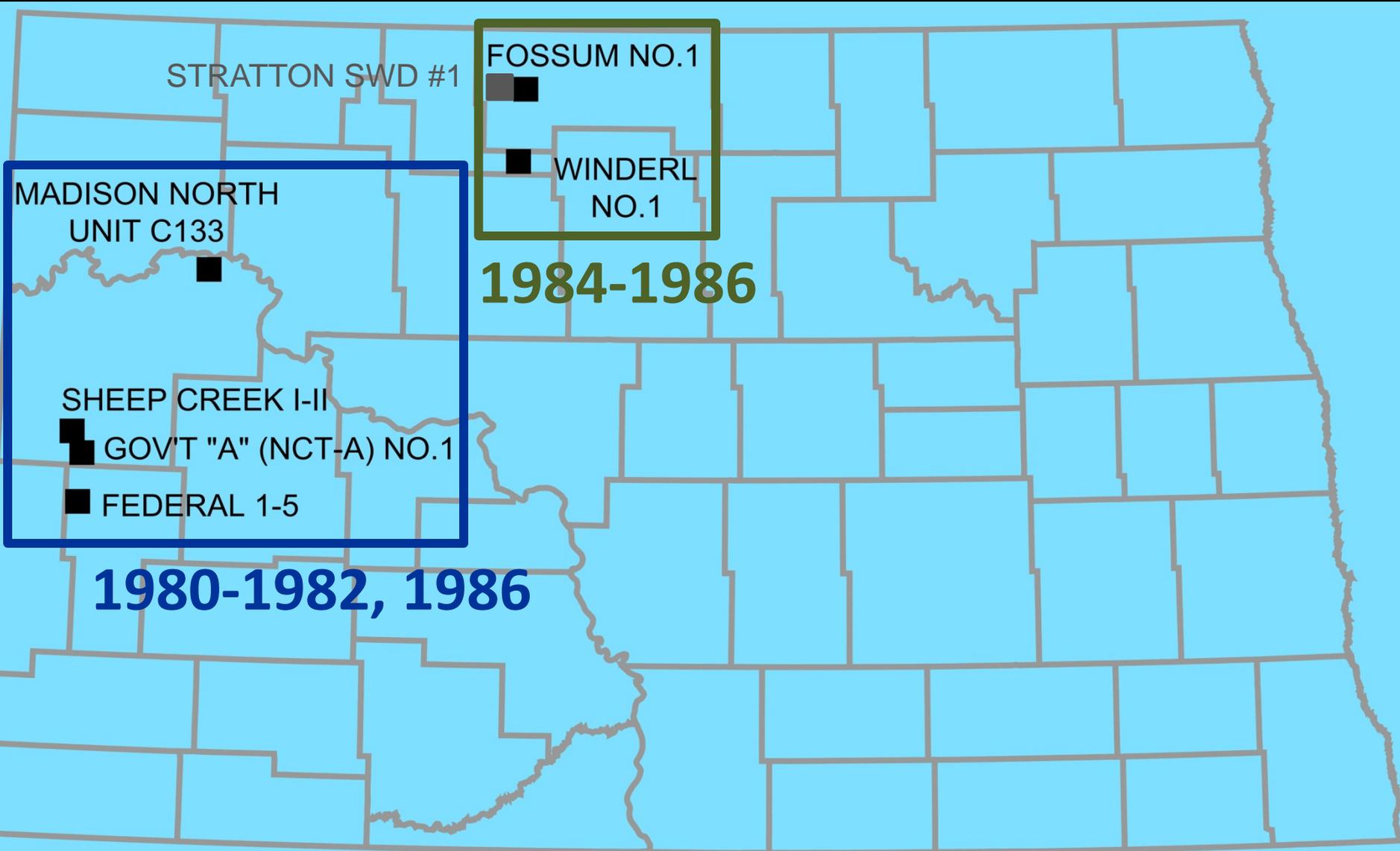


Reserve Pit and Brine Pond Studies in North Dakota

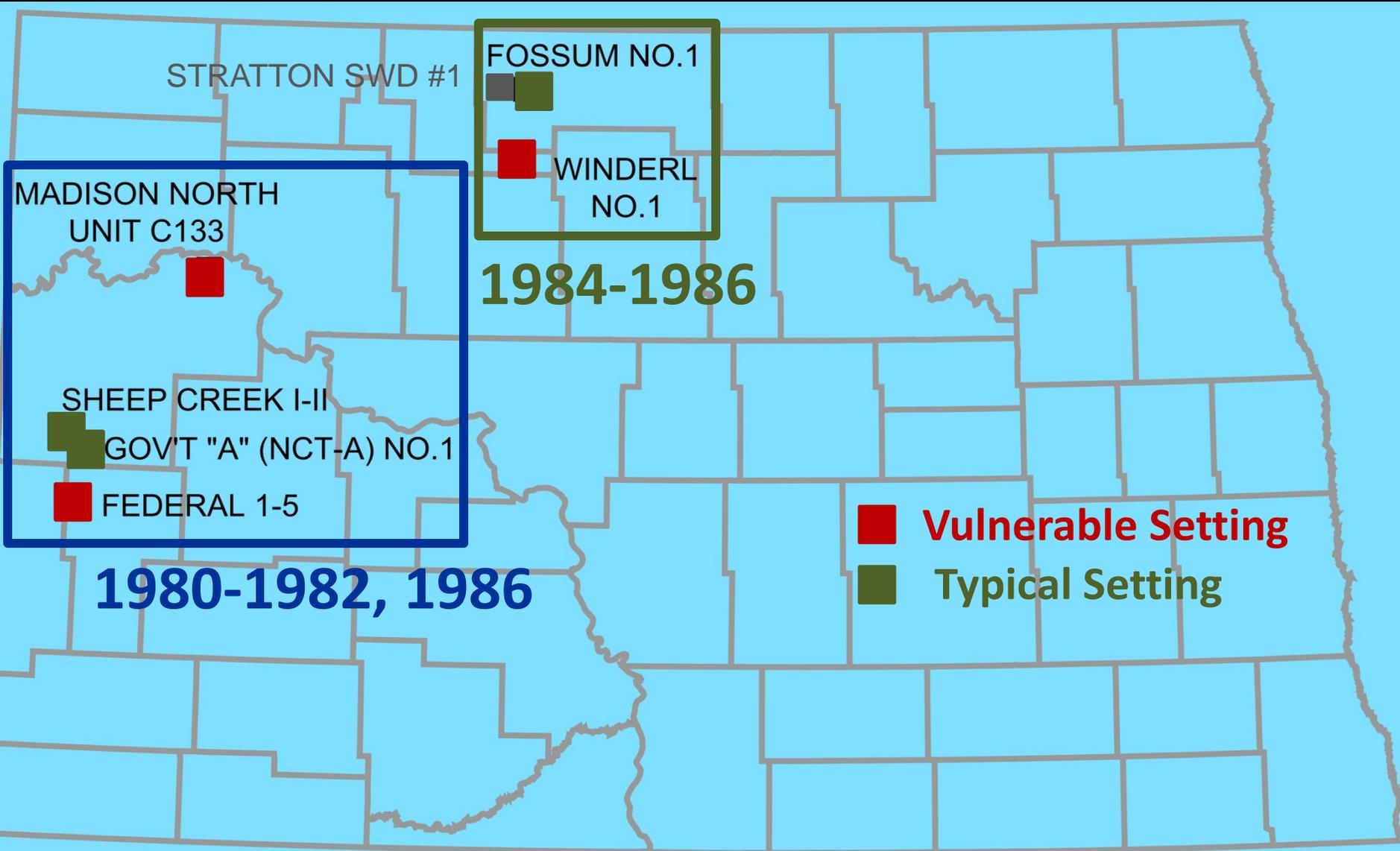
Presented to the
Energy Development and Transmission Committee
Senator Rich Wardner, Chair
Minot, ND
April 8, 2014

Ed Murphy
North Dakota Geological Survey
Geologic Investigations No. 175

RESERVE PIT & BRINE POND STUDIES



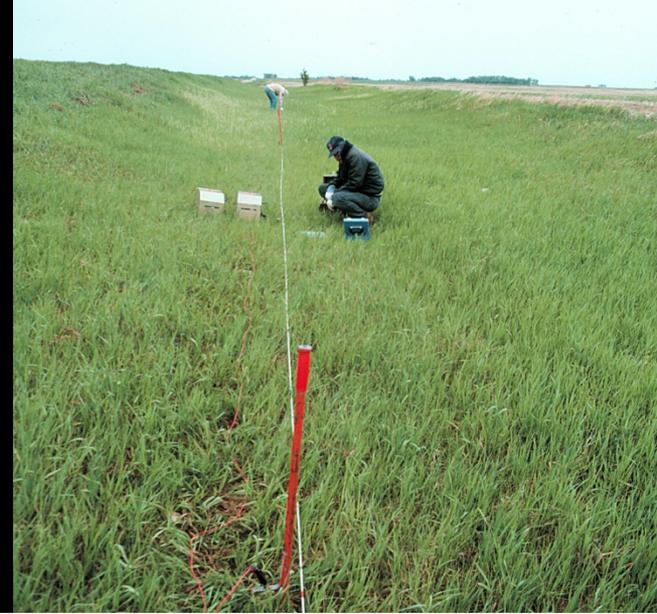
RESERVE PIT & BRINE POND STUDIES



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).

EARTH RESISTIVITY SURVEY



SMALL ELECTRODE
SPACING, A'

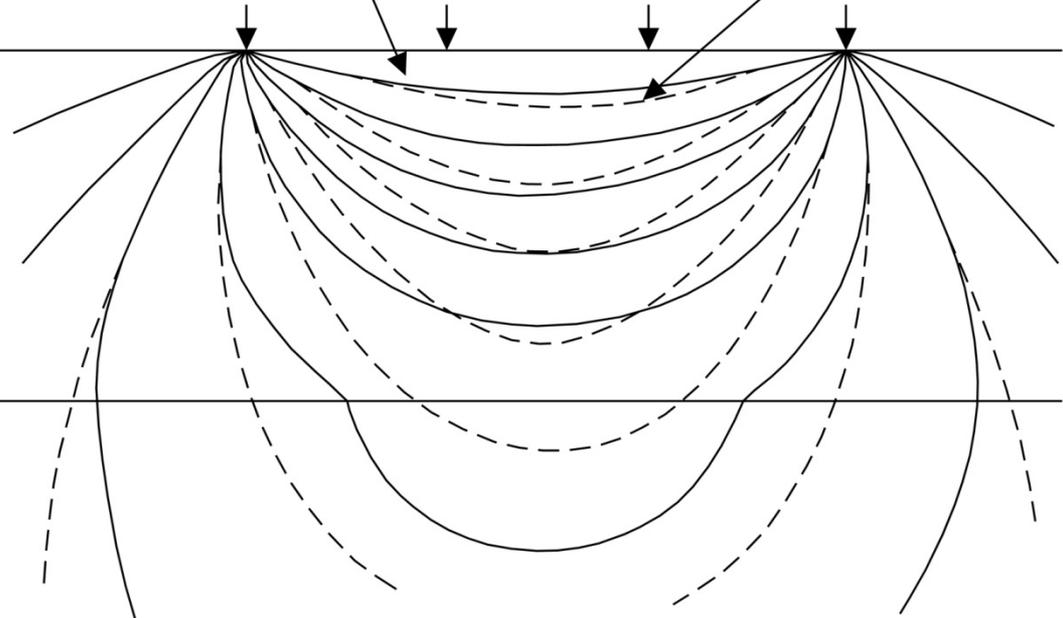
LARGE ELECTRODE
SPACING, A''

ACTUAL CURRENT FLOW

NORMAL LINES OF
CURRENT FLOW

ρ_1 , LOW

ρ_2 , HIGH



MONITORING WELL (PIEZOMETER) INSTALLATION



LYSIMETER (soil water sampler) INSTALLATION





Reserve/Mud Pits

Dimensions:

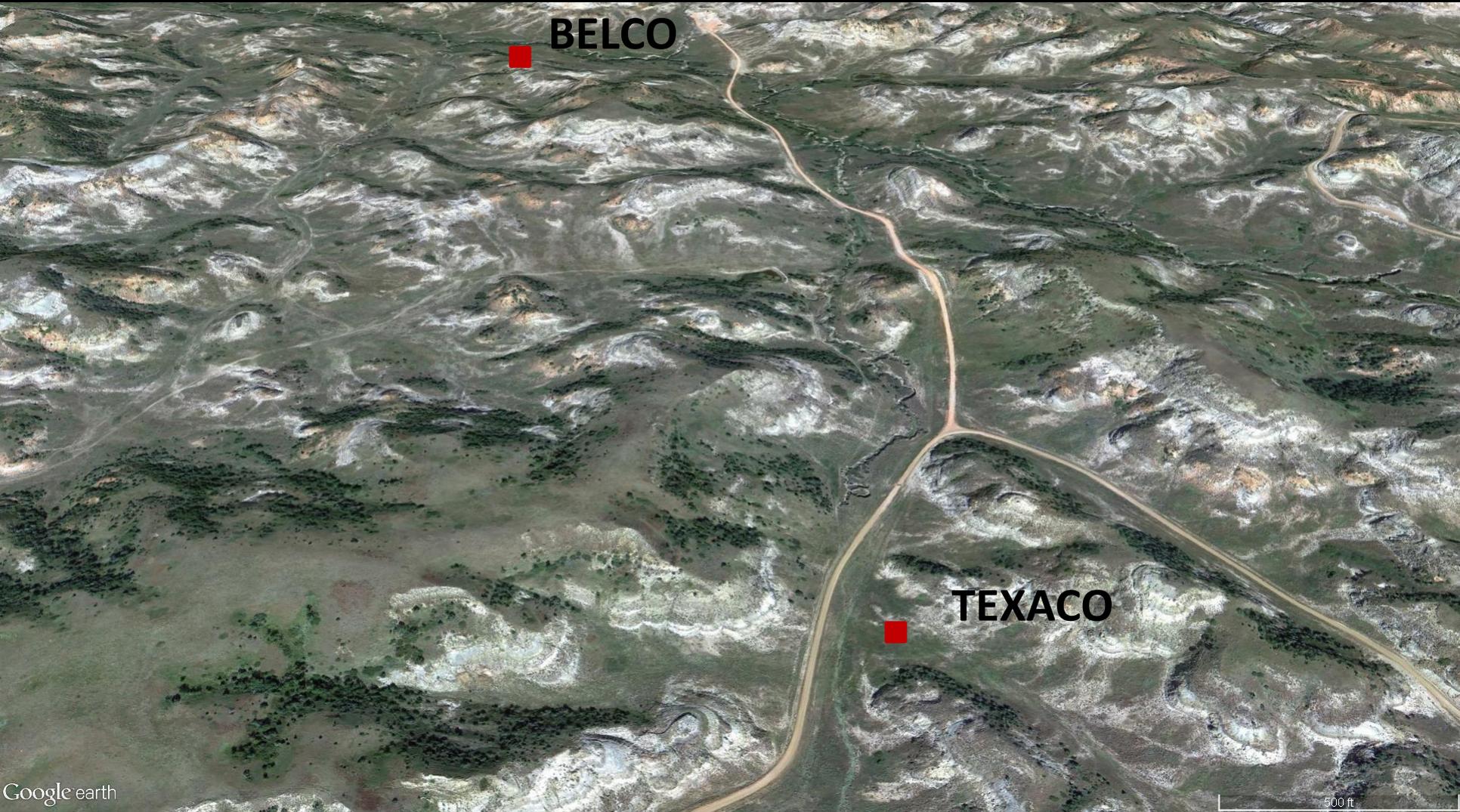
150 feet x 60 feet

10 feet deep

30,000 - 50,000 cubic feet
of waste



1980



TEXACO GOV'T A (NCT-1) #1

drilled in 1960

BELCO PETROLEUM SHEEP CREEK BN 1-11

drilled in 1977



1980

TEXACO GOV'T A (NCT-1) #1 drilled in 1960



Google earth

500 ft

TEXACO GOV'T A (NCT-1) #1

2011

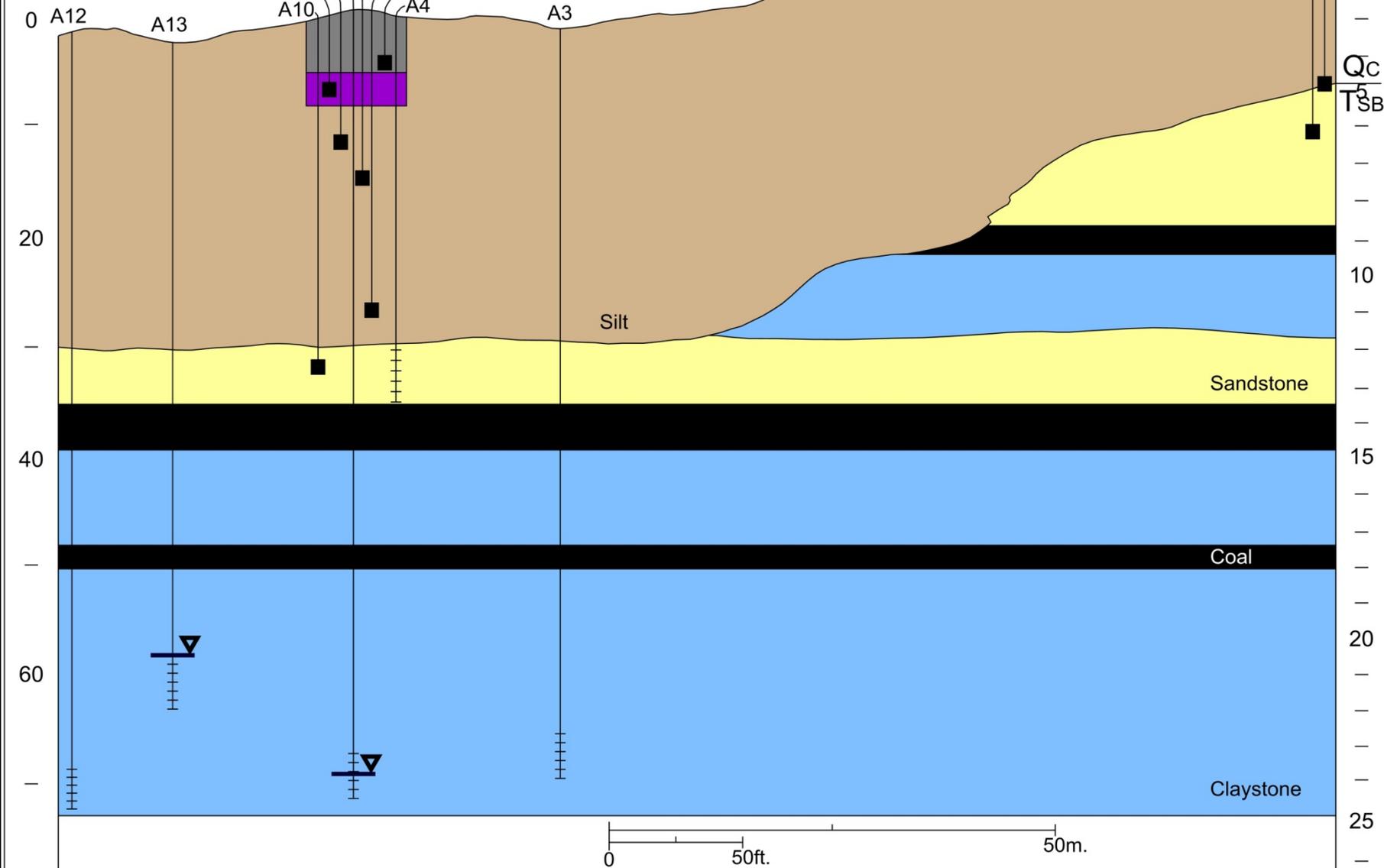
SOUTHWEST

NORTHEAST

TEXACO GOV'T A (NCT-1) #1

FEET

METRES



SOUTHWEST

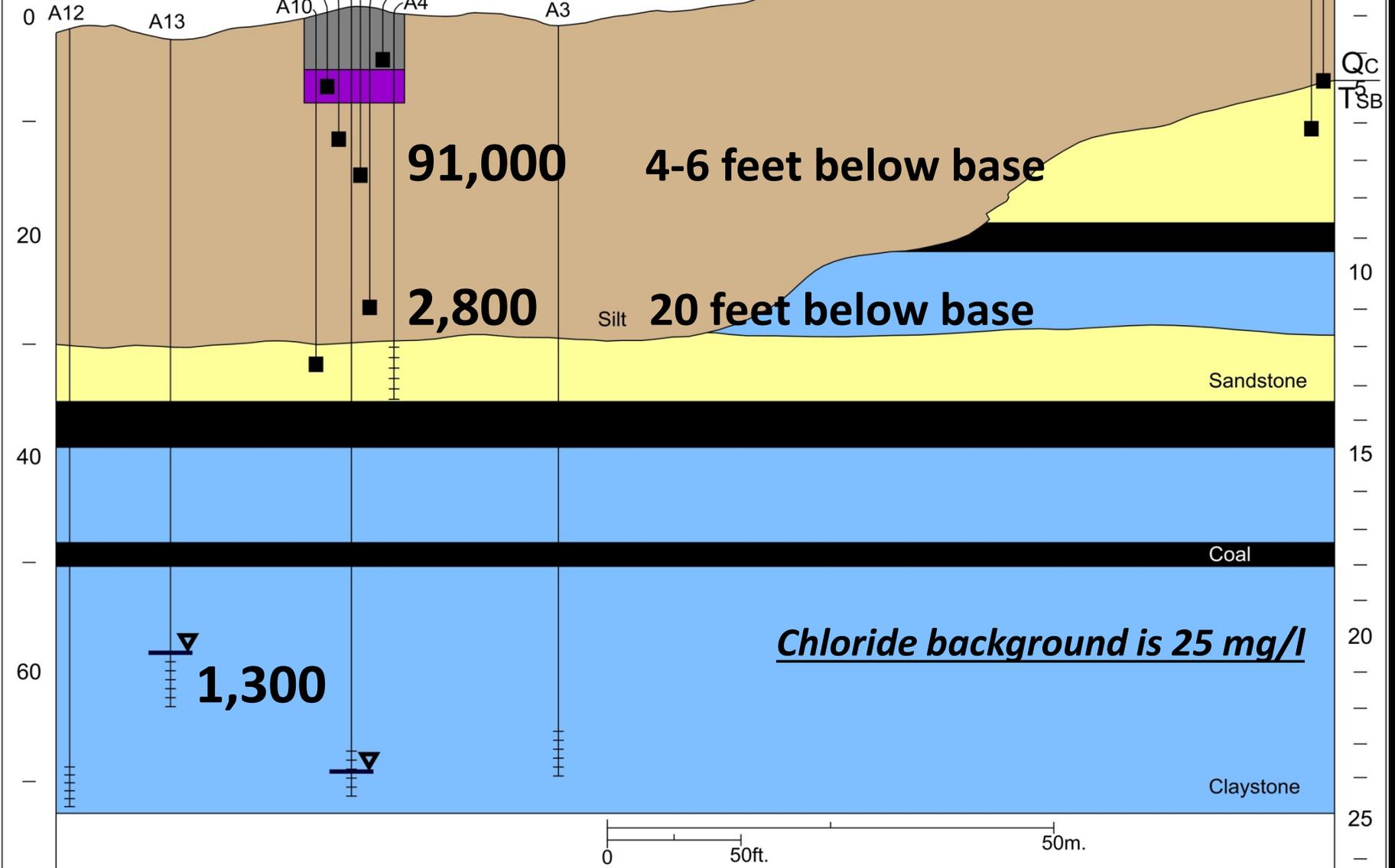
NORTHEAST

TEXACO GOV'T A (NCT-1) #1

Chloride (mg/l)

FEET

METRES





1980

BELCO PETROLEUM SHEEP CREEK BN 1-11 drilled in 1977

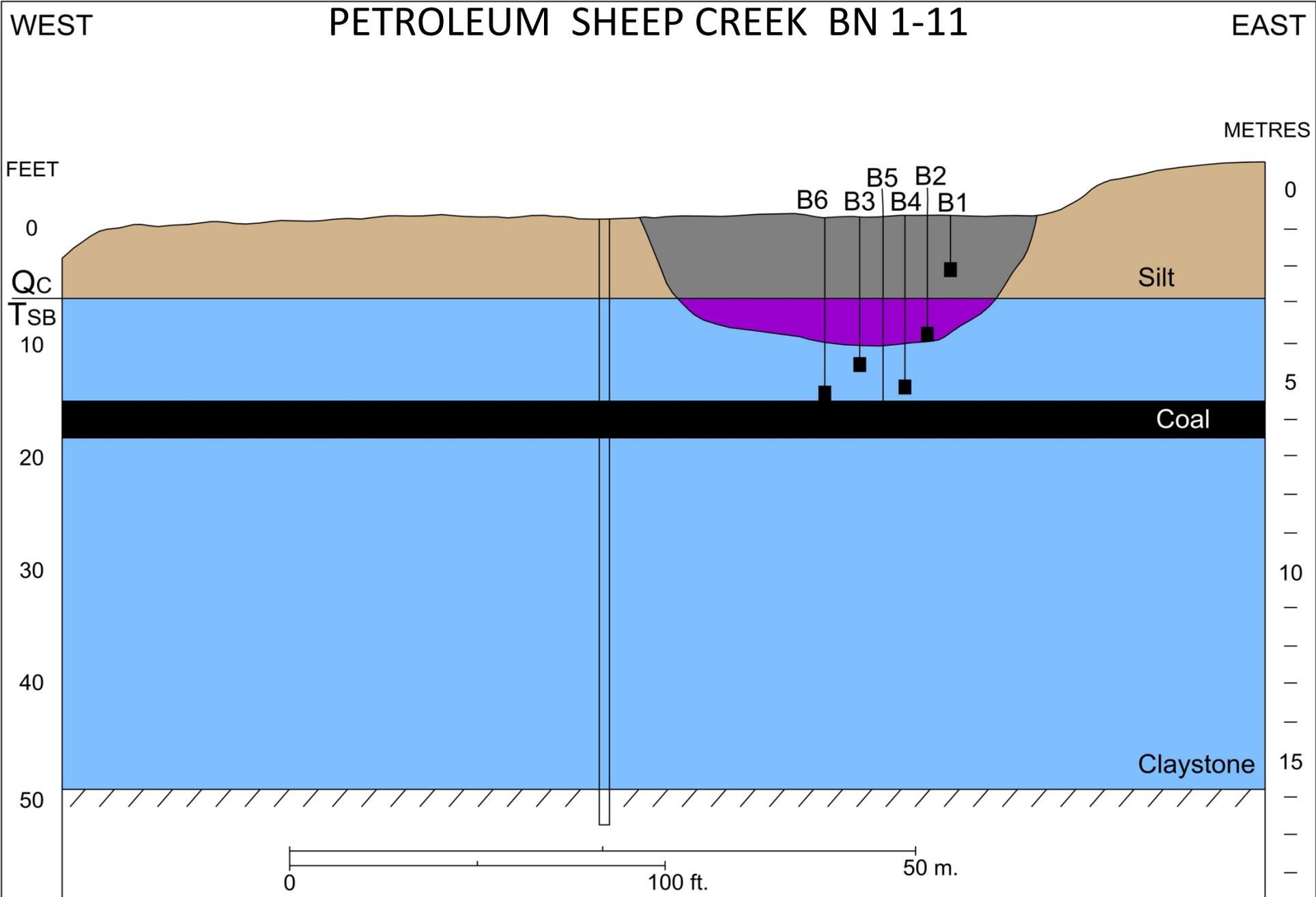


Google earth

100 ft

BELCO PETROLEUM SHEEP CREEK BN 1-11

2011





1981

TEXACO CHARLSON MADISON NORTH UNIT C133

drilled in 1955

TEXACO CHARLSON MADISON NORTH UNIT C133



2010

Produced oil 1955-1966.

