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Review DIAVIK Version 4 Closure and Reclamation Plan

FINAL REPORT TO
ENVIRONMENTAL MONITORING AND ADVISORY BOARD
AUGUST 2017

By Randy Knapp

SIMPLE LANGUAGE SUMMARY

Diavik has submitted Version 4 of the Interim Closure and Reclamation Plan for the Diavik Diamond Mine. The closure plan is similar to previous versions and has been updated to reflect more recent information and revisions to the closure concepts. Details of meetings held with the communities and TK Panel are also included.

The Interim Closure and Reclamation Plan includes some new information. This includes:

- A preliminary plan for revegetation of the site. The vegetation plan as discussed with the TK Panel will focus on target areas disturbed by infrastructure (for example roads). The plan is to smooth these areas to eliminate animal barriers and hazards, roughen the soil and vegetate as appropriate. Caribou trails are to be left with smooth surfaces for safe migration across the site.
- The PK closure plan has been updated but the plan contains many uncertainties. These include: the quality of the pond water and seepage; the stability of the cover and pond shoreline; and whether the plan can be implemented as proposed.
- The plan includes an estimate for the long term monitoring, care and maintenance of the site after closure. The current plan calls for Diavik to leave the site in 2032 however there will remain a long term need for care and maintenance of the site. Diavik's preliminary estimate is that the costs could exceed half a million dollars per year. Who pays these costs remains to be clarified?
- The North Inlet sediment is contaminated with hydrocarbons which appear to originate from the underground mine. The sediment is currently toxic and as a result the plan is to retain the dam that isolates the North Inlet and include a porous section in the dam that allows water to flow through the structure but blocks fish access.
- Diavik also indicated they are investigating options for management of the processed kimberlite. Options include disposal in the open pits or underground mines and possible removal of the fine processed kimberlite from the existing containment. The results of this review will be used to update the final design for closure of the Processed Kimberlite Containment.
- Information was also provided on the fate of potentially acidic waste rock (Type III) that was misclassified and placed in several areas outside the approved locations. The result suggests that the majority of the material is unlikely to be of issue but one area with about 6000 m^3 was identified and will be the subject of additional study. Given the small quantity it makes more sense to simply pick up this material and dispose of it in the North Waste Rock Pile.

Contents

1.0 INTRODUCTION

1.1 Overview

Diavik submitted Version 4.0 of its Closure and Reclamation Plan (CRP) on April 20, 2017. The Wek'èezhìi Land and Water Board (WLWB) completed their conformity check with the Water Licence and distributed the CRP for review on May 19, 2017. This revised Interim CRP contains material changes to a number of sections.

1.2 Scope of Work

Randy Knapp was requested to undertake a technical review of the Diavik Version 4 CRP. The review of the CRP Version 4.0 and Appendices I – XIII will consider Diavik's Type A Water Licence, outstanding requirements from the WLWB, and any EA requirements. Mr. Knapp will use knowledge of current best practices for mine closure and reclamation, including use of Traditional Knowledge and community participation, and comment on the following:

Item 1- Significant changes from ICRP Version 3.2 to CRP Version 4.0

Item 2- Practicality and achievability of the closure plan for the five different mine components with attention to:

- Appendix X-5 PKC Closure Design Concept
- Appendix X-6 North Inlet Closure Options

Item 3- Adequacy and achievability of closure objectives and criteria

Item 4 Flaws, risks, uncertainties

Item 5- Long-term issues that could arise

Item 6- Areas that require further research

Item 7- Appropriateness of expected closure and reclamation costs

Section 2 addresses items 1 to 7. Section 3 of the report includes miscellaneous comments. Appendix 1 includes details of the current issues and concerns associated with the Processed Kimberlite Containment Facility (PKC).

2.0 TECHNICAL REVIEW VERSION 4- DIAVIK ICRP

The following section reviews key aspects of the Diavik Closure plan. The report addresses the specific items as outlined in the scope of work.

2.1 ITEM 1- SIGNIFICANT CHANGES FROM ICRP VERSION 3.2 ICRP VERSION 4.0

The following are some of the key changes that are included in the Version 4 ICRP.

