Determining Effects of Physical Characteristics of Storm Sewer Sheds on Water Quality of an Urban Stream in Bloomington, IL

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PURPOSE

The purpose of this thesis was to determine what characteristics of storm sewer sheds affect water quality. The characteristics thought would change water quality the most are: presence of a retention pond, sewer miles, and presence of sump pumps.

ABSTRACT

There is a strong correlation between urban settings and degraded water quality. Stormwater is a large component of urban water degradation that is poorly understood. Precipitation is quickly transported via underground pipes, from the land to the stream without following water's natural flow path. A question that has not been considered yet is "what characteristics of stormwater sewer sheds impact water quality?" We hypothesized that physical characteristics including area of the storm sewer shed, pipe density, pipe miles, and residential or commercial zoning affect the stormwater quality and therefore the water quality of urban streams. We chose 18 stormwater outlet pipes in Bloomington, IL along Sugar Creek as sampling locations. The storm sewer sheds associated with these pipe outlets varied from 5 acres to 283 acres. Nine of the storm sewer sheds had residential landuse, eight were commercial or road, and three included a park. Half of the storm sewer sheds include sump pumps which prevent basement flooding. At each site we took a grab sample and used a YSI Pro Plus to measure pH, temperature, conductivity and dissolved oxygen in the field. Water samples were filtered as appropriate and we measured chloride, nitrate, phosphate, and total suspended solids in the laboratory using an ion chromatograph and flow injection analysis. Chloride is an indicator of human influence and its sources include wastewater and road salt Stormwater runoff contributes more total suspended solids than point sources. We analyzed the data for relationships and differences among the physical characteristics and water quality parameters using correlation and ANOVA analysis. Ultimately this research could contribute to how storm sewers are built and retrofitted in the future to decrease the water quality degradation from storm events.

INTRODUCTION

There are predictable responses of streams to urban development (Walsh et al., 2005b). One response that is consistent across all study areas is increased nutrient and contaminant concentrations (Meyer et al., 2005; Walsh, 2005b). The majority of contaminants enter streams and rivers as a result of stormwater runoff (Walsh et al., 2005b; EPA, 1999). A storm sewer shed is the land area (Figure 1) from which stormwater drains to and travels through a sewer system and discharges to a surface water body (Figure 2).

It is reasonable to expect that a detention or retention pond will improve water quality (Herrmann, 2012). Detention ponds are basins that dry out in between storm events, while a retention pond continuously holds water. Detention ponds, whether intentionally designed to or not, will provide some water quality control (Marsalek, 2002).

Figure 2. A storm sewer outlet to Sugar Creek from a residential storm sewer shed

