Update on MEND and NOAMI

21th BC-MEND ML/ARD Workshop

Gilles Tremblay and Charlene Hogan
MEND and NOAMI Secretariat
Natural Resources Canada

Presentation Highlights

- Mine Environment Neutral Drainage (MEND)

- National Orphaned and Abandoned Mines Initiative (NOAMI)

MEND Program Overview

- MEND Mission: To provide leadership and guidance on priority ARD issues in Canada
- Extensive national and international MEND Network
- 1989 – 2014
- ~$21M in 25 yrs
- Current research budget ~ $150K/a
- Guided by multi-stakeholder steering committee
- Focused research work plan
- Technology transfer

MEND Steering Committee 2014

A multi-stakeholder consortium:

Industry:

Ben Chalmers (Chair), MAC

Mike Aziz, Goldcorp Canada

Scott Davidson, New Gold

Joe Fyfe, Glencore

Wade Stogran, Silver Standard Corp.

2 industry seats to be filled

CEN and Aboriginal

Ugo Lapointe, coalition Québec meilleure mine

Maya Stano, Sierra Club – BC

John Werring, David Suzuki Foundation

2 Aboriginal seats to be filled

P/F Governments

Kim Bellefontaine / Andrew Rollo Province of BC

Leslie Cooper, Province of Ontario

Cal Liske, Province of Manitoba

Ken Olsen / Charles Dumaresq, Environment Canada

Mike Nahir, Aboriginal Affairs & Northern Development Canada

Bill Price, Natural Resources Canada

Province of Quebec

Secretariat

Gilles Tremblay (MEND Secretariat), NRCan

Charlene Hogan (MEND Secretariat), NRCan

Report Near Completion

Role of Nitrate in the Remobilization and Attenuation of Selenium in Coal Mine Waste ***(Lorax Environmental and SRK)***

- Evaluated drainage chemistry data for eight mine sites in NE and SE British Columbia
- Assessed the potential links between explosive-derived nitrogen compounds and the remobilization and attenuation of selenium associated with coal mine waste materials

Projects on the Go

Diavik Diamond Mine Waste Rock Study

Phase II: 2010 – 2014 *(UBC, U of Alberta, U of Waterloo)*

Scale-up study in cold climates

To evaluate and prevent the possible generation of ML/AD from waste rock

In-Pit Disposal of Tailings and Waste Rock

ARCADIS-SENES

13 case studies detailed - based on available information

Recent Publications

MEND 2.21.6 Modelling the Critical Interactions between Cover Systems and Vegetation (March 2014)

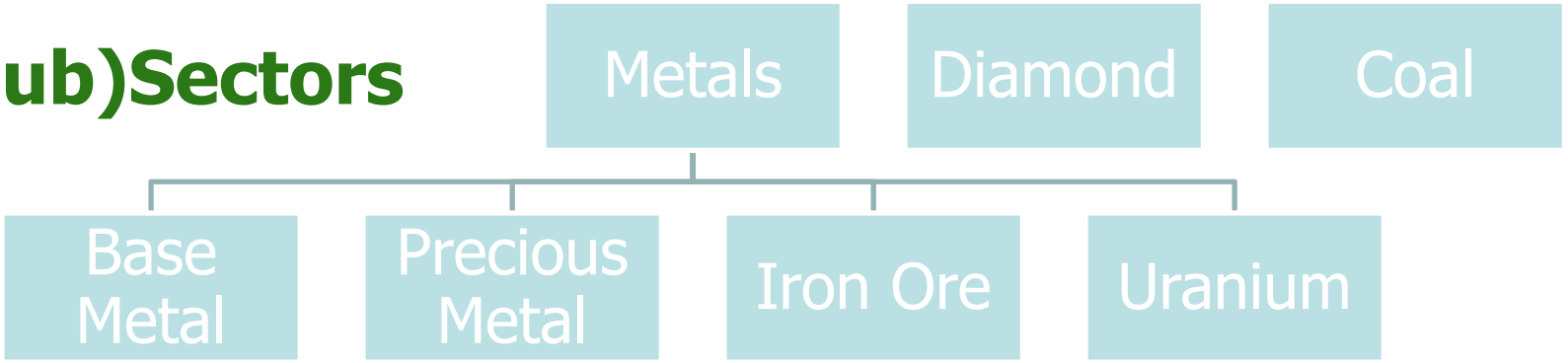
O'Kane Consultants

- A productive vegetation community is critical to ensuring the long term success of a cover system.
- Need to enhance predictive modelling capability to predict the influence of vegetation on performance
- Report determines the preferred approach for numerical simulation of vegetation in cover system design.

MEND 3.50.1 Study to Identify Best Available Techniques Economically Achievable (BATEA) to Manage and Control Effluent from Mines (*Hatch*)

- Review and identify effluent management and control techniques at metal, coal, and diamond mines in Canada
- Provide reference information for proposed changes within the MMER for types of facilities, addition to existing list of parameters, authorized limits of existing parameters
- Study identifies effluent treatment technologies considered BATEA

(Sub)Sectors



Current and Proposed *MMER* Parameters

Current Metals	Proposed Metals	Proposed Diamond	Proposed Coal
pH Arsenic Copper Cyanide Lead Nickel Zinc Radium-226 TSS	Current + Aluminum Iron Selenium Total Ammonia	pH Chloride Phosphorus TSS Total Ammonia	pH Aluminum Arsenic Iron Manganese Selenium TSS Total Ammonia

