



Equilibrium Environmental Inc

Subsoil Salinity Tool (SST)

Technical Manual and FAQ

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Presentation Overview

- **Version 3.0 Technical Manual**
 - Purpose and Contents
 - Examples from different sections
 - General Modeling
 - Chloride
 - SAR/sodium
- **SST FAQ (Frequently Asked Questions)**
- **SST Courses**

SST Technical Manual: Contents

- Existing ‘User Manual’ focuses on use of tool
- ‘Technical Manual’ provides additional supporting detail for the algorithms and modeling approach used in the SST
- Divided into four main sections
 - General Modeling Info
 - Chloride Modeling
 - SAR/Sodium Modeling
 - SAR Effects on Soil

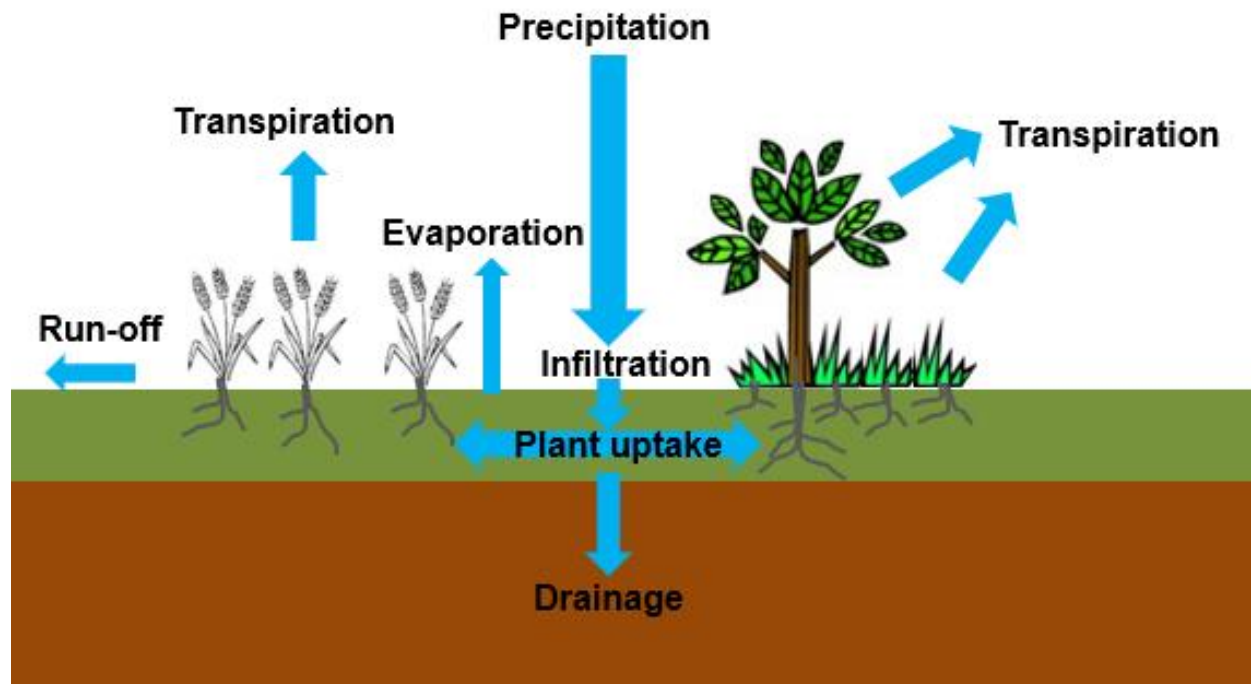
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General Modeling Information

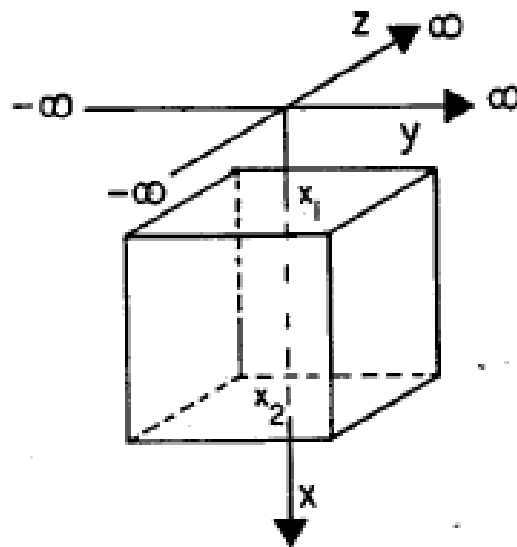
Vertical Transport Modeling

- Discusses details of main vertical transport model (LEACHM) and assumptions
- Complex 1-dimensional model incorporating many aspects of climate, soil, water, and solute transport



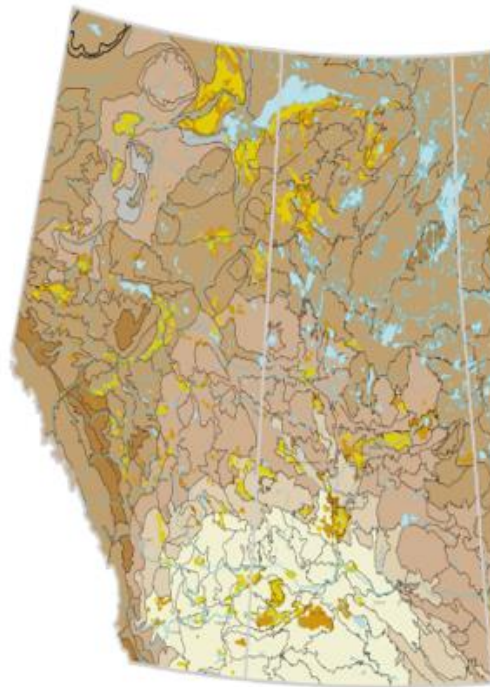
Horizontal Transport Modeling

- Discusses details of main horizontal transport model (3DADE) and assumptions
- Simpler model, but considers diffusion, advection, and dispersion in three-dimensions.
- Used for both lateral transport modeling (eg, to aquatic receptors), and for lateral smearing during vertical transport (eg, to Domestic Use Aquifer)

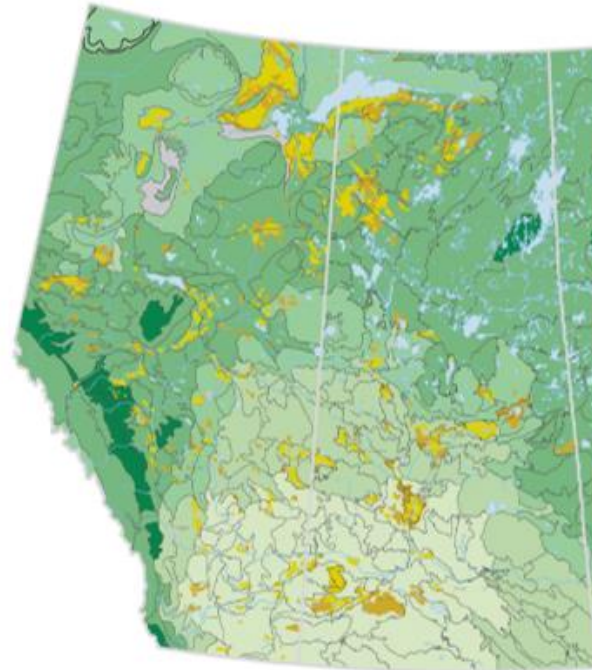
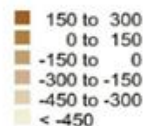


