Effects of Nutrient Management Practices on Water Quality:

Nitrogen
Issues and Concerns

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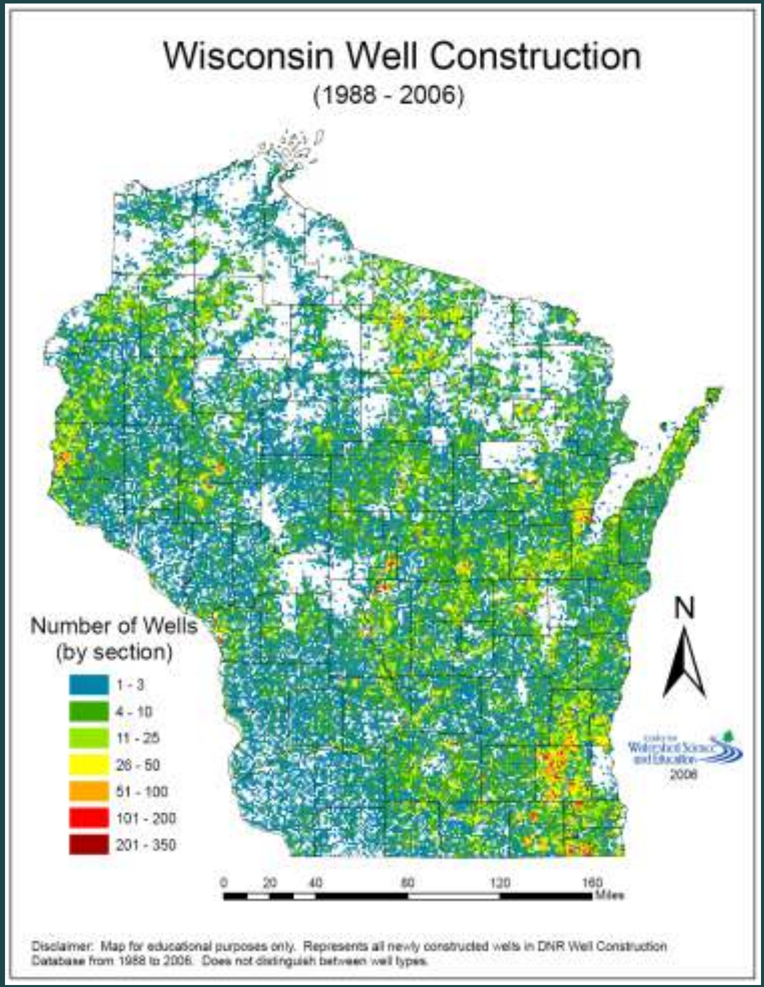
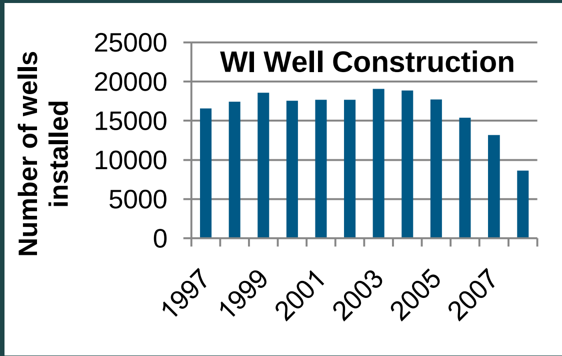
Background

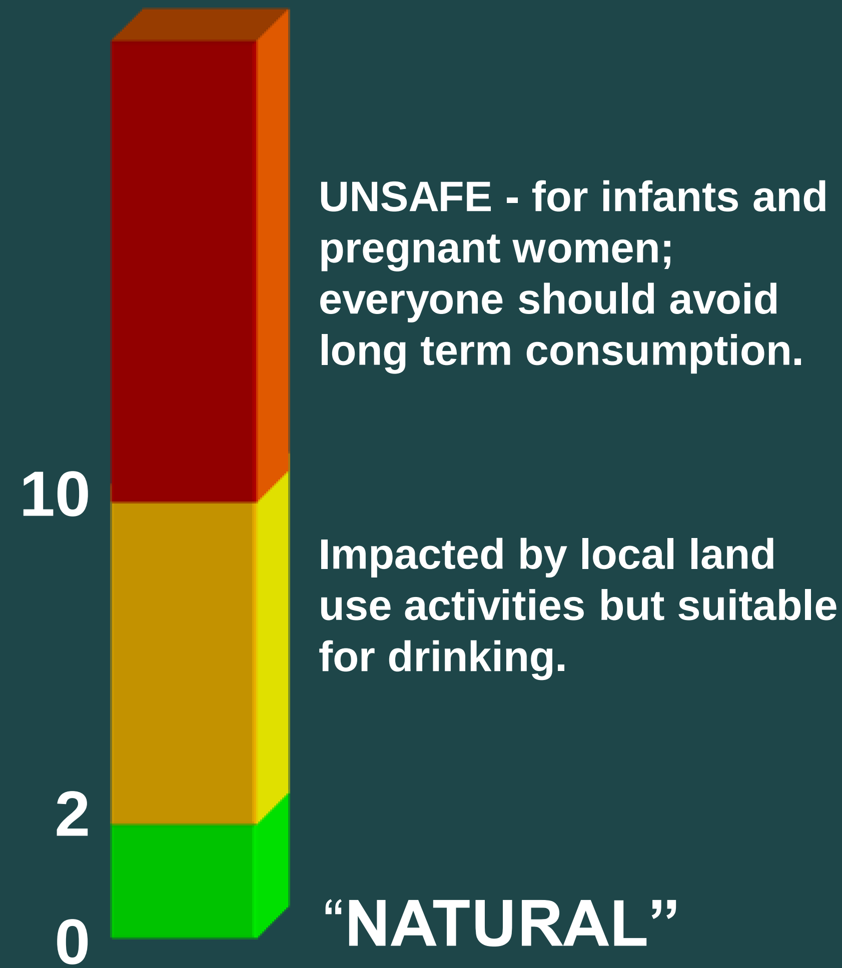
- 70% of WI population relies on groundwater
- 42% (2.25 million people) rely on private wells as their primary water supply
- Estimated 900,000 private wells in WI





Nitrate-Nitrogen

- Most widespread groundwater contaminant in WI
- Health related contaminant – routinely tested for
- Very mobile, good at identifying areas of land-use impacts
- Agriculture is the largest contributor of nitrate to groundwater



Nitrate-impacted Municipal Wells

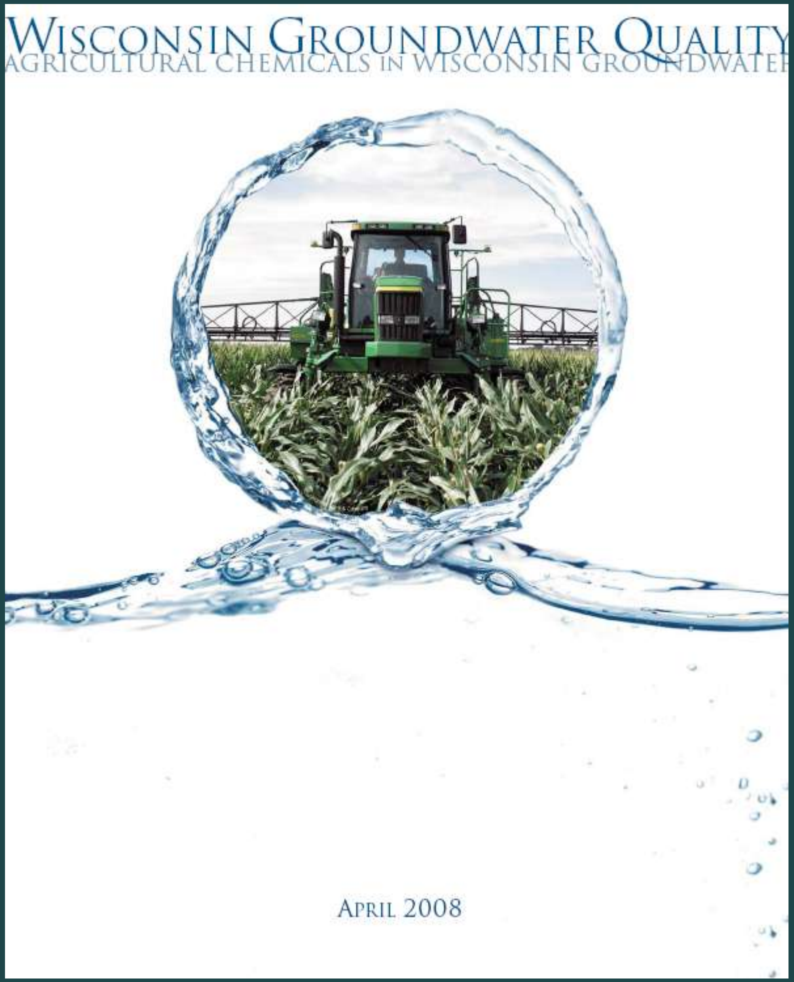
2005 Total of $24 million

- Amherst
- Cambria
- Chippewa Falls
- Crivitz Utilities
- Embarrass
- Fitchburg
- Fontana
- Janesville Water Utility
- Mattoon
- Morrisonville
- Oconomowoc
- Orfordville
- Plover
- Rome
- Sauk City
- Strum Waterworks
- Valders
- Village of Arlington
- Village of Clinton
- Village of Dalton
- Village of Footville
- Village of Friesland
- Waunakee
- Waupaca
- Whiting

Data obtained from Laura Chern of WDNR

Nitrate Impacts to Private Wells

- Estimated 12% of private wells exceed drinking water standard for nitrate
  - 270,000 people
    (~3,000 additional people per year)
  - 108,000 wells
    (1,000-2,000 additional wells per year)



DATCP, 2008

Estimated cost reduce nitrate exposure

# affected	compensation estimate	assumptions	Total estimate
270,000 people + 3K per year	$1.38/gallon	Assuming 0.5 gal/person/d = $252/person/yr	**$68 million/year** **+ $0.75 per year**
108,000 wells + 1-2K per year	$1,000/well requiring treatment	Conservative estimate (device, installation, replacement filters, energy, etc.)	**$108 million + additional $1-2 million per year**

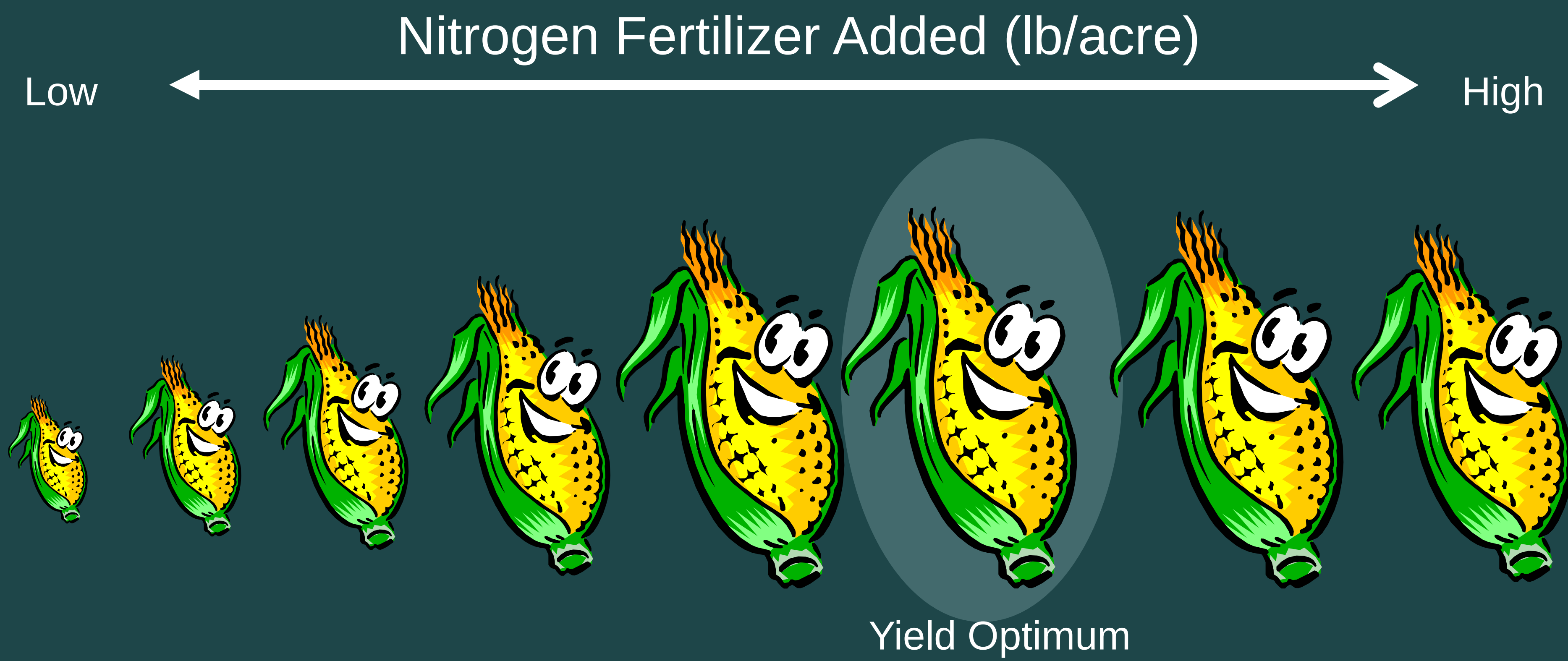
Disclaimer: Not all wells that exceed the drinking water standard are treated. This analysis estimates the cost of providing bottled water to all affected or installation of water treatment on all affected wells.

Nutrient Management and Nitrogen Recommendations

Nitrogen Fertilizer Added (lb/acre)

Low ⟷ High

Nutrient Management and Nitrogen Recommendations

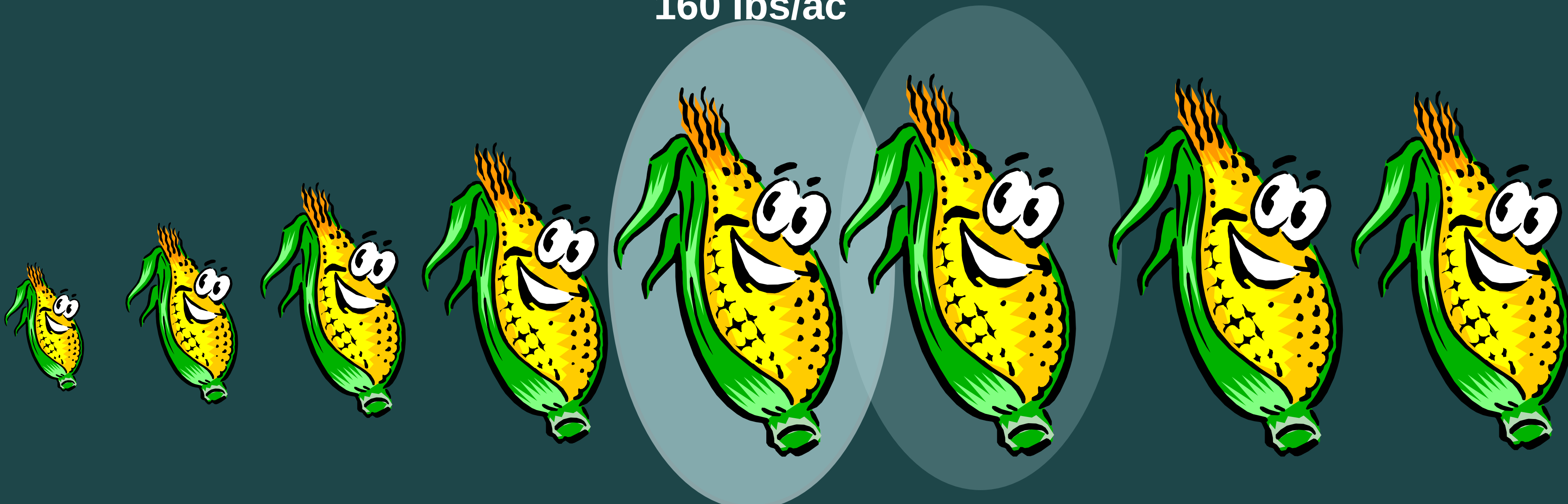


Nutrient Management and Nitrogen Recommendations

Nitrogen Fertilizer Added (lb/acre)

