Using sub-surface tile drains, calcium amendments, straw, and forage to remediate brine-contaminated soil

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Acknowledgements

- Canadian Natural Resources Ltd. for the field sites and the data presented in subsequent slides.
- My advisors: Robert G. Eilers & Dr. Tee Boon Goh.

Who is Good Lands Environmental?

- Service the Oil Industry in SE Saskatchewan & SW Manitoba since 1997.
- Spill response and clean up.
- Reclamation (remove roads and decommission facilities).
- Large remediation projects (tile drainage systems).

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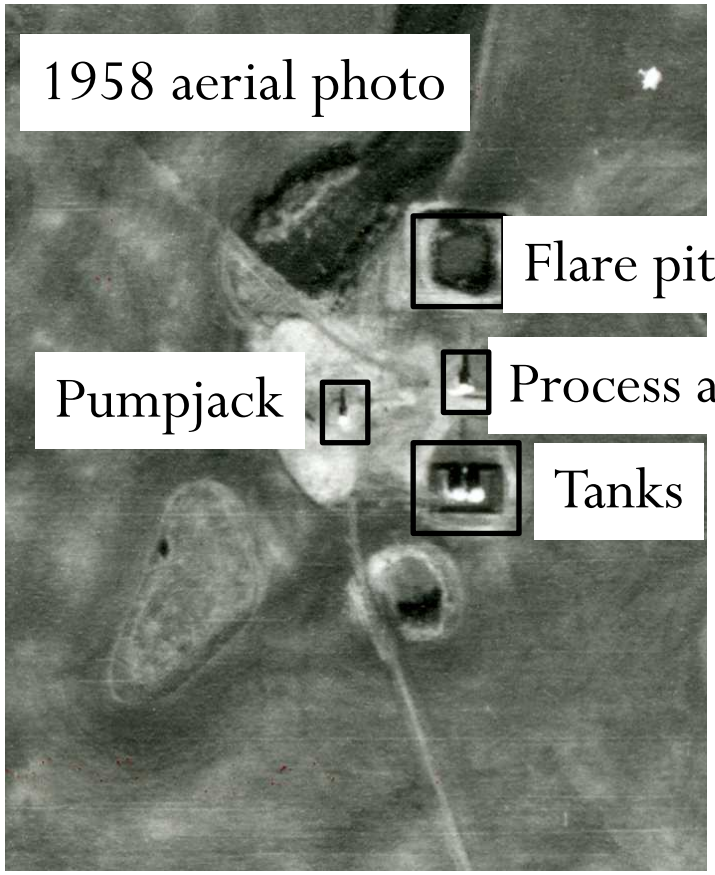
Intro – Oil Production in SE Sask



- Pump-jack extracts emulsion (oil & brine).
- Emulsion is separated into oil and brine.
- Oil is sold and brine is re-injected.
- Flare pits were historically used to flare natural gas and dispose of unwanted oil and brine.
- Flare pits were buried without removing source material.
- Salt migration from the buried flare pits caused salt-affected soil areas.

