TSF – Specific Water Balance as a Standard Practice

A. Scholtz, K.M. Uderstadt, L. de Villiers, G.C. Howell
SRK Consulting, Johannesburg, South Africa

March 2026

Contents

Introduction

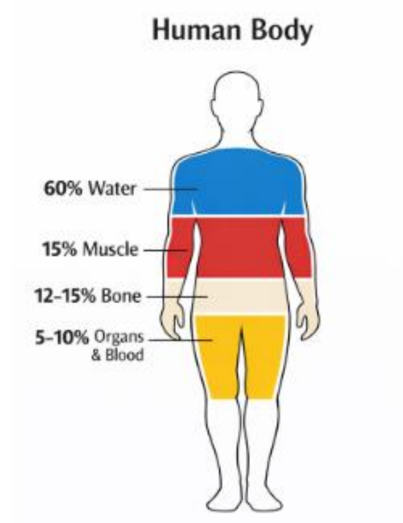
You cannot judge a book by its cover

- When we look at a book in a store, we just see a book and a cover
- The real story is inside – the structure, the chapters, the content, the number of pages among others
- A tailings storage facility (TSF) is no different
- From the outside, we see a mass of deposited material and, perhaps a water pond, the side slopes, and the surrounding topography
- What we **don't** see is what really matters:
  – How much water is stored inside?
  – Where it is?
  – How does it move over time?

Introduction

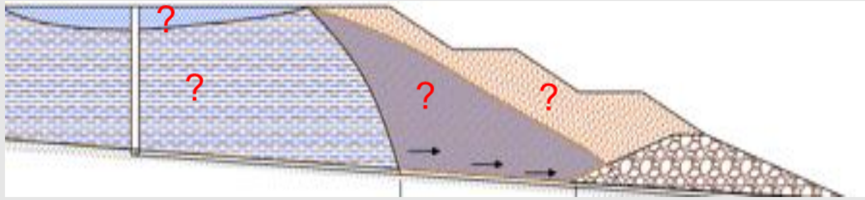
Human Analogy

- Now think about ourselves.
- We do not describe a person as simply “80 kg” and leave it at that.
- That mass is made up of fluid (water), blood, bone, organs, and tissue – each with a role and consequence if it changes.



Contrast with Tailings Facilities

- Yet with TSFs, we often accept exactly that level of understanding:
  - A total mass or volume, without knowing the internal composition – especially the quantum of water in each medium.
  - We understand what water comes into the facility and what water goes out of the facility – and that is as far as it goes.
- Generally, TSFs water balances are managed by appearance, not by understanding.
- Its dynamic is not fully explored!



