NORTH PILE (GEOTECHNICAL) BREAKOUT SESSION
DECEMBER 03, 2002 (DAY 7, EVENING)
DE BEERS BOARDROOM, 3RD FLOOR SCOTIA CENTRE

Attendees: Greg Oryall (AMEC/DBCMI – Chairperson), John Brodie (for DIAND), Chris Burn (for DIAND), Peri Mehling (for DIAND), Mark Watson (EBA for GLL/MVEIRB), Don Hayley (EBA/DBCMI), Terry Eldridge (Golder/DBCMI), Ken DeVos (Golder/DBCMI), Colleen English (DBCMI – Note Recorder)

Issues: 1. Cryo-concentration
2. a) Collection system may be bypassed
   b) Will the ditch leak too much?
3. More water in the system
4. Freezing sooner than expected
   SO WHAT??
   - Impacts to North Arm of Snap Lake
5. Climate change

Greg Oryall, AMEC/DBCMI: if resolve the collection system issue, will all concerns then not be addressed?
Chris Burn, DIAND: If water goes into ditch in winter, what happens then? If the model suggests that the pile is unfrozen and the ground under the pile has up to an 8 meter (m) thaw zone, then I'd guess there is seepage on a long-term basis from the pile throughout the year. During summer, it goes to the ditch, but when it travels at other times of the year – what does it do? Does it go to ditches? Will it flow or freeze in ditches?
Terry Eldridge, Golder/DBCMI: Some ice will build in the ditches, and they will be graded to go to ponds or sumps, all with storage capacity. We expect to have some unfrozen water here over the course of the winter.
Chris: Design is for 90% collection in ditch, correct?
Terry: Right. We have not tried to make a perfect cut off. We have not broken the connection and have then tried to assess the impact of this to Snap Lake.
Chris: 90% is a nice target, but there is no way that will happen.
John Brodie, DIAND: I would expect 90% in a non-permafrost environment, but up here there may be open fractures, so this would not be. Volumes would pour out of the ditch at numerous locations. Ken says it does not matter how/where it goes in to the lake.
Terry: difference is the water is going to the north arm rather than to the diffuser (shown on map). Is there anything that can be done in the model that would convince you of a greater ditch efficiency?
Chris: No, the model is not about ditch efficiency.
Terry: The effects on the ditch are seasonal - freeze and thaw. The active layer progresses down. Water hits the barrier at some time of year and unless it is heated, it backs up when it hits the ditch.
Chris: This is also dependent on the thermal model.
Terry: Does recalculation help?
Chris: That is the water of the first materials deposited into the North Pile. The water in the ponds in the North Pile is not seriously enriched in dissolved material. This would be

close to meteoric water with lots of precipitation, snowmelt and supernatant water in these ponds. I don't think that there would be a big depression in freezing point in that water. The question is what happens to the porewater inside the North Pile.
Terry: 0.01°C is the depression in the freezing point of the process water. It starts off freezing very close to 0°C and concentrates from there. Ekati pk behaves as a silty material and at -0.5°C is fully frozen so there is not a huge freezing depression in the kimberlite.
Chris: I don't know Ekati ground temperatures, but it should be noted that there is a huge section of the Snap Lake pile that would be warmer than -0.5°C.
Terry: I agree, so it is frozen and unfrozen in the middle of the pile and the issue is how these are connected.
John: Water will come out when you try to freeze it anyway.
Terry: Eventually, yes, up and down.
Chris: At the moment, the model does not give a clear sense of where these are or if there is a systematic distribution of frozen and unfrozen zones.
Terry: It is not meant to do that.
Ken DeVos, Golder/DBCMI: If the collection system will be bypassed versus if the ditch is leaking are very different issues. If bypassed, it is limited by the hydraulic conductivity of the kimberlite on how much water enters the fractures. When you look at the hydraulic gradient, it is lowered by two orders of magnitude as you move 100 m into the pile. So, should we bypass the seepage collection system, other factors play into how much water can bypass the system.
John: Any water coming out the bottom of the pile will find fractures in the bedrock and flow as open water, not as groundwater in the conventional sense.
Greg: The fractures are likely not highly interconnected. The path of least resistance is right along the rock and North Pile interface.
Peri Mehling, DIAND: How deep can you go before you reach reasonable rock?
Terry: The permeability of that rock is $1x10^{-5}$m/s.
John: If hypothesize that you build the starter cell and begin operations and you see where/how the water is migrating, could you then go back and deepen the ditches if you had to?
Terry: Yes.
Mark Watson, GLL/MVEIRB: The ditches in some areas are up to 5m deep anyway, are they not?
Terry: Some, yes. The peaty area is within the North Pile footprint itself. Past the toe is better. There is one circle of bog in a low area.
Peri: I thought I heard today that boulders located under the pile will be stripped?
Terry: In the toe area, yes, but not under the pile itself.
Greg: Is the ditch below the strip level of the toe?
Terry: Yes.
Greg: Again, it seems the interface between the rock base and the pile would be an easier path than following fractures with a $1x10^{-5}$ permeability.
Terry: No matter what computer work we do, we would still put in a seepage collection system because we know there will be some water running at or near the surface. How do we enhance that system to get more certainty if its impact is deemed to be significant in the north arm?

