Use of Fresh Water Covers as a Mitigation Strategy at Mines in British Columbia

By Bill Price, British Columbia Ministry of Energy and Mines, at 2001 BC ML/ARD Workshop

Background

The primary objective of a water cover is to insulate the waste from atmospheric O_2. This results from:

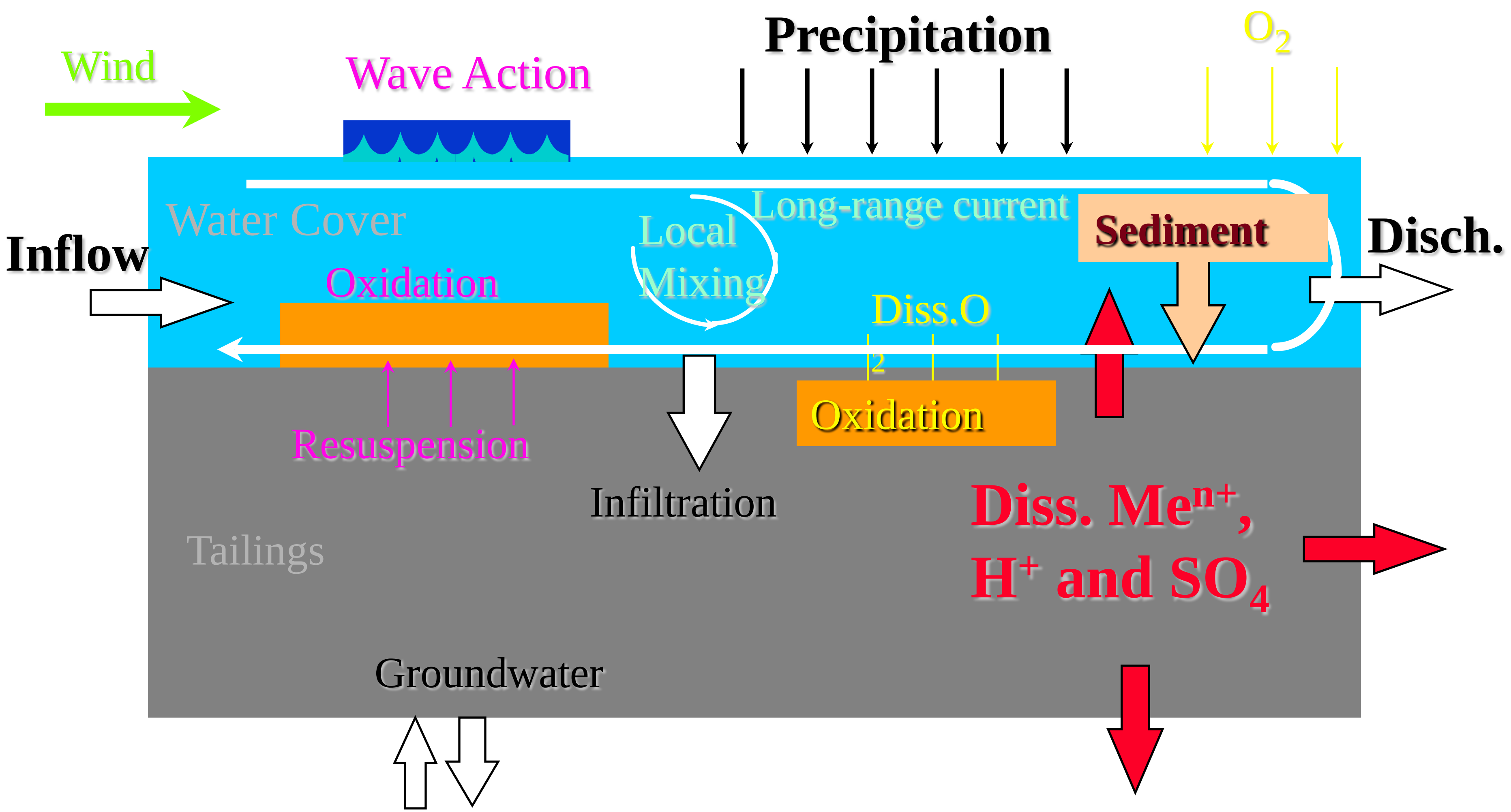
- low O_2 solubility of H_2O (concentration 30 x lower)
- slow molecular migration of O_2 in flooded wastes (diffusion in pore water is ~10,000 x slower than air)

Rate of O_2 supply in flooded wastes can be approx. 300,000 x lower than aerial deposition.

Under ideal conditions, a water cover typically results in:

- exposure of flooded waste to O_2 limited to thin layer at surface
- anoxic conditions beneath the thin oxidized surface

In Reality Many Complex Processes Can Effect the Performance of a Water Cover



Objectives of this Presentation

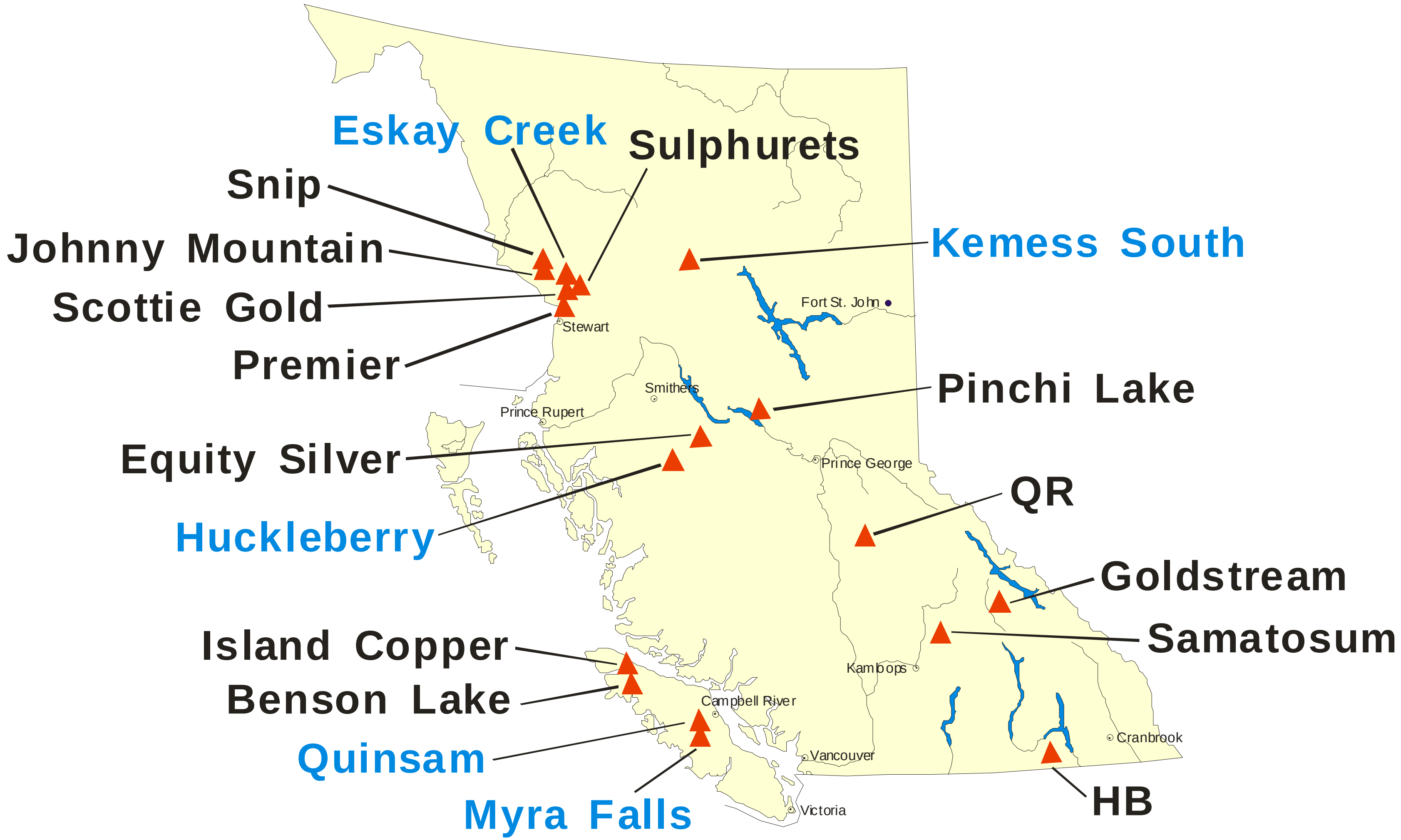
Review geochemical, physical and biological aspects of fresh water covers.