Climate

- Additional detail provided for the climate information used for transport modeling
 - Factors such as Precipitation (P) and Potential Evapotranspiration (PE)
- Affects water balance, drainage rates, and risk to various receptors such as root-zone and DUA



Annual Precipitation Surplus/Deficit
(Penman-Monteith, in mm)



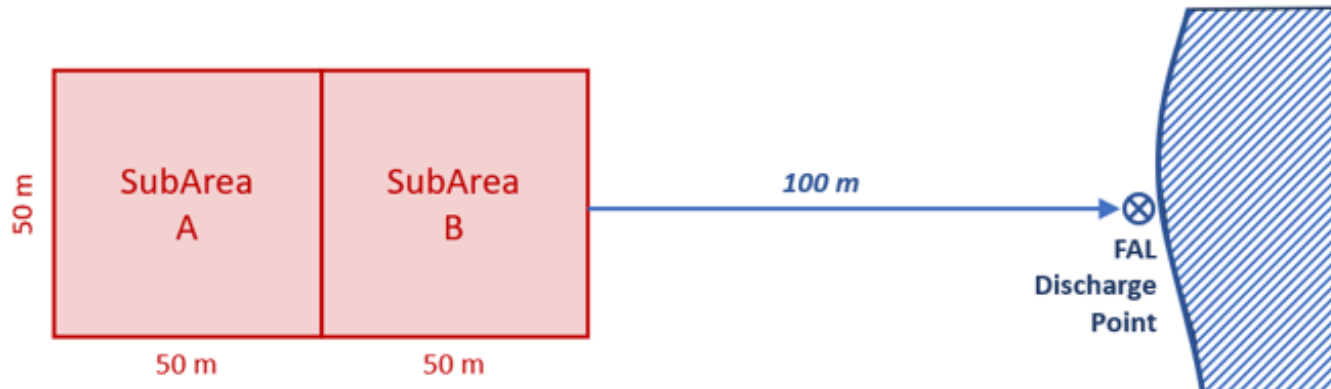
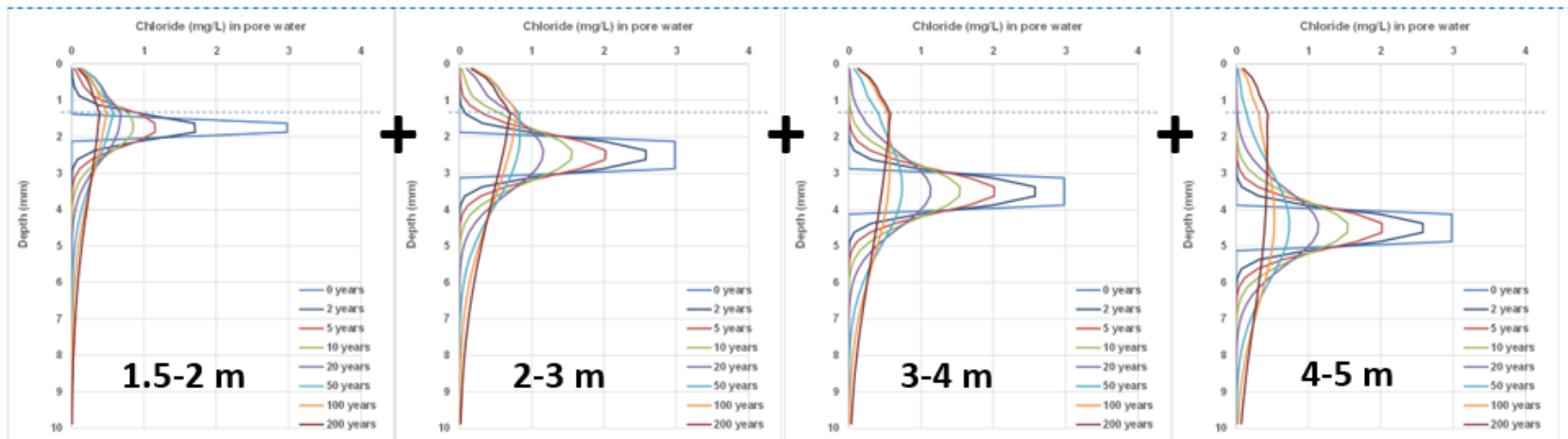
Annual P:PE Ratio
(Penman-Monteith)



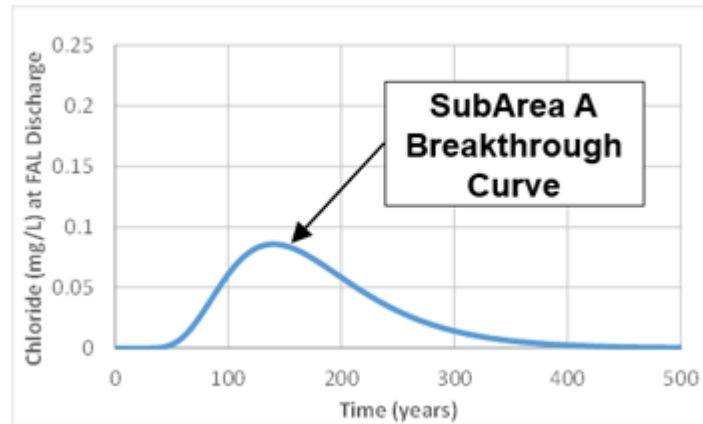
Chloride Transport Modeling

Principle of Superposition

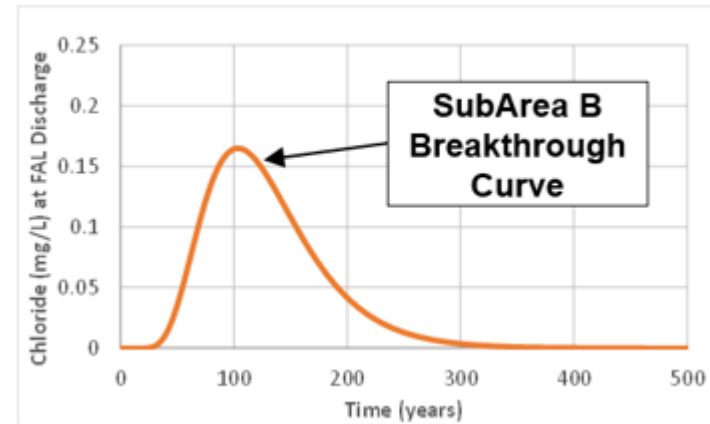
- Key concept to allow wide range of scenarios to be modeled by breaking them into small pieces, modeling each piece, and then recombining
 - Broad application both vertically (top) and laterally (bottom)