- A general approach to re-vegetation at the mine site has been presented. The plan includes an identification of the target areas and a listing of the potential vegetation methods. The plan also includes for the first time a budget vegetation allowance in the RECLAIM model.
- A preliminary budget for post closure care and maintenance of the site. This has been requested by EMAB and is believed to be the first time a mining proponent has provided an estimate of the potential costs for long term care and maintenance of a mine site post closure. Who will pay for these costs remains a material issue. Diavik has not assumed responsibility for long term care.
- Revised closure plan for the North Inlet (NI). The original plan was to breach the main dam to allow fish access. Given the current issue with hydrocarbon contaminated sediments, this option no longer appears to be acceptable and as such a permeable barrier which blocks fish access and allows water to flow in and out of the NI is proposed.
- Potential changes to the closure of the Processed Kimberlite Containment Facility (PKC). The PKC closure plan remains a concern (see Item 2a).
- Updated predictions of post closure water quality.
- Presentation of preliminary results of metals uptake in vegetation. Initial results suggest this is not a material issue however some additional R&D programs are underway.
- Updates to Section 3 -Project Environment to bring the tables and figures up to date (e.g. climate data).
- Provided some 3-dimensional figures of how the mine site will look at closure.

The ICRP continues to develop and is improved over previous versions. Uncertainty remains and these aspects are being addressed in the Reclamation Research Plans.

2.2 ITEM 2- PRACTICALITY AND ACHIEVABILITY OF THE CLOSURE PLAN

2.2.1 The Processed Kimberlite Containment Facility

The PKC closure will involve the placement of 2m of waste rock over the surface of the exposed PK. The PKC will retain a central pond and drainage ditch to a spillway located in the dam. The pond will overflow to Lac de Gras. There remains uncertainty in the long term

success and performance of the plan (see Appendix 1-PKC Closure). The uncertainties include:

- Water quality in the pond post closure. Preliminary modelling was completed but the results remain uncertain.
- Long term stability of the cover. Issues include:
    - Potential for piping of fine PK through the cover.
    - Differential settlement of the cover.
    - Stability of the cover under earthquake loading
    - Future thawing and settling of the cover due to climate change
    - Long term care and maintenance of surface ditches and spillway
    - Long term repair and maintenance of the rock cover.
    - Uncertainty in water balance

Appendix 1 includes more detail on the issues related to the closure of the PKC. It is noteworthy that Diavik is considering modifications to the PKC closure concept. These modifications include but are not limited to placing FPK/CPK in a completed open-pit/underground mine and/or not leaving a pond at closure.

2.2.2 North Inlet

The North Inlet served as the central collection point for site drainage and the sludge disposal from the NI treatment facility. The original closure plan was to breach the Main dyke and allow fish passage into the inlet. Monitoring and toxicity testing has indicated that the bottom sediments are contaminated with hydrocarbons. The primary source appears to be from spillages in the underground mines. The monitoring data suggest the sludge is toxic to some benthic species and as such is currently not suitable fish habitat.

A detailed alternatives analysis was completed to assess the options for cleanup of the bottom sediments. Options ranged from removal to cover to do nothing. Given the high cost of alternatives, Diavik recommended that sediments remain in place in the NI and that the closure plan be revised. The revision would be to keep the NI isolated from fish passage but to provide a pervious section in the NI dam that allows water to pass into and out of the NI. The potential to breach the dam remains an option should sediment quality improve. The final decision would be made after completion of a post closure sediment survey.

The issues at present include:

- No information was provided on the stability of the sediment and the potential or time period for natural degradation of the hydrocarbon. (is there a potential that the sediment quality will improve over time?).

2.2.3 North Waste Rock Pile (NWRP)

A review of the NWRP was previously completed. For detailed comments refer to R. Knapp Technical Memorandum of June 6, 2017.

Development of the South Country Rock Pile (SCRP) WRSA will commence with the pre-stripping of the A21 pit late in 2017. Closure plans for the SCRP-WRSA are not available for ICRP V4.

One of the outstanding issues remains the future handling of the Type III rock from the A-Portal. Diavik recently provided a report on 3 July 2017 "Portal Waste Rock Misclassification" which provides their proposed action plan to deal with the rock. In general seepage monitoring will be used to identify if any areas produce contaminated drainage. The report identified about 6,100 m^3 of potential Type III waste rock that was deposited East of the Waste Transfer. This was the only area visually identified as potentially having material quantities of Type III waste rock. Diavik propose to drill and sample this area to assess the ARD potential. Our recommendation would be to excavate and dispose of this material as the cost is unlikely to be greater than drilling and sampling.