Introduction

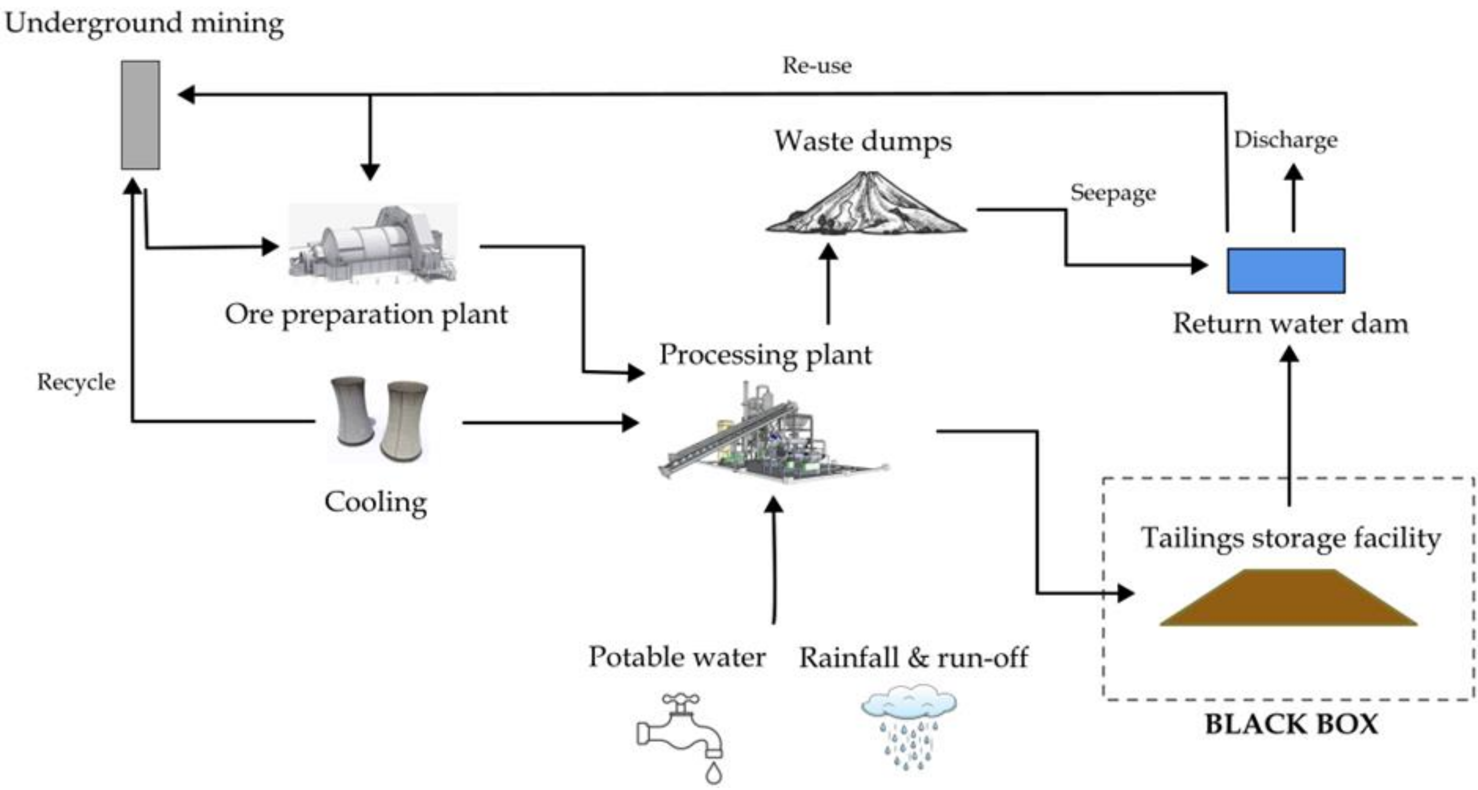
The Wake-up Moment

- Water inside a TSF is not evenly distributed, static, or harmless.
- It controls seepage, phreatic surfaces, stability, and ultimately failure risk.
- If we cannot quantify where the water is and how it changes over time, then we are managing uncertainty – not risk.
- This is why TSF–specific water balances are needed, and why a staged approach makes them practical.

Conventional mine water balances

High level water balances overview

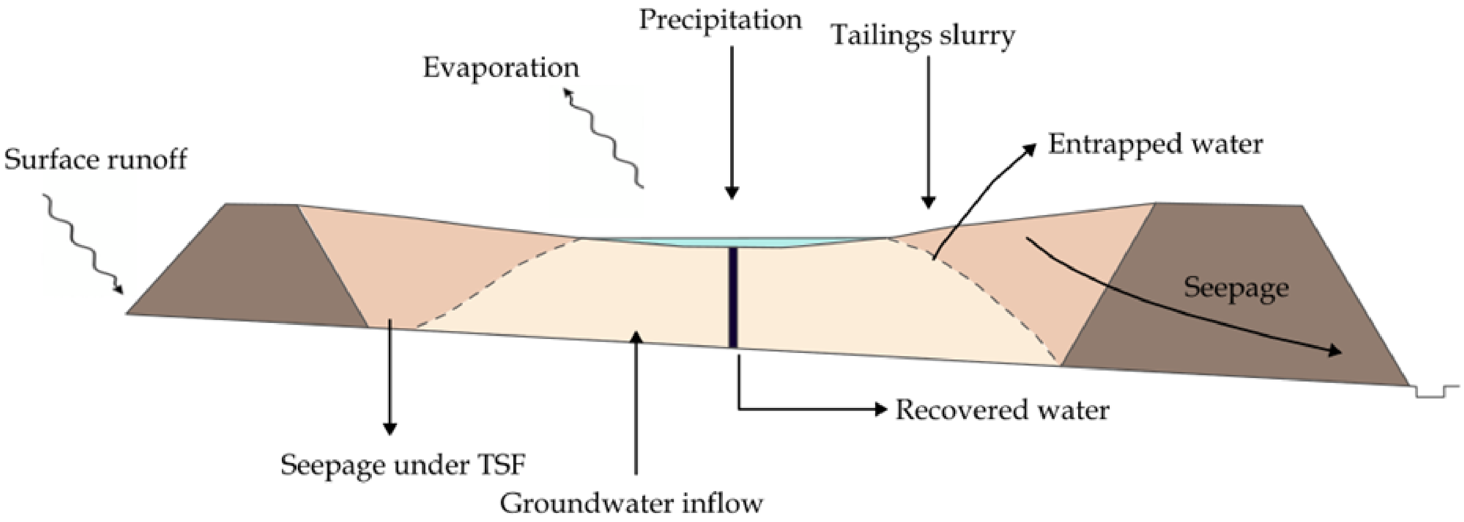
- Reviews all typical mining operations.
- Evaluates water use efficiency.
- Addresses compliance regulations.
- Potential environmental impacts.



