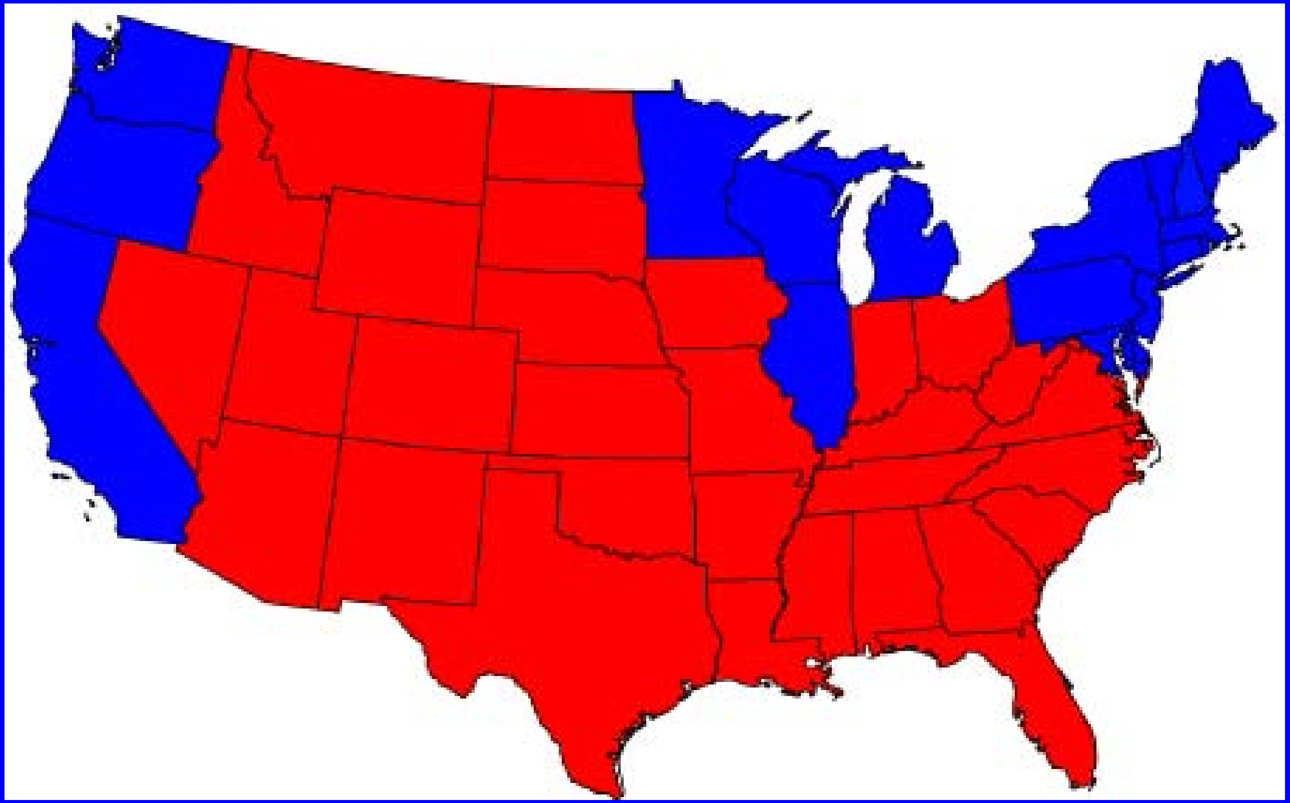
Using GIS to Predict Arsenic Over 10 ppb in Drinking Water

