MAC *Guide on Climate Change Adaptation for the Mining Sector*

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L'association minière du Canada

Acknowledgements

Natural Resources Canada | Ressources naturelles Canada

Environment and Climate Change Canada | Environnement et Changement climatique Canada

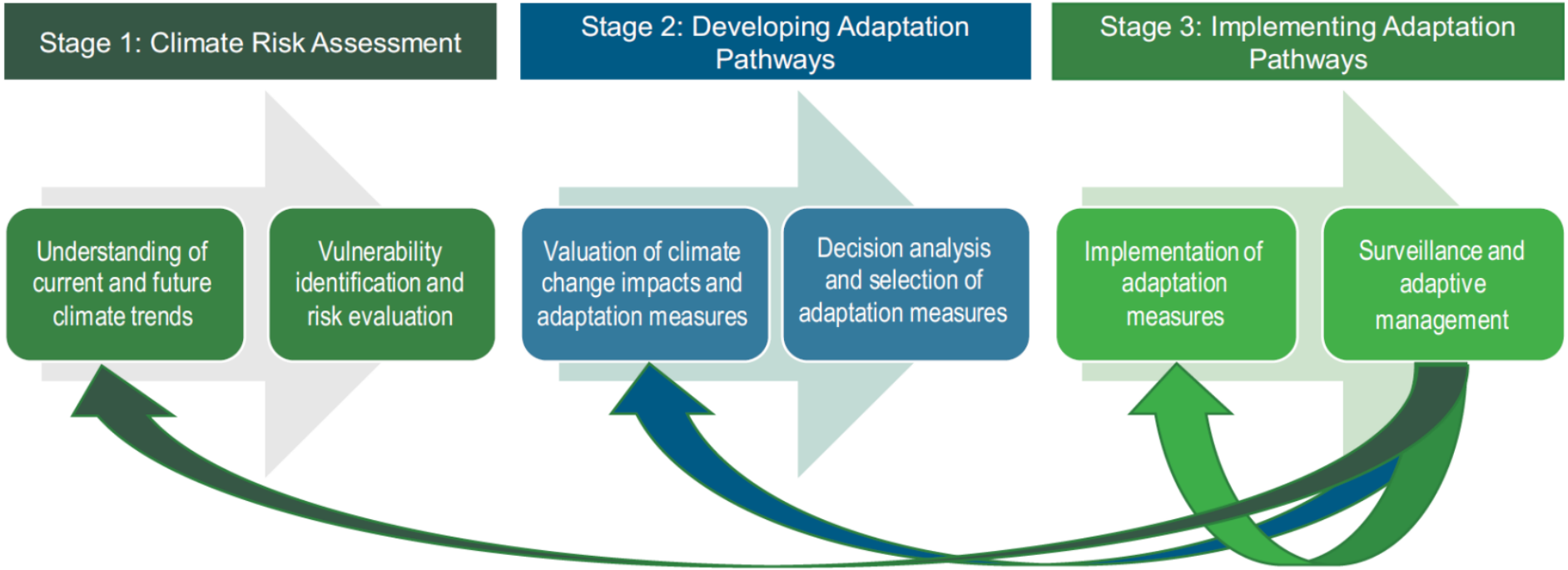
Context

- May 2021: Mining Association of Canada (MAC) introduced:
  - *Climate Change Protocol* to measure corporate and site-level performance related to GHG emissions and mitigation, as well as climate change adaptation
    - Protocol part of MAC's *Towards Sustainable Mining*® (*TSM*®) program, an industry-led program to improve environmental and social performance
  - *Guide to Climate Change Adaptation for the Mining Sector*
  - https://mining.ca/towards-sustainable-mining/

Overview of the Guide

- Guide does not address specific risks and potential adaptation measures
- Describes a stepwise approach to:
  - Increase resilience of mines, reducing potential for impacts and need for more costly adaptation measures later in the life cycle
  - Take advantage of climate change opportunities for improved mine management, such as longer growing seasons that can help enhance revegetation and reclamation activities
- Intent is to provide owners with tools that can be used to consider climate-related risks and opportunities and incorporate climate change adaptation into decision-making