Methodology

- Information Collection
- Identify Mines and Effluent Control Techniques in Use in Canada by Mining (Sub)sector
- Identify best available technologies (BAT)
- Cost estimating for addition of augmentative BATs to model effluent treatment system
- Comparison of BATEA
- Selection of BATEA

Methodology: Model Water Management and Effluent Treatment Systems

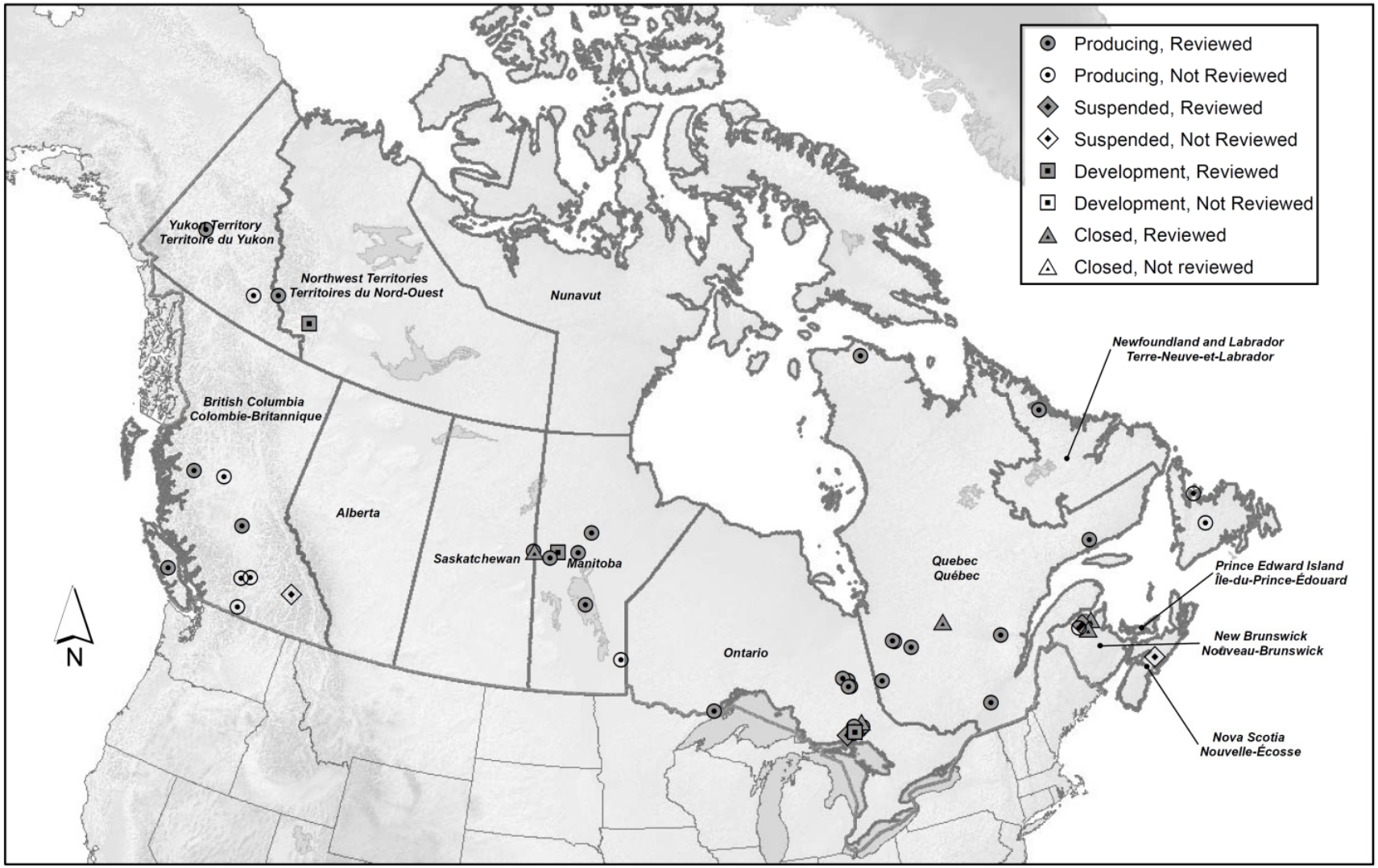
- Base case effluent treatment systems required to identify and cost augmentative technology
- Model systems permit a feasible study scope, schedule, and budget
  - To precisely reflect the conditions unique to each site, would have to perform scoping level study for each operation in Canada
- Model systems reflect the **most common** practices and technologies employed by operations reviewed in each mining (sub)sector

(Sub)Sector Summaries

- Introduction to and overview of (sub)sector
- Water management model
  - Water management around site features (mine(s), ore stockpile(s), waste rock stockpile(s), tailings)
  - Explosives use
- Typical contaminants present in (sub)sector effluent
- Effluent treatment model
  - Technologies employed
- Treated effluent quality and flowrates

