

A Comparison of Streams in the Chequamegon Bay Ecosystem

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Abstract

The Chequamegon Bay ecosystem is a complex region, in part due to the streams that drain into it. This study looks at two of these streams, Sioux River and North Fish Creek, and their respective main tributaries, Little Sioux River and Pine Creek. Data was collected from April to July 2014, and the relationships of discharge and sedimentation were explored. Two methods for sediment analysis were compared, and rating curves were also established for future research use. Finally, discharge per acre and sediment yield per acre were compared between the streams.

Introduction

There are several river systems that influence the ecosystems of Chequamegon Bay of Lake Superior. The Sioux River and North Fish Creek are two of the most important, along with their main tributaries, Little Sioux River and Pine Creek, respectively. Their importance can be perceived even just by their sizes; the Sioux River watershed encompasses over 29,000 acres, and the entire Fish Creek watershed, including both the North Fish Creek and South Fish Creek watersheds, is more than 100,000 acres in area. Being the two main river systems that drain into Chequamegon Bay, researchers are extremely attentive to their fluctuations. Generally, every river is subject to change by the surrounding climate, by the different types of rock they erode away, and by the human activities within their watersheds. This all leads to changes in composition of a river.

Total nitrates, total phosphorous, sediment loads, and the rate and amount of flow are just some of the components for which a river can vary. Nitrates and phosphates are important nutrients for any living organisms in the rivers, but if there is too much, the organisms will grow in numbers and dissolved oxygen levels decrease. The amount of sediment in a stream is important because it determines how much sunlight can get through the water, and therefore is a temperature control. The volume of flow, or discharge, and rate of flow greatly fluctuate with the seasons and weather patterns. Recording discharge conveys how quickly nutrients and sediments are being washed away. Researchers record fluctuations in these components as a way to keep track of changes in the ecosystem.

In the Chequamegon Bay area, a project entitled "Modeling the Chequamegon Bay Ecosystem to Facilitate Climate Adaptation" began in February of 2014. The goal of this project is to estimate the potential impacts of climate change on the water quality conditions of Chequamegon Bay (Lehr, 2013). Nutrients, sediment loads, and general conditions of the tributaries of Chequamegon Bay are being studied, in addition to any changes in water temperature and near-shore conditions (Lehr, 2013). This endeavor is facilitated by the staff and students working at the Sigurd Olson Environmental Institute at Northland College, located one mile from Chequamegon Bay.

This study specifically examined the Sioux River and North Fish Creek river systems, both of which drain to Chequamegon Bay (Figure 1). The goal was to determine whether or not the relationship between Sioux River and Little Sioux River was similar to the

relationship between North Fish Creek and Pine Creek in their amount of flows and sediment loads.



Figure 1. Map of Sioux River, North Fish Creek, and their tributaries in Northern Wisconsin. Map also shows the subwatersheds of each main stream. Credit: J. Daw

The discharge of a river is an important factor in its health and in the surrounding ecosystem. Flow will vary greatly between seasons, such as in the spring when all the snow is melting, and in response to weather patterns, such as a large rain event. However, if no such event occurs, but the flow changes drastically, that is a sign that something unusual, possibly anthropogenic, is affecting the stream.

Stream gauges are a common way to measure the river flow because if placed correctly, they consistently take a reliable measurement every fifteen minutes. In a perfect world, the ideal stream-gauging site would be on the mouth of the river so the flow from all the tributaries would be part of the calculation. Unfortunately, the land around the mouth of a river is very unstable and is often not a good place to install a stream gauge. Additionally, gauges are expensive and fairly sensitive, so “stream gauges are often placed in low flows for the best results” (Soupier, 2009, p. 110). For these reasons, stream gauges are usually placed upstream. In order to account for what the gauge is missing, individual flow measurements are consequently taken downstream. Individual flow and discharge measurements also help to determine the severity of how much a stream changes from low flow to high flow. This can lead to the question of how the surrounding ecosystem adapts to large changes in flow.

The health of a river is also determined by the amount of sediment it carries. Sediment in a body of water tells a lot about the origin and pathway of the water (Hsu, 2010). In general, the more a rock body is weathered, the more sediment is created. Water is capable of both weathering and transporting sediment, which makes it a very powerful force of nature. However, water quality changes with different amounts of sediment because high turbidity levels result in higher water temperatures. This significantly

impacts fish populations and other species within an ecosystem because many species can only survive within a certain temperature range.