Or

How to lie with statistics ***and*** maps

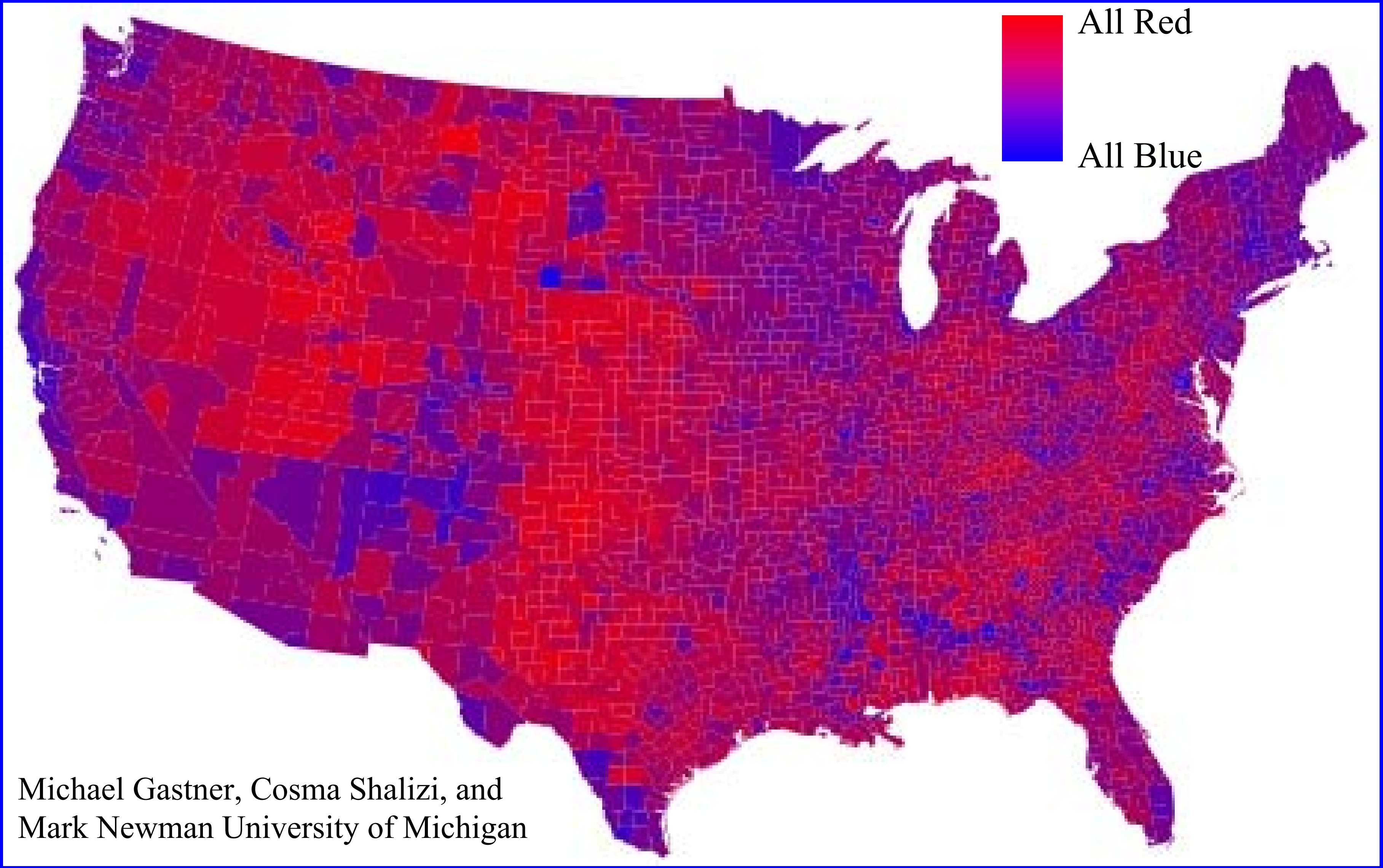
Rich Soule
MDH

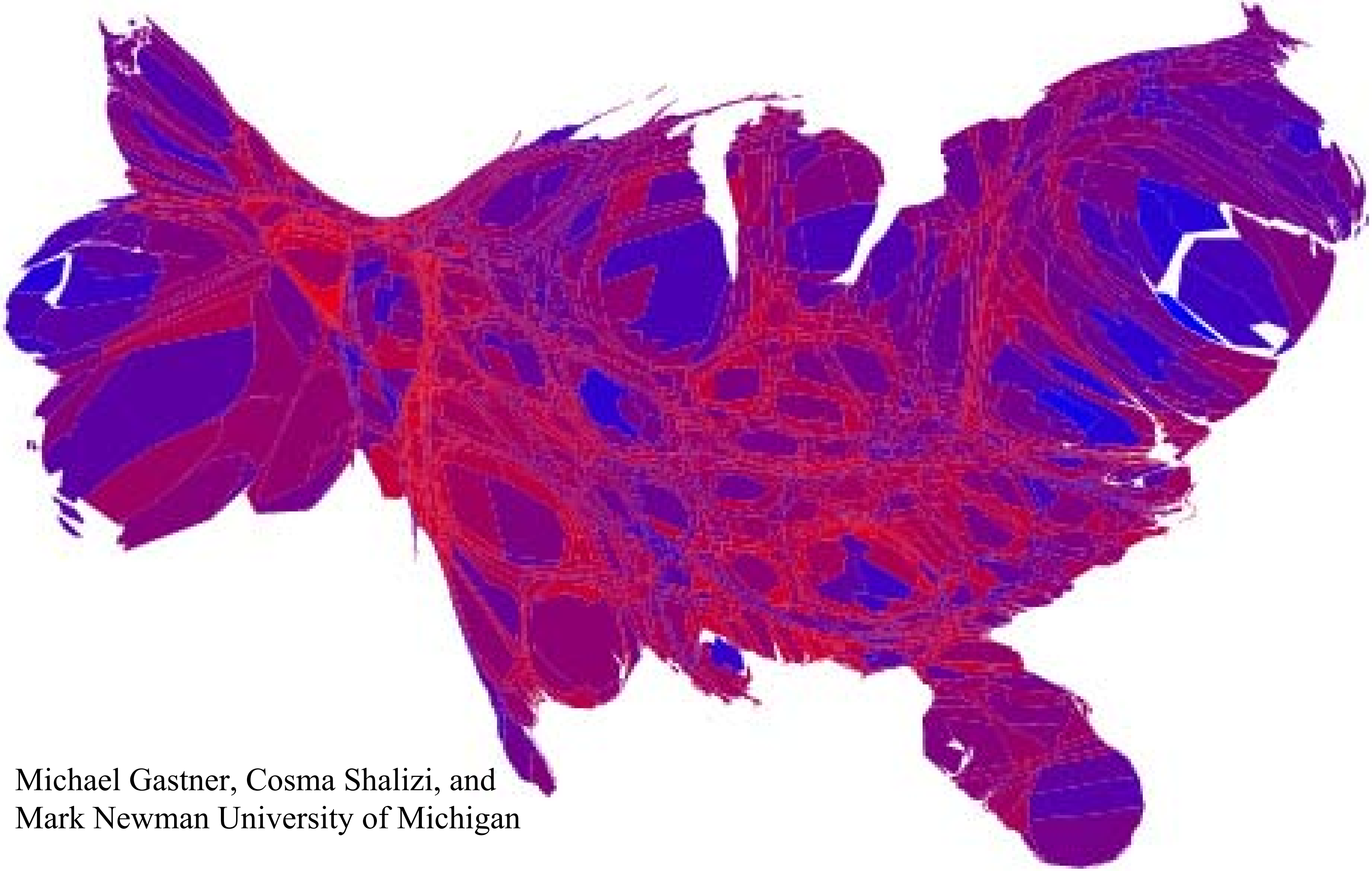


Pre-Civil War Free vs. Slave States

- FREE STATES AND TERRITORIES
- SLAVE STATES
- TERRITORIES OPEN TO SLAVERY


United States
of Canada
Jesusland


All Red
All Blue
Michael Gastner, Cosma Shalizi, and
Mark Newman University of Michigan



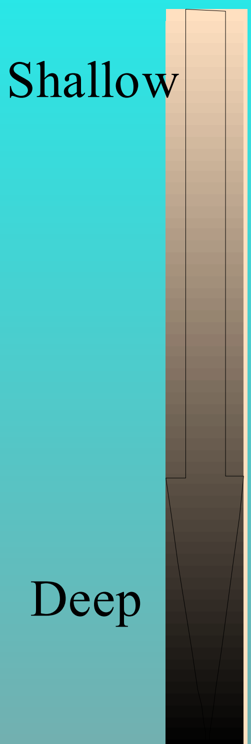
Michael Gastner, Cosma Shalizi, and
Mark Newman University of Michigan

Make a Statewide Map of Arsenic in Groundwater in Less Than 3 Hours

1) Come up with a single physical process.
   - It must be mapped at state scale.
2) Find the data sets representing this process and arsenic.
   - Evaluate data set bias.
3) Generate a Probability Map for Arsenic over 10 ppb.

Oxidized

Red, brown and, tan
Little to no odor.

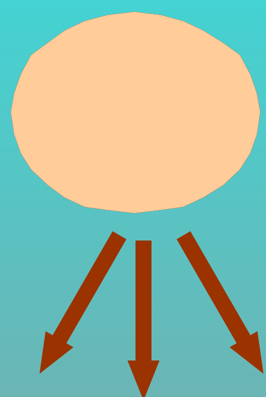


Black, green and grey
Rotten eggs odor.