John: If there is no adverse impact, then in theory, you do not need ditches and could let the water go.
Greg: In effect, that is the case for Snap Lake overall. None of the dissolved solids are removed in the water treatment plant (WTP).
Terry: There is enough suspended solids in the runoff that we don't want to dump it in to the lake, so we collect it.
Greg: This also adds a measure of control to the discharge point as well. If all the water flows out into the north arm, will it have an impact on that portion of Snap Lake?
John: If you were to have a surface load release and see a cloudy plume in the north arm, then obviously there is some issue.
Terry: (diagram on board) There are some potential contingencies: enhance the liner, take the ditch down deeper or add fill before the ditch. Or we can add fill to the other side of the ditch – either way, the purpose would be to break the hydraulic connection. Backing this up into the pile itself is the more attractive option, especially during times of heavy snow. Would we keep these contingency items in hand to modify the design based on the 2 years of performance in the starter cell, or move these into the east cell right away?
Chris: I would think that in the starter cell, you may or may not see the anticipated drainage of porewater. The starter cell is in 3 m layers?
Terry: No. We would cycle around it over the course of 2 years. It will be in wedges of various thickness.
Chris: One source of porewater to the bottom of the North Pile is associated with aggrading of permafrost into that material. As this happens, water turns to ice, expands 9% and has to go somewhere. That is what is pushed out. That is the principal contribution to flow. We see this in permafrost aggradation in the western arctic. The rate and speed of porewater expulsion is not high in the long term, so we may not see a substantial amount of this after only 2 years. Expansion can be accommodated by deforming the surface. After that, only water is pushed away. The timescale may be a problem. That is partly why I'm driving at trying to understand what is happening in the North Pile – whether there is a good quantity of water, or if it is not a big deal.
Greg: If the weight of the pile is too great and water is pushed out during freezing, it would still travel along the interface.
Chris: Would you use the starter cell as an experiment, or build the east cell with boulders to raise the permafrost underneath? You may not know if you need the boulders. If you use the starter cell as an experiment, the design of the east and west cells is predicated on the starter, so if all effects occur within the start-up time, you're fine. If it does not happen that quickly (thermal modeling could help with this prediction) you could say do or do not need the contingency.
Greg: How does the freezing rate affect the efficiency or inefficiency of the collection system?
Mark: The rate of freezing influences how much water goes into the ice lenses.
Greg: All this is occurring above ground. What would cause water to go down into the ground and take the hard path out?
Mark: The containment berm might cause preferential freezing and force the freezing front down at the toe.
Don Hayley, EBA/DBCMI: How would that happen? That would drive permafrost deeper.