Methods

As previously stated, this project studied the relationships between the Sioux River, Little Sioux River, North Fish Creek, and Pine Creek in their discharges and sediment yields. There were many different steps taken to get the results. The researcher learned how to individually measure the discharge of a river, accurately take sediment grab samples, and analyze the samples in two different ways. The researcher also utilized knowledge of GIS to this study and gave the results more meaning by applying the discharge and sedimentation results to the entire watershed.

The FlowTracker is a common device for taking individual flow measurements (Figure 2). First, a cross section was found that is perpendicular to the flow of the stream. This was to ensure that the measurements are taken directly parallel to the flow lines. This is important because the FlowTracker uses Doppler radar to measure the flow velocity, and if measurements are not being taken parallel to the flow, then error results in the form of a high velocity angle. After an appropriate cross section was set, the depth was measured starting at either the right or left edge of the stream and the FlowTracker was set at the appropriate position. This position depended on the depth; if the water was less than 1.5 feet deep, then the FlowTracker measured the flow at sixth-tenths of the depth. However, if the water depth was equal to or more than 1.5 feet, then two measurements were required: the FlowTracker first measured the flow at two-tenths of the depth, then it measured the flow at eight-tenths of the depth, and those two measurements were then averaged. This was to confirm that the measurements were accurate throughout the entire column of water. The results of each measurement were recorded both in the FlowTracker and on paper. This process was continued along the cross section at a certain interval. The interval size was subject to change depending on the flow velocities, and a minimum of twenty-five measurements across the section was needed to ensure a complete profile. Also, the goal was to measure less than 5% of the total flow within each interval because that would permit the least amount of error. After all measurements were taken, the FlowTracker calculated the total discharge. The discharge of an interval is calculated by multiplying the area of water in that interval, measured in square feet, by the flow velocity, measured in feet per second, resulting in cubic feet per second (cfs). The total discharge is the sum of the discharges from every interval.



Figure 2. J. Daw using the FlowTracker at Pine Creek on April 23, 2014.
Credit: E. Alexson, Sigurd Olson
Environmental Institute

The method of determining the sediment concentrations includes testing the total suspended solids (TSS), the suspended sediment concentrations (SSC), or both. For both tests, the samples were first taken and then refrigerated as soon as possible. They needed to be refrigerated quickly because too much heat could change the chemical properties of the sample, which would compromise the analysis. Next, the filters were prepared and dried in an oven for at least one hour and then dried even further in a desiccator for at least fifteen minutes. Filters with a pore size of $1.5\ \mu\text{m}$ were used for TSS, and filters with a $0.7\ \mu\text{m}$ pore size were used for SSC. The filters were weighed before running the sample through; this was called the pre-dry weight. Following this, the sample bottle was shaken well to evenly distribute the sediment. For TSS, a portion of the 1 Liter bottle was poured into a graduated cylinder. This amount varied depending on how much sediment was in the sample because there was a possibility of clogging the filter with too much sediment. The amount in the graduated cylinder was recorded and then filtered. If possible, more was added and the new amount was recorded. The filter was removed and the process was repeated for the rest of the TSS samples. For SSC, the entire contents of the sample bottle were poured into a graduated cylinder, and the amount was recorded. Because of this, the sample bottle size needed to be small, such as a 250 mL bottle instead of a 1 L bottle, if the stream was turbid at the time of collection so that the filter would not clog with too much sediment. The sample was filtered, the filter was removed, and the process was repeated for the rest of the SSC samples. Then, for both TSS and SSC, the filters dried in an oven for at least 8 hours and continued to dry in a desiccator for at least fifteen minutes. Finally, they were weighed, and the post-dry weight was recorded (Figure 3). The difference of the two weights for each sample was divided by the sample volume used to end the analysis.

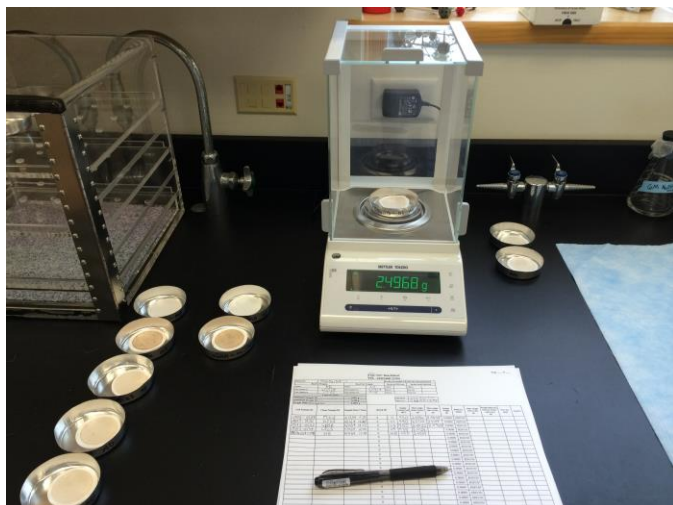


Figure 3. After drying overnight, a round of filters were weighed on June 14, 2014.
Credit: J. Daw

