# Determining the Sources of Water for Conduit "Sandboil" Springs

Nachusa Grasslands, Franklin Grove

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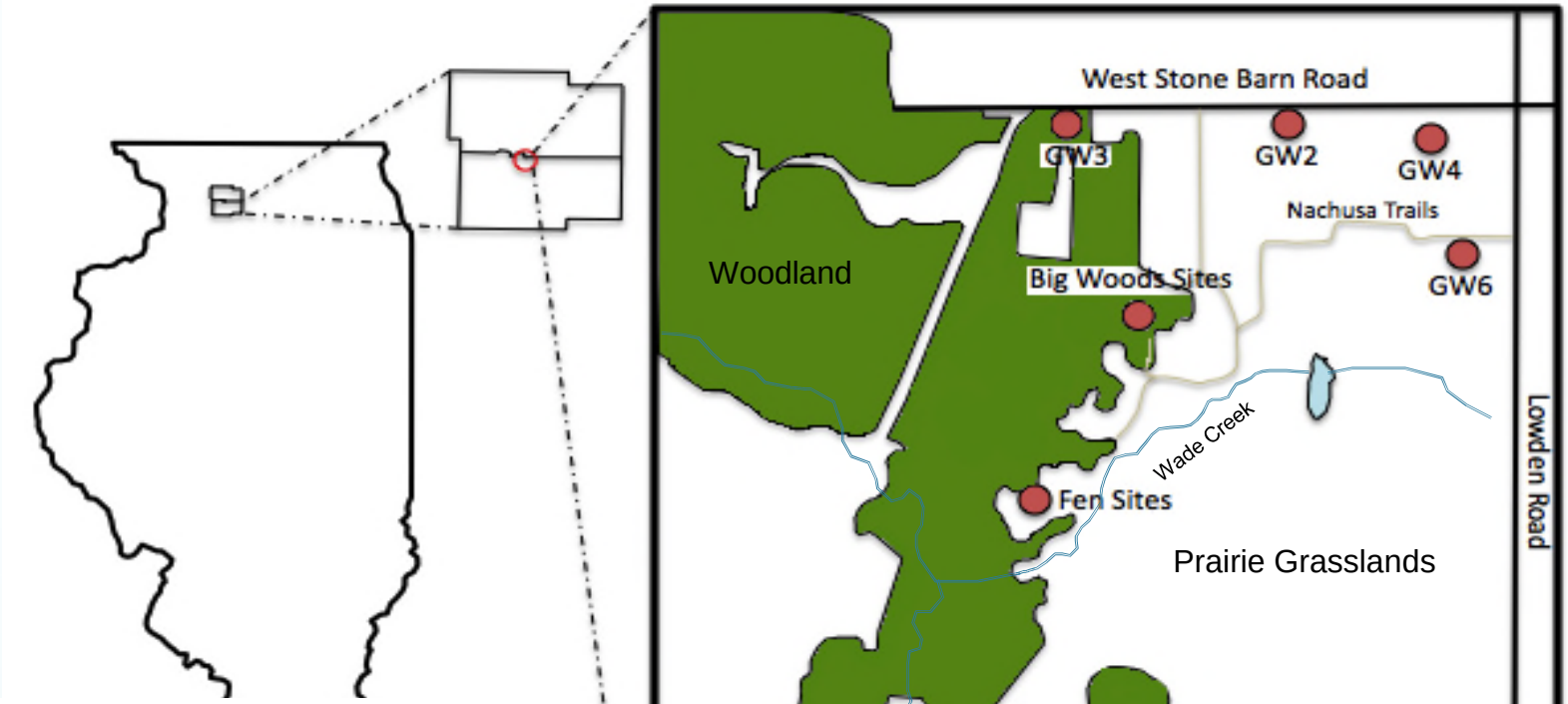
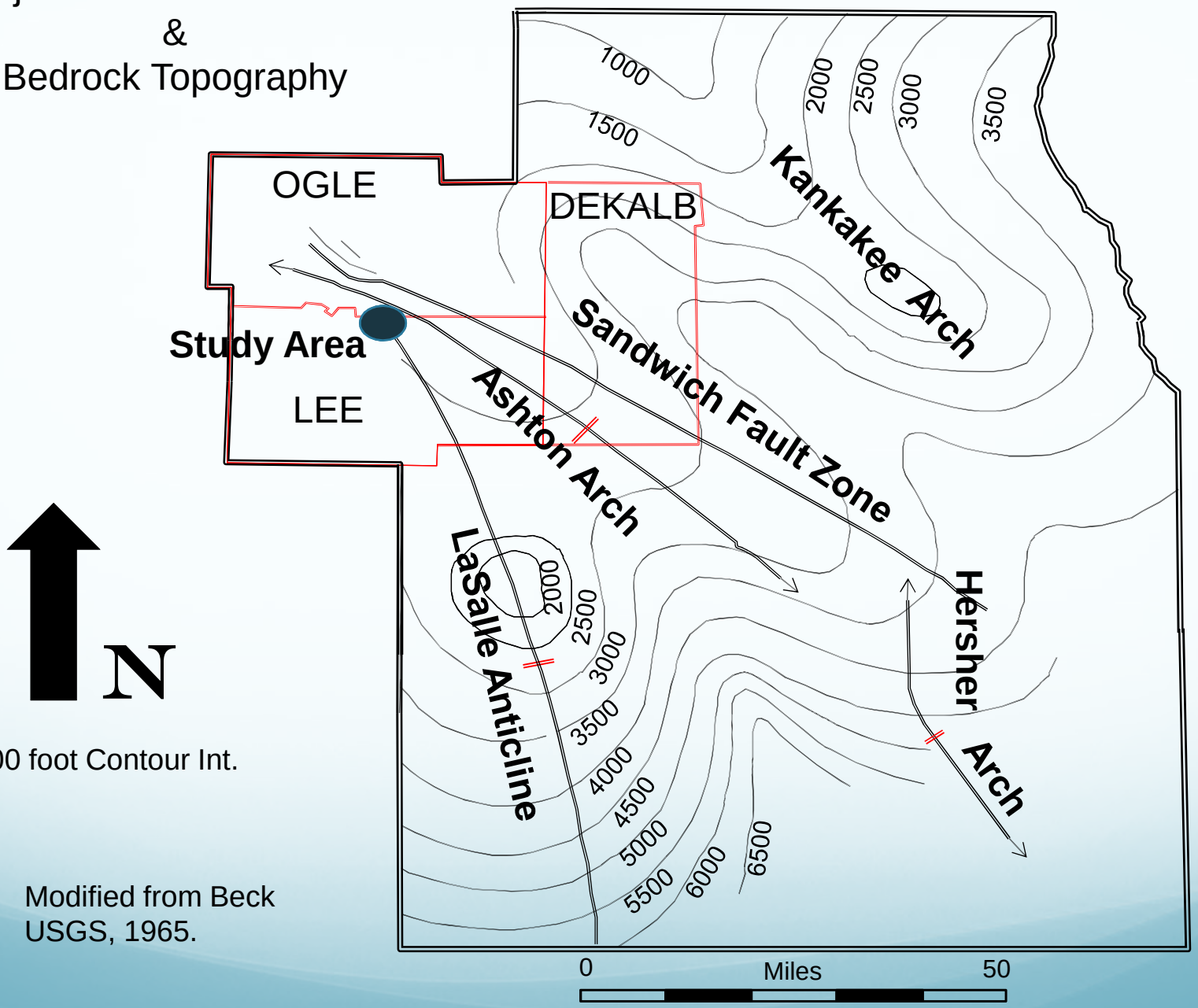
# Nachusa Grasslands



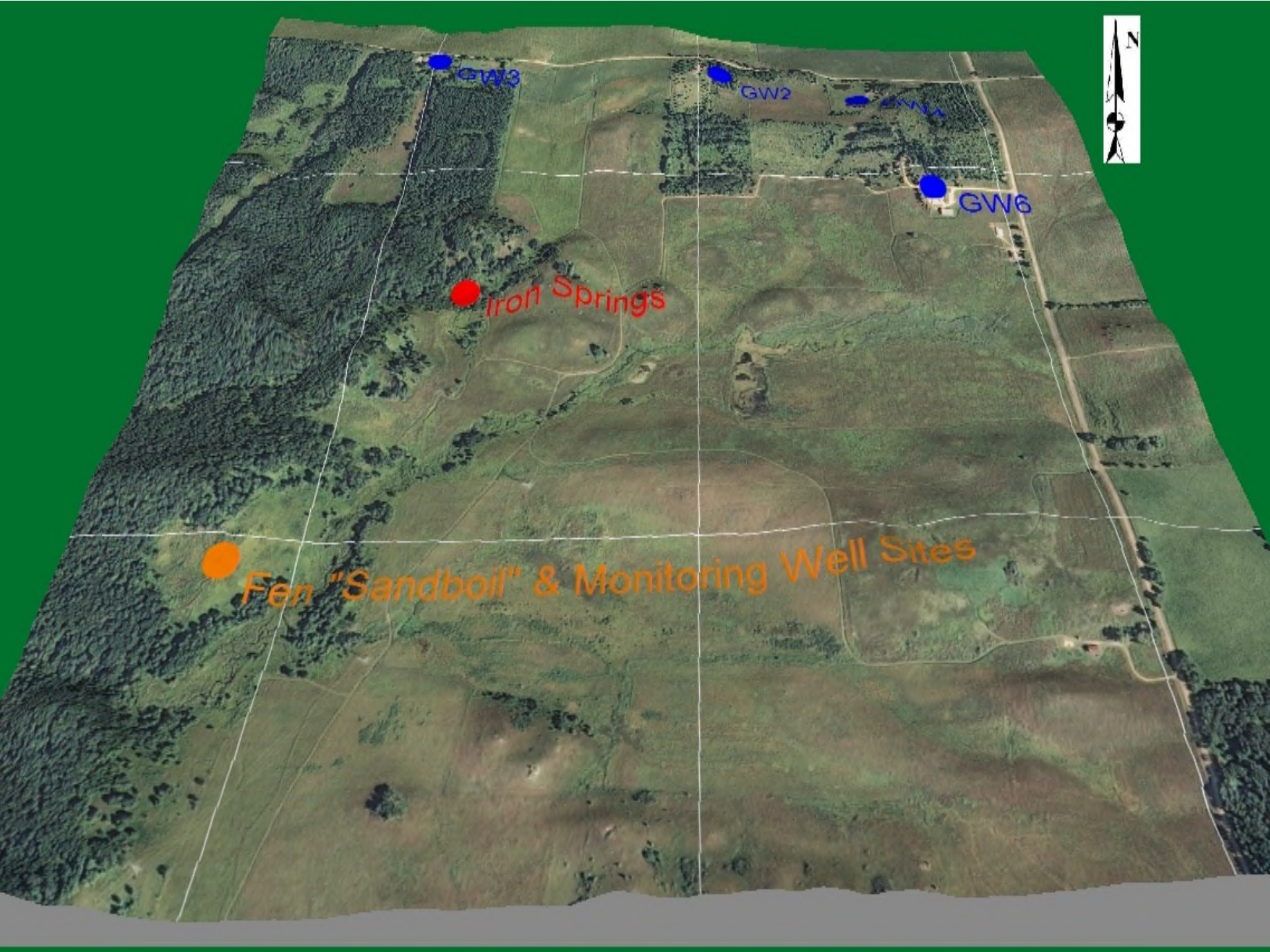

- Fen Spring Site
- Big Woods Unit
- Residential Wells
  - 6 Residential wells bordering the sites
  - Screened in St. Peters sandstone, Prairie du Chien Limestone, or a mixture of both

