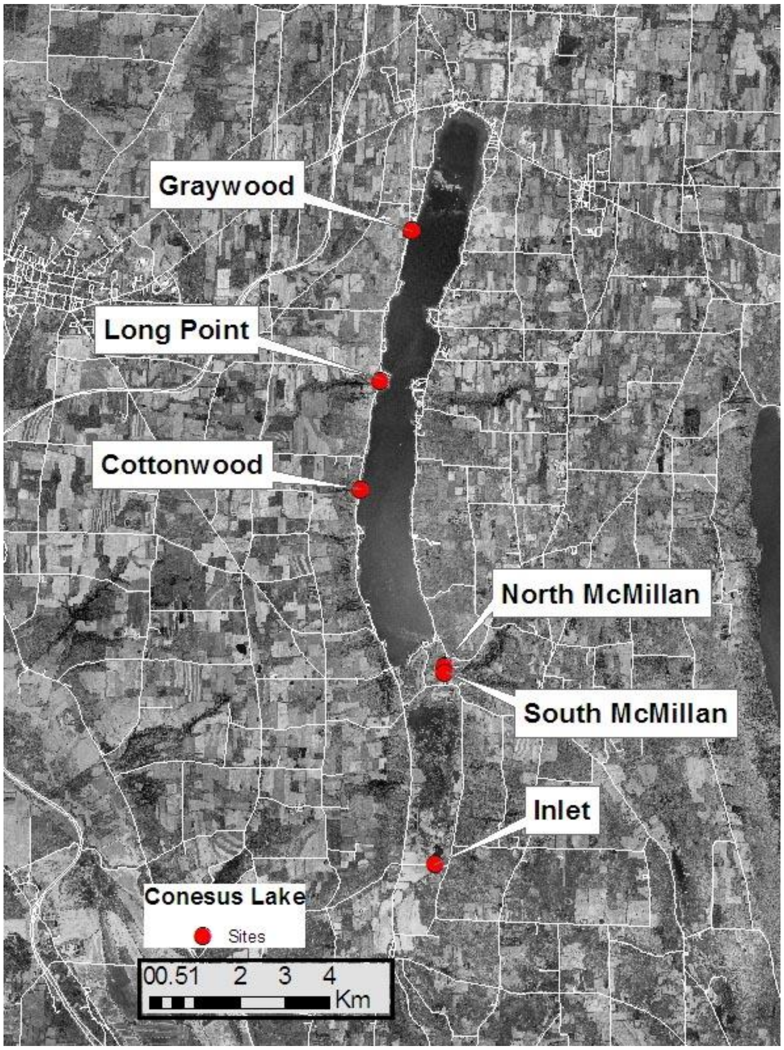
The Development of an Stream Water Quality Assessment Index to Evaluate Stream Health
Conesus Lake Tributaries
Spring 2011

Joseph C. Makarewicz, Theodore W. Lewis, and Blake Snyder
The Department of Environmental Science and Biology
The College at Brockport

State University of New York



November 2011

Table of Contents

Executive Summary

1. The major goal was to develop an assessment tool for watershed health utilizing the USDA data base. Such a tool would allow the county to evaluate the status of watersheds; that is, are they improving, getting worse, or not changing. An evaluation tool of this type would allow further development and direction of the Conesus Lake Watershed Management Plan.

2. Monitoring of two of the USDA streams (Cottonwood Gully and North McMillan Creek) was changed to the spring rather than the summer. This was done as a result of last year's work which suggested that spring monitoring may provide a better Stream Water Quality Assessment Index watershed status than a summer index.

3. A Stream Water Quality Assessment Index was developed based on spring data that has promise for evaluating trends in the impact of land use on Conesus Lake subwatersheds.

Recommendations

1. If financially appropriate, monitoring of watersheds should continue as a mechanism to evaluate land-use changes.

2. Monitoring of streams during the spring period should be the target of future efforts.

3. After implementation of a spring monitoring program, the Stream Water Quality Assessment Index should be evaluated after a trial period.

Introduction

Previous reports (Makarewicz and Lewis 2009, 2010) documented substantial increases in the concentrations of nutrients and soil particles in streams during the summer of 2009 and 2010 (Makarewicz and Lewis 2009, 2010). At Graywood Gully for example, concentrations of soil (TSS), total phosphorus (TP), soluble reactive phosphorus (SRP), total Kjeldahl nitrogen (TKN), and nitrate increased in the stream water. After a 5-year decrease at Cottonwood Gully (Makarewicz *et al*. 2009), nitrate concentration (NO_3+NO_2) increased to levels not observed since 2003. Similar increases were observed in the Southwest, Sand Point, North Gully, Sutton Point, and Long Point subwatersheds. This was of concern as a general decrease in “concentrations” of nutrients and soil from managed watersheds was evident prior to 2009 due to management plans adopted during the USDA study (Makarewicz *et al.* 2009).

Several factors may have contributed to this observed increase in the concentration of dissolved and particulate material; some are natural (variation in rainfall amount and intensity); but others are affected by human actions (changes in land use or management practices). Although the increases observed in all the monitored streams may be related to new or changing farming practices, it could not be ruled out that the significant rainfalls in the spring and early summer of 2009 are not the cause. A limitation of the approach taken in 2008 and 2009 was that discharge was not measured as it was in the USDA study. Concentration of analytes is a function of discharge from streams; that is, as discharge increases, concentrations increase as more material is washed from the land and more material is dissolved. The observed increases could simply be due to the higher than usual rainfalls in May and especially in June. For example, the daily rate of precipitation in June was twice the rate for any other previous year since 2002; May precipitation was the highest since 2003. Also, a visual inspection of these watersheds in the summer of 2009 ruled out any major changes in land use. The increase in nutrient loss from all of the USDA watersheds during the summer of 2009 suggests that the approach taken of using only averaged concentration data over time to evaluate temporal trends may be misinterpreted.

In 2010, we reevaluated the stream concentration approach to assessment of stream water by converting the data in the amount of an analyte lost from a subwatershed and applying a statistical approach that accounts for discharge. This process adjusts or weights the mean concentration and load by discharge and produces an adjusted average loss from the watershed titled the marginal mean load. An increase in total phosphorus, soluble reactive phosphorus, total suspended solids (soil loss), and total Kjeldahl nitrogen was observed in 2009 using the summer data collected via the county sampling design. However, these increases were "not" statistically significant, which implies that we cannot be sure that the increases are not random effects.

