INFORMATION REQUEST RESPONSE

EA No: 0809-001 **Information Request No: Review Board #03**

Date Received:

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Linkage to Other IRs

Review Board IR #8, #12 – 15
Environment Canada IR #4, 6

Date of this Response:

May 31, 2011

Request

Preamble:
The DAR provides some general comments on the long-term behavior of the frozen block:

- "[…] even after 100 years of sustained global warming, the currently assumed number of thermosyphons is likely to be adequate to counteract thawing."
- "[…] It is recognized that the developer's activities on site will continue in some form in perpetuity" (DAR, p. 3-6).

Based on the current DAR it is difficult to predict the potential effort required in the future to maintain the arsenic trioxide encapsulated in frozen block. No considerations, general sensitivity or hazard analysis were presented that would allow for a better assessment of the long-term risks associated with the assumption that the frozen block will exist for perpetuity.

Question:

1. Please provide results of sensitivity analysis, that, independent on any assumed climate change scenario,
   a. show the minimum air freezing index / average seasonal air temperatures required for the frozen block to remain frozen using the passive cooling method;
   b. provide information on the energy consumption required as a function of various air temperatures for an active / hybrid system; and
   c. provide estimates of thaw times as a function of various air temperatures, assuming that active, hybrid or passive systems fail.
2. Please present a series of graphs showing these trends.
3. Please provide electricity demands and related costs if active or hybrid freezing is required over the long term.

4. Please provide a best estimate on the sensitivity of these initial analyses based on current FOS findings. Because the final design strongly depends on the results of the FOS, it is recognized that the results will be initial estimates.
5. Please describe in detail the assumptions about groundwater volume, velocity, temperature and thermodynamics underlying the expectation that passive cooling will be adequate for the long term. Describe available management options should this be the case, and discuss their financial feasibility and implications.
6. Discuss the probability and consequence of a combination in increased groundwater, hydraulic connectivity by unidentified drill holes and voids, thermal loading from saturation water escaping from voids, leaked saline coolant from ruptured pipes, or other factors preventing the initial freeze.

Reference to DAR (relevant DAR Sections):

S.6.2.7 Long-term Freeze Maintenance
S.6.2.8.2 Thawing and Climate Change

Reference to the EA Terms of Reference

S.3.3.1 Arsenic Containment – Detailed Description of Frozen Block, Point 1 b/c
"With the best available information, a prediction of the amount of active freezing, the amount of passive freezing, power requirements, numbers and general locations of thermosyphons that will be necessary to achieve stability (referring here to a state where active management of the site is no longer necessary)."

"An illustration of the stability of the proposed system for a duration of at least 100 years after converting the active freezing system into a passive system."

Summary

Sensitivity analyses are presented for the effects of a range of mean annual air temperatures on:

- the number of thermosyphons required to maintain stability for Chamber 12;
- the time required for the edge of the chamber to reach 0^oC; and
- long-term annual energy consumption and power costs for an active freeze plant.

Results of the sensitivity analysis confirm that the thermosyphons provide more than adequate cooling power in the event of the worst case climate change scenario, as defined by the Intergovernmental Panel on Climate Change (IPCC).

A hypothetical scenario is analyzed to show that additional heat provided by groundwater flow, even through an entirely open drift, would be easily removed by the planned thermosyphons.

