TAHERA
DIAMOND CORPORATION

APPENDIX C

AMEC Earth & Environmental
a division of AMEC Americas Limited
2227 Douglas Road, Burnaby, BC
Canada V5C 5A9
Tel +1 (604) 294-3811
Fax +1 (604) 294-4664
www.amec.com

amec

Review of Total Dissolved Solids in Proposed Discharge from the Jericho Diamond Project

West Kitikmeot
Nunavvt

Submitted to:

Tahera Corporation
Toronto, Ontario

Submitted by:

AMEC Earth & Environmental,
a division of AMEC Americas Limited

Burnaby, BC

June 2004

AMEC File: VE51295

TABLE OF CONTENTS

LIST OF TABLES

IMPORTANT NOTICE

This report was prepared exclusively for Tahera Corporation by AMEC Earth & Environmental Limited. The quality of information, conclusions and estimates contained herein is consistent with the level of effort involved in AMEC services and based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions and qualifications set forth in this report. This report is intended to be used by Tahera Corporation only, subject to the terms and conditions of its contract with AMEC. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

1.0 INTRODUCTION

Tahera Corporation is in the process of applying for a water license to discharge water from the proposed Jericho Diamond Mine. Discharge from the mine will contain elevated concentrations of total dissolved solids (TDS) relative to the receiving environment and, consequently, this review was conducted to evaluate whether the concentrations that are likely to be observed in the receiving environment are of toxicological significance.

TDS reflects the sum of materials that are dissolved in a solution. These materials are primarily comprised of four cations (calcium, magnesium, sodium and potassium) and three anions (sulphate, chloride, and bicarbonate/carbonate), all of which are important in biological structures and functions. A significant number of other trace materials can also contribute to TDS; however, for the sake of this assessment, we will only be considering the major ions.

Toxicity associated with elevated concentrations of TDS generally results from one of three mechanisms:

- The overall ionic strength associated with the combination of ions comprising the TDS can result in toxicity as a result of the inability of organisms to osmoregulate.
- Adverse effects can occur as a result of one or more of the ions which make-up TDS reaching toxicologically significant concentrations.
- An imbalance in the ratio between particular ions can result in toxicity because of disruption of biological mechanisms.

Toxicity test data for cationic components of TDS are always derived from tests with solutions containing an associated anionic component, and vice versa. These ions are present as salts, such as calcium carbonate, calcium sulphate, potassium chloride, etc, which are introduced into the test solutions. Consequently, the degree to which one or other of the co-ions comprising each salt, or any interactions associated with their combined presence, is responsible for toxicity is not entirely known.

Ions which comprise TDS each exhibit a differing degree of toxicological effect. A study on acute toxicity to larval fathead minnows and two species of cladocerans demonstrated that the order of relative ion toxicity is $K^+ > HCO_3^- \approx Mg^{2+} > Cl^- > SO_4^{2-}$. Sodium and calcium ions were generally unrelated to toxicity; toxicity associated with salts containing these two cations was generally caused by the corresponding anions (Mount et al., 1997).

2.0 EFFLUENT DESCRIPTION

Water from mining operations will be contained in the PKCA pond and will be discharged each year while weather conditions permit. Discharge from the PKCA is expected to contain elevated concentrations of TDS. In particular, under average precipitation conditions, average and maximum TDS concentrations are projected to be 1074 and 1635 mg/L, respectively (SRK, 2004). The projected composition of TDS in the effluent under these scenarios is provided in Table 1.

The anionic composition of the effluent is dominated by chloride, which comprises 40 to 45% of the total TDS by weight. Sulphate also contributes substantially to the total TDS (17 to 23%). Cationic components of the effluent collectively contribute approximately 30% of the TDS.

Table 1. Projected average and maximum contributions of major ions to TDS in water in the PKCA under conditions of average rainfall (from SRK, 2004).

	Average concentration (mg/L)	Maximum concentration (mg/L)	Average Composition (%)	Maximum Composition (%)
Calcium	101	202	9%	12%
Magnesium	175	206	16%	13%
Sodium	21	36	2%	2%
Potassium	36	64	3%	4%
Alkalinity	42	70	4%	4%
Chloride	487	647	45%	40%
Sulphate	184	380	17%	23%
TDS	1074	1635	--	--

3.0 RECEIVING ENVIRONMENT DESCRIPTION

Effluent from the PKCA will be discharged through a small stream into Lake C3, which subsequently drains into Carat Lake. These lakes are oligotrophic and very low in TDS (typically less than 20 mg/L). Dilution rates provided by Lake C3 and Carat Lake are estimated to be 50- and 58-fold, although higher concentrations of effluent would be expected to occur proximate to the discharge point.

