EA0607-002:

Tamerlane Ventures Inc.'s Pine Point Pilot Project

Technical Comments on Water Issues

Submitted by the Review Board's Expert Advisory Team

September 24, 2007

Introduction

This memorandum presents technical comments received by the Review Board from its expert advisors on water issues for the EA0607-002 – Tamerlane Ventures Inc's Pine Point Pilot Project. Review Board staff requested that the experts focus their attention on Tamerlane Venture Inc's responses to the MVEIRB 2nd Round of Information Requests (IRs) on the proposed Pine Point Pilot Project (PPPP) dated 27 August 2007 and supplementary information submitted to support those responses. It should be noted that the technical experts have restricted their reviews to "water-related issues".

The experts are Bruce Halbert of SENES Consultants Limited and Christoph Wels of Robertson GeoConsultants Inc. – they are referred to as "our experts" or "the expert advisory team" in this document. Any questions about the validity of the questions or data presented here are welcomed in submissions for the public record, addressed to the Review Board, which will then submit them to the experts for comment. It should also be noted that these recommendations are the opinions only of the experts themselves at this point. None of their recommendations have been adopted by the Review Board and they remain open to debate and interpretation like the opinions of all technical experts (including those of government and the developer) involved with this file.

The purpose of these technical comments is to identify areas where the expert advisors feel outstanding water issues, identified mainly during the Technical Sessions in July, have been dealt with adequately by the developer, and where additional information needs to be supplemented in order to make a responsible determination of the significance of potential environmental impacts. The developer is invited, as they are with all Technical Reports, to determine which of the issues cited below they want to address in any further submissions or during the Public Hearing to be held in Fort Resolution on October 16, 2007. Statements of clarification are welcomed on the Public Record. If the Review Board finds that there are still outstanding questions after the Public Hearing that need to be addressed before a decision can be made, the Work Plan for this environmental assessment leaves room for a "Requests for Clarification" phase prior to the closing of the public record.

If you have questions about this document, contact Alistair MacDonald at the Review Board: amacdonald@mveirb.nt.ca or by phone at (867) 766-7052.

1. Overview of New Commitments and/or Changes from DAR

In their second round Information Request responses, Tamerlane Venture Inc. ("Tamerlane") made several new "commitments" and/or changes to the design specifications provided in the DAR which are briefly listed below for clarity:

- The installation of injection wells for the disposal of process and mine waters as well as treated sanitary waste water as opposed to disposal on surface in an infiltration pond. Tamerlane has committed to the installation of two injection wells from the beginning to allow flexibility in the operation of the deep well injection system, with the second well also serving as a down gradient monitoring well.
- The installation of (limited) "upstream" and "downstream" monitoring (water levels and water quality) in the Presquile formation used for deep well disposal.
- The construction of a lined settling pond as a contingency to store water exceeding discharge limits during "upset" conditions of short duration (~3 days), that result in poor quality water that is not suitable for direct discharge to the injection well, for later treatment (e.g. allow settling of suspended solids and/or batch treatment).
- Running the manifold pipes for the brine solution in a lined peripheral ditch to prevent spillage of brine solution in the event of failure of the manifold pipes.

These four commitments will, in the expert advisory team's opinion, reduce the potential of significant adverse environmental effects on aquatic resources (groundwater and/or surface water). In other words, these changes to the original design described in the DAR represent a significant improvement over the original design and our experts strongly support these changes. There are however, some residual factors that need further clarification or investigation on these four commitments, as discussed below.

In addition, Tamerlane has proposed the addition of floatation circuits to the dense media separation (DMS) process to create both lead and zinc concentrates for shipment off-site. This will involve the use of several reagents in the flotation circuit that were not required in the DMS plant, which may increase concentrations of contaminants of concern (e.g., copper, lead, zinc) in the end-of-pipe discharge back into the groundwater system. Tamerlane has also revised the overall water balance on the ore processing facility and on the mine water flow to take into account changes made in the mine water inflow estimate and in the addition of a flotation circuit to ore processing facility. Tamerlane's water and load balance calculations suggest that the new process (DMS plus froth flotation) will require significantly more water for processing than originally proposed in the DAR, and also that there will be significantly higher inflows of water at the base of the mine than previously estimated. The implications of this proposed change in processing for environmental impacts are also discussed further below.

In summary then, Tamerlane has made some proactive changes to its development plan that can be supported in principle but may require some additional technical detail. In contrast, experts feel the proposed froth flotation circuit needs to be examined closer largely because it represents the potential to significantly increase contaminant loading in the end-of-pipe discharge. In addition, the new estimates of water inflows at the base of the mine need to be fully incorporated into process outcome estimates, contaminant loading and fate analyses, mitigation options and contingency planning.