Low ⟵⟶ High

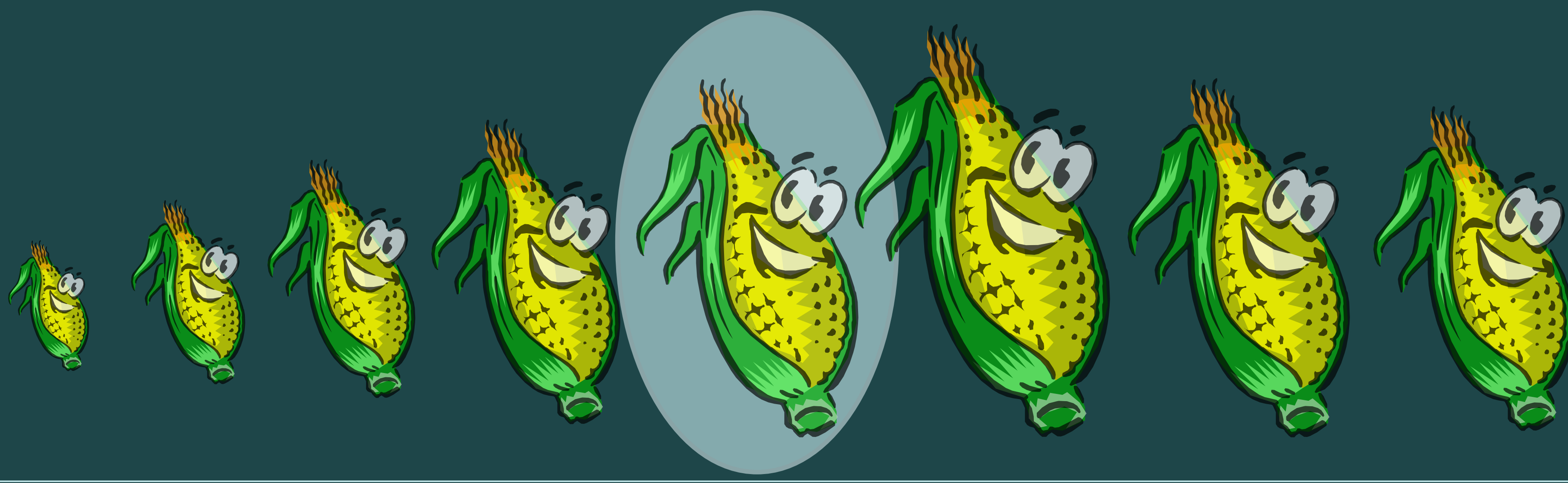
160 lbs/ac



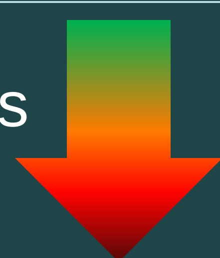
economic optimum
that maximizes
profitability

Nitrogen Fertilizer Added (lb/acre)

Low ⟷ High

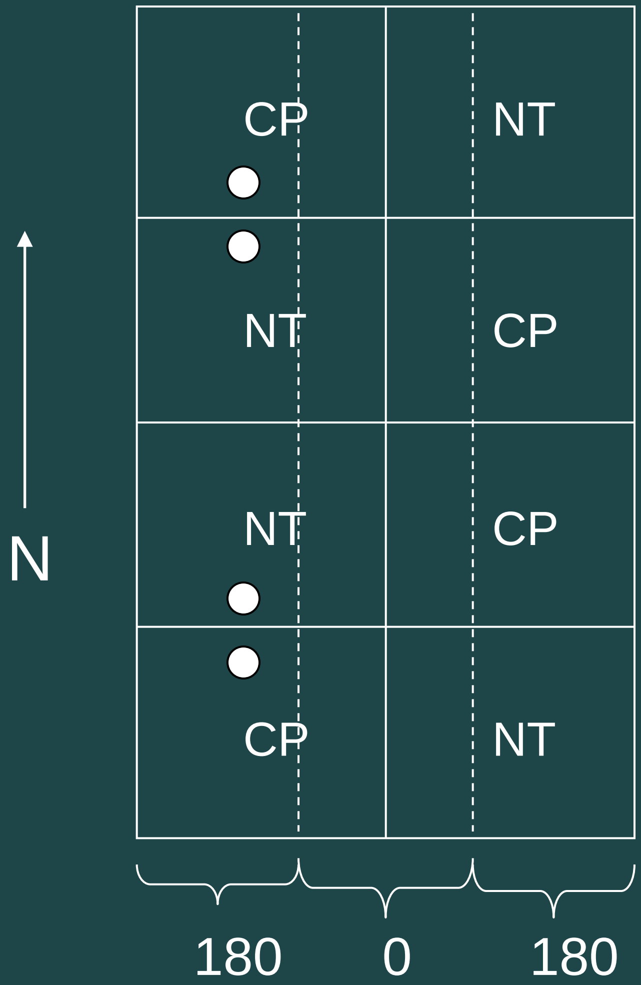


Nitrogen Leaching Loss



What is the ability of nitrogen nutrient recommendations to meet groundwater performance standards?

7-year Nitrate Leaching Study



kg N/ha

CP = Chisel Plow

NT = No Till

● Lysimeters

- 26 year old restored prairie

Plano Silt Loam soil at Arlington Research Station

Long-term Nitrate Leaching Study

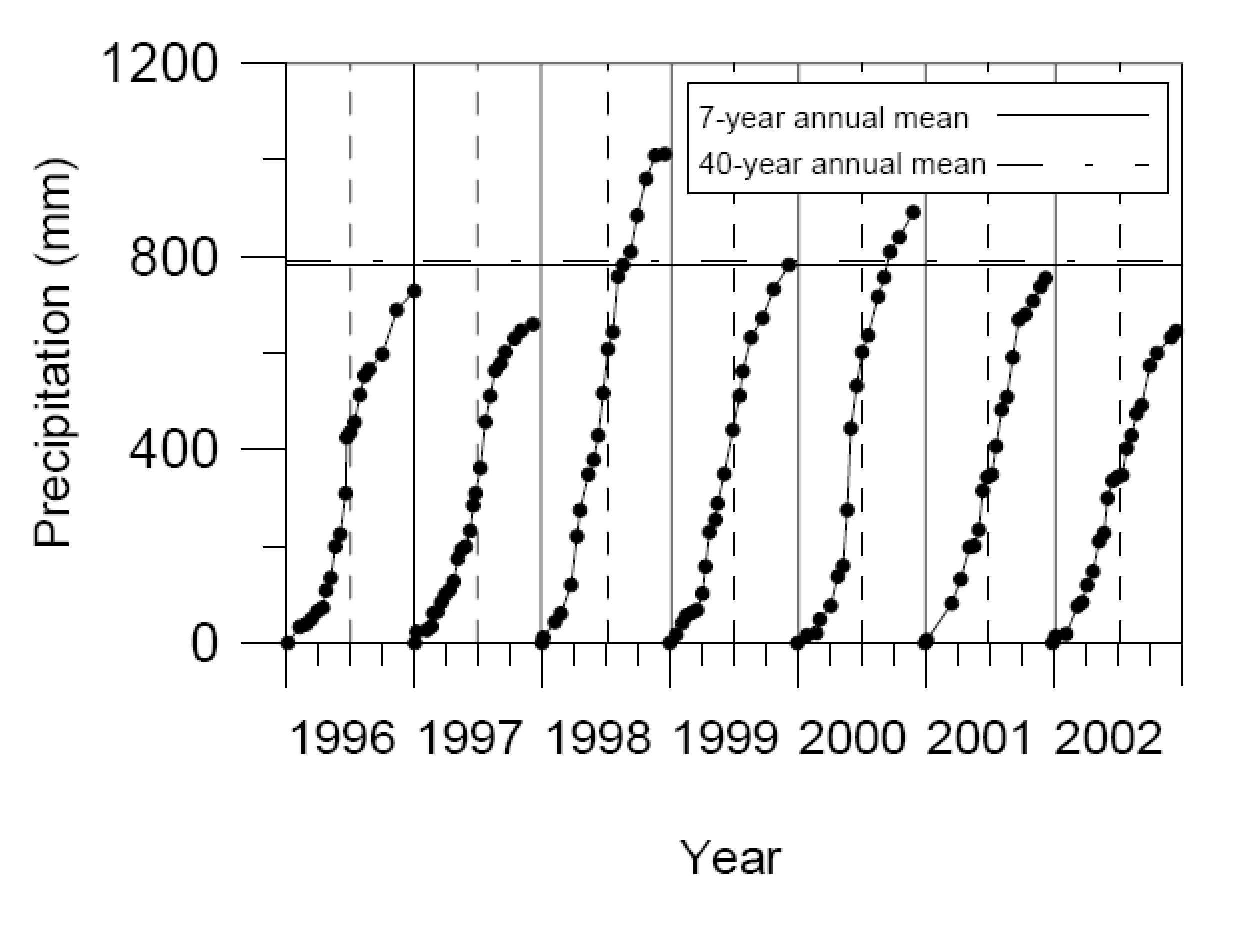
	Sub-optimal	Optimal	Optimal + manure
	----------kg N ha^{-1}----------		
1996-2002	10	190	-
2002	10	190	190+145*
2003	10	190	190+128*

Pelletized ammonium nitrate used as the inorganic fertilizer

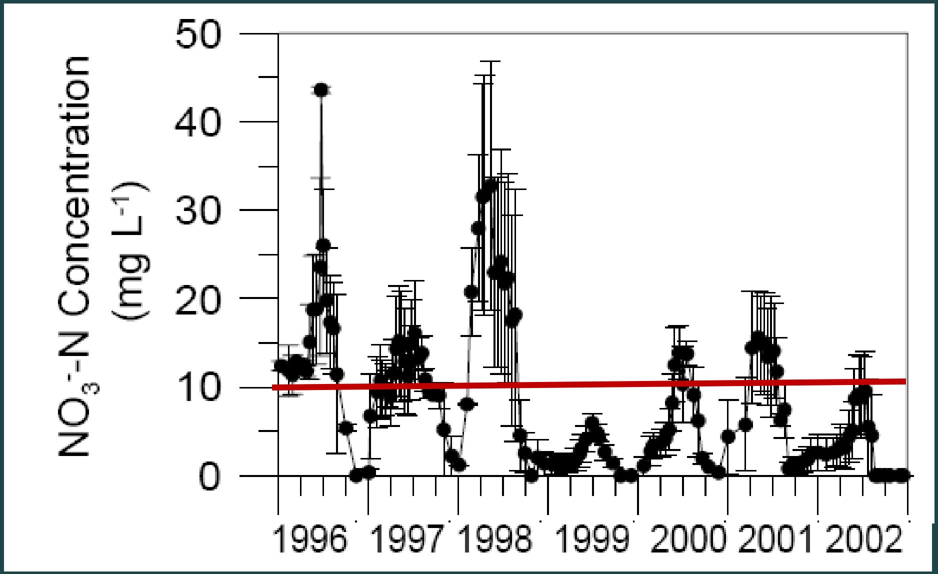
*Based on estimated available nutrient credit in 1st year of application

