Some challenges in tailings management: a young professional's perspective

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About Myself

- Tony
  - One cold morning in 2011, I hitchhiked with a co-worker from reclamation department on a grand tour of Suncor's tailings ponds.
- Mentors from the industry
  - You should consider graduate studies but wait until the downturn
  - You will find little distraction in Edmonton
- Mentors at University of Alberta
  - You should stay relevant to the industry
  - You should take advantage of the resources available to graduate students

UAlberta Geotechnical Centre

- Weekly graduate research seminar series (Undergraduates welcome) Virtually on Zoom with recordings available at:

  https://www.youtube.com/c/UAlbertaGeotech

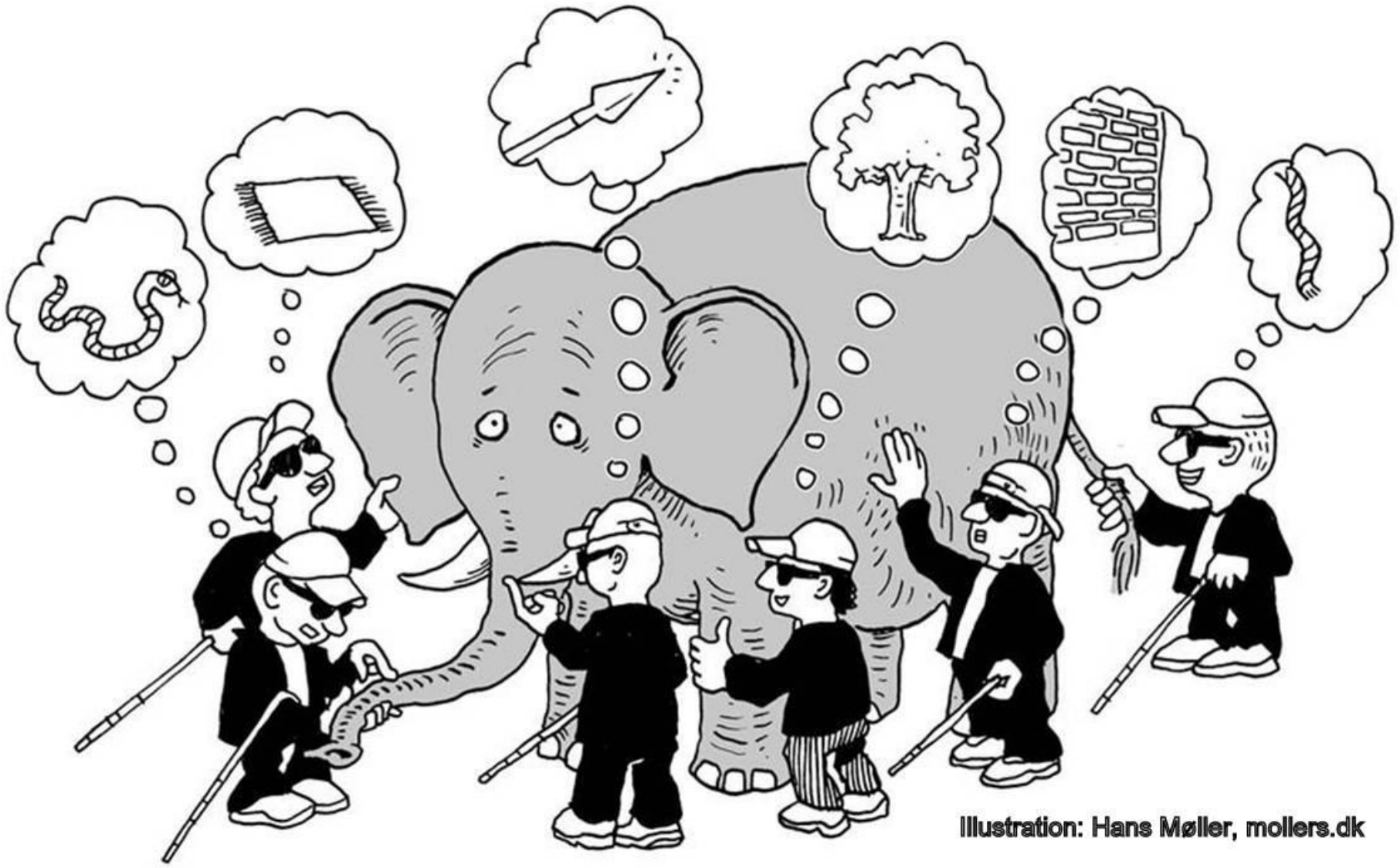
- Canadian Geotechnical Society U of A Student Chapters

  https://sites.google.com/ualberta.ca/uacgs/home

- Oil Sands Tailings Research

  https://www.ostrf.com

Tailings Management System



Challenge #1: Common Language

- A typical engineering team with a focus on tailings consists of:

Mining engineers
Geologists
Geotechnical Engineers
Hydrogeologists

Mining

Chemical Engineers
Mechanical Engineers
Electrical Engineers

Processing

Chemical Engineers
Mechanical Engineers

Slurry Transport
And Treatment

Mining Engineers
Geotechnical Engineers
Hydrogeologists
Environmental Engineers

Deposition

Challenge #1: Common Language

- Typical theoretical frameworks used by tailings specialists:

Geology
Rock Mechanics
Operation Research

Mining

Fluid Mechanics

Processing

Non-Newtonian Fluid Mechanics

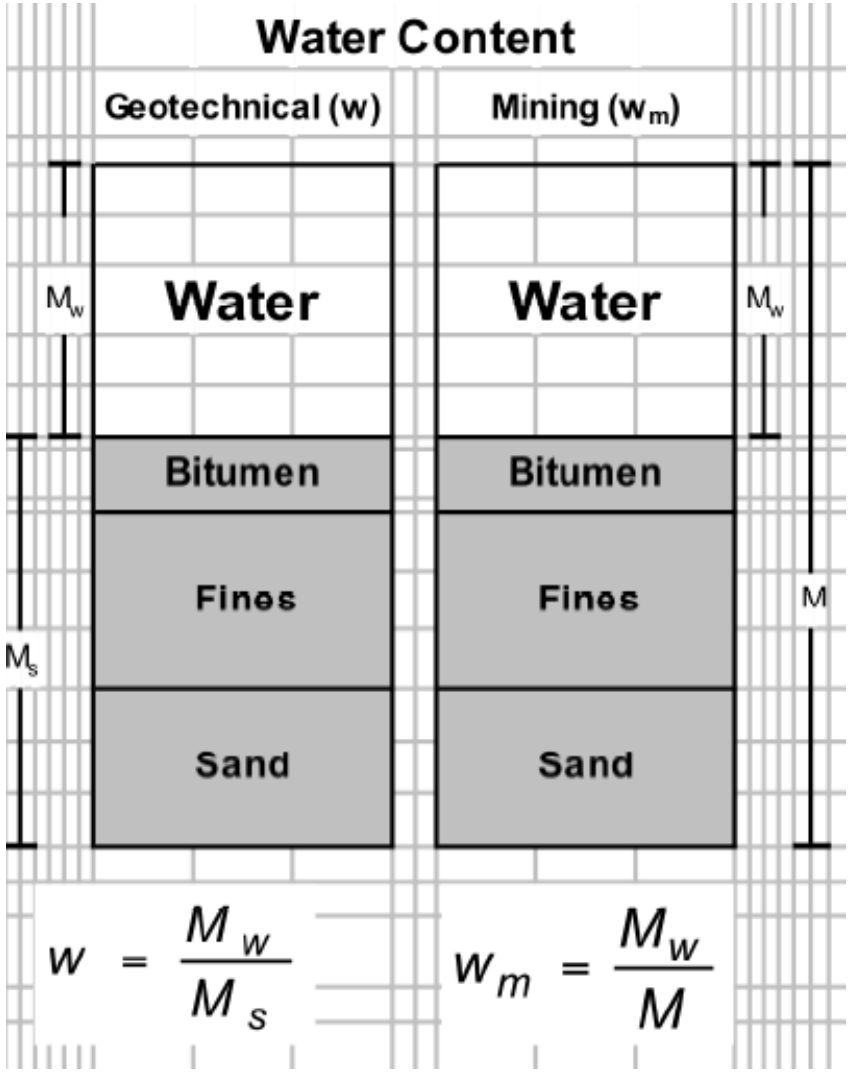
Slurry Transport
And Treatment

Soil Mechanics
Hydrology
Hydrogeology

Deposition

Challenge #1: Common Language

- Consider a block of tailings material



Source: https://www.ualberta.ca/engineering/media-library/rg-geotechnical/publications/definitionsandconversionequationsforoilsandstailings2003.pdf

