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Lessons Learned in the Reporting of Geochemical Characterization Studies in Canada

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Lauchie MacLean[2] (Impact Assessment Agency of Canada)

1- presenting author
2- currently Health Canada

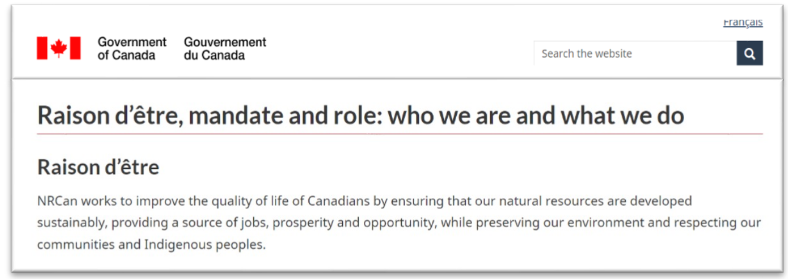
2023 BC MEND ML/ARD Annual Workshop

Canada

CanmetMINING’s Review of Geochemical Studies

Objective and effective reviews:

- Driven by NRCan mandate
- Following applicable guidance
- Consistent across federal, territorial, & provincial jurisdictions
- Tailored to each project


Français

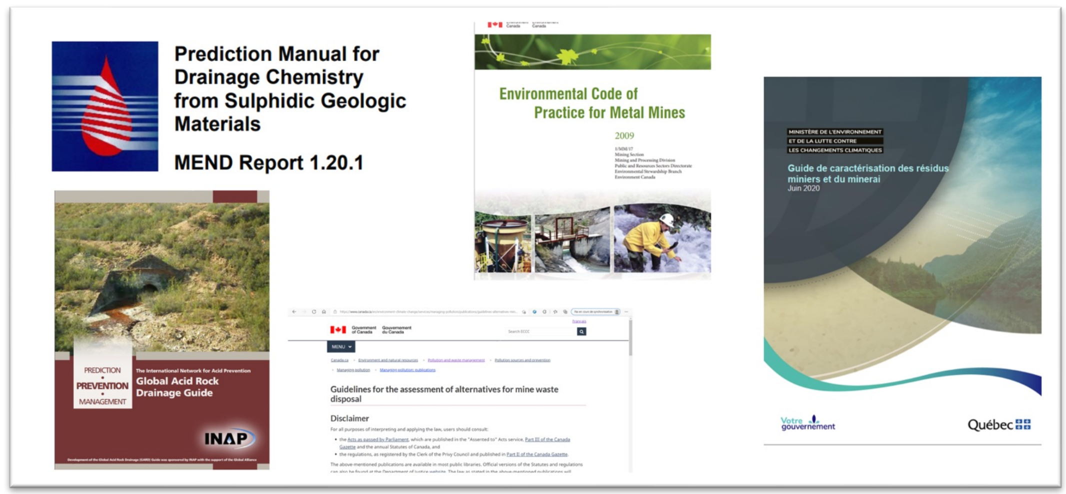
Government of Canada Gouvernement du Canada

Search the website

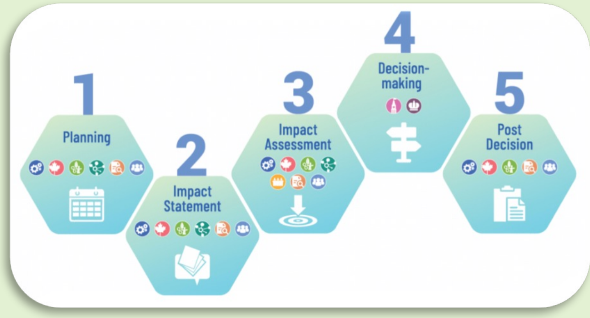
Raison d’être, mandate and role: who we are and what we do

Raison d’être

NRCan works to improve the quality of life of Canadians by ensuring that our natural resources are developed sustainably, providing a source of jobs, prosperity and opportunity, while preserving our environment and respecting our communities and Indigenous peoples.



Geochemistry under Impact Assessment Act (2019)



1) Upfront emphasis on planning

2) Streamline review of Impact Statement

Tailored Impact Statement Guidelines Template (generic version)

For designated projects subject to the *Impact Assessment Act*

Version 2.2 - Revised December 2022

Tailored Impact Statement Guidelines
Document outlining the information and studies required in the Proponent's Impact Statement.

!! New Section !!

(TISG-IAA 2019)

Environmental Geochemistry Database

Task

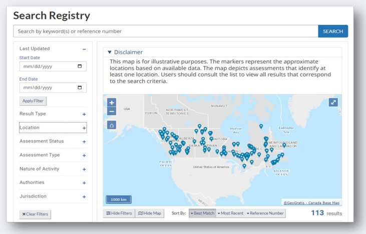
Objectives:

What can we learn from previous assessments to inform the guidelines?

Tailored Impact Statement Guidelines
Document outlining the information and studies required in the Proponent's Impact Statement.

