Could I Model That?

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Reactive Water Quality Modelling for Mine Sites

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Outline

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- Introduction to water quality modelling
- Types of models & their applications – case studies
- Cheat sheet for reference

Water Quality @ Mines

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- Monitoring of mine site water quality is essential for environmental management of a mining and mineral processing operation
- Historical trends don't always point to root causes and rarely an indicator of potential future issues
- Risk assessment on water quality impact/changes are increasingly in regulatory requirements/expectation

Why Model?

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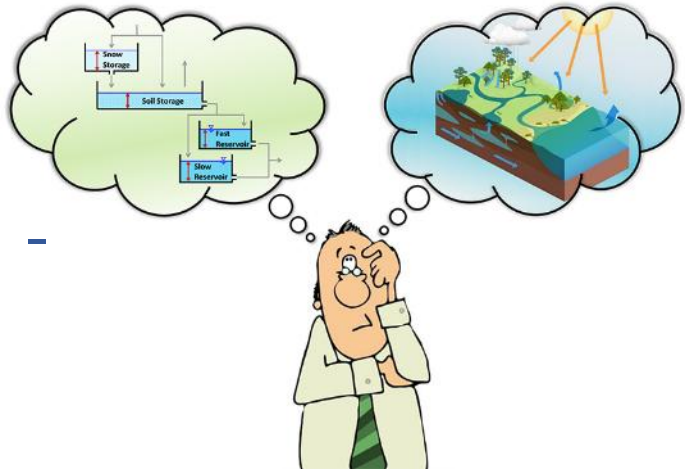
- Models provide insight into cause and effect of water quality impact/ changes
- Define risk scenarios:
  - Qualitatively understood but “actual” (quantitative) risk is not
  - Management decisions required
- Requires collaboration from many teams – avoid silos
- Now becoming an essential part at all stages of mining - approvals to closure



What is Water Quality Modelling?

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- Estimation of water quality along:

$$\text{Source} \rightarrow \text{Pathway} \rightarrow \text{Receptor}$$

- For example:
  - Natural water bodies affected by mine water discharge
  - Seepage from WRD or TSF
  - Pit lake – during operational changes, after closure & over long term

What is Water Quality Modelling?

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- Water quality depends on concentration and flow:

Load (mg/d) = Conc (mg/L) x Flow (L/d)

- Depends on size and complexity of modelled system
- Values change over time
- Data collected and stored by different teams (enviros vs engineers) – may rarely be seen together
- Overall risk is often not easily judged or often communicated well

Types of Water Quality Models

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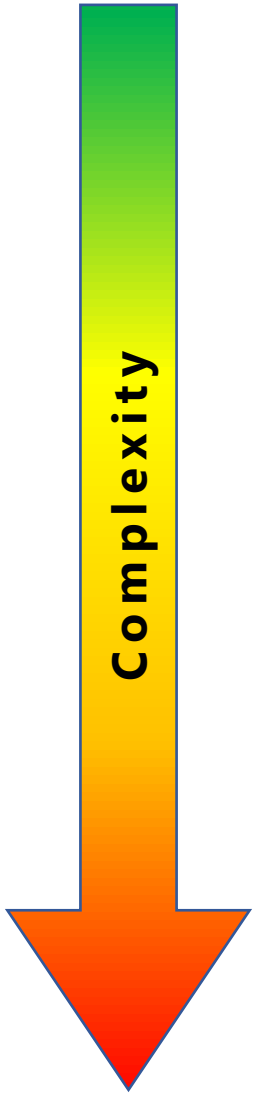

Mixing Models

- Estimate composition at one or more locations
- With or without geochemical reactions
- Big picture risk scenario
- All stages of mining
- e.g. Site-wide water quality, aquifer re-injection

Seepage Models

- Simplified flow conditions (1-D or 2-D)
- Focus on geochemical reactions
- Specific risk scenario
- e.g. AMD in WRD, TSF seepage impacts

Pit Lake or Groundwater Flow Models

- Large scale and complex geochemical reactions
- Requires collaboration from various disciplines
- Closure risk scenarios
- Often long term – updated to address changes in operation strategies & closure scenarios.

