Environmentally Responsible Closure Planning

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Presentation Overview

1. Introduction – Why Environmentally Responsible Closure Planning
2. Tailings dams and closure
3. Design for Closure
4. Best Practice Principles
5. Opportunities and Social Responsibility
6. Conclusions – the future of closure planning

1. Introduction – Why Environmentally Responsible Closure Planning

1. Introduction – The Need for Environmentally Responsible Closure Planning

- Legacy of old orphan / abandoned mine sites
- Regulatory frameworks - only in the late ‘60s – early ‘70s, but not for closure !
- Closure planning – ‘80s
- Driven by potential liability left behind
- Increased awareness

Introduction (cont'd)

- Nowadays mine closure plans required for :
  - Advanced exploration
  - Mine operation
  - Before you even start digging!
- Bonds come with the package…
- Legislation in almost every major jurisdiction
- In Canada – Yukon is the most recent

Introduction (cont'd)

- The good news:
  - 82% of accidents and 91% on failures have occurred in **active** ponds / **operating** mine sites (USCOLD, 1994). Closed sites look good!

- Now the "not so good news":
  - It is estimated that less than 1% of all tailings dams in the world are actually closed AND have a properly implemented Closure Plan. And that is a very optimistic number, apparently….

Need for Responsible Closure Planning

2. Tailings Dams and Closure

Closure: Water Retention vs. Tailings Dams

- Water Retention Dams
  - Well known construction history
  - Often "closure" not addressed
  - If addressed – towards the end of the life cycle
  - Can be decommissioned
  - Assets that could be replaced / upgraded?

- Tailings Dams
  - Unavoidable "cost", not asset
  - Will be there "forever"
  - "Walk away" design solution is ideal but seldom attainable
  - More recent: Reprocessing tailings = are we moving the problematic to a different site?

Challenges at Closure

- Design adjusted over the life of the mine
- QC records – not always great
- Ground and structural monitoring instrumentation
  - Limited for small and medium size
  - Much better for large dams
  - Focus more on environmental aspects
- Other changes occur (ore body, TMA expansions, deposition points/methods, geochemistry, available borrow materials, etc.)
- Modest amount of in situ testing available

So where do we start Designing for Closure ??

3. Design for Closure

3. Design for Closure – Simple Rules

#1: The Closure Plan is a Living Document

- Original Closure Plan – a concept only
- Prepare concept with long term vision – plan ahead
- Update often – think sustainability

#2: Keep Good Records

- Construction, QC, Monitoring
- Use information wisely
- Do not overcomplicate things
- Plan closure in advance – not at closure!

3. Design for Closure – Simple Rules

#3: Exercise Due Diligence

- Act when problems arise
- Use proper tools & techniques
- Manage risk (DSIs, DSRs, OMS, EPPs)

#4: Implement Progressive Rehabilitation Measures

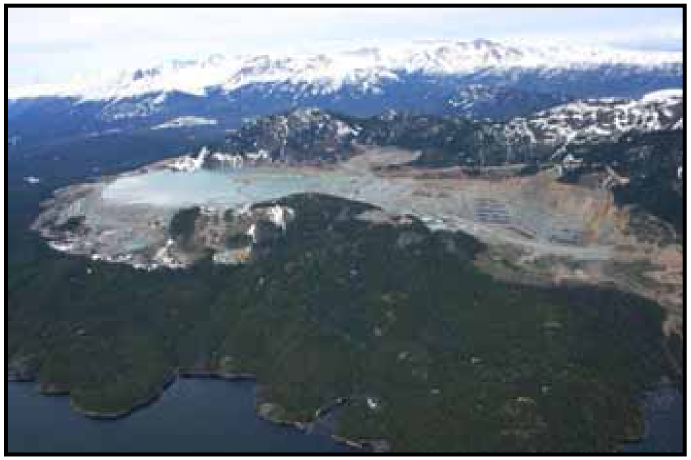
- Do not wait to the last minute
- Saves time and $$
- Minimizes risk

