MINISTRY OF ENVIRONMENT AND PARKS
PROVINCE OF BRITISH COLUMBIA

OKANAGAN AREA
CAHILL CREEK AND ITS TRIBUTARIES
WATER QUALITY ASSESSMENT AND OBJECTIVES

TECHNICAL APPENDIX

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1. INTRODUCTION

1.1 BACKGROUND

The Ministry of Environment and Parks is preparing water quality assessments and objectives in priority water basins. This technical appendix describes the water quality within the Cahill Creek watershed, based upon data collected since 1983 by the proponent for a mining development (Mascot Gold Mines Limited).

Cahill Creek is a tributary to the Similkameen River (see Figure 1), a water body for which provisional water quality objectives have been developed[3]. Cahill Creek enters the Similkameen River from the east, about three kilometres south from Hedley. Water quality objectives, and designated water uses for Cahill Creek, must be such that designated water uses and provisional water quality objectives for the Similkameen River are not compromised.

Cahill Creek is about nine kilometres in length, with a drainage area of about 25 km^2. Sunset Creek is a tributary which meets Cahill Creek about five kilometres upstream from the Similkameen River. Just upstream from this junction, Nickel Plate Mine Creek joins Sunset Creek. Red Top Gulch Creek is a creek to the north from Cahill Creek, and a tributary to the Similkameen River. Cahill Creek and its tributaries are "fed by springs in the headwater area as well as along the slopes flanking the water-courses"[1].

1.2 PROVISIONAL WATER QUALITY OBJECTIVES - BASIC PHILOSOPHY

Water quality objectives are established in British Columbia for water-bodies on a site-specific basis[2]. The objective can be a physical, chemical or biological characteristic of water, biota or sediment, which will protect the most sensitive designated water use at a specific location with an adequate degree of safety[2]. The objectives are aimed at protecting the most sensitive designated water use with due regard to ambient water quality, aquatic life, waste discharges and socio-economic factors[2].

Water quality objectives are based upon working water quality criteria which are characteristics of water, biota, or sediment[2] that must not be exceeded to prevent specified detrimental effects from occurring to a water use[2]. The working criteria upon which the proposed provisional objectives are based come from the literature, and are referenced in the following chapters. The B.C. Ministry of Environment and Parks is in the process of developing criteria for water quality characteristics throughout British Columbia, to form part of the basis for permanent objectives.

As a general rule, objectives will only be set in reaches where man-made influences threaten a designated water use, either now or in the future. Provisional objectives proposed in this report are to be reviewed as more monitoring information becomes available and as the Ministry of Environment and Parks establishes water quality criteria.

2. WASTE DISCHARGES

There are no operations discharging effluents to Cahill Creek or its tributaries. A proposed operation, Nickel Plate Mine, has been discussed in detail in reference 1. Some of the more relevant information about this operation from reference 1 is reproduced below.

2.1 NICKEL PLATE MINE PROJECT

The Nickel Plate Mine is 42 kilometres west from Penticton and about 19 kilometres by road east from Hedley. Mining and milling of gold ore at and near this site began in 1904, with the final mine shutdown in 1955, when all the physical plant was removed or destroyed. Mascot Gold Mines Limited plans to mine in the same general area. Recovered minerals in the past have included gold, silver and copper.

"The main sulphide minerals are pyrrhotite, arsenopyrite, pyrite, chalcopyrite, and sphalerite"[1]. Other minerals include magnetite, native copper, scheelite, pyrargyrite, galena, molybdenite, and breithauptite[1].

Mascot Gold Mines plans to "employ standard open-pit mining methods utilizing drilling, blasting, loading and hauling"[1]. Blasting will use ANFO (ammonium nitrate/fuel oil). "Underground mining is not planned to begin until at least one year after the start-up of open pit operations"[1]. The open-pit will be an elongated "S" shape, about 1200 m long, 300 m wide, 200 m deep, with 60° side slopes.

2.1.1 MILLING PROCESS

The plant will process 2 450 tonnes per day. Ore will be crushed to <150 mm with a jaw crusher, to < 15 mm with a head cone crusher, subsequently to be transferred to the uncovered crushed ore stockpile. From the crushed ore stockpile, ore will be ground in a rod mill, ball mill, and three pebble mills, followed by hydrocyclone classifiers, with the cyclone overflow being pre- aerated. Following thickening, the pulp will be washed using dewatering drum filters, with the filter cake being re-pulped prior to the first stage of cyanidation. After leaching with cyanide solution the pulp would then be fed to cyanide filters, the filtrate from which would be pregnant solution. The filter cake would be re-pulped, subjected to further agitation leach, filtered using drum filters, with the filtrate pumped to the pregnant solution tank. The filter cake, which will be the final tailing, will be re-pulped with treated cyanide solutions prior to discharge to the tailings pond. Gold is to be extracted from the pregnant solution using the Merrill-Crowe/zinc precipitation/ refining processes to produce dore bars. Tailings from the mineral processing circuit are to be conveyed to the tailings pond by a gravity pipeline.

The principal reagents to be used(1) are as follows:

Reagent	Consumption (kg/tonne of ore)
Sodium cyanide	1.38
Lime	2.68
Muriatic acid (HCl solution)	0.05
Lead Nitrate	0.005
Flocculent	0.02
Zinc dust	0.03
Filter Aid	0.025

It is likely that consumption rates will fluctuate, depending upon the grade of the ore.

2.1.2 EFFLUENT TREATMENT

It is proposed that effluents with cyanide will be treated using the SO_2/air or hydrogen peroxide processes. Clear solutions resulting from the filtration of the pulp will be treated, prior to being combined with washed solids and discharged to the tailings pond. The supernatant from the tailings pond is to be returned to the mill, and no discharge, other than seepage, is anticipated from the pond(1).

The SO_2/air process will use three reactors in series to minimize short-circuiting , each with a 30-minute retention time. Air and SO_2 are dispersed as a fine stream of gas bubbles in the effluent converting free cyanide to thiocyanate which is relatively non-toxic. Lime is added to control pH, as required. Copper sulphate crystals are used as a catalyst in the first reactor. Although laboratory tests indicate that arsenic and free cyanide would be reduced to less than 1 ppm, Macot Gold Mines Limited speculates that these concentrations would be 5 to 10 ppm under operating conditions[(1)]. Projected reagent requirements are 1.38 kg/t SO_2, 0.5 kg/t lime and 0.825 kg/t $CuSO_4$, or less. Consideration is also being given to using hydrogen peroxide as the primary treatment reagent instead of using the SO_2/air process.

The tailings pond will be located 1200 m southeast from the open pit mine. A drainage blanket is to be incorporated into the downstream half of the starter dam for seepage control. Other seepage control measures will include a barrier of pumping wells along the downstream toe of the tailings impoundment, and a drainage collection ditch. Water from the pumps could be used as fresh make-up water, or recycled (with ditch water) to the tailings impoundment. Water from the tailings impoundment will be recycled to the mill.

Drainage water would originate in the open pit and underground mining areas, the waste rock stockpile, as seepage from the tailings pond, and as runoff from above and around the tailings pond.

The waste rock stockpile has little potential for acid generation[(1)]. However, runoff from it could be contaminated with nitrate, nitrite and ammonia from blasting and arsenic from the ore. Due to the permeable nature of the gravels located at the toe of the waste rock stockpile, no discharge to surface waters is expected by the company. A collection well has to be drilled so that seepage through the gravels can be pumped to the mill. Runoff is to be diverted from above the waste rock dump past the collection dam. The operation will usually be short of water, although water excesses could exist in the May through August period (average surplus flow of 0.033 m^3/s) which could necessitate some discharges.

2.1.3 MUNICIPAL-TYPE WASTE

Combustible and domestic solid waste will be hauled to Penticton for disposal at a landfill site. Sewage will be treated in septic tanks and discharged to the tailings pond.

2.1.4 RECLAMATION

After permanent shut-down, Mascot Gold Mines Ltd. has indicated it will remove all physical structures; regrade and vegetate the tailings pond, dam, and waste rock storage area; construct stormwater runoff diversion channels around the tailings pond; and construct a permanent spillway on or adjacent to the tailings pond, if necessary.

3. HYDROLOGY

Flows in Cahill Creek (Table 1) ranged from 0.033 m^3/s to 0.675 m^3/s in 1983 and from 0.006 m^3/s to 0.362 m^3/s in 1984 at the proposed location of the tailings pond. The average flow over both years was 0.166 m^3/s. Flows ranged from 0.024 m^3/s in October 1985 to 0.116 m^3/s in June 1985 (Table 2), with an average of 0.046 m^3/s. Since the drainage area at this point is about 15.6 km^2 and the total estimated drainage area at the Similkameen River is about 25 km^2, it is projected that the average flow into the Similkameen River based upon the more complete 1983/1984 data set would be about 0.245 m^3/s.

Flows in Nickel Plate Mine Creek (Table 1) ranged from 0 m^3/s to 0.090 m^3/s (mean flow of 0.006 m^3/s) in 1983/1984 and 0.007 m^3/s to 0.032 m^3/s (mean 0.018 m^3/s) in 1985. Those in Sunset Creek ranged from 0.002 m^3/s to 0.227 m^3/s (mean flow of 0.066 m^3/s) in 1983/1984 and 0.011 m^3 to 0.116 m^3/s (mean 0.035 m^3/s) in 1985 (Table 2).

Based on historical data for Hedley Creek, it is likely that maximum flows occur in May or June, yearly, as a reflection of snowmelt. Minimum flows likely occur under ice cover, from January through March.

4. WATER USES

Mascot Gold Mines Ltd. performed electrofishing at four pools in Cahill Creek downstream from highway #3. Rainbow trout, longnose dace and sculpin were found. No fish were encountered upstream from the highway or near the proposed tailings pond, although habitat at these locations was acceptable. The stream grade in Cahill Creek increases substantially upstream from the highway crossing, with a large number of small falls. The Fisheries Branch (Penticton) has indicated that improving Cahill Creek for fisheries is a low priority.

On Cahill Creek, one licensed water withdrawal exists for the use of 1 147 140 m^3/year for irrigation by the Chuckuwayha Indian Reserve #2. This licensed quantity also includes water which can be withdrawn from Winters Creek, a tributary to the Similkameen in the next southerly watershed adjacent to the Cahill Creek drainage. The irrigated land consists of rubble, gravelly sandy loam, and sandy loam, the latter being coarse textured with a high pH[10].

It is not known if there are any water withdrawals along Cahill Creek for human consumption, since domestic water users withdrawing small quantities do not require a water licence. It will be assumed that some use of Cahill Creek is or will be made for drinking water. Conversely, due to the isolated location of Sunset and Nickel Plate Mine Creeks, it will be assumed that no domestic consumption of these waters will occur. Mascot Gold Mines Limited does have a water license on Sunset Creek for 295 m^3/d for mining purposes.

