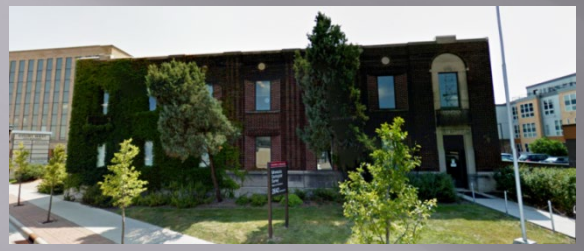
MINNESOTA GEOLOGICAL SURVEY

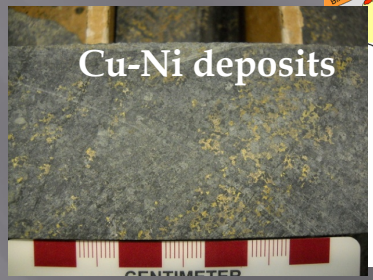
UNIVERSITY OF MINNESOTA

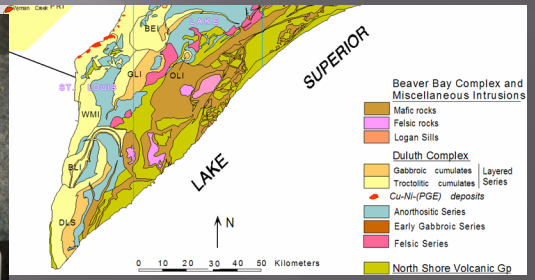
Unit of the Newton Horace Winchell School of Earth Sciences

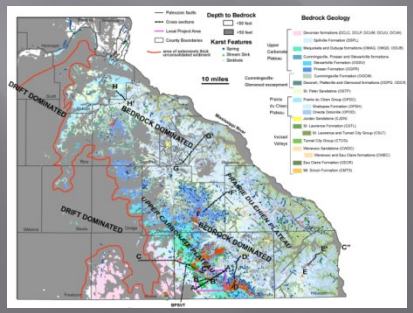


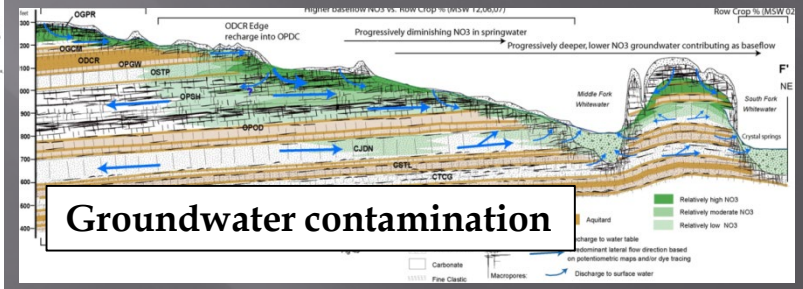
- About 21 scientists and 12 staff (GIS, database, IT, Admin.)

- Primary source of Earth science information for state of Minnesota.





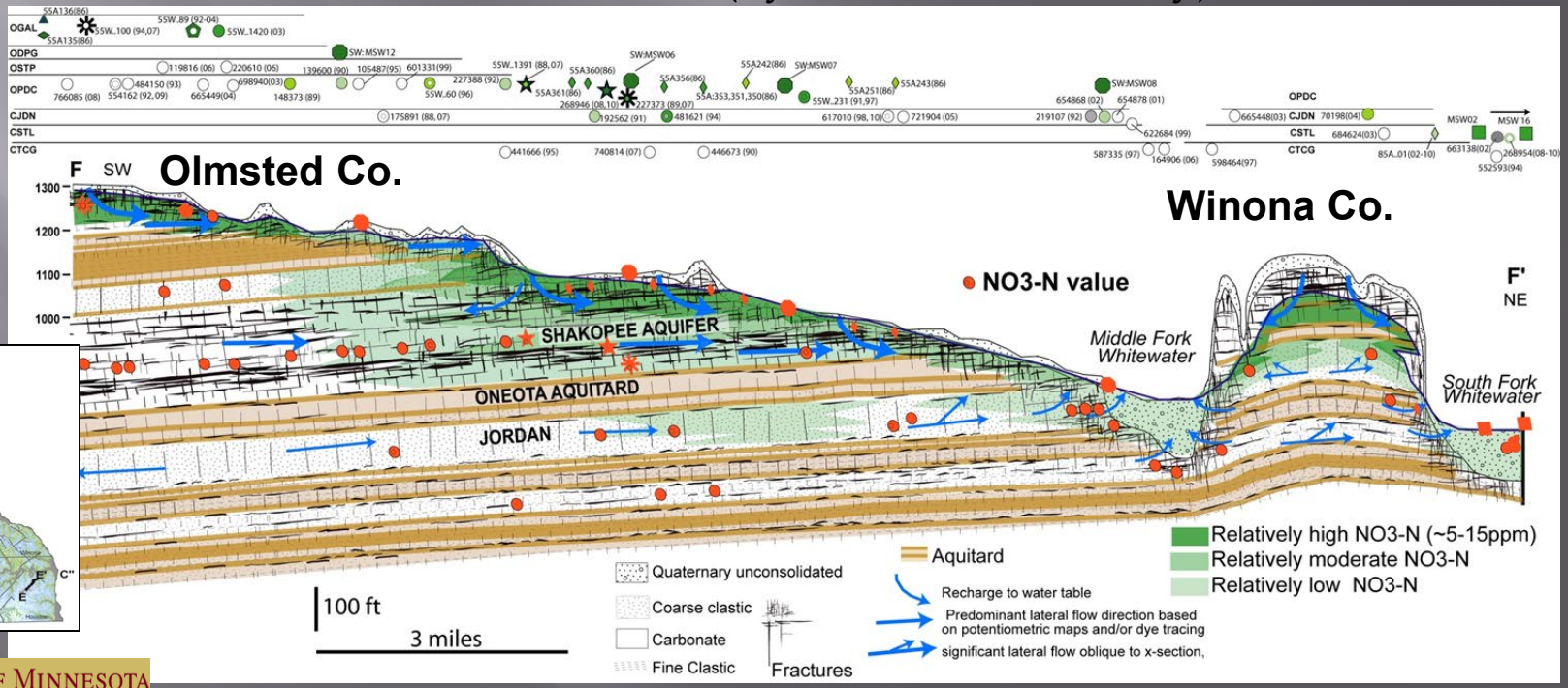


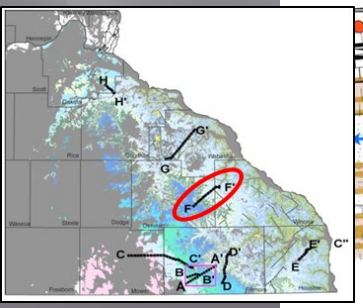


Nitrate in southeastern Minnesota

Presentation overview

- General background on nitrate problem and geology/groundwater conditions of southeastern Minnesota
- MGS 2014 project on geologic controls on nitrate transport
- Nitrate trends over time. The "lag-time" phenomenon
- Olmsted County examples
- Groundwater residence time in Rochester (hydrochemical survey)

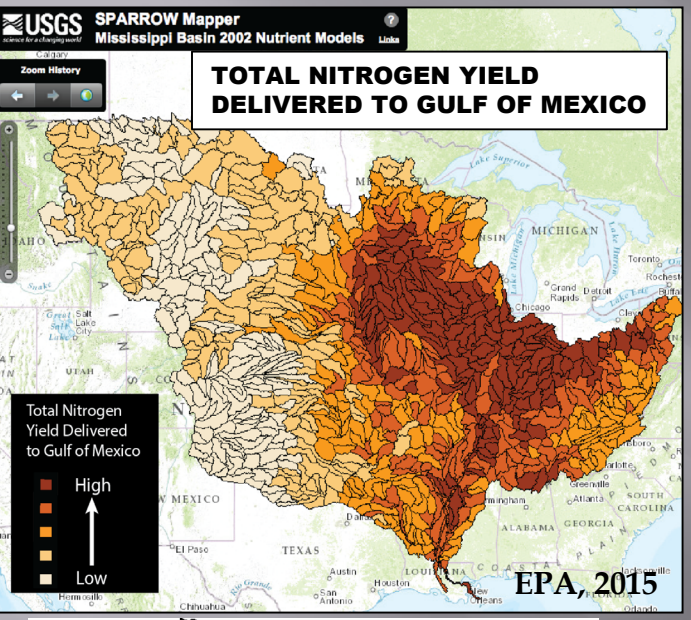


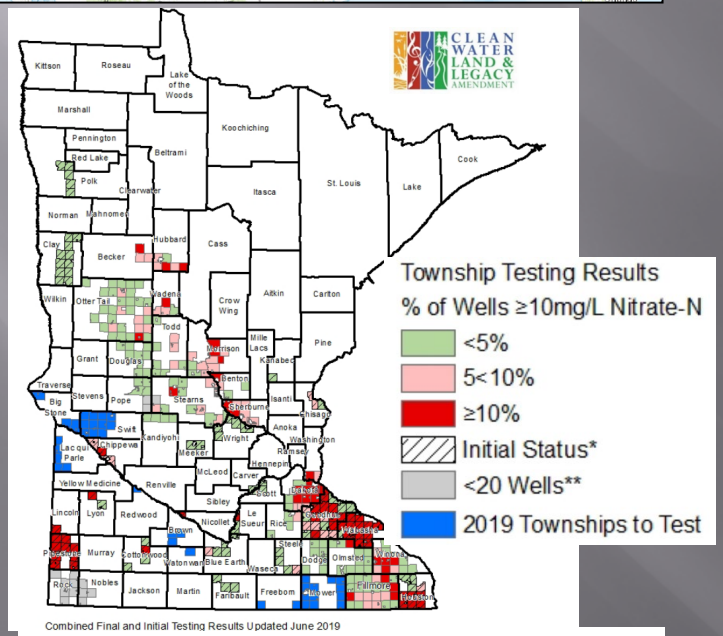


THE NITRATE PROBLEM

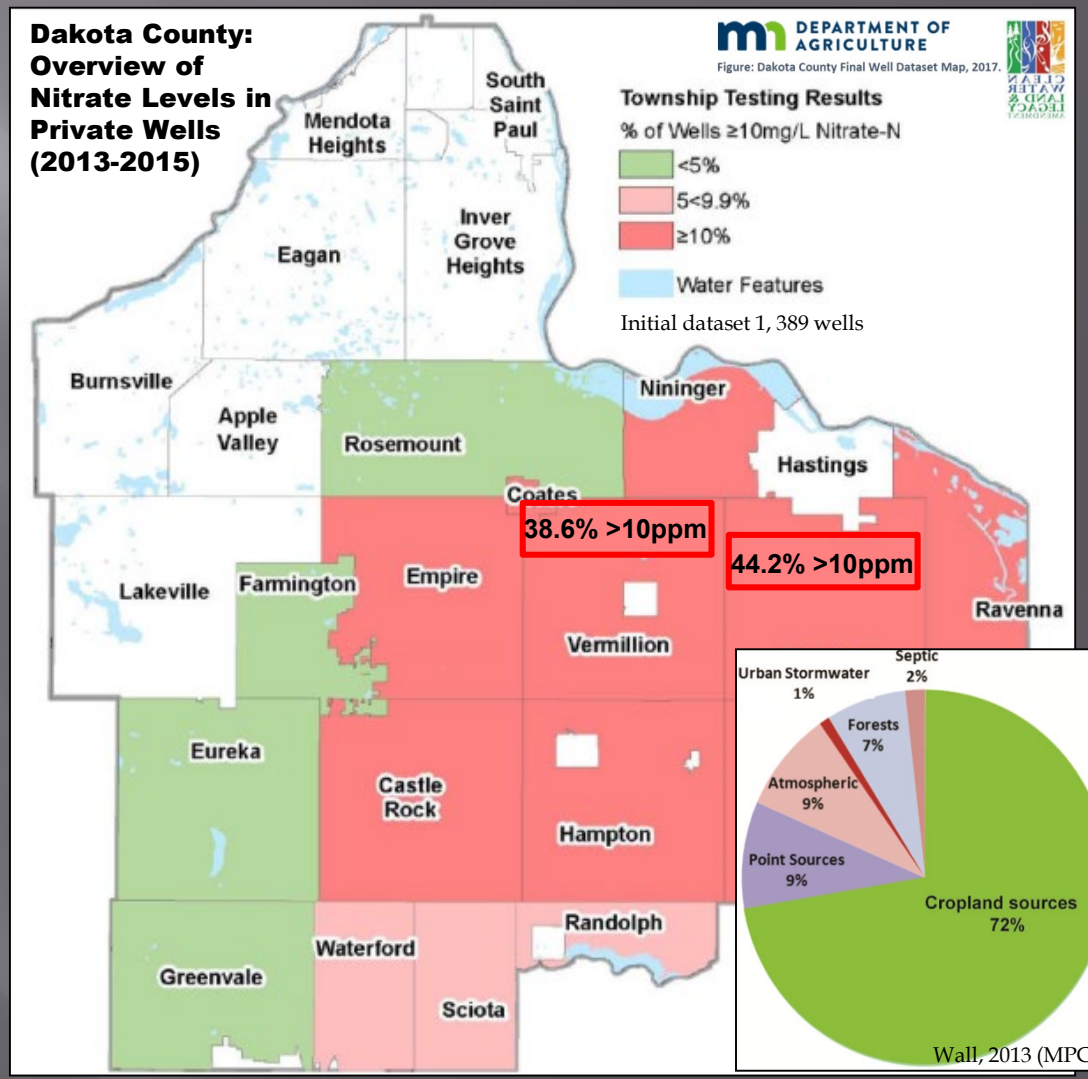
- Nitrate Pollution widespread in Southern Minnesota, Star Tribune, 2013
- Minnesota drinking water threatened by nitrates | Minnesota Public Radio, 2015
- Report finds widespread water contamination in Minnesota ...Star Tribune, 2016

