CASE STUDIES OF ML/ARD ASSESSMENT AND MITIGATION: PLACEMENT OF THE SULPHURETS WASTE ROCK IN BRUCEJACK LAKE

MEND Report 9.1c

This work was done on behalf of MEND and sponsored by The Mining Association of Canada and the Mining and Mineral Sciences Laboratories of Natural Resoures Canada

July 2005

CANMET Mining and Mineral Sciences Laboratories

CASE STUDIES OF ML/ARD ASSESSMENT AND MITIGATION: PLACEMENT OF THE SULPHURETS WASTE ROCK IN BRUCEJACK LAKE

Produced as part of a series of case studies documenting ML/ARD assessment and mitigation at mines in Canada. Produced on behalf of MEND with support from The Mining Association of Canada and Natural Resources Canada

by William Price
CANMET-MMSL

Project: 602656
Report CANMET-MMSL 05-023(CR)

Version: July 2005

Natural Resources Canada   Ressources naturelles Canada

Canada

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

SUMMARY

The Sulphurets Project was an advanced exploration project that is located in the coastal mountains of British Columbia, approximately 1375 meters asl. Underground workings were excavated in the West Zone Deposit at Sulphurets between 1986 and 1990, as part of an advanced exploration and bulk sampling program. The underground workings were 5,276 m in length and consisted of a decline and four levels: 1350m, 1300m, 1250m and 1200m (Bruce McLeod, pers. communication). The underground was excavated in the West Zone deposit, a structurally controlled, complex stock work, epithermal silver-gold-base metal quartz vein located at a volcanic-sedimentary contact. Construction of the underground workings generated approximately 124,000 tonnes (44,300 m^3) of waste rock. The waste rock was placed as a shallow pad along the southern boundary of Brucejack Creek and used as the foundation for the camp and other facilities. Two small piles of low-grade ore were placed at the back of the pad and two small streams, Camp and Little Camp Creek, were piped under the pad.

The underground workings and the waste rock pad are adjacent to Brucejack Creek, just downstream of Brucejack Lake. Brucejack Creek flows for 2.4 km from Brucejack Lake to the Sulphurets Glacier. It then goes for a further 4 km under the Sulphurets Glacier, eventually emerging in Sulphurets Creek, which flows 14 km prior to entering the Unuk River. A 30 m waterfall limits fish access to the lower 1 km of Sulphurets Creek. The mean annual temperature was estimated to be -2ºC, with a mean annual precipitation between 1,800 and 2,500 mm, the majority of this being snow. Snow and access difficulties are major impediments to work at the site. Snow covers the site for at least 8 months of the year.

In 1989, the operator Newhawk Gold Mines Ltd., was issued a Mine Development Certificate for an underground mine, an on-site mill, and subaqueous disposal of fine tailings, mine water and potentially ARD generating waste rock into Brucejack Lake. Due to economic considerations the operation never went into production and the underground was allowed to flood. In 1998 development plans were suspended indefinitely and Newhawk initiated a review of the potential reclamation options. The main focus of the reclamation was on the waste rock, which had been placed in a shallow pad outside the adit and adjacent to Brucejack Creek.

Metal Leaching / Acid Rock Drainage Prediction

The main source of information on the ML/ARD characteristics of the waste rock was the test work conducted in support of the mine proposal: acid base accounting (ABA), measurements of elemental concentrations, humidity cell tests and leach tests using acetic acid and sulphuric acid. ABA data for the waste rock came from six individual samples collected from inside the underground workings and a composite waste rock sample. The waste samples had a paste pH of 7.7 to 8.6, AP values of 86 to 211 kg $CaCO_3$/t and NP values of 10 to 92 kg $CaCO_3$/t. Six of the waste samples had NPR values between 0.07 and 0.39. One had an NPR of 1.08. NPR values < 1 indicate that when exposed, the majority of the rock at the site would eventually be ARD generating. The low NP and NPR values (i.e., NP values of 10 to 16 kg $CaCO_3$/t and NPR values < 0.14) suggest that ARD could occur relatively quickly, especially if a significant portion of the NP was from silicate rather than Ca or Mg carbonate minerals.

Elemental concentrations in the waste rock samples exceeded the upper limits found in unmineralized rock for Ag (14 to 45 mg/kg compared to 0.1 mg/kg), As (10 to 225 mg/kg compared to 2 mg/kg) and Sb (10 to 25 mg/kg compared to 0.2 mg/kg). Concentrations of other trace metals in the waste rock samples were: Cd < 0.5 to 3 mg/kg, Cu 29 to 42 mg/kg, Pb 30 to 84 mg/kg and Zn 15 to 354 mg/kg. Trace metal concentrations in samples of sediment taken from Brucejack Creek and Brucejack Lake were similar to those of the waste rock.

Six waste rock humidity cell tests were conducted. Within the 10-week test period, all the cells produced drainage pH values between 7 and 8. Metal concentrations in the humidity cell leachate were generally less than the relatively high detection limits. The exceptions were Ca, Mg and Mn, which were released in relatively high concentrations, and Ba and Zn, which had lower detection limits. The highest Mn concentration in the humidity cell leachate was 2.42 mg/L. The highest Zn concentration in the humidity cell leachate was 0.08 mg/L. The high Mn concentration perhaps indicates the presence of $MnCO_3$.

The average sulphate production rate for weeks 2 to 10 ranged from 0.0137 g/kg/wk for the quartz vein to 0.0453 g/kg/wk for the silicified andesite. Based on the average sulphate production rate measured in the humidity cells, the rate of calcite depletion[1] would range from 0.7 to 2.4 kg $CaCO_3$/t and it would take 7 to 87 years to exhaust the sample NP and 4 to 14 years to deplete an NP of 10 kg $CaCO_3$/t. A four-fold slower sulphide oxidation and NP depletion rate was predicted under field conditions due to the 20ºC difference between the laboratory and the mean annual site temperature of -2ºC and a doubling of the Arrhenius activity for every 10ºC temperature rise. The report did not mention factors potentially accelerating the onset of ARD, such as the heat produced by sulphide oxidation (which may increase temperatures within the waste), NP depletion by processes other than dump sulphide oxidation (e.g., leaching by groundwater); or, if some of the NP was unavailable or insufficiently reactive. It also failed to point out that oxidation rates can accelerate greatly after weeks 10 to 20 despite near-neutral conditions (Morin & Hutt, 1997a and 1999).

Water Quality Monitoring

At the request of the BC Ministry of Water, Land and Air Protection, starting in 1987, Newhawk monitored water quality at various locations around the site. The monitored drainages and the starting dates were as follows:

- Brucejack Creek above and below the waste rock pad, and discharge from the portal (Portal), starting in 1987;
- Brucejack Lake, starting in 1988;
- two standpipes (WSP and ESP) installed in the waste rock dump in 1989;
- Camp Creek immediately upstream of the waste rock pile (inflow), starting in 1989;
- Camp Creek below the waste rock pile just prior to it entering Brucejack Creek (outflow), starting in 1993; and
- Little Camp Creek immediately upstream of the waste rock pile (inflow) and below the waste rock pile just prior to it entering Brucejack Creek (outflow), starting in 1993.

The west and east standpipes (WSP and ESP) were installed to monitor the progress of waste rock weathering and the quality of drainage flowing from the pile towards Brucejack Creek. The water table was at the base of the standpipe and the standpipe drainage was removed with a pump. The drainage pH in 1989, the year the standpipes were installed, varied from 6.6 to 7.2. From 1991 to 1996, the pH of the WSP drainage was between 2.4 and 3.1. The pH of the ESP drainage was between 5.1 and 6.6 from 1991 to 1993, 3.8 to 4.2 in 1994 and 3.4 to 3.7 in the three samples from 1995 to 1998. In 1998, WSP and ESP had drainage pH levels of 3.6 and 3.4, respectively.

Elevated sulphate and base and trace metals concentrations were measured in the drainage extracted from both standpipes, with the highest concentrations observed in the drainage of WSP. Maximum trace

---

[1] Assuming the following reaction $CaCO_3 + \underline{2H^+} = Ca^{2+} + H_2CO_3$

element concentrations for WSP and ESP, respectively, were As 2.4 and 0.31 mg/L, Cd 92 and 4 µg /L, Cu 2.0 and 0.25 mg/L, Pb 0.6 and 0.1 mg/L and Zn 4.5 and 0.9 mg/L. Most elements largely occurred in the dissolved form. The high concentrations of dissolved Fe in the WSP drainage (> 200 mg/L in three samples), indicated that this drainage could have significant acidity. Another notable observation from the standpipe monitoring was that after drawdown it took many hours for the standpipes to fill sufficiently to take another sample, suggesting that loadings from this source were limited (Bruce Mcleod, pers. communication). A slow rate of water entry may also be due to the fact that the screen became plugged with sediments and/or precipitants.

There were two types of portal discharge. During construction and exploration underground (1987 – June 1990), drainage was removed from the workings by pumping. After pumping ceased in 1990, the workings quickly flooded and by November 1990 the portal discharge was the overflow from the flooded workings. During the period of pumping, the portal discharge had high TSS (up to 5320 mg/L), a pH of 7.5 to 8.3, sulphate 81 to 339 mg/L, alkalinity 52 to 356 mg/L, As 10 to 610 µg/L, Cu < 1 to 1720 µg/L, Fe < 0.03 to 83 mg/L, Pb < 1 to 1490 µg/L and Zn < 5 to 2310 µg/L. During pumping, maximum dissolved trace element concentrations (As 95 µg/L, Cu 17 µg/L, Fe <0.05 mg/L, Pb 96 µg/L and Zn 69 µg/L) were significantly lower than the total concentrations. Peak TSS and total metal concentrations presumably occurred during periods of mining.

After the pumping stopped, the water table rose quickly and the only unflooded portion of the mine above the portal was a small air raise. Compared to the pre-flooding conditions, the following changes were observed in the discharge from the flooded workings:

- little or no TSS (< 1 to 9 mg/L);
- pH initially decreased to 6.8 to 7.2, and then increased to 7.4 to 7.8;
- alkalinity decreased from a median of 116 to 76 mg $CaCO_3$/L;
- sulphate concentrations decreased slightly from a median of 148 to 120 mg $CaCO_3$/L;
- concentrations of total-Fe were <0.03 to 1.0 mg/L, while D-Fe was < 0.12 mg/L; and
- like TSS, total trace element concentrations decreased substantially; As 0.6 to 22 µg/L, Cd 0.2 to 0.6 µg/L, Cu <1 to 23 µg/L, Pb <1 to 12 µg/L and Zn 16 to 255 µg/L.

Although the differences were less pronounced after flooding than when the workings were active, for most species median total trace element concentrations remained higher than dissolved concentrations; As 7.6 µg/L versus 2.5 µg/L, Cd 0.4 µg/L versus < 0.2 µg/L, Cu 2 µg/L versus < 1 µg/L, Pb 6 µg/L versus < 1 µg/L and Zn 46 µg/L versus 42 µg/L. However, the maximum post-flooding total and dissolved concentrations were similar for most trace elements. The notable exception was Pb.

Monitoring was conducted immediately upstream (inlet) and downstream (outlet) of the pad of Camp Creek and Little Camp Creek, two small creeks were conducted in 24-inch culverts under the waste rock pad. The elevated sulphate and trace metal concentrations in the inflows for Camp and Little Camp Creeks indicate a significant natural contaminant source upstream of the waste rock pad, especially for Little Camp Creek. According to Bruce McLeod (pers. communication), the source was natural as the disturbance associated with exploration in these areas was limited to road building and drilling. The low alkalinity and occasionally depressed pH of the Camp Creek inflow indicates depleted NP in the rock upstream. Groundwater with similar chemistry to Camp Creek or leaks in the Camp Creek culvert could increase the dissolution of carbonate minerals within waste rock, potentially accelerating pH depression at the base of the pile.

There was very little difference between upstream and downstream metal concentrations in Camp Creek. Median total and dissolved concentrations of Camp Creek input were As 0.3 and 0.2 µg/L, Ca 13.7 and

14.6 mg/L, Cd 0.4 and 0.5 µg/L, Cu 3 and 3 µg/L, Fe 0.21 and 0.03 mg/L, Mg 0.73 and 0.70 mg/L, Mo < 1 and < 1 µg/L, Pb < 1 and < 1 µg/L, and Zn 32 and 30 µg/L.

From the inlet to outlet of Little Camp Creek, median concentrations of sulphate decreased from 156 to 51 mg/L, D-Cd decreased from 6.6 to 0.6 µg/L, D-Cu decreased from 54 to 8 µg/L, D-Zn decreased from 784 to 62 µg/L, D-Ca decreased from 65 to 18 mg/L, and D-Mg decreased from 3.1 to 0.9 mg/L; while median concentrations of T-As increased from 0.4 to 0.9 µg/L, D-As increased from 0.2 to 0.4 µg/L, T-Pb increased from 7 to 16 µg/L, D-Pb increased from 2 to 13 µg/L, D-Fe increased from 0.08 to 0.45 mg/L and T-Fe increased from 0.27 to 0.54 mg/L. Alkalinity decreased from 14 to 42 mg/L to < 1 to 11 mg/L as creek crossed the waste rock pad. Median pH values of the inlet and outlet of Little Camp Creek were similar, 6.6 in the inflow and 6.2 in the outflow, but for the last two dates (Sept 1994 and July 1998), from the inlet to the outlet, the pH decreased from 6.3 to 4.7 and 6.7 to 4.2.

Potential explanations for the changes in Little Camp Creek include drainage additions from the dump and the underlying natural ground and Brucejack Creek. Evidence of the extent to which Brucejack Creek flooded the base of the dump is provided by the width of the creek after the waste rock was removed. Variation in the height of the water table and Brucejack Creek may account for some of the variability in the outflow chemistry of Little Camp Creek.

Between 1987 and 1998, Upper Brucejack Creek had a pH of 6.6 to 7.9, TSS of < 1 to 14 mg/L, hardness of 14 to 26 mg/L, alkalinity of 11 to 21 mg/L and sulphate of 2 to 12 mg/L. Despite the natural mineralization and activities upstream of Brucejack Lake at the Goldwedge property[2], total and dissolved concentrations of most trace metals were below the detection limits (Cd < 0.2 µg/L, Cu < 1 µg/L, Mo < 1 µg/L, Pb < 1 µg/L and Zn < 5 µg/L). The exception was As, with median values of 1.8 µg/L T-As and 1.2 µg/L D-As and maximum values of 15 µg/L T-As and 8 µg/L D-As. Total-Fe increased in 1991 and peaked (0.72 mg/L) in July 1992. The maximum TSS (14 mg/L) and T-As (15 µg/L) were also recorded in July 1992.

The water quality results for Brucejack Lake, which was only monitored from 1988 to 1991, were very similar to Upper Brucejack Creek.

Compared to Upper Brucejack Creek (UBC), Lower Brucejack Creek (LBC) had:

- a slightly lower median and minimum pH (7.2 and 6.3 in LBC versus 7.3 and 6.6 in UBC);
- similar alkalinity (median of 16 mg/L in LBC and 17 mg/L in UBC);
- higher median and maximum concentrations of sulphate (9 and 38 mg/L in LBC versus 6 and 12 mg/L in UBC), hardness (23 and 46 mg/L in LBC versus 22 and 26 mg/L in UBC), and TSS (8 and 111 mg/L in LBC versus 3 and 14 mg/L in UBC);
- slightly lower median concentrations of D-As (1.2 versus 0.9 µg/L); and
- slightly higher median concentrations of T-As (1.8 versus 1.9 µg/L), T-Cu (2 versus < 1 µg/L), T-Fe (0.18 versus 0.08 µg/L), T-Pb (1 versus < 1 µg/L) and T-Zn (< 5 to 6 µg/L), and more samples with concentrations above the detection limits.

The concentrations of TSS and T-Fe in LBC were both quite variable. TSS showed a general decline once exploration activity decreased. A similar reduction was not evident for T-Fe. Despite up to three orders of

---

[2] Waste disposal at the Goldwedge project, which is on Catear Creek a tributary of Brucejack Lake, included on-land and lake disposal of an un-quantified volume of waste rock and approximately 4000 t of tailings from a small underground mine (Doug Flynn, pers. communication).

magnitude, higher trace metal concentrations in the drainages entering Brucejack Creek, like UBC, median dissolved concentrations of Cd, Cu, Mo, Pb and Zn at LBC were below the detection limits. The lack of a significant impact to metal levels in Brucejack Creek was presumably due to the relatively small rate of flow of the portal, dump and Camp Creeks relative to Brucejack Creek.

<u>General Reclamation Requirements and a Review of Potential Mitigation Options for the Waste Rock</u>

In 1996, the Sulphurets property was placed on care and maintenance. In 1998, development plans for the project were indefinitely suspended and Newhawk Gold Mines Ltd. decided to "fully reclaim the property to reduce the environmental liability and keep holding costs to a minimum". Newhawk Gold Mines Ltd. submitted a proposal to the Ministry of Energy and Mines and the Ministry of Water, Land and Air Protection (Ministry of Environment) requesting approval in principle to dispose of the exploration wastes underwater in Brucejack Lake. The proposed plan was to haul the rock to the deposition site by truck, end dump it onto a bermed causeway extended out into the lake, and at the end of dumping to doze it a minimum of 1 meter beneath the surface of the lake. The undulating terrain and wet conditions were expected to make it practically impossible to remove all of the waste rock. However, Newhawk committed to removing all the waste rock above the water table.

BC MEM requirements for site reclamation included:

- removal of all machinery, equipment and building superstructures;
- disposal of all scrap material in an acceptable manner;
- recontouring of disturbed areas to approximate original site contours; and
- placement of all materials in a manner which minimizes the production and release of ML/ARD and assures protection of environmental quality.

Deep snow cover and cool sub-alpine climate result in minimal soil development and vegetation growth, and consequently Sulphurets had no revegetation requirements. Both BC MWLAP and Environment Canada indicated that the environmental protection goal at Sulphurets should be the protection of fish habitat in lower Sulphurets Creek. The criteria usually used for determining whether ML/ARD mitigation measures protect environmental quality are the discharge limits set to prevent adverse impacts to the downstream receiving environment. Since the Sulphurets property did not have discharge limits, the reclamation objective of BC MEM was to minimize impacts to water quality in Brucejack Creek.

Since the underground workings were almost entirely flooded, the main ML/ARD concern was the waste rock which, based on the ABA data, was predicted to be potentially ARD generating. Remediation strategies that BC MEM initially considered for the PAG waste rock and small amount of ore were:

- leave the waste rock in its present location;
- use a soil cover to limit leaching;
- collection and lime treatment of the drainage;
- underwater disposal in a constructed impoundment; and
- underwater disposal in Brucejack Lake.

Based on its previous experience, BC MEM conducted a qualitative assessment of the effectiveness, costs, liability and environmental risks of each strategy (Price & Errington, 1998, and Price, 2001, 2004a and 2004b). A key aspect of the review was a recognition that for mitigation to be successful it had to be compatible with the project and its biogeoclimatic conditions. Key site-specific considerations in the assessment of potential remediation strategies were the isolation, poor weather and difficulty reaching the site. Low cloud cover, a deep snow cover and poor visibility (white-outs) are common occurrences during much of the year. Consequently, unless there was a clear environmental reason to do otherwise, from the perspective of minimizing risk and liability, the best mitigation strategy would be one requiring minimal monitoring and maintenance. Another important impediment, in part because this was an advanced exploration project rather than a mine, was the lack of information regarding the materials and the site, the future performance of the waste rock (e.g., future weathering rates), surficial materials (e.g., suitability of soils for covers or dam construction) and relevant features of the disposal environment (e.g., the potential attenuation of dump contaminants prior to Sulphurets Creek).

The conclusion of BC MEM's initial review of potential mitigation strategies was that, if the water quality impacts resulting from the dissolution of built-up weathering products could be shown to be insignificant, disposal of waste rock in Brucejack Lake would result in the lowest liability and environmental risk. Disadvantages with flooding the waste rock in a constructed impoundment were the long-term dam maintenance requirements, the probable lack of suitable construction materials in such a high precipitation, steep, rocky area, and the high capital costs of constructing the impoundment. Major disadvantages of drainage treatment included the large runoff, treatment sludge disposal, the difficulty in operating a treatment plant in such a harsh and isolated environment, and the high capital and operating costs. Major disadvantages of a dry cover were uncertainty about their durability and effectiveness in such a high precipitation site, the long-term maintenance and monitoring requirements, the long-term risk posed by weathering products accumulating under the cover, and future replacement and repair costs. Cover costs would depend on the availability of suitable soil materials. The 'do nothing' option was rejected due to uncertainty regarding future acid and metal loadings and their environmental impact, and the resulting logistical and financial requirements for long-term monitoring and financial security.

Fisheries Act requirements to prevent impacts to fish habitat usually prevent lake disposal of mine wastes. In this case, Environment Canada stated that Brucejack Lake was not fish habitat. For that reason, the disposal of waste rock in the lake could be considered.

Advantages in using Brucejack Lake for waste rock disposal included:

- The relatively small volume of waste rock compared to the large dilution and potential metal attenuation provided by Brucejack Creek, the Sulphurets Glacier and Sulphurets Creek, prior to the area of fish habitat, would limit the impact of contaminant discharge.
- The large drainage inputs from the surrounding glaciers and the large snow pack would ensure material placed beneath the elevation of bedrock at the lake outlet would remain flooded.
- There would be no geotechnical structures to maintain or post-mining maintenance requirements, unlike the case if water retaining dams would be present.

The primary concern with waste rock disposal in the lake was the length of time since the material was excavated and the potential build-up of soluble weathering products and impact on water quality. Other concerns with waste rock disposal in the lake included the potential for additional sulphide oxidation if there would be a significant flow of oxidized water through the flooded pile and the remobilization of fines and entrained debris during and after deposition. Site attributes that would limit flow through deposited waste rock included: the quiescent nature of a lake and the snow cover for much of the year, which would limit turbulence and mixing and the relatively high sediment inputs into the lake. Various cost-effective supplemental mitigation measures were suggested including: applying lime to neutralize acidity and attenuate potentially soluble trace metals in the waste rock; dumping the waste rock in a quiescent location in the lake; and installing sediment curtains to catch debris and minimize remobilization.

Analysis of Solute Concentrations and Potential Water Quality Impacts

To assess concerns regarding the solute load within the pile and the potential impact on water quality, BC MEM required Newhawk to:

- conduct shake flask tests on representative samples collected from different areas of the waste rock pad;
- calculate the load of potentially soluble contaminants in the waste rock;
- use the results to predict the impact of waste rock disposal on water quality in Brucejack Lake and Creek; and
- determine what, if any supplemental mitigation may be required.

A total of nine grab samples were collected from backhoe holes excavated in the waste pad and ore piles. The majority, seven of the nine samples, had shake flask pHs of 8.1 to 8.5. This was the same pH as that reported for the waste rock samples collected underground, indicating that after 10 years exposure, the fines in the majority of the waste rock and ore still contained significant NP. Only one of the nine samples had a low pH (pH 3.6), suggesting that the low pH observed in the drainage from both standpipes may not be typical of the majority of the waste rock. One sample had a neutral pH (pH 7.2). As expected, the concentration of sulphate and soluble metals was much higher in the leachate from the acid shake flask sample compared with the samples whose pH varied from 8.1 to 8.5: sulphate 1670 versus 52 to 355 mg/L; Al 9 versus < 0.004 to 0.05 mg/L; As 20 versus 1 to 8 µg/L; Cd 6 versus < 0.1 to 1.6 µg/L; Co 42 versus 0.1 to 0.8 µg/L; Cu 308 versus 17 to 38 µg/L; Fe 50 versus < 0.01 to 0.01 mg/L; Ni 39 versus < 0.1 to 1 µg/L; Pb 100 versus < 2 to 10 µg/L; and Zn 2.2 versus 0.006 to 0.03 mg/L. The concentrations of alkalinity in the pH > 7 samples were 47 to 87 mg/L. The concentration of acidity in the acid sample was 200 mg/L.

Three sets of calculations were made using the shake flask results. The first two sets of calculations used the average metal concentrations in the leachate from the shake flask tests to calculate the metal loading from the waste rock; one assumed complete mixing of the metal load in Brucejack Lake and the other assumed the metal load reports to Brucejack Creek. The third set of calculations assumed all the waste rock had the same metal load as the West Standpipe and calculated the water quality assuming complete mixing of the metal load in Brucejack Lake.

The pre-waste rock deposition loadings in Brucejack Creek or Brucejack Lake were calculated by multiplying elemental concentrations by the volume of water, using data from the 1989 mine proposal (Newhawk Gold Mines Ltd., 1989a). The volume used for Brucejack Lake was 29 x 10^6 m^3. The volume used for Brucejack Creek assumed that: dumping would occur over four months, from June to September; metal loadings from the waste rock migrated directly to the lake outlet; and the volume of diluting drainage was the mean monthly flow of 2.88 m^3/s, a total of 29.8 x 10^6 m^3 over four months. The similar volumes and water quality of Brucejack Lake and Brucejack Creek meant that the resulting calculated values were also very similar.

The calculations included a number of probable divergences from reality. In the metal loading calculation, it was assumed that the whole mass of waste rock would perform like the < 2 mm size fraction used in the shake flask tests. A more likely scenario was that the coarse fragments, with relatively little surface area, would contribute very little dissolved metals. Another assumption was that there would be complete mixing of the soluble metals in the waste rock in Brucejack Lake or Brucejack Creek. Mixing within the lake would depend on a number of properties, including circulation within the lake, and was unlikely to be 100%.

Due to the relatively small load of soluble material in the waste rock and the large dilution in the lake and creek, average shake flask concentrations resulted in little or no increase for many species and relatively minor increases for the others (Tables 11 and 12). The load of As, Ca, Cd, Mg, Na and Pb, in Brucejack Creek and Brucejack Lake were at least an order of magnitude higher than the projected load from waste rock deposition, and thus the calculations suggested that deposition of the waste rock would result in little or no change to their concentration. The species present in relatively higher amounts in the waste rock compared to the creek or lake were: sulphate with a load of 165,949 kg, Cu with a load of 22 kg, Zn with a load of 115 kg and Mn with a load of 497 kg.

In Brucejack Lake, the loading calculated from the average concentrations of shake flask sulphate was predicted to increase from 4.6 to 10.3 mg/L, Cu was projected to increase from 0.7 to 1.4 µg/L, Zn was projected to increase from 1 to 5 µg/L and Mn was projected to increase from 5 to 22 µg/L (Table 11). In Brucejack Creek, the loading calculated from the average concentrations of shake flask sulphate was predicted to increase from 5.3 to 10.9 mg/L, Cu was projected to increase from 0.1 to 0.8 µg/L and Zn was projected to increase from 2.5 to 6.4 µg/L (Table 12). Due to the relatively small load of soluble material in the waste rock (Mo 14 kg, Sb 22 kg and Se 2 kg), and the large dilution, there was also unlikely to be an exceedance of British Columbia water quality criteria by the trace elements for which there was no lake data.

As a check on the potential impact in the case that the proportion of acid waste rock was higher, the impact on the lake water quality was calculated applying the acid West Standpipe shake flask results to the entire mass of waste rock. For As, Ca, Cd, K, Mg, Mn and Na, use of only the acid shake flask data had little or no impact, either because the existing load in the lake was still much higher than the projected load from the waste rock or the acid and average shake flask results were not that different. The projected lake pH remained neutral with significant alkalinity (18 mg/L) because of the much greater alkalinity load in the lake compared to the acidity in the acid waste rock. Use of the acid rather than average shake flask data in the calculations noticeably increased lake concentrations of sulphate from 10 to 26 mg/L, Cu from 1.4 to 4.7 µg /L, Fe from 2 to 640 µg /L, Pb from 1.0 to 2.3 µg/L and Zn from 5 to 29 µg/L.

Conclusions of the review of the shake flask results and use of the results to predict the impact of waste rock disposal on water quality were the following:

- Although the waste rock contained elevated total and soluble concentrations of a number of trace metals, because of the relative small mass of the waste rock compared to dilution and alkalinity in Brucejack Creek and Brucejack Lake, deposition in the lake was unlikely to have a significant impact on downstream water quality.
- The shake flask tests indicated that the primary source of the soluble metals was the acid waste rock, and that acidic waste rock disposal could markedly raise the concentrations of species such as Fe and Zn. The shake flask test suggested that very little of the waste rock was presently acidic. However, the shake flask sampling was limited and, as a precautionary measure and to reduce metal loading into the aquatic environment, BC MEM required Newhawk to monitor the pH during excavation and to neutralize any acidic waste rock.

Previous lake disposal of weathered waste rock produced by pre-mine adit construction at the nearby Eskay Creek Mine had shown that lime additions could be very effective in reducing the solubility of Fe and Zn when acidic waste rock was disposed of in a lake.

BC MEM Permit Conditions for Waste Rock Disposal

Conditions for waste rock removal and deposition were as follows:

- All waste rock and ore shall be removed from the waste rock pad and placed in the lake to the extent practicable.
- The pad area shall be recontoured to the extent practicable to maximize the flooding of remaining waste rock and approximate original ground contours.
- The Permittee shall estimate the quantity and map the location(s) of any remaining waste rock.
- The Permittee shall predict the drainage pH of the waste rock to be excavated and placed in the lake the following day by measuring the rinse pH of material collected from a transect along the exposed face of the excavated material.
- The dump shall be located in a region of the lake with minimal flow and permitting a large dilution volume prior to contaminants in the drainage reaching Brucejack Creek.
- Upon completion, waste rock deposited in Brucejack Lake must be covered by a minimum of one meter of water during periods of minimum water level in the lake.
- In order to neutralize acidity and suppress metal solubility, the operator must either blend any waste that has a rinse pH of less than 4.5 with a similar mass of neutral waste material or alkalinity equivalent to 75 g $CaCO_3$/tonne of waste rock (2.0 kg $CaCO_3$/25 tonne truck load of waste rock).
- No lime is to be applied when the daily pH in Brucejack Lake exceeds 7.5.

Water quality monitoring requirements were as follows:

- During waste disposal, daily monitoring of field pH in Brucejack Lake on the Brucejack Creek side of the disposal site, at the mouth of Brucejack Creek and on Brucejack Creek immediately downstream the mine site.
- During waste disposal and in each of the subsequent four weeks, biweekly monitoring of total and dissolved copper, iron, lead, zinc, TSS and pH in Brucejack Lake on the Brucejack Creek side of the disposal site, at the mouth of Brucejack Creek and on Brucejack Creek immediately downstream of the mine site.
- Starting at least a month prior to and ending one month after the completion of waste disposal, monthly monitoring of total and dissolved metals, pH, alkalinity, conductivity, TSS, hardness, Cl and sulphate at the inlet sampling sites on Camp Creek and Little Camp Creek, the Portal, Brucejack Lake on the Brucejack Creek side of the disposal site, at the mouth of Brucejack Creek and on Brucejack Creek immediately downstream the mine site.
- In July and September of 2000 and 2001, monitoring of total and dissolved metals, pH, alkalinity, conductivity, TSS, hardness, Cl and sulphate in Brucejack Lake on the Brucejack Creek side of the disposal site, at the mouth of Brucejack Creek, on Brucejack Creek immediately downstream the mine site and at the portal.

Waste Rock Removal and Disposal in Brucejack Lake

Removal of the waste rock pad and disposal in the lake occurred from July 27th to August 27th, 1999. Visually, the waste rock was almost all removed from the pad, precluding a need to recontour and map the location of residual material. Deposition of waste rock in Brucejack Lake was done from a causeway-like pad, with the waste rock being placed in berms and then dozed over the side into the lake. Once all the waste rock was placed on the causeway, the surface was lowered approximately 1 m below the height of the lake. Waste rock removal was the majority of the cost of the reclamation program, which was estimated to be $800,000.

Visually, waste rock pushed into the lake went straight to the bottom with no observable entrainment of fines at the lake surface. This was confirmed by the TSS in 1999 in Brucejack Lake on the Brucejack Creek side of the disposal site and Upper Brucejack Creek, which had the same range as the results prior to waste rock deposition (<3 to 8 mg/L). Higher TSS was measured in 1999 in Lower Brucejack Creek (<3 to 14 mg/L), presumably as a result of creek and groundwater flow over the newly exposed ground.

Eleven percent of the waste rock samples had a rinse pH from 3 to 4.5, 34% were pH 4.5 to 7, 28% were pH 7 to 8 and 27% were pH 8 to 9. Compared to the shake flask samples, there was a similar proportion of pre-excavation samples with a pH < 4.5, a much higher proportion with a rinse pH of 4.5 to 7 and 7 to 8, and a lower proportion of samples had a pH > 8. The discrepancy between the rinse pH and the shake flask pH results point to the difficulty in collecting representative samples from the waste rock. Drilling is not recommended for sampling old waste rock piles because it breaks the particles masking changes caused by weathering. Typically characterization of old waste rock piles is done by sampling trenches excavated across the surface. The rationale of this sampling design is that the surface of end-dumped waste rock piles contains a cross-section of all the material placed on the pile. The Sulphurets example illustrates the need to sample material at the base of dump if this potentially has a differing weathering regime. At Sulphurets, there appeared to be accelerated weathering of at least a portion of the base of the pile due to increased leaching by groundwater.

A total of 577 kg of lime were added during excavation. The pH ranged from 6.8 to 8.3 in Brucejack Lake, 6.5 to 8.4 in Upper Brucejack Creek and 6.2 to 8.4 in Lower Brucejack Creek. The lowest pH values for Lower Brucejack Creek were at the start of excavation and were likely due to leaching of residual material after removal of the low pH waste rock around the portal. The highest pH values, 8.3 and 8.4 at the three monitoring locations occurred at the end of excavation, and were presumably due to the leaching of the cumulative lime addition to the pile.

Once waste rock and lime deposition stopped, the pH decreased to 7.4 to 7.7. In 2000, the year following waste rock deposition, the pH was 7.6 to 8.0 in Brucejack Lake, 7.6 to 7.8 in Upper Brucejack Creek and 7.5 to 7.7 in Lower Brucejack Creek. In 2001, the pH values were 7.5, 7.8 and 7.7, respectively.

The laboratory results of eight weekly samples collected in 1999, the two samples from 2000 and the sample collected in 2001 indicated that changes in water quality in Brucejack Lake and Brucejack Creek during and following waste rock disposal were relatively minor in nature. During waste rock deposition in 1999, sulphate in Upper Brucejack Creek increased from 8 to 13 mg/L, alkalinity increased from 16 to 21 mg/L, T-As decreased, T-Ag reached a high of 0.4 µg/L, T-Pb reached a high of 3 µg/L and T-Cd, T-Cu and T-Zn remained at or below the detection limit. Similar values were observed in Brucejack Lake on the Brucejack Creek side of the disposal site. Although the disposal period was 1.5 rather than 4 months, the 5 mg/L increase in sulphate and negligible increases in trace metals in Upper Brucejack Creek and Brucejack Lake were similar to the changes predicted from the shake flask calculations. In 2000 and 2001, sulphate in Upper Brucejack Creek was 10 and 11 mg/L, alkalinity was 16 and 17 mg/L, T-As remained below historic median of 1.8 µg/L, T-Ag and T-Pb decreased to below the detection limits of < 0.1 and < 1 µg/L, respectively, and T-Cd, T-Cu and T– Zn remained below the detection limits.

The largest changes observed in water quality during and following waste rock disposal occurred in Lower Brucejack Creek. During waste rock removal in 1999, sulphate in Lower Brucejack Creek was up to 30 mg/L, alkalinity was up to 26 mg/L, hardness was up to 39 mg/L, D-Cd was up to 0.5 µg/L, T-Cu was up to 20 µg/L, D-Cu was up to 10 µg/L, T-Fe was up to 1 mg/L, D-Fe increased to 0.32 mg/L and D-Zn increased to 70 µg/L. Concentrations in Lower Brucejack Creek declined in 2000-2001, although sulphate (18 to 22 mg/L), hardness (29 to 35 mg/L) and D-Cd (0.2 µg/L) remained elevated. Although modest, the increased concentrations in Lower Brucejack Creek compared to Brucejack Lake and Upper

Brucejack Creek indicate that the main short-term impact of the mitigation work was leaching of the disturbed pad area rather than waste rock placement in Brucejack Lake. In hindsight, it might have been advisable to apply some lime to former areas of acid waste rock in the pad area to reduce metal solubility.

A large amount of non-electric blasting caps and wire mixed in with the waste rock floated to the surface when the waste rock was pushed into the lake. Several hundred garbage bags of this material were collected from the mesh fences erected at the mouth of Brucejack Creek and along the shores of the lake.

The waste rock causeway was between the mouth of a creek and the outlet of the lake, which was not ideal in terms of minimizing flow through the pile. However it was anticipated that the glacial sediment entering the lake from this and other creeks would soon create a fine-textured layer that would limit seepage through the causeway. The much greater volume of flow in Brucejack Creek explained why site drainage had only a limited impact on Brucejack Creek water quality.

Conclusions

Despite their relatively small size, the costs and potential impacts make the mitigation of metal leaching and ARD at historic mine sites and exploration projects, like Sulphurets, quite challenging. In common with many historic mine sites and exploration projects, challenges at Sulphurets included limited information regarding the site and the materials, access difficulties and an adverse climate, in this case a limited snow-free period. The high access costs, lack of site personnel and small budget made it difficult to collect additional information. Access difficulties and climate constraints were also a major consideration in the review of potential mitigation measures. Mitigation constraints included a probable lack of suitable soil materials for the construction of covers and dams, a deep snow cover much of the year and the resulting large runoff, and the difficulty operating facilities and conducting monitoring and maintenance in such a harsh climate and remote site. As a result of these constraints, the conclusion of BC MEM's initial review of potential mitigation strategies was that, if the water quality impacts from the dissolution of built-up weathering products could be shown to be insignificant, disposal of waste rock in Brucejack Lake would result in the lowest liability and environmental risk.

A large number of variables determine water quality impacts when waste rock is flooded, including:

- the interaction between different types of waste rock and between the waste rock and the lake;
- potential contaminant mixing and migration within the lake; and
- the location of neutralization and precipitation.

As many of these properties are difficult, if not impossible to measure, the prediction approach taken by BC MEM was to use simple measurements and assumptions. Prediction of the potential load of soluble metals was done using data from shake flask tests run on samples collected from holes dug in the waste rock pile with a backhoe. A crude estimation of the impact of lake disposal on water quality was calculated using the soluble load and monitoring results for the water quality and the volume of water in Brucejack Creek and Brucejack Lake. The calculations indicated that flushing of weathering products when waste rock was placed in the lake would result in minimal changes to water quality in Brucejack Lake and Brucejack Creek. Although removal of the waste rock from the pad and deposition in the lake took far less time than that used in the predictive calculations (1.5 versus 4 months), the overall prediction results turned out to be correct.

Although not significant in terms of the overall outcome, several aspects of the project were unexpected: as follows:

- According to the rinse pH data, the majority of the waste rock had a pH of 4.5 to 7 and 7 to 8, and only a small proportion of the waste rock had a pH > 8, which had been the predominant pH of the samples taken the previous year to predict potential water quality impacts.
- The largest changes in water quality observed during and following waste rock disposal were in Lower Brucejack Creek. Although modest, the increased concentrations in Lower Brucejack Creek compared to Brucejack Lake and Upper Brucejack Creek indicate that the main short-term impact of the mitigation work was leaching of the disturbed pad area rather than waste rock placement in Brucejack Lake.
- After the waste rock was removed, Brucejack Creek flooded a portion of the former pad-site.

The discrepancy between the rinse pH and the shake flask pH results appears to result from accelerated weathering at the base of the pad and illustrates the danger in assuming near-surface samples are representative samples from weathered waste rock dumps. Typically characterization of old waste rock piles is done by sampling trenches excavated across the surface. The rationale for this sampling procedure is that the surface of end-dumped waste rock piles contains a cross-section of all the material placed on the pile and that drilling will break apart particles potentially masking weathering conditions. The situation at Sulphurets, with low alkalinity, slightly acidic groundwater potentially leaching the base of parts of the pile, illustrates that there may be a need to sample material at the base of a dump. Another potential cause for accelerated weathering at depth is if, as is often the case in acidic dumps, this is the hottest area of the dump.

The experience at Sulphurets also illustrates the need to consider hydrogeology when selecting a disposal site and the importance of characterizing soil hydrology prior to waste rock disposal. Even if it is just an exploration project due care and attention is required in selecting a disposal site for sulphidic waste rock. Factors that may need to be considered include groundwater inputs, upslope drainage diversion, down slope drainage collection and ease of removal. A soil and vegetation survey should be conducted to collect the required information on the height of water table throughout the year.

Lastly, Sulphurets posed a number of regulatory challenges. For the proponent, this included dealing with several agencies with a similar interest in ML/ARD, but differing approaches to the risks and information required with differing mitigation options. An issue for BC MEM at the time it reviewed this project was the limited number of personnel with the training to deal with the large number of projects with ongoing ML/ARD concerns. Transportation costs and time constraints made it difficult for the ARD reviewers to inspect the site during the assessment in 1998 and in 1999 once the mitigation work was underway. The good corporate memory and record keeping, by both Newhawk and BC MEM, was very helpful to the technical review. Record keeping is an important regulatory task at sites such as Sulphurets that go into care and maintenance for a number of years.

SOMMAIRE

Le projet Sulphurets visait à exécuter des travaux d'exploration détaillés dans les montagnes côtières de la Colombie-Britannique, à quelque 1375 m au-dessus du niveau de la mer. Pendant sa réalisation, des chantiers souterrains ont été aménagés dans le gisement West Zone, entre 1986 et 1990, dans le cadre d'un programme d'exploration et d'échantillonnage en vrac. Ces chantiers mesurent 5276 m de longueur et consistent en une descenderie et en quatre niveaux situés respectivement à 1350 m, à 1300 m, à 1250 m et à 1200 m de profondeur (Bruce McLeod, communications personnelles). Tel que mentionné précédemment, ils ont été creusés dans le gisement West Zone, qui consiste en un filon quartzeux

épithermal complexe renfermant de l'argent, de l'or et des métaux communs, au point de contact de roches volcaniques et de roches sédimentaires. Leur construction a produit environ 124 000 t (44 300 m^3) de stériles, lesquels avaient été déposés en couche mince le long du bord sud du ruisseau Brucejack, et utilisés comme fondation pour le camp et les autres installations rattachés au projet. Deux petits tas de minerai à basse teneur avaient été déposés à l'arrière des stériles, et deux petits cours d'eau, soit le ruisseau Camp et le ruisseau Little Camp, avaient été redirigés sous les rejets.

Les chantiers souterrains et les stériles étaient contigus au ruisseau Brucejack et situés en aval du lac Brucejack. Le ruisseau Brucejack coule sur 2,4 km, depuis le lac Brucejack jusqu'au glacier Sulphurets, sous lequel il circule sur 4 km, puis il se jette dans le ruisseau Sulphurets qui, après 14 km, afflue dans la rivière Unuk; une chute de 30 m empêche le poisson d'atteindre la partie amont du ruisseau Sulphurets sur 13 km. Dans la région, la température annuelle moyenne est estimée à - 2 ºC, et les précipitations annuelles moyennes, principalement de la neige, totalisent entre 1800 et 2500 mm. La neige, qui recouvre la région pendant au moins huit mois par année, et des problèmes d'accès ont nui à l'exécution des travaux sur le site du projet Sulphurets.

En 1989, l'opérateur Newhawk Gold Mines Ltd., avait obtenu un certificat lui permettant d'aménager une mine souterraine, ainsi qu'une usine de traitement connexe, et de confiner dans le lac Brucejack les résidus fins et les eaux de la mine, de même que des stériles pouvant entraîner un drainage acide. Pour des raisons économiques, la mine n'a jamais été mise en exploitation et les chantiers souterrains se sont inondés. En 1998, Newhawk avait indéfiniment renoncé à ses plans d'exploitation et entrepris l'évaluation de diverses techniques de restauration, celles-ci visant principalement les stériles déposés à l'extérieur de la galerie d'accès de la mine et le long du ruisseau Brucejack.

Prévision sur la lixiviation des métaux et le drainage minier acide

Les principaux renseignements sur la lixiviation des métaux (LM) et le drainage minier acide (DMA) découlant des stériles ont été recueillis lors d'essais exécutés à l'appui du projet de mine, soit un bilan acide-base (ABA), les concentrations élémentaires, des essais en cellule d'humidité et des essais de lixiviation par acide acétique et par acide sulfurique. Le ABA des stériles portait sur six échantillons distincts prélevés dans les chantiers souterrains et sur un échantillon composite. Les échantillons de stériles présentaient un pH de la pâte variant entre 7,7 et 8,6, un potentiel acidogène (PA) se situant entre 86 et 211 kg de $CaCO_3$/t et un potentiel de neutralisation (PN) allant de 10 à 92 kg de $CaCO_3$/t. Six des échantillons de stériles présentaient des rapports de PN/PA s'établissant entre 0,07 et 0,39, dont un présentant un rapport de 1,08. Les PN/PA < 1 indiquent qu'en cas d'exposition, la majeure partie de la roche sur le site produira éventuellement un DMA. Des PN et des PN/PA faibles, c'est-à-dire des valeurs de PN comprises entre 10 et 16 kg de $CaCO_3$/t et des PN/PA < 0,14, laissent supposer qu'un DMA pourrait survenir assez rapidement, surtout si le PN était davantage attribuable à des minéraux silicatés qu'à des minéraux carbonatés renfermant du Ca ou du Mg.

