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: 1-1-3

Source:	*Mackenzie Valley Review Board*
To:	*Tyhee*
Issue:	***Effluent Treatment Options***

Background

Tyhee estimates the effluent from the TCA to be "on the lower end of the toxicity scale for cyanide" without explaining how this estimation was reached – in the DAR Tyhee states that no detailed analysis of processes in the TCA was undertaken. The technical memo by EBA presenting modeling results for Narrow Lake indicates that arsenic, cyanide, and copper require additional treatment to meet CCME guidelines. In the DAR Tyhee indicates that treatment options exist but does not propose any treatment for cyanide and copper. For cyanide Tyhee relies on further natural attenuation in a 165 meter stretch between the last point of control and when the effluent reaches Narrow Lake in its determination that the effluent will not likely be toxic to aquatic life. Similarly, in the DAR Tyhee provides relatively little information on treatment options and their proposed implementation for other effluent constituents, such as arsenic and copper.

In the Review Board's view, CCME guidelines may serve as an appropriate standard to mitigate to, although meeting CCME may not in all cases prevent significant impacts on the environment. While the DAR identifies the goal Tyhee intends to achieve - that is meeting CCME guidelines - it is silent about the means to achieve it. The Review Board requires a description of the means to achieve CCME guidelines. Further, the Review Board requires a reasonably detailed description of the treatment options and their reliability, as well as some information on how they would be implemented.

Request

1. *Please provide a description of how Tyhee reached the conclusion that the effluent from the TCA will be "on the lower end of the toxicity scale for cyanide".*
2. *Please provide a description of what "on the lower end of the toxicity scale for cyanide" means in terms of its potential to cause significant adverse effects.*
3. *Please provide a concise description of treatment options available for cyanide and other elements identified in the DAR.*
4. *Please identify under which conditions treatment options would be implemented, including an outline of how they would be implemented.*
5. *Please submit contingency plans for how Tyhee will ensure that no significant adverse impacts on the environment are likely and CCME guidelines are met at all times, while treatment options are being implemented.*

Tyhee NWT Corp Response (Revised May 31, 2012)

It is understood that IR 1-1-3 seeks information concerning what options are available to achieve CCME guidelines in Narrow Lake. This IR response will focus on meeting MMER guidelines at the controlled discharge point, and will specify treatment options and contingency plans for meeting MMER guidelines in any discharges from the TCA. Based on the evaluation of the changed mine plan and associated water balance, no continuous discharge is anticipated during processing operations; however, as mentioned in other IR responses, Tyhee expects that discharge from the TCA to the downstream environment will occur at some point during operations. Thyee expects that the capability to release water from the TCA will be included in the projects water license, issued following the Regulatory Phase. Further evaluation of the solute concentrations in the TCA and the effect on Narrow Lake of the reduced discharge quantity and quality indicate that compliance with the guidelines is attainable. Should a discharge be needed, the first step would be to evaluate the concentrations of key parameters in the TCA. If the criteria are not met, then the water can be held in the TCA pending further evaluation.

Request:

1. *Please provide a description of how Tyhee reached the conclusion that the effluent from the TCA will be "on the lower end of the toxicity scale for cyanide".*

Estimates of the water quality of the TCA in the DAR were based on a project which processed ore from both Nicholas Lake and Ormsby. Recent geochemical characterization of tailings produced from processing only Ormsby ore indicates that the cyanide concentration in the TCA will be considerable lower than the MMER effluent requirements for Total Cyanide at the time of the expected greatest concentration, and therefore will be "on the lower end of the toxicity scale".

The following is a brief description of the cyanide destruction circuit, the functioning of the tailings pond and how these lower levels of cyanide will be achieved. The exclusion of Nicholas Lake Ore has been shown to reduce the overall cyanide usage, as a smaller percentage of ore will be entering the concentrate circuit when less sulphide ore is being processed in 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 6 percent of the original ore volume for cyanide leaching, while the remaining 94percent will be sent to the TCA as flotation tailings without cyanide.

The barren leached concentrate slurry, consisting of approximately 6 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 to 50 percent. 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 cells of the TCA, 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 19 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 Total Cyanide standard of 1 mg/L.

As discussed in the response to IR 1.1.2, the residual cyanide after the destruct process ranged from <0.05 mg/L for sample DT-6 to 6.43 mg/L for DT-2. The final total CN concentrations for samples DT-3 through DT-6 were all below 1 mg/L. The final total CN concentration for DT-1, the continuous test system, was 2.88 mg/L. Optimization of the process during operation is expected to produce a supernatant with less than 1 mg/L. However, to be conservative, the values calculated were based on a post detoxed leach tailings total cyanide concentration of 2.88 mg/L. The leach tailings represent approximately 6 % of the total tailings material.

