Integrated Environmental Management Process for Critical Infrastructure at Agnico Eagle.

Michel Julien, ing., PhD, FEAC, FEIC, ASC

Vancouver BC
December 2nd 2025

AGNICO EAGLE

OUTLINE

1. The Discussion on Risk and Uncertainty
2. Our Governance Model at Agnico Eagle Mines
3. Our Journey (2018-2025)
4. The Big Topics
5. Benefits and Challenges

1. THE DISCUSSION ON RISK AND UNCERTAINTY

A group of professionals and experts is gathered to discuss an issue related to mine waste and water management.

What will most likely happen?

1. THE DISCUSSION ON RISK AND UNCERTAINTY

What often happens when group conversations occur:

1. The collective experience tends to recognize that projects are always more complex than anticipated - and preventive/mitigation measures are not a *nice to have* but a *must have*.

2. Irrespective of the technical facts, at the end of the day the collective opinion will often drift toward a more conservative and precautionary position, specially when there is a wide range of opinions

3. Then follows the challenge of internal (and external) communication of these complex discussions involving risk and uncertainty (e.g. Due Diligence).

1. THE DISCUSSION ON RISK AND UNCERTAINTY

The process:

1. It starts with solid (and often robust) technical conversations. **Safe spaces need to be created**: a key intent behind our internal governance model.
2. The goal is to achieve alignment on risk and uncertainty and converge toward a reasonable position between a more precautionary and an optimistic view (without killing the project).
3. Finally, we need to communicate in a language that will be understood **and useful** to the management the outcome of these conversations. It should be simple and convincing. Talking using financial considerations makes the conversation easier.

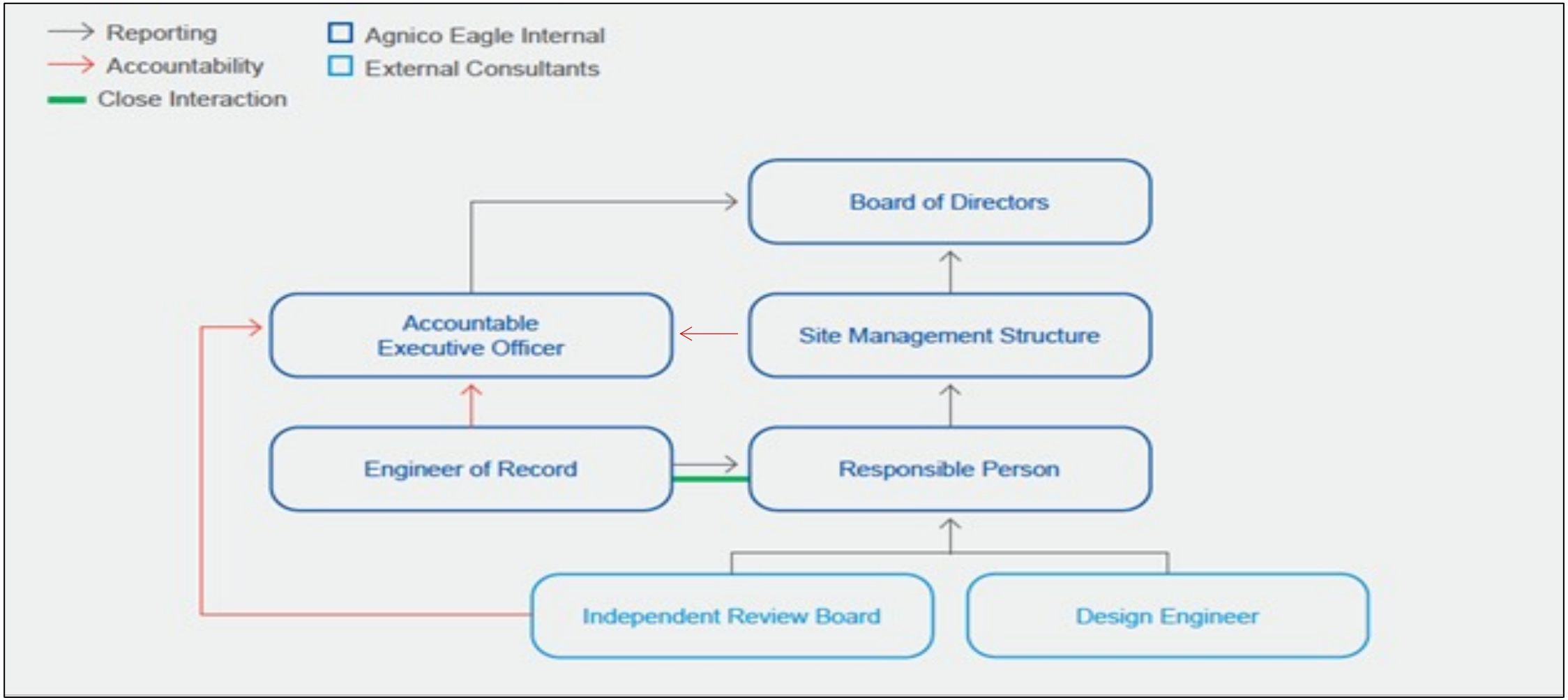
2. GOVERNANCE OF ENVIRONMENTAL CRITICAL INFRASTRUCTURE

- Follows the **Mining Association of Canada** (MAC): *A Guide to the Management of Tailings Facilities v3.2 (2021).*
- A governance model with respect to tailings management with more clarity on roles and responsibilities by identifying a certain number of functions with their specific responsibilities :
  - The Owner
  - The Accountable Executive Officer (AEO)
  - The Responsible Person (RP)
  - The Design Engineer (DE)
  - The Engineer of Record (EoR)
  - The Independent Review Board (IRB)

