Components of Successful Mine Reclamation and Environmental Protection

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- Overall Objectives
- Requirements
- Challenges
- Components of Successful Reclamation and Environmental Protection
- Conclusions

Overall Objectives

A Mine Site

During Mining

- Jobs
- Resource Production
- Taxes

During and Afterwards

- Neighboring Land Use
- Potential Contamination of Land and Water*
- Mitigation and Regulation Costs

*If not prevented, there are potential impacts with toxic drainage from most metal and at least some coal and diamond mines

1. Prevent impacts downstream or on surrounding land;
2. Prevent impacts to wildlife and people using site;

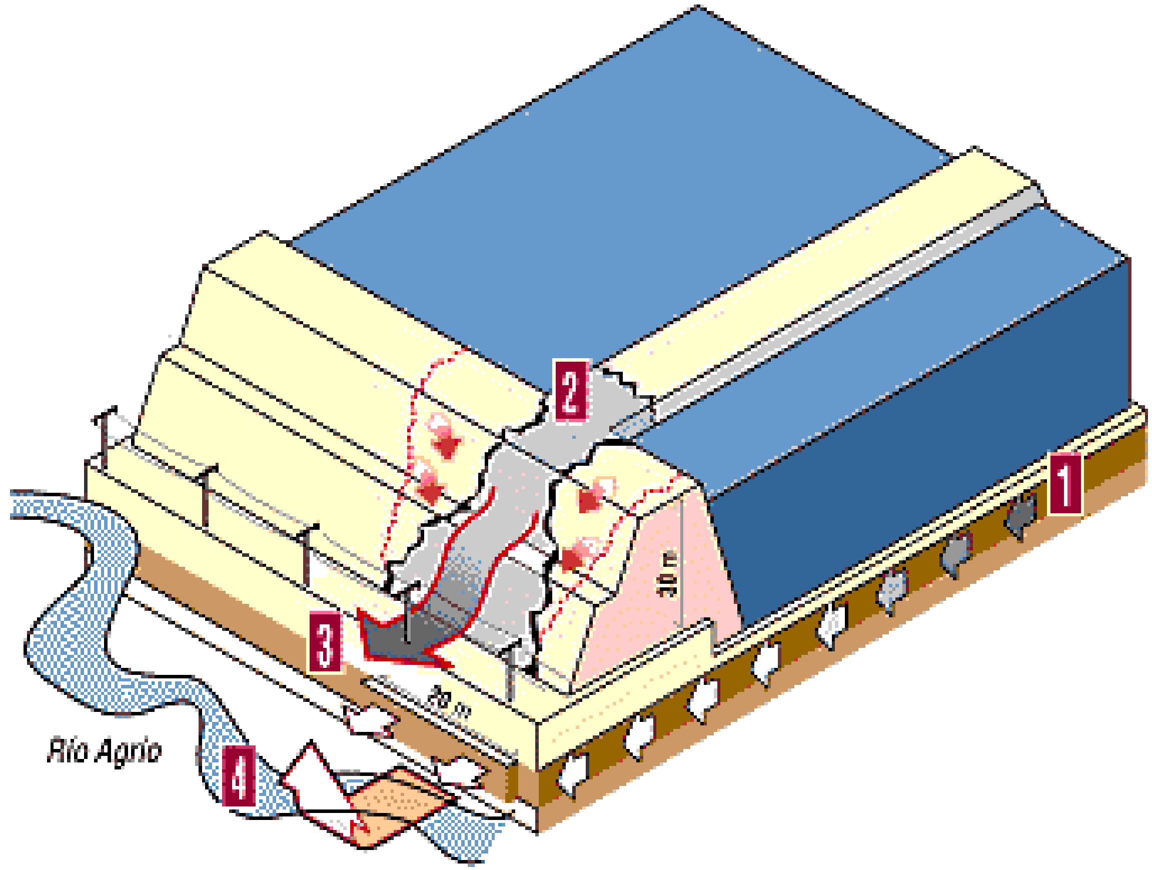
3. Minimize costs to public; and
4. Maximize post-mining productivity.

Protecting off-site fish & wildlife are usually first priorities because:

- mine itself has a relatively small footprint; and
- potentially large remediation costs or off-site impacts.

Often the major concern is metal leaching or acid rock drainage. Once conditions conducive to sulphide oxidation and leaching have been created, contamination or mitigation costs may persist for hundreds of years or longer.

Sediment loss from mass wasting and surface erosion by wind and water can also impact large areas.



Access roads potentially have large impact on surrounding land.