Review the performance and design and management issues at water cover facilities in British Columbia.

Workshop will not tackle:

- the geotechnical issues with dam stability or constraining waste and overlying water cover
- lake disposal vs impoundments or
- submarine disposal.

BC Mine Sites Using Fresh Water Covers



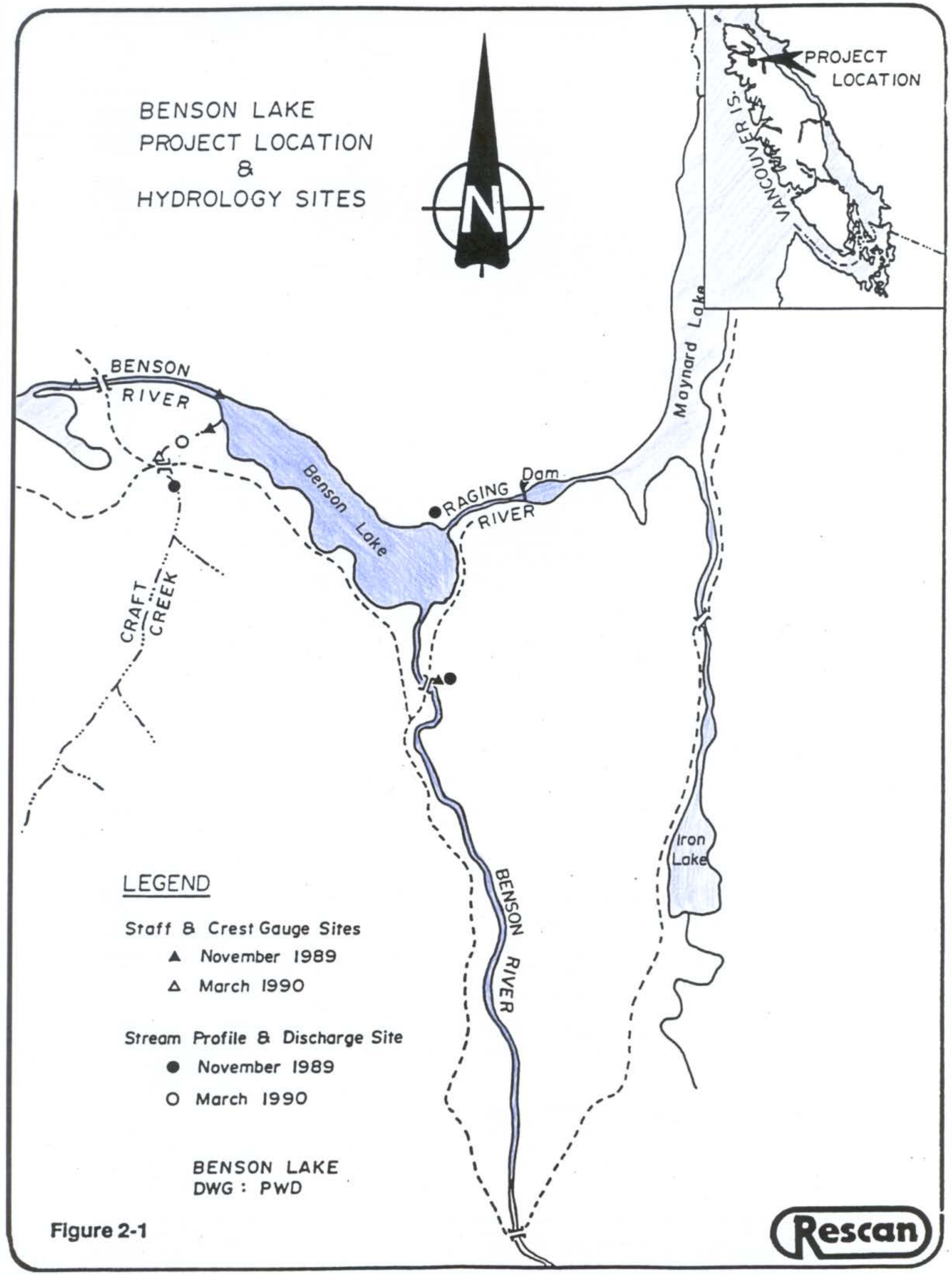
QR Gold placed PAG waste rock in the subsequently flooded open pit and the tailings impoundment.

Quinsam backfills potentially ARD generating coarse coal rejects into a flooded pit

The Myra Falls Mine deposited Cu, Zn and Pb-rich tailings in Buttle Lake from 1984 to 1996.

Buttle Lake

Detailed research on flooded tailings was conducted by the BC AMD Task Force and MEND at Buttle Lake, Benson Lake (shown here) and the Equity Silver impoundment. Buttle Lake and Benson Lakes are two of many fish-bearing lakes in British Columbia where previously deposited mine tailings are now covered by sediment.



Requirements of a Water Cover System

Flooding must be maintained.

- impoundments must be able to withstand extreme climate and seismic events

- Design compatible with site specific requirements and constraints
  - Meet effluent discharge limits
  - No significant ecological impacts
- Resources, understanding and intent to conduct the above
  - e.g., long-term monitoring and maintenance

Understand Waste Characteristics

Mass, volume, particle size, geology, chemical composition and ML/ARD potential

Info. used to determine:

- What material requires flooding
- Required storage capacity
- Soluble constituents, now & in future
- How fast it must be flooded
  - Time to onset of ARD

Understand the Disposal Site

Storage capacity, discharge requirements, geotechnical conditions, water balance, rate of flooding and potential for re-suspension

Info. used to determine:

- Drainage inputs
- Variation in depth of flooding
- Long term performance of impoundment
- Extent & timing of flooding

Waste & Disposal Site Characteristics

Info. used to predict or determine:

- Required depth of water cover
- Significance of wave action
- Cover water quality
- Quantity & quality of discharge
- Ecological impacts
- Need for additional mitigation
- Monitoring & maintenance requirements
- If water cover is appropriate

Understand Mining Constraints and Requirements

- Cannot backfill into pit or flood mine workings until mining is complete
- Costs typically lowered if closure requirements identified early in mine life and incorporated into mine plan
  - At least conceptually, probable constraints and requirements must be identified in EIA.
  - It may not be feasible to add 'protective' layer on top of waste after mine or mill closure

Mining Constraints

Costs of :

- constructing a permanent dam
- re-handling backfilled wastes
- dam maintenance and drainage management
- supplemental or contingency measures
- uncertainty regarding future performance
- studies

Performance of Water Cover Systems in British Columbia

During Mining:

- Impoundments are typically closed systems with no discharge of drainage
  - Use drainage in pond as process water and divert potential upslope input
  - Exception is lake disposal
- This is fortunate, because without additional mitigation, during waste deposition, water cover may exceed effluent discharge limits for:
  - TSS
  - Nitrate
  - Elements soluble at high pH (e.g., Mo, Sb)

Immediately after closure:

- Achieve effluent discharge limits, with some minor exceedances of generic provincial water quality objectives in cover itself.

- Treatment of process water may be required at some sites. But BC does not have sites where highly acidic wastes were flooded (e.g., Elliot Lake, Ontario) and long term treatment is required.

Long-term performance:

- There are a number of outstanding issues regarding post-closure management and long-term performance.