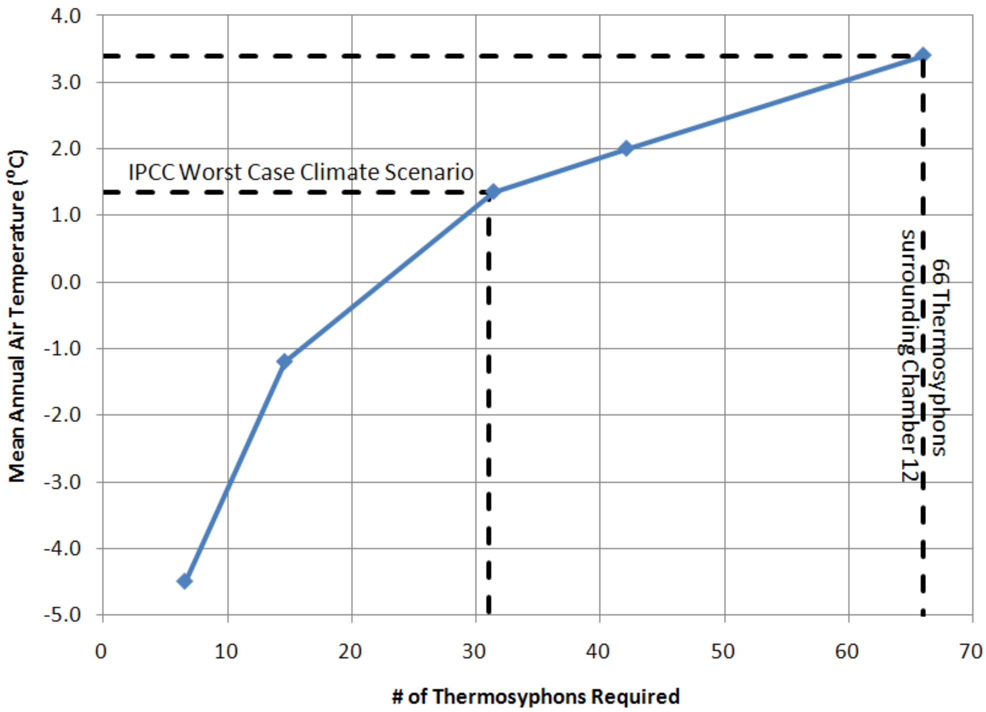
Response 1a

Section 6.2.8.2 of the Developer's Assessment Report (DAR) presents a simplified model for Chamber 12 that evaluates the theoretical number of thermosyphons required to maintain stability for various climate change scenarios. Chamber 12 was used in the calculations as previous model simulations have shown it to be the most sensitive to thawing due to its location in a prominent bedrock outcrop. The resulting number of thermosyphons ranged from 13 to 52 for the IPCC worst case global warming scenario. As the current plan includes 66 thermosyphons around the chamber, the simplified model concluded that there is adequate cooling capacity to keep Chamber 12 frozen. Further details of the model calculations are presented in Section 6.2.8.2.

The simplified model presented in the DAR assumed each thermosyphon had a radiator size of 19.5 m^2. The thermosyphons currently used in the FOS have 39 m^2 sized radiators. The figure below shows the results of the same calculations, using the revised thermosyphon radiator size and a wider range of climate change scenarios. The scenarios have mean annual air temperatures ranging from the current -4.5 ^oC to +3.4 ^oC.

Calculations using a mean annual air temperature of 3.4 ^oC resulted in 66 thermosyphons being required, matching the layout shown in the DAR. The DAR describes the simplifying assumptions used in the analysis. The limitations means the model should not be relied upon for design, but does show the robustness of the current concept.

Figure 1: Simplified Model Sensitivity Analysis for Thermosyphon Performance at Chamber 12



