Investigating Intra-Annual Variability of Well Water Quality in Lincoln Township

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Conservation
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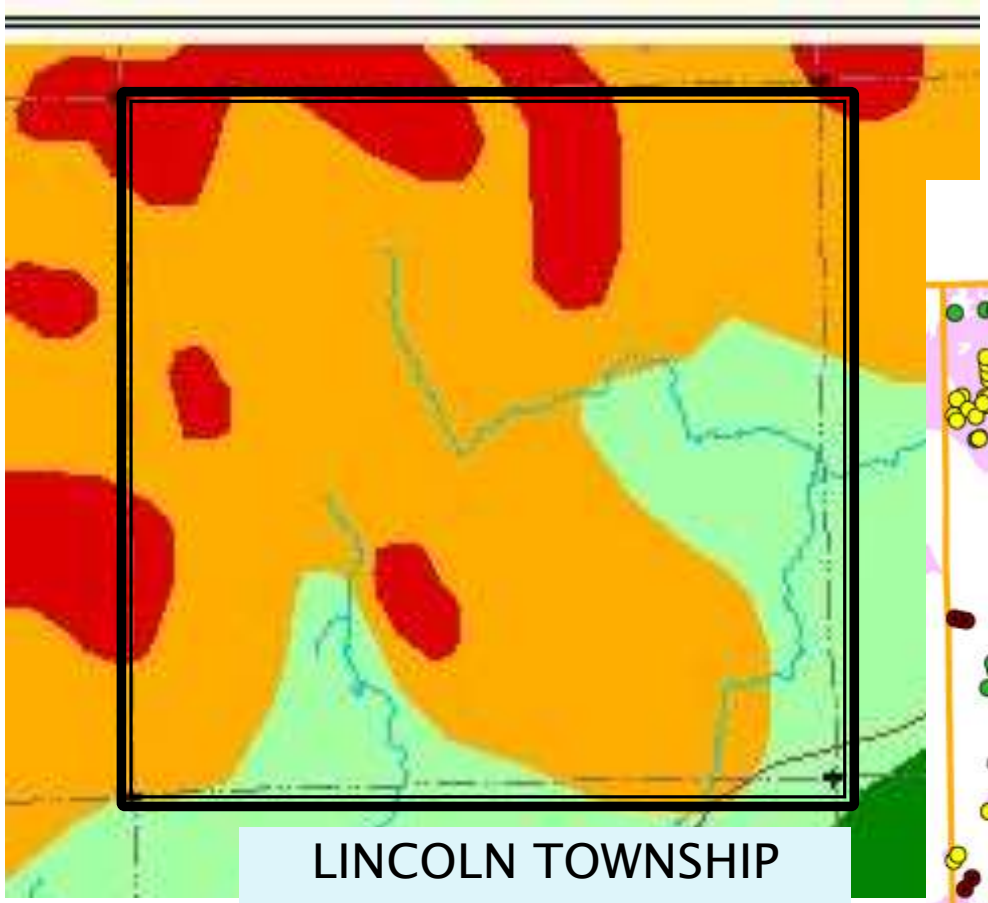
College of Natural Resources
University of Wisconsin-Stevens Point

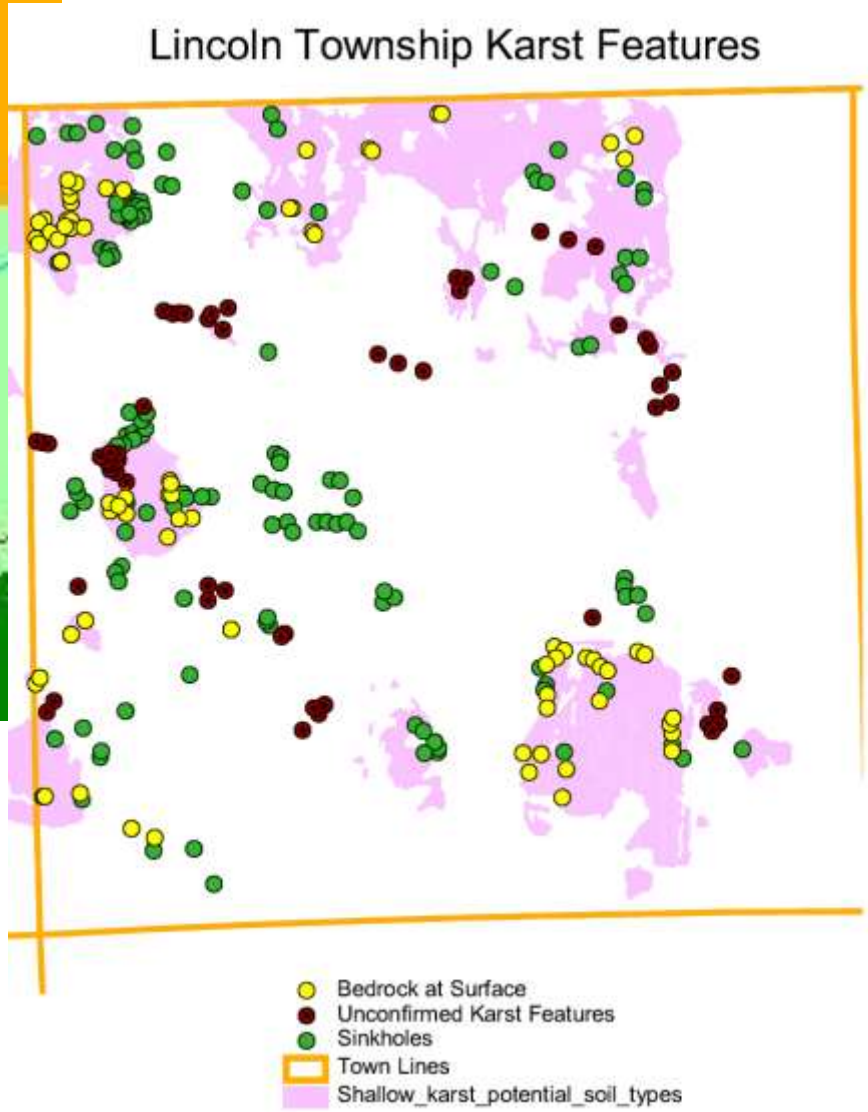
Lincoln Township: Background

- Silurian Dolomite bedrock Karst Aquifer
- Private Wells – Groundwater water supply
- 334 Households
- 384 Sanitary Permits (63 are holding tanks)
- 70% Agriculture; 21% Wetland; 6% Forest
- Approximately: 13,500 cows (dairy/calves/beef/heifers)

Susceptible Geology

Photos courtesy of Brown Co. LCD



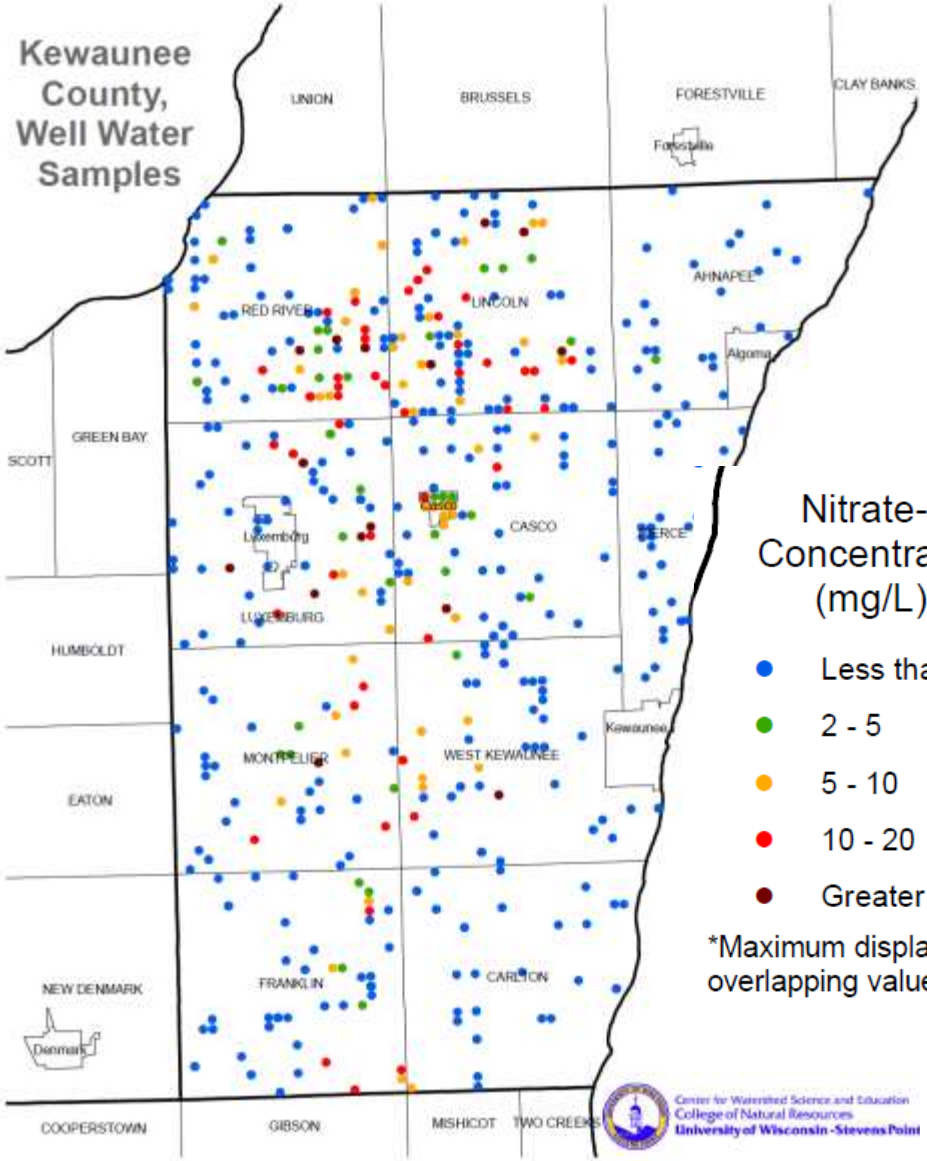


Depth to Bedrock:

- < 5 ft (>70% of area)
- < 5 ft (35% - 70% of area)
- 5 to 50 ft
- 50 to 100 ft
- > 100 ft

Previous Sampling Data

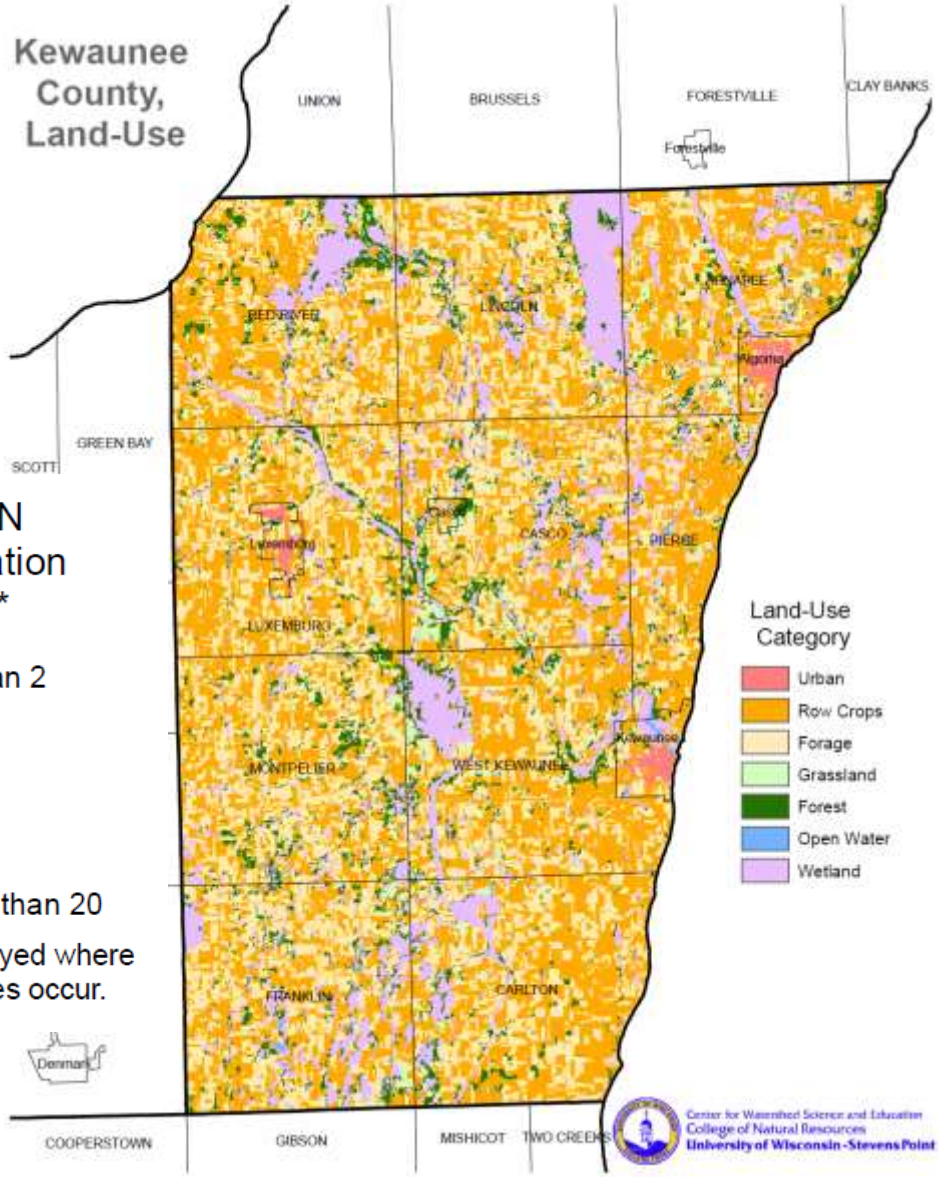
- 2004-2014: 159 Well Water Samples
  (UW-Stevens Point)
- 32% Positive for Coliform Bacteria
  State Average 15%
- 20% >10 ppm nitrate
  State Average 9%
- 50% – nitrate concentrations above background/natural (2 ppm)



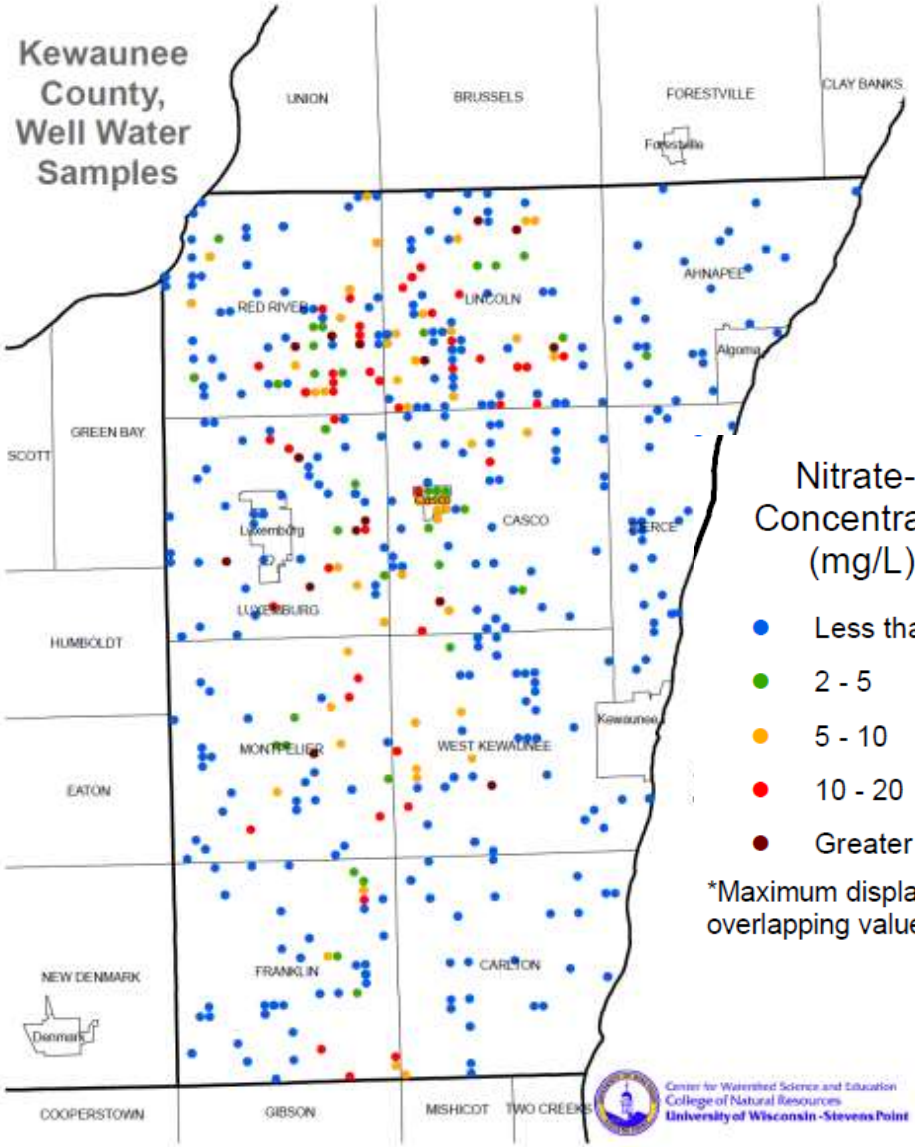
Nitrate-N Concentration (mg/L)*

- Less than 2
- 2 - 5
- 5 - 10
- 10 - 20
- Greater than 20

*Maximum displayed where overlapping values occur.



Disclaimer: This map represents data in the Center for Watershed Science and Education database for the period from 2004-2014. It does not represent all known private well tests and does not represent a scientifically conducted study.



