MODELING ASSISTED EVALUATION OF SALINITY REMEDIATION APPROACHES



Understanding chloride remediation in soils



OUTLINE

- 1. Soil Salinity Relationships
 - Relating field parameter to concentrations
- 2. Feasibility of "Soil Washing"
- 3. Prairie Case Study
 - Mass distribution (samples \rightarrow 3D distribution)
 - Remediation Considerations
 - Existing System Design typical approach
 - Simulation Tools
 - Approach
 - Options Evaluation (effectiveness and cost)
 - Collaborative Research



Soll Description CVC EC Understand 3 = 8ag J = Jar IJTHOLOSY: #siture, octour, structure, selection, constance, procipitales, industora, stating, parent matrial, effencescence, procipitales, industora, stating, parent matrial, effective, industora, statin					-				
Sample Lepth Wey Sample Lepth B = Bag J = Jar Lithology B = Bag J = Jar Surface Expression: box (Most 2006 Gradient / Destion: Level/Upsiop Land Use: Lesse Vegetation: None 0.0000 0.0000 Surface Expression: box (Most 13733110701. Surface Expression: box (Gradient / Destion: Level/Upsiop Land Use: Lesse Vegetation: None 0.0000 0.0000 0.0000	Ø	l jî	(e)		Soil Description		VC	50]
Bentome Final Stand Sand	Per s		elat	Sample Depth	LITHOLOGY: texture, colour, structure, plasticity, consistency, roots,		VC	EC	
Image of the second	Sore letic	E ·		B = Bag	moisture, gleying, coarse fragments, effervescence, precipitates,	p	pm	uS/cm	
S A		e bt	atio	J = Jar	inclusions, staining, parent material, remarks			_	
Bentonte 0-30cm (#032) B 0-40cm (#033) B 0-40cm (#033) B 0-40cm (#033) B 0-40cm (#033) B 0-40cm (#033) B 0-120cm (#035) B SAND and CLAY: (0-100cm) brown to dark brown, moist, iron oxides, (Admixed Topsoli and Subsoli). 9900 1/600 Bentonte 900-120cm (#035) B 120-150cm (#036) B SAND Y CLAY: (100-350cm) brown, moist. 10700 Solution 120-150cm (#038) B 200-250cm (#038) B SANDY CLAY: (100-350cm) brown, moist. 10700 Solution 150-200cm (#038) B 200-250cm (#038) B SANDY CLAY: (100-350cm) brown, moist. 10700 Solution 100-250cm (#038) B 200-250cm (#048) B SANDY CLAY: (100-350cm) brown, wet. 10700 Solution 900-350cm (#048) B SANDY CLAY: (100-3500cm) brown, wet. 14700 Solution 450-450cm (#044) B SAND: (350-500cm) brown, wet. 14700 Solution 450-500cm (#044) B SAND: (350-500cm) brown, wet. 14700 Highest salt in sand, deep migration laterally, too deep for culvert trench system 1600 1600 HEAVY CLAY: (500-600cm) brown, moist. 530 530 530	ŭ 🦉		LIBV	MSI 13733110701	Surface Expression: Land Use: Lease Slope Gradient / Position: Level/Upslope Vegetation: None	÷ -	6 6	1000	
Bentonie			° <mark>~:/:/:/</mark> :/:	0-30cm (#032) B	SAND and CLAY: (0-100cm) brown to dark brown, moist, iron oxides,			9900	Ì
Bertonte 90-1200m (#036) B 120-150cm (#036) B 120-150cm (#036) B 120-150cm (#037) B 150-200cm (#037) B 200-250cm (#038) B 200-250cm (#038) B 200-250cm (#038) B 200-250cm (#038) B 200-350cm (#040) B 200-350cm (#040) B 300-350cm (#040) B 350-400cm (#041) B 300-350cm (#041) B SAND: (350-500cm) brown, wet. 450-400cm (#041) B SAND: (350-500cm) brown, wet. 14700 14700 120-450cm (#043) B 500-550cm (#044) B 500-550cm (#044) B HEAVY CLAY: (500-600cm) brown, moist. 1000 10000 11900 10000 120-150cm (#044) B 1400 120-1500cm (#044) B 100 120-1500cm (#045) B 100 120-1500cm (#045) B 100 120-1500cm (#045) B 100 120-1500cm (#045) B				60-90cm (#034) B	(Admixed Topsoil and Subsoil).			10800	
Bentonle				00.100-m (#025) D				40000	ŧ
Bentonie 120-150cm (#039) B Bentonie 150-200cm (#039) B 150-200cm (#039) B 150-200cm (#039) B 200-250cm (#039) B 200-250cm (#039) B 200-250cm (#039) B 200-300cm (#049) B 300-350cm (#040) B 300-350cm (#040) B 300-350cm (#040) B 300-350cm (#040) B 300-350cm (#040) B SAND: (350-500cm) brown, wet. 400-450cm (#041) B SAND: (350-500cm) brown, wet. Highest salt in sand, deep migration laterally, too deep for culvert trench system 14700 450-500cm (#044) B HEAVY CLAY: (500-600cm) brown, moist. 1600 TD = 600cm TD = 600cm TD = 600cm				90-120cm (#035) B				10200	ŧ
Bentonie Iso-200cm (#037) B 150-200cm (#038) B 200-250cm (#038) B 200-250cm (#038) B 260-300cm (#039) B 300-350cm (#040) B 300-350cm (#040) B 300-350cm (#041) B 360-400cm (#041) B 400-450cm (#041) B SAND: (350-500cm) brown, wet. Highest salt in sand, deep migration laterally, too deep for culvert trench system 14700 HEAVY CLAY: (500-600cm) brown, moist. 1600 TD = 600cm TD = 600cm		7+	7 <mark>///</mark>	120-150cm (#036) B				10700	I
