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Tailings and Mine Rock Management

MEMORANDUM

To: Mr. Brent Murphy, Vice President Environment Affairs

From: Dirk van Zyl, Principal Engineer

Subject: **Review Comments on Best Available Technology (BAT) Study for Tailings Management at the KSM Project**

Date: August 1, 2016

1. Introduction and Scope

I, Dirk van Zyl, was engaged by Seabridge Gold Inc. (Seabridge) to review the *"Best Available Technology (BAT) Study for Tailing Management at the KSM Project"*, recently completed by Klohn Crippen Berger (KCB, 2016). The Application for an Environmental Assessment Certificate/Environmental Impact Statement for the KSM Project (Application/EIS) was approved on July 30, 2014 by the BC Government and on December 19, 2014 by the Canadian Government. The BAT study is part of the ongoing evaluations by Seabridge as a voluntary study to further review the proposed tailings[1] management strategy for the project.

The scope of work for this review consists of evaluating the KSM BAT Report and commenting on the overall approach, including the review of filtered tailings options for this site, the multiple accounts analysis (MAA), as well as the outcomes and conclusions.

2. Evaluation Approach

2.1. Summary of Approach

Chapter 3 of KCB (2016) describes the evaluation process. Table 1, prepared on the basis of Chapter 3, provides a summary of the approach. Further comments by the author are included in this Table. The overall approach of the BAT evaluation by KCB (2016) was to evaluate the siting and tailings options for the KSM project using Environment Canada's (EC) *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* that was developed for Schedule 2 sites as listed in the *Metal Mining Effluent Regulations* (MMER). Schedule 2 of the MMER lists water bodies designated as tailings impoundment

[1] Note that the author prefers the use of "tailings" vs. "tailing" used by KCB (2016), both terms will therefore appear in this report.

Table 1
Summary of Approach to BAT Evaluation

Parts	Components	Comments
Part 1. BAT and BAP Review and Assessment of Filtered Tailing for the KSM Project	1.Review Best Available Technology (BAT) and Best Available Practice (BAP)	All components are considered in Chapters 4 and 5 of the report
	2.Review and Assess Tailing Technologies	
	3.Review Case Histories	
	4.Assess Feasibility of Filtered Tailing for the KSM Project	
	5.Risk Review	
Part 2 – Tailing Management Alternatives Assessment	Step 1: Identify Candidate Alternatives	The framework for this assessment is based on Environment Canada's *Guidelines for the Assessment of Alternatives for Mine Waste Disposal* that was developed for Schedule 2 sites as listed in the *Metal Mining Effluent Regulations* (MMER), which is a federal legislative action. The MMER, enacted in 2002, were developed under subsections 34(2), 36(5) and 38(9) of the *Fisheries Act* to regulate the deposit of mine effluent, waste rock, tailings, low-grade ore and overburden into natural waters frequented by fish. Schedule 2 of the MMER lists water bodies designated as tailings impoundment areas (TIAs).
	Step 2: Pre-screening Assessment	
	Step 3: Alternative Characterization	
	Step 4: Multiple Accounts Ledger	
	Step 5: Values-based Decision Process	
	Step 6: Sensitivity Analysis	
	Step 7: Document Process	
Part 3 - BAT Study Conclusions	Conclusion 1: The Teigen-Treaty site is the Preferred TMF site	Overall conclusion is that the Teigen-Treaty cyclone sand TMF is the preferred TMF site and that filter tailings technology is not practical for the KSM Project.
	Conclusion 2: Filter tailing technology is not practical for the KSM Project	
	Conclusion 3: The Teigen-Treaty Cyclone Sand TMF is the Preferred Management Strategy for the KSM Project Tailing	

areas (TIAs). These guidelines outline a rigorous approach to assessment of alternatives for mine waste disposal at the project level. Applying these guidelines with a more detailed focus on alternative tailings disposal technologies as compared to conventional methods implied that the tailings management options and siting were addressed in detail despite the previous work performed during the EA process. It provided a "fresh look" and approach to arriving at an outcome.