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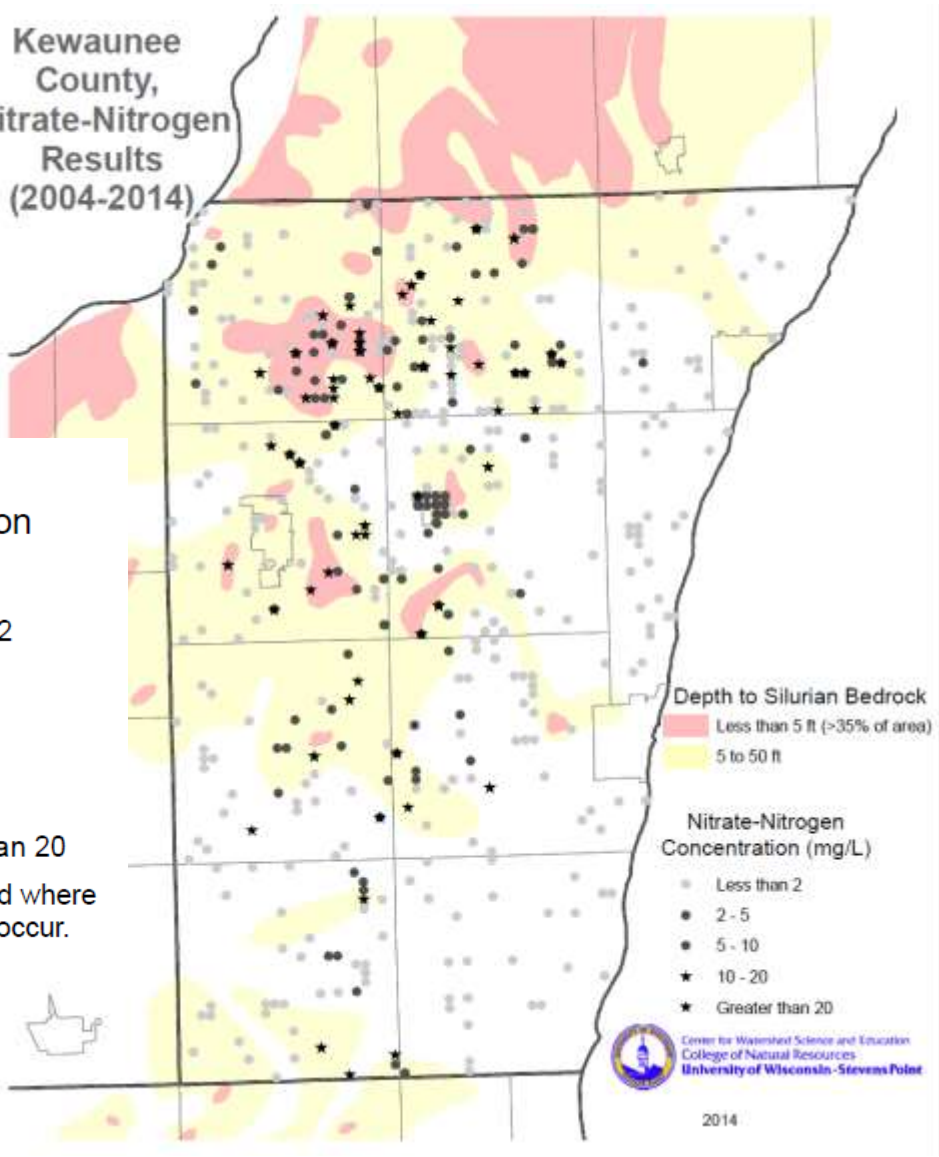

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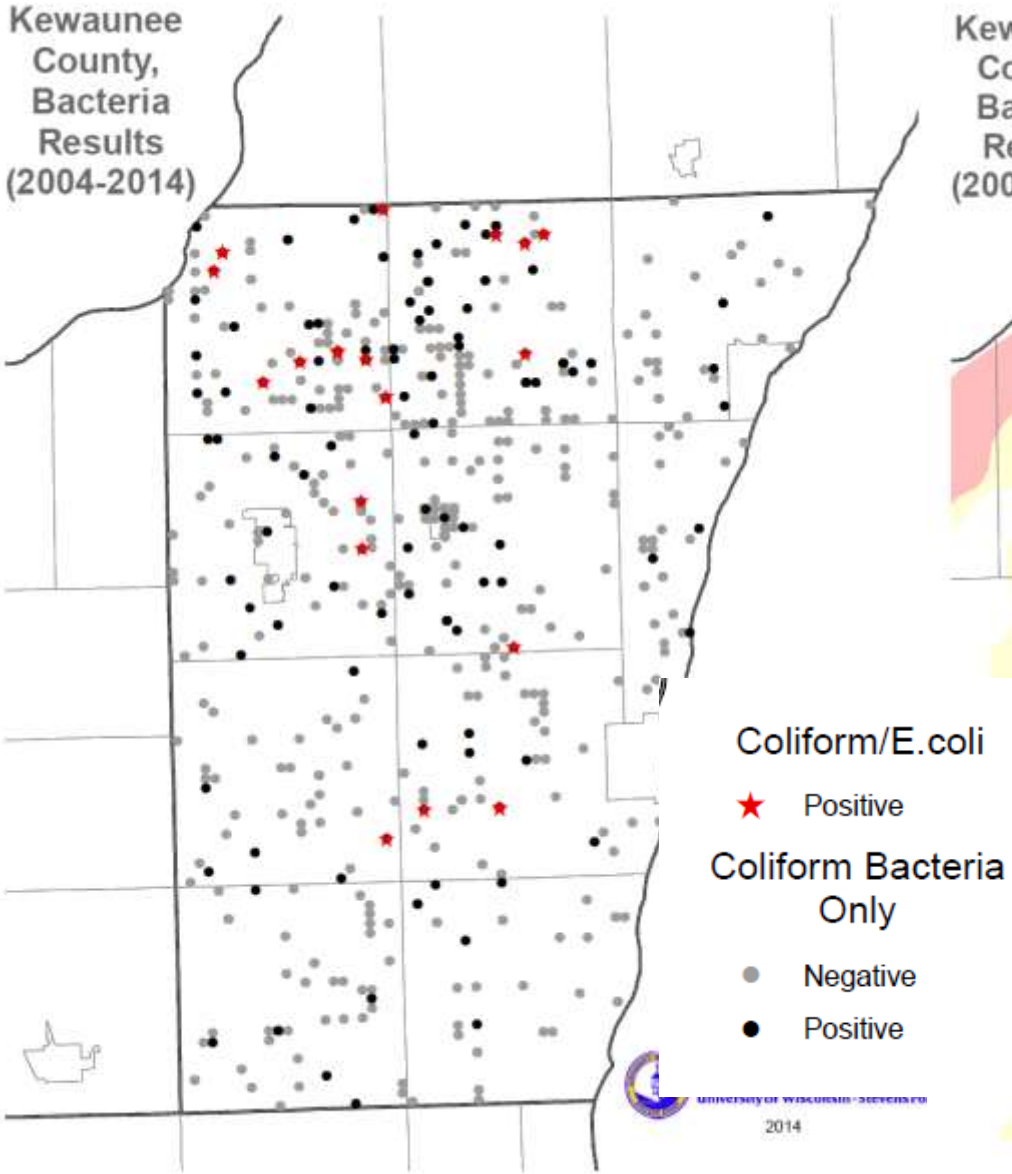
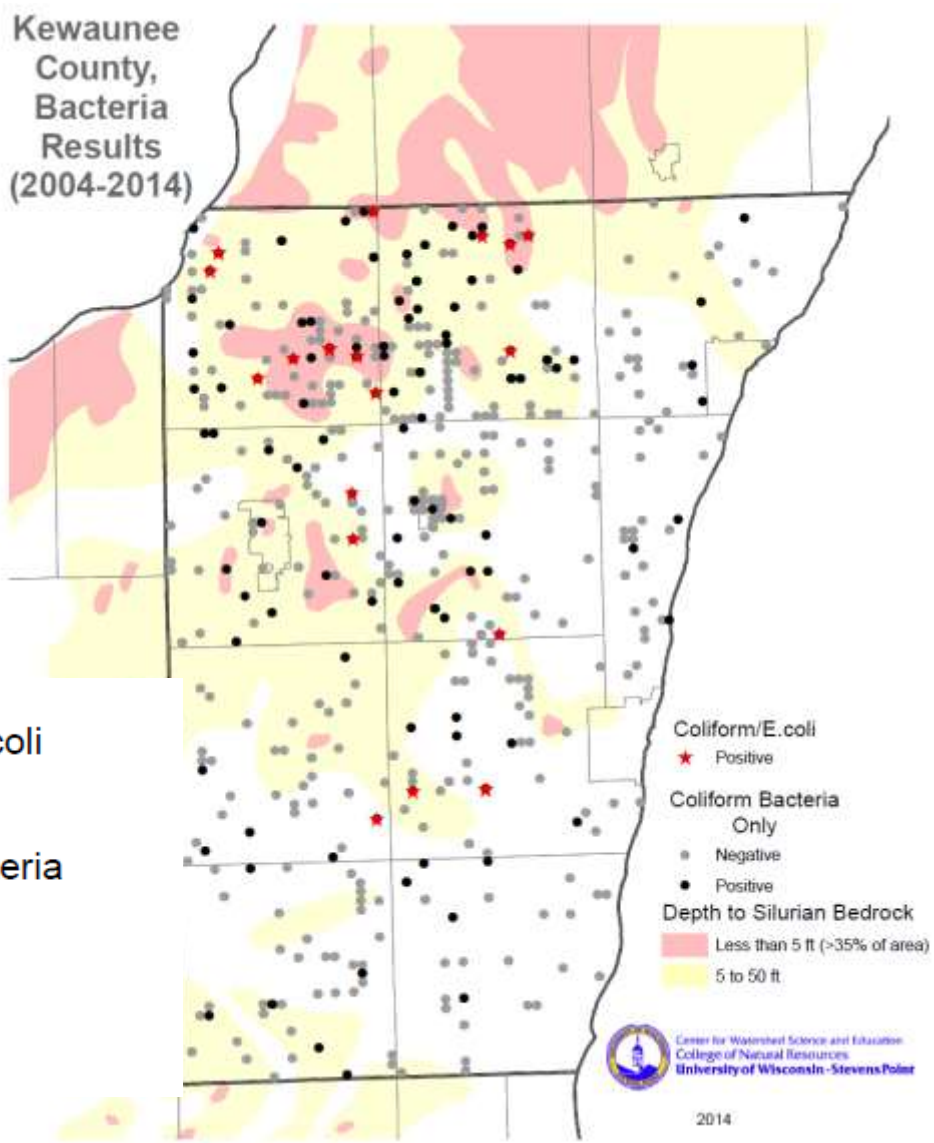