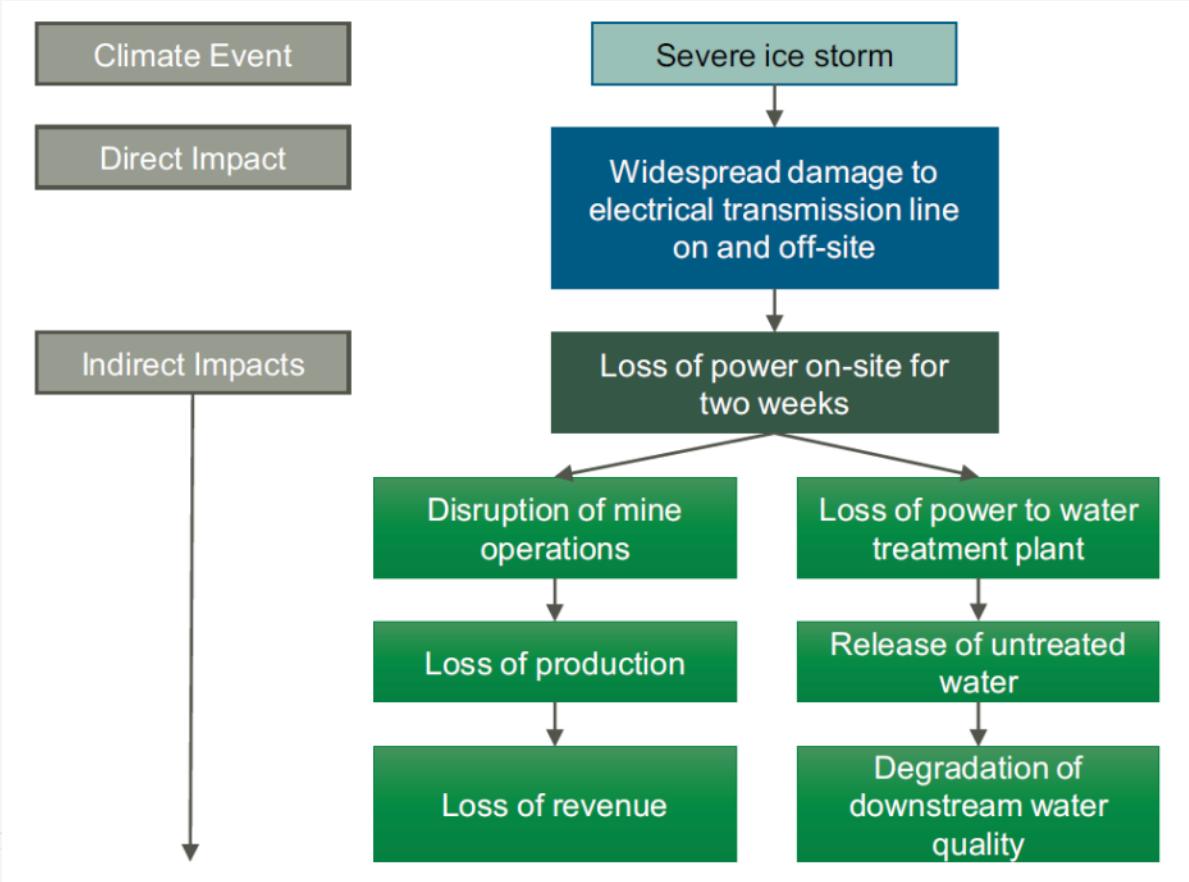
Overview of the Guide



Stage 1: Climate Change Risk Assessment

- Establish baseline climate conditions based on observed climate conditions for the site
- Project future climate conditions using accepted modelling tools and approaches
- Identify vulnerabilities by identifying:
  - Infrastructure components
  - Operations both on and off-site
  - Ecosystem impacts and relationships to reclamation
  - Potential impacts on human health
- Assess both direct and indirect risks associated with climate change for vulnerable infrastructure and operations
- Identify potential opportunities that may arise from changing climate conditions