Designated water uses in the Similkameen River have to be protected. These uses are for drinking water, aquatic life, wildlife, recreation, livestock and irrigation[3]. It seems reasonable that Cahill Creek should also have suitable quality water for wildlife. Recreation is not likely to be a use. Some of the irrigation water licensed for withdrawal is withdrawn from Cahill Creek just upstream from the highway. However, some is also diverted to Red Top Gulch. Therefore irrigation can be of concern throughout most of Cahill Creek. Cattle grazing near the mining operation "is considered an important facet of local terrain use"[1].

Designated water uses will apply to the entire length of Cahill Creek or to that reach downstream from the highway (#3) crossing. Designated water uses for all of Cahill Creek include drinking water (with filtration or equivalent plus disinfection), wildlife, livestock, and irrigation. Designated water uses for that reach downstream from the highway (#3) crossing also include protection of aquatic life.

Designated water uses in Sunset and Nickel Plate Mine Creeks will be for protection of wildlife, and livestock watering. In Red Top Gulch, designated water uses will be wildlife, livestock watering, drinking water (filtration or equivalent plus disinfection) and irrigation. In addition, downstream from the highway #3 crossing, aquatic life should also be protected.

5. AMBIENT WATER QUALITY

Mascot Gold Mines Limited sampled Nickel Plate Mine Creek, Sunset Creek and Cahill Creek in 1983 and 1984, and at some new sites in 1985. Red Top Gulch Creek was sampled in 1985 just upstream from the highway crossing.

Cahill Creek was sampled upstream (site #1-Table 2) from the confluence of Sunset and Nickel Plate Creeks, just downstream from the proposed tailings impoundment (site #2-Table 2) and just upstream from the highway crossing (site #3- Table 2). Site #2 on Cahill Creek had also been used in the earlier sampling.

Sampling sites used in 1983 and 1984 in the upper reaches of Sunset and Nickel Plate Mine Creeks were abandoned in favour of sites on these creeks just prior to their confluence.

It is expected that ambient water quality in Cahill Creek could be affected by seepage from the tailings impoundment or discharges from the settling basin. Nickel Plate Mine Creek could be affected by runoff from the waste rock stockpile. Red Top Gulch Creek might also be affected by discharges from the settling basin. Sunset Creek might be affected by general activities near the creek.

5.1 pH AND ALKALINITY

From 1983 to 1985 (Tables 1 and 2), Cahill Creek had a pH range from 6.4 to 8.0, Sunset Creek had a range of values from 6.5 to 7.6, Nickel Plate Mine Creek had a range of values from 7.2 to 8.0, and values in Red Top Gulch Creek ranged from 7.6 to 8.0. Values for pH increased along the length of Cahill Creek. Lower pH values were usually found in the upper reaches of the creeks.

Although acid generation tests indicate that acid mine drainage should not be a problem, proper blending of the waste rock in the pile is necessary to ensure that acid generating materials are not concentrated in one location.

Working water quality criteria for pH for the protection of aquatic life, and for use of the water for drinking are 6.5 to 9.0[4] and 6.5 to 8.5[5], respectively. In order to protect the waters of Cahill Creek, Red Top Gulch Creek, and Nickel Plate Mine Creek from the influence of the mining operation, an objective is proposed for pH. In Red Top Gulch Creek, it will apply along the length of the creek. In Cahill Creek, it will apply along the length of the creek, exclusive of the initial dilution zone of the tailings impoundment. In Nickel Plate Mine Creek, it will apply along the length of the creek, exclusive of the initial dilution zone of the waste rock pile. The initial dilution zone will extend up to 100 m below the point of input from the waste rock pile or the toe of the tailings impoundment. In Nickel Plate Mine Creek, the initial dilution zone will be between the toe of the waste rock dump and the sampling site above the confluence with Sunset Creek. The objective is that the pH should be in the range 6.5 to 8.5. This range is applicable to discrete samples collected outside the initial dilution zones.

This objective is the same as exists for the Similkameen River, and should usually be achievable in all the creeks.

The alkalinity of the creeks was considerable, with mean values of about 65 mg/L in Cahill Creek, 30 mg/L in Sunset Creek, and 100 mg/L in Nickel Plate Mine Creek (Table 1). These levels could provide some buffering to acidic inputs.

5.2 HARDNESS AND METALS

Hardness values increased along the length of Cahill Creek, with a maximum value in 1985 of 106 mg/L at Site 3 (Table 2). Nickel Plate Mine Creek had more hardness and Sunset Creek less hardness than Cahill Creek as a whole. Red Top Gulch Creek was slightly harder than Nickel Plate Mine

Creek. Hardness can be an important characteristic in reducing the acute toxicity of certain metals.

Arsenic is a metalloid which can be expected to be liberated as a result of the milling process due to the presence of arsenopyrite. The company reported the following range of dissolved arsenic values for mine drainage water from three old adits during 1983/1984.

Dissolved Arsenic Values in Mine Drainage Water (mg/L)

Adit	Maximum	Minimum	Mean
Bulldog	0.273	0.049	0.202
A	1.109	0.052	0.548
3750	1.181	0.019	0.801

In 1983 and 1984 the dissolved fractions of arsenic were as high as 0.008 mg/L in Cahill Creek, 0.005 mg/L in Sunset Creek, and 0.003 mg/L in Nickel Plate Mine Creek (Table 1). Maximum dissolved values in 1985 were 0.04 mg/L, 0.010 mg/L and 0.005 mg/L, respectively (Table 2). The maximum value in Red Top Gulch Creek was 0.017 mg/L. The working water quality criterion for total arsenic is 0.05 mg/L to protect drinking water supplies, aquatic life and recreation[4]. In order to protect the designated water uses in Cahill Creek and Red Top Gulch Creek, a water quality objective is proposed for arsenic. The objective will apply to the entire length of Red Top Gulch Creek and Cahill Creek, exclusive of the initial dilution zones described in Section 5.1. The proposed objective is that the maximum total arsenic concentration in any discrete sample should not exceed 0.05 mg/L. In Nickel Plate Mine Creek, designated uses are wildlife and livestock. Livestock are able to consume as much as 0.5 mg/L arsenic; however, no criteria were proposed by Environment Canada for wildlife[8]. Therefore in Nickel Plate Mine Creek, the maximum total arsenic concentration should not exceed 0.5 mg/L.

Dissolved aluminum values were measured in 1983 and 1984. The means of values greater than the detection limit of 0.01 mg/L were 0.22 mg/L in Cahill Creek, 0.47 mg/L in Sunset Creek, and 0.01 mg/L in Nickel Plate Mine

Creek (Table 1). These data suggest that the high dissolved aluminum values were associated with Sunset Creek drainage, since coincident values were not measured on Nickel Plate Mine Creek. Sunset Creek receives drainage from areas where waste rock from a former operation (the Canty Mine) was placed. The high values in Cahill and Sunset Creeks were recorded in April and May of 1983, and May 1984. Flows in the creeks at those times were high. Presumably, the high dissolved aluminum values were associated with acidic conditions and snowmelt or mine drainage from previous workings, and the release of aluminum from the waste rock piles.

Working water quality criteria[6] for aluminum between pH 4.4 and 7.0 to protect aquatic life can be calculated from:

Total Aluminum (mg/L) = $e^{(0.66 \exp 0.34 \text{ pH})-8.3}$

Thus, working criteria would range from 0.083 mg/L at pH 6.4, to 0.30 mg/L at pH values between 7.0 and 8.5[6].

If aluminum is used with the ammonium nitrate/fuel oil blasting compound to increase its explosive strength, aluminum values in Nickel Plate Mine Creek or Cahill Creek could be increased. Working water quality criteria to protect irrigation and livestock watering are 5 mg/L[16]. Since these criteria are extremely high compared to the aquatic life criterion which is appropriate to protect the designated use at the mouths of Cahill Creek and Red Top Gulch Creek, the following provisional objective is proposed. <u>In Cahill and Red Top Gulch Creeks below the highway #3 crossings, total aluminum should not exceed 0.30 mg/L if the pH is between 7.0 and 8.5. For lower pH values, total aluminum should not exceed the value calculated from the formula $e^{(0.66 \exp 0.34 \text{ pH})-8.3}$</u>.

Higher aluminum values have been recorded near the mine site. In such situations, aluminum should not be increased in the surface waters due to the mining activities. Upstream concentrations in Cahill Creek should be calculated from:

$$Al_C = \frac{(Al_{NP} \times F_{NP}) + (Al_S \times F_S) + (Al_{CA} \times F_{CA})}{(F_{NP} + F_S + F_{CA})}$$

where: Al_C = Aluminum concentration calculated for the upstream location in Cahill Cr.

Al_{CA} = Aluminum concentration measured in Cahill Cr. upstream from the Sunset Creek confluence.

Al_{NP} = Aluminum concentration measured in Nickel Plate Mine Cr. near its mouth.

Al_S = Aluminum concentration measured in Sunset Cr. at mouth.

F_{NP} = Flow in Nickel Plate Mine Cr. near its mouth.

F_s = Flow in Sunset Creek at mouth.

F_{CA} = Flow in Cahill Creek upstream from Sunset Creek.

When upstream values in Cahill Creek exceed the aforementioned proposed provisional objectives, there should be no significant increase over upstream values. To take into account vagaries of sampling and analytical precision and accuracy, values below the highway #3 crossing on Cahill Creek should increase by less than 20% of upstream values. This percentage increase is meant to define the practical level above which the water quality objective will be considered as not having been achieved.

Dissolved boron values in all three creeks were low and below the detection limit of 0.005 mg/L (Table 1). Some detectable boron levels were found in drainage water from old mine adits, with the maximum concentration being 0.115 mg/L[1]. This is well below the most restrictive working water quality criterion for total boron of 0.75 mg/L which is for continuous irrigation use on all soils. Therefore, no objective will be proposed for boron, even though it can be released from the ores, since levels are expected to be well below criteria in the receiving waters.