- State seeks to amend Nitrogen Fertilizer Rule - St. Cloud Times, 2017
- Farmers challenge draft Nitrogen Fertilizer Rule www.thelandonline.com, 2017





MDA Township Testing Program, Nitrate Testing
Results for Private Wells as of June 2019



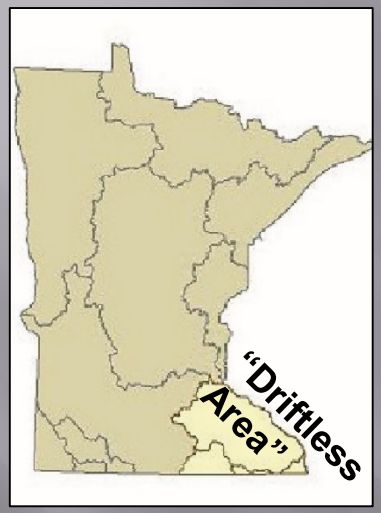
The MGS Role: 2012-2014 Project "Geologic Controls on Baseflow Nitrate Concentration in Cold Water Streams, Southeastern Minnesota"

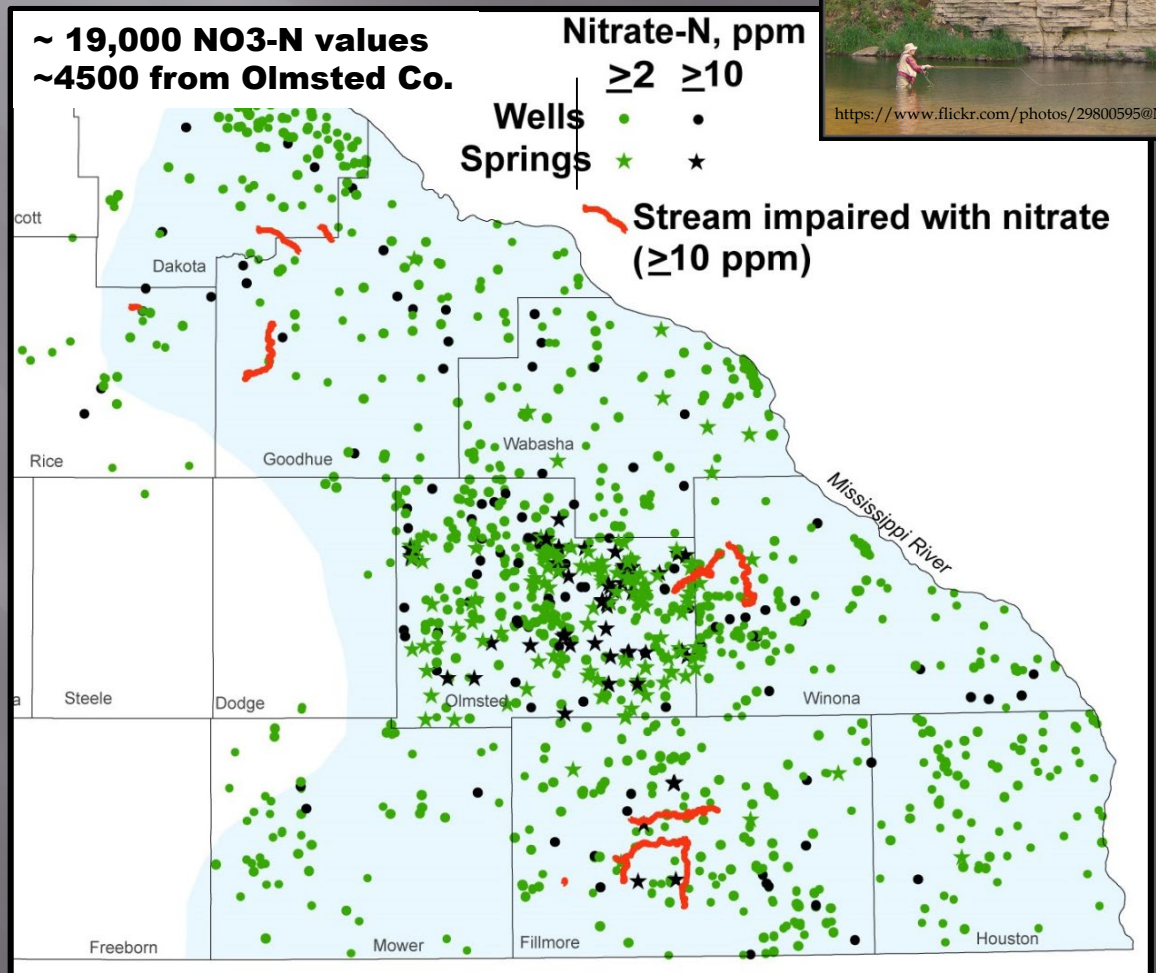
Anthony Runkel, Julia Steenberg, Bob Tipping, Andrew Retzler,
Minnesota Geological Survey

PAID FOR BY MPCA WITH
MINNESOTA CLEAN WATER FUNDS

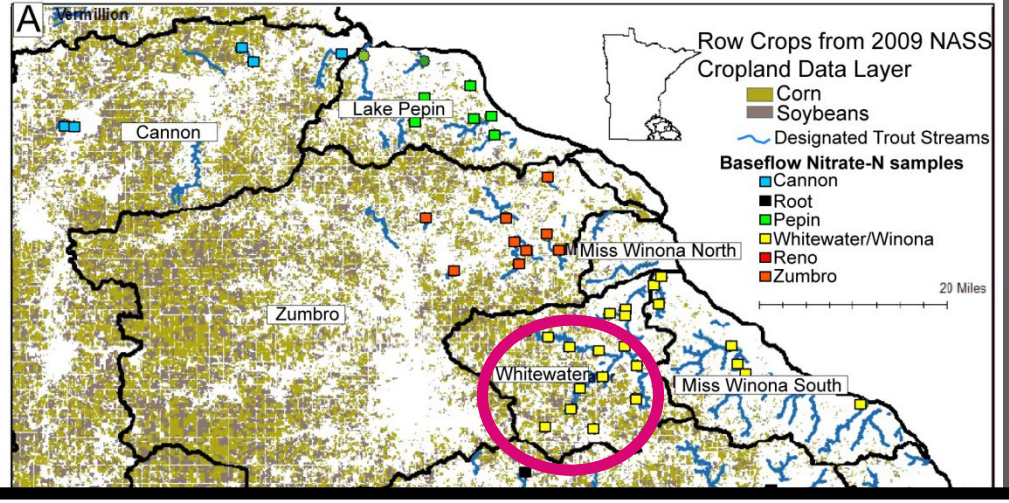
Our job:

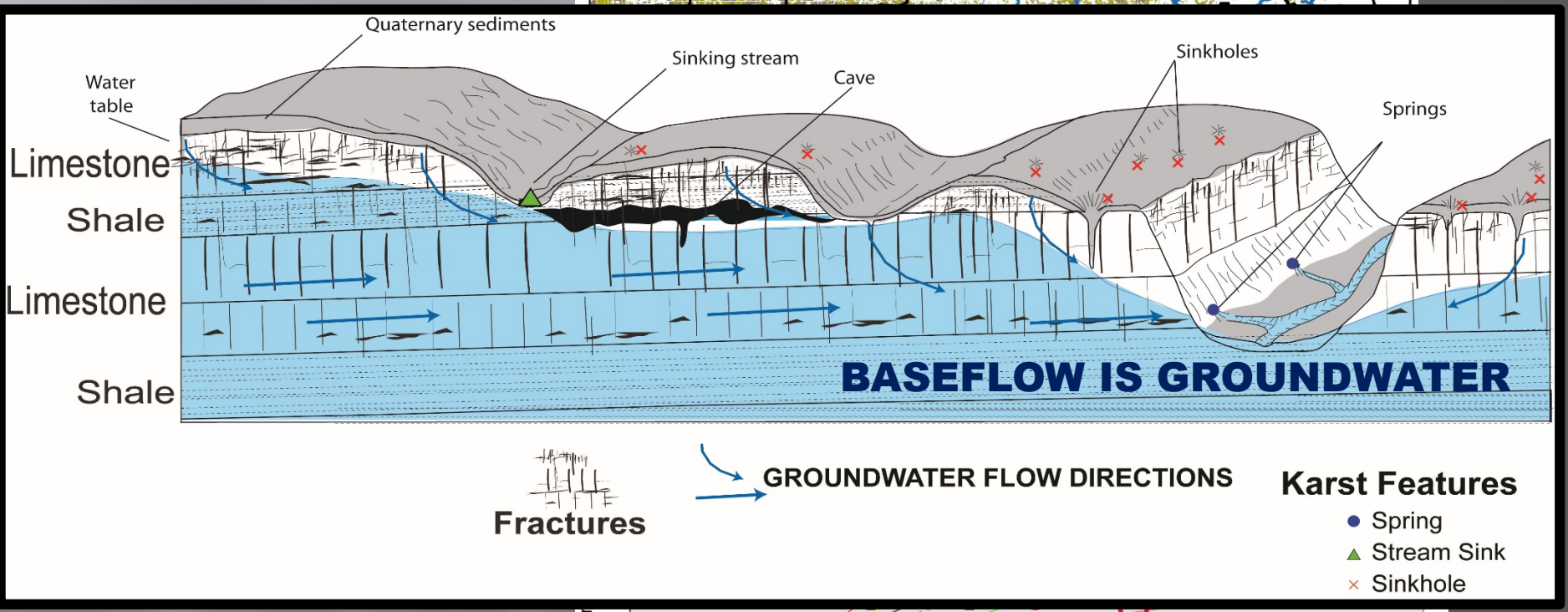
- Compile a database of nitrate values
- Place the samples in geologic context
- Our job: How is nitrate is transported in the groundwater-surface water system?

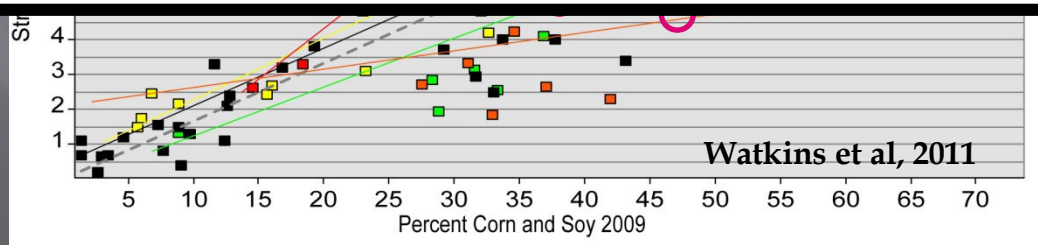




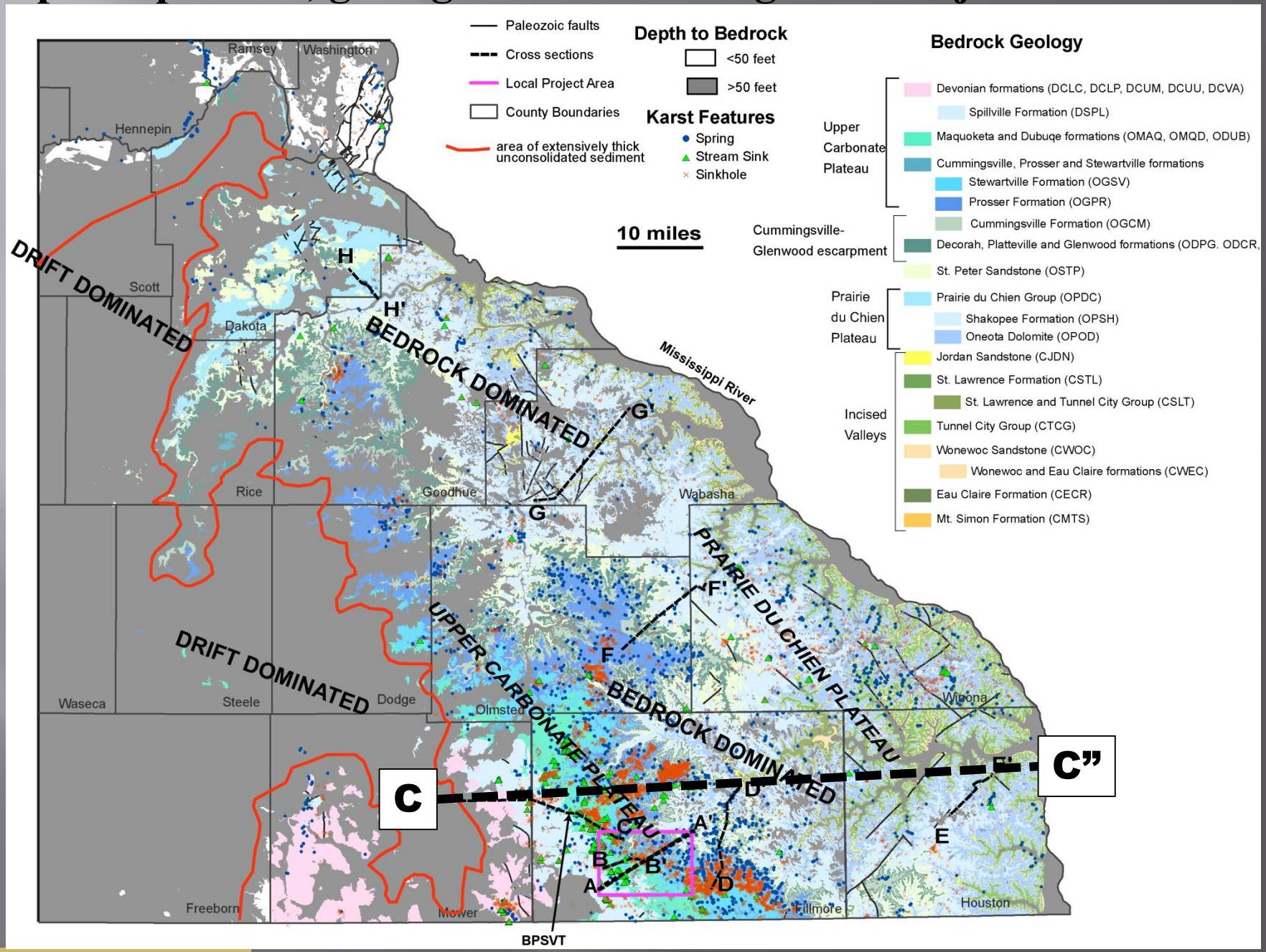
Accounting for variability in correlation between baseflow nitrate and row crop activity

