Total Suspended Solids-Turbidity Correlation in Northeastern Wisconsin Streams

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Abstract

To estimate sediment loading, total suspended solids (TSS) and turbidity are sampled with automated sampling equipment within the Lower Fox River watershed in northeastern Wisconsin. Knowledge of sediment loading is fundamental to assessing non-point source pollution. However, collection and analysis of sediment samples is costly. These costs could be reduced if TSS could be accurately estimated from continuously monitored turbidity. This poster presents 2003-2004 turbidity and storm event sample data for Apple, Ashwaubenon, Baird, and Duck Creeks. YSI-6200 multi-parameter sondes were deployed for continuous turbidity measurement. Linear regression (R^2) ranged from 0.78-0.98. We hypothesize that the weaker relationships are due to variances in hydrologic response and watershed land use. Certain Sonde data were excluded due to equipment-associated false spikes in turbidity. In conclusion, continuous monitoring of turbidity appears to offer a viable alternative for TSS estimation in these locations. Evaluation of pollutant transport under changing land use could be accelerated with this straightforward information alternative.

Introduction and Project Objectives

Estimation of sediment loading in a stream typically requires utilizing automated event samplers to collect a limited number of total suspended solids (TSS) samples for laboratory analysis. Other studies have found that continuously monitored turbidity measurements may closely correlate with TSS concentrations in streams (Christensen 2000). Turbidity is a measurement of the decrease in transparency of stream water as light is scattered by suspended matter (Ziegler 2002). Because optical sensors can be used to continuously monitor turbidity throughout a storm event, turbidity-derived predictions of TSS may yield an accurate estimate of sediment fluctuations minus the costs associated with manual sampling. Particle properties-such as color, shape, and size distribution-may impact turbidity readings (Ankcorn 2003). Although general TSS-turbidity relationships have been reported, relationships must be established on a site-by-site basis, and reliability may vary due to water color and suspended particle composition (Packman et al 1999).

This poster presents research conducted to establish TSS-turbidity relationships for Apple, Ashwaubenon, Baird (north and south branch), and Duck Creeks in Northeastern Wisconsin as part of a larger watershed monitoring project.

Figure X. YSI-6200 sonde.

Figure X. Refrigerated ISCO sampler.

Methods

Established USGS methods were used for gaging streamflow and for collecting, processing, and analyzing water samples (Shelton 1994). Sampling was conducted at two locations on Baird Creek from April to July 2004 (Figure 1). A fully automated water sampling station (USGS station) was located at Superior Road on the main channel of Baird Creek. Equipment at this station consisted of an ISCO 3700R automated sampler, a rain gauge, a gas-bubble water level measuring system, a data logger, and a modem (Figure 2). Water sampling during flow events was triggered by changes in water levels, and was structured to be representative of the entire hydrograph. An additional sampling site was located upstream of the USGS station on the North Branch of Baird Creek, which has a predominantly agricultural watershed. This station consisted of an ISCO Model 1392 Wastewater Sampler, which was manually activated to collect samples at timed intervals during a flow event (Figure 3). Biweekly baseflow samples were also collected at each site using the equal width increment (EWI) method (Thornton 1988). In addition to the sampling equipment, YSI-6200 multi-parameter sondes were deployed at each site and logged T, pH, DO, specific conductance, depth, and turbidity at 10 minute intervals (Figure 4). The optical turbidity sensors had automated wipers to prevent fouling.

Sonde data was censored to remove anomalous spikes in turbidity due to debris on the wipers and protective case. Linear regression analysis was used to generate the predictive relationships between TSS and turbidity. Comparisons were also made between samples taken on the rising versus falling limbs, event versus low-flow, between-site, and seasonality of flow event hydrographs. Software used to analyze the data included Microsoft Excel 2003 and SAS for Windows 9.1 (SAS Institute Inc. 2003).