Generally, these summer data do not strongly mimic the large declines resulting from BMPs implemented in these watersheds (Makarewicz et al. 2009). The reason for this difference has to do with the data being used. In Makarewicz *et al.* (2009), weekly seasonal data were collected for an entire year. Many, if not all of the management plans implemented by the USDA project, were designed to reduce nutrient and soil loss via water being lost directly from the watershed. That is, water carrying nutrients or soil was generally directed to buffer strips, de-watered, infiltrated into the soil, etc. Results from BMPs would have a major effect during the winter and spring during the wet part of the year. During the summer when flows are low, these impacts from BMPs would not necessarily be observed. Also, planted vegetation in the summer is actively taking up nutrients and serving to retain soil on the land. With more data points for Graywood Creek, the observed increased in 2009 may become statistically significant. In retrospect, it may have been better to monitor the watersheds from March through June to capture the period of time when the agricultural community is actively tilling the land and planting crops. Thus in 2011, the Conesus Lake work plan was changed to initiate a spring rather than a summer sampling period. Also, using loading data and a statistical analysis approach was work intensive and expensive. An index based on analyte concentration may be easier for the county to work with in the future. The major goal was to develop an assessment tool based on spring, rather than summer data, utilizing the spring 2003 to 2007 USDA data base. Such a tool would allow the county to evaluate the status of Conesus Lake subwatersheds; that is, are they improving, getting worse, or not changing. An evaluation tool of this type would allow further development and direction of the Conesus Lake Watershed Management Plan.

The 2011 objectives were:

1. Change the monitoring of two of the USDA streams (Cottonwood Gully and North McMillan Creek) from the summer to the spring. Last year's work suggested that spring monitoring may provide a better index of stream status than a summer index; and

2. Develop a spring-based Stream Water Quality Assessment Index.

Methods

Stream samples were taken at two former USDA monitoring sites (Makarewicz *et al.* 2009) at the base of the Cottonwood Gully and the North McMillan Creek sub-watersheds (Fig. 1). Water samples were taken every Tuesday morning from 1 March to 31 May 2011. In addition, ISCO water samplers were placed in each stream to take samples during hydrometeorologic events that exceeded a rise in stream level of 1 inch/30 minutes. A total of eight event and 14 nonevent water samples were taken, preserved, and analyzed using approved standard methods (USEPA 1979, APHA 1999). Sample water for dissolved nutrient analysis (SRP, NO_3+ NO_2) was filtered immediately on site with 0.45-µm MCI Magna Nylon 66 membrane filters and held at 4°C until analysis the following day. Stream samples were analyzed for TP (APHA Method 4500-P-F), TKN (USEPA Method 351.2), NO_3+ NO_2 (APHA Method 4500-NO_3-F), and TSS (APHA Method 2540D). Except for TSS, analyses were performed on a Technicon AutoAnalyser II. Method Detection limits were as follows: SRP (0.48 µg P/L), TP (0.38 µg P/L), NO_3+ NO_2 (0.005 mg N/L), TKN (0.15 µg N/L), and TSS (0.2 mg/L).

Quality Control:

All water samples were analyzed at the Water Chemistry Laboratory at The College at Brockport, State University of New York (NELAC – EPA Lab Code # NY01449) within approved sample handling times. In general, this program includes biannual proficiency audits, yearly annual inspections and documentation of all samples, reagents, and equipment under good laboratory practices. All quality control (QC) measures are assessed and evaluated on an on-going basis. As required by NELAC and New York's ELAP certification process, method blanks, duplicate samples, laboratory control samples, and matrix spikes are performed at a frequency of one per batch of 20 or fewer samples. Field blanks (events and nonevents) are routinely collected and analyzed. Analytical data generated with QC samples that fall within prescribed acceptance limits indicate the test method was in control. For example, QC limits for laboratory control samples and matrix spikes are based on the historical mean recovery plus or minus three standard deviations. QC limits for duplicate samples are based on the historical mean relative percent difference plus or minus three standard deviations. Data generated with QC samples that fall outside QC limits indicate the test method was out of control. These data are considered suspect and the corresponding samples are reanalyzed. As part of the NELAC certification, the lab participates semi-annually in proficiency testing program (blind audits, Table 1) for each category of ELAP approval. If the lab fails the proficiency audit for an analyte, the lab director is required to identify the source and correct the problem to the certification agency.

Results and Discussion

Development of a Stream Water Quality Assessment Index

We considered several different approaches in developing a Stream Water Quality Assessment Index. For example, we evaluated discharge versus loading for both spring and summer data, evaluated the development of an index number based on the average concentration of a nutrient over time, and considered a statistical approach (ANCOVA) based on spring nonevent data. After much trial and error, we developed a graphical index of discharge versus concentration based on spring data from 2002 to 2006. Figure 2 shows the data grouped by regression lines using the Pre-BMP and Post-BMP data from the USDA work of Makarewicz *et al* (2009). From this graphic it is evident analyte concentration varied over time and with discharge - in general, the higher the discharge the higher the analyte concentration. Also, concentration was higher early in the USDA study period when BMPs had not been introduced and was reduced after the BMPs were implemented. This approach suggests that if future measurements of an analyte were made, a mechanism would be available to determine whether the watershed and its associated stream are improving or degrading in water quality.

This approach was further modified in Figure 3. This figure represents the regression line of all measurements made during the spring period of 2003 to 2007. The curved lines below and above the middle line represent the 99% confidence interval. If an analyte concentration is in the dark red area and above the upper 99% confidence interval, the water quality of this stream discharging into Conesus Lake would be considered as having a degraded or having a reduction in water quality compared to the 2003-2007 period. If the analyte concentration was below the lower 99% confidence interval and in the green area, water quality of the stream discharging into Conesus Lake is improving. If analyte concentrations fall within the 99% confidence interval, there is no certainty whether the stream water is improving or degrading. For example, the data for spring 2011 are plotted as triangles. The preponderance of the points is in the green area of the graph suggesting the loss of total phosphorus from the Cottonwood watershed is below the Pre-BMP period; thus the water quality of the stream is better than it was historically and therefore improving.

Monitoring Trends

Using this approach on the two creeks monitored during spring of 2011, trends in water quality are observed. With total phosphorus, total suspended solids, and total Kjeldahl nitrogen, all analytes that tend to increase with increasing discharge in Cottonwood Gully, the preponderance of the 2011 sampling points is in the green area (Fig. 4). This result suggests that the improvements in stream water quality observed during and after implementation of the USDA Best Management Plans are being maintained into 2011. For analytes that tend to decrease with increasing water volume/discharge (sodium and nitrate), the 2011 data points are in the green area, again suggesting the improvements in stream water quality observed during and after implementation of the USDA Best Management Plans are being maintained into 2011. Only with soluble reactive phosphorus (SRP) were the number of data points equally divided between the red and green areas. This result suggests that the loss of SRP from the watershed is often above historical concentrations from the 2003 to 2007 period when BMPs were initiated. This may represent a new agriculture fertilization regime of crops in the watershed. It would be interesting to discuss this with the Livingston County Soil and Water Conservation District personnel as they may have some idea of the fertilization rates and applications.