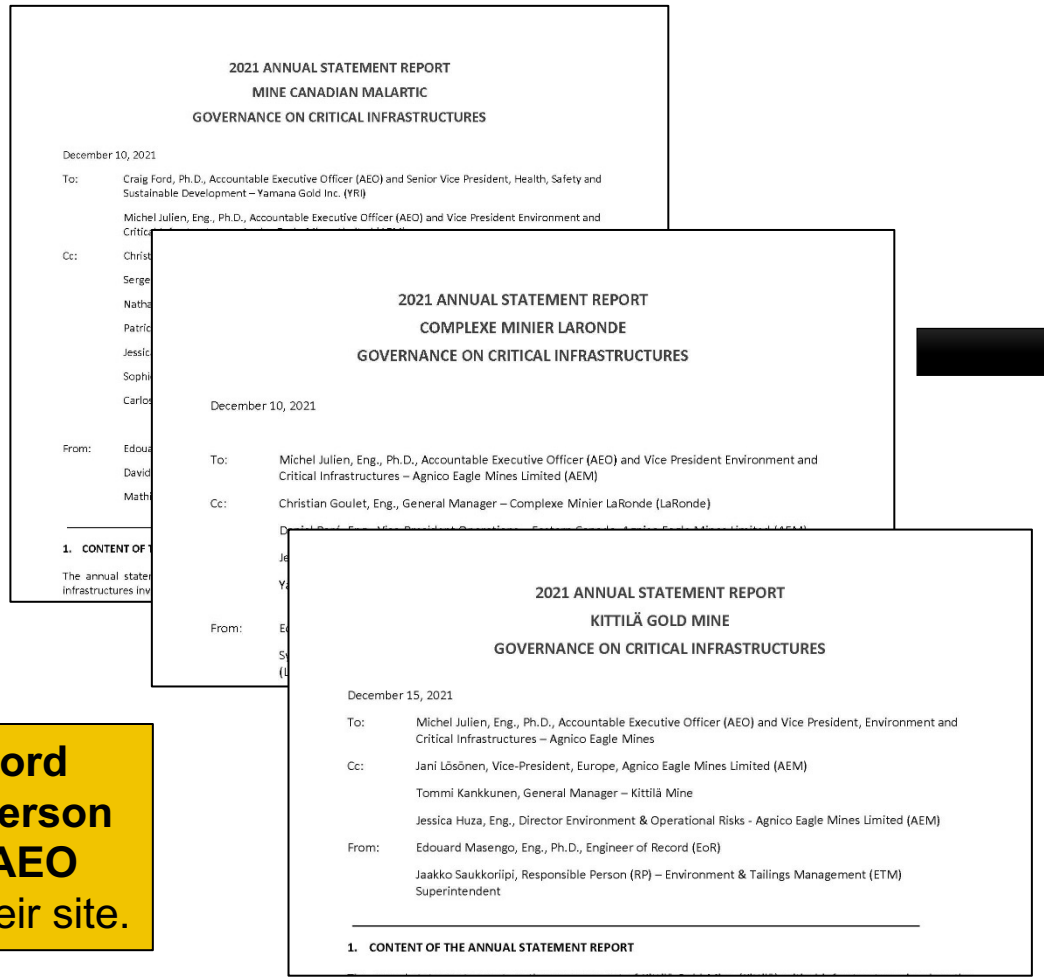
2. GOVERNANCE OF ENVIRONMENTAL CRITICAL INFRASTRUCTURE

- Our governance was implemented in 2018;
- Unique to Agnico and an example among others;
- Provide consistency;
- Roles and responsibilities are better defined;
- Notion of accountability is embedded;
- Challenges with growth.

2. GOVERNANCE OF ENVIRONMENTAL CRITICAL INFRASTRUCTURE



2. GOVERNANCE OF ENVIRONMENTAL CRITICAL INFRASTRUCTURE



2021 ANNUAL STATEMENT REPORT
MINE CANADIAN MALARTIC
GOVERNANCE ON CRITICAL INFRASTRUCTURES

December 10, 2021

To: Craig Ford, Ph.D., Accountable Executive Officer (AEO) and Senior Vice President, Health, Safety and Sustainable Development – Yamana Gold Inc. (YRI)

Michel Julien, Eng., Ph.D., Accountable Executive Officer (AEO) and Vice President Environment and Critical Infrastructures – Agnico Eagle Mines Limited (AEM)

Cc:

From:

1. CONTENT OF T

2021 ANNUAL STATEMENT REPORT
COMPLEXE MINIER LARONDE
GOVERNANCE ON CRITICAL INFRASTRUCTURES

December 10, 2021

To: Michel Julien, Eng., Ph.D., Accountable Executive Officer (AEO) and Vice President Environment and Critical Infrastructures – Agnico Eagle Mines Limited (AEM)

Cc: Christian Goulet, Eng., General Manager – Complexe Minier LaRonde (LaRonde)

From:

2021 ANNUAL STATEMENT REPORT
KITTILÄ GOLD MINE
GOVERNANCE ON CRITICAL INFRASTRUCTURES

December 15, 2021

To: Michel Julien, Eng., Ph.D., Accountable Executive Officer (AEO) and Vice President, Environment and Critical Infrastructures – Agnico Eagle Mines

Cc: Jani Lösönen, Vice-President, Europe, Agnico Eagle Mines Limited (AEM)

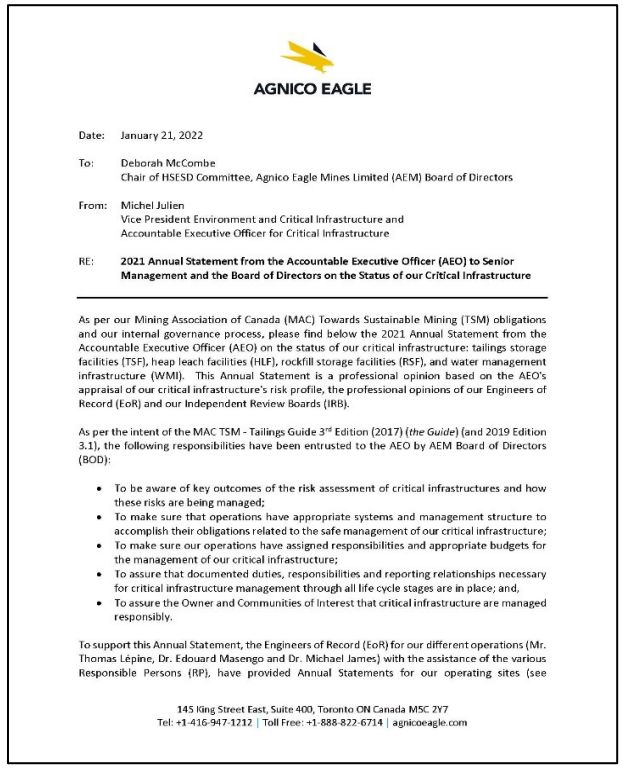
Tommi Kankkunen, General Manager – Kittilä Mine

Jessica Huza, Eng., Director Environment & Operational Risks - Agnico Eagle Mines Limited (AEM)

From: Edouard Masengo, Eng., Ph.D., Engineer of Record (EoR)

Jaakko Saukkoriipi, Responsible Person (RP) – Environment & Tailings Management (ETM) Superintendent

1. CONTENT OF THE ANNUAL STATEMENT REPORT



AGNICO EAGLE

Date: January 21, 2022

To: Deborah McCombe
Chair of HSESD Committee, Agnico Eagle Mines Limited (AEM) Board of Directors

From: Michel Julien
Vice President Environment and Critical Infrastructure and
Accountable Executive Officer for Critical Infrastructure

RE: **2021 Annual Statement from the Accountable Executive Officer (AEO) to Senior Management and the Board of Directors on the Status of our Critical Infrastructure**

As per our Mining Association of Canada (MAC) Towards Sustainable Mining (TSM) obligations and our internal governance process, please find below the 2021 Annual Statement from the Accountable Executive Officer (AEO) on the status of our critical infrastructure: tailings storage facilities (TSF), heap leach facilities (HLF), rockfill storage facilities (RSF), and water management infrastructure (WMI). This Annual Statement is a professional opinion based on the AEO's appraisal of our critical infrastructure's risk profile, the professional opinions of our Engineers of Record (EoR) and our Independent Review Boards (IRB).