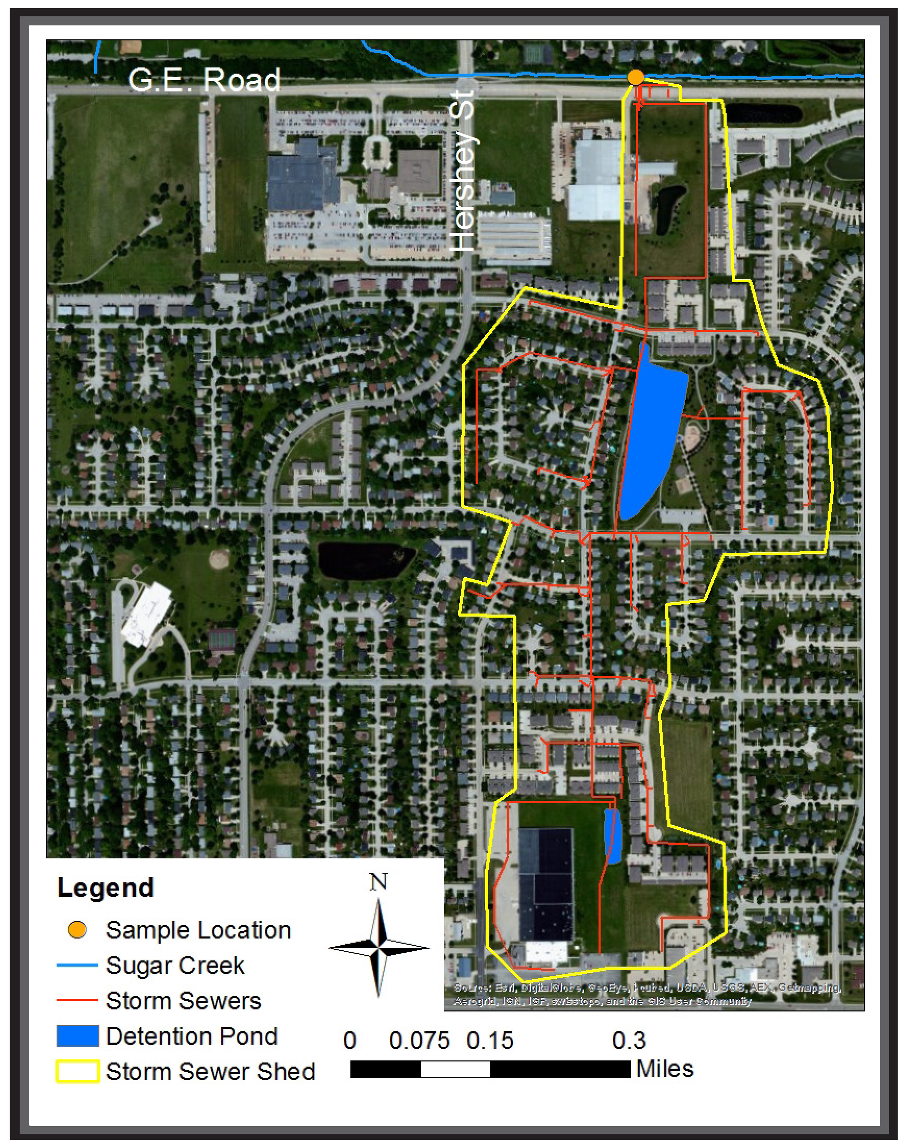

Figure 1. Aerial view of a commerical storm sewer shed

METHODS

- ArcMap 10.2 was used to identify locations and run preliminary spatial analysis
- Samples were collected during six storm events (Table 1)
- Collection points are at storm sewer outlets to the river (Figure 1 & Figure 3)
- Immediately after collection samples were processed for total suspended solids (Figure 4)
- Samples were preserved by freezing
- Chloride and sulfate were analyzed using an ion chromatograph
- Ammonia, nitrate, phosphate and total phosphorous were analyzed using flow injection analysis
- Five storm sewer sheds have either a retention pond or detention pond present
- Sump pumps are used in central Illinois to drain water in wet soils away from building foundations. Nine of the storm sewer sheds sampled have sump pumps.
- The date of sampling was considered as categorical data for the purpose of analysis
- The amount of precipitation was retrived from the National Climatic Data Center (NOAA, 2014). It was retrived as a daily total.
- Data was log transformed as necessary

Table 1. Magnitudes of the storm events during which sampling took place in 2014

Storm Date	Precip (mm)
March 27	10.4
May 9	11.9
June 8	42.2
June 10	2.8
July 25	2.5
September 15	24.1