Reduced

Geochemical Model

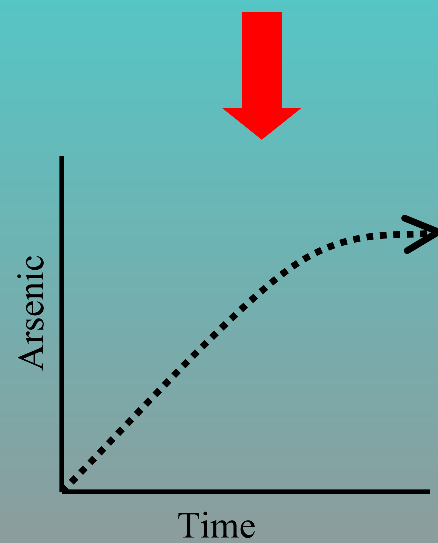
As^{+5}
$HAsO_4^{-2}$



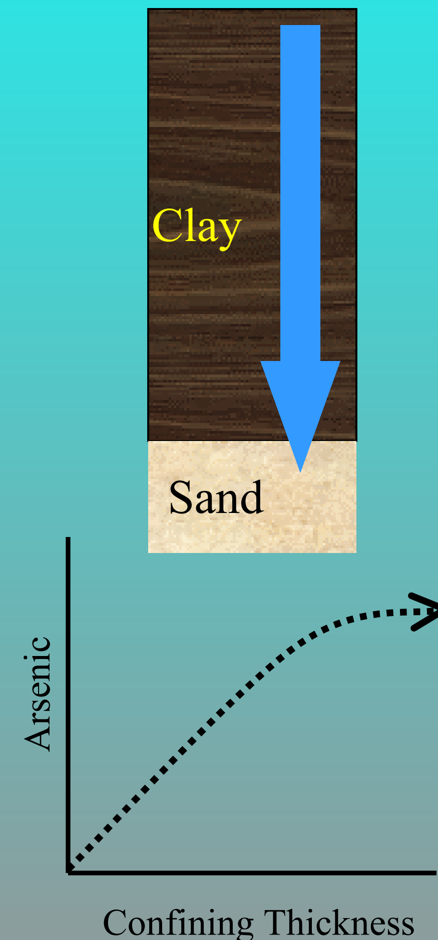
As^{+3}
H_2AsO^3

Biological Model

Oxygen
+
Carbon
+
Microbes



Hydrogeologic Model

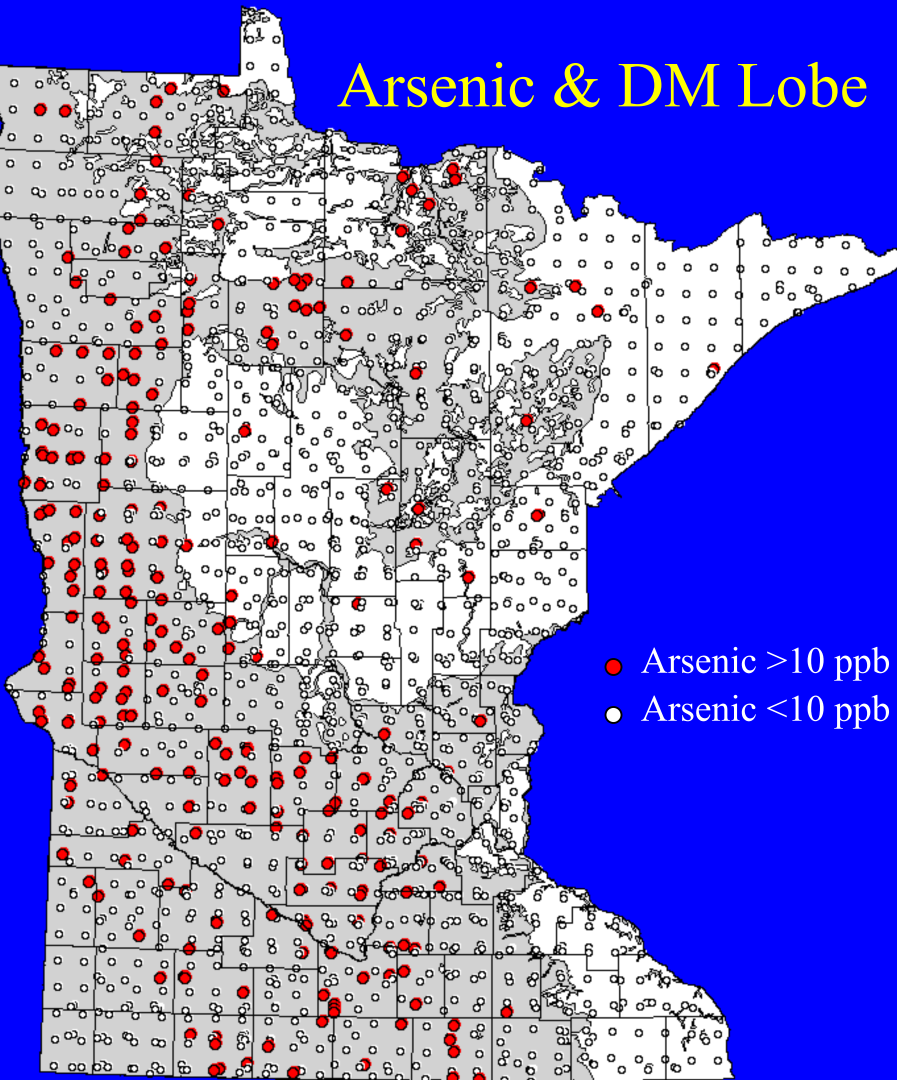


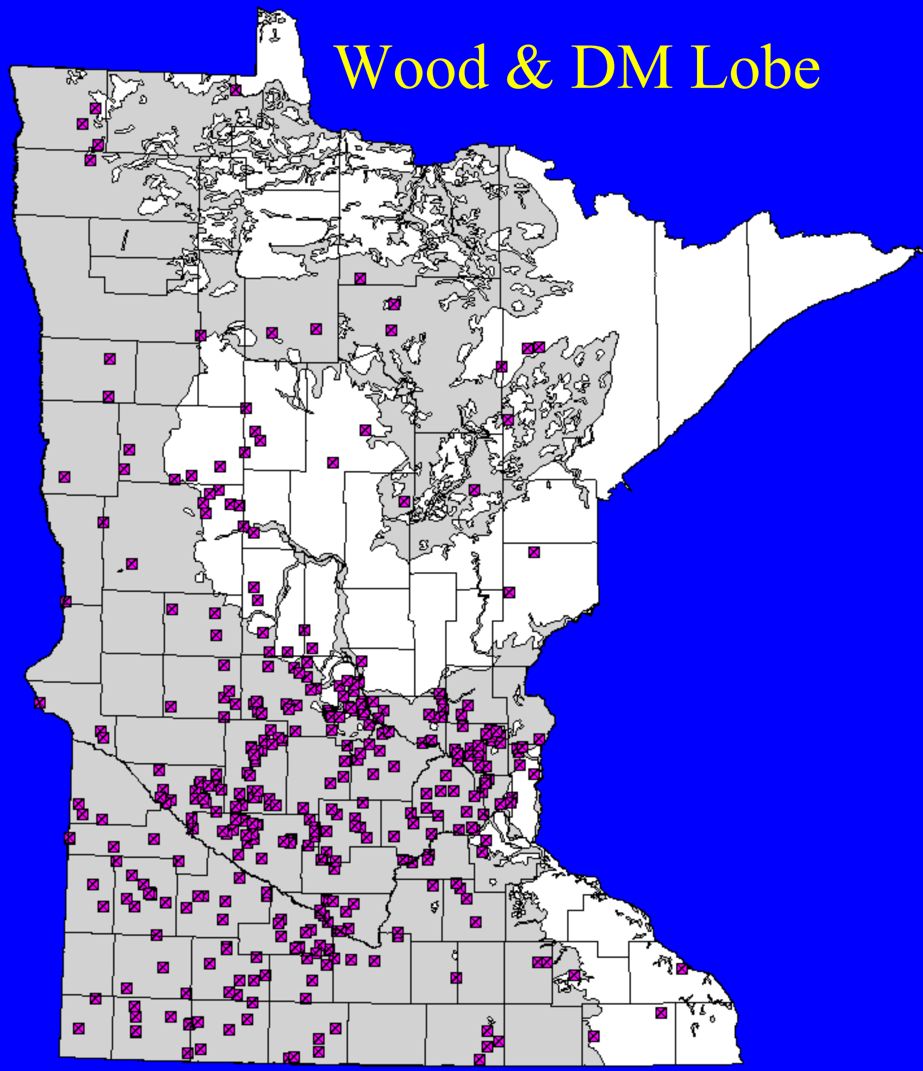
Conceptual Model

- Pr(As) > 10 ppb ≈ Clay Thickness.

- Groundwater is reduced by microbes at a constant rate and is limited by electron acceptors (O_2, $FeNO_{3,}$ Fe).
- The flow of electron acceptors is determined by vertical groundwater recharge.
  - Q=KiA, Assume average "K" and "i" .
- Assume Steady State.

