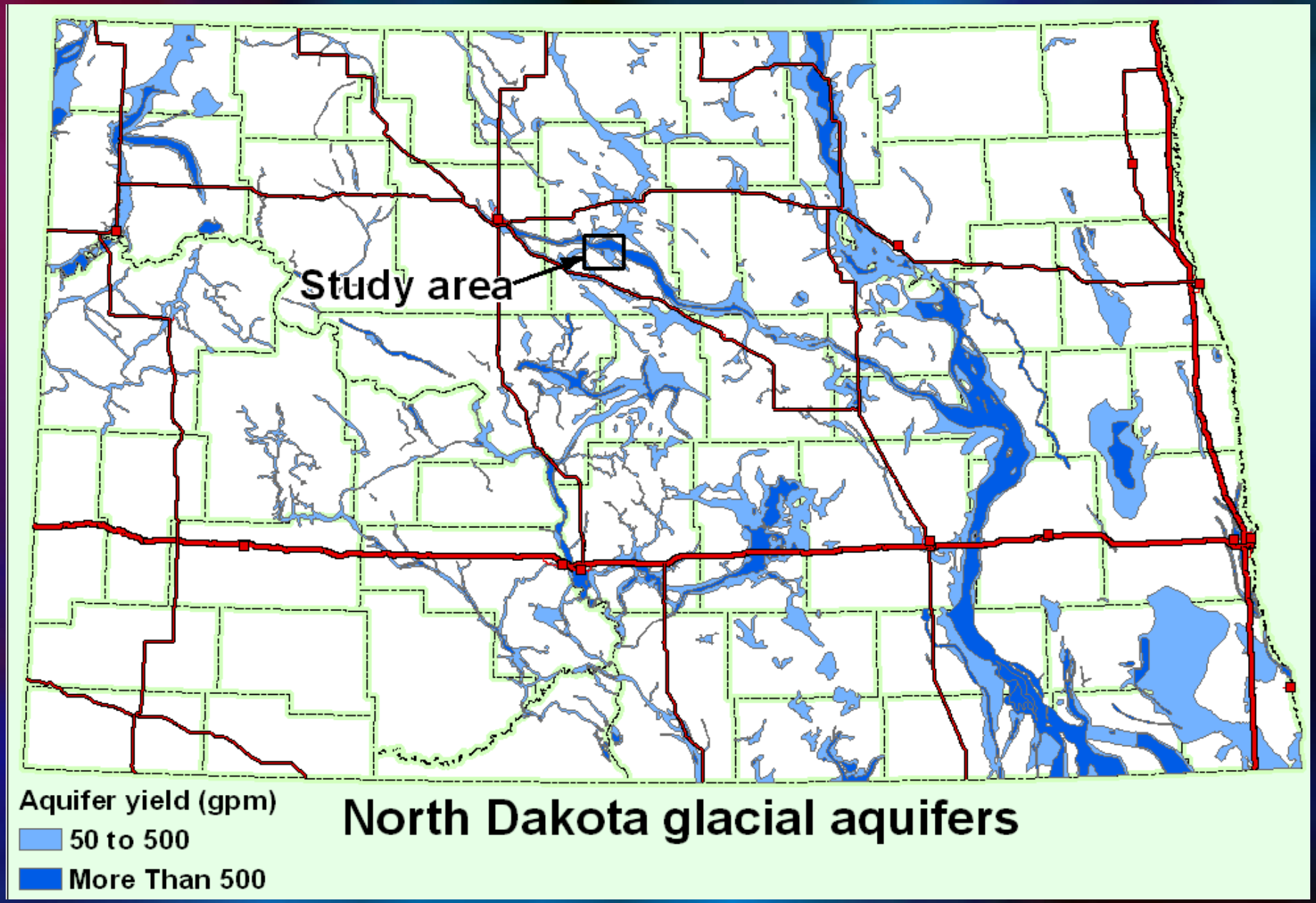
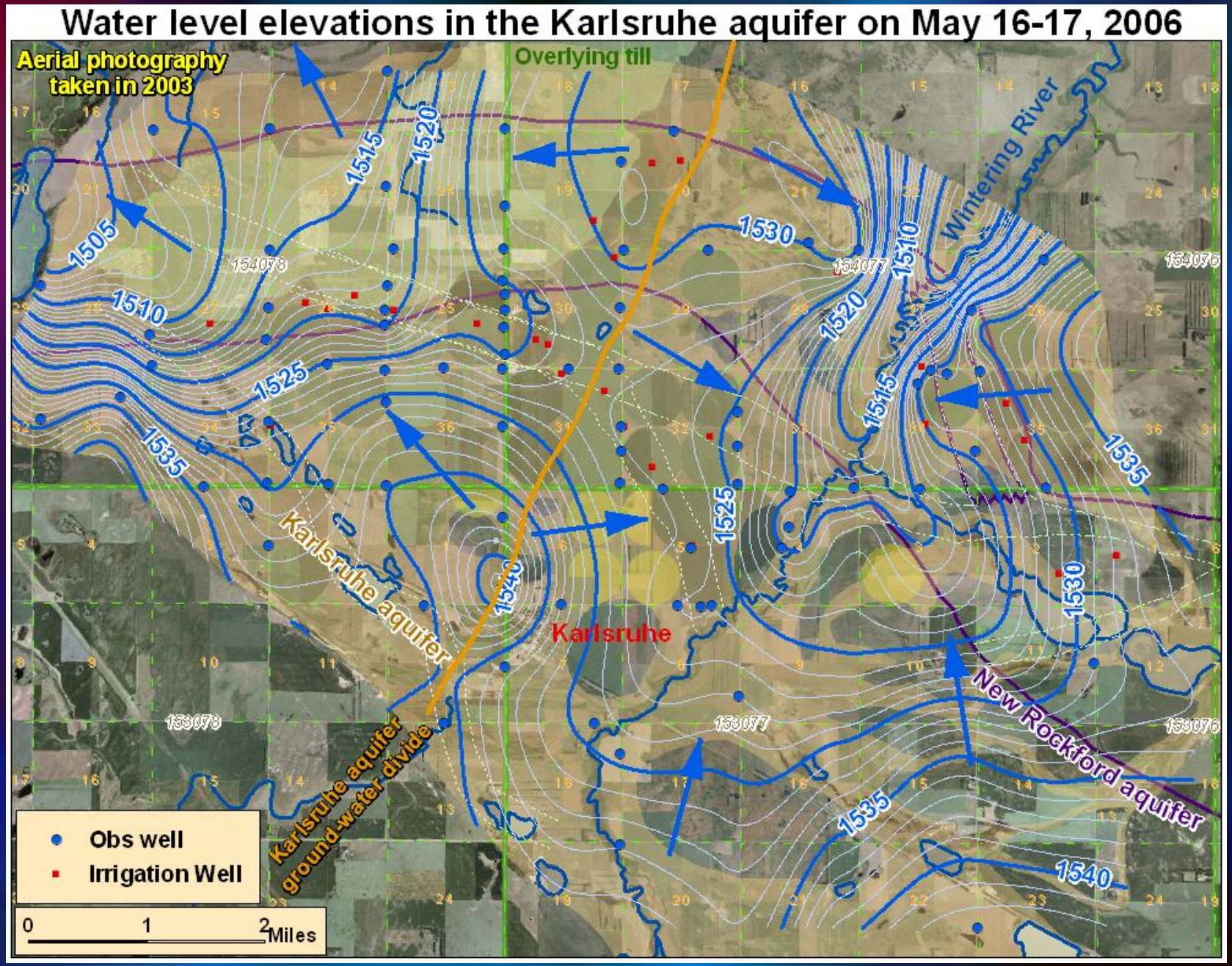
Nitrate-N Loading & Remediation

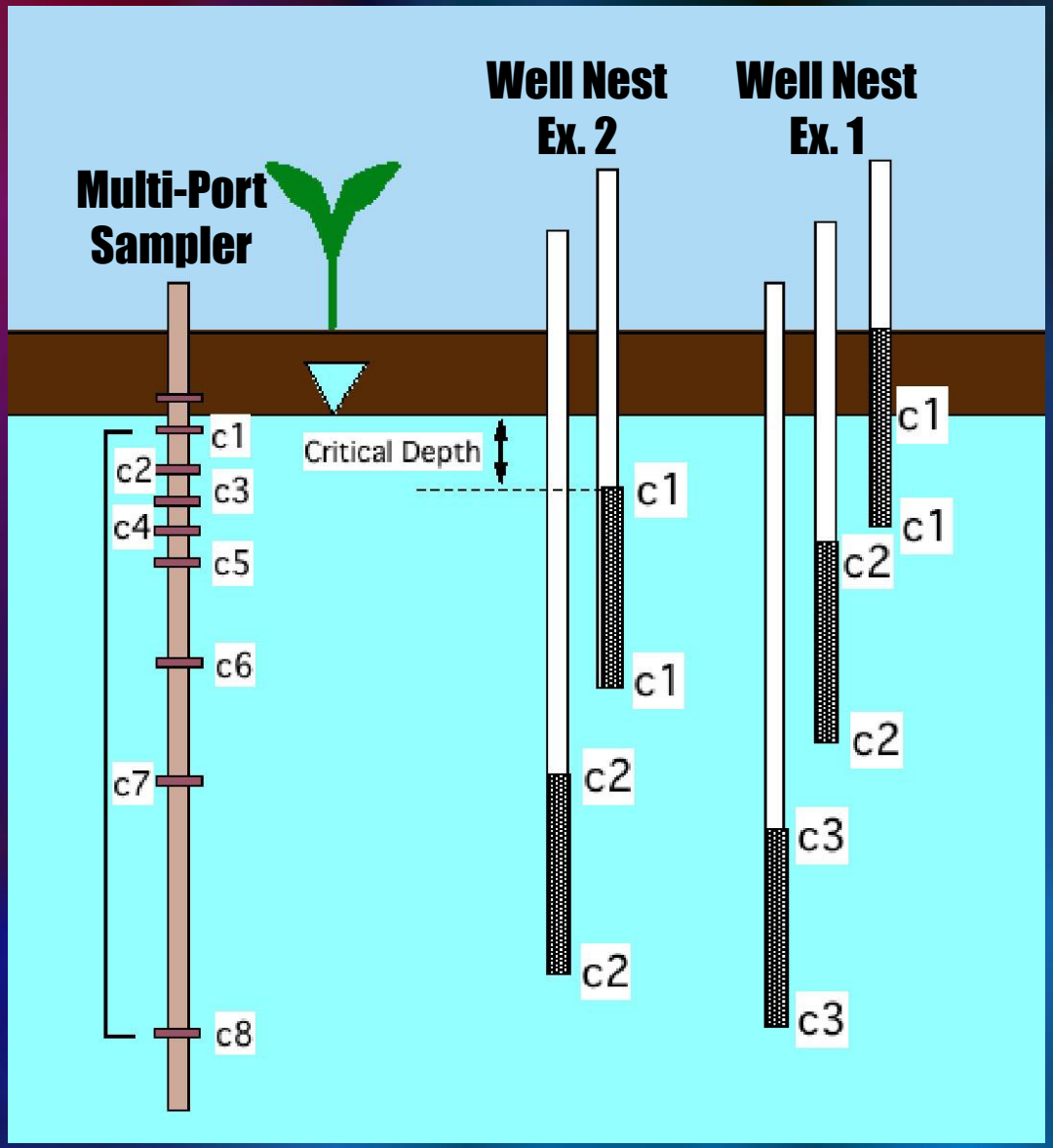
in the Karlsruhe & New Rockford Aquifers Near Karlsruhe, McHenry County, ND

North Dakota State Water Commission


Study area
Aquifer yield (gpm)
50 to 500
More Than 500
North Dakota glacial aquifers

Water level elevations in the Karlsruhe aquifer on May 16-17, 2006





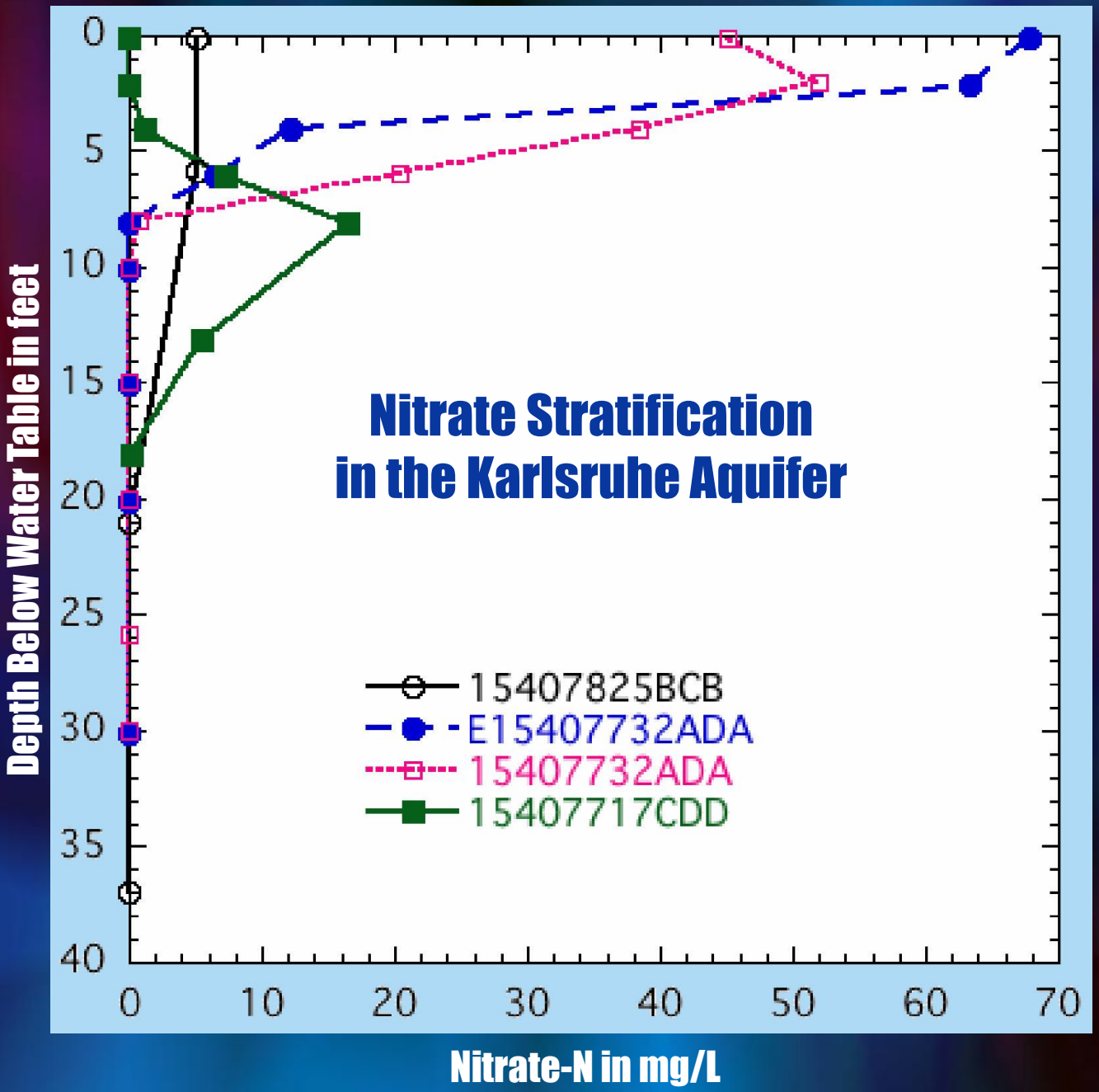
Some Selectors

- If top of shallowest well > 5 feet bwt, discard
- If wt intersects top well screen, use wt to bottom of well screen

Multi-Port Samplers

Design Problems for Assessment and Remediation of Stratified Nitrate

- Stratification
- Interpretation - Agricultural/Toxicology
- Spatial Interpretation
- Toxicological Assessment
- Goals


Nitrate Stratification
in the Karlsruhe Aquifer
Depth Below Water Table in feet
Nitrate-N in mg/L
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
15407825BCB
E15407732ADA
15407732ADA
15407717CDD