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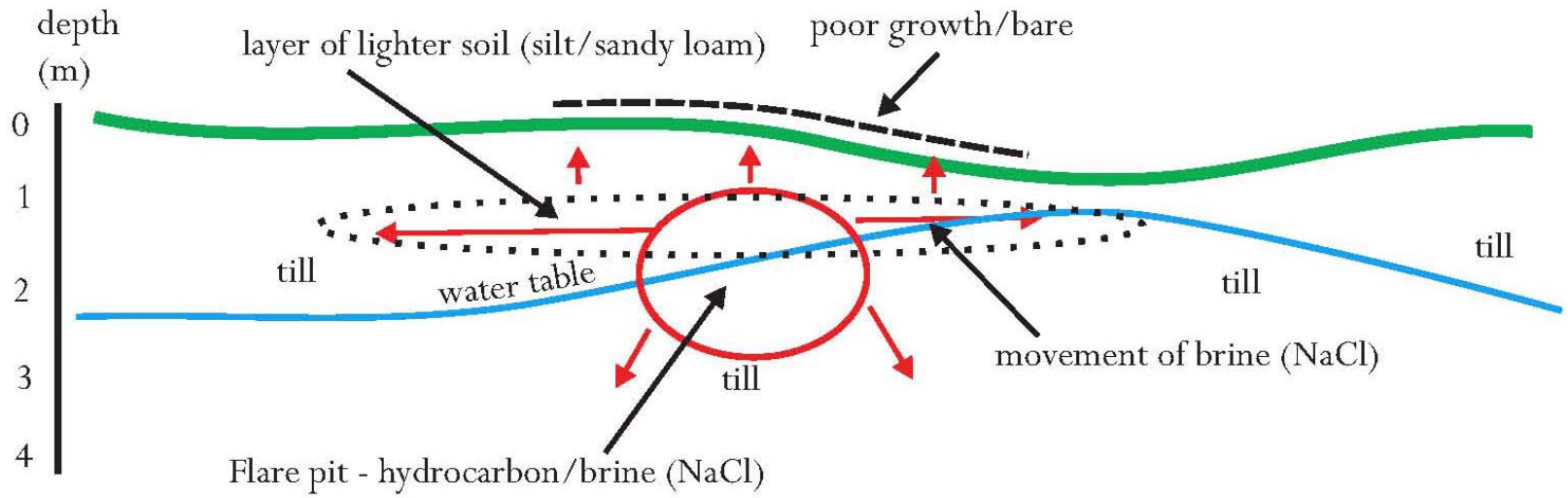
Schematic of Flare Pit Contamination



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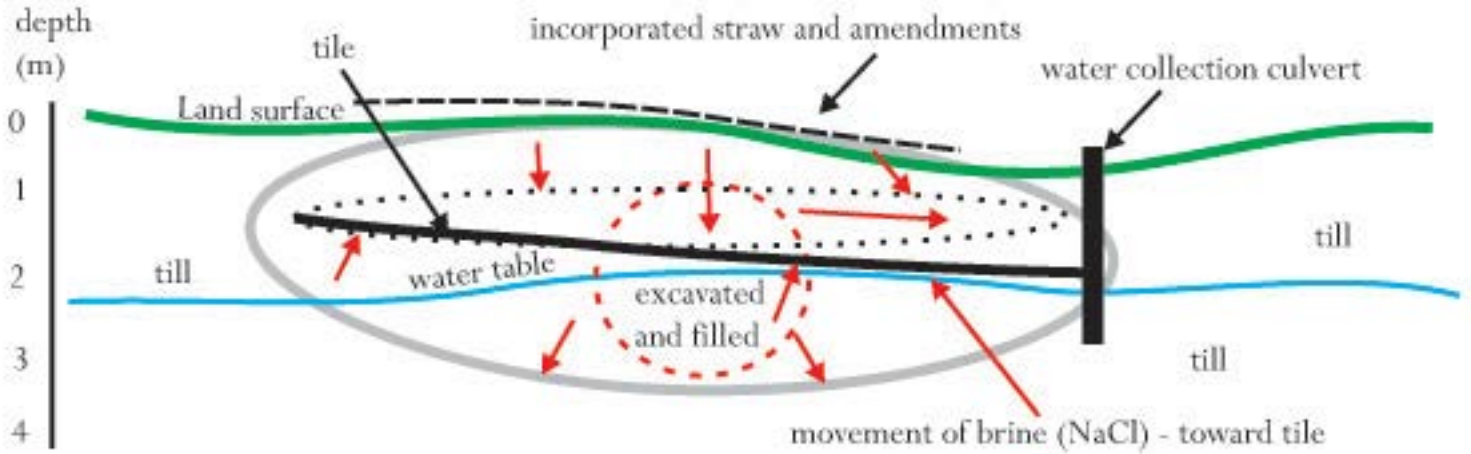
Flare Pit Excavation and Tile Drainage System Installation



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Remediation Process

1. Remove source (flare pit).
2. Install sub-surface tile drains
3. Add surface amendments (calcium nitrate gypsum & straw).

