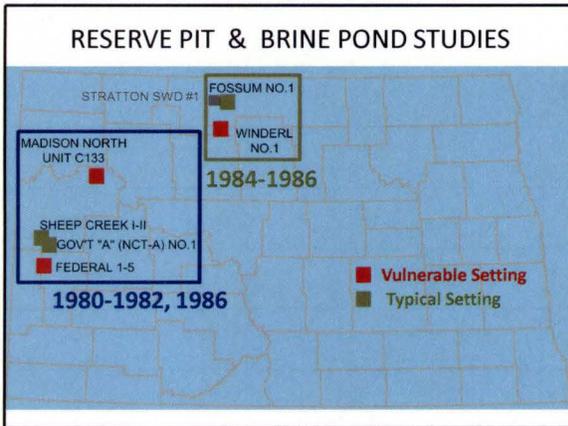


**Reserve Pit and
Brine Pond Studies in North Dakota**

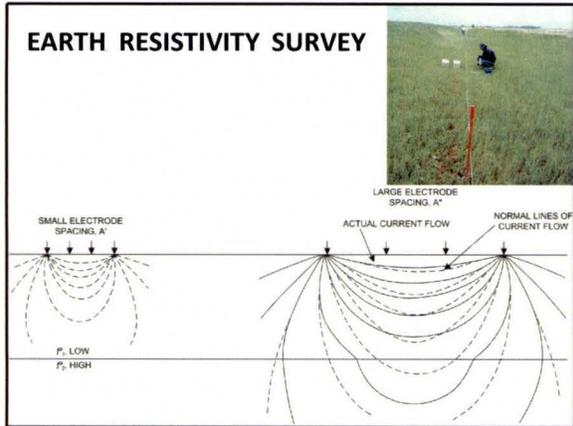
Presented to the
Energy Development and Transmission Committee
Senator Rich Wardner, Chair
Minot, ND
April 8, 2014

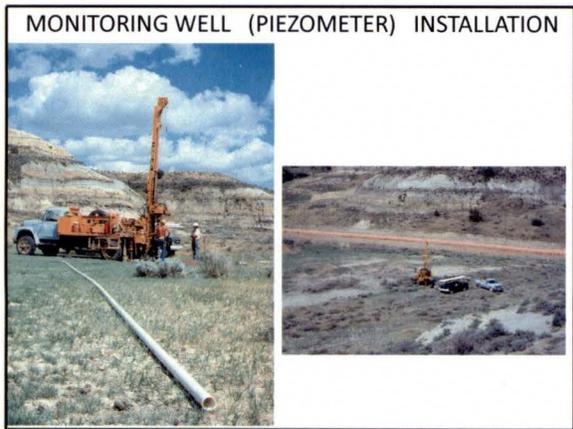
Ed Murphy
North Dakota Department of Mineral Resources
Geological Survey

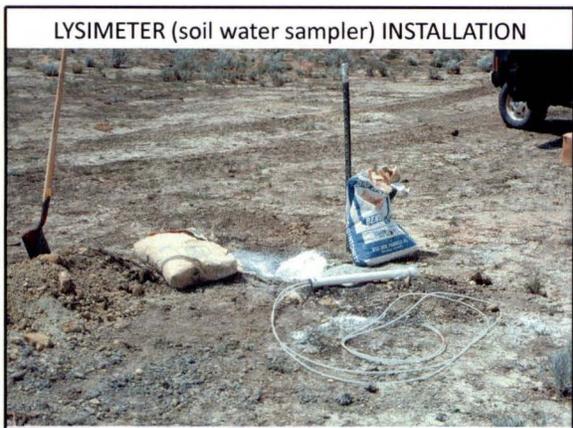


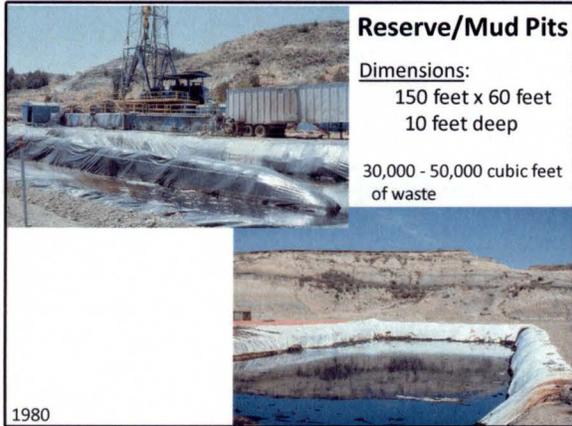
NORTH DAKOTA GEOLOGICAL SURVEY

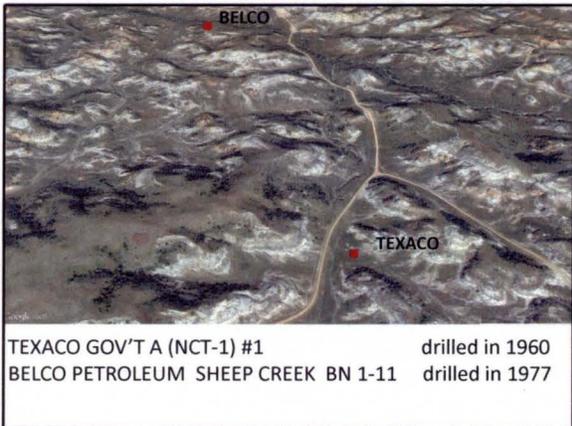
- **1980 - 1982** Studied **four buried reserve pits** in western North Dakota (one report, one paper, numerous presentations).
1986 Resampled **Apache site** (one report, one presentation).
- **1984 - 1986** Studied **two buried reserve pits** in north-central North Dakota (one report, several presentations).
- **1984 - 1985** Studied an **abandoned brine holding pond** in north-central North Dakota (two reports).