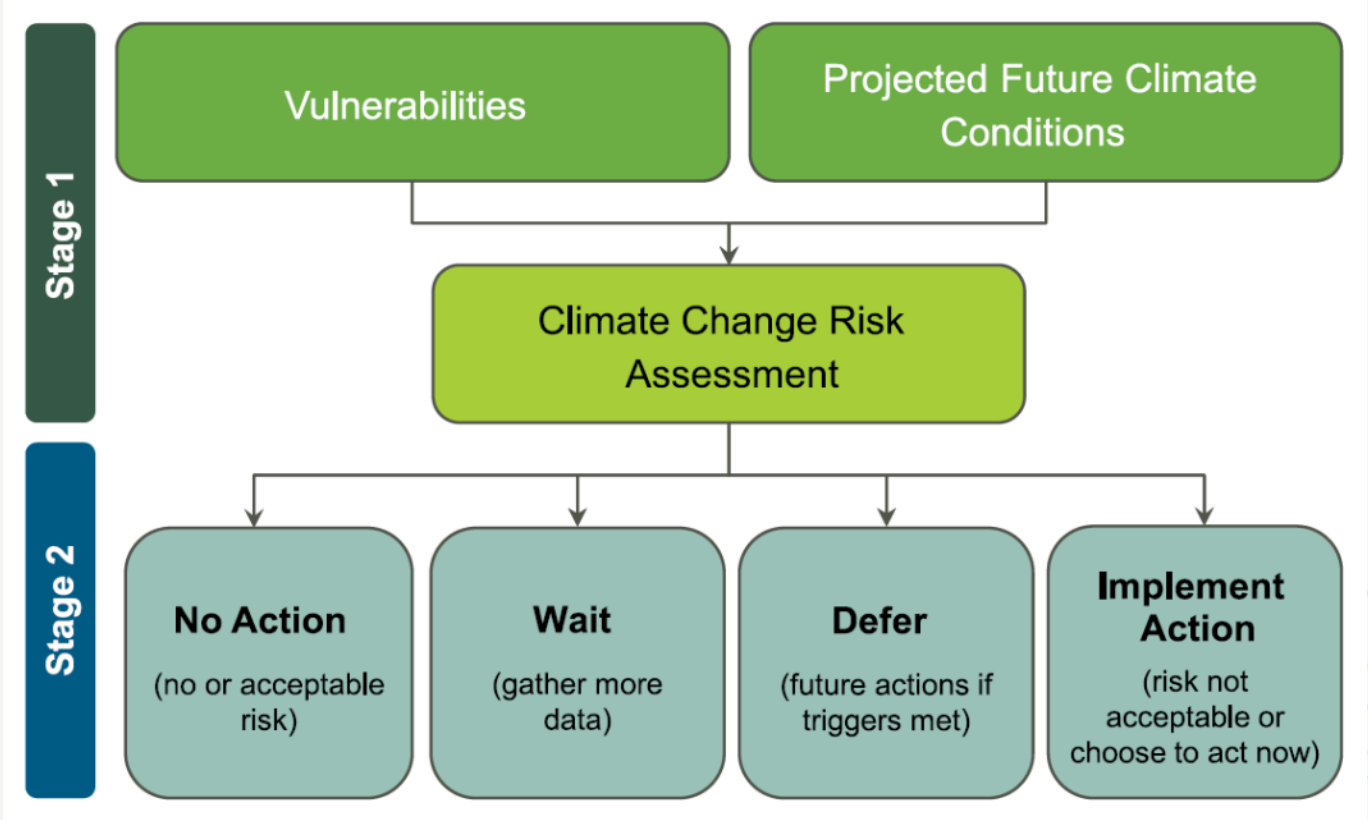
How a climate event may cause both direct and indirect impacts



Stage 2: Develop Adaptation Pathways

- Identify potential adaption measures, such as changes to:
  - Infrastructure
  - Policies or practices
  - Operation, maintenance, or surveillance activities
- Develop potential adaptation pathways that describe different options to address risks or opportunities, including timing (short, medium, or long-term) of implementation
- Apply decision analysis tools to inform selection of preferred adaptation pathway
- Conduct sensitivity analysis
- Select preferred adaptation pathways and identify triggers and thresholds for further actions

