Slope stability management within a tailings (Dam) Safety Management System

18 October 2018

Abstract

›The implementation of a robust Dam Safety Management System (DSMS) for tailings includes many elements, with slope stability analysis and monitoring generally at the core of the system. Guidance for implementation of DSMS is provided by both the Mining Association of Canada (MAC) and the Canadian Dam Association (CDA), as well as several other organizations. The elements of a DSMS will be discussed, and how the systems have changed with time. At the core of a DSMS for a tailings dam and/or tailings embankment is ongoing slope stability analysis and, often, The Observational Method and Risk Management. The strategies for slope stability management have been evolving in industry, new guidance has been issued, and the key concepts of analysis and presentation of results will be provided.

Statistics

"For a world inventory of 18401 mine sites, the failure rate over the last one hundred years is estimated to be 1.2%" [1]

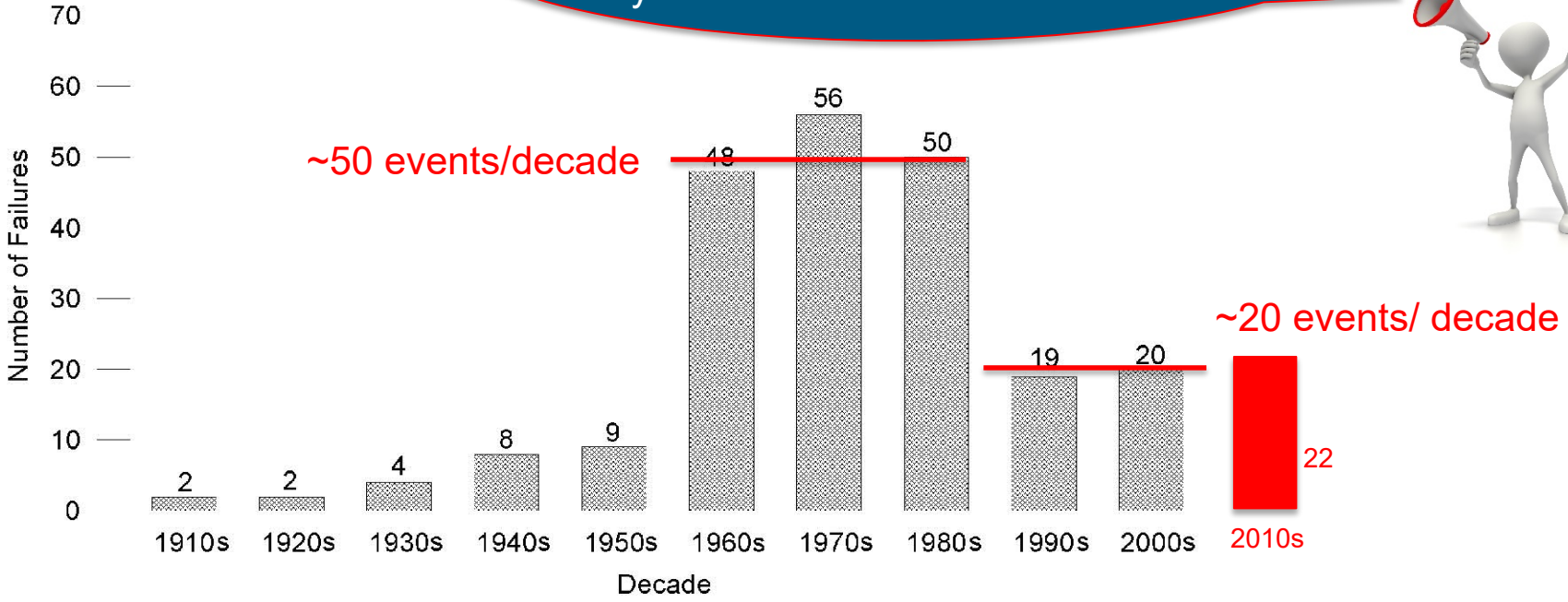

Figure 1. Failure events over time.