Bentonie 150-200cm (#037) B 200-250cm (#038) B 200-250cm (#038) B 200-250cm (#038) B 250-300cm (#038) B 300-350cm (#040) B 300-350cm (#040) B 300-350cm (#041) B 360-400cm (#041) B 400-450cm (#042) B 400-450cm (#042) B 450-500cm (#043) B 500-550cm (#044) B 500-550cm (#044) B 500-550cm (#044) B 500-550cm (#044) B 500-550cm (#044) B TD = 600cm TD = 600cm			/:/:/:/:/:		SANDY CLAY: (100-350cm) brown, moist.				ł
Sand 9 9 9 200-250cm (#038) B 250-300cm (#039) B 350-400cm (#040) B 350-400cm (#040) B 350-400cm (#040) B 350-400cm (#041) B 350-400cm (#041) B 350-400cm (#042) B 14700 14700 Sand 9 9 9 9 600-550cm (#043) B SAND: (350-500cm) brown, wet. 14700 14700 Weil 450-500cm (#043) B 500-550cm (#044) B Highest salt in sand, deep migration laterally, too deep for culvert trench system 1600 Weil 550-600cm (#044) B HEAVY CLAY: (500-600cm) brown, moist. 630 TD = 600cm TD = 600cm TD = 600cm 630	Bentoni	te –		150-200am (#027) R	Flevated salt in surface soil GW not			10000	ŧ
Sand Weil Weil Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q				150-200cm (#057) B				10000	1
Sand Weil Weil Weil Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q		2	~ <mark><!--/</mark--></mark>		shallow enough for trench/culvert,				
Sand		1.1		200-250cm (#038) B	treat as second impact source			6400	
Sand 250-300cm (#039) B 300-350cm (#040) B 300-350cm (#040) B 300-350cm (#041) B Sand 350-400cm (#041) B 400-450cm (#042) B 400-450cm (#042) B 14700 Weil 450-500cm (#043) B 500-550cm (#044) B 14700 11900 Weil 500-550cm (#043) B 500-550cm (#044) B HEAVY CLAY: (500-600cm) brown, moist. 1600 TD = 600cm									
Sand 300-350cm (#040) B Sand 350-400cm (#041) B 400-450cm (#042) B 400-450cm (#042) B 450-500cm (#043) B 450-500cm (#043) B 500-550cm (#044) B 500-550cm (#044) B HEAVY CLAY: (500-600cm) brown, moist. 1600 TD = 600cm TD = 600cm				250-300cm (#039) B	originating at surface			5300	
Sand 300-350cm (#040) B Sand 350-400cm (#041) B 400-450cm (#042) B 400-450cm (#042) B 450-500cm (#043) B 450-500cm (#043) B 500-550cm (#044) B 500-550cm (#044) B Feature 500-550cm (#044) B HEAVY CLAY: (500-600cm) brown, moist. 1600 TD = 600cm TD = 600cm									
Sand 350-400cm (#041) B Sand 400-450cm (#042) B 400-450cm (#043) B 450-500cm (#043) B 500-550cm (#044) B 500-550cm (#044) B 500-550cm (#044) B HEAVY CLAY: (500-600cm) brown, moist. TD = 600cm TD = 600cm		٣Ť	° <u>~~~</u>	300-350cm (#040) B				3200	
Sand Well Screen 350-400cm (#041) B 350-400cm (#041) B SAND: (350-500cm) brown, wet. 400-450cm (#042) B 400-450cm (#042) B Highest salt in sand, deep migration laterally, too deep for culvert trench system 14700 Well Screen 450-500cm (#043) B Highest salt in sand, deep migration laterally, too deep for culvert trench system 1600 HEAVY CLAY: (500-600cm) brown, moist. TD = 600cm TD = 600cm									
Sand Sand Weil Screen Q Q Q Q Q Q Q Q Q Q Q Q Q				350-400cm (#041) B	SAND: (350,500cm) brown, wet	1 🛉		14700	
Sand Well Screen Sand Well Screen Sol-550cm (#042) B 450-500cm (#043) B 500-550cm (#044) B 500-550cm (#044) B 550-600cm (#045) B TD = 600cm			·.·.·		SAND. (350-300cm) brown, wet.				
Sand Well Soreen Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q Q	•≓⊟•:	4+	4 <mark></mark>	400-450cm (#042) B	Highest salt in sand, deep migration			11900	ł
Sand - - 450-500cm (#043) B 1000 deep for curvert trench Weil -					laterally too doop for culvert trench				•
Screen	Sand	1	• • • • • • • • • • • •	450-500cm (#043) B	laterally, too deep for curvert trench	ΙT		2200	
φ φ φ φ 600-550cm (#044) B HEAVY CLAY: (500-600cm) brown, moist. 1600 630 φ φ φ φ TD = 600cm TD = 600c	Screen			450-500011 (#045) D	system				
φ φ φ φ φ φ φ φ φ TD = 600cm TD		φ	ب <mark></mark>	500 550 (10 40 5				4000	
550-600cm (#045) B TD = 600cm		1.4		500-550cm (#044) B	HEAVY CLAY: (500-600cm) brown, moist.			1600	
φ φ φ φ 630 TD = 600cm TD = 600cm 0 0								1	
φ φ	<mark>·⊨</mark> ·:	$ $		550-600cm (#045) B				630	
TD = 600cm									
TD = 600cm		ΨŤ	φ						
					TD = 600cm				

