Subsoil Salinity Tool Application on Abandoned Well Sites in Southern Alberta: Industry and Consulting Perspectives, Challenges, and Solutions

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October 16, 2014
Outline

- Remediation before the Subsoil Salinity Tool (SST)
- The SST – Cenovus learnings
- Results, challenges, solutions
Site history

Six salt impacted sites in SE Alberta

• Drilled: 1969 – 1980
• Depth: 723 – 1245 m
• Target: gas
• Soils with elevated sodium and chloride
  • exceedance of Alberta Tier 1 (AESRD, 2010) for EC and SAR
Remediation before the SST

Remediation guidelines for EC and SAR:

• Alberta Tier 1 (AESRD, 2010)
• Background

What about chloride?

• 250 mg/kg?
• 500 mg/kg?
• 1000 mg/kg?
• Doesn’t matter?
Example Site – ‘Capone’

Phase 2 ESAs identified salinity issues

Remediation targeted EC, SAR and chlorides <250 mg/kg

EC and SAR were naturally elevated in background soils
Example site ‘Capone’
Example site ‘Capone’
Example site ‘Capone’
SST – Cenovus Perspective

Undertook SST analysis on six sites
• Tier 2a, Tier 2b and Tier 2c

Thought remediation was over

Example site ‘Gotti’
• Preliminary chloride guideline of 190 mg/kg
SST – Cenovus Perspective

Left with some questions:

• Was such a low guideline required to be protective of receptors?

• How did the remediation requirements from SST compare to Alberta Tier 1 (AESRD, 2010)?

• Can you use Alberta Tier 1 (AESRD, 2010) for soils with elevated chlorides?
Findings

- Cost/Benefit
- Three challenges
## Results

### Table 1: Estimated Volumes and Remediation Costs at Five Sites

<table>
<thead>
<tr>
<th></th>
<th>Exceeding Tier 1 Guidelines*</th>
<th>Exceeding 250 mg/kg* Chloride</th>
<th>Exceeding SST Guidelines**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of Soil (m³):</td>
<td>21,700</td>
<td>24,662</td>
<td>14,214</td>
</tr>
<tr>
<td>Remediation Cost:</td>
<td>$2,389,387</td>
<td>$2,715,533</td>
<td>$1,565,588</td>
</tr>
</tbody>
</table>

*root zone plus subsoil estimates

**includes root zone soil exceeding Tier 1 guidelines and subsoil exceeding SST guidelines
## Results

<table>
<thead>
<tr>
<th></th>
<th>Relative to Tier 1</th>
<th>Relative to 250 mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil not landfilled (m³):</td>
<td>7,486</td>
<td>10,448</td>
</tr>
<tr>
<td>Saved worker hours:</td>
<td>3,267</td>
<td>4,560</td>
</tr>
<tr>
<td>Saved truck loads:</td>
<td>363</td>
<td>506</td>
</tr>
<tr>
<td>Remediation cost savings:</td>
<td>$824,283</td>
<td>$1,150,429</td>
</tr>
<tr>
<td>Cost of SST data collection and analysis:</td>
<td>$184,128</td>
<td>$184,128</td>
</tr>
<tr>
<td>Net Cost Savings:</td>
<td>$640,155</td>
<td>$966,301</td>
</tr>
</tbody>
</table>

And just as protective to the environment.
Challenge 1: When to use SST?

- Justifications/rationale
- Tier 1 versus Tier 2 (SST or other methods)
- Optional versus mandatory scenarios
- Cost savings?
- Mock scenarios / gap analysis
- Avoiding over or under remediating
- Higher certainty with endpoint ~ more defensible closure ~ simplified liability management?
### Challenge 2: Stringent SST Guidelines?

