Meeting record
Agnico Eagle Mines (AEM) at Natural Resources Canada (NRCan)
Meadowbank In-Pit Tailings Disposal Modification (NIRB File No. 03MN107)
Hydrogeology and Permafrost Discussion

Date: September 25, 2018
Location: NRCan office (601 Booth Street, Ottawa, ON – Room 240)
Participants:

NRcan	*AEM*	*SNC-Lavalin*	*Golder*	*CIRNAC*
Marc Hinton	Jamie Quesnel	Emmanuelle Millet	Donald Chorley	Michelle Blade*
Sharon Smith	Michel Groleau	Guillaume Comeau		**on the phone*
Aruna Dixit				
Peter Unger				

Purpose of meeting:

The purpose of this meeting was to discuss NRCan's outstanding concerns with permafrost and groundwater studies related to the assessment of potential impacts from the in-pit tailings modification at AEM's Meadowbank Mine in Nunavut, Canada. The NIRB had set out a shortened review process with one round of IRs and no public hearing and NRCan experts had outstanding concerns at the end of this process, and submitted a set of twelve comments to the Nunavut Water Board (NWB). This meeting was set to resolve these issues for the regulatory phase of the project.

Meeting Summary

AEM brought a presentation that addressed NRCan's 12 comments specifically. As indicated in the submission to NWB, comments 4, 5 and 6 were resolved. NRCan comment #10, regarding seepage from the Central Dyke, still required clarification, so this was added to the agenda.

The first meeting topic was an update on the Version 3 of the hydrogeological modelling, which NRCan stated was notably improved from Version 2. A review of two scenarios run in this model (Goose Pit filled with tailings, and all pits are filled with tailings and flooded), updated boundary conditions, permafrost data from existing (100 year) thermal modelling, and updated contaminant considerations were presented. Several cross-sections from the model, within and below the pits, were discussed.

Following review of the model, NRCan's comments were discussed in sequence, beginning with the thermal modelling. Discussion focussed on how best to model permafrost degradation and how best to present the data. Specific locations for cross-sections within the model were discussed. NRCan and AEM reached agreement on the cross-sections to be presented in the next version and AEM committed to running the thermal modelling for 20,000 years and include this data, in steps, in the hydrogeological model.

Boundary conditions for the hydrogeological model were discussed next, with NRCan's proposed boundary conditions compared to those in Version 3 of the hydrogeological model. Key issues raised by NRCan were that the boundary conditions should represent the upwelling at the edge of the permafrost

that could be a possibility and that the flow paths should represent the regional flow model prepared by Golder in 2004. Discussion included the elevation of the heads, which NRCan had adjusted to account for differences between lake levels in the Golder (2004) regional model and SNC Lavalin models, as well as changing the distribution of the boundary segments to better represent the flows shown in the Golder regional model.

A discussion on diffusion of contaminants ensued. AEM demonstrated that even using the highest concentration of chloride predicted in any of the water bodies at closure, the chloride flux into the Third Portage Lake would be quite low. NRCan agreed to this, but indicated that chloride was acting as a proxy for other contaminants and it is not certain that other contaminants would also be diffusing in concentrations that are not a concern. Donald Chorley and NRCan noted that the advection of contaminants towards the overlying Third Portage Lake needed to be assessed in light of the Version 4 model results, particularly where permafrost thaws beneath the Portage A pit and upward flow may occur.

A discussion of the Groundwater Monitoring plan focused on the operational and closure phases of the monitoring plan, the locations of wells, including how they are chosen and the timing of their installation. AEM indicated that wells were set to collect baseline data as well as to monitor during operations. Some wells are limited by permafrost depth, and closure monitoring wells will be selected based on data collected during operations and a refined hydrogeological model informed by this data. AEM agreed to include the monitoring table requested by NRCan in their operational phase groundwater monitoring plan, and to update it for the closure phase. NRCan's suggestions regarding monitoring were primarily to ensure that each well's location is assessed based on the hydrogeological model. NRCan and CIRNAC suggested that closure monitoring wells be installed well in advance of closure in order to collect background data. AEM agreed that wells would be installed within a one to two year window before closure.

Seepage from the Central Dyke was addressed briefly. AEM explained that an area of high permeability under the Central Dyke resulted in a seepage pathway 50m wide, but that this had been reduced with the addition tailings with lower hydraulic conductivity. NRCan stated that this does not appear to be a serious issue and is of far less concern than the thermal modelling and boundary conditions. AEM asked if this issue was resolved and NRCan confirmed that it was.

AEM asked if all of NRCan's comments had been addressed, and NRCan confirmed that they had. AEM committed to running the thermal modelling based with the changes discussed and for 20,000 years, to run the hydrogeological model (Version 4) with the updated thermal data and boundary conditions and to have this ready in approximately two to four weeks. NRCan committed to providing audio recordings of the meeting to all attendees that day and to have a summary of the meeting prepared by the following week.

Meeting Agenda

1) Update on the current status of thermal and hydrogeological modelling (e.g. version 3).

2) Discussion on thermal modelling and permafrost extent. Specific emphasis on the thermal modelling and the permafrost extent/thaw beyond 100 years and the development of open talik beneath the pits. Discussion on implications for hydrogeological modelling.

3) Discussion on model boundary conditions proposed by AEM and NRCan, and resulting implications for horizontal and vertical groundwater flow.

4) Discussion of assessment of contaminant migration from tailings to overlying Third Portage Lake.

5) Discussion on the groundwater monitoring plan and the locations of groundwater monitoring wells with respect to contaminant plumes.

6) Discussion of NRCan comment #10 – The possibility of areas of high permeability near the Central Dike.*

**Added during the review of the agenda at the beginning of the meeting.*

Detailed Synopsis

Introductions and review of Agenda

- All participants introduced themselves.
- The agenda was briefly reviewed and discussion of NRCan's comment #10 (High permeability near the Central Dike) was added as an item.
- **Jamie Quesnel (AEM)** reviewed the regulatory timeline, specifically the NIRB decision and the expected timeline for the NWB decision. NRCan's outstanding comments were briefly reviewed, with agreement that NRCan's comments numbered 4, 5, and 6 had been resolved.

Hydrogeological modelling – Version 3

- A table and a map comparing the boundary conditions in the third version of the hydrogeological model to those recommended by NRCan was displayed. Four sections of the boundary were indicated as being agreed upon.
- **Jamie Quesnel (AEM)** stated that agreement on the boundary conditions and the next iteration of the hydrogeological model are the key objectives for the meeting.
- **Emmanuelle Millet (SNC Lavalin)** gave a presentation of the updates to the hydrogeological model, which included:
    - Two scenarios, one with Goose Pit filled with tailings for the entire duration of Portage Pit filling, and a second, representing post-closure conditions, with all pits filled with tailings and flooded.
    - Updated boundary conditions
    - The addition of Goose Dump
    - Permafrost degradation results from version 2 used in version 3
    - Consideration of the tailings as a contaminant source at all depths
- A fixed head boundary was used for all the area of Third Portage Lake with a head of 133.6m, a head of 132.9m was used for the Second Portage Lake, while a no flow boundary condition was set for the rest of the model in the first layer (slide 7 in the presentation).
- For permafrost (layers 1-39) and sub-permafrost boundary conditions (layers 40-50), sections of fixed head and no flow were described, with gradients in between (slide 8).
- The parameters of Scenario 1 (Goose Pit filled with tailings) were described (slide 10). These included the addition of the Goose Dump material with an assumed hydraulic conductivity of $1x10^{-3}$ m/s. Tailings were assumed to be filled to 100 masl in Goose Pit, water up to 126 masl (the highest water level). There was an assumption that it would take 12 years to fill the Portage Pit, that the North and South

cells tailings are still unfrozen, that the Central pond SD is still pumping, no permafrost degradation, chloride concentrations of 22mg/L (taken from the water quality and balance forecast report), and that Portage pits A and E are considered under dewatering conditions (to avoid variable boundary conditions and to assume a worst case scenario).

