

REVIEW COMMENT TABLE

Diavik - WL Amendment - PK to Mine Workings - DDMI Response to WLWB Information Request (W2015L2-0001) (WLWB)

File(s): [W2015L2-0001](#)
Proponent: Diavik Diamond Mines (2012) Inc.
Reviewer Comments Due By: Dec 18, 2018
Proponent Responses Due By: Jan 8, 2019
Documents: [Diavik - WL Amendment - PK to Mine Workings - DDMI Response to WLWB Information Request](#) 16MB
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Item Description

On June 4, 2018, Diavik Diamond Mines (2012) Inc. (DDMI) submitted an application to amend the Diavik Water Licence (W2015L2-0001) to allow for the deposition of Processed Kimberlite (PK) material into mine workings. DDMI's application also includes a proposed change to the term of the Licence from October 18, 2023 to October 18, 2025, as well as several proposed administrative amendments to the Licence.

The Application was distributed for [public review](#) on June 15, 2018. Under the Preliminary Screening Requirement Regulations of the *Mackenzie Valley Resource Management Act* (MVRMA), the Board must conduct a preliminary screening for an amendment request. As part of the public review, reviewers were encouraged to provide comments and recommendations to assist the Board with making its preliminary screening determination. Reviewers were asked to provide comments by August 2, 2018.

Proponent responses were received by the deadline of August 23, 2018. On August 31, 2018, the Board determined that insufficient information was available on the record to inform a preliminary screening determination and issued an [Information Request \(IR\) to DDMI](#). On September 14, 2018, DDMI provided a [timeline response](#) to the IR, indicating that it anticipated providing a full response no later than November 9, 2018.

DDMI provided its Response to the WLWB's IR on November 6, 2018.


Reviewers are invited to submit comments and recommendations on DDMI's IR Response using the Online Review System (ORS) by the review comment deadline specified below. If reviewers seek clarification on the submission, they are encouraged to correspond directly with the proponent prior to submitting comments and recommendations. Once again, reviewers are encouraged to provide comments and recommendations (e.g., on impacts and mitigation measures) to assist with the completion of the Preliminary Screening.

All documents that have been uploaded to this review are also available on our public registry. If you have any questions or comments about the ORS or this review, please contact Board staff identified below.

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Comment Summary

Diavik Diamond Mines (2012) Inc. (Proponent)				
ID	Topic	Reviewer Comment/Recommendation	Proponent Response	Board Staff Response
1	General File	Comment Cover Letter - DDMI Response to Reviewer Comments and Recommendations re: Water Licence W2015L2-0001 Amendment Request for the Deposition of Processed Kimberlite to Mine Workings Recommendation		
2	General File	Comment Attachment 1 Recommendation		
3	General File	Comment Attachment 2 Recommendation		
4	General File	Comment Attachment 3 Recommendation		
5	General File	Comment Attachment 4 Recommendation		
6	General File	Comment Attachment 5 Recommendation		
7	General File	Comment Attachment 6 Recommendation		
8	General File	Comment Attachment 7 Recommendation		
9	General File	Comment Attachment 8 Recommendation		
10	General File	Comment Attachment 9 Recommendation		
12	General File	Comment Attachment 10 Recommendation		
13	General File	Comment (Submitted after Due Date) DDMI Response to WLWB Post-Technical Session IRs Recommendation		
Environment and Climate Change Canada: Russell Wykes				

ID	Topic	Reviewer Comment/Recommendation	Proponent Response	Board Staff Response
6	General File	<p>Comment  Cover Letter</p> <p>Recommendation</p>		
1	Tables 1 through 3	<p>Comment The tables provided in the technical memorandum do not indicate whether the metal concentrations reported are dissolved or total concentrations. If the metal concentrations are based on dissolved concentrations, the presented results are not directly comparable to CCME guidelines or site-specific benchmarks, which are based on total concentrations.</p> <p>Recommendation ECCC recommends that the Proponent provide clarification on whether the modelling inputs and outputs are presented in total or dissolved metal concentrations.</p>	<p>Jan 8: There are two primary water quality inputs: 1) AEMP water quality for Lac de Gras and 2) Pore water quality from the PKC research program. The AEMP metals water quality data are as total. The PKC pore water was analyzed after filtering with a 0.45um. The model output is therefore a mix between dissolved and total however the >0.45um contribution from pore water is not expected to contribute materially to water quality at surface where it is compared with AEMP benchmarks but ECCC's comment is noted.</p>	
2	Section 2.2 - Model Inputs	<p>Comment To account for the influence of processed kimberlite (PK) settling and the releasing of pore water on surface water quality, a conceptual consolidation model was developed to predict the pore water volume released to the pit lake as a result of PK consolidation. The only information provided on the PK consolidation is that it is conceptual and based on estimates of the PK material properties. No information is provided on what inputs and properties were used in the consolidation model or whether any lab scale consolidation experiments have been undertaken to describe PK and slime consolidation and pore water release. In addition, although the Proponent indicates that the modelling did not differentiate between PK with and without slimes, as all PK includes slimes, it may be expected that the slimes would consolidate differently than the PK. The overall consolidation of material will have implications for the volumes and quality of the pore water that is released. Therefore, the process of consolidation needs to be fully described to understand the potential impacts to overall water quality.</p> <p>Recommendation ECCC recommends that the Proponent provide additional discussion on any current investigations/studies into consolidation of PK and PK slimes, including how PK slimes may consolidate differently than PK, and how this may impact overall water quality.</p>	<p>Jan 8: The consolidation and pore water release estimates are preliminary and are not based on Diavik specific material testing. The basis for the estimates are further described in Attachment #1. DDMI has initiated research on PK consolidation and pore water release with the University of Alberta and attach for information the research proposal (Attachment #2). Two PK materials have been selected for testing: 1) PK slimes collected from the PKC and 2) A 50:50 blend of PK from A154N and A21 which is intended to be representative of PK material that is currently being considered for deposition in the mine workings. A sensitivity analysis is being conducted that includes the sensitivity of PK consolidation rates to model predictions (see EMAB-14 Sensitivity Run #6). The results of this analysis will be provided for the Technical Session January 16-17, 2019.</p>	
3	Section 2.2.4 - Water Quality Inputs	<p>Comment Water quality for the PK pore water was represented by the average water quality monitoring results collected in beach pore water samples. DDMI indicates that this approach is conservative since non-detect values are represented by the detection limit in the calculations. Based on the model results, the release of pore water from the PK is the primary source of contaminants; therefore, the outcome of the model depends highly on the data input regarding PK pore water. There is no information on the number of sampling events that the average concentrations are based on, or the range of concentrations that has been encountered in the beach pore water. While sensitivity analyses involving the depth of the freshwater cap have been investigated, there is no discussion on how differing quality of pore water may impact the overlying freshwater cap or the stability of meromixis.</p> <p>Recommendation ECCC recommends that the Proponent discuss the range of concentrations encountered in the sampled beach pore water, the number of sampling events that the calculated average was based on, and potential impacts to the freshwater cap water quality and stability of meromixis if the pore water quality differs from what is predicted.</p>	<p>Jan 8: A summary of the PK pore water monitoring results are included in Attachment #3 that shows the number of samples and range percentiles. A sensitivity analysis is being conducted that includes the sensitivity of the PK pore water quality to model predictions (see EMAB-14 Sensitivity Run #7). The results of this analysis will be provided for the Technical Session January 16-17, 2019.</p>	
4	Section 3.0 - Model Limitations and Uncertainty	<p>Comment The modelling excluded several inputs, including groundwater inflows and pit wall runoff. The report identifies these as limitations to the model however, little information is provided on the rationale for exclusion of these components from the model except to state that their inputs were minor or</p>	<p>Jan 8: A sensitivity analysis is being conducted that includes the sensitivity of groundwater inflows (see EMAB-14 Sensitivity Run #9) and the sensitivity of the initial pit lake water quality (i.e. "flushing of the rock wall") (see EMAB-14 Sensitivity Run #8) to model predictions. The</p>	

		negligible. The purpose of this model was to provide a preliminary analysis of the lake hydrodynamics. These inputs may provide valuable data to the model output, however their exclusion may alter the modeling results and therefore the assessment of environmental impacts. Sufficient justification for their exclusion should be provided. Recommendation ECCC recommends that the Proponent provide additional justification to support the assumptions that groundwater flow and flushing of the rock wall will be negligible.	results of this analysis will be provided for the Technical Session January 16-17, 2019.
5	Section 5.0 - Conclusions	Comment The technical memorandum concludes that a freshwater cap of 50 m or more is necessary to isolate PK pore water from the surface water. Given these conclusions, a monitoring program should be developed to monitor water quality during the filling of the pit(s) to ensure that water quality in the pit(s) is behaving according to model predictions and remains stable over time. Recommendation ECCC recommends that the Proponent discuss proposed monitoring during filling of the pit(s) to ensure that water quality predictions are in line with model predictions.	Jan 8: Attachment #4 describes the proposed monitoring program requested by ECCC. It is the form of an SNP Station description and includes sampling during PK deposition, minimum 1 year period after flooding and immediately prior to dike breaching.

Environmental Monitoring Advisory Board: EMAB EMAB

ID	Topic	Reviewer Comment/Recommendation	Proponent Response	Board Staff Response
1	General File	Comment  EMAB Cover Letter Recommendation		
2	General File	Comment  Technical Review - Randy Knapp Consulting Recommendation		
3	General File	Comment  Technical Review - North-South Consultants Recommendation		
4	General File	Comment  Technical Review - Slater Environmental Consulting Recommendation		
5	Meromixis	Comment The Interim Closure and Reclamation Plan Version 4.0 (ICRP) describes proposed closure and reclamation for pits that do not contain PK. This configuration is consistent with the Base Case Scenario in the IR Response modelling. Diavik has stated on page 103 CRP V4 "For these reasons, DDMI continues to prefer a closure design that enhances a meromixis condition instead of one that weakens the meromixis condition. There does not appear to be sufficient rationale for further consideration or research related to options that weaken meromixis, as such none is planned." Section 5.2.4.3.5 describes the closure plan as follows: "The lake area will be very deep with steep sides and relatively small surface area and will be protected from wind-driven mixing by the residual dikes. This lake configuration should result in stable permanently stagnant lower monimolimnion underlying an upper mixolimnion that circulates regularly. Mathematical modelling presented in ICRP V3.2 supports this anticipated condition." The IR Response presents modelling for the same physical scenario (i.e., no PK in pits). The new modelling predicts that the pits will be fully mixed throughout the 100-year modelling period. The ICRP has maintained for many years now that the pit lakes will be stratified at closure. The recent modelling completed by Golder has indicated that none of the flooded pits are projected to be stratified and will be fully mixed. This is a major divergence from all previous comments yet is never acknowledged in the responses. Recommendation Given that Golder's 2010 and 2018 modelling reach contradictory conclusions about the same model scenario, Diavik should provide additional explanation about the reasons for the different conclusions. Diavik needs to acknowledge and address this material change. If Diavik has concluded that its	Jan 8: The pit lakes will be created by filling the empty, inactive pits and underground with water pumped in from Lac de Gras and groundwater that naturally seeps into mine area. Depending on the length of the filling period, the contribution of groundwater seepage to the total fill volume will vary – with faster filling rates leading to smaller volumes of groundwater. If the pit lake is created by pumping water from Lac de Gras over one open water period, then the contribution from groundwater seepage is very small. If the water pumped from Lac de Gras occurs over several years, then the contribution from groundwater rises. The following response provides a comparison of hydrodynamic studies undertaken in 2010 and in 2018. 2010 Study In 2010, Golder undertook a "Preliminary Pit Lake Study", dated December 9, 2010. A Base Case and seven other scenarios were considered. In this study, only the largest Pit, the A154 pit, was simulated. In the Base Case, it was assumed that the water pumped from Lac de Gras would be sufficient to fill the pit over one open water season (estimated to be pumped at 4.4 m3/s). Over the same period, groundwater inflow, based on observed inflows to the mine, varies from a high of 0.33 m3/s when the pit is empty to zero when the pit is full. At the maximum inflow of 0.33 m3/s, groundwater inflow represents less than 8 percent of the total water flooding the pit. Lake Total Dissolved Solids (TDS) concentration, based on observations was assumed to be 18.5 mg/L and the groundwater concentration was assumed to be 375 mg/L based on concentrations measured in monitoring ports prior to mining. The TDS of groundwater inflow to the A154 has been consistently between 300 mg/L to 400 mg/L since December 2010. For this Base Case scenario, it was predicted that TDS concentrations in the second year after full flooding of the pit would vary from TDS	

new modelling provides a more likely prediction of future pit conditions, it needs to address implications for closure of pits even if PK disposal in pits is not approved.

of about 25 mg/L at the bottom of the mine (163 to 172 masl) to a TDS concentration of about 20 mg/L in the upper sections of the mine (381 to 380 masl, water level in Lac de Gras is at about 416 masl). Ten years after full flooding, it is predicted that the pit lake would be fully mixed through its entire depth at a concentration of about 20 mg/L. Seven alternative scenarios were undertaken that assumed that the pit would initially be filled with groundwater to a specified level prior to being filled with water pumped from Lac de Gras in one open water period. The seven scenarios consisted of three different groundwater levels of 195 masl, 295 masl, and 411 masl and three elevations in which the wind speeds were doubled (W2) for these groundwater elevations namely 195 masl W2, 295 masl W2, and 411 masl W2. One additional scenario calculated the effect of a 60% lower infill rate from surface water during the open water season (denoted as 295 W2 RedQ). Conclusions drawn from the initial pit lake mixing study were as follows:

- The simultaneous introduction of surface water and groundwater in one open water season to the pit was found to likely lead to a high degree of mixing.
- Initially filling of a portion of the pit with groundwater, which is then carefully covered with surface water from Lac de Gras, is likely to result in a stratified system that will persist over time. However, the system becomes less stable as the elevation of the groundwater in the pit increases. Groundwater placed in the pit above an elevation of 360 masl is likely to be mixed into the overlying surface water. The following comments are relevant to the IR:
- The simultaneous introduction of surface water and groundwater to the pits over one open water season in the Base Case simulation results in a high degree of mixing with TDS concentrations predicted to be about 20 mg/L, which is only 8% higher than the median of the observed TDS in Lac de Gras of 18.5 mg/L.
- Initially filling the bottom of the pit with groundwater results in a stable stratified system. The length of time for natural groundwater seepage to fill the bottom of the pit to an elevation of 195 masl would take about 1 ½ months, to 295 masl about 20 months and to an elevation of 411 masl about 10 years. To reach 360 masl, where the analyses indicates that groundwater placed in the pit above this elevation is likely to be mixed into the overlying surface water would take about 5 years.
- The above two results indicate that stratification or full mixing of the pit lake is highly dependent on the pit filling schedule. These scenarios can be viewed as two end members – if the mines are filled simultaneously with groundwater and surface water, the pit lake tends to be vertically mixed. If the groundwater seeps into the mine prior to introduction of surface water pumped from Lac de Gras it is predicted to produce a stable stratification.

2018 Study The objectives of the 2018 hydrodynamic modelling were to determine the following:

- Whether the pit lake water column will turn over or remain stratified over the long term.
- The influence of PK consolidation on pit lake water quality. Two main model scenarios were considered – the Base Case Scenario where no PK was deposited in the pits (consistent with the 2010 model), and the Development Scenario where PK was deposited in the pits with 150 m of fresh water cap. Neither of these scenarios consider groundwater inflow during closure. For the purposes of comparison to the 2010 model, the following will focus on the Base Case Scenario (no PK deposited). In the 2018 Base Case Scenario, it was assumed that the pits would be filled instantly by water from Lac de Gras and therefore, groundwater inflow during filling and after the pits were filled was negligible. This assumption is slightly different from that used

			<p>in 2010, but the results of the 2010 model show that the filling period can be safely assumed to result in fully mixed conditions if the pit is rapidly filled. The reasons for not considering groundwater seepage in this modelling are to understand the effects of the consolidation of PK only on the stability of the water column, and because the total groundwater inflow will be small under a rapid fill scenario, as demonstrated by the 2010 model. For the Base Case Scenario where PK is not deposited in the pits, the 2018 modelling predicts that the water column will be mixed over the entire vertical depths. Similarly, it was shown in the 2010 study that this would be the case if the pit were filled rapidly with natural groundwater seepage and water pumped from Lac de Gras over one open water season. The 2010 modelling study showed that a fully mixed water column or a stable stratified water column was highly dependent on the filling schedule. Rapid filling generally resulted in a fully mixed water column; whereas allowing groundwater to seepage into the mines before carefully pumping water from Lac de Gras resulted in a stable stratified water column. In the 2018 study, it was assumed that the pits would be filled instantaneously by water from Lac de Gras resulting in negligible groundwater inflow, which was shown by the 2010 model to be a reasonable assumption. Although some assumptions in the model led to a slightly different level of stability of the water column in the pit, the long-term water quality results were similar because the 2010 modelling predicted vertical mixing, albeit more gradual.</p>	
6	Meromixis and long term stability of the stratification.	<p>Comment The quality of the water in the stratified layer is of major concern if this layer was to mix with surface water in Lac de Gras. The layer will contain essentially all of the porewater released from PK consolidation and could also be anoxic (no oxygen). Mixing of this mass of porewater with the surface water could have a material impact on water quality and fish in the pit lake. The mixing of the stratified water with Lac de Gras was modelled and indicated some elevated levels of several contaminants. The report suggests this will be a short-term issue (one to two months) based on Sensitivity Scenario 2 (20 m water cap) however this has not been demonstrated. The 150 m water cap scenario would be expected to take longer to reach equilibrium with Lac de Gras due to the higher volume of water in the cap. The base case suggested mixing is most likely to occur in October just prior to freeze up, which would also be expected to delay mixing. It will therefore be important to model water quality for this period to assess how long elevated conditions exist and whether this will have any impact on fisheries. The Pit Lakes post closure are planned to provide nursery and rearing habitat for fish, in particular Lake Trout and Cisco. These life stages may be more sensitive to degradation of water quality. Could infrequent mixing of the water column result in the mortality of juveniles inhabiting these areas?</p> <p>Recommendation Diavik should rerun the case where the pit destratifies and fully mixes. The modelled destratification should occur in October just prior to freeze up. Define a "short lived" duration for the 150 m water cap scenario ie. how long would it take for conditions to return to levels below the AEMP benchmarks? Assess what effect low DO levels and contaminants of concern have on water quality and fish. Please provide an assessment of the sensitivity of early life stages of fish to the potential infrequent mixing of the water column.</p>	<p>Jan 8: To assist in providing context to this unlikely event duration Golder has provided a further consideration of potential effects and duration of infrequent mixing of the water column in Attachment #8.</p>	
7	Fish use of habitat in the pit lake	<p>Comment The licence application indicated that the depth of the closure cap would limit resuspension of PK post-closure and will optimize the elevation of PK to limit potential</p>	<p>Jan 8: Four key fish habitat zones were identified in the pit lakes: the inside edge of the dike, reclaimed shoreline, the pit shelf, and the pelagic zone (i.e., deep water) (Golder 2003;</p>	

		<p>for direct interaction with fish. It was erroneously understood in NSC's previous comments (NSC 2018) that DDMI had assumed that fish are expected to use the upper 10 m of the water column. In the closure plan (V4), the primary focus for habitat creation inside of all dikes is based on providing spawning, nursery, rearing and foraging habitat. Target species include Lake Trout, Arctic Grayling, Burbot, Longnose Sucker, Round Whitefish, Cisco, Lake Whitefish, Northern Pike, and Slimy Sculpin. The primary gains in habitat are expected to relate to rearing habitat for Lake Trout, Cisco, and Slimy Sculpin. Open water habitat is expected to be suitable for pelagic species such as Cisco as well as potentially as over-wintering habitat. To what depth are fish expected to use the pelagic habitat in pit lakes and what is the basis of this expectation?</p> <p>Recommendation Please provide a description of anticipated fish use of specific habitat in the pit lakes, in particular the use of pelagic habitat at a range of depths and the effect of predicted water quality on this habitat use.</p>	<p>2008; 2017). A description of the anticipated fish use of pelagic habitat at a range of depths in the pit lakes is provided in EMAB-28. The inside edge of the dike with a water depth of 0 to 2 m is expected to provide spawning habitat for Slimy Sculpin (<i>Cottus cognatus</i>) and foraging and rearing habitat for other species. The pit shelf with a water depth of 3 to 5 m will provide shallow foraging and rearing habitat for most species of fish present in Lac de Gras. In A418 pit lake (Development Case), surface water is anticipated to remain below AEMP benchmarks, which are protective of fish and fish habitat. Therefore, the water quality within these habitat zones is expected to be suitable for early-life stage and adult fish. References Golder (Golder Associates Ltd.). 2003. Fish Habitat Design for the Pit Shelf Areas at the Diavik Mine. Submitted to Diavik Diamond Mines (2012) Inc. March 2003. Golder. 2008. Fish Habitat Design for the A418 Pit Shelf Area at the Diavik Diamond Mine. Submitted to Diavik Diamond Mines Inc. December 2008. Golder. 2017. A21 Dike Fish Habitat Design. Submitted to Diavik Diamond Mines (2012) Inc. Ref. No. 1648005-1568-R-Rev2-12000. March 2017.</p>
8	<p>Potential indirect effects of PK on fish</p>	<p>Comment The assessment has focussed on water quality modelling and a demonstration that conditions within surface waters are within AEMP benchmarks though conditions at depth exceeded benchmarks at some times for some parameters. Is there a potential for indirect effects to fish (e.g., migration of zooplankton between deep and shallow waters potentially being a source of metals to fish consuming zooplankton).</p> <p>Recommendation Please describe whether there is a potential for indirect effects to fish from PK storage (e.g., due to effects within food web).</p>	<p>Jan 8: If predicted surface water quality is below AEMP benchmarks for the protection of aquatic life (Golder 2018), then effects on fish health or fish food organisms are not expected. Some parameters have predicted concentrations above AEMP benchmarks in Pit Lake A418 at depth under the Development Case, but concentrations are within AEMP benchmarks in the surface water layer (see EMAB-28). Some fish may use the pelagic zone for thermal refuge (see EMAB-28) and may venture into deep waters, although it is unlikely that they will spend a prolonged period at depth in the pits. Parameters with the potential to biomagnify (i.e., selenium and mercury) accumulate in fish primarily via diet, rather than directly from lake water. Since small bodied fish and benthic invertebrates are not expected to inhabit the pelagic zone of the pits due to lack of suitable habitat (see EMAB-7), it is unlikely that large bodied fish will be exposed to elevated concentrations of selenium or mercury via their diet from these food sources. Zooplankton may also contribute to trophic transfer of contaminants, and may inhabit the pelagic zone of the pits where AEMP benchmark exceedances are predicted, although the depth to which plankton migrate will be dependent on water quality conditions (e.g., dissolved oxygen) and potentially other factors (e.g., swimming ability, food availability). Some nutrients and trace metals may be of concern in relation to direct effects to zooplankton that frequent the pelagic zone at depth where AEMP benchmark exceedances may occur (see EMAB-6), but increased exposure to fish from exposure to these metals via trophic transfer is unlikely because they do not biomagnify. Additionally, effects (if they occur) would be limited to organisms that frequent the pelagic zone of the pit lakes, because elevated concentrations are predicted to have a limited spatial extent. Given the considerable depth of the pit lakes, these organisms would be unlikely to transfer metals from deep water to shallow water in amounts that could affect fish health. References Golder. 2018. Aquatic Effects Monitoring Program Design Plan Version 5.0. Prepared for Diavik Diamond Mines (2012) Inc., Yellowknife, NT. March 2018.</p>
9	<p>Water circulation between the pit lake and Lac du Gras</p>	<p>Comment The Closure and Reclamation Plan V. 4 (App X2, page 8) notes that with regard to water circulation within the diked area, several features should be incorporated to reduce circulation. The shallow nature of the breaches, shallow nature of the pit shelf, and the creation of shoals on the pit shelf will reduce circulation</p>	<p>Jan 8: The model applied in Golder (2018) is a 2-dimensional hydrodynamic model with limited connection to Lac de Gras. It cannot be used to examine fine details regarding currents within a complex habitat. Rather, it is focused on the bulk movement of water through breached dykes. The two sets of predictions are</p>

		<p>and wind and wave action. The shallow water is expected to warm up quickly in the spring relative to open areas of the lake, because of the limited water circulation within the enclosed area. As with other rearing habitats in Lac de Gras, warmer water should, therefore, assist in increasing biological productivity inside the dike by providing a warmer refuge, and foraging area. The water quality modeling report (Section 4.3, page 36) states that it is expected that shortly after lake turnover, water quality in the pit lake, at least near the surface, to quickly return closer to lake concentrations due to the high volume of water exchange with Lac de Gras. Are these two descriptions of water circulation (residence time) in the pit lakes contradictory or do they represent different spatial areas?</p> <p>Recommendation Please provide a description of the expected water circulation within the pit lake and interchange with Lac du Gras. If possible, include residence times considering the different descriptions noted.</p>	<p>therefore applicable to different spatial and temporal domains and are not comparable. As discussed in EMAB-22, occasional wind-driven mixing in the pit lake is expected to cause some water at the pycnocline upward, and this water will be replaced with lake water. Also, normal seasonal stratification will affect the water circulation, likely restricting it to the epilimnion. For these reasons, the residence time will vary throughout the lake. To estimate the residence time at all depths of the pit lake, a generic water quality constituent was added to the water inflowing from Lac de Gras with a concentration of 1. The tracer concentration was set to zero everywhere else in the model domain. The resulting value provides an estimate of the amount of replacement, which would be similar to residence time. It is noted that this is not exactly the same as residence time since it does not account for water parcels that repeatedly enter and leave the model domain. However, it provides a reasonable estimate. Contour plots of tracer concentrations are shown below. The results for all three pit lakes show that residence times for the top 20 m of water is one open-water season or less, which confirms a high volume of water exchange between the pit lakes and Lac de Gras. At lower depths, the residence time appears to be slightly longer than 10 years. Near the bottom, it appears from these simulations that virtually no lake water reaches the sediment-water interface, and the residence time would be very long (see to Figures 1, 2, and 3 of contour plots of predicted tracer concentrations in A418, A154, and A21 pit lakes in Attachment #9).</p>
10	Long term load of contaminants from PK to Lac de Gras	<p>Comment Model results indicate that in the long-term, dissolved constituents will diffuse to surface layers. In addition, there is a potential for infrequent turnover and/or deeper mixing within the pit lakes. In both instances, the report noted that surface water quality would be maintained/restored due to rapid exchange with Lac de Gras. Therefore, constituents from the PK must be moving into Lac de Gras.</p> <p>Recommendation What is the long term load (both anticipated based on model results and unanticipated due to lake turnover) from PK storage to Lac de Gras?</p>	<p>Jan 8: The long-term Total Dissolved Solids (TDS) load to Lac de Gras as a result of PK pore water release in A418 Pit Lake, under both anticipated and unanticipated mixing conditions were estimated. The long-term load to Lac de Gras was also estimated for A154 and A21 pit lakes under the anticipated mixing conditions (see Table 1 in Attachment #9 for long-term TDS load to Lac de Gras).</p>
11	Mitigation measures	<p>Comment The scope of work indicates that the reviewers are to consider whether any mitigation measures to limit potential impacts to fish and fish habitat have been identified and considered. The IR response does not include a discussion of potential mitigation measures beyond the consideration of the depth of the water cap and the implications of increasing the size of the breach. In the event that mixing were to occur, mitigation and management measures should be identified to limit impacts to aquatic biota and to prevent impacts in potential future mixing events.</p> <p>Recommendation Provide a discussion of management and mitigation measures that would be employed in the event of mixing in the pit lakes.</p>	<p>Jan 8: DDMI is not aware of any practical mitigations or management measures that could be employed to mitigate potential effects to fish or fish habitat in the unlikely scenario where a de-stratification event occurred. It should be noted that if this unlikely de-stratification scenario occurred it would likely be after the dike had been breached and the mine site closed with no permanent site presence. If such an event occurred and caused significant environmental harm or it was determined that this even was more likely than predicted a possible management response to prevent additional future events would be to permanently close the dike breach to avoid any recurrence. DDMI suggests that mitigation and management measures should instead be focused on practical measures to that would reduce the probability and/or potential consequence of a de-stratification event. As noted by EMAB the depth of cover appears to be the best mitigation/management measure identified to date</p>
12	Risk analysis of unanticipated effects	<p>Comment The previous review had requested a risk assessment of infrequent events as follows (EMAB 29) : "... DDMI should provide a risk analysis. The current closure plan indicates breaching the dikes and joining to Lac du Gras once water quality is acceptable (DDMI 2017). However, processes such as the accumulation of saline groundwater at depth or the accumulation of metals from porewater in the PK in deep waters may occur over time and, although the initial quality of deep water may be acceptable, over time its quality may</p>	<p>Jan 8: The event DDMI assumed for the risk analysis was a pit wall failure of sufficient magnitude that the sudden energy release would cause complete mixing of the water within the pit area. This was provided as a reasonable worst-case scenario from which to consider potential environmental effects. DDMI has committed to completing an evaluation of pit wall stability after flooding with specific emphasis on risk of a wall failure causing mixing of deep water with surface water (Page 109 CRP V4.0). DDMI does not at this time have</p>

		<p>decrease. Furthermore, processes that mix deep water with shallower water may occur rarely, as a result of an intermittent event (e.g., strong winds, specific thermal gradient, rockfall from the mine wall) potentially resulting in the introduction of poor quality water to surface waters within the pit and Lac du Gras. There is currently no assessment of the potential water quality at depth, the likelihood or frequency at which mixing with surface waters might occur, and the risk to aquatic biota within the surface waters of the pit or Lac du Gras if such an event were to occur." In the response, DDMI had indicated that the above-stated question would be addressed in the water quality model report. Although the report provides information related to water quality in surface waters and at depth, and the risk to biota (in terms of comparisons to AEMP benchmarks) it does not provide a discussion of the potential frequency of unanticipated events that may result in mixing of the water column (or if such an event would not occur). For example, sub-aquatic or sub-aerial landslides into deep water or supersaturation of dissolved gases have been shown to cause sudden mixing of meromictic lakes.</p> <p>Recommendation Please provide a discussion of the potential for infrequent events resulting in the mixing of the water column.</p>	<p>a geotechnical assessment that discussed the potential frequency of a pit wall failure occurring that is large enough to de-stratify the pit lake. Such an assessment will be completed as part of the final closure design but could also be provided as a condition of this proposed Water License Amendment. Please see response to EMAB-13 with regard to dissolved gases causing de-stratification.</p>	
13	<p>Potential build-up of dissolved gases at depth with periodic catastrophic release</p>	<p>Comment Meromictic lakes, including pit lakes, have been found to accumulate dissolved gases (e.g., carbon dioxide and methane) in the monimolimnia. Recent instances of catastrophic degassing of meromictic lakes (i.e., limnic eruption) in which humans and livestock were killed have been reported (e.g., Lake Nyos, Cameroon). There are believed to be a number of key pathways through which excessive gas buildup may occur in meromictic lakes. While some of these pathways such as introduction of volcanic gases are not applicable, others may be applicable to the present case (e.g., decomposition of organic materials). The report lacks any consideration of the potential for gases to accumulate in the pit lakes and the associated potential risk in the event of sudden degassing (e.g., such as during a sudden lake mixing event).</p> <p>Recommendation Provide a discussion of the potential for dissolved gas accumulation in the monimolimnia of the pits and describe potential for limnic eruptions and associated risks to humans and wildlife.</p>	<p>Jan 8: Lake Nyos erupted 32 years ago; Lake Monoun erupted 35 years ago; and Lake Kivu is thought to erupt every 1000 years but has not been observed in recent times. Eruptions in all three of these lakes are due to input of gases through volcanic vents, and as noted by EMAB, are not relevant to Diavik's pit lakes. It is not clear which recent examples of limnetic eruption the reviewer is referring to that would be relevant to Diavik's pit lakes. The potential for gas generation in pit lakes has been documented in pit lakes that contain substantial proportions of organic matter, such as oil sands pit lakes where the deposited tailings have residual bitumen, organic acids and solvents (Vandenberg et al. 2015). Even in these pit lakes, which were both predicted (Prakash et al. 2016) and observed (Dompierre et al. 2016) to generate gases, the quantities generated are insufficient to create a limnetic eruption. Additionally, both the predicted conceptual model of subaqueously disposed tailings and field observations suggest that bubbles form in the sediment, then grow to a size and pressure that cracks the sediment, releasing the bubble to the surface. This process prevents much of the generated gas from dissolving in the water column, and instead it rises as bubbles. The pit lakes under consideration will not have excessive amounts of organic material that could generate and accumulate gases that could erupt in the event of a sudden turnover. The Base Case pit lake scenario does not contain submerged mine waste, so there is no potential for any such gas generation. The Development Case does include mine waste, but that material is primarily comprised of ground rock that is devoid of organic matter. For the reasons listed above, this process was not considered relevant to Diavik's pit lakes. Accordingly, it was not discussed in Golder (2018). References Dompierre, K. A., M. B. J. Lidsay, P. Cruz-Hernández, and G. M. Halferdahl. 2016. Initial geochemical characteristics of fluid fine tailings in an oil sands end pit lake. <i>Science of The Total Environment</i> 556:196–206. Prakash, S., J. A. Vandenberg, and E. M. Buchak. 2015. Sediment Diagenesis Module for CE-QUAL-W2 Part 2: Numerical Formulation. <i>Environmental Modeling & Assessment</i> 20:249–258. Vandenberg, J. A., S. Prakash, and E. M. Buchak. 2015. Sediment Diagenesis Module for CE-QUAL-W2. Part 1: Conceptual Formulation.</p>	

			Environmental Modeling & Assessment 20:239–247.
14	Model Calibration	<p>Comment The User Manual (Cole and Scott 2015) states “Results will be suspect at best and will not withstand scrutiny at worst if the model is applied with insufficient and/or inadequate calibration data.” As noted by Golder in the modelling report, “because the pit lake is not yet constructed, model calibration is not possible”. In lieu of calibration data for the pit lake, Golder used data from other regional modelling studies. The most recent of the of the studies referred to was Vandenberg et al. 2015. It is noteworthy that the authors of this study note that “the calibration was considered to be approximate because the true values of a large proportion of the measured data were not known. All of these inputs and assumptions carry inherent variability and uncertainty, which impose and propagate uncertainty on model predictions.” Although we have a useful tool, it is clear that calibration is essential for reliability of the predictions. Given the caution expressed by both the Users Manual and Vandenberg et al. 2015 regarding model calibration, one needs to treat the model results with a bit of skepticism and adopt a cautious approach.</p> <p>Recommendation Diavik should complete sensitivity analyses for a range of potential inputs to the model (e.g. meteorological conditions, lake temperature, porewater quality, dissolved oxygen content, etc.).</p>	<p>Jan 8: A sensitivity analysis is being conducted with the results of the analysis to be provided for the Technical Session January 16-17, 2019. The sensitivity analysis includes the following scenarios, which will all be run for the A418 Development Scenario described in Golder (2018): 1. PK/sediment temperature 2. Local runoff from mine area 3. Wind sheltering coefficient 4. Wind speed 5. Air temperature 6. Consolidation rate – PK pore water release rate 7. PK pore water chemistry 8. Initial pit lake condition (include 5m of pore water before filling & contribution from wall rock runoff) 9. Groundwater inflows</p>
15	PK Consolidation Model	<p>Comment Section 2.1.1 of the IR Response describes the use of a consolidation model to support the water quality predictions. Consolidation of PK in the pit is an important component of the water quality prediction because the PK will release porewater to the pit lakes as it consolidates. Diavik suggests that the porewater is an important source of contaminant loading to the pit lakes in the water quality model. Pore water quality was estimated from the mean conditions measured in “beach pore water samples provided by DDMI”. The amendment application did not provide clear information or rationale about consolidation conditions, assumptions, data, analysis or modelling. In the absence of this information it is not possible to evaluate the adequacy and sensitivity of the model or the implications on predictions of water quality and potential environmental effects.</p> <p>Recommendation Additional explanation should be provided to demonstrate that the PK consolidation model is representative for the conditions that can be expected in the pits at Diavik. The WLWB should request that Diavik provide this information before it proceeds with its preliminary screening.</p>	<p>Jan 8: The consolidation and pore water release estimates are preliminary. The basis for the estimates are further described in Attachment #1. A summary of the beach pore water quality results are included as Attachment #3. DDMI expects that the pore water release assumed for the preliminary modelling is worst-case rather than being representative of the conditions that could be expected at Diavik. Using A418 as an example, Figure 2 - Attachment #1 shows that in total 11.3 Mm3 of pore water would be released from 23.9 Mt of PK. This is the assumption used as the pore water release in all A418 modelling scenarios. Whereas the scenario that would be representative of the conditions that could be expected at Diavik would only include 4.1Mt of PK – less than 20 percent of what was assumed in the preliminary modelling. Additionally DDMI is conducting a sensitivity analysis to demonstrate the effect of pore water chemistry and pore water release rate on model results (see EMAB-14 Sensitivity Runs #6 and #7). The sensitivity analysis results will be provided for the Technical Session January 16-17, 2019. It is DDMI's view that the above should be sufficient to inform the preliminary screening as requested by EMAB.</p>
16	Section 2.2, Model Inputs, page 4	<p>Comment The report indicates that groundwater and local surface drainage were not incorporated into the modeling. How would inclusion of these inflows affect stability of stratification in the lakes? How would it affect predicted water quality? Note that in the closure plan (V4) strong stratification was predicted based on groundwater input.</p> <p>Recommendation Please provide a sensitivity analysis that includes groundwater and local surface drainage as inflows and discuss any changes in conclusions, notably in relation to the stability of stratification and concentration of key parameters in the water column.</p>	<p>Jan 8: A sensitivity analysis is being conducted that includes the sensitivity of groundwater inflows (see EMAB-14 Sensitivity Run #9) and local surface runoff (see EMAB-14 Sensitivity Run #2) to model predictions. The results of this analysis will be provided for the Technical Session January 16-17, 2019.</p>
17	Section 2.2.2, Meteorological data, page 6	<p>Comment The report indicates that the meteorological inputs are key drivers of lake circulation and thermal dynamics. On-site data collected from 2014-2017 were used, as well as data from nearby stations 1999-2013. Are there differences between the on-site station and the nearby stations? If weather is different in the future (e.g., climate change) will there be a material change in model results, in particular related to the stability of the water column in</p>	<p>Jan 8: The description of meteorological data sources in Section 2.2.2 requires clarification. The majority of the meteorological data applied in the model were measured at the Diavik station. For some variables, a small gap would be filled using the record from a similar day at Diavik or interpolation. Where larger gaps in the data existed, these gaps were filled from nearby stations. The choice of which station to use for filling gaps was prioritized</p>

		<p>the pit lakes?</p> <p>Recommendation Please indicate whether there is a material difference between weather (e.g., wind speed and direction) measured on-site and at the nearby stations and, if so, how this could affect modeling results. Please provide a sensitivity analysis considering a range of weather conditions.</p>	<p>based on proximity to Diavik. Therefore, data from nearby mines were applied if available; otherwise, Environment Canada Yellowknife data were applied. The approach to filling gaps is described in the response to GNWT-11. When filling gaps, the data used to fill the gaps are compared to the Diavik dataset to confirm they are representative. The comparison includes a combination of simple statistics and visual examination. All data from other stations were confirmed during the QA/QC process to be representative of Diavik's environment, with minor differences that are not anticipated to affect the hydrodynamic modelling results or conclusions. A sensitivity analysis is being conducted that includes the sensitivity of weather conditions (see EMAB-14 Sensitivity Run #4 (wind speed) and Sensitivity Run #5 (air temperature)) to model predictions. The results of this analysis will be provided for the Technical Session January 16-17, 2019.</p>	
18	Section 2.2.4.1, Water Quality Inputs, Lac de Gras, page 7	<p>Comment The report notes that water temperature data are lacking for Lac de Gras and the data from the nearby Snap Lake were used in the modeling. As water temperature is a critical parameter, this represents a data gap.</p> <p>Recommendation Recommend installing temperature loggers at several sites in the Lac de Gras to collect site-specific temperature data.</p>	<p>Jan 8: DDMI deploys temperature loggers every 3 years as part of the AEMP slimy sculpin surveys that record continuous temperatures at several locations around Lac de Gras at single depths from April to late August. During the AEMP water quality sampling events temperature profiles are collected from each water quality sampling location. See also ENR-11.</p>	
19	Section 2.2.4.1, Water Quality Inputs, Lac de Gras, page 7	<p>Comment Lac de Gras water quality was defined using data from monitoring sites located near the pits. However, the report notes that open-water season data were used. It is unclear whether the modeling would be materially changed if measured winter water quality data were incorporated.</p> <p>Recommendation Please provide a discussion of the implications of completing the modeling using only open-water season water quality data.</p>	<p>Jan 8: Upon review, it was identified that the statement that only open-water season water quality data were used is erroneous. Water quality of Lac de Gras was characterized in the model based on both open-water and ice-covered season data collected as part of AEMP sampling program.</p>	
20	Section 2.2.4.1, Water Quality Inputs, Lac de Gras, Table 1, pages 8-9	<p>Comment Modeling results were compared to AEMP benchmarks, as summarized in Table 1. As benchmarks have not been developed for all parameters as part of the AEMP, benchmarks are not provided for all parameters.</p> <p>Recommendation Recommend identifying benchmarks for the purposes of this report for those water quality parameters lacking AEMP benchmarks.</p>	<p>Jan 8: Benchmarks have been developed for all parameters of concern. PK pore water and its chemical composition currently forms part of the operational discharge from the North Inlet Water Treatment Plant and as such is already a factor in the existing benchmark parameter selection. If there are specific parameters that do not have benchmarks that EMAB has identified as being of potential concern, DDMI would consider these but developing benchmarks for every element measured or modelled simply for completeness is not warranted</p>	
21	Section 2.3, Model Scenarios, page 11	<p>Comment The model assigned a temperature of 5 oC to PK and sediments. There is no reference or rationale provided for this setting. As temperature is a critical variable with respect to modeling and ultimately predictions regarding mixing, this setting should be discussed.</p> <p>Recommendation Please provide a rationale for use of 5 oC for PK and sediments.</p>	<p>Jan 8: It is acknowledged that the sediment temperature of the future pit lake is not known. It is expected that PK in a deep pit can be slightly warmer than natural lake sediment for some time after deposition. At the time of deposition, it is expected that deposited PK will be a few degrees warmer than natural sediment because it is warm during the processing. To evaluate whether a difference of a few degrees in sediment temperature could affect hydrodynamic results, different sediment temperatures were included in the sensitivity analysis as described in the response to the EMAB-14.</p>	
22	Section 2.4, Quality Assurance, page 12	<p>Comment The report states: "The calibrated model predicts that ice starts forming on the lake around mid-October and melts by mid- to late June, in agreement with available measured proxy data. The predicted time for ice melting in the pit lakes leads to an open-water season which is longer than that observed at Lac de Gras, where ice melt generally occurs in mid-July. The extended open water season represents a more conservative approach, as the exposure to wind-driven forces over the pit lakes surface is extended over time." The text is somewhat unclear. What are the "proxy data" referred to in the text above?</p>	<p>Jan 8: Measuring ice formation and melting rates is challenging because lake ice is not safe to traverse during the initial stages of formation and the final stages of melting. Therefore, the goal of modelling ice on lakes is to approximate the general time frame when atmospheric processes such as wind mixing and thermal insulation occur, rather than to precisely predict the date of ice formation on an annual basis. Proxy data refers to the accumulated dataset of lake ice-cover periods in the region that have been measured as part of baseline and operational monitoring for Diavik and other mines. The dataset is limited to ice thickness during the middle of the ice-</p>	

		<p>Recommendation Please clarify what is referred to as "proxy data".</p>	<p>cover period and discrete dates indicating ice-covered and ice-free conditions.</p>
23	Initial Water Quality used for the modelling	<p>Comment The initial conditions for the modelling exclude groundwater inputs or contributions of source contaminants from wall rock. Saline groundwater inputs were understood to be the primary source of high salinity water that would result in the stratification of the pits. Previous modelling was completed to assess the impacts of wall rock on pit water quality. It is not clear why one would exclude these sources of contamination into the model. Certainly, for the cases where PK is placed into the pits, pit wall rock contributions are likely insignificant. However, groundwater will continue to be a material source of TDS until such time as the pits are flooded and hydraulic gradients to the pit are diminished.</p> <p>Recommendation Diavik should defend why groundwater was not included as a source of salinity to the pits for all cases modelled. It would also be reasonable to rerun the models with saline groundwater input for all cases.</p>	<p>Jan 8: For this preliminary modelling it was assumed that the pits would be filled instantly by water from Lac de Gras and therefore, groundwater inflow during filling and after the pits were filled was negligible. The reasons for not considering groundwater seepage in this preliminary modelling is because the focus was on understanding the effects of the consolidation of PK on the stability of the water column, and because the total groundwater inflow will be small under a rapid fill scenario, as was demonstrated by the 2010 model. Please see also response to EMAB-5. A sensitivity analysis is being conducted that includes the sensitivity of groundwater inflows (see EMAB-14 Sensitivity Run #9) to model predictions. The results of this analysis will be provided for the Technical Session January 16-17, 2019.</p>
24	Initial Water Quality used for the modelling - start conditions	<p>Comment The starting point for modelling does not consider the phase of pit water management that may be the most challenging: the transition from operations PK disposal to closure pit lakes with water quality that is acceptable for reconnection with Lac de Gras. The Golder memo identifies the starting conditions as a limitation of the modelling. It is unclear how the pit will be filled with water and this could have a material effect on the initial water quality in the pit. The model assumes the start conditions is a pit lake filled with uncontaminated Lac de Gras water. One would expect in order to not disturb the PK upon flooding that a layer of several meters of PK slurry water would need to be present over the PK. This process water would be similar to PK porewater and would mix with the Lac de Gras water used to flood the pit. The model assumes that somehow, Lac de Gras water is placed and does not mix in any way with the PK or PK process water. This is not a rational assumption as used in the model. Because the IR Response focuses entirely on the post-closure period, it does not provide any additional clarification about operational water management or the transition period. Water balance and water management will be critical for any PK disposal because the material will be transported to the pit as a slurry. During operations, the water that accumulates in the pit will be primarily process water from deposit of PK slurry. It will also include inflows from groundwater, pit walls and the local catchment.</p> <p>Recommendation Diavik should extend the temporal scope of modelling to address the transition period for pit filling and establishment of conditions that are suitable for connection of pits to Lac de Gras. Initial conditions for this period should include an initial of a layer of process water mixed with Lac de Gras water in the pit (if any) at the onset of pit filling and any other load sources. The WLWB should request that Diavik provide this information before it proceeds with its preliminary screening.</p>	<p>Jan 8: A sensitivity analysis is being conducted that includes the sensitivity of initial pit lake conditions (see EMAB-14 Sensitivity Run #8) to model predictions. The results of this analysis will be provided for the Technical Session January 16-17, 2019. It is DDMI's view that the above should be sufficient to inform the preliminary screening as requested by EMAB.</p>
25	Initial Water Quality used for the modelling - start conditions (continued)	<p>Comment The amendment application stated that water from the pit may be returned to the process plant or it may be transferred to the North Inlet. Once PK disposal is complete, any water remaining in the pit will contribute loading to the pit as it is filled. Initial rinsing of pit walls and local waste rock materials will also contribute loading. Previous modelling for pit closure considered mine water related loading and concluded that meromictic conditions at or soon after the conclusion of pit filling would lead to surface water quality that would be suitable for connecting pit lakes with Lac de Gras. The current modelling predicts that the pits will be fully mixed at the conclusion of</p>	<p>Jan 8: Noted</p>

		<p>filling, with meromictic conditions establishing over time, but then weakening in the long-term. The establishment of the meromictic conditions likely relies in part on inflows from Lac de Gras at surface to maintain low Total Dissolved Solids (TDS) in the surface water. If loading during the transition period is higher than expected, then connection with Lac de Gras as an ongoing source of low TDS water could be delayed and modelling results may be invalid.</p> <p>Recommendation None</p>	
26	Section 4.1.1, Model Results, A418 Pit Lake, page 14	<p>Comment The report indicates: "For the Development Case and Sensitivity Scenario 1, the contour plots show a reduced stability of the stratification over time (predicted TDS concentrations display diffusion over time, as seen in Figure 5). However, the diffusion is thought to be over-estimated in these simulations because they do not account for the dynamic settling of PK, which will lead to a substantially deeper and more narrow pool of water with elevated density, and both of these factors will increase the strength of stratification over the long term. Beyond these time scales, it is anticipated that a very small amount of this water will reach the surface through chemical diffusion and occasional wind mixing; however, both the conceptual and numerical models suggest that this amount will be very small compared to the exchange with lake water and will likely be unmeasurable. If such an exchange does occur, it will reduce the mass of constituents stored at the lake bottom over time." It is unclear what "occasional wind mixing" refers to. Are the lakes predicted to undergo mixing in the future? If the lakes are expected to undergo mixing, please provide a discussion of how it was determined that this will be a "very small" amount of water that would be introduced to the surface layer(s).</p> <p>Recommendation Please clarify if the lakes are expected to undergo mixing between surface and deep waters, and if so, provide a discussion of how it was determined that this will be a "very small" amount of water that would be introduced to the surface layer(s).</p>	<p>Jan 8: In both scenarios referred to by EMAB, the pit lake is predicted to be stratified, meaning that there will be a measurable gradient in TDS and other constituent concentrations at depth. However, even with this stratification, there is predicted to be some mixing at the interface, as shown by the upward diffusion of mass over time. The effect of this process is illustrated by the gradual increase in concentrations above the interface for these scenarios in Figure 5 of Golder (2018). The occasional wind mixing refers to the upward diffusion that will occur during wind events over the 100-year period that will bring mass to the surface but that will not completely break down the pycnocline. This is sometimes referred to as "partial mixing" because it falls somewhere between an effectively isolated monimolimnion and a full turnover event. The small amount of water that will be introduced to the surface layers was estimated by use of a generic tracer, as described in Section 2.1.3 and presented in Figure 6 of Golder (2018). This tracer was then used to estimate the concentrations of water quality constituents as presented in Appendix A.</p>
27	Section 4.1.1, Model Results, A418 Pit Lake, page 15 and Figure 4, page 17	<p>Comment As there is no definition provided for what are referred to as "surface layers" it is not possible to ascertain what the potential effects are to surface water and ultimately biota. Figure 4 for example shows high concentrations of TDS for the development case below 30 m; the scale of the figures in this and other sections of the report is inadequate to identify the maximum concentrations predicted for shallow depths.</p> <p>Recommendation Recommendation 1: Please quantitatively define "surface layers" (i.e., water depth). Recommendation 2: Please revise all figures such that model predictions for shallower depths (notably what is referred to as "surface layers") are legible (e.g., provide figure insets where applicable).</p>	<p>Jan 8: Figures presenting concentrations of surface layers are reproduced in Attachment #6, for all three pit lakes for Development Case Scenario, with higher resolution and detailed elevation range for the surface layers. The range of elevations considered to calculate "surface layers (Top Section)" and "Lower Section" are presented in the legend for each figure.</p>
28	Attachment 1, Water Quality Results - Figures A-1 to A-9	<p>Comment The report discusses effects on water quality for the "surface layers" and figures presented in Attachment 1 present modeling results for the upper 5 m of surface water and the lower portion of the water cap (e.g., for the development case, results represent the lower 126-150 m of the water column). Based on TDS figures presented in the report (e.g., Figure 4, page 17), water quality conditions in the water column between these depth ranges would be intermediate. As presented in Figures A-1 through A-9 (Appendix 1) exceedances of benchmarks are predicted to occur for some parameters in deep water. The information is insufficient to determine at what water depth benchmark exceedances are predicted. Can DDMI provide the depth to which water quality would be suitable for aquatic life (as defined by benchmarks) and describe effects to aquatic life resident within or moving through deeper</p>	<p>Jan 8: It is anticipated that fish will not reside in or pass through deeper water where AEMP benchmark exceedances are expected. A description of anticipated fish use of specific pit lake habitat (i.e., the inside edge of the dike, reclaimed shoreline, the pit shelf, and the pelagic zone) is provided in EMAB-7. AEMP benchmark (Golder 2018) exceedances by depth for year 0 and year 100 are provided in Table 2 for Pit Lake A418 under the development case scenario (see Attachment #9). Total depth (from the top elevation of PK) in the pit lake is 150 meters with AEMP benchmark exceedances expected at approximately 145 m depth in model year 0 to 39 m depth in year 100 (for nitrate as N); most parameter exceedances are predicted to occur at depths greater than or equal to 40 m. While these depths are predicted by the model, the actual depths are likely to be deeper, because the assumed bathymetry in the 2-dimensional</p>

waters where benchmarks are exceeded?
Recommendation Please provide the depth of the water column for the development case where AEMP benchmarks will be met and describe effects to aquatic life that may be resident within or pass through deeper waters where benchmarks are exceeded.

model leads to an over-estimate of vertical mixing. It is anticipated that Lake Trout (*Salvelinus namaycush*), Lake Whitefish (*Coregonus clupeaformis*) and Cisco (*Coregonus artedii*) may reside within the pelagic zone (i.e., free open water) of the pit lakes. Therefore, this response will focus on the expected depth distribution of these fish species in the pit lakes and their potential interaction with the deeper waters of pit lake A418 (development case). Smaller fish, such as Slimy Sculpin (*Cottus cognatus*), are not expected to inhabit deep water (i.e., the pelagic zone) in Lac de Gras (Gray et al. 2005). The pelagic habitat was designed for use as a thermal refuge for fish (Golder 2003; 2008; 2017). It was anticipated that the pelagic zone would be used primarily by pelagic feeding fish (e.g., Cisco) but that it also could provide overwintering habitat. In northern environments, Lake Trout are typically found at depths greater than 10 m in the pelagic zone of lakes (Richardson et al. 2001). As surface water temperatures rise in the summer and lakes stratify, Lake Trout seek deeper, cooler waters located below the thermocline (Richardson et al. 2001). The hydrodynamic model results indicate that for the A418 pit lake, the thermocline is located approximately 5 to 15 m below surface, depending on the season. Below the seasonal thermocline, temperatures are predicted to be uniform at less than 5°C. In general, Lake Trout prefer temperatures of approximately 10°C and reside just below the thermocline (Scott and Crossman 1973). Lake Whitefish are frequently found at water depths greater than 10 m for most of the year and have been found at depths greater than 100 m (Richardson et al. 2001). However, Scott and Crossman (1973) noted that in northern environments that lack critical thermal stratification it may be unnecessary for Lake Whitefish to migrate to deeper waters in the summer months. Therefore, it is unlikely that they will seek refuge in the deeper water of the pit lakes given the shallow thermocline. Similar to Lake Trout, Cisco are a pelagic species that migrate to deeper waters as temperatures increase in the late summer, and Cisco will reside just below the thermocline (Scott and Crossman 1973). Therefore, it is predicted that Cisco will not frequent water greater than 40 m depth in the pit lake. In summary, it is not anticipated that Lake Trout, Lake Whitefish or Cisco will reside at depths greater than 40 m in the pelagic zone of the pit lake and therefore, they are not anticipated to have sufficient exposure to the deep water to result in adverse effects. References Golder (Golder Associates Ltd.). 2003. Fish Habitat Design for the Pit Shelf Areas at the Diavik Mine. Submitted to Diavik Diamond Mines (2012) Inc. March 2003. Golder. 2008. Fish Habitat Design for the A418 Pit Shelf Area at the Diavik Diamond Mine. Submitted to Diavik Diamond Mines Inc. December 2008. Golder. 2017. A21 Dike Fish Habitat Design. Submitted to Diavik Diamond Mines (2012) Inc. Ref. No. 1648005-1568-R-Rev2-12000. March 2017. Golder. 2018. Aquatic Effects Monitoring Program Design Plan Version 5.0. Prepared for Diavik Diamond Mines (2012) Inc., Yellowknife, NT. March 2018. Gray M, Munkittrick K, Palace V, Baron C. 2004. Final Report: Assessment of Slimy Sculpin (*Cottus cognatus*) Collected from East Island, Lac de Gras, NWT. 2005. p. 30. Richardson ES, Reist JD, Minns CK. 2001. Life History Characteristics of Freshwater Fishes Occurring in the Northwest Territories and Nunavut, with Major Emphasis on Lake Habitat Requirements. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2569. July 2001. Scott WB and Crossman EJ. 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada, Ottawa 1973. Bulletin 184.

