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Organismo Supervisor de la Inversión en Energía y Minería

The Impact and Response in Canada to the Failure at the Mount Polley Tailings Storage Facility

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Acknowledgements

- Report on the Mount Polley Tailings Storage Facility – Independent Expert Engineering Investigation and Review Panel (IEEIRP) January 30, 2015. https://www.mountpolleyreviewpanel.ca/
- Dr. Andy Robertson – The Value of Failure

Introduction

- A breach occurred within the perimeter embankment of the Mount Polley Tailings Storage Facility on August 4, 2014.
- The loss of containment was sudden and occurred without warning.
- An Independent Expert Engineering Investigation and Review Panel was commissioned by the British Columbia Ministry of Energy and Mines.
- The PANEL consisting of Norbert Morgenstern (Chair), Stephen Vick, and Dirk van Zyl released their report on the Mount Polley Tailings Storage Facility Breach on January 30, 2015.

Media, Public Interests and Opinions

- Reactions in the media were as expected
- Steven Hume at the Vancouver Sun who on February 11, 2015, wrote, “It is now pretty clear what happened at Mount Polley leading up to the dam bursting last August and spilling 24,000,000 m^3 of toxic mine tailings, silt and waste water into the Quesnel, and ultimately the Fraser River systems, potentially putting thousands of people and millions of migrating salmon at risk”.
- No matter how theatrical and spectacular we believe such reports are, they capture the paradigm of the culture within which we must operate and ultimately obtain social license.

Facts and Opinions

- While it is an event we consider to be of extremely high consequences, it may well be a blessing in disguise. (Opinion)
- It could have been much worse in terms of loss of life, environmental damage & financial cost if the event occurred at another site. (Fact)
- We recall the Hungarian 2012 failure
  10 fatalities and flooded > 8 km^2
  of the surrounding terrain. (Fact)
- There are a number of significant tailings impoundments in close to large urban Canadian populations (Fact)

Facts and Opinions

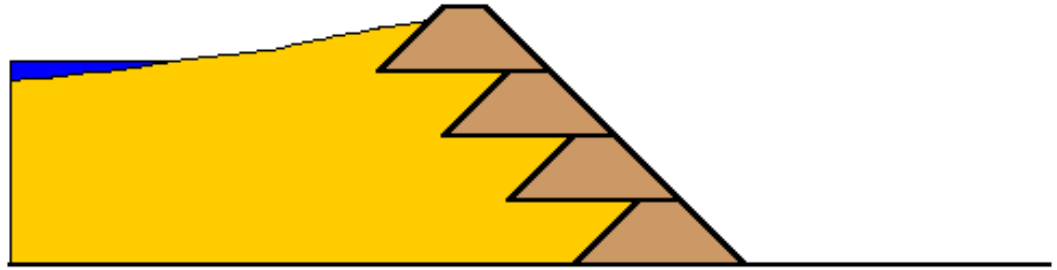
- Alberta has some of the largest tailings dams in the world (Fact)
- Internationally respected Dr. David Schindler declared, “If any of those tailings ponds were ever to breach and discharge into the river, the world would forever forget about the Exxon Valdes”. (Opinion)
- The writer believe that the dam safety systems for the oil sands in the Province of Alberta are of the best worldwide. (Opinion)
- In contrast to this opinion, at the time of the event, the Auditor General of Alberta stated, “The department’s dam safety group has no requirement to document its work, and without such reports, it’s hard to know if Alberta’s dams are safe”. (Reasonable Question)

Failure Mechanisms

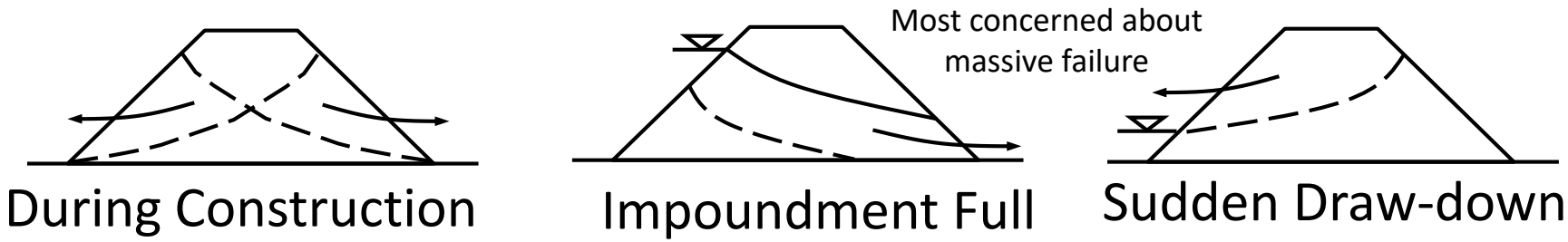
- Over-Topping of the Dam
- Slope or Foundation Failure
- Piping or Erosion Failure
- Cracking
- Seismic Loading and/or Liquefaction