As per the intent of the MAC TSM - Tailings Guide 3rd Edition (2017) (*the Guide*) (and 2019 Edition 3.1), the following responsibilities have been entrusted to the AEO by AEM Board of Directors (BOD):

- To be aware of key outcomes of the risk assessment of critical infrastructures and how these risks are being managed;
- To make sure that operations have appropriate systems and management structure to accomplish their obligations related to the safe management of our critical infrastructure;
- To make sure our operations have assigned responsibilities and appropriate budgets for the management of our critical infrastructure;
- To assure that documented duties, responsibilities and reporting relationships necessary for critical infrastructure management through all life cycle stages are in place; and,
- To assure the Owner and Communities of Interest that critical infrastructure are managed responsibly.

To support this Annual Statement, the Engineers of Record (EoR) for our different operations (Mr. Thomas Lépine, Dr. Edouard Masengo and Dr. Michael James) with the assistance of the various Responsible Persons (RP), have provided Annual Statements for our operating sites (see

145 King Street East, Suite 400, Toronto ON Canada M5C 2Y7
Tel: +1-416-947-1212 | Toll Free: +1-888-822-6714 | agnicoeagle.com

Each site **Engineer of Record** (EOR) and **Responsible Person** (RP) have provided to the **AEO** an Annual Statement for their site.

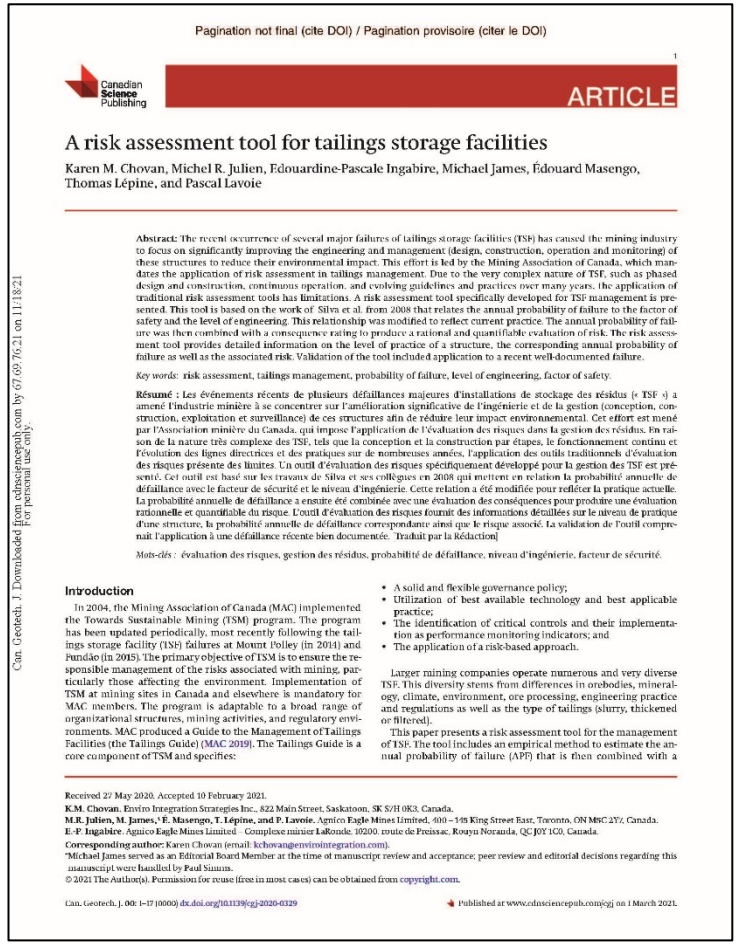
Annual Statement from Accountable Executive Officer (AEO) of Critical Infrastructure completed as per our governance model and our TSM obligations -provided to the Board of Directors.

Internal reporting process

2. GOVERNANCE OF ENVIRONMENTAL CRITICAL INFRASTRUCTURE

- The importance of disclosure;
- Evaluation of risk is a complex process particularly for low probability and high consequence events.

Disclosure and risk assessment



Pagination not final (cite DOI) / Pagination provisoire (citer le DOI)

Canadian Science Publishing

ARTICLE

A risk assessment tool for tailings storage facilities

Karen M. Chovan, Michel R. Julien, Édouardine-Pascale Ingabire, Michael James, Édouard Masengo, Thomas Lépine, and Pascal Lavoie

Abstract: The recent occurrence of several major failures of tailings storage facilities (TSF) has caused the mining industry to focus on significantly improving the engineering and management (design, construction, operation and monitoring) of these structures to reduce their environmental impact. This effort is led by the Mining Association of Canada, which mandates the application of risk assessment in tailings management. Due to the very complex nature of TSF, such as phased design and construction, continuous operation, and evolving guidelines and practices over many years, the application of traditional risk assessment tools has limitations. A risk assessment tool specifically developed for TSF management is presented. This tool is based on the work of Silva et al. from 2008 that relates the annual probability of failure to the factor of safety and the level of engineering. This relationship was modified to reflect current practice. The annual probability of failure was then combined with a consequence rating to produce a rational and quantifiable evaluation of risk. The risk assessment tool provides detailed information on the level of practice of a structure, the corresponding annual probability of failure as well as the associated risk. Validation of the tool included application to a recent well-documented failure.

Key words: risk assessment, tailings management, probability of failure, level of engineering, factor of safety.

Résumé : Les événements récents de plusieurs défaillances majeures d'installations de stockage des résidus (« TSF ») a amené l'industrie minière à se concentrer sur l'amélioration significative de l'ingénierie et de la gestion (conception, construction, exploitation et surveillance) de ces structures afin de réduire leur impact environnemental. Cet effort est mené par l'Association minière du Canada, qui impose l'application de l'évaluation des risques dans la gestion des résidus. En raison de la nature très complexe des TSF, tels que la conception et la construction par étapes, le fonctionnement continu et l'évolution des lignes directrices et des pratiques sur de nombreuses années, l'application des outils traditionnels d'évaluation des risques présente des limites. Un outil d'évaluation des risques spécifiquement développé pour la gestion des TSF est présenté. Cet outil est basé sur les travaux de Silva et ses collègues en 2008 qui mettent en relation la probabilité annuelle de défaillance avec le facteur de sécurité et le niveau d'ingénierie. Cette relation a été modifiée pour refléter la pratique actuelle. La probabilité annuelle de défaillance a ensuite été combinée avec une évaluation des conséquences pour produire une évaluation rationnelle et quantifiable du risque. L'outil d'évaluation des risques fournit des informations détaillées sur le niveau de pratique d'une structure, la probabilité annuelle de défaillance correspondante ainsi que le risque associé. La validation de l'outil comprenait l'application à une défaillance récente bien documentée. [Traduit par la Rédaction]

Mots-clés : évaluation des risques, gestion des résidus, probabilité de défaillance, niveau d'ingénierie, facteur de sécurité.

