City of Minnetonka Watershed Analysis

Presented by:
Patrick Baldwin, Paula Kalinosky, and Molly Wynia
Outline

1. Watershed delineation
2. Road salt estimation
3. Biomass estimation
4. Phosphorous estimation
Watershed Delineation

• Watershed data obtained from City of Minnetonka
  – Crane Lake and Lake Windsor catchments overlapped
Watershed Delineation - Hydrology Tools

- Obtained LiDAR DEM
  - Focused on Crane Lake and Lake Windsor

- Fill Tool for sinks greater than 30 cm

- Converted raster to TIN
  - Reduce nodes

- Burn Features
  - Burn storm water conveyances and gravity mains

- Topo to Raster Tool
  - Created surface and subsurface drainage

- Hydrology tools used to delineate watersheds
Watershed Delineation-Manual Evaluation

- Inspect and process flow direction
  - Elevation contours, storm water conveyances, gravity mains, inlets, outlets

- Assigned “Flows To” attribute
  - Identified the subsequent subwatershed
Watershed Conclusions

• Once both watershed delineation procedures were finished, we made a final decision:
  – Hydro tools produced small, insignificant watersheds. Most likely due to error.
  – Manual delineation produced generalized watersheds.
  – Drainage through storm sewer network is the primary path for road salt and nutrient transport.

In the end, we chose to use the given watershed data, but limited to storm water drainage patterns and with proximity to the lake qualified.
Road Salt Estimation

• Road Salt Application Data
  – In a 1,000 foot buffer from the lake, the following amount of salt was used:
    • Shady Oak Lake: 113,974lbs
    • Crane Lake: 73,576lbs
    • Glen Lake: 70,180lbs
    • Lake Windsor: 250,568
Road Salt Estimation

- Obtained road data
  - Clipped to 1,000 foot buffer
  - Extracted municipal roads

- Calculated salt pounds per meter
  - Done for each of the 4 watersheds
  - Calculated average salt pounds per meter
Road Salt Calculation

- Calculated length of road sections (in meters)
- Roads have more than one lane
  - Multiplied the amount of lanes by the length
  - Total length a truck will drive when salting

- Applied average salt usage to each road
  - This gave the total salt that would be used on each road segment

- Busier roads require extra salt for safety
  - Determine a “traffic factor” and apply this to roads
    - Freeways, highways, major roads = 3
    - Residential roads=1
How Much Salt is Reaching the Water?

- Consider evaporation and absorption
  - 100% of salt will not reach the water

- Consider proximity
  - 100% of salt will not reach the water if it is in an outlying sub watershed
Biomass Estimation

• To determine phosphorus loads, net biomass of watersheds was needed.
• Trunk diameter, height, and GPS/GNSS locations were measured for 25 trees from each watershed.
• Then needed link between biomass and provided LiDAR imagery.
Laser Penetration Ratio (LPI)

$$LPI = \frac{g}{(g+v)}$$
LPI and Biomass

• Needed allometric equation

\[
\ln Y = b_0 + b_1X + b_2S
\]

– Y is the leaf area (m2) or dry-weight biomass (grams)
– X is dbh (centimeters)
– S is the average shading factor by species.
LPI vs. Biomass

LPI Vs. Leaf Biomass

\[ y = -24031x + 35031 \]
\[ R^2 = 0.0327 \]
Biomass Calculations
Normalization
“Active Surfaces”
Deriving Leaf Litter Phosphorus Estimates from Biomass Data

Key Questions

1) Quantity exported to street surfaces and lakes from the tree canopy?

2) Mechanisms and pathways by which phosphorus transported?

3) Quantity of phosphorus delivered via each pathway?
Questions #1 – Biomass Export to Streets and Lakes

Currently street sweeping study in Prior Lake, MN shows strong correlation between percent overhead tree canopy and biomass loads to streets.

\[
R^2 = 0.87673
\]

\[
R^2 = 0.8787
\]

\[
R^2 = 0.8693
\]
Question #1

If biomass is well correlated to % overhead tree canopy ⇒ use Prior Lake regressions to estimate biomass export in Minnetonka.