Les concentrations élémentaires des échantillons de stériles surpassaient les limites maximales relevées dans la roche non minéralisée, et ce, dans le cas de l'Ag (de 14 à 45 mg/kg comparativement à 0,1 mg/kg), de l'As (de 10 à 225 mg/kg comparativement à 2 mg/kg) et du Sb (de 10 à 25 mg/kg comparativement à 0,2 mg/kg). Les concentrations de d'autres métaux traces dans les échantillons de stériles étaient les suivantes : Cd, moins de 0,5 à 3 mg/kg, Cu, de 29 à 42 mg/kg, Pb, de 30 à 84 mg/kg et Zn, de 15 à 354 mg/kg. Les concentrations de métaux traces dans les échantillons de sédiments prélevés dans le ruisseau et le lac Brucejack étaient similaires à celles des stériles.

Six essais en cellule d'humidité avaient été effectués. En moins de dix semaines, toutes les cellules présentaient un pH de drainage variant entre 7 et 8. Les concentrations de métaux dans le lixiviat des cellules étaient généralement inférieures aux seuils de détection, qui étaient relativement élevés, à l'exception des concentrations de Ca, de Mg et de Mn, qui étaient assez élevées, et des concentrations de Ba et de Zn, dont les seuils de détection étaient inférieurs. Dans le lixiviat, les plus fortes concentrations de Mn et de Zn s'élevaient respectivement à 2,42 mg/L et à 0,08 mg/L; la concentration élevée de Mn témoignait peut-être de la présence de $MnCO_3$.

Pendant les semaines 2 à 10, la production moyenne de sulfates se situait entre 0,0137 g/kg par semaine, dans le filon quartzeux, et 0,0453 g/kg par semaine, dans l'andésite silicifiée. D'après le taux de production moyen de sulfates mesuré dans les cellules d'humidité, le taux d'épuisement de la calcite[3] devait se situer entre 0,7 et 2,4 kg de $CaCO_3$/t. Toujours selon ce taux, de 7 à 87 ans devraient s'écouler avant l'épuisement du PN des échantillons dans les cellules et de 4 à 14 ans pour l'épuisement d'un PN de 10 kg de $CaCO_3$/t. Un taux quatre fois plus lent d'épuisement du PN et d'oxydation des sulfures avait été prévu dans des conditions *in situ* en raison d'une différence de 20 ºC entre la température en laboratoire et la température annuelle moyenne sur le site (- 2 ºC), et à cause d'un doublement de l'activité découlant de la loi d'Arrhenius, à toutes les hausses de 10 ºC. Le rapport ne faisait mention d'aucun facteur pouvant hâter le DMA, comme la chaleur produite par l'oxydation des sulfures (qui peut accroître la température dans les stériles), un épuisement du PN résultant d'autres processus que l'oxydation des sulfures dans les stériles (p. ex. la lixiviation par les eaux souterraines), un manque de PN ou un PN trop peu réactif. Le rapport n'indiquait pas non plus si la vitesse d'oxydation pouvait considérablement augmenter après les semaines 10 à 20, malgré des conditions presque neutres (Morin et Hutt, 1997a et 1999).

Suivi de la qualité de l'eau

À la demande du British Columbia Ministry of Water, Land and Air Protection, en 1987, Newhawk avait commencé à surveiller la qualité de l'eau à divers endroits autour du site. Les postes de suivi et les dates de début étaient les suivants :

- ruisseau Brucejack, au-dessus et en dessous du dépôt de stériles en couche mince, et les eaux s'écoulant du portail de la mine; 1987;
- lac Brucejack; 1988;
- deux tuyaux verticaux (est et ouest) installés dans les stériles en 1989;
- ruisseau Camp, juste en amont des stériles (écoulement entrant); 1989;
- ruisseau Camp, juste sous les stériles et avant sa confluence avec le ruisseau Brucejack (écoulement sortant); 1993;
- ruisseau Little Camp, juste en amont des stériles (écoulement entrant) et sous celui-ci, et juste avant sa confluence avec le ruisseau Brucejack (écoulement sortant); 1993.

Les tuyaux est et ouest avaient été installés pour surveiller l'altération des stériles et la qualité des eaux de drainage s'écoulant de ceux-ci vers le ruisseau Brucejack. La nappe phréatique se trouvait à la base des tuyaux, dont les eaux de drainage étaient récupérées au moyen d'une pompe. En 1989, lors de l'installation des tuyaux, le pH des eaux variait entre 6,6 et 7,2. De 1991 à 1996, il se situait entre 2,4 et 3,1 dans le tuyau ouest. Dans le tuyau est, il allait de 5,1 à 6,6 entre 1991 et 1993, de 3,8 à 4,2 en 1994 et de 3,4 à 3,7 dans trois échantillons prélevés entre 1995 et 1998. En 1998, le pH des eaux de drainage recueillies était de 3,6 dans le tuyau ouest et de 3,4 dans le tuyau est.

---

[3] En supposant la réaction suivante : $CaCO_3 + \underline{2H^+} = Ca^{2+} + H_2CO_3$

Des concentrations élevées de sulfates, de métaux communs et de métaux traces avaient été mesurées dans les eaux de drainage prélevées dans les deux tuyaux; les plus fortes concentrations avaient été observées dans les eaux du tuyau ouest. Les concentrations maximales de métaux traces étaient les suivantes dans les tuyaux ouest et est respectivement : 2,4 et 0,31 mg/L d'As, 92 et 4 µg/L de Cd, 2,0 et 0,25 mg/L de Cu, 0,6 et 0,1 mg/L de Pb, ainsi que 4,5 et 0,9 mg/L de Zn. La plupart des éléments détectés étaient dissous. Les fortes concentrations de Fe dissous dans les eaux de drainage du tuyau ouest (> 200 mg/L dans trois échantillons) montraient que ces eaux pourraient présenter une grande acidité. De plus, une des observations notables effectuées pendant le suivi indiquait qu'après un prélèvement, de nombreuses heures devaient s'écouler avant que les tuyaux ne se remplissent suffisamment pour permettre un nouvel échantillonnage, ce qui laissait supposer que leurs charges étaient faibles (Bruce Mcleod, communications personnelles). Le faible débit des eaux remplissant les tuyaux pouvait également résulter d'une obstruction de leur filtre par des sédiments, des précipités ou les deux.

Deux types d'eaux de drainage s'écoulaient du portail de la mine. Pendant les travaux de construction et d'exploration souterraine (de 1987 à juin 1990), les eaux de drainage étaient pompées des chantiers. Après l'interruption du pompage, en 1990, les chantiers ont été rapidement inondés, de sorte qu'en novembre 1990, les eaux de drainage débordant du portail provenaient des chantiers submergés. Durant leur pompage, les eaux de drainage présentaient un total des solides en suspension (TSS) élevé, celui-ci atteignant 5320 mg/L, un pH variant entre 7,5 et 8,3, une concentration de sulfates allant de 81 à 339 mg/L, une alcalinité se situant entre 52 et 356 mg/L, une teneur en As comprise entre 10 et 610 µg/L, une concentration de Cu s'établissant entre < 1 et 1720 µg/L, une teneur en Fe allant de < 0,03 à 83 mg/L, une concentration de Pb se situant entre < 1 et 1490 µg/L et une teneur en Zn allant de < 5 à 2310 µg/L. Durant le pompage, les concentrations maximums en métaux traces dissous (As, 95 µg/L, Cu, 17 µg/L, Fe, < 0,05 mg/L, Pb, 96 µg/L et Zn, 69 µg/L) étaient de beaucoup inférieures aux concentrations totales. Le TSS et les concentrations totales de métaux étaient vraisemblablement à leur maximum pendant les travaux d'extraction.

Après l'interruption du pompage, la nappe phréatique s'était rapidement élevée au-dessus du portail, seule une petite cheminée d'aération demeurait hors de l'eau. Voici les propriétés ou les changements que les eaux de drainage des chantiers présentaient, après l'inondation de ces derniers :

- TSS faible ou nul (de < 1 à 9 mg/L);
- baisse initiale du pH jusqu'à l'intervalle de 6,8 à 7,2, puis augmentation à celui de 7,4 à 7,8;
- passage de l'alcalinité médiane de 116 à 76 mg de $CaCO_3$/L;
- légère baisse des concentrations médianes de sulfates de 148 à 120 mg de $CaCO_3$/L;
- concentrations de Fe total allant de < 0,03 à 1,0 mg/L, et concentrations de fer dissous atteignant < 0,12 mg/L;
- à l'instar du TSS, forte diminution des concentrations totales de métaux traces : As, intervalle de 0,6 à 22 µg/L, Cd, intervalle de 0,2 à 0,6 µg/L, Cu, intervalle de < 1 à 23 µg/L, Pb, intervalle de < 1 à 12 µg/L et Zn, intervalle de 16 à 255 µg/L.

Bien que les changements étaient moins marqués après l'inondation des chantiers que pendant leur utilisation, la majeure partie des concentrations totales médianes de métaux traces demeuraient supérieures aux concentrations de métaux dissous : As, 7,6 µg/L comparativement à 2,5 µg/L, Cd, 0,4 µg/L comparativement à < 0,2 µg/L, Cu, 2 µg/L comparativement à < 1 µg/L, Pb, 6 µg/L comparativement à < 1 µg/L et Zn, 46 µg/L comparativement à 42 µg/L. Cependant, les concentrations maximums de métaux totaux et de métaux dissous étaient similaires pour la plupart des métaux traces après l'inondation des chantiers, la principale exception étant le Pb.

Le suivi avait été entrepris juste en amont (écoulement entrant) et en aval (écoulement sortant) des stériles du ruisseau Camp et du ruisseau Little Camp, lesquels avaient été déviés sous les rejets, au moyen de conduites de 24 po. Les fortes concentrations de sulfates et de métaux traces dans l'écoulement entrant du ruisseau Camp et du ruisseau Little Camp témoignaient d'une importante source de contamination naturelle en amont des stériles, en particulier dans le cas du ruisseau Little Camp. D'après Bruce McLeod (communications personnelles), cette source de contamination était effectivement naturelle, car les perturbations découlant de l'exploration aux environs de ces cours d'eau n'étaient attribuables qu'à l'exécution de travaux routiers et de forages. La faible alcalinité et la baisse occasionnelle du pH de l'écoulement entrant du ruisseau Camp montraient un épuisement du PN de la roche reposant en amont. Les eaux souterraines d'une composition chimique similaire aux eaux du ruisseau Camp ou aux fuites de la conduite du ruisseau Camp pouvaient accroître la dissolution des minéraux carbonatés dans les stériles et ainsi accélérer le fléchissement du pH à la base de la halde. Il y avait très peu de différence entre les concentrations de métaux relevées en amont et en aval du ruisseau Camp. Les concentrations médianes de métaux totaux et de métaux dissous étaient respectivement les suivantes : As, 0,3 et 0,2 µg/L, Ca, 13,7 et 14,6 mg/L, Cd, 0,4 et 0,5 µg/L, Cu, 3 et 3 µg/L, Fe, 0,21 et 0,03 mg/L, Mg, 0,73 et 0,70 mg/L, Mo, < 1 et < 1 µg/L, Pb, < 1 et < 1 µg/L, et Zn, 32 et 30 µg/L.

Entre l'écoulement entrant et l'écoulement sortant du ruisseau Little Camp, les concentrations médianes de sulfates passaient de 156 à 51 mg/L, celles de Cd dissous, de 6,6 à 0,6 µg/L, celles de Cu dissous, de 54 à 8 µg/L, celles de Zn dissous, de 784 à 62 µg/L, celles de Ca dissous, de 65 à 18 mg/L et celles de Mg dissous, de 3,1 à 0,9 mg/L, tandis que celles de l'As total passaient de 0,4 à 0,9 µg/L, celles de l'As dissous, de 0,2 à 0,4 µg/L, celles du Pb total, de 7 à 16 µg/L, celles du Pb dissous, de 2 à 13 µg/L, celles du Fe dissous, de 0,08 à 0,45 mg/L et celles du Fe total, de 0,27 à 0,54 mg/L. L'alcalinité passait de l'intervalle de 14 à 42 mg/L à celui de < 1 à 11 mg/L, après que le ruisseau eut traversé les rejets. Le pH médian de l'écoulement entrant et celui de l'écoulement sortant du ruisseau Little Camp étaient similaires, soit 6,6 et 6,2 respectivement, mais lors des deux derniers prélèvements, effectués en septembre 1994 et en juillet 1998, ils passaient respectivement de 6,3 à 4,7 et de 6,7 à 4,2.

Les changements dans le ruisseau Little Camp pouvaient notamment s'expliquer par des eaux de drainage supplémentaires provenant des stériles, ainsi que du sol naturel et du ruisseau Brucejack sous-jacents. La largeur du ruisseau Brucejack observée après avoir déménagé les stériles témoignait de l'étendue sur laquelle il avait inondé la base de la halde de stériles. La fluctuation du niveau de la nappe phréatique et du ruisseau Brucejack pouvait avoir influé, dans une certaine mesure, sur la composition chimique variable de l'écoulement sortant du ruisseau Little Camp.

Entre 1987 et 1998, la partie supérieure du ruisseau Brucejack présentait un pH allant de 6,6 à 7,9, un TSS compris entre < 1 et 14 mg/L, une dureté se situant entre 14 et 26 mg/L, une alcalinité variant entre 11 et 21 mg/L et une concentration de sulfates atteignant 2 à 12 mg/L. Malgré la minéralisation naturelle et les activités en cours en amont du lac Brucejack, dans la propriété Goldwedge[4], les concentrations totales et sous forme dissoute de la plupart des métaux traces étaient inférieures aux seuils de détection, soit Cd, < 0,2 µg/L, Cu, < 1 µg/L, Mo, < 1 µg/L, Pb, < 1 µg/L et Zn, < 5 µg/L, sauf pour l'arsenic, qui présentait des valeurs médianes de 1,8 µg/L pour l'As total et de 1,2 µg/L pour l'As dissous, de même que des valeurs maximums de 15 µg/L pour l'As total et de 8 µg/L pour l'As dissous. En 1991, les concentrations de Fe total avaient augmenté jusqu'à ce qu'elles culminent à 0,72 mg/L en juillet 1992, mois pendant lequel le TSS maximum a atteint 14 mg/L et les concentrations d'As total, 15 µg/L.

---

[4] La disposition des rejets, dans le cadre du projet Goldwedge, situé le long du ruisseau Catear, qui prend source dans le lac Brucejack, comprenait le placement sur terre et sous l'eau d'une quantité inconnue de stériles et d'environ 4000 t de résidus provenant d'une petite mine souterraine (Doug Flynn, communications personnelles).

La qualité de l'eau du lac Brucejack n'avait été surveillée que de 1988 à 1991, et les résultats de ce suivi s'étaient avérés étroitement similaires à ceux concernant la partie supérieure du ruisseau Brucejack.

Voici une comparaison des parties supérieure et inférieure du ruisseau Brucejack :

- pH médian et minimum de 7,2 et 6,3 respectivement dans sa partie inférieure comparativement à 7,3 et 6,6 dans sa partie supérieure;
- alcalinité médiane de 16 mg/L dans sa partie inférieure comparativement à 17 mg/L dans sa partie supérieure;
- concentrations médiane et maximum de sulfates de 9 et 38 mg/L respectivement dans sa partie inférieure par rapport à 6 et 12 mg/L dans sa partie supérieure, duretés médiane et maximum de 23 et 46 mg/L dans sa partie inférieure comparativement à 22 et 26 mg/L dans sa partie supérieure et TSS médian et maximum de 8 et 111 mg/L dans sa partie inférieure par rapport à 3 et 14 mg/L dans sa partie supérieure;
- concentrations médianes d'As dissous de 1,2 µg/L comparativement à 0,9 µg/L;
- concentrations médianes de 1,8 µg/L comparativement à 1,9 µg/L pour l'As total, de 2 µg/L par rapport à < 1 µg/L pour le Cu total, de 0,18 µg/L comparativement à 0,08 µg/L pour le Fe total, de 1 µg/L par rapport à < 1 µg/L pour le Pb total et de < 5 µg/L par rapport à 6 µg/L pour le Zn total; d'autres échantillons présentaient des concentrations surpassant les seuils de détection.

Le TSS et les concentrations de Fe total dans la partie inférieure du ruisseau Brucejack variaient considérablement. Le TSS avait généralement fléchi une fois que l'exploration avait commencé à ralentir, ce qui ne fut vraisemblablement pas le cas des concentrations de Fe total. Les concentrations médianes de Cd, de Cu, de Mo, de Pb et de Zn dissous étaient inférieures aux seuils de détection, même si les concentrations de métaux traces des eaux de drainage se jetant dans le ruisseau Brucejack, comme dans la partie supérieure de ce ruisseau, pouvaient s'avérer jusqu'à trois ordres de grandeur supérieures. L'absence de répercussions importantes sur les concentrations de métaux dans le ruisseau Brucejack était vraisemblablement attribuable au débit relativement faible des eaux de drainage du portail de la mine, dans les stériles et des ruisseaux Camp par rapport au débit des eaux de drainage du ruisseau Brucejack.

Exigences générales en matière de restauration et évaluation des méthodes potentielles d'atténuation concernant les stériles

En 1996, la propriété Sulphurets a été mise en état d'entretien et de maintenance. En 1998, Newhawk Gold Mines Ltd. a indéfiniment abandonné ses plans d'exploitation et décidé de remettre en état la totalité de la propriété, afin d'y réduire les risques environnementaux et d'en abaisser au maximum les coûts de possession. La société a alors déposé une proposition aux Ministry of Energy and Mines (MEM) et au Ministry of Water, Land and Air Protection (MWLAP – Ministry of Environment) de la Colombie-Britannique demandant une autorisation de disposer les rejets d'exploration dans le lac Brucejack. Dans sa demande, elle proposait de camionner les rejets jusqu'au lac, plus précisément jusqu'à un pont-jetée qui s'étendrait jusque dans le lac, où les matériaux seraient ensuite poussés par un bulldozer et nivelés à une profondeur minimum de 1 m sous la surface. Newhawk s'attendait à ce que le relief onduleux et les conditions humides du site rendent presque impossible l'élimination de tous les stériles. Aussi, la société s'était engagée à enlever tous rejets qui reposaient au-dessus de la nappe phréatique.

Voici quelques-unes des exigences du MEM en matière de restauration :

- élimination intégrale de la machinerie, du matériel et des superstructures;
- élimination de tous les déchets, dans la mesure du possible;
- nivellement des zones perturbées d'après le relief d'origine approximatif du site;

- dépôt de l’ensemble des matériaux de manière à réduire au maximum la LM et le DMA et à assurer le maintien de la qualité de l’environnement.

Une épaisse couche de neige et un climat subalpin froid atténuent considérablement la productivité du sol et la croissance des végétaux dans la région, de sorte qu’aucune exigence en matière de revégétation n’était rattachée à la remise en état de la propriété Sulphurets. Le MWLAP et Environnement Canada avaient tous deux signalé que la protection environnementale dans cette propriété devait être axée sur l’habitat du poisson dans la partie inférieure du ruisseau Sulphurets. Habituellement, les critères permettant de déterminer si les mesures d’atténuation de la LM et du DMA protègent efficacement l’environnement sont les limites de rejets fixées pour prévenir toute répercussion sur le milieu récepteur en aval. Puisque la propriété Sulphurets ne faisait l’objet d’aucune limite de rejets, le MEM exigeait que la restauration vise la réduction maximale des répercussions sur la qualité de l’eau du ruisseau Brucejack.

Depuis l’inondation quasi intégrale des chantiers souterrains, les principales préoccupations en matière de LM et de DMA étaient causées par les stériles qui, d’après le bilan acide-base, pouvaient entraîner du DMA. Voici les stratégies de restauration que le MEM envisageait initialement pour de petites quantités de minerai et les stériles potentiellement acidogènes :

- ne pas déplacer les stériles;
- recouvrir les stériles d’une couverture de sol pour atténuer la lixiviation;
- récupérer et traiter à la chaux les eaux de drainage;
- disposition subaquatique des stériles dans un bassin aménagé à cette fin;
- submerger les stériles dans le lac Brucejack.

D’après des travaux antérieurs, le MEM avait réalisé une évaluation qualitative de l’efficacité, des coûts, des responsabilités et des risques environnementaux rattachés à chacune des stratégies susmentionnées (Price et Errington, 1998, et Price, 2001, 2004a et 2004b). Un des principaux critères d’évaluation de l’efficacité des stratégies était la compatibilité de celles-ci au projet ciblé et aux conditions biogéoclimatiques. Parmi les aspects clés propres au site abordés pendant l’évaluation des stratégies d’atténuation potentielles, mentionnons l’isolement d’un site, les mauvaises conditions climatiques qui y sont observées et les problèmes rencontrés pour y accéder. Un plafond nuageux bas, une épaisse couche de neige et une mauvaise visibilité (voiles blancs) prédominent pendant une grande partie de l’année dans la région du projet Sulphurets. Par conséquent, la meilleure stratégie de réduction des risques et des responsabilités comporterait peu de travaux de surveillance et d’entretien, à défaut que des préoccupations environnementales en exigent manifestement davantage. Le projet Sulphurets ne consistait pas autant à exploiter une mine qu’à effectuer de l’exploration poussée, ce qui contribuait à un autre obstacle important, soit le manque de renseignements sur les matériaux présents sur le site, l’état du site, l’évolution des stériles (p. ex. leurs futurs taux d’altération), les matériaux superficiels (p. ex. l’efficacité du sol comme couverture ou pour construire des digues) et les propriétés du milieu de confinement (p. ex. la capacité d’atténuer les contaminants potentiels de la halde en amont du ruisseau Sulphurets).

Dans son évaluation initiale des stratégies d’atténuation potentielles, le MEM avait conclu que la disposition des stériles dans le lac Brucejack serait celle qui comporterait le moins de responsabilités et de risques environnementaux, s’il était démontré que la dissolution des produits d’altération accumulés aurait des répercussions négligeables sur la qualité de l’eau. L’inondation des stériles dans un bassin artificiel était jugée désavantageuse, car elle nécessiterait un entretien prolongé des digues, l’utilisation de matériaux de construction probablement trop rares dans ce milieu rocheux et escarpé où les précipitations sont fortes, ainsi que l’investissement de capitaux importants pour construire le bassin. Quant au traitement des eaux de drainage, il exigerait la récupération d’eaux de ruissellement abondantes, l’élimination des boues de traitement, l’aménagement d’une usine de traitement difficile à exploiter dans un milieu si isolé et inhospitalier, de même que l’investissement de capitaux importants, notamment à des fins d'exploitation. Pour ce qui est de l'utilisation d'une couverture sèche, elle comportait comme principaux désavantages de présenter une durabilité et une efficacité incertaines dans un milieu à fortes précipitations, d'exiger un suivi et un entretien prolongés, de poser des risques à long terme attribuables aux produits d'altération accumulés sous la couverture et de nécessiter des investissements à des fins de remplacement et d'entretien. De plus, le coût d'une couverture sèche varierait selon l'abondance des matériaux convenable pour la construction. Le MEM avait rejeté l'idée de laisser le site tel quel en raison des incertitudes rattachées à l'évolution et aux répercussions environnementales des charges en métaux et en acides et des exigences logistiques et financières liées au suivi et aux garanties financières à long terme.

La *Loi sur les pêches* exige la prévention des répercussions sur l'habitat du poisson, ce qui exclut généralement la disposition des rejets dans un lac. Dans le cas du projet Sulphurets, Environnement Canada affirmait que le lac Brucejack ne constituait pas un habitat pour le poisson, ce qui permettait d'envisager la disposition des stériles dans ce plan d'eau.

La disposition subaquatique des stériles dans le lac Brucejack présentait notamment les avantages suivants :

- réduction des répercussions causées par les rejets de contaminants, en raison de la faible quantité de stériles comparativement au grand potentiel de dilution et d'atténuation du ruisseau Brucejack, du glacier Sulphurets et du ruisseau Sulphurets, en amont de l'habitat du poisson;
- inondation permanente des matériaux déposés sous le niveau du substratum rocheux, à la décharge du lac, grâce aux grandes quantités d'eau provenant des glaciers environnants et des neiges abondantes;
- aucun entretien du site ou de structures géotechniques, contrairement à la stratégie recourant à des digues pour retenir l'eau.

La plus grande préoccupation liée à la disposition subaquatique des stériles dans le lac Brucejack concernait le temps qui s'était écoulé depuis l'excavation des matériaux, l'accumulation possible de produits d'altération solubles et les répercussions potentielles sur la qualité de l'eau. D'autres inquiétudes avaient été soulevées au sujet de la disposition subaquatique des stériles, dont une oxydation supplémentaire possible des sulfures par l'eau oxydée traversant les stériles inondés, de même que la remobilisation des fines et des débris entraînés pendant et après le dépôt des stériles. Le lac présentait toutefois des caractéristiques qui pourraient restreindre l'écoulement de l'eau à travers les stériles, notamment sa nature calme et la couche de neige qui le recouvre pendant une grande partie de l'année, lesquelles réduisent la turbulence, le mélange et la quantité assez grande de sédiments charriés habituellement jusque dans l'eau. Diverses autres mesures d'atténuation économiques avaient été proposées, y compris l'épandage de chaux pour neutraliser l'acidité et atténuer les répercussions de métaux traces potentiellement solubles, de même que le placement des stériles dans une zone particulièrement calme du lac et l'installation de rideaux pour piéger les sédiments et réduire la remobilisation.

<u>Analyse des concentrations des solutés et des répercussions potentielles sur la qualité de l'eau</u>

Pour évaluer les préoccupations à propos des charges dissoutes dans les rejets et des répercussions potentielles sur la qualité de l'eau, le MEM avait imposé les exigences suivantes à Newhawk :

- analyse en fioles agitées d'échantillons représentatifs prélevés à divers endroits dans les stériles;
- calcul des charges en contaminants potentiellement solubles dans les stériles;
- utilisation des résultats obtenus pour prévoir les répercussions de la disposition subaquatique des stériles sur la qualité de l'eau du lac et du ruisseau Brucejack;
- identification de mesures d'atténuation supplémentaires, s'il y avait lieu.

Au total, neuf échantillons avaient été prélevés au hasard dans des trous creusés au moyen d'une pelle rétrocaveuse dans la halde de stériles et les tas de minerai. La plupart des échantillons, soit sept sur neuf, présentaient un pH de 8,1 à 8,5 dans les fioles agitées. Ce pH correspondait à celui des échantillons de stériles prélevés sous terre, ce qui montrait qu'après dix ans d'exposition, les fines de la majeure partie des stériles et du minerai présentaient toujours un PN important. Sur les neuf échantillons, un seul présentait un pH faible (3,6), ce qui laissait croire que le faible pH relevé dans les eaux de drainage des deux tuyaux enfoncés dans la halde n'était peut-être pas caractéristique de l'ensemble des stériles. Un des échantillons présentait un pH neutre (7,2). Comme prévu, les concentrations de sulfates et de métaux solubles étaient beaucoup plus fortes dans le lixiviat de l'échantillon acide analysé en fioles agitées que dans ceux dont le pH variait entre 8,1 et 8,5 : sulfates, 1670 mg/L comparativement à 52 à 355 mg/L, Al, 9 mg/L par rapport à < 0,004 à 0,05 mg/L, As, 20 µg/L comparativement à 1 à 8 µg/L, Cd, 6 µg/L par rapport à < 0,1 à 1,6 µg/L, Co, 42 µg/L comparativement à 0,1 à 0,8 µg/L, Cu, 308 µg/L par rapport à 17 à 38 µg/L, Fe, 50 mg/L comparativement à < 0,01 à 0,01 mg/L, Ni, 39 µg/L par rapport à < 0,1 à 1 µg/L, Pb, 100 µg/L comparativement à < 2 à 10 µg/L et Zn, 2,2 mg/L par rapport à 0,006 à 0,03 mg/L. L'alcalinité des échantillons d'un pH > 7 se situait entre 47 et 87 mg/L. L'acidité de l'échantillon acide s'élevait à 200 mg/L.

Trois séries de calculs avaient été exécutées d'après les résultats d'analyse en fioles agitées. Les deux premières séries de calculs reposaient sur les concentrations moyennes de métaux du lixiviat d'analyse en fioles agitées, et celles-ci visaient à déterminer la charge en métaux des stériles. La première supposait le mélange complet de la charge en métaux dans le lac Brucejack, la deuxième, une charge en métaux issue du ruisseau Brucejack et la troisième, une charge en métaux correspondant, pour l'ensemble des stériles, à celle du tuyau ouest, cette série de calculs visant à déterminer la qualité de l'eau en présumant le mélange complet de la charge dans le lac Brucejack.

Les charges du ruisseau ou du lac Brucejack antérieures au dépôt des stériles avaient été calculées en multipliant les concentrations élémentaires par le volume d'eau, d'après des données présentées aux fins du projet d'exploitation de 1989 (Newhawk Gold Mines Ltd., 1989a). Le volume était de 29 x 10^6 m^3 pour le lac Brucejack. Celui utilisé pour le ruisseau Brucejack reposait sur l'hypothèse que la disposition subaquatique des stériles s'échelonnerait sur quatre mois, soit de juin à septembre, que les charges en métaux des stériles seraient directement charriées dans la décharge du lac et que le volume de dilution des eaux de drainage équivalait à un débit mensuel moyen de 2,88 m^3/s, pour un total de 29,8 x 10^6 m^3 sur quatre mois. La similarité des volumes et de la qualité de l'eau du lac et du ruisseau Brucejack montrait que les valeurs calculées présentaient, elles aussi, une très grande similarité.

Les calculs comprenaient un certain nombre de différences possibles avec la réalité. Aux fins du calcul des charges en métaux, on présumait que la totalité des stériles réagirait comme l'échantillon de < 2 mm utilisé lors des analyses en fioles agitées. Il aurait été plus réaliste de s'attendre à ce que les fragments grossiers, dont la surface efficace était assez petite, produisent probablement très peu de métaux dissous. On supposait également un mélange complet des métaux solubles dans les stériles dans le lac ou le ruisseau Brucejack, alors qu'un tel mélange n'était pas certain à 100 %, celui-ci étant tributaire d'un certain nombre de phénomènes, dont la circulation de l'eau dans le lac.

En raison de la charge en matériaux solubles assez petite dans les stériles et du fort potentiel de dilution du lac et du ruisseau, les concentrations moyennes en fioles agitées n'avaient présenté que de faibles augmentations, voire aucune, pour nombre d'éléments ou des augmentations relativement minimes pour les autres (tableaux 11 et 12). La charge en As, Ca, Cd, Mg, Na et Pb du ruisseau et du lac Brucejack était d'au moins un ordre de grandeur supérieure à celle prévue lors du dépôt des stériles, si bien que les calculs laissaient supposer que le dépôt des stériles n'entraînerait qu'un faible changement des concentrations, voire aucun. Les éléments et composés dont les concentrations étaient plus élevées dans les stériles que dans le ruisseau ou le lac étaient les suivants : sulfates, charge de 165 949 kg, Cu, charge de 22 kg, Zn, charge de 115 kg et Mn, charge de 497 kg.

Dans le lac Brucejack, la charge calculée d'après les concentrations moyennes en fioles agitées devait passer de 4,6 à 10,3 mg/L pour les sulfates, de 0,7 à 1,4 µg/L pour le Cu, de 1 à 5 µg/L pour le Zn et de 5 à 22 µg/L pour le Mn (tableau 11), tandis que dans le ruisseau Brucejack, elle devait passer de 5,3 à 10,9 mg/L pour les sulfates, de 0,1 à 0,8 µg/L pour le Cu et de 2,5 à 6,4 µg/L pour le Zn (tableau 12). En raison de la charge en matériaux solubles relativement faible dans les stériles (Mo, 14 kg, Sb, 22 kg et Se, 2 kg), et du fort potentiel de dilution, on ne s'attendait pas à ce que les critères de la Colombie-Britannique sur la qualité de l'eau soient surpassés par les concentrations lacustres de métaux traces sur lesquelles aucune donnée n'avait été recueillie.

Afin d'évaluer les répercussions potentielles d'une proportion plus élevée de stériles acides, celles influant sur la qualité de l'eau lacustre avaient été déterminées en appliquant à l'ensemble des stériles les résultats d'analyse en fioles agitées obtenues du tuyau ouest. Dans le cas de l'As, du Ca, du Cd, du K, du Mg, du Mn et du Na, les données sur les acides analysés en fioles agitées montraient des répercussions négligeables, voire nulles, soit parce que la charge existante dans le lac demeurait de beaucoup supérieure à celle prévue pour les stériles, soit parce que les résultats moyens d'analyse en fioles agitées et les résultats de cette analyse concernant les acides n'étaient pas très différents. Le lac présentait toujours un pH prévu neutre et une alcalinité élevée (18 mg/L), car la charge alcaline du lac était considérablement supérieure à l'acidité des stériles. L'emploi des résultats d'analyse en fioles agitées sur les acides plutôt que des résultats moyens aux fins des calculs avait entraîné une augmentation appréciable des concentrations lacustres : sulfates, de 10 à 26 mg/L, Cu, de 1,4 à 4,7 µg /L, Fe, de 2 à 640 µg /L, Pb, de 1,0 à 2,3 µg/L et Zn, de 5 à 29 µg/L.

Les conclusions suivantes découlaient de l'évaluation des résultats d'analyse en fioles agitées et de l'utilisation de ces résultats pour prévoir les répercussions de la disposition subaquatique des stériles sur la qualité de l'eau :

- Le dépôt des stériles ne devait pas avoir d'importantes répercussions sur la qualité de l'eau en aval, même si les stériles contenaient des concentrations élevées pour un certain nombre de métaux totaux et de métaux traces solubles, en raison du volume relativement petit de stériles comparativement au potentiel de dilution et à l'alcalinité du ruisseau et du lac Brucejack.
- Les résultats d'analyse en fioles agitées montraient que les stériles acides constituaient la principale source de métaux solubles et que la disposition de ces stériles pouvait accroître de façon marquée les concentrations de métaux, comme le Fe et le Zn. Ils laissaient également supposer que très peu de stériles étaient acides au moment de l'analyse. Cependant, le nombre d'échantillons analysés était restreint et le MEM exigeait de Newhawk qu'elle surveille le pH pendant les travaux d'excavation et qu'elle neutralise tous les stériles acides, à titre de mesure préventive et pour réduire les charges en métaux dans le milieu aquatique.

Non loin, la disposition subaquatique des stériles acides altérés produits pendant l'excavation d'une galerie d'accès, préalablement à l'aménagement de la mine Eskay Creek, avait montré que l'ajout de chaux réduisait très efficacement la solubilité du Fe et du Zn.

<u>Conditions du MEM rattachées aux permis de disposition des stériles</u>

Les conditions pour le déménagement et la disposition des stériles étaient les suivantes :

- La totalité des stériles et du minerai doit être éliminée et placée dans le lac, dans la mesure du possible;

- La zone perturbée doit être nivelée, d'après le relief d'origine approximatif, de manière à maximiser l'immersion des stériles restants;
- Le détenteur du permis doit quantifier approximativement et localiser sur une carte tous les stériles restants;
- Le détenteur du permis doit prévoir le pH des eaux de drainage des stériles devant être excavés et puis confinés dans le lac le jour suivant, en mesurant le pH du produit de rinçage des matériaux prélevés dans un transect suivant la partie exposée des matériaux excavés;
- La halde doit se trouver dans une partie du lac où la circulation de l'eau est la moins forte, afin de permettre la dilution d'une grande quantité de contaminants avant que les eaux de drainage n'atteignent le ruisseau Brucejack;
- Une fois déposés dans le lac Brucejack, les stériles doivent être recouverts d'au moins 1 m d'eau lorsque le niveau de l'eau est à son plus bas;
- Pour neutraliser l'acidité et la solubilité des métaux, l'exploitant doit mélanger tous les stériles d'un pH après rinçage inférieur à 4,5 avec une quantité similaire de stériles neutres ou d'une alcalinité correspondant à 75 g de $CaCO_3$/t de stériles (2,0 kg de $CaCO_3$ par chargement camionné de 25 t);
- Aucune chaux ne doit être épandue lorsque le pH quotidien du lac Brucejack dépasse 7,5.

Les exigences en matière de suivi de la qualité de l'eau étaient les suivantes :

- Pendant la disposition subaquatique des stériles, surveiller quotidiennement le pH du lac Brucejack sur le côté de la halde contigu au ruisseau Brucejack, à l'embouchure du ruisseau Brucejack et dans le ruisseau Brucejack, juste en aval du site minier;
- Pendant la disposition subaquatique des stériles et durant chacune des quatre semaines suivantes, surveiller deux fois par semaine les concentrations de Cu, de Fe, de Pb et de Zn totaux et dissous, ainsi que le TSS et le pH du lac Brucejack sur le côté de la halde contigu au ruisseau Brucejack, à l'embouchure du ruisseau Brucejack et dans le ruisseau Brucejack, juste en aval du site minier;
- Pendant une période commençant au moins un mois avant la disposition aquatique des stériles et finissant un mois après celui-ci, surveiller mensuellement les concentrations de métaux totaux et de métaux dissous, le pH, l'alcalinité, la conductivité, le TSS et la dureté, de même que la teneur en Cl et en sulfates des sites d'échantillonnage de l'écoulement entrant du ruisseau Camp et du ruisseau Little Camp, du portail, du lac Brucejack sur le côté de la halde contigu au ruisseau Brucejack, à l'embouchure du ruisseau Brucejack et dans le ruisseau Brucejack, juste en aval du site minier;
- En juillet et en septembre 2000 et 2001, surveiller les concentrations de métaux totaux et de métaux dissous, le pH, l'alcalinité, la conductivité, le TSS et la dureté, de même que la teneur en Cl et en sulfates du lac Brucejack sur le côté de la halde contigu au ruisseau Brucejack, à l'embouchure du ruisseau Brucejack, dans le ruisseau Brucejack, juste en aval du site minier, et à l'entrée de la mine.

Déplacement et disposition subaquatique des stériles dans le lac Brucejack

Le déplacement et la disposition subaquatique des stériles dans le lac Brucejack s'étaient échelonnés du 27 juillet au 27 août 1999. Visuellement, les rejets semblaient avoir été presque entièrement extraits du site, ce qui rendait inutile un nivellement du site et la localisation sur une carte des stériles restants. Le dépôt des stériles dans le lac avait été effectué avec l'aide un pont-jetée, dans des talus qui avaient ensuite été poussés par un bulldozer dans le lac. Une fois que l'ensemble des stériles avait été déposé sur la voie d'accès, la surface des matériaux avait été abaissée à environ 1 m sous le niveau du lac. Le déménagement et la disposition subaquatique des stériles représentait la majeure partie des coûts du programme de restauration, qui étaient estimés à 800 000 $.

Visuellement, les stériles poussés dans le lac semblaient être tombés directement au fond, sans laisser de matières en suspension visibles à la surface, ce qui fut confirmé en 1999 par le TSS du lac relevé sur le côté de la halde contigu au ruisseau Brucejack et par celui du ruisseau Upper Brucejack, qui correspondaient à ceux préalables au dépôt des stériles (de < 3 à 8 mg/L). Un TSS supérieur (de < 3 à 14 mg/L) avait été obtenu en 1999, dans le ruisseau Lower Brucejack, vraisemblablement en raison de l'écoulement du ruisseau et des eaux souterraines sur le sol récemment exposé.

Le pH du lixiviat des échantillons de stériles se situait entre 3 et 4,5 dans 11 % des cas, entre 4,5 et 7 dans 34 % des cas, entre 7 et 8 dans 28 % de ceux-ci et entre 8 et 9 dans 27 % de ceux-ci. Comparativement aux échantillons analysés en fioles agitées, les échantillons prélevés avant les travaux d'excavation étaient aussi nombreux à présenter un pH < 4,5, beaucoup plus nombreux à présenter un pH du lixiviat de 4,5 à 7 et de 7 à 8 et moins nombreux à présenter un pH > 8. La différence entre les pH du lixiviat et les pH d'analyse en fioles agitées témoigne des difficultés à prélever des échantillons représentatifs dans les stériles. Il n'est pas conseillé de forer pour échantillonner de vieux stériles, car les forages séparent les particules pouvant témoigner des conditions d'altération. En général, la caractérisation de vieux stériles implique le creusement de tranchées d'échantillonnage. Cette technique d'échantillonnage repose sur l'hypothèse que la surface de stériles déversés par l'arrière renferme un échantillon représentatif de tous les matériaux déposés dans la halde. La restauration de la propriété Sulphurets avait montré qu'il est nécessaire d'échantillonner les matériaux à la base de la halde, car le degré d'altération peut s'y avérer différent, ce qui était effectivement le cas, du moins dans une certaine partie de l'assise de la halde, où les eaux souterraines avaient accru la lixiviation.

Au total, 577 kg de chaux avaient été épandus pendant les travaux d'excavation. Le pH variait entre 6,8 et 8,3 dans le lac Brucejack, entre 6,5 et 8,4 dans le ruisseau Upper Brucejack et entre 6,2 et 8,4 dans le ruisseau Lower Brucejack. Les plus faibles pH dans le ruisseau Lower Brucejack avaient été relevés au début des travaux d'excavation et étaient probablement attribuables à la lixiviation des matériaux résiduels, après le déménagement des stériles d'un faible pH autour du portail. Les plus forts pH, soit 8,3 et 8,4, avaient été relevés aux trois postes de suivi, à la fin des travaux d'excavation, et résultaient vraisemblablement de la lixiviation de chaux déposées sur le site.

Après le dépôt des stériles et de la chaux, le pH était tombé à l'intervalle de 7,4 à 7,7. En 2000, soit l'année suivant le dépôt des stériles, le pH variait entre 7,6 et 8,0 dans le lac Brucejack, entre 7,6 et 7,8 dans le ruisseau Upper Brucejack et entre 7,5 et 7,7 dans le ruisseau Lower Brucejack. En 2001, il s'établissait à 7,5, à 7,8 et à 7,7 dans ces trois entités respectivement.

L'analyse en laboratoire de huit échantillons prélevés hebdomadairement en 1999, de deux échantillons prélevés en 2000 et d'un échantillon extrait en 2001 montrait que les changements de qualité de l'eau survenus dans le lac et le ruisseau Brucejack pendant et après la disposition subaquatique des stériles étaient relativement faibles. Durant le dépôt des stériles, en 1999, les concentrations de sulfates étaient passées de 8 à 13 mg/L dans le ruisseau Upper Brucejack, l'alcalinité était passée de 16 à 21 mg/L, les concentrations d'As total avaient fléchi, celles d'Ag total avaient culminé à 0,4 µg/L et celles de Pb total avaient plafonné à 3 µg/L, tandis que les concentrations de Cd, de Cu et de Zn totaux étaient demeurées équivalentes ou inférieures au seuil de détection. Des valeurs similaires avaient été relevées dans le lac Brucejack, sur le côté de la halde contigu au ruisseau Brucejack. Même si la période de disposition n'avait duré qu'un mois et demi plutôt que quatre, l'augmentation de 5 mg/L des concentrations de sulfates et la progression négligeable des concentrations de métaux traces dans le ruisseau Upper Brucejack et dans le lac Brucejack s'avéraient similaires aux changements prévus d'après l'analyse en fioles agitées. En 2000 et en 2001 respectivement, les concentrations de sulfates dans le ruisseau Upper Brucejack se chiffraient à 10 mg/L et à 11 mg/L, l'alcalinité était de 16 mg/L et de 17 mg/L, les concentrations d'As total demeuraient inférieures à la médiane antérieure de 1,8 µg/L, celles d'Ag et de Pb totaux étaient inférieures à leurs seuils de détection respectifs de 0,1 et de 1 µg/L, tandis que les concentrations de Cd, de Cu et de Zn totaux demeuraient sous les seuils de détection.

Les plus importants changements touchant la qualité de l'eau pendant et après le dépôt des stériles ont été observés dans le ruisseau Lower Brucejack. Pendant la période de déménagement des stériles, en 1999, diverses valeurs avaient augmenté. Les concentrations de sulfates étaient passées à 30 mg/L, l'alcalinité, à 26 mg/L, la dureté, à 39 mg/L, les concentrations de Cd dissous, à 0,5 µg/L, celles de Cu total, à 20 µg/L, celles de Cu dissous, à 10 µg/L, celles de Fe total, à 1 mg/L, celles de Fe dissous, à 0,32 mg/L et celles de Zn dissous, à 70 µg/L. Les valeurs rattachées au ruisseau Lower Brucejack ont généralement diminué de 2000 à 2001, mais elles demeuraient élevées dans le cas des sulfates (de 18 à 22 mg/L), de la dureté (de 29 à 35 mg/L) et du Cd dissous (0,2 µg/L). Même si elles étaient peu élevées, les concentrations du ruisseau Lower Brucejack étaient supérieures à celles du lac Brucejack et du ruisseau Upper Brucejack, ce qui indiquait que les principales répercussions à court terme des travaux de restauration ne résultaient pas autant du dépôt même des stériles dans le lac Brucejack que de la lixiviation de la zone perturbée ou se trouvait les stériles avant leurs déplacement. Rétrospectivement, il se serait peut-être avéré judicieux d'épandre un peu de chaux aux endroits dans la zone perturbée où des stériles acides reposaient afin de réduire la solubilité des métaux.