- The hydraulic heads for Scenario 1 were described (Slide 11)
- The transport of chloride was described using slice 27 from the model (slide 12). Slice 27 was chosen because it best represents visually the plume and chloride transport. Chloride was shown to be moving towards Pit E, under dewatering conditions.
- A cross-section of slice 27 was shown (slide 12). It was clarified that slice 27 intersects the pit. The cross-section shows that the plume is being drawn down towards the Pit E, which is under dewatering conditions at this time.
- The parameters of Scenario 2 (all pits are filled with tailings and flooded) were described (slide 15).
- These included that the Goose waste dump was added, the tailings elevation would be at 125.6 masl (maximum capacity), the water elevation in the pits would be 133.6 masl (maximum possible), the North and South cell tailings are frozen, no more pumping at the Central Dike, permafrost is degraded (thawing from the tailings and climate change impacts were considered for a 100-years climate change period), chloride concentration is 22 mg/L in Goose Pit, 141 mg/L in Pit E, and 116 mg/L in Pit A (maximum concentrations based on water quality and water balance forecast that is updated on a yearly basis as part of the type A water licence).
- Dispersivity was doubled because of numerical errors, resulting in the plume reaching the receptor in the model sooner.
- Initial concentrations for Goose Pit are based on results from Scenario 1 simulations with the contamination extending beyond Goose Pit.
- Scenario 2 was run for 20,000 years to capture long term plume behaviour.
- A hydraulic heads map was displayed and described for Scenario 2 (slide 16). Slice 6 and slice 44 from the model were used for these maps.
- A comparison of the hydraulic head maps from the Golder regional model and SNC Lavalin's Version 3 of the sub-permafrost was described (Slide 17). Version 3 of the sub-permafrost model represents the flows indicated on the Golder regional model.
- **Emmanuelle Millet (SNC Lavalin)** showed the primary flows on the map.
- A cross-section along the main flow path (Slide 18) from the northern limit to the 2nd Portage Lake showed a sub-horizontal flow coming from the north, and an upward flow from the 3rd Portage Lake to the 2nd Portage Lake.
- **Donald Chorley (Golder)** stated that in Version 4, the permafrost degradation would be modelled for a longer time to see if an open talik would be produced from Pit A to the sub-permafrost.
- **Marc Hinton (NRCan)** pointed out that in this cross-section (slide 18), equipotential comes up past the permafrost and that there is a upward gradient at the leading edge of the permafrost, which would be close to where the open talik in Pit A would be, should it form.
- A video of a timelapse of the chloride transport map in permafrost conditions (Slice 6) was played (Slide 20) showing the modelling of chloride transport for 20,000 years.
- **Marc Hinton (NRCan)** asked if the chloride in the area of 2nd Portage Lake was coming from Portage Pit A or Portage Pit E.
- **Guillaume Comeau (SNC Lavalin)** clarified that it was mostly coming from Pit A. A similar video for sub-permafrost conditions was also played.
- Two cross-sections were shown for Portage Pit A to account for different flow behaviour in sections of the pit. One (Slide 21) was using slice 6 (~120 masl) and the second (slide 23) using slice 44 (-500 masl).

- **Guillaume Comeau (SNC Lavalin)** stated that a constant source is used, whereas in reality the concentrations would degrade over time. He also pointed that the piezometric lines in the cross-section (slide 24) are more refined than in the regional cross-section (slide 18), and the upward flow is less clear here. However, that after the thermal modelling was updated, he would look specifically at the location of concern mentioned by **Marc Hinton (NRCan)** earlier.
- **Emmanuelle Millet (SNC Lavalin)** Millet (SNC Lavalin) pointed out that the model had to be run for a long time period to see maximum extension of the plume, and that the plume is going downwards from Pit A and resurfacing at 2nd Portage Lake.
- **Marc Hinton (NRCan)** asked if it was hydraulic gradients driving the plume down or if it was neighbouring permafrost driving it down.
- **Donald Chorley (Golder)** stated that permafrost is having some effect.
- **Emmanuelle Millet (SNC Lavalin)** suggested that the top of the lakes being a fixed hydraulic head could also be a factor.
- Similar cross-sections were shown for Portage Pit E (Slides 25-26) and for Goose Pit (Slides 27-28), both at slice 44 (-500 masl). For Goose Pit, the permafrost was assumed to be completely thawed at the top.
- **Guillaume Comeau (SNC Lavalin)** noted that it is important to take note of the scales on the figures, as the chloride concentrations in Goose Pit are much lower than in the Portage Pits A and E.
- **Marc Hinton (NRCan)** asked for clarification on the distribution of head from Goose Pit and whether the flow shown was the shortest flow path to 2nd Portage Lake.
- **Emmanuelle Millet (SNC Lavalin)** said she chose the slice closest to the flow path.
- **Donald Chorley (Golder)** asked if a particularly high concentration on the Goose Pit cross-section was from another pit.
- **Emmanuelle Millet (SNC Lavalin)** confirmed that it was the plume from Pit E.
- **Marc Hinton (NRCan)** asked if this model included the fault zones, which have slightly higher permeability.
- **Emmanuelle Millet (SNC Lavalin)** confirmed that it did.
- **Marc Hinton (NRCan)** asked for clarification if the fault in Portage Pit E had been redefined.
- **Emmanuelle Millet (SNC Lavalin)** confirmed that more splays have been added, but that it did not matter as they were in the pit and would have been mined out.

Review of NRCan's comments

- **Jamie Quesnel (AEM)** proposed that NRCan's comments be reviewed sequentially.
- **Michel Groleau (AEM)** presented a table of NRCan's comments (Slide 29), indicating that comments 4,5,6, and possibly 10 are resolved; comments 1, 2 and 8 could be resolved over the course of the meeting, with the remaining issues to be resolved in the next iteration of the thermal and hydrogeological modelling and Groundwater Monitoring Plan.
- **Michel Groleau (AEM)** proposed starting with the thermal modelling and permafrost extent, the extent of boundary conditions, and then the contaminant migration from the tailings to the upper layer of 3rd Portage Lake, which he described as being predicted by a diffusion model because they did not see an upward gradient.
- Part of NRCan's recommendation on thermal modelling (NRCan#3) accompanied by a map of the thermistor locations and the cross-section currently used for thermal modelling is displayed. **Marc Hinton (NRCan)** was invited to show where the cross-section should be. Marc was concerned about specific sections of permafrost thawing creating a more direct route for flows. He suggested a different cross-section.
- **Sharon Smith (NRCan)** suggested that a previous map had showed a curved line cutting across the pit.

- **Donald Chorley (Golder)** reminded everyone that the thermal modelling would be done in 2D sections, assuming the section of permafrost on both sides is infinite.
- **Marc Hinton (NRCan)** suggested that this is a weakness of 2D modelling.
- **Donald Chorley (Golder)** suggested that below the pit it works well; however, for a section going through the middle would be problematic.
- **Marc Hinton (NRCan)** confirmed that he asked for this to account for Portage Pit A.
- **Donald Chorley (Golder)** said that what they had done previously to compensate for deficiencies in 2D modelling was to stitch a number of 2D sections together.
- **Michel Groleau (AEM)** noted that large sections of the map would be filled with tailings and capped, and would generate permafrost. He argued that long-term that this would reinforce the permafrost in certain sections of Portage Pit A. He agreed that there might be degradation of permafrost at the south of Portage Pit A, but that the whole pit being open would be unlikely. This was compared to the Whale Tail modelling. However, it was agreed that a cross-section in this area would be valuable, but that the specific location of the cross-section should be agreed upon to meet everyone's needs.
- **Marc Hinton (NRCan)** said that the objective is to see if thawing that area is going to open a more direct flow path that could either reach the lake more quickly or be of a higher concentration. He said that the specific location of the cross-section he leaves to the modellers' professional judgement, but that with the data gathered from Version 3 and the shorter term thermal modelling a cross-section that meets this objective could be located.
- Some discussion of potential NW-SE cross-section locations ensued. **Sharon Smith (NRCan)** noted that the width of the pit is wider than the critical length required for an open talik. She said it is unlikely that the pit will ever freeze to the bottom. She suggested that even running the model with 4 degrees Celsius at the bottom, without accounting for climate change, could give an indication of talik formation, as the largest change in temperature would be from the warm tailings.
- The discussion of the proposed North-South cross-section followed. **Michel Groleau (AEM)** suggested a location for the cross-section.
- **Marc Hinton (NRCan)** suggested that melting would be more likely to happen slightly west of the proposed location between Portage Pit E and the Central Dump and that the objective would be to show where it would open up first. He suggested a number of 2D sections across, but then said that this would not capture the North-South effect. The 2005 baseline permafrost report was referenced for an idea of starting permafrost conditions.
- **Marc Hinton (NRCan)** stated that original permafrost data there was no flow or contaminant transport was indicated.
- **Guillaume Comeau (SNC Lavalin)** stated that in the 100 year thermal model the thawing and the hydraulic connection are present.
- **Jamie Quesnel (AEM)** asked if this meets NRCan's requirements.
- **Marc Hinton (NRCan)** responded that he is also thinking of longer term developments after this thaws.
- **Guillaume Comeau (SNC Lavalin)** asked if the East-West cross-sections stitched together would meet the needs of the model.
- **Donald Chorley (Golder)** suggested that certain North-South sections would give the appearance of the pit being infinite.
- **Marc Hinton (NRCan)** agreed that the North-South section would ignore that there is permafrost on each side.
- **Sharon Smith (NRCan)** suggested that this would give an idea of conditions in the pit and therefore would be of value.
- **Donald Chorley (Golder)** asked for confirmation of the hydraulic connection, which was confirmed by **Emmanuelle Millet (SNC Lavalin)** and **Guillaume Comeau, SNC Lavalin**.

