A Spring Lake Phosphorus Budget Analysis

based on Internal and External Loading Studies

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Ottawa County Water Quality Forum

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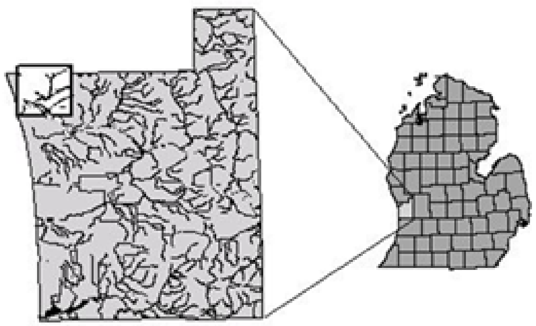


Spring Lake, Michigan

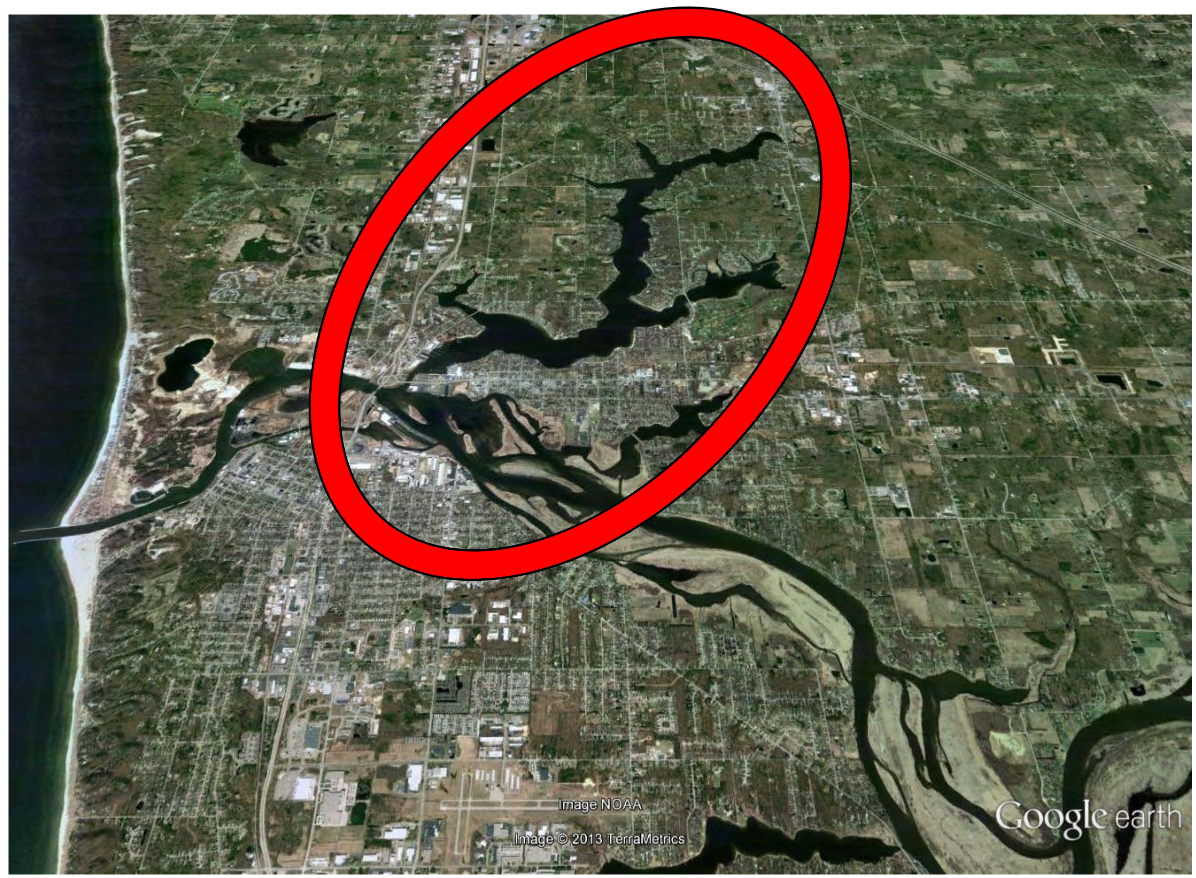
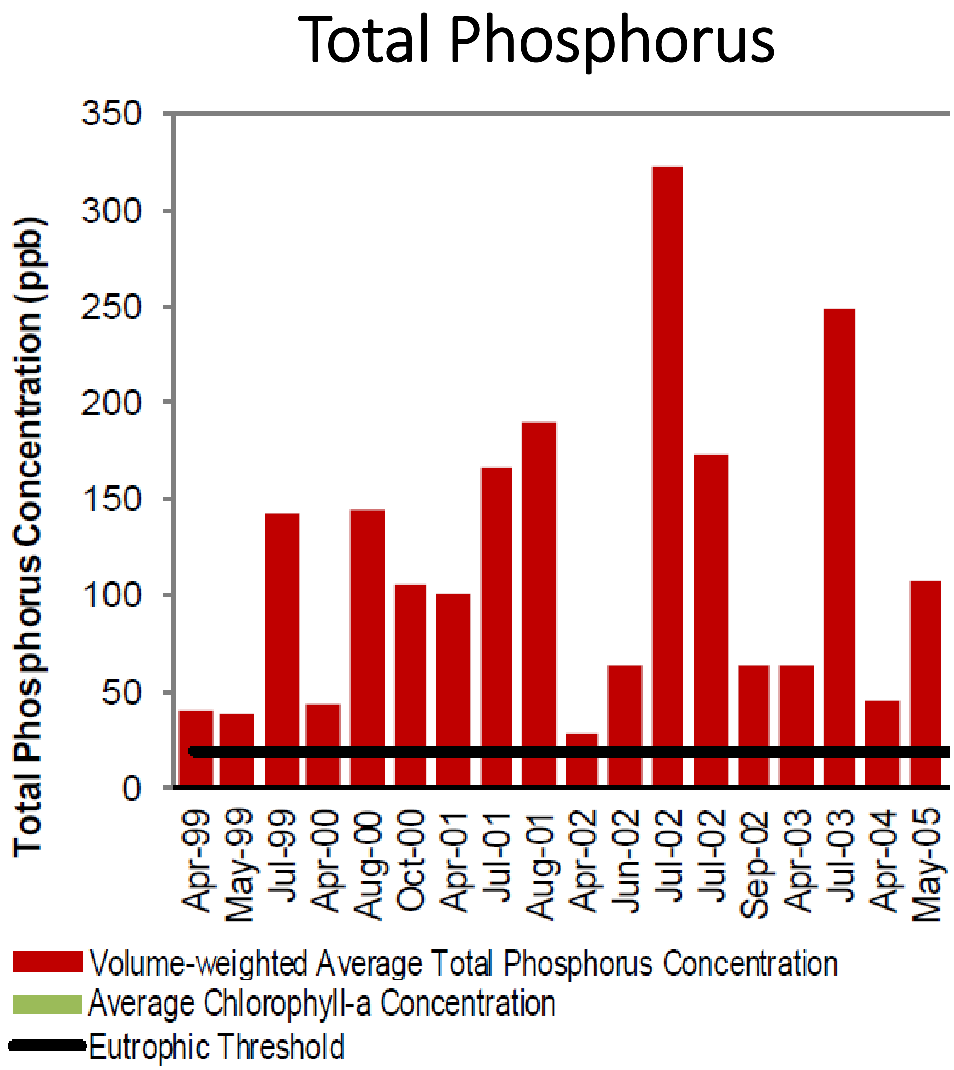



