BRITISH COLUMBIA
Ministry of Energy, Mines and Petroleum Resources

Interrelationships of Water Management, Monitoring, and Modelling

Paul Beddoes MSc PGeo
Senior Environmental Geoscientist

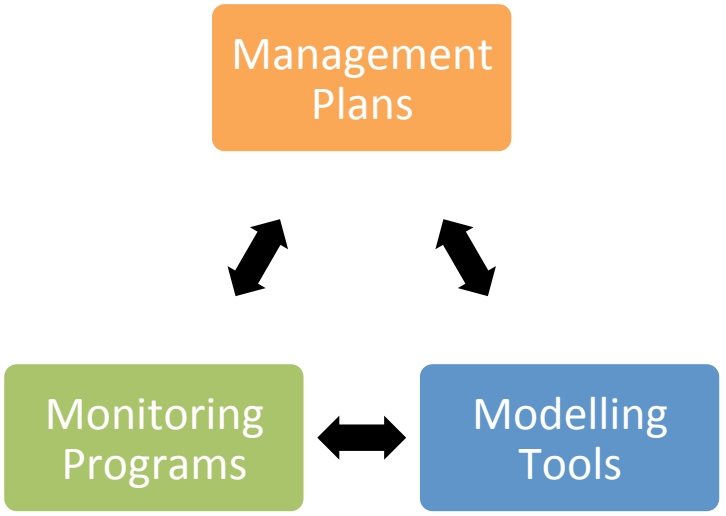
Brenda Bailey PhD PGeo
Senior Environmental Geoscientist

Sean Shaw PhD PGeo
Senior Environmental Geoscientist

Ministry of Energy, Mines and Petroleum Resources
Victoria, British Columbia

Presentation Outline

- Overview of Regulations in BC
- Understanding Interrelationships
- Opportunities and Challenges
  - Verify Assumptions and Uncertainties
  - Comparison of Actual versus Predicted
  - Maintaining Management Tools
  - Contingency and Adaptive Planning
- Summary



Guiding Regulation in BC

Mining and exploration activities in British Columbia will be regulated in a manner which supports the Province's goals of:

- sustainable resource development,
- reclamation,
- environmental protection and
- minimization of economic risks.

Mining projects in BC are subject to approvals under the *Mines Act* and must comply with requirements of the Health Safety and Reclamation Code for Mines in BC

ML/ARD Policy: https://www2.gov.bc.ca/gov/content/industry/mineral-exploration-mining/permitting/ml-ard

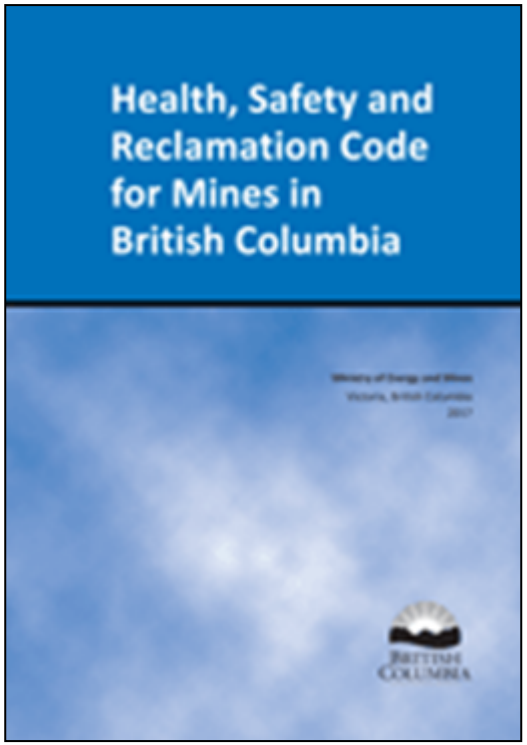
General Regulatory Requirements in BC

Application information requirements are summarised in the HSR Code, Section 10.1.3, including:

- Management Plans
- Monitoring Programs
- Modelling Tools

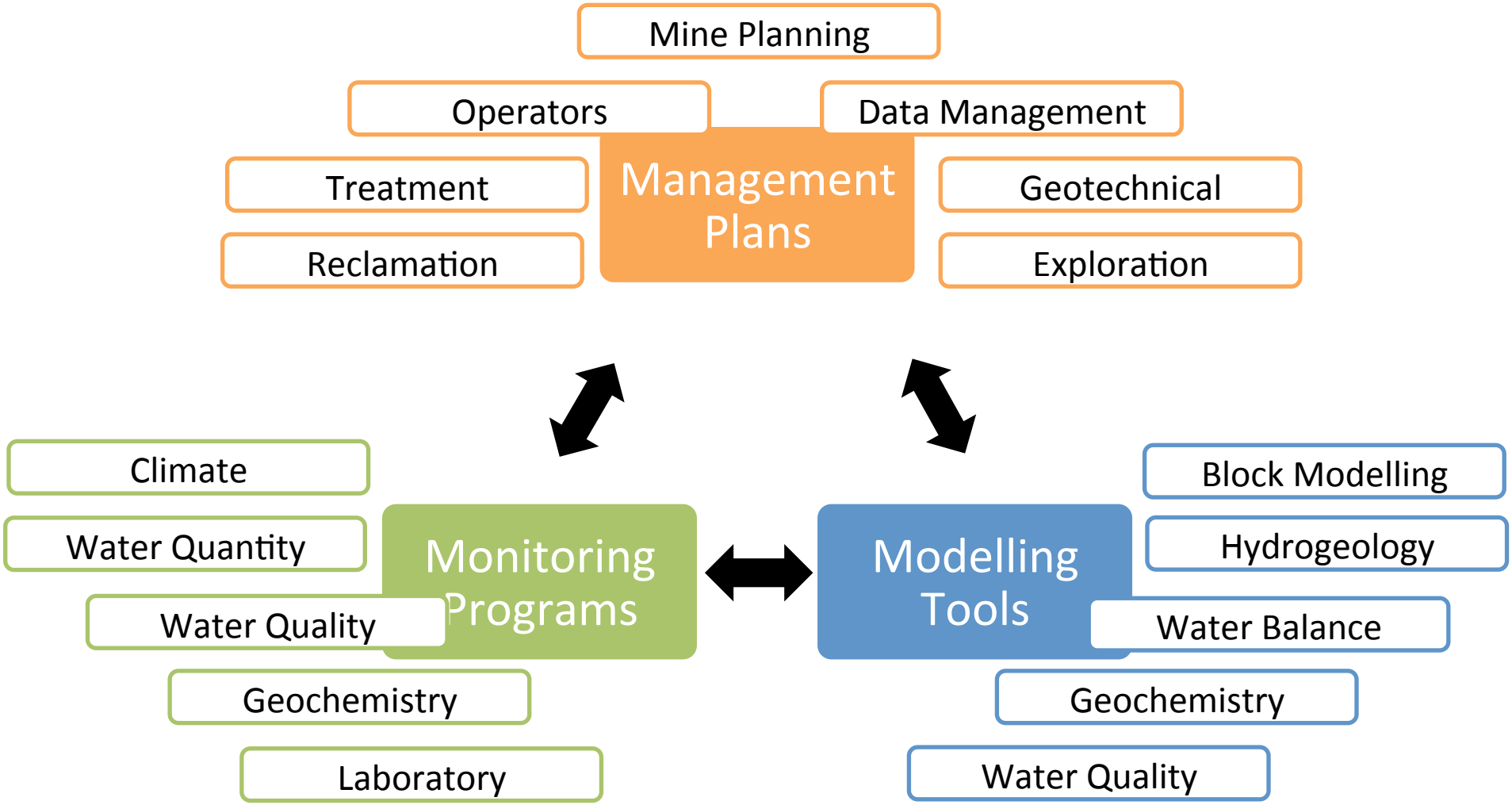
Annual revision and reporting for reclamation and environmental monitoring programs

Plans and models are required to be updated every 5 years, or when there are changes to the approved plan