Dissolved cadmium values in Sunset, Cahill, Red Top Gulch and Nickel Plate Mine Creeks were all less than varying detection limits, the lowest limit being 0.0005 mg/L in 1985 (Table 2). Some detectable dissolved cadmium levels were found in drainage waters from old mine adits, the maximum concentration being 0.036 mg/L. This indicates that cadmium can be released through weathering of the waste rock stockpile, or possibly through the milling process. Working water quality criteria for receiving waters for total cadmium are 0.005 mg/L for drinking water(14), 0.01 mg/L for irrigation, 0.0002 mg/L for aquatic life, and 0.02 mg/L for livestock watering(8). Insufficient information precluded the formulation of working water quality criteria to protect wildlife(8). To protect livestock which might use Nickel Plate Mine Creek, a provisional objective of a maximum concentration of 0.02 mg/L total cadmium is proposed. In Cahill and Red Top Gulch Creeks, two objectives are proposed, one to protect aquatic life downstream from the highway #3 crossings, and a second in the remainder of the streams to protect drinking water, irrigation and livestock water. Downstream from the highway #3 crossings the maximum total cadmium should not exceed 0.0002 mg/L, while in the remainder of Cahill and Red Top Gulch Creeks the maximum total cadmium value should not exceed 0.005 mg/L. In order to maintain the level of 0.0002 mg/L near the mouth of Cahill and Red Top Gulch Creeks, it likely will be necessary to maintain values lower than 0.005 mg/L in Cahill and Red Top Gulch Creeks and 0.02 mg/L in Nickel Plate Mine Creek.

All dissolved copper values in all three creeks were less than the detection limit of 0.00[illegible] mg/L (Table 1) in 1983 and 1984. In 1985 (Table 2), maximum copper values were 0.004 mg/L in Red Top Gulch Creek, 0.005 mg/L in Nickel Plate Mine Creek, 0.003 mg/L in Sunset Creek and 0.005 mg/L in Cahill Creek.

Copper is a mineral which has been extracted in the past from this ore body(1). Therefore it is likely that copper will be released from the waste rock stockpile and in the milling processes. Recent working water quality criteria are 0.002 mg/L total copper to protect aquatic life and wildlife, 0.2 mg/L for irrigation, 0.5 mg/L for drinking water, and 1 mg/L for livestock watering(8).

Recent EPA criteria(7) for copper to protect aquatic life use the formulae: $e^{(0.905\ (\ln \text{hardness})-1.785)}$ to calculate average values and $e^{(0.905\ (\ln \text{hardness})-1.413)}$ to calculate maximum values. For the minimum hardness values of 38 mg/L in Cahill Creek and 65 mg/L in Nickel Plate Mine Creek (Table 1), the calculated average and maximum values are 0.005 mg/L and 0.007 mg/L, and 0.007 mg/L and 0.011 mg/L total copper, respectively in Cahill and Nickel Plate Mine Creeks. These formulae were used in preparing water quality objectives to protect wildlife and aquatic life in the Similkameen River(3). A draft criterion to protect wildlife is 0.3 mg/L(24). These levels will be used for the development of objectives for Cahill Creek. The hardness in Red Top Gulch Creek was not measured before 1985, and in 1985 only a limited number of measurements were made. Therefore for the purpose of discussion it will be assumed that hardness regimes for Cahill Creek will be applicable to Red Top Gulch Creek, as will the copper criteria.

A water quality objective seems appropriate for copper due to the potential for copper to enter Nickel Plate Mine Creek from the waste rock pile, Red Top Gulch Creek from overflows from the settling basin, and Cahill Creek from the tailings impoundment. In Nickel Plate Mine Creek, the proposed water quality objective for copper to protect wildlife is that the maximum value should not exceed 0.3 mg/L, total copper. In Cahill Creek and Red Top Gulch Creek, below the highway crossing, due to the softer nature of the water, the proposed copper objective is that the maximum value should not exceed 0.007 mg/L and the average 0.005 mg/L. In addition in Cahill Creek, should values upstream from the tailings impoundment exceed these values, no significant increase in copper should occur. In order to account for vagaries of sampling and laboratory precision and accuracy, the "no significant increase" will be defined as no increase greater than 20% from upstream to downstream. This increase is meant as the practical level above which the objective will be considered to be exceeded. In Cahill Creek and Red Top Gulch Creek upstream from the highway crossing, the criterion of 0.2 mg/L for irrigation will be the provisional objective.

These objectives apply to any discrete samples collected from outside the initial dilution zones, described in Section 5.1. The average value is to be calculated from five samples collected weekly in a period not to exceed thirty days.

Dissolved iron values were fairly low, with maximum values in Cahill, Sunset, Red Top Gulch, and Nickel Plate Mine Creeks being less than 0.3 mg/L. The working water quality criterion to protect drinking water is 0.3 mg/L[14]. No criteria are available related to the protection of wildlife so, until such information is available, it will be assumed that drinking water criteria will protect wildlife and livestock. Since iron is present in many of the sulphide ores being milled, a provisional water quality objective is proposed for dissolved iron in Cahill Creek and Red Top Gulch Creek to protect drinking water supplies and in Nickel Plate Mine Creek to protect wildlife. The objective is that the maximum dissolved iron concentration should not exceed 0.3 mg/L. The objective applies to all of Cahill Creek and Nickel Plate Mine Creek, except the initial dilution zones described in Section 5.1.

Dissolved lead values have been as high as 0.06 mg/L in Cahill Creek, 0.04 mg/L in Sunset Creek and 0.03 mg/L in Nickel Plate Mine Creek. Lead was not measured in Red Top Gulch Creek. Recent EPA criteria for total lead to protect aquatic life use the formulae: $e^{(1.34\ (\ln \text{hardness})-5.245)}$ to determine average concentrations and $e^{(1.34\ (\ln \text{hardness})-2.014)}$ to determine the maximum allowable total lead concentrations[7]. For the minimum hardness (Table 1) of 38 mg/L in Cahill Creek, 13 mg/L in Sunset Creek and 65 mg/L in Nickel Plate Mine Creek, the calculated average and maximum values are 0.0007 mg/L and 0.017 mg/L, 0.0002 mg/L and 0.004 mg/L, and 0.0014 mg/L and 0.036 mg/L, respectively. Recent Canadian criteria are 0.05 mg/L for drinking water supplies[8], 0.005 mg/L for aquatic life[8], 0.5 mg/L for livestock watering[8], 5 mg/L for irrigation[8], and 0.1 mg/L for wildlife[25]. Thus, the maximum values for all three creeks (Table 1) have exceeded the EPA criteria for aquatic life, the Canadian criteria for aquatic life and wildlife, and in Cahill Creek the drinking water criterion. The detection limit used for the lead analyses was too high to determine if the average values from the EPA criteria were achieved.

Lead nitrate (small quantities) is one of the principal reagents which will be used in the milling process[1]. Since lead values already can exceed criteria for aquatic life, lead values should not be increased. In both Cahill and Red Top Gulch Creeks, the criterion of 0.005 mg/L will be adopted to protect aquatic life. The lower EPA criterion for an average value may be a long-term goal for these waterbodies. Calculated maximum criteria values of 0.017 mg/L and 0.036 mg/L are revised to 0.015 mg/L for objectives for maximum values in Cahill Creek and Red Top Gulch Creek.

Therefore the proposed provisional water quality objective for total lead is that below the highway crossing in Cahill Creek or Red Top Gulch Creek, exclusive of initial dilution zones described in Section 5.1, the average value should not exceed 0.005 mg/L and the maximum value should not exceed 0.015 mg/L. Upstream from the highway crossing to protect drinking water supplies, the maximum value should not exceed 0.05 mg/L. In Nickel Plate Mine Creek, the maximum value should be less than 0.1 mg/L. If upstream values already exceed these proposed objectives in Cahill Creek, no significant increase going from upstream to downstream locations in the creek should occur. For the purpose of monitoring, "no significant increase" is defined as a maximum difference of 20%. This percentage increase is based upon the vagaries of sampling, analytical precision and accuracy, the small data base for lead, and apparently high lead values occurring. This is meant to define the practical level above which the objective will be considered as being exceeded. The average value will be based upon five samples collected on a weekly basis in a period not to exceed thirty days.

Total mercury was detected in 1983-1984 in Cahill Creek at levels as high as 0.00008 mg/L, in Nickel Plate Mine Creek at 0.00005 mg/L, but was not detectable in Sunset Creek (Table 1). In 1985, all values were less than 0.00005 mg/L in the three creeks and in Red Top Gulch Creek (Table 2). Mercury was detected in drainage water from some old mine adits, with the maximum recorded value of 0.00085 mg/L. This indicates that weathering of the exposed orebody can release mercury.

Working water quality criteria for receiving waters are 0.001 mg/L total mercury to protect drinking water supplies, 0.003 mg/L to protect wildlife and livestock, and 0.0001 mg/L to protect aquatic life (consumers of fish)[8]. Since mercury can be released from the operation, provisional objectives are proposed for Nickel Plate Mine Creek, Red Top Gulch Creek, and Cahill Creek. In Nickel Plate Mine Creek, the maximum total mercury concentration should be less than 0.003 mg/L. Two provisional objectives are proposed for Cahill and Red Top Gulch Creeks. Downstream from the highway #3 crossing in Cahill and Red Top Gulch Creeks, the maximum total mercury concentration should not exceed 0.0001 mg/L. In the remainder of Cahill Creek and in Red Top Gulch Creek, the maximum total mercury concentration should not exceed 0.001 mg/L. In addition in these lower reaches, the maximum total mercury in muscle tissues of fish should not exceed 0.5 µg/g (wet weight). These objectives except for fish muscle tissues apply outside initial dilution zones, described in Section 5.1. It is recognized that values lower than the proposed provisional objective may be required in certain upstream reaches if objectives at the mouth of Cahill Creek are to be achieved.

Dissolved molybdenum could not be detected (<0.03 mg/L) in Sunset, Cahill or Nickel Plate Mine Creeks (n=3) in 1983-1984 (Table 1). It is probable that molybdenum was also low in Red Top Gulch Creek. Molybdenum likely will be released in the milling of the ore, since traces of molybdenite are present. Some recently developed criteria[9] for molybdenum are 0.05 mg/L to protect wildlife, 0.25 mg/L to protect drinking water supplies, and from 0.01 mg/L to 0.10 mg/L to protect irrigation waters. The concentration depends upon the crop to be irrigated, drainage conditions in the field, and the copper:molybdenum ratio. All these criteria are well below the criterion of 1.0 mg/L to protect aquatic life[9].

In Nickel Plate Mine Creek, it is proposed that as a provisional objective to protect wildlife, the maximum molybdenum concentration should not exceed 0.05 mg/L. Wildlife also uses Cahill Creek and Red Top Gulch Creeks. However, irrigation waters are withdrawn from the upper reaches of both creeks, but drainage conditions in the fields and copper:molybdenum ratios are not known. In Cahill and Red Top Gulch Creeks, it is proposed that as a provisional objective to protect irrigation water from May to September inclusive, the average total molybdenum concentration should not exceed 0.01 mg/L and the maximum value should not exceed 0.05 mg/L. For the remainder of the year, the maximum value (to protect wildlife) should not exceed 0.05 mg/L. Since a limited data base exists for molybdenum, if upstream values in either Cahill Creek or Nickel Plate Mine Creek exceed these proposed objectives, downstream values should not increase by more than 20%. This percentage increase is meant to take into account such factors as vagaries of sampling and analytical precision and accuracy. It is meant to define the practical level above which the objective will be considered as being exceeded. Average values are to be calculated from a minimum of five samples collected weekly in a period not to exceed thirty days.