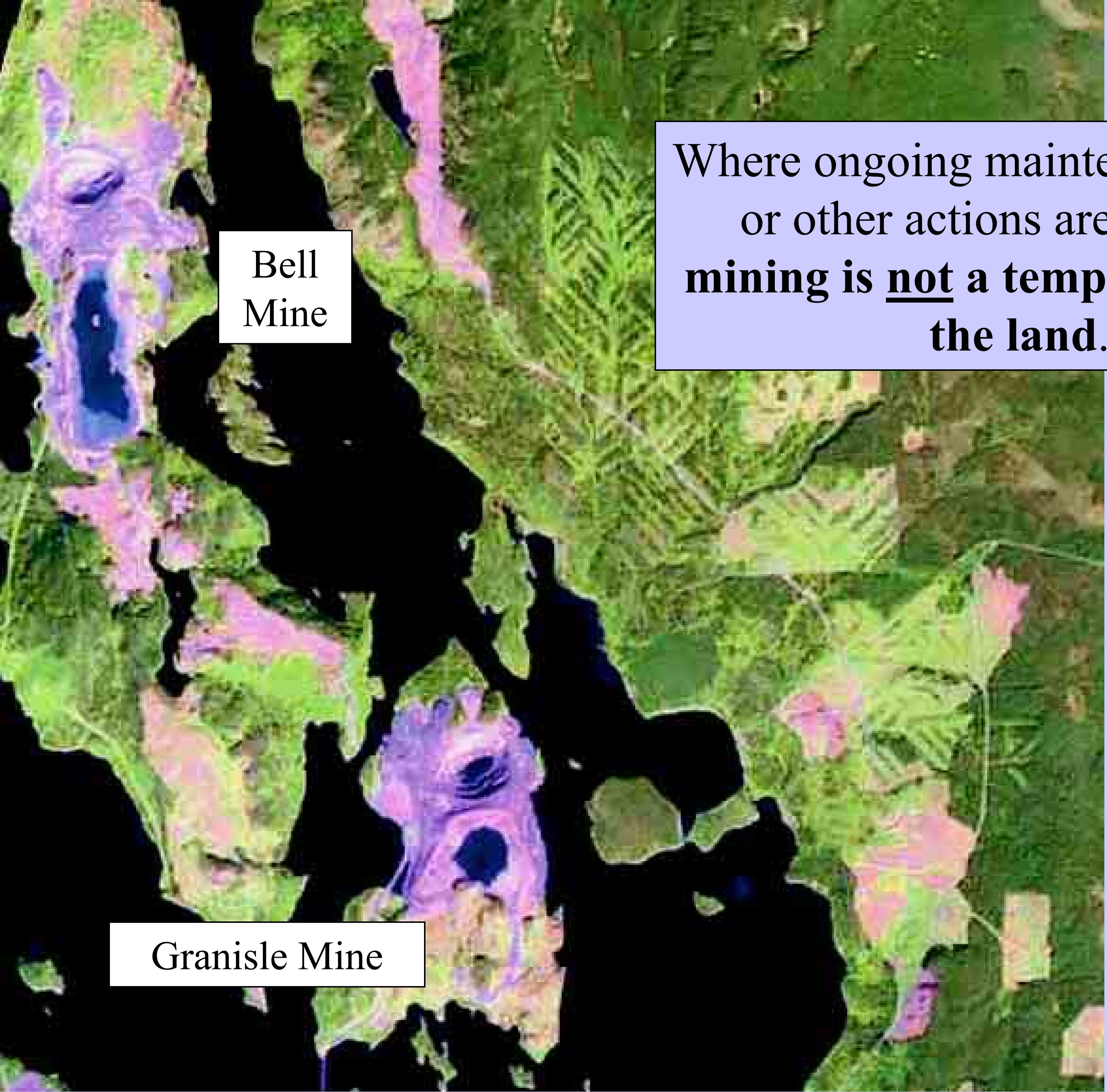
Important considerations

- Will road be required after mining?
- Need to ensure road is not a barrier to wildlife migration or causes increased predation or hunting

Requirements

Requirement: Long-Term Performance

Performance of most measures for water management, waste storage or mitigation of sulphidic rock must be sustained **indefinitely**.



Where ongoing maintenance, repair or other actions are required, **mining is <u>not</u> a temporary use of the land**.