North McMillan Creek and its watershed was the control watershed used in the USDA study, as the watershed is the most forested and had the least amount of agriculture. The data for TP, SRP, TKN, nitrate, and TSS indicate that the preponderance of the 2011 data points are in the green area of the Stream Water Quality Assessment Index (Fig. 5). The conclusion is that the quality of the water leaving this watershed is not degraded and has not changed from the 2003 to 2007 period. The exception to this trend is sodium. Application of deicing salt is roads during the snow and ice period is quite common and expected by the public in the Finger Lakes Region. The data for North McMillan suggest that application rates and/or the number of applications may be higher than in the 2003 -2007 period. The sampling site for this location is near the bridge, and any snowmelt plus salt enters into the creek just above where the samples were taken. Previous reports (Makarewicz and Lewis 2009) have identified that deicing salt levels are slowly increasing over the past 50 years in the Conesus Lake water supply.

The Stream Water Quality Assessment index for the other four USDA creeks (Graywood Creek, Long Point Gully, Sutton Point, and Sand Point) was developed and is in the appendices. No data for these creeks were collected in 2011. All data collected in in 2011 are presented in Tables 2 and 3.

Conclusions/Limitations

The preferred way to evaluate the streams is to sample the entire year during nonevents and events as was done during the USDA project (Makarewicz *et al*. 2009) However, the cost of this approach is beyond the means of Livingston County. As an alternate approach, the Stream Water Quality Assessment Index was developed and appears to be a viable tool for evaluating the water quality of the USDA streams. Any decisions on water quality should be based on the preponderance of sampling results (points) for a given period of time. The larger the number of sampling points over various flow or discharge regimes, the better this tool will be for evaluating status of the streams. With a smaller number of sampling points, a greater amount of uncertainty will be introduced into the evaluation of the stream and watershed, as variability in discharge and analyte measurements over a day can be quite large – especially during events. In the work completed in 2011, discharge was measured over an entire day using an automated recorder. Flow measurements should be based minimally on hourly measurements of discharge to calculate a daily discharge. This is especially true for rain/melt events. Lastly, the Stream Water Quality Assessment was developed for the spring period and not other periods of time. It is not appropriate to use during other seasons. The assumption is that conditions observed in the spring do reflect conditions over the entire year.

References

APHA. 1999. *Standard Methods for the Examination of Waste and Wastewater*. American Public Health Association. 20th ed. New York, NY.

Makarewicz, J.C. and Lewis, T.W. 2009. Conesus Lake Limnology. 2009. Final report to Livingston County Health Department, Geneseo, NY.

Makarewicz, J.C. and Lewis, T.W. 2010. Conesus Lake Tributaries Summer 2010.Final report to Livingston County Health Department, Geneseo, NY.

Makarewicz, J.C., Lewis, T., Bosch, S., and 4 other authors. 2009. The impact of agricultural best management practices on downstream systems: Soil loss and nutrient chemistry and flux to Conesus Lake, New York, USA. J. Great Lakes Res. 35:23-36.

USEPA. 1979. *Methods for the Chemical Analysis of Water and Wastes*. Environmental Monitoring and Support Laboratory. Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-79-020.

Table 1. Proficiency audit of the Water Quality Laboratory at The College at Brockport.

WADSWORTH CENTER
NEW YORK STATE DEPARTMENT OF HEALTH
ENVIRONMENTAL LABORATORY APPROVAL PROGRAM Proficiency Test Report

Lab 11439 SUNY BROCKPORT EPA Lab ID NY01449 Page 1 of 1
WATER LAB LENNON HALL
BROCKPORT, NY 14420
USA

Shipment: 345 Non Potable Water Chemistry
Shipment Date: 12-Jul-2011

Analyte	Sample ID	Result	Mean/Target	Acceptance Limits	Method	Score
Approval Category: **Non Potable Water**						
Sample: **Residue**						
Solids, Total Suspended 159 passed out of 169 reported results.	4502	39.9	40.0	31.5 – 48.5	SM18-20 2540D (97)	Satisfactory
Sample: **Organic Nutrients**						
Kjeldahl Nitrogen, Total 62 passed out of 70 reported results.	4504	26.58	26.0	17.6 – 34.4	EPA 351.2 Rev. 2.0	Satisfactory
Phosphorus, Total 81 passed out of 84 reported results.	4504	2.50	2.48	1.97 - 2.98	SM18-20 4500-PF	Satisfactory
Sample: **Inorganic Nutrients**						
Nitrate (as N) 88 passed out of 89 reported results.	4507	1.11	1.10	0.852 – 1.35	SM18-20 4500-NO3 F (00)	Satisfactory
Orthophosphate (as P) 77 passed out of 79 reported results.	4507	3.60	4.20	3.44 – 4.95	SM18-20 4500-PF	Satisfactory
Sample: **Minerals II**						
Sodium, Total 62 passed out of 68 reported results.	4537	76.02	72.3	61.6 – 83.1	SM 18-20 3111B (99)	Satisfactory
Sample: **Nitrite**						
Nitrite as N 79 passed out of 83 reported results.	4541	3.21	3.35	2.85 – 3.85	SM 18-20 4500-NO2 B	Satisfactory

Table 2. Data collected during the spring (1 March to 31 May 2011) at the Cottonwood watershed of Conesus Lake. NT=Not Taken.

Date Collected		Discharge (m^3/d)	TP (µg P/L)	Nitrate (mg N/L)	TSS (mg/L)	TKN (µg N/L)	Sodium (mg/L)	SRP (µg P/L)
03/01/11	nonevent	2802	121.1	3.00	18.5	NT	18.27	69.7
03/08/11	event	14041	94.5	3.97	8.0	NT	18.09	58.7
03/15/11	nonevent	2802	66.1	4.05	3.5	561	18.64	49.3
03/22/11	nonevent	3233	48.4	4.15	4.9	469	18.40	7.1
03/29/11	nonevent	2325	37.1	3.78	3.6	363	19.99	22.8
04/05/11	event	10754	122.5	4.13	59.8	980	24.15	3.8
04/11/11	event	4922	193.8	3.17	98.5	1464	21.54	5.7
04/11/11	event	5257	41.7	3.56	25.5	448	22.38	11.6
04/12/11	nonevent	4813	32.0	3.41	2.8	382	20.79	12.5
04/19/11	nonevent	2250	20.0	3.33	3.4	323	24.50	7.3
04/20/11	event	9806	129.1	2.14	49.0	2118	22.10	4.4
04/26/11	event	14600	137.3	2.92	84.5	1007	16.03	79.7
04/26/11	event	22620	275.3	2.57	105.5	961	15.18	48.3
04/26/11	nonevent	25267	231.6	2.70	77.7	750	14.96	63.2
05/03/11	nonevent	11577	114.1	2.48	23.6	324	13.63	63.9
05/03/11	event	11745	224.0	1.41	89.0	1897	13.22	18.8
05/03/11	event	20341	201.5	2.72	65.5	1384	15.50	54.2
05/10/11	event	3322	76.7	1.91	3.3	511	14.40	60.9
05/15/11	event	6325	197.2	1.26	87.0	1863	15.33	10.8
05/16/11	event	13493	112.4	2.54	30.2	1052	18.46	25.8
05/17/11	nonevent	3505	65.4	2.52	5.4	262	18.50	4.7
05/24/11	nonevent	6576	66.0	2.50	29.7	566	16.01	56.4
05/27/11	event	12956	175.1	1.20	90.5	1938	13.94	28.5
05/28/11	event	34084	222.0	2.01	79.3	1434	18.13	88.6
05/31/11	nonevent	5257	169.6	2.16	6.5	673	15.59	152.2

