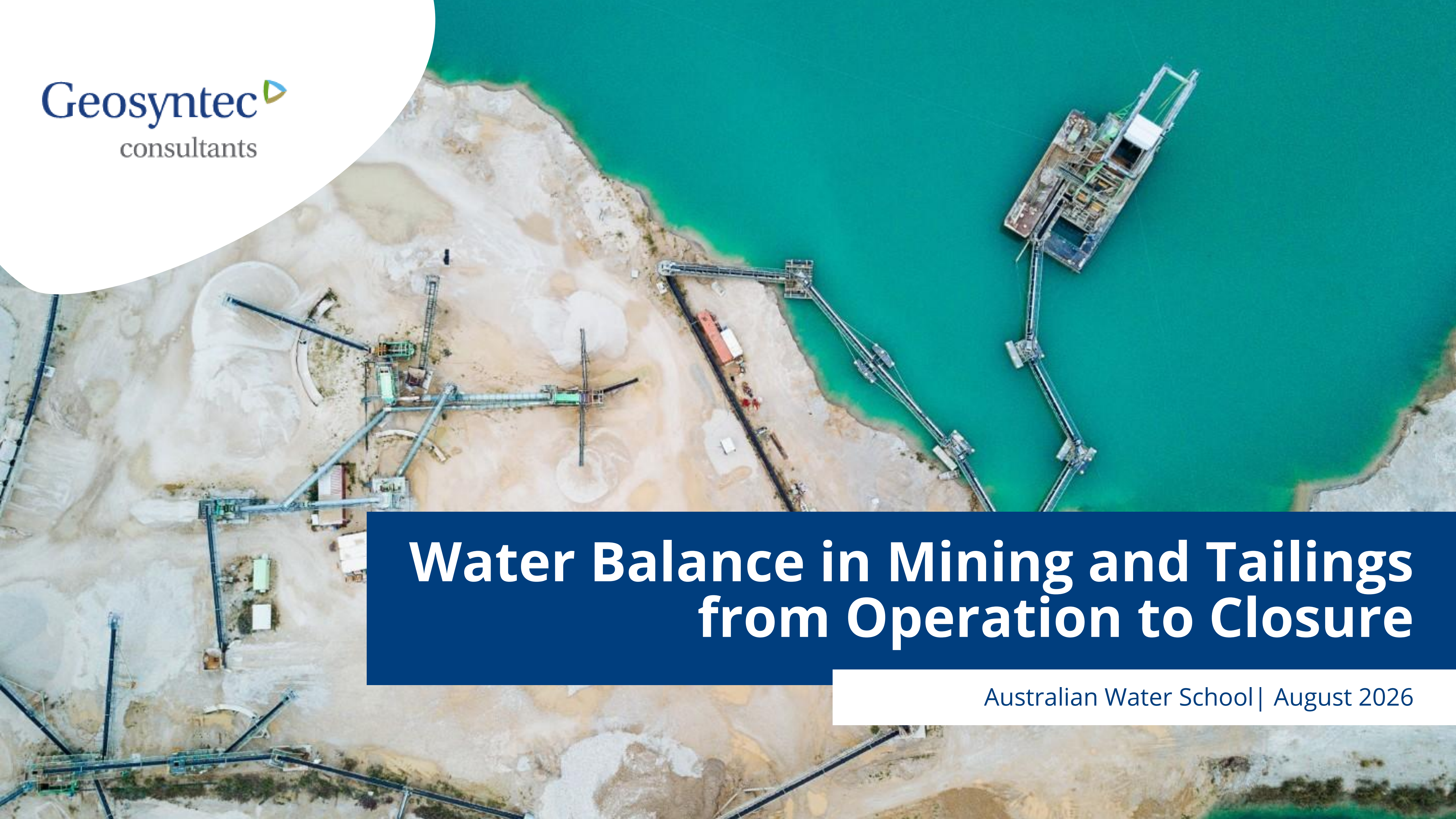
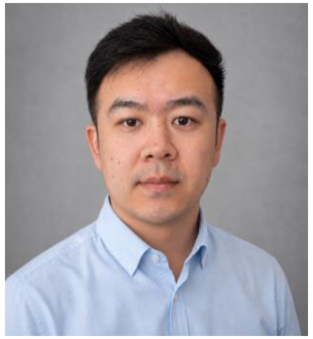


Water Balance in Mining and Tailings from Operation to Closure

Australian Water School| August 2026

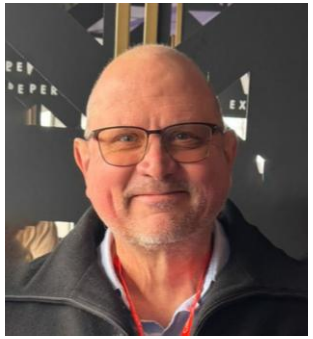
Presenters/Panel members



Mike Liu
Principal - Geosyntec
Brisbane

Jarrad Coffey
Senior Principal – Geosyntec
Brisbane

Gavin Rootsey
Principal Water - Rio Tinto
Brisbane



Rick Kossik
GOLDSIM

Krey Price
International Water
Training Institute

Agenda

- Why Mining Water Balance Matters
- Tailings Storage Facility Water Balance
- Site-wide Water Balance - Owner-operator perspective
- Risk and Decision Making
- Q&A

Geosyntec consultants

Why Mining Water Balance Matter

Mike Liu, Geosyntec

Why does mining water balance model matter

Geosyntec consultants

Problem Definition

- Enough water to supply operation?
- Excess water to store or discharge?
- Water quality issue?
- Manage efficiently?

Robust Water Balance Model is a Powerful Tool

- **Support Informed Decisions**
  Evaluate scenarios and manage uncertainties. Plan with **confidence**.
- **Manage Risks**
  Identify flooding, dam spill, water shortage, uncontrolled release, water quality & compliance risks. Allow proactive **prevention** measures rather than reactive **response**.
- **Improve Efficiency & Save Cost**
  Inform infrastructure sizing, optimise water reuse, reduce freshwater demand and avoid unnecessary expenses.
- **Build Operational Reliability**
  Provide **evidence-based support** for regulatory compliance, dam safety and stakeholder expectations

Figure source: AI-generated

Geosyntec consultants

Tailings Storage Facility Water Balance

Mike Liu, Geosyntec

Tailings Storage Facility Water Balance

Geosyntec consultants

No two TSFs are the same; facility-specific setup

- Type of facility
- Tailings characteristics
- Deposition strategy
- Climate condition

TSF water balance schematic

- Identify key water management **processes**
- Define **model boundary** and determine relevant inflows, outflows and storages
- Confirm assumptions and calculation methods for each component **fit for purposes**