Requirement: Resolve Problems Pro-Actively

Mine sites be designed and operated in a manner that allows **detection and resolution of problems before there are significant environmental impacts**. This requires:

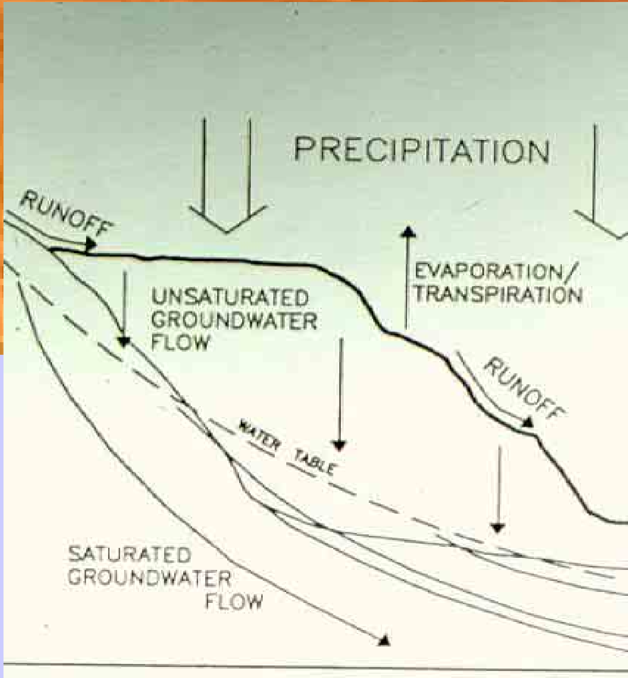
- pre-planning;
- a design with adequate durability and capacity to handle extreme weather;
- monitoring, maintenance* & contingency plans;
- accurate cost estimates;
- field trials to verify predictions;
- studies to fill information gaps; and
- personnel, financial resources and organizational commitment to conduct the above.

*including repair and replacement

The first steps in pro-active detection is **recognizing potential failure mechanisms and the preventative mechanisms**. For example, decreased performance of a cover system may result from scouring, overtopping or damage when snow, ice and other debris are removed.

Requirement: Handle Changing Conditions

Properties of a mine site, such as drainage paths, height of water table, water quality and wildlife activity, are continually changing.