The definition of BAT, as well as the associated considerations, used for this study are described as follows:

> "For purposes of this study the definition of BAT means the combination of technologies, designs and management strategies that most effectively reduce the physical, geochemical, ecological and social risks associated (within a tolerable risk limit) with tailing management during all stages of operation and closure. BAT also includes consideration of cultural, heritage, economic values and site specific conditions. BAT includes site selection considerations, technologies and design features that provide a resilient and robust tailing facility during operations and post-closure. BAT should be implemented at every stage of the tailing life cycle.
>
> "Selection of a BAT should take into account the tailing properties (both physical and geochemical), the tailing disposal site conditions and the project specific requirements. Technologies selected for tailing may differ depending on the minerology, gradation, clay content, type of tailing, and if the tailing are Potentially Acid Generating (PAG) or Not Potentially Acid Generating (NPAG), etc. Furthermore, separating PAG and NPAG tailing streams and adopting separate management strategies can aid in preventing oxidation and the onset of Acid Rock Drainage (ARD). Technologies will differ depending on the disposal site conditions (e.g., topography, climate, geology, geohazards, etc.) and project conditions (e.g., tonnage rate, ore variability, economics, permitting requirements, etc.)".

2.2. Evaluation of Approach

The BAT study followed a logical approach based on the recommendations of the Independent Expert Engineering Investigation and Review Panel Report of the Mount Polley Tailings Storage Facility Breach (Panel Report, 2015). Specific attention is given to the practicalities of using filter tailings technology at the KSM Project considering the project specific characteristics including production rate and climatic conditions.

The EC guidelines were used in the EA, however the focus was on the siting of a preferred location. For the BAT evaluation the focus of the approach was applied to select the best or most appropriate location as well as the most appropriate technology. Additionally for this study additional MAA categories were developed and utilized in the review process.

The definition of BAT adopted for this review is focused on "the combination of technologies, designs and management strategies that most effectively reduce the physical, geochemical, ecological and social risks associated (within a tolerable risk limit) with tailing management during all stages of operation and closure". This definition does

not define or clarify what “a tolerable risk limit” is. It is recommended that this should be clarified as the tolerable risk limit is not the same for all companies and site locations.

The Panel Report (2015) emphasizes the importance of the overall goal of moving to zero TSF failures. The following considerations and quotes from this report provide further clarifications:

- “Thus, the path to zero leads to best practices, then continues on to best technology”.
- “The goal of BAT for tailings management is to assure physical stability of the tailings deposit. This is achieved by preventing release of impoundment contents, independent of the integrity of any containment structures”.
- The key considerations include the mode of tailings release should a tailings containment fail both fluvial and flowslide conditions should be considered. Furthermore, “promoting unsaturated conditions by drainage, reduces the possibility for, and the quantity of, high-mobility flowslide release of tailings”.
- “The overarching goal of BAT is to reduce the number of tailings dams subject to failure”.

The combination of all the site specific considerations including the Best Applicable Practices (BAP) actions and their specific management and controls must be integrated to move towards zero TSF failures at a site. This requires ongoing commitment and pro-active management of all the aspects of tailings management.

My conclusion is that the overall approach followed for the evaluation is logical, balanced and addresses the broad range of site specific considerations. The definition of BAT could be enhanced by specifically addressing the focus of moving towards zero TSF failures at the KSM Project.

3. Filtered Tailings Option

3.1. Summary of Filtered Tailings Option Considerations

An in-depth evaluation is presented of implementing filtered tailings at the KSM Project. This evaluation includes the overall filter plant design and the characteristics of the filtered tailings as well as the behavior of the filtered tailings during placement and beyond. The evaluation proceeds to consider KSM site specific temperature, rain, snow and climate change implications.

Case histories of existing tailings operations are evaluated, specifically with respect to climate impact and constructability of a filtered tailings option at the KSM project. Figure 1 taken from KCB (2016) provides a visual summary of production rate and climatic conditions (plotted as precipitation minus evaporation) for a wide range of projects in various climatic conditions. These results clearly illustrate the conclusion of KCB (2016) that: **There is no precedence for filtered tailing at the scale of the KSM Project production in wet, cold environments.**