Metals: Base Metal Introduction

43 of 57 operations reviewed (33 questionnaires,



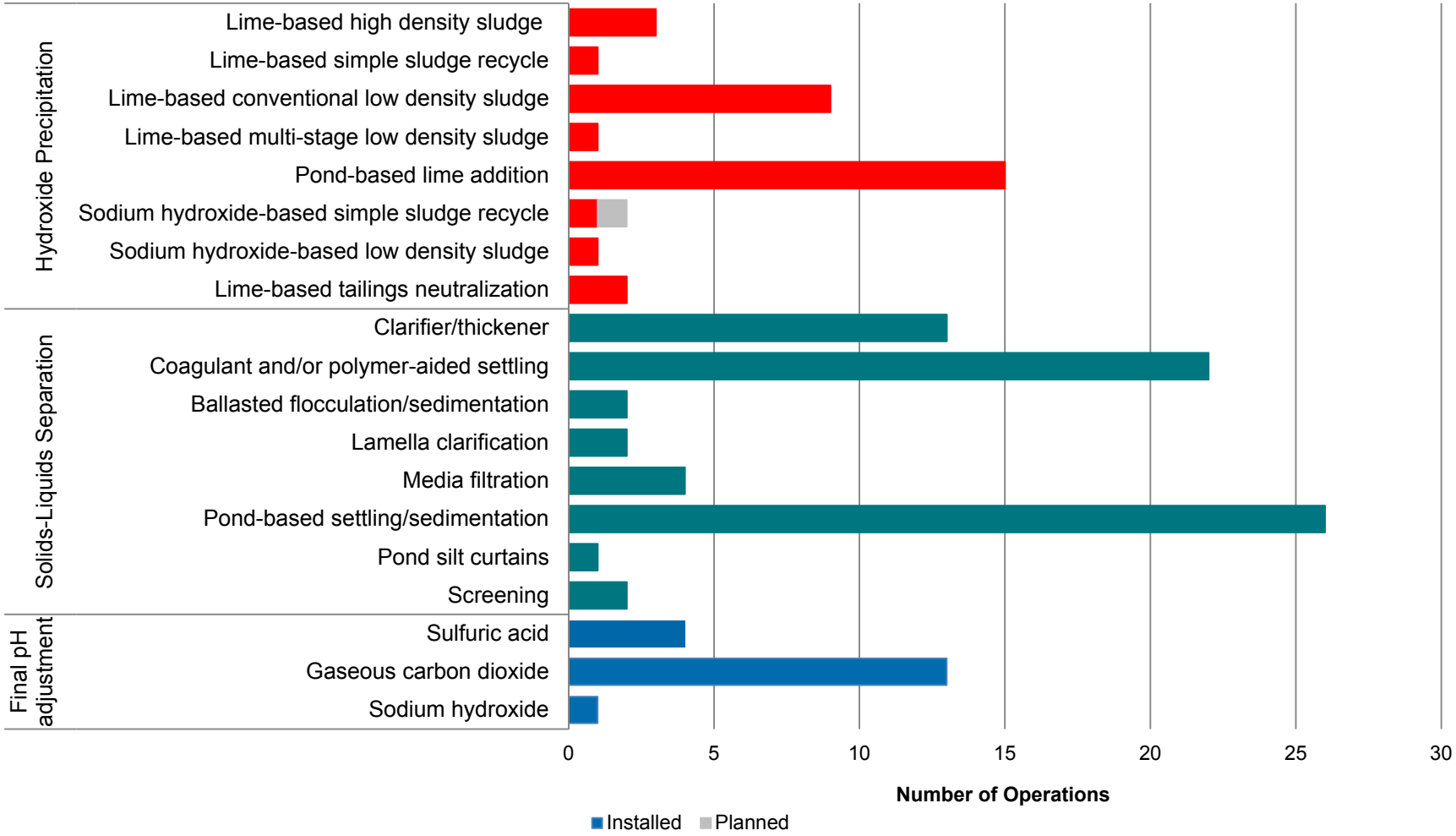
Metals: Base Metal Model System Considerations

- What contaminants are commonly targeted by treatment systems?
  - Copper
  - Nickel
  - pH
  - TSS
  - Zinc

