Building better water balance models for tailings and mine rock stockpiles

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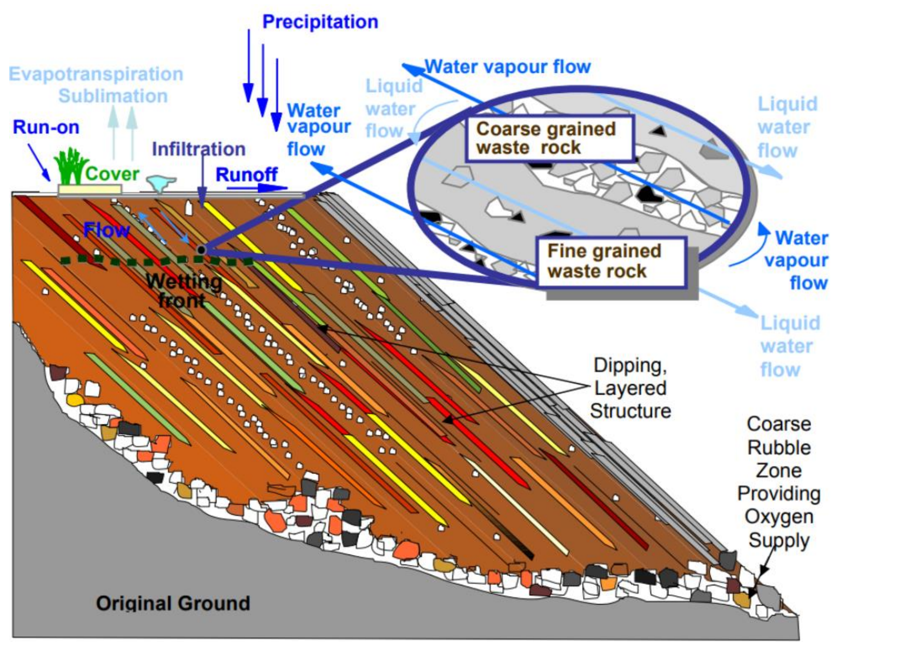
Challenges in Waste Rock

$$FeS_2 + 15/4O_2 + 7/2H_2O = Fe(OH)_3 + 2SO_4^{2-} + 4H^+$$

Metal leaching and acid rock drainage (ML/ARD) is common in waste rocks exposed to air and water from mining

1. **Time horizon**: ML/ARD onset may be delayed for decades
2. **Mine planning** : closure plan developed in silos from operation plans.
3. **Perpetual maintenance**: infrastructure deterioration

