Long Term Data Sets and Nutrient Management:
Bootstrapping Estimates of Phosphorus and Nitrogen Loading
to Cayuga Lake

Presentation to the Water Resources Council
of Tompkins County

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Stephen Penningroth, Executive Director
Community Science Institute
What We Need in Order to Manage Nutrients

• Certified measurements of phosphorus and nitrogen concentrations in streams under diverse flow conditions
• Estimates of nutrient loading based on concentration measurements and flows
• Distinguish between dissolved (100% bioavailable) and soil-bound (less bioavailable) nutrient fractions
• Distinguish between anthropogenic and natural sources of nutrients
• Implementation of BMPs by local governments and stakeholders
• Monitor nutrient reduction and discard ineffective BMPs
Bootstrapping Loading Estimates in Three Parts
(Described in 4/1/2021 presentation to WQMA, available on CSI website)

Part 1: Monitored, gauged streams with long-term nutrient data sets
Certified nutrient data collected with volunteer groups over multiple years are used to calculate loads with e.g. LOADEST software from USGS

Part 2: Monitored, ungauged streams with long-term nutrient data sets
Part 1 loads are used to estimate Part 2 loads based on ratios of stormwater nutrient concentrations and drainage basin areas

Part 3: Unmonitored, ungauged streams lacking long-term nutrient data sets
Parts 1 and 2 loads are used to extrapolate yields to unmonitored drainages. Drainage basin area is multiplied by yield to approximate load.
Bootstrap Part 1: Nutrient Transport in Gauged Streams Monitored with Volunteers

• **Nutrient Load** \( (mass/time) \) = **Nutrient Concentration** \( (mass/volume) \) \( \times \) **Stream Discharge** \( (volume/time) \)

Conventionally, an autosampler is used to collect stream samples under a range of flow conditions **in a single season** and analyze for nutrients. Software (e.g., LOADEST from USGS) is used to estimate and sum nutrient concentrations over all the flows recorded by the gauging station across the entire year.

**Bootstrapping approach:** Volunteers collect certified nutrient data under a range of flow conditions **over multiple years**.

Remainder of protocol is the same.
Bootstrap, Part 1, Works Well:
TP Loading Estimates for Southern Cayuga Lake Agree With Cayuga Lake Modeling Project/Draft TMDL

<table>
<thead>
<tr>
<th>Stream</th>
<th>Drainage Area (mi^2)</th>
<th>Community Science Institute (short tons/year)^a</th>
<th>Draft TMDL, Table 16 (short tons/year)^b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall Creek</td>
<td>129</td>
<td>19.56^c</td>
<td>21.6</td>
</tr>
<tr>
<td>Six Mile Creek @ Bethel Grove</td>
<td>39</td>
<td>5.69^c</td>
<td>6.28</td>
</tr>
<tr>
<td>Cascadilla Creek</td>
<td>13.7</td>
<td>1.07</td>
<td>1.56</td>
</tr>
<tr>
<td>Cayuga Inlet</td>
<td>92.4</td>
<td>8.13</td>
<td>9.12</td>
</tr>
<tr>
<td>Total “Impaired Southern End” TP Load</td>
<td>274</td>
<td>34.45</td>
<td>38.56</td>
</tr>
</tbody>
</table>
Bootstrap Part 2: Nutrient Transport in Monitored, Ungauged Streams Pro-Rated from Part 1 Streams

Bootstrap Part 2 pro-rated nutrient load \((\text{mass/time})\) = “Index Load” of Gauged Stream \((\text{mass/time})\) x Stormwater Nutrient Ratio \((\text{ungauged/gauged})\) x Drainage Basin Ratio \((\text{ungauged/gauged})\).