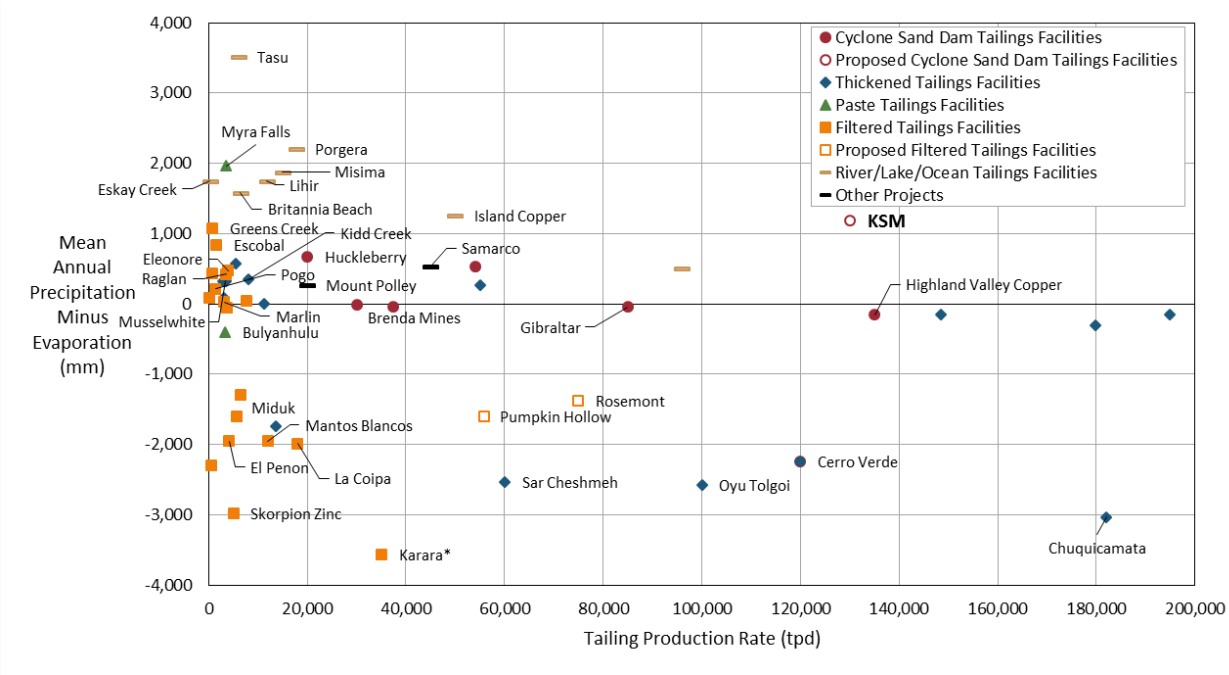

Figure 1. Case Histories of tailings production vs net precipitation versus for a range of tailings management options (from KCB, 2016)

3.2. Evaluation of Filtered Tailings Option Considerations

The evaluation of the filtered tailings option included physical testing of the tailings plus conceptual design of a filter plant and a detailed evaluation of climate and impact and constructability. I conclude that this provides a balanced approach to evaluating the site specific application of filtered tailings at the KSM project. The outcome clearly identifies the site specific operational, environmental and closure issues related to filtered tailings at the KSM project.

The evaluation shows that using filtered tailings at this project is not a feasible option. In the opinion of the author it will not result in moving to zero failures. Adding complexity in tailings management, as filtered tailings will do at the KSM site, does not promote the overall goal of moving to zero failures.

4. Features of Teigen-Treaty Cyclone Sand TMF

The tailings management option that resulted from the overall BAT assessment was the same as that selected in the EA process. The site layout and facility sections are shown in Figures 2 and 3 and described as follows by KCB (2016):

> The TMF in the Teigen-Treaty valley design includes four till-core cyclone sand dams confining three tailings cells: a central lined cell for storing carbon-in-leach (CIL) residue underwater to reduce the potential for acid generation, and north and south cells for non-acid generating tailings. For the first half of the mine life, the

north and CIL cells will be used, with the north cell rising approximately twice as fast as the CIL cell. After the north cell reaches its design height, tailings will be deposited in the south cell. Water management will consist of perimeter diversions, a tunnel diverting the East Valley catchment north to Teigen Creek, and seepage recovery dams below the tailing dams to help recover and treat seepage water. During operations, surplus water will be discharged from the TMF on a schedule designed to mimic seasonal flows.

The technology of cyclone sand dams is well-understood and has more than half a century of precedent. Such dams are simpler to raise than other types of dams, minimizing the risk of human error, and are less prone to failures caused by internal seepage erosion. While impounding water increases the consequence of hypothetical failure, the design of the TMF, including the positioning of long sand beaches in the north and south cells, decreases the likelihood of a catastrophic release of water, were such a failure to occur. Potentially acid-generating materials, such as CIL residue, will be kept below water in the lined central cell to limit seepage and oxidation. On closure, the site will return to flow patterns similar to pre-mine conditions.