Long-term Nitrate Leaching Study

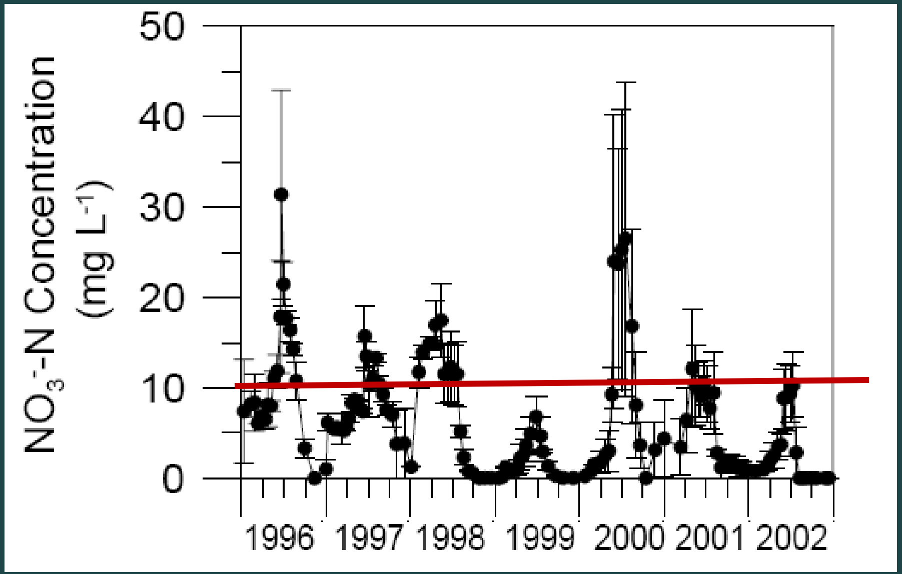
Annual Cumulative Precipitation



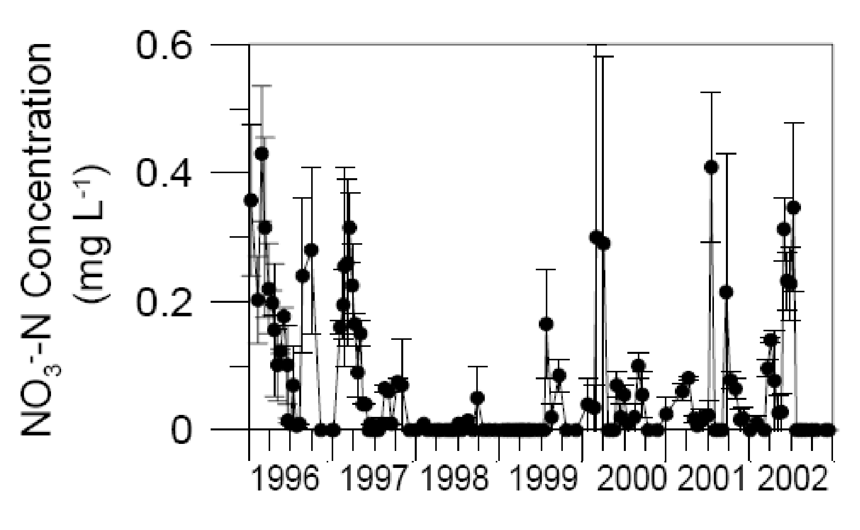
Nitrate Concentrations



No Till

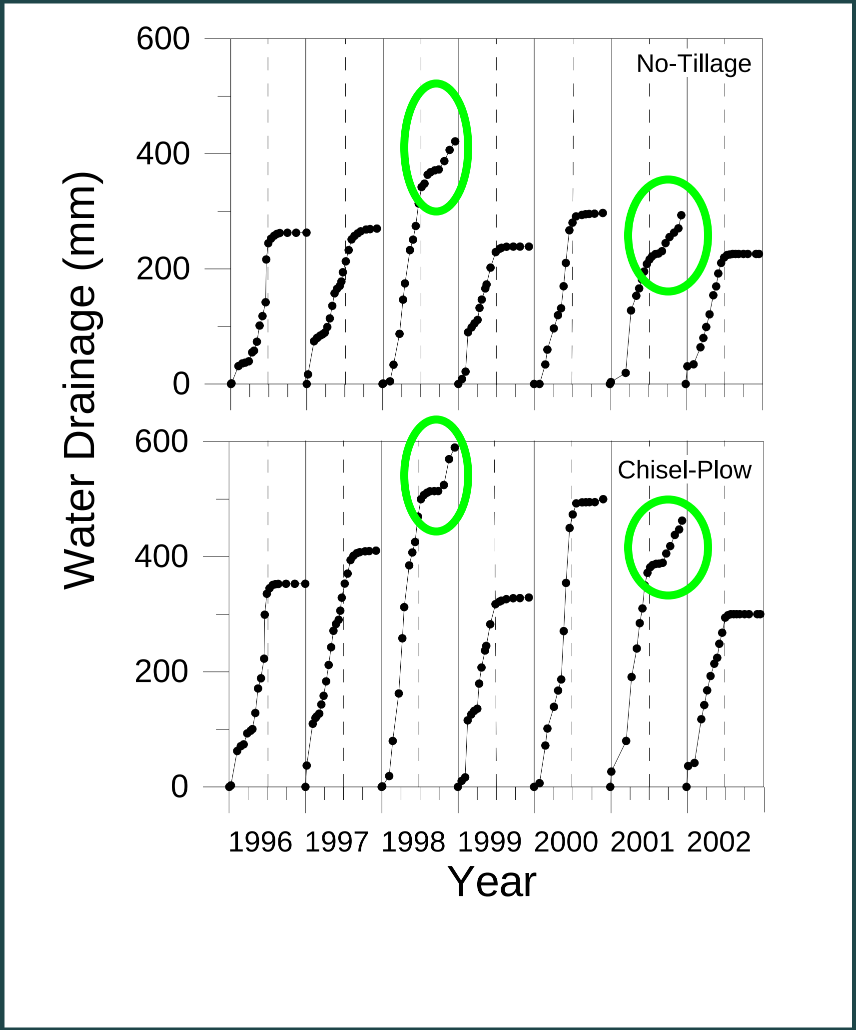


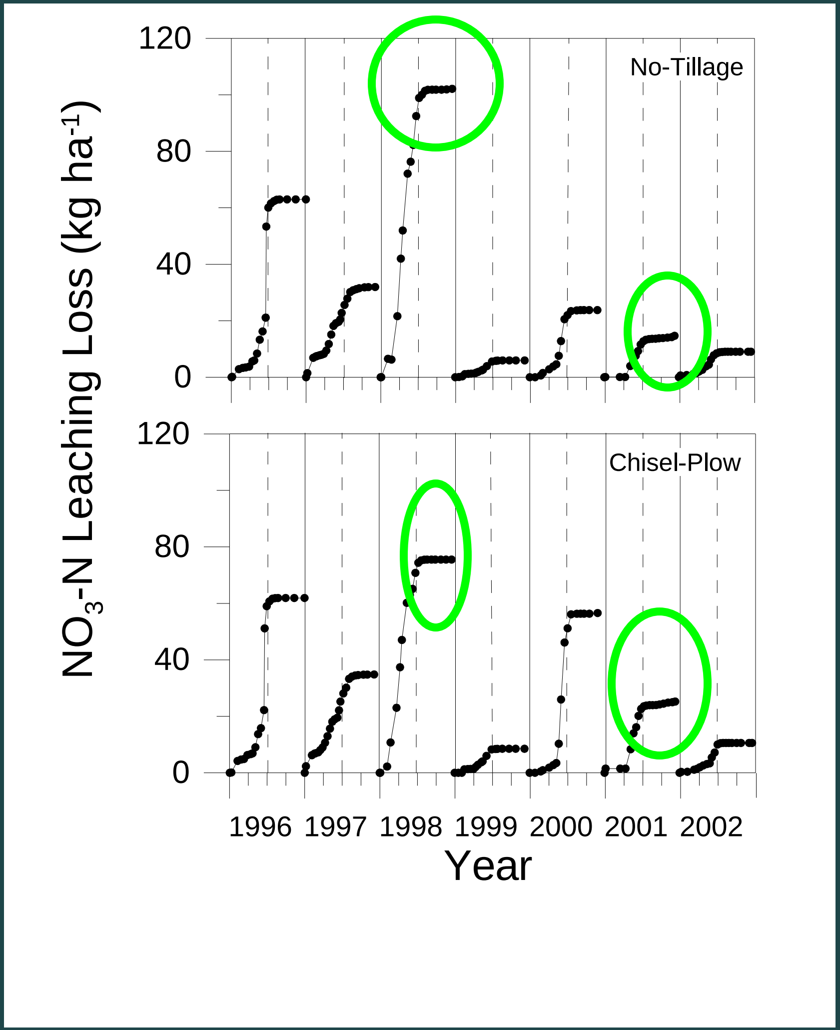
Chisel Plow



Prairie

Annual Cumulative Water Drainage & Nitrate Leaching





Seven Year Summary for Economic Optimal Rates vs. Prairie

	System		
	Chisel-plow	No-tillage	Prairie
Total precipitation (cm)	548	548	548
Total drainage (cm)	295	201	87
Precipitation lost to drainage (%)	54	37	16
Total NO_3^--N leaching loss (kg ha^{-1})	283	268	0.31
Amount N lost to leaching (%)	**20**	**19**	**0.4**
Flow weighted mean NO_3-N Conc. (mg L^{-1})*	**9.6**	**13.3**	**0.04**

*Maximum concentration measured greater than 40 mg/L.

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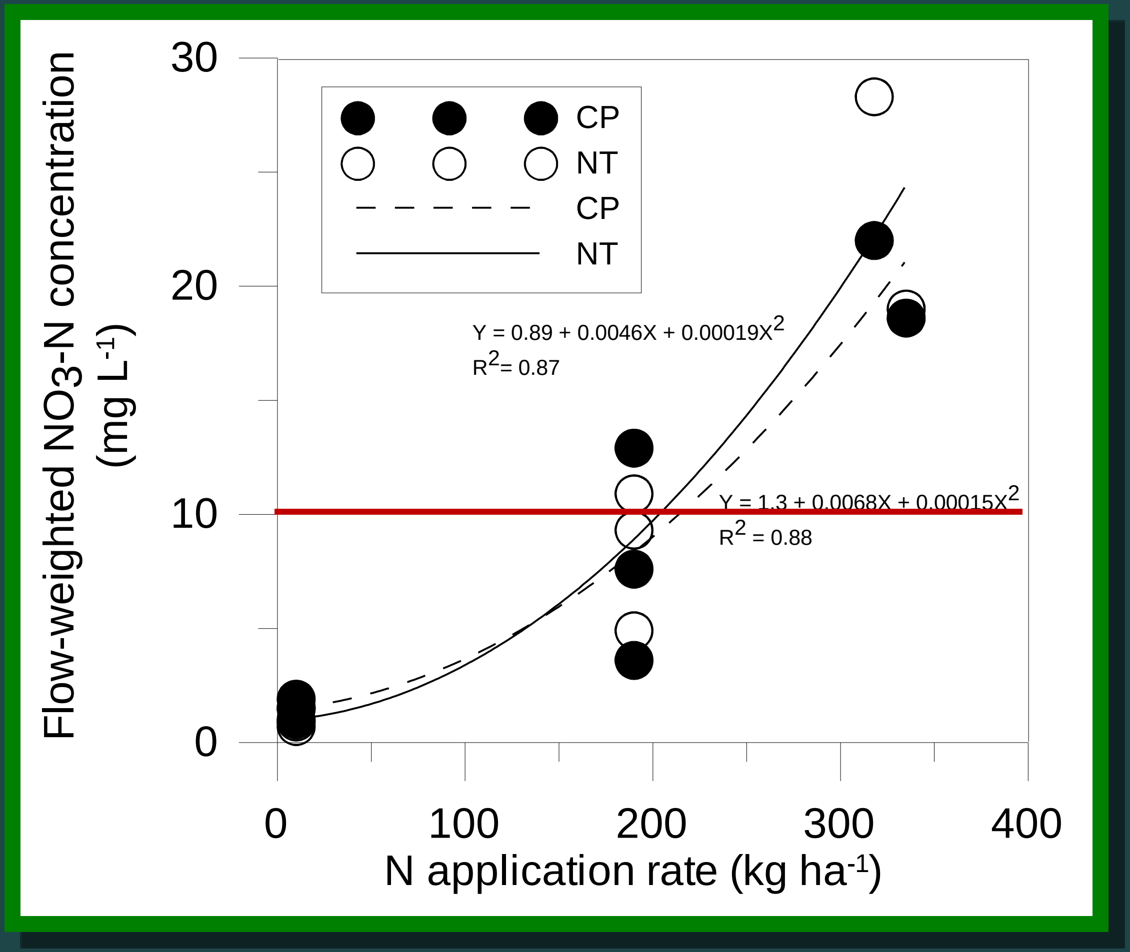
Comparison of sub-optimal, optimal, excess N for 2 years of data



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Additional research investigating this topic -

Table 6. Average NO_3–N concentration and annual NO_3–N loss in subsurface tile drainage water in Iowa (Weed and Kanwar, 1996).

Crop rotation	Tillage†	NO_3–N concentration 1990	NO_3–N concentration 1991	NO_3–N concentration 1992	NO_3–N loss 1990	NO_3–N loss 1991	NO_3–N loss 1992
		mg/L			kg/ha		
Continuous corn	MP	64	34	12	58	63	13
	CP	55	28	10	100	76	13
	RT	44	21	–	83	68	–
	NT	39	19	8	107	62	12
Corn–soybean	MP	39	24	8	41	36	6
	CP	33	21	7	51	36	5
	RT	24	19	3	34	30	3
	NT	19	17	8	32	31	4

† MP, moldboard plow; CP, chisel plow; RT, ridge tillage; NT, no tillage.

Weed, D.A.J., and R.S. Kanwar. 1996. Nitrate and water present in and flowing from root-zone soil. J. Environ. Qual. 25:709–719.

Nitrate Nitrogen in Surface Waters as Influenced by Climatic Conditions and Agricultural Practices

Gyles W. Randall* and David J. Mulla

Table 4. Effect of crop system on flow-weighted annual nitrate N concentrations.

Crop system	Year 1990	1991	1992	1993
	mg NO_3–N/L			
Continuous corn	30	39	40	20
Corn–soybean	22	29	26	14
Soybean–corn	26	38	27	13
Alfalfa	–	4	4	1
CRP†	–	4	1	0.3

† Conservation Reserve Program.

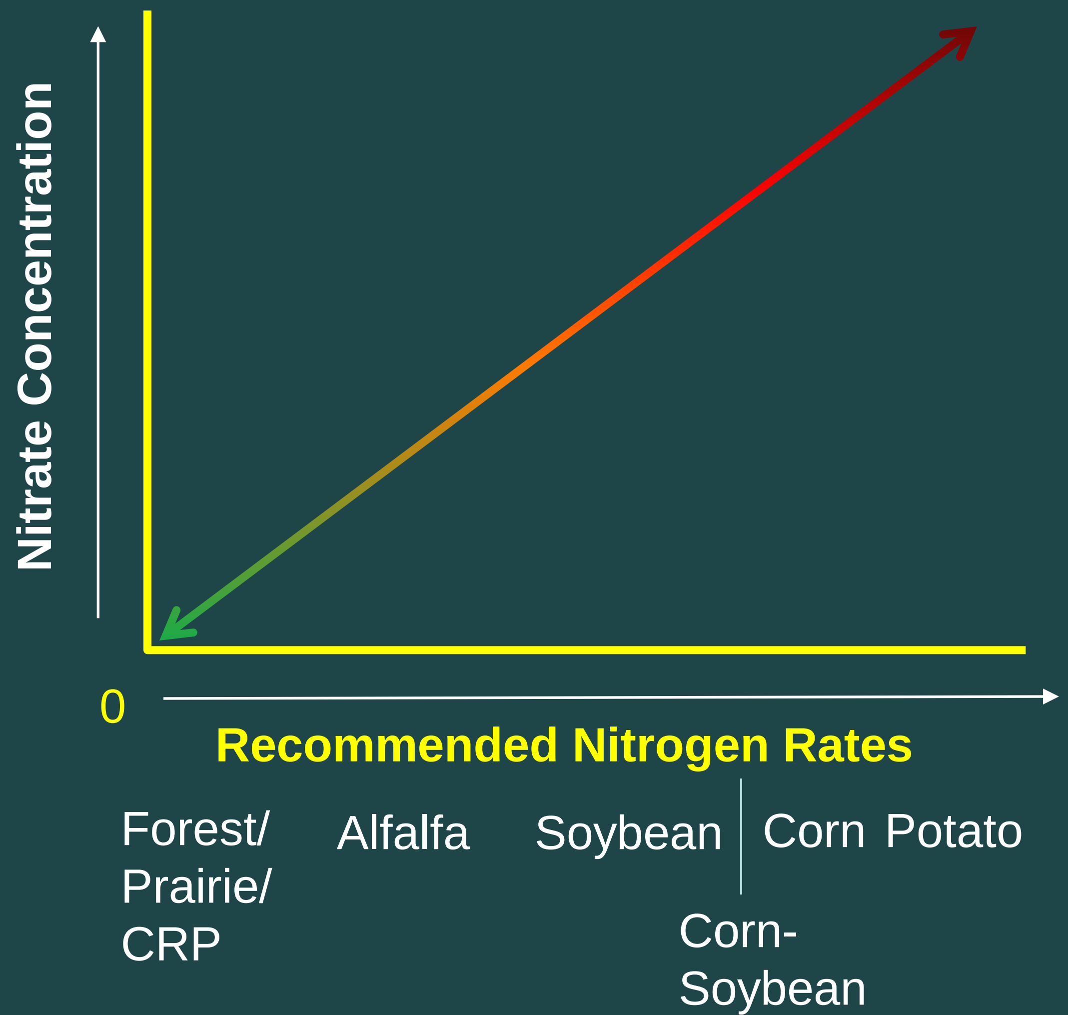
Table 5. Effect of crop system on nitrate N losses in subsurface drainage.

Crop system	Nitrate N lost, 4-yr total
	kg/ha
Continuous corn	217
Corn–soybean	204
Soybean–corn	202
Alfalfa	7
CRP†	4

† Conservation Reserve Program.

J. ENVIRON. QUAL., VOL. 30, MARCH–APRIL 2001

Generalized Nitrate Leaching Potential



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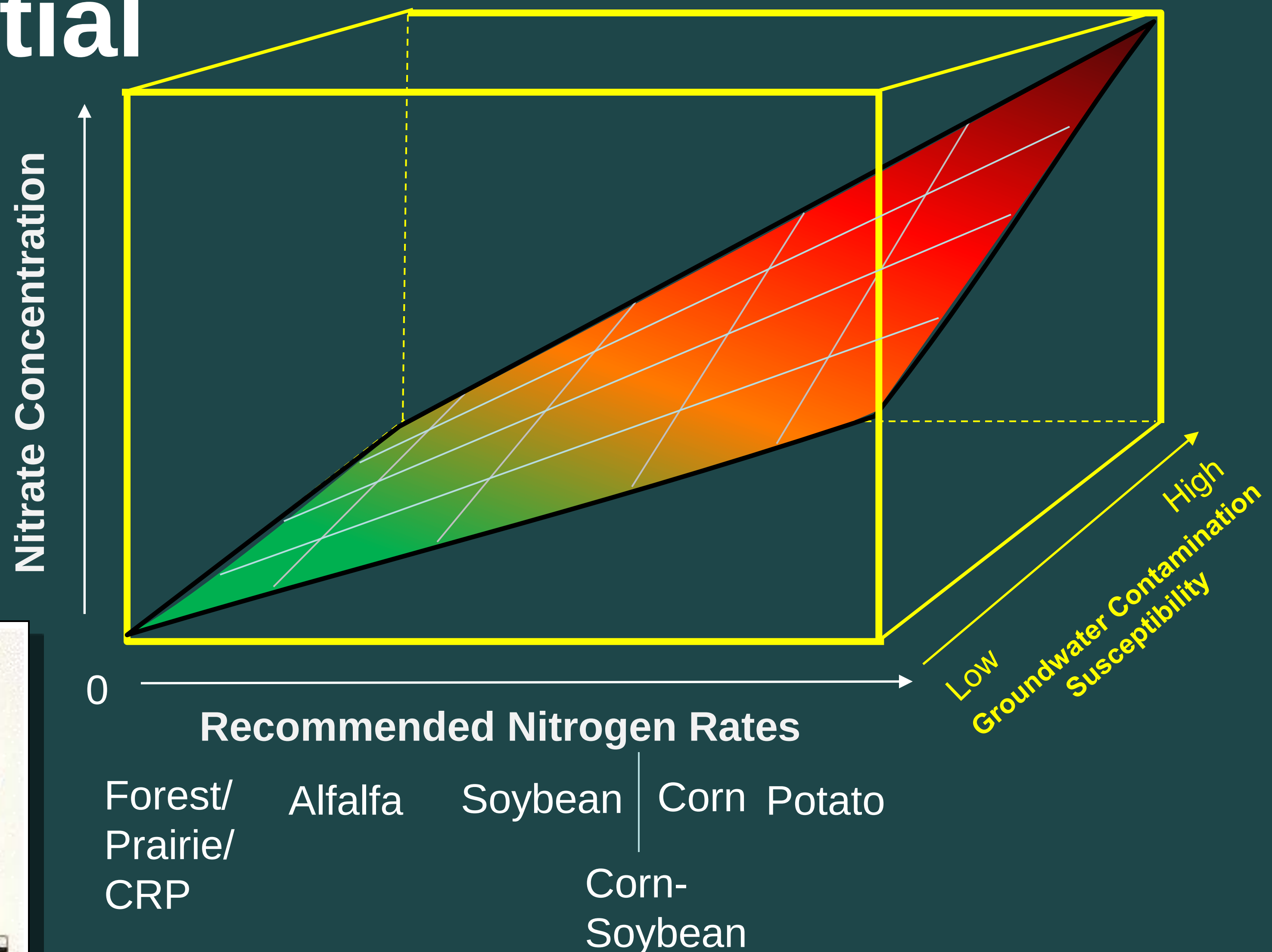
Generalized Nitrate Leaching Potential