# Major Structural Features & Bedrock Topography

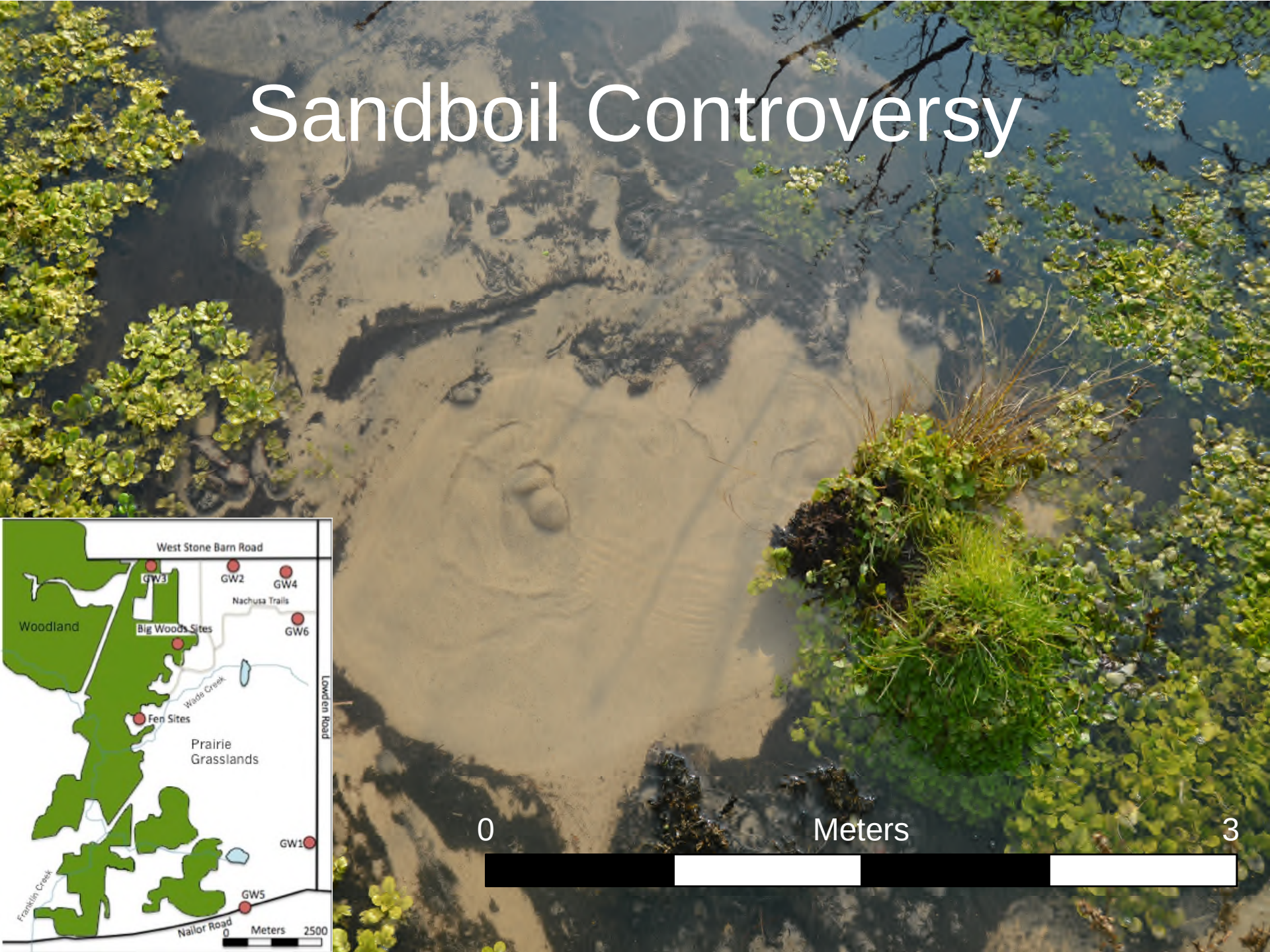



500 foot Contour Int.

Modified from Beck USGS, 1965.


GW3
GW2
GW4
GW6
Iron Springs
Fen "Sandboil" & Monitoring Well Sites
N

# Sandboil Controversy



# Objectives

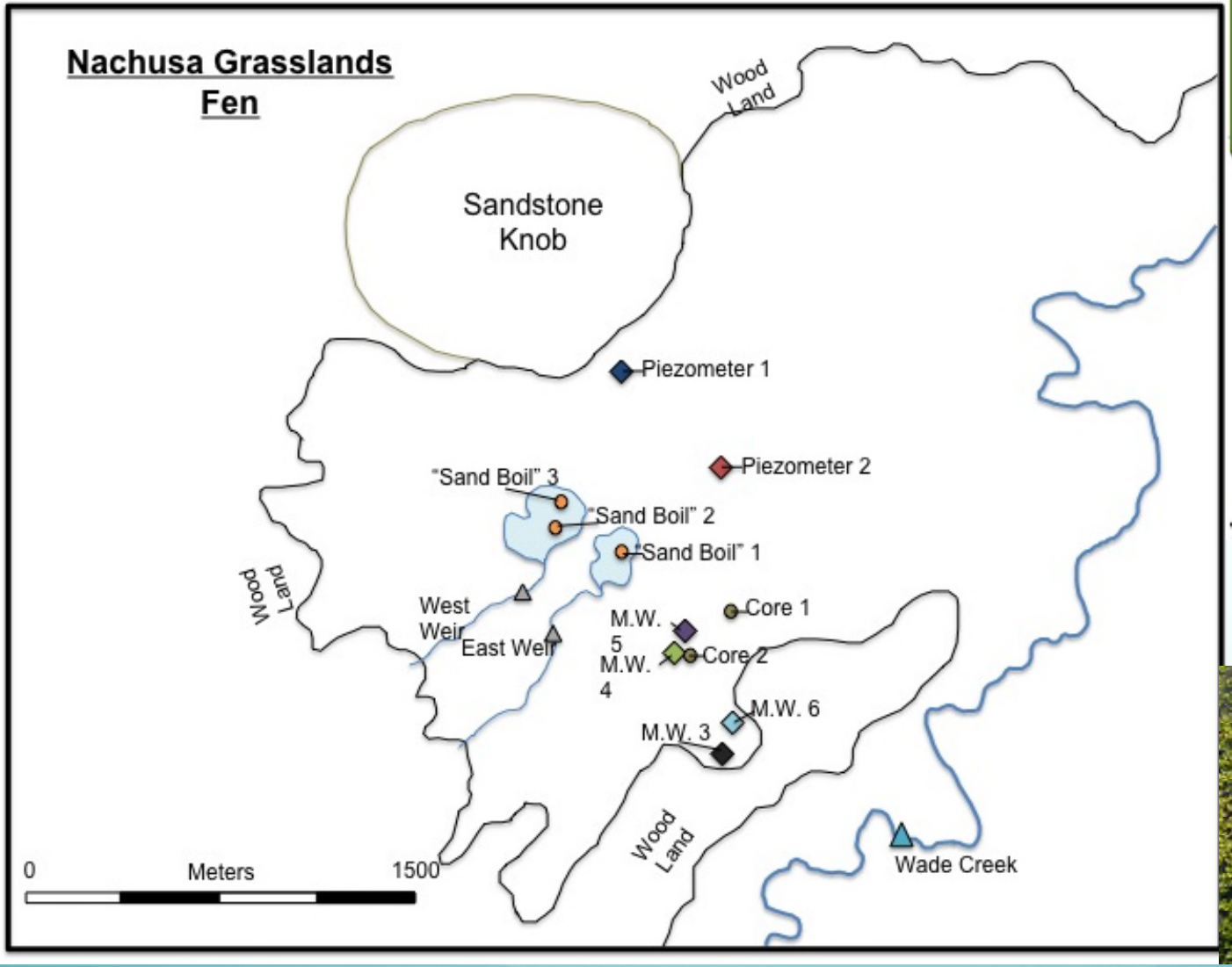
- The purpose of this research was to determine the source of water generating the Nachusa Sandboil springs, by utilizing geochemical and stable isotope groundwater and surface water analyses.

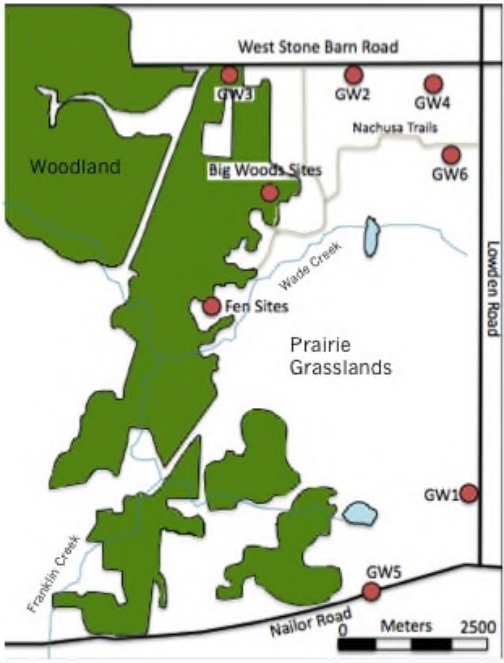
- Project Goals:
  1. Elucidate the subsurface geology influencing the hydrogeologic system (s).
  2. Characterize the geochemistry and stable isotopes of the surface water, sandstone conduits, and groundwater.
  3. Determine the main hydrologic influence of the springs, and any mixing between hydrologic systems.