No brine pond in 1959 aerial photograph.

Saltwater injection well 1966 – 1982.

Plugged and abandoned in 1984.

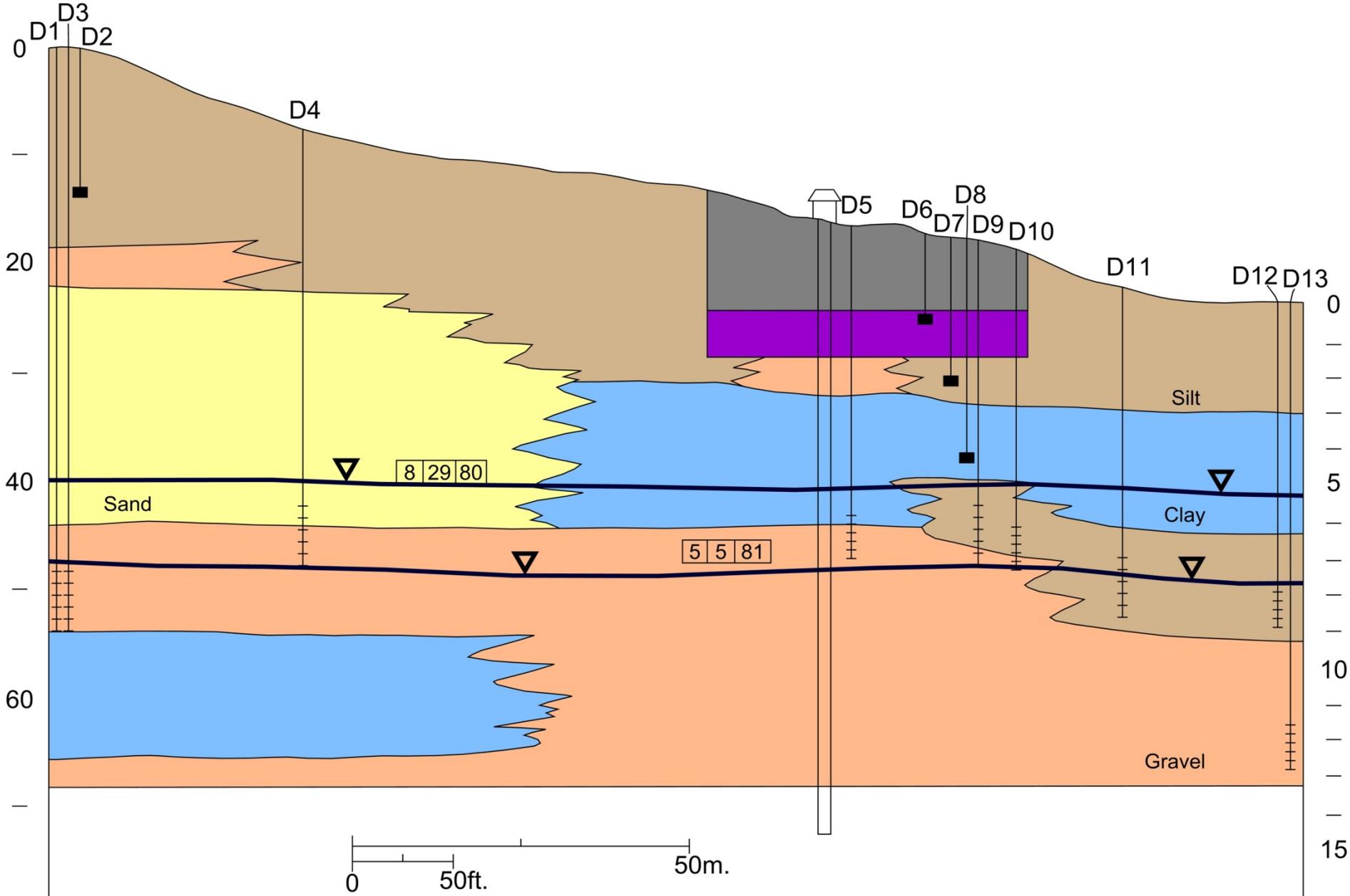
SOUTH

TEXACO CHARLSON MADISON NORTH UNIT #C133

NORTH

FEET

METRES



SOUTH

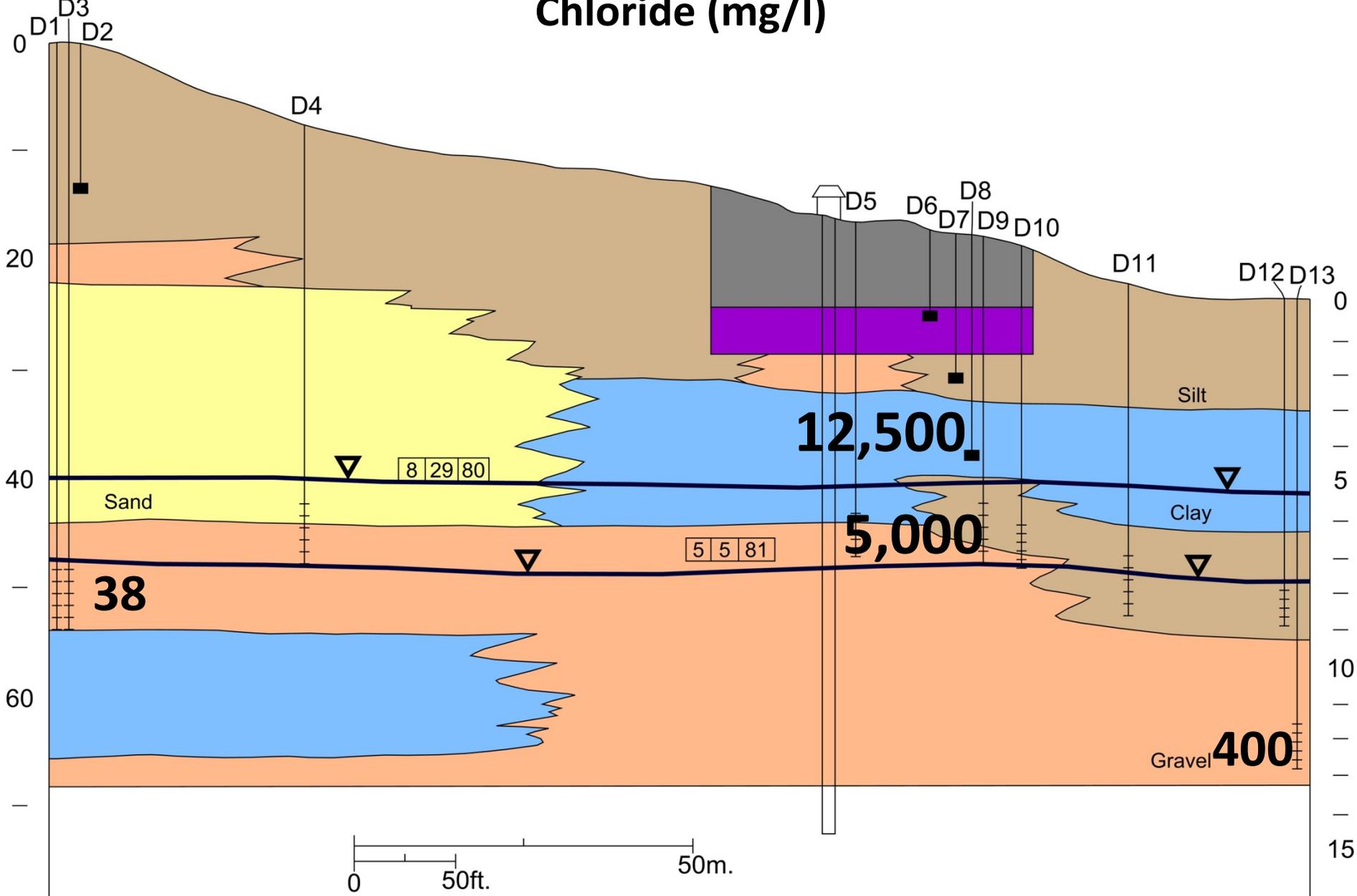
NORTH

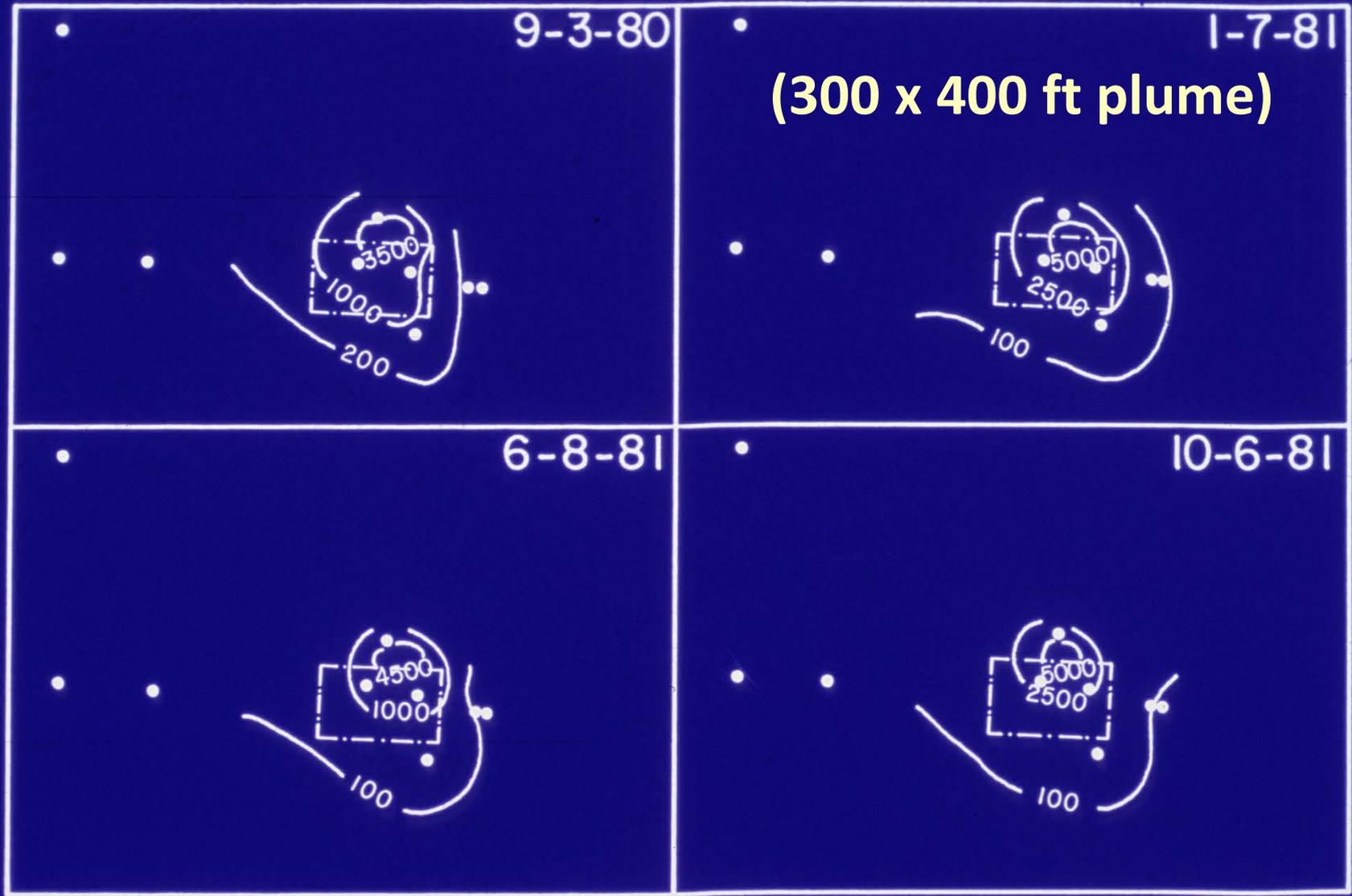
TEXACO CHARLSON MADISON NORTH UNIT #C133

Chloride (mg/l)

FEET

METRES





(300 x 400 ft plume)



CHLORIDE



TEXACO CHARLSON MADISON NORTH UNIT #C133



1980

APACHE FEDERAL 1-5

drilled in 1979



1981

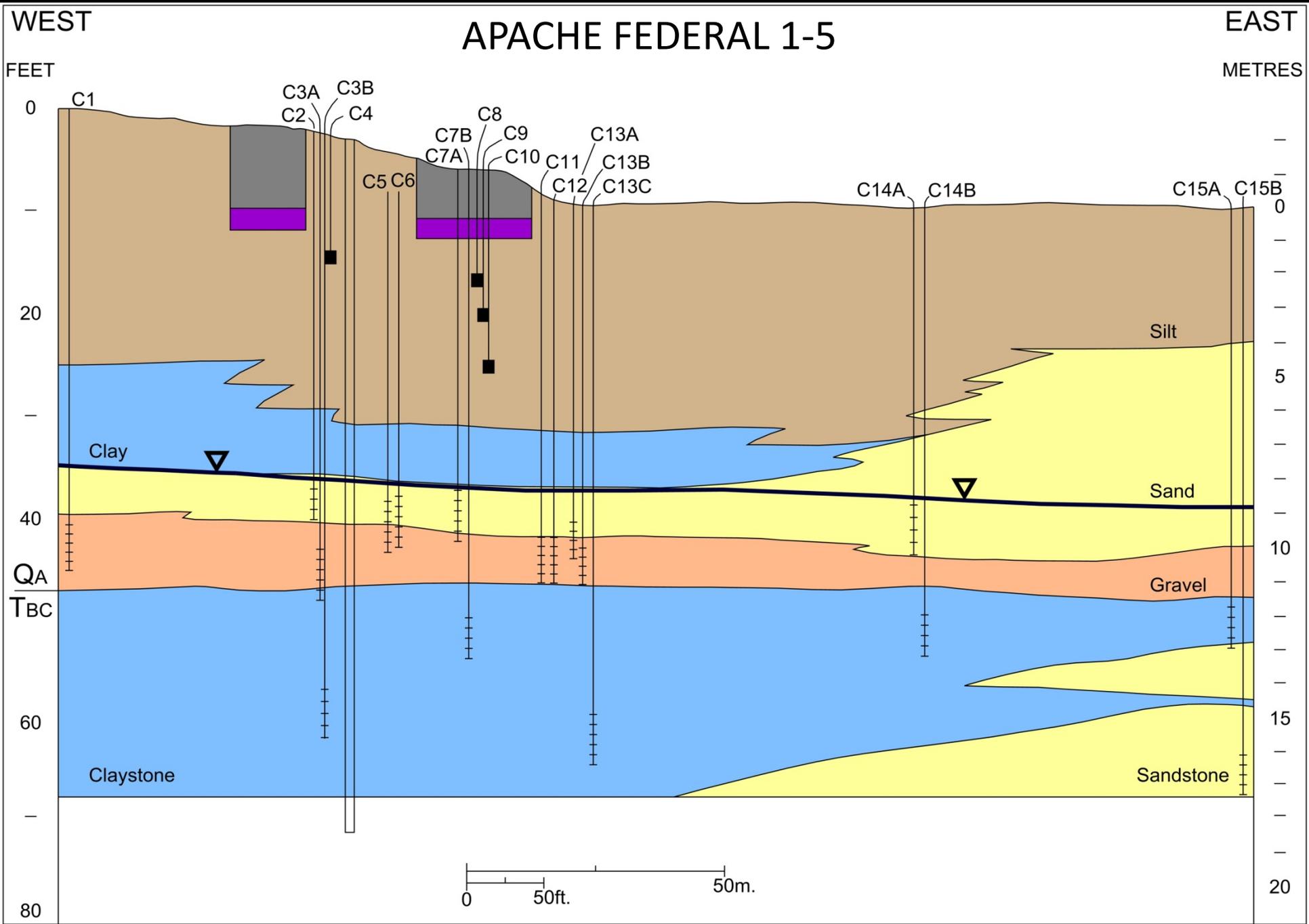
APACHE FEDERAL 1-5 drilled in 1981

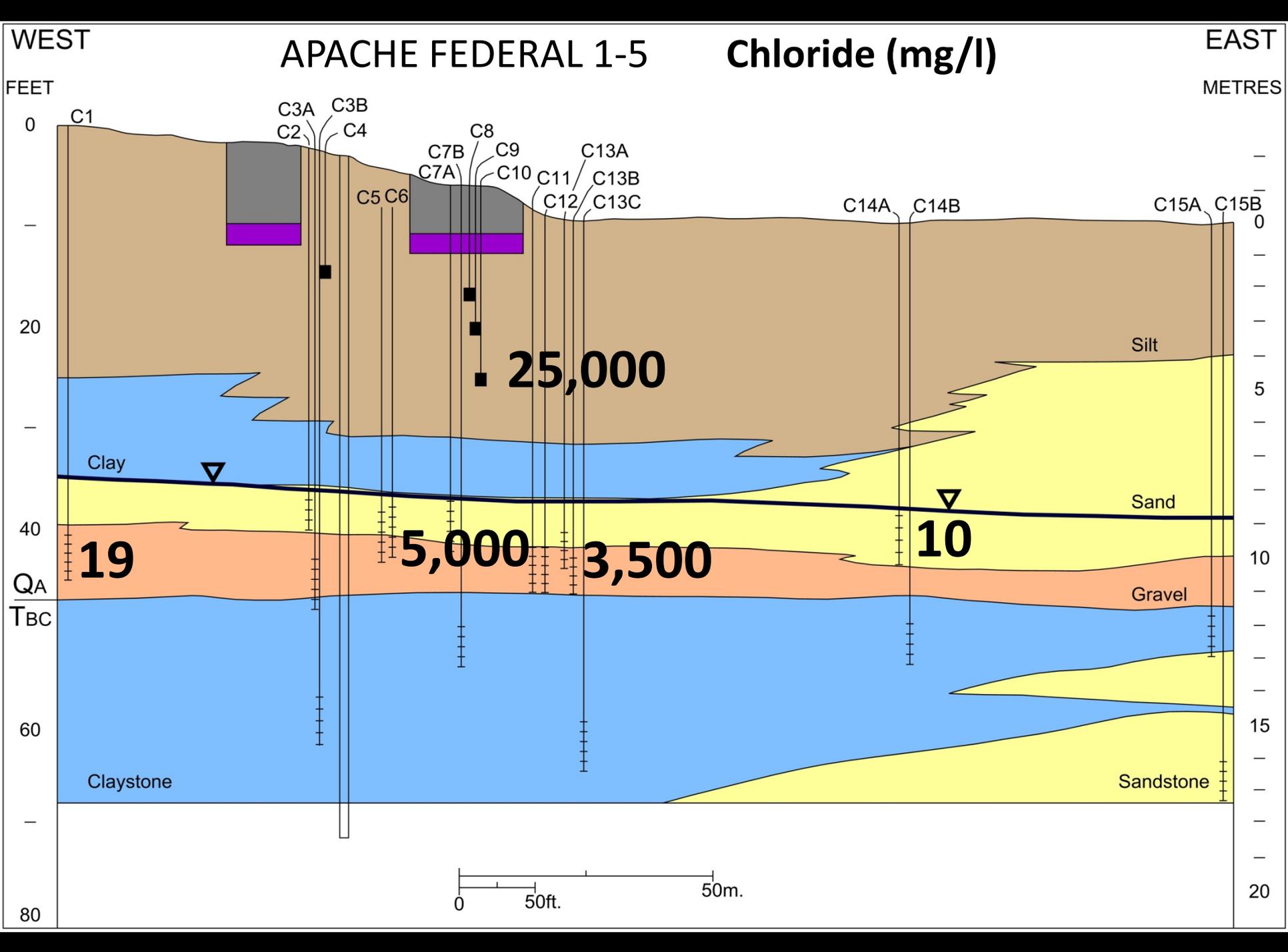


Apache Federal 1-5
Produced oil from 1981 – 1984.
Plugged and abandoned in 1984.