Request:

2. *Please provide a description of what "on the lower end of the toxicity scale for cyanide" means in terms of its potential to cause significant adverse effects.*

(Not Modified from March 28, 2012 submission)

The "lower end of the toxicity scale for cyanide" means a cyanide concentration below the MMRE effluent regulations of 1 mg/L total cyanide and an effluent that is not acutely toxic when subjected to MMER bioassays. However, this is not a comment on the chronic adverse effects of cyanide. What this means in relation to "significant adverse affects" is outlined below.

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). Such complexes can be expected to play an important role in TCA cyanide toxicity. It is expected that 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 guidelines for the protection of aquatic life are 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 water quality guideline of 5 μg/L cyanide, negligible amounts of ammonia will be produced, far below the 1.0 mg/L total ammonia standard.

Adverse Effects of Cyanide Toxicity

The CCME guideline for the protection of aquatic life is 5 micrograms per Liter (μg/L) of free cyanide. This 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.

It should be noted that the cyanide concentrations in the above paragraph are expressed as μg/L free cyanide and that the MMER effluent regulations are expressed as mg/L total cyanide.

Request:

3. *Please provide a concise description of treatment options available for cyanide and other elements identified in the DAR.*

(Not Modified from March 28, 2012 submission)

As previously discussed (IR 1-1-2), the cyanide will first be treated by the INCO (SO_2-Air) process which oxidizes the free cyanide and cyanide complexes. The process occurs at a pH typically between 8 and 11, which is sustained through the addition of lime. Testing of tailings produced from processing Ormsby ores shows that effluent cyanide concentrations below 1 mg/L can be achieved using this process.

Should additional treatment, beyond the natural attenuation previously discussed, be needed, biological oxidation could be utilized either through the addition of phosphate to promote biological activity in the TCA or through biological reaction tanks. These biological reactions can achieve low-level effluent cyanide concentrations. Empirical testing would be needed to evaluate the efficacy of this method.
If additional treatment is necessary to meet the metal concentrations in the MMER discharge criteria, a single or double step precipitation and coagulation treatment approach could be used. Conditions (pH, Oxidation Reduction Potential [ORP], and zeta potential) are varied in each step of a multi-step process to remove metals. Provisions will be made for sludge handling if this water treatment option is found to be necessary. Empirical testing would be performed before implementing this treatment option to determine the best process conditions to meet MMER standards.

Additional removal of heavy metals is possible by the injection of sulfides during the second stage of precipitation/coagulation. The sulfide reacts with the metals to form metal sulfides. The degree of additional removal can only be determined through empirical testing; however, the process is usually capable of producing extremely low-metal effluent concentrations.

Several ion exchange resins are available that selectively remove transitional, heavy, and alkaline earth metals. The process is usually capable of producing extremely low-metal effluent concentrations.

Request:

4. *Please identify under which conditions treatment options would be implemented, including an outline of how they would be implemented.*

(Revised May 31, 2012)
As previously mentioned, no discharge is expected from the TCA during the operation; however, Tyhee expects that the operations water license, issued following the Regulatory Phase will have terms and conditions within that water license that will allow TCA discharge if and when needed. The adaptive management process and the process for determining if treatment options are needed are described in IR 1.1.4.
The implementation of discharge and treatment options would be done in consultation with the MVLWB and Water Resources Officer.

Request:

5. *Please submit contingency plans for how Tyhee will ensure that no significant adverse impacts on the environment are likely and CCME guidelines are met at all times, while treatment options are being implemented.*

(Revised May 31, 2012)
Tyhee approach to preventing significant adverse impacts on the environment is to minimize the amount of water, and hence solutes, discharge from the site in general and the TCA in particular. Based in revised water balance indicating that discharge from the TCA during operation is unlikely and estimates of solute concentration in the TCA showing them to be below MMER discharge criteria, no treatment options are currently under consideration for normal TCA operations. Tyhee would, during the operation, monitor the TCA water quality and undertake any studies that would confirm that the TCA contents

could be discharged to the downstream environment OR if treatment is expected to be required, the appropriate treatment system would be installed to ensure compliance with MMER discharge criteria. Any treatment system put in place, will be maintained and managed per vendor specifications. .

References

To assist the reader the following copies of selected references are included in Appendix A: CCREM 1987, Calffe and Little 2003, Eisler 1991, Logsdon 1999, Mudder et.al, no date, and USEPA 1985.