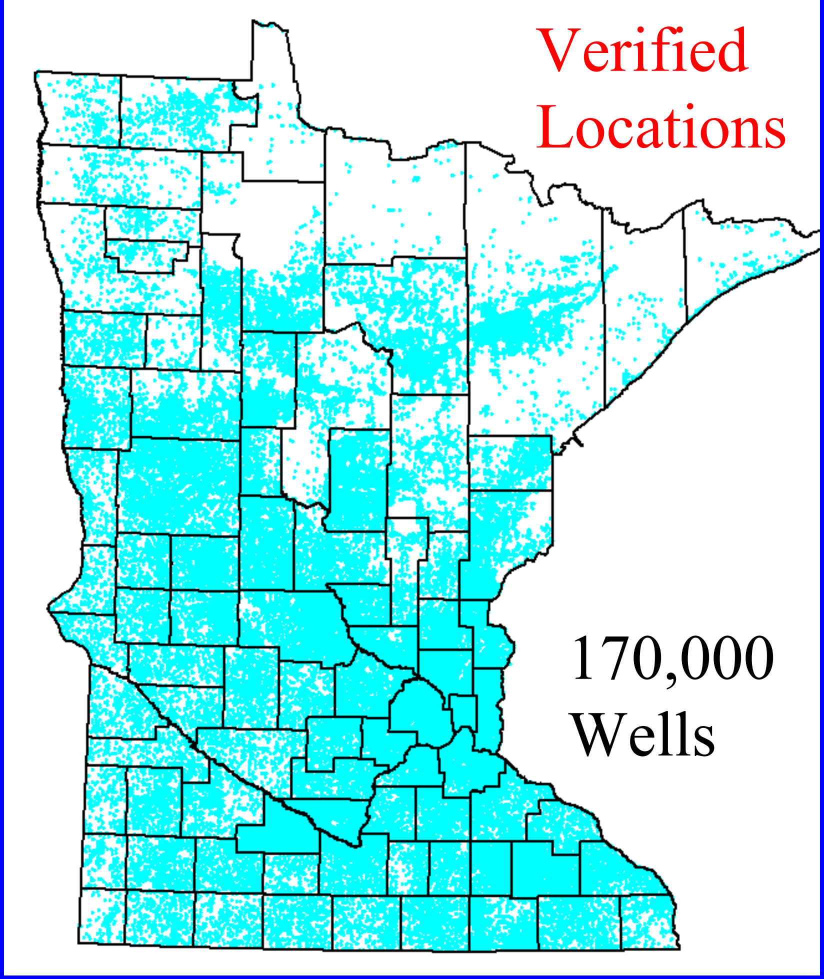
Why?: Spatial Relationships

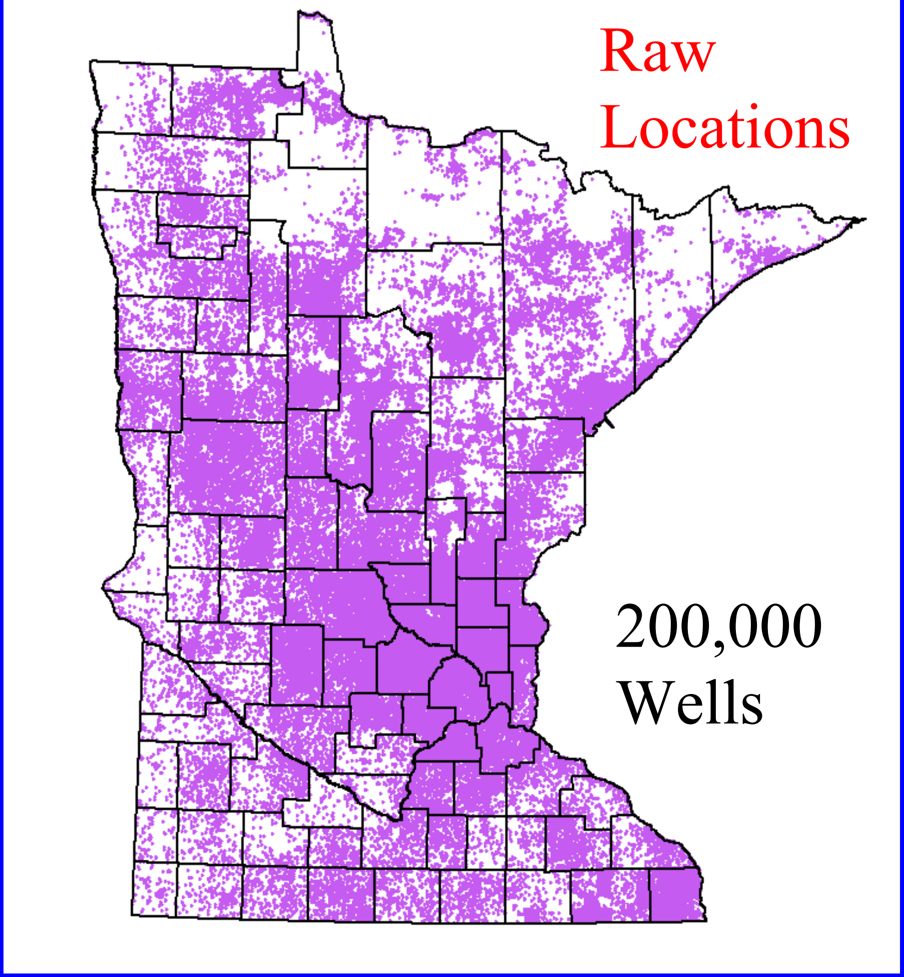




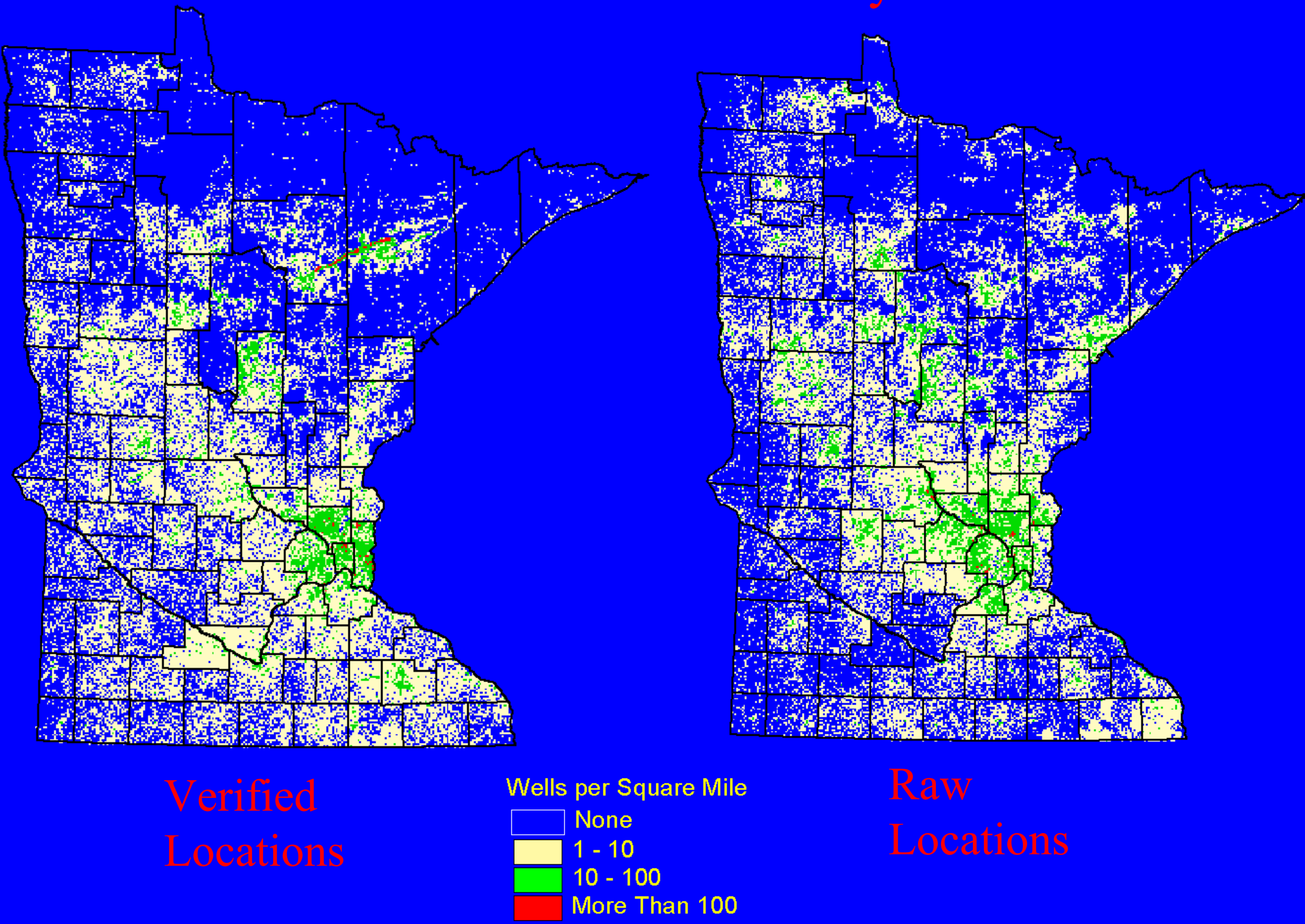
Data Sets: Geology (CWI)

Use it All.





Bias: Well Density



Summarizing Well Logs

Unique Well Number

213981

County Big Stone
Quad Dismal Swamp
Quad Id 148A

MINNESOTA
WELL AND
MINNESOT

Wellname STROBEL, MARTIN

Township	**Range**	**Dir**	**Section**	**Subsection**	**Field Located**	MGS
123	45	W	2	CDDCAC	**Elevation**	1200.00 **ft.**

Contact STROBEL, MARTIN

CLINTON MN 56225 Changed

Description	Color	Hardness	From	To (ft.)
CLAY	YELLOW		0	56
GRAVEL	YELLOW		56	71
SILTY SOFT CLAY & STREAKS O			71	180
FINE SAND			180	185
SILTY SOFT CLAY & STREAKS O			185	206
FINE SAND			206	212
STIFF CLAY			212	227
SAND			227	233

