E.1 An Overview of New Developments in ML / ARD at Mines Sites in British Columbia

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An Overview of New Developments in ML/ARD at Mine Sites in British Colombia

by Bill Price, BC MEM

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Brief Overview of Activities in 2000

Prediction

A critical part of any ML/ARD program is material characterization and assessment.

One of the most important elements of material characterization is the determination of the neutralization potential.

Debate about Static NP Procedures

In the past it has been reported that Sobek procedure gives unrealistic measure while Modified NP is relatively accurate (Lawrence & Wang, 1996).

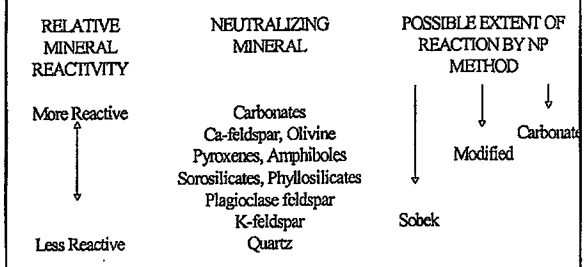


Figure 1: Relationship between mineral reactivity and method of NP determination (from Lawrence and Wang, 1996)

Conclusions of Recent Research

Results reported this year (Jambor et al., 2000) showed that Sobek and Modified NP procedures provide similar results for most common rock forming minerals. In the Jambor et al. study, the Modified NP was higher than the Sobek NP for most minerals. The results supported the results of previous research (Lapakko, 1992) and the work at mines in BC (Price & Kwong, 1997).

Debate about the best static NP procedure is some what academic because no matter what procedure is used, information regarding the NP mineralogy and the sulphide oxidation rates are required to interpret the results.

Both procedures often require corrections. For example, in aerobic weathering both procedures are likely to report Fe and Mn carbonate as a NP source.

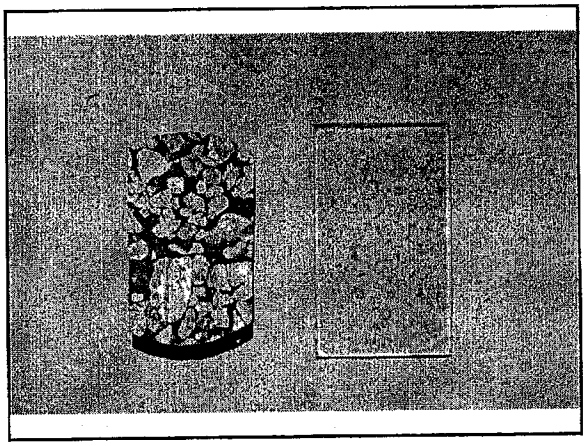
An advantage of the Modified procedure is lack of a fizz test, removing an opportunity for error.

An advantage of Sobek procedure is it takes less time (3 vs 24 hrs), which may be very important where operational characterization is used to separate PAG and non-PAG materials.

Mineralogy

Another critical part of material characterization is the determination of mineralogy. The mineralogy is required to interpret all ML/ARD specific test work.

Previously, the primary source of mineralogical information has been petrographic analysis.



Petrographic Analysis

Petrographic analysis is a good source of information about general lithology, silicates mineralogy, sulphides and texture (e.g., Kemess) and is relatively quick and inexpensive ($100/sample) compared to submicroscopic methods.

The limitations include:

- detection limits of > 100 um and 0.5%
- limited ability to identify minerals (calcite vs ankerite or kaolinite vs smectite)
- requires well trained evaluator

Submicroscopic Procedures

Consequently submicroscopic procedures, such as SEM/EDS, XRD and microprobe, are required to answer many regulatory questions (e.g., Snip, Kemess).

The types of questions include the contribution of:
- Fe and Mn carbonates to NP
- barite to AP
- mineral source for soluble contaminants

Presently there are a lack of places to send samples for submicroscopic work

Some of the greatest prediction challenges in BC are with neutral pH drainage.

Examples of pH Neutral and Alkaline Drainage Issues include those with:

Mo: Brenda, Highland Valley, Endako

Cu: Mt Polley

SO_4^{2-}: Quinsam, QR Gold

Se: Coal mines in Kootenays, Kemess

Hg: Pinchi Lake

Molybdenum

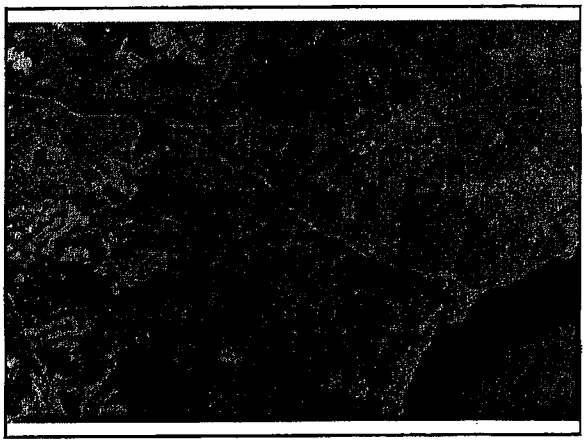
Lots of work has and is being done on Mo. Results were reported in a variety of publications, including a literature review produced in 1994 and the proceedings of a workshop held in 1999.

Ongoing work includes grazing studies at Highland Valley and fish studies at Endako.

Brenda

The following slide shows the Brenda mine site which has the added challenge of having its drainage used by the town of Peachland.

Brenda treating drainage to meet permit limit of 0.25 mg/L. Presently achieving 0.02 mg/L. Use dilution to minimize hardness.

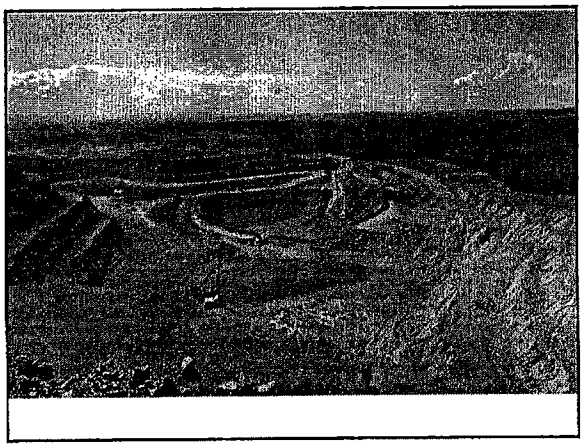


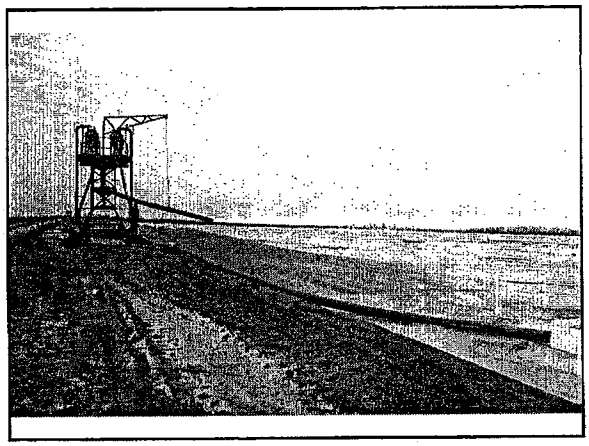
Mt. Polley

Drainage Cu levels will determine post-mining water management requirements. The primary concern is with supergene Cu in the tailings, especially now that cycloned tailings sand is used in the construction of the downstream side of the dam.

Site drainage will be neutral, but there is very little dilution and attenuation prior to sensitive ecological receptor (fish).

Cu concentration will determine whether drainage must be diverted to larger stream. Diversion will require long term maintenance of water management facilities. The objective of much of the work to date has been to determine solubility constraints in laboratory and in the field.



