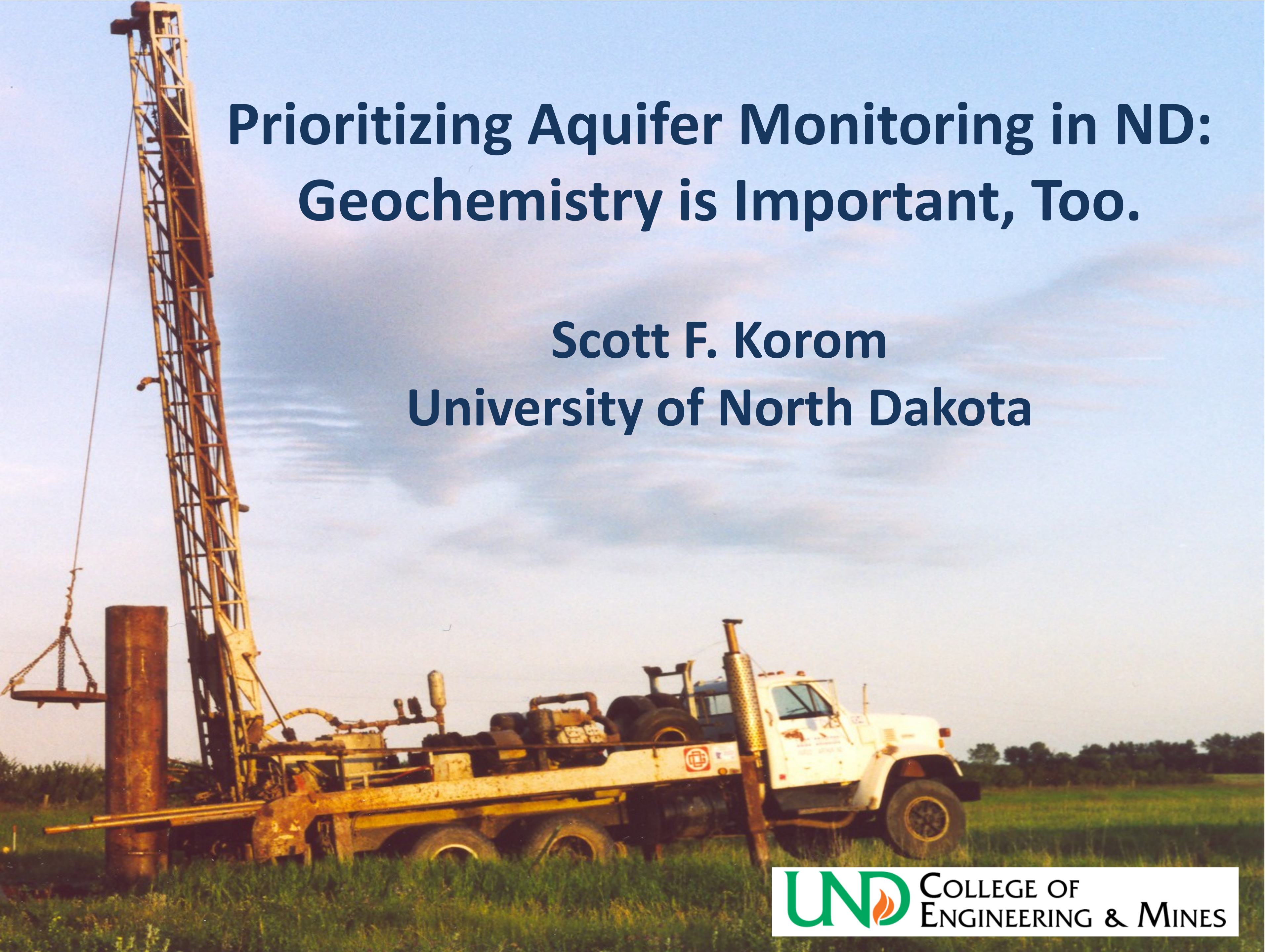
Prioritizing Aquifer Monitoring in ND: Geochemistry is Important, Too.

Scott F. Korom
University of North Dakota



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Extraordinary Aquifers Require an Extraordinary Monitoring System.

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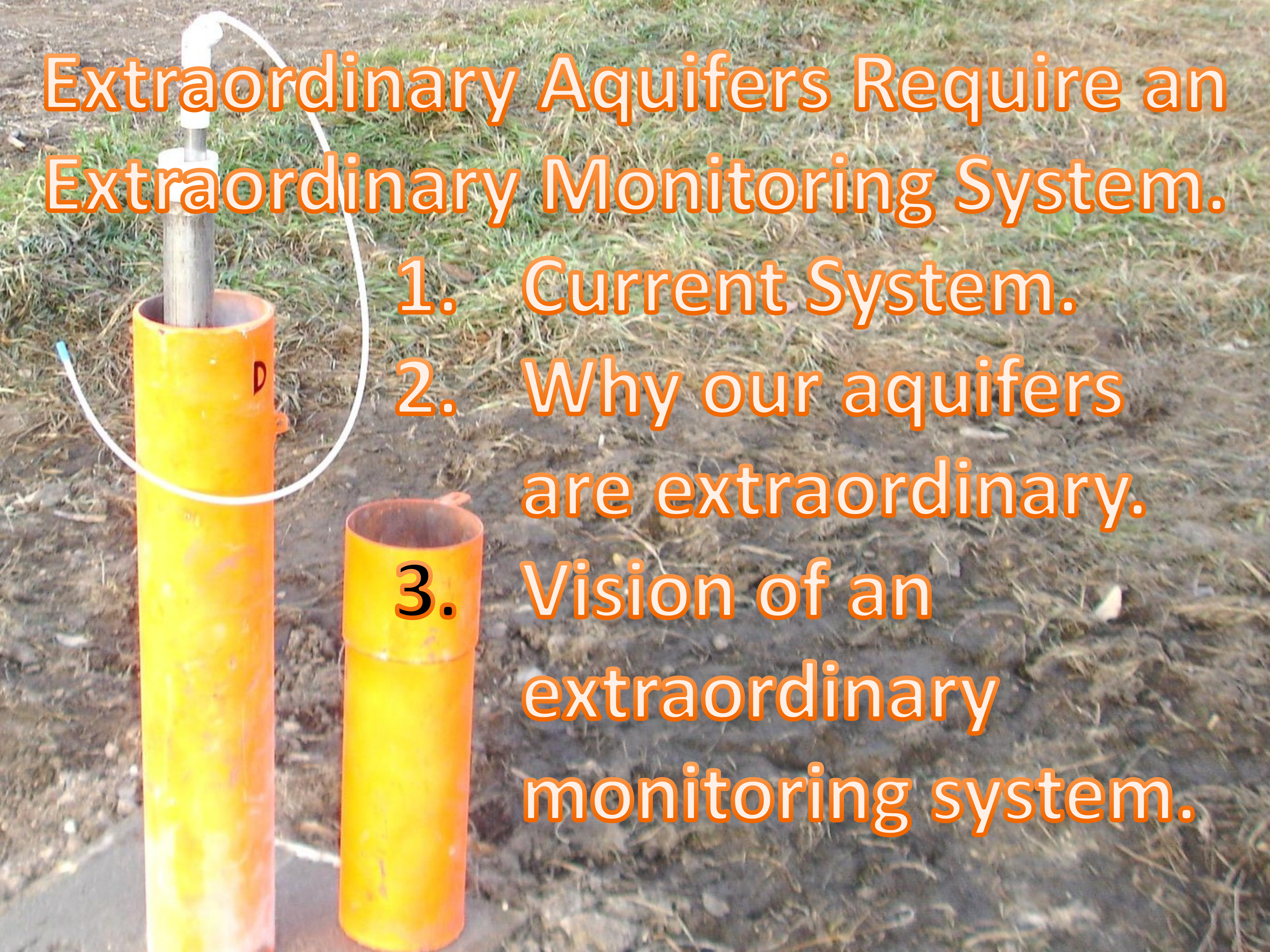
2. Why our aquifers are extraordinary.
D