Beaucoup de détonateurs non électriques et de cordeaux détonants mélangés aux stériles sont remontés à la surface lorsque les stériles ont été poussés dans le lac. Plusieurs centaines de sacs à ordures ont été remplis avec ceux qui ont été piégés dans des grillages, à l'embouchure du ruisseau Brucejack et sur le rivage du lac.

Le pont-jetée pour les stériles a été aménagé(e) entre l'embouchure d'un ruisseau et la décharge du lac, ce qui ne s'est pas avéré idéal pour réduire au maximum l'écoulement à travers les rejets. Toutefois, on s'attendait à ce que les sédiments glaciaires charriés dans le lac par ce ruisseau et d'autres petits cours d'eau forment rapidement une couche fine qui atténuerait l'infiltration à travers le pont-jetée et son accès. Le débit beaucoup plus fort du ruisseau Brucejack expliquait pourquoi le drainage du site n'avait que des répercussions minimes sur la qualité de l'eau du ruisseau Brucejack.

Conclusions

Même s'ils sont relativement peu importants, les coûts et les répercussions potentielles des travaux de restauration rendent très complexe l'atténuation de la LM et du DMA sur d'anciens sites miniers et d'exploration. Comme pour de nombreux autres anciens sites du genre, la restauration de la propriété Sulphurets présentait un certain nombre d'obstacles, dont le manque de renseignements sur le site et les matériaux présents, des problèmes d'accès au site et un climat inhospitalier, qui recouvrait la région de neige pendant une grande partie de l'année. Les coûts d'accès élevés, le manque de personnel sur le site et le petit budget affecté à la restauration ont nui à la collecte de données supplémentaires. Les problèmes liés à l'accès au site et au climat ont beaucoup influé sur le choix des mesures d'atténuation envisagées. Parmi les obstacles aux travaux d'atténuation, mentionnons la disponibilité de matériaux géologiques se prêtant à l'aménagement de couvertures et de digues, l'épaisse couche de neige recouvrant la région pendant une grande partie de l'année, les abondantes eaux de ruissellement générées par cette neige, ainsi que l'isolement du site et le climat rigoureux de la région, qui nuisaient à l'exploitation des installations nécessaires, de même qu'aux activités de surveillance et d'entretien. Pour toutes ces raisons, le MEM avait conclu dans son évaluation initiale des stratégies d'atténuation potentielles que la disposition subaquatique des stériles dans le lac Brucejack représentait la technique qui impliquerait le moins de responsabilités et de risques sur le plan environnemental, s'il était démontré que la dissolution des matériaux altérés accumulés n'aurait que des répercussions négligeables sur la qualité de l'eau.

De nombreux éléments variables influent sur les répercussions des stériles sur la qualité de l'eau après leur immersion. En voici quelques-uns :

- interaction entre les divers types de stériles et entre les stériles et le lac;
- mélange et déplacement potentiels des contaminants dans le lac;
- emplacement où surviennent la neutralisation et la précipitation.

Compte tenu que ces éléments variables sont souvent difficiles ou même impossibles à évaluer, l'approche adoptée par le MEM pour effectuer des prévisions reposait sur des mesures et des hypothèses simples. La charge potentielle en métaux solubles avait été prévue d'après l'analyse en fioles agitées d'échantillons prélevés dans des trous creusés dans les rejets au moyen d'une pelle rétrocaveuse. Une estimation approximative des répercussions de la disposition subaquatique sur la qualité de l'eau avait été effectuée selon la charge en métaux solubles et les résultats du suivi relatifs à la qualité et au volume de l'eau dans le ruisseau et le lac Brucejack. Les calculs effectués montraient que le lavage des matériaux altérés résultant du dépôt des stériles dans le lac ne changerait que légèrement la qualité de l'eau du ruisseau et du lac Brucejack. Bien que le déménagement de la halde de stériles et leur dépôt dans le lac aient pris beaucoup moins de temps que prévu, soit un mois et demi plutôt que quatre, les prévisions s'étaient révélées justes dans l'ensemble.

Même s'ils n'ont généralement pas eu beaucoup d'incidence sur les résultats du projet, les imprévus ci-après sont survenus :

- D'après les pH du lixiviat, la majeure partie des stériles présentait un pH allant de 4,5 à 7 et de 7 à 8, et seule une faible proportion de ceux-ci affichait un pH > 8, alors que cette dernière valeur prédominait dans les échantillons prélevés au cours de l'année précédente pour prévoir les répercussions potentielles sur la qualité de l'eau.

- Les principaux changements quant à la qualité de l'eau ont été observés dans le ruisseau Lower Brucejack, pendant et après le dépôt des stériles. Bien que faibles, les concentrations dans cette partie du ruisseau Brucejack étaient plus élevées que dans le lac Brucejack et du ruisseau Upper Brucejack, ce qui indiquait que les principales répercussions à court terme des travaux d'atténuation se traduiraient davantage par une lixiviation de la zone perturbée que par la disposition subaquatique même des stériles dans le lac Brucejack.
- Après les travaux d'atténuation, le ruisseau Brucejack a inondé une partie du site occupé par l'ancienne halde.

La différence entre le pH du lixiviat et le pH d'analyse par fioles agitées semble découler d'une altération plus rapide de la base de la halde et témoigne des risques posés par la supposition que des échantillons prélevés près de la surface sont représentatifs pour une halde de stériles altérés. Habituellement, la caractérisation des vieilles haldes est effectuée en creusant des tranchées d'échantillonnage à la surface. L'hypothèse sous-tendant cette technique est que la surface des stériles déversés par l'arrière renferme un échantillon représentatif de l'ensemble du dépôt, alors que les forages séparent les particules pouvant témoigner des conditions d'altération. Dans la propriété Sulphurets, l'alcalinité était faible et des eaux souterraines légèrement acides pouvaient entraîner une lixiviation de la base des stériles, ce qui montre l'utilité possible de prélever des échantillons dans cette partie. Comme c'est souvent le cas dans les haldes acides, une altération plus rapide des stériles peut également survenir en profondeur parce que la base de la halde en constitue la partie la plus chaude.

La restauration de la propriété Sulphurets a également montré qu'avant de choisir un site de disposition, il faut tenir compte de sa nature hydrogéologique et hydrologique. Même si un site n'a été utilisé qu'à des fins d'exploration, la décision d'y placer des stériles sulfurés doit être prise judicieusement. Certains facteurs doivent être pris en considération, notamment l'écoulement des eaux souterraines, la déviation et l'accumulation des eaux de drainage par le relief, ainsi que la facilité avec laquelle les matériaux pourront être déplacés. En outre, le sol comme la végétation doivent être étudiés de manière à disposer des données nécessaires sur le niveau de la nappe phréatique pendant l'année.

Enfin, la restauration de la propriété Sulphurets présentait un certain nombre de défis sur le plan réglementaire. L'opérateur devait, entre autres, traiter avec plusieurs organismes responsables de surveiller la LM et le DMA, mais dont les points de vue différaient en ce qui concerne les risques, les données requises et les mesures d'atténuation. De plus, pendant qu'il évaluait le projet, le MEM disposait d'effectifs restreints possédant la formation appropriée pour évaluer les nombreux projets soulevant des préoccupations en matière de LM et de DMA. En 1998, durant l'évaluation du projet Sulphurets, et en 1999, lorsque les travaux d'atténuation étaient en cours, la tâche était ardue pour les inspecteurs évaluant le DMA sur le site en raison des contraintes qui leur étaient imposées quant aux coûts et aux délais de transport. Par contre, la bonne tenue des dossiers chez Newhawk comme au MEM a considérablement facilité la réalisation de l'évaluation technique, car celle-ci joue un rôle réglementaire important dans l'évaluation des sites qui, comme la propriété Sulphurets, sont mis en état d'entretien et de maintenance pour un certain nombre d'années.

ACRONYMS

ABA:	Acid-Base Accounting
AP:	Acid Potential
ARD:	Acid Rock Drainage
BC MEM:	British Columbia Ministry of Energy and Mines
BC MWLAP:	British Columbia Ministry of Water, Land and Air Protection (formerly the Ministry of Environment)
Hcell:	Humidity Cell
ML:	Metal Leaching
NP:	Neutralization Potential
NPR:	Neutralization Potential Ratio (NP/AP)
PAG:	Potentially ARD generating
QA/QC:	Quality Assurance/Quality Control
TSS:	Total Suspended Solids

ACKNOWLEDGMENTS

This review would not be possible without the assistance of the following: Max Holtby of Silver Standard Resources Inc., Bruce McLeod of the Northair Group, Dave Green of Procon, Nora Hutt and Kevin Morin (MDAG), David Koren, Charlene Hogan and Irene Lafferty (CANMET-MMSL), Sylvia van Zalingen, Ecos Environmental Consulting, Sue Moodie and Bill Slater (Canadian Environmental Network), Diane Howe, Kim Bellefontaine, Doug Flynn and Paul Wojdak (BC MEM), and Mark Love and Ian Sharpe (BC MWLAP). BC MEM is thanked for providing access to reports in their library in Smithers.

1.0 INTRODUCTION

The Sulphurets property is located in the coastal mountains of northern British Columbia, 56 kilometres northwest of Stewart, on a high elevation bedrock plateau surrounded by mountain peaks and glaciers (Figures 1 and 2). The exploration camp and underground portal were constructed on the flood plain of Brucejack Creek, near the point where it flows out of Brucejack Lake (Figure 3, Photos 1 and 6). Brucejack Lake has an area of 81 ha, a maximum depth of 88 m and a volume of approximately 29 million m^3. Brucejack Creek flows for 2.4 km from Brucejack Lake to the Sulphurets Glacier (Figure 2 and Photos 1, 2 and 6). The creek drainage then flows for 4 km under the Sulphurets Glacier, before it emerges in Sulphurets Creek, which then flows 14 km prior to entering the Unuk River (Figure 2). A 30 m waterfall limits fish access to the lower 1 km of Sulphurets Creek. The elevation of the site is approximately 1375 meters asl.

The mean annual temperature is estimated to be -2ºC, with a mean annual precipitation between 1,800 and 2,500 mm (Newhawk Gold Mines Ltd., 1989a), the majority of the precipitation being snow. Snow and access difficulties are major impediments to work at the site. The site is covered with snow for at least 8 months a year, restricting many activities to the potentially snow-free period from July to September. Weather permitting, the quickest way to reach the site is by helicopter. Poor weather often prevents flying, especially during the winter. Overland access is from Highway 37, along a logging road to the barge landing on Bowser Lake, by boat up the length of lake (NE to SW end), by dirt road up the Bowser River to toe of the Knipple Glacier and up the mountain to access the glacier, 7 km on an ice road up the Knipple Glacier and finally 1 km on a mine road along southern edge of Brucejack Lake to the Sulphurets Camp (Figure 1). The best times to cross the Knipple Glacier are in the spring and in the late summer, avoiding the period of snowmelt and rotten snow (B. McLeod pers. comm.). The low flow period is during the winter, with maximum leaching and dilution during the summer freshet.

Geologically, Sulphurets property is located within the Stewart Complex, which is typified by Jurassic age, intermediate volcanic and sedimentary rocks intruded by late Jurassic age plutons. The general area is host to several present and past mines (e.g., Eskay, Snip, Johnny Mountain, Granduc and Premier) and numerous advanced exploration projects (e.g., Catear/Goldwedge, Kerr-Sulphurets and Berg). Waste disposal at the Goldwedge project, which is on Catear Creek, a tributary of Brucejack Lake, included on-land and lake disposal of an un-quantified volume of waste rock and approximately 4000 t of tailings from a small underground mine (Doug Flynn, personal communication). The Sulphurets property contains a large number of mineralized showings; with strong iron staining common on rock outcrops and talus (see Photos 1 and 6).

The Sulphurets property had been intermittently explored since the 1930's. Exploration and much of the reclamation were conducted by Newhawk Gold Mines Ltd. As part of advanced exploration and bulk sampling, underground workings were excavated in the West Zone Deposit at Sulphurets between 1986 and 1990. The underground workings were 5276 m in length and consisted of a decline and four levels: 1350m, 1300m, 1250m and 1200m (Bruce McLeod, pers. communication). Construction of the underground workings generated approximately 124,000 tonnes (44,300 m^3) of waste rock (Figure 4). The waste rock was placed in a shallow pad along the southern boundary of Brucejack Creek and was used as the foundation for the camp and other facilities. Two small piles of low-grade ore were placed at the back of the pad and two small streams, Camp and Little Camp Creek, were piped underneath.

In addition to the West Zone underground, Newhawk's work included trenching, surface exploration and drilling at the Shore Zone, which is along the western shore and extends into Brucejack Lake, approximately 0.5 km east of the West Zone. The Shore Zone appeared to be very similar to the West Zone in geology, mineralization, length, grade, width and structure (Newhawk Gold Mines Ltd., 1989a).

Silver Standard Resources Inc. purchased Newhawk Gold Mines Ltd. part way through 1999 and is the present owner.

2.0 ML/ARD INFORMATION GENERATED IN SUPPORT OF THE MINE PROPOSAL

The Sulphurets project entered the provincial environmental assessment process in 1987, applying for a Mine Development Certificate. The primary focus of mine planning was on the West Zone, near Brucejack Lake. The assessment of the ML/ARD characteristics of the rock and the waste rock encountered in the underground workings at the Sulphurets property included information on the lithology, acid base accounting (ABA), measurements of the total elemental concentration, humidity cell analysis and leach tests using acetic acid and sulphuric acid.

2.1 Geological Information

Geological information about the proposed mine was presented in the Sulphurets Joint Venture Prospectus (1987) and Newhawk Gold Mines Ltd. (1989a). Geological information is also found in MINFILE, the mineral occurrence database of the British Columbia Ministry of Energy and Mines.

According to these sources, the West Zone deposit is a structurally controlled, complex stock work, epithermal silver-gold-base metal quartz vein located at a volcanic-sedimentary contact. A northwest-trending zone of alteration about 100 meters wide parallels the contact with a hornblende-feldspar-porphyry-syenite immediately to the west. The area of potentially economic mineralization is confined within an intense sericite-silica-pyrite alteration zone. In 1989, the calculated drill indicated and inferred ore reserves for the West Zone were 774,800 tonnes with 12.14 g/t gold and 786.5 g/t silver. The mineralized veins were described as consisting mainly of quartz, with minor calcite and up to 20% sulphides. Sulphur minerals included pyrite, sphalerite, galena, tetrahedrite, electrum, argentite, pyargyrite, chalcopyrite, barite and molybdenite.

The West Zone waste rock was predicted to be comprised of approximately 33% andesite, 33% silicified andesite, 12% quartz vein, 11% quartz stock work and 11% quartz breccia (Newhawk Gold Mines Ltd. 1989a).

2.2 Acid Base Accounting (ABA) Results

The acid base accounting information provided in support of the mine proposal came from the analysis of:

- six waste rock samples and a composite waste rock sample collected from inside the underground workings (Table 1);
- seven samples, presumably from drill cores, from five different rock types (andesite, silicified andesite, quartz stockwork, quartz breccia and quartz) found in the West Zone deposit (Table 1); and
- pre-test results from the six humidity cell samples (Table 4).

The six individual waste rock samples and the composite sample from inside the underground workings are presumably representative of the average composition of the rock types present in the waste rock pad. The rock samples may illustrate some of the variability within the excavated rock types. No information was provided on how the samples were collected, the type of sample, (e.g., drill core, rock chip, or grab sample) or the specific analytical procedures. ABA results and the calculated parameters are tabulated in Table 1. AP was calculated from total sulphur. The neutralization potential ratios (NPR) were calculated in 1999 by BC MEM (Price and Howe, 1999).

The paste pH of the waste rock samples ranged from 7.7 to 8.6, with only one of the seven samples having a pH < 8. The range in paste pH was similar for the rock samples as a whole, although individual rock types showed some variation within that range. The rock samples with NP values of 2 and 3 kg $CaCO_3$/t had paste pH values of 7.8 and 8.

The waste rock samples had AP values of 86 to 211 kg $CaCO_3$/t and NP values of 10 to 92 kg $CaCO_3$/t. Six of the waste rock samples had NPR values between 0.07 and 0.39. One had an NPR of 1.08. Notably, four of the seven waste rock samples had NP values of 10 to 16 kg $CaCO_3$/t and NPR values of below 0.14.

The range of AP in the rock samples was 12 to 209 kg $CaCO_3$/t, with an average AP of 109 kg $CaCO_3$/t. Notably, many of the samples with an AP < 100 kg $CaCO_3$/t were quartz breccia and quartz, the two rock types not represented in the waste samples. The range of NP in the rock samples was 2 to 316 kg $CaCO_3$/t, however a few samples had an NP > 100 kg $CaCO_3$/t. Fifty-seven percent of the samples had an NP <15 kg $CaCO_3$/tonne and 35% had an NP <10 kg $CaCO_3$/tonne. All the rock types included samples with low NP values. NPR values ranged from 0.07 to 10.99, however only 2 samples had NPR values greater than 1; samples of quartz (10.99) and quartz stock work (2.81). Thirty-six of the 42 samples had NPR values less than 0.5.

The NPR values < 1 indicated that when exposed, the majority of the rock at the site would eventually be ARD generating. The low NP and NPR in many of the samples suggest that ARD could occur relatively quickly, especially if much of the NP was from silicate rather than Ca or Mg carbonate minerals.

Mineralogical parameters important in the interpretation of AP and NP results, such as whether the sulphur is largely pyrite or what minerals contribute the measured NP, were not measured. The low concentrations of Ba and Pb indicate there is little or no acid insoluble sulphate present. The relatively low initial rate of sulphate release in the humidity cells suggests that more soluble sulphate forms were present, but in relatively low amounts. The relatively high total-S in most samples indicates that Ca and Mg carbonate minerals will be required to maintain a neutral pH. From the limited test work, it was not possible to ascertain how much of the measured NP came from the Ca and Mg carbonate minerals. A portion of the measured bulk NP will be derived from silicate minerals, which will only be effective in maintaining a neutral pH if the rate of sulphide oxidation remains low.

2.3 Elemental Composition of the Waste Rock and Sediment from Brucejack Creek and Lake

Elemental analysis was conducted using ICAP procedures on five waste rock samples from the West Zone (andesite, quartz vein, silicified andesite, quartz stock work and quartz breccia) and samples of sediment from Brucejack Creek and Brucejack Lake. The digestion procedure was not indicated, but was presumably a strong acid digestion, such as aqua regia. Results for the waste rock are presented in Table 2, whereas results for the sediment samples obtained from Brucejack Creek and Brucejack Lake are presented in Table 3.

Of the trace metals that are commonly of concern at British Columbia mine sites, the greatest exceedances by the West Zone waste rock of the upper limits found in unmineralized rock, were for Ag (14 to 45 mg/kg compared to 0.1 mg/kg), As (10 to 225 mg/kg compared to 2 mg/kg) and Sb (10 to 25 mg/kg compared to 0.2 mg/kg). Concentrations of other trace metals in the West Zone waste rock were Cd < 0.5 to 3 mg/kg, Cu 29 to 42 mg/kg, Pb 30 to 84 mg/kg and Zn 15 to 354 mg/kg.

Trace metal concentrations in sediment samples from Brucejack Creek and Brucejack Lake were similar to those of the waste rock: Ag 1 to 34 mg/kg, As 110 to 255 mg/kg, Cd < 0.5 mg/kg, Cu 20 to 78 mg/kg, Pb 22 to 182 mg/kg, Sb < 5 to 15 mg/kg and Zn 96 to 286 mg/kg. The concentrations of a number of trace metals in the <11 µm fraction of sediment from Brucejack Lake were higher than those of the waste rock: As 530 to 580 mg/kg, Cd 21 to 24 mg/kg, Cu 119 to 126 mg/kg, and Zn 219 to 226 mg/kg. This is likely a result of the low solubility of these elements. One conclusion that can be drawn from the similarity to natural trace metal concentrations is that under similar weathering and leaching conditions, the waste rock would not increase metal concentrations in the environment. However, accelerated weathering and lower than background pH values, likely occurrences with fresh rock with the NPR values < 1, could result in much higher trace metal mobility and metal loads than is 'natural'.

Notably, the concentration of elements found in carbonate minerals, Ca, Mg and Mn, all occurred in relatively low concentrations in the West Zone waste rock samples; less than 0.1% Mg, 89 to 232 mg/kg Mn, and four of the five samples contained less than 0.5 % Ca. Similar total Ca and Mg concentrations were found in sediment samples taken from Brucejack Creek and Brucejack Lake. The highest concentrations of Ca, Mg and Mn in the sediments were found in the < 10 µm fraction (1.0% Ca, 1.9% Mg and 0.5% Mn).

2.4 Results of Acetic Acid and Sulphuric Acid Leach Tests

Leach tests were conducted as part of the mine proposal using pH 5 solutions of acetic and sulphuric acid. Rock samples were pulverized, placed in acetic acid (20:1 ratio at pH 5.0) and leached for 24 hours. The leachates were analyzed using a 24 element ICP scan, with separate analyses for antimony, arsenic and mercury. The results are shown in Table 4. Part of the reason for re-testing using a pH 5.0 solution of sulphuric acid was to check the dissolved Pb levels, which were anomalously high in the acetic acid solution.

The trace metals leached in highest quantities in the acidic leach tests (pH 5.0) were Cr, Pb and Zn. Acetic acid leachable concentrations were < 5 µg/L As, <1-7 µg/L Cr, 4-50 µg/L Pb, < 4 µg/L Sb, and 1-28 µg/L Zn. The Cr, Pb and Zn concentrations were lower and As was higher in the sulphuric acid leach test. The element with the highest concentration in the leachate was Ca (range of 24 - 900 mg/L, median of 100 mg/L). The relatively low trace element concentrations were likely due to the fact that the samples were unweathered. Test results indicate the solubility of primary minerals at pH 5 or higher, if some neutralization occurs.

The acetic acid leach was the "Special Waste Extraction Procedure" (SWEP) specified under the Provincial Waste Management Act. The original intent of the test procedure was to provide a guide to potential leaching by weakly acid solutions similar to those found in some soils and landfills. The procedure usually provides little or no useful information because the leachate is more acidic than the actual leachate in the field and because there is no consideration of the impact of weathering typically required before elevated metal leaching can occur.

2.5 Humidity Cell Analysis

Humidity cell testing was conducted on pulverized samples for a period of 10 weeks. The samples were leached over a seven-day cycle. Dry air was passed over the cell for the first three days, followed by three days of humidified air. On the 7th day, distilled water was added to the cell. After an hour, the supernatant (slurry) was collected and centrifuged to recover leachate for analyses. The mass of sample and the volume of distilled water were not reported. Results were presented in a supplementary submission to the proposed mine plan (Newhawk Gold Mines Ltd., 1989b).

Humidity cell tests were conducted on six waste rock samples; andesite, quartz, silicified andesite, quartz breccia, quartz stock work and a composite sample. Prior to testing, the samples had NP values of 16 to 62 kg $CaCO_3$/t, AP values of 25 to 174 kg $CaCO_3$/t and NPR values of 0.15 to 0.54, plus one NPR of 2.54 (Table 5). Unlike the previously reported ABA results (Table 1), sulphide-S was used to calculate the AP and sulphate-S was calculated from the difference between total-S and sulphide-S. Based on the difference between total-S and sulphide-S, most samples appeared to contain a small but significant amount of sulphate-S, with the highest proportion in the quartz breccia sample (0.46%). However sulphide-S exceeded total-S in the siliceous andesite, indicating that the calculated sulphate-S values may be subject to significant error. Further evidence of the inaccuracy of the calculated sulphate-S values is provided by the low rates and similar sulphate production of the quartz breccia compared to many of the other lower sulphate humidity cell samples during the initial weeks of testing (Table 6).

Within the 10-week test period, all the cells produced neutral pH leachates, with values generally between 7 and 8. Analytical error was blamed for the anomalously low pH values measured on day 49. Notably the only other instance where the drainage pH was below 6.5 was in the last week of testing of the andesite sample, which had the lowest NP and NPR (Table 6). Sulphate production generally declined during the 10 weeks of testing, with the higher values at the start likely from the leaching of sulphate-S rather than sulphide oxidation (Table 6). The average sulphate production rate for weeks 2 to 10 ranged from 0.0137 g/kg/wk for the quartz vein to 0.0453 g/kg/wk for the silicified andesite (Table 7). Based on the average sulphate production rate measured in the humidity cells, the rate of calcite depletion[5] would range from 0.7 to 2.4 kg $CaCO_3$/t and would take 7 to 87 years to exhaust the sample NP (Table 7) and 4 to 14 years to deplete an NP of 10 kg $CaCO_3$/t (Table 8).

A four-fold slower sulphide oxidation and NP depletion rate was predicted under field conditions due to the 20ºC difference between the laboratory and the mean annual site temperature of -2ºC and a doubling of the Arrhenius activity for every 10ºC temperature rise. Another factor suggested as potentially slowing the rate of NP depletion was the exhaustion of the finer, more easily oxidized pyrite grains, the explanation provided for the observed decline in the rate of sulphide oxidation. The report did not mention factors potentially accelerating the onset of ARD, such as the heat produced by sulphide oxidation, which may increase temperatures within the waste, NP depletion by processes other than dump sulphide oxidation (e.g., leaching by groundwater) or if some of NP was unavailable or insufficiently reactive. It also failed to point out that oxidation rates can accelerate greatly after weeks 10 to 20 despite near-neutral conditions (Morin & Hutt, 1997a and 1999).

Trace metal concentrations in the humidity cell leachate were generally below the relatively high detection limits throughout the 10 weeks: Al, As and Sb < 0.2 mg/L, Cd and Cu < 0.01 mg/L, Cr and Fe < 0.015 mg/L, Pb < 0.05 mg/L, Mo < 0.03 mg/L and Ni < 0.025 mg/L. The exceptions were Ca, Mg and Mn, which were released in relatively high amounts, and Ba and Zn, which had relatively low detection limits. The highest observed Mn concentration was 2.42 mg/L. The highest Zn concentration was 0.08 mg/L.

2.6 Mine Development Certificate

In 1989, a Mine Development Certificate (MDC 92-06) was issued to Newhawk Gold Mines Ltd. (NGML) for underground mining of the West Zone deposit. The Certificate was for an onsite mill, with

---

[5] Assuming the following reaction $CaCO_3 + \underline{2H}^+ = Ca^{2+} + H_2CO_3$

subaqueous disposal of fine tailings, mine water and potentially ARD generating waste rock into Brucejack Lake. Coarse tailings were to be backfilled into the underground workings and flooded at closure.

The test work conducted is inadequate by today's standards. Notable omissions are the lack of mineralogical data, sulphate-S analyses and a carbon assay, and the limited duration of the humidity cell tests. However, the test work was sufficient to establish the strong ARD potential of the wastes and thus support the main objective of the mitigation plan, which was to prevent ARD by flooding. Flooding within Brucejack Lake would presumably be done almost immediately. The main concern would be with the post-closure weathering of coarse tailings backfilled into the underground workings and metal discharge when the underground flooded at closure. The test work indicated that some rock contained very little NP. More test work would be required to estimate metal loads or establish whether there was sufficient Ca and Mg carbonate to prevent acidic drainage.

The project certificate was renewed for a further three years in 1994 and again in 1998. Due to economic considerations, the operation never went into production and in 1998 development plans were suspended indefinitely.

3.0 RESULTS OF WATER QUALITY MONITORING

At the request of the BC Ministry of Water, Land and Air Protection, starting in 1987, Newhawk monitored water quality at various locations around the site. The monitored drainages and the starting dates for monitoring were as follows:

- Brucejack Creek above and below the waste rock pad, and discharge from the portal (Portal), starting in 1987;
- Brucejack Lake, from 1988 to 1991;
- two standpipes (WSP and ESP) installed in the waste rock dump in 1989;
- Camp Creek immediately upstream of the waste rock pile (CCI), starting in 1989;
- Camp Creek below the waste rock pile, just prior to it entering Brucejack Creek (CCO), starting in 1993; and
- Little Camp Creek immediately upstream of the waste rock pile (LCCI) and below the waste rock pile just prior to it entering Brucejack Creek (LCCO), starting in 1993.

The monitoring locations are shown in Figure 3. Site access limited the sampling frequency, with more samples taken during site exploration or reclamation, and less frequent or no sampling being done in 1990, 1995, 1996, 1997 and 1998, years when there was little or no site presence. Complete monitoring results along with the minimum, median and maximum values are shown in Table 9.

3.1 Standpipes in the Waste Rock

The west and east standpipes (WSP and ESP) were installed to monitor the progress of waste rock weathering and the quality of drainage flowing from the pile towards Brucejack Creek. The standpipes were at either end of the main camp building, roughly 120 meters apart. The water table was at the base of the pile and drainage was removed from the standpipes with a pump. The drainage pH in 1989, the year the standpipes were installed, was 6.6 to 7.2. No sampling was conducted in 1990. A large decline in the drainage pH at WSP was observed in 1991. From 1991 to 1996, the pH of the WSP drainage was between 2.4 and 3.1. The decline in drainage pH took longer and in the earlier years was more erratic at ESP. With the exception of one sample in 1991, the pH of the ESP drainage was between 5.1 and 6.6 from 1991 to

1993. The pH of the ESP drainage decreased to 3.8 to 4.2 in 1994 and 3.4 to 3.7 in the three samples from 1995 to 1998. In 1998, WSP and ESP had drainage pH levels of 3.6 and 3.4, respectively.

Elevated sulphate, base metals and trace metals concentrations were measured in the drainage from both standpipes, with the highest concentrations observed in the drainage of WSP. The maximum sulphate concentrations at both sites were measured in September 1992 with 1009 mg/L for WSP and 418 mg/L for ESP. Subsequent sulphate concentrations were 348 to 742 mg/L in the WSP drainage and 102 to 397 mg/L in the ESP drainage. Maximum trace element concentrations for WSP and ESP, respectively, were As 2.4 and 0.31 mg/L, Cd 92 and 4 µg/L, Cu 2.0 and 0.25 mg/L, Pb 0.6 and 0.1 mg/L and Zn 4.5 and 0.9 mg/L.

Considerable variation was observed in the trace element concentrations (e.g., August and September 1992). Most elements largely occurred in the dissolved form. A notable exception was the much higher total-Fe versus dissolved-Fe in the pH 5 to 6 ESP samples. The high concentrations of dissolved Fe in the WSP drainage (> 200 mg/L in three samples) indicated that this drainage could have significant acidity. There appeared to be a correlation between Fe, As, Cd, Cu and Zn.

Another notable observation from the standpipe monitoring was that after drawdown it took many hours for the standpipes to fill sufficiently to take another sample, suggesting that loadings from this source were limited (Bruce McLeod, pers. communication). A slow rate of water entry may also be a result of the screen becoming plugged with sediments and/or precipitants.

3.2 Portal Discharge

There were two types of portal discharge. During construction and exploration underground (1987 – June 1990), drainage was removed from the workings by pumping. After pumping ceased in 1990, the underground workings quickly flooded and by November 1990 the portal discharge was the overflow from the flooded workings. During the period of pumping, the portal discharge had: a TSS concentration of up to 5320 mg/L, a pH of 7.5 to 8.3, a sulphate concentration of 81 to 339 mg/L, 52 to 356 mg/L of alkalinity, high maximum total trace element concentrations and significantly lower dissolved trace metal concentrations. There was a wide range of total trace element concentrations measured in the drainage pumped from the workings: As 10 to 610 µg/L, Cu < 1 to 1720 µg/L, Fe < 0.03 to 83 mg/L, Pb < 1 to 1490 µg/L and Zn < 5 to 2310 µg/L. Maximum dissolved trace element concentrations measured in the drainage pumped from the workings were: As 95 µg/L, Cu 17 µg/L, Fe <0.05 mg/L, Pb 96 µg/L and Zn 69 µg/L. Peak TSS and total metal concentrations presumably occurred during periods of mining.

After the pumping stopped, the water table rose quickly and the only unflooded portion of the mine above the portal was a small air raise. Compared to the pre-flooding, the following changes were observed in the discharge from the flooded workings:

- little or no TSS (< 1 to 9 mg/L);
- pH initially decreased to 6.8 to 7.2, and then increased to 7.4 to 7.8;
- hardness remained unchanged with a median value of 150 mg/L;
- alkalinity decreased from a median of 116 to 76 mg $CaCO_3$/L;
- sulphate concentrations decreased slightly from a median of 148 to 120 mg $CaCO_3$/L;
- concentrations of total-Fe were <0.03 to 1.0 mg/L, while D-Fe was < 0.12 mg/L; and
- like TSS, total trace element concentrations decreased substantially; As 0.6 to 22 µg/L, Cd 0.2 to 0.6 µg/L, Cu <1 to 23 µg/L, Pb <1 to 12 µg/L and Zn 16 to 255 µg/L.

Although the differences were less pronounced after flooding than when the workings were active, for most species median total trace element concentrations remained higher than dissolved concentrations: As 7.6 µg/L versus 2.5 µg/L, Cd 0.4 µg/L versus < 0.2 µg/L, Cu 2 µg/L versus < 1 µg/L, Pb 6 µg/L versus < 1 µg/L and Zn 46 µg/L versus 42 µg/L. However, the maximum post-flooding total and dissolved concentrations were similar for most trace elements. The notable exception was Pb.

Median dissolved concentrations of most trace elements decreased after flooding, the most pronounced being D-As, with a median value of 2.5 µg/L after flooding compared to 24 µg/L prior to flooding, and D-Mo, with a median value of 1 µg/L after flooding compared to 6 µg/L prior to flooding. The opposite occurred for D-Zn, with a median value of 42 µg/L after flooding compared to 5 µg/L prior to flooding. Similar to Snip Mine (Price, 2005), when the Sulphurets workings flooded, the highest concentration of D-Zn (242 µg/L) was in the initial discharge from the flooded workings. The highest measured concentrations of D-As in the discharge from the flooded workings were the three measurements in 1992.

3.3 Camp Creek and Little Camp Creek

Two small creeks were conducted under the waste rock pad in 24-inch culverts: Camp Creek and Little Camp Creek. Monitoring of Camp and Little Camp Creek was conducted immediately upstream (inlet) and downstream (outlet) of the pad. Notable features of these two drainages were as follows.

Camp Creek:

- a variable and at times slightly acidic pH upstream (pH 4.5 to 7.9) and downstream (pH 5.4 to 7.0) of the pad, with a slightly higher median pH measured downstream of the pad (6.3 versus 6.0);
- very low alkalinity, with median values of 2 and 3 mg/L at the inlet and outlet;
- decrease in median sulphate from 35 to 25 mg/L as the creek crossed the waste rock pad;
- with the exception of Fe, metals in the drainage were largely dissolved;
- very little difference between upstream and downstream metal concentrations; and
- median total and dissolved concentrations of creek input were: As 0.3 and 0.2 µg/L, Ca 13.7 and 14.6 mg/L, Cd 0.4 and 0.5 µg/L, Cu 3 and 3 µg/L, Fe 0.21 and 0.03 mg/L, Mg 0.73 and 0.70 mg/L, Mo < 1 and < 1 µg/L, Pb < 1 and < 1 µg/L, and Zn 32 and 30 µg/L.

Little Camp Creek:

- alkalinity decreased from 14 to 42 mg/L to < 1 to 11 mg/L as the creek crossed the waste rock pad;
- median pH values were similar, 6.6 in inflow and 6.2 in outflow, but for the last two outflow samples (Sept 1994 and July 1998), the pH decreased from 6.3 to 4.7 and 6.7 to 4.2;
- with the exception of Fe, metals in the drainage are largely dissolved;
- median value of sulphate in the inflow was similar to East Standpipe (156 versus 169 mg/L);
- from inlet to outlet, median concentrations of sulphate decreased from 156 to 51 mg/L, D-Cd decreased from 6.6 to 0.6 µg/L, D-Cu decreased from 54 to 8 µg/L, D-Zn decreased from 784 to 62 µg/L, D-Ca decreased from 65 to 18 mg/L, and D-Mg decreased from 3.1 to 0.9 mg/L; and
- from inlet to outlet, median concentrations of T-As increased from 0.4 to 0.9 µg/L, D-As increased from 0.2 to 0.4 µg/L, T-Pb increased from 7 to 16 µg/L, D-Pb increased from 2 to 13 µg/L, D-Fe increased from 0.08 to 0.45 mg/L and T-Fe increased from 0.27 to 0.54 mg/L.

The elevated sulphate and trace metal concentrations in Camp and Little Camp Creeks indicate a significant natural contaminant source upstream of the waste rock pad, especially for Little Camp Creek. According to Bruce McLeod (pers. communication), the source was natural as the disturbance associated with exploration in these areas was limited to road building and drilling. The low alkalinity and occasionally depressed pH of the Camp Creek inflow indicates depleted NP in the rock upstream. Diffuse groundwater seepage with similar chemistry into Camp Creek or leaks in Camp Creek culvert could increase the dissolution of carbonate minerals within waste rock, potentially accelerating pH depression at the base of the pile.

The increased median total and dissolved As, Pb and Fe, decreased median alkalinity, sulphate, Ca, Cd, Cu, Mg and Zn and the significantly decreased pH in the last two outflow samples indicates there is some contamination of Little Camp Creek by drainage from the dump, the underlying natural ground or Brucejack Creek as it passes under the waste rock pad. Evidence of the extent to which Brucejack Creek flooded the base of the dump is provided by the width of the creek after the waste rock was removed (Photo 6). Variation in the height of the water table and Brucejack Creek may account for some of the variability in the outflow chemistry of Little Camp Creek.

3.4 Upper and Lower Brucejack Creek and Brucejack Lake

Between 1987 and 1998, Upper Brucejack Creek had a pH of 6.6 to 7.9, TSS of < 1 to 14 mg/L, hardness of 14 to 26 mg/L, alkalinity of 11 to 21 mg/L and sulphate of 2 to 12 mg/L. Despite the natural mineralization and activities upstream of Brucejack Lake at the Goldwedge property[6], total and dissolved concentrations of most trace metals in Upper Brucejack Creek were below the detection limits (Cd < 0.2 µg/L, Cu < 1 µg/L, Mo < 1 µg/L, Pb < 1 µg/L and Zn < 5 µg/L). The exception amongst the measured trace elements was As, with median value of 1.8 µg/L T-As and 1.2 µg/L D-As and maximum values of 15 µg/L T-As and 8 µg/L D-As. Total-Fe in Upper Brucejack Creek increased in 1991 and peaked (0.72 mg/L) in July 1992. The maximum TSS (14 mg/L) and T-As (15 µg/L) in Upper Brucejack Creek were also recorded in July 1992.

The water quality results for Brucejack Lake, which was only monitored from 1988 to 1991, were very similar to Upper Brucejack Creek.

Compared to Upper Brucejack Creek. (UBC), Lower Brucejack Creek (LBC) had:

- a slightly lower median and minimum pH (7.2 and 6.3 in LBC versus 7.3 and 6.6 in UBC);
- similar alkalinity (median of 16 mg/L in LBC and 17 mg/L in UBC);
- higher median and maximum concentrations of sulphate (9 and 38 mg/L in LBC versus 6 and 12 mg/L in UBC), hardness (23 and 46 mg/L in LBC versus 22 and 26 mg/L in UBC), and TSS (8 and 111 mg/L in LBC versus 3 and 14 mg/L in UBC);
- slightly lower median concentrations of D-As (1.2 versus 0.9 µg/L); and
- slightly higher median concentrations of T-As (1.8 versus 1.9 µg/L), T-Cu (2 versus < 1 µg/L), T-Fe (0.18 versus 0.08 µg/L), T-Pb (1 versus < 1 µg/L) and T-Zn (< 5 to 6 µg/L), and more samples with concentrations above the detection limits.

The concentrations of TSS and T-Fe in LBC were both quite variable. TSS showed a general decline once exploration activity decreased. A similar reduction was not evident for T-Fe. Like UBC, median dissolved concentrations of Cd, Cu, Mo, Pb and Zn at LBC were below the detection limits.

---

[6] Waste disposal at the Goldwedge project, which is on Catear Creek a tributary of Brucejack Lake, included on-land and lake disposal of an un-quantified volume of waste rock and approximately 4000 t of tailings from a small underground mine (Doug Flynn, pers. communication).

3.5 Conclusions

Site monitoring indicated up to three orders of magnitude higher trace metal concentrations in site drainages entering Brucejack Creek. Maximum dissolved trace metal concentrations for the three monitored drainage sources were:

- As 2.4 mg/L, Cd 0.09 mg/L, Cu 2.0 mg/L, Pb 0.6 mg/L and Zn 4.5 mg/L in the standpipe drainage;
- As 0.1 mg/L, Cd 0.005 mg/L, Cu 0.02 mg/L, Pb 0.1 mg/L and Zn 0.2 mg/L in the portal discharge; and
- As 0.009 mg/L, Cd 0.01 mg/L, Cu 0.17 mg/L, Pb 0.02 mg/L and Zn 1.3 mg/L in Camp and Little Camp Creeks.

However these drainages had only minor impacts on water quality in Brucejack Creek – maximum dissolved concentrations from 1987 to 1998 were: As 0.003 mg/L, Cd <0.01 mg/L, Cu 0.004 mg/L, Pb 0.004 mg/L and Zn 0.025 mg/L. In 1998, the only measured impacts on dissolved trace metal concentrations in lower Brucejack Creek were slight increases in D-Cu (from < 1 to 3 µg/L) and D-Zn (< 5 to 16 µg/L), and a decrease in D-As (0.9 to 0.3 µg/L). The decrease in D-As is likely due to co-precipitation, as T-Fe in Brucejack Creek increased from 0.18 to 0.43 mg/L.

The lack of a significant impact to metal levels in Brucejack Creek was presumably due to the relatively small rate of flow of the portal, dump and Camp Creeks relative to Brucejack Creek. Flow measurement would have been required to determine the relative importance of the different contaminant sources.

4.0 INITIAL REVIEW OF POTENTIAL REMEDIATION OPTIONS

In 1996, the Sulphurets property was placed on care and maintenance. In 1998, development plans for the project were indefinitely suspended and Newhawk Gold Mines Ltd. decided to "fully reclaim the property to reduce the environmental liability and keep holding costs to a minimum" (McLeod, 1999). At the request of the Environmental Protection Program of the BC Ministry of Water, Land and Air Protection (Letter, J. Hofweber, MoELP, to B. McLeod, Northair Group, October 30, 1998), in accordance with the long-term reclamation and closure plan in the proposed mine development, Newhawk Gold Mines Ltd. submitted a proposal to the Provincial Ministry of Energy and Mines and the Ministry of Water, Land and Air Protection (formerly the Ministry of Environment) requesting approval in principle to dispose of the exploration wastes underwater in Brucejack Lake (McLeod, 1999). The proposed plan was to haul the rock to the deposition site by truck, end dump it onto a bermed causeway extended out into the lake, and at the end of dumping to doze it a minimum of 1 meter beneath the surface of the lake (Figure 4, Photo 5), and Hallam Knight Piesold, 1998). The undulating terrain and wet conditions were expected to make it practically impossible to remove all of the waste rock. However, Newhawk committed to removing all of the waste rock above the water table.

The report was reviewed by the members of the Northwest Mine Development Review Committee, including the two main Provincial regulatory agencies, the BC Provincial Ministries of Water, Land and Air Protection (BC MWLAP) and Energy and Mines (BC MEM), and Environment Canada. Differences existed in the conclusions of the various regulators in their review of the various mitigation options and additional information requirements (Environment Canada, 1998 & 1999 and Ministry of Environment, Lands and Parks, 1999a & 1999b). This report will only describe the assessment of BC MEM.

4.1 Regulation of Exploration and Reclamation

Exploration and reclamation activities on the Sulphurets property were conducted under British Columbia Ministry of Energy and Mines mineral exploration reclamation permit MX-1-86. June 13, 1994, BC MEM requirements for site reclamation included:

- removal of all machinery, equipment and building superstructures;
- disposal of all scrap material in an acceptable manner;
- recontouring of disturbed areas to approximate original site contours; and
- placement of all materials in a manner which minimizes the production and release of ML/ARD and ensures protection of environmental quality.

Since the deep snow cover and cool sub-alpine climate result in minimal soil development and vegetation growth, Sulphurets had no revegetation requirements. The BC MEM Mineral Exploration Code (May, 1998) required "an effective metal leaching and acid rock drainage (ML/ARD) prevention program, including a prediction plan and appropriate mitigation, treatment, maintenance and monitoring measures and a management plan for the excavated waste rock (Section 11.10.1)."

An explanation of BC MEM's generic expectations, information requirements and constraints for different aspects of ML/ARD prediction and prevention/mitigation are outlined in the following documents.

- BCMEM and BCMELP. (1998). Policy for metal leaching and acid rock drainage at minesites in British Columbia. B.C. Ministry of Energy and Mines and B.C. Ministry of Environment, Lands and Parks. p. 17.
- Price, W.A. and Errington, J.C. (1998). Guidelines for metal leaching and acid rock drainage at minesites in British Columbia. B.C. Ministry of Energy and Mines. 86 p.
- Price, W.A. (1997). Draft guidelines and recommended methods for the prediction of metal leaching and acid rock drainage at minesites in British Columbia. B.C. Ministry of Employment and Investment. 141 p. plus appendices. (in 1997, Ministry of Employment and Investment was the former home of the present Ministry of Energy and Mines).