Stratification

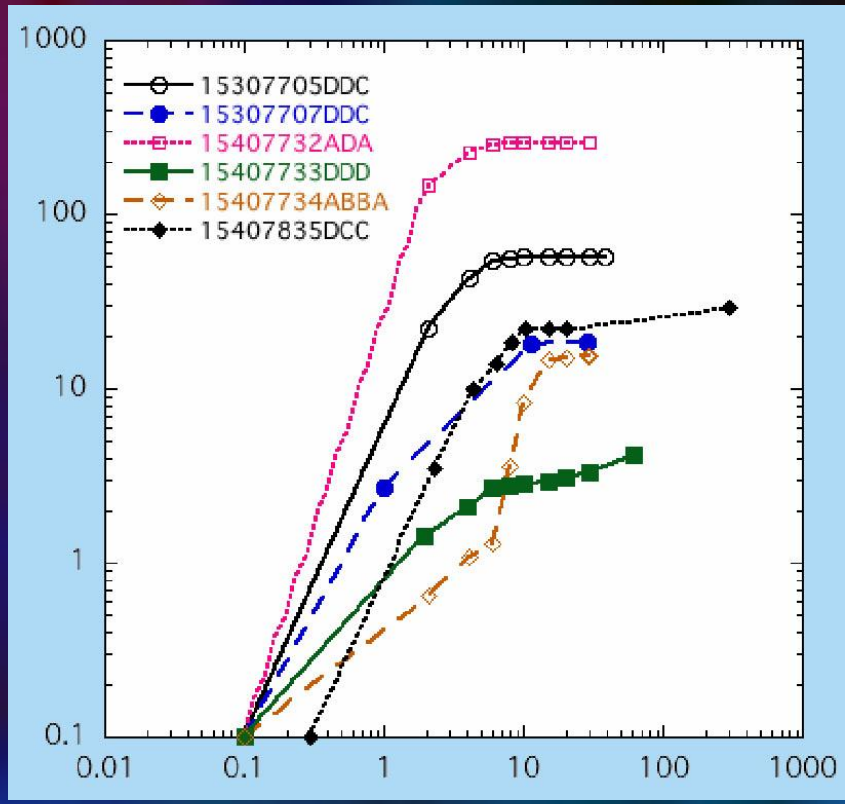
$$[N] = 0.226[NO_3^-]$$

$$N_t^* = \int_o^z [N]\,dz$$

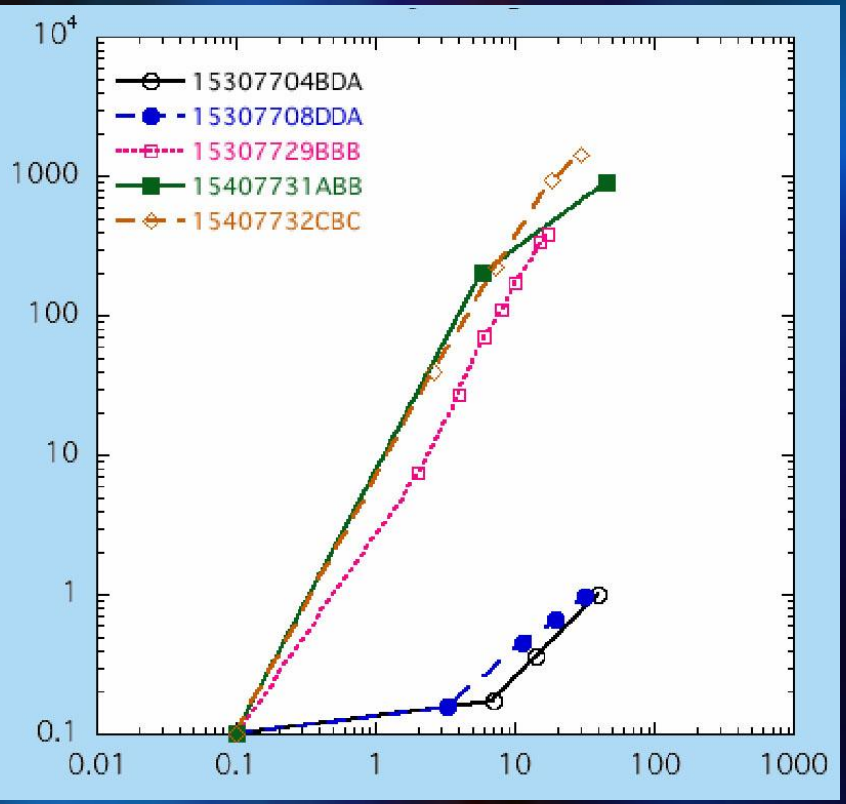
Fully Integrated

Not Fully Integrated

Cumulative N from Water Surface to Depth in Pounds per Acre

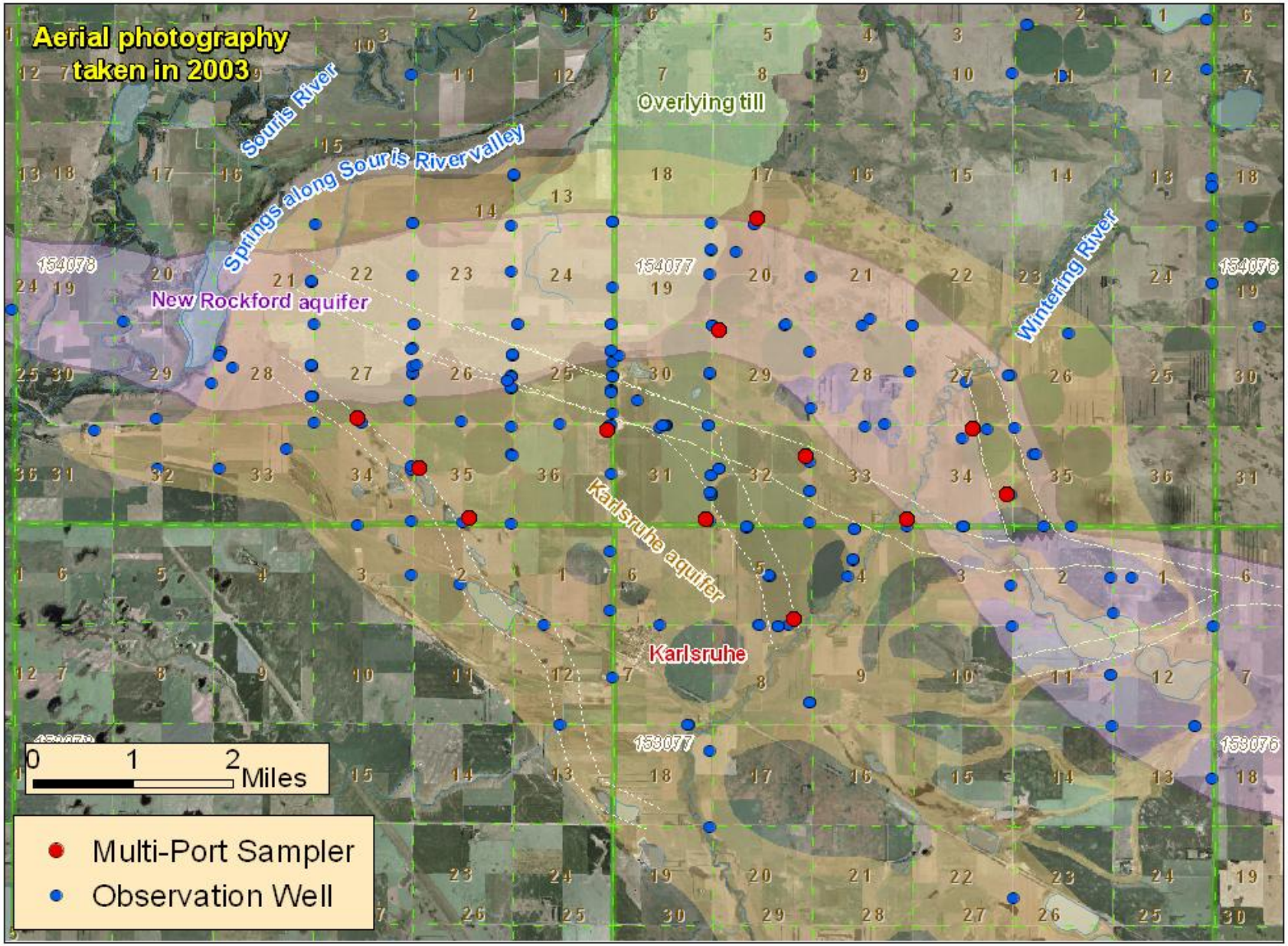


Depth Below Water Table in feet



Depth Below Water Table in feet

Monitoring wells and Multi-port samplers in the Karlsruhe area



Agricultural Cross-Assessment

Fertilizer Loss VS. Aquifer Nitrate-N Concentrations

$$N_t\left(\frac{lb.}{a}\right) = N_t^*\left(\frac{mg\text{-}ft.}{L}\right)\cdot 10^{-6}\left(\frac{mg}{kg}\right)\cdot 10^{3}\left(\frac{L}{m^3}\right)\cdot 4.047\cdot 10^{-6}\left(\frac{m^2}{a}\right)$$

$$\cdot 0.305\left(\frac{m}{ft.}\right)\cdot 2.21\left(\frac{lb.}{kg}\right)\cdot 0.4(dimensionless)$$

$$N_t\left(\frac{lb.}{a}\right) = N_t^*\left(\frac{mg\text{-}ft.}{L}\right)\cdot 1.09\left(\frac{lb.\text{-}L}{a\text{-}mg\text{-}ft.}\right)$$

Spatial Interpretation

1. Local Load

2,500 m^2 nodes

Inverse-Square Distance Interpolation
- discrete, conservative -

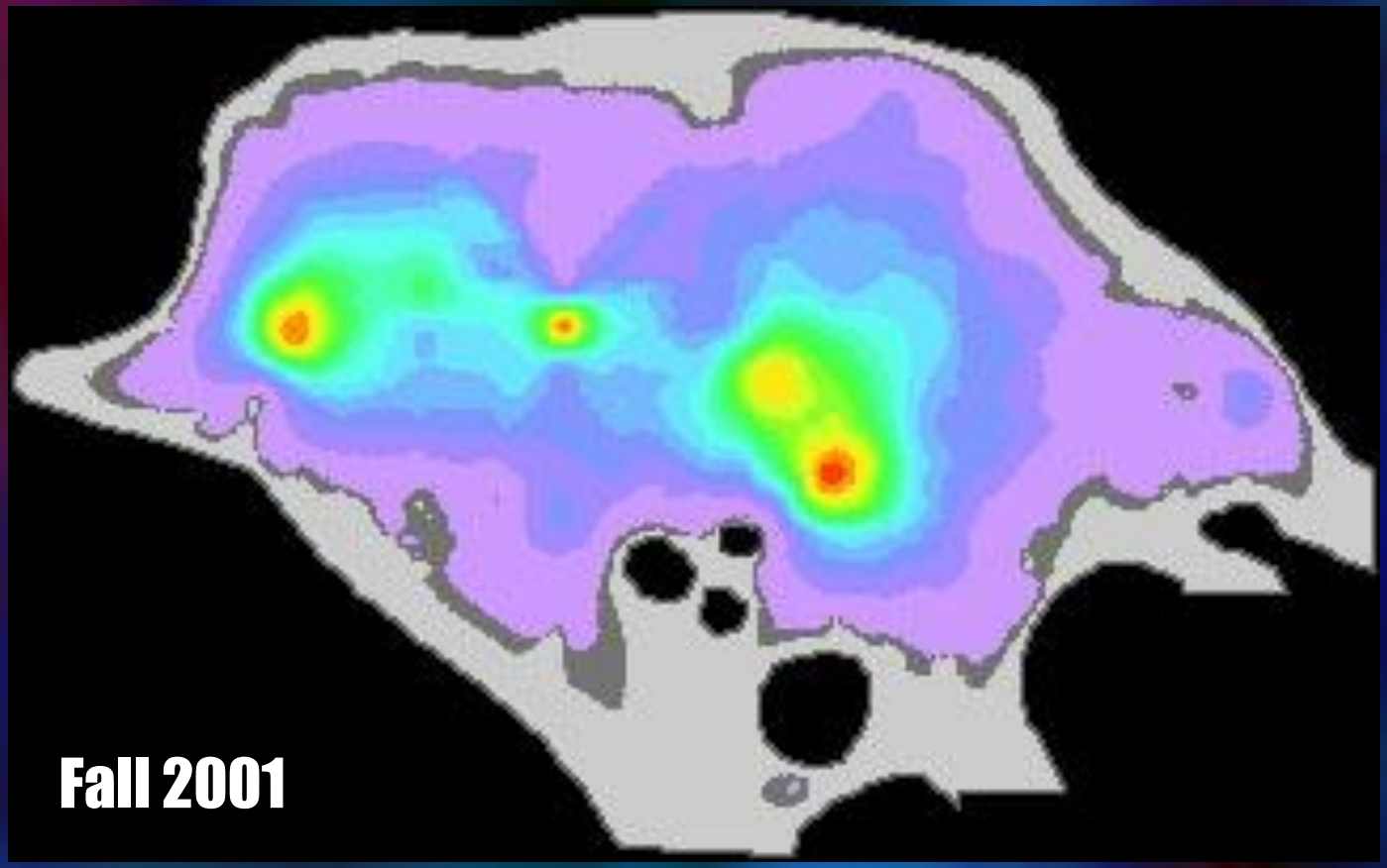
Zero concentration at aquifer boundaries

Spatial Interpretation

2. Total Load

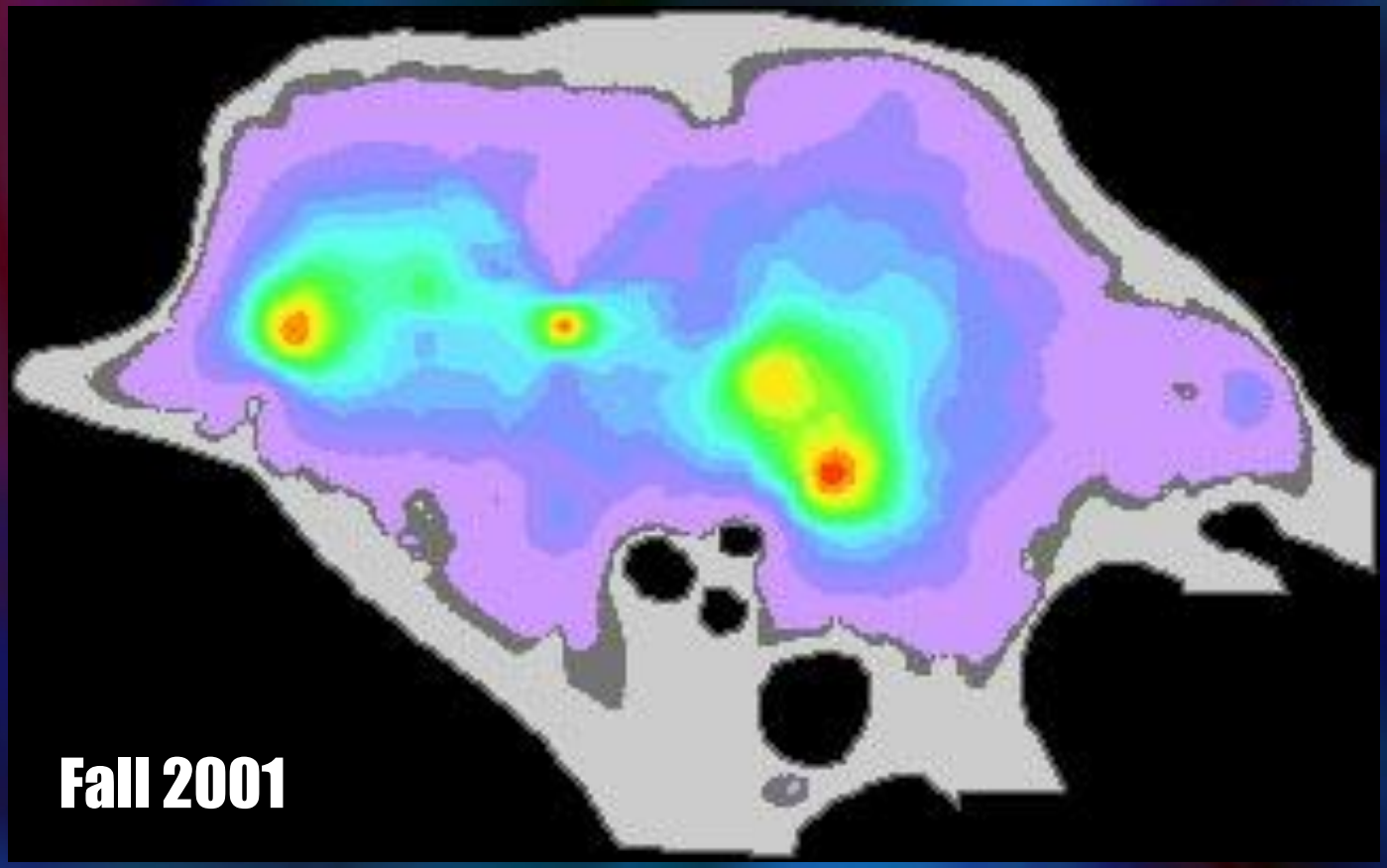
$$N(lb.) = \sum_{i=1}^{n} a_i N_{t,i}$$

Nitrate-N Load



TOTAL N - Pounds Per Acre

Nitrate-N Load



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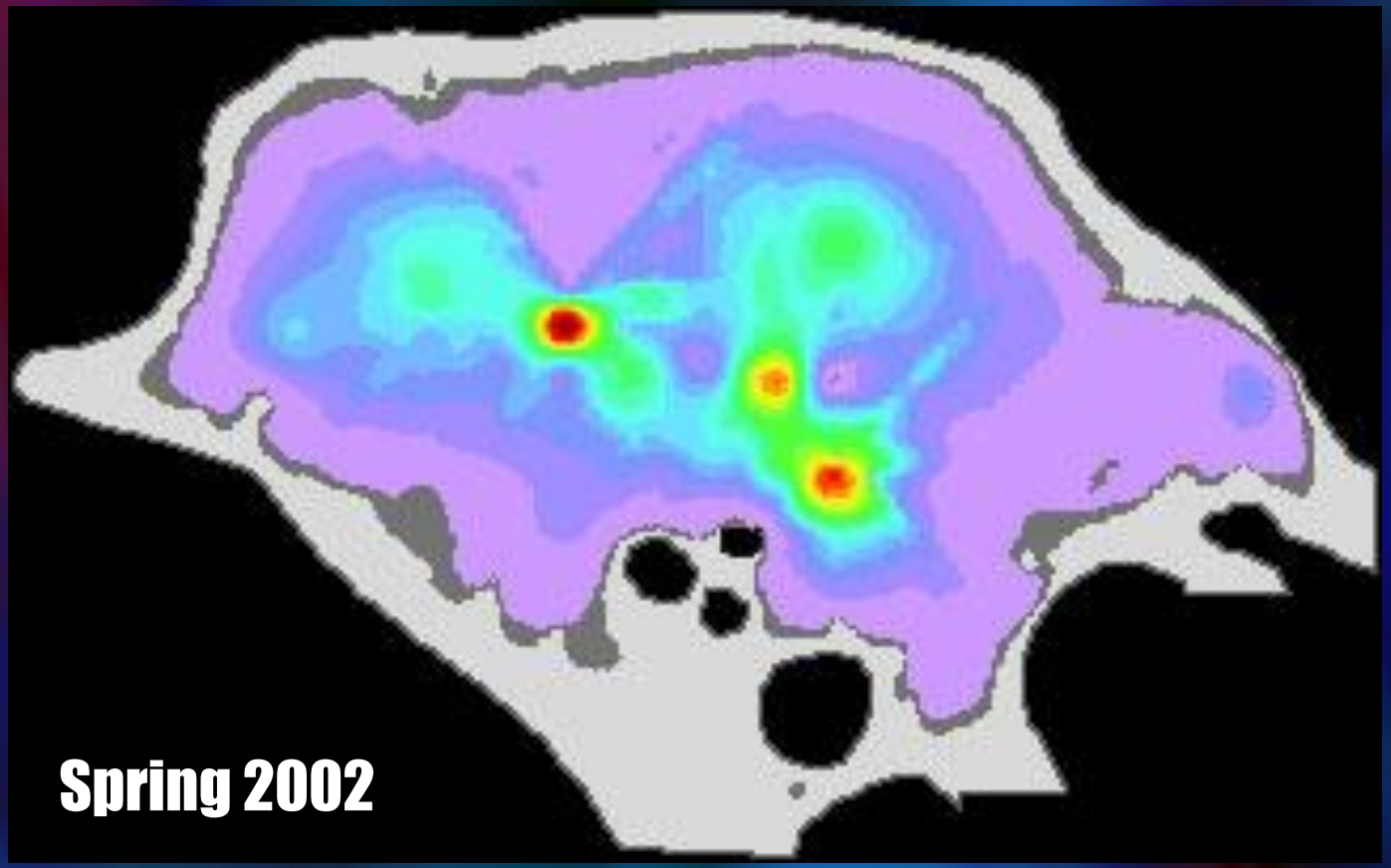