- **Jamie Quesnel (AEM)** asked if a longitudinal section of slice 6 would meet NRCan's needs, while **Guillaume Comeau (SNC Lavalin)** added that stitching the cross-sections together would widen the permafrost degradation.
- **Marc Hinton (NRCan)** stated that the problem with stitching is that the section in the middle of the pit would have the permafrost further away, whereas at the north end of the pit the permafrost would be closer and show slower degradation, while in actuality faster degradation would be expected due to proximity to the Central Dump. Some discussion of the issues related to stitching 2-D sections together ensued.
- **Emmanuelle Millet (SNC Lavalin)** suggested using the maximum permafrost degradation extent in Goose Pit and applying it to Pit E, as this would be a worst case scenario.
- **Guillaume Comeau (SNC Lavalin)** suggested that this could overestimate the degradation in Pit E.
- **Donald Chorley (Golder)** suggested a shorter cross-section. **Marc Hinton (NRCan)** asked what was happening in the north end of the pit in the 100 year model.
- **Emmanuelle Millet (SNC Lavalin)** said that there were not any significant flows there.
- **Marc Hinton (NRCan)** then suggested that the cross-section of the north end of the pit may be a moot point.
- **Marc Hinton (NRCan)**'s concern was that in Version 1, there were contaminant pathways coming from the south end of Portage Pit E, and that this suggested that ultimately these would come from the north end. However, the better understanding of the flows shows that the only real pathway is to the north-east. Therefore the cross-section requested in the second point on Slide 30 is not required, assuming the next thermal model will go beyond 100 years.
- **Guillaume Comeau (SNC Lavalin)** suggested that running the model for longer than 100 years will result in more degradation in Pit E and would just result in a larger talik in that location, and that the current cross-section would show this.
- **Marc Hinton (NRCan)** asked how one cross-section across the middle of the pit was extrapolated to apply north and south to the rest of the pit.
- **Guillaume Comeau (SNC Lavalin)** responded that they took the width of the permafrost degradation from each side of the pit from the cross section and wrapped it around.
- **Donald Chorley (Golder)** asked if NRCan wanted them to show how they accounted for climate change.
- **Sharon Smith (NRCan)** suggested this could be tackled two ways. One would be to ignore climate altogether. The second would be to apply climate models, but that these are not very reliable beyond 100 years. For this reason, **Sharon Smith (NRCan)** suggested that running the model for 1000 years at 4 degrees could be just as good in terms of the hydrogeological modelling.
- **Guillaume Comeau (SNC Lavalin)** stated that in the technical note for thermal modelling they ran two scenarios, one with climate change and one without, and that these indicated that climate change did have an impact.
- **Sharon Smith (NRCan)** confirmed that these models were just run for 100 years.
- **Donald Chorley (Golder)** suggested that running it long term they could level off the temperature increase after a certain period time.
- **Sharon Smith (NRCan)** agreed that models are levelled off at some point as after a certain point all of the inputs that are likely to occur will have and that the key is that heat is added. **Sharon Smith (NRCan)** used the example of the proposed Kiggavik project where the thermal modelling was run for 250 years with constant temperature increases to demonstrate the worst case scenario.
- **Guillaume Comeau (SNC Lavalin)** asked how long they should run the model with the 4 degrees in the tailings.
- **Sharon Smith (NRCan)** said that until the model reaches a steady state. **Sharon Smith (NRCan)** suggested that this would be to match up with the hydrogeological modelling.

- **Donald Chorley (Golder)** added that they would look at the output from the thermal modelling, which would influence the hydrogeological modelling in terms of permafrost degradation as the degradation would be changed in steps rather than gradually and they would need to figure out where those steps are. The degradation would probably be rapid at first and then level off.
- **Guillaume Comeau (SNC Lavalin)** said that they don't want to open all the possible taliks at the beginning of running the model.
- **Marc Hinton (NRCan)** and **Sharon Smith (NRCan)** agreed that this is not desirable.
- **Guillaume Comeau (SNC Lavalin)** added that they would want to do this in steps.
- **Sharon Smith (NRCan)** suggested that in the first part of the modelling, thawing would be due to the added water, and the importance of climate in terms of temperature would increase only later in time. Changes in the first 20 years or so would be due to the disturbance and then the climate influence would become more apparent. By the time 100 years is reached the climate would become important.
- **Guillaume Comeau (SNC Lavalin)** suggested that they would change permafrost degradation in steps during the hydrogeological model.
- **Donald Chorley (Golder)** added that they would have to see what the results of the thermal modelling are.
- **Marc Hinton (NRCan)** added that **Michel Groleau (AEM)**'s earlier point regarding the northern end of Portage Pit A becomes very important for the groundwater modelling, because, from the regional modelling, those hydraulic heads are expected to be higher than the 3rd Portage Lake level. It depends on whether that stuff thaws or not. As was said, there will be permafrost on three sides, and this might make it less likely to thaw, but there is still a lake on there that is 4 degrees and depending on critical dimensions that are idealized.
- **Sharon Smith (NRCan)** added that the threshold for talik formation becomes smaller as you add the climate contribution.
- **Marc Hinton (NRCan)** continued that at some point as the thaw comes down to half the lake, then the opening would occur in the sub-permafrost and groundwater flow would be converging to that point. Ultimately, defining where the boundary of the thaw is will be important in determining whether there will be an upward gradient through the tailings driving into the lake, and also when. For example, if it takes 500 years for that talik to open up, then that means that after 500 years is when you could have flow through the tailings into the overlying water bodies. So, you might have no impacts for that whole period while the permafrost is intact, but once it thaws, the impacts could start then. This is why it is important to know when this could occur and how far North-South that talik is going to open.
- **Sharon Smith (NRCan)** added that it would be important to know what the concentration is at this point, because by then it might not matter. She pointed out that the model has a constant source, but at some point they would likely begin stepping this back. She suggested running the model for longer, adding climate to a certain point could have value, and then it could be levelled off. The changes down to several hundred metres will take a long time to occur no matter what.
- **Guillaume Comeau (SNC Lavalin)** added that there is still a huge mass of permafrost at the northern end still.
- **Donald Chorley (Golder)** then suggested a section on the map that would limit the permafrost on each side and give equal balance to the permafrost and the water.
- **Michel Groleau (AEM)** asked if everyone was in agreement on this one.
- **Jamie Quesnel (AEM)** clarified that this was for item i on Slide 30. He suggested that the meeting keep moving as there were still many items to go through. For section ii, that is a moot point now. Subsection iii?
- **Marc Hinton (NRCan)** responded that the point of sub-section iii was to get an idea of the distribution of open taliks and permafrost beneath Portage A, and the timing of that thaw.

- **Jamie Quesnel (AEM)** asked if we would continue with this, or just draw a line.
- **Guillaume Comeau (SNC Lavalin)** responded that they were planning to use the stitching of all the cross-sections together, to address the north-south section. He asked if everyone was in agreement with that methodology.
- **Marc Hinton (NRCan)** deferred to **Sharon Smith (NRCan)**.
- **Sharon Smith (NRCan)** said yes, but she wanted to include a bit more of the influence of the proximity of the pits and water bodies.
- **Donald Chorley (Golder)** interjected to say that they had defined the melting around the pit based on a certain section and this could be used, and **Guillaume Comeau (SNC Lavalin)** added that it is already talik in certain sections.
- **Donald Chorley (Golder)** said that stitching the cross-sections together would be quite effective.
- **Marc Hinton (NRCan)** said that for point iii, the point wasn't so much the talik around the edge of the pits, but actually the talik beneath Portage Pit A, so he is not sure what the best approach is to model that extent beneath Portage A.
- **Guillaume Comeau (SNC Lavalin)**suggested that there may not be a need to extend through all the pits, but that only an indicated section through Portage A could be used.
- **Donald Chorley (Golder)** said that this specific section would make an assumption that the pit is infinite.
- **Marc Hinton (NRCan)** added that then there would not be a source of cold at the bottom, and that this would be an overestimate of the thaw.
- **Guillaume Comeau (SNC Lavalin)** then indicated that one of the existing sections already captures what is needed. If that was run for a longer time, he thinks they would be able to see when it becomes a true talik.
- **Marc Hinton (NRCan)** asked **Sharon Smith (NRCan)** what she thinks.
- **Sharon Smith (NRCan)** said that if you stitched them together, that may solve the problem.
- **Donald Chorley (Golder)** then said that these solutions don't really account for lake depth, and a deeper lake would thaw more.
- **Sharon Smith (NRCan)** said that this would depend on what the temperature was around the lake.
- **Sharon Smith (NRCan)** said it might not even matter if you thaw it all out.
- **Marc Hinton (NRCan)** thinks it matters further up. **Marc Hinton (NRCan)** said that he was hoping to get some kind of feeling of how far the open talik will progress to the north. Right now, the open talik is pretty well at the southern end of Portage A, and we know that it will move up north, but we don't know how far. Maybe this is something to address in the sensitivity analysis of the model. Varying levels of thawing could be used in different scenarios to see what difference this makes. If all of the hydrogeological models turn out to be the same, or at least similar, then it may not matter.
- **Donald Chorley (Golder)** asked to confirm that the concern is that there could be an upward gradient through the tailings up to 3rd Portage Lake.
- **Marc Hinton (NRCan)** confirmed this.
- **Sharon Smith (NRCan)** suggested that they make the permafrost to look like the scenario that would allow this path through the tailings and then run the hydrogeological model to see if it appears.
- **Marc Hinton (NRCan)** said that the challenge is, looking at the sub-permafrost heads, they are higher at the north end, so there is more chance of an upward gradient at the north end, and as you move to the south end, there is less difference between the sub-permafrost, so the gradient might be smaller. So the further north is thawed, the greater that gradient might be.
- **Guillaume Comeau (SNC Lavalin)** suggested that maybe they could address that.
- **Donald Chorley (Golder)** suggested that discharge could be to Second Portage Lake because of the lower head and bypass the Third Portage Lake, but otherwise it could open up as **Marc Hinton (NRCan)** says.