These documents were developed to assist mines in developing comprehensive, site-specific programs for ML/ARD assessment and if necessary mitigation.

For the BC Ministry of Energy and Mines, protection of environmental quality is defined as preventing ML/ARD impacts to downstream aquatic resources and ensuring there are no significant future financial liabilities or environmental risks. Both BC MWLAP and Environment Canada indicated that the environmental protection goal at Sulphurets should be the protection of fish habitat in lower Sulphurets Creek. The criteria usually used for determining whether ML/ARD mitigation[7] measures protect environmental quality are the discharge limits established by Environmental Protection Program of the BC Ministry of Water, Land and Air Protection (BC MWLAP) to prevent adverse impacts to the downstream receiving environment. Since the Sulphurets property did not have discharge limits, the reclamation objective of BC MEM was to minimize impacts to water quality in Brucejack Creek.

---

[7] The term mitigation refers to all measures taken to avoid a negative impact on the receiving environment, including ML/ARD prevention, reduction and treatment.

4.2 Initial Review of Mitigation Options

Since the underground workings were almost entirely flooded, the main ML/ARD concern in the reclamation of the Sulphurets project was the waste rock pad. An NPR < 1 for five of the six waste rock samples collected during excavation of the underground workings indicated that the majority of the waste rock was potentially ARD generating (PAG). The high concentrations of S and ICP metals and the low NPR indicated that elevated acidity and metal loadings could result if weathering was permitted to deplete the NP. The high concentrations of several trace metals observed in the drainage collected from the two standpipes installed in the waste rock pad supported concerns regarding the increased trace metal discharge and the potential impact if the entire pile was allowed to go acid. The standpipe drainage chemistry suggested that at least a portion of the pile was already ARD generating.

Remediation strategies that BC MEM initially considered for the PAG waste rock and small amount of ore were:

- leave the waste rock in its present location;
- use a soil cover to limit leaching;
- collection and lime treatment of the drainage;
- underwater disposal in a constructed impoundment; and
- underwater disposal in Brucejack Lake.

Based on its previous experience, BC MEM conducted a qualitative assessment of the effectiveness, costs, liability and environmental risks of each strategy (Price & Errington, 1998, and Price, 2001, 2004a and 2004b). A key aspect of the review was a recognition that for mitigation to be successful it must be compatible with the project and its biogeoclimatic conditions. Key site-specific considerations in the assessment of potential remediation strategies were the isolation, poor weather and difficulty reaching the site. Low cloud cover, a deep snow cover and poor visibility (white-outs) are common occurrences during much of the year. Consequently, unless there was a clear environmental reason to do otherwise, from the perspective of minimizing risk and liability, the best mitigation strategy would be one requiring minimal monitoring and maintenance. Another important impediment, in part because this was an advanced exploration project rather than a mine, was the lack of information regarding the materials and the site, the future performance of the waste rock (e.g., future weathering rates), surficial materials (e.g., suitability of soils for covers or dam construction) and relevant features of the disposal environment (e.g., the potential attenuation of dump contaminants prior to Sulphurets Creek.

4.2.1 Leave the Waste Rock in its Present Location

Possible reasons identified for leaving the waste rock in its present location included the following.

- Due to the roughness and the swampy nature of the underlying terrain, it may not be possible to extract all the waste rock.
- The process of removing waste rock, especially along the creek, may result in a short-term increase in contaminant load.
- The relatively small volume of waste rock compared to the large dilution and potential metal attenuation provided by Brucejack Creek, the Sulphurets Glacier and Sulphurets Creek, prior to fish habitat will limit the impact of contaminant discharge.

Drawbacks with the ‘leave in present location’ option were:

- The uncertainty regarding the magnitude of future increases in acid and metal loadings as weathering proceeds, resulting in logistically and financially onerous requirements for long-term monitoring and financial security.
- The need to permanently maintain the structures conducting Camp and Little Camp Creek through the pile.
- The need to indefinitely maintain structures conducting Camp and Little Camp Creek, which would likely require the replacement of the present pipes with open ditches, requiring some movement of waste rock.

4.2.2 Use a Cover to Limit Leaching and Drainage from the Pile

A cover to limit leaching was suggested as an alternative to underwater disposal. The main advantages with the cover were:

- It would avoid the initial flushing of accumulated soluble weathering products that could occur if the waste were placed underneath a water cover.
- It may be possible to collect the leachate.

Draw backs identified with the cover option included (Price, 2004b):

- High groundwater inputs are expected into the pile at the present location on the swampy floodplain of Brucejack Creek. The pile would have to be moved to a location with little or no groundwater inputs in order for the cover to significantly reduce pile drainage.
- The rugged, rocky site is unlikely to have suitable soil cover materials (Bruce McLeod pers. communication) and the cost of buying and transporting a geotextile cover, as an alternative to a soil cover, would be very expensive.
- There was significant uncertainty regarding the effectiveness and durability of a soil cover in such a high precipitation, snowy environment. The high precipitation and snow cover would likely result in seepage through a soil cover. Other potential climate-related problems include the onerous material, design and construction requirements, how to prevent erosion, uncertainty regarding repair and replacement costs, and the difficulty maintaining and monitoring the cover and the associated drainage structures at such a harsh, snowy, isolated site.
- Weathering products may accumulate under the cover, increasing the potential for environmental impacts if there was a significant reduction in cover performance.
- Cover construction would likely require additional equipment to that already present at the site.

Detailed information on relevant geotechnical and hydrogeological properties of both the disposal area and the cover would be required for the cover design. Maintenance and supportive monitoring would be required to detect, prevent and repair the cover and ditches to divert clean drainage off and potentially around the cover.

4.2.3 Collection and Lime Treatment of Drainage

The main advantage treating ARD with lime was that it is a technology with proven success and a track record that illustrates the challenges (Price, 2004b).

Disadvantages included:

- The large area of land and watercourses required for contaminated drainage collection, treatment facilities, discharge ponds, access roads and sludge disposal areas.

- The potentially large costs for transporting reagents, plant operation, pumping drainage, maintenance of the drainage collection and diversion systems, and sludge disposal.
- The difficulty in getting personnel to the site and operating the associated drainage collection and diversion systems at a location with such a high snowfall and harsh weather conditions.

Lime treatment would likely be very expensive at such a remote site due to the transportation, operation, energy and other logistical needs. Other less expensive treatment methods, such as limestone drains or sulphide reduction, were considered unreliable or unsuitable because of process control difficulties and climate constraints (large runoff, snow cover and frequent storms).

4.2.4 Underwater Disposal

Unless there is a high rate of flow of oxygenated drainage through the waste, placement of mine wastes underwater would:

- prevent acidic weathering conditions and drainage, and the associated high contaminant solubility; and
- reduce oxidation of sulphides to levels below those that cause an environmental impact.

Other advantages of underwater disposal included (Price, 2001):

- It is a technology with a proven track record.
- While some monitoring and maintenance may be required, provided there are no containment structures to maintain, typically these requirements would be less than for other mitigation measures.

There were two main concerns with underwater disposal. One concern was that there could be a high rate of flow through the porous waste rock resulting in significant sulphide oxidation in the flooded waste rock.

The second and primary concern with waste rock disposal in the lake was with the length of time since the waste rock was excavated, and the potential build-up of soluble weathering products and their dissolution and impact on water quality, especially when the waste rock was first placed in the lake. Visually, there appeared to be little weathering of the waste rock. However, this observation was in contrast with the drainage chemistry from the two standpipes, which suggested there had been significant weathering and the potential to release significant acidity and high trace metal concentrations from at least a portion of the waste rock when it is placed in the lake.

There were two underwater disposal options; constructing an impoundment and the use of Brucejack Lake.

4.2.5 Underwater Disposal in a Constructed Impoundment

Advantages of constructing an on-land impoundment to contain and flood the waste rock compared to the use of a lake included:

- the ability to control and if required prevent drainage discharge during placement and initial flushing of the waste rock;
- the ability to limit the waste rock footprint and the volume of water potentially coming in contact with the waste rock;
- the impoundment can be designed to limit flow through the waste; and
- disturbance of a lake is avoided.

The main disadvantages were the risk and liability of indefinitely maintaining impoundment dams in such a severe environment. Structures built to create flooded storage conditions must be designed, constructed and maintained in a manner that ensures long-term geotechnical stability and effective performance throughout the entire range of climate conditions. Other disadvantages included:

- a potential lack of suitable soil materials for dam construction;
- alienation of the occupied land from other use;
- disturbance of the land used to access and excavate construction materials and for construction and maintenance activities; and
- the liability; with most of the costs occurring during initial construction and lesser resources required for ongoing maintenance and monitoring.

4.2.6 Disposal in Brucejack Lake

Fisheries Act requirements to prevent impacts to fish habitat usually precludes lake disposal of mine wastes. In this case, Environment Canada stated that Brucejack Lake was not fish habitat. For that reason, the disposal of waste rock in the lake could be considered.

Advantages in using Brucejack Lake for waste rock disposal included:

- The relatively small volume of waste rock compared to the large dilution and potential metal attenuation provided by Brucejack Creek, the Sulphurets Glacier and Sulphurets Creek, prior to the area of fish habitat would limit the impact of contaminant discharge.
- The large drainage inputs from the surrounding glaciers and the large snow pack would ensure material placed beneath the elevation of bedrock at the lake outlet would remain flooded.
- There would be no geotechnical structures to maintain or post-mining maintenance requirements, unlike water retaining dams.

The primary concern with lake disposal was the length of time since the material was excavated and the potential build-up of soluble weathering products and impact on water quality if waste rock was placed in the lake. A large volume of water could be potentially impacted if the loading by solutes in the waste rock was too high.

Other concerns with lake disposal included the potential for:

- additional sulphide oxidation if there was significant flow of oxidized water through the flooded pile; and
- remobilization of fines and entrained debris during and after deposition.

A number of site attributes were identified that would limit flow through deposited waste rock. These included:

- the quiescent nature of the lake;
- the snow cover for much of the year, which would limit turbulence and mixing; and
- the relatively high sediment inputs into the lake.

Other supporting factors were the relatively low rates of weathering observed in the humidity cells and the reduced rate of oxidation under a water cover. Various cost-effective supplemental mitigation measures were suggested, including: applying lime to neutralize acidity and attenuate potentially soluble trace metals in the waste rock, dumping the waste rock in a quiescent location in the lake and installing sediment curtains to catch debris and minimize remobilization.

4.2.7 Conclusions

The conclusion of BC MEM's initial review of potential mitigation strategies was that, if the water quality impacts resulting from the dissolution of built-up weathering products could be shown to be insignificant, disposal of waste rock in Brucejack Lake would result in the lowest liability and environmental risk. Disadvantages with flooding the waste rock in a constructed impoundment were the long-term dam maintenance requirements, the probable lack of suitable construction materials in such a high precipitation, steep, rocky area, and the high capital costs of constructing the impoundment. Major disadvantages of drainage treatment included the large runoff, treatment sludge disposal, the difficulty operating a treatment plant in such a harsh isolated environment, and the high capital and operating costs. Major disadvantages of a dry cover were uncertainty about their durability and effectiveness in such a high precipitation site, the long-term maintenance and monitoring requirements, the long-term risk posed by weathering products accumulating under the cover, and future replacement and repair costs. Cover costs would depend on the availability of suitable soil materials. The 'do-nothing' option was rejected due to uncertainty regarding future acid and metal loadings and their environmental impact, and the resulting logistical and financial requirements for long-term monitoring and financial security.

5.0 ANALYSIS OF SOLUTE CONCENTRATIONS AND POTENTIAL WATER QUALITY IMPACTS

While the standpipe drainage chemistry suggested that at least a portion of the waste rock was already ARD generating, the high pH and lack of iron staining at the surfaces of the pile and the minimal changes to water quality in Brucejack Creek indicated that weathering was not very advanced and net acid conditions had not yet occurred in most of the pile. To assess concerns regarding the solute load within the pile and the potential impact on water quality, BC MEM required Newhawk to:

- conduct shake flask tests on representative samples collected from different areas of the waste rock pad;
- calculate the load of potentially soluble contaminants in the waste rock;
- use the results to predict the impact of waste rock disposal on water quality in Brucejack Lake and Creek; and
- determine what, if any, supplemental mitigation may be required.

5.1 Shake Flask Test Results

A total of nine grab samples were collected from backhoe holes excavated in the waste pad and ore piles. The sample locations were selected to provide general coverage of the pad. The shake flask tests were conducted on a 100 g sample of < 2 mm material sieved from the uncrushed waste rock samples. Each sample was added to 300 mL of distilled water and gently agitated in a rotary extractor for 24 hours in accordance with the method outlined in the *"Draft Guidelines and Recommended Methods for Prediction of Metal Leaching and ARD at Minesites in BC."* Results are shown in Table 10.

Based on the resulting leachate pH, the shake flask samples could be divided into three categories:

- one sample with a low pH (pH 3.6);
- one sample with a neutral pH (pH 7.2); and
- seven samples with pH values between 8.1 and 8.5.

The pH of 8.1 to 8.5 of seven of the nine samples was the same pH range as the paste pH reported for the waste rock samples collected underground (Table 1), and indicates that after 10 years exposure the fines in the majority of the waste rock and ore still contained significant NP. The finding that only one of the nine samples had a low pH suggested that the low pH observed in the drainage from both standpipes may not be typical of the majority of the waste rock. Notably, the acid shake flask sample came from the area of the west standpipe.

As expected, the concentration of sulphate and soluble metals was much higher in the acid shake flask sample than in the samples with a pH of 8.1 to 8.5: sulphate 1670 versus 52 to 355 mg/L; Al 9 versus < 0.00 to 0.05 mg/L; As 20 versus 1 to 8 µg/L; Cd 6 versus < 0.1 to 1.6 µg/L; Co 42 versus 0.1 to 0.8 µg/L; Cu 308 versus 17 to 38 µg/L; Fe 50 versus < 0.01 to 0.01 mg/L; Ni 39 versus < 0.1 to 1µg/L; Pb 100 versus < 2 to 10 µg/L; and Zn 2.2 versus 0.006 to 0.03 mg/L. The pH 7.2 East ore pile sample had high sulphate (1420 mg/L) and had the highest soluble concentrations of the base metals Ca (552 mg/L), Mg (2.2 mg/L), and the trace metals Cd (7 µg/L), Mn (10 mg/L), Sb (99 µg/L) and Se (10 µg/L). As expected from its greater solubility at neutral pH, the shake flask with the highest Mo concentration (134 µg/L) was one of the samples with a pH of 8.1 to 8.5. After Ca, the next most soluble base cation was K, with concentrations of 6 to 18 mg/L.

The concentrations of alkalinity in the neutral pH samples were 47 to 87 mg/L. The concentration of acidity in the WSP was 200 mg/L.

For sulphate and most of the trace metals, there was less than an order of magnitude difference between the concentration in the acid shake flask and the maximum concentrations measured in the drainage from the WSP and ESP standpipes: sulphate 1670 versus 1009 and 418 mg/L; As 20 versus 2390 to 31 µg/L; Cd 6 versus 92 and 4.9 µg/L; Cu 308 versus 1990 and 249 µg/L; Fe 50 versus 267 and 11 mg/L; Pb 100 versus 566 and 105 µg/L; and Zn 2.2 versus 4.5 and 0.9 mg/L. The exceptions were the high maximum concentrations of D-As (2390 µg/L) and D-Cd (92 µg/L) in WSP.

Possible explanations for the discrepancy between the majority of the shake flask pH results and the low pH standpipe drainage were that:

- the standpipes were coincidentally located in waste rock with a low NP;
- intense leaching by the naturally slightly acidic groundwater had removed the NP and accelerated sulphide oxidation in some of the waste rock at the base of the pile; and
- the standpipes measured the pH of the groundwater below the waste rock.

5.2 Predicted Impact of the Flooded Waste Rock on Water Quality

Three sets of calculations were made using the shake flask results (Hallam Knight Piesold Ltd., 1999). The first two sets of calculations used the average metal concentrations in the leachate from the shake flask tests to calculate the metal loading from the waste rock. One calculation assumed complete mixing of the metal load in Brucejack Lake (Table 11) and the other assumed the metal load reports to Brucejack Creek (Table 12). The third set of calculations assumed all the waste rock had the same metal load as the West Standpipe and calculated the water quality assuming complete mixing of the metal load in Brucejack Lake (Table 13).

Average shake flask concentrations of major and base cations were: Ca - 171.1 mg/L, Fe - 5.54 mg/L, K - 8.5 mg/L, Mg - 1.38 mg/L, Mn - 1.3 mg/L, Na - 1.2 mg/L, Sr - 1.09 mg/L and Al - 1.04 mg/L. The highest average shake flask trace element concentrations were: Cu - 0.058 mg/L, Mo - 0.038 mg/L, Sb - 0.058 mg/L and Zn - 0.31 mg/L. The average sulphate concentration was 446 mg/L.

Calculation Steps for Metal Loadings from the Waste Rock:

1. Multiply the shake flask concentrations by 0.3 to convert concentration (mg/L) into the mg released from the 100 g (0.1 kg) shake flask test sample.
2. Multiply by 10 to convert mg released/100g to mg released/kg or g/tonne released from the shake flask test sample.
3. Multiply by 124 to convert g/tonne to kg loadings from the 124,000 tonne pile.

The pre-waste rock deposition loadings in Brucejack Creek or Brucejack Lake were calculated by multiplying elemental concentrations by the volume of water, using data from the 1989 mine proposal (Newhawk Gold Mines Ltd., 1989a). For the most part, the water quality data from the 1989 mine proposal was similar to the 1987-1998 median and 1989 monitoring results for Upper Brucejack Creek and Brucejack Lake (Table 9). Noticeable differences were the higher sulphate (11 versus 5 mg/L) and T-Fe (0.18 µg/L versus 0.002 mg/L) in 1998. The elemental concentrations in Brucejack Creek or Brucejack Lake after waste rock deposition were calculated by adding the pre-deposition and waste rock loadings and then dividing by the volume of water.

The volume used for Brucejack Lake was 29 x 10^6 m^3. The volume used for Brucejack Creek assumed that dumping would occur over four months, from June to September, metal loadings from the waste rock migrated directly to the lake outlet and the volume of diluting drainage was the mean monthly flow of 2.88 m^3/s, a total of 29.8 x 10^6 m^3 over four months. The similar volumes and water quality of Brucejack Lake and Brucejack Creek meant that the resulting calculated values were very similar.

The calculations included a number of probable divergences from reality. In the metal loading calculation, it was assumed that the whole mass of waste rock would perform like the < 2 mm size fraction used in the shake flask tests. A more likely scenario is that the coarse fragments, with relatively little surface area, would contribute very little dissolved metals. The proportion of different particle sizes in the Sulphurets waste rock was not measured. However in most waste rock, coarse fragments are typically more than 70% of the mass.

Another assumption in the loading calculations was that the soluble metal concentration of the waste rock in the lake would be the same as that measured in the shake flask test. The solubility of metals, such as Al, Fe and Cu, is strongly influenced by pH. The high concentrations of soluble Al, Fe and Cu measured in the acidic shake flask sample may decrease due to neutralization when the acid waste rock is mixed with alkaline waste rock during removal from the pad and deposition in the lake, and when the acid waste rock mixes with the alkaline lake water. Conversely, a decrease in the oxidation state within the pile could release elements co-precipitated with ferric-Fe and not soluble under aerobic shake flask conditions in neutral pH waste rock.

A third assumption in the calculations was that there would be complete mixing of the soluble metals in the waste rock in Brucejack Lake or Brucejack Creek. Mixing within the lake will depend on a number of properties, including circulation within the lake, and is unlikely to be 100%. A relatively short mixing zone and thus complete mixing is likely within Brucejack Creek. Deposition is expected during June to September, the period of peak snowmelt and runoff, when flow in Brucejack Creek should exceed the average flow used in the calculations.

5.2.1 Predictions Based on Average Shake Flask Results

Due to the relatively small load of soluble material in the waste rock and the large dilution in the lake and creek, average shake flask concentrations resulted in little or no increase for many species and relatively minor increases for the others (Tables 11 and 12). The load of As, Ca, Cd, Mg, Na and Pb in Brucejack Creek and Brucejack Lake were at least an order of magnitude higher than the projected load from waste rock deposition, and thus the calculations suggested that deposition of the waste rock would result in little or no change to their concentration. The species present in relatively higher amounts in the waste rock compared to the creek or lake were: sulphate with a load of 165,949 kg, Cu with a load of 22 kg, Zn with a load of 115 kg and Mn with a load of 497 kg.

In Brucejack Lake, sulphate was predicted to increase from 4.6 to 10.3 mg/L, Cu was projected to increase from 0.7 to 1.4 µg/L, Zn was projected to increase from 1 to 5 µg/L and Mn was projected to increase from 5 to 22 µg/L (Table 11). In Brucejack Creek, sulphate was predicted to increase from 5.3 to 10.9 mg/L, Cu was projected to increase from 0.1 to 0.8 µg/L and Zn was projected to increase from 2.5 to 6.4 µg/L (Table 12). While some variation in water quality was expected as a result of variation in the rates of deposition and the quality of the waste rock, the rate and direction of flow in the lake and the volume of creek flow, the calculations suggested that concentrations would be well below British Columbia water quality criteria or guidelines recommended for the protection of aquatic life. Due to the relatively small load of soluble material in the waste rock (Mo 14 kg, Sb 22 kg and Se 2 kg), and the large dilution, there was also unlikely to be a significant change in the concentration of Mo, Sb and Se, potentially important trace elements for which there was no lake data.

5.2.3 Prediction Based on West Standpipe Shake Flask Results

A large proportion of the average waste rock load for many metals came from the acidic shake flask sample. Consequently, there was a concern raised regarding whether the proportion of acidic waste rock was higher than the one in nine samples collected for shake flask testing. As a check on the potential impact if the proportion of acid waste rock was higher, the impact on the lake water quality was calculated applying the acid West Standpipe shake flask results to the entire mass of waste rock. The results are presented in Table 13.

For As, Ca, Cd, K, Mg, Mn and Na, use of only the acid shake flask data had little or no impact, either because the existing load in the lake was still much higher than the projected load from the waste rock or the acid and average shake flask results were not that different. The projected lake pH remained neutral with significant alkalinity (18 mg/L) because of the much greater alkalinity load in the lake compared to the acidity in the acid waste rock. Use of the acid rather than average shake flask data in the calculations noticeably increased lake concentrations of sulphate from 10 to 26 mg/L, Cu from 1.4 to 4.7 µg /L, Fe from 2 to 640 µg /L, Pb from 1.0 to 2.3 µg/L and Zn from 5 to 29 µg/L.

5.2.4 Conclusions

Conclusions of the review of the shake flask results and use of the results to predict the impact of waste rock disposal on water quality included the following:

- Although the waste rock contained elevated total and soluble concentrations of a number of trace metals, because of the relative small mass of the waste rock compared to dilution and alkalinity in Brucejack Creek and Brucejack Lake, deposition in the lake was unlikely to have a significant impact on downstream water quality.

- The shake flask tests indicated that the primary source of the soluble metals was the acid waste rock and that acidic waste rock disposal could markedly raise the concentrations of species such as Fe and Zn. The shake flask test suggested that very little of the waste rock was presently acidic. However the shake flask sampling was limited and, as a precautionary measure and to reduce metal loading into the aquatic environment, BC MEM required Newhawk to monitor the pH during excavation and neutralize any acidic waste rock.

5.3 Recommended Lime Addition

Previous lake disposal of weathered waste rock produced by pre-mine adit construction at the nearby Eskay Creek Mine had shown that lime additions could be very effective in reducing the solubility of Fe and Zn when acidic waste rock was disposed of in a lake (Morin & Hutt, 1997b and 2000). Lime additions similar to Eskay were recommended to reduce the trace metal release from the acidic portion of the Sulphurets waste rock. The work at Eskay indicated that trace metal solubility was increased, if the pH was too high or too low, and was the lowest at near-neutral pH, therefore demonstrating the importance of not adding too much lime.

The magnitude of lime addition was calculated assuming:

- the acidity in the fine portion of acid waste rock would be similar to the acidity measured in the west standpipe shake flask sample (200 mg $CaCO_3$/L or 0.6 kg $CaCO_3$/t);
- half of the acidity released when the waste rock was placed in the lake would be neutralized by alkalinity in adjacent alkaline waste rock and/or the lake (0.3 kg $CaCO_3$/t); and
- the only significant source of acidity in the waste rock was the fines, which account for approximately 25% of the waste rock (0.075 kg $CaCO_3$/t).

Based on the above, an alkalinity addition of 75 g $CaCO_3$/t was required to neutralize acidity and prevent high metal concentrations in the lake when acidic waste rock was flooded. Assuming the ratio of acid to neutral samples in the shake flask testing of 1:9 (or 11%) was representative of the 124,000 t of waste rock, the maximum alkalinity amendment required for the whole pad was estimated to be 1 tonne. The proportion of acidity neutralized by alkalinity in adjacent alkaline waste rock and/or the lake and the proportion of fines in the waste rock were crude estimates made by BC MEM staff (Price & Howe, 1999). Based on the alkaline nature of most of the shake flask samples, the conditions set for lake disposal also included the option of blending acid rock with a similar mass of adjacent alkaline waste rock prior to disposal in the lake. In further consultation with Newhawk, blending was defined as either mixing during placement in the truck during removal or mixing of piles on the causeway prior to lake disposal.
To provide feedback on the impact of waste rock deposition and lime amendments on water quality, daily pH monitoring was required in Brucejack Lake on the Brucejack Creek side of the disposal site, at the mouth of Brucejack Creek and on Brucejack Creek immediately downstream the mine site. Newhawk was required to inform the Reclamation Inspector whenever pH values exceeded 7.5 or fell below 6.5, and stop the application of lime whenever the pH in Brucejack Lake exceeded 7.5.

6.0 THE RESULTING MEM PERMIT CONDITIONS FOR WASTE ROCK REMOVAL AND DEPOSITION IN BRUCEJACK LAKE

6.1 Waste Rock Removal

1. Removal Criteria

All waste rock and ore above the water table shall be removed and disposed of in Brucejack Lake. Additional waste rock and ore below the water table shall be removed from the waste rock pad to the extent practicable.

2. Site Recontouring

The waste rock pad area and all other areas of surface disturbance shall be recontoured to the extent practicable to maximize the flooding of remaining waste rock and approximate original ground contours.

3. Inventory of Remaining Waste Rock

The Permittee shall estimate the quantity and map the location(s) of any waste rock remaining in the pad and other areas of the site.

6.2 Lake Disposal Conditions

1. Ensuring Permanent Water Cover Over Waste Rock

Upon completion of the waste rock disposal the Permittee shall ensure that the waste rock deposited in Brucejack Lake is covered by a minimum of one meter of water during periods of minimum water level in the lake.

2. Measurement of the Waste Rock Rinse pH

The Permittee shall predict the drainage pH of the waste rock that is to be placed in the lake by measuring the rinse pH of material collected from a transect along exposed face of the material to be excavated the following day.

3. Neutralization of Acidic pH and Suppression of Metal Solubility

In order to neutralize acidity and suppress metal solubility, the operator will either:

- blend any waste that has a rinse pH of less than 4.5, as determined by the foregoing daily measurements of face material, with a similar mass of neutral waste material or
- add an amount of alkalinity equivalent to 75 g $CaCO_3$/tonne of waste rock (2.0 kg $CaCO_3$ / 25 tonne truck load of waste rock).

No lime is to be applied when the daily pH in Brucejack Lake exceeds 7.5.

4. Location of the Dump

The dump shall be located in a region of the lake with minimal flow thus permitting a large dilution volume prior to the contaminants in the drainage reaching Brucejack Creek.

6.3 Monitoring of Brucejack Creek and Brucejack Lake

1. Daily pH Monitoring

- To determine the impact of waste rock deposition and the lime amendments on water quality, daily pH monitoring with a properly calibrated pH probe is required in Brucejack Lake on the Brucejack Creek side of the disposal site, at the mouth of Brucejack Creek and on Brucejack Creek immediately downstream from the mine site.

- The Permittee shall inform the Reclamation Inspector whenever pH values exceed 7.5 or fall below 6.5.

2. Water Quality Monitoring

- During the period of waste disposal and in each of the subsequent four weeks, biweekly, the Permittee shall sample and analyze water quality in Brucejack Lake on the Brucejack Creek side of the disposal site, at the mouth of Brucejack Creek and on Brucejack Creek immediately downstream of the mine site. The samples are to be analyzed for total and dissolved copper, iron, lead, zinc, TSS and pH using Homestake's Eskay Creek laboratory. When and if this lab is capable, sulphate, alkalinity and conductivity will be incorporated into the analyses.

- Starting at least a month prior to commencement of waste disposal and ending one month after the completion of waste disposal, the Permittee shall conduct monthly sampling and analysis of water quality at the inlet sampling sites on Camp Creek and Little Camp Creek, the Portal, Brucejack Lake on the Brucejack Creek side of the disposal site, at the mouth of Brucejack Creek and on Brucejack Creek immediately downstream the mine site. The analyses shall include the same suite of parameters (total and dissolved metals, pH, alkalinity, conductivity, TSS, hardness, Cl and sulphate) as the annual water quality monitoring.

- The Permittee shall conduct sampling in July and September of 2000 and 2001, the two years following completion of waste rock disposal, in Brucejack Lake on the Brucejack Creek side of the disposal site, at the mouth of Brucejack Creek, on Brucejack Creek immediately downstream of the mine site and at the portal. The analyses shall include the same suite of parameters (total and dissolved metals, pH, alkalinity, conductivity, TSS, hardness, Cl and sulphate) as the annual water quality monitoring.

7.0 WASTE ROCK REMOVAL AND DISPOSAL IN BRUCEJACK LAKE

Removal of the waste rock pad and disposal in the lake occurred from July 27th to August 27th, 1999. Excavation and deposition of the waste rock was done with a dozer, a backhoe and a truck (Photos 1, 3 and 4). The backhoe was used to remove the waste rock from the underlying mud and bedrock. Visually, the waste rock was almost all removed from the pad, precluding a need to recontour and map the location of residual material (Photo 6). The only remaining waste rock was a small amount of material contaminated with hydrocarbons around the mechanics workshop. This material was removed and placed on the hillside southwest of the dumpsite. The waste rock was placed as a pad on a rock moraine (a fairly dry spot as far as ground water), treated with an inoculate and covered with a black plastic tarp. Inoculate was added in 2001.

The disposal location in the lake was 650 m from the waste rock pad, the closest location deep enough that all the waste rock could be placed underwater without blocking water leaving the lake (Figure 4). Deposition of waste rock in Brucejack Lake was done from a causeway-like pad, with the waste rock placed in berms and then dozed over the side into the lake. Booms were placed around the causeway to minimize wave action and a couple of fences were placed at the inlet to Brucejack Creek to catch floating debris (Photo 5). Once all the waste rock was placed on the causeway, a backhoe lowered the surface approximately 1 m below the height of the lake.

Averaging 232 x 8.2 m^3 truck loads or 1,903 m^3 per day, a total of 60,890 m^3 of material was moved and placed in Brucejack Lake. The difference between this volume and the estimate of 44,300 m^3 of waste rock was likely due to underlying natural materials mixed with the waste rock at the base of the pile. Waste rock removal was the majority of the cost of the reclamation program, which was estimated to be $800,000 (McLeod, 1999).

Visually, waste rock pushed into the lake went straight to the bottom with no observable entrainment of fines at the lake surface. This was confirmed by the TSS in 1999 in Brucejack Lake on the Brucejack Creek side of the disposal site and Upper Brucejack Creek, which had the same range as the results prior to waste rock deposition (<3 to 8 mg/L). Higher TSS was measured in 1999 in Lower Brucejack Creek (<3 to 14 mg/L), presumably as a result of creek and groundwater flow over the newly exposed ground.

7.1 Rinse pH Results for the Excavated Waste Rock

Prior to excavation, a square grid was laid out on the surface of the pad (Figure 5) to identify the location of the rinse pH samples and help with the co-deposition of neutral and acidic waste rock. The samples consisted of fines collected from a horizontal transect set up along the excavated face. Rinse pH results for the samples collected from the excavated waste rock are shown in Table 14. Eleven percent of the waste rock samples had a rinse pH from 3 to 4.5, 34% were pH 4.5 to 7, 28% were pH 7 to 8 and 27% were pH 8 to 9.

Samples from each of the four rinse pH categories (pH from 3 to 4.5, pH 4.5 to 7, pH 7 to 8 and pH 8 to 9) occurred all over the pad and sometimes samples from two, and in some cases three, pH categories, occurred within the same grid square. The low pH samples (pH 3 to 4.5) were most common near the portal (grids 1 to 7), at back of the pad (grids 32, 35-37) and along the creek (grids 28, 33, 39, 45). Higher pH samples (pH 8 to 9) were most common towards the back and at the east end of the pad.

Deposition in the lake of material in the three highest pH categories (pH 4.5 to 9) occurred fairly evenly over the month and a half of waste rock excavation. The majority of the low rinse pH material (five of seven samples with a pH < 4.5) was moved prior to August 9th. As a result, the majority of the lime was applied to the work rock during the first half of the operation. One inadvertent advantage of removing the more acidic waste rock at the start was that it was encapsulated within the center of the pile of flooded waste rock.

Compared to the shake flask samples, there was a similar proportion of pre-excavation samples with a pH < 4.5, a much higher proportion with a rinse pH of 4.5 to 7 and 7 to 8, and a lower proportion of samples had a pH > 8. Possible explanations for the much higher proportion of rinse pH samples with a pH < 8 were as follows:

- The holes excavated to collect the shake flask samples failed to reach the base of the pile, while the samples collected along the exposed face of the waste rock pad included material at the base of the pile where leaching by slightly acidic groundwater potentially accelerated NP depletion.

- The shake flask samples were mistakenly crushed prior to the tests. Crushing is a standard part of sample preparation prior to most ML/ARD test work and laboratories sometimes do it even when it is not required.

Accelerated NP depletion and ARD onset has been observed where waste rock was placed in seepage paths at the neighbouring Johnny Mountain mine (Price, 2004). Accelerated NP depletion at the base of the pile from leaching by slightly acidic groundwater, similar in chemistry to Camp Creek, was a possible explanation for the discrepancy between the unweathered appearance of the surface of the waste rock pad and the low pH and high dissolved metal in the standpipe drainage.

7.2 Lime Addition and the pH of Brucejack Lake and Brucejack Creek

In order to neutralize acidity and suppress metal solubility, the BC MEM permit required the operator to either mix the acidic waste rock with a similar mass of neutral pH waste rock or an alkalinity application equivalent to 75 g $CaCO_3$/tonne of waste rock (2.0 kg $CaCO_3$ / 25 tonne truck load of waste rock) whenever any waste rock had a rinse pH < 4.5. No lime was to be applied when the daily pH in Brucejack Lake exceeded 7.5. The lime was applied by adding it to the berms of waste rock on the causeway before they were dozed into the lake. A total of 577 kg of lime were added. The timing and amount of lime added and results for the daily field pH measurement in Brucejack Lake and Upper and Lower Brucejack Creek are listed in Table 14. Weekly laboratory pH data for Brucejack Lake and Upper and Lower Brucejack Creek are listed in Table 9.

The data suggests that lime was also added to the waste rock whenever there was a noticeable decrease in pH of Brucejack Creek. Examples of this were 28/07/99, when the pH in Lower Brucejack Creek was 6.17, and 05/08/99 when the pH in Upper Brucejack Creek was 6.56. The range in field pH was 6.8 to 8.3 in Brucejack Lake, 6.5 to 8.4 in Upper Brucejack Creek and 6.2 to 8.4 in Lower Brucejack Creek. The data suggested that the lime additions reversed several declines in pH of Upper and Lower Brucejack Creek. The lowest pH values for Lower Brucejack Creek were at the start of excavation and were likely due to leaching of residual material after removal of the low pH waste rock around the portal. The highest pH values, 8.3 and 8.4 at the three monitoring locations occurred at the end of excavation (Table 14), and were presumably due to the leaching of the cumulative lime addition to the pile. Once waste rock and lime deposition stopped, the pH decreased to 7.4 to 7.7 (September 14th – Table 9).

No explanation was made for the extremely high laboratory pH (9.2 in Brucejack Lake and 8.5 in Upper Brucejack Creek prior to waste rock deposition – Table 9). The field pH values at these sites on that date (July 12th) were both 7.8.
In 2000, the year following waste rock deposition, the pH was 7.6 to 8.0 in Brucejack Lake, 7.6 to 7.8 in Upper Brucejack Creek and 7.5 to 7.7 in Lower Brucejack Creek. In 2001, the pH values were 7.5, 7.8 and 7.7, respectively.

7.3 Other Post-Deposition Water Quality Results for Brucejack Lake and Creek

The laboratory results of eight weekly samples collected in 1999, the two samples from 2000 and the sample collected in 2001 indicated that changes in water quality in Brucejack Lake and Brucejack Creek during and following waste rock disposal were relatively minor in nature. The failure to collect two samples in 2001 was due to access problems resulting from poor weather.

During waste rock deposition in 1999, sulphate in Upper Brucejack Creek increased from 8 to 13 mg/L, alkalinity increased from 16 to 21 mg/L, T-As decreased, T-Ag reached a high of 0.4 µg/L, T-Pb reached a high of 3 µg/L and T-Cd, -Cu and -Zn remained at or below the detection limit. Similar values were observed in Brucejack Lake on the Brucejack Creek side of the disposal site. Although the disposal period was 1.5 rather than 4 months, the 5 mg/L increase in sulphate and negligible increases in trace metals in Upper Brucejack Creek and Brucejack Lake were similar to the changes predicted from the shake flask calculations.

In 2000 and 2001, sulphate in Upper Brucejack Creek was 10 and 11 mg/L, alkalinity was 16 and 17 mg/L, T-As remained below historic median of 1.8 µg/L, T-Ag and T-Pb decreased to below the detection limits of < 0.1 and < 1 µg/L, respectively, and T-Cd, -Cu and -Zn remained below the detection limits. In September 20th 2000, increases were observed in TSS (12 and 15 mg/L), sulphate (23 and 33 mg/L), T-Fe (0.18 and 0.19 mg/L) and D-Ca (33 and 34 mg/L) in Brucejack Lake. Otherwise, the 2000 and 2001 monitoring results for Brucejack Lake were similar to Brucejack Creek.

The largest changes observed in water quality during and following waste rock disposal occurred in Lower Brucejack Creek. During waste rock removal in 1999, sulphate in Lower Brucejack Creek was up to 30 mg/L, alkalinity was up to 26 mg/L, hardness was up to 39 mg/L, D-Cd was up to 0.5 µg/L, T-Cu was up to 20 µg/L, D-Cu was up to 10 µg/L, T-Fe was up to 1 mg/L, D-Fe increased to 0.32 mg/L and D-Zn increased to 70 µg/L. Concentrations in Lower Brucejack Creek declined in 2000-2001, although sulphate (18 to 22 mg/L), hardness (29 to 35 mg/L) and D-Cd (0.2 µg/L) remained elevated. Like Upper Brucejack Creek and Brucejack Lake, D-Zn in Lower Brucejack Creek exceeded T-Zn, indicating that there was an error in the data.

Although modest, the increased concentrations in Lower Brucejack Creek compared to Brucejack Lake and Upper Brucejack Creek indicate that the main short-term impact of the mitigation work was leaching of the disturbed pad area rather than waste rock placement in Brucejack Lake. In hindsight, it might have been advisable to apply some lime to former areas of acid waste rock in the pad area to reduce metal solubility.

7.4 Other Observations

There was little wood within the waste rock. However unforeseen, at least by the regulators, was the large amount of non-electric blasting caps and wire mixed in with the waste rock. This material floated to the surface when the waste rock was pushed into the lake. Several hundred garbage bags of this material were collected from the mesh fences erected at the mouth of Brucejack Creek and along the shores of the lake (Dave Green, pers. communication).

The waste rock causeway was between the mouth of a creek and the outlet of the lake, which was not ideal in terms of minimizing flow through the pile. However it was anticipated that the glacial sediment entering the lake from this and other creeks will soon create a fine-textured layer that limits seepage through the causeway.

Measurement of the flow in Brucejack Creek, Camp Creek, Little Camp Creek and the Portal was conducted eight times during the construction window in 1999. As expected the measured flow was highest at the start of monitoring in July (6.66 m^3/s), when snow melt would be highest, and lowest in September (3.07 m^3/s), prior to the fall rains when the surrounding snow pack was the smallest. Throughout the construction period the flow measured in Brucejack Creek exceeded the mean monthly flow of 2.88 m^3/s, which was the value used in the calculations to predict the impact of waste rock disposal.

Of the other drainage sources, the flow in Camp Creek (0.02 to 0.04 m^3/s) was more than an order of magnitude higher than Little Camp Creek (0.001 to 0.002 m^3/s) and the portal discharge (0.00045 to 0.002 m^3/s) from the underground (Table 15). Brucejack Creek had more than two orders of magnitude greater rate of flow than the cumulative flow from those three drainage sources, which explains why they had only a limited impact on Brucejack Creek water quality.

8.0 CONCLUSIONS

Despite their relatively small size, the costs and potential impacts make the mitigation of metal leaching and ARD at historic mine sites and exploration projects, like Sulphurets, quite challenging. In common with many historic mine sites and exploration projects, challenges at Sulphurets included limited information regarding the site and the materials, access difficulties and an adverse climate, in this case a limited snow-free period. The high access costs, lack of site personnel and small budget made it difficult to collect additional information. Access difficulties and climate constraints were also a major consideration in the review of potential mitigation measures. Mitigation constraints included a probable lack of suitable soil materials for the construction of covers and dams, a deep snow cover much of the year and the resulting large runoff, and the difficulty operating facilities and conducting monitoring and maintenance in such a harsh climate and remote site. As a result of these constraints, the conclusion of BC MEM's initial review of potential mitigation strategies was that, if the water quality impacts from the dissolution of built-up weathering products could be shown to be insignificant, the disposal of waste rock in Brucejack Lake would result in the lowest liability and environmental risk.

A large number of variables determine water quality impacts when waste rock is flooded, including:

- the interaction between different types of waste rock and between the waste rock and the lake;
- potential contaminant mixing and migration within the lake; and
- the location of neutralization and metal precipitation.

As many of these properties are difficult, if not impossible to measure, the prediction approach taken by BC MEM was to use simple measurements and assumptions. Prediction of the potential load of soluble metals was done using data from shake flask tests run on samples collected from holes dug in the waste rock pile dug with a backhoe. A crude estimation of the impact of lake disposal on water quality was made using the predicted soluble load of the waste rock and monitoring results for the water quality and the volume of water in Brucejack Creek and Brucejack Lake. The calculations indicated that flushing of weathering products when waste rock was placed in the lake would result in minimal changes to water quality in Brucejack Lake and Brucejack Creek. Although removal of the waste rock from the pad and deposition in the lake took far less time than that used in the predictive calculations (1.5 versus 4 months), the overall prediction results turned out to be correct.

Although not significant in terms of the overall outcome, aspects of the project that were unexpected were as follows:

- According to the rinse pH data, the majority of the waste rock had a pH of 4.5 to 7 and 7 to 8, and only a small proportion of the waste rock had a pH > 8, which had been the predominant pH of the samples taken the previous year to predict potential water quality impacts.

- The largest changes in water quality observed during and following waste rock disposal were in Lower Brucejack Creek. Although modest, the increased concentrations in Lower Brucejack Creek compared to Brucejack Lake and Upper Brucejack Creek indicate that the main short-term impact of the mitigation work was leaching of the disturbed pad area rather than waste rock placement in Brucejack Lake.

- After the waste rock was removed, Brucejack Creek flooded a portion of the former pad-site.

The discrepancy between the rinse pH and the shake flask pH results appeared to result from accelerated weathering at the base of the pad and illustrated the danger in assuming near-surface samples were representative samples of the composition of weathered waste rock dumps. Typically, characterization of old waste rock piles is done by sampling trenches excavated across the surface. The rationale for this sampling procedure is that the surface of end-dumped waste rock piles contains a cross-section of all the material placed on the pile and that drilling will break apart particles potentially masking weathering conditions. The situation at Sulphurets, with low alkalinity, slightly acidic groundwater potentially leaching the base of parts of the pile, illustrate that there may be a need to sample material at the base of a dump. Another potential cause for accelerated weathering at depth is if, as is often the case in acidic dumps, this is the hottest area of the dump.

The experience at Sulphurets also illustrates the need to consider hydrogeology when selecting a disposal site and the importance of characterizing soil hydrology prior to waste rock disposal. Even an exploration project requires due care and attention in selecting a disposal site for sulphidic waste rock. Factors that may need to be considered include groundwater inputs, upslope drainage diversion, down slope drainage collection and ease of removal. A soil and vegetation survey should be conducted to collect the required information on the height of water table throughout the year.

Lastly, Sulphurets posed a number of regulatory challenges. For the proponent, this included dealing with several agencies with a similar interest in ML/ARD, but differing conclusions regarding the risks and information required with differing mitigation options. An issue for BC MEM at the time it reviewed this project was the limited number of personnel with the training to deal with the large number of projects with ongoing ML/ARD concerns. Transportation costs and time constraints made it difficult for the ARD reviewers to inspect the site during the assessment in 1998 and when the waste rock was moved in 1999. Very helpful to the technical review was the good corporate memory and record keeping, both by Newhawk and by BC MEM. Record keeping is an important regulatory task at sites such as Sulphurets that go into care and maintenance for a number of years.