Results

Figure 5A shows continuous discharge and TSS concentrations for event samples taken at the Baird Creek USGS Station from May to July 2004. The variability of continuous turbidity observations during storm events is illustrated in Figure 5B. In addition, this figure demonstrates the close correlation between turbidity and TSS. This relationship between TSS and turbidity in Baird Creek was highly significant at the 0.05 significance level for both the USGS Station and the North Branch site:

- All TSS-turbidity between-site relationships are significantly different from each other at the 0.05 significance level (alpha = 0.05).
- The Ashwaubenon-Baird (North branch) Creek relationship was the closest (p = 0.0178 compared to $p < 0.0001$ for all others). Statistically, however, they are different from each other.

Figures 6 and 7 demonstrate the TSS-turbidity relationships for the above equations. Intercepts for these lines did not significantly differ from zero.

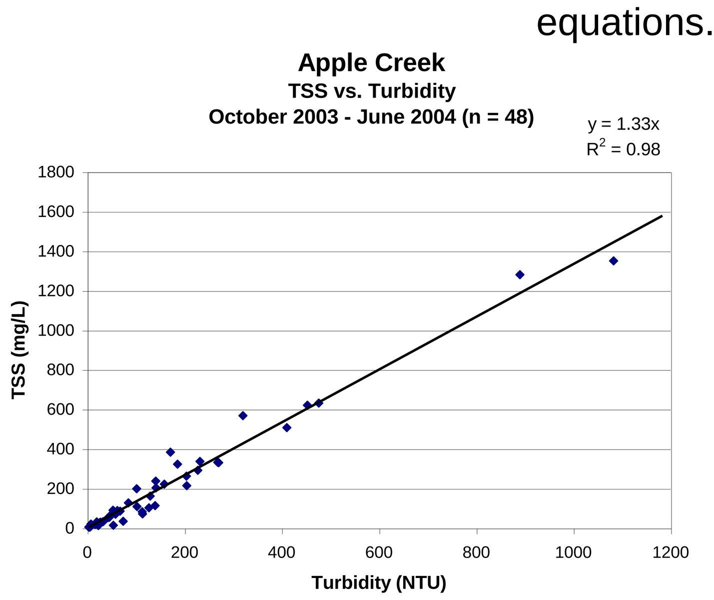

Figure X. Relationship between TSS and Turbidity for Apple Creek.

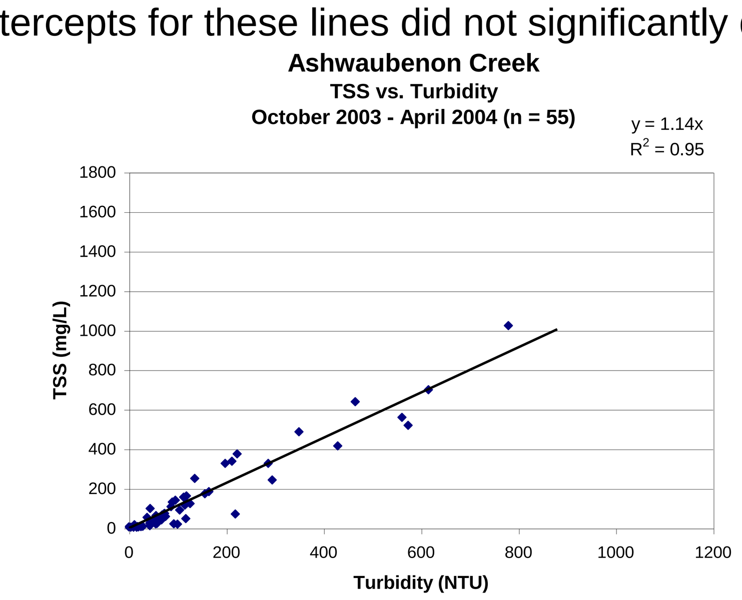

Figure X. Relationship between TSS and Turbidity for Ashwaubenon Creek.