Table 3. Data collected during the spring (1 March to 31 May 2011) at the North McMillan watershed of Conesus Lake. NT= Not Taken.

Date Collected		Discharge (m^3/d)	TP (µg P/L)	Nitrate (mg N/L)	TSS (mg/L)	TKN (µg N/L)	Sodium (mg/L)	SRP (µg P/L)
3/1/2011	nonevent	125155	32.5	0.67	9.5	NT	30.85	10.0
3/8/2011	nonevent	35932	15.3	0.88	2.5	NT	36.76	7.1
3/15/2011	nonevent	72191	12.9	0.59	0.9	NT	29.17	4.2
3/22/2011	event	65306	61.8	0.29	5.3	419	23.96	33.0
3/22/2011	event	164822	14.4	0.28	4.4	509	23.54	14.4
3/22/2011	nonevent	94868	11.4	0.36	3.0	239	28.81	11.4
3/29/2011	nonevent	40066	4.8	0.35	2.1	400	40.01	ND
4/5/2011	event	124233	26.0	0.13	11.6	233	33.10	0.6
4/5/2011	event	213474	8.0	0.13	2.4	230	33.71	3.3
4/5/2011	event	161660	26.0	0.27	16.5	217	29.51	1.9
4/12/2011	nonevent	34933	7.3	0.15	3.5	336	35.02	1.9
4/13/2011	event	59397	64.2	0.20	31.3	550	34.95	2.9
4/13/2011	event	293175	54.5	0.23	61.8	724	39.76	0.3
4/19/2011	nonevent	55610	5.0	0.24	21.5	165	31.47	0.0
4/20/2011	event	174489	135.6	0.24	492.5	2527	29.52	1.6
4/20/2011	event	504848	306.5	0.29	375.8	1839	28.99	2.4
4/26/2011	nonevent	122397	26.9	0.25	22.6	363	23.11	3.6
4/26/2011	event	182197	184.0	0.21	685.5	861	24.03	1.2
4/26/2011	event	416699	47.9	0.23	70.4	239	23.84	5.4
5/3/2011	nonevent	6449	187.2	0.22	188.0	697	25.01	4.4
5/3/2011	event	313236	506.3	0.12	482.0	2200	22.09	3.1
5/3/2011	event	347626	293.5	0.22	327.5	1699	22.37	4.6
5/10/2011	nonevent	41134	4.7	0.09	3.1	336	28.33	1.9
5/17/2011	nonevent	55610	6.3	0.08	1.7	375	24.71	0.3
5/17/2011	event	25676	84.4	0.04	105.0	754	22.34	0.8
5/17/2011	event	23572	13.0	0.07	15.0	548	22.17	1.5
5/24/2011	nonevent	86972	30.7	0.08	10.8	461	21.31	1.1
5/27/2011	event	385410	47.1	0.05	32.0	688	21.98	5.5
5/28/2011	event	891907	18.6	0.09	12.8	467	16.04	5.9
5/31/2011	nonevent	18496	13.1	0.16	2.7	351	27.75	8.5

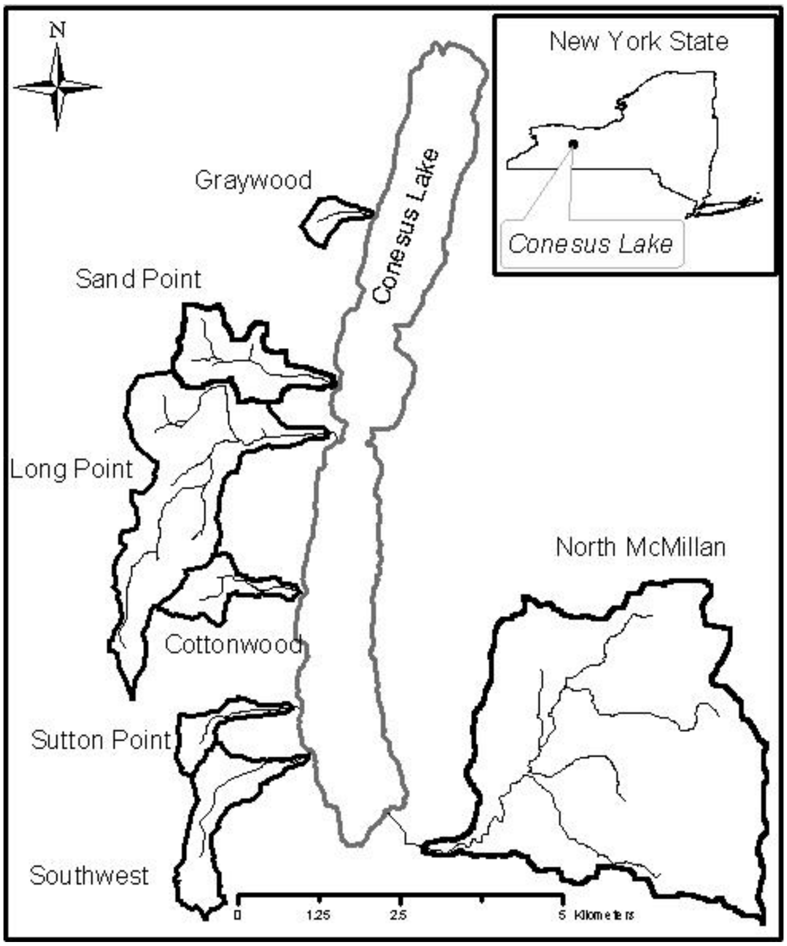


Figure 1. USDA sampling sites of Makarewicz et al. (2009).