Conventional mine water balances

High level water balances overview

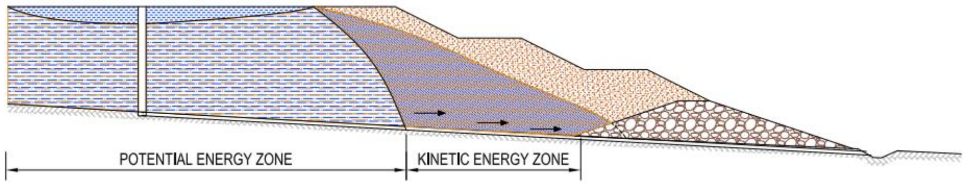
- TSFs are viewed as a black box (blue box).
- Little attention is given to internal storage and redistribution of water.
- Critical insights are missed.
- Typical parameters are detailed in the sketch below.



Energy balance as a foundation for water balances

Potential Energy vs Kinetic Energy

- Stored water possess potential energy.
- Kinetic energy is released when it flows i.e. dam breaks
- Stored vs moving water underpins the risks:
  – Phreatic surfaces.
  – Seepages.
  – Stormwater responses.



$P_E = mgh$

$K_E = \frac{1}{2}mv^2$

March 2026

- The greater the volume stored, the greater increase in potential energy.

Water storage parameters

Saturation, porosity and void ratio

- Engineering parameters of a TSF:
  - Porosity: Volume of voids per total volume of material.
  - Saturation: Fraction of voids filled with water.
  - Void ratio: Volume of voids vs volume of solids.
  - Dry densities of the tailings.
- Together, these factors govern the soil’s water storage, density, and flow characteristics.
- As a TSF fills, particles become compressed, saturation levels increase.
- Gradual increase of pore water pressure with depth.
- Saturation develops at the bottom; voids are filled with water.
- Upper surface – phreatic surface develops.
- Phreatic surface governed by hydraulic gradients, soil permeability and boundary conditions.

Development of a robust water balance model

Three staged integrated approach is considered:

Stage 1: “Matchbox” Approach

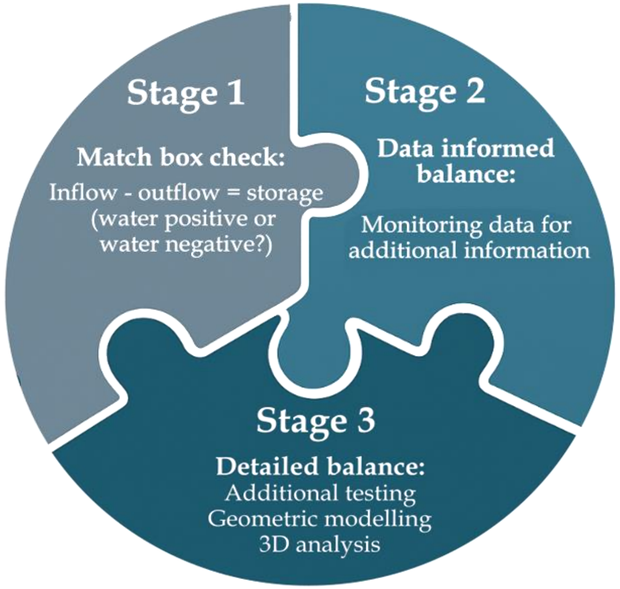
- Inflows and outflows are compared, estimate storage.
- Based on current information at hand – ROM, climate factors, etc.

Stage 2: Informed Approach

- Current data – site monitoring, slurry flows, rainfall, evaporation, pond levels, phreatic surface and seepage flows.
- Geotechnical properties – void ratios SG, porosity, saturation, etc.

Stage 3: Detailed Approach

- 3D analysis, survey data and geotechnical investigations.
- Hydraulic and geotechnical properties- hydraulic modelling, CPTu investigations
- Survey grids and run 3D models, data sets, calibration sets.