Clay → 56 ft
Clay → 37 ft
Clay → 21 ft
Clay → 15 ft

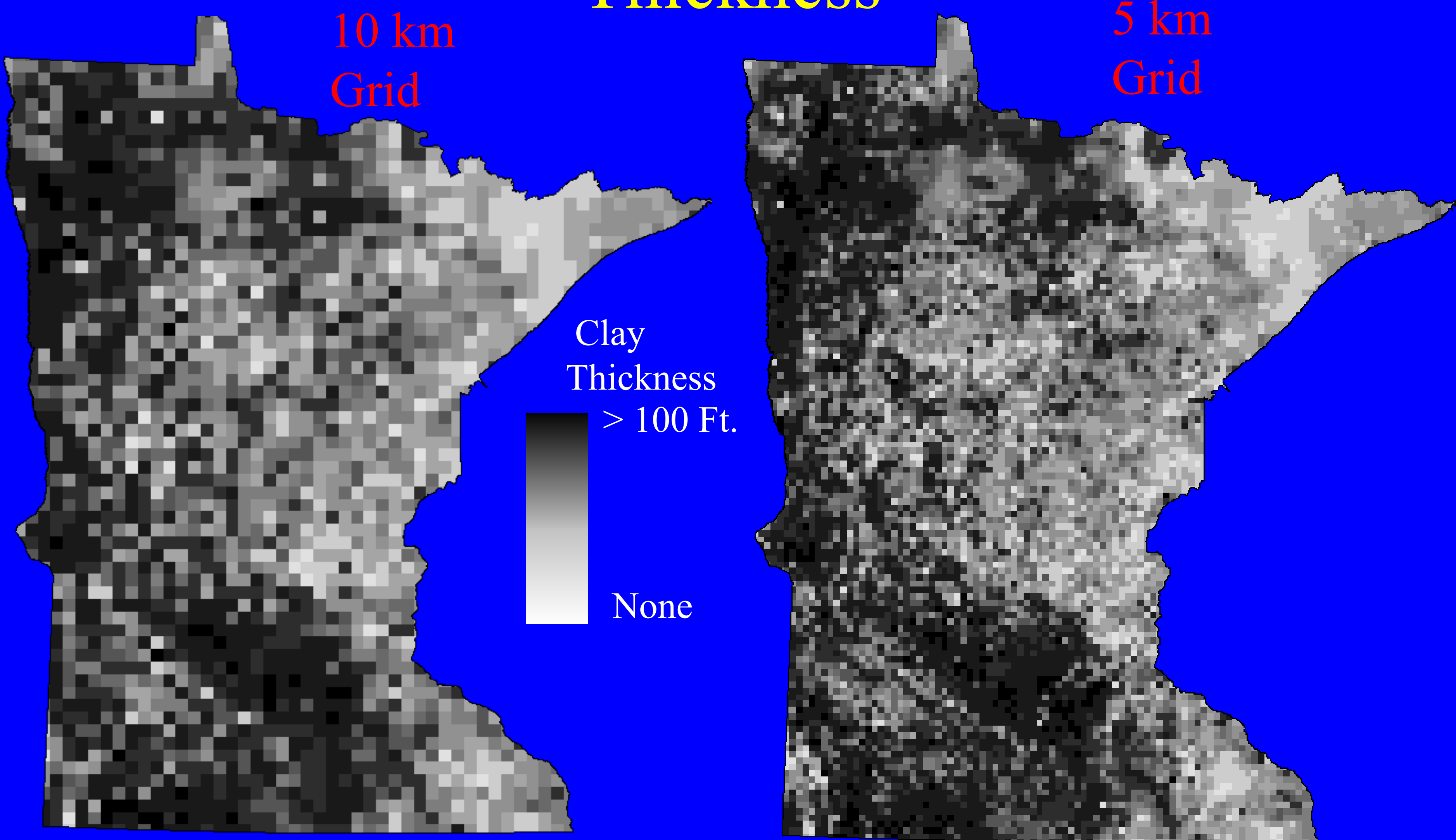
Clay Thickness

56 ft
37 ft
21 ft
15 ft
+

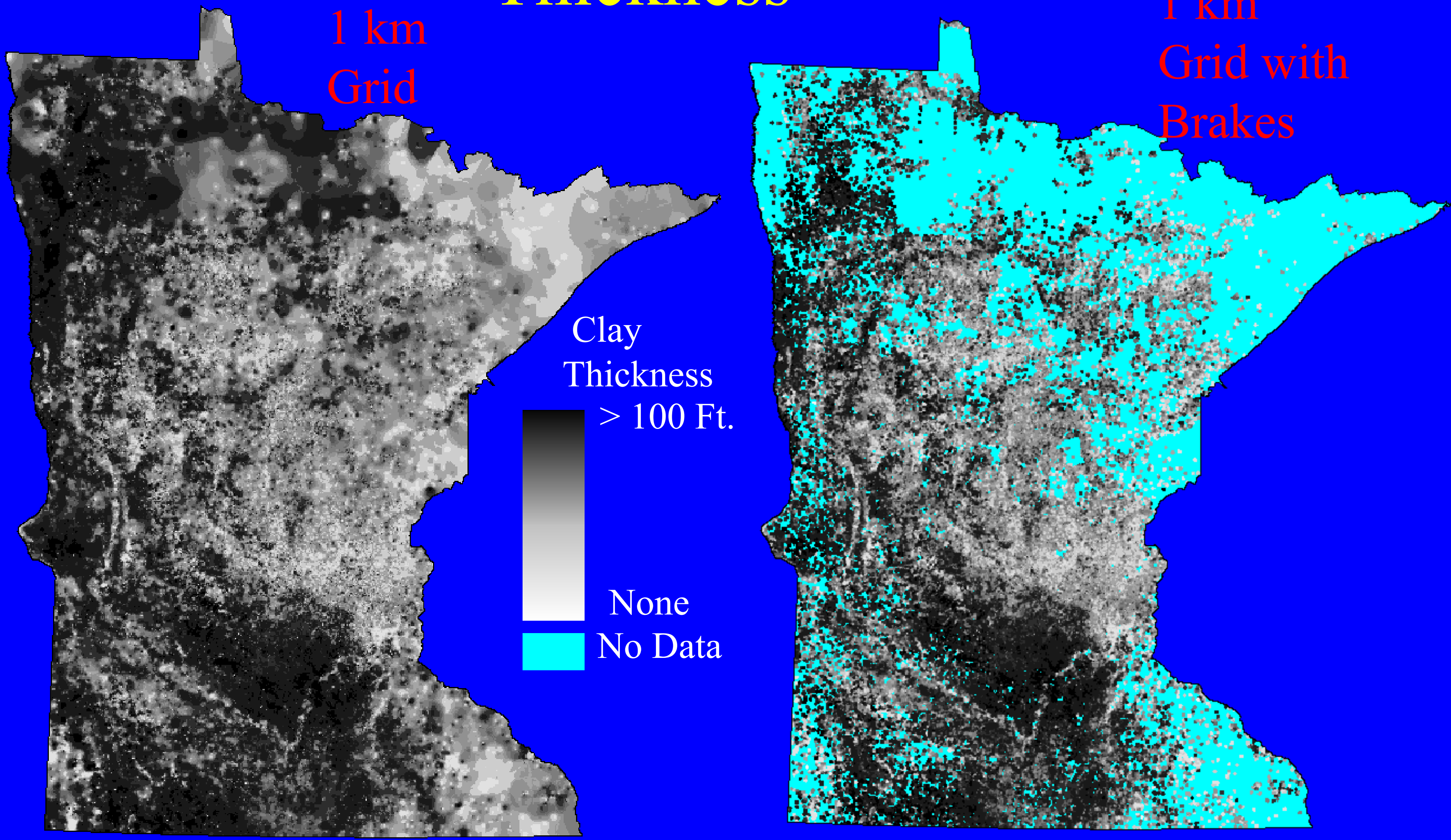
Total 138 ft

Do this 370,000 Times. Takes 20 min.

Grid Clay Thickness

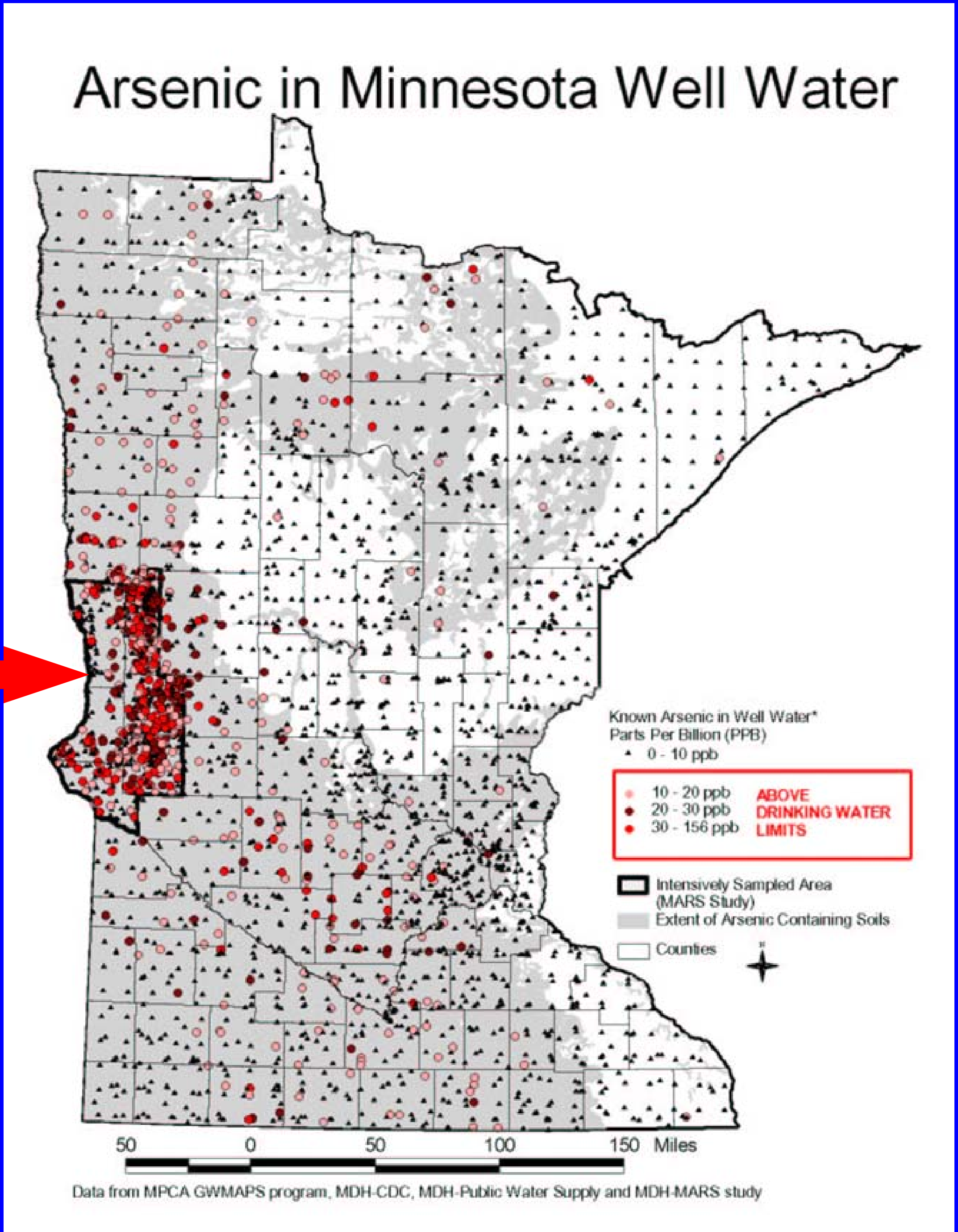


Grid Clay Thickness



MARS
Area

Looks Really Bad….
Population Declining
….Co-incidence?



Data Sets: Arsenic

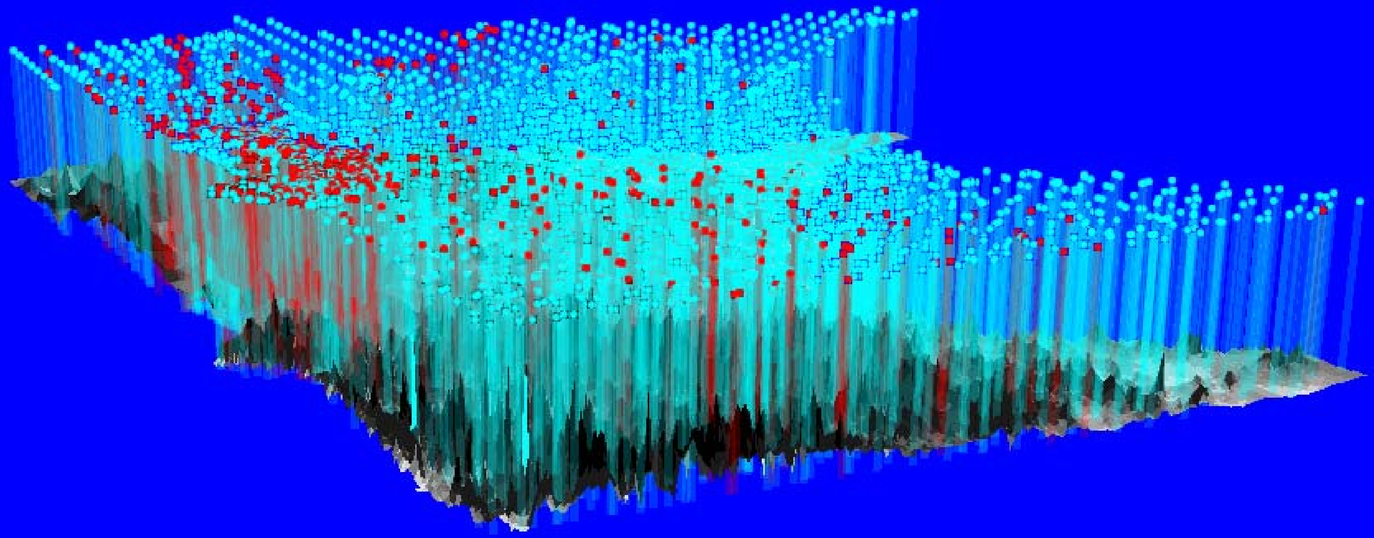
Data	Area	Location	Geology	Bias
GW MAPS	State	Yes	Yes	Deeper? Construction?
CDC/ MDH	State	No	No	No Location Shallower? Construction?
MARS	West Central	Yes	Yes	High As? Deeper?