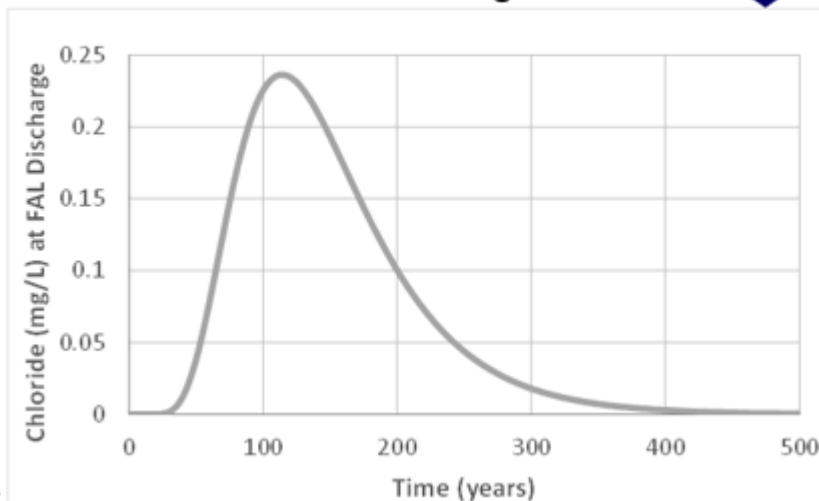
Principle of Superposition: Horizontal



+



Summated A + B Breakthrough Curve

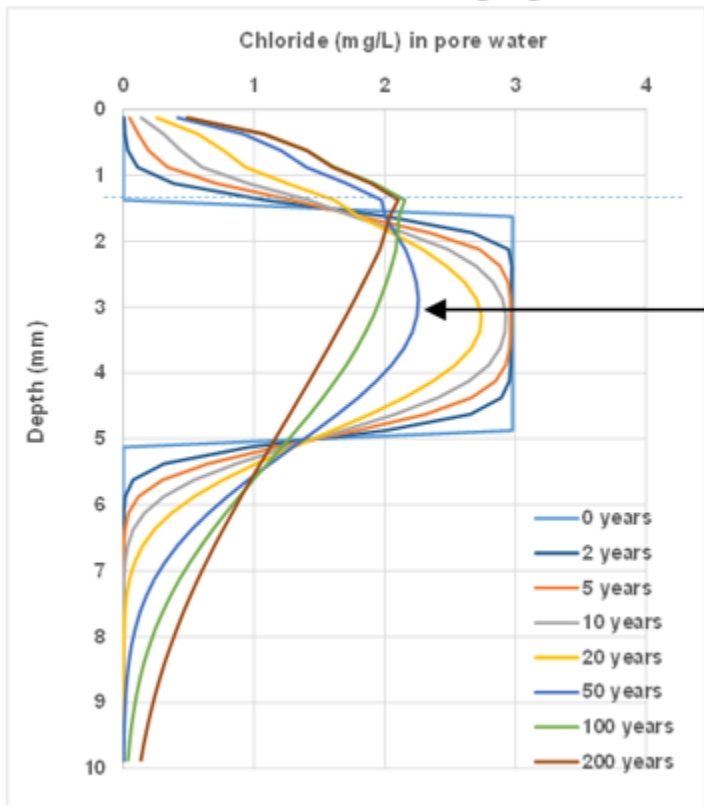


- Tool would not be possible to implement in any practical way without this concept (except for very simple scenarios)

Linear Scaling

- Another key modeling concept allowing runs at standardized concentrations to be performed and concentrations then ‘scaled’ to actual site conditions
 - Like superposition, the SST would not be possible to implement without this technique

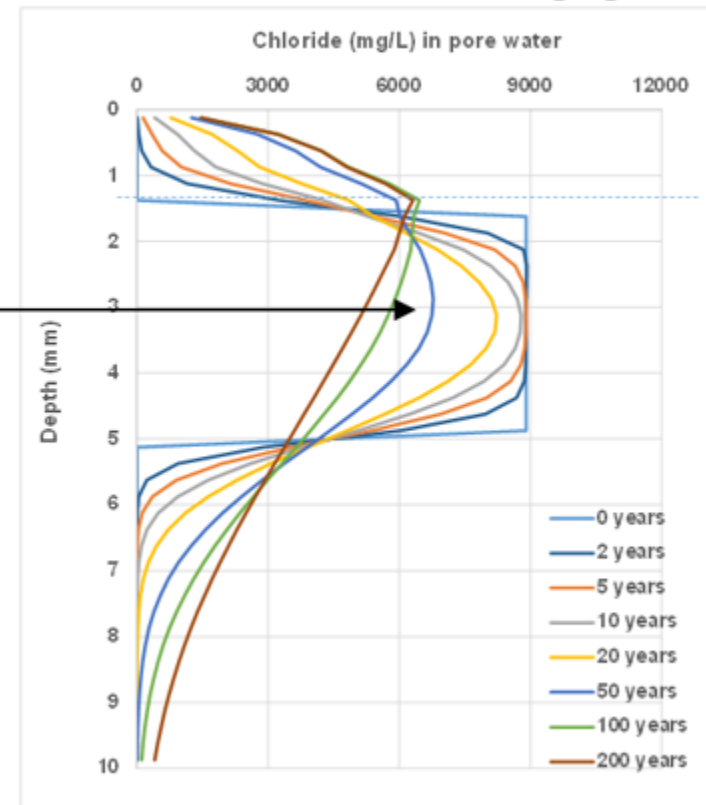
Initial Concentration of 1 mg/kg



Vertical profiles scale linearly for initial concentrations (in this case, two LEACHP runs differ by 3,000-fold but retain same relative behavior)

e.g. at 50 yrs the peak concentration is at 3 m and 76% of initial concentration (regardless of the absolute magnitude of the initial concentration)

Initial Concentration of 3,000 mg/kg



LEACHM Details

- LEACHM is based on solving complex differential equations to model vertical flow of both water and solute
 - LEACHP sub-module most suitable for SST and chloride aspects
- ‘Richards Equation’ for water flow
 - Super-messy (glad the LEACHP program does it...)
 - Uses parameters such as water capacity, pressure head, vertical distance

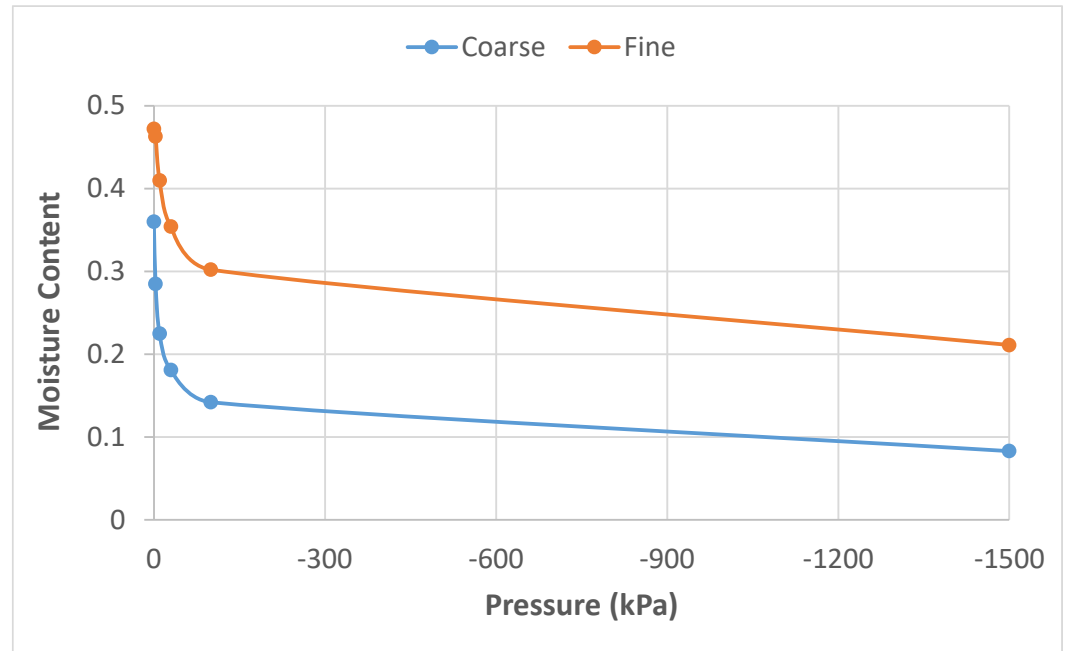
$$\frac{\partial h}{\partial t} C(\theta) = \frac{\partial}{\partial z} \left[K(\theta) \frac{\partial H}{\partial z} \right] - U(z, t)$$