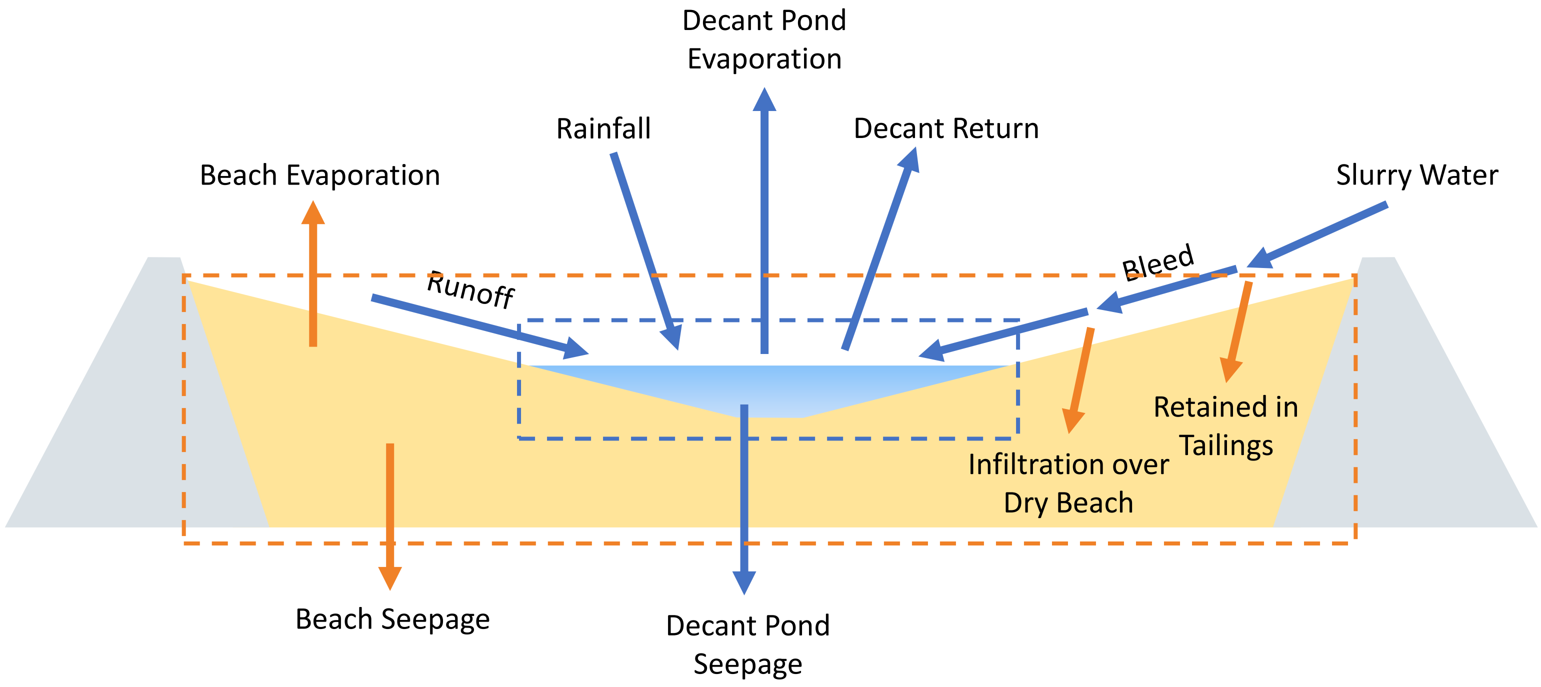
TSFs are dynamic water management systems

- The TSF **changes** through its life cycle (i.e. stage storage relationship, deposition schedule, infrastructure change, operational change)
- Model **objectives and drivers** vary depending on life stage (operational, care and maintenance, closure, and post-closure phases).

TSFs are often among the highest-risk assets on a mine site, and water is a critical factor affecting dam safety and environmental risk.

In many cases, decant water is a major source of process water; having a good understanding of potential water return helps manage water shortage risks and provides a basis for optimising water recovery.

TSF Water Balance Schematic Example:

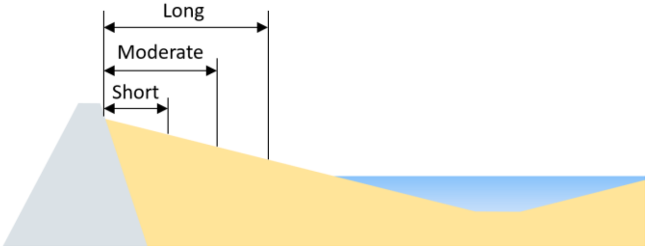


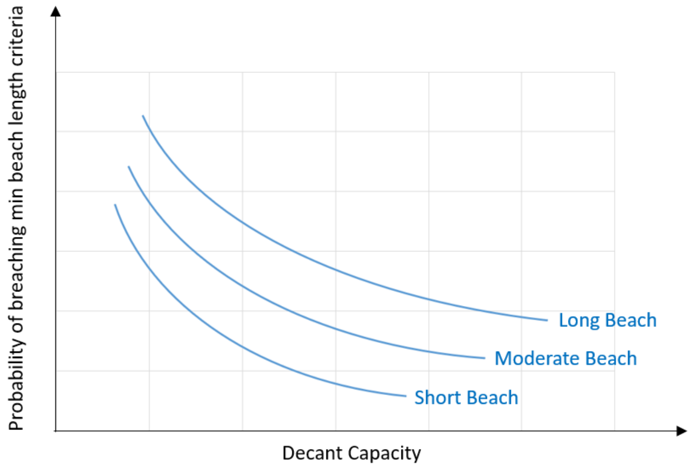
TSF Water Balance Application

Improve Efficiency & Save Cost

TSF Decant Size Optimisation

- Design objective linked to probability of breaching beach length inundation criteria
- Mathematical representation of decant system hydraulic performance.
- Interactive approach to find balance between system performance and cost