2. Residual Issues

Considering information provided in the DAR and subsequent responses to the 1st and 2nd round information requests, the following are the key water quality related issues that have not, in the opinion of the experts retained by the Review Board, been adequately considered by Tamerlane and its consultants, and merit further analysis and discussion to address uncertainties:

- Estimates of groundwater inflow into the mine.
- Water quality predictions for the end-of-pipe discharge.
- Assessment of environmental impacts on groundwater of deep well disposal.
- Operational and post-closure groundwater monitoring.
- Assessment of effects of accidental spills of hazardous materials.
- Design of the injection wells.
- Design of the settling pond.

In addition, the expert advisory team expressed an opinion on the environmental feasibility of co-mingling process, mine and treated sewage waters in the injection well pumping system.

The above issues are addressed separately below in Sections 2.1 to 2.8.

2.1 Estimates of Groundwater Inflow to Mine

IR46 requested new calculations and estimates of basal inflow to the proposed mine development. In their initial response (dated August 17th 2007), Tamerlane put forward a revised "best estimate" for basal inflow of 550 m^3/hr with a "worst-case" scenario of 2,000 m^3/hr (p. 27). According to Tamerlane this proposed range of inflow estimates was "agreed upon" during the technical meeting in Hay River. Our experts did not agree with this statement, nor do they agree with the range of mine inflow estimates put forward by Tamerlane.

Subsequently, Tamerlane submitted a letter report completed by its consultant (EBA Engineering) and entitled "Basal Inflow Estimation, Pine Point, Pilot Project Near Hay River, Northwest Territories" (dated September 7, 2007). This report describes a numerical model which was used to predict the steady-state basal inflow from the Pine Point formation into the proposed mine. Based on this analysis EBA predicted a basal inflow of 941 m^3/hr ("base case"). Sensitivity analyses indicated basal inflows ranging from 696 m^3/hr to as high as 3,120 m^3/hr.

In our experts' opinions, the conceptual model and numerical implementation presented by EBA is adequate for obtaining defensible, albeit preliminary, estimates of basal mine inflow into the proposed mine. Most importantly, the modeling work has shown that the basal inflow to the mine is very sensitive to the hydraulic conductivity of the bedrock at the base of the freeze curtain (at 185m bgs). At present, the only hydraulic information of this bedrock unit at R-190 consists of air permeameter tests performed on two drill cores in the laboratory (Stevenson, 1983). The vertical hydraulic conductivity obtained in those tests ranged from $6x10^{-8}$ m/s to $6x10^{-7}$ m/s. Note that only the two cores with the highest porosity were tested, so the average hydraulic conductivity of this bedrock unit could be substantially lower than the two permeameter tests would suggest. On the other hand, these cores do not account for large-scale effects such as anisotropy due to bedding planes, fractures and/or faults all of which tend to increase the bulk (field-scale) hydraulic conductivity.

Given the paucity of hydraulic information, a definitive (single) mine inflow estimate is, in the expert advisors' opinions, not defensible and mine inflow should be bounded by reasonable upper and lower limits for the purpose of assessing potential environmental impacts. EBA's sensitivity analysis identifies a range of mine inflow rates (696 – 3120 m^3/hr); however, neither EBA (in their memorandum) nor Tamerlane (in their submission) clearly commit to a "best estimate" of an upper and lower bound of mine inflow to be considered for the EA process. Also note that the most recent range of inflow rates presented in the EPA report is higher than the range of inflow rates assumed by Tamerlane in their earlier response to the 2nd round IRs (500 – 2,000 m^3/hr). Tamerlane should clarify which upper and lower limits of inflow estimate it proposes for the purpose of environmental impact assessment.

Our experts argue that the presented range of mine inflow rates (696 – 3120 m^3/hr) is not sufficiently broad considering the lack of hydraulic testing of the basal bedrock unit. EBA's sensitivity analysis only assumed K3 to vary from $6x10^{-7}$ m/s (base case) to 2.4 $x10^{-6}$ m/s. In other words, this critical parameter was only varied <u>upward</u> by a factor of 4. In my opinion, K3 should be varied upward by at least a factor of 5 to 10 to represent the "worst-case" (high) inflow calculations. More importantly, EBA does not represent any sensitivity runs with K3 values <u>lower</u> than their best estimate of $6x10^{-7}$ m/s. Clearly, a reduction in the hydraulic conductivity of the basal bedrock unit (K3) would reduce basal inflow proportionally. Such an estimate of the "lower limit" of basal inflow is important for the EA process because lower basal inflows would reduce water available for mineral processing and would result in higher contaminant concentrations in the end-of-pipe discharge. Tamerlane should carry out further sensitivity analyses to estimate a reasonable lower limit of basal inflow into the mine workings for further use in the EA process.