2.3.4 Open Pits and Underground Mines

Open Pits

The open pits are proposed to be flooded with Lac de Gras water and monitored. When water quality is acceptable, small breaches of the dykes will be made to allow for navigation and fish passage. The pits will include fisheries habitat enhancement per agreements with Fisheries and Oceans Canada.

The closure concepts for the pits are reasonable and likely to perform as expected. The one issue that remains is the stability of the stratified pit (meromixis). The bottom layer of the pit will be salty and more contaminated and as such could impact surface water quality if the pit lake was to mix. Modelling suggests that the meromixis will be stable however this remains to be demonstrated at closure.

The TK panel raised concerns regarding wildlife access and egress from pit A418. Diavik have included an additional ramp in pit A418 shoreline to facilitate wildlife movement.

The open pits are also under study as a potential receptor for PK. The primary advantage would be to allow early closure and monitoring of the surface PK pile.

Overall, the proposed closure plans for the open pits is rational and supported by the information provided.

Underground Mines

The underground mines will be decontaminated and salvageable equipment removed then flooded. Surface openings will be sealed to prevent access. The flooded mines are not expected to be a long term source of contamination. As with the open pits, Diavik is considering the potential for the disposal of PK in the underground mines. This is likely to be far more costly and difficult as compared with surface disposal in the existing facility or in open pits however is worthy of investigation.

The proposed closure concept is rational and supported by the available information.

2.3.5 Surface Infrastructure

The removal of all equipment, buildings, pipelines, power lines and other items for resale/reuse where practical;

• removal of all hazardous materials- The plan is to haul materials off-site for disposal. Hydrocarbon contaminated soils will be managed on-site although a final management plan for hydrocarbon treated soils has not been finalized. The current proposal is disposal within the permafrost zone of the landfill or PKC.

• salvageable materials recycled where practical.

• materials that are not reused or recycled safely disposed of on-site. The mine currently has an approved landfill in the NWRP. Diavik is also considering the option of disposal of inert waste (e.g. building rubble) in the open pits. A final landfill strategy is not in place.

• materials that cannot be safely disposed of on site would be hauled to approved off-site facilities.

• foundations and concrete slabs covered with rock. There are no plans to vegetate these areas.

• fuel tanks removed;

• roads, laydowns, plant sites, airstrip scarified and targeted re-vegetation.

Diavik has had extensive discussions with the TK panel and communities on the final vegetation strategy. Key actions arising from these discussions include:

- Use of amendments to enhance vegetation is accepted as a potential necessary requirement for the disturbed areas.
- Vegetation efforts for the NWRP should focus on the collection ponds.
- Re-sloping of the road berms over natural ground to facilitate wildlife movement and safety.
- Retaining areas where surfaces are smooth and not scarified to facilitate wildlife movement.

Overall the proposed plans for closure of the mine infrastructure are rational. The current plan to scarify the airport runway at closure should be reviewed. The runway is an asset to the area and the TK panel has suggested it should be retained.

The primary issue is the extent of the proposed vegetation as compared with the total disturbed area. Based upon Table 9-3, as of 2018 a total of 1157 ha of area will be disturbed by the mine. Total vegetated area as indicated in the RECLAIM estimate is 131 ha or 11% of the disturbed area.

2.3 ITEM 3-ADEQUACY AND ACHIEVABILITY OF CLOSURE OBJECTIVES AND CRITERIA

The closure objectives and criteria are the focus of other reviewers. A detailed report by Slater "Closure Criteria Recommendations Diavik Mine" March 21, 2017 provides an excellent review.

The proposed change to eliminate closure objective N-1-Reconnection of the North Inlet with Lac de Gras is not accepted. Although the current belief is this may not be possible due to the presence of hydrocarbon in the sediment, this remains the overall objective.

2.4 ITEM 4-FLAWS, RISKS, UNCERTAINTIES

No fatal flaws have been identified. The greatest risks and uncertainty are associated with the closure of the Processed Kimberlite Containment facility. Concerns include:

- Uncertainty in pond and seepage water quality. The primary source of metals in porewater is believed to be associated with the oxidation of sulphides in the unsaturated PK. The unsaturated zone may well be much deeper than modelled increasing metal loadings in seepage and to the pond.
- AMEC Appendix X-5 identified a number of uncertainties including:
    - *Post-closure thermal conditions, particularly as they relate to long-term seepage control. This uncertainty impacts on the post-closure hydrology of the facility, the ability to retain a pond and the location of any releases of pond water to Lac de Gras.* Based upon this statement, there is no guarantee that the pond can be maintained. If not, the fine PK will be exposed.
    - *Closure thermal conditions of beaches and semi-fluid FPK material. This uncertainty relates to the ability to place materials for beach erosion protection and shoreline stability protection over areas with high semi-fluid FPK content*.
- Stability of the cover placed on unconsolidated PK during seismic events. Implications for long term maintenance and the potential for loss of PK to the environment.