Impoundment Design and Management Issues

Premier Gold Mine

Dissolution of Oxidation Products

Sources of oxidation products include:

- Bedrock oxidized prior to mining (e.g., supergene rock at Kemess)
- Delay in flooding
  - waste backfilled into pit (e.g., Huckleberry, Island Copper, Snip & Kemess)
  - change in mine plans (e.g., Sulphurets)
- Oxidized layer at surface of flooded waste
- Waste particles re-suspended in aerated water by wave action

Except for a slight increase in Se, deposition of tailings from oxidized ore has had no adverse impact on impoundment water quality at Kemess.

Presently, waste rock and tailings at the Huckleberry mine are flooded in the tailings impoundment.

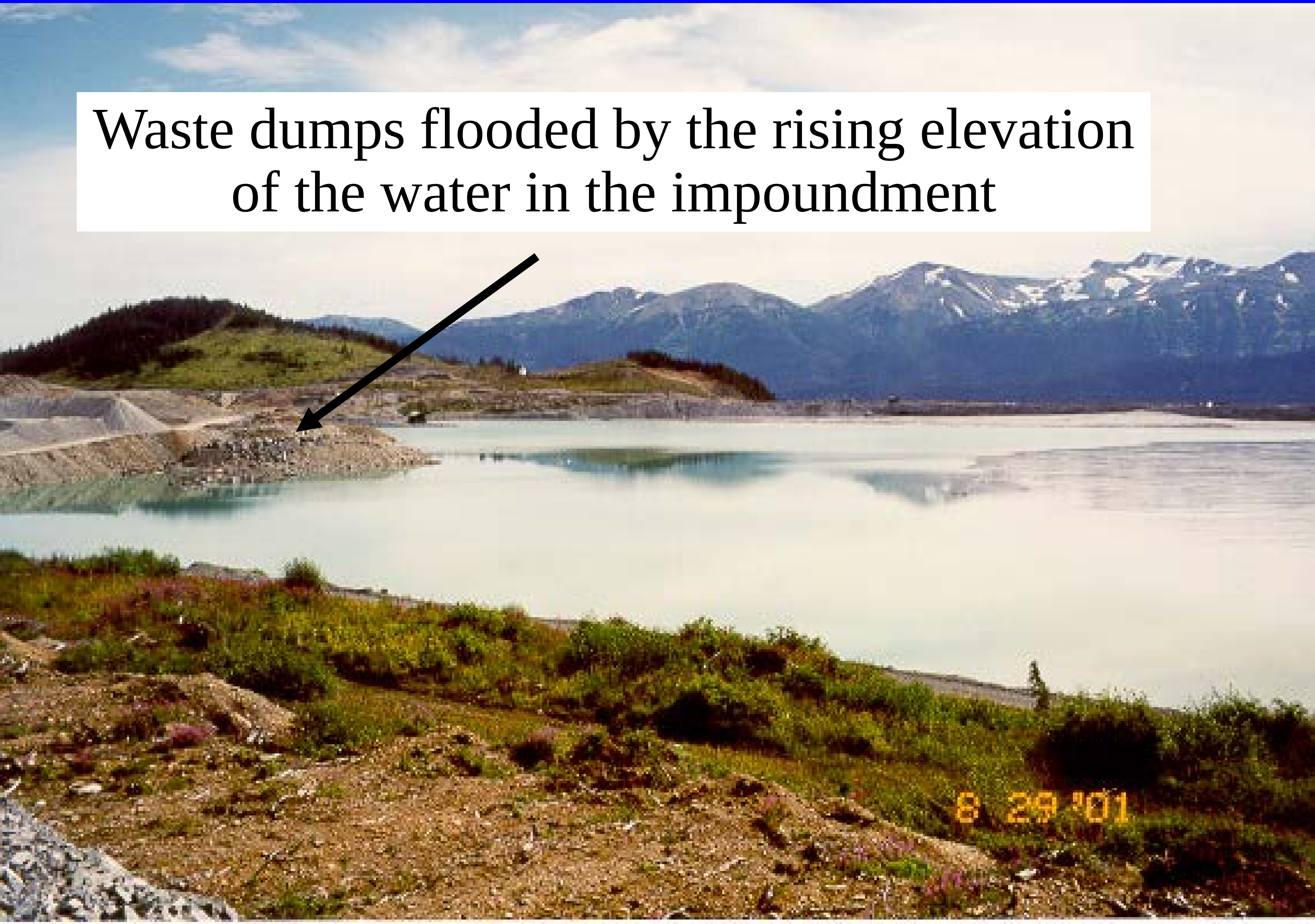
Starting next year, tailings and waste rock will be backfilled and flooded in the Main Zone pit.

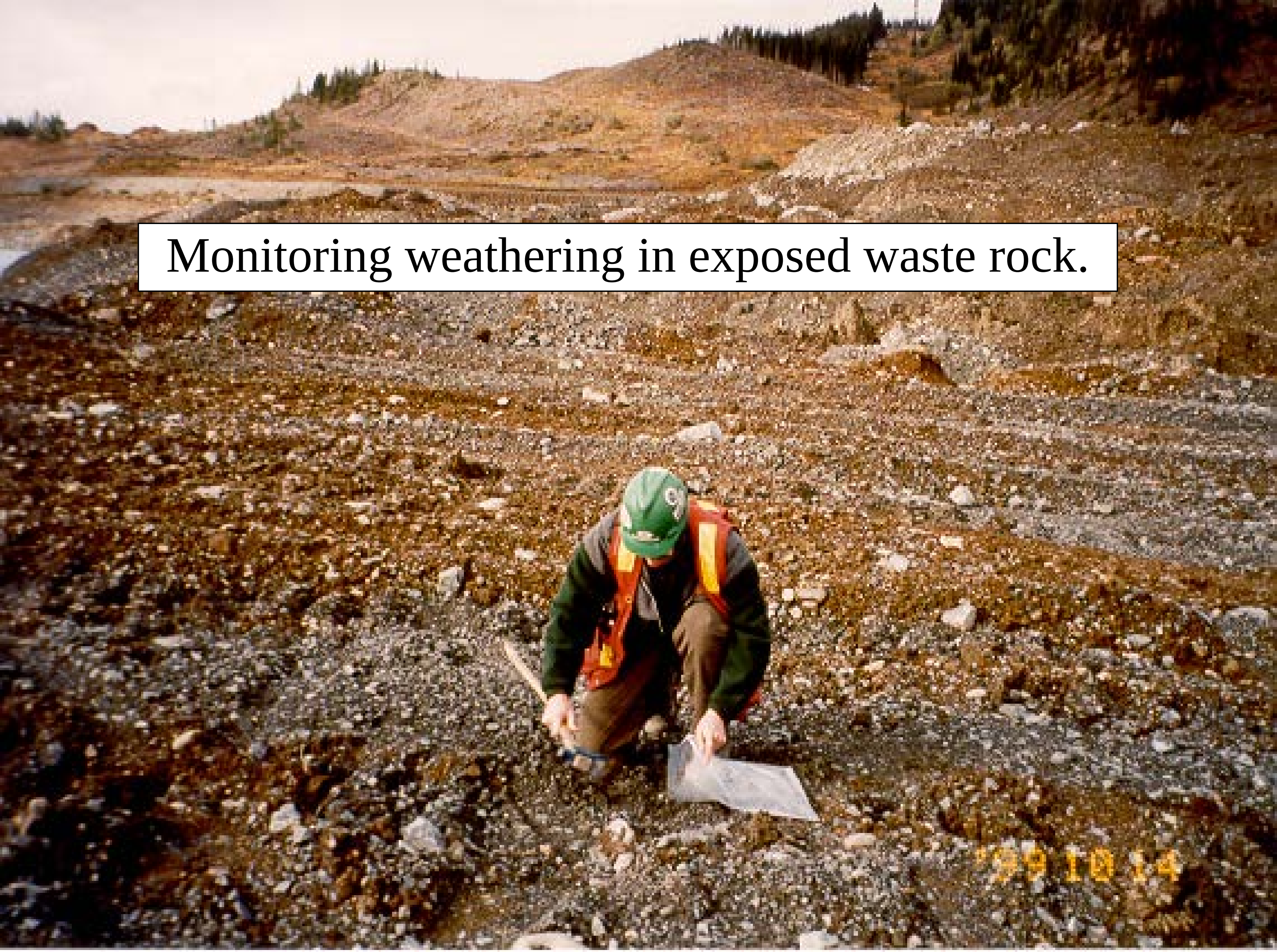
Measures to prevent ARD onset prior to flooding include:

- minimize dump height, limit exposure
- material characterization to identify and fast-flood material with a low NP
- monitoring pH, carbonate and seepage in areas of prolonged exposure
- provision of resources move waste rock underwater if ARD starts
- Identification of supplemental drainage to accelerate the rate of flooding


Tailings Impoundment
Main Zone Pit

Waste dumps flooded by the rising elevation of the water in the impoundment




Monitoring weathering in exposed waste rock.
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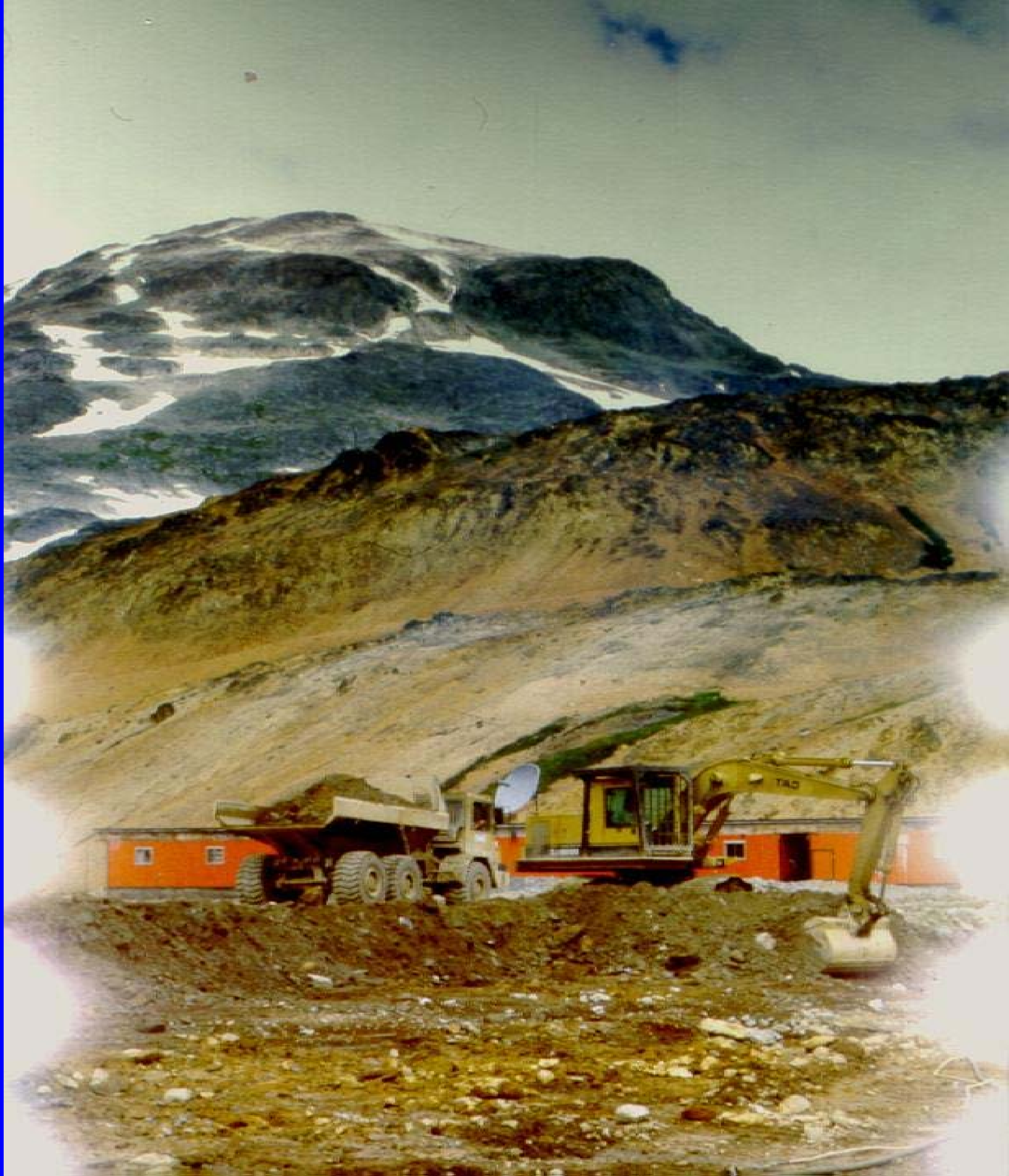
Chemical treatment and amendments may be used on:

– the waste prior to deposition,
– process water and
– the water cover

to reduce metal solubility.

Iron sulphate is used to reduce Sb levels at Eskay Creek. The resulting process fines are discharged in Big Tom Mackay Lake with the tailings.

Both Sulphurets (pictured here) and Eskay Creek added lime to acidic waste rock neutralize the pH of waste rock prior to flooding. In both cases, the waste rock was exposed during exploration.



Development of Oxidized Surface Layer

Oxygen from the aerated water cover creates oxidized conditions in the upper portion of the flooded waste. The resulting sulphide oxidation releases potentially deleterious trace elements into pore water.

Typically deleterious trace metals in pore water of the oxidized surface layer co-precipitate with iron oxyhydroxide and are concentrated in layer.

Exposure to aerated water cover results in development of oxidized surface layer.

Reduction of Oxidized Surface Layer

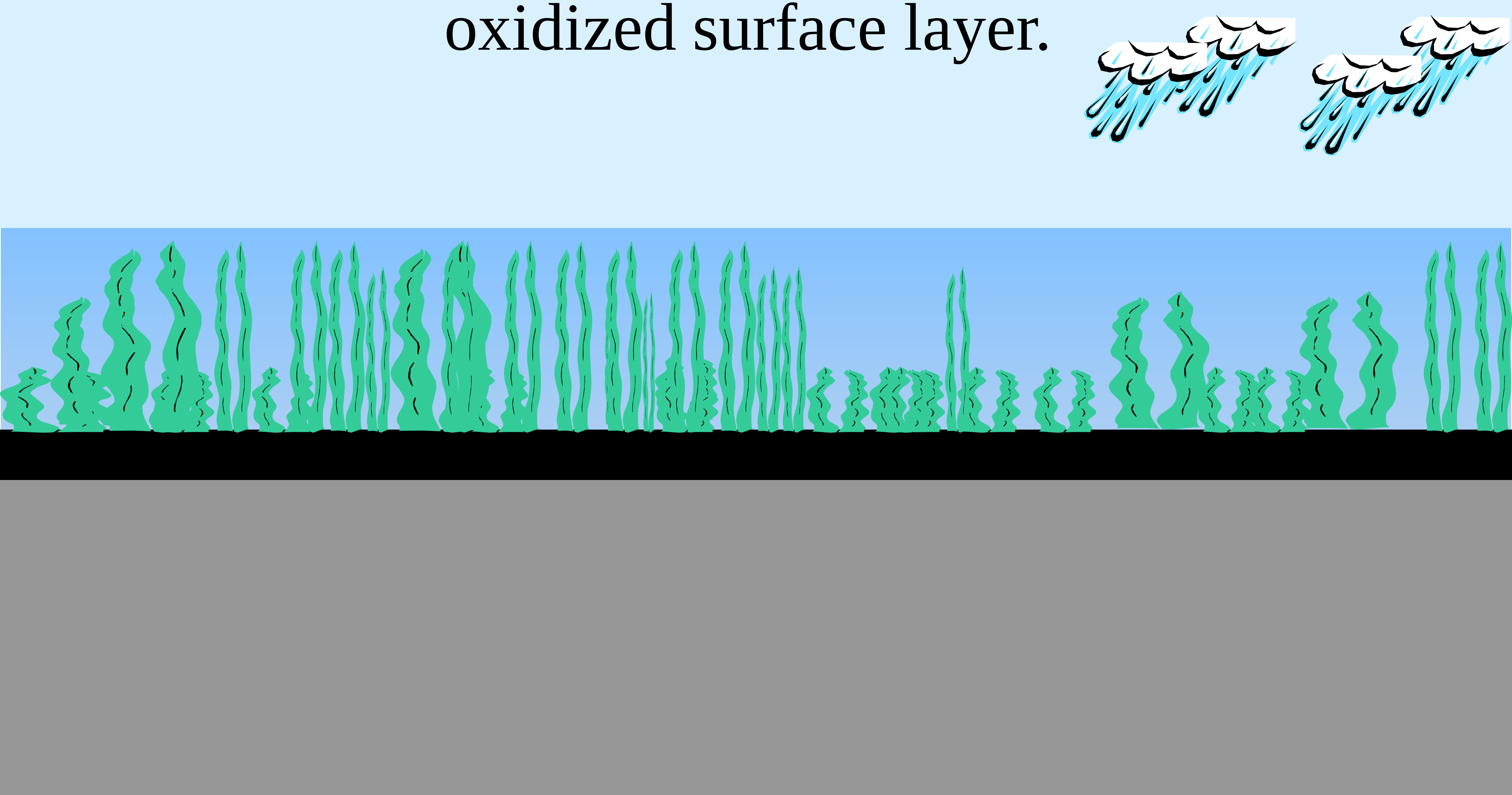
Over time surface sediment and organic additions may cover the waste creating reducing conditions in previously oxidized surface layer. This may also occur if anoxic conditions develop in the winter.

