Agricultural Production and Effects on Groundwater

- Pathogens
- Nitrate
- Pesticides

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Center for Watershed Science and Education

Center for Watershed Science and Education
College of Natural Resources
University of Wisconsin-Stevens Point

UW Extension

Through the University of Wisconsin-Extension, all Wisconsin people can access University resources and engage in lifelong learning, wherever they live and work.

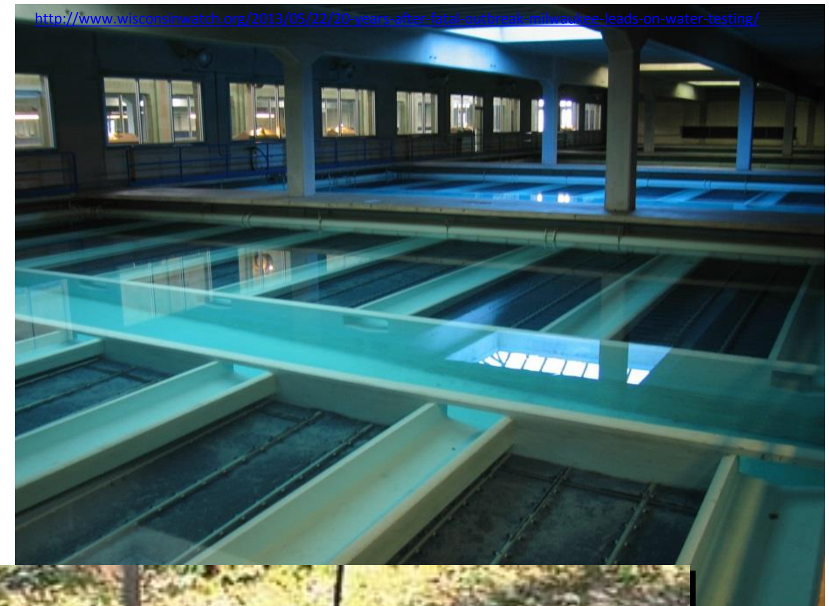
Private vs. Public Water Supplies

Public Water Supplies

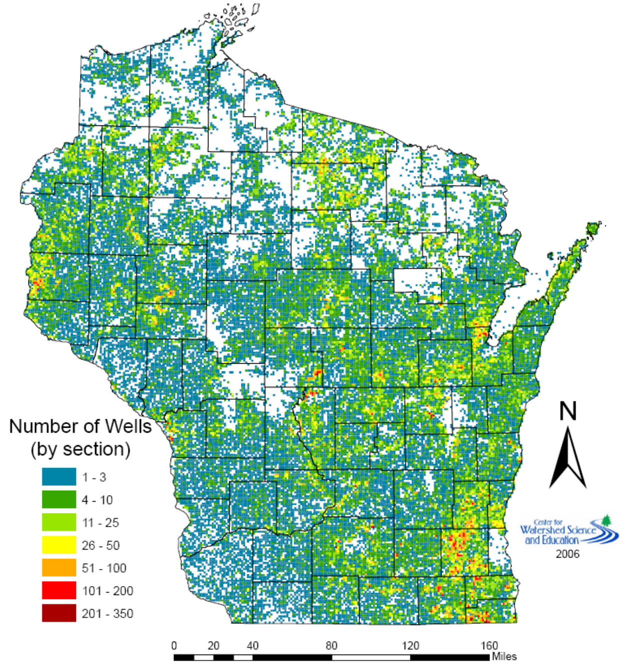
- Regularly tested and regulated by drinking water standards.

Private Wells
(1/3 of WI population)

- Not required to be regularly tested.
- Not required to take corrective action
- Owners must take special precautions to ensure safe drinking water.



Private wells installed 1988-2006

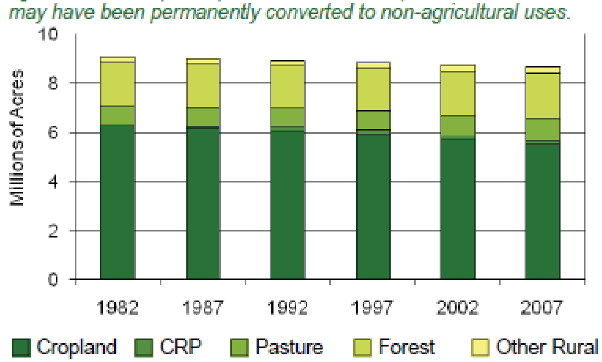


Disclaimer: Map for educational purposes only. Represents all newly constructed wells in DNR Well Construction Database from 1988 to 2006. Does not distinguish between well types.

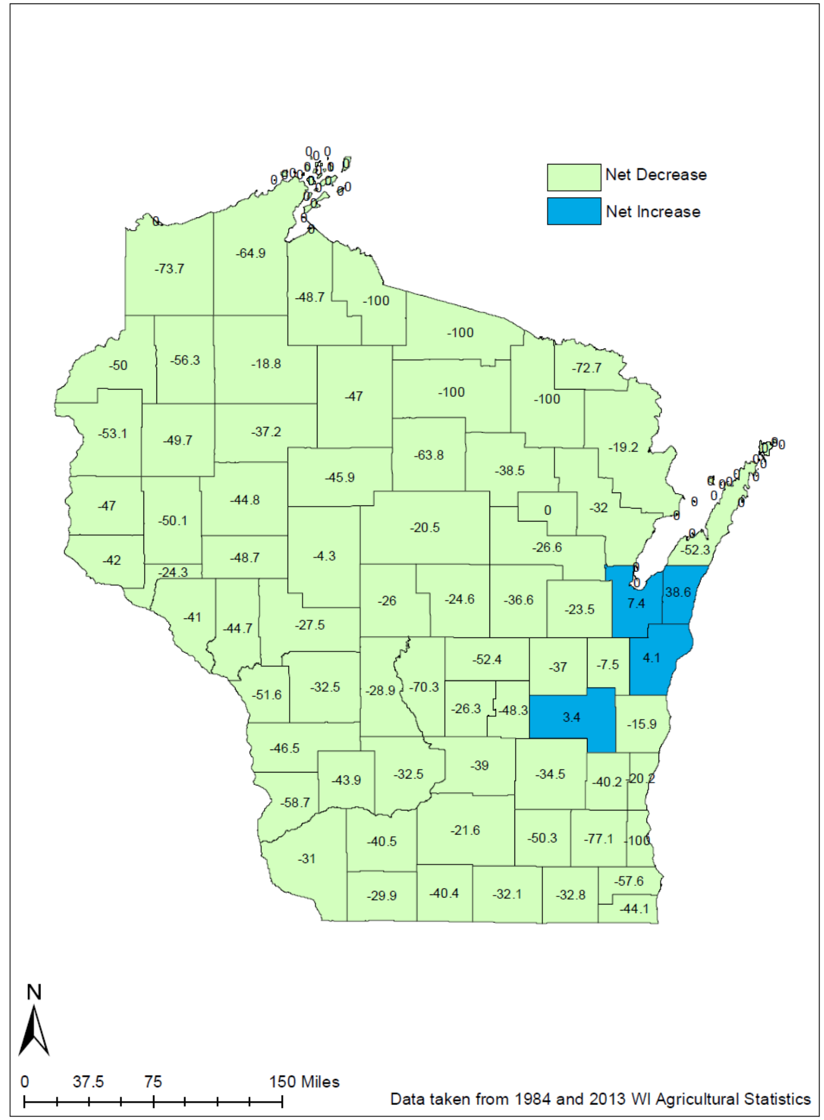
Figure 4

Prime Farmland by Land Cover/Use

Between 1982 and 2007 the state lost nearly 800,000 acres of prime cropland.[10] About half was likely diverted to other agricultural uses (CRP, pasture, forest, other) while the remainder may have been permanently converted to non-agricultural uses.



% Change in Dairy Cow Numbers from 1983-2012 by County



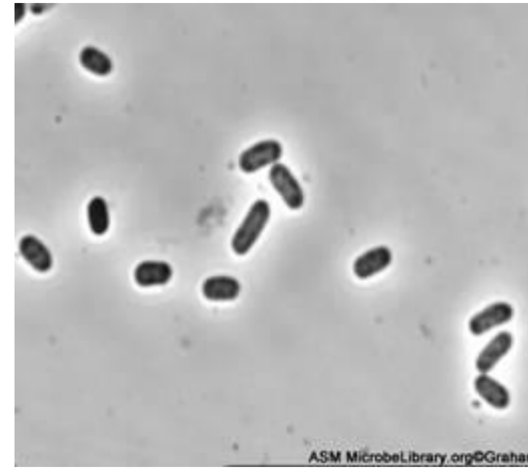
Coliform bacteria test

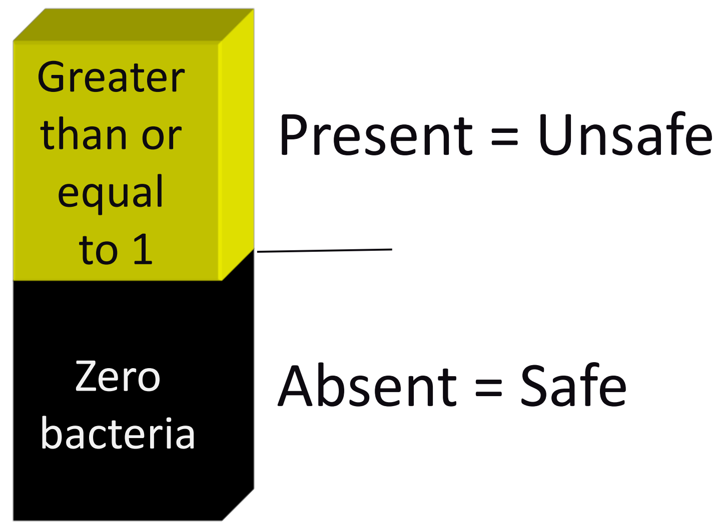
- Generally do not cause illness, but indicate a pathway for potentially harmful microorganisms to enter your water supply.
  - Harmful bacteria and viruses can cause gastrointestinal disease, cholera, hepatitis

- Well Code: "Properly constructed well should be able to provide bacteria free water continuously without the need for treatment"

- Recommend using an alternative source of water until a test indicates your well is absent of coliform bacteria

- Sources:
  - Live in soils and on vegetation
  - Human and animal waste
  - Sampling error





If coliform bacteria was detected, we also checked for e.coli bacteria test

- **Confirmation that bacteria originated from a human or animal fecal source.**
- **E. coli are often present with harmful bacteria, viruses and parasites that can cause serious gastrointestinal illnesses.**
- **Any detectable level of E.coli means your water is unsafe to drink.**

Contaminants	Sources	Symptoms
BACTERIA		
Escherichia coliform (E. coli) *Salmonella* *Campylobacter* *E. coli 0157* (Requires a special water test for detection. Causes similar, but more serious illness than other E.coli strains. Requires medical treatment.)	• Infected human and animal feces • Manure • Septic systems • Sewage	• Gastrointestinal illness • Low-grade fever • Begins 12 hrs - 7 days after exposure
Leptosporidia	• Urine of livestock, dogs and wildlife • Manure	• High fever, severe headache and red eyes • Gastrointestinal illness • Begins 2-28 days after exposure
MICROSCOPIC PARASITES		
Cryptosporidia *Giardia*	• Infected human and animal feces • Manure • Septic systems • Sewage	• Gastrointestinal illness • Begins 2-14 days after exposure
VIRUSES		
Norovirus	• Infected human feces and vomit • Septic systems • Sewage	• Gastrointestinal illness • Low-grade fever & headache • Begins 12-48 hrs after exposure
CHEMICALS		
Nitrate	• Fertilizers • Manure • Bio-solids • Septic systems	Methemoglobinemia or "Blue Baby Syndrome" – No documented cases in Door County, but elevated nitrate levels in well water may indicate risk of contamination by additional pathogens.
Atrazine (trade-name herbicide for control of broadleaf and grassy weeds)	Estimated to be most heavily used herbicide in the U.S. in 1987/89, with its most extensive use for corn and soybeans in the Midwest, including WI. In 1993, it became a restricted-use herbicide nationally. U.S. EPA set a max. contaminant level (MCL) at 3 parts per billion for safe drinking water.	Short-term exposure above the MCL may cause: congestion of heart, lungs and kidneys; low blood pressure; muscle spasms; weight loss; damage to adrenal glands. Long-term exposure above MCL may cause: weight loss, cardio-vascular damage, retinal and some muscle degeneration; cancer.

Information Sources: United States Department of Health and Human Services – Centers for Disease Control and Prevention (www.cdc.gov) and United States Environmental Protection Agency (www.epa.gov)

Manure Contamination of Groundwater

- Bacteria and other pathogens are the most immediate health concerns related to drinking water.
- Areas most at risk have shallow fractured bedrock
- Technology better at determining source but generally not cost effective for the average homeowner
- "Known" Incidents of manure contamination of wells will likely increase:
  - As development spills out into agricultural regions
  - As dairy operations get larger
  - Climate change??