Approach

Identification of Accessible Data



Extract Data Using Python

PDF

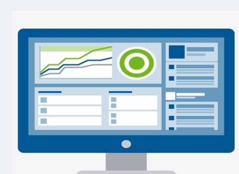
X

Standardization & Amalgamation

python™

Relational Database (e.g., SQL)

Interface / Data Visualization



Outcome

Insights:

- Sample origin
- Analytical methods
- Data presentation
- Integrity and reusability

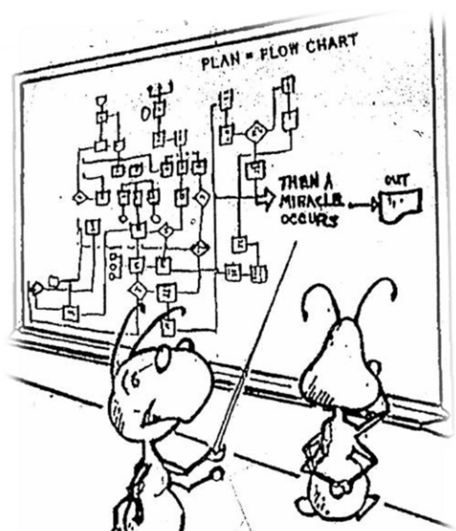
12thICARD 18-24 September 2022 VIRTUAL | Australia
International Conference on Acid Rock Drainage 2022 VIRTUAL

DEVELOPING A PROOF-OF-CONCEPT ENVIRONMENTAL GEOCHEMISTRY DATABASE IN CANADA: LESSONS ON METADATA STANDARDS

J. Cole, A. Cleaver, and J. Deriaz
Natural Resources Canada, Ottawa, Canada; Jennifer.Cole@NRCan-RNCan.gc.ca

Why Should You Care? / Why Is This Important?

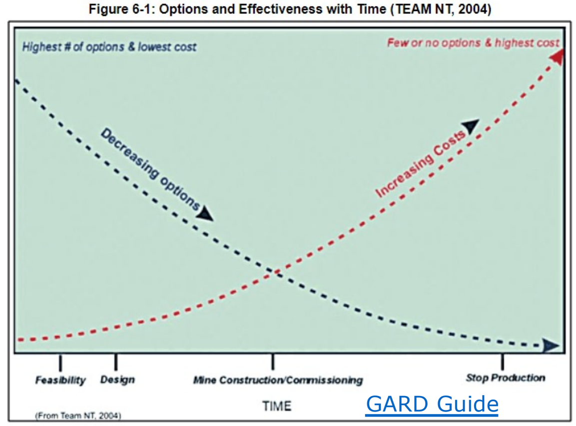
1) Data integrity and reuse



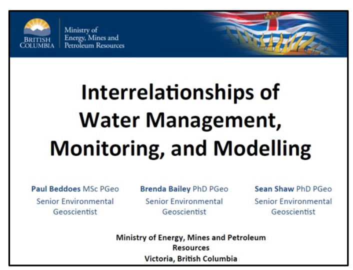
[MEND 1.20.1]

2) Project planning and approvals

Figure 6-1: Options and Effectiveness with Time (TEAM NT, 2004)



[GARD Guide]


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

[Beddoes, Bailey, and Shaw, 2018. BC MEND Workshop]

3) Social licence to operate

[Canadian Minerals and Metals Plan (CMMP)]:

TSM

e3 PLUS
A Framework for Responsible Exploration

Presentation Slide Format and References

Guideline Excerpts:

Tailored Impact Statement Guidelines Template (generic version)

For designated projects subject to the *Impact Assessment Act*

Version 2.2 - Revised December 2022

This is a draft document. Contents may change as a result of ongoing engagement and feedback received. Please check back regularly for updates.

Generic Tailored Impact Statement Guidelines (IAA 2019)

MEND Excerpts:

Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials

MEND Report 1.20.1

MEND 1.20.1

Observations:

- X
- X
- X

Considerations:

- X
- X
- X

Implication: XX

Overall Program Requirement

8.3. Geochemistry of mined or excavated materials

8.3.1. Baseline conditions

The Impact Statement must:

- provide a geochemical characterization of expected mined or excavated materials (and historical waste, if applicable), such as waste rock, ore (including off-site), low grade ore, pit wall materials, underground development ramps, process waste (i.e. tailings, heap leach, treatment sludge, coarse coal rejects, processed kimberlite) overburden and potential construction material (i.e. mine rock, quarries, unconsolidated material);

The assessment of potential environmental impacts requires prediction of the drainage chemistry for all geologic materials that will be or have been excavated, exposed, processed, deposited or otherwise disturbed.

Observations:

- Focus on mine rock and/or process solids only
- Unavailable materials not identified
- Subsequent phases of study not described

Considerations:

- Assess all available materials
- Identify unavailable materials
- Plan to incorporate materials as project advances

Implication: missing data could delay approvals and result in conservative conditions (higher cost)

Sampling Program

- describe the representativeness of samples collected for acid rock drainage and metal(loid) leaching assessment. Present cross-sections or block model images at an appropriate scale that include mine rock samples, geology, mineralized zones, the approximate location of all open pit and underground mine development, borehole traces and identification numbers, and a scale and legend;
- describe the representativeness of tailings solids and process water. Provide a schematic process flow chart including the location that each tested sample represents if various processing streams are tested;

Operational characterization of wastes, drainages and mine walls may include thousands of analyses and hundreds of thousands of dollars of work. All this work and money may be wasted if details such as sample locations, sampling methods, analysis procedures and analytical results are lost.