Model Applications

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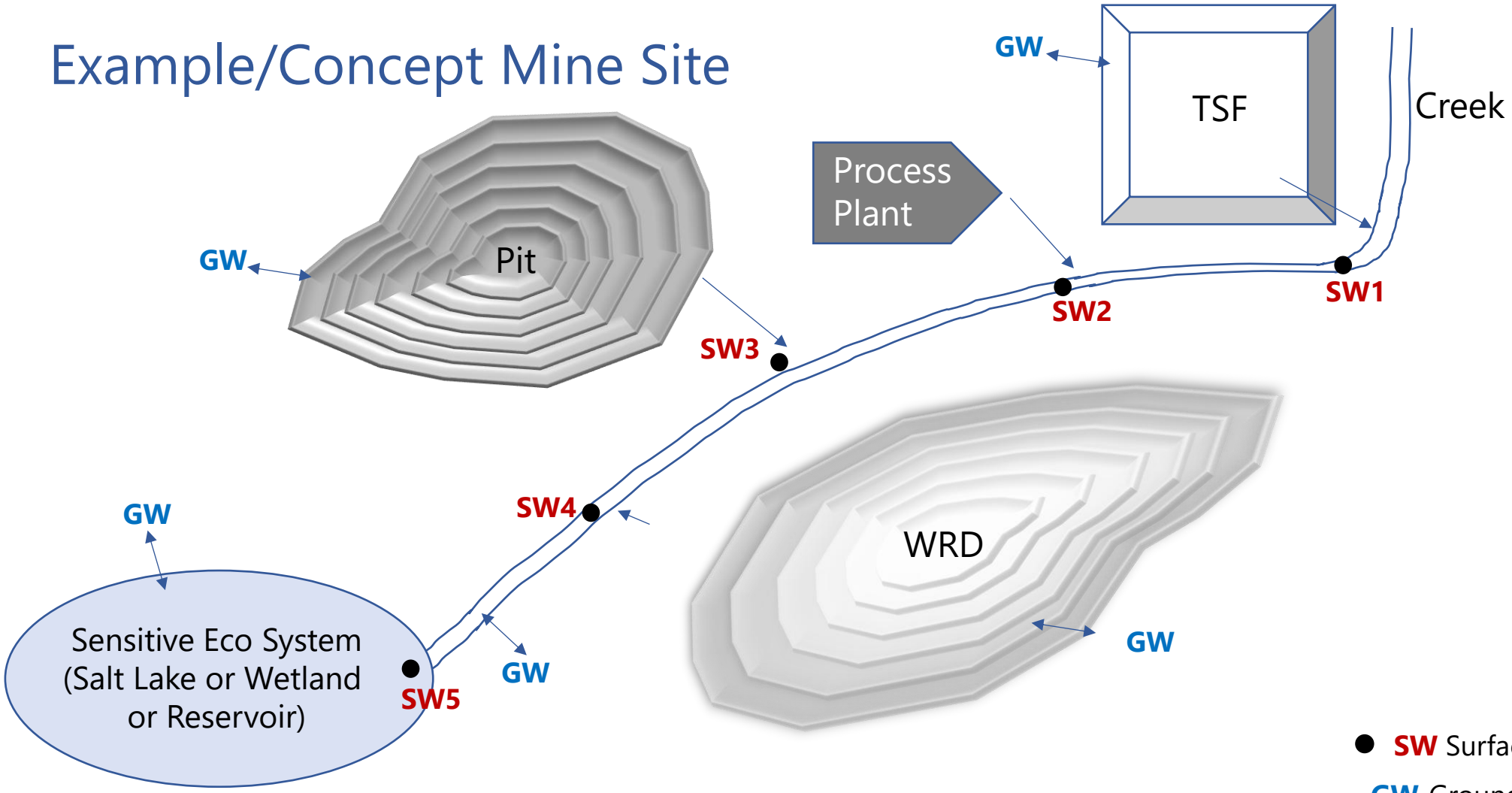
Example/Concept Mine Site



