AN INVESTIGATION OF EXTERNAL NUTRIENT LOADING FROM EIGHT STREAMS INTO HONEOYE LAKE

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INTRODUCTION

Honeoye Lake is the shallowest lake (mean depth of 4.9 m and maximum depth of 9.2 m) among all eleven Finger Lakes (Bloomfield 1978; Gilman 1994). It is relatively small with the water volume of 0.036 km^3. It is an eutrophic lake with an average total phosphorus of 35.3 µg/L in 2007 and 19.2 µg/L in 2008 and an average secchi depth of 4.2 m in 2007 and 4.6 m in 2008 (John Halfman, unpublished data). Submerged aquatic macrophytes are abundant in the lake as in many lakes at similar trophic levels such as Oneida Lake (Gilman 1994; Zhu et al. 2006). Algal blooms are common as well (Starke 2004; 2005). For example, Honeoye Lake experienced severe blue-green algal blooms with extremely high densities in the summer of 2002; and on August 3, 2006, Rochester's Democrat and Chronicle reported on the algal bloom problem in an article titled "Slimy, stinky algae in Honeoye Lake".

It is likely that severe algal blooms and extensive weed growth are associated with nutrient loading into the lake, especially phosphorus and nitrogen (Wetzel 2001). Algal blooms in lakes have been directly linked with nutrient enrichment (e.g., Serruya and Berman 1975; Schindler 1977). Gilman (1994) also found the submerged weeds in Honeoye Lake expanded their growth habitat from 22% of the lake bottom in 1984 to nearly 50% in 1994 and concluded that the extensive growth of weeds was due to the large amount of nutrients available in the sediment. Therefore, it is critical to investigate the nutrient loading into Honeoye Lake to gain an understanding of the weed and algae dynamics by identifying the sources of the nutrients and control their growth by reducing nutrients and managing the watershed.

There are external and internal sources of nutrients. Land uses are usually associated with nutrient enrichment. In the Honeoye Lake Watershed, agricultural, industrial, and commercial land use are not common. However, high density shoreline residences are likely to be one important nutrient source. In addition, there are thirty-five perennial and intermittent streams into Honeoye Lake (Honeoye Lake Watershed Taskforce 2007). Therefore, most of the external sources of nutrients flow into the lake directly from streams or from the shoreline. A "Watershed Model” has been developed by Princeton Hydro for the Honeoye Lake Watershed Task Force to predict nutrient flow into the lake from all tributaries based on known sub-watershed boundaries, land cover (forest, farm, etc.), slope, tributary hydraulics, and weather conditions (Princeton Hydro 2007). The actual measurements of the flow and nutrient levels from representative tributaries are needed to verify the model. Internal sources might be important as dissolved oxygen can be very low in summer (Gilman 1994), which will help release phosphorus from sediment to water column and promote algal growth. However, the internal sources are undetermined. In this study, I investigated external nutrient loading from eight tributaries into Honeoye Lake in order to 1) estimate nutrient loadings during storm events and regular days; 2) estimate annual nutrient loading; 3) compare findings with the watershed model; 4) identify possible pollution sources through stream segment analysis; and 5) give recommendations for future research and remediation.

STUDY SITES AND METHODS

Honeoye Lake is located in the western Finger Lakes region of New York State and its shoreline lies entirely within the Towns of Canadice and Richmond (Figure 1). The center of the lake has an approximate latitude of $42^{o}45'00''$ north and longitude of 77 $^{o}31'00''$ east. It occupies the bottom of a U-shape valley that was eroded into the native sedimentary rocks by glacial action (Gliman 1994).

Water samples were collected at sites (Table 1) in eight tributaries (Inlet, Affolter, Bray, Briggs, plus additional tributaries located at 159 W. Lake, Cratsley Hill Road, Trident Marine, and Times Union, Figure 1) on 06/27/07, 07/25/07, 08/27/07, 09/25/07, 10/22/07, 11/28/07, 2/19/08, 3/17/08, 4/15/08, 5/13/08, and 6/30/08 to establish baseline data that will provide a measure of nutrients flowing into the lake from individual subwatersheds in order to better define nutrient sources. In addition, water samples for each tributary were collected during six hydro-meteorological events (e.g., snowmelt and storm events) on 07/11/07, 10/19/07, 1/7/08, 2/6/08, 3/31/08, and 7/24/08. Due to the low water flow throughout the studied year, the proposed ISCO 6712 automatic water sampler was not used and one or two samples in each tributary were collected during the hydro-meteorological events. Point discharge was estimated from measured cross-sectional areas and water velocities with a Marsh-McBriney flow meter at each sampling.

All samples were analyzed by a state certified laboratory – Life Science Laboratories, Inc. in Canandaigua, NY (699 South Main Street, Phone 585-396-0270). The samples were measured for Total Phosphorus (TP), Soluble Reactive Phosphorus (SRP), Total Kjeldahl Nitrogen (TKN), Nitrate (NO3), and Total Suspended Solids (TSS)

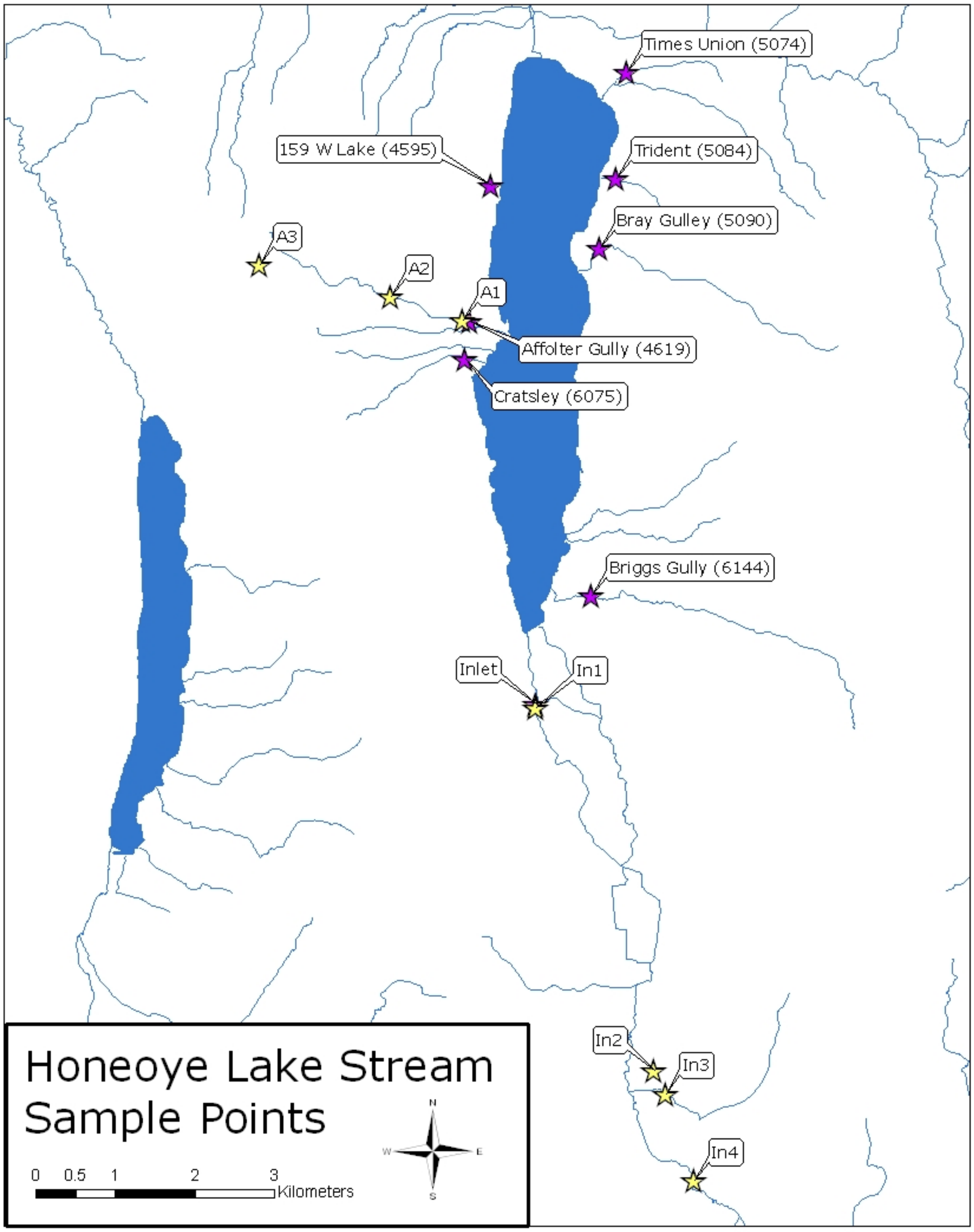


Figure 1. Sampling points in eight streams of Honeoye Lake. Solid stars denote regular sampling points; Hollow stars denote sampling points for segment analysis of two streams Inlet and Affolter Gully. Note the Inlet in this study was a small stream located in Muller Field Station of Finger Lakes Community College.

following the EPA standard methods (APHA 2000). Total nitrogen (TN) was calculated as the sum of TKN and NO3. The annual means of total water discharge and concentrations of TSS, TP, and TN were estimated based on the ratio of 14 regular samplings and 1 storm event sampling (assuming there were 2 storm events in every 30 days). Total loading of TSS, TP, and TN were calculated as the product of total water discharge and concentrations.

Additionally, segment analysis was conducted in Inlet and Affolter Gully to identify possible point-source pollution.

Table 1. Locations of stream samplings and segment analysis

Site ID	**Latitude**	**Longitude**
159 W Lake (4595)	42°46.124'	77°31.172'
Affolter Gully (4619)	42° 45.196'	77°31.335'
Cratsley (6075)	42° 44.937'	77°31.367'
Inlet	42° 42.618'	77°30.622'
Briggs Gully (6144)	42° 43.362'	77°30.139'
Bray Gulley (5090)	42° 45.719'	77°30.159'
Trident (5084)	42° 46.198'	77°30.022'
Times Union (5074)	42° 46.922'	77°29.958'
In1	42° 42.588'	77°30.622'
In2	42° 40.157'	77°29.439'
In3	42° 40.001'	77°29.323'
In4	42° 39.416'	77°29.038'
A0	42° 45.193'	77°31.347'
A1	42° 45.202'	77°31.396'
A2	42° 45.351'	77°32.071'
A3	42° 45.539'	77°33.291'

Note: numbers in ( ) are stream codes listed in USGS maps.