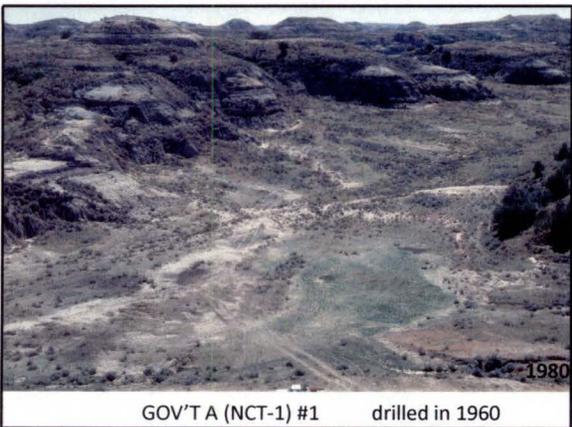


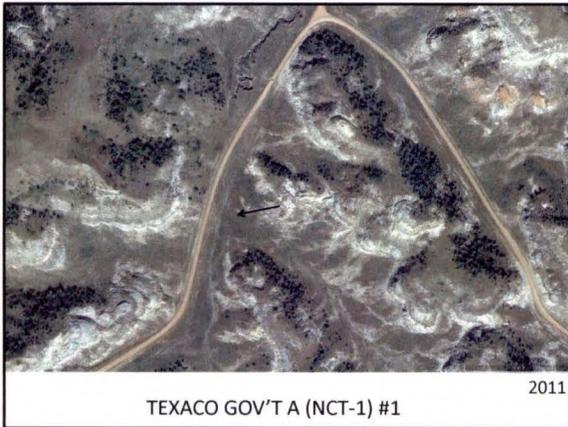


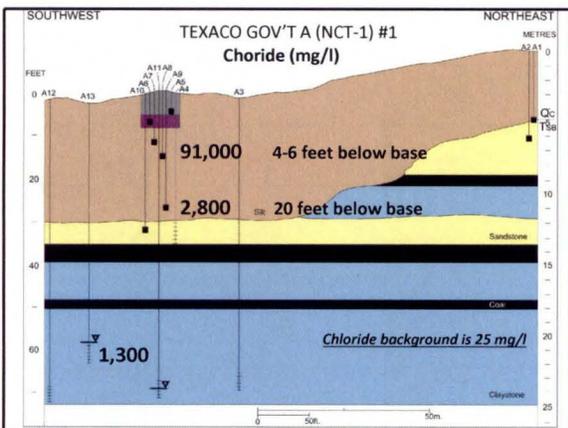


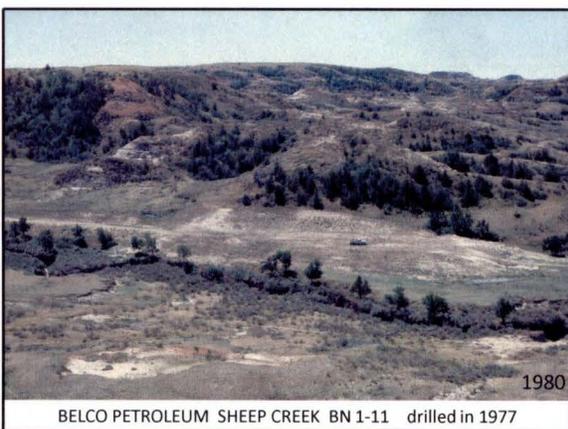


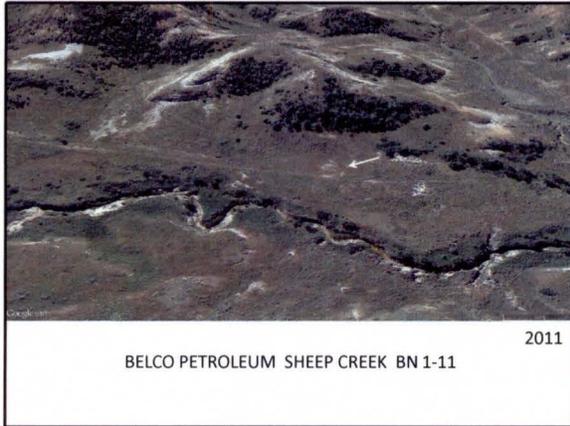


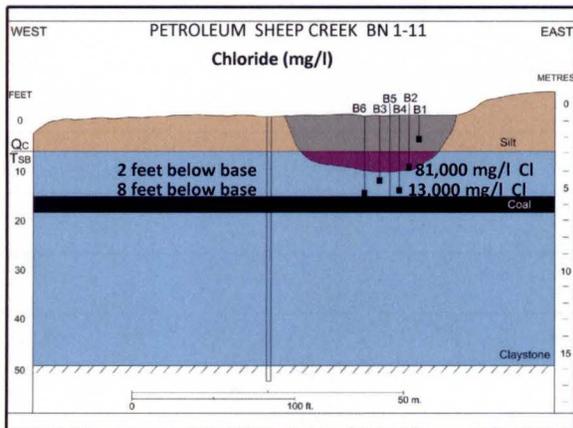


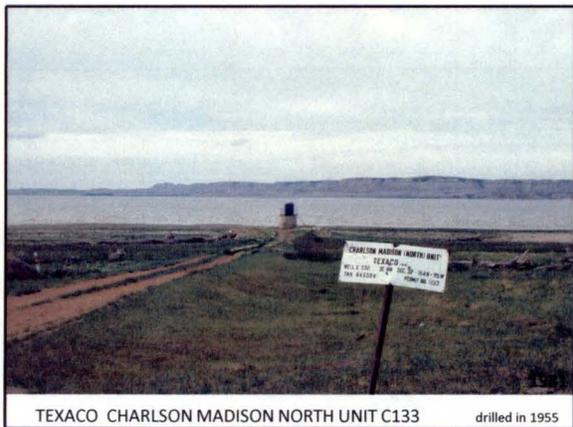


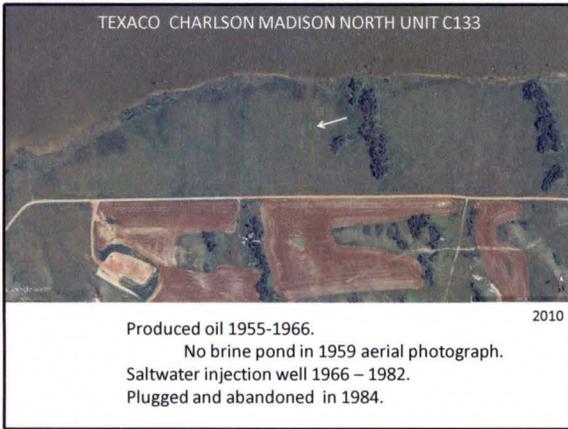


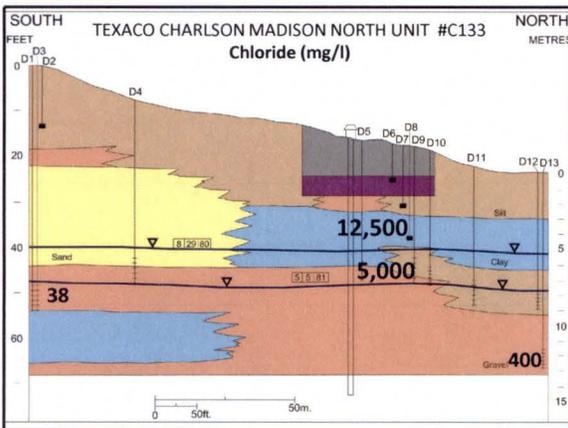


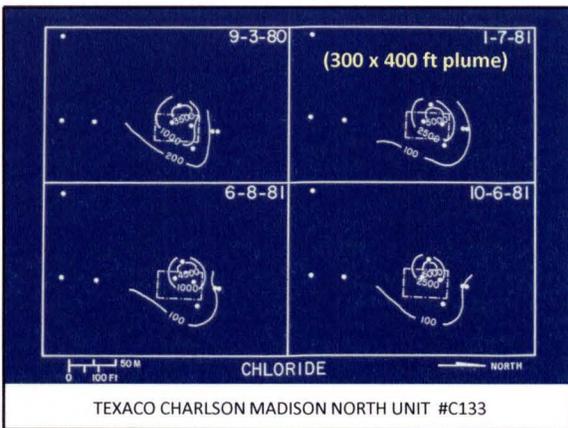




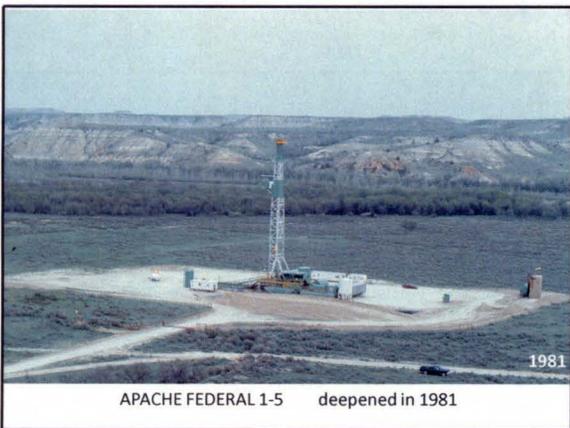


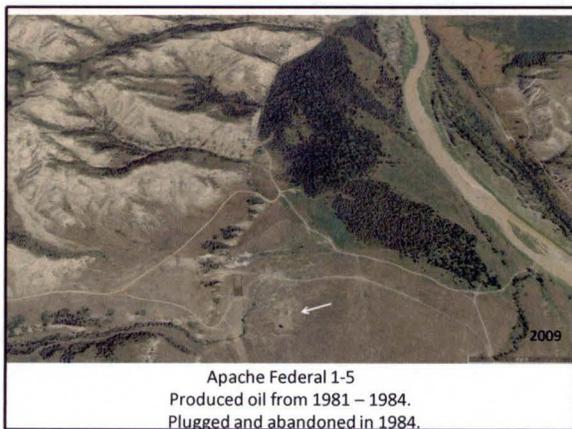


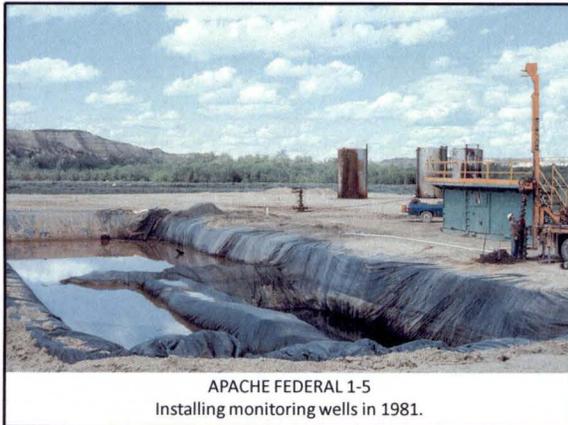


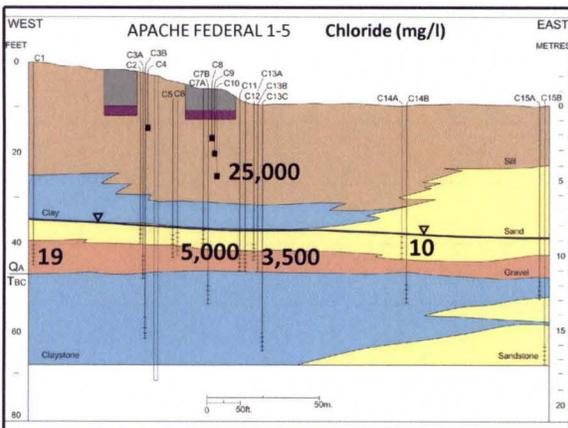


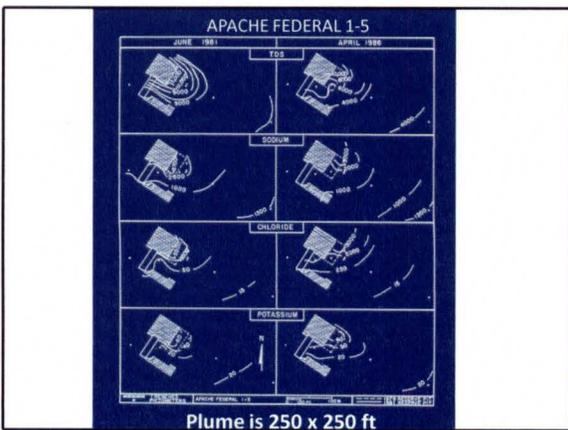












**RESERVE PIT STUDY
WESTERN NORTH DAKOTA**

- Leachate is being generated from buried drilling fluid at each of the four western ND study sites.