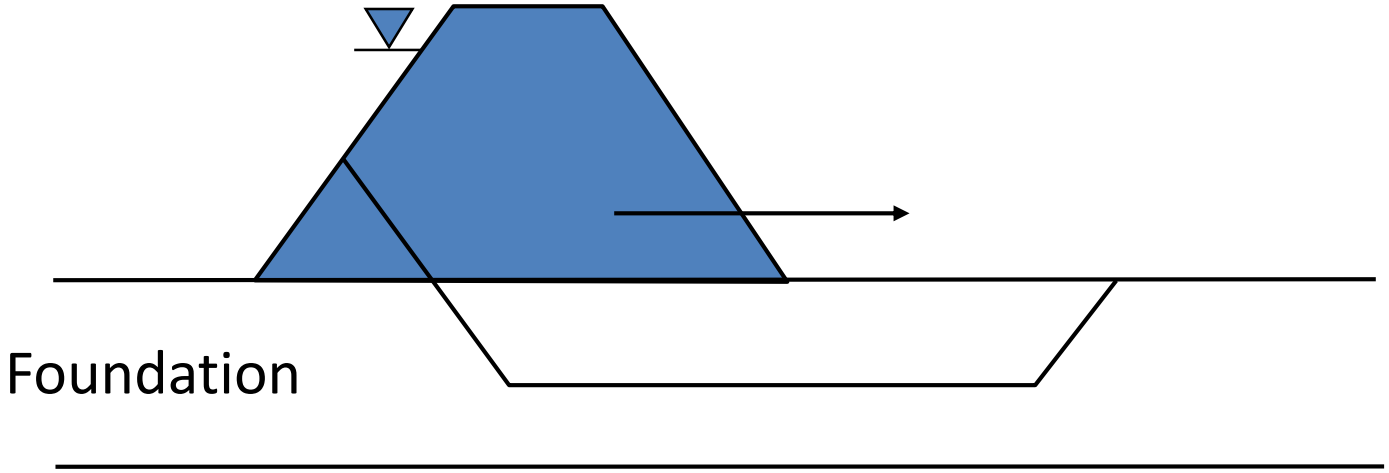
Over-topping of the Dam

- Resulting from inadequate discharge and hydraulic structure capacity
- Heavy rains, dam overtops and fails
- Under estimate design flood hydrology
- Caused by erosion due to freeboard waves



Slope Failure



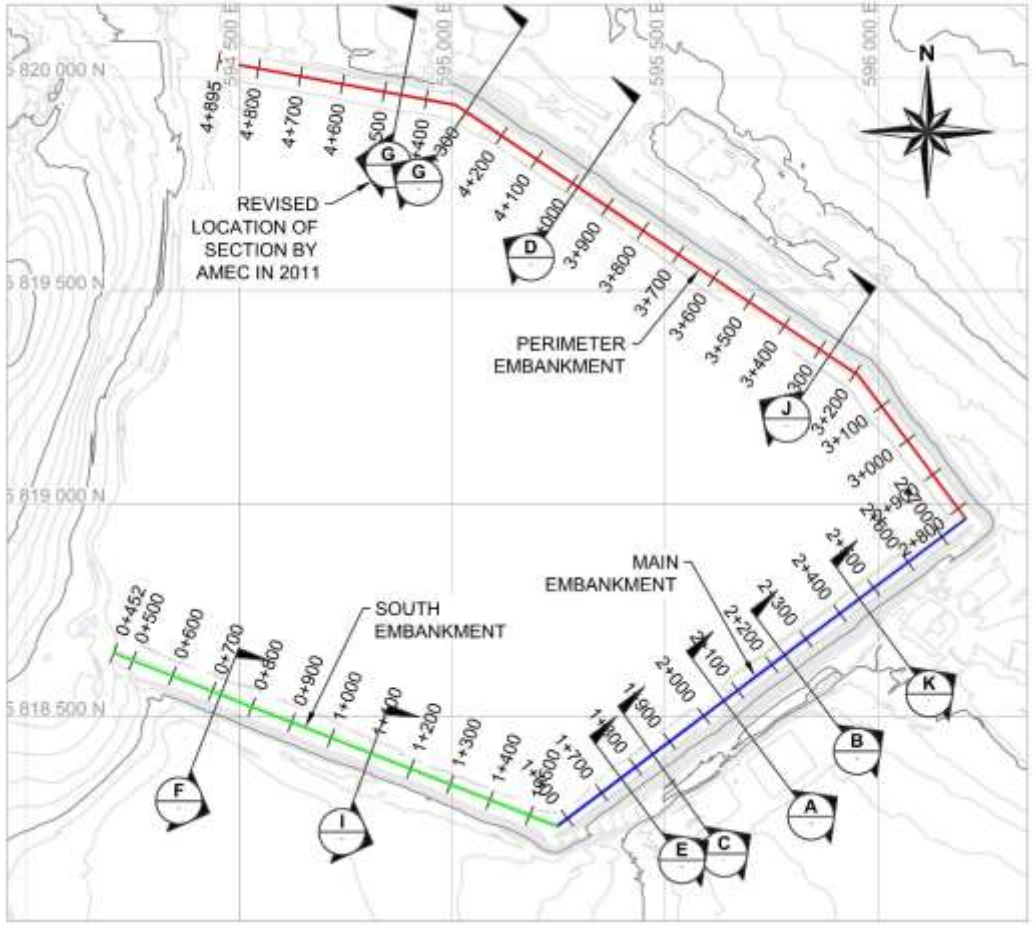


Possibility of a weak foundation layer. Los Frailes is an excellent example. The placement of tailings is not as well controlled as water dams. Need strength and porewater pressures of foundation soils.

Foundation Failure at Los Frailes

Mount Polley Tailings Storage Facility

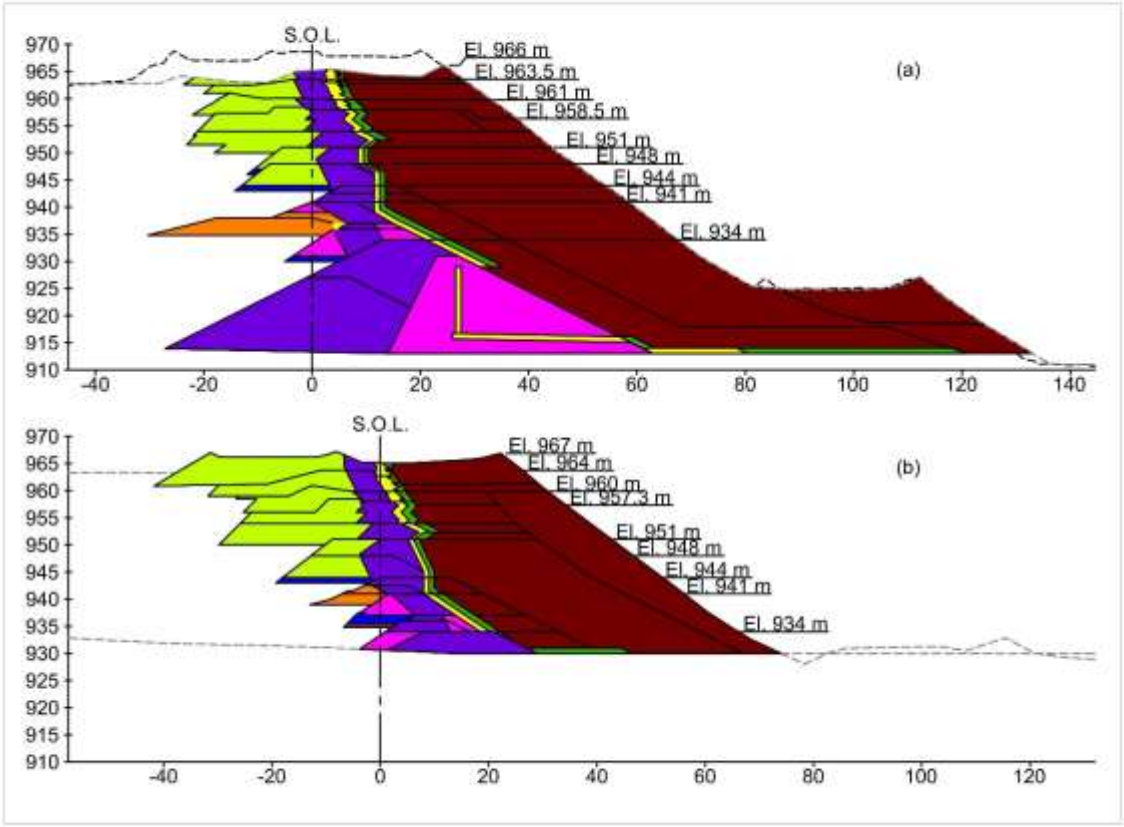
FIGURE 3.1.1: TAILINGS STORAGE FACILITY PLAN



