JERICHO PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT:
EFFECTS OF COPPER ADDENDUM

Prepared for

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Introduction

This technical document has been submitted as an addendum to the Jericho Project Environmental Impact Assessment for Aquatic Biota (RL&L 2000). It provides an evaluation of environmental effects to water quality and aquatic biota that could result from elevated copper concentrations originating from mine effluent. The evaluation process used in this document is identical to that presented in the main body of the environmental impact assessment (RL&L 2000).

Assessment of Potential Effects

Project Activity

Effluents that potentially contain copper include runoff from the mine pit and waste rock dumps (Bruce Ott, Senior Environmental Scientist, Tahera Corporation, pers. comm.). Based on the mine design, this runoff will be contained by collection ditches and directed to a central settling pond that will be situated in a downslope location between the mine operation zone and the southeast corner of Carat Lake (Bruce Ott, pers. comm.). Surface effluent siphoned from the settling pond by a stand pipe will be released into Carat Lake using an outfall pipe.

The effluent is expected to have a median total copper concentration of 0.004 mg/L; the maximum concentration will not exceed 0.016 mg/L (Tahera 2000).

Potential Effects

CCME (1999) water quality guidelines for the protection of aquatic life specify that concentrations should not exceed 0.002 mg/L. Given that background levels in Carat Lake are low (from below detection to 0.0016 mg/L; Tahera 2000) and the predicted concentration in the effluent is above the CCME (1999) threshold, there is the potential for reduced water quality, which in turn, may adversely affect fish and other aquatic biota.

Copper is an essential element and is required for normal functioning of biological organisms (Lewis 1995). In fish, copper forms part of several enzymes and glycoproteins, it promotes iron absorption and transport, and it is necessary for hemoglobin synthesis (Sorensen 1991). At excessive concentrations copper becomes toxic. The toxicity can include damage to tissues and organs, altered physiology and behaviour, and ultimately reduced growth, survival, and reproduction (Sorensen 1991).

Copper is not considered to be a cumulative systematic poison, as most of it is excreted from the body (Falk et al. 1973). Chronic exposure will cause copper to concentrate in the liver, muscle, and brain tissues (Demayo and Taylor 1981). Windom et al. (1973) observed lower trophic levels of fish to have higher concentrations of copper relative to higher trophic levels of fish.

Toxicity of copper to aquatic organisms is complex and highly variable (Lewis 1995). In general, low alkalinity, low hardness, and the absence of organic substances tend to increase toxicity, but absolute effects are controlled by the form of copper causing the toxicity and the presence of other elements in the environment. Copper toxicity varies depending on the taxonomic group and the mode of entry. Copper is a well known biocide (e.g., copper sulphate) used in aquatic systems to inhibit excessive algal and macrophyte growth, therefore, it can be a toxicant to plants (Lewis 1995). In benthic macroinvertebrates, effects will vary depending on Order (Clements et al. 1988) and whether the organisms are herbivores, detrivores, or predators (Leland et al. 1989). In fish, it would appear that salmonids are more sensitive to elevated copper levels than other taxonomic groups and smaller fish are effected more severely than larger fish (Sorensen 1991).

Because water quality of Carat Lake can be characterized as having low alkalinity and hardness (Tahera 2000) and the fish community is dominated by salmonids such as lake trout, Arctic char, and round whitefish (RL&L 2000), there is the potential for adverse effects caused by copper concentrations that exceed CCME (1999) guidelines. It should be noted that acute toxicity values (LC^{50} - concentration causing 50% mortality) identified for fish and other aquatic organisms are typically greater than 0.030 mg/L (Sorensen 1991; Lewis 1995), which is higher than the maximum concentration that would be present in the mine effluent (0.016 mg/L).

Environmental Management and Mitigation

Tahera is committed to taking steps to minimize the toxicity of elevated copper levels in the mine effluent (Bruce Ott, pers. comm.). First, the collection system, which will have the capacity to accommodate all typical runoff events, will ensure that effluent from the mine area does not directly enter Carat Lake. Second, the outfall pipe will be designed to maximize the dilution rate of copper that is released into Carat Lake. The outfall will be located approximately 420 m offshore on the lake bottom in 9.5 m of water (The pipe will be overlain with rock material to protect it from ice damage). The outlet to the pipe will be equipped with a two port diffuser head consisting of two nozzles that will facilitate rapid dilution of the effluent.