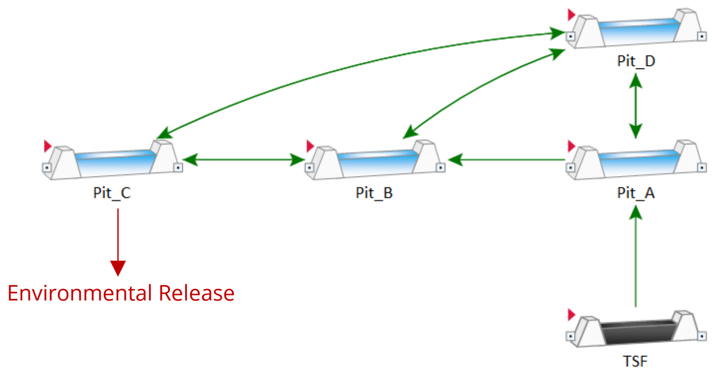


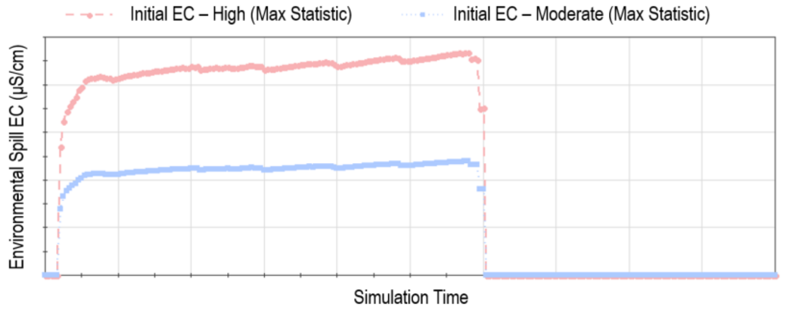


Build Operational Reliability

TSF Spill Environmental Impact Review

- Define potential solute transport paths through hydraulic connectivity between storages
- Evaluate the potential electrical conductivity of environmental release based on dilution and solute mass conservation
- Monte Carlo simulation considers probable spill trigger events to determine critical outcomes.

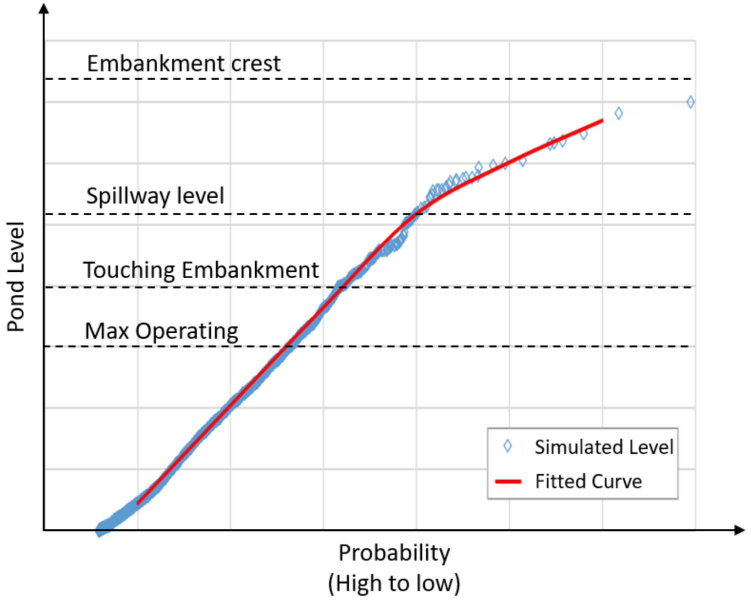




Manage Risks

Advanced hydrological modelling to inform Risk analysis and performance-based design

- Joint probability analysis – Monte Carlo Framework
- Pre-flood dam water level from long-term water balance modelling
- Practical approach for prediction towards extreme event range
- Flood routing with randomly sampled Pre-flood dam water level and hydrological input (i.e. rainfall, rainfall loss, temporal pattern, storm duration)
- Inform spill risk, overtopping risk, ping risk and performance



Site-wide water balance

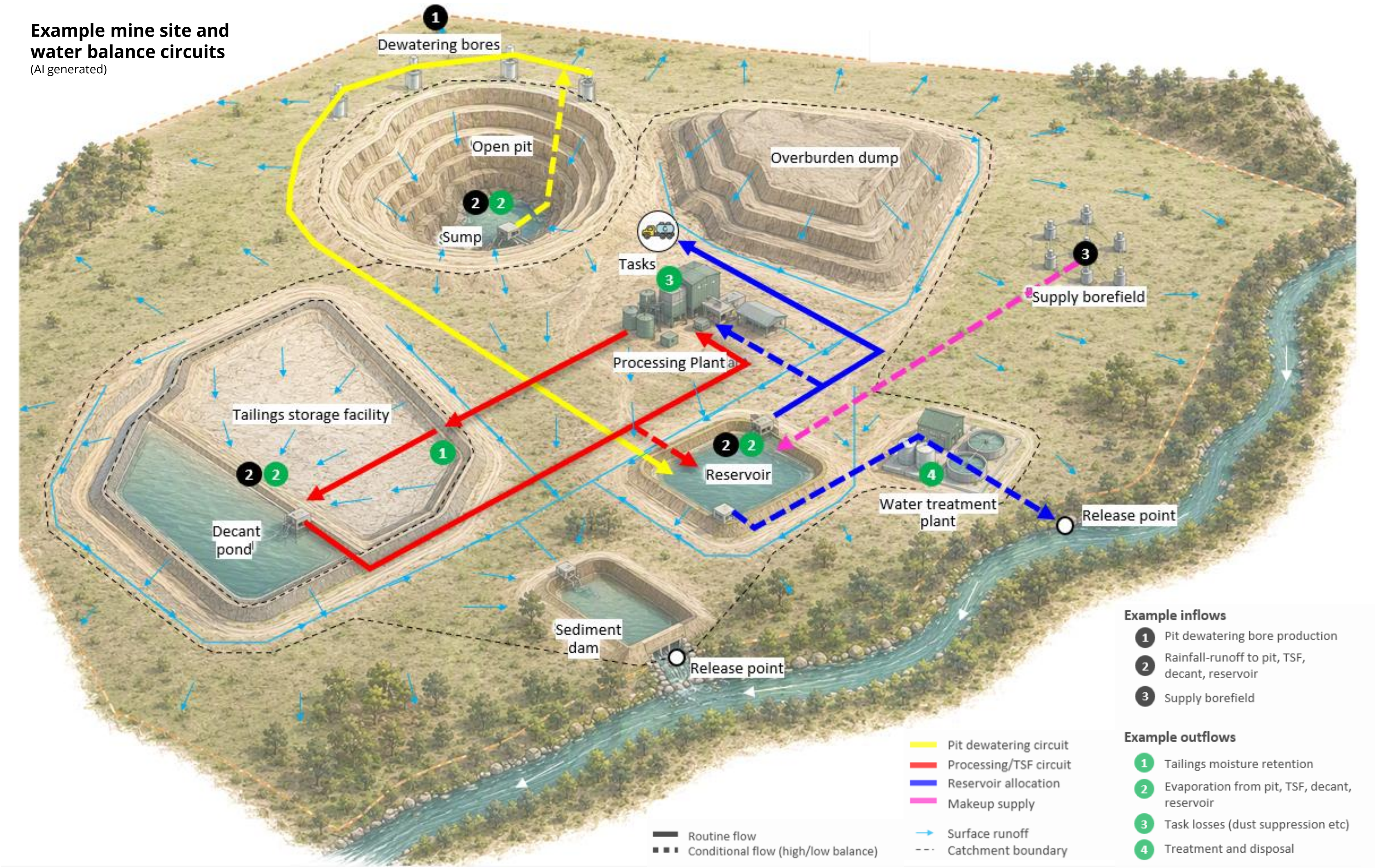
Owner-operator perspective

Gavin Rootsey, Rio Tinto

Connecting technical systems to operating decisions

Geosyntec consultants

Example mine site and water balance circuits
(AI generated)



Common interface

- Connecting specialist models and plans
- Aligning assumptions across teams
- Showing how decisions propagate through the site

Planning & design

- Sizing supplies, storage, treatment, transfers.
- Testing operating rules and constraints.
- Testing design, production and closure scenarios

Risk management

- Identify supply, discharge and excess inventory risks
- Testing risk controls before implementation
- Linking model results to operational decisions.