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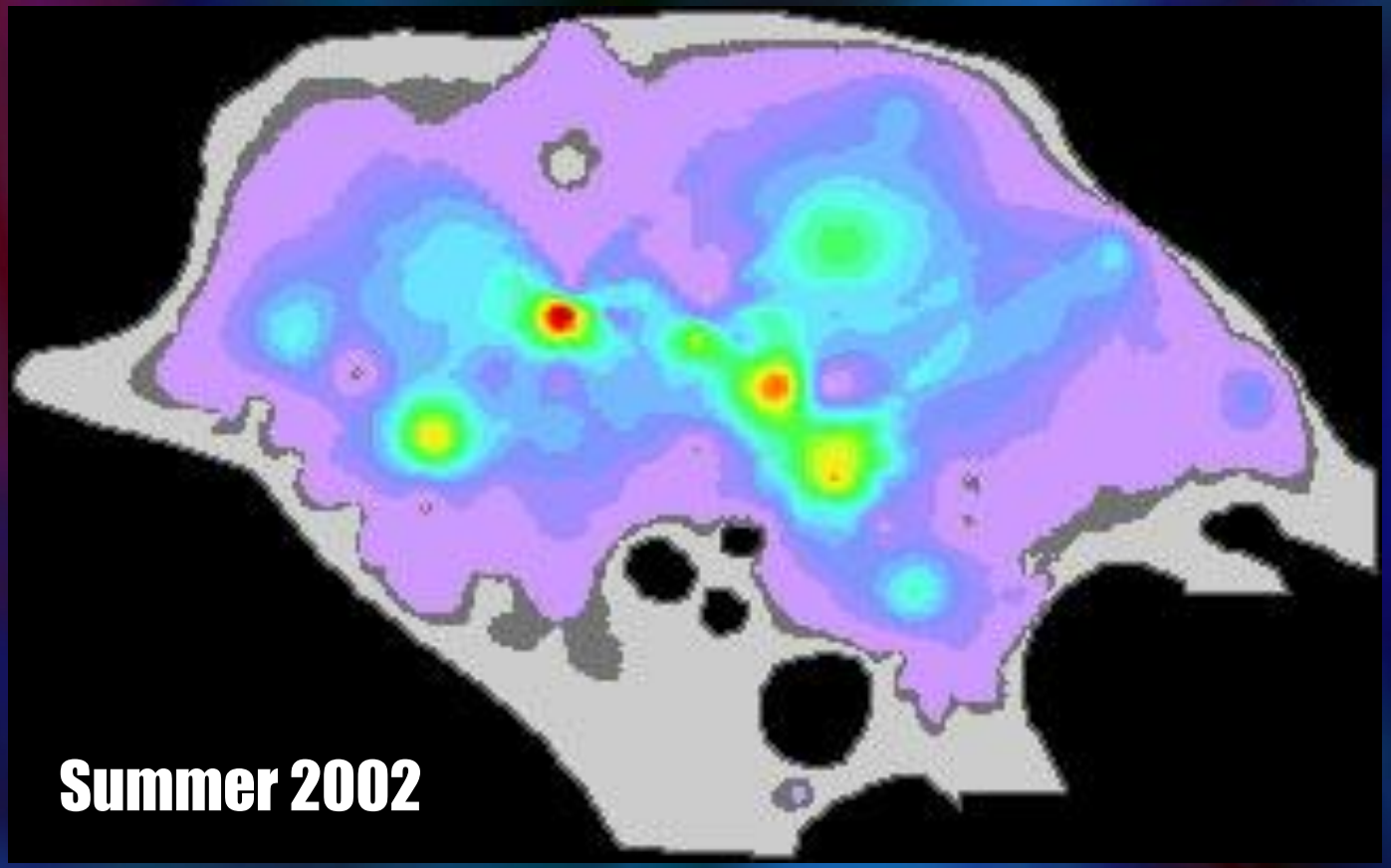
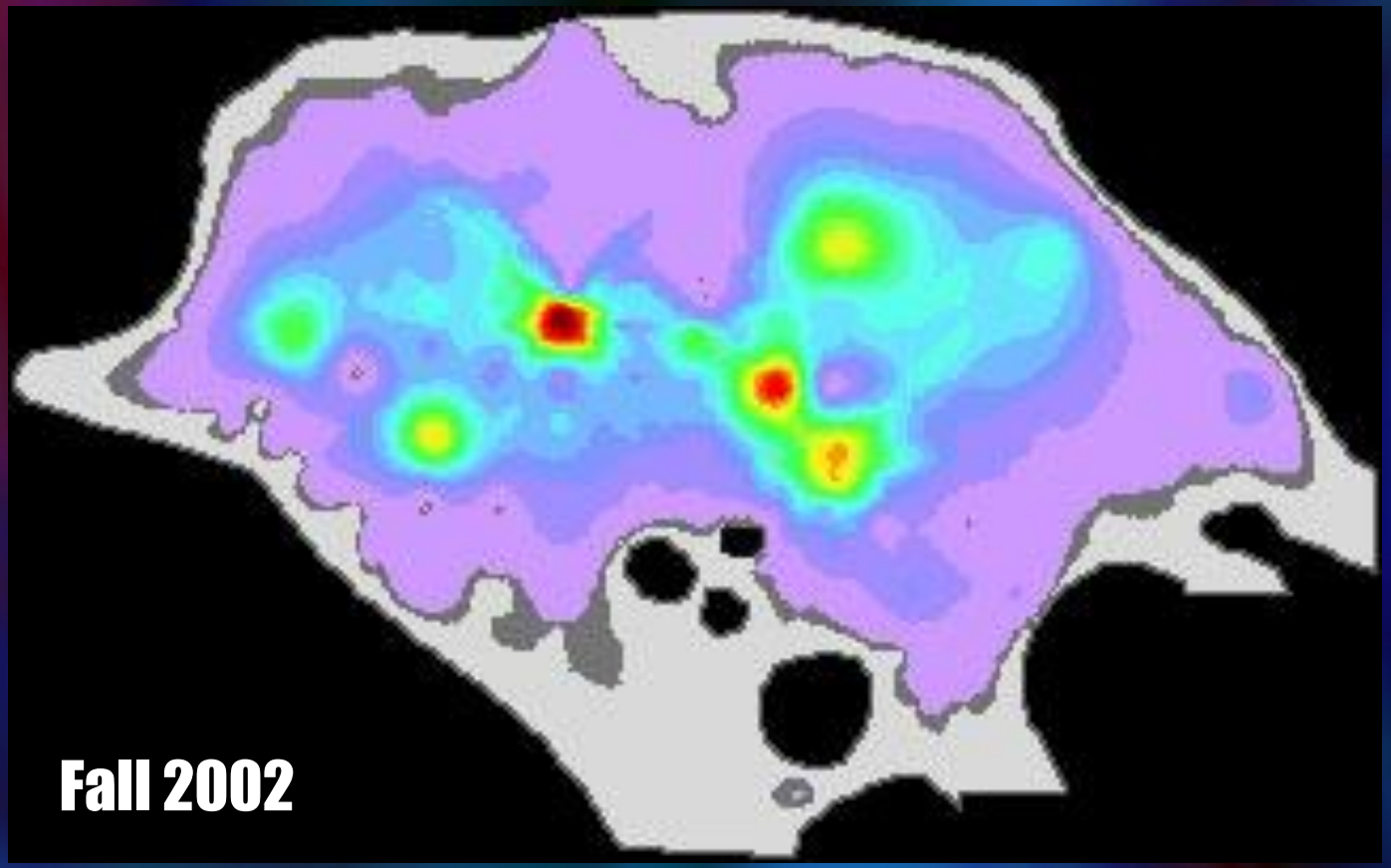


TOTAL N - Pounds Per Acre

Nitrate-N Load



TOTAL N - Pounds Per Acre

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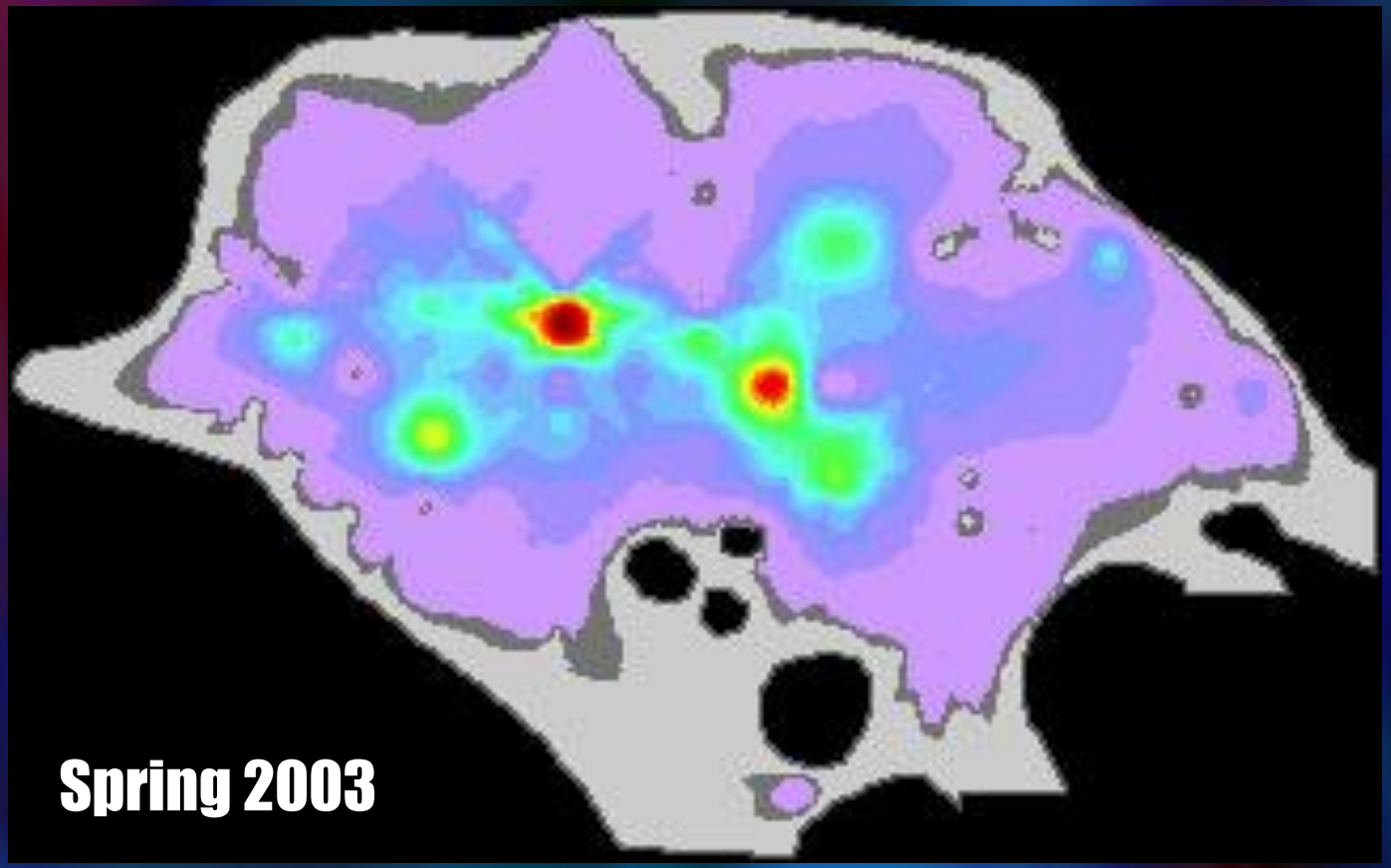

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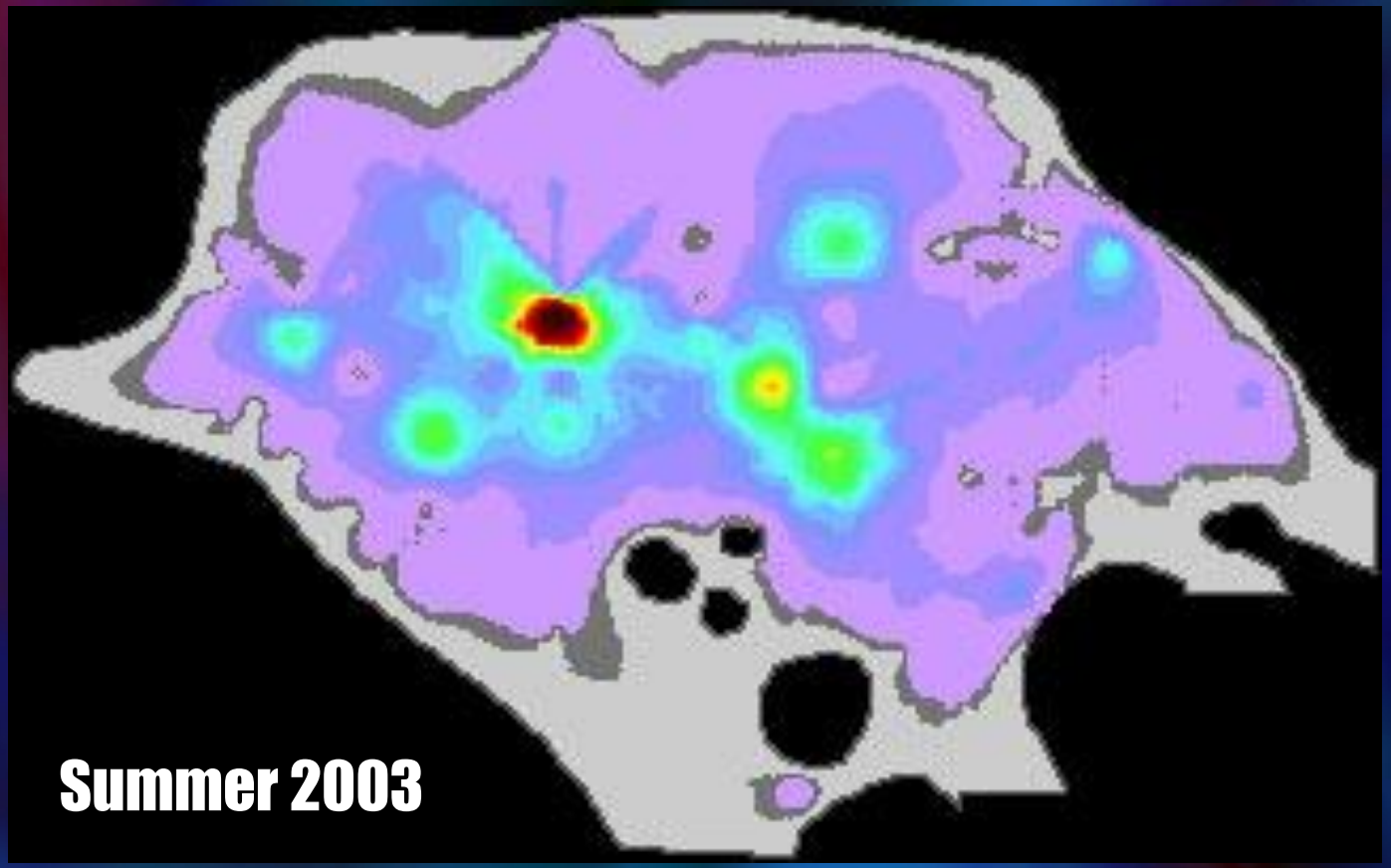

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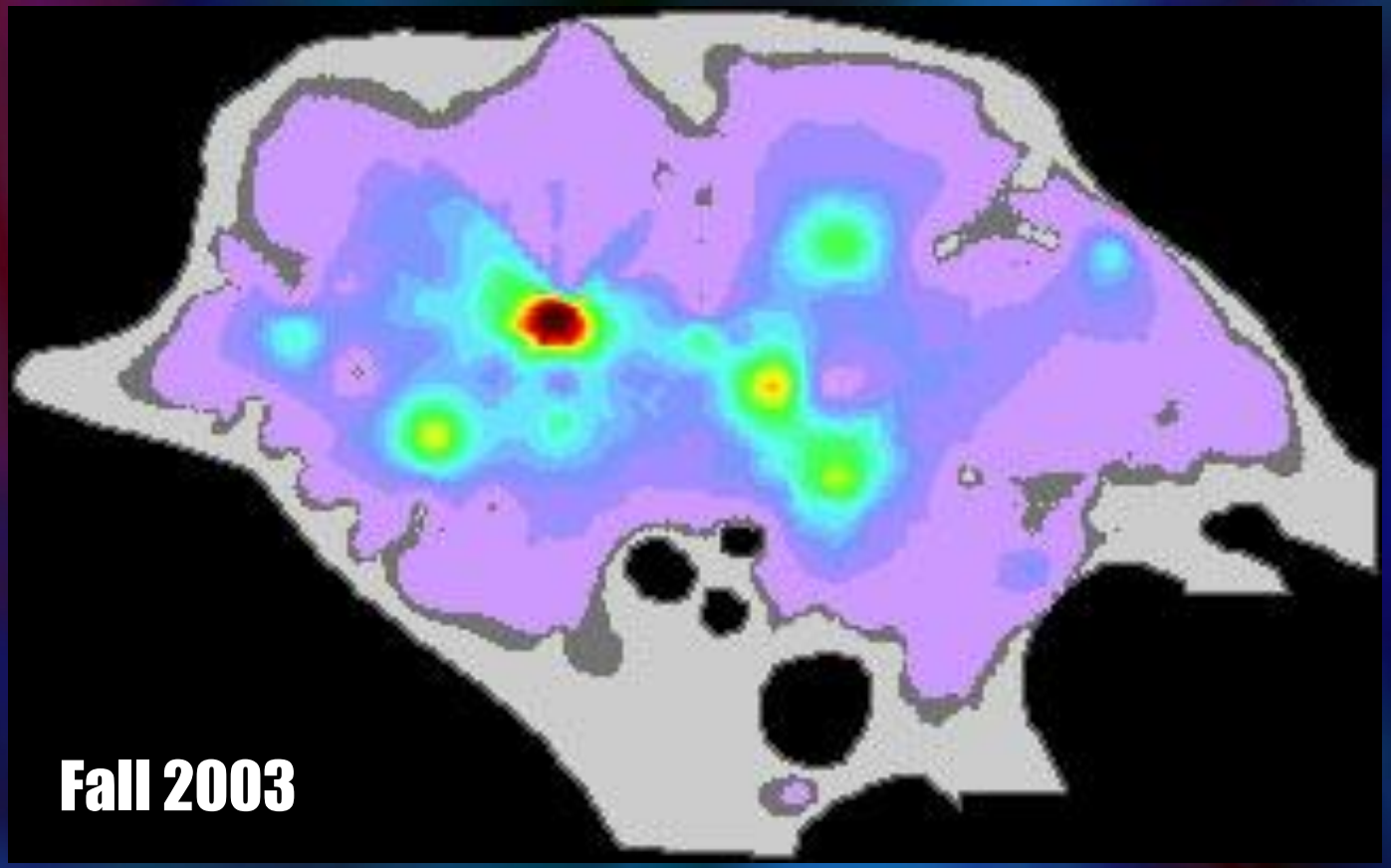

TOTAL N - Pounds Per Acre

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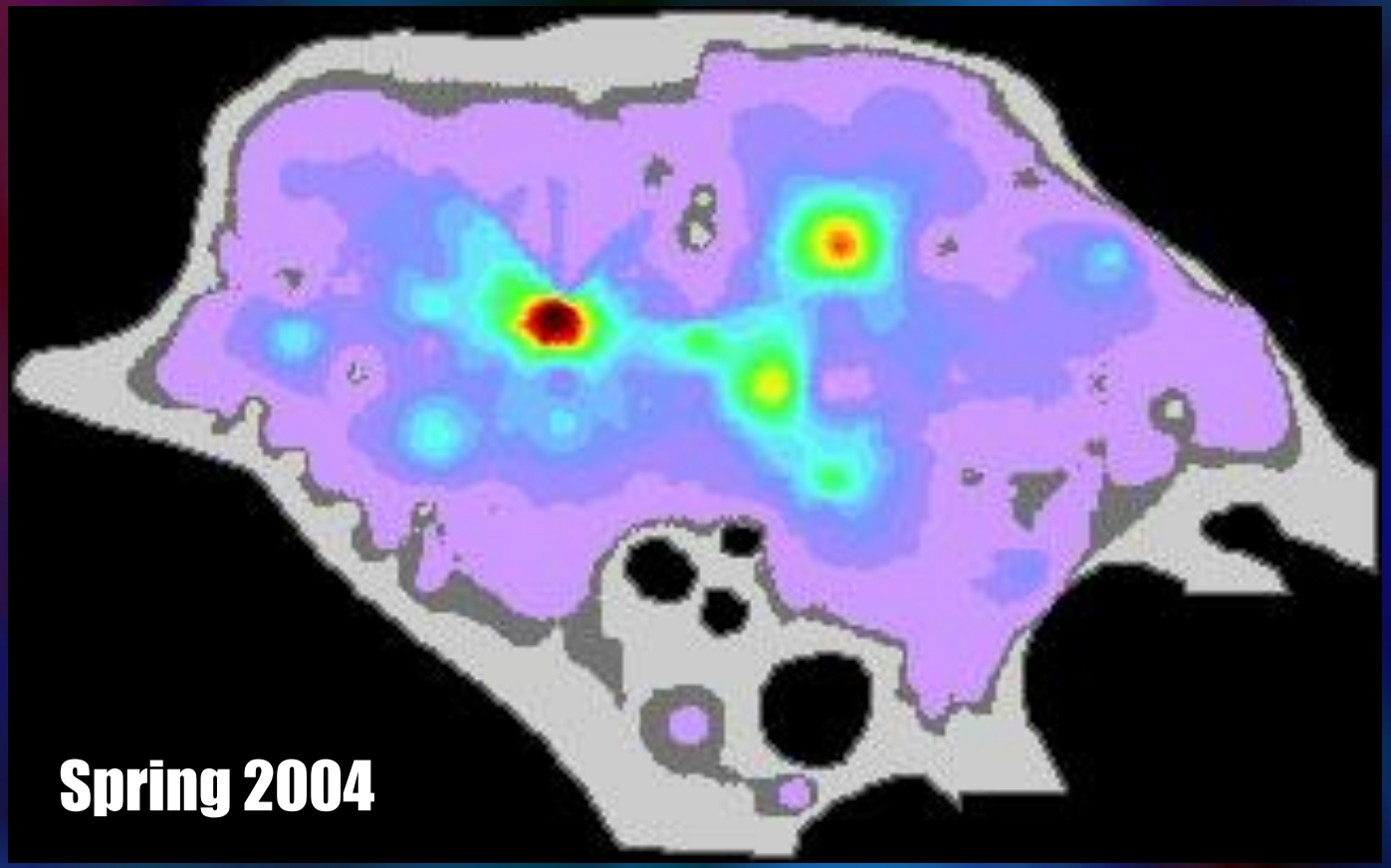