The difference between TSS and SSC may seem slight, but consider a very turbid sample. For TSS, the lab worker would only take a small amount, such as 250 mL or less, of the entire 1 Liter bottle. Even though the bottle was well shaken before, large sediments may sink quickly and will not make it into the amount to be filtered. Therefore, is it truly representing the entire sample taken? This is the main question to consider when performing a TSS test. On the other hand, for SSC, the entire sample bottle needs to be filtered, no matter how turbid the sample is. For this reason, SSC would be a better representation as long as the sample was taken properly. Although, it is possible that a 250 mL sample bottle, which is typically the smallest size bottle, is so turbid that the filter gets clogged, and then the integrity of the test is compromised. These are the challenges with sampling and testing sediment loads, which are the reasons why both tests were performed in this study.

Geographic Information Systems (GIS) was also applied to study the Sioux River watershed and the North Fish Creek watershed, as well as the Little Sioux River subwatershed and the Pine Creek subwatershed. These delineations helped determine the total land area that is represented in a single discharge measurement. This led to calculations such as the total discharge per acre or sediment yield per acre. The delineations from the Department of Natural Resources in 2008 were used to make such calculations (Community GIS Services Inc., 2009).

Results and Findings

The following tables are the calculations acquired by using discharge data, sediment analyses, and total watershed acreage. In the sediment analyses, any duplicates were averaged. Sample duplicates were sometimes taken in the field, and some TSS samples were filtered through two different filters, creating lab duplicates.

The site names SXBR, LTLS, NFO2, and PCO2 represent Sioux River, Little Sioux River, North Fish Creek, and Pine Creek, respectively. The site on Sioux River where measurements and samples were taken was at Big Rock Road in Bayfield County, and this is located before Little Sioux joins Sioux. The measurements and samples were taken from Little Sioux River at Friendly Valley Road in Bayfield County. This was located very close to the confluence of Sioux and Little Sioux. Both North Fish Creek and Pine Creek

measurements and samples were taken at Old U.S. Highway 2 in Bayfield County. The Pine Creek site was very close to the confluence of North Fish and Pine, and the North Fish site was located immediately after the confluence.

Table 1. Compiled discharge, TSS, and SSC results from all sites. * = predicted number calculated from trend line.

Site Name	Date	Gage Height (ft)	Discharge (cfs)	TSS (mg/L)	SSC (mg/L)
SXBR	4/10/14	12.280	249.715	103.76	128.68
	4/15/14	11.850	105.063	*73.07	*84.37
	4/18/14	11.755	55.876	*14.03	*14.90
	4/20/14	11.975	117.497	*88.00	*101.93
	4/21/14	12.440	490.699	625.00	724.84
	4/22/14		*615.860	*686.18	805.82
	5/9/14	12.030	236.221	182.18	226.91
	5/30/14	11.660	23.909	3.30	2.50
	6/4/14	11.710	31.910	*-14.73	5.01
	6/6/14	11.670	26.682	3.65	2.51
	6/13/14	11.700	32.887	4.87	3.73
	6/16/14	11.775	47.357	35.31	*2.87
	6/30/14	11.675	27.539	*-19.98	11.70
	7/14/14	11.250	22.64	2.97	4.26
LTLS	4/22/14	7.290	59.391	119.50	139.55
	5/30/14	5.465	14.123	5.08	5.25
	6/6/14	5.445	16.019	5.82	10.71
	6/13/14	5.570	16.630	12.19	60.00
	6/16/14	5.655	20.815	70.24	*52.88
	7/14/14	5.320	12.017	4.04	9.66
NFO2	3/27/14	4.010	58.920	*-11.24	*3.57
	4/21/14		*635.928	386.24	479.32
	4/23/14	4.910	220.156	56.48	136.63
	5/30/14	4.055	54.911	2.56	2.67
	6/4/14		*59.306	*-10.99	3.89
	6/13/14	4.095	62.83	3.62	4.27
	6/16/14	4.330	98.57	15.51	*36.26
	6/30/14	4.040	54.398	*-14.27	1.46
	7/14/14	4.040	54.398	4.02	4.04
PCO2	4/21/14		*622.740	807.41	900.55
	4/22/14	5.413	58.449	74.53	63.19
	4/23/14	5.260	40.039	29.22	21.15
	5/30/14	4.950	18.956	3.45	2.71
	6/13/14	4.995	21.885	4.00	4.62
	6/16/14	5.045	25.509	8.71	*9.00
	7/14/14	4.625	19.361	3.40	3.04