Mark: Without the benefit of boulders.
Terry: If we move the east cell to provide the distance required, will that cause a loss of capacity? Likely not. Providing space for the boulders is a relatively cheap and easy contingency measure for this issue. If the area is not needed later in the mine life, we can take it back with processed kimberlite (pk). That seems the simplest path forward in terms of field work.
John: Basically, you would move a strip off the toe of the pile.
Don: How wide would the berm be? Have to consider haul trucks.
Terry: 10-15 m.
Chris: So you would basically ring the piles with a low frozen core dam.
Terry: No, we are proposing to leave space to do so if required. We have unlimited granite supply so material is not an issue, we just need to provide the room.
Greg: How wide? (10m)
Chris: If you did do that, would that then be used as haul road?
Terry: No, there is nothing to haul.
Don: The minimum of 10m is needed in order for the truck to place the material.
Terry: This material would be out of a quarry.
Don: The boulder pile would have to be at least 5 m thick for air flow. We are seeing temperatures down to –20°C at Ekati. It is amazing what the convective effects are doing.
Chris: This will raise the permafrost table if you do this, no doubt.
Terry: Correct, but that effect would continue forever though.
Ken: Keeping this in mind as a contingency, lets look at chemical analysis. We would be looking at loadings and if the materials would take a long time to start producing chemicals. I would expect the load amount to be quite small during any given year. It would be interesting to do mass balance on the expected load based on the amount of water infiltrating the system and going into the ditch – I expect this would be quite small.
Chris: I had asked for that this afternoon.
Ken: Have to look at how assigning mass in that pile. We don't look at cryoconcentration per say when assigning mass, and it is not assigned to a specific body of water. We would flow pure water through the system and assign the mass at specific zones. We don't look at cryoconcentration, just the mass release and do a mass balance. We can look at that in more detail.
Chris: Can you get thermal modeling done in a kind of fashion where the model represents field conditions? In some ways, this would predict better than what is indicated at the moment. One of the products of that is the assessment of freezing rate in the North Pile, and over time we could see the frost level and therefore the cryoconcentration.
Peri: This is additive. You would have to add on from the unfrozen mass below the assumed 2 m active layer.
Ken: Yes, we use a 2 m strip at the top of the pile and the rest of the mass added is from kinetic testing. If we redo the thermal model, that would be ok. If we do not do this, there are other mechanisms that limit geochemical release. Temperature is a factor that adjusts the mass release rates. Freezing would not eliminate this, but would lower the released loads a great deal.

Chris: This afternoon you had said that there are areas of ice and frozen kimberlite, and volumes of unfrozen porewater in the pile, and that some of that was confined within the frozen layer. This is also part of the thermal modeling issue – that may be the case but we're not convinced that the model allows us to make that assumption.
Terry: If we were to rerun the model with the boundary conditions and materials properly set, would that be good?
Chris: This would give me the information I need, but not you.
Terry: It depends on when its done; during the EA versus during the detailed design phase.
Chris: It wouldn't be very difficult to determine the unfrozen water content for this material and place that in the code. It is specified in an apparent heat capacity. Don't know quite what is in the code.
Terry: I can print that out with the proper scales.
Chris: That would allow us to think about how similar this is to the material already known. One other issue is why the model does not produce frozen conditions within the pile. That is odd. Calibration of the model is part of the issue. Part of the modeling exercise is to figure out why the difference between the model and the undisturbed field conditions occurs. Put in as much of the local field data as possible.
Terry: Some of the field information is from 2002, but thermal modeling was done with 2001 data.
Ken: It is De Beers call whether to do this work.
Chris: That is up to De Beers. The worst case scenario is that they do nothing. Then, we get to the public hearing and we raise the issues and the Board, who are not technical people, think that we need to do modeling.
Greg: If no more modeling is done, is it still an issue and does it affect the impact predictions?
Chris: I am not convinced that we know the rate of freezing of the North Pile. We do not know how quickly water could be ejected outwards. Then, how effective is the ditch collection system, and then how much of the water ends up in Snap Lake. I don't know the water quality issues in the lake. You may be able to say 'it doesn't matter' and convince the Board of that.
Don: It all comes back to the anticipated discharge rates in the model and....
Ken: Is the mass load currently conservative enough, or not? We have certain factors built in and others you have pointed out that are not built in.
Don: Are there monitoring systems that allow us to sample in the active layer before discharge to lake to ensure that we are meeting discharge criteria?
Ken: If that is the case, it would be better if we stuck with option A. If we need discharge data in the active layer, there is no way to monitor this effectively.
Don: Given what was determined for Ekati, I don't see any other way. Why would they impose different criteria on you than BHP?
Peri: It is an aquatics issue if you see that parameter concentrations at the shoreline are not acceptable. That is my impression from listening to the experts reviewing water quality impacts.
John: I'm looking at the four points raised in the beginning of the session, and I am not wavering on if you have done a good job, but I am getting comfort on the 'so what' part. If there could be impacts, I think that with the starter cell, if there is a good monitoring