Photo credit: Spring Lake – Lake Board

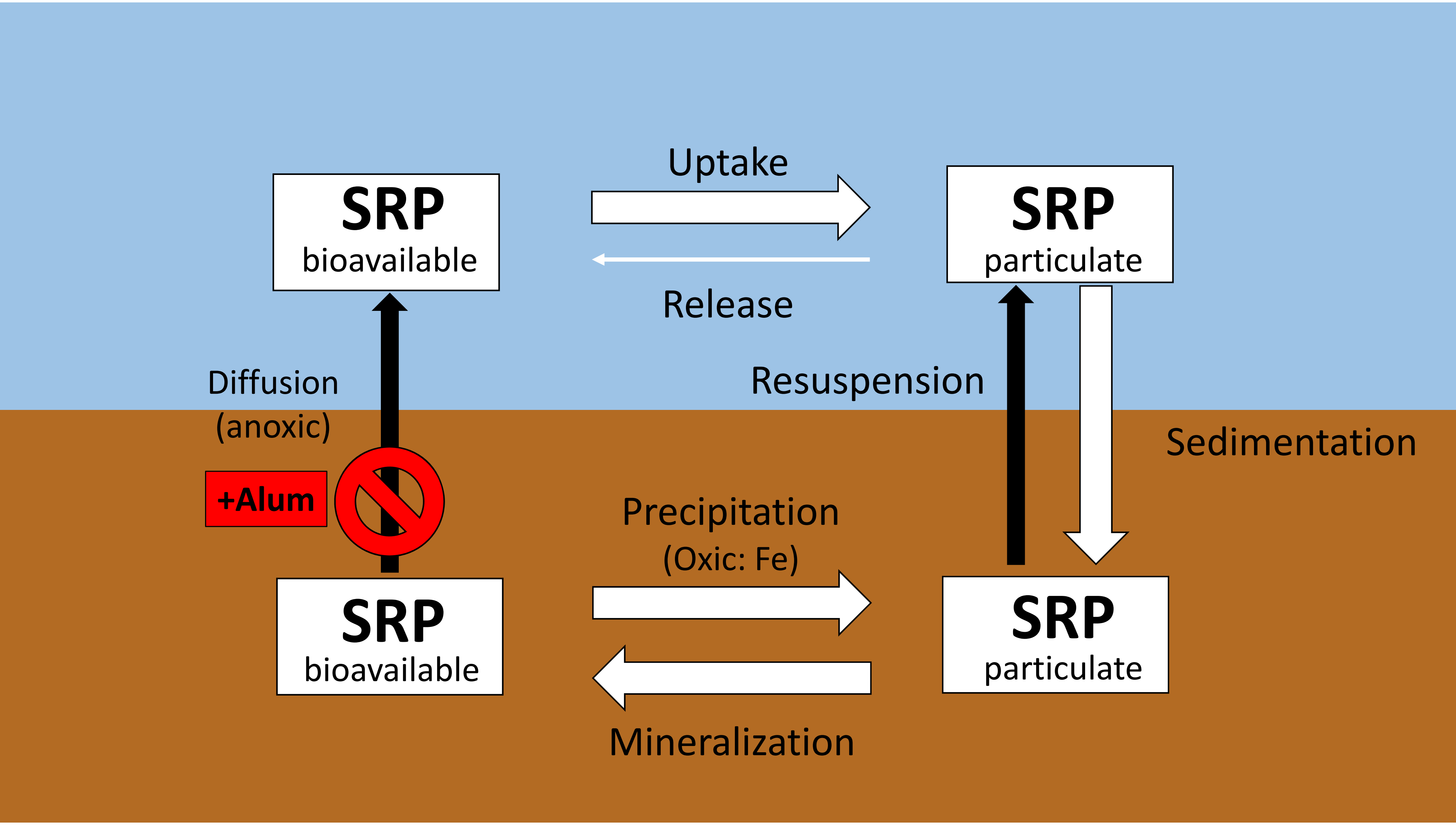
Spring Lake 1999-2005 (Pre-Alum)