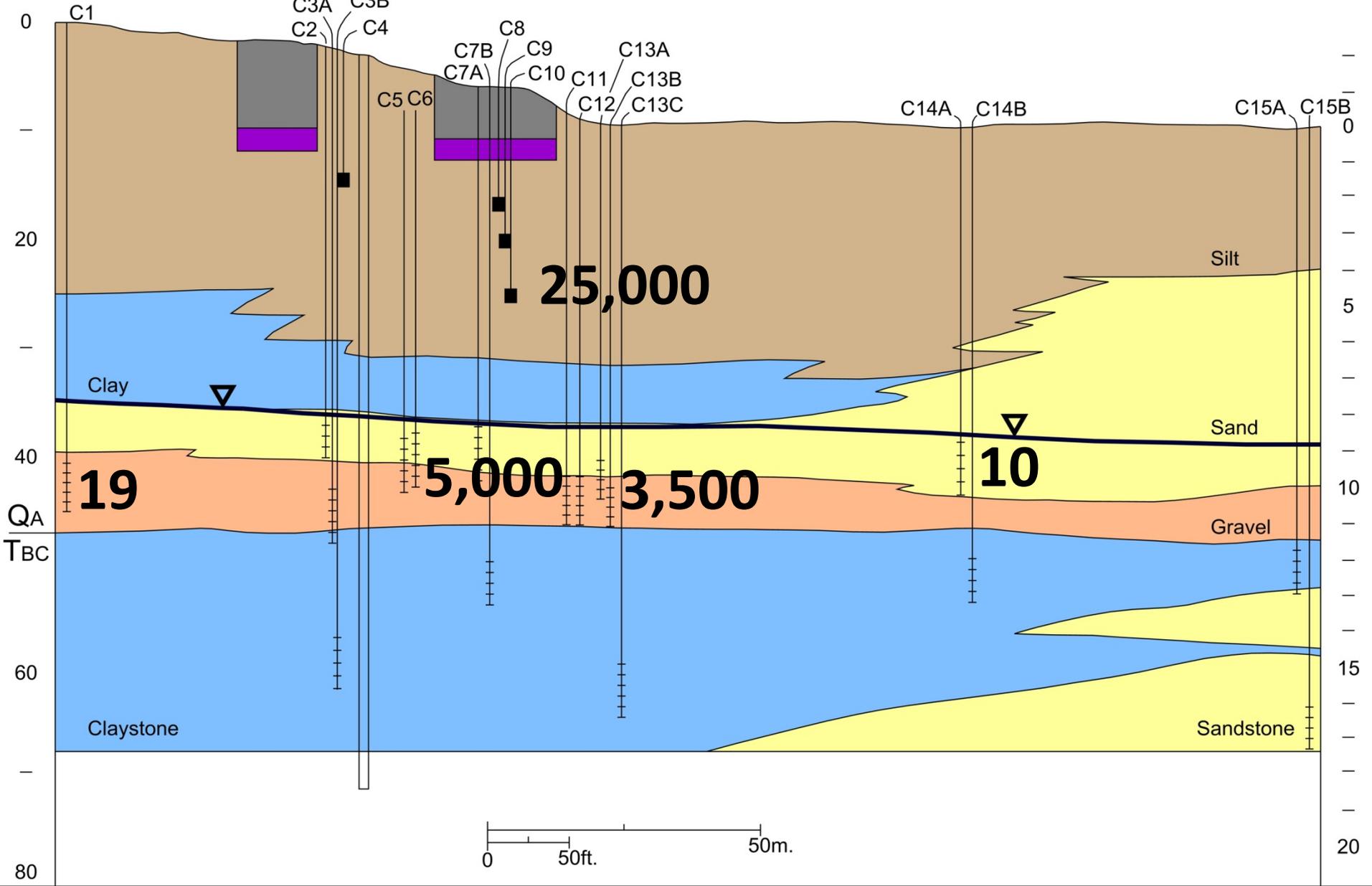
APACHE FEDERAL 1-5
Installing monitoring wells in 1981.





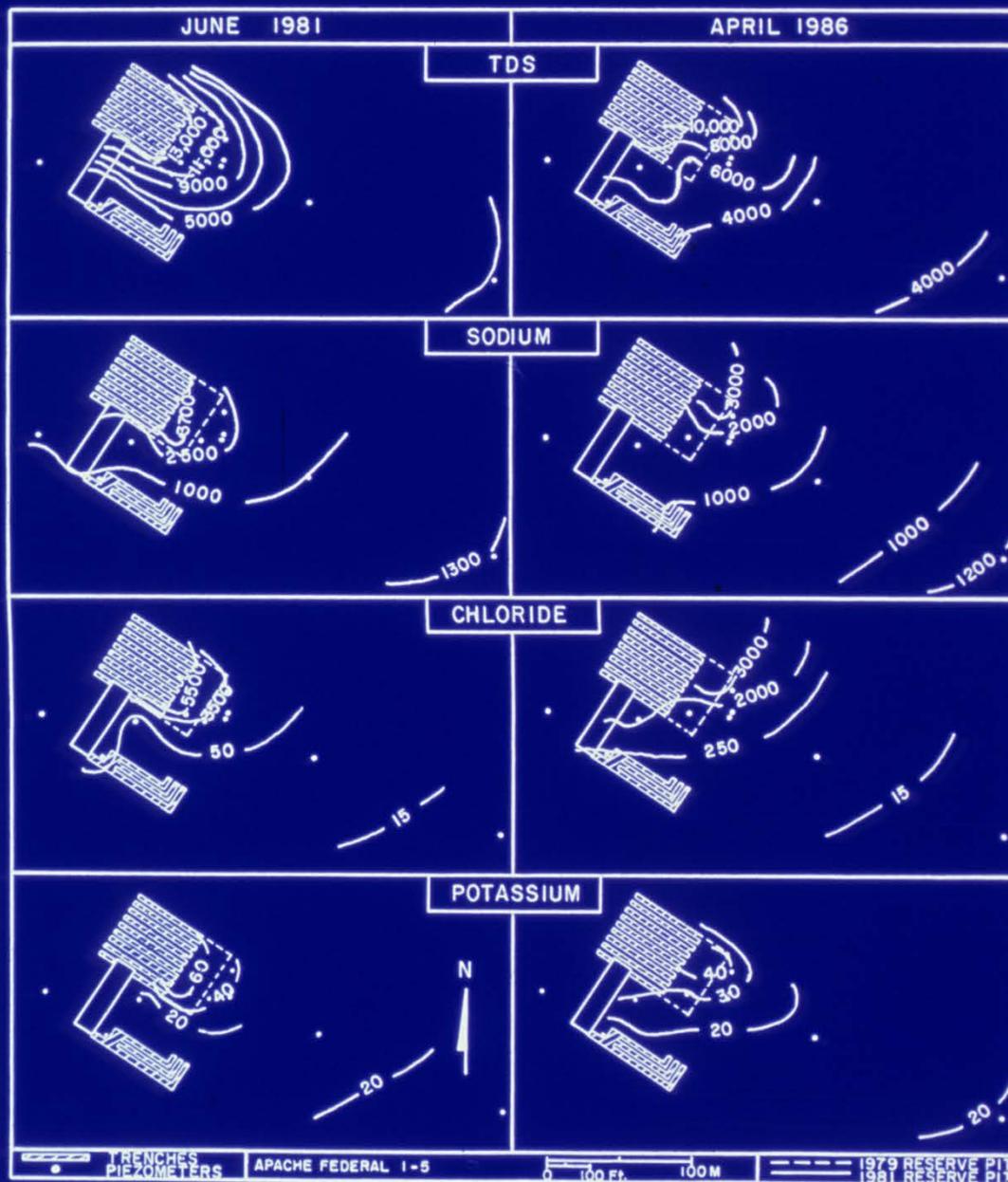
WEST APACHE FEDERAL 1-5 Chloride (mg/l) EAST

FEET METRES



0 50ft. 50m. 0

APACHE FEDERAL 1-5



**Plume is
250 x 250 ft**

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.

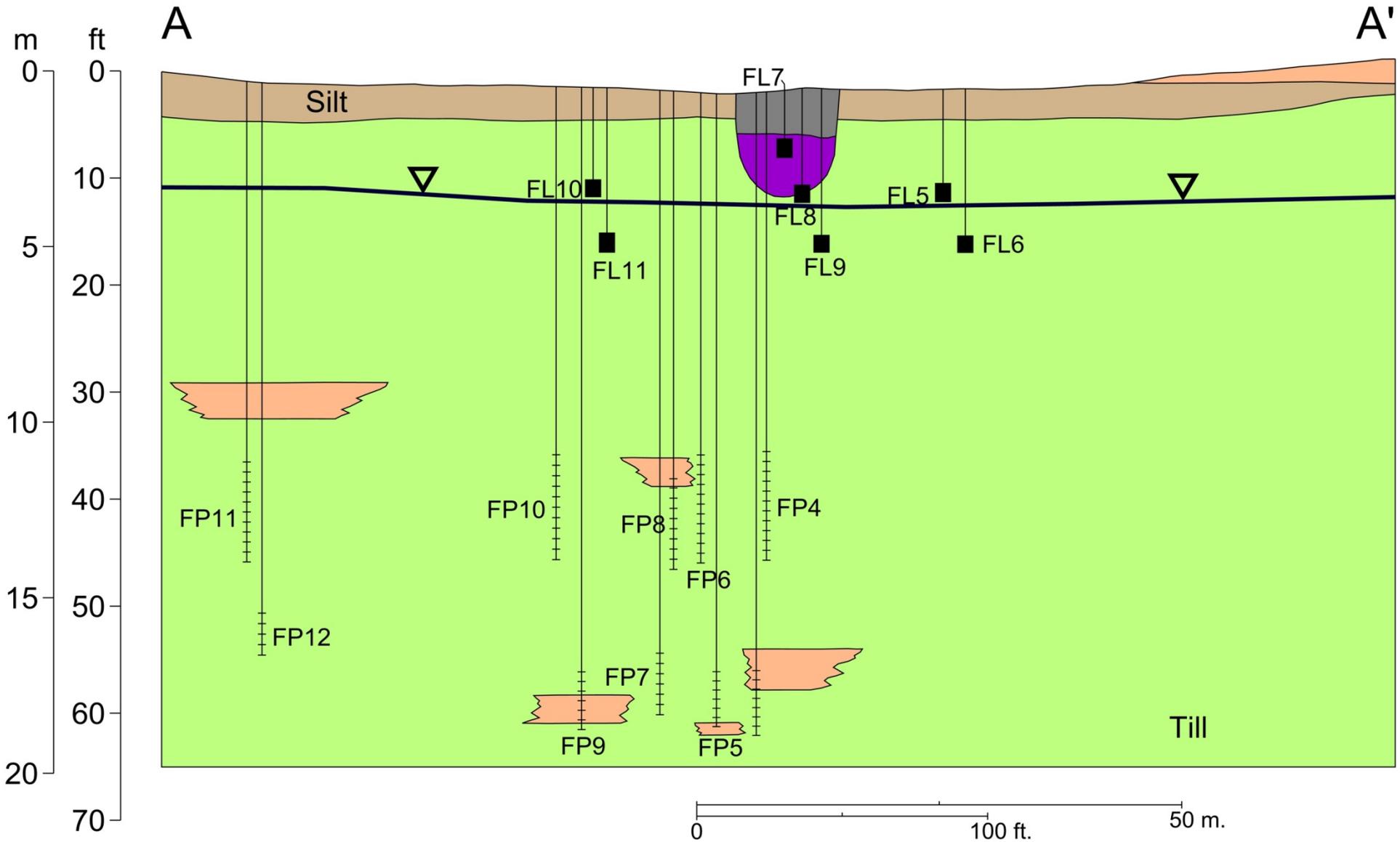


Fossum Federal # 4 drilled in 1978.
Producing oil 1978 – to the present.

South

North

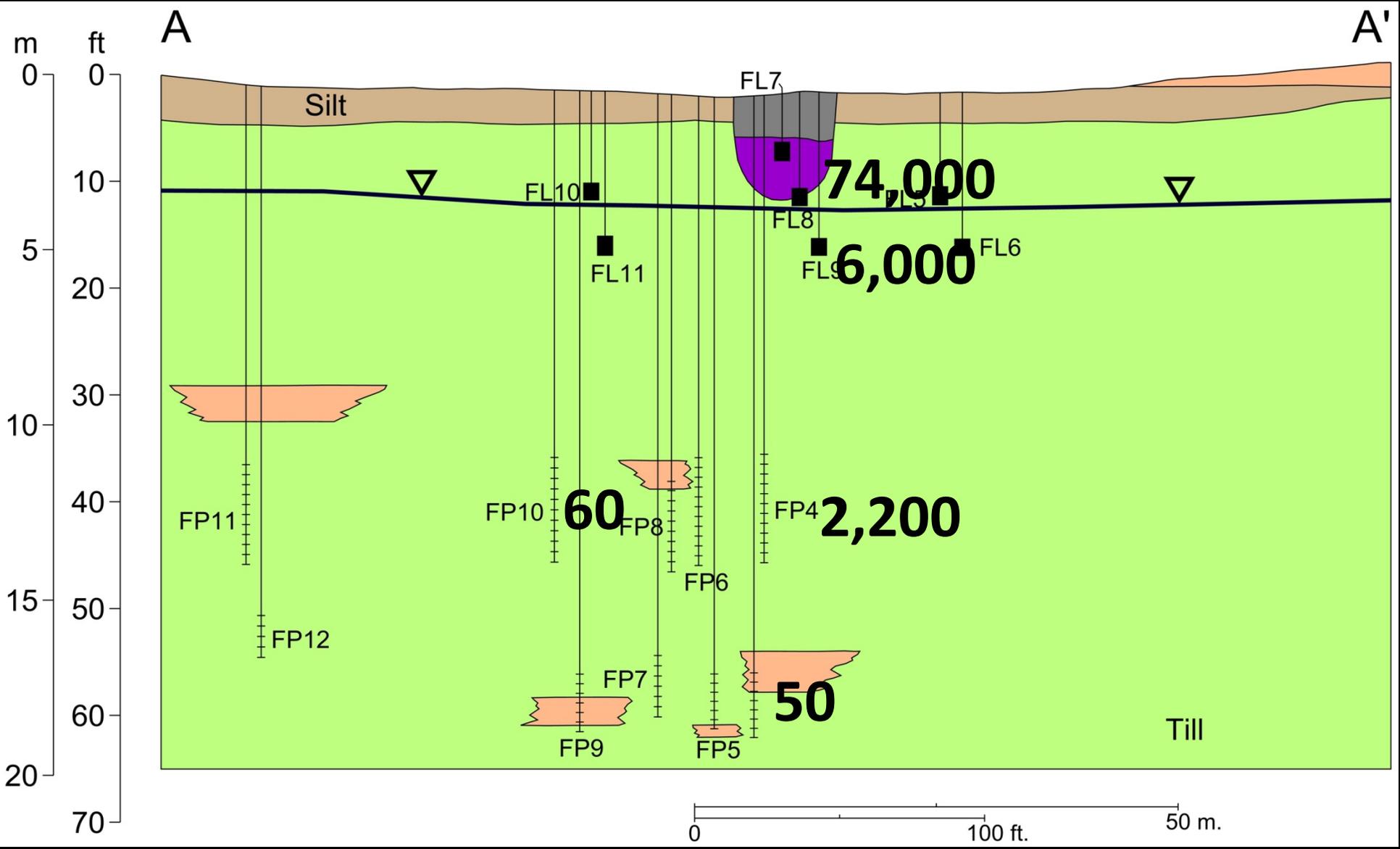
Fossum Federal # 4



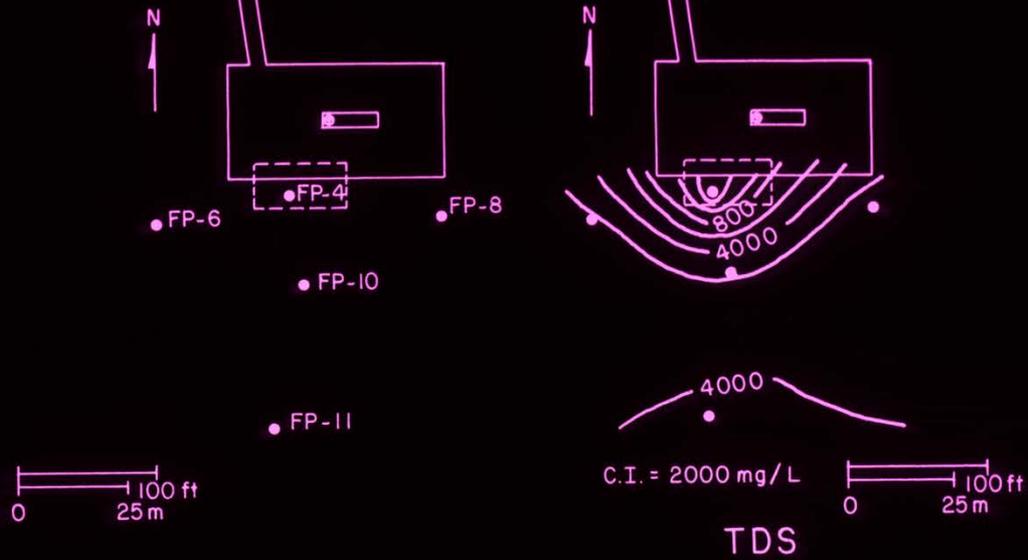
South

North

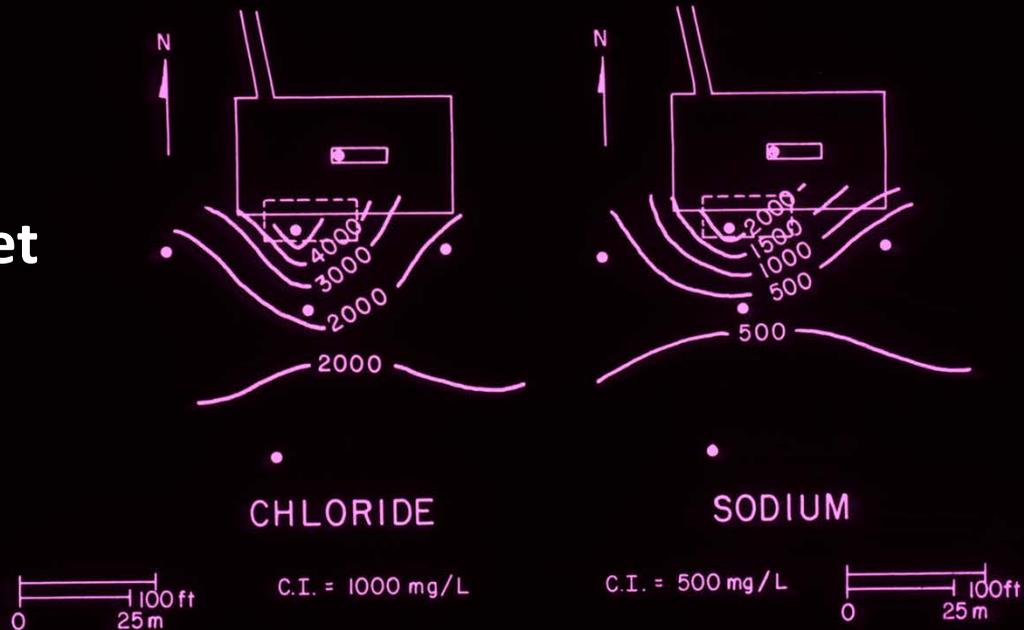
Fossum Federal # 4 -- Chloride (mg/l)

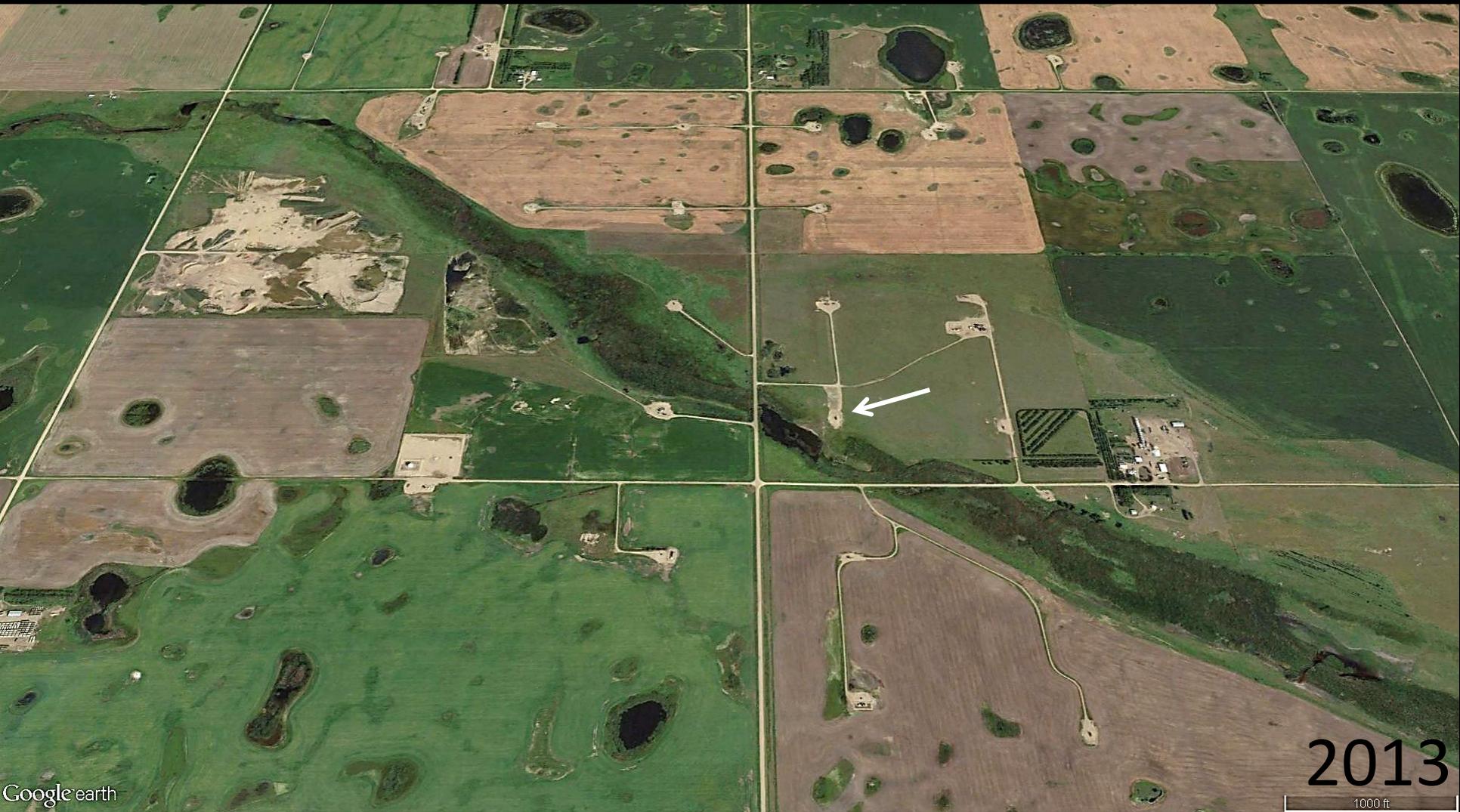


Fossum Federal # 4



**Plume is
100 x 150 feet**





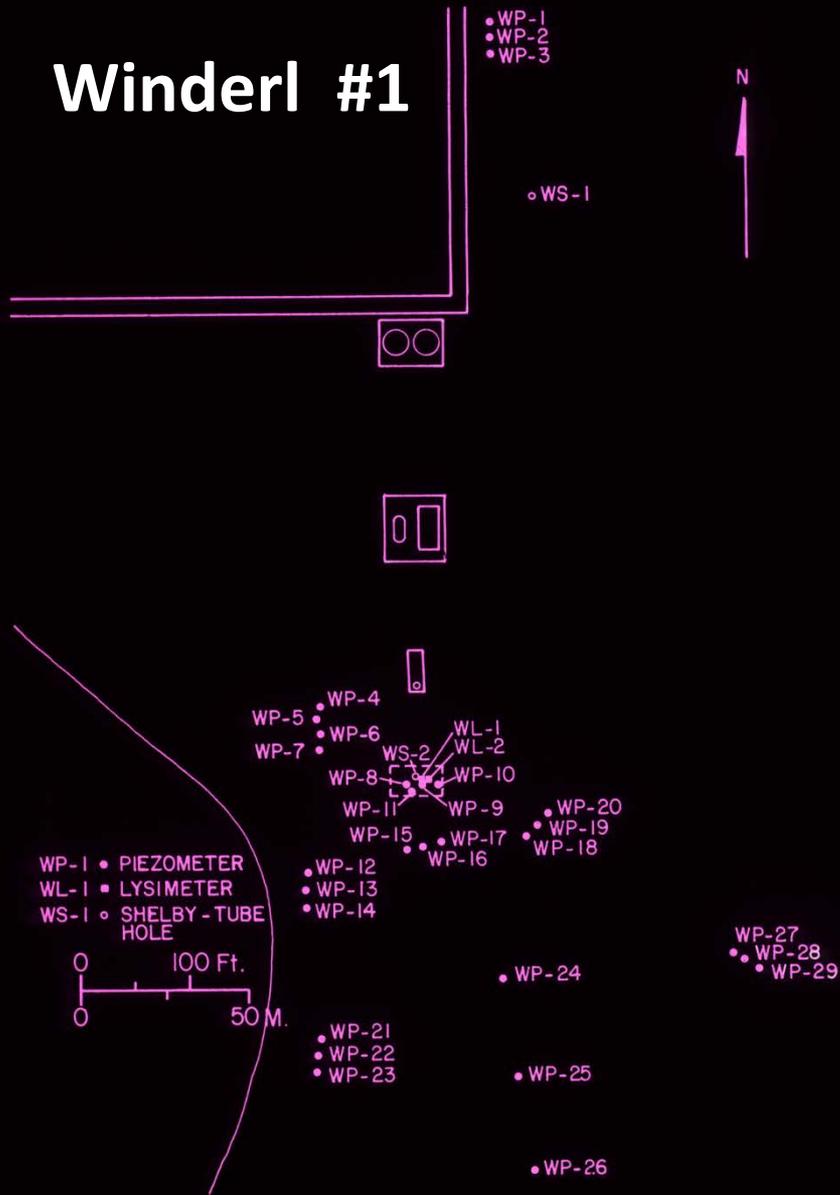
J.J. WINDERL # 1 drilled in 1959 & 1980.
Producing oil 1959 – to the present.