	<p>Missing parameters</p> <p>included in the modeling results.</p> <p>Recommendation Please comment on the potential effects of PK (including slimes) on pH and nitrogen in the pit lakes.</p>	<p>modelling of pH, nitrogen species or dissolved oxygen. These parameters are not appropriate for mass balance modelling. DDMI advised that these parameters would be explicitly excluded from modelling studies in the WLWB approved ICRP V3.2 – Appendix VIII-2 Open Pit, Underground and Dike Area Research Plan - Page 16. Based on limited effect of pore water release on surface water quality demonstrated in the Golder (2018) Base Case modelling, the generally circumneutral pH profiles in the PKC beaches and the relatively low levels of all nitrogen forms (Mocur and Smith 2014) the potential effects on pH and nitrogen in surface water of the pit lakes are expected to be negligible.</p>	
30	<p>Effects on dissolved oxygen</p> <p>Comment Is there a potential for PK (including slimes) to decrease dissolved oxygen (DO) in the pit lakes? If yes, what effect would overturn (i.e., mixing) have on DO concentrations? Given that DO is a critical parameter, is there a potential for DO depletion at depth due to other factors (e.g., groundwater input)?</p> <p>Recommendation Please comment on the potential effects of PK (including slimes) to affect DO in the pit lakes. Please indicate whether DO may become depleted due to other factors and, if so, the potential effect to biota.</p>	<p>Jan 8: Under the normal development case, we do not expect increased productivity as a result of nutrient enrichment in the surface waters of the pit (as per Attachment 1 to the original report, Figure A-1, A-4 and A-7; e.g., phosphorus); therefore, we also do not anticipate dissolved oxygen (DO) depletions in the shallow surface water. As illustrated in figures throughout the report (e.g., Figure 6) and in the response to EMAB-9, the pit lakes are expected to be vertically mixed to different depths under different scenarios and along different time frames. In general, the volumes of water that mix with surface water (shown in blue in Figure 6 and brown in EMAB-9) will be oxygenated (similar to Lac de Gras, which is described below), whereas the waters near the PK-water interface will not. Whether from an oxygen demand in the PK slurry or from decomposition of long-term deposition of detrital matter, the volumes that remain well stratified at the lake bed (shown in brown in Figure 6 and blue in EMAB-9) will become oxygen-depleted over time. The rate and degree to which oxygen is consumed and replenished in the intermediate zone of the pit lake depends on the scenario and was not mechanistically modelled; however, this conceptual model provides information to consider potential effects on biota. Slimes will be limited to the sediment-water interface at the bottom of the pit where no biota are expected to live. It is anticipated that CCME guidelines for DO (and phosphorus, for example), as discussed further below, will be met above approximately 40 m depth in the pits under the normal development case (or deeper in some scenarios) and will not affect biota. In the unlikely event that full turnover occurs in the pit lakes, the degree of oxygen reduction would depend on both the timing and the scenario of the turnover event. In all scenarios, the pits will be filled primarily with surface water that is well oxygenated. A turnover event at this time would have little or no effect on dissolved oxygen levels. As shown in the response to EMAB-9, some lake water is predicted to replace pit lake water to a depth of over 120 m at least once per year in the Development Case. This lake water would also be well oxygenated, and would replenish some oxygen throughout that depth. The zone between 40-m and 120-m depth would likely have fluctuating oxygen concentrations, though it is uncertain what this range would be. With respect to DO, a worst-case turnover scenario would be a lake with a shallow water cap, during the initial period of highest rates of pore water release, and assuming a relatively high oxygen demand. However, this scenario is also less likely to occur, because it occurs at the time of maximum vertical density gradient and therefore maximum water column stability. While thought to be unlikely for the reasons above, a period of anoxia could occur following turnover under some scenarios. The duration of the anoxic period is unknown at this time. Should turnover in the pits occur, it is anticipated fish would move from the pits to</p>	


Lac de Gras to areas of higher DO (i.e., fish typically practice avoidance behaviours when presented with low DO). Should the fish be unable to exit the pits for any reason, mortalities could occur. The dissolved oxygen (DO) water quality guideline for the protection of aquatic life in cold water is 9.5 mg/L for early life stages and 6.5 mg/L for other life stages (CCME 1999). The guideline is considered protective of all forms of aquatic life and all aspects of the aquatic life cycle, including the most sensitive species over the long term. The cold water guideline for early life stages (i.e., 9.5 mg/L) is intended to apply only where and when early life stages occur and, therefore, applies to the shallow areas in the pit lakes where DO is not expected to be depleted. At DO concentrations below 9.5 mg/L or 6.5 mg/L, lethal and sublethal effects to biota may include mortality, loss of equilibrium, lack of opercular movement (in fish), reduced growth and reproduction, altered oxygen uptake and/or consumption, and reduced swimming capacity (CCME 1999). Fish are generally more susceptible to the effects of low DO, particularly under chronic exposure scenarios, relative to invertebrates; the 2 to 5 hour-LC50 concentrations (i.e., concentration that results in 50% lethality in a population) for invertebrates ranged from 0.03 mg/L DO in the mayfly *Ephemera vulgate* to 8.77 mg/L DO in the mayfly *Epeorus sylvicola* (CCME 1999). Some invertebrate species can tolerate low oxygen due to the ability to adapt via anaerobic metabolism, regulation of oxygen uptake, and escape behaviour (CCME 1999). In a review of acutely lethal data for trout species by BC MOE (1997) it was reported that mortality or loss of equilibrium generally occurred at DO concentrations between 1 and 3 mg/L (CCME 1999; BC MOE 1997). Algae and macrophytes are generally unaffected by low DO conditions because they are net producers of oxygen and are located near the surface waters, where DO depletion events are uncommon (in open water; BC MOE 1997). Baseline DO monitoring completed as a requirement of the Fisheries Authorization for the Mine site indicates that while Lac de Gras was generally well oxygenated during summer, there were some areas of decreased DO. Specific locations assessed during ice-cover conditions showed substantial DO gradients with low DO levels (2 to 4 mg/L) within 1 to 2 m of the bottom of the lake. These were natural occurrences (i.e., documented prior to operation of the Mine). In addition, concentrations were frequently below both the DO guidelines discussed above at water depths greater than 10 m. These conditions were confirmed during several years of baseline and early operational monitoring and have also been consistently observed during operational monitoring under the AEMP. These results indicate the existence of naturally low oxygen conditions in Lac de Gras. Based on the monitoring completed to date, there are no clear temporal or spatial patterns that explain the low DO concentrations and the results of recent monitoring do not provide any indication of a link to the Mine effluent discharge. The presence of these low DO conditions likely corresponds to very specific conditions in the lake bed sediments such as the presence of high organic carbon content.

Summary In the unlikely event that turnover was to occur in the pit lakes, a period of low DO could occur under some scenarios (the duration of which is unknown). Fish present in the pelagic zone would be expected to leave the area (i.e., practice avoidance behaviour) or, if fish were unable to egress, fish mortalities due to low DO conditions could occur. Under the Development Case, no significant DO depletions are expected to occur in the surface water, except near the interface with the PK,

			<p>where biota are not expected to inhabit. References CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Dissolved Oxygen (Freshwater). Fact Sheet. BC MOE (British Columbia Ministers of the Environment). 1997. Water Quality: Ambient Water Quality Guidelines for Dissolved Oxygen. Technical Appendix. February 1997.</p>	
31	Climate change	<p>Comment The report and modeling does not consider effects of climate change which may conceptually alter thermal regimes and mixing in the pit lakes. Given that the report notes the importance of meteorological conditions in determining the mixing between Lac de Gras and the pit lake, a sensitivity analysis with respect to future climate change (e.g., altered precipitation, temperature, and wind) effects on mixing with Lac du Gras as well as on the stability of stratification in the pit lake should be conducted.</p> <p>Recommendation Please provide a sensitivity analysis of potential effects of climate change on the modeling predictions.</p>	<p>Jan 8: A sensitivity analysis is being conducted that includes the sensitivity of air temperature (see EMAB-14 Sensitivity Run #5 (air temperature)) to model predictions. The results of this analysis will be provided for the Technical Session January 16-17, 2019.</p>	
32	Section 5.0, Conclusions, page 40	<p>Comment The report indicates that beyond 100 years, "the conceptual model suggests long-term stability of the predicted stratification for the three pits, possibly with a very small amount of upward diffusion of mass". It is not clear if the final conclusion is that stratification will be maintained beyond 100 years post-closure.</p> <p>Recommendation Please provide a statement clarifying the long term stability of stratification.</p>	<p>Jan 8: Both the Development Case (150-m water cap) and the Sensitivity Scenario 1 (50-m water cap) show upward diffusion below about 40-m depth, which appears to level off at or near its steady state within the 100-year time frame. The mixolimnion is predicted to remain similar to Lac de Gras throughout the 100-year time frame, and, based on the conceptual model informed by the first 100 years of model results, would be expected to remain so indefinitely. As noted in Section 4.1.1 (Golder 2018), it is anticipated that some load will reach the surface through chemical diffusion and occasional wind mixing. If this occurs, it will lead to lower concentrations in the monimolimnion over decades and centuries. As discussed in the response to EMAB-10, this load is small in consideration of the water exchange with Lac de Gras. As also noted in Section 2.2.3 (Golder 2018), the model assumed a static and level lake bed, whereas in reality, PK settling will lead to a deeper and narrower pocket of water that is more strongly stratified than predicted by the model. Therefore, over the next century and likely longer, stratification is expected to be stronger than suggested by the present modelling. In the very far future, perhaps centuries or millennia, enough mass may diffuse upward to erode the pycnocline and result in complete lake turnover. While turnover may be possible over very long time frames, it is likely not realistic to predict an accurate time frame for this to occur, as model uncertainty would become large over such a time frame. However, the conceptual model suggests that complete turnover would not occur until the majority of all dissolved mass is diffused from the system, meaning that the water reaching Lac de Gras under this scenario would also have lower concentrations of metals and other constituents.</p>	
33	Closure Objectives and Criteria	<p>Comment The closure objectives for mine workings (ICRP V. 4.0) do not currently contemplate effects associated with PK in the workings. The ICRP would benefit from objectives that address potential for resuspension of PK material (both during pit filling and for post-closure conditions) and interaction of PK material with the aquatic ecosystem. Criteria will be required to define acceptable outcomes for these objectives. These may include criteria that prescribe minimum depth of closure water cap and depth of water needed to avoid potential direct contact of fish with PK. Criteria related to stratification of the closure pit lakes may also be relevant because stratification is likely to remain important for maintaining suitable water quality at the pit lake surface where it interacts with Lac de Gras. The modelling</p>	<p>Jan 8: DDMI agrees that addition of a closure objective and closure performance criteria related to PK resuspension as suggested by EMAB would be appropriate if PK deposition proceeds. We do not agree that minimum depth of closure water cover, interaction of aquatic life with PK or stratification are appropriate closure objectives or criteria. These are closure design options or design criteria that will likely be used to achieve the closure performance criteria.</p>	

		<p>presented in the IR Response considers post-filling resuspension of fines, and concludes that this is unlikely to be an issue even for pits water covers as shallow as 20m. As a result, it should be possible to define achievable criteria for addressing an objective about potential resuspension.</p> <p>Recommendation If the WLWB grants approval for disposal of PK in pits, it should require updating of closure objectives and closure criteria to address changes in potential effects.</p>		
34	Closure Objectives and Criteria (continued)	<p>Comment Establishing criteria related to interaction of PK with the aquatic environment will likely need to consider the perspectives of the TK Panel including the following: "One panel member said that they have set nets 12–14 metres deep on an extremely hot day. One suggestion was to make sure PK was at least 30 metres below the surface of the water, as this is deep enough and fish will not go that deep without a food source to attract them. However, the Inuit contingent suggested that fish can go much deeper, up to roughly 100 metres, which may be a regional difference." (DDMI Traditional Knowledge Panel Session #11, Options for Processed Kimberlite, Section 2)</p> <p>Recommendation None</p>	Jan 8: Noted	
35	Engagement on possibility of using any of the open pits for PK disposal	<p>Comment EMAB discussed engagement with Diavik staff on December 5. Diavik acknowledged that its presentation to EMAB was limited to disposal of PK into the A418 pit, which is consistent with EMAB's view. We do not have access to presentations made to other organizations other than the information provided to the TK Panel, which makes no explicit mention of using pits other than A418 for PK disposal. Based on the above there is no evidence to support Diavik's statement that it requested approval to deposit PK into any mine working during its engagement on this submission.</p> <p>Recommendation Diavik should clarify which communities received presentations where disposal of PK was limited to the A418 pit.</p>	Jan 8: During all community presentations DDMI stated that the most likely mine working to receive PK was A418 based on the current mine. However DDM also clearly stated that if the mine plan were to change and, for example, another mine working would become available, a change could be considered. The diagrams presented and discussions that followed focused on the A418 example but it was stated that the same general concept could occur in another mine working, should one become available. DDMI acknowledges that the presentation and discussion that occurred with EMAB was the very first engagement on this subject and the presentation was limited to A418. The change to the discussion was made subsequent to the EMAB presentation.	

Fisheries and Oceans Canada: Francois Larouche

ID	Topic	Reviewer Comment/Recommendation	Proponent Response	Board Staff Response
1	General File	<p>Comment  Cover Letter</p> <p>Recommendation</p>		
2	Closure and Fisheries Act Authorizatoin	<p>Comment In the Response to WLWB Information Request, DDMI indicated that the proposed deposition of PK and PK slimes in the pits will be mitigated by a 50 meter cover of water. This cover will prevent bottom water mixing with surface water, which will result in water quality benchmarks below the AEMP; therefore no impact of fish and fish habitat are predicted. In the unlikely scenario of an unanticipated mixing event, DDMI believes that there are 13 parameters with potential to harm fish which could exceed the AEMP benchmark in the surface water. This will, however, be mitigated by a fast water dilution due to a high volume of exchange in Lac de Gras and the relatively smaller footprint of a pit in comparison to lake surface area. These two factors will consequently prevent potential risk on fish and fish habitat. DFO-FPP reminds DDMI that any changes to water quality that can affect fish and fish habitat will impact the current Fisheries Act Authorization and the compensation measures that are described in DDMI's No Net Loss Plan (NNLP) dated August 2001. This includes flooded pits that are not reconnected to provide fish habitat (note: reconnection is intended under the Fisheries Act Authorization SC98001), or a mixing event leading to fish mortality.</p> <p>Recommendation DFO-FPP recommends DDMI ensure that the water quality is such that the dyke can be breached and fish can return</p>	Jan 8: DDMI agrees with this DFO-FPP recommendation to ensure water quality such that the dikes can be safely breached. This is an approved closure objective that would remain if the Water License amendment to allow PK deposition to mine workings is approved.	

to this area for habitat as per the confirms of the authorization.

GNWT - ENR: Loretta Ransom

ID	Topic	Reviewer Comment/Recommendation	Proponent Response	Board Staff Response
1	General File	<p>Comment  ENR Cover Letter with Comments</p> <p>Recommendation</p>		
2	Review by Zajdlik & Associates Inc. and ARKTIS Solutions Inc.	<p>Comment ENR retained Zajdlik & Associates Inc. and ARKTIS Solutions Inc. (Zajdlik and ARKTIS) to review the Diavik Diamond Mines (2012) Inc. (DDMI) Response to WLWB Information Request on the deposition of Processed Kimberlite (PK) material into mine workings. This review included corresponding directly with DDMI to clarify several details. ENR would like to acknowledge the effort from DDMI to assist in resolving some of the questions regarding the review through providing further details on the modeling. However, as discussed below, ENR is of the opinion that further modeling and discussion on the modeling exercises is required at this time to better inform the water licensing process. The results of Zajdlik and ARKTIS' review, including the responses from DDMI are included in an attached memorandum, which is provided for the information of the Board.</p> <p>Recommendation n/a</p>	<p>Jan 8: Noted</p>	
3	Processed Kimberlite Leachate Composition	<p>Comment PK leachate data used in the model were obtained from DDMI (Golder 2018 Section 2.2.4.2). In order to better understand this model input, the raw data and a description of the data collection were requested from DDMI via personal communication. The data were obtained following hydrogeochemical evaluation of PK weathering done by DDMI (Moncur and Smith, 2014) in the PKC facility. The data received from DDMI includes summary statistics but not the raw data. As sampling locations were not provided by DDMI it was assumed that the data provided represents "beach pore water" only. ENR notes that the raw data may clarify the makeup of the expected pit porewater. Consistent with the description of PK porewater data as "beach porewater", the beach porewater sampling, results and discussion presented in (Moncur and Smith, 2014) were reviewed by ENR's consultants. The average beach porewater concentrations used by DDMI (Golder 2018) represent four locations within the PKC facility that were sampled over four years (Moncur and Smith 2014 Section 5.3). Moncur and Smith (2014) discuss changes in porewater chemistry that span orders of magnitude as PK weathers and also, lesser changes in concentration with core depth. Concentration changes are attributed to "decreases in moisture content resulting in deeper oxygen diffusion, the downward displacement of ions, and possibly cryoconcentration due to the upward migration of frost expelling dissolved ions". It is not clear how cores from these four locations and years fully represent the PK that is proposed to be deposited within the pits. This is especially significant as the PK deposition plan from DDMI is to pump PK from the processing plant to the A418 pit (Rio Tinto, 2018 Section 3.3.5). Under Sensitivity Scenario 2 (PK deposited in the pits; 20 m freshwater cap above the PK), DDMI (Golder 2018, Table 2) shows that predicted maximum daily concentrations of sulphate, nitrate and selenium in the surface water (top section) of A418 over the 100-year period after closure will exceed the current benchmarks. The coefficients of variation for sulphate, nitrate and selenium were estimated using the data provided in: "PK Pore Water - Provided to ENR Nov 30 2018.xlsx" and are 1.2, 2.4 and 1.3; respectively. The coefficients of variation (CV) are very high suggesting that exceedances could be much more pronounced than those currently predicted. The CVs for</p>	<p>Jan 8: 1) DDMI confirms that the data provided to Golder (included as Attachment #3) is PKC beach pore water quality as described in Moncur and Smith (2014). 2) ENR contacted DDMI on November 26, 2018 to obtain some additional modelling information and noted they would likely have one or two more follow-up questions. ENR followed-up on November 27, 2018 with a request for additional information that included information on the beach pore water quality. As explained by ENR they were looking for information on how much data supported the beach pore water estimates, how variable those measurements are and whether the data are representative of the entirety of the PKC. DDMI responded on November 23, 2018 and provided the summary statistics for the PKC beach pore water which provide both the number of samples and metrics of variability as requested by ENR. DDMI also provided a copy of Smith and Moncur (2014) so that ENR could fully understand how and where samples were collected. While DDMI can certainly provide the data used to calculate the statistics provided, it is unlikely that this raw data would address ENR's apparent concern regarding how representative these data are of pit pore water. The PKC beach pore water data were provided for the preliminary pit lake modelling as described in Golder (2018) as being the best currently available data from which to estimate pit pore water release chemistry. DDMI recognizes both the importance of understanding pit pore water chemistry and the importance of it being as representative of the actual PK material intended to be deposited. As such DDMI has initiated research on PK consolidation and pore water release with the University of Alberta and attach for information the research proposal (Attachment #2). Two PK materials have been selected for testing 1) PK slimes collected from the PKC and 2) A 50:50 blend of PK from A154N and A21 which is intended to be representative of PK material that is currently being considered for deposition in the mine workings. DDMI intends to use these data to be a better representation of pit pore water in future more definitive modelling undertakings planned for 2020, recognizing that PK deposition to mine workings is currently not planned before January 2022. 3) As noted in response to 2 above the PKC beach pore water chemistry is not intended to be representative of the entirety of the PK that may be delivered to the</p>	

elements comprising total dissolved solids (TDS) were also examined by Zajdlik and ARKTIS as an unknown amount of groundwater high in TDS will be moving through the pits and for a specific pit scenario (fixed dimensions and bathymetry, cap depth, fetch, surrounding surficial morphometry, surficial runoff, ice covered season duration, etc.) variation in TDS concentrations plays a key role in stratification. Following DDMI (Golder 2018 Section 2.2.4.2), TDS was represented by the following ions: calcium, magnesium, sodium, potassium, sulphate, chloride, silica and nitrate. The median CV for TDS constituents is 0.9 with a minimum of 0.7 and a maximum of 2.4 suggesting considerable uncertainty in the TDS porewater concentration. The CVs for all the elements provided, range from 0.29 (Sb) to 3 (Be) with a median of 1.2. The CVs suggest that if the full distribution of pore water concentrations is used in modeling, additional analytes may exceed benchmarks. The implications with respect to meromixis are not known as the sensitivity analyses did not include variations in PK pore water.

Recommendation 1) ENR recommends that DDMI confirm that the data provided to Golder for model inputs was comprised of beach porewater only. 2) ENR recommends that DDMI provide the raw data records that represent expected pit porewater. This should include fields describing location, date, sample depth (at time of sampling as this changed over the sampling period), redox potential, pH, alkalinity, dissolved oxygen, weathering time and moisture content. 3) ENR recommends that DDMI provide rationale illustrating that the available beach sample data are representative of the entirety of the PK that may be delivered from the processing plan to the pits under the proposed water licence amendment. 4) ENR recommends that DDMI demonstrate that the PK porewater has been sufficiently sampled using verifiable statistical design criteria to represent the actual material being considered for pit placement, and; that model predictions regarding meromixis and benchmark exceedances are not sensitive to using extremes in the available porewater input dataset.

mine workings. These data represent the best data currently available to support the preliminary modelling conducted (Golder 2018). Pit pore water quality is currently being investigated with the University of Alberta using PK material specifically selected to be representative of material most likely to be deposited in mine workings. 4) Please see 2 and 3 above with regard to representative sampling. A sensitivity analysis is being conducted that includes the sensitivity of PK water chemistry (see EMAB-14 Sensitivity Run #7) to model predictions. The results of this analysis will be provided for the Technical Session January 16-17, 2019. Please also note the response to EMAB-15 regarding the worst-case pore water release volumes assumed in the A418 modelling.

4

Consolidation Model

Comment DDMI (Golder 2018, Section 2.1.1) mentions a conceptual consolidation model in the Water Quality Modeling report. Material provided directly to ENR from DDMI following an information request from ENR ("ENR_IR_Consolidation model.pdf") mentions the Condes 1D model which is a "large strain" model. The specific implementation of this model is not mentioned nor is the method for estimating model input parameters. Geier et al. (2011) in a discussion of consolidation models state: "Although 1D large strain analyses are often the most appropriate modeling tool for conceptual planning or tradeoff studies" ... "3D large strain analyses are preferred for feasibility work". It is acknowledged that Golder (2018) has conducted modeling as a conceptual exercise. It is the opinion of Zajdlik and ARKTIS that a water licence amendment that will identify a preferred alternative should reflect a more detailed feasibility study. Fredlund et al. (2009) also express concerns regarding 1D models stating that "the use of 1D theory only will compromise the analysis such that pore-water pressures would be under-estimated and tailings consolidation times would be under-estimated". As noted by Zajdlik and ARKTIS, changes in tailings consolidation times may affect the rate of pore water expression and consequently affect model predictions.

Recommendation 1) ENR recommends that DDMI provide comprehensive details of the consolidation model used, as described by Zajdlik and ARKTIS. 2) ENR recommends that DDMI present any consolidation tests used to

Jan 8: ENR correctly acknowledges that Golder (2018) has conducted modelling as a conceptual exercise. DDMI accepts ENR's consultants opinion that a more detailed feasibility study is required and it is DDMI's intention to complete this feasibility level study, including updated modelling, prior to seeking WLWB approval to dispose of PK in mine workings in 2022. The PK consolidation testing being conducted by the University of Alberta (see response to ENR-3) is intended to inform this updated modelling.

		parameterize the consolidation model. If consolidation tests were not conducted, DDMI should discuss how coefficients for the consolidation model were selected.	
5	Groundwater	<p>Comment There is uncertainty in the conclusions of the modeling as a result of select assumptions regarding groundwater inflow to the pit. The modeling does not explore the sensitivity of groundwater inflows to the pit to justify the applicability of the assumption that groundwater inflows are not important to the pit lake predicted results. Additional information is requested to demonstrate the validity of not including groundwater inflows to the pit for two different temporal scales: 1) short-term, when the pit is filling; and 2) long-term after the pit is filled and chemical equilibrium between the pit waters and the groundwater is being approached. It is understood that groundwater inflows will affect pit lake water quality in the short term if these flows and associated constituent loading occur. The expected groundwater quantity and quality during pit filling is unknown. The relative contribution of groundwater to surface water to fill the pit is unknown. In the long-term, subject to the hydrogeologic conditions of the site, saline groundwater could enter the pit lake and the pit water quality will equilibrate with the groundwater with regards to quality. No information has been presented in regards to the hydrogeologic conditions in the vicinity of the pit, and the long-term influence of groundwater on pit lake water quality.</p> <p>Recommendation 1) ENR recommends that DDMI describe how it was determined that groundwater source terms were not required in the current model predictions, as well as, present any analysis completed to make this decision. 2) ENR recommends that DDMI discuss the hydrogeologic conditions in the vicinity of the pit including the stratigraphic units and groundwater quality with depth. 3) ENR recommends that DDMI discuss anticipated groundwater inflows to the pit during pit filling, the associated groundwater quality, and the stratigraphic units that contribute to these inflows. 4) ENR recommends DDMI discuss anticipated groundwater inflows/outflows to/from the pit in the long term (after pit is filled). 5) ENR recommends DDMI discuss the quantity of groundwater inflows (short-term and long-term) that is required before this source term becomes important to consider in the model.</p>	<p>Jan 8: 1) For this preliminary modelling it was assumed that the pits would be filled instantly by water from Lac de Gras and therefore, groundwater inflow during filling and after the pits were filled was negligible. The reasons for not considering groundwater seepage in this preliminary modelling is because the focus was on understanding the effects of the consolidation of PK on the stability of the water column, and because the total groundwater inflow will be small under a rapid fill scenario, as was demonstrated by the 2010 model. Please see also the response to EMAB-5. A sensitivity analysis is being conducted that includes the sensitivity of groundwater inflows (see EMAB-14 Sensitivity Run #9) to model predictions. The results of this analysis will be provided for the Technical Session January 16-17, 2019. 2) The pre-mining conceptual model for the site hydrogeology included six hydrostratigraphical units: lakebed sediments; near-surface weathered country rock; competent country rock; kimberlite pipes; contact zone between kimberlite and country rock, and discrete fault zones in the country rock. Hydraulic conductivity in Canadian Shield bedrock typically decreases with depth. The hydraulic conductivity of kimberlite is higher than the surrounding crystalline shield country rock. Baseline field investigations suggested permafrost extends 240 m below East Island, decreasing at the margins of Lac de Gras; under the lake no permafrost is present. Permafrost is considered impermeable. Lac de Gras acted as a constant-head boundary, resulting in a near-hydrostatic groundwater regime prior to mining. Open-pit and underground mining requires dewatering for safe and effective mining, and results in draw-down cones around the mine developments (open pit and underground). Initially, inflows typically consist of a mostly connate water component, but lake water becomes the more prominent component of the pumped water as dewatering progresses. When dewatering ceases, it is expected the hydrogeological regime will return to near-hydrostatic conditions, similar to pre-development conditions. 3) The pit lakes will be created by filling the empty, inactive pits and underground with water pumped in from Lac de Gras and groundwater that naturally seeps into mine area. Depending on the length of the filling period, the contribution of groundwater seepage to the total fill volume will vary – with faster filling rates leading to smaller volumes of groundwater. If the pit lake is created by pumping water from Lac de Gras over one open water period, then the contribution from groundwater seepage is very small. If the water pumped from Lac de Gras occurs over several years, then the contribution from groundwater rises. In 2010, Golder undertook a "Preliminary Pit Lake Study", dated December 9, 2010. In the Base Case, it was assumed that the water pumped from Lac de Gras would be sufficient to fill the pit over one open water season (estimated to be pumped at 4.4 m³/s). Over the same period, groundwater inflow, based on observed inflows to the mine, varies from a high of 0.33 m³/s when the pit is empty to zero when the pit is full. At the maximum inflow of 0.33 m³/s, groundwater inflow represents less than 8 percent of the total water flooding the pit. Lake Total Dissolved Solids (TDS) concentration, based on observations was assumed to be 18.5 mg/L and the groundwater concentration was assumed to be 375 mg/L based on concentrations measured in monitoring ports prior to mining. The TDS of groundwater inflow to the A154 has been</p>

			<p>consistently between 300 mg/L to 400 mg/L since December 2010. At ENR's request, on December 6, 2018 DDMI provided ENR with summary water quality statistics for SNP 1645-75 which represents groundwater inflow to A154/A418. A copy is included as Attachment #5. 4) As provided to ENR on December 4, 2018 once any pit has been flooded, eliminating any differential head, the groundwater flow will return to regional pre-development levels which is very small. We have not modelled this and the view is the professional opinion from the Golder hydrogeological modeller. 5) In 2010, Golder undertook a "Preliminary Pit Lake Study", dated December 9, 2010. Model runs were undertaken that assumed that the pit would initially be filled with groundwater to a specified level prior to being filled with water pumped from Lac de Gras in one open water period. The modelled scenarios consisted of three different groundwater levels of 195 masl, 295 masl, and 411 masl. Initially filling the bottom of the pit with groundwater results in a stable stratified system. The simultaneous introduction of surface water and groundwater to the pits over one open water season in the Base Case simulation results in a high degree of mixing with TDS concentrations predicted to be about 20 mg/L, which is only 8% higher than the median of the observed TDS in Lac de Gras of 18.5 mg/L. For this Base Case it was predicted that ten years after full flooding the pit lake would be fully mixed through its entire depth at a concentration of about 20 mg/L. From this it was concluded that groundwater inflow were most important for establishing initial conditions if there was no PK deposition.</p>	
6	Pit lake re-filling	<p>Comment Although the pits will be "rapidly filled" (Golder 2018 Section 3.0) the time between breaching the dikes and filling of the pit lakes will allow some volume of groundwater to enter the pit. The length of time required for pit filling is unclear at this time.</p> <p>Recommendation 1) ENR recommends DDMI provide additional detail on the anticipated time required to fill the pits.</p>	<p>Jan 8: ENR is directed to the DDMI Closure and Reclamation Plan V4.0 Appendix X-7.1 Pit Filling Pump Rate and Appendix X-7.2 Back-Flooding Design.</p>	
7	Flushing of wall rock	<p>Comment The report discusses that flushing of wall rock is considered to be "negligible in comparison to the "other" inflows to the pit" (Golder 2018 Section 3.0). As groundwater inflows to pits following flooding are also assumed to be negligible as is site runoff, aside from precipitation, what "other" inflows to the pit are being referred to?</p> <p>Recommendation 1) ENR recommends DDMI should discuss in further detail what other inflows aside from precipitation Section 3.0 of the report is referring to.</p>	<p>Jan 8: As listed in Section 2.2.3 of Golder (2018), hydrologic inputs to the A418, A154 and A21 are: 1. inflow from Lac de Gras into the pit lakes through the breaches in the dike 2. direct precipitation on the lake 3. local runoff from the mine area (included in the A418 Pit Lake model only) 4. volume of pore water released to the pit lake as a result of PK consolidation (in scenarios that include PK). The other inflows that were assumed to be negligible, for the purpose of this study, include groundwater inflows during the filling period and rock wall runoff. For ease of comparison the calculated total loads over 100 years from each source is shown in Table 3 (see Attachment #9). The main source of loading is from PK pore water release to the pit lake.</p>	
8	Hydrodynamic model rates and coefficients	<p>Comment As noted by Zajdlik and ARKTIS regarding the hydrodynamic model, the maximum vertical eddy viscosity is set to 0.001 m²/s, which are three orders of magnitude lower than the default (1 m²/s). Comments in C-35 Appendix (Coles and Wells 2011) seem to indicate that choosing a maximum vertical eddy viscosity other than 1 m²/s is for backwards compatibility only. This point has also been raised by GNWT in the past in the context of the Jay Pit development and a verbal answer from Dominion Diamond Mines ULC and Golder during a technical modeling workshop in Mississauga, Ontario on July 6, 2015 was that this was part of the calibration exercise. Cole and Wells (2011) emphasize the requirement for adequate and appropriate calibration. It is understood that calibration cannot occur for a pit lake that has not yet been constructed but the lack of discussion</p>	<p>Jan 8: 1) The value referred to in the model is the "maximum value of the vertical eddy viscosity" or AZMAX. Setting this value to a higher number allows for more turbulent systems, such as the rivers and estuaries that are referred to in the CE-QUAL-W2 User Manual (Cole and Wells 2008). The values provided in that document are 0.00001 m²/s for a stratified reservoir to 1 to 5 m²/s for more turbulent systems such as rivers or estuaries. This maximum value improves model efficiency and does not affect results for low-turbulence systems such as a deep reservoirs because the maximum value is higher than the applied value. As noted by Cole and Wells (2008), "Setting [AZSLC] to EXP and [AZMAX] greater than 1.0E-2 will result in very low model time steps." This, in turn, can lead to long run times and numerical dispersion. For these reasons, the value of 0.001 m²/s was deemed to balance</p>	

		<p>regarding how calibration choices could affect model outcomes is notable. DDMI (Golder 2018 Section 3.0) does state that rates and coefficients are a source of model uncertainty.</p> <p>Recommendation 1) ENR recommends that DDMI discuss why the very low vertical eddy viscosity value was selected. 2) ENR recommends that given the importance Coles and Wells (2011) ascribe to calibration, DDMI should perform a sensitivity analysis of the rates and coefficients used in those variables used to calibrate the model under at least one modeling scenario. 3) ENR recommends that DDMI should provide conceptual drawings for each model with an overall diagram showing linkages between models. This should be accompanied by all default rates and coefficients with a rationalization for the selected values. 4) ENR recommends that DDMI provide a sensitivity analysis to determine which parameters and / or assumptions most affect modelling conclusions.</p>	<p>computational efficiency can be improved by conservatism. The value applied in the model (0.001 m²/s) is on the low to mid end of the range, which is likely conservative because the pit lake would behave more similar to a reservoir. To evaluate whether the value selected for AZMAX affected the results of the model, a value of 1 m²/s was used in the sensitivity analysis (response to EMAB-14). For comparison, the contour plots of TDS and tracer are shown in Figure 4. This figure shows the development case from figures 5 and 6 of the report, along with a sensitivity scenario using AZMAX=1 m²/s. This simulation shows that the vertical mixing was not affected by the choice of a higher value. There are small differences in results, possibly due to changes in time step, or infrequent events. The vertical eddy viscosity does not become as high as the selected maximum value in this analysis, or does so rarely, and does not affect the overall behaviour of the system or conclusions drawn from the simulations completed using the lower value. As mentioned elsewhere, the modelling completed to date is preliminary and provides a suitable level of understanding to proceed to more detailed studies. 2) Please see the response to part 1. 3) There are no linked models for this preliminary modelling. Each pit lake has its own hydrodynamic model, and pore water was entered into the hydrodynamic model as a time series. Model linkages may be included in more detailed evaluations in the future. 4) A sensitivity analysis has been undertaken, as described in the response to EMAB-14.</p>	
9	Water Quality Model	<p>Comment DDMI (Golder 2018 Section 2.2.4.1) uses Lac de Gras input water quality represented by data collected between 2016 and 2018 during the open-water season, from the sampling locations near the pits: "MF3-1 and MF3-2 representing quality of inflows from Lac de Gras to the A418 and A154 pit lakes and MF3-3 and MF3-4 representing quality of inflows from Lac de Gras to the A21 Pit Lake (Table 1)". It is unclear on why DDMI chose to use water from operations as a model input rather than expected water conditions that would be present at closure. Additional details would assist in understanding the assumptions and rationale for this decision by DDMI.</p> <p>Recommendation 1) ENR recommends that DDMI discuss why they chose water quality that represents the operations phase rather than ambient water quality reflecting the post-closure phase.</p>	<p>Jan 8: DDMI chose to assume operational water quality as it is expected to represent a conservative (worst-case) scenario as water quality concentrations are expected to decline over time as the treated effluent discharge is reduced post-closure.</p>	
10	Dike breaches	<p>Comment DDMI (Golder 2018) assumed sizes for dike breaches and assessed the effect of increasing breach size for A418. However, it is unclear how these sizes were selected.</p> <p>Recommendation 1) ENR recommends that DDMI provide the rationale for selection of breach attributes (width, depth and number) and how the assumptions made will affect current modelling conclusions. ENR does note that one sensitivity analysis does address part of this recommendation.</p>	<p>Jan 8: Breaching the dikes (about 2 to 3m depth from low water and 30m wide) will create entrances for fish and some circulation of water. The breach sizes and number have been minimized to restrict water circulation to allow a higher productivity quiescent (motionless) habitat to develop. The minimum size, number and locations of the breaches were determined by Transport Canada based upon requirements for navigation and are a condition of their approval to construct the dikes (Navigable Waters Protection Act Approval of August 3, 2000). Please see also Diavik Closure and Reclamation Plan V4.0 Section 5.2.4.3.</p>	
11	Temperature	<p>Comment In DDMI's Water Quality Modelling report, Section 2.2.4.1, DDMI states that there were no observable water temperature data for Lac de Gras, and therefore used a temperature time-series was developed using data from Snap Lake dated from 2008 and 2012. ENR notes that temperature data are available in the field notes for each AEMP water quality sample. These include temperatures for grab samples and temperature depth profiles. It has been shown that temperature differences have been noted in different parts of Lac de Gras (Golder, 2014, 2017) and temperature is a key driver of water stability.</p>	<p>Jan 8: The hydrodynamic model requires daily input time series of water temperature, which was not available for Lac de Gras for the long-term period. The available monitored daily temperature data for Lac de Gras (May 10, 2013 to September 6, 2013 (Golder 2014); April 19, 2016 to September 18, 2016 (Golder 2017) is plotted (see Figure 5 in Attachment #9) against the monitored data for Snap Lake (2006 to 2017) and the continuous time series used in the hydrodynamic model. The continuous time series was developed based on Snap Lake data:</p> <ul style="list-style-type: none"> • for each month, an average monthly temperature was calculated from available data 	

		<p>Recommendation 1) ENR recommends that DDMI discuss the implications of using temperature time series from the much smaller Snap Lake (Golder, 2018, Section 2.2.4.1) on the water quality modeling results provided to date.</p>	<p>and assigned to the 15th of that month • for months when samples were not collected, the long-term average temperature was used to represent temperature for that month • in addition to monthly average temperature, all samples collected in any given month were also used to represent temperature for that month • data were linearly interpolated to produce a daily time series for the simulation period. As can be seen from Figure 5, the synthetic and observed time series of water temperatures between the two lakes compares reasonably well, with higher temperature fluctuations in Snap Lake.</p>	
12	Cumulative effects	<p>Comment Based on the review of information presented thus far, there may be cumulative effects of contaminant loading from the pit lakes following connection with Lac de Gras relative to anticipated losses from the site (PKC facility, country rock piles, etc.). However, this has not been assessed by DDMI at this time.</p> <p>Recommendation 1) ENR recommends that DDMI assess the cumulative effects of contaminant loading from the pit lakes following connection with Lac de Gras relative to anticipated losses from the site (PKC facility, country rock piles, etc.).</p>	<p>Jan 8: The potential combined effects of various site runoff sources as well as loadings from the pit lakes will be assessed as part of the Closure and Reclamation Plan. The closure hydrodynamic model for Lac de Gras has not yet been developed and will be required to complete this assessment. The output from the pit lake modeling will be an input to the broader lake hydrodynamic model.</p>	
13	Risk assessment of the effects	<p>Comment Zajdlik and ARKTIS have recommended that DDMI address the WLWB's suggestion to conduct a "risk assessment of the effects to surface water quality in the pits and Lac de Gras" particularly now that mixing is predicted to occur.</p> <p>Recommendation ENR recommends that DDMI conduct a risk assessment of the effects to surface water quality in the pits and Lac de Gras, as suggested by the WLWB, particularly now that mixing is predicted to occur.</p>	<p>Jan 8: DDMI has assessed the potential effects to surface water quality in the unlikely event that mixing occurred as a result of an underwater pit slope failure. Please also refer to the response to EMAB-5 relating to meromixis and hydrodynamic conditions.</p>	
14	Additional Modelling	<p>Comment ENR notes that it has been determined during this review process that meromixis may not occur as originally expected by DDMI, which has direct implications to the water quality, biota, and management plans. As described in the attached memorandum from Zajdlik and ARKTIS, there are outstanding concerns regarding the conceptual modeling completed to support the Water License amendment. Based on the importance of potentially adverse environmental effects to pit lakes following closure; that a model is only a prediction of effects based on myriad assumptions; and, that the conclusion regarding meromixis has changed with this more recent model, ENR is of the opinion that DDMI should use a more representative site model to better predict future conditions. ENR has provided general recommendations on what should be included in subsequent modeling exercises to better inform the review process below.</p> <p>Recommendation 1) ENR recommends that DDMI present a discussion of contrasting conclusions if the more detailed modelling outcome differs from that using the previous model. This should also include acknowledgement of the stochastic nature of those model inputs identified in the sensitivity analyses as this may markedly affect modelling conclusions via Monte Carlo analyses.</p>	<p>Jan 8: DDMI does not agree with ENR's assertion that conclusions regarding meromixis have changed and refers ENR to the response provided to EMAB-5. Pending approval of the concept to deposit PK in mine workings, it has always been DDMI's intent to complete additional closure modelling in the future once more specifics are known about the PK to mine workings operation plans and specific investigations are complete. As DDMI has repeatedly stressed, the Golder (2018) modelling is preliminary. It is DDMI's opinion that the additional closure modelling can be conducted as a condition of the Water License Amendment as has been done for other applications to deposit processed kimberlite into mine workings at other NWT mine sites. DDMI also wishes to clarify that Monte Carlo analysis is not practical for hydrodynamic simulations. Monte Carlo simulations may be carried out in a stochastic water balance and water quality model that is intended for that purpose, and can provide probabilistic predictions of pit lake and Lac de Gras water quality. Hydrodynamic simulations are too computationally demanding and as such, uncertainties in inputs are evaluated using sensitivity analysis as described in the response to EMAB-14.</p>	
15	References	<p>Comment Cole T.M. and S. Wells. 2011. CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.7; User Manual. Prepared for US Army Corps of Engineers Waterways Experiment Station. Washington, DC, USA. Fredlund, M.D., M. Donaldson and G.G. Gitirana. 2009. Large-Strain 1D, 2D, and 3D Consolidation Modeling of Mine Tailings. Proceeding, Tailings and Mine Waste Conference, Banff, Canada. Geier, D., G. Gjerapic, and K.E. Morrison. 2011. Determination of Consolidation Properties, Selection of Computational Methods, and Estimation of Potential Error in Mine Tailings</p>	<p>Jan 8: N/A</p>	

Settlement Calculations. Proceedings Tailings and Mine Waste 2011, Vancouver, BC. Golder, 2017. Diavik Diamond Mines (2012) Inc. Aquatic Effects Monitoring Program 2016 Annual Report. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada. Golder. 2014. Fish Report in Support of the 2013 AEMP Annual Report for the Diavik Diamond Mine, NT. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada. Golder. 2018. Diavik Mine – Water Quality Modelling of A418, A154 And A21 Mined Out Pits. November 2, 2018. Moncur, M. and L. Smith. 2014. Four-Year Hydrogeochemical Field Investigation of Processed Kimberlite Weathering at Diavik Diamond Mines Inc. Submitted To: G. Macdonald, Diavik Diamond Mines Inc Oct. 2014. Rio Tinto. 2017. Closure and Reclamation Plan – Version 4.0 Diavik Diamond Mines (2012) Inc. April 2017 Rio Tinto. 2018. Deposition of Processed Kimberlite into Mine Workings W2015L2-0001 Amendment Request. June 1, 2018. WLWB (We?èezhii Land and Water Board). 2018. Information Request for Diavik Water Licence (W2015L2-0001) Amendment Application for Processed Kimberlite to Mine Workings August 31st, 2018.

