Estimating Phosphorus Loading to the Mad River from Surrounding Tributaries

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Abstract:

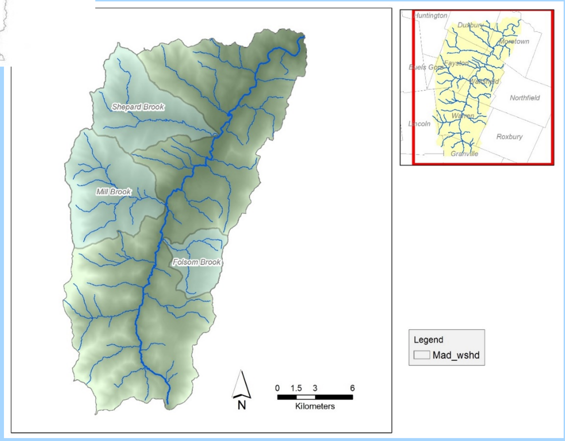
Modeling phosphorus loading into the Mad River from various tributaries using a model allows researchers and policy makers to know approximately how much phosphorus is entering the river, provided one has the stream discharge over known time periods. Since it is not possible to know the flow everywhere in a stream network, the relationship between flow and water level (stage) can be leveraged. Creating a rating curve (graphing flow and stage) provides flow values when the stream height is known. Given these estimated discharge values, phosphorus moving through the river at different stages can be estimated. Previous research shows that Total Suspended Sediment and Discharge are linearly related, and with this knowledge it is with high expectation that Total Phosphorus (TP) and discharge also have a strong relationship. However, many tributaries and other rivers in the Lake Champlain Basin do not have instruments that continuously measure flow; therefore, other manual intensive methods must be used. The loading values I estimated at Shepard, Mills, and Folsom Brook can be compared to the Mad River's main stem, and also implemented for any other tributary that has Total Phosphorus (TP) data, thus giving researchers values for locations feeding the river. Different values from different locations provide the information needed for prioritization of water quality improvement efforts.

Location and Time:

Mad River Watershed

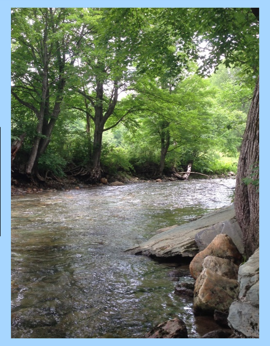
- **Drainage Area: 373 km²**

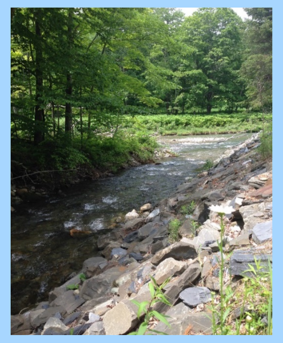
	% Area of Mad River	% Agriculture	% Developed
Mill	13.1	13.9	40.4
Shepard	4.9	21.4	18.8
Folsom	12.0	2.6	28.3
Mad	100.0	28.6	21.2



Maps of Mad River Watershed, courtesy of Kristen Underwood

Three main things were required to calculate the loading: Stage, Discharge, and TP concentrations. Out of the three, stage was the limiting factor for my time period. The stage data for each tributary all had dates for **JUNE 6, 2014 through DECEMBER 5, 2014**, a particularly **dry** season.





Photos of the selected brooks: Shepard, Mill, Folsom (respectively)

Methods:

- Stage and Total Phosphorus data was recorded by a pressure transducer in an ISCO automatic sampler in 2014
- Rating curves, created from previous research on the 3 tributaries using a HEC-RAS (Hydraulic Engineering Center River Analysis System) model, provided the means of calculating the discharges with the collected stage data.
- USGS flow values were copied from the USGS website
- Using the stage, discharge, and TP data, I matched the times of the sampled collected
  - Stage is the height of the water, from the pressure transducer's elevation to the top of the water column.
- In order to calculate the TP values for the entire time period, a relationship was created using the known TP data and the discharge; with new equation, having discharge can estimate TP values
- Multiplying the TP and discharge values results in the phosphorus loading

Picture of Scott Hamshaw with ISCO automatic sampler

Picture of Pressure Transducer (http://www.rbusey.org/junk/2007_06_01_archive.shtml)

The **HEC-RAS equations** from the rating curves are used to find discharge:

- Mill: Q= 11.215*(stage^2.3637)
- Shepard: Q= 27.495*(stage^2.4881)
- Folsom: Q= .444*(stage^3.6938)

Time Sampled	TP (mg/L)	Discharge (cfs)	Discharge (L/s)
6/10/2014 10:22	0.0027	102	2888.318394
6/10/2014 10:22	0.0025	102	2888.318394
6/10/2014 10:22	0.0013	102	2888.318394
6/10/2014 10:22	-0.0012	102	2888.318394
6/12/2014 3:15	#N/A	192	5436.834624
6/12/2014 21:35	0.0459	482	13648.72025
6/13/2014 11:05	0.0033	528	14951.29522
6/13/2014 17:00	0.0719	812	22993.27976
6/14/2014 0:00	0.0712	774	21917.23958
6/15/2014 9:30	0.0111	437	12374.46214
6/16/2014 12:03	0.0006	282	7985.350854
6/17/14 19:30	0.0026	187	5295.250389
6/18/14 8:30	0.0097	431	12204.56106
6/18/14 15:00	0.0150	412	11666.54096