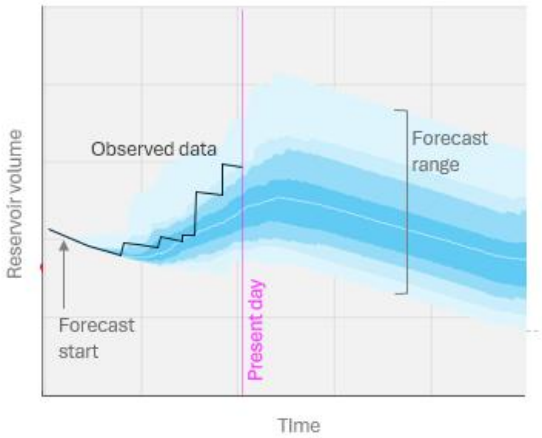
Useful models are trusted, actionable, and maintained

Geosyntec consultants

Trusted

Build confidence by demonstrating models are fit for purpose.

- Clear, complete **documentation**
- **Rationale** for assumptions and inputs (data, benchmarking, reasoning)
- **Calibration** against historical data
- Process for **tracking** forecast vs actual performance.



Forecast tracker example

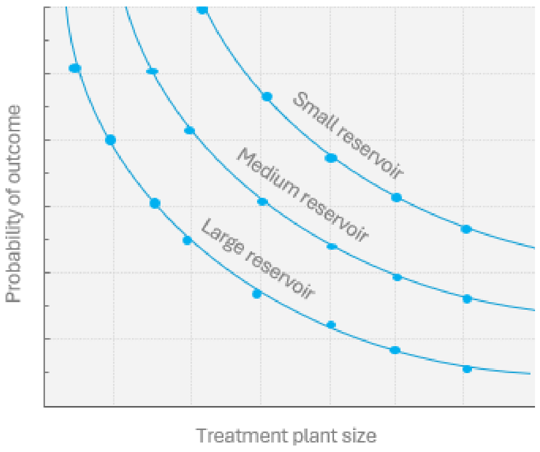
"Is the system performing the way the model said it would – if not, why and what do we need to do."

Tracker concept:

- Actuals tracked against basecase forecast
- Focus on performance metrics and drivers
- Early detection of issues, proactive response (update models, decisions etc).

Actionable

Useful models link decisions and actions to performance/outcomes. Front-loading modelling effort allows design and operational workflows to proceed efficiently.

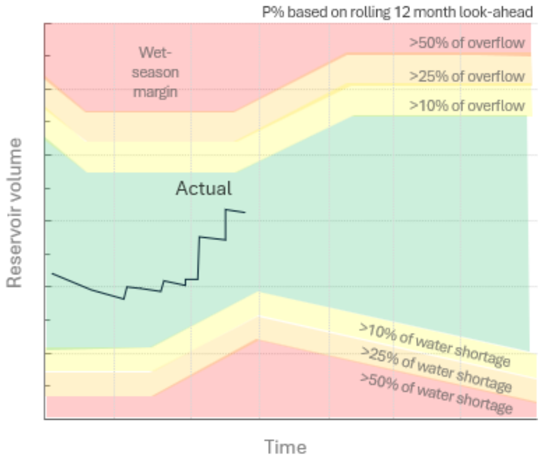


Planning & design example

"What combination of storage and treatment capacity gives an acceptable outcome."

Sizing curve approach:

- **Compressed output** of multiple model runs
- Accommodates **multiple sizing variables**
- Link combinations to **P% outcome**
- **Flexibility** to adapt to other scope constraints
- **Compatible** with cost models
- Highlights inflection points / diminishing returns
- Supports **cost vs performance trade-off** decisions



Operational control example

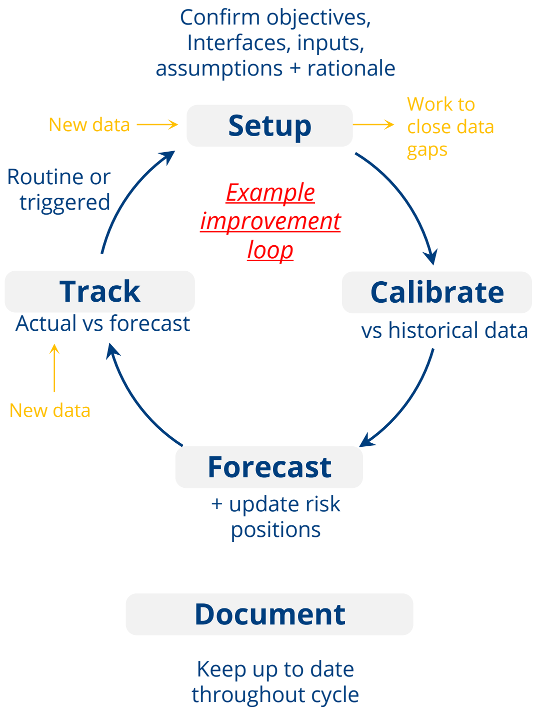
"Given inventory and forecast conditions, what action should the operator take now."

Trigger action response plan chart:

- Zones indicate **P% of outcome for current position** based on rolling 12 month look ahead
- Margins based on multiple water balance runs
- Informs current position **without needing to re-run models** before next update
- Zone **linkable to operator actions** (e.g. when to start/stop treating and releasing)
- Supports **dynamic decision making** (delay release if weather forecast for no rain.)

Maintained

Models aren't single-use – they need to be maintained and improved as conditions, data and decisions change.



Closure: same tools, evolving context

The same water balance tools remain essential for evaluating long-term closure outcomes and risks.