- **Marc Hinton (NRCan)** confirmed that if it did open up, if would be the first point of discharge, so it would tend to focus towards that, and some convergence towards that point would occur if it thaws all the way to the north end of Portage A.
- **Guillaume Comeau (SNC Lavalin)** said that the first step will be to run these cross-sections for 20,000 years and see what the results are. If it seems that the permafrost is melting in this area, they will have the inputs from their hydrogeological model to see if there is a contaminant pathway. If there is no complete degradation, they might initiate more investigations. He said they understand now what NRCan wants to see and what their concerns are.
- **Jamie Quesnel (AEM)** said that it's just the timing of having iteration sensitivity and that if there is agreement on the path forwards, they can always update the model, but he wanted to make sure everyone understands the key objectives. He said they need to meet their timeline for December. There is a little bit of room in front of them for the regulatory side, but if some of these things are later, they can push some of the sensitivities out later too. They can do that, so they meet AEM's objective and NRCan's primary objective, and they can run sensitivities during the operational window too.
- **Jamie Quesnel (AEM)** said he just wanted to make sure that they hit the key objectives that **Marc Hinton (NRCan)** has provided them.
- **Marc Hinton (NRCan)** said that he thinks **Donald Chorley (Golder)** has got it right, and that they are really just trying to understand the potential for flow through the tailings up into the overlying 3rd Portage Lake, so everyone is clear on that.
- **Michel Groleau (AEM)** remarked that it was a useful discussion and asked if he should move on to the next slide.

<u>Boundary conditions discussion</u>

- **Michel Groleau (AEM)** announced Slide 31 and described it as portraying the groundwater flowpaths from the 2004 Golder model, as well as what they are seeing in the sub-permafrost conditions with version 3 of their model. He believes that they are showing in their model the flowpaths that they want to represent and that it's aligned with the flowpaths in the regional model. It is a local model, not a regional model. They prefer using that type of modelling because they need to observe what is going on within the pits and they want high definition. This is why they use the regional model to address boundary conditions. They appreciate that **Marc Hinton (NRCan)** gave a sense of what his expectations were in terms of boundary conditions. This is the discussion they wish to have now and aim for agreement on boundary conditions that will be used for Version 4 of the groundwater model.
- Slide 32 was displayed and **Donald Chorley (Golder)** described the boundary conditions in Version 3 and asked **Marc Hinton (NRCan)** if he was happy with that.
- **Marc Hinton (NRCan)** said that it is a lot closer in terms of the flowpaths than versions 1 and 2. There are similarities and it is definitely a big improvement. He has to think about it a bit more in terms of potential implications on vertical flow.
- **Michel Groleau (AEM)** suggested going through the table to discuss what was used and what NRCan suggested. He said there is agreement on the "No flow" boundaries, more or less. He started with section B-C, and then discussed section C-D, where Version 3 had a No flow boundary, while **Marc Hinton (NRCan)** had suggested a gradient from 133.6-132.2, D-E was agreed upon as no flow, but Version 3 had section E-F as a no flow while NRCan suggested a gradient from 132.9-132.7.
- **Michel Groleau (AEM)** stated that their view is that C-D should have a no flow boundary.
- **Marc Hinton (NRCan)** stated that this is a tough boundary to implement to get the regional flow in and that he tried to make this clear in his notes. He said if you put those values in, what you might get is just downward flow from the lake out the boundary. He realized that if you were trying to simulate the

regional flow system, you might have to potentially put a flux boundary in, so you get a positive flux in. This is why the wording was not prescriptive in his comments. His values were recommendations, but they may not work.

- **Guillaume Comeau (SNC Lavalin)** indicated that they would like to have an outlet while pointing out an area to the left of point F on the map.
- **Guillaume Comeau (SNC Lavalin)** said that they want to reproduce that regional groundwater flow.
- **Marc Hinton (NRCan)** said that this is why he put in a value in the E-F section. He asked to be shown the regional model map on the previous slide and pointed out the flow he was hoping to reproduce. He showed on Slide 32 that Version 3 had outflow from G to F, and that he suggests extending this to E, and that the lowest head would be close to F. That's why he suggested the lowest value of head there. He showed that because a whole section is no-flow, it could force flows to wrap around and discharge. He acknowledged that their moving a boundary did make an improvement. He was suggesting moving it so the lowest head is close to F.
- **Michel Groleau (AEM)** said that they discussed this the day before together and they agreed that there is logic behind the strategy in placing those boundary conditions for Version 3. It's based on the fact that this section is all part of 3rd Portage Lake. It's driven by the same water elevation, which is 133.6. They need consistency in the attribution of boundary conditions. He said they were trying to think of how to add this, so that is why there are all the no flow boundaries for that section. He said that maybe the way to do it would be to add a 133.6 fixed head.
- **Marc Hinton (NRCan)** said that this is part of why this is important because these are sub-permafrost boundary flow conditions. So the lake level is 133.6 from E-F, but in fact the sub-permafrost groundwater level at that end of the lake is actually lower. That means that you are going to have vertically downward flow. In other words, to capture your flow, your plume is probably going to dive down towards that outlet. It's kind of like when the cross-sections were shown of head, where there was a little upwelling where the permafrost ended, but where the permafrost begins, that's also where you have the downward flow. So wherever you have talik, you have upward flow at the high head end of it and downward flow at the down gradient end of the talik. This is why he was suggesting the lower head for this section, because in fact it will drive a downward flow at the southern end of the pits. In the big picture, it will give you a better representation of what we think might be happening. He doesn't think it will have a huge impact on the contaminant migration. It will change where the contaminant plume is maybe over 20,000 years, but Tehek Lake is many thousands of years away in terms of contaminant transport. However, it will drive your flow system differently, and if you have monitors, you'll want to position them correctly based on the flow system. He thinks that all that outward boundary is going to drive flows down, especially if it is extended into the 3rd Portage Lake area. This is why he was pointing out that even though it is a small difference in head, it will change the vertical gradients.
- **Guillaume Comeau (SNC Lavalin)** pointed out that the E-F portion is almost perpendicular to the blue flow line, effectively making it a no flow.
- **Marc Hinton (NRCan)** responded by pointing out the flow in the regional map, and showing on it where he chose the D-E section to be a no flow, and then E-F as being an outflow boundary, so the flow is not hitting it perpendicularly, the flow is at an angle.
- **Michel Groleau (AEM)** asked if the flow lines are referring to the 2004 model, which **Marc Hinton (NRCan)** confirmed and said that this is how he guessed at those values.
- **Marc Hinton (NRCan)** said that in his comments he noted that Golder model assumed an elevation of 132 in 2nd Portage Lake and 133 in 3rd Portage Lake. Therefore, if the contours presented were to be used, then they have to be scaled to these assumptions, as now they have moved from 132 to 132.9 and 133 to 133.6. This is why he said there was a "correction factor" that would be put into all of the heads

that are based on these contours so that you get the correct gradient. So that in instances where you have 136, that is 136 in comparison to 132, though now 132.6 is being used, hence his suggesting 136.6. The difference between the Golder model and Version 3 is the lake elevations are slightly different. The correction factor would have to be between 0.6 and 0.9m. It doesn't really matter which you use. The point is that it is the relative difference between the contour and the lake.

- **Jamie Quesnel (AEM)** said that he thought that the level in the 2nd Portage Lake was correct in the Golder model and the only difference was the 3rd Portage Lake.
- **Marc Hinton (NRCan)** said that he thought the elevation in the Golder model was 132.
- **Guillaume Comeau (SNC Lavalin)** said that they used 132.9 for the 2nd Portage Lake.
- **Marc Hinton (NRCan)** said that he was referring to the Golder model.
- **Donald Chorley (Golder)** said that he also believes that 132 and 133 were used.
- **Marc Hinton (NRCan)** said that this is why it's the relative difference between the contour and the lake that matters.
- **Emmanuelle Millet (SNC Lavalin)** confirmed that it was 132 in the Golder model.
- **Guillaume Comeau (SNC Lavalin)** asked about section H-K.
- **Marc Hinton (NRCan)** said that this is the offset.
- **Guillaume Comeau (SNC Lavalin)** asked if 132 was used at F and then the offset added.
- **Marc Hinton (NRCan)**: said, yes, he guessed. At point F, he said it was actually downgradient of the 132 contour, so he thinks he chose 131.8 but he is not sure. He did try to work that out though. He could let them know how he got those exact numbers later, but he was indicating that F is downgradient and at a lower head than 132, and then adding the correction in. He may have used 131.8 and used a correction factor of 0.9 because they were close to the 2nd Portage Lake and then ended up with 132.7. This was to keep it consistent with the value at G, which he put at lake level, or 132.9. He showed that the contour comes very close to G, and the 132 with the 0.9 correction would be 132.9, which is what SNC had used before. So to keep consistent with that, he figured that F is about 0.2 less than that, just based on gradient and contours.
- **Marc Hinton (NRCan)** said that he is in agreement with the H-K section, with the exception of the offset. That is the only difference between the two sets for this section.
- **Guillaume Comeau (SNC Lavalin)** said that he thinks they can work out the offset. He asked if they agree on H-K.
- **Donald Chorley (Golder)** said that as you get further north it's going to get closer to the 3rd lake elevation and there is a limit to how far you can increase it.
- **Marc Hinton (NRCan)** agreed that they can't go higher than that, but that you could scale this according to your distance from the lake, assuming that in the Golder model the lake was at the right elevation.
- **Michel Groleau (AEM)** said that he didn't think this would generate a big change in the flow system.
- **Marc Hinton (NRCan)** agreed that it won't generate a big change in the flow system, but it will generate a change in head beneath the top of Portage Pit A, and that's going to spread that head through the model and when you get to Portage Pit A, it will have slightly higher heads and more chance of an upward gradient further south.
- **Michel Groleau (AEM)**: From A-E it is preferable to use a no flow boundary to make sure that they are generating that flow from the west to the east and to not create a hydraulic trap.
- **Marc Hinton (NRCan)** said that he understands for the modelling purpose this helps it a lot, and he has thought about this some more. He described some of the flows on the map, and showed that Version 3 was much closer because of these flows. He suggested that no flow could work assuming that the flows in (C-D) and out (A-B) are comparable.
- **Jamie Quesnel (AEM)** asked if we have agreement on a no flow boundary from A-E.