# Hypothesis

- It was my hypothesis that the source of the sandboil springs originated from the upwelling of water from a deeper aquifer system, which flows through a fracture/conduit controlled subsurface within the St. Peter Sandstone Bedrock.

# Fen Sampling Sites



# Methodologies

- **Field Methods**

1. Geophysics and Lithologic Core Analysis
2. Water Sampling
3. Water Quality Analysis

- **Laboratory analytical methods**

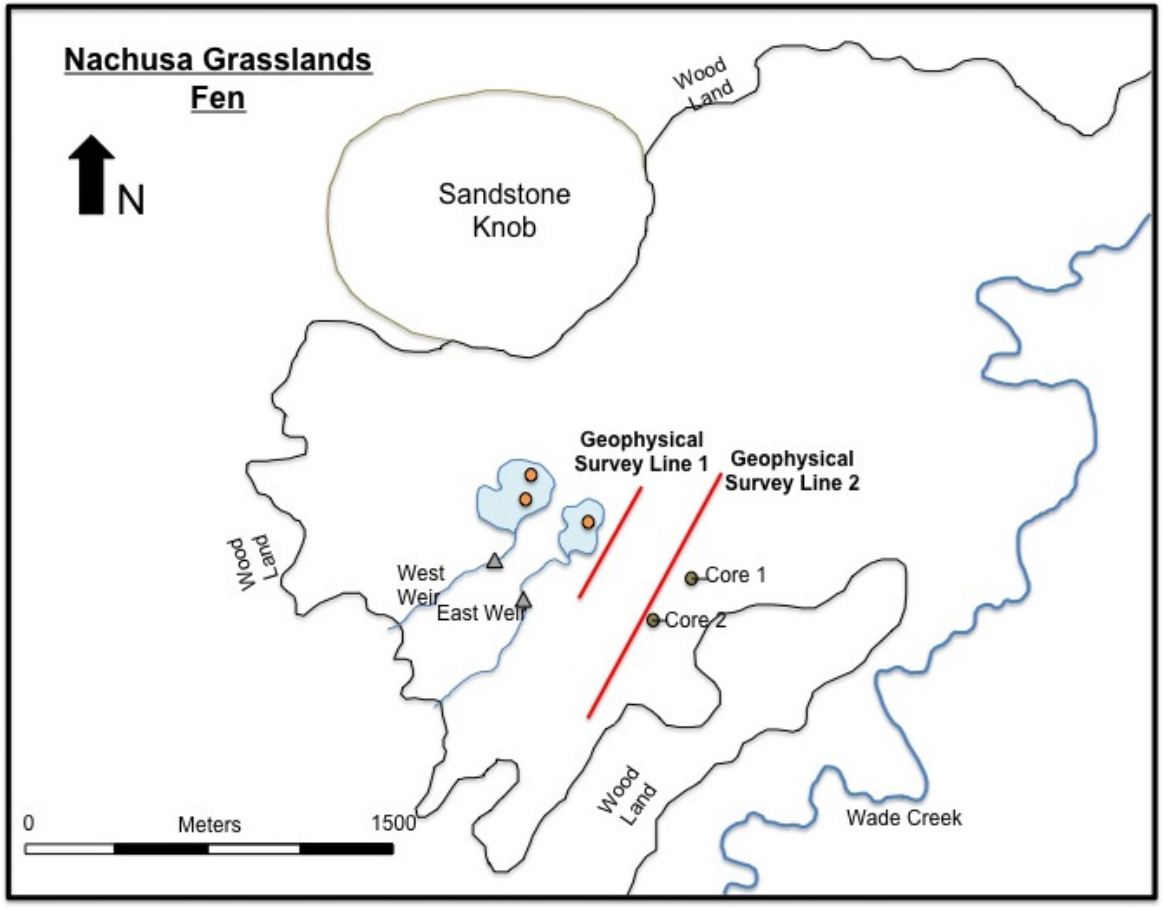
4. Geochemical Analysis
5. Stable Isotope Analysis

# Field Methods

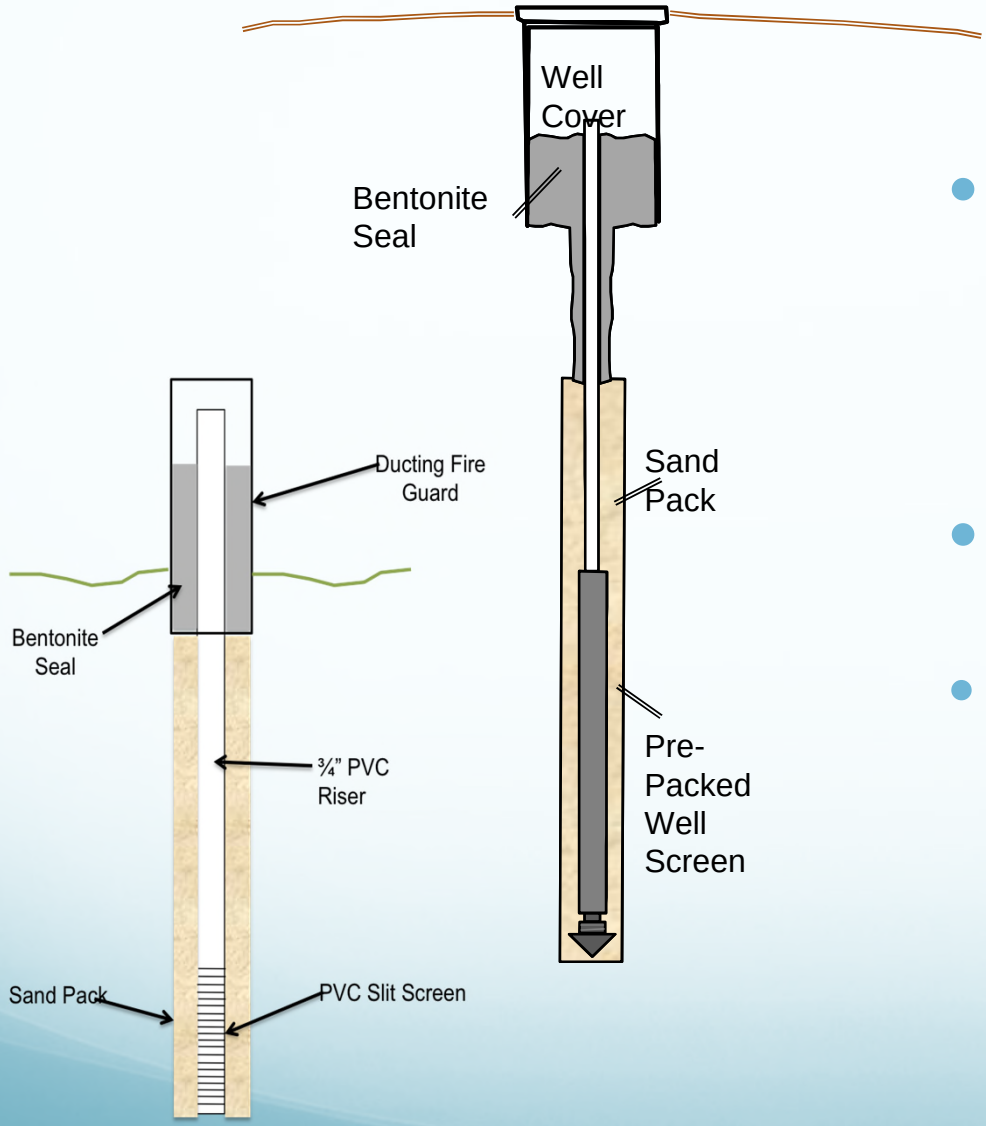
## 1a). Geophysics

- Resistivity Soundings
- Seismic Refraction
- Electromagnetic (EM)
- Ground Penetrating Radar (GPR)

# Survey Lines at the Fen



# Field Methods




## 1b).Well Installation & Coring

- 4-¾" diameter shallow piezometers
  - 5-10 feet deep
  - Screened in soil & Sandy or Limestone residuum
- 2 -1.5" diameter deep monitoring wells into St. Peter
- Cores collected and characterized from each site
  - Particle Size analysis
  - Field texturing and description

# Field Methods

## 2a). Surface Water Sampling

## 2b). Monitoring Well Sampling

## 2c. Residential Well Sampling

- Collected separate samples for bicarbonate, stable hydrogen and oxygen isotopes, major anions, and major cations

# 3). Water Geochemistry

## Major Cations

- ICP/MS Thermo Element 2
- Samples analyzed for Sr88, Ca44, Fe56, Na23, Mg24, K39.
- Followed EPA method 200.7
- Samples preserved with a 1% dilution of 70% nitric acid
- Samples Run both pure and diluted 1:100

## Major Anions

- DIONEX
  - Samples analyzed for $Fl^-$, $Cl^-$, $NO_2^-$ $NO_3^-$, Br-, $SO_4^{2-}$, $P0_4^{3-}$
  - Followed EPA method 300.0
- Bicarbonate $HCO_3^-$
  - HACH DR5000
    - TNT Total Alkalinity Test Kit
    - pH of samples is low enough that Alkalinity = Bicarbonate
  - S&F Analytical
    - 1 control set of samples sent to certified laboratory for titration

# 4). Stable Isotopes

## Hydrogen

- **$\delta^2$H** vSMOW
- Thermo THC/EA (Thermally coupled elemental Analyzer
  - Thermo MAT 253