Demonstration of concept using Fall Creek to pro-rate Six Mile Creek SRP load

• Bootstrap Part 1 annual Fall Creek SRP load (“Index Load”) = 3.81 tons/year
• Long-term (17-year) stormwater SRP ratio (Six Mile Creek/Fall Creek) \((\text{from CSI database})\) = 22.6 ug/L / 24.8 ug/L
• Drainage basin ratio (Six Mile Creek (Bethel Grove)/Fall Creek) = 39 mi\(^2\) / 126 mi\(^2\)

Bootstrap Part 2 pro-rated Six Mile Creek SRP Load = \[3.81 \times (22.6/24.8) \times (39/126)\] = 1.07 tons/year

Bootstrap Part 1 Six Mile Creek SRP Load calculated using LOADEST software = 0.85 tons/year
Bootstrap Part 2: Pro-Rated Nutrient Loads in 14 Monitored, Ungauged Cayuga Lake Tributary Streams with Long-Term Data Sets including Stormwater Concentrations

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Drainage Area (mi²)</th>
<th>Percent Agriculture</th>
<th>Average SRP Load (tons/year)</th>
<th>SRP Yield (tons/year/mi²)</th>
<th>Average TP Load (tons/year)</th>
<th>TP Yield (tons/year/mi²)</th>
<th>Average NOx Load (tons/year)</th>
<th>NOx Yield (tons/year/mi²)</th>
<th>Average TKN Load (tons/year)</th>
<th>TKN Yield (tons/year/mi²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall Creek</td>
<td>129</td>
<td>46%</td>
<td>3.81</td>
<td>0.030</td>
<td>19.56</td>
<td>0.15</td>
<td>156</td>
<td>1.21</td>
<td>124.8</td>
<td>0.97</td>
</tr>
<tr>
<td>Six mile Creek @ Bethel Grove</td>
<td>39</td>
<td>24%</td>
<td>0.85</td>
<td>0.022</td>
<td>5.69</td>
<td>0.15</td>
<td>21.8</td>
<td>0.56</td>
<td>28.5</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Average Approximated Loads and Yields (based on two "Index Loads," above)