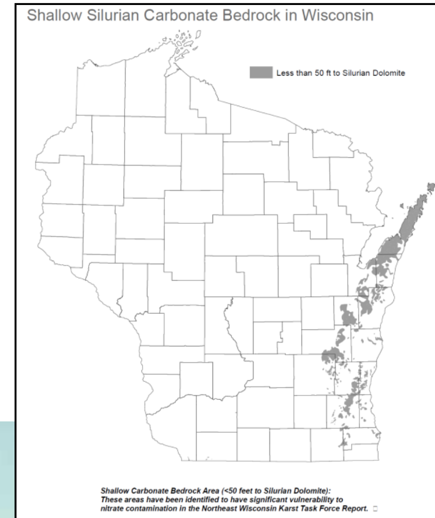
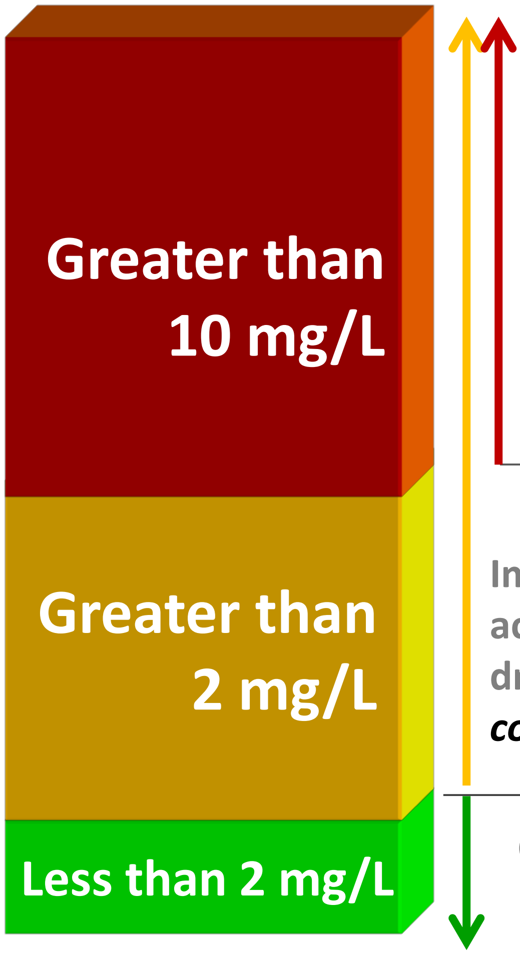


Photo courtesy of Chuck Wagner

Nitrate-Nitrogen Concentration



UNSAFE - for infants and pregnant women; everyone should avoid long term consumption.

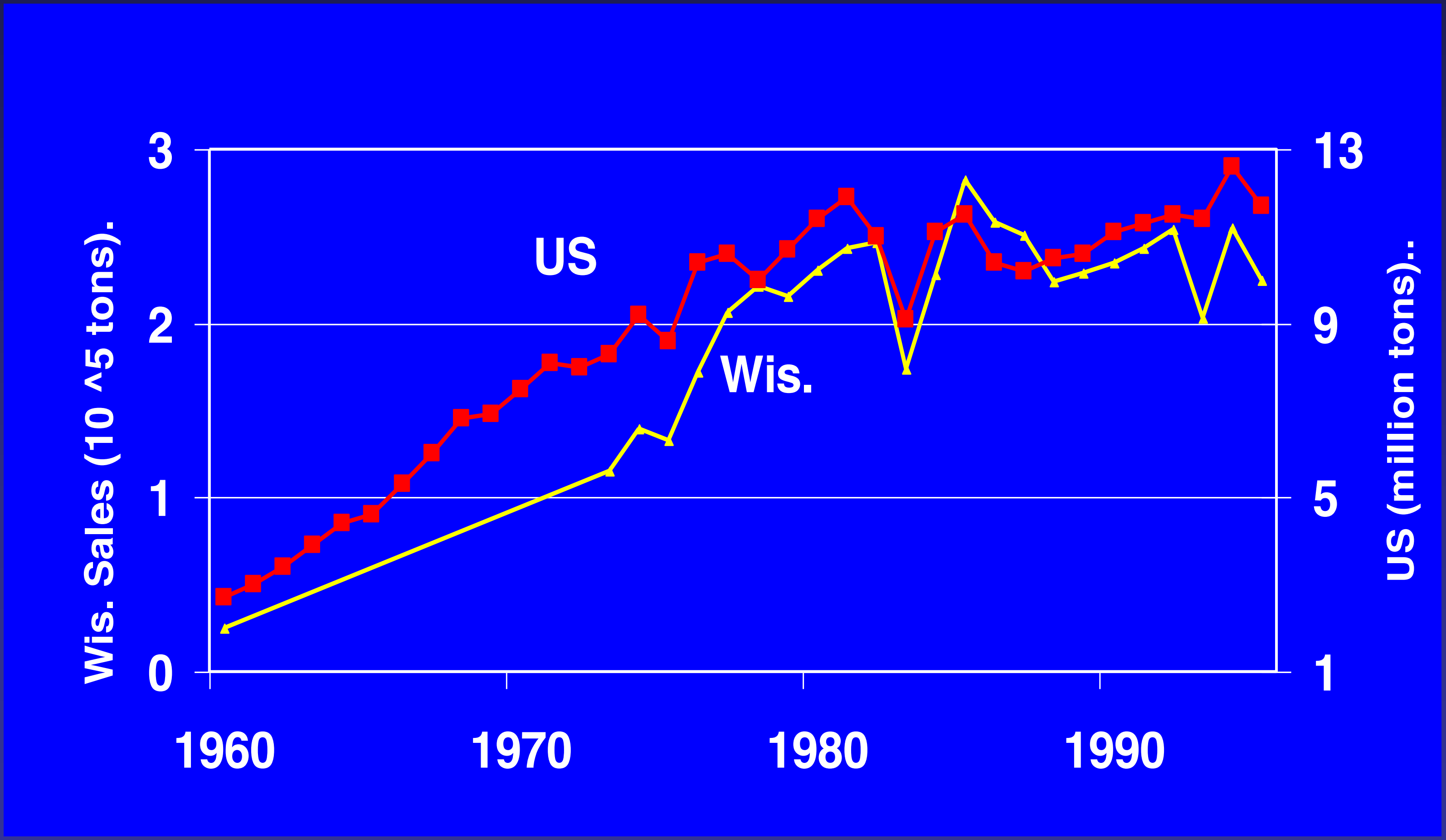
Impacted by local land use activities but suitable for drinking. ***May indicate other contaminants.***

Close to “natural” or background levels

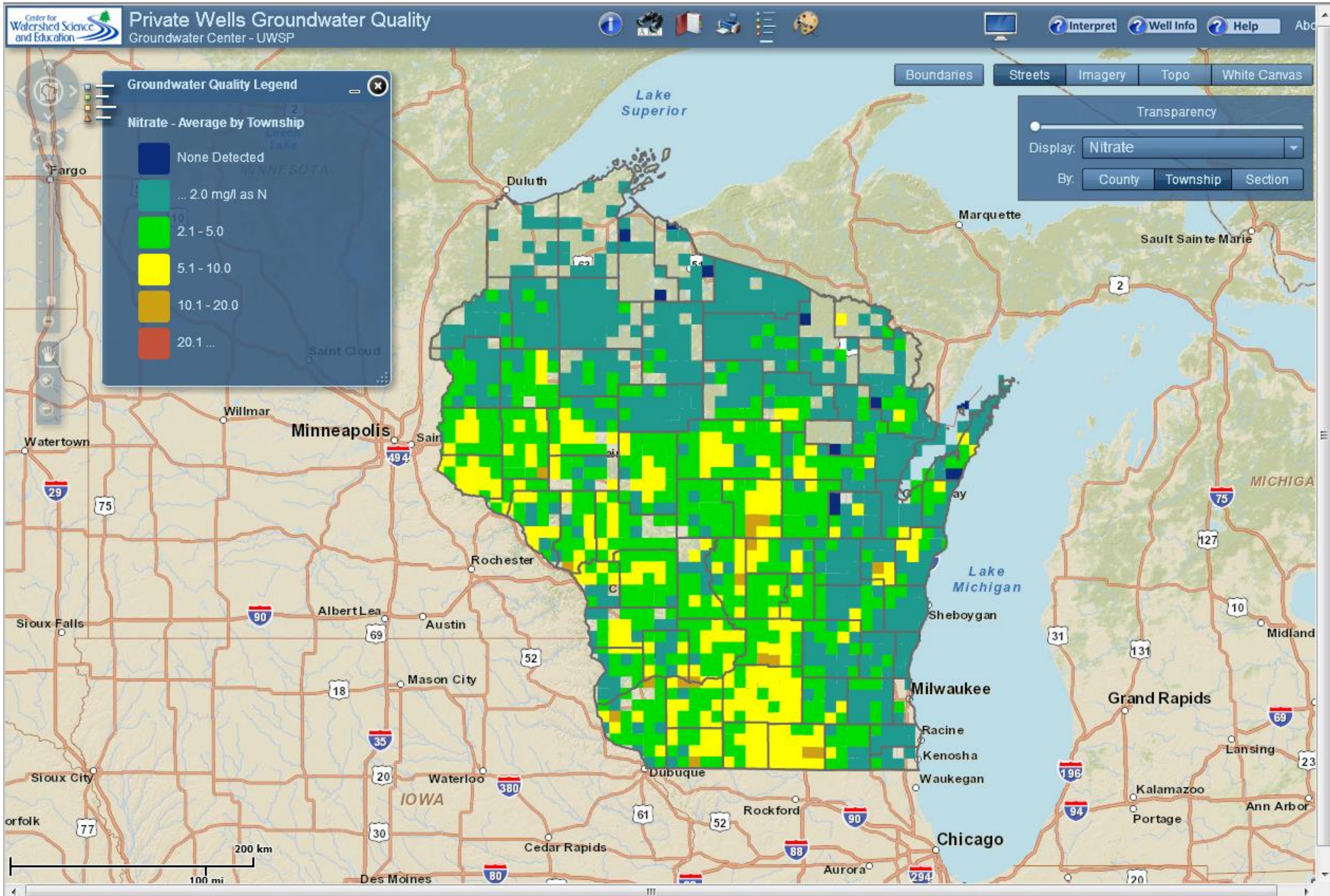
Sources

- Agricultural fertilizer
- Lawn fertilizer
- Septic systems
- Animal wastes
- Decomposing wastes

US & Wis. fertilizer nitrogen use (1960-95)

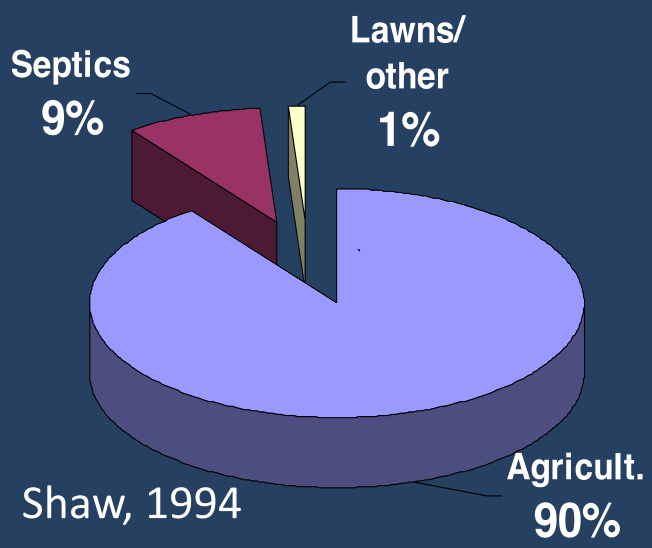


Nitrate concentrations in groundwater will get worse before they stabilize.



http://www.uwsp.edu/cnr-ap/watershed/Pages/wellwaterviewer.aspx

Comparing Land-use Impacts



Shaw, 1994

	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

36 lbs/ac x 20 acres = 720 lbs

16 mg/L

20 acres

20 lbs

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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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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36 lbs/ac x 20 acres = 720 lbs

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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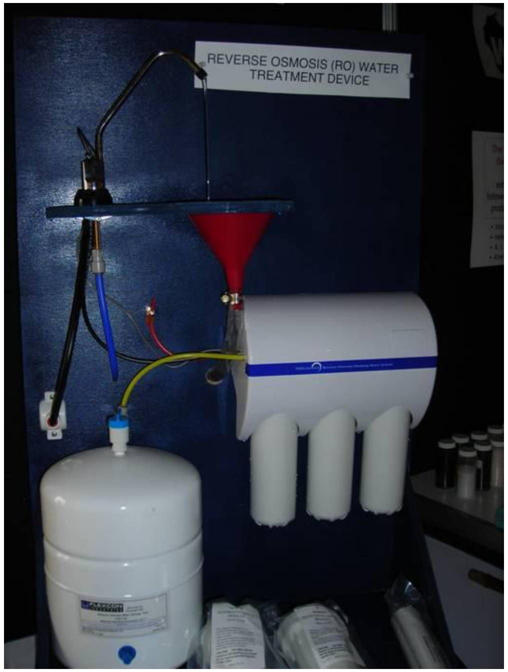
What can I do to reduce my nitrate levels?