- The amount of leachate reaching the water table is assumed minimized by clay attenuation and evapotranspiration.
- Very little leachate is likely reaching the saturated zone at the two study sites in the Roughrider Field based on the reduction seen in the unsaturated zone.

**RESERVE PIT STUDY
WESTERN NORTH DAKOTA**

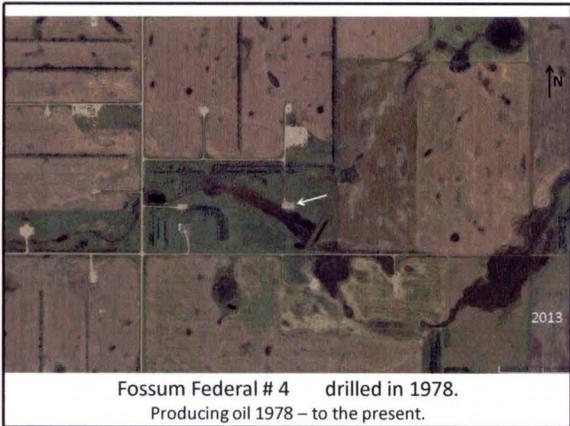
- Leachate at Federal 1-5 covers an area of 250 x 250 feet.
 – Chromates detectable in leachate within the unsaturated zone but not in the saturated zone – levels were higher in the saturated zone in 1986.
- Leachate plume in the Texaco Charlson Madison (North) Unit is approximately 300 x 400 feet in the upper saturated zone (top 40 feet).
- This study determined that leachate will be generated by the current method of reserve pit reclamation. Therefore, it is important to focus attention in areas where leachate will degrade the groundwater.