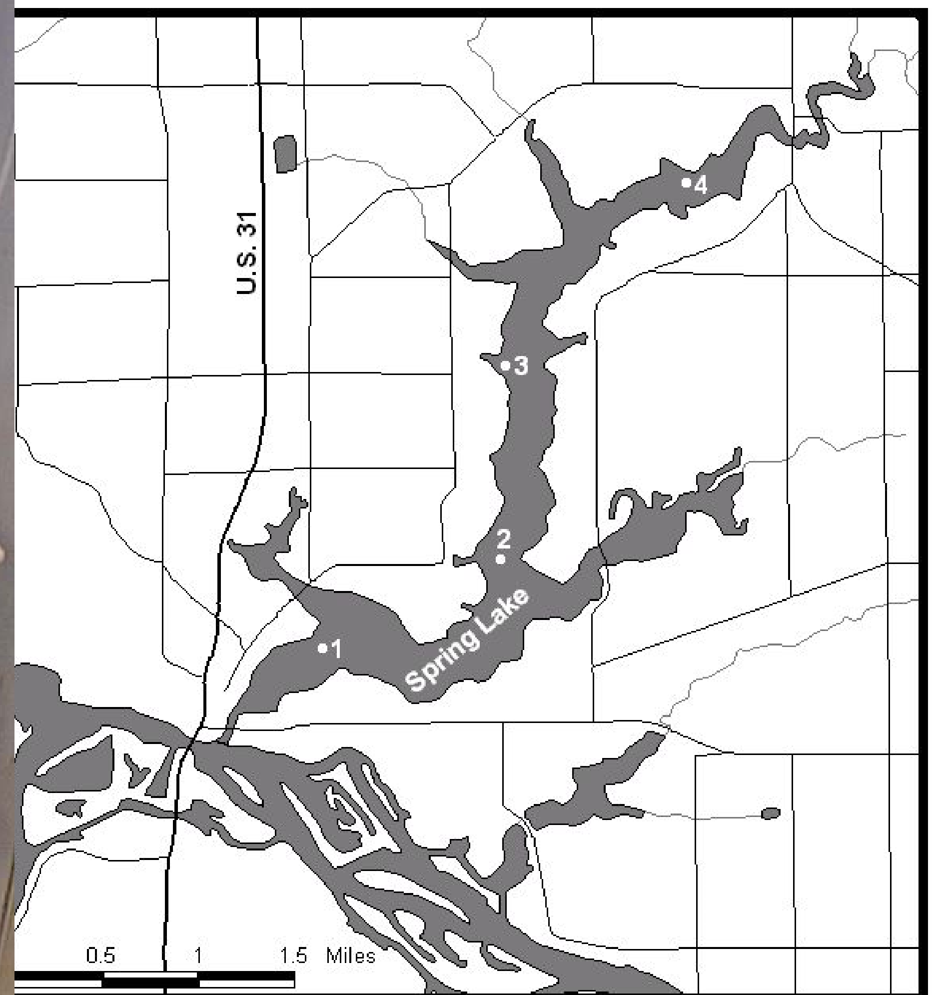


Data: Progressive AE

Objectives: Spring Lake Studies

- 2004: Measure internal P loading and effectiveness of alum (sediment cores)
- 2006: Measure 1 year alum efficacy (sediment cores)
- 2010: Measure 5 year alum efficacy and benthos (sediment cores and ponar grabs)
- 2016: Measure 11 year alum efficacy and benthos (sediment cores and ponar grabs)
- 2017: Measure external loading, microcystins, and nutrient bioassay


SRP
bioavailable
Uptake
Release
SRP
particulate
Diffusion
(anoxic)
+Alum
Resuspension
Sedimentation
Precipitation
(Oxic: Fe)
SRP
bioavailable
SRP
particulate
Mineralization


U.S. 31
1
2
3
4
Spring Lake
0.5
1
1.5 Miles

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Mean TP Sediment Release Rates

(mg P/m2/d; hypoxic conditions)

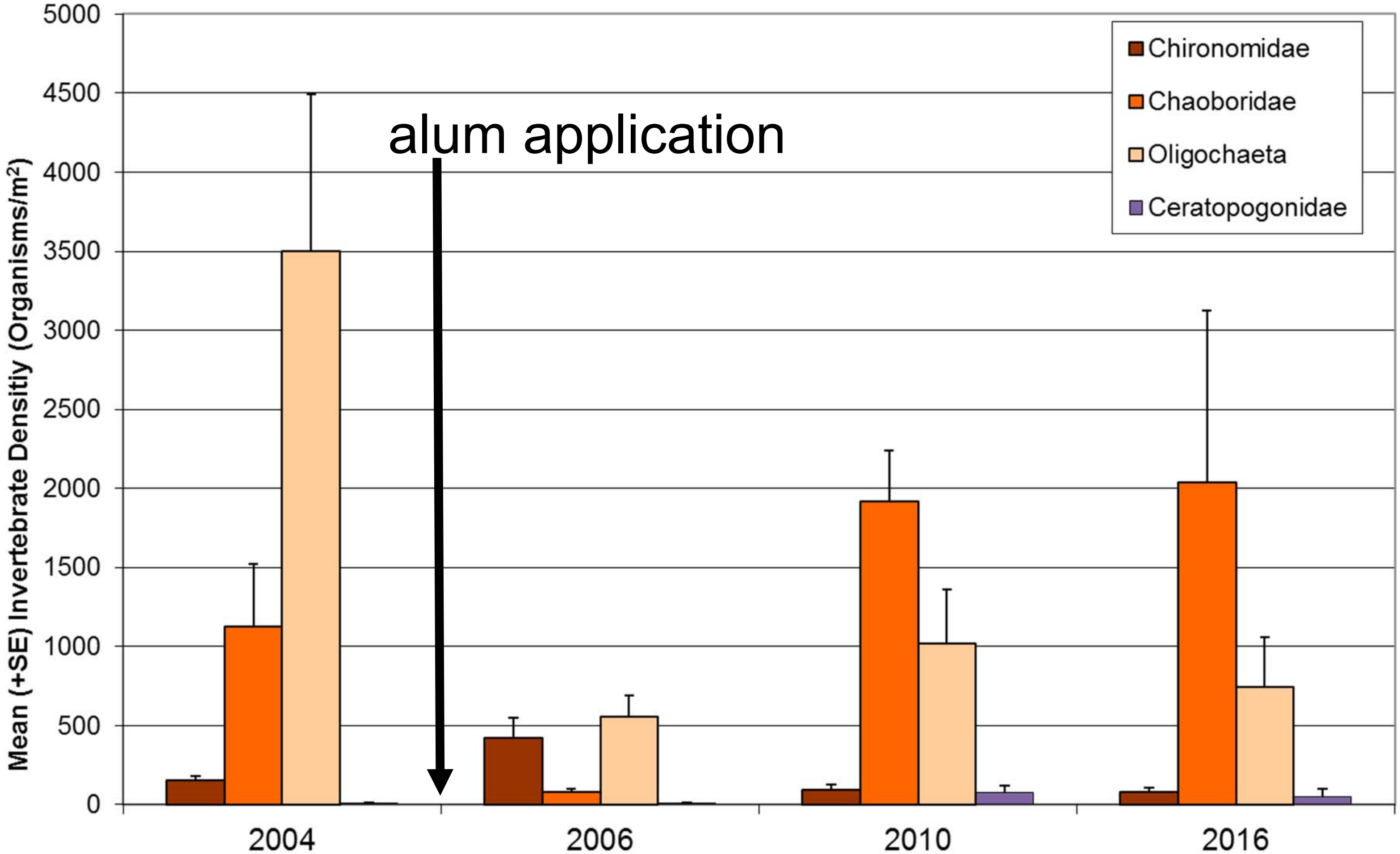
2003 (pre-alum)	2006 (8 months post-alum)	2010 (5 years post-alum)	2016 (11 years post-alum)
17.97[a]	0.41[b]	1.14[c]	1.25[d]