Only one value for dissolved nickel was detected (≥0.01 mg/L) in Cahill, Sunset or Nickel Plate Mine Creeks in 1983-1984 (Table 1). It was measured in Sunset Creek at a level of 0.05 mg/L, a value which exceeded the working criterion of 0.025 mg/L total nickel to protect aquatic life and wildlife[8]. This single value was well within levels of 0.2 mg/L to protect drinking water supplies, and 0.2 mg/L to protect irrigation water (continuous use)[8]. It is not expected that nickel will be generated due to the mining or milling processes, therefore no objectives are proposed. However, some additional monitoring for nickel would clarify the situation.

High levels of dissolved selenium were detected in Sunset, Cahill, and Nickel Plate Mine Creeks in 1983-1984 (Table 1). However, none was detected (<0.0005 mg/L) in 1985 in these three creeks or Red Top Gulch Creek (Table 2). Working water quality criteria for total selenium of 0.01 mg/L for drinking water, 0.05 mg/L for livestock, and 0.02 to 0.05 mg/L for irrigation[8] were exceeded by mean and maximum values in Cahill Creek, and the maximum value in Sunset Creek. The working criterion of 0.001 mg/L to protect aquatic life[26] was exceeded at times in all creeks. Values in drainage waters from old mine adits were as follows.

Selenium (mg/L) in Drainage From Mine Adits

Adit	Maximum	Minimum	Mean
Bulldog	0.93	<0.01	0.18
A	0.26	0.01	0.08
3750	0.73	<0.01	0.22

These data indicate that weathering of the orebodies likely will cause selenium to be released. Therefore provisional objectives are proposed for Cahill, Red Top Gulch, and Nickel Plate Mine Creeks. Since existing selenium levels exceed the criterion to protect aquatic life, no significant increase in selenium should occur in Cahill Creek downstream from the highway #3 crossing. The term "no significant increase" will apply going from upstream to downstream with upstream concentrations being determined from:

$$Se_C = \frac{(Se_{NP} \times F_{NP}) + (Se_S \times F_S) + (Se_{CA} \times F_{CA})}{F_{NP} + F_S + F_{CA}}$$

where: Se_C = Selenium concentration calculated for the upstream location in Cahill Cr.

Se_{CA} = Selenium concentration measured in Cahill Cr. upstream from Sunset Cr.

Se_{NP} = Selenium concentration measured in Nickel Plate Mine Creek, near its mouth.

Se_S = Selenium concentration measured in Sunset Cr upstream from Nickel Plate Mine Cr.

F_{NP} = Flow in Nickel Plate Mine Cr. near its mouth.

F_S = Flow in Sunset Creek upstream from Nickel Plate Mine Creek.

F_{CA} = Flow in Cahill Cr. upstream from Sunset Cr.

Therefore, <u>the proposed provisional objective for total selenium downstream from the highway #3 crossing in Cahill and Red Top Gulch Creeks is that the maximum value should not exceed 0.001 mg/L or no significant increase over the upstream value in Cahill Creek, whichever is greater</u>. For the purpose of monitoring, no significant increase is defined as a maximum difference of 20%, which is meant to account for vagaries of sampling and analytical precision and accuracy. In the remainder of Cahill Creek and Red Top Gulch Greek, the maximum value should not exceed 0.01 mg/L (to protect drinking water) outside initial dilution zones described in Section 5.1. In Nickel Plate Mine Creek, the maximum value should not exceed 0.05 mg/L.

Maximum dissolved silver concentrations have been 0.14 mg/L in Cahill Creek and 0.02 mg/L in Sunset Creek and Nickel Plate Mine Creek. If the one value of 0.14 mg/L in Cahill Creek is excluded, all values in all creeks have been ≤0.02 mg/L. A working criterion of 0.05 mg/L has been proposed to protect drinking water supplies; however, none were put forth to protect wildlife or irrigation due to a lack of information on these topics[8]. Silver will be released in the milling process. It will be assumed that, until better information exists, criteria to protect drinking water supplies will also protect wildlife. A provisional objective is therefore proposed for Cahill and Red Top Gulch Creeks and Nickel Plate Mine Creek. The objective is that the maximum total silver concentration should not exceed 0.05 mg/L. In Cahill Creek and Red Top Gulch Creeks downstream from the highway #3 crossing, the maximum total silver value (to protect aquatic life) should not exceed 0.0001 mg/L. If upstream values in Cahill, Nickel Plate Mine, and Red Top Gulch Creeks exceed these proposed objectives, downstream silver concentrations in those creeks should not increase by more than 20%. The increase of 20% is considered as the practical level above which the objective will be considered as being exceeded.

Dissolved zinc values in Sunset, Cahill and Nickel Plate Mine Creeks have been low, ≤0.01 mg/L (Table 1). It is assumed that similar values would occur in Red Top Gulch Creek. Zinc dust in small quantities is to be used as one of the principal reagents in the milling process[1]. As well, zinc likely will be released in the milling of the ore. The maximum recorded dissolved zinc value in drainage water associated with old workings was 0.067 mg/L. Working water quality criteria[8] for total zinc are 0.05 mg/L to protect aquatic life and wildlife, 5 mg/L to protect drinking water supplies, and 1 mg/L to 5 mg/L to protect irrigation waters, depending upon the soil pH. An objective of 0.05 mg/L as an average and 0.08 mg/L as a maximum has been established for zinc in the Similkameen River based upon hardness. Since zinc may be released from the waste rock stockpile or through seepage from the tailings impoundments and the water is softer than in the Similkameen, a provisional objective for zinc to protect wildlife and aquatic life and maintain existing zinc levels in the Similkameen River is proposed for Cahill, Red Top Gulch, and Nickel Plate Mine Creeks. The objective is that the maximum total zinc concentration should not exceed 0.05 mg/L. This objective applies along the length of the three creeks, exclusive of initial dilution zones described in Section 5.1. It will keep the present values in the creek low, while ensuring the objective in the Similkameen River is not threatened by this input.

Uranium values ranged from 0.01 mg/L to 0.19 mg/L on Cahill Creek, 0.02 mg/L to 0.18 mg/L on Sunset Creek, and 0.03 mg/L to 0.13 mg/L on Nickel Plate Mine Creek (Table 1) in 1983/1984. Mascot Gold Mines Ltd. have indicated that they believe these values to be in error because further analyses which they conducted using a different analytical technique produced concentrations of <0.0001 mg/L in Sunset Creek and 0.0002 mg/L in Cahill Creek[11]. They further cited the fact that samples of creek water just east from the Nickel Plate property had uranium values from 0.00005 to 0.0002 mg/L. These tests had been conducted in 1976 by the Geological Survey of Canada and the British Columbia Mineral Resources Branch. Recent analyses (Table 2) revealed maximum dissolved uranium values of 0.00043 mg/L in Cahill Creek, 0.00025 mg/L in Sunset Creek, 0.00055 mg/L in Nickel Plate Mine Creek, and 0.0038 mg/L in Red Top Gulch Creek.

Working water quality criteria for total uranium are 0.02 mg/L to protect drinking water supplies, 0.2 mg/L for irrigation and livestock, and 0.3 mg/L for aquatic life and wildlife[8]. The 1976 and the more recently collected samples had values which met all these criteria. The results in question, in Table 1, exceed the drinking water criterion and approach the criteria for irrigation and livestock. Since the data from the Geological Survey and Mineral Resources Branch seem to reflect conditions near the mine site, since recent values are low, and since it has not been oxidized in the existing adits, no concern should exist for uranium.

5.3 CYANIDE

Cyanide is ubiquitous in the environment, but in small amounts. The persistence of cyanide in water is highly variable, depending upon its chemical form, concentration, and other characteristics of the water[12]. Singleton[12] has indicated that total cyanide concentrations in wilderness areas can average from 0.7 to 2 µg/L, with the highest concentration of 5 µg/L occurring in the fall and winter. Cyanide could not be detected (<0.005 mg/L) in samples collected in 1985 (Table 2).

Mascot Gold Mines Limited has projected that cyanide concentrations in its tailings will be from 3.7 mg/L CN (average) to 8.2 mg/L CN (maximum)[17]. In its permit application, the company has asked for values of 10 and 25 mg/L, respectively. As well, it anticipates an equilibrium level of thiocyanate (CNS) of below 200 mg/L in the tailings solutions[17].

Consultants[18] for the company assumed the following flows in determining the potential impact of cyanide on Cahill Creek.

Source	Flow (m^3/s)	
	Minimum	Maximum
Seepage	0.0023	0.0045
Groundwater flow	0.005	0.020
Cahill Cr.	0.0062	0.0983

Assuming no reduction of cyanide or interception of groundwater between the pond and Cahill Creek and the maximum seepage rate of 0.0045 m^3/s, the following ranges of cyanide and thiocyanate could be present:

Concentration in Tailings	Seepage Flow (L/S)	Total Flow (L/S)	Resultant Concentration in Cahill Creek
8 mg/L CN	4.5	4.5 + 20 + 98.3	0.3 mg/L CN
8 mg/L CN	4.5	4.5 + 5 + 6.2	2.3 mg/L CN
200 mg/L CNS	4.5	4.5 + 20 + 98.3	7.3 mg/L CNS
200 mg/L CNS	4.5	4.5 + 5 + 6.2	57.3 mg/L CNS

The calculated cyanide concentrations would be reduced from the range of 0.3 to 2.3 mg/L CN if any of the following occurred: the initial concentration in the tailings was less than the maximum expected; the seepage flow was less than the 4.5 L/s; pumping reduced the volume of seepage and groundwater reaching Cahill Creek; and some of the cyanide were to breakdown. In fact, Mascot Gold Mines Limited did indicate in a September 1986 review of this document that seepage flows could be in the range from 0.00095 to 0.0019 m^3/s. Resulting concentrations in the previous table would be 0.12 and 1.16 mg/L-CN and 3.16 and 29 mg/L-CNS. Thiocyanate levels would also be affected by all the same factors except that of breakdown, since thiocyanate is relatively stable in the environment.

A water quality objective for cyanide or thiocyanate is not proposed for Nickel Plate Mine Creek since it will not be affected by any cyanide or thiocyanate in the tailings. In Cahill Creek and in Red Top Gulch Creek (if affected by discharges from the settling basin), drinking water, wildlife, irrigation and livestock watering must be protected along their entire lengths. In addition, aquatic life must be protected downstream from the highway #3 crossing. A criterion of 0.2 mg/L-CN as strong-acid dissociable cyanide plus thiocyanate has been established to protect drinking water, which may also protect wildlife, irrigation and livestock watering(13). To protect freshwater aquatic life, criteria of 0.005 mg/L CN average and 0.010 mg/L CN maximum have been established for weak-acid dissociable cyanide(13). Strong-acid dissociable cyanide includes free cyanide, simple cyanides and complex metal cyanides. Weak-acid dissociable cyanide includes free cyanide, simple cyanides and weak-acid dissociable metallocyanides.