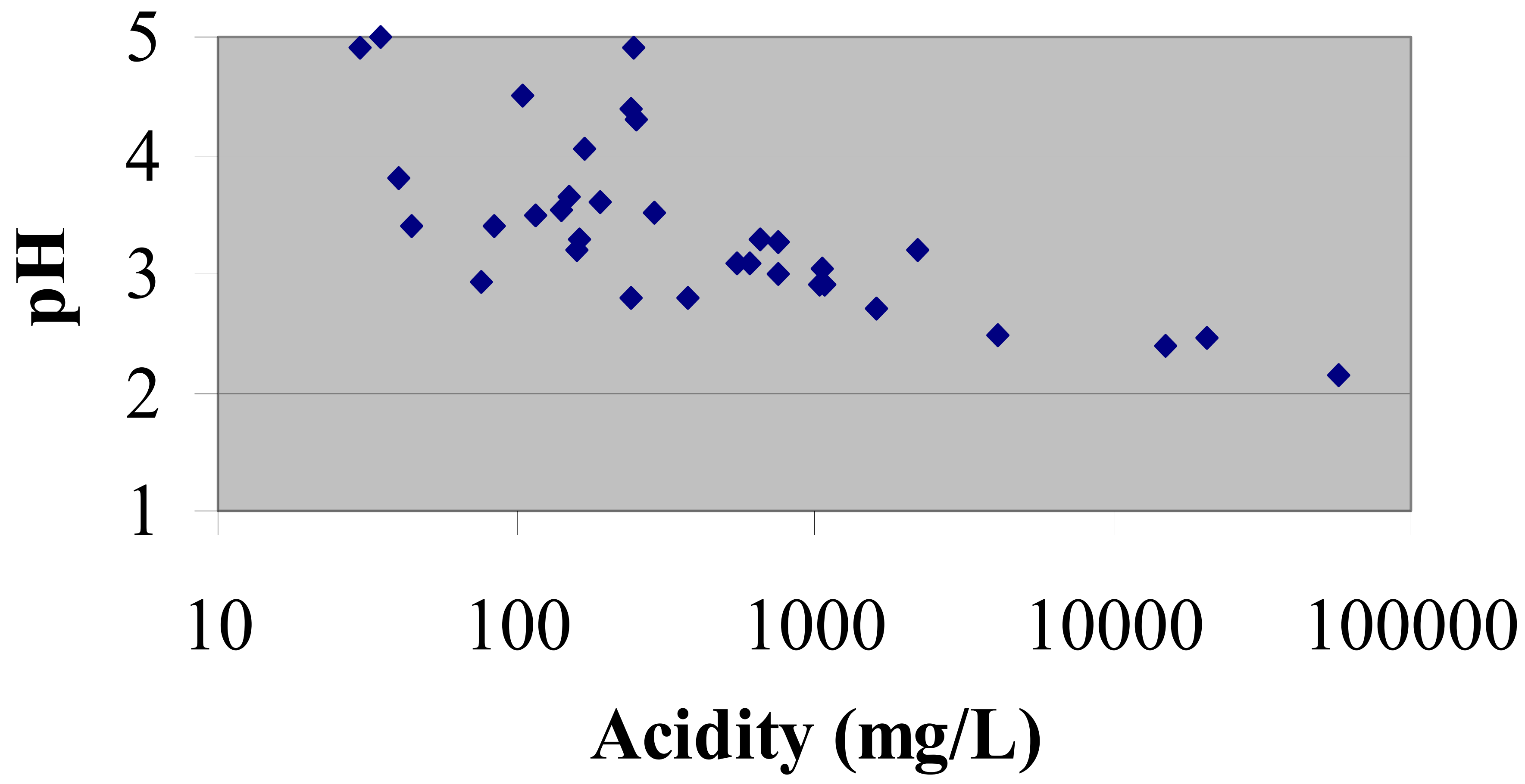


2.6 Conceptual model of water moveme
waste rock dump.

For example, groundwater rebound with pit flooding following mining can change height of the water table, flow, flow paths and drainage chemistry.

Alteration of the rock will change drainage chemistry (e.g., increase acidity and metals), which in turn can increase impacts or costs.

It may take decades before geochemical changes occur.



Requirement: Predict Drainage Chemistry and Potential for a Significant Environmental Impact

Requirements are uncertain at over 40 major mines in British Columbia due to uncertainty about magnitude of metal loading and whether it will have a significant environmental impact.

Concerns with climate change and its impact on metal (Ni) leaching from CKR and kimberlite, black clay and biotite schist waste rock if they do not freeze

Concerns with tailings include settling of clays and water quality.

Discharge chemistry, and habitat quality of the flooded pits and the Long Lake waste disposal system.

A common issue is whether uptake of metals will be a concern for wildlife. Soil covers can be used to minimize contact with the underlying wastes. After reclamation, health and population studies be used to assess impacts to wildlife.

Requirement: Monitoring and Maintenance

Mitigation measures without monitoring and maintenance are equivalent to a car without a wind shield or an oil change - breakdowns and crashes will be inevitable.

Maintenance is required even for simplest components of site mitigation.

Maintenance for a ‘Ditch’ includes:

- removal of vegetation and sediment,
- repair erosion, and
- removal of ice from ditches prior to freshet.

Effective maintenance requires adequate personnel, funding and commitment.

Monitoring is a key part of pro-active management:

- provides early warning of potential problems (e.g., detect a reduction in design capacity);
- informs corrective measures (e.g., direct maintenance); and
- allows adaptive management or contingency plan implementation.

Requirement: Determine Reclamation Objectives

Post-mining land use objectives should guide the mine plan. Land use should be compatible with:

- surrounding land uses;
- environmental conditions;
- mine components; and
- community objectives.

Mining dramatically changes the local landscape. Best post-mining land use might differ from that prior to mining.

Requirement: Waste Disposal

- A mine is a waste storage facility, with waste products remaining on the site after mining.
- Disposal procedure and location can have a large effect on environmental impact and costs.
- The large volumes usually make waste movement after mining prohibitively expensive.
- Consequently, waste handling plan must consider environmental protection and reclamation requirements.
- Problems occur when reclamation, drainage chemistry or mitigation success are not considered or are uncertain.

Requirement: Maximize Post-Mining Productivity

Major potential cost items that need to be resolved include whether dump re-sloping and soil replacement are required. This may depend on specific reclamation objectives and trial results

Revegetation Research - Most site have unique growing conditions

Field trials are required to determine the best revegetation strategy:

- species selection,
- growth medium,
- amendments and
- compatibility with slope or snow cover.

Until they can show they are not needed, the mine should strip and save all potential soil media.

Requirement: Develop the Required Understanding

The 'Best Management Practice' is to develop site-specific reclamation and environmental protection plans.

Predict drainage chemistry, costs, post-mining habitat, etc…

Development of the required understanding may cost $100,000s and take over a year to develop.

However, these costs are minimal compared to the costs when site-specific problems are not understood and addressed.

Operational confirmation of waste composition is as important as ore grades, especially if problematic portion must be segregated so it can be cost-effectively mitigated - 10,000s analyses, $100,000s of work and comprehensive vigilance may be required.

Requirement: Adequate Personnel and Resources

- Adequate number of personnel with the resources, technical training and experience to conduct each phase of the work
- Organizational commitment to conduct comprehensive, detailed, multi-disciplinary technical reviews and follow-up.
- Properly qualified person or personnel accountable for project TOR, methodology and interpretation of results.
- All those involved in the work, not just the specialists, to be properly informed (e.g., truck drivers and persons conducting sample preparation).

Requirement: Maintain Site Knowledge

Corporate memory can be lost with staff changes, mine closure or government downsizing. Consequently, record keeping is very important.

- data base for monitoring and waste handling data;
- manuals for operating, monitoring, maintenance, sampling and analysis;
- as-built drawings for all components showing how and where wastes placed; and
- well maintained and secure storage site for the above.