- **Marc Hinton (NRCan)** said that would probably work and be much simpler numerically, but his only concern is if there is any influence on the vertical gradients by having the head between C and D. Ultimately, E-F has more of an impact on the vertical gradients than C-D.
- **Guillaume Comeau (SNC Lavalin)** suggested just putting 136.6, but later corrected this to 133.6.
- **Marc Hinton (NRCan)** asked if that was from E-F.
- **Guillaume Comeau (SNC Lavalin)** confirmed that one of their thoughts was putting a 133.6 boundary from E-F and this was one way to address this concern.
- **Marc Hinton (NRCan)** said that he doesn't think this is accurate in the sub-permafrost groundwater, as head is being lost along there, and to make it constant head is not allowing water to flow. The gradients are fairly low anyway across the model, the heads are pretty flat. In that sense, 133.6 to 132.7 is still a fairly small gradient across over that distance.
- **Marc Hinton (NRCan)** asked if they could show him the Version 3 heads for the sub-permafrost groundwater.
- **Guillaume Comeau (SNC Lavalin)** said that they are included and **Marc Hinton (NRCan)** asked about a specific head value. Comparing to the boundary conditions under discussion, **Marc Hinton (NRCan)** said that his suggestions provide a bit more of a gradient over this section but that they are not too far apart.
- **Marc Hinton (NRCan)** agreed that numerically it is easier to have to no flow boundaries across A-B and C-D, and that's probably acceptable and not that far off what he recommended, but that they should try the E-F boundary he suggested. The lower head at F and a broader based outflow boundary, because that is flowing out to Tehek, which is huge.
- **Jamie Quesnel (AEM)** asked if **Michel Groleau (AEM)** is clear on the math for the recommendation from **Marc Hinton (NRCan)**.
- **Michel Groleau (AEM)** agreed.
- **Jamie Quesnel (AEM)** asked if **Michel Groleau (AEM)** agrees to run the model based on these recommendations, and that the only change would be E-G with the numbers from NRCan and H-K with **Marc Hinton (NRCan)**'s recommendation, plus the thermal bit.
- **Jamie Quesnel (AEM)** asked if **Michel Groleau (AEM)** was ok with this, then if SNC Lavalin and **Donald**
- **Chorley (Golder)** felt good about it. All agreed.
- **Donald Chorley (Golder)** asked if we could go through it again. The lake levels were reviewed.
- **Donald Chorley (Golder)** confirmed how much **Marc Hinton (NRCan)** had changed.
- **Marc Hinton (NRCan)** reiterated that he was basing the elevation on the contour near G and how this affected his boundary estimates. He explained that he used a 0.9 correction and attempted to use this consistently.
- **Jamie Quesnel (AEM)** asked if in Version 3, 132.9 was used for F-G, which is pretty close to what **Marc**
- **Hinton (NRCan)** is recommending, and if keeping E-F at 132.9 would work.
- **Marc Hinton (NRCan)** said that might be possible and it is not very different in terms of model implementation.
- **Marc Hinton (NRCan)** suggested that this would shift the outflow and could influence the vertical gradient, and that his recommendation was intended to address this and get that downward flow.
- **Donald Chorley (Golder)** was concerned that putting in so many constant heads would constrain the model.
- **Marc Hinton (NRCan)** said that the model is currently constrained with the current boundaries, he was just trying to represent more closely what is shown in the Golder model.
- **Donald Chorley (Golder)** said that the constant head is not a big deal when flow is going down, but it's more when predicting dewatering that it becomes an issue because it starts flowing from the boundary.
- **Marc Hinton (NRCan)** agreed. **Donald Chorley (Golder)** said that if you had E-G all at 132.9 that would satisfy that because he would still get a flow out that boundary as it would be the lowest point. **Marc**

- **Hinton (NRCan)** confirmed that he had 132.9 at E, which **Guillaume Comeau (SNC Lavalin)** considered quite low for E.
- **Marc Hinton (NRCan)** said that this was through doing his corrections for lake level, but if you wanted to have to keep the same correction, a different value might need to be assigned. However, this is a different issue, as **Donald Chorley (Golder)** was concerned about the proximity of E to the pumping.
- **Donald Chorley (Golder)** said it doesn't matter that much as when there is pumping it will go north.
- There was silence for several seconds and **Peter Unger (NRCan)** suggested a bathroom break.

END OF RECORDING 1 – START OF RECORDING 2

- **Peter Unger (NRCan)** Unger (NRCan) indicated that **Sharon Smith (NRCan)** had to leave due to other obligations, but could be called back if her expertise was needed.
- **Jamie Quesnel (AEM)** asked if we wanted to return to Slide 32, which was displayed.
- **Marc Hinton (NRCan)** mentioned that he had a thought about the heads from E to G during the break. He showed how having 132.9 at E and G and 132.7 at F and the 132.9 contour crossing the model, the groundwater flow would be to the southeast, and the value of having that there is this southeastern flow.
- **Donald Chorley (Golder)** mentioned that they had discussed as well during the break and invited **Guillaume Comeau (SNC Lavalin)** to present their idea.
- **Guillaume Comeau (SNC Lavalin)** said that they would like to keep the same boundary they had but extending it so they get the same outflow.
- **Marc Hinton (NRCan)** asked if they were worried about extending the model too far into the lake, to which **Guillaume Comeau (SNC Lavalin)** agreed.
- **Guillaume Comeau (SNC Lavalin)** suggested that moving point F and keeping the same boundary conditions could achieve the same flow that **Marc Hinton (NRCan)** was aiming to reproduce and is shown in the regional groundwater model.
- **Marc Hinton (NRCan)** said that if you move E towards the contour, then the contour goes from E to G and is an equipotential, and you will get roughly the same direction of flow as in the Golder model.
- **Guillaume Comeau (SNC Lavalin)** stated that this is what they want.
- **Marc Hinton (NRCan)** said he is good with that.
- **Donald Chorley (Golder)** said let's do that then.
- **Jamie Quesnel (AEM)** asked for confirmation that it would be kept as 132.9, if E to G is 132.9, and E is moved closer to F, closer to the contour.
- **Marc Hinton (NRCan)** said yes.
- **Jamie Quesnel (AEM)** did a recap: agreement that from A-E is all no flow, agreement that E to G is 132.9 with E moving closer to the contour between E and F, then between H and K they would use the NRCan recommendations.
- **Marc Hinton (NRCan)** interjected to ask if they did not want to use the 132.7 at F, or if that matters to them.
- **Jamie Quesnel (AEM)** restated that they were thinking 132.9 right from E to G.
- **Donald Chorley (Golder)** said with the new location of E, it didn't really matter.
- **Marc Hinton (NRCan)** hesitated but agreed, saying it is not a big difference.
- **Jamie Quesnel (AEM)** continued with his recap: H to K they would use the NRCan recommendations, with the additional 0.6. This will be the Version 4 iteration when combined with the new thermal modelling.
- **Jamie Quesnel (AEM)** asked for agreement around the table and received it from everyone.

Diffusion discussion

- **Marc Hinton (NRCan)** asked if they wanted to move on to the diffusion issue and all agreed.
- **Michel Groleau (AEM)** asked **Guillaume Comeau (SNC Lavalin)** and **Emmanuelle Millet (SNC Lavalin)** to present their work on this issue.
- **Guillaume Comeau (SNC Lavalin)** said that in the Version 3 simulations there is still no upward flow to the overlying pit lake. However, they still did a calculation based on **Marc Hinton (NRCan)**'s recommendation using the formula on Slide 33 to get a sense of how many mg per day per m^2 they would have in the event that there was upward flow. They used the highest concentration of 141 mg Cl/L and they applied this to a thickness of 1m, just to have a sense of what the diffusion rate would be.
- **Guillaume Comeau (SNC Lavalin)** showed that the resulting diffusion rate on Slide 33 is quite low.
- **Donald Chorley (Golder)** said that they would have to see after they model the degradation of the permafrost whether they do actually have an upward flow.
- **Guillaume Comeau (SNC Lavalin)** added that in that case they would have to add the diffusion rate to the advective transport.
- **Marc Hinton (NRCan)** said that this result is for chloride, which serves as an indicator, and there are other contaminants of concern. He said that because of the close proximity of the tailings to the lake, even contaminants with high retardation could eventually make it into the lake.
- **Guillaume Comeau (SNC Lavalin)** said that this is only a risk over the short term after deposition and not over hundreds of years in his view, because the upper layer will get diluted by the diffusion.
- **Marc Hinton (NRCan)** said yes that's true, but there is advection that could drive it.
- **Donald Chorley (Golder)** agreed that any advection would overwhelm it while **Guillaume Comeau (SNC Lavalin)** added that they would watch for advection in the model.
- **Marc Hinton (NRCan)** said that he agreed that the chloride values are pretty low and that chloride is being used as a tracer for knowing what the plume path is, while other contaminants are of greater concern.
- **Marc Hinton (NRCan)** reiterated that even where there is retardation, it has to be ensured that those other contaminants are not entering the lake.