Extraordinary Aquifers Require an Extraordinary Monitoring System.
1. Current System.
2. Why our aquifers are extraordinary.
3. Vision of an extraordinary monitoring system.
D

ND Geographic Targeting System for Groundwater Monitoring (Radig, 1997)

1. **Sensitivity.** Uses the market value of agricultural production as a surrogate for the usage of agricultural chemicals and fertilizers.
2. **Risk.** Uses the value of loss of the beneficial use of water should an aquifer become contaminated.

ND Geographic Targeting System for Groundwater Monitoring (Radig, 1997)

1. Sensitivity. Uses the market value of agricultural production as a surrogate for the usage of agricultural chemicals and fertilizers.
2. Risk. Uses the value of loss of the beneficial use of water should an aquifer become contaminated.
3. Vulnerability. Uses DRASTIC (Aller et al., 1987), "A standardized system for evaluating ground water pollution potential using hydrogeologic settings."

D R A S T I C (Aller et al., 1987)

D – Depth to water
R – Recharge (Net)
A – Aquifer Media
S – Soil Media
T – Topography (Slope)
I – Impact of the Vadose Zone Media
C – Conductivity (Hydraulic) of the Aquifer

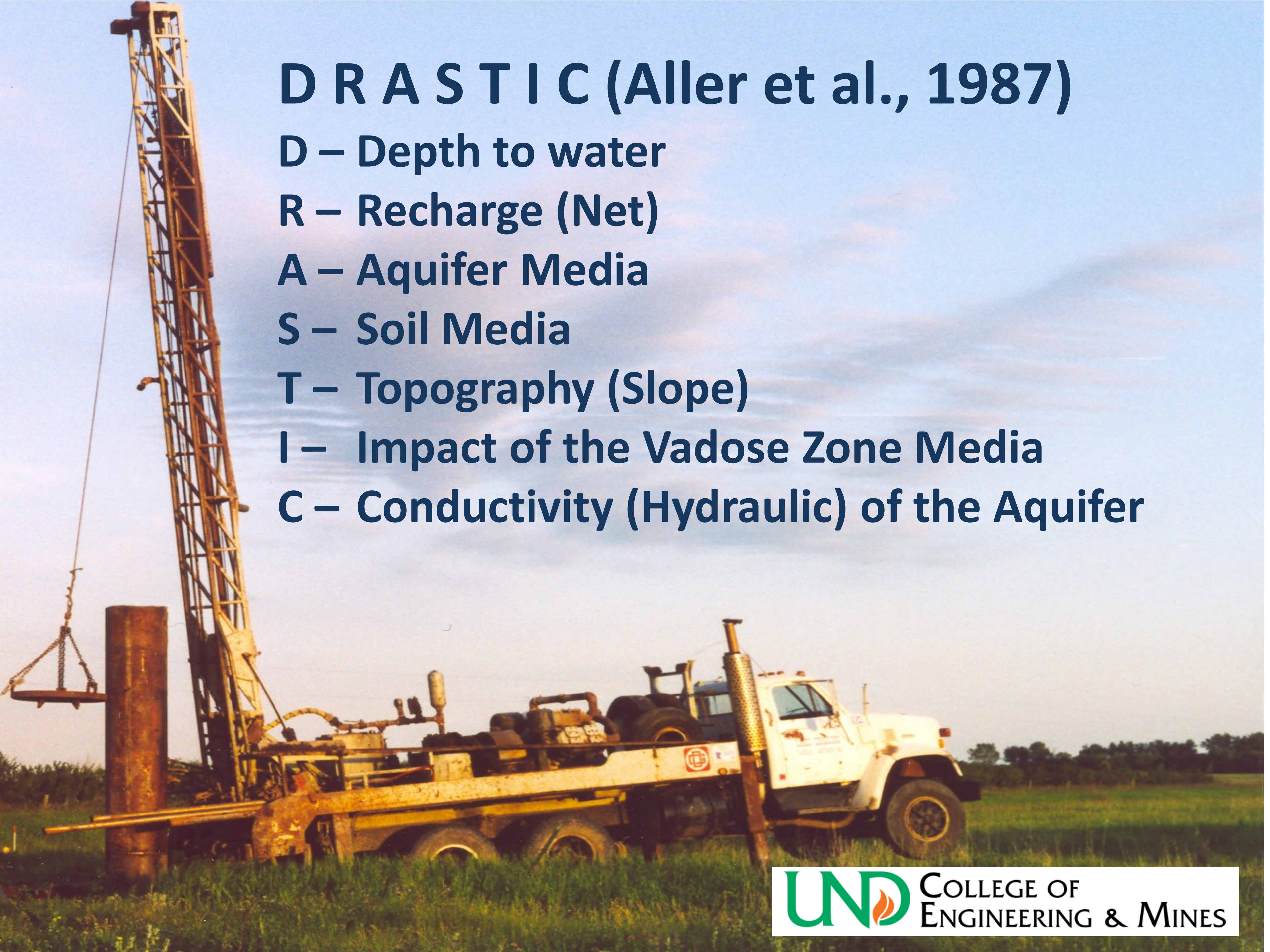


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Figure C-2. Pesticide DRASTIC Scores for Major Glacial Drift Aquifers in North Dakota