[a]Steinman et al. (2004)
[b]Steinman et al. (2008)
[c]Steinman and Ogdahl (2012)
[d]Steinman et al. (2018)

Mean Water Column TP Concentrations

Site	Depth	TP Concentration (µg/L)			
		2004	**2006**	**2010**	**2016**
1	Surface	60	30	60	38
2	Surface	110	30	50	40

Spring Lake Invertebrate Densities



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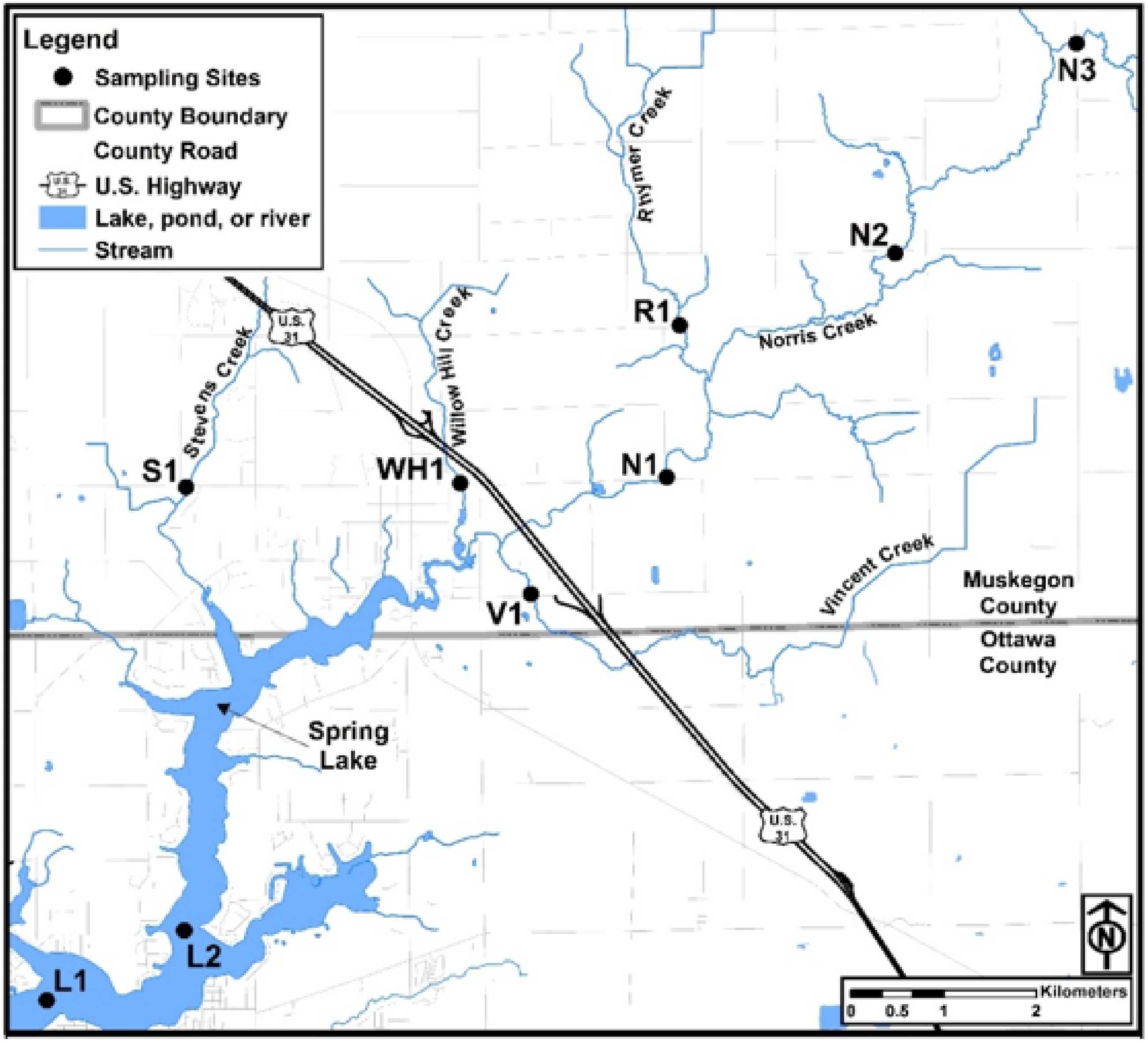
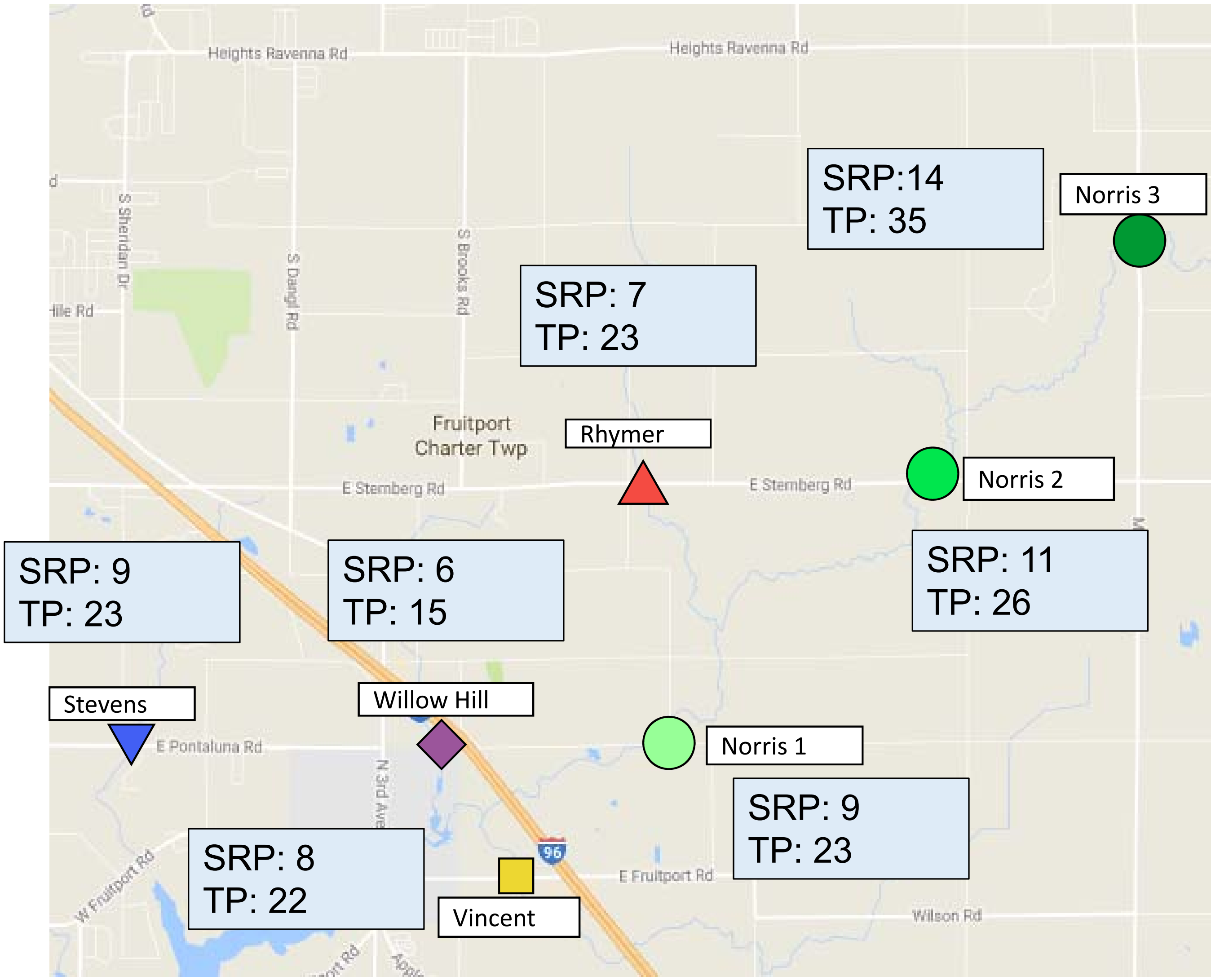
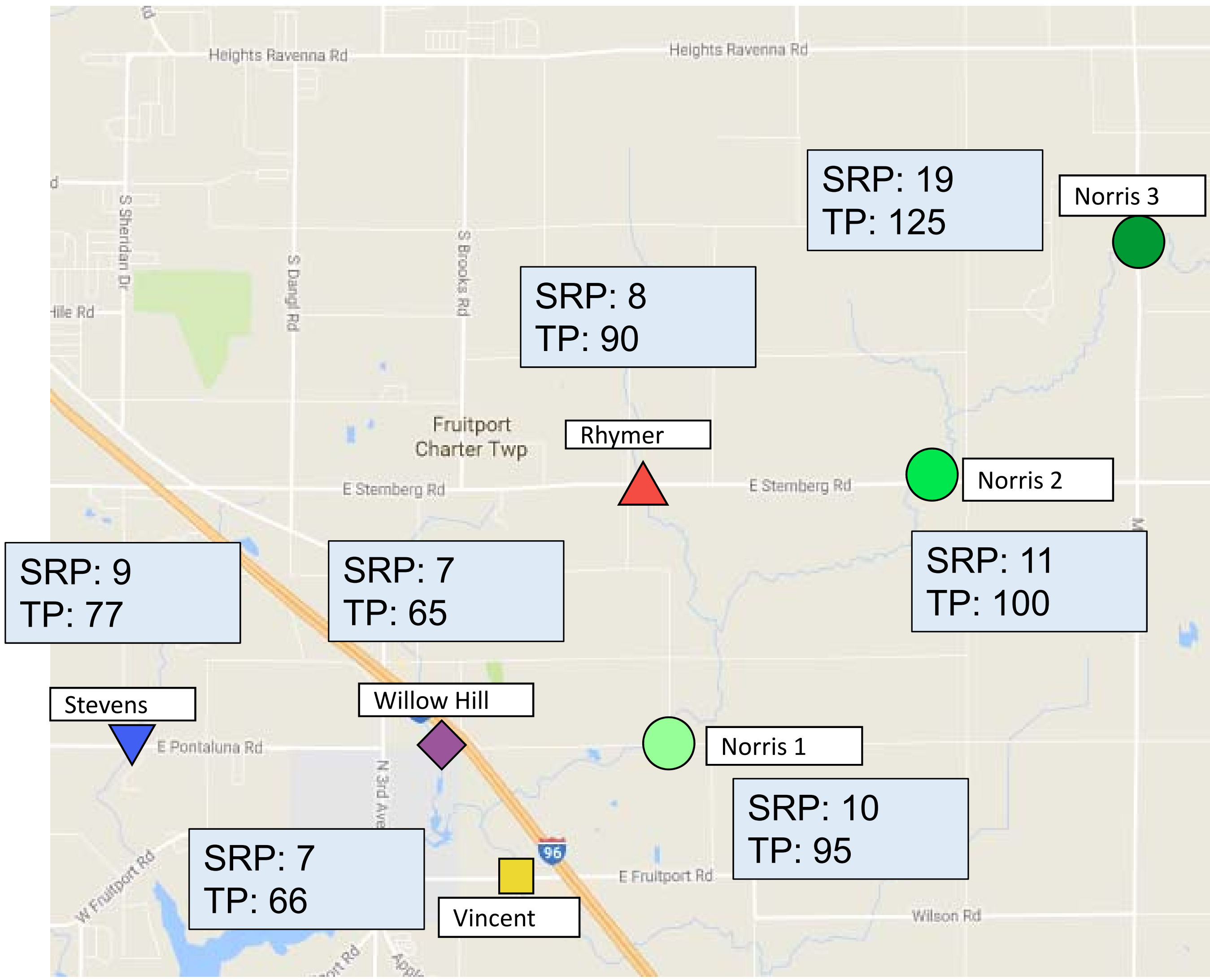