Chain trencher, sock tile, & crushed rock

4. Grow forages and dewater the tile system.

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Keys to Tile System Success

1. Vegetation
   - Establish vegetation on surface.
2. Water
   - Manage the water – de-water the tile system.
3. Soil
   - Add calcium-sourced amendments (gypsum and or calcium nitrate).

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Tile System Assessment

- Three key components of the assessment:
  1. Vegetation
  2. Water: Surface and ground
  3. Soil

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Detailed Assessment of Tile System
1. Vegetation

Detailed Assessment

- Visual assessment.
- GPS mapping of poor growth areas.

Goals

- Vegetation comparable to off site.
- No bare areas.
- Minimize presence of salt tolerant vegetation.

1. Vegetation Assessment

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Detailed Assessment of Tile System
2. Water

Detailed Assessment

- Surface water
  - Influence of topography on how surface water flows.
- Groundwater
  - Depth to water table.
  - Seasonal changes in depth to the water table and quality of water.

Goals

- Surface water
  - Engineering controls to prevent surface water ponding.
- Groundwater
  - >2 m below ground surface (mbgs).
  - Low salinity if <2 mbgs.
  - Comparable to control?

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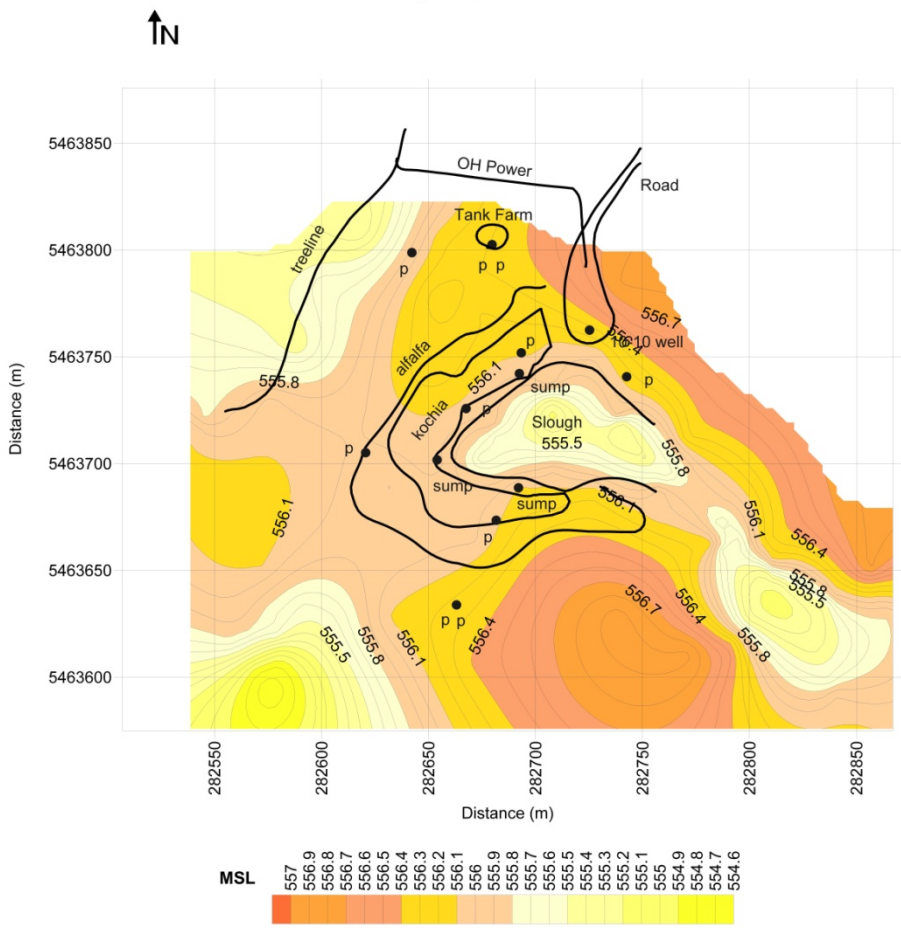
2. Water: Topography