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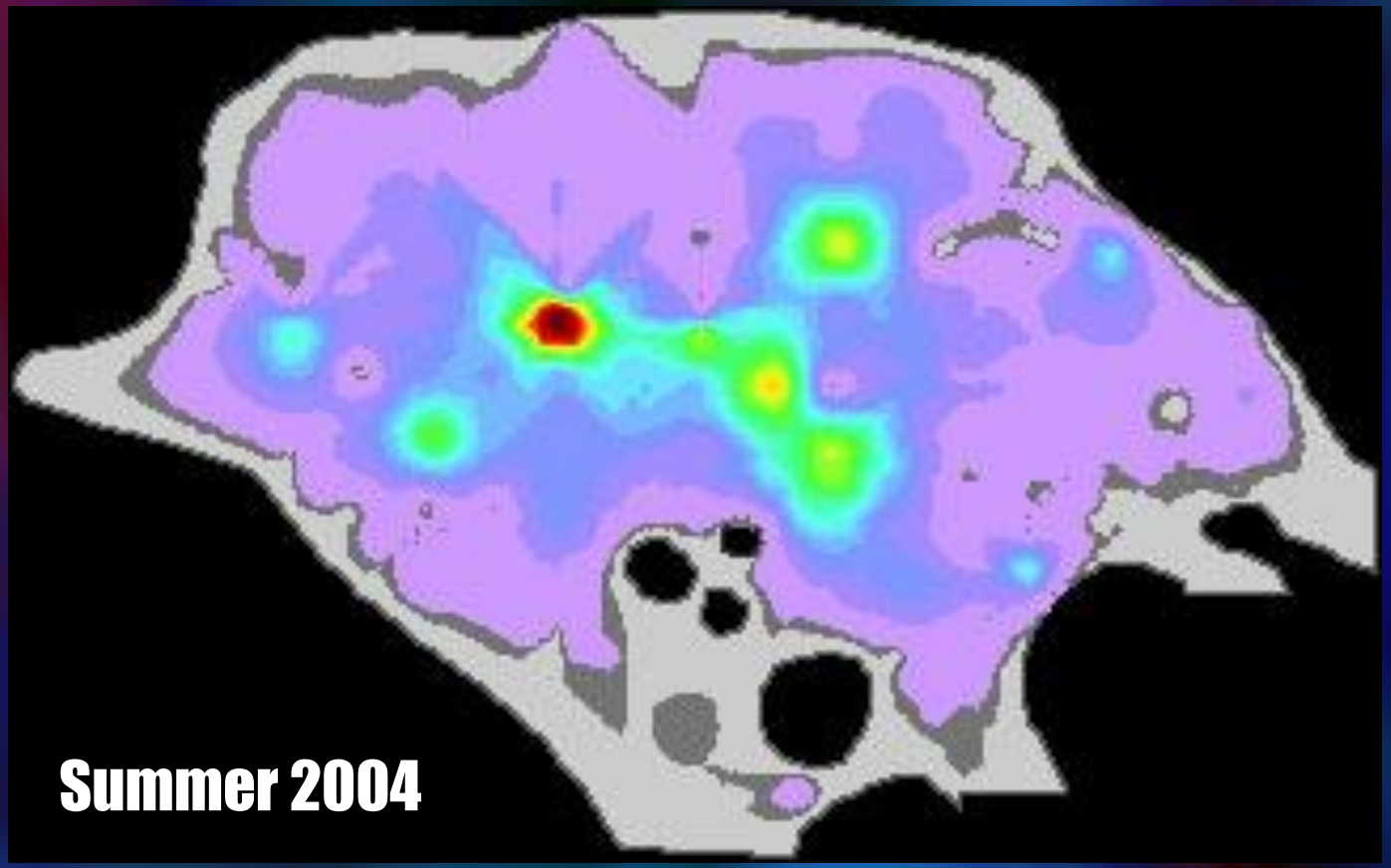
Nitrate-N Load



TOTAL N - Pounds Per Acre

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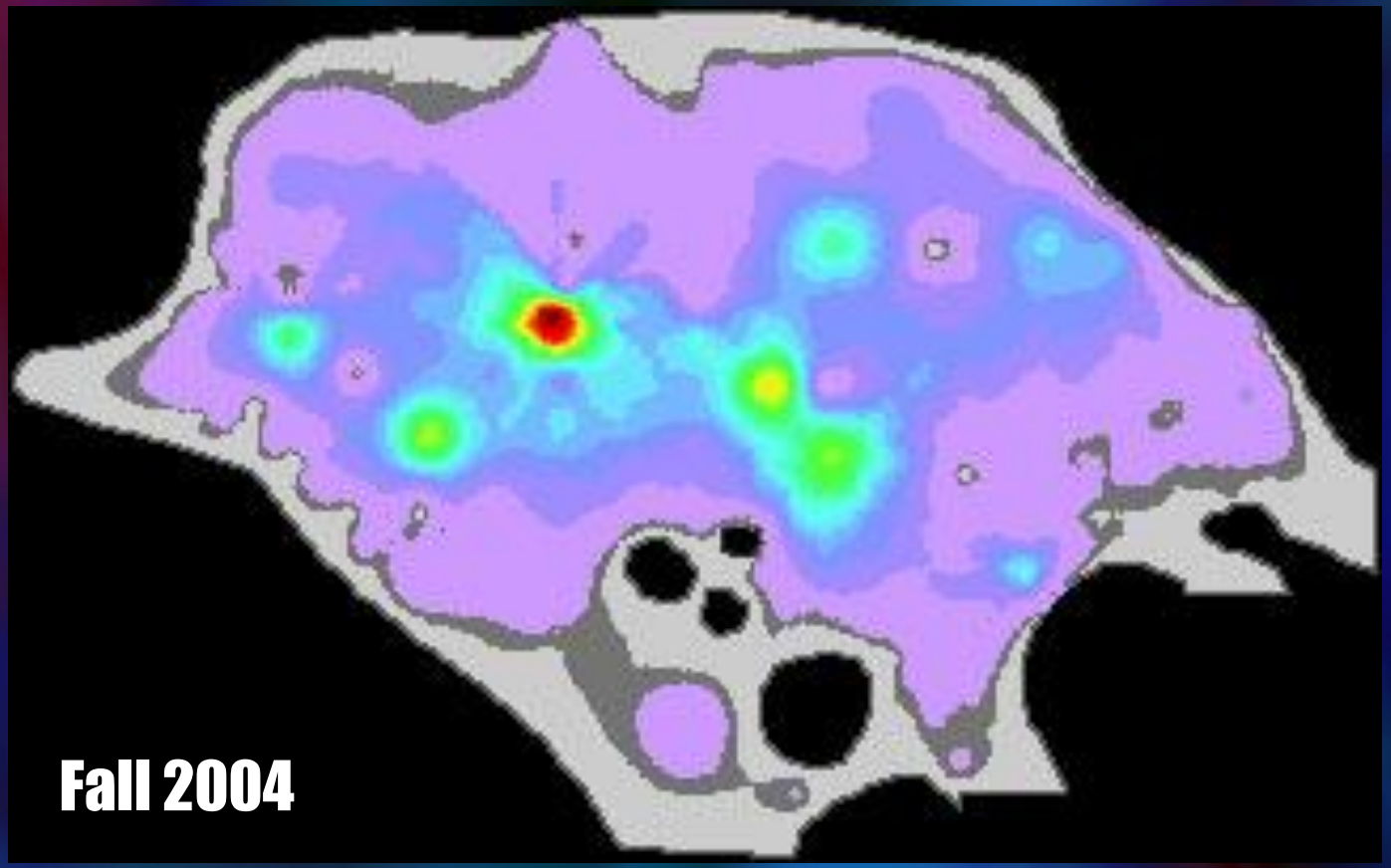

TOTAL N - Pounds Per Acre

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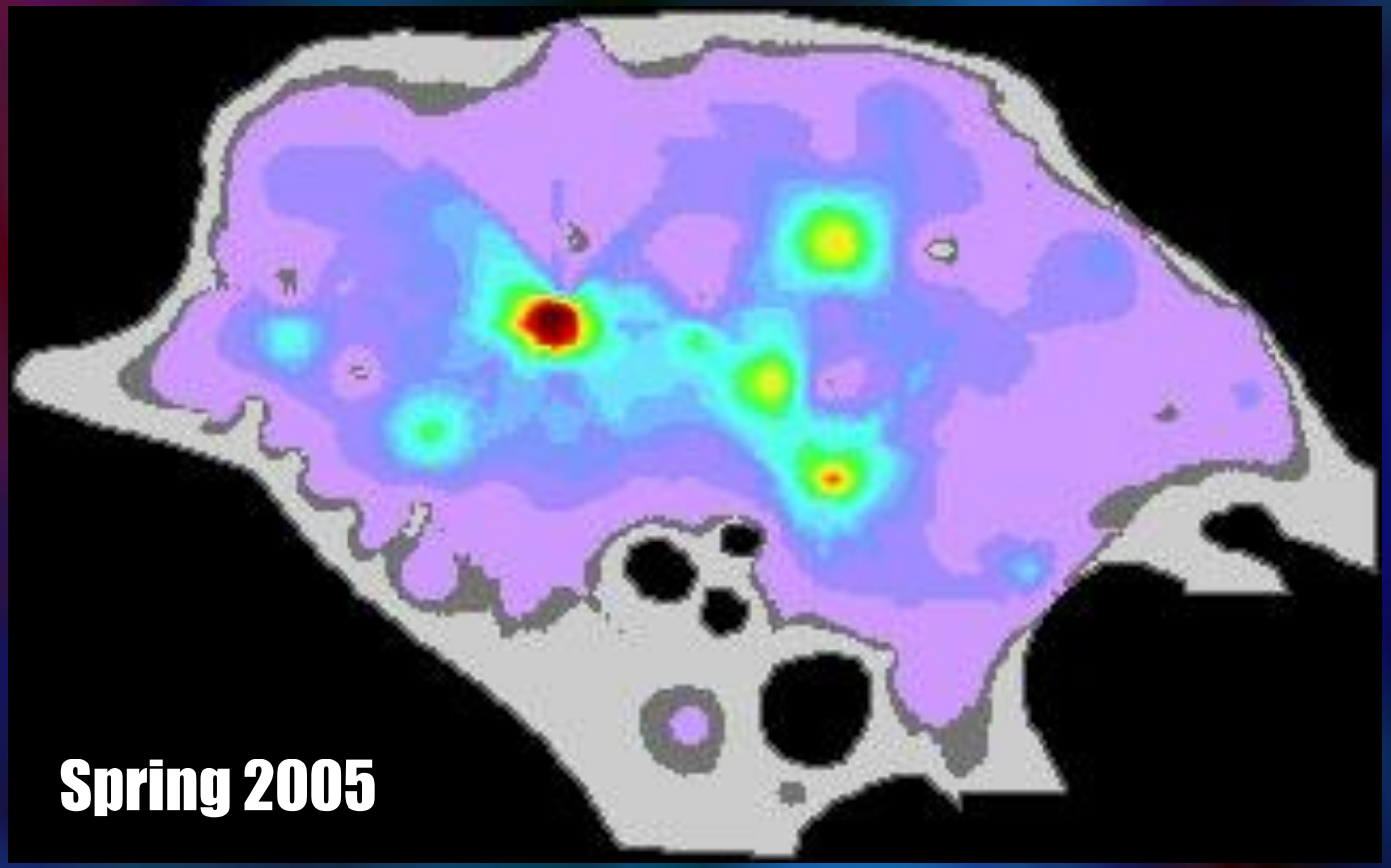

TOTAL N - Pounds Per Acre

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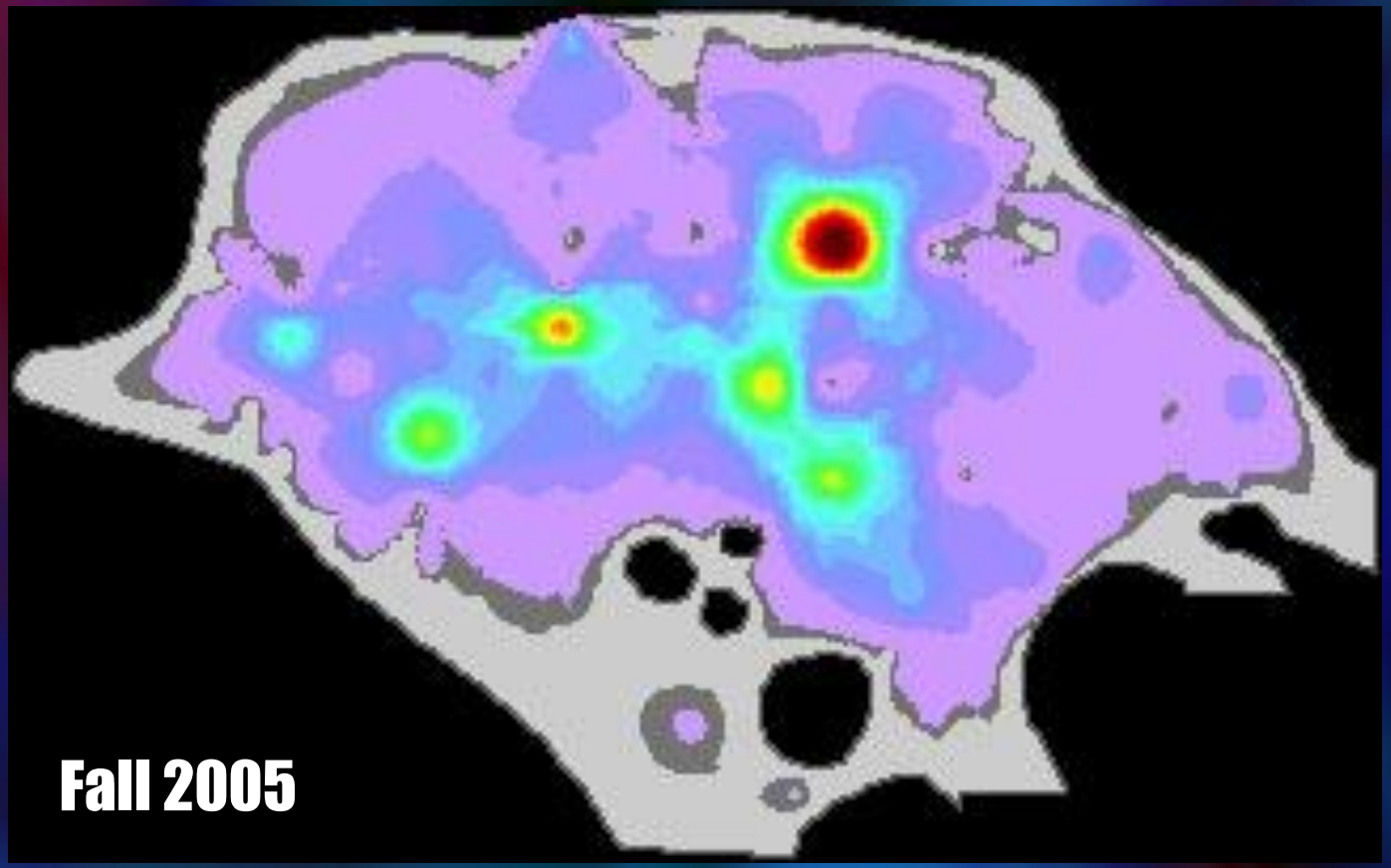
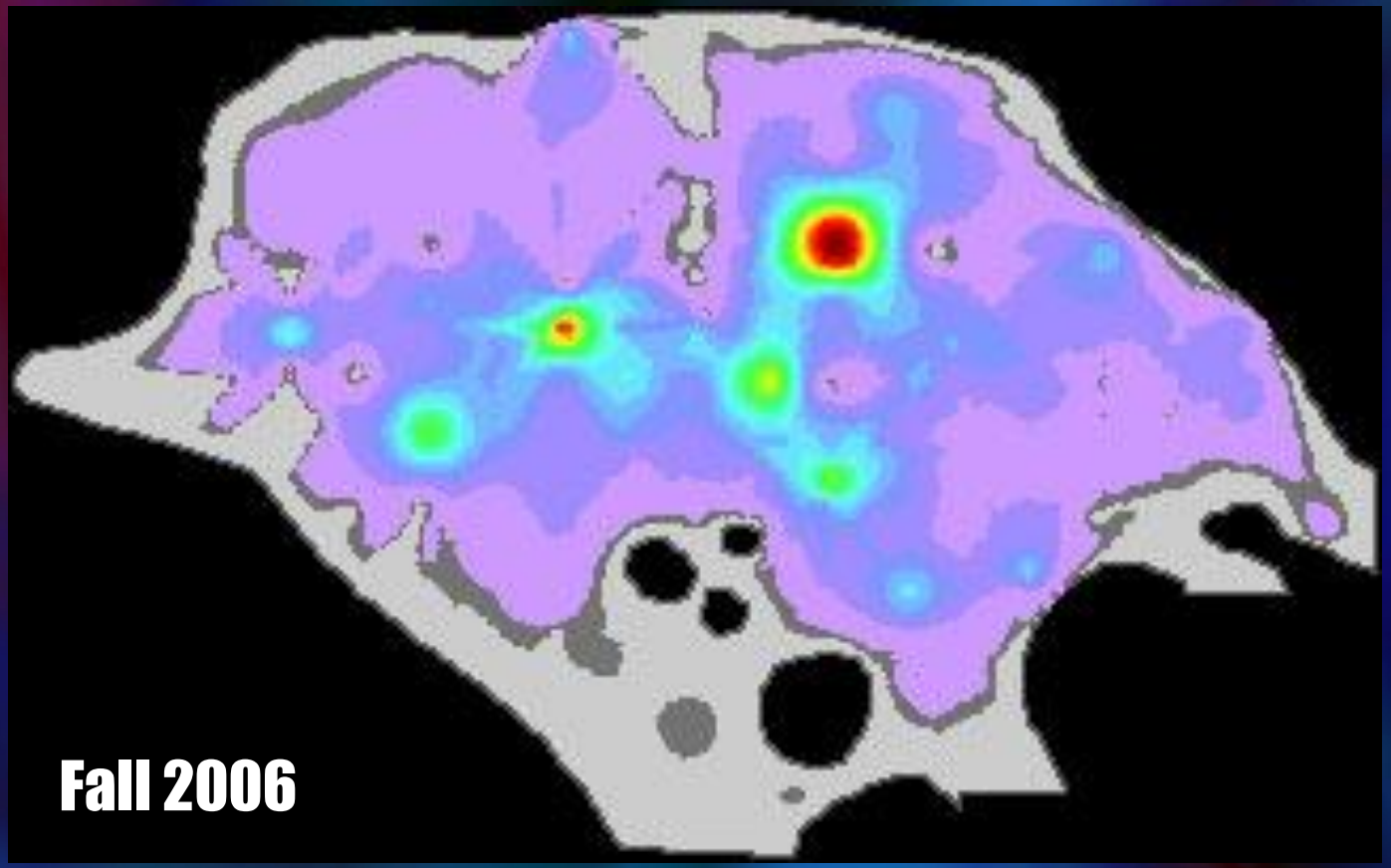