Norecol, Dames & Moore (2000) has provided an evaluation of the effectiveness of this design based on the predicted copper concentrations in the effluent, the background copper concentration, the characteristics of Carat Lake (depth, temperature, water currents), and the configuration of the outfall pipe. For the median concentration in the effluent (0.004 mg/L), the target copper concentration (0.002 mg/L) will be achieved within 1 m of the outfall. At the maximum copper concentration (0.016 g/L), a dilution zone exhibiting a horizontal radius of 7 m and a height of 5 m will be required to achieve the required target concentration.

Assessment of Potential Effects

Based on this evaluation, the concentration of copper released into Carat Lake is expected to meet CCME (1999) guidelines very rapidly once it is released into Carat Lake; however, there will be a zone in the immediate vicinity of the outfall that may have adverse effects on aquatic biota. The copper concentrations in this zone are not expected to be acutely toxic, but there may be sublethal residual effects on aquatic organisms.

Evaluation of Residual Effects

Evaluation Approach

Significance of elevated copper concentrations will be evaluated using rating criteria outlined in RL&L (2000). Rating criteria developed under the Canadian Environmental Assessment Act will be employed as follows:

- magnitude;
- geographic extent;
- duration;
- frequency;
- reversibility;
- ecological context;
- level of confidence; and,
- certainty.

Magnitude

Magnitude describes the nature and extent of the environmental effect. The magnitude of an effect is quantified in terms of the amount of change in a parameter or variable from an appropriate threshold value, which may be represented by a guideline or baseline conditions. In the case of copper, magnitude will be categorized by the change in concentration relative to the ambient level (0.0016 mg/L) and the CCME guideline threshold (0.002 mg/L). The three categories to be employed are low, medium, and high as follows:

- Low - concentration does not exceed ambient level;
- Moderate - concentration exceeds ambient, but not threshold level; and,
- High - concentration exceeds the threshold level.

Geographic Extent

Geographic extent is based on the spatial boundaries of the development and can be separated into three categories:

- Sublocal (L) - includes a specific area of Carat Lake within the immediate influence of the project (pipe outfall and southeast section);
- Local (M) - includes all of Carat Lake; and,
- Regional (H) - includes all of Carat Lake and Contwoyto Lake drainage basins, excluding the local study area.

Duration

Duration is defined as a measure of the length of time that the potential effect could last. It is closely related to the project phase or activity that could cause the effect. The four project phases that are related to duration include construction, operation, closure, and post-closure.

Duration is divided into three categories:

- Short-term (L) - effects lasting for less than one year (associated with the construction period, or other short-term activities);
- Mid-term (M) - effects lasting from one to eight years (associated with the life of the mine); and,
- Long-term (H) - effects lasting longer than 8 years (persist beyond the closure of the mine).

Frequency

Frequency is associated with duration, and defines the number of occurrences that can be expected during each phase of the project. Frequency is divided into three categories:

- Low (L) - effects occur infrequently (< 1 per month during each project phase)
- Moderate (M) - effects occur frequently (from 2 to 15 per month during each project phase); and,
- High (H) - effects occur continuously.

Reversibility

Reversibility is the ability of the aquatic biological community (e.g., fish) to return to conditions that existed prior to the adverse environmental effect. The two ratings that will be used are: reversible (R) and not reversible (NR).

Ecological Context

Ecological context is a measure of the relative importance of the affected ecological component to the ecosystem, or the sensitivity of the ecosystem to disturbance. It indicates the degree to which an effect on the component would affect the ecosystem. The ecological context rating criteria are specific to each effect, but they can be grouped into three general categories: low (L), moderate (M), and high (H).

Level of Confidence

Using the criteria described above, the significance of the adverse environmental effect is evaluated based on a review of project data, literature, and professional opinion. The assessment will also include a rating system that evaluates the level of confidence in the prediction of significance. Three rating criteria will be used to assess the level of confidence: low (L), moderate (M), and high (H).