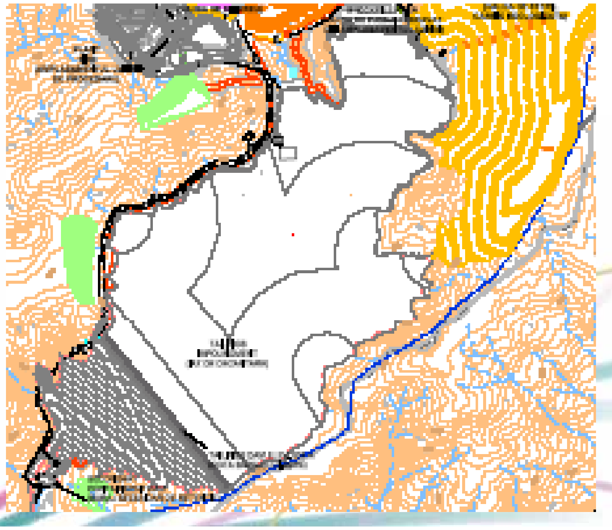
Design Criteria for Closure

- Design Criteria:
  - 1:1000 years events – minimal maintenance acceptable
  - Probable Maximum Flood (PMF) and Maximum Credible Earthquake (MCE) – major repair work acceptable, but not failure
  - Include natural hazards (droughts, landslides, avalanches, etc)
  - Design for long term chemical effects (ARD, ML) and ensure long term compatibility of materials (brine vs. clay liners, acidic seepage vs. synthetic liners, etc)

Design Criteria for Closure – Recent examples

- Huckleberry Mine, BC:
  - Long term TMF Spillway design criteria is: 4-day duration PMF plus a 1:100 snowmelt event
- Rosia Montana Mine, Romania
  - TMF designed to contain equivalent of two PMF events
  - At closure, spillway designed for PMF





Design Criteria for Closure (cont'd)

- The Environmental Design Flood (EDF) is explicitly addressed in the British Columbia 1998 guidelines: ARD contaminated waters must not be released under a 1 in 200 years flood (minimum design criterion)

- Regarding stability analyses: the minimum design safety factor for shear failure under static loading is suggested to be increased (e.g. to 1.6 - 1.8 from the conventional 1.5, Davies & Szymanski, 2003)

4. Best Practices

4. Best Practice Principles

- Minimize risk of failure
- Minimize water quality issues
- Minimize issues related to maintenance

Best Practices to Minimize Risk of Failure

- Some Considerations to Include in Closure Design:
  - Minimize the amount of water in the pond
  - Ponded water away from the dam and close to the spillways
  - Avoid complex systems for drainage, intricate covers
  - Use wide, well graded filter zones to minimize piping potential
  - Embedded pipes & culverts - not desirable anymore!
  - The 'dry' spillway concept - a dry spillway should be considered standard practice, particularly for remotely located tailings dams
  - Reshape, re-grade and re-vegetate to blend with the surrounding landforms and the environment → Minimize visual impact

Best Practices to Minimize Risk of Failure

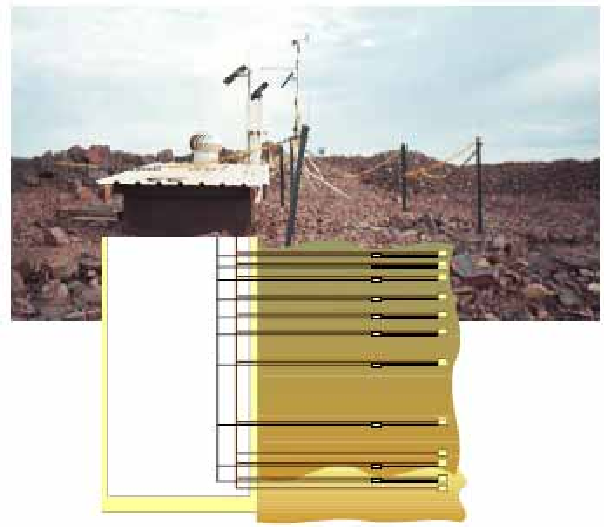
- **Post-closure monitoring**
  - Collect data and USE IT!
  - Regularly check on instrumentation effectiveness
  - Safely store data – priceless for years to come
- **Dam safety**
  - Continue the DSIs
  - DSRs still required 10 – 15 years, especially if extreme events do occur at the site.
  - DSRs could be triggered by actual or anticipated changes in meteorological or seismic database.
  - Consequence classification to be reviewed
  - Closed tailings dam - subject to many revisions (as opposed to conventional water retention dams)

