



MILLENNIUM
EMS Solutions Ltd.

USE OF A 3-D SALT MODEL TO REDUCE REMEDIATION VOLUMES

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Outline

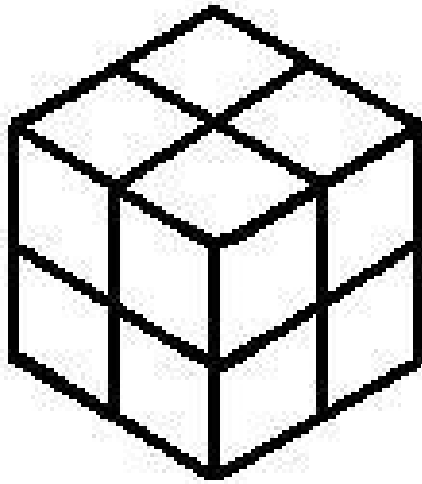
- Introduction – what problems are we trying to solve?
- 3-D salt model development
- Case studies
- Challenges and path forward

Introduction

- Tier 1 or Tier 2A/B approaches work fine for many but not all sites
- Needed a defensible and affordable approach for Tier 2C (SSRA) for large or complex sites
- Need to consider net environmental benefit

Introduction

- Problem: How can we realistically represent chloride spatial distribution?



What if my salt plume doesn't look like this...



...but looks more like this?

Introduction

- How can we best identify remediation required to protect relevant receptors?

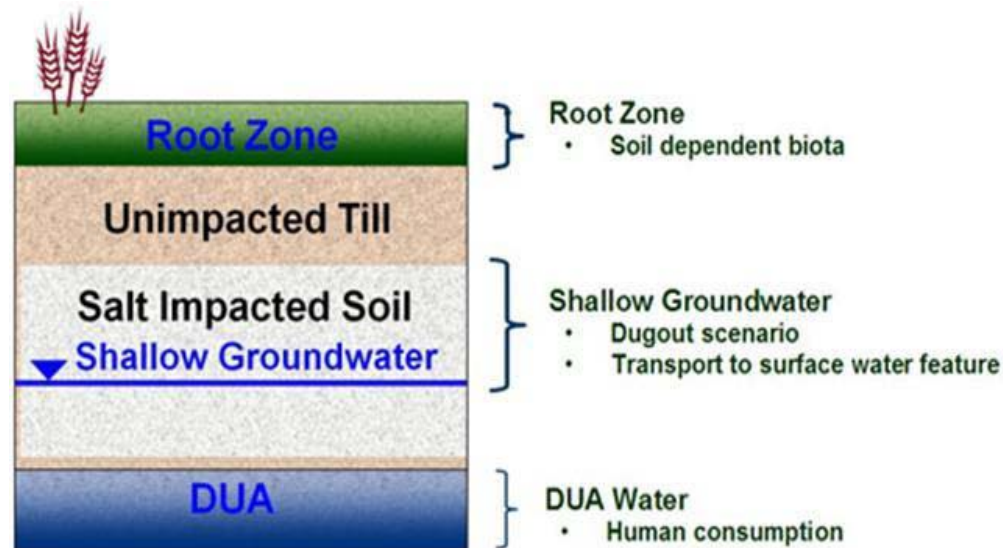


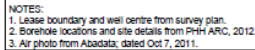
Initial considerations:

- Solute plumes are not homogenous blocks
- Let's trace migration moving forward
- Let's make it truly site-specific and avoid blanket assumptions
- **Let's make it quick, accurate and affordable**