There is a Reclamation and Research plan in place to address some of these issues but the work has been delayed to 2020. This work would appear to be critical to confirm the concept and needs to proceed.

2.5 ITEM 5-LONG-TERM ISSUES THAT COULD ARISE

The current schedule for closure assumes that the mine will close in 2025 and final closure works implemented post 2025 with all work and monitoring completed by 2032. Financial assurance is allotted for completion of the work and monitoring to 2032. Diavik has assumed that their responsibility for the site ends in 2032. Beyond 2032 there are a myriad

of issues that could arise and a number of care, maintenance and monitoring requirements. These will include:

- Geotechnical Inspection of Dams (e.g. PKC) per Canadian Dam Safety Guidelines.
- Care and maintenance of PKC ditches and spillway.
- Care and maintenance of the rock covers on the NWRP and PKC
- Environmental Monitoring
- Repair/replacement of instrumentation (e.g. thermistors, inclinometers)

There is also the potential that predictions for seepage quality and pond water quality in the PKC and possibly seepage quality from the waste piles is not protective of the aquatic ecosystem. Should this occur, treatment could be required and this could occur well into the future especially as the climate warms.

Accessibility to the site may also become problematic. Currently there are ice roads that service multiple mines. As mines close, and if others do not open, the costs for mine access will increase and thus greatly increase the costs for long term care and maintenance. Furthermore, as the climate warms, the availability for ice roads will decrease, making ice road access in future more difficult and possibly not practical.

2.6 ITEM 6-AREAS THAT REQUIRE FURTHER RESEARCH

Diavik has a well-developed Research and Reclamation program that has been in place since the mine was developed. The plan has effectively addressed a number of issues and is ongoing. The greatest uncertainty is related to the PKC. A research plan is in place but much of the work associated with effects of climate change and predictions of future water quality (pond and seepage) has been deferred.

Additional work should also be completed related to:

1) The potential effects of a probable magnitude earthquake on the stability of the PKC.
2) Improved modelling of the water balance with explicit emphasis on the impacts of extended drought. The question to answer here is what are the effects of extended drought on pond water levels and exposure of fine PK.

2.7 ITEM 7- APPROPRIATENESS OF EXPECTED CLOSURE AND RECLAMATION COSTS

Diavik has applied the RECLAIM model to develop costs for closure and reclamation of the site. The RECLAIM summary is provided in Appendix VII of the ICRP. The text to support the summary tables is not provided although there is a footnote on the Summary of Costs Table that the complete report can be found at (blank). It would be worthwhile for Diavik to update and file the text so that reviewers better understand the current basis for the estimate.

Overall, the cost estimate is well done and there are no material issues. The costs are reasonable and well documented. The primary issue is that there is no financial assurance for long term monitoring, care and maintenance.

Diavik provided a preliminary estimate of what potential cost for long term care of the mine could be in Attachment #3 to the North Waste Rock Pile Final Closure plan. Although the costs are not detailed, they provide a good first cut at the potential order of magnitude costs that will be required to assure pong term care and maintenance of the site. The estimated annual costs for maintenance of the site is about $570,000. This is a material cost and needs to be financed. As noted previously, these costs could increase significantly if ice road access was not available.

3.0 MISCELLANEOUS OBSERVATIONS AND COMMENTS

The following are miscellaneous comments on the Version 4 ICRP.

Page 103 – Open Pit Closure- *No reviewer has identified a benefit to mitigating meromixis. For these reasons, DDMI continues to prefer a closure design that enhances a meromixis condition instead of one that weakens the meromixis condition.* Can Diavik outline measures other than minimizing the size of the dyke breach, that they propose to enhance meromixis?

Page 106- Open Pit Closure- *Over time the deep water in the pit will equilibrate with the natural groundwater chemistry. This meromictic condition will provide better aquatic habitat conditions than if the entire water column regularly mixed as this would introduce more groundwater constituents into the surface waters.*

The statement that meromixis provides better aquatic habitat is misleading. Much of the pit lake below the surface zone will become anoxic and unsuitable habitat.