Observations:

- Sample representativeness not demonstrated
- Sample origin not clearly documented
- Inconsistent or undefined nomenclature

Considerations:

- Spatial, geological, and volumetric documentation of sample representativeness
- Detailed documentation of sample metadata
- Clearly defined site-specific nomenclature

Implication: missing data could delay approvals and result in conservative conditions (higher cost)

Examples: Sample Metadata Documentation

Example 1: No sample identification

Appendix 3-1: Sample Locations and Drill Core Details

Hole ID	From (m)	To (m)	Lithology	Grade

Example 2: Lab cert only

[redacted] Sample No	Sample ID

Example 3: No borehole information

Sample ID	Zone	Logged Lithology	Geological Unit

Examples of more robust (but still limited) sample metadata:

Sample Number	Year (analysis)	from (m)	to (m)	Rock Type	Deposit	Location

Testing Phase	DDH No.	Sample /Tag No.	From	To	Interval	Zone	Rock Unit Code	Rock Unit Description
			m	m	m			

Sample ID	Drillhole ID	From (m)	To (m)	Age	Consultant	Waste Classification	Lithology Name

Table A2-2: Elemental Content Analytical Results - Waste Rock Results

Sample ID	Hole ID	From (m)	To (m)	Lithology	Oxidation Facies

Potential sample metadata __to consider__ for thorough documentation of sample origin:

Sample ID	Material Type	Material Source	Lithology Code / Name	Lithology Reference	Zone / Deposit / Mine Component	Temporal Information	UTM	Borehole Information	Sample Type	Sample Mass (kg)	Description
Unique, consistent, considers historical programs; laboratory ID if applicable	*e.g., tailings, ore, low grade ore, waste rock, overburden, etc.*	*e.g., exploration drill core, outcrop, test pit, bench or pilot test*	*Per log or block model, plus other attributes such as alteration*	*e.g., borehole logs, block model, sample collector, etc.*	*e.g., zone, pit, deposit, waste rock facility, tailings facility, etc.*	*e.g., drilling date, sampling date, study / sampling program, seasonality*	*Zone, NAD, Northing, Easting*	*e.g., borehole ID, from-to, collar location, azimuth, dip, etc.*	*e.g., entire length, composite, grab*	*field (fish weighing scale) or lab*	*Visual characteristics (e.g., colour, apparent grain size, visible mineralogy, etc.)*

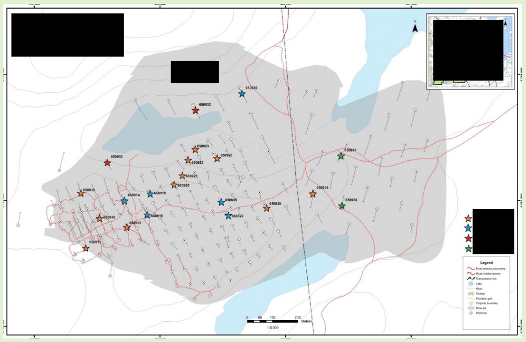
Implication: specific sample results and trends cannot be validated; data reuse is limited

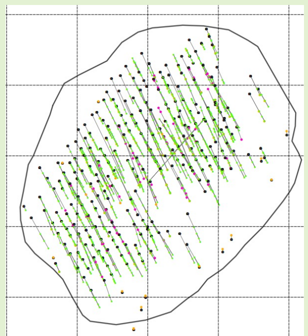
Examples: Mine Rock Sample Location

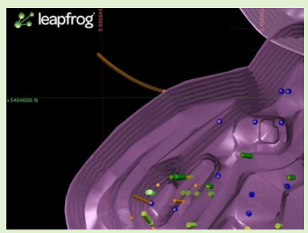
- describe the representativeness of samples collected for acid rock drainage and metal(loid) leaching assessment. Present cross-sections or block model images at an appropriate scale that include mine rock samples, geology, mineralized zones, the approximate location of all open pit and underground mine development, borehole traces and identification numbers, and a scale and legend;

Sampling sites for pre-mine drill core, blast hole cuttings and post-blast waste rock should be recorded in block models and shown on cross sections and plan view maps.

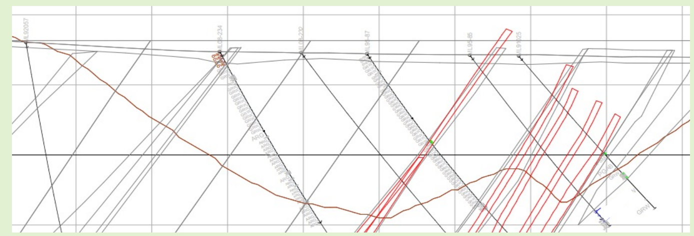
Aerial View Only:

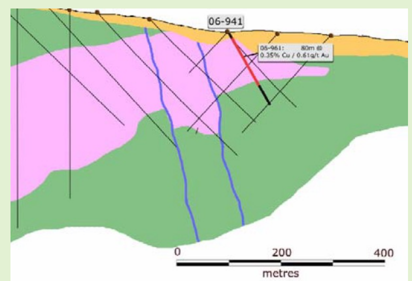


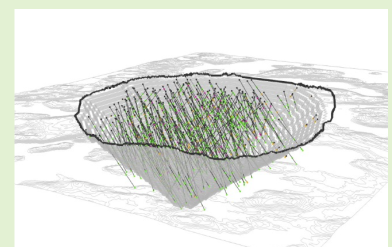




Cross Sections with Incomplete Metadata :







Implication: Spatial sample distribution, trends, and management approach cannot be validated

Analytical Program, Data Presentation, QA/QC

- provide a detailed summary of analytical methods used to evaluate mineralogy, acid rock drainage and metal(loid) leaching. The Mine Environment Neutral Drainage (MEND) report 1.20.1 is recommended as guidance to support study design;
- describe the quality assurance/quality control procedures. Provide laboratory certificates of analysis that include information related to analytical methodology and quality assurance/quality control; and

The "devil is typically in the details" in drainage chemistry prediction. Raw data should always be included in prediction reports along with the resulting interpretations.