Recommendation n/a

WLWB: Anneli Jokela

ID	Topic	Reviewer Comment/Recommendation	Proponent Response	Board Staff Response
1	PK Characterization	<p>Comment Some kimberlite tailings have been shown to have significant clay content which can have an important effect on settling characteristics of the solids and quality of the supernatant water. There is no discussion of clay mineralogy in the document; however, slimes within the PKC are described as extremely slow to consolidate (Amendment Request, page 29). If settleability is an issue, it could impact the rate and magnitude of consolidation. It could also preclude decanting of water, which could prevent DDMI from operating at its stated target water levels in the pit.</p> <p>Recommendation (1) Is testing available from the A21 pit and other remaining underground areas to evaluate the mineralogy and settleability of fine PK? (2) If so, please provide findings and conclusions on how test work was integrated into consolidation analysis and resuspension analysis. (3) If not, please describe the feasibility and time requirements for completing such tests.</p>	<p>Jan 8: The consolidation and pore water release estimates are preliminary and are not based on Diavik specific material testing. DDMI has initiated research on PK consolidation and pore water release with the University of Alberta and attach for information the research proposal (Attachment #2). Two PK materials have been selected for testing 1) PK slimes collected from the PKC and 2) A 50:50 blend of PK from A154N and A21 which is intended to be representative of PK material that is currently being considered for deposition in the mine workings. A final report with the testing results is expected in Q4 2019.</p>	
2	PK Characterization	<p>Comment The model was run using a generic settleable water quality constituent to evaluate the resuspension of fines associated with turbulent mixing of the lake (Golder memo, page 3). However, very little information is provided on the characteristics that are represented by the settleable material (e.g., particle size).</p> <p>Recommendation To better support the conclusion that a 20 m water cap is sufficient to prevent resuspension of fines, demonstrate that the generic 'settleable' tracer used in the modelling is representative of PK characteristics expected to be deposited to the pits.</p>	<p>Jan 8: The generic settleable constituent in CE-QUAL-W2 represents a discrete fraction of material, whereas the actual material is distributed along a continuum of particle sizes. The CE-QUAL-W2 demonstrates a conceptual notion of particle settling and is not intended to demonstrate the full range of particle behaviour – that is beyond the scope of that model. A stronger line of evidence is the analog data, as shown in the response to WLWB-3.</p>	
3	PK Characterization	<p>Comment To further support that little resuspension is expected with a 20 m water cap, a number of literature references were cited (Golder memo, page 15). All analogues identified in these references are metal mines (i.e., Colomac, Equity Silver, Faro, Mt. Polley and Premier Gold).</p> <p>Recommendation (1) Demonstrate that cited mines are appropriate analogues. (2) Are better analogues available, such as other pits backfilled with PK or PK storage facilities? (3) Are settling tests available from the A21 pit and other remaining underground areas to draw comparisons with other facilities? If so, please provide these results and comparisons. If not, please describe the feasibility and time requirements for completing such tests.</p>	<p>Jan 8: To consider whether the cited analogs are appropriate, turbidity profile data from Ekati's Beartooth Pit were evaluated alongside the cited empirical data from Vandenberg and Litke (2017). Turbidity provides an indirect measure of all particulate matter in the water column. The comparison is shown in Figure 6 at similar scales to show all data, and the data are shown in Figure 7 in finer scale to provide resolution at the low turbidity measured within the top 40 m of water. The comparison shows that Beartooth Pit has a similar overall pattern of turbidity and therefore a similar pattern of suspended particulate matter. In both pits, the majority of the water column has low turbidity (about 5 NTU in Springer Pit and 1 NTU in Beartooth Pit). Both pits occasionally have</p>	

		<p>slightly elevated turbidity at surface, likely due to wind mixing events or inputs from the mine. For example the Beartooth Pit was still receiving processed kimberlite up until June 2017. Both pits have highly elevated turbidity above the sediment-water interface, likely due to resuspension of particulates immediately above the interface or from incomplete settling within that zone. As shown in Figures 8 to 11, some of the particulate metals behave similarly to the TSS, indicating that they are being removed from the water column. There is a concordance between Beartooth Pit and Springer Pit, from which assumptions were drawn to develop this model, suggesting that the systems are behaving similarly overall, and supports the use of Springer Pit as a proxy system. From this comparison, the following conclusions can be drawn: 1. The use of analog data to support the assumptions around settling of particulates in Diavik's future pit lakes is reasonable. 2. The pit lake that contains PK demonstrates the same overall patterns of particulate settling as described in Vandenberg and Litke (2017) – notably, the residence time in Springer Pit Lake was demonstrated to provide sufficient settling capacity to bypass the water treatment plant and use Springer Pit water as permitted discharge water. Beartooth pit lake has lower turbidity throughout the top 40 m of water column than Springer Pit, and demonstrates similar particulate metal settling. 3. All of Diavik's envisioned deposition scenarios include more than 40 m of water column above the PK. Therefore, multiple lines of evidence (conceptual model, numerical model, analog data) unanimously support the notion that the majority of particulate matter will effectively settle in the pit lakes. Additional testing of Diavik's materials would not be deemed necessary unless there is some property of these materials that is significantly different from the cited analogs that would indicate the foregoing comparison to be invalid. References Vandenberg, J., and S. Litke. 2017. Beneficial Use of Springer Pit Lake at Mount Polley Mine. Mine Water and the Environment.</p>		
4	Initial conditions	<p>Comment DDML's responses to the Information Request provides water quality predictions for post-closure (Golder memo). Recommendation Are there any implications for water quality during operations? Please consider scenarios both with and without the ability to draw reclaim water from the pit.</p>	<p>Jan 8: With the ability to reclaim decant water from the pit area where the PK slurry was deposited DDML does not anticipate any material implications for operations water quality. In concept the reclaim from within the mine working area would operate the same as the reclaim pond in the PKC. Both reclaim waters would be either sent to the North Inlet for reuse or treatment and discharge or sent directly to the process plant for re-use. The main difference would be the location of the reclaim barge/pump. Some groundwater inflow would be included in the reclaim from the mine workings possibly influencing the reclaim water quality itself but given reclaim water and mine water all mix in the North Inlet anyway (regardless of the location of the reclaim barge/pump) there would be no impact on operational water quality in the North Inlet. WLWB Staff asked that we also consider the case where decant water is not able to be reclaimed from the mine working area but do not provide any rationale or assumption around when or why this might happen. Assuming for some reason that there could be no reclaim of decant water from the mine working area where PK had been deposited there would be a positive impact on operational water quality. The water quality parameters that are currently associated with PKC pond water and would be associated with decant water from a mine area with deposited PK would no longer be released to the North Inlet and so would no longer influence the operational water quality of the North Inlet or water quality of the North Inlet Water Treatment Plant operational discharge. To a</p>	

			<p>lesser extent the groundwater inflow that would report to the mine working that contained PK would no longer be pumped to the North Inlet and this reduced volume of mine groundwater going to the North Inlet could also influence the North Inlet water quality.</p>
5	Initial conditions	<p>Comment The starting point for the water quality modelling is after flooding of the pit and breaching of the dykes. There is no information on the expected rate of filling. Information provided in the interim Closure and Reclamation Plan indicates that lake water would be siphoned into the open pits at a rate that would not impact lake levels or outflow rates. The presence of fine tailings in the pit and setting up conditions that will support meromixis may also be important considerations in determining both the rate and method of filling.</p> <p>Recommendation Provide further information on the expected rates of filling, methods for minimizing disturbance of fine tailings during the filling period, and potential effects of filling method on subsequent development of meromixis.</p>	<p>Jan 8: WLWB Staff are referred to the DDML Closure and Reclamation Plan V4.0 Appendix X-7.1 Pit Filling Pump Rate and Appendix X-7.2 Back-Flooding Design for further information regarding rates of filling. If the Water License Amendment is approved and PK can be deposited in mine workings then further consideration will be given to the closure design given the presence of fine PK material and the filling method/rate on development of meromixis.</p>
6	Initial conditions	<p>Comment The starting point for the water quality modelling is after flooding of the pit and breaching of the dykes. At that point in time, the model assumes that the pit is filled with lake water over unconsolidated tailings. Water quality inputs are the lake water quality and porewater quality from the current PKC Facility beach areas. This assumption appears to omit other types of water and sources of loading that will report to the pit during the closure (i.e., before the pit reaches the spill point). According to capacity calculations presented in Section 3.3.2 of the Application, excess slurry water will be released from the tailings as they settle, groundwater will enter the pit, and reclaim water will be removed from the pit during operations. At the end of operations, under the Development case presented in Section 3.3.2 of the Application, the pit will contain 5.23 Mm³ of tailings, 0.79 Mm³ of combined process water and groundwater, and 28 Mm³ of lake water. Additionally, alternative decant strategies referenced in the Application may result in higher amounts of process water and groundwater. During filling, groundwater will continue to enter the pit - albeit at a progressively decreasing rate. The amount of groundwater entering the pit will depend on the rate of filling and changes in the hydraulic gradient over time. Additional sources of loading include contributions from underground backfill and oxidized rock on the pit walls. Note that Research Task 5.4 of Appendix VIII-2 of the interim CRP Version 4.0 discussed DDML's intentions to improve models of water quality for each of the A21, A418, and A154 pits. Specifically, DDML stated "Estimates of initial flooded water quality will be updated by applying the results of the wall washing experiments, pit wall lithology mapping and ongoing mine water inflow and quality and quantity monitoring. A range of lake fill rate and initial groundwater fill level scenarios will be considered." Stratification relies on the difference in densities between layers. In this case, density will be governed by the dissolved solids content of the water. The assumption that the surface water layer will be unaffected by groundwater inflow, site runoff, other contributing sources, and/or some mixing of pore water upon filling is not conservative.</p> <p>Recommendation (1) Provide further information on the initial concentrations expected in the pit lake at the start of the model given the expected range of inflows and sources of loading that could occur during filling. This should include a scenario with a higher decant level. (2) Additionally, provide a</p>	<p>Jan 8: A sensitivity analysis is being conducted that includes the sensitivity of initial model conditions (see EMAB-14 Sensitivity Run #8) to model predictions. The results of this analysis will be provided for the Technical Session January 16-17, 2019.</p>

		<p>stability run using water quality for the freshwater cap that reasonably accounts for mixing of pore water with filling, and other contaminant sources not specifically modelled.</p>	
7	Initial conditions and Application, Attachment 1 - Section 3.3.2	<p>Comment DDMI has indicated that decant (reclaim) volumes would be contingent on the decant strategy, which has not yet been developed. The amount of water recovered from the mine workings and reclaimed to the Process Plant could affect the amount of available reclaim water for process operations, water quality during the pit filling period, the time required to fill the pit, and potentially the limnology of the pit.</p> <p>Recommendation (1) Provide more details/information on the decant strategy or decant alternatives. (2) Explain how the decant strategy would affect the rate of reclaim water withdrawal and the potential rate of freshwater makeup water withdrawal. (3) Describe potential effects of the decant strategy on the resulting pit water quality. (4) If no additional information is available at this time, outline when the decant strategy will be finalized.</p>	<p>Jan 8: The decant strategy will be finalized with the Processed Kimberlite Containment in Mine Workings Design Report with water balance considerations addressed in Water Management Plan – Update for PK to Mine Working. As per the List and Schedule of Studies Relating to the PK to Mine Workings Amendment previously submitted and referenced in WLWB-26 below, the Design report is scheduled for submission H1 2020 and the updated Water Management Plan in H1 2021.</p>
8	Initial conditions	<p>Comment The interim Closure and Reclamation Plan indicates that stable meromictic conditions have always been expected in the pit lakes at closure due to higher salinity groundwater and geometric conditions. In contrast, the base case in the Golder model shows well mixed conditions and does not consider the influx of groundwater.</p> <p>Recommendation (1) Clarify whether there is further information on groundwater inflows or chemistry that has been considered in the more recent modelling. (2) If there has been no change, clarify why groundwater inflows have not been considered.</p>	<p>Jan 8: 1) There is further information on groundwater inflow quantities and quality that will be considered in the sensitivity scenarios described in the response to EMAB-14. 2) The 2018 study assumed that the pits were filled instantaneously by water pumped from Lac de Gras, resulting in negligible groundwater inflow. Further detail can be found in the response to EMAB-5. Model sensitivity scenarios described in EMAB-14 will consider filling of the A154 and A418 open pits with groundwater inflow and water pumped from Lac de Gras.</p>
9	Initial conditions	<p>Comment There is no data for ammonia in the tailings porewater samples used to represent consolidation water. Additionally, it is not clear whether the tailings porewater samples represent water in the saturated or unsaturated zone of the PKC facility.</p> <p>Recommendation (1) Explain why ammonia data for the PK porewater was not provided? (2) If available, provide ammonia data for the PK porewater. If not available, please describe the feasibility and time requirements for obtaining this data. (3) Please clarify the source of the tailings porewater results used in the modelling, and whether this is representative of saturated or unsaturated conditions.</p>	<p>Jan 8: 1) Please see response to EMAB-29. 2) Ammonia data for the PK pore water can be found in Moncur and Smith (2014) that has previously been submitted to the WLWB. See also response to WLWB-10. 3) The beach pore water data are from Moncur and Smith (2014) with the specific data provided for Golder (2018) included here as Attachment #3. Of the data summarized in Attachment #3 about half are from unsaturated intervals (n=28) and half are from saturated intervals (n=27).</p>
10	PK porewater quality	<p>Comment Appendix VIII-2 of the interim CRP, Version 4.0 describes research completed with respect to PK porewater quality. There are several references to documents that could provide insights into porewater quality. Three examples include the following: (1) Moncur, M.C., Smith, L.J.D. 2014. Four-Year Hydrogeochemical Field Investigation of Processed Kimberlite Weathering at Diavik Diamond Mines Inc. Prepared for Diavik Diamond Mines Inc. October 2014; (2); Moncur, M.C., Smith, L.J.D., Paktunc, D. 2015. Comparison of laboratory and field-scale predictions of processed kimberlite effluent in the Arctic. Proceedings from the 10th International Conference on Acid Rock Drainage. April 20-25, Santiago, Chile; and (3) Moncur, M.C., Birks, S.J., Taylor, E. 2015. Sources of Dissolved Ions to the Processed Kimberlite Containment Facility at Diavik Diamond Mines Inc. Prepared for Diavik Diamond Mines Inc. September 2015.</p> <p>Recommendation (1) Confirm whether these reports have been previously provided to the WLWB. (2) If yes, please confirm which submission they have been provided with. (3) If not, please provide these reports as part of DDMI's responses. (4) Summarize how the findings of these reports may inform the prediction of water quality in the pits that have received any PK.</p>	<p>Jan 8: 1) Report #1 and #3 have been previously submitted to the WLWB. 2) Report #1 was submitted as Appendix II-1 of the 2014 Annual Interim Closure and Reclamation Progress Report – October 2014. Report #3 was submitted as Appendix II-1 of the 2015 Annual Interim Closure and Reclamation Progress Report – January 2016 3) Report #2 is included as Attachment #7 4) The PKC beach pore water data have been used in the preliminary Golder (2018) pit lake modelling as the best current estimate of pore water quality. The data used are included as Attachment #3. DDMI has initiated investigations with the University of Alberta to collect more specific and representative information on pore water quality to inform future model updates (Attachment #2).</p>

11	Sensitivity analysis	<p>Comment A 1D consolidation analysis is provided with no supporting data or assumptions (Golder memo, page 10). It seems possible that the rate and magnitude of consolidation could be different than that predicted and modelled.</p> <p>Recommendation (1) Evaluate the sensitivity of the modelling to the consolidation curve input to determine how important this factor is in determining water quality outcomes. (2) If the model is determined to be sensitive to the rate and magnitude of consolidation, provide support for the data and assumptions used in the consolidation analysis.</p>	<p>Jan 8: A sensitivity analysis is being conducted that includes the sensitivity of the consolidation rate (see EMAB-14 Sensitivity Run #6) to model predictions. The results of this analysis will be provided for the Technical Session January 16-17, 2019.</p>	
12	Sensitivity analysis	<p>Comment The consolidation model assumes that the pit is filled with 23.9 Mt of tailings and releases a total of 11.3 Mm³ of porewater over a 200-year consolidation period (most within the first 50 years). The actual development case assumes that 4.2 Mt of tailings would be deposited in the pit. Assuming that the amount of consolidation is proportional to mass, the actual porewater release would be expected to be less (likely on the order of 2 Mm³). The assumption of 11.3 Mm³ of porewater may not be conservative in terms of modelling the stability of the water column.</p> <p>Recommendation Provide a sensitivity analysis showing the potential effects of lower porewater volumes on the stability of the water column.</p>	<p>Jan 8: A sensitivity analysis is being conducted that includes the sensitivity of the consolidation rate – PK pore water release rate (see EMAB-14 Sensitivity Run #6) to model predictions. The results of this analysis will be provided for the Technical Session January 16-17, 2019.</p>	
13	Sensitivity analysis - Unanticipated Mixing	<p>Comment As described in the previous comment, the amount of porewater assumed to be released during consolidation does not appear to have been adjusted to reflect expected tailings volumes. As a result, this may be overestimating the amount of porewater released. Overestimating the amount of porewater released could lead to a highly conservative estimate of metals concentrations in the unanticipated mixing calculations.</p> <p>Recommendation Provide calculations to show the potential effects of lower porewater volumes on concentrations occurring in the unanticipated mixing scenario to show whether stable conditions are essential for protecting water quality.</p>	<p>Jan 8: It is acknowledged that the inputs used to represent pore water volumes and chemistry in the model may be conservatively high. However, the model bathymetry leads to over-estimation of mixing, as described in the response to EMAB-32, and this is likely a much more important factor than the uncertainties related to pore water expression. The current model presents a reasonable level of understanding for proceeding to a more detailed effort to reduce such uncertainties, as discussed in the response to GNWT-14.</p>	
14	Sensitivity analysis	<p>Comment Several other model inputs were not evaluated through sensitivity analysis. Specifically, downward turbulent mixing (which will affect stratification) may be sensitive to the maximum vertical eddy viscosity (non-default value used in the model), and wind speed and direction. Based on results for Scenario 1, where wind mixing is evident in the upper contour plots, 18 years of historical wind data appears to have been applied in a repeating loop.</p> <p>Recommendation (1) For vertical eddy viscosity, provide the typical range and explain how the model is influenced by these values. Are model results for the marginal case (i.e., 50 m water cap) sensitive to a reasonable range for this parameter? (2) For wind speed, does this data set include events representative of extreme events? Can an extreme event that causes complete degradation of stratification be estimated, and is that event realistic? (3) In other meteoric input data, has climate change been considered?</p>	<p>Jan 8: (1) Please see the response to GNWT-8. (2) The wind speed record spans nearly two decades, and is considered representative of conditions. It is possible that more extreme events than have been recorded during this period could occur, and such events are included in the sensitivity analysis described in the response to EMAB-14. (3) A climate change scenario is included in the sensitivity analysis described in the response to EMAB-14.</p>	
15	Sensitivity analysis	<p>Comment Sensitivity analyses have not been provided for the 50 m water cap scenario, which has been shown to be stable in the current model. This cover has been recommended as a minimum water depth for ensuring stable conditions in the pit.</p> <p>Recommendation Demonstrate that the 50 m water cap is stable under a range of conditions, including different starting concentrations, breach size, eddy viscosity, and wind.</p>	<p>Jan 8: A sensitivity analysis is being conducted of potentially significant drivers of pit lake conditions. The list of sensitivity runs/scenarios is provided in EMAB-14. The results of this analysis will be provided for the Technical Session January 16-17, 2019. The sensitivity analysis is being conducted on the A418 Development Scenario from Golder (2018), which has a 150 m water cap and is more representative of DDMI's current plans. Should DDMI's plans change to include a water cap thickness significantly different from what is proposed in the Development Scenario,</p>	

			updated model simulations will be provided to evaluate the change.
16	Sensitivity analysis	<p>Comment The model currently extends to 100 years. There is some breakdown in meromixis in the Development case and Scenario 1 near the end of the modeled period. Maximum concentrations in the surface layer of the pit in the Development case occurred at the end of the 100 year modelled period.</p> <p>Recommendation Clarify whether concentrations in the upper part of the water column are likely to increase significantly beyond the modelled timeline.</p>	<p>Jan 8: As discussed in the response to EMAB-32, concentrations in the top of the water column are not expected to increase beyond the modelled 100-year time frame.</p>
17	Mixing mechanisms	<p>Comment The timing of ice-off for the pit lake is predicted to occur before Lac de Gras (mid-June compared to mid-July). As both water bodies warm in summer months, and with exchange possible through the breach, it is possible for colder Lac de Gras water to enter the pit lake. If this happened, cold water from Lac de Gras would likely plunge to the depth where it is neutrally buoyant. This density current could bring in kinetic energy that could affect mixing.</p> <p>Recommendation (1) Has this mechanism been considered in the modelling? (2) If not, can this be modelled and if so, when could these results be provided? (3) Can DDMI describe what the thermocline both inside and outside the pit is expected to be during representative periods through the year and explain how this might influence mixing?</p>	<p>Jan 8: The modelling domain did not allow for a mechanistic understanding of ice formation of the pit lakes when they will be connected to Lac de Gras. Only a small segment of Lac de Gras was represented in this 2-dimensional model to allow for a simulation of water exchange, based on observed water level fluctuations in the near-field. The ice formation was de-coupled from Lac de Gras, which leads to a longer ice-free period, which is conservative because it also leads to more wind mixing, as discussed in Section 2.4 Golder (2018). In reality, the ice melting dates of the pit lakes are anticipated to be similar to those of Lac de Gras, especially after the dykes are breached. However, even if this is not the case, water would not plunge to the bottom of the pit because melting ice is 0°C, which is less dense than the 4°C water that will comprise most of the pit lake (see Golder (2018) figures, e.g., Figure 3). Water at 0°C would remain near the surface where it is neutrally buoyant; this is a fundamental property of water that leads to reverse stratification under ice in natural lakes.</p>
18	Mixing mechanisms	<p>Comment In Scenario 1 and 2, pore water is slowly released to the surface layer, which is then lost through flow exchange with Lac de Gras. A potential risk here is that mixing occurs more quickly than indicated by the model and a greater flush rate to the surface is realized, resulting in higher surface concentrations. Also, if density stratification is insufficient, there is potential for a mixing event where stratification is not strong enough to withstand mixing. This could lead to stratification degrading quickly and releasing a large loading to the surface. Little oscillations in the upper contours of the Scenario 1 plots indicate that wind mixing plays a large role in moving upper loadings through the water column, suggesting that instability is possible. In an earlier Information Request (IR1f), the WLWB requested a risk assessment to show the effects on surface water quality in the pits and Lac de Gras in the event that unanticipated mixing occurs. DDMI has provided predictions for the pits, but not for Lac de Gras. The above comment suggests that mixing may be possible and that an analysis of the effects on Lac de Gras should be provided. The unanticipated mixing scenario shows that several parameters would exceed AEMP benchmarks. DDMI has commented that this would occur for a relatively short duration and has cited the results for breakdown of meromixis in Scenario 2 to show the expected duration of effects. However, Scenario 2 has a shallower water column than the Development scenario and would be expected to exhibit more rapid flushing and exchange of water.</p> <p>Recommendation (1) Provide a risk assessment that includes potential effects to Lac de Gras. (2) To more clearly show the potential effects of the unanticipated mixing scenario, consideration should be given to modelling dispersion of contaminants in Lac de Gras following a mixing event.</p>	<p>Jan 8: For this preliminary modelling and results analysis DDMI has considered effects to Lac de Gras based on conservative (worst-case) modelling assumptions and by assessing the water quality results only within the pit area where the concentrations would be highest, i.e. again worst-case. Changes in water quality within the broader Lac de Gras area would be significantly less than within any of the pit lakes. To determine how much less and over what extent, application of a hydrodynamic model for the whole of Lac de Gras would be required. As also noted in response to ENR-12, DDMI intends to develop this whole lake hydrodynamic model to assess combined effects of various site runoff sources as well as loadings from pit lakes as part of the Closure and Reclamation Plan. This modelling will include the dispersion of contaminants in Lac de Gras following a possible mixing event as suggested by WLWB Staff.</p>
19	Studies on pit filling rates and flooding designs	<p>Comment Appendix VIII-2 of the interim CRP, Version 4.0 describes research completed with respect to closure of the open pits, underground and dyke area. Two reports are referenced as providing information related to</p>	<p>Jan 8: 1) Confirmed 2) They are included with CRP V4.0 as Appendix X-7.1 and X-7.2 respectively. 3) n/a 4) If the Water License Amendment is approved PK deposition to mine workings would reduce the amount of water</p>

		<p>the impact of fill rate on water quality: (1) Golder. 2017a. Description of Underground and Pit Filling Rates Estimate. Submitted to Diavik Diamond Mines (2012) Inc. January 5, 2017; and (2) Golder. 2017b. Scoping-Level Back-Flooding Design Description for Interim Closure and Reclamation Plan. Submitted to Diavik Diamond Mines (2012) Inc. January 5, 2017.</p> <p>Recommendation (1) Confirm whether these reports have been previously provided to the WLWB. (2) If yes, please confirm which submission they have been provided with. (3) If not, please provide these reports as part of DDMI's responses. (4) Summarize how the findings of these reports are influenced by the proposal to deposit PK into the pits and/or how they may inform the prediction of water quality in the pits that have received any PK.</p>	<p>required to flood the mine workings in areas where PK has been deposited. The reports provide a range of possible fill rates that will be used in support of the final closure flood design.</p>
20	FPK:CPK ratio	<p>Comment The storage volume requirements are based on assumptions regarding the split of FPK and CPK, called the FPK:CPK ratio. The following is stated in the Application: (a) Original design ratio = 68:32; (b) Pre 2016 actual ratio = 87:13; (c) Target ratio with "degritter" = 40:60; (d) Low end ratio with "degritter" = 50:50; (e) High end ration with "degritter" = 70:30; (f) Design ratio without "degritter" for A418 backfill = 75:25. The volumes as stated in Table 5 (Amendment Request, page 18) use the 75:25 ratio; however, based on the pre-2016 actual ratio realized without the "degritter" (as is planned during depositing into A418), it appears that a ratio of 87:13 should be applied. A ratio of 87:13 would increase FPK by 12% in the pit and would likely affect the resulting decant volumes and consolidation calculations.</p> <p>Recommendation (1) Confirm which ratio would be used during deposition of PK into mine workings. (2) If different than the one used in the calculation for storage volume requirements, demonstrate how the anticipated ratio influences decant volumes and consolidation calculations. (3) If different than the one used in the calculation for storage volume requirements, describe how this influences the predicted effects to water quality and formation/stability of meromictic conditions.</p>	<p>Jan 8: 1) Detailed design of PK deposition has not yet been completed so the final ratio that will be applied cannot be confirmed at this time. As noted 75:25 is the current planning assumption. 2) If a higher FPK ratio is used (i.e. something like 87:13) this would increase the total amount of FPK that would be deposited into the mine workings and increase the amount of pore water released. 3) As noted in EMAB-15 DDMI expects that the pore water release assumed for the preliminary modelling is worst-case. The A418 preliminary modelling assumed a total pore water release of 11.3 Mm3 from 23.9 Mt of PK whereas the scenario that would be representative of the conditions that could be expected at Diavik would only include 4.1Mt of PK – less than 20 percent of what was assumed in the preliminary modelling. Changing the assumed FPK:CPK ratio assumption to 87:13 would increase the total amount of PK from 4.1 Mt to around 4.8 Mt which is still well below the 23.9 Mt used in the preliminary modelling so it would not change the preliminary modelling results or conclusions.</p>
21	FPK Density	<p>Comment DDMI states that field trials indicate a current FPK density of 0.75 t/m3 (Amendment Request, page 18). For design volumes, FPK density was conservatively assumed to be 0.8 t/m3 (Amendment Request, page 21). Later in the Amendment Request (page 29), when discussing how slimes from the PKC Facility would be pumped to A418 at closure, the density of FPK slimes in the PKC Facility and in A418 are stated to be 0.4 t/m3 and 0.5 t/m3, respectively.</p> <p>Recommendation (1) Provide clarification for why design volumes used a higher dry density for FPK compared to field trials. (2) Provide rationale for why a higher density is assumed for PK slimes in the A418 Pit as compared to the PKC Facility. (3) Describe the implications of this assumption on the predicted effects to water quality and formation/stability of meromictic conditions.</p>	<p>Jan 8: DDMI believes this question has already been asked and answered within the first round of review comments on DDMI's Water License Amendment Application. DDMI directs WLWB Staff to the previous EMAB-17 comment and DDMI's response of August 23, 2018. A sensitivity analysis is being conducted that includes the sensitivity of PK consolidation rates to model predictions (see EMAB-14 Sensitivity Run #6). The results of this analysis will be provided for the Technical Session January 16-17, 2019.</p>
22	Deposition Methods - Application Attachment 1 - Figure 8	<p>Comment Although DDMI has described the alignment of the tailings discharge pipeline to the A418 pit and part way down the haulage ramps, there is no description of how tailings will be discharged into the mine workings, including drifts and backfilled or partially backfilled stopes. Deposition methods will need to be resolved to ensure that there are no large voids that do not fill with tailings, as these could collapse during later stages of filling or post-filling, and result in rapid settling and disturbance of the tailings solids - and potentially lead to release of suspended sediments.</p> <p>Recommendation Explain how tailings</p>	<p>Jan 8: Specifics of deposition methods have not yet been developed. DDMI acknowledges the concern raised by WLWB Staff and will ensure it is considered in the planning of the deposition methods that will proceed if the Water License Amendment is approved.</p>

		discharge will occur during filling of the underground workings to prevent formation of void spaces in the workings.	
23	Effects on fish habitat	<p>Comment The responses provided by Diavik in the Information Request Response regarding questions on potential effects on fish habitat appear to only consider potential water quality effects.</p> <p>Recommendation (1) Describe potential changes in fish habitat conditions (other than potential effects to water quality) at closure/post-closure because of the proposed Amendment. (2) Demonstrate how potential mitigation measures may limit these potential impacts to fish habitat.</p>	<p>Jan 8: 1) The only anticipated physical change to fish habitat is the depth of the deep water (pelagic) habitat. As described in response to EMAB-28 the pelagic habitat was designed for use as a thermal refuge for fish. The hydrodynamic model results indicate that for the A418 pit lake for example, the thermocline is located approximately 5 to 15 m below surface, depending on the season. Below the seasonal thermocline, temperatures are predicted to be uniform at less than 5°C. In the Development Scenario the pelagic zone would be at least 150 m deep so deposition of PK material would not impact the amount of usable pelagic habitat. 2) No potential impacts to physical fish habitat have been identified from deposition of PK to mine workings. The mitigation proposed for water quality of a minimum 50m water cover would also ensure adequate pelagic habitat.</p>
24	Effects on fish	<p>Comment DDMI states that "...surface water quality is predicted to remain below AEMP benchmarks with deposition of PK and PK slimes, provided the closure water cap is a minimum of 50m deep. AEMP benchmarks are expected to be protective of fish and fish habitat. As such, fish and fish habitat are unlikely to be impacted at closure/post-closure and no further analysis/demonstration was required." This appears to assume no interaction between fish and the PK at the bottom of the pit lake because DDMI's explanation is focussed on the water quality within the 50 m cap.</p> <p>Recommendation (1) Are DDMI's conclusions related to effects on fish based solely on predicted water quality concentrations within the freshwater cap? (2) If not, please explain what other factors were considered. (3) If so, provide supporting information for why fish are not expected to interact with, or be affected by, the PK deposited in the pits.</p>	<p>Jan 8: 1. DDMI's conclusions related to effects on fish are based on predicted water quality in the surface water, not at depth near the sediment-PK interface (i.e., not within the freshwater cap). 2. A number of factors were considered, either as part of the initial reporting or as part of these comment responses. These factors include modelled water quality under the development scenario, modelled water quality under a pit lake turnover event scenario (see EMAB-6), the likelihood of pit lake turnover, fish habitat use in the pit lakes (i.e., pelagic and surface water; see EMAB-7), trophic interactions (EMAB-8), available toxicity data specifically for Diavik's processed kimberlite (e.g., Liber and Doig [2016], see EMAB-6), dissolved oxygen (DO) thresholds for aquatic life (see EMAB-30), and consideration of AEMP benchmarks and/or generic acute toxicity benchmarks under development conditions (see EMAB-28), or a worst-case (i.e. maximum concentrations) modelled pit lake turnover event (see EMAB-28). 3. As above. References: Liber K., Doig L. 2016. Characterization of Extra Fine Processed Kimberlite Tailings from Diavik Diamond Mine Processed Kimberlite Containment Pond. Final Report. Submitted to Diavik Diamond Mines Inc. January 2016.</p>
25	Connection between A418 and A154 - Figure 4.1 of the ICRP version 4.	<p>Comment The figure shows a schematic of the three underground mining areas with a haulage ramp connecting to deeper levels in the A418 deposit. It also shows a large number of connections between the A154N and A154S workings.</p> <p>Recommendation (1) Clarify whether the haulage tunnels shown in green in that figure have been constructed or are still planned, and if so, where bulkheads are envisioned to limit connections between the A418 pit and the other workings during filling of A418 pit. (2) Assuming DDMI is still considering use of the A154S or A154N workings, please describe how the A154S or A154 N would be isolated from the other workings.</p>	<p>Jan 8: 1) DDMI confirms that the haulage tunnels shown in green on Figure 4.1 of CRP V4.0 have either been constructed since the figure was produced or are planned for construction before 2022 (lower elevations). DDMI recommends WLWB Staff refer to Figure 6 of DDMI's Water License Amendment Application – Attachment-1 Amendment Overview – Deposition of Processed Kimberlite into Mine Workings. Figure 6 shows the potential locations for 3 bulkheads between the A418 and A154 mine areas. These are shown at the 9266m, 9130m and 9085m elevations. 2) Bulkhead requirements have not been considered for possible PK deposition in A154S or A154N. These would be identified if DDMI determines PK deposition into A154N or A154S is planned and will depend on what activities are occurring in the connected mine areas. DDMI expects that if the Water License Amendment is approved, bulkhead locations and designs will be submitted to the WLWB prior to PK deposition and included as a Water License condition.</p>
26	Schedule of Studies Relating to the Amendment	<p>Comment In response to public review comments on the Amendment Application, DDMI provided an attachment that outlined the schedule of studies relating to the PK to mine workings Amendment Application.</p> <p>Recommendation (1) Please confirm if that schedule is still reflective of DDMI's current plan for completing these studies. If not, please</p>	<p>Jan 8: An updated schedule of reports and studies, including those being proposed as submissions for WLWB approval, is provided in Attachment #10.</p>

	provide an updated schedule. (2) Outline which of the studies listed in the schedule are being proposed as submissions requiring Board approval.	
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Joseph Mackenzie, Chair
Wek'èezhii Land and Water Board
PO Box 32
Wekweètì, NT X1A 3S3
Canada

8 January 2019

Dear Mr. Mackenzie:

Subject: DDMI Response to Reviewer Comments and Recommendations re: Water Licence W2015L2-0001 Amendment Request for the Deposition of Processed Kimberlite to Mine Workings

Diavik Diamond Mines (2012) Inc. (DDMI) submitted an Application to the Wek'èezhii Land and Water Board (WLWB or 'the Board') to amend Water Licence W2015L2-0001 to allow for the deposition of Processed Kimberlite (PK) into mine workings on June 1, 2018. As part of the Board's preliminary screening process, reviewers provided comments and recommendations on DDMI's November 6, 2018 response to Information Requests (IRs). DDMI is pleased to provide its response to reviewer comments and recommendations in the Board's approved tabular format.

DDMI has included the following additional information as attachments in response to reviewer comments and recommendations:

- Consolidation model summary (Attachment #1) – ECCC-2; EMAB-15
- Fine tailings consolidation and release water characterization study proposal (Attachment #2) – ECCC-2; GNWT-ENR-3; WLWB-1 and 10
- Pore water quality summary (Attachment #3) – ECCC-3; EMAB-15; GNWT-ENR-3; WLWB-9 and 10
- Proposed mine workings sample plan (Attachment #4) – ECCC-5
- Summary statistics for groundwater (Attachment #5) – GNWT-ENR-5
- Predicted time series of A418 pit lake constituent concentrations (Attachment #6) – EMAB-27
- Comparison of laboratory and field-scale predictions of processed kimberlite effluent in the Arctic (Attachment #7) – WLWB-10
- Meromixis and longterm stability of the stratification (Attachment #8) – EMAB-6
- Tables and figures (Attachment #9) – EMAB-9, 10 and 28; GNWT-ENR-7 and 11; WLWB-3
- Updated schedule of studies for the PK to Mine Workings Proposal (Attachment #10).

DDMI appreciates the specificity of review comments received as these were useful for informing our ongoing studies and advancing the conceptual analyses. To this end, we are conducting the following requested model sensitivity analyses that will be provided for the Technical Session on January 16-17, 2019:

- PK/sediment temperature
- Addition of local runoff from mine area
- Wind sheltering coefficient
- Wind speed
- Air temperature
- Consolidation inflow rate
- PK pore water chemistry
- Initial pit lake condition (to include 5m of pore water before filling & contribution from wall rock runoff)
- Groundwater inflows

Given the time available to respond to the reviewer comments and recommendations, and that the Board's Preliminary Screening decision is scheduled to occur following the Technical Session and Technical Session Information Requests and Responses, DDMI views this as a suitable and necessary approach.

DDMI's response to reviewer comments and recommendations, including related attachments, has been uploaded to the Board's Online Review System.

Please do not hesitate to contact the undersigned if you have any questions related to this submission.

Sincerely,



Sean Sinclair
Superintendent, Environment

cc: Anita Ogaa, WLWB
Anneli Jokela, WLWB

To predict post-closure water quality of Diavik pit lakes, an estimation of fine PK settlement within the pits was required to provide rates of pore water release into the pit lake water column. For this preliminary water quality assessment, a simple one dimensional consolidation model (Condes 1D) was developed to estimate post closure fine PK settlement in the A418 and A154 pits over 200 years.

The consolidation model was run using available properties of Diavik Fine PK. The model assumed a 330 m thick deposit of fine PK placed in one year and the following input material properties:

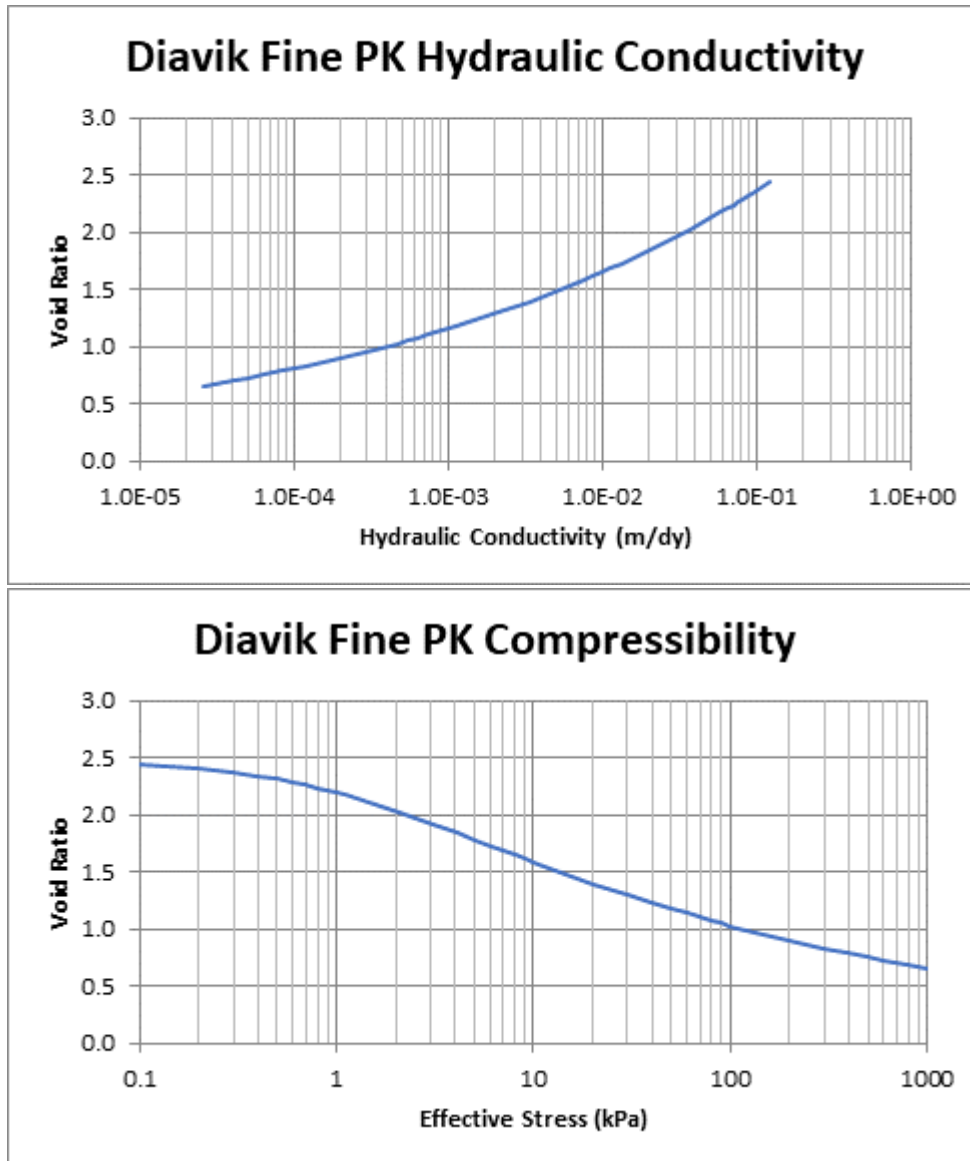


Figure 1: Input compressibility and permeability (hydraulic conductivity) curves used in the consolidation model

The one-dimensional consolidation model results provide the change in density for this 330 m thick deposit over 200 years post-closure.

The change in density of this 330 m thick one-dimensional fine PK column was used to estimate a unit of pore water release per year per tonne of tailings. This was then scaled into three dimension, for each of the A418 and A154 pits based on the estimated total tonnage of fine PK to be placed in these pits. Model results are presented in Figure 2 and Table 1. A21 was assumed to have the same release rate profile as A154.

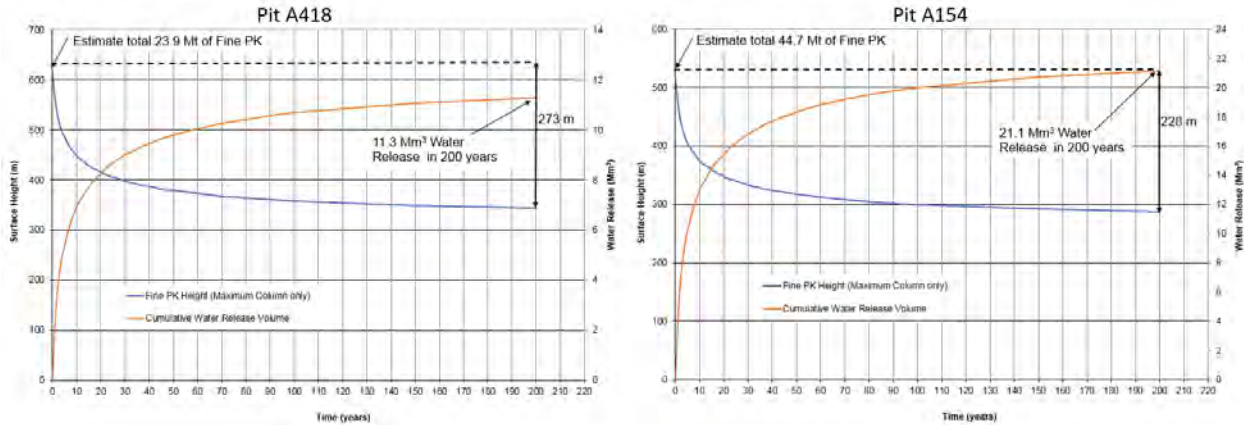


Figure 2: Estimated Pit Post Closure PK Settlement and Water Release

Table 1: Predicted PK Pore Water Release for A418 and A154 Pit Lakes

Time (Day)	A418		A154	
	PK Pore Water Release (Mm ³)	Cumulative PK Pore Water Release (Mm ³)	PK Pore Water Release (Mm ³)	Cumulative PK Pore Water Release (Mm ³)
0	0	0	0	0
730	2.2	2.2	4.0	4.0
1095	1.3	3.4	2.4	6.4
1460	0.85	4.3	1.6	8.0
1825	0.62	4.92	1.2	9.2
2190	0.49	5.41	0.91	10.11
2555	0.4	5.81	0.74	10.86
2920	0.33	6.14	0.62	11.48
3285	0.29	6.43	0.54	12.02
3650	0.25	6.67	0.47	12.48
4015	0.22	6.9	0.41	12.9
4380	0.2	7.09	0.37	13.26
4745	0.18	7.27	0.33	13.6
5110	0.16	7.43	0.3	13.9
5475	0.15	7.58	0.28	14.18
5840	0.14	7.72	0.25	14.43
6205	0.13	7.84	0.24	14.67
6570	0.12	7.96	0.22	14.89
6935	0.11	8.07	0.2	15.09
7300	0.1	8.17	0.19	15.28

ATTACHMENT #1

7665	0.096	8.268	0.18	15.46
8395	0.18	8.44	0.33	15.79
9125	0.16	8.6	0.29	16.08
9855	0.14	8.74	0.27	16.35
10585	0.13	8.87	0.24	16.59
11315	0.12	8.99	0.22	16.81
12045	0.11	9.1	0.2	17.01
12775	0.1	9.2	0.19	17.2
13505	0.093	9.292	0.17	17.38
14235	0.087	9.379	0.16	17.54
14965	0.081	9.46	0.15	17.69
15695	0.076	9.535	0.14	17.83
16425	0.071	9.607	0.13	17.97
17155	0.067	9.674	0.13	18.09
17885	0.063	9.738	0.12	18.21
18615	0.06	9.798	0.11	18.32
22265	0.26	10.06	0.48	18.81
25915	0.21	10.26	0.38	19.19
29565	0.17	10.43	0.31	19.5
33215	0.14	10.57	0.26	19.76
36865	0.12	10.69	0.22	19.98
55115	0.39	11.08	0.74	20.72
73365	0.22	11.3	0.4	21.12



PROPOSAL: Diavik Fine Tailings Consolidation and Release Water
Characterization

Prepared For:

Leanna Smith

Diavik

Prepared by:

Dr. N.A. Beier, PhD, PEng

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Department of Civil and Environmental Engineering

University of Alberta Geotechnical Centre

21/08/2018

1	COST OF PROPOSAL SUMMARY.....	1
2	PROJECT DELIVERABLES AND SCHEDULE.....	1
3	LABORATORY SERVICES SUMMARY.....	2
3.1	LARGE STRAIN CONSOLIDATION TEST.....	2
3.2	HYDRAULIC CONDUCTIVITY (PERMEABILITY) TEST.....	3
3.3	PORE FLUID SAMPLING.....	4
3.4	UNDRAINED SHEAR STRENGTH.....	4
3.5	SEDIMENTATION TEST.....	6
3.6	PARTICLE SIZE DISTRIBUTION (PSD).....	6
3.6.1	<i>Dispersed Hydrometer-Sieve Test.....</i>	<i>6</i>
3.6.2	<i>Non-dispersed Hydrometer-Sieve Test.....</i>	<i>6</i>
3.7	DETERMINATION OF BASIC PROPERTIES.....	7
3.8	PRINCIPAL INVESTIGATOR HONORARIUM.....	7
	APPENDIX A STANDARD OPERATING PROCEDURE FOR ON-SITE GEOCHEMICAL ANALYSES OF EXPELLED POREWATER AND PREPARING SAMPLES FOR EXTERNAL WATER ANALYSES.....	8

3 LABORATORY SERVICES SUMMARY

3.1 LARGE STRAIN CONSOLIDATION TEST

The objectives of the LSC tests are to determine the following parameters for 4 separate PKC samples in a cold room at nominal air temperature of 4 to 5 C.

- To determine the relationship between effective stress and void ratio.
- To determine the relationship between void ratio and hydraulic conductivity.
- To determine the relationships between void ratio and shear strength and effective stress and shear strength.

Diavik will provide four tailings mixtures to be tested. We can accommodate only four LSC setups in the cold rooms at one time (i.e. two cells for geotechnical analyses and two duplicate cells for geochemical analyses). It is anticipated up to 16 weeks would be needed for consolidation to complete. Therefore, two rounds of LSC testing will be required in order to test all four tailings mixtures (with duplicates).

An LSC test will be performed in a standard consolidation apparatus (150 mm dia. x 300 mm high). The LSC apparatus used in this testing program confines the slurried material so it can be tested at any water content. The first applied stress, the self-weight of the slurry, can be about 0.3 to 0.5 kPa. Effective stresses up to about 10 kPa are applied by dead loads acting on the piston (Figure 5). Effective stresses over 10 kPa are applied in a loading frame by an air pressure Bellofram. Subsequent loads are incrementally doubled for each load step up to 600 kPa. The setup of the LSC test used at the geotechnical centre of the University of Alberta is shown in Figure 1 and 2.

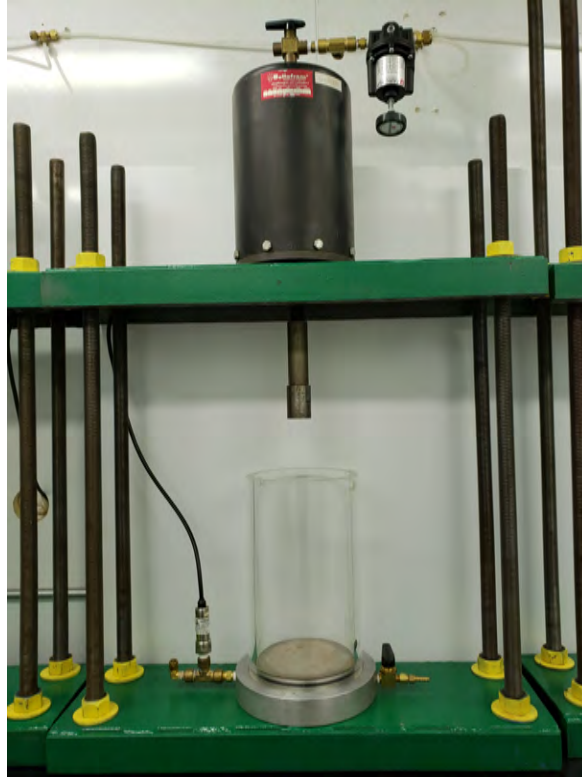


Figure 1. Setup of the large strain consolidation LSC test at the Geotechnical Centre of the University of Alberta.

3.2 HYDRAULIC CONDUCTIVITY (PERMEABILITY) TEST

The permeability is measured at the end of consolidation for each load step. An upward flow constant head test is performed with the head difference h ($h=h_0-h_1$) being kept small enough so that seepage forces will not exceed the applied stress and cause sample fracturing during the permeability test (Figure 2).

In one dimension, water flows through a fully saturated soil sample in accordance with Darcy's empirical law is given by:

$$q = Aki$$

or

$$v = \frac{q}{A} = ki$$

Where q = volume of water flowing per unit time, A = cross-sectional area of soil sample corresponding to the flow q , k = coefficient of permeability, i = hydraulic gradient, and v = discharge velocity. The hydraulic gradient, i , is given by:

$$i = \frac{h}{l} = \frac{h_o - h_1}{l}$$

Where

l = the length of the sample.