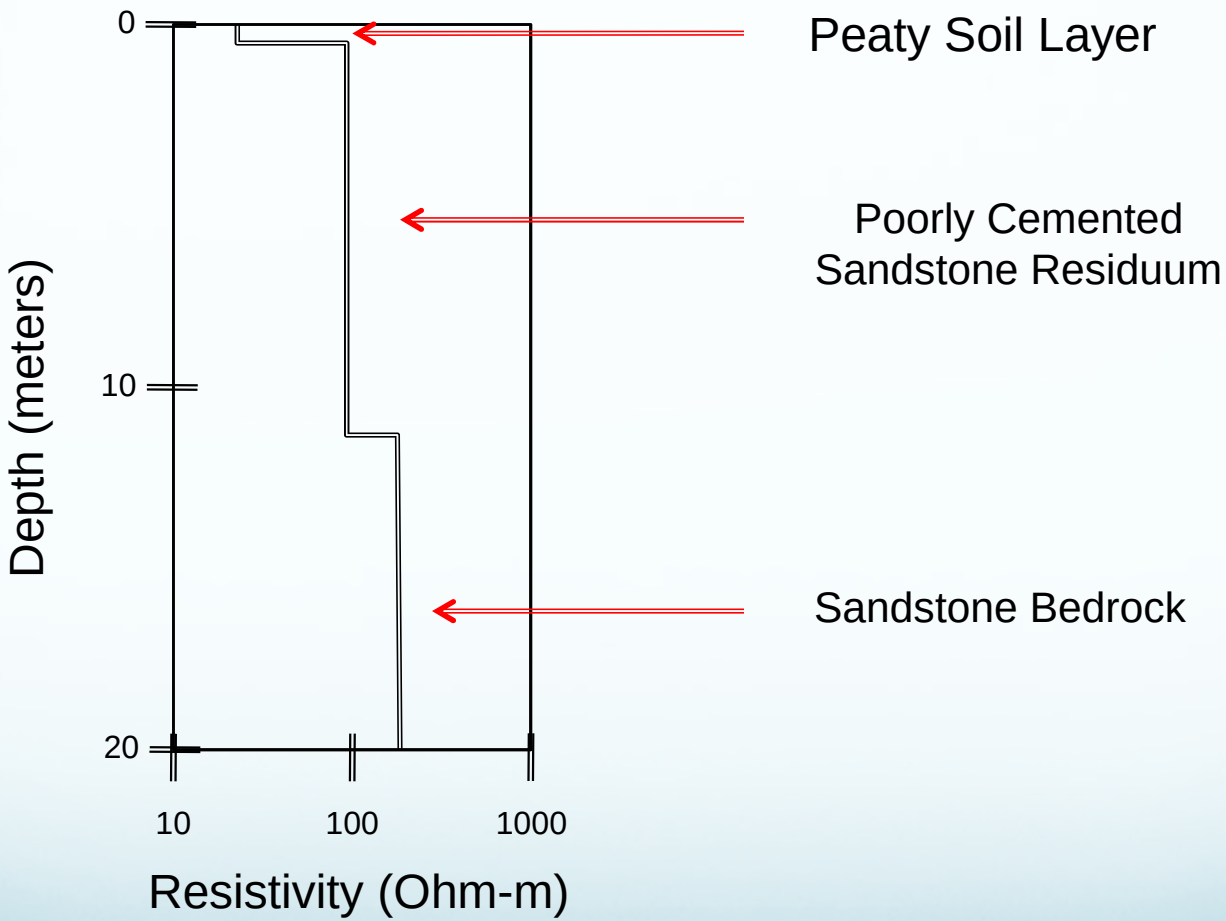
## Oxygen

- **$\delta^{18}$O** vSMOW
  - Gas Bench
- Thermo MAT 253

# RESULTS

# Subsurface

# Geophysics: Resistivity Results



# Particle Size Analysis (PSA)

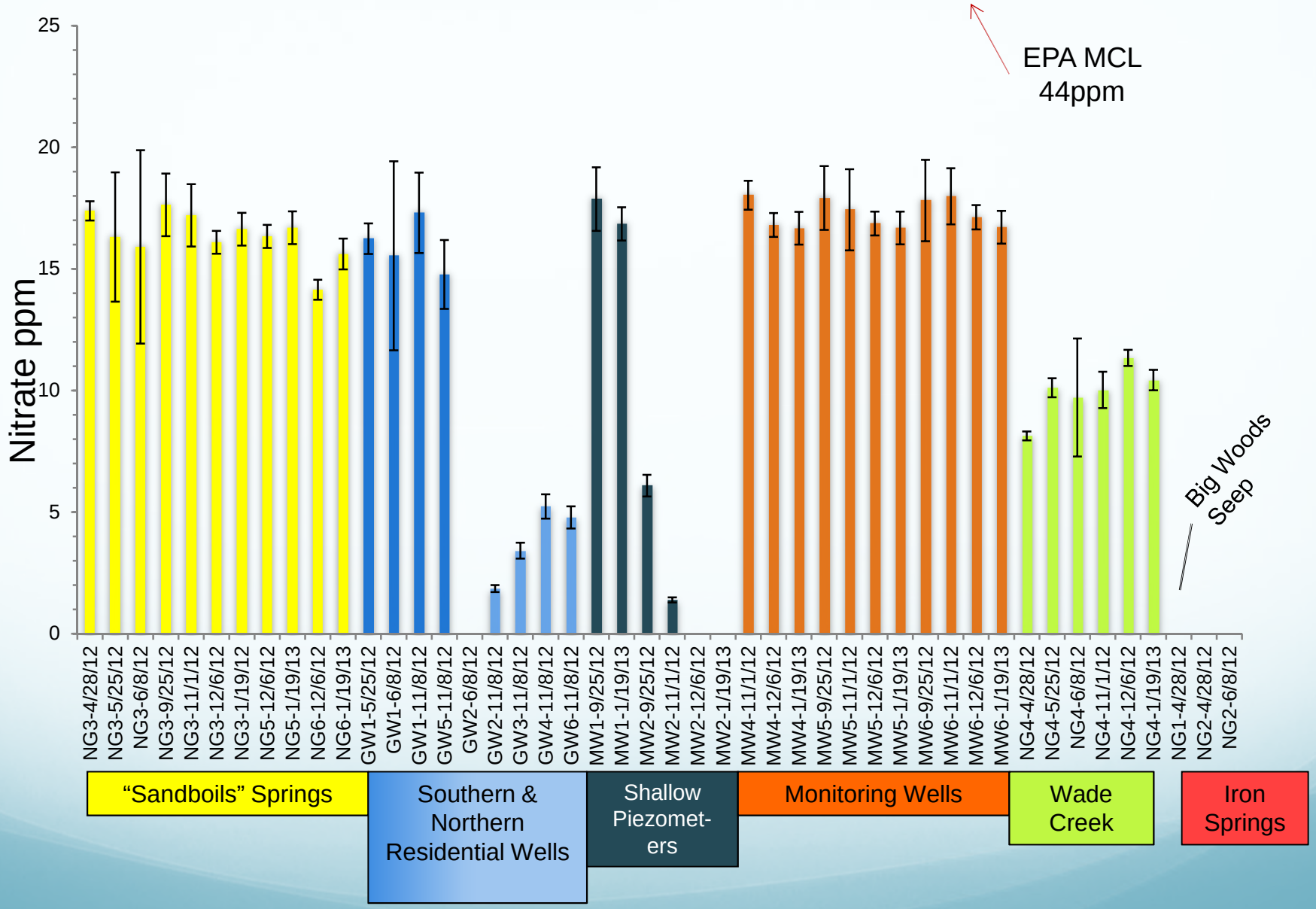
| | Wentworth Geometric Progression | | | | | | | | | | | | | | | USDA | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sand (mm) | | | | | | Silt (mm) | | | | | | | | Clay | Sand | Silt | Clay |
| Sample | VCS | CS | MS | FS | VFS | TS | VCSi a | VCSi b | VCSi | CSi | MSi | FSi | VFSi | TSi | TC | TS | TSi | TC |
| ID | 2-1 | 1-0.5 | 0.5-0.25 | 0.25-0.125 | 0.125-0.063 | 2-0.063 | 63-53 | 53-32 | 63-32 | 32-16 | 16-8 | 8-4 | 4-2 | 63-2 | < 2 mm | 2-0.053 mm | 53-2 mm | < 2 mm |
| MW6 (0-1') | 0.4 | 5.5 | 23.0 | 25.3 | 3.7 | 57.9 | 0.0 | 3.9 | 3.9 | 13.1 | 8.5 | 1.8 | 3.9 | 31.2 | 10.8 | 57.9 | 31.2 | 10.8 |
| MW6 (1-1.9') | 2.1 | 4.9 | 20.0 | 25.9 | 3.6 | 56.5 | 0.1 | 2.3 | 2.4 | 12.0 | 6.1 | 1.2 | 3.3 | 25.0 | 18.5 | 56.6 | 24.9 | 18.5 |
| MW6 (1.9-2.4') | 0.0 | 0.9 | 6.0 | 9.5 | 2.4 | 18.8 | 6.1 | 10.9 | 17.1 | 12.6 | 14.2 | 3.1 | 6.0 | 52.9 | 28.2 | 24.9 | 46.8 | 28.2 |
| MW6 (2.4-3.9') | 0.4 | 5.5 | 36.3 | 42.6 | 5.5 | 90.2 | 0.0 | 0.0 | 0.0 | 5.5 | 0.5 | 0.1 | 0.7 | 6.8 | 3.0 | 90.2 | 6.8 | 3.0 |
| MW6 (3.9-8.7') | 0.1 | 5.8 | 44.2 | 34.8 | 2.3 | 87.2 | 0.0 | 0.6 | 0.6 | 8.0 | 2.8 | 0.4 | 0.4 | 12.3 | 0.4 | 87.2 | 12.3 | 0.4 |
| MW6 (8.7-11.5') | 0.0 | 7.2 | 55.5 | 28.0 | 2.0 | 92.8 | 0.0 | 0.2 | 0.2 | 3.2 | 0.4 | 0.4 | 0.7 | 4.9 | 2.3 | 92.8 | 4.9 | 2.3 |
| MW6 (15.5-19.5') | 0.1 | 8.5 | 45.9 | 36.9 | 2.3 | 93.7 | 0.0 | 0.0 | 0.0 | 2.8 | 0.4 | 0.4 | 0.4 | 4.1 | 2.2 | 93.7 | 4.1 | 2.2 |
| MW6 (19.5-23.5') | 0.0 | 3.7 | 58.6 | 34.9 | 0.6 | 97.8 | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.4 | 1.0 | 1.8 | 0.3 | 97.8 | 1.8 | 0.3 |
| MW6 (23.5-27.5') | 0.2 | 11.5 | 63.1 | 21.5 | 0.5 | 96.9 | 0.0 | 0.0 | 0.0 | 0.2 | 1.1 | 1.1 | 0.3 | 2.7 | 0.4 | 96.9 | 2.7 | 0.4 |
| MW6 (27.5-31.5') | 0.0 | 6.3 | 47.1 | 41.7 | 1.3 | 96.3 | 0.0 | 0.0 | 0.0 | 1.1 | 0.3 | 1.1 | 0.5 | 2.9 | 0.7 | 96.3 | 2.9 | 0.7 |
| C2 (5.3-7.5') | 1.1 | 9.4 | 38.7 | 41.0 | 4.7 | 94.9 | 0.0 | 0.2 | 0.2 | 0.3 | 0.6 | 1.0 | 2.6 | 4.7 | 0.4 | 94.9 | 4.7 | 0.4 |
| C2 (17.5-18.3') | 0.0 | 9.0 | 39.1 | 49.3 | 0.4 | 97.9 | 0.0 | 0.0 | 0.0 | 0.2 | 0.6 | 0.7 | 0.2 | 1.7 | 0.4 | 97.9 | 1.7 | 0.4 |
| C2 (18.3-18.8') | 2.5 | 10.1 | 44.3 | 36.7 | 0.5 | 94.1 | 0.0 | 0.0 | 0.0 | 0.8 | 2.0 | 1.9 | 0.9 | 5.6 | 0.3 | 94.1 | 5.6 | 0.3 |
| C1 (Grab ~ 7.5') | 0.9 | 16.8 | 70.3 | 8.5 | 0.0 | 96.5 | 0.0 | 0.0 | 0.0 | 0.1 | 1.8 | 1.0 | 0.2 | 3.2 | 0.3 | 96.5 | 3.2 | 0.3 |
| C1 (Grab ~11.5') | 50.3 | 21.3 | 8.6 | 4.7 | 0.0 | 84.9 | 0.0 | 0.0 | 0.0 | 0.2 | 7.7 | 6.4 | 0.3 | 14.6 | 0.5 | 84.9 | 14.6 | 0.5 |
| NG3 (Grab Sample) | 1.1 | 22.9 | 69.2 | 3.7 | 0.0 | 96.9 | 0.0 | 0.0 | 0.0 | 0.2 | 2.4 | 0.1 | 0.3 | 3.0 | 0.2 | 96.9 | 3.0 | 0.2 |
| NG5 (Grab Sample) | 2.6 | 47.3 | 43.9 | 4.2 | 0.0 | 98.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.3 | 0.9 | 1.6 | 0.4 | 98.0 | 1.6 | 0.4 |
| NG6 (Grab Sample) | 0.0 | 4.4 | 36.4 | 55.2 | 0.9 | 96.9 | 0.0 | 0.0 | 0.0 | 0.4 | 0.5 | 0.3 | 1.6 | 2.7 | 0.4 | 96.9 | 2.7 | 0.4 |