An aerial photograph showing a coastal area with various structures and terrain. The image is divided into several rectangular sections by white lines, possibly representing property boundaries or survey lines. In the upper right section, there are several small, light-colored structures or buildings. In the lower right section, there is a large, dark, irregularly shaped area that could be a pond or a large structure. The overall terrain appears to be a mix of flat and slightly elevated areas.

Winderl #1

1961

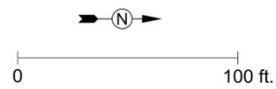
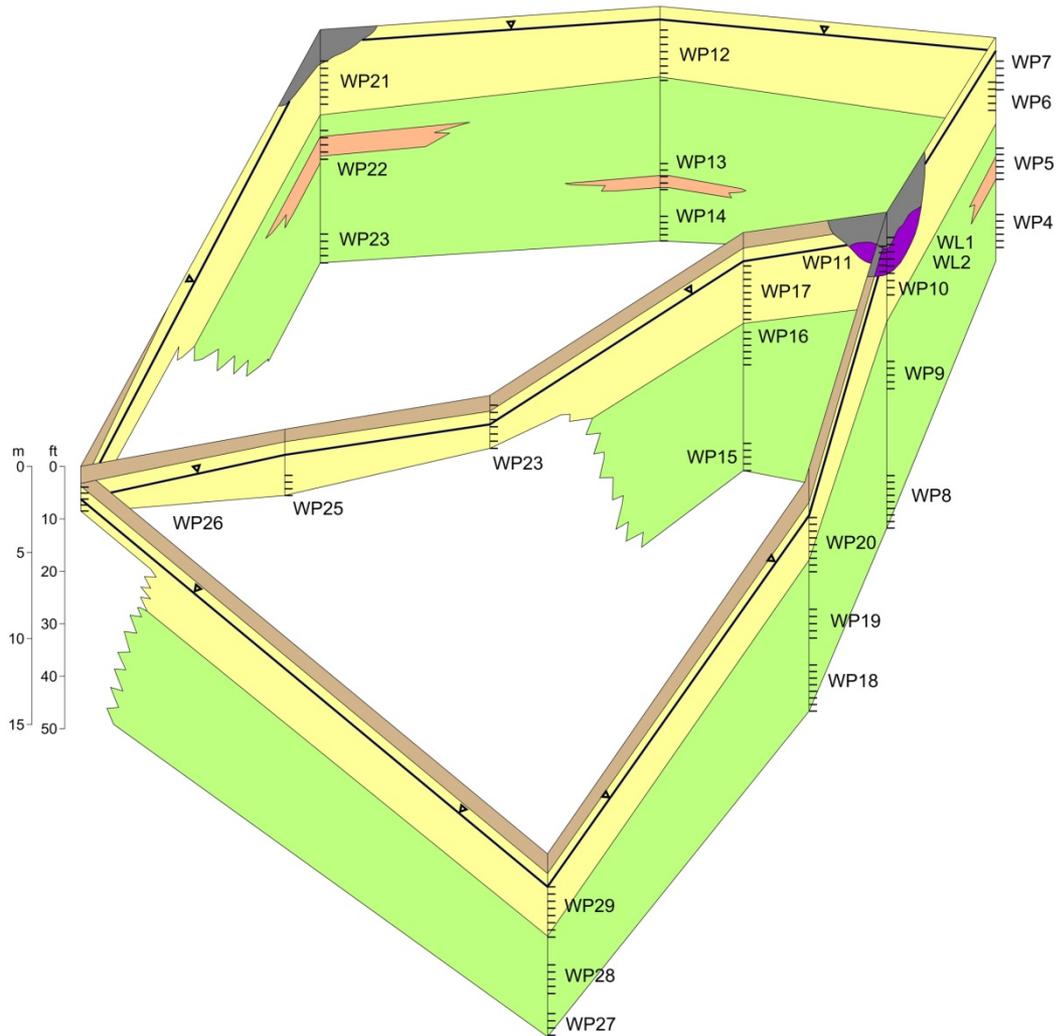
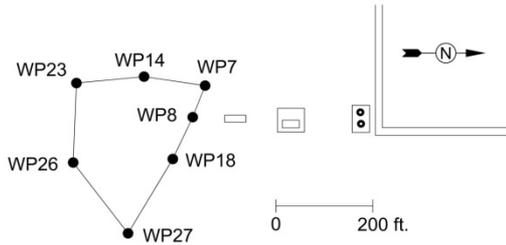
Winderl #1

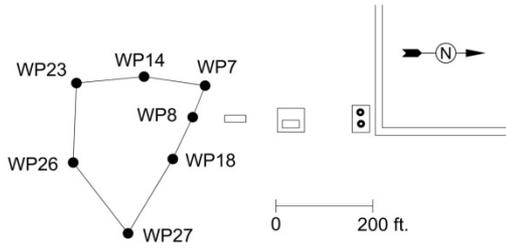




Winderl # 1 looking south

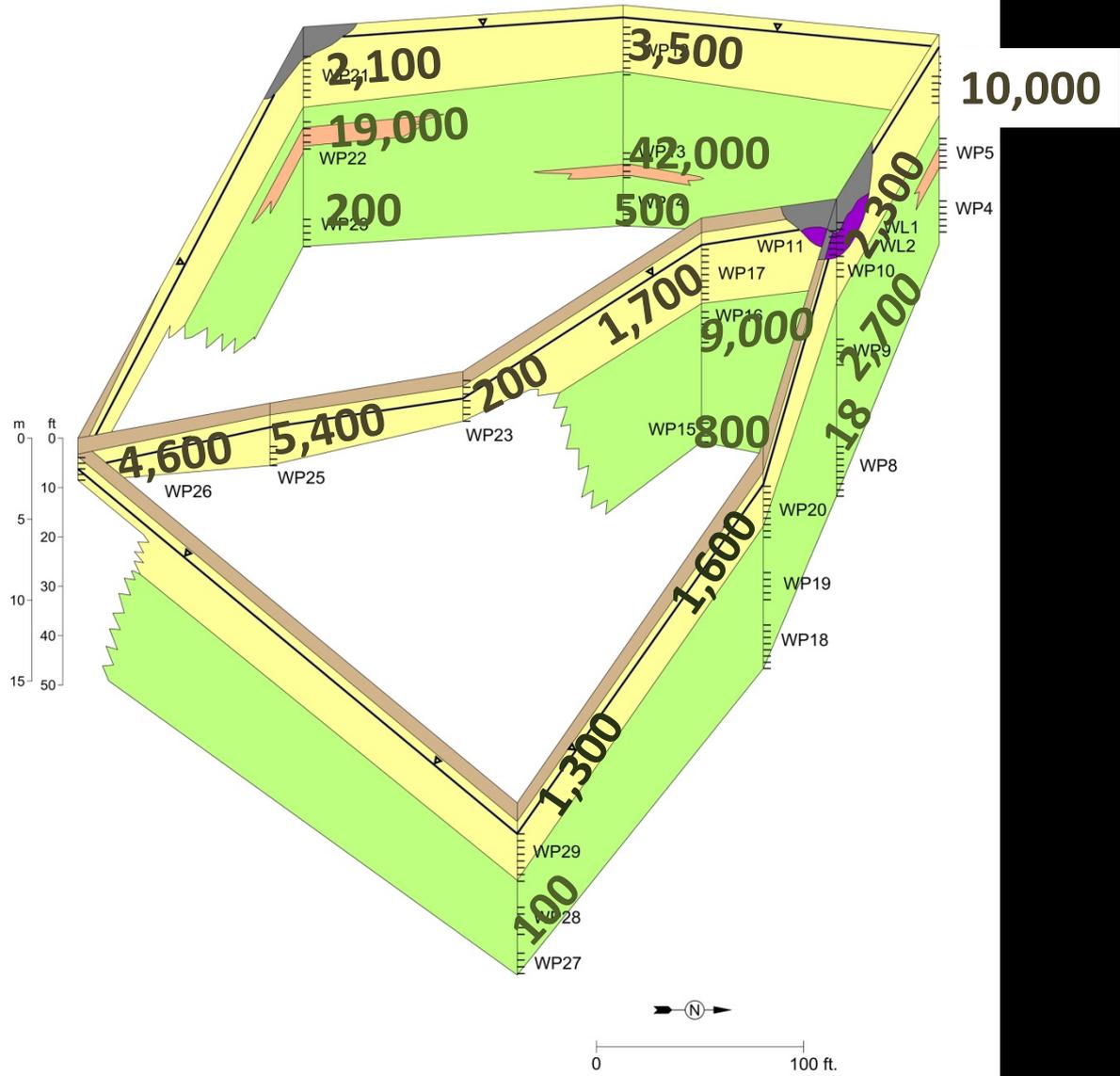
WINDERL #1

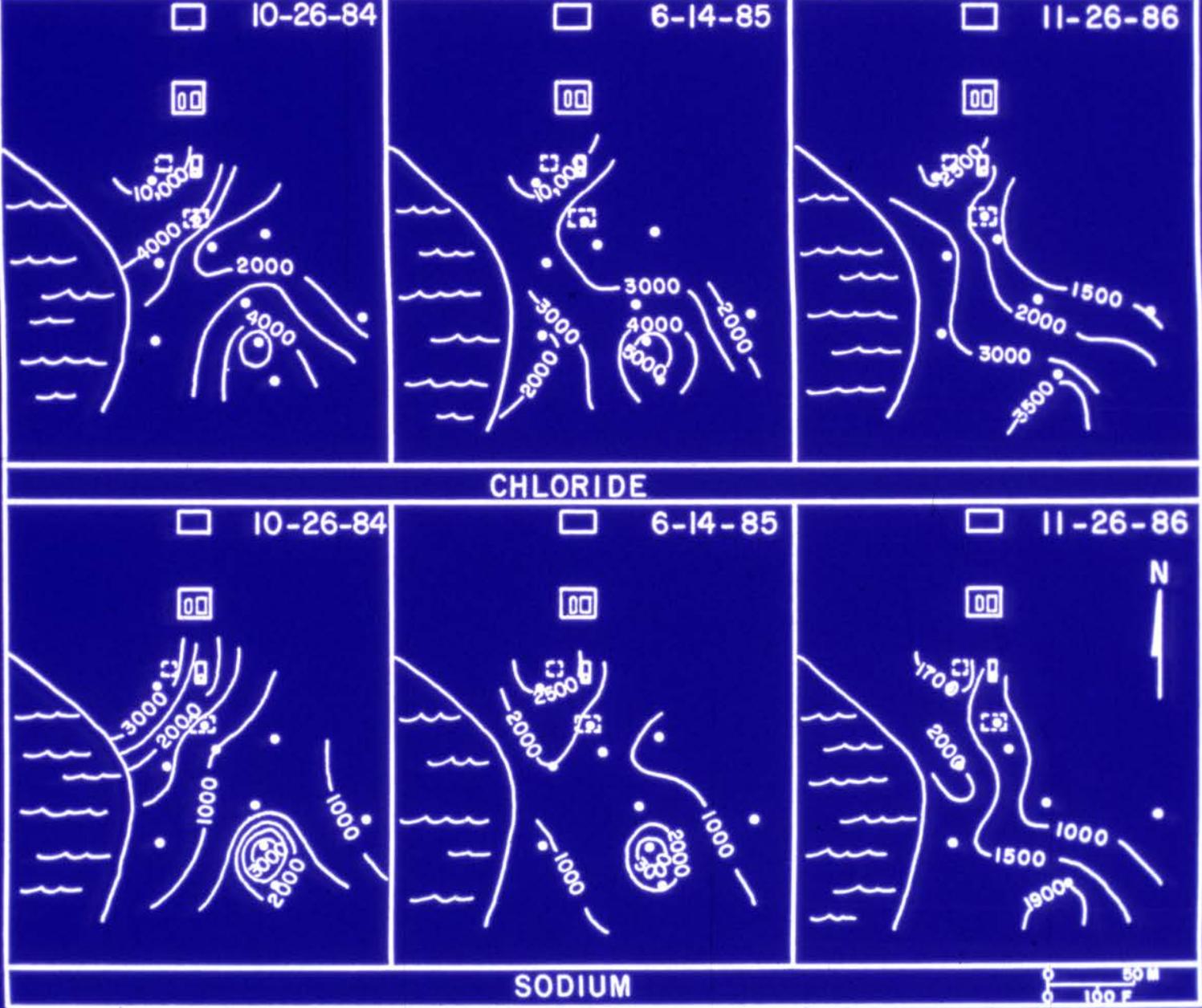




WINDERL #1

Chlorides (mg/l)

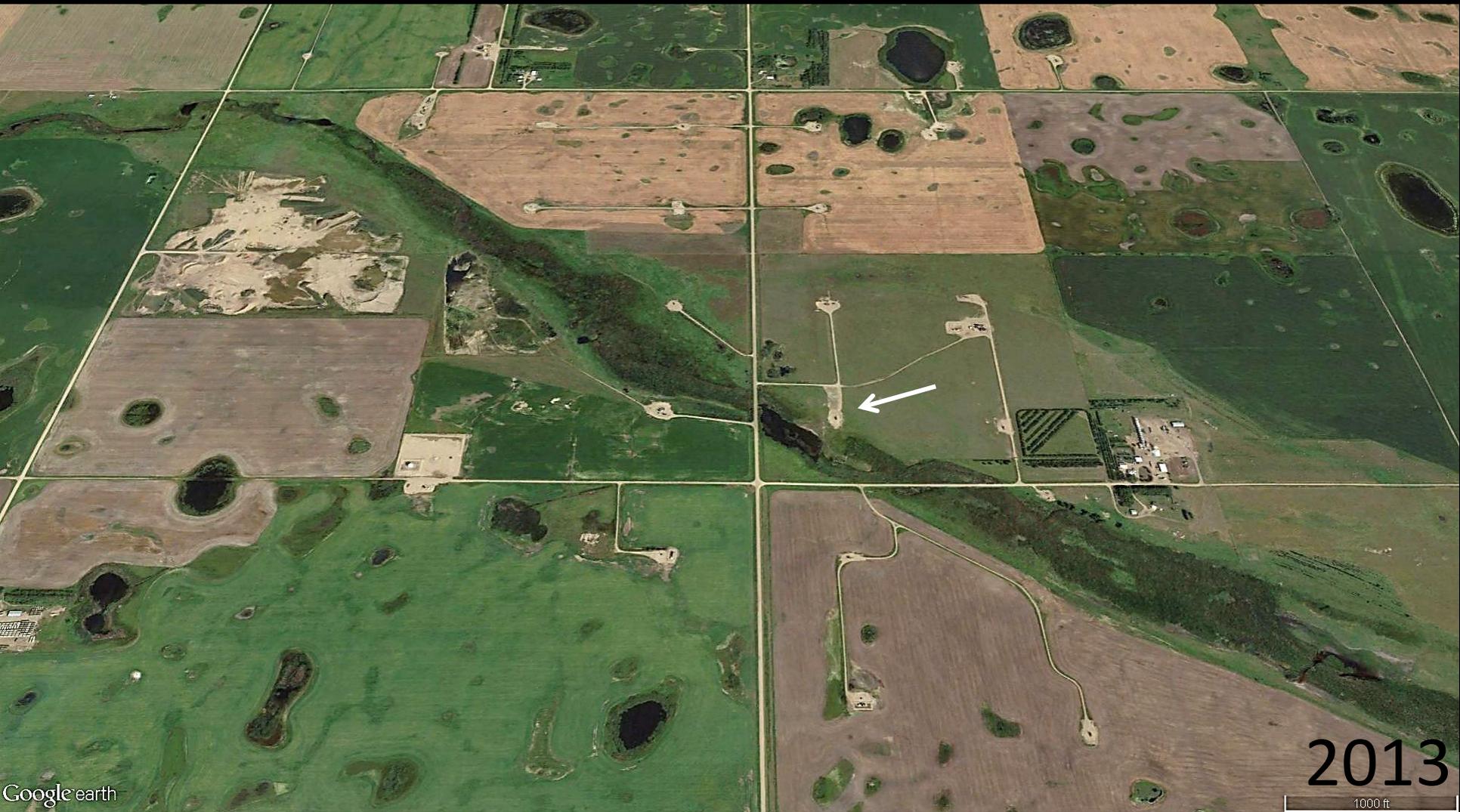




Winderl #1 Plume is > 500 feet

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.



J.J. WINDERL # 1 drilled in 1959 and deepened in 1980



Under today's rules, these locations (X) would require a closed mud system due to a **high watertable** and **near surface sand and gravel** deposits.



Gravel pit

Abandoned
Gravel pit

X

X

X

BRINE HOLDING PONDS



1961

WILEY FIELD

Madison Pool

CUMULATIVE PRODUCTION (as of 1/1/82)

9,078,035 Barrels of oil
18,063,255 Barrel of salt water



Total Dissolved Solids (TDS) of brines in the Wylie Field range from 19,000 to 250,000 mg/l (seawater 30,000 – 50,000).

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

STRATTON SWD #1

Stratton SWD #1

Fossum Federal #4

2013





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).

Stratton SWD #1 site (Edson Brown #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). 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.

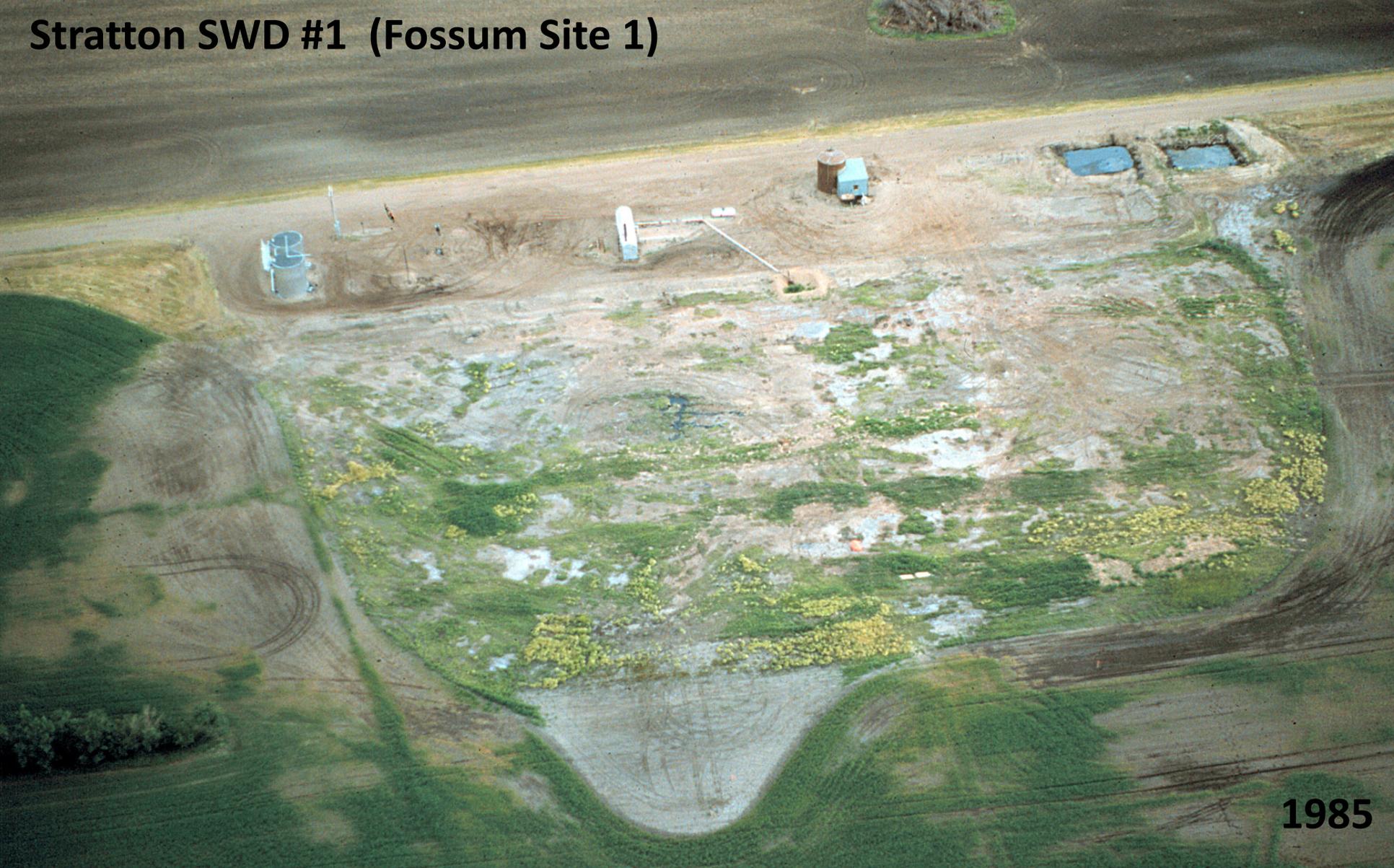
Electromagnetic soil conductivity meter (EM-38):

58 stations, 116 readings.

55 shallow Giddings cores (10-15 feet deep).

630 saturated paste extract analyses.

Stratton SWD #1 (Fossum Site 1)



1985

NDSU estimated 500 tons of NaCl in the top 10 feet of the Stratton Site. This works out to 22 tons per acre for this site.

WYLIE FIELD STUDY

1984-1985

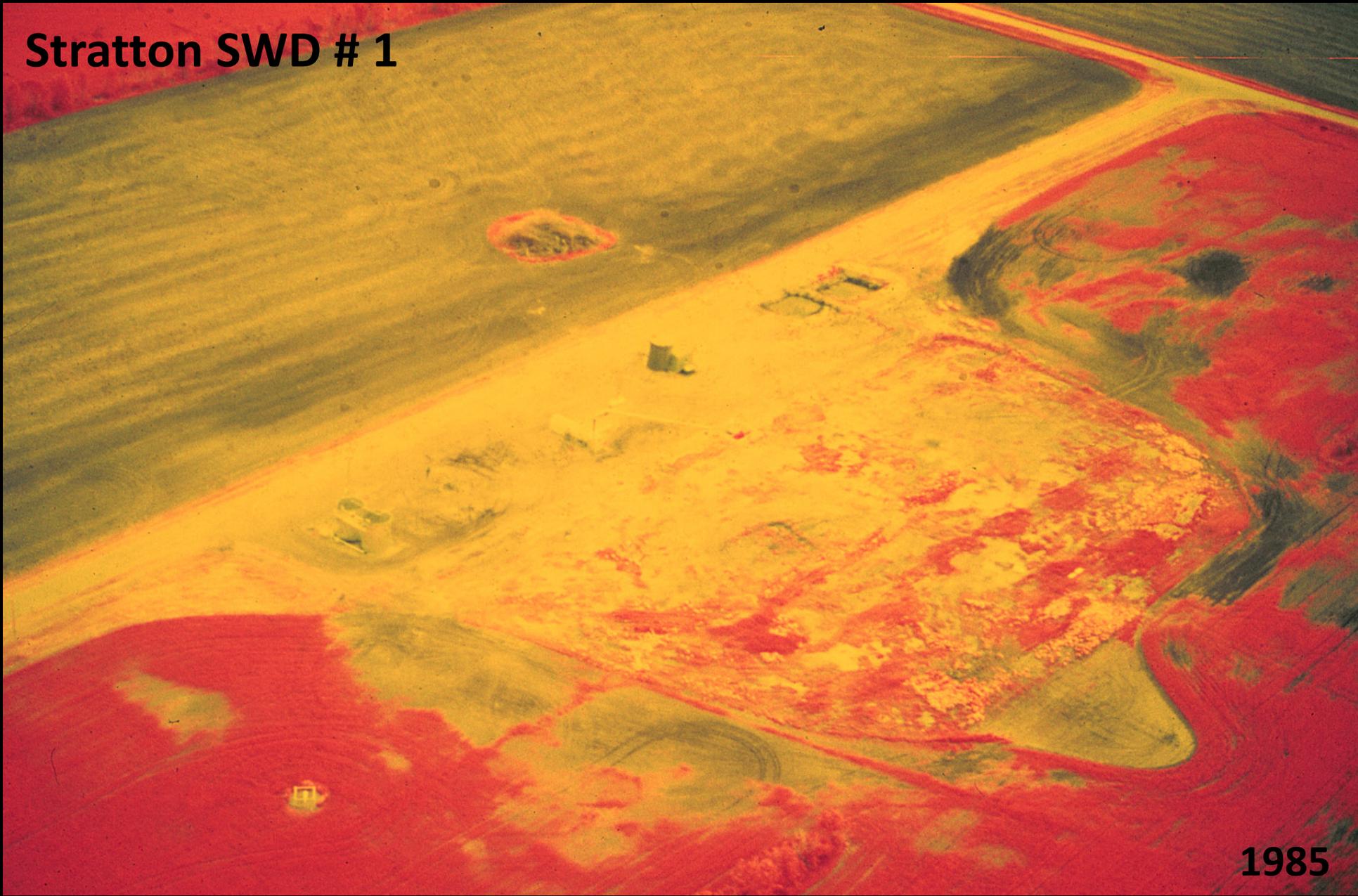
Soil Science Department, NDSU

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).