In this context it should be noted that the model employed by EBA assumes that the aquifer units surrounding the freeze curtain and dewatered mine are not affected by the dewatering activities in the mine workings. This assumption is implemented numerically by assuming constant head boundaries in the basal aquifer at the base of the freeze curtain (at 300m distance). This assumption may approximate the actual flow conditions during the early stages of dewatering. However, continued dewatering will likely result in a reduction in the potentiometric head in the basal aquifer ("depressurization") over time. This depressurization would result in a gradual decline of basal inflow to the dewatered mine workings.

To demonstrate this effect, our experts completed preliminary flow modeling using a simplified three-dimensional model which allows depressurization of the surrounding aquifer units. The main difference to the EBA model was that the model boundaries were extended several kilometers outward to allow a decline of the potentiometric heads in the basal aquifer unit. All simulations assumed steady-state inflow and an impervious freeze wall to a depth of 185 meter (as assumed in the EBA model). Table 1 summarizes the predicted inflows to the mine for different assumed hydraulic conductivities and thickness of the basal aquifer (beneath the freeze wall). Note that these flow estimates do not consider additional inflows due to initial (transient) dewatering effects and/or potential flow through "imperfections" in the freeze wall. In other words, the actual inflows could be higher than those predicted by the model.

Table 1. Preliminary estimates of basal inflow (using a simplified MODFLOW model).

Run ID	Thickness of Basal aquifer (m)	Kh (m/s)	Kv (m/s)	Q into Base (m3/d)	Q into Base (m3/hr)
Run 1	25	6.60E-06	6.60E-07	11,280	470
Run 2	65	6.60E-06	6.60E-07	13,699	571
Run 3	125	6.60E-06	6.60E-07	14,340	598
Run 4	65	6.60E-06	6.60E-06	37,731	1,572
Run 5	65	6.60E-07	6.60E-07	4,181	174

Note that Run 5 is almost analogous to the "base case" presented in the EBA report and illustrates the effect of the different (assumed) boundary conditions on mine inflow estimates. The assumption of constant heads at the base of the freeze curtain (EBA model) produces about 5 times higher inflow estimates compared to the scenario of a depressurized aquifer (Table 1). As stated earlier, the EBA model likely better describes condition at the start of mine dewatering whereas the modeling results shown in Table 1 better describe conditions towards the end of mining when steady-state conditions are approached. A transient groundwater flow model would be required to simulate the transient effects of aquifer depressurization and resulting changes in mine inflow over time. Our experts recommend that such a transient model be developed for actual mine dewatering planning. However, such a model is not required for the purpose of the EA process.

The hydraulic conductivities assumed in the base case scenarios ($Kh=6x10^{-6}$ m/s and $Kv = 6x10^{-7}$ m/s) are "best estimates" for the basal aquifer based on the (very limited) information available (Stevenson Groundwater Consultants, 1983) and our experts therefore recommend using a steady-state basal inflow of ~500m^3/hr as a "best estimate" of basal inflow to the mine for design purposes.

The preliminary flow modeling has shown that basal inflow to the proposed mine is almost directly proportional to the assumed horizontal hydraulic conductivity. Considering the lack of any direct hydraulic testing in the basal aquifer (at a depth of >185m), our experts recommend using a flow range of 50 to 5,000 m^3/hr for contingency planning of "worst-case scenarios". The upper end of the inflow estimate (5,000 m^3/hr) is a worst-case scenario in terms of mine dewatering/deep well injection and is more likely to occur for shorter-term duration (e.g. during initial dewatering and/or when hitting a permeable zone during mine advance). The lower end of the mine inflow estimate (50 m^3/hr) is a worst-case scenario in terms of process water requirements and water quality of end-of-pipe discharge (see below). Our experts feel that the implications of the full range of likely inflow rates on the overall water balance and on end-of-pipe concentrations from the combined mine water and ore beneficiation process should be assessed and presented by Tamerlane.

2.2 Water Quality Predictions for End-of-Pipe Discharge

In IR49 and 53, the developer was asked to provide updated predictions of water quality for the end-of-pipe discharge. In their response, Tamerlane has provided predicted concentrations for the following contaminants of concern: pH, TDS, copper, lead and zinc. Concentrations in the end-of-pipe discharge were predicted for the DMS process only (p.65) and for DMS plus froth flotation (p.46). These predicted end-of-pipe concentrations were calculated assuming a basal mine inflow ("groundwater seepage") of 550 m^3/hr. In the text, Tamerlane concedes that the end-of-pipe concentrations would change depending on the actual mine dewatering rates but no upper or lower concentration ranges are provided.