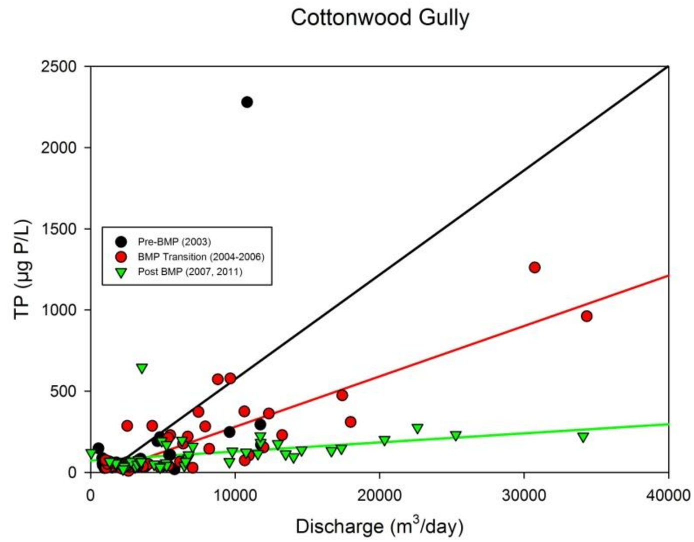


Figure 2. Cottonwood Gully spring discharge versus total phosphorus concentration for the 2003 to 2006 and 2011 period. Lines plotted are regression lines for the Pre-BMP period, Post-BMP period, and the transition period.

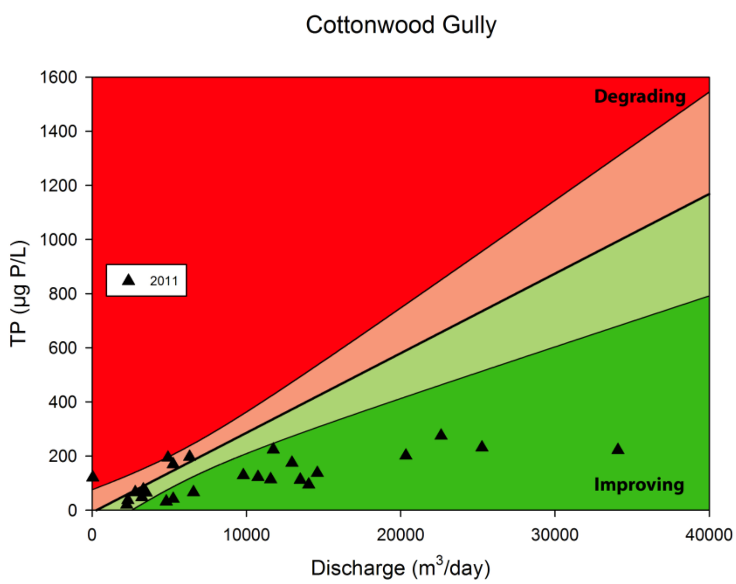


Figure 3. Cottonwood Gully Stream Water Quality Assessment Index. The triangles represent samples taken in 2011. See text for further explanation of the graph.

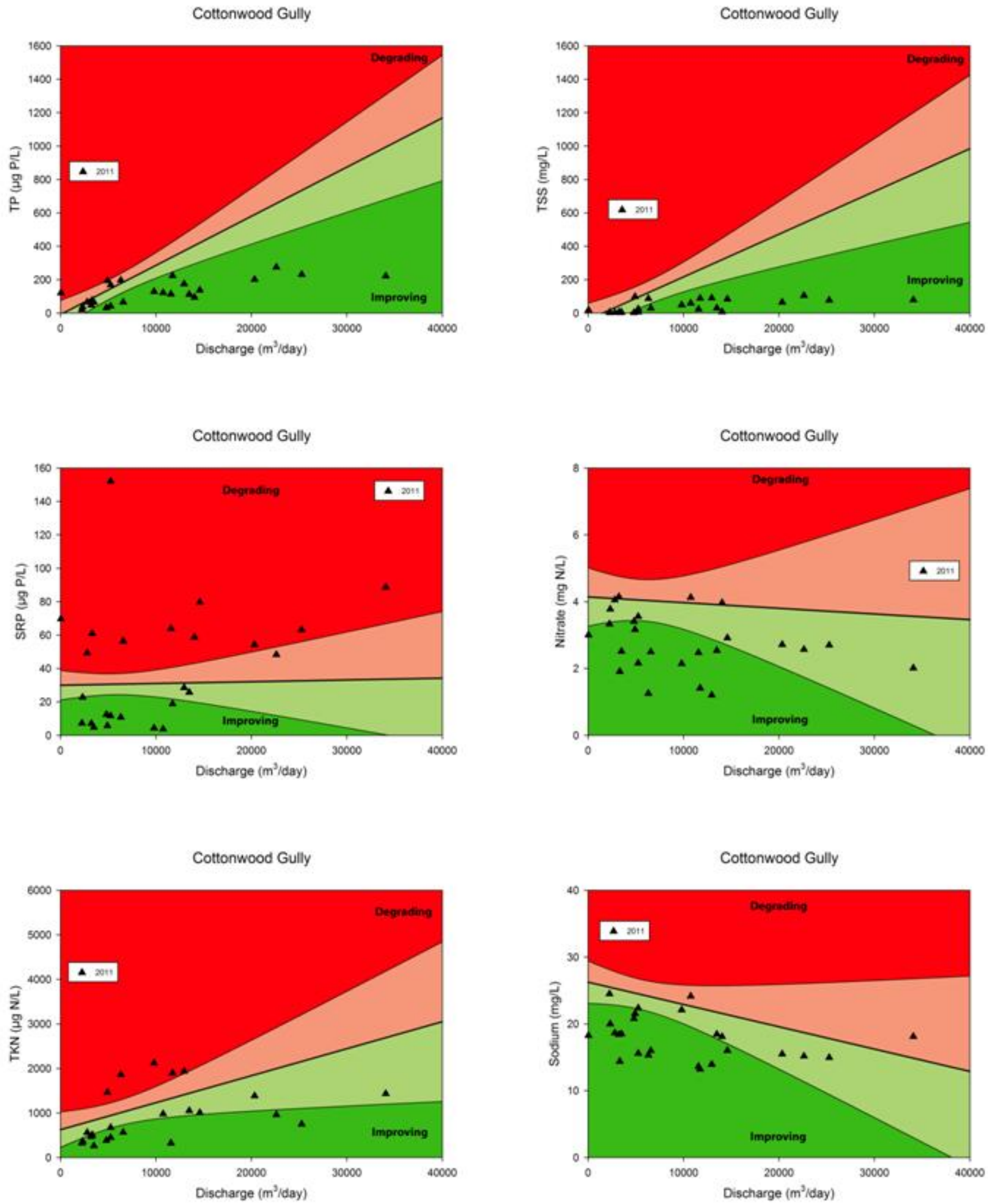


Figure 4. Cottonwood Gully Stream Water Quality Assessment Index for total phosphorus, soluble reactive phosphorus, total suspended solids, nitrate, total Kjeldahl nitrogen, and sodium.