Stratton SWD # 1



1985



Stratton SWD # 1

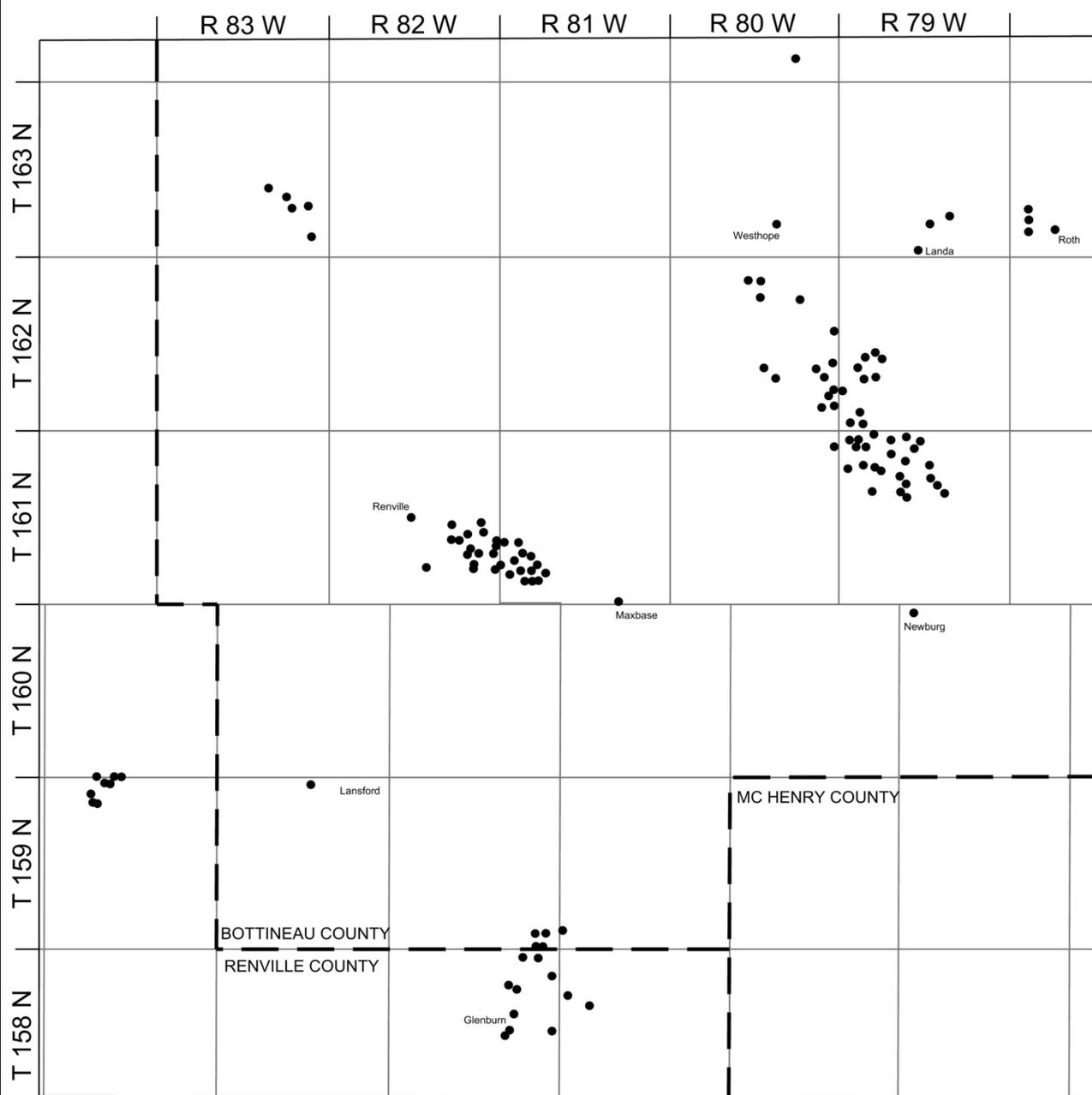
1985

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.

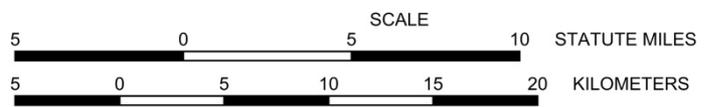
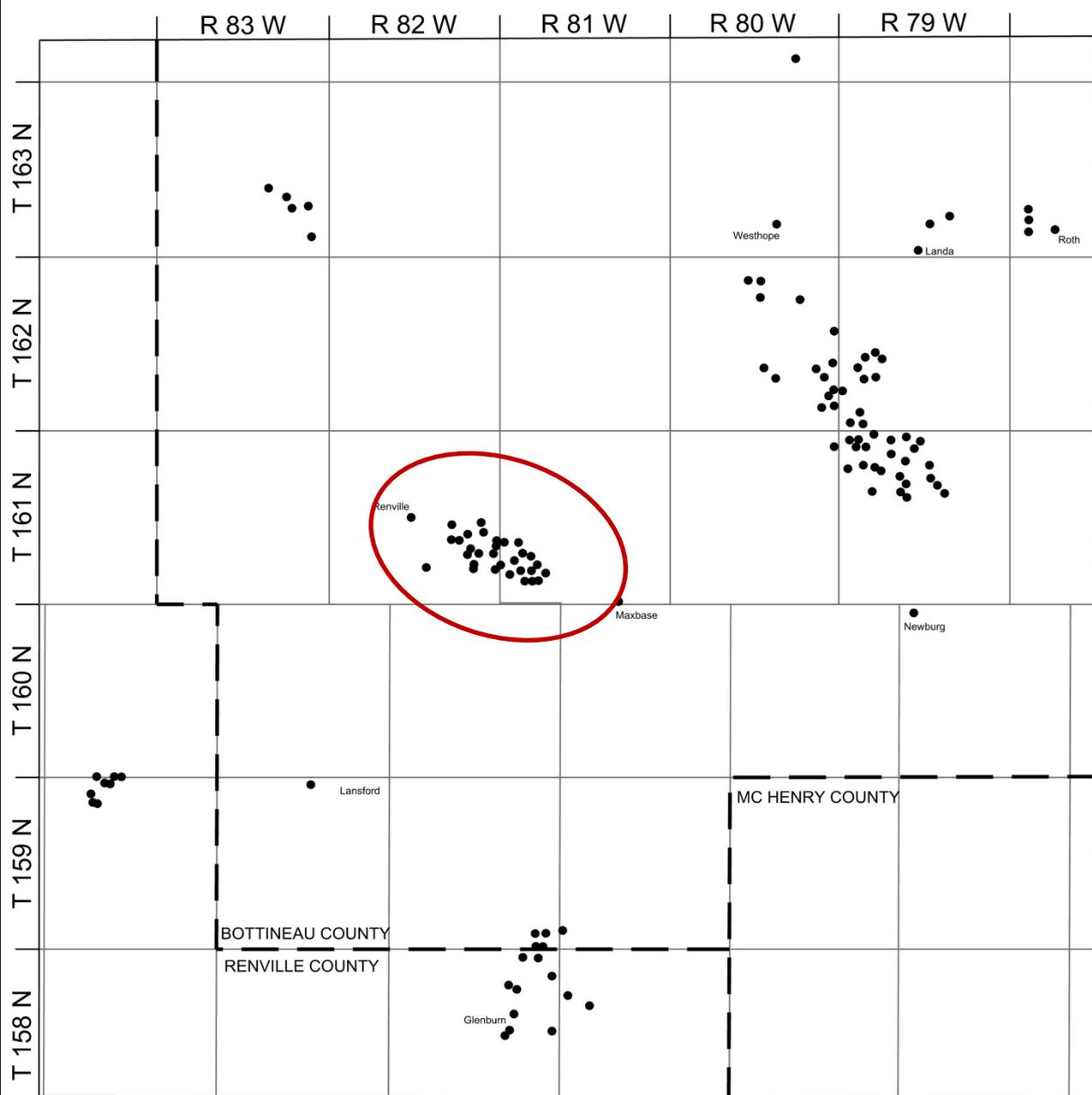


NDSU SOILS DEPT 1984 STUDY

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.

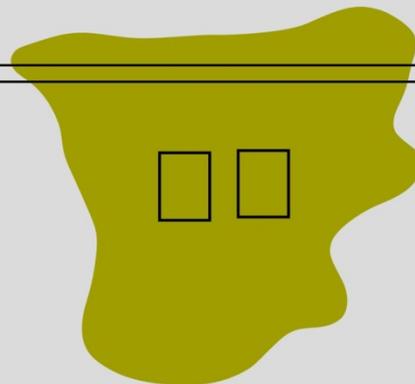
Average impact of 11.5 acres per site.

Total impact of 266 acres.

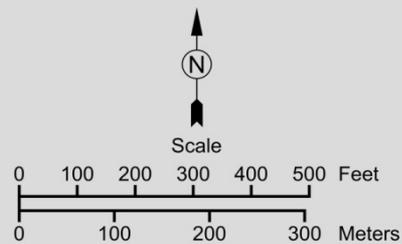
Electromagnetic soil conductivity meter (EM-38).

Stratton SWD

(Site 58)



1979 **7 acres**

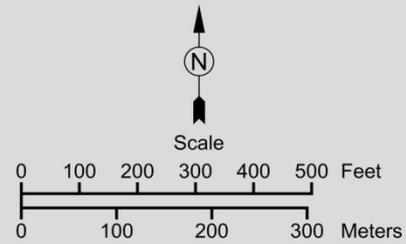


Stratton SWD

(Site 58)

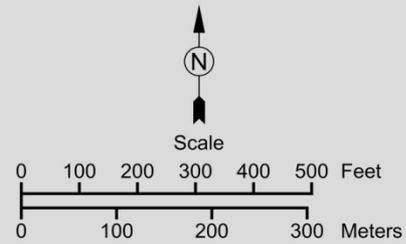


1984 **11 acres**



Stratton SWD (Site 58)

1985 **15 acres**



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

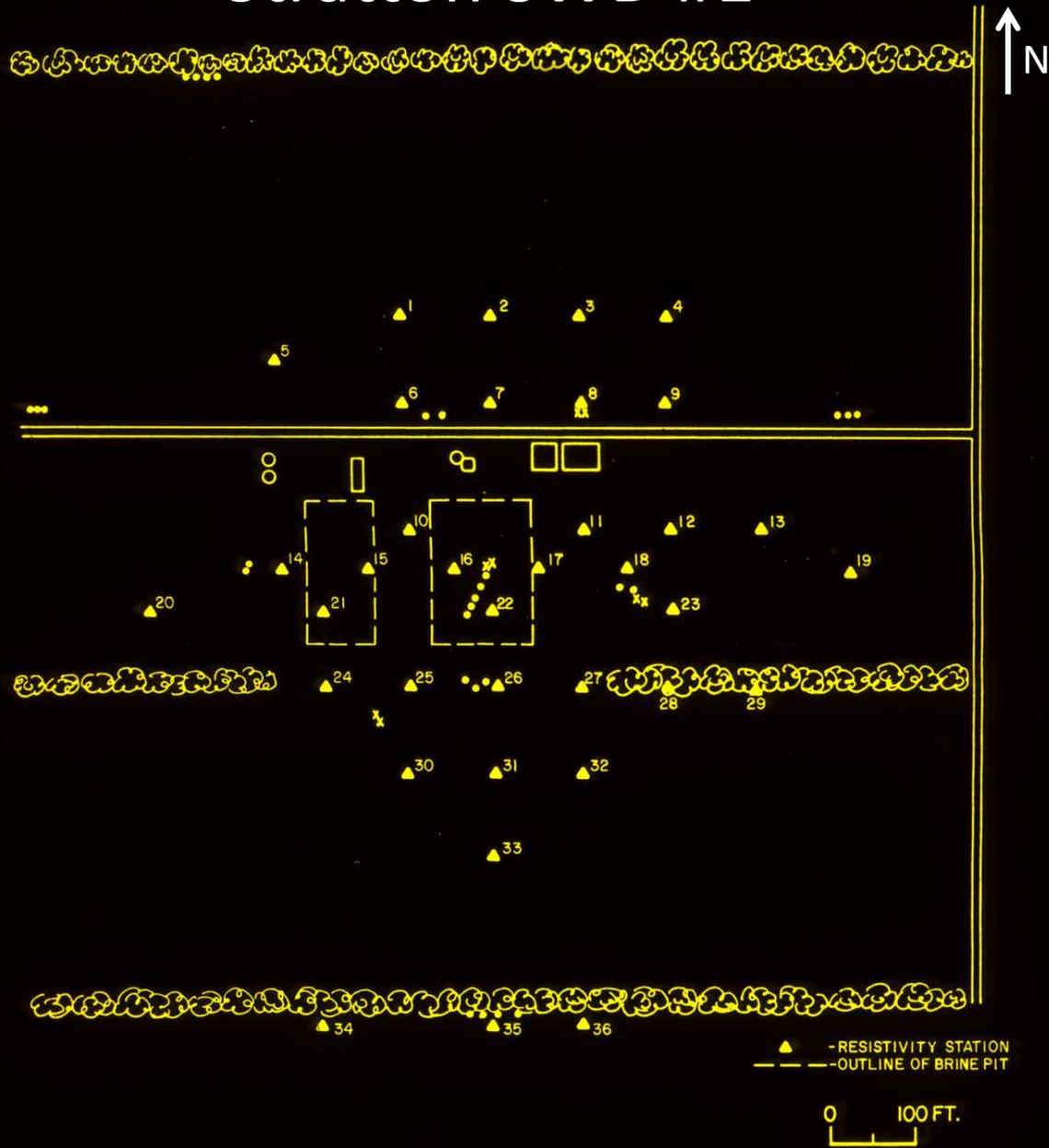
Studied only the Stratton SWD #1

28 piezometers (down to 220 feet), 8 lysimeters.

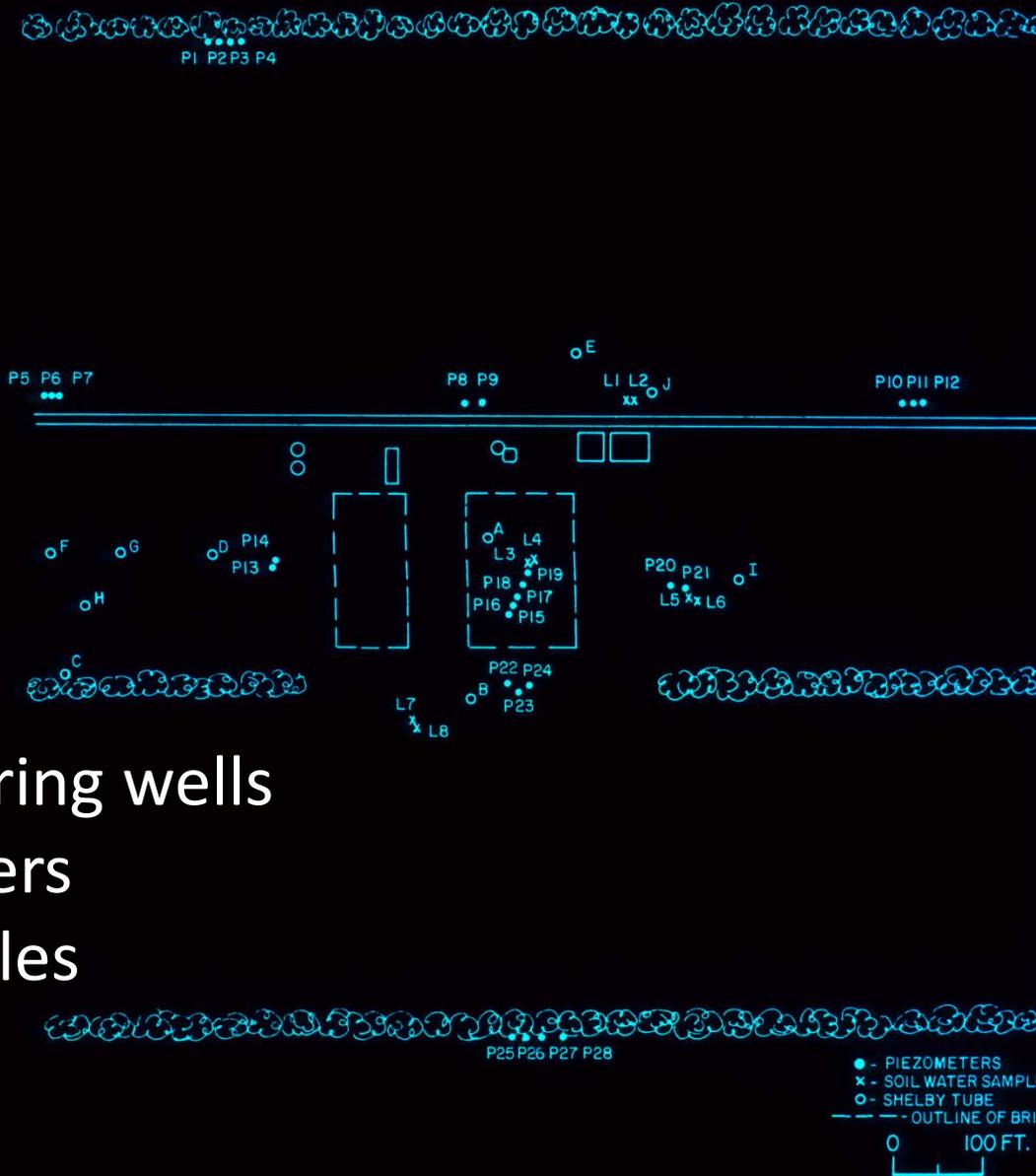
60 water samples.

36 resistivity stations (504 readings).

Stratton SWD #1



Stratton SWD #1



28 monitoring wells

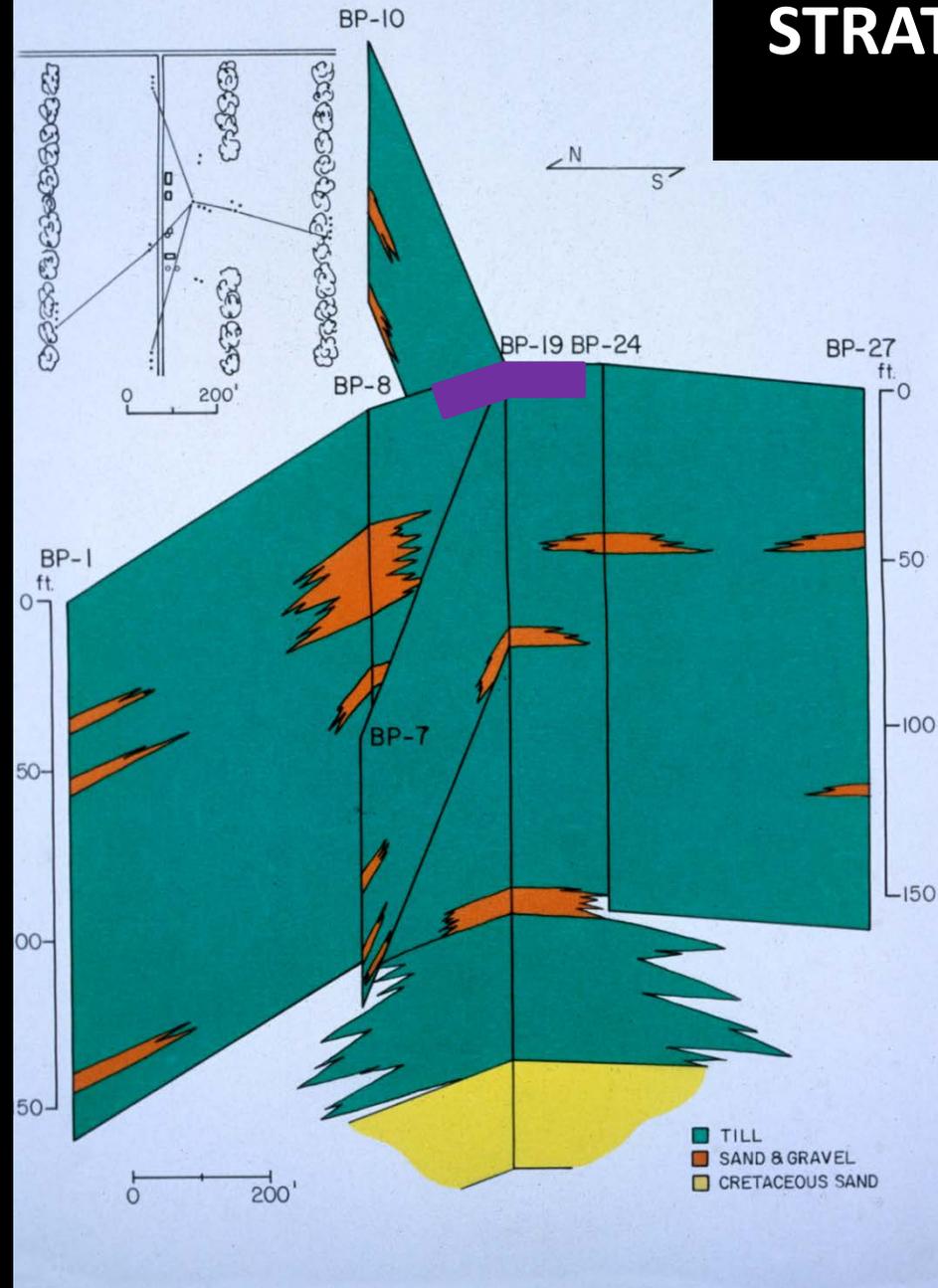
8 lysimeters

10 core holes



Installing monitoring wells at the Stratton SWD #1 in 1984.

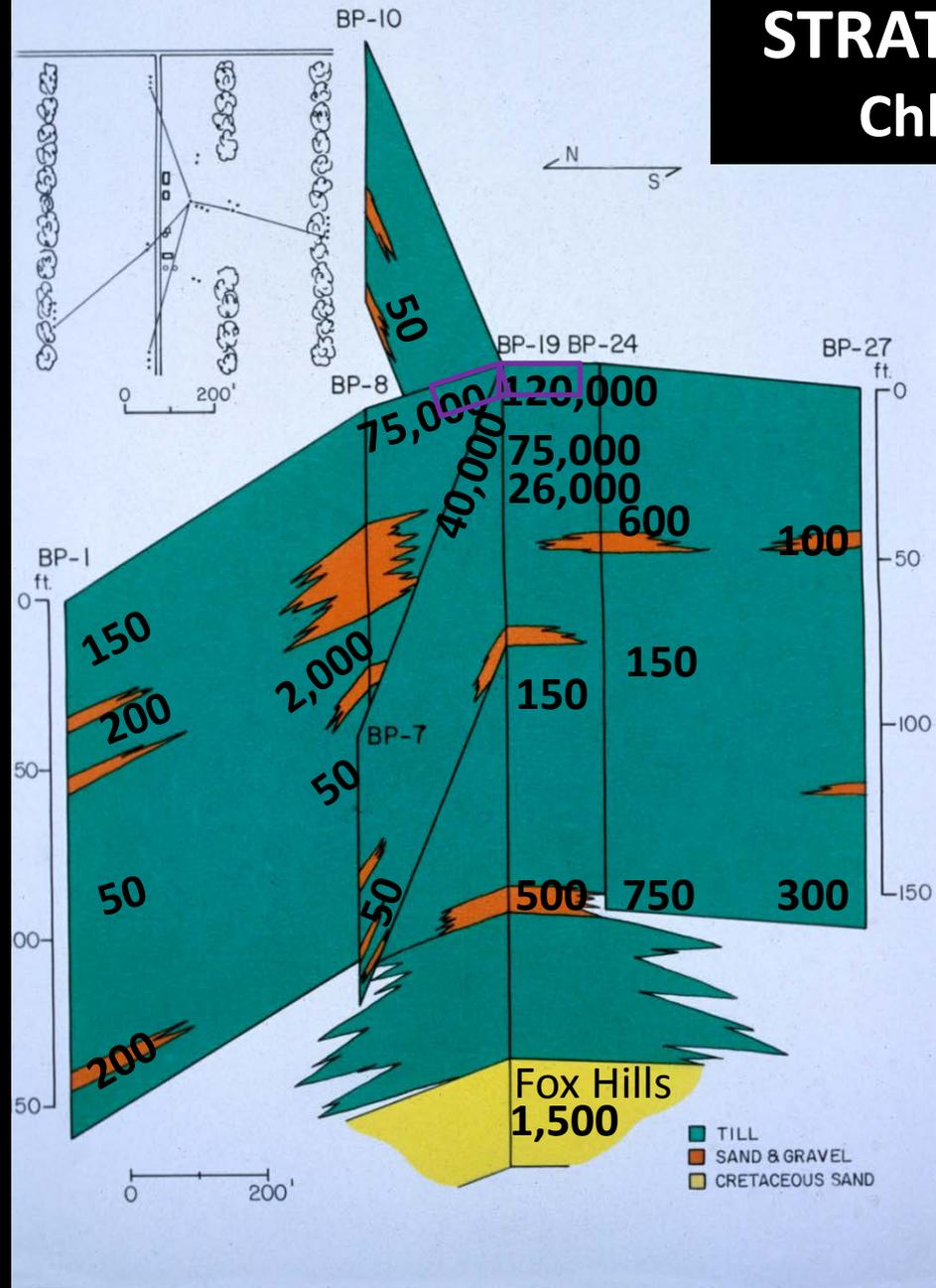
STRATTON SWD #1



The site is underlain by 210 feet of till overlying the Fox Hills Formation.