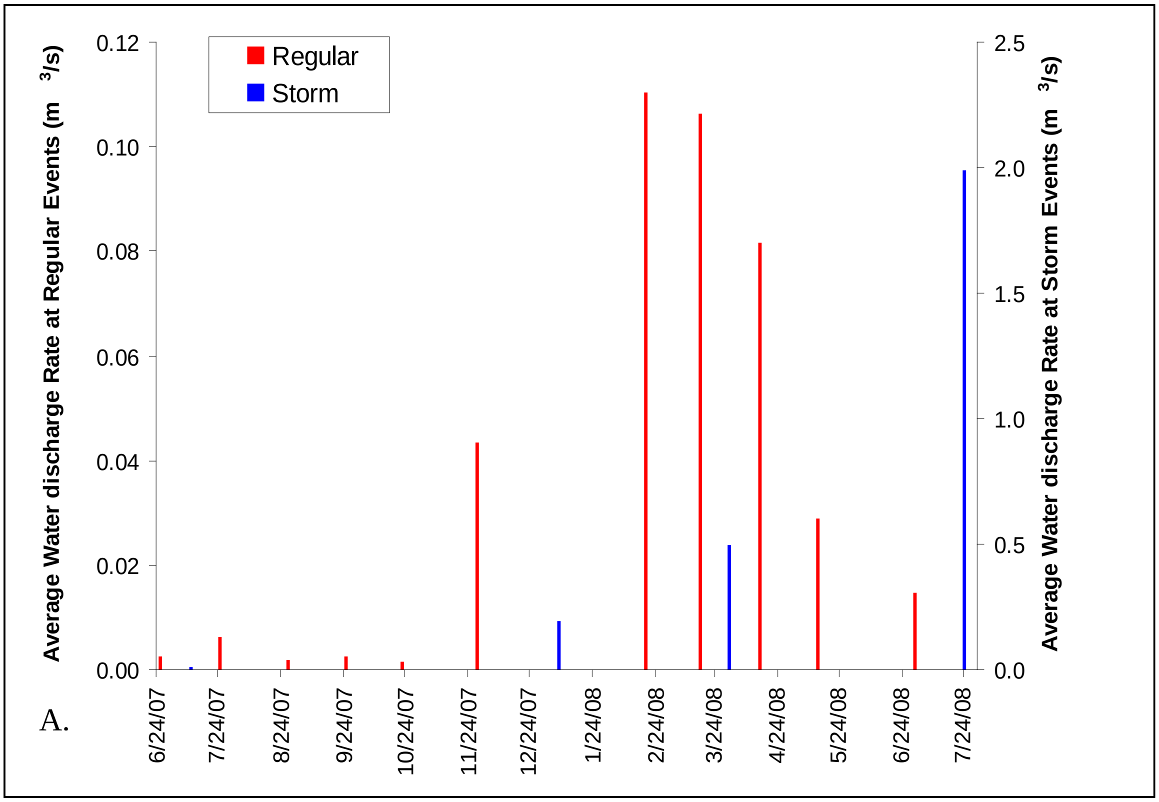
RESULTS

Water Discharge

The average water discharge rate of the eight streams varied dramatically at the different sampling events: from 0.0014 to 0.11 m^3/second during the 11 regular samplings and from 0.0027 to 1.98 m^3/second during the storm or snow-melting events (Figure 2A). Due to the dry summer of 2007, the first several storm events had similar water flow as or even slower flow than those in the regular samplings. For example, the average water discharge rate on July 11, 2007 and October 19, 2007 were 0.0069 and 0.0027 m^3/second respectively, similar to regular events. Other than those, water discharge rate was much larger at storm events than during regular samplings throughout the study period (June 2007-July 2008).

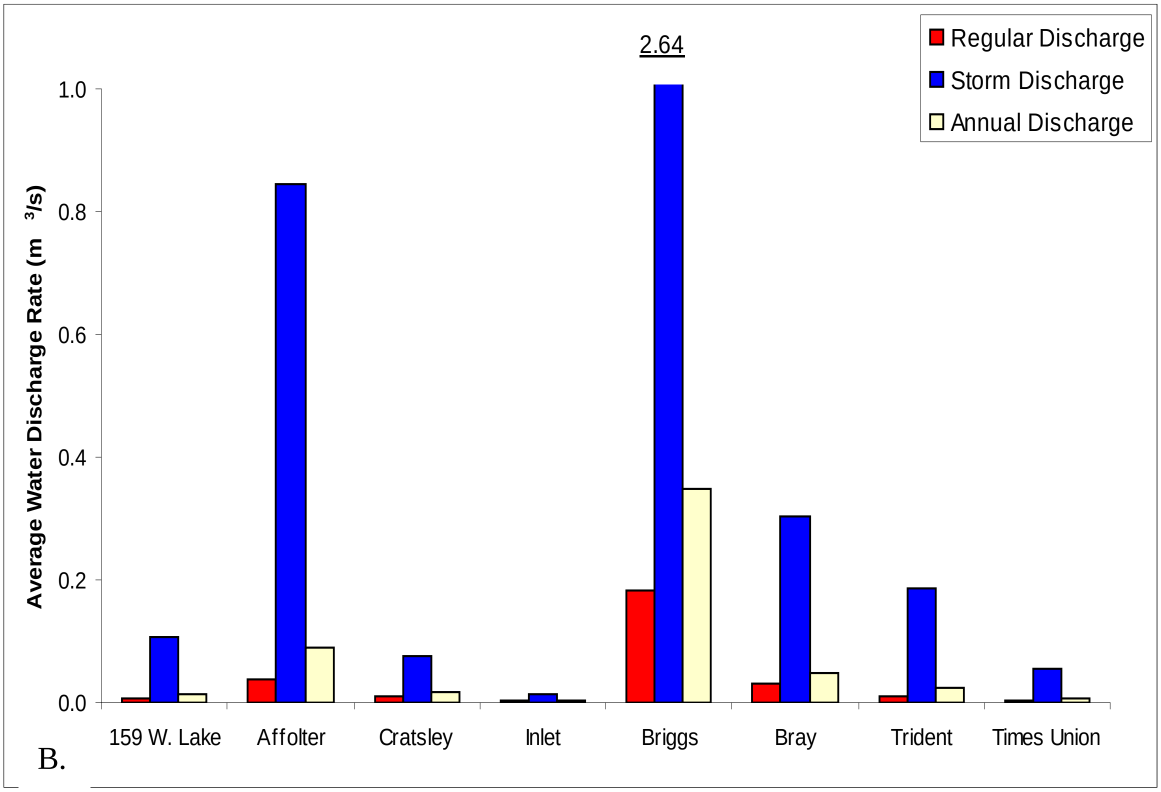
Average water discharge rate at each individual stream also varied significantly at regular events and storm events with Briggs having the highest discharge rate, Affolter the second highest, and Bray the third (Figure 2B). The estimated annual discharge rate showed a similar trend and ranged from 0.0047 m^3/second in Inlet to 0.348 m^3/second in Briggs.

Annual total water discharge from the eight streams reached 0.0174 km^3 (Figure 2C), which is almost half of the volume of Honeoye Lake. Briggs had the largest discharge (10.97×10^6 m^3) followed by Affolter (2.84×10^6 m^3) and Bray (1.54×10^6 m^3). The three streams accounted for 88.2% of the total water discharge of all eight streams. Despite the rare frequency of large storm events during this study, storm events contributed a significant of water to the annual total discharge as there was more storm water than regular water annually in five of the eight streams (Figure 2C).



Regular
Storm
Average Water discharge Rate at Regular Events (m³/s)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Average Water discharge Rate at Storm Events (m³/s)
2.5
2.0
1.5
1.0
0.5
0.0
6/24/07
7/24/07
8/24/07
9/24/07
10/24/07
11/24/07
12/24/07
1/24/08
2/24/08
3/24/08
4/24/08
5/24/08
6/24/08
7/24/08

A.



Regular Discharge
Storm Discharge
Annual Discharge
2.64
Average Water Discharge Rate (m³/s)
1.0
0.8
0.6
0.4
0.2
0.0
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union

B.

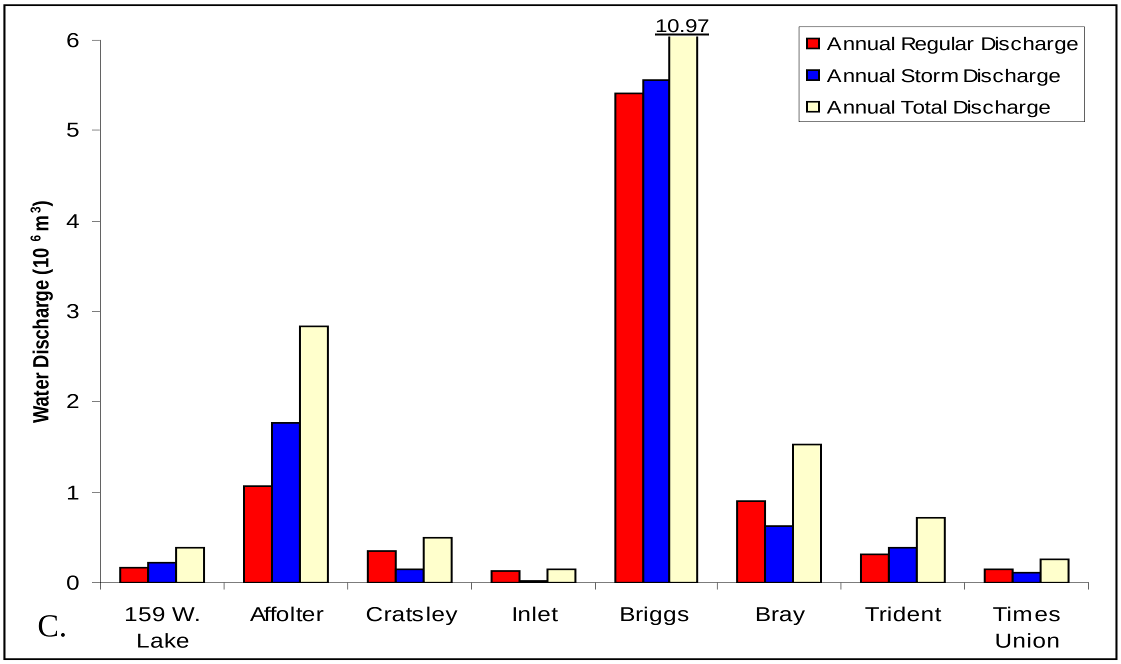
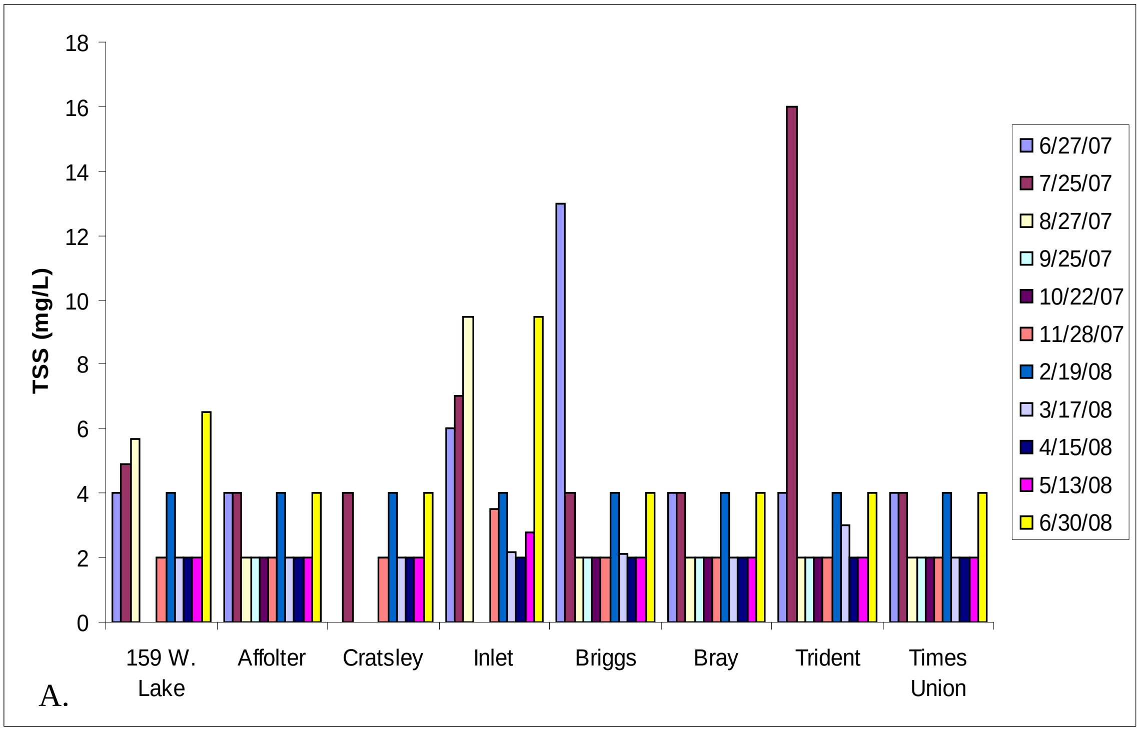