Best Practices to Minimize Water Quality Issues

- Water covers for minimizing ARD potential:
  - Use of natural lakes – where possible
  - Confirm and ensure long term positive water balance
  - Include in design a five-year sequence of dry years climatic data
  - Most cases requires fish habitat compensation
- Redirect surface runoff away from the TMF

Best Practices to Minimize Water Quality Issues – cont’d

- Use engineered (evapo-transpiration or capillary barriers) covers only where supported by laboratory and in situ trials
- Evaluate purpose of the cover system (Oxygen ingress? Net percolation?)
- Laboratory is useful but test plots - a must!
- Or do you need / want encapsulation (HDPEs, GCLs)?
- Locally available borrow material vs. liners = always a $$$ issue.



O’Kane Consultants, 2004

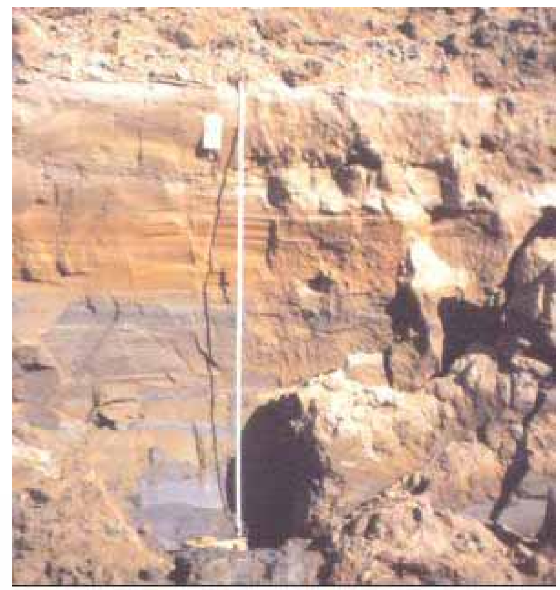
Best Practices – Capping of Tailings

TAILINGS ACIDITY

ACID GENERATING POTENTIAL	HIGH pH	CIRCUMNEUTRAL	LOW pH
HIGH AGP	Moderate Risk Potentially High Salinity/Phytotoxicity	Moderate to High Risk Potentially High Salinity/Phytotoxicity	High Risk Typically High Salinity/Phytotoxicity
MODERATE AGP	Moderate Risk Potentially High Salinity/Phytotoxicity	Moderate Risk Potentially High Salinity/Phytotoxicity	High Risk Typically High Salinity/Phytotoxicity
LOW AGP	Low Risk/Benign Moderate Salinity	Low Risk/Benign Moderate Salinity	Moderate Risk Potentially High Salinity/Phytotoxicity

Cover Depth

GeoSystem Analysis Inc.



Do you need a cap? What type?

Minimize Potential for Eventful Maintenance Programs

- Avoid water treatment plants
  - Use natural attenuation / treatment/ phytoremediation
  - Construct sustainable ecosystems
  - Use passive barriers
- Avoid pumps / mechanical / hydraulic equipment
- Implement more robust alternatives if some data is missing (e.g. coarser riprap, etc.) – don't be shy
- Use "belt and suspenders" approach in higher risk cases, i.e. redundancy, to get warnings

Post-Closure – Critical Aspects to Look For

- Signs of internal erosion
- Long term changes in material properties - could affect drainage, surface runoff, infiltration rates
- The effect of the hydraulic gradient on slope stability
- Interaction between deposited tailings and sealing elements / foundation within the tailings dam
- Seepage points
- External erosion on slopes
- Sustainability of revegetated areas