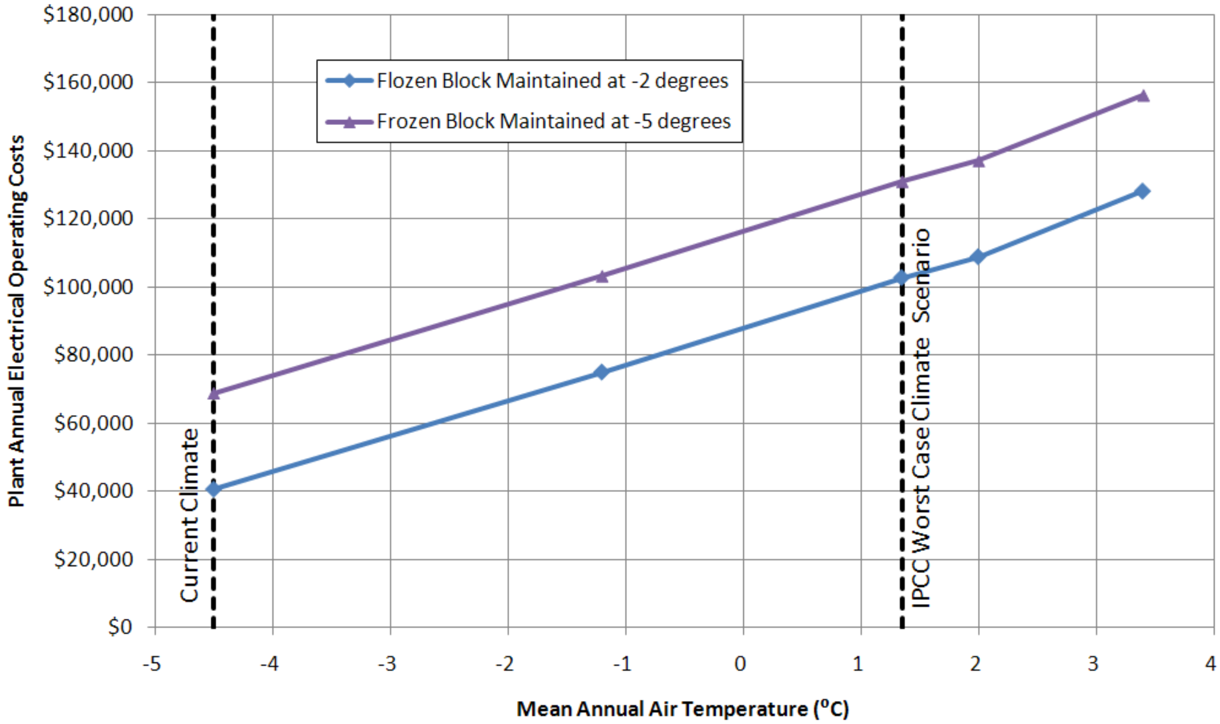
Response 1b

The same simplified model presented above and in Section 6.2.8.2 of the DAR was used to estimate electricity requirements for an active freezing system. Heat flux estimates into Chamber 12 were derived for the same range of temperatures and using the same methodology described in Section 1A (above). The resulting heat flux was then used to estimate the heat extraction per pipe for the entire site. This method is likely to be conservative as Chamber 12 has a larger in-flux of heat than other chambers due to its location on a bedrock outcrop.

Estimates of the annual electricity costs for all chambers and stopes are shown in Figure 2 (below). They were calculated using the methodology described in the report "Conceptual Engineering for Ground Freezing" and an assumed power cost of \$0.12/kWh (2006). Costs are shown for two cases, one with the frozen blocks maintained at -5°C and the other with the frozen blocks allowed to reach -2°C. Allowing the frozen blocks to reach the higher temperature would reduce the temperature gradient between the ground surface and the frozen block, resulting in lower electricity costs.

The estimates in Figure 2 are for a fully active system. If a hybrid system were installed, electricity costs are expected to be significantly less.

Figure 2: Simplified Model Sensitivity Analysis of Long-Term Electrical Operating Costs for an Active Freeze Plant