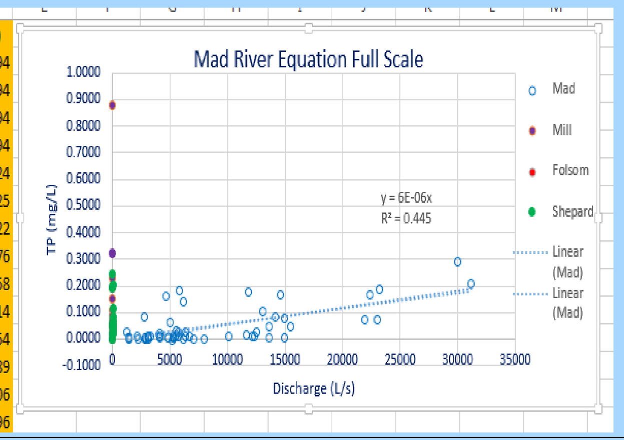
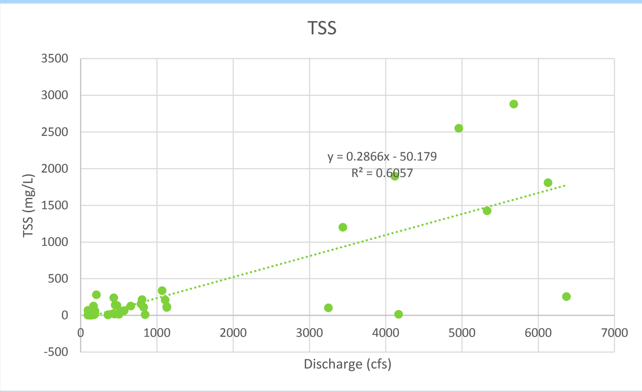
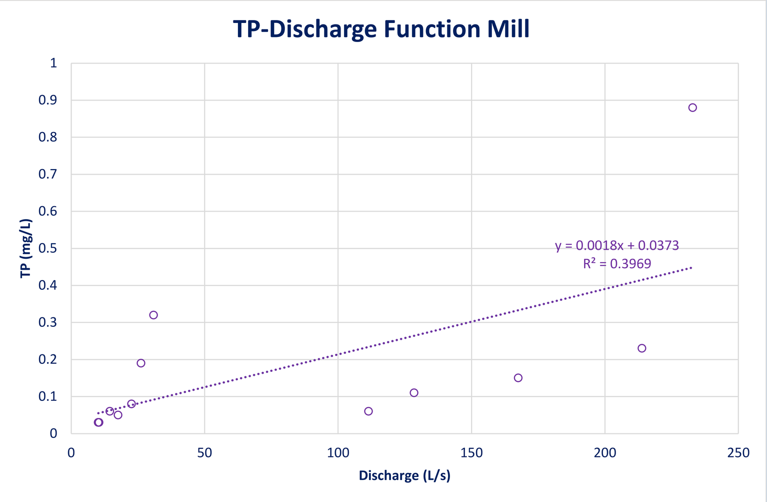
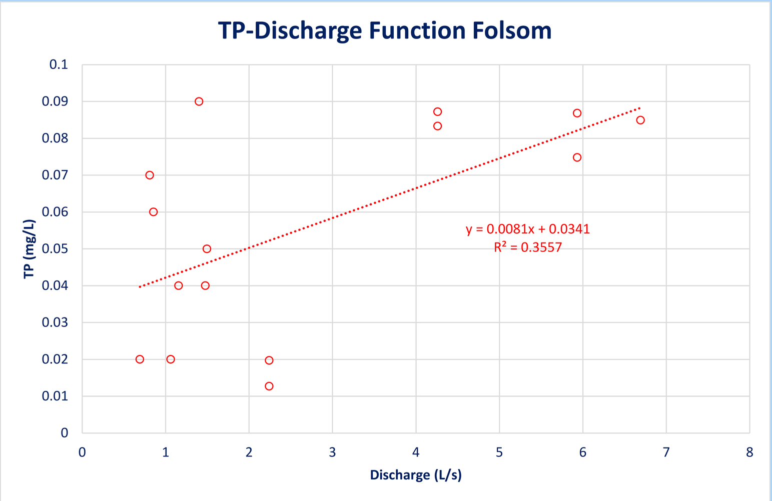