Challenge #1: Common Language

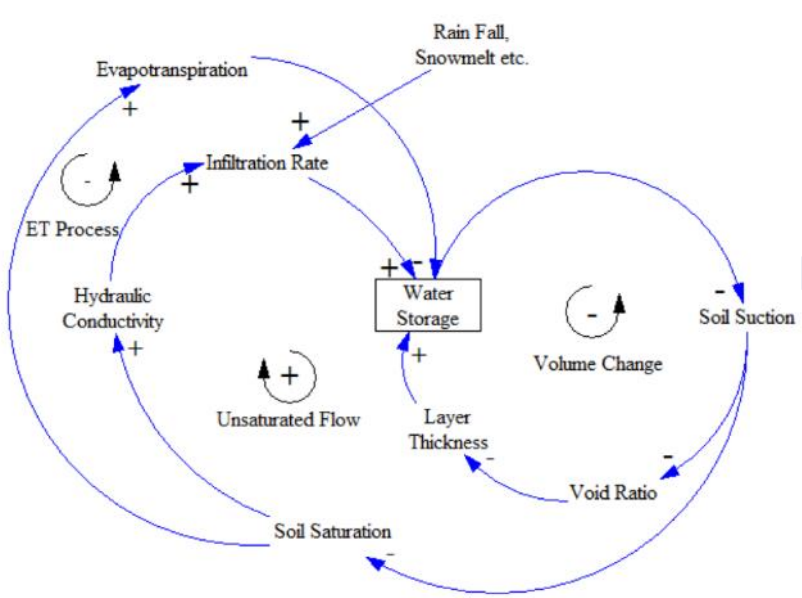
Imagine if you just received an email that the contractor is placing 360 metric tonnes of bulk waste material (~payload of a CAT 797F) and you were told that the waste material has a water content of 20% (assume water density = 1kg/L)

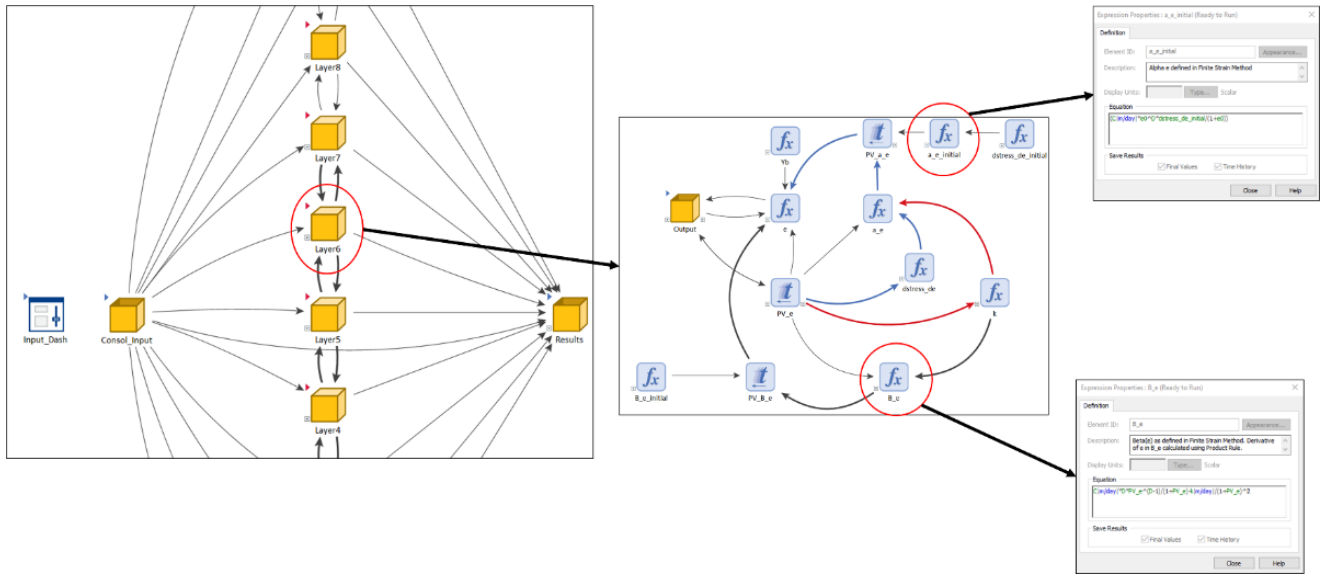
Geotechnical Engineer:

Mining Engineer:

Challenge #1: Common Language

System Dynamics:
An Explicit, Open-Source, Top-Down Method of Simulating Physical and Non-Physical Processes Across Disciplinary Boundaries





Qualitative Model → Quantitative Model

Source: https://era.library.ualberta.ca/items/f156d998-a6b8-423d-b565-db5989487923