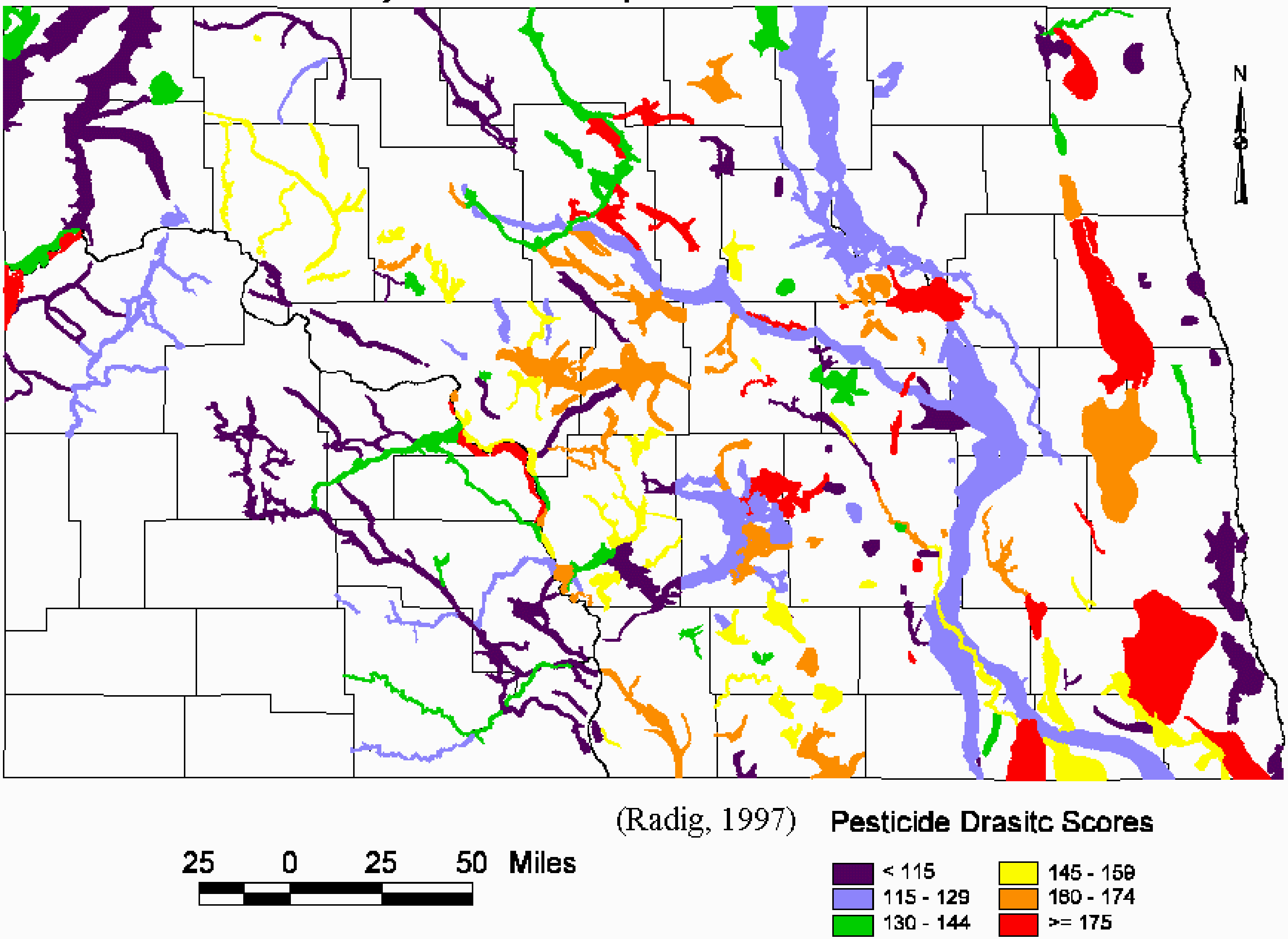
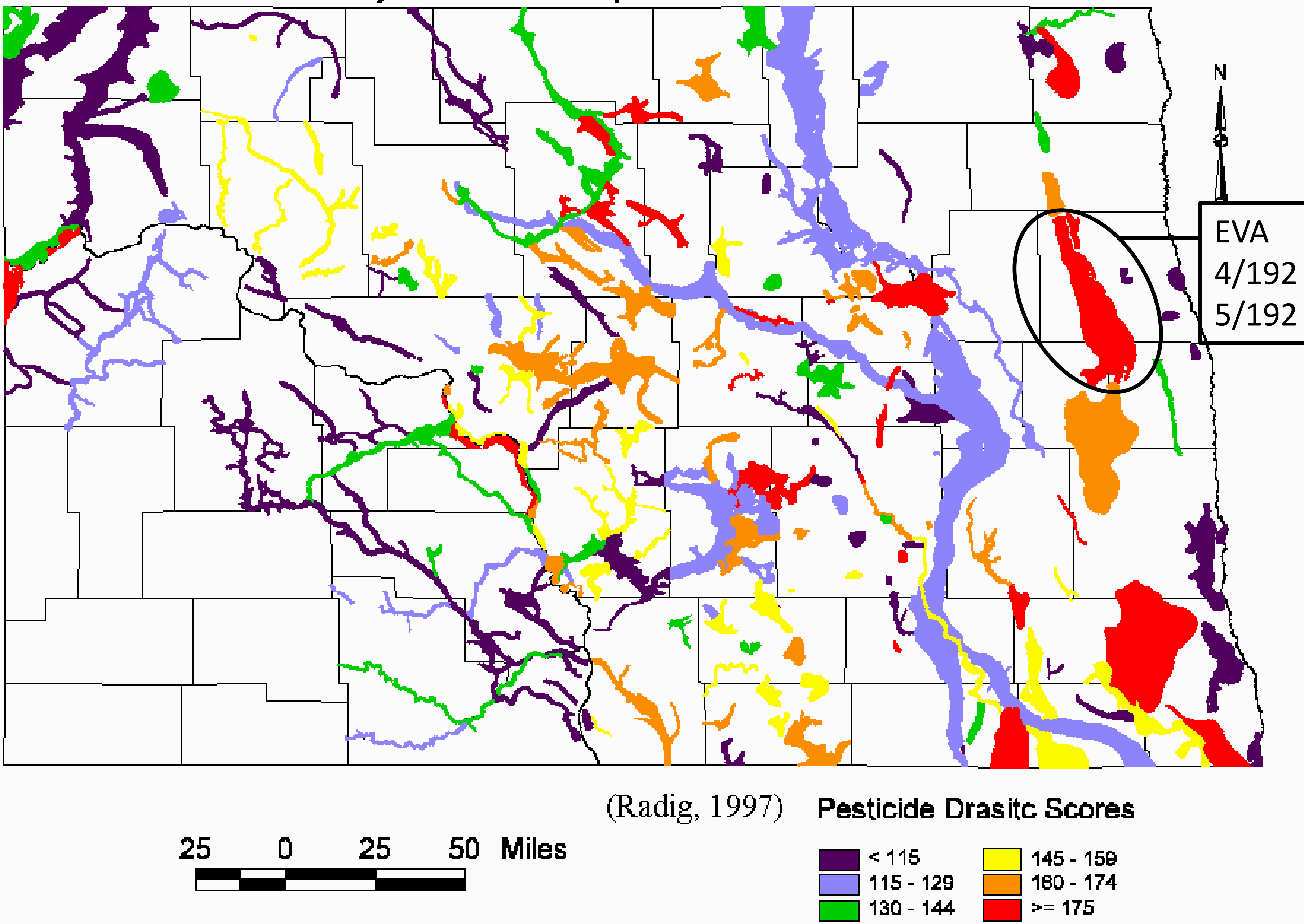


