TECHNICAL MEMORANDUM

To: Bruce Graff, P.Eng. **Date: April 9, 2009**

From: Andrew Rollo, P.Geo. **Project #: 489-2**

Subject: Pine Creek Water Quality Impact Predictions and Receiving Environment Monitoring Point Objectives

The following memorandum describes the conceptual methodology that will be used to predict impacts to Pine Creek resulting from operations at the Yellowjacket Mine as well as present proposed site specific water quality objectives (SSWQOs) for Pine Creek downstream of the Yellowjacket Gold Project. Monitoring station PC-2 has been selected as the potential receiving environment monitoring point on Pine Creek, as it is downstream of all mine-related influences and well upstream of fish-bearing habitat. Following a discussion of the proposed development at the Yellowjacket Project (Section 1), a description of the conceptual approach that will be used in receiving environment water quality impact predictions will be presented (Section 2). Additionally, site specific water quality objectives (SSWQOs) will be proposed for parameters that may exceed generic BC water quality objectives (BCWQOs; Section 3). The approach used for SSWQO development for Pine Creek is based on experience gained from other sites within British Columbia.

1 Background

The Yellowjacket Project has a small footprint (18.4 ha), which is comprised of:

- Placer mining of surficial materials (145 m x 90 m);
- Open pit mining of mineralized zones (70 m x 40 m);
- Process plant – jaw crusher, SAG and grinding mills, Knelson concentrator (gravity flow);
- Material stockpiles and dumps;
- Tailings/Sedimentation Pond containing tailings and process plant supernatant. Discharge of water from this pond will be through exfiltration to alluvial gravels;
- Processing groundwater extraction, including pumps and pipelines;
- Access roads including internal roads within the pit;

- Diesel generator for electrical power including on-site transmission;
- A fuel storage and handling facility (double walled enviro tank system);
- Office and first aid trailers.

All of the mine components listed above are currently in place, and the proposed mine plan involves the development of a series of pits similar in dimension to the bulk sample pit (70 m x 40 m). These pits, which will be developed over five to seven years, will extend approximately 500 m eastward (upstream) along the strike of the Pine Creek fault. Development during 2009 will involve the extraction and processing of approximately 30,000 tonnes of material from the open pit. Tailings generated from processing of ore material (Knelson Gravity Concentration) will be deposited, along with process plant discharge supernatant solution, to the tailings/sedimentation pond. Water will not be surface discharged from the tailings/sed pond; rather it will be allowed to exfiltrate into the alluvial gravels that line the floodplain in the area of proposed development and enter Pine Creek downstream of the mine site.

Currently, the 2009 environmental monitoring program for the Yellowjacket Project is comprised of two components; water quality monitoring and a metal leaching (ML) / acid rock drainage (ARD) characterization. The water quality monitoring program involves the collection of monthly water samples from four locations within Pine Creek (PC-1, PC-6, PC-2 and PC-5) as well as from the tailings/sedimentation pond and bulk sample pit (Lorax 2009a). The ML/ARD program, on the other hand, will involve the collection of waste generated during the 2007 bulk sample program and drill hole material from the region of proposed development (Lorax 2009b). Static testing will be conducted on all materials, including acid base accounting, multi-element geochemistry, and mineralogical analysis. As well, field leach bin testing will be conducted to evaluate the metal leaching behaviour of waste materials that will remain on surface and backfilled to the open pits.

2 Receiving Environment Water Quality Predictions

During operations, ore will be processed by Knelson Gravity Concentration, without the use of additional chemicals. Discharge from the process plant will be deposited within the sedimentation pond, and the supernatant will be allowed to exfiltrate to groundwater within the alluvial gravels lining the Pine Creek flood plain. As well, precipitation will infiltrate into waste rock piles leaching soluble metals, ultimately discharging to groundwater within the alluvial gravels. This site influenced groundwater plume, comprised of tailings/sed pond and waste rock discharge water, will flow downstream until it eventually enters Pine Creek. Therefore, the main sources of site contact waters include:

- process plant supernatant;
- discharge from ore and waste rock piles; and,
- Open pit sump discharge.