Criteria to protect aquatic life have not been recommended for cyanate or thiocyanate. The lowest concentrations of these substances reported to cause mortality to rainbow trout after 96 hours were 7.3 mg/L and 8.0 mg/L, respectively. Other tests have resulted in 96 h LC_{50} values of greater than 20 mg/L and 150 mg/L, respectively. These values were expressed as CNO and CNS, respectively(13).

Cyanide could not be detected (<0.005 mg/L) in any of the creeks in measurements made in 1985 (Table 2). Objectives are proposed in Cahill and Red Top Gulch Creeks to protect aquatic life downstream from the highway #3 crossing, and to protect drinking water, wildlife, irrigation, and livestock watering along its entire length. In that reach of Cahill and Red Top Gulch Creeks between the highway #3 crossing and the Similkameen River confluence,the average weak-acid dissociable cyanide should not exceed 0.005 mg/L CN and the maximum value should not exceed 0.010 mg/L CN. Along the entire length of Cahill and Red Top Gulch Creeks, the strong-acid dissociable cyanide plus thiocyanate should not exceed 0.20 mg/L CN. It is not certain whether cyanide will be removed using the SO_2/air process, hydrogen peroxide, or both. The company has also considered the use of alkaline-chlorination. Since cyanates are formed with the alkaline- chlorination process, a provisional objective for cyanates in Cahill and Red Top Gulch Creeks between the highway #3 crossing and the Similkameen River confluence is proposed. The objective is based upon the lowest concentration of cyanate (7.3 mg/L $^-$CNO or 4.5 mg/L $^-$CN) to cause mortality to rainbow trout after 96 hours and an application factor of 0.1. Using these data, a criterion to protect aquatic life from cyanate is 0.45 mg/L (4.5 mg/L x 0.1). The provisional objective for cyanate ($^-$CN) is that the maximum cyanate ($^-$CN) concentration should not exceed 0.45 mg/L.

The objective for strong-acid dissociable cyanide plus thiocyanate applies to the entire length of Cahill and Red Top Gulch Creeks, except the initial dilution zones described in Section 5.1. The average value outlined for weak-acid dissociable cyanide applies to a minimum of five samples collected weekly during a period of thirty days. The following recommendations for sampling are extracted from Singleton(13), with some minor revisions.

When testing to check if aquatic life objectives are being achieved, measurements of strong-acid dissociable cyanide should also be made. If the values for strong-acid dissociable cyanide exceed the objective expressed as weak-acid dissociable cyanide, then further sampling should be carried out even if weak-acid dissociable cyanide objectives are being met. The sampling should be repeated hourly and preferably during bright sunlight (between 1100 and 1400 hours). Such tests will check whether the possible photolysis of iron-cyanide complexes has produced free cyanide at levels which may be unacceptable. In cases where sampling sites are located a considerable distance from the suspected source, then the sampling time frame should be extended to allow the water, which had been exposed during peak sunlight hours, to reach that site. Samples should be kept in the dark (i.e., out of sunlight) immediately after collection and during transport to the lab.

5.4 NUTRIENTS

Total phosphorus values were measured in 1983-1984 (Table 1). Values in Sunset and Cahill Creeks were similar, with maximum values of 0.36 and 0.32 mg/L, respectively and mean values of 0.09 and 0.11 mg/L, respectively. Values in Nickel Plate Mine Creek were considerably lower, a maximum value of 0.10 mg/L and mean value of 0.06 mg/L.

Dissolved phosphorus values in drainage water associated with old mine workings were as follows:

	Dissolved Phosphorus (mg/L) in Drainage	
	Maximum	Mean
Bulldog Adit	0.17	0.07
A Adit	0.09	0.04
3750 Adit	0.46	0.18

These values indicate that the high dissolved phosphorus values in Cahill and Sunset Creeks may originate from the host rock in the area.

Due to the steep slope of Cahill Creek and to the fact that drainage water may not increase phosphorus concentrations, existing algal growths near the mouth of the creek should not change significantly. Mascot Gold Mines Limited has reported that in Cahill Creek, patches "of algae were noted throughout, but in relatively low densities"(1). Higher concentrations of periphyton exist between the highway crossing and the Similkameen than upstream from the highway crossing. It was speculated that this relates to the passage of Cahill Creek through a farmstead[1].

Nitrite and nitrate were measured in Cahill Creek, Sunset Creek, Nickel Plate Mine Creek and Red Top Gulch Creek in 1985 (Table 2). The maximum recorded nitrate nitrogen value of 1.25 mg/L occurred in Nickel Plate Mine Creek. It is expected that nitrate levels could be increased from the leaching of blasting compounds. The most restrictive working water quality criterion for nitrate is related to protection of drinking water supplies, with a maximum acceptable concentration of 10 mg/L[15]. Therefore, to protect consumers of drinking water, a provisional objective is proposed for nitrate. The objective, applicable to Cahill Creek outside the initial dilution zone described in Section 5.1 and to Red Top Gulch Creek, is that the maximum nitrate nitrogen value should not exceed 10 mg/L. Drinking water is not a proposed designated use for Nickel Plate Mine Creek. The working water quality criterion to protect wildlife is 100 mg/L[15] and is appropriate for Nickel Plate Mine Creek. Therefore a provisional objective of a maximum 100 mg/L nitrate nitrogen is proposed for Nickel Plate Mine Creek, outside the initial dilution zone, described in Section 5.1. It is recognized that values will have to be significantly lower than this in Nickel Plate Mine Creek if the objective is to be achieved in Cahill Creek.

Ammonia was detected in 1985 (Table 2) in all of the creeks, with the highest level being 0.12 mg/L in Sunset Creek. Ammonia can be toxic to aquatic life. B. C. water quality criteria for total ammonia to protect aquatic life are in Tables 3 and 4. Ammonia levels in the creeks adjacent to the mine complex are likely to increase since an ammonium nitrate/fuel oil mixture is to be used as the blasting compound. However, no objectives will be proposed for total ammonia in Nickel Plate Mine Creek since the protection of aquatic life is not a designated use of that creek and no criteria have been proposed to protect the other designated uses[15]. A provisional objective is proposed for Cahill and Red Top Gulch Creeks, downstream from the highway #3 crossing, to protect aquatic life. The objective is that the maximum concentration and the 30-day average concentration should not exceed values listed in Tables 3 and 4. The average value is to be calculated from a minimum of five samples collected on a weekly basis in a period no longer than thirty days.

Nitrite nitrogen was detected in 1985 (Table 2) in all the creeks except Red Top Gulch Creek. The maximum value was 0.016 mg/L in Cahill Creek, upstream from the Sunset Creek confluence. B. C. water quality criteria to protect aquatic life from nitrite are 0.02 mg/L as an average value and 0.06 mg/L as a maximum value[15]. To protect drinking water and recreation, a value of 1 mg/L nitrite nitrogen has been proposed. To protect wildlife and livestock, a value of 10 mg/L nitrite nitrogen has been proposed. Since nitrite can be formed when ammonia is incompletely oxidized to nitrate, a provisional objective of a maximum 1 mg/L nitrite (as N) is proposed for Red Top Gulch Creek and Cahill Creek, outside the initial dilution zones described in Section 5.1. In Nickel Plate Mine Creek, a provisional objective of 10 mg/L nitrite (as N) is proposed. In addition, to protect aquatic life downstream from the highway #3 crossing on Cahill and Red Top Gulch Creeks and in the Similkameen River, the average nitrite (as N) concentration should not exceed 0.02 mg/L while the maximum nitrite (as N) concentration should not exceed 0.06 mg/L. The average value is to be calculated from at least five samples collected weekly in a period not to exceed thirty days.

5.5 SOLIDS

Dissolved solids were measured in the Cahill, Sunset, Red Top Gulch and Nickel Plate Mine Creeks only in 1985. The maximum recorded values were 235 mg/L in Cahill Creek, 230 mg/L in Nickel Plate Mine Creek, 276 mg/L in Red Top Gulch Creek, and 97 mg/L in Sunset Creek. If acid generation is a problem in the waste rock stockpile, dissolved solids could be increased in Nickel Plate Mine Creek or in Red Top Gulch Creek from discharges from the settling basin. Similarly, dissolved solids in Cahill Creek could be increased by seepage from the tailings impoundment.

Working water quality criteria for the protection of drinking water supplies[20] or for protection of irrigation waters[19] are 500 mg/L. Since maximum recorded values in each of the creeks are at least one-half this level and values in Nickel Plate Mine Creek will influence Cahill Creek, it seems reasonable that the same levels of objectives should apply to each creek. Therefore, in Nickel Plate Mine Creek, Red Top Gulch Creek and Cahill Creek, a provisional objective of 500 mg/L maximum total dissolved solids is proposed. The objective is to apply along the total length of each creek, except in the initial dilution zones described in Section 5.1.

Suspended solids concentrations reported for Cahill and Sunset Creeks in 1983-1984 and also Red Top Gulch Creek in 1985 were all less than 25 mg/L. Concentrations of this magnitude are low enough to provide a high level of protection to aquatic life. A maximum value of 60 mg/L was recorded in Nickel Plate Mine Creek, although most values were also less than 25 mg/L. Approved water quality criteria to protect wildlife are that induced suspended solids concentrations should be a maximum of 20 mg/L if upstream concentrations are ≤100 mg/L, or a maximum 20% increase if upstream values exceed 100 mg/L[21]. This is the proposed water quality objective for Sunset and Nickel Plate Mine Creeks, and Cahill and Red Top Gulch Creeks from their headwaters to the highway #3 crossing, since wildlife and agriculture uses are to be protected. Upstream values in Sunset and Nickel Plate Mine Creeks are to be for samples collected in the creeks upstream from the mining operation. The upstream concentration in Cahill Creek is to be calculated from the following:

$$Ss_C = \frac{(Ss_{NP} \times F_{NP}) + (Ss_S \times F_S) + (Ss_{CA} \times F_{CA})}{F_{NP} + F_S + F_{CA}}$$

where: Ss_C = Suspended solids concentration calculated for the upstream location in Cahill Creek.

Ss_{CA} = Suspended solids concentration measured in Cahill Creek upstream from Sunset Creek.

Ss_{NP} = Suspended solids concentration measured in Nickel Plate Mine Creek, near its mouth.