Groundwater Monitoring Plan

- **Michel Groleau (AEM)** introduced the two next slides as being about the groundwater monitoring plan and groundwater monitoring well system. Slide 34 displayed part of the text from NRCan comment #9 along with a sample table below it.
- **Michel Groleau (AEM)** read the last sentence printed on the slide aloud and then described the table that could be added to the Groundwater Monitoring Plan. He said that the plan is to wait for the results of the Version 4 model to see if there are any new requirements for monitoring wells, and then assess the Groundwater Monitoring Plan. He said there are two phases to the GWMP, one for the operational phase, where wells would be closer to the pits, and one for closure. However, closure phase of the GWMP will be refined prior to closure. As per their water licence requirement, they need to put together a final monitoring plan for closure and the models will be recalibrated based on data collected during operations.
- **Michel Groleau (AEM)** offered that they would commit to the table for operational needs, and then re-update the table for their final monitoring and management plan.
- **Jamie Quesnel (AEM)** added that they do not yet have their water licence for closure, so while they know all of their requirements for operations, such as the MMERs, they do not know all the requirements for closure, but they will be given the requirements at closure. Meadowbank has

numerous management plans, approximately 27, so this would be covered in that monitoring plan. After Version 4, they would agree on locations and no additional wells and they will finalize that in the management plan. In the regulatory phase right now, AEM has management plans with the NWB as per their submission, the NIRB reconsideration resulted in no changes to their project certificate, so with the water board, in February of 2018 they submitted management plans with their application. Assuming they get their approval from NWB, 60 days after that the management plans would have to be updated.

- **Peter Unger (NRCan)** interjected to ask if **Michelle Blade (CIRNAC)** had questions and then described the table displayed.
- **Michelle Blade (CIRNAC)** wanted to know about the timing. She was familiar with a Groundwater Monitoring Plan version 8, dated January 2018, which had three groundwater sampling points from 2017, with one additional well planned for 2018.
- **Michelle Blade (CIRNAC)** asked if additional monitoring wells would be placed before tailings deposition began in the pits, and what the plan was for the timing of their installation and the beginning of sampling.
- **Michel Groleau (AEM)** responded that the installation of the groundwater wells in 2017 was to collect baseline data, which they did, collecting water from those wells in the summer and that the objective of these wells was achieved. If any new wells are installed, it will be to monitor change in the groundwater system and will be compared to the baseline data just gathered. If any new wells are required based on the updated Version 4 hydrogeological model, they will establish a plan and a schedule to ensure that there are favourable meteorological conditions to establish a groundwater well. However, so far, what they have as a groundwater monitoring system is quite aligned with most of the modelling results they are seeing for operational purposes. The large plume towards the Portage Lakes is in 2000 years or more, so from an operational standpoint they have a system in place to begin deposition in the pits.
- **Michelle Blade (CIRNAC)** then asked about monitoring well IPD-04 (*SNC Lavalin indicated in comments on this summary that it was likely IPD-17-01 that was actually being referred to. CIRNAC clarified that it was MW-IPD-04 on Map 1 in Version 8 of the Groundwater Monitoring Plan*) that was proposed, and asked if it has been installed and to what depth.
- **Michelle Blade (CIRNAC)** added that it was downgradient of the Central Dump.
- **Jamie Quesnel (AEM)** asked **Michel Groleau (AEM)** to confirm that this has been installed.
- **Michel Groleau (AEM)** said that they did a permafrost study in 2017 to identify what is the best location of sampling points and the wells were installed in 2018. One sample has been collected in early summer, and a second would have been collected near the end of August or early September, he would have to confirm with operations.
- **Donald Chorley (Golder)** asked if these are just during operations.
- **Jamie Quesnel (AEM)** said yes, and told **Michelle Blade (CIRNAC)** that she should also remember that the pits are like a sink and the flow is from the lakes to the pits. This discussion is only about post-closure events.
- **Donald Chorley (Golder)** posited that the monitoring wells for closure would probably be at different locations based on the monitoring and observations made during operations.
- **Jamie Quesnel (AEM)** added that the Water Quality Forecast is required every two years according to the water license, but that they often do it every year and that it is intuitive. He said it is updated with the Annual Report and that they are always validating the model and fine-tuning it.
- **Guillaume Comeau (SNC Lavalin)** added that there is already a monitoring well in between Portage and Goose Pits that will be very useful in the recalibration of the model during operations, and that AEM is putting actions into place to put together a strong and robust monitoring well system during closure and post-closure.

- **Michelle Blade (CIRNAC)** asked if federal departments wanted additional monitoring wells installed prior to in-pit disposal, would they need to be captured in the monitoring plan within 60 days of the approved modification by the NWB.
- **Jamie Quesnel (AEM)** responded that there are a couple things to consider. Firstly, they run the Version 4 to have a better understanding, propose conceptual locations, and get agreement on that early. If they have to change things, they will update the monitoring plan in those 60 days after they receive approval from the water board. The next meeting would be based on the Version 4, based on the boundary conditions and the thermal bit and AEM will report back to NRCan and CIRNAC, once they look at the details, and the modelling should be done in two weeks or four weeks, and then schedule another meeting like this to update NRCan and CIRNAC. From that, they will have a fairly good understanding if any adjustments are required based on the monitoring plan. If they have alignment on that, then that can be part of the revised management plan, if required, if they get approval from the NWB, within that 60 day period.
- **Michel Groleau (AEM)** added that they will be able to define the modifications required for the groundwater monitoring plan before the next meeting.
- **Marc Hinton (NRCan)** asked if this is for the operational phase.
- **Michel Groleau (AEM)** and **Jamie Quesnel (AEM)** confirmed this.
- **Jamie Quesnel (AEM)** said that they just wanted to have alignment based on NRCan's comments. The primary focus is the Version 4 modelling with the new boundary conditions and the thermal modelling. This Version 4 would dictate if anything needs to be adjusted.
- **Michel Groleau (AEM)** asked if this makes sense and if there are any comments.
- **Marc Hinton (NRCan)** asked **Michelle Blade (CIRNAC)** if she is finished with her questions.
- **Michelle Blade (CIRNAC)** responded that at this point she does not have further questions.
- **Marc Hinton (NRCan)** said that he is not familiar with the NWB process, but the focus of his comments were the closure phase, and the operational phase was not a concern as water is flowing to the pits. The other part of his comments was that it is easy to set up observation points in FEFLOW, and that they could get their breakthrough curves there. This would tell them if they are on the primary flow path or not. The concern was that in his review of the reported depths of the new monitoring wells, they appeared to be deep, compared to plume depths, and the main concentration appeared to be shallower. However, this may have changed within the Version 3 model, or possibly will with Version 4. However, the point was to use the FEFLOW modelling results to make the predictions of concentration, because then they will know if it is sitting in the main plume or not, because the well is not helpful if it is sitting outside the main plume. A good sense of the well is desirable and they have the tools to place it as best as they can with the knowledge that they have.
- **Guillaume Comeau (SNC Lavalin)** said that they also need to capture what the model says, and that they have people in the field know their sites and that the model and current monitoring well placements were developed based on drilling.
- **Marc Hinton (NRCan)** agreed that wells should be placed in a permeable zone and not based completely on the model, but that it should still be ensured that the well is placed in a permeable zone, but still in the vicinity of the plume.
- **Guillaume Comeau (SNC Lavalin)** says that he got his point about the breakthrough curves.
- **Marc Hinton (NRCan)** said that this is a simple way to discover how appropriate the well locations may be. As the Version 4 model results are available, target areas could be set. Then if drilling at a particular location, they could run the model at different depths and have a target zone. Then when drilling they could find an area of permeability within the target zone and they have justified the well location.
- **Jamie Quesnel (AEM)** said they could do that as an iteration later. He thinks they should focus on the boundary conditions and thermal modelling, and this could be an iteration later to define the locations.

