Risk Assessment & Management Using Layers of Protection Analysis & Bowties

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Tailings storage facilities (TSFs) are to have low likelihood and, typically, high consequence risks.

*Tailings dams are complex systems that have evolved over the years. They are also unforgiving systems, in terms of the number of things that have to go right. Their reliability on consistent flawless execution in planning, in subsurface investigation, in analysis and design, in construction quality, in operational diligence, in monitoring, in regulatory actions, and in risk management at every level. All of these activities are subject to human error.*


*Tailings Dam Failure Axiom - Tailings dam failures are a result of design, construction, and/or operational management flaws - not “acts of god”.*

~Mike Davies (2002)
Some Comments on Risk

Risk is calculated. The key is to focus on the bases of risk:

1. Likelihood
2. Consequence

There’s no such thing as right or wrong, only consequences to your actions.

~Unknown
Assessment and management of the risks associated with TSFs is recognized as international good practice.

The objective of a risk assessment is to understand and determine the risk levels of a TSF.

Identification and mitigation of the risks used to achieve successful long-term operation and performance of the TSF.

Typical approach is the development of a risk ranking “heat map” using likelihood and consequence in pre- and post-mitigated conditions for risk ranking.
Limitations of Heat Map Approach

- With mitigation, typical TSFs are assessed as “medium risk” (high consequence and low likelihood).
- **Key limitation:** critical controls that must be in-place to properly understand, manage, and control the likelihood of an incident from occurring are not clearly communicated. The focus is on the outcome—the lowering of risk ranking.
- Fundamental misunderstanding of TSFs—that consequences of a tailings release cannot be readily mitigated post-event—often results from this approach.

*The single biggest problem with communication is the illusion that it has taken place.*

~George Bernard Shaw
The likelihood of a tailings release from a TSF must be assessed and managed continuously and properly at all times—this is not self-evident from the heat map approach. A typical low likelihood / high consequence risk ranking does not advance this understanding.

The objective to successful TSF operations and performance is to avoid the release of tailings in the first instance and to reduce the consequences post-release.

**Key to achieving the objective:** use of controls to prevent the release of tailings and to reduce the consequences post-release.

**Suggested approach:** use the layers of protection analysis (LOPA) and the associated bowtie diagram.
The primary focus of a properly designed, maintained, and operated TSF is on avoiding the release of tailings.

LOPA developed in the petrochemical industry and successfully used for many years.
- The focus is on the controls to avoid and to reduce the consequences of a release of tailings.

The approach focuses on identifying threat-incident-consequence pathways.
- Controls (i.e., barriers) for pre- and post-threat portions of the pathways are developed.
- Control decay modes identified along with decay mode controls.
- Aligns well with the “3 R’s” approach.
Presentation of a LOPA: Bowtie Diagram

Diagram:

- Threat 1
  - Control 1.1
  - Control 1.2
  - Incident
    - Control 1.3
    - Control 1.4
    - Consequence 1
    - 1.3 Decay mode control
    - Control 1.3 decay mode
- Threat 2
  - Control 2.1
  - Control 2.2
  - Control 2.3
  - Consequence 2
  - Control 2.2 decay mode
  - 2.2 Decay mode control
Simplified Bowtie Diagram for Tailings Release

Incident

Release of tailings from TSF

Environmental Impacts

Downstream Infrastructure damage

Community inundation

Reputational loss

Threats

Crest pipeline failure

Dam overtopping

Dam foundation failure

Dam crest deformation (static & dynamic)

Dynamic liquefaction—earthquake (foundation & tailings)

Static liquefaction of tailings (rate of rise)

Tailings migration through rockfill

Dam failure due to high phreatic surface

Seepage through dam

Consequences

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Bowtie Diagram Excerpt: Simplified Threat-Control-Incident Pathway

Threat
- Static liquefaction of tailings (rate of rise)

Control
- Instrumentation monitoring leading to intervention
- Release of tailings from TSF

Incident
- Trigger-response-action-plan based on design thresholds for stability (section of operation, maintenance, and surveillance manual cited)

Control Decay Mode
- Inadequate response to monitoring
- Review of design by independent tailings review board

Decay Mode Control
- Inadequate design
Bowtie Diagram Excerpt: Simplified Incident-Control-Consequence Pathway

Incident:
- Release of tailings from TSF

Control:
- Emergency response and emergency preparedness plans
  - Community inundation

Control Decay Mode:
- Ineffective emergency plans
- Communication of plans
- Evacuation drills

Decay Mode Control #1:

Decay Mode Control #2:
• LOPA is considered a better tool to understand and communicate the risks (consequences, controls) to properly manage them.
  • Tool for designers, reviewers, review boards, operators, management, board of directors, stakeholders, auditors. Group exercise(s). Include specific references (e.g., sections of the OMS manual).
  • Avoid overly-generalized threats (more detail)—I had to for space, clarity, and presentation purposes.

• Each threat-incident-consequence pathway is considered to be feasible
  • Controls are required to be in-place as barriers for all threats.
  • Post-incident controls are in addition to pre-incident controls—not in lieu of!

• Controls are developed with a “strength in depth” approach
  • Controls must be functional, available, reliable, survivable, independent, and auditable.
  • Three types (in hierarchical order): passive engineering, active engineering, and procedural.
  • Methodologies are available for barrier quality ranking available—our next paper!
Questions? Ask Bill!

I made bow ties cool.

But I made them sexy!

(Bill and I leave it to you to decide which one of us is which!)