Legend
Sampling Sites
County Boundary
County Road
U.S. Highway
Lake, pond, or river
Stream
N3
N2
R1
N1
S1
WH1
V1
L1
L2
Rhymer Creek
Norris Creek
Stevens Creek
Willow Hill Creek
Vincent Creek
Muskegon County
Ottawa County
Spring Lake
U.S. 31
Kilometers
0 0.5 1 2
N

Baseflow Mean P Concentrations: 6/17-6/18 (µg/L); n=12



Stormflow Mean P Concentrations: 6/17-6/18 (µg/L); n=4



External Tributary P Loading

	Site Avg TP (µg/L)	Q (af/season or year)	Tributary Loading (kg TP)
Summer (May-Sep)	28.2	12,307	427
Winter (Oct-Apr)	15.0	34,378	1,194
Annual (12 months)	**20.7**	**46,685**	**1,621**

Spring Lake P Budget

Data	Source	Mean Annual P (kg)	Mean Annual P (%)
Internal loading	Steinman et al. (2017)	1,007	28.6
Tributary loading	Current study	1,621	46.0

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Atmospheric deposition	Brennan et al. (2015)	76	2.2
Septage	Lauber (1999)	491	13.9
Waterfowl	Lauber (1999)	16	0.5
Lawn fertilizer	Lauber (1999)	267	7.6
Shoreland runoff	US EPA (1996)	48	1.4
TOTAL		3,526	100.2

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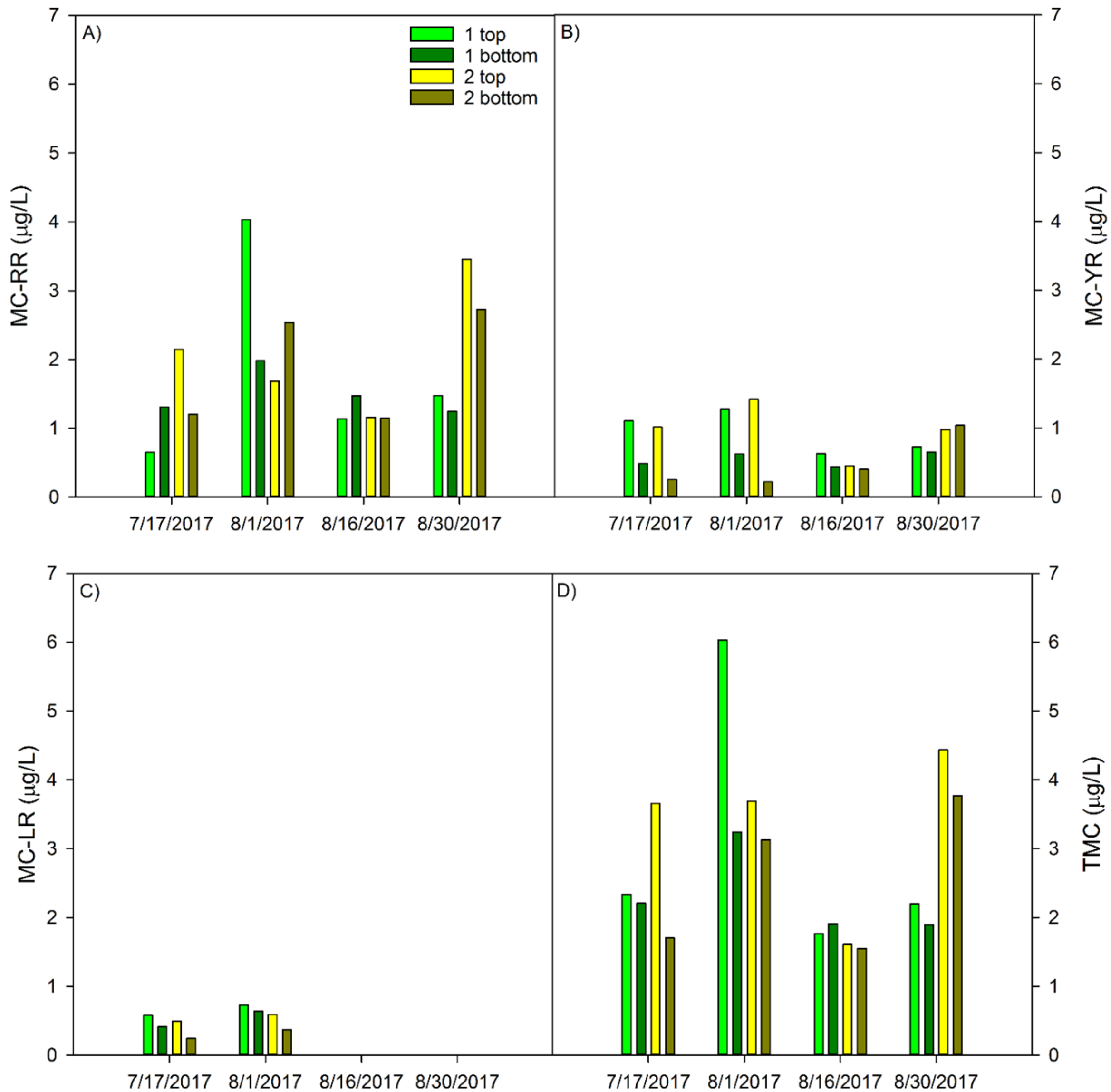
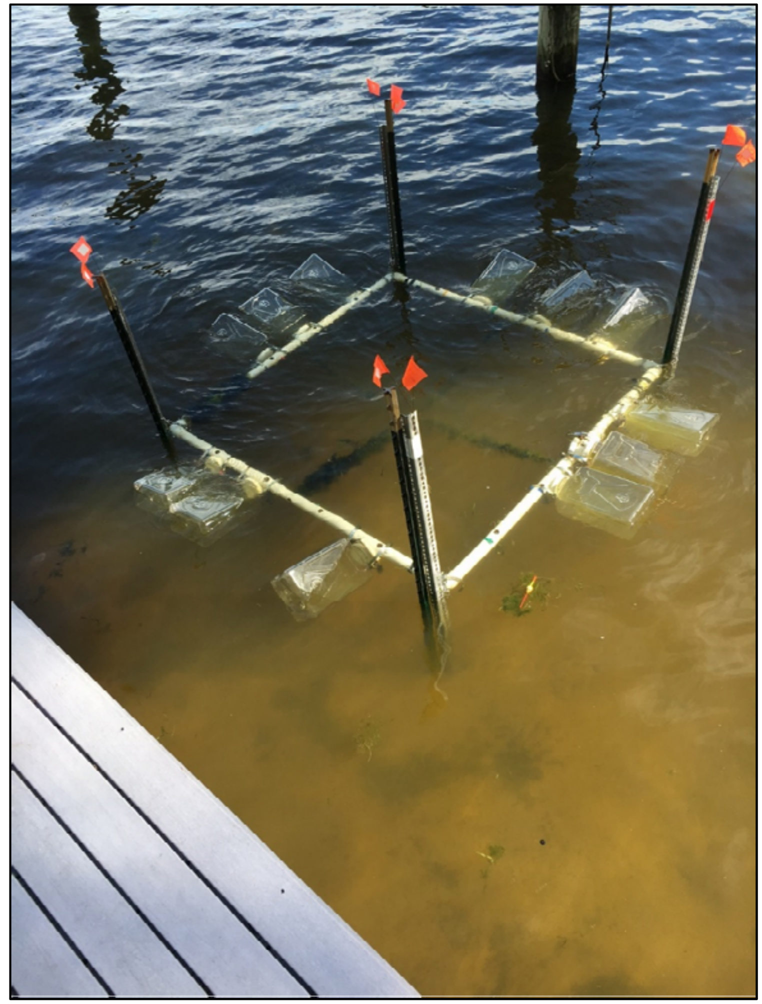
2017 Spring Lake data