The biological community in the lakes that will receive input from the mine is limited by the low productivity of the lakes. Periphyton and phytoplankton are dominated by Bacillariophyta (diatoms), Cyanophyta (cyanobacteria), Chrysophyta (golden-brown algae) and Chlorophyta (green algae). Zooplankton are comprised of cladocerans (52 to 86% of biomass), copepods and rotifers, and benthic invertebrates are predominantly comprised of benthic copepods and chironomid larvae. Smaller numbers of hydracarina, nematodes, oligochaetes, ostracods, pelecypods and turbellarians are also observed. Fish populations present in Lake C3 and Carat Lake are comprised mainly of lake trout, round whitefish and Arctic char (data from a 1999 survey [RL&L, 2000]).

4.0 POTENTIAL FOR TOXICOLOGICAL EFFECTS ASSOCIATED WITH TDS

Evaluations of TDS with respect to potential for toxicological effects are complicated by the fact that they generally rely on laboratory data from toxicity tests with individual ion pairs (i.e., salts). Data from each of these tests must be considered in the context of the possibility that the toxicity was caused by one or other of the pair of ions, or some combination of the two. Furthermore, extrapolation of these effects data to mixtures of all seven of the major ions is complicated by the potential for interaction of the ions with one another. In some cases, the combined presence of multiple ions can reduce the toxicity of individual ions (Mount et al, 1997); however, the combined presence of multiple ions increases the overall ionic strength of the water, and may result in toxicity in cases where the individual ions would not have, if tested alone.

4.1 Anionic contributors to TDS

Sulphate

There are currently no Canadian or USEPA guidelines for the protection of aquatic life for sulphate; however, the BC Ministry of Water Land and Air Protection has established a water quality criterion for this parameter of 100 mg/L (BCMELP, 2000). This guideline is primarily based on sensitivity data for *Hyalella azteca*, a freshwater amphipod, and aquatic mosses.

The BC criteria document for sulphate contains a significant amount of toxicity data that are not published elsewhere; these data were generated in support of the guideline derivation. A subset of these results which are of particular relevance to Jericho have been summarized in Table 2. Although amphipods such as *H. azteca* would not be expected to occur in these lakes, the data for this species have also been included in Table 2 because of the reliance of the guideline on data from this species.

Adverse effects on the cladocerans *Ceriodaphnia dubia* and *Daphnia magna*, the chironomid *Chironomus tentans*, the salmonid *Oncorhynchus mykiss* and the unicellular alga *Selenastrum capricornutum* occurred at substantially higher concentrations than the maximum sulphate concentrations projected in the PKCA of 380 mg/L (i.e., not allowing for any dilution by lakes downstream of the discharge point). Concentrations of sulphate in the PKCA are expected to exceed the lowest effect value presented for *H. azteca*; however, it should be noted that the sensitivity of this species to sulphate is highly hardness dependant, and the toxicity of sulfate is more than an order of magnitude lower at a hardness of 100 mg/L than it is at a hardness of 25 mg/L. Moreover, elevated sulphate concentrations in discharges from the Jericho mine will co-occur with higher hardnesses: for example, at a sulphate concentration of 205 mg/L (the LC50 for *H azteca* in 25 mg/L hardness water), we would anticipate that the discharge would have a hardness of more than 700 mg/L. Thus, even if *Hyalella* were present, we would not anticipate observing adverse effects on survival, and it would appear that the BC criterion for this parameter is overly protective in this instance.

The only other adverse effect data reported in the BC criteria document that were reported at concentrations below the maximum sulphate concentration predicted in the PKCA under average precipitation conditions (380 mg/L) were for larval striped bass (*Morone saxatilus*) which exhibited a 96-hr LC50 of 250 mg/L SO_4; this species does not occur in the receiving environment at the Jericho mine. In addition, evidence has been reported of adverse effects on aquatic mosses, in particular *Fontinalis antipyretica*, at concentrations of sulphate as low as 100 mg/L (Frahm, 1975, cited by BCMELP, 2000); however, these tests were apparently conducted using potassium sulphate rather than sodium sulphate, and it is likely that any observed effect was related to the potassium co-ion rather than to sulphate.

Thus, on the basis of a "worst case" analysis, it would appear that adverse effects associated with elevated concentrations of sulphate would not be likely to occur, even within the PKCA. Furthermore, given the 50-fold dilution available in Lake C3, projected sulphate concentrations in the receiving environment should be well under any known thresholds for toxicity.