● **SW** Surface Water Monitoring

GW Groundwater Interaction

Case Study #1 – Mixing Model

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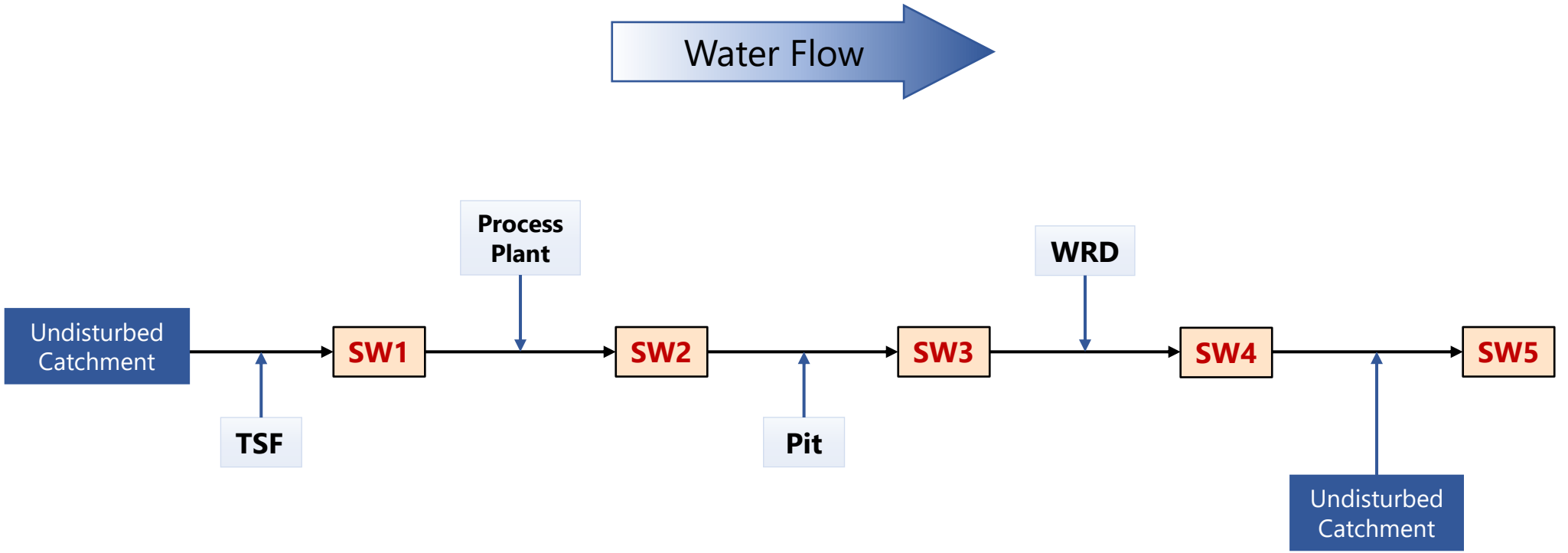
Site-Wide Water Quality



Case Study #1 – Mixing Model

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Site-Wide Water Quality

- **Non-reactive**
  - Weighted averaging of concentration and mixing volumes
  - Conservative estimate – will tend to overestimate concentrations
- **Reactive**
  - USGS PHREEQC database of chemical reactions for solutes
  - Ratios of mixing volumes
  - Solutes could either drop out of water (**Good**) or be released from contact rock (**Bad**)