Kewaunee County, Bacteria Results (2004-2014)
Coliform/E.coli
Positive
Coliform Bacteria Only
Negative
Positive
2014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Objectives

1. Establish Baseline Data of the Intra-Annual Variation of Well Water Quality for 10 wells.
2. Investigate Groundwater and Land-Use Interactions in the Region
3. Recommend a Long-Term Strategy for Monitoring Lincoln Township's Well Water

Methodology

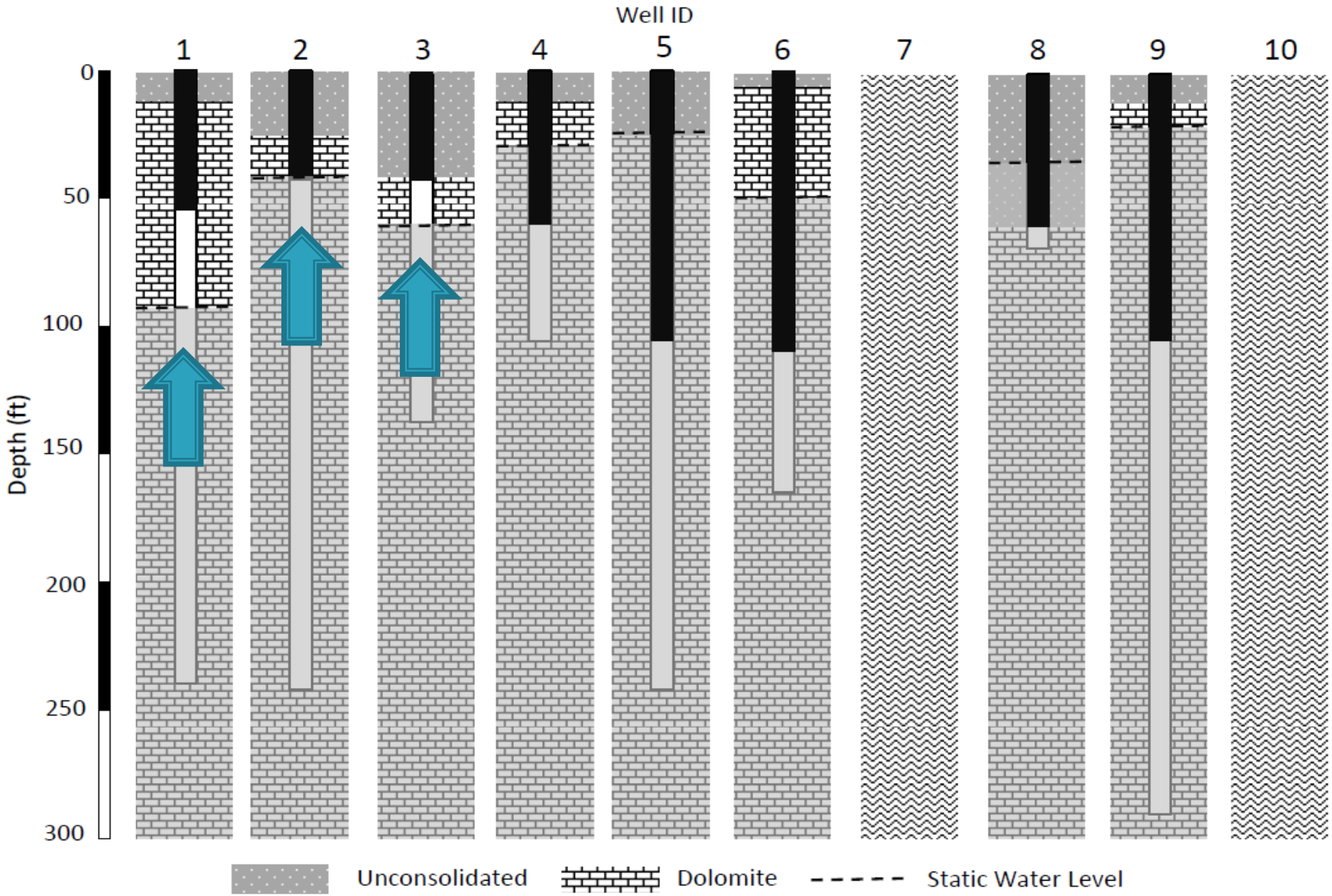
- 10 wells
  - Preferred past Bacteria Positive &/or > 10ppm Nitrates
  - Landowner Permission
  - Variety of Well & Casing Depths

- 12 months (June 2013 – May 2014)
- Pre-Selected Dates
- All Wells Sampled by Davina Bonness (LWCD)
- Tested at UWSP WEAL Lab