Ss_S = Suspended solids concentration measuredupstream from Nickel Plate Mine Creek.

F_{NP} = Flow in Nickel Plate Mine Creek near its mouth.

F_S = Flow in Sunset Creek upstream from Nickel Plate Mine Creek.

F_{CA} = Flow in Cahill Creek upstream from Sunset Creek.

In Cahill and Red Top Gulch Creeks, downstream from the highway #3 crossing, aquatic life is to be protected. Therefore in this reach, maximum induced suspended solids concentrations should be 10 mg/L if upstream values are ≤100 mg/L or 10% of upstream values if these exceed 100 mg/L.

Suspended solids measurements indicate concentrations of materials which can inflict damage to such things as membranes of fish gills. Turbidity measures the transmission of light through water.

Since wildlife and agricultural uses are to be protected in Sunset and Nickel Plate Mine Creeks, the criteria of a maximum induced turbidity of 10 NTU if upstream levels are ≤50 NTU or of a 20% increase if upstream levels exceed 50 NTU[21] are the proposed provisional objectives. In Cahill and Red Top Gulch Creeks, the criteria for raw drinking water with treatment will also protect aquatic life. Therefore in Cahill and Red Top Gulch Creeks, the maximum induced turbidity should be 5 NTU if upstream levels are ≤50 NTU or a maximum 10% increase of upstream values if upstream levels exceed 50 NTU.

5.6 SULPHATE

It is anticipated that sulphate will be generated through the oxidation of the sulphide orebodies. Mascot Gold Mines Ltd. reported the following range of concentrations for sulphate in drainage waters from the old mine workings[1].

Range of Dissolved Sulphate (mg/L)

Adit	Maximum	Minimum	Mean
Bulldog	105	35	65
A	90	30	69
3750	110	65	91

A maximum concentration of 15 mg/L was recorded in Cahill Creek in 1983-1984 (Table 1), 23.6 mg/L in Red Top Gulch in 1985 (Table 2), and 26.2 mg/L in Nickel Plate Mine Crek in 1985 (Table 2). Working water quality criteria for sulphate are 150 mg/L to prevent taste problems in drinking water and 500 mg/L to protect the health of consumers. Large sulphur bacteria growths can cover creek beds and result in significant changes to macroinvertebrate communities[23]. This occurs at an average value of about 71 mg/L (range is 27.7 mg/L to 189 mg/L)[23]. Water clarity and water depth can affect such growths. Therefore an arbitrarily derived average value of 50 mg/L should be considered to prevent such growths. Since levels in Nickel Plate Mine Creek, Red Top Gulch Creek and Cahill Creek are well below this average and since levels in Nickel Plate Mine Creek will influence those in Cahill Creek, it seems reasonable that the same levels of objectives should apply to each creek. Therefore, in each of Nickel Plate Mine Creek, Red Top Gulch Creek and Cahill Creek, provisional objectives of 150 mg/L maximum and 50 mg/L average sulphate are proposed. The proposed objectives are to apply along the total length of each creek, except in the initial dilution zones described in Section 5.1. The average value is to be calculated from at least five samples collected weekly in a period no longer than thirty days.

5.7 CONCLUSIONS

The proposed operation has the potential to release several contaminants into nearby watercourses. The impact that these contaminants will have will depend upon the success that Mascot Gold Mines has in capturing seepage flows from the tailings impoundment and minimizing runoff from the waste rock pile. The success of the projected recycle of supernatant, and the possibility of settling pond overflow entering Cahill or Red Top Gulch Creeks are also important factors.

Analyses of drainage water associated with old mine workings in the area have shown that arsenic, cadmium, mercury, selenium, zinc, and sulphate were high. This indicates that these elements are likely released due to the oxidation of the orebody, or to their presence in the waste rock stockpile and the tailings.

It is expected that several water quality characteristics could be affected due to the mining or milling operation. The release of aluminum, nitrate, nitrite, or ammonia could be associated with use of the ammonium nitrate/fuel oil blasting compound. Lead and nitrate could be increased by use of small quantities of lead nitrate as a principal reagent. Molybdenum, copper, iron, and silver could be released from the milling of the ore. Cyanide, thiocyanate, or cyanate could be released by the gold recovery process or generated in the treatment of the cyanide wastes.

It is expected that turbidity and suspended solids in nearby watercourses could be increased due to land disturbances by mining and construction.

6.0 PROPOSED MONITORING

Mascot Gold Mines Limited presently monitors Cahill, Sunset, Red Top Gulch, and Nickel Plate Mine Creeks monthly. Until the mine/mill comes into operation, this frequency of sample collection should suffice. Characteristics for which objectives have been proposed, in the form they have been proposed, should be measured. The company should also consider sampling weekly for two thirty-day periods per year, so that average values can be determined. This should be undertaken once during freshet (April/ May) when discharges from the settling pond may occur and once during July or August when irrigation water is being withdrawn and seepage contributes to the creek flows.

Once the mine/mill is operational, the monthly frequency of data collection should be maintained. If objectives are exceeded, sampling should be weekly until the objectives are achieved.

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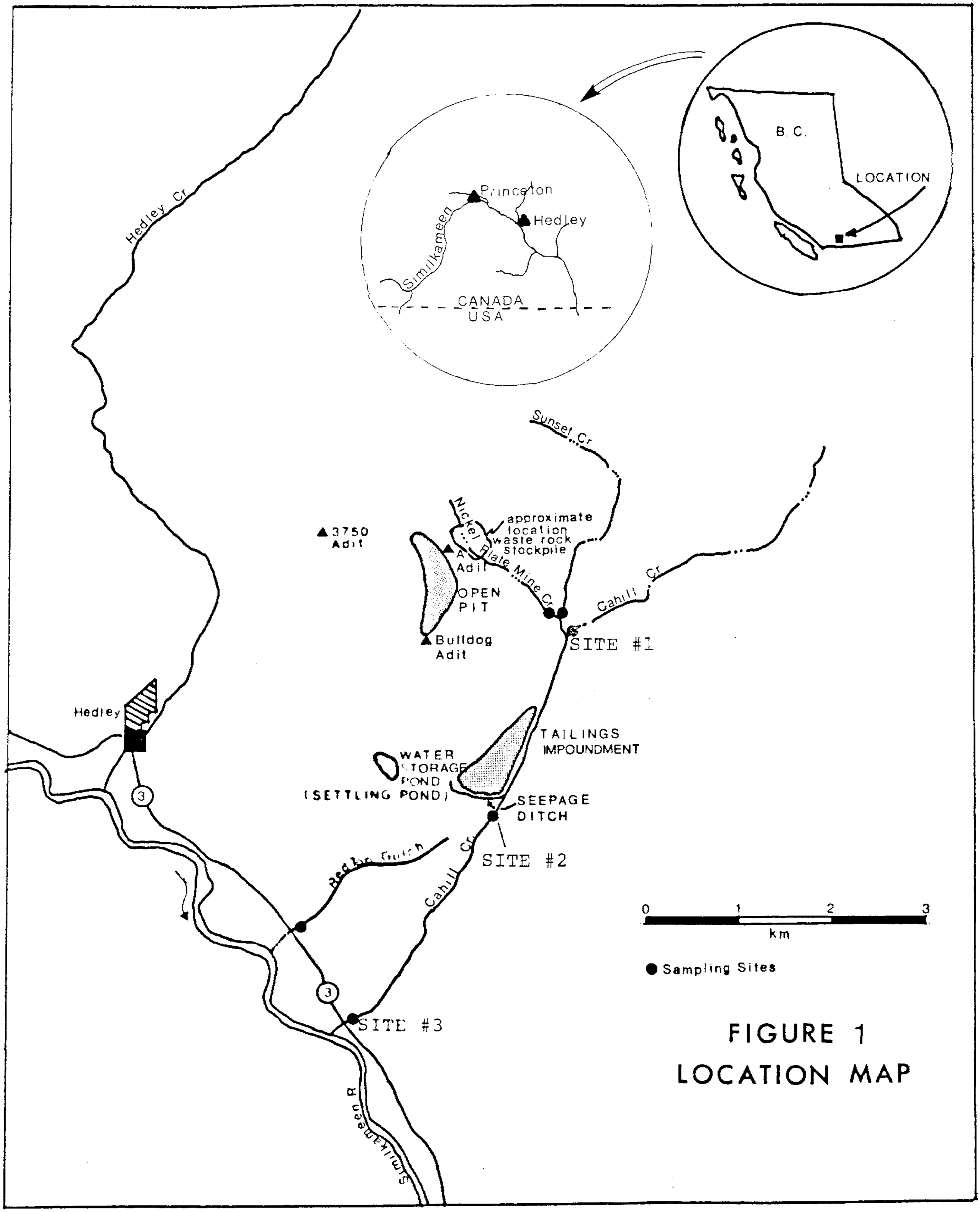

FIGURE 1
LOCATION MAP

Table 1
AMBIENT WATER QUALITY DATA SUMMARY (1983-1984)