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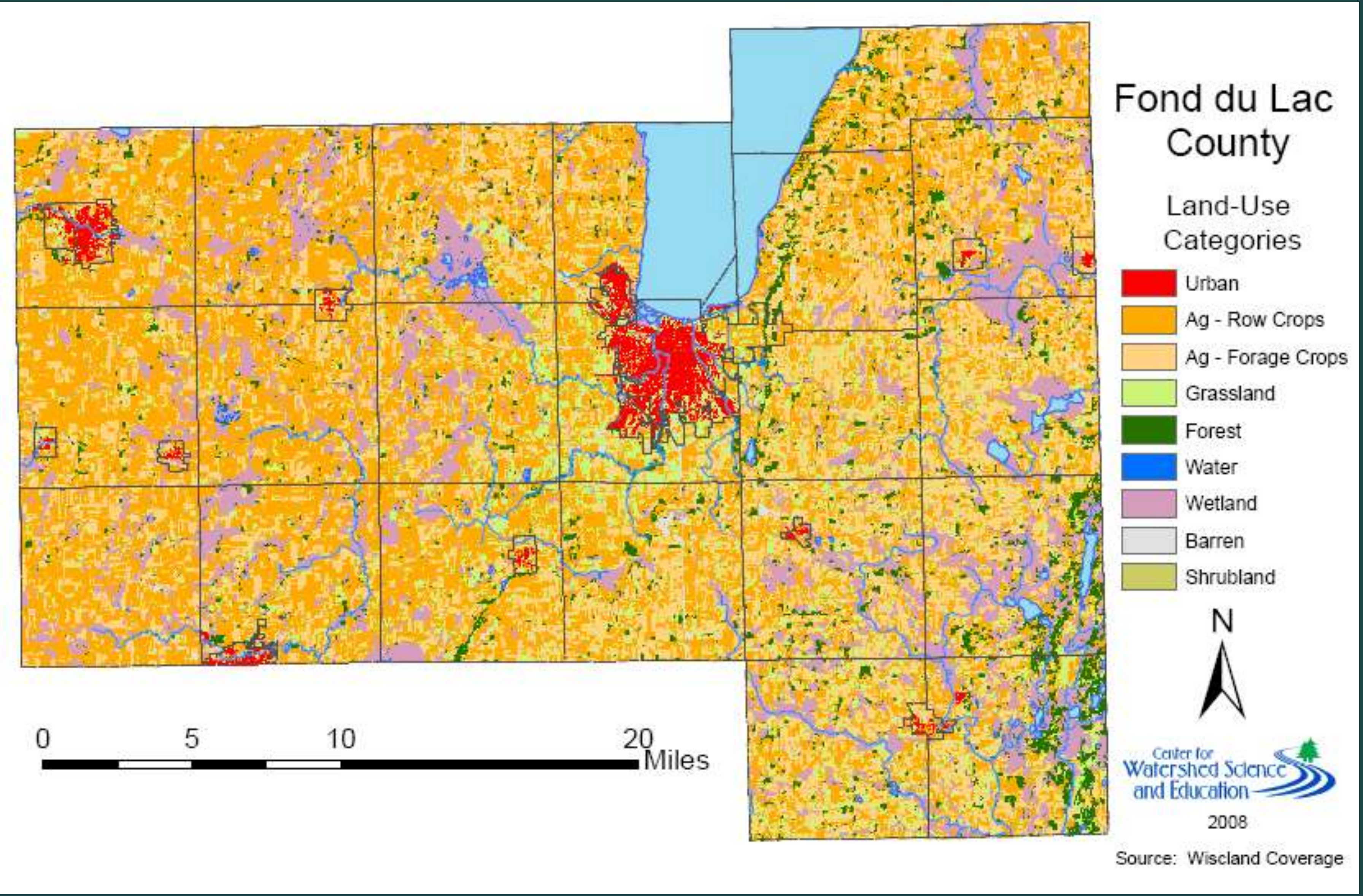
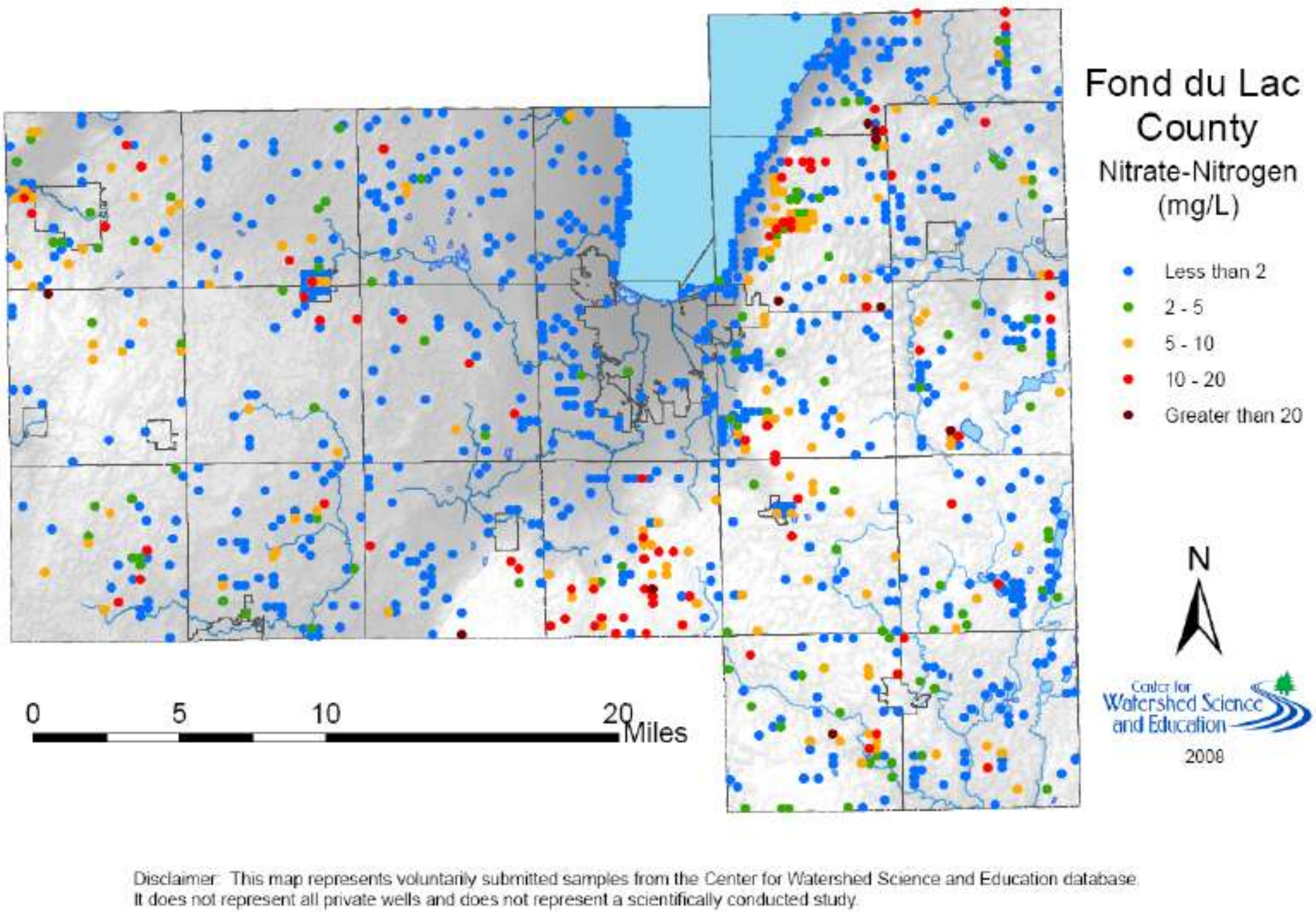
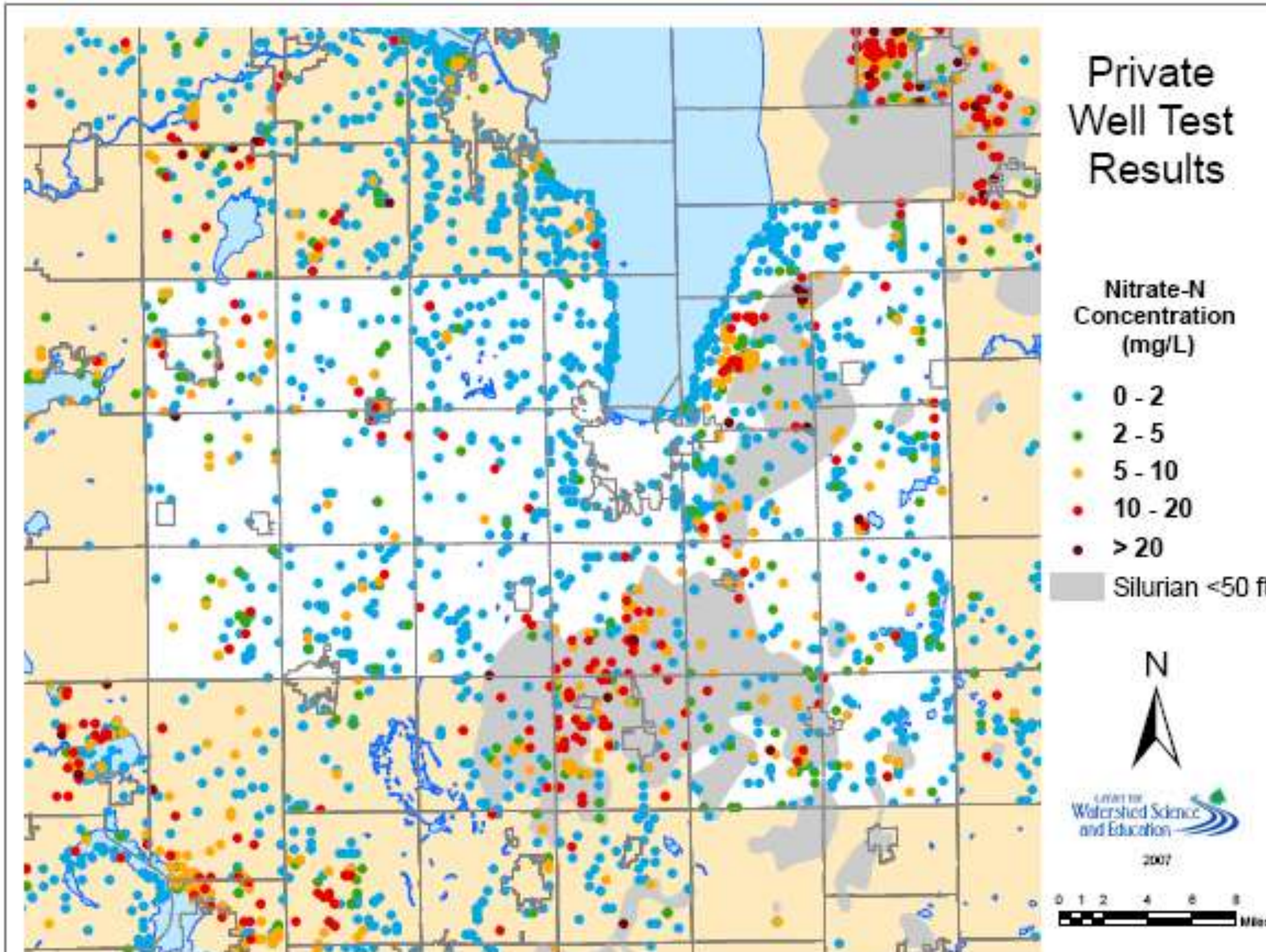
36% of crop acres in Fond du Lac County have nutrient management plans*



*According to DATCP data for 2011



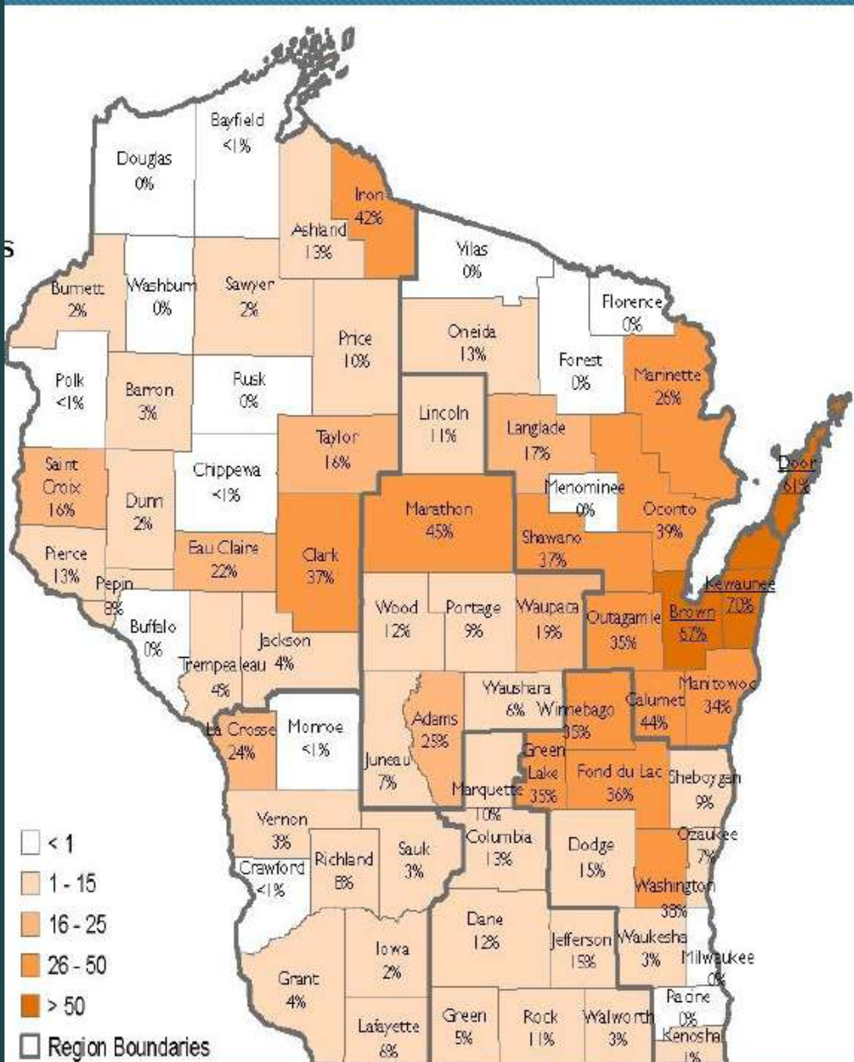
Nitrate-nitrogen concentrations from private well testing programs. (1988-2007 data)

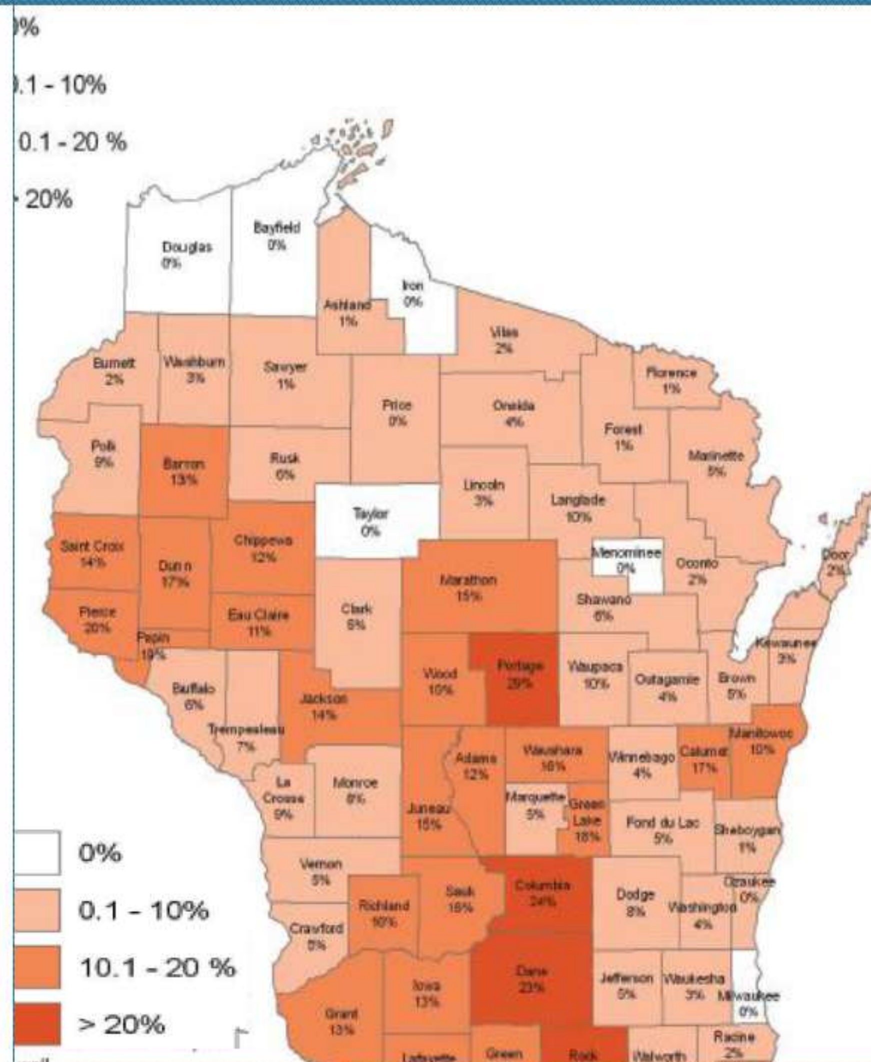


Disclaimer: This map for educational purposes only. It represents private well testing results in the Center for Watershed Science and Education database it does not represent a scientific study.