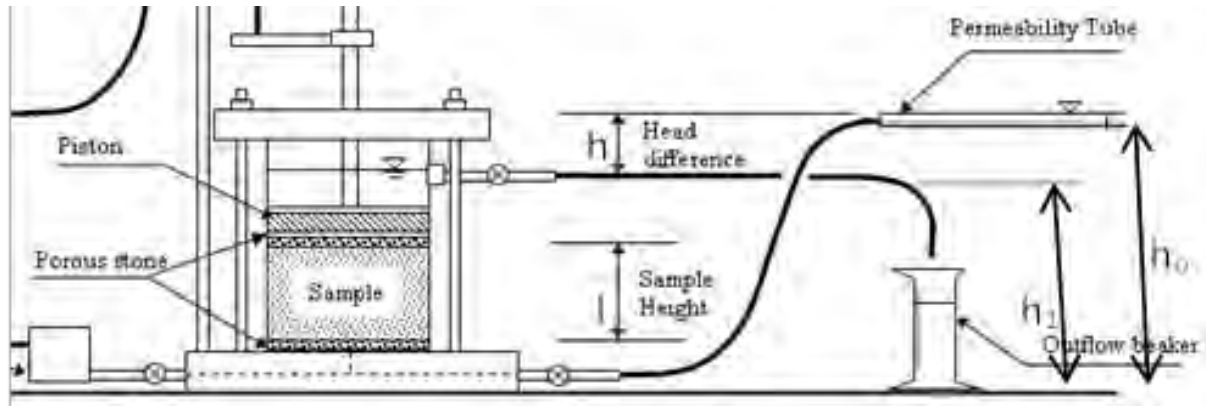


Figure 2. Setup of permeability measurement.

The inflow is monitored to ensure that steady-state flow conditions are obtained. The units of the coefficient of permeability are those of velocity (m/s).

3.3 PORE FLUID SAMPLING

To determine the chemical species present in the consolidation release water, a duplicate LSC test will be run using the same loading procedure described above. Drainage water will be collected into anaerobic sample containers to limit oxygen exposure via the cell's base port (Figure 2).

A Standard Operating Procedure (SOP) was prepared by Diavik (Appendix A) and describes the steps required for sampling porewater expelled from consolidation column tests, including in-laboratory measurements, and the preparation and shipping of samples to an external laboratory for further analyses. All sample collection and analyses will be conducted in accordance with the SOP.

3.4 UNDRAINED SHEAR STRENGTH

The undrained shear strength will be obtained using Brookfield DV2T Rheometer (Figure 3left) for low shear strengths and laboratory vane shear tests using Standard Test Method D 4648-05 for saturated fine-grained clayed soil for higher shear strengths.

The Brookfield Rheometer measures fluid viscosity at given shear rates. The principle of operation is to drive a spindle (which is immersed in the fluid) through a calibrated spring. The viscous drag of the fluid against the spindle is measured by the spring deflection. Spring deflection is measured with a rotary transducer. The measurement range is determined by the rotational speed of the

spindle, the size and shape of the spindle, the container the spindle is rotating in, and the full-scale torque of the calibrated spring.

The laboratory vane shear test (Figure 3 right) consists of inserting a four-bladed vane at the end of a tube sample and rotating it at a constant rate to determine the torque required to cause a cylindrical surface to be sheared by the vane. This torque is then converted to a unit shearing resistance of the cylindrical surface area. The torque is measured by a calibrated torque transducer that is attached directly to the vane. The undrained shear strength is calculated using the following expression:

Where:

$$T = \tau \times K$$

T = torque, lbf.ft (N.m)

τ = undrained shear strength, lbf/ft² (Pa), and

K = vane blade constant, ft³ (m³).

T and K are given as follows (assuming the distribution of the shear strength is uniform across the ends of the failure cylinder and around the perimeter):

$$T = \frac{\pi D_v^3}{2} \left(\frac{H}{D_v} + \frac{1}{3} \right) \tau_y$$

$$\tau_y = \frac{T}{K}$$

$$K = \frac{\pi D_v^3}{2} \left(\frac{H}{D_v} + \frac{1}{3} \right)$$

Where:

D_v = measured diameter of the vane, in. (mm),

H = measured height of the vane, in. (mm).



Figure 3. A; Rheometer and B: Vane shear apparatus

3.5 SEDIMENTATION TEST

Sedimentation tests will be carried out in 1 L cylinders. A tailings sample will be homogenized and then poured into the cylinder to the fill line. The cylinder will be inverted 10 times prior to the test initiation. The interface settling will be monitored and recorded using time-lapse photography for 24 hours. After 24 hours monitoring of the sample interface will occur daily for about two months. The final strain and solids content will be measured at the end of the sedimentation tests. Note: The sedimentation test video will be available as part of this project.

3.6 PARTICLE SIZE DISTRIBUTION (PSD)

3.6.1 Dispersed Hydrometer-Sieve Test

Standard ASTM dispersed hydrometer-sieve tests will be conducted. Sieving will determine the amount of fines ($<75\ \mu\text{m}$). Hydrometer will determine the amount of clay-size material ($<2\ \mu\text{m}$). The term clay-size is used, not clay, as some rock-forming minerals, usually quartz, can be finer than $2\ \mu\text{m}$. Also, as not all clay peds are dispersed in the extraction plant and the laboratory test procedure, there can be considerable clay mineral in the form of peds and booklets coarser than $2\ \mu\text{m}$.

3.6.2 Non-dispersed Hydrometer-Sieve Test

Non-dispersed tests will be conducted. The objective of the non-dispersed tests is to not disperse the clay lumps and peds any more than they are in the mining and extraction processes. The non-

dispersed tests should more accurately reflect the particle size distribution of the MFT material in the tailings pond. The amount of fines ($<75 \mu\text{m}$) will be determined by sieving. The amount of clay-size material ($<2 \mu\text{m}$) will be determined by hydrometer.

3.7 DETERMINATION OF BASIC PROPERTIES

The basic properties including, moisture and solids contents, Atterberg's limits are determined in accordance with respective ASTM standards. The procedure of determination of moisture content involves taking a portion of the sample of interest and finding the mass of water by determining the difference in sample mass before and after at least 24 hours of oven drying at 110°C . The mass of the sample after the oven-drying is taken to be the mass of solids. The mass of water, M_w , divided by the mass of solids, M_s , and multiplying by 100% yields the gravimetric moisture content, w , i.e., $w = 100\% \times M_w/M_s$. The void ratio, e , is the ratio of the volume of voids, V_v , to the total volume of solids, V_s , i.e., $e = V_v/V_s$. The bulk density of soil, ρ , is the ratio of total mass, M , to the total volume, V , of the soil, i.e., $\rho = M/V$. The specific gravity of a soil, G_s , is given by $G_s = M_s/V_s\rho_w$, where ρ_w is the density of water. The degree of saturation, S_r , can be expressed as $S_r = w G_s/e$, or in the case of fully saturated soil, $S_r = 1$, hence, $e = wG_s$.

3.8 PRINCIPAL INVESTIGATOR HONORARIUM

The principal investigator (Dr. Nicholas Beier) will receive an honorarium for services rendered on this project. Services will include project oversight and management of technicians for lab testing, communications with client, review of experimental data and subsequent analysis, and report review (draft and final).

**APPENDIX A STANDARD OPERATING PROCEDURE FOR ON-SITE
GEOCHEMICAL ANALYSES OF EXPELLED POREWATER AND PREPARING
SAMPLES FOR EXTERNAL WATER ANALYSES**

Standard Operating Procedure:

On-site geochemical analyses of expelled porewater and preparing samples for external water analyses

Rev: 0 (DRAFT) L.Smith

Date: 30 July 2018

1 Purpose and scope

This SOP describes the steps required for sampling porewater expelled from consolidation column tests, including in-laboratory measurements, and the preparation and shipping of samples to an external laboratory for further analyses.

2 Health and safety

Ensure all SDS for buffers, standards and reagents are read and understood prior to handling any reagent. Follow all precautions outlined in the SDS. If there are any questions or concerns, do not proceed with the sampling or in-lab testing until all concerns are adequately addressed and all PPE is available and in good condition.

3 Materials and supplies

- Field meter(s) capable of measuring pH, Eh, and EC
- pH probe
- Eh probe
- EC probe
- pH buffers – 4, 7, 10
- Zobell's solution
- Light's solution
- pH filling solution
- pH storage solution
- Eh filling solution
- Latex or nitrile gloves
- Hach Alkalinity kit (25 mL Erlenmyer flask(s), 25 mL graduated cylinder (alternate: balance with 0.1 mg or better accuracy), digital titrator with 0.1600 H₂SO₄ cartridge, phenolphthalein indicator packs, bromocresol green-methyl red indicator packs,
- 15 mL Nalgene bottles (or glass vials or test tubes) for pH, Eh, EC analyses
- 30 mL Nalgene bottles for anion and cation analyses (to be submitted to external lab)
- Laboratory labelling tape
- Thin-tipped Sharpie marker (for labelling sample bottles)
- Regular-tipped Sharpie marker (for labelling syringes)
- New 0.45 um cellulose acetate syringe filters
- New 60 mL syringes
- Deionized water (no additives), or better (e.g. MilliQ water)
- Trace metals grade HNO₃ in a dropper bottle
- KimWipes
- Parafilm (optional)
- Zobell solution waste container
- Light's solution waste container

- Waste container for rinse water
- pH test strips
- Cooler
- Gel-filled ice packs

4 Procedural steps

4.1 Review all SDS and manuals

1. Review all manuals for probes, meters, and alkalinity kit.
2. Review all SDS for reagents, buffers, standards and acids.
3. Prepare all personal protective equipment (PPE) according to the SDS
4. Safety glasses and nitrile gloves should be worn at all times during preparation and procedures

4.2 Preparation

1. Label all 30 mL sample bottles using the convention below (including coloured labelling tape, if practicable) for dissolved metals (top) and anions (bottom)

[Sample Date]	Dissolved metals
[Sample ID]	F: 0.45 um A: HNO ₃
PK consol.	

[Sample Date]	Anions
[Sample ID]	F: 0.45 um
PK consol.	

2. Calibrate probes. If using one meter and changing probes, start with Eh calibration and measurements on all samples; change probe to pH probe and calibrate and measure pH on all samples; finally change to EC probe and calibrate and measure EC on all samples. If using separate meters for each probe, Eh, pH and EC measurements can be made concurrently on aliquots of one sample.
3. Check Eh probe. Transfer an aliquot of Light's solution to a 15 or 30 mL glass vial or Nalgene bottle. Transfer an aliquot of Zobell's solution to a separate 15 or 30 mL glass vial or Nalgene bottle. Transfer sufficient solution of each type to ensure the bottom of the probe is submerged, but the probe is not touching the bottom of the container. This solution can be capped and used for subsequent Eh probe checks. Note that Zobell's solution will turn blue if contaminated with Light's solution, and should be replaced if this occurs. First measuring Light's solution (should read ~ at 25C) and record the measurement. Rinse the probe with DI water,

collecting the rinsate in a separate waste container labelled "Light's solution waste". Measure Zobell's solution (should read ~ at 25C) and record the measurement. Rinse the probe with DI water, collecting the rinsate in a separate waste container labelled "Zobell's solution waste". The measurements may not be exact, but should stabilize at a reading very near the published value.

4. Calibrate pH probe according to user's manual. Start with pH 7 buffer, then pH 4 buffer, then pH 10 buffer. Record the calibration slope. The slope should be higher than 95% to indicate good calibration. If the slope is lower, change aliquots of buffer and re-calibrate.
5. Calibrate EC probe, according to user's manual, using standard solutions 1413 uS and 100 uS standard solutions.

4.3 Collect sample aliquots and conduct immediate Eh, pH and alkalinity analyses

1. Open the package of a 60 mL syringe, but do not discard the package. Write the sample ID directly on the syringe body.
2. If the sample bag is fitted with a valve compatible with Luer-Lok, directly attach the syringe to the sample bag and draw sample into the syringe. Detach syringe from the sample bag. **[This step to be finalized when we know the fitting options for the sample bag]**
3. Dispense a small amount of sample (a few mL) into the Eh measuring container (plastic bottle, glass vial, or test tube), swirl to rinse, and discard into waste container. Repeat two more times. Dispense an aliquot of sample into the Eh measuring container. Place the Eh probe in the sample, ensuring the bottom of the probe is not touching the bottom of the container. Parafilm can be used to wrap the probe to ensure the bottom of the probe stays off the bottom of the container.
 - a. Record the initial measurement, and the measurement when the reading stabilizes. Eh measurements can take some time to stabilize, however, if the reading does not stabilize and continues to drift higher (increasing values), the sample is oxidizing and a measurement will not be reliable. Consider conducting the Eh measurement in an O₂-exclusion atmosphere. Note that reliable measurements are typically obtainable without an O₂-exclusion atmosphere.
 - b. When the Eh has stabilized, and has been recorded, discard the sample, rinse sample container with DI, rinse the Eh probe with DI and return the Eh probe to the storage solution.
4. If only one meter is being used and the probes are changed for each measurement type, proceed to steps 5 and 6 until the Eh reading has stabilized, and then return to steps 4a and 4b. If multiple meters are being used, proceed to step 4a.
 - a. Dispense a small amount of unfiltered sample (1-2 mL) into the pH measuring container and swirl to rinse. Repeat two more times. Dispense a sufficient volume of sample into the pH measuring container, such that the bottom and junction of the pH meter will be covered. The pH measuring container should be a dedicated container, and a different plastic bottle, glass vial, or test tube from the Eh and EC measuring containers. Remove the probe from the buffer solutions or storage solution, rinse the pH probe with DI water and blot with a KimWipe. Place the pH probe in the pH measuring container containing the sample. When the reading has stabilized, record the measurement.

Discard the sample and rinse the pH probe and measuring container with DI. Return the pH probe to the storage solution container.

- b. Dispense a small amount of unfiltered sample (1-2 mL) into the EC measuring container and swirl to rinse. Repeat two more times. Dispense a sufficient volume of sample into the EC measuring container, such that the measuring area of the probe will be covered. The EC measuring container should be a dedicated EC measuring container, separate from pH or Eh measuring containers. Rinse the EC probe with DI water and blow with a KimWipe. Place the EC probe in the EC measuring container containing the sample. When the reading has stabilized, record the measurement. Discard the sample and rinse the probe with DI.
5. Attach a new 0.45 μm filter to the syringe. Push a small amount (one or two mL) of sample through the filter into a waste container. Dispense the remaining sample into the two 30 mL sample bottles (one for metals, one for anions), alternating the dispensing between the two sample bottles such that the bottles are filled at approximately the same time. Repeat steps #2 and #5 until the sample bottles are full, with water mounding at the mouth of the bottle (i.e. no head space). Replace the filter, as necessary, when it becomes very difficult to push water through the filter.
6. Add 10-12 drops of trace metal-grade HNO_3 to the sample bottle for metals analysis ONLY. Use pH test strips (do not use pH probe) to ensure the pH is 3 or lower. If the pH is higher than three, add one or two drops additional acid at a time until the pH is less than 3. DO NOT add acid to the bottle holding the sample for anions analysis.
7. Reattach the syringe to the sample bag to extract the remaining collected sample. Discard all but ~25-40 mL of sample, retaining the ~25-40 mL in the syringe. Attach a filter, and return the syringe and filter to the syringe package. This sample aliquot will be used for the alkalinity measurements.
8. Conduct duplicate sample preparation on one set of samples, provided there is sufficient sample remaining.
9. Refrigerate all metals and anion samples until they are shipped to the University of Waterloo for analysis. Samples can be refrigerated and sent monthly.

4.4 Alkalinity Measurements

1. Follow the instructions provided with the Hach alkalinity kit with the following EXCEPTIONS/clarifications:
 - a. Prior to measuring and recording samples, practice using the digital titrator and identifying the three endpoints on either aliquots of sample, or another solution known to contain some alkalinity. The pink end point is the most important for our purposes (but all should be recorded), and also the easiest to identify. For the pink endpoint, note the number of digits when you think the pink endpoint has been achieved. Add additional H_2SO_4 . If the COLOUR continues to change (note the intensity may increase, but the colour won't), the endpoint has not been reached. Note the digits when the pink endpoint has been reached.
 - b. Dispense 10 mL of sample using the syringe and filter (sample must be filtered for alkalinity measurements) into a 25 mL Erlenmeyer flask.

- c. The 10 mL sample volume can be measured using a balance (best), or a 25 mL graduated cylinder. If using a balance, record the exact mass. Masses should be no less than 10 g, and no more than about 12 g. Similarly, if using a graduated cylinder, volumes of 10-12 mL are fine, provided the volume used is recorded.
- d. Use the 0.1600N H₂SO₄ cartridge with the digital titrator.

4.5 Waste disposal

1. Dispose of all waste appropriately, per the SDS recommendations.
2. Rinse and waste Zobell's solution and Light's solution require special disposal.
3. Rinse from pH buffers, EC standards, alkalinity testing can be flushed down the sink. Kimwipes used for blotting probes can be disposed of in regular garbage collection.

4.6 Sample submission to external lab

From each cell and sampling event, two sample bottles will be filled for analysis at the University of Waterloo: one bottle will contain filtered sample that has been acidified with HNO₃ (for metals analysis), and one bottle will contain filtered sample with no acid added (for anions analysis). The sample for metals and the sample for anions will have the same sample name.

1. Complete a chain of custody (COC) form for each sample submission. A sample COC form is attached to the electronic version of this document.
2. Place the sample bottles in an appropriately-sized cooler (i.e. a smaller cooler) with frozen gel-filled ice packs. If extra space, pack with crumpled paper or other to minimize bottle movement during shipping.
3. Place a copy of the COC in a sealed plastic bag inside the cooler
4. Email an electronic or scanned copy of the COC to:
lianna.smith@riotinto.com (Lianna Smith)
sjhu@uwaterloo.ca (Joy Hu)
5. Ship the samples with 1-day/overnight delivery to:
Joy Hu
EIT 5009, Earth and Env. Sciences Dept.
University of Waterloo
200 University Ave West
Waterloo, ON
N2L 3G1
Tel. 519.888.4567 x 37239

ATTACHMENT #3

PK Pore water quality requested by ENR November 27, 2018

	Ca (mg L-1)	K (mg L-1)	Mg (mg L-1)	Na (mg L-1)
<i>in situ</i> PKC beach sampling				
n samples	55	55	55	55
n >MDL	55	55	55	55
n <MDL -1				
n <MDL -2				
n <MDL -3				
n <MDL -4				
average	208.50	165.68	412.42	155.26
std dev	206.26	115.54	511.65	111.74
25th	14.87	49.49	19.34	61.10
75th	412.80	289.70	676.95	234.90
median	93.44	130.80	145.90	117.50

S (mg L-1)	Si (mg L-1)	Sr (mg L-1)	Li (ug L-1)	Be (ug L-1)	Be (ug L-1)	B (ug L-1)	Al (ug L-1)
55	55	55	55	55		55	55
55	26	36	47	7	55	55	52
	5 <0.07	5 <0.1	2 <0.4	10 <0.007	10		3 <0.04
	6 <0.2	6 <1.0	1 <1.5	8 <0.02	8		
	6 <0.7		2 <3.0	26 <0.08	26		
	12 <2.0		3 <4.0	4 <0.25	4		
782.98	2.42	6.70	3.82	0.27	0.27	56.02	152.85
862.30	1.80	6.56	2.73	0.82	0.82	24.60	419.38
43.20	<0.7	< 1.0	2.09	< 0.02	0.02	44.21	20.77
1382.00	3.88	12.51	5.17	< 0.08	0.08	72.55	92.89
317.50	< 2.0	3.71	3.35	< 0.08	0.08	58.46	51.77

Si (ug L-1)	P (ug L-1)	Ti (ug L-1)	V (ug L-1)	Mn (ug L-1)	Fe (ug L-1)	Co (ug L-1)	Ni (ug L-1)	Cu (ug L-1)
55	55	55	55	55	55	55	55	55
54	8	10	52	55	55	54	55	53
	13 <3.0	9 <0.05	3 <0.25			1 <0.2		2 <0.02
	6 <10.0	8 <0.2						
	26 <35.0	12 <0.5						
	2 <100.0	16 <2.0						
2605.07	64.99	1.77	1.86	82.15	233.97	5.58	189.23	8.65
1904.99	144.24	2.61	2.02	117.12	494.85	8.59	258.80	9.08
842.92	< 10	< 0.2	0.64	11.18	17.99	0.52	8.76	3.00
4264.00	< 35	< 2.0	2.34	116.00	171.15	7.35	267.10	11.83
2355.00	< 35	< 0.5	1.54	30.34	41.16	2.50	75.03	5.80

Zn (ug L-1)	As (ug L-1)	Se (ug L-1)	Mo (ug L-1)	Ag (ug L-1)	Cd (ug L-1)	Sn (ug L-1)	Sb (ug L-1)	Cs (ug L-1)
55	55	55	55	55	55	55	55	0
48	55	42	55	21	55	47	55	
2 <0.2		13 <0.2		15 <0.004		4 <0.03		
1 <0.8				8 <0.05		4 <0.1		
4 <8.5				11 <0.15				
348.14	3.01	18.37	504.45	0.41	0.92	7.30	5.45	
715.13	1.29	23.03	409.47	0.77	0.94	7.29	1.54	
15.39	2.19	1.78	213.45	<0.004	0.28	3.13	4.57	
320.65	3.65	27.51	679.45	0.31	1.18	9.44	6.48	
83.56	2.84	9.17	356.10	< 0.15	0.79	5.35	5.40	

Ba (ug L-1)	Tl (ug L-1)	Pb (ug L-1)	U (ug L-1)	Comments	Fluoride (mg L-1)	Chloride (mg L-1)	NO2 (mg L-1)
55	55	55	55		53	53	53
55	55	55	51		0	53	5
			1 <0.002		21 <0.1		17 <0.1
			2 <0.006		32 <0.4		31 <0.4
			1 <0.02				
448.99	0.65	0.88	1.13			148.99	0.42
555.05	0.74	1.33	2.24			120.87	0.61
123.80	0.26	0.16	0.06			89.37	< 0.1
437.70	0.72	0.79	1.10			156.06	< 0.4
217.30	0.38	0.42	0.27			115.04	< 0.4

Bromide (mg L-1)	NO3 (mg L-1)	Sulfate (mg L-1)	Phosphate (mg L-1)	pH	EC uS cm-1	Alk (as CaCO3)	PO4 mg L-1
50	49	53	53				
34	35	53	1				
5 <0.1	4 <0.1		21 <0.2				
11 <0.4	10 <0.4		31 <0.4				

1.54	96.36	2315.25					
2.09	232.54	2747.37					
< 0.4	<0.4	111.91					
1.69	92.99	4282.98					
1.31	28.07	969.04					

S2-	Fe2	NH4-N	Ehc
ug L-1	mg L-1	mg L-1	mV



ATTACHMENT #4

Surveillance Network Program (SNP) Station 1645-88 (Proposed)

Description:	Mine Workings containing Processed Kimberlite		
Location:	Mine Workings – location dependent on stage in Mine life		
Sampling Frequency:	Bi-weekly from decant water pipeline (when active) during Operations	<p>Following the completion of Mine Working being backfilled with water at one (1) station located in the center of the Open Pit:</p> <p>Monthly Bioprofile to monitor the chemocline development and stability.</p> <p>Quarterly (provided safe access via open water or sufficient ice thickness) one (1) sample shall be collected 2m below surface, one (1) sample shall be collected 2m above the chemocline, one (1) sample shall be collected 2m below the chemocline, and one (1) sample shall be collected 2m above the bottom. If a chemocline is not evident, four (4) samples shall be distributed evenly throughout the water column.</p>	Once prior to breaching dike and reconnecting Mine Workings to Lac De Gras at a minimum of five (5) stations evenly spaced along a longitudinal transect as approved by an Inspector. At each station, samples must be collected 2m below surface and at twenty (20) meter intervals with a final sample 2m above the bottom.
Sampling Parameters:	Total Arsenic, Dissolved Organic Carbon, Dissolved Oxygen, Field Parameters ³ , ICP- MS Metal Scan ¹ (Total and Dissolved), Major Ions ² , pH ⁴ , Nutrients ⁵ , Total Mercury, Total Organic Carbon, Total Suspended Solids, Turbidity, Total Petroleum Hydrocarbons (TPH)	<p>Bioprofile: pH, Turbidity, Temperature, Dissolved Oxygen, Conductivity</p> <p>Sample: Total Arsenic, Dissolved Organic Carbon, Dissolved Oxygen, Field Parameters³, ICP- MS Metal Scan¹(Total and Dissolved), Major Ions², pH⁴, Nutrients⁵, Total Mercury, Total Organic Carbon, Total Suspended Solids, Turbidity, Total Petroleum Hydrocarbons (TPH)</p>	Total Arsenic, Dissolved Organic Carbon, Dissolved Oxygen, Field Parameters ³ , ICP- MS Metal Scan ¹ (Total and Dissolved), Major Ions ² , pH ⁴ , Nutrients ⁵ , Total Mercury, Total Organic Carbon, Total Suspended Solids, Turbidity, Total Petroleum Hydrocarbons (TPH)
Rationale for Station:	Monitor water quality of the Mine Working containing Processed Kimberlite to ensure that water quality is behaving according to model predictions and remains stable over time.		

Summary Statistics for Groundwater at Diavik

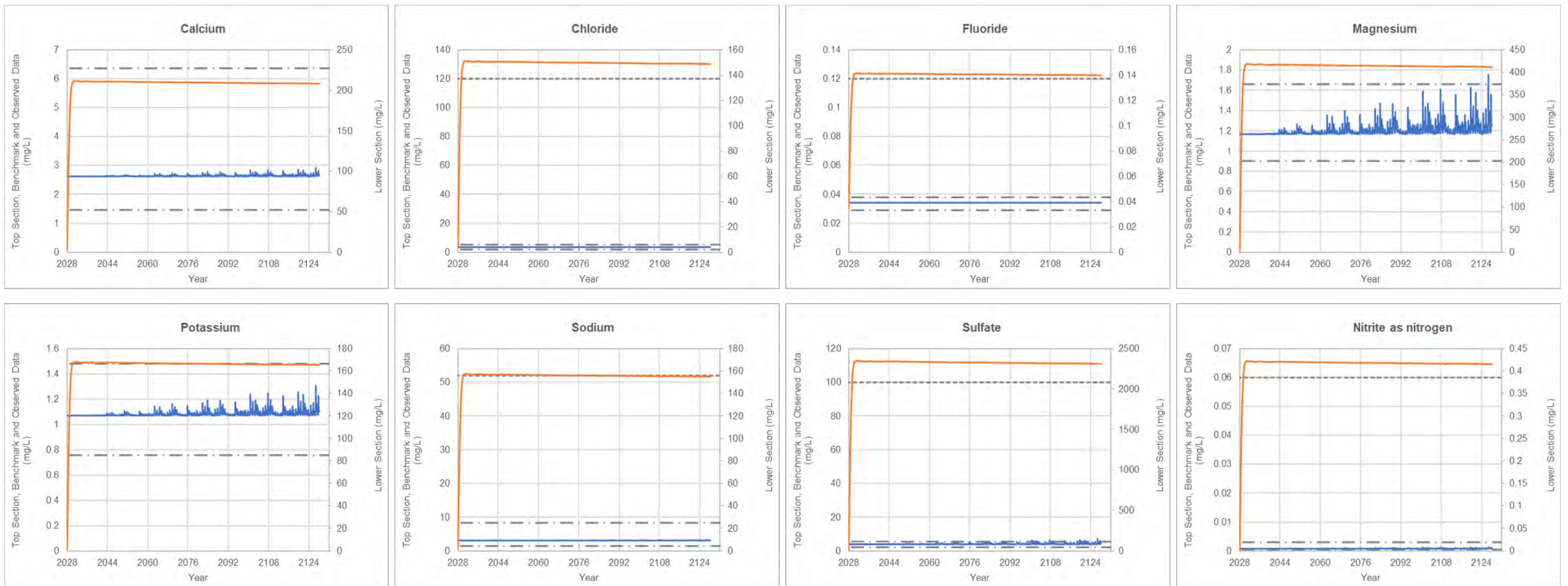
	Summary Statistics			
	COUNT	25th PERCENTILE	MEDIAN	MEAN
Acidity (pH 8.3) (mg/L)	127	0.25	0.25	0.498
Aluminum (Al) - Total (ug/L)	127	26.3	59.4	756
Ammonia (N) (mg/L)	127	0.055	0.063	0.119
Antimony (Sb) - Total (ug/L)	127	0.01	0.01	0.0264
Arsenic (As) - Total (ug/L)	127	5.26	5.51	5.75
Barium (Ba) - Total (ug/L)	127	50.65	61	89.0
Beryllium (Be) - Total (ug/L)	127	0.0	0.0	0.0220
Bismuth (Bi) - Total (ug/L)	127	0.0025	0.0025	0.00850
Boron (B) - Total (ug/L)	127	19.55	20.7	23.1
Cadmium (Cd) - Total (ug/L)	127	0.0025	0.006	0.0445
Calcium (Ca) - Total (mg/L)	127	18.3	20	20.8
Chloride (Cl) - Dissolved (mg/L)	127	75	80	82.4
Chromium (Cr) - Total (ug/L)	127	0.1	0.3	15.4
Cobalt (Co) - Total (ug/L)	127	0.3	0.5	3.82
Copper (Cu) - Total (ug/L)	127	0.1	0.2	2.25
Iron (Fe) - Total (ug/L)	127	357.5	607.0	2644
Lead (Pb) - Total (ug/L)	127	0.0	0.0	0.960
Lithium (Li) - Total (ug/L)	127	12.5	13.3	14.8
Magnesium (Mg) - Total (ug/L)	110	6352.5	6970.0	15114
Manganese (Mn) - Total (ug/L)	127	59.2	64.9	125.4
Mercury (Hg) - Total (ug/L)	74	0.001	0.001	0.001
Molybdenum (Mo) - Total (ug/L)	127	9.08	9.56	10.18
Nickel (Ni) - Total (ug/L)	127	3.44	6.61	62.19
Nitrogen (N) - Total (mg/L)	127	0.137	0.176	0.439
Phosphorus (P) - Total (ug/L)	110	538	572	635
Potassium (K) - Total (ug/L)	110	1963	2145	2255
Selenium (Se) - Total (ug/L)	127	0.0200	0.0200	0.0314
Silicon (Si) - Total (ug/L)	127	5845	6120	7359
Silver (Ag) - Total (ug/L)	127	0.0025	0.0025	0.0127
Sodium (Na) - Total (ug/L)	110	37375	39850	41210
Strontium (Sr) - Total (ug/L)	127	525	577	636
Sulphate (SO4) - Dissolved (mg/L)	127	10.3	11.9	15.0
Thallium (Tl) - Total (ug/L)	127	0.0010	0.0010	0.0053
Tin (Sn) - Total (ug/L)	127	0.0050	0.0110	0.0810
Titanium (Ti) - Total (ug/L)	127	0.78	2.03	22.99
Uranium (U) - Total (ug/L)	127	0.171	0.366	1.562
Vanadium (V) - Total (ug/L)	127	0.10	0.12	2.69
Zinc (Zn) - Total (ug/L)	127	2.85	6.00	18.55
Zirconium (Zr) - Total (ug/L)	127	0.118	0.172	0.279
pH (pH)	298	7.49	7.68	7.65

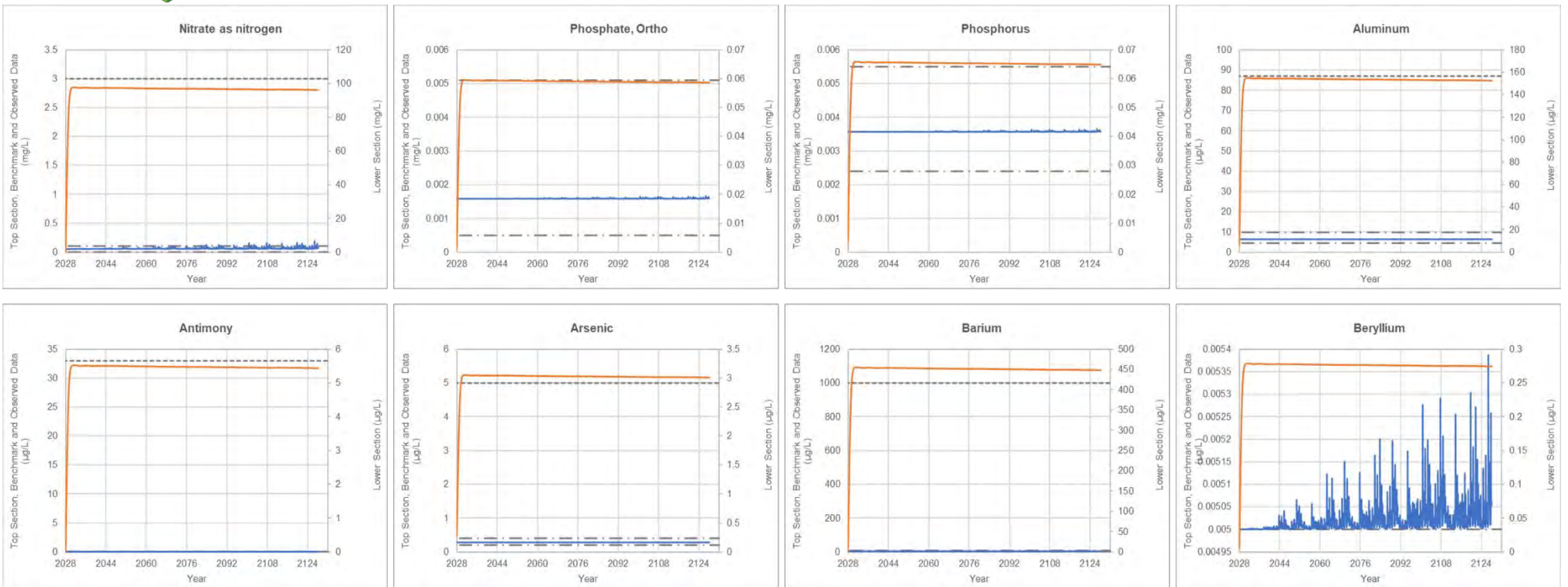
¹ *Blank values indicate no value below DL, or only one DL in dataset*

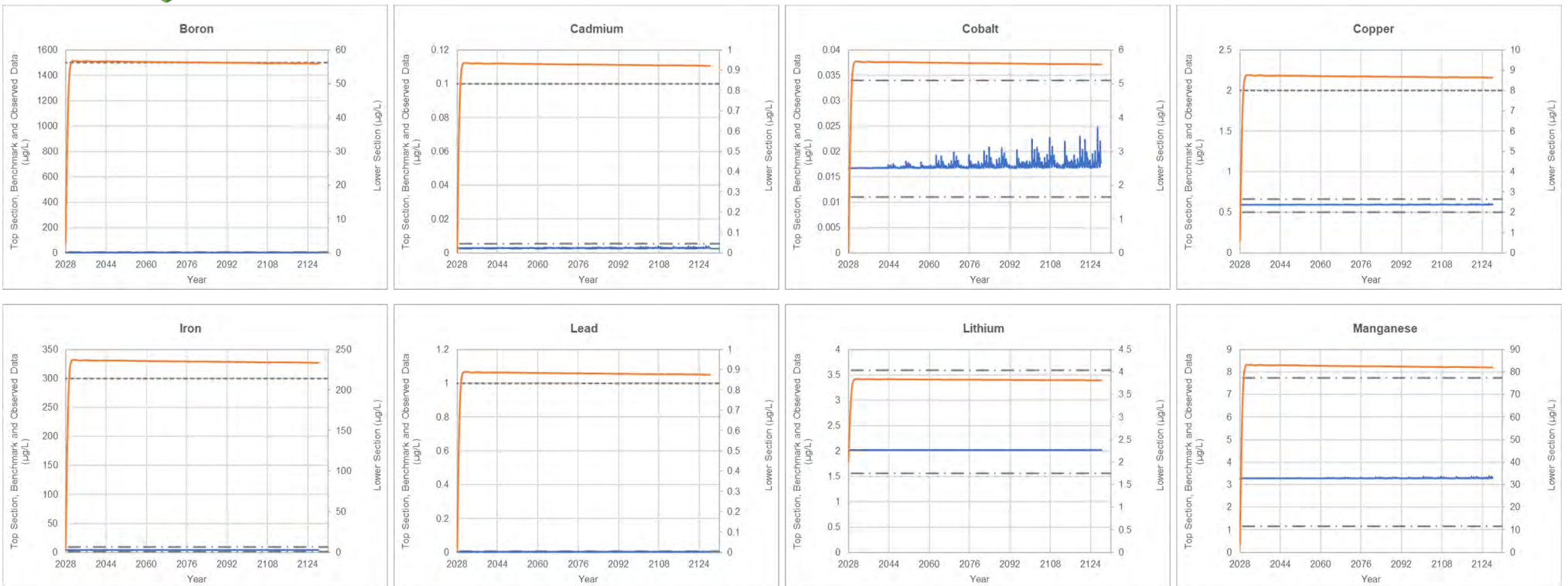
² *Maxxam 2017*

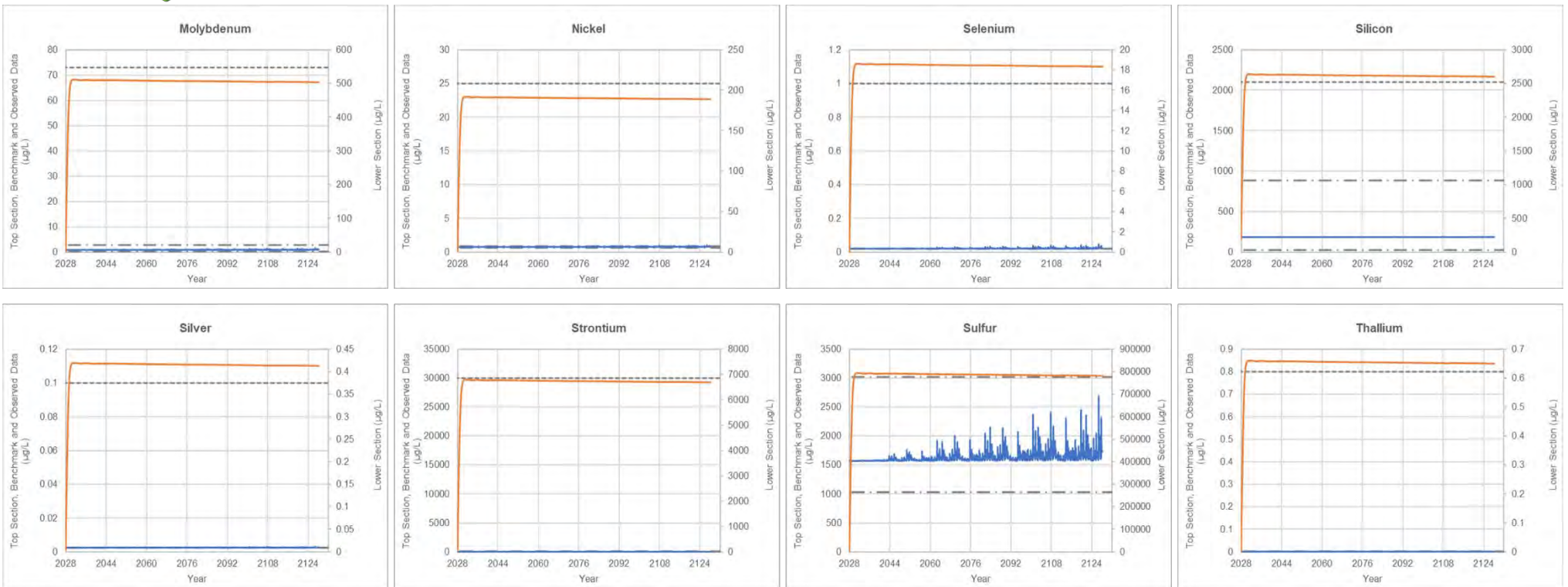
SNP Station 1645-75B

75th PERCENTILE	Detection Limits ¹		
	Reference ²	Lower	Upper
0.5	0		
256.5	0.2	0.5	
0.077	0.005		
0.025	0.02	0.02	0.05
5.785	0.02	0.02	
69.1	0.02	0.02	
0.0	0.01	0.01	
0.0055	0.005	0.005	0.02
22.95	5	5	50
0.0174	0.005	0.00001	0.005
22.25	0.01		
87.5	0.5	0.5	
1.5	0.05	0.05	0.5
1.5	0.005	0.005	
0.7	0.05	0.05	0.1
1160.0	1	1	
0.2	0.005	0.005	0.02
15.0	0.5		
8137.5	10	10	
83.4	0.05	0.05	
0.001	0.01	0.002	
10.60	0.05		
15.55	0.02	0.02	
0.239	0.02	0.001	0.005
605	20	20	
2300	10	10	
0.0200	0.04	0.04	
6685	50	100	
0.0090	0.005	0.005	0.01
43625	10	10	
627	0.05		
15.8	0.05		
0.0040	0.002	0.002	
0.1000	0.01	0.01	0.2
8.28	0.5	0.5	5
0.694	0.002		
0.34	0.1	0.05	0.1
12.25	0.1	0.1	
0.248	0.05	0.05	0.1
7.78	N/A		

Figure 1- Predicted time Series of A418 Pit Lake Constituent Concentrations – Development Case Sensitivity Scenario








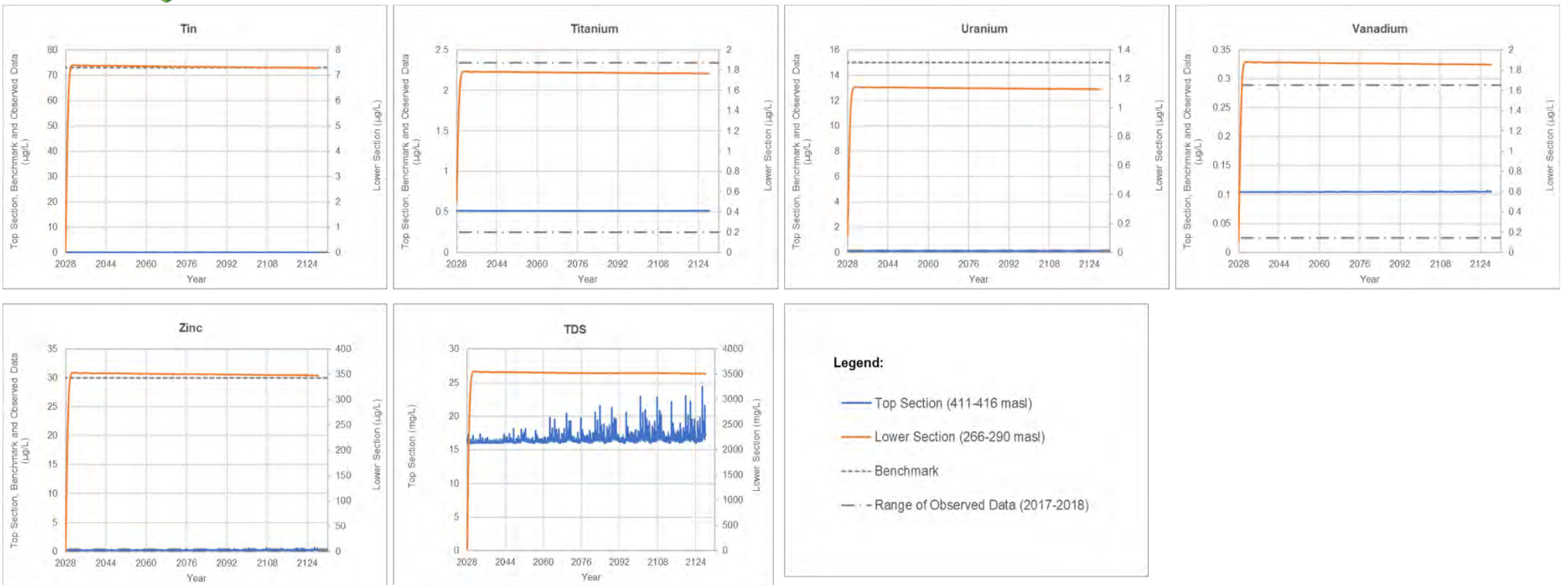
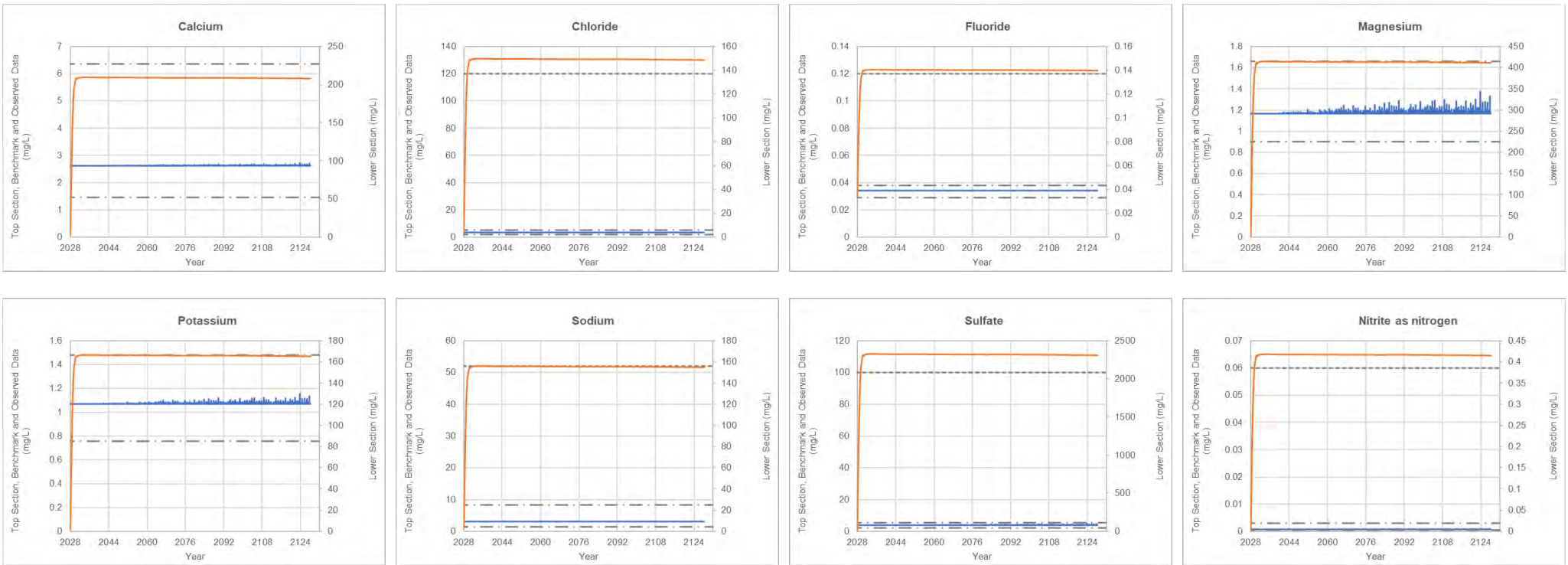
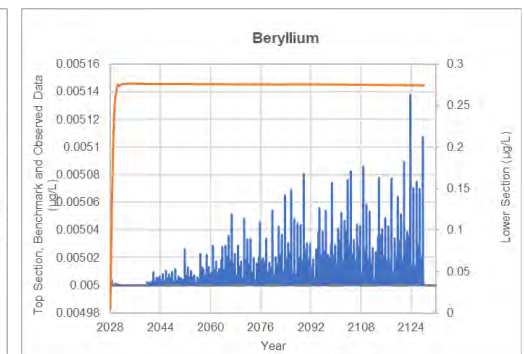
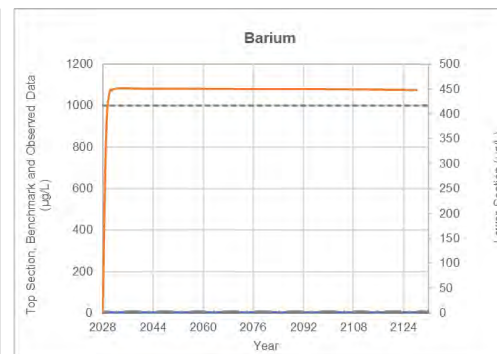
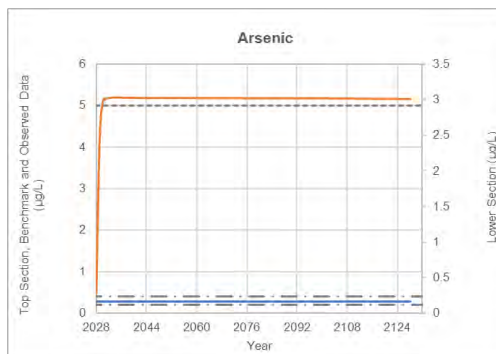
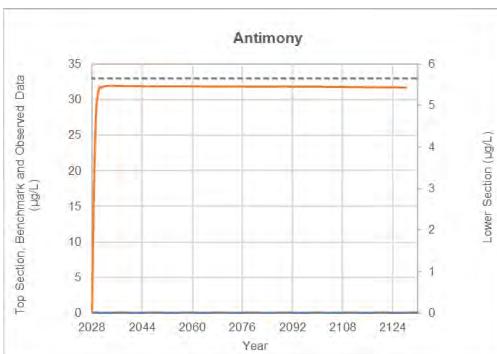
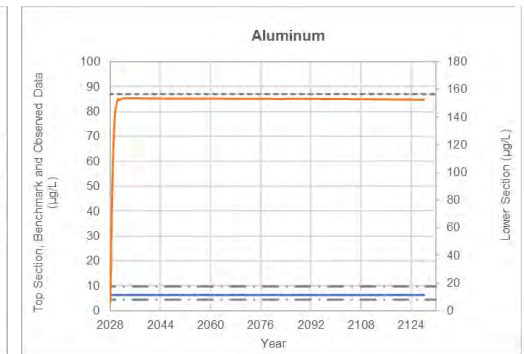
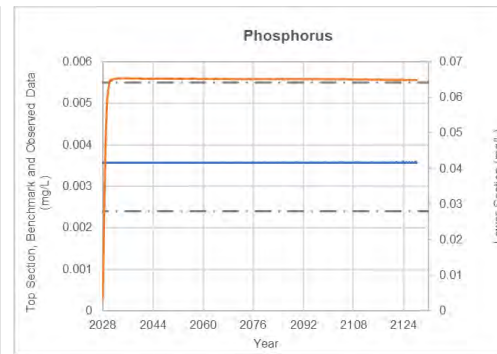
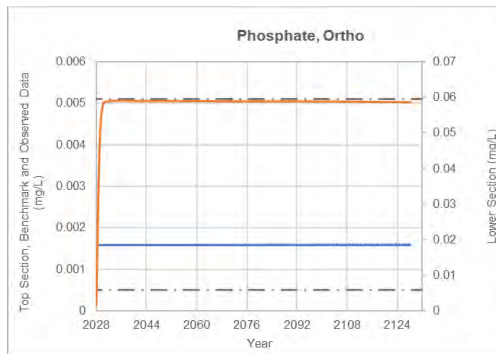
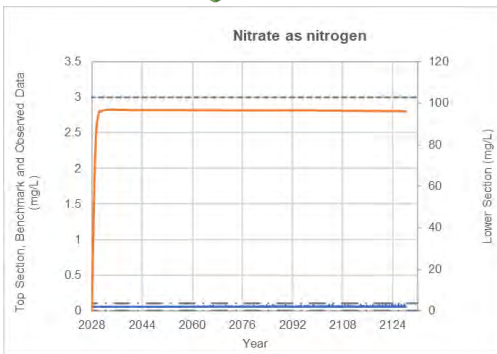
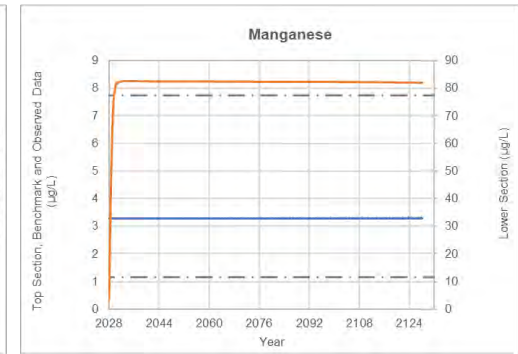
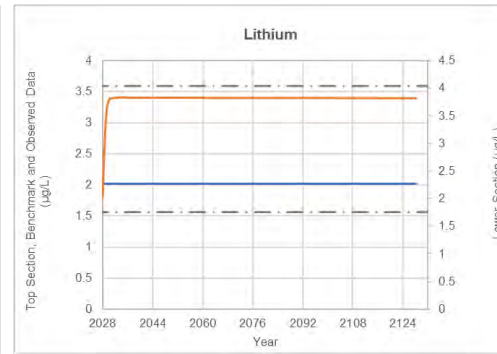
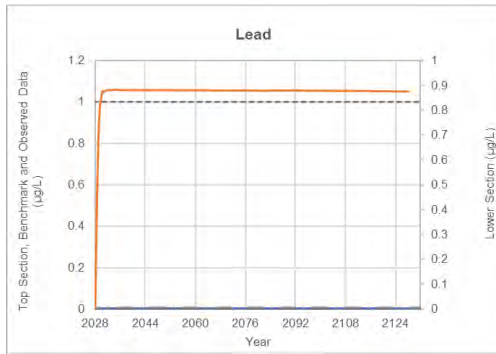
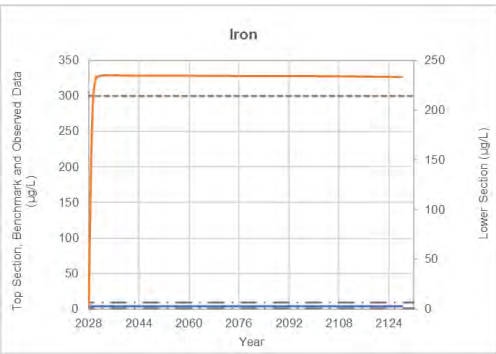
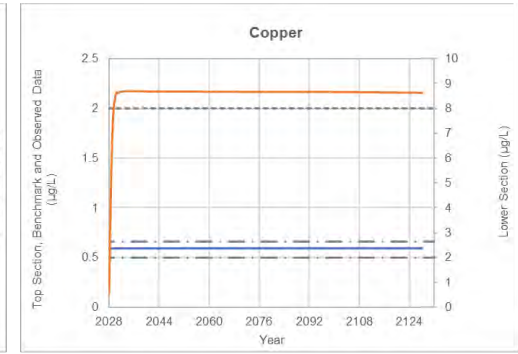
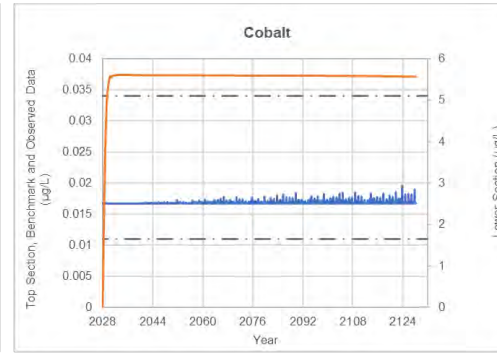
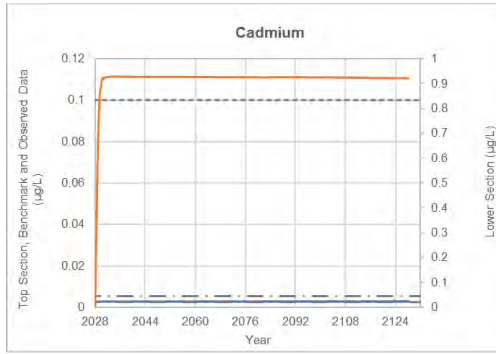
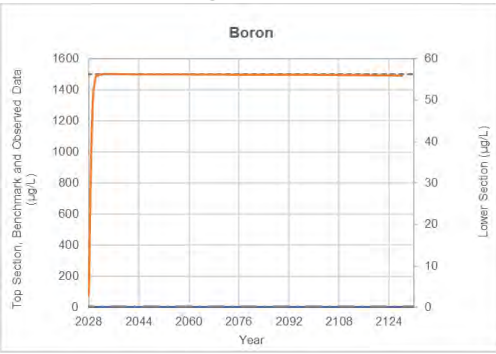