Characteristics (mg/L) Unless otherwise noted	CAHILL CREEK, SITE #2					SUNSET CREEK					NICKEL PLATE MINE CREEK				
	No. of Values	No. of Values <D.L.	Mean of Values >D.L.*	Maximum	Minimum	No. of Values	No. of Values <D.L.	Mean of Values >D.L.*	Maximum	Minimum	No. of Values	No. of Values <D.L.	Mean of Values >D.L.*	Maximum	Minimum
Alkalinity	14	0	66.9	104	48.1	14	0	29.96	46	18.1	4	0	102.6	128.4	73.8
Arsenic (dissolved)	15	3-<0.001	0.005	0.008	<0.001	13	2-<0.001	0.003	0.005	<0.001	4	3-<0.001	0.003	0.003	<0.001
Boron (dissolved)	7	7-<0.005	<0.005	<0.005	<0.005	7	7-<0.005	<0.005	<0.005	<0.005	3	3-<0.005	<0.005	<0.005	<0.005
Chloride	4	3-<1	1	1	<1	4	3-<1	1	1	<1	3	2-<1	1	1	<1
Flow (m^3/s)	28	0	0.166	0.675	0.006	23	0	0.066	0.227	0.002	27	0	0.006	0.090	0.000
Fluoride	14	0	0.048	0.08	0.03	13	0	0.033	0.06	0.02	4	0	0.036	0.046	0.028
Hardness - calcium	15	0	22.67	30.4	12.49	15	0	7.55	10.03	5.18	4	0	35.3	46.3	24.08
- magnesium	14	0	1.88	2.19	1.0	14	0	0.89	1.77	0.38	4	0	1.58	1.82	1.21
- total	14	0	72.4	82.5	38.1	14	0	19.2	33.2	13.09	4	0	94.6	113.9	65.3
Metals: (dissolved)															
Aluminum	11	8-<0.01	0.217	0.45	<0.01	13	8-<0.01	0.474	0.96	<0.01	3	2-<0.01	0.01	0.01	<0.01
Antimony	13	7-<0.001	0.004	0.016	<0.001	10	4-<0.001	0.005	0.016	<0.001	4	0	0.004	0.011	<0.001
Barium	8	8-<0.005	<0.005	<0.005	<0.005	12	7-<0.005	0.007	0.009	<0.005	3	3-<0.005	<0.005	<0.005	<0.005
Cadmium	7	7-<0.005	<0.005	<0.005	<0.005	7	7-<0.005	<0.005	<0.005	<0.005	4	4-<0.005	<0.005	<0.005	<0.001
Chromium	8	8-<0.005	<0.005	<0.005	<0.005	8	8-<0.005	<0.005	<0.005	<0.005	3	3-<0.005	<0.005	<0.005	<0.005
Cobalt	8	8-<0.005	<0.005	<0.005	<0.005	8	8-<0.005	<0.005	<0.005	<0.005	4	4-<0.005	<0.005	<0.005	<0.001
Copper	4	4-<0.005	<0.005	-	-	4	4-<0.005	<0.005	<0.005	<0.005	3	3-<0.005	<0.005	<0.005	<0.005
Iron	12	6-<0.02	0.047	0.16	<0.01	10	6-<0.02	0.225	0.23	<0.01	3	1-<0.02	0.02	0.07	<0.01
Lead	11	5-<0.01	0.02	0.06	<0.01	10	4-<0.01	0.02	0.04	<0.01	4	2-<0.01	0.03	0.03	<0.01
Manganese	3	3-<0.01	<0.01	-	-	3	3-<0.01	<0.01	<0.01	<0.01	3	3-<0.01	<0.01	<0.01	<0.01
Mercury(total)	6	3-<0.00005	0.00006	0.00008	<0.00005	3	3-<0.00005	<0.00005	<0.00005	<0.00005	3	2-<0.00005	0.00005	0.00005	<0.00005
Molybdenum	3	3-<0.03	<0.03	-	-	3	3-<0.03	<0.03	<0.03	<0.03	3	3-<0.03	<0.03	<0.03	<0.03
Nickel	3	3-<0.01	<0.01	-	-	5	4-<0.01	0.05	0.05	<0.01	3	3-<0.01	<0.01	<0.01	<0.01
Selenium	11	4-<0.01	0.121	0.45	<0.01	10	4-<0.01	0.042	0.10	<0.01	4	1-<0.01	0.017	0.03	<0.01
Silver	14	9-<0.01	0.038	0.14	<0.01	12	6-<0.01	0.01	0.02	<0.01	4	1-<0.01	0.013	0.02	<0.01
Strontium	14	0	0.06	0.12	0.02	11	1-<0.01	0.032	0.06	<0.01	4	0	0.055	0.07	0.04
Uranium	12	0	0.07	0.19	0.01	12	0	0.08	0.18	0.02	4	0	0.075	0.13	0.03
Vanadium	14	4-<0.001	0.003	0.006	<0.001	13	4-<0.001	0.005	0.020	<0.001	4	0	0.003	0.005	0.001
Zinc	6	4-<0.001	0.003	<0.01	<0.001	7	5-<0.001	0.007	0.01	<0.001	3	2-<0.001	0.01	0.01	<0.001
pH (units)	15	0	7.35	7.9	6.4	15	0	7.0	7.6	6.5	8	0	7.55	7.9	7.4
Phosphorus (total)	13	3-<0.01	0.11	0.32	<0.01	13	3-<0.01	0.09	0.36	<0.01	4	1-<0.01	0.06	0.10	<0.01
Potassium	12	1-<0.01	0.049	0.09	<0.01	13	2-<0.01	0.028	0.06	<0.01	4	0	0.028	0.04	0.02
Sodium	14	0	1.93	2.24	1.51	14	0	1.39	1.76	1.0	4	0	1.08	1.43	0.92
Solids - suspended	14	1-<1	5.8	23.2	0.1	15	0	3.7	14.9	0.3	4	0	2.5	8.4	0.1
Specific Conductivity (uS/cm)	15	0	118	-	-	15	0	52.3	-	-	4	0	44.7	-	-
Sulphate	13	4-<5	6.67	15	<5	5	3-<5	5	5	<5	3	1-<5	5	5	<5

* D.L. = Detection Limit
DATA SOURCE: MASCOT GOLD MINES LTD.

TABLE 2

AMBIENT WATER QUALITY DATA SUMMARY (1985)

Characteristics (mg/L unless otherwise noted)	Detection Limit	Site 1: Cahill Cr. u/s Sunset Cr. Confluence*				Site 2: Cahill Creek near Proposed Tailings Pond*				Site 3: Cahill Cr. at Highway #3 Crossing**			
		No. of Values <D.L.	Mean of Values >D.L.*	Maximum	Minimum	No. of Values <D.L.	Mean of Values >D.L.	Maximum	Minimum	No. of Values <D.L.	Mean of Values >D.L.*	Maximum	Minimum
Alkalinity	-	0	18.3	21.6	14.6	0	58.1	83.6	27.5	0	95	182	56.2
Arsenic (dissolved)	-	0	0.0010	0.0021	0.0005	0	0.0070	0.011	0.0005	0	0.0091	0.04	0.0062
Cyanide	0.005	7	-	<0.005	<0.005	7	-	<0.005	<0.005	5	-	<0.005	<0.005
Flow (m^3/s)	-	0	0.024	0.066	0.011	0	0.046	0.116	0.024	0	0.015	0.076	0.009
Hardness	-	0	26.4	31.4	21.9	0	66.5	75.4	50.9	0	85.2	106	56.8
Metals: (dissolved)													
Bismuth	0.05	7	-	<0.05	<0.05	7	-	<0.05	<0.05	6	-	<0.05	<0.05
Cadmium	0.0005	7	-	<0.0005	<0.0005	7	-	<0.0005	<0.0005	6	-	<0.0005	<0.0005
Cobalt	0.001	7	-	<0.001	<0.001	5	0.0015	0.002	0.001	2	0.001	0.002	<0.001
Copper	0.001	0	0.003	0.005	0.002	1	0.002	0.004	<0.001	3	0.003	0.003	<0.001
Iron	0.03	4	0.05	0.08	<0.03	5	0.07	0.08	<0.03	4	0.035	0.04	<0.03
Mercury (total)	0.00005	7	-	<0.00005	<0.00005	7	-	<0.00005	<0.00005	6	-	<0.00005	<0.00005
Selenium	0.0005	7	-	<0.0005	<0.0005	7	-	<0.0005	<0.0005	6	-	<0.0005	<0.0005
Uranium	0.0001	1	0.00013	0.00015	<0.00010	1	0.00017	0.00020	<0.00010	0	0.00037	0.00040	0.00035
Nitrogen: Ammonia	0.020	7	-	<0.020	<0.020	7	-	<0.020	<0.020	4	0.10	0.10	<0.020
Nitrate	0.003	2	0.029	0.091	<0.003	2	0.044	0.10	<0.001	1	0.010	0.018	<0.001
Nitrite	0.001	6	0.016	0.016	<0.001	7	-	<0.001	<0.001	5	0.002	0.002	<0.001
pH	-	0	7.09+	7.31	6.52	0	7.55+	7.71	6.36	0	7.85+	8.02	7.65
Solids: Dissolved	1.0	1	49.4	73	<1	0	95.6	125	56	0	138	235	66
Suspended	1.0	2	3	8.4	<1	3	1.7	2.4	<1	1	2	3.6	<1
Specific Conductivity (µS/cm)	-	0	75	75	-	0	242	242	-	0	-	-	-
Sulphate	-	0	6.4	8.6	3.7	0	9.7	11.9	7.5	0	9.4	14.2	3.2
Temperature (°C)	-	0	5.3	9.5	1.0	0	5.7	12	1.0	0	10.2	18.0	1
Turbidity (NTU)	-	6	1.8	1.8	<1	6	1.8	1.8	<1	4	1.4	1.8	<1

+ Median value

* Seven values for each characteristic except flow (n=5), conductivity (n=1), and uranium (n=3).

** Six values for each characteristic except flow (n=5), conductivity (n=0), cyanide (n=5), and uranium (n=2).

Data Source: Mascot Gold Mines Ltd.

TABLE 2 (Continued)

Characteristics	Detection Limit	Sunset Cr.*				Nickel Plate Mine Creek*				Red Top Gulch Creek*			
		No. of Values <D.L.	Mean of Values >D.L.*	Maximum	Minimum	No. of Values <D.L.	Mean of Values >D.L.*	Maximum	Minimum	No. of Values <D.L.	Mean of Values >D.L.*	Maximum	Minimum
Alkalinity	-	0	46.2	54.2	32.4	0	119	132	94.1	0	154	169	143
Arsenic (dissolved)	-	0	0.0065	0.010	0.0050	0	0.018	0.025	0.014	0	0.012	0.017	0.010
Cyanide	0.005	6	-	<0.005	<0.005	6	-	<0.005	<0.005	6	-	<0.005	<0.005
Flow (m³/s)	-	0	0.035	0.116	0.011	0	0.018	0.032	0.007	0	0.007	0.0082	0.002
Hardness	-	0	[illegible]	[illegible]	[illegible]	0	142	155	121	0	164	178	155
Metals: (dissolved)													
Bismuth	[illegible]	7	-	[illegible]	[illegible]	[illegible]	-	<0.05	<0.05	7	-	<0.05	<0.05
Cadmium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	<0.0005	<0.0005	7	-	<0.0005	<0.0005
Cobalt	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.004	<0.001	2	0.002	0.002	<0.001
Copper	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.005	<0.001	5	0.003	0.004	<0.001
Iron	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.06	<0.03	6	0.05	0.05	<0.03
Mercury (total)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	<0.00005	<0.00005	7	-	<0.00005	<0.00005
Selenium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7	-	<0.0005	<0.0005	7	-	<0.0005	<0.0005
Uranium	0.0001	0	0.00015	0.00025	0.00010	0	0.00033	0.00055	0.00010	0	0.0034	0.0038	0.0027
Nitrogen: Ammonia	0.020	6	0.12	0.12	<0.020	7	-	<0.020	<0.020	6	0.052	0.052	<0.020
Nitrate	0.003	1	0.022	0.040	<0.001	0	0.40	1.25	0.098	2	0.042	0.061	<0.001
Nitrite	0.001	6	0.001	0.001	<0.001	5	0.005	0.008	<0.001	7	-	<0.001	<0.001
pH	-	0	7.52+	7.6	6.86	0	7.72	7.95	7.22	0	8.02+	8.15	7.62
Solids: Dissolved	1.0	0	72.4	97	58.6	0	179	230	125	0	202	276	174
Suspended	1.0	4	2.1	3.6	<1.0	2	15	60.4	<1	1	7.5	19.6	<1.0
Specific Conductivity (µs/cm)	-	0	119	119	-	0	244	244	-	0	331	331	-
Sulphate	-	1	2.9	4.0	<1.0	0	22.5	26.2	13.6	0	17.0	23.6	10.5
Temperature (°C)	-	0	6.7	9.0	1.0	0	4.7	7.0	2.0	0	9.1	12	6
Turbidity (NTU)	-	5	1.2	1.4	<1.0	4	2.3	4.8	<1.0	4	3.7	6.6	<1

\+ Median Value
* Seven values for each characteristic except flow (n=5)
Conductivity (n=1), cyanide (n=6) and uranium (n=3)

Data Source: Mascot Gold Mines Ltd.