TOTAL N - Pounds Per Acre

Nitrate-N Load



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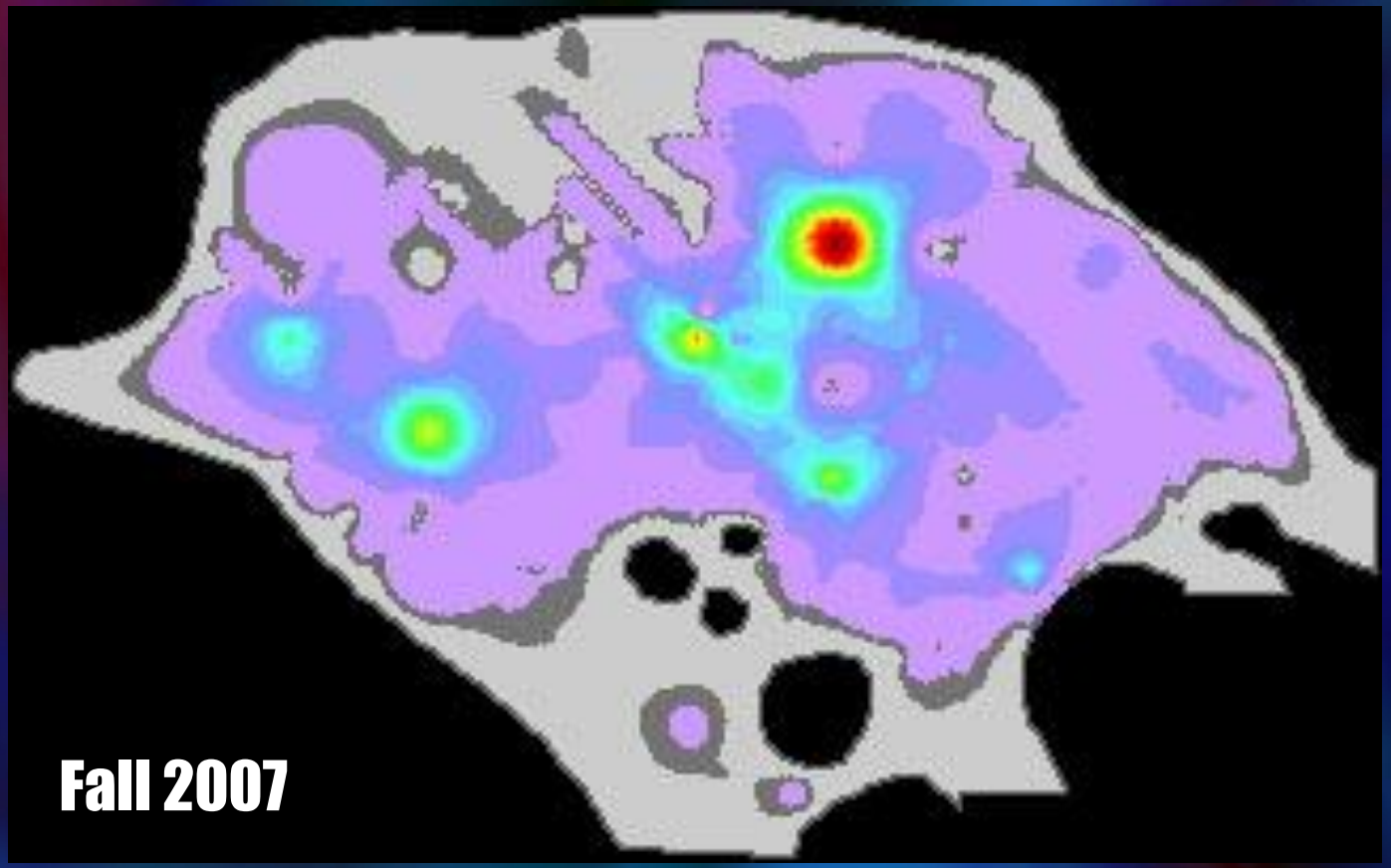
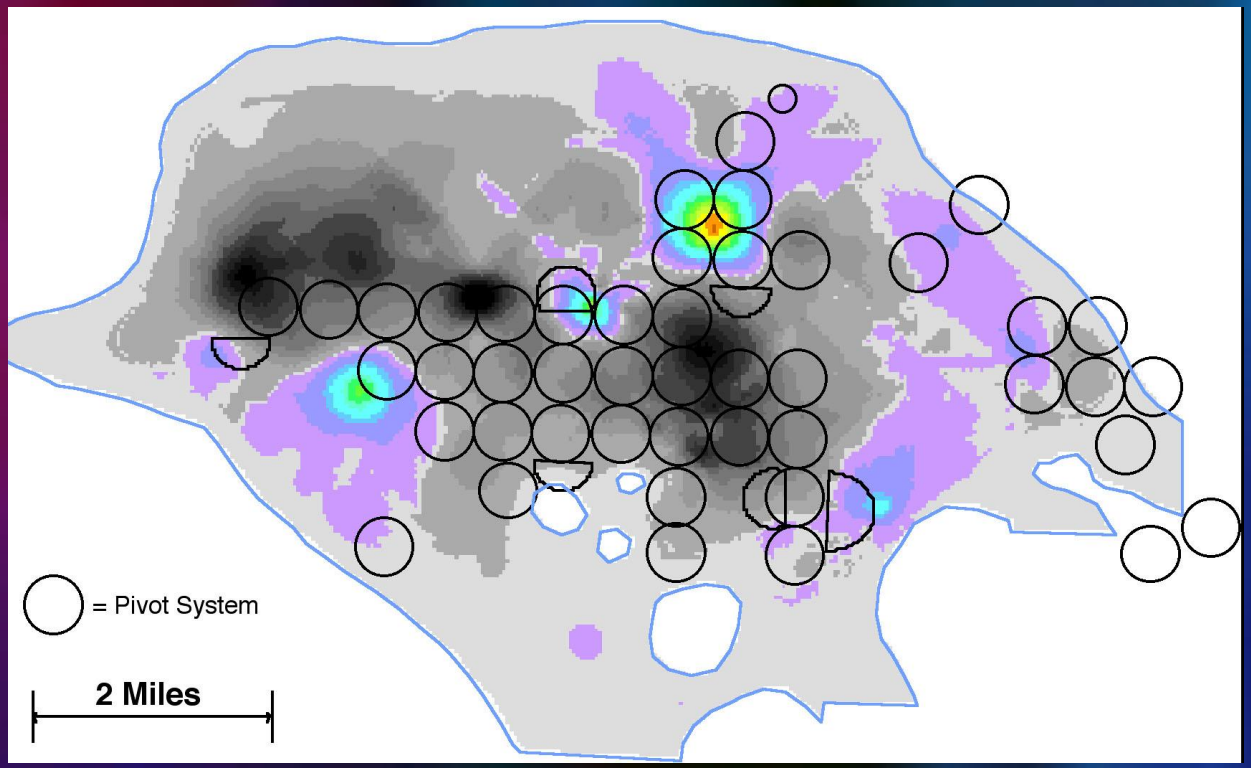


TOTAL N - Pounds Per Acre



Delta Map: Pounds Per Acre Change

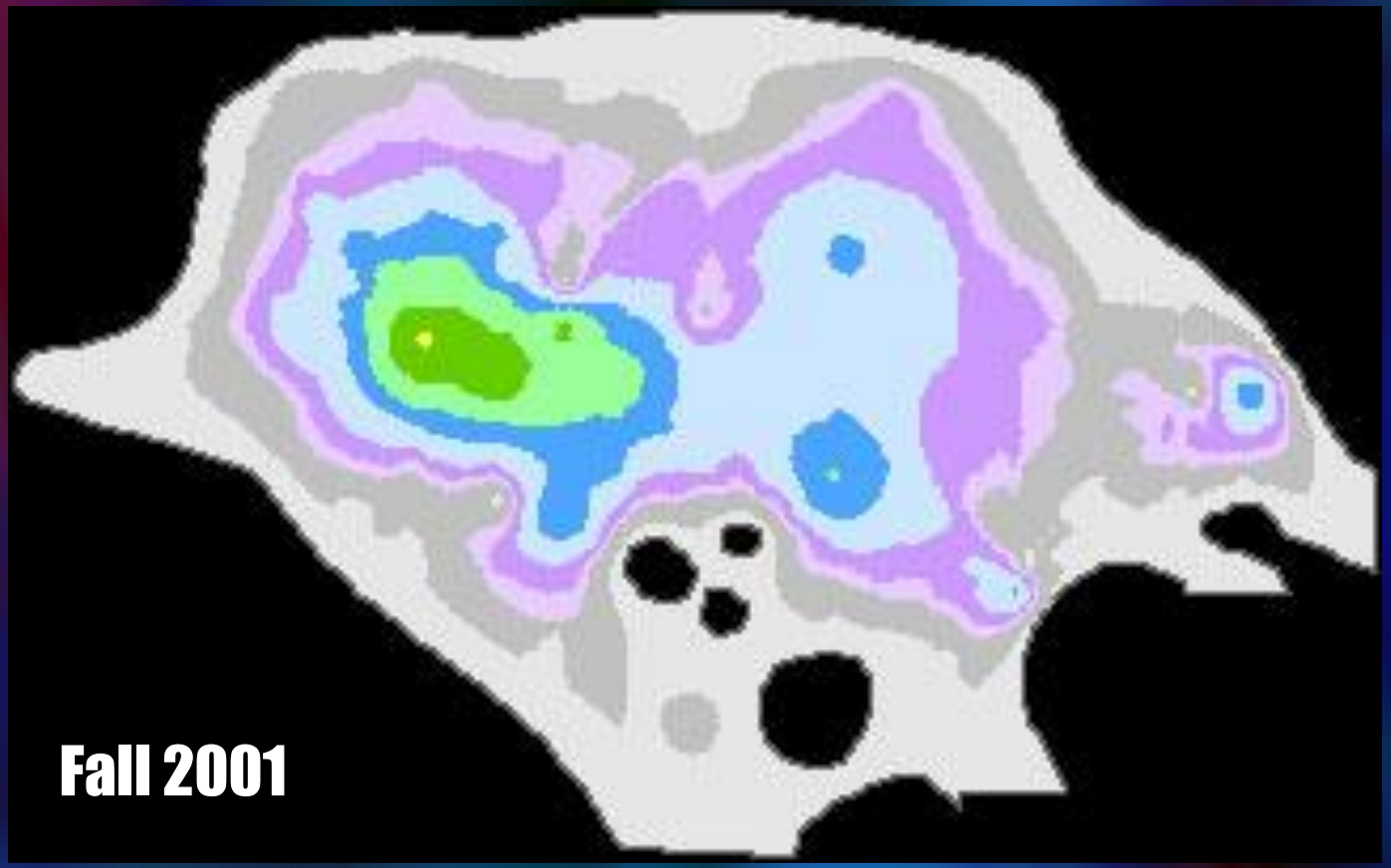
Legend of Total nitrate-N Differences (lbs. Per Acre)

-1240 to -920	-119 to -20	720 to 819
-919 to -820	-19 to 19	820 to 919
-819 to -720	20 to 119	920 to 1019
-719 to -620	120 to 219	1020 to 1119
-619 to -520	220 to 319	1120 to 1219
-519 to -420	320 to 419	1220 to 1319
-419 to -320	420 to 519	1320 to 1330
-319 to -220	520 to 619	
-219 to -120	620 to 719	

Toxicological Assessment

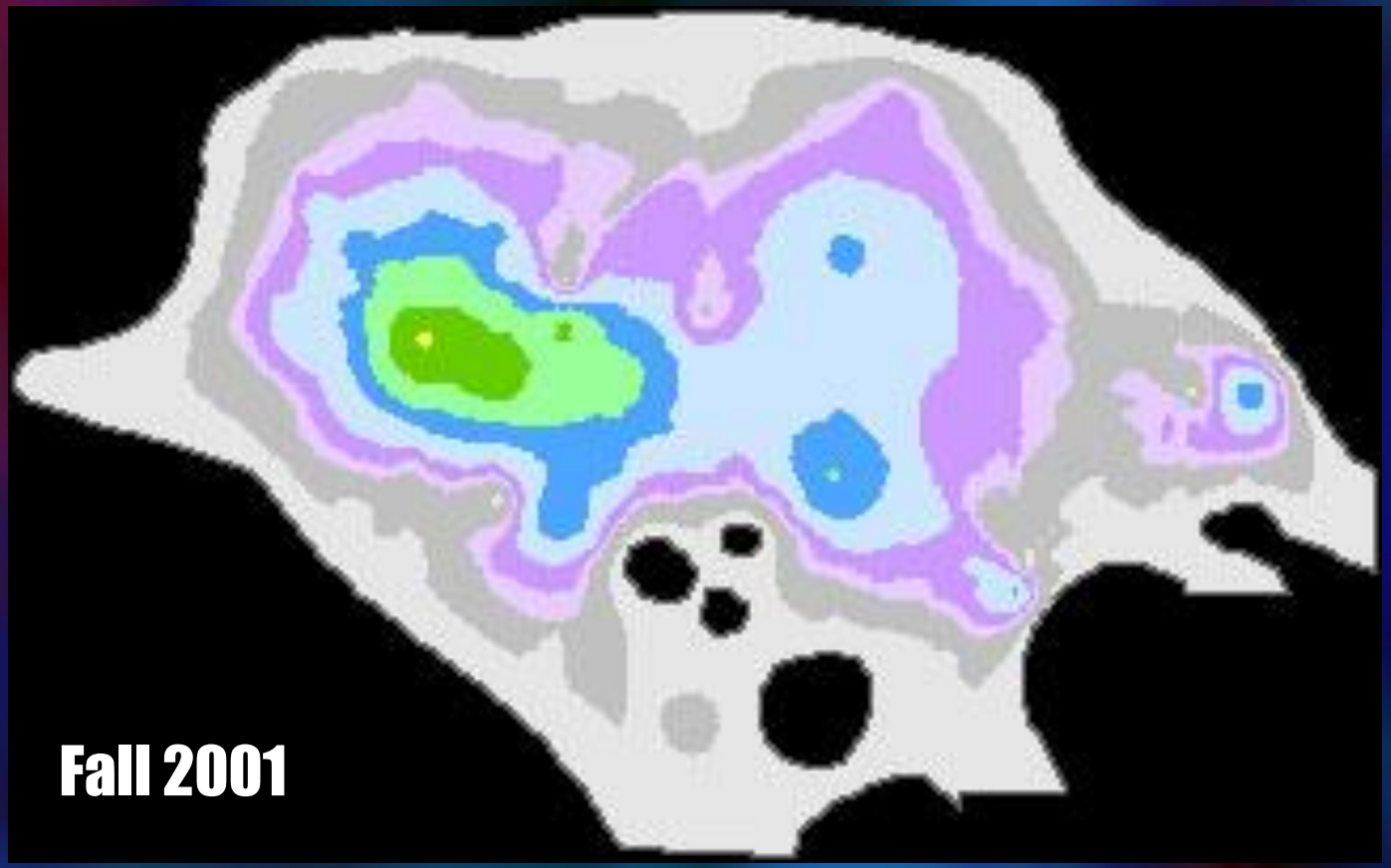
$$PMCI\left(\frac{mg}{L}\right) = \frac{N_t^*}{Z}\left(\frac{mg - ft.}{L}\right) \Big/ ft.$$

Toxicological Assessment



PMCI in mg/L

Toxicological Assessment



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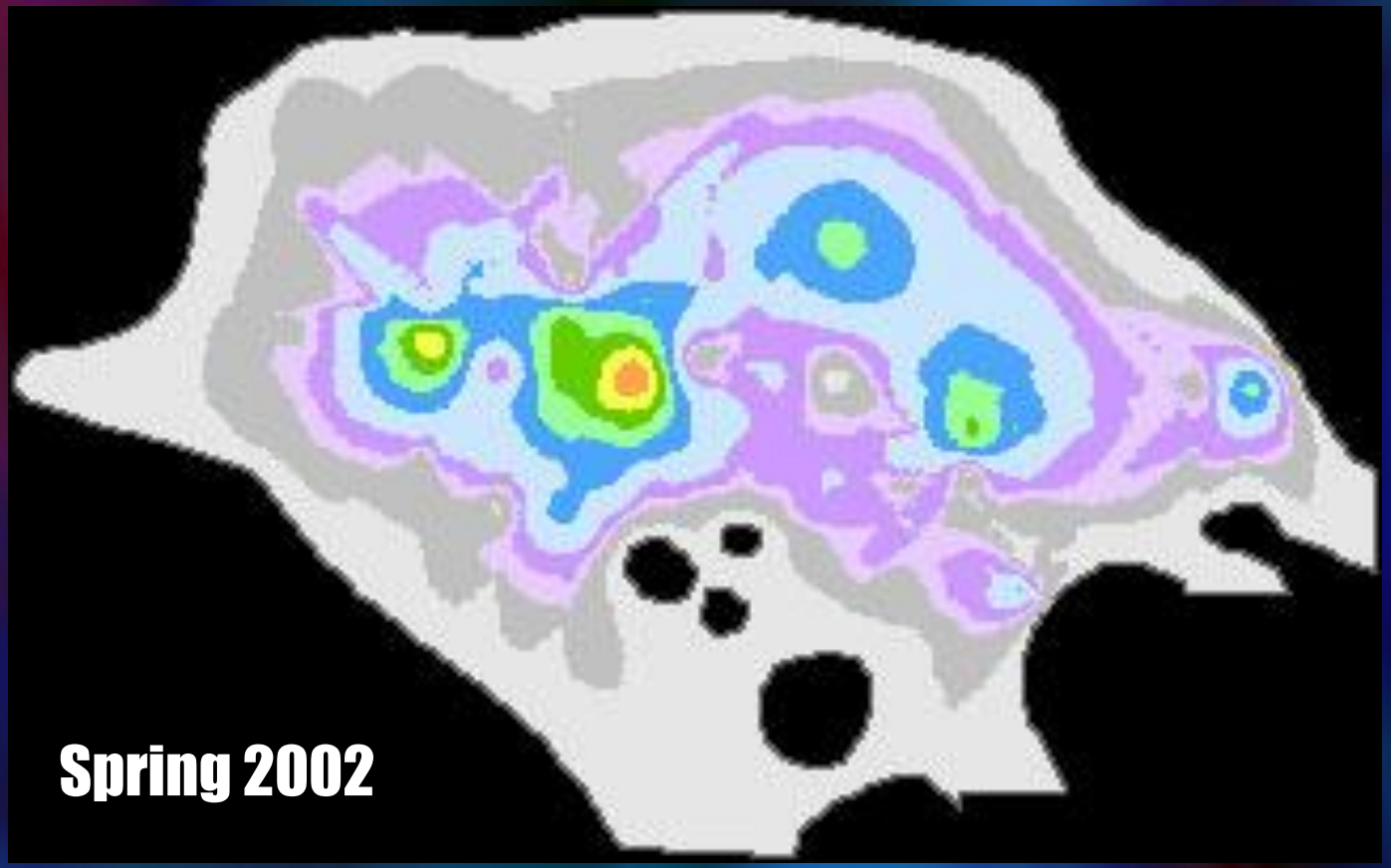