% crop acres under NM plan (1.8 million ac. reported in 2011)

% of Drinking Wells Exceeding 10 mg/L Nitrate-N

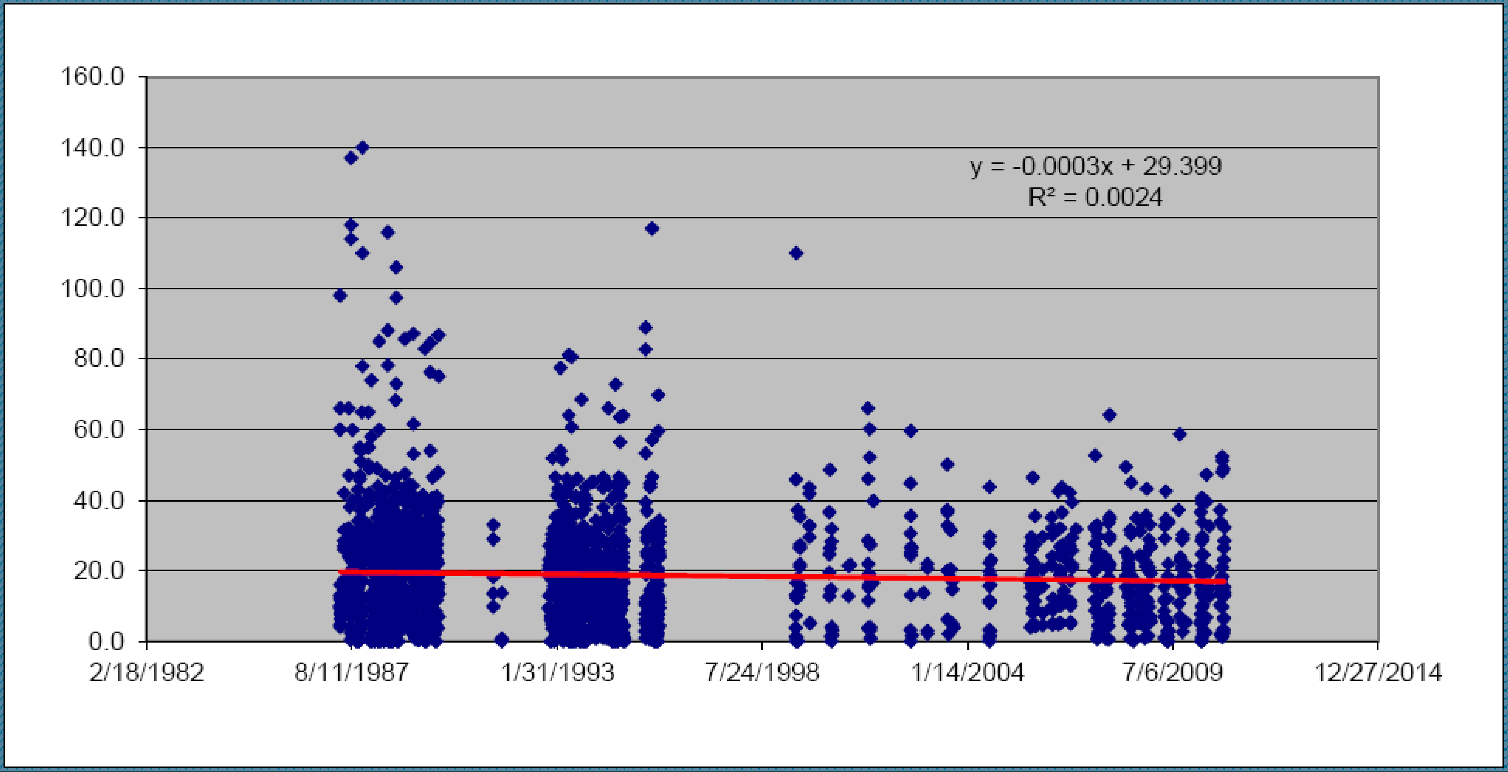




Slide courtesy of Jim Vanden Brook, DATCP

Nitrate Trends in DATCP Monitoring Wells – Irrigated Sands

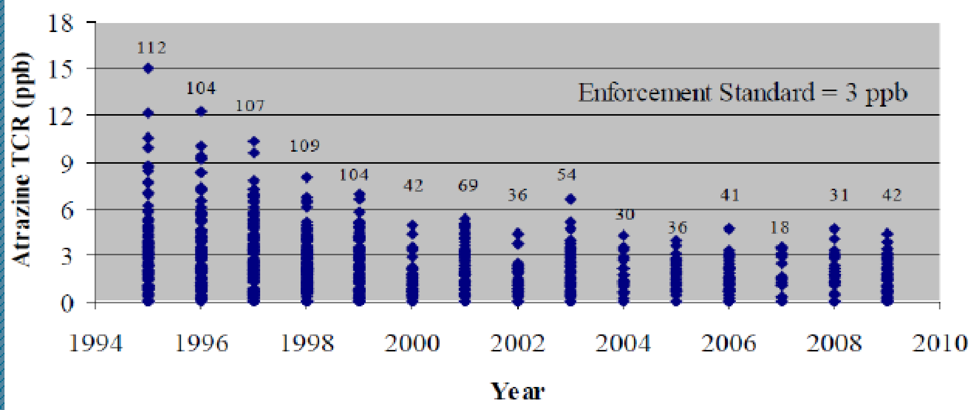
- Average N concentrations essentially constant since 1987
- Very high N concentrations have declined
- Compliance rates w/NM standard not known at these sites



Slide courtesy of Jim Vanden Brook, DATCP

Nitrate in Private Wells in Atrazine Prohibition Areas

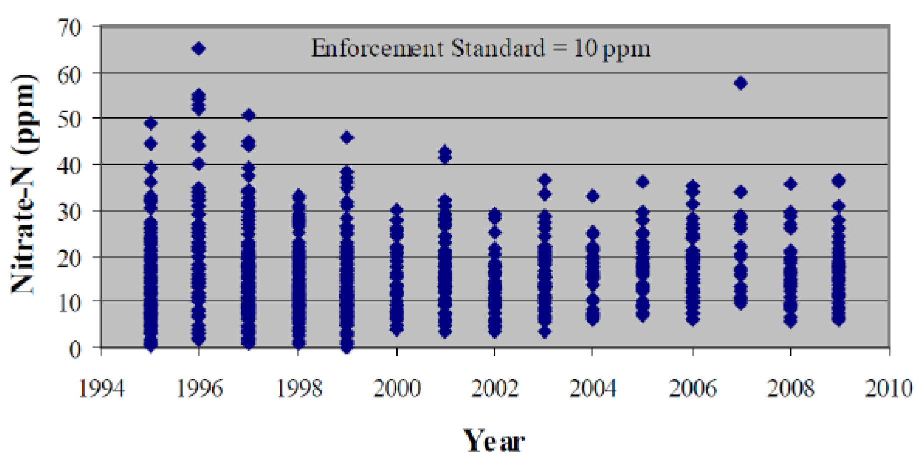
Figure 2. Distribution of Atrazine TCR Results and Number of Samples in the EX Survey, by Year



* From "15 Years of DATCP Exceedence Well Survey"

Average atrazine concentrations decline over time with high degree of management

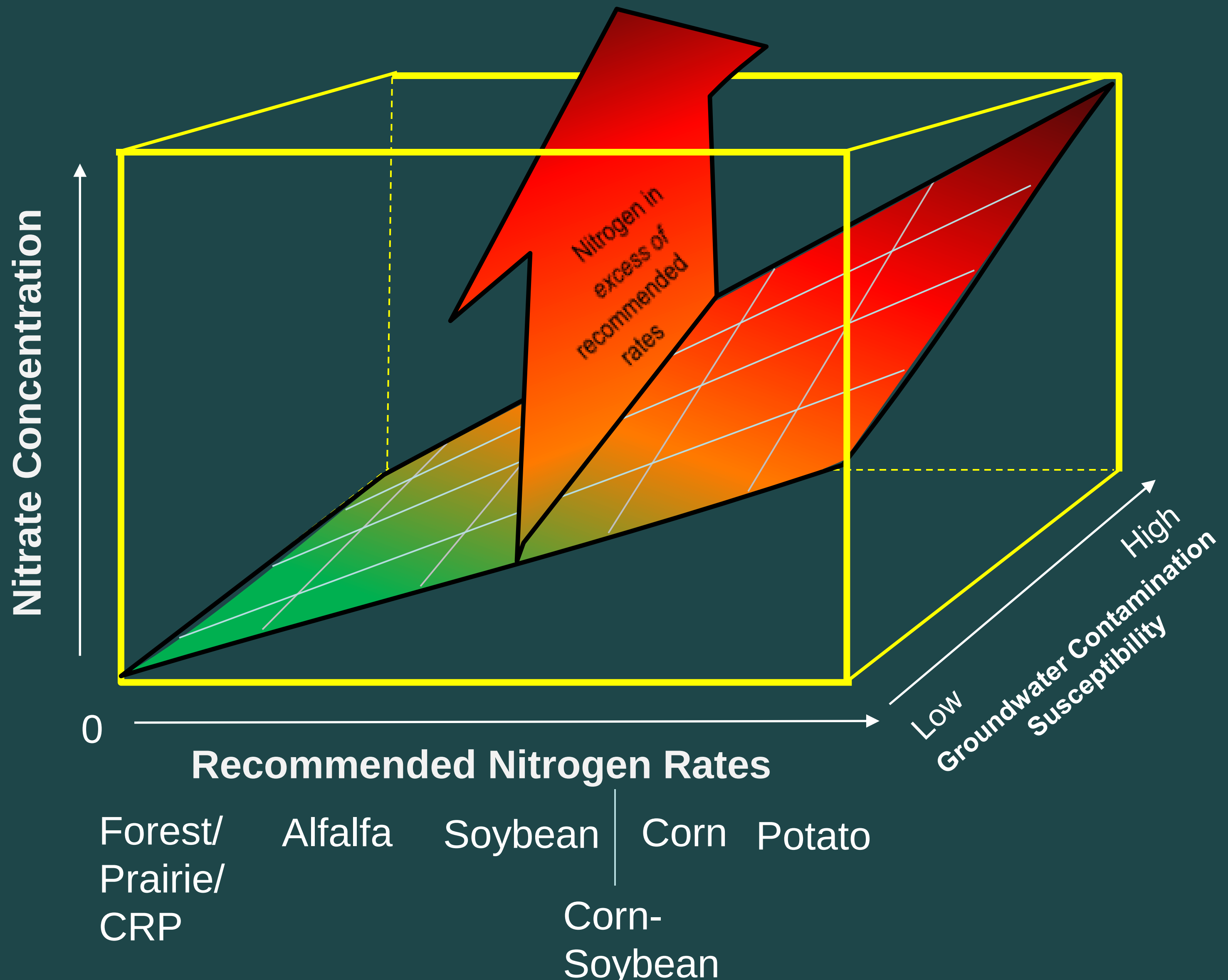
Figure 5. Nitrate-N Results by Year in the EX Survey



Average nitrate levels slightly increase over time with low degree of management

Slide courtesy of Jim Vanden Brook, DATCP

Nitrate = f(Crop N Requirements + Excess N + Soils/Geology)



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Comparing Land-use Impacts

	Corn[1] (per acre)	Prairie[1] (per acre)	Septic[2] System
Total Nitrogen Inputs (lb)	169	9	20-25
Nitrogen Leaching Loss (lb)	36	0.04	16-20
Amount N lost to leaching (%)	20	0.4	80-90

1 Data from Masarik, Economic Optimum Rate on a silt-loam soil, 2003
2 Data from Tri-State Water Quality Council, 2005 and EPA 625/R-00/008

Comparing Land-use Impacts

20 acres

36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs

20 acres

20 lbs

36 lbs/ac x 20 acres = 720 lbs

16 mg/L

20 lbs/septic system x 1 septic systems = 20 lbs

1/36th the impact on water quality

0.44 mg/L

Assuming 10 inches of recharge -

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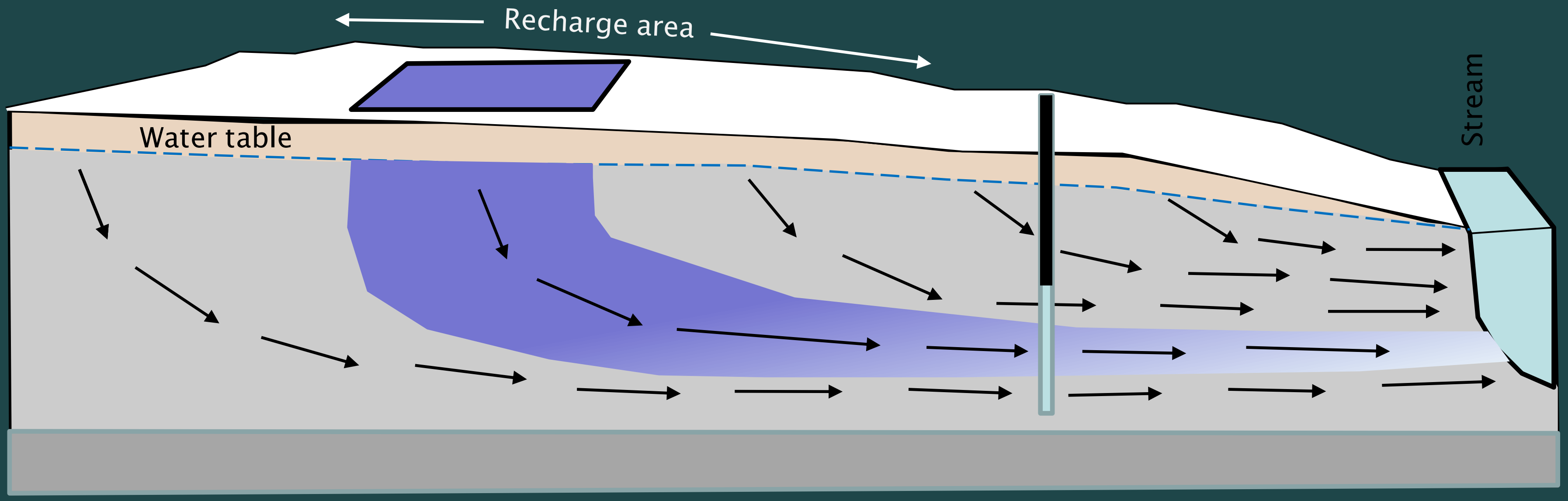
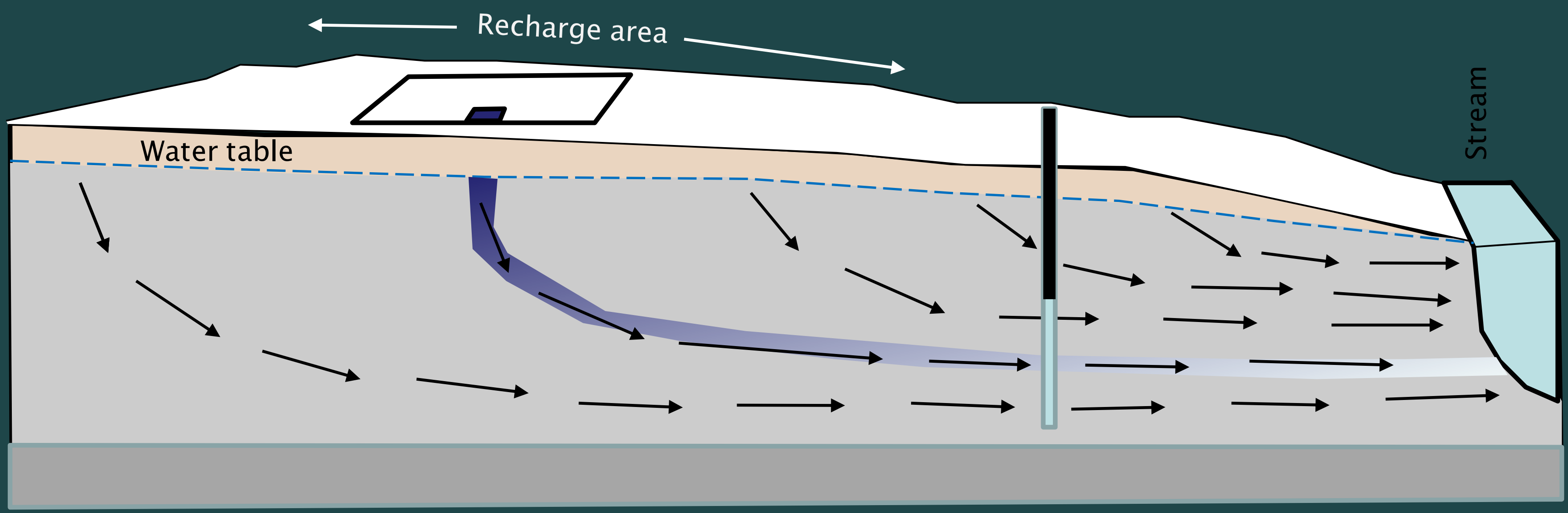
36 lbs/ac x 20 acres = 720 lbs