Spring Lake Microcystin monitoring 2017:

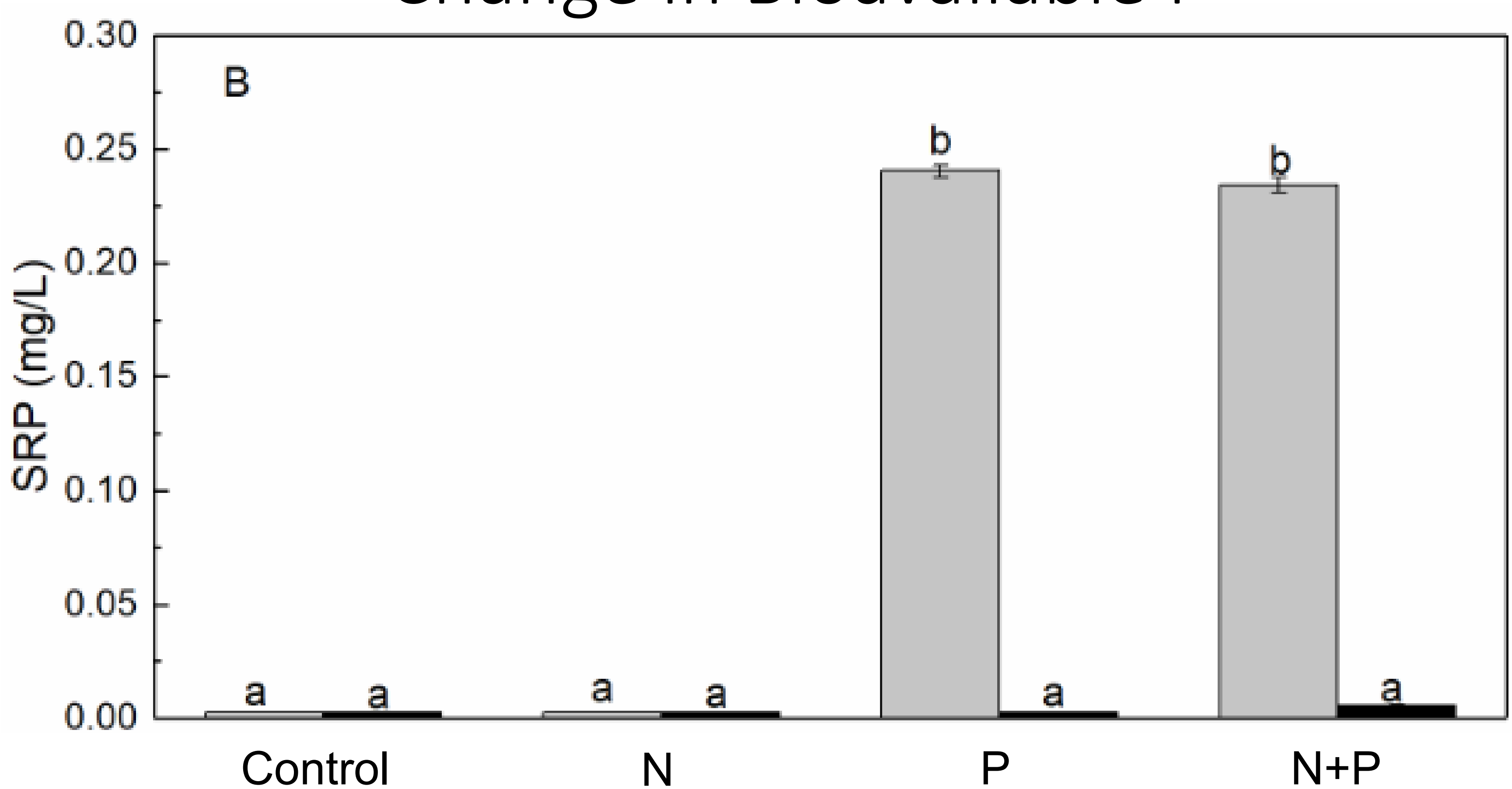


Nutrient Bioassay

- 4 treatments:
  - Control
  - Nitrogen alone
  - Phosphorus alone
  - N+P
- 3 replicates/treatment
- 7-day incubation
- Measure Δ in nutrients and Chl-*a*