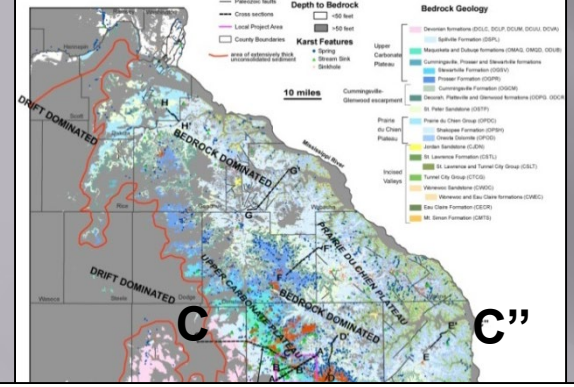


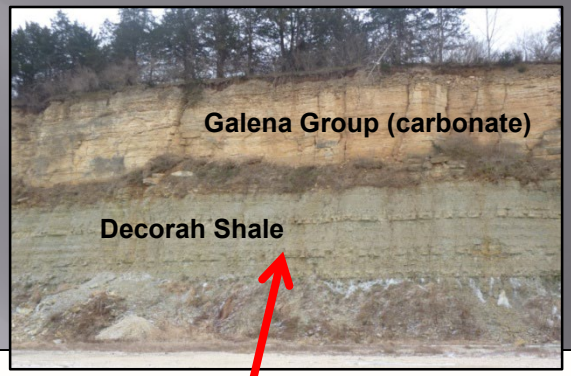


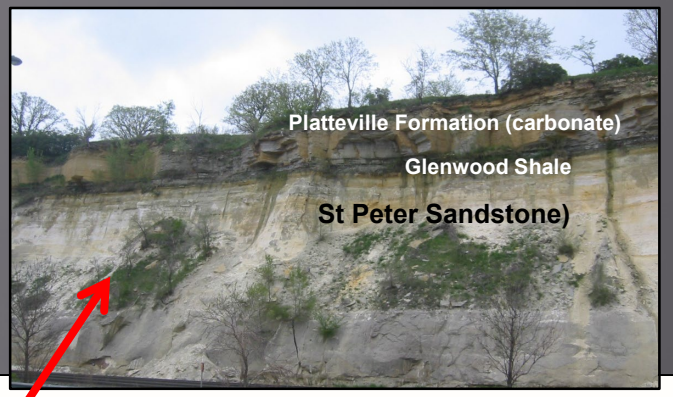


Map compilation, geologic overview: Regional Project area



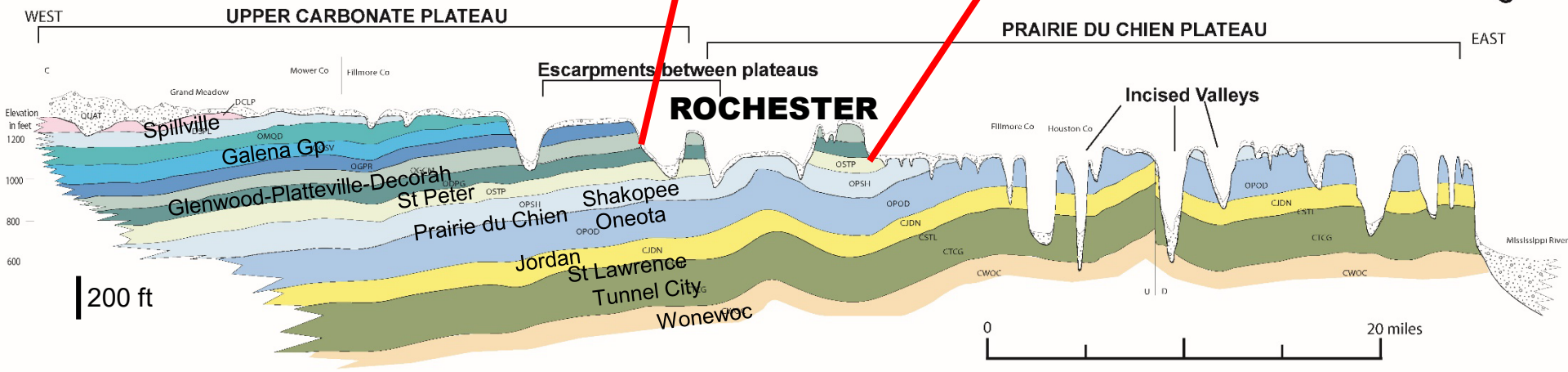

Depth to Bedrock
Bedrock Geology
Karst Features
10 miles
DRIFT DOMINATED
BEDROCK DOMINATED
PRAIRIE DU CHIEN PLATEAU
UPPER CARBONATE PLATEAU
C
C”

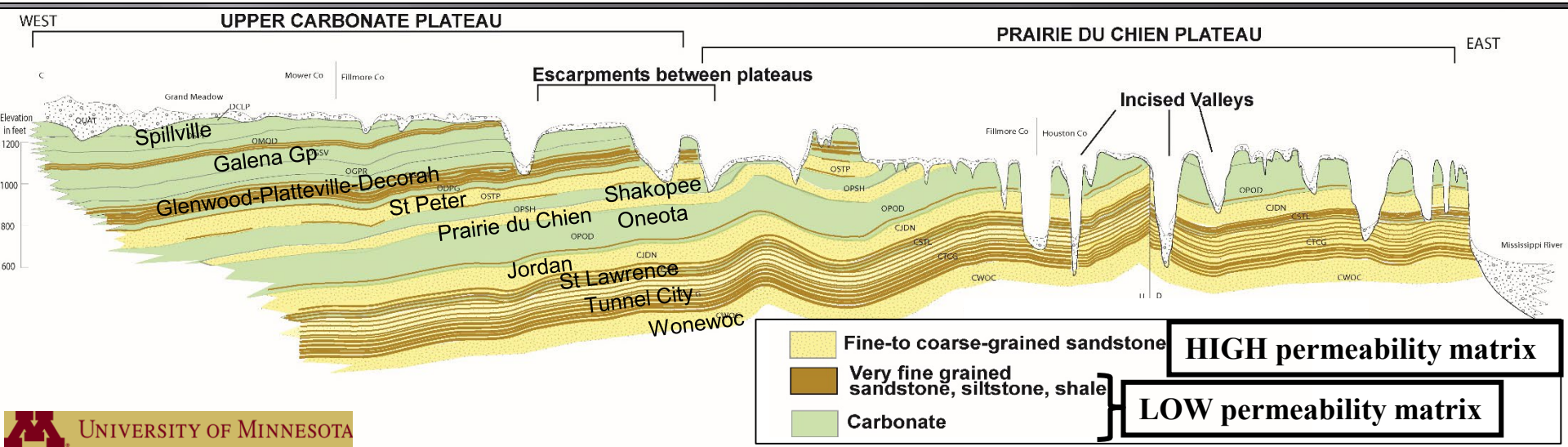

Galena Group (carbonate)
Decorah Shale


Platteville Formation (carbonate)
Glenwood Shale
St Peter Sandstone)

C

C"


WEST
UPPER CARBONATE PLATEAU
PRAIRIE DU CHIEN PLATEAU
EAST
Escarpments between plateaus
ROCHESTER
Incised Valleys
Mower Co
Fillmore Co
Houston Co
Grand Meadow
Elevation in feet
1200
1000
800
600
QUAT
DCLP
Spillville
OMOD
Galena Gp
OSV
OGPR
Glenwood-Platteville-Decorah
OGCM
ODPG
St Peter
OSTP
OPSH
Prairie du Chien
Shakopee
Oneota
OPOD
CJDN
Jordan
CSTL
St Lawrence
CTCG
Tunnel City
CWOC
Wonewoc
200 ft
Mississippi River
0
20 miles


WEST
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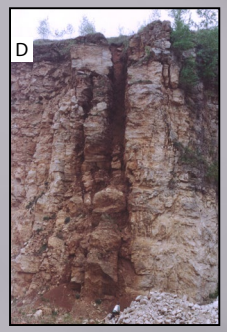
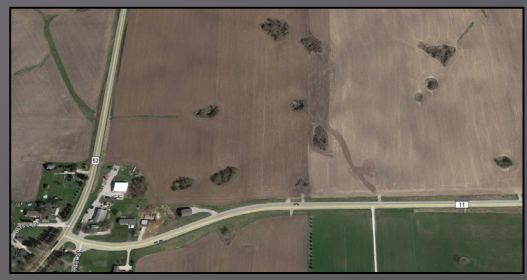
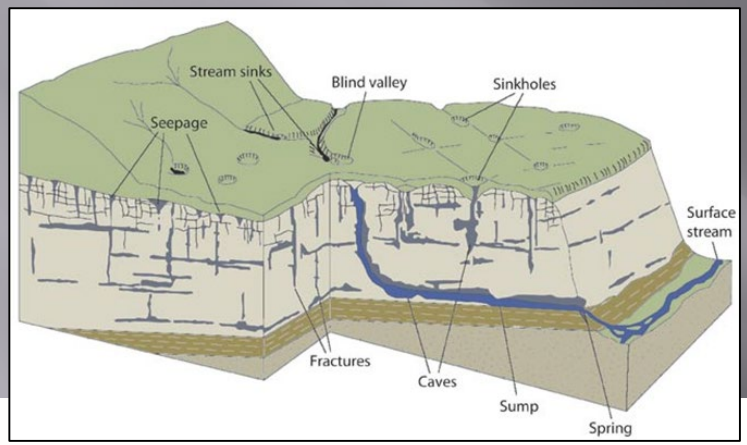
OSV
OGPR
Glenwood-Platteville-Decorah
ODPG
St Peter
OSTP
OPSH
Prairie du Chien
Shakopee
Oneota
OPOD
CJDN
Jordan
CSTL
St Lawrence
CTCG
Tunnel City
CWOC
Wonewoc
Mississippi River
Fine-to coarse-grained sandstone
Very fine grained sandstone, siltstone, shale
Carbonate
HIGH permeability matrix
LOW permeability matrix

FRACTURED ROCK AND KARST







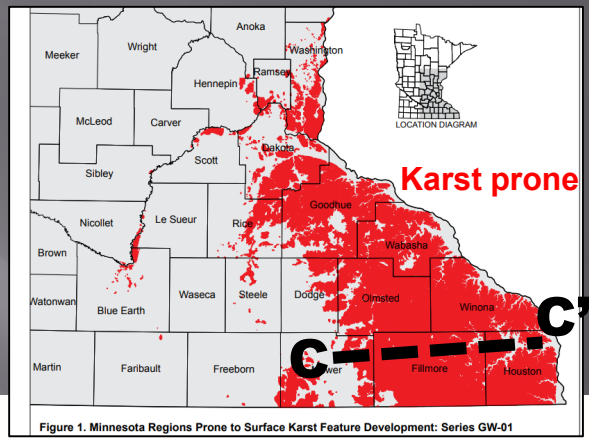


Figure 1. Minnesota Regions Prone to Surface Karst Feature Development: Series GW-01

C

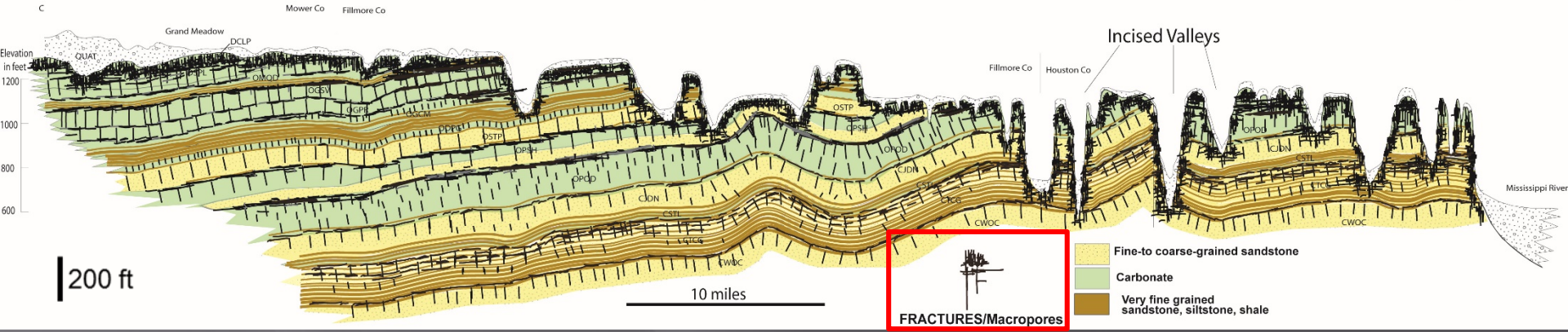
WEST

UPPER CARBONATE PLATEAU KARST

PRAIRIE DU CHIEN PLATEAU KARST

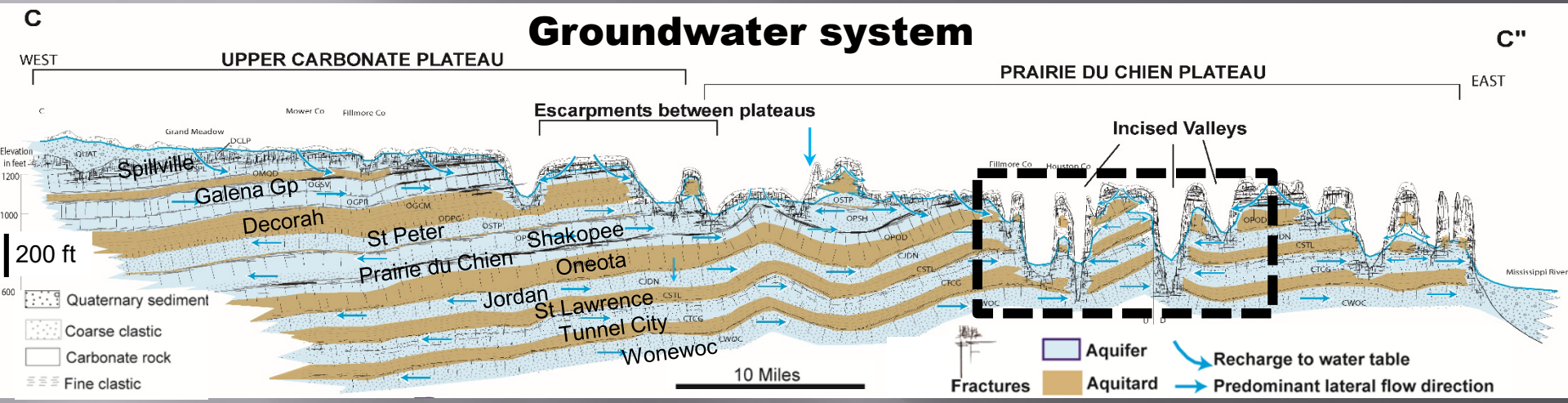
EAST

C"