Assumption: Tree canopy distribution and species are comparable.
## Estimated Biomass Loads to Roads and Lakes

**From Regression Analysis** – 0.034% of biomass found within 50ft of the curb line will be exported to streets

<table>
<thead>
<tr>
<th>Leaf Litter Inputs, Fall only (kg)</th>
<th>Crane Lake</th>
<th>Lake Windsor</th>
<th>Glen Lake</th>
<th>Shady Oak Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf Biomass to Lake</td>
<td>176</td>
<td>349</td>
<td>201</td>
<td>2189</td>
</tr>
<tr>
<td>Leaf Biomass to ponds in the watershed</td>
<td>1419</td>
<td>970</td>
<td>1181</td>
<td>928</td>
</tr>
<tr>
<td>Leaf Biomass to Streets</td>
<td>6706</td>
<td>3370</td>
<td>5962</td>
<td>3671</td>
</tr>
<tr>
<td>Leaf Biomass transfer: Streets to storm sewers</td>
<td>3017</td>
<td>1516</td>
<td>2683</td>
<td>1652</td>
</tr>
<tr>
<td>Leaf Biomass transfer: storm sewer to water bodies</td>
<td>217</td>
<td>142</td>
<td>292</td>
<td>94</td>
</tr>
</tbody>
</table>
Lake Windsor Biomass Loads
Direct biomass inputs to streets and open water

Biomass Loads (kg/ha)
- 0 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500
- 501 - 600

Aboveground Biomass (g/m²)
- High: 21941
- Low: 0

Minnetonka, MN
Figure No. A-1
# Question #2 – Pathways by which Phosphorus is Delivered

## Included in Estimates

**Fall Leaf Litter Drop:**
- Direct input of biomass to water bodies.  
  \[ [P] = 1.5 \text{ mg/g} \]
- Leaching of phosphorus from leaves on streets  
  \[ [P] = 0.086 \text{ mg/g short-term} \]
- Leaching of phosphorus from leaves in storm sewer  
  \[ [P] = 0.750 \text{ mg/g long-term} \]

## Additional Sources
- Biomass inputs at time other than fall (leaves, seeds, flowers, grass)
- Soil-like sediments found on streets
- Other phosphorus carried in surface run-off (fertilizer, pet waste)
- Inputs from groundwater
## Estimated Phosphorus Loads

<table>
<thead>
<tr>
<th></th>
<th>Crane Lake</th>
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<th>Shady Oak Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phosphorus, Direct Leaf Biomass Inputs, Fall only (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaf biomass to Lake</td>
<td>0.16</td>
<td>0.31</td>
<td>0.18</td>
<td>1.97</td>
</tr>
<tr>
<td>Leaf biomass to ponds in the watershed</td>
<td>1.28</td>
<td>0.87</td>
<td>1.06</td>
<td>0.84</td>
</tr>
<tr>
<td>Leaf biomass transferred from storm sewer to water bodies (after leaching)</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td><strong>Phosphorus, Leaching from Street and Storm Sewer (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immediate leaching leaf biomass on street</td>
<td>0.64</td>
<td>0.32</td>
<td>0.57</td>
<td>0.35</td>
</tr>
<tr>
<td>Subsequent leaching, leaf biomass retained on street</td>
<td>0.35</td>
<td>0.18</td>
<td>0.31</td>
<td>0.19</td>
</tr>
<tr>
<td>Long term leaching leaf biomass in storm sewers</td>
<td>2.26</td>
<td>1.14</td>
<td>2.01</td>
<td>1.24</td>
</tr>
<tr>
<td>WATERSHED TOTAL, fall inputs</td>
<td><strong>4.7</strong> (0.26 kg/ha)</td>
<td><strong>2.8</strong> (0.67 kg/ha)</td>
<td><strong>4.1</strong> (0.17 kg/ha)</td>
<td><strong>4.6</strong> (0.13 kg/ha)</td>
</tr>
</tbody>
</table>
## Alternate Estimate, Phosphorus Loads