- Long-term:
  - Reduce or eliminate nitrogen inputs

- Short term (Lewandowski et. al. 2008)
  - Change well depth or relocate well (not guaranteed) - $7,200
  - Bottled water - $190/person/year
  - Water treatment devices - $800 + 100/yr
    - Reverse osmosis
    - Distillation
    - Anion exchange



Chippewa Falls Nitrate Removal

Total Costs

- $2.3 million = Capital Costs
- $72,000 = Operating and Maintenance

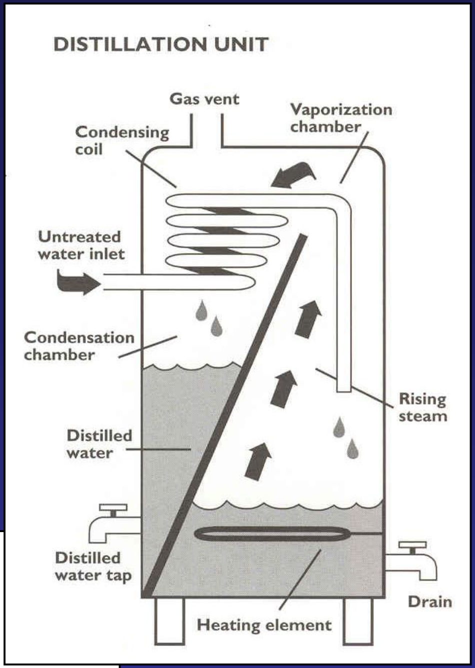
Cost per pound of NO_3-N

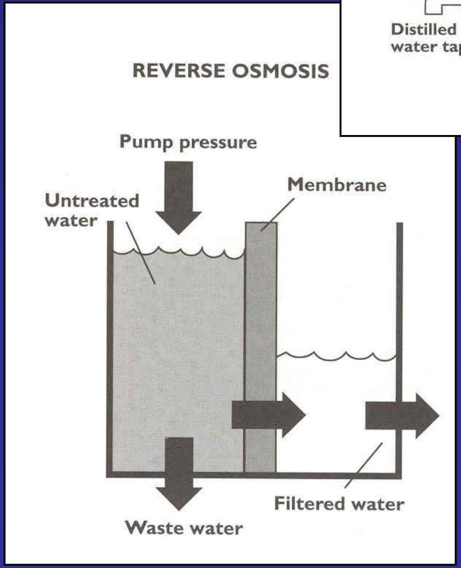
- $0.82 per pound (just O & M)
- $2.12 per pound (includes capital costs/20 y)

City of Chippewa Falls
Home of The World's Purest Water

Private Well Nitrate Removal

- Most residential treatment systems are point-of-use systems.
  - Reverse Osmosis
  - Distillation
- Treat only a small quantity of water (~10 gal/d)
- $83 per pound
  - Conservative estimate, includes only cost of equipment assuming lifespan of 20 years.





Pesticides in Drinking Water

- Insecticides, herbicides, fungicides and other substances used to control pests.
- Health standards usually only account for parent compound.
- Parent compounds breakdown over time.
- Little research into health effects from the combination of chemicals..

- Most frequently detected pesticides in WI:
  - Alachlor* (Lasso) and its chemical breakdown products (Alachlor ESA)
  - Metolachlor (Dual) and its chemical breakdown products (Metolachlor ESA)
  - Atrazine** and its chemical breakdown products
  - Metribuzin
  - Cyanazine and its chemical breakdown products.

- * WI public health groundwater standard for breakdown component Alachlor ESA.
- ** WI public health groundwater standard is for the total chlorinated atrazine residue

Agricultural Chemicals in Wisconsin Groundwater

- The statewide estimates of the proportion Of wells containing atrazine, atrazine TCR, nitrate-nitrogen over 10 mg/l, metolachlor ESA and alachlor ESA did not show statistically-significant changes between 2001 and 2007.
- The estimate for the proportion of wells that exceeded the 10 mg/l enforcement standard for nitrate-nitrogen was 9.0%.
- The statewide estimate of the proportion of wells that contained a detectable level of a pesticide or pesticide metabolite was 33.5%.
- Alachlor ESA and metolachlor ESA were the most commonly detected herbicide compounds with identical proportion estimates of 21.6%.
- The statewide estimate of the proportion of wells that contained atrazine TCR was 11.7%.
- The estimate for the proportion of wells that exceeded the 3 ug/l enforcement standard for atrazine TCR was 0.4%.

Table 2B

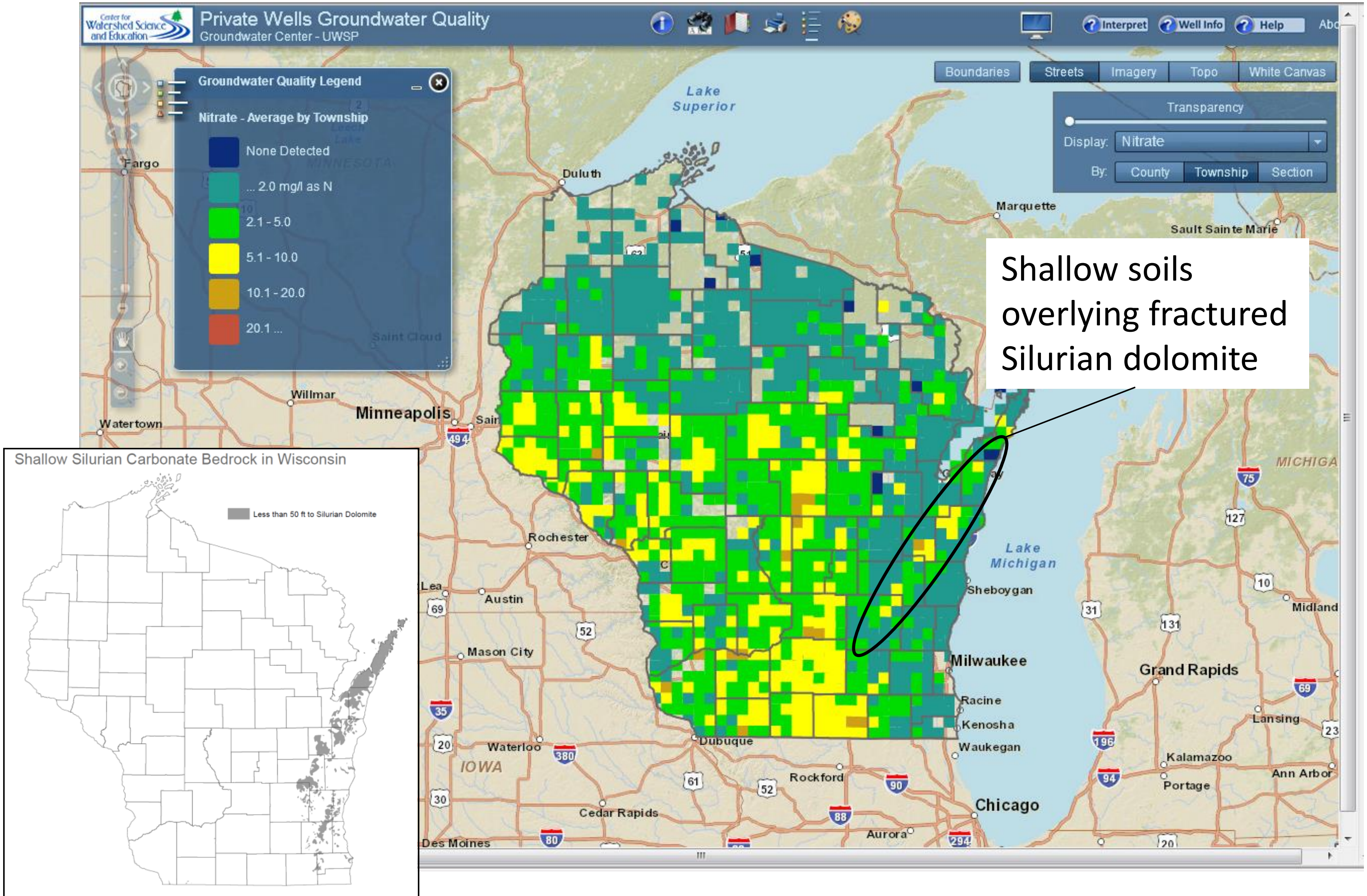
Percentage of Detects* by NASS Strata** and Parameter in the 2007 Survey.

NASS Strata	Strata Description	Number of Samples	Percentage of Detects					
			Atrazine	TCR	Alachlor ESA	Metolachlor ESA	Nitrate-N	Nitrate-N> 10 mg/l
11	>75% Cultivated	134	5.2	17	36	46	63	21
12	51-75% Cultivated	50	2.0	20	28	22	60	10
20	15-50% Cultivated	150	7.3	13	20	18	61	8.6
40	<15% Cultivated	59	5.1	5.1	12	10	47	1.7

* quantifiable and non-quantifiable detects
** the percentages for the Agri-Urban stratum are not included because of the small number of samples

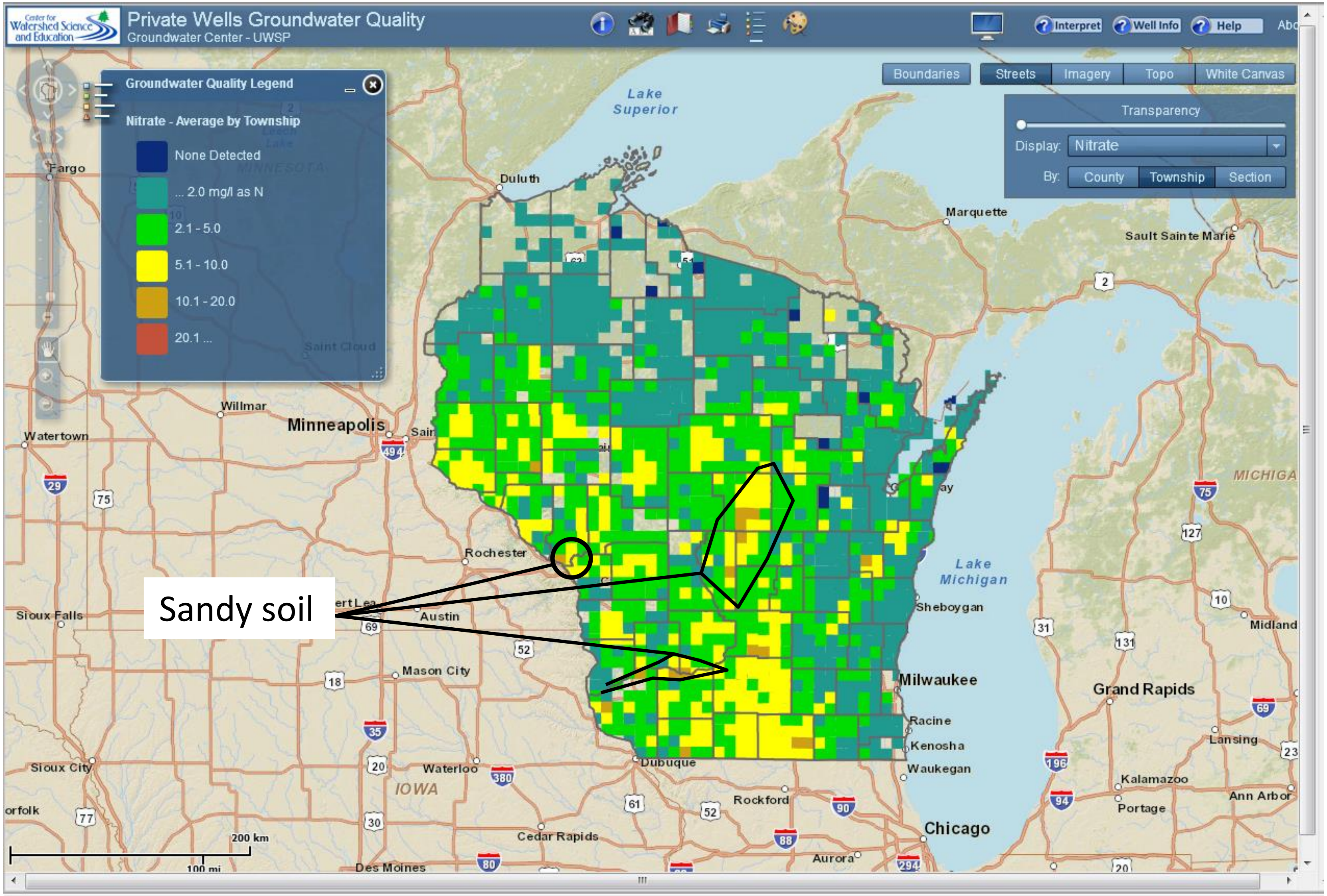
For additional copies, contact
Wisconsin
Department of
Agriculture,
Trade, &
Consumer Protection
Environmental Quality Section
PO Box 8911 · Madison · Wisconsin · 53708-8911 · 608.224.4500
ARM PUB 180.qxd 03/08