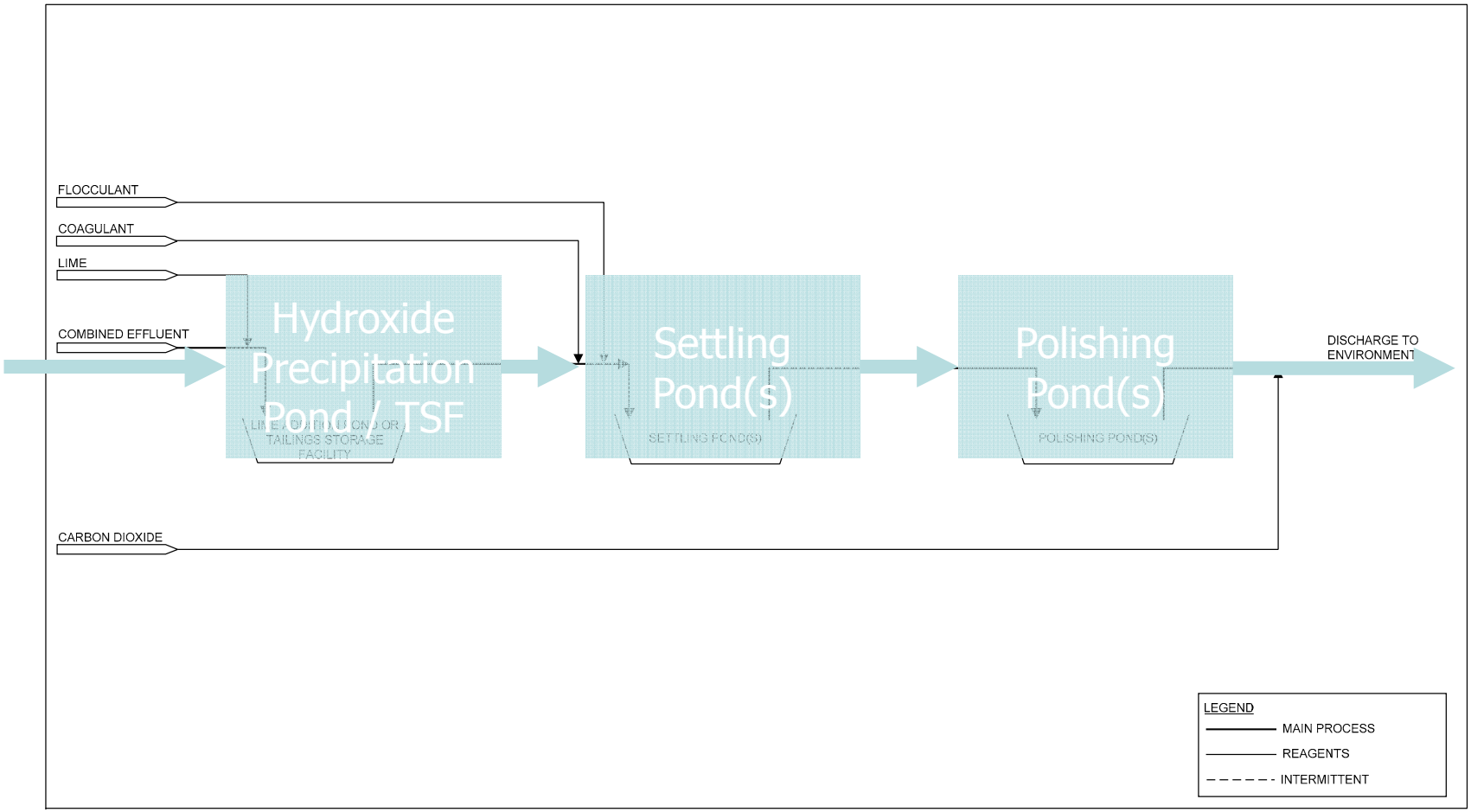
- What treatment technologies are commonly used?
  - Hydroxide Precipitation
  - Solid/liquid separation

Metals: Base Metal Model Effluent Treatment System Considerations

- How are common technologies applied?



Metals: Base Metal Effluent Treatment Model



Metals: Base Metal Model Treatment System Capacity & Quality

- Capacity:

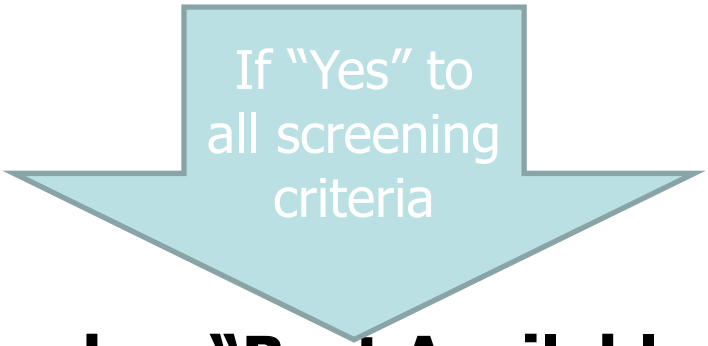
Nominal	Design
870 m^3/h	2,000 m^3/h

- Effluent Quality:

Parameter	Concentration
Arsenic	<0.01 mg/L
Copper	<0.06 mg/L
Lead	<0.015 mg/L
Nickel	<0.36 mg/L
Zinc	<0.30 mg/L
Radium-226	<0.11 Bq/L
Cyanide	<0.05 mg/L
TSS	<10 mg/L
Aluminum	<0.79 mg/L
Iron	<1.05 mg/L
Selenium	<0.04 mg/L
Total Ammonia	<4 mg-N/L

Technology Screening: Criteria

- Can this technique achieve current *MMER* discharge limits?
- Has this technique been demonstrated at full scale on mining effluent?
- Has this technique been demonstrated under representative climate conditions?



Carried forward as "Best Available Technology" (BAT) to be considered in BATEA Selection

Screening:
Preliminary List of Effluent Treatment Techniques

- Neutralization & Hydroxide Precipitation
- Sulfide Precipitation
- ~~Carbonate Precipitation~~
- Ferric Iron/Aluminum Salt Co-Precipitation
- Barium Chloride Co-Precipitation
- ~~Ferrous Hydroxide Reduction & Co-Precipitation~~
- Metal Oxidation
- Reacidification
- Solid/Liquid Separation
- Enhanced Coagulation & Settling
- Cyanide Destruction
  - ~~Alkaline Chlorination~~
  - INCO SO_2/Air ~~and CombinOx®~~
  - Hydrogen Peroxide
  - ~~Ferrous Iron Complexation~~
  - ~~Hemlo Gold Process~~
  - ~~Caro's Acid~~
  - ~~Ozonation~~
- Air Stripping
- Ion Exchange
  - Selective Ion Exchange
  - Clinoptilolite Zeolite Ion Exchange
- Adsorption
  - ~~Activated Carbon~~
  - ~~Activated Alumina & Functionalized Alumina~~
  - ~~Peat-based Media~~
  - Zero Valent Iron
  - ~~Cameco Corporation Technology~~
- Biological Oxidation/Reduction
  - Aerobic Biological Oxidation
  - ~~Subsurface Nitrification/Denitrification~~
  - Active Anoxic/Anaerobic Biological Reduction
- ~~Electrobiochemical Reduction~~
- ~~Electrochemical Oxidation & Reduction~~
- Membrane Size/Charge Exclusion
  - Reverse Osmosis
  - Nanofiltration
- ~~Evaporation~~
- ~~Evaporation/Crystallization~~
- Passive Treatment
  - Natural Degradation
  - Aeration Cascades
  - ~~Anoxic Limestone Drains & Open/Oxic Limestone Drains~~
  - ~~Aerobic/Anaerobic Wetlands~~
  - ~~Passive/Semi-Passive Anoxic/Anaerobic Biological Reduction~~
  - ~~RAPS/SAPS~~
  - ~~Permeable Reactive Barriers~~
  - ~~Phytoremediation~~