The BAT and BAP related features for the Teigen-Treaty TMF are listed in Attachment 1 (taken from KCB, 2016). It is important to note that “remaining key risks that need to be effectively controlled through design, operations and post-closure” are listed. This clearly highlights the transparent approach used in the design and permitting of the KSM Project. It demonstrates an ongoing commitment to design, operating and closure components that will move towards zero tailings failures.

5. MAA and Outcome

a. MAA Summary

As part of the EC guidelines a Multiple Accounts Analysis (MAA) is conducted to evaluate the preferred tailings siting and management option. The account weightings used in the MAA are summarized in Table 2. There were 4 accounts in the 2013 MAA. For the BAT study, one account (risks and potential impacts) and several sub-accounts and indicators were added to differentiate between cyclone sand and filtered tailings.

Table 2
Account Weightings for the MAA

Accounts	Weightings
Environment	6
Risk and potential impacts	4
Socio-economic	3
Technical	3
Project economics	1.5

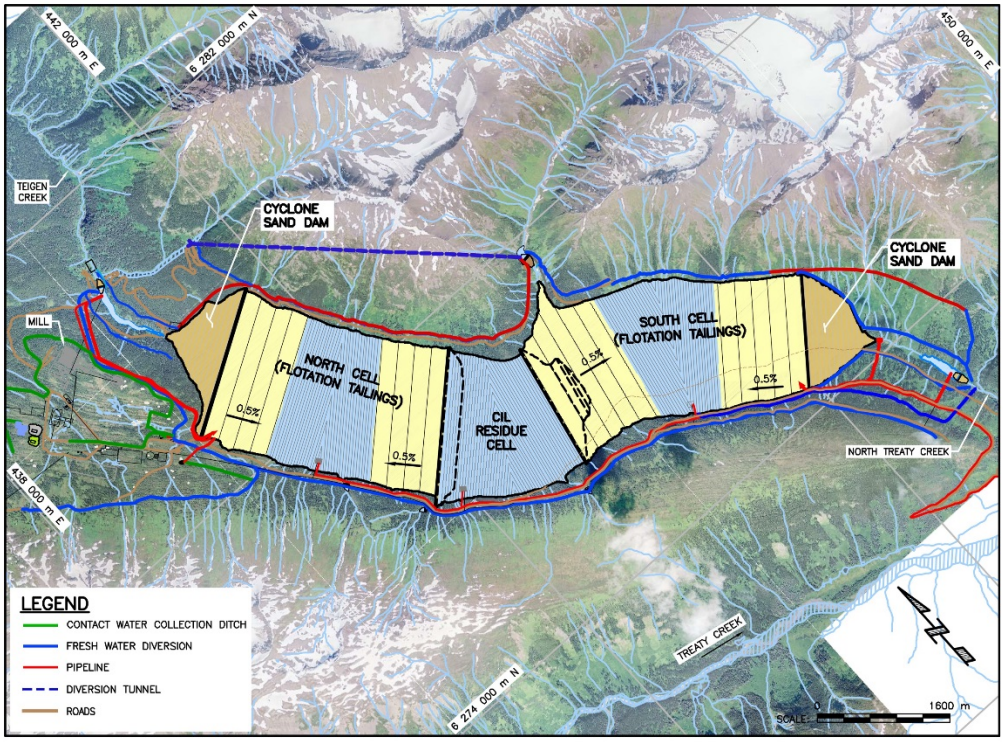

Figure 2. EA-Approved Teigen-Treaty Cyclone Sand Tailings Management Facility General Arrangement

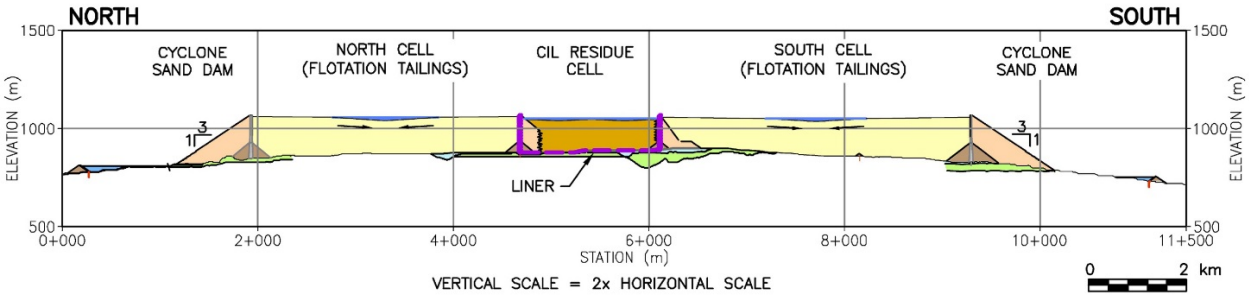

Figure 3. EA-Approved Teigen-Treaty Cyclone Sand Tailings Management Facility Design Section