TABLE 3

MAXIMUM CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE
(mg/L-N)

pH	Temp. 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	27.7	28.3	27.9	27.5	27.2	26.8	26.5	26.2	26.0	25.7	25.5
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8	25.5	25.2	25.0	24.7
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9	24.6	24.4	24.1	23.9
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9	23.6	23.4	23.1	22.9
6.9	24.6	24.2	23.9	23.6	23.3	23.0	22.7	22.5	22.2	22.0	21.8
7.0	23.2	22.8	22.5	22.2	21.9	21.6	21.4	21.1	20.9	20.7	20.5
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9	19.7	19.5	19.3	19.1
7.2	19.9	19.6	19.3	19.0	18.8	18.6	18.3	18.1	17.9	17.8	17.6
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7	16.5	16.3	16.2	16.0
7.4	16.2	16.0	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4
7.5	14.4	14.1	14.0	13.8	13.6	13.4	13.3	13.1	13.0	12.9	12.7
7.6	12.6	12.4	12.2	12.0	11.9	11.7	11.6	11.5	11.4	11.3	11.2
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10.0	9.92	9.83	9.73	9.65
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57	8.48	8.40	8.32	8.25
7.9	7.82	7.71	7.60	7.51	7.42	7.33	7.25	7.17	7.10	7.04	6.98
8.0	6.55	6.46	6.37	6.29	6.22	6.14	6.08	6.02	5.96	5.91	5.86
8.1	5.21	5.14	5.07	5.01	4.95	4.90	4.84	4.80	4.75	4.71	4.67
8.2	4.15	4.09	4.04	3.99	3.95	3.90	3.86	3.83	3.80	3.76	3.74
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09	3.06	3.03	3.01	2.99
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47	2.45	2.43	2.41	2.40
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98	1.96	1.95	1.94	1.93
8.6	1.69	1.67	1.65	1.63	1.61	1.60	1.59	1.58	1.57	1.56	1.55
8.7	1.35	1.33	1.32	1.31	1.30	1.29	1.28	1.27	1.26	1.26	1.25
8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.02	1.02	1.02
8.9	0.871	0.863	0.856	0.849	0.844	0.839	0.836	0.833	0.832	0.831	0.831
9.0	0.703	0.697	0.692	0.688	0.685	0.682	0.681	0.681	0.680	0.681	0.682

pH	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	25.2	25.0	24.8	24.6	24.5	24.3	24.2	24.0	23.9	23.8
6.6	24.5	24.3	24.1	23.9	23.8	24.6	23.5	23.3	23.3	23.2
6.7	23.7	23.5	23.3	23.1	23.0	22.8	22.7	22.6	22.5	22.4
6.8	22.7	22.5	22.3	22.2	22.0	21.9	21.8	21.7	21.6	21.5
6.9	21.6	21.4	21.3	21.1	21.0	20.8	20.7	20.6	20.5	20.4
7.0	20.3	20.2	20.0	19.9	19.7	19.6	19.5	19.4	19.3	19.2
7.1	18.9	18.8	18.7	18.5	18.4	18.3	18.2	18.1	18.0	17.9
7.2	17.4	17.3	17.2	17.1	16.9	16.8	16.8	16.7	16.6	16.5
7.3	15.9	15.7	15.6	15.5	15.4	15.3	15.2	15.2	15.1	15.1
7.4	14.2	14.1	14.0	13.9	13.9	13.8	13.7	13.6	13.6	13.5
7.5	12.6	12.5	12.4	12.4	12.3	12.2	12.2	12.1	12.1	12.0
7.6	11.1	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.6	10.5
7.7	9.57	9.50	9.43	9.37	9.31	9.26	9.22	9.81	9.15	9.12
7.8	8.18	8.12	8.07	8.02	7.97	7.93	7.90	7.87	7.84	7.82
7.9	6.92	6.88	6.83	6.79	6.75	6.72	6.69	6.67	6.65	6.64
8.0	5.81	5.78	5.74	5.71	5.68	5.66	5.64	5.62	5.61	5.60
8.1	4.64	4.61	4.59	4.56	4.54	4.53	4.51	4.50	4.49	4.49
8.2	3.71	3.69	3.67	3.65	3.64	3.63	3.62	3.61	3.61	3.61
8.3	2.97	2.96	2.94	2.93	2.92	2.92	2.91	2.91	2.91	2.91
8.4	2.38	2.37	2.36	2.36	2.35	2.35	2.35	2.35	2.35	2.36
8.5	1.92	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.91	1.92
8.6	1.55	1.54	1.54	1.54	1.54	1.54	1.55	1.55	1.56	1.57
8.7	1.25	1.25	1.25	1.25	1.25	1.26	1.26	1.27	1.28	1.29
8.8	1.02	1.02	1.02	1.02	1.03	1.03	1.04	1.05	1.06	1.07
8.9	0.832	0.834	0.838	0.842	0.847	0.853	0.861	0.870	0.880	0.891
9.0	0.684	0.688	0.692	0.698	0.704	0.711	0.720	0.729	0.740	0.752

TABLE 4

AVERAGE 30-DAY CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE
(mg/L-N)

pH	Temp. 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.6	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.7	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.8	2.08	2.05	2.02	1.99	1.96	1.94	1.92	1.90	1.88	1.86	1.84
6.9	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.0	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.2	2.08	2.05	2.02	1.99	1.96	1.95	1.92	1.90	1.88	1.86	1.85
7.3	2.08	2.05	2.02	1.99	1.97	1.95	1.92	1.90	1.88	1.86	1.85
7.4	2.08	2.05	2.02	2.00	1.97	1.95	1.92	1.90	1.88	1.87	1.85
7.5	2.08	2.05	2.02	2.00	1.97	1.95	1.93	1.91	1.88	1.87	1.85
7.6	2.09	2.05	2.03	2.00	1.97	1.95	1.93	1.91	1.89	1.87	1.85
7.7	2.09	2.05	2.03	2.00	1.98	1.95	1.93	1.91	1.89	1.87	1.86
7.8	1.78	1.75	1.73	1.71	1.69	1.67	1.65	1.63	1.62	1.60	1.59
7.9	1.50	1.48	1.46	1.44	1.43	1.41	1.39	1.38	1.36	1.35	1.34
8.0	1.26	1.24	1.23	1.21	1.20	1.18	1.17	1.16	1.15	1.14	1.13
8.1	1.00	0.989	0.976	0.963	0.952	0.942	0.932	0.922	0.914	0.906	0.899
8.2	0.799	0.788	0.777	0.768	0.759	0.751	0.743	0.736	0.730	0.724	0.718
8.3	0.636	0.628	0.620	0.613	0.606	0.599	0.594	0.588	0.583	0.579	0.575
8.4	0.508	0.501	0.495	0.489	0.484	0.479	0.475	0.471	0.467	0.464	0.461
8.5	0.405	0.400	0.396	0.381	0.387	0.384	0.380	0.377	0.375	0.372	0.370
8.6	0.324	0.320	0.317	0.313	0.310	0.308	0.305	0.303	0.301	0.300	0.298
8.7	0.260	0.257	0.254	0.251	0.249	0.247	0.246	0.244	0.243	0.242	0.241
8.8	0.208	0.206	0.204	0.202	0.201	0.200	0.198	0.197	0.197	0.196	0.196
8.9	0.168	0.166	0.165	0.163	0.162	0.161	0.161	0.160	0.160	0.160	0.160
9.0	0.135	0.134	0.133	0.132	0.132	0.131	0.131	0.131	0.131	0.131	0.131

	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.6	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.7	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.8	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.42	1.32	1.22
6.9	1.82	1.81	1.80	1.78	1.77	1.64	1.53	1.42	1.32	1.22
7.0	1.83	1.81	1.80	1.79	1.77	1.64	1.53	1.42	1.32	1.22
7.1	1.83	1.81	1.80	1.79	1.77	1.65	1.53	1.42	1.32	1.23
7.2	1.83	1.81	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.3	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.4	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.5	1.83	1.82	1.81	1.80	1.78	1.66	1.54	1.43	1.33	1.23
7.6	1.84	1.82	1.81	1.80	1.79	1.66	1.54	1.43	1.33	1.24
7.7	1.84	1.83	1.81	1.80	1.79	1.66	1.54	1.44	1.34	1.24
7.8	1.57	1.56	1.55	1.54	1.53	1.42	1.32	1.23	1.14	1.07
7.9	1.33	1.32	1.31	1.31	1.30	1.21	1.12	1.04	0.970	0.904
8.0	1.12	1.11	1.10	1.10	1.09	1.02	0.944	0.878	0.818	0.762
8.1	0.893	0.887	0.882	0.878	0.874	0.812	0.756	0.704	0.655	0.611
8.2	0.714	0.709	0.706	0.703	0.700	0.651	0.606	0.565	0.527	0.491
8.3	0.571	0.568	0.566	0.564	0.562	0.523	0.487	0.455	0.424	0.396
8.4	0.458	0.456	0.455	0.453	0.452	0.421	0.393	0.367	0.343	0.321
8.5	0.369	0.367	0.366	0.366	0.365	0.341	0.318	0.298	0.278	0.261
8.6	0.297	0.297	0.296	0.296	0.296	0.277	0.259	0.242	0.227	0.213
8.7	0.241	0.240	0.240	0.241	0.241	0.226	0.212	0.198	0.186	0.175
8.8	0.196	0.196	0.196	0.197	0.198	0.185	0.174	0.164	0.154	0.145
8.9	0.160	0.161	0.161	0.162	0.163	0.153	0.144	0.136	0.128	0.121
9.0	0.132	0.132	0.133	0.134	0.135	0.128	0.121	0.114	0.108	0.102

- the average of the measured values must be less than the average of the corresponding individual values in Table 4.
- each measured value is compared to the corresponding individual values in Table 4. No more than one in five of the measured values can be greater than one-and-a-half times the corresponding criteria values in Table 4.