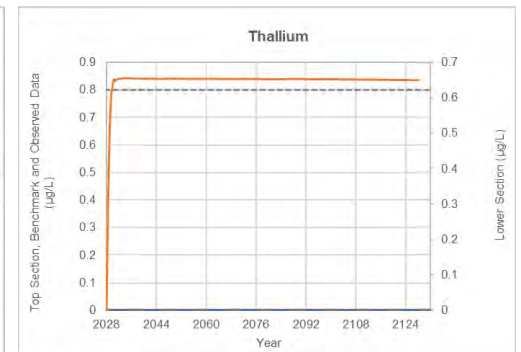
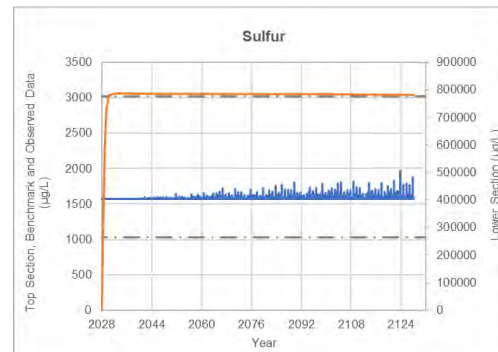
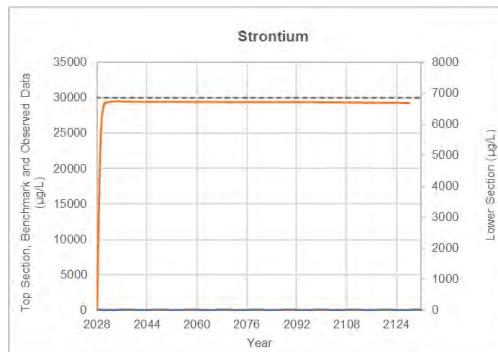
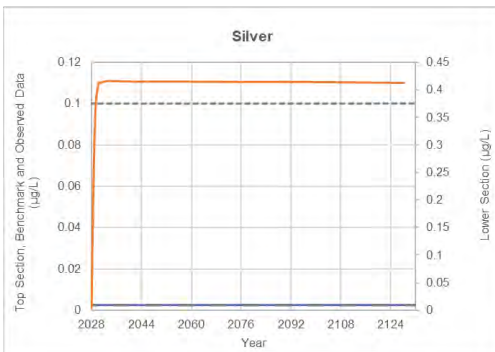
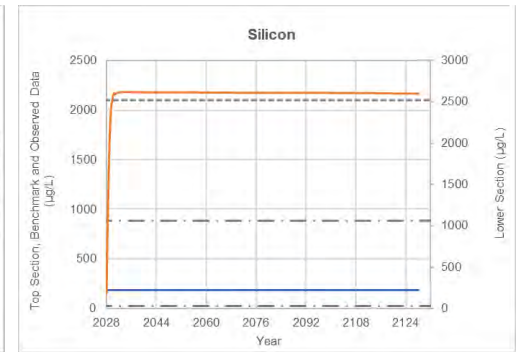
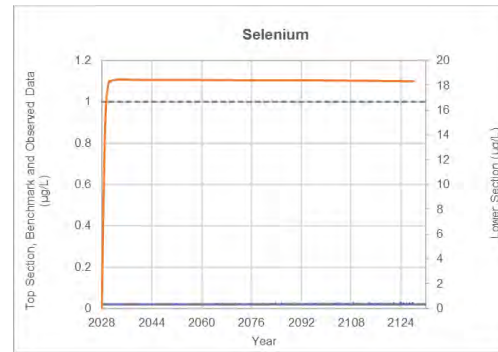
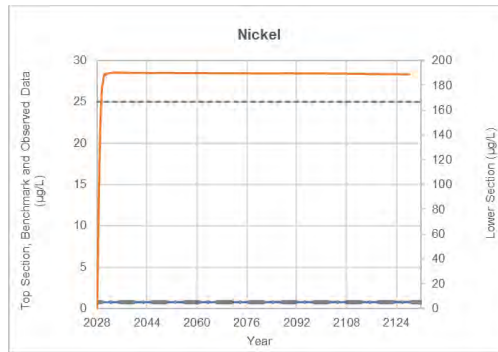
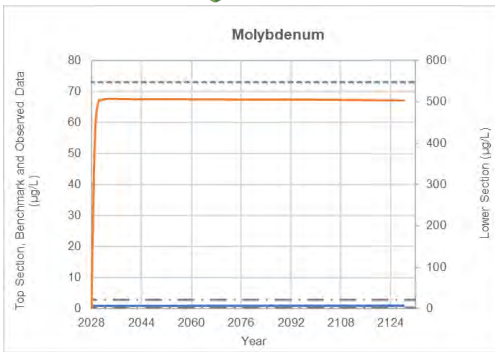


Figure 2- Predicted time Series of A154 Pit Lake Constituent Concentrations – Development Case Sensitivity Scenario









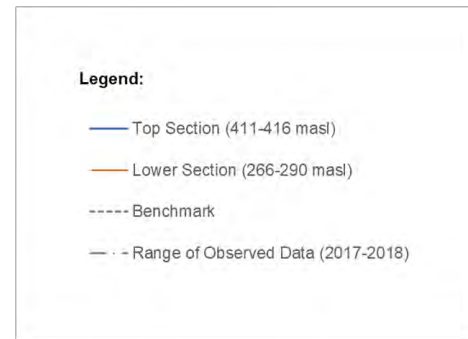
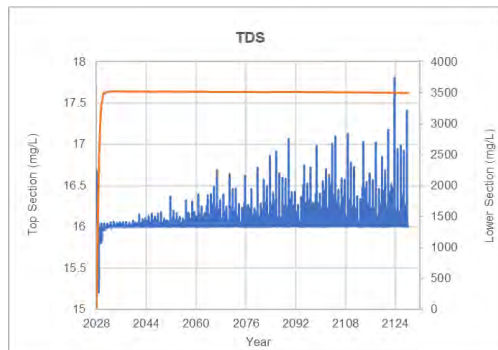
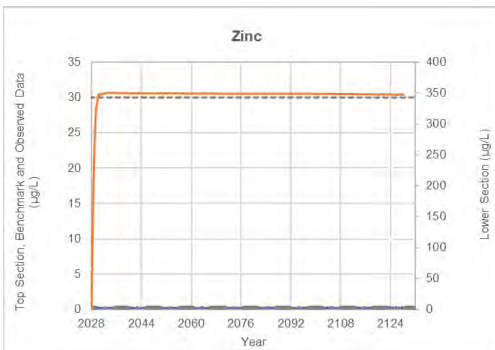
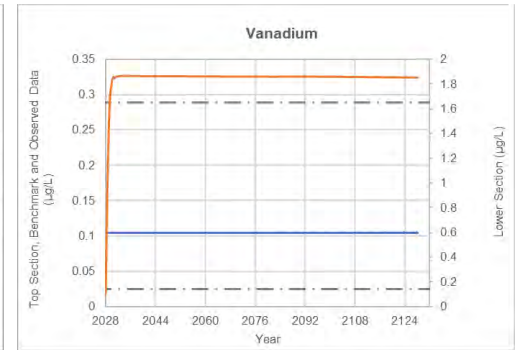
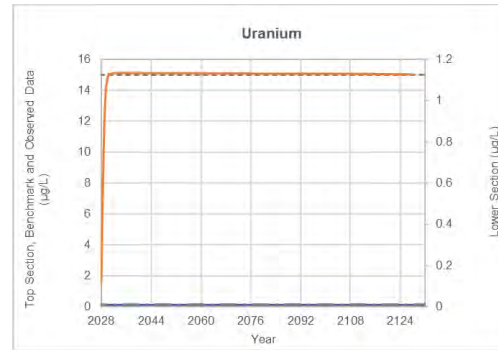
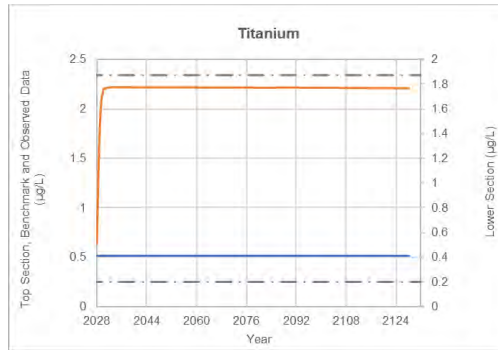
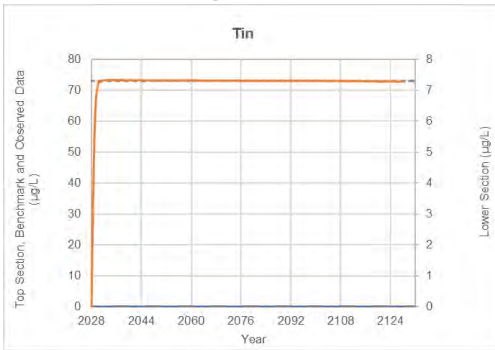
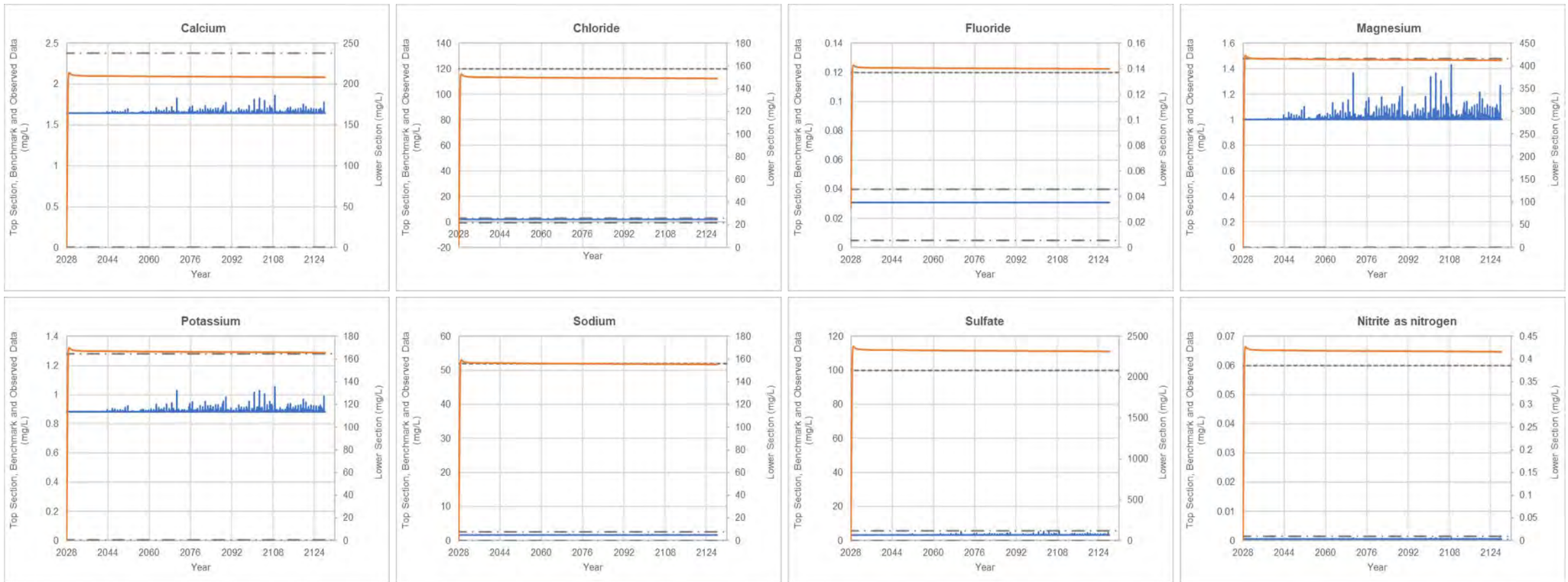
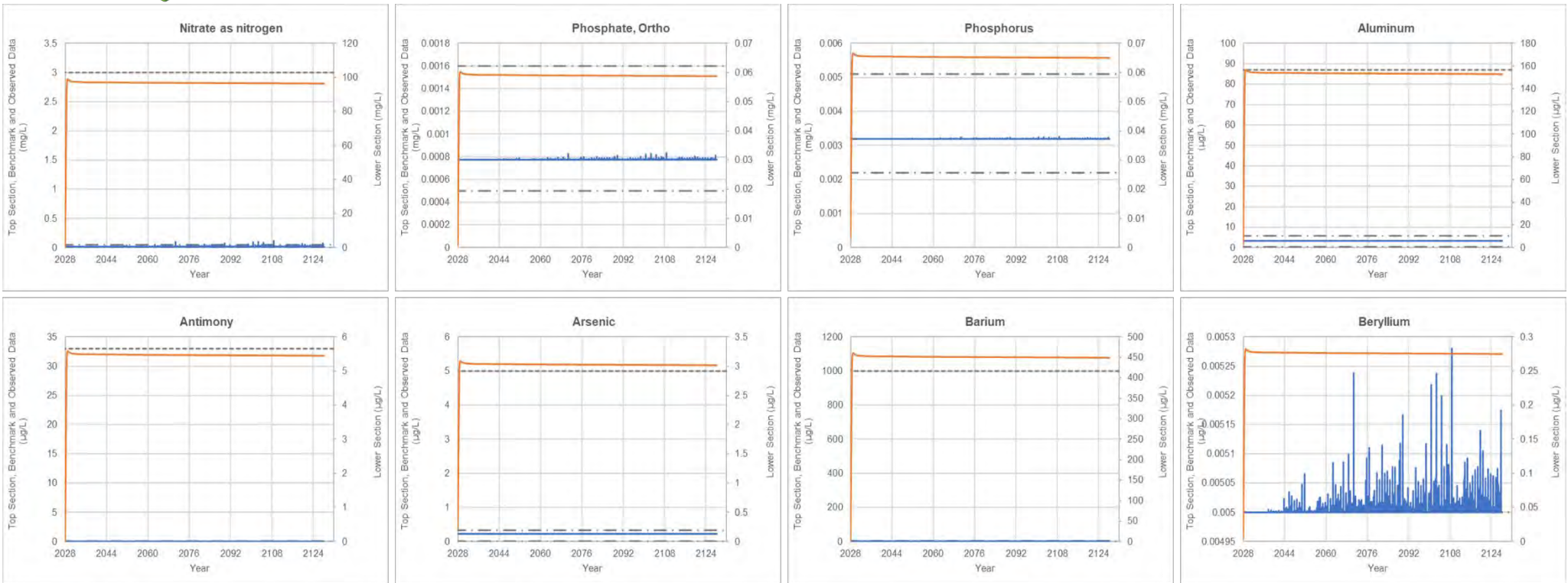
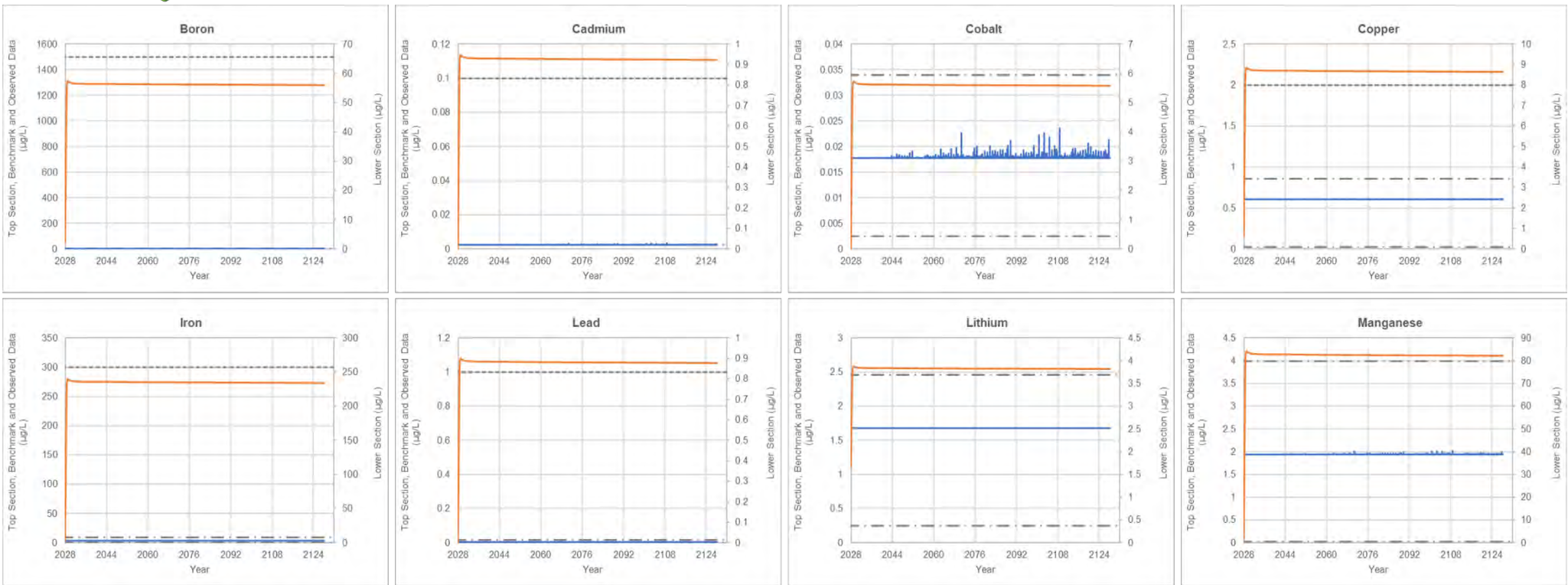


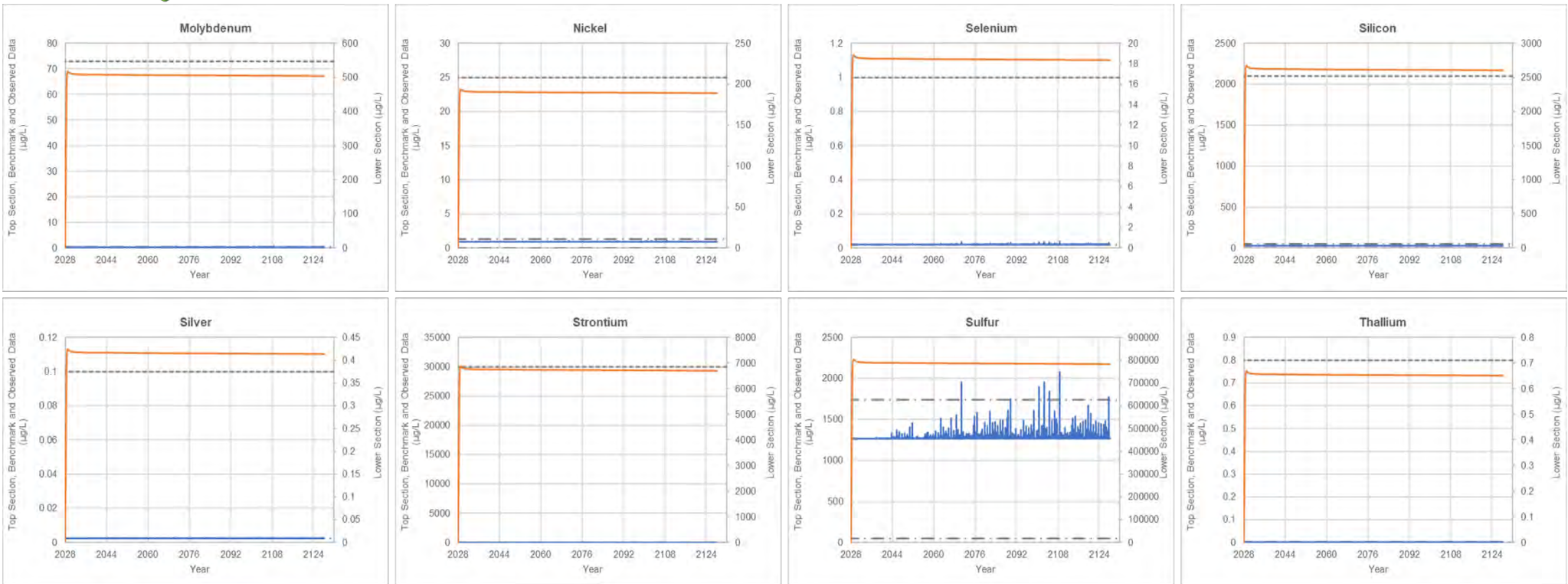


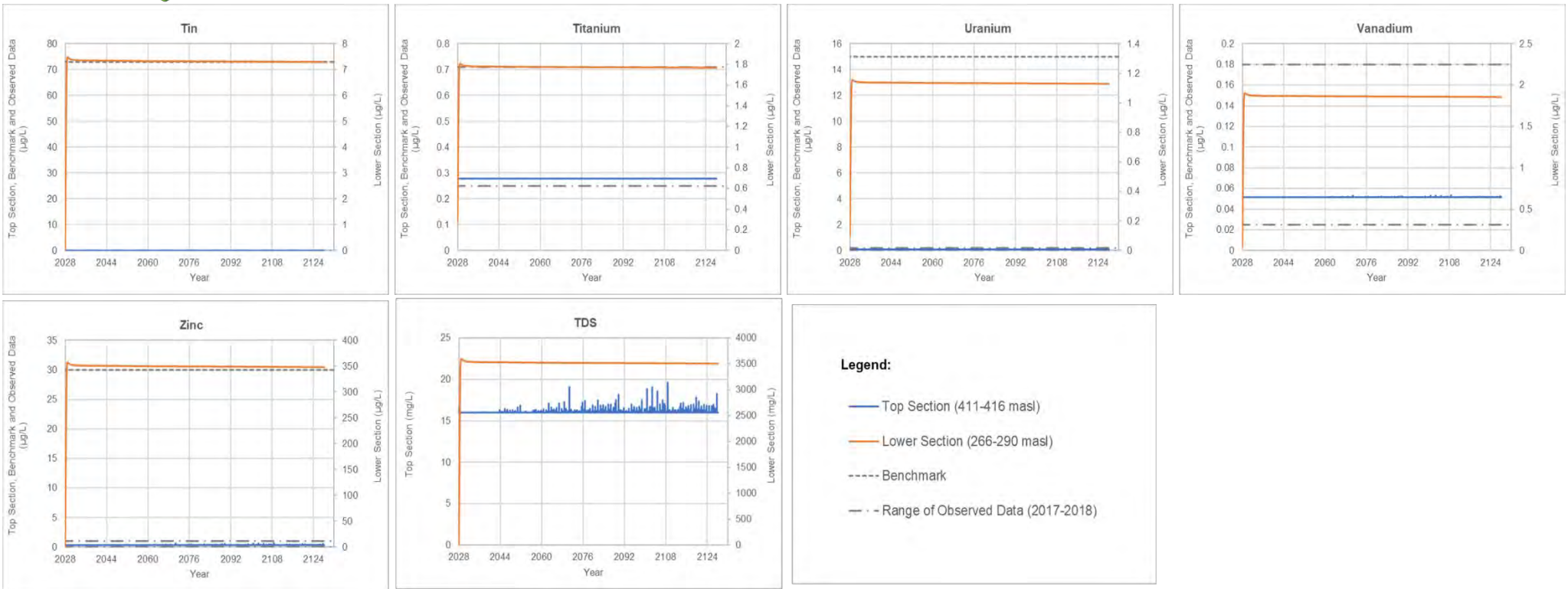
Figure 3- Predicted time Series of A21 Pit Lake Constituent Concentrations – Development Case Sensitivity Scenario










Legend:

- Top Section (411-416 masl)
- Lower Section (266-290 masl)
- - - Benchmark
- Range of Observed Data (2017-2018)

Comparison of Laboratory and Field-Scale Predictions of Processed Kimberlite Effluent in the Arctic

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3. *CANMET Mining and Mineral Sciences Laboratory, Natural Resources Canada*

ABSTRACT

When assessing mine closure options, predicting mine waste effluent water quality is a particular challenge. Conventional static and kinetic tests on small sample volumes are typically used to assess if the mine wastes will be acid generating. However, using these small scale tests to assess if or when field-scale waste piles will release poor quality effluent requires recognizing scale-up issues between laboratory and field conditions. At the Diavik Diamond Mine, up to 42 million tonnes of fine processed kimberlite (FPK) will be deposited onsite for permanent storage. To evaluate the effectiveness of using lab scale experiments to predict mineral weathering and the evolution of porewater geochemistry from the FPK storage impoundment, testing was done to quantify the relationship between laboratory humidity cells and large field-scale tanks. Three fractions of FPK were used for the humidity cell experiments including fine, medium and coarse grained fractions of slurry-deposited FPK. Humidity cells representing the three grain sizes were run for 80 weeks in duplicate at 4°C and 20°C, following the ASTM method. Concurrently, three 5700 L high-density polyethylene tanks were filled with the same fractions of FPK material as the humidity cells. The three tanks were constructed to represent unsaturated conditions. Each tank was instrumented in detail to measure pore water geochemistry, gas-phase concentrations and oxygen diffusion, matrix pressure and flow, evolution of temperature, as well as to resolve mass and flow balances. Results from this study will be used for closure plans at Diavik and potentially other Diamond mines in the Canadian North.

Keywords: Sulfide oxidation, neutralization, processed kimberlite, humidity cells, scale-up

INTRODUCTION

Processed kimberlite (PK) is discharged by slurry to permanent tailings impoundments at diamond mines in Canada's arctic. The Diavik Diamond Mine (Diavik) is an operating mine with two completed open pits and an underground mine. Up to 42 million tonnes of slurry-deposited fine processed kimberlite is expected to be permanently retained on-site in the Processed Kimberlite Containment (PKC) facility. Slurry-deposited PK is defined by Diavik as the < 1 mm fraction of the PK stream and is referred to as fine PK (FPK). Diavik is located 300 km northeast of Yellowknife, NT, Canada (Figure 1) in the remote barren lands of the Canadian arctic. The area is dry and cold with a mean annual temperature, rainfall, snowfall and lake evaporation of -12°C, 164 mm, 187 mm and 271 mm, respectively.

Laboratory humidity cell experiments and *in situ* 5700 L tank experiments were initiated in 2012 to complement an on-going *in situ* PKC experiment at the Diavik Diamond Mine (Moncur and Smith, 2012) to understand better the complexities of using small-scale laboratory experiments for long-term predictions of seepage quality.

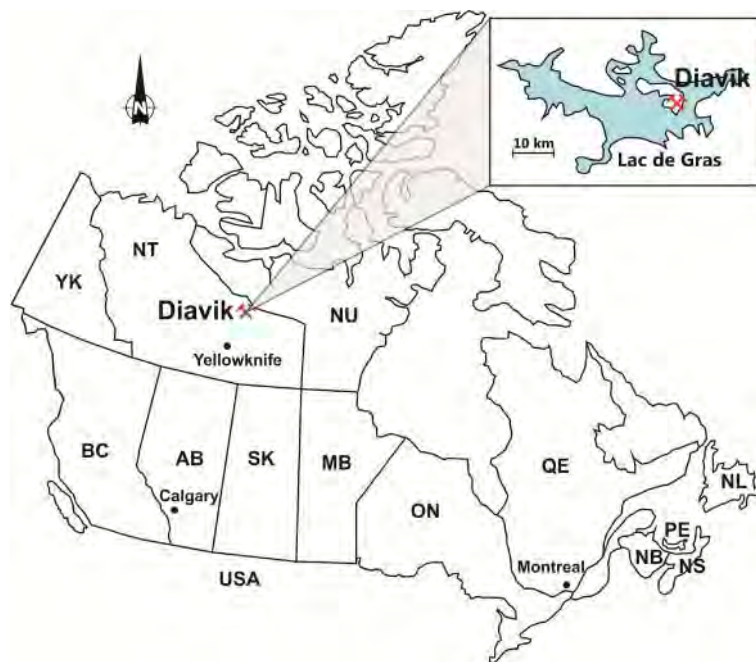


Figure 1 Location of Diavik Diamond Mines in NT, Canada.

METHODOLOGY

Processed kimberlite used for this study was deposited by slurry in 2011 on the East Beach of the PKC. Using a track hoe, FPK was excavated and transported by dump truck on August 2, 2012 to the experiment site. The coarse fraction of FPK (CT) was collected near the toe of the containment dam; the fine fraction of FPK (FT) was collected approximately 200 m from the dam, adjacent to the standing pond water; and the medium FPK fraction (MT) was collected mid-way between the pond

and the containment dam. During FPK excavation every attempt was made to remove the overlying unsaturated FPK to prevent the collection of previously weathered material. Material collected for the tanks was excavated from within the saturated and frost zones of the impoundment.

Tank design and construction

Instrumentation was selected to measure pore water geochemistry, gas-phase concentrations and oxygen diffusion, matrix pressure and flow, evolution of temperature, as well as to resolve mass and flow balances, developed after Smith et al. (2013).

Each tank was constructed from a 2 m in height by 2 m diameter 5700 L HDPE tank. The top of each tank was cut off at a 1.8 m and a 44.5 mm drainage hole was drilled in the wall of the tanks near the bottom for drainage. Water discharging from the bottom of each tank was channeled through a 37.5 mm schedule 40 PVC pipe into a sealed sample cell (Figure 2). Overflow from the sample cell discharged into a data-logging tipping bucket rain gauge so that a continuous record of flow could be maintained to provide bulk chemistry and volume of flow from each tank.



Figure 2 Photos showing (A) completed PK tanks, from left to right FT, MT, CT (B) tank bottom drain pipe discharging into the sample cell and tipping bucket (C) instrumentation on tank tops.

Soil water solution samplers (SWSS) were installed in each tank to provide point measurements of pore water solute concentrations by extracting pore water using applied suction from an area of influence around the probe tip. SWSS were installed at depths of 0.25, 0.5, 1.0, 1.5 and 1.7 m.

Decagon Devices ECH₂O-TE probes were installed in each tank at depths of 0.25, 0.5, 0.75, 1.0 and 1.5 m to provide discrete measurements of electrical conductivity (EC), volumetric water content and temperature. Measurements of volumetric water content through space and time can be used to monitor the wetting front propagation through each tank in which discontinuous zones of ice may form, and may indicate the locations and/or transient nature of any preferential flow paths. Continuous monitoring of EC at various depths will provide an understanding of the evolution of pore water during weathering, precipitation and freeze/thaw events. All ECH₂O probes were connected to a Decagon Devices EM50 data logger that continually records measurements every 4 hours.

A thermistor string consisting of 10 thermistors was installed at 0.0, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5 and 1.75 m depths through each tank to allow the determination of spatial and temporal variations in permafrost formation, as well as the quantification of thermal contributions from exothermic sulfide oxidation reactions. Nine of the thermistors were attached to a 37.5 mm PVC stand pipe for support, with the bottom thermistor placed on the tank bottom. The PVC stand pipe was filled with FPK to prevent the conduction of air temperatures down the pipe annulus. Thermistor strings were connected to Lakewood Systems UltraLogger data loggers for continuous measurements.

Gas sampling lines consist of 0.63 mm I.D. low density polyethylene tubing installed at 0.1, 0.2, 0.3, 0.4, 0.5, 0.7, 0.9, 1.1, 1.3, 1.5 and 1.7 m depths within each tank. Internal gas compositions in each tank will be used to understand O₂ gas transport mechanisms, O₂ consumption rates from the oxidation of sulfide minerals, and CO₂ production or consumption rates from the dissolution or precipitation of carbonate minerals. Measured O₂ consumption rates can be used to determine sulfide mineral oxidation rates assuming sulfide oxidation is the only process consuming O₂ (Linklater, Sinclair and Brown, 2005).

Soil moisture 2725ARL Jet FI11 tensiometers were installed in the unsaturated zone of the tanks to measure pressure potential (matrix potential) in the FPK at depths of 0.25, 0.5, 1.0, 1.5 and 1.7 m. Pressure potential measurements will be used to calculate the gradient pressure in order to determine the rate of water movement through the unsaturated zone in the tanks.

Each tank was filled with the assigned FPK fraction in lifts of 0.3 to 0.4 m. Filling the tanks in lifts was necessary to accurately place the instruments and insure material was applied uniformly and compacted. Tanks were filled with FPK to a height of 1.7 m above the tank bottom. During filling of the tanks, a 20 L composite sample from each tank was collected for humidity tests and analyses of mineralogy, grain size, total sulfur and carbon, whole rock analyses, acid-base accounting and neutralization potential. All tanks were filled and instrumented on August 3, 2012 and remain exposed to ambient conditions year-round.

Sampling

Water sampling was initiated on August 28, 2012. Porewater was collected into SWSS by applying a vacuum of approximately 70 kPa two days prior to sampling. Water samples were collected from SWSS and drain sample cells using 60 mL polyethylene (PE) syringes. Measurements of pH, Eh and electrical conductivity (EC) were made on unfiltered samples in the field. The resulting water samples were passed through 0.45 µm filters and split into three aliquots. One aliquot of water was acidified with 12 N trace-metal grade HNO₃ to a pH of <1 for cation analysis, and another aliquot was left unacidified to use for anion analysis. The remaining water was used for alkalinity and NH₃ analyses. Water samples collected for anion and cation analyses were immediately refrigerated until analyses. Determination of major cations and trace elements was performed by inductively coupled plasma-optical emission spectroscopy (ICP-OES) and inductively coupled plasma-mass spectrometry (ICP-MS), respectively. Ion chromatography was used to measure inorganic anion concentrations. Concentrations of O₂ and CO₂ gas were measured from gas lines using a Grafton Model 902 O₂/CO₂ analyzer. Air temperature and precipitation data from site was provided by Diavik.

Humidity Cells

Two samples of each the fine-, medium- and coarse fractions of FPK were split from the tank material for an 80 week kinetic testing program. Kinetic testing followed the ASTM (1996) 5744-07

protocol, with the exception that samples were not crushed. Original size fractions were maintained in order to observe any geochemical variation caused by differences in grain size distributions. One set of fine, medium and coarse humidity cells was operated at room temperature (~22°C) and one set was operated at 4°C. The cells were subjected to a weekly cycle of a 3-day dry period (0% relative humidity), 3-day wet period (>95% relative humidity), and a 1-day flood leach with 500 mL of DI water. Effluent from each humidity cell was analyzed weekly for pH, ORP, acidity, alkalinity and SO₄. Dissolved metals, Cl and F were analyzed weekly from week 1-20, bi-weekly from week 20-40, and every six weeks from week 40-80.

RESULTS AND DISCUSSION

Mineralogy

The kimberlite pipes at Diavik are intrusions within supracrustal rocks and late Archean granitoids of the Slave structural province (Moss, Russell, and Andrews, 2008). The pipes are composed of bedded volcanoclastic kimberlite, consisting of both kimberlite and mudstone xenoliths. Processed kimberlite used for this study was composed of olivine, calcite, quartz, garnet, lizardite, biotite, albite, saponite, and both framboidal and massive pyrite. Pyrite grains are mostly encapsulated in fragments of serpentine and aluminosilicate clays. The acid generating potential (AP) and neutralizing potential (NP) of the FPK were calculated following the Modified ABA test described by MEND (1991). The AP values are similar among the three grain size fractions, 5.3 - 7.8 kg CaCO₃ eq/t, however not all of the AP would be available due to the occurrence of some pyrite as locked particles in other mineral fragments. The NP of the samples are similar, 165 - 218 kg CaCO₃ eq/t, and far exceed the acid generating potentials (Table 1). Olivine and calcite were the primary neutralizing minerals.

Sieve analyses using sieves +20, -20+35, -35+60, -60+100, -100+120, -120+200, -200+270 and -270 show the differences in grain size between the FPK in the three tanks and humidity cells (Table 1). The FPK from the FT and MT samples were similar with FT having slightly finer FPK, whereas the FPK from CT was coarser with a lower uniformity coefficient (Table 1).

Table 1 Grain size distribution, sulfur content, neutralization potential (NP), acid-generating potential (AP) and net neutralizing potential (NNP) for the tank and humidity cell experiments.

Tank	d10	d60	Uniformity Coefficient	Sulfur (%)	NP (kg CaCO ₃ eq/t)	AP (kg CaCO ₃ eq/t)	NNP (kg CaCO ₃ eq/t)
FT	0.07	0.39	5.8	0.23	218.4	5.3	213
MT	0.08	0.44	5.3	0.34	203.1	7.8	195
CT	0.18	0.82	4.6	0.26	165.3	6.6	159

Processed kimberlite tanks

The pH from the tank drains were circumneutral to alkaline and showed little variation between tanks during the active period of June 1, 2013 to August 31, 2013 (Figure 3). The Eh and alkalinity trends were similar to that of pH, with all tanks exhibiting oxidized conditions and alkalinity typically >40 mg L⁻¹ (as CaCO₃) (Figure 3), consistent with calculated NNP. Concentrations of SO₄ remained relatively constant for each tank but with the FT tank drain having much lower concentrations (Figure 3). The CT tank had slightly higher concentrations than the MT tank (Figure 3). The EC trends for the tanks mirror the SO₄ concentration trends with the highest concentration of dissolved SO₄ observed from the CT tank and the lowest from the FT tank (Figure 3).

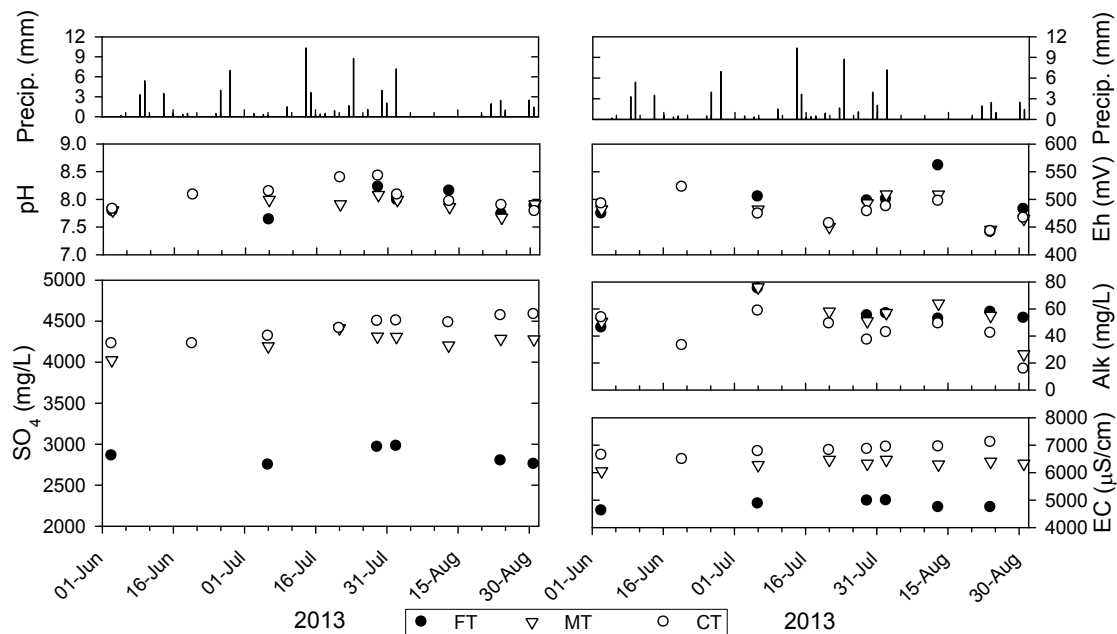


Figure 3 Temporal variation of precipitation, pH, SO₄, Eh, alkalinity and EC from the PK tanks between June 1, 2013 and August 31, 2013.

The pH in the SWSS from all three tanks remained circumneutral to alkaline at all depths and was slightly higher in the MT and CT tanks for 2013 than for 2012 (Figure 4), possibly as accumulated reaction products began to flush through the tanks. Similarly, alkalinity concentrations in all tanks at all depths remained similar for both 2012 and 2013 (Figure 4), consistent with calculated NP values and alkalinity concentrations measured in porewater from the unsaturated zone at the PK facility (Moncur and Smith, 2012). Dissolved sulfate concentration in PK slurry water from the end-of-pipe ranged from 59 to 380 mg/L. Porewater concentrations of dissolved sulfate in the tanks approached 5000 mg L⁻¹ and remained relatively constant between 2012 and 2013 sampling events (Figure 4). These elevated dissolved sulfate concentrations suggest that sulfide oxidation is likely occurring throughout the tanks (Lindsay et al., 2015). Depletions in O₂ in the FT and MT tanks were observed for 2012, but O₂ concentrations remained near atmospheric levels in 2013 and for both years in the CT tank (Figure 4). Volumetric water content (VWC) was typically higher in 2012 than in 2013 but varied with depth. The similar peaks and trends between sample years suggest the changes in VMC are not an artefact of sample timing dates (i.e. sampling during a particularly dry or wet time) and may suggest compositional differences by depths that affect wetting front propagation.

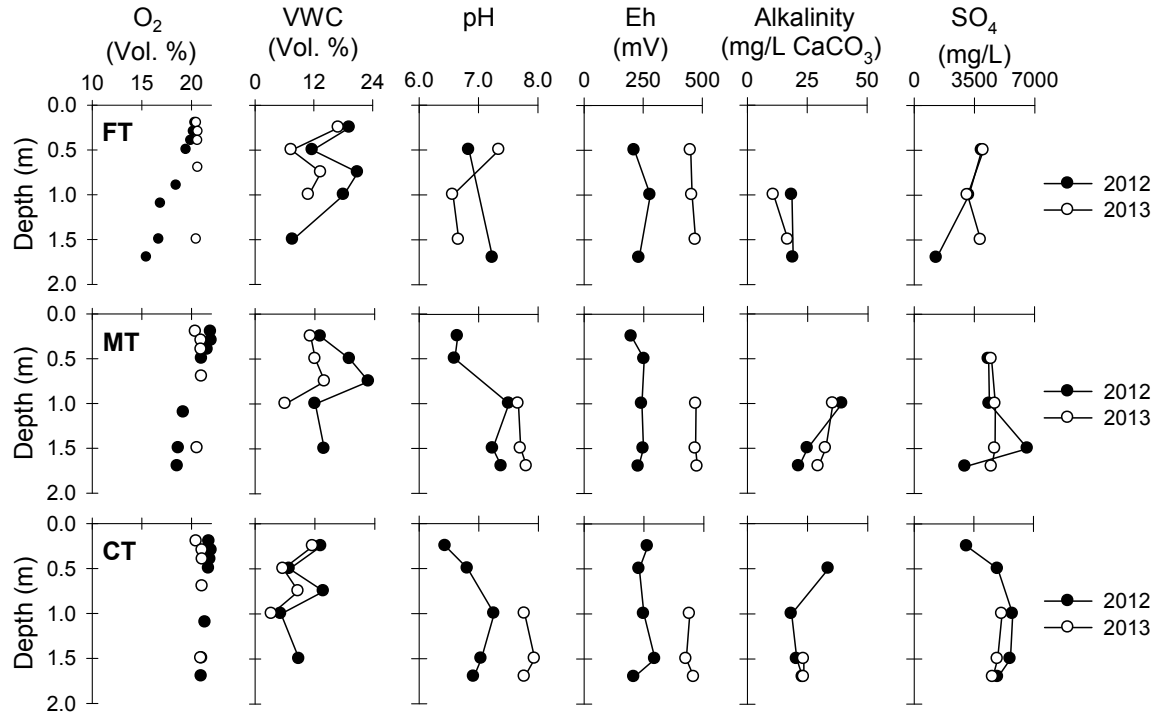


Figure 4 Depth profiles of oxygen gas, volumetric water content (VWC) and selected porewater chemistry from the PK tanks measured in 2012 and 2013.

Humidity cells

The pH in all humidity cell charges remained circumneutral to alkaline for the duration of the experiment with pH values ranging from 7.1 to 8.4 (Figure 5). The cells in the cold room consistently exhibited higher pH compared to the corresponding cell at room temperature. The room temperature cell with CT material exhibited lower pH and erratic fluctuations compared to the other five cells, possibly as a result of preferential flow paths reducing contact and reaction time with the cell material. However, alkalinity measurements from the same cell did not exhibit the same erratic behavior. Alkalinity remained >60 mg/L (as CaCO₃), for the duration of the experiment (Figure 5). Conditions within all cells remained oxidized with ORP ranging from 300 to 450 mV, consistent with the tank data.

Sulfate release rates were slightly higher for room temperature cells than for cells operated at 4°C, and in descending order, FT, MT and CT cells (Figure 5). Data from the first three weeks represent flushing of accumulated reaction products. Release rates from week 4 – 24 declined rapidly, and then declined at a more moderate rate from week 24 – 55. Sulfate release rates become more stable after week 55 until the end of the experiment at week 80 (Figure 5). Mass calculations suggest 77-85% of total sulfur and 73-81% of sulfides remain in the test charges after the 80 week experiment; however the decreasing rates suggest available sulfide surfaces are becoming limited by a reduction of available free grains, sulfide armoring or other limiting processes within the test cells.

Preliminary pH and alkalinity tank data are typically consistent with both the humidity cell experiments and the static tests which indicate that there is an excess of neutralization potential

over acid-generating potential. On-going monitoring of the tanks will determine if SO₄ release rates in the tanks follow the observed humidity cell trends of rapidly declining release rates despite >70% of measured sulfides remaining in the samples. Though not directly comparable, the difference between tanks in drain SO₄ concentration trends from humidity cell release rate trends suggest additional processes are occurring *in situ*. These processes need to be identified and evaluated for any scaling calculations.