Page 109-Open Pit Closure- *Specific engineering design items to be addressed include: …*

• *evaluation of pit wall stability after flooding with specific emphasis on risk of a wall failure causing mixing of deep water with surface water.*

Has this work been initiated and is there a scope of work?

Page 110- Pit Closure-Contingency Planning- *Possible contingency actions have been developed based on our current understanding of uncertainties and risks (see Section 5.2.4.6):*

• *aerial application of lime, alum or a synthetic polymer to assist in clarifying mine area pool water to achieve acceptable water quality before dike breaching;*

Can Diavik provide examples of where aerial application of chemicals has been applied to open pits?

• *possibility of not breaching dikes if breaches would put Lac de Gras at significant risk.*

Can Diavik explain what is meant by significant risk? Does the water quality not have to meet closure criteria before the dykes are breached?

Page 119- PKC Closure- *Removal of the semi-fluid FPK material is a contingency measure.*

Can Diavik explain how the FPK material would be removed and where the material would be disposed?

Page 120-PKC Closure- *Minimizing the post-closure pond size will enable the greatest extent of permafrost development within the PKC Facility, enhancing seepage control.*

Although a reduced pond level will reduce seepage, will pond water quality be impacted? The source of metals leaching appears to be oxidation of sulphides in the unsaturated zone. One would expect that lowering of the pond would reduce the water table and expose more PK to oxidation. Golder's preliminary modelling suggests that the unfrozen zone could extend up to 5 m with climate change. Does Diavik plan to investigate the option of retaining a larger pond and assess how pond levels may impact upon the amount of PK that would be unsaturated and how this may impact discharge water quality?

Page 120-PKC Closure- *The advantages of this revised closure concept design are: …*

• *Allows for progressive reclamation opportunities with cover placement starting during operations. Progressive reclamation allows construction procedures to be confirmed during operations when all available resources are on site*.

Based upon the conceptual plan, it would appear that the final surface will be shaped by placing PK from the perimeter in preparation for rock cover. What waste rock cover placement is proposed during operations and how much rock cover would be progressively applied?

Figure 5-14 shows the closure concept. The concept shows run of mine rock will be applied to the surface of the exposed PK to a point below the water. Golder (Figure 3 in Appendix X-5 in their Technical Memorandum to AMEC on 21 November 2013) show a small area of geogrid would also be used to support rock fill in portions of the cover below water. At this point in time there does not appear to be any attempt to provide a filter zone to prevent migration of slimes at other locations. At several other sites where rock cover has been applied over fine tailings, piping of tailings to surface has occurred as pore pressures are dissipated. How will Diavik avoid piping of the fine PK to surface?

Page 164- Integrated Schedule-*Decommissioning North Inlet Dams – When NI water and sediment quality have been confirmed, the east and west dams will be decommissioned.*

The decommissioning of the NI dams is confusing. A dam can only be decommissioned if it is no longer required which suggests the dams will be breached (Diavik has clarified that

the dam will include a pervious zone constructed to below the frost depth to assure that the zone will not freeze and impound water). Objective N-1 which is to reconnect for the North Inlet with Lac de Gras was dropped. It is recommended that Diavik reinstate Closure Objective N-1 as this is the preferred option.

Appendix VI-1 Post Closure Monitoring and Reporting - Open Pit, Underground and Dike Areas

Twice per year deep water quality samples will be collected from approximately 25 m above the pit bottom, if feasible.

Why would it not be feasible to sample 25 m above the pit bottom?

Appendix VI-3 Post Closure Monitoring and Reporting – Processed Kimberlite Containment Area

Observation wells, collection wells, thermistors and slope inclinometers have been installed in the PKC area to monitor operational performance. Much of this instrumentation is expected to remain post-closure, however the final determination of post-closure instrumentation will not be made until the final closure plan is prepared.

Are there any provisions for maintenance/replacement of instruments given most of these have a limited life span?

Appendix VI-3 Post Closure Monitoring and Reporting – Processed Kimberlite Containment Area- Section 1.2

if the estimated flow volume from 1645-42, 69 or 44 is greater than 10 L/s following breaching of the collection ponds then a sample will also be collected quarterly and assessed for acute lethality to rainbow trout

What is the basis for the 10 L/s cutoff for monitoring acute lethality. It is probable that lower flows would have less dilution and as such more likely to be lethal.