- ‘Convection-Dispersion Equation’ for solute flow
 - Also super-messy
 - Uses parameters such as concentrations, diffusion coefficients

$$\frac{\partial(\theta c)}{\partial t} = \frac{\partial}{\partial z} \left[\theta D(\theta, q) \frac{\partial c}{\partial z} - qc \right]$$

LEACHP Details (cont'd)

- Other parameters used in LEACHP modeling also discussed
 - bulk density, porosity
 - hydraulic conductivity
 - moisture retention

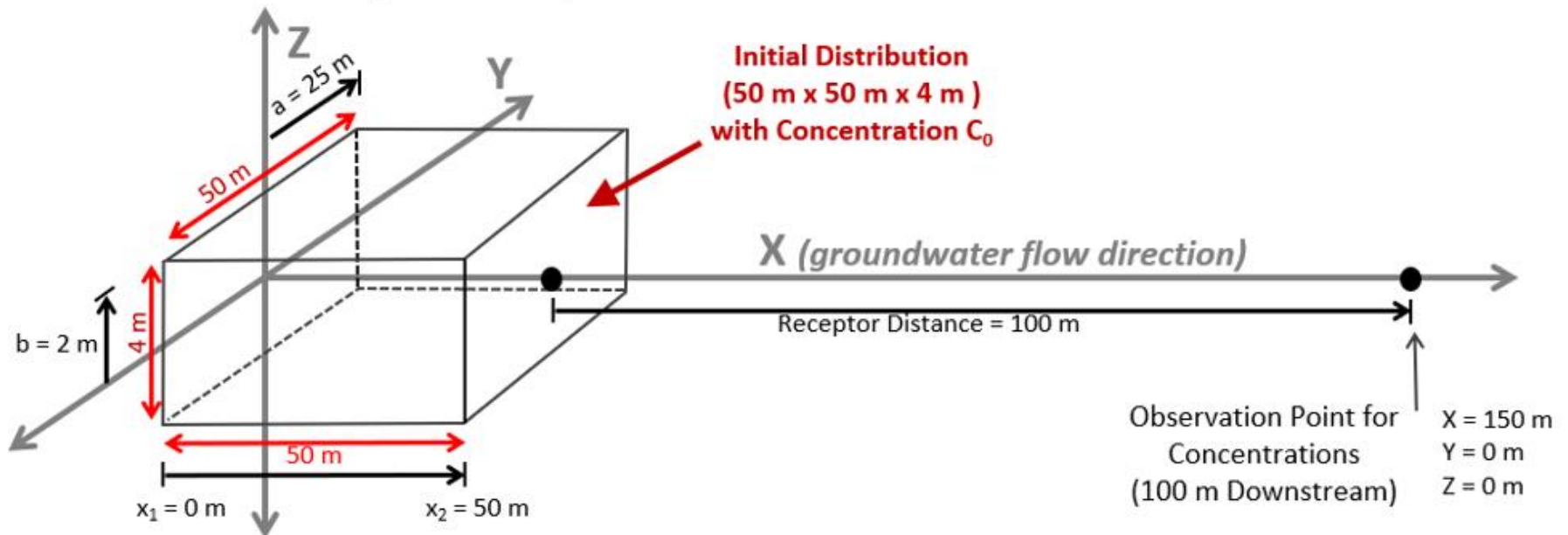


Parameters	Fine Texture (median < 75 μm)	Coarse Texture (median > 75 μm)
Bulk Density (g/cm^3)	1.4	1.7
Total Porosity	0.47	0.36
Hydraulic Conductivity at Saturation (mm/d)	0.88	8.8
Hydraulic Conductivity at Saturation (m/s)	1.0×10^{-8}	1.0×10^{-7}
Campbell's Parameter 'a'	-3.47	-0.938
Campbell's Parameter 'b'	7.54	5.058
Moisture Content at -3 kPa	0.463	0.285
Moisture Content at -10 kPa	0.410	0.225
Moisture Content at -30 kPa	0.354	0.181
Moisture Content at -100 kPa	0.302	0.142
Moisture Content at -1500 kPa	0.211	0.083

3DADE Details

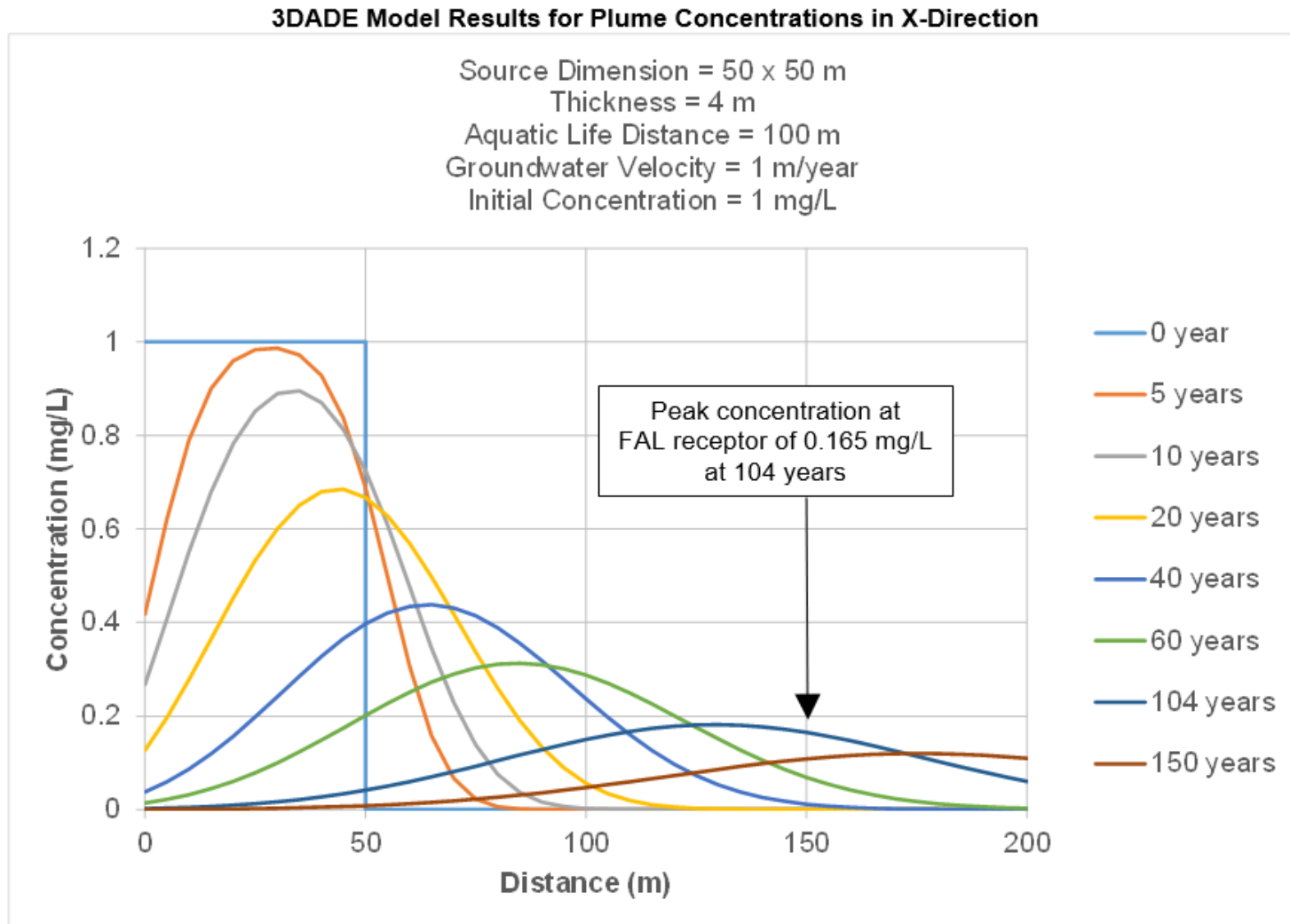
- **3DADE used to model lateral transport of water and solute over three dimensions**
- **Primary use in SST is for lateral transport to aquatic life receptors (FAL)**
- **Based on defining parameters for different subareas such as:**
 - **Source dimensions**
 - **distances to receptors**
 - **groundwater velocity**
 - **impact thicknesses**