Introduction

In 2004, the Mining Association of Canada (MAC) implemented the Towards Sustainable Mining (TSM) program. The program has been updated periodically, most recently following the tailings storage facility (TSF) failures at Mount Polley (in 2014) and Fundão (in 2015). The primary objective of TSM is to ensure the responsible management of the risks associated with mining, particularly those affecting the environment. Implementation of TSM at mining sites in Canada and elsewhere is mandatory for MAC members. The program is adaptable to a broad range of organizational structures, mining activities, and regulatory environments. MAC produced a Guide to the Management of Tailings Facilities (the Tailings Guide) (MAC 2019). The Tailings Guide is a core component of TSM and specifies:

- A solid and flexible governance policy;
- Utilization of best available technology and best applicable practice;
- The identification of critical controls and their implementation as performance monitoring indicators; and
- The application of a risk-based approach.

Larger mining companies operate numerous and very diverse TSF. This diversity stems from differences in orebodies, mineralogy, climate, environment, ore processing, engineering practice and regulations as well as the type of tailings (slurry, thickened or filtered).

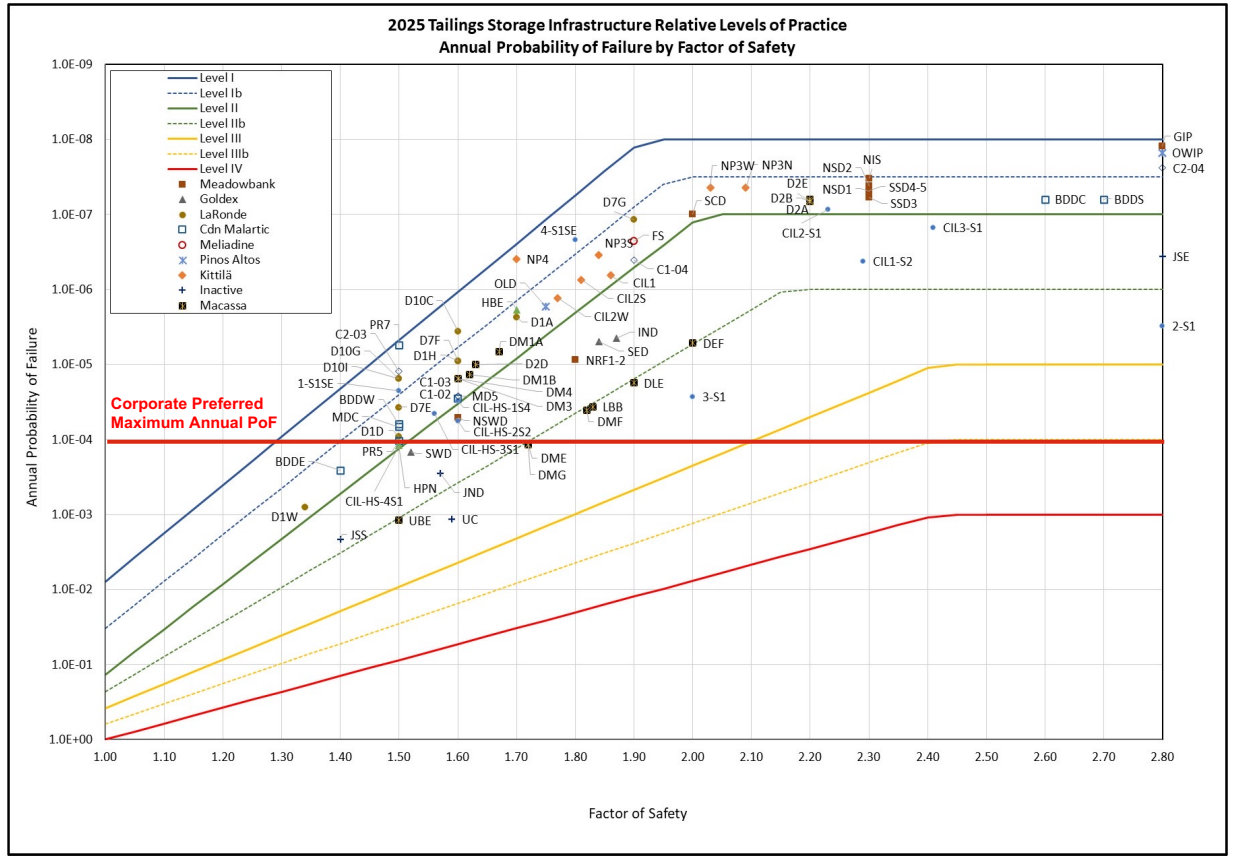
This paper presents a risk assessment tool for the management of TSF. The tool includes an empirical method to estimate the annual probability of failure (APF) that is then combined with a

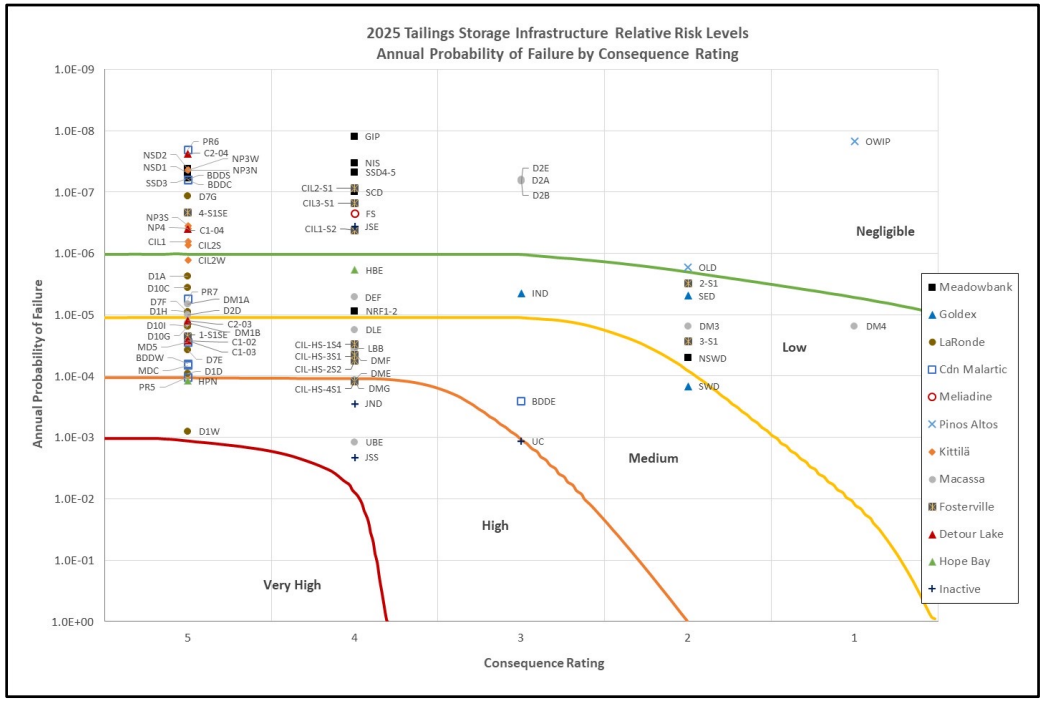
Received 27 May 2020. Accepted 10 February 2021.