Bacteria and Nitrate Issues

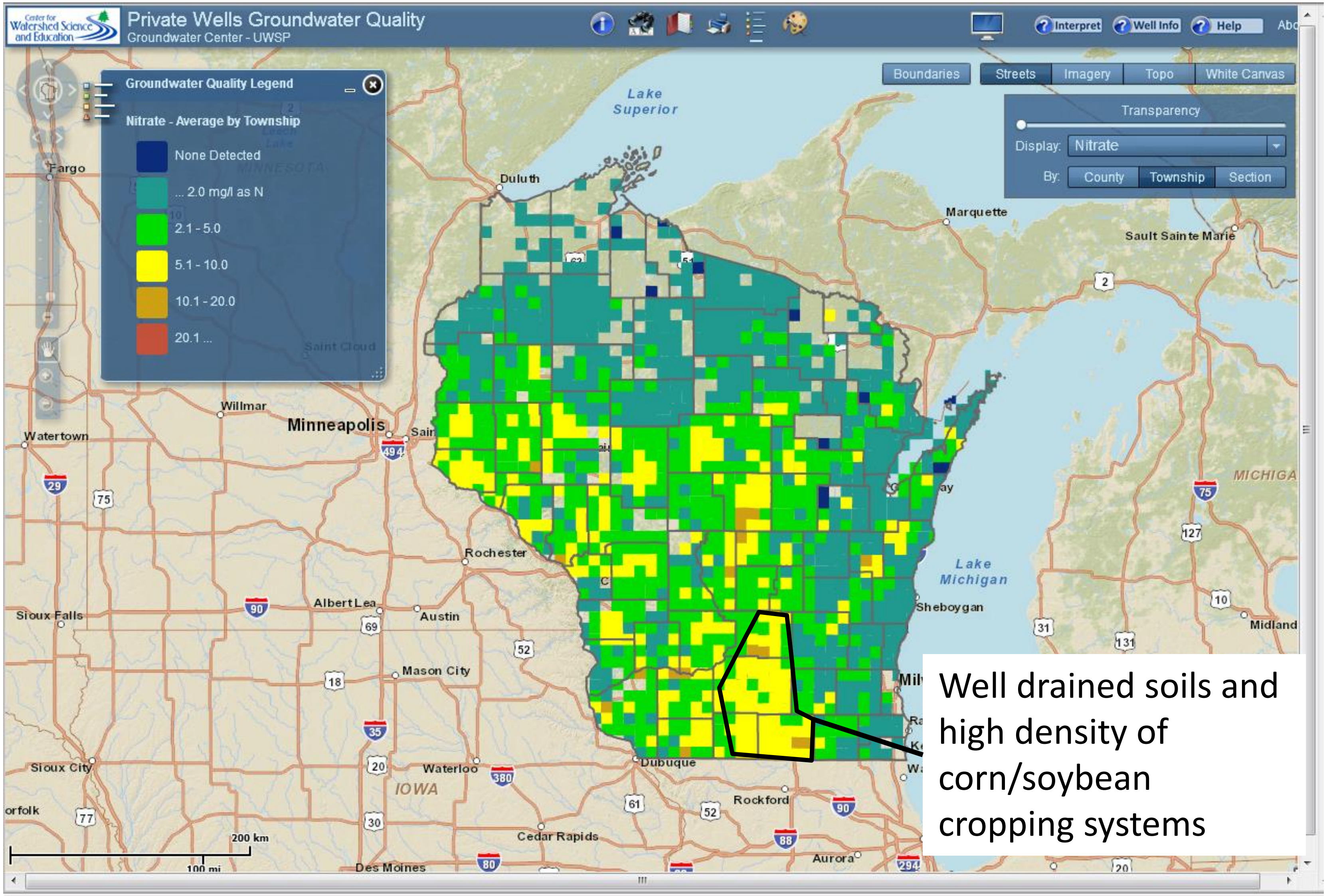


Shallow Carbonate Bedrock Area (<50 feet to Silurian Dolomite): These areas have been identified to have significant vulnerability to nitrate contamination in the Northeast Wisconsin Karst Task Force Report.

Sandy Regions

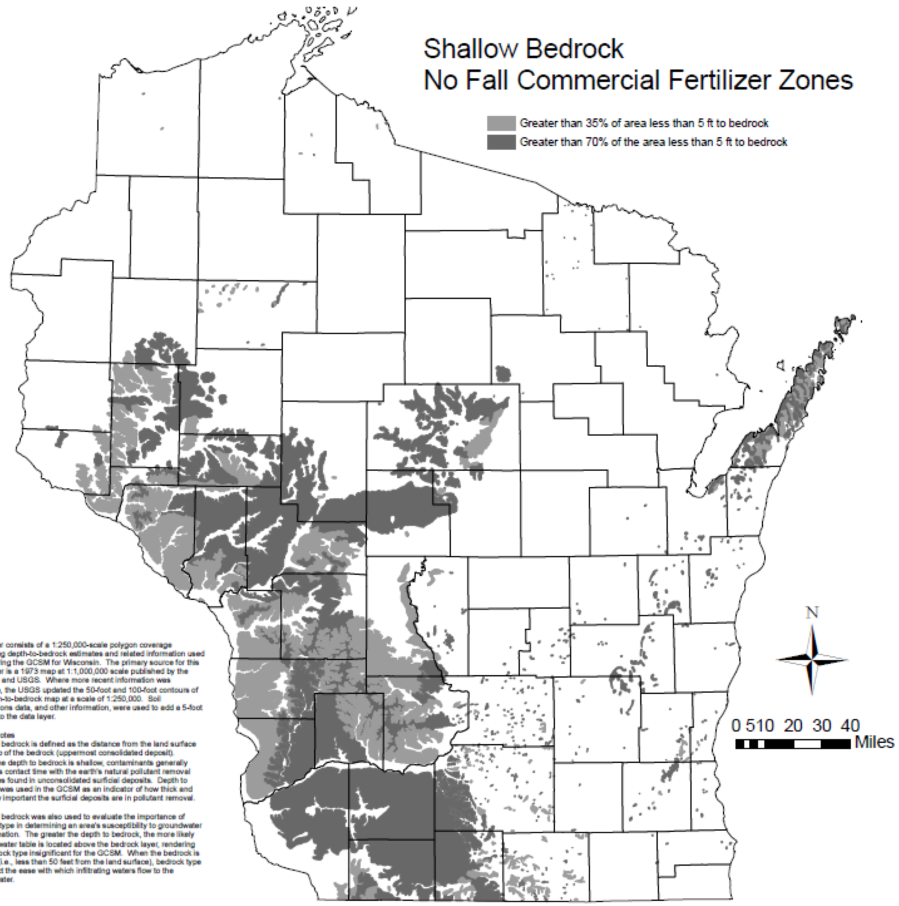


Elevated Nitrate Regions



Well drained soils and high density of corn/soybean cropping systems

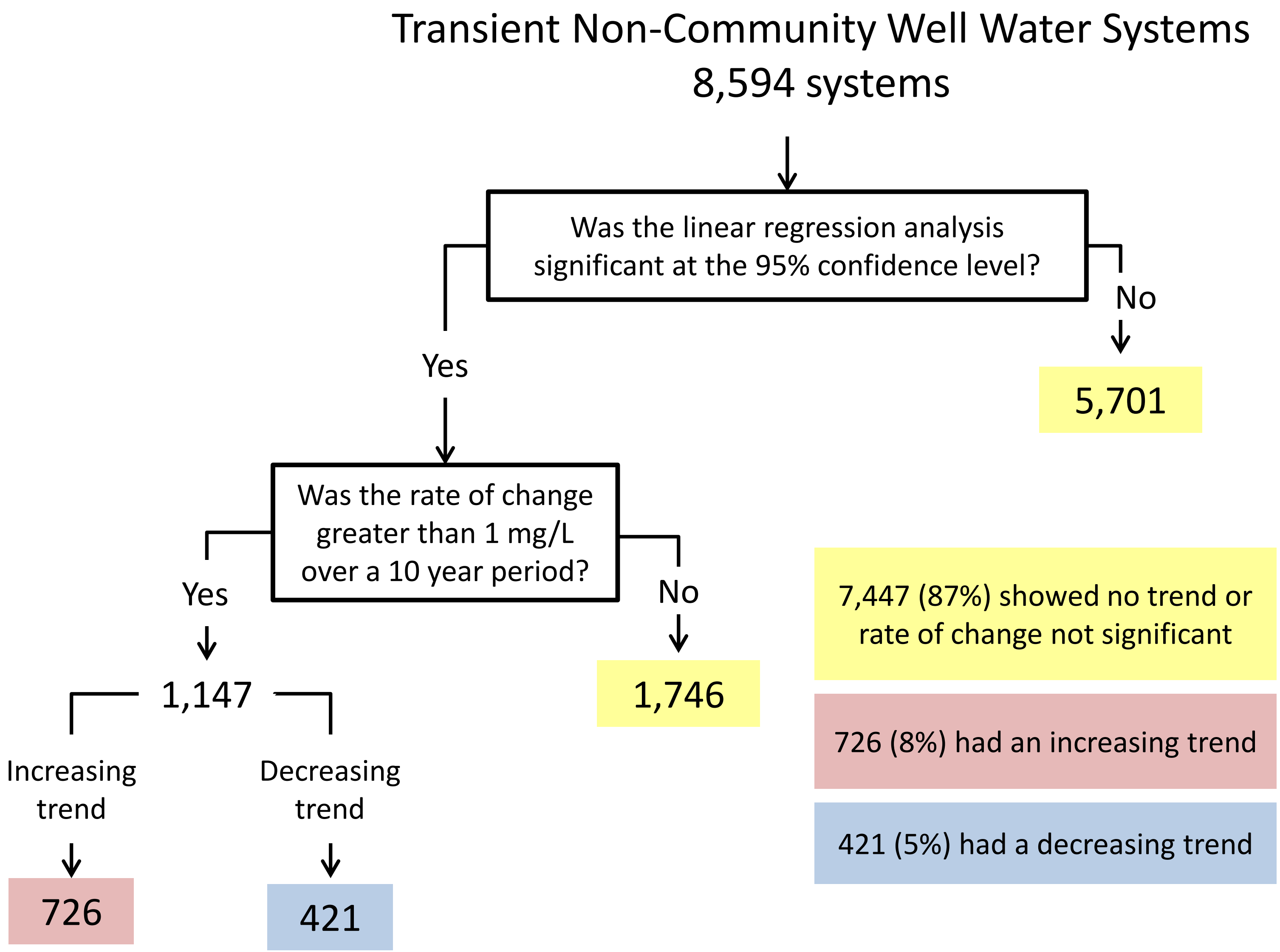
Shallow Bedrock
No Fall Commercial Fertilizer Zones



Source:
This layer consists of a 1:250,000-scale polygon coverage containing depth-to-bedrock estimates and related information used in preparing the GCSM for Wisconsin. The primary source for this data layer is a 1973 map at 1:1,000,000 scale published by the WGNHS and USGS. Where more recent information was available, the USGS updated the 50-foot and 100-foot contours of the depth-to-bedrock map at a scale of 1:250,000. Soil associations data, and other information, were used to add a 5-foot contour to the data layer.

Usage Notes
Depth to bedrock is defined as the distance from the land surface to the top of the bedrock (uppermost consolidated deposit). Where the depth to bedrock is shallow, contaminants generally have less contact time with the earth's natural pollutant removal processes found in unconsolidated surficial deposits. Depth to bedrock was used in the GCSM as an indicator of how thick and thus how important the surficial deposits are in pollutant removal.

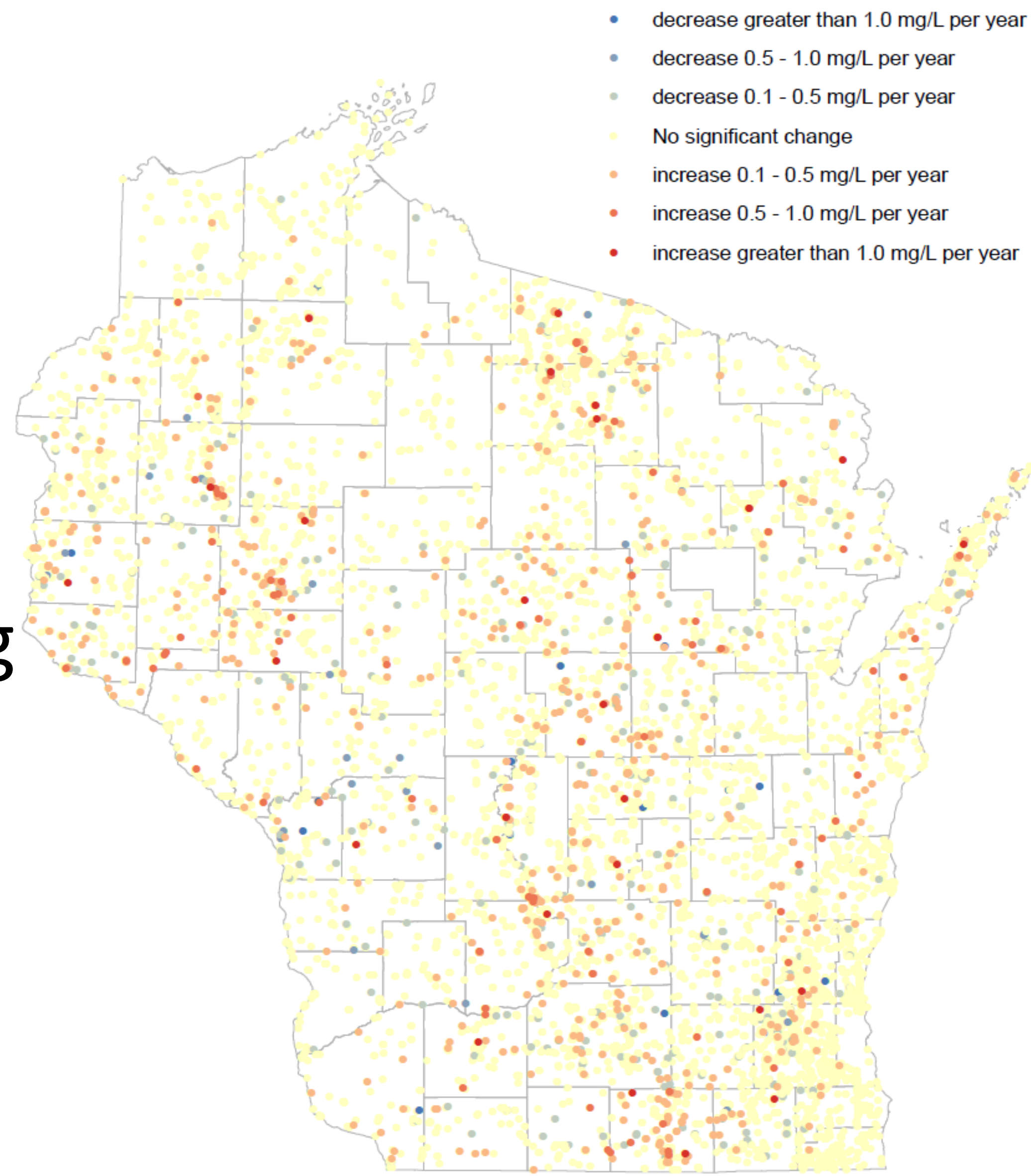
Depth to bedrock was also used to evaluate the importance of bedrock type in determining an area's susceptibility to groundwater contamination. The greater the depth to bedrock, the more likely that the water table is located above the bedrock layer, rendering the bedrock type insignificant for the GCSM. When the bedrock is shallow (i.e., less than 50 feet from the land surface), bedrock type can affect the ease with which infiltrating waters flow to the groundwater.