Table 2. Effects concentrations for sulphate for selected data generated as part of derivation of the BC criteria for this parameter.

	Species	Endpoint	Hardness (mg/L)	Effect concentration (mg/L SO_4)
Cladoceran	*C. dubia*	7-d reproduction IC25	100	1267
	D. magna	21-day reproduction IC25	100	883
		48 hr survival LC50	25	537
		48 hr survival LC50	100	6281
Amphipod	*H. azteca*	96-hr survival LC50	25	205
		96-hr survival LC50	100	3711
		96-hr survival LC50	250	6787
Chironomid	*C. tentans*	96-hr survival LC50	25	6667
Salmonid	*O. mykiss*	96-hr survival LC50	25	5000
		7-day embryo EC25	100	1280
Alga	*S. capricornutum*	72-hr IC25	NR	2210

NR = Not reported

Chloride

The USEPA has established an ambient water quality criterion for chloride of 230 mg/L (USEPA, 1988). This value is based on laboratory toxicity tests using sodium chloride (NaCl). Chlorides of other co-ions (e.g., potassium, magnesium) are expected to exhibit a greater degree of toxicity; however, mixtures of ions are expected to exhibit lower overall toxicity than solutions of individual salts. Invertebrates were generally more sensitive to chloride than vertebrates, and *Daphnia* (a cladoceran) was the most sensitive genus evaluated.

There is currently no Canadian water quality guideline for chloride; however, Environment Canada have produced a report on use of road de-icing salts in which an HC_5 (the concentration that would be expected to protect 95% of the potentially exposed taxonomic groups) value of 212.6 mg/L chloride was reported (Environment Canada, 2001).

The BC water quality criterion for chloride is 150 mg/L (BCMWLAP, 2003). This was derived based on dividing data for the most sensitive species for which data were available (*C. dubia*) by a safety factor of five. The AMEC toxicity laboratory in Fife, Washington, uses sodium chloride as a reference toxicant in chronic tests with this cladocerans species. Based on the last twenty tests, a 50% reduction in reproductive output of *C. dubia* was observed at 1083 ± 329 mg/L NaCl (657 ± 200 mg/L Cl^-). Bailey et al. (2000) reported results for reference toxicant tests for the same species using potassium chloride (KCl) of 192 ± 23 mg/L (92 ± 11 mg/L Cl^-). The higher toxicity observed with the use of KCl, rather than NaCl, suggests that toxicity in the KCl tests was related primarily to the presence of potassium rather than chloride.

A risk assessment has recently been conducted for the Ekati mine in which a site-specific species sensitivity distribution was calculated for chloride for organisms that occur in the receiving environment (EVS, 2004). This approach involved calculating a threshold value designed to protect 95 percent of the species by extrapolation of the distribution of toxicity data for taxonomic groups (or reasonable surrogates) that occur in the community. It should be noted that this derivation relied largely on acute toxicity data, and used the acute to chronic ratio published in the EPA criteria document for this parameter to determine the chronic HC_5 from the acute HC_5. The acute and chronic values were 1369 and 180 mg/L chloride, respectively.

Cladocerans, in particular, *C. dubia*, are the most sensitive taxonomic group for which data are available. A substantial amount of data from the AMEC toxicity laboratory for *C. dubia* (n=20) indicates that the IC50 occurs at or above 257 mg/L chloride (i.e., two standard deviations less than the mean response) in 97.5% of the tests. Thus, the EPA and BC criteria values (230 and 150 mg/L, respectively), and the site-specific species sensitivity distribution conducted for Ekati (180 mg/L) appear to be protective of effects to this species.

Based on the site-specific value for chloride of 180 mg/L prepared for Ekati, concentrations in the PKCA (up to 650 mg/L) exceed effects levels for chloride by nearly 4-fold. However, these concentrations will be rapidly diluted to levels well below toxicity thresholds once the discharge reaches Lake C3.

Alkalinity (bicarbonate/carbontate)

The alkalinity in the water associated with discharge from the PKCA is relatively low even under worst-case scenarios and well-within the range tolerated by freshwater organisms. Consequently, no adverse effects associated with alkalinity would be anticipated.