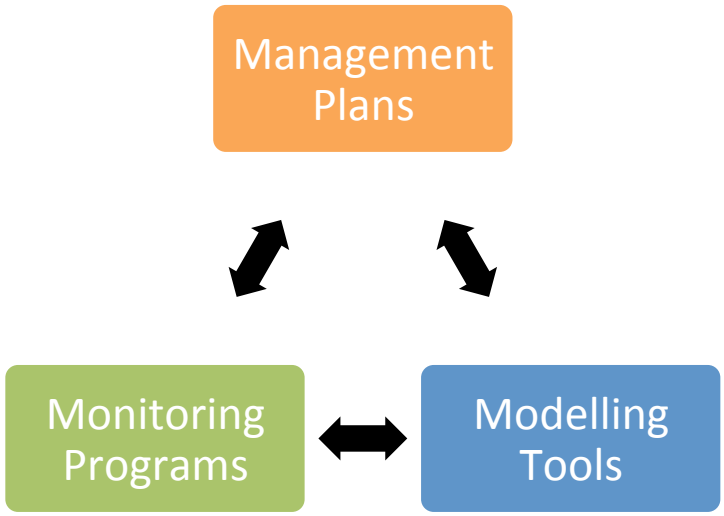


HSR Code: https://www2.gov.bc.ca/gov/content/industry/mineral-exploration-mining/health-safety/health-safety-and-reclamation-code-for-mines-in-british-columbia

Understanding Interrelationships



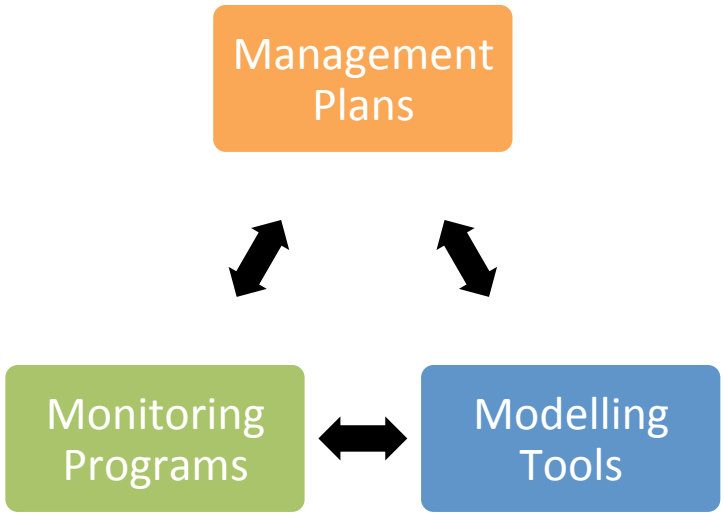
1. Overall management approach is developed, including monitoring and model development
2. Predictive tools based on available data are developed to reflect management approach
3. Tools are used to refine management plan and support decision making
4. Monitoring program is developed to verify the assumptions and uncertainties
5. Models updated and refined based on monitoring data and changing conditions
6. Contingency and adaptive plans may be triggered based on ongoing monitoring



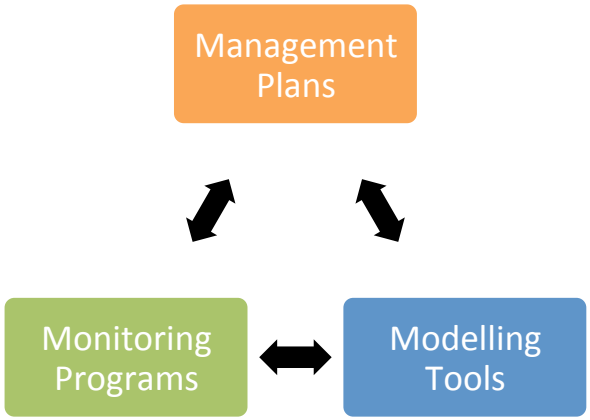
Opportunities

Key interrelationships in this process can support efficient management planning and robust decision making:

- Verify Assumptions and Uncertainties
- Comparison of Actual versus Predicted
- Maintaining Management Tools
- Contingency and Adaptive Planning



Verify Assumptions and Uncertainties



OPPORTUNITY

Assumptions, uncertainties, source terms, and other inputs should be verified through ongoing monitoring

EXAMPLE 1: Lack of post-depositional sampling

- Mine relied on PAG/Non-PAG blending of waste rock
- Blended rock was not sampled
- Success of blending was not confirmed
- No ability to proactively manage possible onset of acidification

Verify Assumptions and Uncertainties

EXAMPLE 2: Omitting material type from monitoring

- Tailings assumed to be “benign” and omitted from monitoring
- Assumptions could not be confirmed
- Early warning of contaminant load from tailings not possible

EXAMPLE 3: Inadequate monitoring locations

- Lack of seepage surveys and sampling
- Monitoring occurred at central collection ponds
- Source of loading increases could not be resolved
- Source term assumptions could not be verified