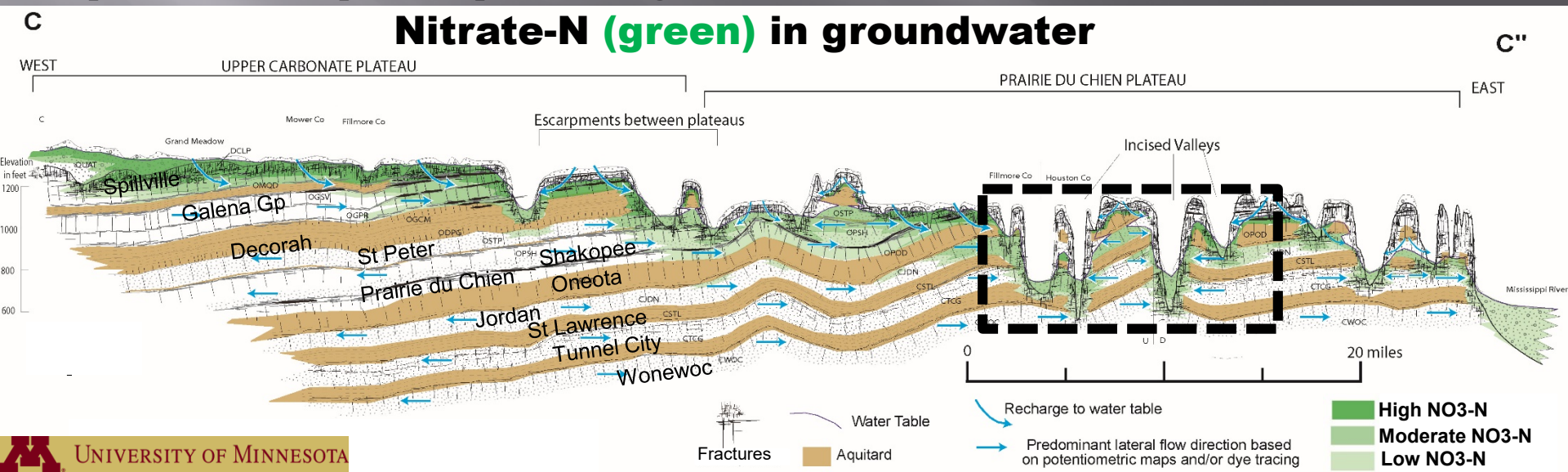


REGIONAL GROUNDWATER SYSTEM

- Rapid recharge into heavily fractured uppermost bedrock
- Stacked layers of aquifers and aquitards
- Rapid lateral flow, especially along BPPs
- Slower downward leakage, especially retarded at aquitards.



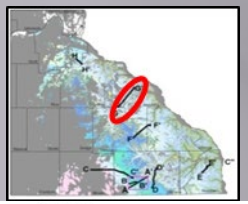
- Nitrate rapidly transported to upper bedrock, with high concentrations
- Aquitards slow deeper transport, causing stratification

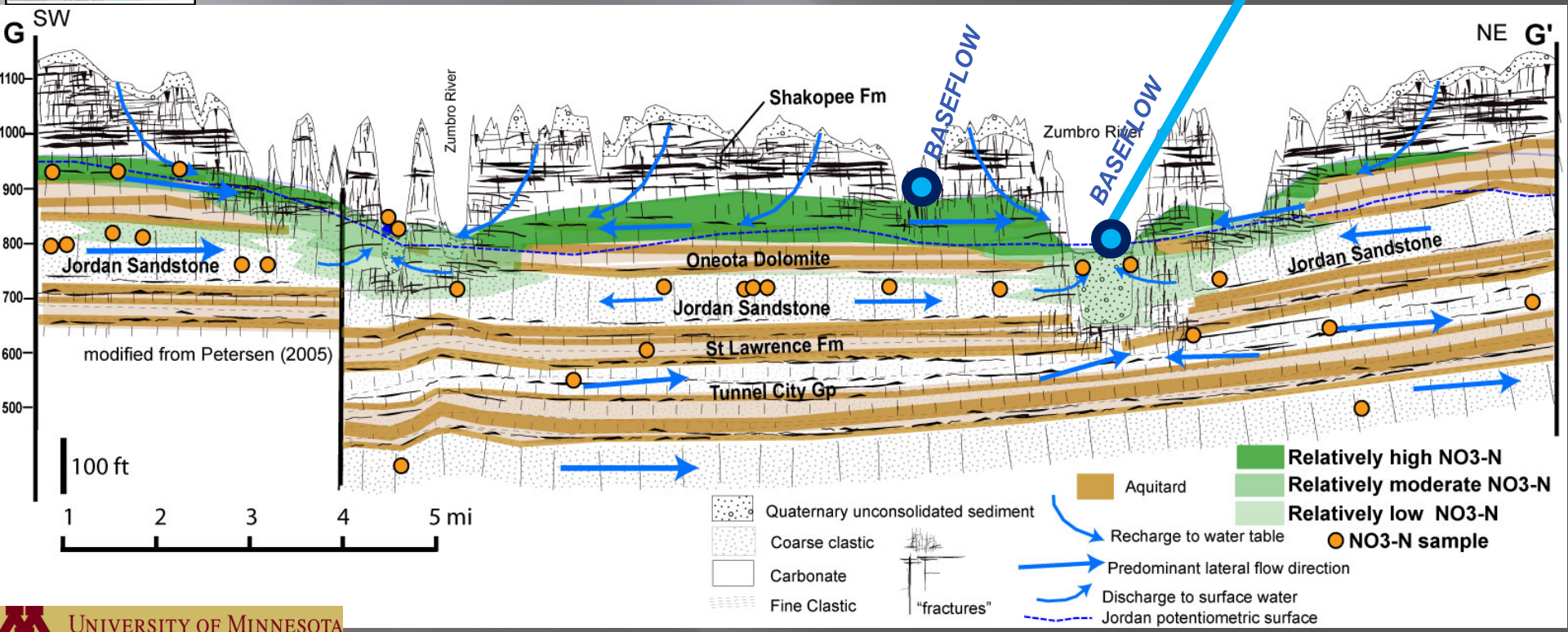


Anisotropy leads to a stratified groundwater system

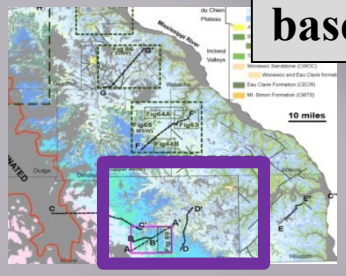
- Rapid recharge
- Rapid lateral flow
- Slow downward leakage across aquitards
- This causes stratification in age

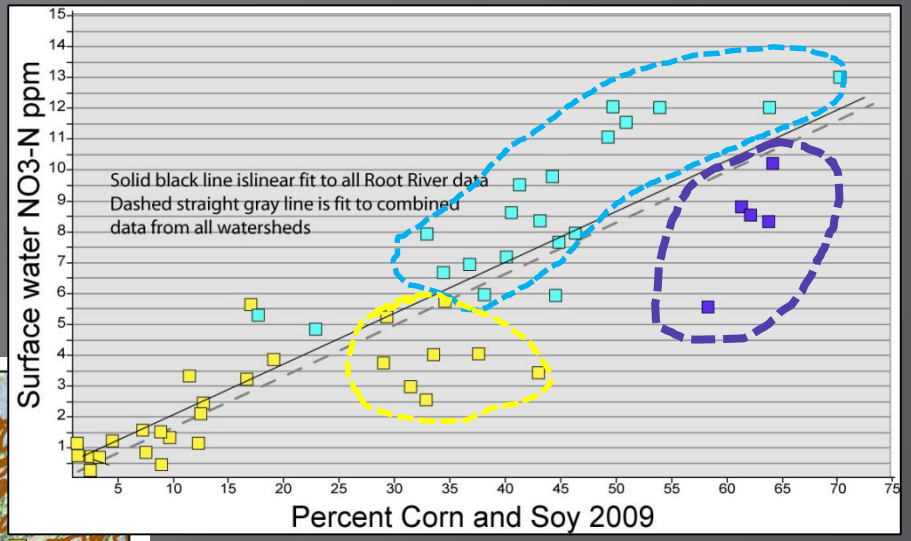
- Flow towards incised valleys to discharge as baseflow
- Baseflow average age thus variable