9.0 LITERATURE REVIEWED

Sulphurets Project Related

- Environment Canada, 1998. Letter from Robert McCandless to Catherine Daniel, Ministry of Energy and Mines, Smithers. (December 16).
- Environment Canada, 1999. Letter from Robert McCandless to Sylvia Van Zalingen, Ministry of Energy and Mines, Smithers. (April 27).
- Hallam Knight Piesold Ltd., 1998. Sulphurets Project Interim Clean-up Measures.
- Hallam Knight Piesold Ltd., 1999. Underwater Disposal of Waste in Brucejack Lake.
- McLeod, D.B. 1999. Reclamation Report on the Sulphurets Project. Newhawk Gold Mines Ltd.
- Mine Development Steering Committee, 1989. Mine Development Review Process, Detailed Government Review Comments.
- Ministry of Energy and Mines, Minfile #104B 022.
- Ministry of Environment, Lands and Parks, 1998. Letter from Craig Stewart to Bruce McLeod, Newhawk Gold Mines Ltd. (December 18).
- Ministry of Environment, Lands and Parks, 1999a. Letter from Craig Stewart to Bill Price. (January 8).
- Ministry of Environment, Lands and Parks, 1999b. Letter from Craig Stewart to Bruce McLeod, Newhawk Gold Mines Ltd. (April 29).
- Newhawk Gold Mines Ltd., 1987. Sulphurets Joint Venture Prospectus.

- Newhawk Gold Mines Ltd., 1989a. Stage I Environmental and Socioeconomic Impact Assessment for the Sulphurets Property.
- Newhawk Gold Mines Ltd., 1989b. Supplementary Submission to the Stage I Report Sulphurets Property.
- Newhawk Gold Mines Ltd., 1998a. Water quality results provided to BC MEM by B. McLeod, December 18, 1998.
- Newhawk Gold Mines Ltd. 1998b. Interim Clean Up Measures. North West Mine Development Review Committee. 1998. Summary notes from a technical workshop held December 18th. Mines Branch, Ministry of Energy and Mines (BC MEM), Smithers.
- Price, W.A. and D. Howe. August, 1999. Review of Metal Leaching and Acid Rock Drainage Aspects of Proposed Disposal of Waste Rock in Blackjack Lake. B.C. Ministry of Energy and Mines, Reclamation Section. 31 p.

ML/ARD Assessment and Mitigation

- BCMEM and BCMELP. 1998. Policy for metal leaching and acid rock drainage at minesites in British Columbia. B.C. Ministry of Energy and Mines and B.C. Ministry of Environment, Lands and Parks. p. 17.
- Morin, K.A. and N.M. Hutt. 2000. Relocation and submergence of net-acid-generating waste rock for control of acidic drainage: A case study. In: Proceedings from the Fifth International Conference on Acid Rock Drainage, May 20-26, Denver, USA, Volume II, p. 819-825. Society for Mining, Metallurgy, and Exploration, Inc., Littleton, CO, USA.
- Morin, K.A. and N.M. Hutt. 1999. Humidity Cells: How Long? How Many? In: Proceedings of Sudbury ‘99, Mining and the Environment II, Volume 1, p.109-117, Sudbury, Canada, September 13-15.
- Morin, K.A. and N.M. Hutt. 1997a. Environmental Geochemistry of Minesite Drainage: Practical Theory and Case Studies. MDAG Publishing, Vancouver, Canada. ISBN 0-9682039-0-6.
- Morin, K.A. and N.M. Hutt. 1997b. History of Eskay Creek Mine’s Waste-Rock Dump from Placement to Disassembly. MEND Report 1.44.1.
- Price, W.A. 2005. ML/ARD Assessment and Mitigation at the Snip Mine. MEND Project (in press).
- Price, W.A. 2004a. Information and Design Requirements for Dry Covers. In: Price, W.A. and K. Bellefontaine (editors). Dry Covers. 11th British Columbia MEND Metal Leaching and Acid Rock Drainage Workshop. December 1-2.
- Price, W.A. 2004b. Information and Design Requirements for Drainage Treatment. In: Tremblay, G. et al. (editors) Sludge Management and New Treatment Technologies. 2004 MEND Ontario Workshop, Sudbury, Ontario, May 26-27.
- Price, W.A. 2004c. List of Potential Information Requirements in Metal Leaching and Acid Rock Drainage Assessment and Mitigation Work. MEND Project 5.10E. 22 p.
- Price, W.A. and D. Yeager. 2004. ML/ARD Assessment and Mitigation at the Johnny Mountain Gold Mine. MEND Project. 67 p.
- Price, W.A. 2001. Use of Fresh Water Covers as a Mitigation Strategy at Mine Sites in British Columbia. In: Price W.A. (editor) Summary Notes, 8th Annual BC MEM - MEND Metal Leaching and ARD Workshop, Vancouver, British Columbia, November 28-29.
- Price, W.A. and Errington, J.C. 1998. Guidelines for metal leaching and acid rock drainage at minesites in British Columbia. B.C. Ministry of Energy and Mines. 86 p.
- Price, W.A. 1997. Draft guidelines and recommended methods for the prediction of metal leaching and acid rock drainage at minesites in British Columbia. B.C. Ministry of Employment and Investment (now Ministry of Energy and Mines). 141 p. plus appendices.

Despite their relatively small size, the costs and potential impacts make the mitigation of metal leaching and ARD at historic mine sites and exploration projects, like Sulphurets, quite challenging. In common with many historic mine sites and exploration projects, challenges at Sulphurets included limited information regarding the site and the materials, access difficulties and an adverse climate, in this case a limited snow-free period. The high access costs, lack of site personnel and small budget made it difficult to collect additional information. Access difficulties and climate constraints were also a major consideration in the review of potential mitigation measures. Mitigation constraints included a probable lack of suitable soil materials for the construction of covers and dams, a deep snow cover much of the year and the resulting large runoff, and the difficulty operating facilities and conducting monitoring and maintenance in such a harsh climate and remote site. As a result of these constraints, the conclusion of BC MEM's initial review of potential mitigation strategies was that, if the water quality impacts from the dissolution of built-up weathering products could be shown to be insignificant, the disposal of waste rock in Brucejack Lake would result in the lowest liability and environmental risk.

A large number of variables determine water quality impacts when waste rock is flooded, including:

- the interaction between different types of waste rock and between the waste rock and the lake;
- potential contaminant mixing and migration within the lake; and
- the location of neutralization and metal precipitation.

As many of these properties are difficult, if not impossible to measure, the prediction approach taken by BC MEM was to use simple measurements and assumptions. Prediction of the potential load of soluble metals was done using data from shake flask tests run on samples collected from holes dug in the waste rock pile dug with a backhoe. A crude estimation of the impact of lake disposal on water quality was made using the predicted soluble load of the waste rock and monitoring results for the water quality and the volume of water in Brucejack Creek and Brucejack Lake. The calculations indicated that flushing of weathering products when waste rock was placed in the lake would result in minimal changes to water quality in Brucejack Lake and Brucejack Creek. Although removal of the waste rock from the pad and deposition in the lake took far less time than that used in the predictive calculations (1.5 versus 4 months), the overall prediction results turned out to be correct.

Although not significant in terms of the overall outcome, aspects of the project that were unexpected were as follows:

- According to the rinse pH data, the majority of the waste rock had a pH of 4.5 to 7 and 7 to 8, and only a small proportion of the waste rock had a pH > 8, which had been the predominant pH of the samples taken the previous year to predict potential water quality impacts.

- The largest changes in water quality observed during and following waste rock disposal were in Lower Brucejack Creek. Although modest, the increased concentrations in Lower Brucejack Creek compared to Brucejack Lake and Upper Brucejack Creek indicate that the main short-term impact of the mitigation work was leaching of the disturbed pad area rather than waste rock placement in Brucejack Lake.

- After the waste rock was removed, Brucejack Creek flooded a portion of the former pad-site.

The discrepancy between the rinse pH and the shake flask pH results appeared to result from accelerated weathering at the base of the pad and illustrated the danger in assuming near-surface samples were representative samples of the composition of weathered waste rock dumps. Typically, characterization of old waste rock piles is done by sampling trenches excavated across the surface. The rationale for this sampling procedure is that the surface of end-dumped waste rock piles contains a cross-section of all the material placed on the pile and that drilling will break apart particles potentially masking weathering conditions. The situation at Sulphurets, with low alkalinity, slightly acidic groundwater potentially leaching the base of parts of the pile, illustrate that there may be a need to sample material at the base of a dump. Another potential cause for accelerated weathering at depth is if, as is often the case in acidic dumps, this is the hottest area of the dump.

The experience at Sulphurets also illustrates the need to consider hydrogeology when selecting a disposal site and the importance of characterizing soil hydrology prior to waste rock disposal. Even an exploration project requires due care and attention in selecting a disposal site for sulphidic waste rock. Factors that may need to be considered include groundwater inputs, upslope drainage diversion, down slope drainage collection and ease of removal. A soil and vegetation survey should be conducted to collect the required information on the height of water table throughout the year.

Lastly, Sulphurets posed a number of regulatory challenges. For the proponent, this included dealing with several agencies with a similar interest in ML/ARD, but differing conclusions regarding the risks and information required with differing mitigation options. An issue for BC MEM at the time it reviewed this project was the limited number of personnel with the training to deal with the large number of projects with ongoing ML/ARD concerns. Transportation costs and time constraints made it difficult for the ARD reviewers to inspect the site during the assessment in 1998 and when the waste rock was moved in 1999. Very helpful to the technical review was the good corporate memory and record keeping, both by Newhawk and by BC MEM. Record keeping is an important regulatory task at sites such as Sulphurets that go into care and maintenance for a number of years.

9.0 LITERATURE REVIEWED

Sulphurets Project Related

- Environment Canada, 1998. Letter from Robert McCandless to Catherine Daniel, Ministry of Energy and Mines, Smithers. (December 16).
- Environment Canada, 1999. Letter from Robert McCandless to Sylvia Van Zalingen, Ministry of Energy and Mines, Smithers. (April 27).
- Hallam Knight Piesold Ltd., 1998. Sulphurets Project Interim Clean-up Measures.
- Hallam Knight Piesold Ltd., 1999. Underwater Disposal of Waste in Brucejack Lake.
- McLeod, D.B. 1999. Reclamation Report on the Sulphurets Project. Newhawk Gold Mines Ltd.
- Mine Development Steering Committee, 1989. Mine Development Review Process, Detailed Government Review Comments.
- Ministry of Energy and Mines, Minfile #104B 022.
- Ministry of Environment, Lands and Parks, 1998. Letter from Craig Stewart to Bruce McLeod, Newhawk Gold Mines Ltd. (December 18).
- Ministry of Environment, Lands and Parks, 1999a. Letter from Craig Stewart to Bill Price. (January 8).
- Ministry of Environment, Lands and Parks, 1999b. Letter from Craig Stewart to Bruce McLeod, Newhawk Gold Mines Ltd. (April 29).
- Newhawk Gold Mines Ltd., 1987. Sulphurets Joint Venture Prospectus.
- Newhawk Gold Mines Ltd., 1989a. Stage I Environmental and Socioeconomic Impact Assessment for the Sulphurets Property.
- Newhawk Gold Mines Ltd., 1989b. Supplementary Submission to the Stage I Report Sulphurets Property.

- Newhawk Gold Mines Ltd., 1998a. Water quality results provided to BC MEM by B. McLeod, December 18, 1998.
- Newhawk Gold Mines Ltd. 1998b. Interim Clean Up Measures. North West Mine Development Review Committee. 1998. Summary notes from a technical workshop held December 18th. Mines Branch, Ministry of Energy and Mines (BC MEM), Smithers.
- Price, W.A. and D. Howe. August, 1999. Review of Metal Leaching and Acid Rock Drainage Aspects of Proposed Disposal of Waste Rock in Blackjack Lake. B.C. Ministry of Energy and Mines, Reclamation Section. 31 p.

ML/ARD Assessment and Mitigation

- BCMEM and BCMELP. 1998. Policy for metal leaching and acid rock drainage at minesites in British Columbia. B.C. Ministry of Energy and Mines and B.C. Ministry of Environment, Lands and Parks. p. 17.
- Morin, K.A. and N.M. Hutt. 2000. Relocation and submergence of net-acid-generating waste rock for control of acidic drainage: A case study. In: Proceedings from the Fifth International Conference on Acid Rock Drainage, May 20-26, Denver, USA, Volume II, p. 819-825. Society for Mining, Metallurgy, and Exploration, Inc., Littleton, CO, USA.
- Morin, K.A. and N.M. Hutt. 1999. Humidity Cells: How Long? How Many? In: Proceedings of Sudbury '99, Mining and the Environment II, Volume 1, p.109-117, Sudbury, Canada, September 13-15.
- Morin, K.A. and N.M. Hutt. 1997a. Environmental Geochemistry of Minesite Drainage: Practical Theory and Case Studies. MDAG Publishing, Vancouver, Canada. ISBN 0-9682039-0-6.
- Morin, K.A. and N.M. Hutt. 1997b. History of Eskay Creek Mine's Waste-Rock Dump from Placement to Disassembly. MEND Report 1.44.1.
- Price, W.A. 2005. ML/ARD Assessment and Mitigation at the Snip Mine. MEND Project (in press).
- Price, W.A. 2004a. Information and Design Requirements for Dry Covers. In: Price, W.A. and K. Bellefontaine (editors). Dry Covers. 11th British Columbia MEND Metal Leaching and Acid Rock Drainage Workshop. December 1-2.
- Price, W.A. 2004b. Information and Design Requirements for Drainage Treatment. In: Tremblay, G. et al. (editors) Sludge Management and New Treatment Technologies. 2004 MEND Ontario Workshop, Sudbury, Ontario, May 26-27.
- Price, W.A. 2004c. List of Potential Information Requirements in Metal Leaching and Acid Rock Drainage Assessment and Mitigation Work. MEND Project 5.10E. 22 p.
- Price, W.A. and D. Yeager. 2004. ML/ARD Assessment and Mitigation at the Johnny Mountain Gold Mine. MEND Project. 67 p.
- Price, W.A. 2001. Use of Fresh Water Covers as a Mitigation Strategy at Mine Sites in British Columbia. In: Price W.A. (editor) Summary Notes, 8th Annual BC MEM - MEND Metal Leaching and ARD Workshop, Vancouver, British Columbia, November 28-29.
- Price, W.A. and Errington, J.C. 1998. Guidelines for metal leaching and acid rock drainage at minesites in British Columbia. B.C. Ministry of Energy and Mines. 86 p.
- Price, W.A. 1997. Draft guidelines and recommended methods for the prediction of metal leaching and acid rock drainage at minesites in British Columbia. B.C. Ministry of Employment and Investment (now Ministry of Energy and Mines). 141 p. plus appendices.

TABLES, FIGURES AND PHOTOS

Table 1. ABA Results from Mine Proposal (Newhawk Gold Mines Ltd., 1989a)						
Waste Rock Samples	Paste pH	% Total S	AP	NP	NNP	NPR
Hangingwall waste andesite	8	5.12	160	34	-126	0.21
Hangingwall waste andesite	8.3	6.74	211	82	-129	0.39
Foot wall waste silicified andesite	8	4.15	130	10	-120	0.08
Foot wall waste silicified andesite	8.3	3.69	115	16	-99	0.14
East wall waste quartz stockwork	8.2	3.75	117	15	-102	0.13
West wall waste quartz-carb stockwork	8.6	2.74	86	92	6	1.08
Waste Rock Composite	7.7	4.29	134	10	-124	0.07
Rock Samples						
Andesite	8	5.64	176	29	-147	0.16
	8	6.68	209	26	-183	0.12
	7.6	1.13	35	8	-27	0.23
	7.8	0.89	28	3	-25	0.11
	7.8	5.3	166	9	-157	0.05
	8	2.26	71	6	-65	0.08
	7.4	4.17	130	9	-121	0.07
Quartz	8.3	0.37	12	8	-4	0.69
	8.6	0.75	23	7	-16	0.3
	8	0.4	13	2	-11	0.16
	8.5	1.24	39	6	-33	0.15
	8.4	2.93	92	29	-63	0.32
	8.6	0.52	16	6	-10	0.37
	8.5	0.92	29	316	287	10.99
Silicified Andesite	7.5	6.68	209	9	-200	0.04
	7.9	4.6	144	10	-134	0.07
	8.3	5.25	164	34	-130	0.21
	8	5.62	176	25	-151	0.14
	7.7	5.74	179	12	-167	0.07
	8.1	6.03	188	11	-177	0.06
	8.4	5.44	170	55	-115	0.32
Quartz Stockwork	8	3.25	102	7	-95	0.07
	8.5	3.67	115	13	-102	0.11
	8.2	0.8	25	14	-11	0.56
	7.9	4.97	155	13	-142	0.08
	8.4	3.88	121	18	-103	0.15
	8.5	2.38	74	209	135	2.81
	8.6	2.8	88	39	-49	0.45
Quartz Breccia	8.4	3.6	113	10	-103	0.09
	8.2	4.8	150	11	-139	0.07
	8.1	3.85	120	10	-110	0.08
	8.1	0.88	28	4	-24	0.15
	8.2	3.13	98	10	-88	0.1
	8.4	2.81	88	8	-80	0.09
	8.5	3.09	97	41	-56	0.42
Results for NP, AP, and NNP in tonnes $CaCO_3$/1000 tonnes of material.						

Table 2. ICAP Elemental Results for Waste Rock (Newhawk Gold Mines Ltd., 1989a)								
Elements			West Zone					Crustal Abundance
			Andesite	Quartz Vein	Silicified Andersite	Quartz Stockwork	Quartz Breccia	
Aluminum	Al	(%)	0.65	0.07	0.55	0.13	0.23	8.23
Antimony	Sb	(ppm)	15	20	15	10	25	0.2
Arsenic	As	(ppm)	225	10	90	95	85	1.8
Barium	Ba	(ppm)	110	60	70	30	90	425
Beryllium	Be	(ppm)	<0.5	<0.5	<0.5	<0.5	<0.5	3
Bismuth	Bi	(ppm)	<2	<2	<2	<2	<2	0.0085
Cadmium	Cd	(ppm)	0.5	<0.5	2.0	2.0	3.0	0.15 – 3
Calcium	Ca	(%)	1.43	0.32	0.43	0.30	0.43	4.15
Chromium	Cr	(ppm)	53	250	55	83	139	102
Cobalt	Co	(ppm)	20	<1	22	12	12	25
Copper	Cu	(ppm)		42	38	29	31	60
Gallium	Ga	(ppm)	<10	<10	<10	<10	<10	19
Iron	Fe	(%)	5.24	0.51	6.58	2.82	3.22	5.63
Lanthanum	La	(ppm)	20	<10	10	<10	10	39
Lead	Pb	(ppm)	30	42	76	78	84	14
Magnesium	Mg	(%)	0.06	<0.01	0.04	0.02	0.01	2.33
Manganese	Mn	(ppm)	232	131	127	106	89	950
Mercury	Hg	(ppm)	<1	3	<1	<1	<1	0.085
Molybdenum	Mo	(ppm)	8	1	1	1	2	1.2
Nickel	Ni	(ppm)	8	3	8	5	6	84
Phosphorus	P	(ppm)	2240	60	1580	990	1030	1050
Potassium	K	(%)	0.40	0.03	0.34	0.10	0.20	2.085
Selenium	Se	(ppm)	3	<1	3	1	1	0.05
Silver	Ag	(ppm)	20.0	24.2	19.6	14.4	45.2	0.075
Sodium	Na	(%)	0.01	<0.01	<0.01	<0.01	0.01	2.355
Strontium	Sr	(ppm)	84	18	45	41	86	370
Thallium	Tl	(ppm)	<10	<10	<10	<10	<10	0.85
Titanium	Ti	(%)	<0.01	<0.01	<0.01	<0.01	<0.01	0.565
Tungsten	W	(ppm)	10	5	10	5	5	1.25
Uranium	U	(ppm)	<10	<10	<10	<10	<10	2.7
Vanadium	V	(ppm)	19	1	21	6	9	120
Zinc	Zn	(ppm)	57	15	226	222	364	70

Table 3. ICAP Elemental Results for Brucejack Creek and Lake Sediment (Newhawk Gold Mines Ltd., 1989a)

Elements			Brucejack Creek								Brucejack Lake				Crustal Abundance
			Upper Foot Bridge		60m Below Portal		Downstream Gage		Below Camp Waterfall		30 m Depth	88 m Depth	< 10 µm Sediment Fraction		
			1	2	1	2	1	2	1	2				(Dup)	
Aluminum	Al	(%)	0.60	0.61	0.85	0.90	1.43	1.37	1.07	1.16	2.4	2.39	4.25	4.14	8.23
Antimony	Sb	(ppm)	15	15	10	10	5	5	5	5	5	<5	<20	<20	0.2
Arsenic	As	(ppm)	155	160	140	135	255	245	110	140	145	155	530	580	1.8
Barium	Ba	(ppm)	220	270	330	210	240	240	140	260	610	520	1100	1170	425
Beryllium	Be	(ppm)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5			3
Bismuth	Bi	(ppm)	<2	<2	24	<2	<2	<2	<2	<2	<2	<2			0.0085
Cadmium	Cd	(ppm)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	21 [2]	24 [2]	0.15
Calcium	Ca	(%)	0.08	0.09	0.27	0.33	0.29	0.29	0.40	0.37	0.57	0.54	0.961	1.01	4.15
Chromium	Cr	(ppm)	<1	4	4	2	4	2	3	3	5	5	46	50	102
Cobalt	Co	(ppm)	8	8	12	12	19	17	18	20	20	19	3	4	25
Copper	Cu	(ppm)	21	20	35	46	78	71	52	53	42	37	119 [1]	126 [1]	60
Gallium	Ga	(ppm)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10			19
Iron	Fe	(%)	4.01	4.46	4.18	4.51	5.51	5.63	3.97	4.91	4.15	4.25	8.00 [1]	8.40 [1]	5.63
Lanthanum	La	(ppm)	10	10	10	10	20	20	10	10	20	20			39
Lead	Pb	(ppm)	182	108	60	100	86	98	36	74	22	22	8 [1]	11 [1]	14
Magnesium	Mg	(%)	0.20	0.18	0.33	0.34	0.48	0.48	0.47	0.43	0.94	0.88	1.96	1.9	2.33
Manganese	Mn	(ppm)	798	948	1430	958	1165	1030	1670	1820	2190	2200	5260	5470	950
Mercury	Hg	(ppm)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1			0.085
Molybdenum	Mo	(ppm)	4	3	1	1	<1	1	<1	<1	<1	<1	<10	<10	1.2
Nickel	Ni	(ppm)	1	<1	1	2	4	1	7	4	2	2	6	6	84
Phosphorus	P	(ppm)	960	1150	1020	1190	1370	1500	1200	1430	1020	1180			1050
Potassium	K	(%)	0.13	0.14	0.13	0.12	0.14	0.12	0.10	0.12	0.39	0.34			2.085
Selenium	Se	(ppm)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10			0.05
Silver	Ag	(ppm)	20.2	11.2	12.2	33.6	6.6	7.4	4.4	12.0	1.0	1.0	1.71 [1]	1.74 [1]	0.075
Sodium	Na	(%)	<0.01	<0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.02	0.02			2.355
Strontium	Sr	(ppm)	11	12	23	28	21	21	17	23	47	43			370
Thallium	Tl	(ppm)	10	<10	10	<10	10	<10	<10	10	10	10			0.85
Titanium	Ti	(%)	<0.01	<0.01	<0.01	0.01	0.02	0.02	<0.01	0.01	0.07	0.08			5650
Tungsten	W	(ppm)	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5			1.25
Uranium	U	(ppm)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10			2.7
Vanadium	V	(ppm)	13	15	18	23	32	32	27	30	70	66			120
Zinc	Zn	(ppm)	107	96	120	215	286	267	127	154	112	103	219 [1]	226 [1]	70

Note: .
< = Less than detection limit
Dup = Duplicate digestion
[1] Determined by specific atomic absorption techniques
[2] Spectral interfaces suspected

Table 4. Acetic and Sulphuric Acid Leach Test Results for Waste Rock (Newhawk Gold Mines Ltd., 1989a)

Elements (mg/L)		WEST ZONE WASTE ROCK								Special Waste Leachate Quality Criteria
		WITH ACETIC ACID				WITH SULPHURIC ACID				
		East Wall	West Wall	Hanging Wall	Foot Wall	East Wall	West Wall	Hanging Wall	Foot Wall	
Aluminum	Al	<100	<100	100	100	<100	<100	<100	<100	
Antimony	Sb	<0.004	<0.004	<0.004	<0.004					
Arsenic (diss.)	As	0.0046	0.0011	0.0010	0.0013	0.0660	0.0220	0.0200	0.0360	5.0
Barium	Ba	10	20	<10	10	<10	<10	<10	<10	100.0
Beryllium	Be	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Bismuth	Bi	<2	<2	<2	<2	<2	<2	<2	<2	
Boron	B					0.40	<0.40	<0.40	<0.40	500.00
Cadmium	Cd	<0.05	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
Calcium	Ca	4100	24100	900	11200	3100	2.20	0.08	0.50	
Chromium	Cr	<1	2	7	4	<1	<1	<1	<1	5.0
Cobalt	Co	<1	<1	<1	<1	<1	<1	<1	<1	
Copper	Cu	<1	<1	<1	<1	<1	<1	<1	<1	
Iron	Fe	<100	100	400	100	<100	<100	<100	<100	
Lead	Pb	36	48	10	4	2	4	<2	<2	5.0
Lithium	Li									
Magnesium	Mg	<100	<100	100	100	<100	<100	100	<100	
Manganese	Mn	139	810	34	474	107	804	21	221	
Mercury	Hg	0.0014	0.00	0.0005	0.0006	0.0040	0.0020	0.0040	0.0040	0.1
Molybdenum	Mo	<1	<1	<1	<1	<1	<1	<1	<1	
Nickel	Ni	<1	1.00	1	<1	<1	1	<1	<1	
Phosphorus	P	<10	<10	<10	<10	<10	<10	<10	<10	
Potassium	K	200.00	200.00	300	300	400	400	300	300	
Selenium	Se					<0.08	<0.08	<0.08	<0.08	1.0
Silicon	Si									
Silver	Ag	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Sodium	Na	<100	<100	<100	<100	<100	<100	<100	<100	
Strontium	Sr	24	136.00	9	23	19	116	6	16	
Thorium	Th									
Titanium	Ti	<100	<100	<100	<100	<100	<100	<100	<100	
Tungsten	W	<10	<10	<10	<10	<10	<10	<10	<10	
Uranium	U									2.0
Vanadium	V	<1	<1	<1	<1	<1	<1	<1	<1	
Zinc	Zn	8	28	2	1	3	9	<1	<1	
Zirconium	Zr									

Table 5. Pre-Test ABA Results for Humidity Cell Samples (Newhawk Gold Mines Ltd., 1989b)							
Waste Rock	Total Sulphur %	Sulphide Sulphur %	Sulphate Sulphur % **	Paste pH	AP *	NP *	NPR **
Andesite	3.56	3.4	0.16	7.3	106	16	0.15
Sil. Andesite	5.19	5.58	?	8.2	174	39	0.23
Quartz Vein	0.91	0.8	0.11	8.7	25	62	2.48
Quartz Stockwork	3.3	3.22	0.08	8.5	101	54	0.54
Quartz Breccia	3.12	2.74	0.46	8.6	86	25	0.3
Composite	3.9	3.83	0.07	8.4	120	56	0.47

* kg $CaCO_3$/tonnes
** calculated by MEM using sulphide-S

Table 6. Humidity Cell Results for pH and Sulphate (Newhawk Gold Mines Ltd., 1989b)						
Weekly pH values						
Days	Andesite	Silicified Andesite	Quartz Vein	Quartz Stockwork	Quartz Breccia	Composite
7	7.12	7.19	7.68	7.64	7.39	7.81
14	7.47	7.68	7.89	7.73	7.51	7.66
21	7.17	7.47	7.68	7.68	7.13	7.57
28	7.26	7.54	8.02	7.81	7.37	7.67
35	7.46	7.68	8.18	7.92	7.51	7.81
42	7.26	7.49	7.93	7.63	7.42	7.55
49	7.85	5.27	7.38	7.07	6.59	7.1
56	6.95	7.18	7.62	7.37	7.08	7.24
63	6.84	7.46	7.91	7.56	7.28	7.43
70	6.37	7.13	7.79	7.25	6.98	7.28
Weekly Sulphate Production Rate (mg/100g/wk)						
Days	Andesite	Silicified Andesite	Quartz Vein	Quartz Stockwork	Quartz Breccia	Composite
7	13.2	10.5	6.2	10.3	12.1	10.6
14	7.8	7.8	3.5	5.9	6.5	6.1
21	4.9	6.2	0.9	7.1	5.5	5.9
28	6.7	5.1	1.3	4.3	5.5	5.5
35	6.8	3.9	0.8	3.6	4.7	6.1
42	5.4	4.7	1	3.8	3.5	4
49	3.1	3.7	2.3	2.2	2.3	1.8
56	2.4	2.9	0.7	1.7	1.9	2.5
63	3.2	3.5	0.6	2.2	1.6	2.1
70	0.2	3	0.6	1.7	2	2.6

Table 7. Projected Time to Deplete NP in Humidity Cell Samples (Newhawk Gold Mines Ltd., 1989b)				
Rock Type	Average Sulphate Production Rate (kg/tonne/week)	Neutralization Potential (kg/tonne)	Weeks to Exhaust the Neutralization Potential	Years to Exhaust the Neutralization Potential
Andesite	0.045	16	355	7
Silicified Andesite	0.0453	39	870	17
Quartz Vein	0.0137	62	4,525	87
Quartz Stockwork	0.0368	54	1,465	28
Quartz Breccia	0.0372	25	685	13
Composite	0.0407	56	1,390	27

Table 8. Projected Time to Deplete NP of 5, 10 and 20 kg/t based on 10 Week Humidity Cell Results (Newhawk Gold Mines Ltd., 1989b)			
Sulphate Production	NP = 5	NP = 10	NP = 20
Rate = 0.0453 (Sil. Andesite)	110 weeks	220 weeks	442 weeks
Rate = 0.0137 (Quartz Vein)	365 weeks	730 weeks	1460 weeks (28yrs)
Rate = 0.0407 (Composite)	122 weeks	245 weeks	491 weeks (9.5yrs)

NP reported as kg $CaCO_3$/tones.

Table 9. Site Water Quality Monitoring Results

Date	pH	pH	Cond	TDS	TSS	Hard	Alk.	Cl	SO_4	T-Ag	T-As	T-Ca	T-Cd	T-Cu	T-Fe	T-Hg
	(Field)	(lab)	(uS/cm)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ug/L)	(ug/L)	(mg/L)	(ug/L)	(ug/L)	(mg/L)	(ug/L)
EAST STAND PIPE																
98-Jul-09	-	3.4	430	301	1	146	<1.0	<0.5	155	0.2	1.3	55.5	2.6	45	1.5	<0.01
96-Sep-06	-	3.7	643	443	1	251	<1.0	<0.5	299	0.1	1.5	99.2	3.8	50	5.1	<0.01
95-Aug-25	-	3.4	899	375	21	345	<1.0	<0.5	397	0.5	16.4	129	4.1	228	11.6	<0.01
94-Sep-27	3.7	4.0	596	453	<1	282	<1.0	<0.5	283	0.1	0.6	107	2.3	31	0.7	<0.01
94-Aug-31	3.9	3.8	679	544	2	320	<1.0	1	323	0.1	0.5	123	3.7	25	3.0	<0.01
94-Aug-15	4.4	4.1	527	408	7	242	<1.0	<0.5	243	<0.1	1.4	92.0	3.0	16	1.6	0.020
94-Jul-27	-	4.2	316	218	6	137	<1.0	<0.5	136	<0.1	1.2	52.3	1.0	10	0.4	<0.01
94-Jun-29	-	4.1	363	258	6	155	<1.0	<0.5	153	<0.1	0.4	59.8	1.0	15	0.5	<0.01
93-Sep-01	5.7	5.7	563	419	73	288	7	1	288	0.3	6.5	111	1.8	17	2.4	<0.01
93-Aug-16	-	5.5	481	398	3	233	7	<0.5	234	<0.1	0.6	88.4	1.6	8	0.9	<0.01
93-Jul-06	-	5.6	239	172	3	88	7	<0.5	102	<0.1	1.2	33.2	0.4	13	0.4	0.010
93-May-28	4.7	3.8	344	275	51	125	<0.1	1	145	1.2	71.7	47.7	2.0	41	10.4	0.010
92-Sep-21	-	5.8	680	591	17	573	16	<0.3	418	2.5	96.0	218	8.0	240	17.8	<5
92-Sep-08	-	6.6	364	313	5	218	22	0	195	<0.1	<3	82.6	<1	5	1.2	<5
92-Aug-19	-	5.9	365	245	<0.1	169	15	1	179	1.5	2.0	64.4	<1	<1	0.1	<10
92-Aug-05	-	6.1	232	193	16	134	16	<0.3	81	1.3	22.0	50.9	1.0	4	3.2	<0.05
92-Jul-23	-	6.2	262	219	798	136	21	<0.3	81	9.7	305	47.5	3.0	70	36.0	<0.05
91-Sep-15	-	8.0	420	336	3	173	79	<0.5	126	0.1	3.1	-	-	<1	0.1	-
91-Jul-26	-	5.1	305	244	150	146	4	<0.5	98	6.8	780	-	-	26	45.5	-
89-Nov-08	-	6.7	542	490	91	153	48	4	185	<0.1	1.9	-	-	2	0.1	-
89-Aug-08	-	7.2	463	400	402	216	74	3	140	2.2	48.0	-	-	26	7.8	0.120
89-Jun-25	-	6.9	437	214	133	180	86	3	159	<0.1	9.4	-	-	5	0.9	-
Minimum	3.7	3.4	232	172	<0.1	88	<0.1	<0.3	81	<0.1	0.4	33.2	0.4	<1	0.1	<0.05
Median	4.4	5.6	434	325	7	177	7	0	169	0.1	2.0	82.6	2.0	17	1.6	<0.01
Maximum	5.7	8.0	899	591	798	573	86	4	418	9.7	780	218	8.0	240	45.5	<10
WEST STAND PIPE																
98-Jul-09	-	3.6	812	568	53	286	<1.0	<0.5	382	3.0	160	102	3.4	92	22.3	0.010
96-Sep-06	-	2.9	1690	929	2	442	<1.0	1	441	9.1	584	164	7.8	548	145.0	<0.01
95-Aug-25	-	3.1	1100	651	165	282	<1.0	<0.5	413	2.9	235	101	5.5	349	96.7	<0.01
94-Sep-27	2.5	2.8	1210	813	16	313	<1.0	1	486	5.2	132	117	9.3	375	95.6	<0.01
94-Aug-31	2.8	2.7	1360	956	4	302	<1.0	2	527	4.8	418	110	17.0	504	148.0	<0.01
94-Aug-15	2.7	3.0	1360	970	16	359	<1.0	1	360	8.0	2440	122	39.0	842	270.0	<0.01
94-Jul-27	-	2.6	1990	1250	55	384	<1.0	1	637	13.0	1850	139	24.0	850	251.0	0.010
94-Jun-29	-	3.0	899	619	24	232	<1.0	1	361	4.8	50	87.2	5.9	240	61.7	<0.01
93-Sep-01	3.0	2.8	1430	926	55	295	<1.0	1	484	4.9	875	106	19.3	717	172.0	<0.01
93-Aug-16	-	3.1	890	608	13	237	<1.0	<0.5	348	2.0	239	88.6	9.6	205	63.4	0.020
93-Jul-06	-	2.8	1650	1440	19	278	<1.0	16	747	16.0	1780	99.8	17.0	787	226.0	0.040
92-Sep-21	-	2.4	2050	1618	157	642	<0.05	<0.3	1009	21.8	1420	228	95.0	2200	260.0	<5
92-Sep-08	-	2.7	756	610	51	35	<0.05	0	308	<0.1	<3	12.7	2.0	45	40.9	<5
92-Aug-19	-	2.6	980	636	39	228	-	1	387	0.6	59	84.9	7.0	167	26.1	<10
92-Aug-05	-	3.0	648	372	522	269	<0.05	<0.3	280	94.9	717	93.8	14.0	194	80.9	<0.05
91-Jul-26	-	2.9	950	760	92	196	<1.0	<0.5	337	4.3	38	-	-	252	20.9	-
89-Nov-08	-	6.5	952	460	25	166	17	2	334	<0.1	0.5	-	-	5	0.1	-
89-Aug-23	-	5.7	487	460	206	202	4	5	157	<0.1	5.4	-	-	19	1.4	<0.05
89-Aug-03	-	7.2	274	250	8	83	50	2	81	<0.1	0.7	-	-	10	0.2	-
89-Jun-25	-	6.7	227	111	18	77	27	2	63	<0.1	0.8	-	-	14	0.3	-
89-May-30	-	6.6	586	270	21	198	48	2	187	<0.1	0.9	-	-	7	0.1	-
89-May-09	-	6.8	563	260	17	11	44	11	173	<0.1	0.8	-	-	29	0.1	-
Minimum	2.5	2.4	227	111	2	11	<0.05	<0.3	63	<0.1	0.5	12.7	2.0	<1	0.1	<0.01
Median	2.8	3.0	951	628	25	253	1	1	361	3.7	146	102	9.6	223	62.6	0.010
Maximum	3.0	7.2	2050	1618	522	642	50	16	1009	94.9	2440	228	95.0	2200	270.0	<10

Where applicable the data reported as < detection limit were used in the statistics.

Table 9. Site Water Quality Monitoring Results (Continued)															
Date	T-Mg	T-Mo	T-Pb	T-Zn	D-Ag	D-As	D-Ca	D-Cd	D-Cu	D-Fe	D-Hg	D-Mg	D-Mo	D-Pb	D-Zn
	(mg/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(mg/L)	(ug/L)	(ug/L)	(mg/L)	(ug/L)	(mg/L)	(ug/L)	(ug/L)	(ug/L)
EAST STAND PIPE (continued)															
98-Jul-09	1.75	1	24	305	0.2	0.4	55.7	2.6	53	1.40	-	1.75	<1	24	308
96-Sep-06	3.22	<1	21	519	0.2	0.9	95.2	3.8	47	4.74	-	3.12	<1	20	506
95-Aug-25	4.60	<1	60	784	<0.1	3.1	131.0	4.9	249	10.70	-	4.66	<1	60	887
94-Sep-27	3.82	<1	32	292	<0.1	0.4	106.0	2.3	31	0.69	-	3.82	<1	31	292
94-Aug-31	4.09	<1	32	270	<0.1	0.4	121.0	3.6	24	2.96	-	4.06	<1	31	270
94-Aug-15	3.12	<1	22	222	<0.1	0.8	91.6	<0.2	2	1.54	-	3.12	<1	22	215
94-Jul-27	1.48	<1	25	113	<0.1	1.0	52.2	0.8	6	0.35	<0.01	1.48	<1	18	113
94-Jun-29	1.87	1	32	146	<0.1	0.3	59.2	1.0	12	0.44	-	1.86	<1	<1	141
93-Sep-01	3.93	<1	6	213	0.3	4.6	109.0	1.8	9	2.10	-	3.86	<1	4	213
93-Aug-16	3.05	<1	6	109	<0.1	0.2	88.4	1.5	7	0.84	-	3.05	<1	5	109
93-Jul-06	1.23	<1	6	44	<0.1	<0.1	33.1	0.4	5	0.19	-	1.23	<1	3	42
93-May-28	1.59	<1	150	166	<0.1	2.1	47.7	1.9	33	0.68	-	1.56	<1	105	140
92-Sep-21	7.05	28	<1	583	0.7	31.0	215.0	3.0	50	5.43	<5	7.03	93	3	353
92-Sep-08	3.02	3	19	65	<0.1	<3	18.0	<1	2	0.94	<5	0.83	1	13	67
92-Aug-19	1.98	<1	<5	56	0.5	2.0	63.2	1.0	<1	0.08	<10	2.09	<1	<5	57
92-Aug-05	1.69	<1	<5	33	<0.1	<3	43.9	<1	2	0.39	<0.05	1.17	<1	<5	19
92-Jul-23	4.12	2	119	102	0.4	7.0	47.3	<1	1	0.56	<0.05	1.42	2	<5	13
91-Sep-15	-	2	2	93	<0.1	2.0	59.6	-	<1	<0.03	-	5.72	2	<1	74
91-Jul-26	-	2	125	114	<0.1	0.1	55.0	-	5	0.03	-	2.20	<1	2	94
89-Nov-08	-	1	4	47	<0.1	1.6	56.5	-	2	<0.03	-	2.91	<1	<1	42
89-Aug-08	-	4	360	180	<0.1	0.8	81.7	-	3	<0.03	<0.05	2.80	3	4	65
89-Jun-25	-	3	3	40	<0.1	1.5	67.4	-	2	<0.03	-	2.74	3	2	29
Minimum	1.23	<1	<1	33	<0.1	<0.1	18.0	<0.1	<1	<0.03	<0.01	0.83	<1	<1	13
Median	3.05	<1	22	130	<0.1	1.3	61.4	1.5	6	0.62	<0.05	2.77	<1	4	111
Maximum	7.05	28	360	784	0.7	31.0	215.0	4.9	249	10.70	<10	7.03	93	105	887
WEST STAND PIPE (continued)															
98-Jul-09	3.06	3	26	633	0.6	12.0	108	3.5	115	10.8	-	3.91	2	13	627
96-Sep-06	8.07	2	47	1170	2.4	544	164	7.2	594	144	-	8.07	2	41	1360
95-Aug-25	5.67	<1	60	763	0.8	103	104	5.5	307	82.1	-	5.60	<1	42	762
94-Sep-27	5.17	<1	55	1150	5.2	123	117	9.0	375	94.9	-	5.17	<1	55	1150
94-Aug-31	6.66	<1	133	1450	4.8	418	110	17.0	504	148	-	6.66	<1	133	1450
94-Aug-15	14.10	5	155	2420	2.7	2390	121	28.0	840	267	-	14.10	5	155	2380
94-Jul-27	10.30	6	119	2060	3.6	1790	137	23.0	846	245	-	10.30	5	110	2030
94-Jun-29	4.11	<1	80	977	2.4	48.6	86.3	5.9	237	60.7	-	4.07	<1	70	968
93-Sep-01	7.24	1	100	2190	2.5	875	106	17.5	717	170	-	7.24	<1	100	2170
93-Aug-16	4.93	<1	120	927	0.6	235	86.9	9.6	204	61.9	-	4.84	<1	110	906
93-Jul-06	6.98	2	247	1860	15.0	1620	99.8	8.0	787	226	-	6.98	2	247	1860
92-Sep-21	14.70	50	432	5450	5.8	1180	198	92.0	1990	186	<5	14.60	50	370	4470
92-Sep-08	0.82	<1	72	747	<0.1	<3	6.0	<1	40	14.3	<5	0.30	<1	57	631
92-Aug-19	4.00	<1	360	562	0.4	73.0	76.8	7.0	154	26.1	<10	3.56	<1	335	545
92-Aug-05	8.51	12	939	829	2.1	25.0	93.8	5.0	65	15.3	<0.05	4.46	<1	250	445
91-Jul-26	-	1	566	1000	0.2	3.6	69.1	-	252	20.9	-	5.64	<1	566	1000
89-Nov-08	-	<1	20	210	<0.1	0.4	60.2	-	4	<0.03	-	3.62	<1	7	94
89-Aug-23	-	<1	120	190	<0.1	0.8	74.1	-	10	<0.03	<0.05	4.04	<1	13	17
89-Aug-03	-	<1	8	55	0.1	0.5	34.0	-	8	<0.03	-	1.81	<1	2	52
89-Jun-25	-	1	13	100	<0.1	0.5	28.4	-	11	<0.03	-	1.37	<1	7	100
89-May-30	-	2	33	120	<0.1	0.4	-	-	5	<0.03	-	-	2	<1	110
89-May-09	-	2	23	160	<0.1	<0.1	-	-	1	<0.03	-	-	<1	<1	<5
Minimum	0.82	<1	8	55	<0.1	<0.1	6.0	<1	<1	<0.03	<0.05	0.30	<1	<1	<5
Median	6.66	1	90	878	0.7	60.8	96.8	8.0	221	43.4	<5	5.01	<1	64	834
Maximum	14.70	50	939	5450	15.0	2390	198	92.0	1990	267	<10	14.60	50	566	4470
Where applicable the data reported as < detection limit were used in the statistics.															