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Drainage Area (mi²)</th>
<th>Percent Agriculture</th>
<th>Average SRP Load (tons/year)</th>
<th>SRP Yield (tons/year/mi²)</th>
<th>Average TP Load (tons/year)</th>
<th>TP Yield (tons/year/mi²)</th>
<th>Average NOx Load (tons/year)</th>
<th>NOx Yield (tons/year/mi²)</th>
<th>Average TKN Load (tons/year)</th>
<th>TKN Yield (tons/year/mi²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cayuga Inlet</td>
<td>92.37</td>
<td>36%</td>
<td>1.63</td>
<td>0.02</td>
<td>8.13</td>
<td>0.09</td>
<td>39.87</td>
<td>0.43</td>
<td>49.27</td>
<td>0.53</td>
</tr>
<tr>
<td>Cascadilla Creek</td>
<td>13.7</td>
<td>24%</td>
<td>0.55</td>
<td>0.04</td>
<td>1.07</td>
<td>0.08</td>
<td>5.40</td>
<td>0.39</td>
<td>7.58</td>
<td>0.55</td>
</tr>
<tr>
<td>Taughannock Creek</td>
<td>66.8</td>
<td>57%</td>
<td>1.89</td>
<td>0.03</td>
<td>7.90</td>
<td>0.12</td>
<td>183.39</td>
<td>2.75</td>
<td>57.82</td>
<td>0.87</td>
</tr>
<tr>
<td>Trumansburg Creek</td>
<td>13.07</td>
<td>66%</td>
<td>0.56</td>
<td>0.04</td>
<td>0.94</td>
<td>0.07</td>
<td>35.21</td>
<td>0.56</td>
<td>11.71</td>
<td>0.90</td>
</tr>
<tr>
<td>Salmon Creek</td>
<td>89.2</td>
<td>71%</td>
<td>6.33</td>
<td>0.07</td>
<td>15.34</td>
<td>0.17</td>
<td>740.83</td>
<td>8.31</td>
<td>121.19</td>
<td>1.36</td>
</tr>
<tr>
<td>Town Line Creek</td>
<td>1.7</td>
<td>75%</td>
<td>0.17</td>
<td>0.10</td>
<td>0.24</td>
<td>0.14</td>
<td>19.34</td>
<td>1.13</td>
<td>15.19</td>
<td>1.45</td>
</tr>
<tr>
<td>Mill Creek</td>
<td>1.4</td>
<td>86%</td>
<td>0.19</td>
<td>0.14</td>
<td>0.41</td>
<td>0.29</td>
<td>21.27</td>
<td>1.45</td>
<td>15.19</td>
<td>1.04</td>
</tr>
<tr>
<td>Paines Creek</td>
<td>15.3</td>
<td>76%</td>
<td>2.02</td>
<td>0.13</td>
<td>2.73</td>
<td>0.18</td>
<td>126.01</td>
<td>8.24</td>
<td>15.40</td>
<td>1.01</td>
</tr>
<tr>
<td>Deans Creek</td>
<td>3.2</td>
<td>76%</td>
<td>0.89</td>
<td>0.28</td>
<td>1.00</td>
<td>0.31</td>
<td>43.21</td>
<td>5.80</td>
<td>13.50</td>
<td>1.81</td>
</tr>
<tr>
<td>Burroughs Creek</td>
<td>3.7</td>
<td>74%</td>
<td>0.75</td>
<td>0.20</td>
<td>1.35</td>
<td>0.36</td>
<td>23.00</td>
<td>6.22</td>
<td>8.34</td>
<td>2.25</td>
</tr>
<tr>
<td>Williamson Creek</td>
<td>1.4</td>
<td>80%</td>
<td>0.22</td>
<td>0.16</td>
<td>0.54</td>
<td>0.39</td>
<td>6.53</td>
<td>4.66</td>
<td>2.63</td>
<td>1.88</td>
</tr>
<tr>
<td>Great Gully Creek</td>
<td>15.56</td>
<td>79%</td>
<td>2.88</td>
<td>0.18</td>
<td>4.44</td>
<td>0.29</td>
<td>72.54</td>
<td>4.66</td>
<td>29.60</td>
<td>1.90</td>
</tr>
<tr>
<td>Canoga Creek</td>
<td>5.83</td>
<td>75%</td>
<td>0.78</td>
<td>0.13</td>
<td>1.50</td>
<td>0.26</td>
<td>27.70</td>
<td>4.75</td>
<td>9.27</td>
<td>1.59</td>
</tr>
<tr>
<td>Yawger Creek</td>
<td>24.91</td>
<td>80%</td>
<td>3.87</td>
<td>0.16</td>
<td>8.34</td>
<td>0.33</td>
<td>120.86</td>
<td>4.85</td>
<td>60.26</td>
<td>2.42</td>
</tr>
</tbody>
</table>
Bootstrap Part 3: Nutrient Loads in Unmonitored, Ungauged Drainages Based on Approximated Yields

• Surprisingly, nutrient yields in Bootstrap Part 1 and 2 streams are biphasic with respect to % ag land use:
  <67% agriculture, they are almost flat;
  >67% agriculture, they rise sharply.
This empirical observation of ~order-of-magnitude differences in yield provides an opportunity to estimate loads for drainages <67% and >67% ag.
Example: Drainage Area >67% ag (mi$^2$) x Avg Nutrient Yield in Part 1 and 2 streams with >67% ag (tons/year/mi$^2$) = Approx. nutrient load (tons/year)
“Tipping Point” in Nutrient Yield if Agricultural Land Cover >~65-70%
Monitored Drainage Areas: 516 sq. mi.

Monitored Drainage Areas in the Cayuga Lake Watershed Grouped by Two Agricultural Land Cover Categories based on NLCD

- Lansin Direct Streams
- Northwest Ithaca Direct Streams
- North Lansing Direct Streams
- King Ferry Direct Streams
- Aurora Direct Streams
- Scipio Direct Streams
- Hayt Corners Direct Streams
- Union Springs Direct Streams
- Seneca Outlet and Tributaries Direct Streams
- Northern Marshes Direct Streams

Unmonitored Drainage Areas: 245 sq. mi.