1. Source: **Azam, Li** – "Tailings Dam Failures – A review of the last 100 years" Geotechnical News – December 2010

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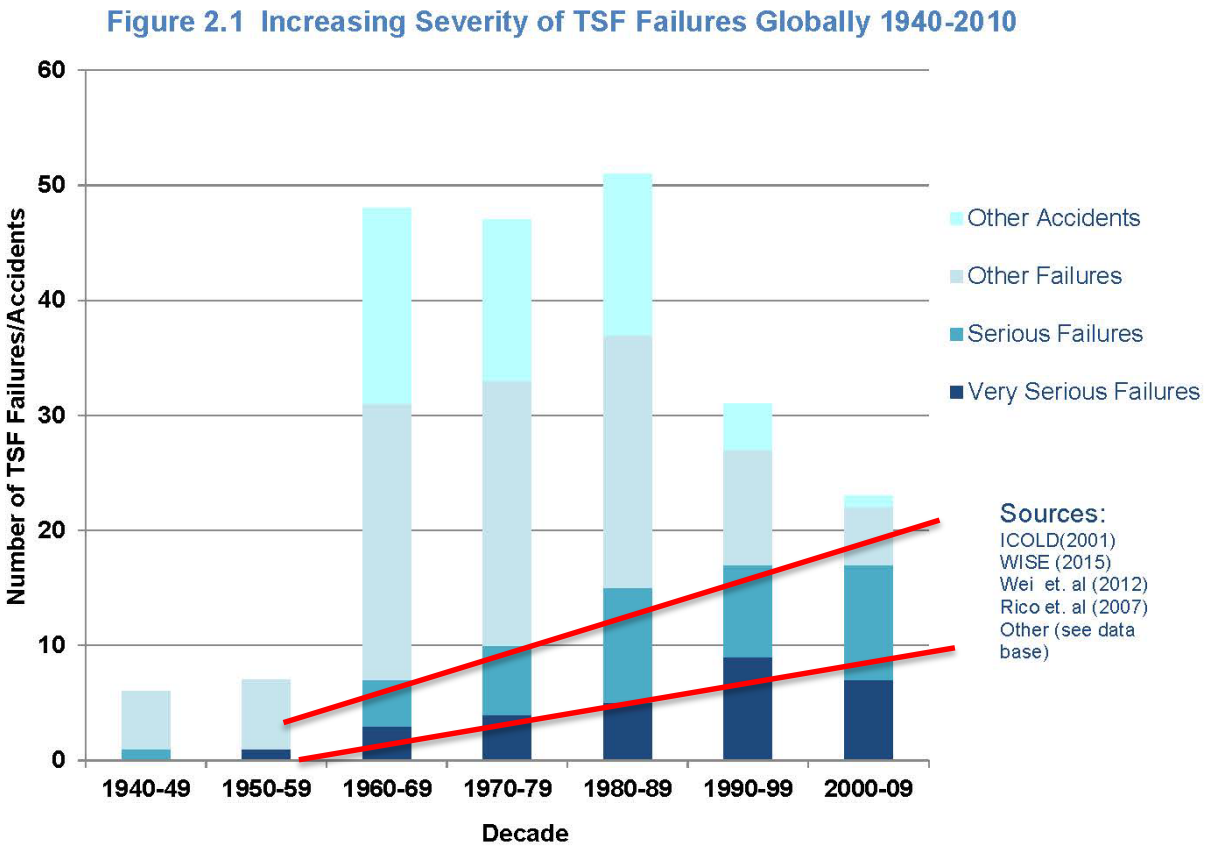
Statistics

Source: **Bowker & Chambers** – "The Risk, Public Liability & Ecomonmics of Tailings Storage Facility Failures" July 2015



NEW OCT 2018: Tailings Failure Database
https://worldminetailingsfailures.org/

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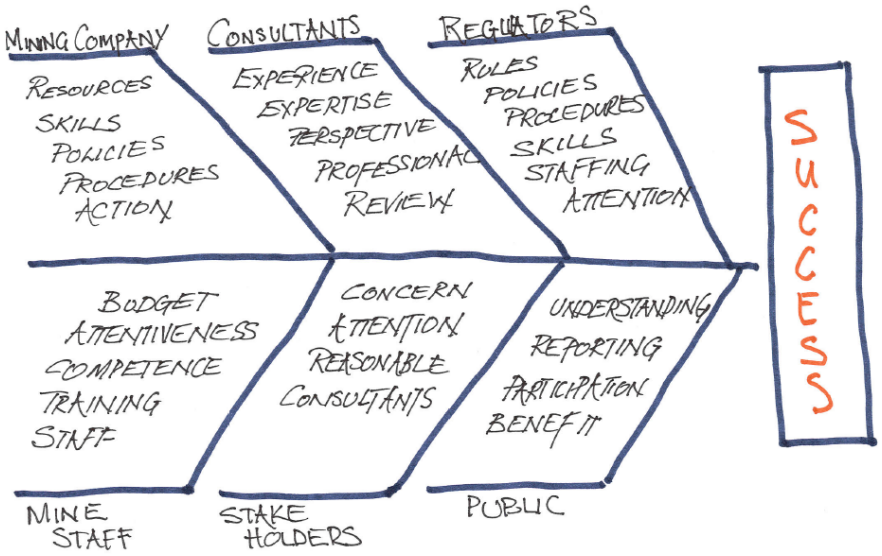
Tailings Failures