Relevant observations from the MAA results are (KCB, 2016, Section 8.4: Sensitivity Analysis: pages 90-91):

- The Teigen-Treaty Cyclone Sand TMF scored the highest for all of the Accounts. It has the lowest impact on environmental considerations, is the most technically feasible to construct, operate and close in a safe manner, has the fewest associated socio-economic concerns and is the best strategy to manage overall risk throughout the life of the project.
- The Teigen-Treaty site is the preferred site; all other sites scored lower.
- The Teigen-Treaty Filtered TMF Option 2 (storage of thickened CIL residue) is preferred over the Teigen-Treaty Filtered TMF Option 1 (storage of filtered CIL residue), but still scored much lower than the Teigen-Treaty Cyclone Sand TMF.

b. Evaluation of MAA Process

The MAA followed the EC guidelines which represent a state-of-the-practice approach that is well accepted in the evaluation of tailings siting and management alternatives. I agree with the process and the outcomes from this process.

6. Conclusions

Based on this review it is concluded that:

- The BAT evaluation approach, following the EC guidelines, was well designed and implemented.
- The EA was approved shortly before the Mount Polley failure and this voluntary update of the alternatives assessment focusing on BAT demonstrates the willingness of the company to evaluate the tailings alternatives following updated requirements of the EA Office issued in 2015.
- The outcome confirms that north and south centerline cyclone tailings impoundments and a central CIL lined pond at the Teigen-Treaty site is the preferred option.
- The evaluation further shows that filtered tailings is not a feasible option at the KSM Project due to the higher production rates as well as the site climatic conditions.
- The Teigen-Treaty cyclone sand TMF represents BAT for this Project. The specific BAT and BAP features of the selected tailings siting and management option are listed in Attachment 1.
- An important consideration in identifying BAT is that it includes the commitment to move towards zero tailings failures. The combination of BAT and BAP features listed in Attachment 1 plus the identification of “remaining key risks” demonstrates the commitment of the company to move towards zero risk in their project development intentions.

Based on this review I fully support the approach and outcome of the KCB report.

7. References

Klohn Crippen Berger (KCB), Best Available Technology (BAT) Study for Tailing Management at the KSM Project, June 2016

Panel Report, Report on Mount Polley Tailings Storage Facility Breach, January 30, 2015 (https://www.mountpolleyreviewpanel.ca)

Attachment 1
BAT and BAP Outcomes (KCB, 2016)

The key BAT features of the proposed Teigen-Treaty Cyclone Sand TMF are:

- **Site Selection**
  - Located at a catchment divide, therefore able to minimize upstream catchment area for flood management.
  - Favourable geology and foundation conditions for stability and hydrogeological containment.
  - Good storage capacity to dam volume ratio therefore able to minimize footprint.
  - Area is exposed to fewer geohazards compared to the surrounding region.
  - No high value fish habitat (i.e. food fishery) within the footprint of the facility.
- **Design Features Providing Physical Stability**
  - Compacted NPAG centerline raised cyclone sand dams with low permeability cores provide a dense, gradient controlled, free draining and de-saturated containment structure.
  - Over 50 years of precedence constructing centerline raise sand dams in the mining industry. Raising of these structures is simpler than other types of dams, minimizing the risk of human error.
  - Dams are designed with 3H:1V downstream slopes which results in Factors of Safety (FOS) that exceed CDA guidelines (CDA 2013).
  - Cyclone sand dams are not as prone to piping failures as other dam types, such as zoned rockfill dams, as cyclone sand is filter compatible with the glacial till core and tailing.
  - Long tailing beaches between the ponds in the flotation tailing cells and the tailing dams decrease the likelihood of piping failures and catastrophic release of the pond if a hypothetical dam failure were to occur.
- **Design Features Providing Geochemical Stability**
  - De-sulphuring of the tailing by flotation so the majority of the tailing is NPAG.
  - PAG CIL residue is kept saturated in a lined cell to limit seepage and oxidation preventing ARD.
  - Flotation tailing contains <0.3% sulphides by weight. The majority of the flotation tailing will be stored behind a low permeability core and will remain at or close to saturation, which will limit sulphate generation.
- **Closure**
  - The TMF configuration allows two (redundant) spillways to be cut into rock, and allows drawing the closure pond down to a minimal volume. The redundancy adds to the resiliency of the TMF during a hypothetical failure of one of the spillways.
  - Lowering the spillway invert on final closure minimizes the pond volume stored on the tailing surface and increases the distance from the dam crests to the pond,

decreasing the likelihood of a hypothetical overtopping failure and the likelihood the pond will be released during a hypothetical slumping failure of the dam.