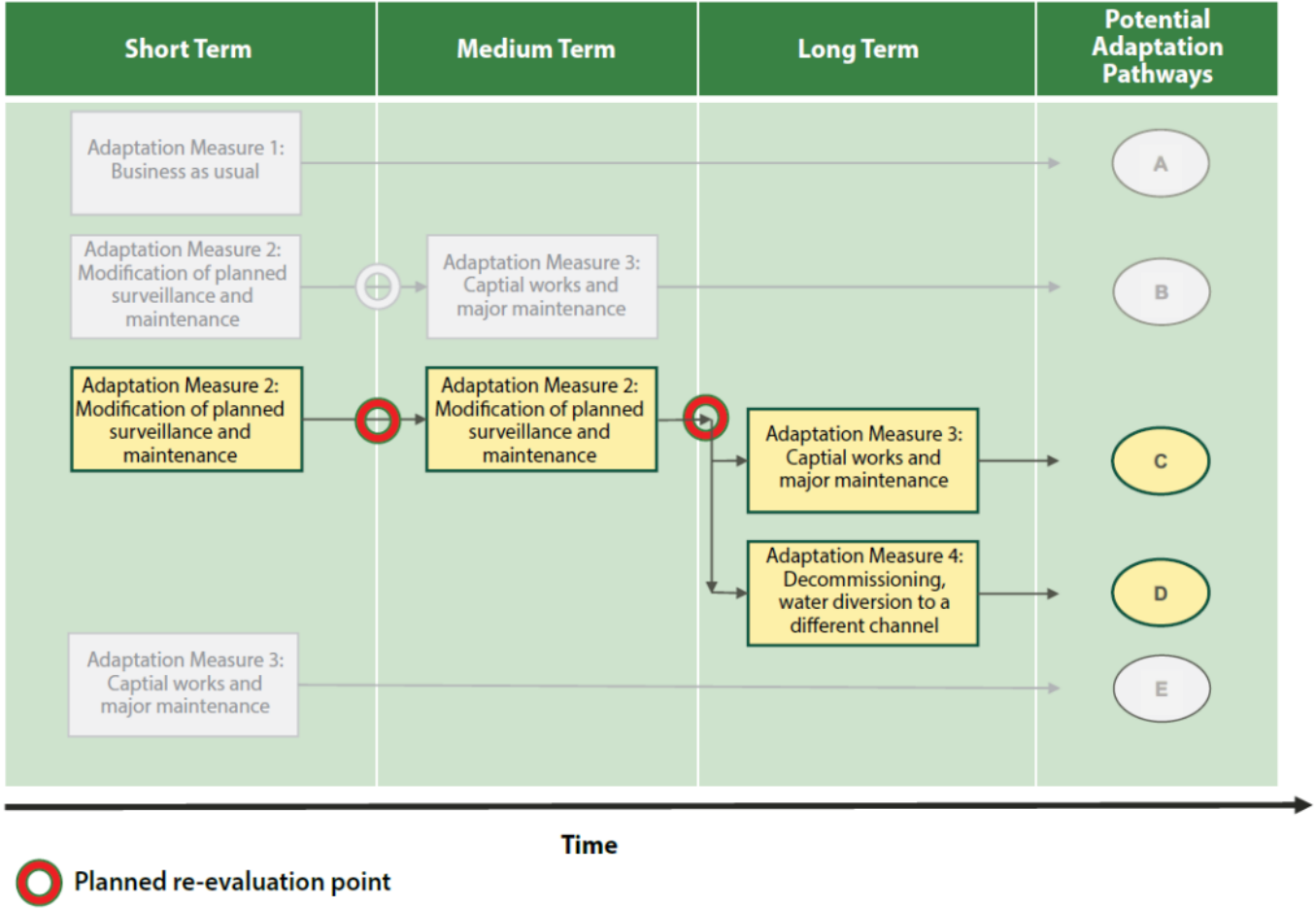
Decision-making: if and when to implement adaptation measures