How to prevent tailings dam failures

My view: A comprehensive Dam Safety Management System incorporating Risk management and Best practices

** An entire course could be spent on this topic **

- Constantly evolving
- Good guidance from organizations
- Good regulations/legislation
- Qualified people
  - Competent Responsible Engineer (EOR)
  - Intelligent ITRB (reviews)
  - Engaged Staff
  - Committed Management
  - Educated Regulators
  - Informed Stakeholders
- Risk Management a function of Slope Stability



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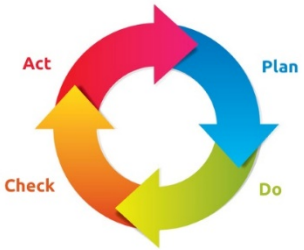
www.infomine.com/library/publications/docs/Howtoavoidfailure.pptx

Tailings/Dam Safety Management System

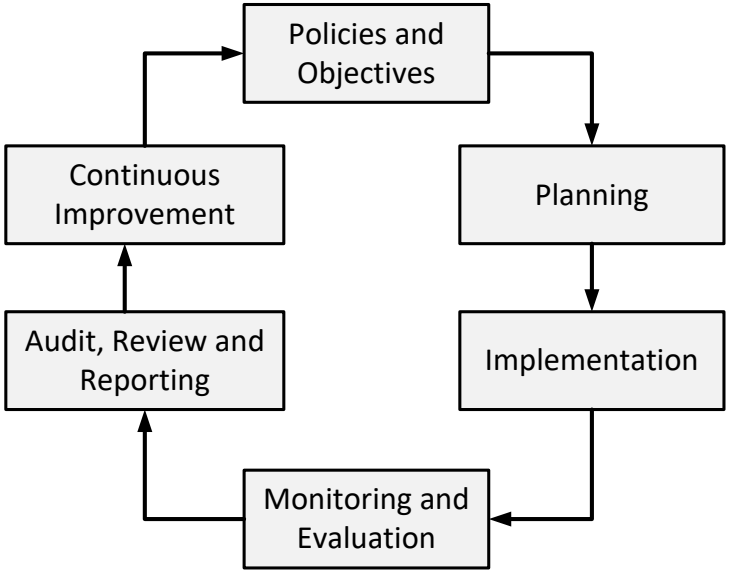


Two excellent references:

- CDA 2007 Dam Safety Guidelines (rev. 2013), and Mining Dams Bulletin (2014)

- Mining Association of Canada: Guide to the Management of Tailings Facilites (2017)

- Dam Safety Management System
  - *A function of Owner's policies and priorities, which is a function of Public Policy*
- Process Driven
- Flow Chart of Plan, utilizes **Plan, Do, Check, Act** philosophy



From ICOLD Bulletin 154 (2011)

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Resources Available - Guidance

MAC Guidance Documents: Under review and revision (ongoing)

The Mining Association of Canada (MAC), has published a document entitled “A Guide to the Management of Tailing Facilities”, to monitor the tailing dam

- This Guide includes:
  - A framework of management principles, policies and objectives
  - Checklists for implementing the framework through the life cycle of a tailings facility
  - Lists of technical considerations