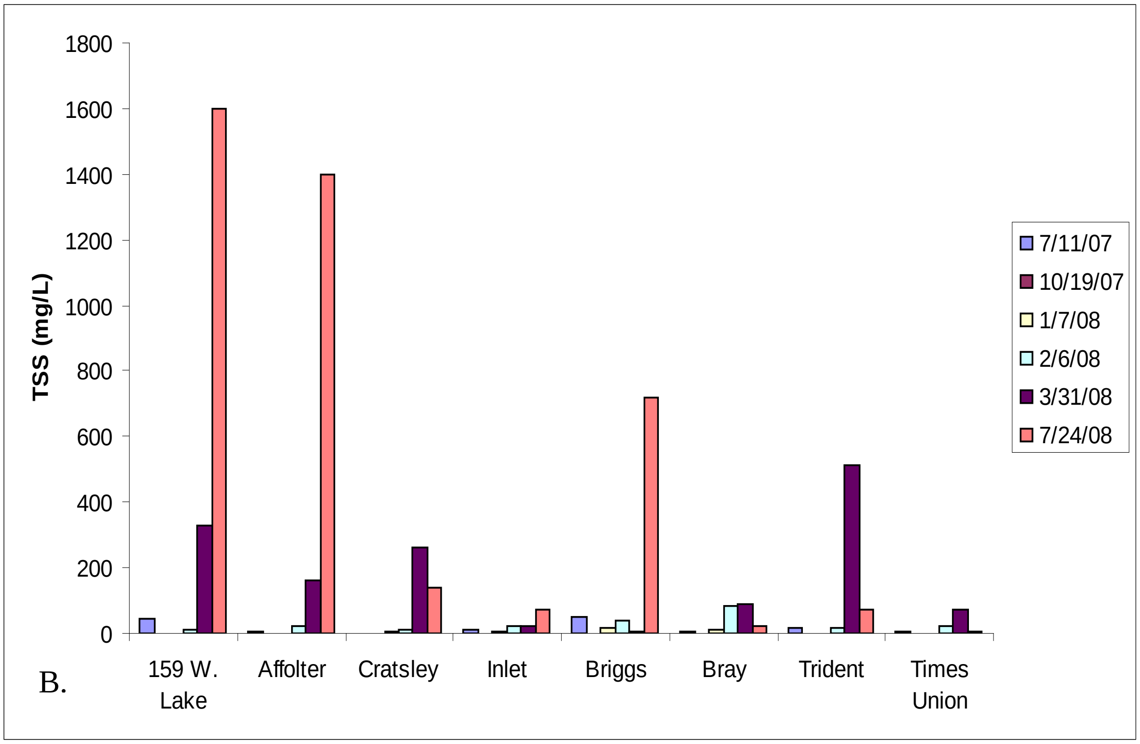
Figure 2.Water discharge from eight streams of Honeoye Lake. A. Total water discharge rate at the regular sampling events (Regular) and storm events (Storm) from the eight streams throughout the sampling period; B. Average water discharge rate from individual stream at regular samplings, storm samplings and its annual estimate; and C. Annual total water discharge from the eight streams.

Total Suspended Solids Concentration

The total suspended solids (TSS) concentration can be an index of soil erosion. It is extremely low during the regular sampling events because most of the concentrations were below the detection limit (2 or 4 mg/L, Figure 3A). But during storm events, TSS concentration was much higher and reached over 1600 mg/L in 159 W Lake, followed by Affloter (1400 mg/L) and Briggs (720 mg/L) on July 24, 2008 (Figure 3B). In terms of the mean TSS concentration, there were no dramatic changes among sites during the regular events (Figure 3C) whereas huge differences were observed during the storm events (Figure 3D). For example, mean TSS concentration was 332 mg/L at 159 W Lake but it is only 17.8 mg/L at Times Union.


18
16
14
12
10
8
6
4
2
0
TSS (mg/L)
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union
6/27/07
7/25/07
8/27/07
9/25/07
10/22/07
11/28/07
2/19/08
3/17/08
4/15/08
5/13/08
6/30/08

A.


1800
1600
1400
1200
1000
800
600
400
200
0
TSS (mg/L)
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union
7/11/07
10/19/07
1/7/08
2/6/08
3/31/08
7/24/08

B.

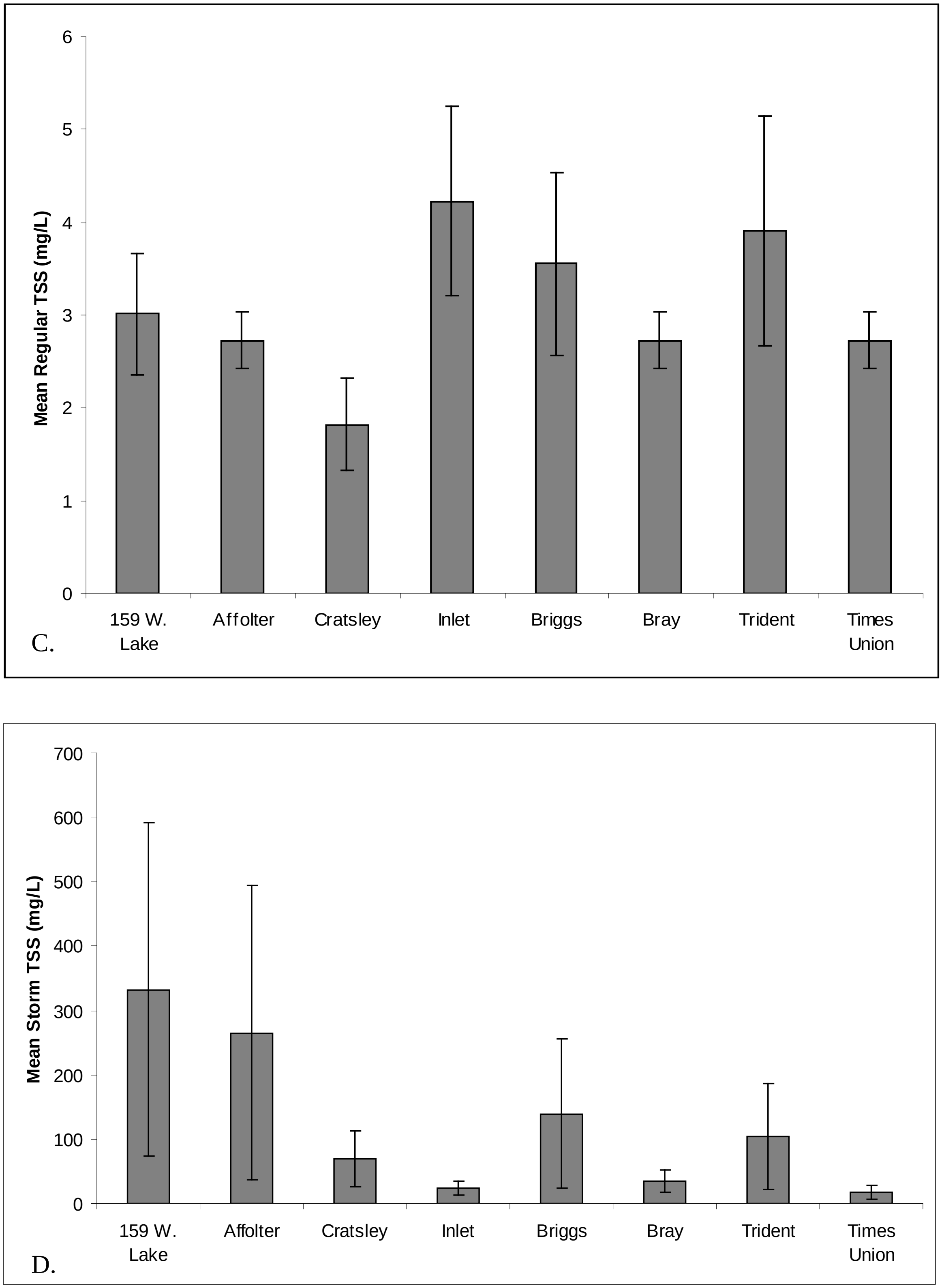
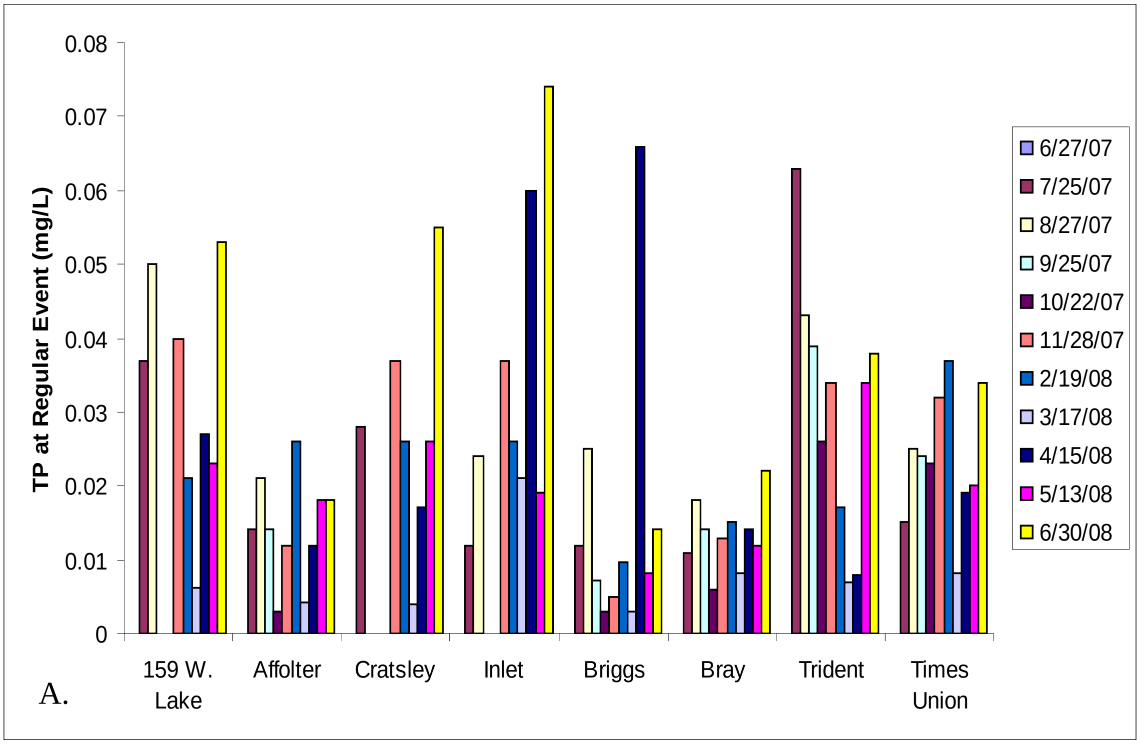


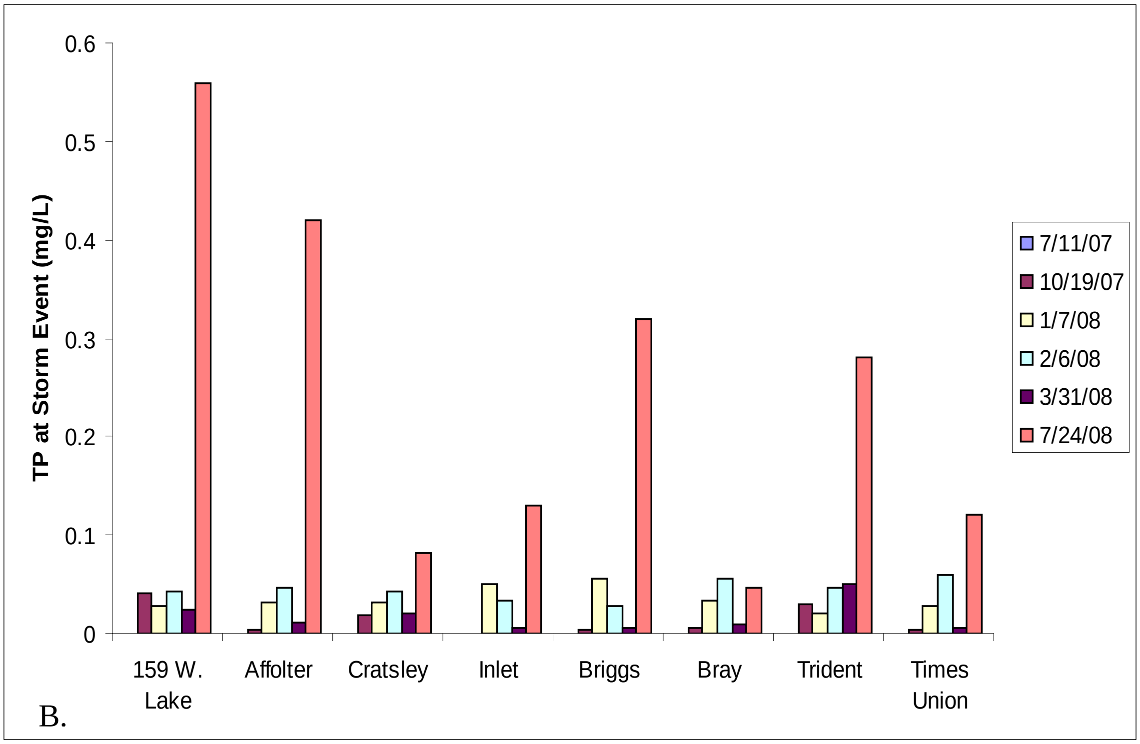
Figure 3. Total suspended solids concentrations during the regular (A and C) and storm (B and D) sampling events. Vertical bar indicates 1 standard error.