Canoga Creek
Williamson Creek
Burroughs Creek
Yawger Creek
Great Gully
Deans Creek
Johnsons Creek*
Paines Creek
Sheldrake Creek*
Mills Creek
Town Line Creek
Milliken Creek*
Trumansburg Creek
Taughannock Creek
Salmon Creek
Cayuga Inlet
SixMile Creek at Bethel Grove
Cascadilla Creek
Fall Creek

*Monitored but lack stormwater nutrient data. Not included in load calculations for monitored drainage areas.
Approximated Nutrient Loads in Ungauged, Unmonitored Drainages Based on Yields Extrapolated From Bootstrap Parts 1 and 2 Monitored Drainages

<table>
<thead>
<tr>
<th>Unmonitored Drainages within Cayuga Lake Watershed</th>
<th>Approximated Loads (drainage area x average yield in monitored drainages for either &lt;67% or &gt;67% agriculture category)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed</td>
<td>Drainage Area (mi^2)</td>
</tr>
<tr>
<td>Lansing Direct Streams</td>
<td>19.66</td>
</tr>
<tr>
<td>Northwest Ithaca Direct Streams</td>
<td>23.5</td>
</tr>
<tr>
<td>King Ferry Direct Streams</td>
<td>14.29</td>
</tr>
<tr>
<td>North Lansing Direct Streams (includes Miliken Creek)</td>
<td>15.8</td>
</tr>
<tr>
<td>Aurora Direct Streams</td>
<td>9.21</td>
</tr>
<tr>
<td>Scipio Direct Streams</td>
<td>7.74</td>
</tr>
<tr>
<td>Union Springs Direct Streams</td>
<td>14.44</td>
</tr>
<tr>
<td>Northern Marshes Direct Streams</td>
<td>6.95</td>
</tr>
<tr>
<td>Seneca Outlet and Tributaries</td>
<td>75.21</td>
</tr>
<tr>
<td>Hayt Corners Direct Streams (includes Johnsons Creek and Sheldrake Creek)</td>
<td>80.00</td>
</tr>
</tbody>
</table>
Monitored and Unmonitored Drainage Areas in the Cayuga Lake Watershed Grouped by Two Agricultural Land Cover Categories in NLCD

Monitored and Unmonitored Drainage Areas in the Cayuga Lake watershed: **782 sq. mi.**

*sum of monitored and unmonitored drainage areas listed in the tables

Monitored Drainage Areas: 516 sq. mi.
- Canoga Creek
- Williamson Creek
- Burroughs Creek
- Yawger Creek
- Great Gully
- Deans Creek
- Johnsons Creek*
- Paines Creek
- Sheldrake Creek*
- Mills Creek
- Town Line Creek
- Milliken Creek*
- Trumansburg Creek
- Taughannock Creek
- Salmon Creek
- Cayuga Inlet
- SixMile Creek at Bethel Grove
- Cascadilla Creek
- Fall Creek

Unmonitored Drainage Areas: 267 sq. mi.
- Lansing Direct Streams
- Northwest Ithaca Direct Streams
- North Lansing Direct Streams
- King Ferry Direct Streams
- Aurora Direct Streams
- Scipio Direct Streams
- Hayt Corners Direct Streams
- Union Springs Direct Streams
- Seneca Outlet and Tributaries Direct Streams
- Northern Marshes Direct Streams

* Monitored but lack stormwater nutrient data. Not included in load calculations for monitored drainage areas.
Pause to Consider the Value of “Bootstrapping” Loading Estimates on the Basis of Long-term Nutrient Data Sets Collected with Dedicated Volunteer Partner Groups

• Bootstrap estimates address a yawning void in data-driven assessments of phosphorus and nitrogen loading in the northern half of the Cayuga Lake watershed.

• Bootstrap estimates empower community volunteers who collect stream samples year after year, building data sets that reliably characterize nutrient concentrations under diverse flow conditions.