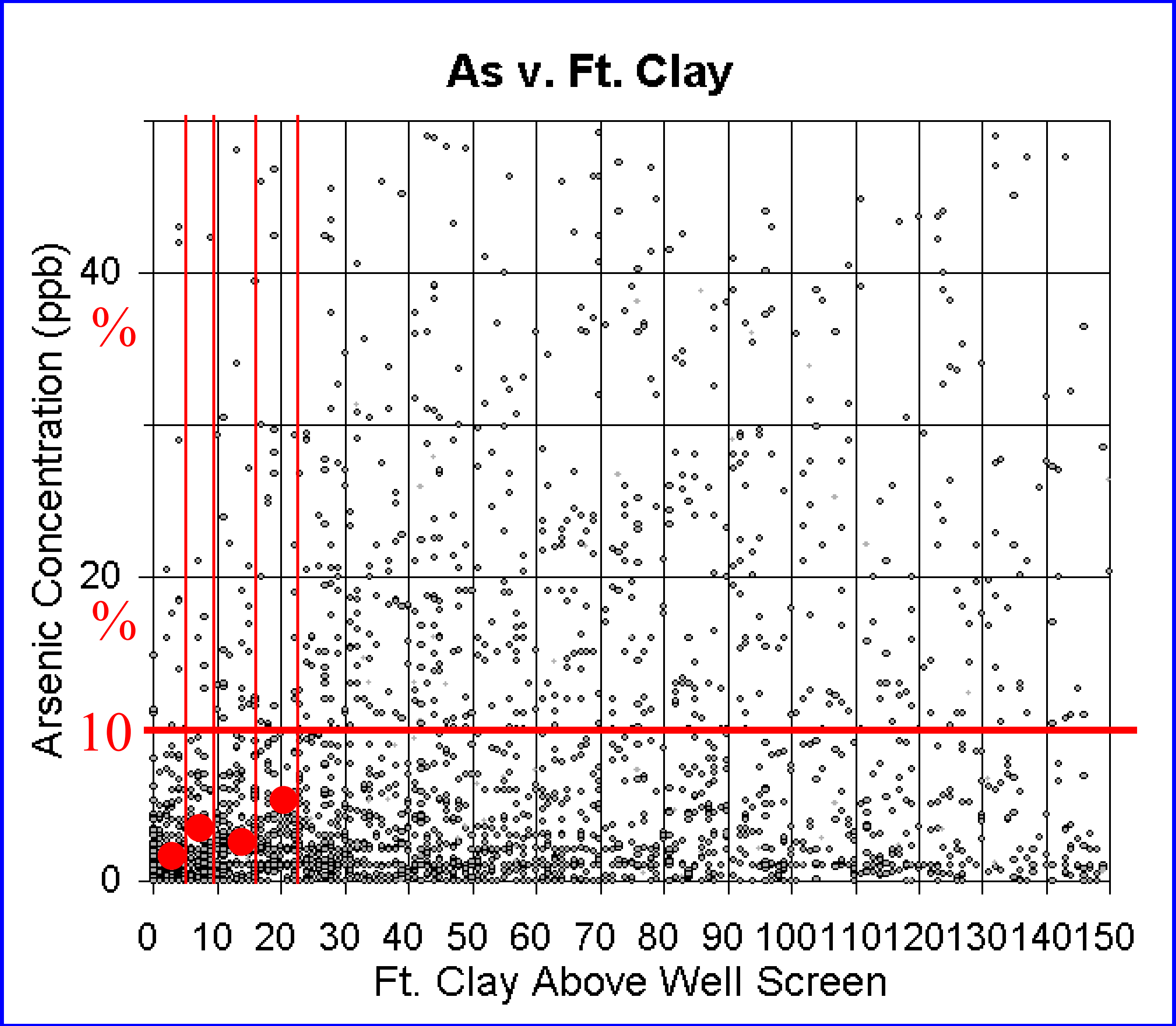
Use MARS Data?

Data Set	Number in Area	Over 10 ppb
MARS	893	52%
GWMAPS	50	48%
CDC	47	49%

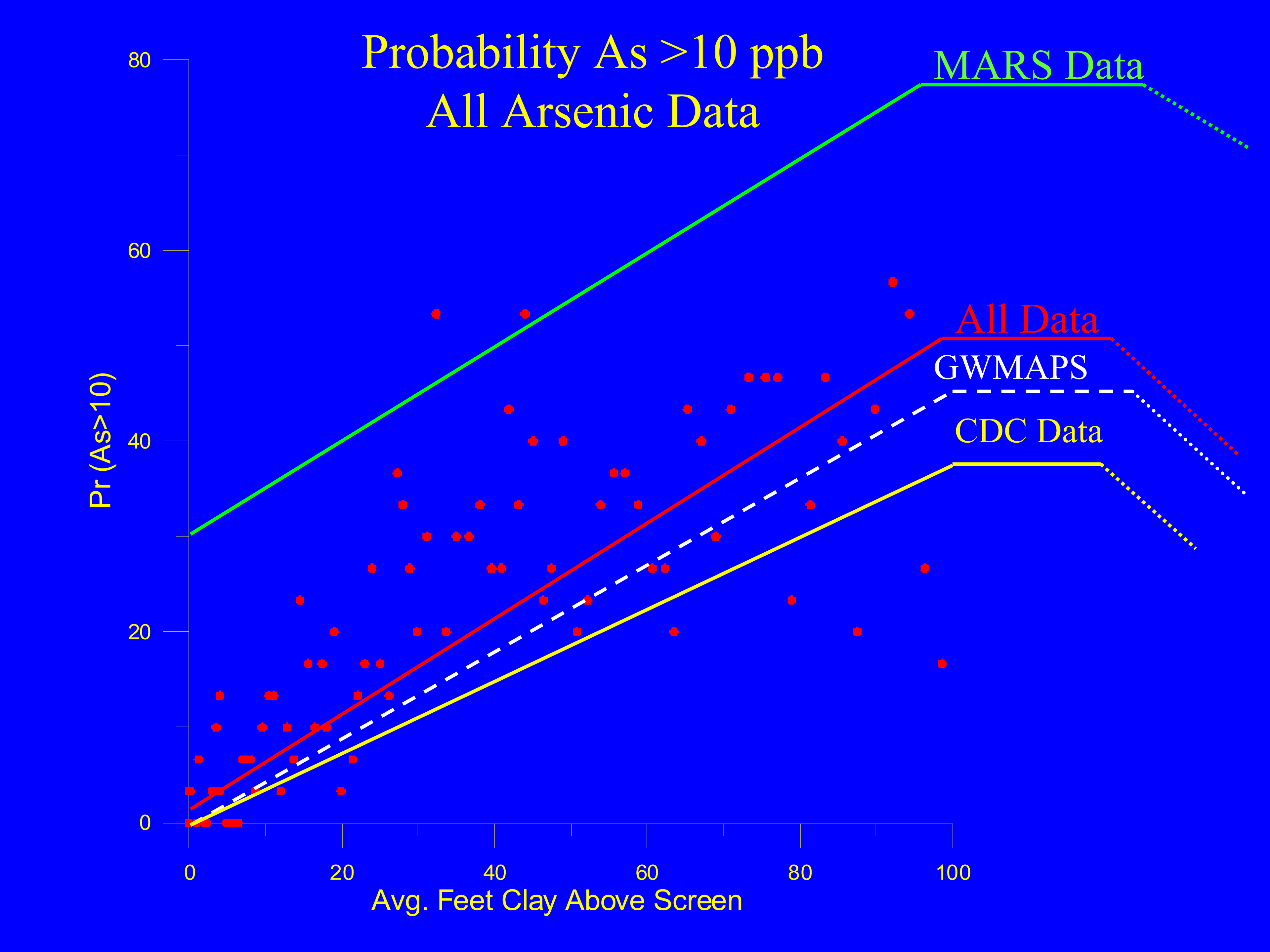
Yes, but cautiously.

