. *Please provide an analysis of cyanide breakdown compounds, their toxicity, and their concentrations and distribution."*

Free and Dissociable Cyanide

Free cyanide is the toxic fraction (CCREM 1987; Eisler 1991; USEPA 1985) and from a toxicological perspective the distinction between free cyanide and other forms (generally reported as total cyanide or weak acid dissociable [WAD] cyanide) is critical. Free cyanide is defined and measured as the sum of HCN and the CN^-. Total cyanide is the summation of all of the cyanide species including free cyanide, water-soluble salts (e.g., NaCN, KCN), salts of alkali, alkaline earth, or heavy metals (e.g., $Zn(CN)_2$, $Cd(CN)_2$), and less toxic complex metallocyanides (such as $Cu(CN)_2^-$ and $Fe(CN)_6^{4-}$) (Eisler 1991; Exall et al. 2011). Weak acid dissociable (WAD) cyanide is the fraction of bound cyanide that will release the free cyanide anion (CN^-) following the addition of a weak acid. WAD cyanide is often measured in the environment to account for the fraction of cyanide that may become free and toxic with relatively small changes in environmental conditions (i.e., pH). Many factors can affect the form of cyanide, including pH, temperature, salinity, the concentration of metal ions and complexation materials, dissolved oxygen, and sunlight (USEPA 1985). In addition to the various species of cyanide, there are a number of breakdown and by-products that co-occur in the aquatic environment, including cyanates (-OCN), thiocyantes (-SCN), and ammonia in addition to non-toxic forms of carbon and nitrogen.

Cyanide Breakdown Compounds

The breakdown and by-products of cyanide such as cyanates (-OCN), thiocyanates (-SCN), ferrocyanate complexes (e.g., $Fe(CN)_6^{4-}$), and ammonia (NH_3) are considerably less toxic than cyanide itself. Simple thiocyanates, such as the products of cyanide detoxification, are on the order of 12-times less toxic than cyanide (Eisler 1991) and therefore pose considerably less threat to aquatic life (Lanno et al.1996; Exall et al. 2011). The majority of risk associated with the formation of cyanates, thiocyanates, and metal-cyanide complexes is in their potential to re-release cyanide following decomposition by UV or change in pH (Eisler 1991; Calffe and Little 2003). The production of ammonia (NH_3) from the degradation of cyanide is not considered a risk to the aquatic environment at Tyhee's Yellowknife Gold Project. The CCME water quality guideline for the protection of aquatic life is 0.019 mg/L un-ionized ammonia. At 10°C, a pH of 8, and 1.0 mg/L total ammonia, the percent un-ionized ammonia would be 18.25, or a concentration of 0.018 mg/L ionized ammonia (CCME 2010). At the CWQG of 5 µg/L cyanide, negligible amounts of ammonia will be produced, far below the 1.0 mg/L needed to reach the CWQG.

Cyanide Toxicity

Cyanide(CN^-)- can be toxic as it asphyxiates cells by binding to and deactivating cytochrome c. oxidase inhibiting cellular respiration (Eisler 1991). Cyanide toxicosis is rapid following the absorption of a lethal dose, as it can enter the blood stream and cross cell membranes regardless of route of exposure. At sub-lethal concentrations, cyanide can be detoxified and excreted, and is done so by thiosulfate conjugation by specialized liver enzyme rhodenase to produce thiocyanates, which are considerably less toxic and easily excreted in the urine (Eisler 1991). Owing to efficient cyanide detoxification, it has been suggested that sub-lethal concentrations of cyanide can be tolerated in some animals over extended periods of time (Eisler 1991). In the aquatic environment, fish are considered to be the most sensitive organisms to cyanide (USEPA 1985; Sarkar 1990; Eisler 1991).

The CCME guideline of 5 micrograms per Liter (µg/L) for the protection of aquatic life is based on the U.S. Environmental Protection Agency (USEPA) criterion of 5.2 µg/L for the protection of aquatic life (USEPA, 1985), as well as a review of the effects on aquatic organisms carried out in 1987 (CCREM 1987). For example, the lowest concentration to which rainbow trout exhibit an acute response (i.e., mortality) was 27 µg/L (Kovacs and Leduc 1982a), while a 50 percent reduction in performance of cold water fish species was observed following the continuous exposure to 10 µg/L free cyanide (Kovacs and Leduc 1982b; CCREM 1987). The USEPA criterion is based on a calculated value, whereby the Species Mean Acute Value (SMAV) for Rainbow trout (Onchorynkus mykiss) of 44.7 µg/L is divided by an acute-chronic ratio to give 8.1 µg/L; a conservative value of 5.2 µg/L is therefore effective in avoiding chronic toxicity.