and testing program, we will be able to better anticipate what the problems may be and implement design changes to the east cell to counteract these. I am not convinced that you know the answer, but there is enough opportunity to do something before it becomes a problem. This then becomes more of a regulatory issue.
Terry: That works if we have the room to do what is needed, ie: more room at the toe of the rock berm. Are there alternatives for slowing water flow?
Mark: Dig the ditches deeper; its not nice, but it will do.
Greg: What will the coarse rock berm do?
Chris: At the toe of the pile, two big snow banks will form; one in the ditch, one at the rocks. The rock pile will have a convective effect and will cool the ground. This is attractive as it indicates that permafrost will aggrade that way and reduce the chances of deep seepage. The closer this material seepage is retained to the pk pile, the better.
Don: That will build up ice into the core rock, but no flow will go through the original active layer, therefore it will then get caught in the ditch. I would expect that to freeze up over time and nothing would end up going to the ditch. At closure, it would be nice to fill in that ditch. With coarse rock like that, even at temps of –4°C or -5°C, water will still flow through as it doesn't act like a dam. But it will serve to freeze off the original active layer. We could turn this into a toe berm like Ekati, but I don't personally think you need that. This in combination with a ditch is a much better control mechanism.
Terry: This is a contingency to be carried through in the detailed design phase.
Chris: If you show aggradation of permafrost beneath the rock piles, you would be cutting off the environmental impact. This is likely as good a design as making a huge hole and installing a large liner.
Don: The University of Alaska is studying this in relation to building roads in areas of discontinuous permafrost. It has been quite successful. There is a paper on this in the Yellowknife permafrost conference from 1998. You have to ensure you have open voids in the rock size and eliminate fines. A uniform size of material gives maximum porosity. We could use development rock and screen it.
Greg: Could we practice that in the starter cell as a construction method?
Chris: By the end of the second winter, you could tell if these things are working at this scale.
Don: We'd be able to tell in the first winter. See if there is supercooling of the permafrost.
Terry: Could likely see in the first summer by noting the depth of the active layer.
Peri: So you would lose water in that first summer?
Terry: We could, yes, but this would be in the starter cell which is quite far back from the shore of Snap Lake.
Peri: I raise that because if you do lose water in that first year and you do not have pk under the internal ponds you could lose a lot of water to the lake, and lose a lot of credibility.
Greg: But we will still have the ditch.
Terry: The ditch will leak, the question is how much?
Ken: And what is the water quality?
Peri: You will lose some runoff. I also cannot see the ditch collecting 90% of the expected seepage. But if the permafrost is encouraged to come up, that will substantially

improve this value. But what will happen to the runoff? Will it come down and run through the coarse rock?
Chris: Will you put a coarse rock berm all the way around the pile, wherever there is a ditch?
Terry: No. I would only put it along the Snap Lake side. The area to the east has a collection system in place, the area to the west flows down to a ditch and pond, and in the area to the south, the ground slopes down underneath the pile with a long flow distance and no connections. The entire length of the rock berm would be about 1500 m or so. There is a pond on this side and I wouldn't want to put this berm between the pond and the North Pile. That would be about 75 000m^3 of material – not a lot. Expect it would be about 5 m thick.
Greg: Point number 3 – more water in the system – what is that?
John: This is more water, or porewater quality water, to the north arm of Snap Lake. This came up only as part of a sequence of the other issues. This is the most manageable. Some of those are operational factors – what I'd previously mentioned about being tempted to go to the wetter end of the paste range, but I don't think this is critical. If there is a contingency to keep the water from going to the lake, it doesn't matter if one or all four of the issues are not addressed at this time.
Chris: I have a concern if it freezes slower as you would end up with higher cryoconcentrations. A slower freezing rate means slower expulsion.
Peri: This would mean changes in Ken's assumptions.
Ken: Then is becomes more a question of balancing what we used in the model and seeing if the level of conservatism is still effective.
Terry: Temperatures in the active layer – year after year this will develop.
Peri: It is more to do with how much material is sitting there providing mass load effecting discharge quality.
Ken: If we scrap the idea of the whole pile being frozen, we have to seriously revisit the mass release functions. But this does not mean that we necessarily have to scrap everything.
Peri: It also does not necessarily change much either.
Terry: If we break the connection from the pile to the lake, all the issues go away.
Don: Can we say that the core is unfrozen until we get the hydraulic fractioning, and then the water would be squirting out.
Chris: I don't know as the rate of freezing is not known. Those kinds of pressures take 10 to15 yrs to develop and the required volumes would not be there until at least 10 yrs into the mine life. This would likely be a closure issue.
Terry: We would see what the east cell would do after 10 years of sitting, as it is complete 10 years before closure.
Ken: Once we are operating, we will have thermisters so we will know the rate of freezing.
Chris: No, you will be able to obtain temperatures, but you are not able to find out if the ground is frozen from thermisters alone.
Ken: But our monitoring plans in the operations phase will give us this information.
Chris: I want to determine the pressure in the porewater in the pile.
Terry: This is easy to do. Get total stress cells in there.
Ken: We can measure these.