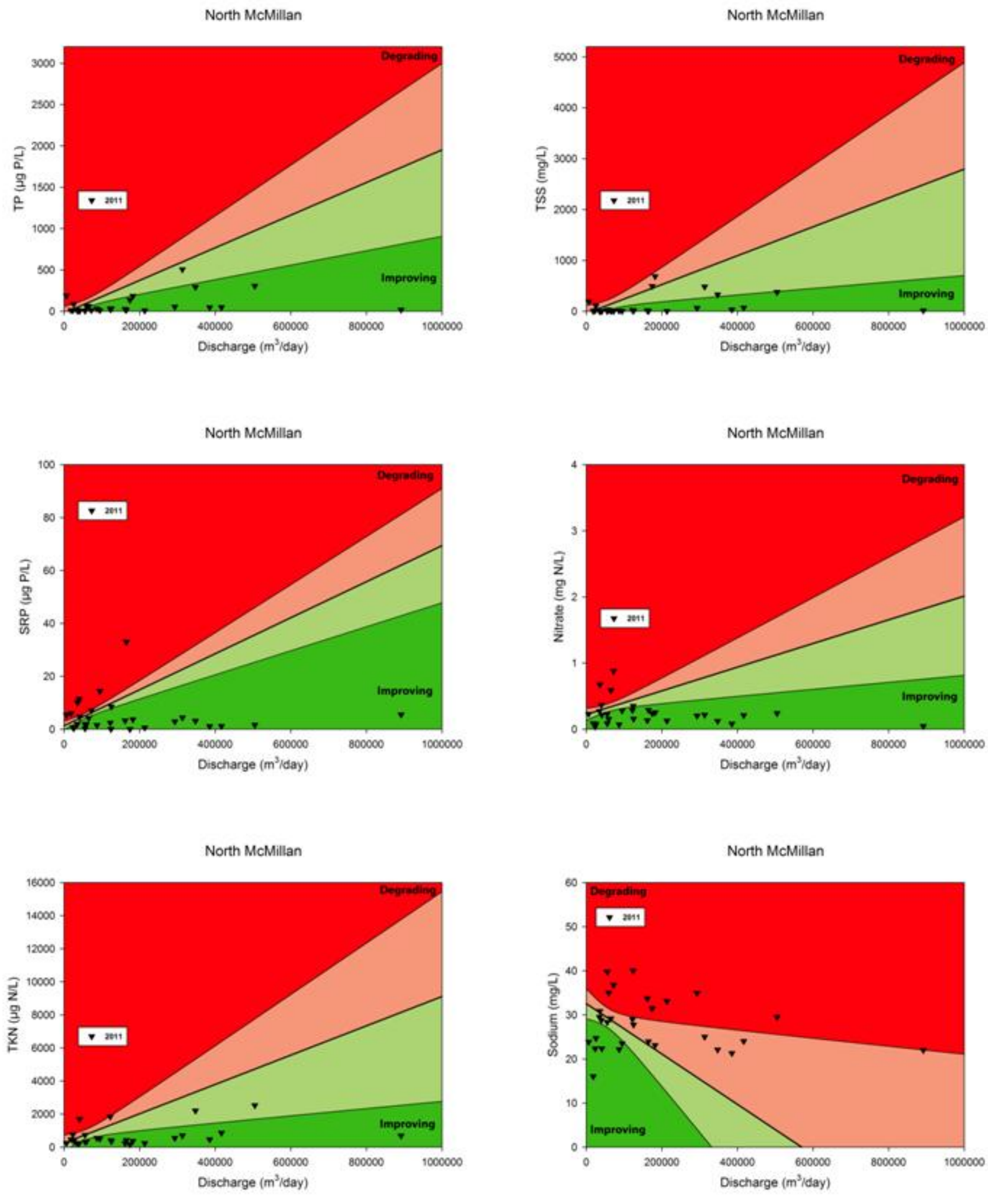
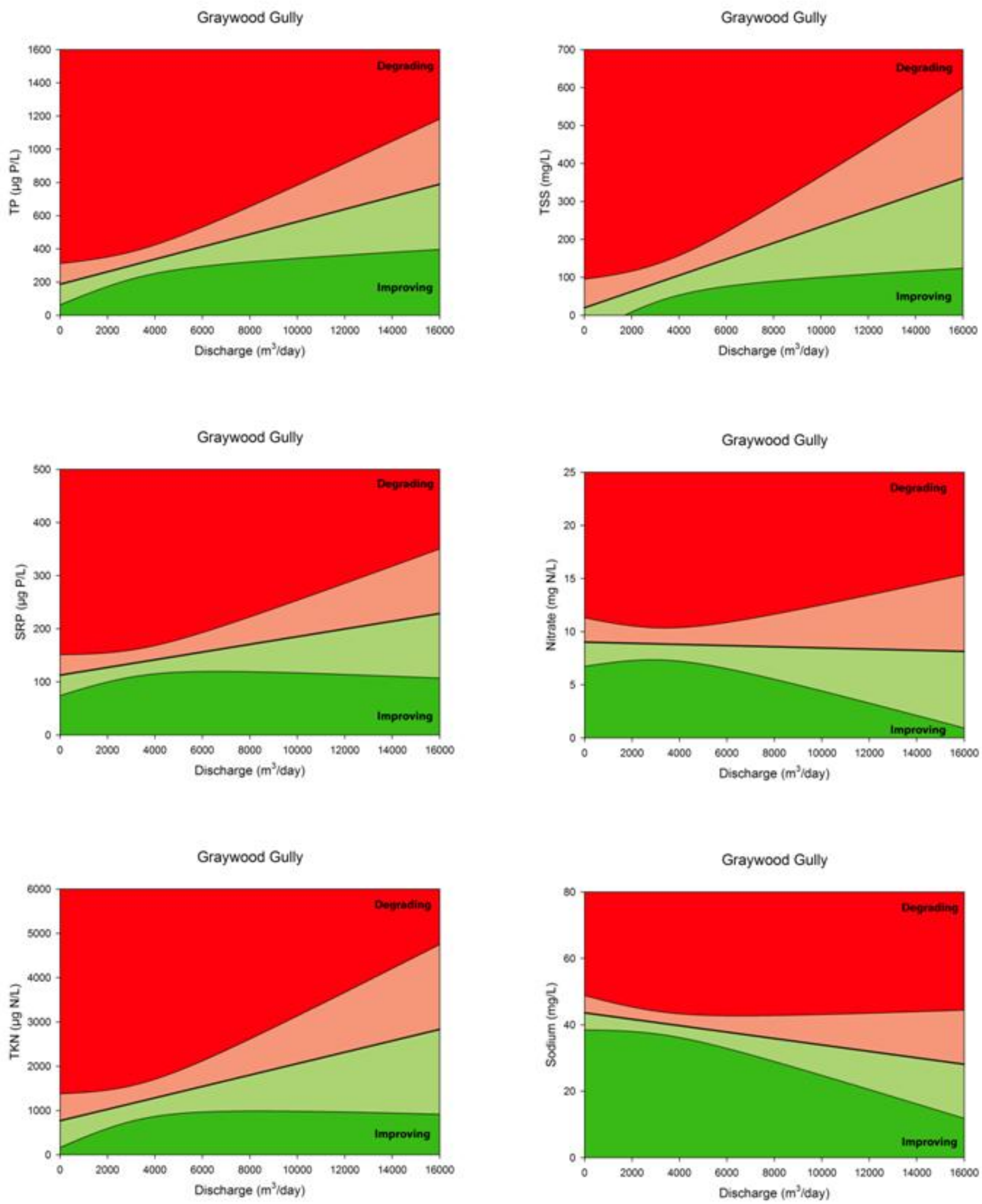