IEEIRP (2015)

Dam Configuration

FIGURE 5.4.10: DAM CONFIGURATION ON AUGUST 3, 2014. (a) MAIN EMBANKMENT (b) PERIMETER EMBANKMENT AT BREACH SECTION



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View Looking Downsteam

FIGURE 5.1.2: VIEW LOOKING DOWNSTREAM SHOWING UPSTREAM SIDE OF DAM AND REMAINING TAILINGS

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View Looking Upstream

FIGURE 5.1.1: VIEW LOOKING UPSTREAM THROUGH THE BREACH (ARROW SHOWS DIRECTION OF OUTFLOW)

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Rotation of Left Abutment

FIGURE 5.1.5: APPARENT BEDDING ROTATION ON LEFT ABUTMENT OF BREACH (SEPT. 4, 2014 PHOTO)

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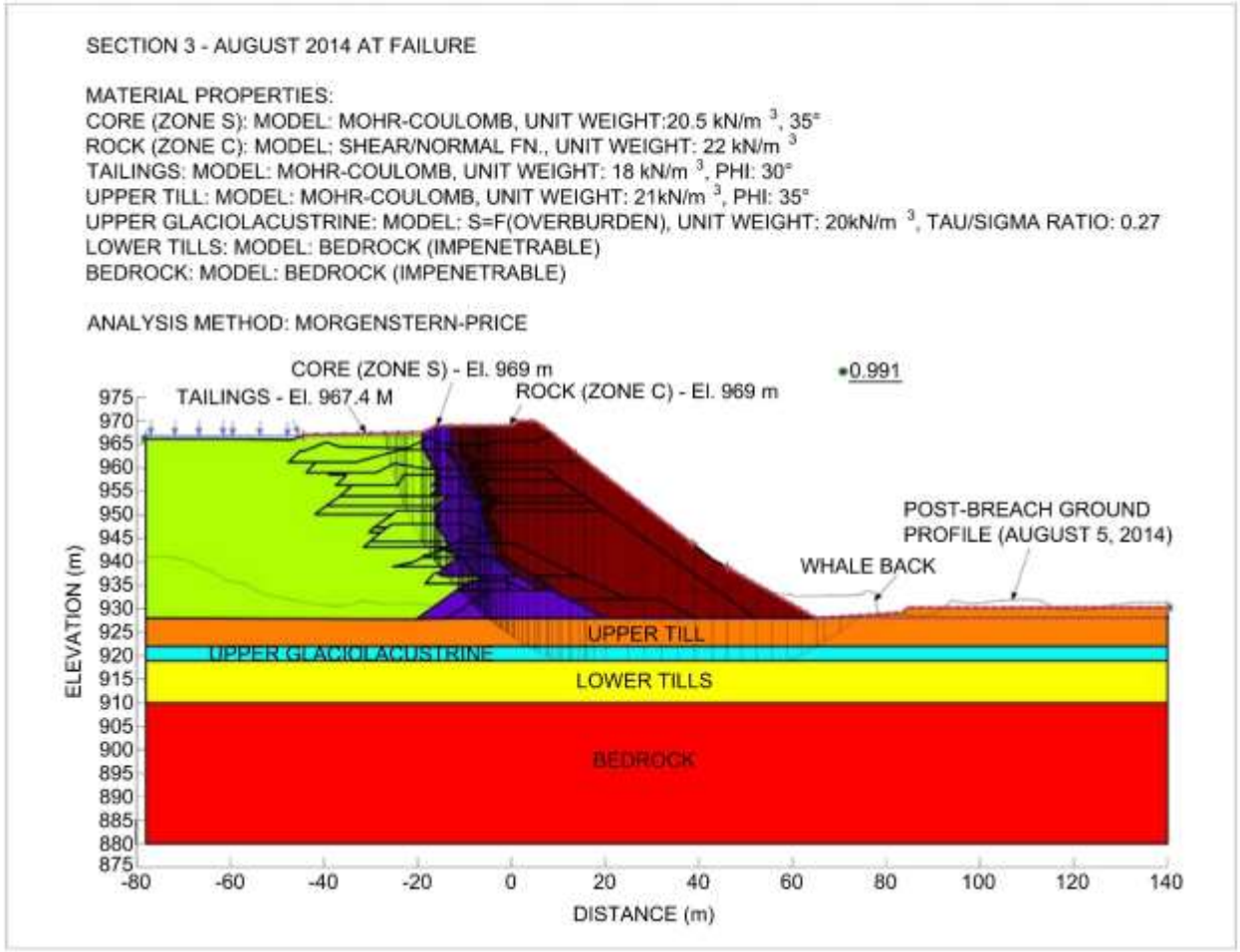
Detailed Section for Limit Equilibrium Analysis

FIGURE 6.2.1: DETAILED SECTION USED FOR LIMIT EQUILIBRIUM ANALYSIS (HIGH WATER TABLE, UNDRAINED STRENGTH RATIO 0.27)