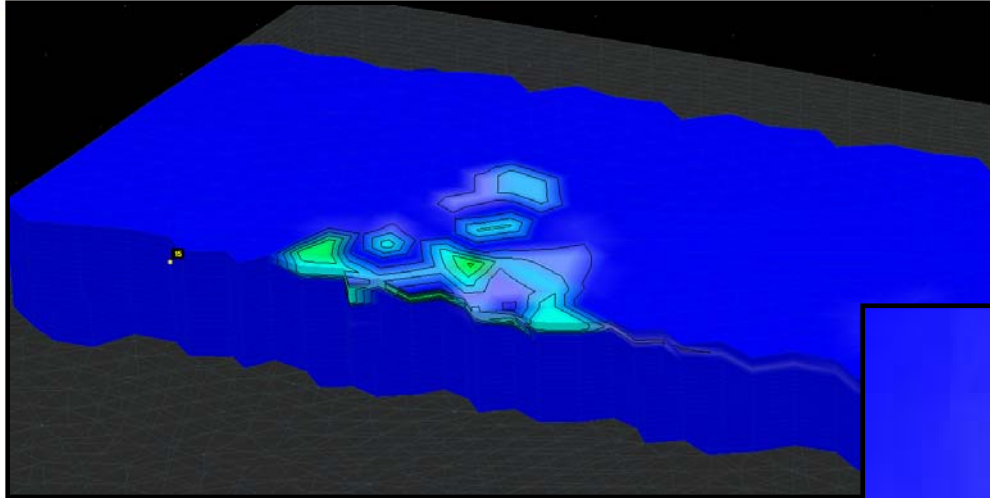
3-D Salt Model

- Multiple modules
- Primarily based on Hydrus 3D
 - 3D movement of water, heat & solutes in variably saturated media
- Use site-specific data over default assumptions
- Peer review