Risk focus changes through closure

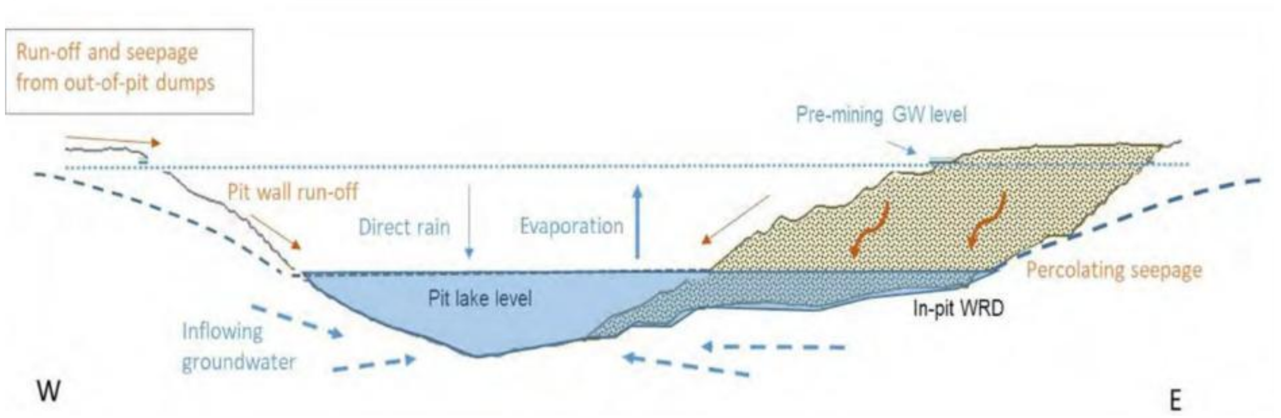
- Less emphasis on operational water supply; more
- When does inventory need to be reduced to avoid constraining rehabilitation earthwork schedules?
- What needs to be done to achieve that reduction?
- How will future pit lakes behave and what controls are required?
- What long-term discharge risks remain and how should they be managed?

Planning timescales extend post-closure

- Operational phase (dynamic)
- Transitional rehab phase (multi-year)
- Post-closure (decades to centuries)

Existing tools & knowledge need to be adapted

- Site conditions continue evolving after operations cease.
- Calibration becomes increasingly difficult as conditions change.
- Longer forecasting horizons increase uncertainty.
- Climate change may influence rainfall, runoff and evaporation assumptions.
- Proactive monitoring and progressive rehabilitation reduce uncertainty.
- Apply a precautionary approach where uncertainty remains.



Example pit lake water balance
Expected water level and quality trends?
Equilibrium timeframes?
Catchment and geography trade-offs?
Interactions with surrounding systems?

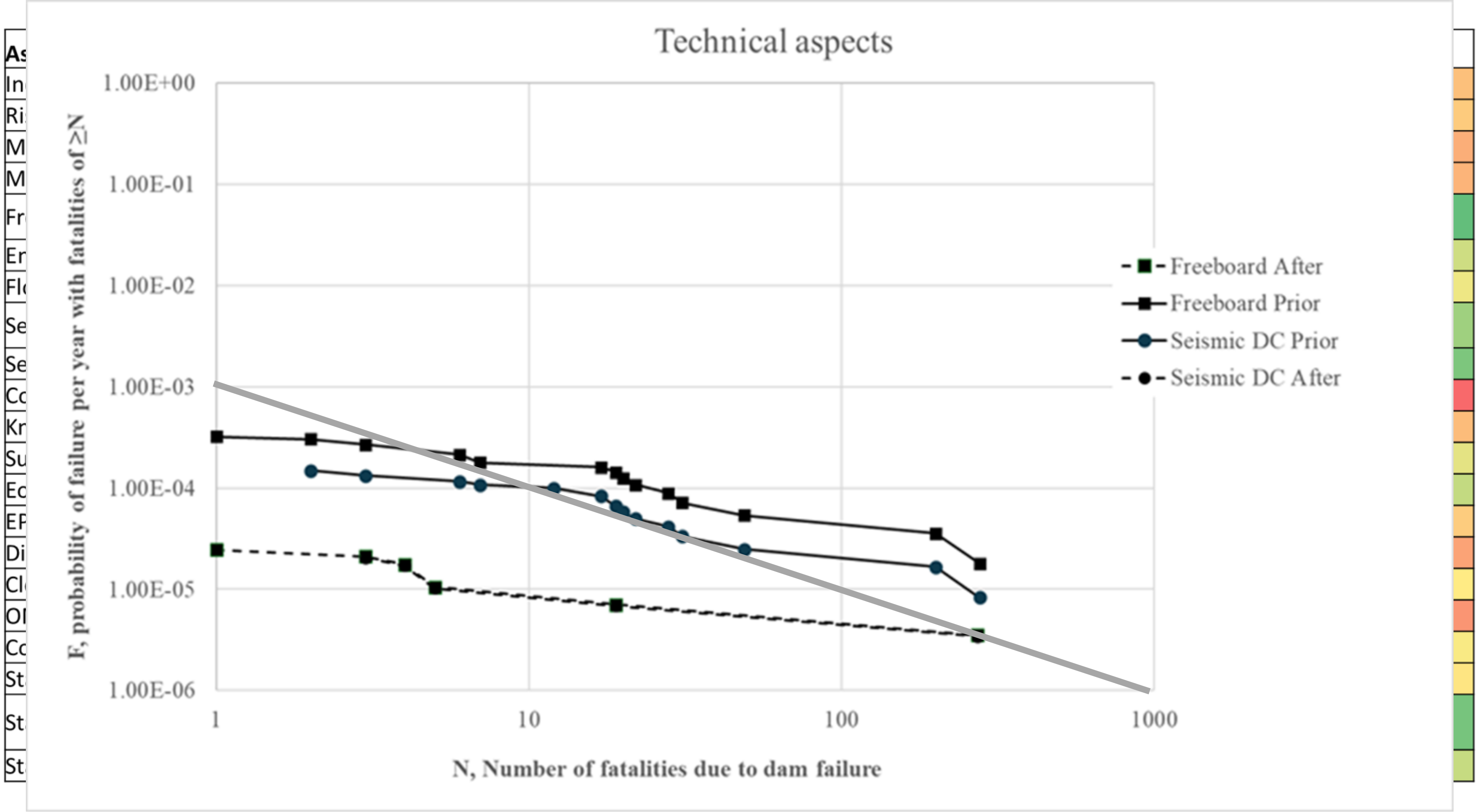
Pit lake image source: Linklater, C., et al., (2017), published by Sustainable Mineral Institute, University of Queensland Brisbane (via https://books.gw-project.org/hydrogeology-and-mineral-resource-development/chapter/open-pit-mines/)

Risk and Decision Making

Jarrad Coffey, Geosyntec

Risk Context

Geosyntec consultants



Source: Conformance, compliance and risk reduction in tailings dam management. Coffey, Pereira, Prabhu, Urbina, 2026. ICOLD Annual Meeting and Conference.