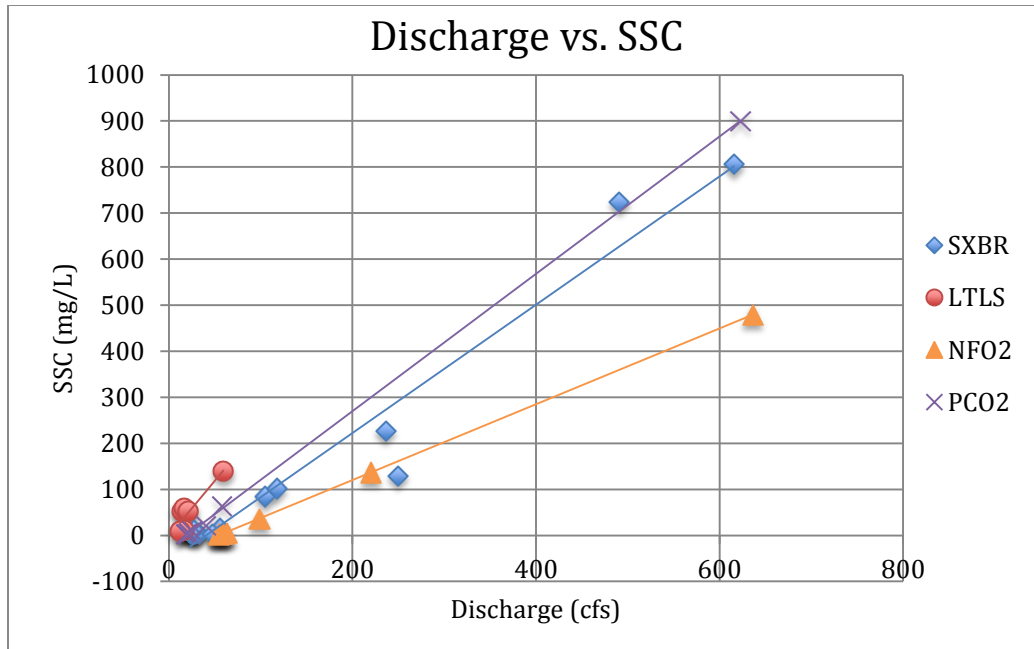


Figure 4. Plotted discharge and SSC results of all four sites, including predicted values, with their best-fit trend lines, all of which are linear.