#### Table 3: Tier 2 Chloride Guidelines

<table>
<thead>
<tr>
<th>Site</th>
<th>Initial SST Output*</th>
<th>Refined Guideline</th>
<th>Limiting Pathway / Receptor</th>
<th>Example Peripheral Subarea Guideline</th>
<th>Shallow Groundwater Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moran</td>
<td>370</td>
<td>1,030</td>
<td>Root zone</td>
<td>1,000</td>
<td>-</td>
</tr>
<tr>
<td>Luciano</td>
<td>1,400</td>
<td>1,600</td>
<td>Root zone</td>
<td>2,100</td>
<td>6,000</td>
</tr>
<tr>
<td>Costello</td>
<td>400</td>
<td>1,160</td>
<td>Aquatic Life</td>
<td>1,100</td>
<td>-</td>
</tr>
<tr>
<td>Gambino</td>
<td>170</td>
<td>700</td>
<td>Aquatic Life</td>
<td>700</td>
<td>1,700</td>
</tr>
<tr>
<td>Gotti</td>
<td>190</td>
<td>1,080</td>
<td>Aquatic Life</td>
<td>670</td>
<td>1,000</td>
</tr>
</tbody>
</table>

*Prior to implementing techniques described in this presentation.

Guidelines are approximate, expressed in mg/kg for subsoil and mg/L for groundwater.
Guideline Interpolation

- Aquatic Life Guideline Relative to Depth of Impact

\[ y = 215817x^{-2.749} \]
\[ r^2 = 0.9981 \]
SST Soil Chloride Guideline Interpolation
- relative to distance to nearest surface water body: for source length (SL) and top of impact (TOI) categories
SST Soil Chloride Guideline Interpolation
- relative to source length: for precise distance to nearest surface water body and top of impact (TOI) categories

TOI: 5 m; NSWB: 280 m
\[ y = 830143x^{-1.596} \]
\[ r^2 = 0.9989 \]

TOI: 4 m; NSWB: 280 m
\[ y = 718556x^{-1.604} \]
\[ r^2 = 0.9986 \]

TOI: 3 m; NSWB: 280 m
\[ y = 546426x^{-1.572} \]
\[ r^2 = 0.998 \]
Challenge 2: Stringent SST Guidelines?

- Solonetzic soils interspersed with chernozemic soils
Challenge 2: Stringent SST Guidelines?

- Solonetzic soils interspersed with chernozemic soils = bimodal EC
  - Outlier analysis of bimodal data may overlook natural salinity on the landscape? (Solution: three iterations)
  - Practical to stratify a spatially heterogenous area?
  - Reasonable to use backfill soil with low EC?
  - Provide causal reasoning
Challenge 3: Applying Subarea Guidelines

- Refine lateral closure and avoid over remediating the edges
- Prescriptive: extract worst case soils and conserve peripheral salvageable soil – balance volumes
- Impact area divided into subareas, each with a customized guideline

**ORANGE G.L.:** 1,500 mg/kg  
**TOI:** 3 metres  
**BOI:** 7 metres

**BLUE G.L.:** 1,000 mg/kg  
**TOI:** 1.5 metres  
**BOI:** 6 metres
Conceptual Profile of SST Subareas (#) and Respective Guidelines

- **Clean fill EC<0.5**
- **Possible excavation limits**
- **Impact Extent**

**Notes:**
- IRZ: Impacted Root Zone (Chloride: 400 mg/kg)
- Subarea sizes may vary based on confirmatory sampling

**Subareas:**
1. **Base:** 1030 mg/kg, **Wall:** 1,000 mg/kg
2. **Base:** 1000 mg/kg, **Wall:** SCARG
3. **Base:** 420 mg/kg, **Wall:** SCARG
Remediation Plan

- Prescriptive
- Test pits (blue squares) and confirmatory samples supplement and confirm predicted trends
Summary

- SST was useful on several sites
- Remediation was required
- Net cost savings
- Stringent guidelines: pathway elimination, pre- and post-processing work to avoid over-remediating
- Subarea application: soil conserved by removing worst case and maximizing salvage
- Higher certainty of remedial endpoints, protecting receptors (liability management / closure) – avoid under-remediating
References