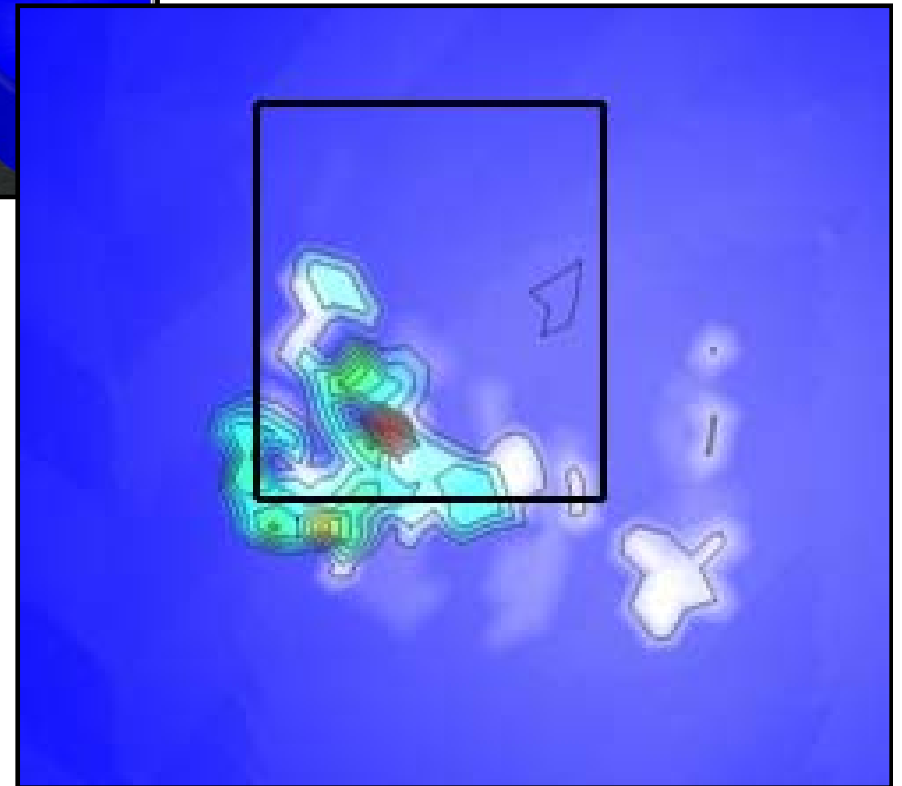


Initial Solute Input

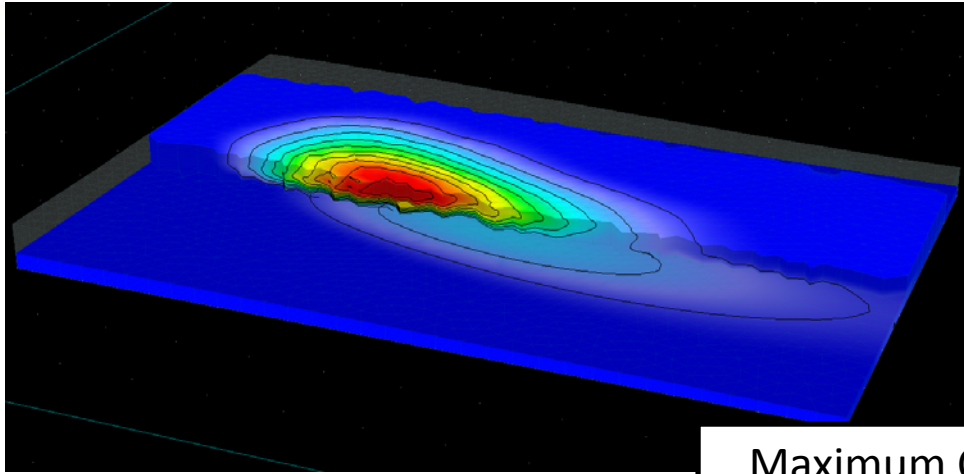


Three-dimensional input of
concentration data

Clear visualization of “hot
spots” via layering



DUA Assessment

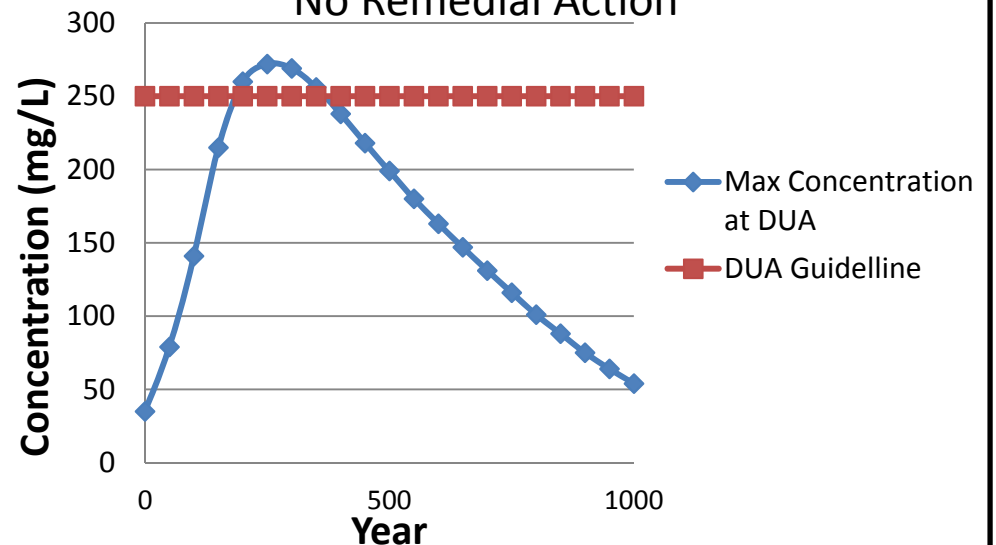


Temporal and spatial visualization of plume migration

Layering to determine maximum concentration reaching the DUA

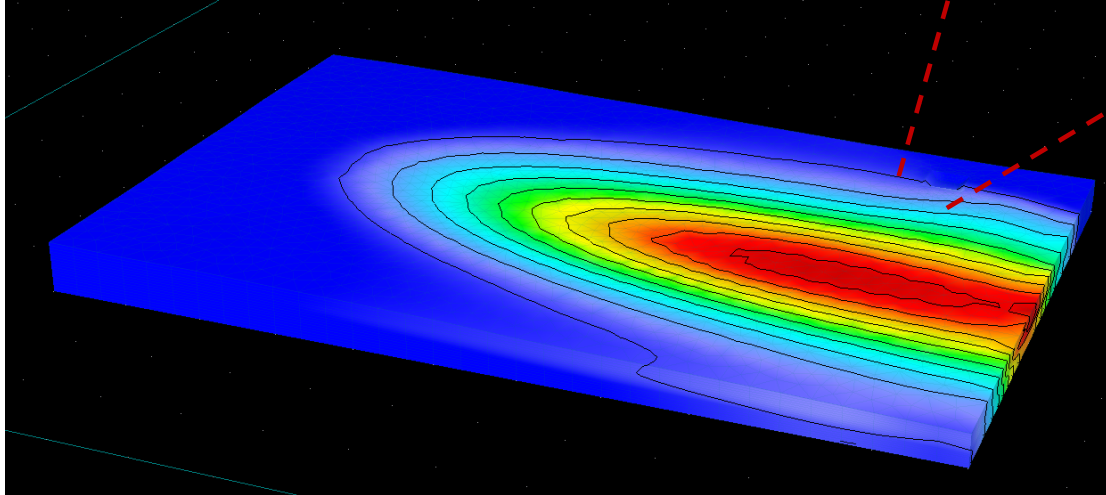
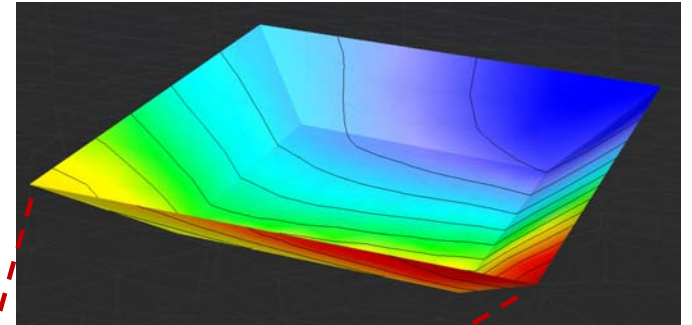
Maximum chloride concentration reaching DUA is 272 mg/L at 250 years