• Bootstrap estimates, while imperfect and unconventional, nevertheless provide estimates of phosphorus and nitrogen loading in Cayuga Lake tributary streams that are sufficiently accurate to guide nutrient management strategies.
Bootstrap Guidance 1: Correct TP and SRP Loading Estimates in Draft Cayuga Lake TMDL

- Draft TMDL relied on SWAT model to estimate phosphorus loading
- SWAT model was calibrated using data from southern Cayuga Lake tributary streams, and it was validated using CSI data for Fall Creek
- As shown in earlier slide, CSI and Draft TMDL/SWAT loading estimates agree well for southern streams where nutrient data were collected
- Draft TMDL applied SWAT model to estimate phosphorus loading across the entire Cayuga Lake watershed without collecting nutrient data to validate the model in northern tributary streams
- CSI-volunteer stream monitoring partnerships have collected samples and documented high dissolved nutrient concentrations and loading in northern streams beginning in 2009, contrary to SWAT model predictions
Draft TMDL Underestimates Total Cayuga Lake SRP Loading by a Factor of 3 Compared to CSI and Two Other Estimates

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Draft TMDL, Table 17 (2021)</th>
<th>CSI (2021)(^b)</th>
<th>Haith et al (2012)(^c)</th>
<th>Likens (1970-71)(^c,d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall Creek</td>
<td>2.06</td>
<td>3.81</td>
<td>11.2</td>
<td>10.9</td>
</tr>
<tr>
<td>Combined Cayuga Inlet(^e)</td>
<td>3.14</td>
<td>3.03</td>
<td>10.4</td>
<td>29.2</td>
</tr>
<tr>
<td>Salmon Creek</td>
<td>4.26</td>
<td>6.33</td>
<td>8.7</td>
<td>5.8</td>
</tr>
<tr>
<td>Taughannock Creek</td>
<td>1.28</td>
<td>1.89</td>
<td>4.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Great Gully</td>
<td>0.82</td>
<td>2.88</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Cayuga Lake</td>
<td><strong>17</strong></td>
<td><strong>49</strong></td>
<td><strong>64</strong></td>
<td><strong>74</strong></td>
</tr>
</tbody>
</table>

Mean CSI, Haith et al, Likens = **62 +/- 13** (SD) short tons dissolved phosphorus/year
Draft TMDL Overestimates Total Cayuga Lake TP loading by a Factor of 2 Compared to CSI and Two Other Estimates

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Draft TMDL, Table 16 (2021)</th>
<th>CSI (2021)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Haith et al (2012)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Likens (1970-71)&lt;sup&gt;b,c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall Creek</td>
<td>21.6</td>
<td>19.6</td>
<td>18.6</td>
<td>22.8</td>
</tr>
<tr>
<td>Combined Cayuga Inlet&lt;sup&gt;d&lt;/sup&gt;</td>
<td>17.0</td>
<td>14.9</td>
<td>20.0</td>
<td>37.6</td>
</tr>
<tr>
<td>Salmon Creek</td>
<td>39.9</td>
<td>15.3</td>
<td>14.6</td>
<td>11.0</td>
</tr>
<tr>
<td>Taughannock Creek</td>
<td>10.9</td>
<td>7.9</td>
<td>7.9</td>
<td>5.6</td>
</tr>
<tr>
<td>Great Gully</td>
<td>17.9</td>
<td>4.4</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Cayuga Lake</td>
<td><strong>207</strong></td>
<td><strong>124</strong></td>
<td><strong>108</strong></td>
<td><strong>114</strong></td>
</tr>
</tbody>
</table>

Mean CSI, Haith et al, Likens = **115 +/- 8.1** (SD) short tons TP/year
Bootstrap Guidance 2: Allocating Nutrient Loading in Counties Bordering Cayuga Lake

• As we have seen, nutrient loading is correlated with agricultural land use as defined by the National Land Cover Database.

• In addition to the absolute number of acres in agriculture, nutrient loading is impacted by the percent of a stream’s drainage area in agriculture, as defined by the NLCD.

• When the percent of agricultural land in a stream’s drainage exceeds approximately 67% based on the NLCD, the nutrient concentration in runoff, i.e., the nutrient yield, reaches a “tipping point” and rises sharply.