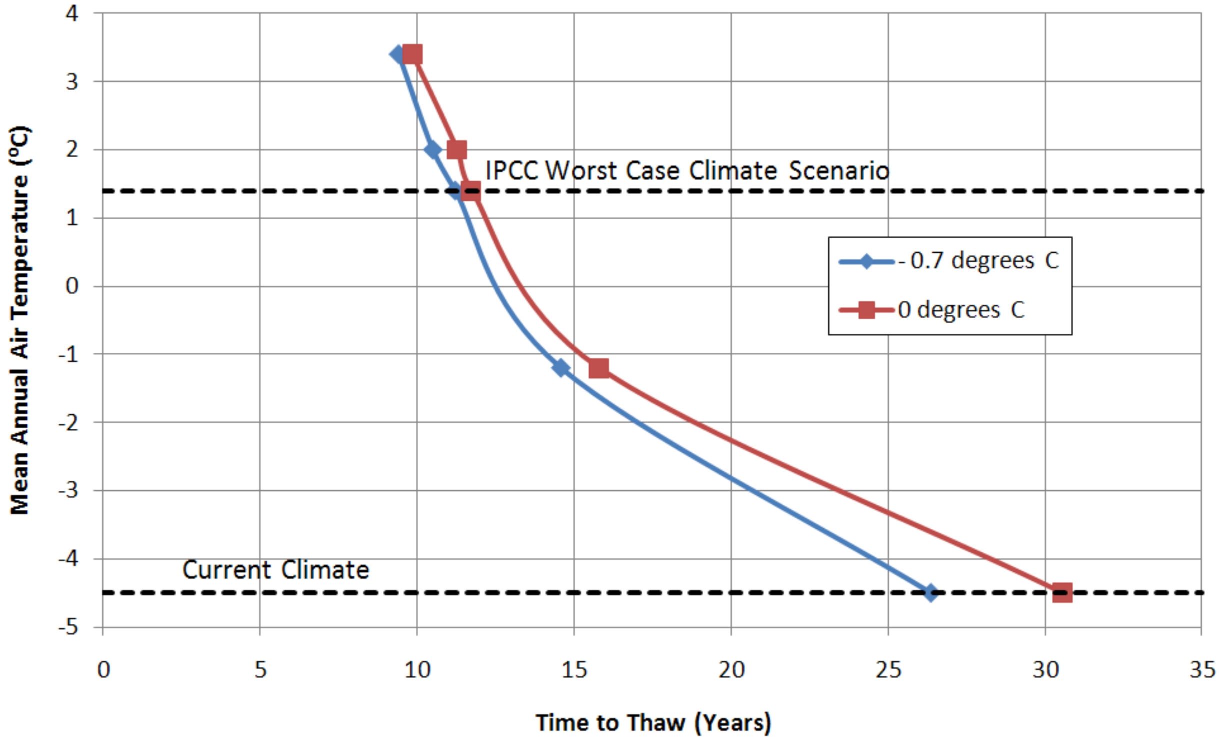


Response 1c

For the hypothetical scenario of a complete failure of all of the thermosyphons, the thaw times for Chamber 12 were estimated over the same mean annual temperature range presented in Section 1A (above). Thaw times are presented as the time required for the edge of the chamber to reach -0.7 ^{o}C (start of phase change for the arsenic dust) and 0^{o}C (end of phase change). The model simulations were the same as those presented in Figure 3.13 of the "Conceptual Engineering for Ground Freezing" report.

The model simulations are similar to those reported in Table 3.3 of the "Conceptual Engineering for Ground Freezing" report which predicts a 26 year thaw time for the 0^{o}C isotherm to reach the top of the chamber. The minor variation in results is due to the exact monitoring point for the model not being known. The variation in results would become smaller for higher mean annual air temperatures. The results show that for the worst case climate scenario, as defined by IPCC, the shortest thaw period for all of the chambers would be over 10 years.

Figure 3: Time for Ground Surface Thaw Zone to Reach Top of Chamber 12 for Case with No Thermosyphons and Various Mean Annual Air Temperatures



Response 2

See graphs in Section 1.

Response 3

If additional cooling capacity is required once the passive system is in place, it would most likely be to address a local area of deficiency and the most economical option would be to install additional thermosyphons within the localized area.

However, in the unlikely event that active or hybrid freezing is required over the long term, Section 1b above provides estimates of the annual electrical demands and power costs for freeze plant operation for various mean annual air temperatures. Other related costs include maintenance of the freeze plant. Maintenance for the long-term active freezing system would be similar to that for the initial active freezing system, which has been estimated at an average annual cost of $272,000. That cost is only about $62,000 per year higher than estimated long-term care and maintenance costs for the passive freezing system.

Response 4

The ground freezing system in the FOS was only turned on in March 2011. Data collected to date are preliminary only and do not change the sensitivity analyses presented in Section 1.

Response 5

The long-term groundwater level within the mine will be controlled by the year-round removal of minewater for treatment. Flooding of the mine to levels that would allow groundwater to contact the frozen blocks would only occur in the unlikely event of a failure of the pumping system. A long-term condition where groundwater contacts the frozen blocks would require that the pumping failure be completely un-mitigated over the long-term.