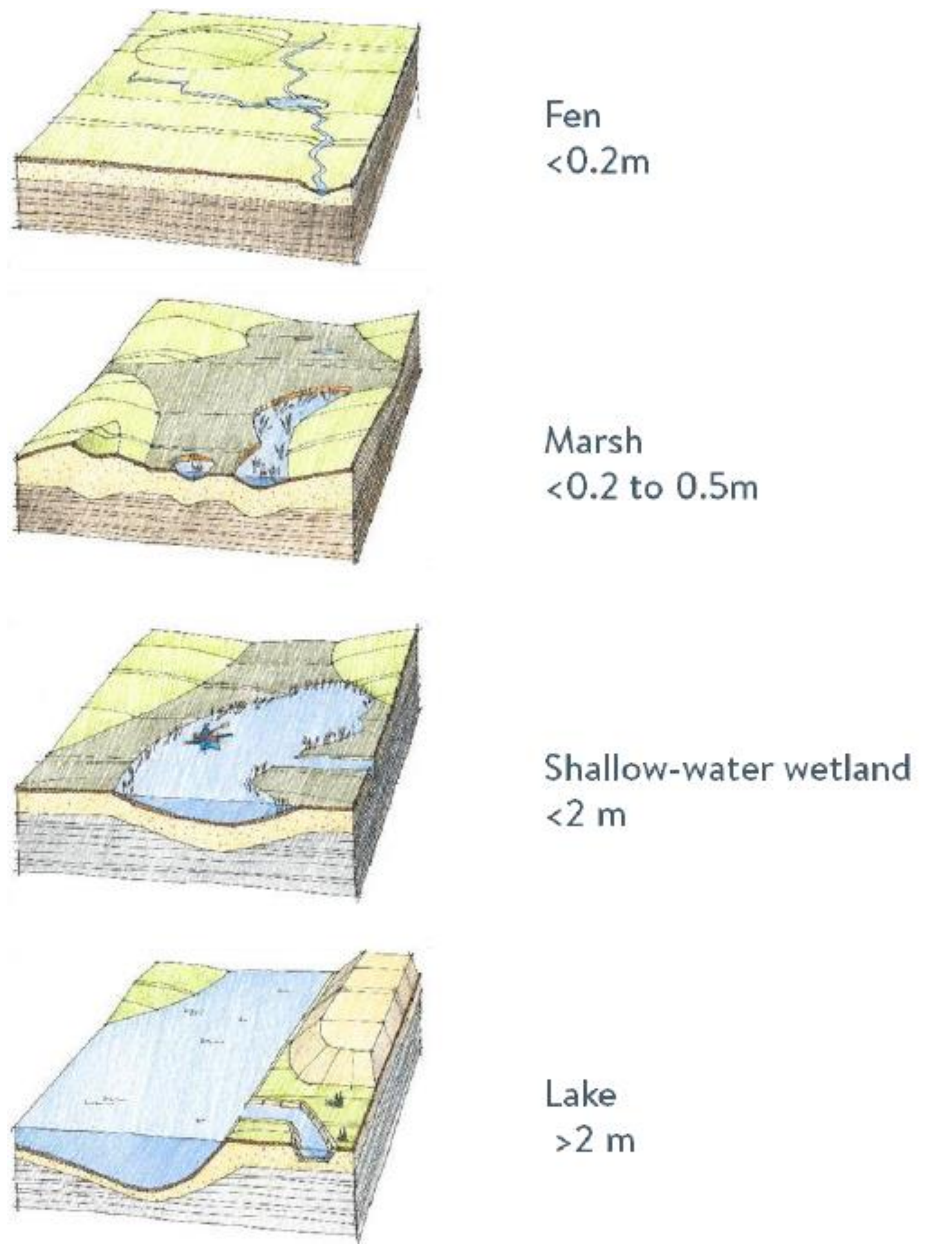


Herasymuik (1996)

Challenges in Tailings

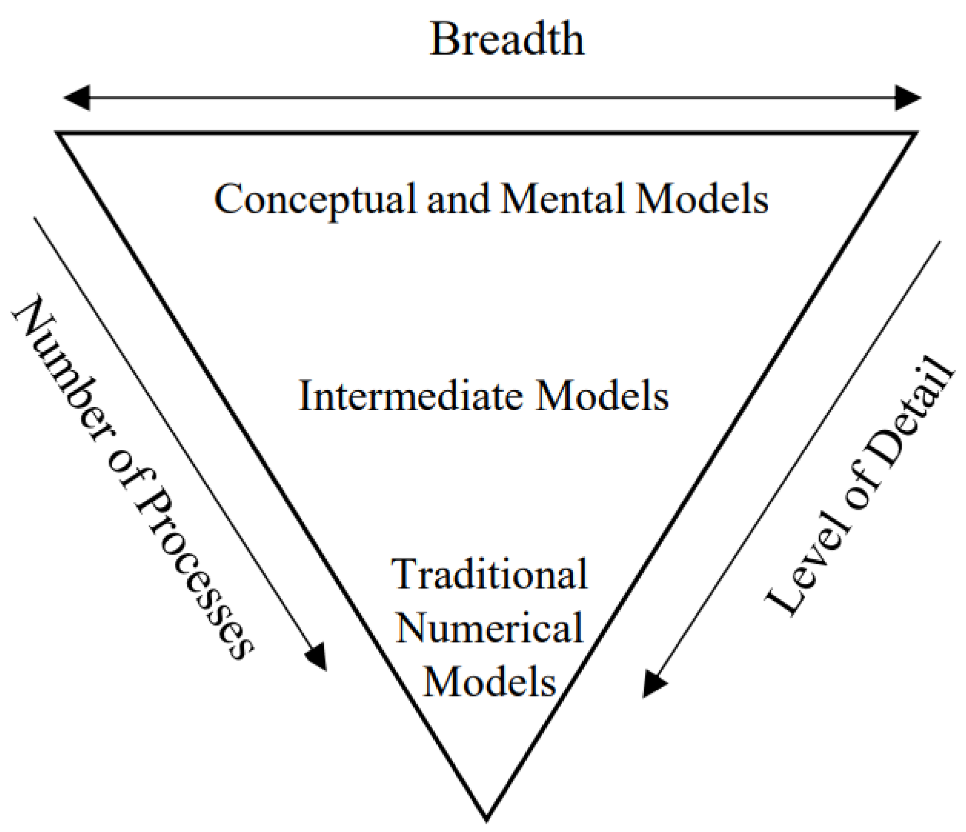
Tailings pose heightened risks in closure landform and weak strength to support reclamation activities:

1. **Settlement**: landform and contaminant transport
2. **Weak strength**: liquefaction and dam safety
3. **Pre-deposition treatment**: technology readiness



CEMA (2012)

Intermediate Models in GoldSim



Zheng and Beier (2018)

Benefits

1. **Integration**: ability to integrate with site-wide water balance models in GoldSim
2. **Complexity**: appropriate for sensitivity analysis and sanity check
3. **Communication**: GoldSim Player facilitates stakeholder engagement

Definition

1. **Type**: physics-based or semi-empirical
2. **Methodology**: finite difference, first-order non-linear
3. **Spatial setup**: discretized 1D or pseudo 2D and 3D
4. **Complexity**: dominant material properties and mechanisms captured

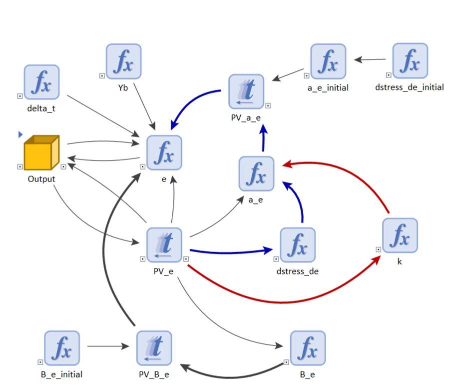
Limitations

1. **Stakeholder acceptance**: too simple for some; too complex for others
2. **Complexity**: risk of incorporating excessive, unnecessary details
3. **Classification**: need clear definition to guide model development

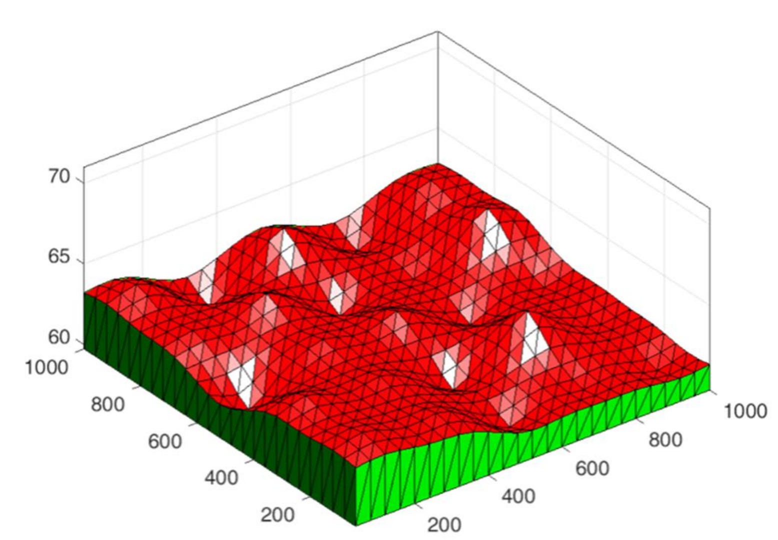
Case Study #1: Tailings settlement

$$e_{i,j} = e_{i,j-1} - \left(\frac{\Delta t}{\gamma_w}\right)\left\{\left[\gamma_b \beta\left(e_{i,j-1}\right) + \frac{a\left(e_{i+1,j-1}\right) - a\left(e_{i-1,j-1}\right)}{2H_s}\right]\left(\frac{e_{i+1,j} - e_{i-1,j-1}}{2H_s}\right) + a\left(e_{i,j-1}\right)\left(\frac{e_{i+1,j-1} - 2e_{i,j-1} + e_{i-1,j-1}}{H_s^2}\right)\right\}$$

