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Review of 2004 Waste Rock Storage Area Seepage and Waste Rock Survey Report, prepared for Ekati Mine by SRK

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1.0 Introduction

1.1 Objectives of the Waste Rock Storage Area Seepage and Waste Rock Survey Report

The stated objectives of the annual Waste Rock Storage Area Seepage and Waste Rock Survey Report (The Report) are to present the results of:

- Monitoring of water quality in three mining (Panda-Koala-Beartooth, Misery and Fox) and two reference (Beartooth-Bearclaw and Sable) areas
- Geochemical characterization of waste rock from four pits (Beartooth, Koala North and South, Misery and Fox)
- Monitoring of thermal conditions for Panda-Koala-Beartooth WRSA[1], Misery WRSA and Coarse Kimberlite Reject SA

Seepage monitoring is a requirement of the Water License N7L2-1616, BHP Billiton. Characterization of the waste rock is a requirement of the Waste Rock and Ore Storage Management Plan.

Additional seepage, soil and waste-related studies in 2004, included: an MSc. Thesis Evaluating the Potential Use of Processes Kimberlite to Sequester CO2, three MSc. Theses addressing permafrost issues, an MSc. Thesis on The Response and Resilience of Arctic Soils Exposed to Nitrogen, the Long-Lake Containment Facility Downstream Dilution Study and Ekati Mine Processed Kimberlite Containment Facility – Summary of Lessons Learned from 5 Years Performance Review. None of these studies were referenced in The Report. In 2003, SRK conducted detailed monitoring in the vicinity of SEEP-018 and SEEP-019 to better understand the cause of the observed depression of seepage pH.

> *Recommended Action:* The *Report* should include a list of ongoing studies and relevant previously produced reports.

1.2 Objectives of This Review

The review was conducted at the request of the Independent Environmental Monitoring Agency for the Ekati Mine. The terms of reference for the review were as follows:

1) Using the CANMET-MMSL review of the 2003 Seepage Report as background material, complete a technical review of BHPB's 2004 Seepage Report and determine:

- the extent to which the recommendations from the review of the 2003 Seepage Report were incorporated into the methodology and analysis used in the 2004 Seepage Report;
- if the analysis is based on the data provided;
- if the conclusions are fairly drawn from the analysis made;
- if the appropriate recommendations have been made for future work and/or management action;
- if there are emerging issues that might be drawn to the attention of the Agency; and
- the advisability of reviewing future seepage reports.

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[1] WR: waste rock
SA: storage area

2) Review the most recent Waste Rock Management Plan (February 2000) and Addendum #1 (related to Fox Waste Rock) and determine:

- if the seepage reports reflect the same management regime as in the plans, and if the predictions from the management plans are confirmed by the seepage reports.

3) Contact BHPB's consultants to seek any clarification that may be necessary while reviewing the 2004 Seepage Report, prepare a written report of your analysis and include suggestions or recommendations for improving the report, the analysis of data or the monitoring programs and any other issues in accordance with communications with Director Tony Pearse and/or Manager Kevin O'Reilly.

In addition to the 'Waste Rock Storage Area Seepage and Waste Rock Survey Report', information was obtained from:

- BHP Billiton. Feb 2000. Waste Rock and Ore Storage Management Plan. Ekati Diamond Mine.
- BHP Billiton. June 2002. Waste Rock and Ore Storage Management Plan (for Fox Pit). Ekati Diamond Mine.
- BHP Billiton. March 2003. 2002 Waste Rock Storage Area Seepage and Waste Rock Survey Report. Ekati Diamond Mine.
- BHP Billiton. 2004. 2003 Waste Rock Storage Area Seepage and Waste Rock Survey Report. Ekati Diamond Mine.
- BHP Billiton. April 2005. Environmental Agreement and Water Licenses - Annual Report 2004. Ekati Diamond Mine.
- Day, S., K. Sexsmith and J. Millard. 2003. Acidic Drainage from Calcareous Coarse Kimberlite Reject, Ekati Diamond Mine, Northwest Territories, Canada, 6th ICARD, Cairns, QLD, July 12 –18
- IEMA. 2002-2003 and 2003-2004 Technical Annual Reports.
- Norecol, Dames and Moore. 1997. Acid/Alkaline Rock Drainage (ARD) and Geochemical Characterization Program. December 31.

Draft review comments were circulated to Kevin O'Reilly and Tony Pearse of IEMA and Stephen Day of SRK. Comments from Stephen that were not resolved remain inserted (e.g., Comment [SD1]: ….).

1.3 The Monitoring Objectives

The purposes for seepage, waste composition and mitigation (freezing) monitoring are to[2]:

- verify pre-mining predictions of the composition of the waste materials, the resulting weathering, the performance of mitigation measures (freezing), and the resulting drainage chemistry;
- determine if the present monitoring is adequate and what refinements are required;
- show that the mine is presently meeting the discharge limits and protecting the environment; and
- identify information gaps and concerns regarding future ability to protect the environment and reclaim the site and, if required, where refinements are required to the

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[2] The list of reasons is based on my experience at other mines.

waste disposal and mitigation plans, what those refinements should be and / or what additional studies or monitoring information are required.

1.4 Mine Plan and Waste Materials

The Ekati mine started production in November 1998. Mining has been and will in the future primarily be from open pits. The exceptions are the planned underground mining below the Panda and Koala open pits. BHPB has indicated to the monitoring agency that an increasing part of their ore will come from underground operations unless there are some new finds (this statement seems to contradict the previous one) (Kevin O'Reilly pers. comm.). Bedrock is broken apart using 311 mm diameter drill holes on roughly a 7.5 m grid and blasting with ANFO.

Waste materials include waste rock, processed kimberlite (coarse and fines) and naturally unconsolidated surficial materials (i.e., till and lake sediments). Rock types in the waste rock are also exposed in mine walls and the resulting talus. Two hundred and eighteen tonne trucks are used to remove blasted waste rock to the waste rock storage areas (WRSA) adjacent to each pit.

The majority of the waste rock is granitic rock containing low concentrations of sulphide-S and potentially problematic trace metals, and little or no carbonate. The other forms of waste rock have higher sulphide and trace element concentrations: kimberlite and black clay in the Koala pipe waste rock, biotite schist and diabase in the Misery waste rock, and minor amount of diabase and kimberlite in the Fox waste rock. Pre-mine ABA data and humidity cell tests indicated that a portion of the biotite schist and diabase waste rock was potentially ARD generating (Norecol Dames and Moore, 1997).

Leachate chemistry from the various rock units were predicted using short-term humidity cell rates and assuming the majority of the rock was granite, reactions rates in the field were 4 times lower than observed in the humidity cells due to lower temperature and only 10% of the waste rock was leached. An exception was made regarding the lower reaction rates for the Misery Schist due to the potential heat from sulphide oxidation. The predicted drainage chemistry for the Panda/Koala WRSA was pH 7.5 – 8.5, Al 0.5 – 1.0 mg/L and Zn > Cu > Pb > As > Ni.

The overburden consists of till and lake bottom sediments. Most of the focus has been on lake bottom sediments, which are quite fine, have a high water content and unless they are frozen, difficult to handle. The disposal plan for till and lake sediments was placement in areas with drainage control and surrounded by waste rock. According to some reports, the pH of the lake sediments is typically from 5 to 6, although there is some confusion about this (Stephen Day, pers. comm.). According to thesis work reported in the 2004 Environmental Agreement and Water License Report (EA&WLR), the pH and organic-C in 96 samples at the proposed Misery atomization site was 3.6 to 4.6 in the O horizon and 3.6 to 5.0 in the C horizon.

The ore, which consists entirely of kimberlite, is moved directly to the main ore storage area or to the interim storage area on the rim of the Misery open pit. The coarse size fraction of the processed kimberlite is first stored in a temporary stockpile and then moved to the Panda/Koala WRSA. Processed kimberlite fines are now stored in the Long Lake containment area. Later in the mine life they may be placed in the Panda pit.

1.4.1 Mineralogy of Mine Wastes

The mineralogy of the various rock types analysed in pre-mine test work was as follows.

Quartz diorite: (> 5%) plagioclase, biotite, quartz > (1-5%) K feldspar, amphibole, chlorite, epidote, muscovite, sericite, sphene > calcite, apatite, chalcopyrite, tourmaline, pyrite

Biotite Schist: plagioclase, biotite, quartz > (1-5%) K feldspar, amphibole, chlorite, sericite > sillimanite, pyrrhotite, ilmenite, rutile, apatitie, tourmaline

Diabase: plagioclase, clinopyroxene, amphibole > (1-5%) chlorite, magnetite, sericite, biotite > sphene, K feldspar, pyrrhotite, pyrite

Kimberlite: highly variable, olivine, phlogopite, serpentine, chlorite, chromite, chrome diopside, calcite, garnet, quartz, smectite (Fox pit)

2.0 Methodology

2.1 Geochemical Characterization of the Wastes

2.1.1 Sampling

The different rock types are visually identified. Sampling for the geochemical characterization of different waste rock types is done from post-blast muck. The frequency of sampling is based on the tonnage mined and depends on the particular rock type and pit. The ABA pit sampling guidelines (Nov 2002) suggest that samples be taken at two locations from different parts of the blast so that each sample represents approximately 50% of the blast. These guidelines provide useful safety and labeling information.

2.1.2 Geochemical Analysis

Geochemical analysis consists of ABA analysis and less frequent elemental analysis. Total-S was measured and the maximum potential acidity (MPA) was calculated for all samples. Paste pH, fizz test, and Sobek-NP were measured and the NP-AP (NNP) and NP/MPA (NPR) were calculated for most samples. Sulphate-S, inorganic-CO_2 were measured and sulphide-S (S2-S) and CO_3-NP/MPA were calculated for a few samples. Sulphide-S was measured directly on an even smaller number of samples.