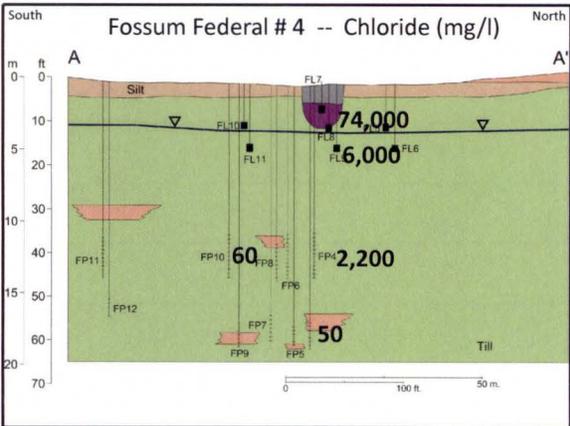
**RESERVE PIT STUDY: WESTERN NORTH DAKOTA
1986 CONCLUSIONS**

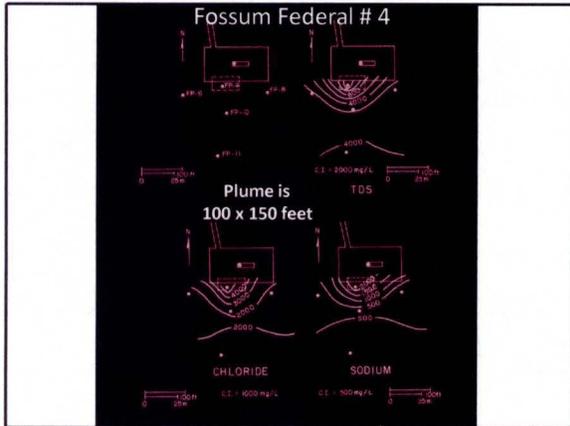
- In general, groundwater chemistries and the extent of the leachate plume relatively unchanged from 1981 to 1986 at Apache Federal 1-5 site.
- Suggested alternative methods for environmentally sensitive sites including closed mud system, solidification, solids control system, central disposal sites – noted central disposal sites must be carefully chosen because the increased volume increases the chances for widespread groundwater contamination.
- There are settings such as the Little Missouri River floodplain, Little Muddy, etc where there should be no burial of waste drilling fluid.

RESERVE PIT STUDY
NORTH-CENTRAL N. DAK. 1984

- Two reserve pits studied; one in till (Fossum) the other in sand and gravel (Winderl).
- Installed 45 piezometers and 13 lysimeters, took 700 resistivity readings, obtained 160 water samples for analysis.



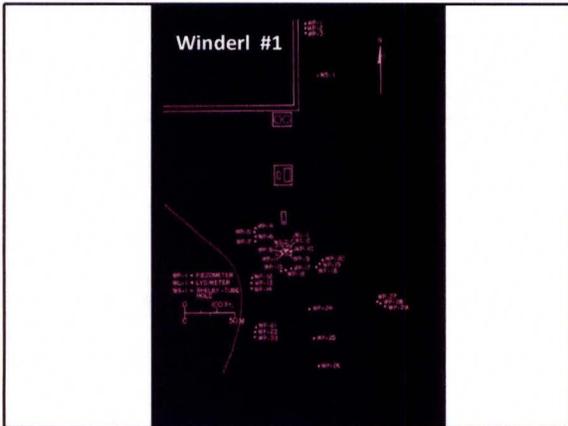




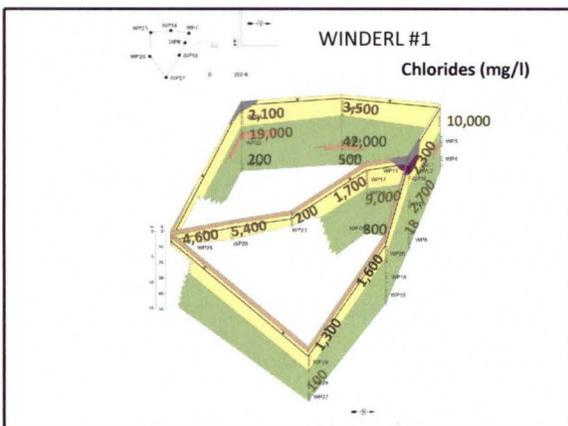


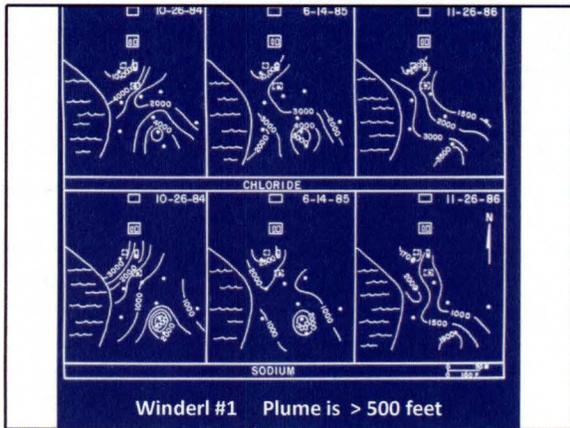
J.J. WINDERL # 1 -- drilled in 1959 and deepened in 1980. Producing oil 1959 – to the present.