Well ID Location

		5			
			1		
2					
9, 10					
	3, 8		4, 6		
7					

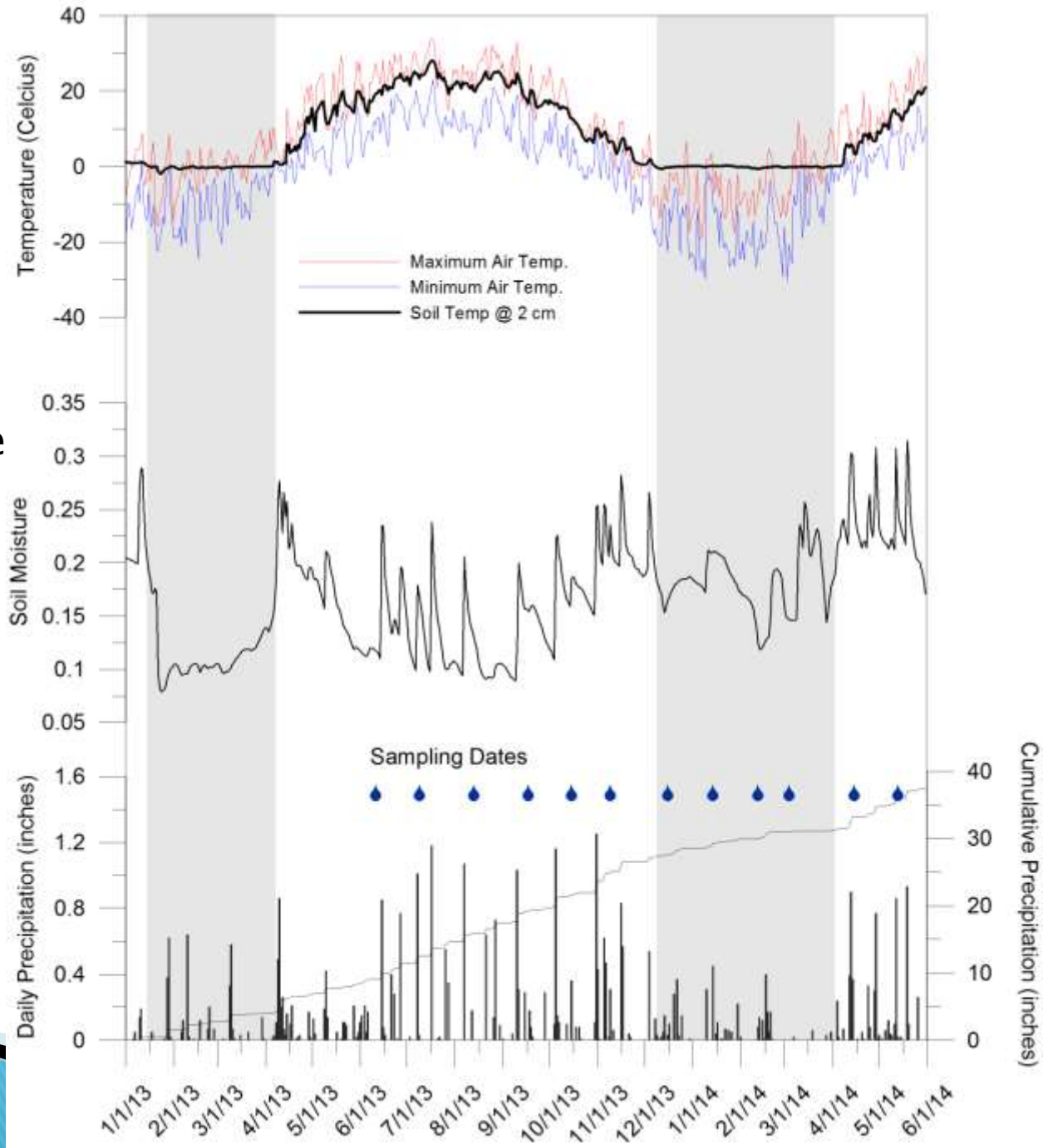
Well Construction Report Diagram



Testing Parameters

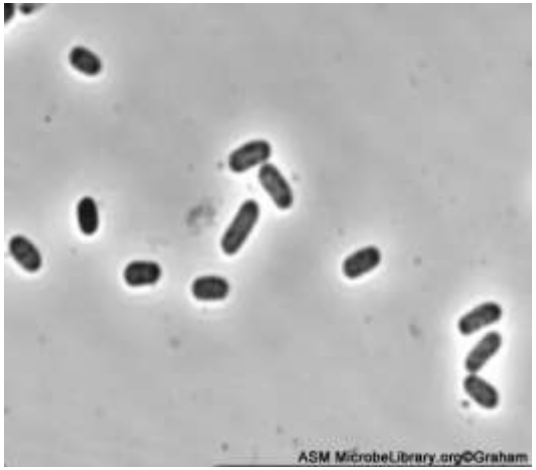
- Total Coliform / E-Coli (MPN cfu/100mL)
- Nitrate-nitrogen (mg/L)
- Chloride (mg/L)
- Total Hardness (as mg/L $CaCO_3$)
- Alkalinity (as mg/L $CaCO_3$)
- Conductivity (µs/cm)
- pH

Weather
Soil Temp
Soil Moisture



Coliform bacteria

- Any present makes water unsafe
- Not harmful themselves, but may indicate pathogens (*E.coli*)
- Pathogens can cause gastrointestinal disease, cholera, hepatitis
- Sources:
  - Sampling error
  - Soils
  - Human and animal waste
  - Well construction faults
  - Maintenance issues



Unsafe – Present --total counts

Safe – Absent

COLIFORM BACTERIA

- Detected at least once in 6 wells
- Levels were generally low
- No Wells tested Positive for E-Coli

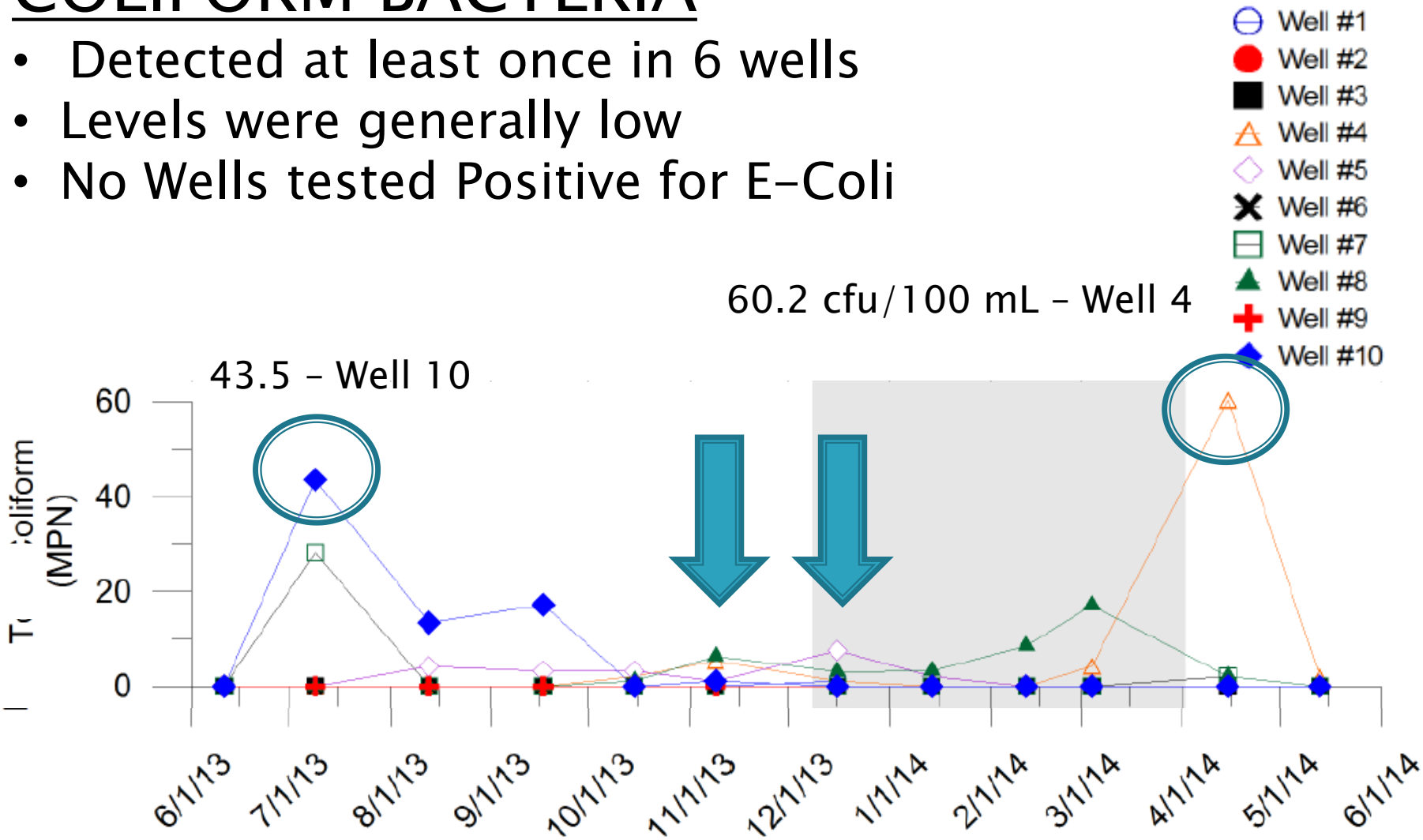
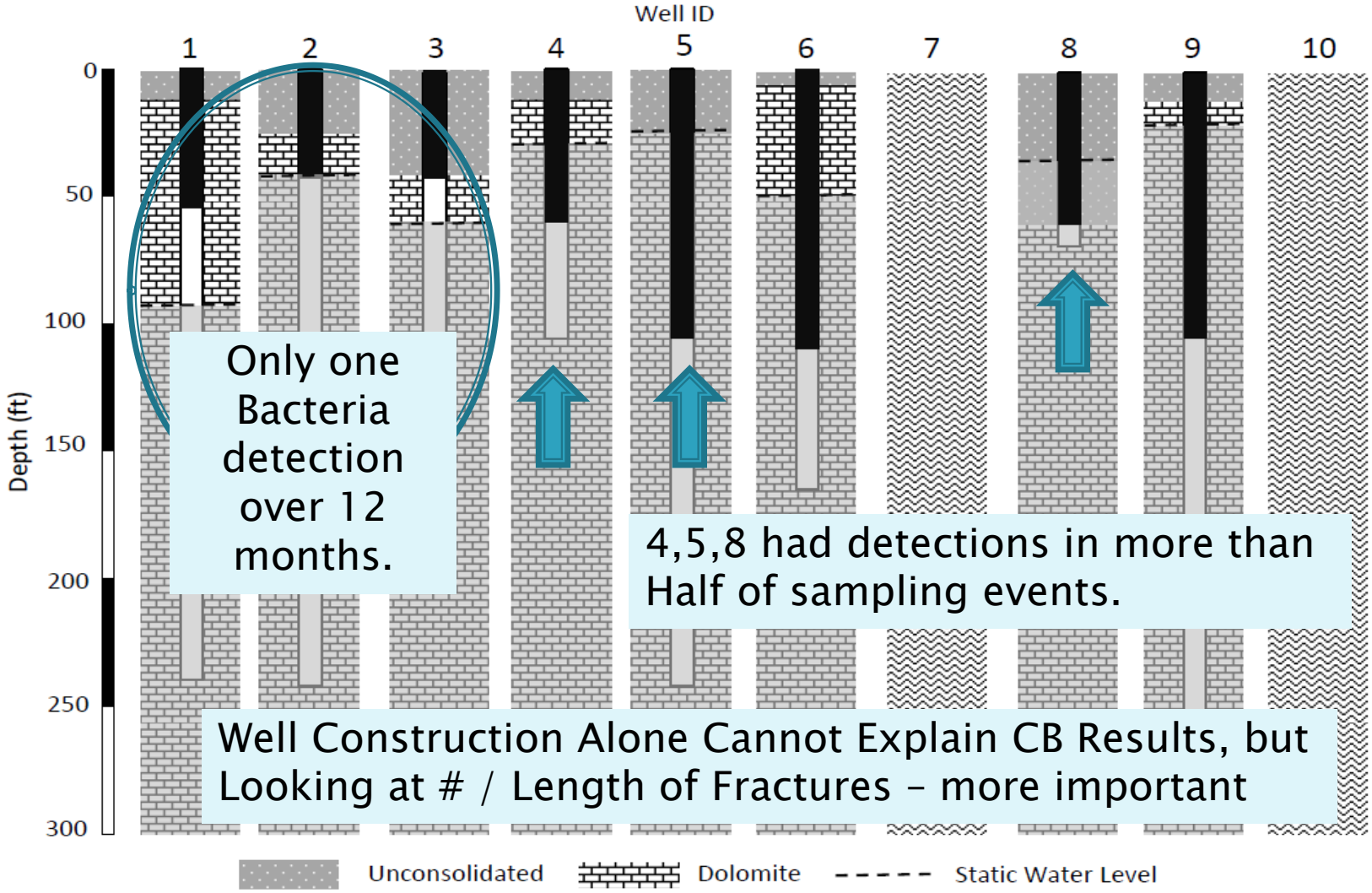


Figure 4. Monthly sample result for each of the 10 wells sampled. Shaded region represents period when maximum soil temperature at 2 cm was less than or equal to 0 degrees Celcius.