Decision Context

Geosyntec consultants

- Risk assessment should be structured to **answer a question**
- Just defining a risk level can be a means to an end but usually we are **determining if more should be done** to manage the risk
- ICOLD Bulletin 130 explores in detail
- Potential points to consider:
  - Owner commitments and policies
  - Societal values
  - Legal and regulatory requirements
  - Stakeholder concerns
  - How will be evaluation be completed?

  How complex does the model need to be to adequately inform the above?

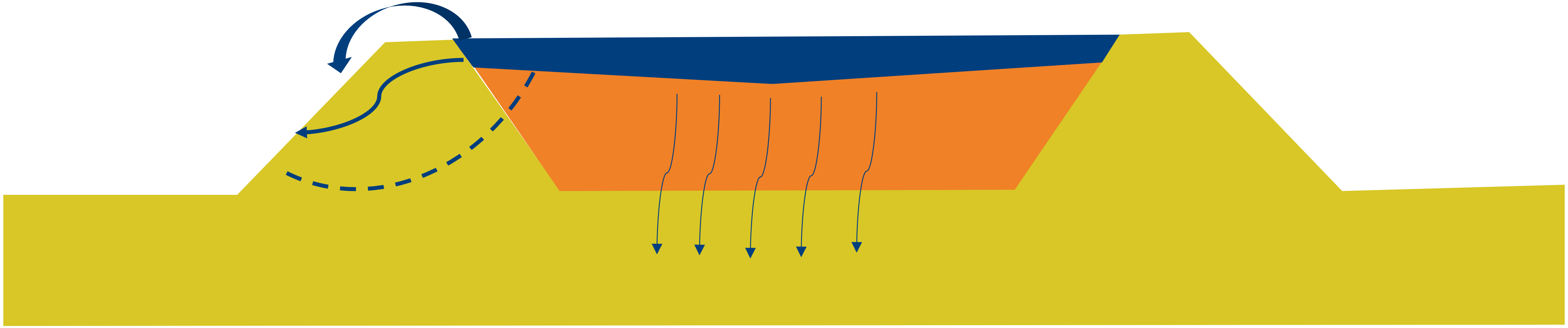
Why?

What?

How?

When?

Impact on Failure Modes



How does water balance modelling fit?

Risk Assessment:

Risk identification → Risk analysis → Risk evaluation → Action

Typical event tree for dam safety failure mode:

A	B	C	D	E	F
Management control absence or failure	Physical initiating event	Failure initiation	Progression	Failed intervention	Consequences manifest

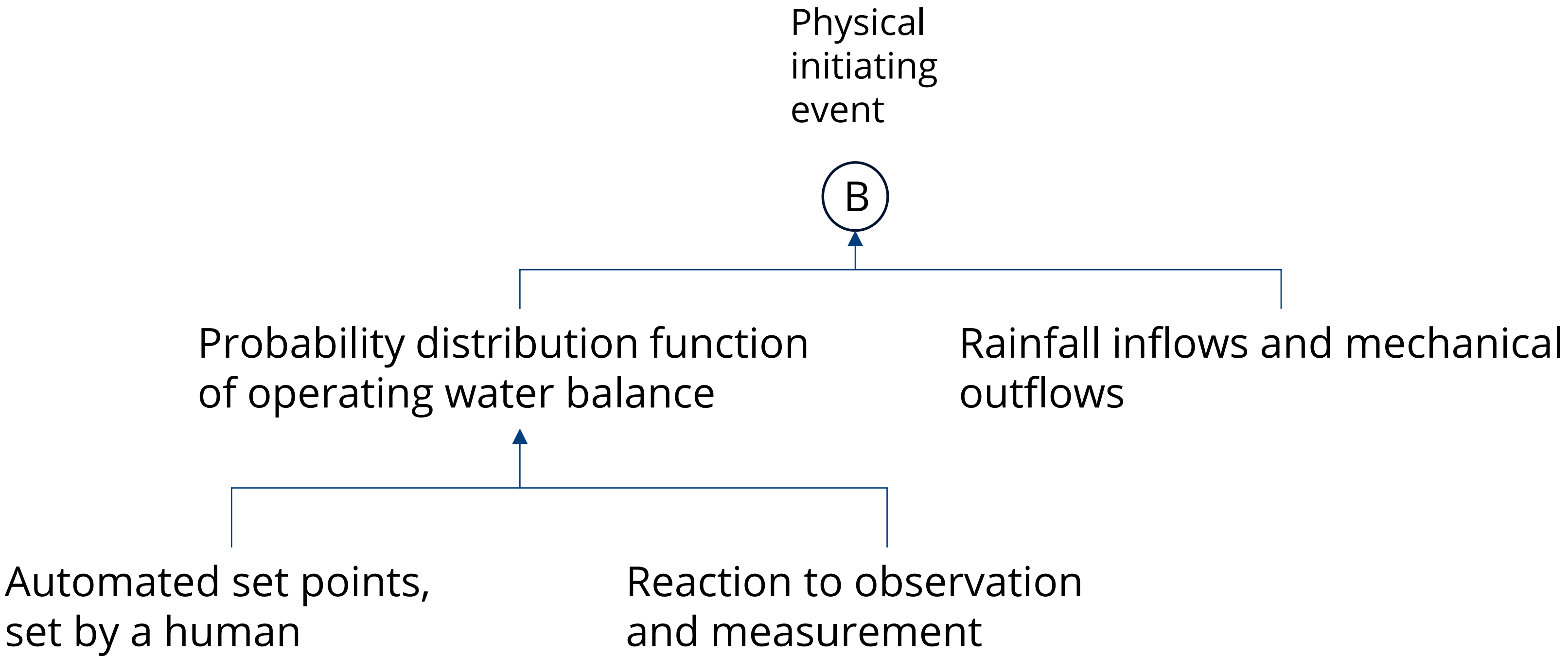
Degree of Belief

While stochastic modelling can give us what appear to be very precise outputs, there is still a lot of judgement applied in a TSF risk assessment

Frequentist: probability is interpreted as the long-run relative frequency of occurrence of an event in a large number of repeated trials