Physics-based finite difference code



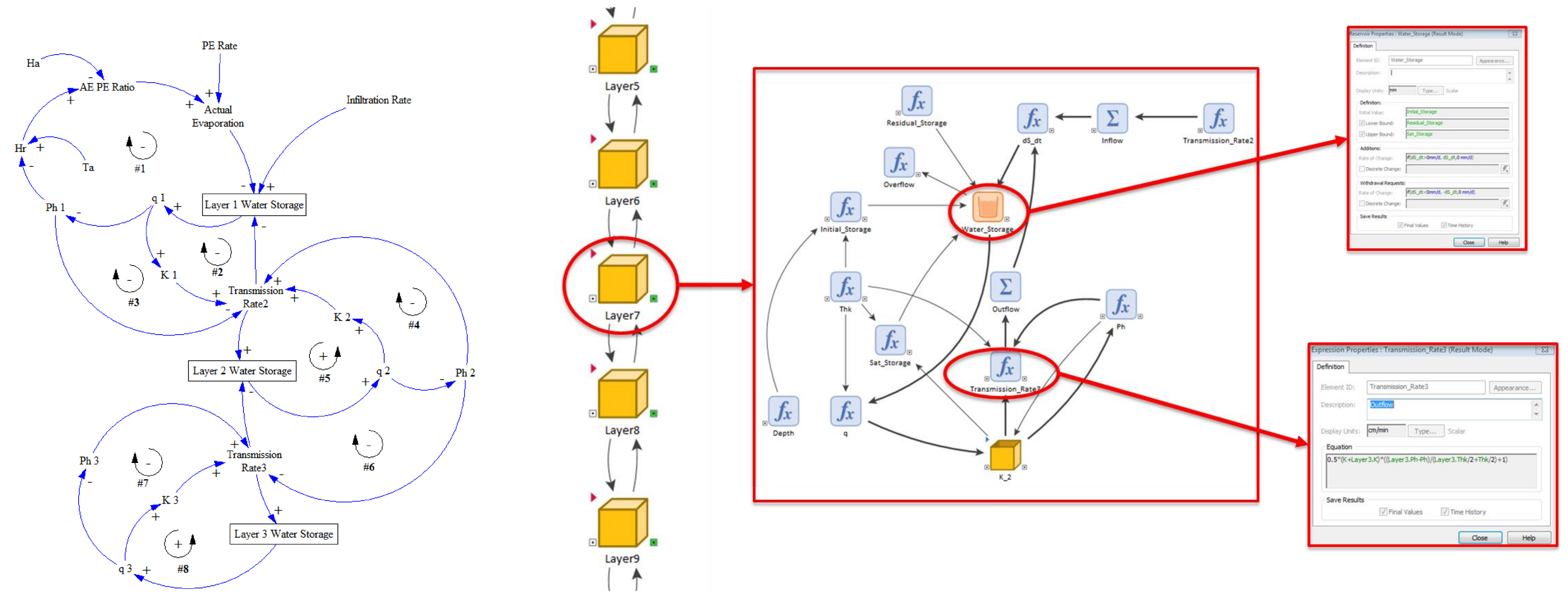
Zheng and Beier (2021)



Badiozamani and Beier (2022)

Case Study #2: Unsaturated flow in cover systems and waste rock

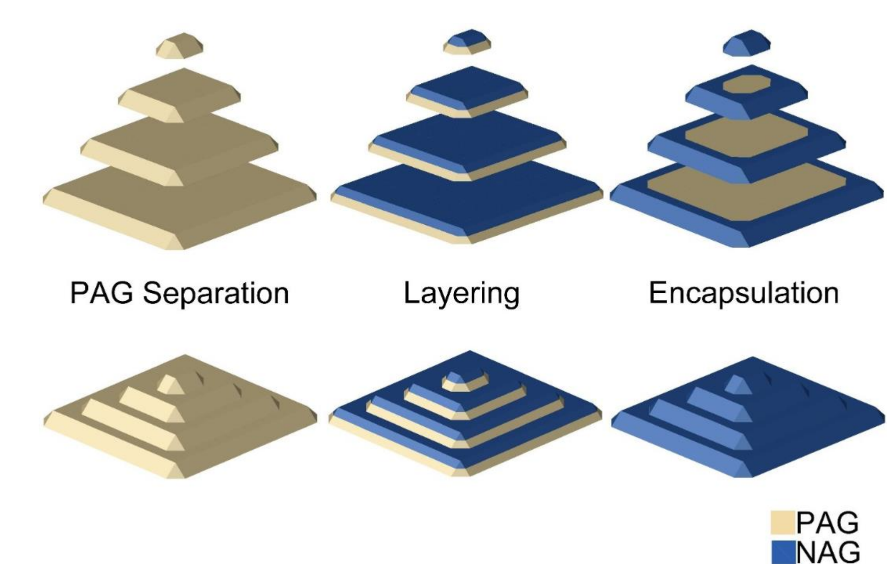
Physics-based formulation with semi-empirical assumptions