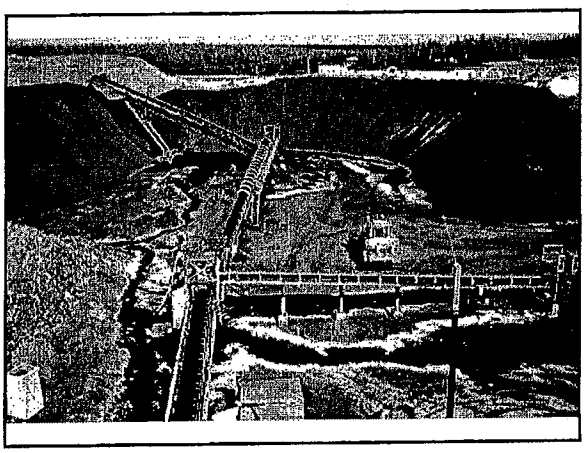


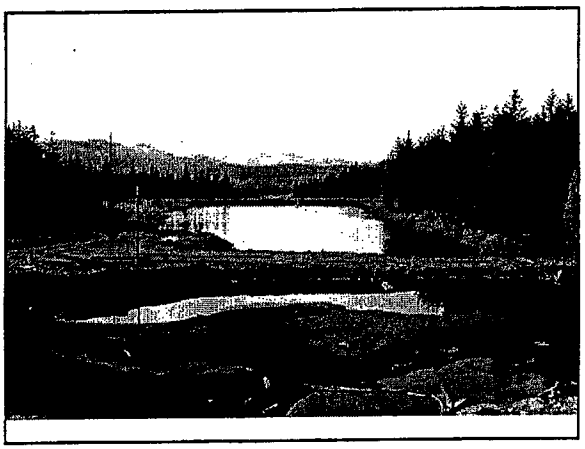
Quinsam Coal

Operating underground coal mine, located on central Vancouver Island. Aerial blending with tailings and subaqueous disposal of PAG coal refuse in mined out pits.

Elevated sulphate in surface drainage and groundwater is product of gypsum dissolution and sulphide oxidation (1680 mg/L sulphate & 960 mg/L hardness, not atypical of sulphidic mine)

Concern is 75-184 mg/L in Long Lake (hardness 72-146 mg/L). Mine is conducting hydrogeological studies to determine pathways of sulphate to the environment and potential remediation measures.



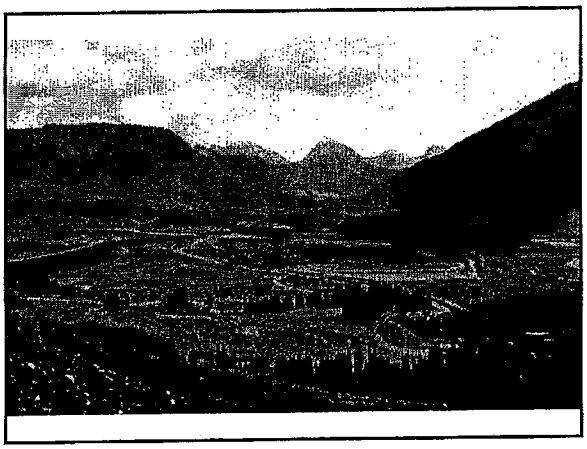


Selenium

Elevated concentrations discovered in waste materials and drainage from Kootenay coal mines shown in following picture. Program underway to determine more about source and mechanisms of weathering and leaching and whether this is having a significant environmental impact.

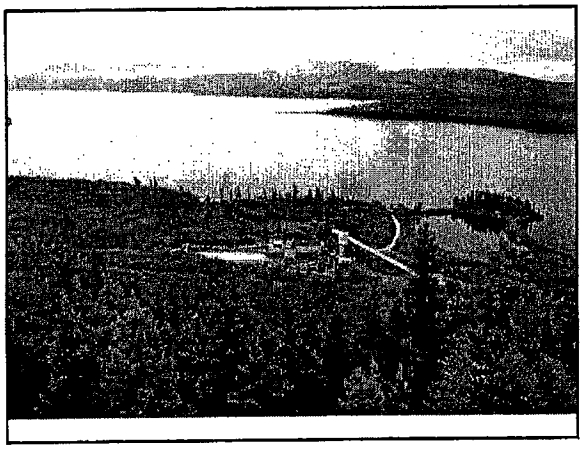
Research also ongoing at Kemess on rock type with high Se.

Se workshop held in Williams Lake last June.



Pinchi Lake

Work in last year includes measures to prevent erosion and studies of fish in Pinchi Lake and adjacent lakes some of which are naturally elevated in Hg.



Prediction Mis-Information

Sulphide-S < 0.3% and Subsoil pH < 5.5

- "Intended for work in non-mineralized terrain" in BC.
- 0.3% sulphide-S is equivalent to an AP of 10. Most rock has NP > 15.
- Not intended for mine sites or highly leached tropical soils or other rock with potential for very low NP.
- If effective NP is low, 0.3% will be and has been sufficient to generate ARD.

ABA Criteria for PAG Waste
(from MEND/UBC Mining Report)

Jurisdiction	NPR Criteria
British Columbia	4 WRONG
California	3
Montana	3
Idaho	2
Montana	1.2

Mitigation

Underwater Storage

- generally the most effective means of preventing ARD
- often reduces metal leaching to levels that no longer pose a concern (see comments on solubility of As and Sb at Eskay)
- very common for tailings
- increasing use for waste rock

- must maintain flooding for ever
- require supportive hydrological and geotechnical conditions
- design geotechnical structures to maintain flooding for ever
- critical components include
  - dams
  - spillways
  - ditches

Snip

A good example of a flooded impoundment is provided by the recently closed Snip mine. At closure the dams were constructed to withstand extreme flood and earthquake events. The spillway was excavated in bedrock.

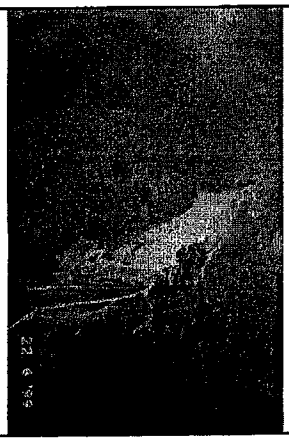
A short time after the mine closed, beaver prints were spotted on the tailings.

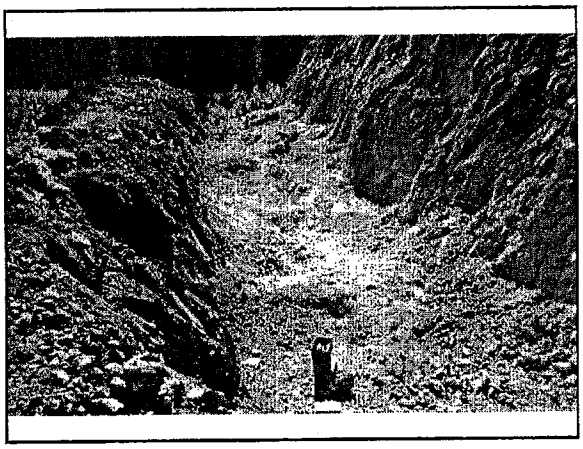
Snip is a remote site with no remaining staff and thus one of the reclamation objectives was to limit the need for monitoring and maintenance.

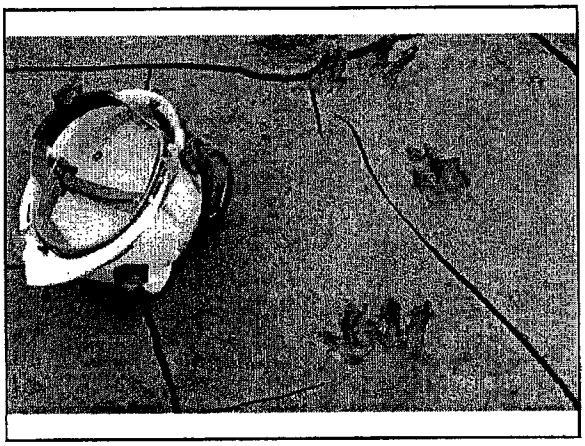
One of the requirements in impoundment design are measures to prevent beaver from building dams which could reduce the stability and ability of the impoundment to withstand extreme limit climate events.