Need regular review of procedures and data

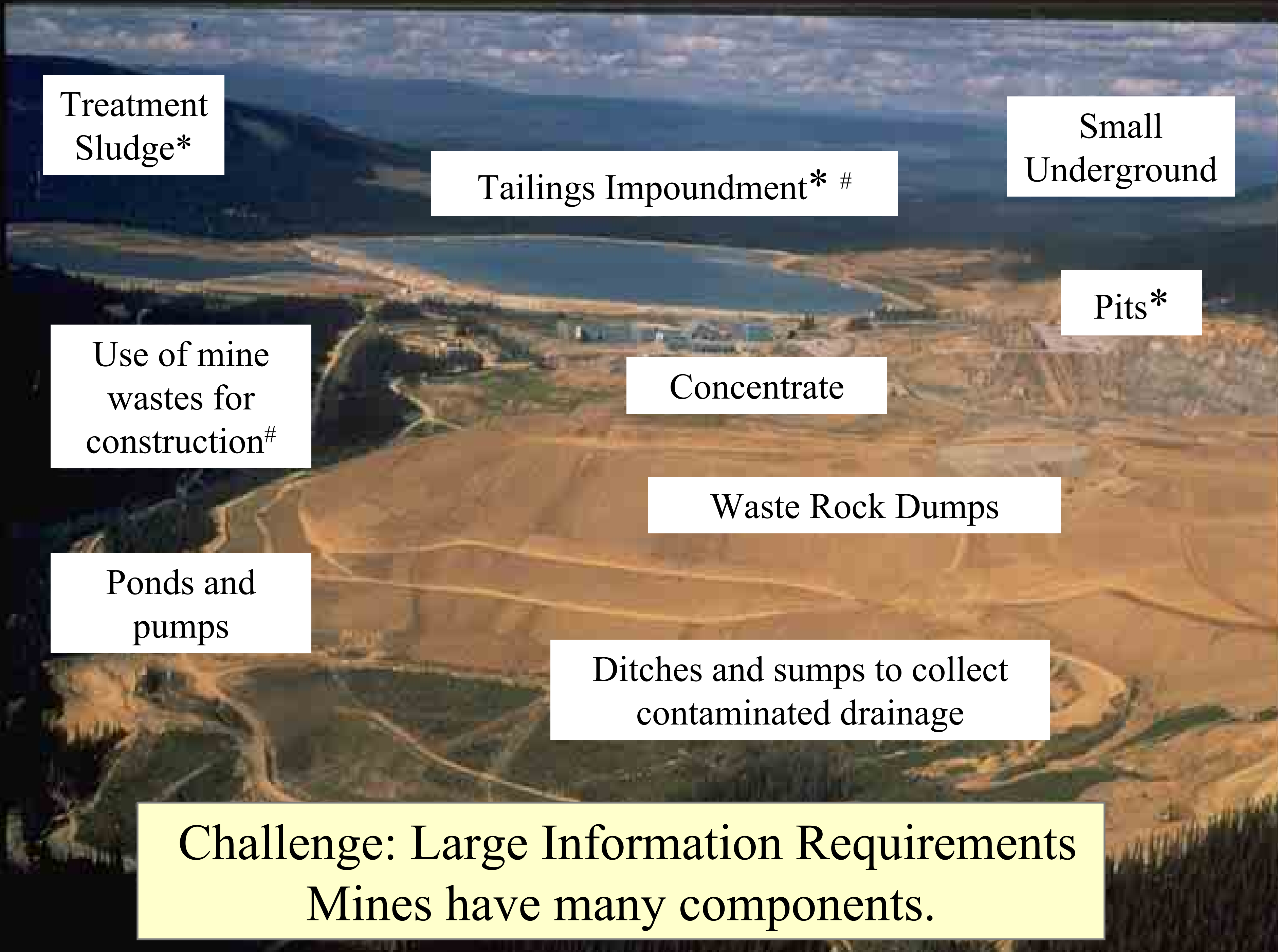
Requirement: Collect Information in Time to Make Decisions

- Results of planning and studies and field trials must be available before decisions need to be made – typically this is either prior to mine opening or closure
- Cost effective to do test work when site is operational
- Mine closure can be a difficult time to conduct work (budgets cut and valuable personnel leave)
- Time of mine closure depends on ore reserves <u>not</u> completion of reclamation test work or planning

