Technical Memorandum

To: John McCullum, P.Eng., Executive Director
Environmental Monitoring and Advisory Board

From: Randy Knapp, P. Eng.

Date: June 6, 2017

Re: **Review of the Diavik North Country Rock Pile- Waste Rock Storage Area Closure Plan**

OVERVIEW

EMAB has requested that Randy Knapp complete a Technical Review of the Closure Plan for the Diavik North Country Rock Pile Waste Rock Storage Area (WRSA). The technical review of the Plan and Appendices was to focus on the current Best Practices for mining reclamation, restoration and closure, including use of Traditional Knowledge and community participation, and comment on:

I) Critical components that have been left out or described in insufficient detail
II) Flaws, uncertainties and risks
III) Components requiring further research or improvement
IV) How well Traditional Knowledge and Community Concerns were integrated into the Plan
V) Scope and Cost of Long-term Monitoring and Maintenance (Main document, Attachment #3)
VI) Thermal predictions and modelling
VII) Seepage potential and quality and Diavik's approach to this post-closure
VIII) Adequacy of the Closure Objectives and Criteria, and how well the Plan will achieve them

TECHNICAL REVIEW

The following section of this memo specifically address items I) to VIII) as listed above. The comments represent the opinion of Randy Knapp based upon more than 40 years of participation in the development and review of mine closure plans.

I) Critical components that have been left out or described in insufficient detail

A primary concern identified by the TK panel and community has always been caribou safety. The closure plan indicates that the TK panel would be satisfied if the surface access ramps were at the 3:1 side slopes and the surface was similar to the experimental test pile. The concerns are as follows:

- This test pile has no visual large rocks and may not represent what the final surface of the re-sloped WRSA looks like. The test piles are known to contain a higher percentage of fine material and as such do not represent the grain sizes of the waste rock cover from the A21 Pit.
- The waste from the A21 pit will have highly variable sizes from fine rock to very large boulders. There is no assurance that there will not be voids and spaces where caribou could injure their feet and legs. (note: One of the failure mechanisms for the cover discusses by Golder is the roll out of boulders from the cover).
- The QA/QC procedure has no control on grain size or voids spaces for the re-sloped surface of the pile and simply says the QA/QC is to be controlled by visual inspection. The requirements for a safe surface are unclear.
- The TK panel were shown a 3D representation of the designated caribou pathway access areas where that align with old migration routes. Diavik indicate these routes would be free of any such obstacles and allow for safe caribou movement on and off the pile. It is unclear from the design drawings where these pathways are and what quality control will be provided to assure the surfaces are safe for travel.

Diavik should discuss in more detail the requirements, specifications and quality assurance program to assure final waste rock surfaces along caribou pathways are safe and do not contain voids where feet and legs could be injured. The final design drawings should also show these routes on the engineered drawings.

II) Flaws, uncertainties and risks

Extensive thermal modelling was completed by Diavik for the WRSA and a “SUPPLEMENTAL THERMAL MODELLING report was completed by Tetra Tech and provided in Appendix XI . Key points to consider for the Tetra Tech review are as follows:

- The data uses the mean value for expected climate change over 100 years. The predicted mean temperature increase is 5.6^{o}C. No sensitivity analysis was completed for a less conservative climate change projection.
- Sensitivity analysis has shown that the key factor that can affect thaw depth is the moisture content of the till. Moisture content of below 10% could result in seasonal thawing below the cover on the side slopes. The Specification for the till as outlined in Appendix X-NCRP Design by Golders in section 3.3.3 of Appendix B to the design report is “The Till to be placed on the re-sloped and crest surfaces of the NCRP shall be a silt, sand and gravel mixture with a maximum particle size of 1.5 m or lift thickness, with 30 to 70% passing the No. 40 sieve (0.42 mm). The maximum water content of placed till is 25%.”

Diavik should address the following issues:

1) Given that the thaw depth on the side of the pile is predicted to be 4.1 m for the mean climate change scenario, would the seasonal thaw depth extend into the Type III rock for a less conservative climate scenario (i.e. greater change than the mean scenario modelled)?
2) Given the sensitivity of thaw depth to the moisture content of the till, the till specification should include a minimum water content for the till.