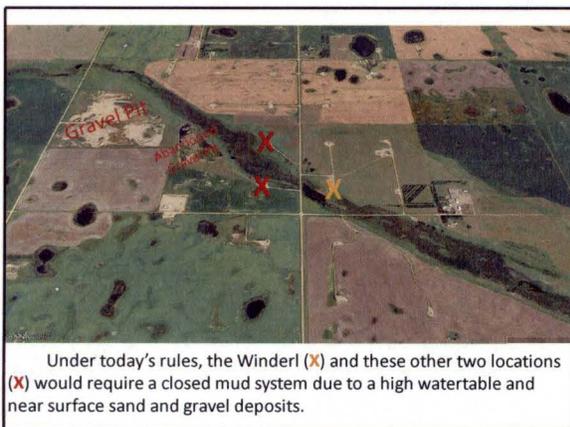


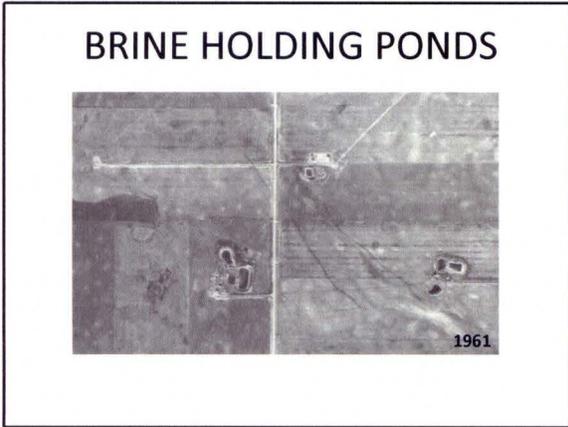


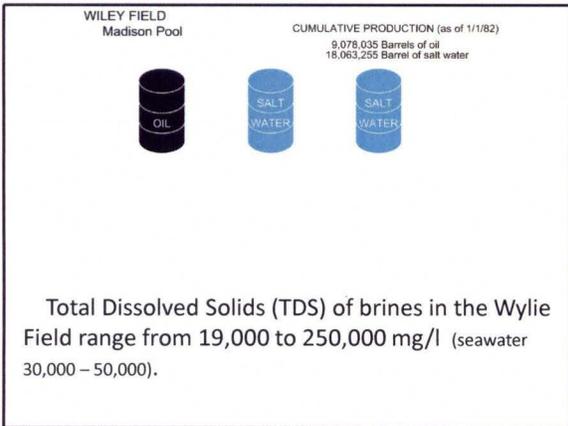


RESERVE PIT STUDY: NORTH-CENTRAL N. DAK.
1985 CONCLUSIONS

- Leachate at Fossum site was detected in an area 100 x 150 feet and to a depth of at least 60 feet around the buried drilling mud.
- Leachate at the Winderl site migrated beyond the 500 foot study area.







BRINE HOLDING PONDS

Operated in North Dakota from 1951-1982.

NDGS personnel began field investigating and condemning brine holding ponds in the 1960s.

The exact number of brine ponds that existed from 1951-1982 is unknown (*est. 2,000 – 3,000*).

BRINE HOLDING PONDS

Dimensions:
45 x 60 ft up to 90 x 180 ft
4 to 9 feet deep

- 1) Unlined
- 2) Clay liner
- 3) Polyethylene liner

WYLIE FIELD STUDY
1984-1985

NDSU Soil Science Department
NDSU Chemistry and Geology Department
NDSU Land Reclamation Research Center
UND Geology Department
ND Mining and Minerals Resources Research Institute
North Dakota Geological Survey

Doll, Wollenhaupt, Carter, Foss, Richardson, Prunty, Sweeney,
Cudworth, Hoag, Kulla, McCarthy, Elless, Steinwand, Keller,
Groenewold, Kehew, Beal, and Murphy.

[440 page report](#)





Drilled in 1959 by Cardinal Petroleum (**Edson Brown #1**). Produced oil from 1959-1970. Converted to a saltwater disposal well by Phillips Petroleum in 1978 (**Stratton SWD #1**).



The site contained two brine holding ponds from 1959 to at least 1970 (with dimensions of 100 x 90 ft and 60 x 100 ft and 5 feet deep). This well produced 178,000 barrels of saltwater.

WYLIE FIELD STUDY
1984-1985

NDSU Chemistry and Geology Department
 NDSU Soil Science Department.

Characterization of Detrimental Effects of Salts and Other Chemical Constituents Carried in Surface and Subsurface Water from Mine and Drilling Fluid Disposal Pits Buried During Oil Development

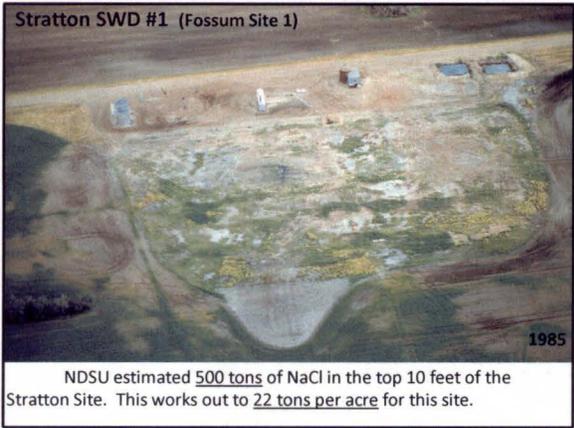
Studied seven sites, Stratton SWD #1 is their F1 Site.
 48 shallow Giddings cores (10-15 feet deep).
 193 saturated paste extract
 80 XRD analyses.

WYLIE FIELD STUDY
 1984-1985

NDSU Land Reclamation Research Center
 Eugene Doll, Nyle Wollenhaupt, Frank Carter
Salt Movement in Buried Brine Disposal Pit Areas as Related to Chemical and Physical Properties of the Soil and Geologic Materials and to the Surrounding Landscape

Studied two sites, Stratton SWD # 1 is their Fossum Site 1.

Electromagnetic soil conductivity meter (EM-38):
 58 stations, 116 readings.
 55 shallow Giddings cores (10-15 feet deep).
 630 saturated paste extract analyses.

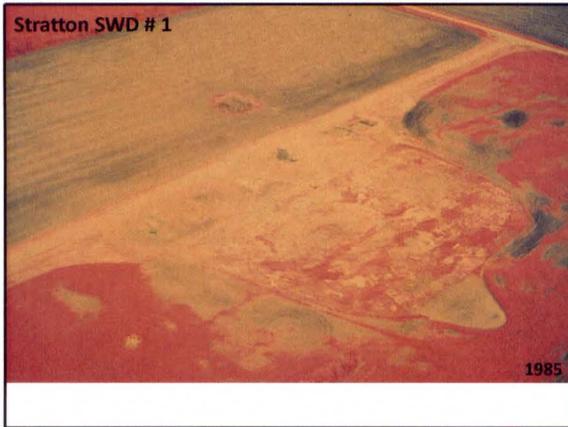


WYLIE FIELD STUDY
 1984-1985

Soil Science Department, NDSU
 John Foss, Jimmy Richardson, Lyle Prunty, Mark Sweeney,
 Doug Cudworth, Brian Hoag

Identification of Salt-Seepage Areas from Oilfield Brine Pits

Analyzed aerial photographs (existing and generated).
 Electromagnetic soil conductivity meter (EM-38).



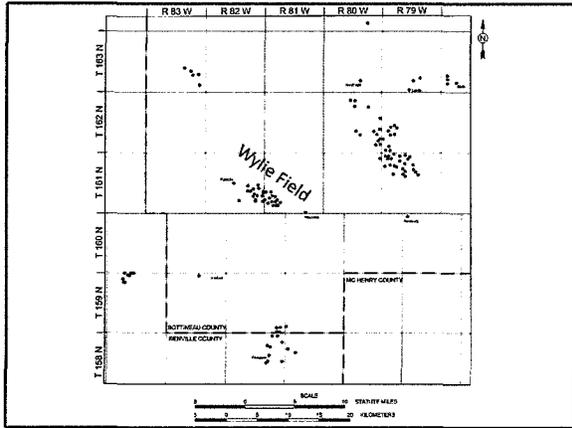


NDSU SOILS DEPT 1984 STUDY

Identified 121 old brine pond sites in Bottineau and Renville Counties.