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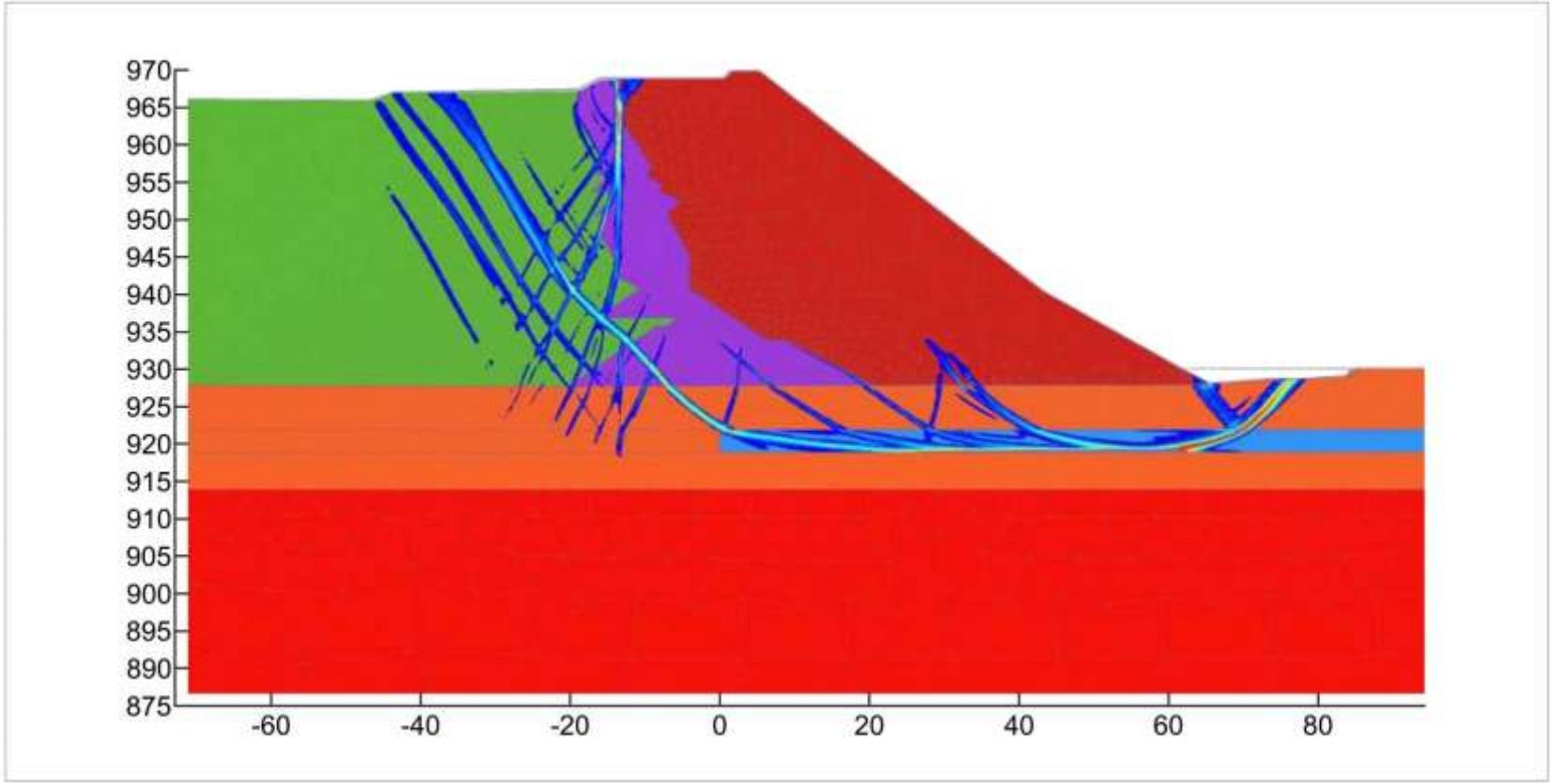
Plaxix Model at Collapse

FIGURE 6.2.3: PLAXIS MODEL AT COLLAPSE (UNDRAINED STRENGTH RATIO 0.29)



IEEIRP (2015)

Right Abutment September 4, 2014

FIGURE 5.1.6: SLIDING-RELATED FEATURES AT RIGHT ABUTMENT (SEPT. 4, 2014 PHOTO)

IEEIRP (2015)

The Value of Failure

- Possibly the greatest lasting consequence of this failure is the breach in trust that has occurred in the reliability of modern tailings dams.
- Perhaps the greatest benefit that can come from this is the great and lasting change that is occurring in the mining industry worldwide.
- One could argue that the greatest value found in any one failure is that it rivets attention and forces us to examine and re-evaluate all of our structures and systems.

The Report

- The report on the Mount Polley Tailings Storage Facility Breach issued by the PANEL is comprehensive. The principal finding was that the breach as a result of a foundation failure the Upper GLU.
- Historical record of active tailings dams in the province of British Columbia during the 46 years since 1969, and the 7 failures that have occurred during this period.
- The province can expect (on average) that there will be 2 failures every 10 years.
- Based on this analysis, “the panel firmly rejects any notion that business as usual can continue”.