Figure 3. Sampling at storm sewer on March 27

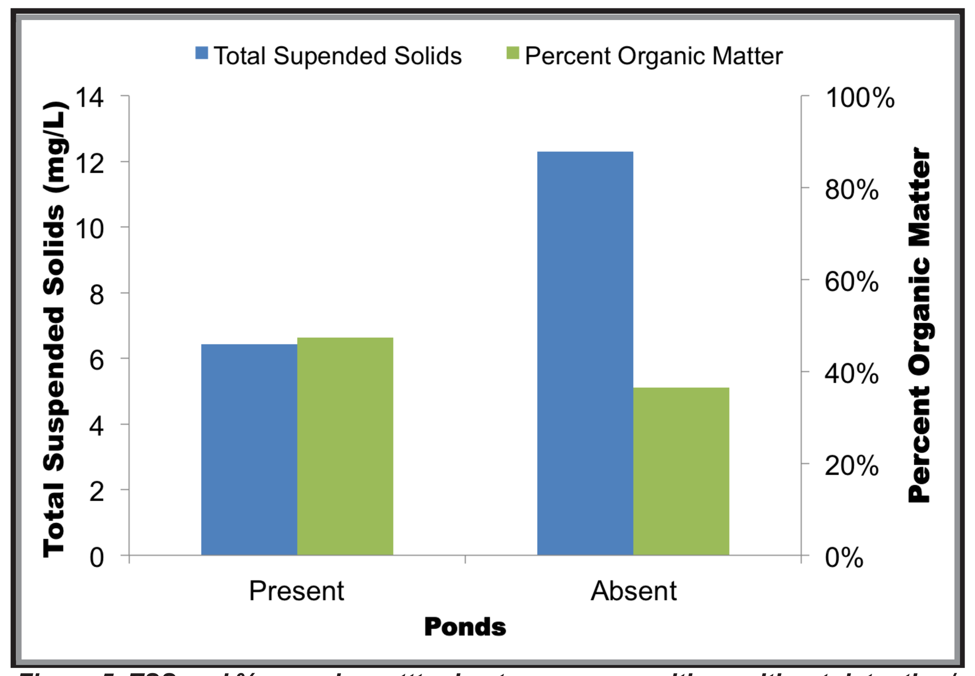

Figure 5. TSS and % organic mattter in storm sewers with or without detention/ retention ponds. TSS is significantly lower p<0.01. % organics is signficantly higher p<0.05. The median value is plotted.

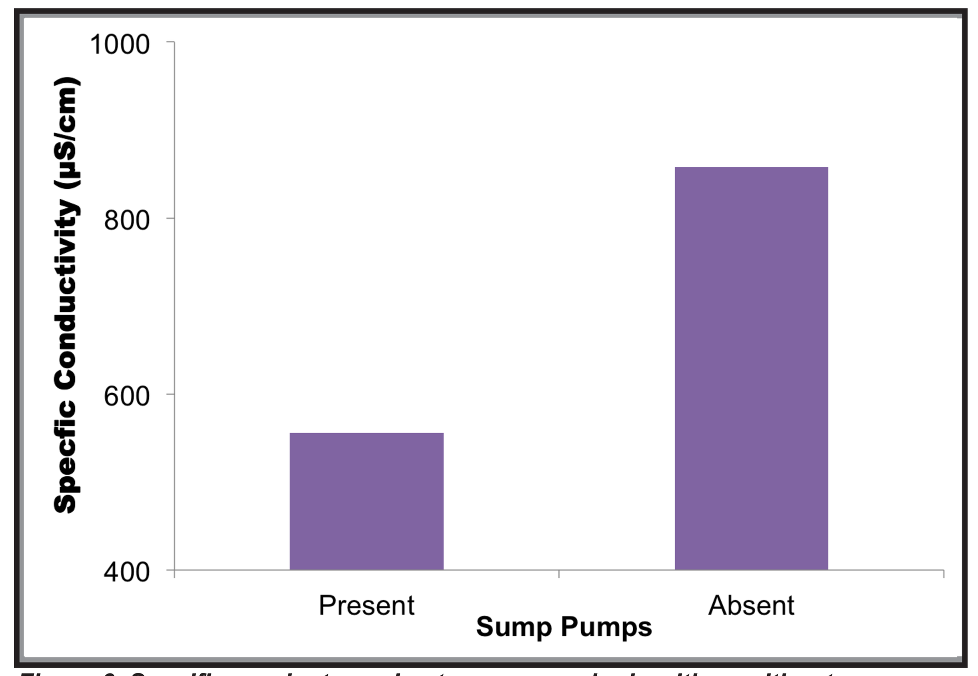

Figure 6. Specific conductance in storm sewer sheds with or without sump pumps. Those with pumps had signifcantly lower conductivity p<0.01. Median values are plotted.