Our experts had the following concerns with these water quality predictions:

- The calculated end-of-pipe quality values given in the table on page 46 of the response to IR49 are misleading as they are calculated using the results of laboratory tests performed at SGS Lakefield using feed water that was not representative of groundwater that will be used in the full-scale system. The water quality of process water was assumed to be equal to the "locked cycle" samples determined in the laboratory; no information is provided on the source water used in the lab test, however, the source water appears to have been much more dilute (TDS ~ 200-500 mg/L) than the groundwater that will be used for processing (TDS ~3140 mg/L); if correct, the predicted water quality (at least pH, TDS and sulphate) of the process water and hence end-of-pipe water are in error and should be revised. For most constituents, our experts would expect that the end-of-pipe concentrations will be higher than shown on the table.

- It is also unclear what effects the use of very hard water (proposed for processing) will have on the DMS and froth flotation process and the resulting metal concentrations in the process water. Ideally, this issue should be addressed by rerunning the test with source water of similar chemical composition as the proposed groundwater from the Tamerlane site. It is suggested by our experts that the calculated end-of-pipe concentrations presented on the tables in point #3 of the response to IR53 be revised to take into account the use of site groundwater as feed water to the ore processing plant as opposed to the lab water used in the metallurgical test work.

- The constituent concentrations in the water to be discharged to the deep well system may vary substantially depending on the volume of water pumped to surface from underground. Accordingly, the characterization of end-of-pipe quality should be undertaken considering a range of mine water inflow rates and ANFO emulsion losses.

- It would be preferable to have a summary of all constituents of potential concern presented in the tables in the IR53 response. It is noted that the analytical tests performed at SGS Lakefield did not include all constituents of interest (for example, the lab test report does not include sulphate or total dissolved solids). Hence, it appears the range of values shown for sulphate and TDS on the table in the response to point #1 are estimated values. The basis used to estimate these values should be clarified. Note that it is doubtful that the sulphate and TDS levels in the process discharge can be lower than in the underground seepage water that will be used as makeup water in the DMS and floatation circuit processes.

- The assessment of the fate of ammonia in the groundwater system is questionable as it is unlikely that it will be oxidized. If oxygen is present in the end-of-pipe discharge, it will be readily utilized in the oxidation of organics that may be present in the process water as a result of the addition of flotation reagents. As there is no other source of oxygen, our experts estimated it is very unlikely that ammonia oxidation will be a factor. Also, it is questionable whether ammonia removal by physical processes (e.g. adsorption or ion exchange) will occur. It will depend on whether specific minerals such as aluminum silicates (zeolites) are present in the Presquile dolomite horizon. A range of possible ammonia concentrations should be predicted given the uncertainty in the water inflow rate to the mine workings. In addition, there is uncertainty in the amount of ANFO emulsion that may be lost and dissolve in the mine water. This factor should also be considered and incorporated into an assessment of the possible range of ammonia and nitrate levels in the end-of-pipe discharge. As shown in Section 2.3 below, significant dilution of the end-of-pipe discharge may occur only at considerable distance from the point of injection.

- The reagent consumption figures listed on page 54 of the 2nd Round IR Responses are not clear. The column header indicates grams/tonne ore but the footnote say that the figures are based on 3,000 tonnes of ROM ore per day. Clarification on the units of the consumption figures is required. MSDS (material safety data sheets) have been provided as requested on the reagents that will be used in the process. These sheets provide toxicological information on the reagents that would be used in the flotation circuit, in addition to data on the chemical and physical characteristics of the reagents. Tamerlane should present information on the efficiency of reagent usage (capture) in the process, based on either it own test work or test work carried out by suppliers, and on the likely concentrations in the end-of-pipe discharge water. This information should then be used by Tamerlane to assess the environmental effects, if any, of residual reagent concentrations discharged to the deep groundwater aquifer.

- The end-of-pipe concentrations assume a 2.75 fold dilution (377 to 137) by excess mine water not used in the ore process; however, if mine dewatering rates are $\leq$173 m^3/hr[1] there will be no dilution and the metal concentrations at the "end-of-pipe" will be equal to those of the process water (i.e. 0.495 mg/L Cu; 0.302 mg/L Pb and 0.186mg/L Zn based on the initial "lock cycle test" results).

The expert advisory team felt the above concerns should be addressed by Tamerlane before finalization of water quality criteria for end-of-pipe discharge of the Pine Point Pilot Project.