Figure C-2. Pesticide DRASTIC Scores for Major Glacial Drift Aquifers in North Dakota



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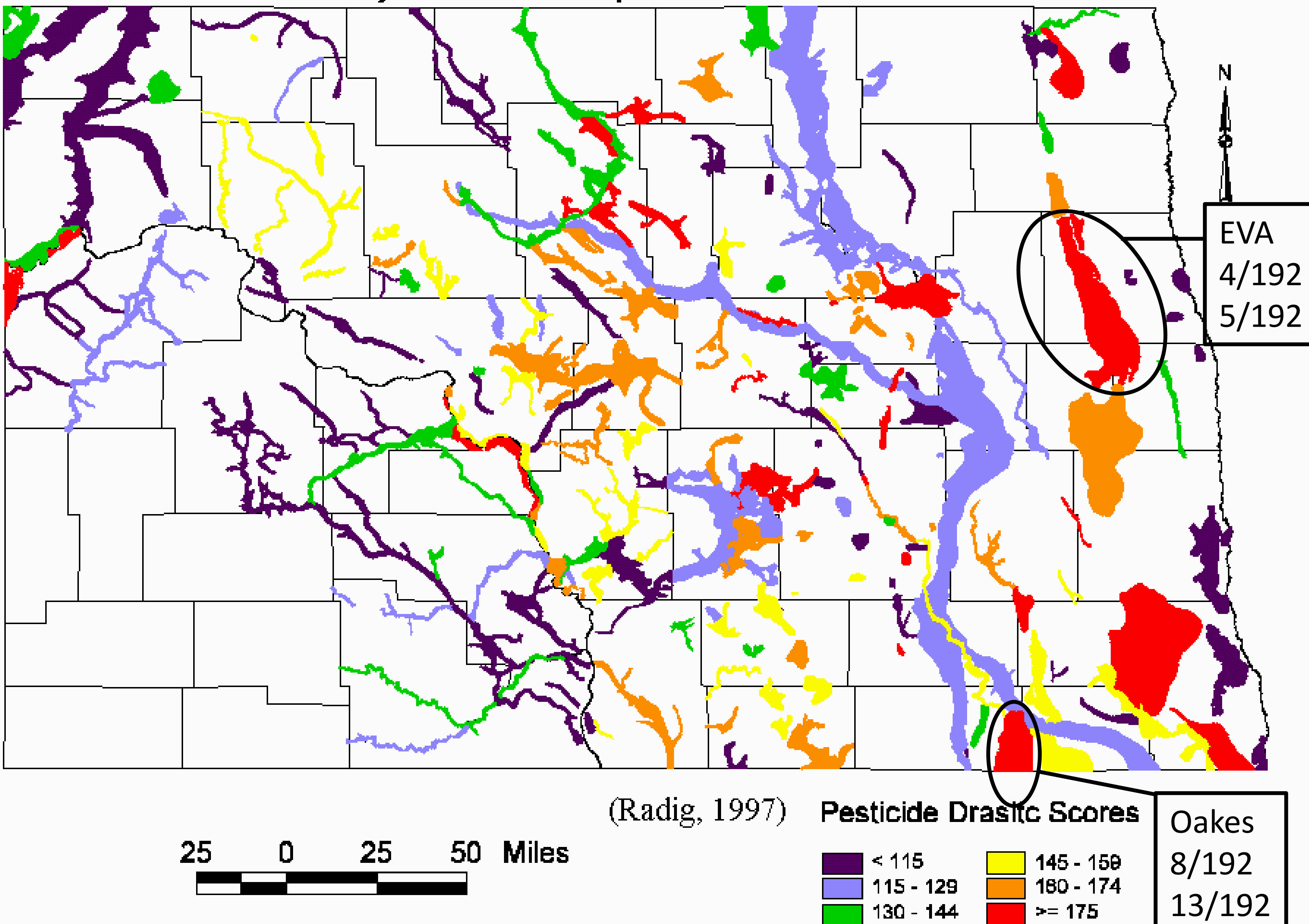
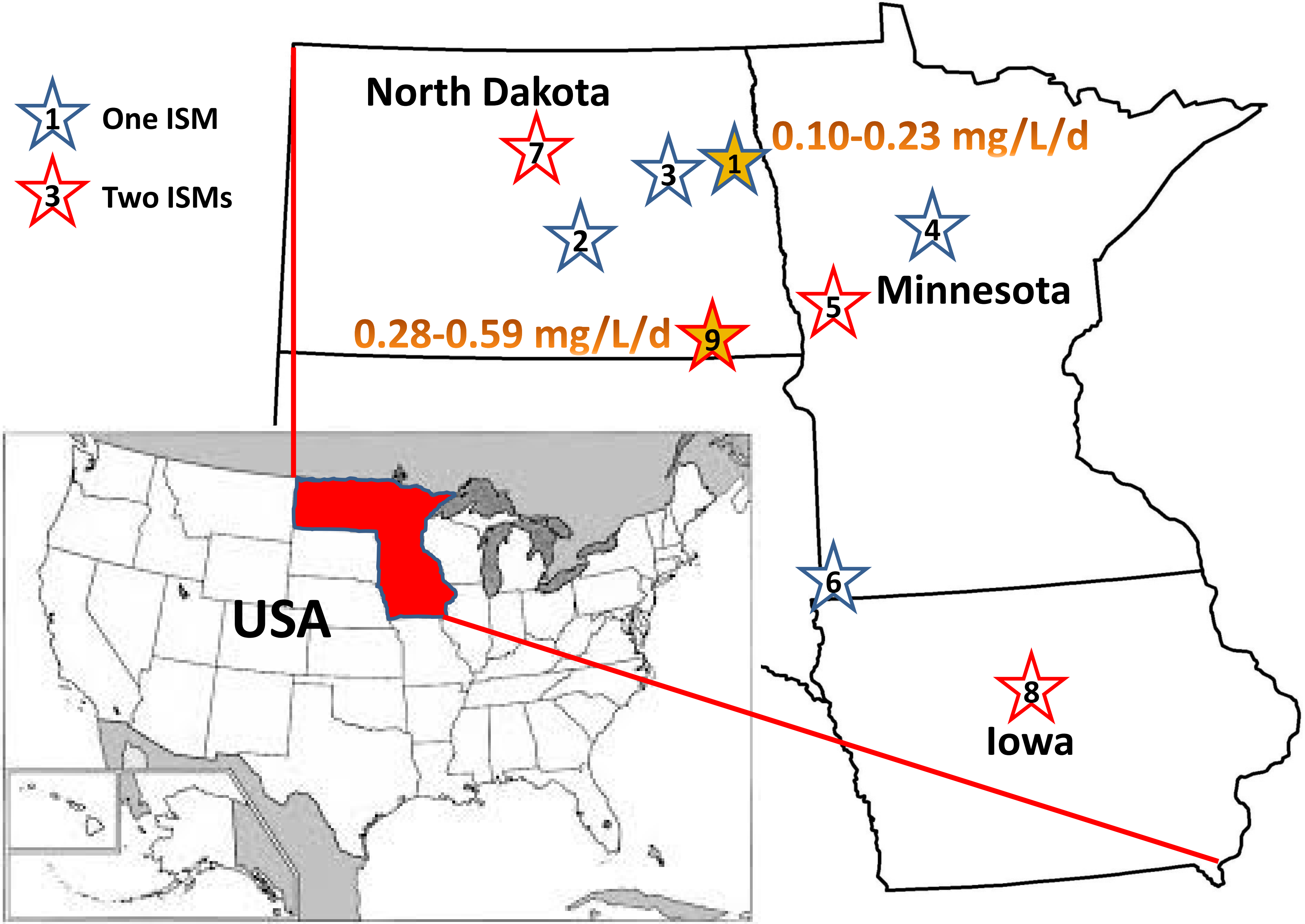
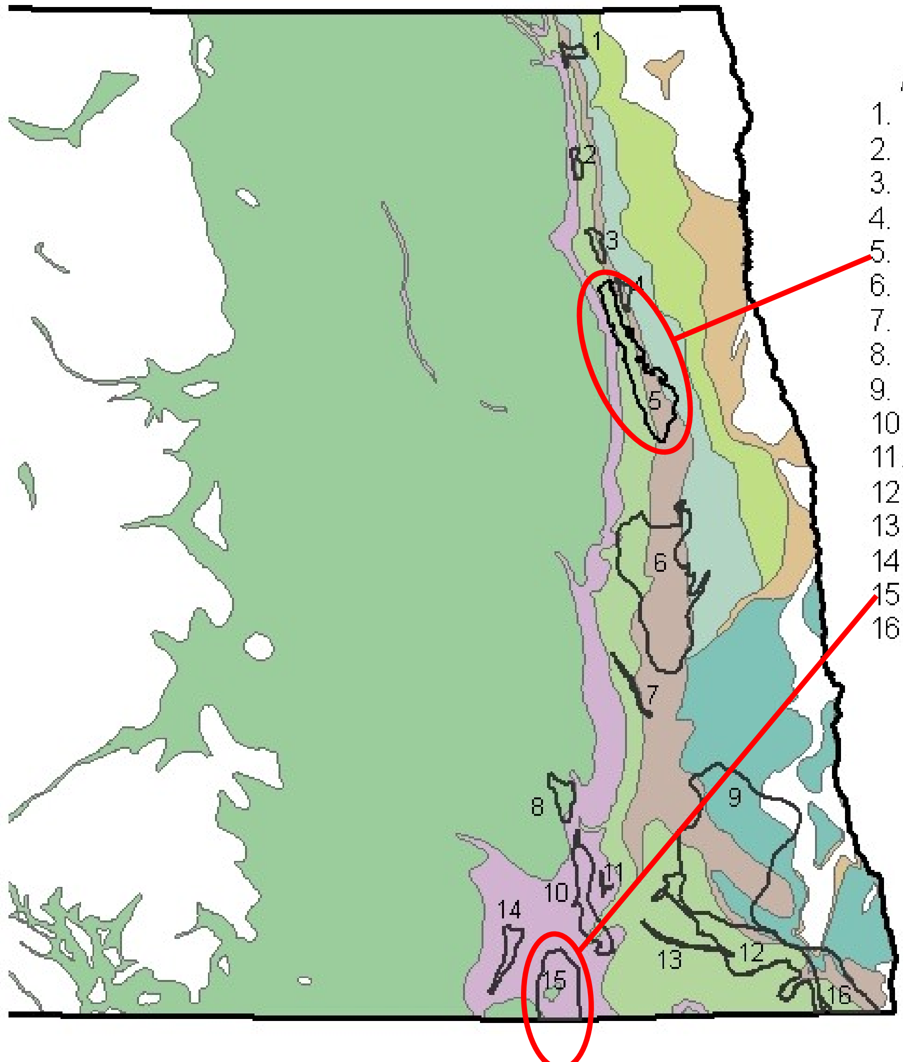