20 lbs/septic system

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Comparing Land-use Impacts

20 acres

36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs
36 lbs	36 lbs	36 lbs	36 lbs
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20 acres

20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs
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20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs
20 lbs	20 lbs	20 lbs	20 lbs

20 lbs/septic system x 36 septic systems = 720 lbs

Using these numbers: 36 septic systems on 20 acres (0.55 acre lots) needed to achieve same impact to water quality as 20 acres of corn

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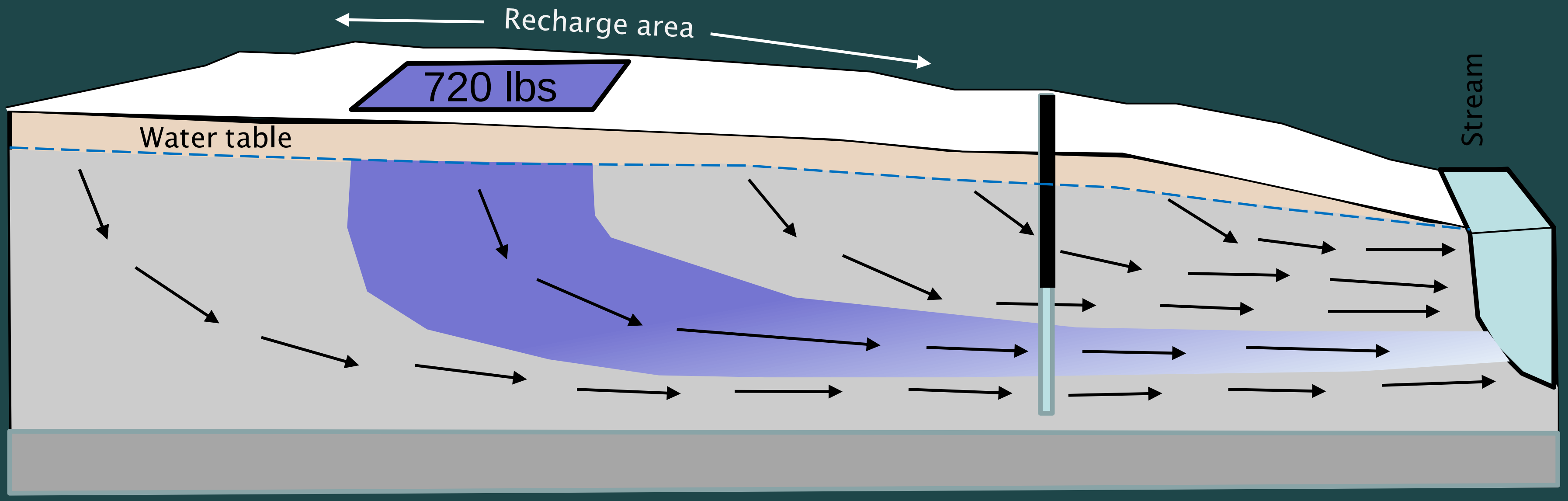
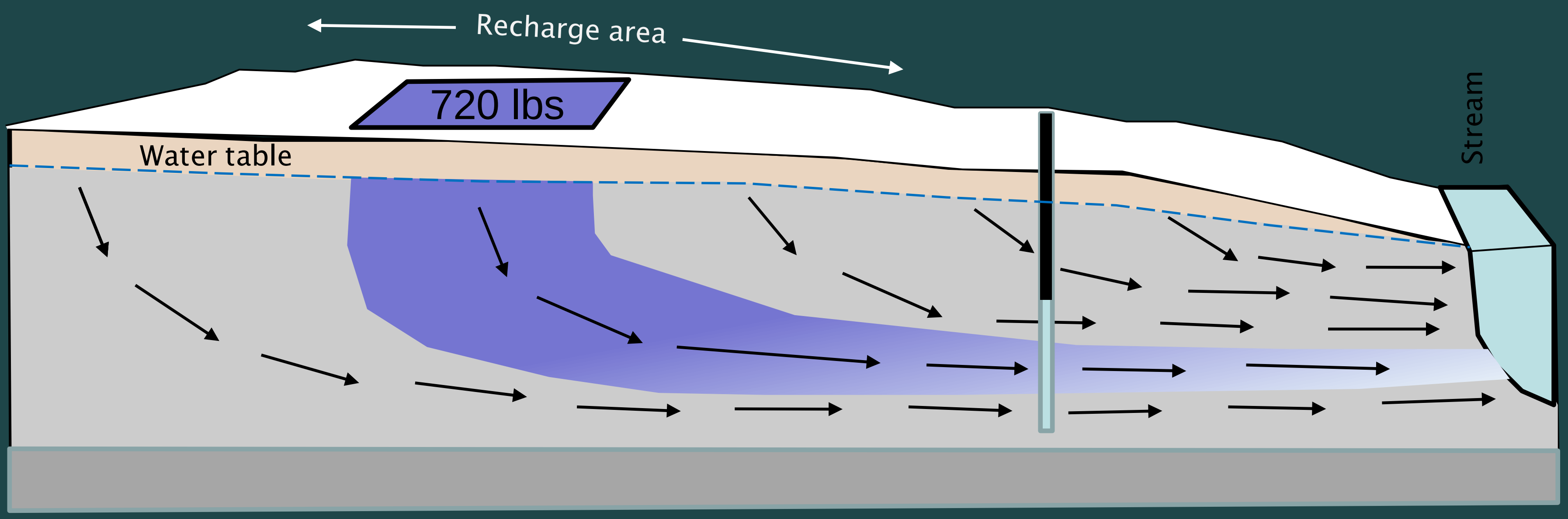
36 lbs/ac x 20 acres = 720 lbs





20 lbs/septic system x 36 septic systems = 720 lbs

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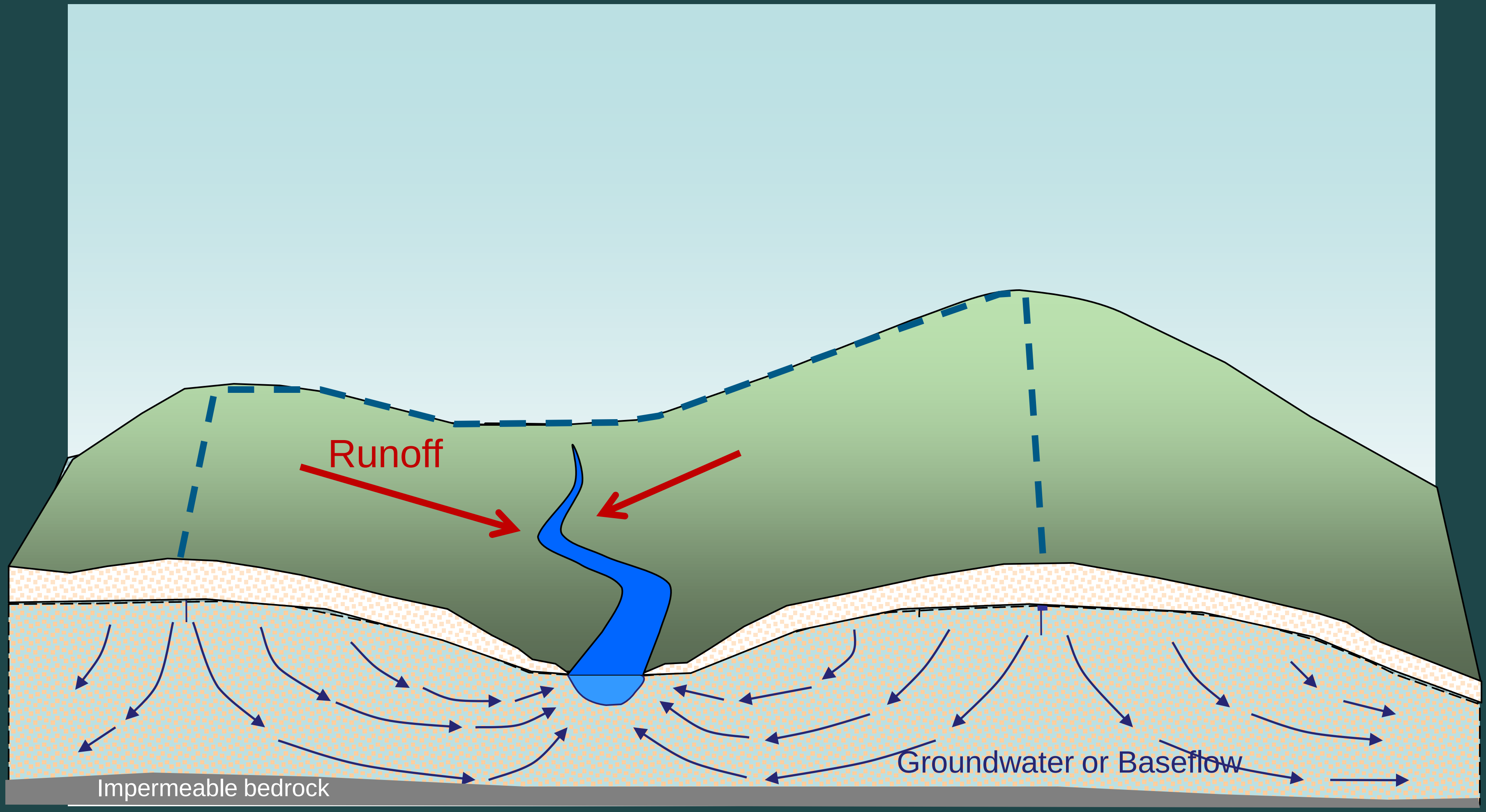
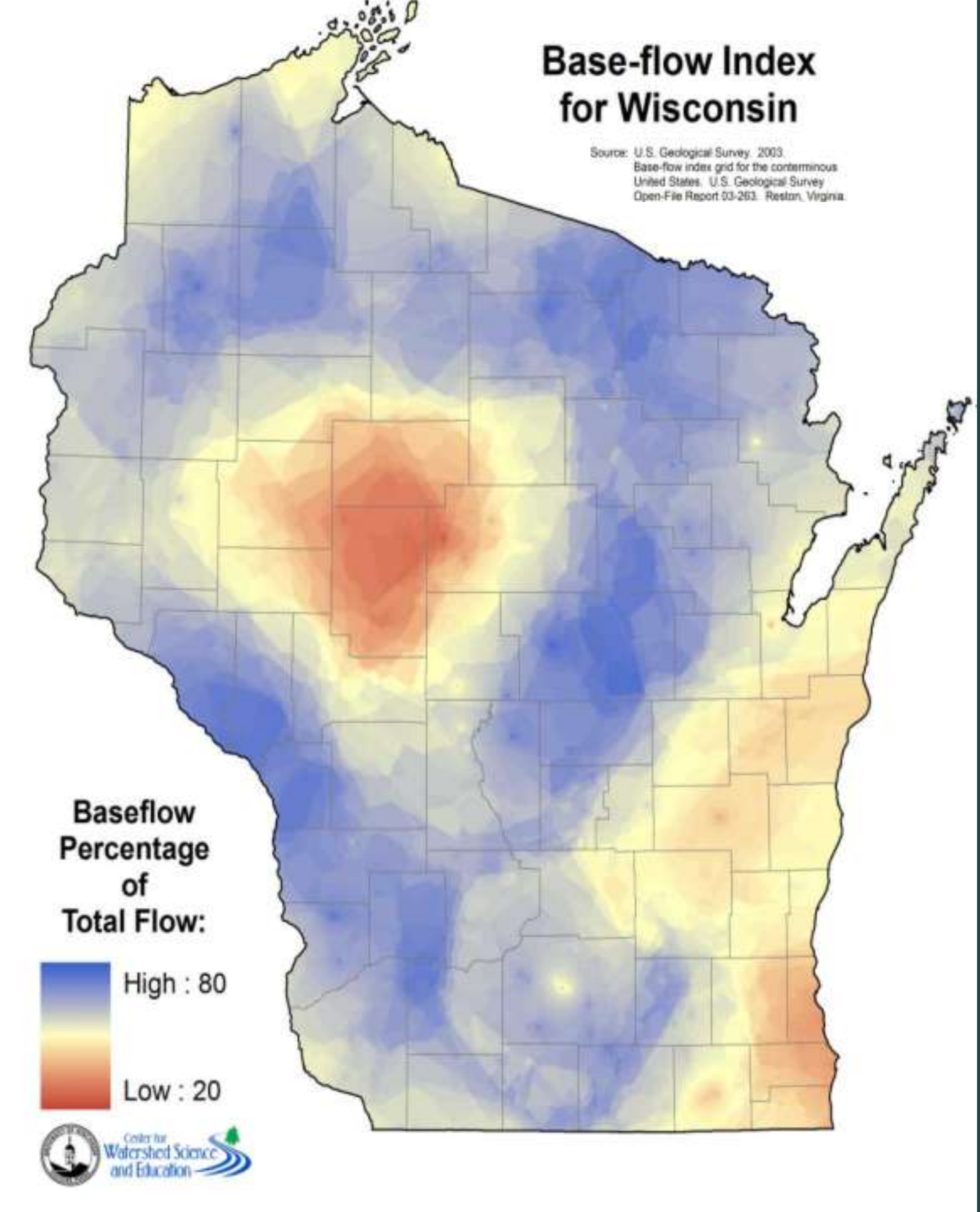
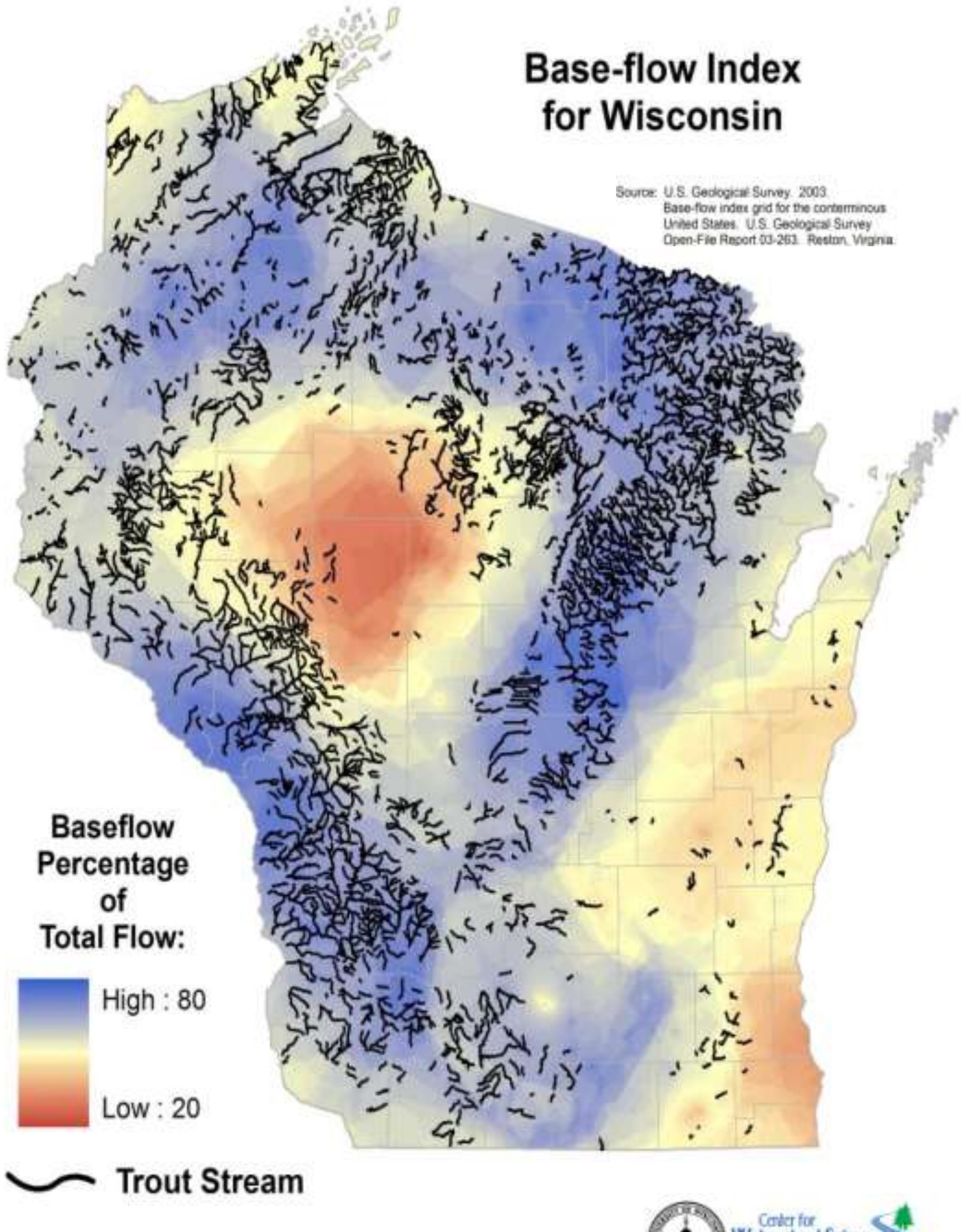
Land-use effects on surface waters