Terry: We would want it in the unfrozen parts of pile.
Chris: This is why the model would be useful to identify roughly where to go.
John: Could put these out in the summer as you know it won't be frozen.
Don: But we would want it at depth, so would have to put it in after.
Terry: Could we maybe put them in while depositing the pk and bury them?
Don: They would never last. You would have to install them with a drill rig later.
Greg: Can a pressure release system be incorporated within the pile?
Chris: Some places have pipes with heating cables in them. If the pipe is thawed, the water comes up and is collected from the pipe. This was suggested for Diavik, but this is not the same issue. When stuff comes up to surface, if has a freezing point depression that is measurable; this is not the stuff that you want on the surface.
John: You had said that in the east cell, this process would be going on in wedges that are of irregularly configured material. Will freezing expel the water? Where the pond sits, you will have unfrozen material down to the original ground, and the biggest volume of water discharge would come from the pond area.
Terry: The ponds are emptied before the winter. The plan is for them to be relatively empty, except during periods of high flow. We want to get rid of the water, we don't want it on the pile. It will be pumped out and transported to the WTP.
John: So you will let the bleed water that comes out of the paste in winter freeze in place at the pond?
Terry: Yes.
John: If this is the case, then you may not get much water out of the pile at closure, if there is no excess water content to start with. If there is no surplus water, some material would already be frozen and the whole thing would grow by maybe a centimeter or two and then you are done. I find it difficult to see a significant amount of water coming out of this.
Terry: To maximize freezing of pk, you need to be placing the pk at a rate of 1 to 3 m per year. We are in that range.
Chris: In summer when the paste comes out, you said the slope is 6%, what is the elevation close to the spigot? (Answer from Terry: 5 to 6 m) So 1 to 3 m would be about half of each lift?
Terry: We would cycle over each place about twice a year; once in the summer, and once in the winter in the same place.
Chris: So the annual lift is effectively 3 m then?
Terry: Yes.
John: So, locally it would be thicker and thinner than that.
Terry: This is just the starter cell. We have focused our thinking on this, so that we know how to address steeper slopes for the winter. We typically wouldn't plan further than the starter cell.
Peri: Do you still have any paste material to play with?
Ken: Honestly, no, we have very little. It was material from the advanced exploration program (AEP).
Peri: I would like to see a freezing characterization test.
Greg: If this is a small lab test there may not be a problem with that.
Don: But you would really want materials with the same grain size.
Ken: We need to start looking at the time scale for addressing these issues.