By progressing through these stages, the water balance evolves, by a simple short-term check to medium- and long-term evaluations.

Timing guidelines for robust water balance model

Planning guidelines:

- Typical timelines for implementation considered are:

Stage 1: Immediate	Stage 2: Near term	Stage 3: Long term
(days → weeks)	(weeks → 3 months)	(3 – 12 months)

- The above can vary according to geographical locations and procurement considerations.

Tolerances & basic parameters for a robust water balance model

Recommended Practical Tolerances

- Rainfall: ± 2 – 10% (gauge siting and wind effects)
- Evaporation: ± 10 – 15% (seasonal considerations)
- Pond WL: ± 0.02 – 0.05 m (regular surveys)
- Bathymetry depth: ± 0.1 – 0.5 m depending on depth
- Piezometers: ± 0.01 – 0.05 m
- Stage – area – volume relationship: ±5% of volume (depends on survey resolution and frequency).
- Slurry density: ± 2 – 5%
- Seepage / drainage flows: ± 10 – 20%
- Return flow meters: ±2 – 5% reading

Best Practice Parameters(SA)

- Rainfall resolution: ± 600mm / year
- Evaporation: ± 1500mm / year
- Slurry density: 1.45 – 1.55 t / m^3
- Tailings void ratio: (e) 0.7 – 0.9
- Hydraulic conductivity: $1x10^{-7}$ to $1x10^{-8}$ m/s
- Phreatic surface: > 5m from downstream crest, > 50m from downstream toe
- Water recovery: 60 – 75%
- Seepage collection efficiency: >80%

Worked examples

Worked Example 1 – Point in time

For the Stage 1 approach, typical values from mine records can easily be attained i.e.

- Dry tonnages: 240kt / month, slurry density: 1.5t /m³, SG: 3.3, slurry water: 1.2 m³ of water per dry ton, void ratio: 0.9
- Direct rainfall: 800mm , evaporation: 1 500mm / yr
- Areas: Dam: 112 Ha, Pool: 7 Ha, dam volume: 22 400 000 m³,
- Other factors: Return water pumped back to plant, drainage systems, seepage losses: 10% of inflows (estimate)
- From the above, the following was calculated:

– Total inflows:	486 000m³ / month
– Total outflows:	127 680m³ / month
– Net Storage:	358 920m³ / month
– OMW / M:	1.36
– Or OMW/M	74%

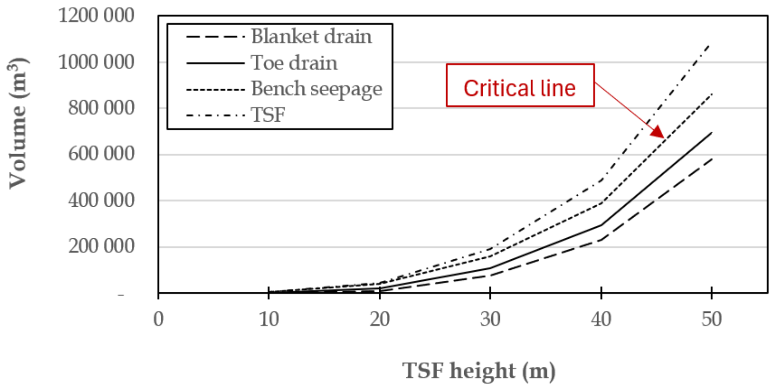
Worked Example 2 – Overall

Tons of tailings: Current operation	54 720 000 t
Dry Density:	1.80 t / m³
Volume of TSF:	30 400 000 m³
Pool water volume:	50 000 m³
Percentage pool water:	0.16 %
Saturated moisture content of tailings:	0.3 Mw / Ms
Saturated moisture content of tailings of TSF:	80 %
Mass of water in saturated tailings (below wt)	13 132 800 t
Volume of water in saturated tailings:	13 132 800 m³
Moisture content of tailings in shell:	0.22 Mw / Ms
Partially sat moisture content of tailings of TSF:	20 %
Mass of water in part saturated tailings(above wt)	2 407 680 m³
Volume of water in partially saturated tailings:	2 407 680 m³
Total volume of water:	15 540 480 m³
Percentage of water per volume of TSF:	51.12 %
OMW / T:	1.96
Or OMW/T	51%