USA Network of In-Situ Denitrification Mesocosms (ISMs)



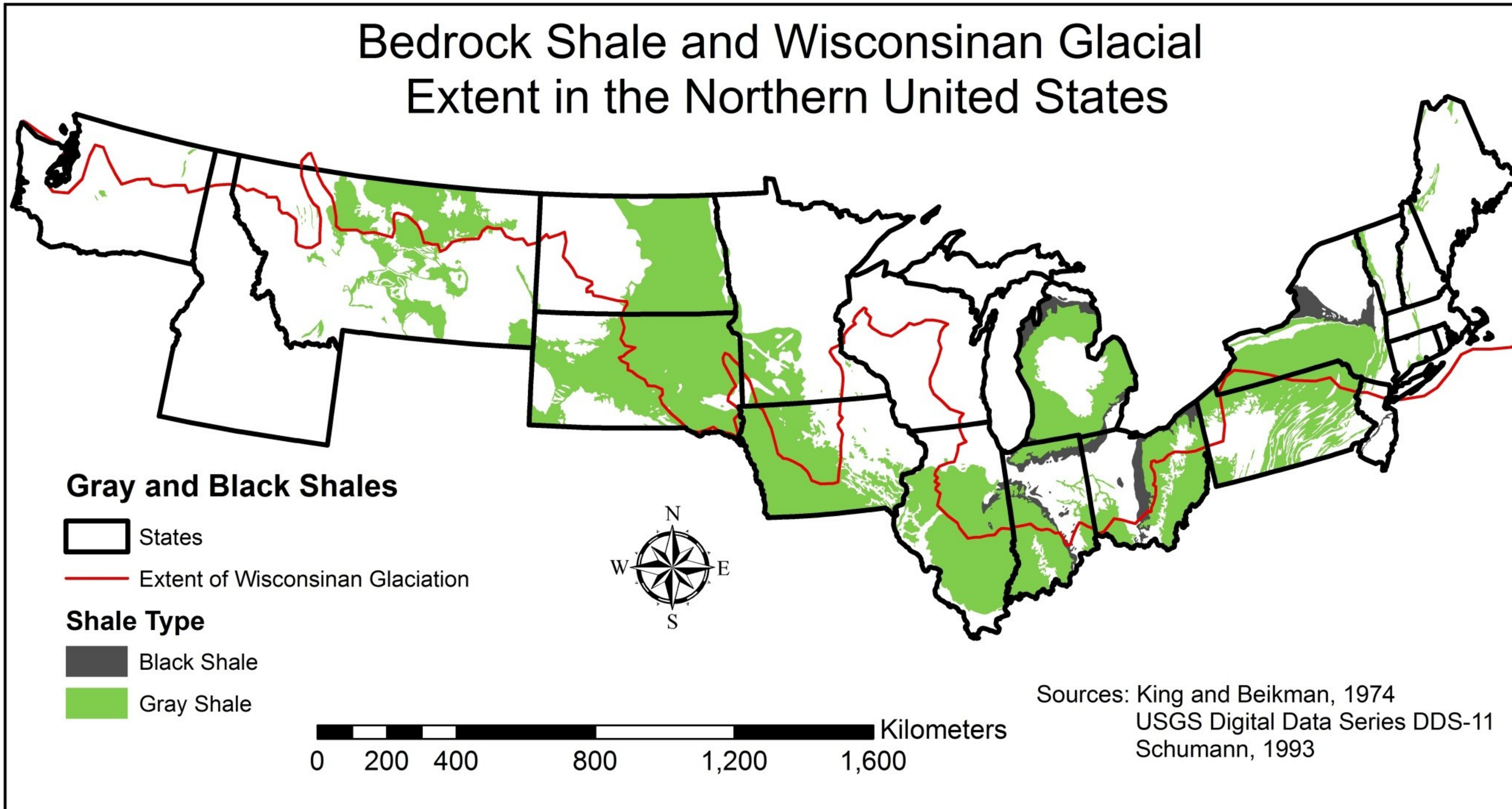
Bedrock Shale and Aquifers with High e^- Donor Potential in Eastern North Dakota