K.M. Chovan. Enviro Integration Strategies Inc., 822 Main Street, Saskatoon, SK S7H 0K3, Canada.
M.R. Julien, M. James,[a] É. Masengo, T. Lépine, and P. Lavoie. Agnico Eagle Mines Limited, 400 – 145 King Street East, Toronto, ON M5C 2Y7, Canada.
É.-P. Ingabire. Agnico Eagle Mines Limited – Complexe minier LaRonde, 10200, route de Preissac, Rouyn Noranda, QC J0Y 1C0, Canada.
Corresponding author: Karen Chovan (email: kchovan@enviro integration.com).
[a]Michael James served as an Editorial Board Member at the time of manuscript review and acceptance; peer review and editorial decisions regarding this manuscript were handled by Paul Simms.

Can. Geotech. J. 00: 1–17 (0000) dx.doi.org/10.1139/cgj-2020-0329 Published at www.cdnsciencepub.com/cgj on 1 March 2021.

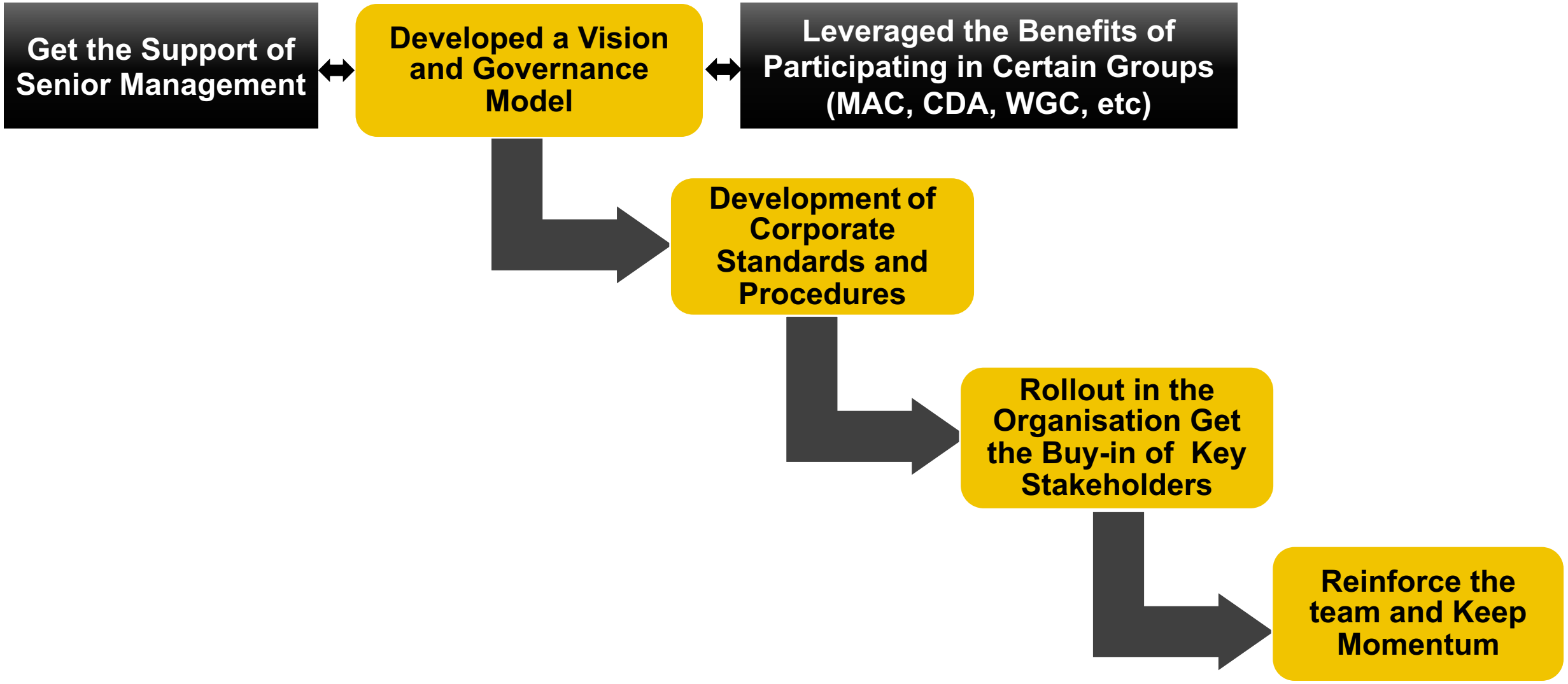
SEMI-QUANTITATIVE RISK ASSESSMENT – TAILINGS STORAGE FACILITIES





The intent was to allow prioritization of interventions and facilitate internal communication

3. OUR JOURNEY (2018-2025): INTERNALLY



3. OUR JOURNEY (2018-2025)

Design and monitoring considerations for heap leach pad facilities constructed in environments with steep topography and complex hydrogeological regime

GEO Regina 2014

Michel R. Julien
Agnico Eagle Mines Limited, Toronto, Ontario, Canada
Fiona Esford & Gerd Janssens
Golder Associates Limited, Burnaby, British Columbia, Canada

ABSTRACT
The design of heap leach facilities in areas with significant topographic relief is done on a routine basis. In these cases, certain design aspects require detailed analysis (i.e. material testing, stability analysis, hydrogeologic assessment) or at the very least, additional sensitivity analysis should be conducted to understand potential risks. Ore gradation is typically assumed during design based on some preliminary crushing tests of small samples of ore that may or may not include agglomeration. Experience tends to show that conditions vary during operation with different rock types or degree of weathering encountered resulting in varying gradations with time that in turn affects permeability, solution levels, and ultimately ore recovery. Such variability may have an impact on the hydraulic conductivity of the ore placed in the heap leach facility and may also affect stability. Designs should therefore include some allowances to account for the possible variability of these aspects during the operation. Shear strength parameters of the different materials constituting the liner system also need to be properly characterized and accounted for within the design stability analysis. Underdrain system can be impacted by evolving hydrogeological conditions during operation, and is a critical component to the heap leach facility system. Overall, more emphasis should be placed on-going monitoring during ore placement and after to verify design assumptions and to allow the identification of potential issues that may be developing during the course of the operation so that mitigation measures can be implemented, if required.