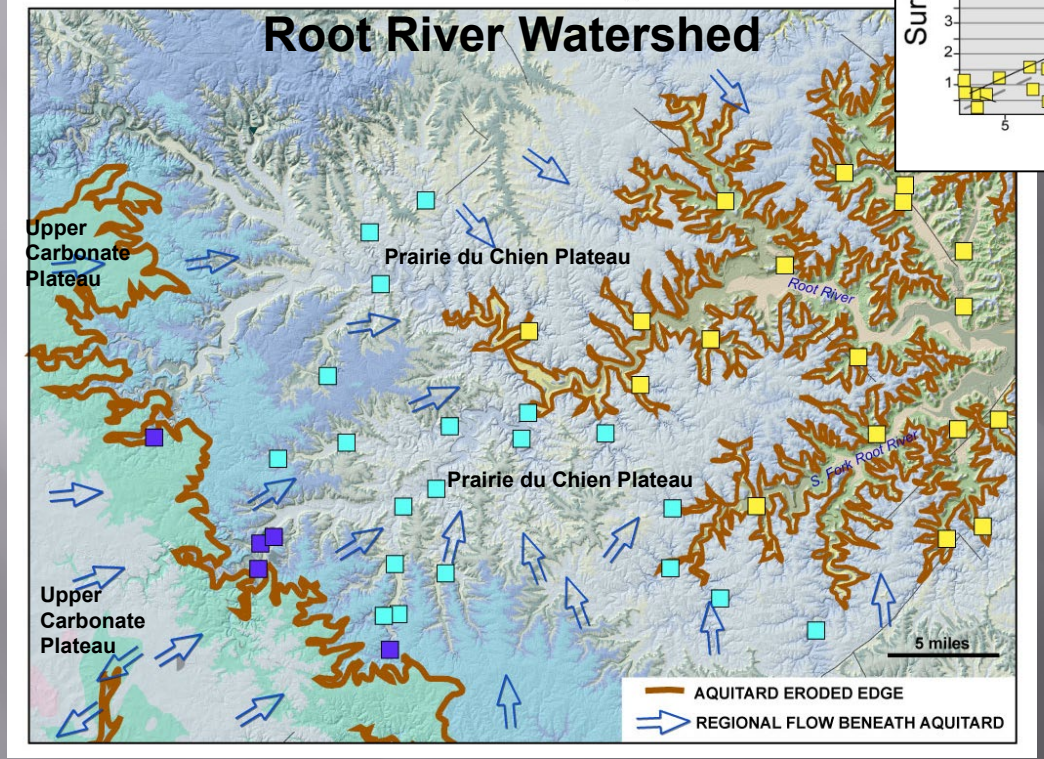


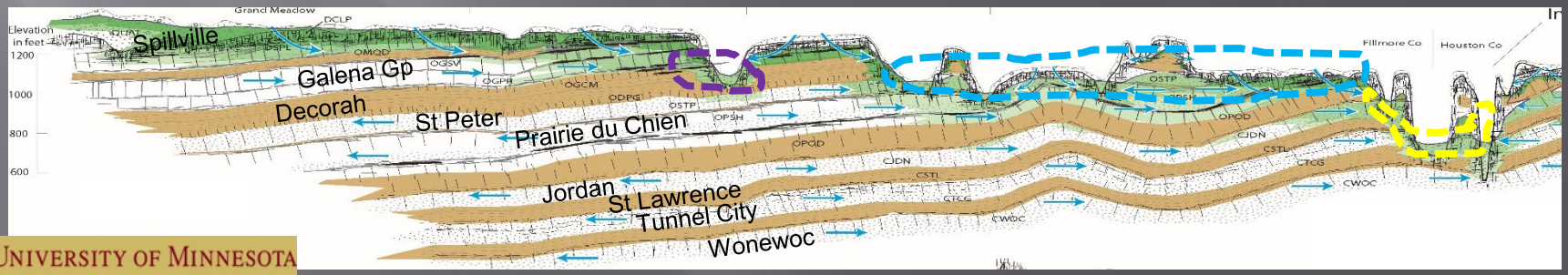


Explaining variability in stream baseflow nitrate concentrations









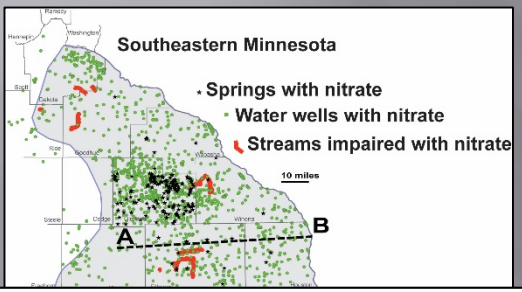
CONCLUSIONS FOR MPCA

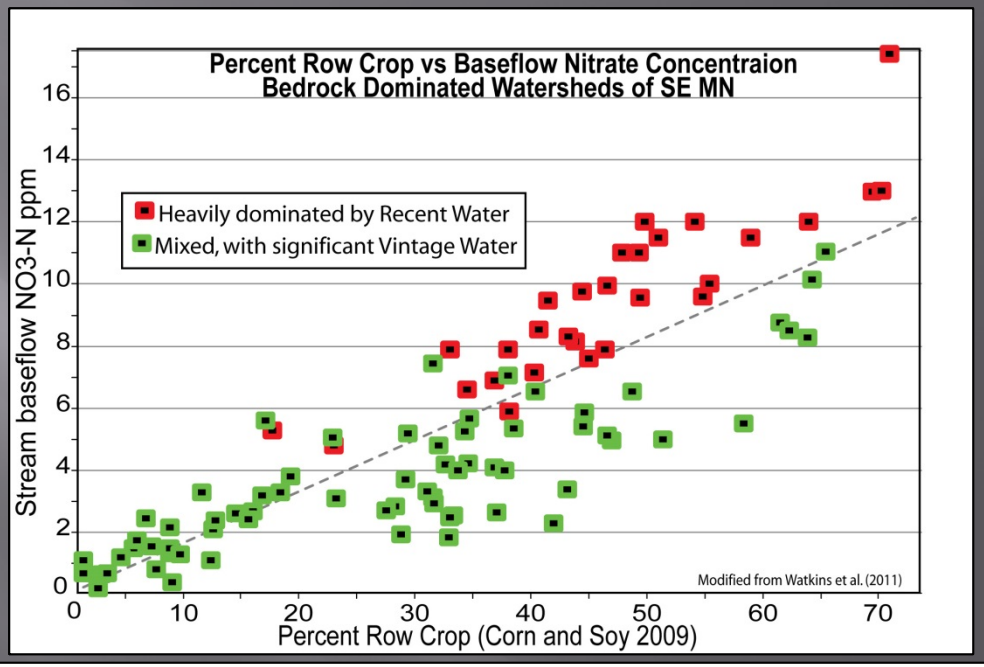
Hydrogeologic conditions can account for variability in correlation of land use to baseflow nitrate concentration

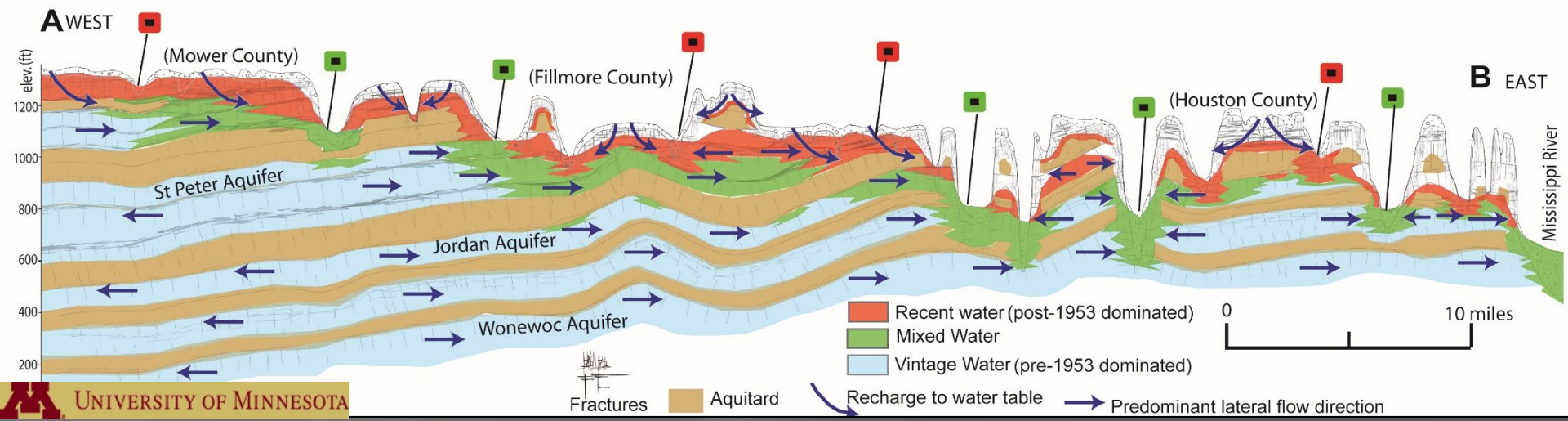
The degree to which older, nitrate poor water is mixed with younger nitrate-enriched water is important

The mixing may be generally predictable based on setting in landscape

Runkel et al., 2013







WHICH DECADE ARE WE MONITORING? THE LAG TIME ISSUE

Nitrate pollution the focus of dairy debate

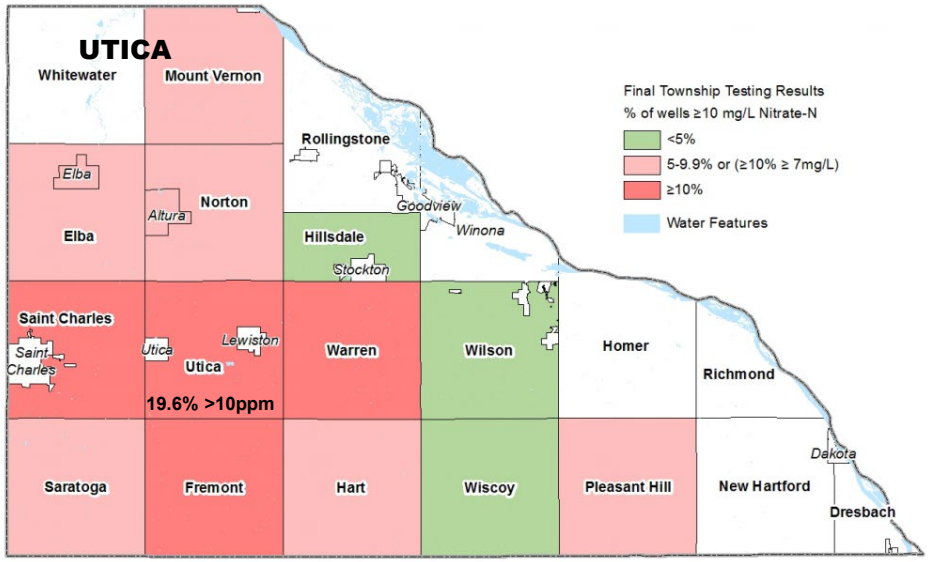
(10/5/2017)
by CHRIS ROGERS, WINONA POST

““We have a nitrate problem in Utica Township, and if we don’t begin addressing it, it’s going to get worse,” Stanage stated”

“Winona County Farm Bureau leaders like Glen Groth and Duane Wirt see efforts to pin nitrate pollution on current farming practices as unfair”

“Groth and Wirt contend that nitrates in groundwater are largely the remnants of less careful farming practices from years ago”.

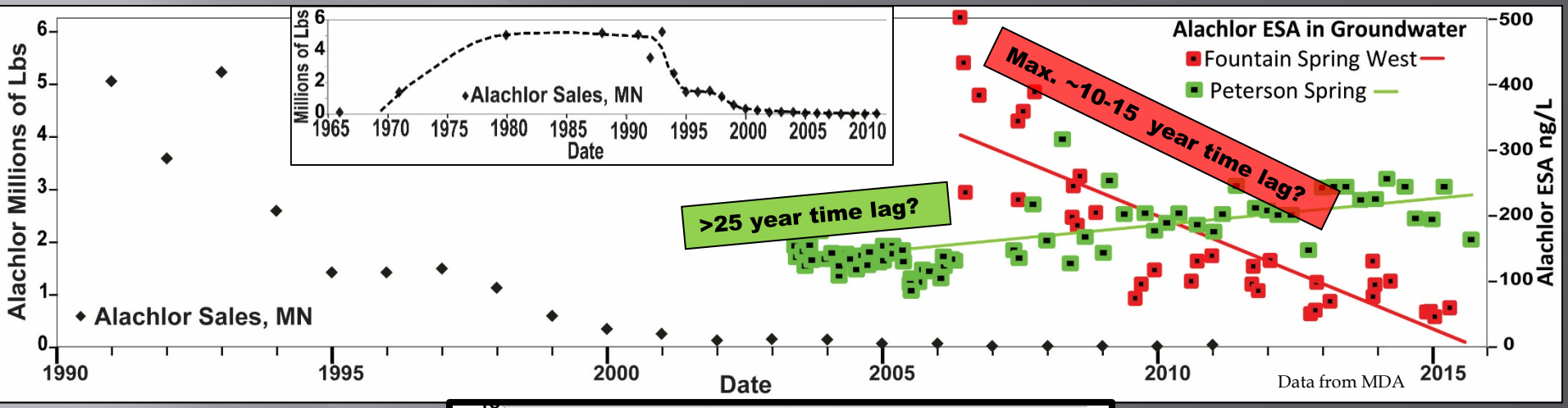
Figure: Winona County Final Well Dataset Map, 2018.

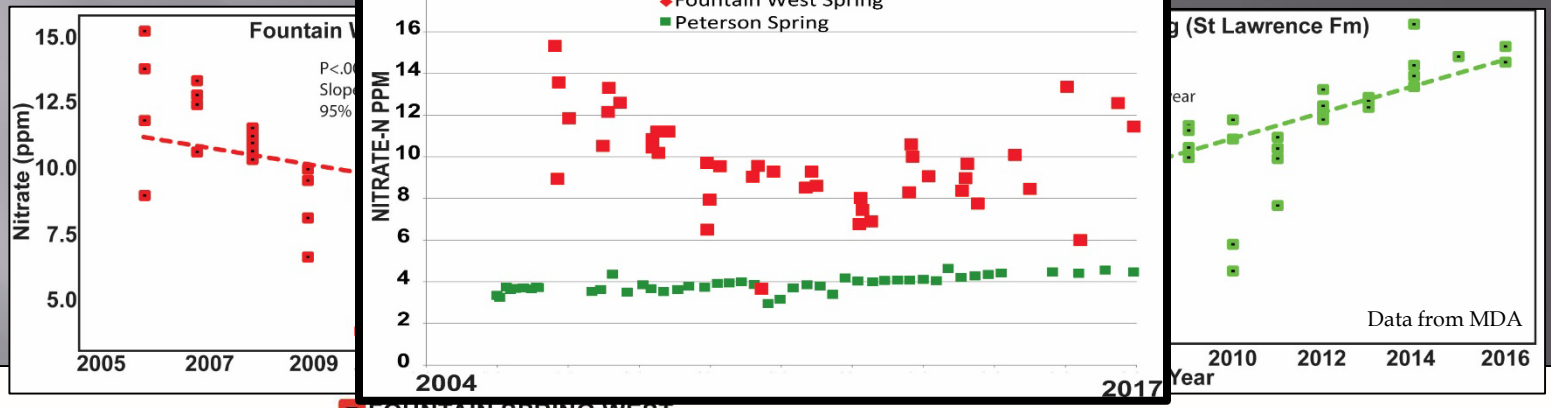


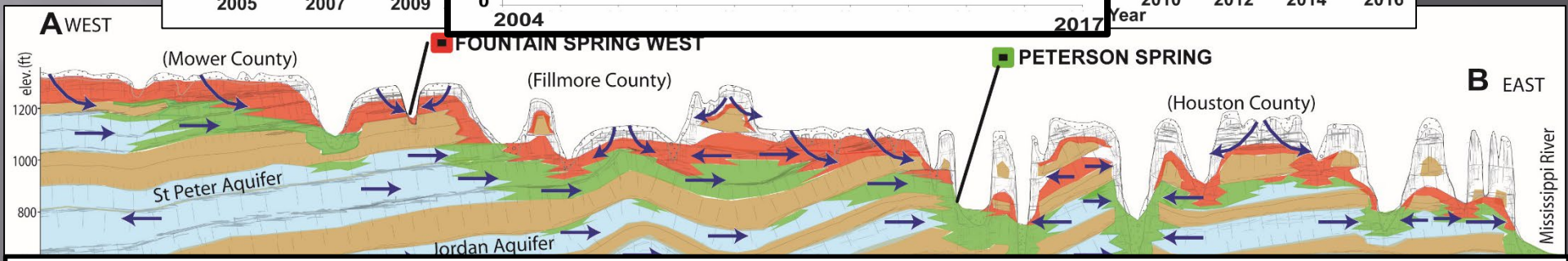
DEPARTMENT OF AGRICULTURE

Winona County: Final Overview of Nitrate Levels in Private Wells (2016-2017)