The geochemical characterization did not include regular checks on mineralogy.

Pit	Material	2004 Production tonne	Total # Samples	04 Analyses ABA (units?)	04 Analyses Elemental (units?)
Koala	**total**		339		
	granite	1,676,355	297	24	?
	kimberlite		20	2	0
	black clay		22		
	CKR		91	16	
Fox	**total**		199		
	granite	24,756,649		100	?
	black clay	7,334			
	till	3,504,004			

	sandy kimberlite	14,485,103		40	40
Panda	**total**		397		
	granite	1,410			
Misery	**total**		606		
	granite	4,005,377		9	
	diabase			2	
	schist			9	
	granite/schist			2	
Beartooth	**total**		30		
	granite	5,163,930		30	8
	till	126,062			
	schist	266,801			
Underground	**granite**	566,627			
Ore		4,519,871			

2004 production was from 2004 EA&WLA Report

2.1.3 Data Analysis

In addition to calculated ABA parameters, data analysis included probability plots for total-S and the calculation of descriptive statistics for the various ABA parameters. Probability plots were used to identify samples with high, elevated or unusually low total sulphur concentrations.

2.2 Seepage Monitoring

Seeps were monitored in spring freshet (June) and late summer (September), with limited sampling in early July and mid August). The data included a range of field measurements and observations and laboratory analyses, with thorough data quality controls. The seepage sampling guidelines were appended.

3.0 Results of Geochemical Characterization

Mining has occurred in a number of locations: Panda open pit (1998-spring 2003), Koala open pit (since 2000), Koala North open pit (since 2001), Koala North underground (since 2002), Beartooth open pit (since 2003), Misery open pit (mined until 2003, shut down, but planned to be re-opened) and Fox open pit (since 2002).

3.1 Panda/Koala/Beartooth Waste Rock and Overburden Storage Area

The Panda/Koala/Beartooth waste rock storage area is planned to eventually contain:

- 193 million tonnes of waste granite, not including 11 million used as construction material around the site, from 11 years of production;

- 15 million tonnes of lake sediments from P pit and till from the P, K, KN and B pits;
- 4.5 million tonnes of barren kimberlite from K pit;
- 31 million tonnes of coarse kimberlite reject; and
- 1000 tonnes of non-hazardous solid waste, scrap metal, incinerator ash, sewage sludge, etc., disposed of in several locations and eventually covered with waste rock.

4.5 million tonnes of barren kimberlite from K pit is less than 3% of total mass of material in the storage area. In 2004 all the rock placed in the WRSA came from the Koala and Beartooth Pits.

Disposal objectives are as follows.

- Most of the drainage will report to LLCA, although it may go via Panda Pit or Koala Pit/sump
- Drainage from the extreme NE portion will drain towards Beartooth Lake and the northern remnant of Panda Lake (note that a sump was placed to collect drainage, which was then sent to Beartooth Pit).
- Once mining is complete, create topography similar to the low height, irregular surface, stoney ridges and outcrops that existed prior to mining.
- Avoid drainage to u/g shafts.

P/K Topsoil Storage Area (TSA) contains lake sediments from the Panda open pit, tills from Panda, Koala, Koala North and Beartooth open pits, and a limited amount of waste rock added during transportation. Kimberlite mudstone is stockpiled next to the TSA. Waste kimberlite is placed in several areas of the TSA and co-disposed with the granite. Koala and Beartooth lake sediments that were considered not useful for reclamation are mixed with the waste rock in the western portions of WRSA. The southwestern extension of the WRSA now surrounds the CKRSA with zones of granite or a mix of granite, kimberlite and till.

3.1.1 Panda Granitic Waste Rock

2003: As in previous years, Panda granitic waste rock had almost no AP (< 1 kg/t), no CO_3-NP (<0.2 % detection limit) and Sobek-NP of 10 to 20 kg/t, with fizz rating of 1. As a result, the Sobek-NPR was much greater than 2. Low total trace metals meant that exceedances of typical background trace metal concentrations were rare. The lack of sulphate-S permitted the use of total-S in calculating the AP. With the exceptions noted subsequently, the correct fizz rating was used in the NP measurement. Monitoring results were for drill chips, a measure of the composition of the whole rock rather than fines.

2004: Mining was completed in 2004 with removal of the last kimberlite. There was no waste mined or sampled in 2004.

3.1.2 Koala Blast Rock – Granite, Black Clay and Waste Kimberlite

2003: Separate descriptive statistics were generated from the 1999-2003 ABA results for granite, black clay and kimberlite. For granite, 5th and 95th percentile %S (0.01-0.1%) and Sobek-NP (8-24 kg/t) were both low. Maximum %S is only 0.26%. Most samples with a higher %S (0.1 and 0.26% S) were collected close to the kimberlite pipes. 5th and 95th percentile NPR values are 4.9 and 77.

Black clay and kimberlite rock units had a higher %S and very much higher NP than granite. For black clay, 5th and 95th percentiles were 0.32 to 0.47 %S (max of 0.93%), 216 to 326 kg/t Sobek-NP and 73 to 175 kg/t CO_3-NP. For kimberlite, 5th and 95th percentiles were 0.11 to 0.28 %S (max of 0.31%), 91 to 296 kg/t Sobek-NP and 29 to 42 kg/t CO_3-NP. Ankerite was noted to be part of carbonate mineralogy. There was also likely to be significant $MgCO_3$.

Trace element concentrations in Koala granite were similar to, although slightly higher than the Panda granite. The main difference in trace element concentrations between the granitic waste rock, and the black clay and kimberlite were the elevated Cr and Ni present in the latter.

- 400 to 1300 ppm Cr and 250 to 750 ppm Ni in black clay.
- 400 to 1200 ppm Cr and 700 to 1800 ppm Ni in and kimberlite.

2004: A threshold of 0.092% separated the granite samples into two populations. The low-S samples were entirely granite. The high-S population was granite with minor kimberlite or a localized concentration of pyrite. Only four of the samples had %S > 0.9%. The 1999-2004 descriptive statistics were similar to the previous year. The granite had 5th percentile NP/MPA of 4.8 and a minimum of 1.5.

The two kimberlite samples had, assuming they were the last two samples on the list, the highest measured %S (0.91 and 0.96%), although the NP/MPA was 8.9 to 9.5 due to the high NP. The waste kimberlite had 5th percentile and minimum NP/MPA of 9.5 and 8.9 and a 5th percentile and minimum CO_3-NP/MPA of 3.1 and 2.0. The waste kimberlite had 5th percentile and minimum NP/MPA of 15 and 7.0 and a 5th percentile and minimum CO_3-NP/MPA of 4.8 and 2.5. An NPR above 2 indicates that all the black clay and waste kimberlite and virtually all the granite waste rock is not potentially ARD generating. The low mass and %S and relatively high NPR (1.5-2.0) indicates that the granite with an NPR <2 will not significantly impact drainage chemistry.

Other observations and questions were as follows.

- What was the mass of waste kimberlite and black clay this year and in total?
- Total-S > acid soluble sulphate-S plus sulphide-S in some granite ABA samples (see Section 3.5.5)
- There is a large difference between Sobek-NP and CO3-NP in the kimberlite and black clay samples indicating a significant contribution of silicate minerals to Sobek-NP (Section 3.5.4).

3.1.3 Beartooth Granite

The 30 ABA and 8 elemental analyses in 2004 were the first operational analysis of the Beartooth waste rock: All the samples were classified as granite. The 5th - 95th percentile % total-S (0.01-0.13 %), Sobek-NP (9.5-16 kg/t) and NP/MPA (3.3-28) were similar to the Koala granite. Only two samples had total-S > 0.1%. The main concern was with sample BG-440-12-1, which had a sulphur content of 0.24% and an NP/MPA of 1.9. One potential explanation is that the sample contained schistose material with a higher S content. Other samples in the blast and the surrounding area had much lower %S and higher NP/MPA.

The rock types that will be encountered in the Beartooth pit, including whether mining will intercept significant schistose rock, are outlined in the Waste Management Plan (S. Day pers. comm.).

Median and 95th percentile elemental concentrations were similar to those of the Koala granite.

3.2 Misery Pit and Waste Rock Storage Facilities

The Misery Pit is 29 km from the process plant. Construction started in August 2000. The Misery Storage facilities will eventually contain:

- 26 million tonnes of granitic waste rock, some of this granite will be used as construction material around the site;
- 22 million tonnes of biotite schist waste rock;
- 3 million tonnes of diabase dyke;
- 2 million tonnes of till and lake sediments from M pit;
- 1 million tonnes of barren kimberlite from M pit;
- no coarse kimberlite reject; and
- non-hazardous solid waste, which will be placed in several locations and eventually covered with waste rock

In test work, the Misery Schist produced low pH water and elevated metal release. The biotite schist is a concern in both the storage area and exposed walls in the pit. In humidity cells, the pH of the Misery Schist cell decreased to pH 4 by week 33, and remained between pH 3.6 and 4.4. Around week 30, sulphate production increased from 20 mg/kg/wk, eventually reaching a maximum of 85 mg/kg/wk. The increased sulphate production ceased near week 100, eventually dropping to < 10 mg/kg/wk. The decrease in sulphate production was considered to be due to the small sulphide concentration. Increased Cu, Pb and Zn leaching were thought to be a product of pyrite weathering.