Case Study #1 – Mixing Model

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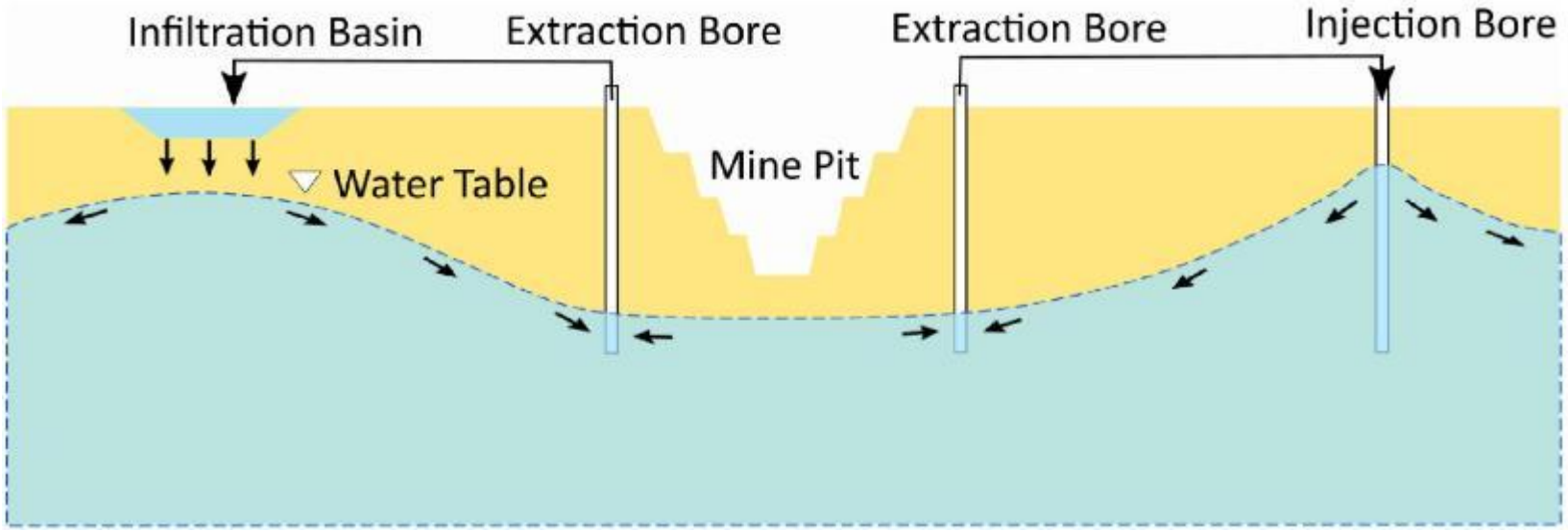
Other Applications:

- Aquifer re-injection (clogging or dissolution)
- Process water or mine water discharge



Model Applications

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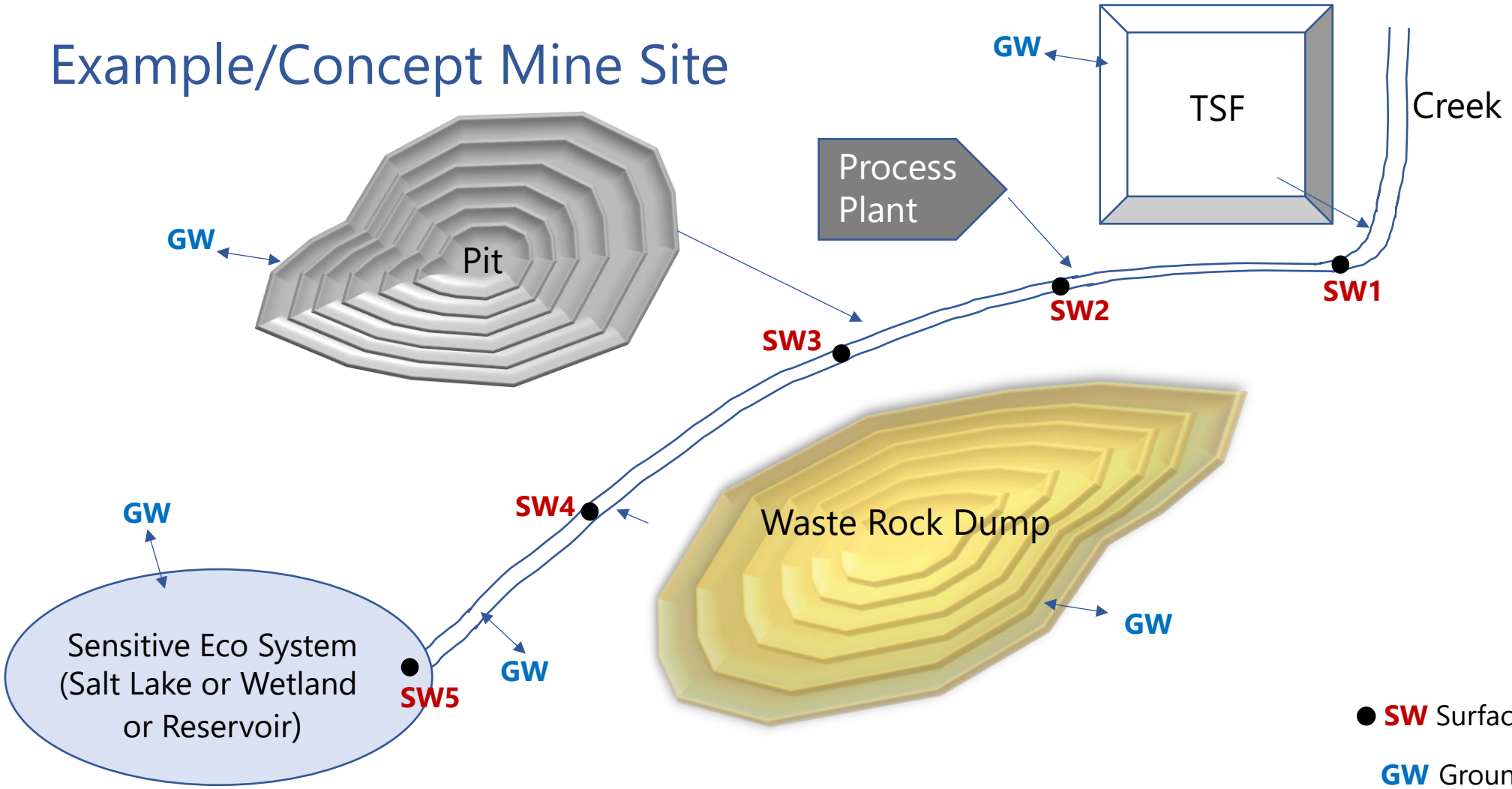
Example/Concept Mine Site