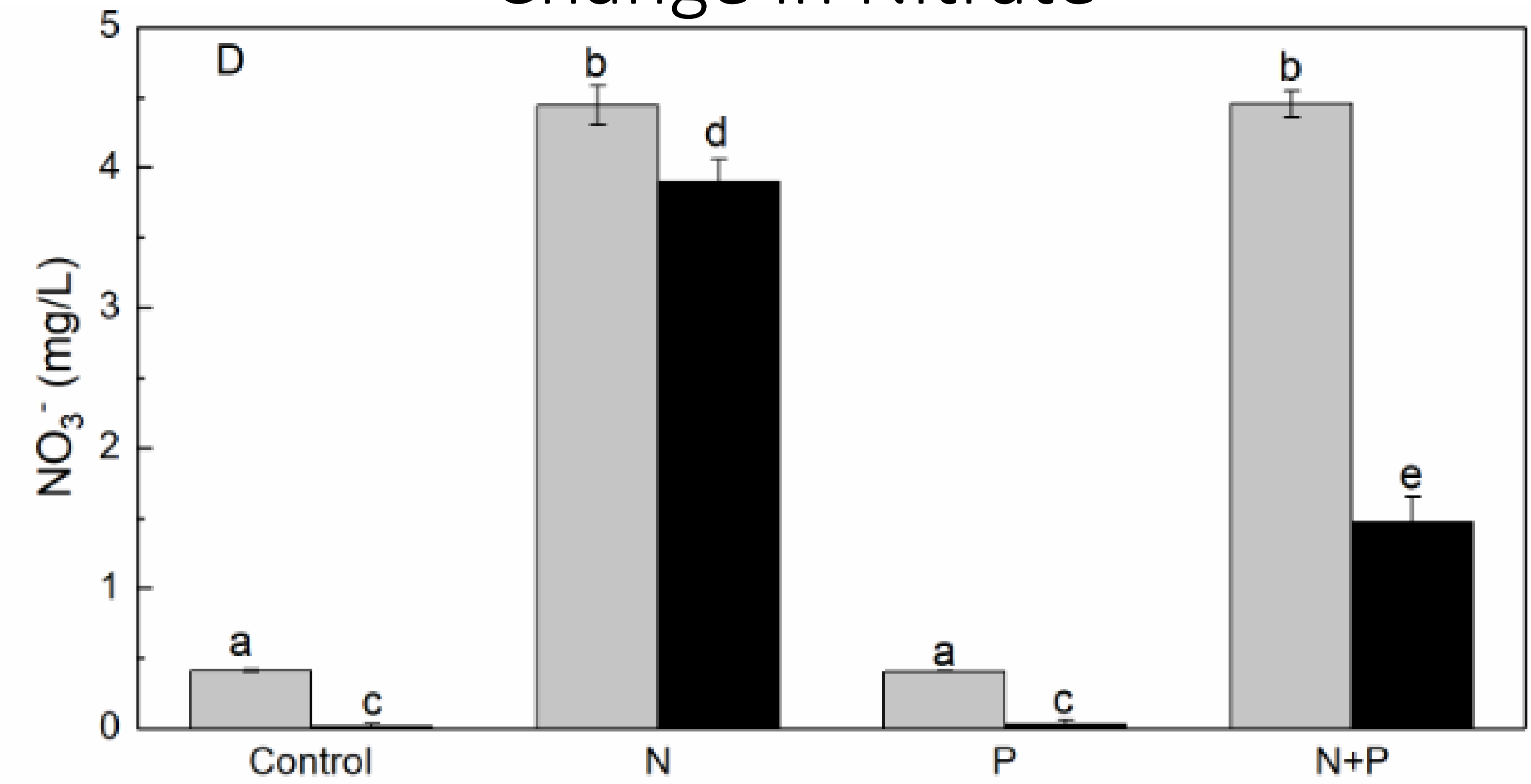


Change in Bioavailable P



Su et al. (In Preparation)

Change in Nitrate



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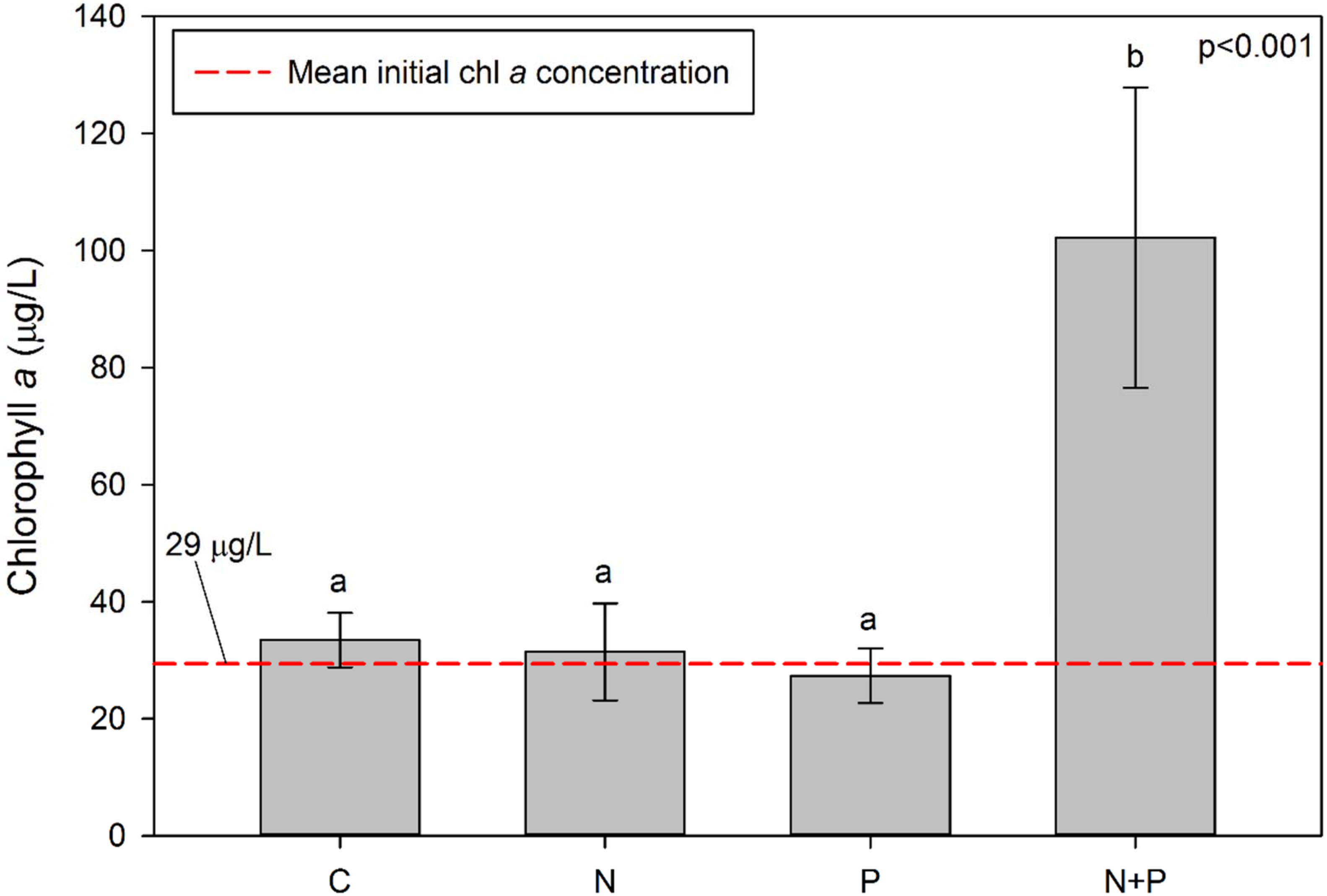

Su et al. (In Preparation)

Summary

- Alum application has been effective for >10 years
- Efficacy may be starting to wane at deeper sites; continued monitoring recommended
- External P loading is a major source of P to Spring Lake
- Long-term solutions to P management should include BMPs to reduce or mitigate external P from the Spring Lake watershed
- Control of N also important for Spring Lake management

Acknowledgements

- Funding: Spring Lake – Lake Board; MI Sea Grant
- Progressive AE: Tony Groves, Pam Tyning
- Lake access: The Steffel Family
- AWRI: Brian Scull, Rick Rediske, Kurt Thompson, Lidiia Iavorivska, Xiaomei Su, Emily Kindervater, Kim Oldenborg, Paige Kleindl, Brooke Ridenour

Questions?