3DADE Model Inputs for an Impact Source Dimension of 50 x 50 m and FAL distance of 100 m



3DADE Results Interpretation

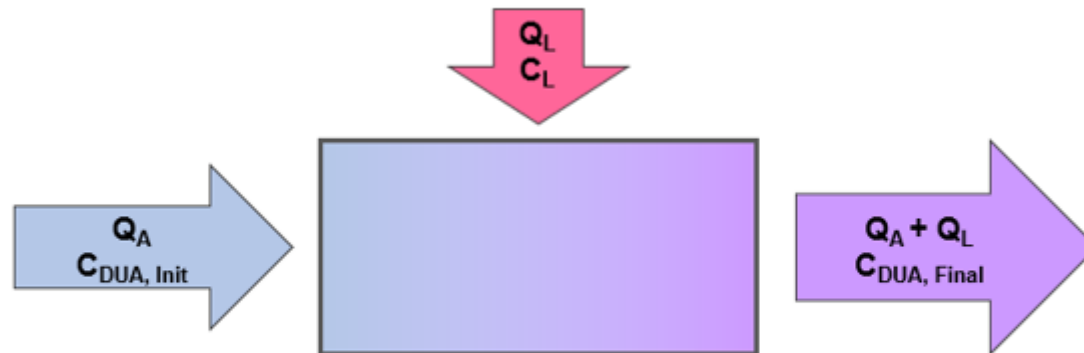
- 3DADE output processed to provide “Breakthrough Curves” which are used throughout the SST for guideline calculation
- Peak breakthrough concentrations and times are key outputs



DUA Guideline Calculations

- DUA pathway is a complex pathway where both LEACHP and 3DADE components are used for transport (3-D)
- Combined with additional ‘dilution’ calculations into DUA
 - Dilution calculations used in SST are a more generalized implementation of “DF3” used in Tier 1 / Tier 2 model
- Single Subarea implementation:

Summers Mixing Model (Mass Balance) Approach for DUA Dilution

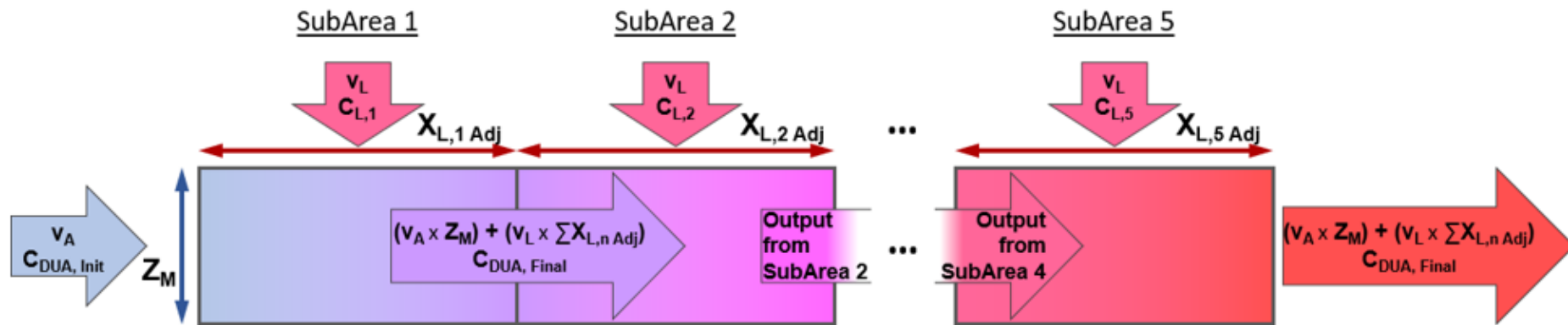


$$C_{DUA, Final} = \frac{Q_L \times C_L + Q_A \times C_{DUA, Init}}{Q_L + Q_A}$$

DUA Guideline Calculations (cont'd)

- Also implemented for multiple subareas
- More complex calculations, but necessary for most sites
- Algorithm ensures that DUA is protected not only below each subarea, but for the combined loading of all subareas

Stepwise Summers Mixing Model for DUA Dilution of Multiple SubAreas

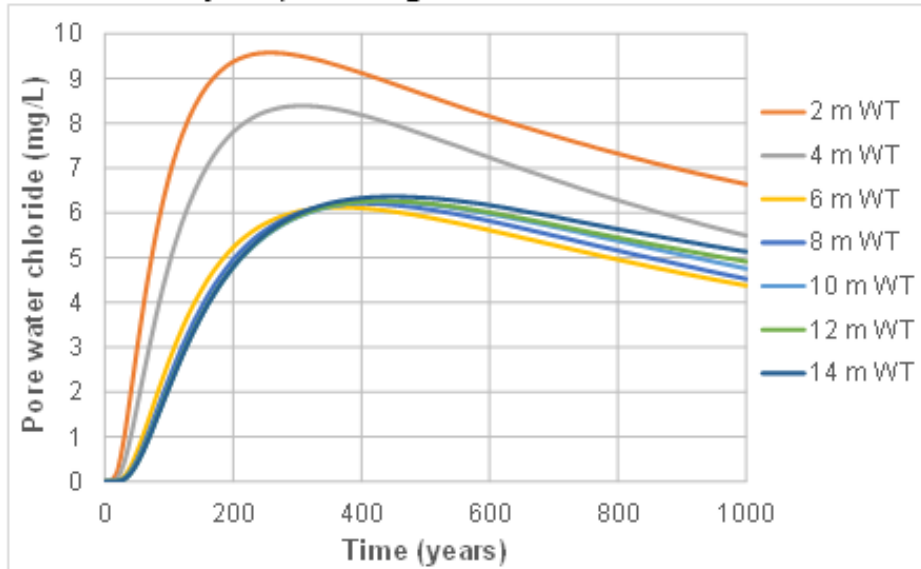


$$C_{DUA, Final} = \frac{(v_A \times Z_m) \times C_{DUA, Init} + v_L \times \sum_1^n (C_{L,n} \times X_{L,n} Adj)}{(v_A \times Z_m) + v_L \times \sum_1^n (X_{L,n} Adj)}$$