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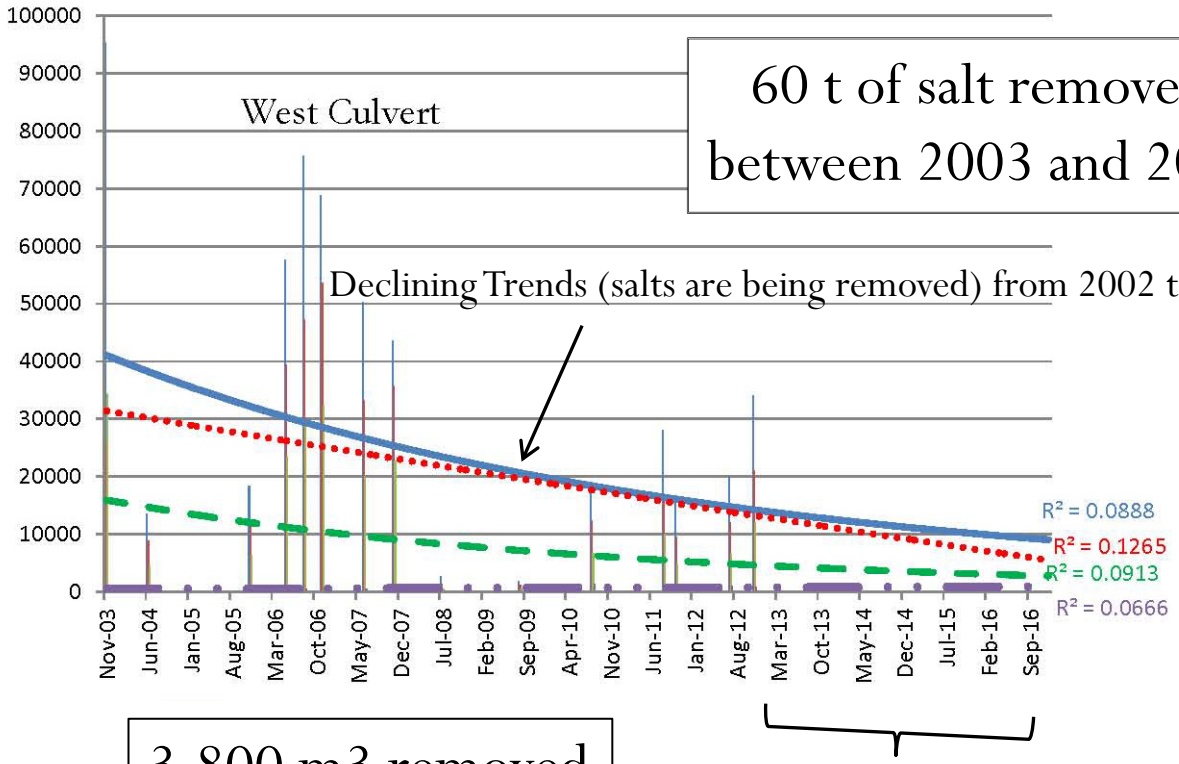
2. Water: Pump Out Water Quality of Tile System

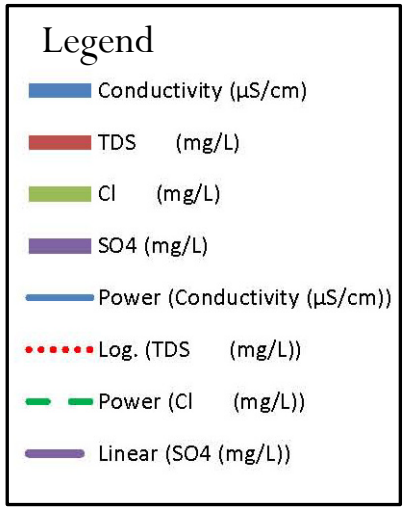


60 t of salt removed between 2003 and 2012

Declining Trends (salts are being removed) from 2002 to 2012 (Conductivity, TDS and Cl)