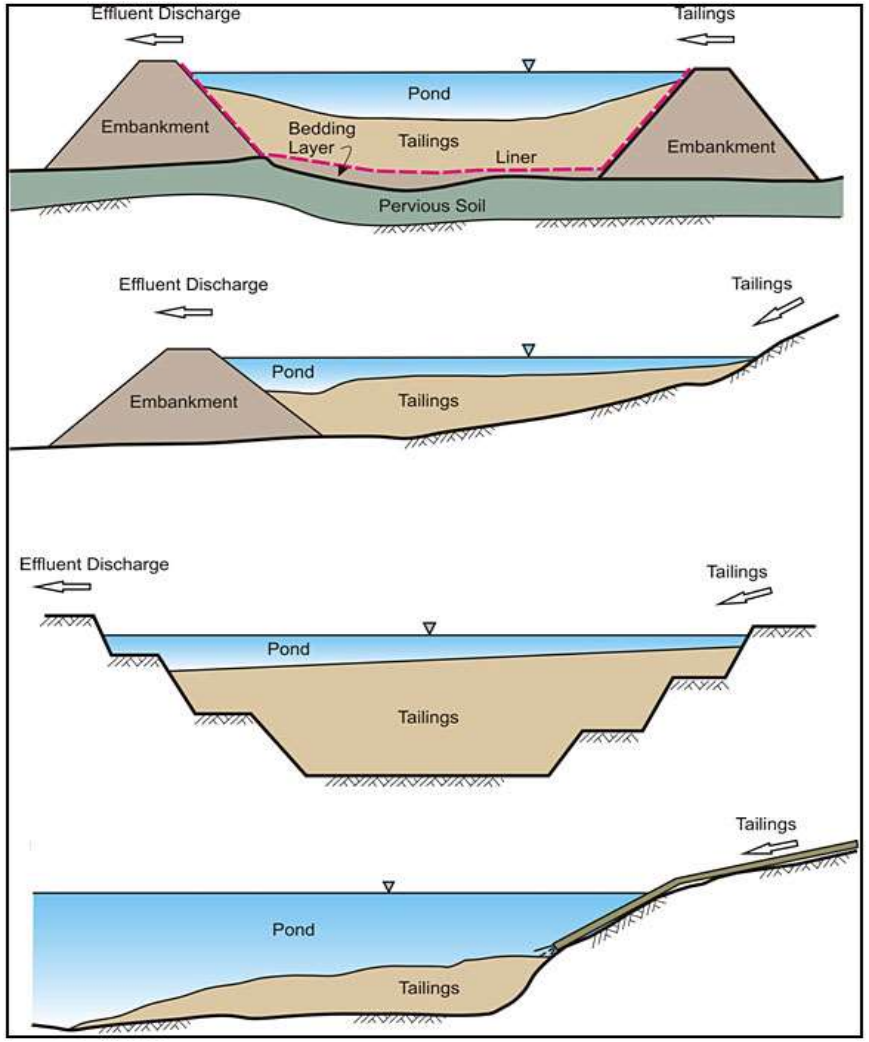
BAT Principles

With respect to risk-based dam safety practice, “the panel does not accept the concept of a tolerable failure rate for tailing dams”. This assertion resulted in the panel recommending the implementation of the best available tailings technology (BAT) based on the BAT principles that are outlined as follows:

1) Eliminate surface water from the impoundment.
2) Promote unsaturated conditions in the tailings with drainage provisions.
3) Achieve dilatant conditions throughout the tailings deposit by compaction.

GARD Guide - Subaqueous Tailings Disposal

- Water covers are routinely employed as a preferred strategy for the long-term closure of reactive tailings worldwide as outlined by the global acid rock drainage (GARD) guide.



BAT Principles

- The panel recognized the issue of chemical stability associated with the elimination of water from the tailings deposits, but BAT principles stand as a strong recommendation for future tailings deposits.
- Implementation of the BAT principles for the surface storage of tailings can lead to the use of filtered tailings technology.
- When properly designed and formed can satisfy each of the BAT components. The panel points to the Greens Creek mine in Alaska as an example where “dry stack tailings” have been successfully constructed in a wet climate similar to many sites in British Columbia.

Greens Creek Filtered Tailings Stack

For Clarity

- The Panel report on the Mount Polley Tailings Breach and were written for the Government of British Columbia.
- For clarity, it is important to point out that the mandate given was for the ‘Safety Case’ and not environmental issues.
- The panel points out “water covers run counter to the BAT principles” and that “the Mount Polley failure shows why physical stability must remain foremost and cannot be compromised”.
- Greens Creek was given by the panel as an example for the application of BAT principles, and that other methods of tailings disposal can achieve these principles and should also be evaluated.

Implications

- Adoption of the BAT principles will create new challenges.
- Implementation of BAT principles for physical stability (BAT-PS) is not BAT for chemical stability (BAT-CS).
- Geochemists will reject the implementation of the BAT-PS principles due to the potential for acid rock drainage and metal leaching (ARD/ML).
- The key design principle for the prevention of ARD for tailings is to maintain full saturation within the profile.

Implications

The general principles laid out in the GARD guide (BAT-CS) contradict the BAT-PS principles, leaving mine waste professionals faced with competing or conflicting design criteria. The PANEL, along with geotechnical engineers and geochemists recognize this “Catch 22” situation.

Chemical Stability

Physical Stability

Expertise in BAT-CS

- British Columbia's expertize in ARD/ML is world renowned with aquatic standards used worldwide.
- The tradition of expertise in British Columbia dates back to 1989 with the publication of the Draft Acid Rock Drainage Technical Guide - British Columbia Acid Mine Drainage Task Force.
- The Annual BC-MEND ARD/ML Workshop has enjoyed more than 20 years of success, regularly attracting worldwide experts.
- The expertise available within the technical community of British Columbia will be successful in the integration of the BAT-PS principles with the well-established principles for the prevention of acid rock drainage and metal leaching (BAT-CS).