- At closure, the surface will be contoured to return the flow patterns similar to pre-mine conditions to achieve environmental objectives identified during the EA review process.
- Rock cover on dam slopes will minimize erosion.
- PAG CIL residue will be covered with flotation tailing and the phreatic surface will be maintained above the CIL residue, maintaining saturation of the CIL residue to limit oxidation and prevent ARD.
- Lower long term risk of high concentrations of sulphate generation due to hydrogeological containment of the majority of the flotation tailing. The majority of flotation tailing are stored behind a low permeability core and will remain saturated, which will limit the amount of residual sulphides in the flotation tailing exposed for potential generation of sulphate.

The key BAP features of the proposed EA approved Teigen-Treaty Cyclone Sand TMF are:

- **Corporate TSF Design Responsibility**

  Seabridge has taken a long-term planning approach to the KSM Project mine development, rather than a small initial mine plan and subsequent ad hoc design additions. In doing so, the TMF has been designed for the mine life.

  The design of the TMF, which has evolved over the EA review period, continues as the project moves towards development, and takes into account the extensive geological, seismic, hydrogeological and geomorphological site investigations and interpretations for the site.

  As part of the TMF design, design criteria were set out in terms of beach widths, rate of rise, water balance and construction material balancing. These will become part of the Quantitative Performance Objectives (QPOs) in later stages of design and ultimately incorporated into the Operations, Maintenance and Surveillance (OMS) manual.

- **Independent Tailings Review Board (ITRB)**

  Seabridge established an Independent Geotechnical Review Board (IGRB) in January 2015 to independently review and to provide expert opinion and oversight for the KSM Project's TMF and Water Storage Dam (WSD) with a focus on their structural stability and integrity throughout the design, construction, operation and closure of the project. This was following Seabridge's commitment in mid-August 2014 in light of the Mount Polley incident and their belief that such commitment was required to ensure the continued acceptance of KSM Project's design by the project's stakeholders.

  The IGRB has presented a series of recommendations for Seabridge to consider during the ongoing development of the KSM Project, which are being addressed through the design.

  Seabridge and/or the KSM operating partner will continue to interact with the IGRB during design, construction, operations and post-closure. During design, Seabridge will host at least one IGRB meeting per annum and make the reports publically available.

- **Professional Practice and Canadian Dam Association (CDA) Guidelines**

  Extensive geological, seismic, hydrogeological and geomorphological site investigations and studies have been conducted to understand the dam foundation conditions.

  Seismic and stability assessments based on the results of foundation site investigations, the consequences of failure, and the loading conditions resulted in exceeding the minimum required factors of safety outlined by the CDA guidelines.

- **Closure should move to low risk landforms and should be consistent with First Nations values (BC First Nations Energy and Mining Council 2015)**

  The TMF closure plan was developed based on engagement with the Working Group, which includes Aboriginal groups, municipal officials, and regulatory authorities, during the EA review. The robust and resilient closure design is aimed at creating a low risk landform that will return the area back to similar hydrologic conditions.

Even with the BAT and BAP features of the TMF design, there are remaining key risks that need to be effectively controlled through design, operations and post-closure. These are already being considered through the design process and will become part of operating controls.

- **Physical Stability**
  - Ponded water in the flotation cells will need to be kept at a minimum to meet operational and environmental objectives. Close attention to the water balance of the facility is fundamental to minimizing facility risks.
  - Impounded water increases the consequence of a hypothetical failure, particularly the CIL Residue Cell during Stage 1 (Year 0 to Year 25) when water is impounded adjacent to the cyclone sand dam.
  - Cyclone sand is erodible; management of erosion of the cyclone sand dam slopes will require erosion mitigation and control.
- **Geochemical Stability**
  - Maintaining saturation and limiting oxidation of the PAG CIL residue will require effective water management.
- **Closure**
  - Long-term erosion mitigation and control of the dam slopes will require an erosion resistant closure cover.
  - A water management trade-off between maintaining a small closure pond to achieve environmental objectives (e.g. geochemical stability of the CIL residue), and decreasing the closure pond volume to further minimize risk.