- **Michel Groleau (AEM)** added that he appreciates **Marc Hinton (NRCan)**'s comments and agrees with **Marc Hinton (NRCan)**'s approach, but that there are phases to the project and they need to be taken into consideration. The current wells are based on the permafrost depth so that the wells are able to collect water. He acknowledged that the project would be melting permafrost by mining the pits. The purpose of the current wells are to monitor activity close to the pit during operation, in the most permeable units they have on site. That was a success. They will monitor that and calibrate their model with that information. They do not currently know the quantity of tailings they will have at the end of closure. They are currently approved to dispose of 8.3 million tons of tailings in the pits for the Whale Tale project. Things might change, they might put 15 million. The model assumes 32 million tons of tailings. It's the maximum capacity scenario. At closure they will be somewhere between 8.3 and 32 million tons. At that point they will need to rerun the model and assess what will be the source and location of those plumes.
- **Jamie Quesnel (AEM)** clarified that **Marc Hinton (NRCan)** was saying let's use it as a tool, which they can, but that's going to be an iteration later. He just doesn't want to do it now, because they should focus on the boundary conditions and the thermal modelling.
- **Marc Hinton (NRCan)** added that it's a process and that their point is well taken on the progression of the thaw as well. He brought up these comments earlier in the IRs because he was looking at the wells and wondering what would be left when they flood and how would they monitor it afterwards. He made the comment so that it is discussed and considered because the locations become limited once they are flooded, possibly to the dyke or in proximity to the dykes for monitoring well locations.
- **Jamie Quesnel (AEM)** said they could build finger dykes up to the monitoring wells to access them, and would do so if an existing well was a good monitoring well.
- **Marc Hinton (NRCan)** added that one other aspect of the comments was that if you are going to have a monitoring well for the post-closure period there is value in holding back on putting in up to a certain point, but not necessarily all the way until closure. It would be desirable to get some background conditions in being able to monitor that well, and even the head changes in the well to help validate the models for when they go into post-closure. Maybe not this year, but down the line they will want to have those wells with enough advance notice that they can actually use the data from those and have the background data before they flood the pits and change the conditions in the vicinity of those wells, so that when you do flood you are seeing the effects of the flooding.
- **Jamie Quesnel (AEM)** said, exactly.
- **Marc Hinton (NRCan)** said I think we're all on the same page here.
- **Jamie Quesnel (AEM)** said it's just a timing issue.
- **Marc Hinton (NRCan)** then said he considered adding other parameters to the table, but that this was the bare bones table trying to make sure that they look at each well and assess whether it is well placed according to the model. That was the underlying purpose of that recommendation, to make sure that each well's location is kind of justified.
- **Michel Groleau (AEM)** suggested that the way to answer that recommendation or technical comment would be to agree to update the table for the operational monitoring plan, including the operational monitoring wells, and then AEM would re-evaluate the table for the final closure plan. This plan needs to be submitted one year prior to initiating closure and flooding. The regulatory process with the Nunavut Water Board is well designed for those purposes because they need to be prepared and package all the information one year in advance.
- **Marc Hinton (NRCan)** said that the table is not going to be much use for the operational phase, but having it there as the structure that is built on for the closure phase will make it useful to include.
- **Donald Chorley (Golder)** said that he thinks for monitoring plans a method is provided, and maybe this is the methodology.

- **Jamie Quesnel (AEM)** said that yes, this is what he said earlier, they will use this methodology, but it's just the timing. They will clarify the timing with the water board.
- **Donald Chorley (Golder)** agreed.
- **Aruna Dixit, NRCan** asked if there were any other comments related to monitoring.
- **Marc Hinton (NRCan)** said he did not believe there were.
- **Jamie Quesnel (AEM)** said that comment 12 is next and then they will go back to number 10. Slide 35 is displayed. Comment 12 is on the timetable for updating the GWMP and the content of the GWMP.
- **Marc Hinton (NRCan)** said that he can't remember the exact reference, but he believes that in reference to a query from CIRNAC about when the monitoring plan would be updated that was responded with a specific model condition that **Marc Hinton (NRCan)** said could possibly never occur. He was concerned that by tying certain things together, then if one doesn't happen, the other doesn't happen either. He was concerned that the update just might not happen, and this is why he suggested a timetable.
- **Marc Hinton (NRCan)** said it was recommendation, but he is not familiar with the NWB process, so they can take or leave the recommendation as they see fit.
- **Jamie Quesnel (AEM)** said that the last point with three bullets on the slide is basically the process with the water board. First of all, they will complete the Version 4, as discussed and as per the water licence requirements. They will also update it one year in advance of final closure in the final closure plan. They also have to submit interim closure plans every two years. However, one year out from final closure they have to submit final plans and enter into discussions with the water board, the Kivalliq Inuit Association, CIRNAC and other intervenors based on closure. They have a closure plan but it's adjusted every two years based on progressive reclamation and if they have added new assets.
- **Marc Hinton (NRCan)** said it is a moving target.
- **Jamie Quesnel (AEM)** agreed.
- **Marc Hinton (NRCan)** called it adaptive management at its best.
- **Marc Hinton (NRCan)** said that he doesn't think there is any real disagreement on this subject. They have a process and they are feeding into it, NRCan just wants to make sure that the wells are located in useful places.
- **Jamie Quesnel (AEM)** said yes, they are very costly.
- **Michelle Blade (CIRNAC)** said that they do want the wells placed correctly, but that the timing should be there too. Right now there is an operational groundwater management plan, and groundwater well placement as part of the closure plan that is provided at a later date. However, if they want some of those wells put in prior to closure a way to capture them would be in the current groundwater monitoring plan, with the caveat that they would be put in one year or two years prior to a closure plan being provided. This would be a way to get them in there prior to the closure plan.
- **Jamie Quesnel (AEM)** said that yes, they could set up that timeline and may put things in earlier than that based on the availability of drills. They would look at one year or two years prior so they can put that type of language in the plan. A lot of times there are drills there being put to different uses and they can tack on different programs to minimize the costs for installation. They would have to keep that flexibility but the sunset clause for installation would be about a one to two year window.
- **Michel Groleau (AEM)** added that there will be some work that will have to be done after pit flooding. It will not be all done before the beginning of closure. The process will take many years. It's not a one year window, so they will need to wait for the stabilization of certain thermistors and to know where the monitoring wells should go, so they understand the requirements for strong baseline data. He believes that the monitoring they have in place now will meet that target, but it's a bit early for him to comment on the sequencing of the installation of the closure groundwater monitoring wells because they do not have the information that they will gain through operations.

- **Jamie Quesnel (AEM)** said that yes, but that he thinks we can agree that it will be in that window prior to closure. They are re-evaluating everything on an annual basis, so if it has to move than they can adjust. He thinks they will have a general understanding of where some of the wells are going to be. They just have to ensure that they have that alignment.
- **Marc Hinton (NRCan)** said that you just want to make sure that if you have logistical and operational difficulties in drilling wells, such as weather and availability of drills, that you build in enough of a buffer to compensate for a bad year.
- **Jamie Quesnel (AEM)** asked if that was sufficient for **Michelle Blade (CIRNAC)**.
- **Michelle Blade (CIRNAC)** responded that a discussion to have another time is the current groundwater monitoring plan for Meadowbank dates back to 2015, and while a new groundwater monitoring plan is put forth in front of the Nunavut Water Board, if there are things that they want to capture in the future, including them now would be most efficient. This was her closing thought.
- **Jamie Quesnel (AEM)** said that they agree. They are always for optimization and efficiency. I guess we'll have to go back to number 10.
- **Marc Hinton (NRCan)** said that he doesn't think this has to be a big issue.
- **Jamie Quesnel (AEM)** said that he just wants address it.
- **Donald Chorley (Golder)** said that he is hoping there will be new technology by the actual date. Cheaper technology.

<u>Seepage from the Central Dyke</u>

- **Marc Hinton (NRCan)** said that number 10 is the high permeability issue that stems from the high flow underneath the Central Dike. This is something that wasn't anticipated and arose operationally.
- **Marc Hinton (NRCan)** has not been through all of the technical documents. He knows that studies were done on the dyke, and the pathways, and some geophysics. He has not looked through the technical stuff, but it would be useful to understand the hydraulic connection between the pond and the tailings coming through under the dyke.
- **Marc Hinton (NRCan)** is concerned with the fault zone going through there and going of into 2nd Portage Lake, as it could have implications for contaminants getting into 2nd Portage Lake through that fault zone. The recommendation was to address the possibility of a high permeability zone happening to be where a plume is. This is why he mentioned this as part of a sensitivity analysis to see what difference increasing permeability makes. It's not to say that this is the prediction, but just to get a sense of what is the worst case scenario.
- **Marc Hinton (NRCan)** said that AEM's response was to say that is very localized.
- **Marc Hinton (NRCan)** said that he knows it is not across the whole area, but the idea is to have an appreciation of what might happen if you had a higher permeability zone somewhere else, and maybe he could be told where that higher permeability zone came out from the technical studies.
- **Michel Groleau (AEM)** said that it was a channel observed in the upper bedrock. The geophysics study they did identified two seepage pathways. They then placed more than 50 monitoring holes in the dyke to identify those specific zones. The seepage model computed a 50m wide seepage path.
- **Marc Hinton (NRCan)** asked to clarify what they meant by a channel in the bedrock, did they mean a quaternary channel excavated through the bedrock or a channel as in a sedimentary channel.
- **Michel Groleau (AEM)** said he would like to reword that and that what has been identified have been two seepage pathways.
- **Marc Hinton (NRCan)** said that this is not necessarily a geological feature.
- **Michel Groleau (AEM)** agreed.
- **Marc Hinton (NRCan)** said that it is just a zone of higher flow.