Note also that the water quality predictions assume that the process requires 173 m^3/hr of make-up water (see note #1 below). This amount is substantially higher than the 28 m^3/hr of make-up water assumed in the water balance presented in the DAR. Presumably, the difference is due to the added step of froth flotation but this should be confirmed by the developer. If the higher water requirement is correct, it raises a concern whether mine dewatering rates will be adequate for ore processing. For example, in the case of mine dewatering rates falling to 50 m^3/hr (the expert advisory team's lower estimate of basal inflow) an additional 123 m^3/hr of water would be required for processing. Tamerlane should describe their contingency plans in the event of mine dewatering rates being lower than process water requirements.

2.3 Assessment of Environmental Impacts of Deep Well Disposal

In IR47 (point 2) the developer was asked to "*describe the environmental impact, if any, of the operation of the injection well with respect to changed groundwater quality and levels, and with respect to availability of water resources for other uses during and after operation. The assessment should address all contaminants that are expected to be higher in the combined discharge than in the groundwater entering the mine, including metals and other elements that contribute to total dissolved solids*".

Tamerlane provided estimates of the extent of the mounding height based on initial feasibility calculations carried out by EBA. In the opinion of our experts, the mounding calculations carried out by EBA and presented by Tamerlane are reasonable and suggest very limited pressure mounding. It should be noted that the Presquile aquifer is confined and if the upper (shallow) aquifer(s) and confining layers are cased off (as recommended, see below) the "mounding" will express itself as a "pressure mound" and not a groundwater table mound (as incorrectly illustrated in the figure on p. 33 accompanying Tamerlane's response).

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1 NOTE: this estimate takes into account the process losses of 36m3/hr inferred from the differences between the 550m3/hr inflows and the 514m3/hr end-of-pipe water estimated on page 35 of the August 15 IR responses.

In contrast, Tamerlane did not provide any environmental effects analysis (e.g. dilution and/or transport analysis) or estimates of the resulting groundwater quality in the Presquile aquifer receiving the mine and process water discharge. In their response, Tamerlane simply asserted that there "*are no other users of groundwater in the area*" (p. 33) and that "*likely dilution would be extremely large due to the vast amounts of water in the aquifer*" (p. 35). No analysis or calculations were provided to back-up these assertions.

Tamerlane in fact questions the need for (effluent) water quality criteria "*as the water to be pumped down-hole will be comparable to the existing groundwater environment and will not contain hazardous materials of any kind.*" This point has not been demonstrated, as tests thus far have not been an adequate proxy of real life conditions. For example, the quality of the water used in the laboratory for the metallurgical test work presumably had a very different composition then groundwater water from the mine site that will actually be used as makeup water in the ore beneficiation process.

Our experts stated that the response provided by Tamerlane with respect to the potential water quality impacts due to deep well injection is inadequate for the EA process. At a minimum, simple dilution calculations should be presented by the developer to demonstrate the radial distance required to reduce the metal concentrations to background concentrations in the Presquile aquifer. Such information is required to alleviate any concerns the general public may have with respect to downstream water quality impacts. In addition, such calculations would assist in the design of an appropriate groundwater monitoring system (e.g. number and location of monitoring wells, duration of post-closure monitoring etc).

In the absence of any calculations provided by the developer our expert team calculated the dilution potential in the Presquile aquifer to allow a preliminary assessment of water quality impacts in the aquifer. Table 2 lists the estimated "dilution potential" in the Presquile aquifer for different radial distances (assuming a porosity of 15% and an aquifer thickness of 48m). The second column shows the estimated volume of groundwater in the Presquile aquifer. The third and fourth columns show the dilution potential, expressed as a ratio of resident groundwater to injected discharge water and as a percentage, respectively, assuming complete mixing of the injected water (500 m^3/hr over 365 days).

Note that the estimated total volume injected over 1 year (4.38 million m^3) equals the estimated total volume of resident groundwater in the Presquile aquifer over a radial distance of approximately 400 to 500m from the injection well.

The estimated dilution potentials shown in Table 2 can be used to bracket the likely dilution of any contaminant injected with the process water. The actual amount of dilution depends on the degree of mixing of the process water with the resident groundwater. At one end of the spectrum, the injected discharge water may not mix at all but instead move as "piston flow" into the formation. In this scenario, the aquifer would be "impacted" for a radial distance of 400-500m with contaminant concentrations in the aquifer being very close to those of the "end-of-pipe" concentrations.

At the other end of the spectrum the injected discharge water may mix completely due to dilution and dispersion along the flow path. Complete mixing is rarely achieved but will be approached over larger transport distances. Assuming complete mixing over a radial distance of 1,000 to 2,000m, contaminant concentrations can be expected to be reduced by a factor of 5-20 (Table 2).