See Table 8.1 in report for details

Technical Characterization

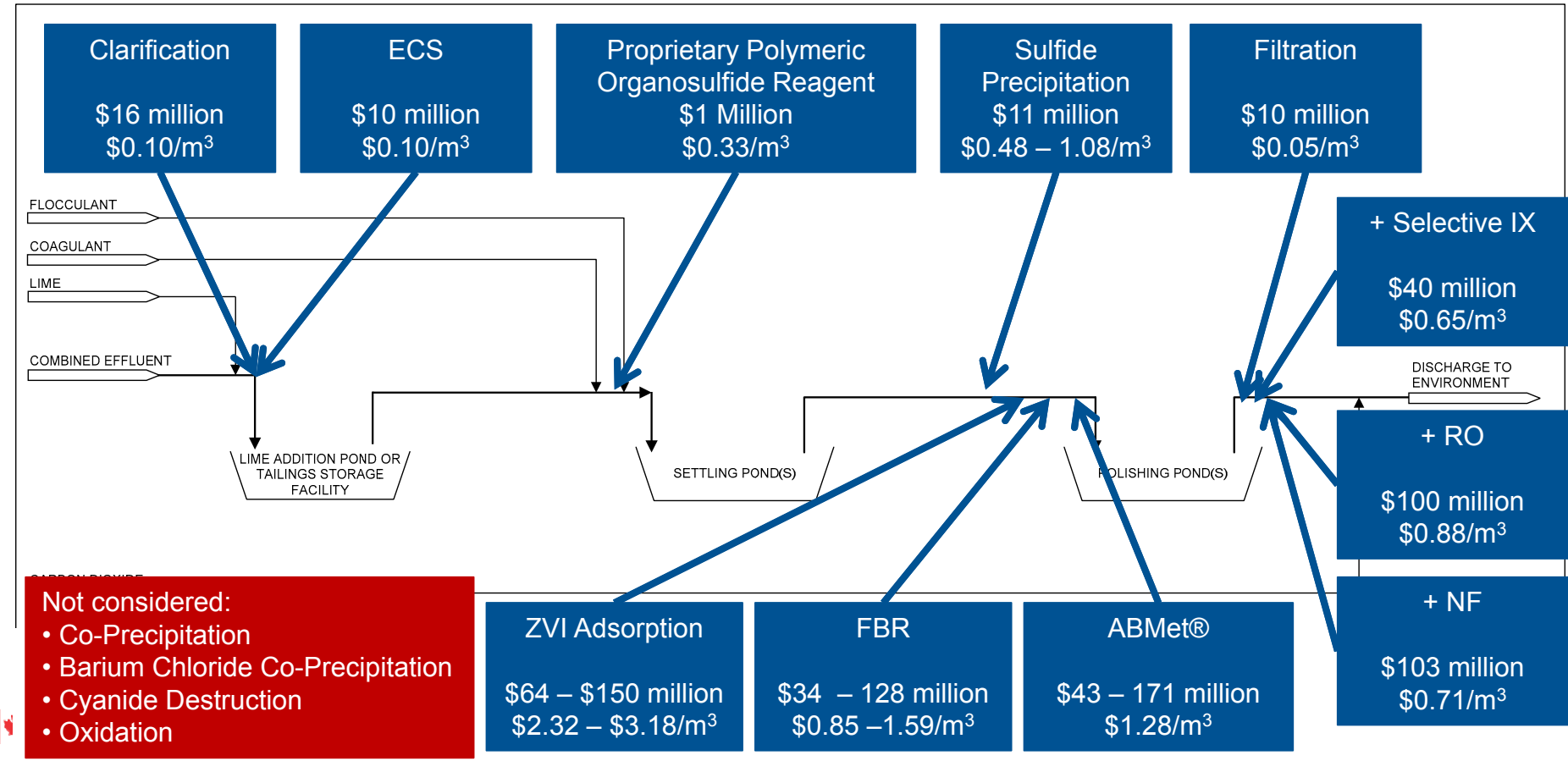
- Report Section 8, for each BAT:
  - Description of major chemical, physical, and/or biological mechanisms
  - Removal efficiency or achievable concentration
  - High level discussion of factors that affect performance, synergies, and challenges
  - Residuals
  - Prevalence in Canadian mining industry
  - Major equipment and simplified process flow diagram
  - Capital cost considerations and cost curves
  - Sustaining capital cost considerations, if any
  - Operating cost considerations

Technology Cost Estimating and BATEA Selection

- Model effluent treatment system "base case" capital and operating cost range from questionnaire responses
- Retrofit/upgrade "base case" cost range from questionnaire responses
- Only BAT which augment performance model system estimated or discussed
- Order of magnitude incremental cost estimates based on vendor questionnaires, in-house information, CAPEX reported from operations questionnaires, relative OPEX proportions from operations questionnaires, and literature
- BATEA selection based on professional judgement of trade-off between achievable performance augmentation and cost