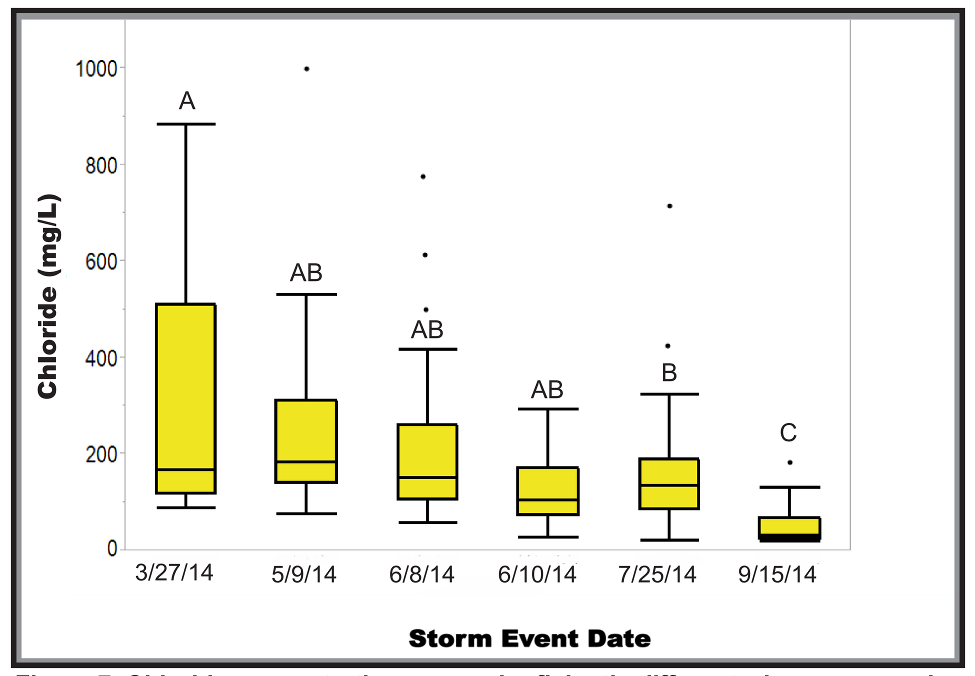

Figure 7. Chloride concentrations were signficiantly different when compared across dates categorically. The highest concentrations occur in the spring and the lowest occured in the fall.

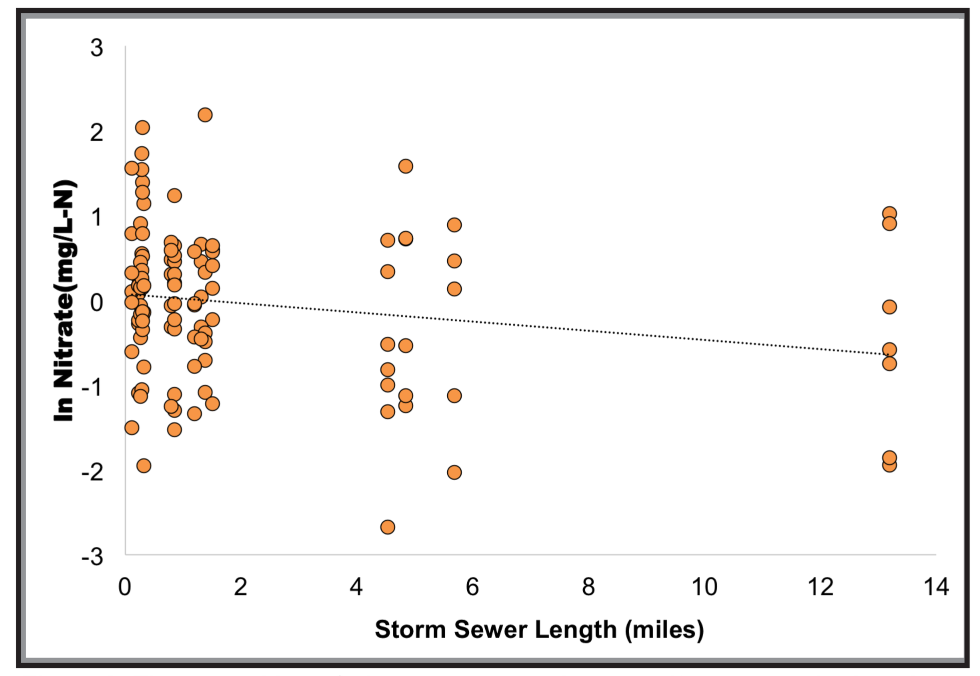

Figure 8. The natural log of nitrate concentrations as nitrogen graphed against storm sewer miles. There is a negative correlation p<0.05. Concentrations ranged from 0.0688 mg/L-N to 8.89 mg/L-N

RESULTS AND CONCLUSIONS

TSS was significantly lower in storm sewer sheds with a ponds (Figure 7, p<0.001). However, percent organics were significantly higher in storm sewer sheds with a pond (Figure 7, p<0.01). Ponds allow stormwater to slow and particulates can settle out; organic particles may be gained through biological processes or may be less likely to settle.