General reference documents

- MAC Guidelines
- CDA Guidelines –

  limited applicability but a good resource
- Provincial regulations and guidelines – useful info
- ICOLD Bulletins on tailings dams, from #44 (issued in 1982) to #121 (issued in 2001)
- Technical papers - conference proceedings, journals
- Research reports (CANMET, MEND, etc)

5. Opportunities and Social Responsibility

5. Opportunities at Closure

A multitude of options available:

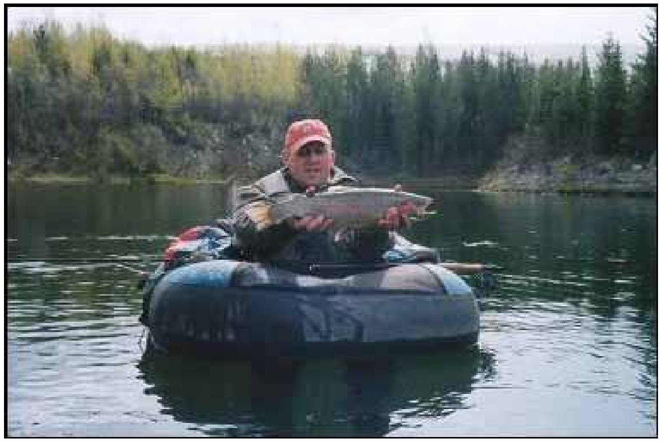
- Teaming up with other stakeholders
- Reuse and reclaim land
- Involve local organizations
- Use opportunities for research, testing, social aspects.

Opportunities at Closure (cont'd)

- Co-disposal of waste:
  - Co-disposal options related to mixing of tailings and waste rock
  - Sub-aqueous disposal of PAG waste rock into TMFs
  - Co-disposal of waste from other sources (municipal sludge, dewatered paper sludge residue) with tailings
- Research & Development
  - Partner with research centers to undertake / evaluate alternative methods and materials
  - Example: EU initiative on new materials; UBC on co-disposal of waste, UofM & UofA on direct revegetation of tailings and of oil sands; CANMET and the MEND program, etc., etc., etc.

Opportunities at Closure (cont'd)

- Co-disposal of waste:
  - Example: Highland Valley Copper, BC: evaluation of using biological treatment to lower molybdenum levels in the pit lakes (uptake of metals into algae)
  - Also, reuse of biosolids from Greater Vancouver Regional district to improve and sustain revegetation and tree planting (1.7 million tree seedlings and shrubs).



More Opportunities at Closure

- Partnership with Government and Local communities
  - Example: Xstrata Nickel Manibridge Mine in MB;
  - Partner with MB Conservation, local Boys and Girls Club, and the local school for a “Plant a Tree” environmental awareness days.
  - Ecosystem re-establishment.
- Explore Post-Mining Usage of TMAs
  - Examples: BC, Highland Valley Copper – used as a pasture

6. Conclusions – the Future of Closure Planning

Conclusions

- Closure plans must address (at least) the following aspects of long term closure of tailings facilities:
  - Physical stability and integrity of the dams and their appurtenant structures
  - Chemical and geochemical stability of tailings
  - Water management
  - Sustainable land reclamation for the return of the site to a viable post-mining land use
- Strategic partnerships and community involvement in closure planning have been beneficial for all stakeholders

Conclusions (cont'd)

Due Diligence + Best Practice + Engineering Judgment + Community engagement

↓

Optimized, lower risk, more sustainable closure plan

Questions / Comments ?

A final message on Closure Planning

The process of closure planning is like the process of loss …of the mine

- The first step is **denial** – This can't be what's required to close the mine??
- The second is **bargaining** – Why me??
- The third is **anger** - The bond is how much?
- The fourth is **despair** – This is never coming off the books!!
- The fifth and last step is **acceptance** – I guess I never lost the mine after all

Thank you!