● **SW** Surface Water Monitoring

GW Groundwater Interaction

Case Study #2 – Seepage Model

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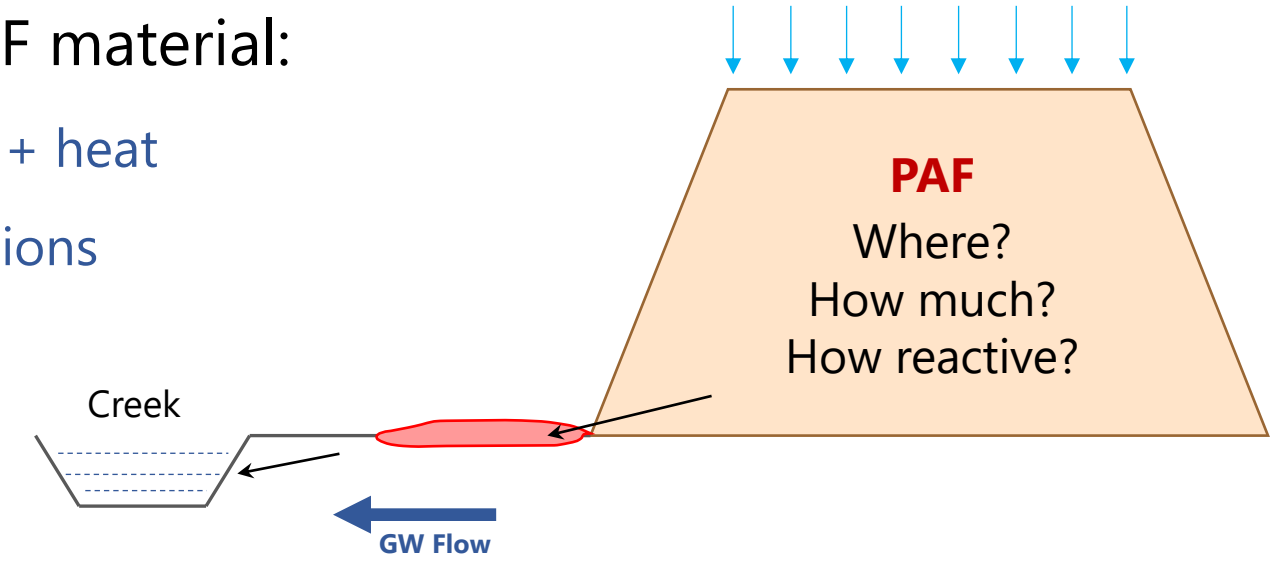
- Suspected AMD from Waste Landforms
  - Geochem characterisation – PAF location, quantity, reaction rate?
- Modelling (1D or 2D):
  - Climate conditions to simulate water seepage
  - Chemical reaction – oxidation of PAF material:

    PAF + water + oxygen → low pH + metals + heat

    Adsorption, precipitation, dissolution reactions



Case Study #2 – Seepage Model

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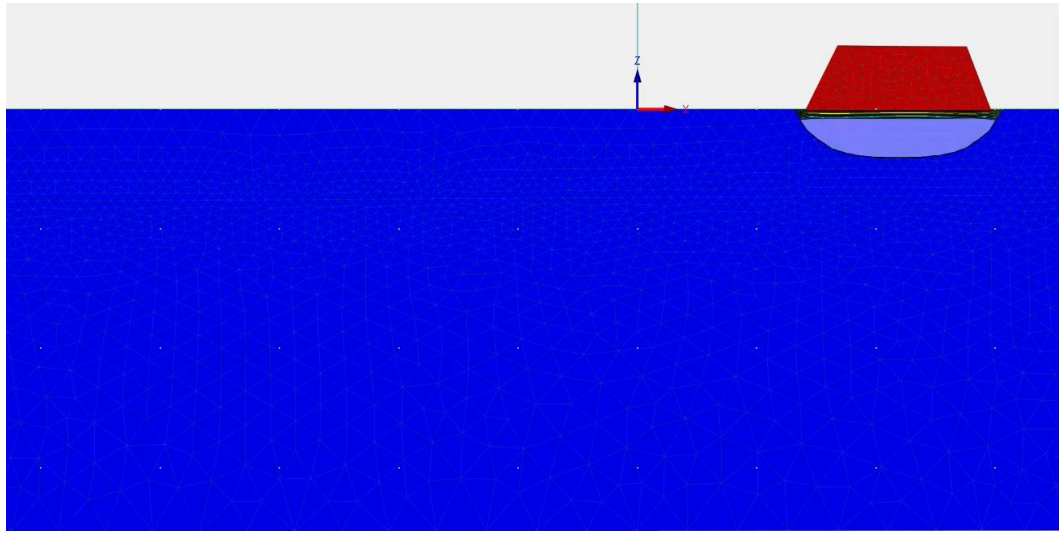
- Model Results (2D):
  - Plume of water quality indicators (e.g. sulfate, iron, pH) over time
  - Observations at a sampling point used for model calibration
  - Predict long term seepage water quality