The temporary kimberlite storage areas in the Misery area, include a temporary ore storage area and an area used to store material undergoing further diamond testing. Both areas were prepared by stripping away organic soils and adding a granite waste rock base.

3.2.1 Misery Blasted Rock

2003: The Misery granite had almost no AP (<1 kg/t), no CO3, < 10 kg/t Sobek-NP and relatively low trace metal concentrations. The diabase had an AP of 2 to 3 kg/t, almost no CO_3, a Sobek-NP of 10 to 30 kg/t and a relatively low concentration of trace metals. The biotite schist had an AP of 1 to 7 kg/t, almost no CO_3, and a Sobek-NP of 7 to 13 kg/t and an NP/MPA > 1. The reactivity of Sobek-NP is questionable given the ARD generated in the biotite schist humidity cell. Ten samples of waste kimberlite had similar compositions and therefore the same issues as waste kimberlite from the Koala pipe.

2004: In 2004, two diabase, eleven schist, nine granite and two mixed granite/schist samples were taken from the Misery blast rock. According to the 2004 EA&WLA Report, mining in the Misery Pit consisted of 4 million tones of granite, with no indication of the mining of the other rock types..

The text indicates that the higher-S portion (90%) of the schist samples from 2001-2004 had a mean %S of 0.14% and a 95th percentile of 0.30%. The 2004 schist samples had a lower than average NP and contained samples with 0.3% S. Several of the granite samples had relatively low NPR values (2.3, 2.9 and 1.5).

The failure to list sample dates in the lists of sample data in the appendix and the lack of table showing descriptive statistics for different rock types made it impossible to check the data selectively and resulting conclusions provided in the text. The use of the detection limit when the CO_2 inorganic is less than the detection limit produces misleading CO_3-NP and CO_3-NP/MPA data.

- Why did the *2003 and 2004 Reports* not provide the same table of descriptive statistics used for other areas of the mine?

3.3 Fox Pit and Waste Rock and Overburden Storage Area

Stripping of the pit began in 2002. The storage facility will contain till, lake bottom sediments, waste country rock (granite plus minor amount of diabase) and waste kimberlite. Granite will be co-disposed with till and lake bottom sediments. Kimberlite will be segregated and stored in the south-central and northwest side. Toe berms to limit seepage will be constructed in the fall and winter of 2004.

In test work, Fox Pipe Diabase produced low pH water. The conclusion that the diabase was not a concern was based on the assessment that the test sample was unrepresentative (PAG portion was only 2% of the diabase, see Fox WROSMP p24 for discussion).

The pH 10 water released from Fox and Leslie kimberlite in test work were presumed to be due to the abrasion of olivine and the release of Mg hydroxides. BHPB predicted a subsequent decline to pH 7 due to buffering by Mg carbonates.

3.3.1 Fox Blast Rock – Granite

2003: Similar to other sites, 5th and 95th percentile values were low for both %S (0.01-0.06%) and Sobek-NP (12-204 kg/t). Maximum %S was only 0.09%. Concentrations of trace metals were not above normal background.

2004: The 5th - 95th percentile % total-S (0.01-0.06 %), Sobek-NP (12-22 kg/t) and NP/MPA (9-48) for 2003 and 2004 were similar to the Koala granite. Only three samples had total-S > 0.1%. Two had elevated NP suggesting the sample included some kimberlite material. The other sample came from a blast where the other samples had more normal results suggesting the elevated S was due to the interception of a local feature, such as a xenolith or veinlet. Metal concentrations were similar to the values reported for the Beartooth and Koala granite.

3.3.2 Fox Blast Rock – Waste Kimberlite

2003: No kimberlite results exist for 2003.

2004: The 5th - 95th percentile results were 0.18-0.56 % total-S, 214-326 kg/t Sobek-NP, 48-131 kg/t CO_3-NP, NP/MPA of 13-54 and CO_3-NP/MPA of 2.8-12. The three samples with the highest % total-S (0.56, 0.63 and 0.65%) had CO_3-NP/MPA of 2.4 to 2.8. The acid soluble sulphate-S content was 0.02 to 0.09%. Like other waste kimberlite, the Fox kimberlite had elevated Cr and Ni concentrations. Compared to the Koala kimberlite, the Fox kimberlite had lower average concentrations of Ni, Co and Cr and higher average Cu and Zn.

3.4 Coarse Kimberlite Rejects

Coarse kimberlite rejects (CKR) are 0.5 – 8 mm in size, with the consistency of beach sand. CKR are 40-53% of kimberlite feed and produced at 200 tonnes per hour. Material is initially stored in a temporary stockpile and then permanently stored in the Koala waste rock storage area (KWRSA), which drains into Long Lake CA. In test work. CKR produced leachate that was initially high in Cu and Al. The disposal site at KWRSA is constrained by abutments of granite waste rock. The granite is intended to provide thermal insulation and will eventually be used as a cover to keep CKR out of the active permafrost zone. The WRSA now fully surrounds CKRSA.

2004: The Materials and Methods section indicates that metal and ABA results for the 16 samples collected in 2004 and the 91 in total were provided in Appendix A.4. It appears that Appendix A.4 has only 14 samples from 2004. No descriptive statistics were provided for the CKR results and there was no discussion of the results in the text of the report.

A cursory evaluation indicated that the composition of the CKR was similar to the kimberlite waste: < 0.7 % total-S; acid soluble sulphate-S < 0.09%; 200-350 kg/t Sobek-NP; 40-80 kg/t CO_3-NP; NP/MPA of >20; and CO_3-NP/MPA of 2.5-10. Like the waste kimberlite waste, the CKR had elevated Mg, Cr and Ni concentrations.

3.5 Long-Lake Containment Facility

The Long-Lake Containment Facility (LLCF) was not part of the objective of the report but is included in the review because of its connection to the waste characterization and seepage monitoring. The Long-Lake Containment Facility (LLCF) consists of a number of cells. It receives:

- Drainage from Beartooth pit, Panda pit, Koala pit and Koala underground after portable flocculant/coagulant treatment;
- Fox pit water after portable separate flocculant/coagulant treatment;
- Pigeon pit water (in the future);
- Processed Kimberlite fines, a mix of solids and water; and
- Treated sewage effluent and site drainage.

- ➢ What happens to the wastes from the various flocculant/coagulant treatments?

The decline observed in zooplankton abundance and diversity in the cells is attributed to flocculants and coagulants. A thin organic layer on the surface is thought to prevent benthic recolonization.

Processed kimberlite fines (< 0.5mm) are hydraulically transported to Long Lake Containment Area. In pre-mining test work, simulated processed kimberlite from Panda had a pH of 8.5 and from Fox had a pH of 10. Both sites had Sobek-NP > 330 kg/t, but carbonate NP < 100 kg/t. Three of four samples were subjected to 8 weeks column leaching (one Fox sample was too fine to produce leachate). Resulting column leachate was pH 7-8 for Panda and pH 8.5 – 9, with high Ni and Al, for Fox.

According to Stephen Day (pers. comm.):

- high non-carbonate-NP is due to solubility of Mg silicates under acid conditions;
- carbonate-NP comes mainly from Mg carbonate minerals; and
- precipitous decline in non-carbonate-NP in the pre-test and post-test humidity cell test materials resulted from the use of lower fizz rating for post-test analyses.

One challenge identified in pre-mining characterization was the potential difficulty in settling high smectite kimberlite fines from Fox pit.

Although they are a significant waste product, sampling and analysis and assessment of the results for the processed kimberlite fines were not part of the terms of reference for this report.

> *Recommended Action:* The geochemical characterization of the processed kimberlite fines should be included in this *Report*.

3.6 Discussion of Geochemical Characterization

Although segregation is based on visual properties and therefore is not an objective in waste characterization, levels of distinguishing properties, such as S, NP and Ni, along with proximity to contacts, are used to infer whether samples contain minor amounts of other rock types (e.g., a granite sample, with elevated S, NP and Ni, from close to the kimberlite contact may contain some kimberlite).

3.6.1 Characterization of Different Rock Types

Descriptive statistics were only provided for some rock type/waste/pit combinations (e.g., not for the Misery pit and the CKR). The descriptive statistics were for the total data set and not for the 2004 data. No analysis was provided for the CKR.

> *Recommended Action:* Tables showing descriptive statistics for the total and for the 2004 data should be provided for all rock unit/pipe/pit combinations. Where significant differences occur, distribution plots should be used to highlight (e.g., bold points) differences in the current year from previous year's data.

> *Recommended Action:* The *Report* should include an assessment of the CKR results.

> *Recommended Action:* BHPB should check the number of CKR samples. Although there were said to be 16 samples analyzed; only 14 sample results from 2004 were reported in Appendix A.4.

> *Recommended Action:* Given its potential impact on site discharge quality, the mine should conduct operational characterization of till and lake sediments. This information may already be collected as part of the characterization of soils for reclamation, but refinements may be required to address the issues associated with waste disposal, water management and ML/ARD mitigation.

3.6.2 Sampling Frequency

There is no data on the amount of different material mined or the sampling frequency for each rock type/waste/pit combination.

Recommended Action: BHPB should review the consistency of the results for the different rock type/waste/pit combinations and where the geology is homogeneous and there are no drainage chemistry concerns suggest reductions in the sampling frequency.

Recommended Action: The *Report* should indicate the tonnage mined and the frequency of sampling for different rock types in different pits, in the past year and in total. The *Report* should also indicate past changes in the # of tonnes per sample and the number of samples collected from each blast, including where no samples were collected. [SD1]

Recommended Action: The waste rock monitoring data should show the date each sample was collected, the blast and the disposal location.