Reduction of iron oxyhydroxide releases deleterious trace metals into pore water.

Release of deleterious trace metals from pore water into overlying cover may significantly impact water quality.

May eventually need to treat drainage.

Over time surface sediment and organic additions will cover the waste creating reducing conditions in previously oxidized surface layer.



Remedial Measures

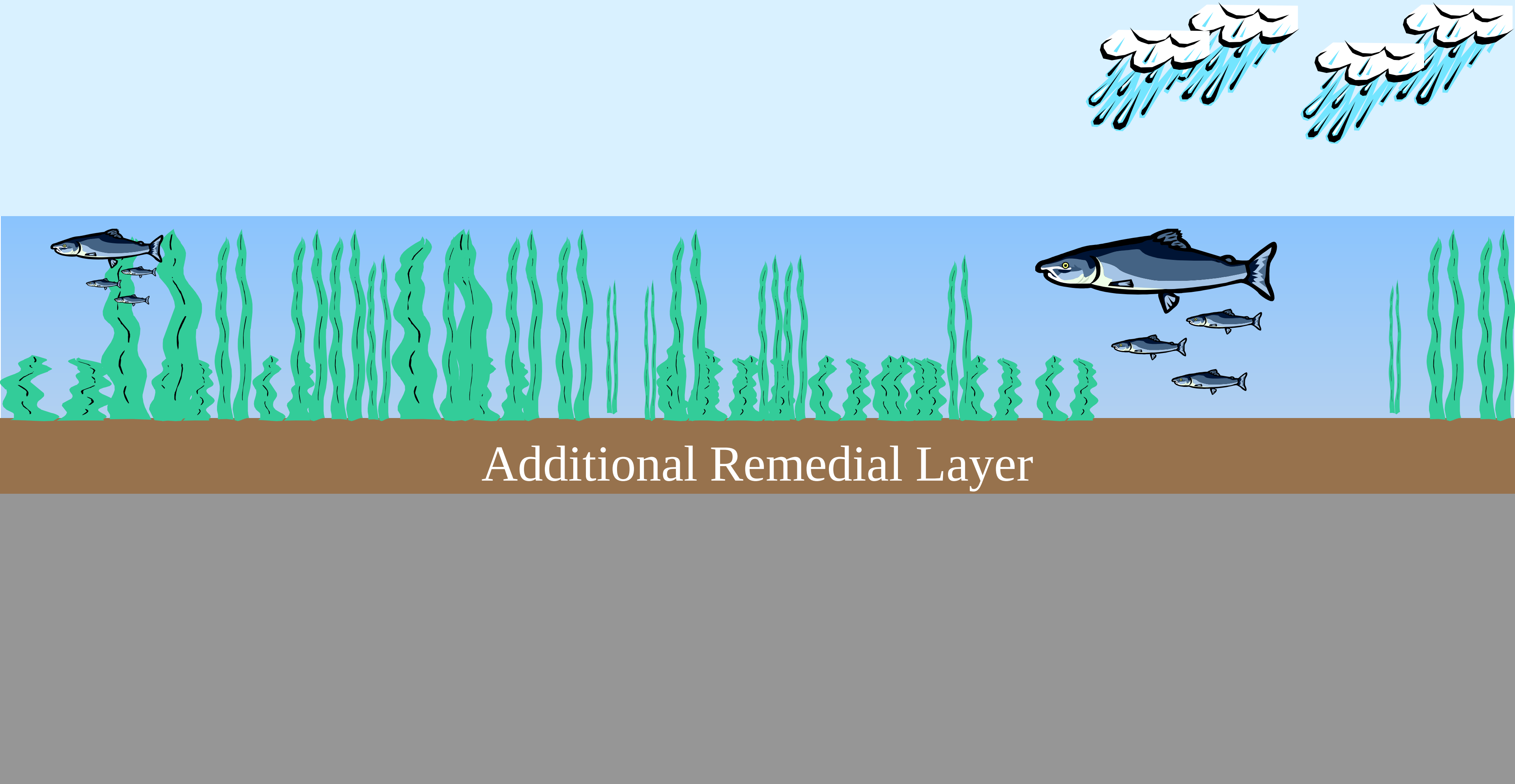
Create conditions (e.g., high sulphate concentration) which cause released trace elements to precipitate as sulphides.

Apply oxygen consuming or diffusion barrier at the end of mining to prevent initial development of oxidized surface layer in mineralized waste.

It is much more expensive to apply the cover once the mine is under care and maintenance.

Opportunity to avoid metal release may be lost if you do not prevent initial oxidation in mineralized waste.

A remedial layer can be added to prevent waste oxidation. The layer will also provide an inert substrate for invading biota.



Remedial Surface Layer

- Organic materials may be used as O_2 consuming layer
- Desulphurized tailings or natural sediment may be used as a diffusion barrier
- Remedial surface layer also provides physical barrier to biota preventing metal uptake and prevents waste movement by ice or waves.
- Application can be expensive and it is difficult to predict in advance whether additional layer is required.

Snip Mine used a soil layer as a physical barrier.

Trace Element Solubility may Increase with Changes in Water Chemistry

Changes in chemistry of water cover may result from:

- Stopping input of alkalinity in process water and waste
- Re-divert upstream drainage into impoundment
- Acidic precipitation and soil drainage (e.g., pH 5.5-6.0 for coastal precipitation)
- Oxidation of components in waste (e.g., sulphides) or water cover (e.g., oxidation of NH_4^+ from CN) produce acidity
- Inputs from exposed walls or mine wastes

Depth of the Water Cover

The depth of the water cover must:

- ensure flooding during periods of drought (e.g., favourable water balance)
- Minimize re-suspension by wave action (e.g., depends on fetch, wind speed, etc..)

The depth of water cover also impacts biological use and dam stability.

A depth of 1 m has been used at exploration sites lacking site specific information .

The objective at Snip is to minimize depth of the overlying water. This is possible due to the high precipitation (favourable water balance) and the application of a surface soil cover.

Wave Action

Measures available to limit re-suspension of waste wave action include:

- increased depth of water cover,
- covering waste with non-mineralized material, and
- use berms or baffles to reduce fetch.