Maximum Chloride Concentration at DUA with No Remedial Action



FAL Assessment

Mesh Sections to define FAL bodies



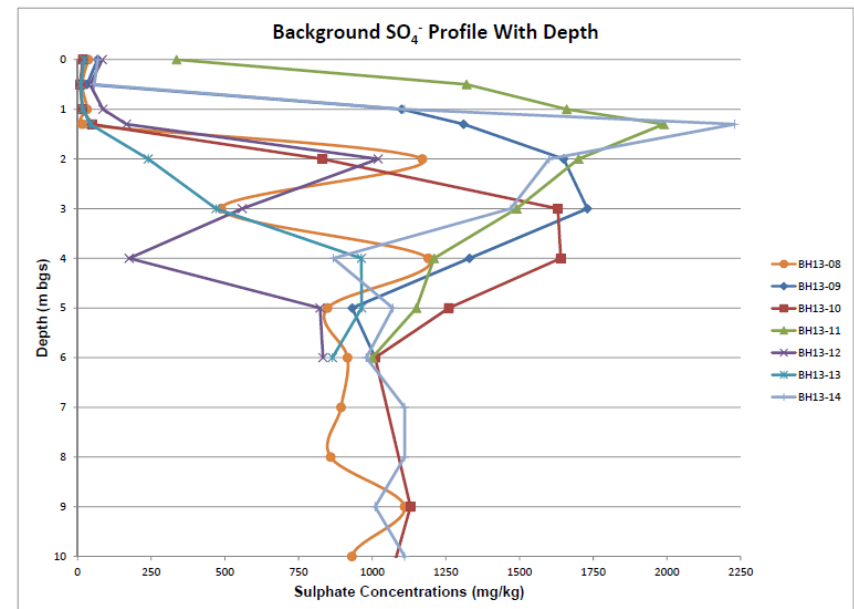
Maximum
concentration at
point of compliance
does not exceed
background values

Rooting Zone Assessment

- Based on theoretical modeling and analytical data
- Replaces blanket default assumptions with site-specific data
- HYDRUS 1D
 - Daily precipitation and potential evapotranspiration (PET)
- Soil analytical
 - Distribution of anions in rooting zone and subsoil