Summary of Total Coliform / E-coli. Values represent the annual mean with standard deviation provided in parentheses.

Well	Total Coliform	Total Coliform	E-Coli
	Sample Periods Positive	MPN Cfu 100 mL-1	Sample Periods Positive
1	1	0.9 (0.3)	0
2	0	ND	0
3	0	ND	0
4	**6**	6.2 (17.1)	0
5	**6**	1.7 (2.4)	0
6	0	ND	0
7	2	2.5 (8.1)	0
8	**7**	3.4 (5.1)	0
9	0	ND	0
10	4	6.3 (13.1)	0

Bacteria Conclusion Cont.

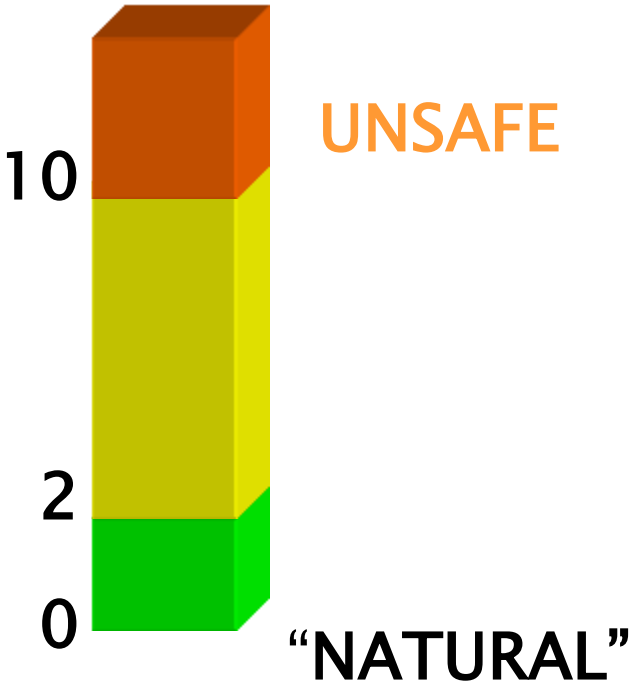


Bacteria Conclusion

- Bacteria testing once/year –could be a false sense of well safety – karst geology
- Inconclusive – Source
- CB are detections were variable month-month
- Contamination period may be as little as one month or less
- REMEMBER: SAMPLE DATES PRE-SELECTED

Nitrate Nitrogen

- Greater than 10 mg/L
  Exceeds State and Federal Limits for Drinking Water
- Between 2 and 10 mg/L
  Some Human Impact
- Less than 2.0 mg/L
  "Transitional"
- Less than 0.2 mg/L
  "Natural"

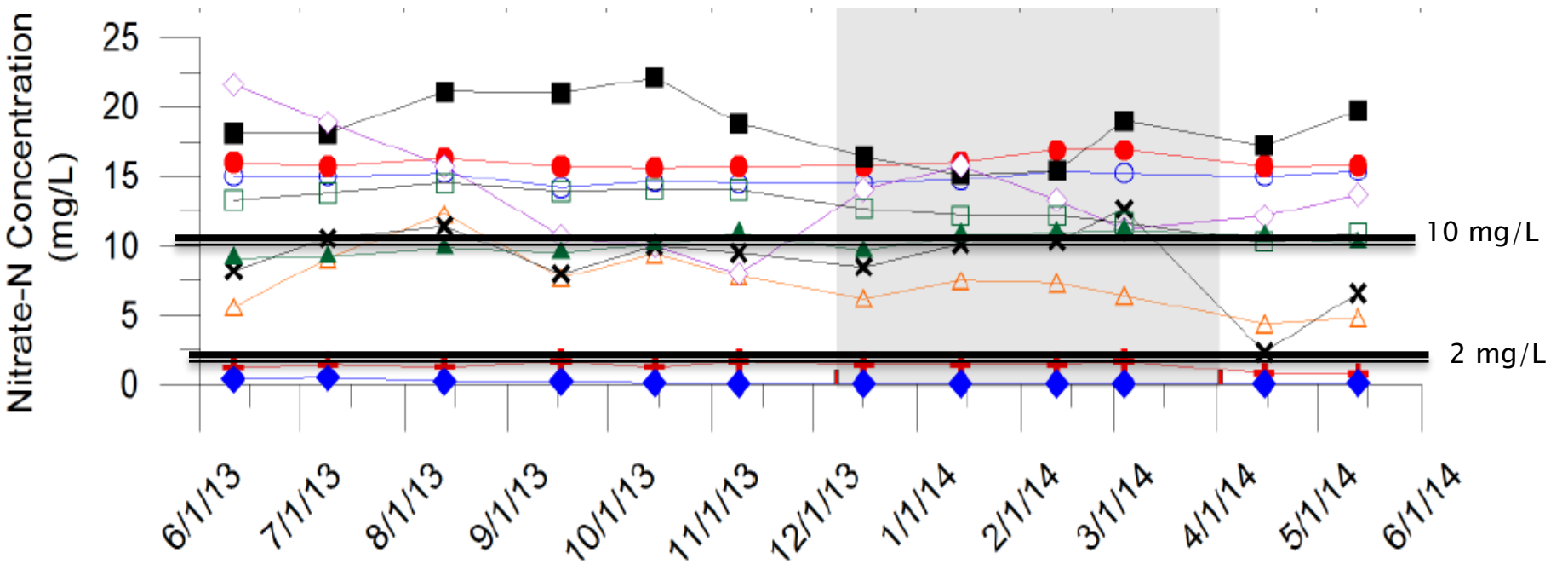


NITRATE – NITROGEN

- Very Mobile in Soils / Groundwater
- Fertilizer (lawn/ag), manure, bio-solids, leaking septics, septic drain fields

Wells 1, 2, 3, 7 – > 10 mg/L – all 12 Months

Well 9 –< 2 mg/L Well 10 – < 1 mg/L



Summary for the 12 month period (annual mean with standard deviation provided in parentheses)

Well	Nitrate (mg L-1)
1	14.9 (0.4)
2	16.0 (0.5)
3	18.5 (2.2)
4	7.4 (2.2)
5	13.8 (3.8)
6	9.0 (2.7)
7	12.8 (1.4)
8	10.2 (0.7)
9	1.4 (0.3)
10	0.2 (0.2)

Standard Deviation > 1.0 mg/L
Greater Degree of Intra-Annual Variability

Had max N above 10 mg/L
and one/more months less than standard

½ Mile Radius Source Assessment

This HALF MILE RADIUS assessment is NOT AN ACCURATE REPRESENTATION OF THE ACTUAL RECHARGE AREA of the 10 Wells

BUT assists in quantifying general land-uses.

6	167	21	393	79	393	100	25	31	79	31,383	6	150
7	127	25	375	75	185	49	26	44	69	25,916	9	225
8	293	58	209	42	191	91	13	33	47	9,762	14	350
9	45	9	457	91	337	74	38	54	92	41,943	11	275
10	134	27	368	73	368	100	33	51	83	30,706	14	350
Average	**158**	**32**	**344**	**68**	**303**	**89**	**25**	**46**	**71**	**25,391**	**8.6**	**215**

DISCLAIMER: Average nitrate concentrations were not correlated to local geology, well construction, or source assessment

THEREFORE:

89% cropland under Nutrient Management Plans…..

–We can conclude that the elevated nitrates are a result of acceptable agricultural management practices and not the result of gross mismanagement or negligence.