3,800 m3 removed between 2003 and 2012

Trend lines are extended to 2016 to predict future water quality



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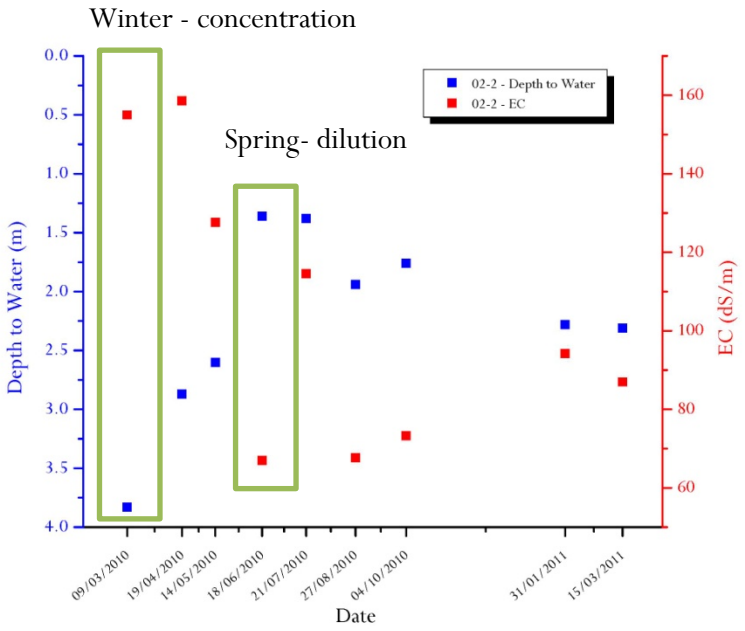
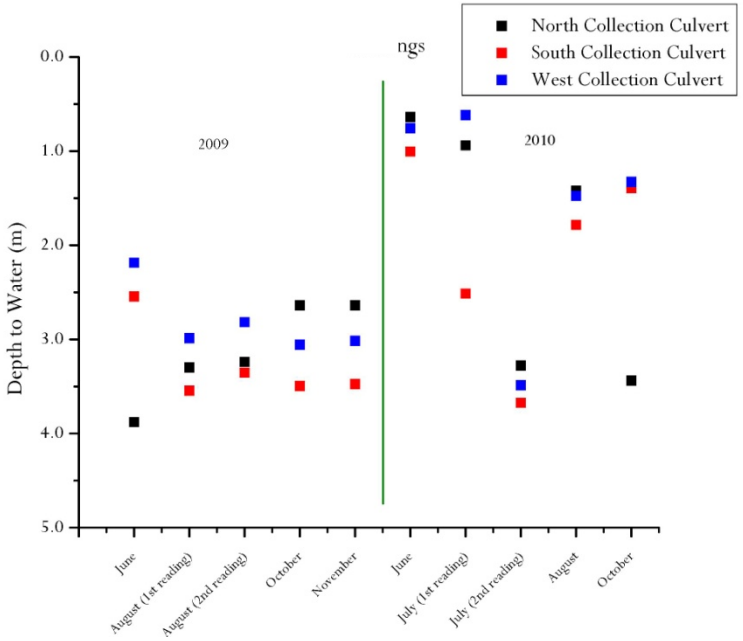
2. Water: Groundwater

Seasonal changes in groundwater depth and quality



Influences of tile on groundwater depth



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Detailed Assessment of Tile System
3. Soil

Detailed Assessment

- EM38h (0-60 cm, upper root zone)
- EM38v (0-120 cm, lower root zone)
- EM31v (0-600 cm)
  - Original EM31v compared to new EM31v
- Soil profile.

