A Spring Lake Phosphorus Budget Analysis
based on Internal and External Loading Studies

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Grand Valley State University – Annis Water Resources Institute
Ottawa County Water Quality Forum
November 2018
Spring Lake, Michigan
Spring Lake 1999-2005 (Pre-Alum)
Total Phosphorus

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

Resuspension

Precipitation
(Oxic: Fe)

Mineralization

SRP
bioavailable

Diffusion
(anoxic)

+SAlum

SRP
particulate

Sedimentation
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Mean TP Sediment Release Rates (mg P/m²/d; hypoxic conditions)

<table>
<thead>
<tr>
<th>Year</th>
<th>2003 (pre-alum)</th>
<th>2006 (8 months post-alum)</th>
<th>2010 (5 years post-alum)</th>
<th>2016 (11 years post-alum)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17.97&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.41&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.14&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.25&lt;sup&gt;d&lt;/sup&gt;</td>
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<sup>a</sup>Steinman et al. (2004)
<sup>b</sup>Steinman et al. (2008)
<sup>c</sup>Steinman and Ogdahl (2012)
<sup>d</sup>Steinman et al. (2018)
### Mean Water Column TP Concentrations

<table>
<thead>
<tr>
<th>Site</th>
<th>Depth</th>
<th>TP Concentration (μg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Surface</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>Surface</td>
<td>110</td>
</tr>
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Spring Lake Invertebrate Densities

alum application
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Baseflow Mean P Concentrations: 6/17-6/18 (µg/L); n=12
**Stormflow** Mean P Concentrations: 6/17-6/18 (µg/L); n=4

- **Norris 1**: SRP: 10, TP: 95
- **Norris 2**: SRP: 11, TP: 100
- **Norris 3**: SRP: 19, TP: 125
- **Rhymer**: SRP: 8, TP: 90
- **Willow Hill**: SRP: 7, TP: 65
- **Vincent**: SRP: 7, TP: 66
- **Stevens**: SRP: 9, TP: 77
## External Tributary P Loading

<table>
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<tr>
<th></th>
<th>Site Avg TP (µg/L)</th>
<th>Q (af/season or year)</th>
<th>Tributary Loading (kg TP)</th>
</tr>
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<tbody>
<tr>
<td><strong>Summer (May-Sep)</strong></td>
<td>28.2</td>
<td>12,307</td>
<td>427</td>
</tr>
<tr>
<td><strong>Winter (Oct-Apr)</strong></td>
<td>15.0</td>
<td>34,378</td>
<td>1,194</td>
</tr>
<tr>
<td><strong>Annual (12 months)</strong></td>
<td>20.7</td>
<td>46,685</td>
<td>1,621</td>
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### Spring Lake P Budget

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<th>Mean Annual P (kg)</th>
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<td>Lauber (1999)</td>
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<td>Lauber (1999)</td>
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<td>7.6</td>
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<td>US EPA (1996)</td>
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<td>1.4</td>
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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-α
Change in Bioavailable P

Su et al. (In Preparation)

SRP (mg/L)

Control  N  P  N+P

Su et al. (In Preparation)
Change in Nitrate

Su et al. (In Preparation)
Chlorophyll a (μg/L)

- C
- N
- P
- N+P

Mean initial chl a concentration

29 μg/L

p < 0.001

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 Oldenburg, Paige Kleindl, Brooke Ridenour
Questions?