If the Goal is Long-Term Reduction of Nitrates in Groundwater:

Then

Need to reduce nitrogen inputs beyond the current source, rate and timing risk management strategies outlined in existing nutrient management plans

Nitrate Conclusions

Given Large Variability in Nitrate Concentrations:

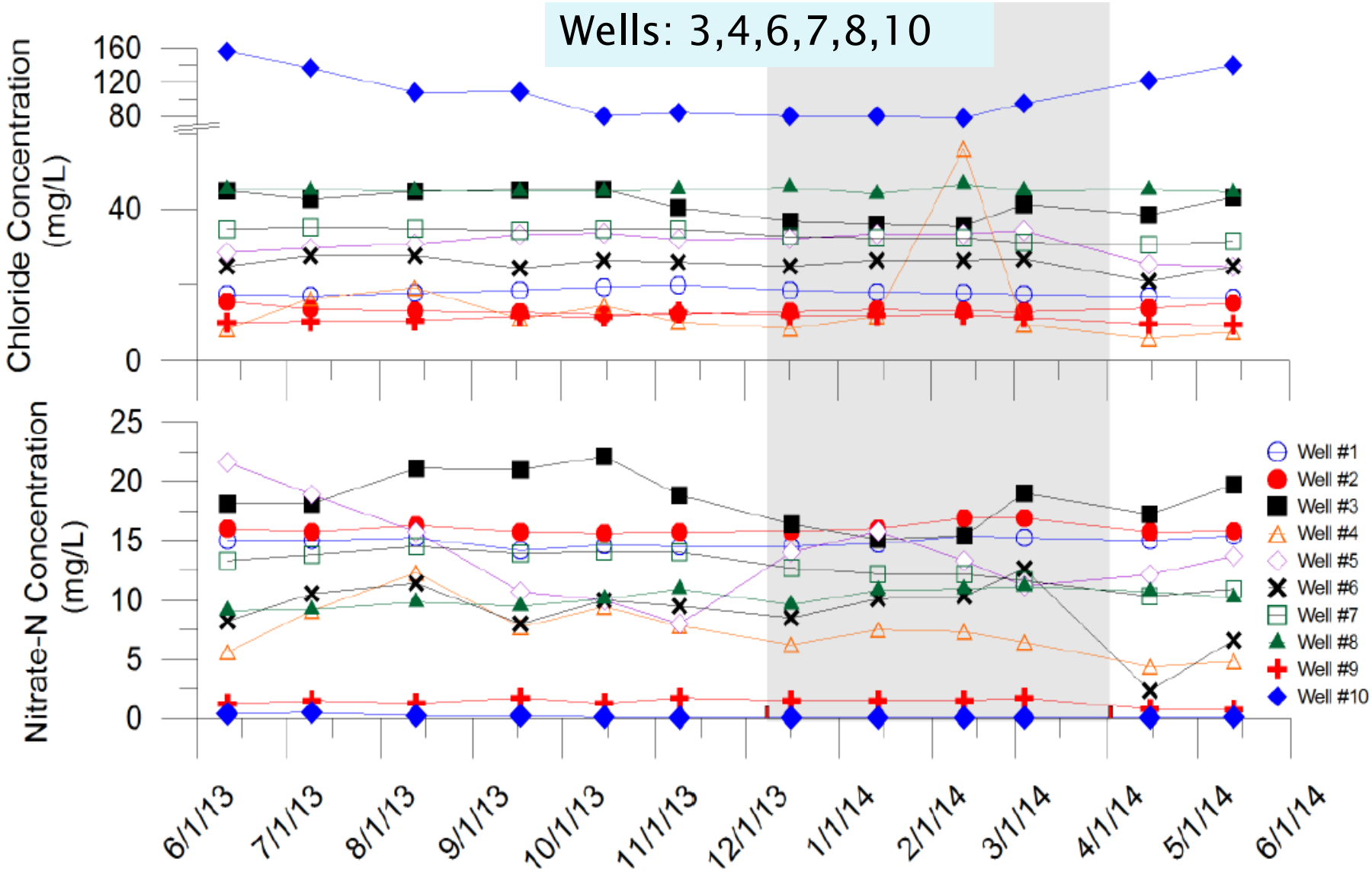
Anyone with a nitrate test **above 2 mg/L and less than 10 mg/L** and is concerned about drinking water above 10 mg/L

Should consider testing more frequently than once/year.

Water Quality Correlations

1. Indication of changes in water quality
2. Increase understanding of groundwater movement

Water Quality Correlations – Nitrogen & Chloride



Conductivity

- Measure of total ions
- Usually responds to rapid influx of surface water
- Can be used to indicate presence of contaminants
- Should be 2x the hardness

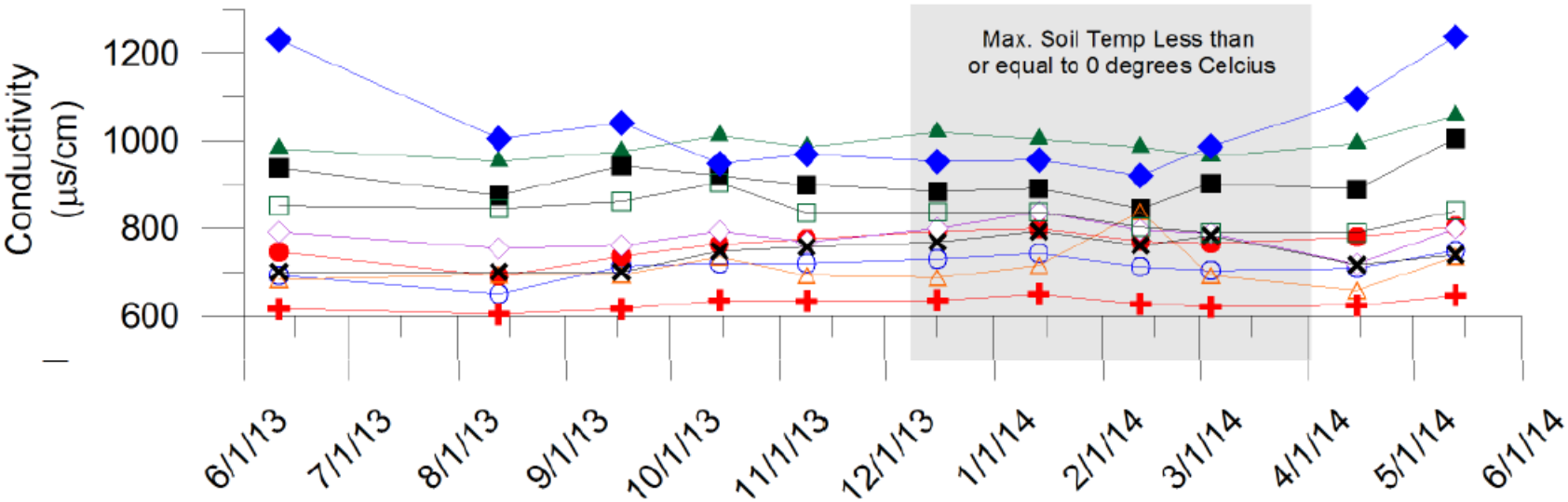


Figure 4. Monthly sample result for each of the 10 wells sampled. Shaded region represents period when maximum soil temperature at 2 cm was less than or equal to 0 degrees Celcius.

Intra-Annual Variability & Long-Term Monitoring

- Groundwater quality is better, worse, or staying the same?

<u>Standard Deviation:</u>

- Measure of the average distance of values from the mean
- Standard way to measure and express variability.