III) Components requiring further research or improvement

The closure plan has a thorough R&D program much of which is ongoing. With respect to the WRSA Closure Plan, additional research or improvements are not suggested.

IV) How well Traditional Knowledge and Community Concerns were integrated into the Plan

Diavik has integrated much of the information relayed by the TK panel and community into the WRSA Closure Plan. Specific suggestions that were incorporated into the plan include:

- Provision for caribou ramps with reduced slopes along former caribou transport corridor routes across the pile.
- Provision for selected areas where angle of repose slopes are maintained to provide denning habitat for wolverine and other mammals.

Areas where specific consideration of input from the TK has not been adopted at this time include:

TK Panel/community Request	Diavik Response
Create barriers between the rock pile and PKC to discourage animals from going into the PKC area; use traditional techniques (e.g. flags, trees, inuksuit) to keep caribou away from areas that are unsafe	Engineered cover slope of1.5H:1V adjacent to PKC, consideration of additional deterrents would only be considered as a contingency, once the cover is complete.
Use fine crushed rock on passage-ways to protect the feet of the caribou	Placement and levelling of cover will create surface similar to covered test pile, which has been identified as safe for caribou use; placement of additional materials on caribou pathways would only be considered as a contingency, once the cover is complete.

V) Scope and Cost of Long-term Monitoring and Maintenance (Main document, Attachment #3)

Further to requests by EMAB and the Water , Diavik was asked to address long term costs for monitoring, care and maintenance post closure. This is the period after which the closure work and the monitoring programs are completed (about 10 years after the mine closes). Diavik have provided a first cut at the potential costs for long term care, maintenance and monitoring.

The first impression is that the costs are staggering at a cost of $560,000/year. Funding of long term costs at other mine sites is typically done by using the Net Present Value of these costs. The net present value is the sum of money that would need to be put into a fund such that the investment would have a return adequate to fund the long term maintenance costs. With NPV calculations, the future costs are discounted. The discount rate typically is the difference between the rate of return of the investment and inflation. A commonly used discount factor is 3%. For a $560,000 annual cost, at a 3% discount factor, the NPV would be approximately $18.7 million. There could be support for using a lower discount factor given the poor rates of return available in most government secured investments (e.g. treasury bonds). This would increase the NPV.

There are only general details provided in Attachment 3 but overall the allowances included would appear to be rational. It would be worthwhile for Diavik to provide additional details (e.g. the type of equipment, storage location, fuel requirements etc.) to better assess the validity of the estimate.

VI) Thermal predictions and modelling

The initial work on modelling was completed by a doctorate student, H. N. Pham. His thesis reference is "Pham, H.N., 2013- *Heat Transfer in Waste-Rock Piles Constructed in a Continuous Permafrost Region*. PhD Thesis. Department of Civil and Environmental Engineering, University of Alberta. Spring 2013". The modelling completed for the thesis confirmed there was a need for the till layer and confirmed that a cover with 3m waste of clean rock and 1.5 m of till would prevent thawing of the potentially acid generating Type III rock.

The Water Board required an independent check of the thermal modelling completed by Pham and this was undertaken by Tetra Tech. Tetra Tech undertook a detailed model using their best judgement of input data and concluded that the cover design would maintain frozen conditions below the cover for 100 years using the average climate warming predictions. They also undertook sensitivity analysis on the predictions by varying several input assumptions. The key factor which impacted thaw depth was the moisture content of the till. They demonstrated that thaw depths will exceed 4.5 m if the moisture content of the till was less than 10%.

Overall, two independent sources have confirmed that cover should perform to retain frozen conditions and this leads to a high level of confidence that the cover will meet expectations.

VII) Seepage potential and quality and Diavik's approach to this post-closure

Diavik has undertaken an extensive test program to estimate seepage quality from the WRSA. This work included the construction of several large-scale field test plots with extensive instrumentation and monitoring. The field programs provide measured data for rates of metal production and are the most effective tool for providing data for long term modelling. The predictions of seepage quality where prepared by Smith 2013-*Prediction of Seepage Quality at Closure from Waste Rock Piles*. This work has been review by several of the leading geochemical modellers in North America which leads considerable credence to the model validity. The seepage quality predictions were verified using the test pile seepage data and typically indicated an over prediction of metals leaching potential. Additional seep monitoring is also performed on the waste pile seepage.

