Temporal Variability of Phosphorus Concentration in the stream to Squam Lake, New Hampshire during Storm Events

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NH Water and Watershed Conference
3/24/2017
Introduction

- Phosphorus (P) is the primary limiting nutrient
- Essential for the growth of algae in most freshwater aquatic systems
- Eutrophication
- Non point Sources contributes more P to stream and lake
- Storm water runoff is major sources of P
- Large knowledge gap about the concentration of P in streams and its relation with flow during storm event in Northern New England region
Objectives

1. To measure the P concentration in the stream at hourly resolution during storm events

2. To measure the temporal variability of different P species during storm events

3. To explore the contribution of different flow paths to P concentration and species during the event
Study Sites

Source: http://map.opcguide.com/map-of-new-hampshire-2/
Livermore Cove Brook

- Drainage area = 1.77 Km²
- **Forested land** = 91.7 %
  - Deciduous Forest = 60.9 %
  - Evergreen forest = 29.6 %
  - Mixed forest = 1.2 %
- **Wetland** = 3.4 %
- Developed open space = 2.1 %
- Slightly developed area with houses= 0.05 %
- Pasture land = 2.5 %
- Shrub land = 0.4 %
1. Event Sampling

<table>
<thead>
<tr>
<th>Sampling Sites</th>
<th>Storm event of 06/05/2016</th>
<th>Storm event of 07/09/2016</th>
<th>Storm event of 08/12/2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Livermore Cove Brook</td>
<td>Done</td>
<td>Done</td>
<td>Done</td>
</tr>
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</table>

- ISCO sampler
- Hourly basis

Total number of samples

LMC = 47 + 48 + 48 = 143
2. Lab Analyses

- Specific conductivity (SC, μS cm\(^{-1}\))
- Turbidity (Turb, NTU)
- Total suspended solid (TSS, mg L\(^{-1}\))
3. Phosphorus Analyses

**Total P (TP)**

- **Total dissolved P (TDP)**
- **Soluble reactive P (SRP)**
- **Dissolved organic P (DOP)**

**Total particulate P (TPP)**

- \( TPP = TP - TDP \)
- \( DOP = TDP - SRP \)
4. Stable isotope analysis

• Concentration of deuterium isotope (²H) was used in two-component mixing analysis to calculate % of new water (%NW)

\[ x = \frac{C_t-C_o}{C_n-C_o} \times 100 \]

Where, \( X = \) % of new water

- \( C_t = \) Concentration of deuterium isotope of sample
- \( C_o = \) Concentration of deuterium isotope of stream water during pre-storm flow
- \( C_n = \) Concentration of deuterium isotope of rain water
5. Unit Discharge

- Flow meter
- Discharge in Hubbard Brook
- Discharge measured by Jeff Schloss in Livermore
Are the three events similar?  
NO, not at all

<table>
<thead>
<tr>
<th>Event</th>
<th>Event One</th>
<th>Event Two</th>
<th>Event Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total rain (mm)</td>
<td>41.91</td>
<td>19.6</td>
<td>39.87</td>
</tr>
<tr>
<td>Max. %NW</td>
<td>92.6</td>
<td>45.01</td>
<td>61.69</td>
</tr>
<tr>
<td>Max. UD (mm d⁻¹)</td>
<td>17.82</td>
<td>1.05</td>
<td>3.22</td>
</tr>
</tbody>
</table>

• Storm generates higher Discharge and high % of New Water (%NW)
Specific conductivity (SC) and Turbidity

- Higher the %NW higher is the turbidity
- Higher the %NW lower is the SC
- SC decreased with increase in turbidity
TSS vs Turbidity

Event one
• Highly significant relation
• Higher mobilization of sediments

Event two
• Less significant relation
• Mobilization of finer sediments

Event three
• Highly significant relation
• Higher mobilization of sediments
Time series of P

- Storm generates higher concentration of P
- The SRP was minor component during event but was more significant during baseflow periods.
- SRP also lagged Discharge, suggesting its more consistent groundwater source.
Ratio of P

- Most of TP is in the form of DOP, at all times, fluctuating between 95% (baseflow) to 50% (event flow).
- TPP becomes a significant component (up to 46%) during high event flows.
- SRP is ~15-20% of TP during baseflow but declines in contribution during event flows because of disproportionate inputs of DOP & TPP.
Hysteresis Between P and Discharge in Event One

- TP, TDP, TPP and DOP had made clockwise hysteresis.

- P concentrations on rising limb of hydrograph were much higher than on falling limb which resulted in clockwise hysteresis.

- SRP had made anticlockwise hysteresis indicating that it was from different source.
Before Storm Event

- Suspended sediments are settled down on the stream

During Storm Event

- Sediments are mobilized
- SRP moves to stream from subsurface flow
- DOP and PP moves through surface flow and overland flow
Conclusions

- Storms generate higher Discharge, concentration and yield of P in the stream.

- Dissolve P is more dominant than particulate P and among dissolved P, organic P is more dominant than inorganic P.

- Storm events contribute a disproportionate amount of P to Livermore Cove Brook load.
Conclusions (contd..)

- The SRP was minor component during event but was more significant during baseflow periods. SRP also lagged Discharge, suggesting its more consistent groundwater source.

- P concentrations on rising limb of hydrograph were much higher than on falling limb which resulted in clockwise hysteresis. SRP had made anticlockwise hysteresis indicating that it was from different source.

- This study is useful to find the approximate natural P loading in other watersheds of Squam Lake nearby and control the anthropogenic P loading in the stream.
Acknowledgements

• Dr. Lisa Doner, my research committee member
• Todd Dickinson for helping me in field and lab work
• Jeff Schloss since I used the discharge measured by him
• Hubbard Brook Experimental Forest (HBEF) for discharge
• Donovan King and Daniel Evans for teaching how to use logging sensors
• Faculty members from ES&P and CFE
• Friends from Graduate studies
• Family
Questions ??

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### TP Yield

<table>
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<tr>
<th>Events</th>
<th>TP yield (kg/ha/event)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>0.0075</td>
</tr>
<tr>
<td>Two</td>
<td>0.0003</td>
</tr>
<tr>
<td>Three</td>
<td>0.0012</td>
</tr>
<tr>
<td>Total</td>
<td>0.009</td>
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</tbody>
</table>

- The 3 events had made 5-10% annual TP yield.
**Methods**

1. Event Sampling

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</tr>
<tr>
<td>North Brook</td>
<td>Not Done</td>
<td>Done</td>
<td>Done</td>
</tr>
<tr>
<td>Eagle Cliff Brook</td>
<td>Not Done</td>
<td>Not Done</td>
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**Total number of samples**

**LMC** = 47 + 48 + 48 = 143  
**NB** = 2 + 48 + 48 = 98  
**EC** = 48  
**Total** = 289

- Hourly basis
- ISCO sampler

Setting ISCO sampler to catch storm event

ISON Sampler

Samples in Laboratory