3.6.3 Laboratory and Data Analysis

The QA/QC lacks a check on the mineralogy of potential NP and metal leaching sources.

Recommended Action: Where there is a drainage chemistry concern and mineralogy may be important (e.g., Ni minerals in black clay and kimberlite and NP minerals in kimberlite, black clay, diabase and Misery schist), the geochemical characterization should include additional regular checks on the mineralogy using Rietveld XRD procedure.

When concentrations are less than the detection limit, the calculated statistics are misleading.

Recommended Action: In the data tables, CO_3-NP should be reported as < 5 kg/t when CO_2 inorg is < detection limit of 0.2% and CO_3-NPR should indicate that CO_2 inorg is < detection limit rather than a value calculated value using a CO_3-NP of 5kg/t (0.2% = 5 kg/t).

Most of the granite samples are below the CO_2 detection limit and thus the data is of little use.

Recommended Action: Lower the CO_2 detection limit used for the granite samples or drop the analysis.

3.6.4 Sobek-NP

A comparison of the CO_3–NP and Sobek-NP is commonly used to assess the relative amounts of CO_3–NP and silicate-NP, and the contribution of silicate-NP to the Sobek-NP. Additional information, including quantitative mineralogical information, is required to assess the reactivity of silicate-NP contribution to the Sobek-NP. In most silicate rocks (e.g., granitic rock), the difference between the Sobek-NP and CO_3–NP is 5 to 15 kg $CaCO_3$/t. The main causes of higher differences (i.e., larger contributions of silicate-NP) are very reactive silicate minerals (e.g., Mg silicates) or the addition of too much acid (i.e., acid additions far in excess of the neutralizing CO_3–NP). A simple way to check whether excess acid was added is to compare the amount of acid added (the fizz rating) with the CO_3–NP and resulting Sobek-NP values.

<u>Amount of Acid Corresponding to Each Sobek Fizz Rating</u>:

None	20mL of 0.1 N HCl	= 50 kg $CaCO_3$/tonne
Slight	40 mL of 0.1 N HCl	= 100 kg Ca CO_3/tonne
Moderate	40 mL of 0.5 N HCl	= 500 kg $CaCO_3$/tonne
Strong	80 mL of 0.5 N HCl	= 1000 kg $CaCO_3$/tonne

> *Recommended Action:* For 2003 data, check how PPW 345-43 1A had a Sobek-NP of 153 kg/t when fizz rating of 2 is only equivalent to 100 kg/t . A similar check is required for KK-Dump-5A Koala Kimberlite with Sobek-NP of 76 kg/t, since a fizz rating of 1 is only equivalent to 50 kg/t. Hopefully, these discrepancies do not uncover something generically wrong with the analysis procedure or the calculation of data.

The acid addition should be only slightly higher than the CO_3–NP and the resulting Sobek-NP values, and should be repeated using a more appropriate acid addition if either is not the case. For example, moderate or strong fizz ratings are too high if the CO_3–NP and resulting Sobek-NP are less than 50 kg $CaCO_3$/tonne. Important considerations resulting from the above include:

- the need to report the fizz rating, which BHPB does,
- the potential to substitute the CO_3–NP for the fizz rating in selecting the appropriate acid addition, and
- the potential problems caused by an uncertain but significant amount of Fe and Mn CO_3.

The Report infers that all the CO_3-NP is Ca or Mg CO_3 and since the CO_3-NP/MPA is > 2, the kimberlite and black clay have no ARD potential.

> *Recommended Action:* Regular checks on the carbonate mineralogy using Rietveld XRD procedure are required to confirm that the CO_3-NP is Ca or Mg CO_3.

There is a large difference between the Sobek-NP and CO_3-NP, indicating a significant contribution of silicate minerals to Sobek-NP in the kimberlite and the black clay samples. In most of the rock, this would indicate that the Sobek-NP greatly overestimates the neutralizing capacity. According to S.Day (pers. comm.), the excess NP in the black clay and kimberlite comes from Mg-silicates, minerals which can provide real buffering capacity. The only way to check this would be to perform an assessment of what minerals contribute to the measured CO_3-NP and Sobek-NP, using Rietveld XRD to measure the concentrations of the potential mineral sources. The MSc. thesis investigating CO_2 sequestration may provide some useful information on mineral reactivity. Given the large excess CO_3-NP/MPA in the black clay and kimberlite, if all the CO_3-NP is Ca or Mg CO_3, the magnitude and reactivity of Mg silicates will not impact the non-PAG rating. It may however impact the potential for significant Ni release (see Section 3.6.7).

3.6.5 Acid Potential

When sulphide-S is low, as is the case for most of the rock units at Ekati, acid soluble and insoluble sulphate-S can potentially contribute a significant portion of the total-S and sulphide-S, potentially causing a significant over-estimation of the AP It is therefore very important to verify this. The total-S > acid soluble sulphate-S plus sulphide-S in some granite ABA samples could be explained by the low total-S and significant non-acid soluble sulphate. However according to S.Day (pers. comm.), it is more likely that the sulphide-S is not a reliable determination, as barite is very unlikely in this setting, and Ba and Sr are more likely associated with feldspars in granites.

As a gauge of whether it is important, the maximum potential concentration of acid insoluble sulphate can be estimated from the concentration of Ba, Pb and Sr, assuming all the Ba, Pb and Sr are in this form. At Ekati, Pb concentrations are typically < 50 ppm, and therefore $PbSO_4$ is not likely to be significant. Ba and Sr concentrations are 100s and 1000s of ppm. The concentration of Ba was 500 to 1000 ppm in the Kaola granite, 1000 to 2000 ppm in the kimberlite and 1000 to

3000 ppm in the black clay (Appendix A2). Assuming the entire Ba in the black clay occurs in barite, 3000 ppm Ba would result in approximately 700 ppm or 0.07 % barite-S.

Given the low Ba, Pb and Sr content and the high NPR, there is no reason for more detailed AP assessment of the granite and kimberlite.

3.6.6 Concentration of AP and NP in the Fine Fraction versus Larger Size Fractions of Waste Rock

The geochemical characterization does not include post-blast sampling to check that the composition of drill chips is the same as that of the post-blast fines. The finer particles (e.g., < 2 mm grains), which are only a small portion of the total rock and pre-blast drill chip mass, typically determine drainage chemistry, because of the high surface area and exposure to oxygen and water, while most of the mineral grains in coarse fragments are occluded and unable to react. One reason for a difference between the composition of the whole rock and the fines is because sulphide minerals often occur in veins or on fractures, and therefore preferentially report to the finer particles. As a result they may be more exposed and therefore more reactive than neutralizing minerals, resulting in an effective NPR that is lower than the overall NPR values. The potential for the NPR of the reactive fines to be significantly lower than that predicted from a ‘whole waste rock’ ABA is a concern in geochemical characterization of waste rock,

Rock fines analyzed as part of 2003 characterization in Seep 019 area were 3 times higher the average total-S (0.06% versus 0.02%), but still within the normal range for granite. There was no analysis of the coarse fragments from the same location. According to S. Day (pers. comm.), the 2000 Report (p.13) shows there is an enrichment of both S and NP in the fines

> *Recommended Action:* Geochemical characterization should include regular sampling of post-blast fines and coarse fragments to check that drill chip analysis provides an accurate assessment of the composition of fines and the likely range in composition of the fines. The frequency of sampling should depend on the variability and ML/ARD concerns associated with the waste/rock type.

3.6.7 Potential for Elevated Ni in Neutral pH Drainage from Black Clay and Kimberlite Rock

One of the challenges in pre-mine ML/ARD test work is the relatively crude, short-term nature of ML/ARD prediction tests. Consequently, most mines have some degree of uncertainty associated with their ML/ARD prediction. The cursory review of Ekati reports indicated that wastes containing kimberlite and black clay contained high concentrations of a number of trace elements, especially Ni, which raised questions regarding the potential for significant long-term contaminant loadings even if the drainage remains neutral pH. The Ekati 2000 report states that ‘Alkaline drainage concerns are considered short-term, except for a small portion of kimberlite ore.’ This conclusion appears to be based on the leaching observed in short-term humidity cells. It is important that these predictions be checked with longer-term studies and an assessment of the potential contaminant sources. Elevated Ni is observed in non-acidic water in the CKRSA (S. Day, 2003).

Full mineralogical characterization is a requirement of the Water License (Tony Pearse pers. comm.).

> *Recommended Action:* BHPB needs to address the question of whether there is a potential for significant long-term contaminant leaching from wastes containing kimberlite and black clay. This should include: microprobe assays of the relevant rock types and wastes to identify the mineral sources for potential contaminants of concern, especially Ni; review of drainage at mines with similar Ni minerals (asbestos mines?); and construction of field test pads to provide information on the potential for Ni release in the various disposal scenarios and environments of kimberlite and black clay.

It is important to note that significant Ni leaching can occur under neutral pH conditions, and other mines have noted that a delay in Ni release can impede its detection in pre-mining test work (e.g., Raglan Mine). There is no mention of Ni sulphides in geological description so presumably the Ni occurs in silicate minerals, such as serpentine. Serpentine is less reactive than Ni sulphides, but relatively reactive compared to most silicate minerals.

3.6.8 Field Test Pads

Field test pads can provide very useful information on weathering under field conditions and long-term metal leaching. This information can be used to calibrate laboratory results and show what would occur if mitigation measures are only partially successful.

> *Recommended Action:* BHPB should construct 'field test pads' for potentially problematic rock types, such as biotite schist and the CKR, to verify pre-mining predictions of future weathering and drainage chemistry, and assess the risks if the WRSA do not completely freeze.