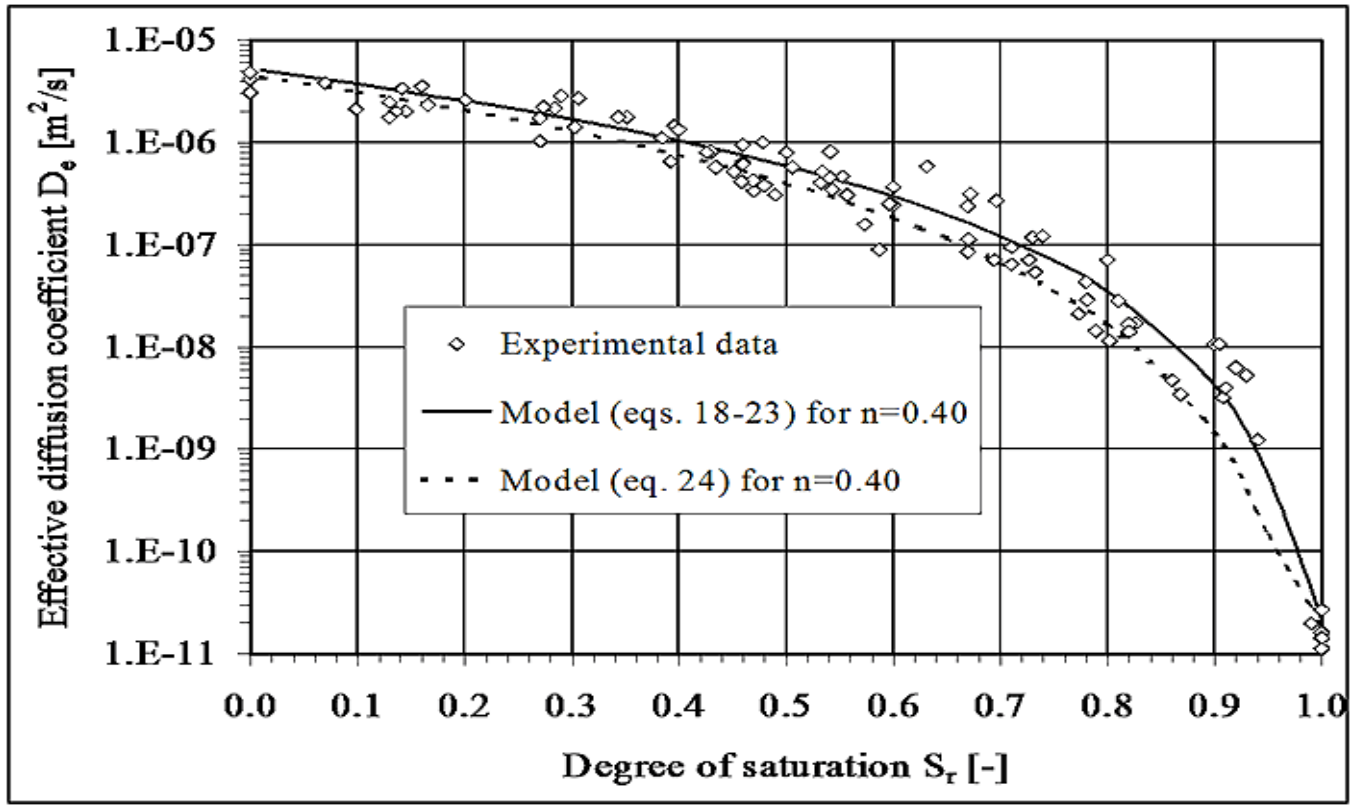
New Opportunities

A key component for the design of dry tailings stacks will be the degree of water saturation within the tailings profile

1) Tailings profiles with water saturation levels less than 85% are considered resistant to liquefaction.

2) Conversely, tailings profiles with water saturation levels greater than 85% are considered resistant to oxygen diffusion and subsequent ARD.

Diffusion vs Saturation

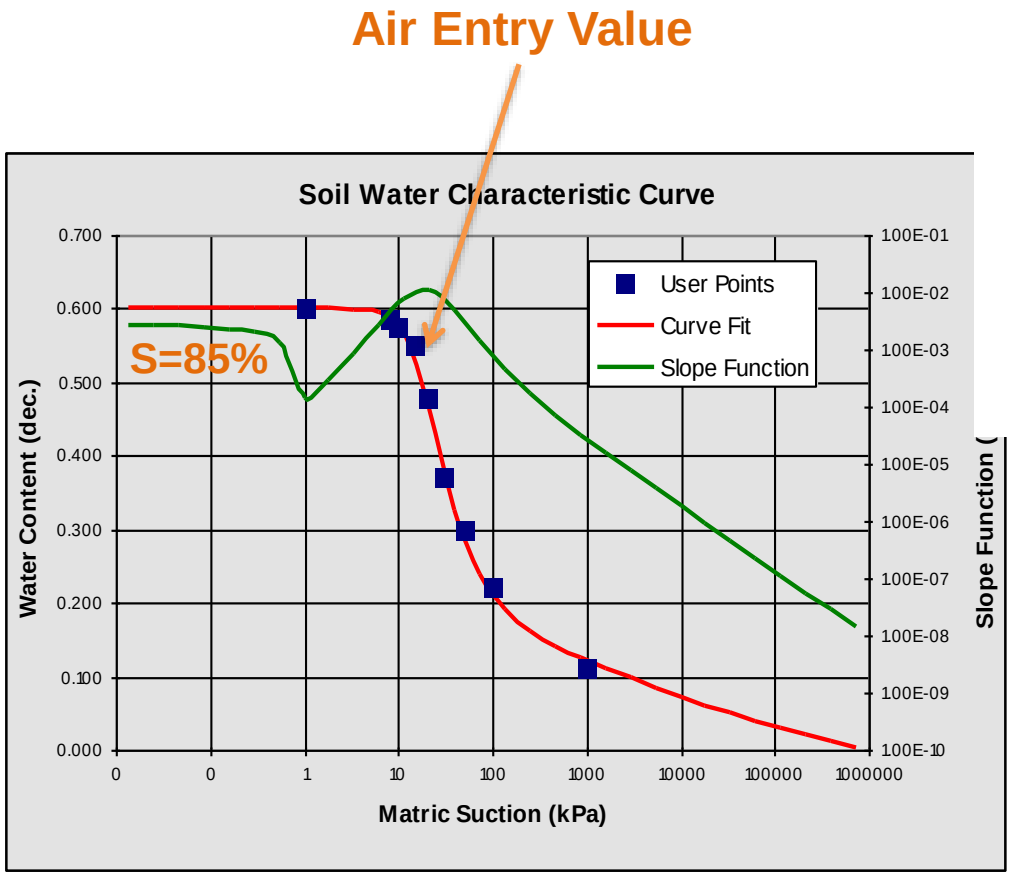


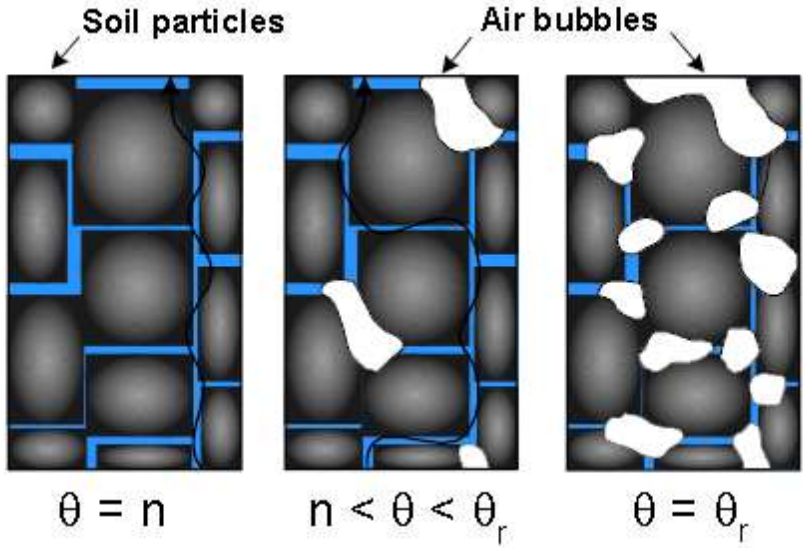
Coefficient of Diffusion versus Degree of Saturation for Saturated Porous Media (from Aubertin, 2005)