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Phosphorus, Direct Leaf Biomass Inputs, (Fall only – other season cannot be estimated) (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaf biomass to Lake</td>
<td>0.30</td>
<td>0.59</td>
<td>0.34</td>
<td>3.72</td>
</tr>
<tr>
<td>Leaf biomass to ponds in the watershed</td>
<td>2.41</td>
<td>1.65</td>
<td>2.00</td>
<td>1.58</td>
</tr>
<tr>
<td><strong>Phosphorus, Direct Coarse Organic Inputs, Annual (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse organics transferred from storm sewer to water bodies</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td><strong>Phosphorus, Estimated Annual Organic Inputs (Fall leaves included) (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial leaching of coarse organics on streets</td>
<td>0.49</td>
<td>0.24</td>
<td>0.43</td>
<td>0.26</td>
</tr>
<tr>
<td>Subsequent leaching, coarse organics retained on street</td>
<td>0.22</td>
<td>0.11</td>
<td>0.19</td>
<td>0.12</td>
</tr>
<tr>
<td>Long-term leaching, coarse organics in storm sewer</td>
<td>3.93</td>
<td>1.97</td>
<td>3.49</td>
<td>2.15</td>
</tr>
<tr>
<td><strong>ESTIMATED ANNUAL PHOSPHORUS LOAD, Coarse organic Sources</strong></td>
<td><strong>7.4</strong> (0.41 kg/ha)</td>
<td><strong>4.6</strong> (1.11 kg/ha)</td>
<td><strong>6.5</strong> (0.26 kg/ha)</td>
<td><strong>7.8</strong> (0.22 kg/ha)</td>
</tr>
</tbody>
</table>
## Magnitude of Watershed Loads

What if biomass phosphorus were delivered as a single pulse to each lake?

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<thead>
<tr>
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<th>Glen Lake</th>
<th>Shady Oak Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phosphorus (mg/L)</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Average Phosphorus</strong></td>
<td>0.039</td>
<td>0.188</td>
<td>0.031</td>
<td>0.018</td>
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<tr>
<td>Concentration, 2009</td>
<td></td>
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<td></td>
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<tr>
<td>(mg/L)</td>
<td></td>
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</tr>
<tr>
<td>Direct input of leaf</td>
<td>0.01</td>
<td>0.13</td>
<td>&lt;0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>biomass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total P, Fall Leaf</strong></td>
<td>0.27</td>
<td>1.14</td>
<td>0.07</td>
<td>0.04</td>
</tr>
<tr>
<td>Litter Inputs</td>
<td></td>
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<td></td>
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<tr>
<td>(watershed total from</td>
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<td>table 3)</td>
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<tr>
<td><strong>Total P, Estimated</strong></td>
<td>0.35</td>
<td>1.42</td>
<td>0.09</td>
<td>0.04</td>
</tr>
<tr>
<td>Annual Coarse Organic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inputs</td>
<td></td>
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<tr>
<td>(watershed total from</td>
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<td>table 4)</td>
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</tbody>
</table>
### Comparison to TMDLs Allocations

<table>
<thead>
<tr>
<th>Lake, Location</th>
<th>Surface Area (ha)</th>
<th>Watershed Area (ha)</th>
<th>Watershed/Lake Ratio</th>
<th>External Load (kg/ha)</th>
<th>Internal Load (kg/ha)</th>
<th>Total Load (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweeney Lake, Golden Valley, MN</td>
<td>27</td>
<td>947</td>
<td>35:1</td>
<td>0.27*</td>
<td>0.07*</td>
<td><strong>0.34</strong></td>
</tr>
<tr>
<td>Spring Lake, Prior Lake, MN</td>
<td>260</td>
<td>5127</td>
<td><strong>20:1</strong></td>
<td>0.11</td>
<td>0.05</td>
<td><strong>0.16</strong></td>
</tr>
<tr>
<td>Upper Prior Lake, Prior Lake, MN</td>
<td>136</td>
<td>6522</td>
<td>48:1</td>
<td>0.07</td>
<td>0.14</td>
<td><strong>0.21</strong></td>
</tr>
</tbody>
</table>

For Sweeney Lake, Golden Valley, MN: Seasonal value only, June 1 - September 30.
Recommended Research and Analysis

Stormwater Modeling

Use P8, or other stormwater modeling tool to model loads /load reductions along stormwater flow path.

Figure 2: Bass Creek Business Park Flow Network.

From: http://stormwaterbook.safl.umn.edu/content/case-study-7-monitoring-test-p8-model-bass-creek-business-park
Conclusions

• Biomass, road salt and phosphorus data developed provides information about relative load intensities within watersheds.

• Preliminary analysis shows that road salt and nutrient loads to area lakes are significant and do present potential management concerns.

• Street loading data developed in the project could be incorporated into stormwater modeling software to:
  – Quantify salt, nutrient loads to lake
  – Assess potential water quality impacts