Model Applications

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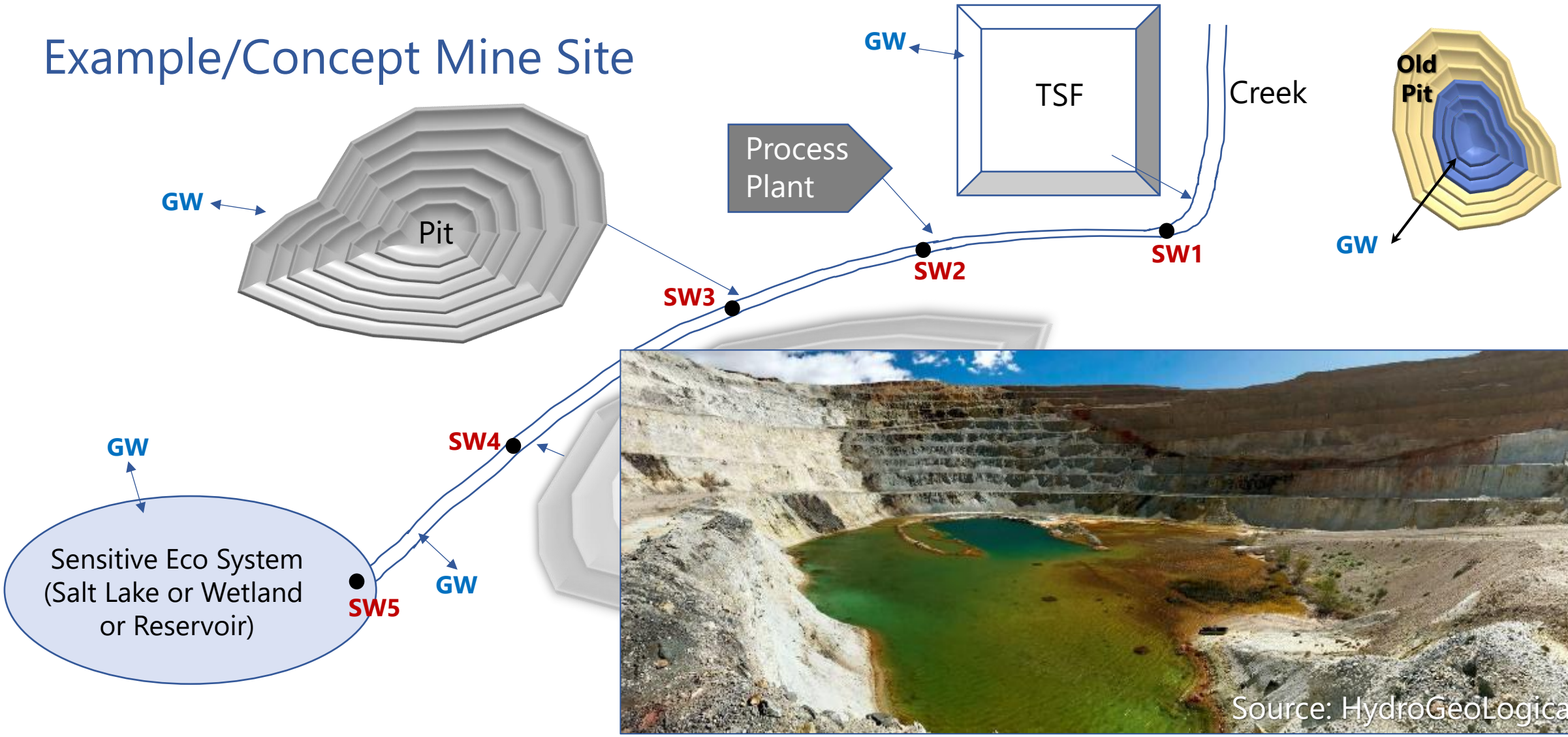
Example/Concept Mine Site