Don: It would be beneficial to do a frost heave test as well, to ensure this material expels the water. We need to properly characterize it. It may be a frost susceptible material that attracts water. At Ekati, they are expulsion materials.
Chris: In one pore size distribution chart, the percent of fines, 0.125 mm is likely not frost susceptible, but 0.05 mm could be. Doing what Don suggested would be useful. With a predominately coarse material, I would be very surprised if it absorbed all the water, unless it was freezing very, very slowly. This goes back again to rate of freezing, which we don't know.
Ken: Is it fair to say there may be uncertainty related to the North Pile, but can we move ahead with contingency and programs in place to address these things?
Peri: There was concern raised about the high sulphide content of the metavolcanic backfill – it is my impression that there is not enough high sulphide material to worry about, even for strength issues.
Terry: Other mines with acid generating rock send it back underground to flood after closure.
Peri: This is counter to the way that this issue was raised, ie: as a potential to increase metal leaching.
Terry: If you go to Nova Scotia, there is cemented sulphide backfill and it works well. The cold slows down the reactions. There are lots of analogues for high sulphide content backfill working well.
Peri: You don't have high sulphide content materials anyway.
Ken: That's true, the highest values are only 7% - and that was only reached in 2 samples out of 100. The average was actually only 0.3%.
Greg: Some work was done on that and it was found to be a suitable aggregate material for underground concrete pillars from a strength point of view. Additionally, this material is only encountered in the first couple of years of mining, as that is when we are excavating the metavolcanics. We can put this back underground, or in the North Pile.
Chris: I had not seen the Golder report with the appendix of lab data until this morning.
Terry: On the backfill issue, I am not best to address this as I really haven't been involved.
Peri: In regards to the potentially acid-generating rock (PAG) stockpile – do you have a ballpark figure on the volumes anticipated?
Terry: 200 000 tonnes. That is the total of all the metavolcanics.
Greg: Appendix III.1 states 175 000 tonnes, including that extracted in the AEP.
Terry: That value represents all the metavolcanic rock, not all of which are PAG, but we made the decision early on to handle it all in the same manner, as if it was PAG.
Peri: Does anything need to be done about it? You already have PAG stored on surface from the AEP, so I think the issue can be easily addressed.
Ken: We are monitoring that now and the concentrations are very low. This is ongoing.
Peri: This is a new issue that should be addressed. For example, there is likely a need to identify where it is, how much there is, and what you would do to contain it. I mentioned it today so that it is out there.
Ken: Do we expect a temporary stockpile of that material?
Terry: It depends on the backfill schedule.
Greg: I think we have stated that we will put it in the North Pile until it is needed underground.

Peri: I don't think it really matters, as you already have a PAG pile on site.
Chris: We didn't discuss climate change today. What do you think is the issue that is bubbling there? The EA requires something on it. What you think is required? I am at a loss.
Greg: I think there are two things here: will it affect initial freezing, and then what happens later after pile has been established. Really, it is about whether it is a short term or a long term effect. Is climate change a 20 or 50 year business?
Chris: NRCan is saying that the air temperature regime that is driving the thermal model of the pile is warming day by day. I think this is NRCan's issue. I can't see how you can get away dealing with climate change without dealing with temperature.
Greg: It all relates to structural stability, with or without freezing.
Chris: So stability is the issue then?
Terry: If the climate warms a degree on average, the active layer gets a bit deeper.
Chris: I would expect the ground temperature in the area is –2°C or –3°C, so for that kind of feature, the temperature will be higher than that. What actually is long term evolution of the feature? That one degree might change this.
Terry: Yes, but that would take a very long time.
Chris: I'm personally just interested to know as it was not discussed today.
Mark: I see this as more of a reclamation issue that will come up tomorrow.
Ken: We do not allow for depletion of mass in the pile. We have also undergone 50-100 years of depletion in the upper layer, so we don't expect it to be an issue.
Don: These are long term closure issues, so you can add this to your model. We have to remember that with climate change there is a time lag between air and ground temperature differences, so it will be a very long time before we would see any significant effects. Some work has been done which states that different levels of analysis are required, depending on the predicted consequences of climate change.
Peri: I'd still like the opportunity to sit down and try some things out on the model.
Chris: I did not realize that the modeling was done for the purposes of operating the cell – I thought it was for designing the pile. EA perspective: how being designed, will it be safe…deals with concepts at a general level.

*Overall concensus that it was good to get the chance to sit down and talk face to face to work though some of the details around this work.

Summary:

- Geotechnical issues with respect to water release and ditch efficiency are resolved with detailed monitoring of the starter cell and a contingency plan to modify the ditch/pile geometry before deposition in the east cell.
- Geothermal issues are not resolved.
- Geochemical issues with respect to leaching in the thawed state and cryoconcentration are not resolved.