Challenges

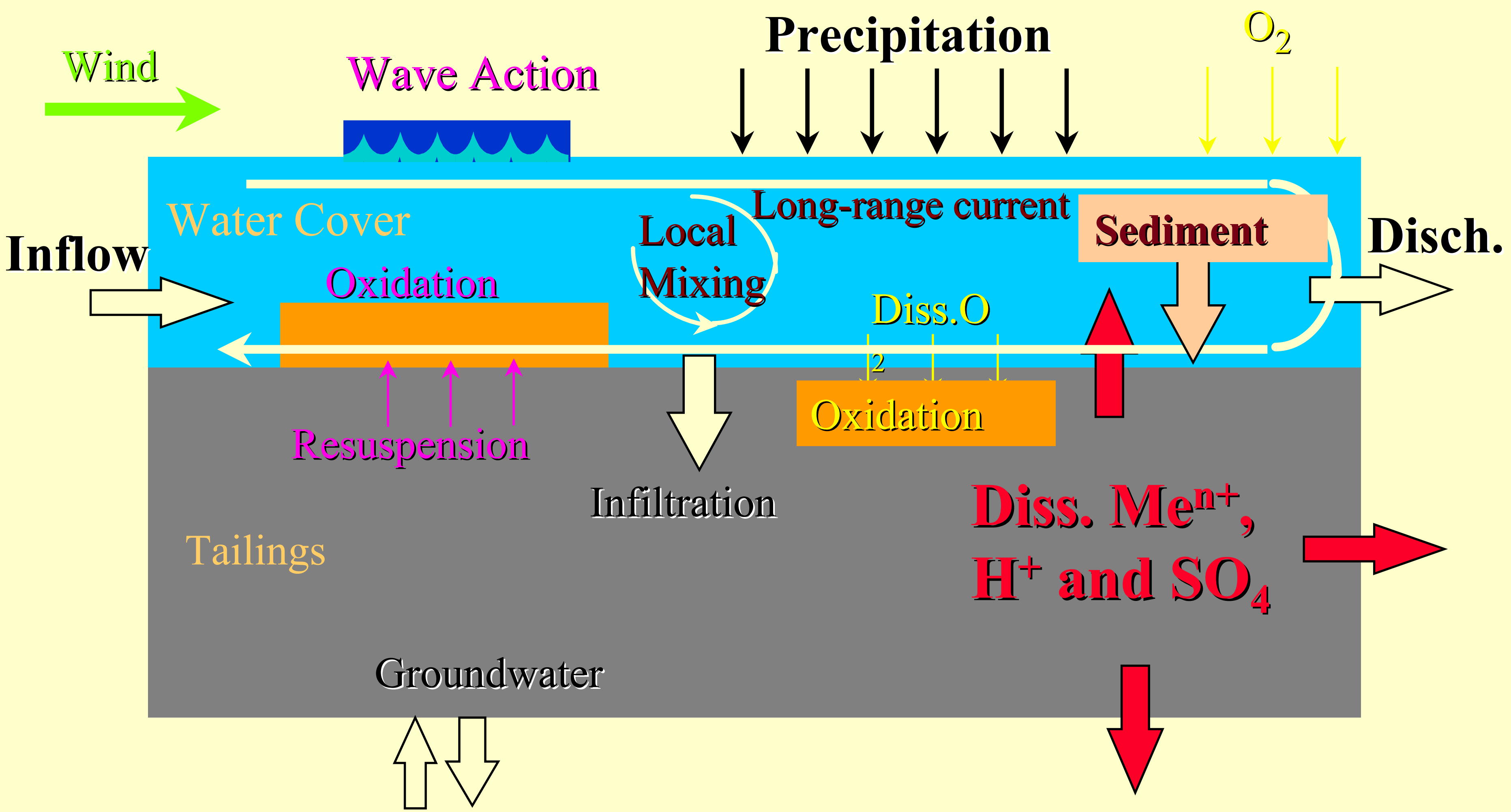
Challenge: Large Information Requirements

Without supporting data, plans are just wishful thinking.



Challenge: Large Information Requirements
Mines have many components.

And each component potentially has a large number of influential factors, processes and complex interactions – potentially confusing or overwhelming.



Detailed studies required prior to mining, during mining and post-closure.

- Water quality / Sediments
- Hydrology /Groundwater
- Fisheries / Stream Biota
- Rock composition and weathering (geochemistry)
- Vegetation / Wildlife
- Air Quality
- Geotechnical test work
- Soils

- Need to learn from previous mistakes.
- Many past failures resulted from decisions based on optimistic professional judgement or computer models rather than scientific evidence. Need “great information” rather than “great experts”.
- Devil is in the details – dangerous to simplify or generalize.