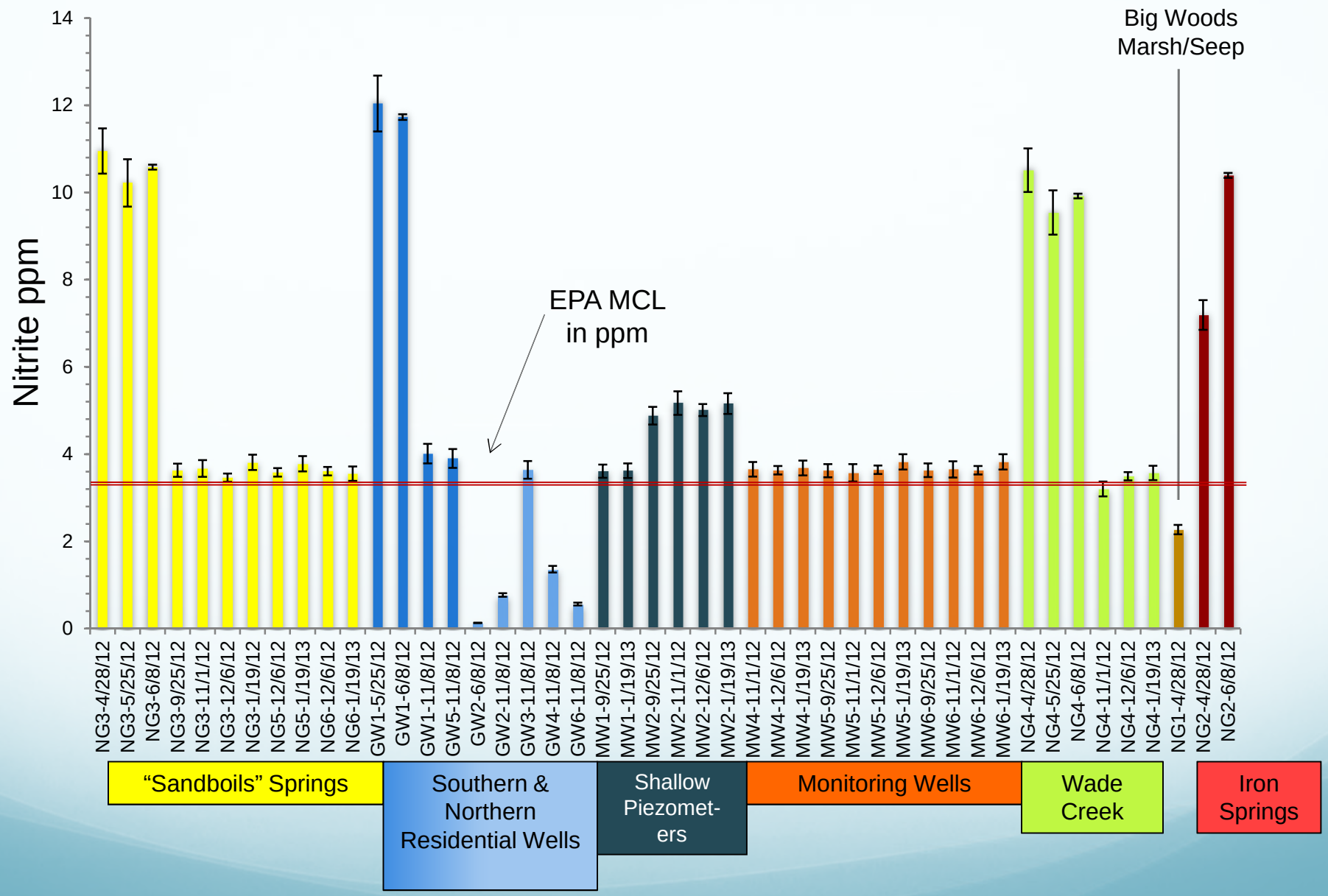
Heaving Sand/Gravel Anomaly

Sandboils

St. Peter Sandstone

# Water Quality


Nitrate ppm
25
20
15
10
5
0
EPA MCL
44ppm
Big Woods
Seep
NG3-4/28/12
NG3-5/25/12
NG3-6/8/12
NG3-9/25/12
NG3-11/1/12
NG3-12/6/12
NG3-1/19/12
NG5-12/6/12
NG5-1/19/13
NG6-12/6/12
NG6-1/19/13
GW1-5/25/12
GW1-6/8/12
GW1-11/8/12
GW5-11/8/12
GW2-6/8/12
GW2-11/8/12
GW3-11/8/12
GW4-11/8/12
GW6-11/8/12
MW1-9/25/12
MW1-1/19/13
MW2-9/25/12
MW2-11/1/12
MW2-12/6/12
MW2-1/19/13
MW4-11/1/12
MW4-12/6/12
MW4-1/19/13
MW5-9/25/12
MW5-11/1/12
MW5-12/6/12
MW5-1/19/13
MW6-9/25/12
MW6-11/1/12
MW6-12/6/12
MW6-1/19/13
NG4-4/28/12
NG4-5/25/12
NG4-6/8/12
NG4-11/1/12
NG4-12/6/12
NG4-1/19/13
NG1-4/28/12
NG2-4/28/12
NG2-6/8/12
"Sandboils" Springs
Southern & Northern Residential Wells
Shallow Piezomet-ers
Monitoring Wells
Wade Creek
Iron Springs