A common concern is how much information to provide.

Observations:

- Analytical methods are not described sufficiently
- Inconsistent / undefined nomenclature
- Summarized data only or lab certificates only
- QA/QC program not described

Considerations:

- Thorough methods documentation
- Robust metadata and consistent nomenclature use
- Lab certificates provided for all samples and tests
- Describe QA/QC methods for all aspects of the study

Implication: cannot validate analytical methods, source terms and proposed management

Examples: Neutralization Potential Documentation

NP Methods (not exhaustive):

Standard Sobek et al., 1978
Modified Sobek:
- Lawrence & Wang 1996 (MEND 1.16.3)
- Lawrence et al / Coastech Research Inc. 1989 (MEND 1.16.1a)
- *State modifications, provide fizz ratings, indicate if pH checked & test rerun*

Siderite Corrected NP:
- Skousen et al 1997 (specify which method: Sobek, Boil, H2O2, SobPer)

Other methods:
- BC Research (MEND 1.20.1)
- Lapakko 1993
- Quebec M.A.110 ACISOL 1.0

Effective NP: clearly describe methods and assumptions

Limited documentation by labs:

- *Schedule of fees:*

Sobek Method
Modified Sobek (M) Option
Siderite Correction (S) Option

Our scope of static ARD tests includes:
- Modified Acid Base Accounting

- *Lab certificate:*

ABA - Modified Sobek

NP method used: Modified ABA Method (Lawrence et al., 1989)

CODE	DESCRIPTION
[redacted]	Modified NP

- *Well referenced methods:*

Peroxide Siderite Correction for Sobek NP: Skousen, J., Renton, J., Brown, H., Evans, P., Leavitt, B., Brady, K., Cohen, L. and Ziemkiewicz, P. (1997), Neutralization Potential of Overburden Samples containing Siderite, Journal of Environmental Quality, v26, n3, p673-681.
Modified ABA (Sobek) NP: MEND Acid Rock Drainage Prediction Manual, MEND Project 1.16.1b (pages 6.2-11 to 17), March 1991.

Examples of NP reporting:

1) Modified Sobek method reference not provided

[redacted] The modified neutralization potential (NP) is used to represent the NP of the materials for this site. [redacted]

Modified NP
kg $CaCO_3$/t

Modified NP is obtained by the modified Sobek method.

2) Standard Sobek reference; specific modifications not provided

- Acid-generating potential (Sobek and coll. 1978, Modified);

3) Standard Sobek reference; modified Sobek indicated

Acid-Base Accounting (ABA) was conducted to evaluate the acid generation potential and neutralization potential of the three samples (MEND, 2009). A modified Sobek procedure was used to determine the following parameters: paste pH, sulphur species (total sulphur, sulphate and sulphide content), acid potential (AP) and neutralization potential (NP), and carbon species (total carbon and carbonate) (Sobek et al., 1978).

NP[(1)]

Notes:
(1) Neutralization potential (NP) is determined using the Sobek method (Sobek, 1978).

4) Inconsistent reporting between text and tables

ABA testing included paste pH, total sulphur, sulphate-sulphur, sulphide-sulphur, Modified Sobek NP, total carbon, total organic carbon, and total carbonate analyses. The results from these analyses were utilized to calculate the carbonate NP (Carb-NP), acid generating potential (AP), net neutralization potential (NNP), and Sobek NPR and Carbonate NPR (Carb-NPR).

Neutralization Potential (Sobek-NP)[1]

1. Analyzed by [redacted] using the Sobek method.

Implication: cannot validate NP methods; erodes trust in determination of ARD potential

Examples: Carbon Species Documentation

Example 1: Carbon Species

- Methods not described in the text
- Methods cannot be validated (no lab certificate)
- CaNP replicated with CO2 value (assumed TIC as %CO2)

[redacted] The carbonate NP (CaNP) is calculated using the assumption that the total inorganic carbon (TIC) content is present as calcium carbonate. [redacted]

Total C	CO_2	CO_3	CaNP
%	%	%	*kg $CaCO_3$/t*
0.1	0.4	0.5	9.1

Example 2: Carbon Species

- Inconsistent nomenclature between lab certificate (left), lab fee schedule (bottom), and report table (right)

C- GAS05	C- GAS05
C	CO2
%	%

Parameter	Paste pH	S_{Total}	TIC	AP	Carbon. NP
Units	pH Units	wt. %		kg$CaCO_3$/t	
[redacted]	8.80	1.84	0.82	57.4	68.1

CODE	ANALYTES & RANGES (%)		DESCRIPTION
C-GAS05	CO_2 (Carbonate)	0.2%-50%	$HClO_4$ digestion and CO_2 coulometer. 0.1g sample

Implication: methods cannot be verified; erodes trust in determination of ARD potential

Example: Analytical Method Documentation

Method Documentation from Report:

- Total sulphur and sulphate sulphur speciation analysis to determine sulphide sulphur content, by the difference between the two;
- Total inorganic carbon analysis to determine carbonate content;
- Whole rock analysis by XRF;
- Acid Base Accounting (ABA) using the Modified Sobek method; and,
- Multi-element (trace metals) analysis by ICP-OES scan.