Summary of HYDRUS 1-D Model for Case Study Site

Total Infiltration	353 mm downward
Total Evapotranspiration	312 mm downward
Annual Rooting Zone Drainage	39 mm downward



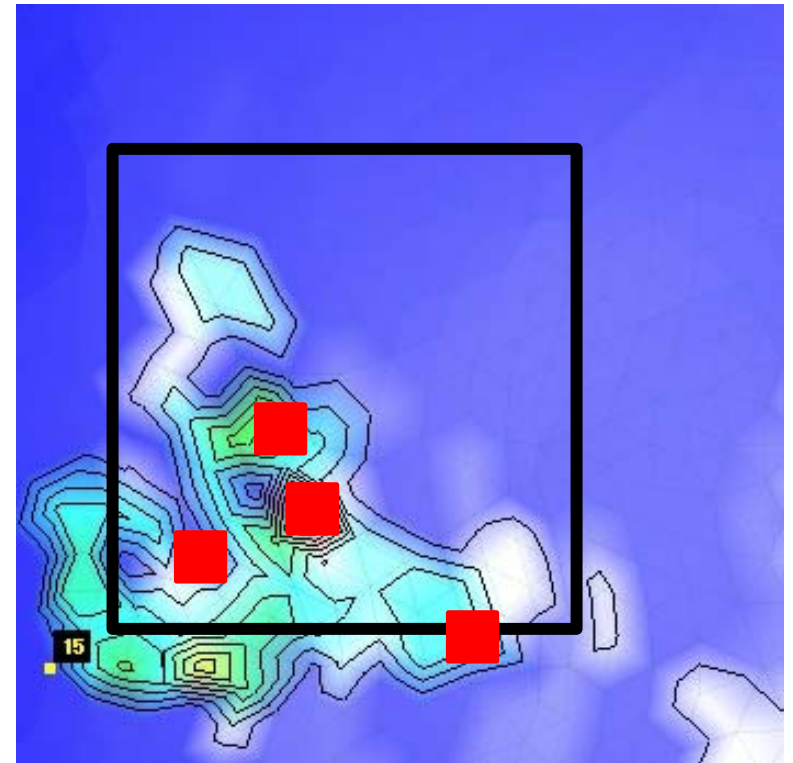
Dugout Assessment

- Considers Alberta Agriculture Guidance on dugouts
 - Design/placement
 - Surface topography
 - Catchment area
 - Water requirements
- Guidelines based on site-specific groundwater & surface water data
- Dilution based on soil texture