Nitrite ppm
14
12
10
8
6
4
2
0
EPA MCL
in ppm
Big Woods
Marsh/Seep
NG3-4/28/12
NG3-5/25/12
NG3-6/8/12
NG3-9/25/12
NG3-11/1/12
NG3-12/6/12
NG3-1/19/12
NG5-12/6/12
NG5-1/19/13
NG6-12/6/12
NG6-1/19/13
GW1-5/25/12
GW1-6/8/12
GW1-11/8/12
GW5-11/8/12
GW2-6/8/12
GW2-11/8/12
GW3-11/8/12
GW4-11/8/12
GW6-11/8/12
MW1-9/25/12
MW1-1/19/13
MW2-9/25/12
MW2-11/1/12
MW2-12/6/12
MW2-1/19/13
MW4-11/1/12
MW4-12/6/12
MW4-1/19/13
MW5-9/25/12
MW5-11/1/12
MW5-12/6/12
MW5-1/19/13
MW6-9/25/12
MW6-11/1/12
MW6-12/6/12
MW6-1/19/13
NG4-4/28/12
NG4-5/25/12
NG4-6/8/12
NG4-11/1/12
NG4-12/6/12
NG4-1/19/13
NG1-4/28/12
NG2-4/28/12
NG2-6/8/12
"Sandboils" Springs
Southern & Northern Residential Wells
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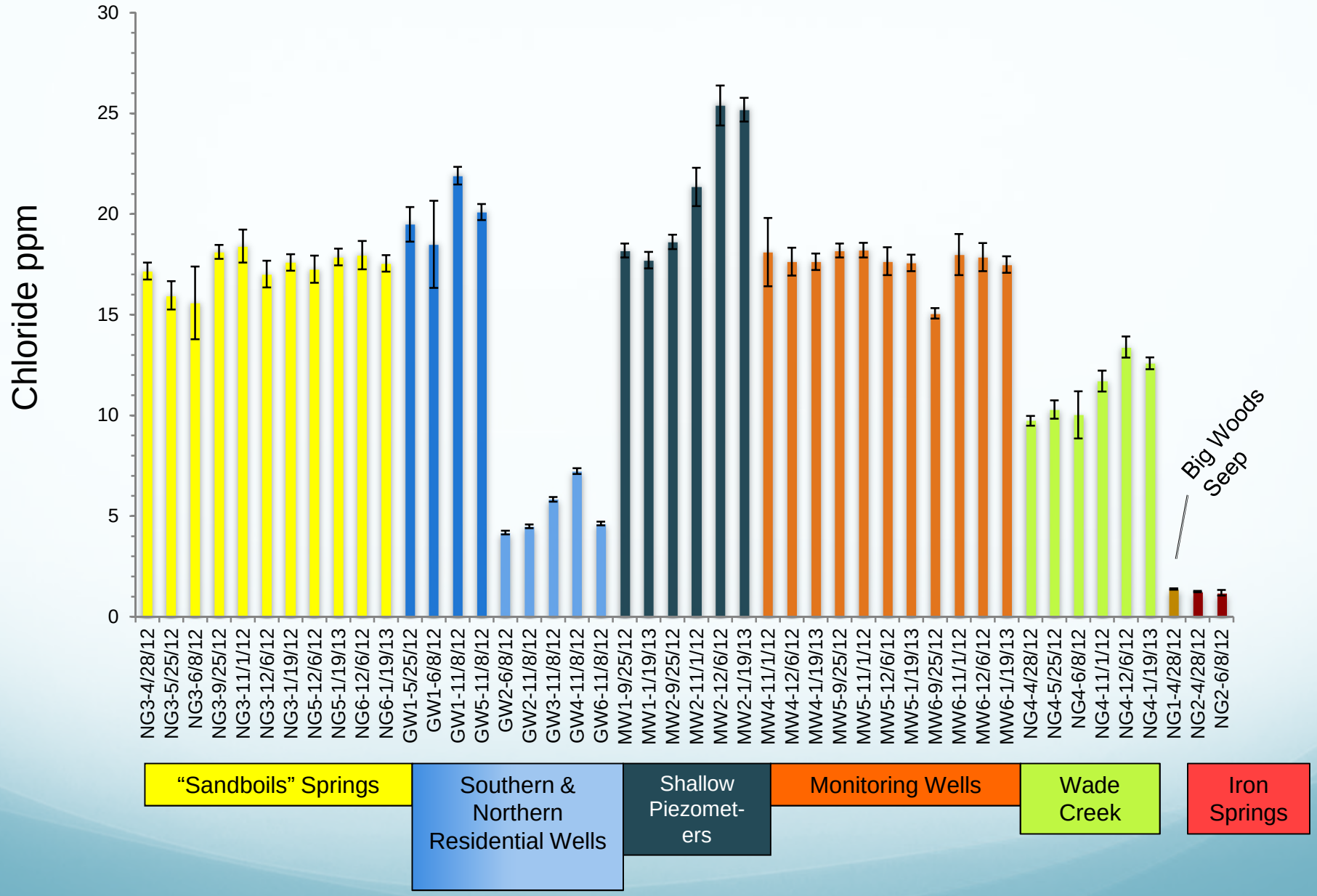
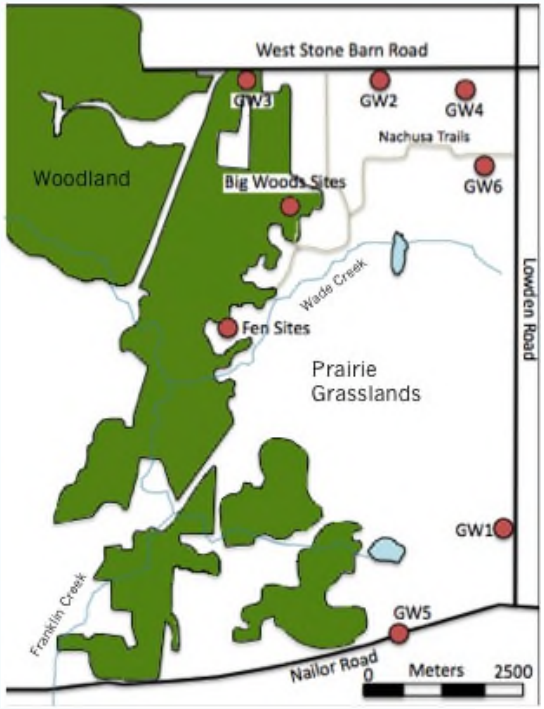
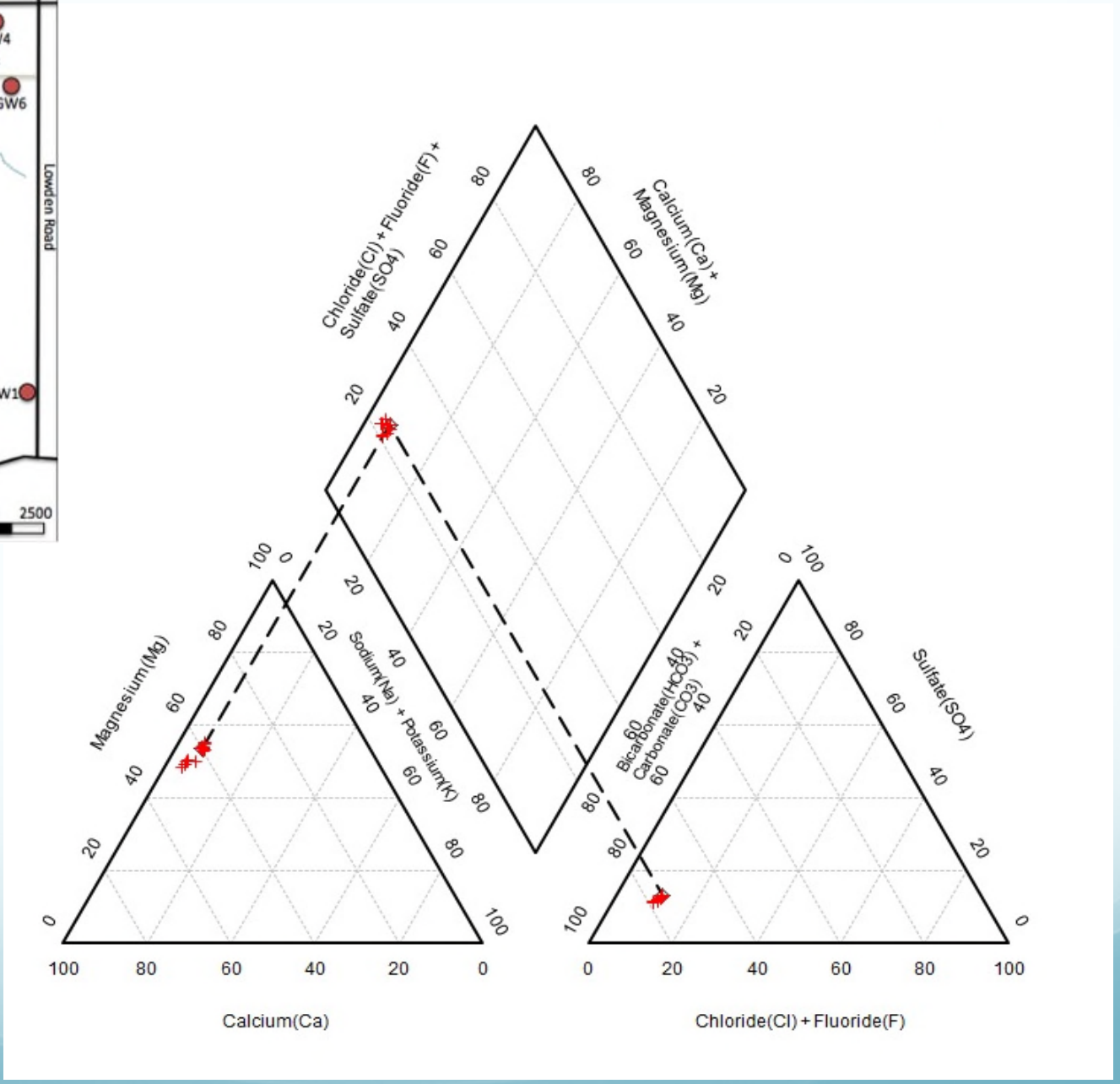
Iron Springs


Chloride ppm
30
25
20
15
10
5
0
NG3-4/28/12
NG3-5/25/12
NG3-6/8/12
NG3-9/25/12
NG3-11/1/12
NG3-12/6/12
NG3-1/19/12
NG5-12/6/12
NG5-1/19/13
NG6-12/6/12
NG6-1/19/13
GW1-5/25/12
GW1-6/8/12
GW1-11/8/12
GW5-11/8/12
GW2-6/8/12
GW2-11/8/12
GW3-11/8/12
GW4-11/8/12
GW6-11/8/12
MW1-9/25/12
MW1-1/19/13
MW2-9/25/12
MW2-11/1/12
MW2-12/6/12
MW2-1/19/13
MW4-11/1/12
MW4-12/6/12
MW4-1/19/13
MW5-9/25/12
MW5-11/1/12
MW5-12/6/12
MW5-1/19/13
MW6-9/25/12
MW6-11/1/12
MW6-12/6/12
MW6-1/19/13
NG4-4/28/12
NG4-5/25/12
NG4-6/8/12
NG4-11/1/12
NG4-12/6/12
NG4-1/19/13
NG1-4/28/12
NG2-4/28/12
NG2-6/8/12
Big Woods Seep
"Sandboils" Springs
Southern & Northern Residential Wells
Shallow Piezomet-ers
Monitoring Wells
Wade Creek
Iron Springs