www.mining.ca

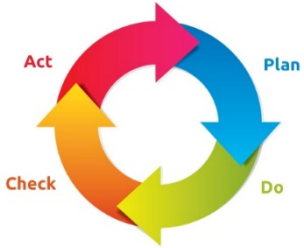
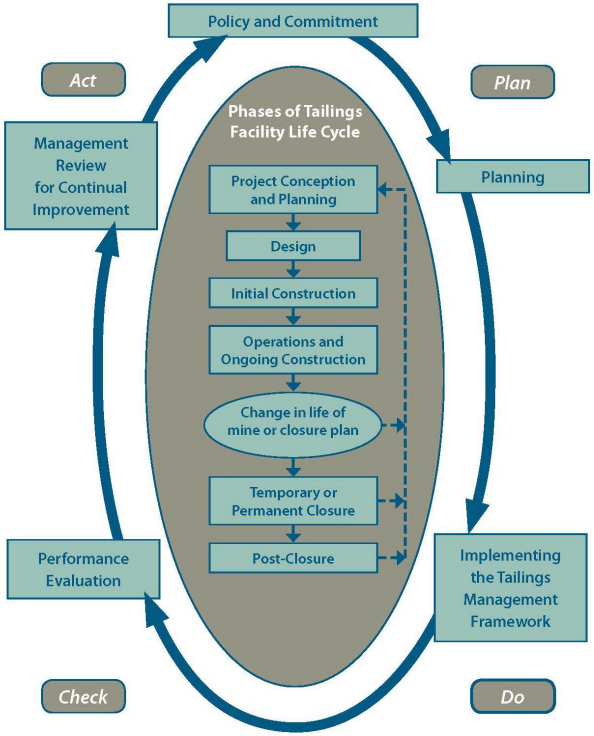


Figure 1: Elements of the Tailings Management Framework



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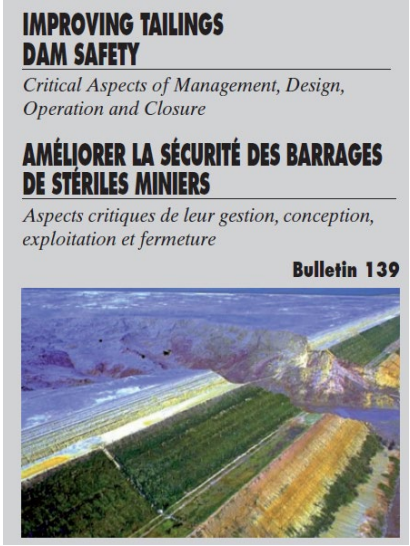
Other Resources Available

International Commission on Large Dams

- “Parent” organization to CDA
- Over 170 technical bulletins



International Council on Mining and Metals

- Largest mining companies in the world are members (sort of the international MAC)
- Following Samarco tailings failure, a global review of leading tailings practices
- 14 pages, easy read, with key recommendations
- No new information but potential implications to mining worldwide

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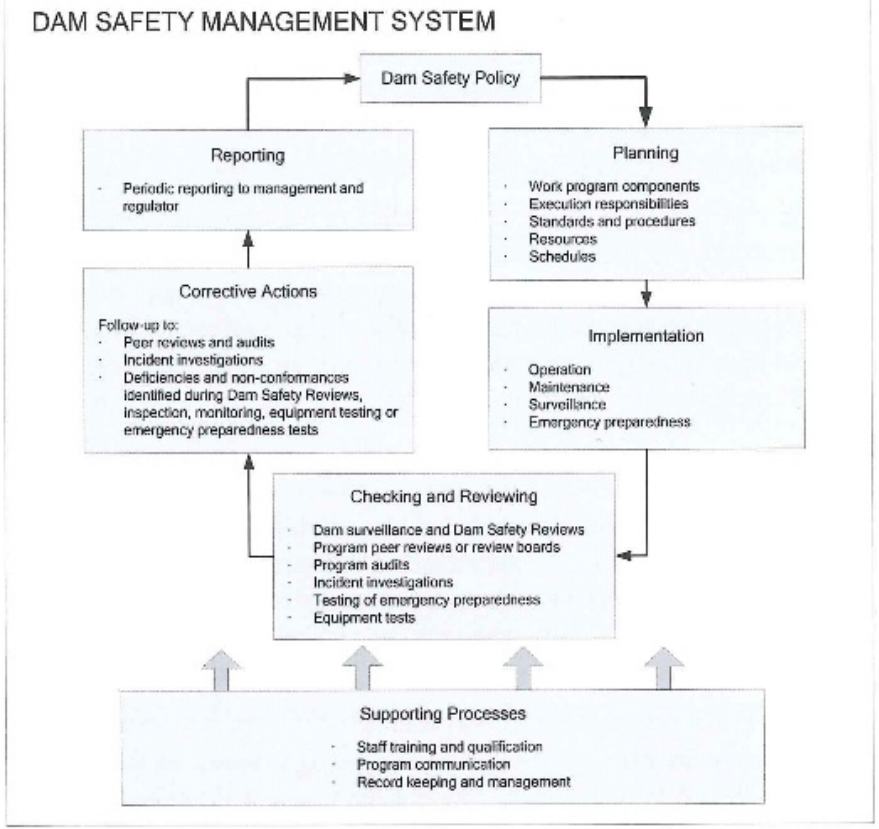
Dam Safety Management System