Challenge #1: Common Language

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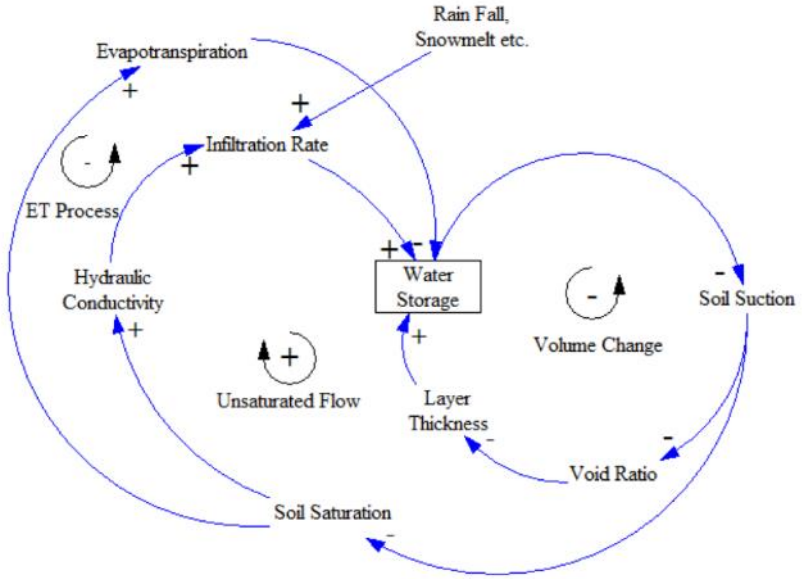


Source: https://era.library.ualberta.ca/items/f156d998-a6b8-423d-b565-db5989487923

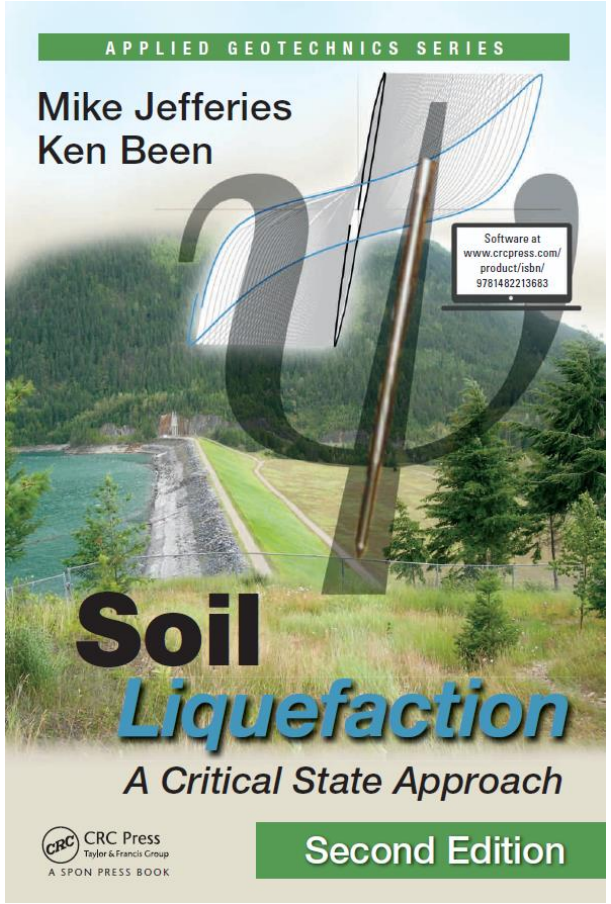
Hager, G.M., Kopainsky, B., Nyanga, P.H. 2015. Learning as conceptual change during community based group interventions. A case study with smallholder farmers in Zambia. 33rd International Conference of the System Dynamics Society, July 19-23, 2015, Cambridge, MA.

Challenge #2: Static (Flow) Liquefaction

- Sudden significant **loss of strength** or stiffness resulting in flow failure of **saturated**, **loose** material (Robertson 2010)

- Major Case Studies (Mine Waste)
  - Aberfan (South Wales, UK, 1966) (Coal)
  - Stava (Italy, 1984) (Fluorite)
  - Sullivan (BC Canada, 1991) (Lead, Zinc, Silver)
  - Merriespruit (South Africa, 1994) (Gold)
  - Fundao (Brazil, 2015) (Iron Ore)
  - Cadia (Australia, 2018) (Gold, Copper)
  - Feijao (Brazil, 2019) (Iron Ore)

- Challenges
  - How loose is loose ?
  - Failure can occur without warning
  - Failure is rapid
  - Same syndrome (soil liquefies) but multiple trigger mechanisms



Challenge #2: Static (Flow) Liquefaction

Which one is more dangerous to a mine?