WHICH DECADE ARE WE MONITORING? THE LAG TIME ISSUE



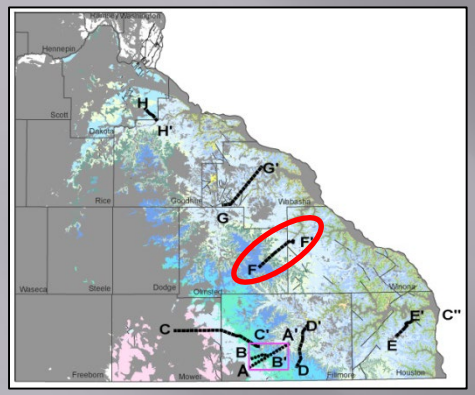


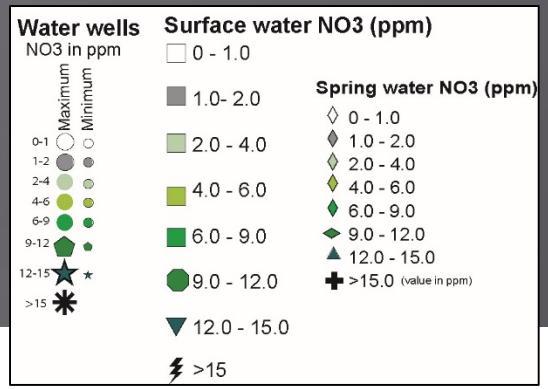


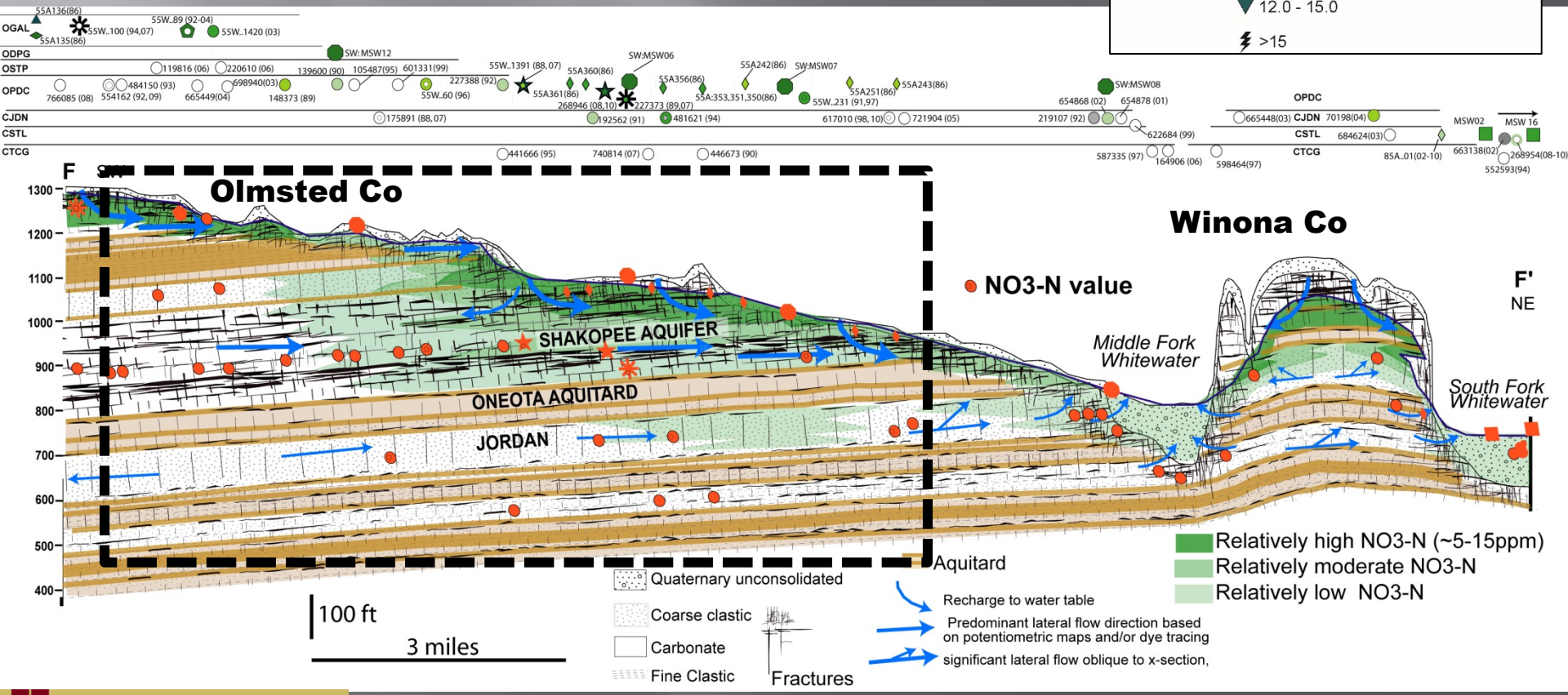
Implications

- Much of the groundwater we sample is old water that reflects land surface conditions of decades ago
- If we want to track the effect of recent changes in Ag practices, regular (time series) monitoring, especially of more "recent" (i.e. young) water sites is needed

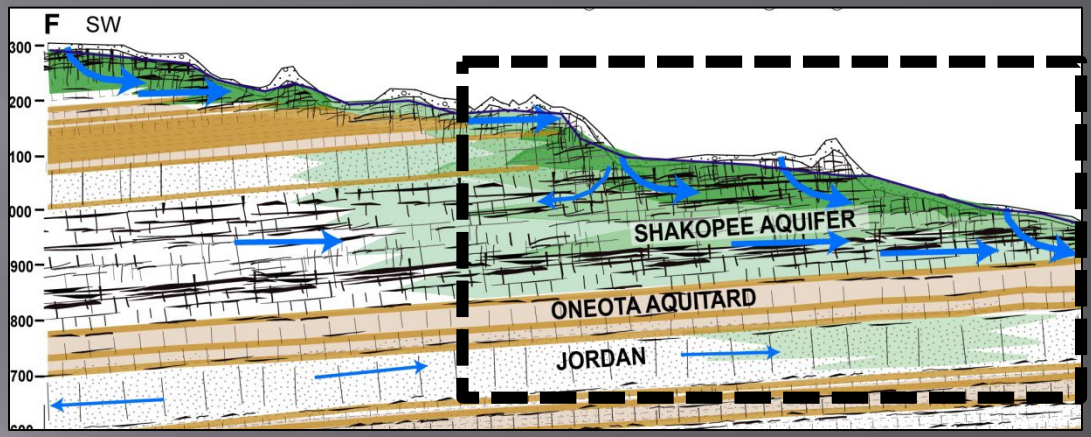
OLMSTED COUNTY EXAMPLE OF NITRATE IN GROUNDWATER

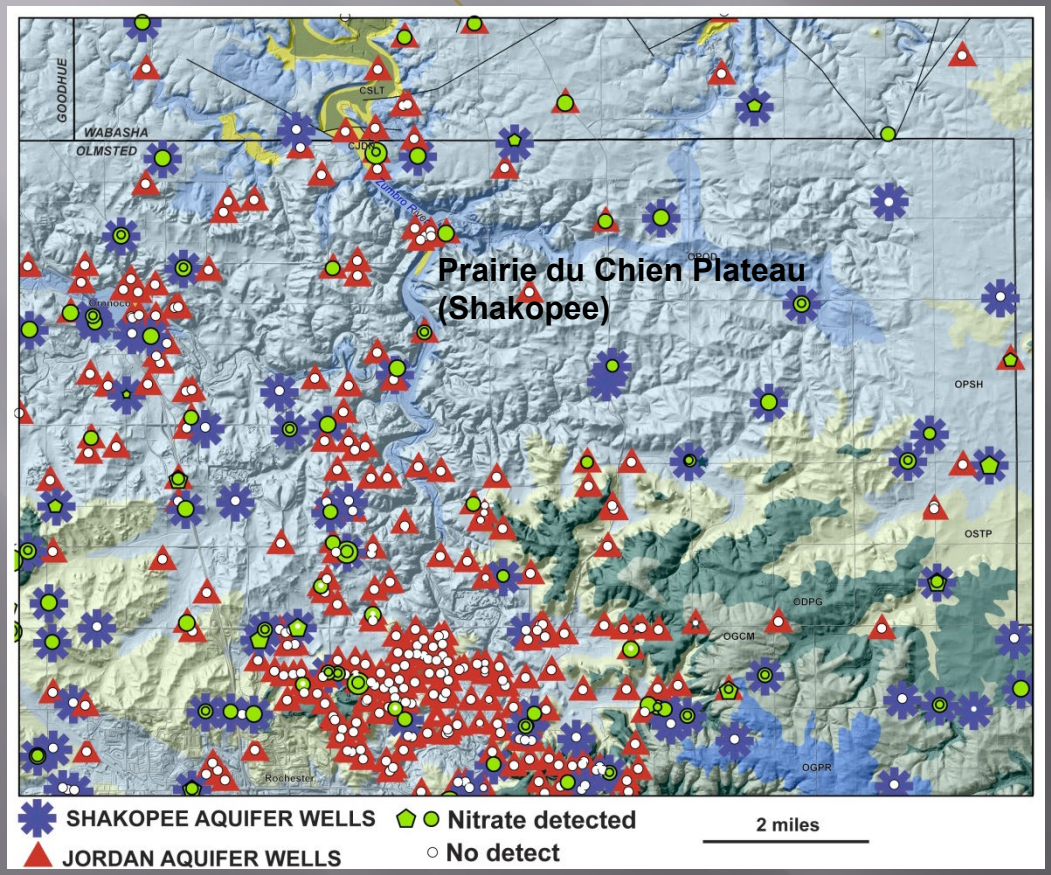


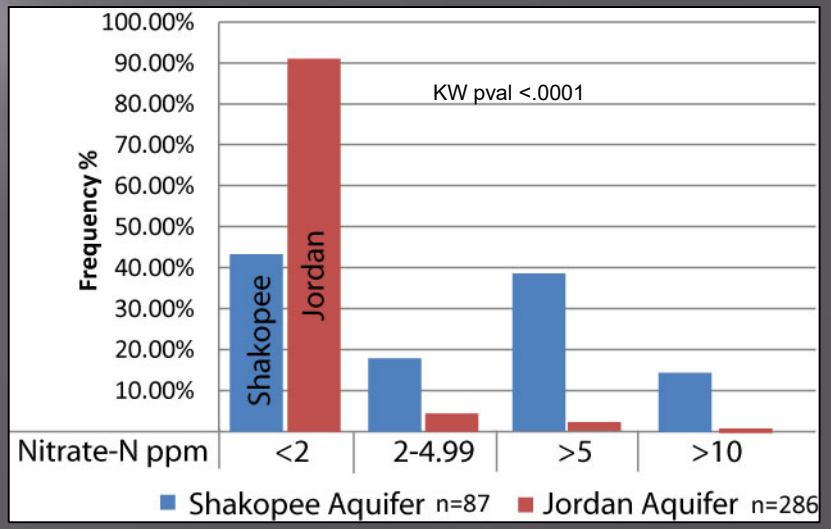




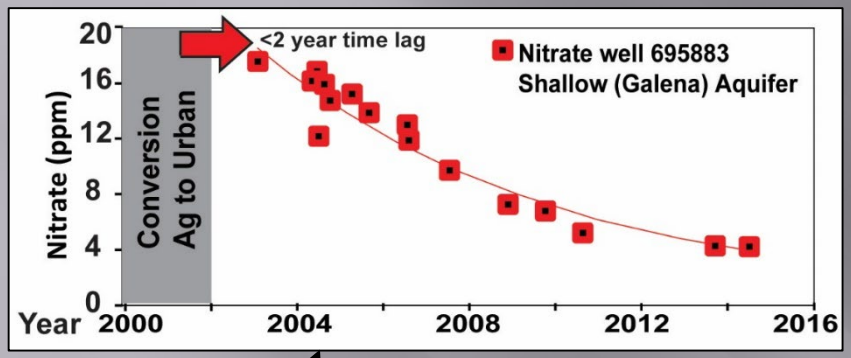
Nitrate stratification: northern Olmsted Co.