Transient Non-Community Well Water Systems
8,594 systems
Was the linear regression analysis significant at the 95% confidence level?
Yes
No
5,701
Was the rate of change greater than 1 mg/L over a 10 year period?
Yes
No
1,147
1,746
Increasing trend
Decreasing trend
726
421
7,447 (87%) showed no trend or rate of change not significant
726 (8%) had an increasing trend
421 (5%) had a decreasing trend

Transient Non-Comm Systems

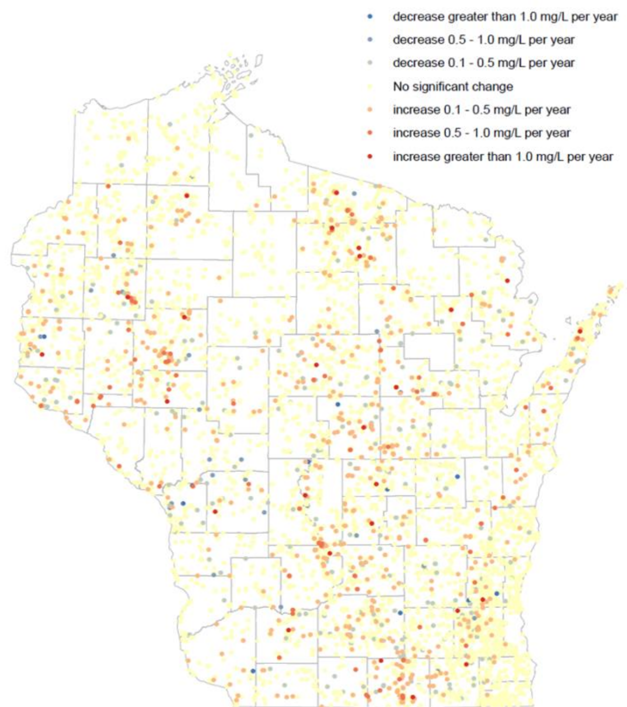
Linear Regression Results

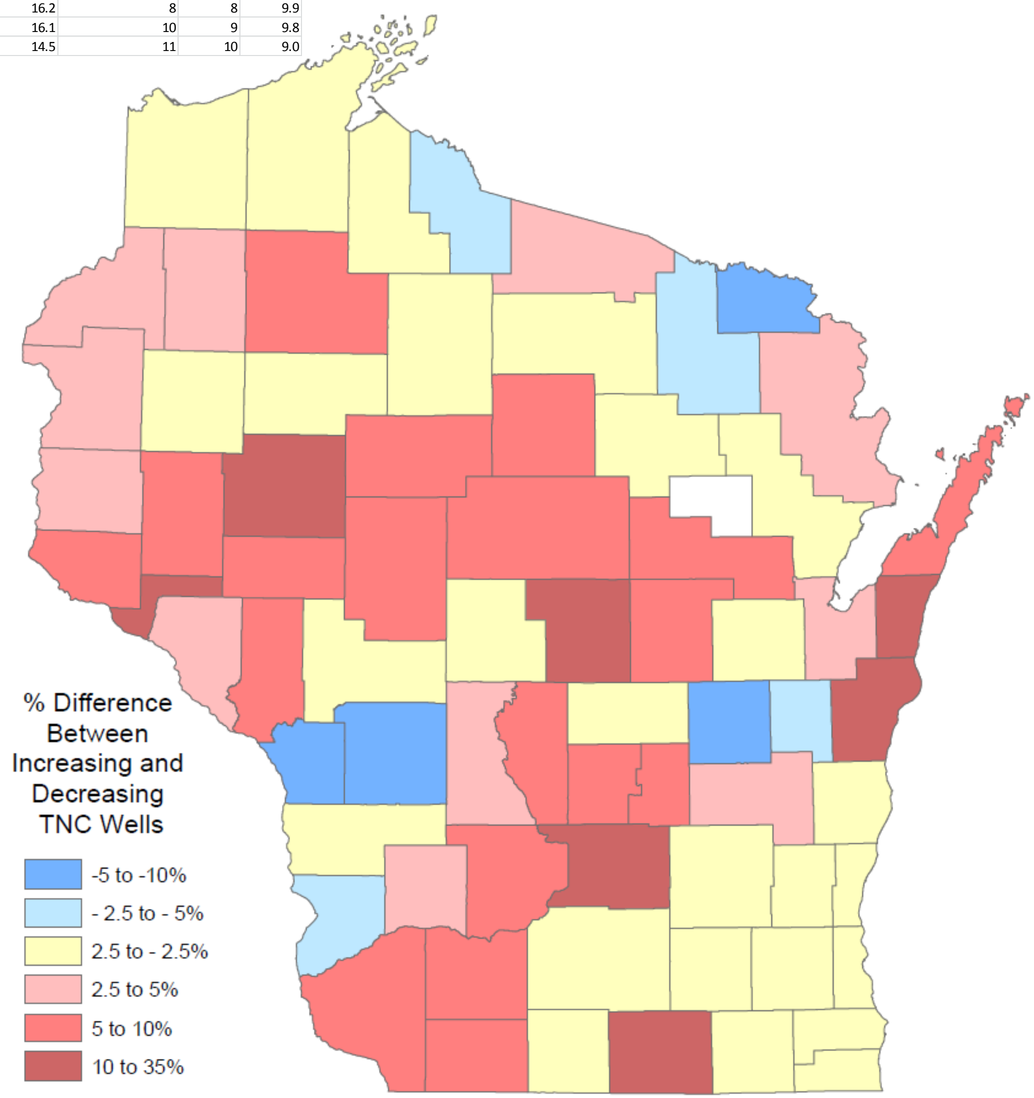
- Orange-Red – Increasing
- Blue – Decreasing
- Yellow – no significant trend



% Difference = % Increasing - % Decreasing

CTY_NAME	N	N*	Mean	SE Mean	StDev	SIG_DECREASE	NOT_SIG	SIG_INCREASE	TOTAL	% DECREASE	% NO CHANGE	% INCREASE	% INCREASE_RANK	MEAN_RA	%_differe
Pepin	21	0	0.333	0.105	0.483	0	14	7	21	0.0	66.7	33.3	1	1	33.3
Rock	160	0	0.2438	0.0441	0.5579	10	101	49	160	6.3	63.1	30.6	2	2	24.4
Chippewa	169	0	0.1183	0.0383	0.4978	12	125	32	169	7.1	74.0	18.9	4	3	11.8
Manitowoc	68	0	0.1176	0.0535	0.4415	3	54	11	68	4.4	79.4	16.2	9	4	11.8
Portage	118	0	0.1102	0.0522	0.5667	13	79	26	118	11.0	66.9	22.0	3	5	11.0
Kewaunee	48	0	0.1042	0.0446	0.3087	0	43	5	48	0.0	89.6	10.4	24	6	10.4
Columbia	119	0	0.1008	0.0468	0.5108	10	87	22	119	8.4	73.1	18.5	6	7	10.1
Marathon	191	0	0.0995	0.0337	0.4652	12	148	31	191	6.3	77.5	16.2	8	8	9.9
Shawano	112	0	0.0982	0.0439	0.4642	7	87	18	112	6.3	77.7	16.1	10	9	9.8
Sauk	166	0	0.0904	0.034	0.4379	9	133	24	166	5.4	80.1	14.5	11	10	9.0





Summary
UWEX Private Well Project

Sauk County Well Water Testing
Town of Spring Green

12/29/2011
3:55 PM

Total Number Samples: 146

Sample Dates: 3/14/1988 to 12/13/2011

Reason for Test		Last Test (yr		Problems		Treatment Sys		Depth (ft) Well		Casing	Water	Well Diam (in)	
Curious	18 %	Never	2 %	Color	3 %	Softener	40 %	... 25	3 %	1 %	9 %	... 3	33 %
Problems	7 %	< 1	3 %	Taste	7 %	R/O	3 %	26-50	12 %	9 %	8 %	4 - 9	28 %
Regular	5 %	1 - 2	6 %	Odor	5 %	Carb Filt	<1 %	51-100	3 %	5 %	4 %	10 - 18	0 %
Required	0 %	2 - 5	21 %	Corr	1 %	Neutral	0 %	101-150	5 %	6 %	<1 %	18 +	0 %
Bac Retest	0 %	5 - 10	21 %	Health	0 %	Part Filt	3 %	151-200	4 %	0 %	3 %		
Disinfect	0 %	10 +	11 %	Other	2 %	Iron Filt	<1 %	201 ...	3 %	0 %	0 %		
Infant...	0 %	Unk	18 %	None	58 %	Other	2 %						
Other	5 %												

pH		
... 5.00	0	0 %
5.01 - 6.00	0	0 %
6.01 - 7.00	4	3 %
7.01 - 8.00	24	21 %
8.01 - 9.00	89	76 %
9.01 ...	0	0 %
Avg: 7.89	for	117 Samples

Conductivity (umhos/cm)		
... 100	5	4 %
101 - 250	24	21 %
251 - 500	56	48 %
501 - 750	28	24 %
751 - 1000	4	3 %
1001 ...	0	0 %
Avg: 393	for	117 Samples

Alkalinity (mg/L CaCO3)		
... 50	9	8 %
51 - 100	43	37 %
101 - 200	31	26 %
201 - 300	32	27 %
301 - 400	2	2 %
401 ...	0	0 %
Avg: 139	for	117 Samples

Total Hardness (mg/L CaCO3)		
... 50	15	13 %
51 - 100	19	16 %
101 - 200	42	36 %
201 - 300	34	29 %
301 - 400	6	5 %
401 ...	1	<1 %
Avg: 160	for	117 Samples

Nitrate (mg/L as N)		
None Detected	8	6 %
... 2.0	43	30 %
2.1 - 5.0	21	15 %
5.1 - 10.0	27	19 %
10.1 - 20.0	20	14 %
20.1 ...	24	17 %
Avg: 8.8	for	143 Samples

Chloride (mg/L)		
None Detected	1	<1 %
... 10	49	42 %
11 - 50	59	50 %
51 - 100	7	6 %
101 - 200	1	<1 %
201 ...	0	0 %
Avg: 18.2	for	117 Samples

31% of private well samples above the standard.

Saturation Index		
... -3.0	3	3 %
-2.9 - -2.0	3	3 %
-1.9 - -1.0	4	3 %
-0.9 - 0.0	33	28 %
0.1 - 1.0	70	60 %
1.1 ...	4	3 %
Avg: 0.1	for	117 Samples

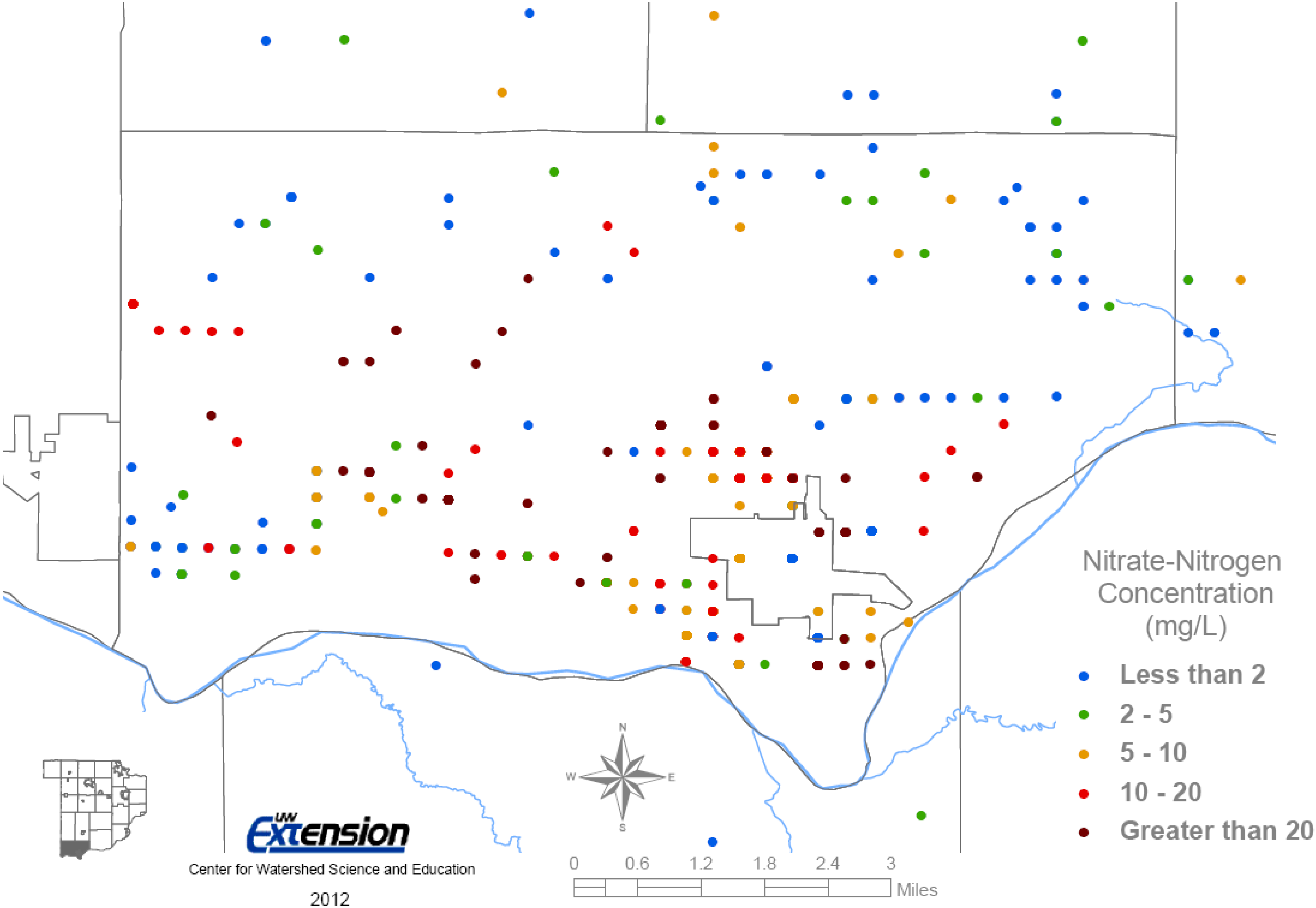
Coliform Bacteria		
Bact Samples	119	
Pos Bacteria	7	6 %