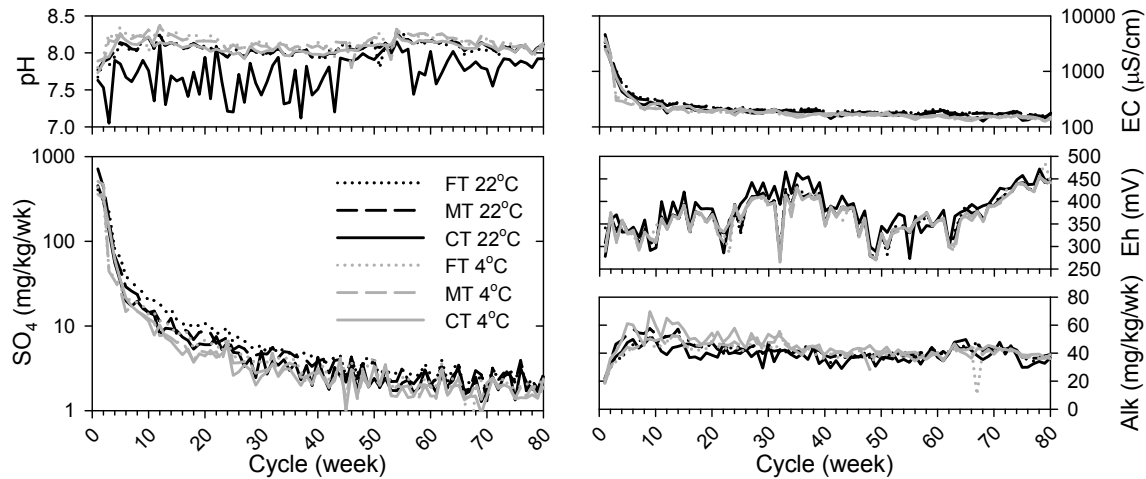


Figure 5 Temporal variation of pH, SO₄, EC, Eh and alkalinity of leachate from the FT, MT and CT humidity cells at 22°C and 4°C.

CONCLUSION

Comparing humidity cell reaction rates to the *in situ* tank experiment results are preliminary because the low amount of precipitation and infiltration and short thaw season limits the release of reaction products from the tanks and products are expected to take more than one thaw year to flush from the tanks. On-going monitoring of the tank experiments will permit the calculation of an *in situ* sulfate release rate(s) that accounts for local climatic factors that affect sulfide oxidation. Tank release rates can then be compared to humidity cell release rates to determine the applicability of using the small-scale tests to predict long-term seepage quality from the PKC facility. Diavik will use the results from the tank and humidity cell experiments to predict and refine long-term seepage quality from the PKC facility.

ACKNOWLEDGEMENTS

We would like to thank David Blowes, Kevin Tattrie, Jeff Bain, Sean Sinclair, Kent Richardson, David Wilson, Gord Macdonald, Emily Taylor, and the Diavik Environment team for their advice and technical assistance. This project was funded by Rio Tinto-DDMI. We thank an anonymous reviewer for their constructive evaluation of this manuscript. The use of trade names is for descriptive purposes only.

NOMENCLATURE

PK	Processed kimberlite
PKC	Processed kimberlite containment facility
FPK	Fine processed kimberlite
FT	Tank with fine FPK fraction
MT	Tank with medium FPK fraction
CT	Tank with coarse FPK fraction
SWSS	Soil water suction sampler
EC	Electrical conductivity

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EMAB-6**EMAB Comment:**

The quality of the water in the stratified layer is of major concern if this layer was to mix with surface water in Lac de Gras. The layer will contain essentially all of the porewater released from PK consolidation and could also be anoxic (no oxygen). Mixing of this mass of porewater with the surface water could have a material impact on water quality and fish in the pit lake. The mixing of the stratified water with Lac de Gras was modelled and indicated some elevated levels of several contaminants. The report suggests this will be a short-term issue (one to two months) based on Sensitivity Scenario 2 (20 m water cap) however this has not been demonstrated. The 150 m water cap scenario would be expected to take longer to reach equilibrium with Lac de Gras due to the higher volume of water in the cap. The base case suggested mixing is most likely to occur in October just prior to freeze up, which would also be expected to delay mixing. It will therefore be important to model water quality for this period to assess how long elevated conditions exist and whether this will have any impact on fisheries.

The Pit Lakes post closure are planned to provide nursery and rearing habitat for fish, in particular Lake Trout and Cisco. These life stages may be more sensitive to degradation of water quality. Could infrequent mixing of the water column result in the mortality of juveniles inhabiting these areas?

EMAB Recommendation:

Diavik should rerun the case where the pit destratifies and fully mixes. The modelled destratification should occur in October just prior to freeze up. Define a "short lived" duration for the 150 m water cap scenario ie. how long would it take for conditions to return to levels below the AEMP benchmarks? Assess what effect low DO levels and contaminants of concern have on water quality and fish.

Please provide an assessment of the sensitivity of early life stages of fish to the potential infrequent mixing of the water column.

DDMI Response:

As model results show (Section 4.1), the pit lakes are predicted to develop strong stratification under the Development Scenario (150 m water cap) over a 100-year simulation period. A "what if" scenario was assessed which assumed unanticipated mixing of the water column in the pit lakes. The results of this "what if" scenario were presented in Section 4.3 Golder (2018). The predictions for this scenario were made by calculating the fully mixed concentration of the tracer at every day of the simulation period.

- For the response to this IR, a hydrodynamic model for A418- Development Case Scenario was setup as follows to consider the "what if" scenario:
- The worst case scenario (for Development Case) was to assume the unanticipated mixing occurs on the last day of year 100 (PK porewater entered the pit lake for 100 years)
- Fully mixed TDS concentration of pit lake water column (assuming a turn over) was calculated for that day
- Initial TDS concentration in the pit lake water column was set to this value
- The first day of simulation period was set to mid-October (just before freeze up)

- The model then was run for 100 years to see how long it will take for the concentrations in the surface waters to drop below AEMP benchmarks

The first day of the simulation (i.e., when the turnover occurs) had the highest maximum concentration, after which concentrations decrease in the water column as a result of flow exchange between the pit lake and Lac de Gras. The concentrations over the 100 year simulation period are presented in Figure 1. A discussion of the potential for DO depletion during an unanticipated mixing event and the potential effects of low DO on fish (including early life stages) is presented in the response to EMAB-30.

Time series of predicted constituent concentrations compared with the AEMP benchmarks (i.e. chronic effects benchmarks) are presented in Table 1. If AEMP benchmarks were exceeded, the predicted constituent concentrations were compared to generic (i.e., non-AEMP) acute water quality guidelines (WQG) to evaluate the potential for acute effects to aquatic organisms during a “what if” scenario. Acute WQGs for the protection of aquatic life in freshwater were selected from Canadian Council of Ministers of the Environment (1999), British Columbia Ministry of the Environment (2017), or United States Environmental Protection Agency (2016). The most conservative acute water quality guideline from among these agencies was selected for comparison. In one instance where no guideline was available for nickel from these agencies, the Government of Alberta guideline (2018) was used. If no guideline was available, the constituent was not screened.

Table 1: Predicted Maximum Daily Concentrations in the Surface Water (Top Section) of A418 Pit Lake for the Development Case Scenario over 100-year Period after Closure

Parameters	Unit	AEMP benchmark	Acute Water Quality Guideline	Maximum Concentration in the Surface Water of A418 Pit (Development Scenario)
Calcium	mg/L	-	-	75
Chloride	mg/L	120	-	55
Fluoride	mg/L	0.12	-	0.071
Magnesium	mg/L	-	-	146
Potassium	mg/L	-	-	59
Sodium	mg/L	52	-	57
Sulfate	mg/L	100	-	817
Nitrite as nitrogen	mg/L	0.06	0.60 ^(a)	0.15
Nitrate as nitrogen	mg/L	3	33	34
Phosphate, Ortho	mg/L	-	-	0.022
Phosphorus	mg/L	-	-	0.025
Aluminum	µg/L	87	-	58
Antimony	µg/L	33	-	1.9
Arsenic	µg/L	5	-	1.2
Barium	µg/L	1000	-	160
Beryllium	µg/L	-	-	0.1
Boron	µg/L	1500	-	22
Cadmium	µg/L	0.1	2.80 ^(b,c)	0.33
Cobalt	µg/L	-	-	2.0

Copper	µg/L	2	40	3.4
Iron	µg/L	300	-	85
Lead	µg/L	1	-	0.31
Lithium	µg/L	-	-	2.7
Manganese	µg/L	-	-	31
Molybdenum	µg/L	73	2,000	178
Nickel	µg/L	25	6,545 ^(b)	67
Selenium	µg/L	1	44 ^(d)	6.5
Silicon	µg/L	2100	-	1037
Silver	µg/L	0.1	3.0	0.15
Strontium	µg/L	30000	-	2381
Sulfur	µg/L	-	-	276604
Thallium	µg/L	0.8	-	0.23
Tin	µg/L	73	-	2.6
Titanium	µg/L	-	-	0.96
Uranium	µg/L	15	-	0.47
Vanadium	µg/L	-	-	0.72
Zinc	µg/L	30	126 ^(c,e)	123

Bolded predicted concentrations exceeded AEMP benchmarks

Underlined predicted concentrations exceeded acute water quality guidelines.

a) guideline is chloride-dependent. The guideline was calculated using the predicted chloride concentration in the surface water under mixed conditions (55 mg/L)

b) guideline is hardness-dependent. The guideline was calculated using the predicted hardness in the surface water under mixed conditions (2,254 mg/L as CaCO₃). Hardness was calculated using predicted calcium and magnesium concentrations according to the following equation: Hardness, mg equivalent CaCO₃/L = 2.497[total Ca, mg/L] + 4.118[total Mg, mg/L].

c) guideline is for the dissolved fraction but was applied to the total fraction as a conservative approach.

d) guideline is an intermittent exposure water criterion element concentration. It is intended to limit cumulative exposure to selenium that could result in bioaccumulation and is derived from the chronic 30-day water criterion and duration of exposure (US EPA 2016). The guideline was calculated assuming a 1-day intermittent exposure and a background concentration of selenium in the A418 pit lake of 0.046 µg/L. Direct acute toxicity from short-term exposure to selenium is rare.

e) guideline is dependent on hardness and dissolved organic carbon (DOC). The guideline was calculated using the maximum validated hardness of 250 mg/L as CaCO₃ and the minimum validated DOC of 0.3 mg/L as a conservative approach. The guideline should not be calculated with hardness and DOC outside of the validated range.

Because mixed conditions may pose an acute toxicity risk, maximum concentrations in the surface water of the A418 pit exceeding AEMP benchmarks (i.e., chronic effects benchmarks) were screened against generic acute WQGs. Nitrate was the only parameter to exceed the acute WQG of 33 mg/L. However, the predicted maximum concentration (34 mg/L) fell just above the acute WQG; therefore, it is unlikely that acute toxicity would occur with exposure to nitrate. Overall, acute toxicity to aquatic organisms (including early life stages of fish) is not expected to occur as a result of mixed conditions under a “what if” scenario.

In the A418 pit lake, under the “what if” scenario (i.e., if turnover occurred), surface water will exceed AEMP chronic effects benchmarks for sodium (as a proxy for total dissolved solids), sulfate, nitrite as nitrogen, nitrate as nitrogen, cadmium, copper, molybdenum, nickel, selenium, silver and zinc. As the time series presented below show (Figure 1), it would take an estimated one to two years for conditions within the pit to fall below AEMP benchmarks for all parameters following turnover.

A study by Liber and Doig (2016) evaluated the chronic toxicity of extra fine processed kimberlite tailings (EFPKT) from Diavik with freshwater algae (*Pseudokirchneriella subcapitata*), chironomid (*Chironomus*

dilutes), epi-benthic aquatic invertebrate (*Hyaella azteca*), water flea (*Daphnia pulex*), and Rainbow Trout (*Oncorhynchus mykiss*). The study identified nitrogenous substances (primarily ammonia and nitrite) as potential sources of toxicity from the EFKPT, and also noted that chromium and nickel may have been potential sources of toxicity (i.e., these metals appeared to be available for uptake by biota) (Liber and Doig 2016). Nitrogenous substances and nickel exceeded AEMP benchmarks under the predicted mixed concentrations (i.e., in the “what-if” scenario); chromium concentrations following turnover were not predicted by the model. The study reported no effects to Rainbow Trout exposed to leachate during acute (4-d) or chronic (28-d) exposures using early life stage fish. Effects on growth and/or survival were noted in the invertebrates *C. dilutus* and *H. azteca* exposed to whole EFKPT sediment, but the response was not statistically significant relative to control. Therefore, a variable toxicity response was demonstrated in organisms in close proximity to processed kimberlite sediment (i.e., chironomid and *H. azteca*) but not in fish (i.e., Rainbow Trout).

There were differences between trace metal concentrations tested in the Liber and Doig (2016) study relative to the predicted surface water concentrations in the model. For example, measured concentrations of several trace metals (e.g., copper, nickel, selenium and zinc) were lower in the pore water and leachate in the study relative to the predicted mixed condition concentrations. The predicted concentrations in Table 1 reflect a maximum, worst-case scenario.

Pit lake water quality in the surface water under the unanticipated “what if” scenario is unlikely to pose a risk to early life stages of fish, but may affect benthic and aquatic invertebrate species in the pits. There is some uncertainty associated with the toxicity of trace metals (e.g., copper, selenium and zinc) to fish for those parameters that exceeded AEMP benchmarks and had higher predicted maximum concentrations relative to concentrations tested in toxicity studies with Diavik pore water and leachate (Liber and Doig 2016).

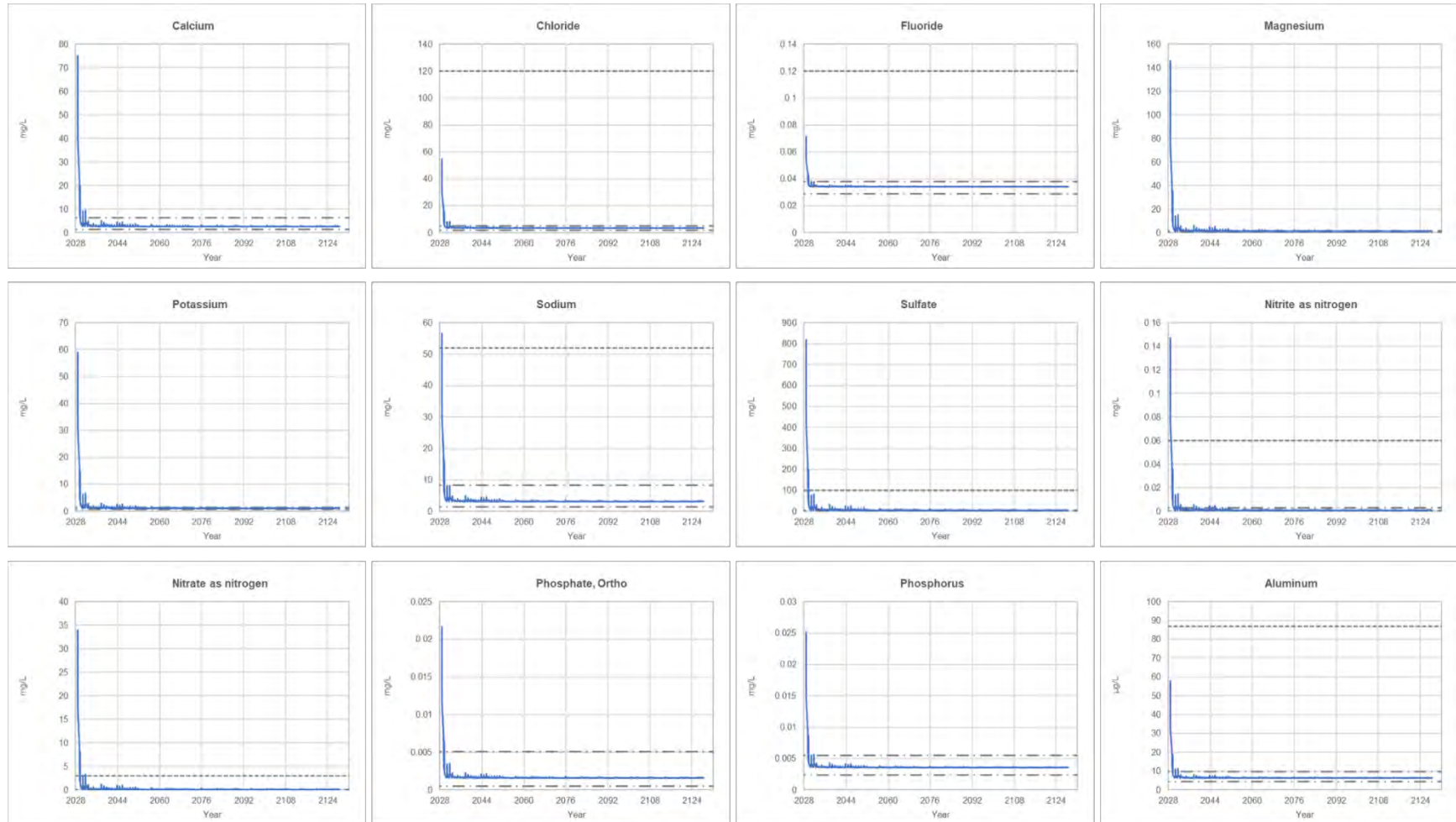
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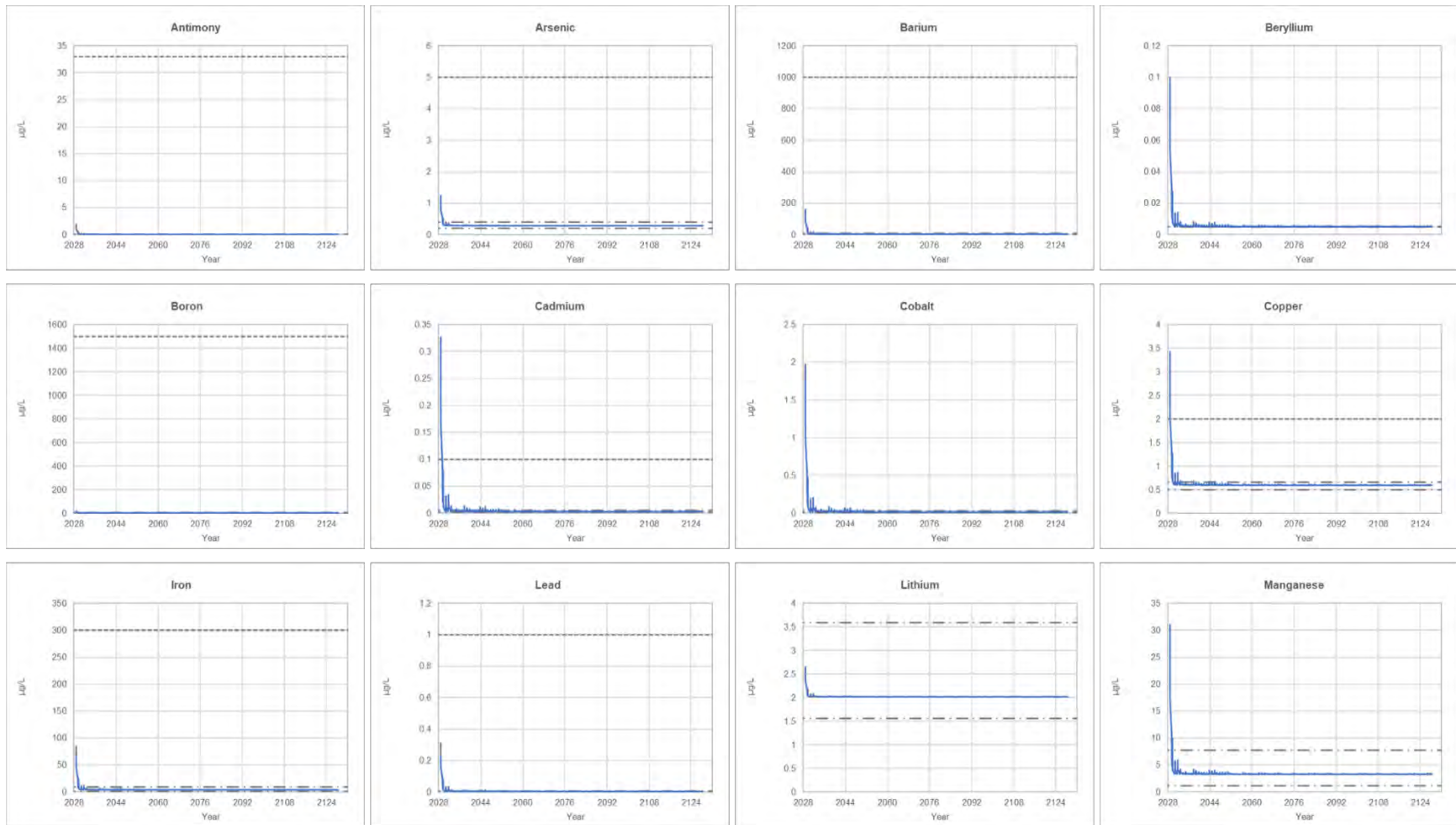
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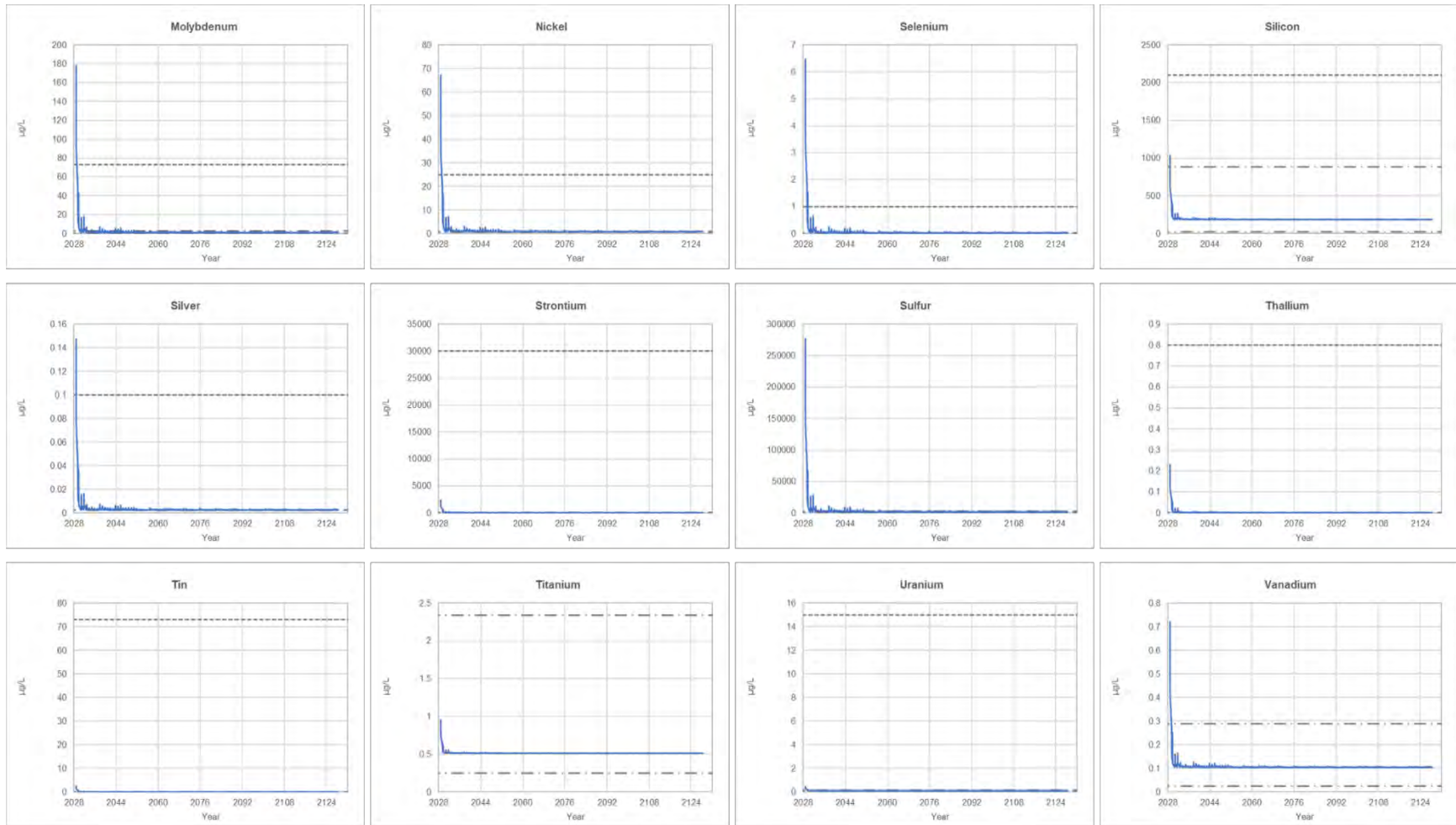
Figure 1: Time Series for A418 Pit Lake Parameters under “What If” (Turnover) Scenario



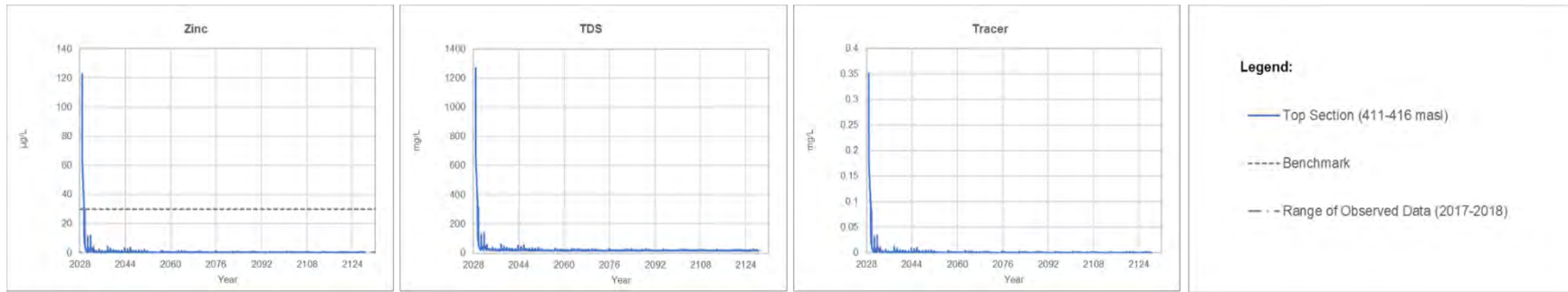
ATTACHMENT #8



ATTACHMENT #8



ATTACHMENT #8



ATTACHMENT #9: TABLES AND FIGURES**DDMI Response to EMAB-10**

Table 1: Long-term Total Dissolved Solids (TDS) load to Lac de Gras

Pit Lake	Scenario	Load (Tonne) over 100 Years
A418	Development Case - anticipated mixing conditions	600
A154	Development Case - anticipated mixing conditions	2200
A21	Development Case - anticipated mixing conditions	2600
A418	Development Case - unanticipated mixing conditions	15000

DDMI Response to EMAB-28

Table 2. AEMP Benchmark Exceedances by Year in Pit Lake A418 - Development Case

Parameter	Depth (m)	
	Year 0	Year 100
Chloride	145	95
Fluoride	145	95
Sodium	145	63
Sulfate	145	40
Nitrite as nitrogen	145	51
Nitrate as nitrogen	145	39
Aluminum	145	77
Cadmium	145	47
Copper	145	53
Molybdenum	145	51
Nickel	145	49
Selenium	145	42
Silicon	145	95
Silver	145	58
Zinc	145	45

DDMI Response to GNWT-ENR-7

Table 3. Total TDS load per source over 100 years

Loading Source	Total TDS Load (Tonnes/100 years)
PK Porewater	33147
Direct Runoff from Mine Area	2692
Groundwater Inflows	408
Rock Wall Runoff	2.3

DDMI Response to EMAB-9

Figure 1: Contour Plots of Predicted Tracer Concentrations in the A418 Pit Lake

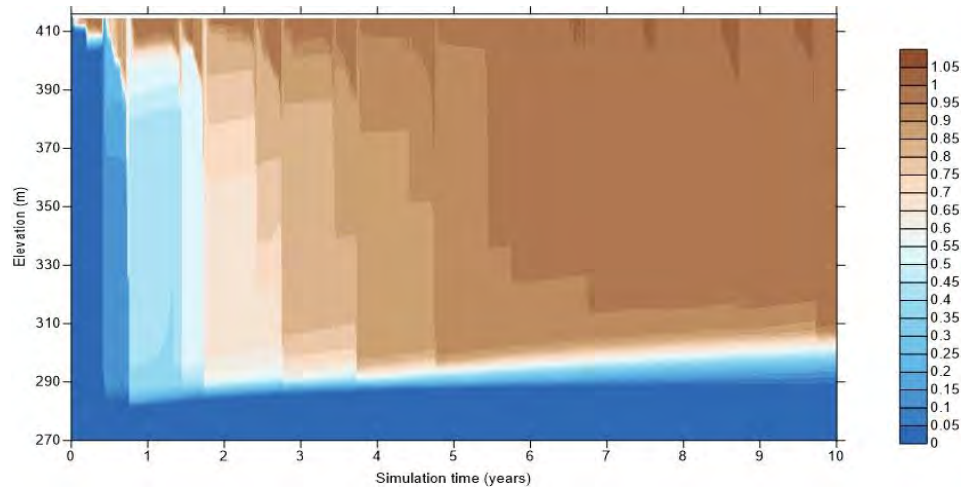


Figure 2: Contour Plots of Predicted Tracer Concentrations in the A154 Pit Lake

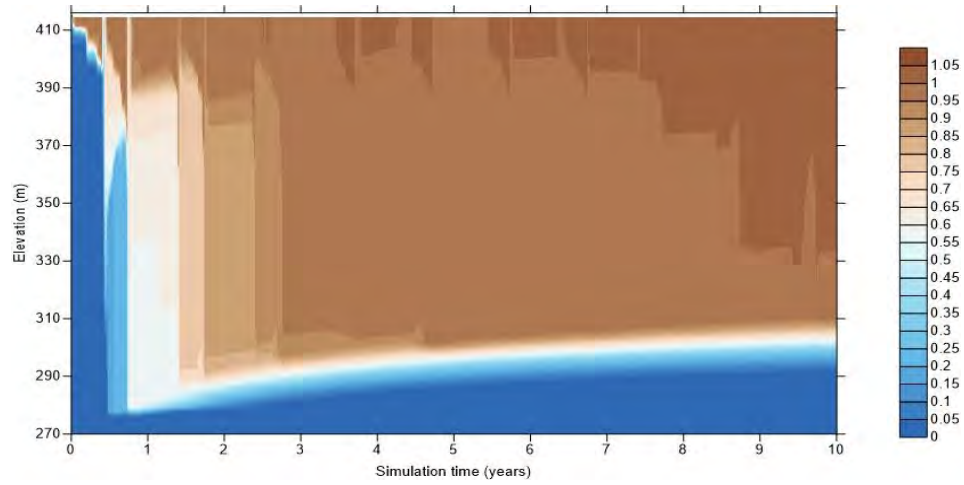
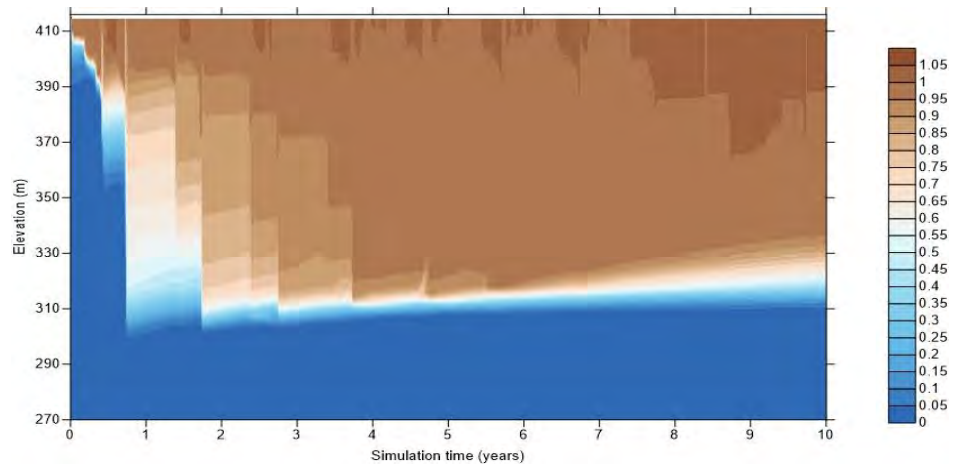


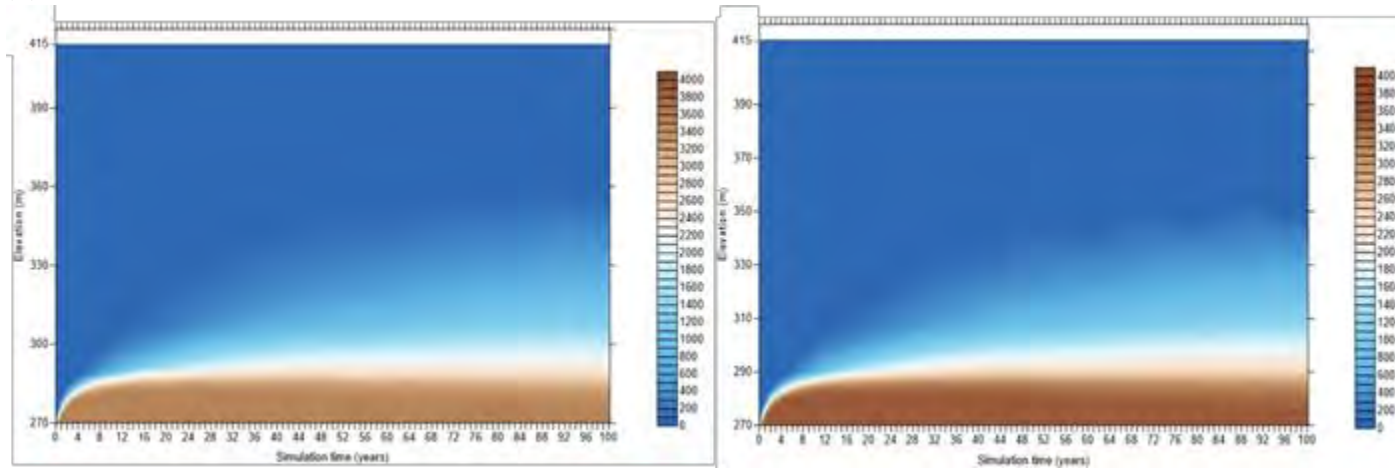
Figure 3: Contour Plots of Predicted Tracer Concentrations in the A21 Pit Lake



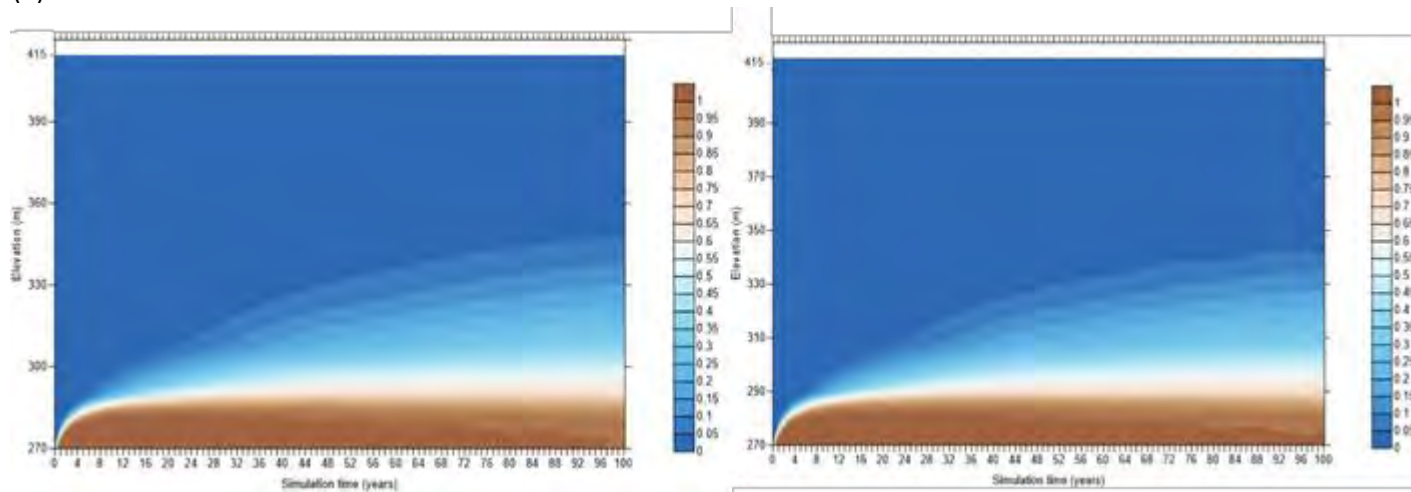
DDMI Response to GNWT-ENR-8

Figure 4: Contour Plots of Predicted Total Dissolved Solids and Tracer Concentrations in the A418 Pit Lake: Development Case Scenario with AZMAX 0.001 m²/s (on the left); Development Case Scenario with AZMAX 1 m²/s (on the right)

(a) TDS:

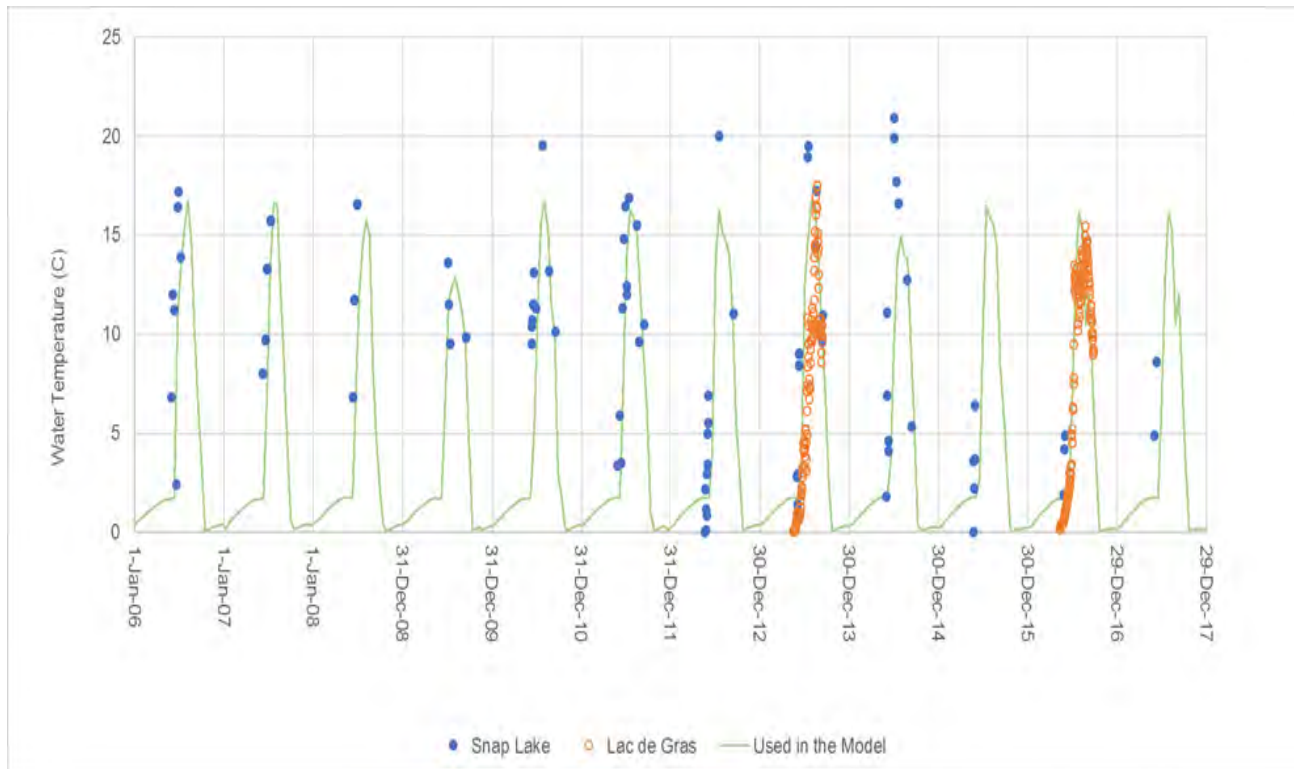


(b) Tracer:



DDMI Response to GNWT-ENR-11

Figure 5. Monitored daily temperature data for Lac de Gras (May 10, 2013 to September 6, 2013; April 19, 2016 to September 18, 2016) and for Snap Lake (2006 to 2017)



DDMI Response to WLWB-3

Figure 6 – Left: Turbidity profiles from Springer Pit and Right: Beartooth Pit

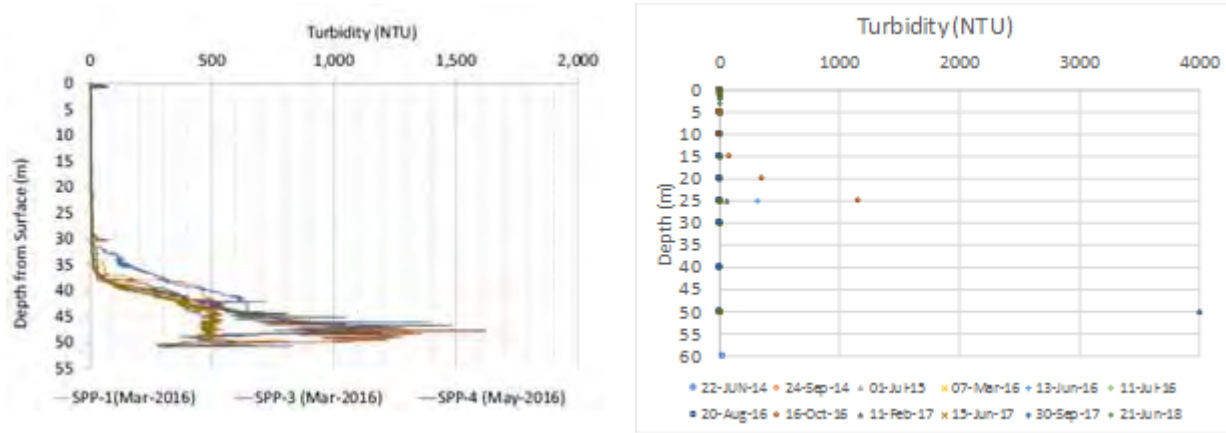


Figure 7 – Left: Turbidity profiles from Springer Pit and Right: Beartooth Pit – both figures shown at finer resolution to evaluate zone of low turbidity

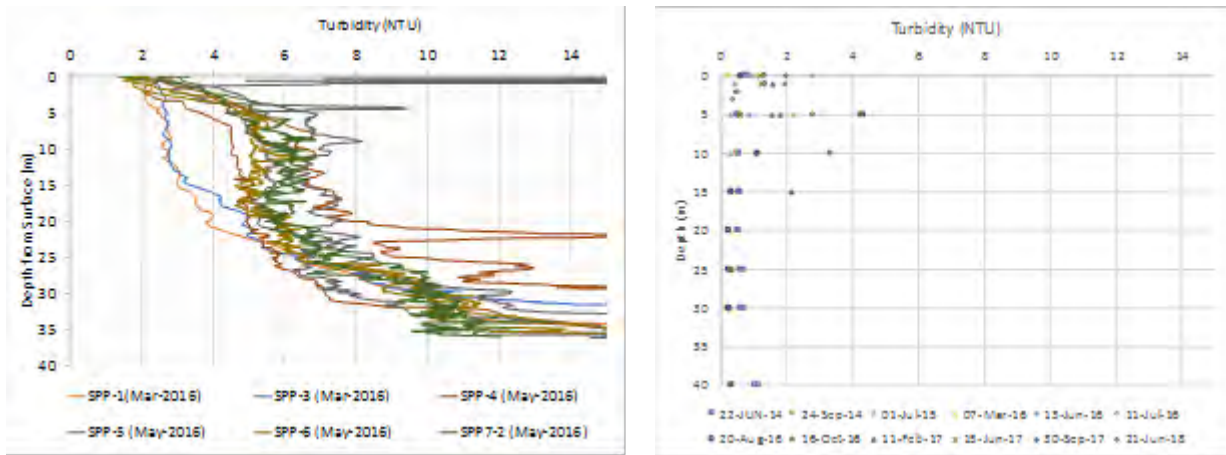


Figure 8 – Vertical Profiles of Total Aluminum

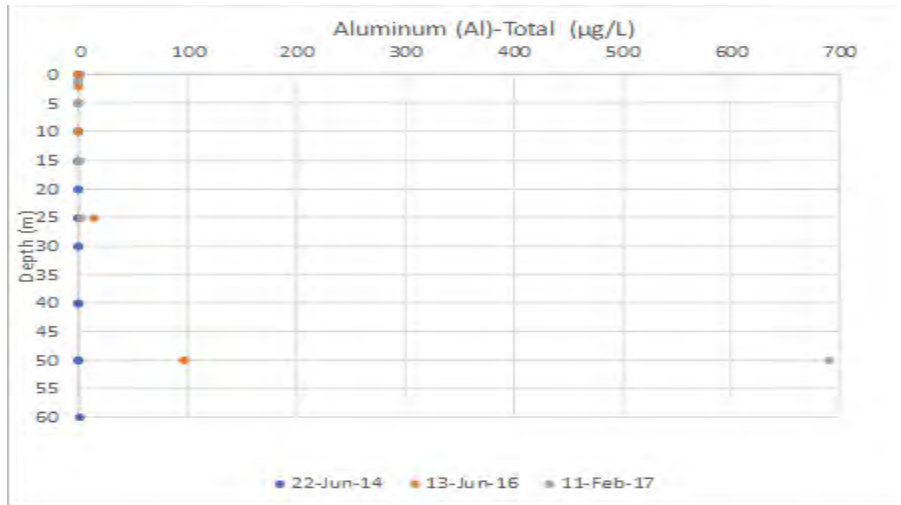


Figure 9 – Vertical Profiles of Total Iron

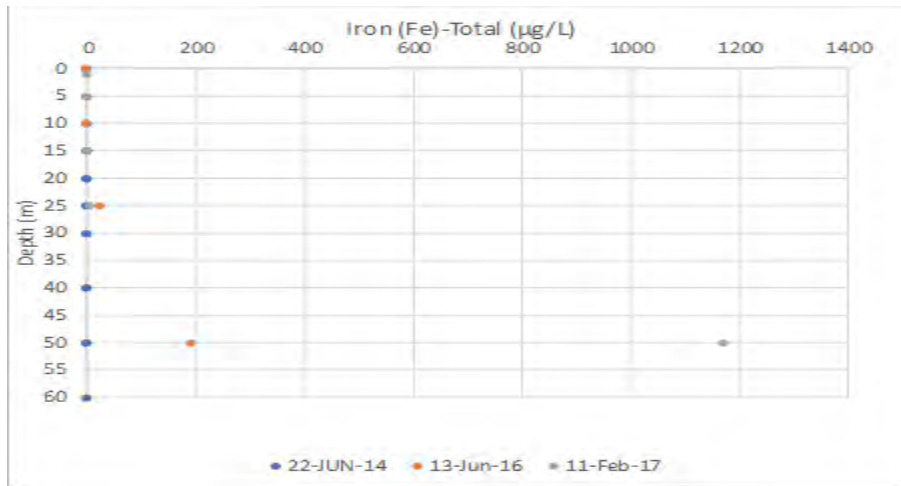


Figure 10 – Vertical Profiles of Total Phosphorus

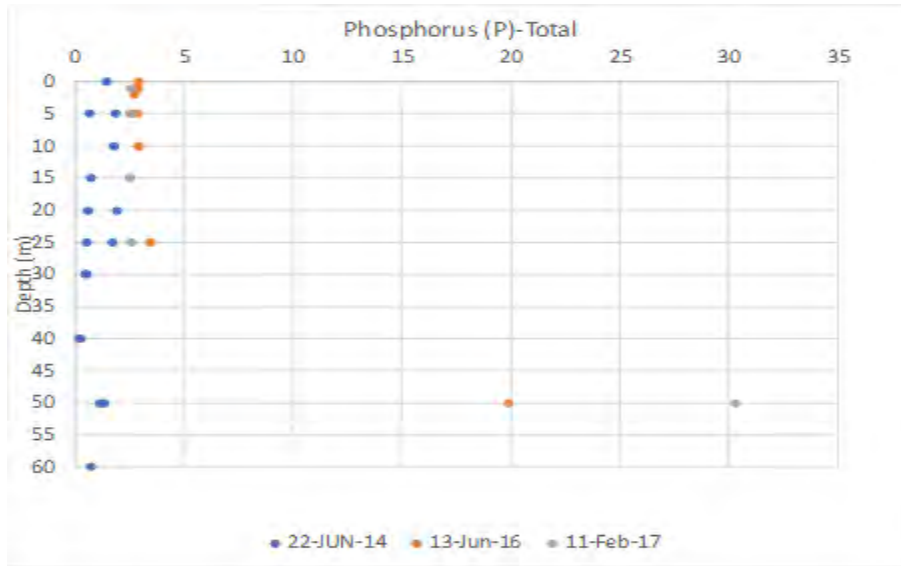
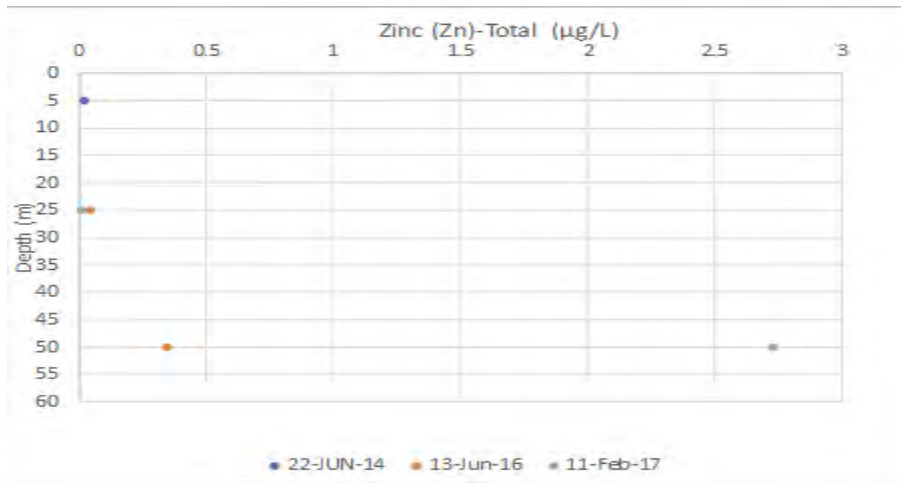


Figure 11 – Vertical Profiles of Total Zinc



ATTACHMENT #10

Studies & Reports Schedule	Complete	2019		2020		2021		2022		2023		2024		2025
		H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1
Pit Lake Water Quality Modelling - Preliminary ¹	█													
Pit Lake Water Quality Modelling - PK to Mine Working			█	█										
Pit Lake Water Quality Modelling - Slimes to Mine Working					█									
PK Laboratory Consolidation Testing		█												
Hydrogeological and Geotechnical Fatal Flaw Assessment - PK to Mine Working	█				█									
Hydrogeological and Geotechnical Assessment - PK to Mine Working			█											
Mine Working Bulkhead Concept Review	█		█											
Processed Kimberlite Containment in Mine Working Design Report ²				█										
Processed Kimberlite Facility Management Plan - Update for PK to Mine Working ²						█								
Water Management Plan & Water Balance - Update for PK to Mine Working ²						█								
Contingency Plan - Update for PK to Mine Working ²						█								
Waste Management Plan - Update for PK to Mine Working ²						█								
Slimes Removal from PKC - Feasibility Assessment				█										
PKC Closure Options Assessment - Dry Cover vs Wet Cover					█									
Closure and Reclamation Plan ²								█						
Operations PK to Mine Working								█	█	█	█	█	█	█

Note:

1. Assessment complete and findings summarized in Amendment Application. No formal report prepared for distribution.
2. Studies & Reports proposed as submission requiring WLWB approval.