- Tailings / Dam safety policy (corporate recognition)
- Planning
  - *Work Program Component (the details)*
  - *Execution Responsibilities*
  - *Standards and Procedures*
  - *Resources*
  - *Schedules*
- Implementation
  - *Operation*
  - *Maintenance*
  - *Surveillance*
  - *Emergency Preparedness*

Figure 2-2: Overview of an Owner's Dam Safety Management System



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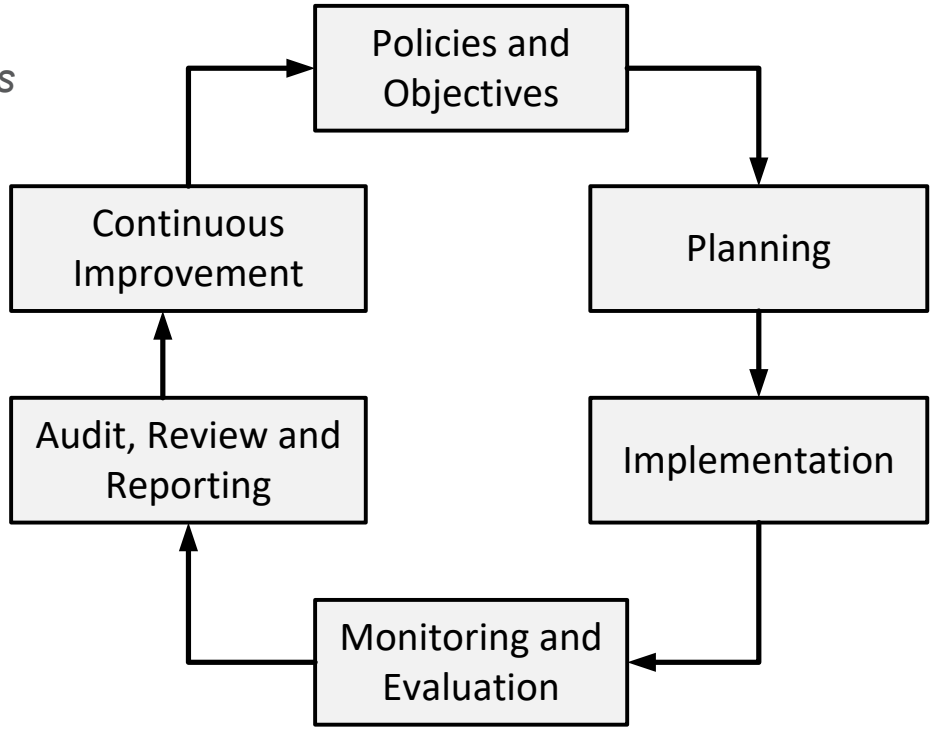
Dam Safety Management System

- Checking and Reviewing
  - *Dam Surveillance and Dam Safety Reviews*
  - *Program peer reviews or review boards*
  - *Program Audits*
  - *Incident investigation*
  - *Testing of emergency preparedness*
  - *Equipment tests*
- Corrective Actions – follow up to:
  - *Peer Reviews and Audits*
  - *Incident investigations*
  - *Deficiencies and non-conformance*



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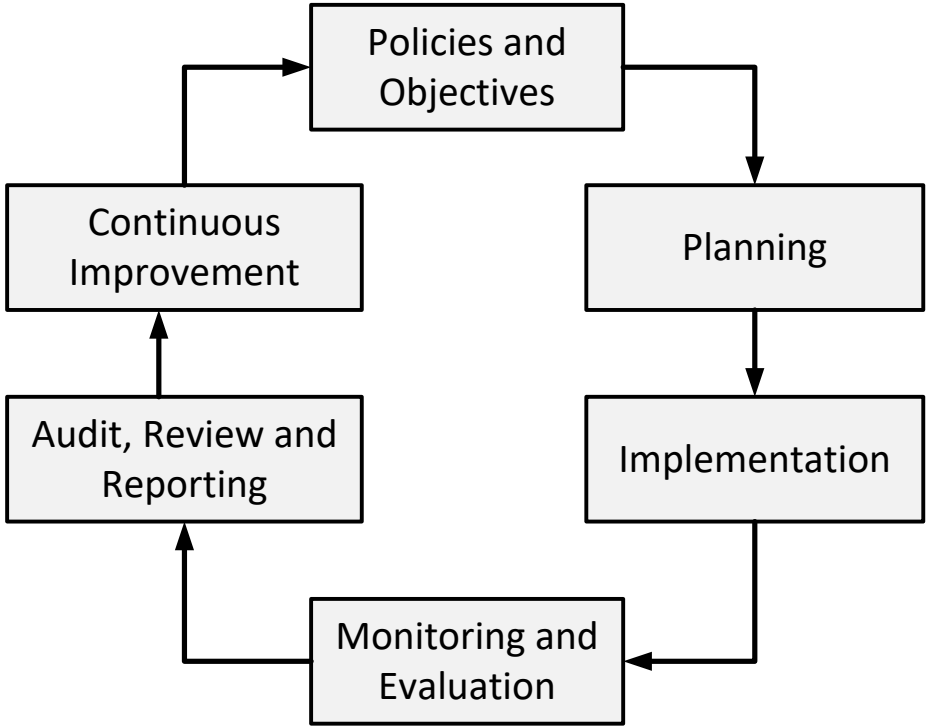
Dam Safety Management System