Table 2. Estimated Groundwater Volume in Presquile Aquifer and Resulting Dilution Potential.

	Volume[1]	Dilution Ratio[2]	Dilution Factor[2]
Radial Distance	m3	unitless	%
r=100 m	226,080	0.05	5%
r=200 m	904,320	0.21	21%
r=440 m	4,376,909	1.00	100%
r=500 m	5,652,000	1.29	129%
r=1000 m	22,608,000	5.16	516%
r=2000 m	90,432,000	20.65	2065%
r=5000 m	565,200,000	129.04	12904%

Notes:
1) assume b=48m and porosity = 0.15
2) assuming 500 m3/hr injected for 365 days

The above calculations provide a basis for estimating concentrations of any contaminant of concern at a given reference distance from the injection well. For example, assuming an end-of-pipe copper concentration of 0.133 mg/L the resulting copper concentration in the Presquile aquifer at a distance of 1,000m may range anywhere from 0.133 mg/L (no dilution) to 0.027 mg/L (assuming complete mixing).

Note that these dilution calculations assumed a homogeneous aquifer of infinite areal extent. In practice the freeze wall and local heterogeneities will reduce the volume of resident groundwater available for dilution. In our expert's opinion, a realistic dilution potential for a distance of 1,000m (assuming an injection rate of 500 m^3/hr) would be in the order of 2-3.

These simple calculations demonstrate that elevated metal concentrations (significantly above background) can be expected in the local aquifer. Tamerlane stated that there are no potential uses for the local groundwater. In light of the above calculations this statement should be further qualified. For example, which aquifer(s) is Tamerlane referring to and within what distance of the injection wells is there expected to be no current and/or future groundwater use?

Tamerlane also does not consider the potential impacts of deep well injection to surface water via discharge of deep groundwater to surface. In our expert's opinion, Tamerlane should assess the potential for discharge of this impacted deep groundwater to surface water. If there is a potential for surface water discharge, Tamerlane should provide estimates of groundwater quality at likely discharge points.

Finally, Tamerlane should explain which precautions will be taken to prevent "contamination" of shallow groundwater (in the overlying overburden) by deep well injection.

In summary, the impact assessment provided in Tamerlane's response is, in our expert advisory team's opinion, inadequate for the EA process. Their own preliminary dilution calculations suggest that the dilution potential is limited, at least within distances of a few 100 meters of the injection well. They recommend that Tamerlane carry out a more in-depth analysis of the environmental impacts of deep well injection. This analysis should include estimated concentrations of potential contaminants of concern (in particular metals introduced by ore processing such as copper, lead, zinc) for various distances from the injection well(s), taking into account the effects of dilution and dispersion.

2.4 Operational and Post-closure Groundwater Monitoring

IR47 (point 4) and IR51 requested further detail on the proposed monitoring of groundwater quality changes during active mining and post-closure, respectively. In response, Tamerlane proposed to monitor groundwater quality in "*monitoring wells upstream from the injection wells ...within a couple hundred meters. These wells will also be utilized for upstream (background) monitoring of the primary injection well. With two injection wells, the backup well can and will be located down-gradient of the primary injection well and used to monitor groundwater quality in the Presquile aquifer.*"

Our experts agreed that more than one injection well should be installed as a contingency measure. In their opinion, however, the proposed monitoring plan is inadequate for deep well injection into an aquifer with contaminant concentrations significantly higher than natural background. It is understand that a detailed monitoring plan cannot be developed until the locations of the injection wells are finalized. Nevertheless, the developer should commit to several dedicated monitoring wells to monitor the effects of deep well injection. Our experts feel the back-up injection well is not a suitable monitoring well as it may not be available throughout the life of the project.

Note that deep well injection will result in pressure mounding (and hence potential contaminant transport) in all directions (i.e. radially away from the injection well(s)). As a result the terms "upstream" and "downstream" monitoring wells are somewhat misleading. Assuming that the injection wells will be completed along the east-west "hinge axis" (as proposed) groundwater monitoring wells should be completed on both sides of the injection wells along this east-west axis of higher permeability. For initial planning and costing purposes, our experts would recommend that 2 dedicated monitoring wells be screened in the Presquile aquifer on either side of the two injection wells at distances of approximately 200m and 1,000m (for a total of 4 wells). The back-up injection well and selected "upstream" monitoring wells located at strategic locations near the freeze wall may also be included in the groundwater monitoring plan (in addition to the 4 purpose drilled monitoring wells proposed above).