December 18, 2018

Joseph Mackenzie
WLWB Chair
Wekeezhii Land and Water Board
#1-4905 48th Street
Yellowknife, NT
X1A 3S3

Dear Mr. Mackenzie,

**Re: Diavik Diamond Mines (2012) Inc. (DDMI)
WL Amendment - PK to Mine Workings W2015L2-0001
DDMI Response to WLWB Information Request
Request for Comment**

The Department of Environment and Natural Resources (ENR), Government of the Northwest Territories has reviewed the information at reference based on its mandated responsibilities under the Environmental Protection Act, the Forest Management Act, the Forest Protection Act, the Species at Risk (NWT) Act, the Waters Act and the Wildlife Act and provides the following comments and recommendations for the consideration of the Board.

Topic: Review by Zajdlik & Associates Inc. and ARKTIS Solutions Inc.

Comment(s):

ENR retained Zajdlik & Associates Inc. and ARKTIS Solutions Inc. (Zajdlik and ARKTIS) to review the Diavik Diamond Mines (2012) Inc. (DDMI) Response to WLWB Information Request on the deposition of Processed Kimberlite (PK) material into mine workings. This review included corresponding directly with DDMI to clarify several details. ENR would like to acknowledge the effort from DDMI to assist in resolving some of the questions regarding the review through providing further details on the modeling. However, as discussed below, ENR is of the opinion that further modeling and discussion on the modeling exercises is required at this time to better inform the water licensing process. The results of Zajdlik and ARKTIS' review, including the responses from DDMI are included in an attached memorandum, which is provided for the information of the Board.

Recommendation(s):

n/a

Topic: Processed Kimberlite Leachate Composition**Comment(s):**

PK leachate data used in the model were obtained from DDMI (Golder 2018 Section 2.2.4.2). In order to better understand this model input, the raw data and a description of the data collection were requested from DDMI via personal communication. The data were obtained following hydrogeochemical evaluation of PK weathering done by DDMI (Moncur and Smith, 2014) in the PKC facility. The data received from DDMI includes summary statistics but not the raw data. As sampling locations were not provided by DDMI it was assumed that the data provided represents “beach pore water” only. ENR notes that the raw data may clarify the makeup of the expected pit porewater. Consistent with the description of PK porewater data as “beach porewater”, the beach porewater sampling, results and discussion presented in (Moncur and Smith, 2014) were reviewed by ENR’s consultants.

The average beach porewater concentrations used by DDMI (Golder 2018) represent four locations within the PKC facility that were sampled over four years (Moncur and Smith 2014 Section 5.3). Moncur and Smith (2014) discuss changes in porewater chemistry that span orders of magnitude as PK weathers and also, lesser changes in concentration with core depth. Concentration changes are attributed to “decreases in moisture content resulting in deeper oxygen diffusion, the downward displacement of ions, and possibly cryoconcentration due to the upward migration of frost expelling dissolved ions”. It is not clear how cores from these four locations and years fully represent the PK that is proposed to be deposited within the pits. This is especially significant as the PK deposition plan from DDMI is to pump PK from the processing plant to the A418 pit (Rio Tinto, 2018 Section 3.3.5).

Under Sensitivity Scenario 2 (PK deposited in the pits; 20 m freshwater cap above the PK), DDMI (Golder 2018, Table 2) shows that predicted maximum daily concentrations of sulphate, nitrate and selenium in the surface water (top section) of A418 over the 100-year period after closure will exceed the current benchmarks. The coefficients of variation for sulphate, nitrate and selenium were estimated using the data provided in: “PK Pore Water - Provided to ENR Nov 30 2018.xlsx” and are 1.2, 2.4 and 1.3; respectively. The coefficients of variation (CV) are very high suggesting that exceedances could be much more pronounced than those currently predicted.

The CVs for elements comprising total dissolved solids (TDS) were also examined by Zajdlik and ARKTIS as an unknown amount of groundwater high in TDS will be moving through the pits and for a specific pit scenario (fixed dimensions and bathymetry, cap depth, fetch, surrounding surficial morphometry, surficial runoff, ice covered season duration, etc.) variation in TDS concentrations plays a key role in stratification. Following DDMI (Golder 2018 Section 2.2.4.2), TDS was represented by the following ions: calcium, magnesium, sodium, potassium, sulphate, chloride, silica and nitrate. The median CV for TDS constituents is 0.9 with a minimum of 0.7 and a maximum of 2.4 suggesting considerable uncertainty in the TDS porewater concentration. The CVs for all the elements provided, range from 0.29 (Sb) to 3 (Be) with a median of 1.2. The CVs suggest that if the full distribution of pore water concentrations is used in modeling, additional analytes may exceed benchmarks. The implications with respect to meromixis are not known as the sensitivity analyses did not include variations in PK pore water.

Recommendation(s):

- 1) ENR recommends that DDMI confirm that the data provided to Golder for model inputs was comprised of beach porewater only.
- 2) ENR recommends that DDMI provide the raw data records that represent expected pit porewater. This should include fields describing location, date, sample depth (at time of sampling as this changed over the sampling period), redox potential, pH, alkalinity, dissolved oxygen, weathering time and moisture content.
- 3) ENR recommends that DDMI provide rationale illustrating that the available beach sample data are representative of the entirety of the PK that may be delivered from the processing plan to the pits under the proposed water licence amendment.
- 4) ENR recommends that DDMI demonstrate that the PK porewater has been sufficiently sampled using verifiable statistical design criteria to represent the actual material being considered for pit placement, and; that model predictions regarding meromixis and benchmark exceedances are not sensitive to using extremes in the available porewater input dataset.

Topic: Consolidation Model

Comment(s):

DDMI (Golder 2018, Section 2.1.1) mentions a conceptual consolidation model in the Water Quality Modeling report. Material provided directly to ENR from DDMI following an information request from ENR (“ENR_IR_Consolidation model.pdf”) mentions the Condes 1D model which is a “large strain” model. The specific implementation of this model is not mentioned nor is the method for estimating model input parameters.

Geier et al. (2011) in a discussion of consolidation models state: “Although 1D large strain analyses are often the most appropriate modeling tool for conceptual planning or tradeoff studies” ... “3D large strain analyses are preferred for feasibility work”. It is acknowledged that Golder (2018) has conducted modeling as a conceptual exercise. It is the opinion of Zajdlik and ARKTIS that a water licence amendment that will identify a preferred alternative should reflect a more detailed feasibility study. Fredlund et al. (2009) also express concerns regarding 1D models stating that “the use of 1D theory only will compromise the analysis such that pore-water pressures would be under-estimated and tailings consolidation times would be under-estimated”. As noted by Zajdlik and ARKTIS, changes in tailings consolidation times may affect the rate of pore water expression and consequently affect model predictions.

Recommendation(s):

- 1) ENR recommends that DDMI provide comprehensive details of the consolidation model used, as described by Zajdlik and ARKTIS.
- 2) ENR recommends that DDMI present any consolidation tests used to parameterize the consolidation model. If consolidation tests were not conducted, DDMI should discuss how coefficients for the consolidation model were selected.

Topic: Groundwater

Comment(s):

There is uncertainty in the conclusions of the modeling as a result of select assumptions regarding groundwater inflow to the pit. The modeling does not explore the sensitivity of groundwater inflows to the pit to justify the applicability of the assumption that groundwater inflows are not important to the pit lake predicted results. Additional information is requested to demonstrate the validity of not including groundwater inflows to the pit for two different temporal scales: 1) short-term, when the pit is filling; and 2) long-term after the pit is filled and chemical equilibrium between the pit waters and the groundwater is being approached.

It is understood that groundwater inflows will affect pit lake water quality in the short term if these flows and associated constituent loading occur. The expected groundwater quantity and quality during pit filling is unknown. The relative contribution of groundwater to surface water to fill the pit is unknown. In the long-term, subject to the hydrogeologic conditions of the site, saline groundwater could enter the pit lake and the pit water quality will equilibrate with the groundwater with regards to quality. No information has been presented in regards to the

hydrogeologic conditions in the vicinity of the pit, and the long-term influence of groundwater on pit lake water quality.

Recommendation(s):

- 1) ENR recommends that DDMI describe how it was determined that groundwater source terms were not required in the current model predictions, as well as, present any analysis completed to make this decision.
- 2) ENR recommends that DDMI discuss the hydrogeologic conditions in the vicinity of the pit including the stratigraphic units and groundwater quality with depth.
- 3) ENR recommends that DDMI discuss anticipated groundwater inflows to the pit during pit filling, the associated groundwater quality, and the stratigraphic units that contribute to these inflows.
- 4) ENR recommends DDMI discuss anticipated groundwater inflows/outflows to/from the pit in the long term (after pit is filled).
- 5) ENR recommends DDMI discuss the quantity of groundwater inflows (short-term and long-term) that is required before this source term becomes important to consider in the model.

Topic: Pit lake re-filling

Comment(s):

Although the pits will be “rapidly filled” (Golder 2018 Section 3.0) the time between breaching the dikes and filling of the pit lakes will allow some volume of groundwater to enter the pit. The length of time required for pit filling is unclear at this time.

Recommendation(s):

- 1) ENR recommends DDMI provide additional detail on the anticipated time required to fill the pits.

Topic: Flushing of wall rock

Comment(s):

The report discusses that flushing of wall rock is considered to be “negligible in comparison to the “other” inflows to the pit” (Golder 2018 Section 3.0). As groundwater inflows to pits following flooding are also assumed to be negligible as is site runoff, aside from precipitation, what “other” inflows to the pit are being referred to?

Recommendation(s):

- 1) ENR recommends DDMI should discuss in further detail what other inflows aside from precipitation Section 3.0 of the report is referring to.

Topic: Hydrodynamic model - rates and coefficients**Comment(s):**

As noted by Zajdlik and ARKTIS regarding the hydrodynamic model, the maximum vertical eddy viscosity is set to 0.001 m²/s, which are three orders of magnitude lower than the default (1 m²/s). Comments in C-35 Appendix (Coles and Wells 2011) seem to indicate that choosing a maximum vertical eddy viscosity other than 1 m²/s is for backwards compatibility only. This point has also been raised by GNWT in the past in the context of the Jay Pit development and a verbal answer from Dominion Diamond Mines ULC and Golder during a technical modeling workshop in Mississauga, Ontario on July 6, 2015 was that this was part of the calibration exercise.

Cole and Wells (2011) emphasize the requirement for adequate and appropriate calibration. It is understood that calibration cannot occur for a pit lake that has not yet been constructed but the lack of discussion regarding how calibration choices could affect model outcomes is notable. DDMI (Golder 2018 Section 3.0) does state that rates and coefficients are a source of model uncertainty.

Recommendation(s):

- 1) ENR recommends that DDMI discuss why the very low vertical eddy viscosity value was selected.
- 2) ENR recommends that given the importance Coles and Wells (2011) ascribe to calibration, DDMI should perform a sensitivity analysis of the rates and coefficients used in those variables used to calibrate the model under at least one modeling scenario.
- 3) ENR recommends that DDMI should provide conceptual drawings for each model with an overall diagram showing linkages between models. This should be accompanied by all default rates and coefficients with a rationalization for the selected values.
- 4) ENR recommends that DDMI provide a sensitivity analysis to determine which parameters and / or assumptions most affect modelling conclusions.

Topic: Water Quality Model

Comment(s):

DDMI (Golder 2018 Section 2.2.4.1) uses Lac de Gras input water quality represented by data collected between 2016 and 2018 during the open-water season, from the sampling locations near the pits: “MF3-1 and MF3-2 representing quality of inflows from Lac de Gras to the A418 and A154 pit lakes and MF3-3 and MF3-4 representing quality of inflows from Lac de Gras to the A21 Pit Lake (Table 1)”. It is unclear on why DDMI chose to use water from operations as a model input rather than expected water conditions that would be present at closure. Additional details would assist in understanding the assumptions and rationale for this decision by DDMI.

Recommendation(s):

- 1) ENR recommends that DDMI discuss why they chose water quality that represents the operations phase rather than ambient water quality reflecting the post-closure phase.

Topic: Dike breaches

Comment(s):

DDMI (Golder 2018) assumed sizes for dike breaches and assessed the effect of increasing breach size for A418. However, it is unclear how these sizes were selected.

Recommendation(s):

- 1) ENR recommends that DDMI provide the rationale for selection of breach attributes (width, depth and number) and how the assumptions made will affect current modelling conclusions. ENR does note that one sensitivity analysis does address part of this recommendation.

Topic: Temperature

Comment(s):

In DDMI’s Water Quality Modelling report, Section 2.2.4.1, DDMI states that there were no observable water temperature data for Lac de Gras, and therefore used a temperature time-series was developed using data from Snap Lake dated from 2008 and 2012. ENR notes that temperature data are available in the field notes for each

AEMP water quality sample. These include temperatures for grab samples and temperature depth profiles. It has been shown that temperature differences have been noted in different parts of Lac de Gras (Golder, 2014, 2017) and temperature is a key driver of water stability.

Recommendation(s):

- 1) ENR recommends that DDMI discuss the implications of using temperature time series from the much smaller Snap Lake (Golder, 2018, Section 2.2.4.1) on the water quality modeling results provided to date.

Topic: Cumulative effects

Comment(s):

Based on the review of information presented thus far, there may be cumulative effects of contaminant loading from the pit lakes following connection with Lac de Gras relative to anticipated losses from the site (PKC facility, country rock piles, etc.). However, this has not been assessed by DDMI at this time.

Recommendation(s):

- 1) ENR recommends that DDMI assess the cumulative effects of contaminant loading from the pit lakes following connection with Lac de Gras relative to anticipated losses from the site (PKC facility, country rock piles, etc.).

Topic: Risk assessment of the effects

Comment(s):

Zajdlik and ARKTIS have recommended that DDMI address the WLWB's suggestion to conduct a "risk assessment of the effects to surface water quality in the pits and Lac de Gras" particularly now that mixing is predicted to occur.

Recommendation(s):

- 1) ENR recommends that DDMI conduct a risk assessment of the effects to surface water quality in the pits and Lac de Gras, as suggested by the WLWB, particularly now that mixing is predicted to occur.

Topic: Additional Modelling

Comment(s):

ENR notes that it has been determined during this review process that meromixis may not occur as originally expected by DDMI, which has direct implications to the water quality, biota, and management plans. As described in the attached memorandum from Zajdlik and ARKTIS, there are outstanding concerns regarding the conceptual modeling completed to support the Water License amendment.

Based on the importance of potentially adverse environmental effects to pit lakes following closure; that a model is only a prediction of effects based on myriad assumptions; and, that the conclusion regarding meromixis has changed with this more recent model, ENR is of the opinion that DDMI should use a more representative site model to better predict future conditions. ENR has provided general recommendations on what should be included in subsequent modeling exercises to better inform the review process below.

Recommendation(s):

- 1) ENR recommends that DDMI present a discussion of contrasting conclusions if the more detailed modelling outcome differs from that using the previous model. This should also include acknowledgement of the stochastic nature of those model inputs identified in the sensitivity analyses as this may markedly affect modelling conclusions via Monte Carlo analyses.

Topic: References

Comment(s):

Cole T.M. and S. Wells. 2011. CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.7; User Manual. Prepared for US Army Corps of Engineers Waterways Experiment Station. Washington, DC, USA.

Fredlund, M.D., M. Donaldson and G.G. Gitirana. 2009. Large-Strain 1D, 2D, and 3D Consolidation Modeling of Mine Tailings. Proceeding, Tailings and Mine Waste Conference, Banff, Canada.

Geier, D., G. Gjerapic, and K.E. Morrison. 2011. Determination of Consolidation Properties, Selection of Computational Methods, and Estimation of Potential Error in Mine Tailings Settlement Calculations. Proceedings Tailings and Mine Waste 2011, Vancouver, BC.

Golder, 2017. Diavik Diamond Mines (2012) Inc. Aquatic Effects Monitoring Program 2016 Annual Report. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada.

Golder. 2014. Fish Report in Support of the 2013 AEMP Annual Report for the Diavik Diamond Mine, NT. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada.

Golder. 2018. Diavik Mine – Water Quality Modelling of A418, A154 And A21 Mined Out Pits. November 2, 2018.

Moncur, M. and L. Smith. 2014. Four-Year Hydrogeochemical Field Investigation of Processed Kimberlite Weathering at Diavik Diamond Mines Inc. Submitted To: G. Macdonald, Diavik Diamond Mines Inc Oct. 2014.

Rio Tinto. 2017. Closure and Reclamation Plan – Version 4.0 Diavik Diamond Mines (2012) Inc. April 2017

Rio Tinto. 2018. Deposition of Processed Kimberlite into Mine Workings W2015L2-0001 Amendment Request. June1, 2018.

WLWB (Wek'èezhii Land and Water Board). 2018. Information Request for Diavik Water Licence (W2015L2-0001) Amendment Application for Processed Kimberlite to Mine Workings August 31st, 2018.

Recommendation(s):

n/a.

Comments and recommendations were provided by ENR technical experts in the Water Resources Division and the North Slave Region and were coordinated and collated by the Environmental Assessment and Monitoring Section (EAM), Conservation, Assessment and Monitoring Division (CAM).

Should you have any questions or concerns, please do not hesitate to contact Patrick Clancy, Environmental Regulatory Analyst at (867) 767-9233 Ext: 53096 or email patrick_clancy@gov.nt.ca.

Sincerely,



Patrick Clancy
Environmental Regulatory Analyst
Environmental Assessment and Monitoring Section
Conservation, Assessment and Monitoring Division
Department of Environment and Natural Resources
Government of the Northwest Territories

Att: Zajdlik Associates Inc - Review of Diavik Mine – Water Quality Modelling of A418, A154 And A21 Mined Out Pits

**Review of Diavik Mine – Water Quality Modelling of
A418, A154 And A21 Mined Out Pits**

Prepared for:

**B. Pain, R. Walbourne
Government of the Northwest Territories**

Prepared by:

Zajdlik & Associates Inc.

and

ARKTIS Solutions Inc.

December, 2018

Table of Contents

1	Introduction.....	1
2	Model Input Terms	3
2.1	Processed Kimberlite Leachate Composition	3
2.1.1	Recommendations.....	5
2.2	Consolidation Model.....	6
2.2.1	Recommendations.....	7
2.3	Hydrodynamic Model	7
2.3.1	Groundwater	7
2.3.2	Rates and Coefficients	8
2.3.3	Recommendations.....	8
2.4	Water Quality Model.....	10
2.4.1	Recommendations.....	10
3	Conclusion and Overarching Recommendations.....	11
4	General Recommendations	12
5	References.....	13

List of Tables

Table 1: Acronym Definitions ii

Table 1: Acronym Definitions

Acronym	Definition
CV	coefficient of variation
DDMI	Diavik Diamond Mine Inc.
GNWT ENR	Government of the Northwest Territories, Environment and Natural Resources Division
PK	processed kimberlite
PKC	Processed Kimberlite Containment
TDS	total dissolved solids
WLWB	Wekèezhii Land and Water Board

1 Introduction

Zajdlik & Associates Inc. and Arktis Solutions Inc. were retained by the Government of the Northwest Territories (GNWT), Environment and Natural Resources (ENR) to review various aspects of the water quality modelling of A418, A154 and A21 mined out pits at the Diavik Diamond Mine Inc. (DDMI) site as presented in Golder (2018).

Golder. 2018. Diavik Mine – Water Quality Modelling of A418, A154 And A21 Mined Out Pits. November 2, 2018.

The modelling was conducted in response to information requests from the Wek'èezhii Land and Water Board (WLWB) after review of an application to deposit processed kimberlite (PK) into mine workings (June, 2018). The WLWB (2018) information requests were:

1. “Demonstrate how the water quality in each pit (i.e., A148, A154, and A21) will be impacted at closure/post-closure because of deposition of PK and PKC Facility “slimes” and demonstrate whether the water quality at closure/post-closure will be impacted such that the pits (i.e., A148, A154, and A21) may not be able to be reconnected to Lac de Gras, once flooded. This may include:
 - a. The potential effects of tailings on the water quality of the freshwater cap for all potential closure scenarios (i.e., with/without slimes, variable PK fill elevations);
 - b. Predicted water quality in deep waters of the mine pits and how this will change over time because of the deposition of PK;
 - c. The proposed maximum PK fill elevation within each pit in relation to overlying water quality, including an assessment of the water cover depth;
 - d. Identification of contaminants of potential concern within the freshwater cap over the tailings, and mitigation measures for any contaminants of concern;
 - e. The likelihood of PK material being re-suspended;
 - f. A risk assessment of the effects to surface water quality in the pits and Lac de Gras in the event that unanticipated mixing occurs;

5. If DDMI has not engaged specifically on the deposit of PK into all three mines, provide a timeline for completing additional engagement (i.e., not associated with the Board's process) related to PK deposition in the A154 and A21 pits and updating the engagement record".

In response to these directives Golder (2018) conducted a "preliminary modelling analysis of pit lake water quality and expected mixing conditions in each of the three mine areas at closure/post-closure, with and without the deposition of PK in these areas. This preliminary modelling did not differentiate between "PK" and PKC Facility "slimes" from the perspective of an impact on water quality as PK already includes a slimes fraction". The evaluated scenarios are:

1. Base Case Scenario: No PK deposited in the pits; filled with fresh water
2. Development Scenario: PK deposited in the pits; 150 m fresh water cap above the PK
3. Sensitivity Scenario 1: PK deposited in the pits; 50 m freshwater cap above the PK
4. Sensitivity Scenario 2: PK deposited in the pits; 20 m freshwater cap above the PK
5. Sensitivity Scenario 3: Increased size of the two breaches in the A418 dike (only assessed with a 20 m freshwater cap above the PK; breaches increased to 60x60m at 2 m deep vs 30x60m at 2 m deep)

2 Model Input Terms

2.1 Processed Kimberlite Leachate Composition

PK leachate data used in the model were obtained from DDMI (Golder 2018 §2.2.4.2). In order to better understand this model input, the raw data and a description of the data collection were requested from DDMI. The data were obtained following hydrogeochemical evaluation of PK weathering (Moncur and Smith, 2014) in the PKC facility. The data received from DDMI includes summary statistics but not the requested raw data. As sampling locations were not provided by DDMI it was assumed that the data provided represent "beach pore water" only.

Consistent with the description of PK porewater data as “beach porewater”, the beach porewater sampling, results and discussion presented in (Moncur and Smith, 2014) were reviewed.

The average beach porewater concentrations used by Golder (2018) represent 4 locations within the PKC facility that were sampled over 4 years (Moncur and Smith 2014 §5.3). Moncur and Smith (2014) discuss changes in porewater chemistry that span orders of magnitude as PK weathers and also, lesser changes in concentration with core depth. Concentration changes are attributed to “decreases in moisture content resulting in deeper oxygen diffusion, the downward displacement of ions, and possibly cryoconcentration due to the upward migration of frost expelling dissolved ions”. It is not clear how cores from these 4 locations and years represent the PK that is proposed to be deposited within the pits especially as the PK deposition plan is to pump PK from the processing plant to the A418 pit (Rio Tinto, 2018 § 3.3.5).

Under Sensitivity Scenario 2 (PK deposited in the pits; 20 m freshwater cap above the PK), Golder (2018, Table 2) shows that predicted maximum daily concentrations of sulphate, nitrate and selenium in the surface water (top section) of A418 over the 100-year period after closure will exceed the current benchmarks. The coefficients of variation for sulphate, nitrate and selenium were estimated using the data provided in: “PK Pore Water - Provided to ENR Nov 30 2018.xlsx” and are 1.2, 2.4 and 1.3; respectively. The coefficients of variation (CV) are very high suggesting that exceedances could be much more pronounced than those currently predicted.

The CVs for elements comprising total dissolved solids (TDS) are examined next as an unknown amount of groundwater high in TDS will be moving through the pits and for a specific pit scenario (fixed dimensions and bathymetry, cap depth, fetch, surrounding surficial morphometry, surficial runoff, ice covered season duration, etc.) variation in TDS concentrations plays a key role in stratification. Following Golder (2018 §2.2.4.2) TDS was represented by the following ions: calcium, magnesium, sodium, potassium, sulphate, chloride, silica and nitrate. The median CV for TDS constituents is 0.9 with a minimum of 0.7 and a maximum of 2.4 suggesting considerable uncertainty in the TDS porewater concentration. The CVs for all the elements

provided, range from 0.29 (Sb) to 3¹ (Be) with a median of 1.2. The CVs suggest that if the full distribution of pore water concentrations is used in modelling, additional analytes may exceed benchmarks. The implications with respect to meromixis is not known as the sensitivity analyses did not include variations in PK pore water.

2.1.1 Recommendations

The following recommendations are provided in no particular order.

- DDMI should confirm that the data provided to Golder for model inputs was comprised of beach porewater only.
- DDMI should provide the raw data records that represent expected pit porewater. This should include fields describing location, date, sample depth (at time of sampling as this changed over the sampling period), redox potential, pH, alkalinity, dissolved oxygen, weathering time and moisture content.
- DDMI should discuss why the available beach sample data are representative² of the entirety of the PK that may be delivered from the processing plan to the pits under the proposed water licence amendment.
- DDMI should discuss the sources of PK that will be placed in the pits as weathering has been shown to markedly affect porewater concentrations.
- DDMI should demonstrate that:

¹ This may be due to a large proportion of censored observations given a table of censoring limits. The second highest CV is 2.7 for Al which has a low censoring proportion.

² In a discussion regarding parameterizing consolidation models (see § 5.2, herein) Geier et al. (2011) emphasize the same point stating it “is important to obtain a representative sample of the tailings material, and to prepare test specimens in accordance with the testing objectives.”

- the PK porewater has been sufficiently sampled using verifiable statistical design criteria to represent the actual³ material being considered for pit placement, and;
- that model predictions regarding meromixis and benchmark exceedances are not sensitive to using extremes in the available porewater input dataset.

2.2 Consolidation Model

Golder (2018, § 2.1.1) mentions a conceptual consolidation model. Material provided to ENR following an information request (“ENR_IR_Consolidation model.pdf”) mentions the Condes 1D model which is a “large strain⁴” model. The specific implementation of this model is not mentioned nor is the method for estimating model input parameters.

Geier et al (2011) in a discussion of consolidation models state: “Although “1D large strain analyses are often the most appropriate modeling tool for conceptual planning or tradeoff studies” ... “3D large strain analyses are preferred for feasibility work”. It is acknowledged that Golder (2018) have conducted modelling as a conceptual exercise. It is the authors opinion that a WL amendment that will identify a preferred alternative should reflect a more detailed feasibility study. Fredlund et al (2009) also express concerns regarding 1D models stating that “the use of 1D theory only will compromise the analysis such that pore-water pressures would be under-estimated and tailings consolidation times would be under-estimated”. Changes in tailings consolidation times may affect the rate of pore water expression and consequently affect model predictions.

³ This may include the effect of weathering, suitability of the coarse PK to fine PK ratios following cessation of the degrit process if approved, etc.

⁴ Compressibility and permeability vary with stresses such as increased pressure due to incremental PK deposition.

2.2.1 Recommendations

A recommendation is provided below and another is provided in §2.3, herein.

- DDMI should provide comprehensive details of the consolidation model used.
- Any consolidation tests used to parameterize the consolidation model should be presented. If consolidation tests were not conducted DDMI should discuss how coefficients for the consolidation model were selected.

2.3 *Hydrodynamic Model*

2.3.1 Groundwater

There is uncertainty in the conclusions of the modelling as a result of select assumptions regarding groundwater inflow to the pit. The modelling does not explore the sensitivity of groundwater inflows to the pit to justify the applicability of the assumption that groundwater inflows are not important to the pit lake predicted results. Additional information is requested to demonstrate the validity of not including groundwater inflows to the pit for two different temporal scales: 1) short-term, when the pit is filling; and 2) long-term after the pit is filled and chemical equilibrium between the pit waters and the groundwater is being approached.

It is understood that groundwater inflows will affect pit lake water quality in the short term if these flows and associated constituent loading occur. The expected groundwater quantity and quality during pit filling is unknown. The relative contribution of groundwater to surface water to fill the pit is unknown. In the long-term, subject to the hydrogeologic conditions of the site, saline groundwater could enter the pit lake and the pit water quality will equilibrate with the groundwater with regards to quality. No information has been presented in regards to the hydrogeologic conditions in the vicinity of the pit, and the long-term influence of groundwater on pit lake water quality.

2.3.2 Rates and Coefficients

The maximum vertical eddy viscosity is set to 0.001 m²/s which is 3 orders of magnitude lower than the default (1 m²/s). Comments in C-35 Appendix (Coles and Wells 2011) seem to indicate that choosing a maximum vertical eddy viscosity other than 1 m²/s is for backwards compatibility⁵ only. This point has been raised in the past in the context of the Jay Pit development and a verbal answer was that this was part of the calibration exercise.

Cole and Wells (2011) emphasize the requirement for adequate and appropriate calibration. It is understood that calibration cannot occur for a pit lake that has not yet been constructed but the lack of discussion regarding how calibration choices could affect model outcomes is notable. Golder (2018 § 3.0) does state that rates and coefficients are a source of model uncertainty.

2.3.3 Recommendations

- DDMI should discuss why the very low vertical eddy viscosity value was selected.
- Given the importance Coles and Wells (2011) ascribe to calibration Rio Tinto should perform a sensitivity analysis of the rates and coefficients used in those variables used to calibrate the model under at least one modelling scenario.

⁵ C-35 Appendix: To be backwards compatible with Version 2, set [AZC] to W2, [AZSLC] to EXP, and [AZMAX] to 1.0E-4 even though a value of 1.0E-3 is recommended as a minimum value of the maximum vertical eddy viscosity [AZ]. Note that for all model applications, we recommend using [AZC]=TKE, [AZSLC]=IMP and [AZMAX]= 1 m² s⁻¹.

AZMAX = Maximum value for vertical eddy viscosity, m² s⁻¹

AZC = Form of vertical turbulence closure algorithm, NICK, PARAB, RNG, W2, W2N, TKE, or TKE1

AZSLC= Specifies either implicit, IMP, or explicit, EXP, treatment of the vertical eddy viscosity in the longitudinal momentum equation

- DDMI should describe how it was determined that groundwater source terms were not needed in the current model predictions, as well as, present any analysis completed to make this decision.
- DDMI should discuss the hydrogeologic conditions in the vicinity of the pit including the stratigraphic units and groundwater quality with depth.
- DDMI should discuss anticipated groundwater inflows to the pit during pit filling, the associated groundwater quality, and the stratigraphic units that contribute to these inflows.
- Although the pits will be “rapidly filled” Golder (2018 §3.0) the time between breaching the dikes and filling of the pit lakes will allow some volume of groundwater to enter the pit. DDMI should discuss the timeframe to fill the pit.
- DDMI should discuss whether minimization of resuspension of PK and subsequent entrainment of porewater in the surficial PK layer is necessary and whether such resuspension would affect modelling conclusions.
- Flushing of wall rock is considered to be “negligible in comparison to the “other” inflows to the pit” (Golder 2018 §3.0). As groundwater inflows to pits following flooding are also assumed to be negligible as is site runoff, aside from precipitation, what “other” inflows to the pit are being referred to?
- DDMI should discuss anticipated groundwater inflows/outflows to/from the pit in the long term (after pit is filled).
- DDMI should discuss what quantity of groundwater inflows (short-term and long-term) is needed before this source term becomes important to consider in the model?

2.4 Water Quality Model

Golder (2018 §2.2.4.1) uses Lac de Gras input water quality represented by data collected between 2016 and 2018 during the open-water season, from the sampling locations near the pits: “MF3-1 and MF3-2 representing quality of inflows from Lac de Gras to the A418 and A154 pit lakes and MF3-3 and MF3-4 representing quality of inflows from Lac de Gras to the A21 Pit Lake (Table 1)”.

2.4.1 Recommendations

The following recommendations are made in no particular order.

- DDMI should discuss why they chose water quality that represents the operations phase rather than ambient water quality reflecting the post-closure phase.
- Golder (2018) assumed sizes for dike breaches and assessed the effect of increasing breach size for A418. DDMI should provide the rationale for selection of breach attributes (width, depth and number) and how the assumptions made will affect current modelling conclusions. We note that one sensitivity analysis does address part of this recommendation.
- Temperature data are available in the field notes for each AEMP water quality sample. These include temperatures for grab samples and temperature depth profiles. As temperature differences have been noted in different parts of Lac de Gras (Golder, 2014, 2017) and temperature is a key driver of water stability, DDMI should discuss the implications of using temperature time series from the much smaller Snap Lake (Golder, 2018, § 2.2.4.1) on the water quality modelling results provided to date.

3 Conclusion and Overarching Recommendations

The finding that meromixis may not occur as originally expected is of extreme interest but a detailed review of implications (effects on water quality, biota, management plans) was not conducted at this time due to the limitations of the conceptual modelling exercise conducted to date.

Given 1) the importance of potentially adverse pit lake environmental effects following closure; 2) that a model is only a prediction of effects based on myriad assumptions; and, 3) that the conclusion regarding meromixis has changed with this more recent model, DDMI should use a more realistic site model. Modelling by DDMI should include:

- Conceptual drawings for each model with an overall diagram showing linkages between models. This should be accompanied by all default rates and coefficients with a rationalization for the selected values.
- Rationale for selection of consolidation model or possibly use of another consolidation model;
- An assessment of possible ground water movement effects through the pits;
- A characterization of PK pore water that reflects PK that will actually be deposited in the pits;
- A sensitivity analysis to determine which parameters and / or assumptions most affect modelling conclusions;
- A discussion of contrasting conclusions if the more detailed modelling outcome differs from that using the previous model; and,
- Acknowledgement of the stochastic nature of those model inputs identified in the sensitivity analyses as markedly affect modelling conclusions via Monte Carlo analyses.

Recommendations provided in other parts of this review should also be addressed.

4 General Recommendations

The following recommendations are provided in no particular order:

- The cumulative effects of contaminant loading from the pit lakes following connection with Lac de Gras relative to anticipated losses from the site (PKC facility, country rock piles, etc.) should be assessed.
- DDMI should address the WLWB (2018) suggestion to conduct a “risk assessment of the effects to surface water quality in the pits and Lac de Gras” particularly now that mixing is predicted to occur. in the event that unanticipated mixing occurs.”

5 References

- Cole T.M. and S. Wells. 2011. CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.7; User Manual. Prepared for US Army Corps of Engineers Waterways Experiment Station. Washington, DC, USA.
- Fredlund, M.D., M. Donaldson and G.G. Gitirana. 2009. Large-Strain 1D, 2D, and 3D Consolidation Modeling of Mine Tailings. Proceeding, Tailings and Mine Waste Conference, Banff, Canada.
- Geier, D., G. Gjerapic, and K.E. Morrison. 2011. Determination of Consolidation Properties, Selection of Computational Methods, and Estimation of Potential Error in Mine Tailings Settlement Calculations. Proceedings Tailings and Mine Waste 2011, Vancouver, BC.
- Golder, 2017. Diavik Diamond Mines (2012) Inc. Aquatic Effects Monitoring Program 2016 Annual Report. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada.
- Golder. 2014. Fish Report in Support of the 2013 AEMP Annual Report for the Diavik Diamond Mine, NT. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT, Canada.
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- Moncur, M. and L. Smith. 2014. Four-Year Hydrogeochemical Field Investigation of Processed Kimberlite Weathering at Diavik Diamond Mines Inc. Submitted To: G. Macdonald, Diavik Diamond Mines Inc Oct. 2014.
- Rio Tinto. 2017. Closure and Reclamation Plan – Version 4.0 Diavik Diamond Mines (2012) Inc. April 2017

Rio Tinto. 2018. Deposition of Processed Kimberlite into Mine Workings W2015L2-0001
Amendment Request. June 1, 2018.

WLWB (Wekèèzhii Land and Water Board). 2018. Information Request for Diavik Water
Licence (W2015L2-0001) Amendment Application for Processed Kimberlite to Mine
Workings August 31st, 2018.

From: [Macdonald, Gord \(DDMI\)](#)
To: [Bill Pain](#); [Sinclair, Sean \(DDMI\)](#)
Cc: [Rick Walbourne](#)
Subject: RE: Request for additonal info on WLWB IR request - PK to Mine workings
Date: Friday, November 30, 2018 9:50:57 AM
Attachments: [PK Pore Wate - Provided to ENR Nov 30 2018.xlsx](#)
[ENR IR Consolidation model.pdf](#)
[Appendix II-1 2014 PKC Report_Final_submitted.pdf](#)

Bill,

Please find attached:

- Description of how PK consolidation assumptions were derived
- Xls with summary statistics of pore water chemistry
- Report that describes how the pore water samples were collected

Please let me know if you have any additional questions.

Gord

From: Bill Pain [mailto:Bill_Pain@gov.nt.ca]
Sent: Tuesday, November 27, 2018 12:58 PM
To: Sinclair, Sean (DDMI) <Sean.Sinclair@riotinto.com>
Cc: Rick Walbourne <Rick_Walbourne@gov.nt.ca>; Macdonald, Gord (DDMI) <Gord.Macdonald@riotinto.com>
Subject: RE: Request for additonal info on WLWB IR request - PK to Mine workings

Thanks Sean – I appreciate the quick reply.

I do have a follow up request from our consultant on the modeling as well:

- The pore water chemistry used to populate the CE-QUAL model was provided in loc. cit. 2017b. This is: DDMI. 2017b. Personal Communication. Email from Gord Macdonald to Michael Herrell re: Diavik Pit Lake Evaluation – PK Water Chemistry. 14 November 2017 11:48AM.
- Can we request the data in an electronic format as well as a description of what the "beach pore" experiment represents in the following sentence: "Water quality of the pore water (Table 1) was represented by the average constituent concentration from water quality monitoring results collected in beach pore water samples provided by DDMI (DDMI 2017b, pers. comm.)."
- Specifically we are looking for information on how much data supports the inflow measurements, whether those data are representative of the entirety of the PK that will be deposited, and how variable those measurements are.

Regards,

Bill

From: Sinclair, Sean (DDMI) [<mailto:Sean.Sinclair@riotinto.com>]
Sent: Tuesday, November 27, 2018 7:23 AM
To: Bill Pain
Cc: Rick Walbourne; Macdonald, Gord (DDMI)
Subject: RE: Request for additoanl info on WLWB IR request - PK to Mine workings

Hi Bill,

Thanks for getting in touch prior to the ORS review deadline. I have forwarded this request to our consultant working on the model and we should have something together for you by Friday. If you would like we can also arrange a call to discuss the model inputs and conclusions. I am on vacation for a week starting Friday, but Gord (cc'd) can be available.

Regards,

Sean Sinclair, M.Sc., B.Sc., M.I.T. (NAPEG)
Superintendent, Environment, HSE

Rio Tinto
Diavik Diamond Mines (2012) Inc.

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From: Bill Pain <Bill_Pain@gov.nt.ca>
Sent: Monday, November 26, 2018 2:42 PM
To: Sinclair, Sean (DDMI) <Sean.Sinclair@riotinto.com>
Cc: Rick Walbourne <Rick_Walbourne@gov.nt.ca>
Subject: Request for additoanl info on WLWB IR request - PK to Mine workings

Hi Sean,

With respect to the PK to mine working IR review, would it be possible for DDMI to provide us some additional info on the modeling?

A Consolidation Model is mentioned in section 2.1.1 of the report. However, details of the model structure, estimates (PK constituent concentrations) used for inputs and how those estimates were generated and choices for diffusion and other coefficients are not provided. This info will help us better understand the conclusions provided.

We will likely have one or 2 more additional information requests this week, but I wanted to get you this one as time is of the essence.

Let me know if you have any other questions or concerns on this request.

Sincerely,

Bill

Mársi | Kinanaskomitin | Thank you | Merci | Hąı' | Quana | Qujannamiik | Quyanainni | Máhsı | Máhsı | Mahsi
Bill Pain, M.Sc., E.P.
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From: [Macdonald, Gord \(DDMI\)](#)
To: [Bill Pain](#)
Cc: [Sinclair, Sean \(DDMI\)](#)
Subject: RE: Additional information request - Groundwater
Date: Thursday, December 06, 2018 8:42:05 AM
Attachments: [2018-12-5 1645-75B Summary Statistics.xlsx](#)

Bill,
Attached is a summary of water quality from SNP 1645-75.
Below is a summary of pit volumes.
Gord

Modelled Scenario	Volume of Water (Mm ³)		
	A418	A154	A21
Base Case (No PK)	30.3	60.3	23.3
Development Case (150m Water Cap)	28	51.8	22.7
Sensitivity Scenario 1 (50m Water Cap)	14	26	13
Sensitivity Scenario 2 (20m Water Cap)	6.8	13.5	6

From: Macdonald, Gord (DDMI)
Sent: Tuesday, December 04, 2018 1:59 PM
To: Bill Pain <Bill_Pain@gov.nt.ca>
Cc: Sinclair, Sean (DDMI) <Sean.Sinclair@riotinto.com>
Subject: RE: Additional information request - Groundwater

Bill,

- 1) We can provide summary water quality statistics for SNP 1645-75 which is A154/A418 groundwater. Will provide once compiled.
- 2) Once any pit has been flooded, eliminating any differential head, the groundwater flow will return to regional pre-development levels which is very small. We have not modelled this and the view is the professional opinion from the Golder hydrogeology modeler.
- 3) Will extract the requested volumes from the model and send once complete.

Gord

From: Bill Pain [mailto:Bill_Pain@gov.nt.ca]
Sent: Tuesday, December 04, 2018 9:37 AM
To: Macdonald, Gord (DDMI) <Gord.Macdonald@riotinto.com>
Cc: Sinclair, Sean (DDMI) <Sean.Sinclair@riotinto.com>
Subject: RE: Additional information request - Groundwater

Thanks Gord for the reply.

My understanding is, yes, we are aware that the model does not include groundwater or surface runoff as inputs. The intent of the request was to qualitatively assess the significance of those simplifications on the conclusions reached using the best currently available information.

Regards,

Bill

From: Macdonald, Gord (DDMI) [<mailto:Gord.Macdonald@riotinto.com>]
Sent: Tuesday, December 04, 2018 9:23 AM
To: Bill Pain
Cc: Sinclair, Sean (DDMI)
Subject: Re: Additional information request - Groundwater

Bill

The modelling is preliminary and focused on PK deposition. The simplified model does not include groundwater or surface runoff as inputs. I believe this is clearly stated in the Golder (2018).

Gord

On Dec 3, 2018, at 12:17 PM, Bill Pain <Bill_Pain@gov.nt.ca> wrote:

Hi Sean and Gord,

Our consultants have inquired if we could get some info on the groundwater inputs for the modeling to help our understanding of the volumes. Please see their request below. Let me know if you have any questions or concerns on this request.

With respect to the proposed water license amendment, can we please request the following information regarding groundwater reporting to the DDMI pits? We are interested in:

- 1) The chemical composition of groundwater reporting to the pits. If groundwater varies among pits we would like to know how the composition changes. This need not be an exhaustive undertaking. We are looking to understand the ionic composition of groundwater that will be moving through the pits following closure.
- 2) The expected volume of water moving through each pit after it has been flooded. This may take the form of best professional judgement if no modelling has been conducted to date.
- 3) Estimated pit volumes when filled, with and without PK.

Regards,

Bill

Mársi | Kinanaskomitin | Thank you | Merci | Hąı' | Quana | Qujannamiik | Quyanainni | Máhsı |
Máhsı | Mahsı
Bill Pain, M.Sc., E.P.

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EXECUTIVE SUMMARY

Diavik has applied to the Wek'èezhii Land and Water Board (WLWB) to amend their operating licence. The key aspects of the amendment include the provision for placement of processed kimberlite into the mine voids and to extend the licence by 2 years to 2025 coinciding with the end of commercial operations. Following review of the Application, the Wek'èezhii Land and Water Board (WLWB) on 31 August 2018, the Board determined that there was insufficient information available on the record to inform a preliminary screening and requested additional information. This additional information has been reviewed and the key findings from this review are summarized in this report.

In general terms, Diavik has provided a response to all issues and requests raised by the WLWB. However, the responses may not adequately address all issues and concerns. The key findings from this review include:

1. The ICRP has stated that all of pits once flooded would remain stratified (meromictic) with a stable layer of dense salty water at depth. Modelling has indicated this will not be the case. This is a significant finding and this change that was not discussed in the amendment responses.
2. Modelling was used to assess the effects of the PK disposal in all three pits at Diavik mine on the water quality in Lac de Gras. The model predicts that the depth of water cover is important with greater depths of water cover having less mixing and producing more stable stratification. In all cases, some contamination from depth enters Lac de Gras and over the very long term (more than 100 years), it is expected (although not stated) that the stratification will eventually break down.
3. There is limited site-specific data for calibration of the model. The User Manual (Cole and Scott 2015) states "*Results will be suspect at best and will not withstand scrutiny at worst if the model is applied with insufficient and/or inadequate calibration data*". Although this model is an excellent tool, given the warning by the authors of the user manual, one need to cautious when placing great emphasis on the results when calibration data are inadequate/insufficient.
4. Given the concern with calibration, one need to assured that if the model is wrong and the lake mixes, that the results will not be catastrophic. This could be the case if metal levels were much greater than projected in the PK porewater, or if reducing conditions at depth lead to oxygen depletion. Mixing under these conditions, even if only persisting for a short period, could have significant impacts on water quality and fish.
5. It is unclear how the pit will be filled with water and this could have a material effect on the initial water quality in the pit. One would expect in order to not disturb the PK upon flooding that a layer of several meters of PK slurry water would need to be present over the PK. This process water would be similar to PK porewater and would mix with the Lac de Gras water used to flood the pit. The model assumes that somehow, Lac de Gras water is placed and does not mix in any way with the PK or PK process water. This is not a rational assumption as used in the model.
6. The model assumes that there is an ongoing displacement of porewater as the PK settles. The rate of consolidation has not been measured but was estimated based upon the properties of the PK. Consolidation testing would have been useful to confirm the rate of porewater release to the stratified layer over time, however, this is likely not a significant deficiency.

Having stated the above, the primary concern remains how Lac de Gras water quality would be affected if the model is not accurate and the pit lakes turn over. Diavik need to better address this issue to assure

everyone that if the pit lake turns over, a major impact will not occur to the water quality and fish in Lac de Gras.

1.0 INTRODUCTION

1.1 Overview

Diavik has applied to amend their Water Licence (W2015L2-0001) to allow Processed Kimberlite (PK) to be placed into former mine workings at the Diavik Mine. Diavik is also asking to extend the Water Licence term from 2023 to 2025 and to make administrative changes. The Wek'èezhìi Land and Water Board (WLWB) distributed the application on June 15, 2018. Proponent responses were received by the WLWB August 23. On August 31, 2018 the WLWB determined insufficient information was available on the record to inform a preliminary screening decision and they issued an Information Request (IR) to Diavik. Diavik responded to the IR on November 6, 2018 and the WLWB distributed the item for review.

In this regard, EMAB is conducting a review of the application and has requested that Randy Knapp to prepare a report to address specific aspects of the Diavik licence amendment. The following sections address the scope of work and present the findings of this review.

1.2 Scope of Work

The scope of work was to complete a technical review of Diavik's Responses to the IR and comment on:

- How well did the IR response address issues identified during the review of the original application?
- Have any additional information gaps been identified?
- Water quality predictions for each pit under the scenarios examined.
- The assessment of meromixis under the model scenarios examined.
- Other potential environmental impacts of the project that require further investigation, and a description of information needed to allow assessment of the environmental effects.

2.0 FINDINGS

The findings from this review are organised under the following headings.

- Meromixis and its Long Term Stability
- CE-QUAL-W2 Model and Calibration
- Model Inputs
- Fatal Flaws

2.1 Meromixis and Long Term Stability

The ICRP has maintained for many years now that the pit lakes will be stratified at closure. Specifically, Diavik has stated on page 104 CRP V4 *“For these reasons, DDMI continues to prefer a closure design that enhances a meromixis condition instead of one that weakens the meromixis condition. There does not appear to be sufficient rationale for further consideration or research related to options that weaken meromixis, as such none is planned.”*

The recent modelling completed by Golders has indicated that the none of the flooded pits are projected to be stratified and will be fully mixed. This is a major divergence from all previous comments yet is never acknowledged in the responses. Diavik need to address this material change.

Model results have shown that the meromixis is stable in the short term for water covers of 50m and 150m. However, overtime the high salinity layer at depth is diluted and mixes with overlying waters. For example, as shown in Figure 10 (reproduced on the following page), with the 20 m water cover over PK in the breakdown in complete in about 12 years with the lake fully mixed. For the 50 m water cover, the stratified layer expands rapidly over the first 8-12 years followed by a slow but steady dilution of the layer with Lac de Gras surface water. Based upon the trend shown, it is likely full mixing will occur in the next 50 to 100 years after the initial 100 years shown on the Figure 10. With the 150 m deep water cover, the stratification is much stronger however, stratified layer continues to mix with overlying waters and it is anticipated that in the future, this layer will eventually mix with Lac de Gras.

The quality of the water in the stratified layer is of major concern if this layer was to mix with surface water in Lac de Gras. The layer will contain essentially all of the porewater released from PK consolidation and could also be anoxic (no oxygen). Mixing of this mass of porewater with the surface water could have a material impact on water quality and fish in the pit lake. The mixing of the stratified water with Lac de Gras was modelled and indicated some elevated levels of several contaminants. The report suggests this will be a short- term issue however this has not been demonstrated. The base case suggested mixing is most likely to occur in October just prior to freeze up. It will therefore be important to model water quality for this period to assess how long elevated conditions exist and whether this will have any impact on fisheries.