Table 9. Site Water Quality Monitoring Results (Continued)																
Date	pH (Field)	pH (lab)	Cond (uS/cm)	TDS (mg/L)	TSS (mg/L)	Hard (mg/L)	Alk. (mg/L)	Cl (mg/L)	SO_4 (mg/L)	T-Ag (ug/L)	T-As (ug/L)	T-Ca (mg/L)	T-Cd (ug/L)	T-Cu (ug/L)	T-Fe (mg/L)	T-Hg (ug/L)
WEST / R8 PORTAL																
01-Sep-08	-	7.9	352	212	<3	136	64	1	109	<0.1	7.0	45.4	0.3	2	0.2	<0.2
01-Sep-08 Dup	-	8.0	354	220	<3	134	66	1	108	<0.1	7.0	45.7	0.3	3	0.2	<0.2
00-Sep-20	7.4	7.6	375	231	<3	136	71	1	113	<0.1	12.1	48.7	0.3	2	0.4	<0.01
00-Aug-12	6.8	7.8	369	214	<3	115	70	<0.5	111	0.1	9.0	37.1	0.2	2	0.2	<0.01
00-Aug-12 Dup	6.8	7.9	370	185	<3	104	67	<0.5	109	<0.1	9.4	40.0	0.3	2	0.2	<0.01
99-Sep-14	6.9	7.6	385	239	<3	141	73	1	117	<0.1	7.6	49.4	0.3	2	0.2	<0.01
99-Sep-02	6.9	7.4	380	239	7	143	73	1	116	<0.1	9.1	52.5	0.3	2	0.3	<0.01
99-Aug-04	7.7	7.4	353	247	<3	147	70	1	117	<0.1	8.6	51.3	0.3	2	0.2	<0.01
99-Jul-12	7.1	7.6	394	276	<3	152	69	<0.5	120	<0.1	11.4	53.2	0.3	2	0.3	<0.01
98-Jul-09	-	7.5	394	276	<1	158	63	<0.5	124	<0.1	5.9	52.8	0.4	3	0.3	<0.01
97-Jul-08	-	7.4	375	227	2	126	75	<0.5	96	<0.1	12.6	43.2	0.4	4	1.0	<0.01
96-Sep-06	-	7.8	405	222	<1	142	80	1	113	0.1	4.4	50.5	0.2	1	0.2	<0.01
95-Aug-25	-	7.6	405	265	<1	154	82	<0.5	123	<0.1	7.1	52.9	<0.2	1	0.1	<0.01
94-Sep-27	8.0	7.4	402	256	9	155	81	<0.5	116	<0.1	9.6	54.6	0.4	2	0.4	<0.01
94-Aug-31	6.8	7.7	413	281	<1	161	82	<0.5	123	<0.1	8.8	55.8	0.3	2	0.2	<0.01
94-Aug-15	7.6	7.4	412	276	<1	161	81	1	120	<0.1	8.5	55.9	0.4	2	0.2	<0.01
94-Jul-27	-	7.3	410	271	1	134	80	<0.5	127	<0.1	7.3	45.1	0.5	2	0.2	<0.01
94-Jun-29	-	7.2	411	284	4	176	76	<0.5	125	<0.1	7.6	61.7	0.4	2	0.3	<0.01
93-Sep-01	-	7.3	396	295	3	164	83	1	122	0.1	9.5	57.0	0.2	2	0.2	<0.01
93-Aug-16	-	7.4	402	300	<1	161	80	<0.5	120	<0.1	7.4	56.4	0.6	8	0.1	<0.01
93-Jul-06	-	7.2	404	320	<1	136	75	<0.5	126	<0.1	7.3	46.0	0.5	2	0.2	<0.01
93-May-28	6.9	6.8	413	330	<1	146	76	1	134	<0.1	5.1	61.2	0.5	2	0.3	<0.01
92-Sep-21	-	7.2	360	294	<1	209	103	<0.3	106	1.1	22.0	84.0	<1	23	0.0	<5
92-Aug-19	-	7.0	410	271	2	148	73	<0.5	137	<0.1	11.0	50.8	<1	3	0.1	<10
92-Jul-23	-	7.0	389	296	<1	169	75	<.3	120	0.5	5.0	58.6	<1	2	0.2	<0.05
91-Sep-15	-	7.6	424	339	1	174	79	1	126	0.1	3.1	-	-	<1	0.1	-
91-Jul-24	-	6.9	468	374	<1	221	82	<0.5	161	<0.1	1.1	-	-	<1	<0.03	-
91-Jun-26	-	7.5	510	-	-	212	79	-	172	<0.5	7.0	74.4	<10	3	0.5	-
90-Nov-21	-	7.1	544	343	3	227	59	<0.5	167	0.1	0.6	-	-	<1	0.1	-
90-Jun-26 MOE	-	7.8	468	440	149	187	89	<0.5	152	0.3	10.0	-	-	1	<0.015	-
90-Jun-06	-	7.9	659	580	256	150	116	2	207	<0.1	20.0	-	-	1	0.0	-
90-Apr-06	-	8.3	636	520	31	76	130	31	171	0.2	26.0	-	-	1	0.1	-
90-Mar-03	-	8.3	643	570	173	77	130	3	190	0.8	30.0	-	-	<1	<0.03	-
89-Dec-13	-	7.9	671	590	417	87	130	4	163	100.0	90.0	-	-	140	9.3	-
89-Nov-08	-	7.8	667	560	5320	107	107	16	132	1.0	38.0	-	-	3	<0.03	-
89-Oct-02	-	7.8	596	540	2240	172	125	2	137	880.0	170.0	-	-	82	31.1	-
89-Aug-23	-	7.8	633	570	196	123	116	3	147	28.0	59.0	-	-	56	1.4	-
89-Aug-02	-	7.8	519	480	402	134	116	1	150	3.6	73.0	-	-	15	3.6	-
89-Jul-03	-	8.0	518	480	806	157	110	1	155	29.0	180.0	-	-	31	17.4	-
89-May-29	-	7.8	583	270	66	156	90	2	265	3.5	36.0	-	-	6	0.7	-
89-May-04	-	7.9	646	300	1500	180	102	11	339	75.0	160.0	-	-	130	27.6	-
89-Apr-11	-	7.9	661	480	790	150	127	5	337	10.0	64.0	-	-	23	3.8	-
89-Feb-28	-	7.8	307	303	1850	149	125	3	138	30.0	240.0	-	-	450	28.2	0.200
88-Nov-30	-	7.5	806	450	3550	209	191	3	148	52.0	150.0	-	-	900	38.7	0.710
88-Oct-28	-	7.8	381	290	505	108	92	1	81	43.0	81.0	-	-	40	10.1	0.080
88-Oct-03	-	7.8	461	360	1880	149	93	1	96	6.5	96.0	-	-	1720	0.0	-
88-Aug-30	-	7.6	381	310	1380	142	102	<0.5	111	120.0	610.0	-	-	17	73.9	0.180
88-Jul-28	-	7.6	451	350	5230	157	356	<0.5	93	350.0	600.0	-	-	410	82.7	-
88-Mar-31	-	8.0	462	340	272	33	100	1	123	<0.1	53.0	-	-	20	11.0	-
87-Sep-25	-	8.2	413	399	104	140	52	<0.5	97	<0.5	20.0	-	-	<1	0.1	-
1987 - June 1990																
Minimum	NA	7.5	307	270	31	33	52	<0.5	81	<0.1	10.0	NA	NA	<1	0.0	0.080
Median	NA	7.8	583	450	505	149	116	2	148	10.0	73.0	NA	NA	23	3.8	0.190
Maximum	NA	8.3	806	590	5320	209	356	31	339	880.0	610.0	NA	NA	1720	82.7	0.710
July 1990 - 2001																
Minimum	6.8	6.8	352	212	<1	115	59	<0.3	96	<0.1	0.6	37.1	<0.2	<1	<0.03	<0.01
Median	7.0	7.4	402	276	1	154	76	<0.5	120	<0.1	7.6	52.9	0.4	2	0.2	<0.01
Maximum	8.0	7.9	544	374	9	227	103	1	172	1.1	22.0	84.0	<10	23	1.0	<10
Where applicable the data reported as < detection limit were used in the statistics.																

Table 9. Site Water Quality Monitoring Results (Continued)															
Date	T-Mg (mg/L)	T-Mo (ug/L)	T-Pb (ug/L)	T-Zn (ug/L)	D-Ag (ug/L)	D-As (ug/L)	D-Ca (mg/L)	D-Cd (ug/L)	D-Cu (ug/L)	D-Fe (mg/L)	D-Hg (ug/L)	D-Mg (mg/L)	D-Mo (ug/L)	D-Pb (ug/L)	D-Zn (ug/L)
WEST / R8 PORTAL (continued)															
01-Sep-08	4.10	1	9	<50	<0.1	2.0	47.5	<0.2	<1	<0.03	<0.2	4.40	1	<1	<50
01-Sep-08 Dup	4.20	1	9	<50	<0.1	2.0	46.7	<0.2	<1	<0.03	<0.2	4.30	1	<1	<50
00-Sep-20	4.64	1	8	50	<0.1	2.7	47.2	0.3	<1	<0.03	-	4.54	1	<1	71
00-Aug-12	3.71	<1	6	40	<0.1	2.4	39.5	<0.2	<1	<0.03	-	3.89	<1	<1	40
00-Aug-12 Dup	3.94	<1	7	42	<0.1	2.6	35.9	0.3	<1	<0.03	-	3.59	<1	<1	55
99-Sep-14	4.61	1	7	45	<0.1	2.4	48.8	<0.2	1	0.06	-	4.54	1	7	38
99-Sep-02	4.95	1	8	46	<0.1	2.2	49.6	<0.2	<1	<0.03	-	4.68	1	<1	42
99-Aug-04	5.05	1	5	41	<0.1	2.6	50.5	<0.2	<1	<0.03	-	4.97	1	<1	39
99-Jul-12	5.17	<1	4	46	<1	3.7	52.4	<0.2	<1	0.04	-	5.11	1	<1	<0.1
98-Jul-09	5.08	1	4	16	<0.1	1.6	54.7	<0.2	1	<0.03	-	5.23	1	<1	45
97-Jul-08	4.15	1	10	50	<0.1	2.7	43.6	0.2	12	<0.03	-	4.12	1	<1	40
96-Sep-06	4.90	1	6	35	<0.1	2.5	49.1	<0.2	1	0.03	-	4.80	<1	<1	31
95-Aug-25	5.22	<1	2	28	<0.1	7.1	52.9	<0.2	1	0.12	-	5.22	<1	2	28
94-Sep-27	5.21	1	7	49	<0.1	1.6	53.5	<0.2	<1	<0.03	-	5.17	<1	<1	40
94-Aug-31	5.21	2	6	33	<0.1	2.6	55.8	<0.2	<1	<0.03	-	5.20	<1	<1	25
94-Aug-15	5.46	2	8	41	<0.1	2.6	55.6	<0.2	<1	<0.03	-	5.44	2	<1	35
94-Jul-27	5.07	1	6	43	<0.1	2.3	45.1	<0.2	<1	<0.03	-	5.07	<1	<1	43
94-Jun-29	5.77	1	5	49	<0.1	2.5	61.0	0.2	<1	<0.03	-	5.68	1	<1	42
93-Sep-01	5.40	3	2	31	0.1	3.0	56.9	<2	<1	<0.03	-	5.39	2	<1	28
93-Aug-16	5.55	6	4	36	<0.1	3.4	55.4	0.2	1	<0.03	-	5.44	2	<1	30
93-Jul-06	5.42	<1	9	56	<0.1	2.3	45.7	0.4	<1	<0.03	-	5.38	<1	<1	50
93-May-28	6.03	2	6	52	<0.1	1.5	48.9	0.5	2	<0.03	-	5.76	1	<1	48
92-Sep-21	6.60	13	3	113	1.5	15.0	92.3	<1	18	0.01	<5	6.58	22	3	105
92-Aug-19	5.08	1	8	46	<0.1	8.0	50.9	<1	3	0.05	<10	5.02	<1	8	46
92-Jul-23	5.47	1	<5	54	0.4	4.0	58.6	<1	2	0.05	<0.05	5.47	1	<5	46
91-Sep-15	-	2	2	78	<0.1	1.9	59.8	-	<1	<0.03	-	5.72	2	<1	58
91-Jul-24	-	2	<1	72	<0.1	1.0	76.0	-	<1	<0.03	-	7.39	2	<1	63
91-Jun-26	6.53	<0.5	12	-	<0.5	1.0	74.3	<10	1	0.02	-	6.53	<0.5	<1	180
90-Nov-21	-	2	<1	255	<0.1	0.5	79.1	-	<1	<0.03	-	6.99	<0.05	<1	242
90-Jun-26 MOE	-	4	<1	63	0.2	8.6	64.6	-	<1	<0.015	-	6.12	3	<1	63
90-Jun-06	-	<1	2	13	<0.1	18.0	49.0	-	1	<0.015	-	4.85	<1	<1	<5
90-Apr-06	-	2	<1	6	<0.1	26.0	24.8	-	1	<0.03	-	3.39	2	<1	5
90-Mar-03	-	6	<1	<5	<0.1	27.0	25.5	-	<1	<0.03	-	3.21	3	<1	<5
89-Dec-13	-	16	420	560	0.9	24.0	29.5	-	5	<0.03	-	3.16	3	12	16
89-Nov-08	-	5	20	14	<0.1	25.0	36.1	-	<1	<0.03	-	3.97	4	1	<5
89-Oct-02	-	20	400	<5	270.0	9.4	58.8	-	3	<0.03	-	6.07	7	4	<5
89-Aug-23	-	1	250	220	0.1	43.0	42.1	-	17	<0.03	<0.05	4.17	5	5	<5
89-Aug-02	-	20	40	510	<0.1	3.0	46.0	-	6	<0.03	<0.05	4.51	20	<1	11
89-Jul-03	-	17	280	240	<0.1	53.0	54.1	-	<1	<0.03	-	5.20	17	<1	<5
89-May-29	-	12	19	90	<0.1	28.0	-	-	<1	<0.03	-	-	10	2	64
89-May-04	-	86	260	410	<0.1	13.0	-	-	2	<0.03	-	-	15	1	69
89-Apr-11	-	1	270	130	<0.1	42.0	-	-	3	<0.015	-	-	6	2	6
89-Feb-28	-	15	1490	1680	<0.1	33.0	-	-	3	<0.03	<0.05	-	12	7	<5
88-Nov-30	-	32	500	730	<0.1	3.3	-	-	<1	<0.03	<0.05	-	6	1	<5
88-Oct-28	-	9	230	340	<1	48.0	-	-	<1	<0.03	<0.05	-	9	2	12
88-Oct-03	-	6	<1	87	<1	95.0	-	-	<30	<0.001	-	-	3	<1	<5
88-Aug-30	-	36	1000	1390	0.2	8.3	-	-	2	<0.03	<0.05	-	13	96	20
88-Jul-28	-	93	1490	2310	<0.1	14.0	-	-	1	<0.03	-	-	8	<0.5	5
88-Mar-31	-	20	22	94	<0.1	11.0	-	-	6	0.03	-	-	<1	5	<5
87-Sep-25	-	<5	-	40	<0.5	10.0	-	-	<1	0.05	-	-	<5	<1	20
1987 - June 1990															
Minimum	NA	<1	<1	<5	<0.1	3.0	24.8	NA	<1	<0.001	<0.05	3.16	<1	<0.5	<5
Median	NA	12	240	130	<0.1	24.0	44.1	NA	1	<0.03	<0.05	4.34	6	1	5
Maximum	NA	93	1490	2310	270.0	95.0	64.6	NA	17	0.05	<0.05	6.12	20	96	69
July 1990 - 2001															
Minimum	3.71	<0.5	<1	16	<0.1	0.5	39.5	<0.2	<1	0.01	<0.05	3.89	<0.05	<1	<0.1
Median	5.19	1	6	46	<0.1	2.5	52.9	<0.2	<1	<0.03	1.300	5.22	1	<1	42
Maximum	6.60	13	12	255	1.5	15.0	92.3	<10	18	0.12	<10	7.39	22	8	242
Where applicable the data reported as < detection limit were used in the statistics.															

Table 9. Site Water Quality Monitoring Results (Continued)

Date	pH	pH	Cond	TDS	TSS	Hard	Alk.	Cl	SO_4	T-Ag	T-As	T-Ca	T-Cd	T-Cu	T-Fe	T-Hg
	(Field)	(lab)	(uS/cm)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ug/L)	(ug/L)	(mg/L)	(ug/L)	(ug/L)	(mg/L)	(ug/L)
CAMP CREEK INFLOW																
01-Sep-08	-	6.2	146	88	<3	57	1	1	59	<0.1	<0.1	21.0	0.5	8	0.27	<0.2
00-Sep-20	6.0	5.9	144	105	<3	55	1	1	60	<0.1	<0.1	20.3	0.4	4	0.07	<0.01
00-Aug-12	6.2	6.8	81	48	3	18	2	<0.5	30	<0.1	0.1	3.7	0.2	2	0.06	<0.01
99-Sep-14	5.6	5.8	177	106	<3	69	2	2	73	<0.1	<0.1	25.9	0.6	5	0.11	<0.01
99-Sep-02	5.3	5.3	159	99	3	64	2	1	66	<0.1	0.1	22.9	0.6	7	0.19	<0.01
99-Aug-04	5.8	5.0	54	38	13	19	<1.0	<0.5	19	<0.1	0.7	7.2	0.2	3	0.33	<0.01
99-Jul-12	6.6	7.6	80	56	5	29	1	<0.5	31	<0.1	0.2	10.7	0.2	90	0.19	<0.01
98-Jun-19	-	5.6	96	67	3	38	1	1	38	<0.1	0.2	13.7	0.3	5	0.29	<0.01
94-Sep-27	6.2	5.3	163	101	12	65	2	<0.5	62	<0.1	0.3	24.2	0.4	3	0.10	<0.01
94-Sep-13	4.4	5.4	123	76	67	44	<1.0	<0.5	47	0.2	3.3	16.0	0.7	8	1.96	0.010
94-Jul-14	-	5.2	65	40	14	25	<1.0	1	25	<0.1	0.3	9.5	<0.2	3	0.36	<0.01
93-Sep-22	-	7.0	109	77	<1	48	5	<0.5	43	<0.1	<0.1	17.9	<0.2	2	<0.03	<0.01
93-Aug-16	-	6.9	55	35	13	22	3	<0.5	19	<0.1	0.6	8.2	0.2	1	0.13	<0.01
93-Jul-20	-	6.1	50	39	10	20	2	<0.5	18	<0.1	1.9	7.4	<0.2	<30	0.15	<0.01
93-Jul-06	-	5.8	61	39	4	19	<1.0	<0.5	23	<0.1	0.2	7.0	<0.2	2	0.24	<0.01
93-Jun-13	-	5.5	-	-	2	39	-	-	41	<15	<0.1	14.5	<10	6	0.30	-
93-May-28	6.2	4.5	119	95	2	41	<1.0	1	48	<0.1	0.2	15.3	0.4	9	0.22	<0.01
92-Sep-21	-	5.6	230	162	2	60	8	<0.3	104	1.0	6.0	21.8	<1	2	0.20	<5
92-Sep-08	-	7.9	77	55	9	48	14	<0.5	35	<0.1	<3	17.9	<1	2	0.38	<5
92-Aug-19	-	7.0	70	30	6	28	5	1	26	0.1	<3	10.4	<1	39	0.15	<10
92-Aug-05	-	6.1	54	53	9	23	8	<0.3	19	0.1	<3	8.7	<1	<1	0.20	<0.05
92-Jul-23	-	6.6	67	67	12	29	10	<0.3	29	0.5	7.0	10.6	<1	7	0.43	<0.05
91-Jun-26 MOE	-	6.5	-	-	0	25	-	-	-	<0.5	1.0	9.1	<10	2	0.40	-
89-Aug-23	-	6.5	44	30	45	19	2	<0.5	13	<0.1	2.1	-	-	3	1.39	0.080
Minimum	4.4	4.5	44	30	<1	18	<1.0	<0.3	13	<0.1	<0.1	3.7	<30	<30	<0.03	<0.01
Median	6.0	6.0	80	62	5	33	2	<0.5	35	<0.1	0.3	13.7	0.4	3	0.21	<0.01
Maximum	6.6	7.9	230	162	67	69	14	2	104	7.5	7.0	25.9	5.0	90	1.96	<10
CAMP CREEK OUTFLOW																
98-Jun-19	-	5.8	100	70	3	40	2	<0.5	38	<0.1	0.3	15.4	0.3	4	0.23	<0.01
98-Jul-09	-	5.8	100	70	3	40	2	<0.5	38	<0.1	0.3	15.4	0.3	4	0.23	<0.01
97-Aug-07	-	6.3	60	35	18	19	3	<0.5	20	<0.1	0.7	7.6	<0.2	2	0.27	<0.01
96-Sep-06	-	5.7	124	69	2	44	2	<0.5	11	0.1	0.3	16.2	0.3	6	0.24	<0.01
95-Aug-25	-	6.5	75	46	43	27	3	<0.5	25	<0.1	<0.1	10.2	0.2	2	0.78	<0.01
94-Sep-13	5.3	5.4	129	85	41	50	<1.0	<0.5	51	0.2	2.8	18.5	0.6	5	1.52	<0.01
94-Jul-14	-	7.0	54	33	4	26	16	1	9	<0.1	1.3	9.9	<0.2	<1	0.14	<0.01
93-Sep-22	-	6.9	111	76	3	47	7	<0.5	42	0.4	0.2	17.4	<0.2	1	<0.03	<0.01
93-Aug-16	-	6.7	62	39	17	25	4	<0.5	20	<0.1	0.8	9.2	0.2	2	0.16	<0.01
Minimum	5.3	5.4	54	33	2	19	<1.0	<0.5	9	<0.1	<0.1	7.6	<0.2	<1	<0.03	<0.01
Median	5.3	6.3	100	69	4	40	3	<0.5	25	<0.1	0.3	15.4	0.2	2	0.23	<0.01
Maximum	5.3	7.0	129	85	43	50	16	1	51	0.4	2.8	18.5	0.6	6	1.52	<0.01
LITTLE CAMP CREEK INFLOW																
99-Aug-04	6.5	6.4	414	290	<3	198	20	<0.5	177	0.3	0.4	73.7	10.9	178	0.46	<0.01
99-Jul-12	7.1	6.5	318	223	<3	151	14	<0.5	135	<0.1	0.2	51.8	5.2	90	0.19	<0.01
98-Jul-09	-	6.3	480	336	2	238	19	<0.5	212	0.2	0.4	92.3	10.8	163	0.32	<0.01
94-Sep-13	5.9	6.7	778	499	<1	322	42	<0.5	264	0.3	0.5	120.0	8.1	26	0.21	<0.01
94-Jul-14	-	7.0	225	156	<1	111	30	1	73	<0.1	0.2	42.2	1.5	3	0.22	<0.01
93-Aug-16	-	6.7	244	174	20	115	33	<0.5	78	<0.1	2.7	42.8	1.6	12	2.23	0.010
Minimum	5.9	6.3	225	156	<1	111	14	<0.5	73	<0.1	0.2	42.2	1.5	3	0.19	<0.01
Median	6.5	6.6	366	257	2	175	25	<0.5	156	0.1	0.4	62.8	6.7	58	0.27	<0.01
Maximum	7.1	7.0	778	499	20	322	42	1	264	0.3	2.7	120.0	10.9	178	2.23	0.010
LITTLE CAMP CREEK OUTFLOW																
98-Jul-09	-	4.7	155	108	8	60	<1.0	<0.5	59	0.4	1.8	22.7	2.2	76	2.64	<0.01
94-Sep-13	2.7	4.2	207	130	42	70	<1.0	1	79	0.5	20.4	27.0	1.9	34	6.54	<0.01
94-Jul-14	-	6.4	91	60	<1	38	5	1	33	<0.1	0.9	14.6	0.4	8	0.53	<0.01
93-Sep-22	-	6.7	133	100	3	47	11	1	51	<0.1	0.4	17.6	<0.2	3	0.08	<0.01
93-Aug-16	-	6.2	83	55	11	35	4	<0.5	29	<0.1	0.5	12.9	0.6	4	0.31	<0.01
Minimum	2.7	4.2	83	55	<1	35	<1	<0.5	29	<0.1	0.4	12.9	<0.2	3	0.08	<0.01
Median	2.7	6.2	133	100	8	47	4	1	51	<0.1	0.9	17.6	0.6	8	0.53	<0.01
Maximum	2.7	6.7	207	130	42	70	11	1	79	0.5	20.4	27.0	2.2	76	6.54	<0.01

Where applicable the data reported as < detection limit were used in the statistics.

Table 9. Site Water Quality Monitoring Results (Continued)

Date	T-Mg	T-Mo	T-Pb	T-Zn	D-Ag	D-As	D-Ca	D-Cd	D-Cu	D-Fe	D-Hg	D-Mg	D-Mo	D-Pb	D-Zn
	(mg/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(mg/L)	(ug/L)	(ug/L)	(mg/L)	(ug/L)	(mg/L)	(ug/L)	(ug/L)	(ug/L)
CAMP CREEK INFLOW (continued)															
01-Sep-08	1.10	<1	<1	50	<1	<10	20.9	0.5	7	0.09	<0.2	1.10	<1	<1	60
00-Sep-20	1.03	<1	<1	39	<0.1	0.4	20.4	0.6	3	0.03	-	1.05	<1	<1	60
00-Aug-12	0.19	<1	<1	15	<0.1	0.5	6.5	0.4	2	<0.03	-	0.30	<1	<1	28
99-Sep-14	1.36	<1	<1	47	<0.1	<0.1	25.4	0.7	5	0.06	-	1.33	<1	<1	48
99-Sep-02	1.26	<1	<1	52	<0.1	0.1	23.4	0.7	7	0.13	-	1.28	<1	1	60
99-Aug-04	0.37	<1	<1	15	<0.1	0.5	73.6	0.2	3	0.23	-	0.36	<1	<1	17
99-Jul-12	2.55	<1	7	481	<0.1	<0.1	56.0	5.2	90	0.03	-	2.74	<0.1	4	517
98-Jun-19	0.73	<1	<1	29	<0.1	<0.1	13.9	0.3	6	0.07	-	0.71	<1	<1	30
94-Sep-27	1.18	<1	<1	35	<0.1	0.1	24.2	0.4	2	<0.03	-	1.18	<1	<1	35
94-Sep-13	1.05	<1	2	50	<0.1	<0.1	16.0	0.7	8	0.17	-	0.89	<1	<1	50
94-Jul-14	0.44	<1	<1	20	<0.1	<0.1	9.5	<0.2	3	<0.03	-	0.43	<1	<1	20
93-Sep-22	0.78	<1	2	13	<0.1	<0.1	17.8	<0.2	2	<0.03	-	0.76	<1	<1	13
93-Aug-16	0.40	<1	<1	11	<0.1	<0.1	8.0	<0.2	<1	<0.03	-	0.38	<1	<1	6
93-Jul-20	0.29	<1	<1	6	<0.1	1.2	7.4	<0.2	<1	<0.03	-	0.27	<1	<1	<5
93-Jul-06	0.43	<1	<1	19	<0.1	<0.1	7.8	<0.2	2	<0.03	-	0.42	<1	<1	19
93-Jun-13	0.71	<30	1	49	<15	<0.1	14.4	<10	6	0.06	-	0.70	<30	<1	49
93-May-28	0.81	<1	1	70	<0.1	0.2	15.2	0.4	9	0.21	-	0.78	<1	<1	70
92-Sep-21	1.26	17	<1	17	<0.1	4.0	22.3	<1	2	<0.002	<5	1.25	13	<1	18
92-Sep-08	0.73	1	<5	50	<0.1	<3	14.6	<1	<1	0.23	<5	0.54	1	<5	40
92-Aug-19	0.44	<1	7	186	0.1	<3	10.6	<1	22	0.07	<10	0.57	2	7	47
92-Aug-05	0.40	<1	<5	11	0.1	<3	8.7	<1	<1	<0.03	<0.05	0.40	<1	<5	11
92-Jul-23	0.56	<1	<5	28	0.5	<3	10.2	<1	2	0.04	<0.05	0.50	6	<5	17
91-Jun-26 MOE	0.47	-	-	40	-	-	-	-	-	-	-	-	-	-	-
89-Aug-23	-	<1	3	20	<0.1	0.2	6.9	-	<1	<0.03	<0.05	0.32	<1	<1	11
Minimum	0.19	<1	<1	6	<0.1	<0.1	6.5	<0.2	<1	<0.002	<0.05	0.27	<0.1	<1	<5
Median	0.73	<1	<1	32	<0.1	0.2	14.6	0.5	3	0.03	<0.2	0.70	<1	<1	30
Maximum	2.55	17	7	481	7.5	5.0	73.6	5.2	90	0.23	<10	2.74	15	7	517
CAMP CREEK OUTFLOW (continued)															
98-Jun-19	0.78	<1	1	33	<0.1	0.1	14.6	0.3	6	0.05	-	0.73	<1	1	36
98-Jul-09	0.78	<1	1	33	<0.1	0.1	14.6	0.3	6	0.05	-	0.73	<1	1	36
97-Aug-07	0.36	<1	<1	17	<0.1	0.2	7.0	<0.2	3	0.10	-	0.35	<1	<1	12
96-Sep-06	0.78	<1	1	36	0.1	<0.1	16.4	0.3	3	0.06	-	0.80	<1	1	38
95-Aug-25	0.65	<1	<1	21	<0.1	<0.1	10.0	<0.2	<1	<0.03	-	0.49	<1	<1	11
94-Sep-13	1.00	<1	2	51	<0.1	<0.1	18.5	0.6	4	0.11	-	0.91	<1	<1	51
94-Jul-14	0.32	<1	<1	6	<0.1	0.8	9.8	<0.2	<1	0.04	-	0.31	<1	<1	169
93-Sep-22	0.77	<1	1	41	<0.1	<0.1	17.4	<0.2	1	<0.03	-	0.75	<1	<1	41
93-Aug-16	0.42	<1	<1	28	<0.1	0.3	9.2	<0.2	<1	0.03	-	0.42	<1	<1	25
Minimum	0.32	<1	<1	6	<0.1	<0.1	7.0	<0.2	<1	0.02	-	0.31	<1	<1	11
Median	0.77	<1	1	33	<0.1	0.1	14.6	<0.2	3	0.05	-	0.73	<1	<1	36
Maximum	1.00	<1	2	51	0.1	0.8	18.5	0.6	6	0.11	-	0.91	<1	1	169
LITTLE CAMP CREEK INFLOW (continued)															
99-Aug-04	3.40	<1	12	1050	<0.1	0.3	73.6	10.7	172	<0.03	-	3.41	<1	3	1050
99-Jul-12	2.55	<1	7	481	<0.1	0.2	56.0	5.2	90	0.03	-	2.74	<1	4	517
98-Jul-09	4.01	1	13	1140	<0.1	0.2	88.8	10.5	157	0.05	-	3.91	<1	8	1110
94-Sep-13	5.66	1	5	1350	0.1	0.2	120.0	7.9	18	0.12	-	5.51	<1	<1	1340
94-Jul-14	1.58	2	1	172	<0.1	0.2	41.9	0.4	3	0.18	-	1.58	2	<1	169
93-Aug-16	2.04	2	6	120	<0.1	0.9	42.8	1.5	8	0.48	-	2.04	1	<1	97
Minimum	1.58	1	1	120	<0.1	0.2	41.9	0.4	3	0.02	-	1.58	<1	<1	97
Median	2.98	1	7	766	<0.1	0.2	64.8	6.6	54	0.08	-	3.08	<1	2	784
Maximum	5.66	2	13	1350	0.1	0.9	120.0	10.7	172	0.48	-	5.51	2	8	1340
LITTLE CAMP CREEK OUTFLOW (continued)															
98-Jul-09	1.04	<1	33	260	0.3	0.3	22.5	2.3	78	0.71	-	1.04	<1	23	260
94-Sep-13	1.20	1	26	183	<0.1	0.9	26.3	1.9	31	1.50	-	1.09	<1	18	179
94-Jul-14	0.56	<1	16	60	<0.1	0.7	14.2	<0.2	8	0.45	-	0.56	<1	13	59
93-Sep-22	0.85	<1	8	62	<0.1	0.4	17.6	<0.2	2	0.08	-	0.85	<1	4	62
93-Aug-16	0.57	<1	12	64	<0.1	0.2	0.0	0.6	2	0.17	-	0.57	<1	5	61
Minimum	0.56	<1	8	60	<0.1	0.2	0.0	<0.2	2	0.08	-	0.56	<1	4	59
Median	0.85	<1	16	64	<0.1	0.4	17.6	0.6	8	0.45	-	0.85	<1	13	62
Maximum	1.20	1	33	260	0.3	0.9	26.3	2.3	78	1.50	-	1.09	<1	23	260

Where applicable the data reported as < detection limit were used in the statistics.

Table 9. Site Water Quality Monitoring Results (Continued)																
Date	pH (Field)	pH (lab)	Cond (uS/cm)	TDS (mg/L)	TSS (mg/L)	Hard (mg/L)	Alk. (mg/L)	Cl (mg/L)	SO_4 (mg/L)	T-Ag (ug/L)	T-As (ug/L)	T-Ca (mg/L)	T-Cd (ug/L)	T-Cu (ug/L)	T-Fe (mg/L)	T-Hg (ug/L)
BRUCEJACK LAKE																
01-Sep-08	-	7.5	65	34	<3	29	18	<0.5	12	<0.1	<1	10.9	<0.2	<1	0.05	<0.2
00-Sep-20	7.7	7.8	120	94	15	84	27	1	23	<0.1	1.0	34.1	<0.2	<1	0.19	<0.01
00-Sep-20 Dup	7.7	8.0	149	123	12	88	34	1	33	<0.1	1.0	35.3	<0.2	<1	0.18	<0.01
00-Aug-12	6.9	7.6	65	40	4	26	18	<0.5	12	<0.1	1.7	9.6	<0.2	<1	0.18	<0.01
99-Sep-14	7.8	7.7	69	38	4	29	18	2	12	0.4	0.9	11.3	<0.2	<1	0.11	<0.01
99-Sep-02	8.0	7.9	68	34	<3	28	16	1	11	0.4	1.0	10.8	<0.2	<1	0.10	<0.01
99-Aug-25 Eskay	8.1	7.4	53	-	2	-	23	-	9	-	-	-	-	20	0.07	-
99-Aug-19	7.7	7.0	51	29	<3	22	16	<0.5	8	0.2	1.4	8.5	<0.2	<1	0.08	<0.01
99-Aug-11 Eskay	7.6	7.6	52	-	2	-	14	-	12	-	-	-	-	<10	0.04	-
99-Aug-04	6.9	6.8	50	35	<3	26	17	<0.5	9	0.3	1.4	8.4	<0.2	<1	0.07	<0.01
99-Jul-29 Eskay	7.1	7.1	47	-	8	-	15	-	10	-	-	-	-	<10	0.08	-
99-Jul-12	7.8	9.2	57	40	4	18	9	<0.5	8	<0.1	0.8	6.8	<0.2	<1	0.10	<0.01
91-Sep-15	-	7.7	52	42	7	24	15	<0.5	9	<0.1	1.1	-	-	<1	0.39	<0.05
91-Jul-24	-	7.4	48	38	3	22	17	<0.5	5	<0.1	1.2	-	-	<1	0.17	0.006
90-Nov-21	-	7.0	56	40	3	24	17	<0.5	10	<0.1	2.0	-	-	<1	0.12	<0.5
89-Aug-23	-	7.0	47	40	<1	22	15	<0.5	4	<0.1	1.4	-	-	<1	0.06	<0.05
89-May-29	-	7.3	51	20	3	23	19	1	5	0.2	1.0	-	-	1	<0.03	-
89-Feb-28	-	6.9	48	34	<1	23	20	<0.5	4	<0.1	1.8	-	-	<1	0.03	<0.05
88-Oct-28	-	6.8	45	35	6	23	18	1	5	<0.1	1.6	-	-	<1	0.10	<0.05
88-Aug-30	-	6.9	45	30	8	22	18	<0.5	6	5.0	2.4	-	-	<0.5	0.09	1.200
88-Aug-03	-	-	-	-	2	-	-	-	-	-	-	-	-	<1	0.05	-
88-Jul-28	-	7.3	44	30	<1	23	14	<0.5	5	<0.1	1.8	-	-	<0.5	0.05	-
88-Jun-30	-	7.7	50	40	<1	26	12	1	6	<0.1	2.3	-	-	<0.5	0.30	-
1988 - 1998																
Minimum	NA	6.8	44	20	<1	22	12	<0.5	4	<0.1	1.0	NA	NA	<0.5	<0.03	0.006
Median	NA	7.2	48	37	3	23	17	<0.5	5	<0.1	1.7	NA	NA	<1	0.09	<0.05
Maximum	NA	7.7	56	42	8	26	20	1	10	5.0	2.4	NA	NA	1	0.39	1.200
1999 - 2001																
Minimum	6.9	6.8	47	29	2	18	9	<0.5	8	<0.1	0.5	6.8	<0.2	<1	0.04	<0.01
Median	7.7	7.6	57	37	<3	27	17	<0.5	11	0.1	1.0	10.2	<0.2	<1	0.08	<0.01
Maximum	8.1	9.2	120	94	15	84	27	2	23	0.4	1.7	34.1	<0.2	20	0.19	<0.2
Where applicable the data reported as < detection limit were used in the statistics.																

Date	T-Mg (mg/L)	T-Mo (ug/L)	T-Pb (ug/L)	T-Zn (ug/L)	D-Ag (ug/L)	D-As (ug/L)	D-Ca (mg/L)	D-Cd (ug/L)	D-Cu (ug/L)	D-Fe (mg/L)	D-Hg (ug/L)	D-Mg (mg/L)	D-Mo (ug/L)	D-Pb (ug/L)	D-Zn (ug/L)
BRUCEJACK LAKE (continued)															
01-Sep-08	0.30	<1	<1	<50	<0.1	<1	10.9	<0.2	<1	<0.03	<0.2	0.30	<1	<1	<50
00-Sep-20	0.77	<1	<1	<5	<0.1	0.8	32.6	<0.2	<1	<0.03	-	0.71	<1	<1	<5
00-Sep-20 Dup	0.78	<1	<1	<5	<0.1	1.0	34.0	<0.2	<1	<0.03	-	0.72	<1	<1	17
00-Aug-12	0.30	<1	<1	<5	<0.1	1.1	9.8	<0.2	<1	<0.03	-	0.27	<1	<1	7
99-Sep-14	0.35	<1	2	9	<0.1	0.4	11.2	0.2	<1	<0.03	-	0.34	<1	<1	6
99-Sep-02	0.35	<1	2	6	<0.1	0.4	10.6	<0.2	<1	<0.03	-	0.34	<1	<1	<5
99-Aug-25 Eskay	-	-	-	10	-	-	-	-	10	0.02	-	-	-	-	<10
99-Aug-19	0.29	<1	2	<5	<0.1	0.7	8.4	<0.2	<1	<0.03	-	0.28	<1	<1	<5
99-Aug-11 Eskay	-	-	-	<10	-	-	-	-	<10	0.02	-	-	-	-	<10
99-Aug-04	0.27	<1	2	5	<0.1	0.9	9.8	<0.2	<1	<0.03	-	0.26	<1	<1	<5
99-Jul-29 Eskay	-	-	-	<10	-	-	-	-	<10	0.04	-	-	-	<1	<10
99-Jul-12	0.28	<1	<1	<5	<0.1	0.3	6.6	<0.2	<1	<0.03	-	0.25	<1	<1	<5
91-Sep-15	-	<1	1	<5	<0.1	1.2	8.9	-	<1	<0.03	-	0.31	<1	<1	<5
91-Jul-24	-	<1	<1	<5	<0.1	1.1	8.3	-	<1	<0.03	-	-	<1	<1	<5
90-Nov-21	-	<0.1	<1	11	<0.1	0.4	-	-	<1	<0.03	<0.05	-	<1	<1	7
89-Aug-23	-	<1	<1	<5	<0.1	1.4	-	-	<1	<0.03	<0.05	-	<1	<1	<0.5
89-May-29	-	<1	<1	<5	<0.1	1.0	-	-	1	<0.03	<0.05	-	<1	<1	<0.5
89-Feb-28	-	<1	<1	5	<0.1	1.0	-	-	<1	0.03	<0.05	-	<1	<1	5
88-Oct-28	-	<1	<1	<5	<0.1	1.6	-	-	<1	<0.03	<0.05	-	<1	<1	5
88-Aug-30	-	6	<0.5	170	<0.1	0.7	-	-	<0.5	<0.03	<0.05	-	<1	4	6
88-Aug-03	-	-	1	<0.5	-	-	-	-	-	-	-	-	-	-	-
88-Jul-28	-	<1	<0.5	6	<1	1.8	-	-	<0.5	<0.03	<5	-	-	<0.5	<0.1
88-Jun-30	-	<1	<0.5	4	<0.1	2.3	-	-	<0.5	0.01	-	-	1	<0.5	4
1988 - 1998															
Minimum	NA	<0.1	<0.5	<0.5	<0.1	0.4	8.3	NA	<0.5	0.01	<0.05	0.31	<1	<0.5	<0.1
Median	NA	<1	<1	<5	<0.1	1.2	8.6	NA	<1	<0.03	<0.05	0.31	<1	<1	3
Maximum	NA	6	1	170	<1	2.3	8.9	NA	1	0.03	<5	0.31	1	4	7
1999 - 2001															
Minimum	0.27	<1	<1	<5	<0.1	0.3	6.6	0.1	<1	<0.03	<0.2	0.25	<1	<1	<5
Median	0.30	<1	1	5	<0.1	0.6	10.2	0.1	<1	<0.03	<0.2	0.29	<1	<1	5
Maximum	0.77	<1	2	25	<0.1	1.1	32.6	0.2	10	0.04	<0.2	0.71	<1	<1	<50

Where applicable the data reported as < detection limit were used in the statistics.