Base-flow Index
for Wisconsin
Source: U.S. Geological Survey. 2003.
Base-flow index grid for the conterminous
United States. U.S. Geological Survey
Open-File Report 03-263. Reston, Virginia.
Baseflow
Percentage
of
Total Flow:
High : 80
Low : 20
Center for
Watershed Science
and Education



Base-flow Index
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Source: U.S. Geological Survey. 2003.
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Baseflow
Percentage
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High : 80
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Trout Stream
Center for
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and Education

Fever River Study

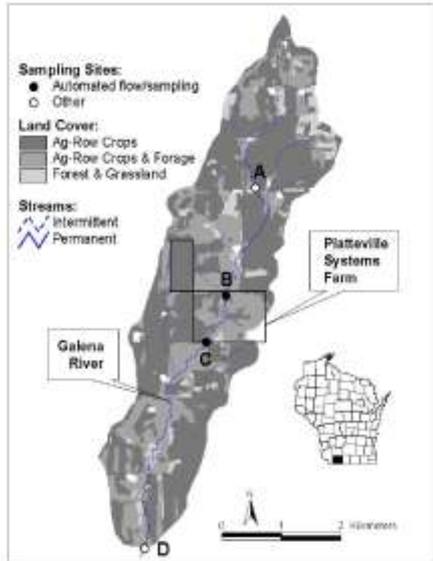


Figure 1. Study watershed, land cover, and stream sampling locations.

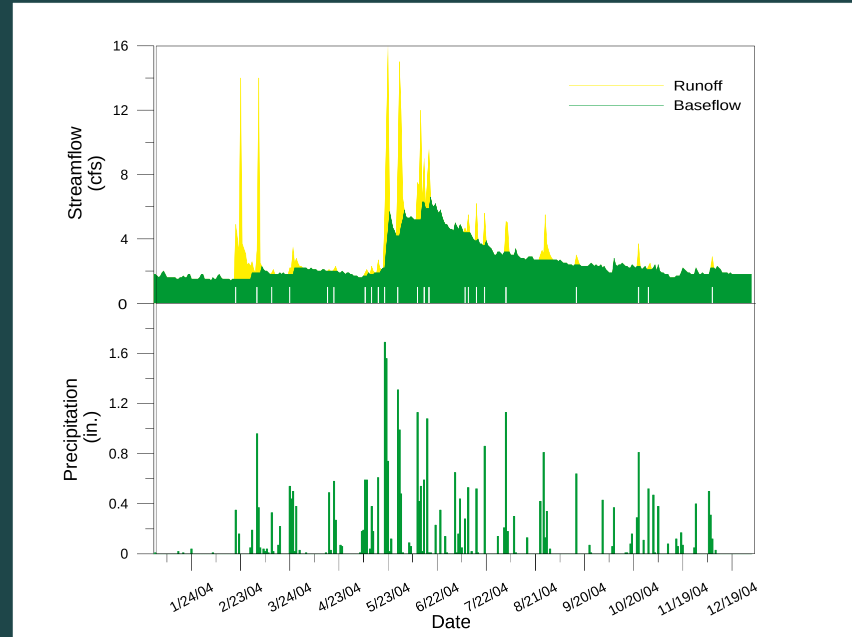
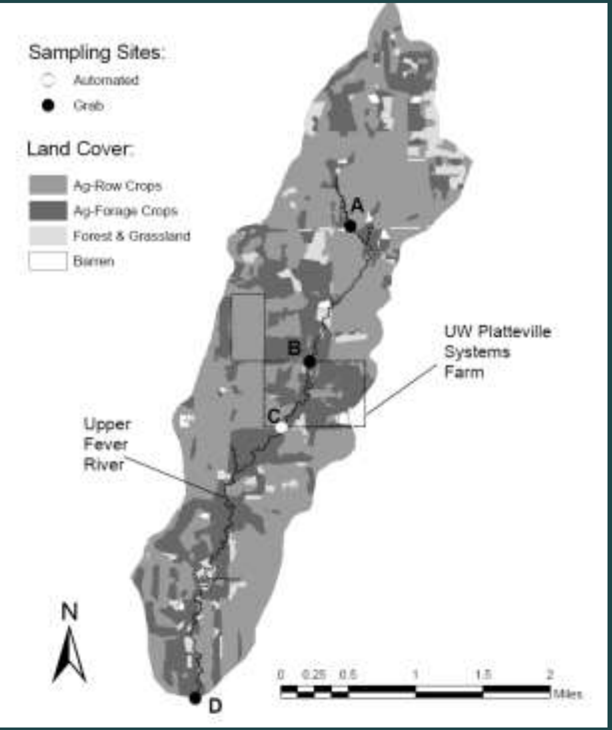


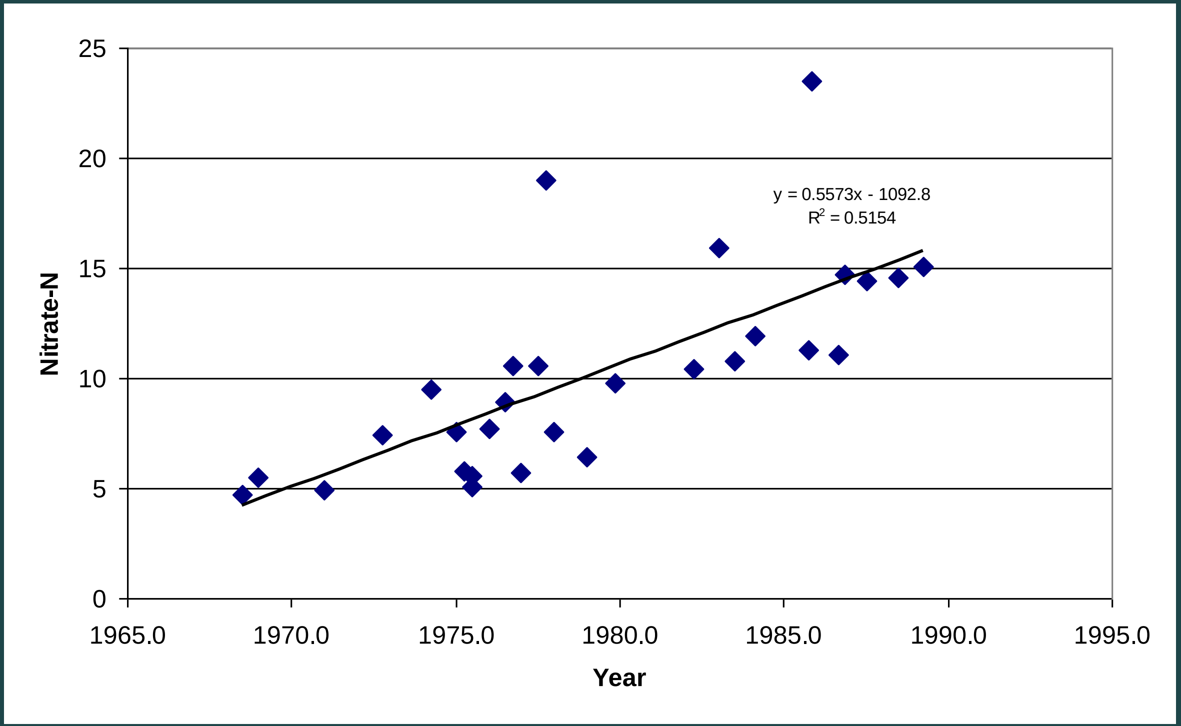
Table 4.2 Comparison of streamflow and pollutant export during baseflow and runoff event periods at site C.

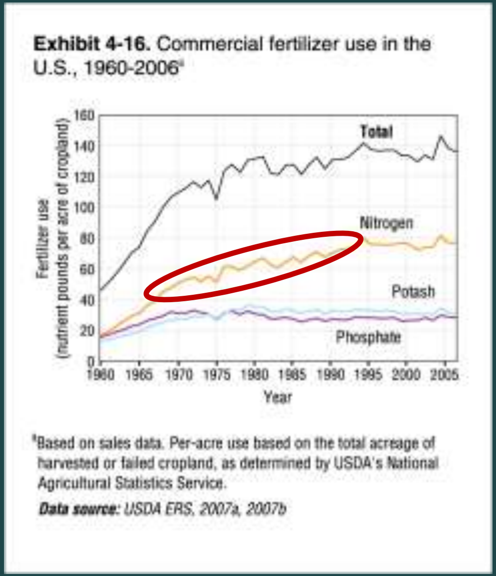
	Flow	NO_3-N	NH_4-N	TKN	TP	DRP	Cl	Suspended Sediment
	$ft^3\ s^{-1}$	Concentration ($mg\ L^{-1}$)						
Baseflow	1.9	10.3	0.06	0.55	0.09	0.04	18.9	21
Runoff	0.3	1.8	1.02	11.14	3.15	0.42	9.6	2,237
	ft^3	Load ($kg\ yr^{-1}$)						
Baseflow	1.23×10^8	18,006	105	3,041	154	77	33,041	37,062
Runoff	1.93×10^7	497	278	965	859	116	2,620	610,532
Total	1.42×10^8	18,503	383	4,006	1,013	193	35,661	647,594
	$in\ yr^{-1}$	Yield ($kg\ ha^{-1}\ yr^{-1}$)						
Baseflow	8.9	23.4	0.14	3.95	0.20	0.10	42.9	48
Runoff	1.4	0.6	0.36	1.25	1.11	0.15	3.4	792
Total	10.3	24.0	0.50	5.20	1.31	0.25	46.3	840
	%							
Baseflow	86	97	27	24	15	40	93	6
Runoff	14	3	73	76	85	60	7	94

http://www4.uwsp.edu/cnr/watersheds/Reports_Publications/Reports/fever_07.pdf

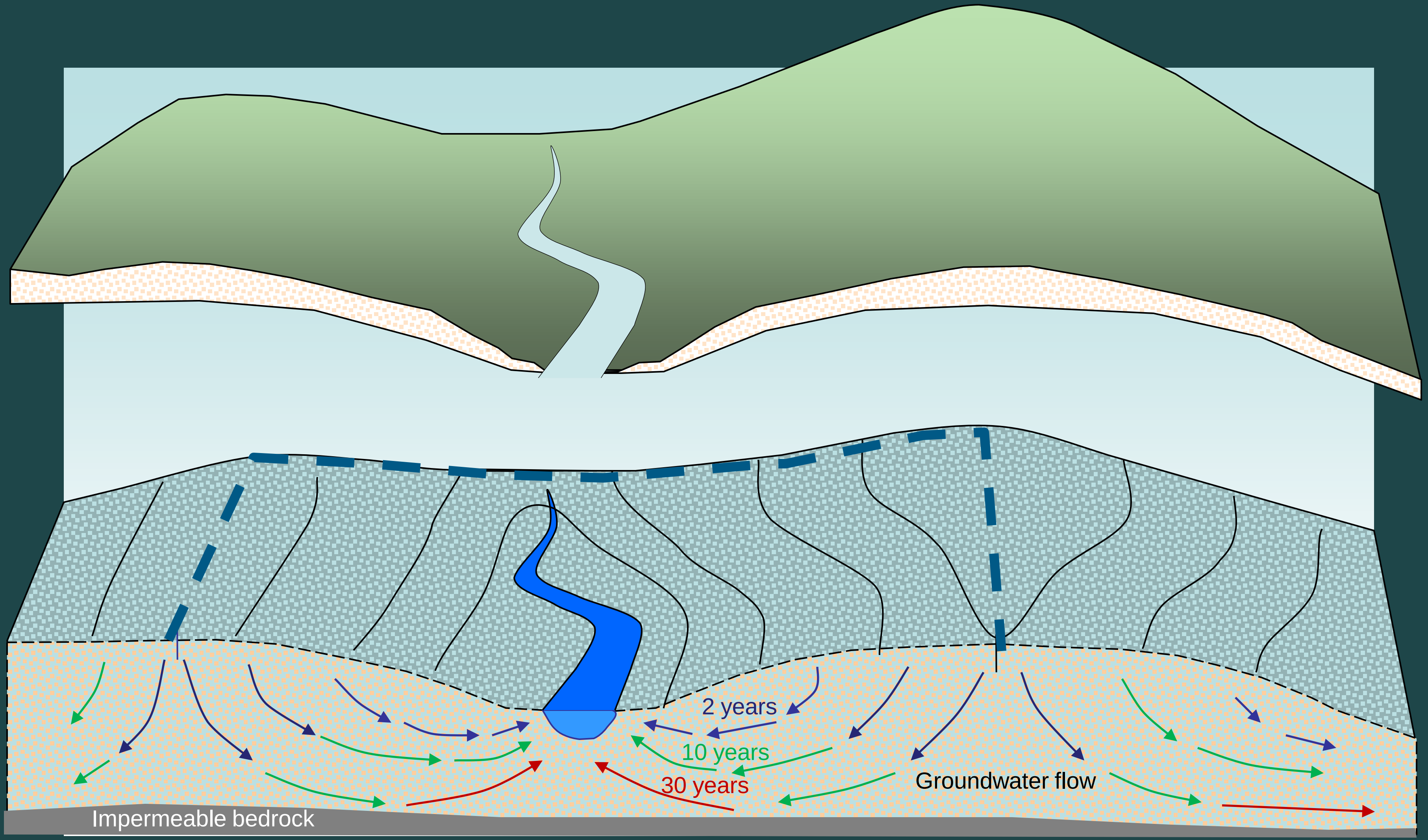
Nitrate and age-dates of groundwater discharge features to Fever River