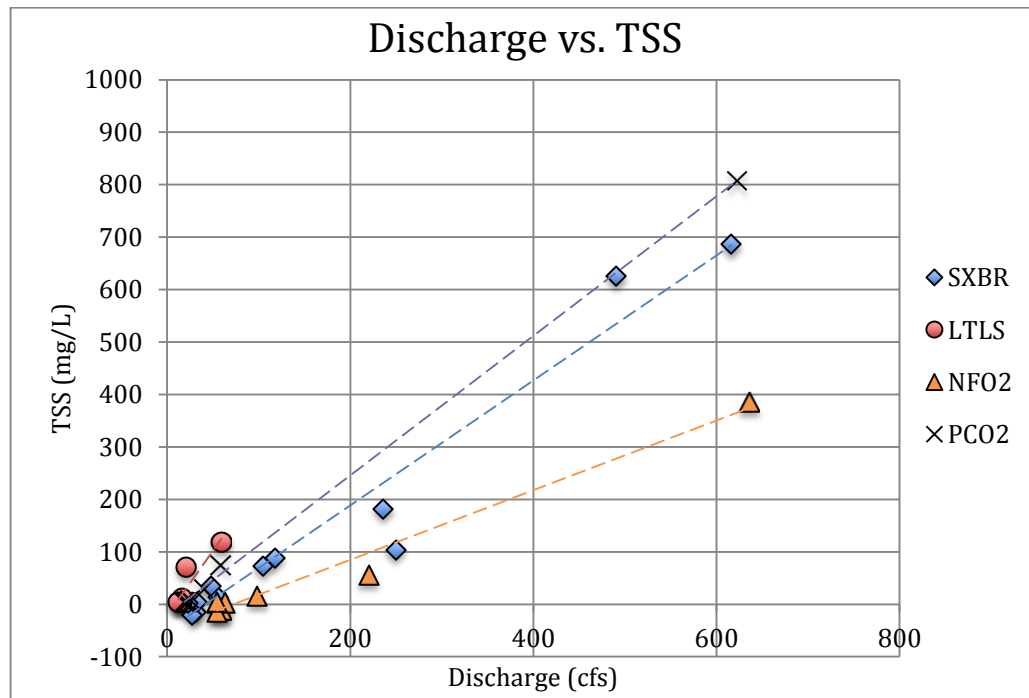


Figure 5. Plotted discharge and TSS results of all four sites, including predicted values, with their best-fit trend lines, all of which are linear.

When comparing the sediment results, TSS and SSC behave very similarly (Table 1). This is also clear when comparing Figure 4 and Figure 5. The effects of high discharge are very apparent in the sediment results, and the same can be said for the effects of low

discharge. Generally, it is thought that SSC would have higher results than TSS because the filters used for SSC have a smaller pore size. Thus, less sediment can get through, leading to a greater filter weight. This is mostly represented in the results. However, there are a few cases where the TSS result was greater than the SSC result. All of these cases involved discharge values that were very low, so it is possible that the samples were taken during a time where the low amount of sediment was flowing inconsistently.

Another problem with these results is that some of the predicted sediment values are negative. A negative TSS or SSC result would mean that there was more weight before the sample was filtered than after. When filtering water samples with obvious amounts of sediment, it is impossible for the result to be negative unless there was an error on the scale. Therefore, this phenomenon shows the amount of error in the trend lines. The trend lines that best fit the data were all linear with negative values as the y-intercept (Figure 4, Figure 5). This means that as a discharge value approaches zero, the predicted TSS or SSC result would be negative. Consequently, it is very possible that the data acts exponentially with smaller discharge values and linearly with middle to large discharge values. The exponential characteristic would not allow negative TSS or SSC predicted results for discharge at base flow.

Table 2. Discharge per acre on selected dates that discharge was measured.

Site Name	Total Acres	4/22/14	4/23/14	5/30/14	6/6/14	6/13/14	6/16/14	6/30/14	7/14/14
SXBR	18364.10			0.001302	0.001453	0.001791	0.002579	0.001500	0.001233
LTLS	7314.33	0.008120		0.001931	0.002190	0.002274	0.002846		0.001643
NFO2	17756.79		0.012398	0.003092		0.003538	0.005551	0.003064	0.003064
PCO2	6953.38	0.008406	0.005758	0.002726		0.003147	0.003669		0.002784

As seen in Table 2, when comparing the discharge per acre of Sioux River and Little Sioux River before they converge, Little Sioux River and its tributaries supplied 10-50% more discharge per acre than the Sioux River and its tributaries. Furthermore, when comparing North Fish Creek and Pine Creek, Pine Creek and its tributaries supplied 50-90% of the discharge per acre of North Fish Creek after the confluence of the two. Even though these two comparisons are different, it is clear that both Little Sioux River and Pine Creek contribute significantly to their river system. Additionally, these percentage ranges are fairly wide, showing the variations in flow.

Table 3. Sediment yield per acre on selected dates that SSC was measured.

Site Name	Total Acres	4/21/14	4/22/14	4/23/14	5/30/14	6/6/14	6/13/14	7/14/14
SXBR	18364.10	0.039470	0.043880		0.000136	0.000137	0.000203	0.000232
LTLS	7314.33		0.019079		0.000717	0.001464	0.008203	0.001321
NFO2	17756.79	0.026993		0.007695	0.000150		0.000240	0.000228
PCO2	6953.38	0.129512	0.009088	0.003042	0.000390		0.000664	0.000437

As seen in Table 3, 80% of the days resulted in a greater sediment yield per acre for Little Sioux River and Pine Creek when SSC was measured in both Sioux River and Little Sioux River or both North Fish Creek and Pine Creek. This also means that there was only

one time where both North Fish Creek and Sioux River supplied more sediment per acre than Pine Creek and Little Sioux River, respectively. Table 3 also shows that Little Sioux River supplied more sediment yield per acre than Pine Creek on every day where SSC was measured for both streams. This is very peculiar because even though the acreages are roughly the same, the Little Sioux River watershed is almost completely forested, and the Pine Creek watershed is mostly agricultural. It is believed that the conversion of croplands to forest would reduce erosion and sedimentation (Fitzpatrick, 1999). Thus, the fact that Little Sioux River contributed more sediment yield per acre than Pine Creek is conflicting.