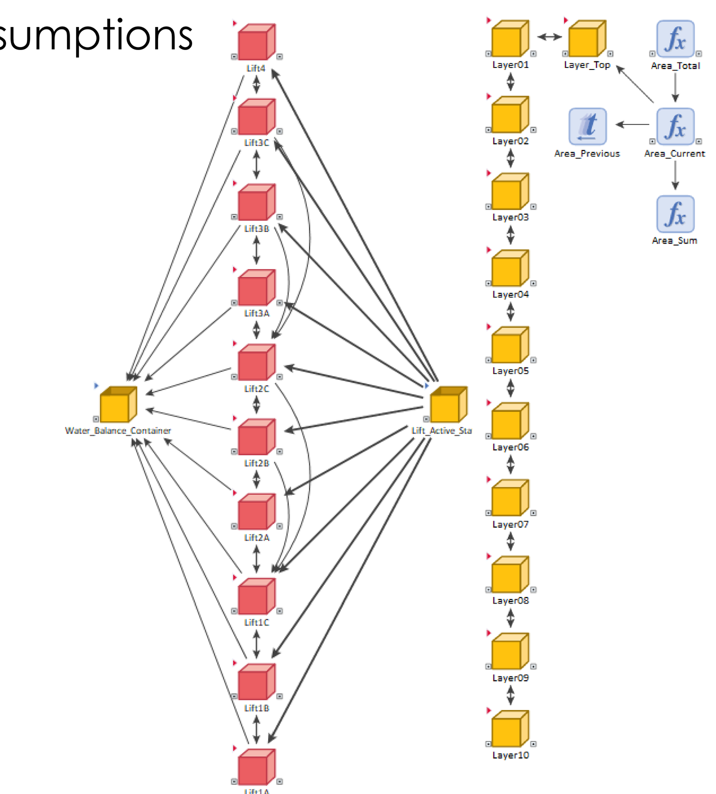


Zheng and Beier (2021)

Case Study #3: Strategic waste rock management

Physics-based formulation with semi-empirical assumptions

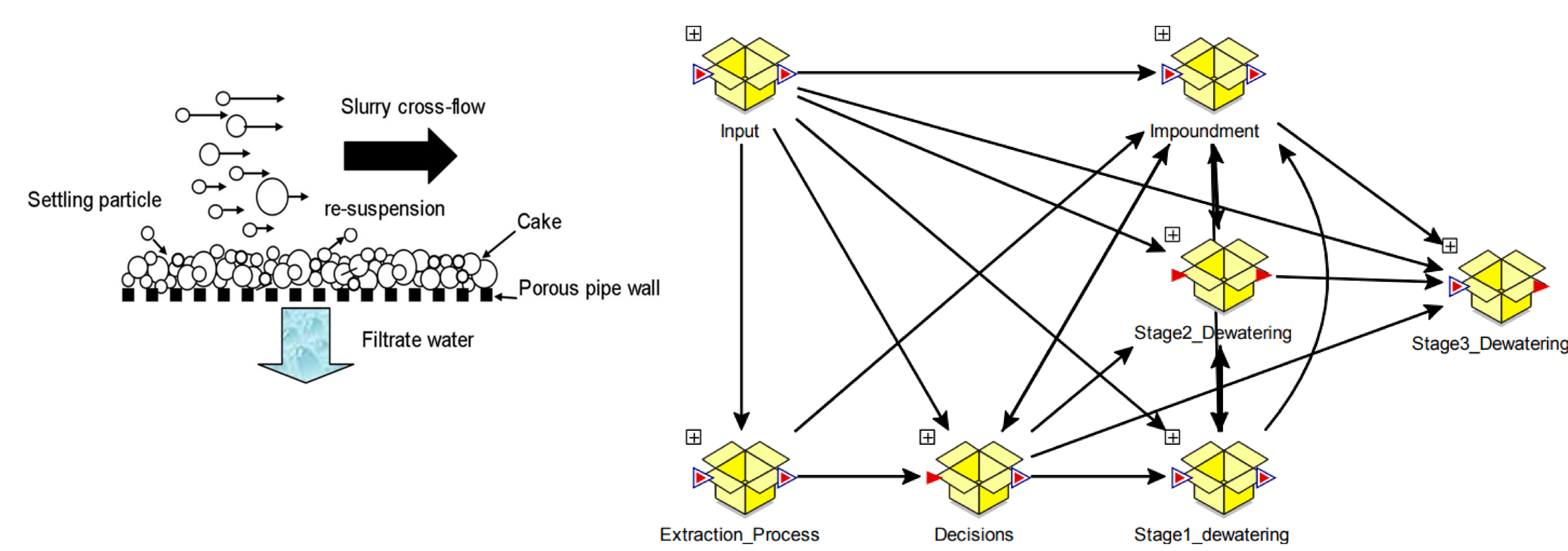




Hurtubise (2022)

Case Study #4: Tailings dewatering technology evaluation

Semi-empirical formulation with coupling to commercial software



Beier et al (2020)

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