4.0 Waste Disposal and ML/ARD Mitigation

BHPB has used a variety of disposal strategies, depending on the rock type and pit, and in some cases the disposal strategy has changed over time (e.g., kimberlite mudstone in the P/K/BWRSA). Segregation of kimberlite waste rock is now part of the disposal plan for the Koala WRSA, and from the start has been part of the disposal plan for the Fox WRSA. Segregation and controlled disposal of schist in layers, sandwiched between layers of granite from the start has been part of the disposal plan for the Misery WRSA.

> *Recommended Action:* The 2000 Waste Rock and Ore Storage Management Plan is out of date. Many of the ML/ARD mitigation measures do not appear to have been used. The waste management and control portion of the 2000 Waste Rock and Ore Storage Management Plan should be updated.

- Does the segregation of kimberlite waste rock in the Koala WRSA also include black clay?

The question of waste composition came up in the 'Detailed Investigations of the SEEP-019 Area (2003 report, Appendix C)', when the chemistry of dump seepage from the northeast corner of the Panda/Koala SA was attributed to kimberlite mixed in with the granitic waste rock. The issue of kimberlite inclusion in the waste rock was recognized in the 2000 report and has been a constant theme (S. Day pers. comm.). The variety of different disposal strategies (e.g., segregation, placement on granite pads and granite cover layers) makes it difficult to know what was done where and when in the different WRSA. The air photos are a good way to show the seepage monitoring sites. However they do not provide a clear outline of where the different wastes were placed and where different disposal strategies were used (e.g., where a layer of granite rock was placed under the CKR).

Recommended Action: To allow a reviewer to understand and interpret the results and as a record of what happened, the *Report* should provide:

- larger-scale as-built plans for the SAs that outline past, current and future waste management and mitigation plans (e.g., CKR was originally deposited directly on tundra soils, presently it is being deposited in layers and encapsulated within granitic rock);
- list any modifications, errors or omissions (e.g., where material were co-disposed, misclassified or handled in different manner); and
- updated cross-sections and plan views of the SAs showing where different wastes are located and different disposal strategies have been used.

In 2004, BHPB placed a toe berm to promote freezing and limit seepage in the northeast side of the P/K/B SA.

- ➢ What happens to the incident precipitation and groundwater inputs when the waste freezes? Does ice continue to accumulate?

4.1 Use of Freezing to Prevent Weathering and Leaching

Although the Waste Rock and ore Storage Management Plan (2000) suggests various mitigation options, the main mitigation strategy to prevent ARD or significant neutral pH metal leaching from the mine wastes appears to be freezing. While the present data appear promising, uncertainty with this strategy includes the extent to which freezing of the higher S rock types (e.g., black clay, schist and kimberlite) will be inhibited by heat produced by sulphide oxidation or compromised by future climate fluctuations. Potential consequences of a failure to freeze include ARD and metal leaching from the Misery schist and significant Ni leaching from the coarse kimberlite rejects, the kimberlite waste rock and black clay waste rock.

4.1.1 Panda/Koala/BeartoothThermal Monitoring

2003: The freezing in the Koala granite waste rock is noted to be occurring faster than expected in the Panda granitic portion of WRSA. Cold temperatures are expected to reduce reaction rates and minimize leaching. 2003 thermal monitoring data was provided in Appendix D.1, but there was no further discussion of the results. The thermal data from two monitoring stations in the CKR (#1468 and 1469) indicate that the CKR presently remains at or above 0^{o}C.

2004: Results are provided in Appendix C. No discussion of results in the *Report* .

- ➢ What is the composition of the fill in holes #1-4 in the Panda WRSA?
- ➢ Why is the depth of the CKR less than the waste rock?
- ➢ Is there any waste kimberlite, black clay or overburden mixed with the waste rock in the thermistor holes?
- ➢ How successful have the toe berms been?

4.1.2 Misery Thermal Monitoring

The method to be used to freeze the Misery schist is layering and encapsulation by weakly reactive diabase and granitic waste rock, with 10 m layers of biotite schist sandwiched between 5 m layers of granite and covered with a layer of granite so the active freeze/thaw zone is within the granite; the far more porous granite is placed to remove heat and increase the likelihood of freezing

2003: Results are provided in Appendix D.1. The results appear mixed with freezing of the Misery schist occurring in some locations (WRP#3) and not in others (WRP#1). The reasons for these results and their implications to the overall plan are not discussed in the test.

2004: Results are provided in Appendix C. No discussion was provided in the text

4.1.3 Fox Thermal Monitoring

2004: Monitoring cables were only installed during the winter of 2003 and the spring of 2004. Therefore there were no results reported.

4.1.4 Discussion of Freezing

> *Recommended Action:* Given its importance to the post-closure environmental protection, future editions of the *Report* need to address the issue of freezing in greater detail. This should include:
>
> - whether the thermistor locations (e.g., P/K WR) are representative of the potential range in SA conditions;
> - the impact on and of adjacent frozen rock units on drainage from the unfrozen material;
> - the influence of climate variability (e.g., cold versus warm years and climate change); and
> - contingencies for where climate and waste conditions are warmer than was previously estimated.

4.2 Potential for Tundra Soils to Increase Metal Leaching from Mine Wastes

The acidic pH and organic acids in at least a portion of the tundra soil has the potential to accelerate weathering, decrease NP and increase the solubility of metals in the drainage from mine wastes. Non-PAG wastes mixed with underlying soils or acidic lake sediments may become acidic and/or with accelerated weathering of silicate minerals and leaching of the weathering products. The potential for acidic tundra soils underlying, deposited peripherally or mixed in the dumps to significantly increase NP depletion and metal leaching from waste rock is indicated by the relatively high total acidity in the soil/CKR mixing experiment and the relatively high Al and Fe in the drainage from the un-mined reference areas.

The material with the lowest NP is the granitic rock. Elevated leaching of Al may occur at low pH from granitic materials. However, the thermistor data suggest that the granitic wastes will be frozen. Consequently the main concern may be with wastes where freezing is as yet uncertain.

> *Recommended Action:* BHPB needs to clarify the measures it is taking with the various pit/rock types to minimize contact between tundra soil (underlying or stripped) and waste

materials with high trace metals (e.g., kimberlite and black clay) or significant sulphides (e.g., biotite schist and kimberlite).

Recommended Action: Future versions of the *Report* need to discuss the implications of past placement of waste materials in contact with the acidic tundra soils, its potential impact on seepage chemistry and loadings to the environment, where materials are assumed to be frozen and, if required, how the elevated metal leaching will be mitigated both during operation and after the mine closes.

5.0 Seepage Chemistry

The mine has an extensive program of seepage monitoring, including reference sites and detailed QA/QC. The *Report* included tables showing compliance for each of the major seepage areas (see Tables 3.3, 3.4, 4.1, 4.2).

5.1 Sable and Beartooth-Bearclaw Reference Areas

Drainage collected from Sable monitoring sites generally has low TSS, although there have been some excursions. Typically, the pH was < 6, with up to 8 mg/L Fe and 2 mg/L Al, and < 5 mg/L sulphate. TOC concentrations range from 7 to 30 mg/L, with 10 to 20 mg/L in most samples.

The results of a soil survey in the Sable and Beartooth-Bearclaw Reference Areas were reported in the 2000 report (S. Day pers. comm..).

- *Were the surficial materials and soil chemistry in Sable and Beartooth-Bearclaw Reference Areas similar to the various areas of mining?*[SD2]

5.2 Panda/Koala/Beartooth Seepage Monitoring

Drainage from the Panda/Koala storage area reports to the following:

- Panda WRSA – Long lake Cell C (via Koala catchment), Beartooth and Bearclaw Lakes
- Panda Sediment Storage Areas – Long Lake Cell C (via Koala catchment)
- Koala Sediment Storage Areas – Long Lake Cell C (directly and via Koala catchment)
- Koala WRSA/Coarse Rejects Storage Area – Long Lake Cell C and D
- Ore Storage Area - Long Lake Cell C (via site drainage collection)

Monitoring sites generally have low TSS, although there were more exceptions than at Sable reference sites and excursions were higher, often over 50 mg/L. Compared to the reference site, there also appeared to be more samples with a lab pH of 4.5 to 5.5 and 6.5 to 8.0, and a slightly wider range in TOC (i.e., 5 to 40 mg/L). Sulphate concentrations were highly variable. According to the text, Ni, Mn and sulphate concentrations increased at a number of sites where the monitoring location was moved due to dump expansion.

A number of seepage monitoring sites had a lab pH < 4.5 (7D, 7E, 8, 24A, 25 and 318), in addition to Seep 019 area.

2004: The text makes mention of increased NH_4 in 011B south of CKRSA and the establishment of SW-314 to replace 022A..

5.2.1 Seep 018/019 Area

2003: As a result of the proximity to the receiving environment (this is the area of the WRSA that does not naturally report to the LLCA), increasing sulphate concentrations and a concern regarding low pH and high Al in Seep 018/019 Area, in 2003 BHPB:

- constructed a sump to collect drainage and pumped it to Beartooth Pit; and
- conducted a detailed evaluation of water chemistry along the flow path between the Panda WRSA and Bearclaw Lake.

The sump and pump has enabled the mine to stay in compliance with its water license.