- Reporting
  - *Periodic reporting to management and regulator*

- Supporting Processes
  - *Staff training and qualification*
  - *Program communication*
  - *Record keeping and Management*



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Dam Safety Management System

- Slope Stability Analysis involved at all stages:
  - Planning
  - Implementation
  - Checking & Reviewing
  - Corrective Actions
  - Reporting

- Observational Method
  - Predicted behaviour vs. Observed Behaviour

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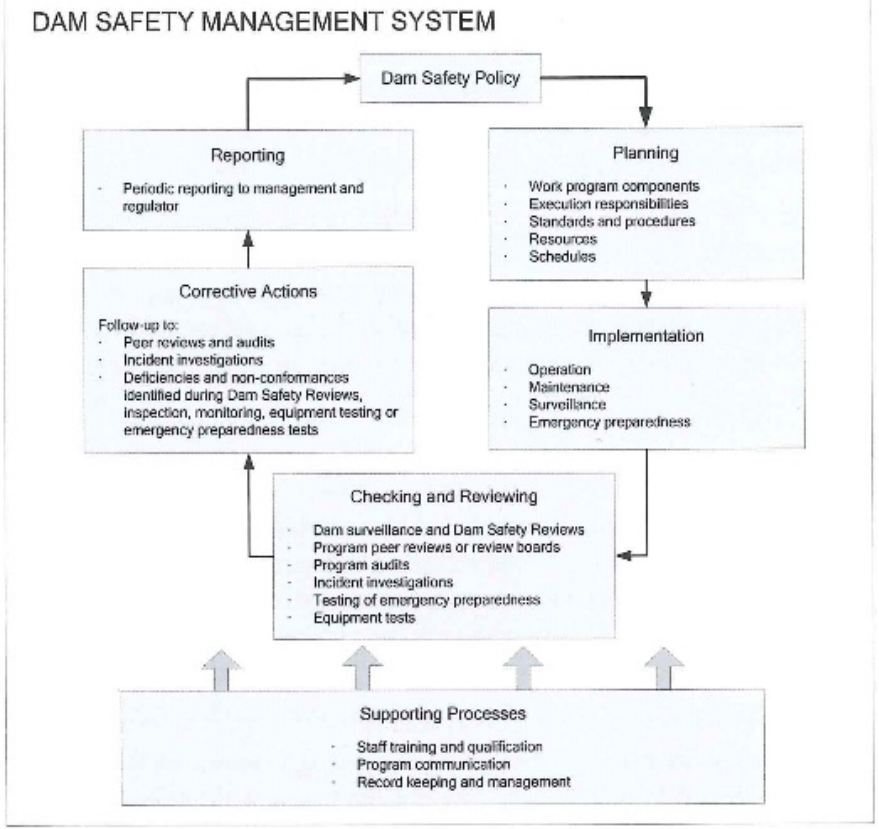

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Slope Stability: Foundation of many DSMS

- Where tailings embankments and/or tailings dams are constantly increasing in size, with consequence of failure being an uncontrolled release, ongoing Slope Stability Analysis is often a foundation of the DSMS
- The Overall DSMS represent a process to reconcile pieces of a management system with primary components:
  - *Slope Stability Management*
  - *Performance Management*
  - *Monitoring and Surveillance*
  - *Risk Management*

- A DSMS without sound Slope Stability Analysis is not complete
- Slope Stability Analysis alone isn't a DSMS