ARD potential for the major lithological units and mine components for the Project was evaluated using Acid-Base Accounting (ABA) by the modified Sobek method and the total sulphur analysis.

Total Sulphur (Wt.%)	Sulphate S (Wt %)	Sulphate (Wt%)	Sulphide (Wt%)	Total Inorganic Carbon	Acid Production Potential	Neutralizing Potential
0.249	0.241	0.005	0.236	< 0.01	7.8	4.7
0.11	0.256	0.001	0.255	0.04	3.4	13.4
0.041	0.057	0.001	0.056	0.02	1.3	10.4
1.17	0.943	0.002	0.941	0.03	36.6	10.8

Specific information not provided:

- Trace metals – digestion method
- NP – specific modifications to Sobek, fizz ratings
- Total sulphur and sulphate methods

Cannot replicate:

- Sulphide by difference (total sulphur minus sulphate)
- Acid potential based on total sulphur

Implication: calculated results cannot be replicated; erodes trust in determination of ARD potential

Analytical Program – Mineralogy Testing

- provide a detailed summary of analytical methods used to evaluate mineralogy, acid rock drainage and metal(loid) leaching. The Mine Environment Neutral Drainage (MEND) report 1.20.1 is recommended as guidance to support study design;

As a minimum, prediction programs generally should include visual descriptions, petrographic analysis and X-ray Diffraction analysis.

The rate of weathering and element release depends not only on the chemical composition, but also on the physical properties of minerals.

Observations:

- Not included or limited samples per lithology
- Not representing all risk scenarios or not used to determine ARD/ML potential and source terms
- Quantitative techniques only (high detection limits)
- Mineral texture or associations not accounted for
- Methods unable to identify source minerals and their control on ARD and/or ML potential

Considerations:

- Conduct fulsome testing of samples that represent all risk scenarios for each lithology
- Consider advanced mineralogy techniques that provide information on mineral occurrence in addition to modal mineralogy
- Clearly describe how mineralogy is considered in evaluation of ARD/NMD/ML potential

Implication: cannot validate source terms and proposed management

Data Analysis: Estimating ARD/NMD/ML Potential

- describe the approach and methods for the prediction of acid rock drainage and metal(loid) leaching, including identification of potential parameters of concern. Provide initial leaching potential results based on short-term leach tests and an analysis of the representativeness of laboratory and field kinetic tests based on static test results;
- provide estimates of the potential for all materials to be sources of acid drainage, neutral mine drainage, and/or metal(loid) leaching, timing to its onset, and short- and long-term loading rates calculated from kinetic testing for both neutral and acidic conditions, with consideration for the use of a proxy (i.e. historical mine waste, analytical tests replicating acidic conditions) if kinetic tests have not produced acidic leachate, if applicable.

Detailed static test information should demonstrate that the kinetic test samples do represent the intended portion of the project component.

The rate of weathering and element release depends not only on the chemical composition, but also on the physical properties of minerals.

Observations:

- ARD designation approach and assumptions not clearly defined (e.g., PAG designation, depletion calculations, ARD onset timing, etc.)
- Elements of environmental interest not identified
- Kinetic test sample representativeness not demonstrated ; does not account for all scenarios

Considerations:

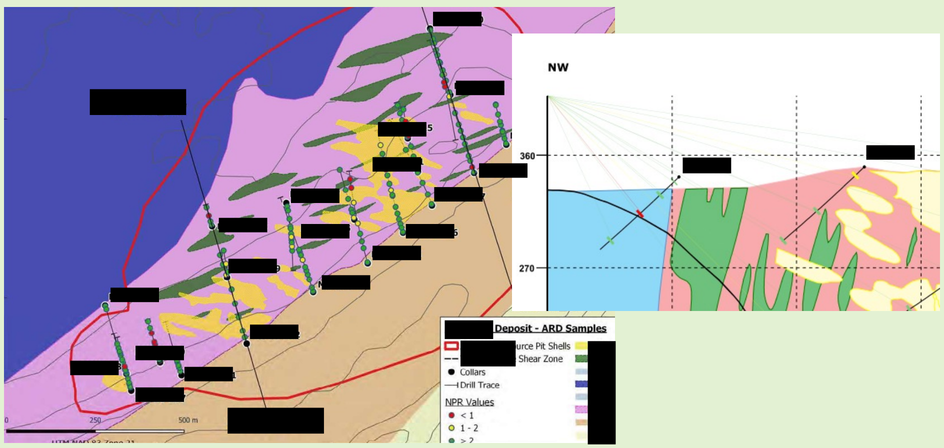
- Fulsome documentation of methods / assumptions
- Elements of interest clearly defined, including new and emerging contaminants
- Sufficient documentation of kinetic sample representativeness
- Kinetic testing and loading rates for all ARD/NMD/ML scenarios; consider proxies

Implication: deficiencies in estimation of ARD/ML potentially results in inadequate source terms

Example: ARD Risk, Data Gaps, Management Plan

Proposed project:

- Minimal sampling of unit that comprises pit wall, contains some PAG samples
- No kinetic testing on PAG material
- Proposed management approach relying on estimated lag times from neutral kinetic tests



NRCan request:

- ❑ Additional sampling to address spatial data gaps and refine understanding of ARD potential for unit

-or-

- ❑ Comprehensive ARD/ML management plan that addresses data gaps and ARD risk

Outcome:

- ✓ Updated ARD/ML management plan addressed risk
- ✓ IA approved with conditions
- ✓ Program transitioned into permitting with
  - Additional sampling to address data gaps
  - Additional testing of PAG materials
  - Development of ARD block model

Implication: additional follow-up required before approval with conservative conditions

Example: Use of Proxy for ARD

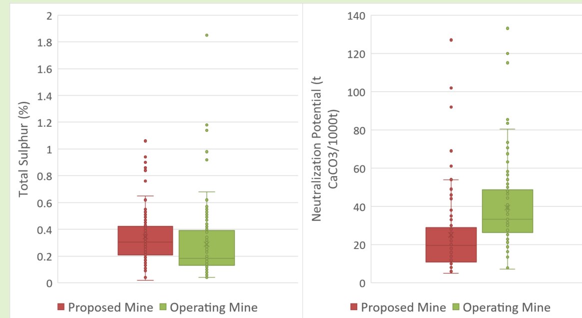
Example

- Using site monitoring data from an operating mine as a proxy for contact water at proposed project

Approach is appropriate geologically, but geochemical justification was not provided:

- Static test comparison by CanmetMINING:
    1) higher S and lower NP values for samples from proposed project
- Kinetic tests on PAG samples (insufficient duration):
    2) Proposed project: decreasing pH (red series)
    3) Operating mine: neutral leachate

1)



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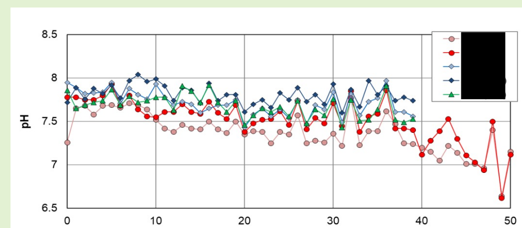
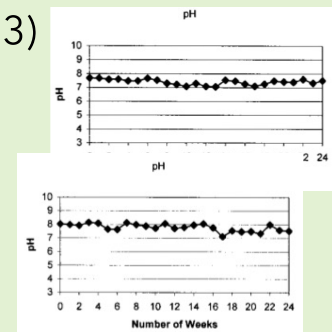


3)



Implication: additional follow-up to ensure adequate prediction of ARD risk

Data Analysis: Source Term Development

Observations:

- Data gaps not identified / no plan to address them
- Life of mine tonnages and sequencing not available
- Input parameters and assumptions not defined

Considerations:

- Clear plan to address data gaps as project advances
- Transparent source term development methods
- Consideration of proactive mine waste management and mitigation strategies during impact assessment

Prediction data will play a major role in the selection of mitigation measures and their design.

There is never complete understanding and perfect prediction, and thus a critical part of any drainage chemistry prediction program is identifying and dealing with uncertainty.

8.3.2 Effects to chemical release rates

The Impact Statement must describe the effects of the project on the rate at which chemicals may be released from mined or excavated materials, including:

- present chemical release rates from all major sources of mine or excavated materials and mine wastes, to be used as source terms in an integrated chemical mass balance model described in Section 8.6.2 Effects to groundwater and surface water, for all phases considering:
  - the results of the geochemical characterization study that evaluated the potential for acid rock drainage, neutral mine drainage, and/or metal(loid) leaching for all materials described in Section 8.3.1,
  - potential release of cyanide from gold mines,
  - exposure of potentially acid generating and metal(loid) leaching rock in pit walls,
  - baseline groundwater and surface water quality as described in Section 8.6.1,
  - potentially acid-generating rock volumes and tonnage for the lifecycle of the project, and
  - mine waste disposal, management and mitigation methods and their affects on acid rock drainage and/or metal(loid) leaching potential;
- provide a clear description and rationale for all input parameters and assumptions;
- provide base case (i.e. most likely, mean, median) and worst case (e.g. 75th to 90th percentile) scenarios, plus applicable sensitivity scenarios; and
- describe potential effects to groundwater and surface water and sediment quality from acid rock drainage, neutral mine drainage, and/or metal(loid) leaching, as described in Section 8.6.2 Effects to groundwater and surface water.

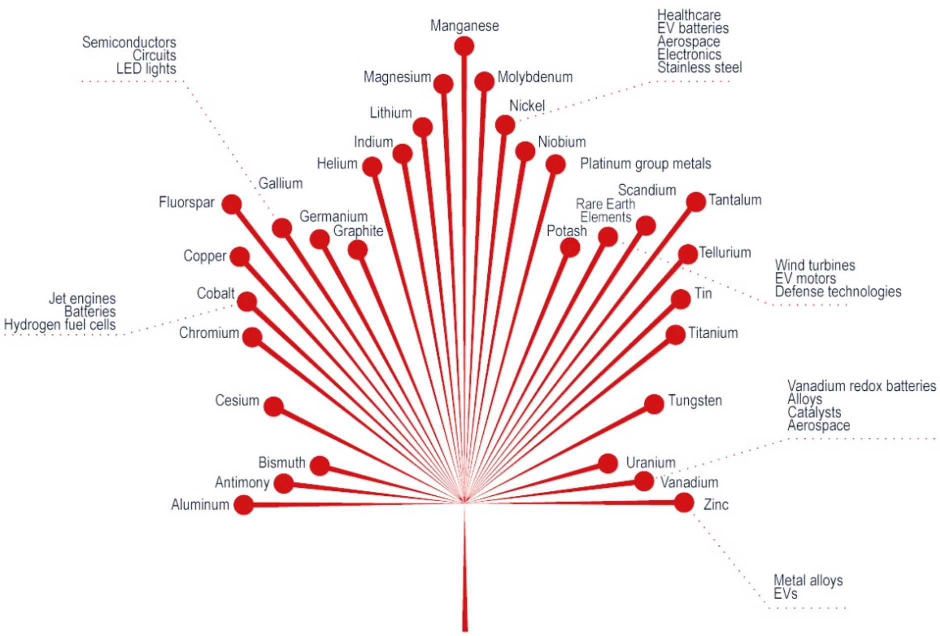
8.3.3 Mitigation and enhancement measures