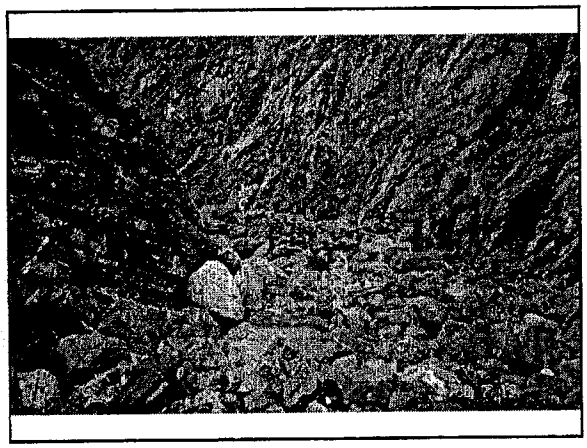
This took the form of measures to limit the occurrence of surface flow and the consequent need for frequent monitoring.

- filling the spillway with boulders
- covering the tailings with waste rock and various soil materials to raise the surface level within the impoundment above the predicted height of the water table

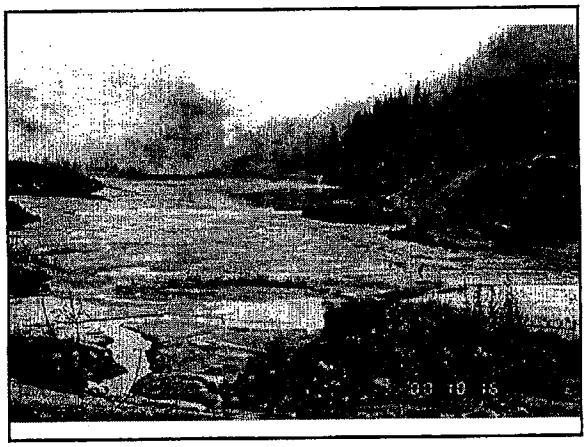








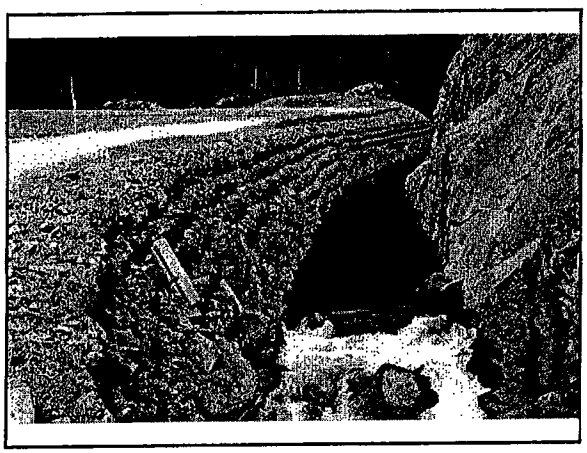
Premier

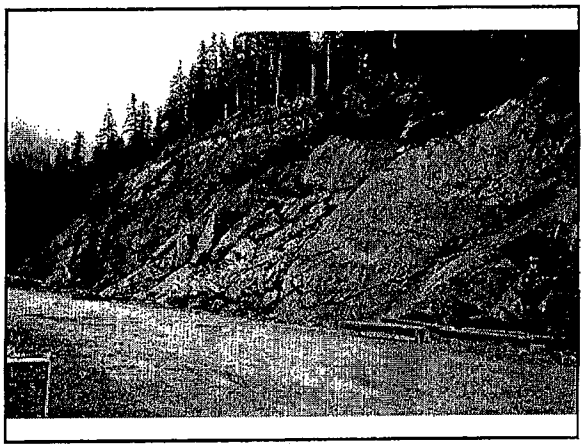


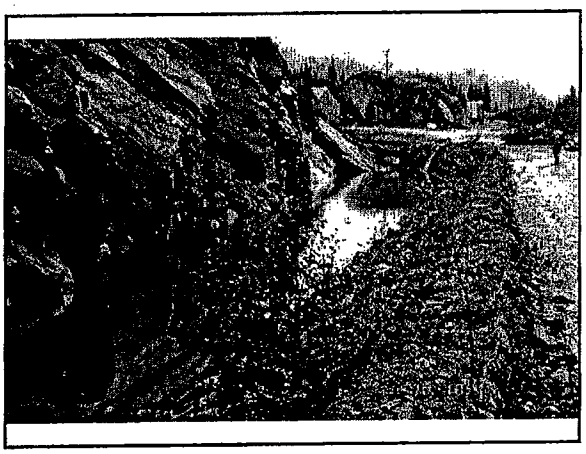
A major protective measure for the Premier tailings impoundment, at least in the short term, is the diversion of Cascade Creek.

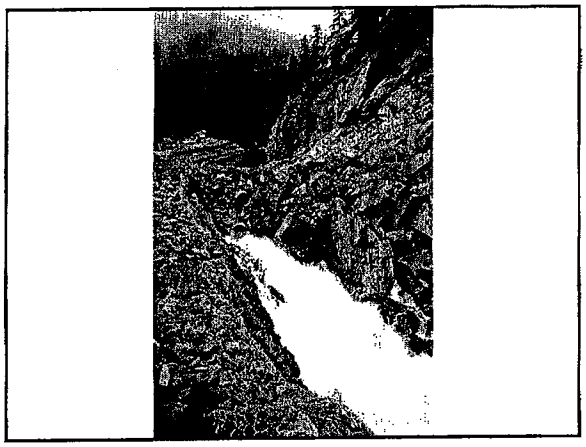
This year a rock fall dammed up part of the flow. Material characterization showed that the rock contained 3% sulphide-S.

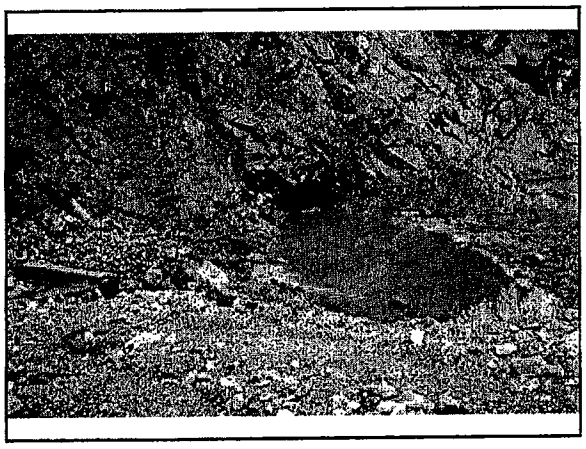
The rock and other loose material was removed to the tailings impoundment where it will be eventually flooded.