Goals

- EM38h – Weak (ECe = 2-4 dS/m)-Moderate salinity (ECe = 4-8 dS/m)

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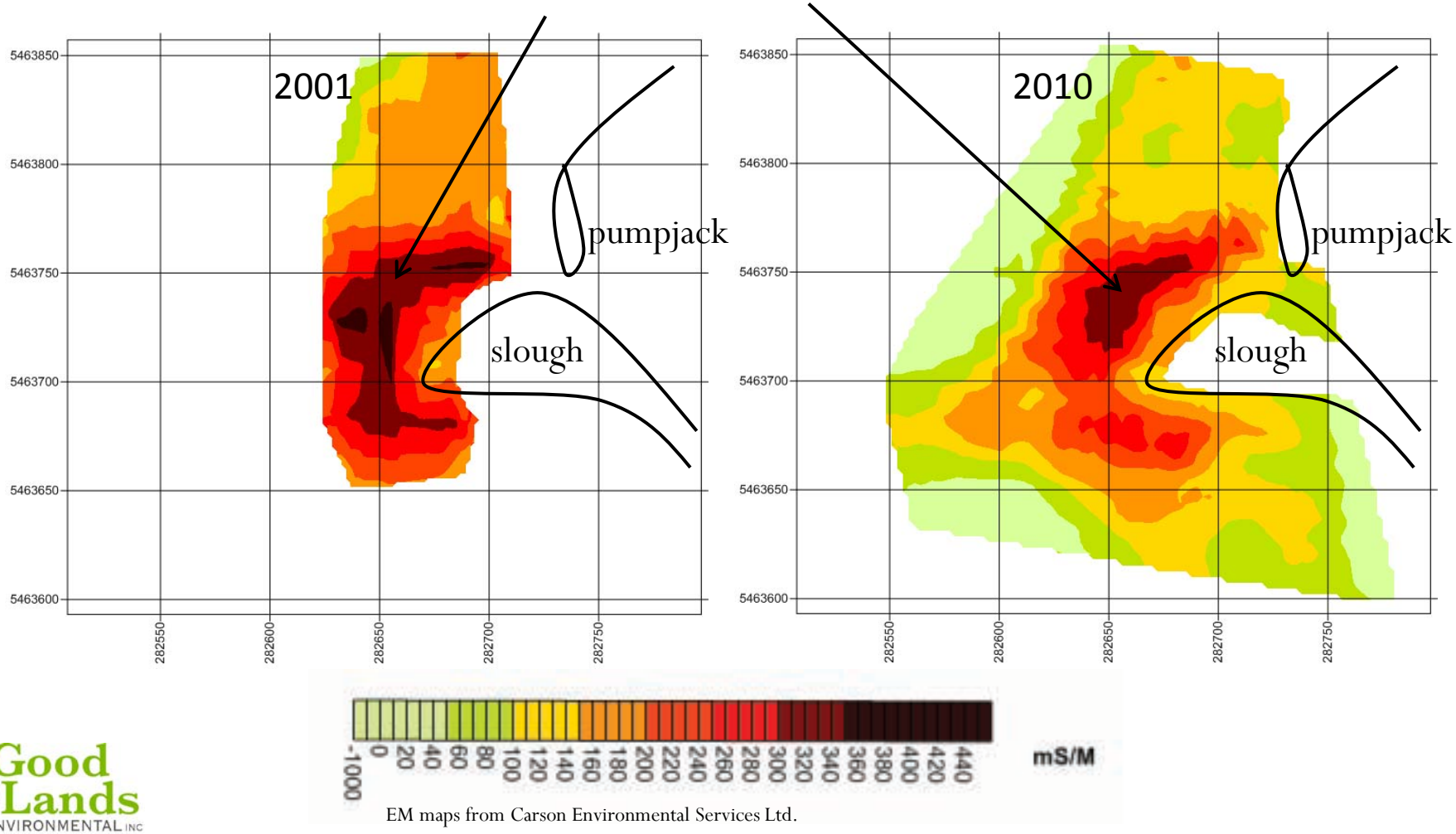
3. Soil: Comparison of 2001 and 2010 EM31v

(0 – 600 cm)

62% reduction in area >300 mS/m



EM maps from Carson Environmental Services Ltd.