Get Clay Grid Values

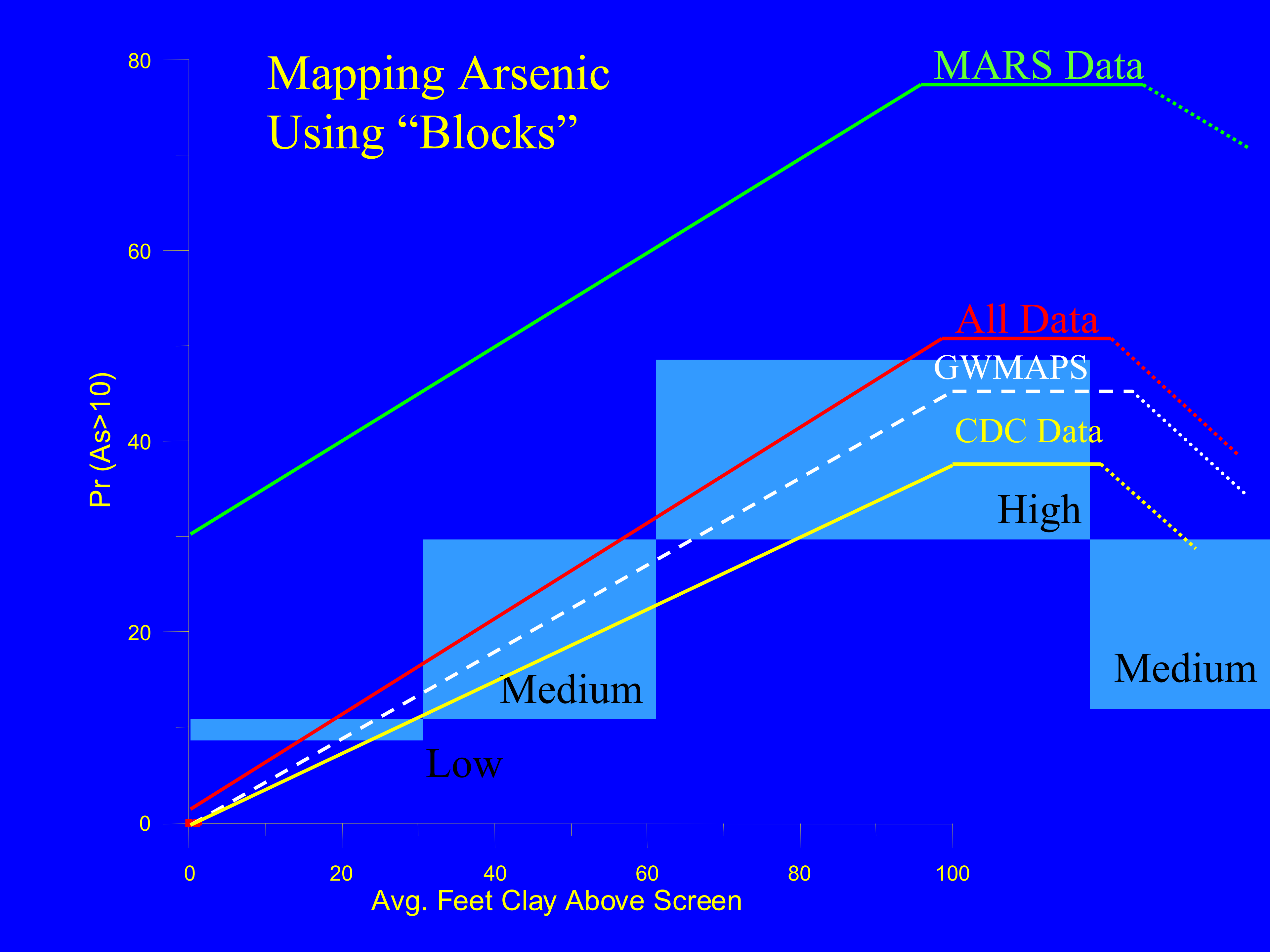




As v. Ft. Clay
Arsenic Concentration (ppb)
40
%
20
%
10
0
0 10 20 30 40 50 60 70 80 90 100110120130140150
Ft. Clay Above Well Screen

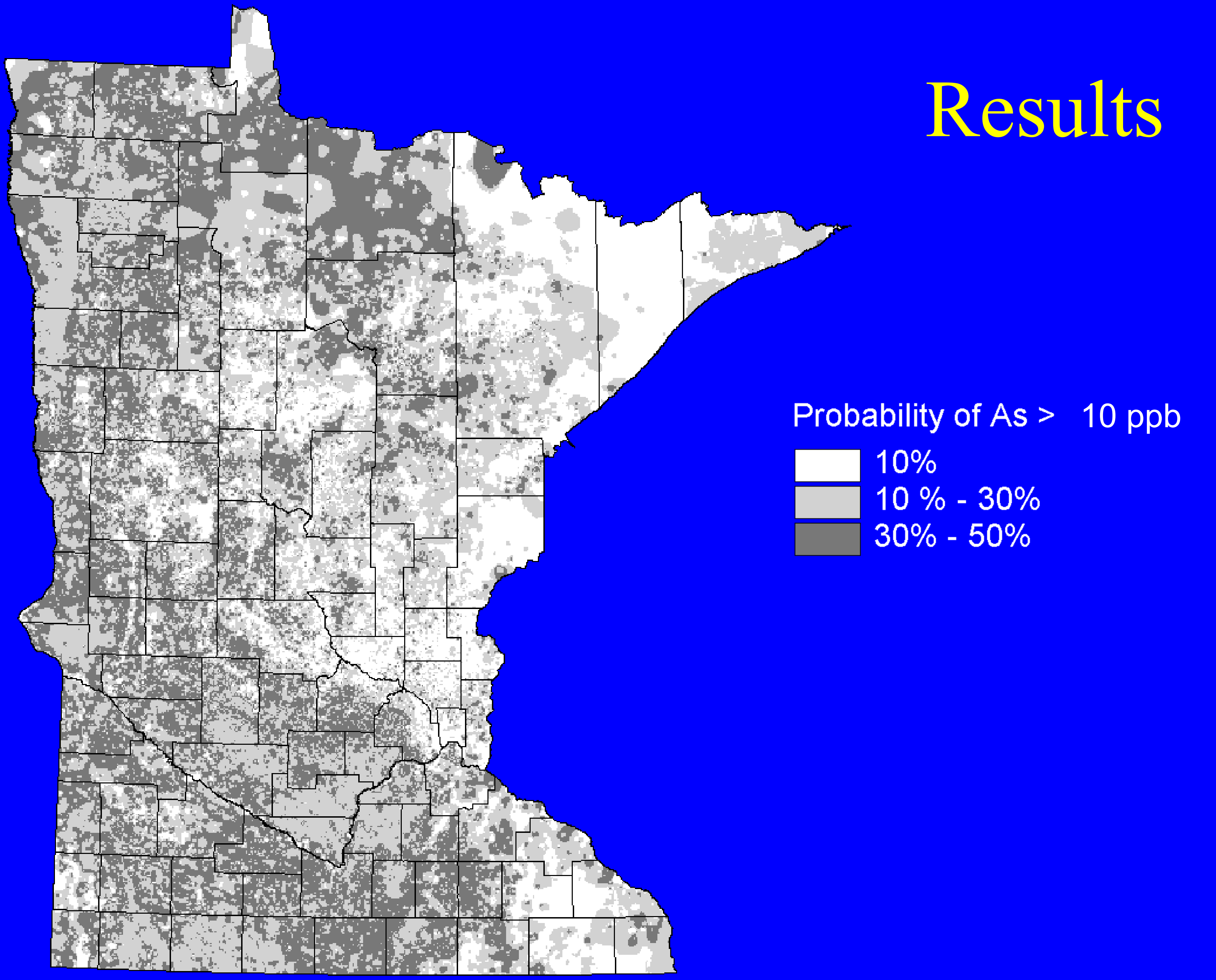


Probability As >10 ppb
All Arsenic Data
MARS Data
All Data
GWMAPS
CDC Data
Pr (As>10)
80
60
40
20
0
0
20
40
60
80
100
Avg. Feet Clay Above Screen