AQUIFERS
1. Pembina Delta
2. Edinburg
3. Fordville
4. Inkster
5. Elk Valley
6. Galesburg / Page
7. Tower City
8. Sand Praire
9. Sheyenne Delta
10. Englevale
11. Elliott
12. Milnor Channel
13. Gwinner
14. Guelph
15. Oakes
16. Hankinson

Adapted from Klapperich (2008)

Sources:
North Dakota State Water Commission
North Dakota GIS Hub
Clayton et al., 1980
Radig, 1997


Bedrock Shale and Wisconsinan Glacial
Extent in the Northern United States
Gray and Black Shales
States
Extent of Wisconsinan Glaciation
Shale Type
Black Shale
Gray Shale
N
W
E
S
Kilometers
0
200
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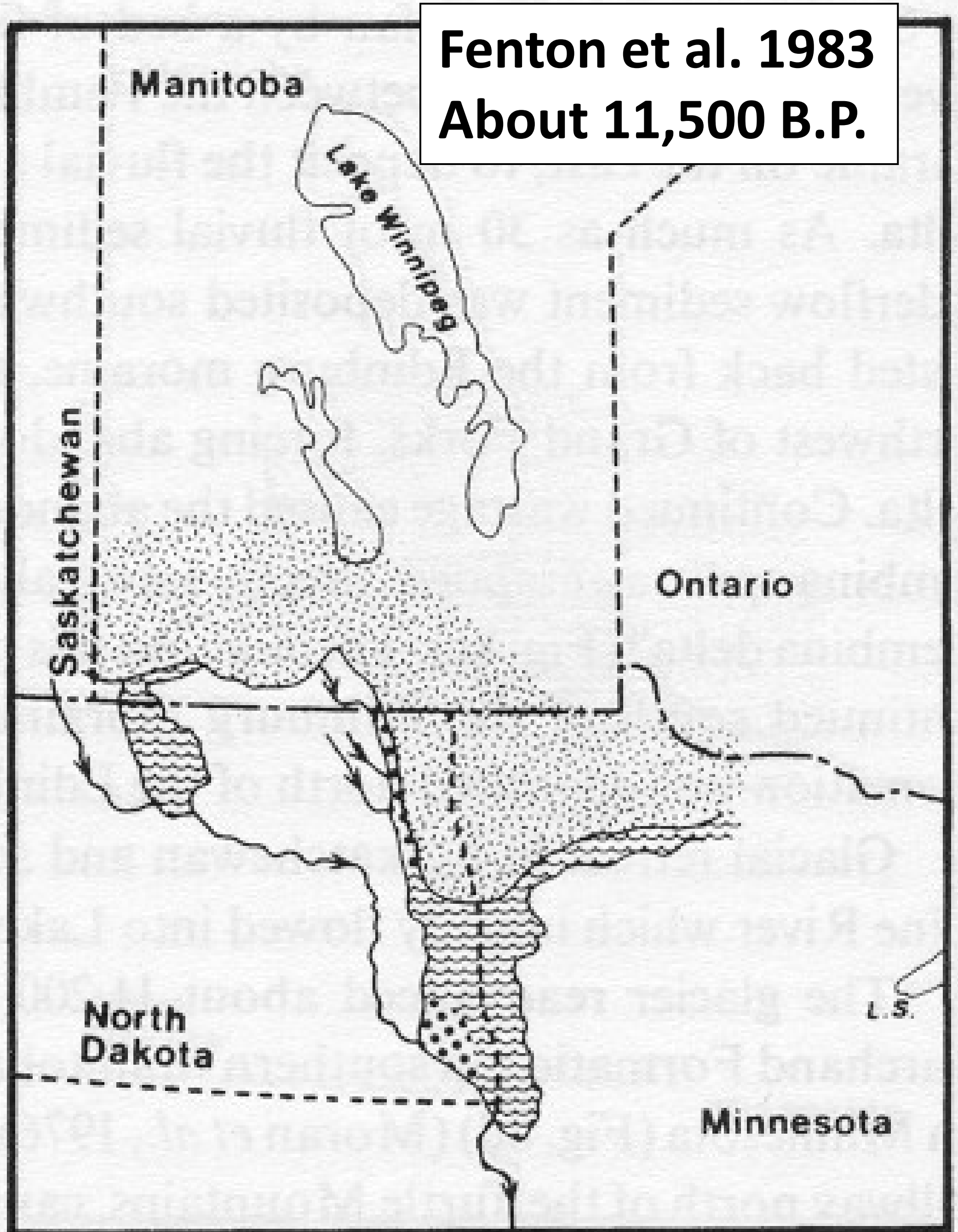
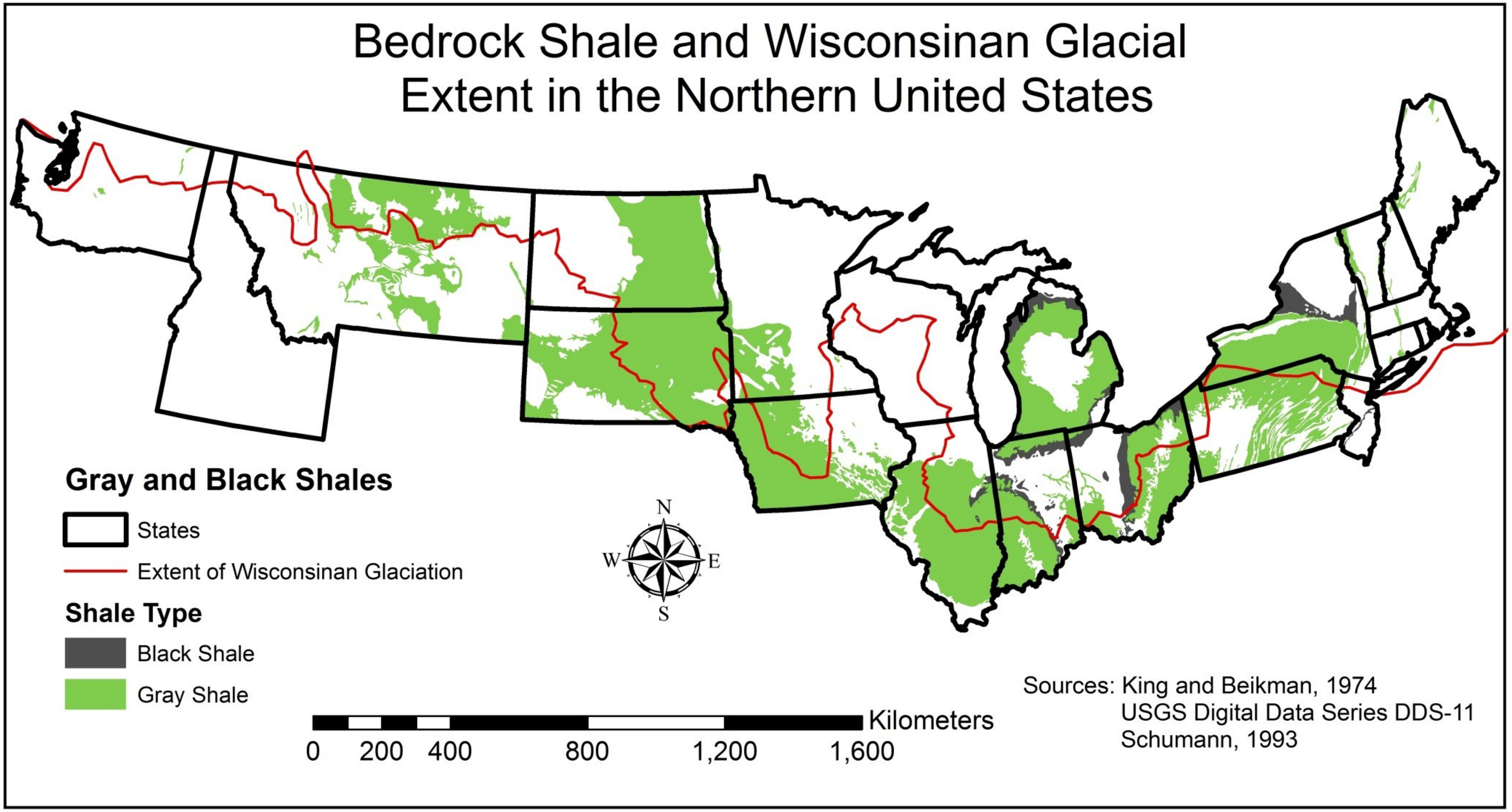
800
1,200
1,600
Sources: King and Beikman, 1974
USGS Digital Data Series DDS-11
Schumann, 1993