Seismic Liquefaction Trigger

Probability of M6+ Earthquake

Static Liquefaction Trigger

Probability of:

1) Inadequate Beach Width
2) Overtopping
3) High Dam Rise Rate
4) Intense Rainfall
5) (Slow) Rise of Phreatic Surface (Pore Pressure)
6) Erosion
7) A Combination of Above

Challenge #2: Static (Flow) Liquefaction

- To assess liquefaction susceptibility, we need to answer the following questions:
  1. Where is the danger zone ? (aka critical state line and instability zone)
  2. Where are we right now ? (i.e. the current state of tailings)
  3. How far are we from the danger zone ?
  4. How are we getting to the danger zone from the current state ?

- Solutions
  1. Advanced geotechnical testing (triaxial etc.)
  2. In-situ testing (CPT, Pressuremeter, flat-plate dilatometer etc)
  3. Numerical Modelling
  4. Failure mode analysis, risk management

Challenge #2: Static (Flow) Liquefaction

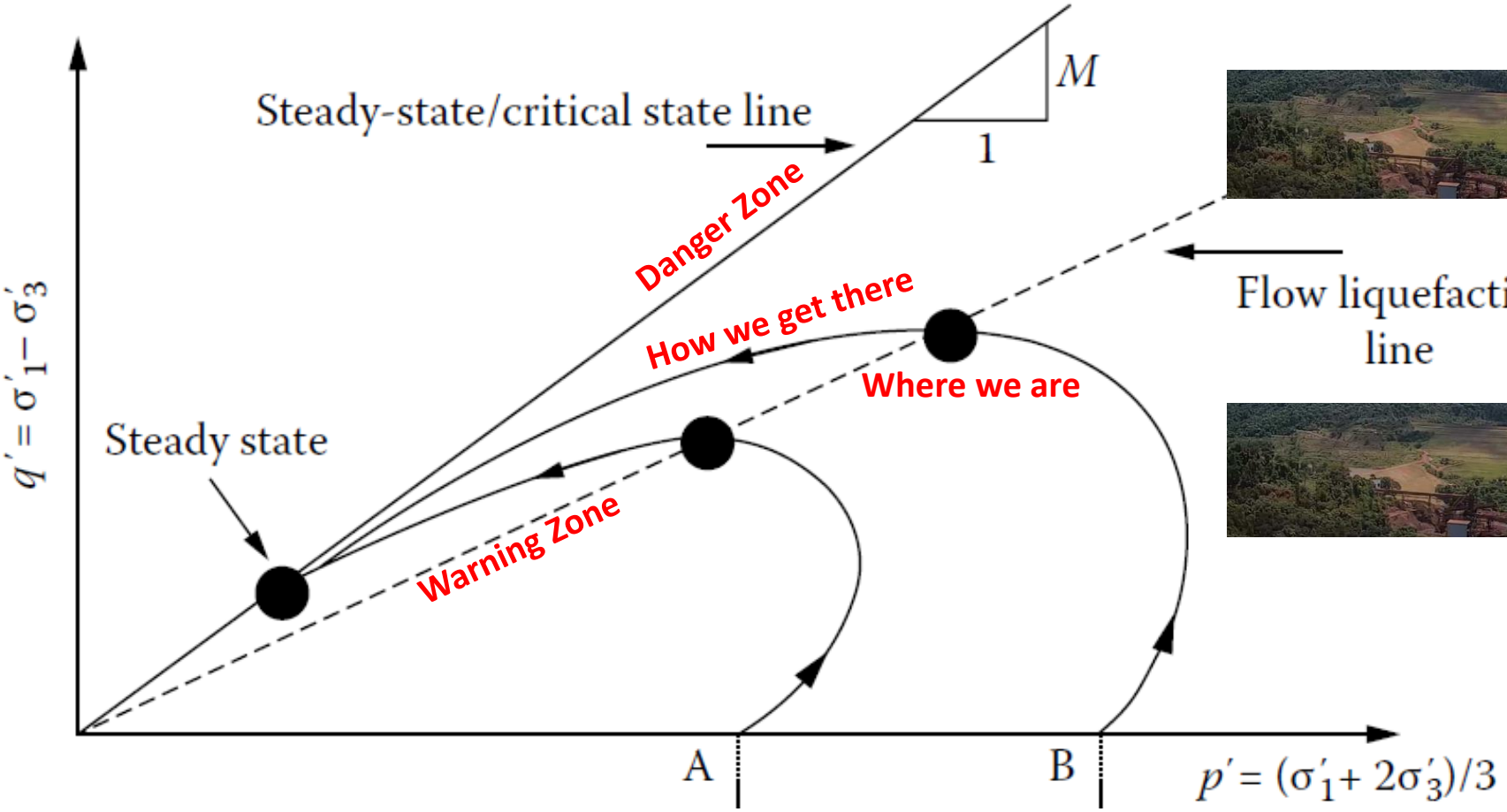


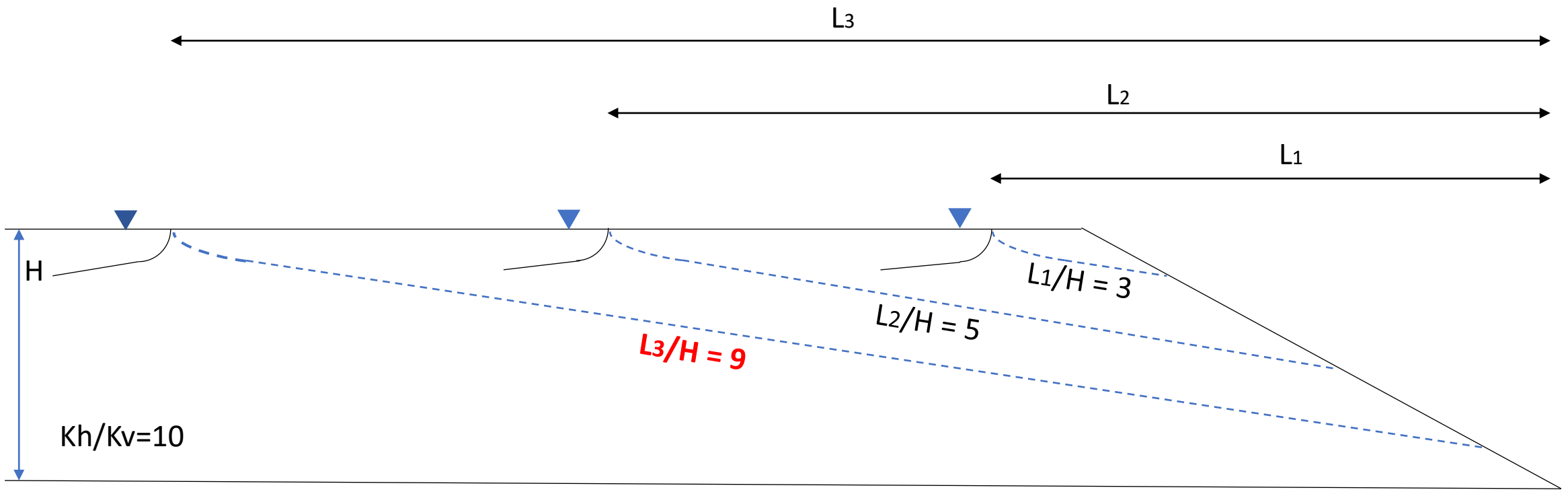
Image Source: http://www.b1technicalinvestigation.com/

Jefferies, M.G., and Been, K. 2016. Soil liquefaction – A critical state approach, 2nd edition. Taylor and Francis Group, London and New York

Yang, J. 2002, "Non-uniqueness of flow liquefaction line for loose sand", Géotechnique, vol. 52, no. 10, pp. 757-760.

Challenge #2: Static (Flow) Liquefaction

Beach Width Requirement Changes Over Time



Homogenous anisotropic **upstream** embankment on an impermeable foundation

Source: Modified Figure 8.3, Planning, Design, and Analysis of Tailings Dams by Steven G.Vick (1990)

Challenge #3: Consolidation - Overview

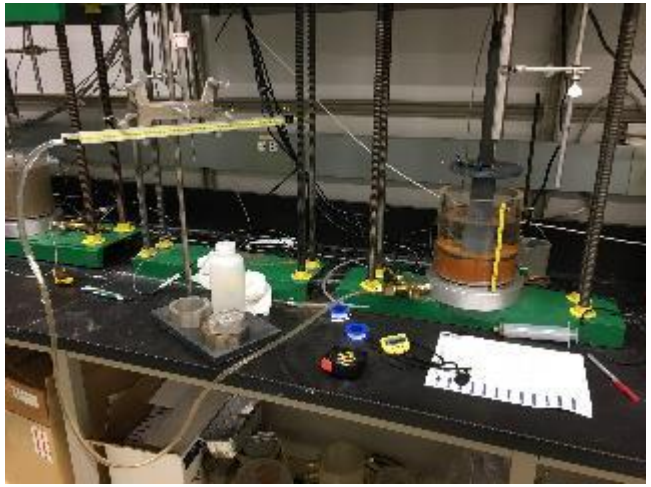
- **Consolidation**: expulsion of pore water due to imposing load and self-weight represented physically by settlement and water release.