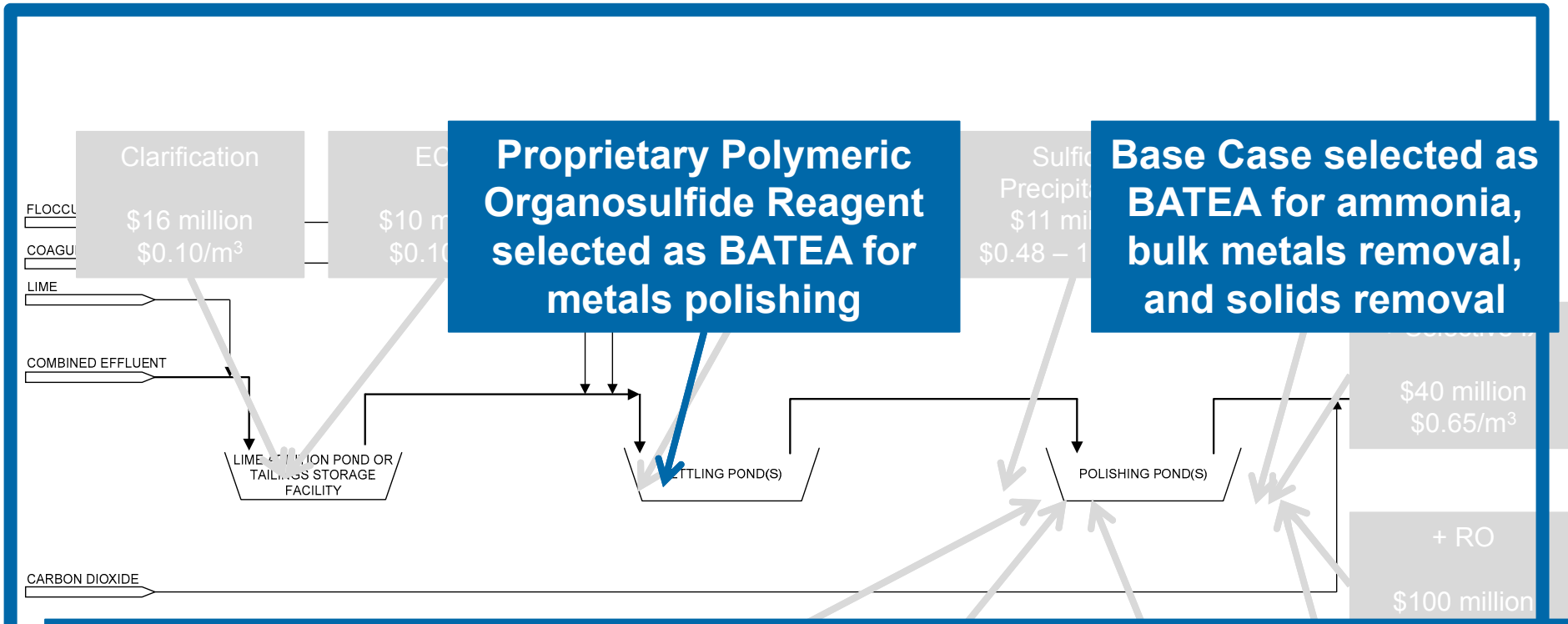
Technology Cost Estimating Metals: Base Metal

Nominal Flowrate (m^3/h)	Design Flowrate (m^3/h)	Model CAPEX Range ($)	Model OPEX Range ($/m^3$)	Range of Previous Upgrades/Retrofits ($)
870	2,000	2.6 – 22 million	0.02 – 0.34	<5 million



Not considered:
- Co-Precipitation
- Barium Chloride Co-Precipitation
- Cyanide Destruction
- Oxidation

Technology Cost Estimating
Metals: Base Metal



Suggestions:

- Optimize performance of existing systems
- Equipment-based solid/liquid separation for greenfield operations
- Explosives Selection and Best Management Practices to address ammonia issues
- Active anoxic/anaerobic biological reduction is least cost prohibitive for Se removal

BATEA Selection Limitations

- Removal efficiencies and/or achievable effluent concentrations are typical but may not be achievable at every operation
- BATEA selection bounded by strict criteria for BAT and in the (sub)sector model non-greenfield context
- BATEA is not universally applicable due to site-specific technical and economic constraints
- Proprietary polymeric organosulfide reagents should only be considered BATEA for operations that are capable of and dedicated to careful control of operating regimes to prevent effluent toxicity as well as careful control of residuals storage conditions to prevent long term instability and the potential generation of acid through sulfide oxidation and metals remobilization.

MEND Website

- **Advanced Search Functionality; completed November 2013**
- **Enhance accessibility of MEND reports to civil society via plain language summary of reports and increased search capacity**
- **Next Step: Translate into French - 2015**
- **Website: www.mend-nedem.org**

Technology Transfer Activities

Guidance Documents

Workshops and Conferences(>36)

- Annual BC-MEND ML/ARD Workshops
- Regional workshops
- MEND Technology Transfer Workshops to Community Groups/Academia