Table 9. Site Water Quality Monitoring Results (Continued)

Date	pH (Field)	pH (lab)	Cond (uS/cm)	TDS (mg/L)	TSS (mg/L)	Hard (mg/L)	Alk. (mg/L)	Cl (mg/L)	SO_4 (mg/L)	T-Ag (ug/L)	T-As (ug/L)	T-Ca (mg/L)	T-Cd (ug/L)	T-Cu (ug/L)	T-Fe (mg/L)	T-Hg (ug/L)
UPPER BRUCEJACK CREEK																
01-Sep-08	-	7.8	60	30	<3	25	17	<0.5	11	<0.1	<1	9.7	<0.2	<1	0.06	<0.2
00-Sep-20	7.3	7.6	63	54	<3	24	17	1	10	<0.1	1.7	9.2	<0.2	<1	0.20	<0.01
00-Aug-12	6.4	7.6	60	34	<3	24	16	<0.5	10	<0.1	1.6	8.6	<0.2	<1	0.17	<0.01
99-Sep-14	6.9	7.5	61	<30	4	27	18	1	10	0.4	0.9	10.3	<0.2	<1	0.08	<0.01
99-Sep-02	8.1	7.7	60	30	7	25	16	1	10	0.4	1.4	9.8	<0.2	<1	0.21	<0.01
99-Aug-25 Eskay	8.0	7.3	54	-	3	-	21	-	13	-	-	-	-	10	0.08	-
99-Aug-19	7.6	7.1	52	30	<3	21	15	<0.5	9	0.3	1.2	8.1	<0.2	<1	0.06	<0.01
99-Aug-11 Eskay	7.6	7.8	50	-	2	-	14	-	10	-	-	-	-	<10	0.03	-
99-Aug-04	6.5	7.1	44	31	<3	22	14	1	7	0.2	1.4	8.4	<0.2	<1	0.08	<0.01
99-Jul-29 Eskay	7.0	7.1	56	-	5	-	14	-	10	-	-	-	-	10	0.08	-
99-Jul-12	7.8	8.5	59	42	<3	23	16	<0.5	8	<0.1	0.8	6.8	<0.2	<1	0.10	<0.01
98-Jun-19	-	7.2	51	36	1	24	12	<0.5	11	<0.1	1.8	8.9	<0.2	<1	0.18	<0.01
97-Aug-07	-	7.1	54	29	4	19	17	<0.5	6	<1	1.5	7.2	<0.2	<1	0.05	<0.01
96-Sep-06	-	7.5	52	30	<1	23	17	1	8	0.1	1.8	8.5	<0.2	2	0.15	<0.01
95-Aug-25	-	7.3	48	20	1	21	16	<0.5	5	<0.1	1.4	8.2	<0.2	1	0.14	<0.01
94-Sep-27	8.0	7.3	47	25	10	20	15	<0.5	5	<0.1	2.7	8.2	<0.2	1	0.32	<0.01
94-Aug-31	7.9	7.9	-	-	-	21	-	-	-	<0.1	2.5	7.9	<0.2	1	0.23	<0.01
94-Aug-15	7.6	6.6	48	30	7	22	18	<0.5	5	<0.1	2.4	8.5	<0.2	1	0.23	<0.01
94-Jul-27	-	7.2	49	28	6	23	16	<0.5	5	<0.1	1.5	8.8	<0.2	1	0.11	<0.01
94-Jun-29	-	7.2	52	32	3	25	17	<0.5	7	<0.1	1.9	9.4	<0.2	<1	0.06	<0.01
93-Sep-22	-	7.4	46	29	5	22	16	1	6	<0.1	2.2	8.6	<0.2	2	0.03	<0.01
93-Aug-16	-	7.4	45	27	<1	21	17	<0.5	4	<0.1	2.3	8.5	<0.2	7	0.11	<0.01
93-Jul-20	-	7.5	46	36	3	18	15	<0.5	6	<0.1	0.9	6.6	<0.2	<1	0.26	<0.01
93-Jul-06	-	7.3	45	34	2	17	17	<0.5	6	<0.1	1.8	6.4	<0.2	<1	0.19	<0.01
93-Jun-13	-	7.4	-	-	1	21	-	-	6	<15	1.6	7.9	<10	<1	0.10	-
93-May-28	7.9	7.0	51	41	2	21	14	1	6	<0.1	1.3	8.0	<0.2	<1	0.09	<0.01
92-Sep-21	-	6.7	42	28	7	14	21	<0.3	9	<0.1	5.0	4.8	1.0	2	0.15	<5
92-Aug-19	-	7.3	41	36	13	22	15	<0.5	6	1.1	<3	13.5	<1	<1	0.35	<10
92-Jul-23	-	7.3	52	66	14	25	18	<0.3	11	0.5	15.0	8.7	<1	2	0.72	<0.05
91-Sep-15	-	7.7	52	42	7	24	15	<0.5	9	<0.1	1.1	-	-	<1	0.39	<0.05
91-Jul-24	-	7.4	48	38	3	22	17	<0.5	5	<0.1	1.2	-	-	<1	0.17	0.006
90-Jun-26	-	7.6	56	50	3	24	17	<0.5	8	<0.1	1.6	-	-	<1	0.08	<0.005
90-Jun-06	-	7.4	84	60	7	26	17	<0.5	10	<0.1	1.1	-	-	<1	0.08	0.031
90-Apr-06	-	7.8	51	40	5	24	19	15	9	<0.1	1.6	-	-	<1	0.03	0.005
90-Mar-03	-	6.8	63	40	<1	22	17	<0.5	5	<0.1	1.4	-	-	<1	<0.03	0.005
89-Dec-13	-	7.7	52	40	3	19	18	<0.5	12	2.3	2.1	-	-	<1	<0.03	0.010
89-Nov-08	-	7.0	50	40	<1	22	11	<0.5	5	<0.1	1.2	-	-	<1	<0.03	0.005
89-Oct-02	-	6.8	49	40	4	24	14	<0.5	6	<0.1	1.0	-	-	<1	<0.03	<0.05
89-Aug-23	-	7.0	47	40	<1	22	15	<0.5	4	<0.1	1.4	-	-	<1	0.06	<0.05
89-May-29	-	7.3	51	20	3	23	19	1	5	0.2	1.0	-	-	1	<0.03	-
89-Feb-28	-	6.9	48	34	<1	23	20	<0.5	4	<0.1	1.8	-	-	<1	0.03	<0.05
88-Oct-28	-	6.8	45	35	6	23	18	1	5	<0.1	1.6	-	-	<1	0.10	<0.05
88-Oct-03	-	6.8	44	40	8	24	21	<0.5	7	<0.1	1.5	-	-	70	<0.001	-
88-Aug-30	-	6.9	45	30	8	22	18	<0.5	6	<0.1	2.4	-	-	<0.5	0.09	0.080
88-Aug-03	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	0.05	-
88-Jul-28	-	7.3	44	30	<1	23	14	<0.5	5	<0.1	1.8	-	-	<0.5	0.05	-
88-Jun-30	-	7.7	50	40	<1	26	12	1	6	<0.1	2.3	-	-	<0.5	0.03	-
88-May-05	-	7.4	47	40	<1	24	14	<0.5	8	<0.1	2.1	-	-	<1	<0.03	-
88-Mar-30	-	7.4	44	40	3	24	16	<0.5	5	<0.1	0.5	-	-	<1	<0.03	-
87-Dec-15	-	7.7	42	40	2	20	16	<0.5	5	<0.1	2.2	-	-	<1	<0.03	-
87-Nov-22	-	7.4	42	33	4	23	15	<0.5	6	<5	1.9	-	-	<1	<0.03	-
87-Oct-23	-	7.6	43	32	4	22	21	<0.5	6	<0.5	0.8	-	-	<1	<0.03	-
87-Sep-25	-	7.8	42	39	1	20	21	6	2	<0.5	1.9	-	-	1	0.12	-
87-Aug-27	-	7.4	42	33	1	21	14	<0.5	3	<0.5	2.4	-	-	<5	0.08	-
87-Jul-28	-	7.4	32	8	1	-	-	-	6	-	2.0	-	-	<1	<0.03	-
1987 - 1998																
Minimum	7.6	6.6	32	8	<1	14	11	<0.3	2	<0.1	0.5	4.8	<0.2	<0.5	<0.001	<0.005
Median	7.9	7.3	48	36	3	22	17	<0.5	6	<0.1	1.8	8.5	<0.2	<1	0.08	<0.01
Maximum	8.0	7.9	84	66	14	26	21	15	12	<15	15.0	13.5	<10	70	0.72	<10

Table 9. Site Water Quality Monitoring Results (Continued)																
Date	pH (Field)	pH (lab)	Cond (uS/cm)	TDS (mg/L)	TSS (mg/L)	Hard (mg/L)	Alk. (mg/L)	Cl (mg/L)	SO_4 (mg/L)	T-Ag (ug/L)	T-As (ug/L)	T-Ca (mg/L)	T-Cd (ug/L)	T-Cu (ug/L)	T-Fe (mg/L)	T-Hg (ug/L)
UPPER BRUCEJACK CREEK (continued)																
1999 - 2001																
Minimum	6.4	7.1	44	15	<3	21	14	<0.5	7	<0.1	<1	6.8	<0.2	<1	0.03	<0.01
Median	7.5	7.6	59	31	<3	24	16	<0.5	10	0.1	1.3	8.9	<0.2	<1	0.08	<0.01
Maximum	8.1	8.5	63	54	7	27	21	1	13	0.4	1.7	10.3	<0.2	10	0.21	0.100
Where applicable the data reported as < detection limit were used in the statistics.																

Date	T-Mg (mg/L)	T-Mo (ug/L)	T-Pb (ug/L)	T-Zn (ug/L)	D-Ag (ug/L)	D-As (ug/L)	D-Ca (mg/L)	D-Cd (ug/L)	D-Cu (ug/L)	D-Fe (mg/L)	D-Hg (ug/L)	D-Mg (mg/L)	D-Mo (ug/L)	D-Pb (ug/L)	D-Zn (ug/L)
UPPER BRUCEJACK CREEK (continued)															
01-Sep-08	0.30	<1	<1	<50	<0.1	<1	9.6	<0.2	<1	<0.03	<0.2	0.30	<1	<1	<50
00-Sep-20	0.35	<1	<1	<5	<0.1	1.3	9.2	<0.2	<1	<0.03	-	0.31	<1	<1	21
00-Aug-12	0.28	<1	<1	<5	<0.1	1.1	9.2	<0.2	<1	<0.03	-	0.27	<1	<1	6
99-Sep-14	0.34	<1	2	9	<0.1	4.0	10.3	<0.2	1	<0.03	-	0.31	<1	<1	<5
99-Sep-02	0.33	2	3	<5	<0.1	0.5	9.7	<0.2	<1	<0.03	-	0.29	<1	<1	<5
99-Aug-25 Eskay	-	-	-	10	-	-	-	-	<10	0.03	-	-	-	-	<10
99-Aug-19	0.27	<1	2	<5	<0.1	0.7	8.1	<0.2	<1	<0.03	-	0.28	<1	<1	<5
99-Aug-11 Eskay	-	-	-	<10	-	-	-	-	<10	0.01	-	-	-	-	<10
99-Aug-04	0.26	<1	2	<5	<0.1	0.8	8.3	<0.2	<1	<0.03	-	0.26	<1	<1	<5
99-Jul-29 Eskay	-	-	-	10	-	-	-	-	10	0.03	-	-	-	-	10
99-Jul-12	0.28	<1	<1	<5	<0.1	0.3	6.6	<0.2	<1	<0.03	-	0.25	<1	<1	<5
98-Jun-19	0.33	<1	<1	<5	<0.1	0.9	9.0	<0.2	<1	<0.03	-	0.29	<1	<1	<5
97-Aug-07	0.26	<1	<1	<5	<0.1	1.2	7.1	<0.2	1	<0.03	-	0.23	<1	<1	<5
96-Sep-06	0.29	3	<1	6	<0.1	1.1	8.7	<0.2	1	<0.03	-	0.30	3	<1	<5
95-Aug-25	0.28	<1	<1	6	<0.1	1.1	8.0	<0.2	1	<0.03	-	0.29	<1	<1	<5
94-Sep-27	0.32	<1	<1	<5	<0.1	1.2	7.5	<0.2	<1	<0.03	-	0.27	<1	<1	<5
94-Aug-31	0.28	<1	<1	<5	<0.1	1.0	7.8	<0.2	<1	0.08	-	0.24	<1	<1	<5
94-Aug-15	0.31	<1	<1	<5	<0.1	1.4	8.5	<0.2	<1	0.04	-	0.26	<1	<1	<5
94-Jul-27	0.30	2	<1	<5	<0.1	1.2	8.8	<0.2	<1	0.04	-	0.28	1	<1	<5
94-Jun-29	0.32	<1	<1	<5	<0.1	1.9	9.4	<0.2	<1	0.06	-	0.32	<1	<1	<5
93-Sep-22	0.29	<1	<1	5	<0.1	1.1	8.5	<0.2	<1	0.03	-	0.29	<1	<1	5
93-Aug-16	0.29	<1	<1	<5	<0.1	1.6	7.9	<0.2	<1	<0.03	-	0.27	<1	<1	<5
93-Jul-20	0.33	<1	3	11	<0.1	<0.1	6.6	<0.2	<1	0.03	-	0.33	<1	<1	11
93-Jul-06	0.29	<1	<1	<5	<0.1	1.3	6.4	<0.2	<1	0.05	-	0.29	<1	<1	<5
93-Jun-13	0.27	<30	1	<5	<15	1.4	7.8	<10	<1	0.05	-	0.26	<30	<1	<5
93-May-28	0.31	<1	<1	<5	<0.1	1.0	7.8	<0.2	<1	<0.03	-	0.27	<1	<1	<5
92-Sep-21	0.53	13	<1	3	0.5	5.0	4.3	1.0	3	0.03	<5	0.52	12	3	3
92-Aug-19	0.92	<1	<5	<5	0.8	<3	8.8	<1	<1	<0.03	<10	<0.001	<1	<5	<5
92-Jul-23	0.72	<1	<5	19	0.4	4.0	8.0	<1	<1	0.07	<0.05	0.30	<1	<5	13
91-Sep-15	-	<1	1	<5	<0.1	1.2	8.9	-	<1	<0.03	-	0.31	<1	<1	<5
91-Jul-24	-	<1	<1	<5	<0.1	1.1	8.3	-	<1	<0.03	-	0.29	<1	<1	<5
90-Jun-26	-	<1	<1	<5	<0.1	0.9	8.9	-	<1	0.08	-	0.30	<1	<1	<5
90-Jun-06	-	3	<1	6	<0.1	0.8	9.3	-	<1	<0.015	0.013	0.33	<1	<1	<5
90-Apr-06	-	<1	<1	<5	<0.1	1.1	9.1	-	<1	<0.03	0.005	0.29	<1	<1	<5
90-Mar-03	-	<1	<1	<5	<0.1	1.2	8.4	-	<1	<0.03	0.025	0.26	<1	<1	<5
89-Dec-13	-	<1	1	<5	0.1	1.3	7.3	-	<1	<0.03	<0.005	0.25	<1	<1	<5
89-Nov-08	-	<1	<1	<5	<0.1	1.1	8.2	-	<1	<0.03	0.005	0.28	<1	<1	<5
89-Oct-02	-	<1	<1	<5	<0.1	1.0	9.0	-	<1	<0.03	<0.05	0.30	<1	<1	<5
89-Aug-23	-	<1	<1	<5	<0.1	1.4	8.3	-	<1	<0.03	<0.05	0.25	<1	<1	<5
89-May-29	-	<1	<1	<5	<0.1	1.0	-	-	1	<0.03	-	-	<1	<1	<5
89-Feb-28	-	<1	<1	<5	<0.1	1.0	-	-	<1	<0.03	<0.05	-	<1	<1	<5
88-Oct-28	-	<1	<1	<5	<0.1	1.6	-	-	<1	<0.03	<0.05	-	<1	<1	<5
88-Oct-03	-	<1	<1	<5	<0.1	1.1	-	-	<30	<0.001	-	-	<1	<1	<5
88-Aug-30	-	<1	<0.5	<5	<0.1	1.5	-	-	<5	<0.03	<0.05	-	<1	<5	<5
88-Aug-03	-	-	1	<0.5	-	-	-	-	-	-	-	-	-	-	-
88-Jul-28	-	<1	<0.5	6	<0.1	1.8	-	-	<0.5	<0.03	-	-	<1	<0.5	<5
88-Jun-30	-	<1	<0.5	4	<0.1	2.3	-	-	<0.5	0.01	-	-	<1	<0.5	4
88-May-05	-	<1	<1	<5	<0.1	1.5	-	-	<1	<0.03	-	-	<1	<1	<5
88-Mar-30	-	1	<0.5	21	<0.1	0.4	-	-	<1	<0.03	-	-	1	<0.5	11
87-Dec-15	-	<5	<1	<5	<0.1	2.2	-	-	<1	<0.03	-	-	<1	<1	<5
87-Nov-22	-	<5	<1	<5	<0.5	1.9	-	-	<1	<0.03	-	-	<5	<1	<5

Table 9. Site Water Quality Monitoring Results (Continued)															
Date	T-Mg (mg/L)	T-Mo (ug/L)	T-Pb (ug/L)	T-Zn (ug/L)	D-Ag (ug/L)	D-As (ug/L)	D-Ca (mg/L)	D-Cd (ug/L)	D-Cu (ug/L)	D-Fe (mg/L)	D-Hg (ug/L)	D-Mg (mg/L)	D-Mo (ug/L)	D-Pb (ug/L)	D-Zn (ug/L)
UPPER BRUCEJACK CREEK (continued)															
87-Oct-23	-	<5	<1	<5	<0.5	8.0	-	-	<1	<0.03	-	-	<5	<1	<5
87-Sep-25	-	<5	<1	<5	<0.5	1.9	-	-	<1	0.04	<5	-	-	<1	<5
87-Aug-27	-	<5	<1	<5	<0.5	2.4	-	-	<5	<0.03	-	-	<5	<1	<5
87-Jul-28	-	-	<1	<5	-	2.0	-	-	<1	<0.03	-	-	-	<1	<5
1987 - 1998															
Minimum	0.26	<1	<0.5	<0.5	<0.1	<0.1	4.3	<0.2	<0.5	<0.001	<0.005	<0.001	<1	<0.5	<5
Median	0.31	<1	<1	<5	<0.1	1.2	8.3	<0.2	<1	<0.03	<0.05	0.29	<1	<1	<5
Maximum	0.92	<30	3	21	<15	8.0	9.4	<1	<30	0.08	<10	0.52	<30	3	13
1999 - 2001															
Minimum	0.26	<1	<1	<5	<0.1	0.3	6.6	<0.2	<1	0.01	<0.2	0.25	<1	<1	<5
Median	0.29	<1	1	<5	<0.1	0.8	9.2	<0.2	<1	<0.03	<0.2	0.28	<1	<1	5
Maximum	0.35	2	3	<50	<0.1	4.0	10.3	<0.2	10	0.03	<0.2	0.31	<1	<1	<50
Where applicable the data reported as < detection limit were used in the statistics.															

Table 9. Site Water Quality Monitoring Results (Continued)

Date	pH (Field)	pH (lab)	Cond (uS/cm)	TDS (mg/L)	TSS (mg/L)	Hard (mg/L)	Alk. (mg/L)	Cl (mg/L)	SO_4 (mg/L)	T-Ag (ug/L)	T-As (ug/L)	T-Ca (mg/L)	T-Cd (ug/L)	T-Cu (ug/L)	T-Fe (mg/L)	T-Hg (ug/L)
LOWER BRUCEJACK CREEK																
01-Sep-08	-	7.7	86	46	<3	35	16	1	22	<0.1	<1	12.9	0.2	3	0.15	<0.2
00-Sep-20	7.6	7.6	82	64	4	33	19	1	18	<0.1	1.9	12.0	<0.2	2	0.24	<0.01
00-Aug-12	7.0	7.5	78	38	8	29	15	<0.5	19	<0.1	1.7	10.6	<0.2	2	0.22	<0.01
99-Sep-14	7.3	7.4	74	40	<3	32	16	1	17	0.4	1.2	0.0	0.2	4	0.24	<0.01
99-Sep-02	8.0	7.3	74	39	<3	30	15	1	18	0.5	1.2	11.9	<0.2	3	0.22	<0.01
99-Aug-25 Eskay	7.8	7.2	54	-	2	-	26	-	14	-	-	-	-	10	0.14	-
99-Aug-19	7.8	6.9	77	39	11	28	11	<0.5	22	0.5	2.3	10.6	0.3	7	0.42	<0.01
99-Aug-11 Eskay	7.5	7.6	77	-	13	-	14	-	29	-	-	-	-	<10	0.03	-
99-Aug-04	7.4	6.7	86	60	7	39	11	<0.5	30	0.5	3.0	14.6	0.5	10	1.00	<0.01
99-Jul-29 Eskay	6.7	6.7	66	-	14	-	12	-	23	-	-	-	-	20	0.85	-
99-Jul-12	7.5	7.6	80	56	8	32	13	<0.5	20	<0.1	2.0	11.9	0.2	5	0.74	<0.01
98-Jul-09	-	7.2	62	43	2	28	13	<0.5	13	<0.1	2.1	10.5	<0.2	4	0.43	<0.01
98-Jun-19	-	7.2	62	43	2	28	13	<0.5	13	<0.1	2.1	10.5	<0.2	4	0.43	<0.01
97-Aug-07	-	6.5	69	37	12	21	13	<0.5	15	<0.1	1.6	7.9	<0.2	2	0.21	<0.01
96-Sep-06	-	7.5	53	31	1	24	16	<0.5	9	0.1	1.4	8.8	<0.2	1	0.11	<0.01
95-Aug-25	-	7.4	56	29	12	21	15	<0.5	11	<0.1	0.3	9.1	<0.2	12	0.25	<0.01
94-Sep-27	7.8	7.0	53	30	34	22	15	<0.5	9	<0.1	3.5	8.3	<0.2	<1	<0.03	<0.01
94-Aug-31	7.6	7.3	46	28	12	21	15	<0.5	5	<0.1	2.4	8.2	<0.2	2	0.26	<0.01
94-Aug-15	7.5	7.0	50	29	6	22	16	<0.5	5	<0.1	2.3	8.8	<0.2	1	0.24	<0.01
94-Jul-27	-	7.1	50	29	4	23	16	<0.5	7	<0.1	1.5	9.1	<0.2	3	0.16	<0.01
94-Jun-29	-	7.0	65	37	6	26	16	<0.5	8	<0.1	1.8	9.8	<0.2	1	0.12	<0.01
93-Sep-22	-	7.3	62	39	5	27	16	1	11	<0.1	1.8	10.3	<0.2	3	<0.03	<0.01
93-Aug-16	-	7.3	48	29	4	22	16	<0.5	7	<0.1	2.1	8.2	<0.2	<1	0.13	<0.01
93-Jul-20	-	7.4	47	38	3	20	17	<0.5	6	<0.1	2.0	7.4	<0.2	<1	0.13	<0.01
93-Jul-06	-	7.4	48	35	4	17	15	<0.5	8	<0.1	1.6	6.5	<0.2	2	0.16	0.010
93-Jun-13	-	6.8	-	-	9	26	-	-	14	<15	2.0	9.6	11.0	3	0.28	-
93-May-28	6.6	6.3	62	50	<1	26	12	1	15	<0.1	1.7	47.7	<0.2	7	0.44	<0.01
92-Sep-21	-	6.6	46	30	5	21	17	<0.3	11	0.7	<3	7.0	<1	2	0.18	<5
92-Aug-19	-	7.3	51	44	6	21	17	1	7	0.4	<3	8.6	<1	<1	0.19	<10
92-Jul-23	-	7.2	49	59	12	23	20	<0.3	10	0.3	<3	8.4	<1	2	0.49	<0.05
91-Sep-15	-	7.6	107	86	21	46	31	<0.5	38	<0.1	0.9	-	-	<1	0.18	-
91-Jul-24	-	6.5	48	39	3	22	15	<0.5	6	<0.1	0.7	-	-	<1	0.20	-
89-Dec-13	-	7.8	86	70	15	23	24	<0.5	15	<0.1	3.9	-	-	<1	0.08	-
89-Aug-23	-	6.9	44	30	24	17	10	<0.5	9	<0.1	3.0	-	-	3	0.57	-
89-May-29	-	7.2	86	30	13	31	20	1	18	0.2	2.2	-	-	3	0.20	-
88-Oct-28	-	7.0	62	56	17	31	22	1	10	<0.1	1.9	-	-	<1	0.03	<0.05
88-Oct-03	-	6.8	50	40	21	30	17	<0.5	9	<0.1	2.0	-	-	-	0.04	-
88-Jul-28	-	7.2	44	49	34	24	14	<0.5	7	<0.1	1.5	-	-	<0.5	<0.03	-
88-Feb-09	-	6.8	45	30	8	22	16	<0.5	7	<0.1	3.6	-	-	<0.5	0.04	<0.05
87-Sep-25	-	7.6	64	56	111	27	19	<0.5	14	<0.5	2.2	-	-	<1	0.62	-
1987 - 1998																
Minimum	6.6	6.3	44	28	<1	17	10	<0.3	5	<0.1	0.3	6.5	<0.2	<0.5	<0.03	<0.01
Median	7.6	7.2	52	38	8	23	16	<0.5	9	<0.1	1.9	8.8	<0.2	2	0.18	<0.01
Maximum	7.8	7.8	107	86	111	46	31	1	38	<15	3.9	47.7	11.0	12	0.62	<10
1999 - 2001																
Minimum	6.7	6.7	54	38	<3	28	11	<0.5	14	<0.1	0.5	0.0	<0.2	2	0.03	<0.01
Median	7.5	7.4	77	43	7	32	15	<0.5	20	0.2	1.8	11.9	0.2	5	0.24	<0.01
Maximum	8.0	7.7	86	64	14	39	26	1	30	0.5	3.0	14.6	0.5	20	1.00	<0.2

Where applicable the data reported as < detection limit were used in the statistics.

Table 9. Site Water Quality Monitoring Results (Continued)															
Date	T-Mg	T-Mo	T-Pb	T-Zn	D-Ag	D-As	D-Ca	D-Cd	D-Cu	D-Fe	D-Hg	D-Mg	D-Mo	D-Pb	D-Zn
	(mg/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(mg/L)	(ug/L)	(ug/L)	(mg/L)	(ug/L)	(mg/L)	(ug/L)	(ug/L)	(ug/L)
LOWER BRUCEJACK CREEK (continued)															
01-Sep-08	0.60	<1	<1	<50	<0.1	<1	13.0	0.2	3	0.04	<0.2	0.60	<1	<1	<50
00-Sep-20	0.57	<1	<1	16	<0.1	1.4	12.1	0.2	<1	0.05	-	0.57	<1	<1	29
00-Aug-12	0.45	<1	<1	16	<0.1	1.0	10.8	0.2	<1	<0.03	-	0.42	<1	<1	19
99-Sep-14	0.48	<1	2	25	0.1	0.7	12.0	0.5	2	0.15	-	0.46	2	1	25
99-Sep-02	0.47	<1	2	25	<0.1	0.4	11.4	<0.2	1	0.06	-	0.44	<1	<1	22
99-Aug-25 Eskay	-	-	-	10	-	-	-	-	<10	0.05	-	-	-	-	50
99-Aug-19	0.46	<1	3	36	<0.1	0.4	10.4	0.1	3	0.09	-	0.45	<1	<1	32
99-Aug-11 Eskay	-	-	-	70	-	-	-	-	<10	0.01	-	-	-	-	70
99-Aug-04	0.55	<1	4	49	<0.1	0.5	14.7	0.5	5	0.32	-	0.53	<1	<1	48
99-Jul-29 Eskay	-	-	-	40	-	-	-	-	10	0.17	-	-	-	-	40
99-Jul-12	0.44	<1	3	29	<0.1	0.3	11.9	0.2	3	0.15	-	0.41	<1	<1	30
98-Jul-09	0.42	<1	1	18	<0.1	0.3	10.5	<0.2	3	0.09	-	0.39	<1	<1	16
98-Jun-19	0.42	<1	1	18	<0.1	0.3	10.5	<0.2	3	0.09	-	0.39	<1	<1	16
97-Aug-07	0.31	<1	<1	7	<0.1	0.5	10.5	<0.2	3	0.09	-	0.39	<1	<1	16
96-Sep-06	0.31	<1	<1	<5	0.1	0.8	9.0	<0.2	1	0.05	-	0.32	<1	<1	6
95-Aug-25	0.28	<1	<1	6	<0.1	0.3	9.2	<0.2	<1	<0.03	-	0.36	<1	<1	6
94-Sep-27	0.32	<1	<1	<5	<0.1	1.2	7.5	<0.2	<1	<0.03	-	0.27	<1	<1	<5
94-Aug-31	0.30	<1	<1	<5	<0.1	0.8	8.0	<0.2	<1	<0.03	-	0.24	<1	<1	<5
94-Aug-15	0.33	<1	21	<5	<0.1	1.1	8.2	<0.2	<1	0.04	-	0.28	<1	<1	<5
94-Jul-27	0.32	<1	<1	6	<0.1	0.9	8.9	<0.2	3	0.04	-	0.28	<1	<1	<5
94-Jun-29	0.35	<1	1	6	<0.1	1.6	9.3	<0.2	<1	0.06	-	0.35	<1	<1	6
93-Sep-22	0.40	<1	2	8	<0.1	0.8	10.1	<0.2	<1	<0.03	-	0.40	<1	<1	8
93-Aug-16	0.30	<1	<1	<5	<0.1	1.1	8.2	<0.2	<1	<0.03	-	0.30	<1	<1	<5
93-Jul-20	0.28	<1	<1	<5	<0.1	1.0	7.4	<0.2	<1	<0.03	-	0.27	<1	<1	<5
93-Jul-06	0.30	<1	1	6	<0.1	0.6	6.5	<0.2	1	0.05	-	0.30	<1	<1	6
93-Jun-13	0.38	<30	5	16	<15	0.4	9.6	<10	3	0.11	-	0.37	<30	2	16
93-May-28	0.42	<1	3	25	<0.1	<0.1	9.5	0.4	3	0.05	-	0.41	<1	<1	25
92-Sep-21	0.82	24	2	15	0.9	<3	5.8	<1	4	0.01	<5	0.90	18	4	15
92-Aug-19	<0.001	<1	<5	<50	0.4	<3	8.6	<1	<1	<0.03	<10	<0.001	<1	<5	<5
92-Jul-23	0.50	<1	<5	20	0.3	<3	8.1	<1	2	0.06	<0.05	0.32	<1	<5	10
91-Sep-15	-	<1	1	17	<0.1	0.7	16.6	-	<1	<0.03	-	1.10	<1	<1	10
91-Jul-24	-	<1	<1	7	<0.1	0.7	8.4	-	<1	<0.03	-	0.30	<1	<1	<5
89-Dec-13	-	3	4	<5	<0.1	2.8	8.6	-	<1	<0.03	-	0.42	2	3	<5
89-Aug-23	-	<1	2	9	<0.1	0.4	6.4	-	2	<0.03	<0.05	0.28	<1	<1	<5
89-May-29	-	<1	13	16	<0.1	0.7	-	-	0	<0.03	-	-	<1	2	14
88-Oct-28	-	<1	<1	<5	<0.1	1.4	-	-	<1	<0.03	<0.05	-	<1	<1	<5
88-Oct-03	-	<1	<1	<5	<0.1	1.8	-	-	-	<0.03	-	-	<1	<1	<5
88-Jul-28	-	<1	1	<5	<0.1	1.5	-	-	<0.5	<0.03	-	-	<1	<0.5	<5
88-Feb-09	-	<1	<0.5	<5	<0.1	1.2	-	-	<0.5	<0.03	<0.05	-	<1	<0.5	<5
87-Sep-25	-	<5	14	1	<0.5	1.6	-	-	<1	<0.03	-	-	<5	4	<5
1987 - 1998															
Minimum	<0.001	<1	<0.5	1	<0.1	<0.1	5.8	<0.2	0	0.01	<0.05	<0.001	<1	<0.5	<5
Median	0.32	<1	1	6	<0.1	0.9	8.6	<0.2	<1	0.02	<0.05	0.32	<1	<1	<5
Maximum	0.82	24	21	25	<15	2.8	16.6	<10	4	0.11	<10	1.10	18	4	25
1999 - 2001															
Minimum	0.44	<1	<1	10	<0.1	0.3	10.4	<0.2	<1	0.01	<0.2	0.41	<1	<1	19
Median	0.48	<1	2	25	<0.1	0.5	12.0	0.2	3	0.06	<0.2	0.46	<1	<1	30
Maximum	0.60	<1	4	70	0.1	1.4	14.7	0.5	10	0.32	<0.2	0.60	2	1	70
Where applicable the data reported as < detection limit were used in the statistics.															

Table 9. Site Water Quality Monitoring Results (Continued)

Date	pH	pH	Cond	TDS	TSS	Hard	Alk.	Cl	SO_4	T-Ag	T-As	T-Ca	T-Cd	T-Cu	T-Fe	T-Hg
	(Field)	(lab)	(uS/cm)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ug/L)	(ug/L)	(mg/L)	(ug/L)	(ug/L)	(mg/L)	(ug/L)
EAST STAND PIPE																
Minimum	3.7	3.4	232	172	<0.1	88	<0.1	<0.3	81	<0.1	0.4	33.2	0.4	<1	0.1	<0.05
Median	4.4	5.6	434	325	7	177	7	0	169	0.1	2.0	82.6	2.0	17	1.6	<0.01
Maximum	5.7	8.0	899	591	798	573	86	4	418	9.7	780	218	8.0	240	45.5	<10
WEST STAND PIPE																
Minimum	2.5	2.4	227	111	2	11	<0.05	<0.3	63	<0.1	0.5	12.7	2.0	<1	0.1	<0.01
Median	2.8	3.0	951	628	25	253	1	1	361	3.7	146	102	9.6	223	62.6	0.010
Maximum	3.0	7.2	2050	1618	522	642	50	16	1009	94.9	2440	228	95.0	2200	270.0	<10
WEST / R8 PORTAL																
1987 - June 1990																
Minimum	NA	7.5	307	270	31	33	52	<0.5	81	<0.1	10.0	NA	NA	<1	0.0	0.080
Median	NA	7.8	583	450	505	149	116	2	148	10.0	73.0	NA	NA	23	3.8	0.190
Maximum	NA	8.3	806	590	5320	209	356	31	339	880.0	610.0	NA	NA	1720	82.7	0.710
July 1990 - 2001																
Minimum	6.8	6.8	352	212	<1	115	59	<0.3	96	<0.1	0.6	37.1	<0.2	<1	<0.03	<0.01
Median	7.0	7.4	402	276	1	154	76	<0.5	120	<0.1	7.6	52.9	0.4	2	0.2	<0.01
Maximum	8.0	7.9	544	374	9	227	103	1	172	1.1	22.0	84.0	<10	23	1.0	<10
CAMP CREEK INFLOW																
Minimum	4.4	4.5	44	30	<1	18	<1.0	<0.3	13	<0.1	<0.1	3.7	<30	<30	<0.03	<0.01
Median	6.0	6.0	80	62	5	33	2	<0.5	35	<0.1	0.3	13.7	0.4	3	0.21	<0.01
Maximum	6.6	7.9	230	162	67	69	14	2	104	7.5	7.0	25.9	5.0	90	1.96	<10
CAMP CREEK OUTFLOW																
Minimum	5.3	5.4	54	33	2	19	<1.0	<0.5	9	<0.1	<0.1	7.6	<0.2	<1	<0.03	<0.01
Median	5.3	6.3	100	69	4	40	3	<0.5	25	<0.1	0.3	15.4	0.2	2	0.23	<0.01
Maximum	5.3	7.0	129	85	43	50	16	1	51	0.4	2.8	18.5	0.6	6	1.52	<0.01
LITTLE CAMP CREEK INFLOW																
Minimum	5.9	6.3	225	156	<1	111	14	<0.5	73	<0.1	0.2	42.2	1.5	3	0.19	<0.01
Median	6.5	6.6	366	257	2	175	25	<0.5	156	0.1	0.4	62.8	6.7	58	0.27	<0.01
Maximum	7.1	7.0	778	499	20	322	42	1	264	0.3	2.7	120.0	10.9	178	2.23	0.010
LITTLE CAMP CREEK OUTFLOW																
Minimum	2.7	4.2	83	55	<1	35	<1	<0.5	29	<0.1	0.4	12.9	<0.2	3	0.08	<0.01
Median	2.7	6.2	133	100	8	47	4	1	51	<0.1	0.9	17.6	0.6	8	0.53	<0.01
Maximum	2.7	6.7	207	130	42	70	11	1	79	0.5	20.4	27.0	2.2	76	6.54	<0.01
BRUCEJACK LAKE																
1988 - 1998																
Minimum	NA	6.8	44	20	<1	22	12	<0.5	4	<0.1	1.0	NA	NA	<0.5	<0.03	0.006
Median	NA	7.2	48	37	3	23	17	<0.5	5	<0.1	1.7	NA	NA	<1	0.09	<0.05
Maximum	NA	7.7	56	42	8	26	20	1	10	5.0	2.4	NA	NA	1	0.39	1.200
1999 - 2001																
Minimum	6.9	6.8	47	29	2	18	9	<0.5	8	<0.1	0.5	6.8	<0.2	<1	0.04	<0.01
Median	7.7	7.6	57	37	<3	27	17	<0.5	11	0.1	1.0	10.2	<0.2	<1	0.08	<0.01
Maximum	8.1	9.2	120	94	15	84	27	2	23	0.4	1.7	34.1	<0.2	20	0.19	<0.2
UPPER BRUCEJACK CREEK																
1987 - 1998																
Minimum	7.6	6.6	32	8	<1	14	11	<0.3	2	<0.1	0.5	4.8	<0.2	<0.5	<0.001	<0.005
Median	7.9	7.3	48	36	3	22	17	<0.5	6	<0.1	1.8	8.5	<0.2	<1	0.08	<0.01
Maximum	8.0	7.9	84	66	14	26	21	15	12	<15	15.0	13.5	<10	70	0.72	<10
1999 - 2001																
Minimum	6.4	7.1	44	15	<3	21	14	<0.5	7	<0.1	<1	6.8	<0.2	<1	0.03	<0.01
Median	7.5	7.6	59	31	<3	24	16	<0.5	10	0.1	1.3	8.9	<0.2	<1	0.08	<0.01
Maximum	8.1	8.5	63	54	7	27	21	1	13	0.4	1.7	10.3	<0.2	10	0.21	0.100
LOWER BRUCEJACK CREEK																
1987 - 1998																
Minimum	6.6	6.3	44	28	<1	17	10	<0.3	5	<0.1	0.3	6.5	<0.2	<0.5	<0.03	<0.01
Median	7.6	7.2	52	38	8	23	16	<0.5	9	<0.1	1.9	8.8	<0.2	2	0.18	<0.01
Maximum	7.8	7.8	107	86	111	46	31	1	38	<15	3.9	47.7	11.0	12	0.62	<10
1999 - 2001																
Minimum	6.7	6.7	54	38	<3	28	11	<0.5	14	<0.1	0.5	0.0	<0.2	2	0.03	<0.01
Median	7.5	7.4	77	43	7	32	15	<0.5	20	0.2	1.8	11.9	0.2	5	0.24	<0.01
Maximum	8.0	7.7	86	64	14	39	26	1	30	0.5	3.0	14.6	0.5	20	1.00	<0.2

Where applicable the data reported as < detection limit were used in the statistics.

Table 9. Site Water Quality Monitoring Results (Continued)															
Date	T-Mg (mg/L)	T-Mo (ug/L)	T-Pb (ug/L)	T-Zn (ug/L)	D-Ag (ug/L)	D-As (ug/L)	D-Ca (mg/L)	D-Cd (ug/L)	D-Cu (ug/L)	D-Fe (mg/L)	D-Hg (ug/L)	D-Mg (mg/L)	D-Mo (ug/L)	D-Pb (ug/L)	D-Zn (ug/L)
EAST STAND PIPE (continued)															
Minimum	1.23	<1	<1	33	<0.1	<0.1	18.0	<0.1	<1	<0.03	<0.01	0.83	<1	<1	13
Median	3.05	<1	22	130	<0.1	1.3	61.4	1.5	6	0.62	<0.05	2.77	<1	4	111
Maximum	7.05	28	360	784	0.7	31.0	215.0	4.9	249	10.70	<10	7.03	93	105	887
WEST STAND PIPE (continued)															
Minimum	0.82	<1	8	55	<0.1	<0.1	6.0	<1	<1	<0.03	<0.05	0.30	<1	<1	<5
Median	6.66	1	90	878	0.7	60.8	96.8	8.0	221	43.4	<5	5.01	<1	64	834
Maximum	14.70	50	939	5450	15.0	2390	198	92.0	1990	267	<10	14.60	50	566	4470
WEST / R8 PORTAL (continued)															
1987 - June 1990															
Minimum	NA	<1	<1	<5	<0.1	3.0	24.8	NA	<1	<0.001	<0.05	3.16	<1	<0.5	<5
Median	NA	12	240	130	<0.1	24.0	44.1	NA	1	<0.03	<0.05	4.34	6	1	5
Maximum	NA	93	1490	2310	270.0	95.0	64.6	NA	17	0.05	<0.05	6.12	20	96	69
July 1990 - 2001															
Minimum	3.71	<0.5	<1	16	<0.1	0.5	39.5	<0.2	<1	0.01	<0.05	3.89	<0.05	<1	<0.1
Median	5.19	1	6	46	<0.1	2.5	52.9	<0.2	<1	<0.03	1.300	5.22	1	<1	42
Maximum	6.60	13	12	255	1.5	15.0	92.3	<10	18	0.12	<10	7.39	22	8	242
CAMP CREEK INFLOW (continued)															
Minimum	0.19	<1	<1	6	<0.1	<0.1	6.5	<0.2	<1	<0.002	<0.05	0.27	<0.1	<1	<5
Median	0.73	<1	<1	32	<0.1	0.2	14.6	0.5	3	0.03	<0.2	0.70	<1	<1	30
Maximum	2.55	17	7	481	7.5	5.0	73.6	5.2	90	0.23	<10	2.74	15	7	517
CAMP CREEK OUTFLOW (continued)															
Minimum	0.32	<1	<1	6	<0.1	<0.1	7.0	<0.2	<1	0.02	-	0.31	<1	<1	11
Median	0.77	<1	1	33	<0.1	0.1	14.6	<0.2	3	0.05	-	0.73	<1	<1	36
Maximum	1.00	<1	2	51	0.1	0.8	18.5	0.6	6	0.11	-	0.91	<1	1	169
LITTLE CAMP CREEK INFLOW (continued)															
Minimum	1.58	1	1	120	<0.1	0.2	41.9	0.4	3	0.02	-	1.58	<1	<1	97
Median	2.98	1	7	766	<0.1	0.2	64.8	6.6	54	0.08	-	3.08	<1	2	784
Maximum	5.66	2	13	1350	0.1	0.9	120.0	10.7	172	0.48	-	5.51	2	8	1340
LITTLE CAMP CREEK OUTFLOW (continued)															
Minimum	0.56	<1	8	60	<0.1	0.2	0.0	<0.2	2	0.08	-	0.56	<1	4	59
Median	0.85	<1	16	64	<0.1	0.4	17.6	0.6	8	0.45	-	0.85	<1	13	62
Maximum	1.20	1	33	260	0.3	0.9	26.3	2.3	78	1.50	-	1.09	<1	23	260
BRUCEJACK LAKE (continued)															
1988 - 1998															
Minimum	NA	<0.1	<0.5	<0.5	<0.1	0.4	8.3	NA	<0.5	0.01	<0.05	0.31	<1	<0.5	<0.1
Median	NA	<1	<1	<5	<0.1	1.2	8.6	NA	<1	<0.03	<0.05	0.31	<1	<1	3
Maximum	NA	6	1	170	<1	2.3	8.9	NA	1	0.03	<5	0.31	1	4	7
1999 - 2001															
Minimum	0.27	<1	<1	<5	<0.1	0.3	6.6	0.1	<1	<0.03	<0.2	0.25	<1	<1	<5
Median	0.30	<1	1	5	<0.1	0.6	10.2	0.1	<1	<0.03	<0.2	0.29	<1	<1	5
Maximum	0.77	<1	2	25	<0.1	1.1	32.6	0.2	10	0.04	<0.2	0.71	<1	<1	<50
UPPER BRUCEJACK CREEK (continued)															
1987 - 1998															
Minimum	0.26	<1	<0.5	<0.5	<0.1	<0.1	4.3	<0.2	<0.5	<0.001	<0.005	<0.001	<1	<0.5	<5
Median	0.31	<1	<1	<5	<0.1	1.2	8.3	<0.2	<1	<0.03	<0.05	0.29	<1	<1	<5
Maximum	0.92	<30	3	21	<15	8.0	9.4	<1	<30	0.08	<10	0.52	<30	3	13
1999 - 2001															
Minimum	0.26	<1	<1	<5	<0.1	0.3	6.6	<0.2	<1	0.01	<0.2	0.25	<1	<1	<5
Median	0.29	<1	1	<5	<0.1	0.8	9.2	<0.2	<1	<0.03	<0.2	0.28	<1	<1	5
Maximum	0.35	2	3	<50	<0.1	4.0	10.3	<0.2	10	0.03	<0.2	0.31	<1	<1	<50
LOWER BRUCEJACK CREEK (continued)															
1987 - 1998															
Minimum	<0.001	<1	<0.5	1	<0.1	<0.1	5.8	<0.2	0	0.01	<0.05	<0.001	<1	<0.5	<5
Median	0.32	<1	1	6	<0.1	0.9	8.6	<0.2	<1	0.02	<0.05	0.32	<1	<1	<5
Maximum	0.82	24	21	25	<15	2.8	16.6	<10	4	0.11	<10	1.10	18	4	25
1999 - 2001															
Minimum	0.44	<1	<1	10	<0.1	0.3	10.4	<0.2	<1	0.01	<0.2	0.41	<1	<1	19
Median	0.48	<1	2	25	<0.1	0.5	12.0	0.2	3	0.06	<0.2	0.46	<1	<1	30
Maximum	0.60	<1	4	70	0.1	1.4	14.7	0.5	10	0.32	<0.2	0.60	2	1	70
Where applicable the data reported as < detection limit were used in the statistics.															