It is my opinion that this approach is state-of-the-art, well documented and as thorough as can be expected. Although models may be wrong, the test pile data are a good measure of potential seepage quality. Given the model tends to overpredict metals levels, the use of the model predictions could be considered a conservative approach. Little additional work would appear to be warranted.

Should predictions be incorrect and water quality does not meet discharge criteria, Diavik has indicated it will implement contingency plans which include : i) the additional of Type I material to target batter areas if inadequate seepage quality is identified; ii) the addition of till cover to target batter areas if inadequate seepage quality is identified; iii) the collection and treatment of seepage water until quality/quantity is adequate for release into Lac de Gras; and iv) enhanced passive treatment of targeted seepages.

The WRSA will be closed in advance of the mine closure and as such there will be time to assess the effectiveness of the cover and to monitor seepage quality. Should there be an indication that seepage quality will be unacceptable for discharge, a portion of the financial security could be retained to provide for interim/long term treatment.

It would be helpful for Diavik to provide an estimated cost for the long term operation of the water treatment plant. This will provide a basis for assessing the potential financial security requirements should long term treatment be required.

VIII) Adequacy of the Closure Objectives and Criteria, and how well the Plan will achieve them

This adequacy of the closure objectives and criteria are being addressed by others. Several of the closure objectives and criteria remain unachievable, these include:

- Closure Objective SW9. Landscape features (topography and vegetation) that match aesthetics and natural conditions of the surrounding natural area. The criteria to demonstrate that the objective is met is NCRP As-Built Report conforms adequately with Golder (2016- the design report). Given there will be no vegetation except through natural recolonization (perhaps over 100 years) the objective is meaningless and certainly cannot be met by meeting the design.

- Closure Objective W2. Rock and till pile features (shape and appearance) that match aesthetics of the surrounding natural area. The criteria is NCRP As-Built Report conforms adequately with Golder (2016). As with SW9, the aesthetics of this pile of broken rock will not match the aesthetics of the local area and building it as designed does nothing to confirm the objective is met.

These objectives are simply not going to be met with the current plan.

SUMMARY

The North Waste Rock Pile-Waste Rock Storage Area Closure Plan as presented is a thorough document that meets requirements. The updated closure plan has been responsive to requirements of the Water Board and has incorporated much of the requests by local communities and TK panel. No fatal flaws have been identified.

Past concerns of not including vegetation for the surface of the waste pile remain as this would be considered best practice for the mining industry. However, there would appear to be an overall acceptance by the community and TK panel that vegetation is not essential and that the pile will revegetate (heal) with time.

Diavik has provide extensive data and information to support the closure plan. The following are potential aspects that should be addressed in more detail.

1) Diavik should discuss in more detail the requirements, specifications and quality assurance program to assure final waste rock surfaces along caribou pathways are safe and do not contain voids where feet and legs could be injured. The final design drawings should also show these routes on the engineered drawings. There is a concern that the test piles are not representative of the final cover surface given these piles contain no visible boulders and are known to have a greater fraction of fine particles.
2) Given that the thaw depth on the side of the pile is predicted to be 4.1 m for the **mean** climate change scenario, Diavik should rerun the thermal model for a less conservative climate scenario (i.e. greater change than the mean scenario modelled) to assess whether the seasonal thaw depth would extend into the Type III rock.
3) Given the sensitivity of thaw depth to the moisture content of the till, the till specification should include a minimum water content for the till.
4) Diavik has prepared a first cut at long term monitoring costs for the post closure period. There are only general details provided in Attachment 3 but overall the allowances included would appear to be rational. It would be worthwhile for Diavik to provide additional details (e.g. the type of equipment, storage location, fuel requirements etc.) to better assess the validity of the estimate.
5) It would be helpful for Diavik to provide an estimated cost for the long term operation of the water treatment plant. This will provide a basis for assessing the potential security requirements should long term treatment be required.