New Opportunities

- Successful implementation of the BAT principles for both PS and CS will now relies on understanding of unsaturated soil mechanics.
- The Soil-water characteristic curve (SWCC) of the tailings controls water saturation as a function of matric suction.
- The control infiltration rates and oxygen fluxes for the prevention of ARD is based on coupling hydraulic properties of the SWCC with microclimatic conditions.
- Cover system used for final closure will need to provide infiltrative fluxes that optimize unsaturated flow conditions in the tailings.

Soil Water Characteristic Curve





New Opportunities

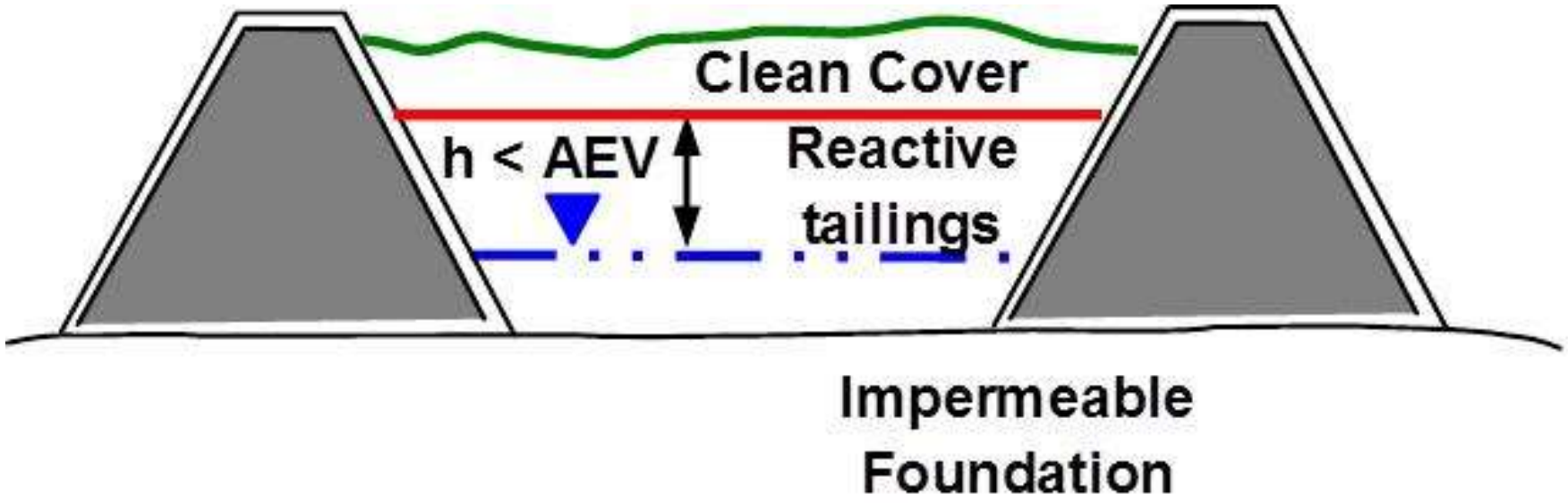
- The design of dry tailings stacks for both operation and closure will advance as BAT-PS & BAT-CS principles are coupled.
- ARD/ML will likely become one of the most significant risks for long-term environmental impacts and closure costs.
- New methods of FMEA to optimize the design of stacks that produce the best combination of BAT-PS and BAT-CS principles will be necessary (Shaw and Robertson, 2015).
- Including both PS and CS failure mechanisms in the FMEA will optimize the trade-offs.

New Opportunities

- Filtered tailings dry stacks are not the only method for BAT-PS. The panel is simply not recommending the use of filtered tailings dry stacks, but more importantly they are recommending BAT Principles.
- Alternates may include paste and thickened tailings, cycloned sand or even conventional slurries with extended beaches, underdrains and compacted lifts.
- Similarly, wet disposal of ARD tailings should not be considered the only method of BAT-CS.
- BAT should be a combination of technologies, that when combined, result in the least risk of physical and chemical instability.

Elevated Water Tables in Tailings

Consider Elevated Water Tables in Reactive Tailings That Maintain Saturation without Water Covers (Aubertin et al, 1999).



New Opportunities

- De-sulphurization and the production of clean tailings will also provide new opportunities. De-sulphurized tailings were applied as clean cover for closure of the tailings beach at Detour Mine in 1999.
- A recent study reported by Cash et al. (2012) demonstrated that that cover has performed very well more than 10 years since closure.