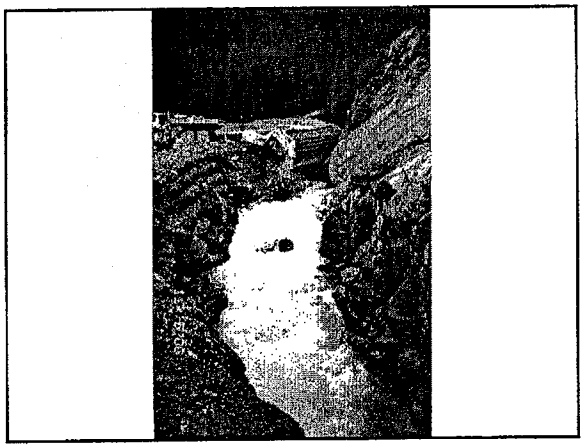


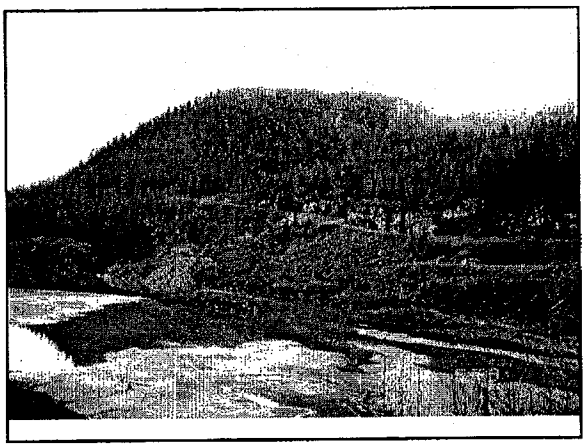




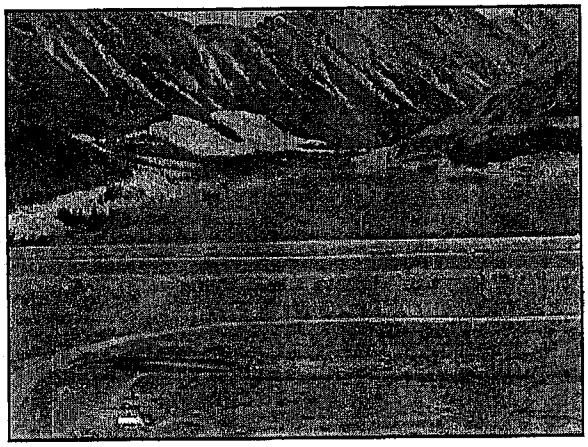








Kemess



The diversion system at Kemess, which is over 14 km long, is required to maintain the flow in South Kemess Creek.

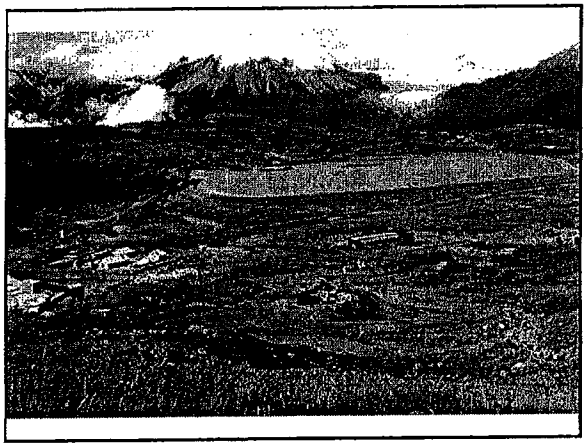
Unfortunately the galvanized pipe has elevated Zn in the drainage.

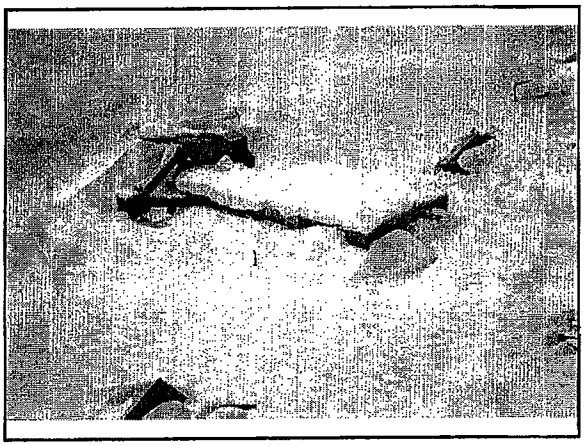
To mitigate the problem another pipe is being inserted in the center.

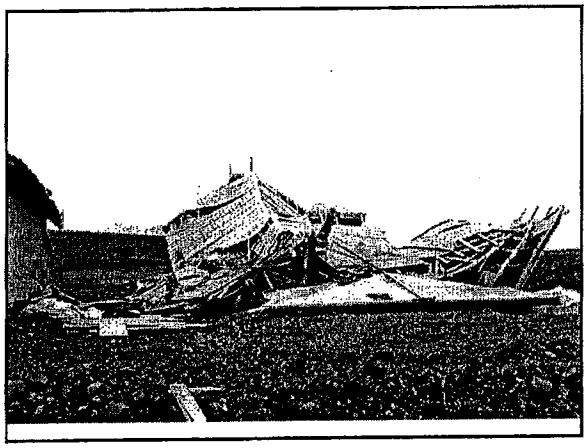
Johnny Mountain

Closure planning is proceeding for the PAG waste rock and tailings. The tailings and some of the waste rock are stored underwater in a flooded impoundment.

Challenges for monitoring and maintenance include difficult site access and a harsh alpine environment.







Alternatives to Constructed Impoundment and their Maintenance Requirements

- Pits and Underground Workings
- Lakes

Eskay Creek

This year Eskay Creek received conceptual approval for waste disposal in Big Tom Mackay Lake in addition to the presently permitted disposal in Albino Lake.

Issues supporting lake disposal versus disposal in a flooded on-land impoundment included:

- impoundment maintenance challenges at this high elevation, heavy snowfall, remote site
- there is considerable dilution of the drainage from the two lakes before fish are first encountered, approximately 15 km and several unpassable canyons downstream at the confluence of the Unuk River and Storie Creek

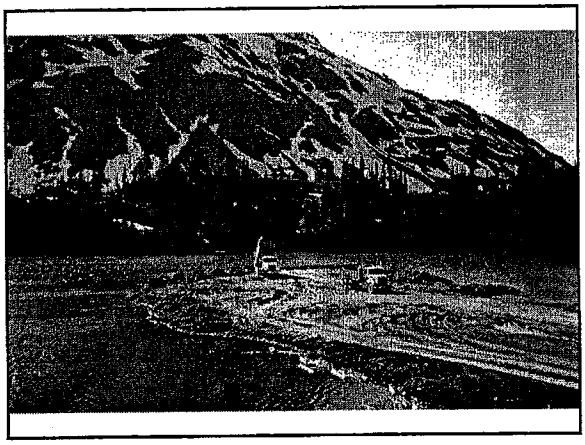
Mitigation measures used in Albino Lake and proposed for Big Tom Mackay lake include:

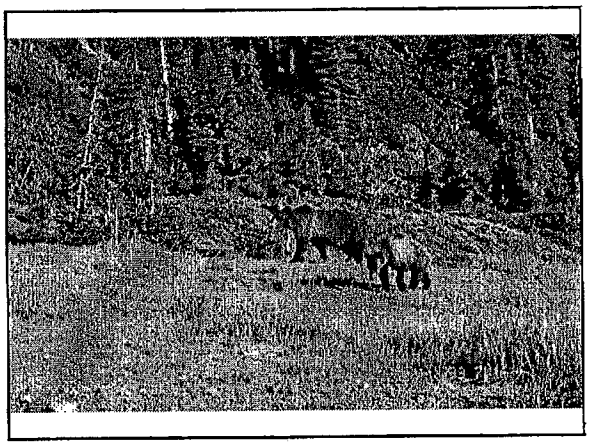
- sediment curtains and booms to restrict wave action and sediment movement
- drainage treatment to lower Sb levels

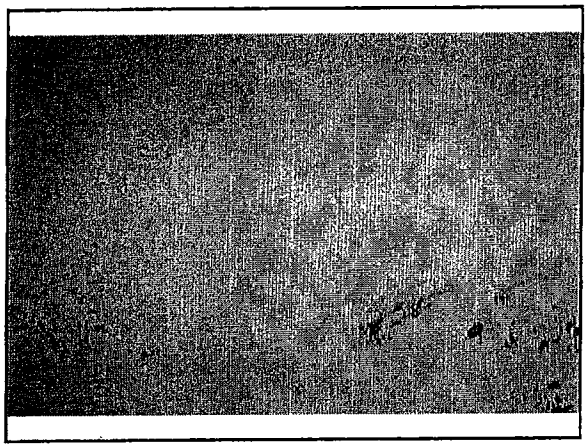
Discharge objectives will be set by MELP based on detailed drainage and environmental effects monitoring.