STRATTON SWD #1

Chlorides mg/l



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

STRATTON SWD #1

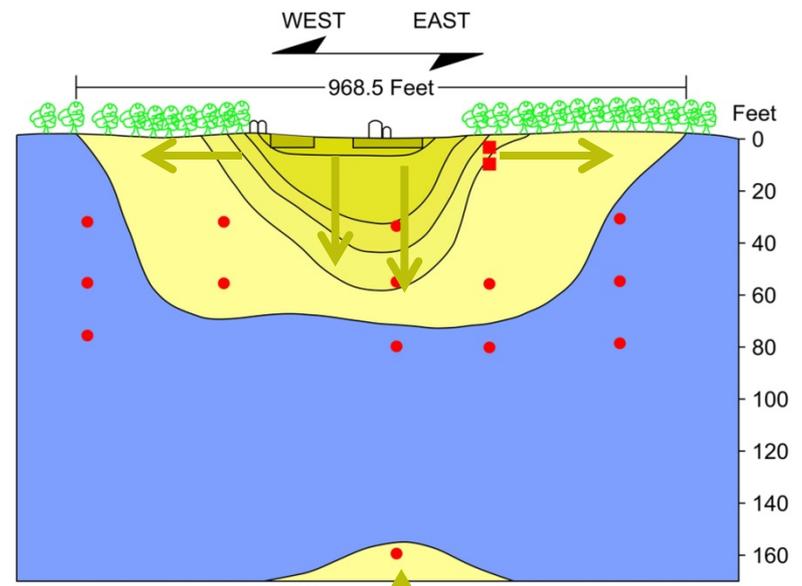
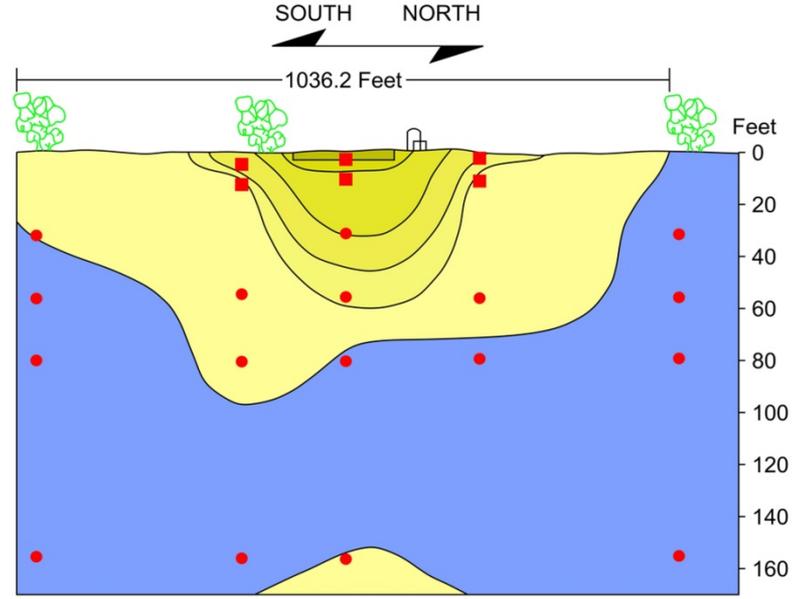
A high salt plume extends laterally around the site over an area of 250,000 ft² (about 6 acres).

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 (hydraulic heads).

Stratton SWD #1



Cl⁻ (Mg/l)
 ■ BRINE PIT
 ■ >100,000
 ■ 75,000 - 100,000
 ■ 50,000 - 75,000
 ■ 25,000 - 50,000
 ■ 500 - 25,000
 ● PIEZOMETER SCREEN
 ■ LYSIMETER

Fox Hills

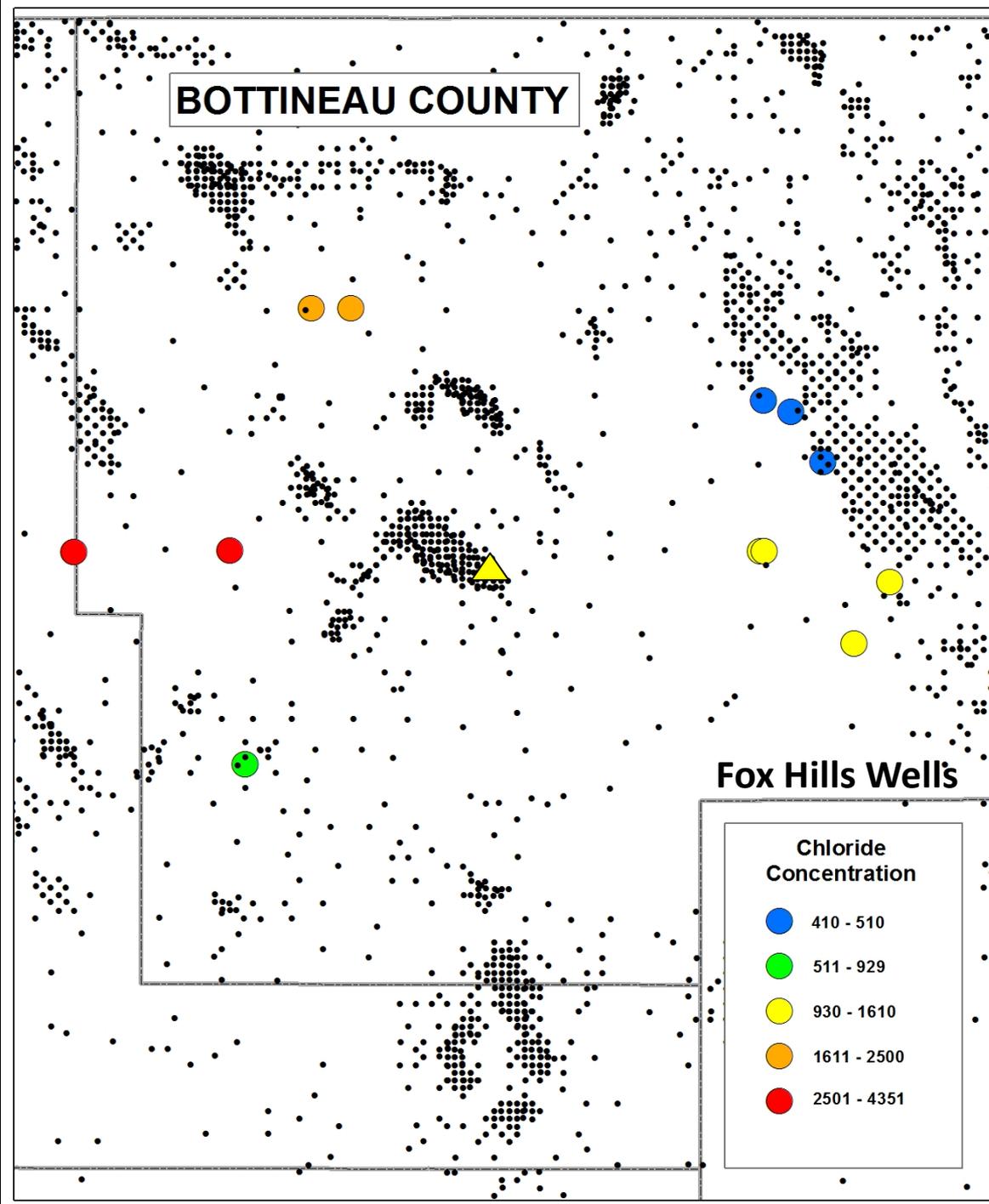
0 100 FEET (30.5m)
 VERTICAL EXAGGERATION OF 4X
 50 FEET (15.2m)

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

FOX HILLS WELLS AND OIL & GAS WELLS

▲ Stratton Site



FOX HILLS WELLS AND SALTWATER DISPOSAL WELLS

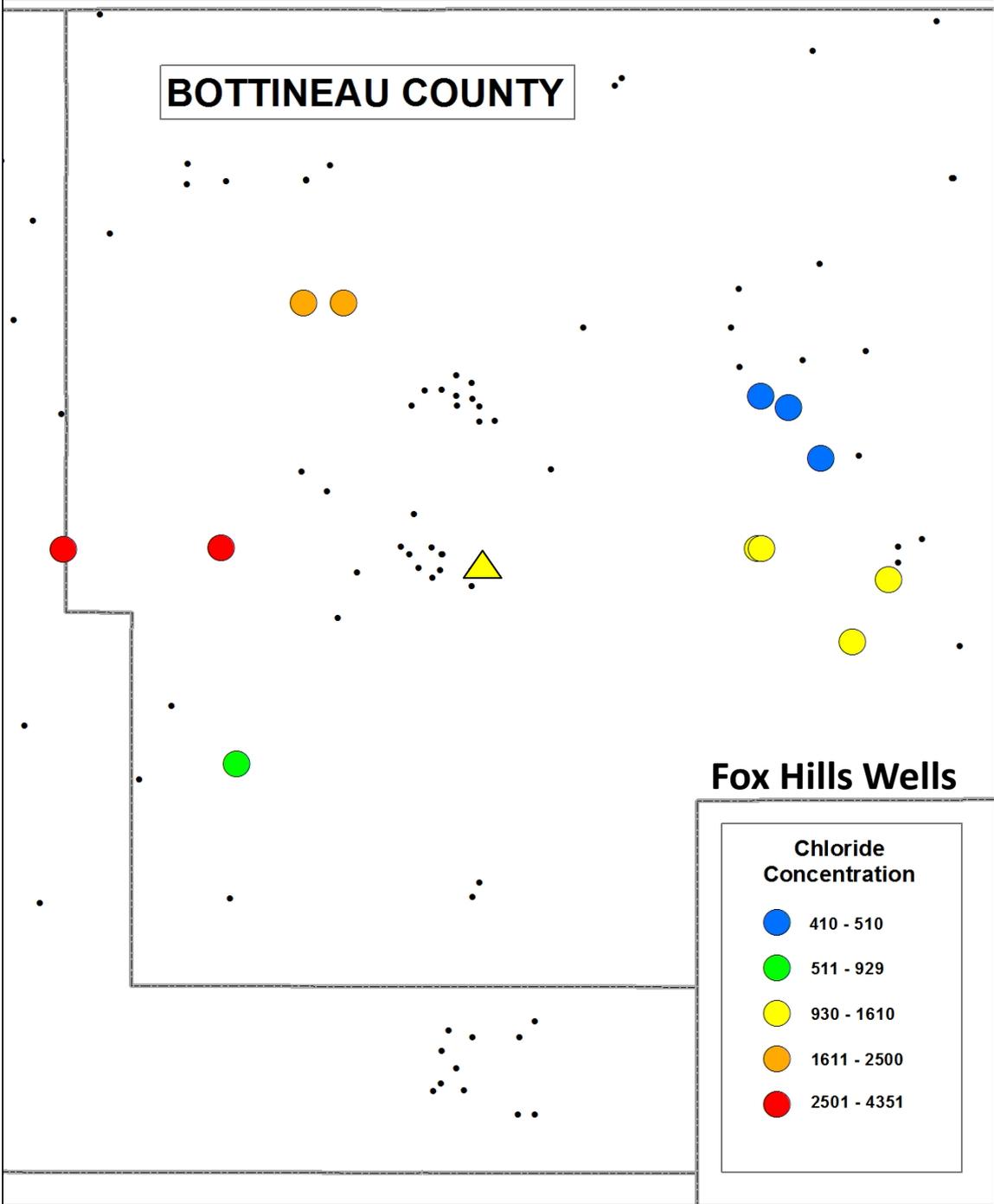
BOTTINEAU COUNTY

▲ Stratton Site

Fox Hills Wells

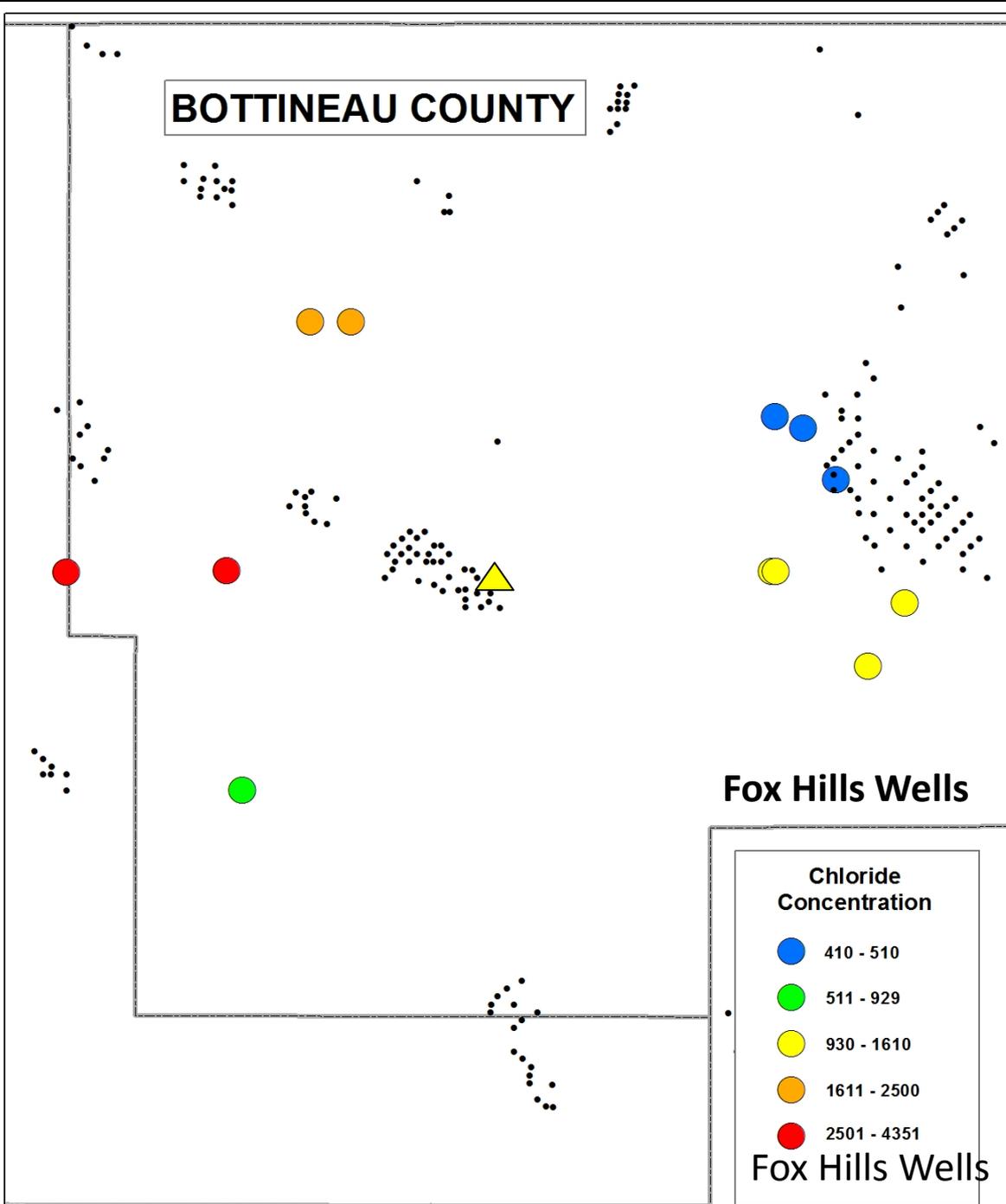
Chloride
Concentration

- 410 - 510
- 511 - 929
- 930 - 1610
- 1611 - 2500
- 2501 - 4351



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.

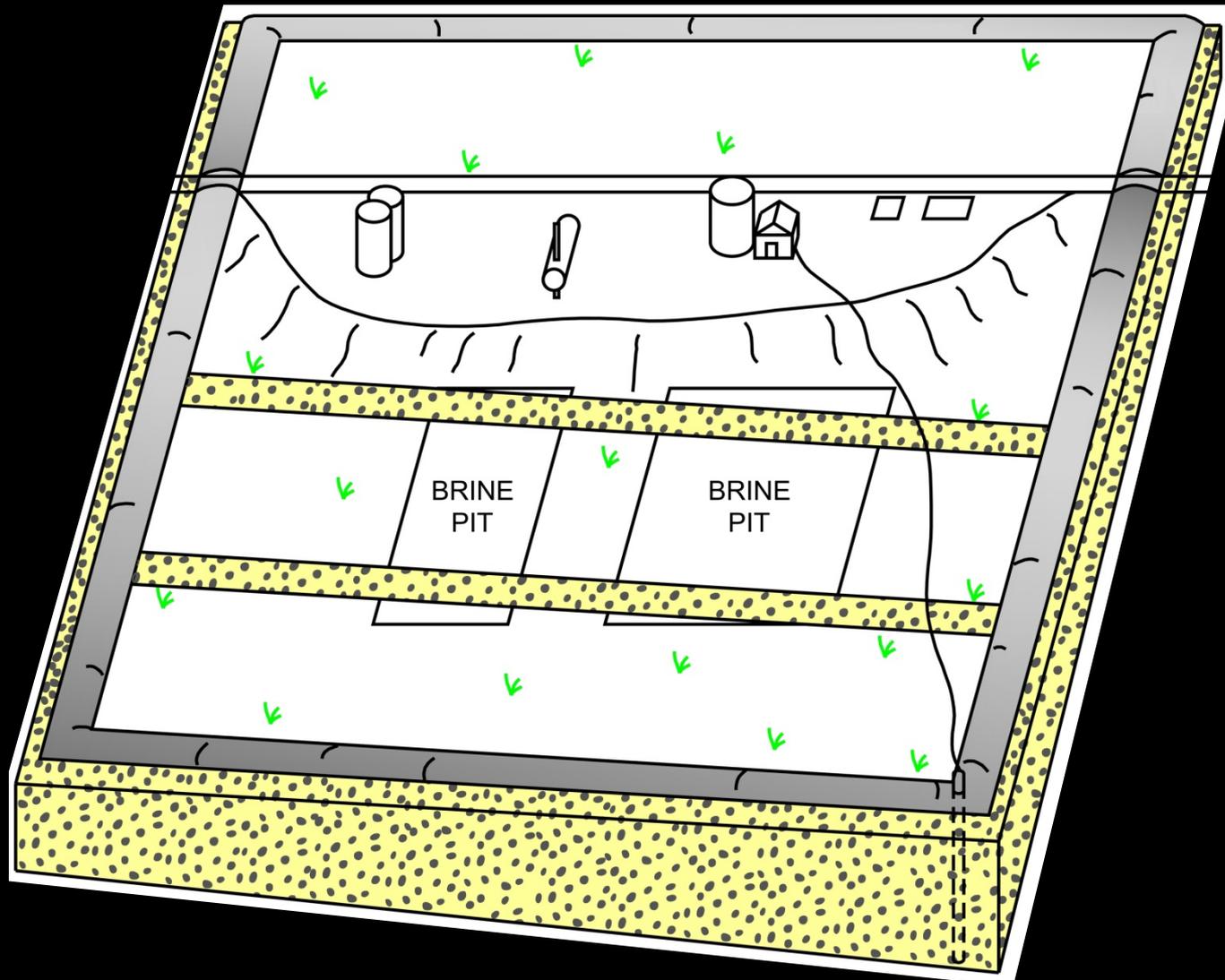
MOUNDING/CAPPING THE SITE

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.

INFILTRATION GALLERY



ERICKSON #1, BOTTINEAU COUNTY



1961

ERICKSON #1, BOTTINEAU COUNTY



1961

Erickson Central Tank Battery, Bottineau County

Drain Tile Trench 19_?_ -- 1997



Drain tile trench approximately 400 ft long, snow fence

1995

Erickson Central Tank Battery, Bottineau County

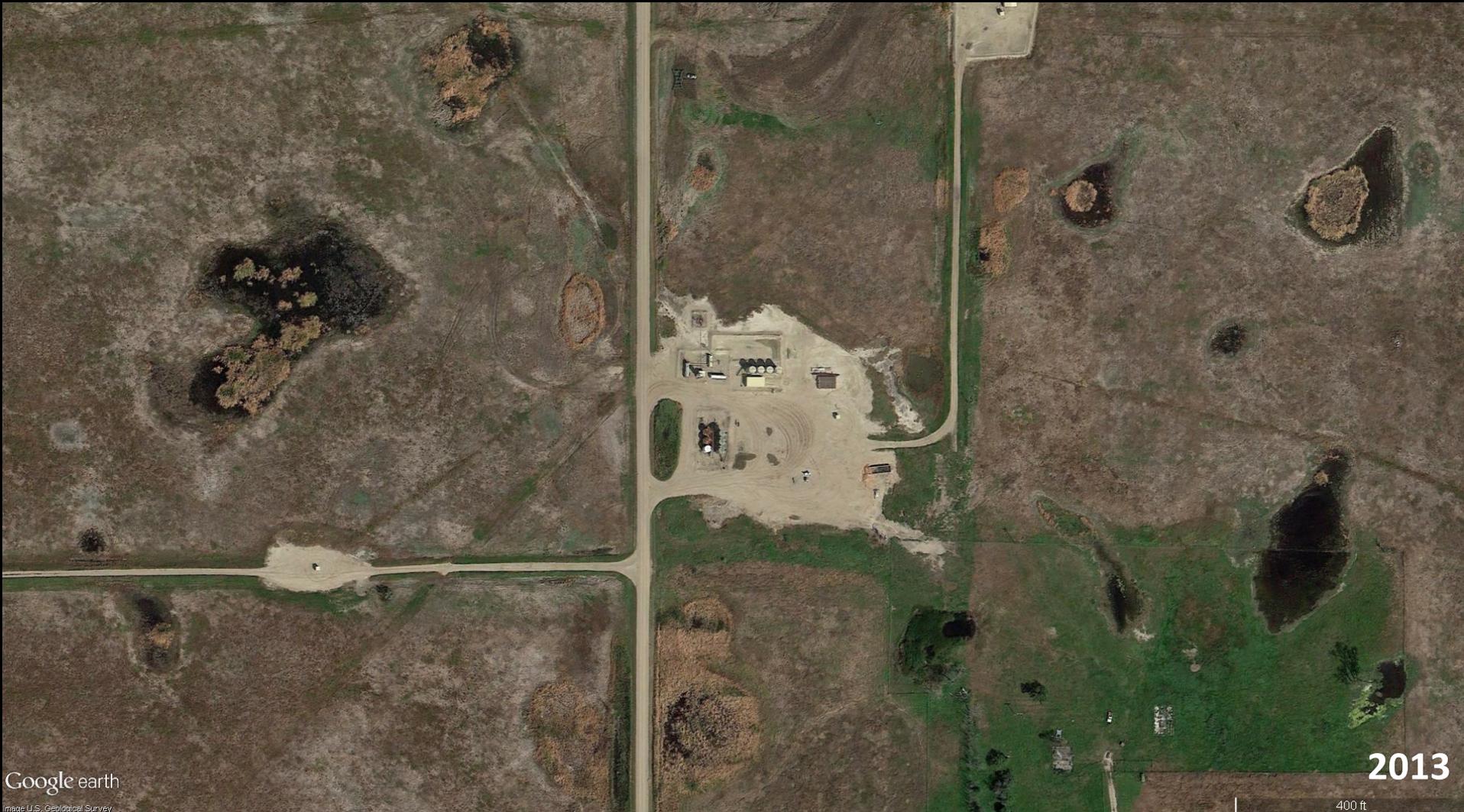
Drain Tile Trench 19_?_ -- 1997



Drain tile trench approximately 400 ft long, snow fence

1995

Erickson Central Tank Battery, Bottineau County



General consensus that vegetation recovered in the drain tile area.