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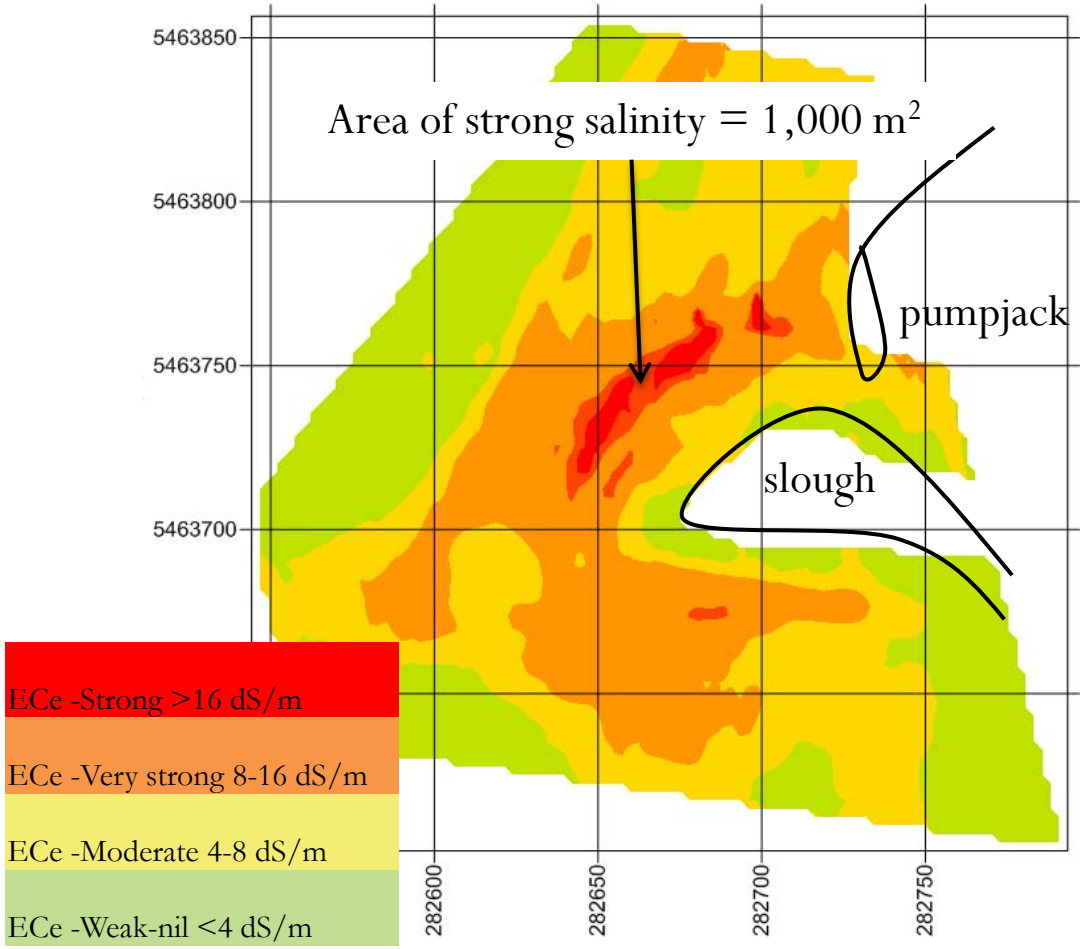
3. Soil: EM38h - upper root zone salinity

(0 – 60 cm)



500	33.8	Strong
400	27.3	>16 dS/m
390	26.6	
380	25.9	
370	25.3	
360	24.6	
350	22.8	
340	22.2	
330	22.7	
320	22	
310	21.3	
300	20.7	
290	20	
280	19.4	
270	18.7	
260	18.1	
250	17.4	
240	16.7	
230	16.1	
220	15.4	Moderately
210	14.8	strong
200	14.1	8-16 dS/m
190	13.5	
180	12.8	
170	12.1	
160	11.5	
150	10.8	
140	10.2	
130	9.5	
120	8.9	
110	8.2	
100	7.5	Moderate
90	6.9	4-8 dS/m
80	6.2	
70	5.6	
60	4.9	
50	4.3	
40	3.6	weak-nil
30	2.9	<4 dS/m
20	2.3	
10	1.6	