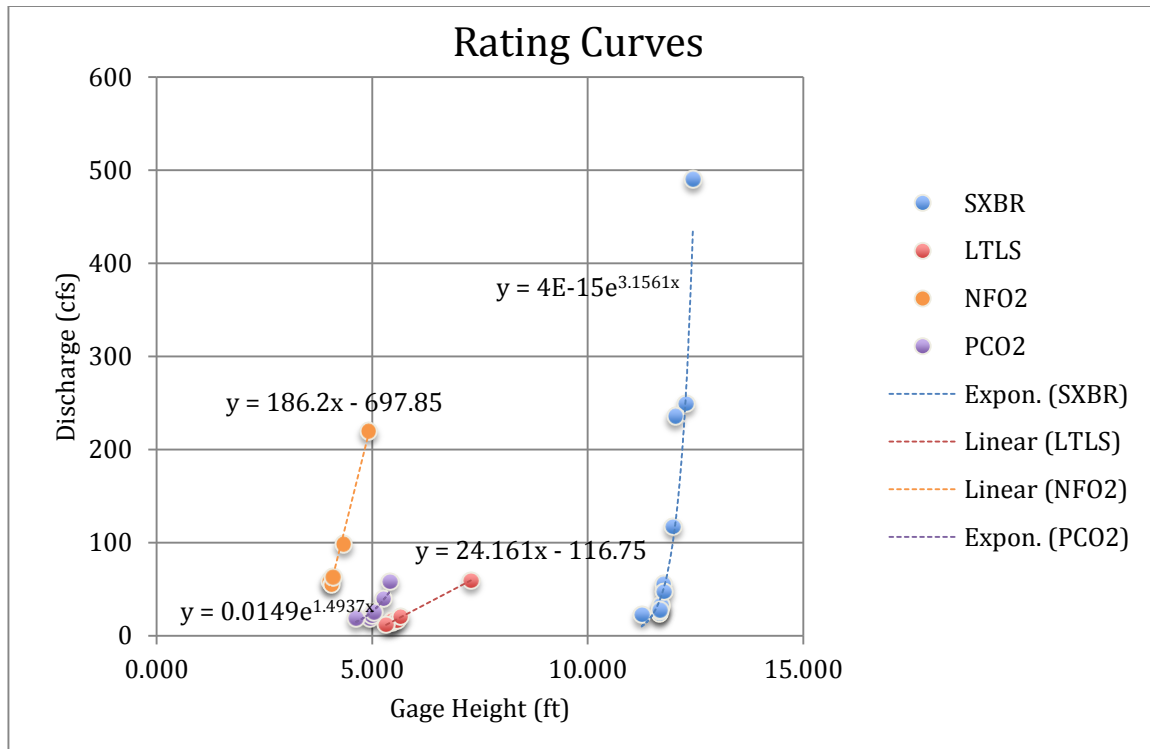


Figure 6. Gage height in feet plotted against measured discharge and the best-fit trend lines for all four sites.

Rating curves are important to establish because it allows researchers to know the discharge without having to take flow measurements. Instead, by just measuring the water level, the discharge can be determined by using the rating curve for that stream. Therefore, rating curves were established with data from this study (Table 1).

Good rating curves have data across the entire spectrum of flows. In other words, it is important to have discharge and water level data from base flow up to high flows, and many other flows in between. The rating curves in Figure 6 have several base flows, maybe a couple mid-flows, and one high flow. Clearly, there are several gaps that should be filled to create better rating curves.

Conclusions

There are many inconsistencies in the results, showing that more data is needed to come to solid conclusions. More data would add to, and possibly change, the relationships

between discharge and sedimentation, and it would provide more complete rating curves for future uses. Discharge and sedimentation are important qualities that show how well a river system, and therefore an ecosystem, is doing. These results show that discharge and sediment relationships do exist between all four streams, and therefore they are worth studying more. All of the data collected represents a portion of the Chequamegon Bay ecosystem, and every bit of sediment collected and discharge measured is what drains into Chequamegon Bay. In order to fully conclude on how healthy this ecosystem is, more results are needed.

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