Challenge: Lack Long-Term Experience

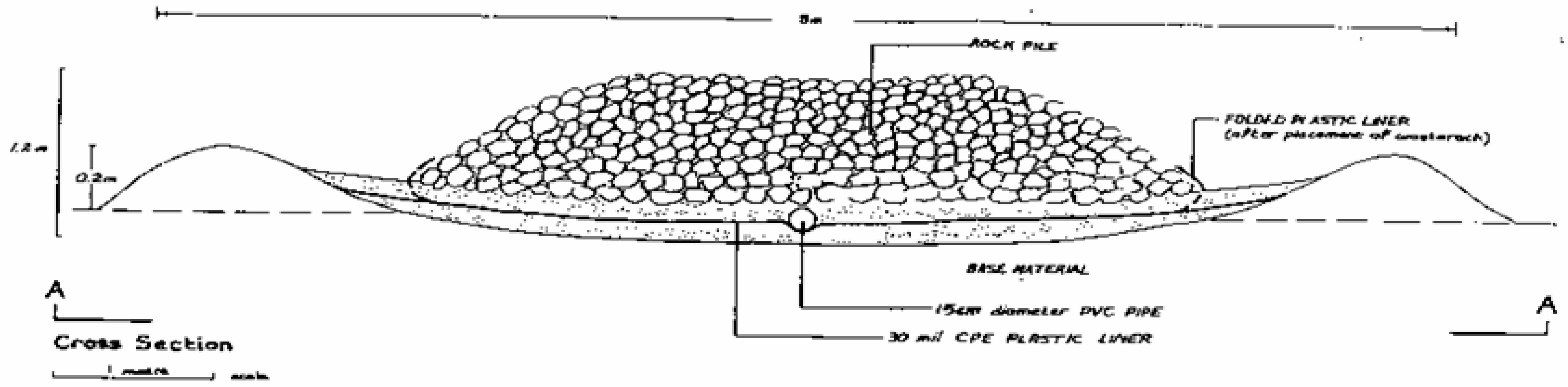
Limited information on durability and impact of processes such as permafrost for most environmental protection measures (e.g., soil covers). This results in uncertainty about long-term performance, repair and replacement costs, when to initiate that work and future costs. In the mean time, must rely on monitoring and contingency plans.

Challenge: Resolving Outstanding Issues

Not all issues can be resolved prior to mining. Most BC mines need operational research to complete closure plan.

Huckleberry is still refining its prediction of the water quality and working on a mitigation plan for the portions of the East Zone pit and plant site that won't be flooded.

Significant differences exist between laboratory and field (e.g., cold temperature impact on carbonate dissolution). Field test pads are being installed at a number of sites to check pre-mine predictions of weathering and drainage quality and loadings.



Challenge: Dealing with Uncertainty

- As a result of limited operating experience and the large number of properties and processes, all mines have some uncertainty. Need to recognize uncertainty and conduct studies to reduce costs and risks.

- Depending on the risks, contingency plans and adaptive management may be the most cost-effective means of dealing with uncertainty. Timing and degree of preparation will depend on the risks, when potential events of concern may occur and the resources required.

Challenge: Limit Footprint

- By using exhausted pits as a second impoundment, mines can reduce the footprint of the mine and the size of its dams.
- But need to be beware of impacts on water quality (e.g., due to slow or delayed flooding).

Challenge: Political and Financial Pressure.

Often strong organizational pressure to approve or reject projects. Pressure to approve development when work was inadequate or personnel inadequately trained, motivated or resourced has cost the public many $100s of millions in the NWT, Yukon and Colorado.

Challenge: Regulatory Overload

- More public consultation and more meetings
- Cumulative increase in mine sites

Mines with ML/ARD Concerns in BC	Number	Cumulative #
Historic	10	10
Closed 1970-1990	18	28
Recently Closed	20	48
Operating	12	60

Components of Successful Reclamation and Environmental Protection

- Removal of buildings and equipment
- Disposal of toxic chemicals (e.g., process or lab chemicals)
- Cleanup contaminated soils (e.g., oil)
- Ensure dumps, dams, impoundments, ditches, tailings, water courses, etc… are geotechnically stable
  - Resloping if required
  - Develop and follow plans for drainage management, dust control, erosion control and sediment retention
  - Monitoring, maintenance and repair
  - Prevent access into or onto unstable mine workings

Metal Leaching and ARD program:

- Develop discharge quality and loading objectives;
- Prediction of material composition, weathering and discharge quality and quantity;
- Operational confirmation of material characterization, weathering and evolution of drainage on-site;
- Mitigation plans and actions, if required;
- Studies to fill information gaps; and
- Contingency plans where there remains significant uncertainty

Site Reclamation:

- Specific objectives, including required habitat type, productivity measurements, vegetation communities, topography, soil media and amendments
- Compatible waste disposal, re-grading and soil handing plan
- Bench marks to be used in judging whether measures are successful (e.g., expected permafrost, soil development and plant succession)
- Development schedule and monitoring and maintenance
- Test of amendments and potential options
- Assessment of contaminant uptake and ecological risk

Mines Must Regularly:

- Monitor drainage quality and quantity, and receiving environment and ecosystem health (EEM)
- Update as-built drawings and monitoring data base
- Estimate liability (outstanding costs) and provide financial security
- Minimize risk of failure by identifying:
  - potential failure mechanisms;
  - existing preventative measures;
  - additional requirements; and
  - schedule for corrective measures.