Equity Silver used the presence of bed form as evidence of wave-induced tailings movement. No movement has occurred beneath a depth of 1.4m.

Water Management

Water management issues include maintaining a favourable water balance, minimizing loadings to the environment, maximizing dilution and conducting flow across or around the impoundment.

Potential benefits of stream flow through an impoundment include maintaining aeration during winter and dilution of metals in the water cover. Potential drawbacks include increased offsite loading and detachment of the waste.

Water Balance for Goldstream Impoundment

Outflow:

- Evaporation 109 m^3 /yr
- Dam seepage 260 m^3 /yr
- Spillway 27 m^3 /yr

Inflow:

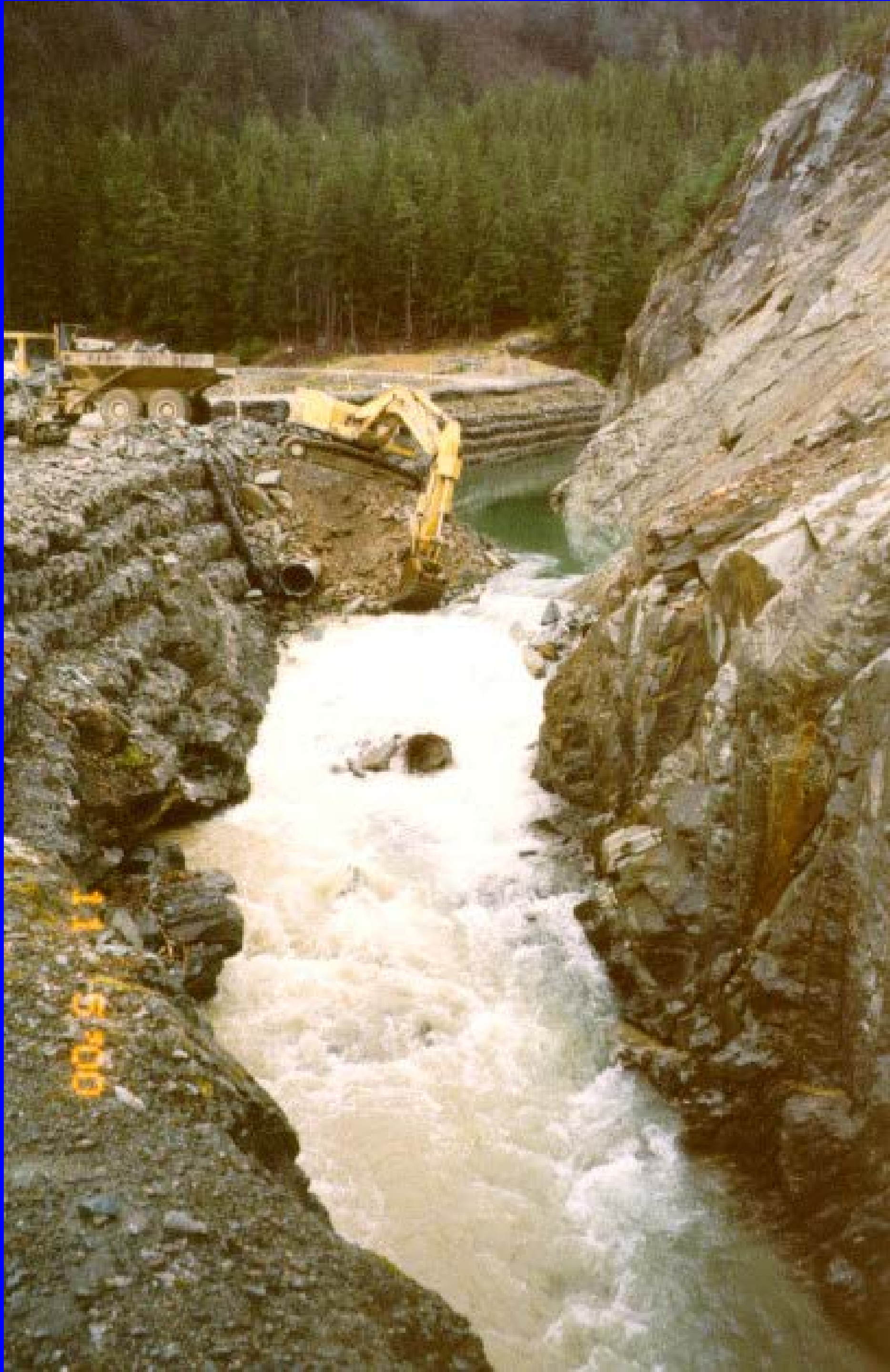
- Precipitation & local runoff 277 m^3 /yr
- Groundwater and diversion ditch 119 m^3 /yr

Note: Inputs from groundwater and diversion ditch required for positive water balance.

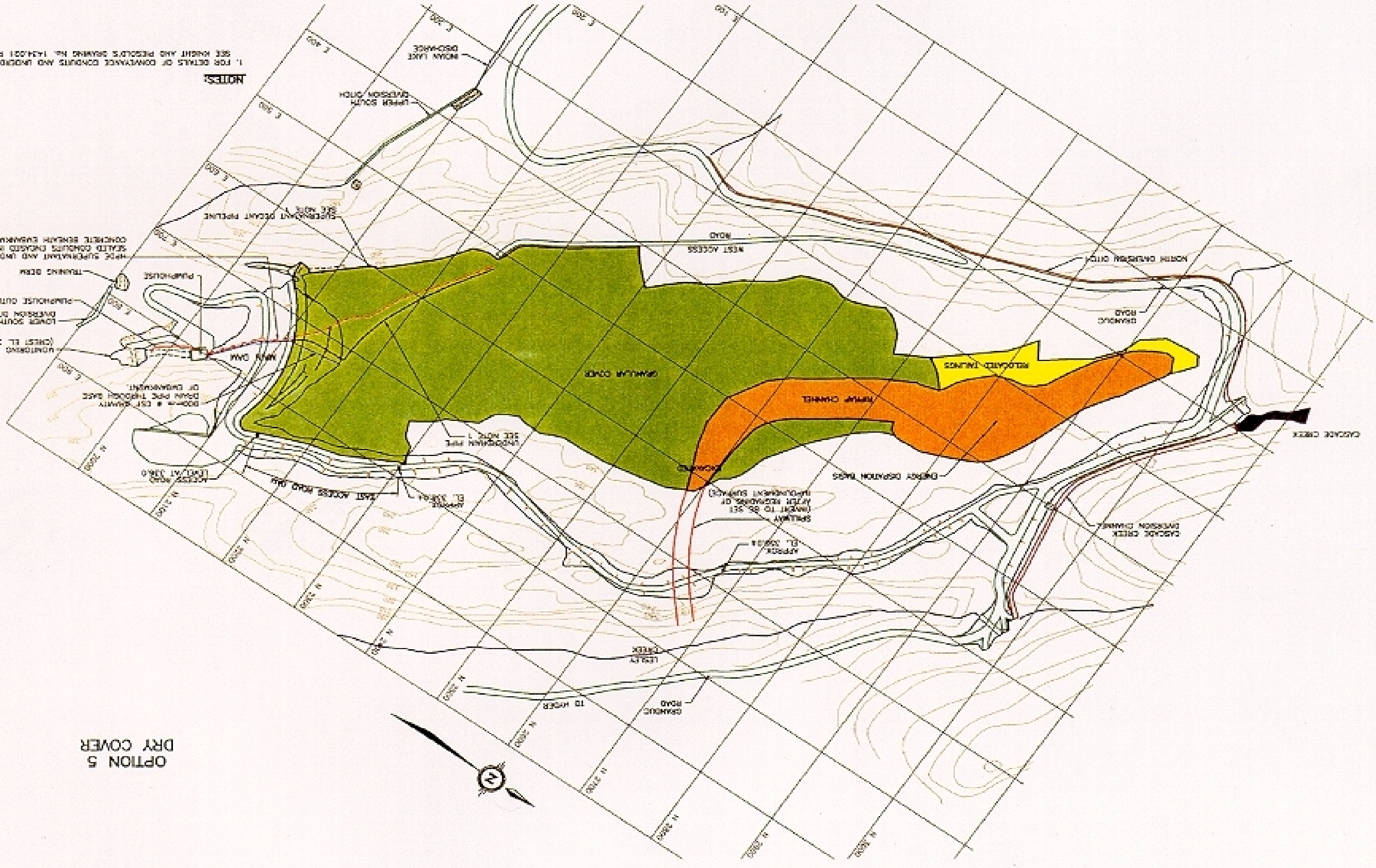
Water management to maintain fish productivity below the impoundment is a major part of the remediation work at Kemess.