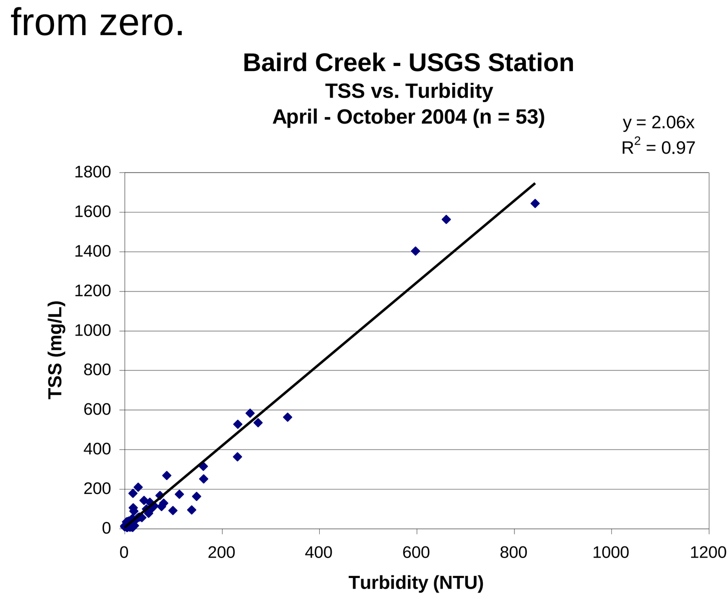

Figure X. Relationship between TSS and Turbidity for Baird Creek, USGS Station site.

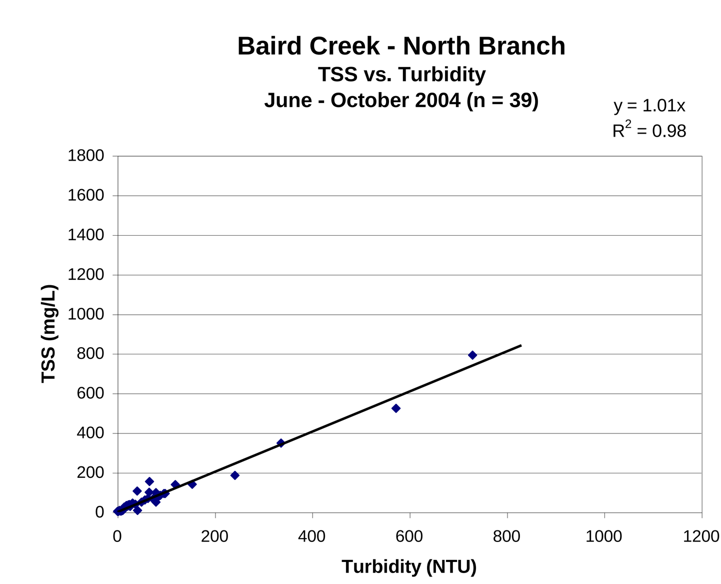

Figure X. Relationship between TSS and Turbidity for Baird Creek, North Branch site.