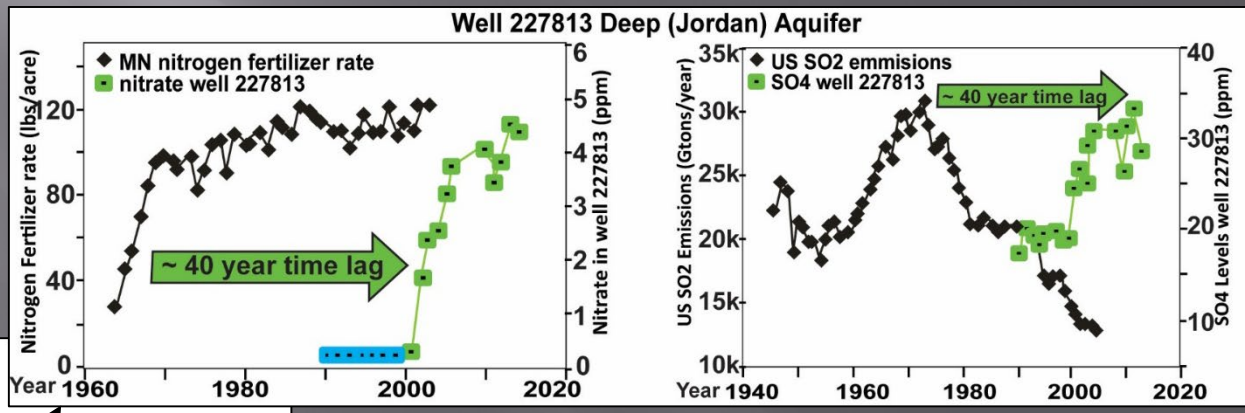


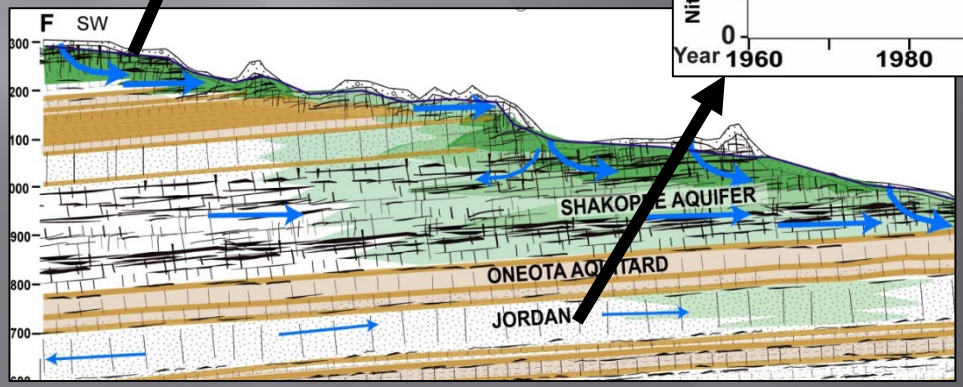


OLMSTED COUNTY EXAMPLE OF LAG TIME ISSUE



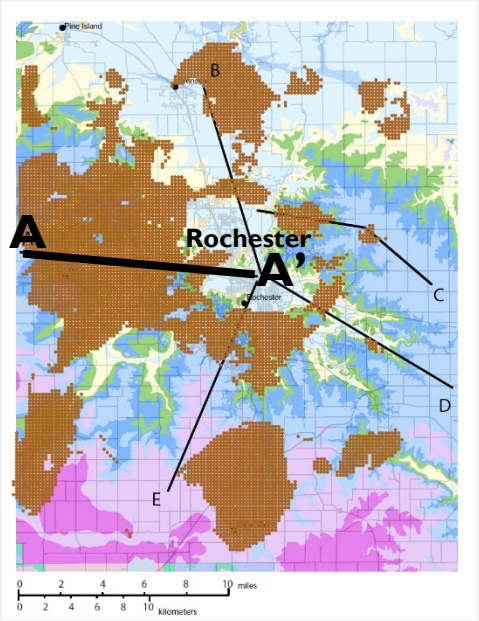
From Terry Lee (Olmsted County) and Kimm Crawford.



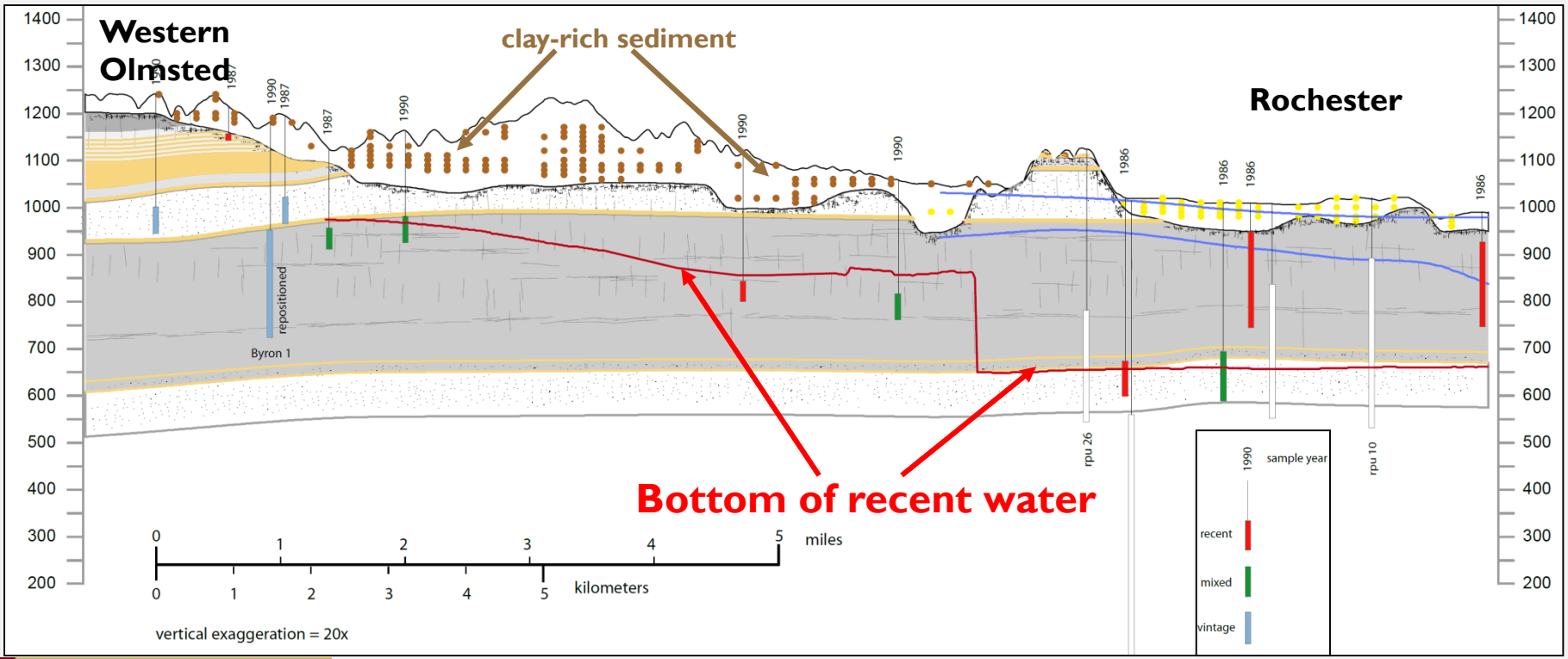


A Hydrochemical Survey of Groundwater Flow in the Rochester Metropolitan Area, Minnesota

Tipping (2014)

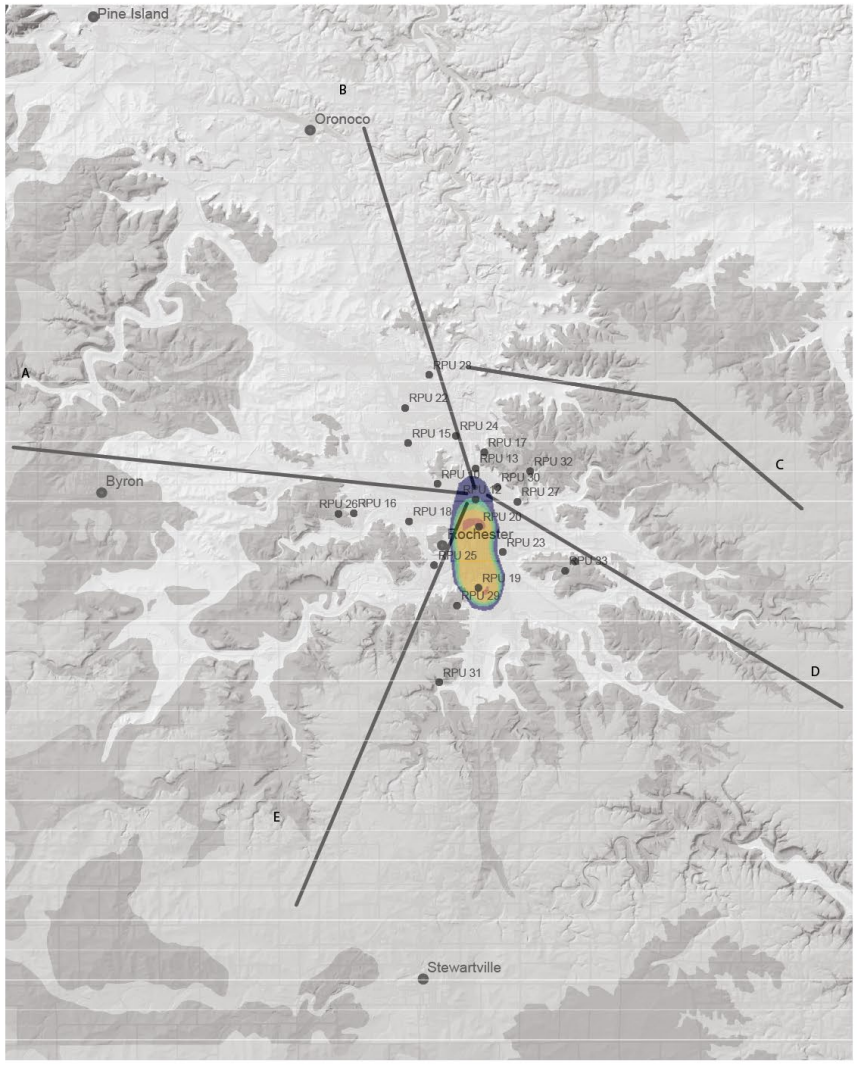


= clay-rich sediment



Rochester, distribution of recent water

1981

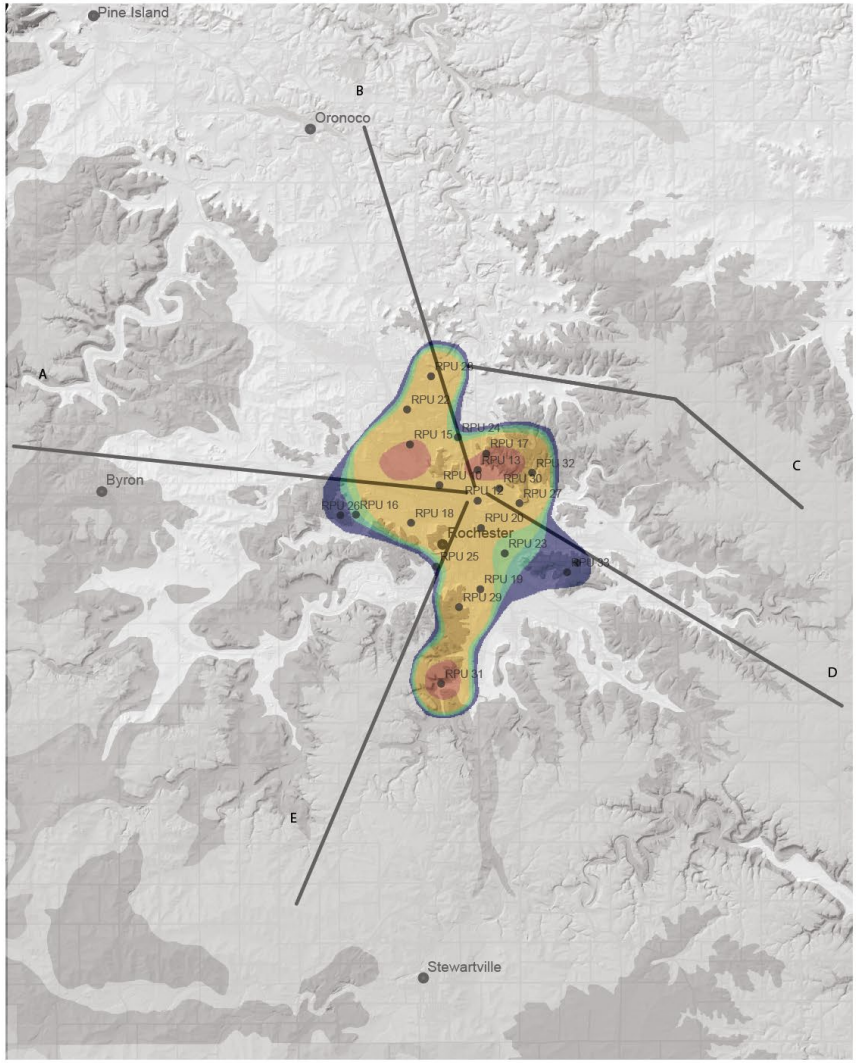


0 2 4 6 8 10 miles

0 2 4 6 8 10 kilometers

A

2011



0 2 4 6 8 10 miles

0 2 4 6 8 10 kilometers

B

elevation, ft. above mean sea level

< 650

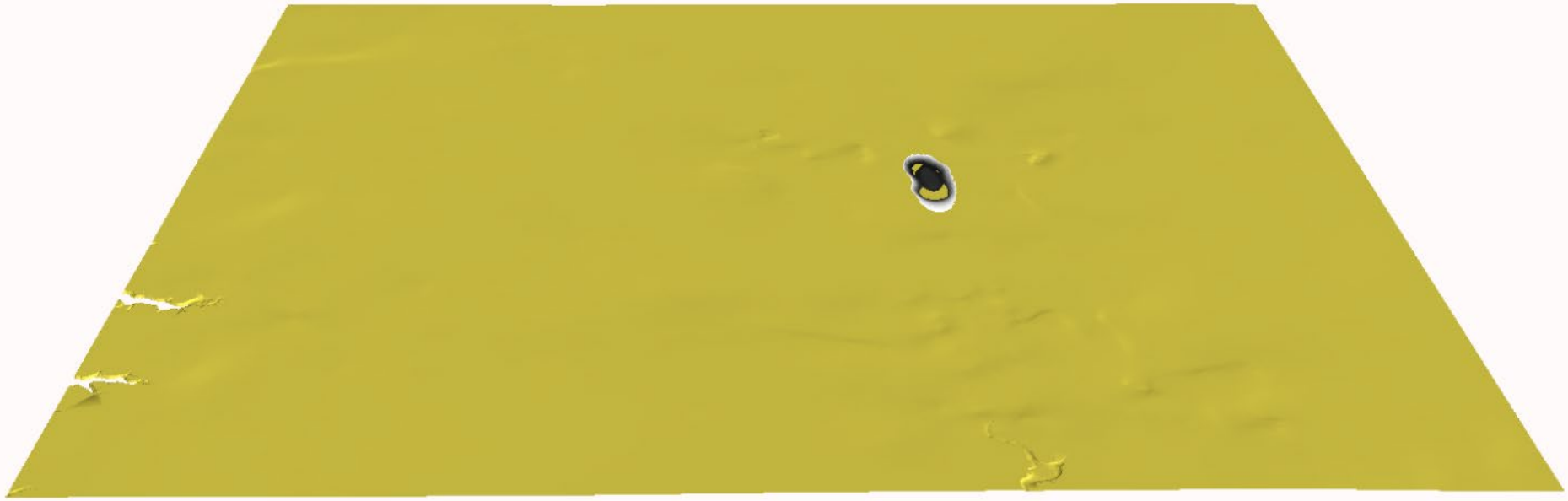
650 - 699

700 - 749

750 - 800

> 800

Rochester, distribution of recent water: 1981



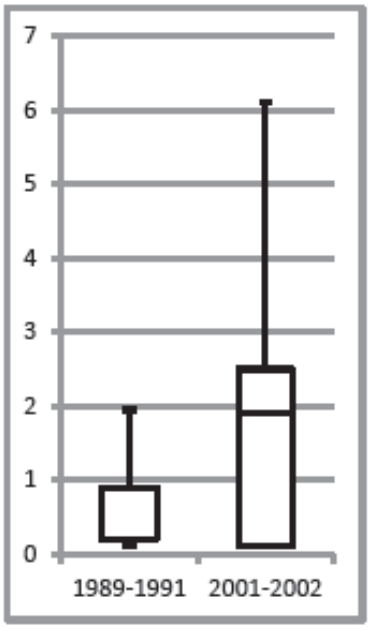
Rochester, distribution of recent water: 2011