4.2 Cationic contributors to TDS

Data used for assessment of chloride toxicity have generally been obtained from tests using sodium chloride. The effect concentrations associated with the USEPA and BC water quality criteria for chloride (230 and 150 mg/L chloride, respectively) and the chronic value from the risk assessment conducted for Ekati for this parameter (180 mg/L chloride) correspond to sodium concentrations of 149, 97 and 115 mg/L, respectively. These values exceed the maximum sodium concentration in the PKCA, indicating that no toxicological effects would be associated with the concentrations of sodium in the discharge.

As described in the section above with regard to chloride, laboratory reference toxicant tests with potassium chloride (Bailey et al., 2000) were more sensitive than data for sodium chloride (AMEC laboratory, unpublished data) by a factor of seven when presented on the basis of chloride. This suggests that potassium is primarily responsible for toxicity in *C. dubia* tests with KCl; the 50% effect concentration in these tests calculated on the basis of potassium was 100 ± 12 mg/L.

The US EPA Ecotox database was reviewed for other toxicity data associated with exposure to potassium chloride. The lowest reported 50% effect value was 61 mg/L, which was obtained from a 21-d survival and reproduction test using *D. magna* (Biesinger and Christensen, 1972). Concentrations of potassium in the PKCA (36 – 64 mg/L) will approach this most sensitive value under worst-case conditions.

Biesinger and Christensen (1972) also reported 21-d EC50 estimates for calcium (220 mg/L Ca^{2+}) and magnesium (125 mg/L Mg^{2+}) for *D. magna*, which were also the most sensitive values reported in the US EPA Ecotox database for their corresponding chloride salts. Concentrations of calcium in the PKCA (101 – 202 mg/L) will approach this effect level for calcium; concentrations of magnesium in the PKCA (175 – 206 mg/L) will exceed the value for magnesium by a maximum factor of 1.6.

Collectively, these data indicate that cladocerans, such as *D. magna* and *C. dubia*, are among the most sensitive species to elevated concentrations of major cations, and that the concentrations of major cations in the PKCA may approach or exceed those associated with adverse effects under worst-case conditions. However, even under worst-case concentrations, a two- to three-fold dilution of the cationic components of TDS present in the PKCA should be sufficient to remove the risk of adverse toxicological effects in the receiving environment.

4.3 Ion ratios

The ratios of cations present in the discharge are somewhat unusual. In natural waters, calcium concentrations typically exceed magnesium, and sodium typically exceeds potassium. However, the reverse is true in the case of this discharge. Calcium to magnesium ratios in natural waters typically range from 1.6:1 to 8:1 (Naddy et al., 2002) on a mass-balance basis. Conversely, in this discharge the ratios will range from approximately 1:1 to 1:2. Potassium is generally present at low concentrations in surface waters and generally well below the concentration of sodium (Stumm and Morgan, 1981), whereas in the discharge from the PKCA, potassium concentrations exceed sodium by up to a factor of two.

It should be noted that the fact that ratios between specific ions are somewhat different than most natural waterbodies does not imply that adverse effects would result. For example, at the EC50 for KCl reported by Biesinger and Christensen (1972) for *D. magna*, the sodium to potassium ratio was 1:60. Thus, this species was able to survive and reproduce normally in waters with potassium concentrations exceeding sodium by a considerable margin.

In general, the ratios of calcium to magnesium and sodium to potassium do not exceed a factor of two and, therefore, it would be unlikely that adverse toxicological responses would occur as a result.

4.4 Other effects

The lake systems associated with the Jericho Diamond mining project are very low in productivity, largely as a result of cold temperatures and low concentrations of nutrients. Consequently, the types of species that can occur in these lakes and their abundances are limited. Increasing the concentration of dissolved solids may result in improved production of some species, which may result in a change in the balance of species that are present; however, these effects are not associated with toxicology but, rather, ecology. While data are available on the response of oligotrophic systems to nutrient enrichment, there is limited information that can be used to reliably predict changes to community structure that are likely to result in response to an increase in TDS. Regardless, the concentrations of TDS predicted in the receiving environment, while different from those currently present in these lakes, are well within those associated with water bodies supporting healthy aquatic ecosystems.

5.0 DIFFERENCES IN CLADOCERAN POPULATIONS OBSERVED IN THE LONG LAKE CONTAINMENT FACILITY, EKATI MINE

A study conducted at the Ekati mine in 2003 demonstrated that cladoceran populations tended to increase with distance from the discharge (Rescan, 2004). In particular, larger populations of cladocerans were observed in Cell E relative to Cell D within the Long Lake Containment Facility. Because cladocerans are relatively sensitive to elevated concentrations of TDS, it is worthwhile evaluating whether this difference could have been related to elevated concentrations of TDS.