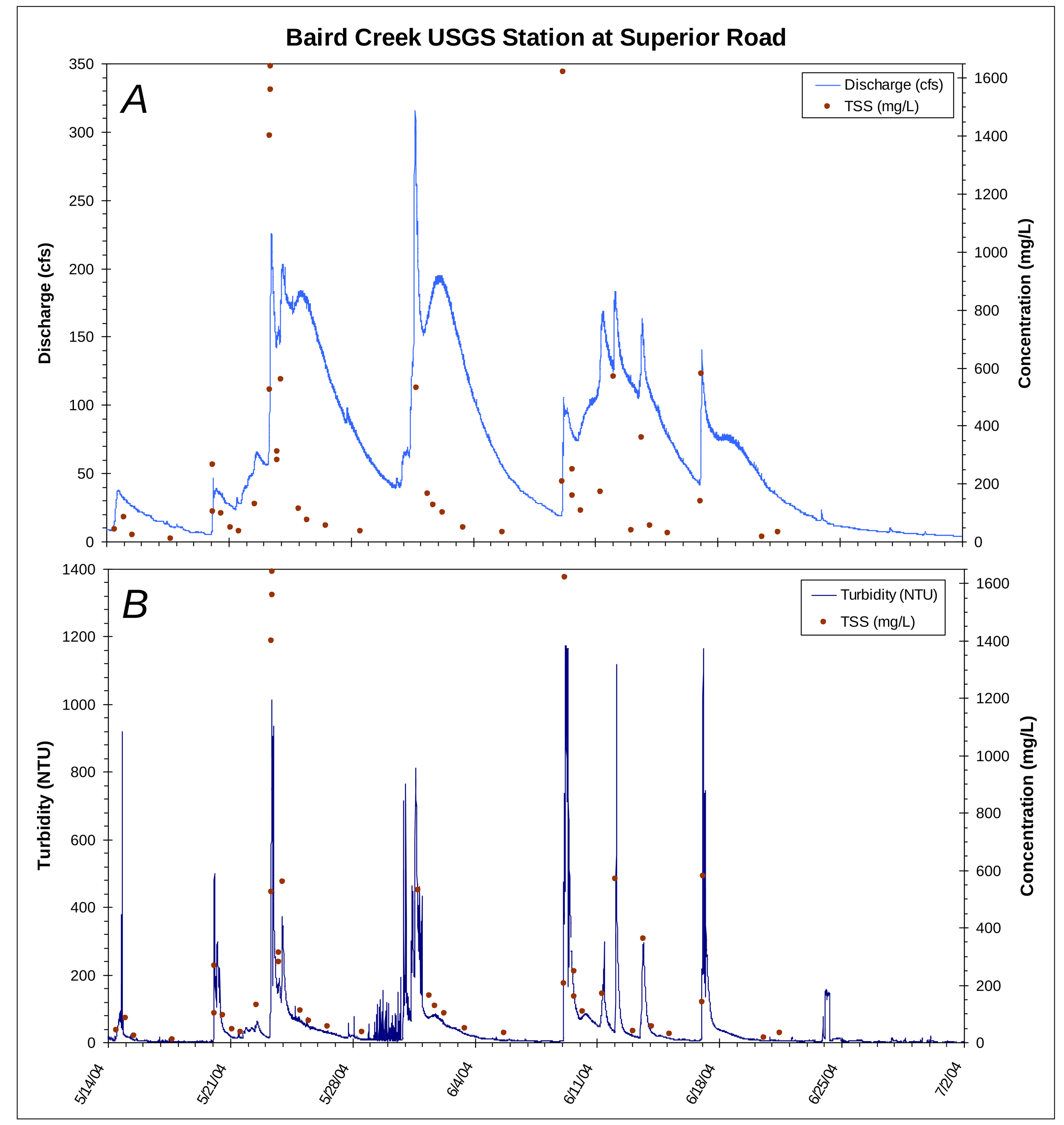

Figure X. Discharge, TSS concentration, and turbidity data from 14 May to 2 July 2004 at the Baird Creek USGS Station.

Figure X. Baird Creek at Superior Road during a runoff event, Fall 2003.

Figure X. Samples showing sediment concentration change over a storm.

Conclusions

The turbidity of the four creeks within the Lower Fox River Watershed is highly dynamic. Increases in turbidity coincided with runoff events and sharp rises in stream discharge. We hypothesize that particle properties contributed to the differences in site-to-site TSS-turbidity relationships. Watershed land use and the associated hydrologic response between the agricultural and urban regions around these creeks also contributed to the relationship variance.

- The greatest dissimilarity was found in the Baird Creek north vs. south branch.
- No significant differences were found due to seasonality, event vs. low flow, or rising vs. falling limb. This, in part, was due to insufficient turbidity data upon which to draw conclusions. The lack of data was due in part to equipment fouling.
- Turbidity data for Duck Creek was deemed too variable to make accurate TSS predictions.

In conclusion, continuous turbidity monitoring appears to be a reasonable surrogate for TSS prediction in Apple, Ashwaubenon, and Baird Creeks, and may provide cost effective and rapidly available information on watershed sediment delivery due to changes in land use. Further research into the effects of particle properties could contribute to fewer false spikes/equipment fouling, and thus, more complete data sets and higher relationship confidence.

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