Results of the evaluation of water chemistry along the flow path in 2003 were provided in Appendix C, a memo from Stephen Day to Jim Millard. The flow path is a well-defined draw, approximately 450 m long. The first visible flow is a series of stagnant pools along the WRSA toe (018). Flow then collected in pools against the Sable Road (SW-320), emerged on the other side of the road and flowed in a channel for 120 m, disappeared for 75 m, re-appeared at a break in the slope (019) and continued in a channel before flowing diffusely into Bearclaw Lake (SW-321). SW-321 is an area of stagnant pools and was the only area where orange precipitates and coatings were noted to occur.

The lowest pH occurred in area 018. From 2001 to 2003, the pH decreased from 6.5 to 3.4, nitrate, ammonium and TDS also decreased, Fe increased to 17.1 mg/L and Ni increased to 2.1 mg/L. Based on the results of monitoring of the CRKSA in 2002 (SRK 2003), SRK concluded that reducing conditions in the tundra soil permitted migration of ferrous-Fe, whose subsequent oxidation and hydrolysis to ferric-Fe hydroxide caused the decline in pH.

Compared to samples collected further downstream, the water samples from area 018 had more than an order of magnitude greater Fe, Al, Cr, Cu, Ni and Zn concentrations, double the sulphate, but lower Mg and nitrate concentrations. The increased Ni, Cr, Cu, Zn and sulphate at 018 can be attributed to kimberlite weathering, and their decrease in downstream drainage to natural attenuation. A visual inspection of the waste rock in the area led SRK to conclude that there were relatively high proportions of kimberlite mixed with granite in this part of the WRSA. Water chemistry at 019 has varied seasonally, generally with higher pH values and lower iron concentrations during the earlier part of the open water season.

2004: Some of the seepage results for pH (4.7-4.9 vs 6-9), TSS (38 & 45 vs 25), and T-Al (1.0 - 1.9 vs 1) exceeded the average criteria in the water license. BHPB indicated that the toe berm built to promote freezing was partially successful in limiting seepage in this side of the P/K/B SA.

5.3 Misery Seepage Monitoring

Drainage from the Misery Storage Area reports to Cujo Lake, Shining and Christine Lake. Mine water management includes various ponds and catchments. To restrict seepage to Lac de Gras, a waste rock dam was built downstream of MWRSA in 2001/2002. Two coffer dams were built south of Desperation Pond to capture seepage from MWRSA. The discharge from the dams is to King Pond, a licensed mine water settling facility. From King Pond, drainage is pumped to Cujo Lake. Water then flows through four lakes before entering Lac De Gras.

2003: Seepage generally had low TSS, although there were more exceptions than Sable and excursions were often over 50 mg/L. Also there was a slightly wider range in TOC (5 to 76 mg/L) than the reference area. Of the seepage monitoring locations, only site 060 had drainage samples with a lab pH < 4.5. The text noted that pH values were below the range specified in the water license. Increases in nitrate and ammonium concentrations were noted at one set of sites and decreases at another, with the reverse for sulphate and trace metals.

2004: 052 - Concentrations of all parameters were lower than in 2003, which were attributed to the relocation of mixed kimberlite and schist waste. However, T-Ni was still > 0.3 mg/L.

5.3.1 Misery Kimberlite Storage Area

2003: At some monitoring sites, there were increases in solutes such as sulphate and Ni.

2004: Some increase in Al and Fe but "construction of the basal granite pad appears to be effective in isolating kimberlite from natural tundra acidity." Low pH's of 4.9 and 5.8 recorded in 081 were likely due to naturally acidic tundra runoff.

5.4 Fox Seepage Monitoring

Discharge from the Fox Storage Areas reports to Nero, Nema and Martine Lakes. The present seeps drain directly to the aquatic environment.

2003: Monitoring sites generally have low TSS, although there were more exceptions than Sable and excursions were often over 50 mg/L. Compared to reference sites and other mined areas, there were more samples with a lab pH of 6.5 to 8.0. But unlike other WRSA, there was a lack of drainage with a pH < 4.5. Other observations were that the field pH was less than the lab pH (e.g., samples 305 to 313) and the wide range in TOC, 4 to 76 mg/L. Sulphate is also highly variable.

High TSS and total-Al concentrations were attributed to lake sediments and the freshet. Silt-fences and interceptor pumps successfully lowered the TSS, but total-Al was above the range specified in the water license (2.0 mg/L versus 5.5 to 31.9 mg/L). A total-Al concentration much higher than the dissolved Al indicates that the source of elevated Al is TSS. BHPB established additional monitoring stations to study the issue and later in the year the total-Al concentration dropped below the required concentration. There is evidence that higher Al concentrations were in part due to disturbance of underlying sediments during the sampling of clear shallow drainage with syringes

There was a slight decrease in the pH compared to previous year's (5.8 – 5.9 versus 6.2 – 6.3). The pH values were comparable to Fox reference stations and thought to be a feature of the natural tundra water.

2004: Toe berms to limit seepage flows from the WRSA were constructed during the fall/winter 2003/2004. There is no information provided on its impact on either seepage or upgradient drainage conditions.

Exceedances of the water license criteria were noted for TSS, T-Al, and NH_4. Most sampling locations were described as stagnant. With the exception of SP-326, the exceedances for TSS were attributed to shallow sample sites and the entrainment of sediment. The pH ranged from 4.8 to 8.5, with most values < 6.

5.5 Presentation of Seepage Results

The large number of seepage monitoring sites and measured parameters, and the lack of descriptive statistics make it difficult to assess the seepage monitoring data. In a few cases, plots were provided.

> *Recommended Action:* Tables showing descriptive statistics for the total data set and for the 2004 data should be provided for all monitoring stations. Where significant differences occur, plots should be used to show differences in the current year from previous year's data.

5.6 General Exceedance of the pH Criteria

The results demonstrate that natural seepage in the area is commonly below the water license criteria for pH.

- If the till, lake sediments and the majority of the tundra seepage are naturally acidic, as suggested by the limited data presented in these reports. Are the lakes downstream slightly acidic and if not what neutralizes acidity added in tundra soil seepage?
- Given the occurrence of naturally acidic soil seepage, when is slightly acidic site seepage a significant environmental concern?
- What is the capacity for additional seepage neutralization and attenuation downstream of the various WRSAs?

Highlighting pH is useful because of its influence on potentially important parameters such as metal solubility, but it is potentially counterproductive to have criteria that may be unrelated to mining. It may lead to disrespect for the criteria. Alternatives to consider include developing site-specific pH criteria based on the answers to the questions listed above or having sulphate or relevant metal triggers with the pH criteria to ensure the measured impact is mining related.

> *Recommended Action:* Reconsider the pH criteria and/or explain the rationale.

5.7 High Concentrations of Solutes in Seepage from the CKR and Other Wastes

High concentrations of solutes, such as sulphate and Mg, are observed in the seepage from the CKR. This is attributed to (2002 Waste Rock Storage Area Seepage and Waste Rock Survey Report):

- Mechanical disturbance during processing;
- Low annual precipitation;
- Fine grained reactive pyrite (albeit at low concentrations);
- Large surface area for weathering reactions;
- Well-graded particle size that allows unrestricted air entry;
- Abundant reactive carbonate and Mg silicate minerals;
- Contact of CKR at base of dumps with tundra soil drainage that creates an aggressive weathering environment due to its low pH and high organic acid content;
- High solubility of Mg sulphate; and
- Magnification of pore water concentrations by freezing.

High solute concentrations may also occur in areas where kimberlite and black clay are segregated or mixed in with granitic waste rock. Seepage with high sulphate and Mg concentrations are observed at other locations around the WRSAs (e.g., 018/019/022). Presently, the mine is handling this water by collecting the drainage in the Long Lake Containment Area and re-using it as process water. The main management question is whether this drainage poses a long-term environmental concern and it will be necessary to collect and treat it after the mine closes.

> Recommended Action: BHPB needs to show how it will determine whether the CKR drainage will affect its ability to meet receiving environment objectives after the mine closes. The plan of action should outline timelines to ensure the required information (e.g., proof of concept regarding freezing) occurs prior to closure precluding many remediation options. A similar process is required for waste types/rock units containing the kimberlite, black clay and biotite schist.

5.8 Potential for Wastes to Decrease pH and Increase Metal Concentrations of Tundra Soil Drainage

Through actions, such as digging holes, piling up different wastes, building dams and adding water, mining can dramatically alter the local landscape, changing the height of the water table, nutrient supply, locations and rates of flow, and water quality. For example, pit construction may depress the height of the water table, while waste disposal, especially wet waste disposal, may increase it. Some of these changes are immediate. For example, addition of process water along with CKR will raise the water table and the addition of process water will increase solute discharge into the receiving environment. Some properties may change more slowly (e.g., contact with the acidic tundra water increases weathering of Mg silicates at the base of the dump) and some changes will be reversed when the mine closes (e.g., depression of water table adjacent to the pits).

The monitoring indicates that the drainage at a number of locations around the waste storage areas have low pH values and relatively high dissolved Fe and Al concentrations (e.g., up to and in rare cases more than 2 mg/L). Presently the main area of concern is the northeast corner of the Panda/Koala WRSA. Since mining and monitoring started in this area, the pH has decreased and dissolved Fe and Al concentrations have increased. In response to the observed changes in water quality, the mine:

- constructed an interceptor sump at Seep-018B to pump drainage to Beartooth Pit; and
- conducted detailed analysis of the upstream wastes and the flow path between the dump and Beartooth Lake.

5.8.1 Oxidation and Hydrolysis of Ferrous-Fe

SRK/BHPB concluded that the observed pH decreases resulted from acidity produced by the oxidation and hydrolysis of ferrous-Fe when groundwater surfaces. Site features and evidence supporting this hypothesis include[3]:

- the lack of buffering in the already slightly acidic tundra drainage;

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[3] List is derived from Appendix C, Day et al. 2003 and my own thoughts.