Rochester, distribution of recent water: 2011

Nitrate concentrations over time, Prairie du Chien Group Rochester area

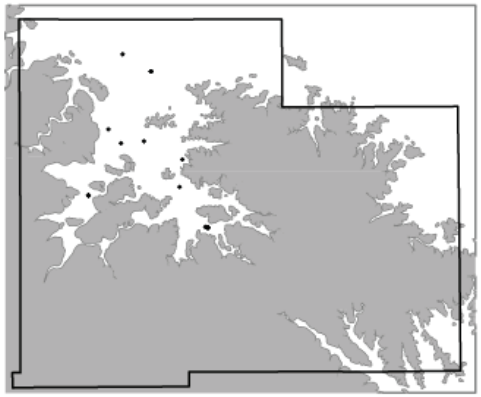
zone 3

	1989-1991	2001-2002	2009-
count	17	9	3
min	0.0999	0.0999	2.5
max	11.1	6.4	5
median	0.2	1.9	3
mean	1	2	4
upper quartile	0.9	2.5	4
lower quartile	0.2	0.0999	2.75
std dev	2.6	2.5	1.3



zone 3

1989-1992

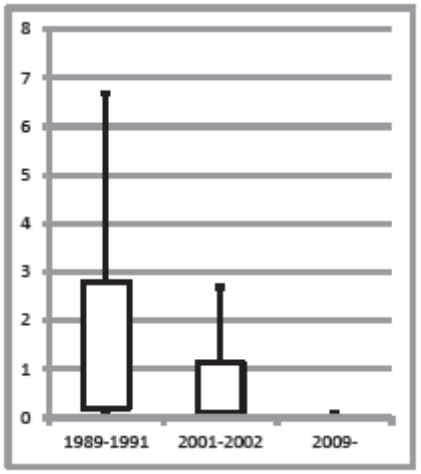


2001-2002

Nitrate concentrations over time, Jordan Aquifer Rochester area

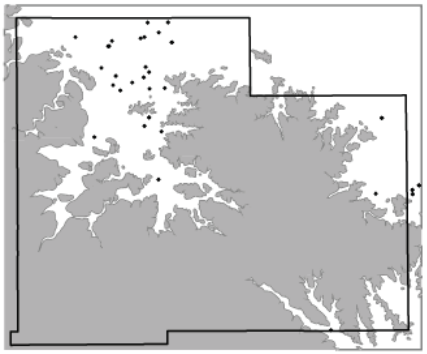
zone 3

	1989-1991	2001-2002	2009-
count	37	24	35
min	0.0999	0.0999	0.0999
max	9.2	10.9	6
median	0.2	0.0999	0.0999
mean	2	2	1
upper quartile	2.8	1.135	0.0999
lower quartile	0.2	0.0999	0.0999
std dev	2.6	2.9	1.4

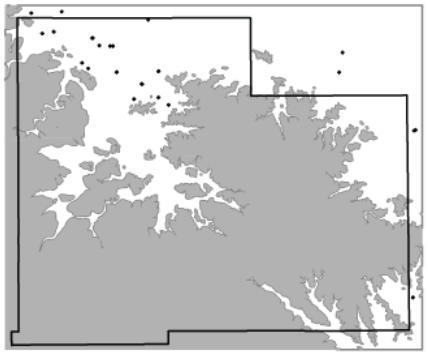


zone 3

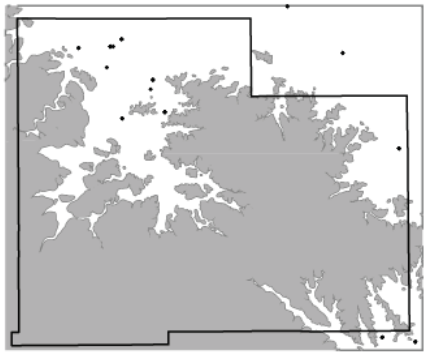
1989-1992



2001-2002



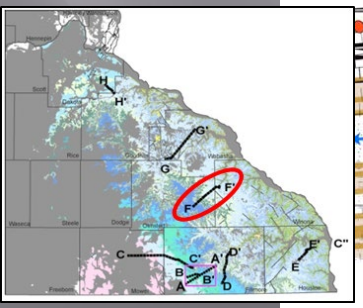
2009-present

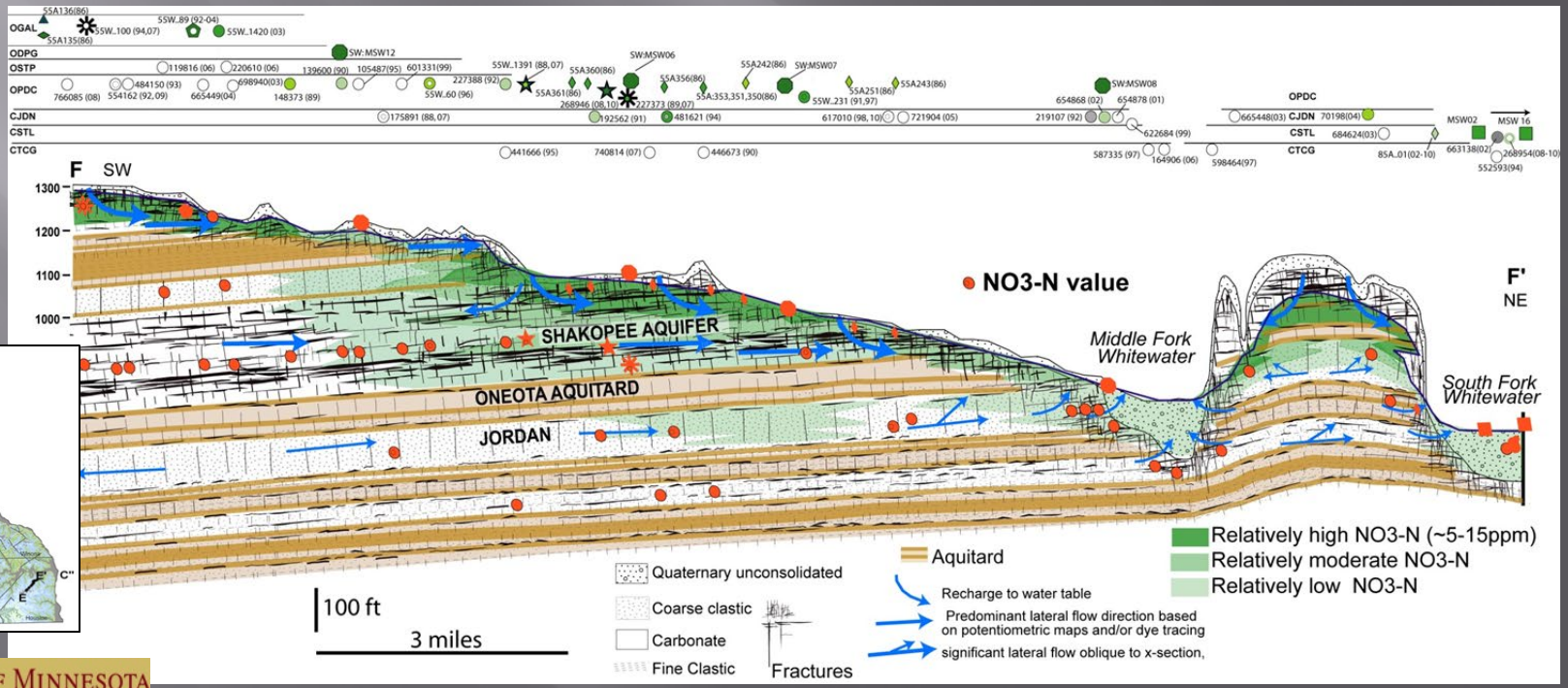


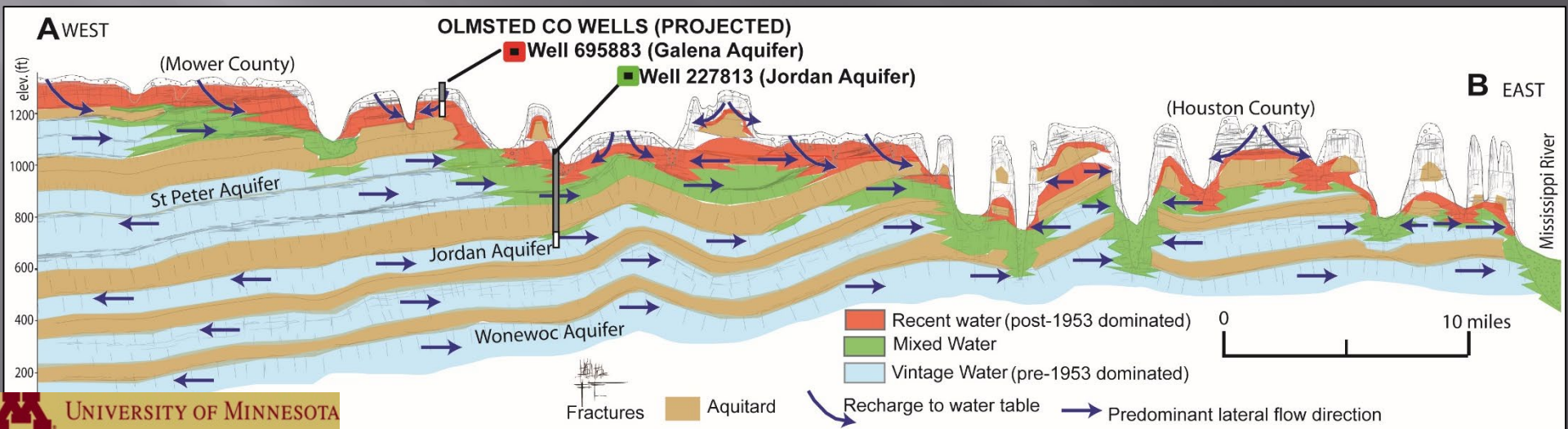
Nitrate in southeastern Minnesota

SUMMARY

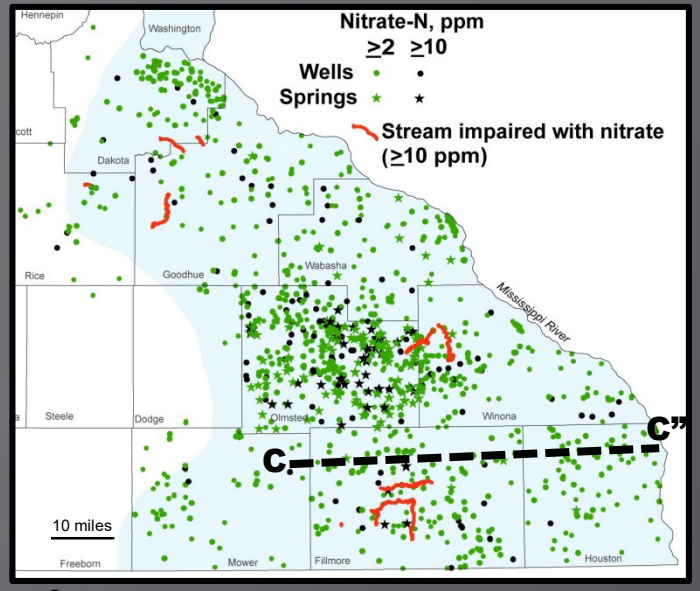
- Geologic conditions have a significant impact on the transport of nitrate
- This includes controlling trends in concentration over time (the “lag time” effect”)
- Geologic mapping, hydrogeologic research, and continued monitoring (strategically planned) together will be needed for effective water quality planning






A WEST
OLMSTED CO WELLS (PROJECTED)
Well 695883 (Galena Aquifer)
Well 227813 (Jordan Aquifer)
(Mower County)
B EAST
(Houston County)
elev. (ft)
1200
1000
800
600
400
200
St Peter Aquifer
Jordan Aquifer
Wonewoc Aquifer
Mississippi River
Recent water (post-1953 dominated)
Mixed Water
Vintage Water (pre-1953 dominated)
0
10 miles
Fractures
Aquitard
Recharge to water table
Predominant lateral flow direction
UNIVERSITY OF MINNESOTA

Generalized, regional view of nitrate-N concentration.



-Nitrate rapidly transported to upper bedrock water in fracture-dominated system

-uppermost bedrock water relatively nitrate-enriched (5-15 ppm NO3)

-aquitards limit nitrate concentration in deeper groundwater, causing stratification of concentration