Specific conductivity was significantly less in storm sewer sheds with sump pumps (Figure 6, p<0.01). TSS concentrations were lower in storm sewer sheds with sump pumps (p<0.05). Chloride was also significantly lower in storm sewer sheds with sump pumps (p>0.0001). The differences are likely a function of dilution.

There was a significant difference in chloride across all dates with the highest concentrations occurring in the spring and lowest concentrations in the fall. Phosphate and ammonia were also significantly different across dates with the lowest concentrations occuring in the summer. Phosphate and ammonia may be tied up during the biologically productive seasons.

The length of a storm sewer system has a negative relationship with TSS (p<0.001) and nitrate (Figure 8, p<0.05). Percent organic matter, however, is positively correlated with storm sewer miles (p<0.0001).

TSS shows a significant decrease in concentration as the magnitude of the storm event increases (p<0.05). Ammonium and phosphate both decreased in concentration with an increase in storm event magnitude with p values of <0.0001 and <0.005 respectively. There is a finite source of contaminants on the surface and larger events will cause dilution

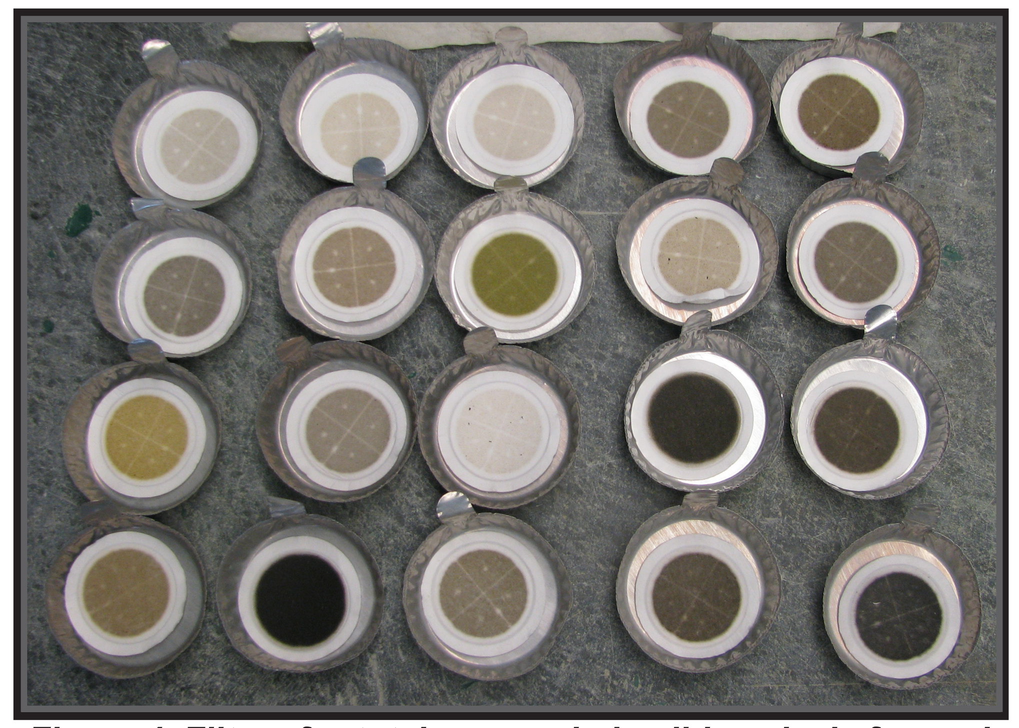

Figure 4. Filters for total suspended solid analysis for each sample on June 10, 2014

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