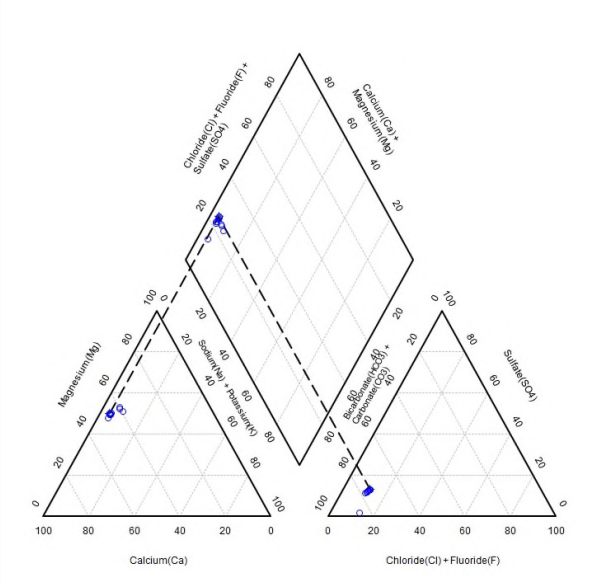
# Geochemistry & Groundwater Evolution

# “Sandboil” Sites

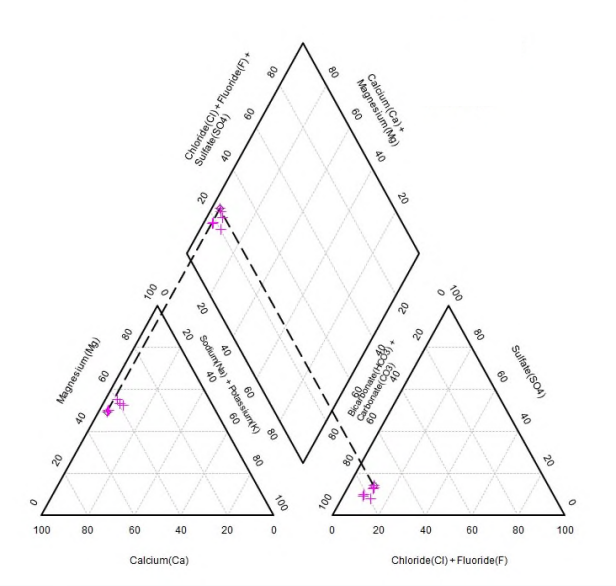


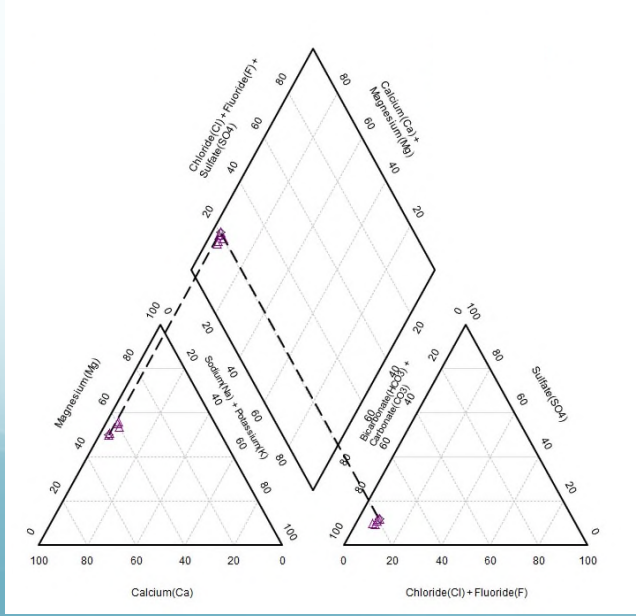
## Monitoring Wells (MW4-6)