- an observed decrease in the proportion of ferrous-Fe observed along the flow path;
- observations of ferric-Fe;
- the decrease in pH observed during the summer, which may result from greater exposure of ferrous-Fe as the water table drops; and
- lower drainage pH in the laboratory versus the field, which is attributed to oxidation and hydrolysis of ferrous-Fe after samples are collected.

The main contrary evidence suggesting that other mechanisms may be contributing to the observed pH decrease is that the only seepage monitoring location where ferric-Fe coatings was noted to occur was SW-321, no ferric-Fe was observed at Seep 018 at the toe of the dump, which had the lowest pH. However, S. Day states (pers. comm.) that Fe precipitates are very common around the CKRSA pile

There are a number of possible sources for ferrous-Fe, but each has limitations. One source for ferrous-Fe is that waste disposal has raised the height of the water table, lowering the redox of the underlying soils and causing inert ferric-Fe soil coatings[4] to be reduced to ferrous-Fe. Ferrous-Fe, unlike ferric-Fe, is soluble at near-neutral pH and dissolves and is transported downstream where it eventually oxidizes, lowering the pH. Mechanisms by which waste disposal may raise the height of the water table include: compaction of the underlying soils, physically filling depressions, the addition of accompanying drainage in the case of lake sediments and till, the addition of fines either directly or through physical collapse of kimberlite or black clay particles after deposition and by changing flow paths. It is important to note that acidity produced downstream by the oxidation and hydrolysis of ferrous-Fe is matched by the alkalinity that is produced upstream by the reduction and de-hydrolysis of ferric-Fe. Overall, there is no net acid production, just a spatial segregation between where the alkalinity and acidity are produced.

Another possible source of ferrous-Fe is the Fe released from pyrite oxidation in the waste rock. However, since pyrite oxidation will only be significant under aerated conditions and waste rock in the Panda/Koala WRSA has excess NP, the drainage within the dump should be aerated and neutral causing Fe released by oxidizing pyrite to precipitate as ferric hydroxide in-situ rather than being leached into the groundwater. One possible exception may be at the base of the dumps, where the depletion of waste rock NP may be accelerated by soil water acidity. Soil organic acids may accelerate from the weathering of pyrite and Fe silicate minerals in the waste rock mixed with tundra soils and, through chelation[5], increase Fe movement downstream. If the released Fe is immediately chelated, it may remain in the ferrous state until the groundwater surfaces or the chelates are degraded. Since the waste rock has excess NP, it would be expected to add alkalinity, raising the pH of any soils it contacts. But as in the previous hypothesis, there may be a spatial segregation between where the alkalinity and acidity are produced.

5.8.2 Oxidation of Ammonium

There are a number of other plausible mechanisms for some or all of the observed pH decrease, in addition to Fe oxidation. Acidity will be generated from the oxidation of ammonium, which is contained in blasting powder and therefore likely to be present in all the wastes. At most sites natural alkalinity is sufficient to neutral the resulting acidity. The low alkalinity makes the

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[4] Precipitated ferric iron coatings provide the brown coatings of mineral soils and are insoluble unless the pH is below 3.5.

[5] A chemical compound in which a metallic ion combines with an organic molecule by means of multiple chemical bonds. The resulting compound is often more soluble than other metal compounds.

groundwater at Ekati more susceptible to acidification. Oxidation of ammonium is responsible for acidification of the low alkalinity water cover over the tailings at the Equity Silver Mine.

5.8.3 Cation Exchange

Another plausible explanation for the decrease in pH, that ties together the presence of kimberlite as a source of base cations and the presence of acidic conditions, is cation exchange. Base cations from the waste rock pore water (e.g. Mg, Ca and Na) adsorbed by organic acids will displace stored acidity (protons) into the surrounding water, lowering the pH. Using this mechanism, sulphate salts are used to acidify agricultural soils. Supporting evidence for the hypothesis that cation displacement is responsible for the observed decreases in drainage pH include:

- the high acidity after mixing of tundra soil and CKR, which suggests the soils have a high reserve of acidity;
- much of the site drainage has significantly higher hardness than alkalinity;
- the high drainage sulphate/cation concentrations at many of the sites with a low pH (007D, 007E, 008, 011, 011A, 024A, 025 and SW318); and
- the relatively low TOC (<10 mg/L) for low pH sites 018B and 019 and higher TOC (16 to 20 mg/L) at the more alkaline site 018, which may result from the greater precipitation of organic acids after the replacement of protons by base cations.

If cation displacement does play a role in the observed pH decreases, it is possible that continual additions of alkaline mine drainage will eventually reverse the trend, raising the soil pH and lowering the concentrations of soluble Fe and Al.

- ➢ Were thiosalts analysed for? The oxidation of thiosalts will also result in a reduction in the pH.

5.8.4 Increased Leaching

In some locations, the lower downstream seepage pH values may result from the leaching of organic acids, Al and Fe either directly from stockpiles of the acidic till and lake sediments[6], or indirectly from the underlying soils by water added with the CKR and till/lake sediments. The relatively low TOC concentration (<10 mg/L) for low pH sites 018B and 019 and higher TOC (16 to 20 mg/L) at the more alkaline site 018 suggest that organic acids leaching is not an important mechanism in this area, but it may be important in other locations.

It is important to note that while chelation by organic acids has the potential to increase iron and trace metal solubility in the receiving environment, it can also reduce their toxicity. A number of mine sites with high TOC in receiving waters have developed site-specific water quality objectives that are higher than provincial aquatic guidelines and criteria (e.g., Bell Mine, B.C. and Detour Lake, Ontario), reducing both the perceived risks and liability.

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[6] The Feb 2000 A&R Plan notes (p.58) that "sediments are acidic, with pHs ranging from 4.33 to 5.84…" and that "there is very little difference in pH either spatially or with depth."

5.8.5 Discussion

The previous discussion (Section 5.8) indicates that there is considerable uncertainty regarding potential mechanisms for the observed decrease in pH and increase in metal concentrations in the tundra soil drainage There is likely to be a combination of mechanisms and factors contributing to the observed pH decreases, with products from the mine wastes directly creating acidity (e.g., oxidation of ammonium) or enhancing the re-distribution of soil acidity causing local impacts. This issue is potentially important for future management if the drainage, which is presently collected, has to be discharged directly to the environment when the mine closes.

> *Recommended Action:* BHPB needs to assess alternative hypotheses for the observed pH changes and develop an acceptable plan for determining the potential magnitude of future pH depression and metal loadings, where it might occur, the significance in terms of meeting discharge requirements after the mine closes, and/or whether some additional mitigation measures or refinements to the mine plan are required. Further controlled studies, along the lines of those in Day et al. (2003), may be required to better understand the mechanisms involved and potential future implications. Better information may also be required on the mechanism and capacity of natural acid neutralization at the site. For example, why is the pH in Beartooth Lake 7 when the pH is < 6.5 in soil drainage going into the lake? What is the neutralization mechanism?

5.9 Overall Conclusions

The *2004 Report*, like the *2003 Report*, was generally a well organized and well-written presentation of the results of the seepage, waste composition and mitigation (freezing) monitoring. The main things the Report lacked were a discussion of:

- the temperature (freezing) data; and
- the implications of the results in terms of the future ability of the site to meet the discharge limits and protect the environment.

The discussion of results focused entirely on present water management and discharge quality. There was little or no analysis of the future implications of the results, the need for future work and/or management action, and whether there were emerging issues that might be of interest to the mine or the Agency.

The 2004 *Report* also made no mention of and did not incorporate the recommendations from the review of the *2003 Report* into the methodology and analysis.

> *Recommended Action:* The terms of reference for the report should be expanded to address the management and closure implications of the monitoring results. The analysis should include:

- comparison of the composition of the waste materials, the resulting weathering, the performance of mitigation measures (freezing), and the resulting drainage chemistry with the pre-mine predictions;

- assess the impact of past and proposed future mining and waste management on the future ability of the operating and closed mine to protect the environment and reclaim the site;
- identification of significant information gaps;
- determine if present monitoring is adequate and what refinements are required; ; and
- identify where refinements are required to the mining, waste management and mitigation plans, what those refinements should be and what additional studies are required.

Recommended Action: It is advisable for the Agency to review future waste rock and seepage monitoring reports.

This review poses a number of questions and recommended actions for BHPB. Many of the recommended actions pertain to the laboratory analyses, data analysis (e.g., include an assessment of the CKR results) and the presentation of results (e.g., tables showing descriptive statistics for the total and for the 2004 data should be provided for all rock unit/pipe combinations).

However, there may be alternative approaches to those suggested in this review. BHPB should be given the opportunity to suggest additional information or approaches that achieve the reclamation and environmental protection objectives in a more cost-effective manner. Answers to some of the questions may remove the necessity for some of the recommended actions.

Probably the most important question regarding the WRSAs is whether there is a potential for significant long-term contaminant leaching from the CKR and the kimberlite, black clay and biotite schist waste rock, and how to handle the uncertainty surrounding this issue. Many of the questions and recommended actions attempt to increase the understanding about whether these wastes will completely freeze, the potential impact on discharge quality if they do not and what to do about the residual risks. It is very important that this issue be addressed prior to closure. Although closure may seem a long way off for staff dealing with a full plate of operating challenges, it is important that these issues not be left until the last moment to resolve. Recognition and addressing information deficiencies as early as possible permits a mine to use its operating facilities, equipment and personnel to resolve key uncertainties and find a solutions.