Verify Assumptions and Uncertainties

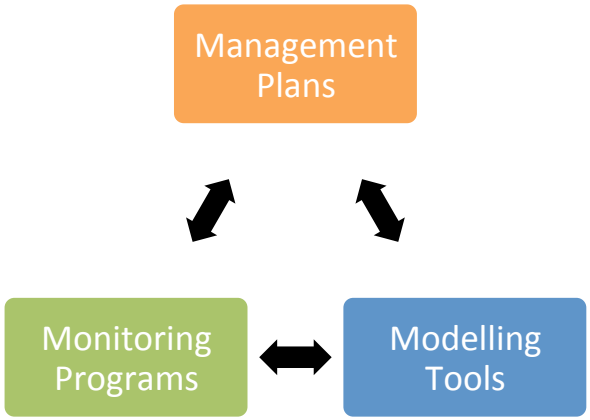
EXAMPLE 4: Key constituents not monitored

- Mine assumed mineral precipitation was controlling metal concentrations
- No verification of assumption through routine observation
- Cause of increased loadings not verified
- Other examples exist where only TSS monitored

Key Message

The success of management objectives can be tracked through comprehensive monitoring programs that are designed to verify assumptions and reduce uncertainties

Comparison of Actual versus Predicted



OPPORTUNITY

Where discrepancies are identified between actual and predicted conditions, models and monitoring can be used to understand differences, inform management changes, and assess effects on an ongoing basis

EXAMPLE 1: Water shortage- Loss of process

- Water availability was necessary for production process
- Water balance predictions not compared with monitoring data
- Water shortage lead to production shut-down while alternative water sources identified and permitted

Comparison of Actual versus Predicted

EXAMPLE 2: Water shortage - exposed PAG material

- Management plan required a permanent water cover on PAG materials to prevent acid onset
- Water balance predictions not verified
- Water cover was not maintained, increasing the risk of ML/ARD

EXAMPLE 3: Water excess - inadequate storage

- Inaccurate water balance predictions were used to size infrastructure
- Excess water, compared to predictions, overwhelmed capacity
- Required emergency work to maintain infrastructure and prevent unauthorized discharge

Comparison of Actual versus Predicted

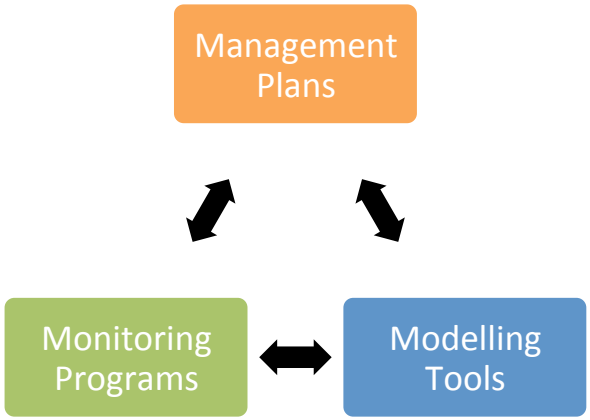
EXAMPLE 4: Emerging water quality issues

- Requirement for mitigation was not predicted during initial modelling
- Actual concentrations trended higher than predicted, effects were unknown
- Lack of comparison throughout mine life led to late stage mitigation planning

Key Message

Comparison of actual versus predicted conditions can provide necessary lead time to develop, consult, permit, and implement solutions

Maintaining Management Tools



OPPORTUNITY

Comprehensive, up-to-date modelling tools are necessary to support ongoing water management and ensure robust decision making

EXAMPLE 1: Water management re-work

- A mine required additional ditches and ponds
- Lack of up-to-date model meant no predictive tool used to inform design
- Constructed infrastructure did not accommodate required flow
- Additional work was required to expand facilities

Maintaining Management Tools

EXAMPLE 2: Mismatched demand and availability

- Lack of a site-wide, comprehensive water balance meant flows were double counted
- Water demands for multiple facilities were met by the same flow in separate models
- Water management plan did not support demands

EXAMPLE 3: Lack of freshet preparedness

- Up-to-date models were not utilized to plan ahead for snow-melt
- Led to multiple emergency water management changes in short time frame
- Insufficient time to plan, consult, permit, and implement solutions