RÉSUMÉ
La conception de plate-forme de lixiviation dans des régions avec beaucoup de topographie se fait de façon routinière. Certains aspects du processus de conception dans ces cas requièrent des analyses détaillées ou à tout le moins des analyses de sensibilité additionnelles. La granulométrie est typiquement considérée durant la phase de conception à partir d'essais de concassage de petits échantillons de minerai pouvant ou non inclure de l'agglomération. L'expérience tend à montrer que les conditions d'opération et le type de roche auront tendance à varier durant la vie de la mine et résulte en une granulométrie qui évoluera au fil du temps. Cette variabilité aura un impact sur la conductivité hydraulique des matériaux sur la plate-forme de lixiviation et sur sa stabilité. Le processus de conception doit alors inclure la possibilité de cette variabilité. Les paramètres de résistance des différents matériaux constituant les différents éléments du système d'étanchéité doivent être de plus bien caractérisés et pris en compte dans les analyses de stabilité. Le système de drainage sous la plate-forme peut par ailleurs être impacté par des conditions hydrogéologiques variant au fil du temps. Plus d'emphase doit être placé également sur le monitoring durant et après la mise en place du minerai afin de vérifier continuellement les hypothèses de conception et afin d'identifier des enjeux durant les opérations et développer des mesures de mitigation si requis.

1 INTRODUCTION

This paper discusses some key aspects associated with the design and operation of heap leach facilities (HLF) in areas with significant topographical relief and associated complex hydrogeological regime. HLF have been a key method for ore extraction in warm and arid climates – at least since the 1980s (Smith, 2008). Now use is expanding in other areas with colder climates and areas with higher precipitation. For example, recent successful applications of the technology have been reported at Kinross Fort Knox mine in Alaska (Bradner, 2012).

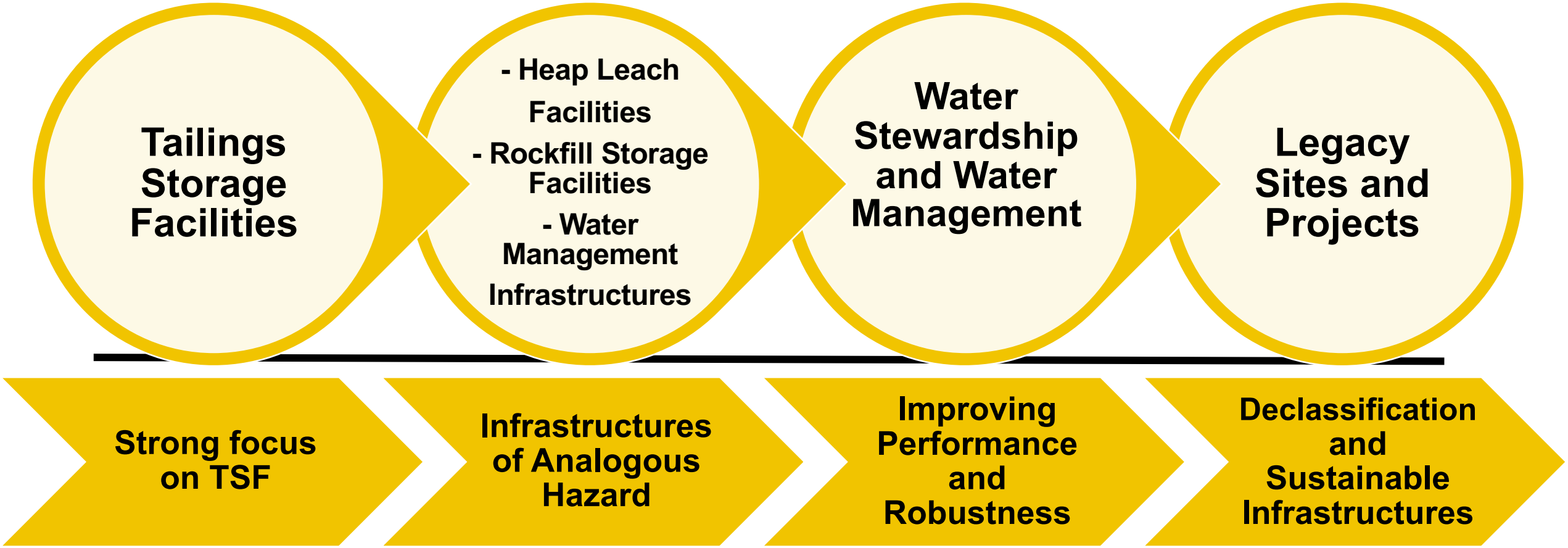
HLF design is influenced and benefited from materials and techniques used in landfill design. These designs share many similarities but also many differences (Renken et.al., 2005). Typically in the mining industry, extractive processes to recover minerals from the orebody are done fairly close to deposit being mined. HLF can therefore be located in challenging terrains and environments, including in areas with significant topographical relief, complex foundations and hydrogeological conditions. In contrast, landfills tend to be located in more suitable locations.

Heap leaching is an attractive technology for mineral extraction offering many advantages when compared to more traditional methods. It allows the exploitation of low grade orebodies, has fairly low operating and capital costs. The mined ore is usually crushed and placed on a low permeability geomembrane and/or clay lined surface where it can be irrigated with a solution that percolates through the ore and gradually dissolves or removes the valuable metals/minerals. The leach solution containing