MEND Reports and CDs

- > 200 reports on Website

Periodic Announcements to MEND/NOAMI e-Network

GARD Guide

www.mend-nedem.org

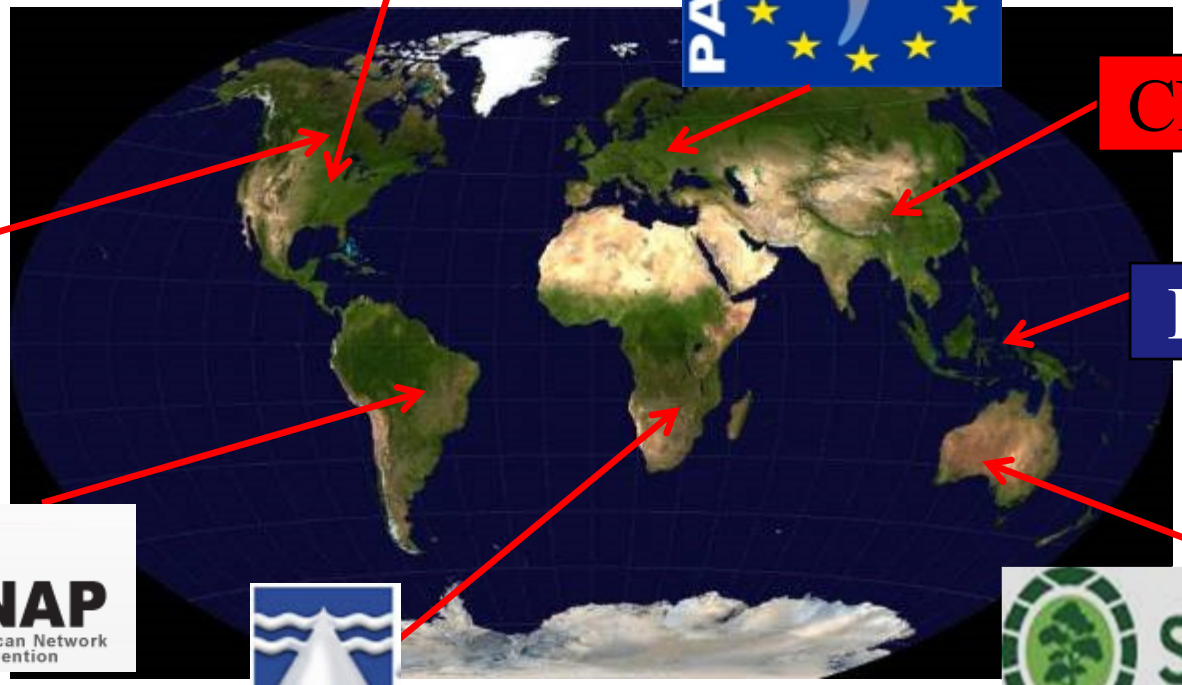
The Global Alliance

INAP

www.inap.com.au

Acid Drainage Technology Initiative

PADRE



CNAMD

INAD

MEND

SANAP
South American Network for Acid Prevention

WATER RESEARCH COMMISSION

SMI
Knowledge Transfer

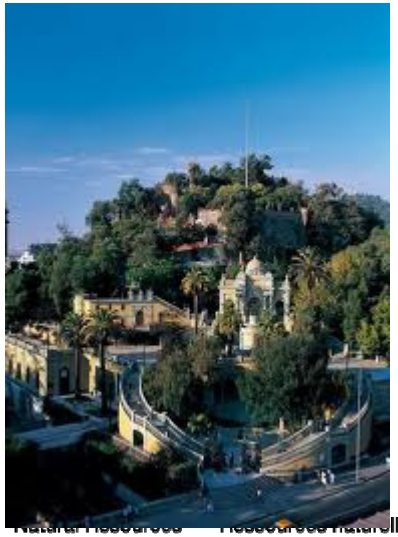
Natural Resources Canada | Ressources naturelles Canada

Canada

SANAP
South American Network for Acid Prevention

10th ICARD

ICARD 2015 in Santiago, Chile – April 20-25



SANAP
South American Network for Acid Prevention

10th ICARD

Conference highlights

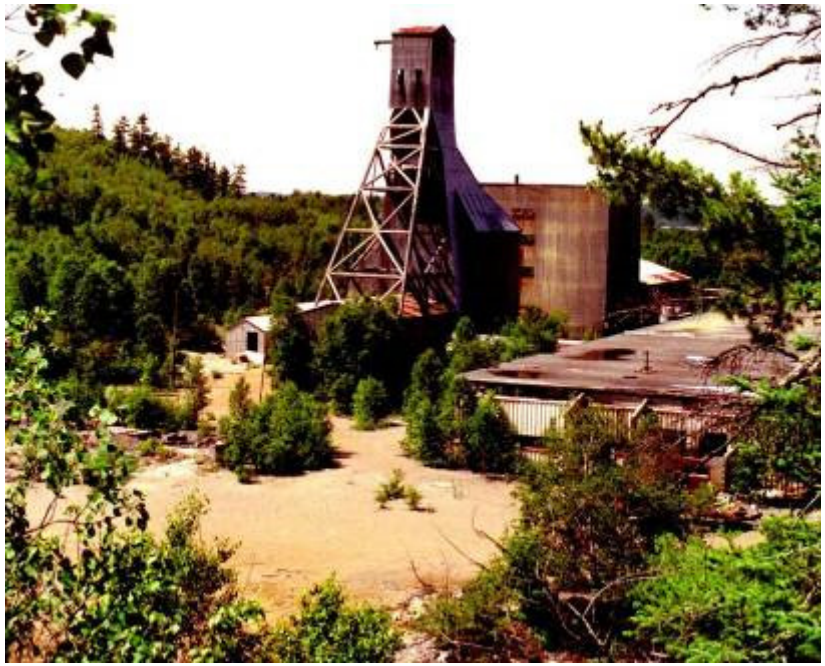
- Date: ***21-24 April 2015***
- ICARD will host IMWA annual conference
- Venue: Grand Hyatt Santiago, Chile
  http://www.santiago.grand.hyatt.com