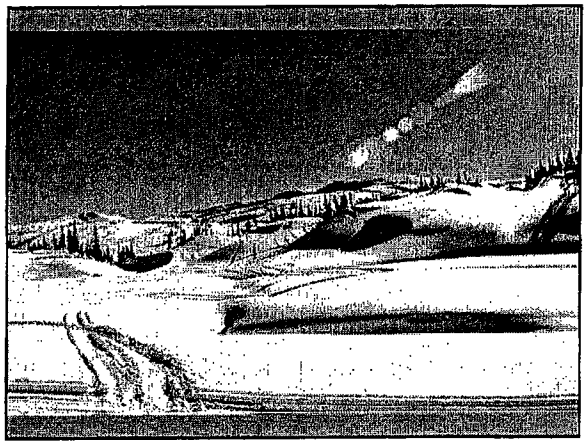
Disposal in Big Tom Mackay Lake was required to ensure Albino Lake retains its lake-like quiescent nature and ability to settle suspended solids.

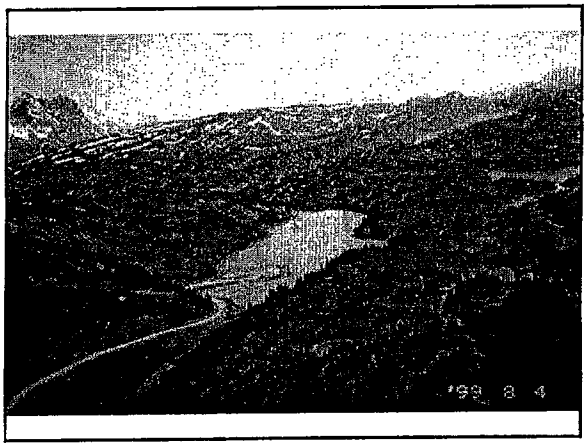
An improvement over Albino Lake is that tailings disposal in Big Tom Mackay Lake will be through a deep water discharge.







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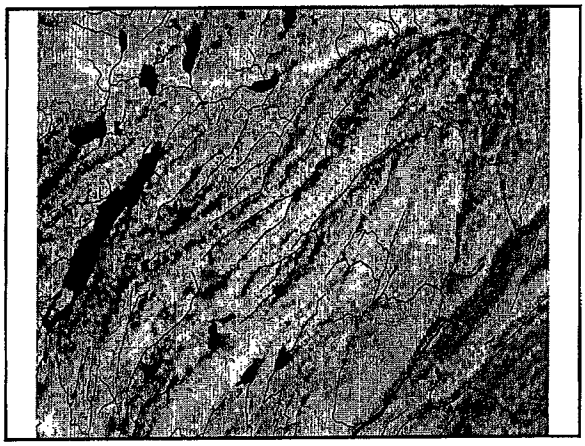
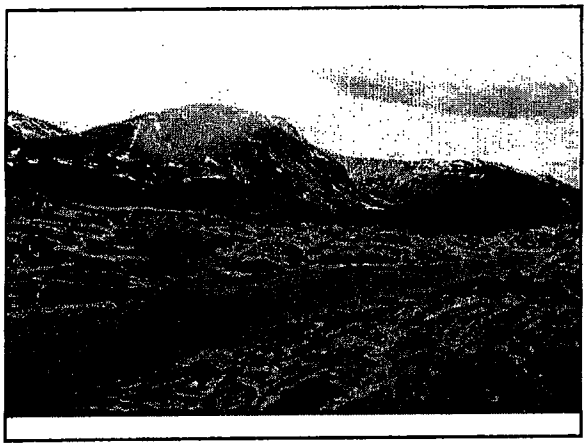
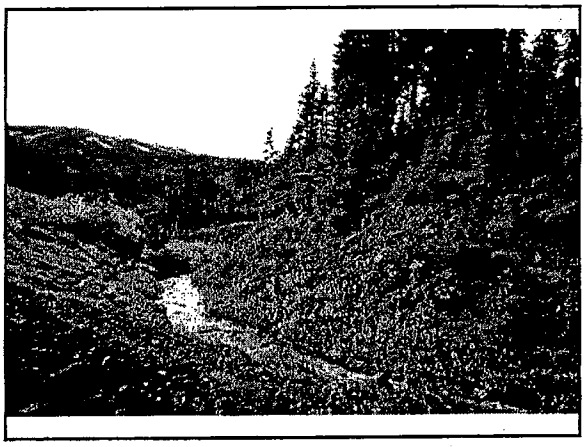
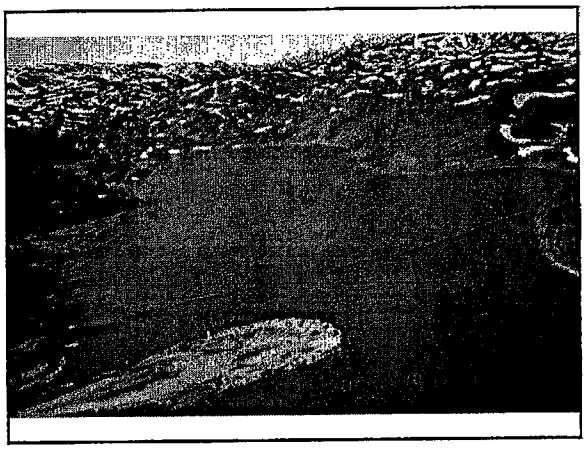
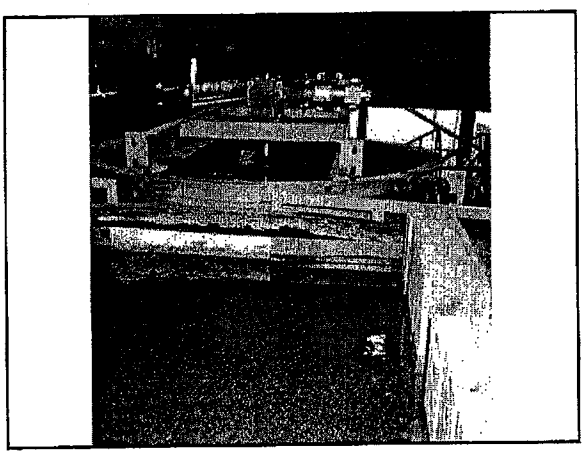








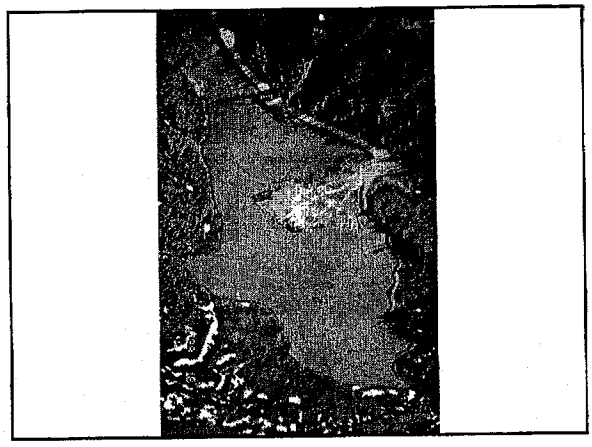


Sb: Fate

- **Concentrations**
  - Albino Discharge Station

  - Tom MacKay & Ketchum Creeks

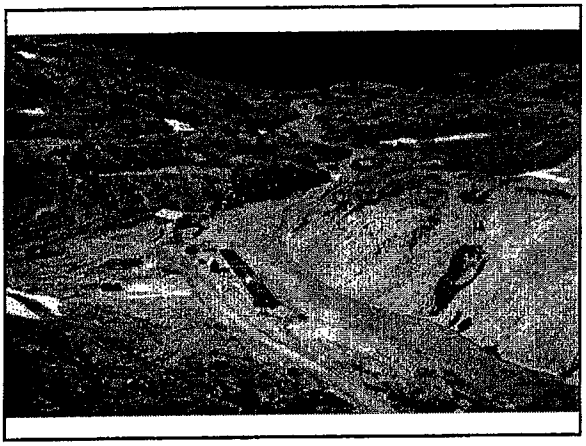
< 0.02 mg/L



Sulphurets

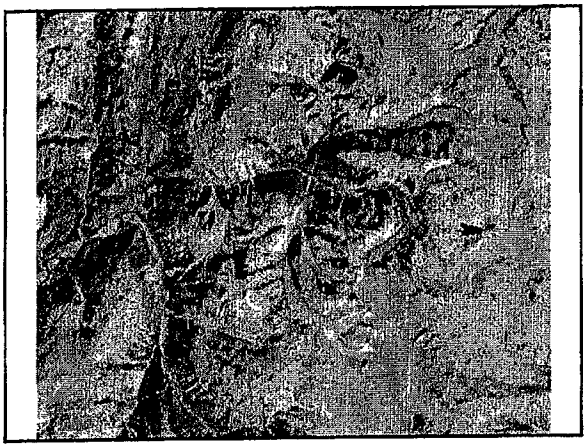
Another recent lake disposal was the disposal of 125,000 t of PAG waste rock, created by advanced exploration at Sulphurets.