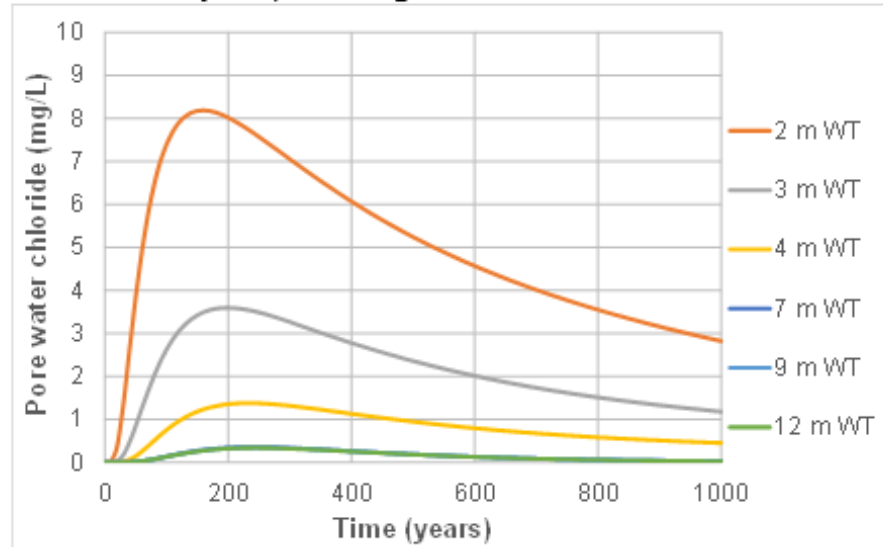
Water Table Effects

- Version 3.0 of SST incorporated much more complex set of algorithms for upward chloride transport into root-zone taking water-table depth into account more directly
- Deeper water table → drier soils → slower upward diffusion
 - More pronounced effect for coarse soils

Chloride Concentrations at 1.5 m (Root Zone)
1 mm/year Down, Fine Soil
4 to 5 m Impact, 100 mg/L Initial Chloride



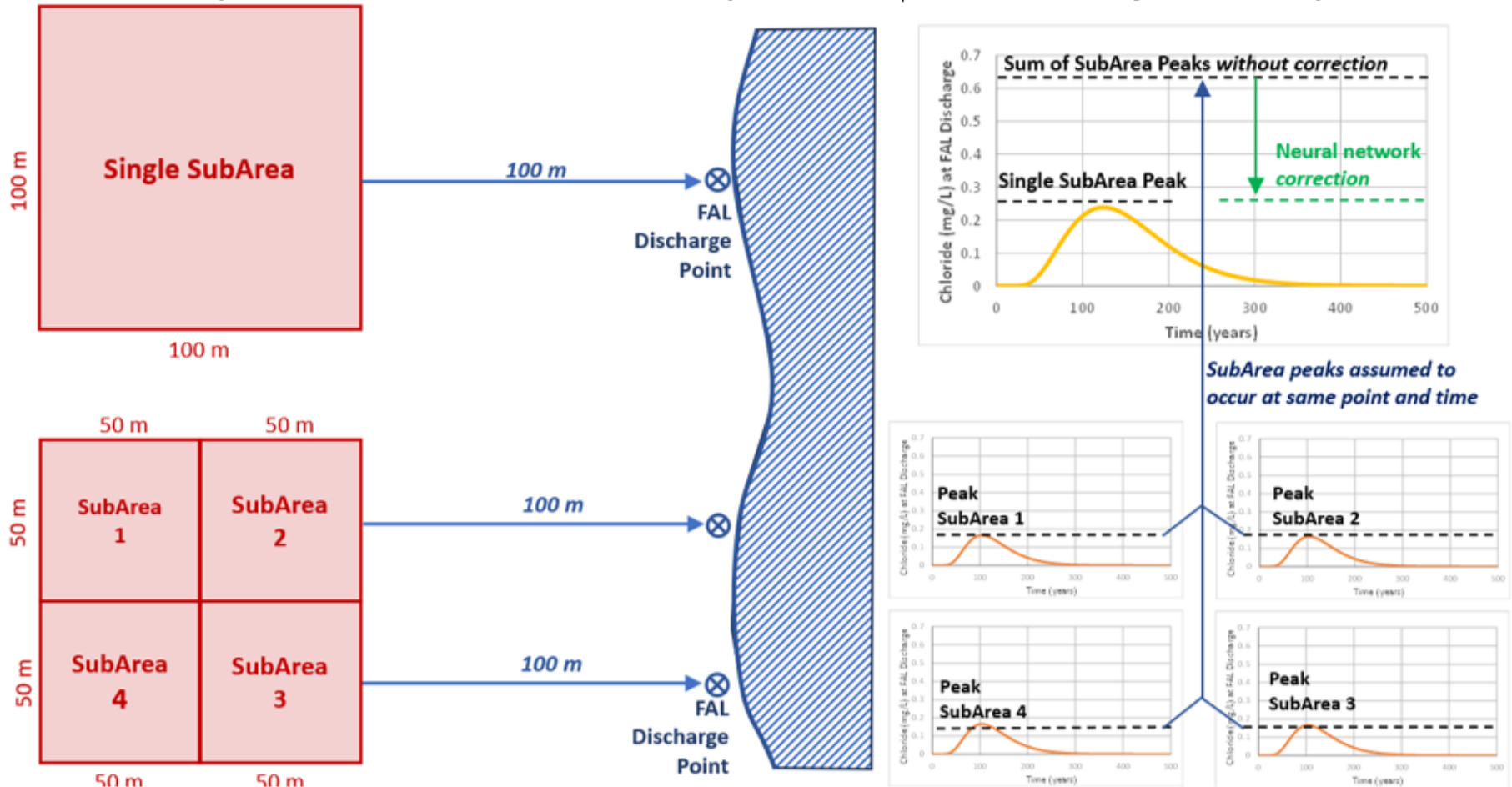
Chloride Concentrations at 1.5 m (Root Zone)
2 mm/year Down, Coarse Soil
4 to 5 m Impact, 100 mg/L Initial Chloride



Aquatic Life Transport

- Complex approach used for multiple subareas for FAL
- Includes a neural network to remove over-conservatism

Example of FAL Over-Conservatism for Multiple SubAreas in Close Proximity to FAL Receptor