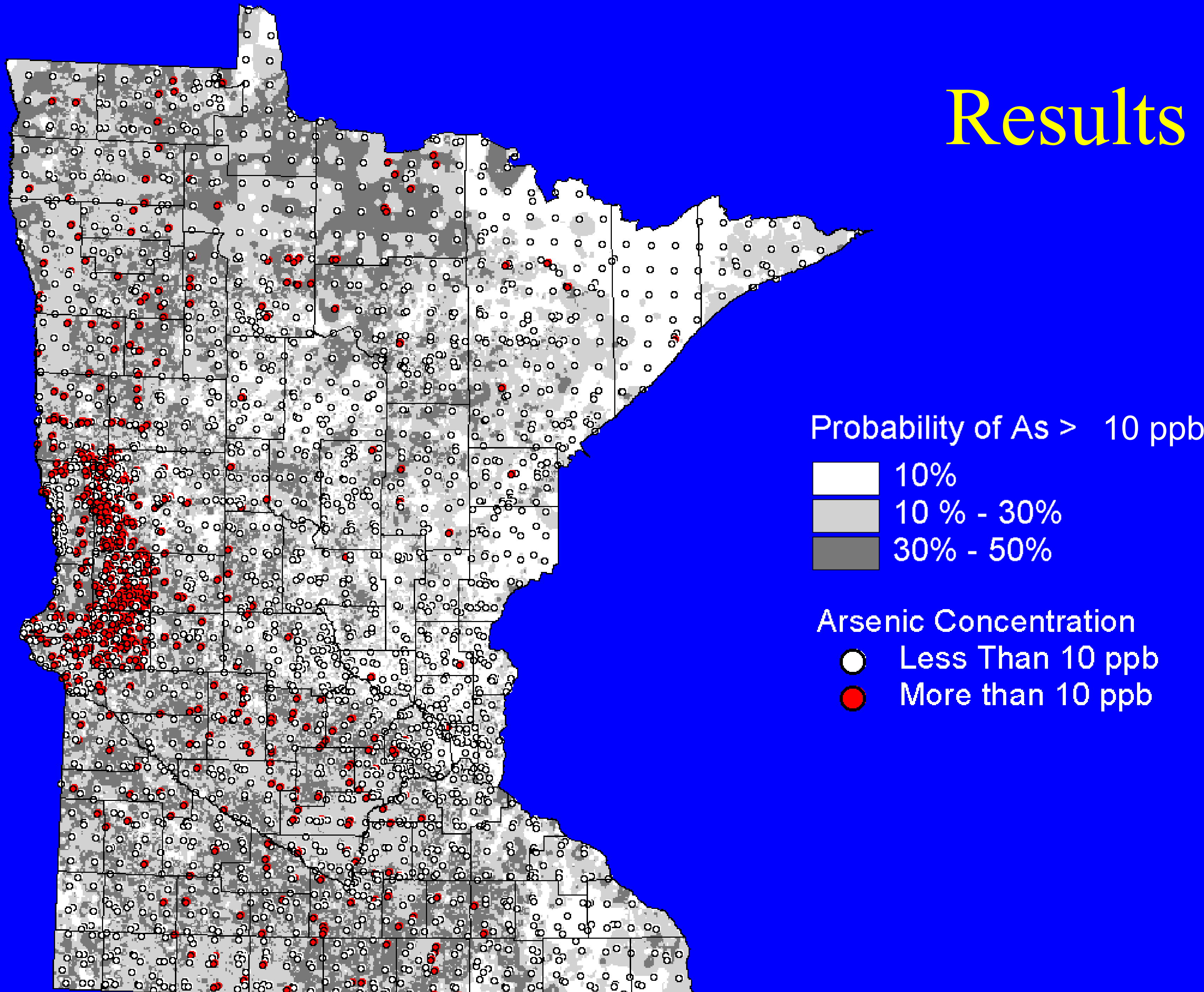


Mapping Arsenic
Using "Blocks"
MARS Data
All Data
GWMAPS
CDC Data
High
Medium
Medium
Low
80
60
40
20
0
Pr (As>10)
0
20
40
60
80
100
Avg. Feet Clay Above Screen

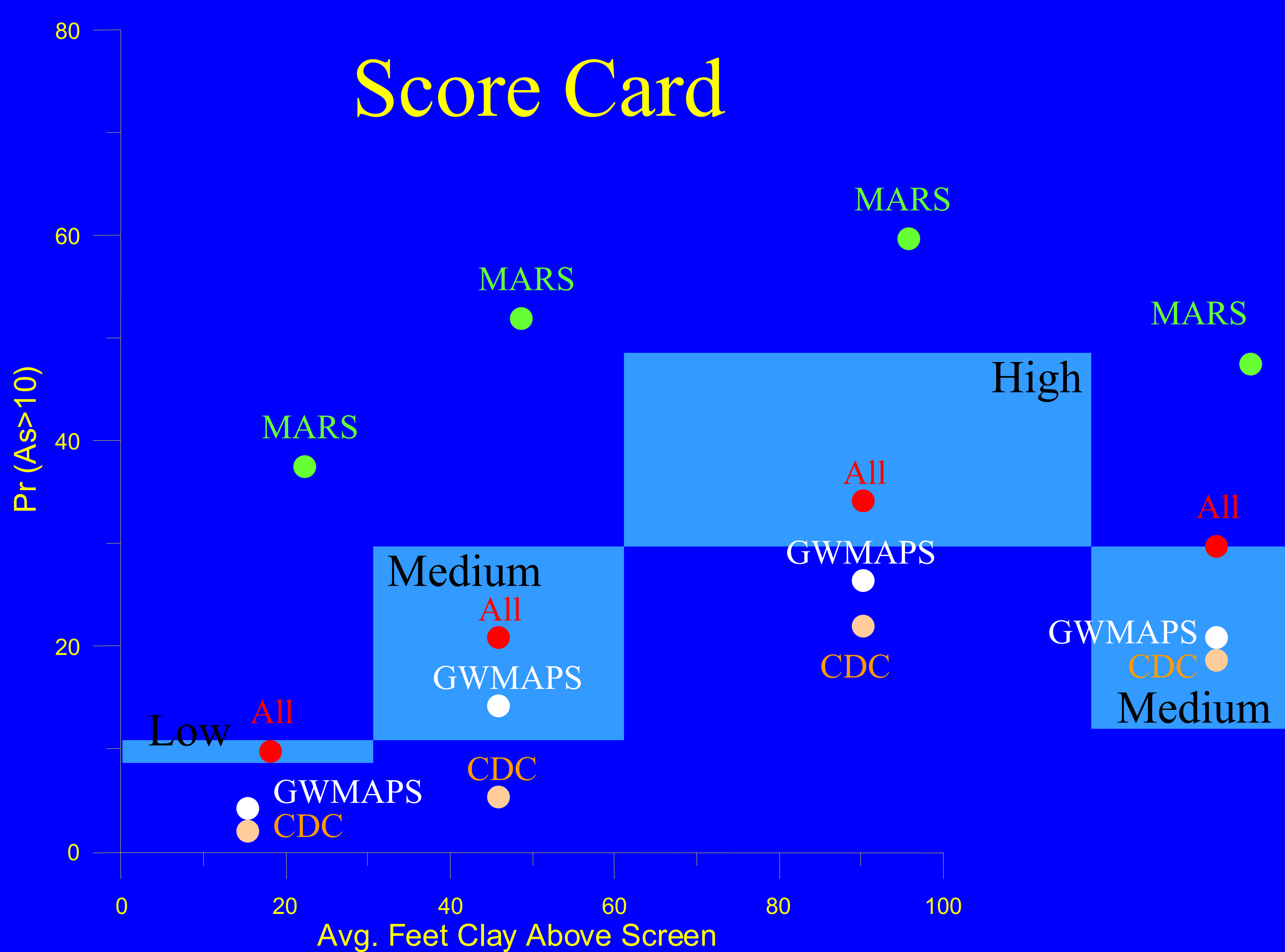
Results



Results


Probability of As > 10 ppb
10%
10 % - 30%
30% - 50%
Arsenic Concentration
Less Than 10 ppb
More than 10 ppb

Score Card

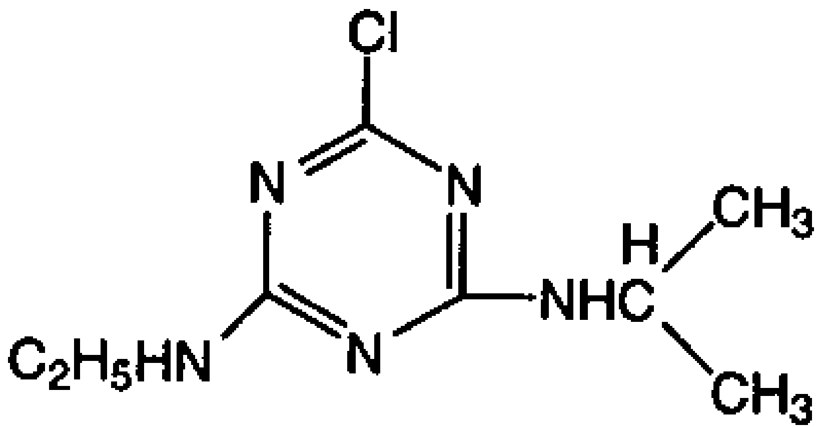


MARS
MARS
MARS
MARS
High
All
All
GWMAPS
Medium
All
GWMAPS
CDC
GWMAPS
CDC
Medium
Low
All
CDC
GWMAPS
CDC
Pr (As>10)
80
60
40
20
0
0
20
40
60
80
100
Avg. Feet Clay Above Screen

Implications

- State Scale: the proposed processes may impact the arsenic concentration in groundwater.
- County Scale: These processes are probably variable (i.e. K, infiltration…).
- Section Scale: The change of the redox state of groundwater through time may be the most important factor.

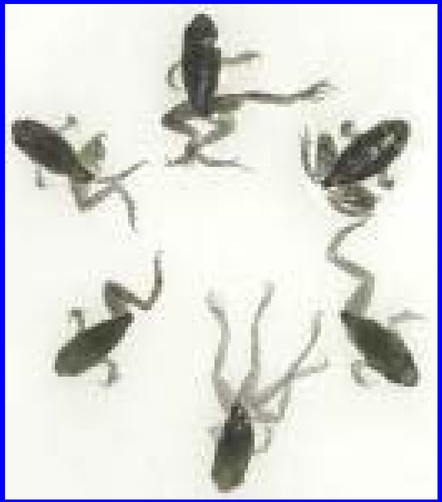
ATRAZINE (Aatrex®)



2-chloro-4(ethylamino)-6-(isopropylamino)-*s*-triazine












MPCA & others

Changing the Redox State

Borehole Chemistry & Microbial Ecosystems

“Reducing Factors” Increase Arsenic:

- Decreasing Infiltration (Tile Drains)
- Increasing Carbon Load (Monoculture)

“Oxidizing Factors” Decrease Arsenic:

- Increased Nitrate Loading

Acknowledgements

- Arsenic Lunch Group:

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