Regulatory Requirements:

- Guidance with regards to acceptable overall objectives, plan and level of supporting information.
  - Baseline data and subsequent monitoring
  - Conditions for geotechnical stability, site productivity, ML/ARD, maintenance, and financial security
- Inspect site
- Review of reports, plans, designs, as-built drawings, studies and monitoring results by mining, reclamation, geotechnical, ML/ARD, discharge quality and habitat specialists

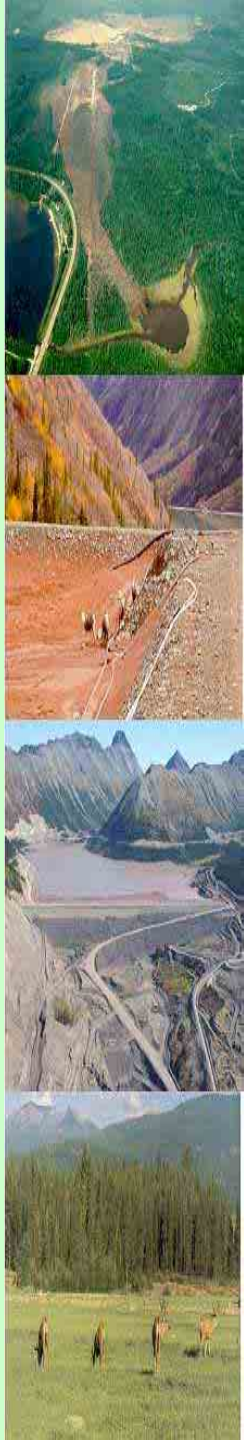
Regular Regulatory Review/Follow-Up

- Regular review of mine plans, site monitoring, material characterization drainage chemistry prediction and mitigation, discharge limits, health of receiving environment, liability and financial security is required for timely problem detection and to avoid costly problems.
- Need regular follow-up to keep up with changes to site conditions and mine (e.g., expansion, closure or global warming) - prior to mining and then periodically (e.g., every 5 years) or prior to significant changes to mine (e.g., expansion or closure) or site conditions (e.g., global warming).

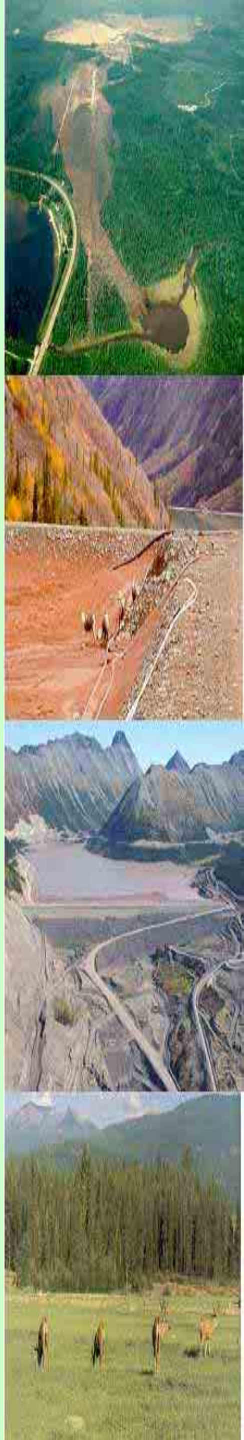
Community Requirements

Check mine completes required tasks:

- Permit compliance
- Progress in addressing outstanding issues
- Response to review comments
- Required submission of monitoring results, as-builts, annual reports, outstanding issues and significant changes are complete in content, action and intent
- Ensure expertise of persons responsible for different technical issues and overall plan.



- Participate with mine in annual review of site changes, monitoring, study results, risk reduction and future plans
- Check that regulator completes tasks each year:
  - Inspections
  - Review of monitoring results, as-builts, annual reports, outstanding issues and significant changes are complete both in content and intent (e.g., both results and proper expertise)
- Independent review of key issues
- Need to enable community understanding of mine in order to obtain constructive input



Conclusions

Mining is a very different business now compared to 10 to 20 years ago, with vastly improved practices.

While practices have improved, major challenges still exist:

- complexity of mines sites and large information requirements;
- potentially high costs;
- lack of long-term operating experience; and
- highly specialized, technical nature of the work.

Lots of hard work and resources are required to ensure industry and government sustain environmentally sound mining practices – success depends on significant commitment by all parties.

Devil is in the details. Need to ensure all issues are being addressed in sufficient detail; by persons with adequate experience and expertise; and in a timely manner.