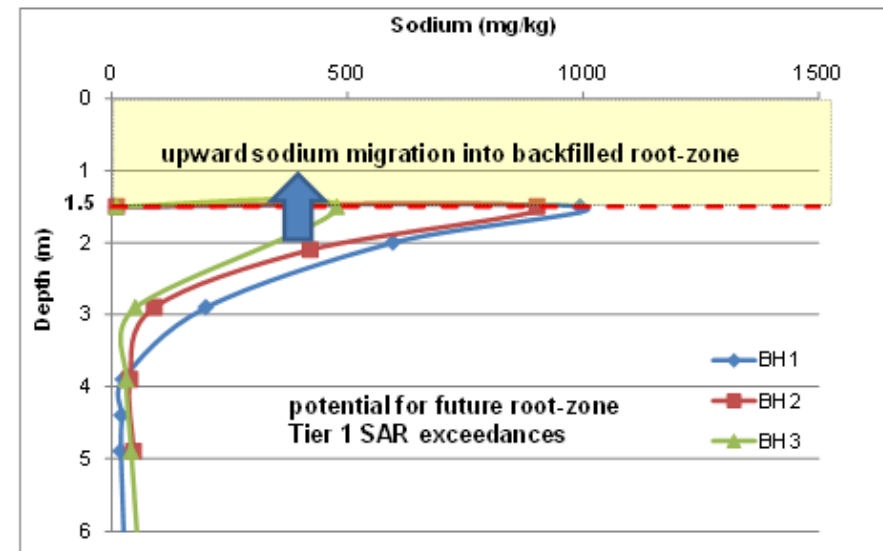
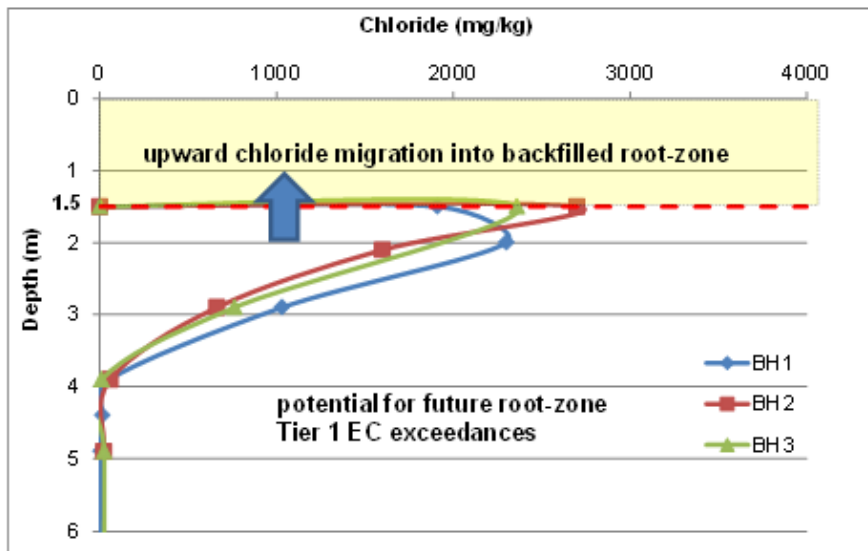


SAR and Sodium Transport Modeling

Sodium Transport

- Sodium transport modelled in SST Version 3.0
 - Primarily modelled upward into root-zone as key pathway
 - Relevant to potential future root-zone SAR exceedances

Example Chloride and Sodium Depth Profiles After 1.5 m Root-Zone Excavation

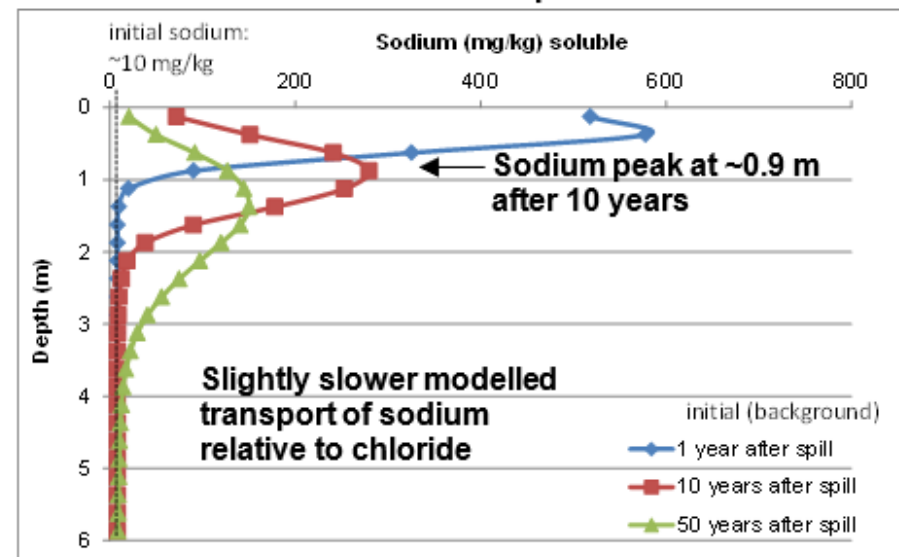
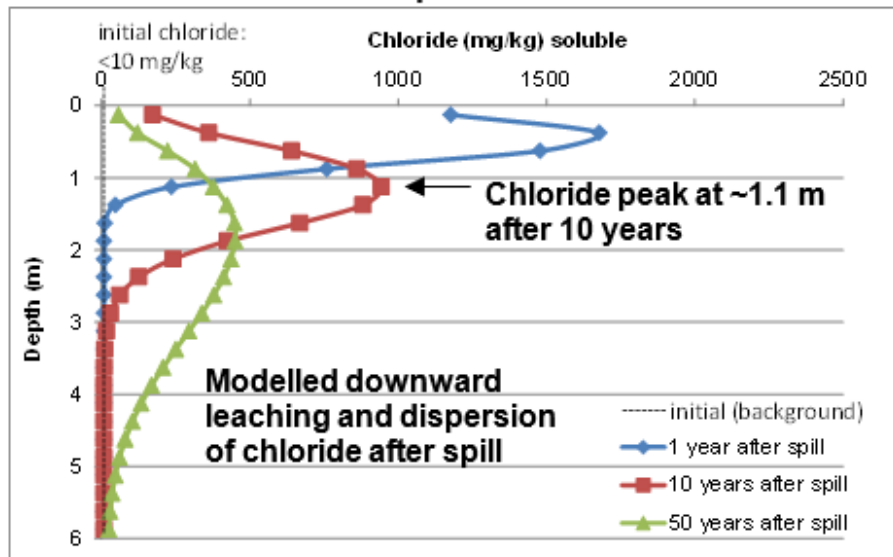


- Sodium modeled similar to chloride, but with adjustments due to cation exchange effects
 - Substantial more complexity, handled in LEACHC sub-module