Additionally, placer mining upstream of the Yellowjacket Project has the potential to impact water quality in Pine Creek downstream of the Yellowjacket site. These placer mining related impacts were not captured during the 2006 – 2007 baseline water quality monitoring program and are not currently operating in the area. Therefore, the current approach to Pine Creek impact predictions resulting from operations at the Yellowjacket Project are based on the case where placer operations are not operating on Pine Creek. However, if placer operations commence upstream of PC-2, the impacts from these operations will have to be considered in water quality predictions as well as the water quality monitoring program outlined in Lorax (2009a).

As mentioned in Section 1, water quality samples will be collected from the process plant and the open pit during 2009. Additionally, static and kinetic characterization will be conducted on waste rock materials generated during the bulk sample program to obtain data on waste rock discharge water quality. These three site source terms will then be combined with water balance calculations and baseline water quality monitoring data to predict the downstream water quality impacts to Pine Creek.

While it is understood that the quality of site affected groundwater entering Pine Creek may be of better quality than process plant discharge water, due to attenuation mechanisms within the alluvial gravels, the water quality measured during tailings/sed pond water quality monitoring will be used to conservatively approximate the composition of this site contact water.

3 Receiving Environment Monitoring Point and Site Specific Water Quality Objectives

Currently, it is estimated that all site contact water will enter Pine Creek via groundwater approximately 200 m downstream of the mine footprint and a water quality monitoring location has been established at this site (PC-6; Lorax 2009b). While this site is expected to detect all site discharges, there is the chance that some groundwater will discharge to

Pine Creek further downstream. As a result, a second water quality monitoring location has been included in the Yellowjacket Water Quality Monitoring Program (PC-2; Lorax 2009b). This monitoring station is located well downstream of mine related influences and is well above fish bearing habitat; therefore, this site has been selected as the receiving environment monitoring point for the Yellowjacket Project.

Summary statistics for baseline water quality data collected from station PC-2 in Pine Creek from 2006 – 2007 are presented in Table 1, including minimum, maximum, 90th percentile, mean, and median values. As well, BC water quality objectives (BCWQOs) for the protection of freshwater aquatic life are included in this table for comparative purposes. These data indicate that the maximum and 90th percentile concentrations of a large number of parameters naturally exceed the maximum BCWQOs during periods of high TSS and high flow. Therefore, site specific water quality objectives (SSWQOs) need to be developed in order to accurately detect impacts to Pine Creek as a result of operations at the Yellowjacket Project.

The methods for deriving SSWQOs published by the BC Ministry of Environment (MacDonald, 1997) recommend that the applicability of SSWQOs for the protection of aquatic life be evaluated in comparison to:

- The background levels of the contaminant;
- The limit of quantification (i.e. analytical detection limit) for the substance;
- The applicability to the site under consideration of the toxicological information that was used to derive the generic WQOs; and,
- The processes and levels of substances that could affect the bioavailability of the contaminant (if these were not accounted for in the derivation of the BCWQOs).

The baseline data for PC-2, summarized in Table 1, show that background concentrations of numerous total metals are greater than the BCWQO values during periods of high suspended sediment loads, including aluminum(dissolved), arsenic, cobalt, copper, lead, manganese, nickel, silver, vanadium, and zinc (Figure 1; Lorax 2009c). When 90th percentile values are considered, this list is reduced to aluminum (dissolved), cobalt, copper, nickel, silver, vanadium, and zinc (Table 1). Therefore, SSWQOs are required for these elements that would apply during periods of elevated TSS (freshet and storm events).

Table 1:
2006 – 2007 Pine Creek Baseline Water Quality Data at PC-2 compared to BC water quality guidelines for the protection of aquatic life (from Lorax 2009c).