Presently Cascade Creek is diverted around the impoundment at the Premier Mine.

Re-diverting stream flow through the impoundment and over tailings would avoid the risks and maintenance associated with the Cascade Creek diversion.



The design for stream flow through the Premier impoundment includes measures to prevent entrainment of tailings.



Exposure of a Portion of the Sulphidic Material

The main input of metals into the water cover often comes from the small portion of the sulphidic material left exposed.

- Tailings beach
- Mine walls
- Movement of waste onto beach or into aerated water column by waves, ice, seiching, stream flow

The impact of acidity and metal inputs from talus on exposed mine walls is an issue for a number of backfilled pits.

A shallow, exposed tailings beach improves dam stability at the Goldstream tailings impoundment.

Huckleberry has completed full scale operational test work showing how it will modify the mill process to create desulphurized, non-PAG tailings to decrease the proximity of the water cover to the dam crest.

Use of the Impoundment to Store a Variety of Different Wastes

Flooded waste facilities may be used to store a number of different materials in addition to tailings and waste rock.

For example, water covers are sometimes proposed as contingency disposal locations for ARD if it occurs unexpectedly or faster than predicted.

Concerns include the impact of future reducing conditions and changes in drainage chemistry.

Equity Silver discharged ARD from one of the dams and the low density lime treatment sludge into the flooded tailings impoundment when the mine was operating. Lime now has to be added to the impoundment to maintain the stability of Cu precipitates resulting from the neutralization of the ARD.

Equity Silver now sends all the ARD to the treatment plant and stores its treatment sludge in the flooded pit.

Ecological Succession

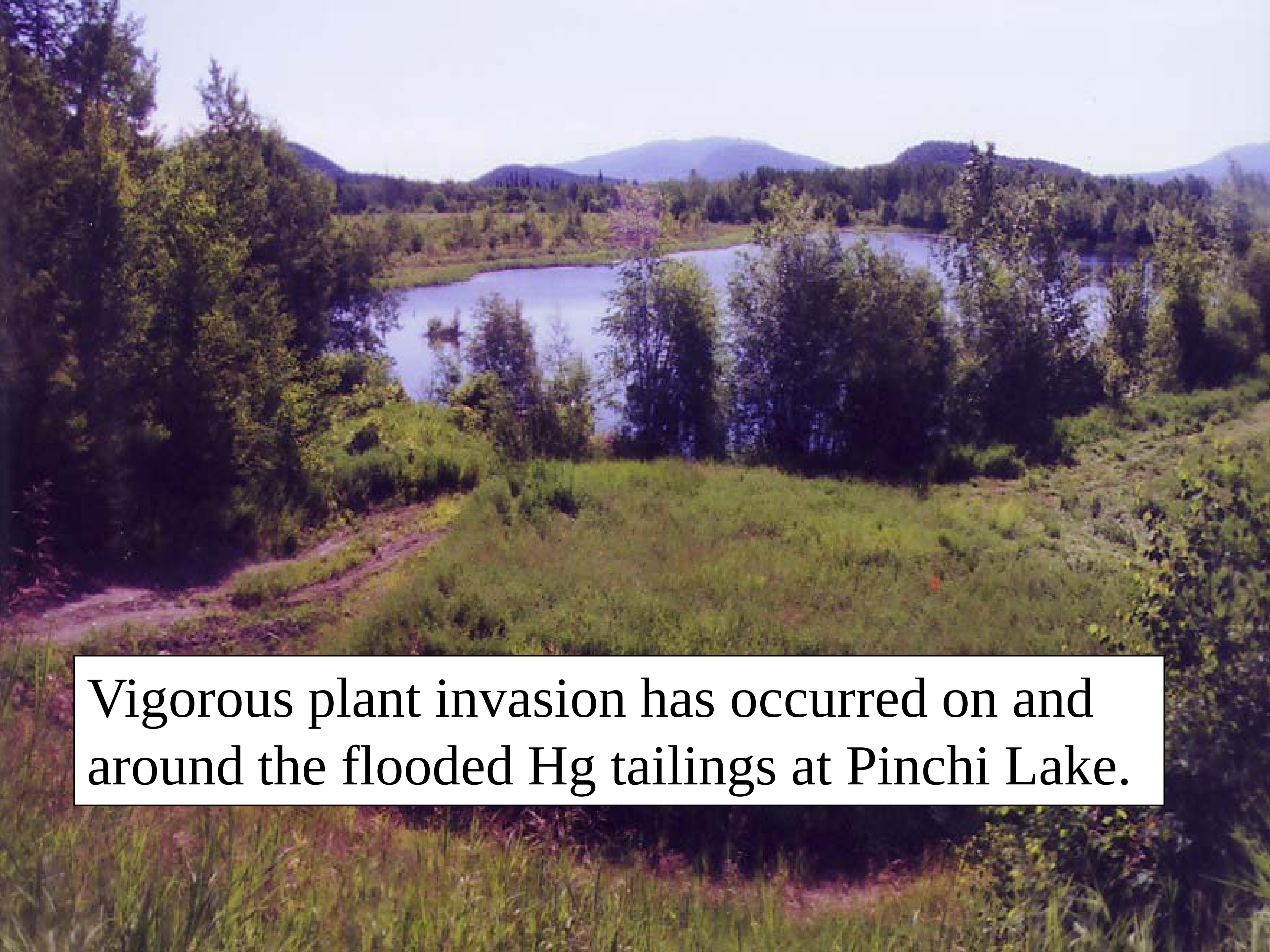
Future soil development and biological invasion of water covered systems is inevitable.

Concerns exist about:

- future metal uptake from the water cover and the underlying waste, and
- the impact of beaver activity.

Measures to discourage biological use include:

- Boats and nets to divert migratory birds until CN degrades
- Fences to prevent Mo uptake by cattle



Vigorous plant invasion has occurred on and around the flooded Hg tailings at Pinchi Lake.

Monitoring and Maintenance

Monitoring and timely maintenance are essential components of successful long-term mitigation, especially where there are outstanding issues regarding post-closure management.