Case Study #3 – Pit Lake Model

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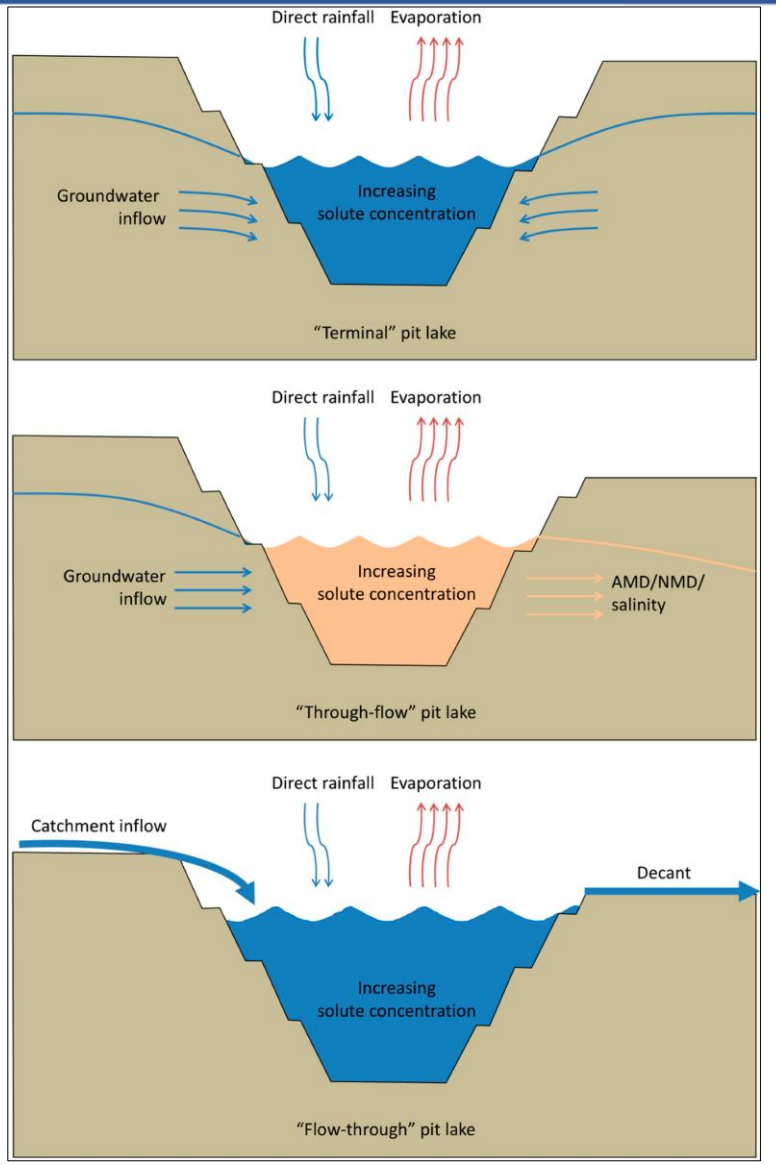
- Pit Lake formation:
  - Terminal, Through-flow or Flow-through?
- AMD or NMD from exposed pit walls
- Closure Scenarios:
  - Long term water quality concerns (≥500 years)
  - In-pit waste rock or tailings disposal
- Model results required to amend MP & MCP
- Risks to downgradient groundwater or surface water receptors



McCullough 2024

Case Study #3 – Pit Lake Model

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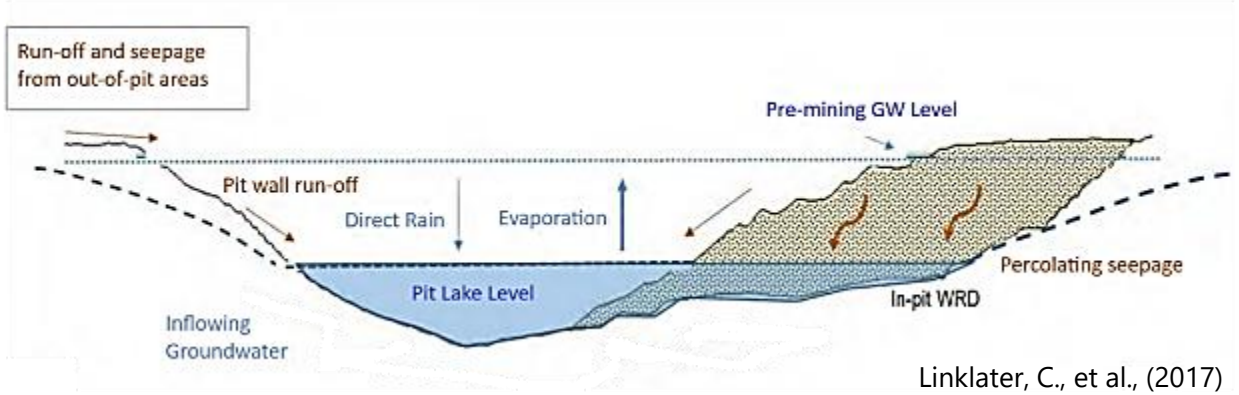
- Flow Model:
  - Climate data, surface and groundwater flows
  - Estimate time required to reach equilibrium
- Geochemical Model:
  - USGS PHREEQC
  - Oxidation, adsorption, precipitation, dissolution reactions



Linklater, C., et al., (2017)

When to Model?

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Modelling for Mine Water Quality Risk Assessment:

- **Approval** – *Simple* – Preliminary, Proof of Concept
- **Operation** – *Complex* – Progressive, Specific Issues
- **Closure** – *Advanced* – Planning, Long Term

Thank You

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Please reach out for a comprehensive modelling cheat sheet