Heap Leach Facility in 2012

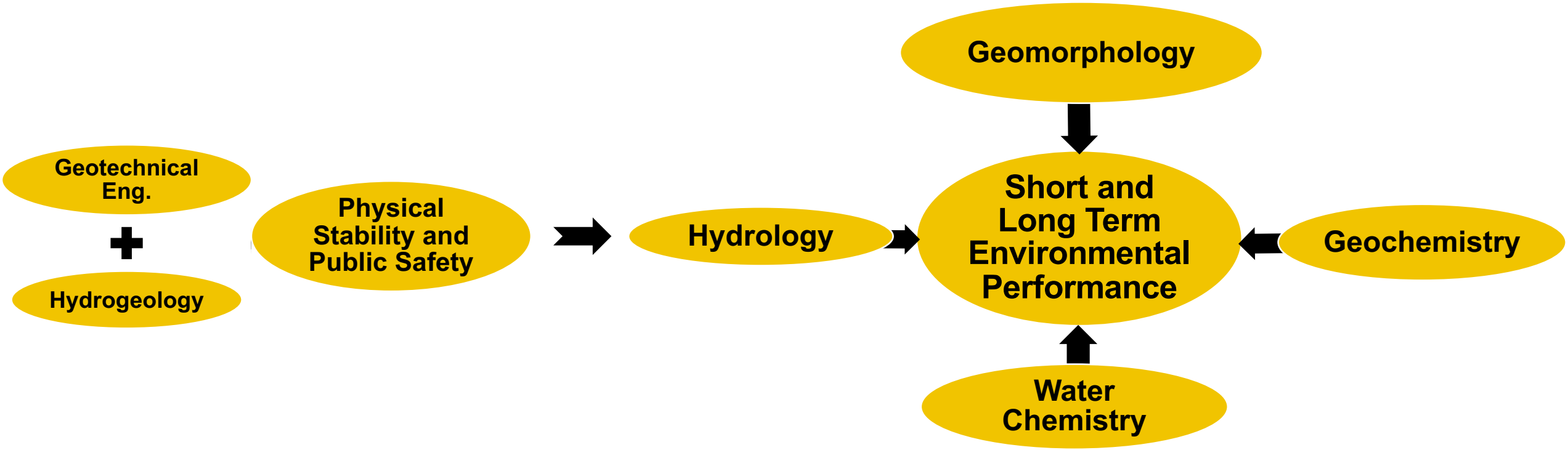
AGNICO EAGLE

Expanding the scope



3. OUR JOURNEY (2018-2025): A LARGE PORTFOLIO OF INFRASTRUCTURES

3. OUR JOURNEY: MORE TECHNICAL DIVERSITY IN REVIEW BOARDS AND TEAM'S BACKGROUND



Strong focus on geotechnical aspects

More integrated approach in review of facilities

4. THE BIG TOPICS

- ✓ The so-called *Brittle Materials* – the materials that could lose their strength with deformation;
- ✓ Undrained or drained analysis - Liquefaction potential;
- ✓ Dam break analysis;
- ✓ Filtered tailings performance;
- ✓ Water management, hydrology and water chemistry;
- ✓ Aging of infrastructures and their retrofit with changing regulations and practice;
- ✓ Climate change and extreme events;
- ✓ Declassification of infrastructure, landforms and closure design.

4. THE BIG TOPICS: CONSTRUCTION ON TAILINGS

The mining industry has been able to master this type of construction

4. THE BIG TOPICS: THE DISCUSSION ON UPSTREAM RAISES

However, I side with the views of Martin & McRoberts (1999) and others (…) ***that there is nothing wrong with upstream tailings dams provided that key principles are adhered to in the design, construction, and operation of such dams*** *(…)*

In my practice, I advocate for purposes of preliminary design that liquefiable deposits that can liquefy be assumed to do so ***and that containment be provided by a buttress of non-liquefiable unsaturated tailings and/or compacted dilatant material****.*

N.R. Morgenstern, 2018 - Victor de Mello Lecture - Soils and Rocks 41(2): 107-129

4. THE BIG TOPICS

AGNICO EAGLE

Observational Method

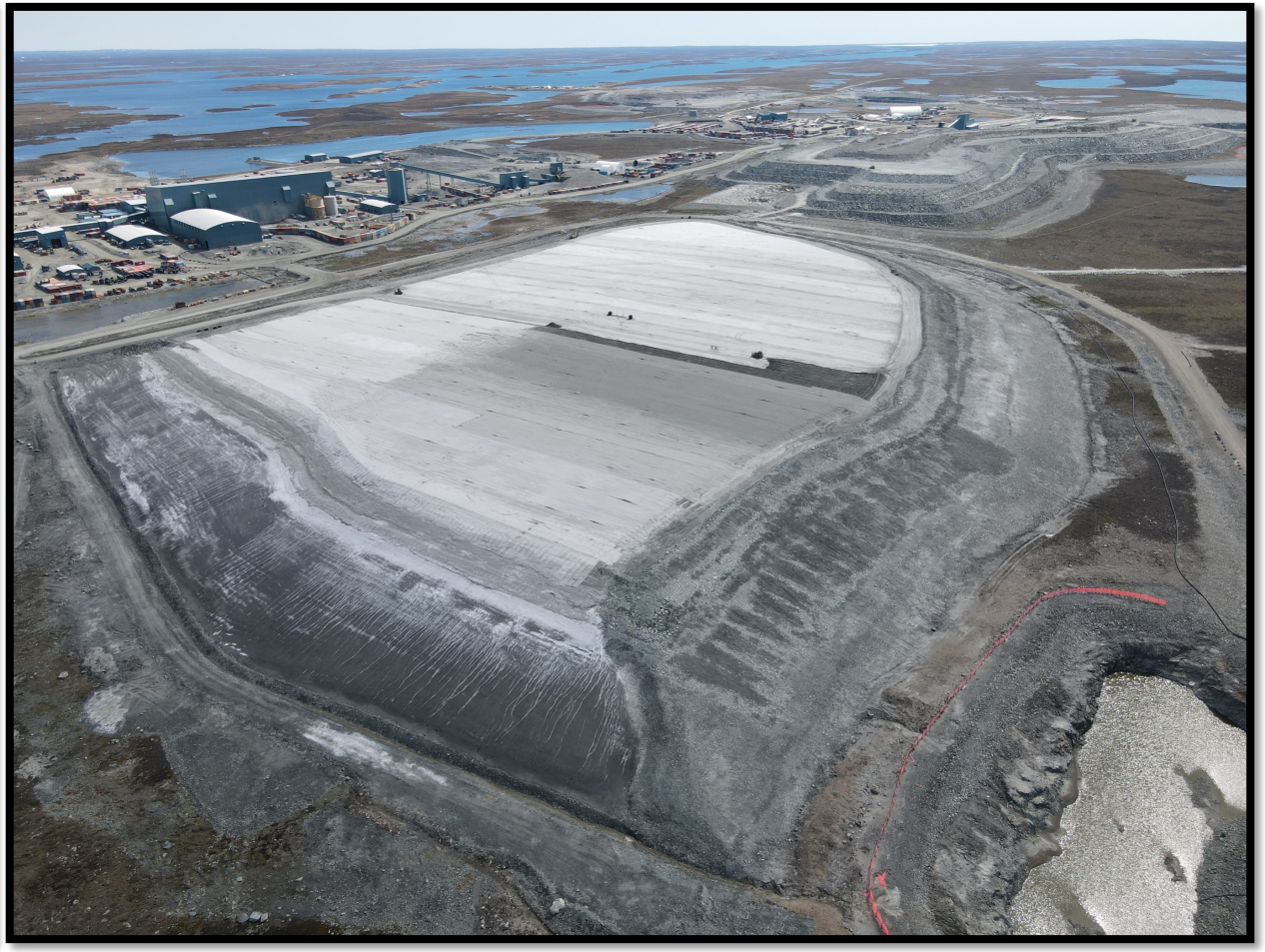
- **Evolution from Observational Method *(Peck, 1960)* to Performance Based Design :**
  - ✓ **Brittle Foundations: Foundations with materials that can exhibit strain weakening/brittleness or a general contractive behavior.**
  - ✓ **Liquefiable Tailings: Contractive tailings that may exhibit loss of strength under static or seismic induced liquefaction (residual or post-liquefaction strength).**

Performance Based Design

- **Performance Based Design (can be a long process) :**
  - ✓ **Develop performance criteria;**
  - ✓ **Understanding material behavior;**
  - ✓ **Modeling it over wide range conditions;**
  - ✓ **Calibration and adjust models with evolution of site;**
  - ✓ **Adapt the design.**

4. THE BIG TOPICS: FILTERED TAILINGS PERFORMANCE

LaRonde Mine



Meliadine Mine

4. THE BIG TOPICS: DAM BREACH ANALYSIS

- State of practice still not well established and based on very approximate techniques and these studies have huge consequences for a project.
- May lead to wide range of scenarios – worse one will always prevail.
- Default assumption: irrespective of engineering controls, the system will fail.
- May lead to difficult conversations – talking about risk is difficult when private properties involved.
- Need to be ready to tackle complex messaging when agreement is reached.
- Realism on what can be achieved with warning and alarm systems.