				Baseline Summary (May-06 to June-07)					Guideline[1]	
Parameters	**units**	**#**	**# <DL**	**min**	**max**	**90th Percentile**	**mean**	**median**	**30-day mean**	**Max**
Physical Parameters										
Hardness	mg $CaCO_3$/L	19	0	46.2	104	101.2	66.5	56.8		
pH	pH	19	0	7.81	8.21	8.2	8.02	8.02	6.5-9	NP
TSS	mg/L	19	3	<3	620	110.2	63.7	11.6		
Turbidity	NTU	17	0	0.97	419	91.72	45.6	8.33		
Anions										
Chloride	mg/L	19	18	<0.5	1.29	<0.5	<0.5	<0.5	150	600
Sulphate	mg/L	19	0	3.53	6.66	6.34	4.85	4.64	NP	100
Fluoride	mg/L	12	0	0.271	0.722	0.71	0.545	0.568	NP	0.3
Nutrients										
Ammonia Nitrogen[2]		19	16	<0.005	0.028	0.0068	0.00653	<0.005	0.37	1.9
Nitrate Nitrogen	mg/L	19	2	<0.005	0.0471	0.044	0.0242	0.0244	40	200
Nitrite Nitrogen[3]	mg/L	19	18	<0.001	0.0019	<0.001	0.00105	<0.001	0.02	0.06
Cyanides										
WAD Cyanide	mg/L	5	5	<0.001	<0.001	<0.001	<0.001	<0.001	5	10
Total Metals										
Aluminum - Dissolved	mg/L	19	0	0.0044	**0.586**	**0.156**	**0.0776**	0.0207	0.05	0.1
Antimony	mg/L	19	14	<0.0001	0.0004	0.00032	0.00015	<0.0001	NP	0.02*
Arsenic	mg/L	19	1	0.0005	0.00894	0.0033	0.00168	0.00087	NP	0.005*
Boron	mg/L	19	19	<0.01	<0.1	<0.01	<0.01	<0.01	NP	1.2
Cadmium[4]	mg/L	19	10	<0.000017	0.000298	0.000117	0.0000584	0.000023	NP	0.000018*
Chromium	mg/L	19	2	<0.0005	0.0887	0.031	0.0122	0.00219	NP	0.001*
Cobalt	mg/L	19	4	<0.0001	**0.0203**	**0.0059**	0.00255	0.00078	0.004	0.11
Copper[4]	mg/L	19	0	0.00058	**0.0335**	**0.0105**	**0.00504**	0.00175	0.002	0.007
Iron	mg/L	19	0	0.063	20.3	4.94	2.41	0.432	NP	0.3*
Lead[4]	mg/L	19	3	<0.00005	**0.00685**	0.00157	0.000833	0.000278	0.005	0.034
Lithium	mg/L	19	18	<0.005	0.0102	0.00604	0.00529	<0.005	NP	0.014*
Manganese[4]	mg/L	19	0	0.0033	0.419	0.1138	0.0561	0.0212	0.825	1.09
Mercury	mg/L	18	17	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00002	0.0001
Molybdenum	mg/L	19	0	0.00127	0.00315	0.00296	0.0024	0.00241	1	2
Nickel[4]	mg/L	19	0	0.00266	0.25	0.0778	0.0338	0.0112	NP	0.025
Selenium	mg/L	19	10	<0.0005	0.001	0.000858	0.000624	<0.0005	0.002	NP
Silver[4]	mg/L	19	12	<0.00001	**0.000126**	**0.0000664**	0.0000284	<0.00001	0.00005	0.0001
Thallium	mg/L	19	18	<0.0001	0.00015	0.00011	0.000103	<0.0001	NP	0.0003*
Titanium	mg/L	19	11	<0.01	0.614	0.178	0.0796	<0.01	NP	2*
Uranium	mg/L	19	0	0.00213	0.00309	0.00306	0.0026	0.00253	NP	0.3*
Vanadium	mg/L	19	8	<0.001	0.0358	0.01096	0.00552	0.0013	NP	0.006*
Zinc[4]	mg/L	19	7	<0.001	**0.0426**	**0.01102**	0.00633	0.0019	0.0075	0.033

Notes:
* Indicates Working Guideline
[1]BC Provincial Guidelines for Protection of Aquatic Life (BC MOE, 2006a);
[2]Guideline based on pH = 8.5 and temperature= 15°
[3]Guideline based on [chloride] <2 mg/L
[4]Guidlines based on a hardness of 50 mg $CaCO_3$/L;
- NP denotes 'None Proposed'; **bold** values indicate exceedences of 30 day mean BC PWQO, shaded values indicate exceedences of maximum BC PWQO,
- Statistics were calculated assuming undetectable values equal to the detection limit.
- DL = detection limit