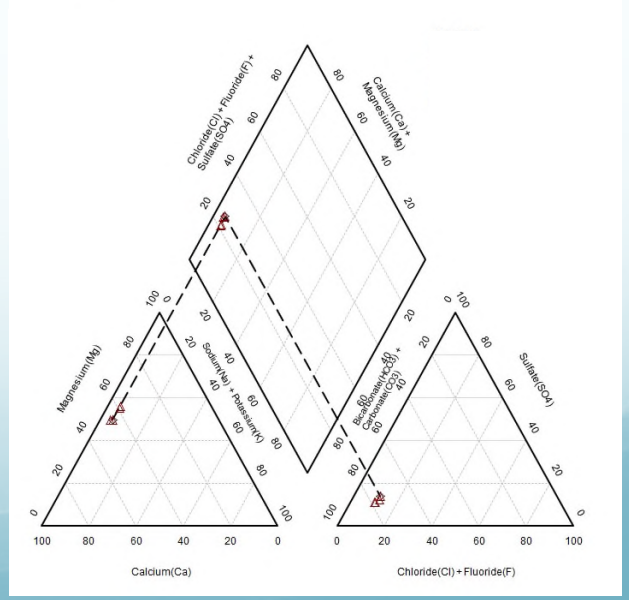

## Shallow Piezometers



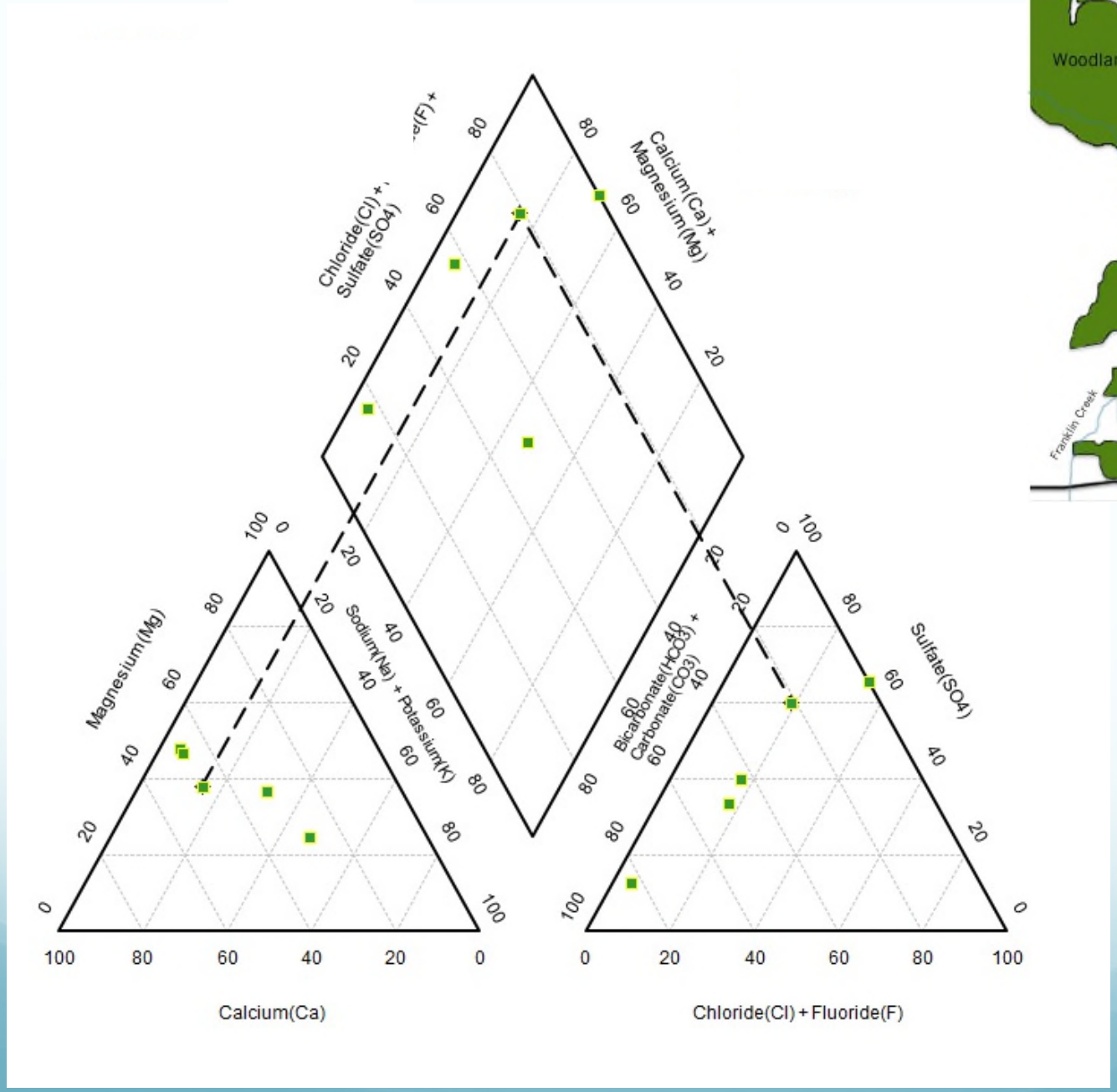

## Wade Creek

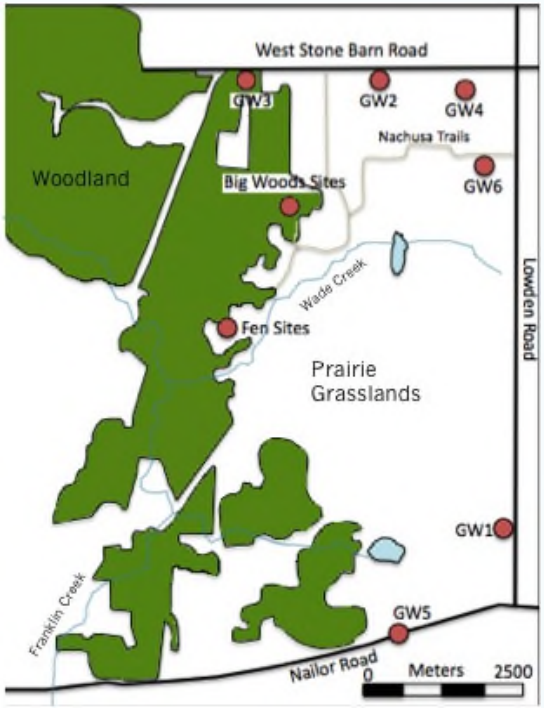



## Southern Residential Wells GW1&5



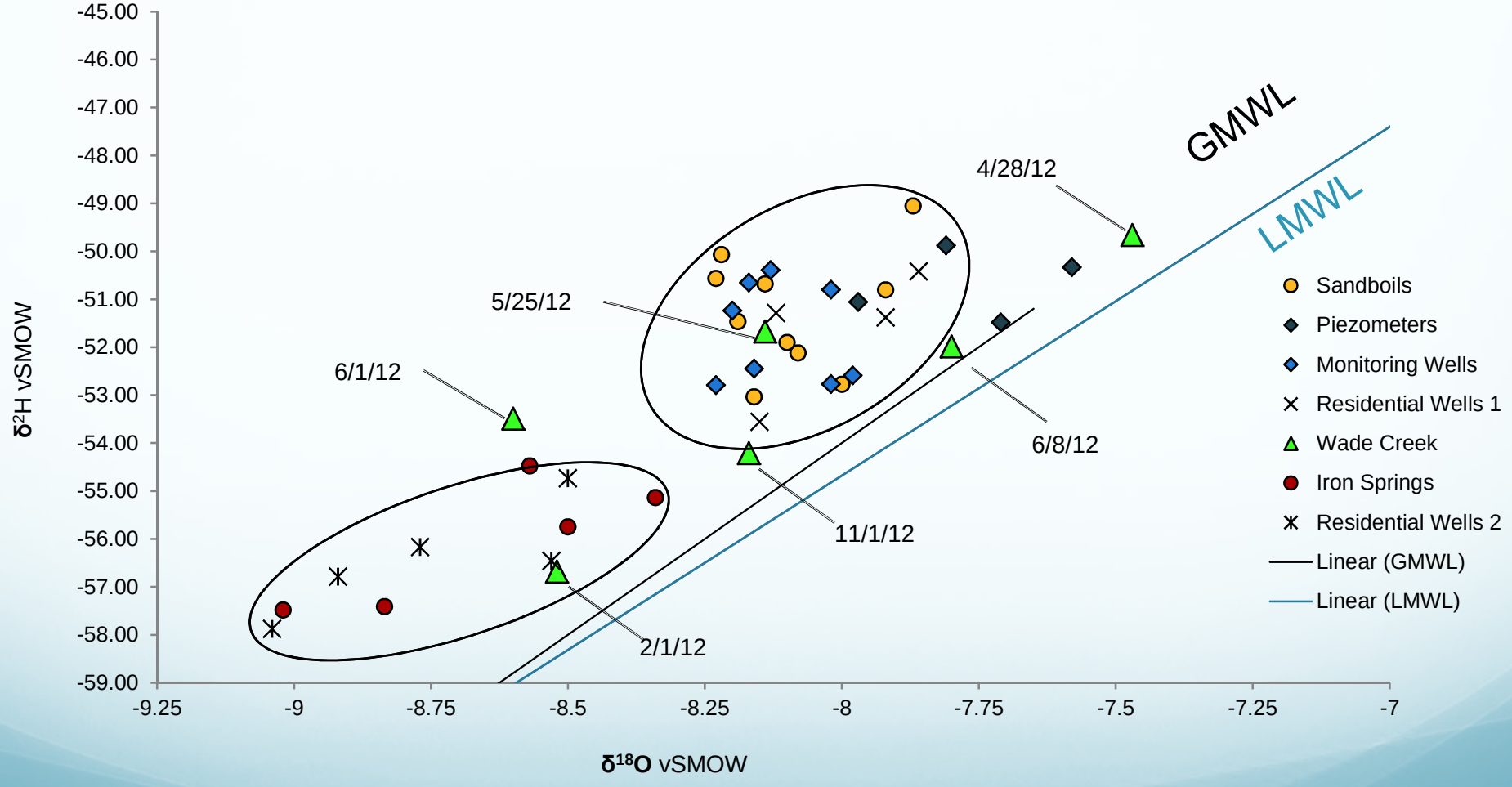
# Northern Residential Wells



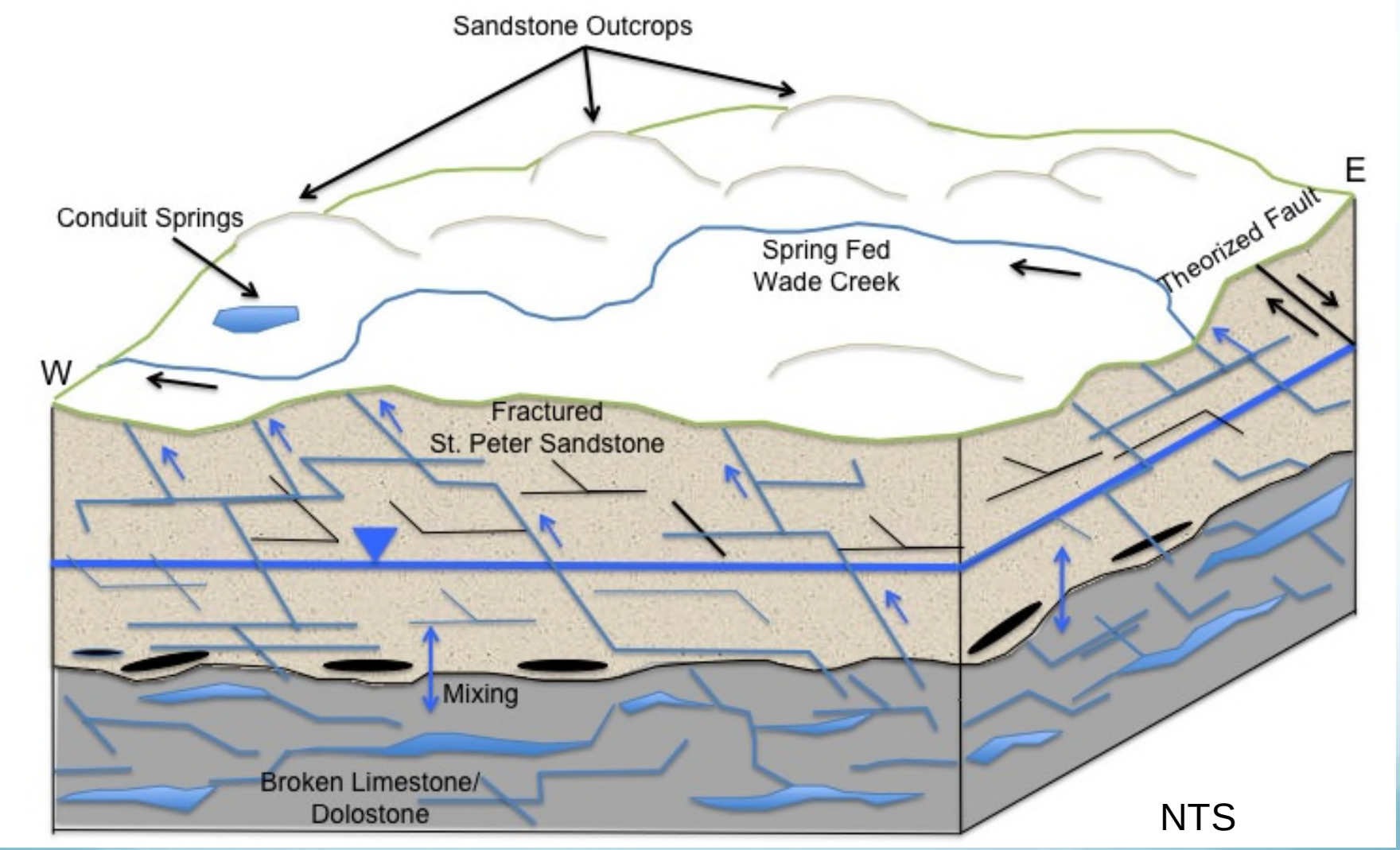



# Stable Isotope Results

# Stable Isotope Analysis



# Nachusa Conceptual Subsurface Model



# Conclusions

- Subsurface geology is heterogeneous with high spatial variation.
- Subsurface geology most likely Ancell group of the St. Peter and overlying Shakopee-New Richmond Limestone formations of the Prairie du Chien Group.
- Two Separate Groundwater Hydrogeologic systems.
- Sandboil springs are groundwater controlled.
- Groundwater source of the sandboil springs is directly connected to surface water.
- Homogeneity in Fen sampling sites suggests upwelling from Prairie du Chien through broken limestone and sandstone conduits.

# THANK YOU

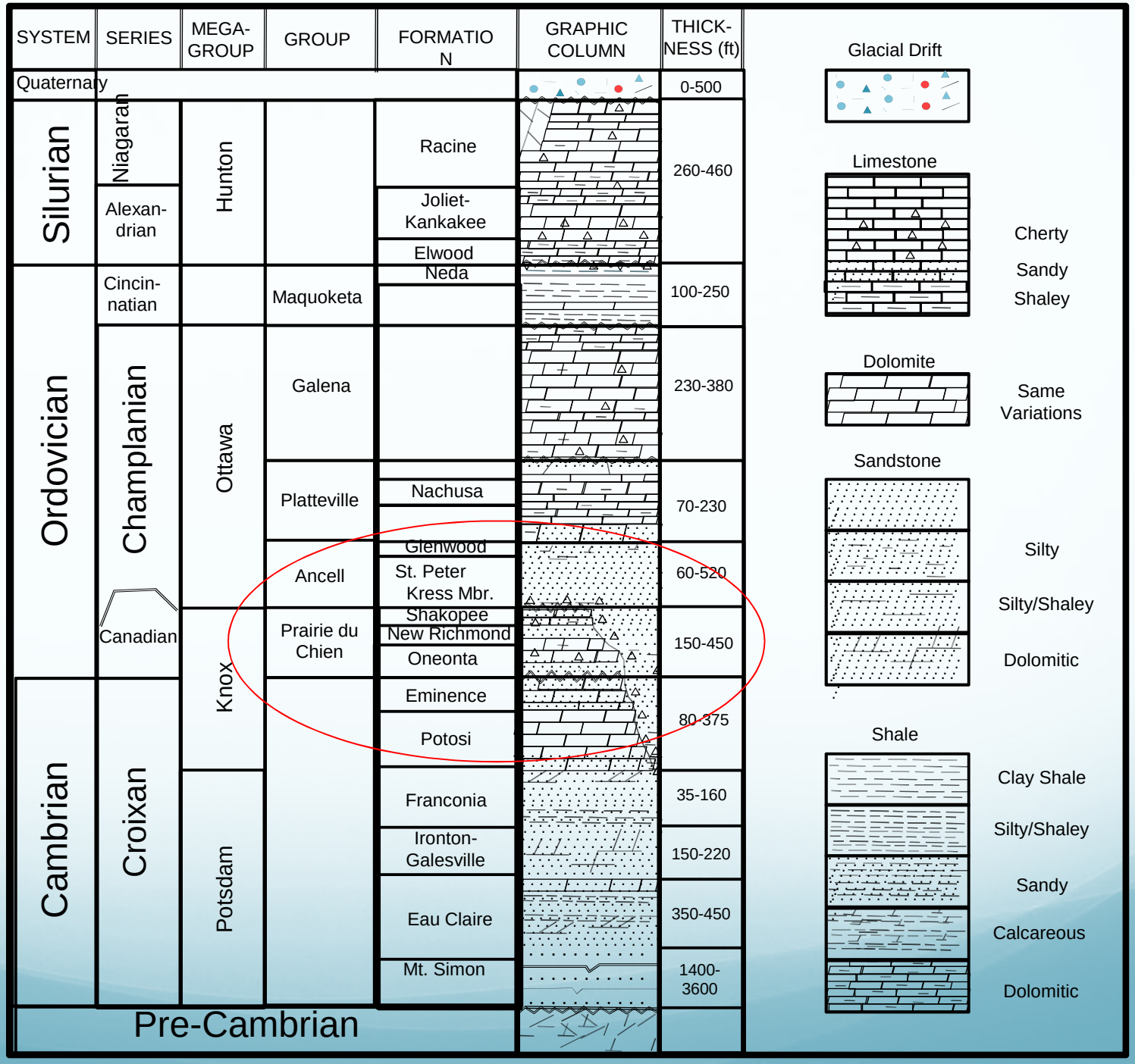
U.S. DEPARTMENT OF THE INTERIOR · GEOLOGICAL SURVEY ·

I G A

FRIENDS OF NACHUSA GRASSLANDS

NORTHERN ILLINOIS UNIVERSITY

General Stratigraphic Column of Northwestern Il.




Modified from Kolata ISGS 1978