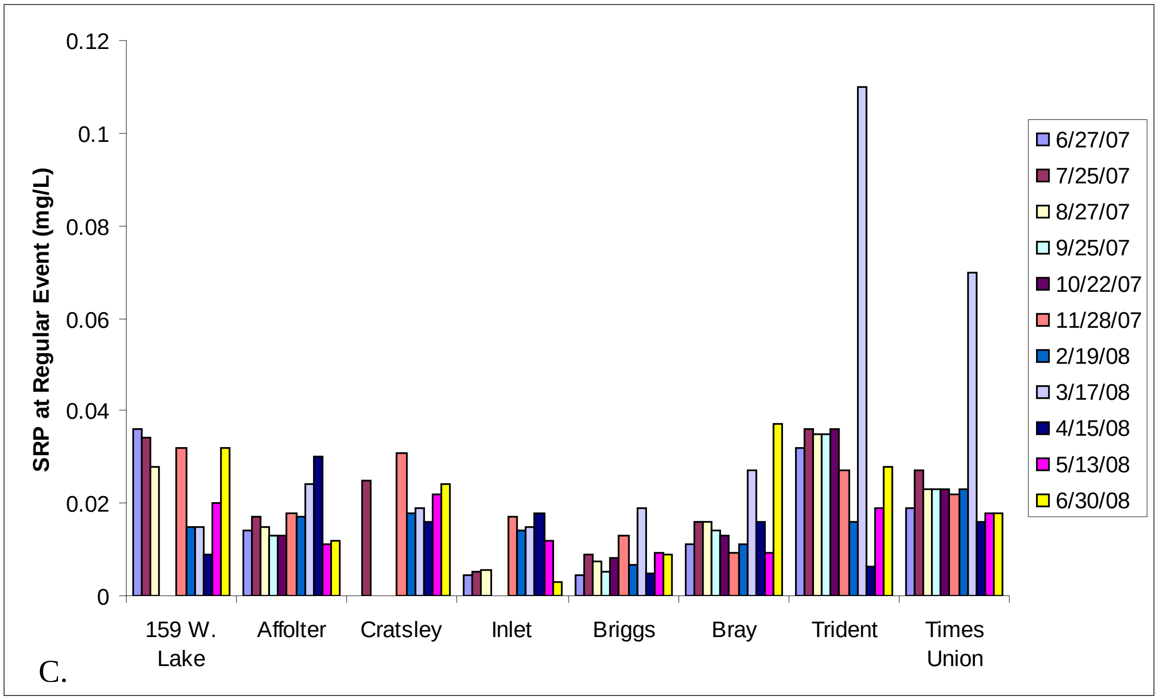
Phosphorus Concentration

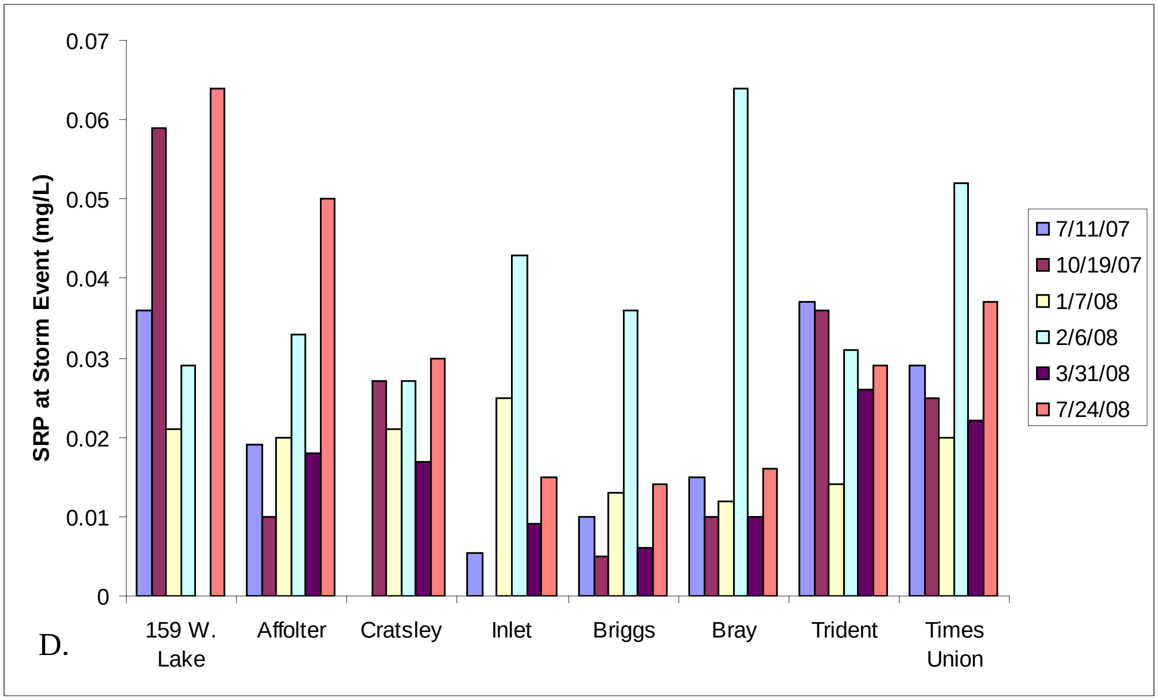
Total phosphorus concentrations fluctuated among the eight streams and among the different sampling dates (Figure 4 A and B). The highest TP concentration (0.074 mg/L) occurred in the Inlet during the regular sampling on June 30, 2008 whereas the TP concentration was highest (0.56 mg/L) in 159 W Lake at the storm event on July 24, 2008. The difference was 7.6 times. In contrast, soluble reactive phosphorus concentrations had very small changes among sites at different dates (Figure 4 C and D) and most of the concentrations kept lower than 0.04 mg/L.

Average TP concentration ranged from 0.013 mg/L in Bray to 0.031 mg/L in Trident during the regular events and from 0.030 mg/L in Bray to 0.139 mg/L in 159 W Lake during the storm events (Figure 4 E and F). It is clear that TP was much higher during the storm events as the lowest concentration (0.030 mg/L) in the eight streams was similar to the highest concentration (0.031 mg/L) at regular events. Although the concentrations were still higher at storm events in general, the difference of SRP concentrations between regular and storm events were much smaller. SRP ranged from 0.009 mg/L in Briggs to 0.034 mg/L in Trident during regular events and it was a major component of TP (Figure 4E). However, SRP ranged from 0.014 mg/L in Briggs to 0.042 mg/L in 159 W Lake during storm events (Figure 4F), which was a small fraction of TP. This suggests that particulate and organic phosphorus were major forms of phosphorus during the storm events.


TP at Regular Event (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union
6/27/07
7/25/07
8/27/07
9/25/07
10/22/07
11/28/07
2/19/08
3/17/08
4/15/08
5/13/08
6/30/08
A.


TP at Storm Event (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union
7/11/07
10/19/07
1/7/08
2/6/08
3/31/08
7/24/08
B.


SRP at Regular Event (mg/L)
0.12
0.1
0.08
0.06
0.04
0.02
0
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union
6/27/07
7/25/07
8/27/07
9/25/07
10/22/07
11/28/07
2/19/08
3/17/08
4/15/08
5/13/08
6/30/08
C.


SRP at Storm Event (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union
7/11/07
10/19/07
1/7/08
2/6/08
3/31/08
7/24/08
D.