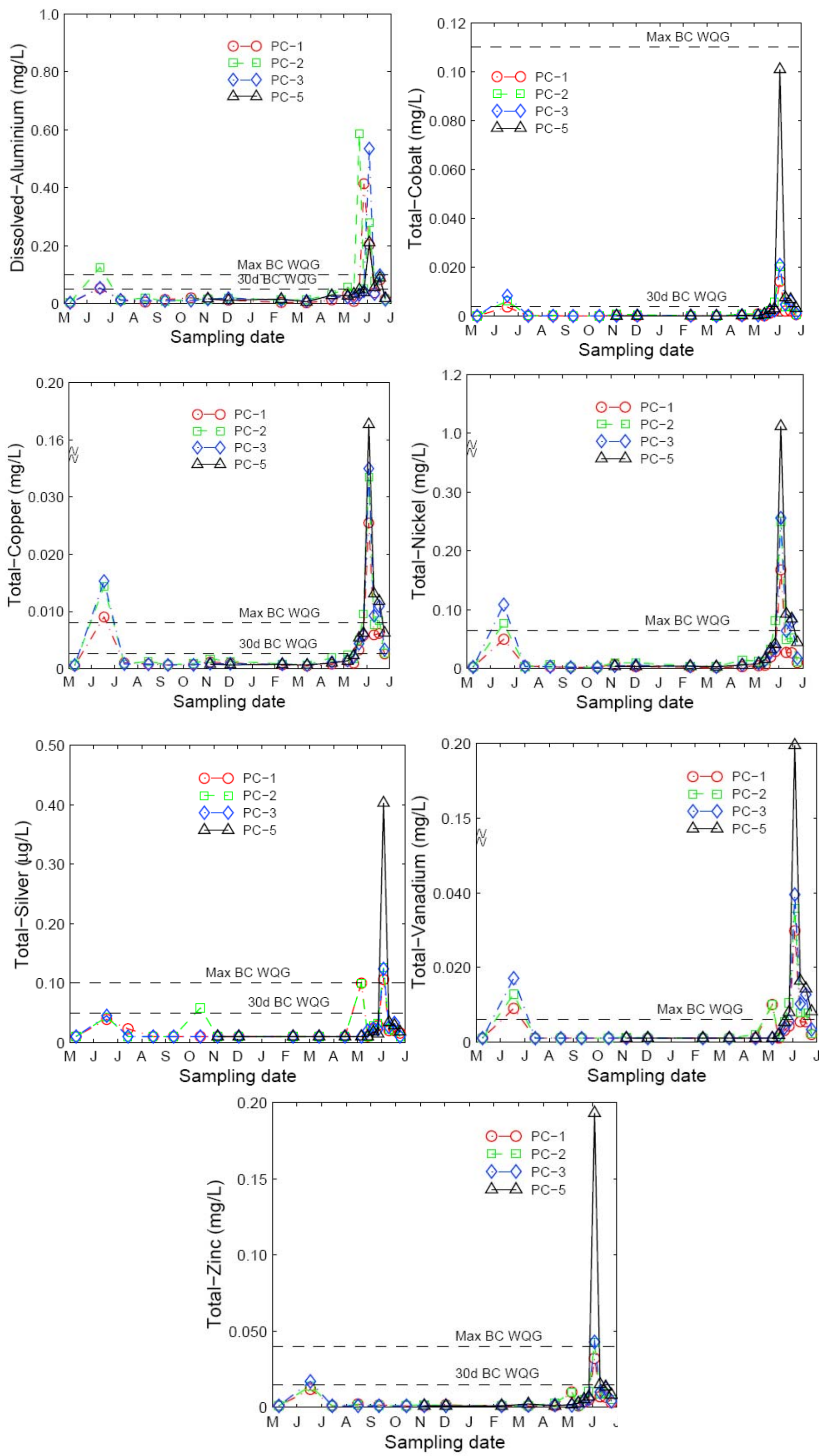

Figure 1: Time series plots for aluminum (dissolved), total cobalt, total copper, total nickel, total silver, total vanadium, and total zinc at station PC-2 in Pine Creek from May 2006 to June 2007 (Lorax 2009c).