- Why important:
  - Storage capacity
  - Depositional strategy
  - Strength
  - Closure

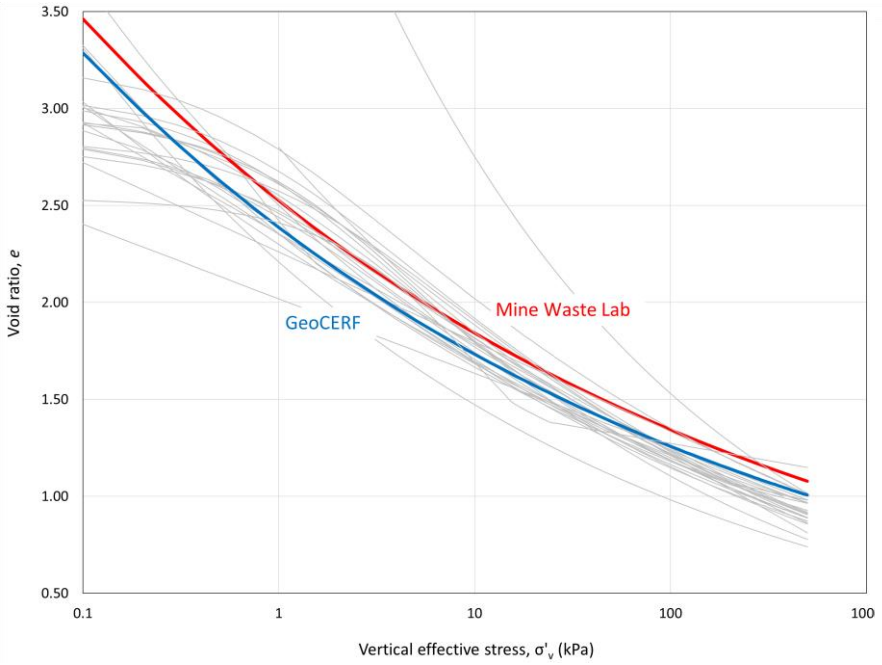
- Key influence factors:
  - Tailings properties
  - Geometry
  - Rate of Rise
  - Geology
  - Climate

Challenge #3: Consolidation – Tailings Properties

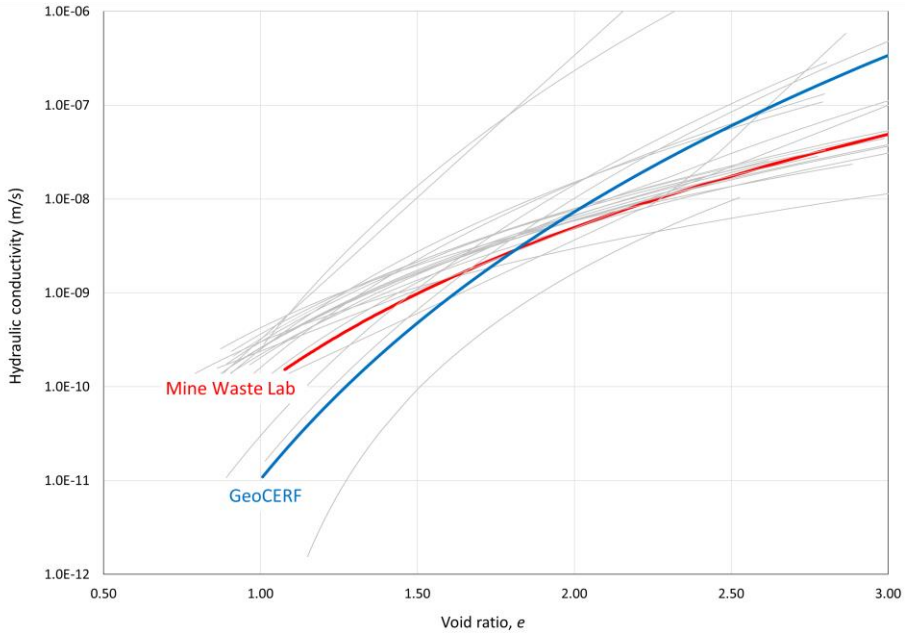
- Large Strain Consolidation (LSC) Test Round-Robin (organized by Univ of Western Australia)
  - 26 Geotechnical Laboratories Worldwide
  - Two entries from U of A: Mine Waste Lab and GeoCERF
  - Objective: study variability in different testing procedures using the same material