Adaptation Pathways

- Adaptation pathways approach was first developed in Netherlands in early 2000s
  - Planning approach addressing uncertainty and challenges of climate change decision-making
  - Enables consideration of multiple possible futures and allows analysis of robustness and flexibility of various options across those multiple futures
  - Supports strategic and structured decision-making
  - Allows decision makers to plan for, prioritize and stagger investment in adaptation measures
- Adaptation pathways can be developed to:
  - Schedule implementation of adaptation measures and associated decisions
  - Identify decisions that need to be taken in short-term and those that can be deferred to longer-term
- Can be developed at different scales, from a specific vulnerable infrastructure component, to a mine site, to the corporate level

Example potential adaptation pathways map for a surface water culvert



Stage 3: Implementation of Adaptation Pathways

- Design and implement selected adaptation pathways
- Conduct surveillance to inform future reviews of and potential updates to:
  - Projected future climate conditions
  - Climate change risk assessment
  - Decision analysis of selected adaptation pathway
- Implement adaptative management process to:
  - Address uncertainty associated with climate change projections
  - Proactively respond to unexpected changes in climate conditions beyond those projected
  - Take additional action in response to changing conditions

Implementation of Process

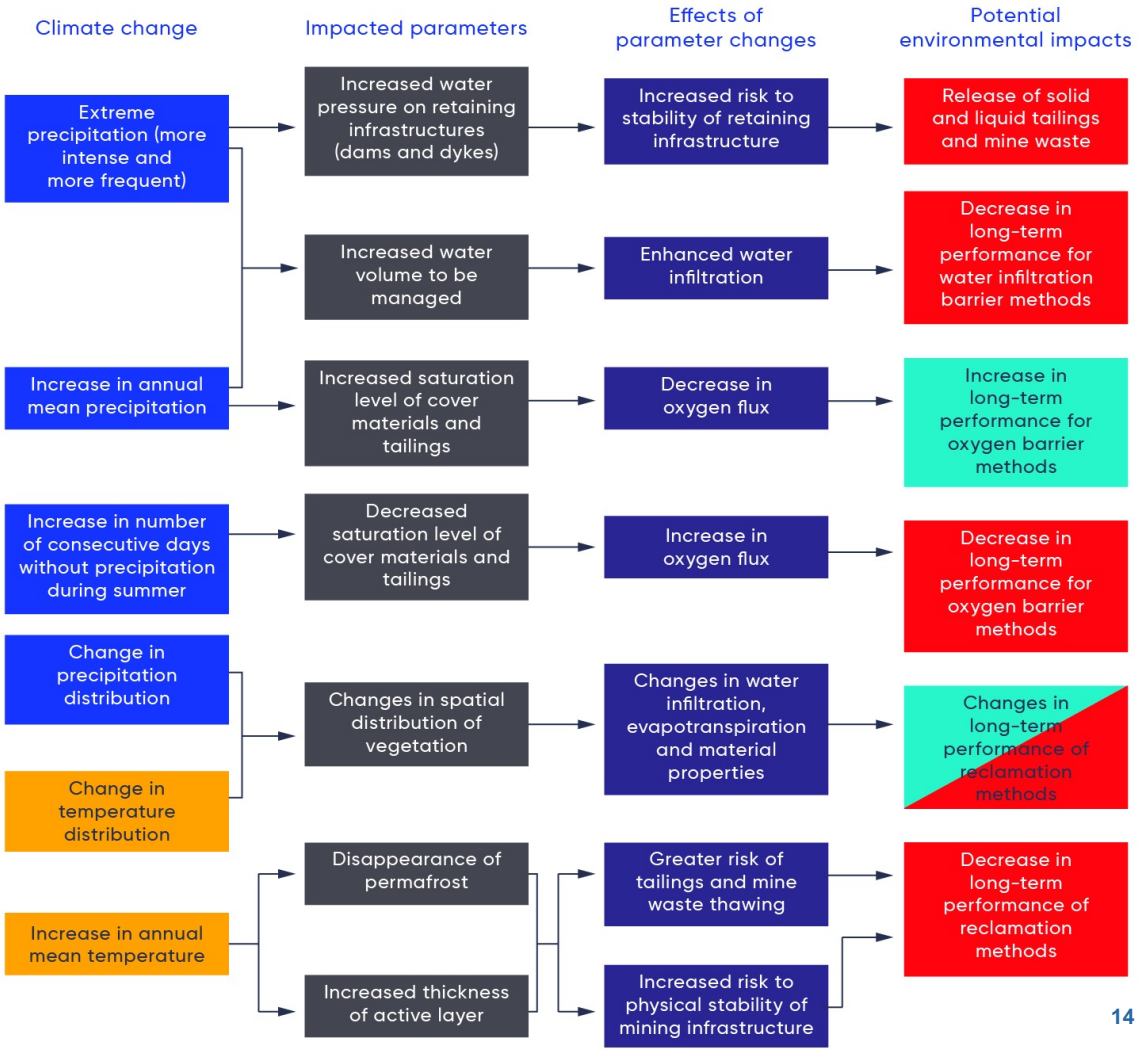
- Process applicable new and existing sites and at the corporate level
- Process intended to be iterative, with vulnerabilities reconsidered, risks re-assessed, and adaptation pathways re-evaluated based on a range of information such as:
  - Results of surveillance activities
  - Changes to infrastructure or operations at the mine site and off-site
  - Changes in climate science
  - Updated projections of future climate conditions
- Process designed to be integrated into existing risk assessment and risk management practices, so that risks associated with climate change can be considered as part of the broader matrix of risks