A comparison of Pine Creek baseline water quality data from 2006 to 2007 have been used to develop SSWQOs for aluminum (dissolved), cobalt, copper, nickel, silver, vanadium, and zinc based on the following criteria (Table 2):

- If the 90^{th} percentile value exceeds the maximum BCWQO, as outlined in Table 1, the proposed SSWQO is based on the 90^{th} percentile baseline value between May 2006 and June 2007 plus 20%. The additional 20% provides a reasonable estimate of the maximum variation in concentrations that would be measured under typical natural high-flow and high suspended load conditions;
- If the 90^{th} percentile value is less than the maximum BCWQO, but greater than the 30-day chronic BCWQO, the maximum BCWQO is adopted during high-flow and high suspended load conditions;
- If the 90^{th} percentile value is less than both the maximum and 30-day BCWQOs, the BCWQOs are applied; and,
- During clear flow periods (*i.e.* low flow and low TSS), the SSWQOs for these metals will be equal to the generic BCWQOs listed in Table 1.

Additionally, there are a number of other parameters that appear to exceed BCWQOs throughout the year, including fluoride, cadmium, chromium, and iron (Figure 3). Site specific water quality objectives were developed for these parameters using the following criteria (Table 2):

- For fluoride, the proposed SSWQO is set at the 90^{th} percentile value plus 20% to account for natural variation due to high-flow and high TSS conditions. This SSWQO is applicable all year as the high fluoride concentrations are observed during clear flow periods (Figure 3).
- For cadmium, the proposed SSWQO is based on the USEPA(2001) hardness dependent guideline (= 0.938[e(0.7409[ln(Hardness)]-4.719]):
  - During high flow and high TSS conditions, it is proposed that the SSWQO be based on a hardness value of 100 mg $CaCO_3$/L; and,
  - During clear flow periods, it is proposed that a hardness value of 60 mg $CaCO_3$/L be used.
- For iron and chromium, the proposed SSWQO is equal to:
  - the 90^{th} percentile value + 20% during high-flow and high TSS conditions; and,
  - The median (50^{th} percentile) value + 20% during clear flow periods.