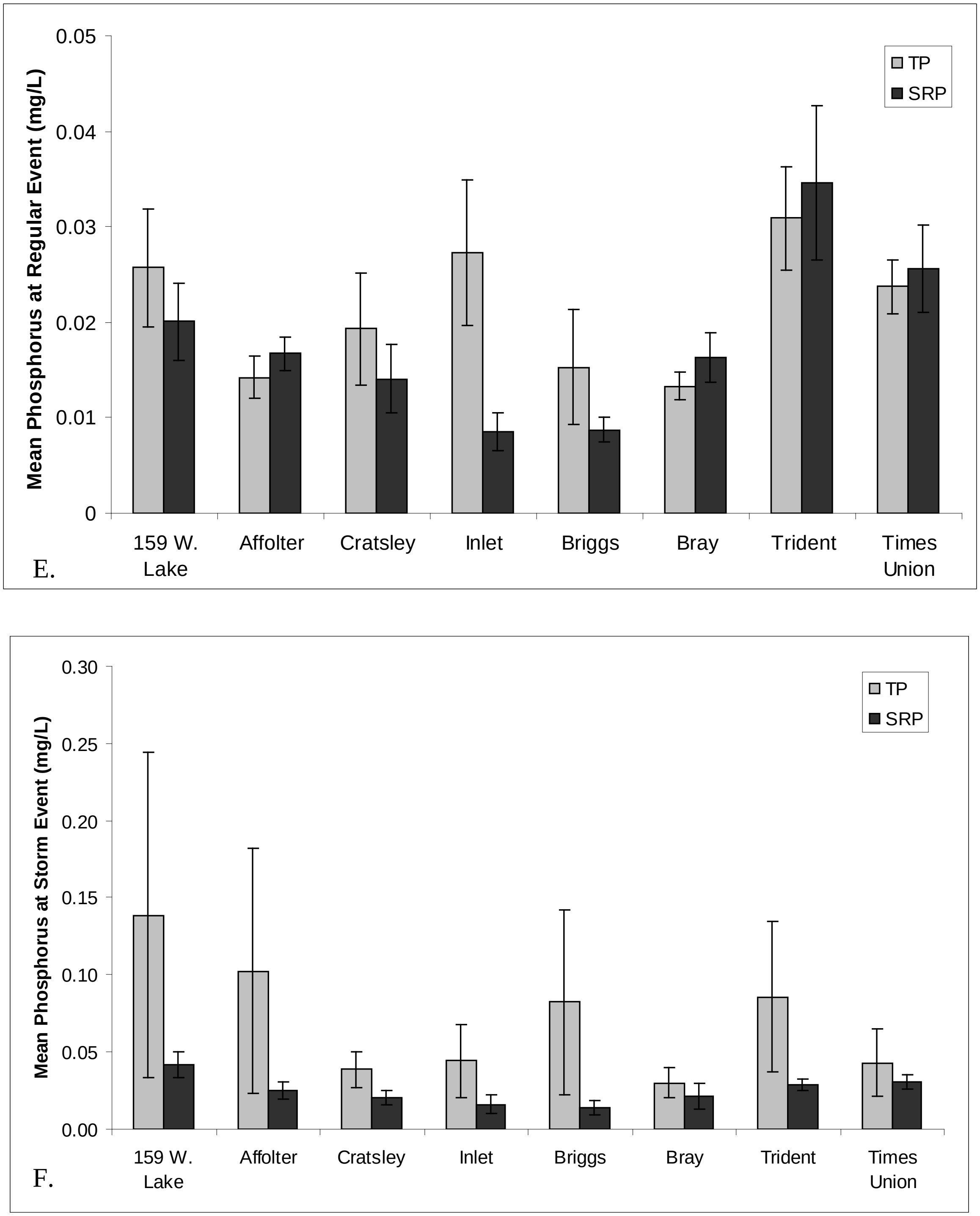
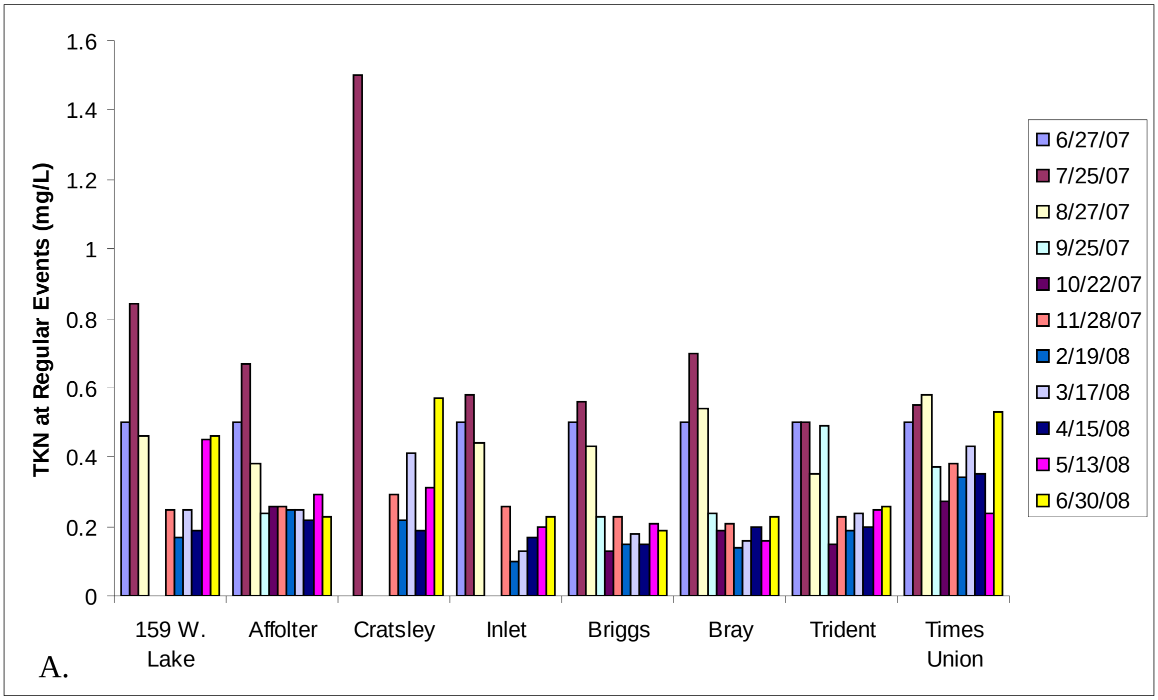
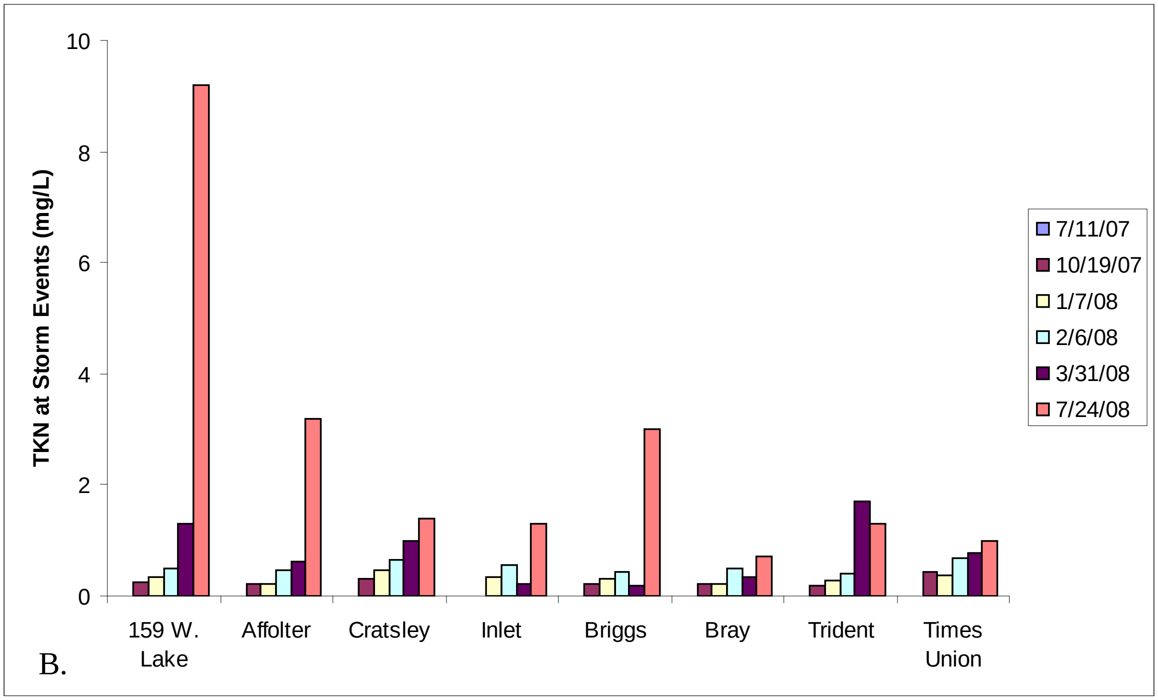


Figure 4. Total phosphorus (TP) and soluble reactive phosphorus (SRP) concentrations at eight streams of Honeoye Lake during regular sampling events (A, C, and E) and storm events (B, D and F). Vertical bar indicates 1 standard error.

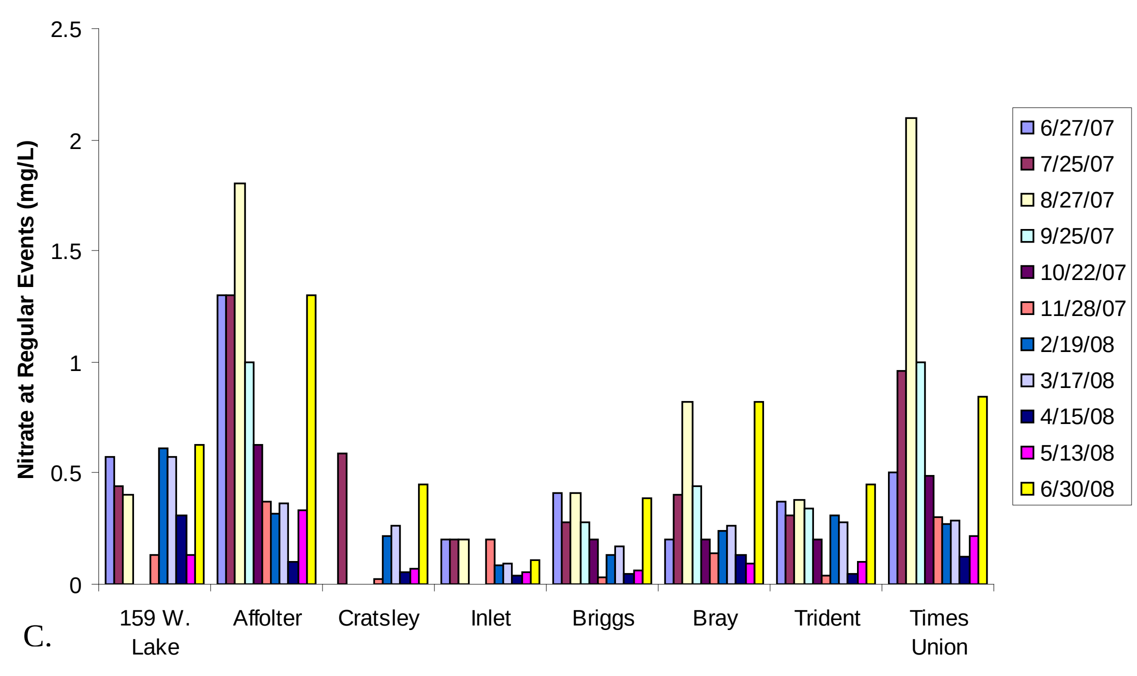
Nitrogen Concentration

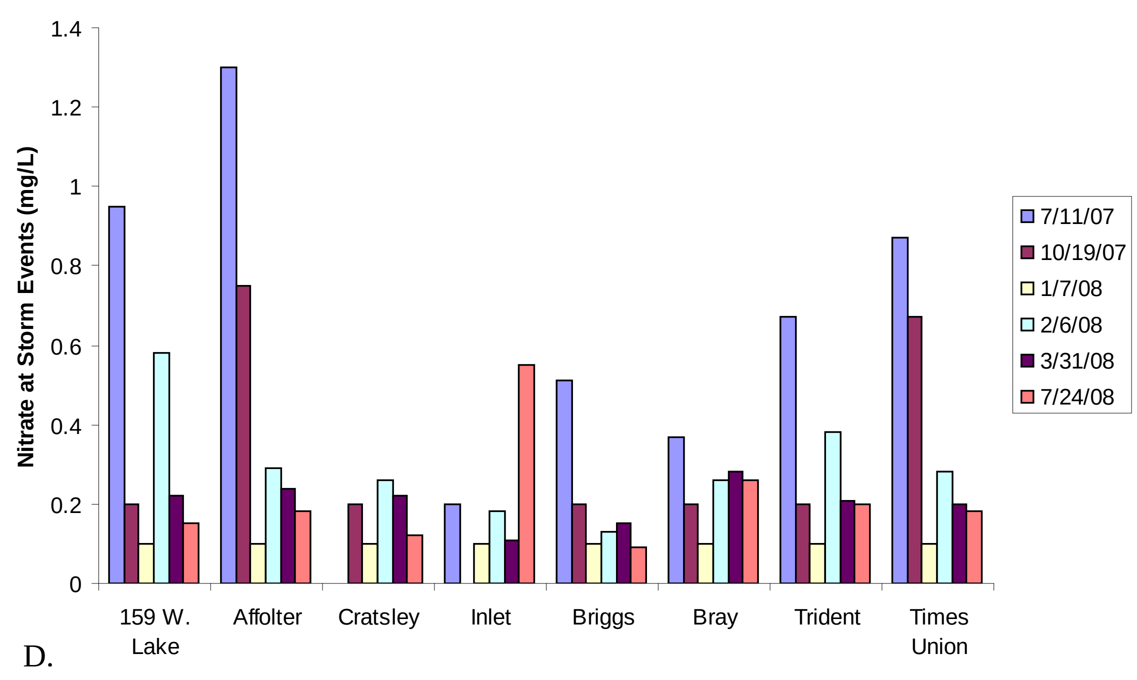


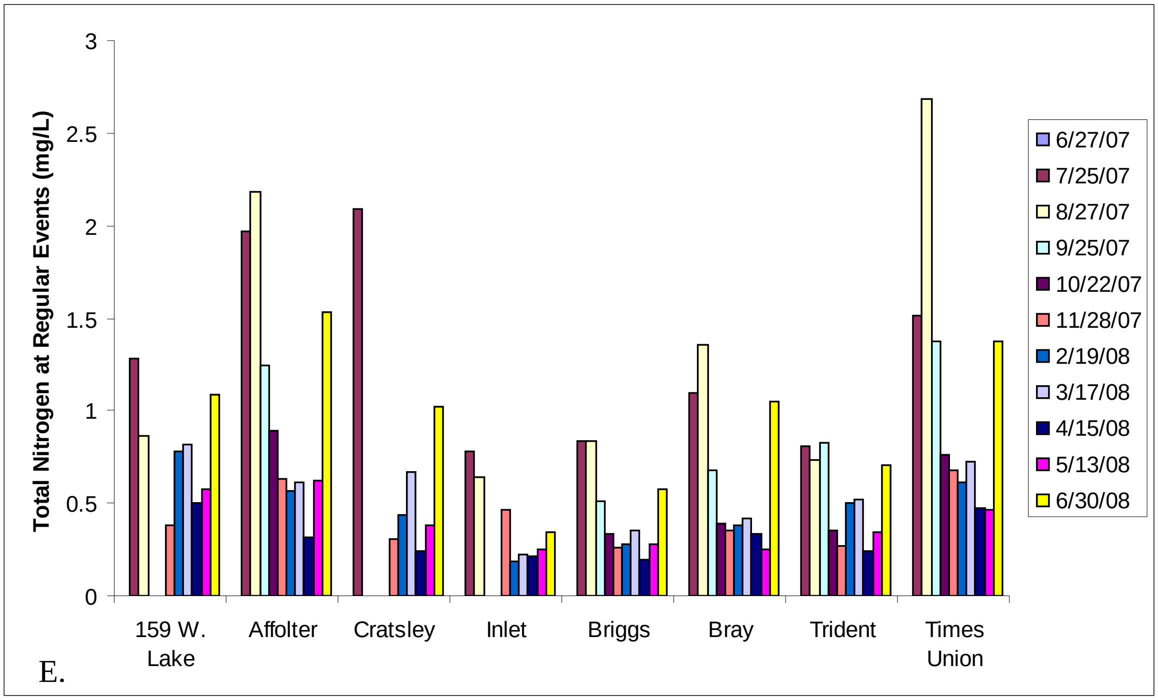
A.