SAMPLING INFLUENCE ON GW AND SOIL CHLORIDE CONCENTRATION RELATIONSHIP



Soil Vs Groundwater - SO4 (> 250 mg/L Cl) Highest Chloride Concentration in Impacted Screened Interval



Soil Vs Groundwater – Chloride (mg/L) Highest Chloride Concentration in Impacted Screened Interval





EM 38 Versus Ave Chloride Concentration



EM 38 Versus Ave EC



SEQUENTIAL SOIL WASHING AND SATURATED PASTE SQUEEZE

LABORATORY SALT REMOVAL TEST RUN



Water Used to Soil Wash - (10,000 mg/L Cl Spill)					
Soil Type	Initial 1 st Wash EC (dS/m)	Soil Wash Iterations to Criteria	Ratio H ₂ O to Soil (m ³ H2O/m ³ impacted soil)		
Peat Soil	11.2	3	1.8		
Clay	13.1	4	4.9		
Sandy Clay Loam	8.6	3	2.8		
Sandy Loam	11.4	4	3.0		
Impacted Top Soil	15.3	4	3.0		



Water Used to Sat Paste Squeeze Soil - (10,000 mg/L Cl Spill)					
Soil Type	Initial 1 st Wash EC (dS/m)	Soil Squeeze Iterations to Criteria	Ratio H ₂ O to Soil (m ³ H2O/m ³ impacted soil)		
Peat Soil	35.3	5	1.4		
Clay	31.1	6	3.4		
Sandy Clay Loam	23.5	6	2.6		
Sandy Loam	24.3	6	1.8		
Impacted Top Soil	34.1	7	1.8		