Appendix A Summary of Questions and Recommended Actions

Introduction

Recommended Action: The *Report* should include a list of ongoing studies and relevant previously produced reports.

Koala Blast Rock – Granite, Black Clay and Waste Kimberlite

- What was the mass of waste kimberlite and black clay this year and in total?

Misery Blasted Rock

- Why did the *2003 and 2004 Reports* not provide the same table of descriptive statistics used for other areas of the mine?

Long-Lake Containment Facility

- What happens to the wastes from the various flocculant/coagulant treatments?

Recommended Action: The geochemical characterization of the processed kimberlite fines should be included in this *Report*.

Characterization of Different Rock Types

Recommended Action: Tables showing descriptive statistics for the total and for the 2004 data should be provided for all rock unit/pipe combinations. Where significant differences occur, distribution plots should be used to highlight (e.g., bold points) differences in the current year from previous year's data.

Recommended Action: The *Report* should include an assessment of the CKR results.

Recommended Action: BHPB should check the number of CKR samples. Although there were said to be 16 samples analyzed; only 14 sample results from 2004 were reported in Appendix A.4.

Recommended Action: Given its potential impact on site discharge quality, BHPB should conduct operational characterization of till and lake sediments. This information may already be collected as part of the characterization of soils for reclamation, but refinements may be required to address the issues associated with waste disposal, water management and ML/ARD mitigation.

Sampling Frequency

Recommended Action: BHPB should review the consistency of the results for the different rock type/waste/pit combinations and where the geology is homogeneous and there are no drainage chemistry concerns suggest reductions in the sampling frequency.

Recommended Action: The *Report* should indicate the tonnage mined and the frequency of sampling for different rock types in different pits, in the past year and in total. The *Report* should also indicate past changes in the # of tonnes per sample and the number of samples collected from each blast, including where no samples were collected.

Recommended Action: The waste rock monitoring data should show the date each sample was collected, the blast and the disposal location.

Laboratory and Data Analysis

Recommended Action: Where there is a drainage chemistry concern and mineralogy may be important (e.g., Ni minerals in black clay and kimberlite and NP minerals in kimberlite, black clay, diabase and Misery schist), the geochemical characterization should include additional regular checks on the mineralogy using Rietveld XRD procedure.

Recommended Action: In the data tables, CO_3-NP should be reported as < 5 kg/t when CO_2 inorg is < detection limit of 0.2% and CO_3-NPR should indicate that CO_2 inorg is < detection limit rather than a value calculated value using a CO_3-NP of 5kg/t (0.2% = 5 kg/t).

Recommended Action: Lower the CO_2 detection limit used for the granite samples or drop the analysis.

Sobek-NP

Recommended Action: For 2003 data, check how PPW 345-43 1A had a Sobek-NP of 153 kg/t when fizz rating of 2 is only equivalent to 100 kg/t. A similar check is required for KK-Dump-5A Koala Kimberlite with Sobek-NP of 76 kg/t; since a fizz rating of 1 is only equivalent to 50 kg/t. Hopefully, these discrepancies do not uncover something generically wrong with the analysis procedure or the calculation of data.

Recommended Action: Regular checks on the carbonate mineralogy using Rietveld XRD procedure are required to confirm that the CO_3-NP is Ca or Mg CO_3.

Concentration of AP and NP in Fine Fraction versus Larger Size Fractions of Waste Rock

Recommended Action: Geochemical characterization should include regular sampling of post-blast fines and coarse fragments to check that drill chip analysis provides an accurate assessment of the composition of fines and the likely range in composition of the fines. The frequency of sampling should depend on the variability and ML/ARD concerns associated with the waste/rock type.

Potential for Elevated Ni in Neutral pH Drainage from Black Clay and Kimberlite Rock

Recommended Action: BHPB needs to address the question of whether there is a potential for significant long-term contaminant leaching from wastes containing kimberlite and black clay. This should include microprobe assays of the relevant rock types and wastes to identify the mineral sources for potential contaminants of concern, especially Ni, review of drainage at mines with similar Ni minerals (asbestos mines?) and construction of field test pads to provide information on the potential for Ni release in the various disposal scenarios and environments of kimberlite and black clay.

Field Test Pads

Recommended Action: BHPB should construct ‘field test pads’ for potentially problematic rock types, such as biotite schist and the CKR, to verify pre-mining predictions of future weathering and drainage chemistry, and assess the risks if the WRSA do not completely freeze.

Waste Disposal and ML/ARD Mitigation

Recommended Action: The 2000 Waste Rock and Ore Storage Management Plan is out of date. Many of the ML/ARD mitigation measures do not appear to have been used. The waste management and control portion of the 2000 Waste Rock and Ore Storage Management Plan should be updated.

- Does the segregation of kimberlite waste rock in the Koala WRSA also include black clay?

Recommended Action: To allow a reviewer to understand and interpret the results and as a record of what happened, the *Report* should provide:

- larger-scale as-built plans for the WRSA that outline past, current and future waste management and mitigation plans (e.g., CKR was originally deposited directly on tundra soils, presently it is being deposited in layers and encapsulated within granitic rock);
- list any modifications, errors or omissions (e.g., where material were co-disposed, misclassified or handled in different manner); and
- updated cross-sections and plan views of the SAs showing where different wastes are located and different disposal strategies have been used.

- What happens to the incident precipitation and groundwater inputs when the waste freezes? Does ice continue to accumulate?

Panda/Koala/BeartoothThermal Monitoring

- What is the composition of the fill in holes #1-4 in the Panda WRSA?
- Why is the depth of the CKR less than the waste rock?
- Is there any waste kimberlite, black clay or overburden mixed with the waste rock in the thermistor holes?
- How successful have the toe berms been?

Discussion of Freezing

Recommended Action: Given its importance to the post-closure environmental protection, future editions of the *Report* need to address the issue of freezing in greater detail. This should include:

- whether the thermistor locations (e.g., P/K WR) are representative of the potential range in SA conditions;
- the impact on and of adjacent frozen rock units on drainage from the unfrozen material;
- the influence of climate variability (e.g., cold versus warm years and climate change); and
- contingencies for where climate and waste conditions are warmer than was previously estimated.

Potential for Tundra Soils to Increase Metal Leaching from Mine Wastes

Recommended Action: BHPB needs to clarify the measures it is taking with the various pit/rock types to minimize contact between tundra soil (underlying or stripped) and waste materials with high trace metals (e.g., kimberlite and black clay) or significant sulphides (e.g., biotite schist and kimberlite).

Recommended Action: Future versions of the *Report* need to discuss the implications of past placement of waste materials in contact with the acidic tundra soils, its potential impact on seepage chemistry and loadings to the environment, where materials are assumed to be frozen and, if required, how the elevated metal leaching will be mitigated both during operation and after the mine closes.

Sable and Beartooth-Bearclaw Reference Areas

- *Were the surficial materials and soil chemistry in Sable and Beartooth-Bearclaw Reference Areas similar to the various areas of mining?*

Presentation of Seepage Results

Recommended Action: Tables showing descriptive statistics for the total data set and for the 2004 data should be provided for all monitoring stations. Where significant differences occur, plots should be used to show differences in the current year from previous year's data.

General Exceedance of the pH Criteria

- If the till, lake sediments and the majority of the tundra seepage are naturally acidic, as suggested by the limited data presented in these reports, are the lakes downstream slightly acidic and if not what neutralizes acidity added in tundra soil seepage?
- Given the occurrence of naturally acidic soil seepage, when is slightly acidic site seepage a significant environmental concern?
- What is the capacity for additional seepage neutralization and attenuation downstream of the various WRSAs?

Recommended Action: Reconsider the pH criteria and/or explain the rationale.

High Concentrations of Solutes in Seepage from the CKR and Other Wastes

Recommended Action: BHPB needs to show how it will determine whether the CKR drainage will affect its ability to meet receiving environment objectives after the mine closes. The plan of action should outline timelines to ensure the required information (e.g., proof of concept regarding freezing) occurs prior to closure precluding many remediation options. A similar process is required for waste types/rock units containing the kimberlite, black clay and biotite schist.

Potential for Wastes to Decrease pH and Increase Metal Concentrations of Tundra Soil Drainage

Recommended Action: BHPB needs to assess alternative hypotheses for the observed pH changes and develop an acceptable plan for determining the potential magnitude of future pH depression and metal loadings, where it might occur, the significance in terms of meeting discharge requirements after the mine closes, and whether some additional mitigation measures or refinements to the mine plan are required. Further controlled studies, along the lines of those in Day et al. (2003), are required to better understand the mechanisms involved and potential future implications. Better information is also required on the mechanism and capacity of natural acid neutralization at the site. For example, why is the pH in Beartooth Lake 7 when the pH is < 6.5 in soil drainage going into the lake? What is the neutralization mechanism?

- Were thiosalts analysed for? The oxidation of thiosalts will also result in a reduction in the pH.

Overall Conclusions

Recommended Action: The terms of reference for the report should be expanded to address the management and closure implications of the monitoring results. The analysis should include:

- comparison of the composition of the waste materials, the resulting weathering, the performance of mitigation measures (freezing), and the resulting drainage chemistry with the pre-mine predictions;
- assess the impact of past and proposed future mining and waste management on the future ability of the operating and closed mine to protect the environment and reclaim the site;
- identification of significant information gaps;
- determine if present monitoring is adequate and what refinements are required; ; and
- identify where refinements are required to the mining, waste management and mitigation plans, what those refinements should be and what additional studies are required.

Recommended Action: It is advisable for the Agency to review future waste rock and seepage monitoring reports.