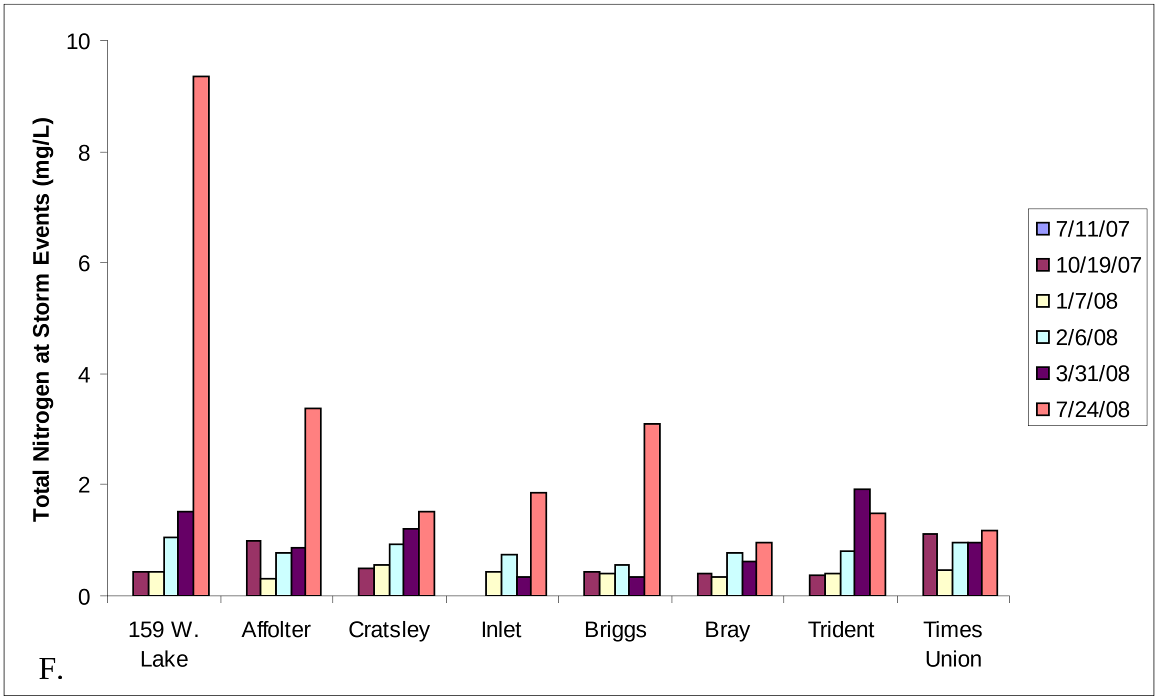
B.


2.5
2
1.5
1
0.5
0
Nitrate at Regular Events (mg/L)
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union
6/27/07
7/25/07
8/27/07
9/25/07
10/22/07
11/28/07
2/19/08
3/17/08
4/15/08
5/13/08
6/30/08
C.


1.4
1.2
1
0.8
0.6
0.4
0.2
0
Nitrate at Storm Events (mg/L)
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union
7/11/07
10/19/07
1/7/08
2/6/08
3/31/08
7/24/08
D.


Total Nitrogen at Regular Events (mg/L)
0
0.5
1
1.5
2
2.5
3
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union
6/27/07
7/25/07
8/27/07
9/25/07
10/22/07
11/28/07
2/19/08
3/17/08
4/15/08
5/13/08
6/30/08

E.


Total Nitrogen at Storm Events (mg/L)
0
2
4
6
8
10
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union
7/11/07
10/19/07
1/7/08
2/6/08
3/31/08
7/24/08

F.

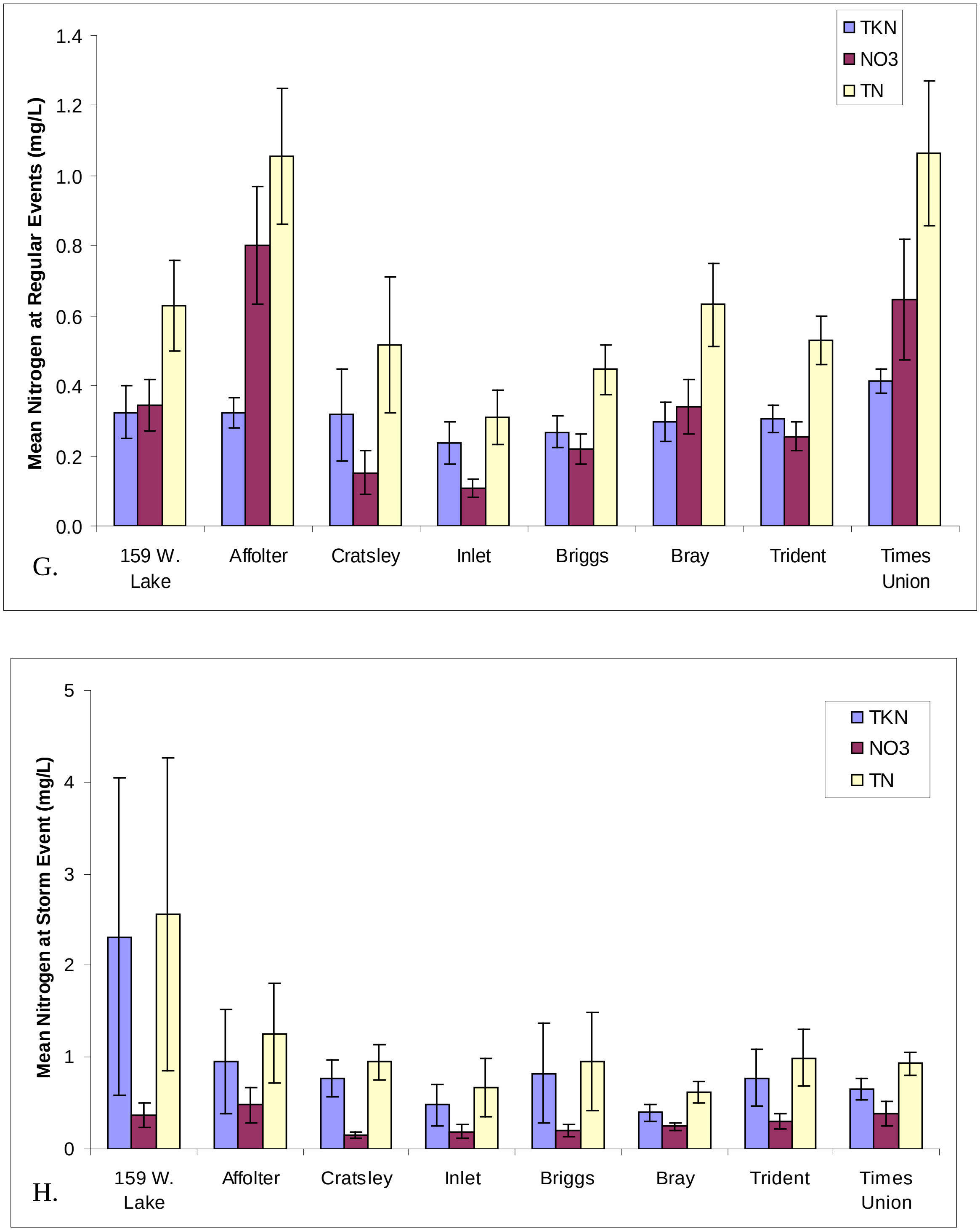
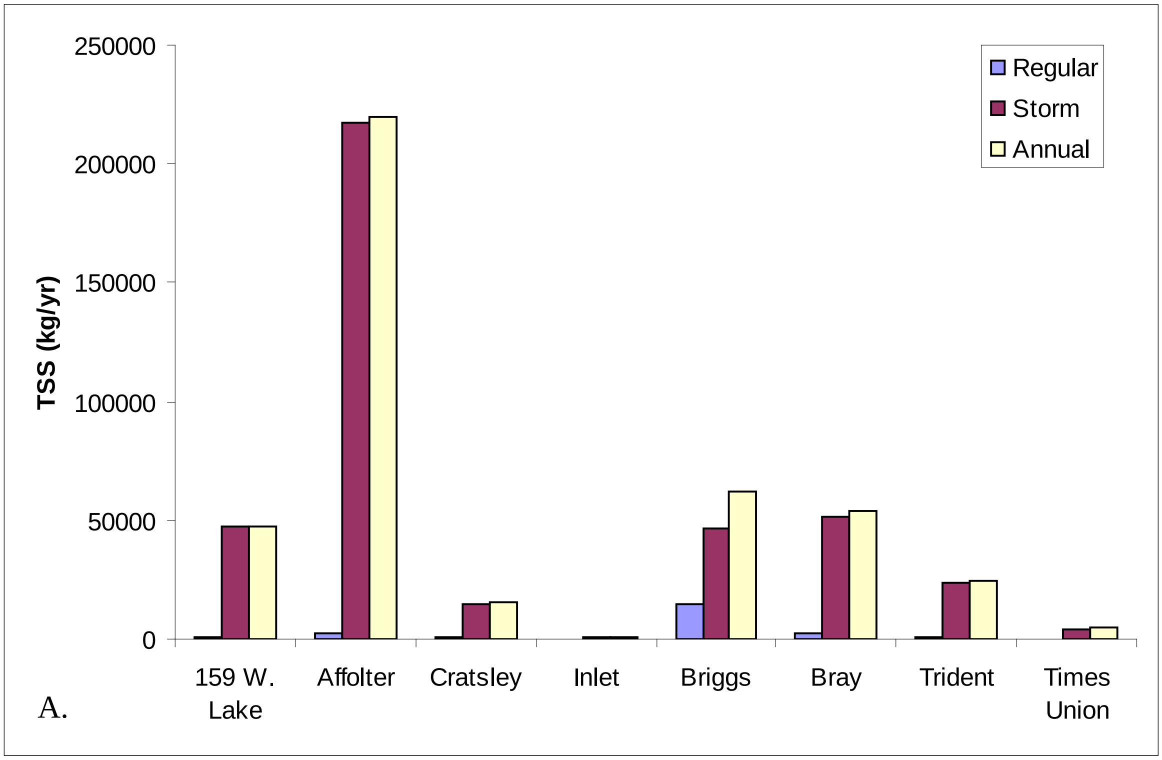


Figure 5. Total Kjeldahl Nitrogen (TKN), Nitrate (NO3), and Total Nitrogen (TN) concentrations in eight streams of Honeoye Lake during regular events (A,C,E, and G) and storm (B, D, F, and H) events. Vertical bar indicates 1 standard error.