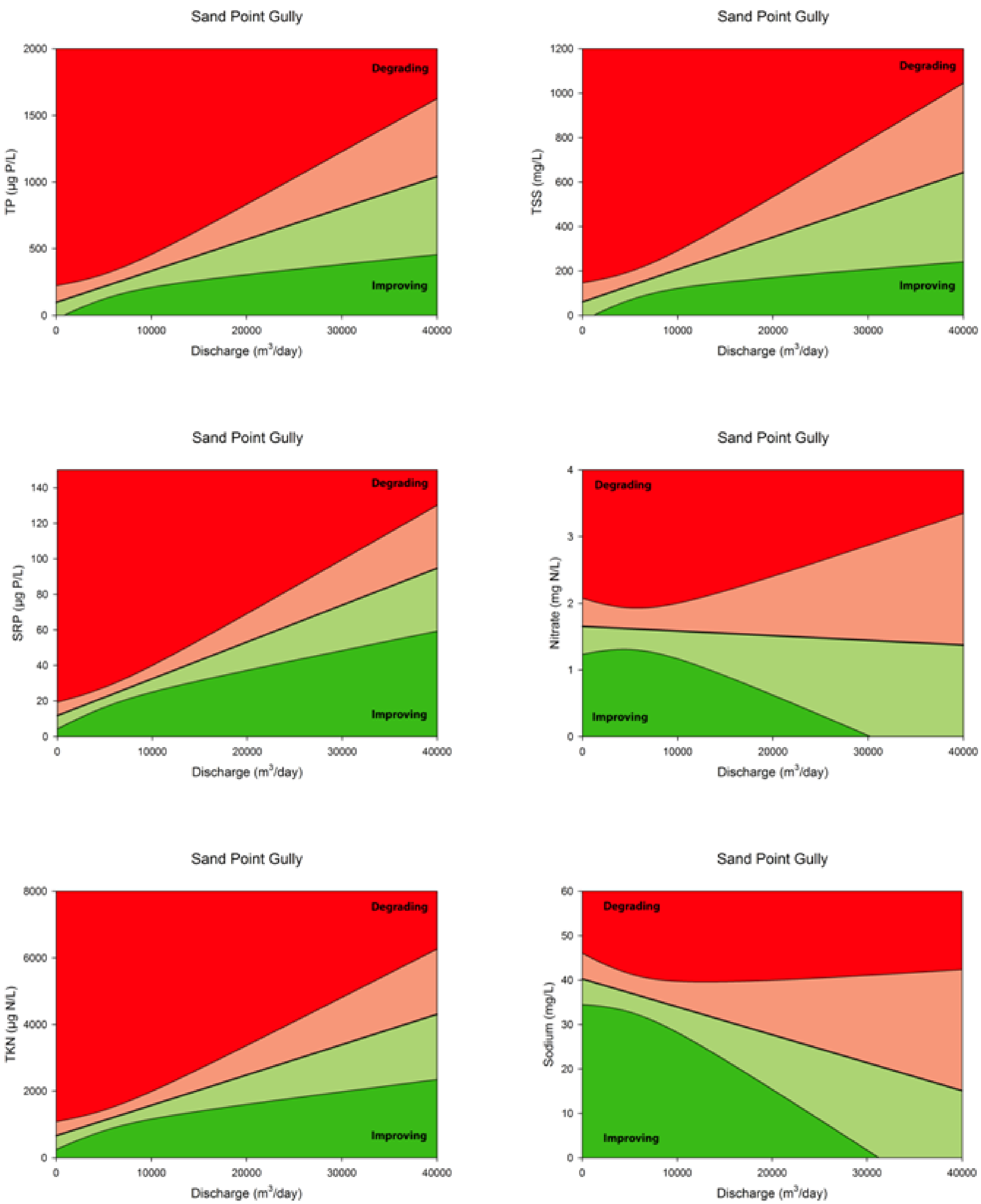