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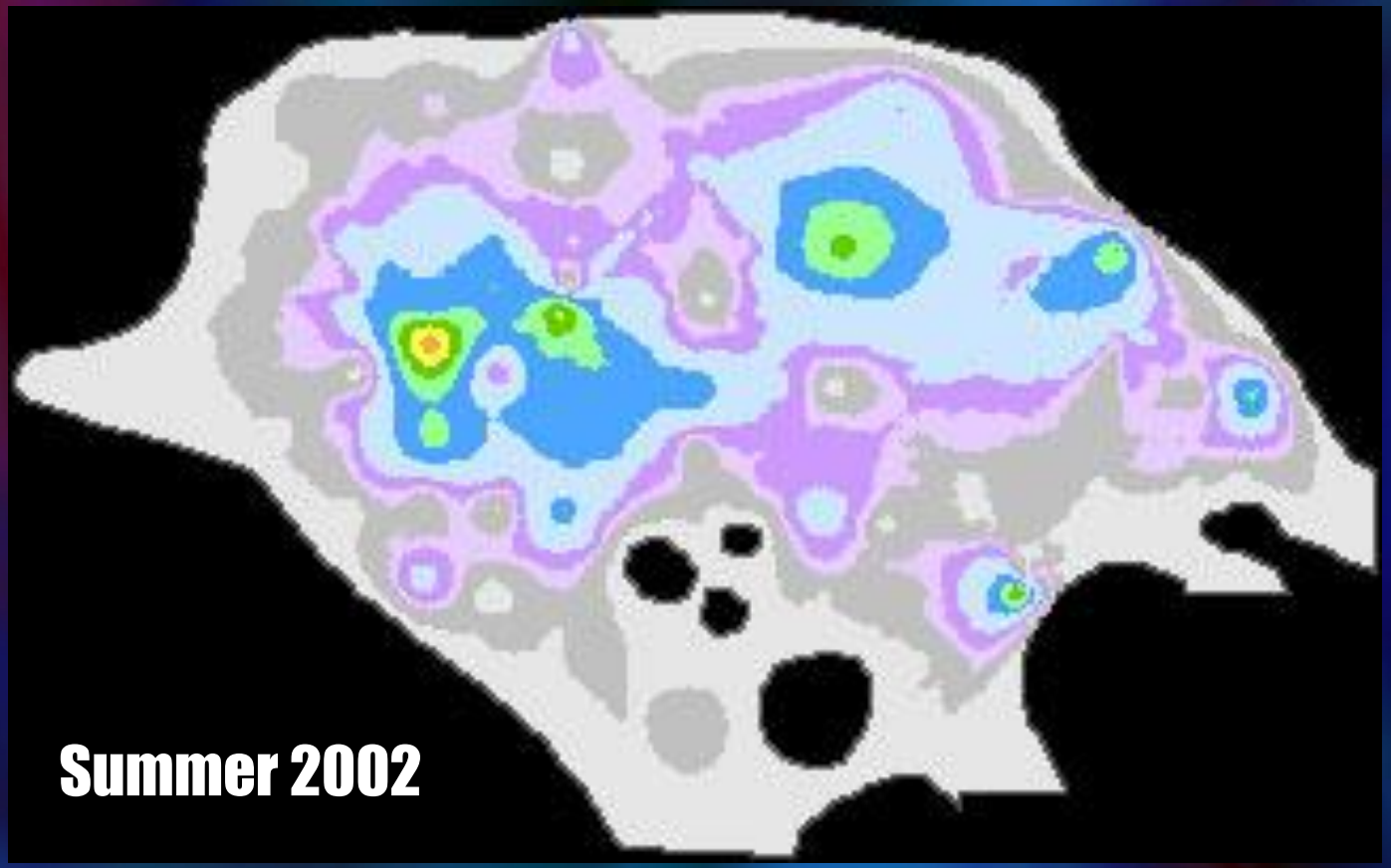
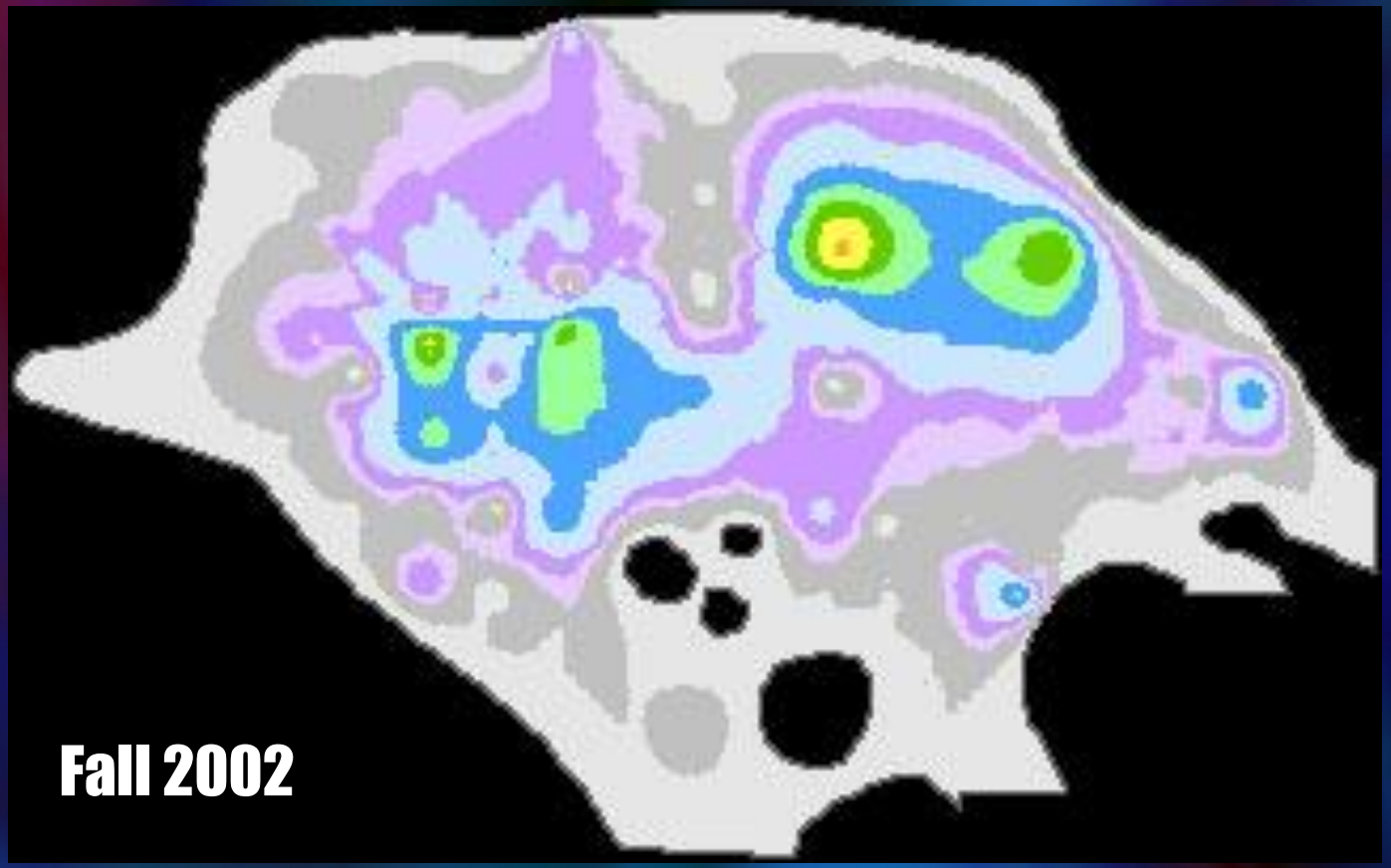
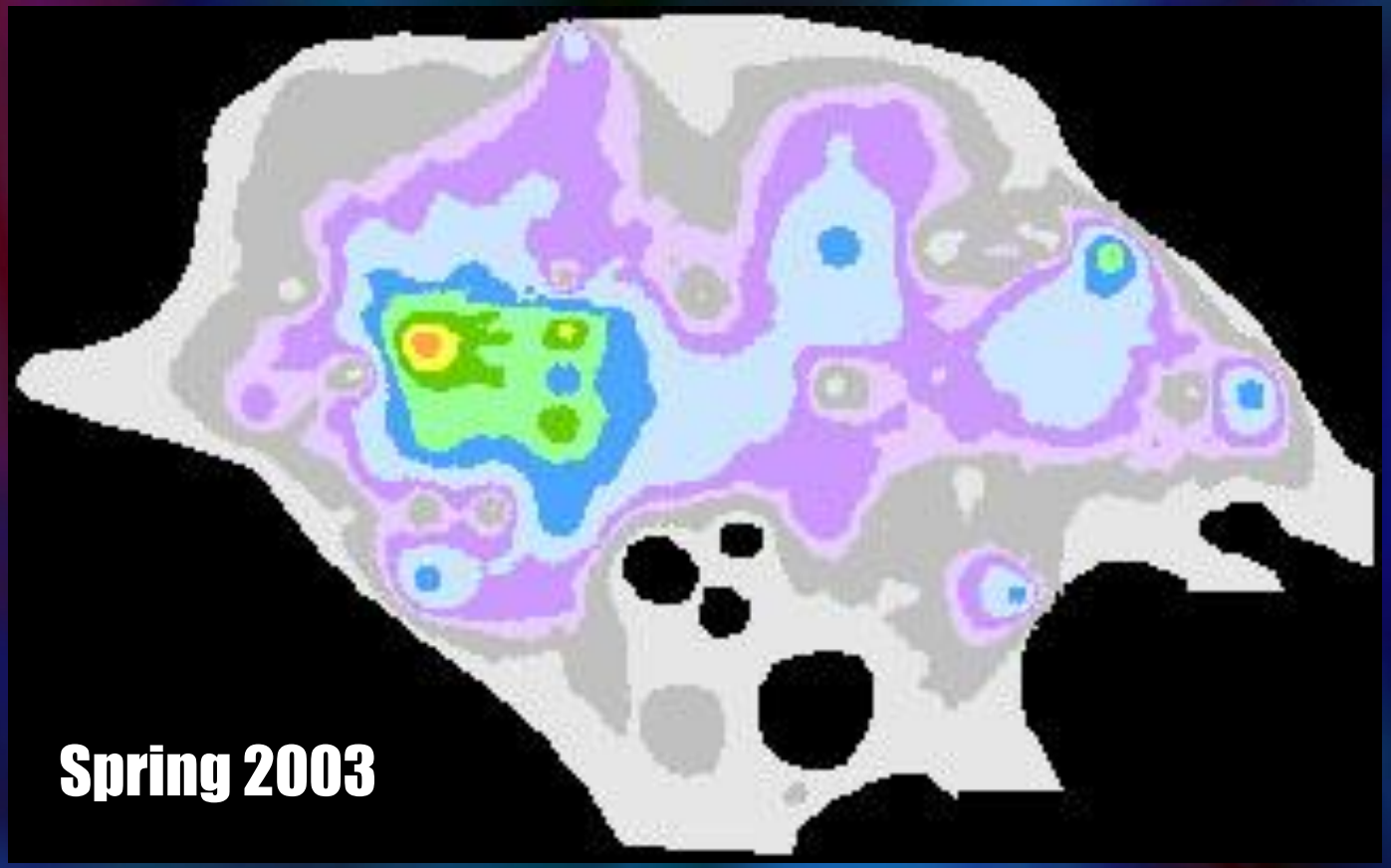


PMCI in mg/L

Toxicological Assessment

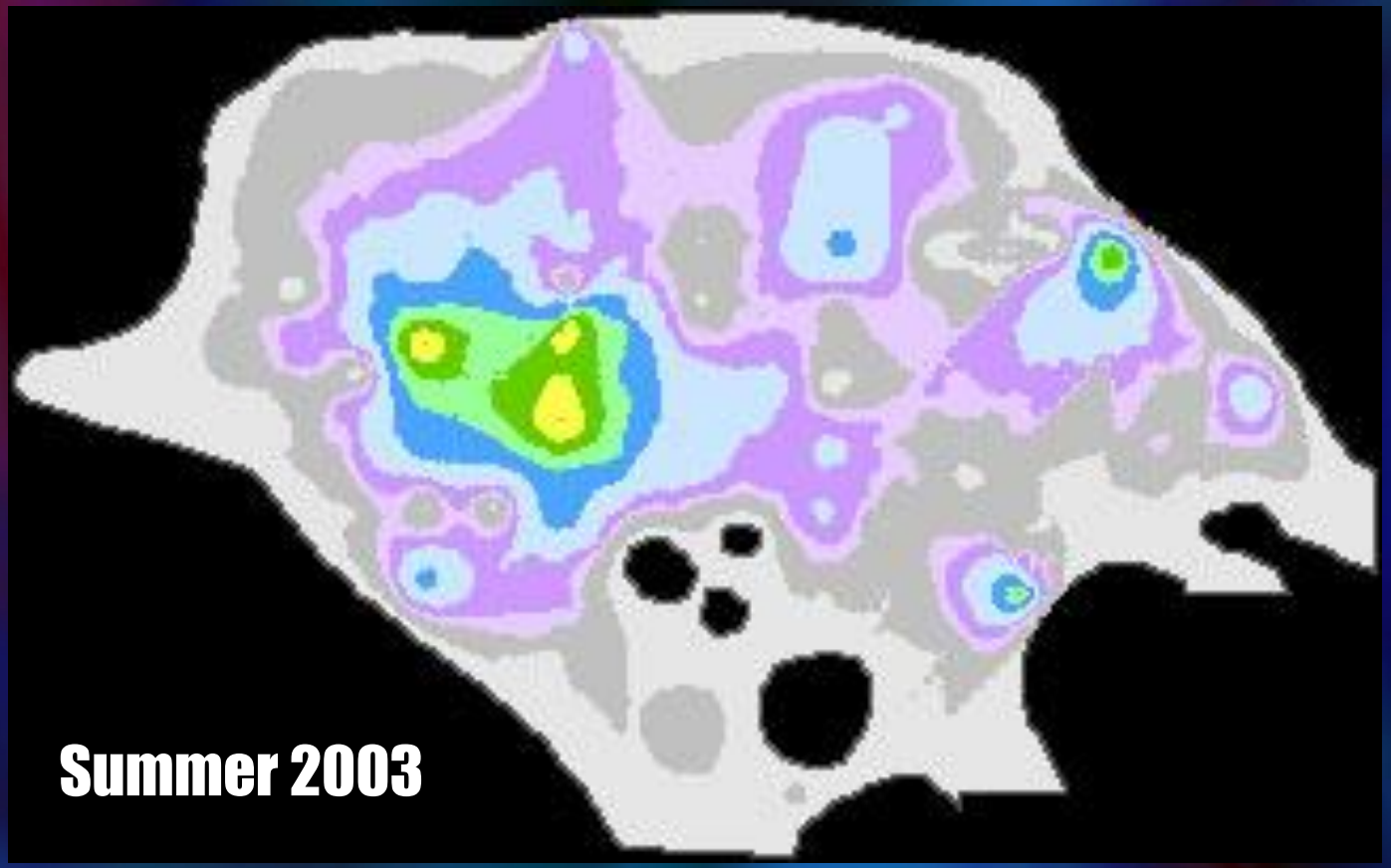


Toxicological Assessment



PMCI in mg/L

Toxicological Assessment



PMCI in mg/L

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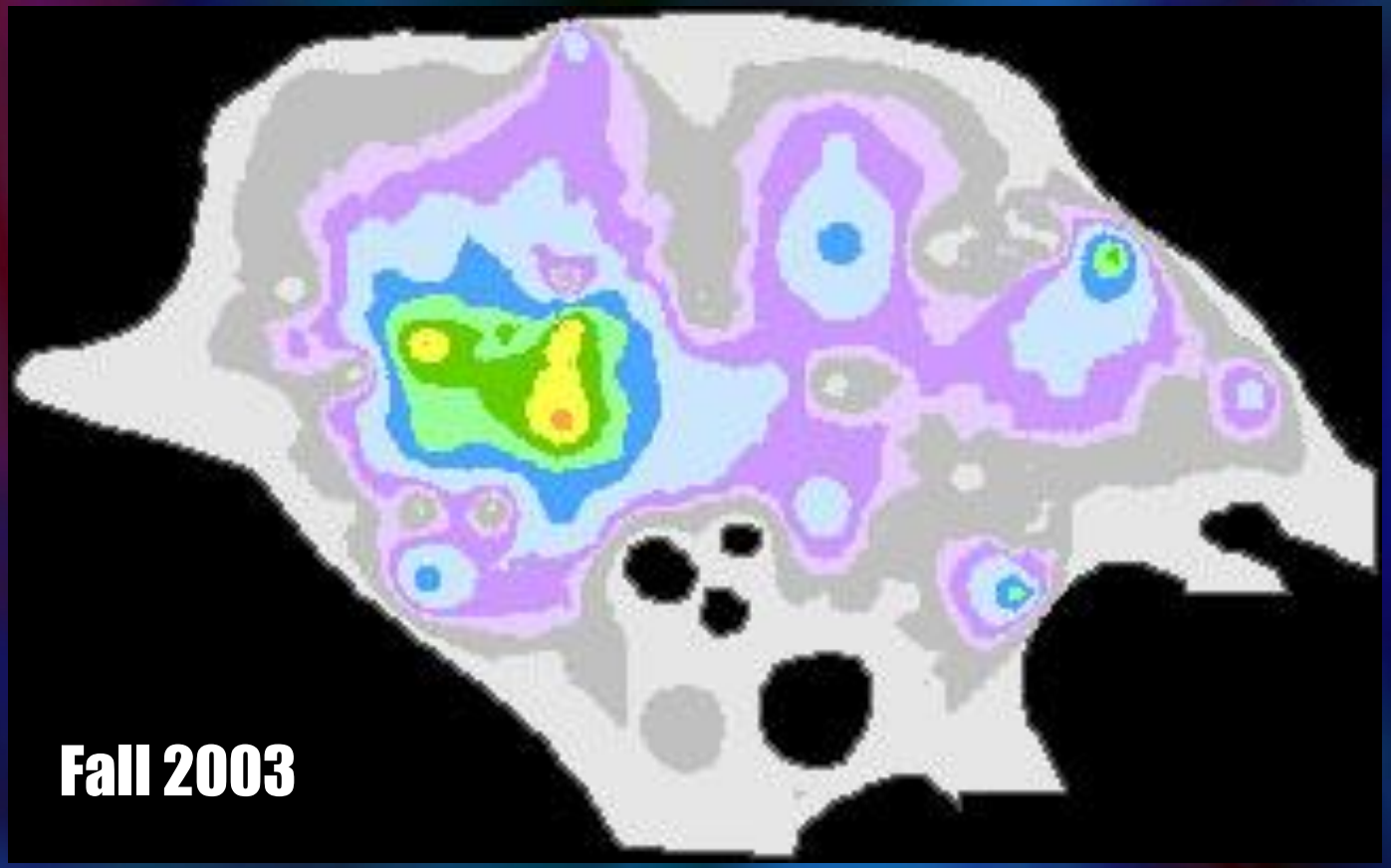