- **Michel Groleau (AEM)** agreed.
- **Marc Hinton (NRCan)** asked to confirm that it is in the bedrock.
- **Michel Groleau (AEM)** said that they did a full investigation and they drilled through the seepage pathway identified by the geophysical studies and found sand within the bedrock at those locations. Therefore, there was a geological seepage pathway that must have formed and that the sand was very white, possibly aligning with the quartzite in the pit. It is very well identified now within the dyke footprint. They excavated the pits and were able to see if there were some recurrence of these features within the pits. This now mapped.
- **Marc Hinton (NRCan)** asked if these features were found in the pits.
- **Michel Groleau (AEM)** said no. These permeable areas were mined out. It was aligned with that junction of the bay fault and the 2nd Portage fault.
- **Marc Hinton (NRCan)** asked them to confirm that it wasn't related to the fault and was a geological structure within the bedrock.
- **Donald Chorley (Golder)** asked if this wasn't a contact and that he believed that at one time there was a contact.
- **Michel Groleau (AEM)** said that this was their initial thought back in 2015, but that very many studies were done as well as three calibrations of the seepage model. At first they were just trying to change the hydraulic conductivity of the upper bedrock unit but they were not able to match up the flow. Then they increased the hydraulic conductivity of a 50m wide seepage path at 10^{-3} and that worked. They were able to monitor seepage rate and water volumes, and did a water balance just on that seepage system, calibrated and they were able to follow the seepage prediction quite well, and it is based on the elevation of the water within the south cell.
- **Donald Chorley (Golder)** said that the key thing here is that within the pits they can see visually if there are any higher permeability zones and they can map them. So they don't have to drill as many holes.
- **Marc Hinton (NRCan)** said that this is what he gathered from the response, that it was basically observations of what is happening on pit faces, which is why he did not include a detailed review comment response or recommendations, as this is a minor point.
- **Marc Hinton (NRCan)**'s additional comment is that a lot of these areas are frozen permafrost, and when they thaw, if there is a high permeability zone that thaws, they could encounter something like that. However, **Marc Hinton (NRCan)** assumes that they will probably do a sensitivity analysis anyway, and so they can choose what to include in this analysis and localized flow can affect it. When a value is that high compared to everything around it, it becomes the local sink. Even if another high permeability zone is encountered not on the main flow path, it might become the sink. This is why he insisted on adding the fill to Goose Pit, because if that fill becomes the high permeability pathway then things will congregate there. That was the rationale behind those comments.
- **Marc Hinton (NRCan)** doesn't think that there is a problem there, but now they understand his logic, which doesn't come through in the comments. This is not as important an issue as the permafrost or boundary conditions.
- **Jamie Quesnel (AEM)** asked if for the water board, as this comment was submitted to the water board and other, could we say that it is resolved?
- **Marc Hinton (NRCan)** agreed that we could.
- **Jamie Quesnel (AEM)** said they could look at the sensitivities, as they are always doing that for planning purposes too, and it's a good point.
- **Michel Groleau (AEM)** said to finish his story about the Central Dyke seepage, what solved the issue was that they placed tailings on the upper bedrock and they sealed the seepage pathway with tailings. **Donald Chorley (Golder)** said they put a beach in.
- **Michel Groleau (AEM)** confirmed.

- **Marc Hinton (NRCan)** said that it froze.
- **Michel Groleau (AEM)** said no, it is just that the hydraulic conductivity of the tailings is lower than the fractured bedrock so the tailings are sealing up the seepage path.
- **Marc Hinton (NRCan)** said that they are seeing lower seepage out of the dyke with the addition of the tailings.
- **Michel Groleau (AEM)** said yes, with the beach extension.
- **Michel Groleau (AEM)** said that if you put that in the context of the tailings in the pits, the geological features encountered will be sealed by the tailings they will place in the pits.
- **Jamie Quesnel (AEM)** said that's a good point.
- **Michel Groleau (AEM)** said that's a good news story to finish up the meeting.
- **Jamie Quesnel (AEM)** asked if that is everything and just wanted to go through the agenda to make sure that they addressed everything, as the presentation was built slightly differently from the agenda.
- **Marc Hinton (NRCan)** confirmed that yes, they had.
- **Jamie Quesnel (AEM)** said that the next step now that there is alignment on the boundary conditions, they agree on the thermal modelling, they will do a Version 4 iteration and then they will communicate back on the timing and also on when they can set up another discussion so they can present what they found in Version 4 and then that could be then reported to the water board, and hopefully this will be the last iteration of the model. That's how they see it.
- **Marc Hinton (NRCan)** added "For now."
- **Jamie Quesnel (AEM)** agreed that just for the water board portion.
- **Marc Hinton (NRCan)** then asked why don't they fill the pits right to surface without a water cap so that they aggrade permafrost right to the bottom and they would get greater capacity.
- **Marc Hinton (NRCan)** asked if this is something they have to do for DFO requirements. This is what they did for the existing two tailings sites. They build them up, they let them freeze and this way they won't be degrading the permafrost, they would be building it up.
- **Michel Groleau (AEM)** said that this is an issue for dyke integrity. The Goose dyke around those pits is a 2.2 km dyke and is not a structure that was designed for long term holding back of the tailings.
- **Marc Hinton (NRCan)** said that especially Portage Pit A, if it was built up to ground surface then it would be frozen and they would not have to worry about contaminant fluxes from the tailings into the lake.
- **Jamie Quesnel (AEM)** asked if this was a recommendation and if he could be included in discussions with DFO.
- **Marc Hinton (NRCan)** said he acknowledges that there are DFO requirements, but he considers it a lot of effort if this is indeed just for a DFO requirement, when these problems could be avoided.
- **Marc Hinton (NRCan)** asked if they could not compensate somewhere else.
- **Jamie Quesnel (AEM)** said that it's a good point, but that it's a balance. They have a lot of stakeholders so they have to find a balance. They are evaluating closure as they progress and are having discussions on these subjects. Right now with offsetting, they have 26 million in letters of credit with DFO on offsetting so it is a major discussion. In comparison, they have 5 million with Whale Tail. It is an ongoing discussion that will take some time, as it is related to the fish habitat. The policy change at DFO means they get very low value at depth in the three pits at Meadowbank. For Whale Tail they get no value, so there are differences. They have to get alignment for which way they are going to go for the north. The other thing is that for reflood DFO doesn't have a reference lake, not like other jurisdictions where they can refer to something. So there is a lot of research, called complementary measures, done off site. So it is not on-site offsetting, it is off-site offsetting. It is called complementary measures and they are getting some latitude from DFO to look at those things. They are looking at ways with the Kivalliq Inuit Association and others to have a reference lake and make this successful with these pit lakes at the end. It's all part of a bigger strategy.

- **Marc Hinton (NRCan)** said that he realizes this but he was just thinking that so many issues could be avoided this way, but surely new issues would arise as a result.
- **Jamie Quesnel (AEM)** said that yes, it is a trade-off. Just with the in-pit, they are using already impacted areas and that this makes sense according to their guiding principles for sustainable mining. Through a proper evaluation, even at closure, with the existing closure plan they had at Meadowbank, they are transferring fresh water to flood the pits. As he mentioned earlier, with the full capacity of 32 million tons, they are reducing that fresh water transfer by 60 percent. Another good news story. They are using existing impacted area, they are reducing their fresh water transfer, and then to take it to the next level they have to evaluate their closure and have those discussions.
- **Marc Hinton (NRCan)** asked if when they flood with 3rd portage lake do they not trigger Schedule 2 of MMER?
- **Jamie Quesnel (AEM)** said no.
- **Marc Hinton (NRCan)** said because they are not depositing into a lake they are actually flooding a lake into a deposit.
- **Jamie Quesnel (AEM)** said that he believes that it is section 5.2a of MMER and section 36, as it is in an anthropogenic zone. So they have a Schedule 2 for the 2nd Portage Lake.
- **Jamie Quesnel (AEM)** said there are no fish in the pits.
- **Marc Hinton (NRCan)** said, well not initially, but eventually when it is flooded.
- **Jamie Quesnel (AEM)** said that the wording for Schedule 2 is "fish are present" not "fish will be present."
- **Marc Hinton (NRCan)** said ok.
- **Peter Unger (NRCan)** Unger said that he would get the audio recordings of the meeting to AEM the same day.
- **Jamie Quesnel (AEM)** asked if we are done, and everyone agreed.
- **Peter Unger (NRCan)** Unger committed to typing up a summary and providing it the same week, and also to send a copy of the presentation and the audio files to **Michelle Blade (CIRNAC)**.
- **Marc Hinton (NRCan)** asked AEM to confirm that they would not produce a report for Version 3, that they would just go and do Version 4 and then report on that.
- **Michel Groleau (AEM)** confirmed and said that the results from Version 3 are what were presented in the presentation.
- **Jamie Quesnel (AEM)** asked if the meeting minutes would be provided to the water board as well.
- **Peter Unger (NRCan)** confirmed that he would.
- **Jamie Quesnel (AEM)** asked if the summary would be circulated for comment first.
- **Peter Unger (NRCan)** agreed that it would.

END RECORDING 2