Table 10
Results from Shake Flask Testing Done on Weathered Waste Rock (Hallam Knight Piesold Ltd., 1999)

Sample Description		East Pipe	West Pipe	East Orepile	West Orepile	Portal Pipe	Yard-A	Yard-B	Yard-C	Yard-D	Average
pH		8.4	3.6	7.2	8.5	8.1	8.2	8.3	8.5	8.2	7.7
Conductivity	umhos/cm	284	2260	2150	210	521	228	415	220	750	782
Alkalinity	mg/L	87	<1	47	52	58	58	55	55	59	52
Acidity	mg/L	<1	200	8	<1	<1	<1	<1	<1	<1	23
SO_4	mg/L	72.7	1670	1420	52.3	197	53.1	146	48.8	355	446
Ag	mg/L	<0.0001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.001	<0.001
Al	mg/L	0.044	8.98	0.1	0.07	0.004	0.034	0.025	0.045	0.05	1.04
As	mg/L	0.002	0.02	<0.010	0.003	0.001	0.006	0.001	0.001	<0.01	0.006
Ba	mg/L	0.0506	0.0445	0.0205	0.0735	0.0443	0.0532	0.0327	0.0373	0.033	0.043
Be	mg/L	<0.001	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005
Bi	mg/L	<0.0001	<0.0005	<0.0005	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.001
Ca	mg/L	43.2	516	552	30.4	89.1	39	73.1	36.8	160.5	171.1
Cd	mg/L	0.0001	0.006	0.007	0.0003	0.0016	<0.0001	0.0001	0.0001	<0.001	0.002
Co	mg/L	0.00014	0.0422	0.0294	0.00014	0.00078	0.00016	0.00028	0.0001	0.0002	0.0082
Cr	mg/L	0.002	0.01	<0.005	0.0015	0.002	0.002	0.002	0.0025	<0.005	0.004
Cu	mg/L	0.0206	0.308	0.055	0.0165	0.0215	0.0376	0.0185	0.0216	0.023	0.058
Fe	mg/L	<0.01	49.5	0.2	<0.01	<0.01	<0.01	<0.01	<0.01	0.1	5.54
Hg	mg/L	<0.001	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01
K	mg/L	6.25	17.5	8	6.7	7.55	8.25	8.2	5.65	8	8.5
Mg	mg/L	1.055	1.32	2.22	1.455	1.795	0.935	1.68	0.459	1.54	1.38
Mn	mg/L	0.00665	0.948	10.12	0.0662	0.762	0.0261	0.016	0.005	0.079	1.336
Mo	mg/L	0.0396	0.015	0.003	0.1335	0.0118	0.0176	0.0368	0.0203	0.06	0.038
Na	mg/L	1	0.5	<0.5	2.45	0.25	1	0.45	4.15	0.5	1.2
Ni	mg/L	<0.0002	0.038	0.02	0.0002	0.0008	0.0002	0.001	0.0002	<0.002	0.007
P	mg/L	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<1.0
Pb	mg/L	0.002	0.1	<0.020	0.006	0.01	<0.002	0.002	0.004	<0.02	0.018
Sb	mg/L	0.0273	0.041	0.099	0.0486	0.0376	0.0109	0.01555	0.0377	0.203	0.058
Se	mg/L	0.001	<0.01	0.01	0.002	0.003	<0.001	<0.001	<0.001	<0.01	0.001
Sn	mg/L	0.0005	<0.005	<0.005	0.0005	<0.001	0.0005	0.0005	<0.001	<0.005	<0.005
Sr	mg/L	0.312	3.06	2.66	0.378	1.26	0.28	0.43	0.22	1.24	1.09
Ti	mg/L	<0.001	<0.01	<0.01	<0.001	0.001	0.003	0.003	0.003	<0.01	0.005
Tl	mg/L	<0.0001	<0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.001	<0.001
U	mg/L	0.00035	0.0005	<0.001	0.0005	0.00035	0.0001	0.00015	0.0001	0.0005	0.0003
V	mg/L	<0.001	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01
Zn	mg/L	0.006	2.21	0.505	0.0065	0.0335	0.0025	0.01	0.0055	0.015	0.31

Notes - Dissolved Metals
- Samples were sieved and 100g of the .2mm size fraction was tested in 300 ml of deionized water
- Analysis by Chemex Labs, Vancouver, 1999
- Average values were determined by assuming that the value in the samples was one half the detection limit
- In cases where there is a mixed detection limit the value was taken as the highest of the detection limits

Table 11. Projected Loadings From Waste Rock and Impacts on Brucejack Lake Water Quality Using the Average Waste Rock Shake Flask Data (Hallam Knight Piesold Ltd., 1999)

Sample Volume = 300 ml		Mass of Sample = 100 g		Brucejack Lake Water Quality (mg/L)	Projected Lake Loading (kg)	Combined Loading (kg)	Resulting Lake Water Quality (mg/L)
Lake Volume = 29×10^6 m^3		Mass of Waste = 124,000 t					
Parameter	Sample Analysis (mg/L)	Loading from Sample (mg/100g)	Projected Loading from Waste (kg)				
pH	7.7			7.9			
Conductivity	782			44.3			
Alkalinity	52	16	10788	21	609000	619788	21
Acidity	23	7					
SO_4	446	134	165949	4.6	133400	299349	10.3
Ag	<0.001			<0.0005			
Al	1.04	0.31	387				
As	0.006	0.002	2	0.0022	63.8	66	0.0023
Ba	0.043	0.013	16				
Be	<0.005						
Bi	<0.001						
Ca	171.1	51	63657	7.34	212860	276517	9.54
Cd	0.002	0.001	1	0.0005	14.5	15	0.0005
Co	0.0082	0.0024	3				
Cr	0.004	0.001	1				
Cu	0.058	0.017	22	0.0007	20.3	42	0.0014
Fe	5.54	1.66	2061	0.002	58	2119	0.073
Hg	<0.01			0.00005	1.45		
K	8.5	2.5	3145	0.07	2030	5175	0.18
Mg	1.38	0.42	515	0.28	8120	8635	0.3
Mn	1.336	0.401	497	0.0049	142.1	639	0.022
Mo	0.038	0.011	14				
Na	1.2	0.4	446	0.36	10440	10886	0.38
Ni	0.007	0.002	3				
P	<1.0						
Pb	0.018	0.006	7	0.001	29	36	0.001
Sb	0.058	0.017	22				
Se	0.004	0.001	2				
Sn	<0.005						
Sr	1.09	0.33	407				
Ti	0.005	0.001	2				
Tl	<0.001						
U	0.0003	0.0001	0				
V	<0.01						
Zn	0.31	0.09	115	0.0009	26.1	142	0.0049

Notes
- Dissolved Metals
- Lake volume obtained from Stage 1 Report
- Maximum lake water quality values obtained from Stage 1 Report
- Values below the detection limit were not extrapolated into loadings
- Acidity loading from the sample was subtracted from alkalinity loading from the sample prior to calculation of the projected alkalinity loading, combined loading, and resulting lake water quality.

Table 12. Projected Loadings From Waste Rock and Impacts on Brucejack Creek Water Quality Using the Average Waste Rock Shake Flask Data (Hallam Knight Piesold Ltd., 1999)

Sample Volume = 300 ml			Mass of Sample = 100 g	Brucejack Creek Water Quality (mg/L)	Projected Creek Loading (kg)	Combined Loading (kg)	Resulting Creek Water Quality (mg/L)
Volume (2.88 m^3/s) = 29.8 x 10^6 m^3			Mass of Waste = 124,000 t				
Parameter	Sample Analysis (mg/L)	Loading from Sample (mg/100 g)	Projected Loading from Waste (kg)				
pH	7.7			7.5			
Alkalinity	52	16	10788	16.9	505310	516098	17.3
Acidity	23	7					
SO_4	446	134	165949	5.3	158470	324419	10.9
Ag	<0.001			<0.0001			
Al	1.04	0.31	387				
As	0.006	0.002	2	0.0018	54	56	0.0019
Ba	0.043	0.013	16				
Be	<0.005						
Bi	<0.001						
Ca	171.1	51	63857				
Cd	0.002	0.001	1				
Co	0.0082	0.0024	3				
Cr	0.004	0.001	1				
Cu	0.058	0.017	22	0.0001	3	25	0.0008
Fe	5.54	1.66	2061	0.018	538	2599	0.087
Hg	<0.01						
K	8.5	2.5	3145				
Mg	1.38	0.42	515				
Mn	1.336	0.401	497				
Mo	0.038	0.011	14	0.001	30	44	0.001
Na	1.2	0.4	446				
Ni	0.007	0.002	3				
P	<1.0						
Pb	0.018	0.006	7	0.0005	15	22	0.0007
Sb	0.058	0.017	22				
Se	0.004	0.001	2				
Sn	<0.005						
Sr	1.09	0.33	407				
Ti	0.005	0.001	2				
Tl	<0.001						
U	0.0003	0.0001	0				
V	<0.01						
Zn	0.31	0.09	115	0.0025	75	190	0.0064

Notes
- Dissolved Metals
- Creek Volumes obtained from the Stage 1 Report for average mean monthly flows for the four months of June,
- July, August and September assuming East Lake outflow to Brucejack Lake
- Projected mean monthly flows of 2.88 m^3/s for Brucejack Creek upstream and downstream of Sulphurets over four months
- Projected metal loadings to Brucejack Creek based on four months at average discharge of 2.88 m3/s (Stage 1 Report)
- Brucejack Creek water quality values at Brucejack Lake outlet obtained from Stage 1 Report, assuming values of one half the detection limit
- Values of below the detection limit were not extrapolated into loadings
- Acidity loading from the sample was subtracted from alkalinity loading from the sample prior to calculation of the projected alkalinity loading, combined loading, and resulting lake water quality.

Table 13. Projected Loadings From Waste Rock Disposal and Impacts on Brucejack Lake Water Quality Using the West Standpipe Waste Rock Shake Flask Data (Hallam Knight Piesold Ltd., 1999)

Sample Volume = 300 ml		Mass of Sample = 100g		Brucejack Lake Water Quality (mg/L)	Projected Lake Loading (kg)	Combined Loading (kg)	Resulting Lake Water Quality (mg/L)
Lake Volume = 29 x 10^6 m^3		Mass of Waste = 124,000 t					
Parameter	Sample Analysis (mg/L)	Loading from Sample (mg/100g)	Projected Loading from Waste (kg)				
pH	3.6			7.9			
Alkalinity	<1			21	609000	534600	18
Acidity	200	60	74400				
SO_4	1670	501	621240	4.6	133400	754640	26
Ag	<0.001			<0.0005			
Al	8.98	2.694	3340.56				
As	0.02	0.006	7.44	0.0022	63.8	71.24	0.0025
Ba	0.0445	0.01335	16.554				
Be	<0.005						
Bi	<0.0005						
Ca	516	154.8	191952	7.34	212860	404812	14
Cd	0.006	0.0018	2.232	0.0005	14.5	16.732	0.0006
Co	0.0422	0.01266	15.6984				
Cr	0.01	0.003	3.72				
Cu	0.308	0.0924	114.576	0.0007	20.3	134.876	0.0047
Fe	49.5	14.85	18414	0.002	58	18472	0.64
Hg	<0.01			0.00005	1.45		
K	17.5	5.25	6510	0.07	2030	8540	0.29
Mg	1.32	0.396	491.04	0.28	8120	8611.04	0.30
Mn	0.948	0.2844	352.656	0.0049	142.1	494.756	0.0171
Mo	0.015	0.0045	5.58				
Na	0.5	0.15	186	0.36	10440	10626	0.37
Ni	0.038	0.0114	14.136				
P	<1.0						
Pb	0.1	0.03	37.2	0.001	29	66.2	0.0023
Sb	0.041	0.0123	15.252				
Se	<0.01						
Sn	<0.005						
Sr	3.06	0.918	1138.32				
Ti	<0.01						
Tl	<0.001						
U	0.0005	0.00015	0.186				
V	<0.01						
Zn	2.21	0.663	822.12	0.0009	26.1	848.22	0.0292

Notes - Dissolved Metals
- Lake volume obtained from Stage 1 Report
- Maximum lake water quality values obtained from Stage 1 Report
- Values below the detection limit were not extrapolated into loadings

Table 14
Rinse pH, Lime Added and Receiving Environment pH During Excavation of Waste Rock (McLeod, 1999)

Date	Grid Location	Rinse pH	Lime Added		Brucejack Lake	Upper Brucejack Creek	Lower Brucejack Creek
			Shift	Kg	pH	pH	pH
12/07/99	36+42	6.50					
13/07/99					7.60	7.60	7.50
26/07/99	26+27	8.90					
27/07/99	3+4	6.82			7.41	6.89	6.85
28/07/99	2+3+4	6.76	Day	12	7.16	7.26	6.17
29/07/99	1+2+3+4	7.33	Day	40	7.07	7.00	6.71
29/07/99	25+26+27	8.18	Night	12			
29/07/99	31+32+36	7.89					
30/07/99	25+26+27	7.37	Day	30	7.10	7.20	7.04
30/07/99	1+2+3+4	3.32	Night	48			
30/07/99	1+2+3+4	3.34					
31/07/99	26+27	8.39	Day	60	7.12	7.40	6.58
31/07/99			Night	100			
01/08/99	5+6+9	6.31	Night	5	7.52	7.10	6.62
01/08/99	26+27	8.30					
02/08/99	15+16+17	7.91	Day	10	7.56	6.99	6.41
02/08/99			Night	30			
03/08/99	25+26+27	8.31			7.39	7.17	6.52
04/08/99	30+31+32	7.35			6.92	6.64	7.21
05/08/99	5+6+7	6.20	Day	25	7.21	6.56	7.02
05/08/99	5+6+7	4.09	Night	40			
06/08/99	7-10-14	6.91	Day	25	6.82	6.48	6.93
06/08/99	18-23-28	6.38	Night	25			
06/08/99	33-39-45-51	5.61					
06/08/99	35-36-37	3.39					
07/08/99	35-36-37	6.10	Day	10	7.59	7.72	7.10
07/08/99	7-8-10	7.16	Night	25			
07/08/99	9-13-18-23	6.73					
07/08/99	28-33-39-45	3.60					
07/08/99	50-55-56	7.15					
08/08/99	41-42-43	8.61			7.70	7.70	7.80
08/08/99	55-60-65	7.90					
08/08/99	64-68-69	7.10					
09/08/99	56-61-66	7.40			7.50	7.30	6.60
09/08/99	47-48-49	8.20					
09/08/99	53-54-59	8.90					
10/08/99	53-54-59	9.00	Day	10	7.10	6.70	7.10
10/08/99	41-42-43	8.10					
11/08/99	12+16	6.80			7.60	7.60	7.50
11/08/99	20+21	7.00					
12/08/99	12+16+17	7.60			7.60	7.80	7.50
12/08/99	22+27+32	9.00					
12/08/99	43+49+54	5.10					
12/08/99	25+26+27	8.10					
13/08/99	17-22-27	6.70			7.70	7.60	7.40

Table 14 (Continued)
Rinse pH, Lime Added and Receiving Environment pH During Excavation of Waste Rock (McLeod, 1999)

Date	Grid Location	Rinse pH	Lime Added		Brucejack Lake	Upper Brucejack Creek	Lower Brucejack Creek
			Shift	Kg	pH	pH	pH
13/08/99	32-37-43	7.40					
14/08/99	20-21-22	5.80			7.40	7.60	7.30
14/08/99	25-26-27	7.90					
14/08/99	27+32+37	4.20					
15/08/99	25-26-27	6.80	Night	20	7.60	7.70	7.30
16/08/99	35-36-37	8.18	Night	20	7.29	7.37	7.21
16/08/99	41-42-43	7.12					
17/08/99	47-48	7.02			7.90	8.00	7.60
18/08/99	56-57	7.90			7.70	7.80	7.60
19/08/99	41-47-53	8.10			7.40	7.40	7.60
20/08/99	56-57	4.40			7.40	7.30	7.90
20/08/99	15-20	6.80					
21/08/99	23-28	4.50	Day	20	7.40	7.20	7.40
21/08/99	24-29	6.00					
22/08/99			Day	10	7.80	7.90	8.00
23/08/99	24-29-34	4.90			7.90	7.90	8.00
23/08/99	19-20	6.20					
24/08/99	34-40	8.60			7.80	7.80	7.30
24/08/99	46-52	8.20					
24/08/99	33+39	8.00					
24/08/99	45+51	6.60					
25/08/99	51+52	5.90			8.10	8.00	7.50
26/08/99	68+69	7.60			8.30	8.40	7.40
27/08/99					8.30	6.90	8.40
28/08/99					8.10	8.10	8.00
29/08/99					8.30	8.30	8.40
30/08/99					7.90	7.90	8.00
Total				577			
Average		6.87			7.56	7.45	7.32
Maximum		9.00			8.30	8.40	8.40
Minimum		3.32			6.82	6.48	6.17
Median		7.11			7.56	7.40	7.30

Table 15 1999 Flow Data for Site (McLeod, 1999)				
Date	Brucejack Creek (m^3/s)	Camp Creek (m^3/s)	Little Camp Creek (m^3/s)	Portal (m^3/s)
1999/07/13	6.66	0.040	0.002	0.002
1999/07/29	4.99			
1999/08/04	4.44	0.020	0.001	0.00045
1999/08/11	3.63			
1999/08/19	3.33			
1999/08/25	3.63			
1999/09/02	3.07	0.020		0.001
1999/09/14	3.07	0.020		0.001

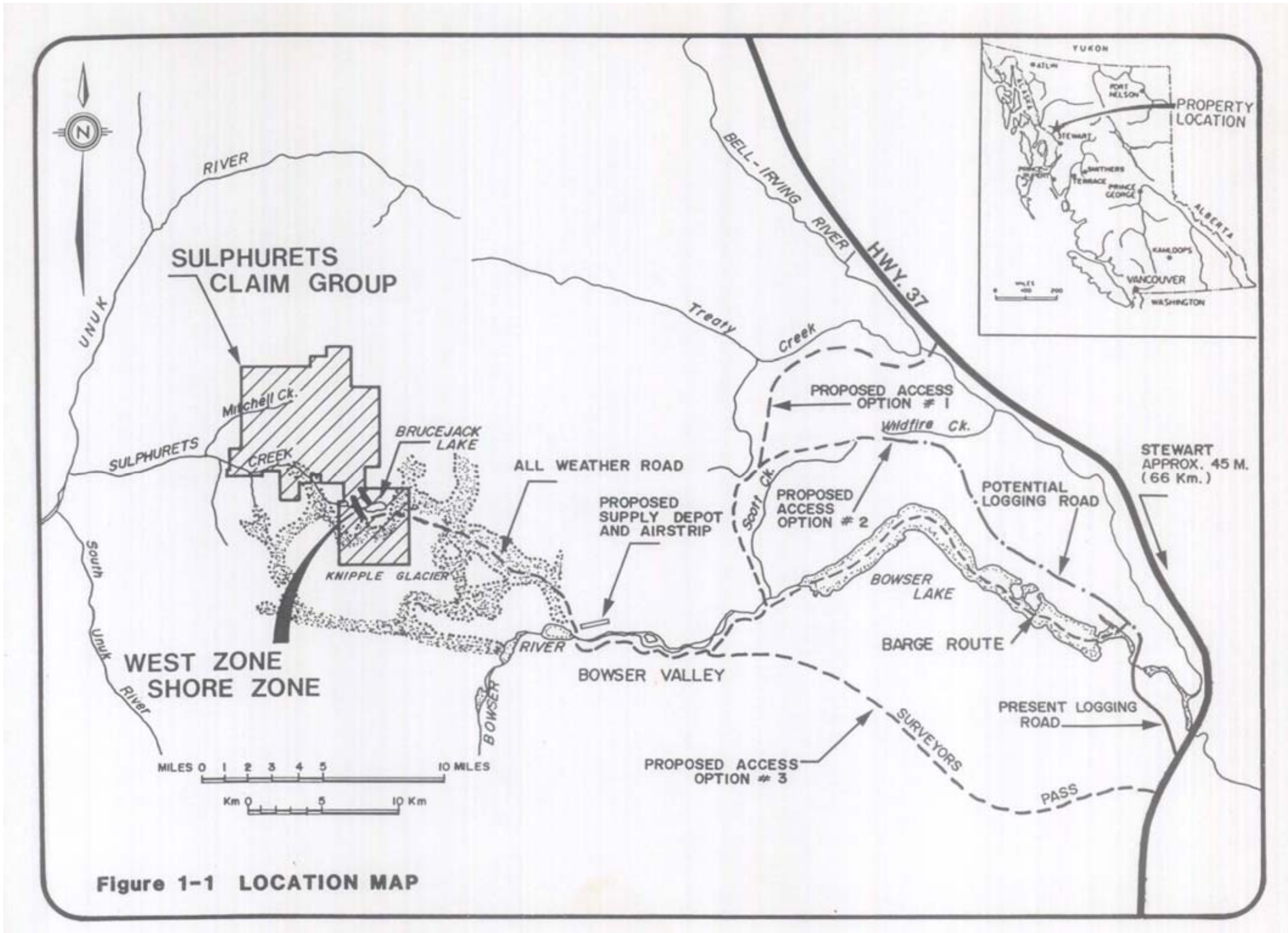

Figure 1-1 LOCATION MAP

Figure 1. Maps showing the location of Sulphurets Project (from Newhawk Gold Mines Ltd., 1989a).

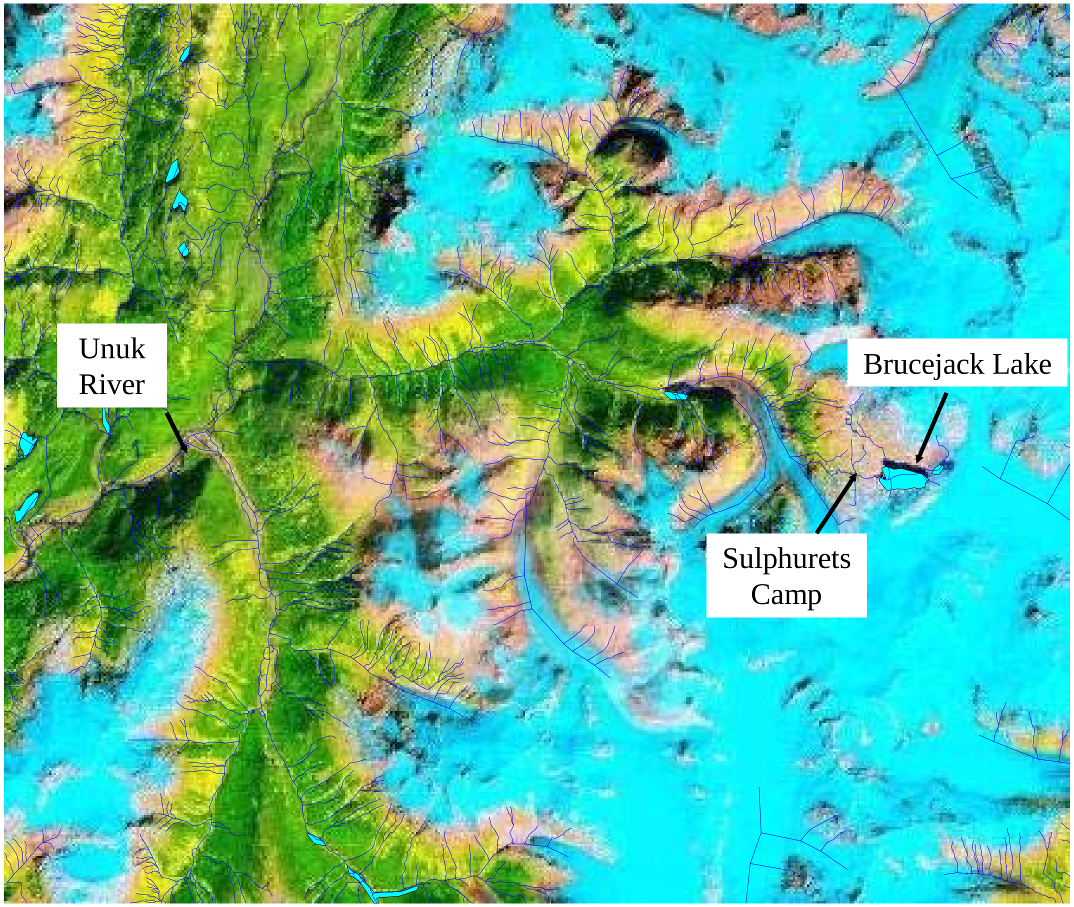

Figure 2. The Landsat image of the Sulphurets area shows the watercourses and the large area covered by glaciers.

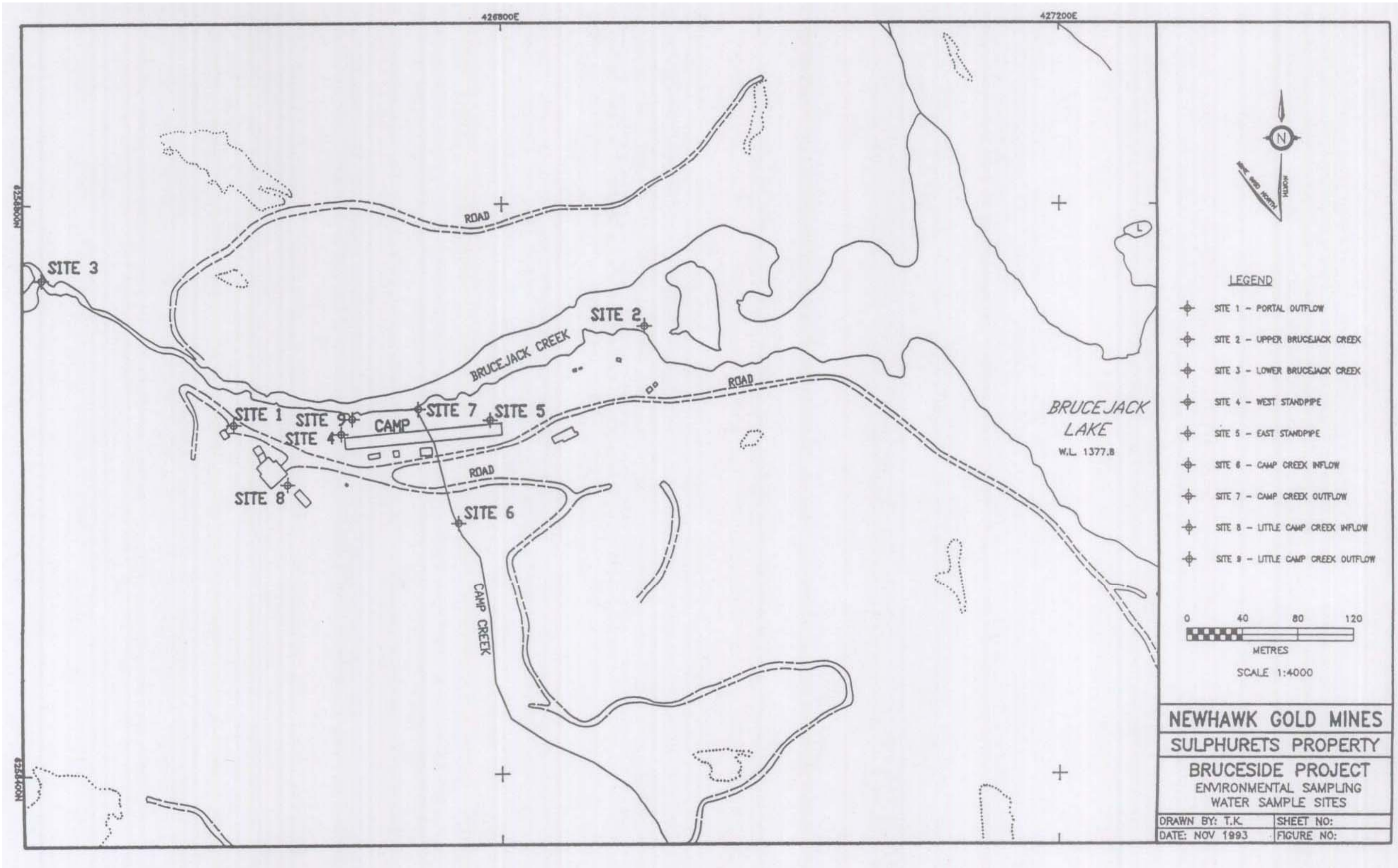

Figure 3. Map of the Sulphurets site showing the locations of the water monitoring stations (Hallam Knight Piesold Ltd., 1998)

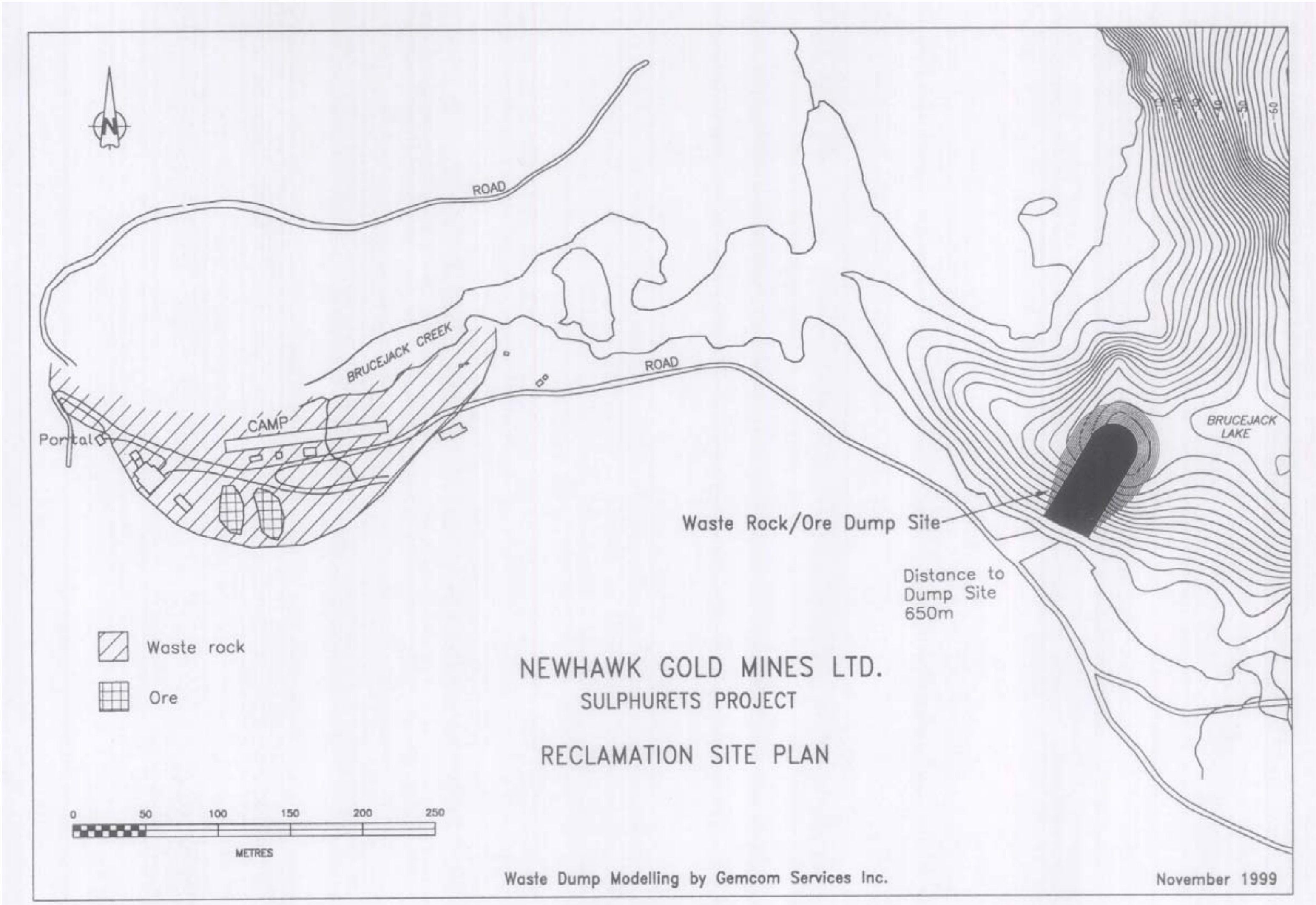

Figure 4. Map of the Sulphurets site, showing locations of the waste rock pad and lake disposal (McLeod, 1999).

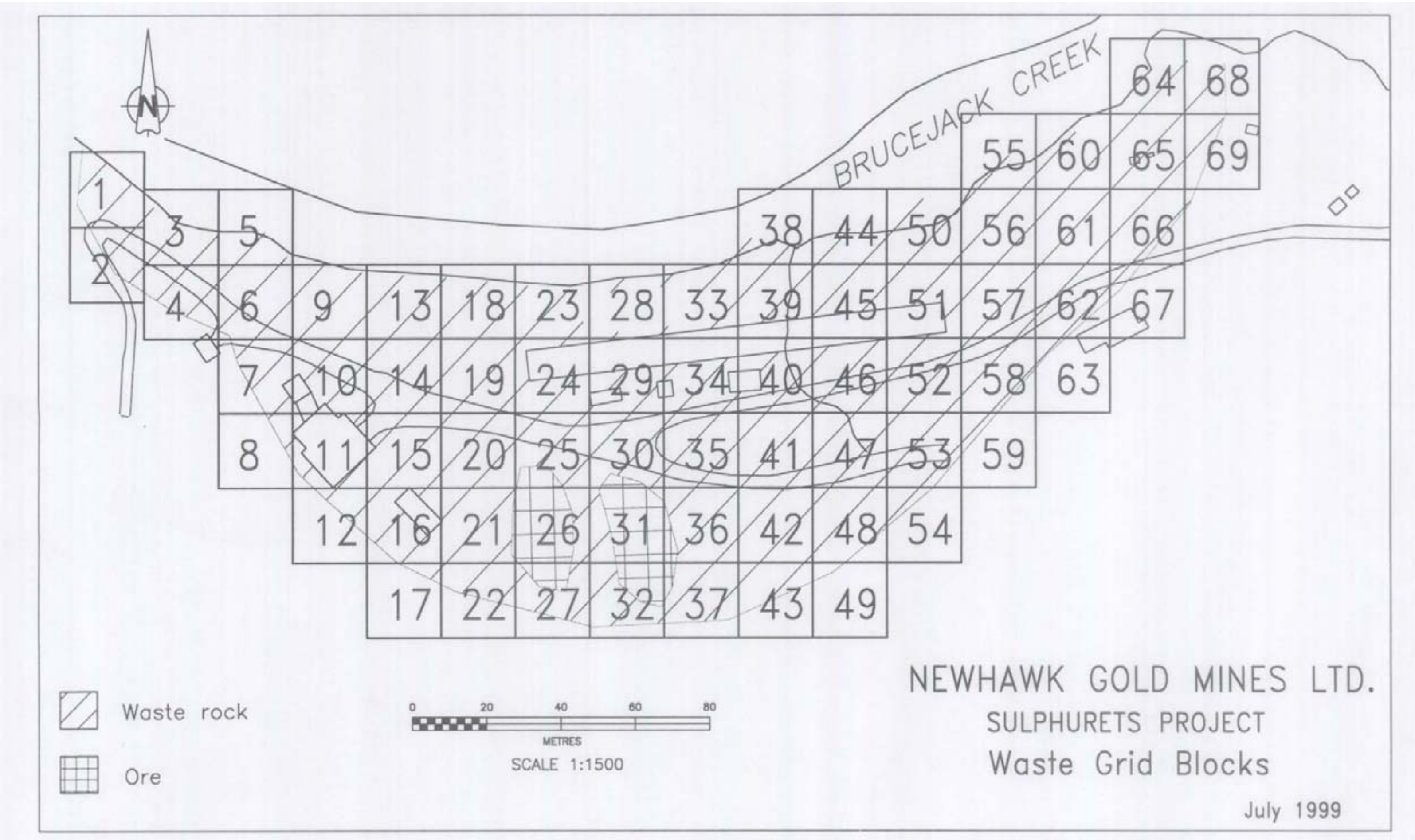

Figure 5. Waste rock grids used for measuring rinse pH (McLeod, 1999).

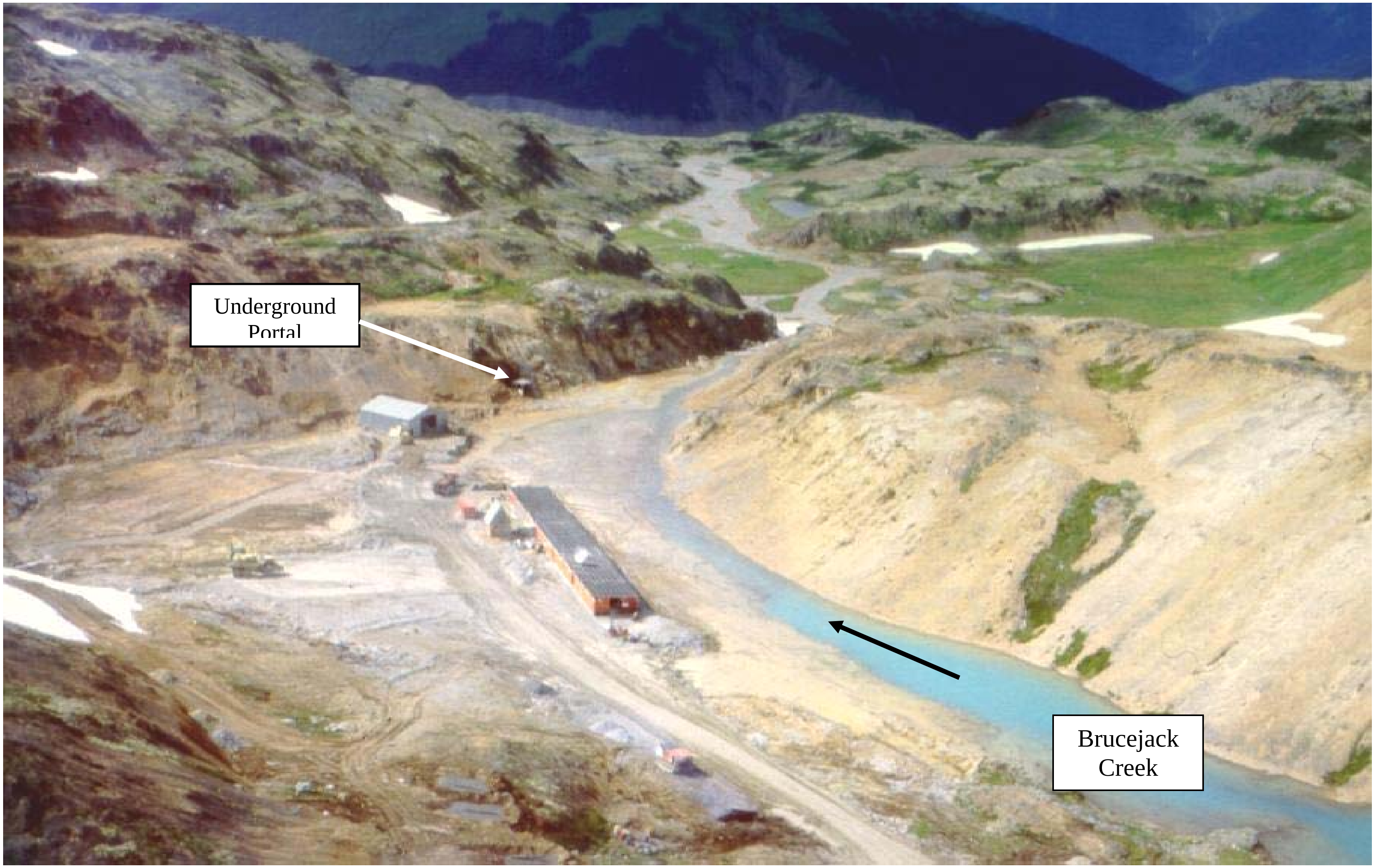

Photo 1. The Sulphurets Camp is located adjacent to Brucejack Creek, on a pad of waste rock excavated from the underground workings.

Photo 2. Brucejack Creek discharges into the Sulphurets Glacier just below the Sulphurets Camp.

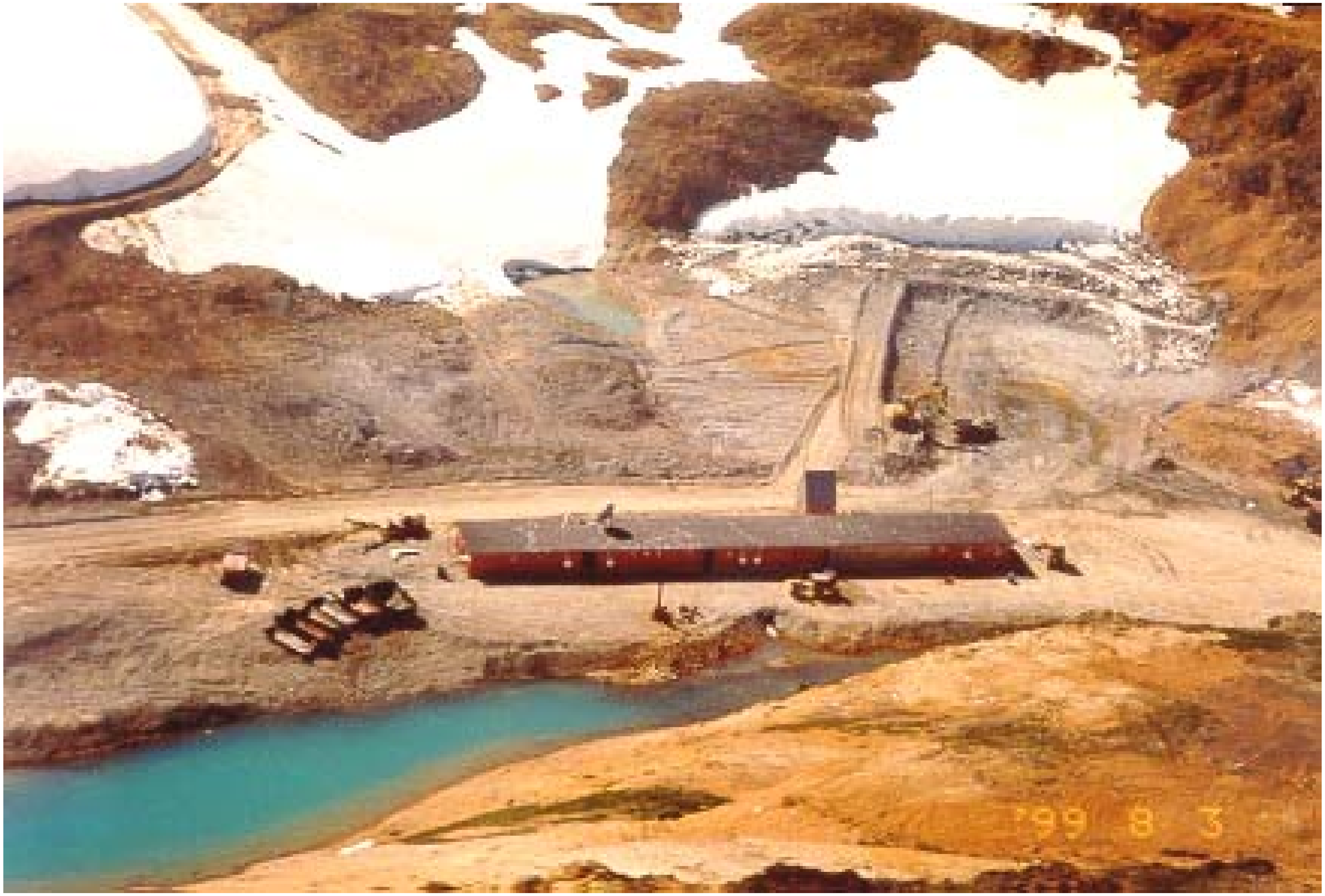

Photo 3. Waste rock excavation was a truck and shovel operation. Note the relatively unweathered, grey colour of the waste rock compared to the weathered, iron-stained colour of the surrounding undisturbed, sulphidic rock.

Photo 4. Waste rock deposition in Brucejack Lake.

Photo 5. During waste rock disposal, a fence was set up at the mouth of Brucejack Creek to catch floating debris.

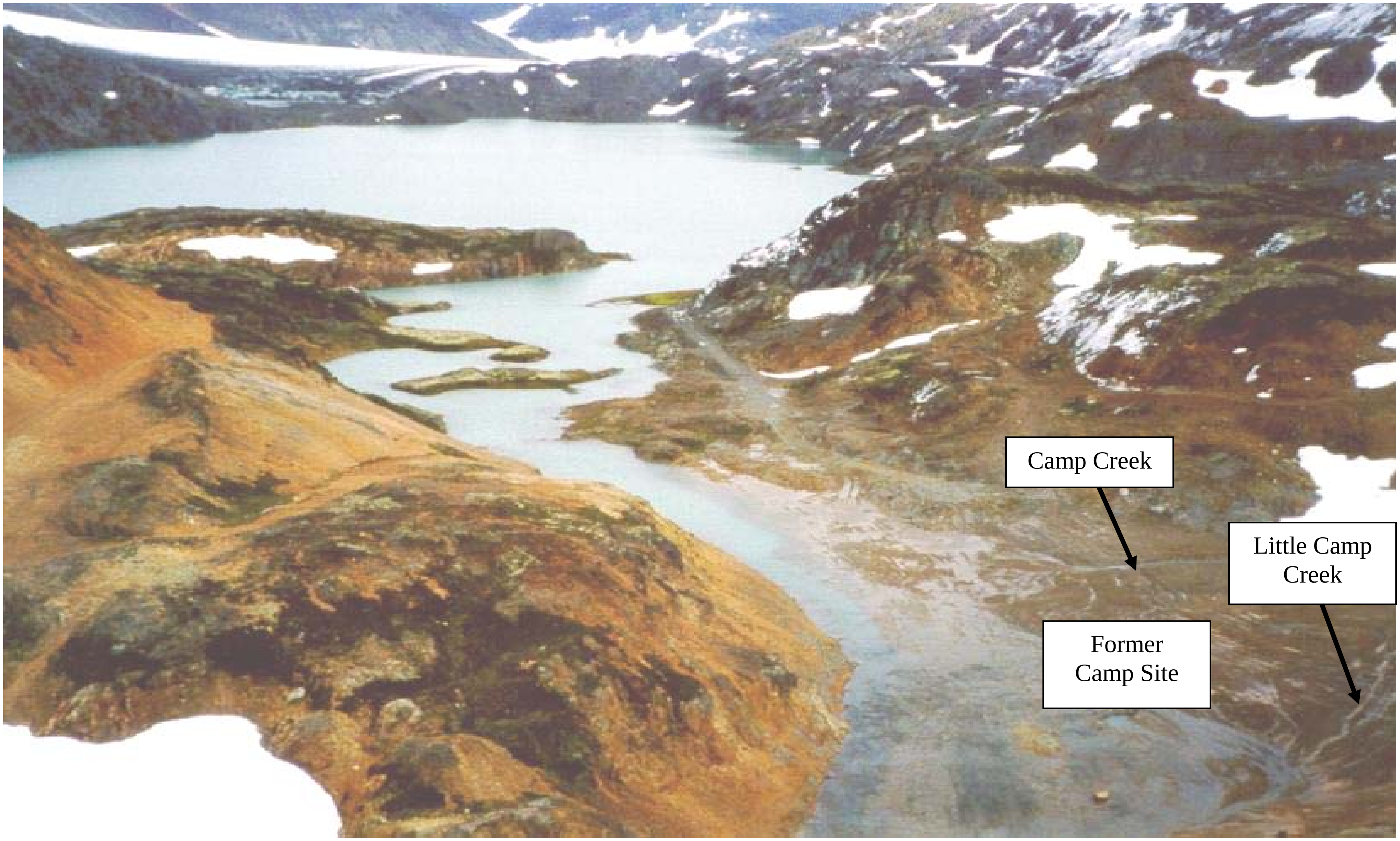

Photo 6. Brucejack Lake and the former campsite after waste rock removal and disposal in Brucejack Lake.