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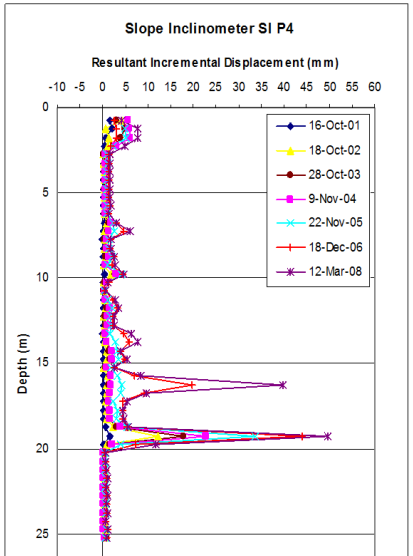
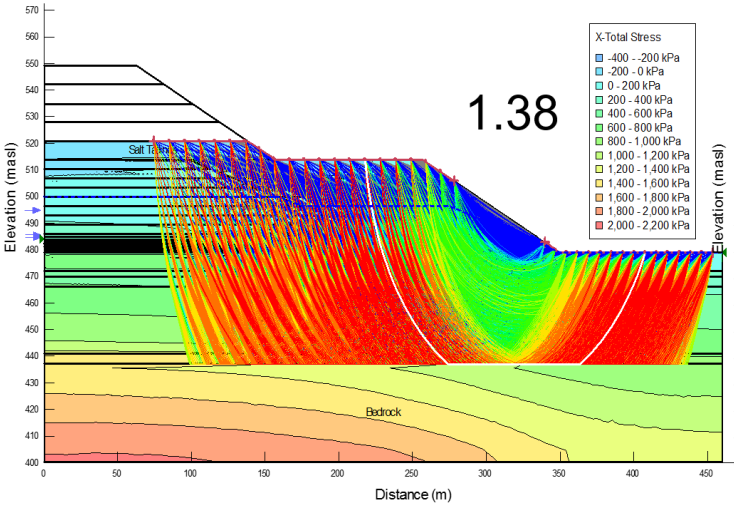
Stress Deformation Stability Analysis

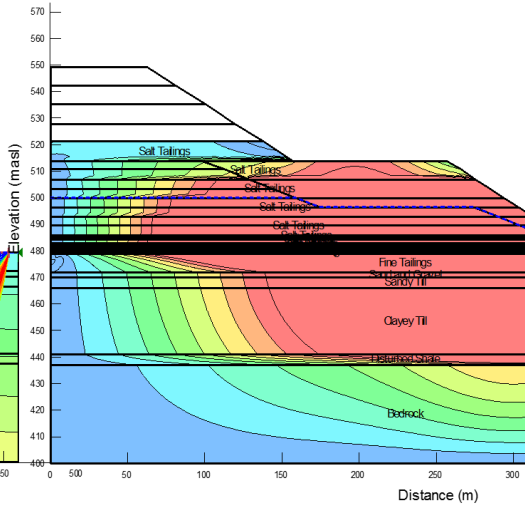
Why movement does not ‘always’ mean FOS=1.0



FOS



Strain



Stability Analysis – What's the Important Stuff?

1. Factor of Safety
2. Site characterization
3. Slope Stability Management
   - *Surveillance & Monitoring*
   - *Performance Management*
   - *Risk Management*

As an Owner, Regulator, Consultant or stakeholder, what are the key things I should understand?

Can we reduce to a TOP 3 LIST?

Factor of Safety

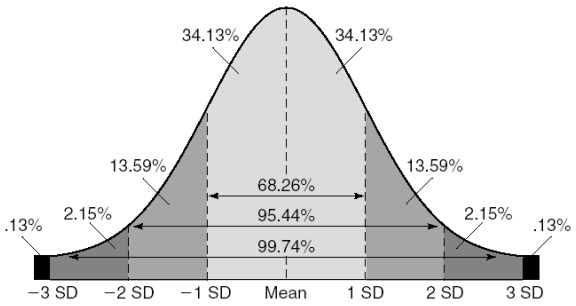
$$FOS = \frac{\text{Resistance to sliding}}{\text{Mobilizing Forces}}$$

- Screening Level criteria
- If met, are generally viewed as acceptable practice (but doesn't guarantee safety)
- However, if not met, further analysis by the design engineer may be required to support modified targets to demonstrate safety of the embankment (deformation analysis, additional investigations, enhanced use of observational method, etc.)