Targeted Remediation

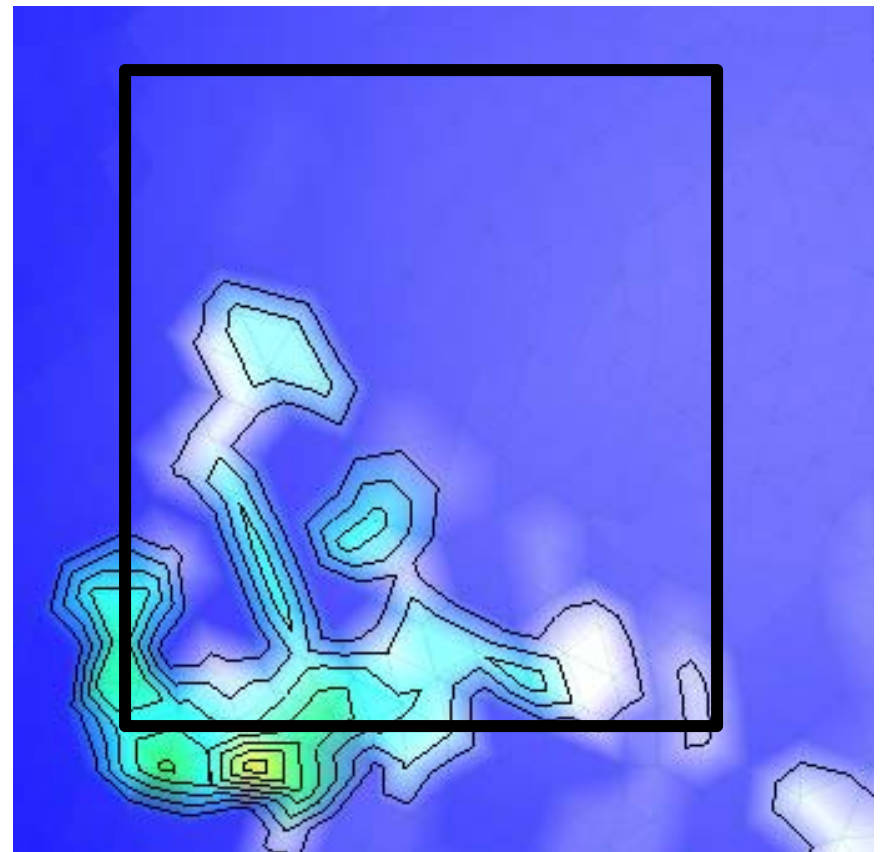
- Current conditions: DUA at risk
- Targeted removal of chloride “hotspots”
- Iterative process with minimal effort
- Strategic remediation based upon other compounding concerns i.e. additional elevated COPC
- Feasibility considerations



Post-Remediation

- Real-time visualization of “hot spot” removal in three-dimensions

Post-Remediation



Results

Comparison of SST Tier 2B and MEMS Tier 2C remediation strategies to achieve protection of DUA at Case Study Site

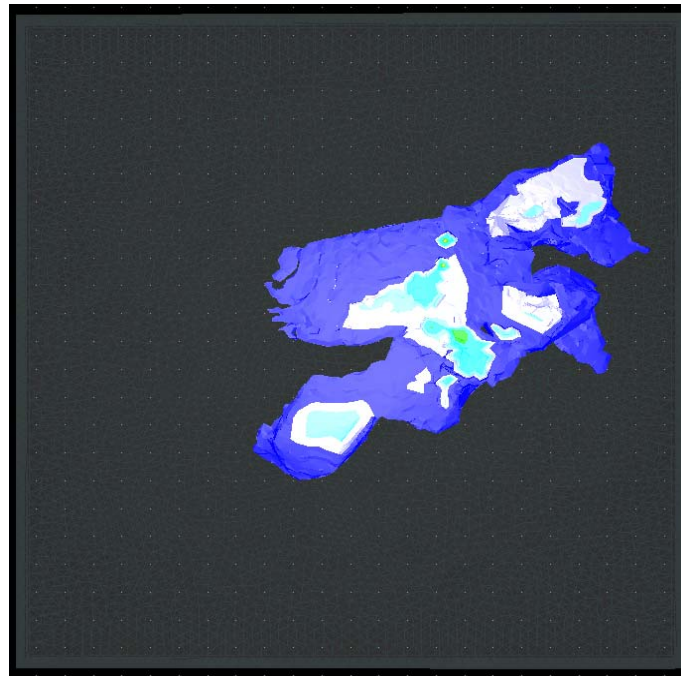
DUA Guideline	250 mg/L	
Initial Mass of Chloride Present*	186,600 kg	
	SST	MEMS
Remedial guideline for excavation area	390 mg/kg	Hot Spot Removal
Mass of chloride to be removed *	177,567 kg	5,640 kg
Soil to be removed*	86,737 m ³	1,630 m ³
Maximum concentration reaching DUA	37 mg/L	230 mg/L