Appendix VI-4 Post Closure Monitoring and Reporting - North Inlet Area. Section 1.3 Sediment Quality

A sediment quality investigation will be conducted at the end of commercial operations to evaluate the sediment conditions in the NI. The investigation will follow the scope and procedures used in 2015.

Would it not be prudent to also complete a sediment survey in 2031 and if the sediment quality is acceptable then the preferred option of reconnection could potentially be implemented at that time?

Appendix VI-5 Post Closure Monitoring and Reporting – Mine Infrastructure Areas Section 3.5 Re-Vegetation

Additional re-vegetation monitoring items may include shoreline vegetation surveys around collection pond areas, PKC outlet, A154, A418, A21 and the North Inlet as well as documentation of areas of natural recovery, plant ingress/egress or identified invasive species.

Why does it say monitoring may include? Is it or is it not proposed?

Re-vegetated areas will be inspected annually for two years following initial planting.

Inspection for 2 years seems to be minimal as vegetation growth is slow and may take many years to be successful. Also, vegetation is proposed for 2031 but all monitoring stops in 2032. This is only one year. Please explain.

Appendix VII- Reclaim Estimate

The Reclaim estimate still shows that allowances have been made for till application to the caribou ramps yet there is no mention of till application in the NCRP closure plan. It is Diavik's position that till addition will not be required but continues to carry this allowance in the Reclaim estimate.

Appendix VIII Research task 4.4.1, 4.4.2 and 4.4.3

These tasks are critical to confirm the viability of the conceptual design and have been deferred. Why is this work being delayed to a later date? It is understood that Diavik are investigating alternatives for PK disposal but the uncertainties associated with the current design need to be addressed such that the design can proceed if the alternatives are not implemented.

DDMI Seepage Survey Annual Report

The 2016 annual seepage survey discussed the issue of ice damming in the downstream shell of the PKC shell and the resultant storage of large quantities of seepage. Diavik has installed seepage collection wells to intercept the seepage and reduce water levels in the upstream shell to control seepage and prevent further ice damming. It is unclear whether the seepage ice dams present an issue for closure. Diavik should provide a discussion of the significance of ice damming and implications for closure of the PKC.

APPENDIX 1- REVIEW OF THE PKC CLOSURE DESIGN

A.1 Overview

The proposed closure design for the Processed Kimberlite Containment is provided in Appendix X-5 of the Version 4 ICRP. The concept for the design was revised and included in 2011 ICRP. AMEC in their report (Diavik Diamond Mine PKC Facility Revised Closure Concept-28 November 2013) provided additional review and details on the design and made suggestions for minor revisions. AMEC concluded the original concept of creating a domed cap over the PKC was not constructible and concluded the revised plan was constructible and should meet closure objectives. The revised design, approved by the Water Board, includes a concave surface sloping down to a central pond which has a drainage ditch with an overflow spillway to Lac de Gras. The surface is to be covered with 2 m of waste rock. The waste rock will extend into the pond.