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

Well Sites

Stratton D01 (Stratton SWD #1)

Bull B1R

Wilms A D01

Haugen B1

Durnin A & D01

2006-2010 Wylie Field Study Sites

Bull

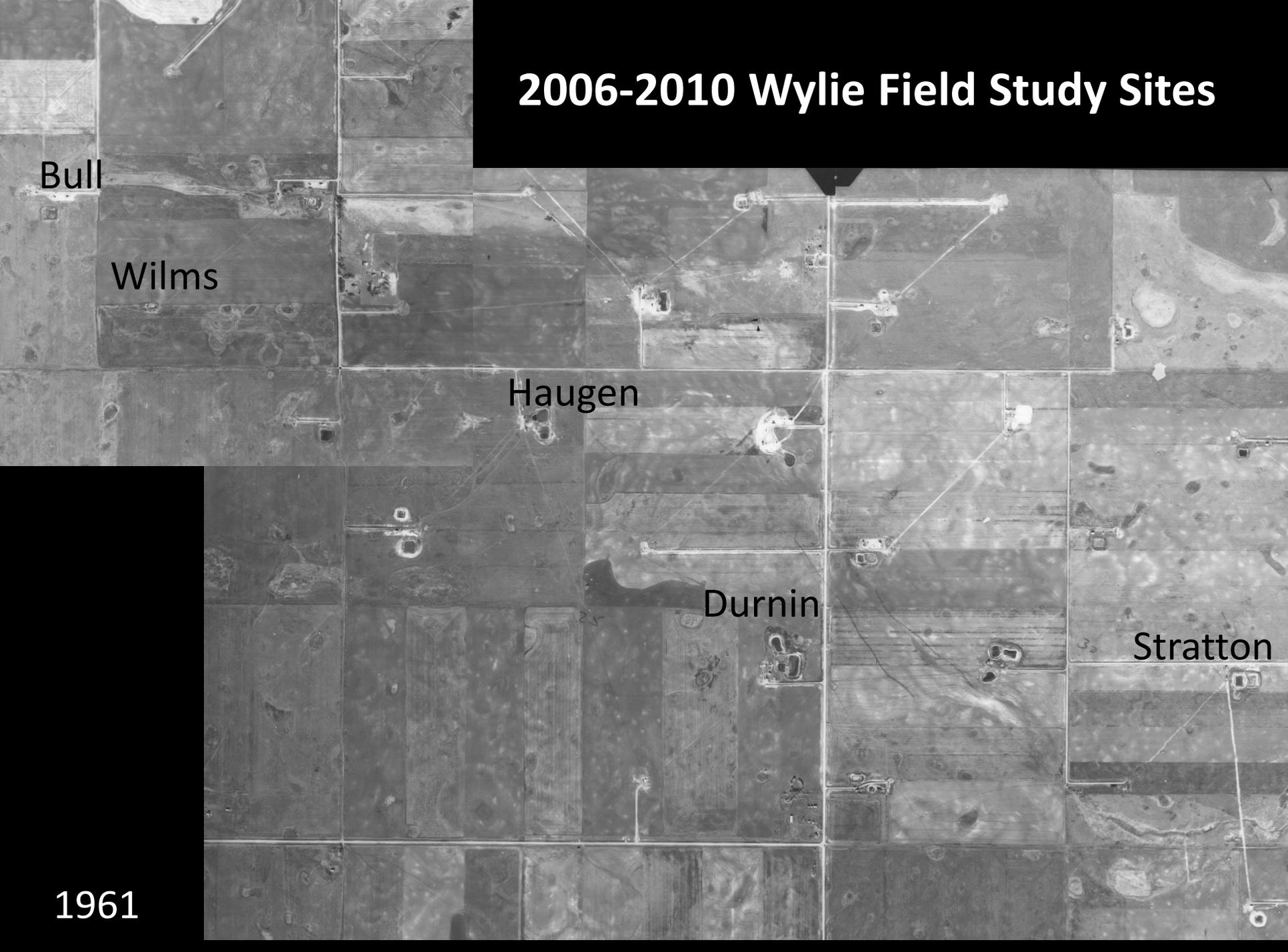
Wilms

Haugen

Durnin

Stratton

1961



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.

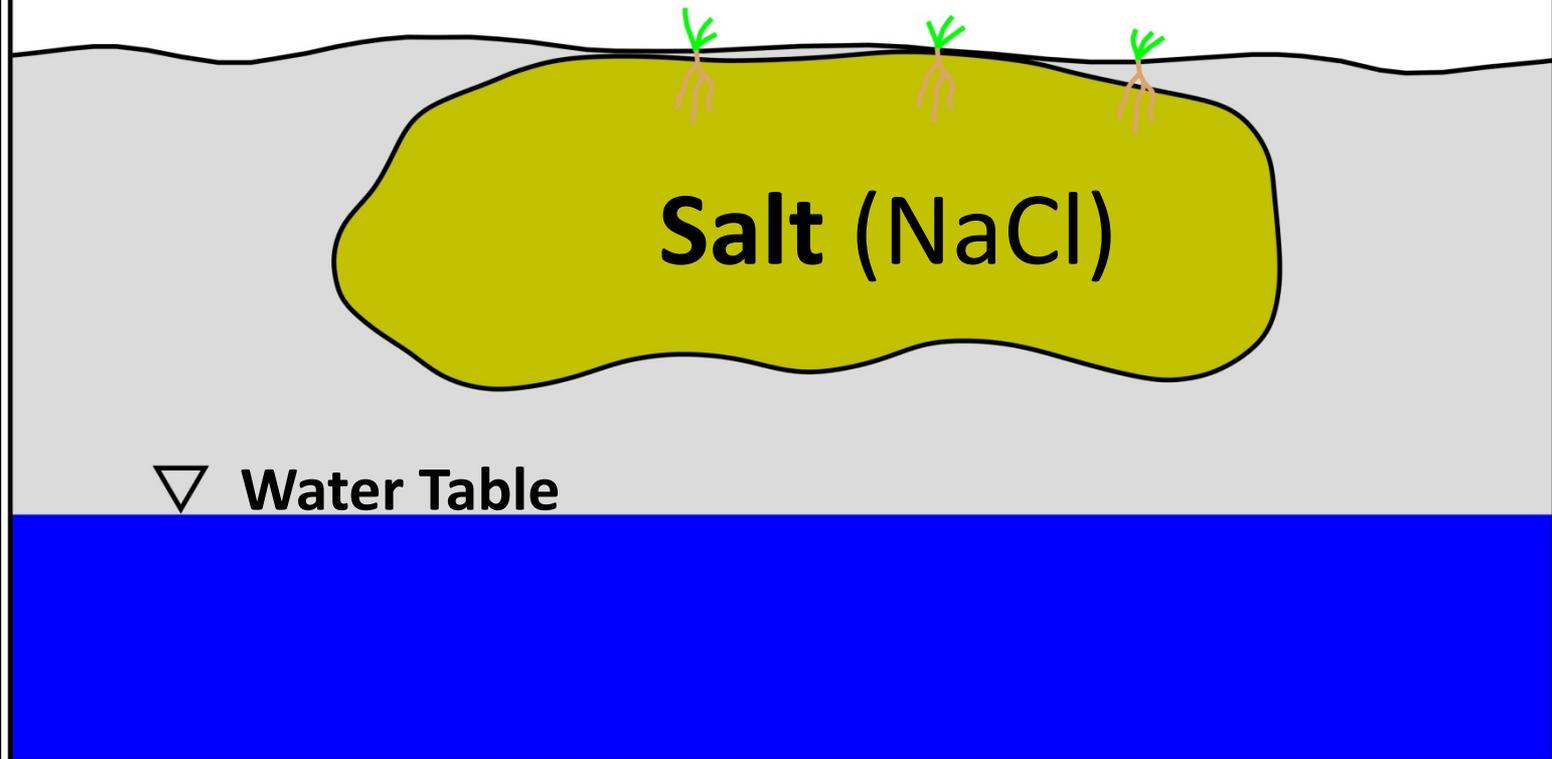
Area of surface scaring reduced from 1.5 acres to 0.5 acres.

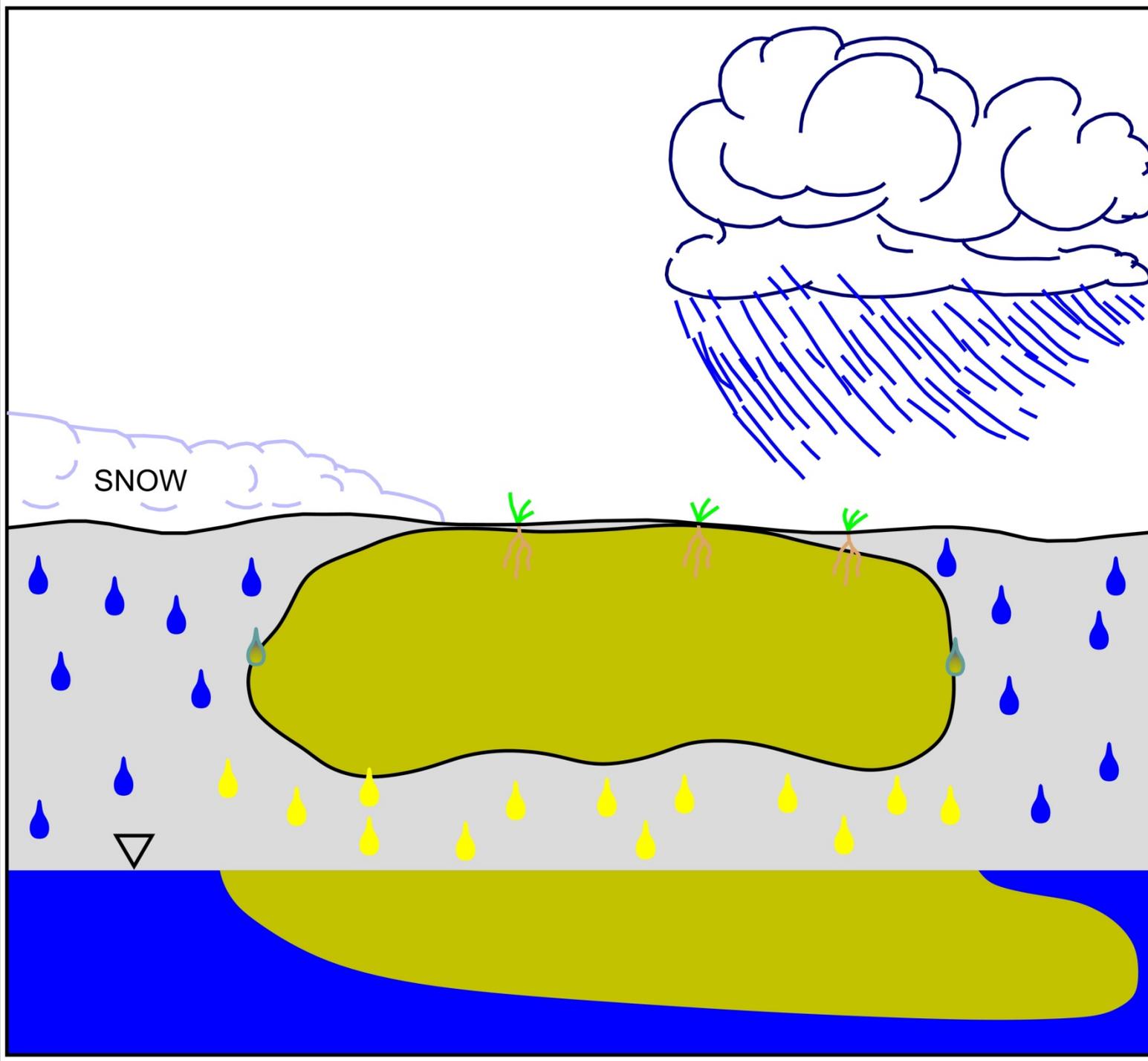
Haugen Site

Chloride levels exhibited a decreasing trend in soils.

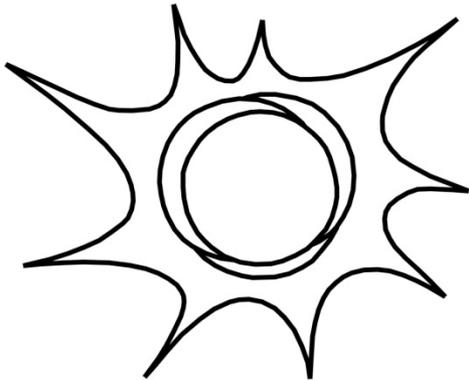
Area of surface scaring reduced from 3.5 acres to 1.75 acres.

OLD BRINE POND SITE

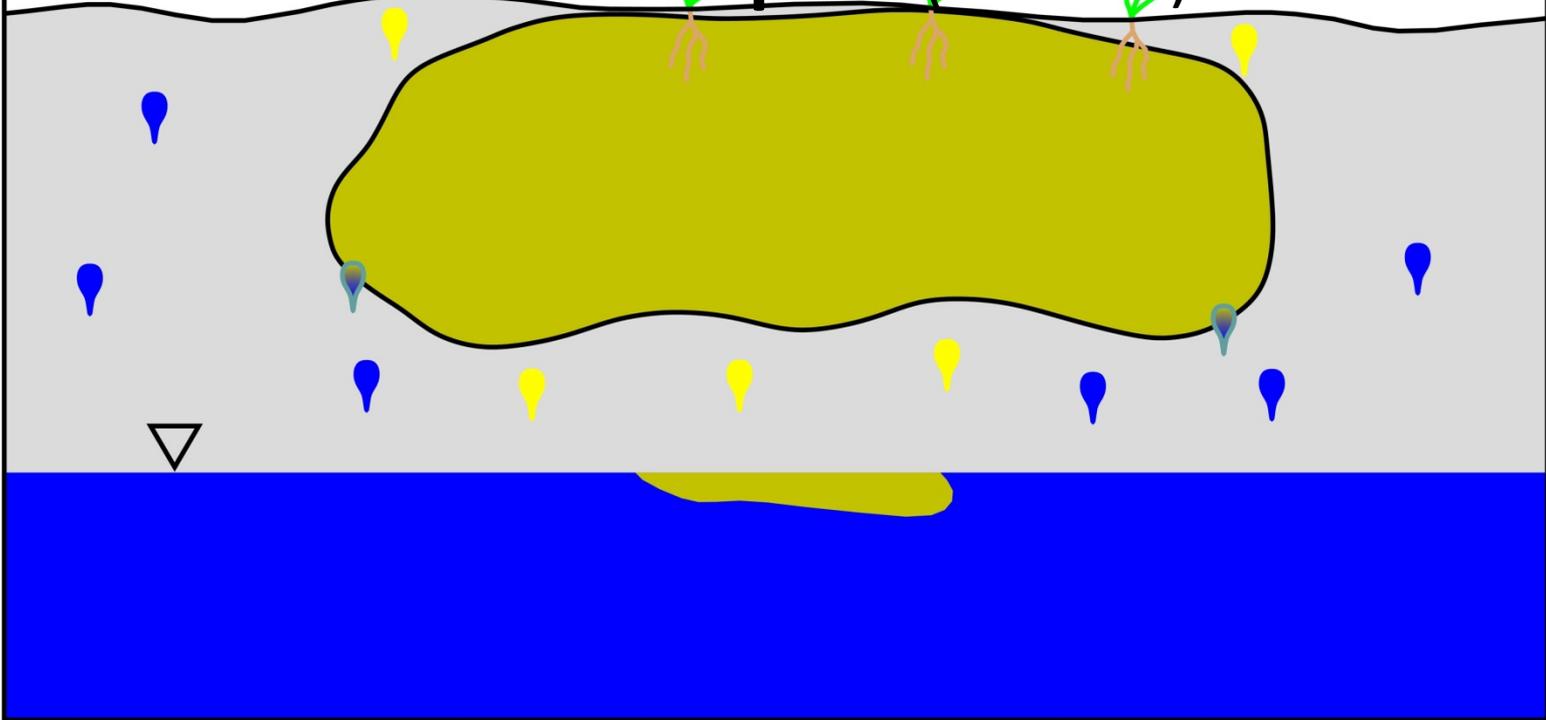


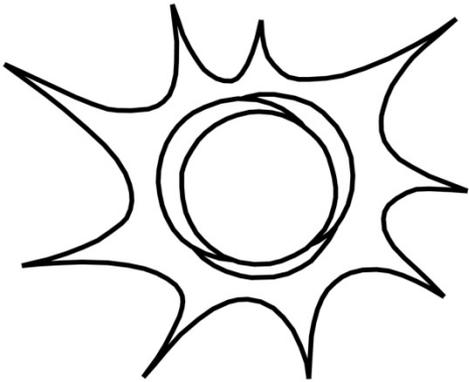


SNOW

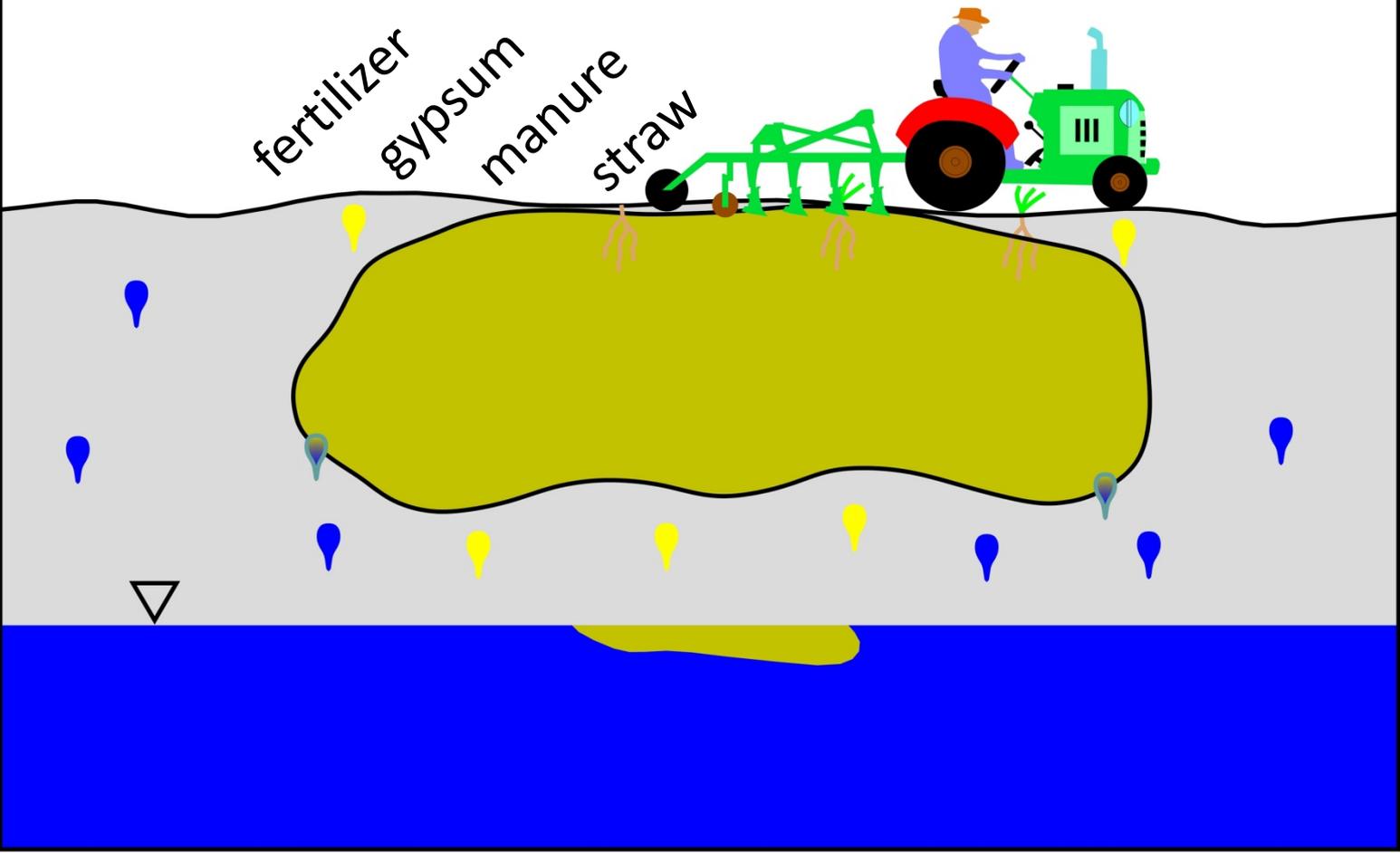


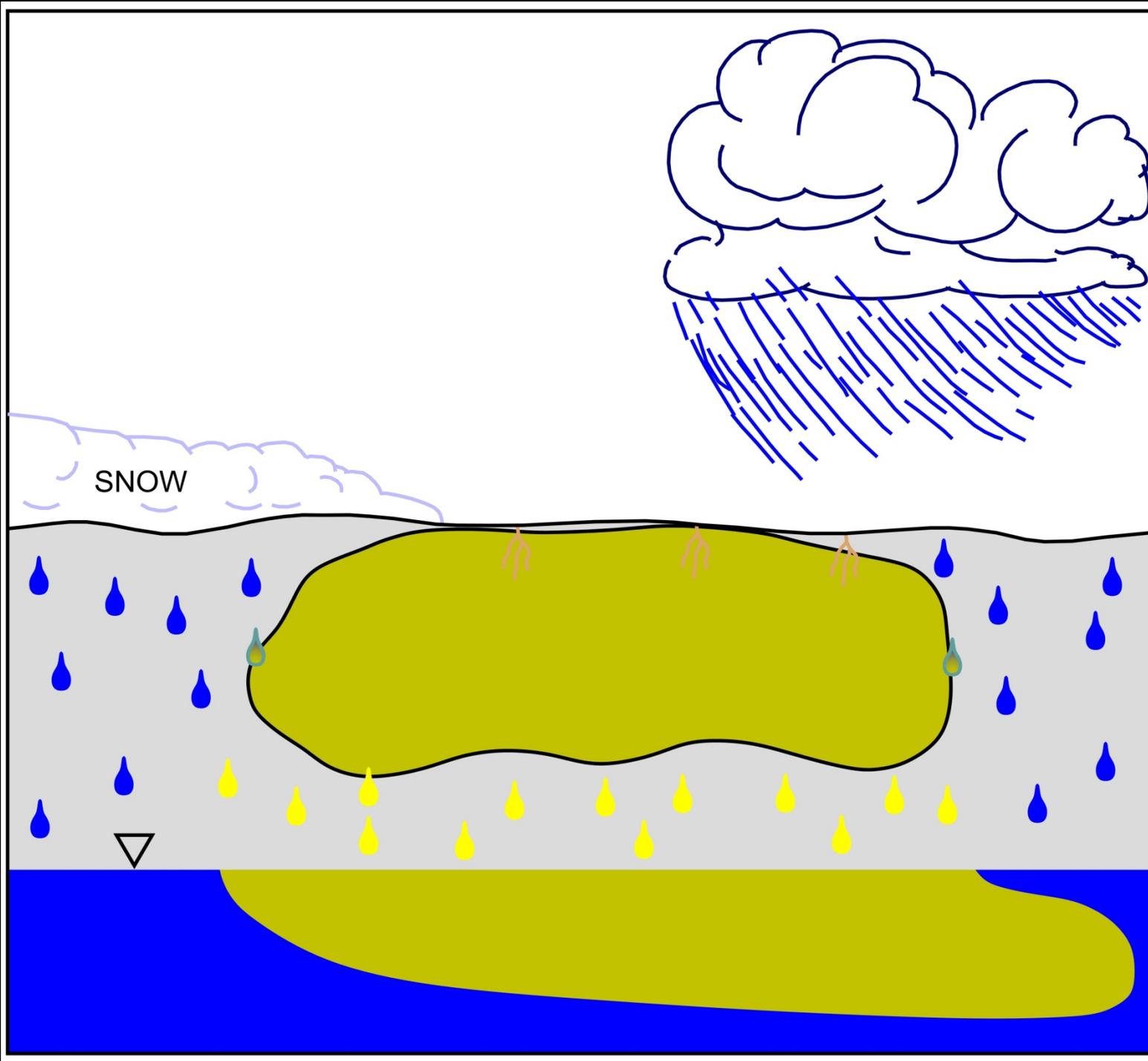
Hardpan (sodium)