It was further recommended that groundwater level monitoring occur in monthly intervals and sampling for groundwater quality (complete major ion chemistry and dissolved metals) at quarterly intervals during active mining and for a minimum of 2 years after cessation of deep well injection. The requirements for longer-term monitoring (beyond 2 years of post-closure monitoring) should be determined after the end of the 2 year post-closure monitoring period.

2.5 Contingencies in the Event of Brine Spills

IR52 requested information on the likely impact of accidental spillage of the brine solution and any contingencies to minimize those impacts. In their response, Tamerlane committed to the use of an HDPE lined perimeter ditch which has the capacity to contain all refrigeration solution in the event of a rupture of the manifold piping system. Our experts feel the proposed contingency for this type of failure (manifold rupture) is adequate to protect spillage of the brine solution into the surface environment and should address all concerns over the failure of one or more lines.

The second potential failure mechanism is the rupture of the freeze pipes and release of the brine solution into the local groundwater system. Tamerlane's response provides information on the mass of salt that could spill into the groundwater system. However, Tamerlane does not provide any information on the likely environmental impacts (i.e. groundwater quality). Tamerlane states that isolation valves could be used to reduce the size of the spill (mass discharged to the groundwater system) but makes no commitment to installing isolation valves.

Based on the information provided by Tamerlane, the total mass of salt that could spill from a single freeze pipe would be about 423 kg (400 gallons at 280 g/L). With 600 freeze pipes, the maximum (total) spillage would be about 255,000 kg of salt. Assuming all brine was spilled (i.e. no isolation valves) and further assuming complete mixing of the spilled brine into an aquifer with an average porosity of 10% and a thickness of 180m (the depth of the freeze pipes) the resulting increase in TDS would be about 450 mg/L within a radius of 100m. However, within a radius of 500m the increase in TDS would be reduced to only 18 mg/L and would be virtually non-detect within a radius of 1,000m. Based on these mixing calculations the environmental impact of a brine spill is limited to a few hundred meters at most.

Our experts recalled from the presentations at the technical sessions in Hay River that each of the freeze pipes would have its own valve so that each pipe can be isolated for maintenance should a leak be detected. If that is the case (and this needs to be confirmed), then the effect of a break in one or two freeze pipes would not pose a risk of serious effect on groundwater quality. Failure of a large number of pipes could affect a large volume of groundwater and the consequence of such an event should be addressed if the system will not feature multiple shutoff valves.

Clarification of the distribution system design and on the size of a possible spill from breakage of freeze pipes is required.

In the opinion of these experts, it may be prudent to install a number of isolation valves (say 6-10) to reduce the loss of brine in the case of an accidental rupture of a freeze pipe. But the number of isolation valves to be installed are, in our experts' opinions, more driven by economics (cost of replacing the spilled brine) than by concerns of an environmental impact.

2.6 Design of Injection Wells

Tamerlane's response to the request for a design of the injection well disposal system (IR47) only provides general descriptions and recommendations (presumably by their consultants) with respect to the design of the injection wells. In the expert advisory team's opinion, the general design guidelines presented in their response are reasonable and should be adopted by Tamerlane. However, no affirmative commitment has (yet) been made by Tamerlane regarding the design of the injection wells. Experts suggested that an affirmative commitment should be sought from the developer with respect to the following (desired) design guidelines:

- Casing off the upper 122m of the injection well to prevent injection of process water into (and potential contamination of) the (shallow) till aquifer and/or confining units (Hay River Shale, Watt formation);
- The injection well should utilize the entire thickness of the productive Presquile aquifer (estimated depth 122 to 170m) to maximize water intake capacity;
- Depending on rock conditions perforated liner or casing with screened sections may be required to prevent borehole collapse; the slot sizing should be designed according to standard design guidelines to minimize well losses;
- A drop pipe should be used to carry water from the well head down to below the static water level (~25m below ground surface) to prevent cascading and aeration of the discharge water to minimize the potential for geochemical reactions and well fouling;
- The well heads of both injection wells should be equipped to allow continuous monitoring of injection rate and water level and allow sampling of discharge water.

Initial feasibility calculations provided by EBA suggest that the Presquile aquifer is sufficiently transmissive to accept target rates of 550 to 2,000 m^3/hr (p. 32). The methods and assumptions used by EBA to estimate the mounding height are reasonable and the expert advisory team agrees with their conclusion that deep well injection is a feasible option for the Tamerlane project.