Implications for ML/ARD

- 2021 Government of Canada report: Canada in a Changing Climate – National Issues

  https://changingclimate.ca/national-issues/

- Section on mining authored by:
  - Bruno Bussière, Université du Québec en Abitibi-Témiscamingue
  - Émilie Bresson, Polytechnique Montréal
- Section focused on potential impacts on chemical and physical stability of tailings containment and reclamation structures



Case Studies

- MAC Guide presents several case studies documenting site-specific examples of incorporating consideration of climate change into risk assessment and management
  - Glencore – Sudbury Integrated Nickel Operations
    - Strong focus on water management
  - Giant Mine Rehabilitation – Climate Change Triggers
    - Focuses on climate change implications for underground storage of arsenic trioxide waste
  - Suncor's Millennium Mine – Adaptive Management in Tailings Management
    - Focuses on climate change implications for a pit lake
  - Agnico Eagle Mines – Using Climate Datasets to Reduce Risks and Inform Cover Design
  - Aitik Mine (Sweden) – Base Case Design and Closure Plan

Case Study – Agnico Eagle Amaruq Mine (Nunavut)

- Amaruq is an open pit gold mine in Nunavut
  - Satellite operation to Meadowbank Mine, about 50 km to south
- Some waste rock is PAG
- Management strategy proposed during environmental assessment was to cover PAG waste rock with non-PAG material of sufficient thickness to promote permafrost formation in PAG
- Vulnerability to increasing temperatures and potential impacts on water quality identified as concern
  - If permafrost does not form in the PAG waste rock, or forms and subsequently degrades due to changing climate, impacts on water quality could occur
- Agnico Eagle assessed minimum cover thickness needed to ensure that PAG waste rock freezes and remains frozen

Case Study – Agnico Eagle Amaruq Mine (Nunavut)

- Climate dataset developed that incorporated information from surveillance program at Meadowbank
- Dataset provided basis for developing future projected monthly mean temperatures for Amaruq
- Projected conditions used as inputs in a thermal modelling study to evaluate freeze-back times and estimate changes in depth of the active layer
- Outputs used to assess cover thickness required, which was incorporated into the final design
- Recognizing uncertainties in climate and modelling, adaptive management plan being implemented:
  - Monitoring weather and ground temperatures on-site, including monitoring freeze back in PAG waste rock and behaviour of active layer under different variables (e.g., sun and wind exposure)
  - Updating thermal modelling based on new data
  - Monitoring data and updated future climate projections will be used to finalize cover design for closure

Case Study – Boliden Aitik Mine (Sweden)