E. coli Bacteria		
E. coli Samples	6	
Pos E. coli	0	0 %

Atrazine Screen* (ppb)		
None Detected	23	61 %
... 0.3	13	34 %
0.4 - 1.0	2	5 %
1.1 - 2.0	0	0 %
2.1 - 3.0	0	0 %
3.1 ...	0	0 %
Avg: <0.1	for	38 Samples

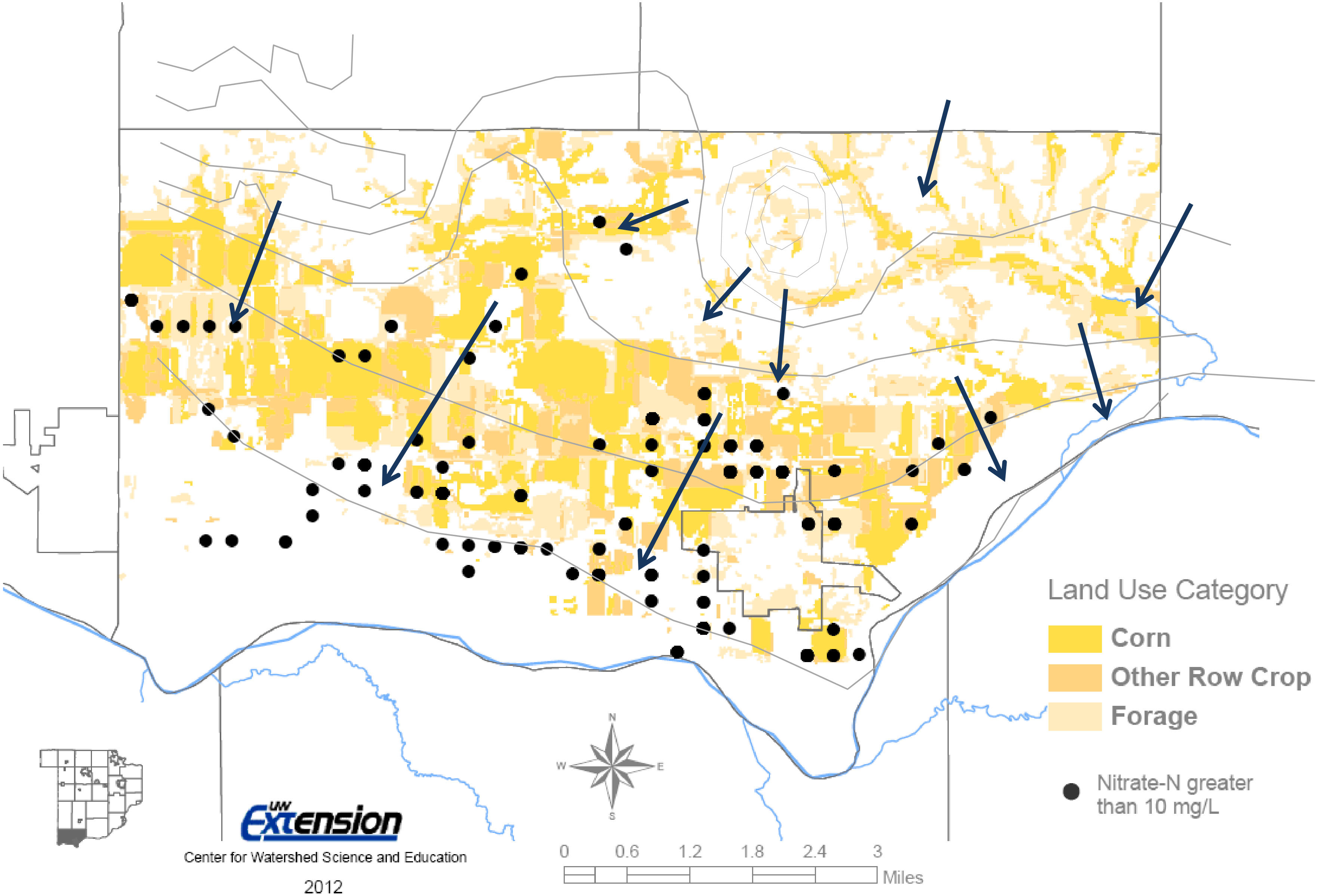
*Triazine screen before June 2008, then Diaminochlorotriazine (DACT).

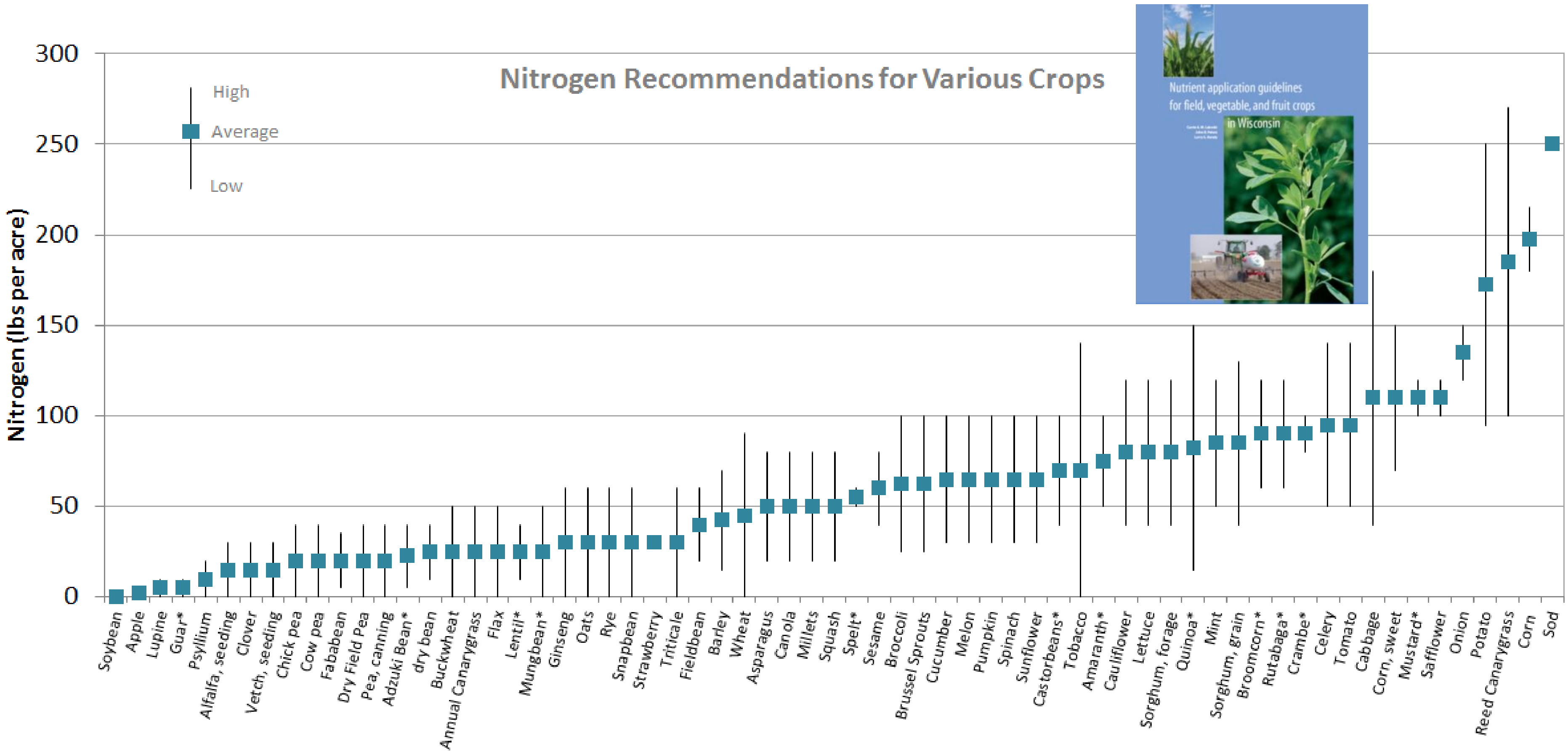
Town of Spring Green, Sauk County, WI



Disclaimer: This map contains voluntarily submitted private well water data from the Center for Watershed Science and Education. It also contains data from the Wisconsin Dept. of Natural Resources Groundwater Retrieval Network. It does not represent all wells and is not considered a scientific study.

Town of Spring Green, Sauk County, WI

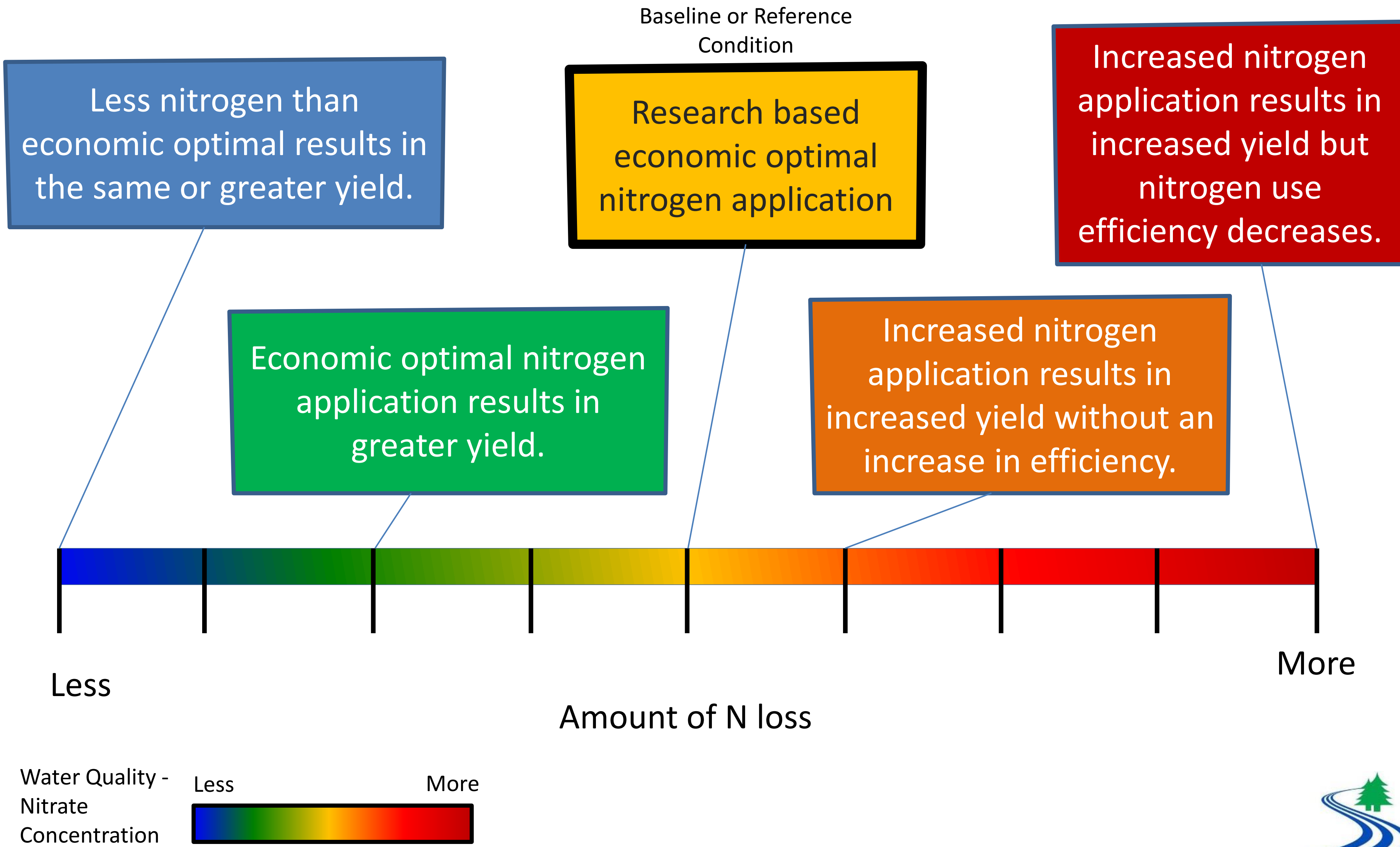




*Alternative Field Crops Manual, 1989. University of Minnesota and University of Wisconsin -Madison
Nutrient application guidelines for field, vegetable and fruit crops

Water quality as a function of Nitrogen Use Efficiency

Studies show efficiency typically about 30-50% (Cassman et. al. 2002)

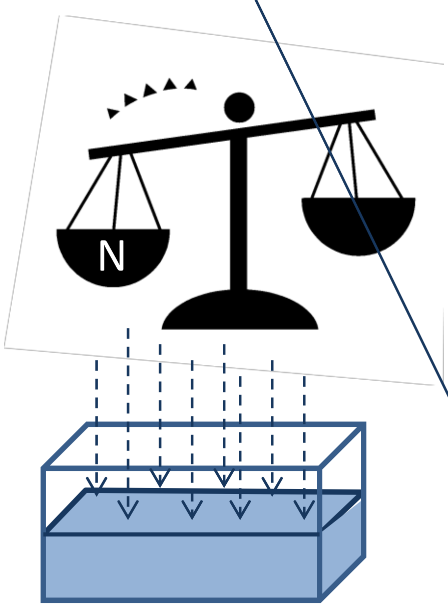


How much nitrogen does it take to raise groundwater nitrate 1 ppm?