Note, however, that the use of two injection wells may be required for injection rates significantly higher than 2,000 m^3/hr. For the highest mine inflow estimate provided by EBA (3,120 m^3/hr) the theoretical mounding height would be 11.5 m (extrapolated from EBA's estimates). Under the expert advisory team's estimate of "worst-case" injection rates of 5,000 m^3/hr (see above) the theoretical mounding height would be 18.5m. With additional well losses, such an injection rate would likely not be possible with gravity feed and the "back-up" injection well would be required. The expert advisory team therefore recommended that the "back-up" injection well be also hooked up to the discharge line at the start of the project to provide more flexibility for discharge, thus reducing the potential for possible downtime.

For the reasons listed above, it was recommended that both injection wells should be pump-tested prior to start of operation to ensure that the injection wells have sufficient capacity to accept the required discharge rates.

2.7 Design of Settling Pond

In response to IR44 and 47 (point 3), Tamerlane proposes the use of a lined settling pond and provided a conceptual drawing of its location and design (p. 34). Our experts generally support the use of a lined settling pond as a contingency to settle out suspended solids and/or store process water of unacceptable discharge water quality for treatment. The proposal to construct a sedimentation pond is a good back-up measure. However, one expert questioned the logic in providing agitation capability to re-suspend the solids that settle in the pond. The concentration of solids in the pond water (if it is possible to re-suspend them) would be very dilute and may not be suitable for direct usage as backfill material as suggested. Simply draining the pond at the end of the operating phase and physically removing the solids for disposal underground may be adequate.

In addition, experts noted that the design of the proposed settling pond is not adequately described to allow a proper assessment. First, the design drawing (plan view and cross-section) have no scale so the dimensions of the foot print area and the height of the berms can not be determined. The expert team feels those design parameters should be provided by the developer.

Second, and related to the above, there is uncertainty about the proposed storage volume of the settling pond. On page 35, Tamerlane states: "*In the event that discharge water quality did not meet water quality criteria outlined in the water license, an above-ground lined sediment settling pond will be constructed for temporary storage with a capacity for over three days of flow (514 m^3/hr x 24 hrs = 12,336 m^3.*" The stated volume only represents 1 day of storage assuming Tamerlane's best estimate of mine inflow (550 m^3/hr). However the text refers to over 3 days of storage which would be greater than 37,000 m^3. Experts feel that Tamerlane should clarify the design volume of the proposed settling pond.

Third, Tamerlane states that "*A thin layer of gravel or waste rock will be laid over the top of the liner to act as protection against puncture*" (p. 35). In most liner applications, the liner is protected by a bedding layer placed <u>beneath the liner</u>. Experts suggest that Tamerlane should clarify whether it is planning to use a protective bedding layer beneath the liner, and if not, why this protective measure is not required. Tamerlane should also provide the proposed specifications of the liner material.

Finally, Tamerlane does not provide sufficient information on the proposed treatment of the stored process water prior to re-injection to the aquifer. On p. 35 Tamerlane states: "*Such an event would only be foreseen for an unlikely and short-term (hours) upset condition. When the upset condition was rectified, the discharge water would be rerouted back to the discharge well system. The stored water would be treated in a batch manner in the tank before releasing into the injection well at a later time.*"

Experts felt that Tamerlane should provide details on the proposed treatment "in the tank". Which treatment process is proposed and which contaminants of concern would be treated? It was also suggested that Tamerlane clarify whether this treatment system will be in place at start of mine dewatering and at what flow rate this batch treatment can be operated.

The additional information requested above will be required before a proper assessment of the proposed settling pond/contingency treatment can be completed.

2.8 Treated Sewage Disposal

In its reply to IR48, Tamerlane proposes to discharge the treated sanitary waste water together with mine water and process water into the deep well environment. Our expert advisors see no problem with the proposal as the treated effluent quality will be good and the volume quite small in comparison to the mine/process water volume (i.e., the discharge from the RBC unit is shown as 0.5 m^3/hr as compared to the combined mine water and process water flows of over 528 m^3/hr on the water balance figure included with the Tamerlane response to IR #47).

Closing Comments

In closing, the expert advisory team indicated that Tamerlane made several commitments (deep well disposal, lined settlement pond and lined manifold) in its response to the second round IRs which, in the opinions of our expert advisory team, significantly reduce the potential for environmental impacts to the downstream aquatic system. However, Tamerlane's responses to several IRs, in particular those relating to the environmental impact of deep well disposal, and groundwater monitoring are, in their opinion, inadequate and/or lack sufficient detail for the EA process. Furthermore, experts called for Tamerlane to clarify their commitments with respect to the proposed design of the injection wells and the lined settlement pond, as wells as make sure that all of the most up to date material on water inflows and process technologies be taken into account when revising end-of-pipe water quality estimates and analysis of potential impacts of water entering the receiving environment.