Table 3-4. Target Factors of Safety for Slope Stability of Mining Dams – Static Loading - Construction, Operation, and Transition Phases

Loading Condition	Minimum Factor of Safety	Slope
During or at end of construction prior to commencing of tailings deposition or impoundment of water	1.3	Downstream and Upstream
After startup, during operations and transition, when tailings or water are being impounded, and during dam raise construction	1.5	Downstream and Upstream
Long term (steady state seepage, normal reservoir level)	1.5	Downstream and Upstream
Full or partial rapid drawdown	1.3	Upstream slope

- The number you get is highly dependent upon input parameters
  - worst case conditions
  - Most probable conditions
    - *Use the 80/20 Rule*



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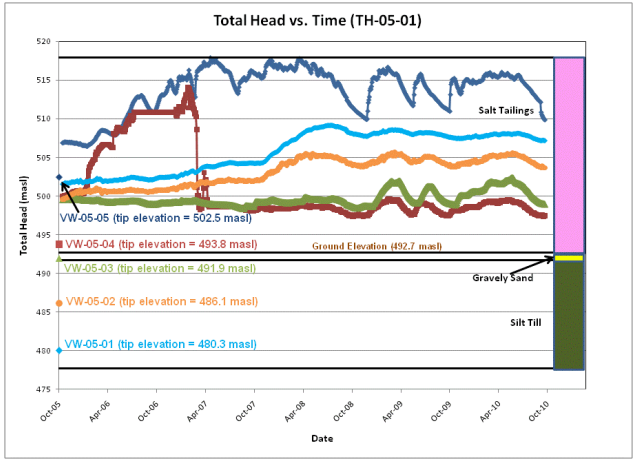
Factor of Safety

Has the design engineer adequately described / accounted for how the input parameters were determined, AND the sensitivity to input parameters

What does <u>this</u> FOS mean?

Site Characterization

- Layers of Materials (stratigraphy)
  - *Geologic History*
  - *Strength / behaviour of materials*
  - *Presence of weak materials*
  - *Presence of contractive soils*



- Hydraulic Conditions
  - *Instrumentation Installation and monitoring*

- Again, the 80/20 rule is important

An entire workshop on it's own

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Site Characterization

Has the design engineer have an adequate understanding of the stratigraphy, hydraulic conditions, and/or made conservative assumptions in the absence of this information ?

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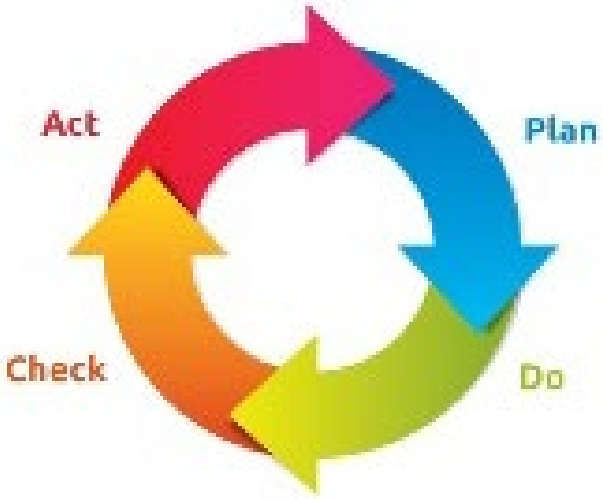
Slope Stability Management

- Surveillance & Monitoring
  - Inspections and Instrumentation monitoring
- Performance Management
  - Observational Method (Peck, 1969)
    - *Predicted vs. Observed behaviour*
    - *Pre-determined mitigation*
- Risk Management
  - Risk a function of likelihood and consequences
    - *Used to prioritize issues*



Ongoing & Improving

Slope Stability Management

Is there an established management system?

Is there a system to evaluate predicted performance vs. observed performance?

Are the Risks understood?

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Summary

› A robust, constantly improving Dam Safety Management System is required for the life of a structure (design through closure)

› Slope stability systems are an integral part of a DSMS where slopes exist (dykes, dams, tailings embankments)

- *Slope stability modeling is applying relatively easy science, but requires significant consideration of the input parameters …. Requires qualified persons*

› Factor of Safety is just a number – what is the slope telling us?

› Site characterization: 80/20 rule

› Slope stability management (Surveillance & Monitoring, Performance Management, Risk Management)

- *More than just reporting a Factor of Safety number*

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Thank-you

Questions, comments, additional info:
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