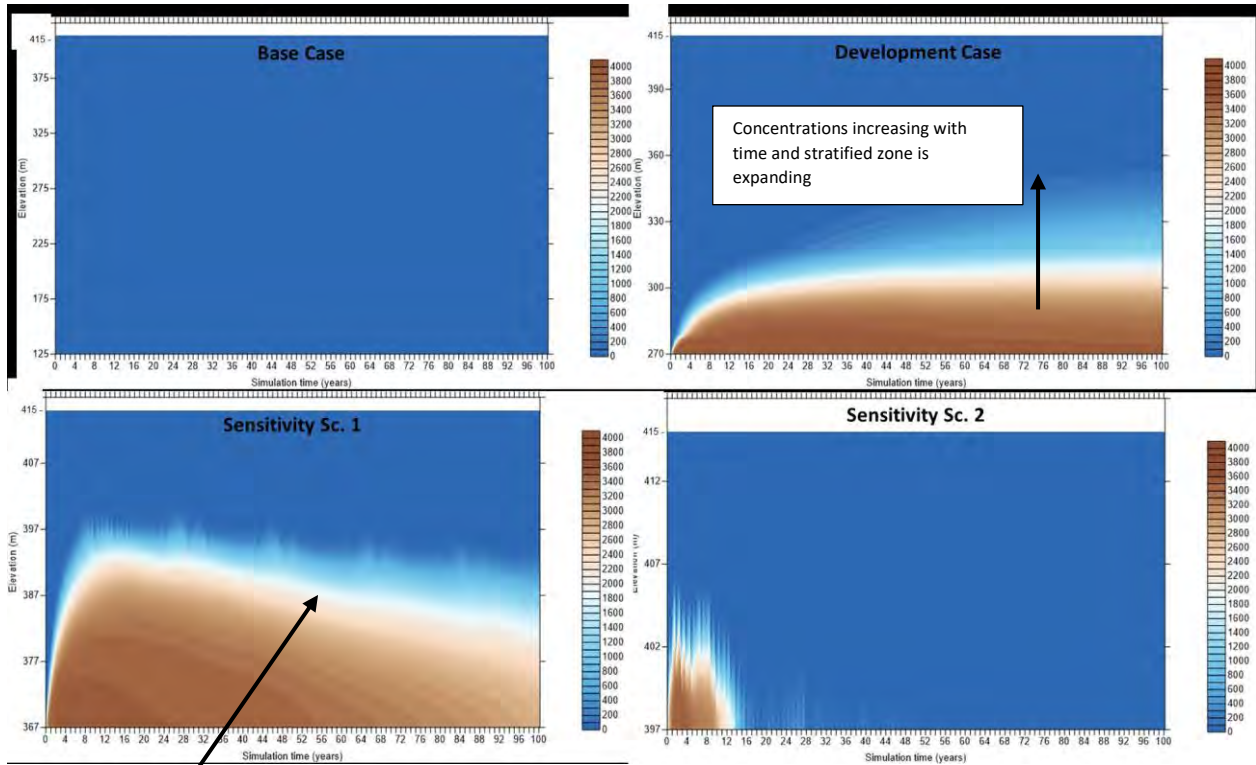


Figure 10: Contour Plots of Predicted Total Dissolved Solids Concentrations in the A154 Pit Lake over the Simulation Period (100 years Post-Closure)

Note that the concentrations in the stratified layer are continuously reducing indicating dilution with Lac de Gras surface water.

2.2 CE-QUAL-W2 Model and Calibration

Golders have used the CE-QUAL-W2 Model to assess the effects of PK placement in the Diavik pits. This model is well known and is used extensively. With all models, results are often highly dependent upon the quality of data available used in the model.

The User Manual (Cole and Scott 2015) states *“Results will be suspect at best and will not withstand scrutiny at worst if the model is applied with insufficient and/or inadequate calibration data.”* As noted by Golder in the modelling report, *“because the pit lake is not yet constructed, model calibration is not possible”*. In lieu of calibration data for the pit lake, Golder used data from other regional modelling studies. The most recent of the of the studies referred to was Vandenberg et al. 2015. It is noteworthy that the authors of this study note for *“the calibration was considered to be approximate because the true values of a large proportion of the measured data were not known. All of these inputs and assumptions carry inherent variability and uncertainty, which impose and propagate uncertainty on model predictions.”*

Although we have a useful tool, it is clear that calibration is essential for reliability of the predictions. **Given the caution expressed by both the Users Manual and Vandenberg et al. 2015 regarding model calibration, one needs to treat the model results with a bit of skepticism and adopt a cautious approach.**

Diavik should complete sensitivity analyses for a range of potential inputs to the model (e.g. meteorological conditions, lake temperature, porewater quality, dissolved oxygen content, etc.).

2.3 Model Inputs

2.3.1 Consolidation Model

The model assumes that there is an ongoing displacement of porewater as the PK settles. The rate of consolidation has not been measured but was estimated based upon the properties of the PK. Consolidation testing would have been useful to confirm the rate of porewater release to the stratified layer over time. It is uncertain how this would affect the model results; however, this is likely not a significant deficiency.

2.3.2 Initial Conditions

The initial conditions for the modelling exclude groundwater inputs or contributions of source contaminants from wall rock. Saline groundwater inputs were understood to be the primary source of high salinity water that would result in the stratification of the pits. Previous modelling was completed to assess the impacts of wall rock on pit water quality. It is not clear why one would exclude these sources of contamination into the model. **Certainly, for the cases where PK is placed into the pits, pit wall rock contributions are likely insignificant. However, groundwater will continue to be a material source of TDS until such time as the pits are flooded and hydraulic gradients to the pit are diminished. Diavik should defend why groundwater was not included as a source of salinity to the pits for all cases modelled.**

It is unclear how the pit will be filled with water and this could have a material effect on the initial water quality in the pit. The model assumes the start conditions is a pit lake filled uncontaminated Lac de Gras water. **One would expect in order to not disturb the PK upon flooding that a layer of several meters of PK slurry water would need to be present over the PK. This process water would be similar to PK porewater and would mix with the Lac de Gras water used to flood the pit. The model assumes that somehow, Lac de Gras water is placed and does not mix in any way with the PK or PK process water. This is not a rational assumption as used in the model. Diavik should rerun the model with the start conditions including an initial of a layer of process water mixed with Lac de Gras water.**

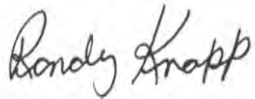
2.4 Fatal Flaw Assessment

It is not known at this time whether there are any fatal flaws. The primary concern remains how Lac de Gras water quality would be affected if the model is not accurate and the pit lake turns over. Diavik need to address this to assure everyone that a major impact will not occur the water quality and fish in Lac de Gras.

3.0 CLOSURE

We trust this draft report addresses your requirements. Should you require clarification or additional information please contact the writer at your convenience.

Yours truly

A handwritten signature in black ink that reads "Randy Knapp". The signature is written in a cursive style with a large initial 'R'.

R. A. Knapp P. Eng.

Environmental Consultant, Mining

REFERENCES

Thomas M. Cole and Scott A. Wells, 2015. CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.72, User Manual, March.

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**REVIEW OF DIAVIK'S WATER LICENCE AMENDMENT -
PROCESSED KIMBERLITE TO MINE WORKINGS – DIAVIK'S
RESPONSE TO WEK'ÈEZHÌI LAND AND WATER BOARD
(WLWB) INFORMATION REQUEST**

Technical Memorandum # 367-18-05

Prepared for:

Environmental Monitoring Advisory Board (EMAB)
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Prepared by:

North/South Consultants Inc.

December 10, 2018

1.0 BACKGROUND AND SCOPE OF WORK

Diavik Diamond Mines (2012) Inc. (DDMI) submitted an application to the Wek'èezhì Land and Water Board (WLWB) on June 1, 2018 to amend their Water Licence (W2015L2-0001) to allow Processed Kimberlite (PK) to be placed into mine workings (A418 pit and A418 underground; DDMI 2018a). Diavik has also requested an extension to the Water Licence term from 2023 to 2025 and to make administrative changes. The WLWB distributed the application on June 15, 2018 and review comments were submitted by August 2, 2018, and Proponent responses were received by the WLWB August 23, 2018. North/South Consultants Inc. (NSC) submitted comments to EMAB on the Licence Amendment Request on August 1, 2018 (NSC 2018).

On August 31, 2018 the WLWB determined insufficient information was available on the record to inform a preliminary screening decision and they issued an Information Request (IR) to Diavik. Diavik responded to the IR on November 6, 2018 and the WLWB distributed the item ("DDMI Response to WLWB Information Request re: Water License W2015L2-0001 Amendment Request for the Deposition of Processed Kimberlite to Mine Workings" – hereafter referred to as DDMI 2018b) for review. The IR response includes a Technical Memorandum (Golder 2018) presenting the results of water quality modeling for the pits.

1.1 SCOPE OF WORK

NSC was contracted to conduct a technical review of the IR Response (DDMI 2018b) with a focus on:

- How well did the IR response address issues identified during the review of the original application. Have any additional information gaps been identified?
- Effects on pit water quality and water quality in Lac de Gras once pit walls are breached;
- Ability to assess potential impacts to fish and fish habitat i.e. would fish go as deep as the PK in search of food? Potential impacts to fish and other aquatic life if PK is ingested?;
- Any mitigative measures to limit potential impacts to fish and fish habitat the Consultant would expect to be present in an undertaking of this type; and
- Other potential environmental impacts of the project related to water quality and aquatic health that require further discussion and investigation, and a description of information needed to allow assessment of the environmental effects.

2.0 PLAIN LANGUAGE BRIEFING

The primary purpose of the licence amendment request is to allow for the option to place PK material into mine workings; the environmental assessment for the Project was completed on the basis that the PK material would be placed in a PK storage area, which has been the process to date. It is anticipated that PK would first be placed in mine workings in 2022.

As noted in DDMI (2018b): “The Board’s IR identified three focus areas where more information was required, namely:

1. How water quality in each pit (i.e., A418, A154 and A21) will be impacted at closure/postclosure in relation to the deposition of PK and Processed Kimberlite Containment (PKC) Facility “slimes”;
2. Whether the anticipated meromictic conditions within the three pits at closure/post-closure would be altered by the deposition of PK; and,
3. Whether fish and fish habitat are likely to be impacted at closure/post-closure because of deposition of PK and PKC Facility “slimes” into each pit.”

The IR response provides a discussion of each of these items.

2.1 KEY COMMENTS ON THE IR RESPONSE

A number of comments were noted in relation to the IR Response. In general, the water quality modeling addressed the majority of previous comments or indicated why this information was not required at this time (e.g., will be addressed through a different management plan). However, in some instances, as noted below, information to substantiate the absence of significant effects to the aquatic environment is still required. In addition, questions related to the model, in particular assumptions and inputs, have been identified.

2.1.1 Meteorological Inputs

The report (Section 2.2.2, page 6) indicates that the meteorological inputs are key drivers of lake circulation and thermal dynamics. On-site data collected from 2014-2017 were used, as well as data from nearby stations collected during 1999-2013. However, there was no assessment as to whether there are differences between the on-site station and the nearby stations, nor was an analysis undertaken to examine the sensitivity of results if weather conditions were different from those recorded during this relatively short time.

Recommendation #1: Conduct an analysis to determine whether there is a material difference between weather (e.g., wind speed and direction) measured on-site and at the nearby stations and, if so, how this could affect modeling results.

Recommendation #2: Conduct a sensitivity analysis considering the effect of a range of weather conditions on model results.

2.1.2 Sediment Pore water Modeling

A consolidation model was developed to estimate the volume of pore water release to the overlying surface water and pore water quality was estimated from the mean conditions measured in "beach pore water samples provided by DDMI" (Section 2.2.3, pages 6-7 and Section 2.2.4.2, page 7).

It is unclear whether these estimates, which form the foundation of the water quality modeling, are appropriate and adequately sensitive to provide confidence in the modeling results and conclusions.

Recommendation #1: Please provide additional details regarding the beach pore water data set used to estimate pit lake pore water quality, including a description of the source of the information, the range of measured pore water quality for each parameter, and a discussion of the applicability of these data for modeling pit lakes.

Recommendation #2: Provide sensitivity analyses for additional scenarios that incorporate the observed variability and/or uncertainty associated with the estimates of volume and chemistry of pore water.

2.1.3 Water Quality Model Results – Mixing Between Deep and Surface Layers

The report indicates: "For the Development Case and Sensitivity Scenario 1, the contour plots show a reduced stability of the stratification over time (predicted TDS concentrations display diffusion over time, as seen in Figure 5). However, the diffusion is thought to be over-estimated in these simulations because they do not account for the dynamic settling of PK, which will lead to a substantially deeper and more narrow pool of water with elevated density, and both of these factors will increase the strength of stratification over the long term. Beyond these time scales, it is anticipated that a very small amount of this water will reach the surface through chemical diffusion and occasional wind mixing; however, both the conceptual and numerical models suggest that this amount will be very small compared to the exchange with lake water and will likely be unmeasurable. If such an exchange does occur, it will reduce the mass of constituents stored at the lake bottom over time." (Section 4.1.1, page 14)

It is unclear what "occasional wind mixing" refers to. If the lakes are expected to undergo mixing, then a discussion of how it was determined that this will be a "very small" amount of water that would be introduced to the surface layer(s) is required.

Recommendation #1: Clarify if the pit lakes are expected to undergo mixing between surface and deep waters, and if so, provide a discussion of how it was determined that this will be a "very small" amount of water that would be introduced to the surface layer(s).

2.1.4 Water Quality Results – Depth of Surface Waters and Effects to Aquatic Biota

The report discusses effects on water quality for the "surface layers" and figures presented in Attachment 1 present modeling results for the upper 5 m of surface water and the lower portion of the water cap (e.g., for the development case, results represent the lower 126-150 m of the water column). Based on TDS figures presented in the report (e.g., Figure 4, page 17), water quality conditions in the water column between these depth ranges would be intermediate. As presented in Figures A-1 through A-9 (Appendix 1) exceedances of benchmarks are predicted to occur for some parameters in deep water. The information is insufficient to determine at what water depth benchmark exceedances are predicted.

To assess effects to aquatic life, the depth to which water quality would be suitable for aquatic life (as defined by benchmarks) is required as well as a discussion of the effects to aquatic life resident within or moving through deeper waters where benchmarks are exceeded.

Recommendation #1: Provide the depth of the water column for the development case where AEMP benchmarks will be met and describe effects to aquatic life that may be resident within or pass through deeper waters where benchmarks are exceeded.

2.1.5 Dissolved Oxygen Not Considered

Dissolved oxygen (DO) is a critical parameter for aquatic life and often decreases to critical concentrations in deep waters with limited mixing, in particular in the presence of an ice cover. Therefore, the potential for PK (including slimes) to decrease DO in the pit lakes should be examined. If DO is decreased, then effects of mixing of the water column on surface DO and the associated risk to aquatic biota should be identified. Given that DO is a critical parameter, is there a potential for DO depletion at depth due to other factors (e.g., groundwater input)?

Recommendation #1: Examine the potential for DO to be affected by PK storage in the pit lakes, in conjunction with other inputs including groundwater.

2.1.6 Effects of Climate Change

Comments on the licence application noted the importance of considering climate change in the assessment. The report and modeling does not consider effects of climate change which may conceptually alter thermal regimes and mixing in the pit lakes. Given that the report notes the importance of meteorological conditions in determining the mixing between Lac de Gras and the pit lake, a sensitivity analysis with respect to future climate change (e.g., altered precipitation,

temperature, and wind) effects on mixing with Lac du Gras as well as on the stability of stratification in the pit lake should be conducted.

Recommendation #1: Provide a sensitivity analysis of potential effects of climate change on the modeling predictions.

2.1.7 Mitigative Measures

The scope of work indicates that the reviewers are to consider whether any mitigation measures to limit potential impacts to fish and fish habitat have been identified and considered.

The IR response does not include a discussion of potential mitigation measures beyond the consideration of the depth of the water cap and the implications of increasing the size of the breach. In the event that mixing was to occur, mitigation and management measures should be identified to limit impacts to aquatic biota and to prevent impacts in potential future mixing events.

Recommendation: Provide a discussion of management and mitigation measures that would be employed in the event of mixing in the pit lakes.

2.1.8 Fish Use of Pit Lakes

The licence application indicated that the depth of the closure cap would limit resuspension of PK post-closure and will optimize the elevation of PK to limit potential for direct interaction with fish. It was erroneously understood in NSC's previous comments (NSC 2018) that DDMI had assumed that fish are expected to use the upper 10 m of the water column.

In the closure plan (V4), the primary focus for habitat creation inside of all dikes is based on providing spawning, nursery, rearing and foraging habitat. Target species include Lake Trout, Arctic Grayling, Burbot, Longnose Sucker, Round Whitefish, Cisco, Lake Whitefish, Northern Pike, and Slimy Sculpin. The primary gains in habitat are expected to relate to rearing habitat for Lake Trout, Cisco, and Slimy Sculpin. Open water habitat is expected to be suitable for pelagic species such as Cisco as well as potentially as over-wintering habitat.

Given that modeling has demonstrated that water quality in surface waters (i.e., upper 5 m of the water column) in the development case is within benchmarks but there are exceedances at greater depths, there is a potential for adverse effects to fish if deeper water habitat is used.

Recommendation: Provide a description of anticipated fish use of specific habitat in the pit lakes, in particular the use of pelagic habitat at a range of depths and the effect of predicted water quality on fish using this habitat.

2.1.9 Water Circulation in Pit Lakes

The Closure and Reclamation Plan V. 4 (Appendix X2, page 8) notes that with regard to water circulation within the diked area, several features should be incorporated to reduce circulation. The shallow nature of the breaches, shallow nature of the pit shelf, and the creation of shoals on the pit shelf will reduce circulation and wind and wave action. The shallow water is expected to warm up quickly in the spring relative to open areas of the lake because of the limited water circulation within the enclosed area. As with other rearing habitats in Lac de Gras, warmer water should, therefore, assist in increasing biological productivity inside the dike by providing a warmer refuge and foraging area.

The water quality modeling report (Section 4.3, page 36) states that it is expected that shortly after pit lake turnover, water quality in the pit lake, at least near the surface, will quickly return to water quality similar to Lac de Gras due to the high volume of water exchange between the pit lake and Lac de Gras.

It is not clear whether these two descriptions of water circulation (residence time) in the pit lakes are contradictory or if they represent different spatial areas.

Recommendation: Provide a description of the expected water circulation within the pit lake and interchange with Lac du Gras. If possible, include residence times considering the different descriptions noted.

2.1.10 Impacts of Unanticipated Mixing

The report indicates that elevated concentrations of various water quality constituents (of up to approximately 1 order of magnitude) in the pit surface water in the event of mixing would be "short lived" (Section 4.3, page 36). The report indicates this is expected based on modeling results for Sensitivity Scenario 2 (20 m water cap) where conditions would reach Lac de Gras concentrations between one to two months following turnover. It is further explained this is due to high volume of water exchange with Lac de Gras.

The development scenario which entails a 150 m water cap would not be expected to come to equilibrium with Lac de Gras with respect to water quality as quickly as for Scenario 2 due to the much larger volume and associated higher water residence time of the water cap.

Recommendation: Please define a "short lived" duration for the development scenario in this context (i.e., how long would it take for water quality conditions in the 150 m water cap to be restored to conditions below AEMP benchmarks?).

2.1.11 Indirect Effects to Fish

The assessment has focussed on water quality modelling and a demonstration that conditions within surface waters are within AEMP benchmarks though conditions at depth exceeded benchmarks at some times for some parameters. Is there a potential for indirect effects to fish (e.g., migration of zooplankton between deep and shallow waters potentially being a source of metals to fish consuming zooplankton)?

Recommendation: Please describe whether there is a potential for indirect effects to fish from PK storage (e.g., due to effects within food web).

2.1.12 Long-term Load of Contaminants to Lac de Gras

Model results indicate that in the long-term, dissolved constituents will diffuse to surface layers. In addition, there is a potential for infrequent turnover and/or deeper mixing within the pit lakes. In both instances, the report noted that surface water quality would be maintained/restored due to rapid exchange with Lac de Gras. Therefore, constituents from the PK must be moving into Lac de Gras.

Recommendation: What is the long-term load (both anticipated based on model results and unanticipated due to lake turnover) from PK storage to Lac de Gras?

2.2 DETAILED COMMENTS

Detailed comments that recommend various analyses or provide questions that would support an analysis of the potential environmental effects of storing PK in the mine workings are provided in Table 1.

Table 1. Technical review comments and recommendations.

TOPIC	COMMENT	RECOMMENDATION
Section 2.2, Model Inputs, page 4	The report indicates that groundwater and local surface drainage were not incorporated into the modeling. How would inclusion of these inflows affect stability of stratification in the lakes? How would it affect predicted water quality? Note that in the closure plan (V4) strong stratification was predicted based on groundwater input.	Please provide a sensitivity analysis that includes groundwater and local surface drainage as inflows and discuss any changes in conclusions, notably in relation to the stability of stratification and concentration of key parameters in the water column.
Section 2.2.2, Meteorological data, page 6	<p>The report indicates that the meteorological inputs are key drivers of lake circulation and thermal dynamics. On-site data collected from 2014-2017 were used, as well as data from nearby stations 1999-2013.</p> <p>Are there differences between the on-site station and the nearby stations? If weather is different in the future (e.g., climate change) will there be a material change in model results, in particular related to the stability of the water column in the pit lakes?</p>	<p>Please indicate whether there is a material difference between weather (e.g., wind speed and direction) measured on-site and at the nearby stations and, if so, how this could affect modeling results.</p> <p>Please provide a sensitivity analysis considering a range of weather conditions.</p>
Section 2.2.3, Hydrologic Inputs, pages 6-7 and Section 2.2.4.2 PK Pore Water (Supernatant Water), page 7	<p>A consolidation model was developed to estimate the volume of pore water release to the overlying surface water and pore water quality was estimated from the mean conditions measured in "beach pore water samples provided by DDMI".</p> <p>It is unclear whether these estimates, which form the foundation of the water quality modeling, are appropriate and adequately sensitive to provide confidence in the modeling results and conclusions.</p>	<p>Please provide additional details regarding the beach pore water data set used to estimate pit lake pore water quality, including a description of the source of the information, the range of measured pore water quality for each parameter, and a discussion of the applicability of these data for modeling pit lakes.</p> <p>Provide sensitivity analyses for additional scenarios that incorporate the observed variability and/or uncertainty associated with the estimates of volume and chemistry of pore water.</p>

TOPIC	COMMENT	RECOMMENDATION
Section 2.2.4.1, Water Quality Inputs, Lac de Gras, page 7	The report notes that water temperature data are lacking for Lac de Gras and the data from the nearby Snap Lake were used in the modeling. As water temperature is a critical parameter, this represents a data gap.	Recommend installing temperature loggers at several sites in the Lac de Gras to collect site-specific temperature data.
Section 2.2.4.1, Water Quality Inputs, Lac de Gras, page 7	Lac de Gras water quality was defined using data from monitoring sites located near the pits. However, the report notes that open-water season data were used. It is unclear whether the modeling would be materially changed if measured winter water quality data were incorporated.	Please provide a discussion of the implications of completing the modeling using only open-water season water quality data.
Section 2.2.4.1, Water Quality Inputs, Lac de Gras, Table 1, pages 8-9	Modeling results were compared to AEMP benchmarks, as summarized in Table 1. As benchmarks have not been developed for all parameters as part of the AEMP, benchmarks are not provided for all parameters.	Recommend identifying benchmarks for the purposes of this report for those water quality parameters lacking AEMP benchmarks.
Section 2.3, Model Scenarios, page 11	The model assigned a temperature of 5 °C to PK and sediments. There is no reference or rationale provided for this setting. As temperature is a critical variable with respect to modeling and ultimately predictions regarding mixing, this setting should be discussed.	Please provide a rationale for use of 5 °C for PK and sediments.
Section 2.4, Quality Assurance, page 12	<p>The report states: "The calibrated model predicts that ice starts forming on the lake around mid-October and melts by mid- to late June, in agreement with available measured proxy data. The predicted time for ice melting in the pit lakes leads to an open-water season which is longer than that observed at Lac de Gras, where ice melt generally occurs in mid-July. The extended open water season represents a more conservative approach, as the exposure to wind-driven forces over the pit lakes surface is extended over time."</p> <p>The text is somewhat unclear. What are the "proxy data" referred to in the text above?</p>	Please clarify what is referred to as "proxy data".

TOPIC	COMMENT	RECOMMENDATION
<p>Section 4.1.1, Model Results, A418 Pit Lake, page 14</p>	<p>The report indicates: "For the Development Case and Sensitivity Scenario 1, the contour plots show a reduced stability of the stratification over time (predicted TDS concentrations display diffusion over time, as seen in Figure 5). However, the diffusion is thought to be over-estimated in these simulations because they do not account for the dynamic settling of PK, which will lead to a substantially deeper and more narrow pool of water with elevated density, and both of these factors will increase the strength of stratification over the long term. Beyond these time scales, it is anticipated that <u>a very small amount of this water will reach the surface through chemical diffusion and occasional wind mixing</u>; however, both the conceptual and numerical models suggest that this amount will be very small compared to the exchange with lake water and will likely be unmeasurable. If such an exchange does occur, it will reduce the mass of constituents stored at the lake bottom over time."</p> <p>It is unclear what "occasional wind mixing" refers to. Are the lakes predicted to undergo mixing in the future? If the lakes are expected to undergo mixing, please provide a discussion of how it was determined that this will be a "very small" amount of water that would be introduced to the surface layer(s).</p>	<p>Please clarify if the lakes are expected to undergo mixing between surface and deep waters, and if so, provide a discussion of how it was determined that this will be a "very small" amount of water that would be introduced to the surface layer(s).</p>
<p>Section 4.1.1, Model Results, A418 Pit Lake, page 15 and Figure 4, page 17</p>	<p>As there is no definition provided for what are referred to as "surface layers" it is not possible to ascertain what the potential effects are to surface water and ultimately biota. Figure 4 for example shows high concentrations of TDS for the development case below 30 m; the scale of the figures in this and other sections of the report is inadequate to identify the maximum concentrations predicted for shallow depths.</p>	<p>Recommendation 1: Please define "surface layers" (i.e., water depth).</p> <p>Recommendation 2: Please revise all figures such that model predictions for shallower depths (notably what is referred to as "surface layers") are legible (e.g., provide figure insets where applicable).</p>

TOPIC	COMMENT	RECOMMENDATION
<p>Section 4.3, Impacts of Unanticipated Mixing, page 36</p>	<p>The report indicates that elevated concentrations of various water quality constituents (of up to approximately 1 order of magnitude) in the pit surface water in the event of mixing would be "short lived". The report indicates this is expected based on modeling results for Sensitivity Scenario 2 (20 m water cap) where conditions would reach Lac de Gras concentrations between one to two months following turnover. It is further explained this is due to high volume of water exchange with Lac de Gras.</p> <p>The development scenario which entails a 150 m water cap would not be expected to come to equilibrium with Lac de Gras with respect to water quality as quickly as for Scenario 2 due to the much larger volume and associated higher water residence time of the water cap.</p>	<p>Please define a "short lived" duration for the development scenario in this context (i.e., how long would it take for water quality conditions in the 150 m water cap to be restored to conditions below AEMP benchmarks?).</p>
<p>Section 4.3, Impacts of Unanticipated Mixing, page 36</p>	<p>The report indicates that elevated concentrations of various water quality constituents (of up to approximately 1 order of magnitude) in the pit surface water in the event of mixing would be "short lived".</p> <p>The Pit Lakes post closure are planned to provide nursery and rearing habitat for fish, in particular Lake Trout and Cisco. These life stages may be more sensitive to degradation of water quality. Could infrequent mixing of the water column result in the mortality of juveniles inhabiting these areas?</p>	<p>Please provide an assessment of the sensitivity of early life stages of fish to the potential infrequent mixing of the water column.</p>
<p>Section 5.0, Conclusions, page 40</p>	<p>The report indicates that beyond 100 years, "the conceptual model suggests long-term stability of the predicted stratification for the three pits, possibly with a very small amount of upward diffusion of mass".</p> <p>It is not clear if the final conclusion is that stratification will be maintained beyond 100 years post-closure.</p>	<p>Please provide a statement clarifying the long term stability of stratification.</p>

TOPIC	COMMENT	RECOMMENDATION
Attachment 1, Water Quality Results - Figures A-1 to A-9	<p>The report discusses effects on water quality for the "surface layers" and figures presented in Attachment 1 present modeling results for the upper 5 m of surface water and the lower portion of the water cap (e.g., for the development case, results represent the lower 126-150 m of the water column). Based on TDS figures presented in the report (e.g., Figure 4, page 17), water quality conditions in the water column between these depth ranges would be intermediate. As presented in Figures A-1 through A-9 (Appendix 1) exceedances of benchmarks are predicted to occur for some parameters in deep water. The information is insufficient to determine at what water depth benchmark exceedances are predicted.</p> <p>Can DDMI provide the depth to which water quality would be suitable for aquatic life (as defined by benchmarks) and describe effects to aquatic life resident within or moving through deeper waters where benchmarks are exceeded?</p>	Please provide the depth of the water column for the development case where AEMP benchmarks will be met and describe effects to aquatic life that may be resident within or pass through deeper waters where benchmarks are exceeded.
General Comment #1 - Missing parameters	pH and total nitrogen are not included in the modeling results.	Please comment on the potential effects of PK (including slimes) on pH and nitrogen in the pit lakes.
General Comment #2 - Define surfac layers	The report refers repeatedly to "surface layers" of the pit lakes but this is not defined in the report.	Please define (quantitatively) what is meant by "surface layers" in the report.
General Comment #3 - Effects on dissolved oxygen	Is there a potential for PK (including slimes) to decrease dissolved oxygen (DO) in the pit lakes? If yes, what effect would overturn (i.e., mixing) have on DO concentrations? Given that DO is a critical parameter, is there a potential for DO depletion at depth due to other factors (e.g., groundwater input)?	Please comment on the potential effects of PK (including slimes) to affect DO in the pit lakes. Please indicate whether DO may become depleted due to other factors and, if so, the potential effect to biota.

TOPIC	COMMENT	RECOMMENDATION
General Comment #4 - Climate change	<p>The report and modeling does not consider effects of climate change which may conceptually alter thermal regimes and mixing in the pit lakes.</p> <p>Given that the report notes the importance of meteorological conditions in determining the mixing between Lac de Gras and the pit lake, a sensitivity analysis with respect to future climate change (e.g., altered precipitation, temperature, and wind) effects on mixing with Lac du Gras as well as on the stability of stratification in the pit lake should be conducted.</p>	Please provide a sensitivity analysis of potential effects of climate change on the modeling predictions.
General Comment #5 - Mitigation measures	<p>The scope of work indicates that the reviewers are to consider whether any mitigation measures to limit potential impacts to fish and fish habitat have been identified and considered.</p> <p>The IR response does not include a discussion of potential mitigation measures beyond the consideration of the depth of the water cap and the implications of increasing the size of the breach. In the event that mixing were to occur, mitigation and management measures should be identified to limit impacts to aquatic biota and to prevent impacts in potential future mixing events.</p>	Provide a discussion of management and mitigation measures that would be employed in the event of mixing in the pit lakes.

TOPIC	COMMENT	RECOMMENDATION
<p>General Comment #6 - Fish use of habitat in the pit lake</p>	<p>The licence application indicated that the depth of the closure cap would limit resuspension of PK post-closure and will optimize the elevation of PK to limit potential for direct interaction with fish. It was erroneously understood in NSC's previous comments (NSC 2018) that DDMI had assumed that fish are expected to use the upper 10 m of the water column.</p> <p>In the closure plan (V4), the primary focus for habitat creation inside of all dikes is based on providing spawning, nursery, rearing and foraging habitat. Target species include Lake Trout, Arctic Grayling, Burbot, Longnose Sucker, Round Whitefish, Cisco, Lake Whitefish, Northern Pike, and Slimy Sculpin. The primary gains in habitat are expected to relate to rearing habitat for Lake Trout, Cisco, and Slimy Sculpin. Open water habitat is expected to be suitable for pelagic species such as Cisco as well as potentially as over-wintering habitat. To what depth are fish expected to use the pelagic habitat in pit lakes and what is the basis of this expectation?</p>	<p>Please provide a description of anticipated fish use of specific habitat in the pit lakes, in particular the use of pelagic habitat at a range of depths and the effect of predicted water quality on this habitat use.</p>

TOPIC	COMMENT	RECOMMENDATION
<p>General Comment # 7 - Water circulation between the pit lake and Lac du Gras</p>	<p>The Closure and Reclamation Plan V. 4 (App X2, page 8) notes that with regard to water circulation within the diked area, several features should be incorporated to reduce circulation. The shallow nature of the breaches, shallow nature of the pit shelf, and the creation of shoals on the pit shelf will reduce circulation and wind and wave action. The shallow water is expected to warm up quickly in the spring relative to open areas of the lake, because of the limited water circulation within the enclosed area. As with other rearing habitats in Lac de Gras, warmer water should, therefore, assist in increasing biological productivity inside the dike by providing a warmer refuge, and foraging area.</p> <p>The water quality modeling report (Section 4.3, page 36) states that it is expected that shortly after lake turnover, water quality in the pit lake, at least near the surface, to quickly return closer to lake concentrations due to the high volume of water exchange with Lac de Gras.</p> <p>Are these two descriptions of water circulation (residence time) in the pit lakes contradictory or do they represent different spatial areas?</p>	<p>Please provide a description of the expected water circulation within the pit lake and interchange with Lac du Gras. If possible, include residence times considering the different descriptions noted.</p>
<p>General Comment #8 Potential indirect effects of PK on fish</p>	<p>The assessment has focussed on water quality modelling and a demonstration that conditions within surface waters are within AEMP benchmarks though conditions at depth exceeded benchmarks at some times for some parameters. Is there a potential for indirect effects to fish (e.g., migration of zooplankton between deep and shallow waters potentially being a source of metals to fish consuming zooplankton).</p>	<p>Please describe whether there is a potential for indirect effects to fish from PK storage (e.g., de to effects within food web).</p>

TOPIC	COMMENT	RECOMMENDATION
General comment #9 - Long term load of contaminants from PK to Lac de Gras	Model results indicate that in the long-term, dissolved constituents will diffuse to surface layers. In addition, there is a potential for infrequent turnover and/or deeper mixing within the pit lakes. In both instances, the report noted that surface water quality would be maintained/restored due to rapid exchange with Lac de Gras. Therefore, constituents from the PK must be moving into Lac de Gras.	What is the long term load (both anticipated based on model results and unanticipated due to lake turnover) from PK storage to Lac de Gras?

TOPIC	COMMENT	RECOMMENDATION
<p>General comment #10 - Risk analysis of unanticipated effects</p>	<p>The previous review had requested a risk assessment of infrequent events as follows (EMAB 29) : "... DDMI should provide a risk analysis. The current closure plan indicates breaching the dikes and joining to Lac du Gras once water quality is acceptable (DDMI 2017). However, processes such as the accumulation of saline groundwater at depth or the accumulation of metals from porewater in the PK in deep waters may occur over time and, although the initial quality of deep water may be acceptable, over time its quality may decrease. Furthermore, processes that mix deep water with shallower water may occur rarely, as a result of an intermittent event (e.g., strong winds, specific thermal gradient, rockfall from the mine wall) potentially resulting in the introduction of poor quality water to surface waters within the pit and Lac du Gras. There is currently no assessment of the potential water quality at depth, the likelihood or frequency at which mixing with surface waters might occur, and the risk to aquatic biota within the surface waters of the pit or Lac du Gras if such an event were to occur."</p> <p>In the response, DDMI had indicated that the above-stated question would be addressed in the water quality model report. Although the report provides information related to water quality in surface waters and at depth, and the risk to biota (in terms of comparisons to AEMP benchmarks) it does not provide a discussion of the potential frequency of unanticipated events that may result in mixing of the water column (or if such an event would not occur). For example, sub-aquatic or sub-aerial landslides into deep water or supersaturation of dissolved gases have been shown to cause sudden mixing of meromictic lakes.</p>	<p>Please provide a discussion of the potential for infrequent events resulting in the mixing of the water column.</p>

TOPIC	COMMENT	RECOMMENDATION
<p>General comment #11 - Potential build-up of dissolved gases at depth with periodic catastrophic release</p>	<p>Meromictic lakes, including pit lakes, have been found to accumulate dissolved gases (e.g., carbon dioxide and methane) in the monimolimnia. Recent instances of catastrophic degassing of meromictic lakes (i.e., limnic eruption) in which humans and livestock were killed have been reported (e.g., Lake Nyos, Cameroon).</p> <p>There are believed to be a number of key pathways through which excessive gas buildup may occur in meromictic lakes. While some of these pathways such as introduction of volcanic gases are not applicable, others may be applicable to the present case (e.g., decomposition of organic materials). The report lacks any consideration of the potential for gases to accumulate in the pit lakes and the associated potential risk in the event of sudden degassing (e.g., such as during a sudden lake mixing event).</p>	<p>Provide a discussion of the potential for dissolved gas accumulation in the monimolimnia of the pits and describe potential for limnic eruptions and associated risks to humans and wildlife.</p>

3.0 SUPPORTING MATERIALS FOR REVIEW

Diavik Diamond Mines (2012) Inc. (DDMI). 2018a. DDMI Water License Amendment Application, including Attachment 1: Amendment Overview-Deposition of Processed Kimberlite into Mine Workings and Attachment 2: W2015L2-0001 Proposed Amendments (in track changes)

DDMI. 2018b. DDMI Response to WLWB Information Request re: Water License W2015L2-0001 Amendment Request for the Deposition of Processed Kimberlite to Mine Workings.

DDMI. 2017. Closure and Reclamation Plan – Version 4.0. April 2017.

North/South Consultants Inc. 2018. Review of Diavik's Water Licence Amendment Request for the Deposition of Processed Kimberlite to Mine Workings. Prepared for the Environmental Monitoring Advisory Board. Technical Memorandum # 367-18-03.

Executive Summary

As requested by the Environmental Monitoring Advisory Board (EMAB), Slater Environmental Consulting reviewed the Diavik Diamond Mine (2012) Inc.'s (Diavik's) *“Response to WLWB Information Request re: Water License W2015L2-0001 Amendment Request for the Deposition of Processed Kimberlite to Mine Workings”* (the ‘IR Response’) dated November 6, 2018.

The IR Response predicts future water quality in the three pits if the pits are used for storage of Processed Kimberlite (PK). The water quality predictions consider water released from PK as it consolidates in the pits. The predictions also consider the movement and mixing of water within each pit lake.

Diavik's predictions do not include the time period for filling of the pits. Instead, they consider only the period after the pits are full, the water is clean, and the pits are connected to Lac de Gras. Some mine-related water could affect water quality during pit filling. The predictions should be expanded to include the pit filling period so that we have a better understanding about potential effects on water quality and whether the proposed closure plan will work.

Diavik's 2018 modelling predicts that pit lakes will be fully mixed if they do not contain PK. 2010 modelling predicted the opposite, that pits would have two permanent layers that would not mix. The earlier predictions concluded that pits would have clean water in a surface layer connected to Lac de Gras and with more contaminated water retained deep in the pit. The current Interim Closure and Reclamation Plan is based on the conclusions of the 2010 modelling. Diavik should provide some additional explanation about why the two models have different conclusions. Diavik should also update its closure plans if it believes that the new modelling provides a more likely outcome.

Diavik predicts that water released from PK as it consolidates in the pit is a primary source of contaminants in the pit lakes. The predictions about these inputs rely on understanding how fast the PK will consolidate and how much water it will release. The IR Response does not provide any detail about the data and analysis used to predict PK consolidation.

Closure objectives and closure criteria in the Interim Closure and Reclamation Plan describe the expected outcomes for mine closure. If the WLWB approves the disposal of PK in pits, the closure objectives and closure criteria need to be updated to address the different effects and issues.

The information provided by Diavik leaves substantial uncertainty about potential environmental effects associated with deposit of PK in pits. The model results do not provide a basis for informed decision-making as part of a preliminary screening.

The concept of depositing PK into mine workings is positive because the mine workings provide permanent, physically stable storage for PK material. This would help to reduce long-term physical risks once the site is closed. As such, it makes sense to pursue the disposal method provided that adverse effects can be addressed.

Memorandum

To: John McCullum, Allison Rodvang – Environmental Monitoring Advisory Board

From: Bill Slater – Slater Environmental Consulting

Date: December 3, 2018

Re: **Diavik Diamond Mine – Response the WLWB Information Request
Water Licence Amendment Request, Deposition of PK to Mine Workings**

1.0 Introduction

I have reviewed Diavik Diamond Mine (2012) Inc.'s (Diavik's) "*Response to WLWB Information Request re: Water License W2015L2-0001 Amendment Request for the Deposition of Processed Kimberlite to Mine Workings*" (the 'IR Response') dated November 6, 2018. The review is a follow-up to my review of the original water licence amendment request, the results of which were provided in a memo dated July 24, 2018. As described in the Environmental Monitoring Advisory Board's (EMAB's) scope of work, my review has considered potential environmental effects and proposed mitigation, and the adequacy of information to understand potential effects. I have also considered the following specific questions, as per the scope of work:

- How well did the IR response address issues identified during the review of the original application? Have any additional information gaps been identified?
- Are there implications for Diavik's proposed closure criteria for the PKC Facility and Open Pits and its ability to meet them? Are there any recommended changes to the criteria?

The IR Response summarizes modelling methods for predicting future water quality conditions in the three pits (A418, A154 and A21) and the results of the modelling, considering the implications of storing Processed Kimberlite (PK) in the pits. The water quality predictions rely on associated modelling for predicting consolidation of PK stored in pits, and hydrodynamic conditions of pit lakes (i.e., movement and mixing of water within each pit lake).

2.0 Scope of Modelling

The modelling period addressed in the IR Response begins once the pits are full and after the pits have been reconnected with Lac de Gras. Modelling then progresses through the post-closure phase. The initial conditions for the model assume that the pits are fully mixed at the beginning of the modelling period. While not clearly stated, it appears that the modelling assumes that water quality at the beginning of the modelling period is the same as water quality in Lac de Gras. This is based on the assumption that the pit will be filled by pumping water from Lac de Gras and that influences from groundwater flows, PK porewater and other sources during filling are negligible.

These initial assumptions for modelling may underestimate the loading in the pit once it is full. The starting point for modelling does not consider the phase of pit water management that may be the most challenging: the transition from operations PK disposal to closure pit lakes with water quality that is acceptable for reconnection with Lac de Gras. The Golder memo identifies the starting conditions as a limitation of the modelling.

As noted in my July 24 memo, the amendment application did not provide details about operational water management associated with PK disposal. Because the IR Response focuses entirely on the post-closure period, it does not provide any additional clarification about operational water management or the transition period. Water balance and water management will be critical for any PK disposal because the material will be transported to the pit as a slurry. During operations, the water that accumulates in the pit will be primarily process water from deposit of PK slurry. It will also include inflows from groundwater, pit walls and the local catchment. The amendment application stated that water from the pit may be returned to the process plant or it may be transferred to the North Inlet.

Once PK disposal is complete, any water remaining in the pit will contribute loading to the pit as it is filled. Initial rinsing of pit walls and local waste rock materials will also contribute loading. Previous modelling for pit closure considered mine water related loading and concluded that meromictic conditions at or soon after the conclusion of pit filling would lead to surface water quality that would be suitable for connecting pit lakes with Lac de Gras. The current modelling predicts that the pits will be fully mixed at the conclusion of filling, with meromictic conditions establishing over time, but then weakening in the long-term. The establishment of the meromictic conditions likely relies in part on inflows from Lac de Gras at surface to maintain low Total Dissolved Solids (TDS) in the surface water. If loading during the transition period is higher than expected, then connection with Lac de Gras as an ongoing source of low TDS water could be delayed and modelling results may be invalid.

Recommendation: In order to understand the practicality and potential environmental effects of the proposed closure approach for PK filled pits, Diavik should extend the temporal scope of modelling to address the transition period for pit filling and establishment of conditions that are suitable for connection of pits to Lac de Gras. Initial conditions for this period should reflect realistic expectations of water that will be stored in the pit (if any) at the onset of pit filling and any other load sources. The WLWB should request that Diavik provide this information before it proceeds with its preliminary screening.

3.0 Consistency with ICRP

The Interim Closure and Reclamation Plan Version 4.0 (ICRP) describes proposed closure and reclamation for pits that do not contain PK. This configuration is consistent with the Base Case Scenario in the IR Response modelling. The ICRP (Section 5.2.4.3.5) describes the closure plan as follows:

“The lake area will be very deep with steep sides and relatively small surface area and will be protected from wind-driven mixing by the residual dikes. This lake configuration should result in stable permanently stagnant lower monimolimnion underlying an upper mixolimnion that circulates regularly. Mathematical modelling presented in ICRP V3.2 supports this anticipated condition.”

The IR Response presents modelling for the same physical scenario (i.e., no PK in pits). The new modelling predicts that the pits will be fully mixed throughout the 100-year modelling period.

The reasons for the contradictory modelling predictions are not provided, but there are some differences in model assumptions. For example, the 2010 modelling incorporates consideration of high salinity groundwater inflows (approximately 28,000 m³/day) and the conclusions in the modelling report suggest that this may be an important influence in the establishment of meromictic conditions, but the influence of groundwater is described as negligible in 2018 modelling.

Recommendations: Given that Golder’s 2010 and 2018 modelling reach contradictory conclusions about the same model scenario, Diavik should provide additional explanation about the reasons for the different conclusions.

If Diavik has concluded that its new modelling provides a more likely prediction of future pit conditions, it needs to address implications for closure of pits even if PK disposal in pits is not approved.

4.0 PK Consolidation Model

Consolidation of PK in the pit is an important component of the water quality prediction because the PK will release porewater to the pit lakes as it consolidates. Diavik suggests that the porewater is an important source of contaminant loading the pit lakes in the water quality model. As described in Section 2.3 of my July 24 memo, the amendment application did not provide clear information or rationale about consolidation conditions, assumptions and modelling. Section 2.1.1 of the IR Response describes the use of a consolidation model to support the water quality predictions. However, the IR Response does not provide any information about data or analysis that were used to develop the consolidation model. In the absence of this information it is not possible to evaluate the adequacy of the model or the implications on predictions of water quality and potential environmental effects.

Recommendation: Additional explanation should be provided to demonstrate that the model is representative for the conditions that can be expected in the pits at Diavik. The WLWB should request that Diavik provide this information before it proceeds with its preliminary screening.

5.0 Considerations for Closure Objectives and Criteria

As noted in my July 24 memo, the closure objectives for mine workings do not currently contemplate effects associated with PK in the workings. The ICRP would benefit from objectives that address potential for resuspension of PK material (both during pit filling and for post-closure conditions) and interaction of PK material with the aquatic ecosystem. Criteria will be required to define acceptable outcomes for these objectives. These may include criteria that prescribe minimum depth of closure water cap and depth of water needed to avoid potential direct contact of fish with PK. Criteria related to stratification of the closure pit lakes may also be relevant because stratification is likely to remain important for maintaining suitable water quality at the pit lake surface where it interacts with Lac de Gras.

The modelling presented in the IR Response considers post-filling resuspension of fines, and concludes that this is unlikely to be an issue even for pits water covers as shallow as 20m. As a result, it should be possible to define achievable criteria for addressing an objective about potential resuspension.

Establishing criteria related to interaction of PK with the aquatic environment will likely need to consider the perspectives of the TK Panel including the following:

“One panel member said that they have set nets 12–14 metres deep on an extremely hot day. One suggestion was to make sure PK was at least 30 metres below the surface of the water, as this is deep enough and fish will not go that deep without a food source to attract them. However, the Inuit contingent suggested that fish can go much deeper, up to roughly 100 metres, which may be a regional difference.” (DDMI Traditional Knowledge Panel Session #11, Options for Processed Kimberlite, Section 2)

Recommendation: If the WLWB grants approval for disposal of PK in pits, it should require updating of closure objectives and closure criteria to address changes in potential effects.

6.0 Closing

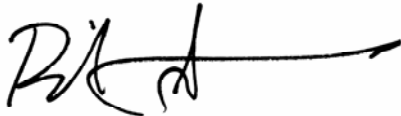
The information provided by Diavik leaves substantial uncertainty about potential environmental effects associated with deposit of PK in pits. The temporal scope of the model does not address the critical transition period, and assumptions about initial conditions do not consider some potential contaminant loads that previous modelling considered important. Diavik has not provided rationale for the fundamentally different outcomes from the two models. It has also not provided any information about the basis for the consolidation model. These issues mean that the model results as presented do not provide a basis for informed decision-making as part of a preliminary screening.

If you have any questions about the review comments or recommendations, I would be happy to discuss them with you.

As noted in my July 24 memo, the concept of depositing PK into mine workings is positive because the mine workings provide permanent, physically stable storage for PK material. This would help to reduce long-term physical risks once the site is closed. As such, it makes sense to pursue the disposal method provided that adverse effects can be addressed.

Thank you for the opportunity to continue working with the EMAB on this project.

Sincerely,

A handwritten signature in black ink, appearing to read "Bill Slater", with a long horizontal line extending to the right.

Bill Slater



Suite 301, 5204 50th Avenue
Yellowknife, NT
X1A 1E2

December 18, 2018

Your files Votre référence
W2015L2-0001

Our file Notre référence
98-HCAA-CA6-00021

Anneli Jokela
Senior Technical Advisor
Wek'eezhii Land and Water Board
1-4905 48th Street
Yellowknife, NT X1A 3S3

Dear Ms. Jokela,

**Re: Diavik Diamond Mines (2012) Inc. – Water Licence W2015L2-0001
Amendment – PK to Mine Workings, DDMI response to WLWB Information
Request**

The Fisheries Protection Program of Fisheries and Oceans Canada would like to thank the Wek'eezhii Land and Water Board (the Board) – WLWB for the opportunity to provide comments on Diavik Diamond Mines (2012) Inc. – DDMI response to the Board's Information Request for the Water Licence Amendment Request.

Our department has reviewed the document: DDMI response to the WLWB Information Request re: Water License W2015L2-0001 Amendment Request for the Deposition of Processed Kimberlite to Mine Workings and is submitting comments via the Board's online review system. DFO's expert advice is provided under the *Fisheries Act*, to maintain the sustainability and ongoing productivity of commercial, recreational and Aboriginal fisheries.

If you or any other parties require further information, please contact Francois Larouche at 867-669-4935, or Francois.Larouche@dfo-mpo.gc.ca

Sincerely,

Angie McLellan
A/Senior Fisheries Protection Biologist
Fisheries Protection Program



Environmental Protection Operations Directorate
Prairie & Northern Region
5019 52nd Street, 4th Floor
P.O. Box 2310
Yellowknife, NT X1A 2P7

ECCC File: 5100 000 015/006
WLWB File: W2015L2-0001

December 17, 2018

Via online submission

Anneli Jokela
Regulatory Manager
Wek'èezhii Land and Water Board
1-4905 48th Street
Yellowknife, NT X1A 3S3

Dear Anneli Jokela:

RE: W2015L2-0001 – DDMI – Diavik – PK to Mine Workings – DDMI Response to WLWB Information Request.

Environment and Climate Change Canada (ECCC) has reviewed the information submitted to the Wek'èezhii Land and Water Board (WLWB) regarding the above-mentioned Information Request response and is submitting comments via the online review system. ECCC's specialist advice is provided based on our mandate, in the context of the *Canadian Environmental Protection Act*, and the pollution prevention provisions of the *Fisheries Act*.

Should you require further information, please do not hesitate to contact Bradley Summerfield at (867) 669-4707 or Bradley.Summerfield@Canada.ca.

Sincerely,

Susanne Forbrich
Regional Director

Attachment: ECCC Comments Excel Sheet

cc: Bradley Summerfield