• How are the high yield drainages distributed in counties around Cayuga Lake?
<table>
<thead>
<tr>
<th>County</th>
<th>Total Land (mi²)</th>
<th>Percent of CLW Total Land</th>
<th>Agricultural Land (mi²)</th>
<th>Percent of CLW Agricultural Land</th>
<th>Forested Land (mi²)</th>
<th>Percent of CLW Forested Land</th>
<th>Wetlands (mi²)</th>
<th>Percent of CLW Wetlands</th>
<th>Developed Land (mi²)</th>
<th>Percent of CLW Developed Land</th>
<th>Open Water (mi²)</th>
<th>Percent of CLW Open Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tompkins</td>
<td>348.9</td>
<td>44%</td>
<td>142.17</td>
<td>33%</td>
<td>144.53</td>
<td>61%</td>
<td>20.05</td>
<td>47%</td>
<td>41.19</td>
<td>54%</td>
<td>0.97</td>
<td>40%</td>
</tr>
<tr>
<td>Cayuga</td>
<td>188.86</td>
<td>24%</td>
<td>131.51</td>
<td>30%</td>
<td>35.82</td>
<td>15%</td>
<td>8.42</td>
<td>20%</td>
<td>12.69</td>
<td>17%</td>
<td>0.41</td>
<td>17%</td>
</tr>
<tr>
<td>Seneca</td>
<td>180.32</td>
<td>23%</td>
<td>122.28</td>
<td>28%</td>
<td>26.56</td>
<td>11%</td>
<td>12.17</td>
<td>28%</td>
<td>18.36</td>
<td>24%</td>
<td>0.94</td>
<td>39%</td>
</tr>
<tr>
<td>Schuyler</td>
<td>44.73</td>
<td>6%</td>
<td>23.10</td>
<td>5%</td>
<td>17.37</td>
<td>7%</td>
<td>1.47</td>
<td>3%</td>
<td>2.74</td>
<td>4%</td>
<td>0.05</td>
<td>2%</td>
</tr>
<tr>
<td>Cortland</td>
<td>29.1</td>
<td>4%</td>
<td>13.80</td>
<td>3%</td>
<td>12.71</td>
<td>5%</td>
<td>0.82</td>
<td>2%</td>
<td>1.73</td>
<td>2%</td>
<td>0.04</td>
<td>2%</td>
</tr>
<tr>
<td>Tioga</td>
<td>0.57</td>
<td>0%</td>
<td>0.08</td>
<td>0%</td>
<td>0.40</td>
<td>0%</td>
<td>0.07</td>
<td>0%</td>
<td>0.01</td>
<td>0%</td>
<td>0.01</td>
<td>0%</td>
</tr>
<tr>
<td>Ontario</td>
<td>0.44</td>
<td>0%</td>
<td>0.07</td>
<td>0%</td>
<td>0.25</td>
<td>0%</td>
<td>0.06</td>
<td>0%</td>
<td>0.06</td>
<td>0%</td>
<td>0.00</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>792.92</strong></td>
<td></td>
<td><strong>433.01</strong></td>
<td></td>
<td><strong>237.64</strong></td>
<td></td>
<td><strong>43.06</strong></td>
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<th>County</th>
<th>CLW Drainage Area</th>
<th>Total Drainage Area</th>
<th>Percent of County CLW Drainage Area</th>
<th>Total Drainage Area</th>
<th>Percent of County CLW Drainage Area</th>
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</thead>
<tbody>
<tr>
<td>Tompkins</td>
<td>349</td>
<td>314</td>
<td>90%</td>
<td>35</td>
<td>10%</td>
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<tr>
<td>Cayuga</td>
<td>189</td>
<td>41</td>
<td>22%</td>
<td>148</td>
<td>78%</td>
</tr>
<tr>
<td>Seneca</td>
<td>180</td>
<td>86</td>
<td>48%</td>
<td>94</td>
<td>52%</td>
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</tbody>
</table>

Map showing drainage areas in Cayuga, Seneca, and Tompkins counties.
Total Cayuga Lake Watershed Nutrient Loads from Two Agricultural Land Cover Categories

Monitored and Unmonitored Drainage Areas in the Cayuga Lake watershed: **782 sq. mi.**
*sum of monitored and unmonitored drainage areas listed in the tables

- **Total Watershed TKN Load:** 836 tons/ year
- **Total Watershed TP Load:** 124 tons/ year
- **Total Watershed SRP Load:** 49 tons/ year
- **Total Watershed NOx Load:** 2,761 tons/ year