Order of magnitude factors for the model

Development of order of magnitude of water (OMW) factors

- OMW factors can be developed for the mine for each stage of the water balance
  - OMW/M = net water storage/volume of TSF ~ 74 % /month in the previous example
  - OMW/T = stored water/ volume of TSF i.e. ~ 51%
- Mine or industry can then set limits based on the risk profile for each facility
- Typical frustrum (circular TSF) volume is modelled against height – impacts of phreatic surface

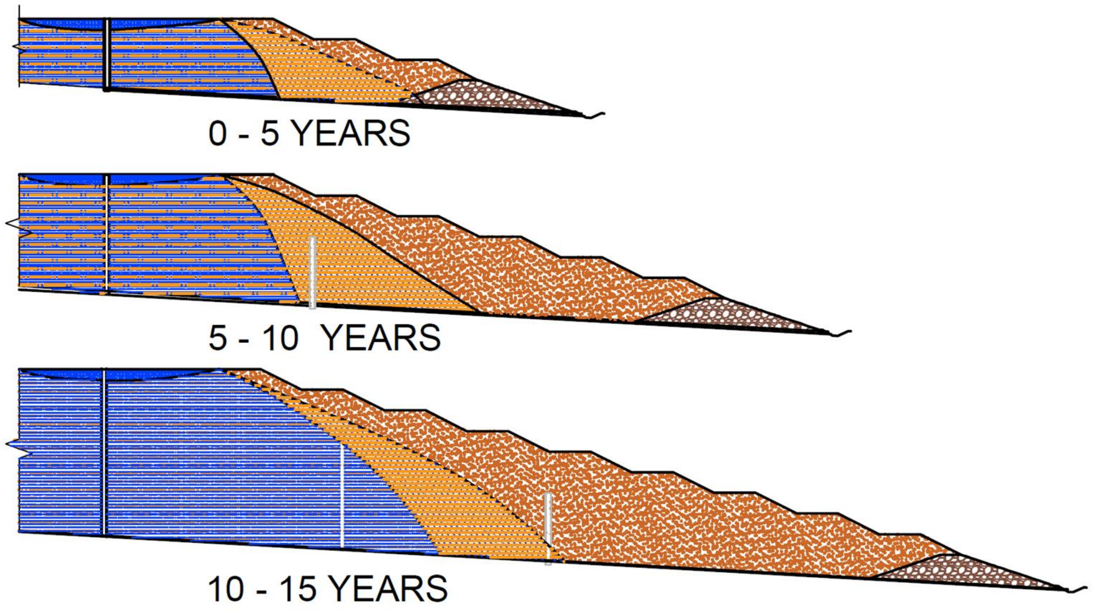


- Further research, development of nomographs/hydrographs to assist site specific water balance

Timeline of OMW parameters

Development of order of magnitude of water (OMW) factors

- OMW factors can be developed for each stage of the TSF development



OMW Factors (M/T) %		
Year 1-5	0.3	17
Year 6-10	0.3	34
Year 11-15	0.3	51

Compliance and Key Findings

Compliance Regulations (SA)

- DWA – registration of dams – risk > 5m > 50 000 m^3
- Licenses issued for construction or modification
- Conformance to GISTM requirements (*Principal 5.3 - development, implementation, and maintenance of a comprehensive water balance model*)
- DWA, DSO appoints APP, responsible people are AE, EOR and RTFE
- Improvement in monitoring & reporting & records
- Pool storage ≠ actual storage volume for a TSF
- Dams cannot be registered on this basis

Key Findings for a Site-specific water balance

- Clarity on water storage
- Assists with early warning risks inflows and outflows, stability issues
- Creates a basis for operational decisions to be made
- Improves water efficiency
- Provides a foundation for a staged approach to be adopted
- Addresses compliance (DWA & GISTM) and creates transparency
- Frequency of water balances – monthly, quarterly, yearly reports
- Storing of water on the TSF must be minimized as far as possible
- Establishment of TARPS & assists with DBA

In closing

Conclusion

- Effectively, water contained in TSF’s must be measured to be managed
- TSF’s store large variable water volumes
- This changes over time- increases
- Risks are increasing with changes in global weather patterns
- If left unquantified, risks become a liability
- What is stored in your TSF box – blue box?

Questions and Answers

Q&A

Thank You

Presented by:

Kurt Uderstadt BSc Civil Pr Eng

Annelie Scholtz BSc Civil MSc

L de Villiers Pri Sci Nat

DR G C Howell ***PrEng***
PhD(Eng), MSc(Eng), BSc(Eng)

SRK Consulting (Pty) Ltd
Johannesburg, South Africa