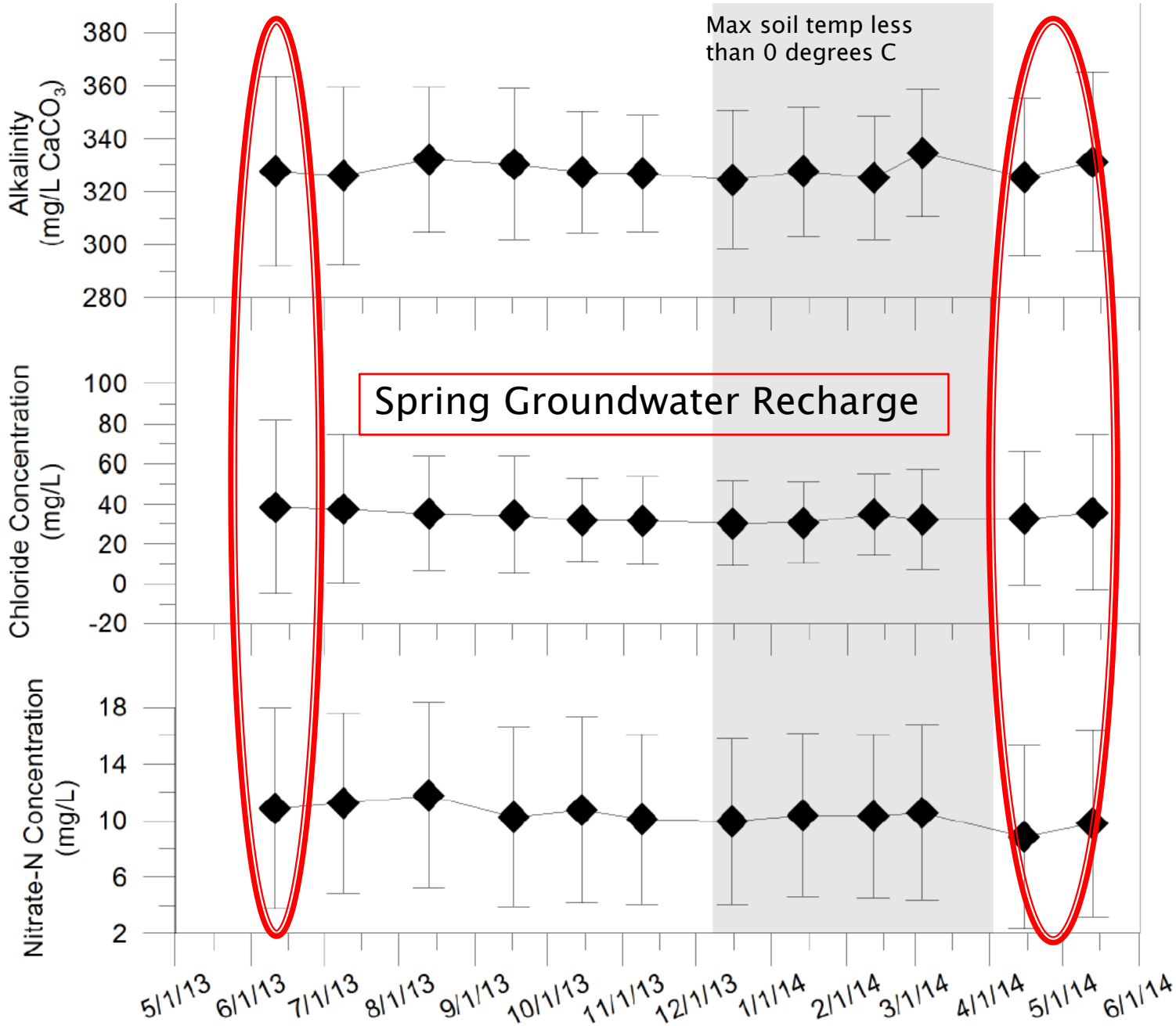
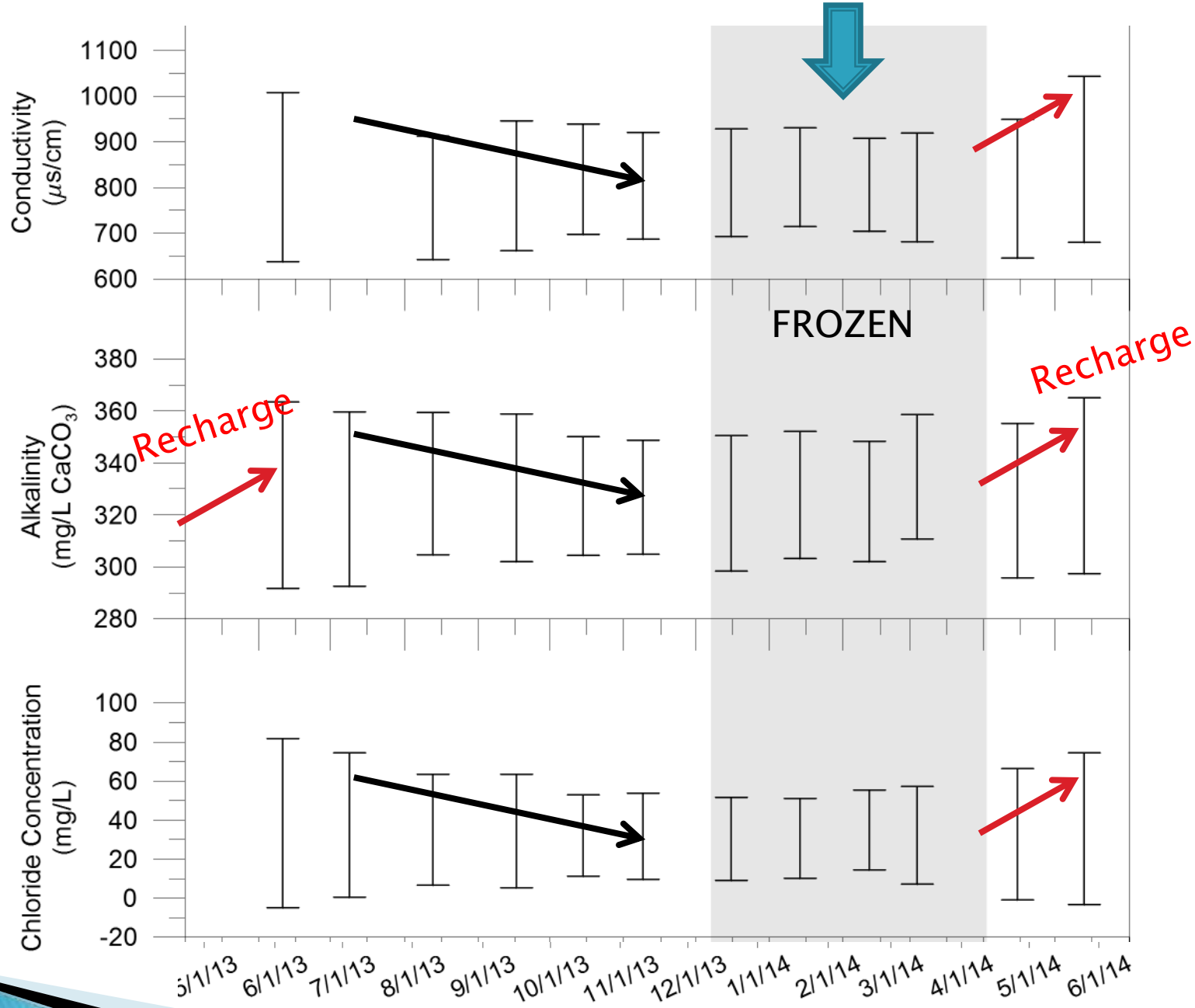


Figure 5. Sample mean of the ten sites for each sampling period. Standard deviation indicated by error bars.


Conductivity (µs/cm)
1100
1000
900
800
700
600
FROZEN
Recharge
Recharge
Alkalinity (mg/L CaCO3)
380
360
340
320
300
280
Chloride Concentration (mg/L)
100
80
60
40
20
0
-20
5/1/13
6/1/13
7/1/13
8/1/13
9/1/13
10/1/13
11/1/13
12/1/13
1/1/14
2/1/14
3/1/14
4/1/14
5/1/14
6/1/14

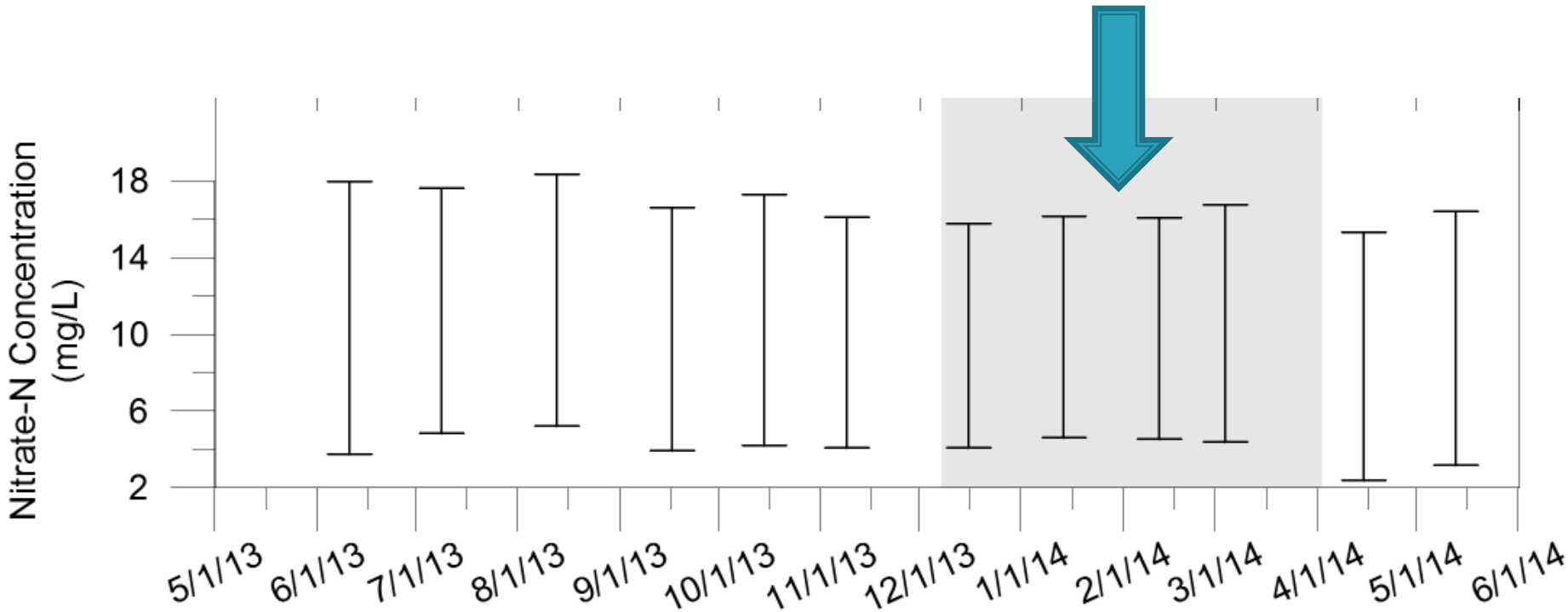


Figure 5. Standard deviation from the average of all ten wells for each sample period indicated by error bars.

Seasonal variability related to the Contamination source
Land-Use Changes
Annual Climatic Variability

Because Greater Variability – Need to Test more Often if Nitrates > 2 mg/L

Implications for Long-Term Monitoring

- Aquifer **most stable** during frozen soil conditions (little recharge occurring)
- **Most variable** – Following snow-melt and spring recharge season
- Gradual decrease during summer/fall – gradual stabilization .. Little/no recharge

THEREFORE

Sampling wells when the aquifer is most stable – best potential to detect trends/changes in groundwater overtime.

Recommendations

- Sample 25 wells bi-annually
  - **January** : when wells are under relatively stable aquifer conditions
  - **June:** to assess groundwater conditions following the spring groundwater recharge period and characterize variability (ex. well, annual, climatic, land-use, etc.)
- Test wells for nitrate, chloride and alkalinity
- Long term sampling of at least 10 years.

Questions

Funded by:

Lincoln Township
AND
Lakeshore Natural Resources Partnership