The Impact Statement must:

- describe the conceptual approach to operational testing to identify and manage potentially acid generating and/or metal(loid) leaching mine waste during mine construction and operations, if applicable; and
- describe methods for the prevention, monitoring, management and control of acid rock drainage, neutral mine drainage, and/or and metal(loid) leaching during all project phases.

Implications: feasibility of proposed mitigation measures cannot be evaluated; potentially conservative conditions

Examples: New and Emerging Elements of Interest



The Canadian Critical Minerals Strategy

Observations:

- Elements not included in leach tests
- No loading rates or source terms developed
- Toxicity information not available and toxicity testing is not undertaken

Considerations:

- New and emerging elements should be included in geochemical testing
- Toxicity testing should be considered to support waste management & receiving environment objectives

Implication: Cannot validate source terms or waste management strategy

Conclusions and Considerations

Detailed and thorough reporting:

- ✓ **Builds trust** for all parties
- ✓ **Streamlines** project reviews
- ✓ Supports **data reuse**

> *Operational characterization of wastes, drainages and mine walls may include thousands of analyses and hundreds of thousands of dollars of work. All this work and money may be wasted if details such as sample locations, sampling methods, analysis procedures and analytical results are lost.*

> *Be proactive using prediction, rather than reactive after a problem arises. This can save time and money and provide more options for a solution. If a solution cannot be selected, at least the issue can be marked for further study and later resolution.* MEND 1.20.1

Consider **robust documentation** of:

- ❑ Sample origin and representativeness
- ❑ Analytical methods
- ❑ Analytical results
- ❑ Source term development

Implications: delays in the approval process and conservative conditions of approval (increased costs)

Acknowledgements

Jesse Karwaski, Albert Stoffers (CanmetMINING); colleagues in the Impact Assessment Division of NRCan; Brian Giles (IAAC)

Support from CanmetMINING and the Impact Assessment Agency of Canada

Contact

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Annexed Slides

Geochemistry under Impact Assessment Act (2019)

TISG Section	The Impact Statement must (summarized):			Implications
8.3.1 Baseline Conditions	✓ provide a geochemical characterization of expected mined or excavated materials such as [etc.];	In particular (provide/ describe):	❑ Sample representativeness ❑ Analytical methods ❑ QA/QC / data presentation ❑ Methods to estimate potential for ARD/NMD/ML	• missing data could delay approvals and result in conservative conditions (higher cost) • cannot validate analytical methods, source terms and proposed management
8.3.2 Effects to chemical release rates	✓ describe the effects of the project on the rate at which chemicals may be released from mined or excavated materials,	including:	❑ Source terms for all facilities and all phases ❑ Input parameters and assumptions ❑ Base case, worst case, and sensitivity scenarios ❑ Potential effects to groundwater, surface water, and sediment quality from ARD, NMD and/or ML	• decreased clarity in ARD/ML risk identification erodes confidence in source terms • additional follow-up required before approval with conservative conditions delays the process and increases costs
8.3.3 Mitigation and enhancement measures	✓ describe the conceptual approach to operational testing to identify and management potentially acid generating and/or metal(loid) leaching mine waste during mine construction and operations, if applicable ✓ describe methods for the prevention, monitoring, management and control of acid rock drainage, neutral mine drainage, and/or and metal(loid) leaching during all project phases.			• feasibility of proposed mitigation measure cannot be evaluated and can result in potentially conservative conditions of approval • Limits data reuse to support proactive mine waste management strategies

Federal Guidelines (IAA 2019)

Sampling Program: Material Selection

- describe the representativeness of samples collected for acid rock drainage and metal(loid) leaching assessment. Present cross-sections or block model images at an appropriate scale that include mine rock samples, geology, mineralized zones, the approximate location of all open pit and underground mine development, borehole traces and identification numbers, and a scale and legend;
- describe the representativeness of tailings solids and process water. Provide a schematic process flow chart including the location that each tested sample represents if various processing streams are tested;

It is important to provide good spatial, geologic and geochemical representation because contaminant discharge may be produced by only a portion of the geologic material.

Sufficient samples should be taken to accurately characterize the variability and central tendency, like the average, median and 10th and 90th percentiles.