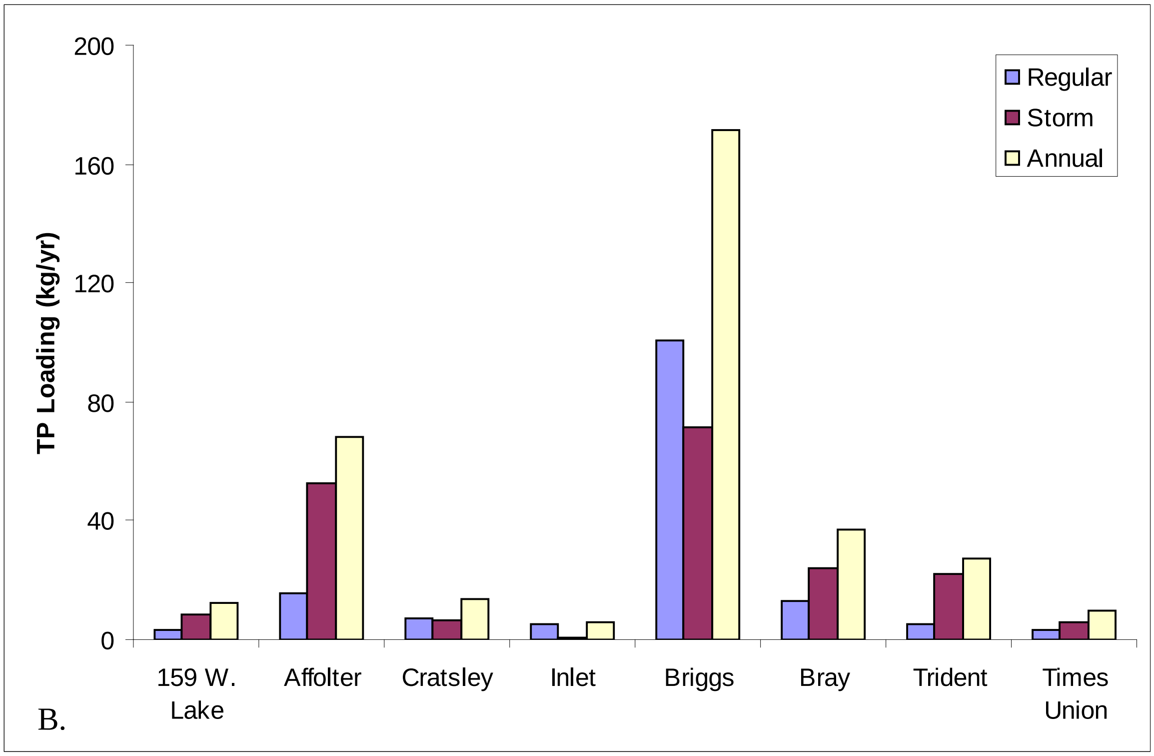
Similar to phosphorus, nitrogen concentrations (TKN, NO3, and TN) varied among sampling dates at either regular or storm events (Figure 5 A-F). The mean TN and NO3 concentrations were highest in Affolter followed by Times Union at regular events whereas 159 W Lake had the highest TN and TKN concentrations followed by Affolter at storm events (Figure 5G and H). During regular events, both TKN and NO3 concentrations were major components of TN (Figure 5G); at storm events, TN concentrations were mostly determined by TKN concentrations because they were all significantly higher than NO3 concentrations (Figure 5H). In addition, nitrogen concentrations at regular events were much lower than those at storm events, similar to water discharge rate, TSS concentration and phosphorus concentration.

Annual Total Loading

The eight streams were estimated to contribute total loading of 429.1 tn/yr TSS, 345.3 kg/yr TP, and 9443.1 kg/yr TN into Honeoye Lake based on the measurement of annual water discharge and annual concentrations. The concentrations varied in different streams: TSS ranged from 0.9 tn/yr in Inlet to 220 tn/yr in Affolter (Figure 6A); TP ranged from 5.9 kg/yr in Inlet to 172 kg/yr in Briggs (Figure 6B); and TN ranged from 51.9 kg/yr in Inlet to 4238 kg/yr in Briggs (Figure 6C). When comparing with data predicted from the "Watershed Model" for selected streams in a report by Honeoye Lake Watershed Taskforce (2007), the estimated data in this study were significantly lower with only two exceptions – water discharge in Briggs and TN in Briggs (Table 2). Water discharge and TN were relatively similar in these two studies compared with TP and TSS that were dramatically different.


TSS (kg/yr)
250000
200000
150000
100000
50000
0
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union
Regular
Storm
Annual

A.


TP Loading (kg/yr)
200
160
120
80
40
0
159 W. Lake
Affolter
Cratsley
Inlet
Briggs
Bray
Trident
Times Union
Regular
Storm
Annual

B.

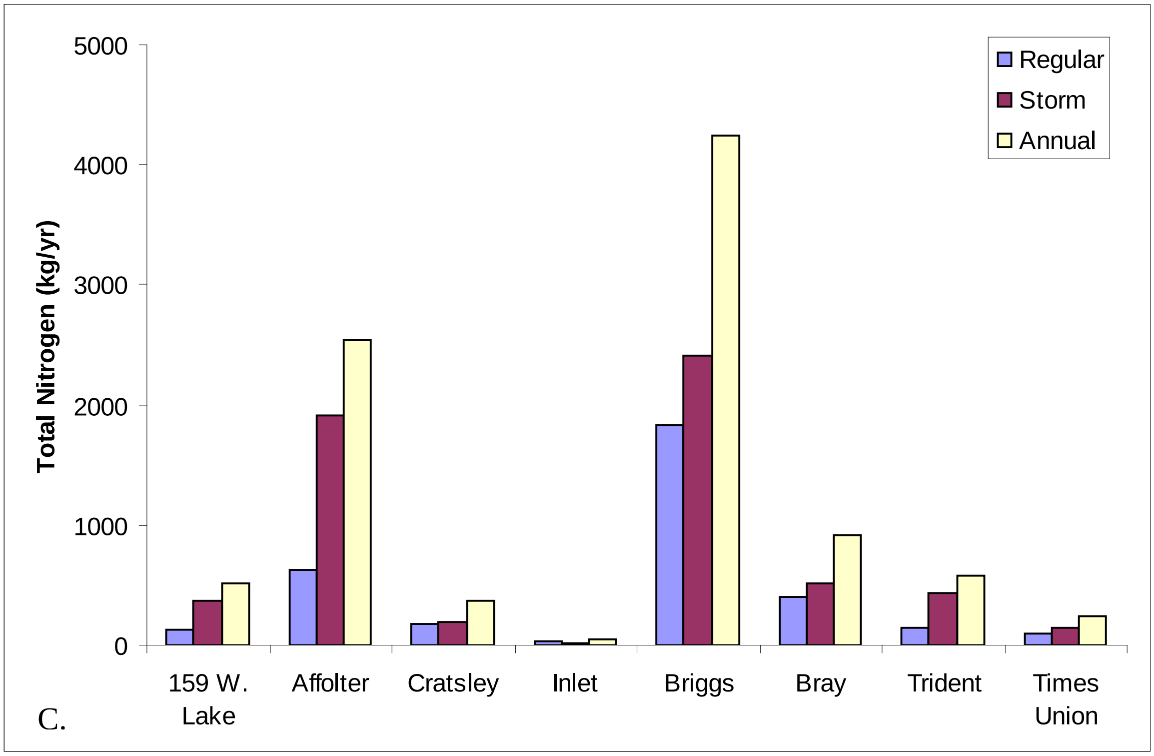


Figure 6. Annual loading of TSS (A), TP (B), and TN (C) in eight streams to Honeoye Lake.

Table 2. Estimated annual nutrient loading in this study and comparisons of selected streams with the "Watershed Model" prediction

Stream	Water Discharge (10^6 m^3)		TSS (10^3 kg/yr)		TP (kg/yr)		TN (kg/yr)	
	Measured	Model	Measured	Model	Measured	Model	Measured	Model
159 W. Lake	0.39		47.6		12.2		510.0	
Affolter	2.84	3.01	219.9	537.5	68.1	219.07	2535.4	3334.86
Cratsley	0.51		15.8		13.4		373.3	
Inlet	0.15		0.9		5.9		51.9	
Briggs	10.97	5.96	61.9	760.0	171.7	352.56	4238.3	3784.55
Bray	1.54	2.21	53.6	249.6	37.1	112.35	916.6	1362.78
Trident	0.71		24.6		27.2		578.6	
Times Union	0.26	1.24	4.7	163.9	9.5	73.44	239.1	960.42
Total	17.37		429.1		345.3		9443.1	

Note: Inlet in this study was different from "Inlet" in the report and therefore it is excluded for comparisons.

Identifying Possible Pollution Sources

Stream comparisons

Comparisons of nutrient concentrations and loadings in the eight streams help to identify which streams are more problematic than others (Table 3). At the regular events, nutrients were highest in Trident and Inlet although the concentrations were generally low. The highest nutrient concentrations occurred in 159 W Lake during the storm events followed by Affloter and Trident. However, the annual total loading was highest in Briggs, Affolter, Bray, and 159 W Lake, which contributed much more external nutrient loading than others into the lake.

Table 3. Comparisons of TSS, TP, TN in eight streams of Honeoye Lake at regular events (R), storm events (S), and annual total loading (Load) by ranking from highest 1 to lowest 5.

Stream	R-TSS	R-TP	R-TN	S-TSS	S-TP	S-TN	TSS Load	TP Load	TN Load
159 W Lake	**4**	**3**	**3**	**1**	**1**	**1**	**2**		**4**
Affolter			**1**	**2**	**2**	**2**	**1**	**2**	**2**
Cratsley								**5**	
Inlet	**2**	**2**							
Briggs	**3**			**4**	**4**	**4**	**3**	**1**	**1**
Bray			**3**				**4**	**3**	**3**
Trident	**1**	**1**		**3**	**3**	**3**	**5**	**4**	**5**
Times Union		**4**	**2**						

Segment analysis

Segment analysis was used to pinpoint the pollution sources after possible problematic streams were identified. For example, Inlet was identified with higher TP and TSS during the regular events; Affolter was identified with higher nutrients during the storm events and with higher total loading. In the Inlet stream (water ran from Site In4 to Site In1), TP was highest in the entrance to the lake and SRP was highest in the furthest point away from the inlet where several residential houses were near the sampling Site In4 (Figure 7A). Most extremely, the TSS, NO3, and TN concentrations were highest in Site In2 (Figure 7B), suggesting a possible pollution source between In2 and In3, where there is a sizable farm located. A clear trend of decreased TP in Affolter from A3 to A0 (water running direction) and highest TSS and TKN concentrations at Site A3 also suggested possible phosphorus pollution sources at or beyond A3 (Figure 8), where a large residential apartment complex is located.