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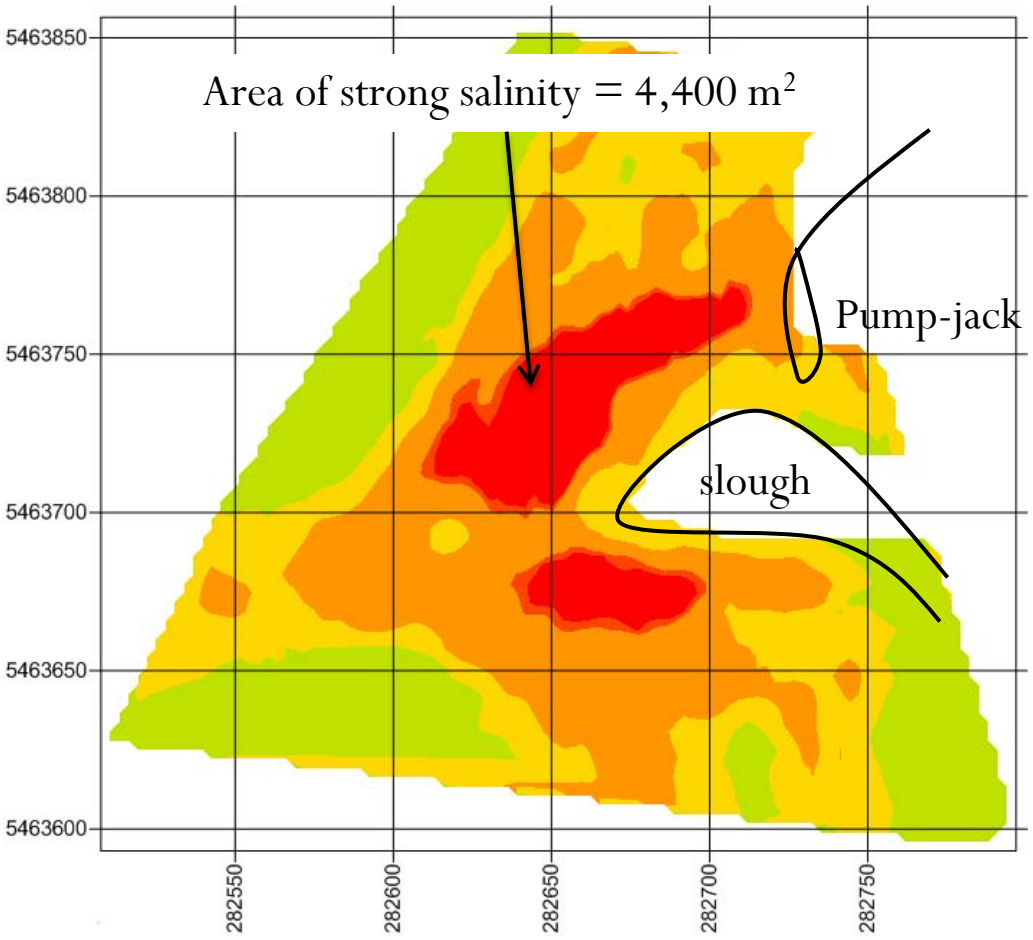
EM maps from Carson Environmental Services Ltd.

3. Soil: EM38v - deep root zone salinity

(0 – 120 cm)



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20	2.3	
10	1.6	

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EM maps from Carson Environmental Services Ltd.

Conclusion

Results of remediation interventions - 2001 to 2010:

1. Extent of severe contamination has been reduced by 62%
2. Bare soil areas have been completely re-vegetated with salt tolerant grasses and forages.
3. Groundwater salinity has declined consistently due to pumping and dilution by spring recharge.
4. Water table has been stabilized at 2 m - depth of the tiles.
5. Extent of strong salinity in the upper root zone has been reduced to 1000 square meters.

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Can Tile be Decommissioned?

1. Vegetation
   - Bare areas eliminated but vegetation not comparable to off site (no alfalfa on tile site).
2. Water
   - Surface water will pond in slough adjacent to tile.
   - Groundwater within 2 m of surface and still saline.
3. Soil
   - Upper root zone (EM38h/0-60 cm)still saline (ECe > 8 dS/m).

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Thank you

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2002:

Before tile system

2013

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