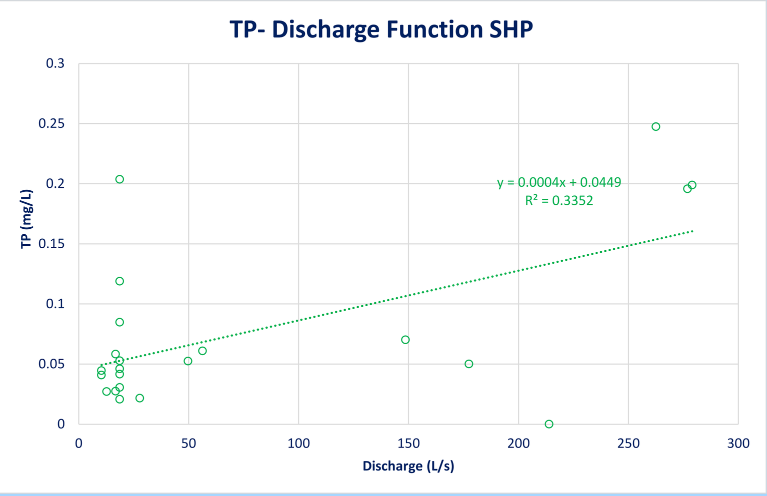
Figure X: The screenshot above has the discharge/TP relationship for the 4 locations. Notice the scales.

Graph below: TSS and Discharge relationship; the basis of why TP and Discharge have a relationship.









Top Figure: TP plotted with Discharge at Mill Brook location

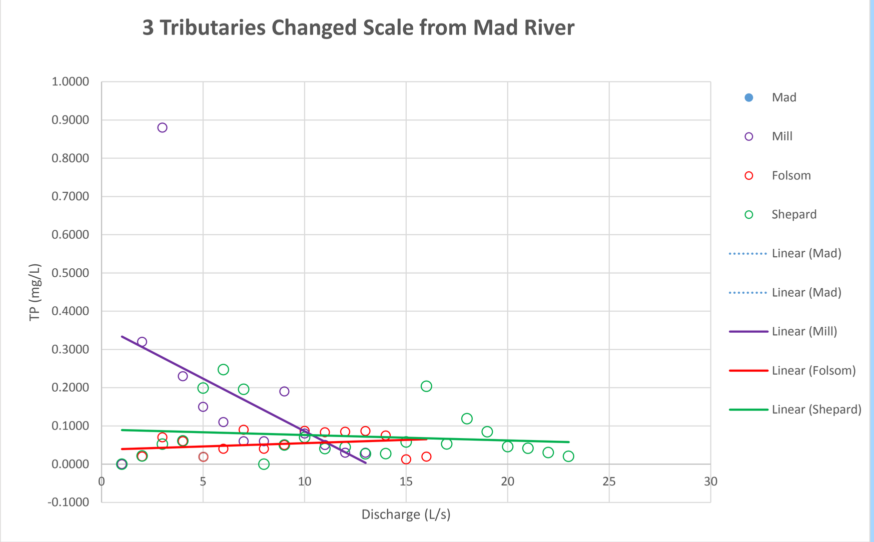
Right Figure: TP plotted with Discharge at Folsom Brook location

Bottom Figure: TP plotted with Discharge at Shepard Brook location

Results:

In order from most importance to least:

1. Mills
2. Shepard
3. Folsom



Graph above: The same graph as figure X, but the scale is smaller, better fitting for the 3 tributaries. Note the Mad River does not even have a point at such discharges.

	TP total using stage (mg/L)	Integrated Discharges (L/s)	Sum of integrated loading (mg/s)
Folsom	914.0	39320.9	76
Mill	1088.2	242672.3	785
Shepard	917.5	333347.4	762
Mad	359.7	59945122.7	2549709

	kg/year	% of Mad River
Mill	1.43	0.4
Shepard	1.37	0.6
Folsom	0.14	0.1
Mad	4814.90	100.0

The two screenshots to the left are visual results. The sums of loading, individual integrated discharges and the concentration are shown. The chart bottommost provides the **LOADING** amount in **kg/year**, as well as the percentage that each tributary contributes to the Mad River

Discussion:

Upon analysis of my results, I found it interesting how body of water with the greatest discharge does not necessarily mean it has the greatest loading. In regards to loading, I was also surprised to calculate that Mill Brook had the greatest sum, considering Shepard Brook has the most agriculture. I was under the false pretense that agriculture practices are worse than developmental practices (where Mill has the greatest), but clearly I would now say that with safe and environmental friendly practices, that is not the case. The farmers near Shepard Brook will be pleased! Furthermore, it is important to note that this research is only 3 tributaries in 1 watershed in the Lake Champlain Basin. The intent behind this research is not to find a solution for the water quality issue of the Lake, but merely propose a starting point for researchers. Ideally, future research would consist of the same methods, in all the watersheds that feed into Lake Champlain. Once all the data is collected, comparing watersheds to each other implements a hierarchy of "most detrimental" to "least detrimental" bodies of water. It is necessary to acknowledge however, that even once phosphorus loadings are estimated, there is a possibility that not all the load reaches the river. Different stream processes make it possible so that the nutrients could be absorbed by soil on the bank or even seeped through the river bed; in these cases, not the full amount estimated would reach the river in the given time.

Acknowledgements:

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