Organisers:

ICARD: ***Gecamin***, Chile, in collaboration with ***South American Network for Acid Prevention*** (SANAP)
IMWA: Gecamin, Chile, in collaboration with **IMWA**

National Orphaned / Abandoned Mines Initiative - (NOAMI)

NOAMI
National Orphaned/Abandoned Mines Initiative
INMOA
Initiative nationale pour les mines orphelines ou abandonnées



North Coldstream Mine - Burchell Lake, ON

- Multistakeholder partnership
- Projects carried out on :
  - Information Gathering (Inventory)
  - Community Involvement
  - Legislative Barriers to Collaboration
  - Funding Approaches
  - Jurisdictional Legislative Review
  - Mine Closure/Return of Mining Lands

NOAMI Highlights

Guidelines and Toolkits:

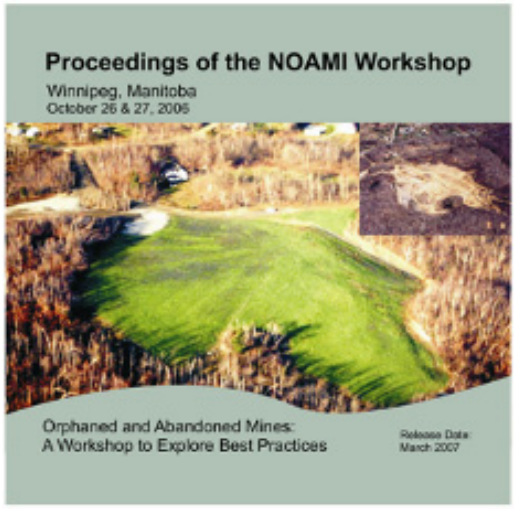
- Pamphlet on Guiding Principles in Community Involvement
- A Toolkit of Funding Options for Abandoned Mine Rehabilitation
- Guidance Document: Mine Closure and Management of Long-Term Liabilities

Published NOAMI Reports

- Reviews of national and international inventories, funding models, and barriers to collaboration
- Community case studies
- Jurisdictional legislative review relating to OAMs

Information Sharing

- Six workshops
- NOAMI website www.abandoned-mines.org
- Newsletters
- Publications at conferences



Activities in 2014

Draft Criteria for the Effective Long-term Stewardship of Closed Mine Sites (Kingsmere Resource Services)

Prepare a draft criterion to be used as a tool by a range of "Users" to assess the condition of orphaned/abandoned mine sites or closed mine sites in Canada

Evaluate for:

- Chemical/physical stability
- Public health and safety risk
- Ecological risks
- Risks to ecosystem services.

Provide the foundation of information to plan for the effective long-term stewardship of such sites

Workshop on Remediation of Orphaned and Abandoned Mine Sites

First Nations Pilot Study Workshop

NOAMI co-sponsor of two training workshops in Quebec in 2014/2015

Organized: First Nations of Quebec and Labrador Sustainable Development Institute.

To ensure environmental managers for First Nation communities are:

- Familiar with regulations and tools for rehabilitation in Quebec
- Identify best practices in the management of abandoned mines.

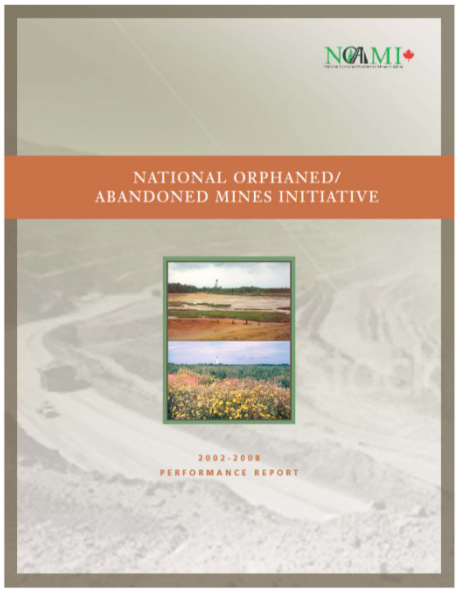
Resource material to include NOAMI workshops and the 2008 Community Compendium Toolkit.

Pilot study to apply NOAMI findings at the First Nations community level and for NOAMI to share the results of these workshops with other communities across Canada.

Performance Report

Performance Report 2002-2008

- Summarized the work of NOAMI,
- Showcased the activities of Cdn. jurisdictions in the remediation of orphaned/abandoned mine sites.
- Widely distributed nationally and internationally



Performance Report 2009-2014 (In progress)

- Brochure - Tighter format
- Highlight NOAMI's major achievements, and the efforts of Canadian jurisdictions to address the potential legacy issues associated with orphaned and abandoned mines across the country.

Web-Based National Inventory of Orphaned/Abandoned Mines

- Linked to jurisdictional databases through portal
- Feature-based classification
  - 4 classes of risk level
- Classification for all jurisdictions complete
- Publically accessible, bilingual inventory
- At present
  - migration of site
  - finalization of site enhancements
  - jurisdictional approval

Next step –Launch and long term maintenance

Mine Environment Neutral Drainage (MEND)
www.mend-nedem.org

National Orphaned/ Abandoned Mines Initiative (NOAMI)
www.abandoned-mines.org

NOAMI
National Orphaned/Abandoned Mines Initiative
INMOA
Initiative nationale pour les mines orphelines ou abandonnées


Thank You
Merci