Observations:

- Disturbed rock units not identified, not all units tested
- Changes in material sequencing over LOM not considered
- <3 samples per material type

Considerations:

- Provide LOM tonnage estimates by rock type
- Consider ore feed changes over LOM
- Test sufficient samples per unit for statistics

Implication: cannot verify sampling program sufficiency or ARD/ML Management approach

Sampling Program: Sample Origin

- describe the representativeness of samples collected for acid rock drainage and metal(loid) leaching assessment.
- describe the representativeness of tailings solids and process water. Provide a schematic process flow chart including the location that each tested sample represents if various processing streams are tested;

Operational characterization of wastes, drainages and mine walls may include thousands of analyses and hundreds of thousands of dollars of work. All this work and money may be wasted if details such as sample locations, sampling methods, analysis procedures and analytical results are lost.

Observations:

- Insufficient information to confirm representativeness
- 'Historic' sample metadata not provided or inconsistent
- Rock type designation source not defined (e.g., logged lithology or management unit)
- Site specific nomenclature / codes not defined
- Use of local formation names
- Composite sample composition not provided

Considerations:

- Thorough documentation of sample origin for all samples
  - Consistent and defined nomenclature
  - All sample locations visually presented

Implication: cannot verify sampling program sufficiency or ARD/ML Management approach

Analytical Program: Documentation of Methods

In particular:

- provide a detailed summary of analytical methods used to evaluate mineralogy, acid rock drainage and metal(loid) leaching. The Mine Environment Neutral Drainage (MEND) report 1.20.1 is recommended as guidance to support study design;

The "devil is typically in the details" in drainage chemistry prediction. Raw data should always be included in prediction reports along with the resulting interpretations.

Observations:

- Method documentation incomplete and/or not referenced
- Calculated sulphur and carbonate species not reproducible
- Lab certificates lack detailed method description
- Inconsistent nomenclature across text, tables, lab certificates, and previous studies

Considerations:

- Thorough documentation of test methods to support program reproducibility
  - Provide method references
  - Provide lab certificates
  - Use clear and consistent nomenclature
  - 'Historic' methods and limitations

Implication: methods cannot be validated; erodes trust in source terms and proposed management

Data Presentation and QA/QC

- describe the quality assurance/quality control procedures. Provide laboratory certificates of analysis that include information related to analytical methodology and quality assurance/quality control; and

A common concern is how much information to provide.

Observations:

- Data provision
  - Summary tables, figures, or statistics only
  - Laboratory certificates not provided
  - Excludes various tested elements
  - Sample metadata limited or omitted
- Data reporting doesn't define
  - Units of measurement, detection limits, #N/A
  - Significant figures truncated; zero values

Considerations:

- Data provision for all samples / tests
  - Lab certificates and QA/QC reports
  - Sample metadata
- Document QA/QC methods
  - Sample collection
  - Lab analysis
  - Data analysis

Implication: analytical data cannot be verified; source terms cannot be validated

Data Analysis: Evaluation of ARD/NMD/ML Potential

- describe the approach and methods for the prediction of acid rock drainage and metal(loid) leaching, including identification of potential parameters of concern. Provide initial leaching potential results based on short-term leach tests and an analysis of the representativeness of laboratory and field kinetic tests based on static test results;

Detailed static test information should demonstrate that the kinetic test samples do represent the intended portion of the project component.

Observations:

- ABA calculation methods not defined
- ARD designation approach and criteria not defined
- Elements of environmental interest
  - Methods to identify are not defined
  - Excludes new and emerging elements
- Kinetic test samples
  - do not target all scenarios for ARD/NMD/ML
  - representativeness not demonstrated
- Modal mineralogy testing only without textural analysis; not used to inform ABA test methods

Considerations:

- Fulsome documentation of all calculation methods and assumptions, including adjustment factors
- New and emerging elements included in geochemical testing
- ARD indicators & elements of interest clearly defined
- Toxicity testing considered to support effluent limits and environmental guidelines
- Kinetic test samples consider all potential scenarios and representativeness is clearly documented
- Fulsome modal and textural mineralogy testing

Implication: decreased clarity in ARD/ML risk identification; erodes confidence in source terms

Data Analysis: Estimation of Release Rates

- provide estimates of the potential for all materials to be sources of acid drainage, neutral mine drainage, and/or metal(loid) leaching, timing to its onset, and short- and long-term loading rates calculated from kinetic testing for both neutral and acidic conditions, with consideration for the use of a proxy (i.e. historical mine waste, analytical tests replicating acidic conditions) if kinetic tests have not produced acidic leachate, if applicable.

The rate of weathering and element release depends not only on the chemical composition, but also on the physical properties of minerals.

Observations:

- Methods and assumptions not provided for:
  - Loading rates
  - Depletion calculations
  - Timing on ARD onset
- Acidic conditions not achieved in kinetic testing
  - Onset timing calculated based on neutral tests
  - Acidic loading rates not available
- Proxies for ARD not implemented; or appropriateness of method not demonstrated
- Mineralogical controls are not considered

Considerations:

- Depletion calculations / ARD onset timing
  - methods and assumptions clearly documented
  - PAG samples utilized (when applicable)
- Loading rates (short- and long-term)
  - Clear documentation of test results utilized
  - Consideration of particle size and test scale
- Use of proxies for acidic conditions (e.g. acidic lab tests, operating sites, etc.) clearly documented
- Implement advanced mineralogy techniques and consider mineral controls on estimates of ML/ARD

Implication: decreased clarity erodes confidence in source terms and waste management plans

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DEVELOPING A PROOF-OF-CONCEPT ENVIRONMENTAL GEOCHEMISTRY DATABASE IN CANADA: LESSONS ON METADATA STANDARDS

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