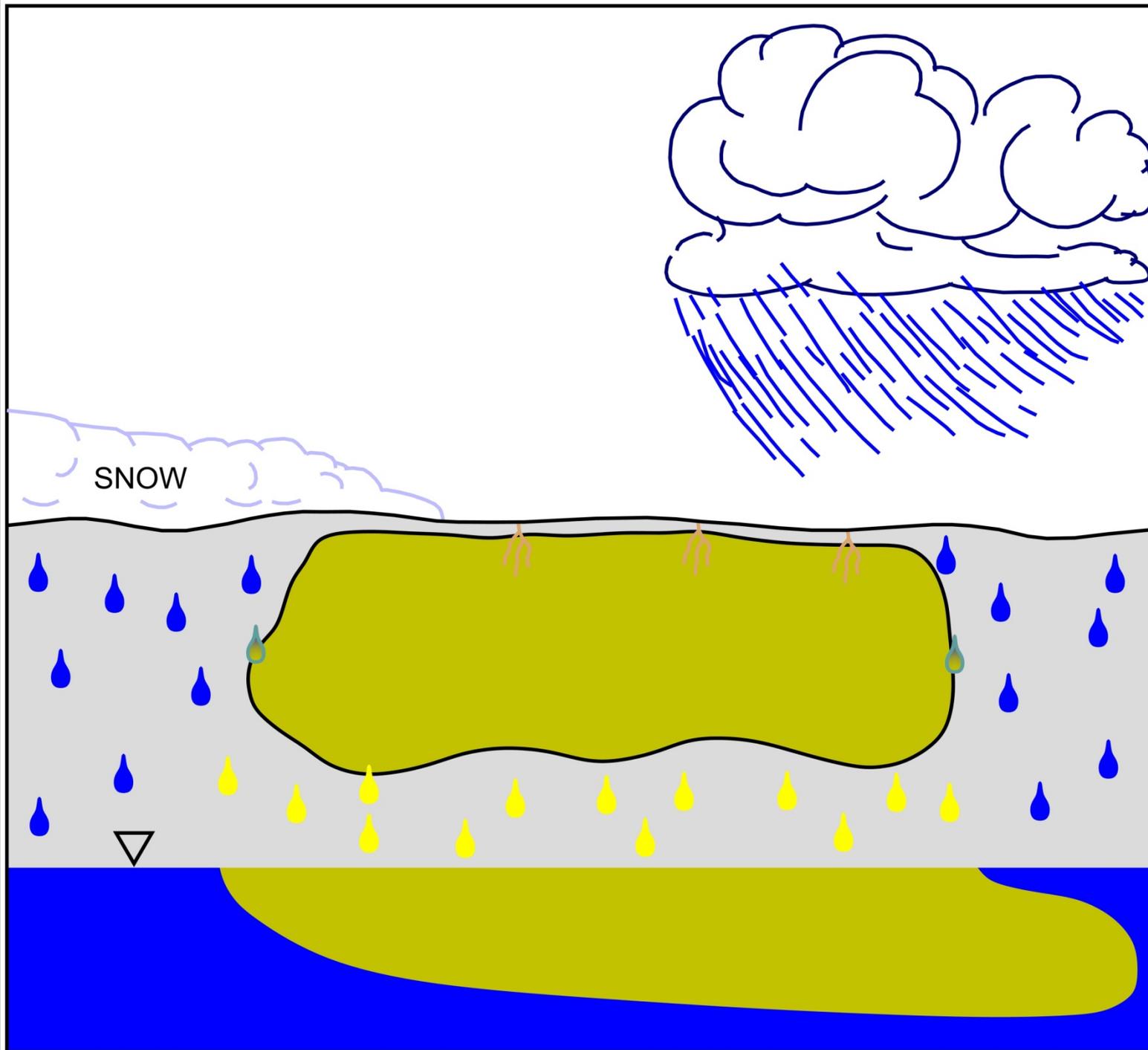


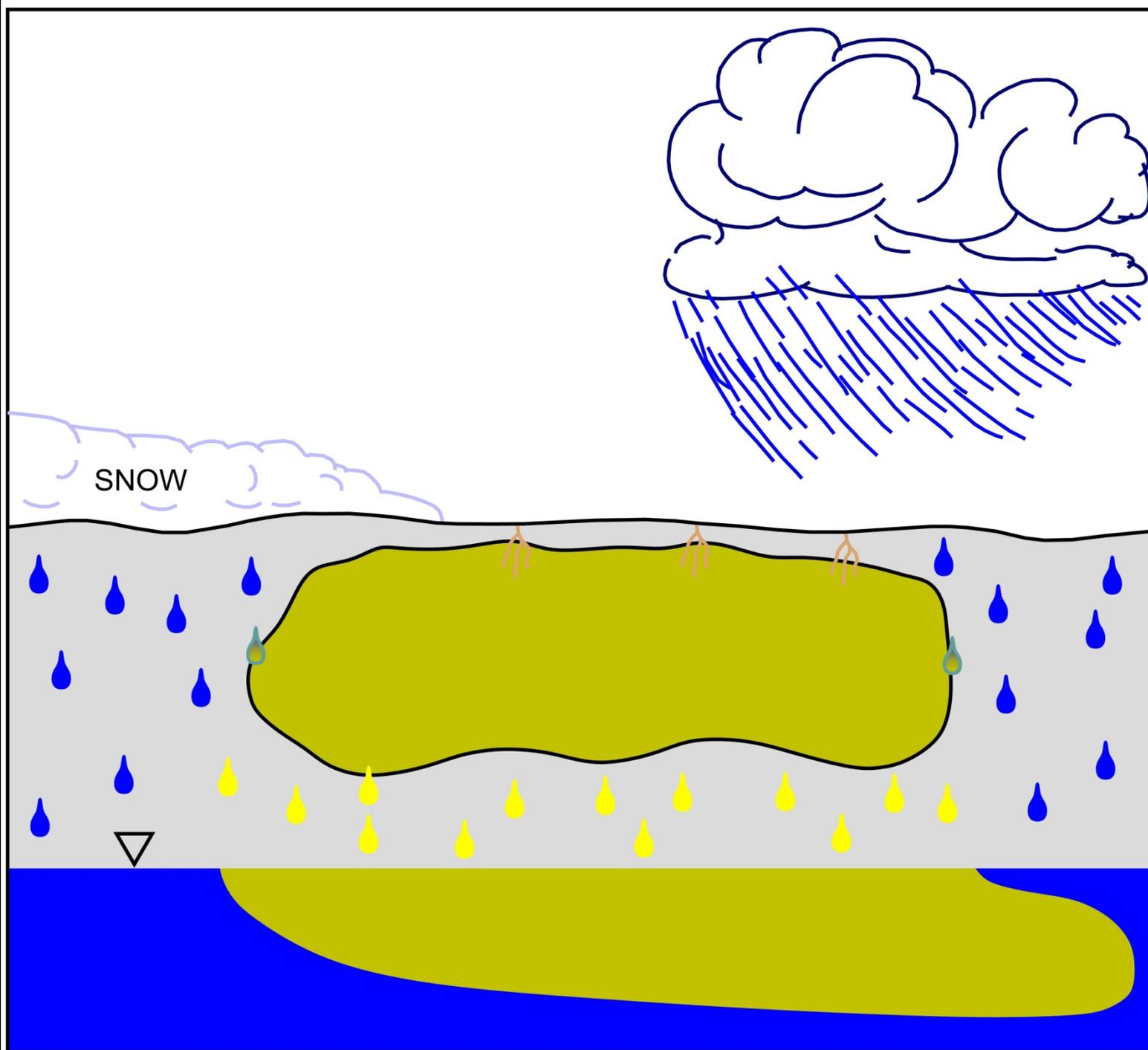


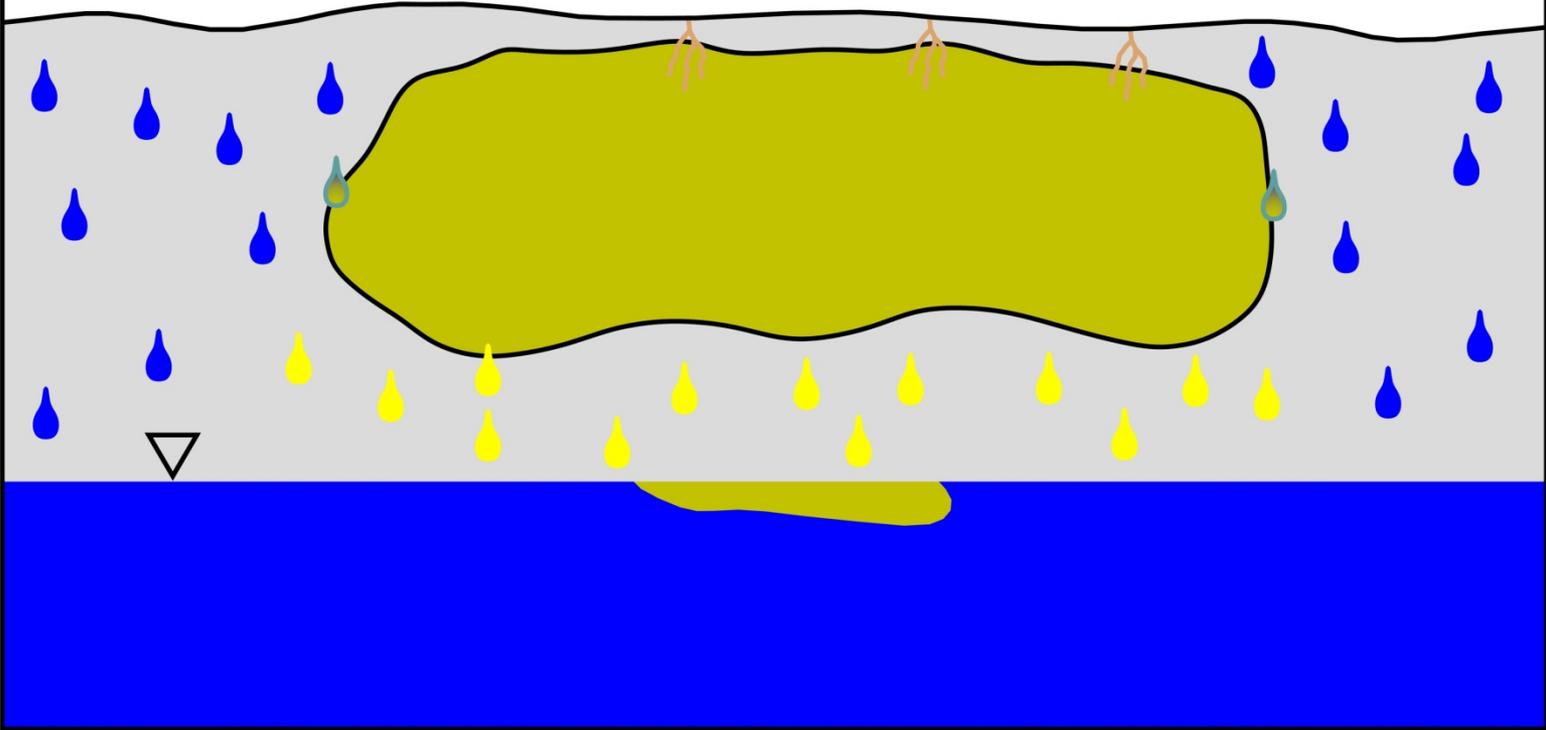
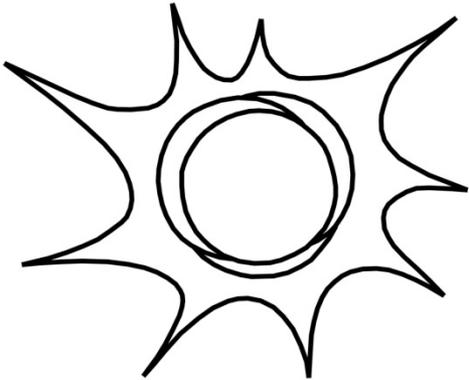
fertilizer
gypsum
manure
straw



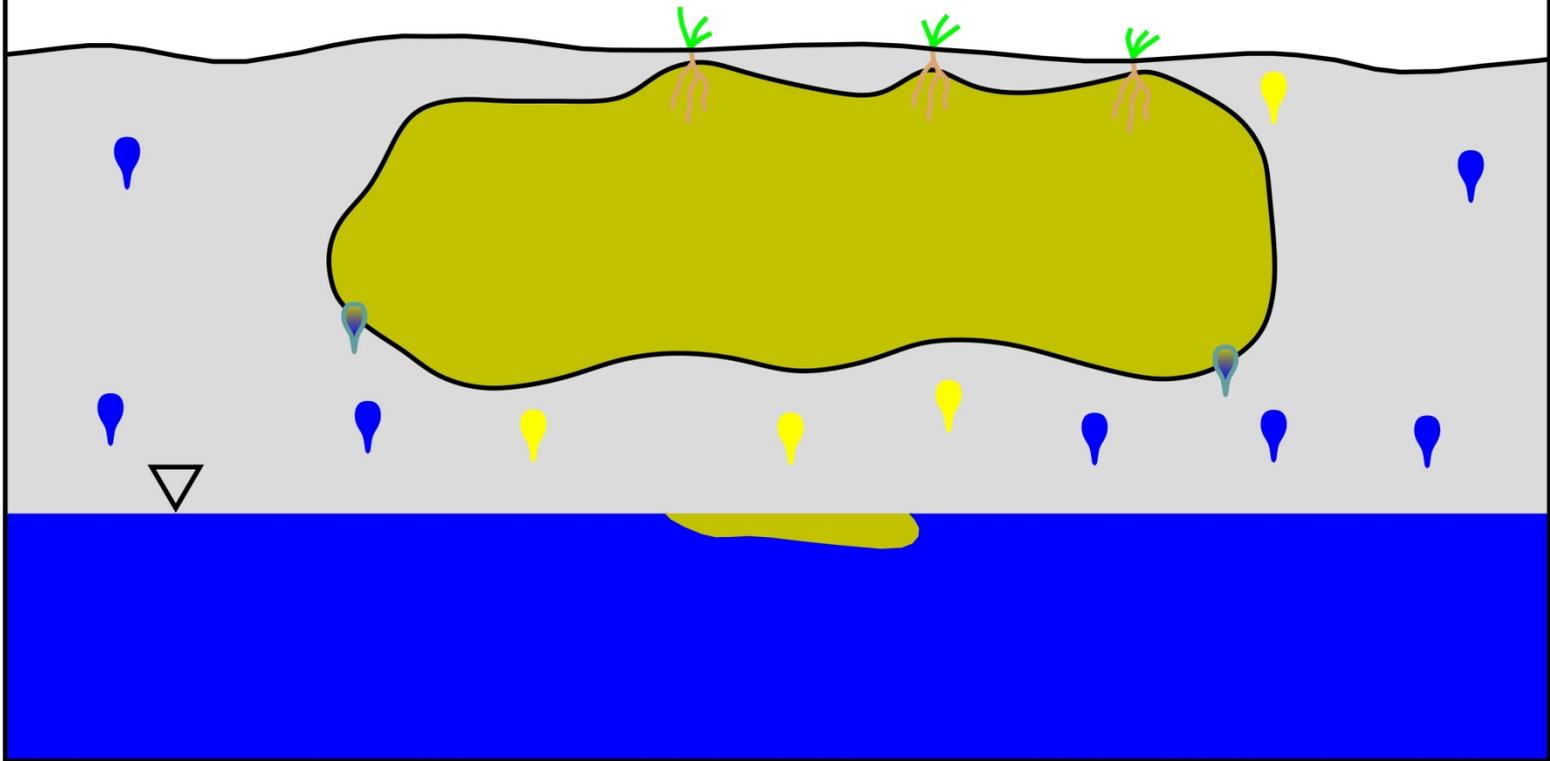
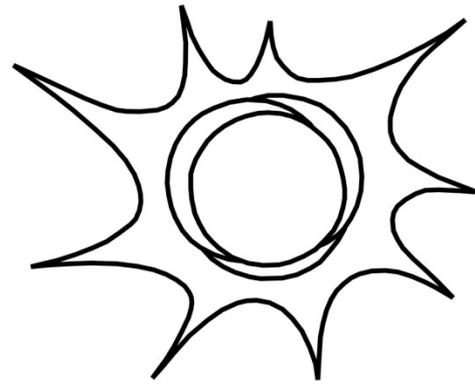




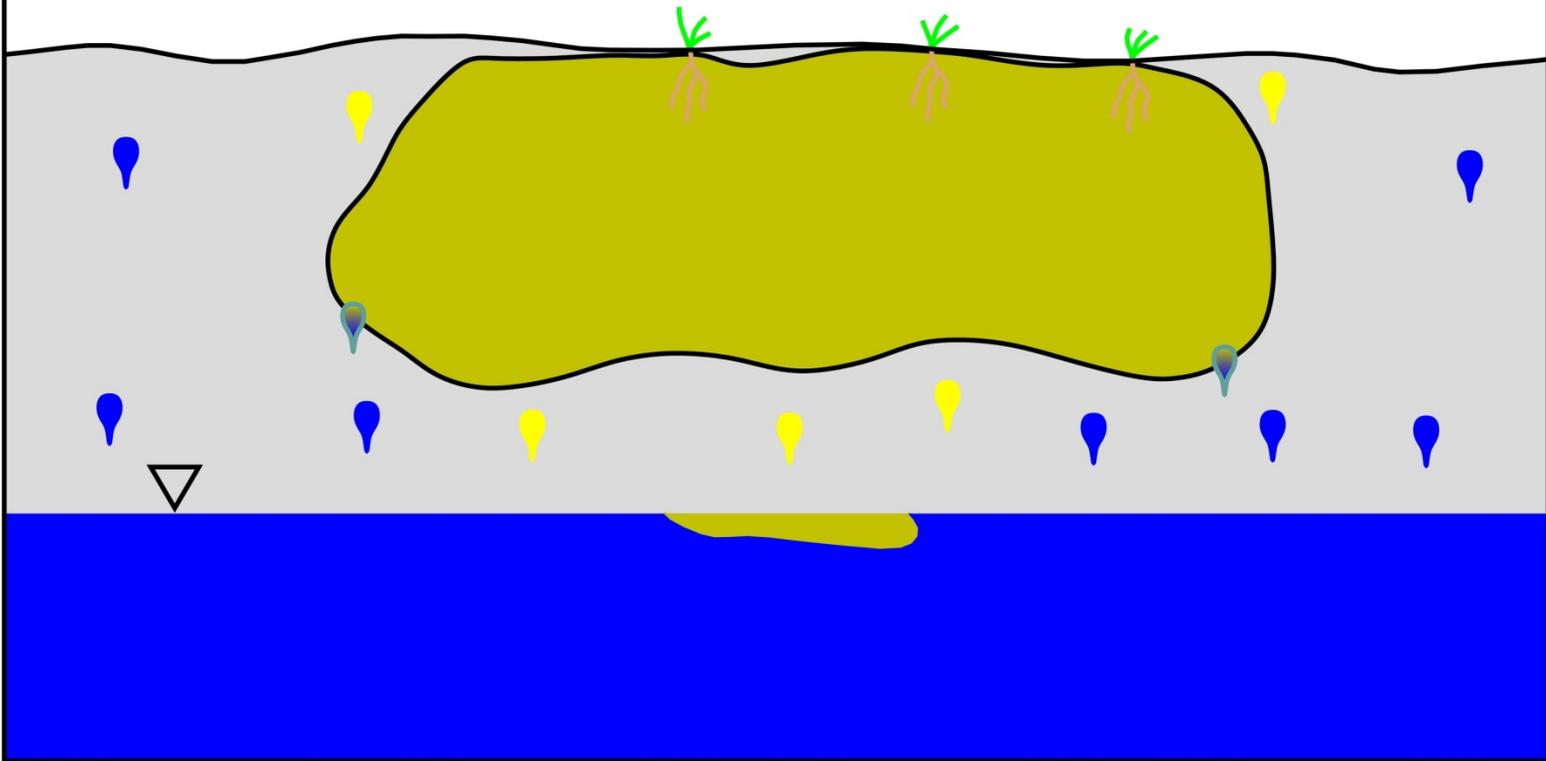
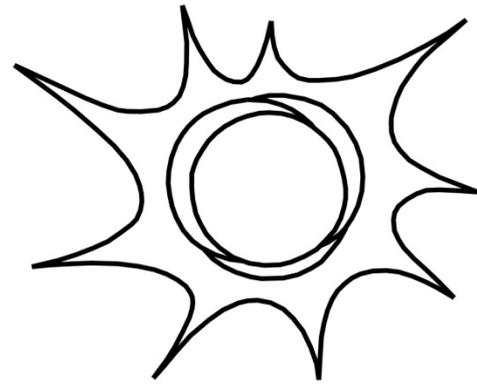




Going Forward



Going Forward



DURNIN SITE

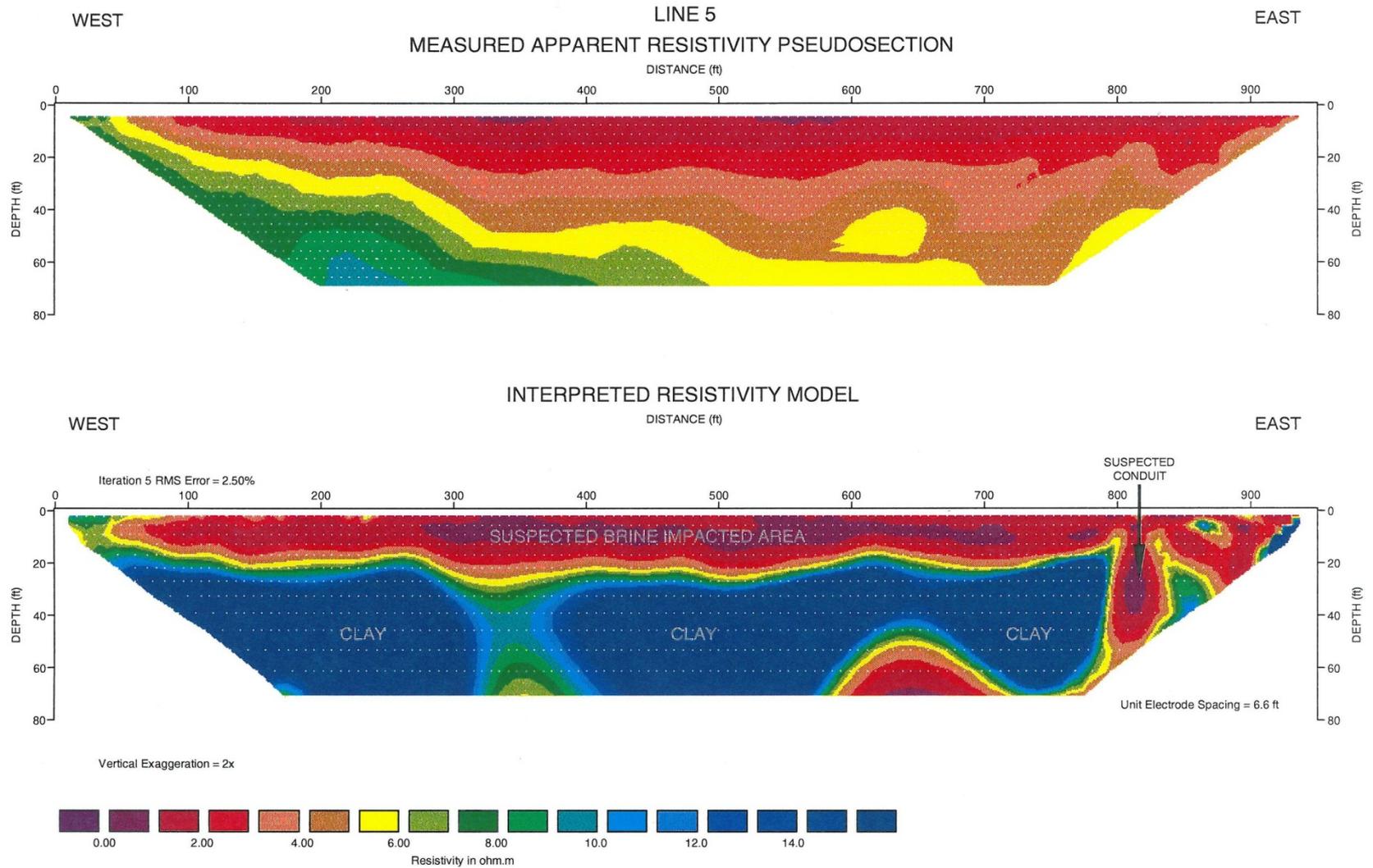


figure 7

ELECTRICAL RESISTIVITY RESULTS - LINE 5
CONOCO PHILLIPS COMPANY - WILEY FIELD
Bottineau County, North Dakota



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.

ADVANCES IN DRAIN TILE AND IRRIGATION FLUID CHEMISTRY



INFILTRATION GALLERY