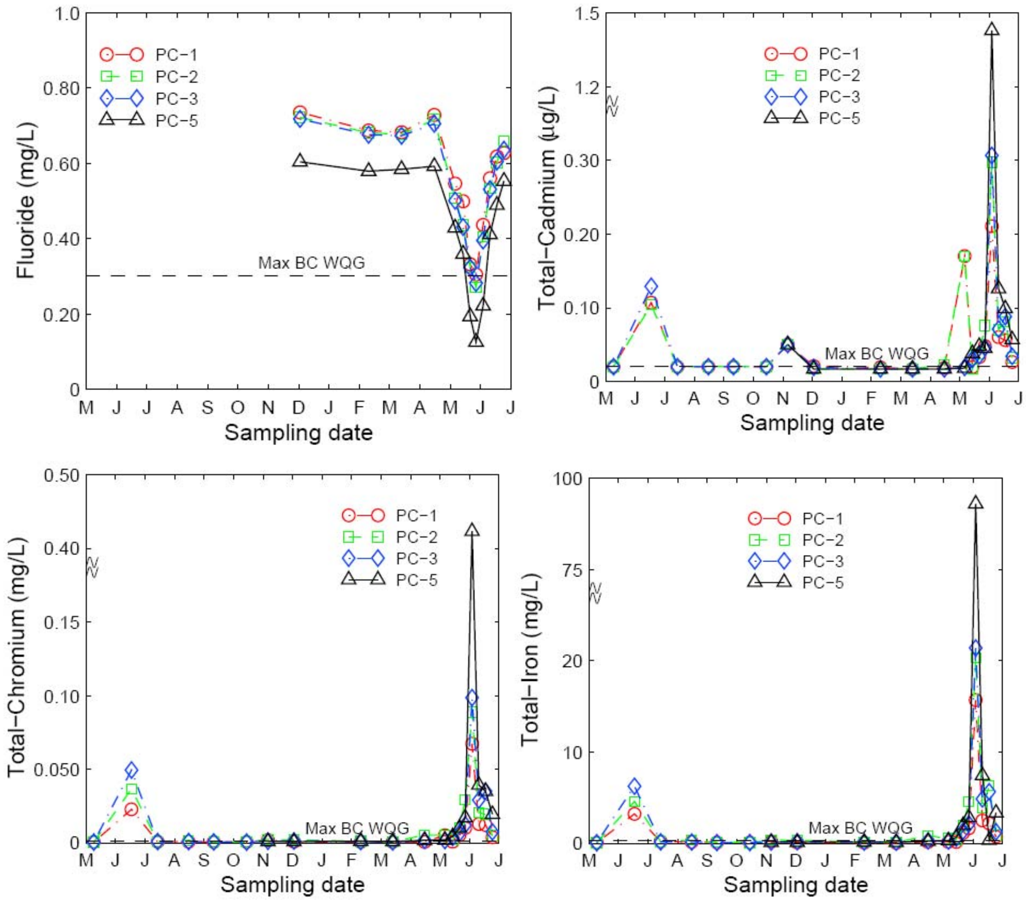

Figure 2: Time series plots for fluoride, total cadmium, total chromium, and total iron at station PC-2 in Pine Creek from May 2006 to June 2007 (Lorax 2009c).

Although the proposed preliminary SSWQOs are intended to cover a majority of flow conditions and concentrations encountered within Pine Creek, extremely high sediment loads occur naturally during peak flows due to entrainment of fine grained material from the alluvial gravels comprising the stream bed. Therefore, it is expected that during periods of high flow within Pine Creek, the proposed SSWQOs will be exceeded as a result of elevated TSS concentrations. This, however, will not necessarily indicate impacts from mining activity at the Yellowjacket Project and care should be taken to properly interpret elevated concentrations during high-flow and high TSS conditions and ensure that the context of the increases is understood. As well, it should be noted that these preliminary SSWQOs have been proposed in the absence of water quality impact predictions. Once impact predictions are available, the proposed SSWQOs should be re-evaluated, through discussions with MOE, to ensure that they appropriately detect mining related impacts while ensuring the protection of Pine Creek water quality.

Table 2:
Proposed preliminary site-specific water quality objectives for station PC-2 in Pine Creek

Parameters	units	Baseline 90th Percentile	Baseline Median Value	High Flow/TSS SSWQO[1]	Clear flow/low TSS SSWQO[2]	
					30-day Mean	Max
Anions						
Fluoride	mg/L	0.71	0.568	0.852[A]	NP	0.852[A]
Total Metals						
Aluminum - Dissolved	mg/L	0.156	0.0207	0.187[A]	0.05[D]	0.1[C]
Cadmium	mg/L	0.000117	0.000023	0.00026[B]	NP	0.00017[E]
Chromium	mg/L	0.031	0.00219	0.0372[A]	NP	0.0026[F]
Cobalt	mg/L	0.0059	0.00078	0.113[C]	0.004[D]	0.11[C]
Copper	mg/L	0.0105	0.00175	0.0126[A]	0.002[D]	0.007[C]
Iron	mg/L	4.94	0.432	5.93[A]	NP	0.52[F]
Nickel	mg/L	0.0778	0.0112	0.0934[A]	NP	0.025[C]
Silver	mg/L	0.0000664	<0.00001	0.0001[C]	0.00005[D]	0.0001[C]
Vanadium	mg/L	0.01096	0.0013	0.0132[A]	NP	0.006[C]
Zinc	mg/L	0.01102	0.0019	0.033[C]	0.0075[D]	0.033[C]

[1] Applicable during naturally high flow and high TSS conditions
[2] Applicable during clear flow and low TSS conditions
[A] = 90th percentile value * 1.2
[B] = based on USEPA (2001) using Hardness = 100 mg $CaCO_3$/L
[C] = Maximum BC WQO from Table 1
[D] = 30-day mean BCWQO from Table 1
[E] = based on USEPA (2001) using Hardness = 60 mg$CaCO_3$/L
[F] = median value * 1.2
NP = none proposed

4 References

MacDonald (1997). Methods for Deriving Site-specific Water Quality Objectives in British Columbia and Yukon. Environmental Sciences Ltd. November 1997.

Lorax (2009a). Memorandum: 2009 Yellowjacket Mine Water Quality Monitoring Program. Submitted to L. Dandy and C. Downie by Andrew Rollo (Lorax Environmental), March 6, 2009

Lorax (2009b). Memorandum: 2009 Yellowjacket Water Quality and Waste Sampling Program. Submitted to B. Graff, L. Dandy by Andrew Rollo (Lorax Environmental), March 10, 2009.

Lorax (2009c). Yellowjacket Gold Project – Baseline Water Quality Conditions (2006-2007). Prepared by Lorax Environmental Services, March 2009.