AN EXAMPLE

Excerpts from an actual report:

XXXX used the estimated solids content (70% to 73%) and the laboratory tested yield strength (20 Pa) of the XXXX tailings to identify their flow behaviour when mobilized.

Both "slurry flow" … and "granular flow" … were proposed as plausible, based on literature sources.

Slurry flow was modelled using the Bingham Non-Newtonian Model, which led to long run-out distances of the mobilized tailings.

Granular flow was modelled assuming a frictional rheology model as well as a plastic rheology model.

AN EXAMPLE

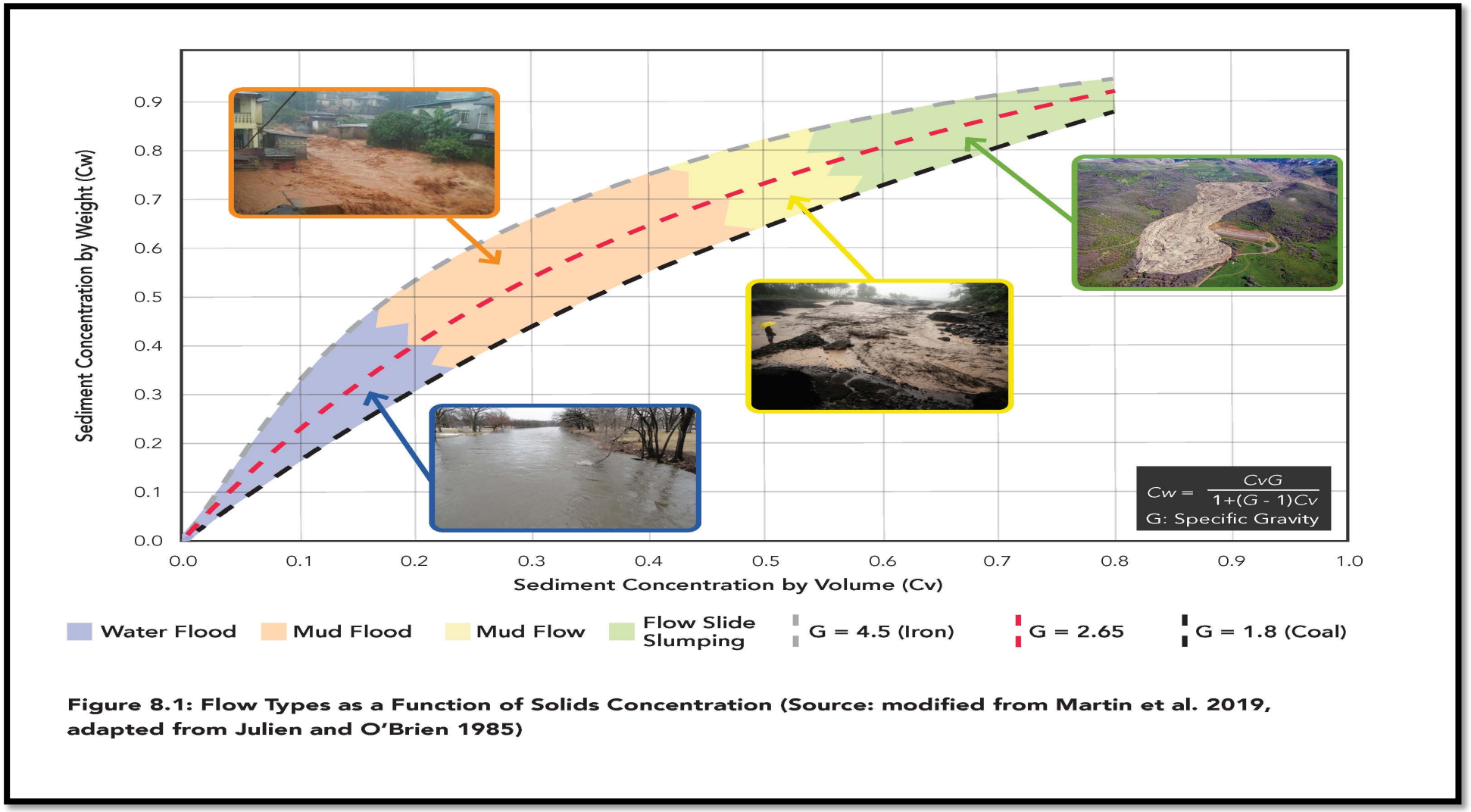


Figure 8.1: Flow Types as a Function of Solids Concentration (Source: modified from Martin et al. 2019, adapted from Julien and O'Brien 1985)

Guidelines for Tailings Dam Breach Analyses *(*Technical *Bulletin Canadian Dam Association, 2020)*

5. BENEFITS AND CHALLENGES

- Achieves consistency and more measurable performance throughout the organisation;
- Creates a more coherent and collaborative environment between operations, designer and EoR;
- Provides redundancy in review;
- Scope creep is happening naturally and requires broader expertise;
- The process requires a lot of work but empowers operations.

5. BENEFITS AND CHALLENGES: INTERNAL EOR

- Regarding the role of the EoR, many models are possible;
- The ultimate objective is to effectively manage risks associated with mining dams and demonstrate our capability to do so;
- The key ingredient is to have a clear governance, well understood and recognizing the role, importance and responsibility of the Owner;
- Over-emphasis exists on the EoR role. The EoR is only one part of the system;
- It is important to create a collaborative environment where roles and responsibilities are clear.

CONCLUSION

- Agnico Eagle governance model of environmental critical infrastructure is one among many others;
- Key: close interactions with operations;
- It addresses many types of infrastructures;
- The scope evolved with time by including more water management and closure aspects;
- Review Board and EoR background becoming more diversified;
- There are big topics: State of Practice has greatly evolved but recurring topics.

AGNICO EAGLE

Trading Symbol:
AEM on TSX & NYSE

Investor Relations:
416-847-8665
info@agnicoeagle.com

agnicoeagle.com

WORLD GOLD COUNCIL