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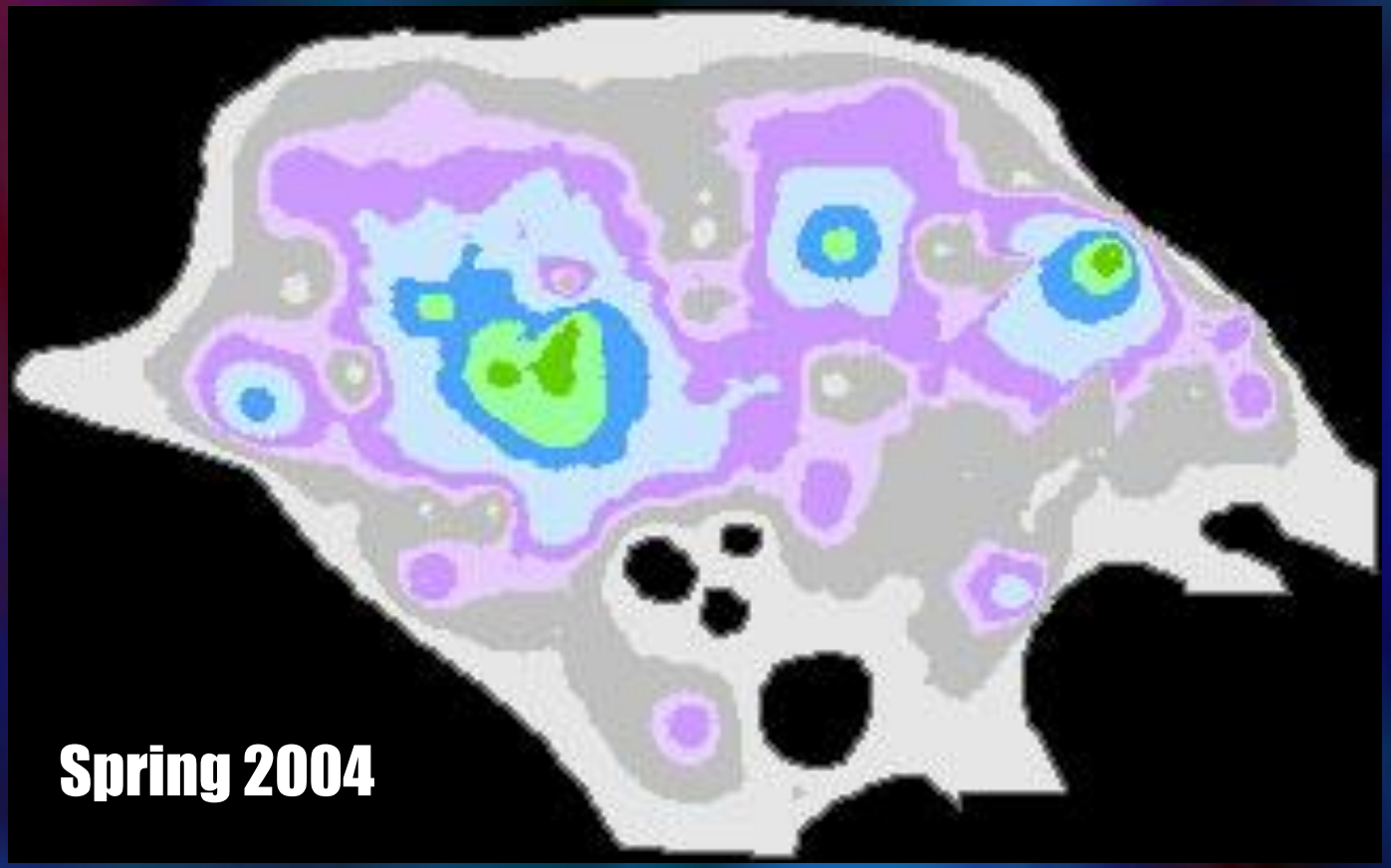
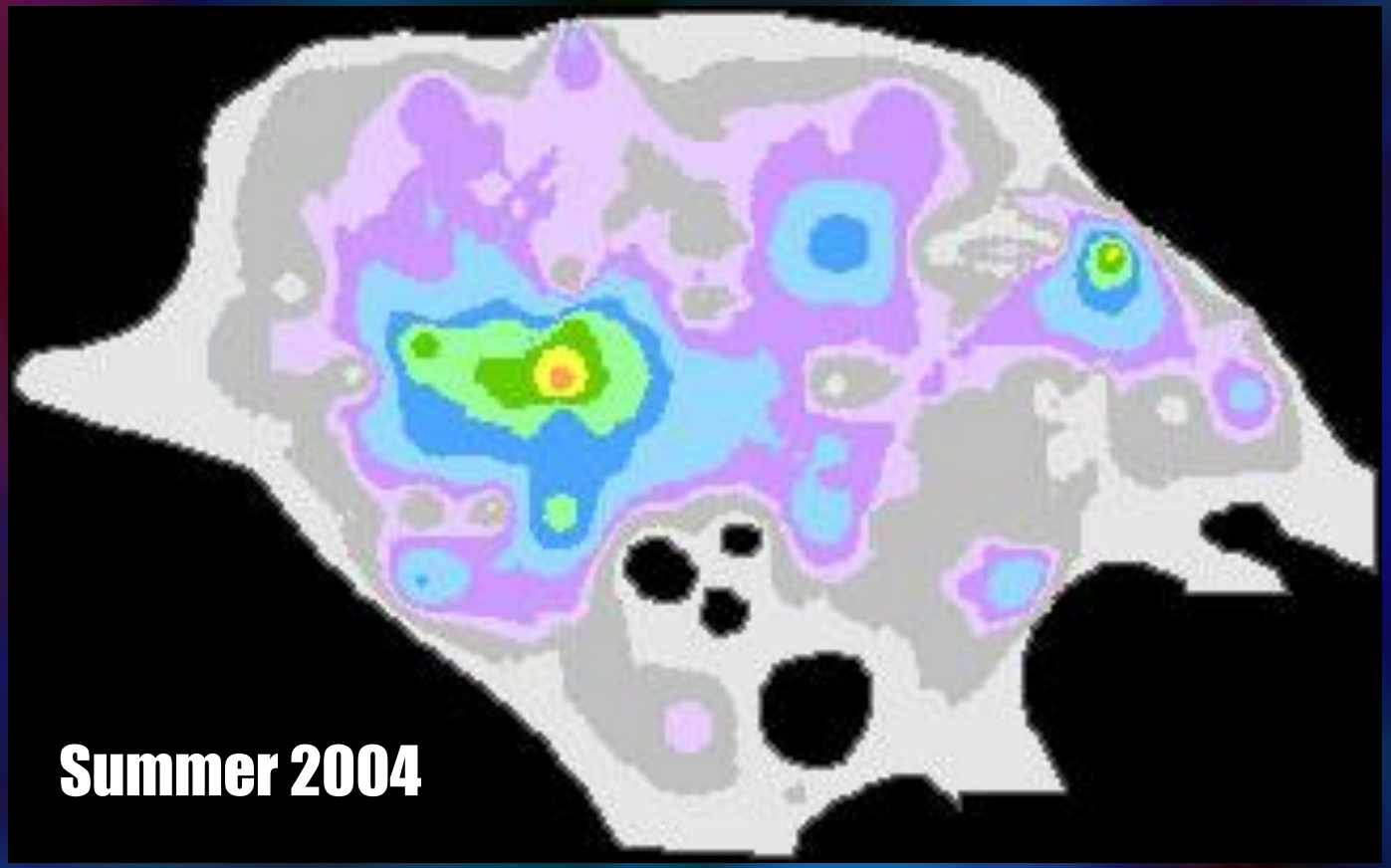


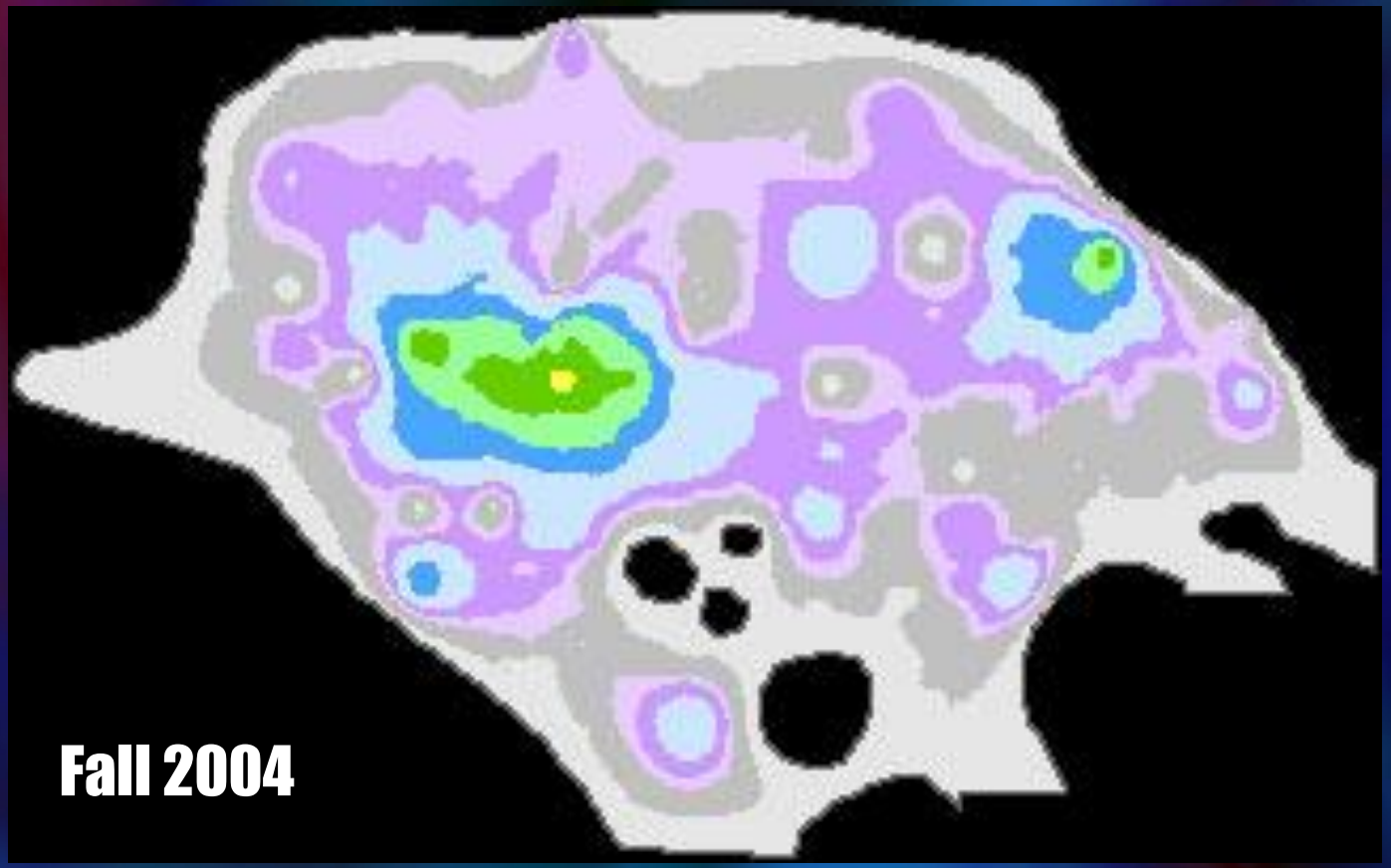
PMCI in mg/L

Toxicological Assessment



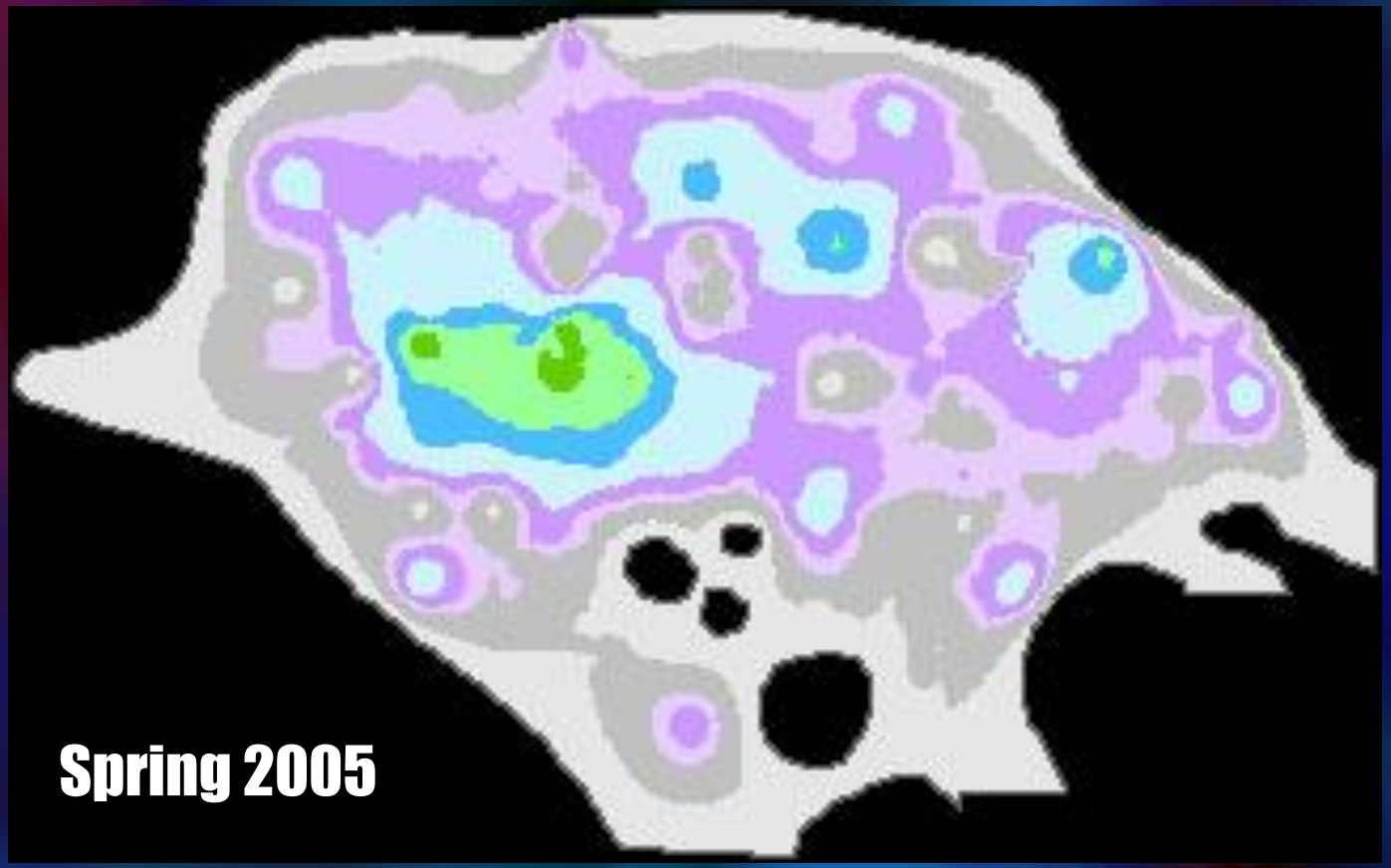
PMCI in mg/L

Toxicological Assessment



PMCI in mg/L

Toxicological Assessment



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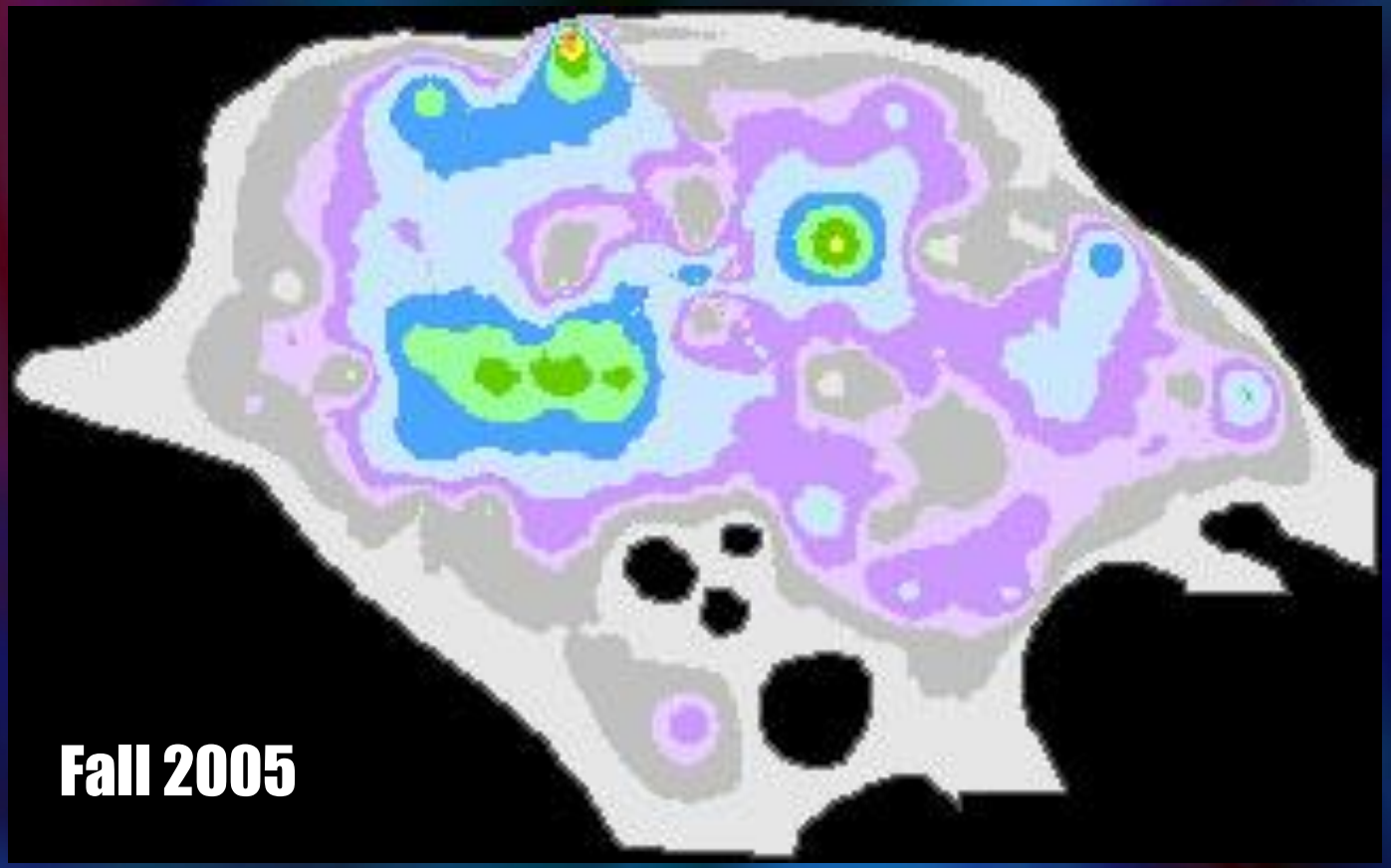

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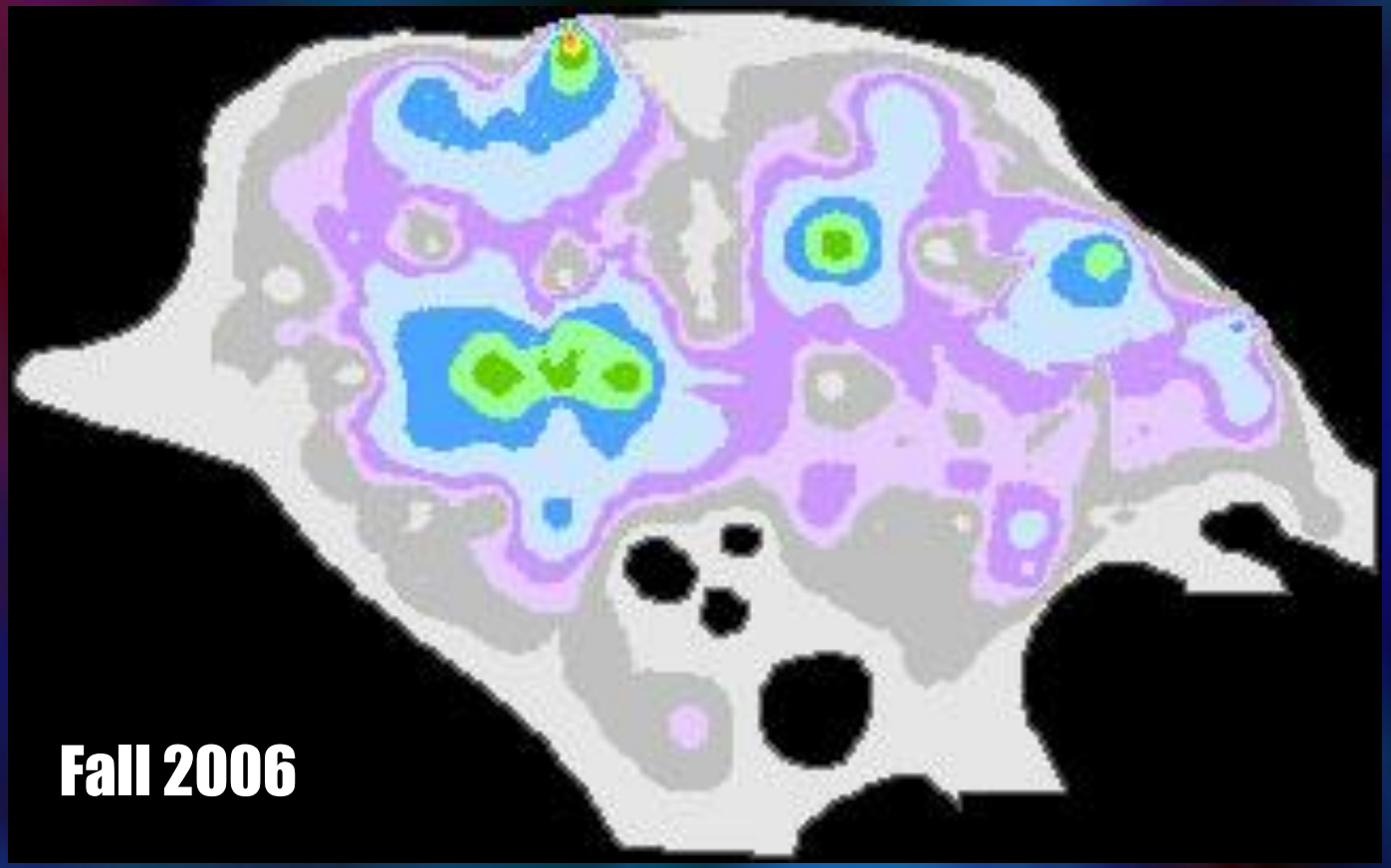
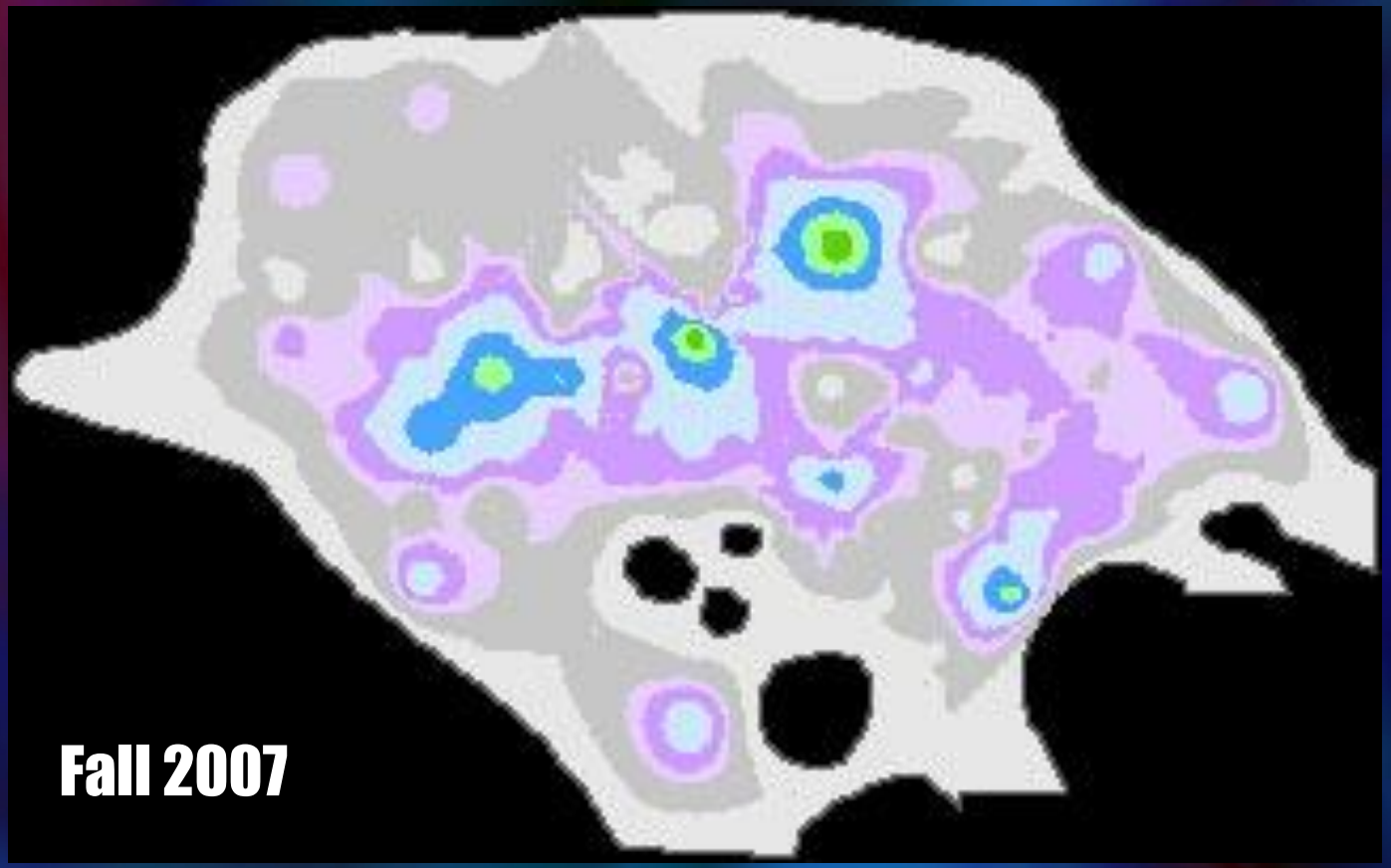