The objective was to flood the high sulphide waste rock prior to the build-up of significant acid weathering products.



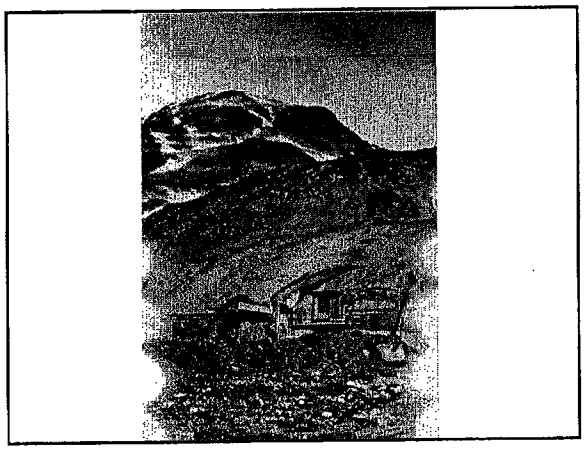
The proposed disposal site was an alpine lake surrounded by glaciers.

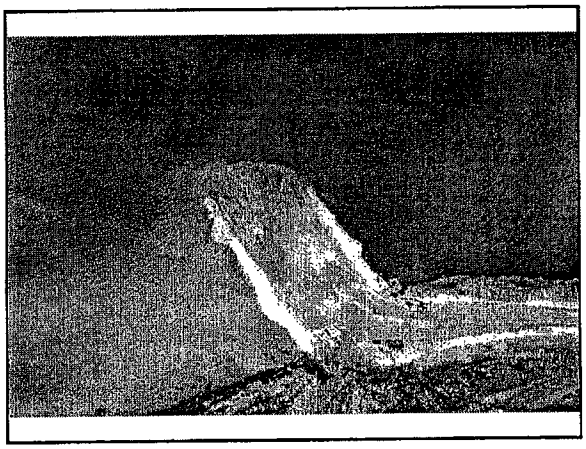
The first fish bearing waters are 20 km, including 4 km of sub-glacier flow, downstream.



Test work showed that 10% of the waste rock was already acid and that the soluble contaminant load was too small to have a significant impact.

As a further measure to reduce the impact on the lake, the pH of the excavated rock was monitored and limestone was used to neutralize any acid material. The rate of limestone addition was calculated from shake flask tests.





After disposal, the surface of the pad was lowered 1 to 2 m below the surface.

Measures to Limit Oxygen Entry

Cover use for this purpose will be discussed in later presentations.

Main Alternative to Underwater Disposal

are

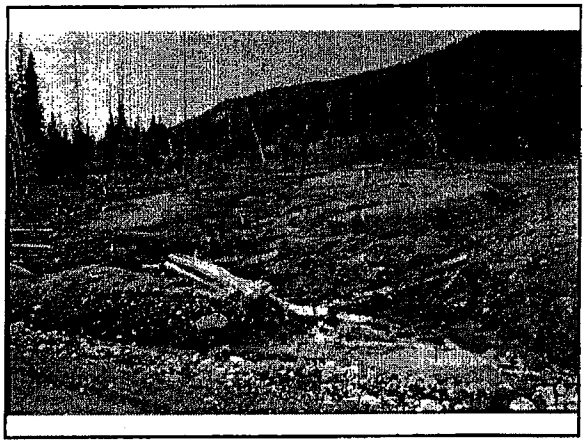
Measures to Limit Leaching

Measures to Limit Leaching

- Disposal location that limits leaching and maximizes dilution prior to sensitive resources
- Measures to divert off-site drainage
- Covers to divert incident precipitation

Duthie

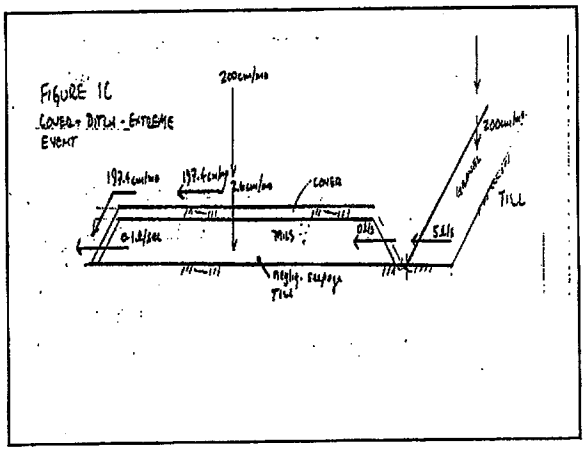
Duthie is a historical Ag-Pb-Zn property mined primarily in the 20's and 50's. The primary concern is with the 50,000 t of AG and PAG tailings.

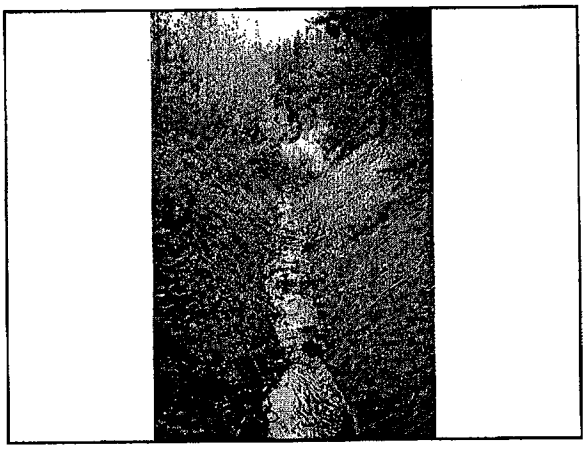


Mitigation has consisted of collecting the spilled tailings which covered a wide area and moving them to a single location

- away from stream flow off the alluvial fan,
- up slope from the areas of maximum groundwater discharge and
- surrounded by perimeter ditches designed to divert groundwater the primary source of contaminated drainage.

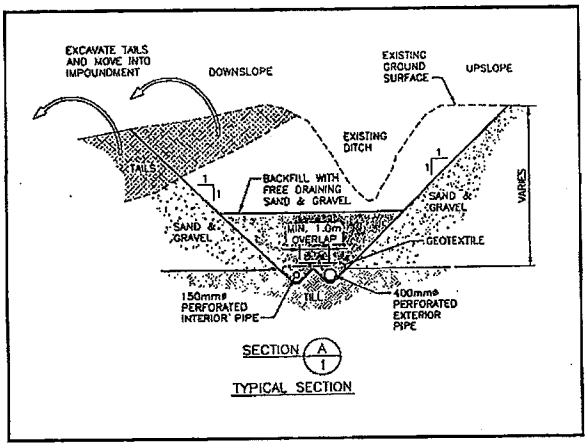
Infiltration of incident precipitation will be limited with a cover.





Success of the plan will depend in large part on the long-term performance of the groundwater interception system - the ditches.

The objectives of the design have been to maximize groundwater interception and minimize long term maintenance requirements.