The extensive groundwater modeling reported in Supporting Document C6 of the Remediation Plan indicates that, even in that very unlikely scenario, the groundwater gradient in the mine area would be extremely low (0.0002 m/m), and that by far the majority of the flow would be through the drifts and other man-made voids. Flow within bedrock, including around the perimeter of frozen blocks, would be insignificant.

To address whether groundwater flow through an open drift or void could have an impact on passive cooling, a worst-case scenario was analyzed. The scenario assumes that a flooded and unplugged drift, 5m wide and 3m high, runs parallel to and along the full length of Chamber 12. (No such drift exists, the assessment is hypothetical only.) Heat from groundwater flowing in the drift then travels through the rock to the edge of the frozen block, which is assumed to be only 5 m away. The groundwater is assumed to be at +4 ^oC. The heat transferred to the frozen block can be estimated from:

$$Q = \frac{kAL(\Delta T)}{d}$$

where: Q is the heat flux (J day^{-1} m^{-1})
k is the bedrock thermal conductivity (300 kJ day^{-1} m^2 $^oC^{-1}$)
A is the drift's surface area per linear m, i.e. its perimeter (30 m)
L is the length of Chamber 12 (62 m)
d is the distance between the drift and the frozen wall (5m)
ΔT is difference in temperature between the frozen wall (-5 ^oC) and water in the drift (+4 ^oC)

The resulting estimated heat transfer is 536 MJ/day. Using the simplified model presented in Section 6.2.8.2 of the DAR, one thermosyphon can remove 240 MJ/day of heat from a frozen block at -5^{o}C. The implication is that, even in this very unlikely scenario, all of the heat contributed by the groundwater could be removed by less than three "extra" thermosyphons. Figure 1 above shows that that the Chamber 12 area plan has over 30 thermosyphons more than the minimum needed to maintain the frozen block, even under the worst case climate scenario.

The management actions for mitigating scenarios like the above would start with mitigating the pumping failure that led to the loss of control over groundwater flow. That would be necessary in any case, in order to continue minewater extraction and treatment.

In the event that uncontrolled groundwater flow was allowed to continue, it would be necessary to review ground temperature monitoring data to identify if and where any thawing was occurring. At the rates of heat transfer estimated above, thawing would be very slow and there would be many years of time for any necessary further investigations.

Again continuing with the assumption that nothing is done to control the overall minewater level, local groundwater flows could be mitigated by constructing remote plugs within the drifts of other conductive features. The plan is to plug all such features prior to the initial freeze, when they are more easily accessible. But if necessary there are methods to remotely place plugs in flooded mine workings.

Another option would be to increase the local cooling capacity. That could be accomplished most simply by installing additional thermosyphons. The annual care and maintenance costs for the passive freezing system include an amount equal to 1% of the initial construction cost, which could easily pay for installation of the three additional thermosyphons required under the above scenario.

Response 6

The factors listed in the information request (groundwater, hydraulic connectivity, coolant leaks, and thermal loading) are either independent or occur during different stages of the freezing process.

During the initial stage of freezing, when the frozen shell is established, the minewater and groundwater levels will be well below the bottom of the lowest chambers and stopes.

The coolant currently being used during active freezing for the FOS is Dynalene HC-40. Any loss of fluid would be detected as a loss of pressure in the piping, and the affected portions of the freeze system would be shut down and assessed. As the bedrock conductivity is low, the loss of fluid within the bedrock would be small. Flow would further be impeded by frozen bedrock conditions.

Water will first be introduced into the stope and chamber areas during the wetting of the arsenic trioxide dust. Wetting will only be initiated after the frozen shells have formed a 10 m wide frozen zone at a temperature below -10^{o}C. The likelihood that an unidentified drill hole or void passing from the chamber to outside of the freeze wall will remain undetected and unsaturated is low. The possibility of water escape through such features is discussed in the response to the Review Board's IR08.