One of the most important maintenance concerns is with beaver dams, which may:

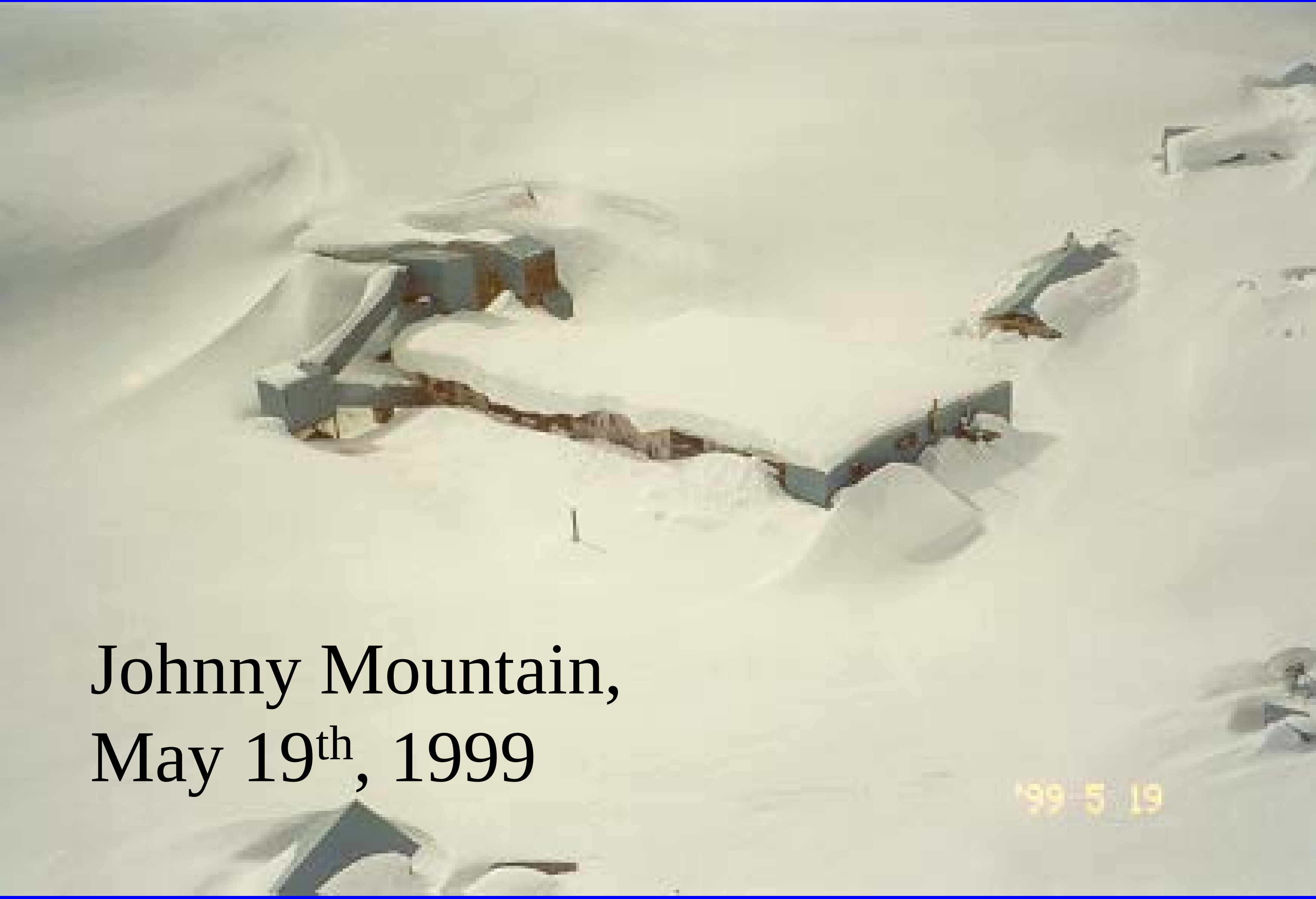
- change the water balance,
- block the spillway,
- flood dam foundations and
- create an upstream tsunami.

In this picture a beaver dam is flooding a small channel conducting groundwater from the flooded impoundment at Goldstream.

Strategies for managing beaver dams include frequent monitoring and removal of dams, frequent trapping to remove beaver or measures to remove watercourses that beaver can dam.

Boulders were placed in the spillway of the flooded impoundment at Snip to prevent beaver dams.

Monitoring and maintenance is especially difficult at isolated, snowy sites such as Johnny Mountain.



Johnny Mountain,
May 19th, 1999

Lake Disposal (Subject of 1999 Workshop)

The minimal maintenance requirements are attractive feature where lake disposal is an option.

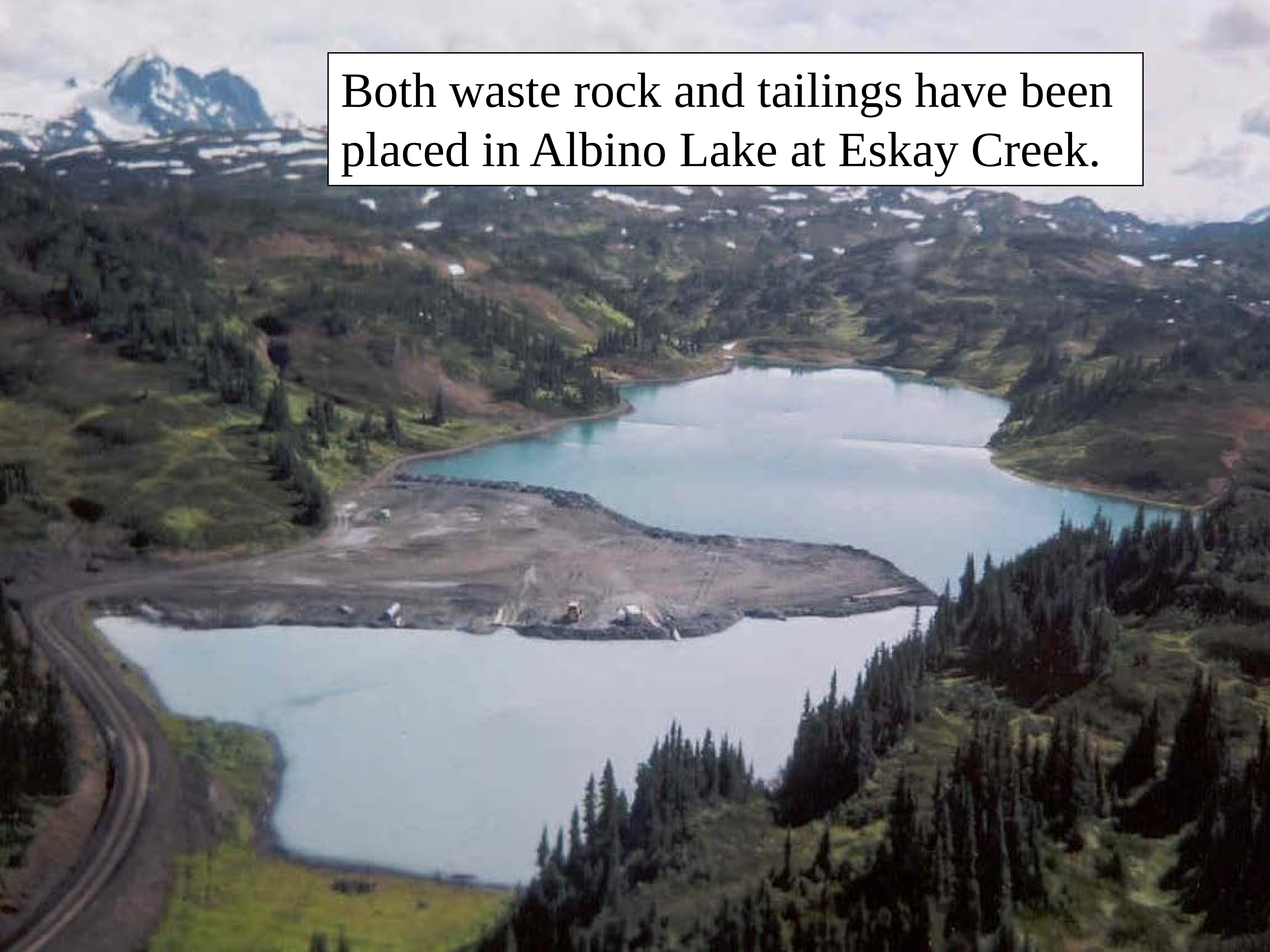
However lakes have a number of other challenges. Important factors at Eskay Creek include:

– acceptability under Fisheries Act

– large dilution prior to fish habitat,

– use of additional measures to reduce TSS and

– pre-treatment to reduce Sb solubility.



Both waste rock and tailings have been placed in Albino Lake at Eskay Creek.

Conclusions

- Water covers is a sound concept.
- Many complex processes affect cover performance. Consequently every site has different needs.
- There are also a number of outstanding issues regarding post-closure management and long term performance.
- Developing the required understanding costs 1,000s of $. However, a lack of understanding could cost millions of $ and the repercussions may last forever.

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