PMCI in mg/L

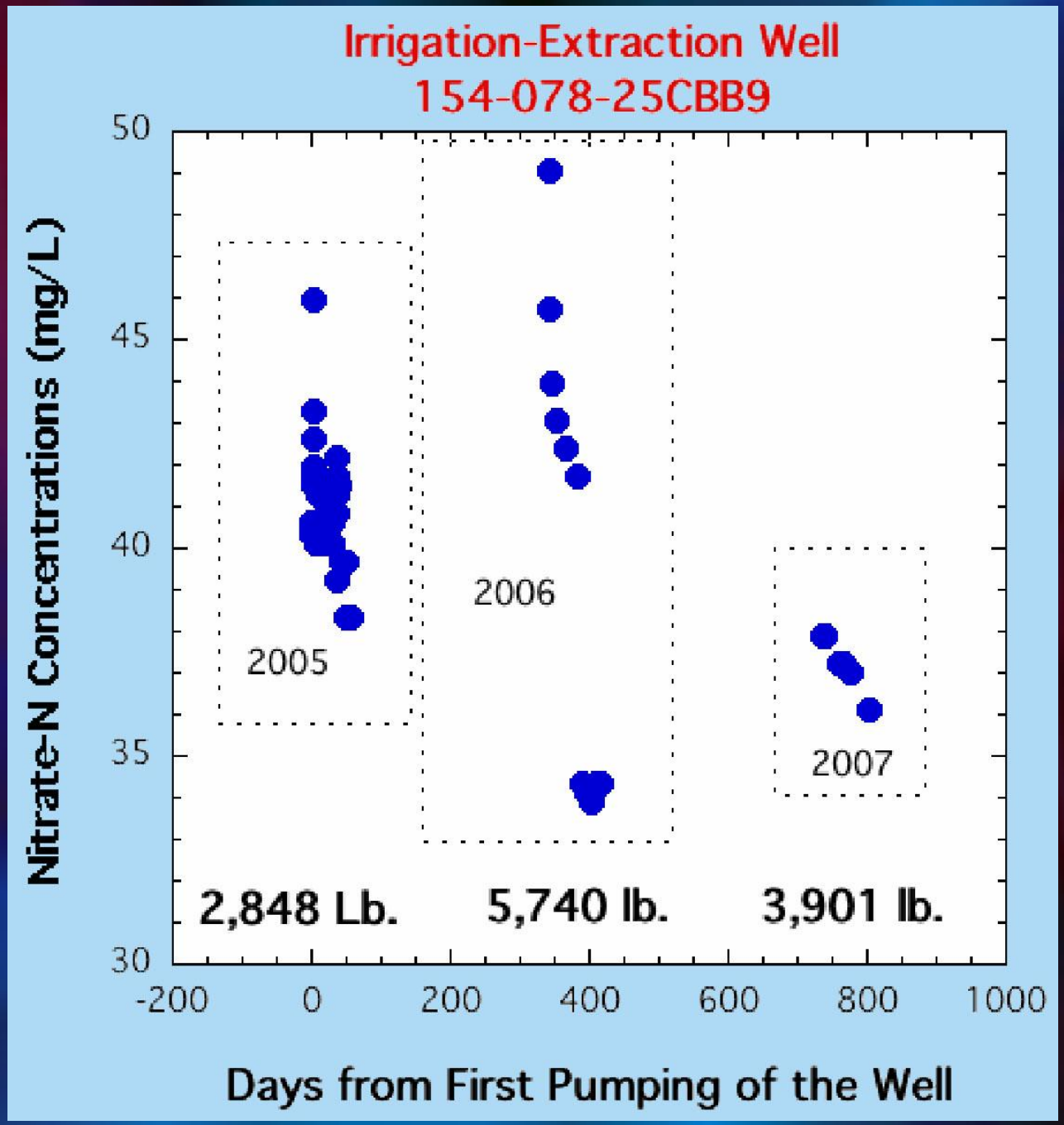
Toxicological Assessment



PMCI in mg/L

Remediation

- Denitrification
- Extraction through Pumping
- River Discharge
- BMPs -
  Environmentally Smart Nitrogen, etc.



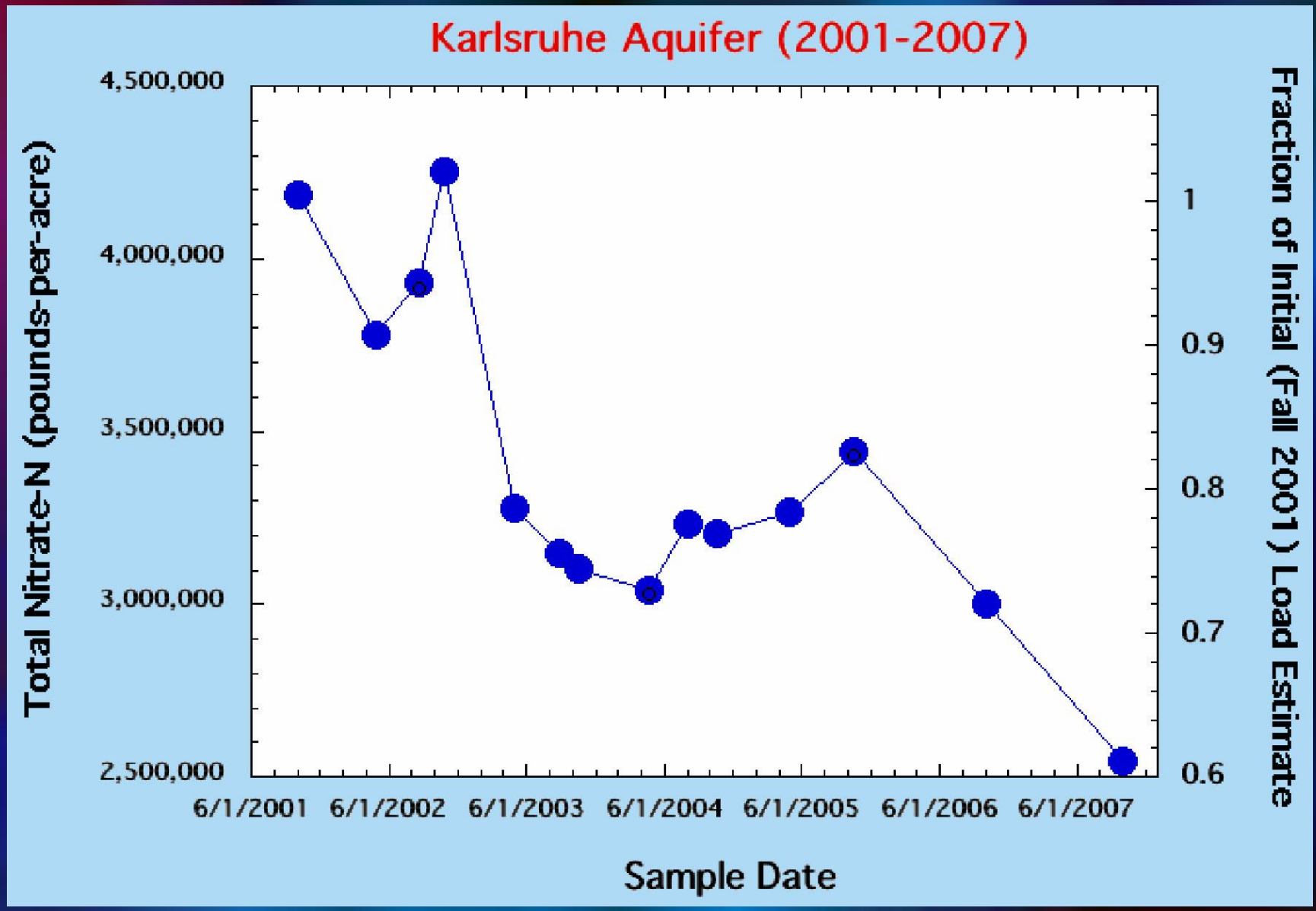
Total:

12,849 lbs.

Wintering River

0.193 mg/L x 4 cfs x 31,536,000 s/y x C

~2,000 Pounds Per Year


Karlsruhe Aquifer (2001-2007)
Total Nitrate-N (pounds-per-acre)
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
Fraction of Initial (Fall 2001) Load Estimate
1
0.9
0.8
0.7
0.6
6/1/2001
6/1/2002
6/1/2003
6/1/2004
6/1/2005
6/1/2006
6/1/2007
Sample Date

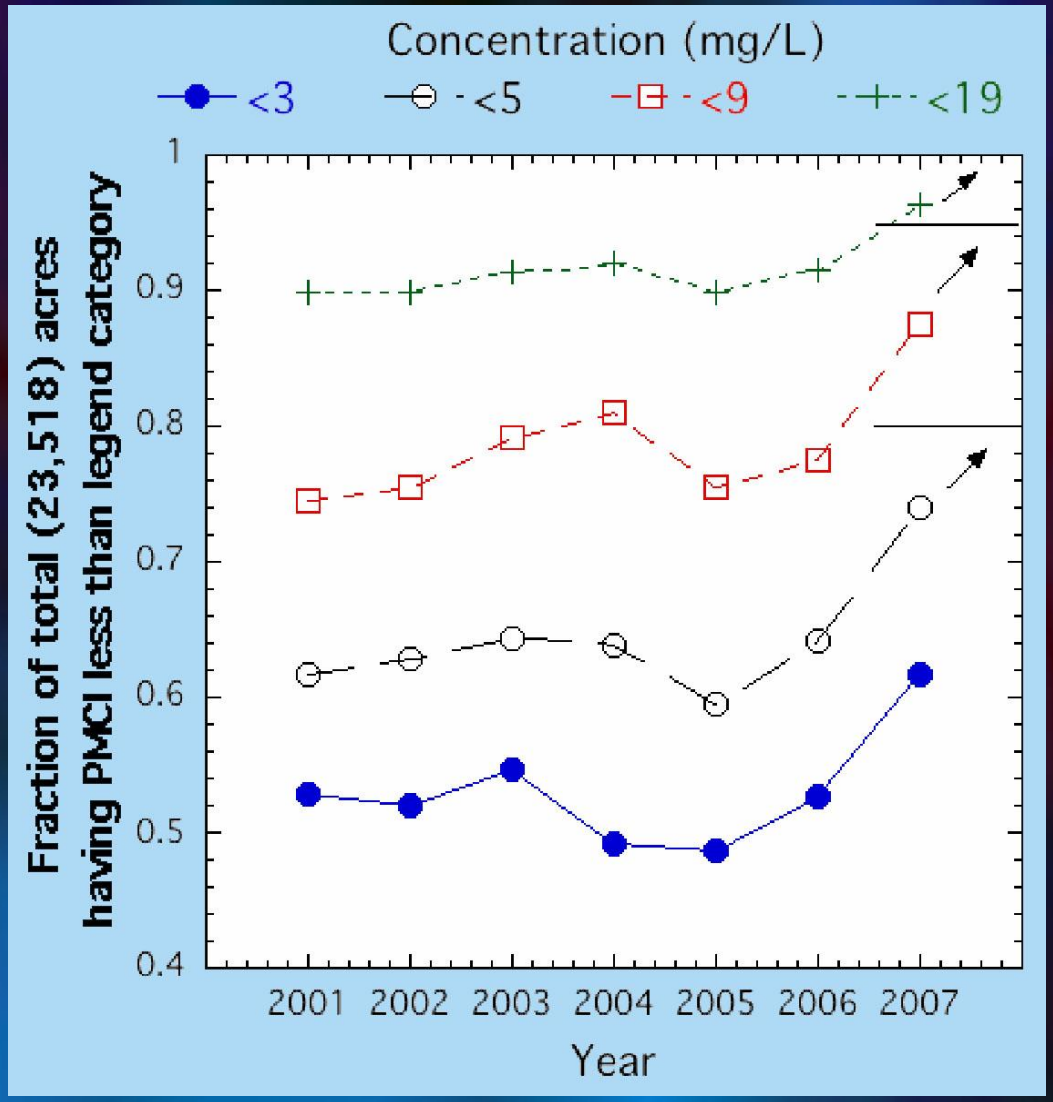
Aquifer Recovery Rates

Estimated:

Discharge	2,000 lb/y
Pumping	4,000 lb/y
Denitrification	145,000 lb/y
	151,000 lb/y

Measured 2001-2007: 225,000 lb/y

GOAL: Completion of Regulatory Action
80% < 5 mg/L, 95% < 9, 100% < 20

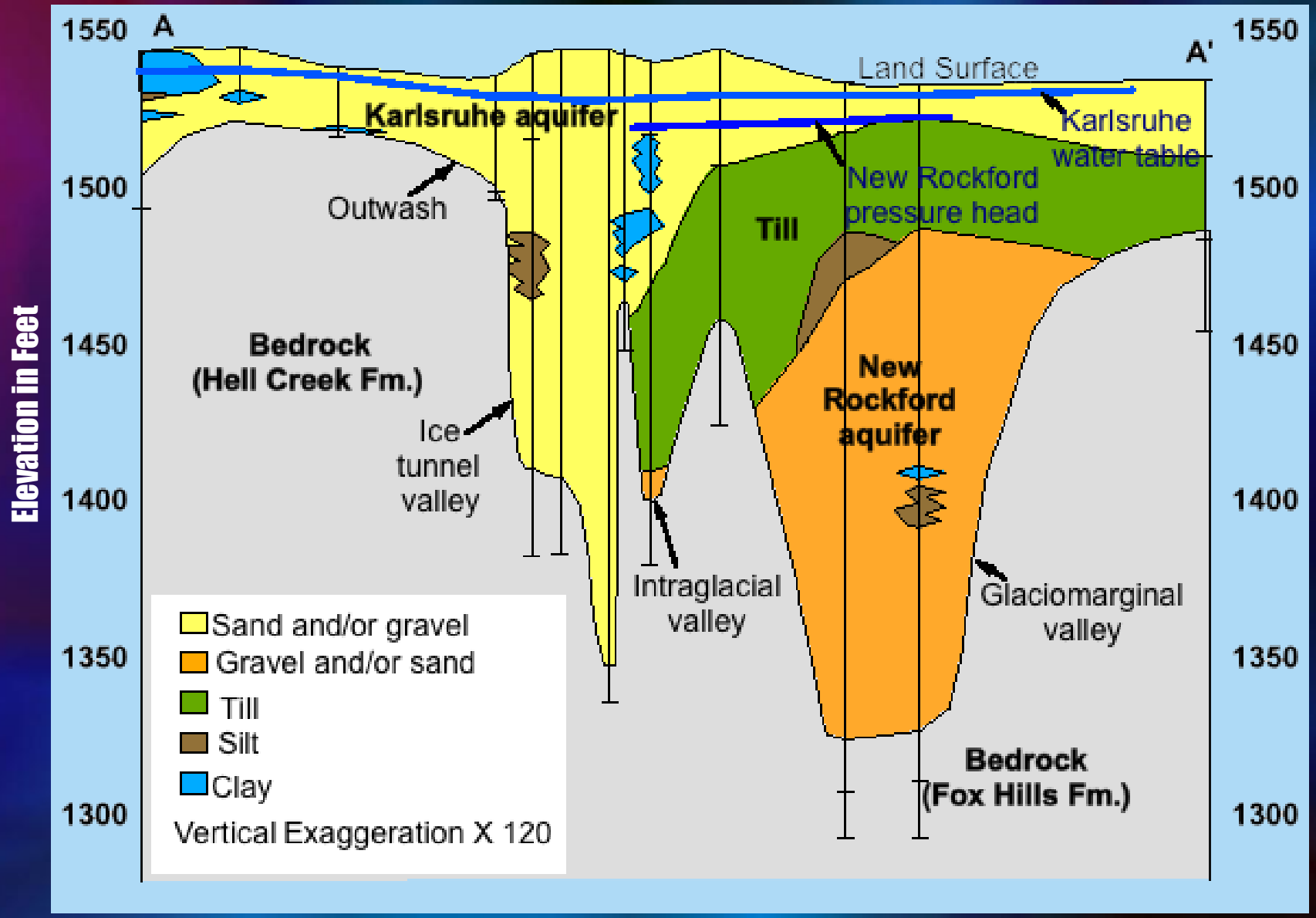


Conclusions

- About 4 million lbs. of Nitrate-N were lost into the Karsruhe aquifer
- Since Fall 2001, remedial factors have included: Voluntary BMPs, Extraction Wells, Natural Discharge, and Denitrification
- Current Nitrate-N load is about 2.5 million lbs. - 40% improvement
- Current bulk rate of Nitrate-N loss - about 224,000 lbs./y
- We hope to achieve total recovery

Any Questions?

Southwest to Northeast Vertical Section
One Mile Northwest of the Wintering River



Wintering River

0.193 mg/L x 4 cfs x 31,536,000 s/y

~2,000 Pounds Per Year