Certainty

To arrive at a high level of confidence for a significance rating, it is usually desirable to apply rigorous scientific and/or statistical methods (quantitative approach). Where such methods are not feasible, professional judgement is usually employed (qualitative approach). Rating the certainty is an additional step that can be used to justify or substantiate the level of confidence in the evaluation. The three rating criteria that will be applied to each of the two certainty categories (quantitative and qualitative) are low (L), moderate (M), and high (H).

Evaluation of Significance

Based on information presented by Norecol, Dames and Moore (2000), the zone of adverse effect will be restricted to the immediate vicinity of the outfall. For the purposes of this evaluation, the impact zone was delineated based on the maximum concentration of total copper (0.016 mg/L) released into Carat Lake, which would result in an affected area within a 7 m radius of the lake bottom around from the outfall or approximately 154 m^2. In terms of volume, approximately 770 m^3 of water within 5 m of the bottom will be affected. It should be noted the median copper concentration in the effluent (0.004 mg/L) would affect a zone many times smaller (3 m^2 area or 3 m^3 volume).

This 'worst case scenario' will have a high magnitude of effect during operation, closure, and post closure because the CCME guideline will be exceeded (Table 1). It is assumed that there will be no effect during construction due to the absence of effluent. The impact zone is very small relative to the surface area of Carat Lake, so the geographic extent is considered low. The duration of the effect is considered to be low to high depending on the time period associated with each phase. It is assumed that the effect will be continuous once mine operation commences and will occur well into the post-closure phase because the waste rock dumps will remain following closure of the mine. As such, the frequency has a high rating. The effect is reversible once effluent release into Carat Lake stops. Finally, the ecological context to the ecosystem of Carat Lake is low due to the restricted area affected and the relatively low concentration of copper released into the lake.

Table 1 Residual environmental effects matrix used to evaluate significance of elevated copper concentrations in effluent released into Carat Lake, Jericho Site.

	Evaluation Criteria for Assessing Significance					
Protect Phase	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological Context**
Operation	H	L	M	H	R	L
Closure	H	L	L	H	R	L
Post-closure	H	L	H	H	R	L

The magnitude of the effect was rated as high because the CCME (1999) guideline will be exceeded. Due to the lack of site-specific effects data (i.e., toxicity levels, species-specific effects), it is assumed that exceedence of the CCME guideline will have direct consequences to aquatic organisms. The copper concentrations in water within the affected zone are not expected to be acutely toxic to fish or other aquatic organisms (including phytoplankton and zooplankton); however, there may be accumulations in the sediment, which, over the life of the project, may become acutely toxic to benthic macroinvertebrates. As such, the effects within the impact zone may include reduced density of benthic invertebrates and a shift in the community structure. At the present time, there are insufficient data to accurately predict the amount of change that will occur. It should be noted that the affected area around the outfall is very small so only a small fraction of the lake's benthic macroinvertebrate community may be influenced.

Using a similar rational, it is unlikely that the fish community in Carat Lake will be seriously affected. The outfall is situated outside any rearing or spawning habitat so the only potential effects would by reduced food production due to lower benthic invertebrate densities and possibly elevated copper levels within individual fish. Overall, the effects on fish are expected to be minor because the affected area is small. Also, fish may not enter the affected zone because they are known to exhibit avoidance behaviour when subjected to elevated copper concentrations (Sorensen 1991).

Based on this information, it is expected that elevated copper concentrations in effluent released into Carat Lake will not have significant adverse effects on water quality, the fish community, or other aquatic organisms (Table 2). For the construction and closure phases, there is moderate confidence in the assessment using a qualitative evaluation based on CCME (1999) water quality guidelines for the protection of aquatic life. The quantitative certainty in the evaluation is low because there are no site-specific data to evaluate effects on aquatic organisms.

There is a low level of confidence in the post-closure rating of not significant because there is uncertainty that the mitigative measures will remain effective over the long-term and the lack of information regarding the time period during which these measures will be required.

Table 2 Summary of residual effects evaluation of elevated copper concentrations in effluent released into Carat Lake, Jericho Site.