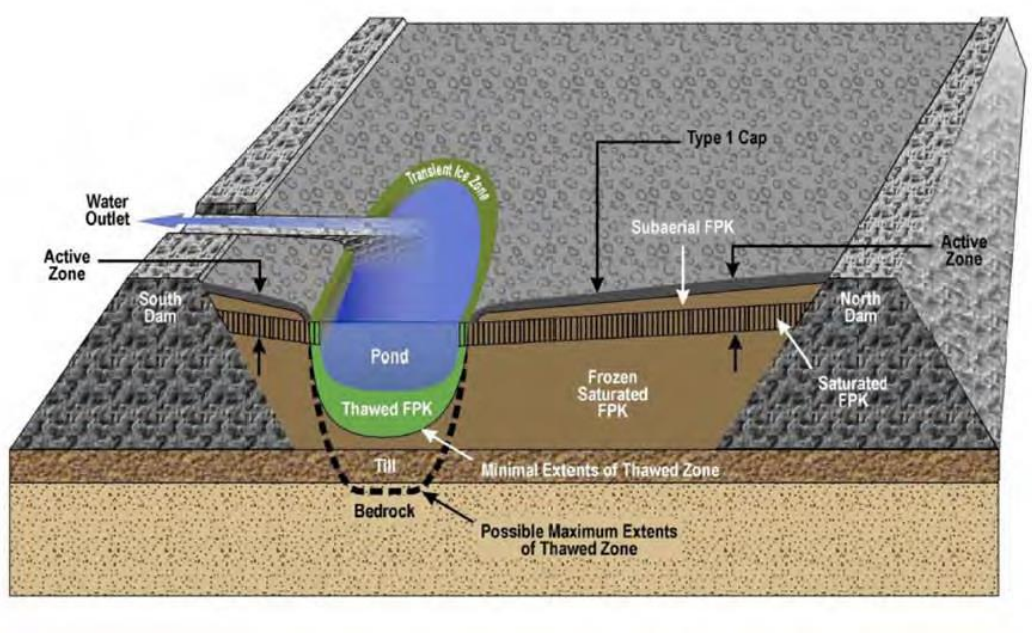

Figure from Diavik 2011 ICRP.

The AMEC review includes information on the water balance for the pond, predictions of future water quality and preliminary thermal modelling by Golder (November 13, 2013).

What is clear from the work is the concept may be valid, however there is a high degree of uncertainty. The uncertainties are raised by AMEC and acknowledged by Diavik.

The primary uncertainties identified by AMEC were:

• Post-closure thermal conditions, particularly as they relate to long-term seepage control.

• Post-closure pond water quality.

• Post-closure shoreline stability along the residual water pond.

• Closure thermal conditions of beaches and the transition to semi-fluid FPK material.

• Community preferences and concerns around closure landscape.

The following are comments and concerns regarding the concept.

A-2 Technical Issues and Concerns with the PKC Closure Concept

A.2.1 SEEPAGE QUANTITY AND QUALITY

Seepage Quantity

There is a substantial degree of uncertainty with regard to the quantity of seepage that will occur in the long term. When conducting the geochemical predictions of pond and seepage water quality, 2 scenarios were considered: one where 100 % of the net precipitation occurs as seepage, and a second where 50% of the net precipitation occurs as seepage. However, when the water balance modelling was completed to assess the impact of wet and dry periods, zero seepage was assumed.

The quantity of seepage is critical because it will determine how much water is stored in the pond and whether or not a pond can be maintained. AMEC indicated in 2013 that the current seepage rates are in the order of about 40 L/s. This level of seepage would not allow a permanent pond to form and would expose the fine PK. Seepage levels are anticipated to decline as freezing progresses. If seepage occurs in future, it is likely there will be conditions (drought) when the pond levels will drop with the potential to expose the fine PK. This exposure represents a potential hazard.

Seepage Quality

Seepage quality predictions are based upon the assumption that metals are formed from the oxidation of sulphide minerals in the PK and the amount of oxidation is based upon the depth of unsaturated/unfrozen PK. AMEC assumed that the active layer for oxidation was .25 to 1 m deep. Golder (Appendix B -Thermal and seepage Analysis) states on age 12 “With the rockfill cover in place, the active layer depth after 100 years in the FPK beach area is estimated to be 2 to 2.2 m for the scenario without the climate change effect; and 3 to 5 m for the scenario with the climate change effect. This suggests that the potential unfrozen zone would be 1-3 m deep as compared with the AMEC assumption of .25 to 1 m. This would greatly increase the amount of PK exposed to oxidation.

Other assumptions include porosity which was set at 0.3 (note this is not typical). One would expect a porosity of closer to .5 for consolidated coarse tailings. Golder in Table 3 of Appendix B show porosity of .44 for coarse PK and 0.6 to 0.75 for fine PK.

This is a simplistic model with highly uncertain inputs some of which are likely invalid and as such the predictions are highly suspect.

A.2.2 DYNAMIC STABILITY

It is unclear what work has been completed to assess the static and dynamic stability of the PK tailings. Failure analysis does not appear to have been completed and will be essential for assessing the viability of the concept. Potential issues and concerns include:

- Liquefaction of the tailings and the fate of pond and FPK during extreme seismic events
- Failure mechanisms for the cover including piping, thawing differential settlement, etc.)
- Dewatering of the pond and exposure of the FPK

A.2.3 PK RECLAMATION RESEARCH SCHEDULE

The additional work for tasks PK research Tasks 4.4 have been delayed to 2020. This is a material concern as this must address key uncertainties in the conceptual design. The final closure plan and engineering for the closure concept is to be completed in 2020 yet the work required to address the uncertainties in the design will not have been completed.