Fenton et al. 1983
About 11,500 B.P.

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Sources and Processes Affecting the Distribution of Dissolved Sulfate in the Elk Valley Aquifer

in Grand Forks County, Eastern North Dakota

W.M. Schuh et al. (2006)
Water Resources Investigation No. 38
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Sources and Processes Affecting the Distribution of Dissolved Sulfate in the Elk Valley Aquifer

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"At measured nitrate loading rates there is sufficient pyrite-S in the EVA to support autotrophic denitrification for 11,000 to 175,000 years depending on location. These estimates assume non-preferential flow, and the gradual and uniform progression of nitrate."

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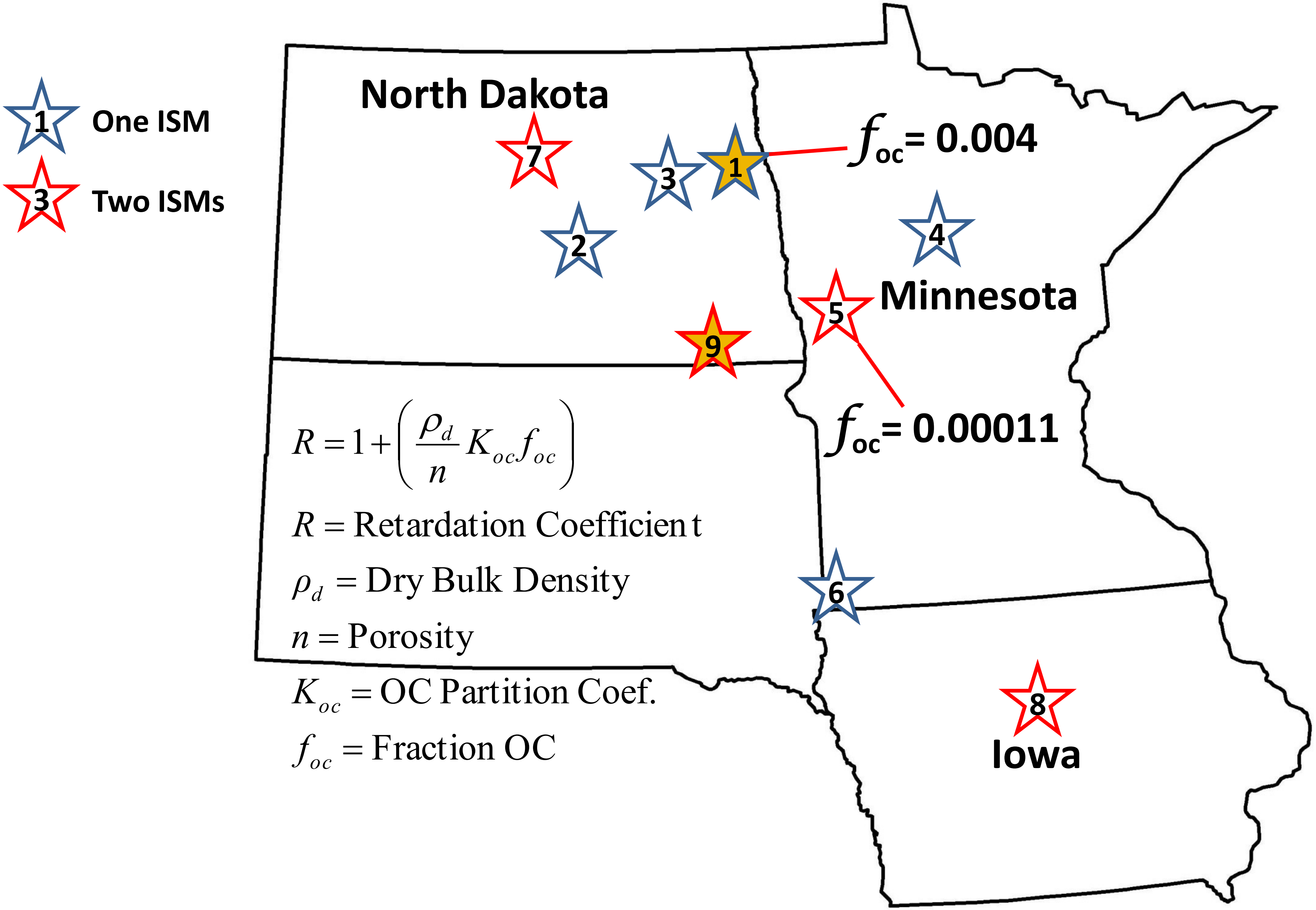
Influence of the Pierre Shale and Equivalent Rocks. (Tourtelot, 1980)

- Chromium (Cr), cadmium (Cd), vanadium (V), copper (Cu), molybdenum (Mo), selenium (Se), arsenic (As), and uranium (U) are concentrated in the organic matter in marine organic-rich shale.