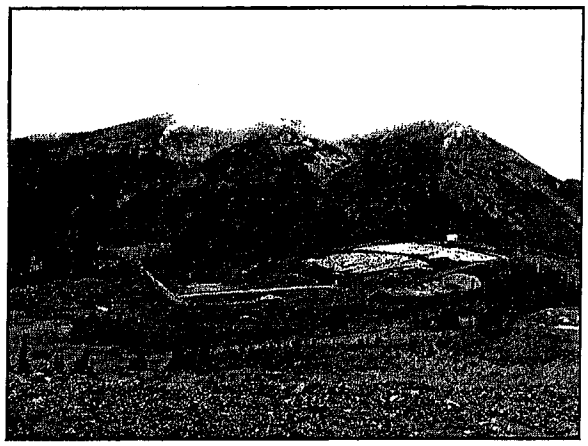


Factors that must be considered when ever covers are proposed for mitigation include:

- precipitation is only part of drainage inputs
- uncertainty regarding effectiveness
  - short-term
  - long-term
- cost
  - initial
  - for monitoring, maintenance and/or replacement

Cirque

This year Cirque installed a geotextile cover on the PAG waste rock produced during exploration.



Long-Term Collection and Chemical Treatment of Drainage is required at a number of BC mines

- Myra Falls
- Sullivan
- Brenda
- Bell
- Premier
- Gibraltar
- Samatosum
- Equity Silver

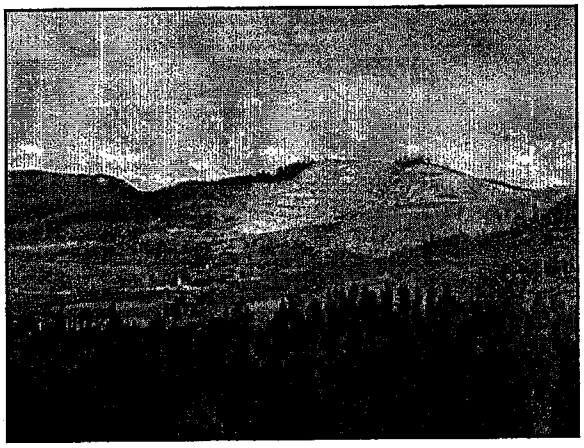
The long-term collection and chemical treatment of drainage is:

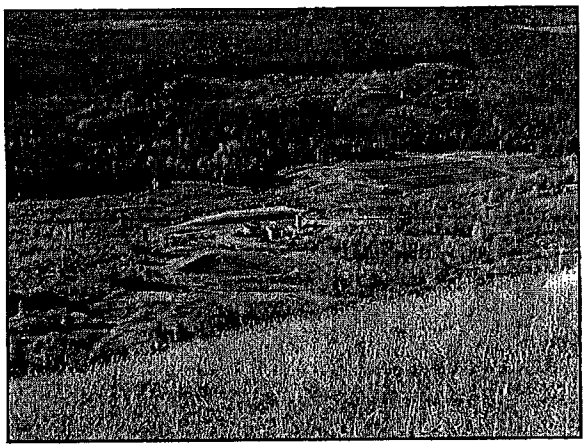
- effective in protecting downstream resources
- creates long-term pollution of site
  - contaminated drainage
  - sludge

Samatosum

At the Samatosum mine, drainage treatment is required for the ARD from the pit, underground workings and the layered waste rock dump.

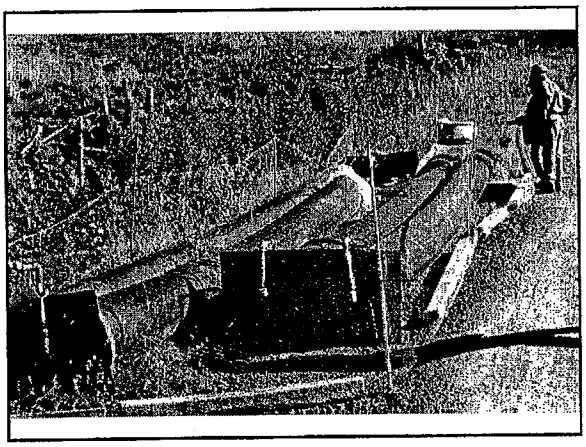
Ongoing work is addressing the need for a long-term disposal site for the treatment sludge. The task is made easier because the mine uses the Cominco process to produce a high density sludge.





"Passive" Drainage Treatment

- large potential benefits
- significant challenges including measures to control key parameters
- under investigation at a number of sites including, Island Copper and Highland Valley
- recently started a pilot scale trial at Equity Silver



Historic Sites

Work ongoing at a number of sites including:

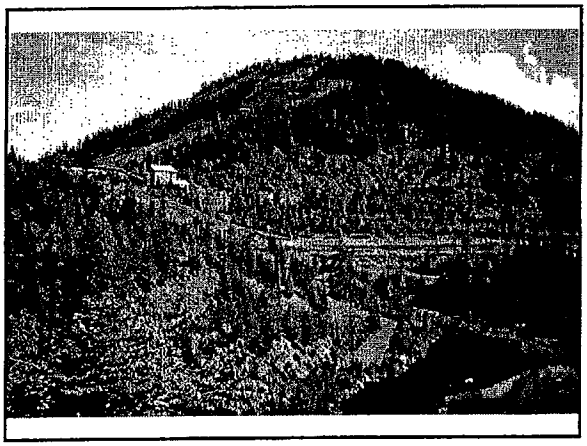
- Pinchi
- Duthie
- Britannia
- Mt. Washington
- Red Mountain Rossland

Red Mountain Mine, Rossland

Open pit Mo mine that operated from 1966-1972. It is located next to the ski hill in Rossland.

Upper oxidized surface of the tailings is acid. Lower unoxidized tailings are PAG.

Work being conducted by Inco includes stabilization of the impoundment, along with ML/ARD and hydrological studies to better understand geochemistry of tailings.

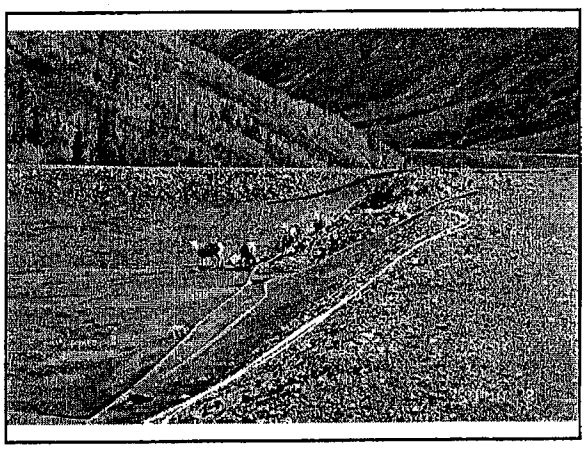


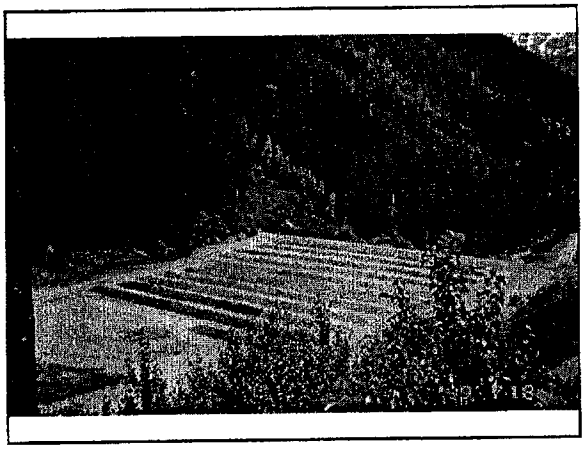
On-Site Reclamation Objectives

- minimize any reduction in the post-mining productive capability
- prevent significant post-mining impacts to biota
  - may require ecological risk assessment
  - may use mitigation measures like soil covers as a physical barrier to biota

A soil cover was used at Golden Bear to prevent sheep from using the Hg/As-rich tailings as a salt lick.

The soil cover placed on the Snip tailings will in part also serve as a barrier to metal uptake.