- Aitik Mine is a large open pit copper, gold, silver mine in northern Sweden
- Case study described in a series of presentations at BC/MEND 2018
  - https://bc-mlard.ca/workshop-proceedings/2018-workshop1
- Conducted climate vulnerability and risk assessment for closure, including:
  - Hydrogeochemical assessments of waste rock and tailings facilities
  - Pit lake water balance and water quality modelling study
  - Water quality/aquatic resources effects assessments for receiving waters
- Current climate classified as continental subarctic or boreal climate
  - Winters similar to northern ON, MB, SK, AB, but summers are much cooler

Case Study – Boliden Aitik Mine (Sweden)

- Projected future climate conditions (2100):
  - Warmer and wetter - mean annual temperature +3°C and precipitation +25%
  - Temperature increases greatest in winter
  - Precipitation increases greatest in summer and autumn
- Projected climate changes expected to lead to changes such as:
  - Earlier onset of freshet, later autumn freeze-up, and a longer ice-free season
  - Shifts with time and changes in proportions of rain versus snowfall
  - Increases in winter baseflow conditions and likelihood of mid-winter or shoulder season melt events
  - Progressive increases in receiving environment flow
- These changes expected to impact hydrogeochemical behaviour of mine facilities (i.e., tailings, waste rock, and open pit), as well as downstream receiving streams

Case Study – Boliden Aitik Mine (Sweden)

- Low-permeability till covers to be used to prevent ARD from PAG waste rock
  - Wetter conditions and changes to cover water balance expected to make covers more effective
- Warmer, wetter conditions result in a shorter fill time for open pit (~15 years) resulting in:
  - Decrease subaerial exposure time and loadings from pit walls
  - Affect timing and duration of water management and mitigation, including water treatment
- Failure Mode and Effect Analysis (FMEA) conducted to identify potential failure modes, effects/pathways, and mitigation measures to reduce likelihood and/or consequences for a given failure pathway
  - Risks and opportunities related to future climate change were assessed
  - Approach effective to inform managing climate risks as part of overall risk profile and provided opportunity to optimize and refine design through additional study and iteration

Case Study – Lorraine Mine (Quebec)

- Case study in National Issues Report summarized work of Hotton (2019): Influence des changements climatiques sur la performance de couverture à effets de barrière capillaire: étude du cas Lorraine
- Lorraine was a copper nickel mine that operated from 1964-1968
- Mine produced about 600,000 t of sulphide-bearing tailings that became a source of ARD
- Government of Quebec initiated remediation program in 1998
  - Installed multi-layer cover with capillary barrier effects (CCBE) to prevent further sulphide oxidation by limiting oxygen migration
- Site has been monitored since the cover construction
  - Cover effective with oxygen fluxes lower than targeted in the design
- Described as part of a presentation at BC/MEND 2004: https://bc-mlard.ca/files/presentations/B.13.pdf

Case Study – Lorraine Mine (Quebec)

- Cover performance depends on maintaining a high degree of water saturation (> 85 %) in one of the cover layers, called the moisture-retaining layer (MRL), to limit migration of oxygen
  - Drought could cause temporary desaturation of MRL and increase potential for acid generation
- Potential impacts of climate change on long-term cover performance have been assessed
- Numerical model of current hydrogeological behavior of cover was developed and validated
- Changes in cover performance assessed using model under three climate change scenarios:
  - High increase of temperatures (+ 7°C) and low increase in annual precipitation (+ 0.7%)
  - Median scenario with 5°C temperature increase and 26.1% increase in annual precipitation
  - High increase in both temperature (+9.9°C) and annual precipitation (+51.1%)
- Potential impacts of extreme drought conditions on cover performance also assessed

Case Study – Lorraine Mine (Quebec)

- Results under different scenarios indicate that hydrogeological behavior of cover could be impacted by changing climate conditions
  - Piezometric levels could drop as much as 42cm under extreme drought conditions
- However, performance criteria of maintaining water saturation in the MRL >85% would continue to be met under scenarios and climate conditions tested
- Thus, climate change until 2100 is not predicted to have a significant impact on cover performance
- Author notes that this approach could be applied at other sites with similarly designed covers

Thank you!

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https://mining.ca/towards-sustainable-mining/

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