Estimated the area contaminated by old brine ponds at 1,450 acres (average of 12 acres per site).

Interpreted aerial photographs from various years and scales.



NDSU SOILS DEPT 1984 STUDY
Wylie Field

Studied an area of 15 square miles in Wylie Field and identified 60 old brine pond locations.

Interpreted aerial photographs from various years and scales.

NDSU SOILS DEPT 1984 STUDY
Wylie Field

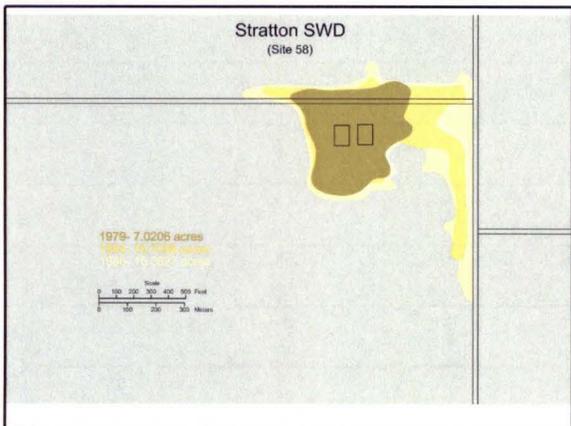
Mapped 23 of the 60 sites.

Salt-impacted area ranged from 0 to 42 acres at each site.

Average impact of 11.5 acres per site.

Total impact of 266 acres.

Electromagnetic soil conductivity meter (EM-38).

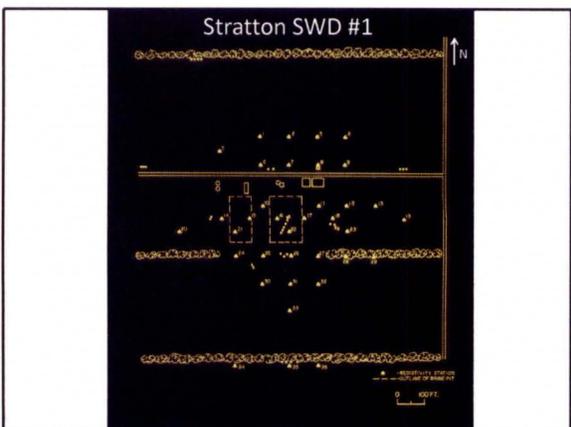


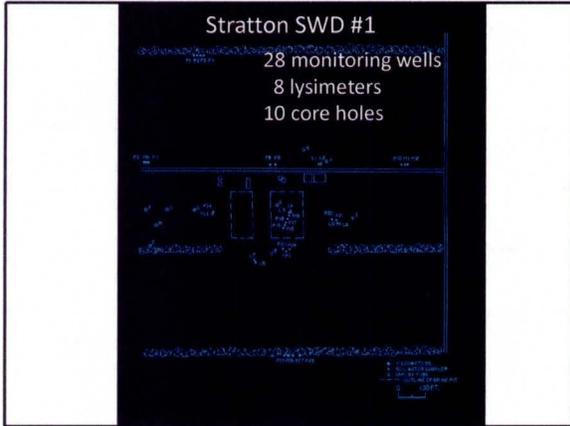
WYLIE FIELD STUDY
1984-1985

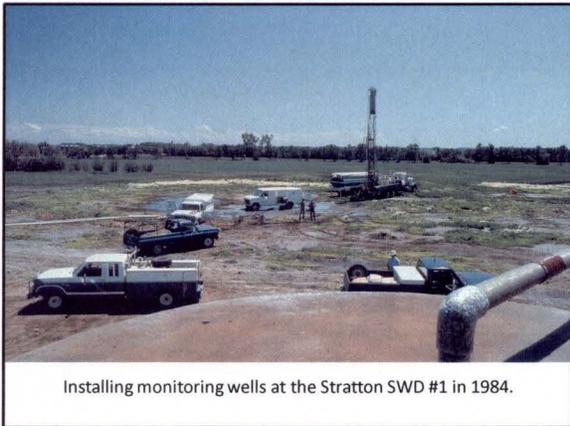
North Dakota Geological Survey
UND Geology Department
ND Mining and Minerals Resources Research Institute
Gerry Groenewold, Alan Kehew, Willie Beal, Ed Murphy

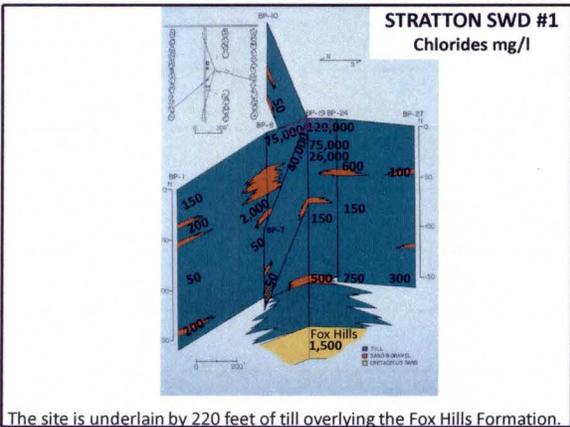
Movement of Leachate From a Buried Oil and Gas Brine-Disposal Pond in the Wylie Field, Bottineau County, ND

Studied only the Stratton SWD #1
28 piezometers (down to 220 feet), 8 lysimeters.
60 water samples.
36 resistivity stations (504 readings).









The site is underlain by 220 feet of till overlying the Fox Hills Formation.

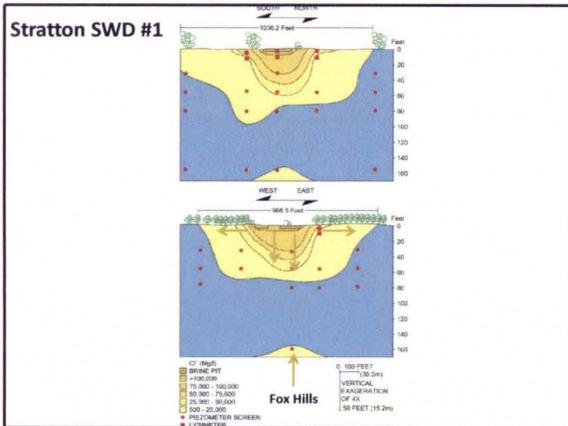
STRATTON SWD #1

A high salt plume extends laterally around the site over an area of 250,000 ft² (about 6 acres).

This plume extends to a depth of more than 80 feet (highest concentrations in top 40 feet).

Brine plume restricted to till and not impacting any useable water supply (ND Health Dept concurred in 2006).