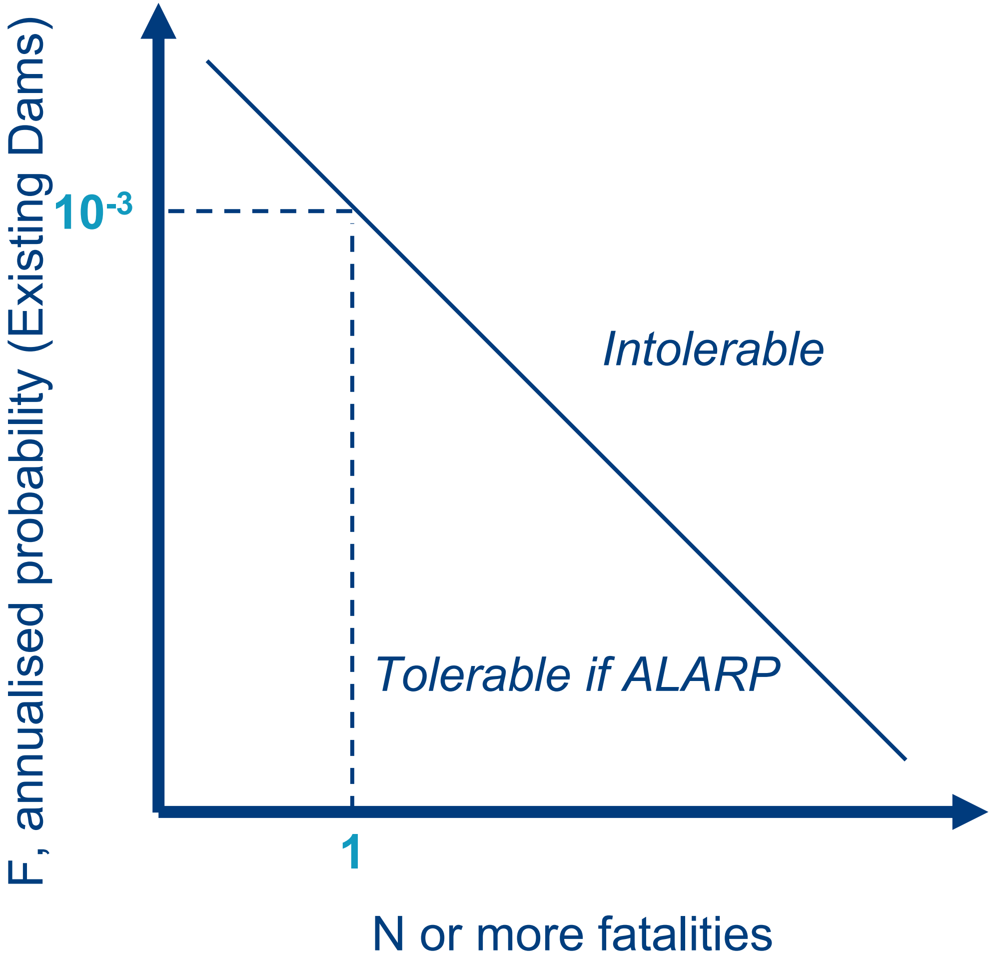
Degree of belief: probability is interpreted as a person's state of belief regarding the occurrence of an event, based on the available information, evidence, and judgment

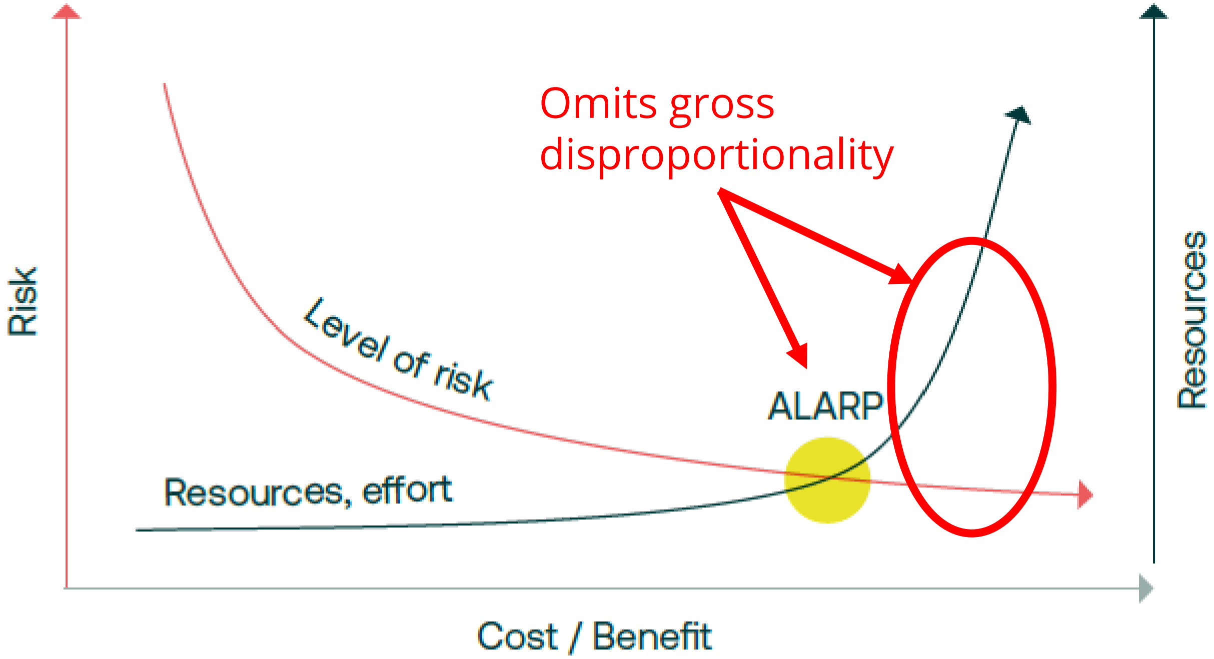
Event Tree Excerpt (overtopping):