Samples from Cell D collected in the summer of 2003 had mean values of approximately 40 mg/L sulphate and 123 mg/L TDS. While these values were higher than those observed in Cell E (approximately 25 mg/L sulphate and 65 mg/L TDS), they are well within the range of tolerance of cladocerans for these parameters. In fact, standardized laboratory reconstituted water for culturing *C. dubia* and *D. magna* is typically prepared to moderately hard standards of 80 – 100 mg/L as $CaCO_3$, and involves addition of more than 200 mg/L of various salts, incorporating more than 80 mg/L of sulphate (USEPA, 2002). Thus, standardized culture water for two sensitive cladoceran species contains higher concentrations of sulphate and overall TDS than that observed in Cell D in the Long Lake Containment Facility. Thus, it appears highly unlikely that differences in cladoceran populations observed between Cell D and Cell E in the 2003 monitoring program at Ekati were a result of toxicological responses to sulphate or TDS.

It should be noted that the differences in community composition observed between Cell D and Cell E in Long Lake at Ekati were only measured on one occasion in 2003. Thus, the differences observed on that occasion may be related to the patchiness or temporal variability inherent in zooplankton populations. Alternatively, they could also be related to the presence of a trace contaminant associated with the discharge or an ecological shift in the balance of the populations associated with nutrient enrichment.

6.0 SUMMARY

From the available toxicity data for TDS and the projected dilution rates available in Lake C3 and Carat Lake, it appears highly unlikely that TDS associated with discharge from the PKCA pond will result in toxicological effects on organisms in the receiving lakes. Conservatively, a three-fold dilution of the effluent under average discharge conditions and a four-fold dilution under worst-case discharge conditions should provide sufficient dilution to remove the risk of any toxicological effects associated with the major ions contributing to TDS, and result in a TDS values of approximately 400 mg/L.

7.0 REFERENCES

Biesinger, K.E. and Christensen, G.M. 1972. Effect of various metals on survival, growth, reproduction and metabolism of *Daphnia magna*. J. Fish. Res. Bd. Canada 29:1691-1700.

Bailey, H.C., Krassoi, R., Elphick, J.R., Mulhall, A., Hunt, P., Tedmanson, L. and Lovell, A. 2000. Application of *Ceriodaphnia dubia* for whole effluent toxicity tests in the Hawkesbury-Nepean watershed, New South Wales, Australia: method development and validation. Environ. Toxicol. Chem. 19:88-93

BCMWLAP. 2003. Ambient Water Quality Guidelines for Chloride. Overview Report. British Columbia Ministry of Water Land and Air Protection, Victoria, BC.

BCMELP. 2000. Ambient Water Quality Guidelines For Sulphate. Technical Appendix. British Columbia Ministry of Environment, Lands and Parks, Victoria, BC.

EVS. 2004. Tier I Ecological Risk Assessment for Chloride. Prepared for BHP Billiton Diamonds Inc. by EVS Environment Consultants Ltd. April 2004.

Mount, D.R., Gulley, D.D., Hockett, J.R., Garrison, T.D., Evans, J.M. 1997. Statistical models to predict the toxicity of major ions to *Ceriodaphnia dubia*, *Daphnia magna* and *Pimephales promelas* (fathead minnows). Environ. Toxicol. Chem. 16:2009–2019.

Naddy, R.B., Stubblefield, W.A., May, J.R., Tucker, S.A. and Hockett, J.R.2002. The effect of calcium and magnesium ratios on the toxicity of copper to five aquatic species in freshwater. Environ Toxicol Chem 21:347–352.

Rescan. 2004. Data Report on Water Quality, Phytoplankton and Zooplankton in the Long Lake Containment Facility, July – September 2003. Prepared for BHP Billiton Diamonds Inc. by Rescan Environmental Services Ltd. January 2004.

RL&L. 2000. Jericho Diamond Project Aquatic Studies Program (1999). Prepared for Tahera Corporation by R.L.& L. Environmental Services Ltd. March 2000.

SRK. 2004. Site Water Management. Report to Tahera Corporation, June 2004. *In prep.*

Stumm, W. and Morgan, J.J. 1981. Aquatic Chemistry. John Wiley & Sons. New York. 780 p.

USEPA. 2002. Short-term methods for estimating the chronic toxicity of effluents and receiving water to freshwater organisms, 4th ed. EPA 821-R-02-013. Washington, DC.

USEPA. 1988. Ambient water quality guidelines for chloride. EPA-440-5-88-001 Washington, DC.