**Drainage Areas >67% Agriculture**

- **Total Watershed TKN Load:** 8% of 836 tons = 67 tons/ year
- **Total Watershed TP Load:** 29% of 124 tons = 36 tons/ year
- **Total Watershed SRP Load:** 24% of 49 tons = 12 tons/ year
- **Total Watershed NOx Load:** 76% of 2,761 tons = 2,100 tons/ year

**Drainage Areas <67% Agriculture**

- **Total Watershed TKN Load:** 92% of 836 tons = 769 tons/ year
- **Total Watershed TP Load:** 71% of 124 tons = 88 tons/ year
- **Total Watershed SRP Load:** 76% of 49 tons = 37 tons/ year
- **Total Watershed NOx Load:** 24% of 2,761 tons = 661 tons/ year
Monitored and Unmonitored Drainage Areas in the Cayuga Lake watershed: 782 sq. mi.*
*sum of monitored and unmonitored drainage areas listed in the tables

<table>
<thead>
<tr>
<th>Counties’ Nutrient Loads and Yields</th>
<th>Nutrient Load (tons/year)</th>
<th>Nutrient Yield (tons/year/mi^2)</th>
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</thead>
<tbody>
<tr>
<td><strong>County</strong></td>
<td>Drainage Area within Cayuga Lake Watershed</td>
<td>SRP Load</td>
</tr>
<tr>
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<tr>
<td>Seneca</td>
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Drainage Areas >67% Agriculture

Drainage Areas <67% Agriculture
Summary and Conclusions

• Stream monitoring partnerships with volunteer groups have generated long-term nutrient data sets in drainages comprising 65% of the Cayuga Lake watershed.

• These comprehensive, long-term data sets make it possible to obtain credible, useful estimates of phosphorus and nitrogen loading to Cayuga Lake including SRP, TP, NOx and TKN.

• Agriculture contributes to nutrient loading in two ways: a) The total number acres, and b) The fraction of a drainage in agriculture.

• The Draft TMDL underestimates SRP loading 3x and overestimates TP loading 2x based on CSI’s results and two published reports for the Cayuga Lake watershed.
Summary and Conclusions (cont’d)

- Tompkins County has roughly twice as much land area in the Cayuga Lake watershed as either Cayuga County or Seneca County.
- All three counties have approx. equal amounts of land in agriculture.
- Tompkins County loads less dissolved phosphorus and dissolved nitrogen to Cayuga Lake than either Cayuga or Seneca County, apparently because its drainages are <67% agriculture and nutrient yields are lower.
- Tompkins County loads greater amounts of TP and TKN, which are nutrient forms that have a significant soil-bound component.
General Recommendations

• In Tompkins County, consider prioritizing erosion control in order to manage soil-bound nutrients

• In Cayuga and Seneca Counties, consider prioritizing reduction of fertilizer and manure runoff to manage dissolved nutrients

• Investigate “hot spots” of soil erosion and nutrient runoff using CSI’s public online database to guide additional sampling by volunteers

• Include in best management practices (BMPs) the monitoring of nutrient levels

• Discontinue BMP if monitoring shows nutrient levels are not reduced
Nine Element Plan for Cayuga Lake

• The long-term nutrient data sets in the CSI database can be used to initiate development of one or more Nine Element Plans for managing phosphorus and nitrogen loading from southern and northern tributary streams

• CSI data for tributaries of Seneca and Keuka Lakes have previously been used to launch a Nine Element Plan for the Keuka-Seneca Lake Watershed

• Alternatively, CSI data can be used to improve the draft TMDL with respect to a) Phosphorus loading estimates, and b) The equitable allocation of SRP and TP load reductions among jurisdictions
Acknowledgements

• Nate Launer, CSI’s Director of Outreach, helped with the calculations and also made all the maps and tables

• Noah Mark is Technical Director of CSI’s certified lab (ELAP ID# 11790) and responsible for maintaining the high quality of the data in this report

• Please welcome Dr. Grascen Shidemantle, who will replace me as CSI Executive Director in July