Project Phase	**Residual Environmental Effects Rating**	**Level of Confidence**	**Certainty**	
			Qualitative	**Quantitative**
Operation	Not Significant	M	M	L
Closure	Not Significant	M	M	L
Post Closure	Not Significant	L	L	L
Project Overall	**Not Significant**	**M**	**M**	**L**

Accidental Spill

There will be a network of collection ditches in place to direct all surface runoff to a central settling pond and the effluent will be released into Carat Lake in a controlled manner. Although highly unlikely, there is the possibility that the outfall pipe used to transport the effluent to Carat Lake could fail or that the design capacity of the collection system will be exceeded by a greater than expected runoff event. In both cases, effluent from the mine could accidentally spill directly into the southeast corner of Carat Lake.

The effect of such a spill on aquatic biota would depend on the volume of the spill, how quickly the spilled effluent would be diluted, and the copper concentration of the effluent. For the purposes of the evaluation, it is assumed that a large volume of liquid would enter Carat Lake, dilution would be minimal (e.g., onshore winds would concentrate the spill along the shoreline), and the concentration would be 0.016 mg/L. It is also assumed that a sufficient amount of copper would be introduced into Carat Lake to cause accumulation in the sediments in the area along the southeast shoreline.

The magnitude of the effect is assumed to be high because the CCME (1999) guideline would be exceeded (Table 3). The geographic extent of the spill would remain low because the effect of the spill would be restricted to the southeast shore. The duration of the effect is expected to be moderate because elevated copper concentrations would remain in the sediments for a certain period following the spill. The frequency is considered low because an accidental spill is an unlikely event. The effects would be reversible assuming that the spill was of very short duration (i.e., identified and corrected immediately).

Table 3 Residual environmental effects matrix used to evaluate significance of elevated copper concentrations in an accidental spill of effluent into Carat Lake, Jericho Site.

Evaluation Criteria for Assessing Significance						**Residual Environmental Effects Rating[a]**	**Level of Confidence**	**Certainty**	
Magnitude	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological Context**			**Qualitative**	**Quantitative**
H	L	H	L	R	L	Significant	L	L	L

The ecological context of this malfunction is largely dependent on the timing of the spill. During summer, the southeast shoreline of Carat Lake is used for feeding and rearing by a variety of fish species. Presumably, a portion of fish subjected to the spill may suffer sublethal effects, as will the benthic invertebrate community. The consequence of a spill in summer would likely be minor given that there should be no concentrations of fish in this area at the time of the spill.

During early spring, just before and during ice out, the effects of a spill to fish become more important. Concentrations of young-of-the-year Arctic char and to a lesser extent, yearling round whitefish and lake trout, have been recorded in this section of Carat Lake. These fish are not highly mobile and are more sensitive to elevated copper concentrations than older juveniles and adult fish (Sorensen 1991). Similarly, a spill in late fall during the spawning and early incubation periods of lake trout, Arctic char, and round whitefish could have negative consequences to these populations. Although no known spawning areas have been identified in the southeast corner of Carat Lake, aggregations of fish of all three species have been recorded, suggesting that spawning does take place in the vicinity.

A second consequence of an accidental spill of mine effluent would be contamination of sediments within Carat Lake. This could result in chronic problems of reduced benthic macroinvertebrate production if the copper is bioavailable.

For the purposes of this evaluation, it is assumed that an accidental spill of mine effluent will not be acutely toxic to aquatic organisms, but there will be sublethal effects over the short-term. It is also assumed that there would be chronic problems associated with elevated levels of copper in lake sediment for a number of years following the spill. It should be acknowledged that absorption/adsorption of copper by the lake sediments could reduce its bioavailability.

Based on this evaluation, there would be significant adverse effects associated with a malfunction that released a large volume of mine effluent into Carat Lake (Table 3). There could be substantial effects on fish populations if the spill occurred in spring or late fall (impacts on young fish and fish eggs), and chronic sub-lethal effects to fish and other aquatic organisms over several years following the spill. It is also likely that fish may be excluded from habitat normally available in the area due to avoidance behaviour associated with elevated copper concentrations (Sorensen 1991). Fish populations in Carat Lake potentially could be affected to the point where they could not recover if a 'worst case' accidental spill were to occur. The level of confidence in this rating is low because there is no way to accurately predict the volume of effluent that could enter the lake, the persistence of the contamination, or the level of the effect on aquatic biota in Carat Lake.

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