Groundwater Residence Time



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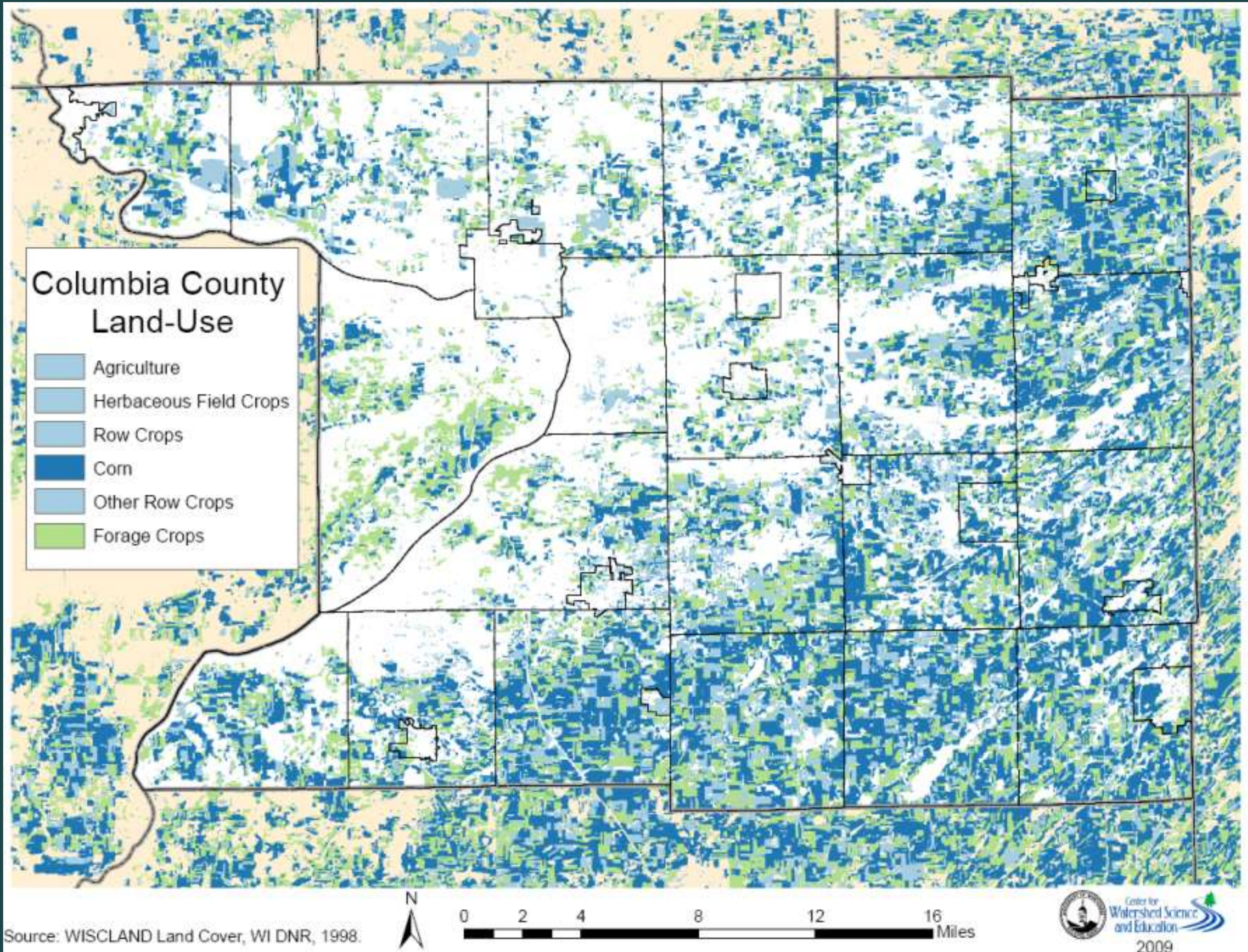
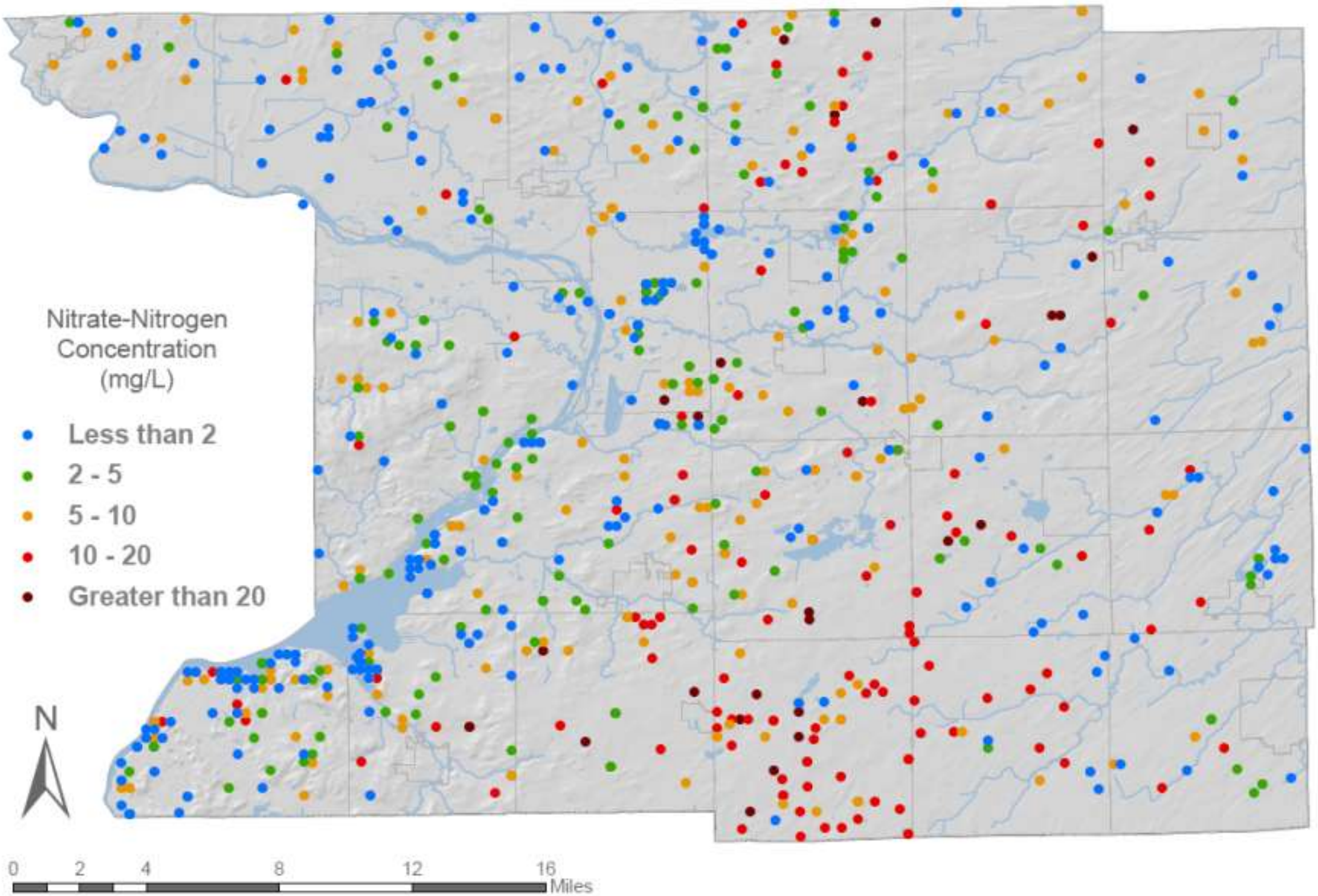
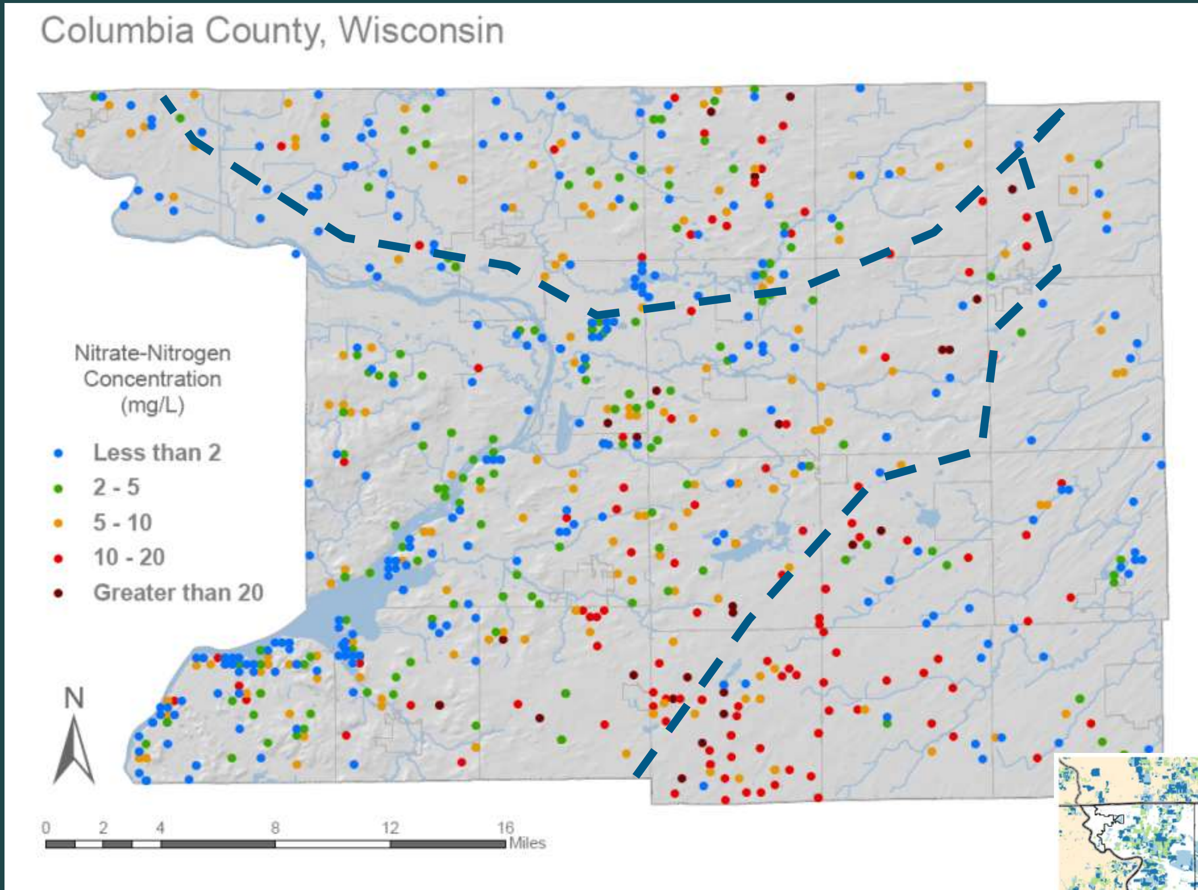
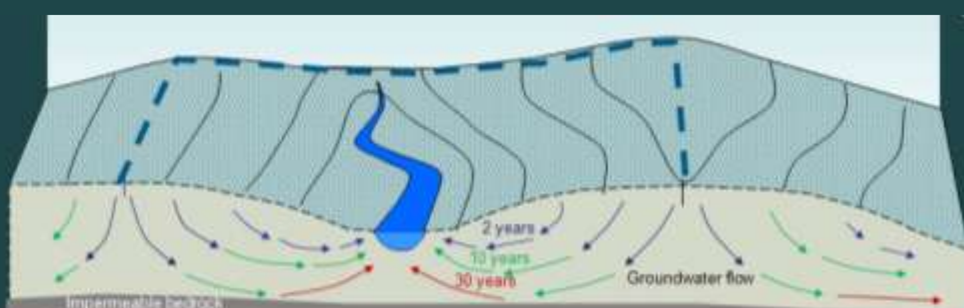
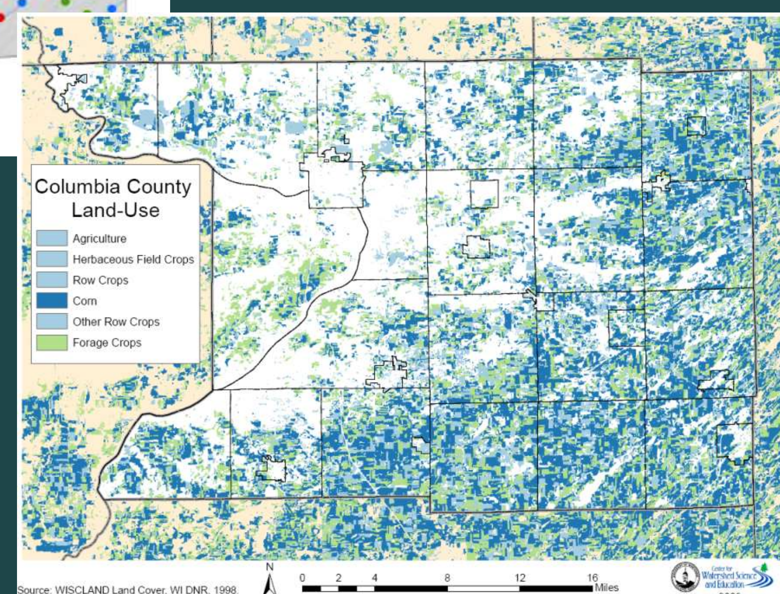

Columbia County Land-Use
Agriculture
Herbaceous Field Crops
Row Crops
Corn
Other Row Crops
Forage Crops
Source: WISCLAND Land Cover, WI DNR, 1998.
N
0 2 4 8 12 16 Miles
Center for Watershed Science and Education
2009

Columbia County, Wisconsin




Columbia County, Wisconsin
Nitrate-Nitrogen Concentration (mg/L)
Less than 2
2 - 5
5 - 10
10 - 20
Greater than 20
N
0 2 4 8 12 16 Miles

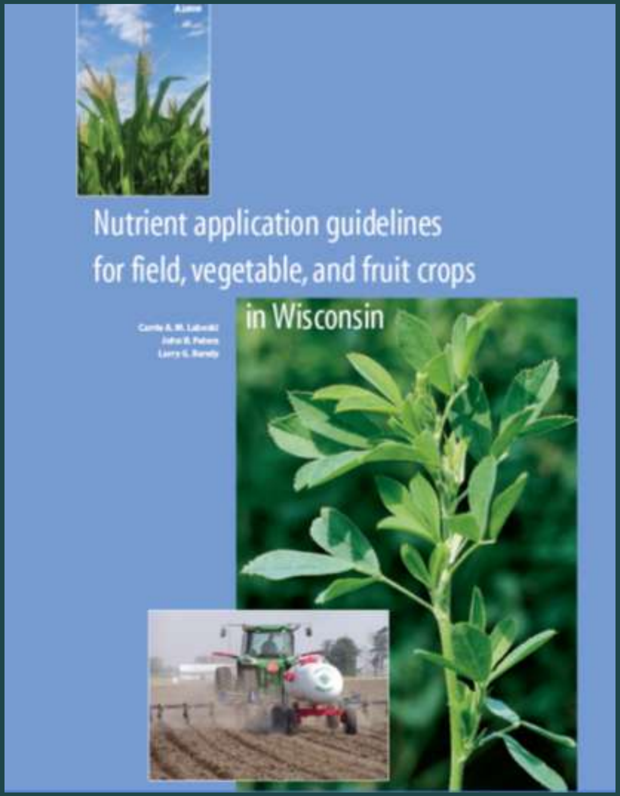

2 years
10 years
30 years
Groundwater flow
Impermeable bedrock


Columbia County Land-Use
Agriculture
Herbaceous Field Crops
Row Crops
Corn
Other Row Crops
Forage Crops
Source: WISCLAND Land Cover, WI DNR, 1998.
N
0 2 4 8 12 16 Miles
2009

What UWEX Nutrient Guidelines Do and Don’t Do:

- **Do** save farmers money by ensuring nitrogen is used efficiently
- **Do** allow farms to maximize profitability while holding everyone accountable to some standard
- **Do** prevent fields from being treated as dumping grounds for manure and other bio-solids
- **Do** help prevent excessively high concentrations of nitrate in groundwater

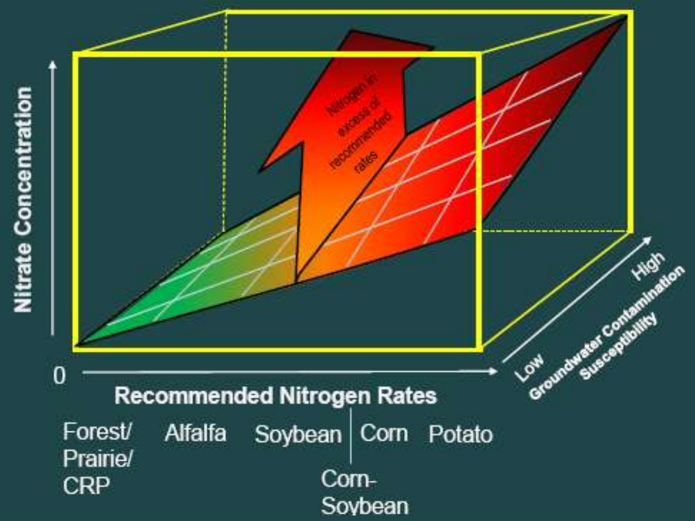
- <u>**Don’t**</u> prevent nitrate from leaching into groundwater
- <u>**Don’t**</u> ensure groundwater quality meets drinking water standards
- <u>**Don’t**</u> ensure that groundwater quality in areas that already apply at economic optimum rates will get better over time



Conclusions

- Significant nitrate leaching can occur even when nitrogen recommendations are followed – no environmental optimum rate
- Better implementation of nutrient management and crediting of N will help reduce extreme nitrate concentrations in groundwater
- Nutrient management is a first step that allows us to stabilize nitrate concentrations in groundwater
- May take years or decades for groundwater quality to reflect changes in land-use practices
- If the goal is safe drinking water, we would need to go beyond nutrient management in areas that are significantly degraded
    - *Beyond nutrient management: Less nutrient intensive crops, N reduction rotations, CRP, perennial, grazing systems, slow-release fertilizers?, cover crops?*

Nitrate = f(Crop + Excess N + soils/geology)



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