Figure 5. North McMillan Creek Stream Water Quality Assessment Index for total phosphorus, soluble reactive phosphorus, total suspended solids, nitrate, total Kjeldahl nitrogen, and sodium.

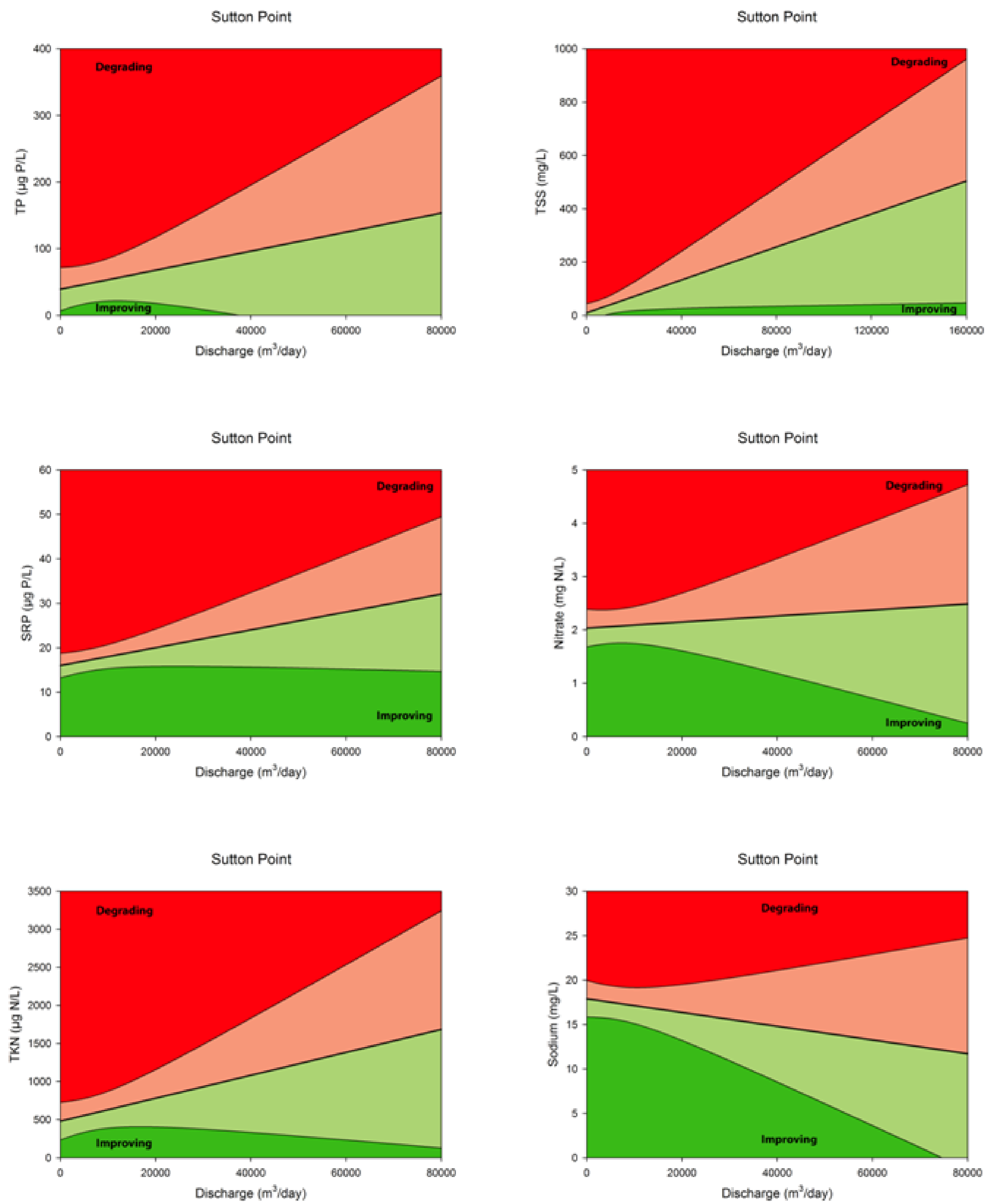
Appendices



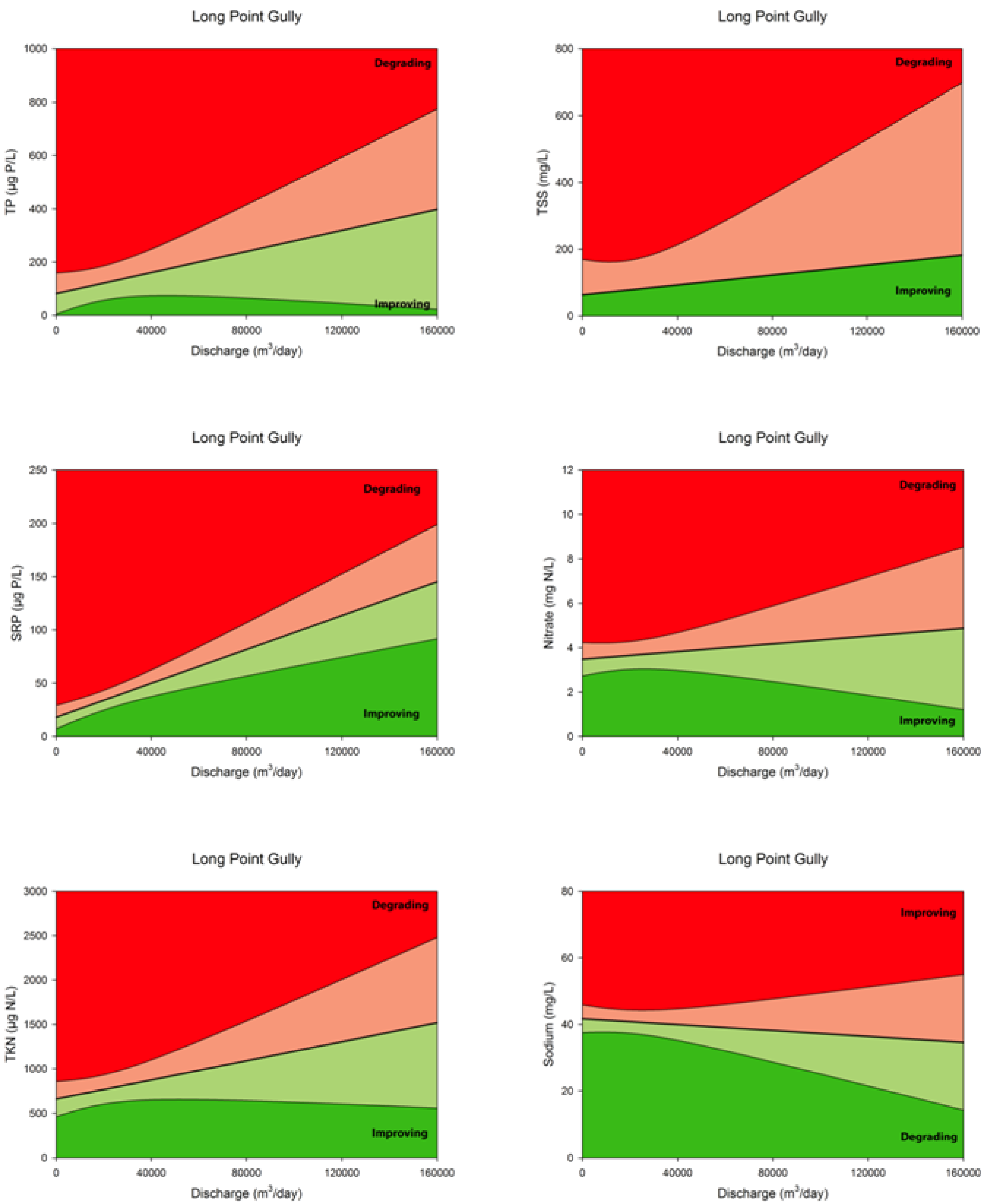
Appendix 1. Graywood Gully Stream Water Quality Assessment Index for total phosphorus, soluble reactive phosphorus, total suspended solids, nitrate, total Kjeldahl nitrogen, and sodium.



Appendix 2. Sand Point Gully Stream Water Quality Assessment Index for total phosphorus, soluble reactive phosphorus, total suspended solids, nitrate, total Kjeldahl nitrogen, and sodium.



Appendix 3. Sutton Point Creek Stream Water Quality Assessment Index for total phosphorus, soluble reactive phosphorus, total suspended solids, nitrate, total Kjeldahl nitrogen, and sodium.



Appendix 4. Long Point Gully Stream Water Quality Assessment Index for total phosphorus, soluble reactive phosphorus, total suspended solids, nitrate, total Kjeldahl nitrogen, and sodium.