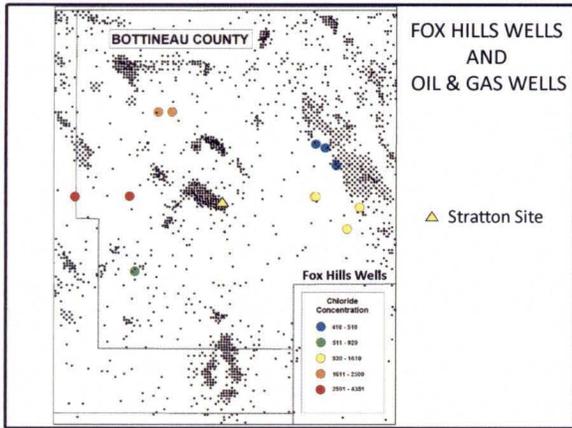
Chloride levels at 160 feet (500 - 750 mg/l) appear to be coming from the underlying Fox Hills Formation.



CHLORIDE LEVELS IN THE FOX HILLS FORMATION

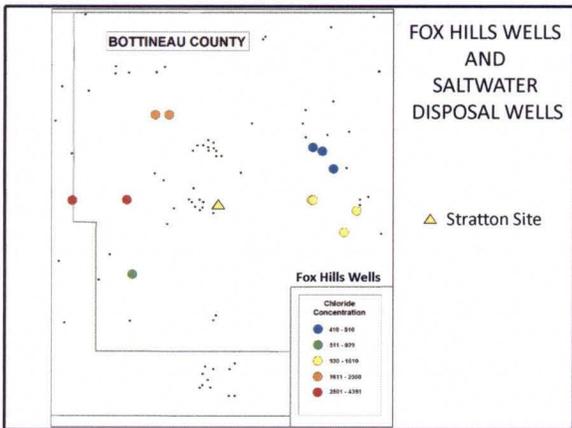
County	Average Chloride Concentration (mg/l)	Number of Water Samples	Number of Wells
Billings	47	43	29
McKenzie	170	34	NA
Mountrail	265	1	1
Williams	491	7	4
Ward	NA	0	0
Divide	1220	7	3
Burke	NA	0	0
Renville	4351	7	1
West Bottineau	1514	11	11
McHenry	654	41	24
East Bottineau	192	8	8
Rolette	282	4	1

Kimberly Fischer, NDSWC, 2014



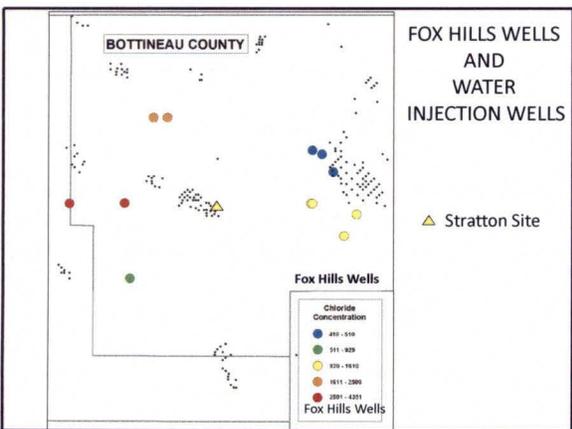
FOX HILLS WELLS AND OIL & GAS WELLS

△ Stratton Site



FOX HILLS WELLS AND SALTWATER DISPOSAL WELLS

△ Stratton Site



FOX HILLS WELLS AND WATER INJECTION WELLS

△ Stratton Site

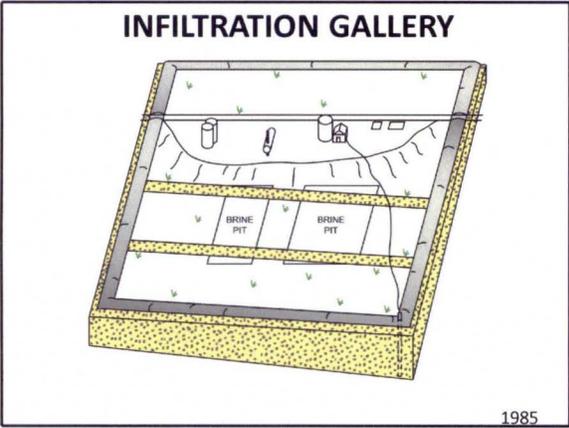
RECOMMENDED REMEDIATION METHODS
1985

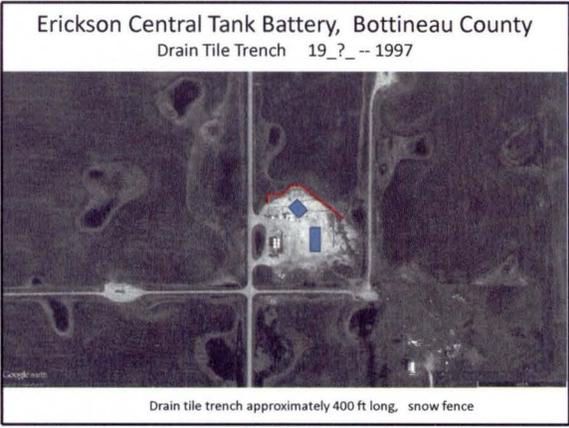
PUMPING WELLS
Hydraulic conductivity of the till is too low to be effective.
Expensive.

IMPERMEABLE MEMBRANE
Would minimize the spread of brine in the unsaturated zone.
Bentonite.
Would not be a long-term solution.

MOUNDING/CAPPING THE SITE
Would reduce the generation of brine leachate from overland flow.
Bentonite and fill.
Would not be a long-term solution.

INFILTRATION GALLERY (Gravel-filled ditch)
Would minimize the spread of brine in the unsaturated zone.
Would be a long-term solution.

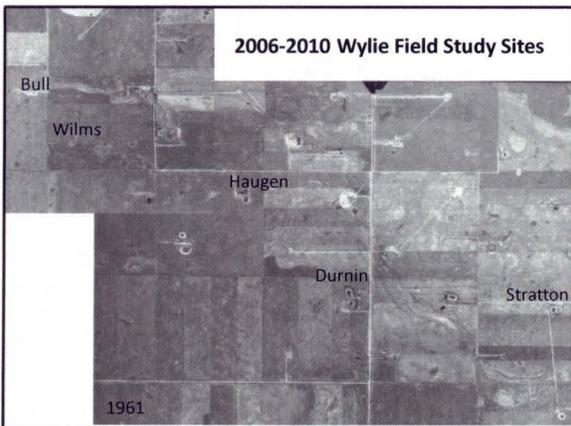






ATTEMPTS TO CLEAN UP OLD BRINE PONDS IN THE WYLIE FIELD
2006 – 2010

Sites
Stratton D01 (Stratton SWD #1)
Bull B1R
Wilms A D01
Haugen B1
Durnin A & D01



**ATTEMPTS TO CLEAN UP OLD BRINE PONDS
IN THE WYLIE FIELD
2006 – 2010**

Soil Parameter Monitoring
Sediment samples from 0-1 feet and 1-2 feet.