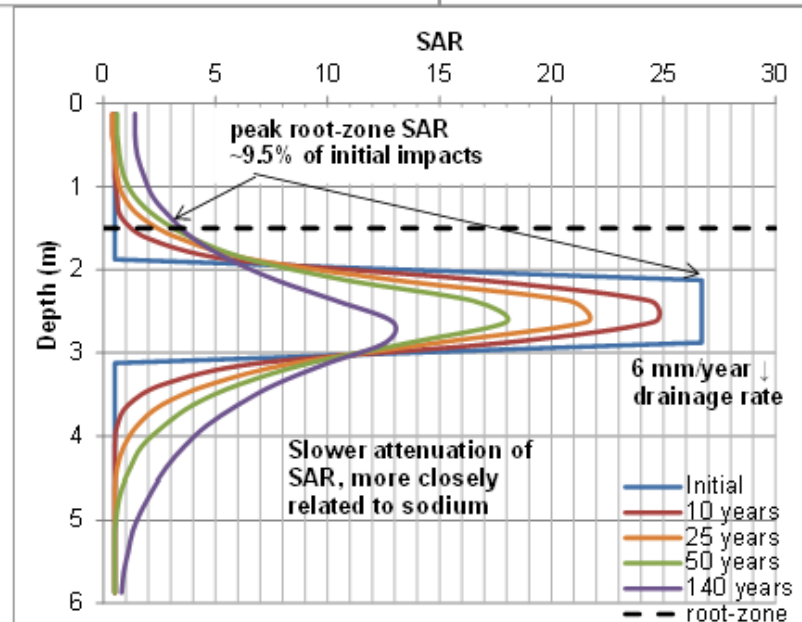
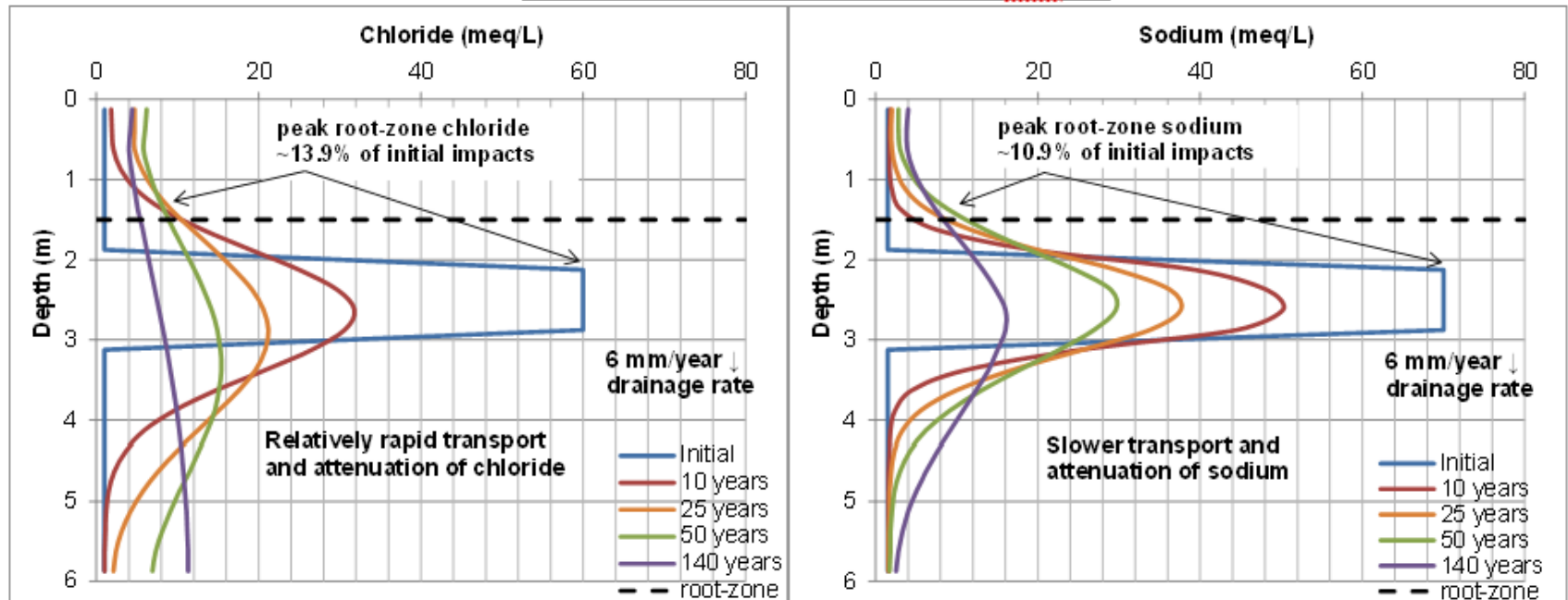
Sodium Transport (cont'd)

- Cation exchange reactions result in slowing of sodium transport relative to chloride
 - Sodium and calcium exchange on cation exchange complex
$$\text{adsorbed calcium} + \text{NaCl} \leftrightarrow \text{adsorbed sodium} + \text{CaCl}_2$$
- Net effect: chloride gets further, faster
 - Sodium has more tendency to linger closer to initial source area
 - Elevated SAR can persist longer than elevated chloride or sodium

Example of Modeled Soluble Ion Concentrations After Produced Water Spill



Example of Modeled Sodium, Chloride, and SAR transport
(initial impacts 2-3 m with CEC=240 meq/kg)



- Chloride, sodium, and SAR all modeled / estimated in SST for guideline calculations

Sodium Guideline Calcs

- Examples provided of the process used to calculate subsoil sodium guidelines to protect root-zone from upward migration
 - Complex, multi-step calculation process (example of first steps below)

Parameter	Value	Source
User-entered parameters		
Soil texture	Fine	User entered (>18% clay as per SST protocol). Assumed consistent for both root-zone and subsoil.
Root-zone scenario	Excavate+backfill	User-entered
Backfill average EC	1 dS/m	User-entered
Backfill average SAR	1	User-entered
Calculated parameters: Tier 1 SAR guideline and SAR buffer		
Root-zone Tier 1 SAR guideline	4	Previously calculated
SAR buffer	4	Previously calculated
Calculated parameters: Initial root-zone		
Initial backfill EC	1 dS/m	Previously calculated
Initial backfill SAR	1	Previously calculated
Initial backfill total cations	12 meq/L	Previously calculated
Initial backfill sodium	2.21 meq/L	Previously calculated
Initial backfill Ca+Mg	9.79 meq/L	Previously calculated
Calculated parameters: Future root-zone		
Initial $(Ca+Mg)^{1/2}/Na$ in root-zone	13.84	Calculated from initial Ca+Mg concentrations (meq/L)
Exponent for relative SAR vs Na increase	0.750	Calculated from fine regression ($y=0.5338x^{0.1292}$)
Relative SAR increase (x-fold)	4	Equivalent to SAR buffer
Relative sodium increase (x-fold)	6.36	Calculated from exponent and relative SAR increase ($=4^{1/0.75}$)
Future root-zone sodium	14.06 meq/L	Based on initial sodium and relative sodium increase
Future root-zone Ca+Mg	24.71 meq/L	Based on future SAR and sodium
Future root-zone EC	3.23 dS/m	Calculated from future total cations
Future root-zone SAR	4	Back-calculated as a check

-all EC, SAR, and cation concentrations above on a saturated paste basis

SAR Effects on Soil Structure

- Section 4 provides a comprehensive summary of the SAR research conducted over the last 10+ years to support subsoil SAR guideline derivation in SST Version 3.0
 - Wide range of topics including literature results, Alberta-specific soil core experiments, water table modeling, and guideline derivation process

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SST Frequently Asked Questions (FAQ)

- **A way for the SST user community to engage and get feedback on important topics / questions**
- **Process:**
 - **Send questions to SSTInfo@eqm.ca**
 - **Questions are announced on EEI LinkedIn page once complete**
 - **Question and Answer provided on FAQ page:**
<https://www.eqm.ca/faq>
- **Answers to key questions will also involve regulatory vetting**

SST Frequently Asked Questions (FAQ)

Six technical questions with vetted answers to be posted shortly:

- **Is there a Tier 1 chloride guideline for soil?**
- **What is the chloride delineation objective for soil?**
- **When should I use the SST?**
- **How do I decide between a Tier 2A and Tier 2B SST assessment?**
- **Is 100 mg/kg chloride ever used as a site-specific remedial objective?**
- **How are SST guidelines used to evaluate confirmatory samples when performing an excavation?**

SST Courses

Full Certification Course (3.5-day)

April 2026 – dates TBD

SST Overview Course (1-day) *NEW*

April 2026 – dates TBD

Advanced SST Techniques Course (1-day) *NEW*

April 2026 – dates TBD

For further information:

Visit our webpage at www.eqm.ca

Or contact SSTinfo@eqm.ca

Or visit our LinkedIn page

Acknowledgements

- **Alberta Environment and Protected Areas**
- **Alberta Energy Regulator**
- **Petroleum Technology Alliance of Canada (PTAC)**

Thank you!

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