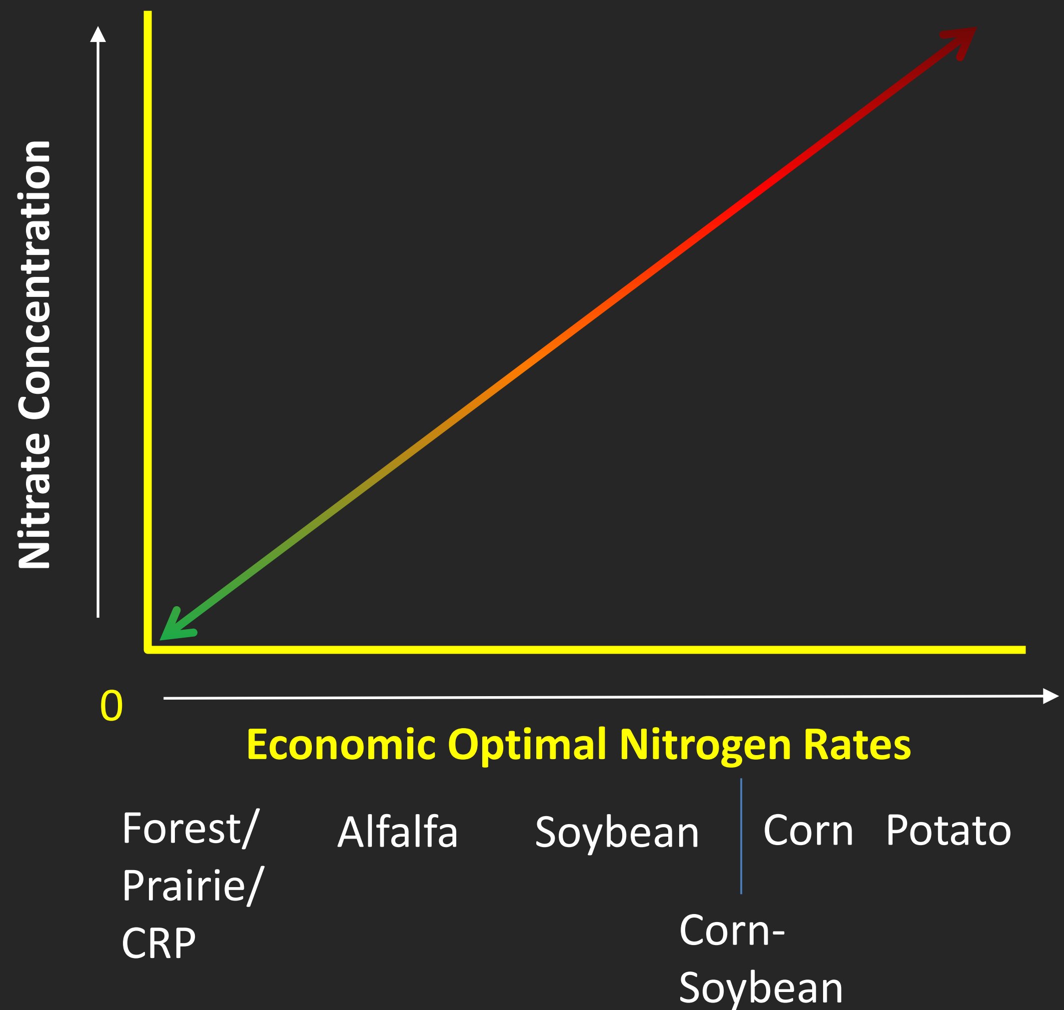
The actual amount will vary based on the amount of recharge. For Wisconsin this is likely somewhere between 6 and 10 inches depending on where you live. For Spring Green we will assume that nitrogen not taken up by the plant will mineralize and nitrify.

$$\frac{8\ \text{in.}}{} \times \frac{10\ \text{mg}\ NO_3\text{-}N}{\text{liters}} \times \frac{43{,}560\ \text{ft}^2}{1\ \text{acre}} \times \frac{1\ \text{ft.}}{12\ \text{in.}} \times \frac{28.32\ \text{liters}}{1\ \text{ft}^3} \times \frac{1\ \text{g}}{1000\ \text{mg}} \times \frac{1\ \text{kg}}{1000\ \text{g}} \times \frac{2.2\ \text{lbs}}{1\ \text{kg}} = 18.1\ \text{lbs N per acre}$$

	Nitrate-Nitrogen Concentration (mg/L)									
	1	2	3	4	5	10	15	20	30	40
Inches of Recharge	lbs of Nitrogen per acre									
1	0.2	0.5	0.7	0.9	1.1	2.3	3.4	4.5	6.8	9.0
2	0.5	0.9	1.4	1.8	2.3	4.5	6.8	9.0	13.6	18.1
3	0.7	1.4	2.0	2.7	3.4	6.8	10.2	13.6	20.4	27.1
4	0.9	1.8	2.7	3.6	4.5	9.0	13.6	18.1	27.1	36.2
5	1.1	2.3	3.4	4.5	5.7	11.3	17.0	22.6	33.9	45.2
6	1.4	2.7	4.1	5.4	6.8	13.6	20.4	27.1	40.7	54.3
7	1.6	3.2	4.7	6.3	7.9	15.8	23.7	31.7	47.5	63.3
8	1.8	3.6	5.4	7.2	9.0	18.1	27.1	36.2	54.3	72.4
9	2.0	4.1	6.1	8.1	10.2	20.4	30.5	40.7	61.1	81.4
10	2.3	4.5	6.8	9.0	11.3	22.6	33.9	45.2	67.8	90.5



Generalized Nitrate Leaching Potential



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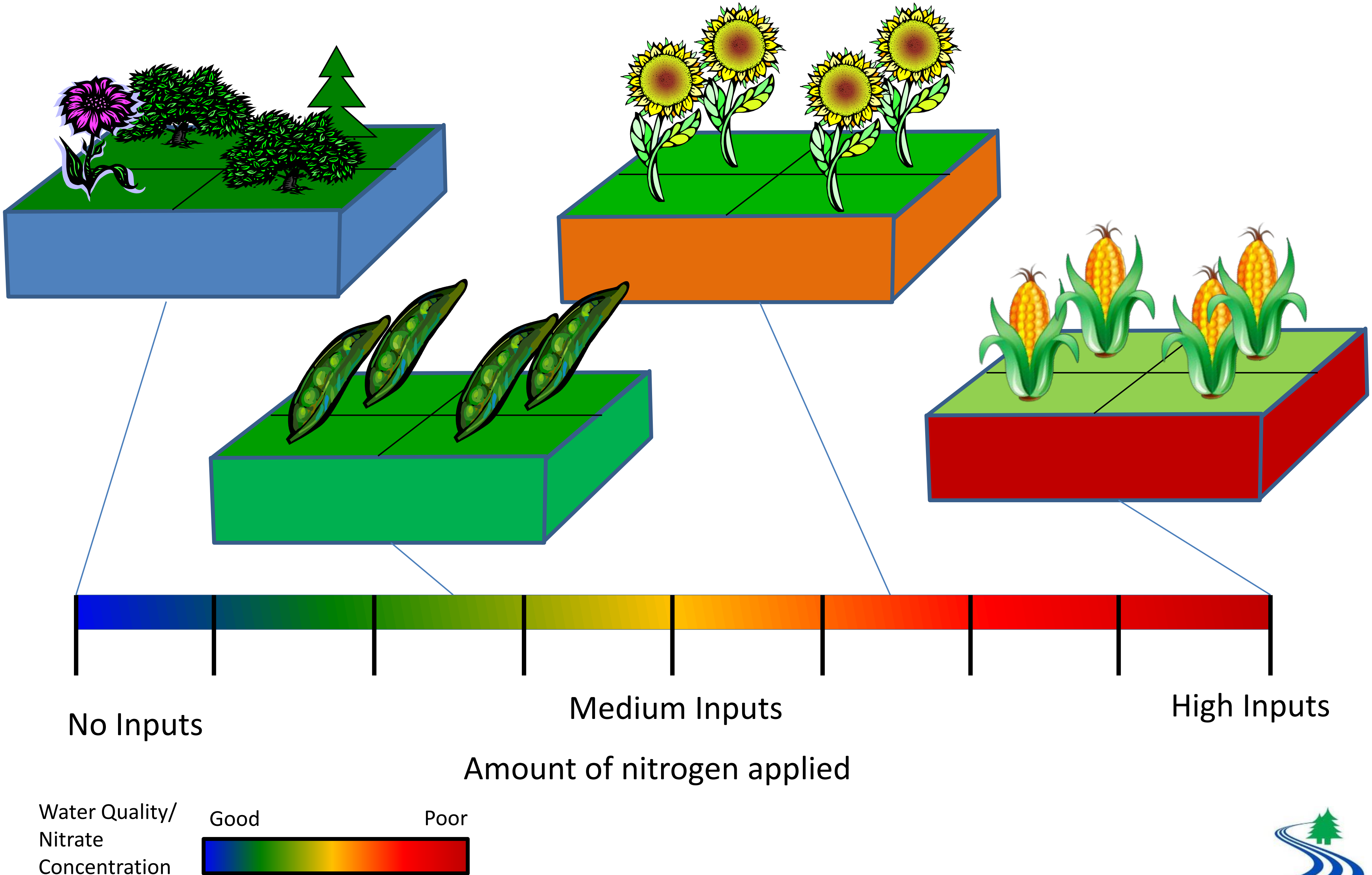
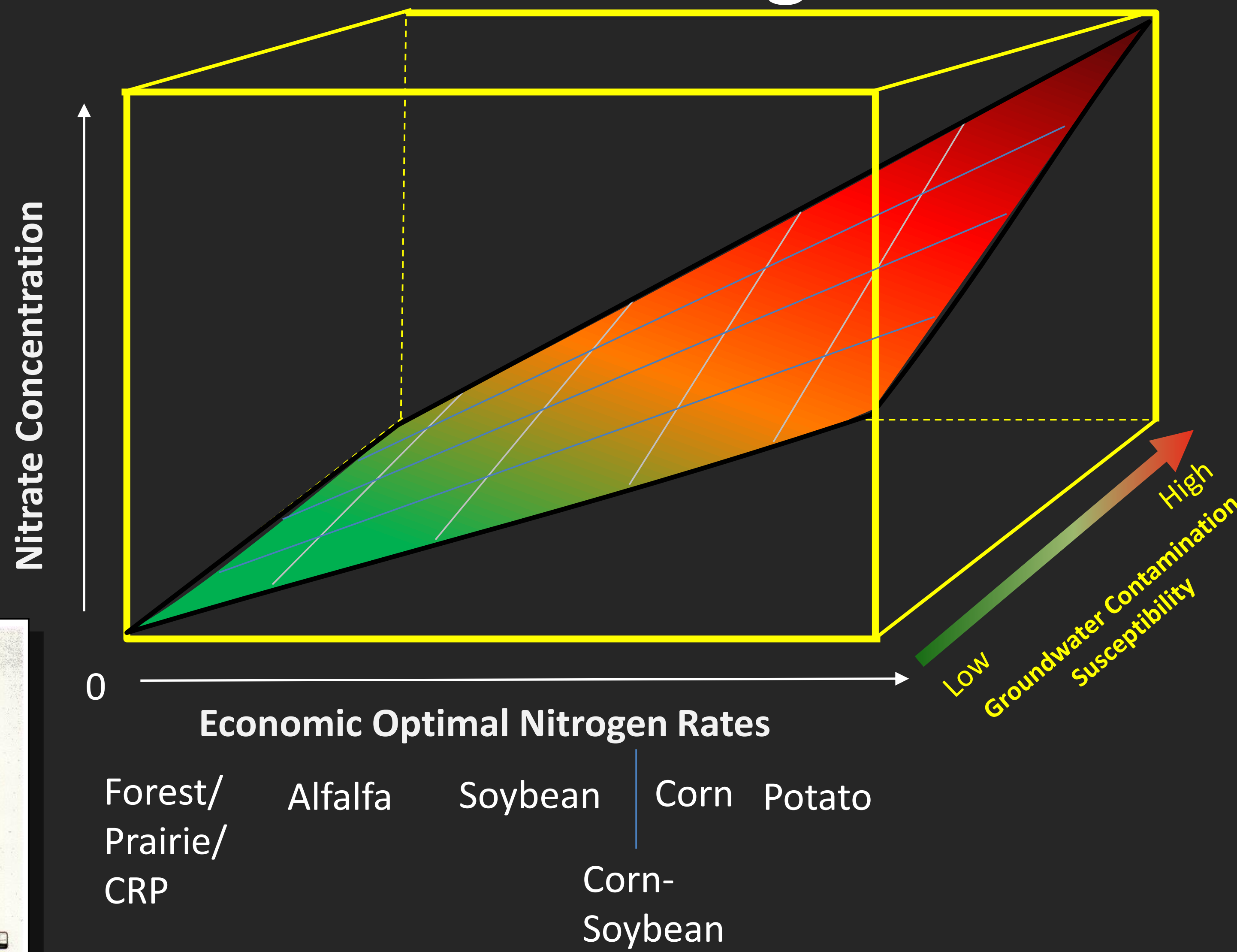
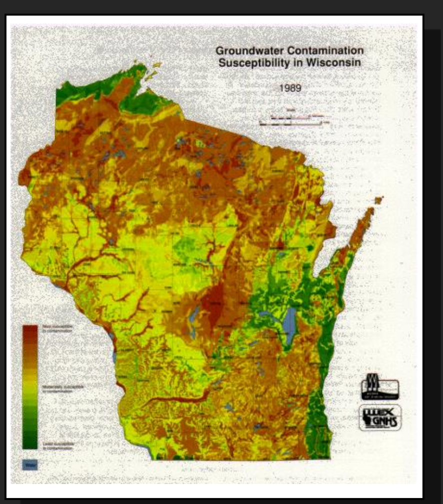
Water quality as a function of crop N recommendations