LSC Test Setup



Effective stress – void ratio relationship

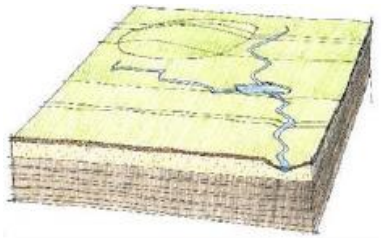


Permeability – void ratio relationship

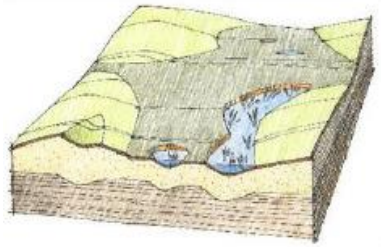
Challenge #3: Consolidation

- Uncertainties in tailings consolidation can have profound impact on mine closure landforms in the long-term

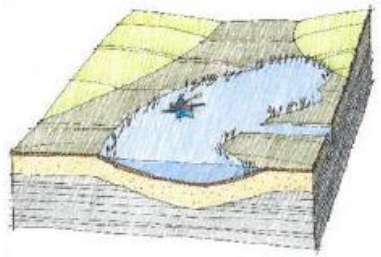
  (scale in decades)



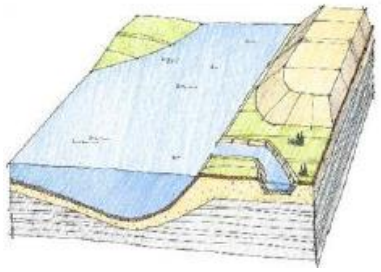
Fen
Consolidation < 0.2 m



Marsh
Consolidation < 0.2 m to 0.5 m



Shallow Water Wetland
Consolidation < 2 m

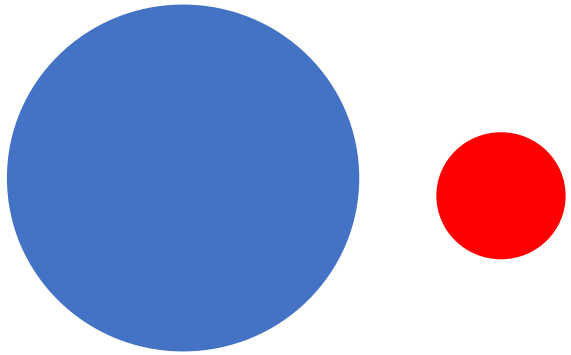


Lake
Consolidation > 2 m

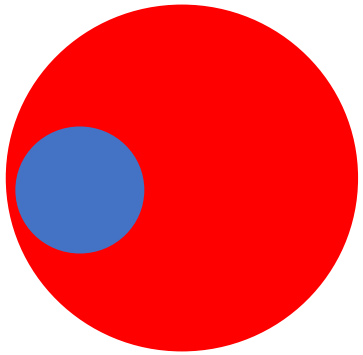
Source: http://mckennageotechnical.com/pdfs/Hyndman_et_al_2019.pdf

Challenge #4: Governance

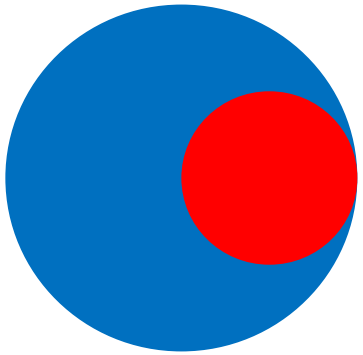
Every mine is different but in general, the tailings planning team is organized in the following fashions:



Primarily In-house (i.e. Oil Sands)



Primarily Consultant (i.e. Fraser Alexander in South Africa)



Primarily In-House with Seconded Consultant

Each organization has their merits and disadvantages: no silver bullet

Challenge #5: Talents

- What it takes to become a “competent” geotechnical engineer in tailings management ?

IDEAL

1. Minimum 15 years of experience
2. Graduate degrees
3. A range of commodities
4. Well-rounded experience in:
    - Design
    - Construction
    - Laboratory Techniques
    - Site Investigation

REALITY

1. Baby boomer retirement
2. Undergraduate degrees
3. Cyclic industry
4. Silo-ed experience

Concluding Remarks

- Challenges come with opportunities:
  - Automation, IoT
  - Advanced Analytics
  - Availability of Knowledge
  - Outreach and Communication
  - Difficult to replace experienced tailings engineers with technology

- Cost of permitting will go up (to be listed on TSX, LSE etc.)
- Majors are best equipped to address those challenges
- Professional development and lifelong learning a must

Discussion and Questions