Maintaining Management Tools

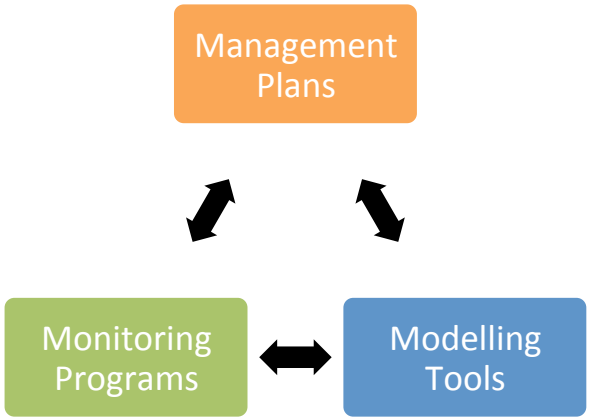
EXAMPLE 4: Lack of incorporation with mine planning

- Mine plan decisions made without consulting predictive tools
- Pit sequencing led to lack of Non-PAG material for blending
- Required redesign of pit, waste rock facility, and closure implications

Key Message

Up-to-date models and monitoring programs can be used to support management decision making throughout mine life

Contingency and Adaptive Planning



OPPORTUNITY

Develop contingency plans and adaptive management approaches early for identified uncertainties and key processes

EXAMPLE 1: Overly optimistic scenarios

- Waste rock assumed to be Non-PAG and used in construction
- Lack of contingency plan if Non-PAG status could not be confirmed
- Monitoring program demonstrated waste rock was PAG
- Led to lack of construction material and appropriate storage

Contingency and Adaptive Planning

EXAMPLE 2: Reliance on "Adaptive Management"

- Management based on "expected case" model results
- Assumed trends to "conservative case" could be managed as needed
- Management plan lacked triggers to implement changes and clear actions take
- Required mitigation not implemented

EXAMPLE 3: Key process shutdown

- Mine relied on lime addition in mill for water quality mitigation
- This process was lost during mill shutdown
- Contingencies to make up this process were not developed

Contingency and Adaptive Planning

EXAMPLE 4: Reagent availability

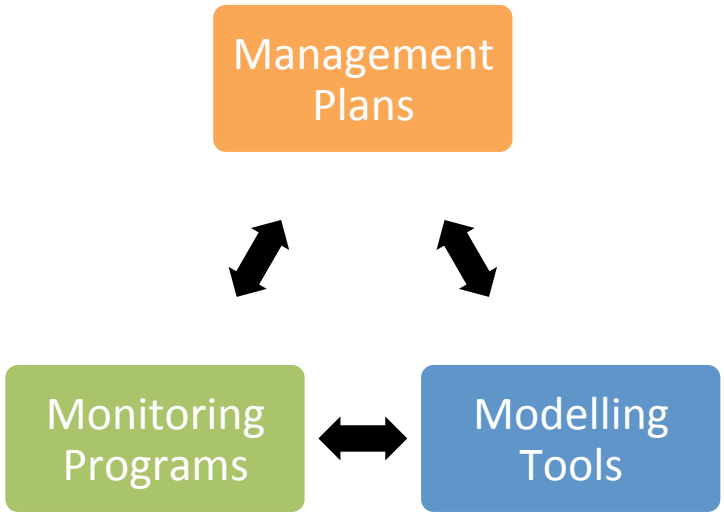
- Mine relied on source and delivery of lime
- Alternative source or delivery method not identified
- Interruptions in lime availability could lead to loss of mitigation process

Key Message

Identify key uncertainties and processes early, develop contingencies and adaptive plans that clearly indicate how to mitigate changing conditions

Summary: Common Challenges

- Verification of assumptions, uncertainties, predictions not complete
- Limited model refinement and updates
- Predictive tools are not comprehensive
- Overly optimistic scenarios and assumptions
- Reliance on “figure it out later” approaches
- Constant state of catch-up due to “unexpected” conditions



Summary: Tools for Improvement

Plan early, plan often

- Consider water/waste management early, collect data early, verify assumptions/decisions

Communicate

- Roles & responsibilities, change management plans, site visits, training

Data management

- Databases, QA/QC, automation for data entry and tracking

Triggers and alerts

- Quantifiable triggers and responses (TARPs), clear protocols in place

Documentation and reporting

- Consistent documentation, report triggers and responses, fulsome annual reporting

Questions?