- Cobalt (Co), nickel (Ni), and Zinc (Zn) seem to be more concentrated in pyrite that is closely associated with the organic matter.

USA Network of In-Situ Denitrification Mesocosms (ISMs)



$$R = 1 + \left(\frac{\rho_d}{n} K_{oc} f_{oc} \right)$$

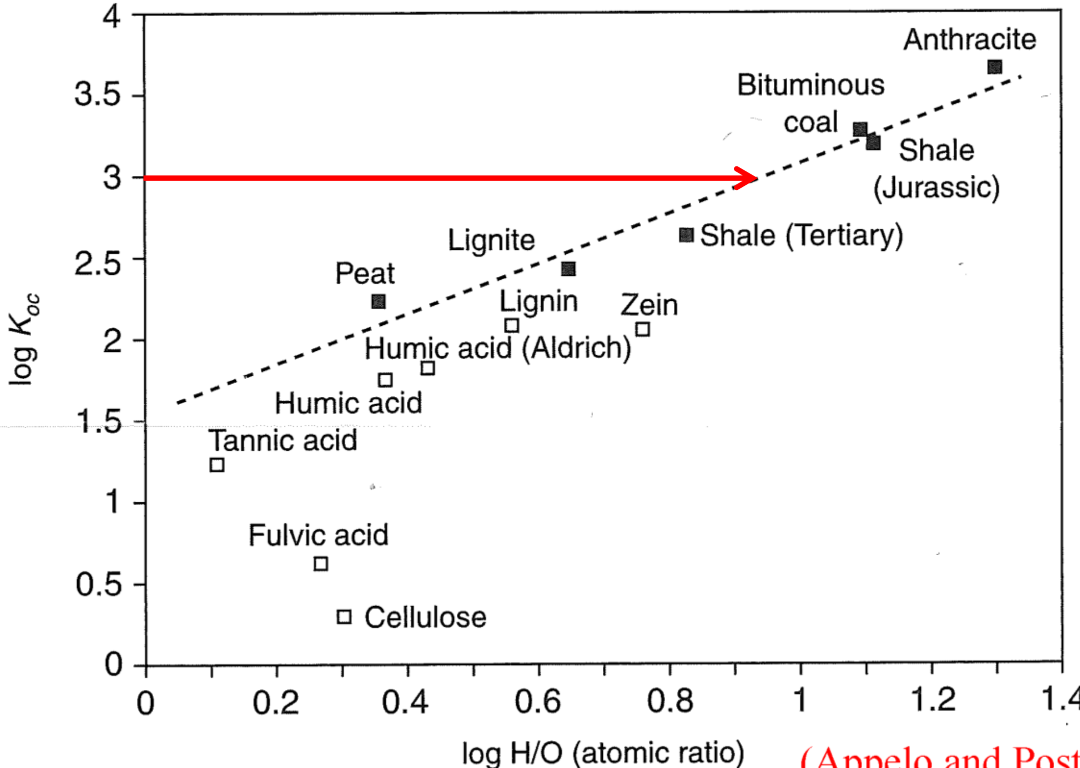
R = Retardation Coefficient

ρ_d = Dry Bulk Density

n = Porosity

K_{oc} = OC Partition Coef.

f_{oc} = Fraction OC



(Appelo and Postma, 2005)

$$R = 1 + \left(\frac{\rho_d}{n} K_{oc} f_{oc} \right)$$

$$\rho_d = 1.81 \ g/cm^3$$

$$n = 0.33 \text{ (Mackay et al., 1986)}$$

$$K_{oc} = 1{,}000$$

$$f_{oc} = 0.004 \quad \text{or} \quad 0.00011$$

Figure 10.11. The distribution coefficient K_{oc} of trichloroethylene (TCE) increases with increasing H/O ratio (Grathwohl, 1990).

$$\frac{R_{EVA}}{R_{OTR}} = \frac{22.9}{1.60} = 14.3$$

In summary

1. Many of our drift aquifers are comprised of reactive shale fragments +
2. They may have pyrite-S contents +
3. They may have high organic C contents +
4. They are among the nation’s youngest aquifers.

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- Extraordinary aquifers!

Heterogeinity of nitrogen removal processes in pleistocene aquifers, northern low plain of Germany

M. Pätsch[1], W. Walther[2], K. Heblack[2], E.Harms[3] (2003)

"The quality of groundwater reflects the mineralogical constituents of the aquifers, the internal biochemical processes and the impacts of loads caused by the land use in the catchment areas."

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M. Pätsch[1], W. Walther[2], K. Heblack[2], E.Harms[3] (2003)

"In many regions of Europe, a water supply from groundwater is often only possible because natural decomposition processes reduce concentrations below drinking water standards, e.g. heterotrophic and autotrophic denitrification and ion sorption. In sedimentary rocks the biologically influenced processes consume reactive material from the aquifer. The storage and lifetime of such reactive material is probably limited and, thus the decomposition capacity of the aquifer. Investigations show that reactive material and, therefore, the reductive capacity is very heterogeneously distributed, depending on the geological history of genesis. This situation can mainly be found in the northern European low plains."

Geohydrochemical districts in The Netherlands and nitrate vulnerability

C.G.E.M. van Beek[1], *W.J. Willems*[2] *and P.L.G.M. Hesen*[1] (2003)

“Division into geohydrochemical districts makes a quick assessment possible of the effects of pollution on the chemical composition of groundwater and consequently also of the effects of remediation.”

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"In this contribution geohydrochemical districts in the Netherlands are classified with respect to the vulnerability of nitrate, but the same approach may be used for estimating the vulnerability. . . for pesticides, chemical pollutants and acid load."

Conclusions, our aquifers

1. May have highly reactive sediments.
    a) Pyrite
    b) Organic C
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- We need a comprehensive program that studies our aquifer sediments.

Acknowledgments

- North Dakota State Water Commission, William Schuh.
- North Dakota Department of Health.
- Land owners.
- Lots of graduate students, many sponsored by the ND Water Resources Research Institute.


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