Case Study 2 – Produced Water Release in Natural Ecosystem



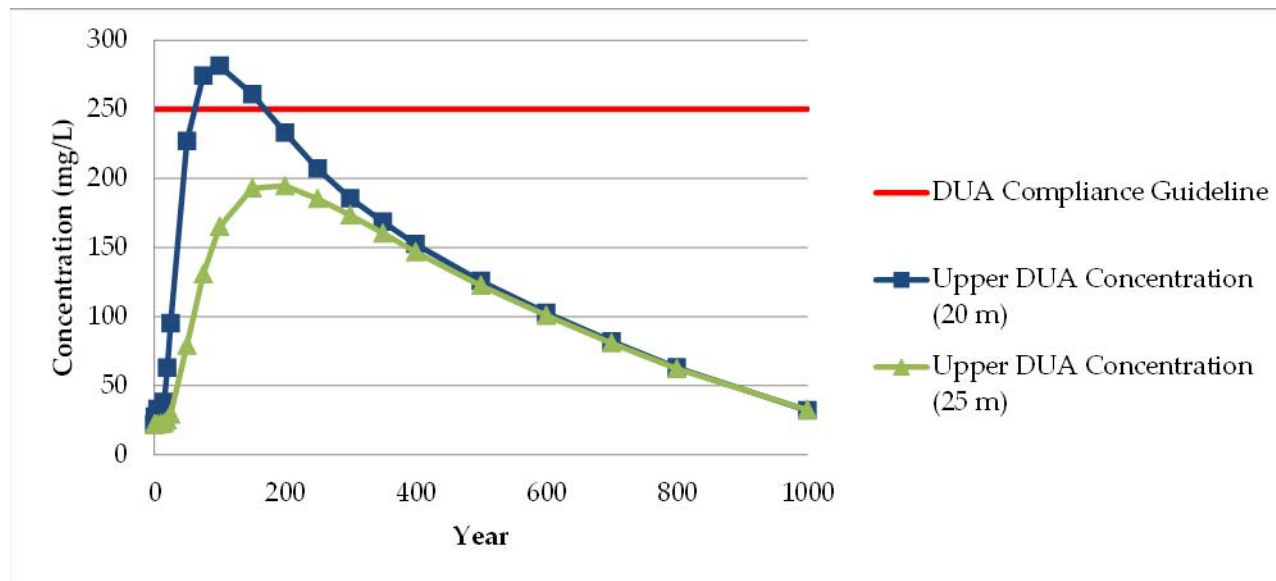
Current Conditions

- Estimated volume of contaminated soil:
55,000 – 71,000 m³
- Long-term water pumping previously
recommended



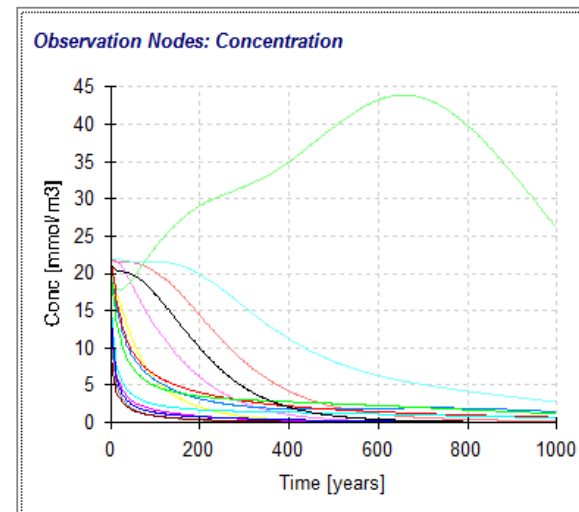
DUA Assessment

- Shallow GW not a DUA
- No known DUA to 23 m
- Predicted possible exceedance at 20 m, not at 25 m



FAL Assessment

- Surface water 140 m from impacts
- Modelling indicates concentrations well below guidelines



Rooting Zone Assessment

- Local climate data used
- Run for average long-term conditions and dry conditions
- Net downward movement of salt predicted



Results

- No predicted impacts to surface water
- No predicted impacts to DUA > 25 m
- Predicted decreasing concentrations in rooting zone
- Combined with ecological risk assessment, concluded no further remediation necessary if DUA > 25 m

Discussion/Path Forward

- 3-D modelling approach with site-specific data reduces remediation costs
- Successfully used on sites for reclamation certificate application
 - What would be needed for remediation certificate?