Risk Evaluation

Geosyntec consultants





Source: ICMM (2025) Tailings Management Good Practice Guide

Management of risks

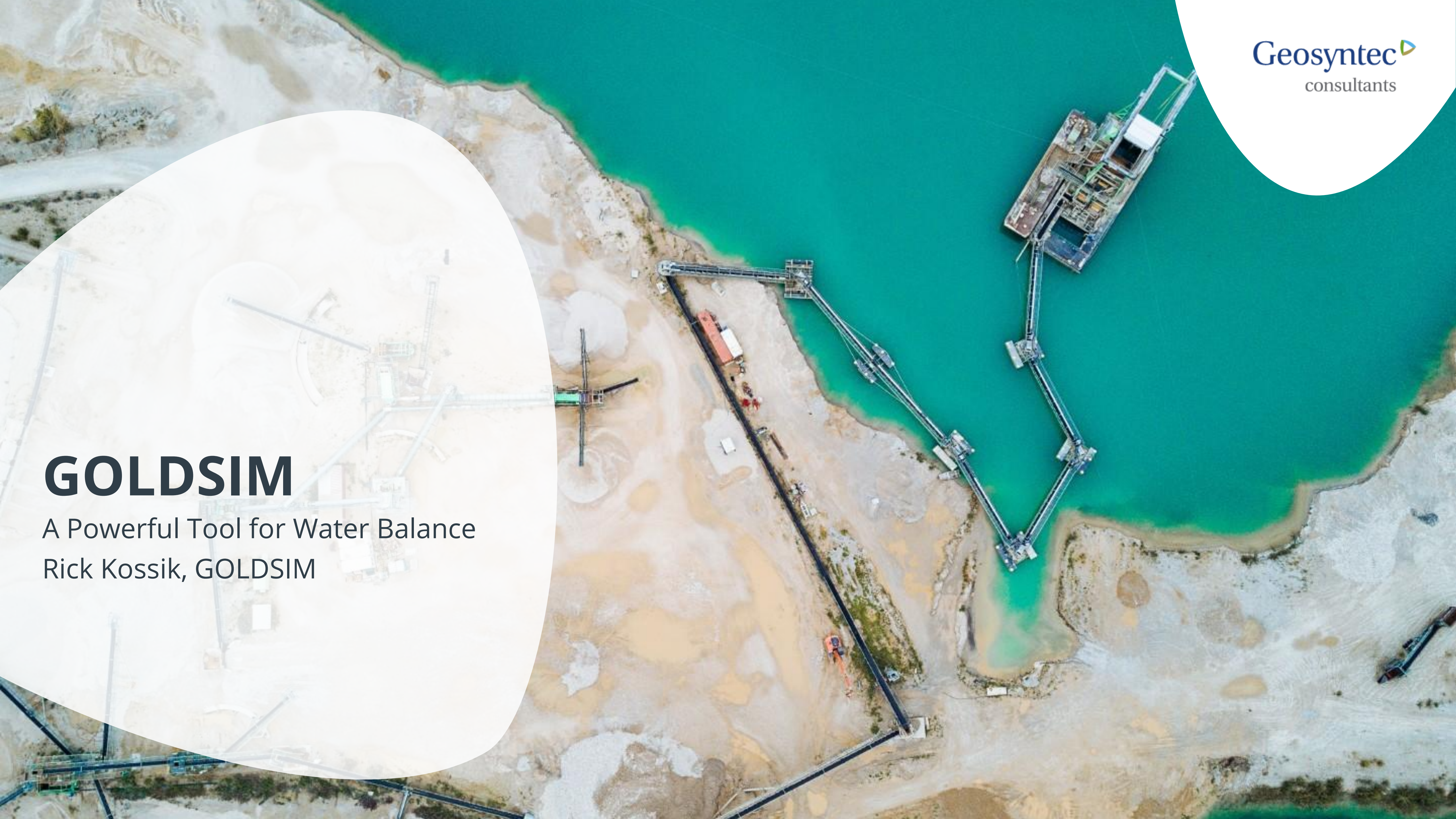
A duty imposed on a person to ensure health and safety requires the person —

(a) to eliminate risks to health and safety, so far as is reasonably practicable; and

(b) if it is not reasonably practicable to eliminate risks to health and safety, to minimise those risks so far as is reasonably practicable.

Source: WA Work Health Safety Act 2020

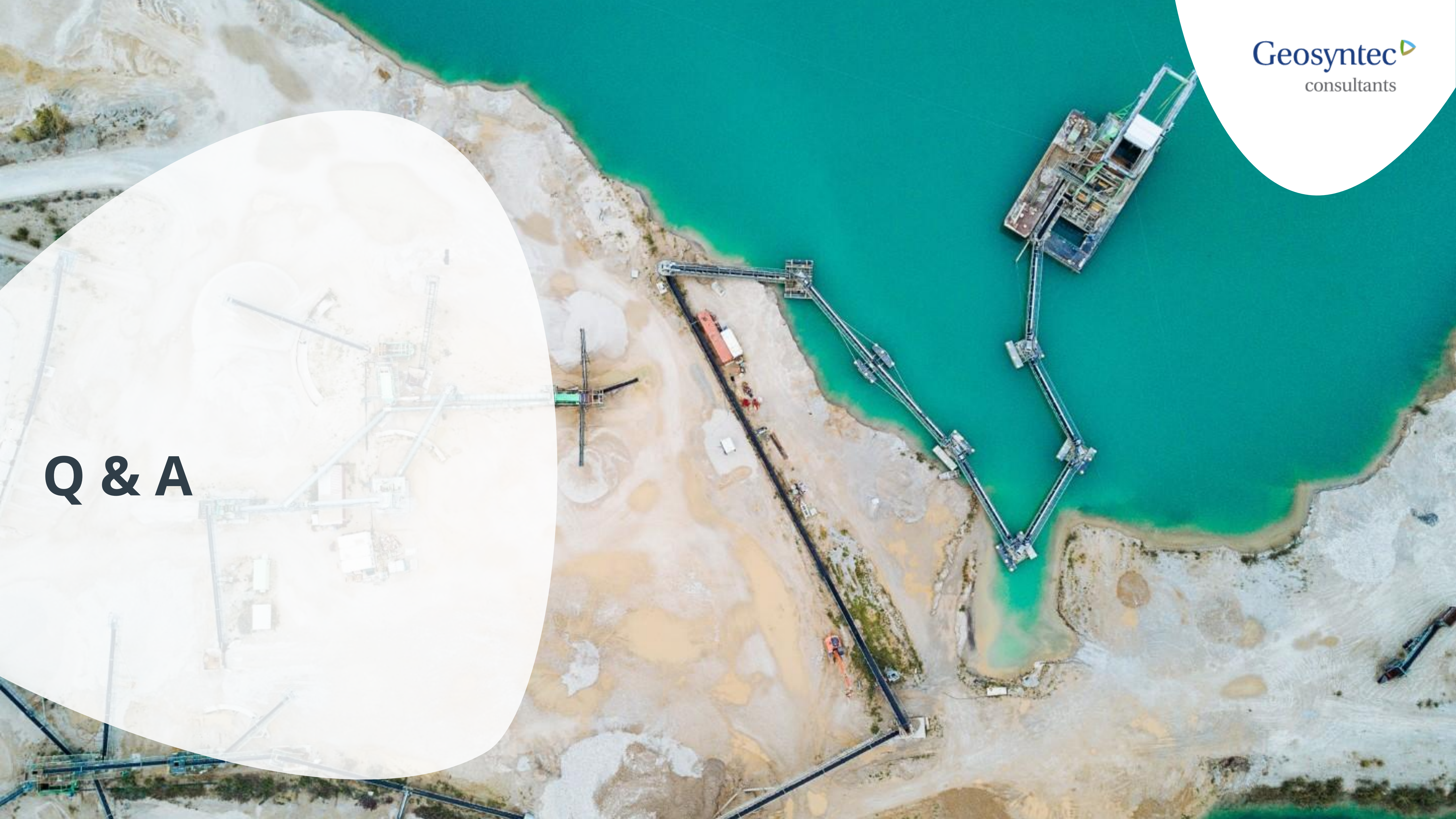
Geosyntec consultants



GOLDSIM

A Powerful Tool for Water Balance

Rick Kossik, GOLDSIM



Q & A

Geosyntec consultants


Geosyntec
consultants
Thank You!