SUMMARY POINTS

- Minor increases in clay content lead to increased water used more so than decreased sand for squeeze
- Higher EC starting point (background) increased water use more for washing than squeezing
- Although water washing requires much more water there is significantly less work events



PRAIRIE SPILL – 3D VISUALIZATION OF PRODUCED WATER IMPACT AREA



STANDARD CULVERT-TILE GW RECOVERY STRATEGY FOR LONG TERM REMEDIATION

Groundwater Recovery	Tile Length (m)	Vol GW recovered (m ³ /year)	Cl Removal Rate (kg/year)	Mass Chloride (kg)	Mass Chloride in Hot Spot	Years for 50% Reduction	Years for 50% Reduction of Hot Spot	Additional Tile for 50% Reduction of Hot Spot in 10 Years (m)
	80	305	2480	177,000	93,000	36	19	151



TRANSPORT MODELLING EXAMPLE APPLICATION



NUMERICAL MODELLING

• Purpose

- Evaluate Groundwater flow and Transport of Saline Process Water
- Evaluate Remediation Alternatives
- Scope
 - Numerical Model with Simplified Parameters
 - Evaluate effectiveness of multiple trench and drain designs
 - Cost benefit analysis



FLOW & TRANSPORT OBSERVATIONS





REMEDIATION OPTIONS

- 1. Do nothing / natural attenuation (dispersion)
- 2. Extraction trenches (multiple designs)
 - a) Single trench
 - b) Multiple trenches
- 3. Root zone excavation
 - a) independent
 - b) with extraction trenches
- 4. Extraction / re-infiltration systems



1. NATURAL ATTENUATION



PREDICTED PLUME MIGRATION WITHOUT ACTIVE REMEDIATION



PREDICTED PLUME MIGRATION WITHOUT ACTIVE REMEDIATION



2A. SINGLE EXTRACTION TRENCH



EXTRACTION TRENCH



Weeping Tile Connected to a Vertical Culvert

Assumptions

 Head at culvert maintained at 2 m below watertable.

2.

 Weeping tile allows water and mass to freely flow toward the culvert.



PREDICTED PLUME MIGRATION WITH SINGLE EXTRACTION





Mass upgradient of weeping tile captured.



Weeping Tile (hot spot)

Weeping Tile (south of hot spot)

More upgradient mass captured and lower concentrations downgradient.



COMPARISON OF TRENCH LOCATIONS



2B. MULTIPLE EXTRACTION TRENCHES





2 EXTRACTION TRENCHES





Weeping Tile

Less contaminant remaining after 100 years.

0



3 EXTRACTION TRENCHES





Weeping Tile

Greater reduction in plume size over the 100 year period.

n



Do Nothing

2 EXTRACTION TRENCHES (1 SOUTH OF PLUME)

Weeping Tile

Less mass downgradient but higher concentration in plume.

lass concentration
- Continuous -
[mg/l]
35000
10845.6
3360.79
1041.42
322.711
100

Do Nothing

3 EXTRACTION TRENCHES (1 SOUTH OF PLUME)

Weeping Tile

Less mass downgradient and reduced concentration in plume.

COMPARISON OF MULTIPLE 3 Trenches TRENCHES



3A. ROOT ZONE EXCAVATION

Extraction of upper 1.5 m across footprint of impacted area.





Do Nothing

ROOT ZONE EXCAVATION (TOP 1.5 M OF PLUME)

Reduced size and concentration of plume.

42,000 m^3 of soil removed = 96,000 kg of salt (32% of total)

COMPARISON OF ROOT ZONE EXCAVATION



4. EXTRACTION / RE-INFILTRATION



Aass concentration - Continuous -[mg/] 35000 10845.6 3360.79 1041.42 322.711 100 Do Nothing Mass concentration - Continuous -[mg/] 35000 - A RE-INFILTRATION TRENCH Weeping Tile

Re-Infiltration Tile (above water table)

Enhanced total mass removal. Down gradient mass nearly all removed after 100 years.

COMPARISON OF RE-INFILTRATION OPTIONS



COST / BENEFIT ANALYSIS