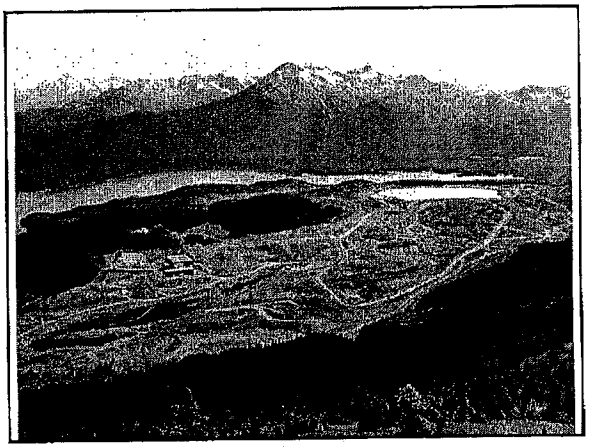


Modern Sulphidic Mines

British Columbia now has a number of mines which addressed ML/ARD concerns and where ML/ARD regulatory conditions were in place right from the start.

- Huckleberry
- QR Gold
- Mt Polley
- Kemess

At last years workshop, Doug Johnson provided a outline of the opportunities, along with the onerous information and communication requirements at the Huckleberry mine.



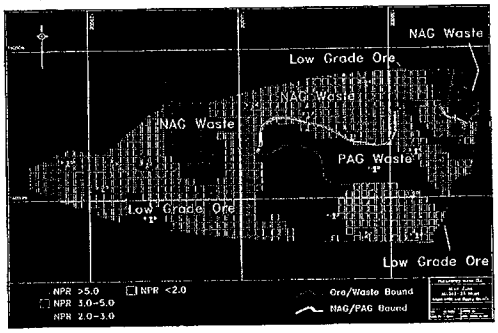
Huckleberry Mines Ltd.

Mine Plan

- Porphyry Copper Deposit
- Both PAG and non PAG waste rock
- non PAG required to construct downstream side of dam
- PAG waste rock used to construct upstream side of dam and for roads and pads
- All PAG waste to be flooded at closure

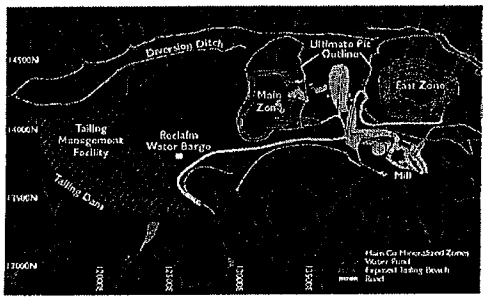
Huckleberry Mines Ltd.

M1042-21 Kriged NPR Values



Huckleberry Mines Ltd.

Site Plan



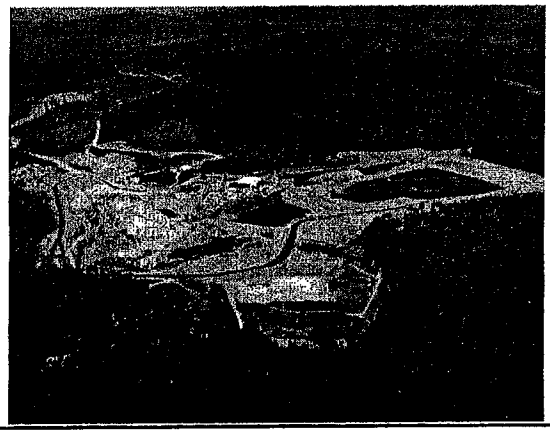
QR Gold

The onerous information requirements more than pay for themselves in reduced long-term mitigation costs. A good example of this is the recently closed QR Gold mine.

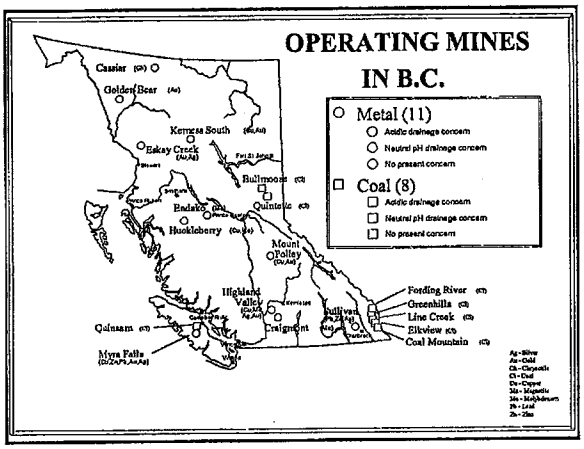
Unlike other similar earlier mines where ARD requirements were overlooked, at QR the only long-term costs are the relatively modest costs of monitoring and maintenance of dams and other drainage structures.

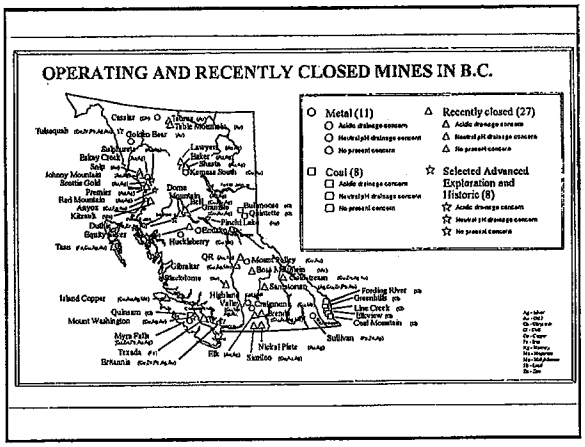
Notable aspects of the ML/ARD program at QR Gold included:

- the detailed material characterization which permitted the separation of PAG and non-PAG waste rock and delayed flooding of PAG materials,
- use of the PAG and non-PAG waste rock for construction, and
- use of the Main Zone pit as a subaqueous disposal site for PAG waste rock from other pits.



Conclusions





Unlike other aspects of mining, the challenges of ML/ARD do not stop at closure, which is a significant regulatory challenge.

From the perspective of the Ministry of Energy and Mines performance measures include:

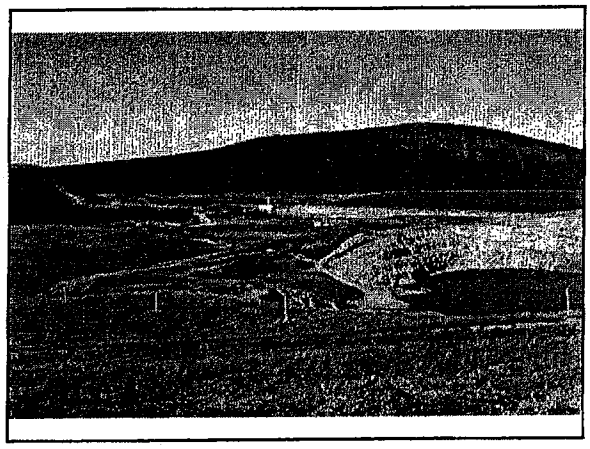
- the support of MEM ML/ARD Guidelines by:
  - Noranda, Cominco, Redfern, Huckleberry, Mt Polley and other mine operators
  - Environmental Mining Council of BC
- Ontario has adopted MEM ML/ARD Guidelines as part of their regulations.
- Placer Dome adopted much of the MEM Prediction Manual.

The large number of mining properties with ML/ARD concerns points to the large amount and great variety of work being done in British Columbia.

As a result, there is a wealth of experience and information available to those interested in almost any aspect of ML/ARD prediction and mitigation.

Within this next picture alone there are:

- 5 mitigation strategies
- 3 MEND research projects and
- 6 additional prediction and mitigation endeavors initiated in the last 18 months



ML/ARD work continues to improve both from the perspective of practices and cost effectiveness

One measure of the high standard of ML/ARD work in British Columbia is the support for the ML/ARD aspects of new mining projects by:

- federal government,
- environmental groups,
- US agencies and
- First Nations.

For example, QR Gold, Kemess, Tulsequah, Huckleberry, Eskay Creek.

Acknowledgments

Thanks for the assistance provided in putting together this presentation to:

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