Groundwater Monitoring
Durnin Site Three, 15 ft deep monitoring well.
Stratton Site Three, 15 ft deep monitoring well.

Soil Amendment Application
Gypsum, fertilizer, manure, straw application-- lightly tilled.

Water Application
Three times per week at each site due to drought conditions.

Geophysical Survey
Conductivity and resistivity surveys at the Durnin site.

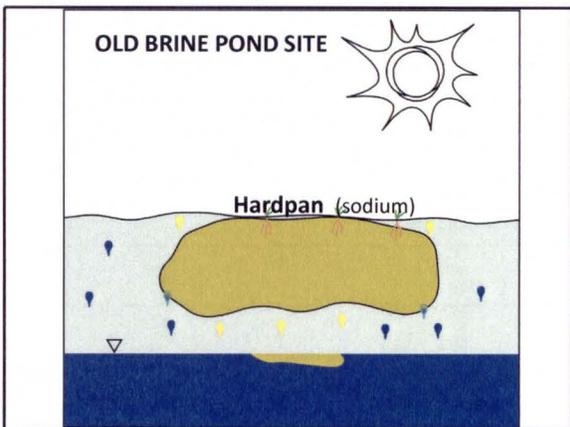
**ATTEMPTS TO CLEAN UP OLD BRINE PONDS
IN THE WYLIE FIELD
2006 – 2010 (50 – 80% reduction)**

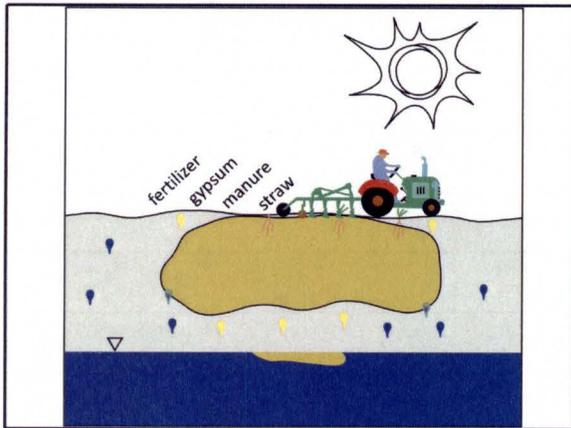
Stratton SWD #1 Site
Chloride levels exhibited a decreasing trend in soils.
Chloride levels did not decrease in groundwater.
Area of surface scaring reduced from 14 acres to 3 acres.

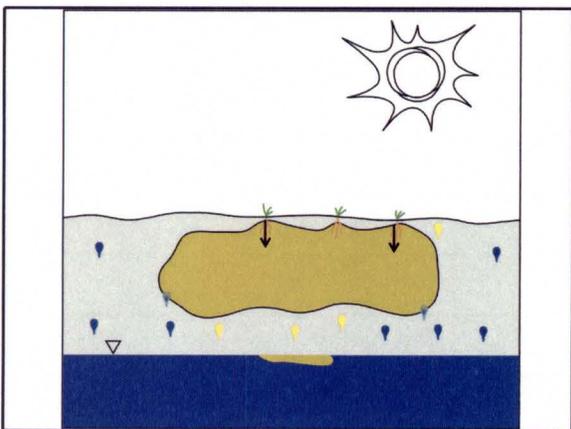
Bull Site
Chloride levels exhibited a decreasing trend in soils.
Area of surface scaring reduced from 3.5 acres to 1 acre.

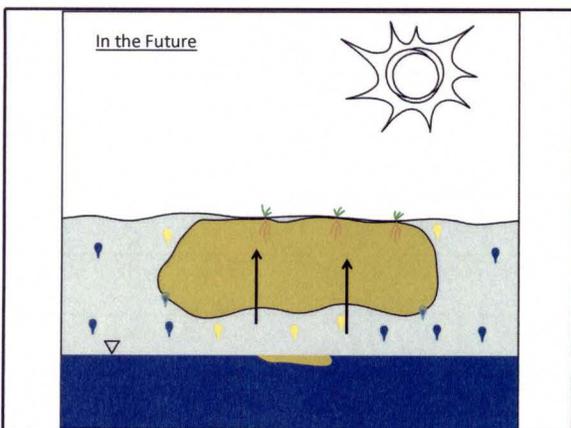
Wilms Site
Chloride levels exhibited a decreasing trend in soils.
Area of surface scaring reduced from 1.5 acres to 0.5 acres.

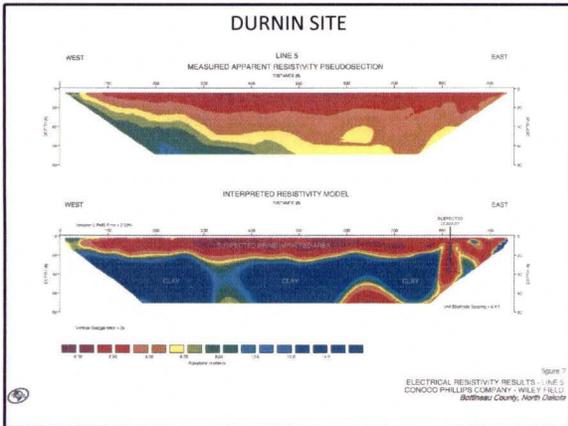
Haugen Site
Chloride levels exhibited a decreasing trend in soils.
Area of surface scaring reduced from 3.5 acres to 1.75 acres.











**REJECTED REMEDIATION METHODS
IN THE WYLIE FIELD
2006 – 2010**

REMOVE IMPACTED SEDIMENT

Evaluated removing salt impacted sediment across six acres to a depth of four feet (38,000 cubic yards).

Install a 30 mil plastic liner.

Replace with clean fill.

Risky due to likelihood that salt would find its way into the clean fill.

**REJECTED REMEDIATION METHODS
IN THE WYLIE FIELD
2006 – 2010**

DRAIN TILE SYSTEM

Evaluated installing a drain tile system down to a depth of 20 feet to dewater and flush the system.

Potential for no viable disposal method.

Believe the groundwater impacted area extends beyond site and would continue to migrate into this site into the future.

ADVANCES IN RESISTIVITY

Taken at depth of interest with vertical electrodes.

Surveys now use AC current verses DC current.

Measure actual soil /ground water resistivity vs. "apparent" resistivity.

Bulk soil measurements can be taken around an electrode, in planes between two electrodes.

Advances in statistical computer modeling can further increase the resolution of the electric data for 2-D or 3-D display.

Hell Creek Environmental Services

ADVANCES IN DRAIN TILE AND IRRIGATION FLUID CHEMISTRY



Agassiz Drain Tile

INFILTRATION GALLERY