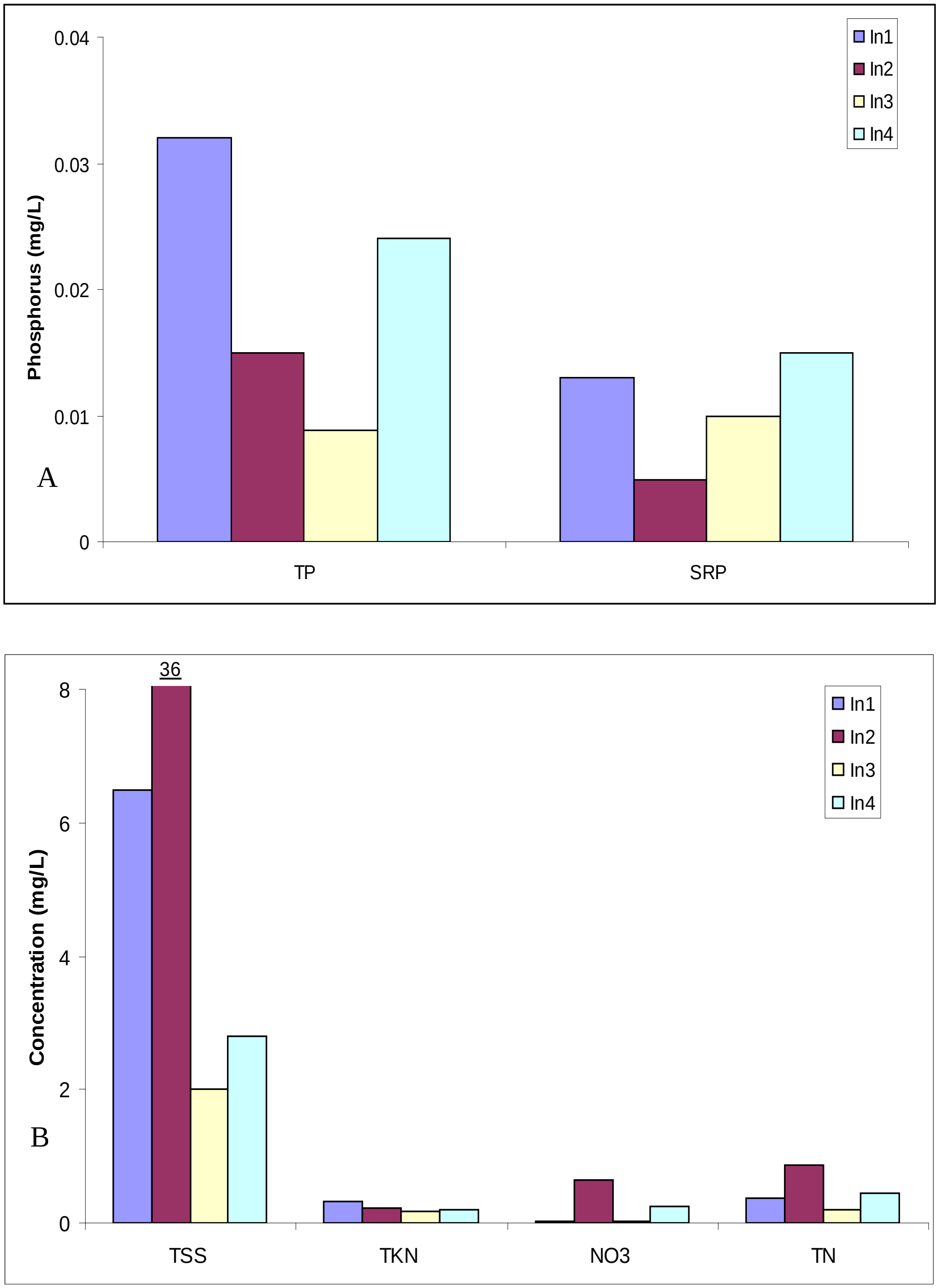


Figure 7. Nutrient concentrations at different locations (In1-4, see Figure 1) along the Inlet stream from segment analysis.

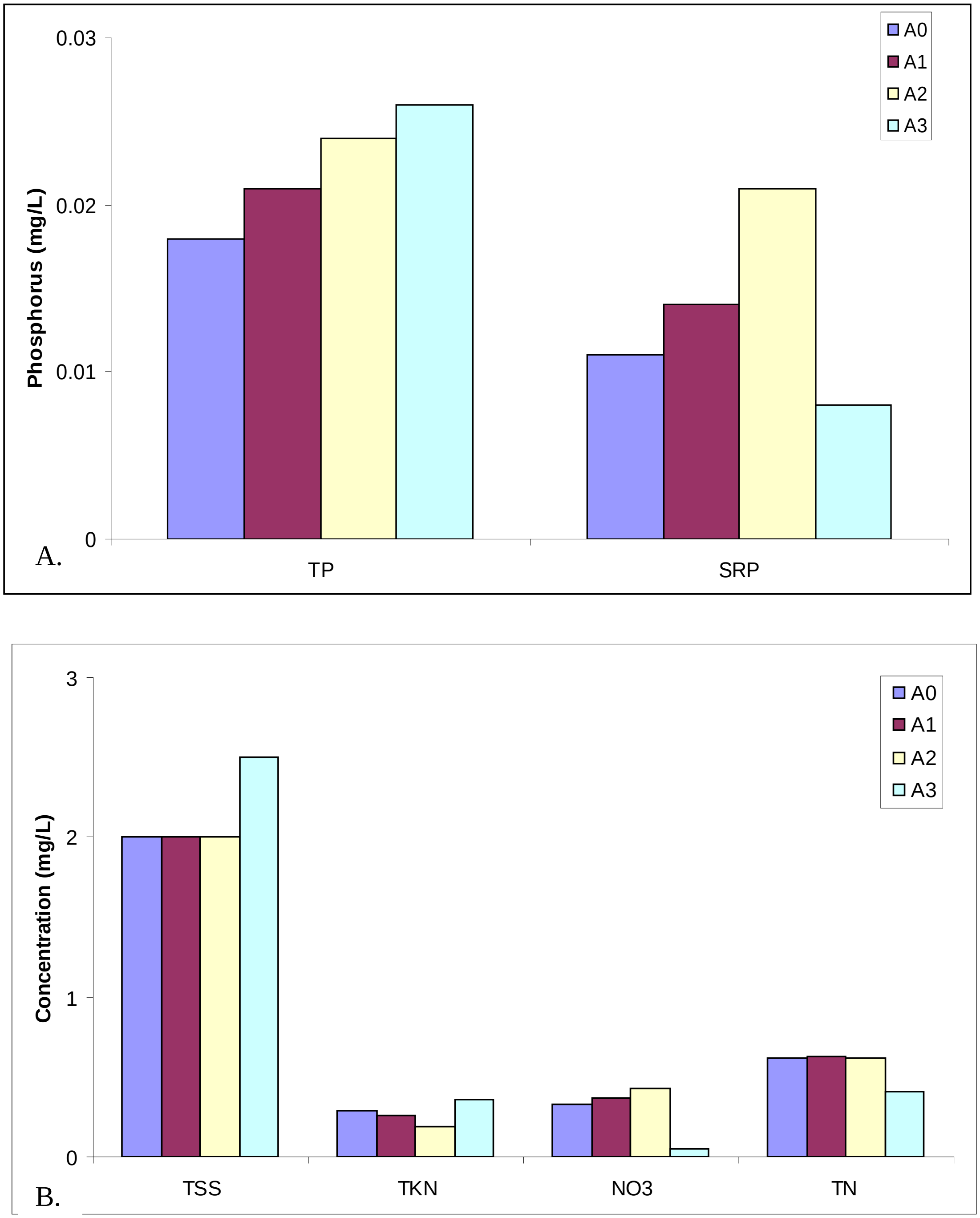


Figure 8. Nutrient concentrations at different locations (A0-3, see Figure 1) along the Affolter Gully from segment analysis.

DISCUSSION

External loading can be one important source contributing to eutrophication of lakes, such as Honeoye Lake. The eight streams were estimated to input more than 420 tons of suspended solids, 9 tons of nitrogen, and 340 kg of phosphorus into Honeoye Lake annually. The concentration range of the measured parameters is similar to that in 2003 measured by Starke (2004). However, the actual number might be even more because the method used in this study is relatively conservative and the survey period experienced a very dry summer in 2007. Due to the dry season, the nutrient concentrations and water discharge were low during regular events and even storm events. For example, Cratsley was completely dry during two regular events and once had no flow even during the rain storm because the water was directly absorbed into the soil. In addition, the dry weather also determined the regular/storm event ratio of 14:1, which was used to estimate the annual mean for nutrient concentrations, water discharge, and total loading. So it is not surprising to observe much less loading in this study than predicted by the "Watershed Model". The larger differences in TSS and TP than those in water discharge and TN between the two studies indicate that the differences were due to less storm events as they can contribute more significant amount of TSS and TP in the streams. However, the estimates in this study were accurate according to the reasonable estimation in the particular surveyed period. Therefore, the watershed model might overestimate the nutrient loading from the streams into the lake. Yet, real time data should be collected in consecutive years to have better estimates and predictions for total nutrient loading from small sub-watersheds consisting of these tributaries into Honeoye Lake.

It is clear that storm events input much more nutrients into the lake. High nutrients occurred during high flow events where there were high total suspended solids, since phosphorus and nitrogen bind with soil particles being carried in the stream flow (Honeoye Lake Watershed Taskforce 2007). Therefore it is necessary to have better management of land use around the tributaries, in such areas as steep slopes, vegetation buffers, residential construction, and timber harvesting. Sound management of all these activities can prevent soil erosion and nutrient loading into the lakes.

Identifying the pollution sources by comparing the streams and conducting segment analysis helps target the streams and design better management strategies. For example, phosphorus and nitrogen loading was found highest in Briggs whereas TSS loading was highest in Affolter. The high nutrient loading in Briggs was mostly due to it being the largest water discharge among all streams. Therefore, the goal to control loading should aim at lowering nutrient concentrations into Briggs. For Affolter, the concern should be focused on soil erosion as the TSS loading was overwhelming, exceeding 200 tons each year. However one year of data collection does not represent the general trends in those streams. Consequently continuous monitoring is needed. In addition, segment analysis helped identify pollution sources along the streams. For example, high TSS and nitrogen were found at Site In2, which was probably caused by the agriculture farm between In2 and In3. The highest TSS and TP occurred at A3 site at the beginning of Affolter Gully, where there is a large residential apartment complex. More segment analyses should be conducted to locate the point-source pollution in the future.

Streams are one of the important sources of external nutrient loading into Honeoye Lake. As pointed out in the executive summary report (Honeoye Lake Watershed

Taskforce 2007), there were other important sources, including septic loading, atmospheric over watershed, atmospheric on lake surface, and even Canada geese. These sources may also contribute to a large amount of nutrient loading into the lake although they are expected to play less significant roles than the direct input from tributaries.

There was another equally important, if not more important source of nutrients in addition to external loading – internal loading. Nutrients can be released from the sediments to water column, especially for phosphorus (Wetzel 2001). Phosphorus is usually bound into sediment when oxygen is abundant but it is released under anoxic conditions. In Honeoye Lake, anoxic conditions have been detected in the deeper water, especially during periods of summer calm (Gilman 1994). Also Honeoye Lake is a small shallow lake, which also makes it easy for phosphorus to be released from the sediment (Sondergaard et al. 2003). Therefore, significant amounts of phosphorus may be released from sediment into the water column, promoting algal bloom in Honeoye Lake. Nonetheless, no studies have been conducted to investigate the internal phosphorus cycling in this lake.

Some current practices in Honeoye Lake may help reduce nutrients in the lake, such as a recent alum treatment and years of plant harvesting. Alum treatment is intended to bind the phosphorus into the sediments and reduce phosphorus from being released. The effectiveness of the alum treatment is currently under investigation. On the other hand, plant harvesting has lasted for many years and can remove some nutrients. Gilman (1994) estimated that plant harvesting removed approximately 60 kg of phosphorus and 380 kg of nitrogen from Honeoye Lake each year when 600 wet tons of plants were harvested. This removed 17.3% of phosphorus and 4% of nitrogen of the annual total loading by the eight streams. Therefore, the harvesting activity should be continued as it seems to help reduce at least the phosphorus levels in the lake.

SUMMARY AND RECOMMENDATIONS

Higher concentrations of total suspended solids, nitrogen and phosphorus occurred during the storm events when there was more water discharge and likely more soil erosion. It is estimated that the eight studied streams contributed TSS 429.1 tn/yr, TP 0.345 tn/yr, and TN 9.44 tn/yr together. These suggest stream input is an important source of external loading into Honeoye Lake although these numbers were much smaller than predicted by the "Watershed Model". Briggs, Affolter, and 159 W. Lake had the highest concentrations and highest loading of TSS, TP, and TN, suggesting that better management and prevention practices should be focused on these streams. Bray and Trident could also be problematic in terms of their nutrient concentrations and loading. Segment analysis could identify some possible causes of excessive nutrient loading. For example, the farm along the Inlet stream and the residential apartment complex at the beginning of Affolter Gully are likely to cause the higher nitrogen and TSS concentrations in Inlet and higher phosphorus levels in Affolter Gully.

Due to the dry survey period (June 2007 – July 2008), the estimated annual loading might be low and unique. Therefore, continuous monitoring of these streams should be conducted to have data for more accurate model to predict and generalize the trend of nutrient loading into the lake from these streams. Secondly, lake water quality monitoring should be conducted to test whether the nutrient change in the lake responds to the change in nutrients in the streams. Thirdly, more segment analyses should be conducted in streams with concerns to identify possible nutrient sources such as Briggs, Affolter, 159 W. Lake, and Trident. In addition, internal nutrient cycling needs to be investigated as this might be even more important for water quality in lakes. Therefore, it is extremely important to know how much nutrients are released from sediment, from macrophyte beds, and from decomposing macrophytes. Finally, a better model should be developed or modified based on the “Watershed Model” to include data collected from proposed studies to create a nutrient budget in Honeoye Lake, targeting major loading sources and improving water quality in Honeoye Lake.

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