Generalized Nitrate Leaching Potential





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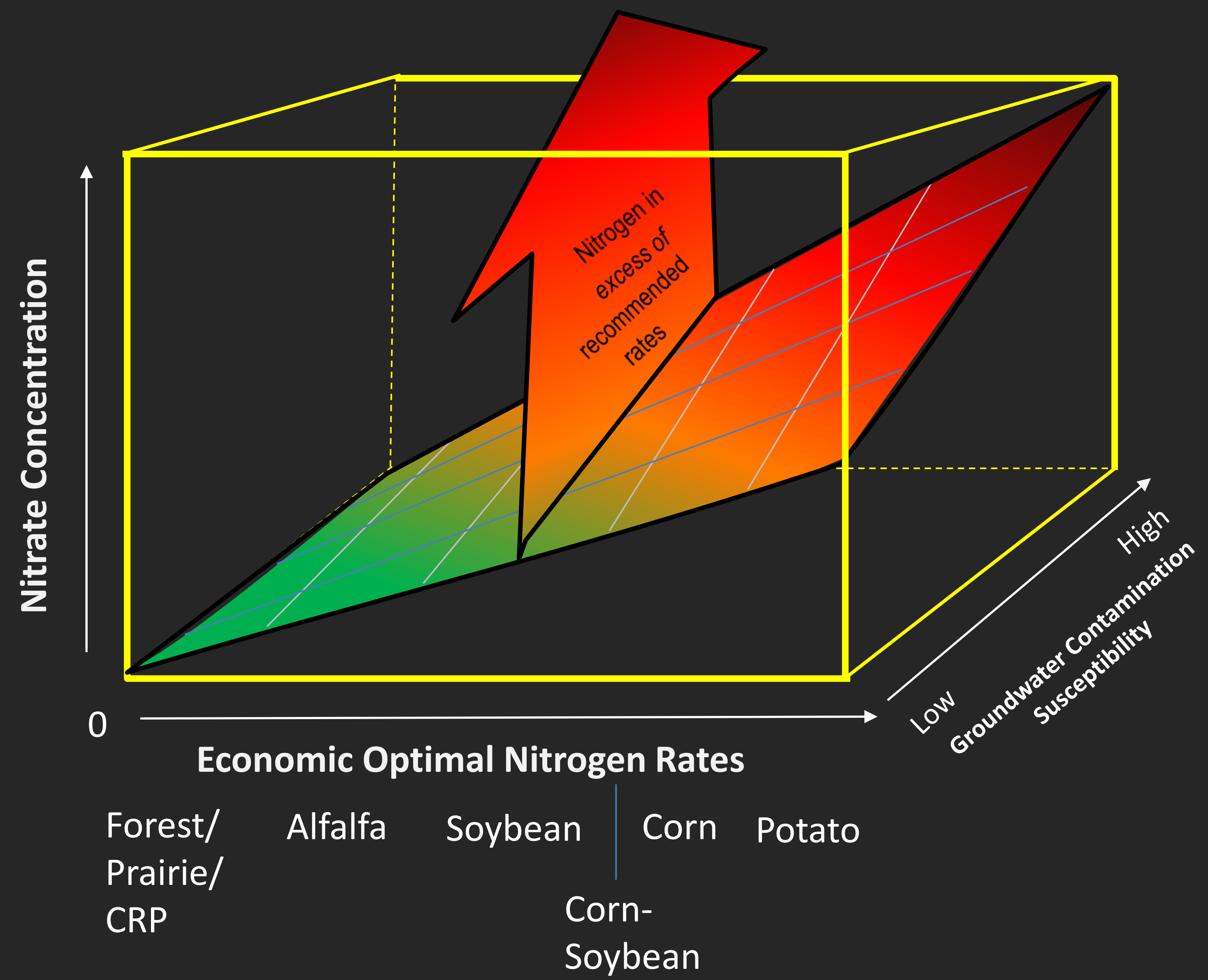
GW NO3-N = f(Crop N Requirements, Excess N, Soils, Geology)



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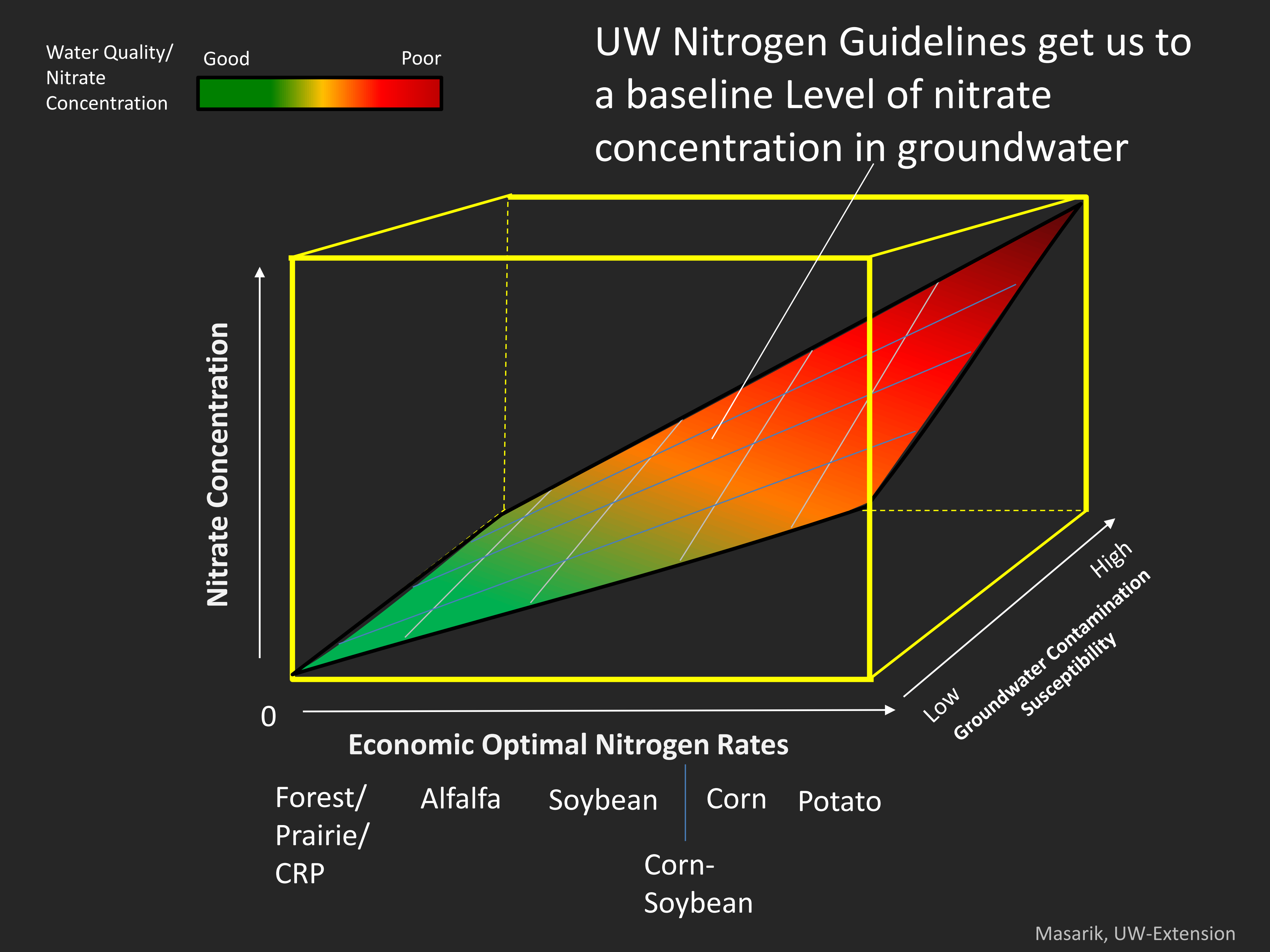

Water Quality/
Nitrate
Concentration
Good
Poor
UW Nitrogen Guidelines get us to a baseline Level of nitrate concentration in groundwater
Nitrate Concentration
0
Economic Optimal Nitrogen Rates
Low
High
Groundwater Contamination
Susceptibility
Forest/
Prairie/
CRP
Alfalfa
Soybean
Corn
Potato
Corn-
Soybean
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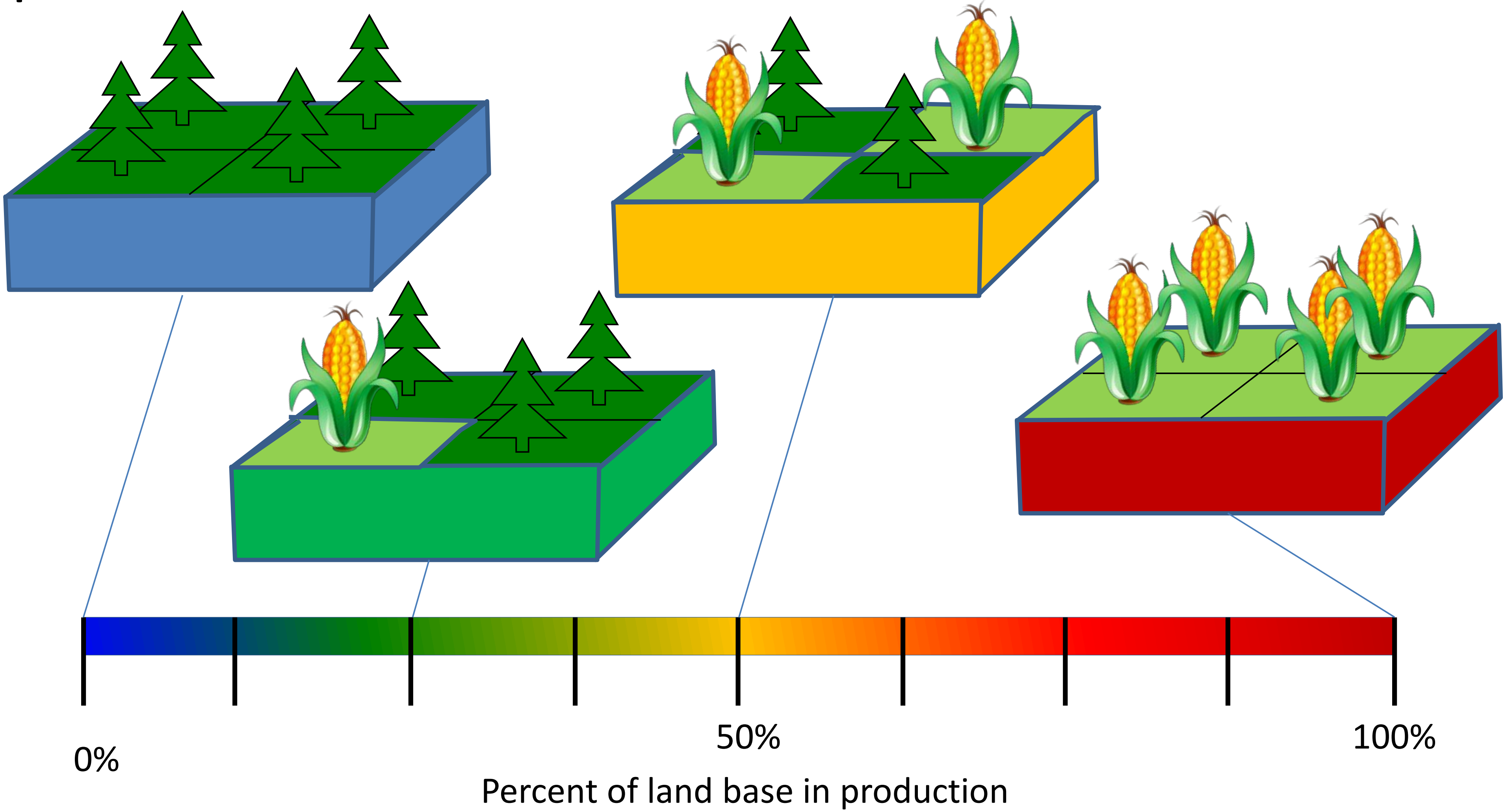
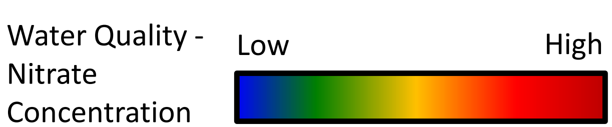
Water quality as a function of watershed area in production





Factors affecting nitrogen loss to groundwater

Somewhat Fixed

- Amount of nitrogen applied
  - As a function of crop type
  - Nitrogen application rate relative to economic optimum
- Percent of land base in production

Limited ability to adjust

- Nitrogen use efficiency

Out of our control

- Geology
- Soil Type
- Precipitation / Climate