New Opportunities

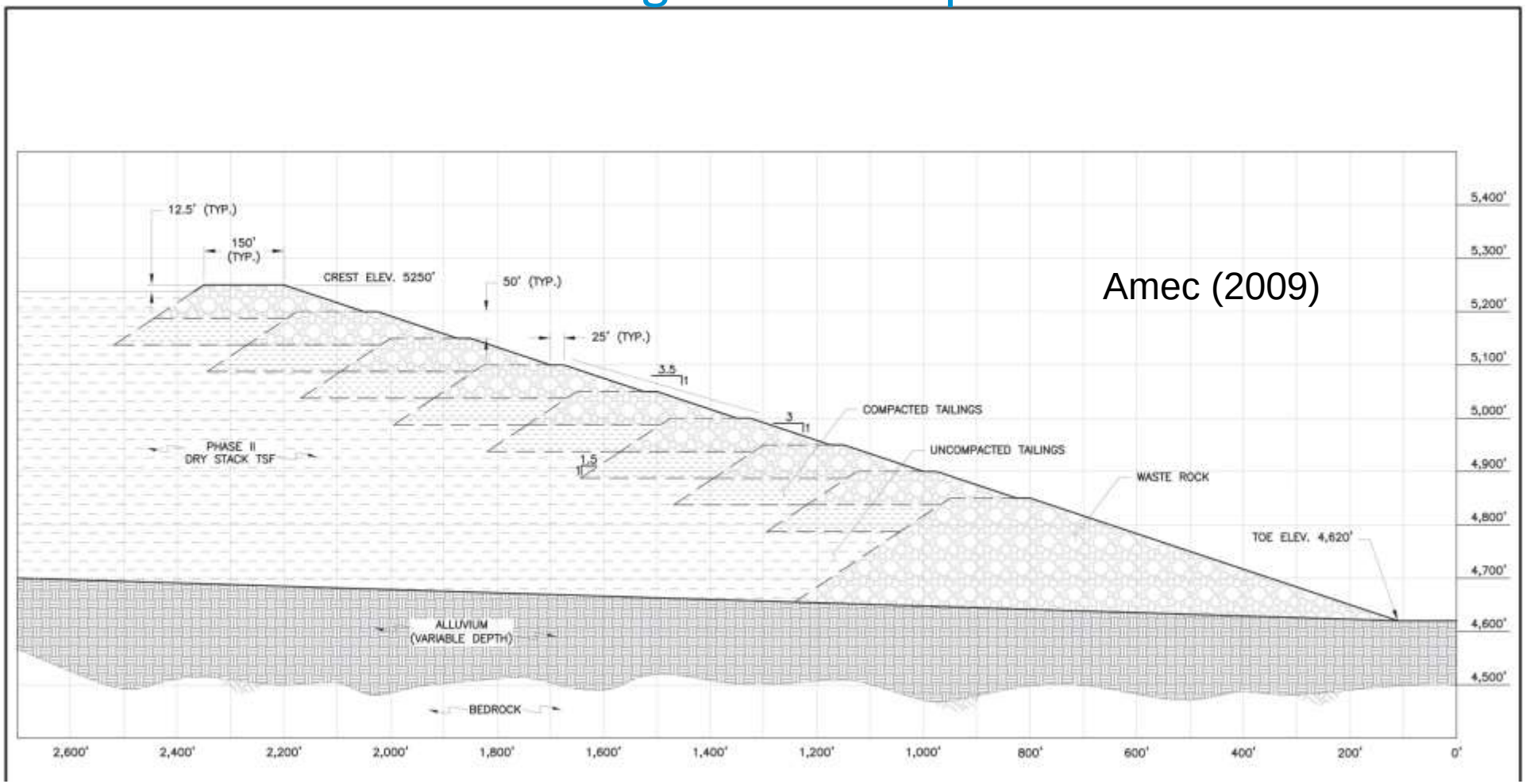
- A transition to filtered tailings may offer other new opportunities for mine waste management.
- An immediate benefit may be the reduction of the footprint required for the tailings impoundment.
- Progressive closure during construction of stacks.
- Co-disposal of reactive mine waste rock layers may be co-mingled with filtered tailings to serve as sealing layers that prevent advection of oxygen in the waste rock.
- Filtered tailings may be blended with waste rock and mixed at an optimum ratio to form a dense high strength paste rock.

New Challenges

- Scale may also present of the additional challenges and difficulties.
- The implementation at large mines may be prohibitively expensive or require logistics that we are not yet capable of.
- While the technology and capacities for filtration systems are rapidly developing, metal mines keep getting bigger with tailings production rates often exceeding 120,000 tpd, and the largest currently under construction at 360,000 tpd.
- The elimination of ponds may be difficult in very wet climates where runoff control has to be practiced, and the construction of stacks may be difficult in high rainfall regions.
- FMEA and MAA evaluations play an increasingly important role in deciding on what is BAT for any individual project.

De-Watering *In-Situ* is Difficult

The Primary Advantage of Dry Stack Tailings is De-watering Prior to Deposition



Amec (2009)

New Questions

- Is there opportunity to ask some soul searching questions about the reliability of our engineering capability?
- Is there vulnerability in our practice when designing tailings dams that are built over decades by a succession of engineers/constractors; as distinct from water dams which are typically designed and constructed by one team?
- Can we steward and perform engineering to the standards that will be expected of the dam during both its long operating life and into the very long term applicable to post closure?

CDA – Dam Safety Guidelines (2014)

Target Factors of Safety for Slope Stability in Construction, Operation and Transition Phases – Static Assessment

Loading Condition	Minimum Factor of Safety	Slope
During or at end of construction	> 1.3 depending on risk assessment during construction	Typically downstream
Long term (steady state seepage, normal reservoir level)	1.5	Downstream
Full or partial rapid drawdown	1.2 to 1.3	Upstream slope where applicable

Target Factors of Safety for Slope Stability in Construction, Operation and Transition Phases – Seismic Assessment

Loading Condition	Minimum of Safety Factor
Pseudo-static	1.0
Post-earthquake	1.2

Failures with Similar Causes

Los Frailes, Spain - 1998

Mount Polley, Canada - 2014

Major changes are the maximum slope angle must not exceed 2H:1V, and

Minimum Factor of Safety during Dam raise construction after start up is 1.5

Accountability and Responsibility

- The MAC Guide outline roles
  https://cda.ca/EN/Announcements/Active/Committee_proposes_change_EOR.aspx
- Accountability for Dam Safety Rests with the Owners Board of Directors
- Boards of Directors Designates an Accountable Executive Officer
- A Responsible Person with Appropriate Qualifications is Delegated Responsibility for Dam Safety Management
- The Owner Must Identify and Retain an Engineer-of-Record

Engineer of Record (EOR)

- Provides technical knowledge related to the safety of the mining dam
- Verifies the design is in accordance with performance objectives and indicators, objectives, applicable guidelines, standards and regulatory requirements
- Verifies the dam has been constructed and is performing, throughout the life of the dam, in accordance with the documented design intent and requirements.
- Advises the owner of discrepancies and makes recommendations for necessary corrections or remedial actions.
- Will be a consultant to the Owner or a member of the Owners' staff

Summary and Conclusions

- There is value arising from the failure at Mount Polley.
- New Dam Safety Standards, Regulations and Management Requirement.
- Expect the drive to evaluate, test and implement emerging and new technology will add knowledge that will generate opportunities to create earth structures on mines that are both physically and chemically stable.
- These new mined earth structures will be easier to reclaim and transition to land uses that are environmentally secure and socially acceptable.

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